A Report on
The Twenty-fourth International
TOVS Study Conference

Tromsø, Norway
16–22 March 2023

Conference sponsored by:	University of Wisconsin-Madison / SSEC Météo France Met Norway CNES EUMETSAT NASA NOAA UK Met Office L3 Harris Orbital Systems / CPII ABB Bomem
Conference supported by:	Met Norway
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Published and Distributed by:	University of Wisconsin-Madison 1225 West Dayton Street Madison, WI 53706 USA
ITWG Web Site:	itwg.ssec.wisc.edu

FOREWORD

The International TOVS Working Group (ITWG) brings together operational and research users and providers of infrared and microwave satellite sounding data. It is convened as a sub-group of the International Radiation Commission (IRC) of the International Association of Meteorology and Atmospheric Physics (IAMAP) and the Coordination Group for Meteorological Satellites (CGMS). The ITWG organizes International TOVS Study Conferences (ITSCs) which have met approximately every 18 to 24 months since 1983. Through this forum, relevant experts exchange information on all aspects of sounder data collection, processing, and utilization, with a focus on inferring information on atmospheric temperature, moisture, and cloud fields. This includes evaluation of new data, processing algorithms, derived products, impacts in numerical weather prediction (NWP), and climate studies. The group considers data from all sounding instruments that build on the heritage of the TIROS Operational Vertical Sounder (TOVS), including hyperspectral infrared instruments.

This Working Group Report summarizes the outcomes of the Twenty-fourth International TOVS Study Conference (ITSC-24) hosted by Met Norway in Tromsø, Norway between 16-22 March 2023. The ITWG Web site contains electronic versions of the conference presentations, posters and publications which can be downloaded (http://itwg.ssec.wisc.edu/). Together, these documents and web pages reflect a highly successful meeting in Tromsø.

We wish to thank Met Norway for their excellent hosting of the conference, and in particular the local organizing committee including Roger Randriamampianina and Stephanie Guedj who ensured a very smooth meeting. The Radisson Blu Hotel in Tromsø provided a brilliant venue for the conference. We also thank Leanne Avila and Maria Vasys of UW-Madison/SSEC/CIMSS for their outstanding support in the conference organization and execution, and we recognize the important contributions by Matthew Freid of the UW-Madison PLACE conference planning service. Financial support for ITSC-24 was generously provided by government agencies and industry sponsors including NOAA, NASA, EUMETSAT, Météo France, Met Norway, CNES, UK Met Office, L3 Harris, Orbital Systems / CPII, and ABB Bomem.

This report contains an executive summary highlighting the main developments and conclusions, followed by the detailed working group reports, the conference program, and abstracts of all presentations and posters.

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Tromsø, Norway: 16-22 March 2023

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ITSC-24 Group Photo

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1. EXECUTIVE SUMMARY

1.1 Introduction

The Twenty-Fourth International TOVS Study Conference, ITSC-24, was hosted by Met Norway at the Radisson Blu Hotel in Tromsø, Norway, between 16-22 March 2023. The conference was attended by 162 participants from 43 organizations, providing a wide range of scientific and technical contributions. Twenty-one countries and three international organizations were represented: Argentina, Australia, Brazil, Canada, China, Finland, France, Germany, India, Italy, Japan, Netherlands, Norway, Singapore, South Korea, Spain, Sweden, Switzerland, United Kingdom, United States, ECMWF, EUMETSAT, and the WMO. Working Groups were formed for key topic areas, leading to very productive discussions.

In addition to the excellent support provided by local host Met Norway, ITSC-24 was sponsored by government agencies including Météo France, Met Norway, CNES, EUMETSAT, NASA, and NOAA. The success of ITSC-24 was due to the excellent work of the local organizing committee from Met Norway including Roger Randriamampianina and Stephanie Guedj, as well as the invaluable administrative and logistical support provided by Leanne Avila and Maria Vasys of SSEC and Matthew Freid of the University of Wisconsin–Madison PLACE Conference Services. The daily weather briefings presented by Met Norway were greatly appreciated by the attendees.

The technical program was organized in seventeen sessions containing 79 oral presentations and 111 posters. The range of issues covered in oral presentations and posters included the following:

- Current, new and future sounder observing systems;
- Calibration and validation of sounder data;
- Reports from satellite operating agencies;
- Reports from NWP centers;
- Assimilation of sounder data for NWP;
- Climate studies;
- Sounder data processing software;
- Advanced sounders;
- Radiative transfer;
- Cloud and precipitation applications; and
- Retrieval science and algorithms.

Working Groups met to consider six key areas of interest to the ITWG, including:

- Radiative Transfer and Surface Property Modelling,
- Climate,
- Data Assimilation and Numerical Weather Prediction,
- Advanced Sounders,
- International Issues and Future Systems, and
- Products and Software.

The Working Groups reviewed recent progress in the above areas, made recommendations on key areas of concern and identified items for action. These were further reviewed in a plenary session at the end of the conference. Activities that had taken place since ITSC-23 were presented in a dedicated session of Working Group status reports. Technical sub-groups also met during ITSC-24 to discuss developments and plans concerning software packages for sounder data processing and radiative transfer modelling. As recommended by CGMS, a dedicated session was set up to exchange information with other CGMS working groups (IPWG and the newly formed IESWG), as well as from the International Telecommunication Union Radiocommunication Sector.

1.2 Conference Summary

The first conference session on Radiative Transfer began with presentations on the status of the radiative transfer models RTTOV, CRTM, Sigma-Forum, ARMS, and then posters describing applications of these models for imagers, aerosol simulations, historical sensors, cloud modelling, clear sky over oceans, comparisons between clear-sky IASI observations and RTTOV, simulations of infrared vs. microwave cloudy simulations, and all sky simulations for ICI. A calibrated lunar microwave RTM and a principal component-based RTM were presented.

Session 2 was on the topic of calibration and validation. Posters were presented on orbital biases in microwave sounder observations, exploitation of end of Metop-A life manoeuvres for calibration, new capabilities for using radiosondes for validation, and monitoring of GEO visible reflectances. Presentations were given on GSICS products and tools, evaluation of HIRAS, MWTS, and MWHS data from the FY-3E satellite launched into the early morning orbit in July 2021, and first results from the CrIS and ATMS sounders on the JPSS-2/NOAA-21 satellite launched in November 2022. Results from the TROPICS Pathfinder mission were presented, along with a comparison of the CMA HSIR sounders vs. IASI, assessment of the CrIS radiometric calibration uncertainty, consistency of the calibration between the ATMS instruments, FY-4B GIIRS performance, and a correction for ringing in CrIS calibrated spectra.

Session 3 was on the topic of GEO imager data assimilation, and it started with the combination of visible and water vapor imagery channel assimilation, followed by a simulation of infrared data in Météo France models and full exploitation of window channel observations at ECMWF. This was followed by session 4 where NWP center reports were presented as posters. Reports were presented by Environment Canada, ECMWF, Météo France, NRL, KMA, NCEP, FMI, CMA, Met Office, KNMI, JMA, NCMRWF, AEMET, BoM, GMAO, and CCRS.

Session 5 was on the topic of climate studies. The group heard presentations on reprocessing of JPSS sounder data, sources of error in the calibration of microwave sounders, harmonization of microwave humidity sounders, preparations for ERA 6, status of the NASA CrIS level 1B product, use of satellite data in a regional reanalysis, a FCDR for microwave imager radiances, climate data records from EUMETSAT, and reprocessing of historical FY satellite data.

Session 6 was on the topic of retrievals and software and the group received poster presentations on NWP-SAF processing packages to support EPS-SG and MTG, the status of the VIIRS and CrIS fusion product, AIRS and CrIS cloud clearing in the NASA GEOS model, ultra-low latency detection of instability and anomalous emissions with CrIS, the Community Satellite Processing Package, hybrid principal component compression, retrieving cloud thickness over land from OCO-2, development of NUCAPS for CSPP real time processing, combined ground-based and sounder data for diagnosing volcanic eruptions, updates on NOAA-21 science products, and retrieval and evaluation of profiles from FY-4A GIIRS. Session 6 continued with presentations on the EUMETSAT hyperspectral infrared level 2 products, the CrIS/VIIRS radiance cluster algorithm, validation of atmospheric products derived from IASI, temperature moisture profile and hydrometeor retrievals from TROPICS, NASA's new microwave sounder retrieval system, evaluation of INSAT-3D sounder temperature retrievals, and a cloud-dependent 1DVAR algorithm for retrieving precipitation from FY3 microwave sounders.

The conference was then fortunate to receive an invited presentation from Dr. William L. Smith on the state of atmospheric infrared sounding from space, describing his perspective on past, present, and future developments. His comprehensive overview of the history and future direction of infrared sounding was very well received.

Session 6 continued with an overview of the EUMETSAT hyperspectral infrared level 2 products, updates on the CrIS/VIIRS radiance cluster algorithm, validation and monitoring of IASI atmospheric products, atmospheric profile and hydrometeor retrievals from TROPICS, NASA's new microwave sounder retrieval system, evaluation of INSAT-3DR sounder temperature retrievals, and a cloud dependent 1DVAR precipitation retrieval for FY-3 microwave sounders.

Session 7 was on the topic of GEO hyperspectral infrared sounder assimilation. Poster presentations were given on initial assessment of FY-4B GIIRS, accuracy of GIIRS retrieved temperature profiles, NWP impact of infrared sounders in GEO orbit, retrieval of atmospheric vertical profiles from MTG IRS, nonlinear bias correction of FY-4A GIIRS radiances, and the impact of assimilating AMVs from Himawari 8 and clear sky radiance from FY-4A GIIRS. Oral presentations were given on the assimilation of MTG IRS into a mesoscale NWP model, and evaluation of the impact on typhoon prediction of a geostationary microwave sounder.

Session 8 was on the topic of small satellites. Poster presentations were given on TROPICS Pathfinder, evaluation of the impact of the CMIM satellite constellation on NWP, evaluation of TROPICS radiances in the IFS, observing system simulation experiments to assess the impact of EPS-Sterna, and assessing the impact of microwave sounder observations from small satellites in NOAA NWP. Oral presentations then covered the topics of assessing future constellations of small satellites carrying microwave sounders, preparing for the Arctic weather satellite data in NWP systems, and a strategy for assimilating data from small satellites.

Session 9 was on the topic of all-sky assimilation. Presentations were given on a framework for assimilating all sky MHS radiance data in the KIM, the JEDI-MPAS facilitation of research to operations for all sky radiance data assimilation, propagating of nonlinearities of the observation operator from microwave radiances within an all sky DA system, all sky assimilation of infrared radiances from Himawari-8 in the DA system at JMA, optimizing all sky assimilation of microwave humidity sounders, and all sky GEO radiance assimilation in JEDU. Poster presentations then covered a sensitivity study into the representation of ice particles for all sky simulation at 183 gigahertz, a plan for all sky radiance assimilation over land in the NCEP model, all sky assimilation in the KIM LETKF system, updates to the all sky radiance assimilation framework for the NCEP global model, and development of all sky assimilation for AMSR3 in the JMA NWP system.

Session 10 was on the topic of surface properties. Posters were presented on the version 3 NASA CAMEL product, AMSU-A window channel assimilation, improved microwave ocean emissivity and reflectivity models, reduced global SST biases from upgrades to the CRTM surface emissivity model, preprocessing of ATMS observations for DA and impact in the KIM, and the PARMIO reference quality model for ocean emissivity and backscatter from microwave to infrared. Presentations were given on improving the assimilation of IASI and CrIS radiances over land, development of a physical infrared emissivity model for snow surfaces within CRTM, assimilation of microwave low-peaking channels in HARMONIE-AROMA, and assimilation of AMSU-A near surface channels in the CMA GFS system.

Session 11 was on the topic of artificial intelligence and machine learning while session 12 was on the topic of observation operators and errors. Poster presentations were given on the use of ML for the detection and classification of observation anomalies, estimating observation impact based on a 3D convolutional RNN, a study on ML based quality control techniques for radiance DA, a nonlinear approach for temperature retrieval from AMSU-A, plans to transition the NCEP DA system to JEDI, bias correction of high-peaking microwave temperature sounding channels, a new strategy to stabilize bias correction of radiance observations in KPOP, a new IASI channel selection method for the KIM DA system, an efficient DFS score based channel selection method, and hybrid PCA representation of CrIS data. Session 11 oral presentations were given on NWP DA based on AI techniques, constrained deep learning bias correction for radiance DA, a neural network approach to cloud detection, optical properties of non-spherical particles via ML, and neural network based methods for simulating cloud and aerosol affected observations. Session 12 oral presentations were given on investigations of scene dependent observation errors related to residual cloud contamination for HSIR, evaluation of assimilation and prediction effects of satellite observation operators in CMA GFS, microwave radiance footprint operator in an Arctic DA system, quantifying homogeneous water vapor concentration effects in infrared and microwave radiances, bias correction in NOAA's next generation regional NWP model, and estimation of the error covariance matrix for IASI reconstructed radiances and the impact at ECMWF.

Session 13 was on the topic of "Earth System Approach." Oral presentations were given on the next generation earth system DA within JCSDA, the impact of a priori contribution on CO retrievals from HSIR measurements, and exploitation of microwave and infrared radiances through extracting and using ocean skin temperature information in a coupled DA system. Posters were presented on updates of radiance forward modeling in the DWD system, multi year changes in IASI LST biases and interchannel error covariance matrices in the Met Office NWP system, detection of the South American tropopause aerosol layer over the Amazon, all sky retrieval of temperature, moisture, clouds, trace gases, and surface properties from HSIR data, and the NAST-I HSIR airborne sensor for air quality monitoring and wildfire research.

Session 14 included reports from international bodies and satellite operating agencies including WMO, JMA, CMA, and NOAA.

Session 15 was on the topic of data impact studies. Poster presentations in this session covered the topics of assimilating shortwave HSIR at ECMWF, small scale atmospheric water vapor gradients captured in HSIR data, humidity sensitive radiances and constrained bias correction at DWD, the benefits of assimilating IASI within the Météo France global model, preparing for assimilation of IASI-NG within the Météo France global model, impact assessment of Himawari-8 radiance assimilation, the merits of assimilation of level 2 profiles versus level 1 radiances, improving CrIS assimilation in the GEOS DA system, assimilation of HY-2B SMR radiance observations at CMA, challenges in shortwave radiance assimilation, updates on clear sky GEO radiance assimilation at NCEP, assimilation of transformed retrievals from IASI radiances at the Met Office, preparing the DA system at NCMRWF for assimilation of Microsat-2B MHS radiances, and impact assessment of IASI temperature and humidity retrievals at ECMWF with scene dependent observation operators. Oral presentations in this session covered the topics of determining the best mix of observations, a multi-year impact assessment of satellite observations in the NCMRWF NWP system, assimilation of FY satellite data in CMA GFS using advanced radiative transfer modeling, and evaluation of FY-3E microwave sensors at ECMWF. Additional oral presentations were given on channel selection and apodization considerations for HSIR data, impact of satellite data in a regional reanalysis system, DBNet reception, processing, and assimilation at NCMRWF, expanding the use of CrIS observations in NOAA's global systems, and studying the interaction between NWP models and DA with OSSEs in ICON-LAM.

Sessions 16 and 17 were on the topic of International Issues and Future Systems. Posters were presented on international data exchange and the transition to WIS 2.0, an overview of the IASI-NG program, mission performance and ground segment development for IASI-NG, JEDI Skylab observation evaluation and use with emerging sensors, and an Australian microwave sounding mission. Oral presentations were given on the WMO unified data policy and core satellite data, the status of DBNet, highlights from the IPWG, a report from CGMS, and an update from the IESWG. The final presentations described an initial validation of the Hyperspectral Microwave Sensor, the status of NOAA's Geo-XO GXS, and an overview of EUMETSAT activities to prepare users for MTG and EPS-SG.

The final session of the conference included information about the election of future ITWG Co-chairs, awards for the best oral and poster presentations at the conference, and reports from the working group meetings.

The detailed conference agenda and PDF versions of the oral presentations and posters can be viewed on the ITWG website
https://itwg.ssec.wisc.edu/conferences/past-itsc-meetings/itsc-24-program/

1.3 Organization

ITSC-24 was organized by the ITWG co-chairs in coordination with the expert assistance of Leanne Avila and Maria Vasys at the Space Science and Engineering Center, University of Wisconsin-Madison. Local organization was provided by Roger Randriamampianina and Stephanie Guedj of Met Norway. Support for conference logistics was provided by PLACE Conference Planning Services at the University of Wisconsin-Madison. The Scientific Committee for ITSC-24 reviewed all the received abstracts and created the agenda for the conference in consultation with the ITWG co-chairs. The highest rated abstracts were granted oral presentations (considering the limited number of oral presentation timeslots) and the remainder of the abstracts were granted poster presentations. Abstracts were reviewed according to their relevance and technical merit, and all attendees regardless of experience, age, race, national origin, gender, religion, disability etc. were invited to submit abstract(s) for consideration. Early career attendees were especially encouraged to attend and present at ITSC-24.

Organizing Committee for ITSC-24

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Matthew Fried, PLACE, UW-Madison
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Dorothée Coppens, EUMETSAT
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Graeme Martin, UW-Madison
Vito Galligani, CIMA
Nathalie Selbach, DWD
Fiona Smith, BoM
David Tobin, UW-Madison
Peng Zhang, CMA
Bill Bell, ECMWF

1.4 Working Group Meetings

The Working Groups of ITWG met in person for one full day at ITSC-24 to consider six key areas of interest to the ITWG, including:

- Radiative Transfer and Surface Property Modelling
- Climate Studies
- Data Assimilation and Numerical Weather Prediction
- Advanced Sounders
- International Issues and Future Systems
- Products and Software

The Working Groups reviewed recent progress in the above areas, made recommendations on key areas of concern and identified items for action. These were further reviewed in a plenary session at the end of the conference. Activities that had taken place since ITSC-23 were presented in a dedicated session of Working Group status reports. Technical sub-groups also met during ITSC-24 to discuss developments and plans concerning specific software packages, shared and in common use. The Radio Frequency Interference technical sub-group has been revived and it met at ITSC-24. Advances from NWP centers covered the all-sky assimilation of both infrared and microwave radiances, and the further use of hyperspectral infrared sounders both on polar and geostationary orbits. As recommended by CGMS, a dedicated session was set up to exchange information with other CGMS working groups

(IPWG and the newly formed IESWG), as well as from the International Telecommunication Union Radiocommunication Sector.

Recommendations arising from ITSC-24 will be formally reported to CGMS for consideration and potential adoption by weather satellite operating agencies. These recommendations are reviewed by the CGMS working groups and a subset of the recommendations is added to the CGMS High Level Priority Plan (HLPP). ITWG recommendations and outcomes are also reported to the International Radiation Commission (IRC) in their annual business meeting.

For more information on ITWG within the framework of CGMS and IRC:
https://cgms-info.org/about-cgms/international-tovs-working-group/
https://www.iamas.org/irc/working-groups/

1.5 Major Conclusions and Recommendations

The ITSC-24 Working Group meetings and discussions documented significant issues in many areas and identified areas for future activity. The full list of action items and recommendations can be found in the detailed reports from each working group. The main conclusions and recommendations are summarised below.

Radiative Transfer Modelling

1. **To developers:** The group recommends the development of cloudy RT model validation datasets.
2. **To community:** Coordinate efforts for LS Emissivity modeling to cover spectral and physical requirements, development of modeling framework.
3. **To community:** New SST / SSE measurements across all spectral ranges highly encouraged, in coordination with RT model developers / researchers with particular emphasis on temperature dependence.

Climate

4. **To satellite agencies:** Satellite agencies should ensure a frequency continuity for all instruments in future sensor designs for developing credible climate data records.
5. **To satellite agencies:** Satellite agencies shall establish programs to conduct absolute calibration or inter-calibration for hyperspectral IR sounders during their life cycles and document and publish the results.
6. **To CGMS:** WG recommends that CGMS emphasize the need to establish an improved global climate benchmark with multiple standards as soon as possible for verifying international progress toward dealing with the threat of climate change.

Data Assimilation and Numerical Weather Prediction

7. **To space agencies**: The constellation of at least three orbits (early morning, morning, and afternoon), each with full sounding capabilities (IR and MW), should be maintained. The overpass times of operational satellites with sounding capability (IR and MW) should be coordinated between agencies to maximize coverage and include a satellite in early morning orbit.
8. **To space agencies**: In support of maintaining a robust global satellite observing system, instrumentation to allow continued sounding of the temperature of the upper stratosphere and mesosphere (as for the SSMIS UAS channels) should be explored.
9. **To satellite operators**: New operational data dissemination infrastructure should be tested at an early stage (well before launch) with simulated data.

10. **To satellite operators**: There should be open and early access to new satellite data for all NWP centers to help with calibration and validation.
11. **To satellite operators**: Satellite agencies should work with their primary user communities to assess the limitations in the exploitation of satellite data, and also engage with users less closely connected to their agencies.
12. **To satellite operators**: Consider, as part of the cost of satellite programmes, providing computational and personnel resources targeted at operational NWP centers to optimize the public's return on investment from these expensive measurement systems.
13. **To satellite operators**: When using PC compression (for hyperspectral infrared sounder data), noise normalisation should be performed using the full noise covariance matrix.
14. **To satellite operators**: Proceed with work on the use of Hybrid PC compression and investigate practical application of this method, including the incorporation of granule-based vectors in BUFR.
15. **To satellite operators**: If a change to data processing results in a change in brightness temperature of 0.1K or 20% of NEdT (whichever is smaller), this should be made clear in notifications to users. These notifications should be made no later than 8 weeks before the change and test data should be provided if possible.
16. **To satellite operators**: The overlap period where one satellite resource is replacing another should be chosen after consultation with the user community and should follow WMO guidelines.
17. **To satellite operators**: In order to facilitate evaluation of new satellite data by NWP centers, aim for distribution in near-real time.
18. **To NASA and NOAA**: Continue to provide AIRS Aqua data in real-time to NWP centers for as long as calibration of the instrument is possible.

Advanced Sounders

19. **To CMA**: Disseminate the HIRAS and GIIRS data six months after launch if possible, and not only via EUMETCAST but also to the Global User Community.
20. **To CMA**: Consider providing as soon as possible the HIRAS spectra at full spectral resolution for all bands. This also applies to all future hyperspectral sounders.
21. **To CMA**: Investigate and consider extending the output range of FY-3D GIIRS spectra to ~680 1/cm.
22. **To Roshydromet and Roscosmos**: Recommend establishing a Direct Broadcast capability for the data on the Meteor-M satellite, particularly for the hyperspectral IKFS-2 data.
23. **To space agencies:** Consistent with numerous previous ITWG and ASWG recommendations, and consistent with the WMO Integrated Global Observing System (WIGOS) Vision for the Global Observing System in 2025 and 2040, the ASWG strongly recommends that space agencies develop and implement plans to fill the gaps in IR hyper-spectral sounding within the Geostationary constellation.
24. **To space agencies**: The constellation of at least three polar orbits (early morning, morning, and afternoon), each with full sounding capabilities (IR and MW), should be maintained. The overpass times of operational satellites with sounding capability (IR and MW) should be coordinated between agencies to maximize their value.
25. **To space agencies**: Implement high spatial resolution and contiguous sampling detector arrays in future hyperspectral infrared sounding instruments.
26. **To space agencies:** To develop, test, and implement an SI-traceable radiometric standard in space as soon as feasible.

International Issues and Future Systems

27. **To space agencies**: Consider building in as much RFI screening and mitigation into their ground segment processing as possible, noting efforts already starting at ESA and in research groups in the US, Japan and China.
28. **To space agencies**: Consider DBNet requirements when designing core ground segment software, and then to make software available to DBNet operators.
29. **To space agencies**: Note that the strong requirement for traceable calibration comes from NWP as well as the climate application area.
30. **To space agencies**: Note that the benefits of satellite missions to the ITWG community are increased when early evaluation is undertaken by many independent centers. Facilitating early access to new data is therefore highly recommended.
31. **To satellite operators**: Consider if the SAF concept would be beneficial for them (other satellite operators), as it has been for EUMETSAT.

Products And Software

32. **To satellite operators:** Implement subscription-based notification of anomalies or events that impact users.
33. **To EUMETSAT**: Provide a schedule for release of different types of test data for both EPS-SG and MTG.
34. **To JAXA:** Consider providing AMSR-2 L1 software for release to the DB community. The CSPP team could host it.
35. **To international telecommunication agencies:** The frequencies used in DB reception (L band and X band) should be preserved, to ensure continued fidelity of downlink reception.

1.6 Future Plans

Following the established practice of ITWG co-chairs serving for three conferences, the group announced and held elections for the next co-chairs after ITSC-24. Anyone who had attended three or more ITSCs was eligible to stand as a candidate. From the four excellent candidates, Fiona Smith (BoM, Australia) and Reima Eresmaa (FMI, Finland) were duly elected by the ITWG membership. They will lead the ITWG for ITSC-25, -26, and -27.

The next ITSC is anticipated in 2025. In the meantime, ITWG will continue to inform the infrared and microwave sounding community of the latest news and developments through its Web site (maintained by the University of Wisconsin-Madison/CIMSS) and via the email list (also maintained by CIMSS).

1.7 Acknowledgements

This report relied on the active participation of all ITSC attendees and those working group chairs. We acknowledge that writing of this report is possible only through the collective work of ITWG members.

SUMMARY OF ACTIONS AND RECOMMENDATIONS

RADIATIVE TRANSFER AND SURFACE PROPERTY MODELLING

Action RTSP-1 on RTSP co-chairs
To update the ITWG RTSP working group website.

Action RTSP-2 on RTSP co-chairs
Particularly, two widely used continuum models were mentioned: MT_CKD model (used by HITRAN) and GEISA. For this reason, an action item is put on contacting Eli Mlawer (AER) for MT_CKD, Iouli Gordon (CFA, Harvard) for HITRAN and Raymond Armante (LMD) for GEISA on updates regarding comparison studies that address model and/or laboratory spectroscopic measurements comparisons.

Recommendation RTSP-1 to spectroscopy researchers
The RTSP-WG recommends promoting research into spectroscopy of higher frequency microwave channels up to 1000 GHz, specially the H2O lines in the sub-mm range of particular importance for the upcoming launch of ICI.

Recommendation RTSP-2 to the spectroscopy community
A strong emphasis should be put on the continuous support of theoretical and laboratory spectroscopic studies. It is crucial that a compilation of basic line parameters is maintained.

Recommendation RTSP-3 to spectroscopy researchers
A strong emphasis should be put on the continuous support of far-IR model developments in preparation for future missions: i.e., sigma-IASI/FORUM model, FIREX requirements.

Recommendation RTSP-4 to the spectroscopy community
The group recommends maintaining the Rosenkranz MW/sub-mm model. There are concerns it might become discontinued.

Action RTSP-3 on RTSP co-chairs
Contact AER about CLBLM status.

Recommendation RTSP-4 to CLBLM developers
Maintain the latest LBRTM version when CLBLM is released.

Recommendation RTSP-5 to spectroscopy community
A strong emphasis should be put on the continuous support of theoretical and laboratory spectroscopic studies. It is crucial that a compilation of basic line parameters is maintained. In this regard, it is recommended to work more closely with the planetary/ astronomy community for knowledge of LBL / spectroscopy information.

Action RTSP-4 on Guido Masiello
Contact Geronimo Villanueva (NASA) regarding LBL modeling.

Action RTSP-5 on Vito Galligani
Contact Juan Pardo (IFF, CSIC) regarding LBL modeling.

Action RTSP-6 on RTSP co-chairs
To contact Sergio de Souza-Machado (UMBC) who is working with the kCARTA model to report on LBLRTM model comparisons. There are other models such as the CNR/Florence Klima LBL model that are relevant for comparison studies.

Action RTSP-7 on RTSP co-chairs
Request links to facilitate access to field experiment datasets for RTM evaluation / validation.

Recommendation RTSP-6
Reach out to the aerosol community and survey their aerosol (physical) needs.

Recommendation RTSP-7 to aerosol community
The group encourages the publication of a literature review that includes new aerosol studies and challenges regarding VIS/near-IR aerosol sensitivities and spectral dependencies.

Recommendation RTSP-8 to aerosol community
The group continually supports field campaigns and the community to use field campaign data for validation studies. The group further recommends to connect aerosol FCs to RT evaluation.

Recommendation RTSP-9
Continue support for refractive index dependence studies on temperature in the far-IR.

Recommendation RTSP-10
Continue support to exploit synergy (i.e., FORUM+IASI-NG) in studies and retrievals.

Action RTSP-8 on co-chairs
To get updates/plans of the Labonnete database, as well as P. Yang's recently funded project to improve ice far-IR refractive index.

Action RTSP-9 on Ben Johnson
Bring IPWG information on cloud properties into ITSC-24.

Recommendation RTSP-11 to RT developers
The group recommends the development/evaluation of fast scattering solvers such as the Chou/Tang phase function scaling methods (i.e., poster 1p.12 presented by Vidot et al.).

Recommendation RTSP-12 to RT developers
The group continues to recommend the development of cloudy RT model validation datasets.

Recommendation RTSP-13
Support sub-grid variability studies (NUBF effects / cloud fraction impact) studies.

Recommendation RTSP-14
Support studies that can assess the impact/importance of habit/PSD parameter on radiance space.

Recommendation RTSP-15 to RT community
To continue the ongoing recommendation of model inter-comparison.

Recommendation RTSP-16 to fast model developers
To incorporate CAMEL v3.0, specially RTTOV / CRTM.

Recommendation RTSP-17 to NWP community
To identify partners for developing improved land surface emissivity models with the explicit intent of improving data assimilation over land.

Recommendation RTSP-18
To investigate AI approaches for land surface emissivity improvements, for example for real time modification of emissivity based on precipitation / flooding / etc.

Recommendation RTSP-19 to funding agencies
To fund 3+ years for AI research into replacing or developing components that get used in operational context (e.g., fast models).

CLIMATE

Action Climate-1 on Bill Bell
To make the presentation on the preparations for ERA6 available on the webpage (either Climate WG subpage or main conference page).

Recommendation Climate-1 to meteorological satellite agencies and other providers of CDRs
To provide updates to CWG / CGMS on the status of their current activities relating to user uptake and impacts of CDRs. This type of activities is seen as important for uptake of the products by users and it is recommended to consider development of similar activities to the above mentioned in case there are no such activities yet.

Recommendation Climate-2 to space agencies
To note the link between (on the one hand) a tendency to small satellite technology, potentially entailing compromised calibration capabilities and (on the other hand the scientific case for independent on-orbit calibration missions, such as CLARREO.

Recommendation Climate-3 to GSICS
Extend the calibration and harmonisation activities to historic sensors to support climate applications, including CDR / ECV production and reanalysis.

Recommendation Climate-4 to satellite providers
To catalogue the available data and supporting information, make information available to users.

Action Climate-2

Establish status and plans for long-term stewardship of L0, FCDRs and CDRs and all relevant metadata and documentation at respective agencies The following group members will provide information on this task:
P. Zhang for CMA (FY-series)
T. Hanschmann for EUMETSAT (Meteosat and Metop programmes),
Joe Taylor for CrIS in NOAA and identify relevant point of contact for wider NOAA data records.

DATA ASSIMILATION AND NUMERICAL WEATHER PREDICTION

Action DA/NWP-1 on Bill Campbell

To circulate information about the COWVR instrument and RFI detection principle to the WG.

Recommendation DA/NWP-1 to DA/NWP WG members

Conduct simulated impact studies to establish optimal revisit times for microwave sounders in both global and regional models, in particular considering low inclination orbits, and report back at next ITSC.

Action DA/NWP-2 on WG co-chairs

Contact Steve English to obtain more information on his proposal for snow and/or sea ice emissivity ISSI project and circulate to Working Group members.

Action DA/NWP-3 on Brett Candy

Report to WG members on any useful discussion that took place on use of microwave data over sea ice, snow or land at EPS-Sterna workshop in April 2023.

Recommendation DA/NWP-2 to CGMS

Communicate to satellite data providers that the stability and consistency of bias and noise for individual passive radiometer instruments within a constellation of Small/CubeSats are very important for implementation. Consistency between instruments within the constellation is also critical.

Recommendation DA/NWP-3 to CGMS

Communicate to satellite data providers that given Recommendation DA/NWP-2, the requirement from NWP Centres for single instrument longevity within any constellation of Small/CubeSats should be a threshold of three years post-commissioning (below which many centres will not use the data) and an objective of five years (where most NWP centres will aim to use the data). If the overall mission is of long duration, the threshold for an individual satellite could be lowered to two years post-commissioning.

Recommendation DA/NWP-4 to CGMS and data providers

Radiance data from new satellite instruments should be disseminated using WMO pre-approved BUFR sequences, consistent with other similar data types where possible.

Recommendation DA/NWP-5 to data providers

Given the positive impact of SAPHIR on numerical weather prediction, and the uniqueness of the inclined orbit for sounding, and the lack of opportunity to use MADRAS data following its early failure, the WG supports a follow on mission that has similar or extended capability relative to SAPHIR and MADRAS in an inclined orbit.

Recommendation DA/NWP-6 to WMO

Continue to engage with commercial satellite providers to convey NWP requirements via industry days etc.

Action DA/NWP-3 on Heikki Pohjola

Share WMO best practice guide on achieving user readiness with commercial satellite providers.

Recommendation DA/NWP-7 on CGMS and WMO members

When commercial satellite data is purchased, ensure provision to users of the necessary data and meta-data required to make use of the data in applications, as early as possible.

Action DA/NWP-4 on WG co-chairs

Organise a task team to perform experiments to establish the impact of data latency in both global and local assimilation systems.

Action DA/NWP-5 on Fiona Smith

Check with Tim Hultberg and Dave Tobin regarding what feedback has been received on hybrid PC-scores and report to CGMS.

Recommendation DA/NWP-8 on WG members

Contact Dave Tobin for testing of hybrid PC-compressed CrIS observations.

Action DA/NWP-6 on WG members

Share impact assessment results for FY-3E with the working group, NOAA and CMA as soon as possible in particular to provide evidence for support of the early morning orbit.

Recommendation DA/NWP-9 to NOAA/NESDIS

Continue provision of LWIR band on S-NPP CrIS after NOAA-21 is declared operational.

Recommendation DA/NWP-10 to data providers

Use SI Standard units for spectral radiance in all BUFR products ($W/m^2/sr/m^{-1}$).

Recommendation DA/NWP-11 to CNES

Cluster analysis of MetImage radiances within IASI-NG FOV is required in the IASI-NG BUFR products.

Action DA/NWP-7 on WG members

Provide feedback to Eric Jurado (eric.jurado@cnes.fr and copy to WG co-chairs) on proposed methodology for MetImage cluster analysis within IASI-NG FOV.

Recommendation DA/NWP-12 to EUMETSAT

Investigate whether a map of the cluster that each MetImage pixel within each IASI-NG FOV falls into could be provided as an additional auxiliary product.

Recommendation DA/NWP-13 to Eva Borbas

Continue to update the CAMEL atlas, extending to VIIRS to ensure continuity beyond the life of MODIS.

Action DA/NWP-8 on WG co-chairs

Remove out of date and unused pages on WG website and update any that require it, including references on satellite data in LAM.

Action DA/NWP-9 on WG co-chairs

Organise a science meeting on verification and validation for satellite experiments in LAM.

Action DA/NWP-10 on WG co-chairs

Update NWP WG survey to include changes proposed at this conference.

Recommendation DA/NWP-14 to ITWG co-chairs

Organise a discussion topic for future conferences on use of coupled systems in sounder radiance assimilation.

Standing Actions and Recommendations

Standing Action DA/NWP-1 on ITWG co-chairs

To bring relevant recommendations to the attention of CGMS.

Standing Action DA/NWP-2 on DA/NWP WG members

Send any evidence of RFI to co-chairs of the RFI Technical SubGroup - Jean Pla (jean.pla@cnes.fr), Richard Kelley (richard.kelley@noaa.gov), Stephen English (stephen.english@ecmwf.int) and Nancy Baker (nancy.baker@nrlmry.navy.mil).

Standing Action DA/NWP-3 on DA/NWP WG members

If you have estimates of revised channel characteristics resulting from post-launch diagnostics, please email these to the radiative transfer working group chairs (Benjamin.T.Johnson@noaa.gov and vito.galligani@cima.fcen.uba.ar).

Standing Action DA/NWP-4 on NWP centres

Continue to provide information on instrument channels assimilated and their observation errors via the working group survey spreadsheet in advance of each conference.

Standing Action DA/NWP-5 on DA/NWP WG Members

Make suggestions and corrections to the DA/NWP Working Group website.

Standing Recommendation DA/NWP-1 to the satellite agencies

In support of maintaining a robust global satellite observing system, instrumentation to allow continued sounding of the temperature of the upper stratosphere and mesosphere (as for the SSMIS UAS channels) should be explored.

Standing Recommendation DA/NWP-2 to funding bodies of NWP centres and space agencies

Consider, as part of the cost of satellite programmes, providing computational and personnel resources targeted at operational NWP centres to optimise the public's return on investment from these expensive measurement systems.

Standing Recommendation DA/NWP-3 to data providers

Include azimuthal viewing and solar angles as appropriate in BUFR for present and future instruments.

Standing Recommendation DA/NWP-4 to space agencies and data providers

When designing new or modified BUFR formats, please circulate drafts to the NWP community via the NWP Working Group for feedback, prior to submission to WMO.

Standing Recommendation DA/NWP-5 to data providers

When using PC compression, noise normalisation should be performed using the full noise covariance matrix.
[HLPP: 4.2.6 Establish together with the user community a commonly agreed approach for retrieval of Principal Component scores and associated parameters from hyperspectral infrared data, minimising information loss including the mutually acceptable update strategy for the principal component basis and to implement such an approach in a coordinated manner.]

Standing Recommendation DA/NWP-6 to data providers

If a change to data processing results in a change in brightness temperature of 0.1K or 20% of NEdT (whichever is smaller), this should be made clear in notifications to users. These notifications should be made no later than 8 weeks before the change and test data should be provided if possible.
[HLPP: 3.17 Develop best practices for operational user notifications.]

Standing Recommendation DA/NWP-7 to data providers

The overlap period where one satellite resource is replacing another should be chosen after consultation with the user community and should follow WMO guidelines.

Standing Recommendation DA/NWP -8 to data providers

Provide NedT estimates for inclusion within BUFR for microwave data.
[HLPP 4.4.2 Agree on standardised procedures to derive NedT estimates for microwave sounders, and include such estimates in the disseminated BUFR data.]

Standing Recommendation DA/NWP-9 to data providers

Make NedT estimates from microwave instruments available as time series on publicly available websites to enable monitoring of instrument health in near real time.

Standing Recommendation DA/NWP-10 to instrument developers

Pre-launch calculation of NEdT should use the same algorithm as will be used in-orbit using warm target counts variability divided by the instrument gain.

Standing Recommendation DA/NWP-11 to data providers
Develop and maintain public instrument status monitoring web pages similar to the Integrated Calibration and Validation System (ICVS) from NOAA/NESDIS.

ADVANCED SOUNDERS

Action AS-1 on NOAA
To further discuss/consider the 3 CrIS configuration at the wind workshop in May.

Recommendation AS-1 to NOAA
To keep the LWIR band, since the LWIR data is very important for NWP.

Action AS-2 on CMA
To circulate to ASWG the preliminary findings of the impact when using the 5:30am orbit.

Recommendation AS-2 to NOAA
To take into account the outcome of the impact study of the 5:30 am orbit and possibly to consider the 5:30 am orbit as beneficial to the community.

Recommendation AS-3 to NOAA
To pursue with the LEO program.

Recommendation AS-4 to NOAA
GEO MW sounder demo mission to be implemented as soon as possible, so that the basis for planning joint operational systems can be established in a timely manner and MW can catch up with IR.

Recommendation AS-5 to apace agencies
Agencies that are implementing GEO IR sounders should also implement companion GEO MW sounders.

Recommendation AS-6 to ITWG co-chairs
To consider including a dedicated session at the next ITSC on sub-mm instruments such as ICI and AWS.

Recommendation AS-7 to space agencies
To pursue/consider very low noise technology for MW sounders.

Recommendation to satellite agencies (NOAA, JMA)
Consistent with numerous previous ITWG and ASWG recommendations, and consistent with the WMO Integrated Global Observing System (WIGOS) Vision for the Global Observing System in 2025 and 2040, the ASWG strongly recommends that space agencies develop and implement plans to fill the gaps in IR hyper-spectral sounding within the Geostationary constellation.

Recommendation to satellite agencies

The constellation of at least three polar orbits (early morning, morning, and afternoon), each with full sounding capabilities (IR and MW), should be maintained. The overpass times of operational satellites with sounding capability (IR and MW) should be coordinated between agencies to maximize their value.

Recommendation to satellite agencies

Implement high spatial resolution and contiguous sampling detector arrays in future hyperspectral infrared sounding instruments.

Recommendation to satellite agencies

To develop, test, and implement an Infrared SI-traceable radiometric standard in space as soon as feasible.

Action on ITWG co-chairs

To re-iterate these recommendations to space agencies via CGMS.

Recommendation AS-8 to space agencies, data providers, and CGMS

To implement the WIGOS Vision 2040 backbone system that includes 3 additional orbits between the current 1330, 0930, and 0530 local times by populating each with advanced IR and MW sounding capability, thereby providing 2 hour temporal spacing.

General recommendation AS-9 to operational centres

To aim to utilize the full spectral, temporal, and spatial information content provided by the international system of satellite hyperspectral sounding sensors.

Action AS-3 on ASWG

To go through the CGMS HLPP and send feedback to the ASWG co-chairs.

INTERNATIONAL ISSUES AND FUTURE SYSTEMS

Action IIFS-1 on Peng Zhang (CMA)

To circulate the report of the WMO-CGMS Tiger team that informed CMA's decision about moving FY-3E to the early-morning orbit to the IIFS group.

Recommendation IIFS-1 to WMO/CGMS

To assemble a new Tiger team to review the achieved impacts of the early-morning orbit, once the NWP impact assessment of FY-3E by the international community is sufficiently mature, in order to support initiatives that could increase robustness of the early-morning orbit coverage.

Standing Recommendation IIFS23-2 to CGMS

To explicitly consider instrument capabilities and data quality as well as data provision in future updates of the CGMS baseline, particularly for the 3-orbit backbone system of LEO passive sounders which plays an important role as a reference-style system, and also for MW imagers.

Recommendation IIFS-2 to EUMETSAT and ESA

To report to CGMS the results of assessments of expected impact conducted in the context of EPS-Sterna.

Recommendation IIFS-3 to CGMS

To advance the implementation of the WIGOS Vision 2040 for passive IR and MW sounding with agency commitments beyond the established 3-orbit baseline. Noting recent assessments of expected impact, the WG recommends complementing the 3-orbit CGMS baseline with a further 3-orbit system that features at least MW sounding capabilities, with equator-crossing times between those of the 3-orbit baseline to optimize time-to-coverage of the overall system.

Recommendation IIFS-4 to CGMS members with initiatives to complement the 3-orbit baseline

To coordinate activities to put such systems in place and to optimize complementarity.

Standing Recommendation IIFS23-4 to NWP centres and other organisations involved in the evaluation of existing data from smaller satellites

To report on experiences with passive sounding instruments from smaller satellites at future ITSCs, including evaluations of data quality and stability, with a view towards future operationalization of such systems.

Recommendation IIFS-5 to providers of data from constellations of smaller satellites

To work towards a standardisation of downlink equipment and data protocols to ease provision of direct broadcast capabilities.

Recommendation IIFS-6 to WMO

To coordinate an update of timeliness requirements, bearing in mind growing applications of rapid-update NWP systems.

Recommendation IIFS-7 to space agencies via CGMS

To continue to explore innovative methods, such as used by GPM, to provide global data with a timeliness that meets the new requirements, for next generation satellite programmes.

Standing Recommendation IIFS22-8 to CGMS

If a mission expects engagement from application areas with an NRT data requirement, budget should be allocated from the start to provide the required technical infrastructure.

Standing Recommendation IIFS23-7 to NWP centres

To conduct impact studies highlighting the benefit of good timeliness of observations, and to report on these at future meetings.

Action IIFS-2 on Niels Bormann

To compile which elements of the ICVS-monitoring are considered most relevant to users, consulting the wider ITWG for input.

Recommendation IIFS-8 to CGMS members

To provide calibration metadata and instrument telemetry monitoring as identified in the above action for operational instruments.

Recommendations IIFS-9 to CGMS members

To perform a backflip manoeuvre for LEO satellites, at least before the end of life, and ideally earlier than that if compatible with the satellite/instrument design, to collect information critical for enhanced calibration performance.

Standing Recommendation IIFS21-8 to CGMS

Recognizing the growing need for assessment and on-orbit optimization of the accuracy of operational hyperspectral IR sounders, the traditional approaches for pre-flight SI traceability and post-flight validation should be enhanced by flying an on-orbit reference standard capability (featuring on-orbit SI verification) with orbits designed to provide inter-calibration capability for refining the calibration of the international fleet of operational sounders.

Recommendation IIFS-10 to space agencies involved in reference missions (CLARREO, TRUTHS, LIBRA)

To work towards harmonized product definitions to make the use of these products easier for inter-calibration exercises.

PRODUCTS AND SOFTWARE

Action PSWG-1 on PSWG co-chairs

To share on the PSWG web site the documents related to containers that were presented at the meeting.

Recommendation PSWG-1

Software providers should, where possible, offer their software with a choice of either pre-built binaries or source code.

Recommendation PSWG-2

For software that will be built from source by the user, software providers should list recommended versions of required external (COTS) libraries.

Recommendation PSWG-3

Costs to users should be considered when migrating software and data distribution to the cloud.

Recommendation PSWG-4

Users should continue to have free access to satellite data.

Recommendation PSWG-5

Software providers are encouraged to provide and test software in a cloud-ready format.

Recommendation PSWG-6 to data providers

Explore the use of principal component (PC) compression to reduce the volume of hyperspectral sounder data in future geostationary direct broadcast or rebroadcast streams.

Recommendation PSWG-7 to space agencies

Consistency in data content and data formats between the various planned smallsat microwave missions would be highly beneficial for users.

Recommendation PSWG-8 to space agencies

Direct broadcast should be preserved for users who cannot get timely data by terrestrial means.

Recommendation PSWG-9 to software developers

Software developed in the cloud should be vendor agnostic.

Recommendation PSWG-10 to software developers

Consider building software packages in a container with a controlled environment, even if the eventual deployment will be outside that container.

Recommendation PSWG-11 to data providers

When creating or releasing test data, it is good practice to state which APIs the data are compatible with, and whether there are any changes (e.g. since the last release) that affect compatibility with the standard reader APIs.

Recommendation PSWG-12 to software providers

Software intended to be run in an operational context should only link to open source 3rd party packages (e.g. on Conda Forge).

Recommendation PSWG-13 to raw data providers

In streaming data formats, metadata should be transmitted inline with the corresponding section of raw data to which it pertains to support near real-time and low latency applications.

Action PSWG-2 on PSWG co-chairs

To port the current list of software packages to the new web site (when available) and to solicit the help of PSWG members to update the tables.

2. WORKING GROUP REPORTS

2.1 Radiative Transfer and Surface Property Modelling

Web site: itwg.ssec.wisc.edu/rtsp/

Working Group Members: Vito Galligani (Co-Chair, CIMA, UBA-CONICET), Benjamin Johnson (Co-Chair, JCSDA), Lei Bi (Zhejiang University), Eva Borbas (UW SSEC), Mary Borderies (CNRM, Météo-France et CNRS), Xavier Calbet (AEMET), Thomas Carrel (CNRM), Krishnamurthy Chandramouli (Centre for Climate Research Singapore), Andrew Collard (NOAA/NCEP/EMC), Marc Crapeau (EUMETSAT), Azadeh Gholoubi (AXIOM at NOAA/NCEP/EMC), Stephanie Guedj (Met Norway), Hanna Hallborn (Chalmers University of Technology), Lingli He (CMA), James Hocking (Met Office), Harumde Ishida (JMA), James Jung (UW CIMSS), Eun-Jin Kim (KIAPS), Hyeyoung Kim (KIAPS), Sumit Kumar (NCMRWF), Thomas Lebrat (CNRM Meteo France), Vincent Leslie (MIT Lincoln Laboratory), Emily Liu (NOAA/NCEP/EMC), Naoto Kusano (JMA), Jean-Marie Lalande (CNRM, Météo France, CNRS), Cristina Lupu (ECMWF), Tiziano Maestri (University of Bologna), Guido Masiello (University of Basilicata), Mahdiyeh Mousavi (DWD), Nick Nalli (NOAA/NESDIS/STAR), Stu Newman (Met Office), Indira Rani (NCMRWF), Mikael Rattenborg (formerly WMO), Hank Revercomb (UW SSEC), David Rundle (Met Office), Tracy Scanlon (ECMWF), Leonhard Scheck (LMU Munich), Roseline Schmisser (CNES), Yi-Ning Shi (CMA), Inchul Shin (KMA), Sreerekha Thonipparambil (EUMETSAT), David Tobin (UW/SSEC/CIMSS), Emma Turner (Met Office), Ethel Villeneuve (CNRM, Université de Toulouse, Météo-France, CNRS), Jun Yang (CMA), Qiguang Yang (SSAI/NASA Langley), Peng Zhang (CMA), Dan Zhou (NASA Langley)

2.1.1 General items

Action RTSP-1 on RTSP co-chairs

To update the ITWG RTSP working group website.

2.1.2 Spectroscopy

The group discussed the uncertainties on continuum absorption/emission modeling in all wavelengths, as well as the need for a characterization of model biases and uncertainties in key relationships/spectroscopic parameters such as line-shapes and line strengths. In a similar note, the need to map uncertainties in spectroscopy into radiance uncertainties.

The NWPSAF Technical report "Literature Review on Microwave and Sub-millimetre Spectroscopy for MetOp Second Generation" (2022) by Turner, E. Fox, F. Mattiolo, V. and Cimini, D was highlighted to be an important reference material (https://nwp-saf.eumetsat.int/site/download/members_docs/cdop-3_reference_documents/NWPSAF_report_submm_litrev.pdf).

Action RTSP-2 on RTSP co-chairs

Particularly, two widely used continuum models were mentioned: MT_CKD model (used by HITRAN) and GEISA. For this reason, an action item is put on contacting Eli Mlawer (AER) for MT_CKD, Iouli Gordon (CFA, Harvard) for HITRAN and Raymond Armante (LMD) for GEISA on updates regarding comparison studies that address model and/or laboratory spectroscopic measurements comparisons.

Recommendation RTSP-1 to spectroscopy researchers
The RTSP-WG recommends promoting research into spectroscopy of higher frequency microwave channels up to 1000 GHz, specially the H2O lines in the sub-mm range of particular importance for the upcoming launch of ICI.

Recommendation RTSP-2 to the spectroscopy community
A strong emphasis should be put on the continuous support of theoretical and laboratory spectroscopic studies. It is crucial that a compilation of basic line parameters is maintained.

Recommendation RTSP-3 to spectroscopy researchers
A strong emphasis should be put on the continuous support of far-IR model developments in preparation for future missions: i.e., sigma-IASI/FORUM model, FIREX requirements.

Recommendation RTSP-4 to the spectroscopy community
The group recommends maintaining the Rosenkranz MW/sub-mm model. There are concerns it might become discontinued.

2.1.3 Line-by-Line Modeling

The group raised concerns regarding the LBL needs in hyperspectral MW missions.

The group discussed the status of the Community LBLM (CLBLM) and noted that the model has not yet been officially released. Doubts were raised regarding the funding of the project.

Action RTSP-3 on RTSP co-chairs
Contact AER about CLBLM status.

Recommendation RTSP-4 to CLBLM developers
Maintain the latest LBRTM version when CLBLM is released.

Recommendation RTSP-5 to spectroscopy community
A strong emphasis should be put on the continuous support of theoretical and laboratory spectroscopic studies. It is crucial that a compilation of basic line parameters is maintained. In this regard, it is recommended to work more closely with the planetary/ astronomy community for knowledge of LBL / spectroscopy information.

Action RTSP-4 on Guido Masiello
Contact Geronimo Villanueva (NASA) regarding LBL modeling.

Action RTSP-5 on Vito Galligani
Contact Juan Pardo (IFF, CSIC) regarding LBL modeling.

Action RTSP-6 on RTSP co-chairs
To contact Sergio de Souza-Machado (UMBC) who is working with the kCARTA model to report on LBLRTM model comparisons. There are other models such as the CNR/Florence Klima LBL model that are relevant for comparison studies.

2.1.4 Field Campaigns for validation / assessment

The group discussed the existence of two relevant field campaigns aiming at analyzing

1. Surface emissivity in the thermal IR
   - AEROSE campaign Nov-Dec 2022 with U. Miami MAERI instrument (N. Nalli)

2. Surface emissivity in the far-IR and midwave IR (600 – 1500 cm-1) clear sky
   - FIRARICAMEL with U. Wisc. ARI instrument (SSEC contact: Eva Borbas)

Action RTSP-7 on RTSP co-chairs

Request links to facilitate access to field experiment datasets for RTM evaluation / validation.

2.1.5 Aerosols

The group discussed the existence of a new UV optical database: the Super-spheroid model (Lei Bi, oral presentation 11.05):

> Kong, S., Sato, K. and Bi, L., 2022. Lidar Ratio–Depolarization Ratio Relations of Atmospheric Dust Aerosols: The Super-Spheroid Model and High Spectral Resolution Lidar Observations. *Journal of Geophysical Research: Atmospheres*, *127*(4), p.e2021JD035629

and the development of ML approaches to parameterize the database and its jacobians

> Yu, J., Bi, L., Han, W. and Zhang, X., 2022. Application of a neural network to store and compute the optical properties of non-spherical particles. Advances in Atmospheric Sciences, 39(12), pp.2024-2039.

It was discussed that the RTTOV OPAC/CAMS database now includes the following species: volcanic ash, Asian dust and the ICON-ARTS species. There is concern by RTTOV developers that there are many users, but they do not know who they are nor their needs.

Recommendation RTSP-6

Reach out to the aerosol community and survey their aerosol (physical) needs.

Recommendation RTSP-7 to aerosol community

The group encourages the publication of a literature review that includes new aerosol studies and challenges regarding VIS/near-IR aerosol sensitivities and spectral dependencies.

Recommendation RTSP-8 to aerosol community

The group continually supports field campaigns and the community to use field campaign data for validation studies. The group further recommends to connect aerosol FCs to RT evaluation.

2.1.6 Clouds

The group raised concerns over the RT and scattering properties developments needed for upcoming missions in the Far-IR. Mainly PREFIRE (launch ~2024) and FORUM (launch ~2027). Concerns were raised over the refractive index of ice variation and its large impact on its optical properties (extinction). There is a need for a better ice refractive index temperature sensitivity characterization.

Recommendation RTSP-9

Continue support for refractive index dependence studies on temperature in the far-IR.

The group discussed that far-IR spectral information content enables additional information on cloud properties, similar to the "scattering index."

Recommendation RTSP-10

Continue support to exploit synergy (i.e., FORUM+IASI-NG) in studies and retrievals.

Regarding optical properties in the far-IR, their parameterization in terms of effective radius was discussed as positive as it then enables analytic jacobian calculations. In this regard, it was mentioned that the Baran optical properties database was extended to the far-IR.

Action RTSP-8 on co-chairs

To get updates/plans of the Labonnete database, as well as P. Yang's recently funded project to improve ice far-IR refractive index.

Action RTSP-9 on Ben Johnson

Bring IPWG information on cloud properties into ITSC-24.

Recommendation RTSP-11 to RT developers

The group recommends the development/evaluation of fast scattering solvers such as the Chou/Tang phase function scaling methods (i.e., poster 1p.12 presented by Vidot et al.).

Recommendation RTSP-12 to RT developers

The group continues to recommend the development of cloudy RT model validation datasets.

The group discussed whether physical consistency across the spectrum in fast models is a priority. The following discussion points were raised:

- Ethel Villeneuve's work (presentation 1.05) on impact of inconsistencies between IR and MW cloudy simulations on NWP model error vs. other sources of error (currently 2nd order in DA system).
- Perturbations of NWP model parameterizations have a larger impact than hydrometeor habit assumptions.
- In radar sensitivity (Ku): convective parameterization / cloud fraction has a larger impact than changing shape / PSD parameters.
- In radiance space: representation of the cloud overlap scheme also has a large impact

  Recommendation RTSP-13

  Support sub-grid variability studies (NUBF effects / cloud fraction impact) studies.
- Open discussion as to whether physical consistency is important: "true" hydrometeor size/shape or spectral "significant" parameters are enough.

  Recommendation RTSP-14

  Support studies that can assess the impact/importance of habit/PSD parameter on radiance space.

Recommendation RTSP-15 to RT community

To continue the ongoing recommendation of model inter-comparison.

2.1.7 Surface properties

Eva Borbas reported on the recent release of CAMEL v3.0 released at NASA DAAC (Borbas, poster 10.p02). It is based on latest calibrated MODIS data and an updated climatology using a new time series updated to 2021. It has been evaluated against selected sites and needs NWP evaluation. Current research to extend certain properties to far-ir: using field campaigns focusing on snow/ice/sand (not yet available).

Recommendation RTSP-16 to fast model developers

To incorporate CAMEL v3.0, specially RTTOV / CRTM.

Similarly, Nick Nalli reported on a new snow surface model (presentation 10.03). This model is dependent on a complex refractive index dataset which is temperature dependent (Hori 2006, Warren and Brandt 2008). It includes only uniform snow surfaces so far and supports far IR.

James Hocking reported a new option available in RTTOV to incorporate subsurface models for snow and ice, as well as specifying per-channel effective skin temperatures.

The group further discussed that microwave observations over land are a problem for data assimilation (DA). The CIMR mission with L-band (6.9 GHz) observations was identified to be useful for land surface modeling. The group wonders whether this can be extended to higher frequencies in cloudy situations.

Recommendation RTSP-17 to NWP community

To identify partners for developing improved land surface emissivity models with the explicit intent of improving data assimilation over land.

Recommendation RTSP-18

To investigate AI approaches for land surface emissivity improvements, for example for real time modification of emissivity based on precipitation / flooding / etc.

The ARMS developers shared some model updates (presentation 15.03) on land emissivity of microwave over land: new complex refractive index for different surface types.

Regarding hyperspectral IR models, the following new studies were noted as relevant for the group:

- Yang, Qiguang, Xu Liu, and Wan Wu. "A hyperspectral bidirectional reflectance model for land surface." Sensors 20.16 (2020): trained on MODIS and extended to other wavelengths
- Vidot, J., Brunel, P., Dumont, M., Carmagnola, C. and Hocking, J. "The VIS/NIR land and snow BRDF atlas for RTTOV: Comparison between MODIS MCD43C1 C5 and C6." Remote Sensing, (2017).

2.1.8 AI / TL / AD sensitivity

The group identified areas where AI is being used effectively. For example:

- Neural network-based methods for simulating cloud- and aerosol-affected solar satellite channels (Leonhard Scheck, presentation 11.06): MFASIS on vis/near-IR/IR 0.4 - 2.2 micron.
- Hatfield, Sam, et al. "Building tangent-linear and adjoint models for data assimilation with neural networks." Journal of Advances in Modeling Earth Systems 13.9 (2021).

The group further identified areas that could benefit from AI approaches. For example:

- Cloud and precip. parameter tuning to decide the best configuration based on a large training dataset for DA. i.e., Geer, A. J.: Physical characteristics of frozen hydrometeors inferred with parameter estimation, Atmos. Meas. Tech., 14, 5369–5395, https://doi.org/10.5194/amt-14-5369-2021, 2021.
- Land surface emissivity.

There was some discussion as to whether it is the task of RT developers to provide this framework, and whether there is funding available for AI developments. In this regard, the EUMETSAT "AI roadmap" was mentioned as being the only "coordinated" effort at operator level that was known in the group. They provide AI Fellowships for 3 years – is this enough?

Recommendation RTSP-19 to funding agencies

To fund 3+ years for AI research into replacing or developing components that get used in operational context (e.g., fast models).

2.2 Climate

Web site: itwg.ssec.wisc.edu/cwsg/

Bill Bell (ECMWF, co-chair), Nathalie Selbach (DWD, co-chair), Likun Wang (Univ. of Maryland), Peng Zhang (CMA), Scott Mindock (UW-SSEC), Stefan Stapelberg (EUMETSAT), Timo Hanschmann (EUMETSAT), Ramesh P. Singh (Chapman University), Jonathan Mittaz (University of Reading), Dimitrios Kilymis (CNES), Heikki Pohjola (WMO), Joe Taylor (UW-SSEC), Per Dahlgren (Met Norway), Valentin Jules (Météo France), Bomin Sun (NOAA/NESDIS), Roger Randriamampianina (Met Norway), Marc Crapeau (EUMETSAT)

2.2.1 Meeting agenda

- Recap: The scope and terms of reference of the Climate Working Group & tour de table, capturing new items for discussion (see AOB)
- ERA6 developments relevant to CWG (Action Climate-1 from ITSC-23)
- Review of Previous Actions
- Review of CGMS Hight Level Priority Plan items of relevance to the CWG
- AOB
- Long-term stewardship of climate data (L0->L2)
- Challenges of capturing user requirements for climate data

2.2.2 Status update on actions and recommendations from earlier meetings

All but one action from the previous WG meetings have been closed. The section below gives the status on the recently closed and ongoing actions and a new update on some of the recommendations.

- **Status on Action Climate23-1 on presentation of preparation for ERA-6 at ECMWF**:
  A short presentation was given by Bill Bell on preparations for ERA6, covering the rationale for data denial experiments at ECMWF to establish the mean state uncertainties in the ERA6 reanalysis, and to identify high quality sensors which could, in principle, be withheld from the reanalysis to validate the estimated uncertainties. The two components of this approach are therefore: run denial experiments to estimate the resulting spread in the mean state (for temperature and humidity) which is one element of the uncertainty budget, and; use withheld reference sensors to validate these uncertainties in observation space. This included initial results from experiments which denied NOAA-20 ATMS, NOAA-20 CrIS and GMI. Broadly - changes in the mean state are typically several 10s mK and several tenths of a % in temperature and humidity respectively.
  This action has been closed at ITSC-24.

  A new action has been added to make the presentation available to the broader public:

  Action Climate-1 on Bill Bell
  To make the presentation on the preparations for ERA6 available on the webpage (either Climate WG subpage or main conference page).

Subsequent discussion in the group raised the suggestion that additional denial OSEs could be run in which additional groups of sensors were denied, to refine the estimate of the mean state uncertainty from the spread in the mean state from these OSEs.

- **Status on Action Climate22-1 to provide information on the status of information about FCDRs in OSCAR to the Climate WG**:
  Development work related to OSCAR/Space is continued, WMO has recently implemented a restful API to retrieve observation records in OSCAR/Space and return them as JSON records. The idea is to make OSCAR/Space WIGOS metadata record compatible allowing users to export information from the OSCAR/Space database based on the XML template, for example regarding the relationship between instruments and variables. The Joint Working Group Climate has been involved. The inclusion of information on FCDRs in OSCAR will be one the upcoming steps based on the recent updates of the OSCAR/Space system.
  This action is still ongoing, as the respective information still needs to be added to the Climate WG webpage.

- **Status on Action Climate23-2**
  To provide information NCEI Data stewardship maturity matrix and C3S convention to Climate WG webpage:
  This action has been closed at ITSC-24. The information is available on the Climate WG webpage.

- **Update on recommendation Climate23-7 to EUMETSAT to consider funding its own dedicated radiosonde program targeting MetOp satellites:**
  EUMETSAT operates a dedicated facility to monitor the performance of the Polar sounding products against radiosondes (MONA LiSA), which will be extended for IASI-NG and MTG-IRS. EPS-SG MWI/ICI instruments require dedicated, collocated radiosondes for instrument calibration, this will happen during the commissioning and Cal/Val phase of the EPS-SG B1 satellite (≥ 2025). This activity is currently expected to last about 3 months. EUMETSAT is currently contacting providers of radiosonde observations as many sondes are needed for this calibration. EUMETSAT is also exploring possibilities to extend this dedicated campaign into a long/longer term monitoring of EUMETSAT satellites. EUMETSAT is considering to have about 5 launches per week, over different latitude bands (preliminary status). EUMETSAT is in contact with GRUAN regarding such a service. GRUAN is currently determining costs per sonde launch, service contract costs, and EUMETSAT is further detailing required inputs for the calibration campaign during commissioning and the possible longer-term monitoring of the EUMETSAT satellites, e.g. how many sondes are needed, what type, what weather conditions, etc.

  Dedicated radiosondes funded by the NOAA JPSS program have been launched synchronized with NOAA polar orbiting satellites (SNPP, NOAA20, and NOAA21) for many years, at the DOE ARM sites (SGP, NSA and ENA) and Beltsville, MD (a GRUAN site). JPSS dedicated radiosondes have also been launched from ocean campaigns (AEROSE, CalWater) on a yearly basis targeting for NOAA and EUMESAT polar orbiting satellites. Those dedicated radiosondes are not assimilated at any NWP data assimilation and forecasting. They are potentially valuable in assessing the NWP reanalyses and forecasts for bias corrections and verification. GRUAN processed dedicated radiosondes are fully characterized, with the quality being suited to provide reference standard for satellite infrared and microwave data calibration/validation. Those dedicated radiosondes (along with GRUAN and conventional radiosondes) are routinely collected in the NOAA Products Validation System (NPROVS), an enterprise products validation system operated at NOAA/STAR, for monitoring and analyzing satellite infrared and microwave retrieval profiles.

- **Update on recommendation Climate-11 from ITSC-23 to satellite data product developers to report statistical uncertainties of the CDR trends together with the calibration uncertainties**.
  A new capability for determining a rigorous estimate of the CrIS measurement Radiometric Uncertainty (RU) for any individual spectrum from NASA L1b, Version 3, calibrated radiance files has been created. An improved version (V4) will become available later in 2023. RU is an upper bound of the bias with respect to the true radiance (coverage factor k=3 or 3-sigma, not including noise), and is scene and instrument environment dependent. RU for any selected spectra can be calculated using the L1b radiance data and a small amount of ancillary information provided in a static file. CrIS NASA L1b Radiometric Uncertainty Tool documentation, sample code, and static RU parameters file are now available via NASA GES-DISC procedure.
  DOIs for the respective GES DISC landing pages for CrIS Version 3 data:

  NOAA-20 FSR: 10.5067/LVEKYTNSRNKP
  SNPP NSR: 10.5067/OZZPDWENP2NC
  SNPP FSR: 10.5067/ZCRSHBM5HB23

  This topic has also been covered at ITSC-24 in a talk by Joe Taylor on the CrIS RU and the NASA L1b tool for calculating the RU for any CrIS spectrum (2.07 “Rigorous and Traceable Assessment of the CrIS Radiometric Calibration Uncertainty”)

2.2.3 Items from the CGMS High Level Priority Plan addressed by the CWG:

HLPP 5.1.1 Update the ECV Inventory of Climate Data Records, Gap Analysis and Coordinated Action Plan (CAP) of CEOS and CGMS and report on status of the implementation of the CAP

The Satellite Application Facility on Atmospheric Composition (AC SAF) is in charge of updating the ECV inventory for EUMETSAT for the GHG parameters. Reprocessing is done at EUMETSAT (and its SAFs) for different CDRs. The information is added to the ECV inventory as it becomes available (planned and released CDRs),

HLPP 5.1.5 Foster the implementation of the architecture for climate monitoring from space by strengthening the analysis of use cases for climate data records to increase usage in climate services and science

It was noted that the analysis (and development of) use cases formed an important part of the Copernicus Climate Change Service (C3S) in Europe and provided an ongoing comprehensive rationale for Earth Observations in support of climate services. The C3S Sectoral Information Systems (SIS) & Evaluation and Quality Control (EQC) components aimed to develop sector specific tools and provide detailed monitoring and analysis of user feedback. In addition, the registered user numbers for the ERA5 Reanalysis had exceeded 100 000 users early in 2023, 5 years after the first publication of the initial reanalysis production streams.

Other initiatives in Europe include ESA CCI and EUMETSATs CM SAF both of which include use case development as well as outreach and training activities to foster the growth of the user base, and uptake of products for operational climate monitoring. The CWG was unaware of the status of similar initiatives in other major regions.

Recommendation Climate-1 to meteorological satellite agencies and other providers of CDRs

> **To provide updates to CWG / CGMS on the status of their current activities relating to user uptake and impacts of CDRs. This type of activities is seen as important for uptake of the products by users and it is recommended to consider development of similar activities to the above mentioned in case there are no such activities yet.**

HLPP 1.1.1 Ensure continuity of passive microwave imager observations

Ensuring continuity of passive microwave imager observation is strongly supported by the climate group, including lower frequencies (e.g. to support SST estimation). The CWG noted the trend to small satellites and therefore higher frequencies with potential compromises in channel availability at lower frequencies. Support for the requirements for lower frequencies remains strong, and heritage channels are required for continuity of CDRs.

An increase in interest and investments in small satellites in both MW and IR was noted as well. This potential trend strengthens the scientific case for independent on-orbit calibration capabilities especially for climate applications (e.g. CLARREO), as small satellite radiometry may have compromised on-orbit calibration capabilities.

Recommendation Climate-2 to space agencies

> **To note the link between (on the one hand) a tendency to small satellite technology, potentially entailing compromised calibration capabilities and (on the other hand the scientific case for independent on-orbit calibration missions, such as CLARREO.**

HLPP 1.2 Advance the response to the Vision for WIGOS in 2040 for space, by the implementation of new capabilities beyond the CGMS baseline

The CWG supports extensions of the capabilities beyond baseline, but expressed concern that such extension could compromise baseline capabilities. For example, planning on LEO/GEO in US potentially foresees more GEO at the cost of reduced LEO capacity. The CWG stressed the importance of maintaining the current LEO configuration (including keeping the 13:30 orbit), especially for climate. In addition, the CWG view is that small satellites should only be complimentary (to the LEO baseline) in the first instance, due to concerns about longevity and calibration stability/accuracy.

The CWG noted the lack of plans for operational limb sounding missions, especially considering the anticipated end of the MLS instrument. The group supports demonstrator missions e.g. the first ESA Scout Mission (ESP-MACCS/ CubeMAP), which delivers observations that could be used in climate applications (UTLS humidity in the tropics) and which could pave the way for low cost extensions to future larger operational missions.

HLPP 1.1 Ensure long-term continuity of OSCAR/Space as a primary tool to support the CGMS

The CWG agreed that OSCAR/Space is a very valuable resource and is widely used in the community. Strengthening the climate aspect in OSCAR/Space is important. It would be beneficial to implement a functionality to indicate FCDR/CDR/ECV links to OSCAR/Space that CDR inventories could feedback into the OSCAR/Space with information on which instruments are being used for which FCDR/CDR/ECV products.

A user workshop for OSACAR/Space took place in February 2023 (https://community.wmo.int/en/meetings/wmo-oscarspace-user-workshop) with the aim to collect feedback as a guidance for the future development strategy of OSCAR/Space.

HLPP 2.2 RFI related issues

This topic is covered in the RFI technical subgroup in detail. The CWG noted that CDRs can be contaminated by RFI. RFI is therefore potentially an issue for climate applications, including trend analysis, esp. in regional applications.

HLPP Items 4.1.1 – 4.1.4 & 4.4

(Re. the role of GSICS in ensuring quality of long-term satellite records for CDRs)

In addition to the methods forming the core techniques of GSICS (e.g. SNO) the group noted the continuing development and successful application of metrology-based approaches (examples include the analysis of MSU biases arising from radiometric and spectral calibration, the increasingly comprehensive uncertainty analyses accompanying CrIS data records and FCDR/CDR production at EUMETSAT). There is a need to standardize vocabulary and terminology in documenting this area.
It was noted that the current focus of GSICS activities is current operational sensors, and climate applications would benefit from increased prioritization of historic sensors.

Recommendation Climate-3 to GSICS

> **Extend the calibration and harmonisation activities to historic sensors to support climate applications, including CDR / ECV production and reanalysis.**

2.2.4 New discussion items

Requirements for long-term stewardship and support for the use of L0, L1 and L2 data

The CWG discussed the issue of long-term support for the use of L0, L1 and L2 data, which does not only cover the data itself but also includes all relevant metadata and documentation. This requirement applies to all sensors used in climate applications, including older satellites. Especially for climate applications re-calibration efforts for historic / non-operational satellites are important in order to ensure high quality of the respective climate data records. Unfortunately, it is sometimes difficult to get information to work with the data (e.g. calibration coefficients, spectral characteristics etc.). Often this is information which exists, but is unavailable to users (e.g., some older non-digitized documentation in an archive at the data provider or knowledge of team members, which might get lost once they leave the respective organization). One idea is to seek to improve the situation for current sensors (by collating existing documentation, establishing a repository for this information, establishing standards for the formats/contents of documentation and data, analysing best practises) in order to have the full characterization of the data available for (climate) applications.

Recommendation Climate-4 to satellite providers

> **To catalogue the available data and supporting information, make information available to users.**

In terms of Actions for the CWG: it was acknowledged that this is a large task, requiring sustained effort across several years, and significant coordination work across agencies. As a constructive start it was decided to identify ‘champions’ within the CWG to agitate within the major meteorological satellite agencies, to act as our point of contacts, and to report status and progress at their respective agencies back to the CWG, in order to enable CWG to report status and progress.

Action Climate-2

Establish status and plans for long-term stewardship of L0, FCDRs and CDRs and all relevant metadata and documentation at respective agencies The following group members will provide information on this task:
P. Zhang for CMA (FY-series)
T. Hanschmann for EUMETSAT (Meteosat and Metop programmes),
Joe Taylor for CrIS in NOAA and identify relevant point of contact for wider NOAA data records.

User requirements/feedback for CDR

The essence of this item is the recognized difficulty in capturing user requirements related to climate applications of sounding data. This includes, among others, the difficulties in accurately sampling user applications in a representative way; quantitatively analysing user requirements for climate data records, and translating these requirements into detailed instrument specifications. It was noted that in Europe the EU's Copernicus Climate Service (C3S) already includes well supported components aimed at developing user applications and capturing user feedback on the products provided. Nevertheless it is acknowledged that this remains a challenge. Discussion on this topic is reflected in the section above on the HLPP Item 5.1.5 ("Foster the implementation of the architecture for climate monitoring from space by strengthening the analysis of use cases for climate data records to increase usage in climate services and science")

Ongoing CDR production at NOAA

It was noted by the NOAA representatives present that the community require more accurate CDRs for climate trend detection to understand how climate changes in response to human emissions of greenhouse gases and for evaluating climate model simulations. The newer satellite instruments have the advantage of measuring and containing more calibration parameters and are likely to serve as references after careful recalibration. NOAA has recently developed a backward merging approach using the latest microwave sounder observations as a reference to recalibrate earlier old MSU instruments. Such an approach could be useful for infrared instruments as well.

2.3 Data Assmiliation and Numerical Weather Prediction

Web site: itwg.ssec.wisc.edu/nwp/

Working group members: Brett Candy (Co-Chair, Met Office), Fiona Smith (Co-Chair, Bureau of Meteorology), Olivier Audouin (CNRM, Météo-France & CNRS), Asmund Bakketun (Met Norway), Nancy Baker (Naval Research Lab), Bill Bell (ECMWF), Niama Boukachaba (Morgan State University/ NASA GSFC/ GMAO), Chris Burrows (ECMWF), Bill Campbell (Naval Research Lab), Thomas Carrel (CNRM), Krishna Chandramoorthy (Centre for Climate Research Singapore), Hui Christophersen (Naval Research Lab), Hyoung-Wook Chun (KMA), Andrew Collard (NOAA/NCEP/EMC), Olivier Coopmann (CNRM, Université de Toulouse, Météo-France and CNRS), Per Dahlgren (Met Norway), Mohamed Dahoui (ECMWF), Thomas Deppisch (DWD), David Duncan (ECMWF), Reima Eresmaa (Finnish Meteorological Institute), Nadia Fourrie (CNRM Meteo-France and CNRS), Stephanie Guedj (Met Norway), Vincent Guidard (CNRM, Météo-France and CNRS), Hanna Hallborn (Chalmers University of Technology), Wei Han (CMA Earth System Modeling and Prediction Centre), Chawn Harlow (Met Office), Lingli He (CMA Earth System Modeling and Prediction Center), Dirceu Herdies (INPE), Hao Hu (CMA Earth System Modeling and Prediction Centre), Han-Byeol Jeong (KIAPS), Erin Jones (UMD CISESS at NOAA/NESDIS/STAR), James Jung (CIMSS/UW-Madison), Eric Jurado (CNES), Bryan Karpowicz (University of Maryland Baltimore County), Eun-Jin Kim (KIAPS), Hyeyoung Kim (KIAPS), Christina Koepken-Watts (DWD), S. (NCMRWF) , Ahreum Lee (KIAPS), Sihye Lee (KIAPS), Magnus Lindskog (SMHI), Emily Liu (NOAA/NCEP/EMC), Haixia Liu (Lynker@NOAA/NCEP/EMC), Cristina Lupu (ECMWF), Joel McCorkel (NASA GSFC), Stefano Migliorini (Met Office), Mate Mile (Met Norway), Jonathan Mittaz (University of Reading), Isabel Monteiro (KNMI), Nick Nalli (NOAA/NESDIS/STAR), Kozo Okamoto (JMA/MRI), Heikki Pohjola (WMO), Samuel Quesada-Ruiz (ECMWF), Roger Randriamampianina (Met Norway), Indira Rani (NCMRWF), David Rundle (Met Office), Benjamin Ruston (JCSDA), Nahidul Samrat (Bureau of Meteorology), Kirsti Salonen (ECMWF), Jana Sanchez-Arriola (AEMET), Tracy Scanlon (ECMWF), Yi-Ning Shi (CMA Earth System Modeling and Prediction Centre), Hiroyuki Shimizu (JMA), Liam Steele (ECMWF), Olaf Stiller (DWD), Jon Taylor (Met Office), Sreerekha Thonipparambil (EUMETSAT), David Tobin (CIMSS/SSEC/UW-Madison), Likun Wang (UMD), Ethel Villeneuve (CNRM, Université de Toulouse, Météo-France, CNRS), Hongyi Xiao (CMA Earth System Modeling and Prediction Centre), Jun Yang (CMA Earth System Modeling and Prediction Centre), Xiaoyan Zhang (NOAA/NCEP/EMC), Lihang Zhou (NOAA), Yanqiu Zhu (GMAO)

The Working Group meeting was held on 18th March 2023.

2.3.1 Actions from the previous meeting

The status of the actions from the previous conference can be found on the DA/NWP website: https://itwg.ssec.wisc.edu/nwp/action-item-status/
Most actions were completed and standing actions can be seen in Appendix 1. The following actions were still outstanding, and were discussed during this meeting and closed:

- **Action DA/NWP 22-13 on WG Members**:
  Share impact assessment results for FY-3E with the group and CMA as soon as possible after data becomes available, in particular to provide evidence for support of the early morning orbit.
  (See section 2.3.6)

- **Action DA/NWP 23-17 on WG members**:
  To review Space Agency contacts page on the website.
  (See section 2.3.10)
- **Action DA/NWP 23-18 on WG members**:
  Provide impact recent LAM study references to WG co-chairs for inclusion on the website
  (See section 2.3.10)

2.3.2 Recommendations from the previous conference

The DA/NWP Working Group has a long list of standing recommendations. which can be found in Appendix 2. The WG endorsed maintaining all of these recommendations.

2.3.3 Radio Frequency Interference

Regarding **Standing Action DA/NWP-2 on DA/NWP WG members** (Send any evidence of RFI to co-chairs of the RFI Technical SubGroup), there had been little progress on this action and the group discussed several observation types that could be used to identify sources of RFI. The COWVR instrument allows a forward and aft look at the same scene which could be very helpful in identifying RFI. NRL have access to this data. A followup action is to provide more information about the COWVR instrument

Action DA/NWP-1 on Bill Campbell

To circulate information about the COWVR instrument and RFI detection principle to the WG.

2.3.4 CGMS HLPP

Relevant parts of the CGMS High Level Priority Plan (HLPP) were reviewed and discussed.

Microwave sounding: Revisit time

The current recommendation from WMO and CGMS is to have microwave sounding in three main orbits (early morning, morning, afternoon) plus three additional orbits. The new WMO vision for the evolution of WIGOS contains a statement that WMO recommend hourly microwave sounding data. Due to the characteristics of the polar orbit, revisit time will vary with location (polar regions would have a higher revisit time than at the equator). It could be assumed that "hourly" refers to orbits with equator crossing times separated by one hour.

Recent research including a presentation at this conference from ECMWF (Katie Lean) demonstrates that three additional orbits of microwave sounding continue to add impact to NWP, supporting the current WMO and CGMS position. Additional orbits that provide data hourly at the equator via sun synchronous orbits may not be the distribution that delivers the best value for NWP. Studies to date have not considered the impact of low-inclination orbits in conjunction with SSO and mid-inclination orbits.

The requirements for observation provision for NWP could be different depending on the physical variable associated with the type of sounding/imaging (e.g. more frequent humidity sounding could be required relative to temperature sounding). Other influencing factors are the model domain and resolution.

There are therefore some open questions which could benefit from additional studies with simulated data.

Recommendation DA/NWP-1 to DA/NWP WG members

Conduct simulated impact studies to establish optimal revisit times for microwave sounders in both global and regional models, in particular considering low inclination orbits, and report back at next ITSC.

Progress on extension of MW sounders over sea-ice and difficult surfaces

Discussion took place on the challenges of using more sounder information over surfaces such as sea-ice and snow. Mixed surface types in the field of view are also difficult to deal with. It was noted that several centres use, or are planning to use, dynamic emissivity retrieval. Other approaches discussed involved using AI or other techniques to derive a fast model from a fuller descriptive model of the snow surface. There were several presentations on this topic at the conference.

Action DA/NWP-2 on WG co-chairs

Contact Steve English to obtain more information on his proposal for snow and/or sea ice emissivity ISSI project and circulate to Working Group members.

It was noted that EPS-Sterna mission with its focus on high latitudes may require a specific approach for treating sea-ice and snow. There is an EPS-Sterna workshop in April, which may highlight areas where more research is required to exploit the data.

Action DA/NWP-3 on Brett Candy

Report to WG members on any useful discussion that took place on use of microwave data over sea ice, snow or land at EPS-Sterna workshop in April 2023.

Recommendations regarding the Microwave Constellation

The WG had already discussed requirements in 2022 on the microwave constellation and it was decided that these were still relevant. The WG previously made the following recommendations which we retain at this meeting:

Recommendation DA/NWP-2 to CGMS

Communicate to satellite data providers that the stability and consistency of bias and noise for individual passive radiometer instruments within a constellation of Small/CubeSats are very important for implementation. Consistency between instruments within the constellation is also critical.

Recommendation DA/NWP-3 to CGMS

Communicate to satellite data providers that given Recommendation DA/NWP-2, the requirement from NWP Centres for single instrument longevity within any constellation of Small/CubeSats should be a threshold of three years post-commissioning (below which many centres will not use the data) and an objective of five years (where most NWP centres will aim to use the data). If the overall mission is of long duration, the threshold for an individual satellite could be lowered to two years post-commissioning.

Additionally, the following recommendation applies equally to infrared and microwave data, but should be conveyed to CGMS in the context of their enquiry about NWP requirements for the microwave constellation.

Recommendation DA/NWP-4 to CGMS and data providers

> **Radiance data from new satellite instruments should be disseminated using WMO pre-approved BUFR sequences, consistent with other similar data types where possible.**

It was reported at the meeting that ISRO has recently launched a humidity sounder on a small sat mission in an orbit with low inclination. A follow-on operational mission similar to the successful SAPHIR mission is also under consideration. The WG considers humidity sounding in this orbit to be very valuable.

Recommendation DA/NWP-5 to data providers

> **Given the positive impact of SAPHIR on numerical weather prediction, and the uniqueness of the inclined orbit for sounding, and the lack of opportunity to use MADRAS data following its early failure, the WG supports a follow on mission that has similar or extended capability relative to SAPHIR and MADRAS in an inclined orbit.**

It is increasingly likely that commercial missions will provide microwave sounding data. Due to the commercial nature there is likely to be a different relationship with the data providers, especially with regards to information about the mission which is considered intellectual property, but nevertheless is critical for assimilation of the data. An example of this is the channel SRFs. The WG is grateful to WMO for their engagement with commercial earth observation providers and recommends that this continues so that the needs of NWP are communicated.

Recommendation DA/NWP-6 to WMO

> **Continue to engage with commercial satellite providers to convey NWP requirements via industry days etc.**

Action DA/NWP-3 on Heikki Pohjola

> **Share WMO best practice guide on achieving user readiness with commercial satellite providers.**

Recommendation DA/NWP-7 on CGMS and WMO members

> **When commercial satellite data is purchased, ensure provision to users of the necessary data and meta-data required to make use of the data in applications, as early as possible.**

Timeliness requirements for sounder observations

DBNet provides very timely observations with a goal of 20 minutes. The timeliness requirement for NWP may vary between centres as it depends on the cycling requirements of the assimilation system. For instance, if rapid update cycling is used, the requirement is for observations to be available within around 20 mins after the end of the assimilation window. It was also noted that observations at the end of the window tend to have the most impact. It was suggested that the WG gain insight into the timeliness impact through running appropriate experiments.

Action DA/NWP-4 on WG co-chairs

> **Organise a task team to perform experiments to establish the impact of data latency in both global and local assimilation systems.**

2.3.5 Principal component compression of hyperspectral IR observations

CGMS have requested guidance on methods for PC-compression of hyperspectral IR observations, and an update on the use of such products. The group has previously recommended that the full noise covariance matrix is used in PC-compression (Standing Recommendation DA/NWP-5) and that working group members assess the promising hybrid compression approach with EUMETSAT IASI data (Recommendation DA/NWP 22-14). However, no feedback has been received by the WG co-chairs on any such tests. Posters on the hybrid compression approach have been presented at this conference by Tim Hultberg (EUMETSAT) and Dave Tobin (CIMSS).

ECMWF have tested the impact of a change in IASI eigenvector basis, and report that it has no impact on subsequent use of the data (Cristina Lupu), though have not examined the use of hybrid PCs. A number of centres have verified that EUMETSAT PC-compressed radiances meet their assimilation needs.

There have been no reports on the evaluation of the experimental CIMSS hybrid PC product for CrIS. WG members are encouraged to continue to evaluate hybrid PC products.
The main purpose of hybrid eigenvectors, instead of purely climatological vectors, is to enable retention of signals that are not contained within the training data, such as unusual events. Whilst this allows retention of spectral information, this is not expected to be of large impact for NWP users, since they would expect to not use observations affected by unusual events in their systems anyway, due to a lack of appropriate forward modelling. Nevertheless, the hybrid approach still seems to be the most reasonable product to meet the needs of all users.

Action DA/NWP-5 on Fiona Smith
> **Check with Tim Hultberg and Dave Tobin regarding what feedback has been received on hybrid PC-scores and report to CGMS.**

Recommendation DA/NWP-8 on WG Members
> **Contact Dave Tobin for testing of hybrid PC-compressed CrIS observations.**

2.3.6 Hyperspectral sounding in early morning orbit

NOAA/NESDIS have requested feedback from the community on the impact of having a hyperspectral IR sounder in the early morning 5.30 AM orbit. At the previous working group meeting, an action was set (DA/NWP 22-13) to share impact assessment results for FY-3E.

No results from FY-3E HIRAS have been presented at this conference, and we therefore update the previous action with a request to provide impact assessment results to NOAA as well as CMA.

Action DA/NWP-6 on WG Members
> **Share impact assessment results for FY-3E with the working group, NOAA and CMA as soon as possible in particular to provide evidence for support of the early morning orbit.**

2.3.7 Proposed switch of S-NPP CrIS to MWIR + SWIR instead of LWIR

NOAA/NESDIS have asked whether the NWP community would support a switch of S-NPP CrIS to a MWIR+SWIR configuration rather than LWIR, once NOAA-21 commissioning is complete. The group were interested to know whether the proposed change was for a permanent switch, and how long the S-NPP data would continue to be provided, given that OSPO previously indicated only two satellites would be processed. OSPO have now confirmed that they will continue to process S-NPP on a best endeavours basis. It is thought that the proposal to switch the bands would be permanent.

The group is interested in the concept of the 3D-winds proposed if the switch occurs, but in general adheres to the previous recommendation, made previously by a WG member consensus via email, that because of the continued impact of the LWIR from S-NPP CrIS, and a requirement for LWIR channels to perform cloud detection before use of MWIR channels, it is preferred to maintain the current configuration with S-NPP CrIS. Many WG members propose to continue assimilation of S-NPP CrIS after NOAA-21 becomes operational.

Recommendation DA/NWP-9 to NOAA/NESDIS

Continue provision of LWIR band on S-NPP CrIS after NOAA-21 is declared operational.

2.3.8 Imager channel cluster analysis for hyperspectral IR sounders

NOAA/NESDIS (Lihang Zhou and Likun Wang) requested feedback from the WG members on the new VIIRS cluster analysis they have produced following recommendations at previous conferences.

Feedback from ECWMF (Chris Burrows) is that the VIIRS clusters for CrIS behave identically to the AVHRR clusters for IASI, and can be used in cloud detection algorithms with the same thresholds. NCEP (Jim Jung) are also evaluating the cluster product. The EUMETSAT NWP-SAF cloud and aerosol detection software will be updated to include the use of the VIIRS cluster data.

Feedback on the representation of the VIIRS clusters within the BUFR file, from ECMWF (Chris Burrows) and NCEP (Andrew Collard) is that the spectral radiance units for the clusters are inconsistent with those of the CrIS channels. This is not the case for IASI. The spectral radiance units are $W/m^2/sr/m^{-1}$ for IASI and AVHRR clusters, $mW/m^2/sr/cm^{-1}$ for CrIS and $W/m^2/sr/\mu m$ for VIIRS Clusters. This is awkward and potentially confusing for users, though may be difficult to change in the CrIS processing change which relies on MODIS heritage for VIIRS.

Recommendation DA/NWP-10 to data providers

Use SI Standard units for spectral radiance in all BUFR products ($W/m^2/sr/m^{-1}$).

The working group received a request from CNES for confirmation whether clustering is required for IASI-NG and whether the algorithm needs to be consistent across instrument types.

Recommendation DA/NWP-11 to CNES

Cluster analysis of MetImage radiances within IASI-NG FOV is required in the IASI-NG BUFR products.

Action DA/NWP-7 on WG members

> **Provide feedback to Eric Jurado (eric.jurado@cnes.fr and copy to WG co-chairs) on proposed methodology for MetImage cluster analysis within IASI-NG FOV.**

Vincent Guidard has previously proposed a map of which cluster each Met-Image pixel is in should be provided in the BUFR. It was noted that due to the large number of Met-Image pixels within each IASI-NG FOV, this represents a massive increase in data volumes. WG members were hesitant to commit to the use of such a product, but are interested to see whether it may be useful.

Recommendation DA/NWP-12 to EUMETSAT

> **Investigate whether a map of the cluster that each MetImage pixel within each IASI-NG FOV falls into could be provided as an additional auxiliary product.**

2.3.9 Extension of CAMEL atlas into VIIRS era

The CAMEL emissivity atlas is noted to be very important for enabling and enhancing the use of IR sounding data over land. Maintaining an up-to-date atlas is seen as critical to meet NWP needs. Eva Borbas has reported at this conference that a new version has just been released based on 2021 climatology. The working group members would like to ensure that the CAMEL atlas is maintained beyond the lifetime of MODIS and therefore recommend that it is extended into the VIIRS era.

Recommendation DA/NWP-13 to Eva Borbas

> **Continue to update the CAMEL atlas, extending to VIIRS to ensure continuity beyond the life of MODIS.**

2.3.10 Working Group matters

The group website can be found here: https://itwg.ssec.wisc.edu/nwp/
Space Agency contacts have not been updated since the last in person conference (despite an action) and were already out of date at that time. WG members do not use this part of the website, so we propose to delete the page.

At the last conference, the WG members maintained interest in keeping the page on regional models as a useful resource for someone starting to use radiances in a LAM. The page has not been updated since the last conference but there is still interest in gathering a list of resources, and to have a science discussion on verification and validation for satellite experiments in LAM.

Action DA/NWP-8 on WG co-chairs

> **Remove out of date and unused pages on WG website and update any that require it, including references on satellite data in LAM.**

Action DA/NWP-9 on WG co-chairs

> **Organise a science meeting on verification and validation for satellite experiments in LAM.**

Regarding the NWP Working Group Survey on use of satellite sounders in NWP, the WG members had worked hard to update the survey before the conference. It remains a valuable resource that members do use between conferences. Some enhancements were suggested:

- Information regarding the use of and method for calculating error covariance matrices

- Channel use over seaice
- Information on the use of coupled systems (e.g. sea ice, SST, ozone and other chemical species)
- Cut-off times for model runs (global and local)

Action DA/NWP-10 on WG co-chairs
Update NWP WG survey to include changes proposed at this conference.

2.3.11 Coupling NWP with other systems

Many NWP centres are moving towards the use of ancillary data from other models, and in many cases towards coupling the models together. These include various surface and chemistry models. The group had a brief discussion about how to engage with other working groups that cover these systems, in such a way that enables cross-system sharing and usage of information. The interaction with the atmospheric community and ITWG is particularly weak at the present time.

This question is more broad than the NWP Working Group, as extending the remit of the conference or encouraging members from the other communities would potentially change the scale of ITWG. Heikki Pohjola (WMO) reported that CGMS are working on future strategy for this, with an activity at WMO last week, which will likely influence the direction that this working group takes. In the meantime, the following recommendation was proposed:

Recommendation DA/NWP-14 to ITWG co-chairs
Organise a discussion topic for future conferences on use of coupled systems in sounder radiance assimilation.

Additionally, the group discussed the remit of the working group regarding the use of imager data - IR imagers are usually considered sounders, but the visible channels are an extension well beyond TOVS capability. In general, the group is interested to discuss the use of visible channels where they are being used for or to aid in retrieval or analysis of temperature and/or humidity.

Appendix 1: DA/NWP Working Group Standing Actions

Standing Action DA/NWP-1 on ITWG Co-chairs: To bring relevant recommendations to the attention of CGMS.

Standing Action DA/NWP-2 on DA/NWP WG members: Send any evidence of RFI to co-chairs of the RFI Technical SubGroup - Jean Pla (jean.pla@cnes.fr), Richard Kelley (richard.kelley@noaa.gov), Stephen English (stephen.english@ecmwf.int) and Nancy Baker (nancy.baker@nrlmry.navy.mil).

Standing Action DA/NWP-3 on DA/NWP WG members: If you have estimates of revised channel characteristics resulting from post-launch diagnostics, please email these to the radiative transfer working group chairs (Benjamin.T.Johnson@noaa.gov and vito.galligani@cima.fcen.uba.ar).

Standing Action DA/NWP-4 on NWP centres: Continue to provide information on instrument channels assimilated and their observation errors via the working group survey spreadsheet in advance of each conference.

Standing Action DA/NWP-5 on DA/NWP WG Members: Make suggestions and corrections to the DA/NWP Working Group website.

Appendix 2: DA/NWP Working Group Standing Recommendations

Standing Recommendation DA/NWP-1 to the satellite agencies: In support of maintaining a robust global satellite observing system, instrumentation to allow continued sounding of the temperature of the upper stratosphere and mesosphere (as for the SSMIS UAS channels) should be explored.

Standing Recommendation DA/NWP-2 to funding bodies of NWP centres and space agencies: Consider, as part of the cost of satellite programmes, providing computational and personnel resources targeted at operational NWP centres to optimise the public's return on investment from these expensive measurement systems.

Standing Recommendation DA/NWP-3 to data providers: Include azimuthal viewing and solar angles as appropriate in BUFR for present and future instruments.

Standing Recommendation DA/NWP-4 to space agencies and data providers: When designing new or modified BUFR formats, please circulate drafts to the NWP community via the NWP Working Group for feedback, prior to submission to WMO.

Standing Recommendation DA/NWP-5 to data providers: When using PC compression, noise normalisation should be performed using the full noise covariance matrix.
[HLPP: 4.2.6 Establish together with the user community a commonly agreed approach for retrieval of Principal Component scores and associated parameters from hyperspectral infrared data, minimising information loss including the mutually acceptable update strategy for the principal component basis and to implement such an approach in a coordinated manner.]

Standing Recommendation DA/NWP-6 to data providers: If a change to data processing results in a change in brightness temperature of 0.1K or 20% of NEdT (whichever is smaller), this should be made clear in notifications to users. These notifications should be made no later than 8 weeks before the change and test data should be provided if possible.
[HLPP: 3.17 Develop best practices for operational user notifications.]

Standing Recommendation DA/NWP-7 to data providers: The overlap period where one satellite resource is replacing another should be chosen after consultation with the user community and should follow WMO guidelines.

Standing Recommendation DA/NWP -8 to data providers: Provide NedT estimates for inclusion within BUFR for microwave data.
[HLPP 4.4.2 Agree on standardised procedures to derive NedT estimates for microwave sounders, and include such estimates in the disseminated BUFR data.]

Standing Recommendation DA/NWP-9 to data providers: Make NedT estimates from microwave instruments available as time series on publicly available websites to enable monitoring of instrument health in near real time.

Standing Recommendation DA/NWP-10 to instrument developers: Pre-launch calculation of NEdT should use the same algorithm as will be used in-orbit using warm target counts variability divided by the instrument gain.

Standing Recommendation DA/NWP-11 to data providers: Develop and maintain public instrument status monitoring web pages similar to the Integrated Calibration and Validation System (ICVS) from NOAA/NESDIS.

2.4 Advanced Sounders

Web site: itwg.ssec.wisc.edu/aswg/

Working Group Co-Chairs: Dorothee Coppens (EUMETSAT), David Tobin (SSEC/UW-Madison

2.4.1 Working Group meeting agenda: 18 March 2023

The ASWG held its working group meeting on 18 March 2023. Co-chairs are Dorothee Coppens and David Tobin. The meeting agenda included the following topics:

1. Discussion on the decision to switch SNPP CrIS to SWIR+MWIR
2. Impact of having a hyperspectral IR sounder in the 5.30 AM orbit
3. How future GEO IR sounders and LEO sounders complement each other
4. Discussion on the GEO-MW
5. Discussion of future/advanced sounders from the MW included in the ASWG
6. Review of long standing recommendations
7. Discussion of optimal use of advanced sounder data in NWP
8. Communication from CGMS/High Level Priority Plan interesting for the ASWG

There were approximately 75 participants. The ASWG email list was updated, and all ASWG participants may be reached via email with the following address: itwg_aswg@g-groups.wisc.edu

The following is a summary of the various topics that were discussed at the working group meeting, generally following the above agenda, along with associated recommendations and actions.

2.4.2 Plans and Questions regarding NOAA satellites

Discussion on the decision to switch S-NPP CrIS to SWIR+MWIR

Context from NOAA: With NOAA-20 and NOAA-21 in-orbit, there are considerations for switching S-NPP CrIS from its current configuration of LWIR+SWIR to MWIR+SWIR. The NOAA requirement is for two satellites in operations, switching the third spare S-NPP should not be an issue. Additionally, NOAA would also like to know if other ITWG participants besides NOAA plan to study exploiting the three CrIS configurations for global AMV retrievals.

Discussion:

- ECMWF stated that the LWIR is currently used to get the cloud information. Using MWIR is under study but far to be operational. Also the switch from LWIR to MWIR is not easy. ECMWF is assimilating as much LWIR instrument data as possible.
- Bill Smith reminded that the boundary water vapour level are coming from the LWIR band. This information is important for the convective models.
- There was discussion on having 2 or 3 sensors for the 3D wind retrievals, and the WG recommended to ask the winds community experts for what is needed. There was further discussion that assimilation of IR data in NWP is producing large impacts/improvements in derived winds, and that direct retrieval of wind data from tracking is not the only way to get wind information.

- There was discussion of what would be the schedule for switching S-NPP CrIS from LWIR+SWIR to MWIR+SWIR. The timeframe for the change would be done step by step. In August or September of this year NOAA will begin this process. If everything goes through, it will be switched next year, although the final decision to make this change is TBR.

Outcomes of the WG discussion:
Action AS-1 on NOAA
To further discuss/consider the 3 CrIS configuration at the wind workshop in May.

Recommendation AS-1 to NOAA
To keep the LWIR band, since the LWIR data is very important for NWP.

Discussion on the impact of having a HS IR sounder in the 5.30 AM orbit
Context from NOAA: While the NWP community largely supports the WIGOS 2040 vision about a 3 orbit global backbone, the impact studies for 3 IR sounders is not well demonstrated. There has been a lot of studies showing the impact of MW sounders with a mix of AMSUs on legacy POES, Metop and ATMS from JPSS. But such global impact studies with hyperspectral IR sounders in 3 orbits is sparse.

Discussion:
- CMA (Wei Han) mentioned that they have studied the impact of the 5:30am orbit using recent HIRAS data and has shown good benefits.
- One of the major impacts is regarding benefits to predicting convection.

Outcomes:
Action AS-2 on CMA
To circulate to ASWG the preliminary findings of the impact when using the 5:30am orbit.

Recommendation AS-2 to NOAA
To take into account the outcome of the impact study of the 5:30 am orbit and possibly to consider the 5:30 am orbit as beneficial to the community.

Discussion on how future GEO IR sounders and LEO sounder compliment each other
Context from NOAA: The LEO program has done several workshops to engage with the sounding community (https://www.nesdis.noaa.gov/current-satellite-missions/currently-flying/joint-polar-satellite-system/jpss-workshops-events). With LEO and GEO both planning to launch IR sounders, the complementarity of similar measurements in LEO and GEO needs better justification. The WIGOS vision says we need them but does not say why.

Discussion:
- GEO and LEO are complementary: spatial/temporal resolution vs spectral resolution/low noise.
- LEO orbits are essential in the polar regions and for the water vapour diurnal variation.
- Northern users don't benefit from GEO orbit because they are located at too high latitude.
- GEO ring is still not guaranteed.
- GEO-XO will be located in the centre. So there are holes in the West and East.

- Coming from IIFS WG: CNES is funding an OSSE to see the impact of the GEO orbit on top of the LEO ones.

Outcomes:
Recommendation AS-3 to NOAA
To pursue the LEO program.

2.4.3 Discussion on GEO MW

Context: Strong evidence have been shown in the last years that:

- A GEO MW sounder can now be implemented (e.g., based on the JPL GeoSTAR design).
- Its performance would exceed that of current LEO MW sounders in many respects.
- It would provide measurements not currently available and that will be of great value in a number of application areas.
- Complementary to GEO IR sounders in providing additional information (e.g., high intensity and high variability precipitation), two systems (GEO/IR and GEO/MW) would provide maximum information if operated together.

Discussion:

- The concept is fully supported by the AS group.
- Comment from UK Met Office that this is a bit in competition of small satellite concept.
- Constellation of small satellites will be slightly considered as different instruments which won't be the case of GEO-MW.
- Need is important for NWP but also for the research studies.

Outcomes:
Recommendation AS-4 to NOAA
GEO MW sounder demo mission to be implemented as soon as possible, so that the basis for planning joint operational systems can be established in a timely manner and MW can catch up with IR.

Recommendation AS-5 to space agencies
Agencies that are implementing GEO IR sounders should also implement companion GEO MW sounders.

2.4.4 Discussion on several MW Topics

Sub-mm and ICI

Context:

- Sub-mm and ICI: Need group discussion of what science topics are key in this domain? Focus topic at the next ITSC?
- Hyperspectral microwave sounders: What is the key for exploiting such next-gen sensors? Does anyone use correlated errors for all-sky MW assimilation or retrievals now?

Discussion:

- Sub-mm, like ICI and MW STERNA: science topics are on the emissivity code and radiative transfer models → This topic was brought to the RT WG.

- HS MW sounder
    - ECMWF mentioned that ATMS with correlated errors for clear sky works well.
    - JPL is building a HS spectrometer → outcome will be presented at the next ITSC.
    - BOM mentioned that there was a survey and an ITSC recommendation which helped at designing the instrument. NASA is working on it.
    - Channel selection for hyperspectral MW → study which bands would benefit most from greater spectral coverage.
    - Whether DA systems would be ready to assimilate hyperspectral MW.

Outcomes:
Recommendation AS-6 to ITWG co-chairs
To consider including a dedicated session at the next ITSC on sub-mm instruments such as ICI and AWS.

Ultra-low-noise MW Sounders
Context:
- Major impact from low noise MW data. This was touched upon at NOAA sounders workshop (Jul 2021), but the impact of a 50GHz sounding suite with ~0.32K noise vs. 0.20K noise is huge for global NWP data assimilation. Not just a topic for small sats!

Discussion:
- 0.2K is needed for NWP to improve the forecast. "If the noise is large the data won't be used."
- Discussion on the tradeoff between more instruments with more noise and less instrument with better noise → NWP said that low noise is the priority 1.
- UK Met Office mentioned that there are ways to reduce the noise at the expense of other resolution (i.e. spatial).
- It was mentioned that future MW sounder concepts will be fully configurable in orbit with spatial and spectral resolution (and thus noise) able to be set by user requirements.
- Low noise is not always the most important factor; For example smaller footprints with higher noise can be more valuable in some circumstances.

Outcomes:
Recommendation AS-7 to space agencies
To pursue/consider very low noise technology for MW sounders.

2.4.5 Re-iterating previous high priority ASWG recommendations

The WG also re-iterates several previous high priority recommendations:

Recommendation to satellite agencies (NOAA, JMA)
Consistent with numerous previous ITWG and ASWG recommendations, and consistent with the WMO Integrated Global Observing System (WIGOS) Vision for the Global Observing System in 2025 and 2040, the ASWG strongly recommends that space agencies develop and implement plans to fill the gaps in IR hyper-spectral sounding within the Geostationary constellation.

Recommendation to satellite agencies

The constellation of at least three polar orbits (early morning, morning, and afternoon), each with full sounding capabilities (IR and MW), should be maintained. The overpass times of operational satellites with sounding capability (IR and MW) should be coordinated between agencies to maximize their value.

Recommendation to satellite agencies

Implement high spatial resolution and contiguous sampling detector arrays in future hyperspectral infrared sounding instruments.

Recommendation to satellite agencies

To develop, test, and implement an Infrared SI-traceable radiometric standard in space as soon as feasible.

Action to ITWG co-chairs

To re-iterate these recommendations to space agencies via CGMS.

2.4.6 Discussion on Additional LEO orbits

Context:

- Spatial coverage configurations that approach 4 km or better footprints, with nearly contiguous coverage.
- Combined temporal coverage of the full system that provides uniform 2 hour delta time coverage by expanding the backbone system to offer 3 additional orbits between the current 1330, 0930, and 0530 local times.

Discussion:

- On the benefits of having better footprints, better than 4km, and 2 hour delta time had unanimous support from the group.

Outcomes:

Based on recent assimilation results demonstrating significant forecast improvements with substantially enhanced wind information using (1) global IR spectral radiances at ECMWF and (2) regional retrievals from the fusion of GEO imager and LEO advanced IR and MW sounder radiances at the University of Wisconsin and Hampton University, the ASWG offers the following clarification of the WIGOS Vision 2040 implementation:

Recommendation AS-8 to space agencies, data providers, and CGMS

To implement the WIGOS Vision 2040 backbone system that includes 3 additional orbits between the current 1330, 0930, and 0530 local times by populating each with advanced IR and MW sounding capability, thereby providing 2 hour temporal spacing.

2.4.7 Discussion on using more available information in NWP

Context:

- Operational centres are using a selection of channels and pixels. They should aim to utilize the full spectral, temporal, and spatial information content provided by the international system of satellite hyperspectral sounding sensors

Discussion:

- Wide ranging discussion took place. It was said that it is hard to take all spectral channels in NWP models. Spectral correlation is an issue. Using PC could be a good alternative.

Outcomes:

General recommendation AS-9 to operational centres

To aim to utilize the full spectral, temporal, and spatial information content provided by the international system of satellite hyperspectral sounding sensors.

2.4.8 Discussion on CGMS/High Level Priority Plan

The WG had no time to go through the HLPP but the plan has been distributed to ASWG members.

Outcomes:

Action AS-3 on ASWG

To go through the CGMS HLPP and send feedback to the ASWG co-chairs.

2.5 International Issues and Future Systems

Web site: itwg.ssec.wisc.edu/iifs/

Working Group members: Peng Zhang (CMA, Co-chair), Niels Bormann (ECMWF, Co-chair), Manik Bali (NOAA/UMD), Kristen Bathmann (Spire), Alain Beaulne (ECCC), Mary Borderies (Meteo France), Dorothee Coppens (EUMETSAT), Philippe Chambon (Meteo France), Simon Elliott (EUMETSAT), Robin Faulwetter (DWD), Wei Han (CMA), Andy Heidinger (NOAA NESDIS), Bjorn Lambrigtsen (JPL/NASA), Katie Lean (ECMWF), Vincent Leslie (MIT Lincoln Lab), Bill Smith (SSEC), Erica McGrath-Spangler (NASA GMAO), Hidehiko Murata (JMA), Roger Randriamampianina (Met Norway), Mikael Rattenborg (CGMS Secretariat), Hank Revercomb (SSEC), Louis Rivoire (Meteo France), Ramesh Singh (Chapman University), Joe Taylor (UW-SSEC), Hu (Tiger) Yang (UMD), Zhiyu Yang (UCAS)

2.5.1 Introduction

The WG met on Saturday afternoon, 18 March 2023, to discuss items relevant to international coordination and the evolution of future observing systems.

2.5.2 Recent evolutions of the global observing system

The WG congratulated CMA on the two milestone launches featuring prominently at ITSC-24, FY-4B and FY-3E (launched in June and July 2021, respectively). FY-4B features the first operational hyperspectral IR instrument in geostationary orbit, and improvements in data quality were noted compared to the experimental predecessor on FY-4A. The FY-3E launch into the early-morning orbit is an excellent example of international collaboration, achieving complementarity of LEO orbits, following consultation of CMA through a WMO-CGMS Tiger team, with strong involvement by ITWG. The international near-real-time (NRT) data dissemination has started recently and first evaluations were reported at the conference; international uptake is expected to accelerate over the coming years.

2.5.3 CGMS risk assessment

Peng Zhang (CMA) presented outcomes of the latest CGMS risk assessment. The risk assessment is performed annually against the CGMS baseline and covers the next 10 years. The risk of a gap in coverage over this period for the passive sounding instruments of the CGMS baseline is now considered relatively low. The main change in this respect is the reduced risk of a gap in the early-morning orbit, thanks to CMA's commitment beyond FY-3E. Nevertheless, WG members noted that the early-morning coverage is not as robust as for the other two orbits of the CGMS 3-orbit baseline, as no secondary satellite is foreseen. NOAA's Quicksounder plans (ATMS on a small satellite in the early-morning orbit) are now fully committed, providing at least partial back-up. The group discussed possibilities to support activities for making the early-morning coverage more robust.

Action IIFS-1 on Peng Zhang (CMA)

> **To circulate the report of the WMO-CGMS Tiger team that informed CMA's decision about moving FY-3E to the early-morning orbit to the IIFS group.**

Recommendation IIFS-1 to WMO/CGMS

> **To assemble a new Tiger team to review the achieved impacts of the early-morning orbit, once the NWP impact assessment of FY-3E by the international community is sufficiently mature, in order to support initiatives that could increase robustness of the early-morning orbit coverage.**

In relation to the CGMS risk-assessment, the WG noted that it is not clear to what extent data quality and capabilities are taken into account when high-level summaries of CGMS risk assessments are provided. While it is stated that such aspects do feed into the risk assessment, there is a danger that high-level summaries do not capture this and hence do not fully reflect user's experiences. This applies to current systems (e.g., wrt to MW imager coverage), and is also highly relevant for potential moves to disaggregated systems in the future. The WG hence decided to restate:

Standing Recommendation IIFS23-2 to CGMS

> **To explicitly consider instrument capabilities and data quality as well as data provision in future updates of the CGMS baseline, particularly for the 3-orbit backbone system of LEO passive sounders which plays an important role as a reference-style system, and also for MW imagers.**

2.5.4 Progress towards implementation of the WIGOS Vision 2040 beyond the current CGMS baseline

The group noted that significant progress has been reported at ITSC-24 to quantify expected benefits of and requirements for passive sounding from LEO satellites from orbits that complement the 3-orbit CGMS baseline, particularly for MW sounding in the context of EPS-Sterna. Given the high relevance to HLPP item 1.2.7, results from these studies should be reported at a future CGMS meeting.

Recommendation IIFS-2 to EUMETSAT and ESA

> **To report to CGMS the results of assessments of expected impact conducted in the context of EPS-Sterna.**

Based on recent results, both in OSSE/EDA studies, but also experiences with real data from the POES heritage satellites, the group can now make more specific recommendations regarding advancing the implementation of the WIGOS Vision 2040:

Recommendation IIFS-3 to CGMS

> **To advance the implementation of the WIGOS Vision 2040 for passive IR and MW sounding with agency commitments beyond the established 3-orbit baseline. Noting recent assessments of expected impact, the WG recommends complementing the 3-orbit CGMS baseline with a further 3-orbit system that features at least MW sounding capabilities, with equator-crossing times between those of the 3-orbit baseline to optimize time-to-coverage of the overall system.**

The WG noted that there are several initiatives (e.g., EPS-Sterna at EUMETSAT, SMBA at NOAA) towards addressing the requirements for MW sounders identified.

Recommendation IIFS-4 to CGMS members with initiatives to complement the 3-orbit baseline

> **To coordinate activities to put such systems in place and to optimize complementarity.**

2.5.5 Experiences with small satellites/cubesats

Small satellites or cubesats are an option to achieve temporal coverage beyond the 3-orbit baseline in a cost-effective way.

The WG noted with appreciation that several contributions at ITSC-24 assessed data quality from existing missions (e.g., TROPICS, COWVR/TEMPEST). However, more work is required to establish operational maturity of such systems, and no NWP impact trials in an operational context were reported at this ITSC.

Standing Recommendation IIFS23-4 to NWP centres and other organisations involved in the evaluation of existing data from smaller satellites

> **To report on experiences with passive sounding instruments from smaller satellites at future ITSCs, including evaluations of data quality and stability, with a view towards future operationalization of such systems.**

The aim of complementing small sat/cubesat constellations is to enhance temporal sampling, which particularly motivates good timeliness. To facilitate this, the WG expressed:

Recommendation IIFS-5 to providers of data from constellations of smaller satellites

> **To work towards a standardisation of downlink equipment and data protocols to ease provision of direct broadcast capabilities.**

2.5.6 Role of commercial data

The WG noted that ITSC-24 saw the first attendance of a delegate from a commercial data provider (Spire), which aims to provide new hyperspectral MW capabilities. It was noted that commercial data providers bring about new ways of responding to user requirements, and requirements gathering as well as implementation might not follow established coordination via CGMS/space agencies/WMO. Engagement of commercial data providers with CGMS groups such as ITWG is encouraged, to ensure that planned systems indeed address user requirements.

It was noted that IROWG has already seen strong engagement with the commercial sector, and can hence be seen as an example of this process. In particular, IROWG has established models for data buys that keep the well-established benefits of global data-sharing principles (ie complementary data buys by different agencies, with global licenses), and this is seen as a good way forward if such data-buys arise for passive sounding data.

2.5.7 Timeliness aspects and their coordination

Data timeliness is critical for any operational application of satellite data and initiatives to improve timeliness of global data are supported, as are low-cost efforts such as DBNet. The transition from GTS to the internet-based WIS 2.0 will address some band-width limitations previously encountered for hyperspectral IR data, as already being demonstrated by CIMSS' provision of full spectral resolution HSIR data from their direct broadcast network.

To facilitate and further improve timeliness, the working group expressed the following recommendations, in line with long-standing views of the group:

Recommendation IIFS-6 to WMO

> **To coordinate an update of timeliness requirements, bearing in mind growing applications of rapid-update NWP systems.**

Recommendation IIFS-7 to space agencies via CGMS

> **To continue to explore innovative methods, such as used by GPM, to provide global data with a timeliness that meets the new requirements, for next generation satellite programmes.**

Standing Recommendation IIFS22-8 to CGMS

> **If a mission expects engagement from application areas with an NRT data requirement, budget should be allocated from the start to provide the required technical infrastructure.**

Standing Recommendation IIFS23-7 to NWP centres

> **To conduct impact studies highlighting the benefit of good timeliness of observations, and to report on these at future meetings.**

2.5.8 Calibration

Information from calibration and instrument telemetry monitoring is extremely useful to users. The group has repeatedly recommended space agencies to make such information available to users (following the example of NOAA's well-established ICVS website). During the WG discussions it emerged that reference to "ICVS-style monitoring" is insufficient to be actionable by space agencies. Furthermore, it is less clear what is considered helpful to users of hyperspectral IR data in this respect.

Action IIFS-2 on Niels Bormann

> **To compile which elements of the ICVS-monitoring are considered most relevant to users, consulting the wider ITWG for input.**

Recommendation IIFS-8 to CGMS members

> **To provide calibration metadata and instrument telemetry monitoring as identified in the above action for operational instruments.**

The benefit of a backflip manoeuvre for obtaining calibration-relevant information was again highlighted when it was performed during the Metop-A end-of-life activities. As such information is highly relevant during the operational phase of the satellite, performing such a manoeuvre earlier in the life of the satellite is considered beneficial if possible. It was, however, recognized that this may not be compatible with the satellite/instrument design (e.g., IASI band 1 was lost as a result of the backflip manoeuvre).

Recommendations IIFS-9 to CGMS members

> **To perform a backflip manoeuvre for LEO satellites, at least before the end of life, and ideally earlier than that if compatible with the satellite/instrument design, to collect information critical for enhanced calibration performance.**

Given the importance of calibration for quantitative uses of the data and the potentially growing need for inter-calibration (e.g., arising from small satellites), the group again supports the implementation of in-orbit reference missions:

Standing Recommendation IIFS21-8 to CGMS

> **Recognizing the growing need for assessment and on-orbit optimization of the accuracy of operational hyperspectral IR sounders, the traditional approaches for**

pre-flight SI traceability and post-flight validation should be enhanced by flying an on-orbit reference standard capability (featuring on-orbit SI verification) with orbits designed to provide inter-calibration capability for refining the calibration of the international fleet of operational sounders.

With three such reference missions being planned, the group felt that harmonization of data products will enhance and facilitate data uptake:

Recommendation IIFS-10 to space agencies involved in reference missions (CLARREO, TRUTHS, LIBRA)
To work towards harmonized product definitions to make the use of these products easier for inter-calibration exercises.

Further aspects of calibration monitoring and inter-calibration are routinely performed and discussed under the GSICS umbrella, and these efforts are supported by the group.

2.5.9 HLPP items

Mikael Rattenborg (CGMS secretariat) guided the group through the HLPP items related to operational continuity and contingency planning considered most relevant to the group. Two items were particularly noted, as they directly relate to the WG's discussions:

- *1.2.4 Work towards ensuring optimised high spectral resolution IR measurements from LEO and GEO orbits to improve time sampling, spatial and spectral resolution and timeliness of observations, including the deployment of HSIR instruments across the GEO ring as per WIGOS vision 2040*

Activities by space agencies towards this item are strongly supported, as expressed in Recommendation IIFS-3. The decision by JMA to establish hyperspectral IR capabilities from geostationary orbit before the end of the decade was announced later at the conference and received as excellent news, and NOAA's plans to pursue hyperspectral IR with GEO-XO during the next decade are also warmly noted.

- *1.2.7: Establish observational requirements for microwave observations (sounder and imager) for NWP and precipitation and perform gap analysis against CGMS baseline*

As noted earlier, strong progress has been reported at ITSC-24, resulting in Recommendation IIFS-2. The communication of such requirements should be coordinated between ITWP and IPWG.

2.6 Products and Software

Web site: itwg.ssec.wisc.edu/pswg/

Working group members: Graeme Martin (Co-Chair, SSEC/UW), Nigel Atkinson (Co-Chair, Met Office), Anna Booton (Met Office), Marc Crapeau (EUMETSAT), Liam Gumley (SSEC), Andy Heidinger (NOAA), Jun-Hyang Heo (KMA), Haruma Ishida (JMA), Naoto Kusano (JMA), Jean-Marie Lalande (Météo-France), Thomas Lebrat (Météo-France), Guido Masiello (Univ. Basilicata), Scott Mindock (SSEC), Nathalie Selbach (DWD), Inchul Shin (KMA), Bomin Sun (NOAA/STAR), Lihang Zhou (NOAA)

Agenda:

1. Introductions
2. Review of open actions and recommendations from ITSC-23
3. Status of existing software packages
4. (CSPP-LEO, AAPP, MWIPP, IRSPP, FY3, CSPP-GEO, IMAPP, PPS …)
5. New and future sensors and plans for supporting software
6. (NOAA-21, FY-4B, FY-3E, EPS-SG, MTG, GEO-XO, EPS-Sterna (AWS), GOSAT-2 FO, GK-2 series, KMA LEO, …)
7. DBNet status and plans
8. Cloud services and cloud data distribution
9. Best practices for software, product distribution and data formats
10. CGMS High Level Priority Plan
11. PSWG web site
12. PSWG co-chairs
13. Any other business

2.61 Introductions

The participants introduced themselves. The group was reminded of the scope of the PSWG:

- Both Level 1 and Level 2 satellite products;
- Software tools and packages for generating, analyzing, and visualizing products;
- Enabling end users to obtain or generate the products they need;
- End user feedback and training;
- Exchange of information for validation of products;
- Informing the user community about requirements for future missions; and
- Informing agencies about requirements of the users.

2.6.2 Review of actions and recommendations

Note: presentations from the 2022 "interim meeting" are linked from https://cimss.ssec.wisc.edu/itwg/itsc/2022interim/index.html.

Actions

- **PSWG22-6**: Migration of the UW/SSEC/CIMSS web site to Wordpress is ongoing. *Action remains open*.

- **PSWG23-1 on VIIRS clusters**: The software for performing the NOAA cluster analysis (presented in talk 6.03) is planned to be integrated into CSPP by the end of 2023, which will provide consistency between NOAA products and direct broadcast

products.
Agreed that the *action can remain open* until that task has been completed.

- **PSWG23-2 on developments in PC representation**: The EUMETSAT "hybrid approach" is due to be made operational in EUMETSAT products on 30th March 2023. This approach has also been used by NOAA and by SSEC.
  It is still desirable to monitor the status therefore the *action remains open*.

- **PSWG23-3 on NOAA CLASS access methods**: Information had been shared at the Interim Meeting. Also, it was noted that there is a new access method for data in the Amazon Cloud called NOAA Open Data Dissemination (NODD).
  Action closed.

- **PSWG23-4 on sharing experiences with working with containers**: Liam has updated his guide for building AAPP, OPS-LRS and Metopizer in *Apptainer*. Graeme also presented a document on CSPP GeoSphere and a document on deploying containers in the Cloud.
  Action closed.

  Other experiences: DWD have done some work on running software in the EUMETSAT cloud. EUMETSAT are considering making containers for the EARS processing software (on physical machines). Liam's poster on ultra-low latency CrIS was noted: this makes use of the Amazon cloud.

  Action PSWG-1 on PSWG co-chairs
  To share on the PSWG web site the documents related to containers that were presented at the meeting.

- **PSWG23-5 on facilitating running software in Windows**. The next release of IMAPP will be via a container that is compatible with Windows.
  Action closed.

- ITSC23-PSWG-6 and 7 have already been closed following input provided during or following ITSC-23.

Recommendations

It was agreed that the following recommendations have continuing value and should be carried over. They are re-numbered below to reflect the fact that they are recommendations from ITSC-24.

Recommendation PSWG-1
Software providers should, where possible, offer their software with a choice of either pre-built binaries or source code.

Recommendation PSWG-2
For software that will be built from source by the user, software providers should list recommended versions of required external (COTS) libraries.

Recommendation PSWG-3

Costs to users should be considered when migrating software and data distribution to the cloud.

Recommendation PSWG-4

Users should continue to have free access to satellite data.

Recommendation PSWG-5

Software providers are encouraged to provide and test software in a cloud-ready format.

It was agreed that a recommendation related to AMSR-2 direct broadcast software could be dropped, as it has been established that there are no plans to make this software publicly available, and no strong user requirement has been identified.

2.6.3 Status of existing software packages

Liam gave a presentation on the status of CSPP LEO. More information is available from the web site of the CSPP User Group Meeting in 2022.

- The next release of CSPP SDR will support OMPS Nadir Profiler and Nadir Mapper (not the Limb instrument).
- CSPP products are mostly defined by NOAA.
- CSPP SDR 4.0 will add support for NOAA-21, and is planned for release in April 2023, after NOAA-21 reaches provisional status.
- CSPP packages currently run on CentOS7, which will reach end of life in June 2024
- CSPP SDR 4.0 will be the last package to be built on CentOS7. All subsequent CSPP LEO releases will be built on Rocky Linux 8.
- Users should avoid processing two JPSS satellites simultaneously. CSPP team recommends the use of 64 cores, 256GB RAM, SSD drive and Rocky Linux 8.

Nigel talked about the EPS-SG direct broadcast level 1 software:

- Being procured by EUMETSAT.
- Separate package for each instrument.
- NWP SAF will test each package and supply wrapper scripts, etc.
- NWP SAF plans to release to users 6 months before launch of the respective satellite (i.e. Metop-SG-A1 or Metop-SG-B1).
- The IASI processor in particular will require a large number of cores if processing is to be completed in a reasonable time, e.g. 88 cores would allow a 12-minute pass to be processed in 16 minutes, but 32 cores would increase this time to 47 minutes. These figures are provisional but are of some concern to users.

Experiences with the FY-3E DB package were shared. The Met Office and EUMETSAT are receiving FY-3E. The first release of the software package had some issues but an update (March 2023) appears to work well. The software has to be requested from CMA, but there are no known restrictions on sharing L0 data.

Graeme presented a slide on CSPP Geo and demonstrated the CSPP GeoSphere interactive website.

Liam reported that funding for the NASA Direct Readout Laboratory (DRL) will cease on 1 July 2023. It was noted that RT-STPS is still an important piece of software and ongoing support to users will be provided, though the exact mechanism for that support is not yet clear.

2.6.4 New and future sensors and plans for supporting software

Andy Heidinger gave a presentation on GEO-XO. This relates to a NOAA satellite with a hyperspectral sounder, for launch in 2036. To occupy a central location over the USA at 105 degrees west. There will be a rebroadcast service (like the current GRB) but it will be via a commercial satellite and will not have capacity to carry all the sounder data, only a subset. Instead, a terrestrial service will be used. It is likely that a PC compression will be used for the sounder but it is unknown whether it will be used for direct broadcast / rebroadcast. The list of products is not yet known.

Recommendation PSWG-6 to data providers

> **Explore the use of principal component (PC) compression to reduce the volume of hyperspectral sounder data in future geostationary direct broadcast or rebroadcast streams.**

Nigel introduced the EPS Sterna mission, pointing out that "Sterna" is an Arctic tern that migrates between the Antarctic and the Arctic. It will have a microwave sounder payload and there will be L-band direct broadcast. In parallel, the US is developing its own smallsat mission called SMBA. They will also be launching a spare ATMS flight model in 2025 called QuickSounder.

It was noted that Spire are also considering developing a microwave mission. (Spire have a highly successful GPSRO constellation).

Recommendation PSWG-7 to space agencies

> **Consistency in data content and data formats between the various planned smallsat microwave missions would be highly beneficial for users.**

It was noted that Himawari-10, due for launch in 2029, will have a hyperspectral IR sounder.

As a general recommendation for new missions:
Recommendation PSWG-8 to space agencies

> **Direct broadcast should be preserved for users who cannot get timely data by terrestrial means.**

2.6.5 DBNet status and plans

Nigel gave a brief summary:

- NOAA-18, NOAA-19, Metop-B, Metop-C, S-NPP and NOAA-20 are received widely and the data disseminated.
- Aqua (AIRS) is received by SSEC stations.
- FY-3D (MWTS/MWHS/MWRI) by EUMETSAT stations.
- NOAA-21 and FY-3E will be added soon.
- New stations in India, Africa and French Guiana were noted.
- More information in Mikael Rattenborg's talk (16.02).

2.6.6 Cloud services and cloud data distribution

This has been largely covered in the review of actions.

A potential problem with cloud processing is that vendors of cloud facilities sometimes provide interfaces that allow users to access their systems, but these interfaces can tie users into the specific cloud system. Users still need to be able to run their software outside the cloud.

Recommendation PSWG-9 to software developers
> **Software developed in the cloud should be vendor agnostic.**

Containers and the cloud are closely related. Two approaches could be considered: either (i) develop the application in a container (not in the cloud) and then migrate to the cloud later, or (ii) develop the application in a container that is in the cloud.

2.6.7 Best practices for software, product distribution and data formats

It was pointed out that containers can be a valuable tool for software build purposes: by building a software package in a container the developer can control exactly what the environment needs to contain, even if the eventual deployment will not be in a container.

Recommendation PSWG-10 to software developers
> **Consider building software packages in a container with a controlled environment, even if the eventual deployment will be outside that container.**

Nigel raised the issue of netCDF4 in which the Fortran API does not support all the features of the netCDF4 standard. Examples include variable length strings and enumerated datasets. These can be found in test data for MTG-IRS released by EUMETSAT. More worryingly, different versions of the test data alternate between using these constructs and not using them – with no mention of this in the EUMETSAT documentation. SSEC had also come across this issue some years ago. A workaround is to use the HDF5 API rather than the netCDF API.

Recommendation PSWG-11 to data providers
> **When creating or releasing test data, it is good practice to state which APIs the data are compatible with, and whether there are any changes (e.g. since the last release) that affect compatibility with the standard reader APIs.**

There was a discussion on the use of Conda. This can be a valuable tool for allowing 3rd party software to be downloaded and run. But operational centres often have constraints on which Conda channels can be accessed.

Recommendation PSWG-12 to software providers
> **Software intended to be run in an operational context should only link to open source 3rd party packages (e.g. on Conda Forge).**

Graeme mentioned an issue with streaming geostationary imagery that has come up before in PSWG discussions. When the data are streamed in chunks, it would help greatly if metadata pertaining to a particular chunk could be transmitted alongside that chunk – rather than waiting for the end of the entire image. This is still a problem with GOES imagery data.

Recommendation PSWG-13 to raw data providers

In streaming data formats, metadata should be transmitted inline with the corresponding section of raw data to which it pertains to support near real-time and low latency applications.

2.6.8. CGMS High Level Priority Plan

Several topics of relevance were picked out from the HLPP guidance issued by ITWG co-chairs:

- Protection of the band 1695-1710 MHz (used for LEO direct broadcast to user stations) from planned new frequency usage by commercial satellite systems, etc.
    - This is relevant to direct broadcast from NOAA POES and Metop. These data are used operationally (e.g. DBNet). L-band is also planned to be used by EPS Sterna, so protection remains important.
- Facilitate the transition to new LEO direct broadcast systems (JPSS, FY-3, MeteorM, Metop-SG).
    - This is an important part of the remit of PSWG. The group has reported progress in software for processing JPSS, FY-3 and Metop-SG.
- Develop efficient standardized data handling for high-resolution imaging and hyperspectral instruments.
    - The principal components ("hybrid") compression was discussed in the PSWG meeting, and is becoming an operationally accepted tool.
- Conduct an intercomparison study between the different methods to derive level 2 data from infrared hyperspectral sounders, recognising that there are several software packages available that utilize AIRS/IASI/CrIS data.
    - NOAA Products Validation System (NPROVS), funded by JPSS operated at NOAA/STAR, is an enterprise products validation system. In conjunction with graphic tools developed, NPROVS has the capability of conducting routine monitoring and analysis of satellite sounding products through comparing them with radiosondes (global conventional, and dedicated and GRUAN radiosondes) and NWP products, and through products intercomparison. NPROVS is capable of conducting the assessment of L2 products derived from new infrared sensors or new retrieval algorithms (POC: Bomin Sun and Tony Reale, NOAA/STAR).
    - The PSWG cannot commission intercomparison studies but what we can do is to make sure that the list of software packages on the PSWG web pages are up to date, so that groups who are in a position to do comparisons have up to date information.

Action PSWG-2 on PSWG co-chairs

To port the current list of software packages to the new web site (when available) and to solicit the help of PSWG members to update the tables.

Finally, the question was asked as to whether FCI will scan south to north or north to south. It would be good if different GEO missions could have some consistency in this aspect.

2.6.9 PSWG web site

Migration to Wordpress is underway. Covered by ongoing action ITSC22-PSWG-6.

2.6.10 PSWG co-chairs
Nigel has been co-chairing this group for 11 years and would like to step down before ITSC-25. Suggestions welcomed for a replacement.

2.6.11 AOB
There was no other business.

ACRONYMS

AAPP: Advanced ATOVS Processing Package
AC: Atmospheric Composition
AEMET: Agencia Estatal de Meteorología (The State Meteorological Agency of Spain)
AER: Atmospheric and Environmental Research
AI: Artificial Intelligence
AIRS: Atmospheric InfraRed Sounder
AMSR: Advanced Microwave Scanning Radiometer
API: Application Programming Interface
ARM: Atmospheric Radiation Measurement
ARMS: Advanced Radiative transfer Modeling System
ASTER: Advanced Spaceborne Thermal Emission and Reflection Radiometer
ATMS: Advanced Technology Microwave Sounder
ATOVS: Advanced TIROS Operational Vertical Sounders
AVHRR: Advanced Very High Resolution Radiometer
AWS: Arctic Weather Satellite
BoM: Bureau of Meteorology (Australia)
BUFR: Binary Universal Form for the Representation of meteorological data
C3S: Copernicus Climate Change Service
CAMEL: Combined ASTER and MODIS emissivity over Land
CCRS: Centre for Climate Research Singapore
CDR: Climate Data Record
CFA: Center for Astrophysics
CGMS: Coordination Group for Meteorological Satellites
CIMSS: Cooperative Institute for Meteorological Satellite Studies
CLARREO: Climate Absolute Radiance and Refractivity Observatory
CLASS: Comprehensive Large Array-data Stewardship System
CLBLM: Community Line By Line Model
CMA: China Meteorological Administration
CMIM: Constellation of MIni sounder for Meteorology
CNES: Centre National d'Etudes Spatiales
COTS: Commercial Off The Shelf
COWVR: Compact Ocean Wind Vector Radiometer
CrIS: Cross-track Infrared Sounder
CRTM: Community Radiative Transfer Model
CSPP: Community Satellite Processing Package
CWG: Climate Working Group
DA: Data Assimilation
DB: Direct Broadcast
DFS: Degrees of Freedom per Signal
DWD: Deutscher Wetterdienst (German Weather Service)
EARS: EUMETSAT Advanced Retransmission Service
ECMWF: European Center for Medium Range Weather
ECV: Essential Climate Variables
EPS: EUMETSAT Polar Satellite
ERA: ECMWF Reanalysis
ESA: European Space Agency
EUMETSAT: European Organization for the exploitation of meteorological satellites
FCDR: Fundamental Climate Data Record

FMI: Finnish Meteorological Institute
FORUM: Far-infrared Outgoing Radiation Understanding and Monitoring
FOV: Field of View
FY-3: LEO satellite from China
GCOS: Global Climate Observing System
GEISA: Gestion et Etude des Informations Spectroscopiques Atmosphériques (Management and Study of Spectroscopic Information)
GEO-XO: Geostationary Extended Observations
GEOS: Goddard Earth Observing System
GFS: Global Forecast System
GHG: Greenhouse Gas
GIIRS: Geostationary Interferometric Infrared Sounder
GMAO: Global Modeling and Assimilation Office (NASA)
GMI: Global Precipitation Measurement (GPM) Microwave Imager
GOES: Geostationary Operational Environmental Satellite
GOSAT: Greenhouses gases Observing SATellite
GPM: Global Precipitation Measurement
GRUAN: GCOS Reference Upper Air Network
GSICS: Global Space-Based Inter-Calibration System
GTS: Global Telecommunications System
GXS: Geo-XO Sounder
HARMONIE-AROMA: AEMET NWP model
HIRAS: Hyperspectral Infrared Atmospheric Sounder
HITRAN: High-resolution transmission molecular absorption database
HLPP: High Level Priority Plan
HSIR: HyperSpectral InfraRed
IAMAP: International Association of Meteorology and Atmospheric Physics
IASI: Infrared Atmospheric Sounding Interferometer
IASI-NG: IASI- Next Generation
ICI: Ice Cloud Imager
ICON-LAM: Icosahedral Nonhydrostatic Weather and Climate Model-Limited Area Mode
ICVS: Integrated Calibration and Validation System
IESWG: International Earth Surface Working Group
IKFS: Russian advanced infrared atmospheric sounder
INSAT: Indian National Satellite System
IPWG: International Precipitation Working Group
IR: Infrared
IRC: International Radiation Commission
IRSPP: Infrared Sounder Pre-Processor
ISSI: Ice Sheet and Sea Ice
ITSC: International TOVS Study Conference
ITWG: International TOVS Working Group
JEDI-MPAS
JMA: Japan Meteorological Agency
JPSS: Joint Polar Satellite System
kCARTA: kCompressed Atmospheric Radiative Transfer Algorithm
KIM: Korean Integrated Model
KMA: Korea Meteorological Administration
KNMI: The Royal Netherlands Meteorological Institute (Netherlands)
KPOP: KIM Package for Observation Processing

LAM: Limited Area Model
LBL: Line By Line
LBLRTM: Line By Line Radiative Transfer Model
LEO: Low Earth Orbit
LETKF: Local Ensemble Transform Kalman Filter
LIBRA: Chinese satellite mission complementary to CLARREO and TRUTHS
LMD: Laboratoire de Météorologie Dynamique
LST: Land Surface Temperature
LWIR: LongWave InfraRed
MADRAS: Microwave Analysis & Detection of Rain & Atmospheric Structures
MetOp: Meteorological Operational
MFASIS: Method for FAst Satellite Image Synthesis
MHS: Microwave Humidity Sounder
ML: Machine Learning
MODIS: Moderate-resolution Imaging Spectroradiometer
MTG-IRS: Meteosat Third Generation - Infrared Radiometric Sounder
MW: Microwave
MWHS: Microwave Humidity Sounder
MWIPP: Microwave Imager Pre-Processor
MWTS: MicroWave Temperature Sounder
NASA: National Aeronautics and Space Administration
NAST-I: NPOESS Aircraft Sounding Testbed- Interferometer
NCEI: National Centers for Environmental Information
NCEP: National Centers for Environmental Prediction
NCMRWF: National Centre for Medium Range Weather Forecasting (India)
NEdT: Noise Equivalent Delta Temperature
NESDIS: National Environmental Satellites, Data, and Information Service
NOAA: National Oceanic and Atmospheric Administration
NPROVS: NOAA PROduct Validation System
NRL: Naval Research Laboratory
NUBF: Nonuniform Beam Filling
NUCAPS: NOAA Unique Combined Atmospheric Processing System
NWP: Numerical Weather Prediction
OCO: Orbiting Carbon Observatory
OMPS: Ozone Mapping and Profiler Suite
OSCAR: Observing Systems Capability Analysis and Review
OSSE: Observing System Simulation Experiment
PARMIO: Passive and Active Reference Microwave to Infrared Ocean
PC: Principal Component
PCA: Principal Component Analysis
PREFIRE: Polar Radiant Energy in the Far Infrared Experiment
PSD: Particle Size Distribution
PSWG: Products and Software Working Group
RFI: Radio Frequency Interference
RNN: Recurrent Neural Network
RT: Radiative Transfer
RTM: Radiative Transfer Model
RTTOV: Radiative Transfer for TOVS
SAF: Satellite Application Facility
SAPHIR: microwave humidity sounder on French-Indian satellite Megha-Tropiques

SDR: Sensor Data Record
SMR: Scanning Microwave Radiometer
SNO: Simultaneous Nadir Overpass
SSE: Sea Surface Emissivity
SSEC: Space Science and Engineering Center
SSMIS: Special Sensor Microwave Imager/Sounder
SST: Sea Surface Temperature
STAR: Center for Satellite Applications and Research
TOVS: TIROS Operational Vertical Sounder
TROPICS: Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats
TRUTHS: Traceable Radiometry Underpinning Terrestrial- and Helio- Studies
UAS: Upper Atmospheric Sounding
UV: Ultraviolet
VIIRS: Visible/Infrared Imager Radiometer Suite
WG: Working Group
WIGOS: WMO Integrated Global Observing System
WMO: World Meteorological Organization

ITSC-24 AGENDA

Thursday, 16 March 2023		
8:30 – 9:00	Opening of ITSC-24	Liam Gumley and Vincent Guidard (ITWG Co-Chairs)
	Welcome words by Met Norway **Weather briefing**	Met Norway
	Practical information	Vincent Guidard, Liam Gumley

9:00 – 10:15 Session 1: Radiative Transfer **Chair-persons: Vito Galligani and Niels Bormann**		
Oral presentations (Presentations 12 minutes + Questions 3 minutes)		
1.01	James Hocking *Met Office*	RTTOV development status
1.02	Benjamin Johnson *JCSDA*	Community Radiative Transfer Model: A Community Model for Operational Contributions
1.03	Guido Masiello *Univeristy of Basilicata*	The new features of the sigma-FORUM Forward Model, the general purpose Fast Radiative Transfer Model for the present and next hyperspectral instruments
1.04	Yi-Ning Shi *CMA Earth System Modeling and Prediction Centre*	All-Sky Radiative Transfer Simulations based on the Advanced Radiative transfer Modeling System (ARMS)
Poster introductions (Presentations 1 minute, no visual aid)		
1p.01	Heo Junhyung (for Junyeob Choi) *National Meteorological Satellite Center, Korea Meteorological Administration*	Estimation and its application of new channel RTTOV coefficients for GK-5 the follow on GK2A
1p.02	Benjamin Johnson (for Cheng Dang) *JCSDA*	Advances in CRTM aerosol simulations with v2.4.1 and v3 releases
1p.03	Vito Sol Galligani *CIMA (CONICET-UBA)*	All-sky intercomparison of the CRTM and RTTOV radiative transfer models with the analysis fields from a 16-day WRF-GSI-LETKF regional data assimilation system
1p.04	Valentin Jules *CNRM, Météo France, CNRS*	Updated radiative transfer modelling to simulate the Pressure Modulated Radiometer (PMR) instrument from the 1970s
1p.05	Christina Köpken-Watts *DWD*	Evaluation of ICON model clouds using visible channel reflectances and RTTOV-MFASIS simulations

1p.06	Naoto Kusano *Japan Meteorological Agency*	Update of the radiative transfer model to RTTOV-13 at JMA
1p.07	Jean-Marie Lalande *CNRM, Météo France, CNRS*	Comparison Study between RTTOV v13, 4A/OP v1.7 and IASI Observations in Clear-Sky over Oceans
1p.08	Tiziano Maestri *University of Bologna*	Fast spectral radiance computations in cloudy conditions at far and mid infrared wavelengths using the sigma-FORUM code
1p.09	*withdrawn*	
1p.10	Inchul Shin *National Meteorological Satellite Center/Korea Meteorological Administration*	Simulation of GK2A visible channel image and its application
1p.11	Emma Turner *Met Office*	Implementing the Zeeman effect in the RTTOV fast radiative transfer model
1p.12	Jérôme Vidot *CNRM/Meteo-France/CNRS*	Improved cloud scattering parameterization for Mid and Far-IR in RTTOV
1p.13	Hu (Tiger) Yang *CISESS, University of Maryland*	A Calibrated Lunar Microwave Radiative Transfer Model Based on Satellite Observations

10:15-10:45 Health Break

10:45 – 11:30 Session 1: Radiative Transfer **Chair-persons: Vito Galligani and Niels Bormann**		
Oral presentations (Presentations 12 minutes + Questions 3 minutes)		
1.05	Ethel Villeneuve *CNRM, Université de Toulouse, Météo-France, CNRS*	Statistical study of inconsistencies between infrared and microwave cloudy simulations
1.06	Hanna Hallborn *Chalmers University of Technology*	All-sky simulations of the Ice Cloud Imager
1.07	Xu Liu *NASA Langley Research Center*	Principal Component-based Radiative Transfer Model (PCRTM) for Hyperspectral Remote Sensors for UV, VVIS, NIR, IR, and FIR Spectral Regions

11:30-11:45 Session 2: Calibration and Validation **Session 3: Geo Imager Assimilation** **Chair-persons: Jonathan Taylor and Wei Han**		
Poster introductions (Presentations 1 minute, no visual aid)		
2p.01	Niels Bormann *ECMWF*	Orbital biases in microwave temperature-sounding observations?

2p.02	withdrawn	
2p.03	withdrawn	
2p.04	Dimitrios Kilymis *CNES*	IASI radiometric error uncertainty budget and inter-comparison results
2p.05	Tim Hultberg (for Imke Krizek) *EUMETSAT*	Exploitation of Metop-A End-Of-Life backflip manoeuvre: estimating MHS mirror reflectivity and revealing scan-dependent biases
2p.06	Bomin Sun *IMSG at NOAA/NESDIS/STAR*	Recent Advances in Global Radiosonde Observations for Their Applications in Satellite Data Calibration/Validation
2p.07	Withdrawn	
3p.01	Cristina Lupu *ECMWF*	Monitoring visible reflectances from geostationary satellites at ECMWF

11:45-12:15 Presentation of ITWG working groups **Chair-persons: ITWG Co-chairs**
Oral presentations (Presentations 5 minutes)
b.01 Climate b.02 Products and Software b.03 International and Future Systems b.04 Radiative Transfer and Surface Properties b.05 Advanced Sounders b.06 Numerical Weather Prediction

12:15-13:15 LUNCH

13:15-13:45 Poster viewing (Sessions 1, 2, 3)

13:45 – 15:15 Session 2: Calibration and Validation **Chair-persons: Jonathan Taylor and Daniel Zhou**		
Oral presentations (Presentations 12 minutes + Questions 3 minutes)		
2.01	Manik Bali *NOAA/UMD*	GSICS Products and Tools for scientific applications
2.02	Peng Zhang *National Satellite Meteorological Center, CMA*	The on-orbit Performance of FY-3E in an Early Morning Orbit
2.03	Flavio Iturbide Sanchez *NOAA/NESDIS/STAR*	Initial Assessment of the NOAA JPSS-2 CrIS Observations
2.04	Chengli Qi *CMA*	FY-3E/HIRAS-II post launch instrument status and data accuracy analysis
2.05	Vincent Leslie *MIT Lincoln Laboratory*	TROPICS Earth Venture Mission: Update on Pathfinder's Yearlong Calibration and Validation
2.06	Bertrand Theodore *EUMETSAT*	How well the new generation of Chinese IR hyperspectral sounders compare with IASI?

15:15-15:45 Health Break

15:45 – 16:45 Session 2: Calibration and Validation (continued) Chair-persons: Jonathan Taylor and Daniel Zhou		
Oral presentations (Presentations 12 minutes + Questions 3 minutes)		
2.07	Joe Taylor *UW-Madison/SSEC*	Rigorous and Traceable Assessment of the CrIS Radiometric Calibration Uncertainty
2.08	Hu (Tiger) Yang *CISESS, University of Maryland*	On the study of the absolute on-orbit calibration consistency between ATMS instruments from SNPP to JPSS-02
2.09	Lu Lee *National Satellite Meteorological Center, China Meteorological Administration*	FY-4B/GIIRS performance after one year on orbit
2.10	Henry Revercomb *UW-Madison/SSEC*	Correction for Ringing in the Calibrated Spectra of the Cross-track Infrared Sounder (CrIS)

16:45 – 17:45 Session 2: Geo Imager Assimilation Chair-persons: Wei Han and Cristina Lupu		
Oral presentations (Presentations 12 minutes + Questions 3 minutes)		
3.01	Christina Köpken-Watts (for Liselotte Bach) *DWD*	Data assimilation of visible and combination with water vapour imager channels for very short-range forecasting
3.02	withdrawn	
3.03	Olivier Audouin *CNRM, Météo-France & CNRS*	Assimilating the infrared data from geostationary satellites within the Météo- France models
3.04	Samuel Quesada-Ruiz *ECMWF*	Towards a fuller exploitation of the window channel from geostationary satellites in NWP

18:00 Icebreaker

Friday, 17 March 2023

8:25 Weather briefing (Met Norway)

8:30-9:20 Session 4: NWP Centre reports Chair-persons: Nadia Fourrié and Kozo Okamoto		
Poster introductions (Presentations 3 minutes, 1 slide)		
4p.01	Alain Beaulne *ECCC*	Recent upgrades and developments in the use of satellite radiances at ECCC
4p.02	Niels Bormann *ECMWF*	NWP centre report: ECMWF

4p.03	Philippe Chambon *CNRM, Météo-France & CNRS*	Ongoing developments on satellite radiance assimilation at Météo-France
4p.04	Hui Christophersen *U.S. Naval Research Laboratory*	Recent observation assimilation advancement for U.S. Navy's numerical weather prediction systems
4p.05	Hyoung-Wook Chun *KMA*	Satellite Radiance Data Assimilation at Korea Meteorological Administration
4p.06	Andrew Collard *NOAA/NCEP/EMC*	Progress and plans for the use of radiance data in the NCEP global and regional data assimilation systems
4p.07	Reima Eresmaa *Finnish Meteorological Institute*	Radiance assimilation in MetCoOp limited-area NWP systems
4p.08	Wei Han *CMA Earth System Modeling and Prediction Centre*	Recent developments in satellite radiance assimilation at CMA
4p.09	Chawn Harlow *Met Office*	State of play of radiance processing in the NWP system at the Met Office
4p.10	Christina Köpken-Watts *DWD*	Status and developments of satellite radiance assimilation at DWD
4p.11	Isabel Monteiro *KNMI*	Use of satellite atmospheric sounding data in United Weather Centres West
4p.12	Hidehiko Murata *Japan Meteorological Agency*	Recent upgrades and progresses of satellite radiance data assimilation at JMA
4p.13	Indira Rani Sukumara Pillai *NCMRWF*	NCMRWF NWP: Current status and future plans
4p.14	Jana Sánchez-Arriola *AEMET*	Radiance assimilation in AEMET Harmonie-AROME model operational run
4p.15	Fiona Smith *Bureau of Meteorology*	Satellite radiance assimilation at the Bureau of Meteorology (NWP Centre Update)
4p.16	Yanqiu Zhu *GMAO*	Status and Progress of Observation Usages in the GMAO GEOS Atmospheric Data Assimilation System
4p.17	Krishnamoorthy Chandramouli *Centre for Climate Research Singapore*	Status of satellite data assimilation in Meteorological Service Singapore

9:20 – 10:05 Session 5: Climate Chair-persons: Nathalie Selbach and Dirceu Herdies		
Oral presentations (Presentations 12 minutes + Questions 3 minutes)		
5.01	Lihang Zhou (for Lin Lin) *NOAA*	Reprocessing of S-NPP/JPSS Sensor Data Records

5.02	Jonathan Mittaz *University of Reading*	Investigating possible sources of error in the calibration of the Microwave Sounding Instrument
5.03	Timo Hanschmann *EUMETSAT*	Applying inter-satellite Harmonisation to various Microwave Humidity Sounders

10:05-10:35 Health break

10:35 – 11:10 Session 5: Climate (continued) **Chair-persons: Nathalie Selbach and Dirceu Herdies**		
Oral presentations (Presentations 12 minutes + Questions 3 minutes)		
5.04	William Bell *ECMWF*	Preparations for ERA6: the assimilation of reprocessed and rescued radiance observations
5.05	Graeme Martin *UW-Madison / SSEC*	Status of the NASA CrIS Level 1B Product for Climate Applications
Poster introductions (Presentations 1 minute, no visual aid)		
5p.01	Per Dahlgren *MET Norway*	Use of satellite data in regional reanalysis
5p.02	Nathalie Selbach (for Karsten Fennig) *DWD*	Fundamental Climate Data Record of Microwave Imager Radiances, Edition 4
5p.03	Nathalie Selbach *DWD*	Climate Data Records of the EUMETSAT Satellite Application Facility on Climate Monitoring
5p.04	Peng Zhang *National Satellite Meteorological Center, CMA*	The Progress of Re-processing Historical FengYun Meteorological Satellite

11:10-11:25 Session 6: Retrieval and Software **Chair-persons: Niama Boukachaba and Marc Crapeau**		
Poster introductions (Presentations 1 minute, no visual aid)		
6p.01	Nigel Atkinson *Met Office*	An update on NWP SAF satellite data processing packages to support EPSSG and MTG
6p.02	Eva Borbas *UW-Madison SSEC*	The status of the Version 2 VIIRS+CrIS Fusion Radiance (NASA FSNRAD) products
6p.03	Niama Boukachaba *Morgan State University/ NASA GSFC/ GMAO*	Implementing Atmospheric Infrared Sounder (AIRS) and Cross-Track Infrared Sounder (CrIS) Cloud-Clearing Algorithm into the NASA GEOS Model: focus on the 2017 Atlantic Tropical Cyclone season
6p.04	Liam Gumley *CIMSS/SSEC, UW-Madison*	Ultra Low Latency Detection of Atmospheric Instability and Anomalous Emissions with CrIS
6p.05	Allen Huang *University of Wisconsin-Madison*	CSPP2 – COMMUNITY SATELLITE PROCESSING PACKAGE (CSPP) for Committed and Sustainable Professional Platform (CSPP)
6p.06	Tim Hultberg *EUMETSAT*	Hybrid Principal Component (PC) Compression
6p.07	Siwei Li *Wuhan University*	Retrieving cloud thickness over land for single-layer liquid clouds from OCO-2

6p.08	Agnes Lim *CIMSS/SSEC*	Development of NUCAPS for CSPP Real-Time Processing of early morning orbit Hyperspectral Sounding Suites
6p.09	Scott Mindock *SSEC*	Community Satellite Processing Package (CSPP) Sensor Data Record (SDR) Version 4.0: Support for NOAA-21
6p.10	withdrawn	
6p.11	Ramesh P Singh *Chapman University*	Combined Ground and Sounder data Show a Strong Coupling between In-situ and Atmosphere Associated with Baghjan oil well blowout and Tonga Volcanic Eruption
6p.12	Lihang Zhou *NOAA*	Updates on NOAA-21 Science Product Validation
6p.13	Junhyung Heo (for Hye-In Park) *National Meteorological Satellite Center, Korea Meteorological Administration*	Retrieval and Evaluation of Atmospheric Temperature and Humidity Profile using FY-4A/GIIRS
11:25 – 11:55 Invited Presentation		
Presentations 25 minutes + Questions 5 minutes		
	William Smith *UW-SSEC*	State of Atmospheric Sounding from Space – My Perspective on Past, Present, and Future, in the Infrared

12:10-13:10 LUNCH

13:10-13:40 Poster viewing (Sessions 4, 5, 6, 7, 8)

13:40 – 15:25 Session 6: Retrieval and software (continued) **Chair-persons: Niama Boukachaba and Marc Crapeau**		
Oral presentations (Presentations 12 minutes + Questions 3 minutes)		
6.01	withdrawn	
6.02	Marc Crapeau *EUMETSAT*	The past, present and future of the EUMETSAT Hyperspectral Infrared Level 2 products
6.03	Likun Wang *UMD*	Updates on CrIS VIIRS Radiance Cluster Analysis Algorithm
6.04	Stefan Stapelberg *Hamtec Consulting Ltd*	Validation and operational monitoring of atmospheric products derived from IASI measurements
6.05	moved to poster 6p.13	
6.06	Ralf Bennartz *Vanderbilt University*	Concurrent temperature/moisture profile and hydrometeor retrievals from the TROPICS Pathfinder mission
6.07	Bjorn Lambrigtsen *Jet Propulsion Laboratory*	NASA's New Microwave Sounder Retrieval System

6.08	Pratiksha Dubey *IMD*	Evaluation of INSAT-3DR sounder derived atmospheric temperature retrievals over India using AIRS, COSMIC-2,High-Resolution ECMWF (European Centre for Medium-range Weather Forecasting) Analyses products and radiosonde measurements
6.09	Hao Hu *CMA Earth System Modeling and Prediction Centre*	The Cloud-dependent 1DVAR Algorithm for Retrieving Precipitation from FengYun-3D/E Microwave Sounders

15:25-15.55 Health break

15:55 – 16:25 Session 7: Geo Hyperspectral Sounder Assimilation **Chair-persons: Stéphanie Guedj and Joel Bedard**		
Poster introductions (Presentations 1 minute, no visual aid)		
7p.01	Chris Burrows *ECMWF*	Initial assessment of GIIRS on board FY-4B
7p.02	Yufen Ma *Institute of Desert Meteorology, China Meteorological Administration*	Accuracy evaluation of GIIRS/FY-4A retrieved temperature profile in the Taklimakan Desert
7p.03	Erica McGrath-Spangler *NASA GMAO/GESTAR II Morgan State*	Global NWP Impacts of Infrared Sounders from Geostationary Orbit
7p.04	Niobe Peinado-Galán *AEMET*	Non-linear Retrieval of atmospheric vertical profiles from MTG-IRS data
7p.05	Haofei Sun *Institute of Atmospheric Physics, Chinese Academy of Sciences*	Nonlinear bias correction of FY-4A GIIRS radiance observations based on EEMD-MLP
7p.06	Qian Xie *Lanzhou University*	Impact of assimilating atmospheric motion vectors from Himawari-8 and clear-sky radiance from FY-4A GIIRS on binary typhoons
Oral presentations (Presentations 12 minutes + Questions 3 minutes)		
7.01	Olivier Coopmann *CNRM, Université de Toulouse, Météo-France and CNRS*	Project to assimilate the future MTG-IRS sounder into the mesoscale NWP model
7.02	Ke Chen *Huazhong University of Science and Technology*	Evaluation of the Potential Impact to the Prediction of Typhoon of Geostationary Microwave Sounder using the GRAPES 4D-Var
16:25 – 16:55 General Discussion: Future format for ITSCs **Chair-persons: Vincent Guidard and Liam Gumley**		
16:55 – 16:25 Session 8: Small Satellites **Chair-persons: Mary Borderies and Kristen Bathmann**		

Poster introductions (Presentations 1 minute, no visual aid)		
8p.01	Bill Blackwell *MIT Lincoln Laboratory*	TROPICS Pathfinder On-orbit Results and Preparations for the NASA TROPICS Constellation Mission
8p.02	Thomas Carrel Billiard *CNRM*	Evaluating the impact of the CMIM satellite constellation on NWP using an OSSE framework
8p.03	David Duncan *ECMWF*	Initial Evaluation of TROPICS Radiances in the IFS
8p.04	Stephanie Guedj *The Norwegian Meteorological Institute*	Implementation of a Regional Observing System Simulation Experiments to assess the potential impact of the EPS-Sterna constellation in AROME-Arctic NWP system
8p.05	Flavio Iturbide (for Min-Jeong Kim) *NOAA/NESDIS/STAR*	Impact Assessment of Microwave Sounder Observations on Small Satellites in The NOAA Global NWP and MIRS 1D-Var Systems
8p.06	Louis Rivoire *CNRM (CNRS – Météo-France)*	A global Observing System Simulation Experiment to evaluate the impact of the EPS-Sterna constellation of microwave sounders
Oral presentations (Presentations 12 minutes + Questions 3 minutes)		
8.01	Katie Lean *ECMWF*	Assessing potential future constellations of small satellites carrying microwave sounders using the Ensemble of Data Assimilations method
8.02	Magnus Lindskog *Swedish Meteorological and Hydrological Institute*	Preparing for and evaluating the arctic weather satellite data in the nordic limited-area numerical weather prediction systems
8.03	William Campbell *U.S. Naval Research Laboratory*	A Strategy for Assimilating Data from Microsats

Saturday, 18 March 2023

8:55 Weather briefing (Met Norway)

9:00-12:00	Working group meetings (10:15-10:45 Health break) Advanced Sounders Climate Radiative transfer and surface properties
12:00-13:15	Lunch
13:15-16:15	Working group meetings (14:45-15:15 Health break) NWP Products and Software International and Future Systems
16:30-17:30	Technical sub-group meeting RTTOV/CRTM RFI

Sunday, 19 March 2023

Day Free
19:00 Banquet

Monday, 20 March 2023

8:30 – 10:05 Session 9: All-sky Assimilation **Chair-persons: Katie Lean and Vincent Guidard**		
Oral presentations (Presentations 12 minutes + Questions 3 minutes)		
9.01	Sihye Lee *KIAPS*	Framework for assimilating all-sky MHS radiance data in the Korean Integrated Model (KIM) forecast system
9.02	Zhiquan (Jake) Liu *National Center for Atmospheric Research*	JEDI-MPAS: facilitating research to operation for all-sky radiance data assimilation
9.03	Mary Borderies *CNRM, Météo-France et CNRS*	Propagating non linearities of the observation operator for microwave radiances within an all-sky data assimilation system
9.04	Kozo Okamoto *JMA/MRI*	All-sky assimilation of infrared radiances at water vapor bands of Himawari-8 in the global data assimilation system at JMA
9.05	David Duncan *ECMWF*	Optimising All-sky Assimilation of Microwave Humidity Sounders
9.06	Gregory Thompson *UCAR/UCP/JCSDA*	All-Sky Geostationary Satellite Radiance Data Assimilation in JEDI Using CRTM
Poster introductions (Presentations 1 minute, no visual aid)		
9p.01	Brett Candy *UK Met Office*	A sensitivity Study into the representation of ice particles for all sky assimilation at 183 GHZ
9p.02	Azadeh Gholoubi Khonacha *AXIOM at NOAA/NCEP/EMC*	The Plan for the All-sky Radiance Assimilation over Land in the NCEP Global Model
9p.03	Han-Byeol Jeong *KIAPS*	All-sky data assimilation in the KIM LETKF system
9p.04	Emily Liu *NOAA/NCEP/EMC*	A Revised All-sky Radiance Assimilation Framework in the NCEP Global Model
9p.05	Hiroyuki Shimizu *Japan Meteorological Agency*	Development for all-sky assimilation of JAXA's future microwave sensor AMSR3 in the JMA's NWP systems

10:05-10:35 Health break

10:35 – 12:00 Session 10: Surface **Chair-persons: Eva Borbas and Tracy Scanlon**

Poster introductions (Presentations 1 minute, no visual aid)		
10p.01	withdrawn	
10p.02	Eva Borbas *UW-Madison SSEC*	The Version 3 NASA MEaSUREs CAMEL Products and its developments
10p.03	David Duncan *ECMWF*	AMSU-A Window Channel Assimilation
10p.04	Lingli He *CMA Earth System Modeling and Prediction Center*	Improved Microwave Ocean Emissivity and Reflectivity Models Derived from the Two-scale Roughness Theory
10p.05	James Jung *CIMSS / UW-Madison*	Reduced Global Sea Surface Temperature Biases from Upgrades to the CRTM Infrared Sea Surface Emissivity Model
10p.06	Jisoo Kim *Ewha Womans University*	Pre-processing of Advanced Technology Microwave Sounder Sea Ice Observations for Data Assimilation and its impact on Korean Integrated Model
10p.07	withdrawn	
10p.08	Stuart Newman *UK Met Office*	PARMIO: A reference quality model for ocean emissivity and backscatter from microwave to infrared wavelengths
Oral presentations (Presentations 12 minutes + Questions 3 minutes)		
10.01	Niama Boukachaba *Morgan State University/ NASA GSFC/ GMAO*	Toward improving the assimilation of IASI and CrIS radiances over land into the NASA GEOS: LST Inversion and Validation
10.02	withdrawn	
10.03	Nicholas Nalli *NOAA/NESDIS/STAR*	Development and Implementation of a Physical Thermal Infrared Emissivity Model for Uniform Snow Surfaces within CRTM
10.04	Stephanie Guedj *The Norwegian Meteorological Institute*	Assimilation of MW low-peaking channels in HARMONIE-AROME at high latitudes
10.05	Hongyi Xiao *CMA Earth System Modeling and Prediction Centre*	Assimilation of AMSU-A Near-Surface Channels in CMA_GFS 4DVar over Land

12:00-12:15 Session 11: Artificial Intelligence and Machine Learning Session 12: Observation operator and Observation errors Chair-persons: Thomas Auligné and Reima Eresmaa		
Poster introductions (Presentations 1 minute, no visual aid)		
11p.01	withdrawn	
11p.02	withdrawn	
11p.03	Mohamed Dahoui *ECMWF*	Use of Machine learning for the detection and classification of observation anomalies
11p.04	Hyeon-Ju Jeon *KIAPS*	Estimating the observation impact based on attentive 3d-convolutional RNN

11p.05	Eun-Jin Kim *KIAPS*	A Study on Machine Learning-Based Quality Control Techniques for the Satellite Radiance Data Assimilation
11p.06	withdrawn	
11p.07	Ashim Mitra *India Meteorological Department*	A non linear approach for temperature retrieval from AMSU-A measurements onboard NOAA-15 and NOAA-16 satellites and a case study during Gonu cyclone
12p.01	withdrawn	
12p.02	Andrew Collard *NOAA/NCEP/EMC*	Plans to transition the NCEP data assimilation system to JEDI
12p.03	Sylvain Heilliette *ECCC*	Bias correction of high peaking microwave temperature sounding channels at Environment Canada
12p.04	Hyeyoung Kim *KIAPS*	A new strategy to stabilize bias correction of satellite radiance observation in KPOP
12p.05	Ahreum Lee *KIAPS*	A new IASI channel selection method for the KIM data assimilation system
12p.06	Olaf Stiller *DWD*	A highly efficient DFS-score based channel selection method suitable for nondiagonal R matrices and the parallel processing of large numbers of atmospheric profiles
12p.07	David Tobin *CIMSS/SSEC/UW-Madison*	Hybrid PCA representation of CrIS data

12:15-13:15 LUNCH

13:15-13:45 Poster viewing (Sessions 9, 10, 11, 12)

13:45 – 15:00 Session 11: Artificial Intelligence and Machine Learning **Chair-persons: Thomas Auligné and Philippe Chambon**		
Oral presentations (Presentations 12 minutes + Questions 3 minutes)		
11.01	Flavio Iturbide (for Sid Boukabara) *NOAA/NESDIS/STAR*	Can we Design NWP Data Assimilation Based Entirely on AI Techniques? Assessing Advantages and Challenges
11.02	Wei Han *CMA Earth System Modeling and Prediction Centre*	Constrained Deep learning Bias Correction (CDBC) for Satellite Radiances in Data Assimilation
11.03	Chris Burrows *ECMWF*	A neural network approach to cloud detection in NWP
11.04	withdrawn	
11.05	Lei Bi *Zhejiang University*	Optical Properties of Nonspherical Particles: Physical Models and Machine Learning
11.06	Leonhard Scheck *Hans Ertel Centre for*	Neural network-based methods for simulating cloud- and aerosol-affected solar satellite channels

	Weather Research / LMU Munich	

15:00-15:15 Group photo

15:15-15:45 Health break

15:45 – 16:15 General Discussion: Future election for ITWG Co-chairs Chair-persons: Liam Gumley and Vincent Guidard		
16:15 – 17:45 Session 12: Observation operator and Observation errors Chair-persons: Reima Eresmaa and Erin Jones		
Oral presentations (Presentations 12 minutes + Questions 3 minutes)		
12.01	Kirsti Salonen *ECMWF*	Investigations on scene dependent observation errors accounting residual cloud contamination for hyperspectral IR
12.02	Jun Yang *Hans Ertel Centre for Weather Research / LMU Munich*	Evaluation of Assimilation and Prediction Effects of Different Satellite Observation Operators in CMA-GFS
12.03	Mate Mile *The Norwegian Meteorological Institute*	Exploring a microwave radiance footprint operator in an Arctic data assimilation system
12.04	Xavier Calbet *AEMET*	Quantification of inhomogenous water vapor concentration effects in IR and MW radiation biases comparing observed versus calculated radiances (sondes + RTTOV)
12.05	Xiaoyan Zhang *NOAA/NCEP/EMC*	Satellite Bias Correction in the NOAA's Next Generation Regional Model – Rapid Refresh Forecast System (RRFS)
12.06	Cristina Lupu *ECMWF*	Estimation of the error covariance matrix for IASI reconstructed radiances and its impact at ECMWF

Tuesday, 21 March 2023

8:25 Weather briefing (Met Norway)

8:30 – 9:40 Session 13: Earth System Approach Chair-persons: Christina Köpken-Watts and David Tobin		
Oral presentations (Presentations 12 minutes + Questions 3 minutes)		
13.01	Thomas Auligné *JCSDA*	JCSDA next-generation Earth system data assimilation
13.02	Hyun-sung Jang *NASA LaRC / National Institute of Aerospace*	Impact of a priori contribution on CO retrievals from infrared hyperspectral measurements
13.03	Tracy Scanlon *ECMWF*	Further exploiting MW and IR radiances through extracting and using ocean skin temperature

		information in a coupled ocean-atmosphere system
13.04	withdrawn	
Poster introductions (Presentations 1 minute, no visual aid)		
13p.01	Robin Faulwetter *DWD*	Updates of radiance forward modelling in the DWD system
13p.02	Chawn Harlow *Met Office*	Multi-year changes in IASI LST biases and inter-channel error covariances seen in the Met Office Global NWP System
13p.03	Dirceu Herdies *National Institute for Space Research – INPE*	The detection of the South America Tropopause Aerosol Layer over the Amazon region
13p.04	Xu Liu *NASA Langley Research Center*	All-sky Retrieval of Atmospheric Temperature, Water Vapor, Clouds, Trace Gases, and Surface Properties from Operational Hyperspectral IR Sounders
13p.05	withdrawn	
13p.06	Daniel Zhou *NASA Langley Research Center*	NAST-I for air quality monitoring and wildfire-related research

9:40 – 10:15 Session 14: Space Agency reports **Chair-persons: Dorothée Coppens and Agnes Lim**		
Poster introductions (Presentations 5 minutes, 2 slides)		
14p.01	Heikki Pohjola *WMO*	The Current Status and The Future Development Plans of WMO OSCAR/Space
14p.02	Kozo Okamoto *JMA*	Status report of space agency: JMA and JAXA
14p.04	Peng Zhang *CMA*	CMA
14p.06	Lihang Zhou *NOAA*	NOAA

10:15-10:45 Health break

10:45 – 12:05 Session 15: Data Impact Studies **Chair-persons: Fiona Smith and Magnus Lindskog**		
Poster introductions (Presentations 1 minute, no visual aid)		
15p.01	Chris Burrows *ECMWF*	Assimilating short-wave infrared radiances from CrIS at ECMWF
15p.02	Zhenglong Li (for Di Di) *CIMSS/SSEC/UW-Madison*	Can the current hyperspectral infrared sounders capturing the small scale atmospheric water vapor spatial gradients?
15p.03	Robin Faulwetter *DWD*	Humidity sensitive Radiances and constrained bias correction in the DWD System

15p.04	Nadia Fourrié *CNRM Meteo-France and CNRS*	What is the real benefit of assimilating IASI within the Météo-France global model ARPEGE?
15p.05	Nadia Fourrié for Robin Marty *CNRM Meteo-France and CNRS*	Preparing the assimilation of IASI-NG within the Météo-France global model ARPEGE using an OSSE framework
15p.06	Nahidul Hoque Samrat *Bureau of Meteorology*	Impact Assessment of Himawari-8 AHI radiance assimilation and VarBC application in the ACCESS-C model
15p.07	Dorothée Coppens (for Tim Hultberg) *EUMETSAT*	The revival of L2 assimilation. Radiances or profiles? That is the question!
15p.08	Bryan Karpowicz *University of Maryland Baltimore County*	Improving CrIS Infrared Assimilation in the GEOS Atmospheric Data Assimilation System
15p.09	ZeTing Li *Center for Earth System Modeling and Prediction of CMA*	Assimilation of HY-2B SMR radiance observations using GRAPES 4DVAR at CMA
15p.10	Zhenglong Li *CIMSS/SSEC/UW-Madison*	Challenges in CrIS shortwave radiance assimilation
15p.11	Haixia Liu *Lynker@NOAA/NCEP/EMC*	Updates on Clear-Sky Radiance Assimilation from Geostationary Satellites at NCEP
15p.12	Stefano Migliorini *Met Office*	Assimilation of Transformed Retrievals from IASI radiances at the Met Office: current results and future perspectives
15p.13	Indira Rani Sukumara Pillai *NCMRWF*	Preparedness of the DA system for the assimilation of Microsat-2B MHS radiances at NCMRWF
15p.14	Kirsti Salonen *ECMWF*	Impact assessment of IASI temperature and humidity retrievals in the ECMWF system with scene dependent observation operators
Oral presentations (Presentations 12 minutes + Questions 3 minutes)		
15.01	Nancy Baker *Naval Research Lab*	What is a good mix of observations?
15.02	Sumit Kumar *NCMRWF*	Multi-year impact assessment of satellite observations in NCMRWF operational Numerical Weather Prediction (NWP) system
15.03	Fuzhong Weng *CMA Earth System Modeling and Prediction Centre*	Assimilation of FengYun Satellite Data in CMA-GFS Using Advanced Radiative Transfer Modeling System (ARMS)
15.04	Liam Steele *ECMWF*	FY-3E Microwave Sensors Evaluation at ECMWF

12:05-12:15 Session 16: International Session 17: Future Systems Chair-persons: Indira Rani and Nancy Baker		
Poster introductions (Presentations 1 minute, no visual aid)		
16p.01	Simon Elliott *EUMETSAT*	International Data Exchange and the transition to WMO's WIS 2.0
16p.02	withdrawn	
17p.01	Francisco Bermudo *Centre National d'Etudes Spatiales*	IASI-NG Program: General Status Overview
17p.02	withdrawn	
17p.03	Eric Jurado *Centre National d'Etudes Spatiales*	IASI-NG mission performances and ground segment development status
17p.04	Benjamin Ruston *JCSDA*	JEDI Skylab Observation Evaluation and Use With Emerging Sensors
17p.05	Fiona Smith *Bureau of Meteorology*	A Microwave Sounding Mission for Australia

12:15-13:15 LUNCH

13:15-13:45 Poster viewing (Sessions 13, 14, 15, 16,17)

13:45 – 15:00 Session 15: Data Impact Studies (continued) Chair-persons: Fiona Smith and Magnus Lindskog		
Oral presentations (Presentations 12 minutes + Questions 3 minutes)		
15.05	David Tobin *CIMSS/SSEC/UW-Madison*	Channel Selection and Apodization considerations for Hyperspectral Infrared Sounder Data
15.06	Per Dahlgren *MET Norway*	Impact of satellite data in a regional reanalysis system
15.07	Indira Rani Sukumara Pillai *NCMRWF*	DBNet data reception, processing and assimilation at NCMRWF
15.08	Erin Jones *UMD CISESS at NOAA/NESDIS/STAR*	On Expanding the Use of CrIS Observations in NOAA's Global Systems: What Has Been, and Still Needs to Be, Done
15.09	Thomas Deppisch *DWD*	Studying the Interaction between NWP Models and Data Assimilation with Observing System Simulation Experiments – Case Studies with SEVIRI Data in ICON-LAM

15:00-15:30 Health break

15:30 – 16:45 Session 16: International Chair-persons: Indira Rani and Bill Bell
Oral presentations (Presentations 12 minutes + Questions 3 minutes)

16.01	Heikki Pohjola *WMO*	WMO Unified Data Policy and Core Satellite Data
16.02	Mikael Rattenborg *WMO*	Status of the Direct Broadcast Network for globally coordinated real-time acquisition, processing and fast delivery of satellite direct readout data, coordinated by the World Meteorological Organization
16.03	Philippe Chambon *CNRM, Météo-France & CNRS*	Research Highlights from the International Precipitation Working Group (IPWG)
16.04	Mikael Rattenborg (for Mitch Goldberg) *WMO*	Report from CGMS
16.05	Benjamin Ruston *JCSDA*	Update from the International Earth Surface Working Group (IESWG)

16:45 – 17:30 Session 17: Future Systems Chair-persons: Nancy Baker and Jérôme Vidot		
Oral presentations (Presentations 12 minutes + Questions 3 minutes)		
17.01	Kristen Bathmann *Spire Global*	Initial Validation of the Hyperspectral Microwave Sensor
17.02	Andrew Heidinger *NOAA/NESDIS*	Status of NOAA's GeoXO Hyperspectral Infrared Sounder (GXS)
17.03	Sreerekha Thonipparambil *EUMETSAT*	An overview of EUMETSAT activities towards preparing users on the uptake of data from Meteosat Third Generation (MTG) and European Polar System – Second Generation (EPS-SG) missions

Wednesday, 22 March 2023

8:30-8:45	**About future co-chair election (15 minutes)**
8:45-8:50	**European Meteorological Society Young Scientist Award**
8:50-9:00	**ITWG Awards for best oral and poster presentations**
9:00-10:00	**Working group reports (15 minutes) Advanced Sounders Climate Products and Software Radiative transfer and surface properties**
10:00-10:25	**Health break**
10:25-10:55	**Working group reports (15 minutes) NWP International and Future Systems**
10:55-11:05	**Technical sub-group reports (5 minutes) RTTOV/CRTM RFI**

11:05-11:20	**Closing**

ITSC-24 ABSTRACTS

Thursday, 16 March 2023

Session 1: Radiative Transfer

1.01 RTTOV development status

Presenter: James Hocking, Met Office
Co-authors: Vasileios Barlakas1, Florian Baur2, Mary Borderies3, Philippe Chambon3, Patrick Eriksson4, Alan Geer5, Christina Köpken-Watts2, Jean-Marie Lalande3, Thomas Lebrat3, Cristina Lupu5, Rohit Mangla3, Marco Matricardi5, Pascale Roquet3, Tracy Scanlon5, Leonhard Scheck2, Olaf Stiller2, Christina Stumpf2, Emma Turner6, Jérôme Vidot3 ; 1EUMETSAT/HE Space Operations, 2DWD, 3Météo-France, 4Chalmers University, 5ECMWF, 6Met Office

Since the last ITSC, two minor releases of RTTOV, v13.1 and v13.2, were made available to users which included various developments. The MFASIS fast visible cloud solver has been extended to support channels at 1.6 microns, and a new neural-network-based version has been implemented resulting in a further speed-up of this fast operator. RTTOV now provides an initial UV simulation capability. RTTOV-SCATT (the microwave scattering model) has undergone updates including a further improvement to the treatment of polarised scattering by frozen hydrometeors. A new fast microwave sea surface emissivity model (SURFEM-Ocean) has been implemented. This is derived from the recently developed PARMIO physical reference model. In addition, the next major release, RTTOV v14.0, is under development. This is a significant update to RTTOV involving the unification of RTTOV with RTTOV-SCATT. This enables all visible/IR/MW scattering simulations to be run through the RTTOV interface, and the science implemented in both models is now shared across the whole spectrum (where relevant). For example, the delta-Eddington solver (from RTTOV-SCATT) may be used for IR sensors. This development paves the way for further improvements in spectral consistency within RTTOV. Highlights of the RTTOV v13.x updates will be presented along with a look ahead to RTTOV v14.0.

1.02 Community Radiative Transfer Model: A Community Model for Operational Contributions

Presenter: Benjamin Johnson, JCSDA
Co-authors: Cheng Dang, Patrick Stegmann, Quanhua Liu, Isaac Moradi, Nick Nalli, Sarah Lu

The Joint Center for Satellite Data Assimilation (JCSDA) Community Radiative Transfer Model (CRTM) is a fast, 1-D radiative transfer model used in numerical weather prediction, calibration / validation, etc. across multiple federal agencies and universities. The key benefit of the CRTM is that it is a satellite simulator, in that it provides a highly accurate representation of satellite radiances by making appropriate use of the specific sensor response functions convolved with a line-by-line radiative transfer model (LBLRTM). CRTM covers the spectral ranges consistent with all present operational and most research satellites, from visible to microwave. The capability to simulate ultraviolet radiances is being added over the next two years in CRTM v3, which also includes full Stokes polarization support. This presentation will highlight the latest developments in CRTM v3.0, and will cover the integration of the CRTM into the JCSDA JEDI-UFO model, which enables access to a large number of data assimilation and modeling frameworks that have been interfaced to the the JEDI framework. We will also discuss a recent intercomparison between CRTM and the RTTOV model.

1.03 The new features of the σ-FORUM Forward Model, the general purpose Fast Radiative Transfer Model for the present and next hyperspectral instruments

Presenter: Guido Masiello, Univeristy of Basilicata
Co-authors: Carmine Serio, Sara Venafra, Giuliano Liuzzi, Pietro Mastro, Tiziano Maestri, Michele Martinazzo, Fabrizio Masin

The forward model σ-IASI has been developed in the framework of several EUMETSAT projects to support the IASI mission. It has been designed for the fast calculation of radiance and its derivatives with respect to atmospheric and spectroscopic parameters. Thanks to its flexibility the forward model was applied successfully both for retrieval applications and spectroscopy validation to IASI measurements and other interferometers and radiometers such as AIRS (the NASA Atmospheric InfraRed Sounder), NAST-I (the NPOESS Aircraft Sounding Testbed- Interferometer), and IMG (the Japanese Interferometer Monitoring Greenhouse Gases), REFIR (Radiation Explorer in the Far Infrared). σ-IASI is a monochromatic radiative transfer model based on a look-up table of optical depths parametrized as a polynomial of the atmospheric temperature and constituents. This

strategy enables fast, accurate radiance and analytical derivatives calculations. The lookup table is built based on the current LBLRTM version, but the model can use other line-by-line schemes and different spectroscopic databases. Recently in the framework of the FORUM-Scienza project, supported by the Italian Space Agency with the goal of creating and sustaining the Italian community focused on the EE9-FORUM mission, the model has been improved by including innovative ice, water clouds, and aerosols' multiple scattering and absorption properties. The FORUM (Far-infrared Outgoing Radiation Understanding and Monitoring) instrument is expected to cover the range 100 to 1600 cm-1, that is, the far-infrared spectral region of the Earth emission spectrum, which is of paramount interest for water vapor and cirrus cloud processes affecting climate and global warming. In this paper, we present the current version of σ-IASI called σ-FORUM. The radiative transfer model collects the legacy of what has been done for IASI by extending the spectral range from 5 to 3000 cm-1 and, therefore, suiting the specifications of both IASI-NG and FORUM. In addition to the extension in the far infrared spectral range, this version introduces two notable innovations. The first concerns the parameterization of clouds and aerosols. The second is a new analytical treatment of the RTE that better simulates heavily non-homogeneous layers. The current version of the model considers ice and water clouds and aerosols by representing their multiple scattering and absorption properties with an improved, analytical parameterization of the so-called Chou approximation combined with Tang correction. Both this and the improvements in the treatments of non-homogeneous layers, which will be described in this work, make σ-FORUM a state-of-the-art fast-forward model capable of computing analytical Jacobian derivatives with respect to ice and water content concentrations and the effective radii. Thus, the new σ-FORUM model is ready for the retrieval of cloud microphysical properties.

1.04 All-Sky Radiative Transfer Simulations based on the Advanced Radiative transfer Modeling System (ARMS)

Yi-Ning Shi, CMA Earth Modeling and Prediction Centre
Co-authors: Ziyue Huang, Ziqiang Ma, Yang Han, Jun Yang, Fuzhong Weng

Satellite data assimilations need a fast and accurate radiative transfer model to establish the relationship between the numerical weather model and satellite observations. In order to support the application of Fengyun meteorological satellites, China Meteorological Administration developed the Advanced Radiative transfer Modeling System (ARMS). The accuracy of ARMS has been widely evaluated and has fully supported data assimilations of Fengyun satellites in clear-sky cases. In order to meet the needs of data assimilations for cloudy cases, all-sky radiative transfer simulations are required. In cloudy cases, the scattering effect of cloud/rain particles should be considered. Therefore, based on ARMS, this study established a cloud/rain particle scattering database in microwave spectrum by using Mie scattering and discrete dipole approximation. The database includes scattering parameters of spherical particles, six bullet shaped ice crystals, graupel and polymer bullet shaped ice crystals. The influence of atmospheric temperature on the complex refractive index of cloud particles is also considered. When we apply the database to all-sky radiative transfer simulations for MicroWave Humidity Sounder onboard the FengYun 3E satellite, we find that the new database can significantly improved results. Compared to the original spherical particle scattering database, the new database performs better, especially for the simulation of ice cloud region. In addition, this study also compared the observations of Advanced Geostationary Radiation Imager onboard the FengYun 4B satellite to ARMS simulations. The ARMS accuracy for all-sky cases in infrared spectrum is also investigated.

1p.01 Estimation and its application of new channel RTTOV coefficients for GK-5 the follow on GK2A

Presenter: Junhyung Heo, KMA (for Junyeob Choi)

KMA is preparing to launch a follow on satellite to the GK-2A in 2029. The satellite will be on boarded sensors more channels thanGK2A's 16 channels. The added channels will be affected the accuracy of the meteorological products of GK-5. So, KMA estimated new channels RTTOV coefficient to determine which channel would have the greatest effect on meteorological products. To verify the accuracy of the new RTTOV coefficient, GK2A coefficient was estimated by AER Line-By-Line Radiative Transfer Model (LBLRTM) and compared with the coefficient provided by NWPSAF. The differences of Brightness Temperature for two coefficients are shown less than 0.5 K for 10 IR channels of GK2A/AMI. So, the coefficient for 2.2 ㎛ and 5.6㎛ were calculated. How these two channels affect meteorological products will be evaluated soon. We will present detailed results in the conference. This work was funded by the Korea Meteorological Administration's Research and Development Program "Technical Development on Weather Forecast Support and Convergence Service using Meteorological Satellites" under Grant (KMA2020-00120).

1p.02 Advances in CRTM aerosol simulations with v2.4.1 and v3 releases

Presenter: Benjamin Johnson, JCSDA (for Cheng Dang)
Co-authors: Benjamin T. Johnson, Patrick Stegmann, Quanhua Liu

The Community Radiative Transfer Model (CRTM) is a fast and multi-layer radiative transfer model for remote sensing and data assimilation (DA) applications in numerical weather prediction (NWP) systems. The accuracy of CRTM relies on the physical assumptions of model components that are often constrained by available theoretical understanding and observational measurements, and thus subject to changes and continuous improvements with the evolution of science and operational requests. Since the release of Community Radiative Transfer Model (CRTM) version 2.4 in 2020, continuous updates have been made to the physical assumptions, model structures, and coefficient generation suites associated with CRTM. This presentation summarizes recent development in aerosol radiative transfer simulations. In particular, we show a list of aerosol tables applicable to AOD and radiance assimilation for aerosol assumptions in CMAQ, GOCART, NAAPS, RTTOV, and WRF-Chem models. We demonstrate ways to switch across different model options and opportunities to customize CRTM with user-request physical assumptions for broader community applications. These developments will be released in the last scaler version of CRTM (version 2.4.1) and continue to be supported/enhanced as CRTM moves onward to polarized radiative transfer calculations in CRTM version 3.

1p.03 All-sky intercomparison of the CRTM and RTTOV radiative transfer models with the analysis fields from a 16-day WRF-GSI-LETKF regional data assimilation system

Presenter: Vito Sol Galligani, CIMA (CONICET-UBA)
Co-authors: Vito Sol Galligani, Paola Belén Corrales, Juan Ruiz and Benjamin Johnson

At the heart of satellite radiance data assimilation and retrieval techniques lies a cost-effective computationally efficient/fast radiative transfer model (RTM). For all-sky conditions, this RTM requires accurate performance in complex scattering media. A number of Operational Numerical Weather Prediction (NWP) centres have started to assimilate all-sky satellite observations (ie., under clear, cloudy, and precipitating conditions). As the operational demand of RTMs under scattering media increases, it is key to evaluate their accuracy. The inter-comparison/validation of full scattering solvers in RTMs provides insights into the strengths and weaknesses of these models. This study aims to contribute to this. This study is also part of the efforts currently underway to implement an all-sky regional mesoscale data assimilation system in Argentina and improve other operational products. We compare two of the most widely used RTMs in NWP centres, the Community Radiative Transfer Model (CRTM, v2.3) and the Radiative Transfer for TIROS Operational Vertical Sounder (RTTOV, v13), for all-sky conditions in South Eastern South America. The evaluation of the all-sky radiative transfer simulations is conducted against (a) all the available microwave sounders and imagers, and (b) GOES-16 Advanced Baseline Imager (ABI) channels during the selected study period (8th - 24th November 2018). The input atmospheric and surface properties fed into the forward models are the analysis fields from a recently implemented WRF-GSI-LETKF system with 10-km horizontal grid spacing where continuous hourly assimilation cycles were conducted The data assimilation process included conventional observations from NCEP's prepBUFR files; a dense network of automatic surface weather stations and satellite clear sky radiances from different microwave and infrared sensors. The chosen study period provides diverse meteorological situations, including several deep convection cases developed over central and northeastern Argentina (Corrales et al., 2022). We will discuss the degree of agreement between the models in all-sky conditions, with special attention on cloud-affected radiances, and consistency between WRF microphysical parameterizations and RTM scattering properties: species particle size distribution (PSD) + single scattering properties (SSP). Regarding CRTM, insight into the latest developments on scattering coefficient tables are analysed.

1p.04 Updated radiative transfer modelling to simulate the Pressure Modulated Radiometer (PMR) instrument from the 1970s
Presenter: Valentin Jules, CNRM, Météo France, CNRS
Co-authors: Jean-Marie Lalande, Thomas Lebrat, Jérôme Vidot

As part of the EU-funded Copernicus Climate Change Service (C3S) program, we contribute to the perspective to rescue, assess and prepare observations from several satellites that flew in the 1970s for the next re-analysis ERA-6. We focus here on the Pressure Modulated Radiometer (PMR) instrument on board Nimbus 6. The purpose of this instrument was to measure the atmosphere's temperature distribution in the upper stratosphere and mesosphere by using the pressure modulation of a CO2 cell placed in the optical path. After a brief investigation of the PMR spectral characteristics, we simulate the transmittance of the CO 2 cell by using the latest version of the Line By Line model LBLRTM that includes updated CO2 spectroscopy. The spectral response function of the instrument then allows us to compute the coefficients of the RTTOV radiative transfer model.

1p.05 Evaluation of ICON model clouds using visible channel reflectances and RTTOV-MFASIS simulations
Presenter: Christina Köpken-Watts, DWD
Co-authors: Christina Stumpf, Leonhard Scheck

In preparation of an assimilation of visible satellite observations in DWD's ICON+EnVAR global NWP system, this study evaluates the model clouds through comparison of simulated and observed SEVIRI reflectances. The use of observations in the visible provides the potential for improved cloud and near-surface analyses and forecasts, particularly in conjunction with all-sky assimilation of infrared radiances due to its higher sensitivity with respect to model some physics aspects like cloud optical thickness influenced by cloud particle radii. Experiments assimilating SEVIRI's 0.6µm channel in DWD's convection-resolving ICON-LAM have demonstrated a consistently positive impact improving cloud representation as well as cloud-related processes and the preparation for the assimilation of visible observations in DWD's ICON+EnVAR global NWP system is ongoing. For the model comparisons we simulate the visible reflectances with the fast forward operator RTTOV-MFASIS (v13). Additionally to these comparisons involving real data, we also perform a systematic uncertainty quantification of MFASIS by comparing its forward computations to results of the DISORT implementation in RTTOV (RTTOV-DOM) for a range of model profiles and stratified according to model cloud situations. Evaluations cover a wide range of atmospheric situations and viewing geometries drawn from two periods in November 2020 and March 2021. The investigation addresses the sensitivity of observation departures with respect to model resolution by including statistics for the full 13km and lower 40km ensemble resolution. Also, the influence of assumed cloud particle radii distributions on the results is studied through using effective cloud and ice particle radii from either the RTTOV parameterizations or from the ICON model. For better understanding the dependence of error characteristics on cloud types, we stratify statistics using Level-2 cloud products, such as EUMETSAT's Optimal Cloud Analysis product OCA for SEVIRI. The results of this study provide feedback on ICON model cloud physics as well as input for the development of situation-dependent observation errors and bias correction, thus paving the way for an assimilation of visible satellite channels into the global ICON model.

1p.06 Update of the radiative transfer model to RTTOV-13 at JMA
Presenter: Naoto Kusano, Japan Meteorological Agency

Various observational data are utilized to obtain initial conditions for numerical weather prediction (NWP) models. Accurate initial conditions lead to small errors of NWP. JMA assimilates satellite radiance data from various sensors such as microwave sounders, microwave imagers, clear sky radiance from geostationary satellites and hyperspectral infrared sounders. A radiative transfer model is necessary for assimilate satellite radiance data. Higher accuracy of radiative transfer model enables to utilize radiance data more appropriately. The radiative transfer model at the JMA's NWP systems (the global system, the meso-scale system and the local system) were updated from RTTOV-10.2 (Saunders et al. 2012) to RTTOV-13.0 (Saunders et al. 2020) in 2022. As a first step, the upgrade was limited to minimal changes such as modules and relevant file formats to ensure the implementation. Therefore the predictor coefficients are still RTTOV-10 and no significant changes in NWP accuracy. When the predictor coefficients are updated, quality control need to be reviewed. For example, a quality control for AMSU-A to eliminate cloud affected data using retrieved cloud liquid water is affected by the new coefficients. Even though the calculated brightness temperatures are more accurate, the number of used data decreases while current thresholds of cloud liquid water are applied. The progress on update of the radiative transfer model to RTTOV-13 including modification of quality control will be presented.

1p.07 Comparison Study between RTTOV v13, 4A/OP v1.7 and IASI Observations in Clear-Sky over Oceans
Presenter: Jean-Marie Lalande, CNRM, Météo France, CNRS
Co-authors: Raymond Armante, Jérôme Vidot

This study focuses on a comparison of the top of the atmosphere (TOA) clear-sky simulations over ocean from two radiative transfer models (RTM) to observations from the IASI instrument using colocated atmospheric profiles from the Analyzed Radio Soundings Archive (ARSA) database. The two RTMs are the last versions of RTTOV-13 and 4A/OP. The main objectives of the study is to evaluate (1) the effect of different spectroscopy for each RTM (HITRAN-based for RTTOV and GEISA-based for 4A/OP), (2) the scientific improvements of both models and (3) the derived Jacobians respective to meteorological variables such as temperature, water vapour and ozone. For RTTOV-13, the spectroscopy was updated with latest version of LBLRTM (v12.8) (including MTCKD 3.5 and AER spectral database version 3.6). As major scientific improvements for RTTOV, a new transmittance model has been implemented and preliminary results are very encouraging in separating contributions from molecules such as water vapour and ozone. For 4A/OP, the latest version 1.7 was used also with up to date spectroscopy (GEISA-2015 line parameters, line mixing, continua $H_2O/N_2/O_2$, etc.). The results of the intercomparison will be presented and discussed.

1p.08 Fast spectral radiance computations in cloudy conditions at far and mid infrared wavelengths using the sigma-FORUM code
Presenter: Tiziano Maestri, Physics and Astronomy Department University of Bologna
Co-authors: Michele Martinazzo, Fabrizio Masin, Guido Masiello, Carmine Serio, Sara Venafra, Giuliano Liuzzi

In September 2019, the European Space Agency (ESA) selected FORUM (Far-infrared Outgoing Radiation Understanding and Monitoring) as the 9th Earth Explorer (EE9) whose launch is foreseen in 2027. The National Aeronautics and Space Administration (NASA), in parallel, will deploy on orbit the PREFIRE (The Polar Radiant Energy in the Far Infrared Experiment) satellite in 2023 to perform infrared and far-infrared measurements of Earth's atmosphere from space. These missions, dedicated to mapping Earth's far-infrared emission globally, will produce an enormous quantity of new data requiring the implementation of fast radiative transfer models applicable to the entire IR spectral region for their analysis. Full physics models (i.e. DISORT) exploit robust and accurate numerical methodologies to solve the radiance field in presence of multiple scattering events for specific scenarios. The complexity of the multiple scattering effects makes this class of models extremely time consuming and inappropriate for large dataset analysis. To save computational time, fast radiative transfer models rely on multiple strategies which might account for approximation of the physical problem, simplified numerical solutions, code parallelization, and the extensive use of parametrizations. A recent fast methodology, widely used in operative frameworks for its simplicity and easy implementation, is the scaling scheme proposed by Chou et al. (1998). Although assembled for irradiance computations in presence of clouds, it is successfully applied to simulate spectral IR radiance. Nevertheless, recent studies have shown that its application to the calculation of the spectral radiance in the FIR produces significant differences with respect to a full-physics approach. To reduce the bias of the Chou scaling method, a correction term is modelled and computed using the solution recently proposed by Tang et al. (2018) to refine the flux computations. In this presentation the Tang methodology is adapted to simulations of radiance fields over the full IR spectral range. Appropriate multiplicative coefficients are computed in the far and mid infrared separately. The range of validity of the new methodology is evaluated by comparing the fast solutions against full physics simulations. The FORUM NESR is used as the metric for testing the accuracy of the fast solution. The results show that the domain of application of the new methodology covers most of the cloudy cases encountered in nature. In particular, the use of the Tang methodology with the new coefficients is accurate for the computation of radiance fields in presence of cirrus clouds which are one of the targets of the FORUM mission. Note that the multiplicative coefficients are computed for the zenith view and 4 additional Gaussian angles allowing an angular characterization of the whole radiance field and a fast and accurate computation of fluxes by Gaussian quadrature. The whole set of radiative parameters needed to solve the radiative transfer equation using the Chou and Tang approximations is parametrized by means of polynomial functions of the effective dimension of the cloud particle size distribution. The parametrized parameters are then implemented in the sigma-FORUM code a pseudo monochromatic radiative transfer model designed for fast calculation of spectral radiance and its derivatives with respect to atmospheric and spectroscopic parameters. The σ-FORUM model is an updated version of sigma-IASI model developed by the University of Basilicata and based on optical depths look-up tables to speed up computations. The strategy enables computations of fast, accurate high-resolution radiance and their analytical derivatives over the full IR spectrum, also in presence of clouds.

1p.09 withdrawn

1p.10 Simulation of GK2A visible channel image and its application
Presenter: Inchul Shin, National Meteorological Satellite Center/Korea Meteorological Administration
Co-authors: Haemin Kim, Byunghyun Song, and Yoonjae Kim

Since 2018, KMA has produced model-simulated images of Infrared (IR) and Water Vapor (WV) channels based on Geo-Kompsat 2A (GK2A). Simulated brightness temperatures are calculated from KMA's various global NWP model's output such as Korea Integrated Model (KIM), Unified Model (UM)), European Centre for Medium Weather Forecasts (ECMWF), and UM-based local NWP. KMA uses meteorological fields from these model outputs using a latest Radiative Transfer for TOVS (RTTOV). This information can be useful for verifying model cloud properties, as well as synoptic scale feature. Especially, Simulated and observed water vapor satellite image comparisons are used to analyze at difference in intensity of large scale feature, such as troughs and dry intrusion within the upper troposphere. To generate additional simulated reflectance of four visible channels (0.4, 0.5, 0.6, 0.8μm), the latest release of RTTOV (v13.0) that use the lookup-table based Method for Fast Satellite Image synthesis (MFASIS) developed by scheck et al. (2016) was employed. The surface reflectance used as input for MFASIS are derived from the RTTOV-BRDF Atlas (Vidot et al., 2018). The model-simulated satellite images of visible channel have been based on the resolution of the global and local NWP model with 1-hourly output from T+0 to T+18. Day-night RGB and true color RGB images are generated by combining simulated visible channel and infrared channel images with RTTOV. Simulated RGB images are expected to be helpful for analyzing cloud properties more detail than the simulated non-combining infrared satellite images. The utilization of this data will also be discussed.

1p.11 Implementing the Zeeman effect in the RTTOV fast radiative transfer model
Presenter: Emma Turner, Met Office

The Zeeman effect causes the spectral lines of molecular oxygen to split in the upper atmosphere under the influence of the Earth's magnetic field. This can produce measured satellite brightness temperatures that are several kelvin different relative to simulations that do not include Zeeman splitting. In order to utilize temperature sounding microwave channels that measure at levels around 12 hPa/30 km or above, such as channels 19-22 of SSMI/S, in NWP models, the effect must be included in the observational operator. This work presents Zeeman affected radiance simulations of such satellite channels using RTTOV, the fast radiance transfer model. Modified spectral absorption routines are implemented in AMSUTRAN, the line-by-line code that trains the coefficients, and RTTOV 13, via fast predictors that include magnetic field strength and the angle between the magnetic field and satellite viewing angle. The results are to be discussed.

1p.12 Improved cloud scattering parameterization for Mid and Far-IR in RTTOV
Presenter: Jerome Vidot, CNRM/Meteo-France/CNRS
Co-authors: Laurent C. Labonnote, James Hocking, Jean-Marie Lalande

The fast radiative transfer model RTTOV (Saunders et al., 2018) has been developed for decades for satellite data assimilation in Numerical Weather Prediction (NWP) models and is increasingly used for direct retrieval of atmospheric parameters from satellite data. In the thermal infrared, the scattering by clouds or aerosols is modelled by the Chou parameterization (Chou et al., 1999), which allows a very fast simulation of the scattering contribution to the total signal. By using a large dataset of realistic cloud profiles from the ECMWF NWP model, we have shown that in the mid-infrared, the Chou parameterization gave very good results for ice clouds and poorer results for liquid or mixed phase clouds. With the recent selection of the FORUM mission as part of the ESA Earth Explorer 9 programme, we also tested the

Chou parameterization in the far-infrared (wavelengths > 18 μm) and were able to show that the results were degraded in this spectral range for ice clouds. A recent paper by Tang et al. (2018) showed that an adjustment of the Chou parameterization improves the simulation of cloud scattering in the infrared. We implemented this in the latest version of RTTOV and compared the simulations to the full scattering model LIDORT. This study shows the performance of the new parameterization on total cloudy radiances as well as on sensitivities (Jacobians) to cloud parameters for both the mid and far-infrared.

1p.13 A Calibrated Lunar Microwave Radiative Transfer Model Based on Satellite Observations

Presenter: Hu (Tiger) Yang, CISESS, University of Maryland

Co-authors: Martin Burgdorf

As a potential external calibration reference for spaceborne microwave sounding instruments, accurate and reliable information of lunar disk-averaged radiance at millimeter band are important and fundamental. Based on study for 2-D lunar scans of the Advanced Technology Microwave Sounder (ATMS) on board the NOAA-20 satellite, the lunar radiance spectrum from 23 to 183 GHz at full moon phase has been reported in our previous work. In this study, the performance of a lunar microwave radiative transfer model (RTM) was investigated. By taking the ATMS observations as the reference truth, the surface emissivity in the lunar RTM can be calibrated. The calibrated RTM model was then evaluated by independent satellite observation data sets from AMSU (Advanced Microwave Sounding Unit) and MHS (Microwave Humidity Sounder) instruments on several NOAA satellites. Results show that with the calibrated model, significant improvement can be made to reduce the uncertainties in the lunar microwave RTM simulations at millimeter wavelengths.

Session 1: Radiative Transfer (continued)

1.05 Statistical study of inconsistencies between infrared and microwave cloudy simulations

Presenter: Ethel Villeneuve, CNRM, Université de Toulouse, Météo-France, CNRS

Co-authors: Philippe CHAMBON and Nadia FOURRIE

The modelling of scattering properties is of major interest in cloudy data assimilation. Across the spectrum from the infrared to the microwave frequencies, these properties have been modelled with various assumptions (hydrometeors shapes, particle size distribution, dielectric properties ...) and methodologies (DDA, T-matrix, ...). They are then used within fast radiative transfer codes like RTTOV. Thus, it can induce inconsistencies between simulations of the different spectral ranges. This study aims at providing quantitative results to evaluate the importance of simulating consistent radiative properties across the spectrum with respect to uncertainties within NWP model microphysical parameterizations. In this study, different sources of inconsistency between infrared and microwave simulations are investigated. A fully simulated framework is used. Observations and first guess are simulated with lagged forecasts from the Météo-France ARPEGE global model. Using RTTOV v13, simulations of several future instruments from Meteosat Third Generation and EUMETSAT Polar System Second Generation missions are made. The Microwave Imager (MWI) and the Ice Cloud Imager (ICI) onboard MetOp Second Generation MetOp-SG-B will provide microwave data and the Flexible Combined Imager (FCI) onboard Meteosat Third Generation MTG-I will provide infrared data. These three instruments are sensitive to various and complementary quantities within clouds and precipitation. The so-called ”1D-Bayesian + 4D-Var” assimilation method (Duruisseau et al., 2019) is used for the assimilation of cloudy microwave observations at Météo-France. It consists of a Bayesian inversion of the brightness temperatures, that retrieves atmospheric profiles from satellite radiances which are then assimilated in the 4D-Var of the global model ARPEGE. Here we use the same assimilation method for the infrared data. Inconsistencies could come from errors in the radiative transfer assumptions or in the model parameterizations. In order to simulate these inconsistencies and compare them to understand which one would be predominant, we build different experiments. The first experiment will be referred as “perfect”: inconsistencies are eliminated by using the same radiative transfer to simulate observation and first guess, and the same model configuration is used for all computations. This experiment is used as the reference to quantify the impact of each source of inconsistencies. These sources of inconsistencies are simulated by perturbations introduced in first guess simulations. Observation remains simulated with the settings of the control experiment. A second type of experiments is set this way introducing one type of perturbation either in the radiative transfer model or in the parameterizations in the model ARPEGE. The third experiment gathers both types of perturbations to understand which one predominates on the other. Statistical results covering a wide sample of profiles from ARPEGE forecast model will be shown to compare the ability of the 1D-Bayesian approach to retrieve correct hydrometeor profiles among the different types of experiment in order to quantify how the different hypotheses between infrared and microwave data involve significant errors.

1.06 All-sky simulations of the Ice Cloud Imager

Presenter: Hanna Hallborn, Chalmer University of Technology
Co-authors: Patrick Eriksson (1), Hanna Hallborn (1), Inderpreet Kaur (1), Eleanor May (1), Simon Pfreundschuh (1), Bengt Rydberg (2), Stefan Buehler (3), Manfred Brath (3), Stuart Fox (4), Alan Geer (5), Christophe Accadia (6), Vasileios Barlakas (6,7), Francesco De Angelis (6), Robin Ekelund (6,7) and Vinia Mattioli (6)
1 Chalmers University of Technology, Sweden
2 Swedish Meteorological and Hydrological Institute
3 University of Hamburg, Germany
4 Met Office
5 ECMWF
6 EUMETSAT
7 HE Space Operations

The upcoming ICI (Ice Cloud Imager) mission aims at improving global observations of ice hydrometeors, to support both weather and climate applications. ICI is a conically scanning instrument having 13 channels between 183 and 664 GHz. Eight of the channels are at sub-mm wavelengths, a region presently not used for operational measurements, making ICI a first-of-its-kind. Due to the novelty of ICI, significant development has been required to reach the state of today when rigorous "all-sky" simulations of ICI can be performed. These efforts will be outlined, with focus on the radiative transfer behind the "day-one" ICI climate product to be produced at EUMETSAT. The core component of these retrievals is a database of simulated ICI radiances. As relatively long computational times can be accepted when creating the database, a high ambition in the realism in the simulation scan be afforded. For example, about 20 pencil beam calculations are performed for each final antenna weighted value, to maintain low simulation noise due to cloud inhomogeneities (beam filling). Single scattering data are taken from the ARTS database, developed largely by the needs raised by ICI. These data are combined with empirically-based assumptions on both size and orientation of the ice particles, to form a number of particle models. For each 3D simulation scene, a random selection among the particle models is made, with the ambition to statistically represent the presence of different ice hydrometeor categories. As validation, the same setup has been used to simulate most similar existing observations (GMI and ISMAR) and so far all comparisons have been satisfactory. In parallel, we have extended RTTOV-SCATT to ensure that ICI radiances can be assimilated into NWP models. The synergy between climate and weather applications is stressed. For example, RTTOV-SCATT has been verified for ICI wavelengths by the more accurate (but more time-consuming) scattering solvers used on the climate side, while a scheme to approximate particle orientation developed for NWP was picked up and extended for the database generation.

1.07 Principal Component-based Radiative Transfer Model (PCRTM) for Hyperspectral Remote Sensors for UV, VVIS, NIR, IR, and FIR Spectral Regions

Presenter: Xu Liu, NASA Langley
Co-authors: Xu Liu, Qiguang Yang, Wan Wu, Xiaozhen Xiong, Ming Zhao, Ping Yang, Robert Spurr, Daniel K. Zhou, and Allen M. Larar

Fast and accurate radiative transfer models are needed to efficiently process satellite hyperspectral remote sensors. We have developed a Principal Component-based radiative transfer model (PCRTM) which can simulate TOA radiance or reflectance spectra in the cloudy atmosphere for far IR, IR, NIR, VIS, and UV spectral regions quickly and accurately. Multi-scattering of multiple layers of clouds/aerosols is included in the model. Polarization components can also be calculated. The computation speed is 3 to 4 orders of magnitude faster than MODTRAN5, LBLRTM, and VLIDORT. The PCRTM calculated radiance spectra agree with reference RTM calculated radiance spectra very well (0.03 K in IR and 0.05% in solar). Comparisons of the PCRTM model calculations with observed AIRS, CrIS, IASI, NAST-I, and SCIAMACHY data will be presented. The solar-PCRTM has been developed for CLARREO PathFinder (CPF) and has been extensively used for CPF science algorithms. The PCRTM can also be used for many current and future NASA future missions such as EMIT, SBG, TEMPO, and PACE.

Session 2: Calibration and Validation
Session 3: Geo Imager Assimilation

2p.01 Orbital biases in microwave temperature-sounding observations?
Presenter: Niels Bormann, ECMWF
Co-authors: Niels Bormann, Linus Magnusson, Mohamed Dahoui, David Duncan

This poster examines orbital biases in microwave (MW) temperature-sounders such as AMSU-A and ATMS when compared against the ECMWF model background. These instruments have been assimilated over many years, and they are contributing significantly to forecast skill. The analysis shows that all AMSU-A observations exhibit biases as a function of the orbital angle, with distinct regular pattern that vary by season and are relatively stable over the 7-year study period considered. While the magnitude varies between different instruments, the pattern are remarkably similar for all AMSU-A instruments and most sounding channels used in the ECMWF system. The biases reach levels that are comparable to the instrument noise or the random errors present in the model background, and they lead to systematic diurnal increments in the ECMWF operational analysis. As other instruments are not showing such bias pattern, it appears likely that this is an instrument-related bias, rather than a bias in the background. However, the origin of the biases is currently not clear. Possible explanations as well as bias correction models will be discussed, and feedback from the ITWG community will be highly appreciated.

2p.02 withdrawn

2p.03 withdrawn

2p.04 IASI radiometric error uncertainty budget and inter-comparison results
Presenter: Dimitrios Kilymis, CNES
Co-authors: Dimitrios Kilymis, Laura Le Barbier, Yannick Kangah, Elsa Jacquette, Xavier Lenot, Jérémie Ansart, Mathilde Faillot, Jean-Christophe Calvel, Olivier Vandermarcq

The IASI (Infrared Atmospheric Sounding Interferometer) mission is a series of three sounders launched on board the Metop satellites between 2006 and 2018 in the framework of a collaboration between CNES and EUMETSAT. After the decommissioning of IASI-A in 2021, two remaining IASI instruments on board Metop-B and Metop-C continue to provide quality data for meteorological models and climate studies [1-3]. IASI is used as a reference for Thermal Infrared sounding systems by the GSICS (Global Space based Inter-Calibration System) therefore it is important to determine an accurate estimation of the radiometric error uncertainties. The major contributors are the non-linearity correction, the black body temperature stability and emissivity, as well as the correction of the scan mirror reflectivity. In this presentation, each of the above contributions are described and their share in the overall uncertainty budget is detailed. Furthermore, we also present the latest inter-comparison results between IASI-B and IASI-C, as well as those obtained with respect to CrIS (Cross-track Infrared Sounder) on-board NOAA-20.[1] Marie Bouillon et al, Ten-Year Assessment of IASI Radiance and Temperature, Remote Sens., 12(15), 2393 (2020).[2] Simon Whitburn et al, Trends in spectrally resolved outgoing longwave radiation from 10 years of satellite measurements, NPJ Clim. Atmos. Sci., 4:48 (2021).[3] Nadia Smith et al, AIRS, IASI, and CrIS retrieval records at climate scales: an investigation into the propagation of Systematic Uncertainty, J. Appl. Meteorol. Climatol., 54(7), (2015).

2p.05 Exploitation of Metop-A End-Of-Life backflip manoeuvre: estimating MHS mirror reflectivity and revealing scan-dependent biases
Presenter: Tim Hultberg (for Imke Krizek)
Co-authors: Imke Krizek, Joerg Ackermann

We estimate the mirror reflectivity of MHS in-flight, and as additional result, we discover a scan-dependent instrumental bias that may be attributed to on-board Radio Frequency Interference. The Metop-A End-Of-Life test campaign in Q3 of 2021 encompassed a backflip manoeuvre of the satellite. During this manoeuvre, the MHS instrument measures deep space in the 90 Earth Views. This offers a unique possibility to observe a constant cold background in the Earth views while the instrument is in orbit, thus providing a valuable means for analysing scan-dependent instrumental effects, whose characterisation is important for (re)calibration. We apply a known theoretical model for this backflip setting, which allows us to estimate the mirror reflectivity from the MHS backflip manoeuvre measurements. The deviations from that model present further insight on the instrument. They reveal an unobscured view on the scan-dependent bias that we can also detect in inter-satellite biases based on monthly means. In view of previous studies on MHS and AMSU-B instruments showing related results, we suspect the origin of those scan-dependent biases in on-board Radio Frequency Interference.

2p.06 Recent Advances in Global Radiosonde Observations for Their Applications in Satellite Data Calibration/Validation
Presenter: Bomin Sun, IMSG at NOAA/NESDIS/STAR
Co-authors: Anthony Reale, Lori Borg, Nicholas Nalli, Cassandra Calderella, and Michael Pettey

Characterization of the accuracy of satellite hyperspectral sounding data, both sensor measurements and atmospheric retrievals, is required for many applications of the data, including numerical weather prediction and environmental monitoring. Balloon-borne radiosonde observations have historically been used as the independent correlative measurements to assess satellite sounding data. However, errors in the radiosonde data and errors from the spatial and temporal mismatch between radiosonde and satellite data are primary factors that can affect the satellite data assessment. This work presents recent advances in global radiosonde observations with respect to their applications in satellite data calibration/validation (cal/val). Improved accuracy of radiosonde temperature and humidity measurements has been achieved through advances in radiosonde sensor technology (e.g., from Vaisala RS92 to RS41) and through advanced radiosonde data processing provided by the GCOS Global Reference Upper Air Network (GRUAN) program. Radiosonde launches supported by the NOAA Joint Polar Satellite System (JPSS) which target polar-orbiting (SNPP and NOAA20) overpasses is another advance which aims to minimize the radiosonde-satellite spatial and temporal mismatch. These "dedicated" radiosondes include those from the Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) sites in Alaska, Oklahoma and the Azores, research campaigns including trans-Atlantic AERerosols and Ocean Science Expeditions (AEROSE) campaigns onboard the NOAA ship Ronald H Brown, and programs of dual (RS92 and RS41) radiosonde launches at selected sites including a multi-year (2018 to 2021) program at ARM (Oklahoma) concurrent with NOAA-20 satellite overpass referred to as Radiosonde Intercomparison and VALidation (RIVAL). All of the radiosondes mentioned have been collected and stored (since 2013) in the NOAA Sounding Products Validation System (NRPOVS, operated at STAR/NESDIS) and subsequently collocated with multiple satellite product systems for use in product assessment. This report provides examples which demonstrate the value of the advanced radiosonde observations described above. These include but not limited to the following areas: 1) Assessment (including uncertainty estimation) of NOAA-Unique Combined Atmospheric Processing System (NUCAPS) soundings derived from Cross-track Infrared Sounder/Advanced Technology Microwave Sounder (CrIS/ATMS) sensors onboard NOAA satellites and EUMETSAT soundings derived from Infrared Atmospheric Sounding Interferometer/Advanced Microwave Sounding Unit (IASI/AMSU) onboard EUMETSAT MetOp satellites, 2) consistency of dedicated/GRUAN radiosondes with satellite sensor data in the context of the Global Space-based inter-Calibration System (GSICS) and 3) satellite atmospheric profiling capability in the Saharan Air layer (SAL) dust environment.

2p.07 withdrawn

3p.01 Monitoring visible reflectances from geostationary satellites at ECMWF
Presenter: Cristina Lupu, ECMWF
Co-authors: Liam Steele, Philippe Lopez, Marco Matricardi, Samuel Quesada Ruiz, Chris Burrows, Angela Benedetti

Radiative transfer models are critical for the successful exploitation of satellite observations. Recent progress in the NWP SAF in radiative transfer modelling for visible wavelengths, are opening the door to active assimilation of visible sensors in the IFS. This poster summarizes the current status and ongoing developments in monitoring cloudy visible reflectance observations from geostationary satellites (GOES-18, Meteosat-11). First-guess and analysis departures will be presented to illustrate how the IFS cloud prediction compares to the ABI/SEVIRI reflectances, both before and after the assimilation of other observations operationally used at ECMWF. Understanding such cloud-related biases might be useful for paving the way to an assimilation of solar reflectances in ECMWF's 4D-Var system. Simulated images in the visible band are also generated from the IFS output meteorological fields on full model levels using RTTOV-13, highlighting the potential scientific and operational values of realistic satellite imagery products based on high-resolution NWP.

Session 2: Calibration and Validation

2.01 GSICS Products and Tools for scientific applications

Presenter: Manik Bali, University of Maryland
Co-authors: Larry Flynn and Mitch Goldberg

GSICS has over 70 satellite inter-calibration products that are distributed via its online product catalog. These products are correction coefficients produced by comparing monitored instruments with globally accepted in-orbit references. This real-time monitoring of satellites has not only helped correct biases in measurements but GSICS-corrected radiances are widely used in generating cloud climatologies (ISCCP), Monitoring Spectral Response Functions, Producing Climate Data records and even used as input to Numerical weather predictions. The goal of this presentation is to give a brief overview of GSICS products. We will give a live (snapshots) demo of the tools developed by GSICS. We will show how users can build processes to ingest GSICS products (with minimal coding) and quickly improve downstream products. We will also introduce a Python Framework that has the unique capability to integrate observing systems (e.g., GPSRO, GRUAN, GSICS). With contributions from data processing teams such as Pygac, Pytroll, and Typhon, this python framework has the ability to bring various components of WIGOS (GPSRO, GRUAN, GSICS) onto one platform wherein inter-comparisons can be made and inter-operability can be tested.

2.02 The on-orbit Performance of FY-3E in an Early Morning Orbit

Presenter: Peng Zhang, National Satellite Meteorological Center
Co-authors: Peng ZHANG, Xiuqing HU, Ling SUN, Na XU, Lin CHEN, Aijun ZHU, Manyun LIN, Qifeng LU, Zhongdong Yang, Jun Yang, Jinsong Wang

Considering the extreme importance of the polar orbiting meteorological satellites to global Numerical Weather Prediction (NWP), the World Meteorological Organization (WMO) proposed in 2009 establishing a three orbit-polar meteorological satellite observing system, i.e., the early-morning (EM) satellite, the mid-morning (AM) satellite, and the afternoon (PM) satellite. Recognizing the absence of the EM satellite in the existing global operational polar-orbiting system, the CMA decided in 2011 to redeploy its fifth satellite in the Fengyun-3 (FY-3) series from AM into EM orbit. After a ten-year development, the satellite has been launched successfully at the Jiuquan Satellite Launch Centre on 5 July 2021 and is named Fengyun 3E (FY-3E). There are 11 instruments onboard FY-3E to maintain the capability for atmospheric sounding, low light imaging, sea surface wind detecting, and space weather monitoring. The platform and the instruments have been fully tested during the six month on-orbit commissioning. In this article, the background and meteorological requirements for the early morning orbit are reviewed, and the specification for FY-3E and the characteristics of the instruments are introduced. The ground segment and the geophysical products are presented briefly as well. The performance of the platform and the instruments during the on-orbit commission test have been demonstrated for applications. FY-3E will be used to optimize the current global operational polar-orbiting systems for providing better distribution of sounding data in the 6-hour NWP assimilation window. It is believed that significant benefits will be achieved by the NWP communities from the improved temporal distribution of observations provided by FY-3E. Further benefits are expected in a number of application areas including severe weather event monitoring, improved sampling of the diurnal cycle for accurate climate data records, more efficient air quality monitoring in thermal infrared, and quasi-continuous monitoring of the Sun for space weather and climate.

2.03 Initial Assessment of the NOAA JPSS-2 CrIS Observations

Presenter: Flavio Iturbide Sanchez, NOAA/NESDIS/STAR
Co-authors: David Tobin, Larrabee Strow, David Johnson, Kun Zhang, Denis Tremblay, Peter Beierle, Lin Lin, Arun Ravindranath and Hank Revercomb

This presentation is dedicated to report on the quality of the NOAA/JPSS-2 CrIS sensor data record (SDR) product after reaching the JPSS level-1 Provisional Maturity level. The JPSS-2 CrIS SDR product is a new NOAA satellite product planned to be transitioned to the JPSS provisional maturity level by the end of January 2023. This participation represents an opportunity to interact with the numerical weather prediction (NWP) community about the latest quality evaluation results of the NOAA/JPSS-2 CrIS SDR product. The NOAA Joint Polar Satellite System (JPSS)-2 spacecraft is scheduled to launch on November 1st, 2022. Once the satellite reaches orbit, the JPSS-2 spacecraft will be renamed as NOAA-21. The launch of JPSS-2 represents a unique opportunity to evaluate and take advantage of the capabilities of a constellation of three CrIS sensors on-orbit. For at least 12 months, intercomparisons between CrIS sensors on-board SNPP, NOAA-20 and JPSS-2 will be carried out mainly to support the calibration and validation activities of the JPSS-2 CrIS sensor. At the same time, NWP centers will have the opportunity to evaluate the impact and benefits of having enhanced temporal and spatial coverage of hyperspectral infrared observations provided by three CrIS sensor operating in the same orbital plane and separated by approximately 25 minutes. In preparation for operational assimilation of JPSS-2 CrIS observations, major numerical weather prediction (NWP) centers, including NCEP and ECMWF, are expected to receive the JPSS-2 CrIS SDR product via the NOAA Production Distribution and Access (PDA) system just after the JPSS-2 CrIS SDR product reaches the beta maturity level. Similarly, direct readout users are expected to receive JPSS-2 CrIS data using the direct downlink capabilities via Direct Broadcast (DB). This presentation will help to inform the NWP community as well as other CrIS data users about the most recent calibration of the CrIS sensors. The JPSS-2 CrIS sensor has been systematically and successfully characterized during instrument- and spacecraft-level environmental testing and is ready for Mission Operations. Disclaimer: The scientific results and conclusions, as well as any views or opinions expressed herein, are those of the author(s) and do not necessarily reflect those of NOAA or the Department of Commerce.

2.04 FY-3E/HIRAS-II post lanuch instrument status and data accuracy analysis

Presenter: Chengli Qi, China Meteorological Administration
Co-authors: Lu Lee, Xiuqing Hu, Mingjian Gu

The FY-3E/HIRAS-II instrument has been launched for more than a year, and the instrument and ground processing system have entered a stable state. Based on a variety of evaluation methods, the spectral and radiometric calibration accuracy and the causes of errors of L1 products have been evaluated and characterized.

2.05 TROPICS Earth Venture Mission: Update on Pathfinder's Yearlong Calibration and Validation

Presenter: Vincent Leslie, MIT Lincoln Laboratory
Co-authors: W. J. Blackwell, M. T. DiLiberto, G. H. Perras

The Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS) mission was selected by NASA as part of the Earth Venture–-Instrument (EVI-3) program. The overarching goal for TROPICS is to provide nearly all-weather observations of 3-D temperature and humidity, as well as cloud ice and precipitation horizontal structure, at high temporal resolution to conduct high-value science investigations of tropical cyclones utilizing a constellation of CubeSats. Before the constellation launches (presently estimated to occur in mid-2023), NASA and Lincoln Laboratory launched the engineering design unit (TROPICS Pathfinder) into a sun-synchronous orbit on June 30, 2021. Pathfinder provided an end-to-end evaluation of the entire space and ground segment. This presentation covers the TROPICS Pathfinder payload calibration and validation over the past year. Each CubeSat hosts an identical high-performance radiometer that provides temperature profiles using seven channels near the 118.75-GHz oxygen absorption line, water vapor profiles using three channels near the 183-GHz water vapor absorption line, imagery in a single channel near 90 GHz for precipitation measurements (when combined with higher resolution water vapor channels), and a single channel near 205 GHz that is more sensitive to cloud-sized ice particles. The Pathfinder radiometer payload commissioning ended on Aug. 8th, 2021. After final spacecraft commissioning in Oct. 2021, Pathfinder has had an uptime of 93% (100% duty cycle). This presentation covers the calibration pre-launch characterization, early-orbit characterization, and calibration sustainment. Pre-launch characterization consisted of antenna pattern measurements, spectral response measurements, and TVac calibration using precision external calibration targets. Early-orbit characterization used a month of observations minus background (O-B) to optimize the calibration parameter by minimizing the difference between the O-B under clear-sky conditions. The pre-launch calibration parameters were used as initial conditions for the early-orbit optimization. After the early-orbit characterization froze the calibration parameters, a causal calibration sustainment system is in place that minimizes the calibration drift due to changes in noise diode output power (i.e., warm calibration point). The entire calibration process was validated against operational microwave sensors. Absolute calibration performance as a function of instrument temperature, scene temperature, and scan position is on par with present operational sounders. Before applying the calibration sustainment correction, the impact of the slowly-varying W- and F-band noise diode drift, measured as a daily mean O-B difference, was less than 1K over the year. The G-band noise drift for the same metric had a larger drift, but was still slow enough to be corrected by the causal calibration sustainment system.

2.06 How well the new generation of Chinese IR hyperspectral sounders compare with IASI?
Presenter: Bertrand Theodore, EUMETSAT
Co-authors: Pierre Dussarrat, Guillaume Deschamps, Dorothee Coppens

With the launches of FY-4B in June 2021 and of FY-3E in July 2021, CMA have added two new hyperspectral infrared spectrometers, respectively GIIRS-2 in geostationary- and HIRAS-2 in sun-synchronous-orbit, with improved characteristics compared to their predecessors. In order to assess the radiometric and spectral performances of these instruments, an inter-comparison has been performed with the IASI instrument on board Metop-B and –C. Thanks to its high spectral resolution covering (almost) the full spectrum of infrared channels and excellent orbital and calibration stability, IASI is recognized as a reference for the inter-calibration of infrared sensors in space. This paper will present the methods used to perform the inter-comparisons, which obviously depends on whether the sensor to be assessed is in geostationary orbit (in which case simultaneous observations can be used) or in low-Earth orbit (in that case large averages or double differences using OBS-CAL are the only possible way to compare the measurements). The first results indicate that HIRAS-2 and GIIRS-2 exhibit very good performances and show a significant improvement with respect to the previous generation. GIIRS-2 and HIRAS-2 products will thus be incorporated into EUMETSAT's routine monitoring of IASI measurements.

2.07 Rigorous and Traceable Assessment of the CrIS Radiometric Calibration Uncertainty
Presenter: Joe Taylor, Space Science and Engineering Center, University of Wisconsin-Madison
Co-authors: D. C. Tobin, H. E. Revercomb, R.O. Knuteson, J. Braun, D. DeSlover, R.K Garcia, M. Loveless, G. Martin, G. Quinn, W. Roberts

The Cross-track Infrared Sounder (CrIS) is an infrared Fourier Transform Spectrometer (FTS) sounder and was designed to provide an optimum combination of optical performance, high radiometric accuracy, and compact packaging. Data is collected in three spectral bands (longwave, midwave, and shortwave) and each band utilizes a 3 x 3 detector array, with a ~14km detector field of view diameter at nadir from 833km altitude. The full spectral resolution data have 2,223 unapodized channels with a spectral sampling resolution of 0.625cm 1. While CrIS was developed primarily as a temperature and water vapor profiling instrument for weather forecasting, its high accuracy and extensive information about trace gases, clouds, dust, and surface properties make it a powerful tool for climate applications. A measurement can never be made to be perfectly exact and is complete only when accompanied by a quantitative statement of its uncertainty. We have developed a new capability for determining a rigorous estimate of the CrIS measurement Radiometric Uncertainty (RU) for any CrIS calibrated radiance, which utilizes a methodology that is consistent with the accepted metrology approach to uncertainty analysis. Radiometric Uncertainty is an upper bound (coverage factor k=3 or 3-σ, not including noise) of the bias with respect to the true radiance and is scene and instrument environment dependent. The documentation of and ability to calculate the uncertainty in the sensor measurements is a critical aspect of a reference sensor and a climate quality measurement record. This presentation will describe the CrIS radiometric calibration uncertainty assessment methodology, summarize the calibration parameter uncertainties, and provide example results of postlaunch validation efforts to assess the predicted uncertainty.

2.08 On the study of the absolute on-orbit calibration consistency between ATMS instruments from SNPP to JPSS-02
Presenter: Hu (Tiger) Yang, CISESS, University of Maryland
Co-authors: Ninghai Sun, Quanhua Liu

The Advanced Technology Microwave Sounder (ATMS) is the microwave radiometer for the current generation of polar-orbiting meteorological satellites operated by NOAA. The first two ATMS instruments are manifested in orbit onboard the Suomi National Polar-orbiting Partnership (SNPP) and NOAA-20 satellites. With the launch of JPSS-02 in November, 2022, there are three satellites running at tandem orbit, with JPSS-02 being set to a quarter orbit ahead of SNPP, and NOAA-20 half orbit ahead of JPSS-02. Previous study shows that even with identical design, the on-orbit absolute calibration accuracy can still be different for each of the different builds. During JPSS-02 postlaunch cal/val test, intensified experiments are carried out to assess the on-orbit performance of the ATMS instrument. In this study, based on the data collected from the special tests, different methods are developed to quantify the calibration difference between SNPP, NOAA-20 and JPSS-02 ATMS instruments. The results will be used to refine the on-orbit ATMS calibration algorithm, improve the accuracy and consistency of TDR and SDR products of ATMS instruments for weather and climate studies.

2.09 FY-4B/GIIRS performance after one year on orbit

Presenter: Lu Lee, National Satellite Meteorological Center, China Meteorological Administration
Co-authors: Chengli Qi, Feng Lu, Changpei Han, Lei Ding

The Geostationary Interferometric Infrared Sounder (GIIRS) is a primary payload onboard the FengYun-4B weather satellite of China. It measures the hyperspectral atmospheric upwelling infrared radiance. With low instrument noise, high spectral resolution and thousands of spectral channels, the radiance spectra provide a critical high vertical resolution information to retrieve the atmosphere's structure of temperature and water vapor in retrieval algorithms and numerical weather prediction (NWP) models, and also supply extensive information about trace gases, surface and cloud properties for climate research. Particularly, the unique combination of the Fourier transform spectrometer and the geosynchronous satellite platform enable the GIIRS observe the successive images of moisture and clouds at different altitudes with a high temporal resolution, that will reveal the motion of small-scale thermodynamic features and trace gas features of the atmosphere. The former provides a measure of the atmospheric wind distribution, and the latter provides a measure of the transport of the pollutant and greenhouse gases. GIIRS was launched on June 3 and the infrared detector was power-on on August 24, 2021. Up to now, this instrument has been on orbit for one year, with first eight months of post-launch calibration and validation, and following four months in quasi-operation. The instrument has a good noise performance with the overall radiance noise levels being less than 0.5 and 0.1 in milliwatts per square meter per steradian per inverse centimeter (mW/m2/sr/cm-1) for the long-wave infrared (LWIR) and mid-wave infrared (MWIR) bands. The estimated absolute spectral calibration uncertainty is less than 7 ppm in the LWIR and MWIR bands. The estimated radiometric calibration bias is about 1 K in the LWIR band and less than 1 K in the MWIR band. The instrument sensitivity and the spectral calibration accuracy are stable within the first year.

2.10 Correction for Ringing in the Calibrated Spectra of the Cross-track Infrared Sounder (CrIS)

Presenter: Henry Revercomb, University of Wisconsin-Madison, Space Science and Engineering Center
Co-authors: Joe Taylor, Dave Tobin, Bob Knuteson, Michelle Loveless, Lori Borg

Ringing is a fundamental property of Fourier Transform Spectrometers that needs to be understood and carefully addressed. While the instrument-dependent ringing artifacts of CrIS are already quite small (occurring in specific spectral regions at less than several 0.1 K), the high calibration accuracy and low noise of CrIS bring them to the forefront for attention. And even though the current NWP impact of CrIS data at ECMWF is high and comparable to IASI (that uses a Gaussian apodization combined with a longer maximum optical path difference to mitigate ringing), future advances in data assimilation may make improvements in the treatment of ringing significant for NWP and other specific applications. Also, understanding how to best handle ringing is important for future instrument approaches. Here, the term "ringing" refers to every-other point, positive and negative oscillatory features that can occur in minimally sampled spectra from a Fourier Transform Spectometer (FTS). Ringing is created by the inherent sinc function spectral Instrument Line Shape (ILS, the Fourier transform of the boxcar sample weighting of the interferogram), in combination with instrument specific properties. The oscillatory nature of the mathematical Gibbs effect is an example created by the Fourier transform of functions with a jump discontinuity. Primary sources of ringing include: 1. The sharp truncation at the maximum Optical Path Difference where measured interferograms are terminated, 2. Finite spectral band coverage of measured spectra, 3. Non-flat instrument spectral response functions inside measured spectral bands, 4. Artifacts of the spectral resampling and self-apodization correction steps of the calibration algorithm, and 5. Lack of perfect circular sampling of the onboard numerical filter. However, it is an important perspective that not all ringing should be considered to be an artifact: If ringing can be accurately included in calculated spectra, it does not cause errors in the difference of observations and calculations (obs-calc) used for sounding. For example, the measured instrument responsivity could be included in calculated spectra to remove ringing of type 3 above from obs-calc signals. However, because of the extra computational burden, this is not normally done and effective techniques to remove this type of ringing are actively being sought. Several approaches that have been applied to minimize the effects of ringing are: 1. Apodization, 2. Include the sensor specific ringing characteristics in calculations, 3. Derive a correction to the calibrated spectrum. The new approach defined here is an example of approach 3 that replaces the ends of the measured interferogram with a nearly ringing-free approximation. In the interferogram domain, ringing contributions are concentrated near the ends, because every other point oscillatory features approach the highest spectral resolution that can be captured. Therefore, apodization functions that are small near the ends of the interferogram can be effective at removing ringing, but they can also remove major parts of the high spectral resolution signal (as has been shown to create major problems when incorrectly using Hamming apodized CrIS data). EUMETSAT has developed a different approach 3 technique to correct MTG-IRS spectra for responsivity induced ringing. The approach proposed here handles all types of ringing that originate from near the ends of interferograms where the ringing signal is concentrated. As will be described, the basic approach involves: 1. Construct approximations to the observed spectra using Principal Components that are free of instrument-specific ringing, 2. Transform both observed and approximate spectra to interferograms, 3. Use a simple, smooth weighting function to remove the ends of the observed interferogram and replace them with the ends of the approximate interferogram, and 4. Transform back to a corrected observed spectrum. This results in a corrected spectrum that inherently contributes very little ringing to observed minus calculated differences, while losing very little information content.

Session 3: Geo Imager Assimilation

3.01 Data assimilation of visible and combination with water vapour imager channels for very short-range forecasting

Presenter: Christina Köpken-Watts, DWD (for Liselotte Bach)
Co-Authors: Thomas Deppisch, Leonhard Scheck, Annika Schomburg, Christina Köpken-Watts, Robin Faulwetter

All-sky assimilation of SEVIRI visible reflectances and WV radiances is being introduced for operational very short range forecasting on the regional scale at DWD. This paper presents the introduction of visible reflectances of the 0.6 um channel to operations for the convection-resolving ICON-D2 and the ICON-Rapid Update Cycle (SINFONY) systems as a first step to this all-sky assimilation setup, aiming specifically at a better analysis and forecast of clouds. Providing valuable information about vertically integrated cloud liquid and ice, effective radii and cloud cover, satellite observations in the visible spectral range uniquely allow for a direct constraint of horizontal cloud positions and cloud optical depth in the analysis. For very-short range forecasting at the convective-scale the strong sensitivity to liquid clouds is of particular importance, since it allows to constrain boundary layer clouds like low-stratus or convection at the stage of its initiation. Further, global radiation forecasts relevant for solar power forecasting strongly benefit from a better representation of clouds in the forecast. We will present the key technical and methodological steps needed for operational data assimilation of the 0.6 µm channel of SEVIRI with a Local Ensemble Transform Kalman Filter. This reaches from superobbing to quality control and from observation-error modelling to a newly-developed innovative bias-correction method that targets the frequency distributions of observed and simulated satellite pictures. We show the behaviour in the data assimilation cycle as well as forecast impact improving cloud cover, precipitation, radar reflectivities, global radiation and screen-level variables. Additionally, we compare the impact in the ICON-D2 system and the SINFONY rapid update cycle rapid update cycle which uses a different setup especially of microphysical parameterizations, and investigate particularly the interaction of model biases and data assimilation. As an outlook, challenges related to the combination of the visible channel with the water vapour channels of SEVIRI are discussed. A key question that arises is how find a data assimilation set-up that maximally exploits the complementary information contained in the visible and water vapour channels.

3.02 withdrawn

3.03 Assimilating the infrared data from geostationary satellites within the Météo-France models

Presenter: Olivier Audouin, CNRM, Météo-France & CNRS
Co-Authors: Olivier Audouin, Nadia Fourrié, Vincent Guidard

Most of the data assimilated in numerical weather prediction are derived from measurements made by instruments carried on satellites (polar orbiting or geostationary). Among these instruments, the infrared imagers onboard geostationary satellites provide high temporal frequency and high horizontal resolution information on temperature and humidity profiles in the atmosphere. Infrared data from imagers on board geostationary satellites can be available in the form of averaged radiances (usually in clear sky condition) or brightness temperatures in pixels, that are closer to the raw measurement. This presentation gives an overview of how these data are assimilated in the Météo-France global model ARPEGE via its 4D-Var assimilation scheme. A focus is made on the assimilation of the ABI imager onboard GOES-16 data as brightness temperatures, which is operational in ARPEGE since June 2022. A study in progress is also presented which proposes to compare the two available infrared data formats for imagers on board geostationary satellites, namely the raw brightness temperatures and the averaged radiances of type CSR or ASR (All-Sky Radiances). Concerning the convection permitting limited-area model AROME, only the data from the SEVIRI imager on board MSG-4 are assimilated in the raw brightness temperature format (as for ABI in ARPEGE). A modification of the thinning algorithm is presented, aiming to improve the way observations are selected in order to limit the risk of assimilating observations too close geographically.

3.04 Towards a fuller exploitation of the window channel from geostationary satellites in NWP

Presenter: Samuel Quesada-Ruiz, ECMWF
Co-authors: Tony McNally, Chris Burrows, ECMWF

Geostationary radiance observations play an important role in the global observing system and are operationally assimilated in the four dimensional variational data assimilation (4D-Var) system of the ECMWF Integrated Forecasting System (IFS). Currently, only water vapour channels from SEVIRI, ABI and AHI instruments are assimilated while the use of the window channel is limited to monitoring and cloud detection purposes. However, window channel observations from geostationary satellites can provide valuable information for ocean and land skin temperature analysis and its diurnal variability. They are in fact the only source of information to constrain the full diurnal cycle of skin temperature in the 4D-Var analysis and will play a key role in the ECMWF coupled Sea Surface Temperature analysis. Moreover, Meteosat Third Generation Infrared Sounder (MTG-IRS) will provide hundreds of surface sensitive channels so we need to gain experience in their exploitation. This work focuses on the ocean skin temperature. A thorough evaluation of the five geostationary window channels has been performed. Monitoring statistics of departures between model first guess and window channel radiances display a clear diurnal cycle, with a warm (positive) bias when the sun is up compared to a cold (negative) bias when the sun is down. The intercomparison of these show that this diurnal cycle bias is consistent across the five instruments. An effort to disentangle the origin of this bias, whether model, radiative transfer or instrument related has been done. Outcome of this investigation has been discussed both externally with satellite data providers and internally with ECMWF's modelling section. Assimilation experiments of these window channel radiances has been explored and preliminary results will be presented.

Friday, 17 March 2023

Session 4: NWP Centre reports

4p.01 Recent upgrades and developments in the use of satellite radiances at ECCC

Presenter: Alain Beaulne, ECCC
Co-authors: Maziar Bani Shahabadi, Patrice Beaudoin, Mark Buehner, Jean-Francois Caron, Ping Du, Sylvain Heilliette, Ervig Lapalme, Thomas Milewski, Zheng-Qi Wang

Environment and Climate Change Canada (ECCC) assimilates radiance data in three operational deterministic (global, regional and high-resolution) systems using an 4D-EnVAR-IAU analysis scheme and one ensemble (global) system using a LETKF analysis scheme. A major innovation upgrade occurred in December 2021, including various refinements to radiance data assimilation methodologies in our operational systems. Work is currently underway developing further refinements for the next major upgrade planned for 2024.Innovation Cycle 3 (IC-3), implemented December 1, 2021, brought over 170 scientific innovations in some 31 atmospheric, oceanic, hydrological and surface forecasting systems. Refinements to radiance data assimilation include slant-path radiative transfer calculations for all satellite radiances, RTTOV computations on model levels, a consolidated processing in a unified data assimilation framework, the assimilation of cloud-affected temperature sensitive radiances from AMSUA channels 4 and 5 over ocean (global deterministic only), new scale-dependent horizontal localization of error covariances calculated exclusively (below 60hPa) from the 256

LETKF 4D ensemble trials and addition of a continuous data assimilation cycle in the high-resolution (2.5 km) deterministic system. Research perspectives include updating the RTTOV observation operator to version 13, extending all-sky assimilation to ATMS and to microwave humidity sensitive channels, assimilation of some surface sensitive channels over land, the use of purely flow-dependent background error covariances and the operationalization of a real-time FSOI monitoring system.

4p.02 NWP centre report: ECMWF

Presenter: Niels Bormann

Co-authors: Niels Bormann, Chris Burrows, Mohamed Dahoui, David Duncan, Stephen English, Alan Geer, Katrin Lonitz, Cristina Lupu, Marco Matricardi, Tony McNally, Samuel Quesada Ruiz, Kirsti Salonen, Tracy Scanlon, Liam Steele

This poster summarises the status of the operational ECMWF assimilation system and use of passive sounding data, and it gives an overview of operational implementations since ITSC-23, with focus on updates relevant to the use of passive sounding data. Since ITSC-23, ECMWF has moved to cycle 47r3 of the Integrated Forecasting System which was implemented on 12 October 2021. In this cycle, AMSU-A assimilation has been moved from clear-sky to all-sky, the assimilation of AIRS benefits from an updated observation-error covariance matrix taking inter-channel error correlations into account, and new RTTOV coefficients are used for hyperspectral IR sensors. The cycle also includes a major upgrade of the moist physics, relevant for all-sky assimilation. A further update of the ECMWF system (48r1) is currently in final pre-operational testing, to be implemented later in 2023. This upgrade will see several major enhancements in the use of satellite radiances. It includes various optimisations for the use of hyperspectral IR sounders and significant observation operator improvements for IR and MW radiances (move to RTTOV-v13 including a major revision of cloud and precipitation microphysics in RTTOV-SCATT, slant-path interpolation for MW sounders used in all-sky, better surface treatment for MW instruments, including taking Lambertian reflection into account over snow and sea-ice for ATMS). The new cycle also features a much extended assimilation of surface-sensitive MW radiances, including, for the first time, the assimilation of window channels at 37, 89/91, and 150/165 GHz over land and polar oceans (for AMSR2, GMI, SSMIS), in a step towards a future more complete all-sky/all-surface exploitation of these observations. The cycle also sees an increased use of humidity-sounding radiances over snow-free land surfaces. The poster will show selected highlights of these implementations and discuss general development strands.

4p.03 Ongoing developments on satellite radiance assimilation at Météo-France

Presenter: Philippe Chambon, CNRM, Météo-France & CNRS

Co-authors: Olivier Audouin, Mary Borderies, Nadia Fourrié, Dominique Raspaud, Marylis Barreyat, Thomas Carrel-Billiard, O. Coopmann, Rohit Mangla, Robin Marty, Louis Rivoire, Nicolas Sasso, Ethel Villeneuve

A large part of assimilated observations in the global model of Météo-France ARPEGE come from satellites radiances (mostly on polar orbiting satellites). Satellite radiances are also assimilated in the meso-scale model AROME-France but represent a smaller fraction of observations with a dominance of MSG SEVIRI. This presentation intends to give an overview of the radiance usage in the French Numerical Weather Prediction models and the status of the current developments. The relative weight of each radiance type will be given in terms of FSOi and compared to the impacts derived from recent OSE experiments. The summary of recent changes in data usage in the future 2023 operational suite will be presented. Among the various developments, highlights will be given on the updates made regarding the use of infrared geostationary data and the observation error cross-correlations for infrared hyperspectral radiances from IASI and CrIS, as well as the all-sky assimilation of several microwave sensors (MHS, MWHS2, GMI and AMSR2). Another highlight will be made on one growing activity of the OBS team related to the assessment of the impact of future sensors with five ongoing projects: OSSE for IRS within AROME, OSSE for IASI-NG within ARPEGE, OSSE for EPS-Sterna with ARPEGE, OSSE for CMIM within ARPEGE, EDA for WIVERN with the ARPEGE EDA.

4p.04 Recent observation assimilation advancement for U.S. Navy's numerical weather prediction systems

Presenter: Hui Christophersen, U. S. Naval Research Laboratory

Co-authors: Patricia M. Pauley, Nancy L. Baker, Rebecca Stone, William Campbell, Dan Tyndall, Steve Swadley, Elizabeth Satterfield

At the U.S. Naval Research Laboratory, we continue to develop and advance the use of Earth observations for the Navy's Numerical Weather Prediction (NWP) systems. The Navy's global and coupled models use hybrid 4DVar (NAVDAS-AR) for data assimilation, while the mesoscale system uses 3DVar (NAVDAS). The Navy's next generation unified model NEPTUNE leverages JCSDA's JEDI framework to develop data assimilation capabilities (currently 3DVar). The Earth observation suite has undergone a series of updates, mainly driven by the observing system upgrades. A number of recent satellite changes have required changes to both regional and global systems, including geostationary satellite swaps from Meteosat-8 to Meteosat-9, Himawari-8 to Himawari-9, and from GOES-17 to GOES-18. We ingest new GNSS-RO data from the NOAA's and EUMETSAT's Commercial Data programs, as well as ground-based GNSS zenith total delay. Satellite radiances from new observing platforms such as Himawari-9, GOES-18, and NOAA-21 will be continuously integrated as they become available. Recent SmallSats missions, such as COWVR, TEMPEST, and TROPICS, pose new challenges in how to best evaluate, monitor and integrate them into our systems. These SmallSats provide high volume of high-temporal resolution data, but SmallSats exhibit higher uncertainty, large variability in sensor performance, shorter lifetimes and unknown biases. Therefore, we must carefully develop new strategies in estimating the uncertainty of the observations and dynamically sample the observations with informed statistics to maximize the extraction of information from them.

4p.05 Satellite Radiance Data Assimilation at Korea Meteorological Administration

Presenter: Hyoung-Wook Chun, Korea Meteorological Administration (KMA)
Co-authors: Ji-Hyun Ha, Chang-Hwan Kim, Young-Soon Cho, Eun-Hee Kim, and Ji-Young Sohn

This presentation describes the current satellite radiance data assimilation of Korean Integrated Model (KIM) which KMA has been operating since April 2020. KIM uses satellite radiance observations such as AMSU-A, MHS, ATMS, AMSR2, MWHS-2, IASI, CrIS, AHI-CSR, AMI-CSR, SEVIRI-ASR. With the transition from MSG-1 to MSG-2 in July of this year, CSR stopped and only ASR was provided. KMA was not yet ready for all-sky assimilation, so we tested the ASR-clear data of MSG-2, and there was no significant difference in forecasting performance with the CSR of MSG-1, so we successfully switched from the MSG-1 to the MSG-2. The addition of the new satellites MetOp-C and NOAA20 to IASI and CrIS improved the 5-day forecast of 500 hPa GPH in the Northern Hemisphere by 2%. Most of the satellite radiance in KIM is still used only over ocean, so efforts are being made to utilize them over land as well. In addition, we are conducting optimization research on thinning, blacklisting, bias correction, observation errors.

4p.06 Progress and plans for the use of radiance data in the NCEP global and regional data assimilation systems

Presenter: Andrew Collard, NOAA/NCEP/EMC
Co-authors: Emily Liu, Haixia Liu, Russ Treadon, Xiaoyan Zhang, Jim Jung, Daryl Kleist, and Xu Li

Since the last International TOVS Study Conference in June 2021, there have been a number of minor operational upgrades to the data assimilation system at NCEP. The main data upgrades were in November 2022.The most significant data assimilation advances in this period were: Precipitation-affected AMSU-A & ATMS radiances Move from assimilating antenna temperatures to brightness temperatures for ATMS, AMSU-A and MHS. Upgrade to CRTM v2.4.0 and move to GFDL cloud microphysics Introduction of VIIRS radiances to constrain the sea surface temperature plus changes to quality control and background error correlation lengths. In early 2023, it is expected that GOES-18 clear sky radiances and radiances from CrIS, ATMS and VIIRS on NOAA-21 (JPSS-2) will be assimilated. The next major upgrade to the GFS will be version 17 in 2024. GFSv17 will be a coupled system and will necessitate a greater focus on the assimilation of surface channels. Also in this timeframe there will be a focus on assimilating data from the MetOp-SG satellite as well as preparation for observations from the MTG-IRS.

4p.07 Radiance assimilation in MetCoOp limited-area NWP systems

Presenter: Reima Eresmaa, Finnish Meteorological Institute
Co-authors: Jostein Blyverket, Stephanie Guedj, Magnus Lindskog, David Schoenach

MetCoOp is a group devoted to advancing kilometric-scale operational NWP in Nordic countries including Estonia, Finland, Norway, and Sweden. MetCoOp maintains and develops non-hydrostatic limited-area systems, currently run in a 2.5 km horizontal grid. Two operational systems are provided: The MetCoOp Ensemble Prediction System (MEPS) includes a three-hourly updating deterministic run and an ensemble of 14 time-lagged perturbed members. The MetCoOp

Nowcasting System (MNWC) is one-hourly updating rapid-refresh nowcasting system with 25-minute observation cutoff and short-range forecast availability of 60 minutes after the nominal analysis time. Both MEPS and MNWC use the three-dimensional variational assimilation (3D-Var) method in the upper-air data assimilation. The use of radiance data includes microwave and infrared sounders from polar orbiters such as Metop, Fengyun, and NOAA satellites. In limited-area NWP, the data availability from each satellite follows a characteristic daily cycle. While adaptive bias correction methods are generally applicable, it has proven difficult to maintain stable evolution of bias correction coefficients. A pragmatic solution is to cycle the bias correction coefficients in 24-hour intervals so that the first guess is always reasonably representative of the present observing geometry. One implication is that the use of each satellite has to be limited to certain analysis times that match the hours of sufficient data coverage. The data use times require regular updates to account for drifting satellites. The ongoing developments at MetCoOp include testing an alternative setup for the bias correction setup, implementing the assimilation of CrIS, and extending the use of low-peaking microwave channels to all-surface conditions. The latter makes use of the dynamic emissivity estimation method. The short-term developments in planning will include updating observation error specifications and including explicit handling of spectrally-correlated errors. We are also investigating the prospect of geostationary radiance assimilation at high latitudes with the help of the slant-path radiative transfer method.

4p.08 Recent developments in satellite radiance assimilation at CMA
Presenter: Wei Han

This poster presents an overview of the recent developments and ongoing research in satellite data assimilation at CMA, and highlights some recent studies on the use of data from FY-3E, FY-4B and HY-2B. Updates in satellite observations include the following: Evaluation of FY-4B GIIRS /AGRI, FY-3E MWTS/MWHS/HIRAS and HY-2B Scanning Microwave Radiometer (SMR) ;Assimilation of FY-4A GIIRS water vapor sounding channels and FY-3E MWHS since August 2022 ;Ongoing developments include: All-sky radiance assimilation using FY-3D MWRI and HY-2B MWRI; Machine learning on bias correction and hyperspectral sounder cloud detection; Joint tuning of thinning distance and observation error.

4p.09 State of play of radiance processing in the NWP system at the Met Office
Presenter: Chawn Harlow, Met Office
Co-authors: Brett Candy

The Met Office has been engaged for the last two years in porting the Observation Processing System (OPS) and 4D-Var DA system (VAR) to a new suite of software based on the code-base of the Joint Effort for Data assimilation Integration (JEDI). This means that the work of the Satellite Radiance Assimilation Group has been focused on a new technical implementation of OPS rather than the development and application of new radiance assimilation techniques. Regardless of this high level of commitment to the technical changes to the OPS, there has been some progress to report in a couple of areas. There has been work ongoing on the assimilation of Transformed Retrievals of IASI spectra as part of a EUMETSAT Fellowship which has recently reached completion, and there has been work on extending the all-skies assimilation of microwave data to precipitating scenes. Both of these are subjects of presentations at this meeting. This poster presentation will summarize the current state of play of radiance assimilation at the Met Office as well as short review the observation impacts with recent FSOI results. If space allows, a short summary will also be given of the plans for day one assimilation of ICI, IASI-NG and MTG-IRS, three of the more challenging of the next generation of sounding radiances to become available in the next 3 years.

4p.10 Status and developments of satellite radiance assimilation at DWD
Presenter: Christina Köpken-Watts, DWD
Co-authors: Robin Faulwetter, Olaf Stiller, Anne Walter, Michael Bender, Silke May, Christina Stumpf, Annika Schomburg, Liselotte Bach, Thomas Deppisch

This poster presents an overview of recent upgrades of the satellite radiance data assimilation at DWD as well as ongoing developments both for the global ICON system and the convection-resolving ICON-D2 and rapid-update SINFONY systems. The NWP systems have seen a forward operator upgrade to the most recent RTTOV v13.2 along with moving to the new v13 predictors representing also an update of the underlying spectroscopy requiring careful testing and tuning in the ICON system. For hyperspectral sounders, the McNally&Watts cloud detection was upgraded to the most recent version CADS v3.1 and additional improvements in observation minus first guess statistics as well as forecast impact could be achieved by introducing variable ozone profiles from ECMWF/IFS forecasts within the forward operator calculations with RTTOV.In terms of data usage, a switch to clear-sky radiances from the ASR data streams for Meteosat and GOES satellites and the introduction of additional radio-occultations from Sentinel-6A and commercial SPIRE was implemented as well as a review and operational update of data selection for water vapour radiances from MHS, ATMS and SSMIS. Additional humidity sensitive radiances from the MWHS-2 instruments have been added together with an adaptation of the used constrained bias correction approach for the upper humidity channels. Work is ongoing to extend the use of microwave radiances over land, snow and ice surfaces with AMSU-A channels 7,8, (and ATMS 8,9) now being assimilated using a standard emissivity retrieval approach, while experiments with AMSU-A channels 5,6 (and ATMS 6,7) are ongoing. For the convection-resolving model, the focus has been on the operationalisation of visible reflectance assimilation from MSG/SEVIRI in the context of the new rapid update cycle system SINFONY as well as for the limited area model ICON-D2. This is complemented with advanced testing for the all-sky assimilation of geostationary water vapour radiances as well as a combination of the water vapour and visible observations. The preparation for the use of the future MTG/IRS radiances is ongoing and will be briefly described both in the regional LETKF system as well as in the global IVON/EnVar. Further developments focus on the implementation of an all-sky assimilation capability for the EnVar and evaluations of global model cloud fields with visible, infrared and microwave radiances.

4p11 Use of satellite atmospheric sounding data in United Weather Centres West

Presenter: Isabel Monteiro, KNMI

Co-authors: Eoin Whelan (Met Éireann), Jan Barkmeijer (KNMI), Mats Dahlbom (DMI), Bjarne Amstrup (DMI) and Sigurdur Thorsteinsson (IMO)

The recently formed United Weather Centres West (UWC-W) collaboration comprises the National Meteorological and Hydrological Services (NMHS) of Denmark (DMI), Iceland (IMO), Ireland (Met Éireann) and The Netherlands (KNMI). It aims to efficiently provide the best short-range weather forecasts for the geographical areas of the four countries. With this objective, UWC-W will soon operate the HARMONIE-AROME limited-area model in two common domains, called DINI (Western Europe) and IC (Iceland/Greenland), replacing the previous operational suites in each of the NMS. The HARMONIE-AROME system allows for two possible operational data assimilation (DA) methods, 3D-Var and 4D-Var. 3D-Var will be the initial operational configuration for DINI and IG with a 4D-Var DINI configuration development suite in parallel targeting for operations in the near future. Concerning satellite observations, UWC-W will use the superset of observations assimilated by each NMHS benefiting from the expertise available in the consortium. The following satellite data types will be considered: (i) Passive temperature and humidity soundings, using radiances directly; (ii) Wind information, using Atmospheric Motion Vectors; (iii) Scatterometry, as near ocean surface winds; and (iv) Radio occultation, using retrieved refractivity. Passive infrared sounders include, IASI on board Metop-B and Metop-C, and, CrIS on board NOAA-20 and Suomi NPP satellites. The Microwave sounders employed are AMSU-A, on Metop-B, Metop-C, NOAA-18, and NOAA-19; MHS, on board Metop-B and Metop-C; ATMS on NOAA-20 and Suomi NPP; and MWHS2 on board FY-3D. The strategy followed on the use of these observations closely follows the current operational implementation in each NMHS. Therefore, channel selection, thinning strategies, variational bias correction schemes and blacklisting are similar to the previous local implementations. The assimilation system will be extended to include IR and MW imagers. In addition to providing continuity to consortium member operations, UWC-W is actively preparing the assimilation system for the uptake of data from new generation hyperspectral sounder MTG-IRS. These observations will provide a high volume of information that constitutes a challenge for data storage and transmission. Thus, in an initial stage, priority will be given to the configuration of UWC-W data acquisition system.

4p.12 Recent upgrades and progresses of satellite radiance data assimilation at JMA

Presenter: Hidehiko MURATA, Japan Meteorological Agency

Co-authors: KONDO Keiichi, KAMEKAWA Norio, KUSANO Naoto, SHIMIZU Hiroyuki, ANDO Akira

The Japan Meteorological Agency (JMA) operates three major data assimilation systems: Global Analysis (GA), Meso-scale Analysis (MA) and Local Analysis (LA). Assimilations of recent-launched satellite data and developments on advanced data usage are implemented into the operational systems simultaneously or separately after assessment on each system. This poster overviews recent upgrades and progresses of satellite radiance data assimilation into the numerical weather prediction (NWP) systems at JMA since the last ITSC-23 in June 2021. Main topics are listed as follows. - Assimilation of Metop-C/AMSU-A and MHS which are already implemented in GA and MA has started in LA in November 2021. - Assimilation of Metop-C/IASI in GA has started in November 2021 after the termination of Metop-A operation. - The top height of the Meso-scale model has been raised from 21.8 km to 37.5 km in March 2022 mainly in order to expand available satellite data such as higher peaking sounder channels. Available channels of AMUS-A have been expanded up to 8 to 11. - Radiative transfer model used in the data assimilation systems have been upgraded from RTTOV-10.2 to RTTOV-13.0 in June 2022 (GA and MA) and August 2022 (LA). As a first step, the upgrade was limited to minimal changes to ensure the implementation. The new coefficients and sea surface emissivity models have not yet been applied because they can change quality control results and then degrade the accuracy of analysis and forecast. Works on the upgrade including quality control modification are still ongoing. - Assimilation of ATMS onboard Suomi-NPP and NOAA-20 has started in MA (June 2022) and LA (August 2022) limited to the water vapor channels. - Assimilation of hyperspectral infrared sounders (IASI and CrIS) in MA and LA, and additional use of humidity sensitive channels in GA are planned in Q1 2023. - JMA maintains the data assimilation systems to keep up with the replacement of geostationary satellites, such as Meteosat-9 taken over IDOC (Indian Ocean Data Coverage) in June 2022, Himawari-9 in December 2022 and GOES-18 in 2023. Furthermore, JMA has started using Meteosat CSR data stored in its ASR products instead of the CSR products discontinued in October 2022.In addition, JMA is currently working on the topics such as additional use of CO2 band of the geostationary satellites' CSR, implementation of all-sky assimilation of microwave radiances in MA and LA, advanced use of microwave sounders' lower peaking channels over land with dynamically estimated emissivity and surface temperature, and all-sky infrared radiance assimilation.

4p.13 NCMRWF NWP: Current status and future plans

Presenter: Indira Rani Sukumara Pillai, NCMRWF
Co-authors: S. Indira Rani, Sumit Kumar, D. Srinivas, V. S. Prasad, John P. George

Overview of the current status and plans for the satellite data assimilation for NWP at NCMRWF. Briefly discusses the global/regional deterministic/ensemble systems of NCMRWF and the DA status since the last ITSC.

4p.14 Radiance assimilation in AEMET Harmonie-AROME model operational run

Presenter: Jana Sánchez-Arriola, AEMET
Co-authors: Joan Campins, Maria Díez, Javier Calvo

In the Spanish weather Service AEMET the non-hydrostatic 2,5 km resolution deterministic limited area model Harmonie-AROME is running operationally each 3 hours to give a 48 hours length forecast over two domains: one that covers the Iberian Peninsula and Balearic Islands and another that covers the Canary Islands .This operational run uses the three-dimensional variational assimilation (3DVar) method in the upper-air data assimilation with a 3 hour cycle to assimilate conventional observations, GNSS ZTD, Radar reflectivities, Scatterometers and radiance data that includes microwave and infrared sounders from Metop and NOAA polar satellites and fromMeteosat-11 geostationary satellite . An adaptive bias correction method is applied each 24 hours for radiances and each 3 hours for GNSS ZTD observations in order to correct the bias of these observations. Apart of the 3DVar run assimilating all the observations described above, another suite of Harmonie-AROME with 4DVar is being prepared to be able to assimilate the same observations, first each 3 hours but later on each 1 hour, using all the available observations distributed in time that are possible. This 4DVar suite will allow to take the advantage of better distributed observations (both conventional and satellite observations) in time. Besides, to improve the distribution in space, some work is currently going on to use a new large domain instead of two little ones. This new domain will cover all Iberian Peninsula, Balearic and Canary Islands, part of Mediterranean Sean and part of Atlantic Ocean. The next observations that will be included in the operational system are IASI for infrared radiances from Metop-C satellite, the microwave and infrared radiances from Fengyun satellites. Also, an update of bias correction for drifting satellites will be necessary.

4p.15 Satellite radiance assimilation at the Bureau of Meteorology (NWP Centre Update)

Presenter: Fiona Smith, Bureau of Meteorology
Co-authors: Fiona Smith, Jin Lee, Nahidul Hoque Samrat, Andrew Smith, Vincent Villani, Monika Krysta, Yi Xiao, Chris Tingwell, Aidan Griffiths, Tan Le, Esteban Abellan Villardon

The Bureau of Meteorology operates a global model (ACCESS-G), seven convective-scale models (ACCESS-C) and a relocatable tropical cyclone model (ACCESS-TC). We are also developing an Australia-wide hourly national analysis system (NAS). This poster will provide an update on the use of satellite radiance data within these systems relative to the last conference. Satellite radiance data continue to provide significant impact in our forecast system, according to forecast sensitivity to observation impact (FSOI) measures. ACCESS-G assimilates brightness temperatures from ATOVS, IASI, ATMS, CrIS, AMSR-2 and Himawari-8. The ACCESS-C and TC models use data from ATOVS, IASI, ATMS and CrIS, mostly from direct readout sources. We have recently run assimilation tests of high-spatial resolution brightness temperatures and 'GeoCloud' retrievals from Himawari, and will upgrade the regional systems with these at the first available opportunity. Following on, we plan to increase the use of GEO sounder data and microwave imagery in the global model.

4p.16 Status and Progress of Observation Usages in the GMAO GEOS Atmospheric Data Assimilation System
Presenter: Yanqiu ZHU, NASA/GSFC/GMAO

The Global Modeling and Assimilation Office (GMAO) has continuously strived to improve analysis and model forecast through enhancing observation usages from various observing systems. The GMAO operational GEOS Atmospheric Data Assimilation Forward Processing (FP) system was upgraded on March 1, 2022. This upgraded both algorithm and input observing system for the analysis component. Moreover, there are ongoing studies to improve aspects of radiance assimilation, such as the impact of hyperspectral radiances in the stratosphere and lower troposphere, microwave radiance usages over land, and revisit of GMI data treatment. Meanwhile, GMAO has focused on the development of a JEDI-based system. Efforts on transition of observing systems capabilities are well underway to support the integration, configuration and validation of the JEDI-based GEOS system.

4p.17 Status of satellite data assimilation in Meteorological Service Singapore
Presenter: Krishnamoorthy Chandramouli, Centre for Climate Research Singapore

No abstract.

Session 5: Climate

5.01 Reprocessing of S-NPP/JPSS Sensor Data Records
Presenter: Lihang Zhou, NOAA (for Lin Lin)
Co-authors: Cheng-Zhi Zou, Xianjun Hao, Bin Zhang, Khalil Ahmad, Ninghai Sun, Yong Chen, Chunhui Pan, Trever Beck, Banghua Yan, Flavio Iturbide-Sanchez, Lihang Zhou

The Suomi NPP (SNPP) satellite was launched successfully on October 28, 2011 and was a pathfinder for the U.S. Joint Polar Satellite System (JPSS) operational satellite series. The primary objectives of the SNPP mission are to provide a continuation of the Earth system observations initiated by the Earth Observing System (EOS) Terra, Aqua, and Aura missions, as well as the NOAA heritage polar-orbiting satellite series; and prepare the operational forecast community with pre-operational risk reduction, demonstration, and validation for selected JPSS instruments and ground processing data systems. Since the launch of SNPP, the Sensor Data Record (SDR) and Environment Data Record (EDR) were in various levels of maturity as the data moved through beta, provisional, and then validated stages. NOAA/STAR reprocessing uses mature algorithms that ensures all JPSS satellite data, starting from the beginning of the time series through the JPSS life cycle, will be consistent on a common reference frame with known uncertainty. Reprocessing of the SNPP SDRs was a first effort in this process. The SNPP baseline SDR reprocessing for ATMS, CrIS, VIIRS, and OMPS has been completed in NOAA/STAR. The reprocessed SDR data are more stable, have fewer anomalies, and show the neutral/positive impacts on EDR and many other applications. Since December 2021, the reprocessing team started the transition of the reprocessed SNPP SDR data to CLASS/NCEI. It’s expected that the transition will be completed in FY23. In the future, SDR reprocessing will be carried out to NOAA-20 and future JPSS satellites to ensure a long-term stable JPSS SDR datasets. The SDR reprocessing supports generation of climate data records for a variety of essential climate variables for climate change monitoring.

5.02 Investigating possible sources of error in the calibration of the Microwave Sounding Instrument
Presenter: Jonathan Mittaz, University of Reading
Co-authors: William Bell

The calibration of the Microwave Sounding Unit (MSU) flown on-board NOAA satellites from TIROS-

N to NOAA-14 has been the subject of much research over the years, in part because the MSU temperature record was one of the first datasets that showed a strong climate change signal. Here we investigate the MSU calibration by looking for patterns of error in the current Level 1 radiance data using reanalysis data (ERA5) coupled with radiative transfer estimates of radiance (using RTTOV) as a pseudo reference. As part of the analysis, we have developed a cloud mask which is based on data from the Advanced Very High-Resolution Radiometer (AVHRR) sea surface temperature (SST) record from the ESA Climate Change Initiative (CCI) which provides locations that are essentially totally cloud/rain free over oceans. By limiting our analysis to MSU footprints which have more than 50% of cloud free AVHRR pixels we should have then minimised the impact of cloudiness on our MW analysis. We have then looked at Observation – RTM radiance differences to look for patterns of error. We show that there is a very clear requirement for a correction based on the MSU instrument temperature in all calibration signals (Earth view, calibration target view and space view) rather than just a corrective term to the calibrated radiance as previously suggested and propose corrective terms inserted directly into the MSU calibration equation. We will then discuss investigations into non-linearity corrections as well as corrections to the channel 3 bandpass based on RTM spectral shifts with the aim of improving data for ingestion into the next reanalysis, ERA6.

5.03 Applying inter-satellite Harmonisation to various Microwave Humidity Sounders

Presenter: Timo Hanschmann, EUMETSAT
Co-authors: Viju John, Ralf Giering, Jörg Schulz

Microwave Humidity Sounder data are a key input to Climate Data Records (CDR) and global reanalysis. Over the last decades, an increasing number of instruments, measuring similar quantities, lead to better temporal and spatial sampling compared to earlier decades. At the same time, the increase number of different satellite sensors lead to inconsistent time series constructed from the data. Firstly, individual sensor time series are not stable over the lifetime, mainly due to sensor aging and improved calibration, and secondly, the different satellite sensors show biases against each other. The first issue is addressed by a reprocessing of the whole time series of a specific sensor with a consistent processor that increases the stability over the sensor lifetime and also incorporates traceable uncertainty estimates. The second issue is addressed by applying a harmonisation method that minimises the differences between individual sensors by optimising the calibration parameters of the sensors but maintaining the characteristic of the individual sensors, such as the spectral response function. The harmonisation method depends on the uncertainty estimate from the reprocessing to weight the input parameters in the optimisation process. Previously, we demonstrated our harmonisation methodology and its strengths in removing any sensor bias against a reference that cannot be explained by known sensor differences. In this presentation, we will present initial results of a harmonised time series of measurements around the 183GHz water vapour absorption. This time series covers data from the late-90s until the end of 2018 and is based on an extended version of the microwave humidity sounder data record, recently released by EUMETSAT. This record includes the following sensors: the Advanced Microwave Sounding Unit B (AMSU-B) on board of NOAA 15-17; the Microwave Humidity Sounder (MHS) on board of NOAA-18, NOAA-19, Metop-A, and Metop-B; the Micro-Wave Humidity Sounder (MWHS) on board of the Chinese satellites Feng Yung-3A to 3C; and the Advanced Technology Microwave Sounder (ATMS) on board of the US Suomi-National Polar-Orbiting Operational Environmental Satellite System Preparatory Project (SNPP) satellite. We will show a quality analysis for all sensors consisting of a comparison to the non-harmonised radiances. A clear reduction of the biases by 0.5 to 3K, depending on the frequency and sensor, has been found, taking MHS on board of Metop-A as the reference. Further, comparisons between the harmonised datasets is performed against a common reference, using the departure-based analysis against ERA5.

5.04 Preparations for ERA6: the assimilation of reprocessed and rescued radiance observations

Presenter: William Bell, ECMWF
Co-authors: Hans Hersbach, Paul Berrisford, András Horányi, Joaquin Muñoz Sabater, Julien Nicolas, Raluca Radu, Dinand Schepers, Adrian Simmons, Cornel Soci, Adrien Oyono Owono, Roberto Ribas, Martin Suttie, Jörg Schulz, Viju John, Timo Hanschmann, Paul Poli, Pascal Prunet, Andrzej Klonecki, Carsten Standfuss, Jon Mittaz, Tom Hall, Bruno Six, Jérôme Vidot, Bruna Barbosa Silveira, Pascale Roquet, Emma Turner, Roger Saunders

As part of the EU's Copernicus Climate Change Service (C3S) ECMWF have supported the reprocessing of several satellite radiance data sets, including: HIRS; ATMS; SSM/T; SSM/T2; MWHS-1 and -2; and Meteosat MVIRI and SEVIRI, in advance of the next generation ECMWF atmospheric reanalysis, ERA6, due to start production in 2024. In addition, ECMWF supports the rescue and assessment of data from several early sounding and imaging missions, mainly from the Nimbus series of satellites, from the period 1966-1978. This includes SIRS, IRIS, PMR, THIR, MRIR, HRIR, NEMS, SCAMS and ESMR. The assessment of all of these datasets has involved detailed quality control and comparison with RT simulations based on ERA5 and RTTOV. These assessments have exposed a range of issues in the original datasets, including spectral and geolocation errors and in several cases improved calibration equations have been applied to the data. Assessments at ECMWF, based on proto-ERA6 configurations of the ECMWF Integrated Forecasting System (IFS), show impacts on forecast performance and in the mean state analysed by 4DVar.

5.05 Status of the NASA CrIS Level 1B Product for Climate Applications

Presenter: Graeme Martin, UW-Madison SSEC
Co-authors: Joe Taylor, Larrabee Strow, Hank Revercomb, Michelle Feltz, Dave Tobin, Bob Knuteson, Ray Garcia, Howard Motteler, Greg Quinn, Jessica Braun, Dan Deslover, Will Roberts

NASA has developed a long-term Cross-track Infrared Sounder (CrIS) Level 1B data record intended for use in studies of climate and atmospheric processes. The Level 1B software is developed and maintained at the University of Wisconsin – Madison and the University of Maryland – Baltimore County, and the data product is generated and distributed publicly by NASA GES DISC. The software shares a theoretical basis with the operational NOAA processing software. However, the primary goal of the Level 1B effort is to achieve a long-term radiance data record that uses optimal calibration parameters through the lifetime of each sensor, and that is consistent across sensors. Additional goals include transparency of software and methodology in a way that can be understood by current and future users, and long-term refinement and validation of the products obtained from all sensors in the SNPP / JPSS series. Multiple reprocessings of the mission dataset will be supported as algorithm improvements are made, as instrument anomalies are analyzed and addressed, and as new instruments come online. Major software updates and associated reprocessed products have been released approximately every 2-3 years. Currently Version 3 of the SNPP and JPSS-1/NOAA-20 products are available, with the SNPP record now spanning more than 10 years. The Version 4 software and product are planned for release in 2023, with an initial version of the JPSS-2/NOAA-21 product to begin flowing by the end of 2023.Recent developments and ongoing work will be highlighted. A rigorous methodology has been developed and documented to calculate radiometric uncertainty for each observation, with support included in the Version 3 product. A test report documenting the methodology and findings of the Version 3 product assessment has been released. A software update was released in connection with the SNPP electronics side failure in early 2021. New features in the upcoming Version 4 product will include full Doppler correction, mitigation of spectral ringing artifacts, and geophysical lunar intrusion prediction. Preparations for JPSS-2/NOAA-21 are underway, including software changes and preliminary calibration parameters. A related product containing VIIRS observations collocated to CrIS footprints (“IMG”) is currently available, and a principal component (PC) based version of the Level 1B product is now being developed. A product monitoring and mission survey/search capability is currently being developed and shows promise as a resource for data discovery and access.

5p.01 Use of satellite data in regional reanalysis

Presenter: Per Dahlgren, MET Norway

The Copernicus Arctic Regional Re-Analysis (CARRA) is a regional reanalysis covering the years 1991 until June 2021. CARRA is produced with a non-hydrostatic mesoscale NWP model, AROME, on a grid mesh with 2.5km spacing and upper-air observations are assimilated with a 3D-Var technique. CARRA assimilates satellite data from a variety of sources such as microwave radiances from the MSU, AMSU-A, AMSU-B and MHS instruments and infrared radiances from IASI. Data derived from satellite measurements are also used like AMV and Scatterometer as well as bending angles from GNSSRO. This poster will give an overview of the reanalysis system with an emphasis on its use of satellite data. Basic performance metrics such as data availability, bias corrections and first guess departure statistics will be presented.

5p.02 Fundamental Climate Data Record of Microwave Imager Radiances, Edition 4

Presenter: Nathalie Selbach, DWD (for Karsten Fennig)
Co-authors: Marc Schröder, Hannes Konrad, Nathalie Selbach

The satellite-based HOAPS (Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data) climatology provides climate data records of precipitation, evaporation and the resulting freshwater flux over the global ice-free ocean between 1987 and 2014. The latest version of HOAPS has been released by CM SAF and is available from the CM SAFs web user interface (https://wui.cmsaf.eu/; DOI: 10.5676/EUM_SAF_CM/HOAPS/V002). The HOAPS climate data records are primarily based on passive microwave measurements from the SSM/I (Special Sensor Microwave/Imager) and SSMIS (Special Sensor Microwave Imager / Sounder) sensor families. In order to derive reliable long-term trend estimates of the global water and energy cycle parameters it is strictly necessary to carefully correct for all known problems and deficiencies of the radiometers as well as to inter-calibrate and homogenise the different instruments. Moreover, all applied corrections need to be clearly documented to provide a complete calibration traceability for a Fundamental Climate Data Record (FCDR). Following these recommendations, CM SAF also provides the underlying Brightness Temperatures as a stand-alone climate data record. The CM SAF FCDR of Microwave Imager Radiances comprises inter-calibrated brightness temperatures from the SMMR, SSM/I and SSMIS radiometers. The recently released 4th edition of this FCDR covers the time period from October 1978 to December 2020 including all available data from the SMMR radiometer aboard Nimbus 7, the SSM/I radiometers aboard F08, F10, F11, F13, F14, and F15 and the SSMIS radiometers aboard F16, F17, and F18. It provides homogenised and inter-calibrated brightness temperatures in a user friendly data format. The homogenization and inter-calibration procedures ensure the long-term stability of the FCDR for climate related applications. All available raw data records have been reprocessed to a common standard, starting with the calibration of the raw Earth counts, to ensure a completely homogenized data record. The data processing accounts for several known issues with the instruments and corrects calibration anomalies due to along-scan inhomogeneity, moonlight intrusions, sunlight intrusions, and emissive reflector. Also, an adjustment to the SSMIS geolocation has been implemented in order to improve the consistency. Corrections for SMMR are limited because the SMMR raw data records were not available. Furthermore, the inter-calibration model incorporates a scene-dependent inter-satellite bias correction and a non-linearity correction to the instrument calibration. The data files contain all available original sensor data (SMMR: Pathfinder Level 1b) and metadata to provide a completely traceable climate data record. Inter-calibration and Earth incidence angle normalization offsets are available as additional layers within the data files in order to keep this information transparent to the users. The data record is complemented with radiometer sensitivities, quality flags, surface types, and Earth incidence angles. The SMMR and SSM/I data records remain unchanged compared to the previous edition 3 while the SSMIS data record has been extended by five additional years. A new adjustment to the SSMIS geolocation has been implemented in the new data record version in order to improve the consistency. Also issues with solar angle depending differences in F17 and F18 data have been identified and corrected, leading to an improved inter-satellite calibration and stability. The consistency and homogeneity of the FCDR are statistically compared using the inter-satellite differences between the individual sensors. Also, differences between GMI and SSMIS and differences between observations and simulated brightness temperatures using ERA-5 and ERA 20c data are analysed. The observed remaining variability in the inter-calibrated brightness temperatures is mainly caused by the natural variability due to differences in overpass times and sampling. Trends of the inter-sensor differences are below 0.03 K/decade and hence fulfil the stability requirements. The 4th edition of the FCDR of Microwave Imager Radiances (DOI:10.5676/EUM_SAF_CM/FCDR_MWI/V004) is now freely available from the web user interface (https://wui.cmsaf.eu/).

5p.03 Climate Data Records of the EUMETSAT Satellite Application Facility on Climate Monitoring

Presenter: Nathalie Selbach, DWD (on behalf of the CM SAF team)

The EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF) generates, archives and distributes widely recognized high-quality satellite-derived products and provides services relevant for climate monitoring. The CM SAF product portfolio covers Climate Data Records (CDRs) for Essential Climate Variables (ECV), as required by the Global Climate Observing System (GCOS) implementation plan in support of the United Nations Framework Convention on Climate Change (UNFCCC). During the current Continuous Development and Operations Phase 4 (CDOP 4, 2022-2027), several new CDRs, Interim CDRs (ICDRs) as well as Fundamental CDRs are being released. They primarily describe properties of atmospheric radiation, clouds, water vapour and precipitation. Thus, users have access to many parameters of the Earth's water and energy cycle based on operational satellite instruments. CM SAF is offering CDRs generated from e.g. ATOVS, AVHRR, VIIRS, SMMR, SSM/I and SSMIS as well as several microwave sounders on different polar orbiting satellites as well as from the MVIRI, SEVIRI and GERB instruments onboard the METEOSAT series and similar instruments on further georing satellites. For the majority of the already available FCDR and CDRs improved and extended versions will become available. Additionally, the range of data records will be extended during CDOP 4 by CDRs based on geostationary data covering the full geo-ring. Work towards the usage of the next generation satellites such as EPS-SG and MTG is ongoing as well. The time series of the currently available CDRs range from 8 to about 45 years with a global coverage for data based on polar orbiting satellites, while those based on geostationary satellite data have a regional coverage (currently Meteosat disk). All CDRs undergo a thorough validation and external review process before their release. While CDRs are based on quality-controlled and inter-calibrated satellite level-1 products, the respective ICDRs, which are based on the same algorithms as the CDRs, have less stringent requirements on the input data. This allows for a release within a few days after observation in order to serve applications with stronger timeliness requirements. For a number of data records, CM SAF already covers the new WMO reference period (1991-2020).

5p.04 The Progress of Re-processing Historical FengYun Meteorological Satellite
Presenter: Peng Zhang, National Satellite Meteorological Center
Co-authors: Peng Zhang, Ling Sun, Na Xu, Lin Chen, Chengli Qi, Shengli Wu, Yang Guo, Dawei An, Hong Qiu, Xiuqing Hu, Songyan Gu

Up to date, there are 19 satellites have been launched in FengYun (FY) Meteorological series since 1988. The historical data has covers more than 30-years in span and 20-years in continuity. The data quality of the historical data was inhomogeneous from the instrument upgrade, systemic difference of the same type instrument on the difference satellite platform, the instrument degradation during the lifetime, the on-orbital status fluctuation of the instrument and satellite platform. To generate the Fundamental Climate Data Record (FCDR) from the FY historical satellite data, the recalibrating Fengyun archived data program which named RICH-FY has been conducted since 2018. Right now, there are 7 sensor type depended FCDRs have been generated. There are VIRR on FY-1A/B/C/D and FY-3A/B/C spanned from 1988 to 2021, VISSR on FY-2A/B/C/D/E/F/G spanned from 1997-2020, MERSI on FY-3A/B/C spanned from 2008-2018, IRAS on FY-3A/B/C spanned from 2010-2020, MWRI on FY-3A/B/C spanned from 2010-2020, MWTS on FY-3A/B/C spanned from 2008-2018, MWHS on FY-3A/B/C spanned from 2008-2020. These FCDRs have been validated with inter-calibration and O-B method. The validations show that the homogenization and harmonization of the FY historic data have been improved. The details information will be given in this presentation. To facilitating the data access, the DOIs have been registered for these FCDRs and the data are available through the web-portal.

Session 6: Retrieval and Software

6p.01 An update on NWP SAF satellite data processing packages to support EPS-SG and MTG
Presenter: Nigel Atkinson, Met Office
Co-authors: Elisabeth Nolland, Anna Booton and Fabien Carminati

In a talk at ITSC-23 (June 2021), the new NWP SAF pre-processing packages were introduced. These are designed to facilitate NWP exploitation of data from Metop-SG-A1, Metop-SG-B1 and MTG-S1, all due for launch in the 2024 to 2025 time frame. In this poster we will give an update on the status of these packages. For EPS-SG direct broadcast applications, software packages are being procured by EUMETSAT to convert from raw data (Channel Access Data Unit, or CADU) to level 1B. The packages will be developed by industry, will be delivered to EUMETSAT and will be tested and distributed to the users by the NWP SAF. It is planned that first version of each package will be released approximately 6 months before launch of the corresponding EPS-SG satellite. Before the data can be assimilated in NWP, several other processing steps may be needed. For example: to perform spatial averaging to reduce noise in MWS; to map MWS to IASI-NG; to map MWI to ICI and to thin the over-sampled level 1B data; and to compute reconstructed radiances for MTG-IRS. These steps will be performed by three software packages developed by the NWP SAF: (i) an AAPP extension to handle MWS and IASI-NG, (ii) an extension to the Microwave Imager Pre-processor (MWIPP) that will include support for MWI and ICI, and (iii) the Infrared Sounder Pre-processor for MTG-IRS (IRSPP).In 2022 the first version of IRSPP was released – compatible with EUMETSAT's official pre-launch test data for MTG-IRS. There has also been an MWIPP update release that can ingest and process test data for MWI and ICI. Users can download these packages, and corresponding test cases containing simulated instrument data, from the NWP SAF web site. Future work will include making these packages compatible with the level 1B BUFR formats currently being defined by EUMETSAT. Information on all three pre-processing packages, including design and specification documents, can be found on the NWP SAF web pages https://nwp-saf.eumetsat.int/site/.

6p.02 The status of the Version 2 VIIRS+CrIS Fusion Radiance (NASA FSNRAD) products

Presenter: Eva Borbas
Co-authors: Elisabeth Weisz, W. Paul Menzel, Bryan Baum, and Geoff P. Cureton

The VIIRS+CrIS Fusion Radiance (FSNRAD) products have been created to provide a path for the continuity of products based on the Terra, Aqua, SNPP, and NOAA-20 platforms. The issue complicating the continuity of cloud products and other valuable applications is the lack of VIIRS measurements in any of the infrared (IR) absorption bands available on the Terra and Aqua MODIS sensors. We addressed this restriction by constructing similar Aqua MODIS IR band radiances for VIIRS based on a fusion method that uses collocated VIIRS and CrIS data. The V2 FSNRAD products were released on March 8, 2022, and are available on the NASA LAADS website. The fusion radiances are provided at the VIIRS Moderate-band (or M-band) resolution of 750m for every VIIRS pixel in the granule for both S-NPP and NOAA-20 with global coverage. We note that the CrIS sounder has a more narrow swath width than VIIRS. The fusion radiance product makes an effort to provide radiances for the full VIIRS swath. In addition, a subsetted FSNRAD product has been developed for the CERES team. The poster will present the V2 products with their methodology and the new updates.

6p.03 Implementing Atmospheric Infrared Sounder (AIRS) and Cross-Track Infrared Sounder (CrIS) Cloud-Clearing Algorithm into the NASA GEOS Model: focus on the 2017 Atlantic Tropical Cyclone season

Presenter: Niama Boukachaba, MSU/NASA GSFC/GMAO
Co-authors: Oreste Reale, Erica McGrath-Spangler, Manisha Ganeshan

Numerical Weather Prediction (NWP) centers assimilate cloud-free infrared (IR) radiances because the assimilation of all-sky IR radiances is not yet operationally achievable. The cloud-clearing procedure offers a simpler, but effective strategy that produces cloud-affected radiances suitable for assimilation in partially cloudy regions. Several studies conducted by this team have demonstrated that IR Cloud-Cleared Radiances (CCRs), if thinned more aggressively than clear-sky radiances, can improve analysis and forecasts, particularly in meteorologically active areas. However, CCRs are not used by operational centers due partly to the thought that the process of cloud-clearing may affect latency and introduce difficult-to-control external dependencies. This study presents the results of implementing an Atmospheric Infrared Sounder (AIRS) and Cross-Track Infrared Sounder (CrIS) cloud-clearing procedure into the NASA Goddard Earth Observing System (GEOS) to demonstrate the portability of the procedure. The AIRS and CrIS cloud-clearing algorithms have been deprived of external dependencies, made customizable to any specific model, and the computational efficiency has been improved via parallelization. The revised AIRS and CrIS cloud-clearing algorithms allow a customized choice of channel selection, the use of a user-specified model's fields as first guess, and can perform in real time. Data assimilation experiments with the hybrid 4DEnVar GEOS system were successfully performed for the 2017 tropical cyclones (TC) season with a focus on three major hurricanes (Harvey, Irma, and Maria). This study shows that assimilation of locally-generated CCRs have a positive impact on both global skill and TC representation, compared to the assimilation of AIRS and CrIS clear-sky radiances, and a comparable or slightly improved impact compared to assimilation of CCRs produced by external sources, such as NASA's Distributed Active Archive Centers and NOAA's Comprehensive Large Array-data Stewardship System. The customization and computational efficiency of the revised procedure would enable its usability in a real-time forecast context.

6p.04 Ultra Low Latency Detection of Atmospheric Instability and Anomalous Emissions with CrIS
Presenter: Liam Gumley, CIMSS/SSEC, UW-Madison
Co-authors: Bruce Flynn, Steve Dutcher, Dave Tobin, Joe Taylor, Elisabeth Weisz

CIMSS/SSEC has developed a system that allows SNPP and NOAA-20 CrIS data to be received via direct broadcast at multiple antenna sites covering North America, and then merged, de-duplicated, geolocated, and calibrated within 60 seconds of observation. The system utilizes antennas at multiple locations to provide redundancy. Calibrated CrIS radiance spectra are analyzed via the Hybrid Principal Component approach, and global + hybrid PC scores are computed. Radiances reconstructed from the PC scores are used in a dual-regression retrieval algorithm to obtain temperature and moisture profiles and estimates of Convective Available Potential Energy (CAPE). CrIS FOVs where CAPE is greater than 500 J/kg are stored in a database and can be retrieved via a Web API by external users. The PC residuals are used to detect the presence of anomalous emissions (e.g., methane) and the locations of these FOVs are likewise stored in a database. The poster will describe the system which implements this workflow, show examples of products from the system, and suggest several use cases for the products.

6p.05 CSPP2 - COMMUNITY SATELLITE PROCESSING PACKAGE (CSPP) for Committed and Sustainable Professional Platform (CSPP)
Presenter: Allen Huang, University of Wisconsin-Madison
Co-authors: Mitch Goldberg

Space Science and Engineering Center (SSEC) and its Cooperative Institute for Meteorological Satellite Studies (CIMSS) have supported the international Direct Broadcast/Readout (DB/DR) user community since 1985 through the development and distribution of the International TOVS and ATOVS Processing Packages (ITPP, IAPP) for NOAA Polar Orbiting Environmental Satellites (POES), and since 2000 via the International MODIS/AIRS Processing Package (IMAPP) for Moderate Resolution Imaging Spectroradiometer (MODIS), Advanced Microwave Sounder (AMSU), Atmospheric Infrared Sounder (AIRS) onboard NASA Terra and/or Aqua. Since 2007, SSEC/CIMSS has supported a DB/DR version of the software for generating Cross-Track Infrared Sounder (CrIS), Advanced Technology Microwave Sounder (ATMS), and Visible Infrared Imaging Radiometer Suite (VIIRS) Sensor Data Records (SDRs) and Environmental Data Records (EDRs). Since 2012 SSEC/CIMSS is continuing the facilitating of efficient use of polar orbiter satellite data through the development of a Community Satellite Processing Package (CSPP) that supports the Suomi-NPP/JPSS and, GOES-16 with CSPP Geosynchronous Earth Orbit (GEO) component, as well as adding support for other international sensors onboard European METOP-A/B/C, Chinese FY-3 LEO satellites and, most recently, Advanced Himawari Imager (AHI) onboard Japanese Himawari 8 and 9 GEO satellites. In this poster presentation, we are to overview the past and then focus on recent developments and plans for CSPP, and IAPP (now released and supported through the CSPP framework) that facilitate the exploitation of global meteorological satellite observing systems. Specifically, we will discuss CIMSS/NOAA commitment to providing a sustainable platform suitable for professional research, operational, and commercial usage.

6p.06 Hybrid Principal Component (PC) Compression
Presenter: Tim Hultberg, EUMETSAT

The hybrid Principal Component (PC) Compression approach for hyperspectral data supplements the usual global PCs with a few additional PCs specific to each individual granule. This captures atmospheric trends, which would otherwise be lost, and improves the ability to represent unusual spectral features. It is the baseline representation of MTG-IRS spectra for dissemination and was introduced operationally for IASI recently. We illustrate the benefits and limitations (for isolated outliers) of the hybrid PC Compression approach with case studies and statistical analyses.

6p.07 Retrieving cloud thickness over land for single-layer liquid clouds from OCO-2
Presenter: Siwei Li, Wuhan University

Satellite-based measurements of cloud geometrical thickness (CPT) play an important role in investigation of cloud microphysics and radiative balance. However, there is few passive retrieval algorithm developed for CPT over land due to the inherent challenges on retrieving atmosphere profiles for most passive ways especially with complicated disturbance from land surface reflection. Here, a passive CPT retrieval algorithm based on OCO-2 satellite measured oxygen A-band (O2A) is developed for single-layer cloud over the land. The disturbance from land surface reflected radiation under cloudy conditions to the retrieval is corrected by estimating white-sky albedo (LWA) in the O2A. The new retrieval algorithm is nearly real-time on retrieving CPT and as accurate as those using full radiative transfer model which is very time consuming. Compared with the satellite-based lidar-radar products, the new algorithm retrieved CPTs with OCO-2 O2A observations have a correlation coefficient of 0.451 over land, with mean biases of 15 hPa and root-mean-square errors (RMSEs) of 64 hPa. When outliers are removed, the correlation coefficient increases to 0.604 over land, and the RMSE decreases to 44 hPa.

6p.08 Development of NUCAPS for CSPP Real-Time Processing of early morning orbit Hyperspectral Sounding Suites

Presenter: Agnes Lim, CIMSS/SSEC
Co-authors: Allen Huang, Chris Barnet, Jim Davies, Zhenglong Li and Mitch Goldberg

With S-NPP/NOAA-20 and the future JPSS satellites flying in early afternoon orbits, METOP satellite series flying in mid-morning orbits, the FY satellites fill in the orbital gaps with FY-3D 30 minutes after NOAA-20 and FY-3E in the early morning orbit. The FY-3 satellites carry the Hyperspectral Infrared Atmospheric Sounder (HIRAS) and Micro-Wave Temperature/Humidity Sounder-2 (MWTS-3 and MWHS-3) which are similar to CrIS/ATMS and IASI/AMSU class of advanced satellite sounding suites. NOAA NWS field offices are provided with two-orbit coverage (9:30 and 13:25) of NUCAPS sounding profiles that are used routinely to assist forecasters in monitoring and forecasting short life cycle convective storms. The FY-3D/3E soundings will mitigate the significant gaps that limit the forecasters' ability to monitor and near-cast the short-lived convective storms. This work will build upon the NOAA Hyper-Spectral Enterprise Algorithm Package (HEAP) software. Since HIRAS-2/MWTS-3/MWHS-3 are similar to CrIS/ATMS, modifications will only be made to NUCAPS's instrument dependent components. This includes data ingest, data quality control, channel selection for HIRAS-2, microwave and infrared tuning coefficients, and statistical retrieval to name a few. First retrieval results for FY-3E using NUCAPS will be presented.

6p.09 Community Satellite Processing Package (CSPP) Sensor Data Record (SDR) Version 4.0: Support for NOAA-21

Presenter: Scott Mindock, SSEC/CIMSS
Co-authors: Kathy Strabala, Nick Bearson, Ray Garcia, Graeme Martin, Liam Gumley, Allen Huang

The SNPP and JPSS spacecraft, host four instruments (VIIRS, OMPS, CrIS, ATMS), two of these ATMS and CrIS produce sounding data. The Community Satellite Processing Package (CSPP) Team supports the Direct Broadcast (DB) and Sounding Community by producing and supporting the CSPP SDR software package. The CSPP SDR package processes DB or CLASS, SNPP, J01 and J02, RDRs (Raw Data Records) into mission quality SDRs (Science Data Records). CSPP SDR leverages the ADL software produced by RAYTHEON for NOAA to ensure mission quality SDRs. are produced. These SDRs can be utilized as inputs to other scientific software packages, including NUCAPS, HEAP and HSRTV, also available from the CSPP team. DB users can produce regional products from these instruments directly after data acquisition. The CSP SDR software is freely distributed by the University of Wisconsin, Madison and is easy to install and maintain. Registration is the only requirement to download the software. To date CSPP SDR has had 1123 users register and download the software. Our users represent 63 countries. The software is easy to install and use. Untar the distribution, set an environment variable and you are ready to start processing data. Excellent support is provided via e-mail and a forum. The SDR 4.0 software installation allows customized installation based on spacecraft. It should be noted that DB data from the J01 and J02 spacecraft provide all CrIS FOVs (Fields of View) in the FSRs produced. CSPP SDR 4.0 provides mission quality SDRs to the DB community wherever you may reside. Proven reliability and excellent support make CSPP SDR 4.0 an excellent choice for your sounding data needs. We have been providing quality CSPP software to the DB community since the launch of SNPP and hope you will join the family of CSPP users.

6p.10 withdrawn

6p.11 Combined Ground and Sounder data Show a Strong Coupling between In-situ and Atmosphere Associated with Baghjan oil well blowout and Tonga Volcanic Eruption

Presenter: Ramesh P Singh, Chapman University

Ground and Atmospheric Infrared Sounder (AIRS) data provide information about the in-situ, atmospheric trace gases and meteorological parameters. Recent analyses of satellite remote sensing have provided a strong coupling between land, atmosphere, meteorological and ionospheric parameters associated with all kinds of natural hazards occurring around the world. In this talk, a detailed analysis of ground, ocean, atmospheric trace gases, and meteorological parameters will be presented with the Baghjan oil well blowout (270 35’ 30”N 950 22’ 30”) on May-June 2020 of Tinsukia district, Assam located in the northeastern parts in India and in the case of Tonga’s Hunga Tonga-Hunga Ha’apai volcano occurred on 15 January 2022. Prior to the oil blowout, the Amphan cyclone brought out a huge amount of precipitation that show the changes in the underground pressure that was the cause of the oil blowout. The oil blowout and volcanic eruption injected a huge amount of trace gases and water into the atmosphere which injected an unprecedented amount of water into the stratosphere, especially with the volcanic eruption. The combined analysis of ground and AIRS data will be discussed to find the pronounced variations in trace gases in the atmosphere associated with the oil blowout and Tonga eruption.

6p.12 Updates on NOAA-21 Science Product Validation

Presenter: Lihang Zhou, NOAA

The Joint Polar Satellite System (JPSS)-2 (will be renamed as NOAA-21 post-launch) is scheduled to launch in November 2022. It will host an array of instruments similar to those currently operating on SNPP and NOAA-20 satellites. The NOAA-21 satellite will produce baseline and new products directly from instrument upgrades and science improvements. This paper will present an overview of the NOAA-21 science algorithm updates and share some early results from NOAA-21 product validation and readiness for operation. The plan and status of transitioning JPSS enterprise algorithms to NESDIS Common Cloud Framework (NCCF) will also be briefed. We will also demonstrate the impacts of low-latency JPSS data products on users' applications.

6p.13 Retrieval and Evaluation of Atmospheric Temperature and Humidity Profile using FY-4A/GIIRS

Presenter: Junghyung Heo, KMA (for Hye-In Park)
Co-authors: Byung-il Lee, Junhyung Heo, Junyeob Choi, Myoung-Hee Lee, Yoonjae Kim

The hyperspectral infrared sounder is known to play an import role in now-casting, data assimilation on NWP, and climate change monitoring. Especially the hyperspectral infrared sounder in GEO is good for monitoring severe weather because it provide a unique look at the atmosphere at unprecedented spatial and temporal sampling. KMA has been developed 1D-VAR based Atmospheric Profile algorithm for FY-4A/GIIRS launched by CMA in December 2016. To develop the algorithm for FY4A/GIIRS, channel selection and systematic bias correction were performed. The retrieved temperature and humidity profiles with the selected channels for three month from June to August 2022 were compared with radiosonde. Despite the use of many channels than GK2A Atmospheric profile retrieval algorithm, the validation result was similar with the GK-2A one, so it is needed various sensitivity tests to get more accurate temperature and humidity profiles using hyperspectral infrared sounder such as the number of channels and wavelength selection used by the algorithm. The detailed results and plans are presented in the conference. This work was funded by the Korea Meteorological Administration’s Research and Development Program “Technical Development on Weather Forecast Support and Convergence Service using Meteorological Satellites” under Grant (KMA2020-00120).

Invited Presentation

State of Atmospheric Sounding from Space – My Perspective on Past, Present, and Future, in the Infrared

Presenter: William Smith, UW-SSEC

Session 6: Retrieval and Software

6.01 withdrawn

6.02 The past, present and future of the EUMETSAT Hyperspectral Infrared Level 2 products

Presenter: Marc Crapeau, EUMETSAT
Co-authors: T. Hultberg, S. Stapelberg, F. Lenti, C. Goukenleuque, T. August, D. Coppens, M. Doutriaux, J. Onderwaater, R. Huckle, G. Corlett, A. O’Carroll

For more than 15 years, the EUMETSAT’s Central Facility has been distributing the IASI Level 2 products in near-real time to its users. Starting with Metop-A, production was extended to Metop-B in 2013 and to Metop-C in 2019. These 15 years have also been marked by a constant improvement in the quality of the products thanks to regular updates of the retrieval algorithms. Over the years, new parameters have been added to the list of products and a version of the IASI L2 processing has been added to the EARS regional data service. All these developments have led to the current version of the IASI L2 products, the seventh iteration of the v6 family initiated in 2014. Among other parameters, the EUMETSAT IASI L2 products suite includes high-quality profiles of atmospheric temperature and humidity provided in full-sky through synergistic microwave-infrared retrieval using machine learning algorithms. With the end-of-life of the Metop-A platform occurring in 2021 and the launch of the next generation of instruments starting in 2024, this is a critical time for the EUMETSAT hyperspectral infrared L2 products. First, this presentation will provide an overview of the current status of the generation, monitoring and validation of the IASI L2 products. We will then take a look into the past with the presentation of the IASI L2 climate data records recently released by EUMETSAT and that provide a full lifetime reprocessing of Metop-A and -B with the latest version of our algorithms. Finally, we will discuss the future of our products and in particular the new instruments (IASI-NG and IRS) and the next major release of our products, the v7, which will take over from the v6 after ten years of service.

6.03 Updates on CrIS VIIRS Radiance Cluster Analysis Algorithm

Presenter: Likun Wang, ESSIC/Univ. of Maryland
Co-authors: Lihang Zhou, Haibin Sun, Banghua Yan, Satya Kalluri, Mitch Goldberg

In support of data assimilation of numerical weather predication (NWP) models, we recently developed an algorithms of Visible Infrared Imaging Radiometer Suite (VIIRS) radiance cluster analysis within Cross-track Infrared Sounder (CrIS) field of view (FOV) to provide sub-pixel scene homogeneity information. In particular, an accurate and fast collocation method to collocate VIIRS measurements within CrIS FOV directly based on the line-of-sight (LOS) pointing vectors is developed. The K-mean clustering method is used to group collocated VIIRS radiance within CrIS FOVs into different clusters based on their radiance values. The mean, standard deviation, and coverage of each cluster are saved for each CrIS FOV. The bow-tie deletion along VIIRS scan line is carefully taken care by assigning the weights to each VIIRS pixel. The test BUFR data generated from the scientific algorithm has been distributed to the NWP centers and the initial feedbacks from the NWP centers are positive. Recently, the CrIS VIIRS cluster analysis algorithm has been approved for operational implementation in NOAA/NESDIS to provide the VIIRS cluster analysis in the existing BUFR datasets. This presentation gives the updates and status on CrIS VIIRS radiance cluster analysis algorithms. First, we set up a produce the BUFR test data routinely and make the data available toward finalizing and testing the algorithms. These long-term data will be important for the NWP centers to carry out data assimilation experiments. Second, we work closely with the Algorithm Scientific Software Integration and System Transition Team (ASSISTT) to deliver and integrate the science codes in the Cloud Containerized Algorithm Package (CCAP). Third, we conduct inter-comparison between our codes and the one in The ATOVS and AVHRR Pre-processing Package (AAPP), both of which has an ability to generate the CrIS-VIIRS cluster analysis. Their difference and similarity will be presented by comparing test datasets. Finally, collaborating with the NWP centers, the preliminary data assimilation results will be reported if the results are available.

6.04 Validation and operational monitoring of atmospheric products derived from IASI measurements

Presenter: Stefan Stapelberg, Hamtec Consulting Ltd
Co-authors: T. August, F. Lenti, M. Crapeau, T. Hultberg, D. Coppens

The thermodynamic profiles and cloud information derived from the hyperspectral Infrared Atmospheric Sounding Interferometer (IASI) are part of the EUMETSAT operational IASI Level 2 products disseminated in near-real time. They provide important information about the atmosphere for different applications, including weather, wind, atmospheric composition and air quality monitoring. The capability to validate new products and perform continuous monitoring of the operational products quality with external reference measurements is critical to ensure meeting the User requirements. The MONALiSA python package has been developed as a platform for the validation of EUMETSAT atmospheric profiles derived from IASI. MONALiSA stands for MONitoring of Atmospheric Level2 SAtellite products and is primarily designed to provide an operational environment for the validation / verification of satellite L2 profiles (Temperature and Water Vapour) with in situ measurement (radiosonde) and for monitoring their stability over long time-series with possible stratification over particular geographic regions, quality classes and other auxiliary information (e.g. cloudiness etc.).In this presentation, we will give an overview of the operational L2 quality-monitoring scheme developed for IASI Temperature and Humidity profiles, and extended for Total-Column-Ozone and Integrated-Water-Vapour. We will draw a bow to an internal cloud mask inter-comparison using established reference datasets, e.g. CALIOP – CALIPSO, including region dependent visual inspections and statistics for different cloud-types and surfaces.

6.05 moved to poster 6p.13

6.06 Concurrent temperature/moisture profile and hydrometeor retrievals from the TROPICS Pathfinder mission

Presenter: Ralf Bennartz, Vanderbilt University
Co-authors: Ruiyao Chen, Bill Blackwell, Vince Leslie

NASA's 'Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats' (TROPICS) mission will consist of four 3U CubeSats, likely to be launched in 2023. TROPICS will enable passive microwave observations of tropical cyclones with an unprecedented temporal resolution. Each satellite is equipped with cross-track scanning microwave sounders covering the 118 GHz oxygen and 183 GHz water vapor absorption bands as well as channels at 92 and 204 GHz. As a precursor to the full mission, the TROPICS Pathfinder satellite was launched in June 2021 and has provided valuable science data since August 2021. With a passive microwave mission dedicated to observing hurricanes, it is important to understand the potential and limitations of passive microwave temperature/moisture retrievals under precipitating conditions. Here, we present a novel approach to study these issues using a K-D tree to simultaneously retrieve temperature and moisture profiles alongside precipitation and ice water path information over ocean from the TROPICS Pathfinder. In a first step, the Pathfinder measurements were collocated with ERA-5 reanalysis temperature and moisture profiles as well as with surface rain rate (RR) and ice water path (IWP) derived Global Precipitation Measurement's (GPM) Dual-Frequency Precipitation Radar (DPR) and Microwave Imager (GMI). This process yields about one million collocations over the period August 2021 – January 2022. Next, these data were sorted into a K-D tree to allow for fast nearest neighbour and range searches within this dataset. This K-D tree forms the basis of the study. In the retrieval step, the K-D tree is queried with observed brightness temperatures to retrieve temperature and moisture profiles alongside ice water and precipitation observations. Retrieved profile information is deemed valid, if their associated brightness temperatures lie within a hypersphere determined by multiples of the NEDT of each TROPICS channel. This process typically yields a set of retrieved profiles that fall within this hypersphere. This set of retrieved profiles, each consistent with the observed brightness temperatures, allows answering several research questions, namely: (1) Representativeness: How well is a given set of observed brightness temperatures represented in the KD- tree and, by extension, is the scene observed rare or does it occur frequently? (2) Uniqueness: Is a given temperature/moisture profile a unique solution to a set of observed brightness temperatures or are there various possible temperature/moisture profiles that would match? (3) How likely is it that the observations were contaminated with precipitation and how different are retrieved temperature/moisture profile retrievals between precipitating and non-precipitating retrieved profiles? In the presentation, we will address these questions and provide initial validation results of our approach both against independent temperature/moisture soundings and against established precipitation products such as the Global Precipitation Climatology Project (GPCP).

6.07 NASA's New Microwave Sounder Retrieval System

Presenter: Bjorn Lambrigtsen, Jet Propulsion Laboratory
Co-authors: Mathias Schreier, Evan Fishbein

Sponsored by NASA, a new microwave sounder retrieval system has been developed at the Jet Propulsion Laboratory, primarily to process data from the Advanced Technology Microwave Sounder (ATMS) operating on NOAA satellites. The Retrieval Algorithm for Microwave Sounders in Earth Science (RAMSES) was a two-track development funded by two consecutive 3-year awards through NASA's Terra-Aqua-SNPP research program. Both developments derived significant heritage from the retrieval system developed for the microwave sounders operated as part of the Atmospheric Infrared Sounder (AIRS) sounder suite, the Advanced Microwave Sounding Unit A (AMSU-A) and the Humidity Sounder for Brazil (HSB). On the first track, RAMSES-I was closely related to the AMSU-HSB system in most respects, while on the second track, RAMSES-II was developed largely from first principles. Eventually, RAMSES-I was abandoned, and RAMSES-II has now been fully developed. The first version of RAMSES-II was delivered to the Goddard Earth Sciences Data and Information Services Center (GES DISC), the distributed active archive center (DAAC) used by NASA for atmospheric data, where the RAATMS data from the S-NPP and NOAA-20 satellites are being processed with RAMSES-II and distributed to the science community. The second version, with greatly improved performance, was recently delivered, along with a performance assessment report and other documentation. A key element in the development of these systems has been an algorithm testbed, which has greatly facilitated the evaluation of a variety of different components and optimization of the retrieval system. RAMSES-II is based on Optimal Estimation, with an a priori derived from the MERRA-2 reanalysis data set. While others have also developed ATMS retrieval systems, NASA's goal is to support the atmospheric research community rather than the operational community. Uncertainty quantification, long term stability, ongoing maintenance, and frequent reprocessing are some of the characteristics of the NASA approach. As resources allow, validation in depth is also an important objective. We will review the development and properties of the RAMSES retrieval system and show sample results as well as performance metrics. Copyright 2022 California Institute of Technology. Government sponsorship acknowledged.

6.08 Evaluation of INSAT-3DR sounder derived atmospheric temperature retrievals over India using AIRS, COSMIC-2, High-Resolution ECMWF (European Centre for Medium-range Weather Forecasting) Analyses products and radiosonde measurements

Presenter: Pratiksha Dubey, IMD
Co-authors: Kavita Navaria, A.K. Mitra

Atmospheric temperature profiles retrieved from a geostationary satellite INSAT-3DR (Indian National Satellite System) sounder at MMRDPS (Multi-Mission Meteorological Data Receiving and Processing System) IMD, New Delhi were evaluated with radiosonde observations, Atmospheric Infrared Sounder (AIRS), COSMIC - 2 and High resolution ECMWF data sets over India and adjoining area. This evolution was carried out in the terms of correlation coefficients, bias, and root-mean-square error (RMSE) at each pressure level from surface 1000 to 100 hPa during 2021. The initial validation of INSAT-3DR temperature profiles with AIRS and ECMWF data were taken as reference and computed for the spatial distribution of correlation coefficient, bias, and RMSE at each pressure level over the Indian region. In addition to that, we also compared the INSAT-3DR temperature retrievals with 12 selected IMD (India Meteorological Department) radiosonde observations at different geographical features over the Indian subcontinent during the same period. In this analysis, for each station at all pressure levels, the correlation coefficients, biases and their corresponding root-mean square errors (RMSEs) were carried out between INSAT-3DR and radiosonde observations. The results of the inter-comparison reveal that temperature retrievals from the INSAT-3DR are a good agreement with AIRS and ECMWF over the land region and a slight degradation performance over the ocean- and coastal regions of Arabian Sea and Bay of Bengal below 850 hPa. The degradation performance over the ocean- and coastal areas associated with maybe possibility of undetected clouds and uncertainty in surface emissivity and also it might be attributed to improper bias correction coefficients used for brightness temperature of clear-sky pixels before physical retrievals in INSAT-3DR algorithm. Furthermore, error statistic of Bias and RMSE with COSMIC and ERA5 were also performed. Overall, the results show that INSAT-3DR temperature retrievals over land are a good agreement with AIRS/ECMWF/COSMIC and ERA5 products then over the ocean. The overall accuracy of retrieved temperature profiles correlation coefficient values more than 0.8, bias 0.6 °C and RMSE 2 °C at each pressure level, except above 300 hPa at all stations shows 4 °C, respectively. The coastal regions the error are slightly higher which need to be analyzed and will be presented for the year 2022 during the conference. The high temporal information available from INSAT-3D sounder profiles can be used in weather forecasting and nowcasting applications. It will be used in the data assimilation system to study the impact of the data on various weather phenomena like cyclone track, rainfall forecast, and monsoon features over India.
Keywords: COSMIC, ERA-5, INSAT-3DR

6.09 The Cloud-dependent 1DVAR Algorithm for Retrieving Precipitation from FengYun-3D/E Microwave Sounders

Presenter: Hao HU, CMA Earth System Modeling and Prediction Centre (CEMC)
Co-authors: Hao HU, Jintao XU, Ziqiang MA, Fuzhong WENG

Previous studies have shown that the accuracy of microwave retrieved temperature and humidity profiles can be significantly improved after using cloud-dependent background error covariances in the one-dimensional variation (1DVAR) algorithm. In this study, the cloud-dependent 1DVAR algorithm is expanded to precipitation retrievals based on microwave sounding instruments onboard FengYun-3D/E satellites. Cloud scene identification is firstly proposed to delineate the different weather conditions, including clear sky, large-scale clouds, and convective clouds, which is greatly helpful for accurately retrieving heavy precipitation amount. The background error covariances for hydrometer profiles are then calculated under different cloudy conditions. Also, the performances of the fast radiative transfer model, ARMS v1.1.2 are evaluated under different cloud conditions to generate cloud-dependent observation operator error matrices. It is shown that for tropical cyclone (TC) conditions, the precipitation retrievals considering cloud scene identification (CC ~ 0.70 and RMSE ~ 1.60 mm/h) outperform those without distinguishing cloud scenes (CC ~ 0.65 and RMSE ~ 1.80 mm/h). Also, the cloud scenes in the variational scheme could significantly improve the accuracy of retrieving extreme precipitation amount, with a high detection rate close to 100%. A FengYun-3 constellation has a great potential for global precipitation retrievals. Additionally, the findings of this study could provide valuable references and pathfinders for further improving the retrieval accuracy of the microwave-based precipitation estimates, especially for the strong convective zones.

Session 7: Geo Hyperspectral Sounder Assimilation

7p.01 Initial assessment of GIIRS on board FY-4B

Presenter: Chris Burrows, ECWMF

The Chinese satellite FY-4B carries the first operational hyperspectral infrared instrument in a geostationary orbit. Not only is this data valuable in its own right, but it provides excellent experience ahead of the launch of the European mission MTG-IRS. FY-4A was an experimental mission, and FY-4B has many significant improvements, both nominally and empirically. The spectral range is increased in the long-wave, so more stratospheric information can be measured. Most importantly, a number of systematic deficiencies that were present in the data from FY-4A have been significantly improved, notably the inconsistency between neighbouring fields of regard. This presentation will highlight major areas of improvement using comparisons with NWP model simulations.

7p.02 Accuracy evaluation of GIIRS/FY-4A retrieved temperature profile in the Taklimakan Desert

Presenter: Yufen Ma, Institute of Desert Meteorology, China Meteorological Administration, Urumqi

GIIRS/FY-4A retrieved temperature profile (ATP) is capable of backup the grand blank of the conventional measurement in the Taklimakan Desert (TD). However, both the land surface temperature and emissivity there might affect the accuracy of the retrieval temperature, especially in the near-ground layers. This calls for further assessments of the GIIRS/FY-4A retrieved temperature profile quality in these desert regions. A set of SYNOP observations from field experiments were conducted on 1-31 Jul 2021 in the hinterland of TD, China. The experimentally observed atmospheric temperature profiles (RAOB) together with 7 conventional RAOB stations are thus used in this study as the reference to quantitatively investigate the spatial bias distribution of GIIRS/FY-4A ATPs in the TD. Analysis of these data shows four main results. First, the maximum percentage of effective GIIRS/FY-4A temperature retrievals out of all grid numbers in and around TD are between 98.75% and 17.45%, with the average value 71.94%. The percentage of unavailable ATPs is between 87.23% and 2.57%, and the percentage of the bad, good and perfect retrievals are smaller than 22.78%, 12.32% and 31.82%, with their minimum 11.78%, 6.38% and 17.93%, respectively. The summed-up percentage of both perfect and good GIIRS/FY-4A ATPs are smaller than 63.66%, with its averaged percentage 35.58%, which means that, 64% percent of all the gridded measurements are with poor quality and are thus not adopted in this study. Second, in the field experimental duration, the maximum air temperature presented by RAOB ATPs ranges from 36.7 ℃ to 45.0 ℃, while 39.0℃ to 55.5℃ for GIIRS/FY-4A ATP. A temperature revere has been obviously detected by the field RAOB in TZ, which has been omitted by GIIRS/FY-4A ATP, and the variation range of both GIIRS/FY-4A and RAOB ATPs in the lower layers is generally larger than that in the upper layers, with the former much larger than the latter in all levels. Third, the absolute value of mean bias of GIIRS/FY-4A ATPs with QC flags equal to 0 and 1 are both generally smaller than 5 K, with both of their RMSE within 8 K, and the RMSE of the latter are larger than that of the former. In addition, the smallest bias and RMSE of GIIRS/FY-4A ATPs appear near the TZ sounding station in the hinterland of TD where the land-surface category are sheer desert and the topography are relatively flatter and far from mountains around the TD. Forth, For the whole observation atmospheric layers, the RMSE of GIIRS/FY-4A ATPs at all 8 stations with qc_flags equal to 0 ranges from 0.18 K to 0.95 K. Meanwhile, the major contributor to large RMSE in the hinterland of the TD are those observations in the near-ground layers with air temperatures between 20 ℃ to 40 ℃, while that for the oasis stations around the TD are the observations in the higher layers. Finally, almost all the PDF distributions of the GIIRT/FY-4A ATP bias possess a nearly Gaussian distribution, and majority of the center values of the Gaussian PDF curve for QC_FLAGs equal to 0 are positive, while negative for QC_FLAGs equal to 1. And the PDF distribution of GIIRT/FY-4A ATP in the whole atmospheric layer are most close to Gaussian, followed by that in the middle layer between 200 ~ 700 hPa, layers above 200 hPa and then that below 700 hPa.

7p.03 Global NWP Impacts of Infrared Sounders from Geostationary Orbit

Presenter: Erica McGrath-Spangler, NASA GMAO/GESTAR II Morgan State
Co-authors: Nikki C. Privé, Bryan M. Karpowicz, Isaac Moradi, Joel McCorkel

The Geostationary eXtended Observations (GeoXO) program, expected to launch in the 2030s, includes a proposed infrared (IR) sounder that would provide persistent atmospheric profile observations over much of the western hemisphere. In preparation, the National Aeronautics and Space Administration (NASA) Global Modeling and Assimilation Office (GMAO) observing system simulation experiment (OSSE) framework was used to assess the impact of such an instrument on global numerical weather prediction (NWP) as part of a global “ring” of such instruments. Building on previous preliminary studies, an evaluation of the impact of geostationary IR sounders will be presented with foci on the analysis, forecasts, and the forecast sensitivity observation impact (FSOI) metric, including an examination of the consequences for tropical cyclone representation. Overall, assimilation of geostationary IR provide a beneficial impact for NWP applications.

7p.04 Non-linear retrieval of atmospheric vertical profiles from MTG-IRS data

Presenter: Niobe Peinado Galan, AEMET

No abstract.

7p.05 Nonlinear bias correction of FY-4A GIIRS radiance observations based on EEMD-MLP

Presenter: Haofei Sun, Institute of Atmospheric Physics, Chinese Academy of Sciences
Co-authors: Wei Han

The adequate treatment of systematic errors in the assimilation of satellite radiances is an essential precondition for their successful use. In geostationary orbit, instruments tend to exhibit nonlinear diurnal bias characteristics due to the influence of solar radiation and other aspects. However, most bias correction methods, relying on linear combinations of predictors at fixed observation time, which could not effectively correct the nonlinear diurnal bias characteristics due to their limit capability to take the temporal cumulative effects into account. In this study, the nonlinear diurnal bias characteristics of the GIIRS temperature channels are analyzed, and the linear static method and methods based on deep learning model are compared. The nonlinear diurnal bias characteristics are discussed in three typical channels, channel 6, channel 27 and channel 87 of GIIRS, which correspond to the upper, middle and lower troposphere layers respectively. In all three channels, Observation minus background (O-B) show obvious diurnal variations, although their regularities differ. In addition, as the GIIRS observe the regional area (in two hours), bias tends to exist oscillation. The cosine of the satellite zenith angle (COS_SAZ) and sine of the solar altitude angle (SIN h) are selected as predictors of the bias correction model because of their correlations with the bias. Four network models (MLP, TCN, LSTM and ConvLSTM) are considered as bias correction model respectively. In the MLP-based model, COS_SAZ and SIN·h at the same time as the observation are chosen as predictors to correct each observation. Unlike the MLP-based model, which implicitly represents temporal information, the other three models correct for bias by forecasting it based on time series consisting of O-B values averaged over 30 minutes. The results show that the TCN-based models provide the greatest improvement in GIIRS bias correction. Compared with the linear static model, the corrected O-B mean of the TCN-based model is closer to zero, and the standard deviation is smaller. From the spatial distribution of O-B, the phenomenon of stripe noise is reduced. The method has been integrated into the numerical forecasting system CMA-GFS of the China Meteorological Administration.

7p.06 Impact of assimilating atmospheric motion vectors from Himawari-8 and clear-sky radiance from FY-4A GIIRS on binary typhoons
Presenter: Qian Xie, Lanzhou University
Co-authors: Qian Xie, Deqin Li, Yi Yang, Yuanyuan Ma, Xiao Pan, Min Chen

Binary typhoons (Maysak and Haishen) uncommonly hit Northeast China in 2020, which brought historical extreme precipitation to this region within less than a week. The impact of high-frequency (15 min) assimilating atmospheric motion vectors (AMVs) from Himawari-8 and clear-sky radiance from Fengyun-4A (FY-4A) Geostationary Interferometric Infrared Sounder (GIIRS) on this rare case has been investigated based on the Weather Research and Forecasting Model (WRF) and three-dimensional variational (3D-Var) data assimilation system. The study indicates that the dynamic adjustment is obvious from assimilated hourly AMVs information, but it still needs to be combined with the 15-min FY-4A thermal field adjustment, which is essential for better forecast simulations of minimum sea level pressure (MSLP) and landfall precipitation. A detailed typhoon structure is accurately reproduced for Maysak (Haishen) with fewer (more) anomalies of upper-level warm temperatures and lower-level negative geopotential heights in the decay (intensification) phase. Meanwhile, the performance of landfall precipitation by Maysak is evaluated with better spatial distribution and higher equitable threat scores (ETS) for the large threshold (20 mm/3 hours), resulting from wet bias reduction by much drier water vapor conditions in the analysis and more precise forecasts of relative humidity, water vapor transportation, and its divergence. However, it achieves neutral to negative impacts on track forecasts for Maysak and wind simulations at different levels. This research may provide guidance for monitoring and forecasting typhoons of assimilation from different satellite information in mid-to-high latitude regions in East Asia.

7.01 Project to assimilate the future MTG-IRS sounder into the mesoscale NWP model
Presenter: Olivier Coopmann, CNRM, Université de Toulouse, Météo-France and CNRS
Co-authors: Nadia Fourrié, Philippe Chambon

IRS (InfraRed Sounder) is an infrared Fourier transform spectrometer that will be on board the Meteosat Third Generation series of the future EUMETSAT geostationary satellites. After its launch planned in 2024, it will be able of measuring the radiance emitted by the Earth at the top of the atmosphere using 1960 channels in two spectral bands between 680 – 1210 cm-1 (long-wave infrared) and 1600 – 2250 cm-1 (mid-wave infrared). It will perform measurements over the full Earth disk with a particular spatial and temporal resolution of 4 km at nadir and 30 minutes over Europe respectively. The assimilation of these new observations represents a great challenge for the improvement of numerical weather prediction models, especially for convective-scale area model such as AROME-France. IRS will indeed provide frequent information which is required especially over the sea. The main objective will be to evaluate the impact of IRS observations in the regional AROME model. To carry out this work, we are building the OSSE (Observing System Simulation Experiments) method. Thus, we will describe here the first step which consists in setting up a realistic atmospheric state (Nature Run) for the global ARPEGE and regional AROME model, which will be used for the simulation of the observing system including IRS radiances and radars for the first time. This NR AROME is used to accurately simulate all the observations assimilated in this model (conventional observations, satellite data and radars). It is important to as close as possible to the operational assimilation system with simulated one in order to reproduce the real impact of the different types of observations. We will compare the weight of the OSSE observations compared to the operational one and we will evaluate the contribution of the different observations by adjusting their errors. The IRS observations will be also simulated from this atmospheric forecast. This study provides the set of tools for the assimilation of the future IRS sounder in a mesoscale NWP system such as AROME at Météo-France. We detail the consideration of reconstructed radiances after decompression of principal component analyses, the diagnostics of observation errors, the use of cloud detection and the configuration for the use of IRS in the 3D-Var. An evaluation in terms of impact on current observations is made as well as a description of the influence of the addition of IRS on the forecasts using forecast scores over two distinct periods. The results show incredibly positive impacts of IRS on weather forecasts, especially in summer, supporting the idea that this instrument will allow a significant improvement of our NWP system in the years to come.

7.02 Evaluation of the Potential Impact to the Prediction of Typhoon of Geostationary Microwave Sounder using the GRAPES 4D-Var
Presenter: Ke Chen, Huazhong University of Science and Technology
Co-authors: Wei Han; Guangwei Wu

The geostationary microwave (GEO-MW) sounders has the all-weather observation capability with high frequency, large field-of-view and cloud-penetrating ability, which makes it a necessity in China's second-generation geostationary meteorology satellite "Fengyun-4" series development. To evaluate the potential impact of assimilating the GEO-MW observation to typhoon prediction, observing system simulation experiments (OSSEs) with the simulated 50–425 GHz observing brightness temperature data were conducted using the sophisticated end-to-end simulation model of a geostationary microwave radiometer (GMR) with a 5 m real aperture antenna and 4D-Var Global/ Regional Assimilation and PrEdiction System (GRAPES) for Typhoons Maria and Mangkhut which occurred in 2018. The results show that the assimilation of the GEO-MW observation data could lead to general positive impacts in this study. Compared with the control experiment, for the two cases, GMR with 50-60GHz, 118GHz, and 425GHz data improves the average 54 h typhoon track forecast accuracy by 35.2% and 16.4%. In additional, the results also indicate that improving the time resolution and decreasing the noise level of GEO-MW observation data can effectively improve the performance of typhoon numerical prediction.

Session 8: Small Satellites

8p.01 TROPICS Pathfinder On-orbit Results and Preparations for the NASA TROPICS Constellation Mission
Presenter: Bill Blackwell, MIT Lincoln Laboratory

The NASA TROPICS Earth Venture (EVI-3) CubeSat constellation mission will provide nearly all-weather observations of 3-D temperature and humidity, as well as cloud ice and precipitation horizontal structure, at high temporal resolution to conduct high-value science investigations of tropical cyclones. TROPICS will provide rapid-refresh microwave measurements (median refresh rate of approximately 60 minutes for the baseline mission) over the tropics that can be used to observe the thermodynamics of the troposphere and precipitation structure for storm systems at the mesoscale and synoptic scale over the entire storm lifecycle. The TROPICS constellation mission comprises four 3U CubeSats (5.4 kg each) in two low-Earth orbital planes. Each CubeSat comprises a Blue Canyon Technologies bus and a high-performance radiometer payload to provide temperature profiles using seven channels near the 118.75 GHz oxygen absorption line, water vapor profiles using three channels near the 183 GHz water vapor absorption line, imagery in a single channel near 90 GHz for precipitation measurements (when combined with higher resolution water vapor channels), and a single channel at 205 GHz that is more sensitive to precipitation-sized ice particles. TROPICS spatial resolution, measurement sensitivity, and calibration accuracy/stability performance is comparable with current state-of-the-art observing platforms. Two launches for the TROPICS constellation mission are expected in the Summer of 2023. Data will be downlinked to the ground via the KSAT-Lite ground network. NASA's Earth System Science Pathfinder (ESSP) Program Office approved the separate TROPICS Pathfinder mission, which launched on June 30, 2021, in advance of the TROPICS constellation mission as a technology demonstration and risk reduction effort. The TROPICS Pathfinder mission continues to yield excellent data over 18+ months of operation and has provided an opportunity to checkout and optimize all mission elements prior to the primary constellation mission. This presentation will describe the on-orbit results for the successful TROPICS Pathfinder precursor mission and will describe the recent improve the data latency and generation of near-real-time products for forecasting applications.

8p.02 Evaluating the impact of the CMIM satellite constellation on NWP using an OSSE framework
Presenter: Thomas Carrel Billiard, CNRM
Co-authors: Robin Marty, Louis Rivoire, Nadia Fourrié, Philippe Chambon, Olivier Audouin, Jérôme Vidot, Sophie Djalal, Josiane Costeraste, Véronique Pascal, Adrien Deschamps, Clémence Pierangelo, Laura Hermozo, Frédéric Bernard, Thierry Martin, Romain Pinède, Laura Le Barbier, Citlali Cabrera

Recent space technologies are currently paving the way for the advent of miniaturized remote sensing instruments onboard small satellites. Numerical Weather Prediction (NWP) increasingly relies on satellite observations and these small satellites could become an important part of the observing system in the upcoming decades. Constellation concepts are therefore being studied to complement existing programs. On that account, the Centre National d'Etudes Spatiales (CNES) is currently investigating the feasibility of a constellation of small sounders in partnership with the Centre National de Recherches Météorologiques (CNRM). This new program, which was given the name of CMIM (Constellation of MIni sounder for Meteorology), aims at complementing existing constellations and improving short and medium range NWP by2030-2035. To achieve this, CMIM aims at densifying temperature and water vapor observations especially in the lower layers of the atmosphere by increasing revisits of Infra-Red (IR) and/or Micro-Wave (MW) instruments. CNRM and CNES with industrial support are currently evaluating the potential impact of CMIM by considering different scenarios: number of satellites, orbits, spectral bandwidth for the instruments,... To identify the optimal configuration in terms of performance, CNRM has selected the Observing System Simulation Experiment (OSSE) approach. In OSSE methodology, an initial long forecast with no data assimilation is computed. This Nature Run (NR), which uses the global ARPEGE model, serves as a reference. Next a simulation forecast samples the NR and adds calibrated noise to the data in order to generate a realistic set of observational data and replicate the observing system as foreseen in 2030-2035.Moreover, observational data are also simulated for the various CMIM constellation configurations. Finally all those observations are assimilated in a forecast using a4D-Var system with a 6h update cycle. By comparing the quality of the forecast with and without the simulated CMIM observational data, both the impact on NWP and the optimal constellation configuration can be determined.

8p.03 Initial Evaluation of TROPICS Radiances in the IFS
Presenter: David Duncan, ECMWF
Co-authors: Niels Bormann

One of the first small satellite constellations with an eye to operational NWP, the NASA TROPICS mission launched a pathfinder in summer 2021 to prepare for later launches of microwave sounders on CubeSat platforms. The TROPICS payload is a microwave sounder with channels similar to MWHS-2, a sensor currently assimilated at ECMWF, but each satellite is a mere 30x10x10 cm platform. Given the great interest in small satellite constellations at several space agencies, we evaluated TROPICS pathfinder data in the IFS to become familiar with this sensor specifically but also to better understand the issues that may arise from future small satellite sensors. The evaluation showed that TROPICS radiances were of reasonable quality at most channels, but some orbital biases related to instrument temperature were evident. Antenna pattern issues also may require attention for later constellation sensors to be suitable for possible assimilation. Longer-term calibration stability was not assessed, as the sample data was only available for a few months before a noise diode anomaly at G-band in November 2021. The unique geometry and channel suite of TROPICS provide some technical challenges for assimilation, and further long-term monitoring of the constellation will be required to establish whether operational assimilation is feasible.

8p.04 Implementation of a Regional Observing System Simulation Experiments to assess the potential impact of the EPS-Sterna constellation in AROME-Arctic NWP system
Presenter: Stephanie Guedj, The Norwegian Meteorological Institute
Co-authors: Stephanie Guedj, Harald Schyberg, Roger Randriamampianina, Christophe Accadia and Joerg Ackermann

A regional Observing System Simulation Experiments (OSSEs) study, supported by EUMETSAT, is being conducted at MET Norway to evaluate the future benefits of the potential EUMETSAT EPS-Sterna polar orbiting microwave sounder constellation (formerly known as the Arctic Weather Satellite program, AWS) on AROME-Arctic NWP forecast system. The promising EPS-Sterna concept could be the basis for a future constellation of several small microwave satellites. AROME-Arctic is a regional convection permitting forecast system at 2,5 km horizontal resolution, running operationally with 3D-variational assimilation, providing forecasts to users in Arctic regions of the North-East Atlantic/Barents Sea. In this study, the current operational observing system, as well as AWS, is being simulated from the Nature Run (global, independent, long free-run forecast - ARPEGE/Météo-France) which is assumed to represent the “true” state of the atmosphere. Calibrated errors are added to all observations using a random-generator. The Nature Run is also used as boundary conditions under some assumptions. Special attention will be given to the simulation and the assimilation of 50 and 183 GHz channels of AWS following the set of constellation scenarios proposed by EUMETSAT (from 2 to 6 satellites). Associated observation errors will be defined following the AWS instrument specification in combination with estimates available from similar microwave operational instruments. Impact will be studied in terms of forecast scores against a control experiment (without AWS) and the Nature Run.

8p.05 Impact Assessment of Microwave Sounder Observations on Small Satellites in The NOAA Global NWP and MIRS ID-Var Systems

Presenter: Flavio Iturbide, NOAA/NESDIS/STAR (for Min-Jeong Kim)

Small satellites with low size, weight, and power requirements provide an opportunity to reduce the cost associated with the construction and launch of large bus platforms. These small satellites, especially in large numbers, may be complementary to existing and planned operational satellite constellations by providing scientific data sets with improved spatial and temporal coverages. This study seeks to evaluate and identify potential impact that small satellite constellations may bring to the numerical weather prediction (NWP) systems and atmospheric retrieval systems used in NOAA. Microwave observations from the Temporal Experiment for Storms and Tropical Systems - Demonstration (TEMPEST-D), Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS), and TEMPEST deployed to the International Space Station (ISS) as part of the Space Test Program - Houston 8 (STP-H8) mission are assimilated in NOAA NCEP's Global Forecast System (GFS) system. TEMPEST and TROPICS observations have also been used to retrieve geophysical products using the operational NESDIS Microwave Integrated Retrieval System (MiRS) 1D-Var retrieval system. As part of the comprehensive assessment, various evaluation metrics are used for the assessments. For the GFS analysis and forecast systems, forecast skills, improvements in NWP analyses, fit to other observations such as radiosondes and precipitation products are used for impact assessment. For the MIRS 1D-Var system, retrieval performances are evaluated by comparing with model data and radiosonde observations. Along with NWP impact assessment, the quality of Smallsat data is primarily evaluated by looking at error analysis. Overall results from this study demonstrate the potential value of microwave radiance data from small satellites to improve NWP forecasts and atmospheric retrievals. Disclaimer: The scientific results and conclusions, as well as any views or opinions expressed herein, are those of the author(s) and do not necessarily reflect those of NOAA or the Department of Commerce.

8p.06 A global Observing System Simulation Experiment to evaluate the impact of the EPS-Sterna constellation of microwave sounders

Presenter: Louis Rivoire, CNRM (CNRS - Météo-France)

Co-authors: Louis Rivoire [1], Thomas Carrel-Billiard [1], Robin Marty [1], Philippe Chambon [1], Nadia Fourrié [1], Olivier Audouin [1], Jean-François Mahfouf [1], Christophe Accadia [2], Jörg Ackermann [2]. [1] CNRM (CNRS - Météo-France), Toulouse, France, [2] EUMETSAT, Darmstadt, Germany

A new constellation of satellites with microwave sounding capability, based on the Arctic Weather Satellite (AWS) developed by the European Space Agency (ESA), is under study at the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) as a complement of the EPS-SG program. One of the aims of this project is to increase the number of satellites with microwave sounding capabilities in space, beyond the ones available from the backbone missions. Called EPS-Sterna, this constellation may be launched from 2030 onward on sun-synchronous low earth orbits. In support of the definition of this constellation, in terms of number of satellites and constellation architecture, the Centre National de Recherches Météorologiques (CNRM) will evaluate the impact of the various scenarios for this constellation on Numerical Weather Prediction (NWP) through an Observing System Simulation Experiment (OSSE). In the CNRM OSSE framework, the global ARPEGE model is used to (i) simulate the full observing system and EPS-Sterna from a known 'truth' which is a long and uninterrupted forecast, and (ii) assimilate these observations using a 6h update cycle 4D-Var data assimilation system. The simulated observations are calibrated in order to correctly simulate all observing types. The new instrument onboard the satellites of the constellation has 19 channels: the 50 GHz and 183,311 GHz channels are both assimilated in our framework and the 325,15 GHz channels are only monitored for future use. This instrument is assimilated in all-sky conditions, over oceans and land using the all-sky approach developed at the European Centre for Medium-Range Weather Forecasts (ECMWF). Benefits that may be expected from such a constellation are evaluated in the context of an observing system considered as realistic for 2030. The impact of the constellation is evaluated during two three-month periods: from August to October and from December to February. The metrics used for the evaluations are forecast errors statistics over the globe and other domains, as well as more integrated scores using a similar norm as Forecast Sensitivity to Observations Impact (FSOI) calculations.

8.01 Assessing potential future constellations of small satellites carrying microwave sounders using the Ensemble of Data Assimilations method

Presenter: Katie Lean, ECMWF
Co-authors: Niels Bormann, Jörg Ackermann, Jean-Christophe Angevain, Ralf Bennartz, Janet Charlton, Sabatino Di Michele, Stephen English, Frank Fell, Sean Healy, Bruno Picard, Dirk Schüttemeyer, Peter Senior

Small satellites are expected to become an important component of the future observing system and will complement a continued backbone of larger, high-performance platforms. An Ensemble of Data Assimilations (EDA) method is employed to evaluate the impact of different potential future small satellite constellations carrying MW sounding instruments to explore the optimal design of a constellation for global Numerical Weather Prediction (NWP). Initially an ESA funded study has investigated broad questions of constellation design around the number of satellites, types of orbits and the trade-off between having 183-GHz humidity sounding channels only or with additional temperature sounding capability in the 50-GHz band. More recently, a complementary EUMETSAT funded study has started to explore options for the specific case of the future Sterna constellation (formerly the Arctic Weather Satellite constellation). Here, critical parameters are considered such as the number of orbital planes and the number of satellites within each plane while the impact of the additional suite of 325-GHz channels will also be assessed. In each study, a number of different potential constellations of small satellites are chosen to probe the key aspects of the constellation design. The small satellite data and accompanying observation errors are simulated, using an all-sky framework, and assimilated in EDA experiments. The benefit from adding the data to the observing system is measured by reducing the spread of the ensemble members which reflects improvement to the uncertainties in analyses and forecasts. Key results from the first, ESA study will be presented which include finding significant added benefit from the temperature sounding channels, suggesting that they are a worthwhile addition where they can be sensibly accommodated on the smaller platforms. The reduction in EDA spread for different variables (e.g. wind and geopotential height) and pressure levels is already significant using a smaller constellation of eight satellites added to existing MW sounders from a 4-satellite baseline. The EDA spread reduction continues as further observations are added although the rate of reduction slows, especially where scenarios only include use of humidity sounding channels. These conclusions are very encouraging for the potential Sterna constellations which explore options with a smaller number of platforms. Preparatory work for the EUMETSAT study and results of early EDA experimentation will also be discussed.

8.02 Preparing for and evaluating the arctic weather satellite data in the nordic limited-area numerical weather prediction systems

Presenter: Magnus Lindskog, Swedish Meteorological and Hydrological Institute
Co-authors: Adam Dybbroe, Bjarne Amstrup, Trygve Aspenes, Roohollah Azad, Vasileios Barlakas, Mats Dahlbom, Per Dahlgren, Reima Eresmaa, Patrick Eriksson, Stephanie Guedj, Susanna Hagelin, Hanna Hallborn, Annakaisa von Lerber, Máté Mille, Ewan O'Connor, Adriaan Perrels, Lars Ørum Rasmussen, Timo Ryyppö, Harald Schyberg, David Schönach, Rasmus Tonboe

The prototype arctic weather satellite is scheduled for launch by ESA in 2024. It provides microwave sounding capability for temperature and humidity important for numerical weather prediction. It also provides new bands with information on cloud ice. This prototype arctic weather satellite is a forerunner for EPS-Sterna, a planned EUMETSAT constellation currently in Phase-B, giving very frequent updates over the Arctic and at high latitudes. The Nordic limited-area numerical weather prediction systems are based on a flavour of the AROME modelling system developed within the European ACCORD modelling consortium and with a computer code collaboration with ECMWF. Here we describe work towards enhancing our system to ensure satisfactory handling of microwave radiances in general and for the future arctic weather satellite prototype and potential constellations, in particular. These enhancements concern handling of surface sensitive channels, satellite footprint, all-sky assimilation and adaptations towards AROME microphysics representation, first investigations of cloud ice frequency bands and simulations of constellation effects. Work plan and project results so far will be presented.

8.03 A Strategy for Assimilating Data from Microsats

Presenter: William Campbell, U.S. Naval Research Laboratory
Co-authors: Hui Christophersen, Elizabeth A. Satterfield, David Sidoti

The Earth observing system is rapidly changing from a few, long-lived, well-calibrated, but expensive legacy satellites towards many smaller, more flexible, and less expensive microsats. A constellation of microsats can provide a high volume of high temporal resolution data, fill data gaps, and mitigate risk via data redundancy; however, microsats exhibit higher uncertainty, larger variability in sensor performance, shorter lifetimes, and unknown biases. We must therefore develop new methods to adapt to microsats and rapidly integrate them into our NWP models. More specifically, we need to develop a capability to optimally sample high-quality, high-impact data, and adaptively weight observations by varying their uncertainty specifications as a function of space and time. We plan to 1) replace our current globally uniform satellite radiance sampling strategy with dynamic sampling concentrated in regions of interest, and 2) replace our static observation uncertainty specifications with adaptive ones. For our first task, essentially intelligent data selection, we will use a large archive of forecast sensitivity to observation impact (FSOI) data and machine learning methods to predict which observations are likely to have the greatest positive impact on our forecasts, and preferentially select those observations. For our second task, we will start by extending the Desroziers 2005 technique to estimate observation error variances and covariances as a function of time and region in order to find the observation uncertainty values that optimize information content. Machine learning methods may prove useful here as well, using a host of metadata as predictors of observation error variance, to augment the Desroziers technique. This is a three-year project that has just started at NRL, and we will present more details on our plans plus any preliminary results obtained prior to the ITSC meeting in March.
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Monday, 20 March 2023

Session 9: All-sky Assimilation

9.01 Framework for assimilating all-sky MHS radiance data in the Korean Integrated Model (KIM) forecast system

Presenter: Sihye Lee, KIAPS (Korea Institute of Atmospheric Prediction System)
Co-authors: Han-Byeol Jeong, Adam Clayton, and In-Hyuk Kwon

An all-sky microwave radiance assimilation system has been developed for the Korean Integrated Model (KIM) forecast system. Initially, RTTOV-SCATT version 13.0 was implemented to assimilate Microwave Humidity Sounder (MHS) 183 GHz channel observations over ocean. Cloud and precipitation are not directly assimilated in our hybrid-4DEnVar system - only temperature and humidity profiles are modified to fit all-sky observations. This study focuses on the framework developed for assimilating all-sky MHS radiance data, and evaluates the performance of various components of the system in a simplified experimental setting. The results from MHS-only experiments demonstrate the ability of the system to assimilate all-sky microwave radiance data when the model forecast produces biases for cloud and precipitation. Additional cycled analysis and forecast experiments show how mass components, in company with dynamic variables such as winds and pressure, are adjusted in response to the all-sky radiance assimilation.

9.02 JEDI-MPAS: facilitating research to operation for all-sky radiance data assimilation

Presenter: Zhiquan (Jake) Liu, National Center for Atmospheric Research
Co-authors: Zhiquan Liu, Junmei Ban, Jonathan J. Guerrette, Byoung-Joo Jung, Yonggang Yu, and Chris Snyder

In recent years, the major numerical weather prediction (NWP) centers made good advancements on all-sky satellite radiance data assimilation (DA) although more research are still needed to explore full benefits from all-sky data. One of obstacles in advancing all-sky DA more rapidly is that operational NWP centers' DA systems are not usually available to the broad research community. Since 2018, a global-/regional-unified data assimilation (DA) system for the Model for Prediction Across Scales - Atmosphere (MPAS-A) has been developed jointly by the National Center for Atmospheric Research and the Joint Center for Satellite Data Assimilation within the framework of the Joint Effort for Data assimilation Integration (JEDI). The first release of JEDI-MPAS (Liu et al., 2022, https://gmd.copernicus.org/articles/15/7859/2022/) was made publicly available in September 2021 (https://www.jcsda.org/jedi-mpas). MPAS-JEDI allows assimilation of conventional observations and clear-sky and all-sky satellite radiance data with various DA algorithms such as 3DVar, 3DEnVar, 4DEnVar, and their hybrid variants. All-sky radiance DA capability is implemented within MPAS-JEDI by introducing hydrometeors as part of analysis variables, applying cloudy radiance operators via CRTM and RTTOV, and developing all-sky observation error models. With the advanced all-sky radiance DA capability of JEDI-MPAS with CRTM, relative and additive values of all-sky radiance DA with AMSU-A window channels from 5 satellites, all-sky MHS water vapor (WV) channels from 4 satellites, and all-sky geostationary ABI/AHI WV channels from GOES-16 and Himawari-8 are recently evaluated with a global hybrid-3DEnVar configuration at 30-km horizontal resolution for a month-long period. The benchmark experiment assimilates non-radiance data, clear-sky AMSU-A temperature sounding channels, and clear-sky MHS WV channels. It was found that all-sky AMSU-A window channels have the greatest impact on the forecast of dynamic and thermodynamic variables as well as cloud and precipitation and the positive impact can last up to day-10 forecast. Switching MHS WV radiance DA from clear-sky to all-sky approach produces slight improvement on moisture fields at lower troposphere. The positive impact from all-sky ABI/AHI WV radiances is mostly on middle and upper tropospheric humidity associated with the peaks of weighting functions of ABI/AHI WV channels radiances. Preliminary results of comparing cloudy CRTM and RTTOV forward simulation of ABI/AHI visible, near IR, and IR channels with two different microphysics schemes will also be presented. JEDI-MPAS will be updated in coming years with advanced all-sky DA capabilities available to the research community, and also for potential operational use.

9.03 Propagating non linearities of the observation operator for microwave radiances within an all-sky data assimilation system

Presenter: Mary Borderies, CNRM, Météo-France and CNRS
Co-authors: Marylis Barreyat, Philippe Chambon, Jean-François Mahfouf, Ghislain Faure

Microwave observations are becoming more and more useful for numerical weather prediction (NWP); especially in an all-sky context within which they can bring highly relevant information content on the vertical distribution of water vapor and hydrometeors. In the parallel suite, to become operational in 2023, both the ARPEGE and AROME models will make use of the allsky assimilation route developed at ECMWF and available in the IFS/ARPEGE common code. In this context, this first operational version will make use of the same options used at ECMWF for the radiative properties' specification of the observation operator, RTTOV-SCATT. This means using a single set of radiative properties for the full globe and all cloud types, which is a rather big simplification of the microphysical processes taking place in nature. With the objective of making use of several radiative properties within the assimilation, we explored the impact of using a random selection of hydrometeor shapes within the ARPEGE Ensemble Data Assimilation system AEARP as a way of propagating errors of the observation operator. In this presentation, we will show the impacts of this multiple particle shapes approach onto the spread of the ARPEGE EDA, as well as the resulting impact onto the forecast scores of a deterministic ARPEGE forecasts using the modified EDA as source for the background error covariances. The results being encouraging, this development may be considered for a future parallel suite.

9.04 All-sky assimilation of infrared radiances at water vapor bands of Himawari-8 in the global data assimilation system at JMA

Presenter: Kozo Okamoto, JMA/MRI
Co-authors: Toshiyuki Ishibashi, Izumi Okabe

Infrared all-sky radiance (ASR) assimilation has been developed for Himawari-8 in the global data assimilation system of JMA. Compared to clear-sky radiance (CSR) assimilation, this development is expected to enhance the observation coverage, reduce dry bias due to a sampling error, and extract more observation information in meteorologically sensitive regions. There are many challenges in the development of infrared ASR assimilation including poor representation in radiative transfer model (RTM) and forecast model in cloud scenes, strong situation-dependency of observation statistics, and high non-Gaussianity and non-linearity. We developed cloud-dependent quality control, bias correction (BC), and observation error (OE) models to address these challenges in addition to using the state-of-the-art RTM (RTTOV ver13). Data assimilation cycle experiments suggested the ASR assimilation of three water vapor bands of Himawari-8 improved short-range forecasts of upper- and middle tropospheric water vapor and temperature over CSR assimilation. Sensitivity experiments demonstrated two important findings: (1) Single band ASR assimilation that was often employed in previous studies was inferior to multiband CSR assimilation, not to mention multiband ASR assimilation (2) OE correlation and cloud-dependent OE standard deviation are important, but cloud-dependency of OE correlation is not so much, (3) cloud-dependent BC predictors are essential in the presence of large (negative) observation-minus-background bias.

9.05 Optimising All-sky Assimilation of Microwave Humidity Sounders

Presenter: David Duncan, ECMWF
Co-authors: Niels Bormann, Alan J. Geer, Peter Weston

Humidity sounder radiances from MHS and MWHS-2 are currently thinned to about 110 km spacing prior to assimilation at ECMWF and used at native resolution. In this paper, the thinning scale and possible averaging of all-sky humidity sounder observations are considered. Averaging the radiances into “superobs” acts as a low-pass filter and provides smoother images of departures whilst decreasing effective sensor noise and thus std(O-B), marginally for 183 GHz channels (5-15%) and significantly for 118 GHz channels (5-55%). The method of superobbing provides more representative observations for assimilation and a better utilisation of total information content than thinned native-resolution radiances, with less overall information discarded. Experimentation in the IFS indicates significant benefits from superobbing of humidity sounder radiances and decreased thinning. These are shown to markedly improve background fits to independent humidity- and wind-sensitive observations---indicative of improved short-range forecasts of humidity and also winds through the 4D-Var tracer effect---when changed in isolation or in combination. Results are relatively insensitive to superob resolution within the resolutions tested (40 to 80 km) and so it is argued that smaller superobs are preferable for diagnostic purposes and future model evolution. The move from native resolution radiances at roughly 110 km spacing to 50 km superobs at 70 km spacing provides about 140% more radiances for assimilation and much-improved spatial information for diagnostic purposes. These augmentations in the processing of humidity sounder radiances lead to significantly improved short-range forecasts and slightly improved wind forecasts in the Southern Hemisphere at medium-range.

9.06 All-Sky Geostationary Satellite Radiance Data Assimilation in JEDI Using CRTM

Presenter: Gregory Thompson, UCAR/UCP/JCSDA
Co-authors: Benjamin Johnson, Benjamin Ruston, and Fabio Diniz

The Joint Center for Satellite Data Assimilation (JCSDA) is processing geostationary satellite radiance data using JEDI (Joint Effort for Data assimilation Integration) software. The Unified Forward Operators (UFO) in JEDI uses the Community Radiative Transfer Model (CRTM) to create numerical model brightness temperature or visible reflectance and near-IR radiances to compare to observations. UFO is also responsible for quality control, assignment of observational errors, and bias correction. The USA GOES-East and GOES-West satellite carries the Advanced Baseline Imager (ABI) which traditionally has been underutilized in global NWP. We are exploring the use of JEDI to ingest and utilize the ABI data more directly. We will present early explorations into the use of the infrared channels and their relation to cloud properties. Testing of quality control procedures and error inflation appropriate for these will be demonstrated. The CRTM v2.4 and above contain capabilities to simulate visible channels. Early examinations of and verification of these capabilities are also underway. In this presentation, we aim to show how JEDI performs while assimilating GOES infrared channels, and explore the CRTM capability for visible reflectances at varying resolutions while using NOAA's Unified Forecast System (UFS) within the GFS model (FV-3).

9p.01 A sensitivity Study into the representation of ice particles for all sky assimilation at 183 GHZ

Presenter: Brett Candy, UK Met Office
Co-authors: Stefano Migliorini

The assimilation of microwave sounding channels in scenes where cloud effects impact on the radiances has been shown to significantly improve forecast skill. For use in such scenes we require an accurate forward model that can account for scattering due to cloud hydrometeors as well as an error inflation model that accounts for the higher radiative transfer uncertainties in such situations. The scattering effects due to ice particles are particularly important for channels with frequencies greater than about 80 GHz, such as the moisture sounding channels in the 183 GHz band. In this study we report on the sensitivity of the forward modelling to ice particle habit. The work focuses on a set of case studies containing both tropical and extra-tropical cloud bands, with comparisons being made between MHS observations and the forward model, in this case RTTOV-SCATT. Operational short-range forecasts from the Met Office global NWP model are used as the source of the atmospheric profiles to drive the forward model. We will also report on the next steps at the Met Office to extend the use of microwave sounding channels within our operational 4D-Var scheme.

9p.02 The Plan for the All-sky Radiance Assimilation over Land in the NCEP Global Model
Presenter: Azadeh Gholoubi Khonacha, Axiom at NOAA/NCEP/EMC
Co-authors: Emily Huichun Liu, Andrew Collard, and Daryl Kleist

The all-sky assimilation of microwave observation in the NCEP Global Forecast Model (GFS) is limited to observations over the ocean. This is because, over the ocean, fast and accurate emissivity models have been developed for NWP that allow the assimilation of channels with strong surface sensitivity. In contrast, the microwave signal emerging from land surfaces depends on frequency, polarisation, and incidence angle. It is also affected by surface types and conditions, making it challenging to model surface emissivity accurately. The complexity of modeling the interaction between all these surface parameters and the microwave radiation has generally restricted the use of observation to temperature and humidity channels, which receive a weak contribution from the surface over land. Therefore, the first step towards using observation over land surfaces is obtaining more reliable surface emissivity estimates. Following the footsteps of ECMWF, the use of an instantaneous emissivity retrieval from MW surface-sensitive channels will be explored along with an emissivity atlas. In addition, the use of soil moisture and soil temperature from the NCEP global surface model in the Community Radiative Transfer Model (CRTM) will be investigated. In this presentation, the plan for the extension of all-sky assimilation of MW radiances to the land surface will be demonstrated and discussed.

9p.03 All-sky data assimilation in the KIM LETKF system
Presenter: Han-Byeol Jeong, KIAPS
Co-authors: Sihye Lee, In-Hyuk Kwon, Adam Clayton, Myoung-Hwan Ahn

In recent years, many operational centers have found benefits from assimilating satellite radiance observations affected by cloud and precipitation, extending the traditional use of clear-sky radiance observations towards all-sky conditions. The Korean Integrated Model (KIM) NWP system that is operational at KMA currently only assimilates clear-sky radiances, so the Korea Institute of Atmospheric Prediction Systems (KIAPS) is developing all-sky assimilation techniques for Microwave Humidity Sounder (MHS) radiances in the KIM Hybrid-4DEnVar system and the associated KIM ensemble, which is based on a Local Ensemble Transform Kalman Filter (LETKF). This study focusses on the ensemble system, using a "stand-alone" version that excludes recentering around hybrid-4DEnVar analyses. In this poster, we describe how support for assimilation of cloud-affected MHS radiances was added to the stand-alone LETKF, including methods for estimating observation error. The ensemble covariances provide vital links between the hydrometeor variables used within cloud-affected radiative-transfer calculations and the other analysis variables. To help build an understanding of these covariances, we assimilated a single MHS pixel affected by cloud and precipitation, with a large negative background departure (O-B), indicating that the model has too little cloud and precipitation. This cloud-affected MHS pixel creates positive analysis increments for humidity and hydrometeors, making the analysis departure (O-A) slightly less in magnitude than the background departure (O-B). We also present results from cycling experiments. When cloud-affected MHS observations are included, the number of MHS observations assimilated approximately doubles. All-sky assimilation of MHS has significant beneficial impacts, not only for humidity, but also for temperature and wind in the troposphere. We also illustrate the impact on precipitation forecast scores.

9p.04 A Revised All-sky Radiance Assimilation Framework in the NCEP Global Model
Presenter: Emily Liu, NOAA/NCEP/EMC
Co-authors: Andrew Collard, Azadeh Gholoubi, Haixia Liu, Daryl Kleist

The cloud-affected microwave (MW) radiances from the Advanced Microwave Sounding Unit-A (AMSU-A) and the Advanced Technology Microwave Sounder (ATMS) over the ocean are assimilated using an all-sky approach in the NCEP operational systems. The all-sky framework has been expanded to include precipitation-affected

MW radiances and is currently under extensive testing for the next implementation (GFS v16.3). In this upgraded all-sky framework, the five hydrometeors, including cloud liquid water, cloud ice, rain, snow, and graupel, are the new control variables, replacing the original total cloud condensate (the sum of cloud water and ice) control variable. Other changes in the upgrade include switching the use of antenna temperature (TDR) to antenna-corrected data (SDR), interfacing the precipitating hydrometeors with CRTM, the calculation of cloud fraction and hydrometeor effective radius based on model physics and cloud microphysics assumptions at each observation field of view, enhancing quality control, and tuning observation error. We also include the latest CRTM release (version 2.4.0) to use the revised cloud optical table constructed based on the same GFDL cloud microphysics assumption used in the forecast model. When calculating cloud fraction, subgrid cloud variability is considered by using an averaged cloud overlap scheme. The revised framework makes consistent use of model cloud parameters in the analysis and significantly reduces the short-term temperature forecast biases in the troposphere. In the GFS v17 implementation, the GFDL cloud physics will be replaced with the Thompson scheme. The development work to update the all-sky work based on Thompson is in process. The detail of the revised all-sky framework and its impact on the NWP system will be presented.

9p.05 Development for all-sky assimilation of JAXA's future microwave sensor AMSR3 in the JMA's NWP systems

Presenter: Hiroyuki Shimizu, Japan Meteorological Agency
Co-authors: Masahiro Kazumori, Misako Kachi

It is important for the numerical weather prediction (NWP) to assimilate microwave radiance data that contain a variety of information on the atmosphere and the earth's surface (e.g., atmospheric temperature and water vapor profiles, cloud, precipitation, surface wind and surface temperature). JAXA's Advanced Microwave Scanning Radiometer 2 (AMSR2) has been operated on orbit since May 2012 and its microwave radiance data have been assimilated in the JMA's NWP systems. JAXA plans to operate AMSR3 carried by the Global Observing SATellite for Greenhouse gases and Water cycle (GOSAT-GW) to be launched in Japanese fiscal year of 2023. AMSR3 have all the frequency channels and polarization combinations of AMSR2 as well as additional three high-frequency channels (165.5 GHz, 183±3 GHz and 183±7 GHz, V-pol). JMA is now preparing for the all-sky assimilation of microwave radiance data from AMSR3.In the global NWP system, JMA assimilates microwave radiance data in all-sky condition and plans to assimilate AMSR3 data in all-sky condition as well. In the regional NWP systems, the microwave radiance data are still assimilated in clear-sky condition. We are currently working on the all-sky radiance assimilation in the regional NWP systems in order to utilize microwave sensors including AMSR3 more effectively. As a result of comparing the brightness temperatures calculated from the model's profile with the observed values, it was found that the calculated brightness temperatures were closer to the observed values when hydrometeor fraction was provided per hydrometeor types in the radiative transfer calculation. Details of the plan to utilize AMSR3 and the progress on development of the all-sky microwave radiance assimilation in the regional NWP systems will be presented.

Session 10: Surface

10p.01 withdrawn

10p.02 The Version 3 NASA MEaSUREs CAMEL Products and its developments

Presenter: Eva Borbas, UW-Madison/SSEC
Co-authors: Michelle Loveless, Glynn Hulley, Robert Knuteson, Kerry A. Cawse-Nicholson, and Simon Hook

As part of a NASA MEaSUREs, Land Surface Temperature and Emissivity project, the University of Wisconsin, Space Science and Engineering Center, and NASA's Jet Propulsion Laboratory have developed a global monthly mean emissivity Earth System Data Record (ESDR). The Combined ASTER and MODIS Emissivity Over Land (CAMEL) ESDR was produced by merging two current state-of-the-art emissivity datasets: the UW-Madison MODIS Infrared emissivity dataset (UWIREMIS) and the JPL ASTER Global Emissivity Dataset v4 (GEDv4). The dataset includes monthly global data records of emissivity, uncertainty at 13 hinge points between 3.6-14.3 µm, and Principal Components Analysis (PCA) coefficients at 5-kilometer resolution for 2000 to 2021. A high spectral resolution algorithm is also provided for HSR applications. CAMEL has been implemented in the RTTOV forward model for immediate use in numerical weather modeling and data assimilation. The CAMEL V2 has been available between 2000 and 2016 since 2018 from the NASA

LP DAAC website. The new Version 3 CAMEL inputs the latest version (Collection 6.1) of combined MODIS MOD11 and MOD21 products, which allows for the extension of the dataset until the end of 2021. We recently studied to improve emissivity over the snow-covered scene by using the Wiscombe-Warren physical model and the extension CAMEL into the Far IR region. The poster will detail these updates and developments further.

10p.03 AMSU-A Window Channel Assimilation
Presenter: David Duncan, ECMWF
Co-authors: Niels Bormann, Alan J. Geer

AMSU-A is now assimilated in all-sky conditions at ECMWF following an upgrade to the IFS in October 2021, covering AMSU-A channels 5-14. In addition to its sounding channels AMSU-A holds three window channels with valuable all-sky information at 23.8, 31.4, and 89.0 GHz, in addition to the mostly sounding channel 4 at 52.8 GHz. The window frequencies are already assimilated on imagers such as GMI and AMSR2, so a strategy for using these channels on AMSU-A could significantly improve temporal sampling of all-sky radiances to better constrain low-level moisture, winds, and clouds. In effect, AMSU-A represents several well-calibrated, 3-channel imagers that have never been exploited in the assimilation. The assimilation of AMSU-A window channels provides clear forecast benefit in a depleted system with no imagers assimilated that is comparable to the overall impact of the imagers. In the full system the benefit is smaller but clear in improving O-B fits to other observations, indicating improved short-range forecasts of low-level winds and humidity. This effect is largest in the tropics, where the interpretation is that the five AMSU-A overpasses help to fill in temporal gaps left by the imagers assimilated. Forecast impacts are neutral to positive if adding channels 1 and 2 (23.8 and 31.4 GHz). Impacts are more mixed when also adding channels 4 and 15 (52.8 and 89.0 GHz), both of which have surface and sounding sensitivity that depends on scan angle, which may indicate that observation error modelling for these channels could use further tuning.

10p.04 Improved Microwave Ocean Emissivity and Reflectivity Models Derived from the Two-scale Roughness Theory
Presenter: Lingli He, CMA Earth System Modeling and Prediction Center

Geometrical Optics (GO) approach and the FAST Emissivity Model (FASTEM) are widely used to estimate the surface radiative components in atmospheric radiative transfer simulations but their applications are limited in specific conditions. In this study, a two-scale reflectivity model (TSRM) and a two-scale emissivity model (TSEM) are developed from the two-scale roughness theory. Unlike GO which only computes 6 non-zero elements in the reflectivity matrix, TSRM include all the 16 elements. For a set of downwelling brightness temperatures (BTs) in microwave frequencies, the reflected upwelling BTs are calculated from both TSRM and GO and compared for their discrepancies. It is shown that the first and second components of Stokes vector in reflected BTs at 23.8 GHz exhibit a large difference (~ 5K) between TSRM and GO. Also, the third and fourth components of the Stokes vector can be only produced from TSRM. For the emitted radiation, BT differences in vertical polarization between TSEM and FASTEM is generally less than 5 K when the satellite zenith angle less than 40 whereas those at the horizontal component is quite significant.

10p.05 Reduced Global Sea Surface Temperature Biases from Upgrades to the CRTM Infrared Sea Surface Emissivity Model
Presenter: James Jung, CIMSS / Univ. of Wisconsin
Co-authors: N. R. Nalli, C. Dang, A. H. N. Lim, E. H. Liu, B. Johnson, and S. Kalluri

The National Centers for Environmental Prediction's (NCEP) Global Forecast System (FV3GFS) has an observed, consistent cold Sea Surface Temperature (SST) bias in colder waters (Liu et al. 2017). Recent upgrades to the Community Radiative Transfer Model (CRTM) Infrared Sea Surface Emissivity (IRSSE) model (Nalli et al. 2022) now includes an emissivity temperature dependency (based on newly rescued temperature-dependent optical constants) to reduce these SST biases. Several changes to NCEP's FV3GFS data assimilation and quality control procedures were developed to help exploit the emissivity temperature dependency in the new IRSSE. This presentation outlines the reduction in errors in the global radiance assimilation and improvements to FV3GFS near surface temperature biases in the analysis and forecasts when implemented. A double-difference technique will be used to show the bias improvements between using the old and new IRSSE for specific Cross-track Infrared Sounder (CrIS) and Infrared Atmospheric Sounding Interferometer (IASI) channels.

10p.06 Pre-processing of Advanced Technology Microwave Sounder Sea Ice Observations for Data Assimilation and its impact on Korean Integrated Model

Presenter: Jisoo Kim, Ewha Womans University
Co-authors: Myoung-Hwan Ahn

Despite the importance of microwave sounder observations in Numerical Weather Prediction (NWP) systems, microwave sea-ice observations from the lower atmospheric channels (53.6, 54.4 GHz) have not been utilized in the Korean Integrated Model (KIM) due to uncertainties in a simulation of sea-ice surface radiation. In this study, we use dynamic emissivity to simulate sea-ice surface radiation and propose a bias correction scheme that minimizes the surface temperature discrepancy between observation and the model simulation. Observation counterparts simulated using the dynamic emissivity show good agreement with Advanced Technology Microwave Sounder (ATMS) observations in summer sea ice. However, in winter sea ice, it is negatively biased (-0.3 K) at 53.6 GHz. A main cause of biases is the difference between emitting layer temperature and the model surface temperature. Here, the biases are corrected using multi-linear regression coefficients with the surface radiation variables, such as surface emissivity, surface temperature, and atmospheric transmittance, as predictors. A one-month assimilation experiment is run for the Northern Hemisphere summer period together with a control experiment. The number of ATMS observations assimilated in the KIM has increased by 7%. The near-surface sea-ice observations have warmed the model temperature by up to 2 K from the surface to 850 hPa over winter sea-ice and reduced the temperature analysis errors by 1.2 K. The results of this study encourage the assimilation of ATMS sea ice observations using the dynamic emissivity and the surface radiation bias correction.

10p.07 withdrawn

10p.08 PARMIO: A reference quality model for ocean emissivity and backscatter from microwave to infrared wavelengths

Presenter: Stuart Newman, UK Met Office
Co-author: S. Abdalla, C. Accadia, M. Anguelova, M. Bettenhausen, J. Boutin, E. Dinnat, C. Donlon, M. Echeverri Bautista, S. English, J. Hocking, J. Hoyer, C. Jimenez, B. Johnson, M. Kazumori, L. Kilic, H. Lawrence, T. Meissner, N. Nalli, A. Parracho, C. Prigent, A. Stoffelen, E. Turner, F. Weng, S. Yueh

The lack of a reference-quality ocean emission and backscatter model has been recognised as a gap in the traceability of radiative transfer modelling for Earth observation. The International Space Science Institute (ISSI) sponsored a multinational team to develop new model capability. The resulting Passive and Active Reference Microwave to Infrared Ocean (PARMIO) model is a two-scale model which superimposes the effect of small-scale roughness (scattering) on top of the influence of large-scale waves (geometric optics). Recent advances in the contribution due to foam are included in the model. Optical properties of seawater combine a state-of-the-art dielectric constant in the microwave region with complex permittivity data extending up to 660 nm. The theoretical basis and current status of the PARMIO model will be described, including its availability in fast model form for the microwave (SURFEM-Ocean) in the latest release of RTTOV.

10.01 Toward improving the assimilation of IASI and CrIS radiances over land into the NASA GEOS: LST Inversion and Validation

Presenter: Niama Boukachaba, MSU/NASA GSFC/GMAO
Co-authors: Yanqiu Zhu, Steven Pawson

Assimilating surface-sensitive radiances over land is still challenging for both infrared (IR) and microwave (WV) essentially because of the large uncertainties of the land physical surface emissivity model used in the CRTM and the uncertainties of land surface state properties. Currently very few IR radiances are assimilated over land in the NASA Goddard Earth Observing System (GEOS). Large number of radiances are rejected by the emissivity sensitivity check as well as the Cloud detection check. This study focuses on enhancing the assimilation of Infrared Atmospheric Sounding Interferometer (IASI) and Cross-track Infrared Sounder (CrIS) over land in the GEOS forecasting and data assimilation framework. To reach this goal, the Land surface Temperature (LST) is first inverted using IR radiances from IASI and CrIS selected channels to use it as surface boundary parameter for the assimilation of the rest of IASI and CrIS surface-sensitive channels. This work will present a full assessment of the quality of this LST by comparing it and its spatio-temporal variability to LST predicted by the GEOS model. The impacts on the quality of the resulting analysis and subsequent forecast will also be discussed.

10.02 withdrawn

10.03 Development and Implementation of a Physical Thermal Infrared Emissivity Model for Uniform Snow Surfaces within CRTM
Presenter: Nicholas Nalli, IMSG Inc. at NOAA/NESDIS/STAR
Co-authors: C. Dang, J. A. Jung, R. O. Knuteson, E. E. Borbas, B. T. Johnson, K. Pryor, and L. Zhou

Accurate thermal infrared (IR) fast forward models are critical to weather forecasting via numerical weather prediction (NWP) radiance assimilation and operational environmental data record (EDR) retrieval algorithms. Thermal IR Information about the lower troposphere and surface is derived from semi-transparent window bands (i.e., surface-sensitive channels) found within 600–3000 cm−1 spectral region. To model accurately the observed radiance within these bands, the surface emissivity and bidirectional reflectance distribution function (BRDF) must also be modeled accurately. NOAA/NCEP global forecast system (GFS) assimilation studies have revealed significant discrepancies between clear-sky hyperspectral brightness temperature calculations (calc) from the Community Radiative Transfer Model (CRTM) and observations (obs) from hyperspectral sounders (e.g., the Metop-B, -C Infrared Atmospheric Sounding Interferometer, IASI, and the SNPP/NOAA-20 Cross-track Infrared Sounder, CrIS) over snow/ice surfaces on the order of >5 K RMSE. In addition, discrepancies of similar magnitudes have also been evident within operationally retrieved lower-tropospheric temperature profiles derived from the NOAA Unique Combined Atmospheric Processing System (NUCAPS) relative to radiosonde observations (RAOBs). These issues are due, in part, to limitations in the emissivity models previously employed by these systems for snow surfaces. This presentation will highlight recent updates to the thermal IR emissivity model used by the CRTM for uniform snow surfaces. The research, development, and implementation of a physically based model (designed especially for practical implementation within fast forward models such as CRTM) will be overviewed. Preliminary validation versus ASTER and other field data (e.g., the ship-based Marine Atmospheric Emitted Radiance Interferometer, MAERI), as well as results from the CRTM implementation within the NCEP GFS assimilation system, will be presented, along with future plans for further improvements, testing, and operational implementation. Disclaimer: The scientific results and conclusions, as well as any views or opinions expressed herein, are those of the author(s) and do not necessarily reflect those of NOAA or the Department of Commerce.

10.04 Assimilation of MW low-peaking channels in HARMONIE-AROME at high latitudes
Presenter: Stephanie Guedj, The Norwegian Meteorological Institute
Co-authors: Stephanie Guedj, Jostein Blyverket and Roger Randriamampianina

Polar regions benefit from a high-density coverage of satellite observations that could compensate for the sparse network of conventional data. However, due to large model errors at these latitudes, the satellite observations are underused. To improve the assimilation of surface-sensitive channels, we need to better model the surface parameters. Karbou et al. (2006) demonstrated that one can retrieve this information using the brightness temperature from a window channel and allocate the retrieval to assimilate adjacent sounding channels at higher frequencies. Positive impacts were obtained at a global scale. However, less is known about the impact in a regional model, this study describes the impact of using a better representation of the surface to improve the radiative transfer simulations and 3D-VAR data assimilation of observations from AMSU-A, MHS, ATMS and MWHS-2 over land, snow and sea ice. Assimilation experiments using the “so-called dynamic emissivity” have been run in the framework of HARMONIE-AROME giving neutral to positive impacts on forecast skills.

10.05 Assimilation of AMSU-A Near-Surface Channels in CMA_GFS 4DVar over Land
Presenter: Hongyi Xiao, CMA Earth System Modeling and Prediction Centre (CEMC)
Co-authors: Wei Han, Juan Li, Hua Zhang

The assimilation of two near-surface channels (CH5/6) of AMSU-A onboard NOAA-15/18/19 and MetOp-A/B is achieved in CMA_GFS over land. The land surface emissivity is calculated by two methods: one is window channel retrieval method, another is TELSEM2 atlas. The quality control procedures for these satellite microwave observations over land are set up. The predictors and regression coefficients which are used for oceanic satellite data are retained during the bias correction over land, and are confirmed to be well-performed. Three batch experiments are implemented in CMA_GFS with four-dimension variational (4DVar), assimilating only the default data, adding the above data over land with land surface emissivity obtained from TELSEM2 atlas, and adding the above data over land with land surface emissivity calculated by window channel retrieval method, respectively. The results prove that the window channel retrieval method can better reduce the departure between the observational brightness temperature and simulated brightness temperature. Over most type of land, the impacts of window channel retrieval method excess that of TELSEM2. Both TELSEM2 and window channel retrieval method can improve the humidity analysis near the ground, as well as the forecast capability globally, particularly those regions where the coverage of land area is higher, such as Northern Hemisphere. Within 6% and 12% growth rate of data utilization, respectively, the additional data of CH6 in every six hours can cover most of the land, where there is no near-surface data being assimilated before. This study marks the beginning of all-surface assimilation in CMA_GFS, and make a breakthrough step for the assimilation of other near-surface channels on other satellite instruments.

Session 11: Artificial Intelligence and Machine Learning
Session 12: Observation operator and observation errors

11p.01 withdrawn

11p.02 withdrawn

11p.03 Use of Machine learning for the detection and classification of observation anomalies
Presenter: Mohamed DAHOUI, ECMWF

For the last few years, an automatic data checking system has been used at ECMWF to monitor the quality and availability of observations processed by ECMWF data assimilation systems (Dahoui et al. 2020). The system is playing an essential role in flagging up observation issues and enabling the timely triggering of mitigating actions. At the heart of the system is the anomaly detection modules based on soft thresholds (computed dynamically to flag sudden changes of observational statistical quantities) and fixed limits (updated on demand to detect drift). The anomaly detection is currently performed separately for each data type without automatic cross-checking of warnings which reduces the possibility of the system to classify warnings not directly related to observations issues. The automatic data checking system was re-designed to include machine learning based algorithms with the aim of improving the reliability of the system and providing better insight of the cause of detected anomalies (gross errors, severe events or DA/model limitations). For each data type two variants of neural network models (LSTM autoencoders) are trained based on long timeseries (typically one year) and short timeseries (typically one month). The long time series are de-seasonalised to remove seasonal variability. Neural network models trained (once every quarter) on the long dataset are designed to detect drift of statistics. This is achievable by comparing the predicted quantities against feedback provided by the data assimilation (e.g. first guess departures, etc). The variant of the neural network trained (each model cycle) on the shorter dataset is used to detect sudden jumps of statistics. Data groups affected by anomalies are excluded from the dataset used for subsequent training (the system is learning from its past outputs). Once the anomaly detection is performed for all data types a consolidation step is performed by cross-checking the warnings from all data types and by using information on the atmospheric variability (areas with increased EDA spread, tropical cyclones, active weather systems), number of instruments/stations affected by the same problem, geographical location of the anomaly, etc. The consolidation part is based on a supervised machine learning module (Random forests classifier) that was trained using a set of previous warnings detected by the system that were labelled semi-manually. The consolidation step would result in a revision of the severity of the events, need for action and the likely cause of the problems.

11p.04 Estimating the observation impact based on attentive 3d-convolutional RNN
Presenter: Hyeon-Ju Jeon, Korea Institute of Atmospheric Prediction Systems (KIAPS)
Co-authors: Jeon-Ho Kang, In-Hyuk Kwon

The Korean Integrated Model (KIM) and a hybrid four-dimensional ensemble variational data assimilation (4DEnVar) system developed by the Korea Institute of Atmospheric Prediction Systems (KIAPS) were used as the current operational model for the Korea Meteorological Administration (KMA). KIM Package for Observation Processing (KPOP) contributes to enhancing the performance of the data assimilation (DA) system by not only adding new observations but also improving the quality of existing observations. To support decision-making for the efficient operation of KPOP, evaluating the impact of the assimilated observations on the forecast performance is necessary. However, existing methods for forecast sensitivity and observation impacts (FSOI) are highly dependent on the type of forecast model and DA systems. For the hybrid 4DEnVar, although ensemble-based or hybrid-based methods have been proposed, there are difficulties to develop a suitable method for KIM since propagating the sensitivity of observation has high complexity from the non-linearity of the forecast model. In this study, we propose a novel approach for estimating the impact of observations in an AI manner. The convolutional neural network (CNN) model, which is widely used for capturing spatial distribution in pattern recognition, is extended to a three-dimensional CNN for learning atmospheric states to consider vertical convection as well as horizontal advection. In addition, we consider various scales and detailed forms of atmospheric phenomena by applying the inception network that reflects the multi-scale of spatial patterns and the attention module that extracts distinguishing features even for regions that exceed the size of the CNN filter, respectively. Then, the time series of the extracted spatial information is trained by the recurrent neural network (RNN) to predict the forecast fields. Finally, we estimate the observation sensitivity by comparing the prediction accuracies from each observation. This method, called Attentive 3D-convolutional RNN, has been developed to evaluate the effects of sensitivity propagation from the analysis field to the forecast field. In further research, we extend the proposed method to estimate the observation impacts on the analysis field. The proposed method based on an end-to-end manner can complement existing studies that rely on numerical and assimilation system biases.

11p.05 A Study on Machine Learning-Based Quality Control Techniques for the Satellite Radiance Data Assimilation

Presenter: Eun-Jin Kim, Korea Institute of Atmospheric Prediction Systems (KIAPS)
Co-authors: Hyeon-Ju Jeon, Jeon-Ho Kang, In-Hyuk Kwon

To improve the accuracy of weather forecasting, research on data assimilation (DA) with various qualified observations is being actively conducted. Among the various observational data used for DA, satellite observations contribute to improving weather forecast accuracy significantly by providing data in an area that conventional observations cannot cover. The Korean Integrated Model (KIM) Package for Observation Processing (KPOP) is used to stably provide high-quality observation to the DA in the new operational weather prediction system of the Korea Meteorological Administration (KMA). KPOP contains some essential components related to the observations' quality control (QC), such as gross-error QC, background ingests retrieving simulated observation at the observation space from the model grid states, bias correction, innovation QC, thinning, and so on. Recently, various machine learning (ML) techniques are applied to the meteorology field. Especially, there are many studies for cloud detection using ML algorithms such as support vector regression, the decision tree, the Artificial Neural Network (ANN), and fusing multi-scale convolutional features. In this study, we develop the QC method based on ML techniques which can provide efficiency and accuracy in the cloud detection area. In our previous study, to estimate the brightness temperature in the MHS channel, we developed a regression module using the Python-based Scikit-learn package. A result comparing the estimated brightness temperature with the actual observed value showed the possibility of detecting abnormal observations. Also, the DA performance was verified through the analysis-forecast cycle with this new ML-based QC. Now developing a deep learning-based cloud detection technique that can be applied to the satellite data infrared channel to verify the DA performance through the cycle experiment is undergoing.

11p.06 withdrawn

11p.07 A non linear approach for temperature retrieval from AMSU-A measurements onboard NOAA-15 and NOAA-16 satellites and a case study during Gonu cyclone

Presenter: Ashim Mitra, India Meteorological Department
Co-authors: Kavita Navria, Pratiksha Dubey

A neural network (NN) technique is used to obtain vertical profiles of temperature from NOAA-15 and 16 Advanced Microwave Sounding Unit-A (AMSU-A) measurements over the Indian region. The corresponding global analysis data generated by National Center for Environmental Prediction (NCEP) and AMSU-A data from July 2006 to April 2007 are used to build the NN training data-sets and the independent dataset of May 2007 to July 2007 divided randomly into two independent dataset for training (land) and testing (ocean). NOAA-15 and 16 satellite data has been obtained in the form of level 1b (instrument counts, navigation and calibration information appended) format and pre-processed by ATOVS (Advanced TIROS Operational Vertical Sounder) and AVHRR

(Advanced Very High Resolution Radiometer) Processing Package (AAPP). The root mean square (RMS) error of temperature profile retrieved with the NN is compared with the errors from the International Advanced TOVS (ATOVS) Processing Package (IAPP). The over all results based on the analysis of the training and independent datasets show that the quality of retrievals with NN provide better results over the land and comparable over the ocean. The RMS errors of NN are found to be less than 3 ºC at the surface, 0.9º to 2.2º between 700 and 300 hPa and less than 2 ºC between 300 and 100 hPa. It has also been observed that the NN technique can yield remarkably better results than IAPP at the low levels and at about 200-hPa level. Finally, the network based AMSU-A 54.94-GHz (Channel-7) brightness temperature (maximum Tb) and its warm core anomaly near the center of the cyclone has been used for the analysis of Gonu cyclone formed over Arabian Sea during 31 May to 7 June 2007. Further, the anomalies are related to the intensification of the cyclone. It has been found that the single channel AMSU-A temperature anomaly at 200 hPa can be a good indicator of the intensity of tropical cyclone. Therefore it may be stated that optimized NN can be easily applied to AMSU-A retrieval operationally and it can also offer substantial opportunities for improvement in tropical cyclone studies.

12p.01 withdrawn

12p.02 Plans to transition the NCEP data assimilation system to JEDI
Presenter: Andrew Collard, NOAA/NCEP/EMC
Co-authors: Emily Liu, Cory Martin, Russ Treadon, Ron McLaren, Haixia Liu, Azadeh Gholoubi, Xuanli Li, and Daryl Kleist

Since May 2007, the Global Data Assimilation System (GDAS) of the National Centers for Environmental Prediction (NCEP) has used the Gridpoint Statistical Interpolation (GSI) software to produce global operational analyses. The GSI (and its predecessors) is the bedrock of global data assimilation (DA) at NCEP, with over 30 years of operational activity but it has become apparent that it is in need of updating with more modern coding practices. The Joint Effort for Data assimilation Integration (JEDI) project, led by the Joint Center for Satellite Data Assimilation (JCSDA), aims to create a new comprehensive DA framework, built with modern software practices in mind. Together with the other JCSDA partners (NOAA-NESDIS, NOAA-OAR, NASA, US Navy, US Air Force) plus the Met Office, the JEDI is a joint project using the same core system but configurable and expandable according to individual centers' needs. JEDI also includes the concept of separation of concerns which, among other advantages, has the potential to simplify the implementation of coupled modeling and data assimilation. The focus of this work is currently the Interface for Observational Data Access (IODA) and Unified Forward Operator (UFO). The IODA converters allow the use of diverse observation formats (including but not limited to BUFR) through their conversion to a common, self-describing format (currently we are using netCDF for this). The UFO handles the forward calculation (employing CRTM for radiance calculations), bias correction, quality control and observation error assignment. All of these are configured through the use of YAML files. For initial acceptance, the aim is to ensure that the UFO can replicate the output of the GSI (including bias correction, quality control and any error inflation that is performed), including any preprocessing that is usually performed before the GSI is invoked. It is expected, however, that these steps may be simplified or otherwise modified before JEDI becomes operational.

12p.03 Bias correction of high peaking microwave temperature sounding channels at Environment Canada
Presenter: Sylvain Heilliette, Environment Canada
Co-authors: Mark Buehner, Josep Aparicio

In this poster, we will present the latest research work performed at Environment Canada on bias correction of high peaking temperature sounding channels from the microwave instruments AMSU-A and ATMS. In the currently operational data assimilation system, these channels (ATMS 14-15 and AMSU-A 13-14) are subjected to a static bias correction in the sense that bias correction is computed from constant coefficients and time varying air mass predictors. Bias correction of the other channels is estimated dynamically via linear regression from O-F statistics of a 3DVar analysis assimilating only anchor observation (i.e. all observations assimilated except airplanes, which are subjected to their own bias correction, and radiances). It was found necessary to use a static bias correction for these high peaking channels to avoid model drift at the top. These static coefficients are problematic at every major system upgrade and for performing research and development experiments because they need to be updated to avoid degradation of the upper atmosphere. The upper part of the model atmosphere model between 2 hPa and model top (0.1hPa) is only weakly constrained by observations. The unphysical boundary condition at model top (sponge layers) tend to lead to an artificial heating. In the poster we present details of of the approach we plan to implement to replace these static coefficients with something more dynamic without risk of drift at the top.

12p.04 A new strategy to stabilize bias correction of satellite radiance observation in KPOP

Presenter: Hyeyoung Kim, Korea Institute of Atmospheric Prediction System
Co-authors: Jeon-Ho Kang, In-Hyuk Kwon

The satellite radiance observations are important elements of data assimilation systems, however, its systematic errors (i.e. biases) should be removed in order to not degrade the quality of analysis and of accuracy of the related forecast. In KPOP (KIM Package for Observation Process), to correct the bias of satellite radiance data, quality control and bias correction are repeatedly performed using iterative adaptive bias correction method. Since this method calculates and corrects the bias of the observation increment every cycle, it is known that the bias can be strengthened if the model is biased. Comparing KIM with the ECMWF analysis field, there is a large bias in the upper layer (higher than 100hPa), and these biases oscillate. Since adaptive bias correction is applied, the bias correction coefficients are also fluctuated with the same period shown in the biases of the KIM analysis field. It means that this bias correction method is correlated with the model filed. Thus, new scheme was designed to consider the statistics of previous observations and background model fields by giving time weights when calculating the bias correction coefficient. As a result of the sensitivity test applying new scheme to ATMS, the error in temperature and geopotential height was consistently reduced, and the error in water vapor at 500-300 hPa was also reduced. Also, the constant term of the bias correction coefficient, which means the mean of the observation increments, seems to be relatively stable in the experiment than the control.

12p.05 A new IASI channel selection method for the KIM data assimilation system

Presenter: Ahreum Lee, KIAPS
Co-authors: Jeon-Ho Kang, In-Hyuk Kwon, and Hyoung-Wook Chun

It has been demonstrated that using IASI observations significantly impacts NWP model prediction skills according to the number of channels used. However, only 91 (81 temperature channels and 10 water vapor channels) out of 8461 IASI channels are used in the Korean Integrated Model (KIM) data assimilation system, providing limited atmospheric information. For the improvement of analysis and forecast from KIM, more IASI observations are essential to be assimilated. Therefore, in this study, a new channel selection method is suggested to expand the use of IASI observation in the KIM data assimilation system. First of all, IASI channels were divided into 20 groups by using the K-means clustering algorithm. A three-dimensional Jacobian profile was calculated for each IASI channel in order to consider the temperature and humidity Jacobians of the channel simultaneously. Among the 20 channel groups, a channel group making the smallest analysis error compared to the ERA5 reanalysis was selected, and then an additional group making the smallest error with the previously selected group was added. By repeating this selection process, total 136 (83 temperature channels and 53 water vapor channels) IASI channels were chosen. It was confirmed that the newly selected IASI channel set has an overall positive impact on the temperature and humidity fields in the KIM, comparing the results using the 91 IASI channel set.

12p.06 A highly efficient DFS-score based channel selection method suitable for non-diagonal R matrices and the parallel processing of large numbers of atmospheric profiles

Presenter: Olaf Stiller, DWD
Co-authors: Olaf Stiller, Mahdiyeh Mousavi, Silke May, Christina Köpken-Watts

The large numbers of channels from hyper-spectral sounders has motivated the development of different automated channel selection methods. These are commonly based on a figure of merit the most prominent of which is the DFS (Degrees of Freedom per Signal). Observation errors clearly play a crucial role for the channel selection and importantly, some of the proposed schemes can deal with fully non-diagonal observation error covariance matrices R as they are now used at many operational centres yielding a positive impact on the forecast accuracy. Including non-diagonal R in the selection process, however, usually comes at increased numerical cost and code complexity. It has to be noted that numerical cost is a limiting factor which requires some compromises and that finding a reasonably large subgroup of channels which strictly minimizes the total DFS for a large group of atmospheric profiles simultaneously would be prohibitive. This poster explains a new, numerically highly effective method for computing the DFS for fully non-diagonal R matrices and large numbers of atmospheric test profiles simultaneously. The method which works sequentially (like previous schemes) is based on an application of the Cholesky decomposition to the DFS. Its high efficiency results from an appropriate ordering of the steps for computing the different terms resulting from the Cholesky partitioning. Applications to the channel selection at DWD are presented and discussed.

12p.07 Hybrid PCA representation of CrIS data
Presenter: David Tobin, CIMSS/SSEC/UW-Madison
Co-authors: David Tobin, Joe Taylor, Flavio Iturbide-Sanchez, Denis Tremblay, Liam Gumley, Michelle Loveless, Bob Knuteson, Hank Revercomb

EUMETSAT has provided a very useful methodology for Principal Component Analysis representation of IASI and future MTG-IRS data that utilizes a Hybrid approach (e.g. Hultberg et al. 2017). The hybrid PCA approach uses global and local (granule) level variability to efficiently represent the data. This presentation will include the methodology and results for application of the Hybrid PCA to CrIS spectra. Considerations for CrIS include noise normalization, Hamming apodizatoin, the combination of all three spectral bands (or not), and the combination of all nine FOVs (or not). Creation of the initial global ensemble and a supplementation methodology to identify include other outlier spectra in the global ensemble is described. Advantages of this hybrid methodology, including compression of about a factor of 21 and random noise filtering, will also be discussed.

Session 11: Artificial Intelligence and Machine Learning

11.01 Can we Design NWP Data Assimilation Based Entirely on AI Techniques? Assessing Advantages and Challenges
Presenter: Flavio Iturbide, NOAA/NESDIS/STAR (for Sid Boukabara)
Co-authors: E. Maddy

A new approach to perform large-volume data fusion and assimilation, based entirely on Artificial Intelligence (AI) modern techniques including machine learning and computer vision techniques, is presented in this study. This approach to data assimilation is applied to real environmental data measured from both satellites-based and surface-based observing systems to reproduce traditional Numerical Weather Prediction (NWP) data assimilation performances from the U.S. National Oceanic and Atmospheric Administration (NOAA). These AI techniques have already been successfully tested in other fields to merge large varieties of data, and this effort aims at assessing the feasibility of leveraging them for the purpose of NWP data assimilation and Earth System Modeling (ESM) in general. We will explore both advantages and challenges. The results confirm that significant efficiency could be achieved in environmental data assimilation using AI. This efficiency allows us to address one of the long-vexing issues of handling the Big data challenge due to the exponential increase in the volume of satellite and ground based data that exists and is expected to increase in the future. We assess this efficiency gain by the amount of satellite data that we can afford assimilating within the same computer resources, or by assessing the reduction of the amount of time required to perform the AI-based assimilation, compared to traditional approaches. In this demonstration of the feasibility of an AI-based system, we focus on performing a multi-variable data fusion/assimilation focusing on a representative but limited set of variables at different levels in the atmosphere. Namely atmospheric temperature, moisture, wind and cloud. The resulting analysis from the data assimilation or fusion modes, i.e. with and without the use of an NWP forecast model as background respectively, is generated at global scales and at varying spatial resolutions. This study shows that physical constraints in the analysis, an important aspect of any data assimilation, could be satisfactorily accounted for to a certain degree, as part of the AI-based training approach. These results are encouraging but are considered only a first initial step toward an entirely AI-based environmental data fusion/assimilation system. This should allow us to easily widen the applicability to a holistic Earth System Model environment, open the door to new nontraditional sources of environmental data, and perhaps more importantly, allow us to handle situations where assumptions of traditional data assimilation techniques are not necessarily valid. For example, in highly non-linear (or even discontinuous) optimal estimation cost functions -for example in rainy conditions- or in cases where observations or geophysical variables have non-Gaussian error characteristics. In this AI-based approach, these assumptions are indeed not necessary since the data assimilation is done using a highly non-linear approach and does not make simplification assumptions in order to parametrize the minimization cost function. We focus in this study on the assessment of the quality of the AI-based NWP analysis by assessing its accuracy when compared to an independent reference, and by assessing its characteristics including spatial variability, inter-parameters correlations, and other assessment metrics to ensure physics constraints are respected.

11.02 Constrained Deep learning Bias Correction (CDBC) for Satellite Radiances in Data Assimilation
Presenter: Wei Han, CMA Earth System Modeling and Prediction Centre (CEMC)
Co-authors: Haofei Sun, Ruoying Yin, Jincheng Wang

Observation bias correction (BC) schemes are of vital importance in the data assimilation (DA) systems used in operational numerical weather prediction (NWP). Satellite radiance observations are typically affected by biases that arise from uncertainties in the calibration, the radiative transfer modeling (observation operator), or other aspects. These biases have to be removed for the successful assimilation of the data in numerical weather prediction (NWP) systems. The BC schemes are used mainly to correct for biases in satellite radiance observations and their observation operators. In practice, these BC schemes attempt to remove satellite radiance observation biases in observations (O) relative to the NWP model background (B) or analysis field (A). There are two key issues that have been identified in current operational satellite radiance BC schemes: Firstly, there is nonlinear dependence of satellite radiance bias on the selected predictors which is not well represented by the current schemes based on the linear combination of several predictors(e.g., scan dependence of the cross-track sensors biases); Secondly, bias corrections can drift towards unrealistic values in regions where there is strong model error(e.g., B or A is biased) and relatively few “anchor” observations. In this study, a novel method for BC using deep learning (DL) is proposed with physical model constraints: Constrained Deep learning Bias Correction (CDBC). By stacking multiple layers of networks, nonlinear features of bias can be learned better by the DL-based method than that of the linear BC model. In addition, data-driven deep learning methods can reduce representation errors caused by the manual selection of predictors. For the second issue, to avoid unrealistic drifts that usually happened by data driven method where the reference data (B or A) is biased, physical constraints are introduced in CDBC to avoid the satellite radiance BC drifts to the imperfect reference data. CDBC has been applied on the FY-3E MWTS and FY-4B GIIRS radiance observations bias correction. The results show that the CDBC can correct the nonlinear features of the observation bias and work well with the physical constraints.

11.03 A neural network approach to cloud detection in NWP
Presenter: Chris Burrows, ECMWF
Co-authors: Chris Burrows, Tony McNally

When assimilating infrared radiance observations in a clear-sky framework, it is essential to screen out cloud-affected observations. The current operational cloud detection at ECMWF makes use of a pattern-matching algorithm to identify which channels are contaminated by cloud in a given scene by comparing the observed radiances with clear-sky simulations. Here, a new technique is presented which performs cloud detection using a neural-network. Different training approaches are considered and comparisons are shown between this new approach and the operational algorithm. A key benefit of this technique is that for each scene, no radiative transfer calculations are required, and computation is extremely fast. This would allow effective cloud screening to be applied outside the time-critical path in an operational framework.

11.04 withdrawn

11.05 Optical Properties of Nonspherical Particles: Physical Models and Machine Learning
Presenter: Lei Bi, Zhejiang University

Light scattering by aerosol, cloud and precipitation particles is a challenging research subject, which requires persistent research effort. This talk will report our recent advancements on atmospheric particle models, the methods of computational electrodynamics, and machine learning approaches. In particular, we will highlight a “universal” particle modeling approach based on a super-spheroidal equation, the (GPU) invariant imbedding T-matrix method, which enhanced the modeling capabilities for computing the optical properties of non-spherical and inhomogeneous particles, and a neural network method for parameterizing the optical properties of atmospheric particles and their Jacobians. Some examples of applying aerosol and cloud optics to polarimetric radiative transfer, Radar simulation, and atmospheric models will be also reported.

11.06 Neural network-based methods for simulating cloud- and aerosol-affected solar satellite channels

Presenter: Leonhard Scheck, Hans Ertel Centre for Weather Research
Co-authors: Florian Baur, Olaf Stiller, Christina Stumpf, Christina Köpken-Watts

Solar satellite channels provide high resolution information on clouds and aerosols, which is often complementary to what can be inferred from thermal channels. The solar channels are sensitive to the microphysical properties of cloud and aerosol particles and contain better information on water content than the thermal channels. In an operational context, the direct assimilation of solar satellite images or using them for the evaluation of numerical weather prediction (NWP) models requires sufficiently fast and accurate forward operators, which solve radiative transfer (RT) problems to compute synthetic images from the NWP model output. As multiple scattering complicates the solution of radiative transfer problems in the solar spectral range, standard RT methods are too slow for this purpose. A sufficiently fast and accurate method based on a compressed look-up table (LUT) computed with standard RT solvers has been developed and was used successfully in first model evaluation and data assimilation experiments. However, the method is limited to non-absorbing channels and does not take aerosols into account. These limitations could be overcome by replacing the compressed LUT by a neural network. It is demonstrated that using neural networks the amount of training data that has to be computed with standard radiative transfer methods can be reduced by several orders of magnitude, compared to the LUT approach, while matching the speed and accuracy of the original method. With the new approach, which has been integrated in the RTTOV package, it is now possible to generate images for the 1.6 micron channel with improved accuracy by using additional input parameters describing the effective droplet and ice particle radius profiles. As a second application, many different aerosol species can now be taken into account in the computation of aerosol-affected visible reflectances.

Session 12: Observation operator and Observation error

12.01 Investigations on scene dependent observation errors accounting residual cloud contamination for hyperspectral IR

Presenter: Kirsti Salonen, ECMWF
Co-authors: Anthony McNally

Hyperspectral infrared radiances from IASI, CrIS and AIRS are assimilated operationally at ECMWF. Measurements are used in clear and in fully overcast scenes. The vast majority of data actively assimilated originate from scenes with presence of non-overcast cloud. In these situations channels which are considered to peak sufficiently above the cloud top can effectively be treated as clear. Investigations have shown that errors are larger in these scenes with stronger inter-channel correlations, compared to data in fully clear scenes. However, currently the used observation errors and error correlations are global and static and diagnosed from completely clear scenes. Analysis of the eigenvalues and eigenvectors of the full IASI observation error covariances for different cloud heights indicates that the leading 1 to 5 eigenvectors represent structures with broad spectral features from residual cloud contamination. Inflating these leading eigenvalues with an empirically tuned factor results in a numerically stable strengthening of correlations which seems to improve the weighting of the infrared data. Combining the IASI modified error variances and correlations in the 4D-Var shows some useful improvements in the analysis. The latest results on the investigations will be presented in the conference.

12.02 Evaluation of Assimilation and Prediction Effects of Different Satellite Observation Operators in CMA-GFS

Presenter: Jun Yang, CMA Earth System Modeling and Prediction Centre

The fast radiative transfer model is a key bridge between satellite observation data and numerical weather prediction (NWP) model. For a long time, in China's NWP operational model, this bridge has always relied on the RTTOV model. Recently, an advanced radiative transfer modeling system (ARMS) has been developed in CMA and formed a stable and reliable version 1.2.0. Now, we have completed the integration of ARMS in the Global Forecasting System of the China Meteorological Administration (CMA-GFS) and realized the convenient choice between the satellite observation operator ARMS and RTTOV without affecting the existing NWP operations. In view of the current situation of satellite data assimilation in CMA-GFS, we designed three groups of experiments to compare the differences between ARMS and RTTOV as satellite observation operators. The tests take 40 days from September 5, 2021 to October 15, 2021. In three groups of experiments, in addition to assimilating other conventional observation data, the assimilating satellite radiance data are only microwave sounding data, only infrared hyperspectral data and all available satellite radiance data, respectively. In terms of satellite observation operator, RTTOV is used for control test and ARMS is adopted for comparison test. The assimilation results show that when ARMS is used to replace RTTOV as the observation operator, the observation and simulation difference (O-B) of each channel of satellite data is not significantly different, and the number of assimilated into the NWP model for each channel is increased slightly. From the prediction results, ARMS has improved the global geopotential height field at different heights to a certain extent, and the accuracy of temperature and water vapor field is basically equivalent to that of control tests. The scoring results of the global 500hpa geopotential height field also show that after replacing RTTOV with ARMS in CMA-GFS, the global predictable days will increase to a certain extent. In the future, to better play the role of ARMS, we will use ARMS to design a new quality control scheme for each satellite instrument in CMA-GFS, and carry out observation error and bias correction accordingly.

12.03 Exploring a microwave radiance footprint operator in an Arctic data assimilation system

Presenter: Mate Mile, The Norwegian Meteorological Institute
Co-authors: Stephanie Guedj, Roger Randriamampianina

Nowadays, satellite observations are providing primary information for initial conditions of state-of-the-art numerical weather prediction systems and the amount of remote sensing data in the Global Observing System increases rapidly. In the operational AROME-Arctic model, satellite data are crucial because the model domain covers the high latitudes of the European Arctic where conventional observations are sparse. In its data assimilation system, satellite observations are already assimilated from many polar-orbiting satellites, however, such data are utilized as point observations which approach is conservative and not optimal for high-resolution models like AROME-Arctic. Our objective is to investigate the footprint representation of AMSU-A and MHS instruments in data assimilation and to explore the importance of more appropriately extracted model information by the use of a footprint observation operator. Here we describe the properties of the implemented microwave footprint operator and the technical challenges of the implementation itself. Besides the operationally used microwave sensors, a future application for Arctic microsatellite constellation will be presented as well. This work has been done in the frame of Arctic projects called ALERTNESS (Advanced models and weather prediction in the Arctic) and ESA AWS (Arctic Weather Satellites).

12.04 Quantification of inhomogenous water vapor concentration effects in IR and MW radiation biases comparing observed versus calculated radiances (sondes + RTTOV)

Presenter: Xavier Calbet, AEMET
Co-authors: Bomin Sun, Tony Reale

It has been shown that inhomogeneous water vapor concentrations in the field of view of IR and MW instruments can lead to a significant bias between observed and calculated radiances (https://doi.org/10.5194/amt-11-6409-2018). In this paper we compare observed versus calculated radiances to quantify the average resulting biases. Calculated radiances are obtained by applying a radiative transfer model (RTTOV) on a significant sample size of radio-sonde observations. Measured radiances come from IR and MW instruments on board of polar satellites. Radiances are calculated, both, taking and not taking into account the sonde measured WV inhomogenetities. Comparisons of observed versus calculated radiances are made in all cases and conclusions about the biases are drawn.

12.05 Satellite Bias Correction in the NOAA's Next Generation Regional Model - Rapid Refresh Forecast System (RRFS)

Presenter: Xiaoyan Zhang, SAIC at NOAA/NCEP/EMC
Co-authors: Emily Liu, Andrew Collard, Ting Lei, Shun Liu, Jacob Carley

The next generation operational regional forecast and data assimilation system at National Oceanic and Atmospheric Administration (NOAA) uses the unified hourly-updated, storm-scale ensemble data assimilation and forecasting system based on the FV3 dynamic core, which will be called the Rapid Refresh Forecast System (RRFS). As an essential component of data assimilation, the bias correction of satellite radiance needs to be re-addressed within this new system by evaluating the performance of existing bias correction initialization and cycle strategies. In order to do so, two basic variational bias correction (VarBC) applications are tested within RRFS, specifically adopting bias coefficients from the global model (GFS) and cycling bias coefficients independently in the RRFS. The latter application is also studied by stopping the bias coefficient and its background error to be updated at the end of data assimilation cycle when data amount of data associated with any channel, after quality control, is less than a prescribed threshold. This step was introduced because the polar-orbiting satellites provide limited and intermittent coverage for limited area modeling systems, such as the RRFS. The bias coefficients could become unrealistic with insufficient sample sizes, thus degrading the satellite radiance assimilation in the next cycle. Compared to these two experiments, better forecast scores for temperature/wind within 3-hours, and for relative humidity within 12-hours, were obtained from cycling bias coefficients independently in the RRFS than with global bias coefficients. More details about how to control the amount of data involved in bias coefficient update, and whether it will benefit to the satellite radiance assimilation and forecast will also be discussed.

12.06 Estimation of the error covariance matrix for IASI reconstructed radiances and its impact at ECMWF

Presenter: Cristina Lupu, ECMWF
Co-authors: Thomas August, Dorothée Coppens; Tim Hultberg, Tony McNally

IASI reconstructed radiances from EUMETSAT principal components products form a plausible alternative route for the exploitation of high spectral resolution infrared sounders in NWP. We showed that reconstructed radiances could be ingested instead of original radiances in an operational environment, using the exact same configuration and preserving the forecasts skills. We also experienced that the eigenvector basis used for PC compression could be updated 'on-the-fly' without impacting the operational continuity and the performance of the forecasts. The success of assimilating IASI reconstructed radiances depends on how well the various elements of the assimilation system are implemented and tuned. The observation error covariance matrix is a crucial element in data assimilation methodology which can considerably impact the forecasting accuracy. It necessitates particular attention for observations presenting some degrees of spectral error correlation, like IASI or the future reconstructed radiances of MTG-IRS. This study investigated different approaches to generate an observation error matrix for IASI reconstructed radiances as if they were new mission data. Initially, same observation-space methods used for IASI original radiances, were applied to reconstructed radiances to estimate the observation error covariance matrices in terms of the error standard deviation and a correlation matrix. The approach was investigated in detail in assimilation experiments, including an assessment of the role of error inflation and reconditioning. Important degradations were noted, suggesting that these methods remain unsatisfactory to deliver a matrix that works within the assimilation system. A new avenue has been proposed to analytically account for the subspace spanned by the reconstructed radiances. Assimilation trials with new covariance estimates assumed for the reconstructed radiance have been carried out and results compared with the ECMWF operational configuration. Progress in this area is very timely in the framework of the MTG-IRS research activities aiming at the day-1 user preparedness with PC products from hyperspectral sounding.

Session 13: Earth System Approach

13.01 JCSDA next-generation Earth system data assimilation

Presenter: Thomas Auligné, Joint Center for Satellite Data Assimilation

The Joint Center for Satellite Data Assimilation (JCSDA) is a multi-agency research center to improve the use of satellite data for analyzing and predicting the weather, the ocean, the climate and the environment. Recent effort has focused on the development, delivery, and support of next-generation Earth system data assimilation for research and operations. Two flagship projects of the JCSDA are the Joint Effort for Data Assimilation Integration (JEDI) and the Community Radiative Transfer Model (CRTM). The main partners involve NOAA, NASA, U.S. Air Force, U.S. Navy, UK Met Office, UCAR/NCAR, as well as several collaborations with academia and the private sector. Using open-science, agile and collaborative best practices, the JCSDA delivers turnkey solutions to the Earth system science community to optimize and accelerate the use of observations of the atmosphere, ocean, cryosphere, land, aerosols, and constituents. This presentation summarizes recent development at the JCSDA, the various products available to the community, as well as opportunities for training and collaboration.

13.02 Impact of a priori contribution on CO retrievals from infrared hyperspectral measurements
Presenter: Hyun-sung Jang, NASA LaRC / National Institute of Aerospace
Co-authors: Xu Liu, Daniel K. Zhou, Wan Wu, Allen Larar, and Qiguang Yang

We studied the impact of a priori contribution on NASA Langley's novel physical retrieval algorithm, Principal Component-based Radiative Transfer Model retrieval algorithm (PCRTM-RA), for CO retrievals over wildfire-affected environments. Conventionally, the PCRTM-RA uses climatology and its variability as a priori information for global CO retrieval. However, the fact that this a priori heavily weights toward global background CO variation (and we wish to ensure retrieval sensitivity to fire-induced deviations from global climatology) motivates us to relax vertical correlations of the background covariance matrix for wildfire-related field campaign data. This study uses National Airborne Sounder Testbed-Interferometer (NAST-I) measurements obtained during the Fire Influence on Regional to Global Environments and Air Quality (FIREX-AQ) field campaign conducted in 2019. In comparison with CO retrieved from the conventional PCRTM-RA optimal estimation approach, CO retrieved from the relaxed background covariance matrix notably has a less clean-air-like vertical structure. A retrieval test using a synthetic dataset containing various CO vertical distributions confirms that using the relaxed background covariance can better reveal the true vertical structure of CO profiles, especially for high-concentration cases. Consequently, we can see an improved agreement between this new CO retrieval and previously-reported NAST-I CO retrievals from a channel-based algorithm. Overall, this study implies that caution would be required to treat a priori information for retrieving CO from infrared hyperspectral measurements. For fire-enhanced CO environments, relaxing the vertical correlation in the background covariance matrix could provide better CO retrievals unless well estimated a priori information is readily available.

13.03 Further exploiting MW and IR radiances through extracting and using ocean skin temperature information in a coupled ocean-atmosphere system
Presenter: Tracy Scanlon, ECMWF
Co-authors: Alan Geer, Niels Bormann, Philip Browne, Tony McNally

A new system has been developed at ECMWF (European Centre for Medium range Weather Forecasts) called RADSST (ECMWF Newsletter 172) where ocean skin-temperature is estimated in the atmospheric 4D-Var analysis from satellite radiances and coupled to the NEMOVAR ocean data assimilation system to constrain the bulk sea surface temperature (SST). It has been demonstrated that hyper-spectral infrared sounders (e.g., IASI and CrIS) in clear-sky conditions can provide useful SST information and lead to an improved fit of the ocean sub-surface to independent in-situ observations. Furthermore, in the outer-loop coupled approach, improvements in the ocean are seen to feedback to improved atmospheric analyses and forecasts. However, where there is significant or persistent cloud cover, infrared sounders provide no information on the ocean surface and there is thus a strong motivation to try and use microwave instruments to fill these data gaps as well as to bring additional information in areas observed by both IR and MW. Allowing the ocean skin temperature to be updated during the assimilation process can also help improve the usage of observations by reducing the possibility that skin temperature errors can be aliased into the atmospheric analysis. For these reasons, the RADSST approach of estimating ocean skin-temperature within 4D-Var is being extended to additionally exploit microwave imager and sounder radiances currently used in the all-sky system. Here, we evaluate the quality and complementarity of the additional skin temperature information provided by microwave sounder and imager radiances (against each other and independent observations) and the impact on analyses and forecasts as part of the coupled data assimilation system.

13.04 withdrawn

13p.01 Updates of radiance forward modelling in the DWD system
Presenter: Robin Faulwetter

This poster presents recent updates in the implementation and use of RTTOV in the DWD system. It is well known that some satellite instruments used in NWP are affected by trace gases and that RTTOV offers the option to supply individual trace gas profiles. We implemented the use of realistic, actual O3 profiles in the DWD system. For this purpose we use ECMWF O3 analyses and forecast fields interpolated to the observation positions. The use of these profiles for IASI has a striking positive impact. Experiments with more realistic CO2 profiles are ongoing. With the release of RTTOV-13 a new version of optical depth predictors was made available. Results of tests and experiments with these new RTTOV-13 predictors in the DWD assimilation system are presented. We plan to start with the operational use of these predictors in winter 2022/2023.During the testing of the new predictors we faced some problems with the convergence of the assimilation algorithm. These problems are explained and a workaround is presented. The root of this problem is not unique to RTTOV-13 predictors.

13p.02 Multi-year changes in IASI LST biases and inter-channel error covariances seen in the Met Office Global NWP System
Presenter: Chawn Harlow

There has been recent progress in the Met Office that has led to the introduction of weakly coupled ocean-atmospheric DA (Data Assimilation) into the Global Model. In addition, the model has been updated from GA7.2.1GL8 to GA8GL9 with associated changes to the drag scheme, the roughness over land surfaces, and convection. It is anticipated that these changes in the model have altered some observational representation and background error characteristics that affect the assimilation of radiances. Evidence of this has been found in changes in the bias between the retrieved and background skin temperature (aka the LST bias) for IASI and CrIS measurements. It is expected that there will also be changes in the diagnosed inter-channel observation error covariances for IASI and CrIS due to these model changes. This poster will present results of an analysis of the last five years of IR skin temperature retrievals using IASI and CrIS and an analysis of changes in the IASI inter-channel observation error correlations from 2013 to present. The LST bias is studied over several land regions of the globe including the Sahel, the Great Plains, northern Australia, southern Australia, eastern Ukraine, central England, and central France. It will be shown that there appears to have been a change in the annual cycle of monthly average LST bias with the recent changes to the model. The long-term trend of the IASI inter-channel observation error covariance matrices will be presented over the period 2013 to 2023. For these trends in both the variances and the correlations will be presented for both raw diagnosed and conditioned matrices, the latter following the guidance of Weston et al. 2014. Correlations in conditioned matrices with the same condition number changed by up to 0.25 between 2013 and 2020. Further work ahead of this presentation will look at the 2020 to 2023 period to see if there are additional changes in observation error covariances due to the most recent changes in the model.

13p.03 The detection of the South America Tropopause Aerosol Layer over the Amazon region
Presenter: Dirceu Herdies, INPE
Co-authors: Caroline Bresciani and Silvio Nilo Figueroa

The Amazon is one of the most important tropical forests in the world because it is a key in the regulation of the global climate. It is the world's largest rainforest, where interactions between the forest and the atmosphere are fundamental to rainfall throughout South America and have an indirect effect on all the regions around the world. Furthermore, the Amazon region may be a source of aerosol that will act as cloud condensation nuclei (CCN). During the rainy season over the Amazon region, in which intense convective activity associated with the South America Monsoon System (SAMS) prevents fires, the primary sources of aerosols include biogenic emissions, dust from the Sahara Desert, and emissions from burning biomass transported from Africa. Besides that, the downward transport of aerosols from the upper troposphere (UT) has been considered a source of particles to the lower troposphere. The particles in the UT over the tropics region have been one of the largest aerosol reservoirs in the atmosphere, which could be from primary aerosols, such as dust, organic carbon and black carbon or secondary aerosol formed by trace gases in the free troposphere. The existence of an aerosol layer at the tropopause level has been observed during June, July, and August in Asia and North America (Asian Tropopause Aerosol Layer - ATAL and North American Tropopause Aerosol Layer - NATAL, respectively) associated with the deep convection of the Monsoons System. Therefore, the aerosol enhancement in the UT and lower stratosphere (LS) and the formation of an aerosol layer over the Amazon region associated with the deep convection of the SAMS during the austral summer are investigated. In the past, field campaigns over South America (SA) (GoAmazon2014/5 experiment) showed aerosol enhancement in the UT. They suggested that new aerosol particles are formed in the UT from biogenic volatile organic material that goes up by upward transport associated with the deep convection. The enhancement of aerosol backscatter values over SA is observed from October to January; it gradually decreases during the following months. The aerosol backscatter inferred from MERRA-2 Reanalysis showed a maximum value of the 2.24x10-5 km-2sr-1 over the Amazon during November and December. The results showed the first evidence of the existence of the South American Tropopause Aerosol Layer (SATAL) that covers the tropical SA and vertically extends up to 80hPa (approximately 18 km), similar to ATAL, and NATAL. The aerosol backscatter inferred from MERRA-2 reanalysis was validated using the attenuated backscatter by CALIOP from CALIPSO satellite. However, field campaigns such as the CAFE-BRAZIL campaign (Chemistry of the Atmosphere: Field Experiment in Brazil), which will be during December/2022 and January/2023 using the HALO (High Altitude Long Range Aircraft) aircraft, are necessary to study the formation of SATAL.

13p.04 All-sky Retrieval of Atmospheric Temperature, Water Vapor, Clouds, Trace Gases, and Surface Properties from Operational Hyperspectral IR Sounders

Presenter: Xu Liu, NASA Langley Research Center
Co-authors: Xu Liu, Wan Wu, Xiaozhen Xiong, Qiguang Yang, Daniel K. Zhou, Allen M. Larar, Hyun-Sung Jang, Liqiao Lei, Qing Yue, Nicholas Nalli, and Lihang Zhou

Operational IR sounders such AIRS, CrIS, and IASI provide high quality hyperspectral measurements for weather and climate applications. We will describe a new all-sky Single Field-of-view Sounder Atmospheric Product (SiFSAP). The uniqueness of this product is that it uses all available channels from hyperspectral sounders and the optimal estimation retrieval is done at a single FOV spatial resolution. The SiFSAP includes atmospheric temperature, water vapor, clouds, trace gases, surface skin, and surface emissivity and will be produced operationally at NASA GES DISC. We will describe the core component of the SiFSAP algorithm, which is the Principal Component-based Radiative Transfer Model (PCRTM), and will show example applications of the SiFSAP product for various atmospheric weather and dynamics studies. We also describe a new Climate Fingerprinting Sounder Product (ClimFiSP), which is derived from spatiotemporally averaged level-1 hyperspectral radiances directly. The ClimFiSP algorithm uses consistent radiative kernels and a robust spectral fingerprinting method. It provides fast and accurate data fusion products from multiple satellite sensors. We have applied this method to both AIRS and CrIS (on SNPP and on NOAA 20) data and generated two decades climate data records for atmospheric temperature, water vapor, cloud, trace gases, and surface skin temperature. The ClimFiSP are being transitioned to NASA data centers for routine generations level-3 products.

13p.05 withdrawn

13p.06 NAST-I for air quality monitoring and wildfire-related research

Presenter: Daniel Zhou, NASA Langley Research Center
Co-authors: Daniel Zhou, Allen Larar, Xu Liu, Xiaozhen Xiong, and Hyun-sung Jang

The National Airborne Sounder Testbed-Interferometer (NAST-I) is an airborne FTS remote sensor that nominally flies on NASA high-altitude aircraft to serve as a spaceborne instrument simulator. NAST-I continues to serve as a pathfinder for future satellite FTS systems and the next generation advanced atmospheric sounders in general. NAST-I provides high resolution spectrally resolved infrared radiances as its level-1 product. NAST-I level-2 products characterizing the surface (i.e., skin temperature and spectral emissivity), atmosphere (i.e., profiles of temperature, moisture, ozone, carbon monoxide, and other trace species), and clouds (e.g., optical depth, particle size, temperature, and height) can be used to support fire-related monitoring and research. NAST-I provided 3-d characterizations of wildfire-induced plumes of CO during the FIREX-AQ field campaign (conducted during 2019) which showed the intensity and size evolution of wildfire plumes at high spatial and temporal resolutions. Wildfire-induced CO plumes, in conjunction with their evolution, transport, and age have been identified and recently published in scientific journals. Other research applications, such as surface emissivity changes due to fire burning of ground landscape, have been under investigation. These NAST-I level 1-3 products could be used in support of wildfire management to better inform decision making and operations for pre-, active, and post-fire environments.

Session 14: Space Agency reports

14p.01 The Current Status and The Future Development Plans of WMO OSCAR/Space

Presenter: Heikki Pohjola, WMO

The WMO Observing System Capability Analysis and Review tool for space-based capabilities (OSCAR/Space) is a publicly available, online resource established and maintained by the WMO Space Programme Office (WMO SP) in the context of the WMO Integrated Global Observing System (WIGOS). It is a key tool and information source to support the WMO Rolling Review of Requirements (RRR) process of the WMO Integrated Global Observing System (WIGOS). Another important application of OSCAR/Space is to conduct the WMO Gap Analysis, which is a key input for the annual risk assessment of coordination group of meteorological satellites (CGMS) to monitor the compliance of CGMS baseline and satellite programmes in the implementation of the space-based component of the Vision for WIGOS in 2040. The information content in OSCAR/Space must therefore be carefully maintained continuously in collaboration with the CGMS and the respective space agencies. The WMO SP is responsible for the OSCAR/Space maintenance. In this presentation we present the current status and future development plans to keep OSCAR/Space as a high-quality information source on satellite programmes, satellites and instruments operated by CGMS members and observers as well as by non-CGMS satellite operators and commercial satellites for the benefit of satellite agencies, NWP centres and satellite data users worldwide.

14p.02 Status report of space agency: JMA and JAXA

Presenter: Kozo Okamoto, JMA/MRI
Co-authors: Misako Kachi, Kotaro Bessho

JMA plans to switch operations from Himawari-8 to Himawari-9 in December 2022. It is in the climax of its study of specification for the Himawari follow-on satellites, aiming at launching in 2028. It considers a hyperspectral infrared sounder as a candidate payload and implements OSSEs to assess its potential impact. JAXA operates GCOM-W/AMSR2, GCOM-C/SGLI, GPM-core/DPR, GOSAT & GOSAT-2, and ALOS-2. It prepares for the launch of ALOS-3, ALOS-4, EarthCARE/CPR, and GOSAT-GW/AMSR3 and /TANSO-3 The status and plans of these observations will be overviewed in the conference.

14p.04 CMA

Presenter: Peng Zhang

No abstract.

14p.06 NOAA

Presenter: Lihang Zhou, NOAA

No abstract.

Session 15: Data Impact Studies

15p.01 Assimilating short-wave infrared radiances from CrIS at ECMWF

Presenter: Chris Burrows, ECMWF
Co-authors: Chris Burrows, Tony McNally, Marco Matricardi

Unlike the long-wave and mid-wave spectral regions, the short-wave part of the infrared spectrum has not been fully exploited at ECMWF. With the possibility of small (and numerous) IR sounders in the future which may not have long-wave capabilities, these investigations may help with future strategies regarding approaches to IR assimilation for NWP. Challenges with this part of the spectrum include the effects of non-local-thermodynamic-equilibrium (NLTE) and the effect of solar contributions, neither of which are negligible at these wavelengths and so must be included in the radiative transfer calculations. Also, an approach to account for the scene-dependence of observation errors is required due to the nonlinearity of the Planck function in the short-wave region. Further considerations include the screening of observations affected by sun-glint, and these aspects will be described in the presentation. For the experiments presented here, some parameters such as channel selection were proposed by NOAA, and ongoing dialogues have taken place between our organisations. Results of global assimilation experiments will be presented showing the impact of adding these channels to the current operational channel set.

15p.02 Can the current hyperspectral infrared sounders capturing the small scale atmospheric water vapor spatial gradients?

Presenter: Zhenglong Li, UW SSEC/CIMSS (for Di Di)

Severe storms are often associated with atmospheric water vapor movement with high temporal and spatial gradients (e.g., cold front). Satellite based hyperspectral infrared (IR) sounders are widely used for measuring the atmospheric vertical distributions for weather forecasting and data assimilation in numerical weather prediction (NWP). However, the current hyperspectral infrared (IR) sounders have spatial resolutions ranging from 12 – 16 km, with future sounders improved to 4 km to 8 km, it is important to understand if the measurements from the current and future hyperspectral IR sounders can capturing the atmospheric moisture gradient, especially during mesoscale scale weather events. Using measurements from three AHI (Advanced Himawari Imager) water vapor absorption channels, different hyperspectral IR sounder resolutions are simulated for sub-footprint moisture gradient analysis, it is clearly shown that the current IR sounders cannot fully capture the small scale water vapor gradient, especially over land and in the pre-convection environment, while the future hyperspectral IR sounders such as MTG IRS with 4 km spatial resolution can capture such small scale moisture gradient for regional applications. Also the high spatial resolution IR sounders provide more clear sky observations for data assimilation and other applications.

15p.03 Humidity sensitive Radiances and constrained bias correction in the DWD System
Presenter: Robin Faulwetter, DWD

In this poster the most recent updates of the assimilation of humidity sensitive radiances in the DWD operational system are presented. An update of the cloud detection scheme increased the number of assimilated MW humidity data noticeably. Most forecast scores were improved by this update. However, an upper-tropospheric tropical humidity bias of the system was reinforced. We found that this is due to a positive feedback loop between model bias and radiance bias correction. In order to break this feedback loop and to diminish the upper-tropospheric tropical humidity bias we introduced a constrained bias correction for the uppermost ATMS and MHS humidity sounding channels. Against this background the implementation of MWHS-2 in our system is problematic because its biases are quite different than the MHS/ATMS biases. The above-mentioned upper-tropospheric tropical humidity bias would be reinforced again, if we were assimilating MWHS-2 similarly to ATMS/MHS with a constrained bias correction. A solution to this problem is presented here. This so-called "offset bias correction" is a descendant of the constrained bias correction.

15p.04 What is the real benefit of assimilating IASI within the Météo-France global model ARPEGE?
Presenter: Nadia Fourrié, CNRM, Météo-France & CNRS
Co-Authors: Olivier Audouin, Philippe Chambon, Nadia Fourrié, Vincent Guidard

Instruments (imagers, sounders, or radar) on board satellites are nowadays the most important data providers to build the initial conditions of NWP models. Among these, infrared hyperspectral sounders on board polar orbiting satellites, such as IASI or CrIS, provide information on temperature and moisture profiles with good precision and good vertical resolution. Among many channels available on this type of instruments, those assimilated for NWP are channels sensitive to different parameters, such as temperature, water vapor or ozone. An OSE (Observation System Experiment) type study (Chambon et al. 2022) has been conducted to determine the relative importance of the IASI instrument (among other observations) in the quality of the forecast for the Météo-France global model ARPEGE, measured by objective scores. Overall results will be presented with a focus on the Infrared instruments. A more detailed experiment is conducted to evaluate the relative importance of IASI channels sensitive to temperature, ozone and water vapor. In order to make the best use of their data, the interchannel correlation of observation errors is taken into account in the form of an observation error covariance matrix, noted R. This matrix is estimated in the assimilation Météo-France system using the Desroziers diagnostic. This presentation shows the importance of updating this matrix when important model evolutions are implemented. In particular, the very positive impacts on the quality of forecasts made by the ARPEGE model when the error correlation matrices for the two sounders IASI and CrIS are updated are shown.

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15p.05 Preparing the assimilation of IASI-NG within the Météo-France global model ARPEGE using an OSSE framework

Presenter: Nadia FOURRIE, CNRM Meteo-France and CNRS (for Robin Marty)
Co-authors: Thomas Carrel-Billiard, Louis Rivoire, Nadia Fourrié, Olivier Audouin, Philippe Chambon

IASI-NG is the successor of the IASI hyperspectral infrared sensors developed by CNES and currently flying onboard the EUMETSAT MetOp satellites. IASI-NG will fly onboard the MetOp Second Generation satellites, to be launched in 2025. It features double the resolution, and half the noise levels of IASI leading to an overall better vertical resolution. IASI-NG data will be used for global and regional forecasting, atmospheric composition studies and climatology. In order to prepare the assimilation of the new instrument's data in operational forecasts, an observation system simulation experiment (OSSE) is designed using the ARPEGE 4D-Var system of Meteo-France. It allows us to prepare the assimilation system for IASI-NG observations before real IASI-NG observations are assimilated, and to assess the quality of the new observational data. The OSSE consists of several experiments: First, a nature run is computed which is a long forecast with no data assimilation that serves as a known truth of the atmospheric state. This forecast needs to be different but physically coherent with what is observable in reality, and the validation of the nature run is explained in this presentation. Secondly, we sample the nature run to simulate observational data (e.g. conventional data, microwave sounding data, infrared imagers onboard geostationary satellites, etc) which will be assimilated along the IASI-NG instrument. A set of observations without IASI-NG will be used as the reference, and a set with IASI-NG will be compared to it. The initial set up for IASI-NG will consist in using the channel selection performed by Vittorioso et al. (2021), a tuned cloud detection from McNally and Watts (2003) scheme as well as a dedicated observation error covariance error matrix taking into account interchannel correlation errors. Lastly, the simulated observations are assimilated in a numerical experiment reproducing the operational forecast system. Using this setup, we compare the quality of the analysis and the forecast with and without the new instrument's data, in our case IASI-NG.

15p.06 Impact Assessment of Himawari-8 AHI radiance assimilation and VarBC application in the ACCESS-C model

Presenter: Nahidul Hoque Samrat, Bureau of Meteorology
Co-authors: Andy Smith, Jin Lee, and Fiona Smith

The Bureau uses the JMA radiance product from the Himawari-8 AHI in the global operational system. However, the regional scale model does not yet assimilate these high-resolution observations. This study focuses on the assimilation of full spatial resolution AHI into the Bureau's hourly cycling high-resolution regional NWP system (ACCESS-C), which employs four-dimensional variational data assimilation (4D-Var). We have carried out an experiment over the ACCESS-C Sydney Domain from Feb-April 2020 to assess the impact of assimilating AHI data in the regional model. We also conducted additional experiments to investigate independent radiance bias correction for the limited area model (ACCESS-C). Currently, the operational ACCESS-C system uses variational bias correction (VarBC) coefficients from the global model, ACCESS-G. We assessed the impact of applying independent VarBC for the limited area model compared with the operational bias corrections. We intend to implement the full resolution AHI radiances in ACCESS-C when operational schedules allow, and it will form the core of the satellite radiance assimilation in our new hourly Australia-wide analysis, the National Analysis System (NAS).

15p.07 The revival of L2 assimilation. Radiances or profiles? That is the question!

Presenter: Dorothée Coppens, EUMETSAT (for Tim Hultberg)
Co-authors: Kirsti Salonen, Thomas August

In the early days of satellite data assimilation, the information on temperature and humidity from atmospheric sounders was assimilated in the form of retrieved profiles. This soon led to problems because of the inherent limited vertical resolution of the retrieved profiles, which damaged the fine scale vertical structures of the NWP model profiles. It became clear that an observation operator was needed to transform the model profiles into an alternative representation excluding vertical structures, which do not influence the measured radiances. Thus, the assimilation of L1 radiances using a radiative transfer forward model as observation operator was introduced and became the dominant approach. The alternative, more direct, approach of representing the profiles as coordinates with respect to a truncated basis spanning only the broader vertical structures which are actually observed by the sounder, was hardly considered. But following a paper in 2012 by Migliorini where the equivalence of L2 and L1 assimilation, in certain conditions, was demonstrated, there has been a renewed interest in L2 assimilation. In a recent EUMETSAT study performed by ECMWF, temperature and humidity profiles, retrieved from IASI observations with the piecewise linear regression (PWLR) machine learning approach, were assimilated using observation operators based on the averaging kernels of the retrievals. After some tuning, a positive impact, similar to, but not quite as high, as for the assimilation of radiances was achieved.

We think, that these promising first results can be further improved and that L2 assimilation is an interesting alternative because it avoids some of the drawbacks associated with the use of a radiative transfer model as observation operator - in particular, the dependency of further geophysical parameters which are not part of the NWP model, as for example surface emissivity, trace gases and the part of the profiles above the model top. Errors in these parameters are problematic because they are not random and have temporal and spatial structure. L1 assimilation is mostly restricted to clear sky (or channels peaking above the cloud top), because the cloud radiative transfer is challenging, whereas the PWLR retrievals are able to extract temperature and humidity information in partly cloudy scenes, which can be fed into the NWP models without the need to model the clouds. The L2 scene dependent observation error covariance can be incorporated in the observation operators, and although some additional tuning was done in the study with ECMWF, we believe that the difficulties of deriving a suitable observation error covariance matrix, which are sometimes observed for L1 assimilation, can be alleviated with L2 assimilation. This presentation will elaborate further on the principles of the assimilation of the PWLR retrieved profiles as well the experiences gained in the study and further, future or ongoing, experiments to consolidate the approach.

15p.08 Improving CrIS Infrared Assimilation in the GEOS Atmospheric Data Assimilation System
Presenter: Bryan Karpowicz, University of Maryland Baltimore County, GESTAR II, NASA Goddard Global Modeling and Assimilation Office

CrIS has long been an integral part of the global observing system in NWP. While CrIS has shown an improvement in forecast skill owing to direct assimilation of observed radiances, it has not had as strong an impact in GEOS atmospheric data assimilation system (GEOS-ADAS), or in the GDAS/GFS data assimilation system. Both systems utilize the Gridpoint Statistical Interpolation analysis system (GSI), and the same cloud detection scheme for all hyperspectral sounders and is suboptimal for CrIS. At GMAO, we have recently observed failed cloud detection has resulted in some strong degradation in Forecast Sensitivity Observation Impact (FSOI). These channels typically peak in the lower Stratosphere but have sensitivity into the upper troposphere making them sensitive to cloud. Some short-term mitigation strategies will be discussed, along with some more long-term strategies. Given the difficulty detecting clouds in these channels, and the recent success of Jones et al. (2021) assimilating Stratospheric channels in the 4.3 µm shortwave infrared (SWIR) band into the GDAS/GFS, replacing problematic longwave Stratospheric channels with select SWIR channels may provide a better sounding in the lower stratosphere. The hypothesis here is that sharper peaking weighting functions which may be more sensitive to the lower stratosphere and less sensitive to clouds in the troposphere. Observing system experiments using the GEOS-ADAS will be used to test this hypothesis, and are discussed.

15p.09 Assimilation of HY-2B SMR radiance observations using GRAPES 4DVAR at CMA
Presenter: ZeTing Li, Center for Earth System Modeling and Prediction of CMA
Co-authors: Wei Han

Early-morning (EM) satellite not only improves and enriches the existing modern meteorological operational observation system but also effectively supplements the shortage of satellite observation in the 6-h assimilation window, providing a significant contribution to the prediction of the northern and southern hemispheres. However, only a few satellite observations are available in early-morning orbits. Haiyang-2B (HY-2B), as the second ocean dynamic environment monitoring satellite, is operating in EM orbit with a local equator crossing time at 6:00 a.m. (descending). Currently, the Scanning Microwave Radiometer (SMR) onboard the HY-2B satellite is the only microwave imager operating in the EM orbit for civil use, which could effectively supplement the shortage of satellite observation in the 6-h assimilation window. Here, it is the first attempt at the direct assimilation of the HY-2B SMR radiance data in the global forecast system for the Chinese Meteorology Administration (CMA). We conducted a one-month cycling assimilation experiment for the period from 10 July 2021 to 10 August 2021. After assimilating the SMR radiance data, the global low-level humidity analysis was significantly improved relative to the control experiment, reduced by 5% in terms of root mean square error for the humidity analysis field at around 850 hPa. Furthermore, SMR observations provide some improvements to forecast scores in the Northern Hemisphere, along with benefits to the geopotential height and temperature fields around the low level of the tropical troposphere.

15p.10 Challenges in CrIS shortwave radiance assimilation
Presenter: Zhenglong Li, CIMSS/SSEC/UW-Madison
Co-authors: Agnes H. N. Lim, James A. Jung, Pei Wang, and Timothy J. Schmit

The Cross-track Infrared Sounder (CrIS) provides accurate hyperspectral temperature radiance measurements in both longwave (around 15µm) and shortwave (around 4.3µm) bands. The shortwave infrared (SWIR) radiances have more temperature sensitivity than longwave and are less contaminated by water vapor and ozone absorption. But their use in numerical weather prediction (NWP) models remains limited. One major challenge is the simulation of Non-Local Thermodynamic Equilibrium (NLTE) effects by radiative transfer models. Evaluations show substantial day/night discrepancies in the observation minus background (OMB) bias for CrIS SWIR radiance observations. Such discrepancies are caused by the limitations in NLTE radiance simulation by Community Radiative Transfer Model (CRTM) and cannot be eliminated by the variational bias correction scheme. This prevents the SWIR radiances from being assimilated due to large biases. Two limitations of CRTM are identified: a) it underestimates daytime NLTE effects by 0.76K, and b) it is incapable of simulating nighttime NLTE effects. An objective methodology has been developed to correct biases in daytime CRTM NLTE simulation. It is followed by applying a quality control procedure to remove SWIR radiances with poor CRTM NLTE simulation. Evaluations using CrIS measurements from both SNPP and NOAA20 show that the day/night discrepancies in the observation minus first guess bias have been much reduced after applying the objective bias correction scheme and the quality control procedure. The bias correction scheme and the quality control procedure will be implemented into the Gridpoint Statistical Interpolation (GSI). The impact on the assimilation of the CrIS SWIR radiances will be investigated.

15p.11 Updates on Clear-Sky Radiance Assimilation from Geostationary Satellites at NCEP
Presenter: Haixia Liu, Lynker@NCEP/EMC

The Clear-Sky Radiance (CSR) product is generated by averaging the brightness temperatures (BTs) for the infrared channels from the clear-sky pixels identified by a cloud mask in a processing segment. The percentage of the clear pixels and the standard deviation of the BTs from the clear pixels within the processing box are reported in the CSR product as well. National Centers for Environmental Prediction (NCEP) has been actively assimilating the CSR data over the past several years in the global data assimilation system (GDAS) from the water vapor channels on several geostationary satellites, such as the ABI-GOES16 operated by the National Oceanic and Atmospheric Administration (NOAA), AHI-Himawari8 operated by Japan Meteorological Agency (JMA), and SEVIRI on two European geostationary satellites: MSG8 and MSG11. Modifications, however, need to be made in the GDAS to support the continuation of operational assimilation of the radiance observations from the geostationary satellites due to recent changes to the existing CSR products. Firstly, the SEVIRI CSR has been discontinued since October 5, 2022, which requires the development of a switch to use SEVIRI ASR. Secondly, the Himawari-8 will be replaced by Himawari-9, the second satellite in the series, on December 13, 2022, so efforts will be made to evaluate the AHI-Himawari9 CSR product and compare it with the AHI-Himawari8 product. The two products are currently provided in parallel for NWP centers to test in their systems. Lastly, GOES-18 (G18) is the third of the GOES-R series of geostationary weather satellites and the CSR data quality from ABI-G18 will be evaluated using the current operational Global Forecast System (GFSv16). The CSR assimilation experiment will then be conducted and its preliminary results of the data impact evaluation will be discussed in this presentation.

15p.12 Assimilation of Transformed Retrievals from IASI radiances at the Met Office: current results and future perspectives
Presenter: Stefano Migliorini, Met Office
Co-authors: Peter Levens

Satellite radiances make up for the vast majority of observations that are routinely assimilated at major numerical weather prediction (NWP) centres. Improvements in the use of these data has led to significant improvements in NWP forecast skill over the last thirty years. With the advent of hyperspectral sensors, capable of measuring infrared radiance emerging from the atmosphere over thousands of channels, data providers and NWP centres have been facing the challenges of distributing, monitoring and assimilating a considerable wealth of data. Forthcoming hyperspectral sensors such as IASI-NG and MTG-IRS will increase even further the amount of data to be considered for assimilation. In this poster we discuss the current results and the next steps for Transformed Retrievals derived from IASI data to provide a viable alternative to the assimilation of IASI radiance data in the Met Office operational data assimilation system. In particular, single cycle assimilation experiments show that temperature and humidity analysis increments from transformed retrievals are consistent with those obtained from assimilating the radiances directly. A summary of the results obtained as part of a EUMETSAT Research Fellowship at the Met Office are presented, as well as further and future developments and a discussion of key issues such as bias correction and random error quantification for producing and assimilating transformed retrievals in a consistent and effective way.

15p.13 Preparedness of the DA system for the assimilation of Microsat-2B MHS radiances at NCMRWF
Presenter: Indira Rani Sukumara Pillai, NCMRWF, Ministry of Earth Sciences, India
Co-authors: S. Indira Rani, Sumit Kumar, John P. George, V. S. Prasad

Megha-Tropiques (MT) was one of the successful Indo-French space missions in the low earth orbit of inclination 20° with continuous coverage over the Tropics. SAPHIR, a sounding instrument with 6 channels near the absorption band of water vapor at 183 GHz, was one of the payloads onboard MT designed to improve the sampling of the diurnal cycle of water vapor and the evolution of convective systems over the Tropics. Major global operational NWP centres have already explored the potential of SAPHIR in clear-sky and all-sky conditions. NWP community is in demand of SAPHIR like channels in the low earth inclined orbit with more repeativity over the Tropics. The International TOVS Working Group (ITWG)-NWP also recommends space agencies to launch future microwave missions operating on a similar low inclination orbit, following the successful use of the SAPHIR instrument. Indian Space Research Organization (ISRO) is planning an experimental mission for the 3D humidity profiling from surface to 12 km; as a follow on mission to SAPHIR. The proposed mission, Microsat-2B with an MHS will be launched in the 37° inclined low earth orbit at an altitude of 450 km and operates in the frequency band of 183±16.25 GHz, with a resolution of 2 km in the vertical and 10 km in the horizontal. NCMRWF is developing the assimilation capability of Microsat-2B MHS radiances in its NWP systems. This presentation briefly discusses the preliminary results from the pre-launch and (immediate post-launch, if available before ITSC-24) data assimilation experiments.

15p.14 Impact assessment of IASI temperature and humidity retrievals in the ECMWF system with scene dependent observation operators
Presenter: Kirsti Salonen, ECMWF
Co-authors: Thomas August, Tim Hultberg, Anthony McNally

EUMETSAT is producing forecast independent statistical retrievals of atmospheric temperature and humidity from IASI hyperspectral infrared radiances. This is done in preparation for the future product generation from MTG-IRS. Novelty of the product, provided in PC space, is to include scene dependent observation operators characterizing the vertical resolution of the retrieval information. The ECMWF system has been modified to enable active assimilation of the retrievals with their observation operators. Assimilation experiments in depleted observing system indicate significant positive impact on short-range forecasts with further improvements when using the retrievals also in cloud affected scenes. Assimilating all sky retrievals in depleted observing system has almost comparable impact to impact from IASI radiance assimilation. Impact assessment in full observing system is ongoing and the latest results will be reported in the conference.

15.01 What is a good mix of observations?
Presenter: Nancy Baker, Naval Research Laboratory
Co-authors: William C. Campbell, Hui Christophersen, Sarah A. King, Elizabeth A. Satterfield, Pat M. Pauley, Bailey R. Stevens, Rebecca E. Stone, Justin Tsu and Daniel P. Tyndall

In atmospheric data assimilation (DA), we often state that a “good mix of observations” is necessary to produce the initial conditions for skillful numerical weather prediction (NWP). But what is a good mix of observations, and how does this vary according to application, the forecast model and DA resolution and the level of sophistication of the underlying DA methodology? We examine these question from the perspectives of the current US Navy global NWP model with hybrid4DVar (NAVGEM/NAVDAS-AR) and the next generation Unified NEPTUNE NWP and DA system where the DA components (currently 3DVar) are being developed using the JCSDA's JEDI.As part of this study, we re-examine aspects of our observation selection, such as the channel selection and horizontal thinning of satellite radiances, generation of super-observations for Atmospheric Motion Vectors (AMVs), and temporal thinning for surface and aircraft observations. Should these thinning strategies vary by region, for example in the tropics vs. mid-latitude where the mass/wind balance isdifferent? To help answer these questions, we use a variety of diagnostic tools (observation sensitivity and impact (FSOI), background and analysis observation departures, analysis increments) and forecast skill metrics including fit to observations. In keeping with underlying a(TOVS) theme of ITWG, we will focus this presentation on the contributions of the ATOVS satellite series to the Global Observing System. JCSDA: Joint Center for Satellite Data Assimilation JEDI: Joint Effort for Data assimilation Infrastructure NAVDAS-AR: NRL Atmospheric Variational Data Assimilation System—Accelerated Representer NAVGEM: NAVy Global Environmental Model NEPTUNE: Navy Environmental Prediction sysTem Utilizing a Nonhydrostatic Engine DISTRIBUTION STATEMENT A: Approved for public release. Distribution unlimited.

15.02 Multi-year impact assessment of satellite observations in NCMRWF operational Numerical Weather Prediction (NWP) system
Presenter: Sumit Kumar, NCMRWF
Co-authors: John P. George

This paper provides a detailed overview of the status of the assimilation of microwave observations, and highlights recent relevant changes in the NCMRWF NWP system. NCMRWF assimilate radiance observations from 15 MW instruments, 5 hyperspectral IR sounders, and 8 geostationary satellites. Recently many instruments have been added into operational NWP system such as NOAA-20, MetOp-C, MWRI, FY3D, GPSRO (Spire, Cosmic2, GeoOptics, KompSat, PAZ), as well as capabilities of microwave instruments are enhanced to include all-sky observation into assimilation. The present work presents forecast sensitivity to observation impact (FSOI) results and thereby aims at providing an expanded view of the contribution of various observing systems for the three years period from 2019 to 2020. The impact of operationally assimilated various microwave sounders on NWP forecast. are aggregated channel-wise and instrument-wise for the three years period. The assessment here finds, that: satellite observations play a major role (~75%) in reducing forecast error with LEO satellite, especially the microwave instruments, contributing the most. Further, in spite the multiplatform measurement each microwave instruments seems to contribute significantly to short forecast error reduction.

15.03 Assimilation of FengYun Satellite Data in CMA-GFS Using Advanced Radiative Transfer Modeling System (ARMS)
Presenter: Fuzhong Weng, CMA Earth System Modeling and Prediction Centre
Co-authors: Jun Yang, Yang Han, Hao Hu, Peiming Dong, and Yining Shi

A fast and accurate radiative transfer model is required for assimilation of satellite data into numerical weather prediction model. In past many years, RTTOV has been operationally used in CMA global forecast system (GFS) for assimilating NOAA, EUMETSAT and FengYun (FY) satellite data. Since in the coming decade, more advanced instruments will be launched onboard Chinese FY satellites, CMA has developed its new generation of fast radiative transfer model (ARMS) to expand RTTOV capabilities and accelerate uses of FY satellites. For FY instruments, the fast atmospheric transmittance models are developed, covering visible, infrared, microwave and terahertz wavelengths for various applications. The new scattering data bases are also generated from the general T-matrix method, covering aerosols, cloud and precipitation hydrometeors. From the two-scale ocean roughness theory, the polarized bidirectional reflection distribution function (PBRDF) matrix is derived to couple with the vector discrete ordinate radiative transfer (VDISORT) solver in ARMS through the lower boundary condition. PBRDF is also used for the observation operator for active sensors such as scatterometers and reflectometers. Our assessments show that ARMS forward and adjoint performances are similar to or better than other observation operators in terms of its accuracy and computational speed and can meet the operational requirements. In 2022, ARMS 1.2.0 has been successfully integrated into CMA-GFS 4dvar system and its full impacts on global forecasts are being evaluated. ARMS 1.1.2 is also used as observation operator in the 1dvar global scene dependent atmospheric retrieval testbed (GSDART). GSDART is running at CMA National Meteorological Center to generate the typhoon precipitation, warm core structures in Pacific region from FY-3, NOAA and METOP satellite microwave sounders.

15.04 FY-3E Microwave Sensors Evaluation at ECMWF
Presenter: Liam Steele, ECMWF
Co-authors: David Duncan, Niels Bormann

FY-3E holds two microwave sounders: MWHS-2 and MWTS-3. Here we evaluate both sounders in the ECMWF all-sky assimilation system using RTTOV-SCATT v13.0, first by monitoring departure statistics and then by performing assimilation experiments. MWTS-3 holds two new window channels compared to its predecessor, allowing it to be used in all-sky conditions following the methodology derived for all-sky AMSU-A. MWHS-2 has been assimilated at ECMWF since 2016 on the FY-3C and FY-3D platforms, using its 118 GHz channels 2-7 and all 183 GHz channels 11-15 over most surfaces. Any early results on assessing the NWP impact of the early morning orbit of FY-3E will be presented. Analysis of cloud-free departures indicates that MWHS-2 channels have a more consistent bias structure than on FY-3C and -3D. Its 183 GHz channels exhibit similar performance in std(O-B) while its 118 GHz channels perform considerably better than on predecessor sensors, a function of improved sensor noise characteristics for this band. MWTS-3 departures show some bias structures that require further examination. These include land/sea contrast in high-peaking channels, scan position biases, and monotonically increasing stratospheric channel biases that may be indicative of spectral shifts. Striping and sensor noise in some mid-tropospheric channels are improved relative to MWTS-2 but remain short of AMSU-A or ATMS performance levels. Assimilation trials with MWHS-2 are promising, with significant improvements in std(O-B) seen for humidity- and wind-sensitive independent observations. Medium-range forecast impact of FY-3E MWHS-2 will also be presented.

Session 16: International
Session 17: Future Systems

16p.01 International Data Exchange and the transition to WMO's WIS 2.0
Presenter: Simon Elliott, EUMETSAT

In the coming years WMO will perform a phased introduction of its next generation information system (WIS 2.0). This brings with it a change of paradigm for both data providers and consumers; it also presents a number of opportunities for the ATOVS community. This talk describes the concepts and overall architecture of WIS2.0, and shows how it has been successfully used to demonstrate the exchange of hyperspectral sounder and geostationary imager data.

16p.02 withdrawn

17p.01 IASI-NG Program: General Status Overview
Presenter: Francisco BERMUDO, Centre National d'Etudes Spatiales
Co-authors: Eric Jurado, Antoine Penquer, Clémence Le fèvre1, Julien Nosavan

CNES is in charge of developing the New Generation of Infrared Atmospheric Sounding Interferometer (IASI-NG), a key payload element of the second generation of European meteorological polar-orbit satellites (MetOp-SG) developed by ESA, dedicated to operational meteorology, atmospheric composition, and climate monitoring. IASI-NG will continue and improve the IASI mission in the next decades (2025-2045) with notable improvements on performances. The performance objective is mainly a spectral resolution and a radiometric error divided by two compared with the IASI first generation ones. The instrument measurement technique is based on an innovative wide field Fourier Transform Spectrometer (operating in the 3.5 - 15.5 µm spectral range) based on an innovative Mertz compensated interferometer to manage the so-called self-apodisation effect and the associated spectral resolution degradation. For the IASI-NG program, a cooperation agreement is implemented between CNES and EUMETSAT. Under this agreement, CNES has oversight responsibility for the development and procurement of the instruments, the Level 1C data processing software (L1C POP) and the IASI NG Technical Expertise Centre (IASTEC) in charge of the in-flight calibration and validation activities, and continuous performance monitoring.

EUMETSAT is in charge of developing the EPS SG System and operating, archiving and distributing IASI-NG data to the users. The paper reports on latest status of IASI NG program, with specific focus on these new highlights. Further two years of instrument integration and tests, the first flight model of IASI-NG instrument has been delivered by CNES in fall 2022 and mounted onto the Metop SG A1 PFM satellite platform. Further to the success of IASI-NG System Critical Definition in 2021, CNES achieved the definition and the validation of the Level 1 C data Processing algorithms and progressed on the development of the L1C Operational processor (L1CPOP) . A L1CPOP V1 preliminary version has been provided to EUMETSAT for integration in the PDAP (Payload Data Acquisition and Processing). A L1CPOP V2 version including the full algorithm processing is under development for completion expected end of 2023.

17p.02 withdrawn

17p.03 IASI-NG mission performances and ground segment development status
Presenter: Eric Jurado, Centre National D'Etudes Spatiales
Co-authors: Clemence Le Fèvre, Quentin Cèbe

IASI-NG system, developed under CNES responsibility, aims at producing data for meteorological and atmospheric chemistry user's community. It is part of the EUMETSAT EPS-SG system. It is composed of a space segment and a ground segment. The space component is the IASI-NG instrument, one model flying on each of the three METOP-SG A that will be launched between 2025 and 2039. The ground segment, consists in the IASI-NG Level 1 Processor, the so-called L1CPOP, which is integrated in EPS-SG Payload and Data Acquisition Processing ground segment, and in the IASI-NG Technical Expertise Center (IASTEC), in CNES premises, dedicated to performance monitoring of both space and ground segments, anomaly investigation, and development of improved processing software. In the frame of the cooperation agreement with EUMETSAT for IASI-NG, CNES is responsible for ensuring the functionality and performances of both the IASI-NG instrument flying aboard METOP-SG and the L1C products disseminated through EUMETSAT system. In the last months, the IASI-NG system has moved through several major steps, such as:-First estimation of both the mission performances using the measurements of the instrument performance tests under vacuum, -First end-to-end validation of the ground processing algorithms chains using the Infra-Red Interferometer Simulator (IRIS), -Development of the first L1CPOP versions to be delivered to EUMETSAT,-Start of development of the L1C ground processor for local users and of the IASI-NG Technical and Expertise Center (IASTEC). In the coming months, some very important milestones will come. A performance test under vacuum will be performed at satellite level and it will enable to check that the satellite configuration does not impact IASI-NG performances, in particular for what concern microvibrations. The first complete L1CPOP version with the full set of algorithms will be provided to EUMETSAT and the first system tests with EUMETSAT and involving IASTEC will be executed soon. The poster will address a presentation of the status on these different topics, including a first assessment of the main mission performances (radiometric noise, spectral and radiometric calibration…) and the current design of the algorithm processing chains.

17p.04 JEDI Skylab Observation Evaluation and Use With Emerging Sensors
Presenter: Benjamin Ruston, JCSDA
Co-authors: Benjamin Johnson, Fabio Diniz, Greg Thompson, Patrick Stegmann, Hui Shao, François Vandenberg, Hailing Zhang, and Linsey Hayden

The Joint Center for Satellite Data Assimilation (JCSDA) and its partners recently introduced an essential tool to bridge research and operations, the Joint Effort for Data Assimilation Integration (JEDI) Skylab application. This tool provides a demonstration application of an integrated Earth System DA capability (currently, starting with atmosphere, ocean, sea ice, land surface, and aerosols) via JEDI. A variety of observing systems are continuously being interfaced with JEDI across the multiple components of the Earth System. As this tool is maturing, new observing systems are being developed. The JCSDA JEDI OBS team is the primary developer of the Unified Forward Operator (UFO) component of the JEDI system. In this component the Community Radiative Transfer Model (CRTM) is included for use with a large range of environmental monitoring sensors. We will show results from the JEDI Skylab applications, for a range of sensors to best cover the range of technologies used by the JCSDA partners. We will show evaluation techniques which have been developed, to monitor and investigate observation impact. An ability to compare the response of system changes in the observation statistics will also be demonstrated. Lastly, the use of CRTM for a range of new emerging sensors will be shown (e.g. TROPICS, TEMPEST and COWVR). The ability to rapidly demonstrate and easily configure the quality control, observation error specification and bias correction via external configuration is being used as a vehicle to decrease the timeline for operational implementation. A goal for the JCSDA with the JEDI Skylab system is to help create configurations for these new sensors for the partner organizations.

17p.05 A Microwave Sounding Mission for Australia
Presenter: Fiona Smith, Bureau of Meteorology
Co-authors: Fiona Smith, Nahidul Hoque Samrat, Agnes Lane

The Bureau of Meteorology is dependent on satellite observations from international data providers. In 2022, the Bureau began working with the Australian Space Agency to design three satellite missions to support our operational requirements. The missions were chosen during 2021 via a workshop at the Australian National Concurrent Design Facility at the University of New South Wales Canberra Space. One of the instruments chosen is a Microwave Sounding Mission, due to the criticality of microwave sounding data for Bureau numerical weather prediction (NWP) performance. This poster will summarise the user requirements for microwave sounding to meet our future NWP and tropical cyclone nowcasting and monitoring needs, and will provide an early overview of the proposed mission to meet those requirements.

Session 15: Data Impact Studies (continued)

15.05 Channel Selection and Apodization considerations for Hyperspectral Infrared Sounder Data
Presenter: David Tobin, CIMSS/SSEC/UW-Madison

Cross-track Infrared Sounder (CrIS) data that is distributed to NWP centers for radiance data assimilation typically has an added spectral smoothing, or apodization, that is applied. Opposed to the operational product which is unapodized, this apodization correlates the signal and noise among neighboring, adjacent spectral channels. The apodization is completely reversible, and the original full information content is recoverable, if adjacent channels are used in the analysis, either by a direct exact reversal of the apodization in spectral or interferogram space, or by properly specifying the apodization coefficients in a noise covariance matrix. However if adjacent channels are not included, and the apodization is not directly or indirectly reversed, then the CrIS data is essentially reduced to that of a broadband (e.g. HIRS) sensor. Despite over ten years of in-orbit CrIS data availability, this result is evident in several prominent center results for real CrIS data. It is also seen in studies of future GEO hyperspectral sounders, greatly underestimating the potential impact of such data. This presentation will review the properties of unapoadized and apodized CrIS data, and present methods for realizing the full information content of the data.

15.06 Impact of satellite data in a regional reanalysis system
Presenter: Per Dahlgren, MET Norway

The Copernicus Arctic Regional Re-Analysis (CARRA) is a regional reanalysisconvering the years 1991 until June 2021. CARRA is produced with a non-hydrostaticmesoscale NWP model, AROME, on a grid mesh with 2.5km spacing and upper-airobservations are assimilated with a 3D-Var technique. CARRA assimilates satellite data from a variety ofsources such as microwave radiances from the MSU, AMSU-A, AMSU-B and MHSinstruments and infrared radiances from IASI. Data derived from satellitemeasurements are also used like AMV and Scatterometer as well as bendingangles from GNSSRO.This talk will present results from data denial observation impact experimentsdone with the CARRA system using the east domain for two separate months. In the first impact experiment period, December 2016, ATOVS (AMSU-A, AMSU-B, MHS),IASI, SCATT, AMV and RO were removed from the system and the impact assessed. Inthe second period, August 2019, ATOVS, IASI and SCATT were denied.

15.07 DBNet data reception, processing and assimilation at NCMRWF
Presenter: Indira Rani Sukumara Pillai, NCMRWF, Ministry of Earth Sciences, India
Co-authors: V. S. Prasad, D. Srinivas, B. P. Jangid and S. Indira Rani

NCMRWF receives real time low earth orbiting satellite operational DBNet data in level-1b format through GTS. This includes the DBNet Regional ATOVs Re-transmission Service (RARS) data from Australia, Korea, Japan, and Hong Kong. NCMRWF also receives EUMETSAT's ATOVS Retransmission Service (EARS) data through EumetCast. Both RARS and EARS are routinely assimilated in the NCMRWF global and regional operational models. Due to the non-functionality of IMD’s existing High Resolution Picture Transmission (HRPT) stations, NCMRWF has taken the initiative to access, process and assimilate the data from DBNet stations installed for Ocean (INCOIS, Hyderabad, India) and remote sensing (NRSC, Hyderabad, India) services. INCOIS DBNet receives data from NOAA-15, NOAA-18, NOAA-19, MetOp-B, and MetOp-C satellites, while the NRSC station receives data from NOAA-20 (JPSS-1) and Suomi-NPP satellites. Arrangements are made at NCMRWF for the regular reception of level-0 data from INCOIS and NRSC DBNet stations within a minimum latency of 30 to 60 minutes. In-house applications are developed to process these level-0 DBNet data and generate level-1b, level-1c, and level-1d data. Open source software and packages, ATOVS and AVHRR Pre-processing Package (AAPP), MetOpizer, and Community Satellite Processing Package (CSPP) Sensor Data Record (SDR) are installed in NCMRWF High Performance Computing System, MIHIR HPCs to process the level-0 data. NCMRWF data assimilation systems use the processed level-1b data. In addition to the processing of level-0 data into different levels, NCMRWF also encodes the INCOIS and NRSC DBNet data into the WMO DBNet BUFR for the possible distribution through GTS. This paper discusses the reception, processing and the assimilation of DBNet data in the NCMRWF DA systems.

15.08 On Expanding the Use of CrIS Observations in NOAA's Global Systems: What Has Been, and Still Needs to Be, Done

Presenter: Erin Jones, UMD CISESS at NOAA/NESDIS/STAR
Co-authors: Kevin Garrett, Kayo Ide, Chris Barnet, Nadia Smith, Bryan Karpowicz, Yingtao Ma, Sid Boukabara

The operational data assimilation of hyperspectral infrared (IR) sounders in NOAA's global systems has historically heavily relied on the use of longwave (LW) channels from the Infrared Atmospheric Sounder Interferometer (IASI) and the Cross-track Infrared Sounder (CrIS). Though some channels from other bands are operationally for each of these sensors, past work to optimize the assimilation of hyperspectral IR data has largely focused on the performance of LW observations in the global system. Recent pushes at NOAA to both investigate the impact of potential future hyperspectral IR sounders on board small platforms (smallsats) and to maximize the benefit of existing hyperspectral IR sounders by using all available bands – LW, midwave (MW), and shortwave (SW) – have led to efforts at NOAA, and now other centers, to research the use of SW channels and the expanded the use of MW channels from hyperspectral IR sensors in global data assimilation and numerical weather prediction. The CrIS instrument is an existing hyperspectral IR sounder with relatively high spectral sampling and relatively low instrument noise that will continue to be in service for many years to come. NOAA's Center for Satellite Applications at Research (STAR) and University of Maryland CISESS have therefore been focused on investigating and assessing the impacts of greater use of data from the CrIS instrument in the NOAA Global Data Assimilation System / Finite-Volume Cubed-Sphere Global Forecast System (GDAS/FV3GFS). CrIS, which samples observations at a 0.625 cm-1 spectral resolution in LW (650 – 1095 cm-1), MW (1210 – 1750 cm-1), and SW (2155 – 2550 cm-1) bands, is currently flying on board the Suomi National Polar-orbiting Partnership (S-NPP) and NOAA-20 (N20) satellites, and is planned to fly on future Joint Polar Satellite System (JPSS) missions. Of CrIS's 2211 channels, a subset of 431 are ingested in to NOAA's operational GDAS/FV3GFS, and of these, only 92 LW channels and 8 MW channels are currently operationally assimilated from N20 CrIS, where all three CrIS bands continue to be functional. The use of SW channels has previously been avoided due to increased instrument noise in the SW region of the spectrum, and due to issues related to non-local thermal equilibrium (NLTE) and solar reflectance (e.g. sun glint and bidirectional reflectance). Use of additional MW channels has also previously been avoided at NOAA, likely due to the challenges inherent in assimilating observations that are sensitive to water vapor. To be discussed here are the steps that have been taken at NOAA STAR to address the challenges that have, up until now, deterred many operational NWP centers from relying too heavily on hyperspectral IR observations outside of the LW part of the spectrum. The methods currently used in a research to operations (R2O) framework to assimilate these observations will be outlined, and results from observation system experiments (OSEs) regarding the impacts of these observations on model analyses and forecasts will be presented. Also to be discussed are the work that is planned to further investigate the use of non-LW hyperspectral IR bands in global data assimilation, as research that still needs to be done at NOAA, and other operational NWP centers, to take full advantage of the benefits that may be had from assimilating MW and SW data from hyperspectral IR sounders.

15.09 Studying the Interaction between NWP Models and Data Assimilation with Observing System Simulation Experiments – Case Studies with SEVIRI Data in ICON-LAM
Presenter: Thomas Deppisch, Deutscher Wetterdienst (DWD)
Co-authors: Liselotte Bach, Annika Schomburg, Christina Köpken-Watts, Christoph Schraff

All-sky data assimilation of radiances (visible and thermal) from the SEVIRI instrument (MSG) in the limited-area model of DWD is currently in the state of operationalization. Implementing these observations into an operational data assimilation system has proven particularly challenging due to the complex information they provide about the atmospheric state. Systematic and conditional biases arising from the interaction of data assimilation and model interactions pose additional problems: For example, various data assimilation experiments with the operational setup at DWD have demonstrated that assimilating reflectances in the visible spectral range of Meteosat SEVIRI reduce the overabundance of high clouds in the limited-area model over Central Europe (ICON-D2). Consequently, biases in the forecast of global radiation and 2m temperature are lessened while an already existing dry bias in the boundary layer is amplified. Reducing the moisture in the boundary layer, however, affects the skill of convective precipitation forecasts in a negative way. Retuning the parameterization of sub-grid scale clouds and their coupling to convection has softened this issue in the ICON model. In order to study such interactions in a more controlled environment, we have developed a setup for Observing System Simulation Experiments (OSSEs) that is close to the operational system used for regional data assimilation system at DWD (KENDA). Within this OSSE setup, we investigate the impact of observations that are generated from a known atmospheric state. We thus can assess the consistency between the analysis derived from an observation and the atmospheric state from which the observation was generated. This knowledge of the true atmospheric state is especially helpful in the context of observations from satellite imagers where the corresponding forward operators are sensitive to sub-grid scale parametrizations, e.g. the diagnostic cloud cover scheme. With these tools at hand, we strive for a better understanding of the atmospheric processes triggered by all-sky assimilation of radiances, especially in the presence of convection. We present results from our research on observations from SEVIRI and their impact on the regional NWP system at DWD compared to radar and conventional data. Our research comprises case studies covering few days in convective situations as well as experiments for more extended periods. Special emphasis is laid on the influence from different observational systems on prognostic model variables such as moisture and temperature. We furthermore evaluate how this influence affects the skill of short-range weather forecasting at the convective scale.

Session 16: International

16.01 WMO Unified Data Policy and Core Satellite Data
Presenter: Heikki Pohjola, WMO

The WMO Space Programme Office, which was initiated by the fourteenth World Meteorological Congress in 2003 with the aim to increase the effectiveness and contributions from satellite systems to WMO Programmes and to coordinate the related environmental satellite matters and activities. Its objectives are achieved through strong partnership with the WMO expert teams, Coordination Group for Meteorological Satellites (CGMS) and the Committee on Earth Observation Satellites (CEOS) and their respective working groups and subsidiary bodies. WMO congress has recently approved new WMO Unified Data Policy to help the WMO community strengthen and better sustain monitoring and prediction of all Earth-system components. The new data policy resolution distinguishes between “core data”, for which data exchange is considered mandatory, and “recommended data”, for which the exchange is strongly recommended. In this presentation an outcome of the work towards defining the core satellite data for Earth Observation and Space Weather will be presented.

16.02 Status of the Direct Broadcast Network for globally coordinated real-time acquisition, processing and fast delivery of satellite direct readout data, coordinated by the World Meteorological Organization
Presenter: Mikael Rattenborg, WMO Space Programme
Co-authors: Zoya Andreeva (WMO)

The Direct Broadcast Network (DBNet) is a highly successful collaborative undertaking of the World Meteorological Organization and its Members. The DBNet system provides fast acquisition, processing and delivery of satellite products from direct readout data, primarily for Numerical Weather Prediction (NWP) applications with stringent timeliness requirements. Since about 10 years, sounding data from the ATOVS suite of instruments has been acquired by receiving stations around the globe, which has improved the availability and impact of satellite sounding data on short-term regional and global NWP. DBNet is has been extended to cover the acquisition of advanced satellite sounder data from instruments such as IASI on METOP and CrIS and ATMS on Suomi-NPP and NOAA-20. Key challenges for the coming years are the support for JPSS-2, Metop-SG and FY-3. To support DBNet operators in this process, a new flexible processing architecture is being implemented, allowing local, centralized as well as cloud processing. The paper will present the DBNet concept and status. DBNet also provides opportunities for local applications of direct readout data, examples of these will be provided.

16.03 Research Highlights from the International Precipitation Working Group (IPWG)
Presenter: Philippe Chambon, CNRM, Météo-France & CNRS
Co-authors: Christian Kummerow, Takuji Kubota, Joe Turk, Viviana Maggioni

The International Precipitation Working Group (IPWG) is a permanent International Science Working Group (ISWG) of the Coordination Group for Meteorological Satellites (CGMS), co-sponsored by CGMS and the World Meteorological Organization (WMO). IPWG provides a forum for the international scientific community to address issues and challenges related to satellite-based precipitation retrievals. Through partnerships and biennial meetings, the group promotes the exchange of scientific and operational information between the producers of precipitation measurements, the research community, and the user community. Specifically, IPWG furthers the refinement of current estimation techniques and the development of new methodologies for improved global precipitation measurements, together with the validation of the derived precipitation products with ground-based precipitation measurements. IPWG promotes international partnerships, provides recommendations to the CGMS, and supports upcoming precipitation-oriented missions. This presentation will highlight some of the latest research findings from the IPWG working groups and presented at the recent meeting which took place in Colorado in June 2022.

16.04 Report from CGMS
Presenter: Mikael Rattenborg, WMO (for Mitch Goldberg)

No abstract.

Session 17: Future Systems

17.01 Initial Validation of the Hyperspectral Microwave Sounder
Presenter: Kristen Bathmann, Spire Global
Co-authors: Manju Henry, Kai Parrow-Souchon, Mo Belal, Jereon Capaert, Steve Parkes, Vladimir Irisov, and Dusanka Zupanski

The Hyperspectral Microwave Sounder (HyMS) is a new remote sensing instrument, capable of sampling the microwave spectrum near the 60 GHz, 89 GHz, and 183GHz absorption lines, at very high spectral resolution. Current state of the art microwave sounders have up to a maximum of 30 channels, which is insufficient to estimate the geophysical state of the atmosphere from space. The HyMS has close to 1000 channels in both the water vapour and temperature bands. When flown in-orbit, this passive sounder can therefore observe the vertical structure of atmospheric temperature, humidity, and cloud features at a higher resolution as compared to traditional microwave sounders. HyMS will be of great benefit to numerical weather prediction and climate studies by providing more detailed vertical information in cloudy and precipitating scenes that the infrared cannot see, improved information on hydrometeors, and improved accuracy of retrieval products. NOAA/NESDIS recently funded Spire Global to develop and demonstrate the HyMS in-orbit sensor on a 16U satellite. This presentation will detail the validation efforts for the HyMS from both airborne studies and simulations of in-orbit demonstrations. The quality of temperature and humidity retrievals from the airborne studies will be assessed, as well the simulations of brightness temperature observations from the top of the atmosphere.

17.02 Status of NOAA's GeoXO Hyperspectral Infrared Sounder (GXS)
Presenter: Andrew Heidinger, NOAA/NESDIS/GeoXO
Co-authors: David Johnson, Zhenglong Li, Dan Lindsey, Joel McCorkel, Tim Schmit, David Tobin and Jim Yoe

With the Geostationary Extended Observations (GeoXO) Hyperspectral Infrared Sounder (GXS), NOAA will add to the growing number of hyperspectral infrared sounders in the GEO-RING. Slated for a first launch in the mid-2030s, the GXS will ride alongside a hyperspectral atmospheric composition sensor located at a central location over North America. The GXS will provide unique information of the vertical structure of moisture, winds, and temperature at high time and spatial scales. While still in the formulation stage, the GXS could provide two orders of magnitude more information over the legacy geostationary sounder. This presentation will provide information on the activities for the formulation of the GXS and user readiness. Specifically, summaries will be given about several studies that are employing various techniques to prove its utility to nowcasting and numerical weather prediction over North America.

17.03 An overview of EUMETSAT activities towards preparing users on the uptake of data from Meteosat Third Generation (MTG) and European Polar System - Second Generation (EPS-SG) missions

Presenter: Sreerekha Thonipparambil, EUMETSAT
Co-authors: Stephan Bojinski

EUMETSAT will launch the first of its next generation satellites, Meteosat Third Generation-I1 (MTG-I1) in December 2022. Following this, there are a series of satellite launches from the MTG and the EPS-SG programmes in the coming years. Both MTG and EPS-SG offer opportunities and pose challenges to the user community through the novelty of their observation missions as well as the enhancements in their heritage observation missions. EUMETSAT has established the User Preparation (UP) projects many years prior launch with the primary aim of supporting the users in an early uptake of the data from the heritage instruments thus ensuring a smooth transition and continuity of operations for the National Meteorological Services. Additionally, the project aims to support the users in realising the benefits from the enhanced capabilities of the heritage missions as well as the novel missions. The paper describes activities in the UP projects in each of the core themes of the project, namely (1) Test data and Format support, (2) Science support, (3) Training (4), User Information and Communication, and (5) Data Access. Through the MTGUP user group and the NWP Core User group, the UP projects maintain a communication channel with the EUMETSAT Member States and understand their progress in getting ready both technically and scientifically for the data from MTG and EPS-SG. The paper will give an overview of the test data from all observation missions that EUMETSAT has provided to users, mostly for format familiarisation but some with scientific representation. EUMETSAT also organised webinars on all MTG and EPS-SG observation missions providing technical and scientific awareness among the user community, the recordings of which are accessible for users from EUMETSAT webpage. In the training front, of particular interesting for the NWP community is the development of a web-based tool based on RTTOV and 1Dvar, which can simulate radiances and Jacobians for the current and future sensors as well as perform temperature and humidity retrievals. EUMETSAT also established severe storms testbed in collaboration with European Severe Storms Lab (ESSL) and aviation testbeds in collaboration with Finnish Meteorological Institute (FMI). The paper will also present the outcome of the three-day “EUMETSAT User Days” event in May-June 2022, bringing together the research community on discussing the research opportunities as well as identifying the challenges and gaps in realising the full potential of MTG and EPS-SG missions for application areas including NWP and Nowcasting among others. The paper will also discuss the baselines for data dissemination from both MTG and EPS-SG as well as preliminary information for direct broadcast users of EPS-SG data.