ITSC-25 ABSTRACTS

Thursday, 8 May 2025

Session 1: Coordination of satellite systems, operations and end-user support

1.01 User preparation for EUMETSAT's next generation sounding missions on MTG-S and EPS-SG

Presenter: Sreerekha Thonipparambil, EUMETSAT
Co-authors: Stephan Bojinski

EUMETSAT's next generation geostationary and polar satellite missions Meteosat Third Generation (MTG) and EUMETSAT Polar System- Second Generation (EPS-SG) are equipped with imaging and sounding observation missions that will provide inputs to earth system applications for the next two decades. In 2025, EUMETSAT is launching two satellites, MTG-S1 into the geostationary orbit in July 2025 and Metop-SG A1 into the polar orbit in September-November 2025. This paper will give an overview of the sounding missions on Metop-SG and MTG-S and how EUMETSAT's user preparation projects (MTGUP and EPS-SG UP) support the users for an early uptake of data. MTG-S is equipped with the hyperspectral Infrared Sounder (IRS) and offers for the first time the capability of sounding mission over Europe from a geostationary orbit, providing temperature and humidity profile data every 30 minutes. EPS-SG sounding missions offers continuity to all the EPS missions with advancements in terms of spectral, radiometric and geometric performances. The UP projects streamline the preparation activities along the five core themes of the project: 1) provision and analysis of test data 2) science support 3) training 4) user information and communication and 5) data access. The paper will present the ongoing activities along the core themes in terms of L1 and L2 products, as well as what has been planned for the next few years. Some highlights include the efforts in preparing and releasing of test data in bufr and netCDF format for MTG-IRS and all of EPS-SG missions, providing information on the timeliness of the MTG-IRS data and information on the Local Area Coverages (LACs) and timeliness of EPS-SG missions, Metop-SG tandem plans with Metop, information on data access platforms for different products including direct broadcast for EPS-SG, animations illustrating measurement techniques, and future plans on communication of commissioning timelines. The paper will also describe the engagement EUMETSAT has established with a core user group comprising global NWP centres and regional NWP consortia in Europe for sharing information and knowledge.

1.02 EUMETSAT Polar System - Second Generation: highlights on the passive microwave missions

Presenter: Vinia Mattioli, EUMETSAT
Co-authors: C. Accadia, F. De Angelis, J. Ackermann, S. Di Michele, I. Krizek, T. Hewison, R. Munro, M. Labriola, G. Bruni, D. Schobert, A. Graziani, C. Mas, V. Barlakas, J. Lu

The existing EUMETSAT Polar System (EPS) is set to transition into its second generation (SG), EPS-SG, at the end of 2025. EPS-SG is EUMETSAT contribution to the Joint Polar System (JPS) shared with NOAA, to provide continuation and enhancement of service from the mid-morning polar orbit in the 2025 – 2046 timeframe. The program will feature a two-satellite configuration in a sun-synchronous orbit, Metop-SGA and Metop-SGB.The system will include three microwave radiometers: the Microwave Sounder (MWS) on Metop-SGA, and the Microwave Imager (MWI) and the Ice Cloud Imager (ICI) on Metop-SGB.MWS, a cross-track scanning radiometer, is equipped with 24 channels ranging from 23.8 to 229 GHz, designed to provide comprehensive temperature and water vapor soundings in all sky conditions. MWS builds on the legacy of

previous instruments from the current EUMETSAT EPS mission, such as the Advanced Microwave Sounding Unit (AMSU) and the Microwave Humidity Sounder (MHS), with improved sensitivity and broad spectral coverage. Notably, it includes a new channel at 229 GHz for improved sensitivity to cloud ice, enhancing the impact of the 183 GHz measurements. MWI and ICI are innovative conically scanning passive imagers. MWI includes 26 channels from 18.7 to 183.31 GHz (18.7 to 89 GHz channels are dual polarised), supporting cloud and precipitation products generation and all-weather surface imagery. It continues the legacy of significant microwave imager missions, such as the Advanced Microwave Scanning Radiometer 2 (AMSR2), and the Global Precipitation Measurement (GPM) Microwave Imager (GMI). MWI features additional channels near 50–60 GHz and at 118 GHz and is optimized for detecting weak precipitation and snowfall.ICI is a novel mission in operational radiometry, focusing on remote sensing of cloud ice. With 13 channels from 183 GHz to 664 GHz, including dual polarisation at 243 and 664 GHz, ICI will operate in both millimetre and sub-millimetre frequencies. This will provide enhanced sensitivity to ice crystal size as well as shape and orientation, helping to fill a gap in microwave observations and enriching global observations of ice clouds. Together, MWI and ICI will offer an unprecedented array of passive microwave measurements, ranging from 18.7 GHz to 664 GHz. This overview will detail the scientific objectives and operational goals of the EPS-SG microwave missions, and discuss activities related to the preparation and calibration/validation of the centrally generated Level 1B products.

1.03 Risks of RFI with environmental satellite sensing based on spectrum proceedings and regulations

Presenter: Jordan Gerth, NOAA

Radio frequency interference (RFI) from active telecommunications such as ground-based transmitters and satellite links is an increasing concern and risk to passive sensing with environmental satellites because even the possibility of contaminated microwave satellite observations reduces their use for numerical weather prediction (NWP) data assimilation. As global observations are necessary to support global NWP, and satellite observations are particularly valuable over remote land areas and the ocean, a consistent approach to, and implementation of, radio regulations is most desired. This presentation will explain the potential impact of RFI, focused in particular on atmospheric sensing in currently exclusive passive bands or those shared with active sensors, and cover the latest international and/or major national proceedings. The significant consequences of spectrum sharing arrangements and adjacent allocation specifications that do not properly protect Earth sensing satellites require evidence of the value of satellite observations for NWP as the utility of microwave spectrum for other purposes continually increases.

1.04 WMO Gap Analysis for Space-based Component of the WMO Integrated Global Observing System (WIGOS) Using WMO OSCAR/Space Tools

Presenter: Heikki Pohjola, WMO
Co-authors: Roger Saunders

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 and 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 including all satellite operators and private sector. OSCAR/Space has become very popular having more than 2000 users per week all over the world supporting around 20 different user applications. In this presentation we present the latest results of WMO Gap Analysis provided in the context of CGMS Working Group III. In addition, we highlight the 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.

1.05 The WMO DBNet service for providing low latency sounder data to NWP centers: Recent progress and future plans

Presenter: Liam Gumley, SSEC, University of Wisconsin-Madison
Co-authors: Mikael Rattenborg, Zoya Andreeva

The Direct Broadcast Network (DBNet) overseen by the WMO provides low latency infrared and microwave sounder data to NWP centers worldwide to enable assimilation of the latest observations in modeling systems that have rapid refresh cycles. DBNet provides sounder data from EUMETSAT Metop (AMSU, HIRS, IASI), NOAA JPSS (ATMS, CrIS), NOAA POES (AMSU, HIRS), and CMA FY-3 (MWTS, MWHS) satellites received at more than 50 antenna sites worldwide, with multiple sites on each continent. DBNet data are processed rapidly via software packages provided by EUMETSAT/NWP-SAF, NOAA/CIMSS, and CMA/NSMC. DBNet data are stored in BUFR format and disseminated worldwide via the Global Telecommunications System (GTS) and over Europe via the EUMETCAST retransmission service. The EUMETSAT NWP-SAF continuously monitors the quality of DBNet products by comparing every locally received dataset to the corresponding global data provided by the satellite operators. An international DBNet Coordination Group meets in person approximately every 18 months to review the status of the stations contributing to the network and to discuss technical challenges, support for new and upcoming satellites, and plan for future evolution of the system. DBNet has already made significant progress in demonstrating dissemination of sounder data via the WMO Information Service (WIS) 2.0, which will replace the GTS by 2030. Recent priorities for the WMO DBNet Coordination Group have included addition of new antenna sites in India, South America, and Africa; adding support for NOAA-21 and FY-3E; planning for Metop-SG; and disseminating BUFR files containing the full set of spectral channels from IASI and CrIS via WIS 2.0. This presentation will provide an overview of recent DBNet activities and describe how DBNet is preparing to support future missions and projects including Metop-SG and the transition to WIS 2.0.

1.06 Global satellite data exchange in the era of WIS 2.0

Presenter: Simon Elliott, EUMETSAT

WMO's next generation information system (WIS 2.0) is operational since the start of 2025. This brings with it a change of paradigm for both data providers and consumers; it also presents a number of opportunities for the meteorological satellite user community. The concepts and overall architecture of WIS 2.0 are introduced, together with a description of the successful early use of WIS 2.0 for the exchange of satellite and space weather data. We will consider what changes will happen in the coming months and years, and how the user ITWG community will be able to capitalize upon them.

1p.01 WMO Core and Recommended Satellite Data

Presenter: Heikki Pohjola, WMO
Co-authors: Zoya Andreeva, Mikael Rattenborg, Roger Saunders and Natalia Donoho

The 2021 Extraordinary Congress approved the WMO Unified Policy for the International Exchange of Earth System Data, which defines Core and Recommended data domains. WMO Members shall exchange Core data on a free and unrestricted basis to underpin the services they provide for the protection of life and property and for the well-being of all nations. The WMO Commission for Observation, Infrastructure, and Information Systems (INFCOM) was tasked to review the data and products specified in the Manual on the WMO Integrated Global Observing System (WMO-No. 1160) and update the list of core satellite data to meet the needs of WMO members. With the WMO Unified Policy for the International Exchange of Earth System Data approved, WMO wants to define the Core satellite data related to satellite data exchange. In order to define the Core data commitments of WMO members and space agencies, we organized the stakeholder consultation within the numerical weather prediction (NWP) community and space agencies to define WMO Core satellite data for global NWP at first place. In 2024 WMO Space Programme together with Expert Team on Space Systems and Utilization (ET-SSU) initiated work to define WMO Core satellite data for nowcasting. This presentation gives an update on defied WMO Core and Recommended satellite data and outlook for the future work defining Core and Recommended satellite data for other WMO application areas.

Session 2: Impact studies

2p.02 NCMRWF operational NWP system: status and observation impact analysis

Presenter: Sumit Kumar, NCMRWF
Co-authors: John P. George and V. S. Prasad

National Centre for Medium Range Weather Forecasting Unified Model (NCUM) NWP system is utilized for operational NWP forecast at NCMRWF. Advanced data assimilation technique of Hybrid-4D-Var is used to effectively assimilate various in-situ and space-borne observational data, to generate the initial conditions every six hour for the NWP model forecast. Since last ITSC many changes/updated are introduced into the NCMRWF's NWP system to keep it up to date. This paper will highlight those changes and their impact on current system. Additionally the impact of assimilated observations especially infrared and microwave sounder radiances on the this system will also be presented.

2p.04 Assessment of NOAA-21 ATMS using NCMRWF Global Forecast System

Presenter: Suryakanti Dutta, NCMRWF/MoES
Co-authors: Ashish Routray and V. S. Prasad

NOAA-21 (National Oceanic and Atmospheric Administration) is a significant addition to the JPSS (Joint Polar Satellite System) series, enhancing our ability to monitor and understand weather patterns and climate changes. The instruments on board, comprising of the Advanced Technology Microwave Sounder (ATMS), Visible Infrared Imaging Radiometer Suite (VIIRS), Cross-track Infrared Sounder (CrIS) and Ozone Mapping and Profiler Suite (OMPS), work together to provide comprehensive data on the physical properties of the atmosphere. The ATMS is critical in measuring the temperature and humidity profiles, essential for accurate weather forecasting. The present study provides a detailed assessment of the ATMS onboard NOAA-21, evaluating its impact on the monsoon months of July and August 2024. An Observing System Experiment (OSE) is employed to evaluate the contributions of the NOAA-21 ATMS data. It is assimilated in the NCMRWF Global Forecast System (NGFS) using the GSI-3DVar (Gridpoint Statistical Interpolation – 3 Dimensional Variational) analysis scheme. The experimental design involves a control (CTRL) and an experimental (EXP) run. The CTRL involves NGFS run without assimilating any sounder data, serving as the baseline for comparison. In the EXP, the NGFS run incorporates ATMS data from only NOAA-21, allowing for direct assessment of its impact on forecasting. The analysis and forecast diagnostics from these experiments are compared and evaluated, assessing factors of precipitation forecasts, temperature and humidity profiles and overall model accuracy and reliability. The evaluation particularly targets the accuracy of predictions for heavy rainfall events across the Indian subcontinent during the monsoon period. The study aims to quantify the enhancements in forecast skill brought about by incorporating ATMS data, thereby demonstrating its value in operational meteorology, especially in regions prone to severe weather during the monsoon season. This research could provide insights into optimizing satellite data usage for improved weather forecasting and disaster preparedness.

2p.05 Impact of Microwave Sounder Data from Polar-orbiting Satellites in NCMRWF Global Forecast System

Presenter: Sujata Pattanayak, National Centre for Medium Range Weather Forecasting, MoES
Co-authors: S. Indira Rani, Suryakanti Dutta, Ashish Routray, and V S Prasad

The assimilation of microwave sounder radiance observations is essential to obtain accurate initial fields for numerical weather prediction (NWP). The present study illustrates an exhaustive analysis and assimilation of Advanced TIROS Operational Vertical Sounder (ATOVS) radiances that includes data from NOAA-18, NOAA-19, MetOp-B, MetOp-C and Advanced Technology Microwave Sounder (ATMS) radiance observations that includes SNPP and NOAA-20 in the NCMRWF Global Forecast System (NGFS). Four sets of experiments are conducted to assess the performance of each type of observation in complementing or supplementing the global analysis. The assimilation experiments are conducted for a few heavy rainfall events during the Indian summer monsoon season in 2024. Experimental results demonstrate significant positive impacts from the assimilation of microwave radiance. The simultaneous use of ATOVS and ATMS microwave radiance data improved upper and middle tropospheric water vapor fields in analyses and forecasts. The statistical analysis in terms of frequency of assimilated observation, bias, root mean square error (RMSE), standard deviation, scatter plot, etc., are calculated. The RMSEs are computed between the bias-corrected analysis and the bias-corrected background. The bias associated with the analysis is less, i.e., it varies from -2 to + 2° K. This initial analysis suggests that the assimilation of microwave sounder data positively impacts the global analysis field and, consequently, the model forecast. It is noticed that about 25% and 20% of ATOVS and ATMS radiance observations, respectively are assimilated in NGFS. The characteristics of the heavy rainfall events are reproduced in the analysis and the forecast as well.Keywords: Microwave sounder Radiance; Global Forecast System; Assimilation; Heavy rainfall, Statistical Skill Score

2p.06 Assimilation of clear-sky radiances from GOES-16 and 18 in the KIM data assimilation system

*Presenter: Ahreum Lee, UMBC, GMAO NASA/GSFC, KIAPS**
Co-authors: Hyoung-Wook Chun, and Jeon-Ho Kang

The Advanced Baseline Imager (ABI) sensor onboard the Geostationary Operational Environmental Satellite (GOES)-16, launched in 2016 at 136.9ºW longitude, and GOES-18, launched in 2022 at 75.2ºW longitude, provides radiance observations of the Western Hemisphere from 16 different channels. This study aims to incorporate clear-sky radiances observed by this sensor into the Korean Integrated Model (KIM) data assimilation system, alongside the clear-sky radiances from other geostationary satellites (e.g., GK2A and Himawari). First, channels 8, 9, and 10, which are sensitive to mid-tropospheric water vapor, are selected, and sensitivity experiments for quality control and bias correction processes within the KIM Package for Observation Processing (KPOP) framework, as well as for observation error optimization within the KIM Variational data assimilation system (KVAR) framework were conducted. Using the developed GOES-16/18 clear-sky radiance assimilation system, we assessed the impact of GOES-16/18 clear-sky radiance data assimilation in the KIM. Additionally, this study examined the global observation impact based on the observational positions of geostationary satellites. We believe that this research establishes a basis for future studies on all-sky radiances from geostationary satellites.

2p.07 The impact of microwave sounder radiance assimilation in convective-scale limited-area NWP over the Nordic region and in the Arctic

Presenter: Reima Eresmaa, Finnish Meteorological Institute
Co-authors: Per Dahlgren, Susanna Hagelin, David Schoenach, Adam Dybbroe

In preparation for microwave sounding data from the Arctic Weather Satellite (AWS) and from the proposed new EUMETSAT programme EPS-Sterna, we evaluate the forecast impact of microwave sounder radiances in short-range numerical weather prediction at high Northern latitudes. The NWP system framework includes two operational HARMONIE-AROME models, that both are run in 2.5 km horizontal resolution. One of the limited-area modelling domains extends from the Northern Atlantic Ocean to Eastern Europe and puts emphasis on Scandinavia, Finland, and Baltic states. The other domain focuses in the Arctic Ocean from the Norwegian coast to Novaja Zemlja region. The impact assessment is conducted using the four-dimensional variational data assimilation.The baseline system for the impact assessment consists of comprehensive data assimilation using conventional observation types, ground-based radars, and scatterometers and infrared sounders on polar-orbiting satellites. Additionally, the baseline system includes the assimilation of humidity-sensitive sounding channels of the FengYun-3D MWHS-2 instrument. The forecast impact from additional microwave sounders is evaluated in two alternative scenarios. In one scenario, the additional data is brought from the ATMS instrument onboard S-NPP and NOAA-20 satellites that are in the same orbital plane as the baseline (FengYun-3D) satellite. In the other scenario, the additional data comes from the AMSU-A and MHS instruments onboard Metop-B and NOAA-19, that is, satellites in orbital planes complementary to the baseline.The evaluation indicates that each new satellite enhances the assimilation system performance. Verification against synoptic ground-based observations shows measurable benefits in particular in the forecast of temperature, humidity and cloud cover. The performance gain is the greatest in the scenario where new radiance data are assimilated from satellites in complementary orbits. The results hint at the potential benefits of the future EPS-Sterna programme (~2029-2042), which is a planned constellation of six small AWS satellites in three orbital planes, offering fast data delivery, suitable for limited-area NWP systems with their short assimilation time windows.This work is supported by the ESA project: Performance Evaluation of Arctic Weather Satellite Data (No. 4000136511/21/NL/IA).

2p.08 Satellite Sounder Absence: Evaluating the Impact of Satellite Sounder Observation Across Diverse Geographic Regions

Presenter: Nahidul Samrat, Bureau of Meteorology
Co-authors: Brett Candy, Fiona Smith, Owen Lewis, James Cotton, Gemma Halloran, Chawn Harlow, Heather Lawrence, Stefano Migliorini, Andy Smith, Christopher Thomas

We have recently conducted complete observational system experiments globally using the Met Office Global NWP system to investigate the potential impact of observation data on weather forecasts. This study mainly explores the global and regional sensitivity of weather forecasts to the absence of satellite sounder observations by conducting a data denial experiment (DDE). The DDEs are run over three months using the observations from December 15, 2022, to March 15, 2023, and use a configuration very close to the Met Office operational global NWP suite. We analysed key atmospheric variables such as temperature, geopotential height, wind, and humidity at different atmospheric levels over the forecast range up to T+144. The results show that removing the MW and IR systems caused a statistically significant reduction in mean forecast skill across different regions, especially the Australian region. Our conclusions provide recommendations on possible evolution of the global observing system for NWP.

2p.09 Satellite Observation Impacts in Australian NWP Models

Presenter: Fiona Smith, Bureau of Meteorology
Co-authors: Nahidul Samrat, Andy Smith, Brett Candy, Christopher Griffin, Jin Lee, Susan Rennie, Owen Lewis, James Cotton, Gemma Halloran, Chawn Harlow, Heather Lawrence, Stefano Migliorini, Christopher Thomas

The quality of the forecasts from the Bureau's convection-permitting small-domain ACCESS-C, and future Australia-wide ACCESS-A, models is dependent on the use of observations. The impact comes both from direct assimilation into the ACCESS-C and A models hourly, providing the most accurate initial conditions for forecasts, and indirectly via assimilation into the global model ACCESS-G, which provides lateral boundary conditions (LBCs) for the ACCESS-C and A domains. The observations directly assimilated into ACCESS-C include radiosonde and aircraft observations, surface observations, Doppler radar winds, and satellite data including infrared and microwave sounders (sensitive to temperature and moisture profiles), atmospheric motion vector (AMV) upper air winds, scatterometer surface winds and ground-based Global Navigation System Satellite (GNSS) measurements sensitive to water vapour. ACCESS-G uses a wider range of satellite observations including GNSS-RO and AMSR-2 radiances.In this presentation, we show the impact of satellite observations on global model forecast skill over the Australian region, from satellite data denial experiments (DDEs) using the Met Office global model, which is similar to ACCESS-G. This gives a guide to which observations are most influential to the quality of the LBCs. The impacts from satellite sounders are stronger in the Australian region than over the globe as a whole, confirming their influence on our local weather predictions.We also show the impact of satellite observations in ACCESS-C using DDEs for the Sydney and Darwin domains. We find the pattern of impact in these experiments appears to vary seasonally and is also domain dependent. This has consequences for the expected pattern of performance over the larger ACCESS-A domain.

Session 3: New microwave capabilities

3.01 The Global Environment Monitoring System (GEMS): a constellation of passive microwave radiometers on a CubeSat platform

Presenter: Allen Huang, University of Wisconsin Madison
Co-authors: Richard Delf, Michael Hurowitz, Roger Carter, Robert Belter, Michael Marques, Albin Gasiewski

The Global Environment Monitoring System (GEMS) is a planned constellation of passive microwave radiometers designed to monitor global temperature, humidity, and precipitation at a 15-minute resolution from a CubeSat platform. The first generation of the GEMS radiometer (GEMS-1) was an 8-channel system centered on the 118 GHz O2 resonance band and hosted on a 3U CubeSat. The system was launched on the IOD-1 mission (2019-2021), successfully demonstrating the capabilities of a very low-cost passive microwave CubeSat on orbit. The GEMS constellation provides a low-cost, high-performance microwave sounding capability for enhancing global weather observations to augment government systems and improve monitoring of extreme weather events. Here we present recent sounder developments made by Weather Stream and discuss the capabilities of the next generation of GEMS radiometer, GEMS2, a dual-band system with sounding channels across the 118 and 183 GHz bands, hosted on a 6U platform. Channels provided on GEMS2 will support global upper stratospheric soundings, monitoring of tropical storm development, and precipitation observations through use of the 165 and 183 GHz bands. We present details and capabilities of the upcoming GEMS2-Amethyst and GEMS2-Beryl missions which will demonstrate the constellation capabilities, providing a low-latency and high-resolution augmentation to global satellite meteorology systems.

3.02 Impact of Microsat-2B Radiance Data Assimilation in the NCMRWF Global Forecast System

Presenter: B R R Hari Prasad Kottu, National Centre for Medium Range Weather Forecasting
Co-authors: Suryakanti Dutta, Ashish Routray, Greeshma M Mohan, Srinivas D, V.S Prasad

Microsat-2B (M2B), launched by the Indian Space Research Organization (ISRO), is a small Earth observation satellite equipped with a six-channel microwave humidity sounder that operates near the 183.31 GHz water vapor absorption band which enhances atmospheric humidity profiling. The M2B provides coverage from ±40° latitude, offering extensive data for monitoring tropical weather phenomena. M2B radiance data was received at the National Centre for Medium Range Weather Forecasting (NCMRWF) near real-time via the Meteorological and Oceanographic Satellite Data Archival Centre (MOSDAC). This data is assimilated into the NCMRWF Global Forecast System (NGFS) using the in-house developed spectral and transmittance coefficients through the "CRTM_coeff" package. This study evaluates the impact of M2B radiance assimilation on the NGFS, using a three-dimensional variational (3DVAR) approach within the Gridpoint Statistical Interpolation (GSI) system. Observing System Experiments (OSEs) were conducted over four months (May-August 2023) to assess the impact of M2B data. A control experiment (CNTL) utilized only conventional data, while the second experiment (M2B) included both conventional and M2B radiances. Results indicate that M2B radiance assimilation improves the accuracy of humidity and temperature fields, with noticeable reductions in mean bias, standard deviation, and root-mean-square error. These enhancements contribute to better initial conditions for forecasts. The simulations of tropical cyclones and monsoon depressions are improved in the M2B experiment, emphasizing the importance of M2B radiance data. This underscores the importance of the data from microwave sounders like M2B, particularly in inclined orbits that maximize tropical coverage, for improving weather forecasts.

3.03 Preliminary assessment of the Arctic Weather Satellite microwave sounder with the ARPEGE global model

Presenter: Hélène Dumas, Météo-France
Co-authors: Mary Borderies, Laurent Chapeau, Philippe Chambon, Nadia Fourrié, Etienne Arbogast, Loïk Berre

A constellation of microwave sounders named the EUMETSAT Polar System–Sterna (EPS–Sterna) is under development at the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), with the aim of complementing the backbone orbits of the global observing system in low Earth orbit. The satellites of this constellation would be similar to the Arctic Weather Satellite (AWS), which was launched by the European Space Agency (ESA) in August 2024. The microwave sounder on board AWS is equipped with temperature sounding channels around the 50-GHz oxygen absorption band, water-vapour sounding channels around the 183- and 325-GHz absorption bands, and also window channels at 89 and 165 GHz. In this presentation, an evaluation of the first data from AWS will be shown with the global NWP model ARPEGE. Two versions of the ARPEGE system will be used, with the operational 4D-Var and with an experimental 4DEnVar. The latter system allows to use hydrometeors in the control vector which could be an asset for the assimilation of AWS data within clouds and precipitation.First guess departure statistics will be shown, intercomparing AWS data with other microwave sensors of the constellation. If the period of available data is sufficiently long, then preliminary impacts of the AWS sensor on the quality of ARPEGE forecasts will be shown as well. At last the status of adding hydrometeors in the control vector of the experimental 4DEnVar which is a long term effort will be given.

3.04 Evaluation of the Arctic Weather Satellite in the ECMWF system

Presenter: David Duncan, ECMWF
Co-authors: Niels Bormann, Katie Lean, Christophe Accadia, Jörg Ackermann, Sabatino Di Michele, Tim Hewison

ESA's Arctic Weather Satellite (AWS) was launched in August 2024, representing the first European microwave sounder on a small satellite and also the first cross-track sounder with sub-mm (300+ GHz) frequencies. Its suite of channels for temperature and humidity sounding make it appealing for use in numerical weather prediction (NWP), following work that found positive forecast impact from assimilation of simulated AWS radiances (Lean et al. 2023). AWS performance is also of great interest for the proposed EPS-Sterna constellation from EUMETSAT, which would use the same instrument.In this study, the quality of level-1 radiances from AWS are assessed using all-sky background departures (i.e. O-B) from the ECMWF system. Relative biases and noise performance are compared against heritage instruments with similar channels, such as AMSU-A, MHS, and ATMS. Performance is analysed along various axes, including as a function of scan position, orbital angle, and scene temperature. Particular attention is paid to analysis of the sub-mm channels; these represent a challenge for traditional calibration/validation activities as they have not been flown before, and thus comparison with equivalent 183 GHz channels is the focus. For these channels, the performance of the RTTOV radiative transfer model is also of key interest, as it is the first time that RTTOV is applied to space-borne sub-mm channels.Assimilation results will also be presented, with AWS assimilated in all-sky conditions following the methods employed for AMSU-A and MHS. Early assimilation trials will focus on the use of 50 and 183 GHz channels, but depending on the quality of forward model simulations and radiometric performance for the sub-mm channels, assimilation of these frequencies will be considered as well.

3.05 The Limb Adjustment of the TROPICS Microwave Sounder Constellation

Presenter: Mitch Goldberg, The City College of New York
Co-authors: Parisa Heidary (CCNY), Satya Kalluri (NOAA), Lihang Zhou (NOAA)

The NASA TROPICS (Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats) mission represents a significant advancement in the monitoring of tropical cyclones using a constellation of cubesats. These small satellites, equipped with scanning microwave radiometers, are designed to measure key atmospheric parameters such as temperature, humidity, precipitation, and cloud properties. The mission's primary objective is to enhance the temporal resolution of observations to support nowcasting applications, particularly for monitoring atmospheric rivers and tropical cyclones.The TROPICS constellation operates in low Earth orbit with a low inclination angle, allowing it to observe the diurnal cycle across latitudes of approximately ±40 degrees. This capability provides valuable insights into the diurnal variations of temperature and water vapor in the tropics, contributing to improved weather nowcasting and a deeper understanding of tropical cyclone dynamics. This study focuses on the adjustment of TROPICS' cross-scan instruments to a common viewing geometry (nadir angle), which is crucial for accurate nowcasting.The limb effect arises due to the increasing atmospheric path length as the instrument scans away from the nadir. This effect leads to variations in brightness temperatures across different viewing angles, which can complicate the use of the data in certain applications. To standardize these observations to a common viewing geometry, a limb adjustment algorithm originally developed for the NOAA Atmospheric Sounding Unit (AMSU) is applied. This two-step algorithm first calculates coefficients to adjust the off-nadir weighting functions to match the nadir weighting function. These coefficients are then refined using real observations to account for systematic biases not captured by the physical radiative transfer algorithm. Furthermore, the algorithm allows adjustments to different viewing angles, not just nadir, to enable imagery for additional layers in the atmosphere, which will also be demonstrated. Limb adjustments are particularly important for applications involving imagery, such as water vapor monitoring, where consistent viewing geometry is necessary for tracking the flow and transport of moisture in the atmosphere. Moreover, the limb-adjusted data facilitate the averaging of observations into level 3 grids, which can be used for a variety of other applications, including climate studies and model comparisons. In addition to nowcasting, the study will include comparisons with the Advanced Technology Microwave Sounder (ATMS) and simulated brightness temperatures from the ECMWF ERA5 reanalysis. These comparisons are essential for assessing the accuracy and stability of TROPICS observations. By comparing TROPICS data with these established datasets and models, we aim to identify and understand any discrepancies. ATMS can serve as a in orbit calibrator for cubesat/smallsat MW constellations.The limb adjustment coefficients are now being included as part of the official NASA TROPICS set of products. We are working with the National Weather Service (NWS) to demonstrate the practical use of limb-adjusted TROPICS data in operational nowcasting. Additionally, we plan to further explore the potential of TROPICS data for improving weather and climate models, especially in understanding the diurnal variations and discrepancies in water vapor measurements. To summarize, at the conference, we will discuss the limb adjustment methodology, demonstrate the application of limb adjusted TROPICS observations for nowcasting applications, and to assess the accuracy and stability of TROPICS measurements we will show comparisons of TROPICS with ATMS over a one-year period, along with comparisons with ECMWF ERA5 simulated brightness temperatures. We will also have results based on the new Tomorrow.IO mission, which has similar microwave sounders as TROPICS.

3p.01 Evaluations and exploratory assimilation trials with data from the TROPICS constellation in the ECMWF system

Presenter: Niels Bormann, ECMWF
Co-authors: David Duncan

This contribution evaluates data from the TROPICS constellation (Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats) within ECMWF's global data assimilation system. TROPICS is an example for a constellation of cubesats, featuring a MW-sounding instrument with channels in the 118 and 183 GHz bands, combined with window channels at 92 and 205 GHz. Evaluation of such data in an NWP context is highly relevant, as cubesats offer the potential prospect of sizeable constellations, giving much improved temporal sampling as a complement to the backbone systems. At the same time, NWP systems have stringent requirements on the data quality, including the accuracy and stability of the calibration, and some of these may be difficult to achieve with a cubesat. Here we evaluate data from the remaining 3 low-inclination satellites of the TROPICS constellation, providing coverage at low latitudes between 40S and 40N, with a view as to whether such systems could be used operationally in a global NWP system. An evaluation of the data quality against the ECMWF background suggests that considerable biases are present in the observations, with a complex dependence on the orbital position and scene temperatures. Orbital biases are particularly prevalent for the 118 GHz channels, whereas departure statistics for the 183 GHz channels are more in line with those for heritage sensors, but nevertheless require tailored corrections to address orbital and scene-dependent biases. With such corrections applied, exploratory assimilation of the 183 GHz channels from TROPICS show a neutral to slightly positive impact on short-range forecasts, but an overall neutral impact on medium-range forecast scores. Further lessons learnt from the TROPICS experience for operational NWP will also be discussed.

3p.02 Forecast impact expected from EPS-Sterna's 325 GHz channels
Presenter: Niels Bormann, ECMWF
Co-authors: Katie Lean, Joerg Ackermann, Sabatino Di Michele, Christophe Accadia, Tim Hewison

EPS-Sterna is a proposed constellation of six small satellites with cross-track MW sounders, featuring channels in the 50, 183, and 325 GHz bands, combined with selected window channels. Previous work showed that significant forecast benefit can be expected from the 50 and 183 GHz temperature and humidity sounding channels of EPS-Sterna, when added on top of an observing system with MW-sounding in the 3-orbit backbone system. Here, we use the Ensemble of Data Assimilations (EDA) method to evaluate the expected additional impact of the new set of 325 GHz channels. We discuss how these channels are simulated and assimilated in an all-sky framework. This includes the development of an observation error model based on a new cloud indicator that exploits the cloud signal in the lowest peaking 325 GHz channel to assign larger observation errors in cloud-affected regions. This leads to a more Gaussian distribution of background departures normalised by the assigned observation error, compared to using the scatter index used as cloud indicator for the 183 GHz channels. EDA spread reductions show that the 325 GHz channels produce a similar positive impact as the 183 GHz channels when each channel set is added separately to the temperature sounding channels at 50 GHz. When added on top of the 50 GHz and 183 GHz sounding channels, the impact of the 325 GHz channels is mostly neutral, with some benefits for relative humidity in the mid-troposphere. Potential options to increase the impact through data assimilation enhancements are discussed.

3p.03 JEDI Skylab use for Observation Evaluation
Presenter: Benjamin Ruston, UCAR/JCSDA
Co-authors: Fabio Diniz, Samantha Maticka, Hui Shao, Lindsey Hayden, Francois Vandenberghe and Ashley Griffin

The Joint Center for Satellite Data Assimilation (JCSDA) is a multi-agency research center, and a primary product of the JCSDA is the Joint Effort for Data Assimilation Integration (JEDI). A primary focus of the JCSDA is to improve the ability to exploit satellite data more effectively. To demonstrate new sensing technologies and assess impact the JCSDA has developed the Skylab demonstration application. This can be used with multiple model interfaces such as MPAS, FV-3, and GEOS. To assess the microwave small satellites we have targeted both the MPAS and FV-3 applications. In addition to these new satellites, there are a variety of observing systems that are continuously being interfaced with JEDI across the multiple components of the Earth System. The JCSDA JEDI OBS team is the primary developer of the Unified Forward Operator (UFO) component of the JEDI system. There are two radiative transfer modeling applications used with JEDI, the Community Radiative Transfer Model (CRTM) which is used for this study, and the EUMETSAT RTTOV. We are exploring sensitivity to two new microwave satellites that are under a pilot project supported by the NOAA NESDIS Commercial Data Program (CDP). These are the Tomorrow.io Microwave Sounder (TMS), and the Orbital Micro System's Global Environmental Monitoring System (GEMS). The TMS sensor has a heritage borne from the NASA Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS) which are also evaluated. This work will focus primarily on the impact of the channels centered around the 118 and 183 GHz bands. This pilot is newly started in 2025 and the preliminary results from the TMS will be presented along with the precursory evaluation of the readiness for the GEMS sensor. Augmentation of the impacts can be performed using the TROPICS data to better understand what a more complete constellation of these microwave radiometers may provide. Developments particular to this project include a finer examination of footprint averaging methods and additional bias predictors such as an orbital bias predictor that has been presented in previous EUMETSAT technical memoranda 912 (Bormann, Magnusson, Duncan and Dahoui, 2023). A goal for this study is for the JCSDA to demonstrate with the JEDI Skylab system, viable configurations for these new sensors that can be rapidly deployed by the JEDI-enabled partner organizations.

3p.04 An initial evaluation of the Sterna radiometer data using Met Office NWP fields

Presenter: Brett Candy, UK Met Office
Co-authors: Nigel Atkinson, Anna Booton and Christina Köpken-Watts

The first EPS Sterna radiometer (see details in OSCAR Space) was launched onboard the Arctic Weather Satellite Proto-Flight Model (AWS-PFM) in August 2024.In this presentation we will show comparisons of AWS-PFM measurements with Met Office & DWD operational NWP fields. The comparisons are performed in measurement space using RTTOV-12.3 within the observation operator. A feature of the radiometer design is that different frequency bands do not have collocatedfootprints and we have used the NWP-SAF AAPP software to remap the data from each band onto a common spatial grid before the Observation/NWP comparisons. Of particular interest will be the performance in terms of fit and stability for the new submillimeter band operating at 325 GHz.

3p.05 Early evaluation of the Arctic Weather Satellite (AWS) data assimilation in regional NWP systems

Presenter: Stephanie Guedj, The Norwegian Meteorological Institute
Co-authors: Per Dahlgren, Magnus Lindskog, Adam Dybbroe

On August 16, 2024, the European Space Agency's (ESA) Arctic Weather Satellite (AWS) was successfully launched from the Vandenberg Space Force Base in California. AWS is a small satellite designed as a prototype to be the precursor of the potential EPS-Sterna satellite constellation program under EUMETSAT. The AWS platform is carrying a single instrument, a microwave sounder with 19 channels (from 50 to 325 GHz). Following some recent studies done at ECMWF, Météo-France, SMHI, FMI and Met Norway, the EPS-Sterna constellation could reach a potential improvement of Numerical Weather Prediction (NWP) forecast skill up to 7% with six "AWS" satellites.MET Norway participates in the Swedish-led, Nordic AWS project funded by ESA (" Performance Evaluation of Arctic Weather Satellite data"), which aims at covering the preparation phase (early data processing and calibration/validation) for the assimilation of AWS radiances in clear-sky conditions. Over the past months, 1) an AWS direct data broadcast ground segment to receive the data in near-real-time has been set up by the Nordic countries and 2) A version of our operational limited area model HARMONIE-AROME NWP system has been prepared to ingest the novel data. As a Cal/Val partner and to provide early feedback to ESA on the data quality, AWS data have been monitored and assimilated on both AROME-Arctic and MEPS domains. Statistics on AWS first-guess departures and bias correction are first discussed as the instrument was monitored. AWS statistics were also compared to other microwave instruments at similar frequencies.Then, a set of "tuned" data assimilation experiments has been run and evaluated in terms of analysis increments and forecast scores.

3p.06 EUMETSAT microwave sounder constellation: the EPS-Sterna Programme

Presenter: Vinia Mattioli, EUMETSAT
Co-authors: C. Accadia, J. Ackermann, F. Bosco, S. Di Michele, I. Krizek, T. Hewison, P. Colucci, A. Canestri, G. Karsli Demirbas and V. Kangas

The EUMETSAT Polar System (EPS) Sterna has been identified as a potential expansion of the EPS and EPS Second Generation (SG) programmes, to complement and expand the services provided by the Joint Polar System (JPS) operated by EUMETSAT and NOAA. EPS-Sterna programme will be fully funded by EUMETSAT and will contribute to the realisation of the WMO Integrated Global Observing System (WIGOS) Vision 2040, in line with the objectives of the EUMETSAT Destination 2030 strategy. The EPS-Sterna System encompasses the Space Segment, the Ground Segment and the Launcher Services. The EPS-Sterna Space Segment consists of a constellation of small polar-orbiting satellites, each equipped with a cross-track scanning microwave sounder, which will allow to retrieve atmospheric humidity and temperature profiles. The initial constellation will consist of six EPS-Sterna satellites and is planned to be deployed in 2029. The satellites of the constellation will be replaced with new satellites throughout the mission lifetime of thirteen years and a total of twenty satellites will be manufactured and launched. The complementarity to EPS-SG and JPS is reflected in the choice of constellation orbits, designed to optimize the overall global coverage of the constellation while keeping the mission affordable. The approval for the EPS-Sterna programme is assumed in mid- 2025. Level 1 products from the EPS-Sterna mission will be disseminated via EUMETCast to support operational meteorology and will enable the generation of higher-level products (e.g., Level 2) supported by the EUMETSAT Satellites Application Facilities (SAFs).The EPS-Sterna programme will capitalise on the experience from the European Space Agency's mission Arctic Weather Satellite (AWS) launched in August 2024, which served as technology demonstrator and protoflight model for the satellites to be used in the constellation. The MicroWave Radiometer (MWR) is the instrument embarked on the Sterna Satellites, which will be based on the AWS instrument, the technology of which has similarities with the EUMETSAT Polar System – Second Generation (EPS-SG) Microwave Sounder (MWS). The MWR is featuring 19 channels covering the millimetre-wave frequency range 50–325 GHz. Together with well-established frequencies in the 50 and 183 GHz bands and windows channel at 89 GHz, the instrument also include 4 channels at 325 GHz, comparable to those of the EPS-SG Ice Cloud Imager (ICI). The antenna system comprises 4 feedhorns, one for each group of channels without any quasi-optics and a more compact design than MWS. This presentation will provide an overview of the EPS-Sterna programme and its status, outlining scientific goals and the operational objectives.

3p.07 Preparations for EPS-SG microwave instruments at ECMWF

Presenter: David Duncan, ECMWF
Co-authors: N. Bormann, A. Geer, C. Accadia, S. Di Michele, F. De Angelis, V. Mattioli

The microwave instruments that will fly on the Metop-SGA and -SGB satellites – MWS, MWI, and ICI – will provide sounding and imaging capabilities from 18 to 664 GHz. The wealth of data and information content from microwave instruments in the EPS-SG programme constitute a great opportunity but also a significant challenge, both at a technical level and for full scientific exploitation of the data. To prepare for these instruments at ECMWF, significant effort has gone into data pre-processing and facilities to monitor the data quality in near-real time. These developments should enable quick feedback to the EUMETSAT Cal/Val teams and facilitate assimilation trials early in the missions of both satellites. Due to the complementary nature of the channel suites on the MWI and ICI radiometers, they will be treated together as a single 'super-sensor' in the ECMWF assimilation system: named "MWIICI." For instance, this permits low frequency channels on MWI to constrain surface emissivity retrievals for ICI. In order to combine MWI and ICI, and also to address their heavy spatial over-sampling, the L1B radiances are spatially averaged in a superobbing procedure prior to combining the instruments. This serves several purposes such as data volume reduction, addressing representation error, regularizing the separate geolocations from each feedhorn, and reducing effective radiometric noise. Averaging MWIICI radiances onto a 40km Gaussian grid reduces the number of level-1 radiances by roughly two orders of magnitude; merging all fifteen feedhorns together reduces the number of unique geolocations by roughly three orders of magnitude. Radiative transfer simulations for MWS and MWIICI will use measured spectral response functions and will also account for variable ozone profiles. As ozone sensitivity generally increases with frequency, the use of climatological ozone profiles rather than those of the analysis were found to cause forward model errors of about 1K at ICI sub-mm channels. The SURFEM-Ocean emissivity model supports the sub-mm channels over sea. For MWS, the initial treatment will follow that of established heritage sensors, using an all-sky approach. Particular attention will be paid to the novel channels available from MWS, such as the lower-peaking 50-GHz channels as well as the new 229 GHz channel.

3p.08 Analysis of Radio Frequency Interference (RFI) from 6.9 to 89 GHz in an NWP system

Presenter: David Duncan, ECMWF
Co-authors: D. Duncan, N. Bormann, S. English, A. Geer, T. Scanlon, R. Oliva, R. Onrubia, Y. Soldo

Unnatural emission in the microwave spectrum can be analysed with an NWP system, with the presence of RFI manifested as positive background departures (i.e. high O-B) because only natural emission sources are simulated by the radiative transfer model and RFI is always positive. The NWP model background can thus be considered a source of significant a priori knowledge for analysis of RFI. As the 3D representation of atmosphere and surface are constrained by the model, radiometric outliers are more apparent. Analysis with an NWP model thus serves as both a method of verifying observations flagged as potentially RFI-affected, and as a way to detect and possibly attribute RFI.First, this study assesses externally-produced RFI flags from Zenithal Blue Technologies (ZBT) with departure-based analysis. As the ZBT method is model-agnostic, analysis of O-B statistics of flagged data provides a validation of its approach. Using a dedicated dataset covering March and October of 2022, this study performed an in-depth evaluation of RFI detection of the type that is not yet consistently available operationally. The study focused on the AMSR2 and AMSU-A instruments, finding that there are significant direct sources of RFI at AMSR2 bands measuring at 6.9, 7.3, 10.65, and 18.7 GHz, plus reflected sources at 7.3 10.65, and 18.7 GHz. No significant sources of RFI are corroborated at AMSR2 or AMSU-A bands from 23.8 GHz and up. Second, departures at the nearby C-band frequencies on AMSR2 (6.925 and 7.3 GHz) are used to identify potential RFI. Following the earlier part of the work with ZBT, this focuses on newly discovered sources of C-Band RFI over sea, particularly in the North Sea and near East Asia and India. This relatively simple screening based on a departure difference helps to remove problematic C-band radiances prior to assimilation of this band that is largely sensitive to SST. Third, some RFI signals seen by the 10.65 GHz channels of AMSR2 over sea can be traced back to reflected RFI from geostationary broadcast satellites. To isolate these signals, background departure statistics were evaluated under glint conditions for satellites, allowing attribution of likely RFI source locations in geostationary orbit. This knowledge can subsequently be used to screen affected observations prior to the assimilation.

Session 4: New infrared capabilities

4.01 Assimilation of GIIRS on-board FY-4B in the ECMWF IFS

Presenter: Naoto Kusano, JMA, ECMWF
Co-authors: Chris Burrows, Guillaume Deschamps, Pierre Dussarrat

The Geostationary Interferometric Infrared Sounder (GIIRS) is a Chinese Fourier transform spectrometer that flies on-board the CMA's FY-4 Series satellites in a geostationary orbit. FY-4B has been operated on the orbit at 133°E since 26th March 2022. It is expected that assimilation of GIIRS on-board FY-4B will improve numerical weather prediction, and the investigation of FY-4B GIIRS is also an opportunity to learn how best to exploit data from geostationary hyperspectral sounder ahead of the Infrared Sounder (IRS) on-board the next generation Meteosat Third Generation soundings satellites (MTG-S).A previous investigation (Burrows et al., 2023) shows the performance of GIIRS on-board FY-4B is much better than that of FY-4A, particularly in the MWIR band, however, there remains systematic deficiencies in both of LWIR and MWIR bands. We analyzed FY-4B GIIRS further and ran assimilation experiments using ECMWF Integrated Forecasting System (IFS) assuming clear-sky condition. The assimilation experiments of GIIRS requires channel selection, pixel selection, and estimation of observation errors, and cloud detection. These results will be presented at the conference.

4.02 Forecast Impact of Simulated GeoHIS based on KIM-OSSE

Presenter: Young-Jun Cho, Numerical Modeling Center, Korea Meteorological Administration
Co-authors: Chang-Hwan Kim, Hyoung-Wook Chun, and Yong Hee Lee

The Korea Meteorological Administration (KMA) will operate the next-generation Geostationary Hyperspectral Infrared Sounder (GeoHIS) for observing temperature and humidity sounding with high temporal and spatial resolution in 2037. It can be used not only directly in very short-range forecast but also as input data for numerical prediction model, which is expected to improve weather forecast. We analyzed the forecast impact of the next-generation GeoHIS, which has high density in the Asia region, using the Korean Integrated Model-Observing System Simulation Experiment (KIM-OSSE). GeoHIS radiances were simulated from ECO1280 (ECMWF Cubic Octahedral1280) Nature Run data distributed by CIRA/CSU(Cooperative Institute for Research in the Atmosphere/Colorado State University). In this study, 96 channels in the range of 700~1,130 cm-1 (8.85~14.29 ㎛) were simulated, and data assimilation used 42 channels located in the CO2 absorption band for the temperature sounding, excluding lower-level observation channels (≤ 1.5 km) due to the effect of surface emissivity and skin temperature. The improvements in forecast impact for the numerical model were confirmed in the 500~250 hPa pressure-level geopotential height and 850 hPa pressure-level temperature of the troposphere in the globe and the Northern Hemisphere. In particular, we confirmed a significant improvement in the mid to upper-level geopotential height (500~250 hPa) in the Asia region.Key words: Korean Integrated Model-Observing System Simulation Experiment (KIM-OSSE), Geostationary Hyperspectral Infrared Sounder (GeoHIS), Data assimilation, Forecast impact.Acknowledgements:This research was supported by the「Development of Numerical Weather Prediction and Data Application Techniques (Grant No.: KMA2018-00721)」 from the Korea Meteorological Administration (KMA). We thank ECMWF for producing and CIRA/CSU for distributing the ECO1280 nature run.

4.03 NOAA's GXS Sounder

Presenter: Andrew Heidinger, NOAA NESDIS GEO
Co-authors: Zhenglong Li, Tim Schmit, Dave Tobin, David Johnson and Yana Williams

NOAA continues to plan for an Infrared Hyperspectral Sounder (GXS) on its Geostationary Extended Observations (GeoXO). In late 2023, British Aerospace (BAE) was selected as the vendor to build the sensor which uses a dispersive grating technology. GXS will provide observations with comparable spectral, spatial and temporal resolutions as those proposed for MTG/IRS and Himawari-10/GHMS. NOAA/NESDIS plans to collaborate with EUMETSAT and JMA on many aspects of data compression, retrieval algorithms and nowcasting approaches. This presentation will highlight some of the design features and capabilities of GXS. The efforts to create GXS proxy data and retrievals for the demonstration of nowcasting application will also be discussed.

4.04 Himawari-10 Sounder Overview and Update

Presenter: John Van Naarden, L3Harris

Co-authors: John Holder, John Ehlert, Christina Simkowski, Lawrence Suwinski

The Japanese Meteorological Agency (JMA) awarded the contract for Himawari-10 to Mitsubishi Electric Corporation (MELCO), which will include the Geostationary Himawari Sounder (GHMS). GHMS adds new capability for Japan by providing hyperspectral sounding observations that will improve numerical weather prediction (NWP) and short-term forecasts of severe weather. Overviews and status of the GHMS payload are provided including key design aspects and details on customized scanning timelines to optimize observations for Japan.

4p.01 Data quality assessment and assimilation of HIRAS-2 on FY-3E
Presenter: Chris Burrows, ECMWF
Co-authors: Lu Lee, Chengli Qi

The unique early morning orbit of FY-3E provides opportunities for exploiting a portion of the diurnal cycle which is not measured by any other hyperspectral infrared sounders. The HIRAS-2 instrument is an improvement on the original HIRAS, including continuous spectral coverage and the same spectral resolution as CrIS. Since gaining access to the real-time HIRAS-2 stream, the files have been converted to BUFR internally at ECMWF, and comparisons against model simulations have been performed. In terms of overall estimates of quality, the statistics are comparable to CrIS and/or IASI in most spectral regions. However, there is a residual bias that is present in several channels that appears to be dependent on a combination of latitude and scan angle. The assimilation methodology has closely followed what has been done for CrIS, and a similar channel selection has been used. The observation error covariance matrix has been estimated based on the covariance of analysis departures in radiance units, and these are mapped into brightness temperatures dynamically for each observed spectrum to account for the nonlinearity of the Planck function. The results of the assimilation experiments will be presented here.

4p.02 Preparation for the next generation hyperspectral infrared sounders MTG-IRS and IASI-NG at ECMWF
Presenter: Chris Burrows, ECMWF
Co-authors: Pierre Dussarrat

In recent years, ECMWF has been actively preparing for the next generation IR sounders in several ways, including testing the assimilation of principal component (PC) scores, reconstructed radiances (in various configurations), Scale Projected States and Level 2 retrievals. As the launch of these instruments draws closer, one option must be chosen in order to be ready for the moment when the first data begins to flow. Of course, this does not prevent refinements being made at later stages. This presentation will give an overview of the plans for these two instruments, along with some more open-ended ideas for discussion. In particular, we will consider the remapping of IASI-NG radiances onto IASI spectral response function (Barnet, private communication) in order to produce an effective IASI instrument with very low noise. Regarding IRS, some new concepts such as nonlinear reconstruction operators and effective spectral response functions will be covered.

4p.03 Preparing Météo-France's Numerical Weather Prediction Models for the Assimilation of anticipated MTG-IRS sounder data
Presenter: Olivier Audouin, Météo-France
Co-authors:, Thomas Carrel-Billiard, Nadia Fourrié, Philippe Chambon, Vincent Guidard, Olivier Coopmann, Jérôme Vidot, Hervé Roquet

The Meteosat Third Generation (MTG) program is EUMETSAT's new generation of geostationary satellites, set to significantly improve Numerical Weather Predictions (NWP) by providing a continuous stream of data in near real-time. Back in 2022, the first Imager of the MTG series, MTG-I1, was successfully launched aboard Ariane 5. Next in line, MTG-S1, the first Sounder of the program, centered at 0° longitude, is expected to be launched in 2025. This satellite embarks IRS (InfraRed Sounder), an infrared Fourier transform spectrometer comprising 1953 channels distributed across 2 spectral bands between 680 – 1210 cm-1 (long-wave infrared) and 1600 – 2250 cm-1 (mid-wave infrared). Thanks to its high spectral resolution (around 0.6 cm-1), the instrument will provide more precise information on temperature and humidity profiles. The full Earth disk will be separated into 4 latitude belts (Local Area Coverage, LAC), that can be scanned in 15 minutes with a spatial resolution of 4km at nadir.In anticipation of the upcoming launch of MTG-S1, several studies based on simulated observations of IRS have already been performed at Météo-France. Assimilation of those simulated observations led to significant improvements in Météo-France's regional NWP model, AROME (Coopmann et. al., 2023). To prepare for the arrival of IRS data, the data pre-processing chain also needs to be adapted to process L1b principal components scores (PCS), in order to provide data assimilation systems with reconstructed radiances. Volumetric investigations with IRSPP, a NWP Satellite Application Facility software for radiance reconstruction, have been performed to size the IRS data reception/pre-process/storage pipeline, satisfying both weather prediction and atmospheric chemistry requirements. Those investigations led to selecting a finer spatial sampling in the LAC4 than for the remaining LACs, to account for the NWP models' horizontal resolutions over Europe. Moreover, to ensure IRS observations can be promptly exploited by NWP operational models once made available, preliminary data assimilation experiments using the test datasets from the full geo-disk (4 LACs) will be carried out within Météo-France's NWP models.

ReferencesOlivier Coopmann, N. Fourrié, P. Chambon, J. Vidot, P. Brousseau, et al.. Preparing the assimilation of the future MTG-IRS sounder into the mesoscale NWP AROME model. Quarterly Journal of the Royal Meteorological Society, In press, ⟨10.1002/qj.4548⟩. ⟨hal-04190181⟩

4p.04 Plans for assimilation of MTG-IRS observations at the Met Office

Presenter: Stefano Migliorini, Met Office

Meteosat Third Generation – InfraRed Sounder (MTG-IRS) on board MTG-S1 satellite will be the first Fourier transform hyperspectral sounder in geostationary orbit at zero degrees longitude with full disk coverage. The instrument makes use of a 2D detector acquiring 160 x 160 spectra over a "dwell". Data are acquired over two bands: LWIR (881 channels between 679.70 and 1210.44 cm-1) and MWIR (1079 channels, between 1599.77 and 2250.54 cm-1) for a total of 1960 channels. Each channel has a 0.60 cm-1 spectral resolution. Dwells are grouped into 4 Local Area Coverage (LAC) zones. For LAC4 (Europe), measurements are repeated every 30 minutes. Spatial resolution at sub-satellite point at the equator is 4 km. In this poster we describe the Met Office's plans for processing and assimilating MTG-IRS data. For the global model we will consider sets with 5x5 FOVs and choose the warmest in the central 3x3 FOVs based on window channel at 925 cm-1. In this way we will thin the data to have one spectrum every 5x5 FOVs. For the UKV regional model we will consider one FOV in every 2x2 FOVs. The initial channel selection will be made of a subset of the 300 channels selected for MTG-IRS by Meteo France. The observation database (MetDB) will store the reconstructed radiances for these channels as well as the principal component (PC) scores so that we will be able to choose different channel selections in the future. Here we show the temperature and humidity weighting functions for the degrees of freedom for signal when using our 1D-Var background error covariance matrix for the full spectrum or separately for the LW and MW band or for the Meteo France channel selection. Finally, we will discuss our plans for assimilation tests with transformed retrievals from MTG-IRS PC scores.

4p.05 Preliminary studies for the assimilation of Himawari-10/GHMS in the JMA's NWP systems

Presenter: Tomoya Urata, Japan Meteorological Agency

Radiance data observed by satellites have been assimilated in the JMA's Numerical Weather Prediction (NWP) systems, contributing significantly to the improvement of their forecast accuracy.JMA's upcoming satellite Himawari-10 is planned to be operational in Japanese fiscal year 2029 with the hyperspectral infrared sounder Geostationary HiMawari Sounder (GHMS) onboard. GHMS is expected to contribute to more accurate weather forecast by taking advantage of its capability to sense three-dimensional atmospheric conditions and its high temporal observation from the geostationary orbit. Currently, some preliminary studies and technological preparations are ongoing using the simulated data of GHMS derived from RTTOV and ERA5.In Numerical Prediction Division, Observing System Simulation Experiments (OSSEs) assimilating the simulated data are conducted. OSSEs are useful not only to investigate the impacts of GHMS on the NWP systems but also to explore several possible options on settings and processes for assimilation of GHMS such as channel selection and Quality Controls (QCs). As the first step, we provisionally selected 90 temperature- and humidity-sensitive channels of GHMS for assimilation and conducted OSSEs on JMA's Global Spectral Model (GSM) and its analysis system. The results showed that GHMS has positive impacts on forecast accuracy and also suggested that there is room for improvement in the cloud screening QC.In addition, OSSEs on JMA's regional systems and Observing System Experiments (OSEs) using FY-4B/GIIRS data are ongoing. At the conference, some results of these experiments and future development plans will be presented.Note that the simulated data used in this study was created with contribution from JAMSS, L3Harris and Météo-France.

4p.06 Evaluation of GEO Sounder Impact for Numerical Weather Prediction

Presenter: Ahreum Lee, UMBC, GMAO NASA/GSFC

Co-authors: Erica L. McGrath-Spangler, N. C. Privé, Bryan M. Karpowicz, Min-Jeong Kim, Andrew K. Heidinger

The international community is in the process of developing and realizing the next generation of Earth observations from space. Included in the future satellite network is a global ring of geostationary (GEO) hyperspectral infrared sounders, consistent with the WMO vision for such a ring by 2040. Contributing to this network are the Chinese Meteorological Administration's (CMA) Geosynchronous Interferometric Infrared Sounder (GIIRS) launched in 2016 and 2021, the European Organisation for the Exploitation of Meteorological Satellites' (EUMETSAT) Infrared Sounder (IRS) expected to launch during the second half of 2025, and the Japan Meteorological Agency's (JMA) Geostationary HiMawari Sounder (GHMS) expected to launch in 2028. The contribution from the United States, the Geostationary eXtended Observations (GeoXO) Sounder (GXS), is expected to launch in the mid-2030s and will provide high temporal refresh vertical profiles of temperature and water vapor over much of the Western Hemisphere. This critical information has many applications, including nowcasting, trace gas monitoring, and weather forecasting. Utilizing an Observing System Simulation Experiment (OSSE) framework, the impact of GXS on numerical weather prediction (NWP) is examined. Multiple potential NWP benefits from GEO IR sounders will be discussed, including hurricane representation, forecasts, and the forecast sensitivity observation impact (FSOI). GXS is responsible for many Western Hemisphere NWP improvements, but complementarities with both the other GEO IR sounders and with IR sounders on a low-Earth orbit (LEO) platform from a global perspective are highlighted.

Friday, 9 May 2025

Session 5: Radiative transfer studies

5.01 The JCSDA Community Radiative Transfer Model

Presenter: Benjamin Johnson, UCAR/JCSDA
Co-authors: Cheng Dang, Quanhua Liu, Yingtao Ma, Lucas Howard, Greg Thompson

This presentation will provide an overview of the latest developments in CRTM, with a focus on the recent enhancements introduced in CRTMv3. Key updates include:Surface Emissivity Models: Significant improvements have been made to the handling of surface emissivity, particularly in the visible and near-infrared spectra, enabling more accurate representation of land and ocean surfaces.Expanded Sensor Support: CRTMv3 includes new and updated coefficients for an expanded range of satellite sensors, ensuring compatibility with the latest Earth observation missions.Computational Optimizations: The model has undergone performance tuning to improve runtime efficiency, critical for real-time operational use in large-scale data assimilation systems.Improved Aerosol and Cloud Radiative Transfer: Enhanced capabilities for aerosol and cloud radiative transfer, including new scattering models, support better assimilation of cloudy and aerosol-affected observations.Data Assimilation Applications: We will showcase the integration of CRTMv3 in operational data assimilation frameworks, with examples from recent implementations that demonstrate improvements in forecast skill and observation impact.We will showcase the integration of CRTMv3 into operational data assimilation systems, with examples demonstrating improved skill and observation impact. The talk will also discuss ongoing collaboration with the JCSDA and the user community to drive future advancements.

5.02 Progress in Advanced Radiative Transfer Modeling System (ARMS)

Presenter: Fuzhong Weng, CMA Earth System Modeling and Prediction Centre
Co-authors: Jun Yang, Yang Han, Yining Shi, Hao Hu

The ARMS version 1.2 has been successfully integrated into the CMA-GFS (China Meteorological Administration Global Forecast System) since May 2023, with no reported malfunctions over the past year. In response to the China Meteorological Administration's requirements for assimilation and simulation of Fengyun satellite data, a series of improvements have been made to ARMS, resulting in the development of ARMS version 1.5. The specific advancements are as follows:1.The atmospheric transmittance calculation scheme in ARMS has been enhanced. Specifically, transmittance calculations based on spectral response function convolution have been implemented in the microwave frequency band, and an advanced water vapor interpolation method has been proposed to significantly reduce biases caused by vertical interpolation in water vapor absorption channels of microwave sensors on satellites. Additionally, sulfur dioxide has been introduced as a variable gas in infrared spectral channels, and nonlocal thermodynamic equilibrium corrections have been completed for upper-level channels.2.A microwave frequency band ice crystal particle scattering calculation scheme has been developed, which frozen cloud particles were modeled as aggregates of bullet rosettes and the optical properties at microwave range were computed based on DDA (Discrete Dipole Approximation).3.A global land surface emissivity dataset inverted from FY-3D satellite microwave radiation imager has been constructed and updated monthly. Parameterization of microwave polarization dual-scale sea surface emissivity matrices has been completed using AI technology.4.The VDISORT (Vector Discrete Ordinate Radiative Transfer) solution scheme has been integrated into ARMS, and accuracy assessments have been conducted for multiple instruments in the microwave and visible light ranges.5.A parallel version of ARMS has been developed and applied to the Fengyun satellite ground simulation system.6.To meet the inversion and assimilation application requirements of ground-based microwave radiometers, ARMS-gb has been developed, and tangent linear and adjoint models have been formulated.

5.03 Enhancing Atmospheric Transmittance Estimation for TOVs through Advanced Statistical Approaches

Presenter: Jean-Marie Lalande, CNRM, Meteo France, CNRS
Co-authors: James Hocking, Viviana Volonnino, Sonia Péré, Jérôme Vidot

Accurate estimation of high-resolution atmospheric transmittances is a critical component in atmospheric sciences, with applications in data assimilation, remote sensing and implications in weather forecasting and climate modeling. In this study, we explore standard and advanced statistical methods to improve the precision of atmospheric transmittance estimations. By refining traditional statistical techniques, we aim to achieve high levels of accuracy and computational efficiency, ensuring that estimations are both reliable and efficient for operational use.We begin with a detailed review of the current atmospheric transmittance estimation technique in RTTOV, emphasizing statistical and regression-based methods commonly used in atmospheric research. We will present the transmittance databases used for estimating the coefficients of the RTTOV parametric model. We then experiment with enhanced statistical models, including multilinear regression with nonlinear features, features analysis and regularization. Comparisons will be made with baseline models as well as emerging AI methodologies to evaluate trade-offs between interpretability, accuracy, and computational efficiency. We will report the initial findings in terms of performance, accuracy, and interpretability of the model. We seek to provide an in-depth examination of statistical methods for atmospheric transmittance estimation for TOVs with direct impact in data assimilation and remote sensing.

5.04 On Fast Computations of Upwelling Far- and Mid-Infrared Radiances for All-Sky analysis

Presenter: Tiziano Maestri, University of Bologna, Physics and Astronomy Department "Augusto Righi"
Co-authors: Michele Martinazzo, Guido Masiello, Giuliano Liuzzi, Carmine Serio

The important role played by Far Infra-Red (FIR) radiation in shaping the Earth's energy balance and its sensitivity to essential climate variables such as temperature, water vapor, surface emissivity, and clouds is now well recognized by the scientific community. At this regard, the European Space Agency (ESA) selected the Far-infrared Outgoing Radiation Understanding and Monitoring (FORUM) mission as its ninth Earth Explorer, scheduled to launch in 2027. FORUM will collect measurements of the outgoing longwave radiation in the spectral range from 100 to 1600 cm^{-1}, with 0.5 cm^{-1} (un-apodized) spectral resolution. On its side, NASA launched, in 2024, two CubeSats loading the Polar Radiant Energy in the Far-InfraRed Experiment (PREFIRE) which are measuring the 0-54 μm region at 0.84 μm spectral resolution.The FORUM and PREFIRE missions boosted the studies of the radiative transfer (rt) community to extend fast radiative routines to the whole IR region, which required the assessment of the ability of commonly used fast solutions to simulate radiance fields at FIR wavelengths. In this work, we focus on the performances of the main rt models based on physical solutions applied to all sky conditions. A special attention is provided to algorithms operating at FIR and in presence of scattering layers (such as clouds and aerosols) which are adopted in inversion processes for the definition of satellite level 2 products or simply for the analysis of spectrally remotly sensed radiance fields.The work discusses the limits of the Chou approximation [Chou et al., 1999; Martinazzo et al., 2021] when applied to radiance simulations and provides a characterization of the impact of the Tang adjustement solution [Tang et al., 2018]. Two different approaches of the Tang

adjustment are discussed. The first one is based on correction coefficients parametrized in terms of the particle size distribution effective dimensions [Masiello et al., 2024; Maestri et al., 2024] while the second one accounts for a spectrally dependent correction coefficient. The MAMA methodology [Martinazzo and Maestri, 2023] is also introduced. The algorithm, offers fast and accurate radiance simulations of the Earth's entire longwave emission spectrum, particularly excelling in scenarios involving optically thin scattering layers like cirrus clouds or aerosols. The solution is obtained through a simplification of the multiple scattering term in the general equation of the radiative transfer in plane parallel assumption. To assess the algorithms performances, results obtained by using fast solutions are compared with those derived with a discrete-ordinate based radiative transfer model (DISORT) for a large range of physical and optical properties of ice and liquid water clouds and for multiple atmospheric conditions. Additionally, we discuss the algorithms effectiveness in simulating a set of ECMWF analyses on a global scale. For this purpose, we compare the fast available solutions to observations of the Infrared Atmospheric Sounding Interferometer (IASI) flying on MetOp B, and C. If available PREFIRE data will also be considered to assessing the codes performances against observations at FIR. Acknowledgements This work is founded by Italian Space Agency (ASI) in the framework of the project FIT-FORUM (Accordo attuativo: n. 2023-23-HH.0).
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5.05 Recent Progress on PCRTM and its Applications in MW, IR, and Solar Spectral Regions

Presenter: Xu Liu, Science Directorate, NASA Langley Research Center

Efficient radiative Transfer Models (forward models) and Retrieval algorithms (inverse model)s for hyperspectral satellite remote sensors are needed due to large number of spectral channels and millions of observations each day. In this presentation, we describe how to use Principal Component Analysis (PCA) to speed up radiative transfer forward model calculations and to numerically stabilize the inversion algorithms. We will describe recent progress on the developed a Principal Component-based radiative transfer model (PCRTM) which can simulate top of atmosphere (TOA) radiance or reflectance spectra in MW, IR, and Solar spectral regions quickly and accurately. It has demonstrated very good accuracy relative to reference line-by-line radiative transfer models and saves orders of magnitude in computational time.We will show examples of the PCRTM model developed for and applied to hyperspectral sensors such as AIRS, CrIS, IASI, NAST-I, SHIS, CPF, TEMPO, EMIS, SBG, OMI, and SCIAMACHY. We will demonstrate how the PCRTM and the PCA-based inversion algorithms are used to retrieve atmospheric temperature and moisture profiles, CO2, CO, CH4, N2O, and O3 profiles, cloud properties (optical depth, size, phase, and height), and surface properties (surface emissivity spectra and skin temperatures) from hyperspectral IR sounders such as AIRS and CrIS. This algorithm is being transitioned to the NASA Sounder SIPS and NASA's Goddard Earth Sciences Data and Information Services Center (GES DISC). More than 20-years of climate data records of the above mentioned products have been generated using Aqua AIRS, SNPP CrIS, and NOAA20 CrIS radiance spectra. We will also show AI-based cloud retrieval using EMIT radiance spectra.

5p.01 Development of new fast radiative transfer coefficients for microwave sensors

Presenter: Brett Candy, UK Met Office
Co-authors: Emma Turner, Mhari Dell, David Rundell and James Hocking

The coefficients representing microwave sensors for the fast radiative transfer model RTTOV are trained using transmittances calculated via the AMSUTRAN line by line model. Recently the water vapour and ozone spectroscopy has been enhanced within AMSUTRAN to extend the range of absorption lines covered to 1750 GHz for water vapour and 1000 GHz for ozone. This is in part to prepare for the new instruments operating in the sub millimeter band, such as the Ice Cloud Imager, but it should also improve the modelling ofexisting instruments. To do this we have made use of the HITRAN 2020 spectroscopic data base for ozone. To represent water vapour we have added the AER line dataset that allows for consistencybetween spectroscopic lines and a model of the continuum (in this case MT-CKD).We will present results examining changes to the fit of channels on operational instruments, such as those on the ATMS and AMSU-A and MHS against simulations from NWP models using the new coefficients. These comparisons will be made using both the Met Office and ECMWF global NWP fields.

5p.02 Exploring how uncertainties in NWP model microphysics are carried through to microwave radiance space / Exploring their relative importance compared with radiative transfer inconsistencies

Presenter: Vito Galligani, Centro de Investigaciones del Mar y la Atmósfera (CIMA)
Co-authors: Hernan Bechis, Maite Cancelada, Paola Salio

In parallel with the increase of computing power in the last decades, numerical weather prediction (NWP) models have achieved convection-resolving grid spacings (i.e., 5 km or less) and have incorporated the microphysical processes that occur at very small scales, resolving the dynamical interactions in convective systems. Microphysics schemes may differ in the number of predicted species, predicted moments, the number of simulated microphysical processes, assumptions regarding the mass–size relationships and size–terminal fall speed relationships, and the assumed particle size distributions. The relative simplicity of this approach has been successful in some aspects of parameterizing microphysics (e.g., the liquid phase by separating drops into two categories: cloud water and rain) and problematic for others (e.g., the ice phase). The parameterization of ice-phase microphysics is more challenging because, unlike liquid drops, ice particles have a wide range of densities and complex shapes with large temporal and spatial variability that affect their growth and decay processes. For NWP model uncertainty, cloud microphysics is considered one of the most significant sources of model error in storm-scale data assimilation. Several studies have also shown that microwave (MW) RT simulations (i.e., Galligani et al., 2017; Kulie et al., 2010) and ice hydrometeor retrievals (e.g., Ekelund et al., 2020; Pfreundschuh et al., 2020; Geer, 2021) are sensitive to ice microphysical properties such as hydrometeor shape and density, that are not entirely constrained by microphysics schemes. This is very challenging because, unlike liquid drops, ice particles have a wide range of densities and complex shapes with large temporal and spatial variability. The present study focuses on exploring how the uncertainties in model microphysics are carried through to (microwave) radiance space using the Radiative Transfer Model for TOV observations (RTTOV) and to evaluate the relative importance of model biases compared to radiative transfer (RT) inconsistencies introduced forcefully in the RT framework - such as the assumptions regarding the scattering properties of ice hydrometeors that must be made. We aim to evaluate two different microphysics schemes from the Weather and Forecasting model (WRF) for a supercell case study in central Argentina from the Intense Observation Period (IOP) of the RELAMPAGO-CACTI field campaign (Nesbitt et al., 2021; Varble et al., 2021). The microphysics schemes analyzed include the WSM6 single moment scheme (Hong and Lim, 2006) and the Predicted Particle Properties scheme (P3, Morrison and Milbrandt, 2015; Milbrandt et al., 2021).

5p.03 Extending the fast forward operator MFASIS-NN for solar channels to NIR and water vapour sensitive channels, and aerosol affected profiles

Christina Köpken-Watts, DWD
Co-authors: Leonhard Scheck, Florian Baur, Phillip Gregor, Christina Stumpf

Visible channels provide detailed information on clouds and aerosols which is highly relevant for numerical weather prediction (NWP), especially also as a complement to information from infrared (IR) and microwave (MW) channels, both for data assimilation and model evaluation. While thermal IR and MW radiances are operationally used in most systems and the operational use of visible channels is emerging, near-infrared channels, like 1.6 micron, are not yet directly assimilated because fast and accurate forward operators have become available only very recently. This frequency is available on many satellites and is particularly interesting for NWP, as this channel is not only much more sensitive to particle radii than visible channels but allows also to distinguish water from ice clouds. Additionally, solar channels sensitive to low-level water vapor like the 0.9 micron channel on the new FCI instrument onboard MTG could complement the IR water vapor channels that cover only the upper half of the troposphere. In this poster we discuss the latest developments and applications of the fast forward operator MFASIS-NN which is also part of the RTTOV package. It is a fast, neural network-based forward operator for solar satellite channels. We will discuss the information content particularly of these new solar channels, review the current state of MFASIS and provide information on planned extensions to water vapor sensitive solar channels and for the simulation of aerosol-affected reflectances. Moreover, reflectance histograms and statistics for the departures of synthetic from observed reflectances based on regional and global forecasts generated with the numerical weather prediction model ICON will be shown.

5p.04 Evaluation of RTTOV-14 in the ECMWF NWP system

Presenter: Cristina Lupu, ECMWF
Co-authors: Alan Geer, James Hocking, Samuel Quesada-Ruiz, Emma Turner, Marco Matricardi

Since the last ITSC, a major release of RTTOV, v14.0, was made available to users by the EUMETSAT NWP-SAF consortium. 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 most RTTOV science options are now available across the spectrum. Other important features of RTTOV-14 are an improved representation of the atmospheric profile that better matches the way that NWP models represent the atmosphere and improvements related to the treatment of surface emissivity and reflectance, including the capability to represent heterogeneous surfaces (for example, land/sea or sea/sea-ice) within the satellite field of view. Extensive testing and scientific evaluation in the IFS have been carried out as part of

ECMWF's contribution to the beta-testing of RTTOV. RTTOV-14 assessment was performed through comparisons of radiative transfer simulations with RTTOV-13.2 and through an analysis of departure characteristics against observations. The impact on forecasts was also investigated through a series of assimilation experiments. This poster gives an overview of the performance of RTTOV-14.0 in the IFS. While initial results look promising, a detailed analysis is still in progress with the aim to include it in the next IFS operational upgrade Cy50r1.

5p.06 A new and extended diverse 40,000 atmospheric profile dataset from the CAMS atmospheric composition forecasting system

Presenter: Emma Turner, ECMWF
Co-authors: Angela Benedetti, Tony McNally

A new dataset of 40,000 diverse atmospheric profiles has been produced based primarily on the latest version of the Copernicus Atmospheric Monitoring Service (CAMS) global atmospheric composition forecasting system at ECWMF. Profiles of meteorological variables and atmospheric composition, the latter comprising greenhouse gases, aerosols and so-called 'reactive gases' have been simultaneously derived for thermodynamic consistency. Excepting three greenhouse gases, CO2, CH4 and N2O, which are instead from the CAMS global inversion-optimised greenhouse gas fluxes and concentrations dataset as this is the most accurate source for these species. Profiles are provided on 137 model levels and are sampled in such a way to preserve the statistical properties of the total distribution. This is a follow-up to the three previous versions of these kind of datasets available from the NWP SAF, which were released in 2012, 2014 and 2016, with the aim of extending the species available and consolidating the contents into one dataset. An additional 22 reactive gases that appear both in the CAMS database and HITRAN molecular absorption database are included.

5p.07 Impact of Spectroscopy on IASI and FORUM Clear-Sky Simulations using RTTOV

Presenter: Viviana Volonnino, CNRM, Université de Toulouse, Météo-France, CNRS
Co-authors: Lalande Jean-Marie, Armante Raymond, Capelle Virginie, Vidot Jérôme

Infrared sounding data play a key role in Numerical Weather Prediction (NWP) models and, among them, the Infrared Atmospheric Sounding Interferometer (IASI) stands out as the most assimilated hyperspectral instrument. With the upcoming IASI-NG promising enhanced capabilities and doubled spectral resolution, accurate forward calculations become crucial to ensure the quality of products and NWP outputs.This study investigates how infrared spectroscopy impacts on clear-sky simulations generated by fast radiative transfer models. Utilizing different spectroscopic databases, specifically HITRAN for RTTOV and GEISA for 4AOP, IASI simulations are compared against satellite observations. To conduct this analysis, a new version of the ARSA database is employed, comprising 19706 atmospheres categorized into five airmass types (Tropical, Midlat1, Midlat2, Polar1, Polar2), all observed over sea surface during nighttime. The database includes vertical profiles of pressure,temperature, H2O and O3 from ERA5 reanalysis, as well as CO2 and CH4 obtained from CAMS datasets.Additionally, a parallel evaluation is conducted for FORUM (Far-infrared Outgoing Radiation Understanding and Monitoring), comparing simulated spectra from RTTOV and 4AOP to assess the role of spectroscopy in the far-infrared spectral domain.

Session 6: Generation of products

6.01 Assimilation of Reconstructed Radiances from IASI and CrIS Principal Component Scores into the GEOS-ADAS

Presenter: Bryan Karpowicz, UMBC/GESTAR II/NASA
Co-authors: Erica McGrath-Spangler

Hyperspectral Infrared sounders such as IASI, AIRS, and CrIS have long been an integral part of radiance assimilation in numerical weather prediction (NWP), providing vertical profiles of water vapor and temperature information. Principal Component Scores (PCS) are a lossy form of compression that retains most information, such as temperature and moisture, by using a large training set of atmospheric profiles. However, PCS may not well represent profiles which are rare events, such as volcanic eruptions, and drops some sources of random noise. There has been an increased interest in the use of PCS as EUMETSAT plans to distribute future geostationary sounder radiances from MTG-IRS via PCS only. NWP centers use two approaches to deal with PCS: direct assimilation of the PCS by modifying the radiative transfer model to produce PCS and the associated Jacobians, or a simpler approach of decompressing the PCS and reconstructing the radiances back into channel space to allow assimilating radiances without modifications to the data assimilation system. EUMETSAT has developed a PCS product for IASI that has been operational since 2011. We utilize this product opting for the simpler approach, decompressing IASI PCS into channel space, and assimilating those radiances using the GEOS-ADAS. We then compare this with a control using the standard IASI radiance product. Similarly for CrIS, the University of Wisconsin has developed a hybrid PCA Rapid Even Detection product available on the NASA GES DISC (disc.gsfc.nasa.gov). Experiments using this product for assimilation purposes via reconstructed radiances will also be presented. Resulting differences in global forecast statistics, differences in Forecast Sensitivity to Observation Impact, along with implications for implementation and quality control are discussed. Implications for future geostationary IR sounders which will only transmit PCS in-lieu of uncompressed radiances will be discussed.

6.02 The Cross-track Infrared Sounder (CrIS) NASA PCA RED Product

Presenter: Joe Taylor, SSEC, University of Wisconsin-Madison
Co-authors: D. C. Tobin, M. Loveless, G. Martin, G. Quinn

The Cross-track Infrared Sounder (CrIS) is an infrared Fourier Transform Spectrometer (FTS) sounder 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 uses 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.The goal of the CrIS NASA L1B project is to support climate research by providing a climate quality Level 1B (geolocation and calibration) algorithm and create long-term measurement records for the CrIS instruments currently on-orbit on the SNPP, JPSS-1 (NOAA-20), and JPSS-2 (NOAA-21) satellites, and those to be launched on JPSS-4 (NOAA-22) and JPSS-3 (NOAA-23). This will support continuity of EOS data records, and will provide a homogenous 40-year high spectral resolution infrared sounder climate record. The NASA CrIS products are available via the NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC) at https://www.earthdata.nasa.gov/sensors/cris. Version 4 of the CrIS L1B products will be released in late 2024.This presentation will summarize a new product within the CrIS NASA L1B product suite that implements Hybrid Principal Component Analysis (PCA) representation of the CrIS L1B data. The Hybrid PCA approach, developed by EUMETSAT for IASI and future MTG-IRS data (e.g., Hultberg et al. 2017), effectively represents the data by incorporating both global and local (granule) level variability. We have adapted and applied the Hybrid PCA technique to CrIS L1B data to create the CrIS PCA RED (Rapid Event Detection) product. The global reconstruction residuals that are captured by the local eigenvectors also provide indicators of events that are not well represented by the global training set. The new PCA RED product will provide approximately 50x data compression and 73% random noise reduction compared to the CrIS NASA L1B FSR product and includes event detection scores for 25 spectral regions associated with trace gas emissions, volcanic eruptions, and biomass burning.

6.03 Hyperspectral infrared L2 product development at EUMETSAT

Presenter: Dorothee Coppens, EUMETSAT
Co-authors: Jonas Wilzewski,Tim Hultberg, Marc Crapeau, Stefan Stapelberg

We present some of the latest developments in the hyperspectral infrared L2 team at EUMETSAT. Version 7 of the IASI L2 product is in the pipeline. It will come with a new product format and will include several improvements. The optimal estimation retrieval of temperature, water vapour and ozone will be removed in favour of a piecewise linear regression (PWLR) retrieval - superior in terms of accuracy and precision – which will be accompanied by an uncertainty estimate at each layer of the profiles. To enable assimilation of the L2 profiles an individual observation operator will be computed for each regression class and made available in an offline dataset - only the index of the relevant regression class needs to be stored in the product. Another innovation consists in the addition of PWLR retrieved profiles using forecast data as prior information to enhance the fine scale vertical structures, as a supplement to the forecast free profiles. While IASI provides limited vertical information on CO_2, offering only the total column amount is insufficient to achieve good agreement between forward model simulations and IASI observations. To improve this, incorporating vertical profile information into the product is necessary. With this goal, an external study is currently underway to validate the PWLR-retrieved CO_2 profiles.Surface emissivity can be represented as a convex combination of selected base spectra. This representation naturally models the combined emissivity in a field of view composed of several different surface types and excludes unrealistic emissivity spectra from the feasible state-space. These natural bounds on the surface emissivity help disentangle the effects of the surface skin temperature and emissivity. We show how to set up and solve a linear programming (LP) model for simultaneous retrieval of surface skin temperature and emissivity subject to the convex combination constraints.

6.04 Planetary Boundary Layer Height Estimation: Methodology and Case Study using NAST-I FIREX-AQ Field Campaign Data

Presenter: Hyun-sung Jang, AMA / NASA LaRC
Co-authors: Daniel K. Zhou, Xu Liu, Wan Wu, Allen M. Larar, and Anna M. Noe

The ratio of potential and dewpoint temperature retrievals from infrared hyperspectral measurements is adopted for better estimating planetary boundary layer height (PBLH) using a given minimal retrieval information. Case study, with National Airborne Sounder Testbed-Interferometer (NAST-I) measurements obtained from the Fire Influence on Regional to Global Environments and Air Quality (FIREX-AQ) field campaign, is presented in this paper. NAST-I retrieval from the Single Field-of-view Sounder Atmospheric Product (SiFSAP) algorithm, which ensures a higher vertical resolution of temperature and moisture associated with its accurate surface temperature and emissivity, with a 2.6-km spatial resolution is used for deriving PBLH. As a result of using the ratio of potential and dewpoint temperature instead of individual thermodynamic retrievals, a more stable parameter is available while keeping its expected vertical sensitivity against the existence of PBLH. A quality control process that tracks the behavior of individual components of the ratio successfully filters out abnormal outliers. Additionally, those outliers are modified using statistics between the ratio and PBLH. High consistency between NAST-I thermodynamic-retrieved PBLH and PBLH from the European Centre for Medium-Range Weather Forecasts Reanalysis-5 (ERA-5), which uses both dynamic and thermodynamic information, successfully supports the significance of our approach.

6p.01 Methodology for determination of the ozone vertical distribution elements from satellite spectral measurements of IR thermal radiation

Presenter: Svetlana Akishina, St. Petersburg State University
Co-authors: Alexander Polyakov, Yana Virolainen

Ozone is one of the climatically important atmospheric gases, therefore its content in the Earth's atmosphere is monitored using different remote sensing methods. To obtain the information about vertical distribution of ozone the method of outgoing thermal radiation can be realized along with other approaches. The equipment of the Russian meteorological satellites of the Meteor-M No. 2 series includes the hyperspectral infrared sounder IKFS-2, which measures thermal radiation spectra in the 660-2000 cm-1 range. Estimates of the IKFS-2 spectra information content demonstrate that the mean number of degrees of freedom for signal with respect to the ozone vertical distribution is close to 4.The inverse problem of deriving the ozone vertical profile is solved using two main approaches: the regression algorithm based on the optimal estimation method and the physical-mathematical algorithm based on the iterative approach. We present the methodology of the physical and mathematical approach for ozone profile determination, which is generalized on the optimal estimation regularisation method to nonlinear problems and contains features to improve the solution convergence. This approach is also used at a pre-processing stage to retrieve the temperature and humidity profiles required for the determination of ozone content profiles. To increase the measurement processing efficiency, we reduce the dimension of the matrices using the principal component method both with respect to the measured spectra and to the retrieved profiles.To estimate the errors and analyse the results of the presented methodology for the IKFS-2 spectra interpretation, we have carried out closed-loop numerical experiments using the simulated outgoing thermal radiation spectra from specified ozone content profiles (ozonesondes data, NCEP GFS data). The spectra of the forward model were calculated with the RTTOV radiative transfer model. We consider the effect of different factors on the solution of the inverse problem: the use of different temperature and humidity profile information, the surface temperature and spectral channels in the ozone absorption band. We found that the differences between the original and retrieved ozone profiles increase for the high-latitude atmospheric states. The authors acknowledge Saint-Petersburg State University for a research grant 116234986.

6p.02 Update on the NWP SAF satellite data processing packages: AAPP, IRSPP and MWIPP

Presenter: Anna Booton, Met Office
Co-authors: Nigel Atkinson, Anna Booton, Elisabeth Nolland, and Fabien Carminati

The Arctic Weather Satellite Proto-Flight Model (AWS-PFM), launched in August 2024, carries a cross-track microwave radiometer – referred to in OSCAR-Space as the “EPS Sterna Radiometer”. In order for the radiometer data to be assimilated in NWP several processing steps may be needed. As such the AAPP software package has been extended at v8.14 to include the “AAPP-AWS” processor, facilitating the remapping of the brightness temperatures from the four feedhorns to a common geolocation, and BUFR encoding of the level 1 product. Plans for the upcoming AAPP v9.0 release will also be presented, including support for the microwave and IR sounders on EPS-SG, and the use of the Conda package manager to aid installation. Updates will also be provided for the MWIPP package, which includes support for the EPS-SG MWI and ICI instruments, and for IRSPP which processes MTG-IRS data.The NWP SAF is also involved in testing and hosting several Direct Broadcast level 1 packages: (i) ESA's DB software for AWS-PFM, and (ii) EUMETSAT's DB software for the EPS-SG "A" and "B" satellites (supporting MWS, IASI-NG, METimage, MWI, ICI and SCA). Preliminary results from these tests will be presented.

6p.03 Retrievals of Water vapor inhomogenities within the field of view
Presenter: Xavier Calbet, AEMET
Co-authors: Niobe Peinado-Galan

It has been shown that WV inhomogeneities within the field of view of infrared or microwave instruments can have a measurable impact in the radiative transfer properties of the atmosphere. It can cause biases between observed and calculated radiances which can range from a few tenths up to 3 Kelvins in brightness temperature.In this presentation, it will be shown how these inhmogeneities can be retrieved using optimal estimation. This will have a direct application into radiance assimilation by NWP.It will also be shown how big biases between observed and calculated radiances can be used to detect unexpected WV inhomogeneities in the field of view of microwave instruments. These can be attributed to effects unforseen by NWP models. As such they can be useful to detect rare events such as, among others, regions with high turbulence, big NWP deviations from reality triggered by nearby storms, etc.

6p.04 Community Satellite Processing Package (CSPP) for Low Earth Orbit (LEO) Satellites: Recent Updates and Future Plans
Presenter: Liam Gumley, SSEC, University of Wisconsin-Madison
Co-authors: Kathy Strabala, Scott Mindock, Geoff Cureton, Matthew Odle, Tom Rink, Jess Braun, Graeme Martin, Allen Huang

The Community Satellite Processing Package (CSPP) for Low Earth Orbit (LEO) Satellites is a collection of freely available software for processing data from environmental satellite constellations including JPSS, Metop, POES, EOS, GCOM, and FY-3. CSPP LEO is funded by the NOAA JPSS program and has been available to the community since 2012. The software in CSPP LEO supports (a) decoding of CCSDS packets to create Level 0 data; (b) geolocation and calibration of sensor observations to create Level 1B data; (c) image processing and resampling to create high quality imagery; and (d) retrieval of atmosphere, land, and ocean parameters to create Level 2 products. CSPP LEO is primarily designed to support users who acquired satellite data via direct broadcast from the satellite, however it is also compatible with global stored mission data formats. CSPP LEO currently supports processing of data from NOAA-21, NOAA-20, Suomi NPP, Metop-B, Metop-C, NOAA-18, NOAA-19, Aqua, Terra, GCOM-W1, FY-3D, and FY-3E. For the JPSS satellites, CSPP LEO supports processing of data from the ATMS, CrIS, OMPS, and VIIRS sensors. CSPP LEO software is used by NOAA NWS in the Pacific and Alaska regions to generate image products for weather forecasting; by EUMETSAT and other agencies to provide low latency sounder data for WMO DBNet; and by SMHI and other groups to detect wildfires (among many other applications). This presentation will highlight recent developments in the CSPP LEO software suite to add support for NOAA-21 ATMS, CrIS, OMPS, and VIIRS; new capabilities for imaging VIIRS geophysical products including land surface reflectance, NDVI, and EVI; new products derived from OMPS including total ozone and sulfur dioxide; and support image products from FY-3E MERSI-LL. The poster will feature examples of applications for CSPP LEO products from users around the world. Plans for future CSPP LEO enhancements will be presented including support for JPSS-3 and JPSS-4.

6p.05 Quality of the ATOVS-derived precipitation amount over Poland during the flood event in September 2024
Presenter: Bozena Lapeta, IMGW-PIB

Co-authors: Tobiasz Gorecki and Artur Rutkowski

Detecting and estimating rainfall amounts based on satellite data is a challenging task, especially when dealing with stratiform rainfall in moderate latitudes. At the same time, prolonged stratiform precipitation can cause flooding and waterlogging, as was particularly vividly demonstrated in September 2024 in southern Poland. This underscore the importance of accurate detection and monitoring of such events within meteorological and hydrological forecasting systems. The satellite derived precipitation estimates may serve as a complement to ground-based and radar precipitation data when its quality is known.In the poster we will show the results of an analysis aimed at evaluating the accuracy of precipitation products derived from ATOVS data using different methods during flood event in Poland in September 2024. The algorithms implemented in the frame of EUMETSAT Satellite Application Facility on Support to Operational Hydrology and Water Management (H SAF) and in the CSPP MIRS package were considered. For the comparison, the combined product RainGRS was used as ground reference data.

6p.07 Level 2 validation and monitoring activities at EUMETSAT for future hyperspectral infrared mission

Presenter: Dorothee Coppens, EUMETSAT
Co-authors: Simon Warnach, Stefan Stapelberg, Marc Crapeau

EUMETSAT's upcoming hyperspectral infrared missions, including the METEOSAT Third Generation (MTG) Infrared Sounder (IRS) and the Infrared Atmospheric Sounding Instrument – New Generation (IASI-NG) aboard the EPS-SG satellite, are set to revolutionize data collection for Numerical Weather Prediction (NWP) and the Atmospheric Composition/Air Quality communities. Building upon the achievements and expertise gained from the IASI instrument, both missions introduce significant enhancements such as reduced radiometric noise. IASI-NG's expanded spectral sampling of up to 0.25 cm^{-1} in the thermal infrared range (645-2760 cm^{-1}) as well as IRS's unprecedented repetition rate of hyperspectral IR measurements every 30 minutes over Europe, mark a considerable leap forward from its predecessor, IASI, and greatly enhancing their utility for users.This poster provides an overview of the Level 2 (L2) validation and commissioning activities within the EUMETSAT hyperspectral infrared group. It highlights the tools developed to streamline the commissioning process and ensure the ongoing quality of routine operations. The IMOEN-NG (IASI Monitoring Environment - New Generation) tool facilitates comparisons between satellite data and NWP models, while also performing self-sanity checks to ensure data integrity. Additionally, the MONALiSA (Monitoring of Atmospheric Level 2 Satellite Products) tool is specifically designed for comparing infrared L2 products with ground-based and in-situ measurements, as well as campaign data.Furthermore, the poster outlines the methodologies and activities undertaken to compare L2 temperature and humidity profiles with aircraft measurements (AMDAR—Aircraft Meteorological Data Relay) and to validate these profiles against other satellite data sources (MAP_GII). Collectively, these efforts complete the comprehensive infrared L2 validation and monitoring activities at EUMETSAT, reinforcing our commitment to delivering high-quality data to the scientific community.

6p.08 Validation of IASI Temperature and Humidity using 11 years of airplane (AMDAR) measurements

Presenter: Dorothee Coppens, EUMETSAT
Co-authors: Jose Luis Villaescusa Nadal, Marc Crapeau, Tim Wagner, Tim Hultberg, Stefan Stapelberg

In 2022, EUMETSAT's released its Infrared Atmospheric Sounding Interferometer (IASI) Climate Data Record (CDR). This product contains all-sky temperature and humidity profiles obtained using the statistical retrieval module Piece Wise Linear Regression (PWLR3) and provides Metop-A and -B observations using a common reprocessing algorithm. This data was previously validated using radiosondes and reanalysis model data, showing positive results1. In this study, we aim to validate 11 years of this CDR (2010-2021) using in-situ temperature (T) and humidity (Q) values from the Aircraft Meteorological Data Relay dataset, since it provides a unique opportunity to validate IASI data in a wider range of geographical locations, times and atmospheric heights. First, we find the collocations between measurements in 3D, latitude, longitude and height. Second, we average the values of all T and Q airplane measurements inside each IASI Field of View (FoV) at each height. Finally, we analyse the value of the average difference with different slices, to see how accurate the IASI CDR is with different angles of observation, latitude values, ascending or descending profiles, clear or cloudy scenes, etc. Results show a close agreement between the two datasets, within 0.5 Kelvin for the temperature and within 0.8 g/kg in humidity. We also note a humidity bias difference unrelated to the measurement footprint size.

Session 7: Exploitation of artificial intelligence and machine learning

7.01 Skilful weather predictions from observations alone: general concept

Presenter: Chris Burrows, ECMWF
Co-authors: Anthony McNally, Christian Lessig, Peter Lean, Eulalie Boucher, Mihai Alexe, Ewan Pinnington, Matthew Chantry, Simon Lang, Marcin Chrust, Florian Pinault, Ethel Villeneuve, Niels Bormann, Sean Healy

In recent years, the prospect of running skilful forecast models based on machine learning techniques, as opposed to those based on physics, has become an area of rapid growth. Following initial work by Keisler, GraphCast and others, ECMWF has developed an AI-based model (AIFS) which is trained on ERA-5 reanalysis and performs as well, if not better than the physics-based NWP model (IFS) according to certain verification metrics. The AIFS model is now run operationally at ECMWF in parallel with IFS. The AIFS model works entirely in gridded model space, and requires an accurate analysis as input in order to make skilful predictions, so the next logical question is whether it would be possible to use machine learning to replace the assimilation step. Unlike earlier concepts (Boukabara et al), ECMWF is developing an exploratory system based purely on observations, with no information from NWP models or reanalysis used in either the training or the inference. This is accomplished by training an AI algorithm to use observations in a given window to predict later observations at a given lead time. Once trained, this model can be run to predict future observations, of which some are direct measures of geophysical quantities (e.g. radiosondes). The important statistical correlations between observation types, notably between in-situ observations and satellite sounders, are learned implicitly by the AI algorithm, via a self-attention mechanism, or through graph connections. This enables, for example, future radiosonde observations, to be predicted at gridded locations over the entire globe, and hence these form an estimate of the global temperature field at some time in the future. Skilful predictions are already being made with lead times of several days, and progress is rapid. The presentation will introduce the general concept and summarise the latest status.

7.02 Skilful weather predictions from observations alone: the role of passive sounders

Presenter: Niels Bormann, ECMWF
Co-authors: Anthony McNally, Christian Lessig, Peter Lean, Eulalie Boucher, Mihai Alexe, Ewan Pinnington, Matthew Chantry, Simon Lang, Chris Burrows, Marcin Christ, Florian Pinault, Ethel Villeneuve, Sean Healy

ECMWF are currently developing an exploratory system that uses machine learning to produce weather forecasts from observations alone, without employing a physically-based forecast model or a traditional data assimilation step. Trained on past data, the system learns relevant relationships between different observations and uses these to make skilful predictions of future observations directly from a set of recent observations. Being entirely data driven, the approach extends naturally to using any kind of observation, including observations that are more challenging to use in a traditional assimilation system. The latter includes observations for which physical modelling or error characterisation is more challenging, such as cloud-affected radiances or surface-sensitive radiances over “difficult” surfaces such as snow and sea-ice. In addition, the system can be readily expanded to forecasting the full Earth system (atmosphere, land, ocean, sea-ice, composition), provided relevant observations are included. This presentation will explore how these aspects affect the role and impact of passive sounding data in such a system, in comparison to their established use in state-of-the-art traditional data assimilation. Strengths and weaknesses will be highlighted, including how both approaches deal with some of the practical aspects of using passive sounding data for weather forecasting.

7.03 Assimilation of all satellite observations using AI: some primary results

Presenter: Wei Han, CMA Earth System Modeling and Prediction Centre (CEMC)
Co-authors: Xiaoze Xu, Zeting Li, Yonghui Li, Hao Li, Xiuyu Sun, Xiaohui Zong, Lei Chen

Both traditional NWP models and recently emerging deep learning-based (DL-based) weather forecasting models rely on initial fields generated by traditional DA systems. At present, DL-based weather forecasting models have demonstrated the potential to rival or even surpass the leading operational NWP models worldwide. This success has prompted the exploration of a DL-based DA framework. DL models possess multi-modal modeling capabilities, enabling the integration of multi-source data within the feature space, which closely resembles the process of assimilating multi-source observational data in DA systems. Here, we developed AI-DA, a generalized DL-based DA framework for assimilating satellite observation data. In experiments assimilating data from the Advanced Geosynchronous Radiation Imager aboard Fengyun-4B, AI-DA exhibited strong assimilation capabilities and demonstrated physical consistency. In our latest study, we employed the latest version of AI-DA to assimilate data from five microwave sounders on three polar-orbiting satellites, along with radio occultation data from the Global Navigation Satellite System, integrating it with the DL-based weather forecasting model FuXi to establish the first AI assimilation forecasting system—FuXi Weather. FuXi Weather operates using a 6-hourly DA and forecast cycle, producing reliable and accurate 10-day global weather forecasts with a spatial resolution of 0.25°. FuXi Weather surpasses the predictability of the European Centre for Medium-Range Weather Forecasts' (ECMWF) high-resolution forecasts (HRES), extending the skillful forecast lead time for key variables such as the 500 hPa geopotential height from 9.25 days to 9.5 days, despite utilizing significantly fewer observational data.Although these results are encouraging, several challenges remain. While FuXi Weather extends the forecast lead time for certain variables, its short-term forecast accuracy still requires further improvement. We believe that through the increased assimilation of observational data, FuXi Weather’s analysis and forecast accuracy can be further enhanced in future work.

7.04 Prototype for bias-correction of microwave radiance observations using machine learning methods

Presenter: Alice Abramowicz, KNMI
Co-authors: Isabel Monteiro, Kirien Whan, Irene Garcia Marti

HARMONIE-AROME is a regional Numerical Weather Prediction (NWP) model used for short-range weather forecasting in several operational centers across Europe. This NWP model relies on data assimilation, which aims to define the most accurate conditions of the state of the atmosphere. Among others, microwave radiance observations are crucial for the forecast skill. However, these observations are subject to systematic biases that need to be considered in the assimilation process. Currently, in HARMONIE-AROME, bias correction of microwave radiance observations is performed using linear models for the bias in an adaptive approach using the variational assimilation system (i.e., VarBC). While this approach is effective, it is closely tied to the assimilation system and the specific model domain. This research explores an alternative way to correct for the biases of microwave radiances before they enter the data assimilation process using data-driven machine learning techniques, such as Neural Networks, Adaptive Boosting, Random Forests, and Quantile Random Forests. The predictions generated by these machine learning models are then integrated into the operational setup to produce short-range weather forecasts for the studied timeframe. These machine learning-based forecasts are then compared with the traditional forecasts. This research uses observations from the Advanced Microwave Sounding Unit (AMSU-A), the Microwave Humidity Sounder (MHS), and the MicroWave Humidity Sounder-II (MWHS2) onboard the Metop-B, Metop-C, and FY-3D satellites. The development of a bias-correction prototype for microwave radiance observations offers significant potential for advancement in several critical areas. First, it could enable more precise corrections in high-resolution, sub-kilometer domains, which are currently challenging for the traditional VarBC methods. Secondly, the machine learning approach could accelerate the spin-up phase for the next generation of Metop-SG satellites, enhancing the efficiency of microwave radiance assimilation for operational forecasting.

7.05 Neural network approach to determination of total and tropospheric ozone columns from spectral measurements of outgoing thermal radiation

Presenter: Alexander Polyakov, Saint-Petersburg University
Co-authors: Yana Virolainen, Svetlana Akishina, Georgy Nerobelov

For monitoring of both total ozone columns (TOCs) and tropospheric ozone columns (TrOCs) in the atmosphere, only satellite remote sensing methods provide global continuous measurements. Methods based on measurements of outgoing atmospheric thermal radiation spectra provide information on TOCs and TrOCs during the polar night period. We consider estimates of TOCs and TrOCs based on such spectra measured by the IKFS-2 instrument aboard the "Meteor M" No. 2 satellite, obtained using artificial neural network (ANN) approaches. Methods for determining the TOCs and TrOCs from the outgoing thermal infrared radiation spectra based on the methods of ANN and principal components have been developed. The approximation error of TOCs when trained by ANN is close to 3 % on average, less than 2 % in the tropical region, and increases to 6-8 % in the polar regions during winter-spring period. The methodology for determining the TOCs has been previously described, so we analyse in detail the ANN for determining the TrOCs only. For this purpose, we considered different types of training data and optimised the structure of the ANN. The approximation error of the TOCs when training the optimal ANN is about 3.4 DU. The techniques have been applied to process the spectra measured from "Meteor M" No2 satellite in 2015 - 2022. The TOC retrievals were compared with the data from TROPOMI and ground-based observations (Dobson and Brewer instruments, direct Sun measurements). The standard deviations of the differences are about 2.7% for both comparisons. The TrOC retrievals were compared to the IRWG-NDACC network observations. On average the standard deviations of the differences between the satellite and ground-based observations are about 3 DU, which is ~15% of the TrOCs derived by the FTIR measurements. The TOC and TrOC IKFS-2 retrievals allowed us to analyse their spatial and temporal variability in the atmosphere. Examples of the analysis are given. In this study, we demonstrate that, although the regression approach is not considered to be optimal for solving the inverse remote sensing problems, the adequacy and completeness of the training data set allows us to obtain valuable results. The research was supported by St. Petersburg University (Project number 116234986).

7p.01 Sea ice surface emissivity modelling using data assimilation and machine learning

Presenter: Niels Bormann, ECMWF
Co-authors: Alan Geer

Assimilation of microwave radiances over sea ice surfaces has been limited by poor knowledge of the surface emission and reflection characteristics, as well as by limitations in knowledge of the sea ice concentration (SIC). Until recently, only channels with weak surface-sensitivity have been assimilated, using a dynamic emissivity retrieval or emissivity atlases. At ECMWF, a new technique has been developed using a combination of machine learning and data assimilation to simultaneously estimate an empirical sea ice surface emissivity model along with the SIC, based on microwave imager radiances from a year-long training dataset. From ECMWF cycle 49r1, which is going operational in late 2024, this surface emissivity model has been used within the atmospheric 4D-Var data assimilation to allow assimilation of strongly surface sensitivity channels from 10 to 89 GHz from microwave imagers. As well as influencing the atmosphere, this provides SIC retrievals at observation locations that are intended for future assimilation in the ocean data assimilation component, replacing external retrievals. A particularly difficult aspect of the sea ice emissivity problem is that the temperature profile, microstructural details and optical characteristics of sea ice and snow are poorly known, so the model takes as input three empirical variables which are intended to represent these unknown controlling factors for the sea ice emissivity. These variables are retrieved from the observations, simultaneously with the SIC, using auxiliary observation space control variables (known as TOVSCV). Although the current approach applies only to microwave imagers with a fixed 53 degree zenith angle, the aim is to extend the technique to cross-track sounders. A first development has been to extend the model up to 183 GHz and this is intended to be active in cycle 50r1. Future developments that will support cross-track sounders are: first, to include the extension to a full range of zenith angles by including ATMS, AMSUA, MHS and MWHS2 in the training dataset; second, to include more physics in the empirical emissivity model, either by accounting for partially Lambertian surfaces or ideally by moving to a fully physical description of radiative transfer in the snow and ice layers; third, to estimate the SIC and possibly some of the empirical state variables at grid locations rather than in observation space, to allow sharing the best knowledge of up-to-date surface characteristics from imagers to sounders. It is intended to apply similar techniques to land surfaces, both with and without snow, over the next few years, thus making a major step forward towards a full earth system utilisation of satellite radiances.

7p.02 Deep Learning Approach to Estimating Uncertainty in the Copernicus Arctic Regional Second Generation Reanalysis: A Prototype

Presenter: Swapan Mallick, Swedish Meteorological and Hydrological Institute (SMHI)
Co-authors: Jelena Bojarova

Copernicus is the Earth observation component of the European Union’s space programme. The European Centre for Medium-Range Weather Forecasts (ECMWF) has been appointed by the European Commission with funding from the EU to operate the Copernicus Climate Change Service on its behalf. Copernicus Arctic Regional Reanalysis Second Generation (CARRA-2), which spans the pan-Arctic region, is a high-resolution (~2.5 km) climate data product. A 3D-VAR data assimilation system, with three-hourly assimilation cycles, is used to provide a more accurate estimate of the atmospheric state by integrating a long time series of conventional and satellite remote sensing observations into the Harmonie-AROME model. A key requirement for CARRA-2 is to compute potential ensemble uncertainties for essential climate variables. This research aims to estimate uncertainty for possible climate variables by utilizing all available information from both observational and model spaces, considering bias, root mean square error, ensemble spread, and cumulative probability distribution. The ultimate goal of this research is to develop an empirical relationship using a machine learning approach, leveraging both coarser-resolution ERA5-EDA ensemble data and high-resolution CARRA-2 ensemble data. Multiple phases of research are underway to build a robust system of deep learning models to predict uncertainty between ensembles. One aspect of this effort involves the empirical downscaling of prognostic variables through a generative diffusion-based super-resolution model using the Denoising Diffusion Probabilistic Model (DDPM). This model, combined with a Convolutional Neural Network (CNN), uses the CNN to progressively remove noise from the data in multiple steps. Further details of the CARRA-2 reanalysis data, methodology, and machine learning approach, along with results, will be discussed.

7p.03 Analysis of severe convection situations in Africa and Europe with the new NWCSAF sSHAI product derived from IASI as a proxy for MTG-IRS data

Presenter: Niobe Peinado-Galan, AEMET
Co-authors: Xavier Calbet

In the coming months, the first Meteosat Third Generation Sounding (MTG-S) will be launched and will be the first operational sounding satellite in a geostationary orbit over Europe. It will include the Infrared Sounder (IRS), which is an interferometer based on an imaging interferometer with a very high spectral resolution, commonly known as hyperspectral infrared sounders. The IRS is set to revolutionise weather forecasting by tracking the three-dimensional structure of atmospheric temperature and humidity for the first time on an operational way.Until the new MTG-IRS is operational, as a starting point, existing hyperspectral sensors on board polar satellites can provide a good approximation to the future MTG-IRS data, such as the Infrared Atmospheric Sounding Interferometer (IASI) instrument. In this work, IASI is used as a proxy for MTG-IRS, since IASI, among others hyperspectral sounders, are used to calculate satellite products from the retrieved atmospheric profiles of temperature and humidity. These products are generated to support real time meteorological applications.In order to obtain the best possible atmospheric profiles from the data provided by MTG-IRS, an algorithm based on Machine Learning/Artificial Intelligence techniques has been developed. For this purpose, IASI-MetOp data (as a proxy for MTG-IRS) have been used to characterise its capabilities in providing information on temperature, humidity and atmospheric instability profiles. The machine learning model presented in this work is able to retrieve accurate atmospheric temperature and humidity profiles under skies with cloud fraction up to 80%. This result is particularly important to provide the information on atmospheric structure needed to improve convective forecasts. The aim is to design a real-time operational machine learning method to help forecasters monitor and analyse the atmosphere and the possible occurrence of severe phenomena such as severe convection. However, the hyperspectral infrared sounders on board satellites have significant limitations in deriving high-quality atmospheric profiles. This is because retrievals lose accuracy in the lower layers of the atmosphere, where it is most critical for instability indices (e.g. CAPE). In this work, a solution is provided by adding ground-based data to complement the Infrared Sounder profiles. The results show a significant improvement in the CAPE values calculated from the atmospheric profiles. Although it is difficult to assess this improvement due to the lack of CAPE reference data to validate the values obtained from the retrieved atmospheric profiles. Several situations of interest are presented in this work, where severe convection had a high impact on the surface causing various damages and flooding. The results show how areas where severe convection occurs are better detected and more accurately defined by CAPE values calculated with physical variables retrieved from the satellite's hyperspectral resolution radiance measurements complemented with surface based data.

7p.04 Estimating Tropospheric Methane from Cross-track Infrared Sounder (CrIS) Spectra using a Machine Learning Method

Presenter: Likun Wang, University of Maryland
Co-authors: Lihang Zhou, and Satya Kalluri

The Cross-track Infrared Sounder (CrIS) on the Joint Polar Satellite System (JPSS) satellites is a Fourier transform spectrometer, providing sounding (temperature and humidity) and trace gas the of the atmosphere with 2221 spectral channels along three infrared bands. This paper presents a Machine Learning (ML) method to retrieve the methane in the middle troposphere from CrIS spectra. The spectral signature of a target trace is a complex function of the methane and the other parameters, such as the state of the atmosphere (atmospheric temperature and humidity profiles) and surface (skin temperature and emissivity), interfering trace gas, and the viewing geometry. Different from traditional physical retrieval methods, the main idea of the ML-based approach is to use a neural network (NN) to approximate the complex inverse function that maps the target trace gas concentration to the CrIS radiances measured based on the training datasets. As the first step, the authors utilize the Thermodynamic Initial Guess Retrieval (TIGR) dataset coupling with a three-dimensional chemical-transport model outputs (e.g., CAMS global greenhouse gas reanalysis) to build the training datasets through radiative transfer model calculations. The training dataset will cover a large range not only of the concentration of the target trace gas but also of the auxiliary parameters on the state of the atmosphere and surface. Competitive networks such as generative adversarial networks (GAN) in which multiple networks (of varying structure) compete will be trained to finally determine model parameters (weights for each node) based on the training datasets. Finally, we will use the real CrIS spectral as inputs to estimate the tropospheric methene from the trained neural network models. The retrieved methane will be compared with the existing sounding products from a physical method (e.g., NUCPAS) as well as those measured from ground and aircraft to further evaluate the proposed ML-based retrieval method.

Session 8: Climate studies

8.01 Embarking the journey of Fundamental Climate Data Records (FCDR) of Indian Meteorological Satellites

Presenter: Shibin Balakrishnan, India Meteorological Department
Co-authors: Viju John, Carlos Horn, A.K Mitra, M.Mohapatra

Since satellites have been tracking the Earth for over 40 years, it is now possible to use Earth observation photos to examine the behaviour of the Earth system over long time periods. Combining data from several instruments is crucial for such long-term investigations, and the oldest datasets are especially crucial for creating a baseline for trend analysis. The magnitude of these image collections makes a manual inspection unfeasible, but strict quality control is crucial because the quality of these older datasets is frequently inferior. As a result, automatic techniques are required to check these Earth observation photos for irregularities. A finite list of anomalies that required to be found in the entire dataset was produced by this preliminary analysis, which was carried out by hand on a sample subset. Long-term, reliable Earth satellite observations known as climate data records (CDRs) are becoming more and more crucial for improving the precision of identifying, attributing, and forecasting changes in the global climate and environment. The various INSAT datasets that are currently accessible and their anomalies are the main focus of the current preliminary investigation. Different training datasets are produced for quality assurance and pattern matching. The orbits offer collocations close to the GEO Sub-Satellite Point (SSP) at set time frames every day and night for geostationary and sun-synchronous satellite inter-calibrations. The region near the GEO

Sub-Satellite Point (SSP), as perceived by the GEO sensor, with a zenith angle below a threshold is known as the GEO Field of Regard (FoR). This study will be vital in addressing the data gap over the Indian Ocean Data Coverage (IODC) region.

8.02 The assimilation of radiances in the ECMWF ERA6 global reanalysis.

Presenter: Bill Bell, ECMWF
Co-authors: Hans Hersbach, Paul Berrisford, Alison Cobb, Paul Poli, András Horányi, Joaquin Muñoz Sabater, Julien Nicolas, Raluca Radu, Dinand Schepers, Adrian Simmons, Cornel Soci, Mikael Kaandorp, Joerg Schulz, Viju John, Timo Hansemann, Andrzej Klonecki, Pascal Prunet, Jon Mittaz, Tom Hall and Carsten Standfuss

The production of the latest generation of ECMWF's atmospheric reanalyses, ERA6, starts in early 2025. Initial production streams will cover the period 2006-present & later streams will be extended back to 1950. ERA6 includes several new developments in the assimilation of radiance observations, including the treatment of time-varying CO2 concentrations in the assimilation of the hyperspectral IR instruments. This development eliminates the long-term drift in the biases analysed by VarBC in earlier reanalyses and improves re-forecast performance for periods tested in 2008 and 2016. In addition, ERA6 will assimilate several reprocessed radiance datasets, including a completely reprocessed dataset of the entire HIRS mission. Tests have shown this improves ERA6 performance. Datasets never previously assimilated in previous reanalyses have been evaluated in readiness for the streams covering earlier epochs, including radiances from the SSM/T-1 and SSMI/T-2 datasets from the DMSP programme in the 1990s. Data from a number of very early satellite instruments have been evaluated, inkling those from NEMS, SCAMS, ESMR, SCR and SSH.

8.03 Microwave temperature sounder fundamental climate data records for climate applications

Presenter: Timo Hanschmann, EUMETSAT
Co-authors: Viju John, Roger Huckle, Joerg Schulz

The upper air atmospheric temperature, particularly the temperature trends in the troposphere and stratosphere are major indicators of a changing climate. In reanalysis, such as ERA-5, these temperatures show larger biases around the stratopause and the stratosphere for times prior to the advent of radio occultation measurements. Further, in the mesosphere ERA-5 suffers from no observations. Microwave temperature sounders provide key observations of global upper air atmospheric temperatures and are assimilated into reanalysis models or considered to be assimilated into upcoming reanalysis. Unfortunately, these measurements are subject to various limitations ranging from the inadequate quality of calibration to aliasing of the temperature diurnal cycle due to drifting orbits of many of the satellites in the series. Apart from NOAA, no organisation has provided corrected radiation data. Here, certain instrument effects such as spectral shifts in some of the Microwave Sounding Unit (MSU) channels have not systematically been addressed, which is necessary to reduce above mentioned biases in reanalyses. In addition, additional measurements such as those from the Special Sensor Microwave - Temperature (SSM/T) instrument, flown on the US Air Force DMSP satellites F10 to F15 in the 1990s with an extended channel set including channels in the middle stratosphere have not been addressed in this context. Further, upper atmospheric measurements, as those from the Special Sensor Microwave Imager / Sounder (SSMIS) instrument onboard of the current DMSP satellites, provide valuable information on the mesospheric temperatures and have not been assimilated yet. This presentation will demonstrate the quality of the additional measurements of the SSM/T that will be used to constrain analysis of stratospheric temperature when assimilated into the ERA-6 reanalysis. The SSM/T measurements have been compiled into a new data record that is available from EUMETSAT. The validation of the data record reveals very good agreement with reference to radio occultation measurements. Consistent and stable standard deviations of the differences against simulated radiances from ERA5 data illustrated that the SSM/T instruments did not degrade in orbit. The SSM/T instruments data also provide additional diurnal sampling, as they were operated in early morning orbit that was not covered by the operational NOAA weather satellites.This presentation will also show the ability of SSMIS upper atmospheric channels to describe the temperature pattern above the upper stratosphere, where observations are sparse. SSMIS radiance data have been processed and compared against simulations based on ERA-5 profiles and AMSU-A channel 14 data. These data can be essential to support the representation of the temperature at high altitudes in ERA-6. In addition, calibration issues are revisited by presenting an alternative calibration approach that will be used with the MSU time series and for the Advanced Microwave Sounding Unit A (AMSU-A) time series. This is based on a modified measurement equation, providing improved calibration accuracy, increased sensor stability, and considering frequency shifts in some of the channels. The presentation will provide an assessment of the new calibration model and frequency shifting of MSU data, and our overall approach for harmonising the instruments in the time series for climate monitoring and assimilation to generate climate quality reanalyses.

8.04 The NASA CrIS Level 1B Version 4 Software and Product

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

The NASA CrIS Level 1B product is a long-term data record of observations from the Cross-track Infrared Sounder (CrIS) instruments, on-board the Suomi NPP and JPSS series of satellites. The product is intended for use in studies of climate and atmospheric processes, and is the basis for retrievals and other NASA-funded sounder science. Datasets are publicly available via NASA GES DISC and EarthData.Key project objectives are to achieve accuracy and consistency over the lifetime of each instrument and among the multiple CrIS instruments, as well as long-term continuity with AIRS and other IR sounder missions. To accomplish this, optimal calibration parameters are developed and applied for different “epochs” of an instrument’s life, delineated by major events such as electronics side changes and sensor failures. Long-term monitoring and assessment will be needed to maintain product quality through the lifetime of the CrIS instruments. The CrIS Level 1B software is developed and maintained by a small, PI-led team located at the University of Wisconsin-Madison and University of Maryland-Baltimore County. In collaboration with the NASA Sounder SIPS, a flexible and efficient workflow has been developed that allows science code to be run directly to generate the final product. Compared to traditional R2O methodologies, this approach constrains the time and effort required to develop and integrate science and software updates, and offers a blueprint for future programs such as NEON.Beyond the primary Level 1B product that is the focus of this presentation, the CHIRP product has been developed, with the goal of eventually homogenizing the CrIS and AIRS records into a single data record. In addition, two value-added products have been developed: an “IMG” product providing VIIRS information within the CrIS footprints, and a principle-component based version of the L1B product (PCA-RED) offering 50x reduction in data volume, reduced noise and rapid event detection.Each major software release to date has offered significant improvements to the underlying algorithm, and has resulted in a full mission reprocessing for each instrument. The Version 4 release adds full support for JPSS-2 (NOAA-21), building on an earlier beta release, and includes a newly developed mitigation for calibration errors introduced while the JPSS-2 spacecraft is exiting from eclipse. Other major improvements include correction for Doppler shift due to the movement of the spacecraft relative to the Earth, detection of lunar intrusion using a physical model, improved polarization correction, and enhanced spectral ringing suppression. Results of an internal product assessment will be shown, including comparisons with previous products, intercomparisons with data from other instruments, and assessment of stability throughout the data record.

8.05 New Stratospheric Temperature Climate Data Records by Merging SSU with AIRS

Presenter: Likun Wang, University of Maryland
Co-authors: Xianjun Hao and Cheng-Zhi Zou

Long-term changes in stratospheric temperatures are important for climate trend monitoring and interpreting the radiative effects of anthropogenic emissions of ozone-depleting substances and greenhouse gases. The Stratospheric Sounding Unit (SSU) onboard the historical NOAA Polar Orbiting Environmental Satellite (POES) series was a three-channel infrared radiometer designed to measure temperature profiles in the middle and upper stratospheres. Although the SSU observations were designed primarily for weather monitoring; however, due to continuity, long-term availability, and global coverage, they comprised an indispensable climate data record that had been playing a key role in estimating temperature trends in the middle and upper stratospheres for the period of 1979–2006 (Wang et al. 2012; Zou et al. 2014). On the other hand, since 2002, the hyperspectral infrared sounding measurements including the Atmospheric Infrared Sounder (AIRS), the Infrared Atmospheric Sounding Interferometer (IASI), and the Cross-track Infrared Sounder (CrIS) provides decades of infrared hyperspectral observations. Owing to their hyperspectral nature and accurate radiometric and spectral calibration, these datasets provide modern period measurements of stratospheric temperature with high data quality. This study presents recent efforts of merging of the SSU stratospheric temperature data with AIRS. We generated the training datasets of SSU and AIRS from the UMBC 48 profiles with different scan angles using the Community Radiative Transfer Model (CRTM). A linear regression method with considering weighting function and instrument noise as constrains is developed to convert AIRS into equivalent SSU based on training datasets. By taking advantage of their overlapping period of SSU and AIRS in 2003-2006, the residual biases are further removed along the scan angels. The effects of increases in atmospheric CO2 concentration on stratosphere temperature records are also removed to make the dataset suitable for stratospheric temperature monitoring. Finnlay, the SSU-AIRS dataset is compared with the existing SSU/AMSU/ATMS dataset (Zou and Qian 2016). The differences of their variability and trend are presented. The new SSU/AIRS dataset provides another long-term observation for stratospheric temperature monitoring.

8.06 Comprehensive Infrared forward-inverse analysis of the Ozone hole with IASI

Presenter: Guido Masiello, University of Basilicata
Co-authors: Tiziano Maestri, Carmine Serio, Giuliano Liuzzi, Michele Martinazzo, Federico Donat, Lorenzo Cassini, Rocco Giosa, Pamela Pasquariello, Marco D'Emilio

The Antarctic ozone hole recurrently appears and develops each spring, reaching its maximum extent and depth in October or November. It usually disappears by December as the temperature in the Stratosphere rises. This warming prevents the formation of Polar Stratospheric Clouds (PSCs), which are the fundamental catalytic mechanism for the chemical reactions destroying ozone. PSCs form when the temperature drops below 195 K, allowing nitric acid and water vapor to condense into iced crystals (typically HNO3-3H2O or NAT).Various satellite instruments closely track the ozone hole, including the Ozone Monitoring Instrument (OMI) and the Tropospheric Monitoring Instrument (TROPOMI). These instruments rely on reflected sunlight to measure ozone concentrations. However, due to their dependence on this reflected light, their ability to monitor ozone during the early stages of the ozone hole, when the polar region is still dark, is significantly limited, and they do not sense nitric acid and water in the gas phase.HNO3 is typically monitored by limb-sounding Microwave instruments such as MLS/AURA (Microwave Limb Sounder), working at coarser spatial resolution with respect to the sensors dedicated to ozone monitoring. Moreover, these instruments have no sensitivity to the thermodynamic conditions (i.e. temperature) of the UT/LS region.Recent improvements in forward (doi:10.1016/j.jqsrt.2023.108814) and inverse (doi:10.1016/j.jqsrt.2024.109211) radiative modelling have enabled the simultaneous retrieval of thermodynamic parameters, O3, and HNO3 in the Upper Troposphere in all-sky conditions from the Infrared Atmospheric Sounding Interferometer (IASI) measurements that, from its polar orbit, provides excellent spatial and temporal coverage of the regions affected by the ozone hole phenomenon.This study analyzes IASI data collected over Antarctica during 2021-2023 to investigate the ozone hole and nitric acid (HNO3) concentrations. Our findings reveal a significantly more extensive and deeper ozone hole than the ECMWF analysis, which ingests TROPOMI and OMI data that are limited during winter, mainly in the Antarctic interior.We demonstrate a correlation between decreasing HNO3 concentrations and upper tropospheric temperatures below 195 K, supporting the role of NATs in ozone depletion. IASI spectra near the pole confirm the presence of NATs. Our analysis of HNO3 spatial patterns from IASI and MLS/AURA shows excellent agreement, further indicating that the observed HNO3 decline occurs primarily in the Upper Troposphere under cold conditions conducive to NAT formation.

8p.01 25 Years of a Sustained Generation of Satellite-Based Climate Data Records by EUMETSAT CM SAF

Presenter: Nathalie Selbach, Deutscher Wetterdienst

Co-authors: Rainer Hollmann, Marc Schröder and the CM SAF team

In recent decades, climate variability and change have caused impacts on natural and human systems on all continents. Observations are needed to understand and document these impacts and their causes. Such observations are increasingly based on remote sensing data from satellites which offer a continuous coverage on a global scale. Only long-term and consistent observations of the Earth system allow us to quantify climate variability and change and their impacts on the natural and human dimension.Since more than 25 years, the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Satellite Application Facility on Climate Monitoring (CM SAF, https://www.cmsaf.eu) has been developing capabilities for a sustained generation and provision of Climate Data Records (CDRs) derived from primarily operational meteorological satellites. The product portfolio of the CM SAF comprises long time series of Essential Climate Variables (ECVs) related to the energy and water cycles as defined by the Global Climate Observing System (GCOS). Currently available CM SAF CDRs include, among others, precipitation, radiative fluxes at the surface and top of the atmosphere, cloud products, upper tropospheric humidity, surface albedo and temperature as well as latent heat flux/evapotranspiration. The recent CDR versions cover the WMO reference period from 1991-2020. Several of the CM SAF CDRs have a temporal coverage of more than 40 years. In order to serve applications with strong timeliness requirements, CM SAF also produces so-called Interim Climate Data Records (ICDRs), which are typically released within a few days after the observations. All products are well-documented, carefully validated and have been externally reviewed prior to product release.A short introduction to CM SAF and an overview of available and upcoming CDRs and ICDRs from CM SAF will be presented.

8p.02 22 Years of Hyperspectral Infrared Satellite Observations: Creating Climate Data Records and Examining Trends in Top-of-atmosphere Spectral Radiances, Integrated Nadir Longwave Radiance (INLR), and Outgoing Longwave Radiation (OLR)
Presenter: David Tobin, CIMSS/SSEC
Co-authors: Hank Revercomb, Joe Taylor, Bob Knuteson Larrabee Strow, Sergio DeSouza-Machado

Starting with the Atmospheric Infrared Sounder (AIRS) in 2002 and continuing with the Cross-track Infrared Sounders (CrIS) on S-NPP and the JPSS satellites, we now have 22 years of measurements of top-of-atmosphere infrared spectral radiance from the 1330 orbit. This poster will summarize efforts to create and validate the radiance products, focusing on the spectral and radiometric traceability, accuracy and stability needed for climate products and long term studies, and present resulting trends in spectral radiances, Integrated Nadir Longwave Radiance (INLR) and Outgoing Longwave Radiation (OLR).

Monday, 12 May 2025

Session 9: Advances in assimilation methods

9.01 Adaptive Estimation of ATMS Observation Uncertainty to Improve Atmospheric Prediction
Presenter: Chris Hartman, U.S. Naval Research Laboratory Marine Meteorology Division
Co-authors: Christopher M. Hartman, William Campbell

We are currently in an exciting era with an unprecedented number of novel observations for data assimilation systems. This abundance of new observations necessitates finding optimal ways to use them. One key challenge is the estimation of their uncertainty. For satellite observations, most operational centers assume they are well calibrated and that their observation errors do not vary spatially or temporally. In this study, we relax both of those assumptions for radiance observations and demonstrate on the ATMS (Advanced Technology Microwave Sounder) instrument. The ATMS, with 22 channels, is capable of providing temperature and humidity profiles in all-weather conditions, as well as precipitation information. We estimate the observation uncertainty using a proven Desroziers method, which uses the residuals of observation-minus-analysis (O-A) and observation-minus-background (O-B). We adaptively estimate both the uncertainty (in terms of standard deviation) of each channel, as well as the error correlation of each channel, for ATMS observations across various geographic regions and time. Finally, the impact of adaptively estimating the ATMS observation uncertainties, both homogeneously and heterogeneously represented in time and/or space, is evaluated in the US NAVy Global Environmental Model (NAVGEM) forecasts initialized from analyses that made use of these estimates.

9.02 Expanding the use of geostationary satellite data at ECMWF
Presenter: Ethel Villeneuve, ECMWF
Co-authors: Samuel Quesada-Ruiz, Angela Benedetti, Chris Burrows, Cristina Lupu, Philip Browne

The use of geostationary satellites has been of significant benefit to the field of Numerical Weather Prediction, providing data with high spatial and temporal resolution that facilitate the monitoring of atmospheric processes on both regional and global scales. Clear-sky infrared radiances from water-vapour affected channels are routinely assimilated in many forecasting systems, including the ECMWF Integrated Forecasting System (IFS). Benefits of these observations include a better characterisation of the humidity fields as well as horizontal winds through the tracing effect in the 4D-Var analysis. Window channel radiances at 10.8 microns from Meteosat-SEVIRI, 10.3 microns from GOES-ABI and 10.4 microns from

Himawari-AHI are at the moment only used to support the cloud screening of the water vapour channels over ocean but are not actively assimilated. This presentation will highlight the use of these window channel observations in the assimilation and their impact on the NWP prediction through the analysis of the standard scores and the fit to other observations. The presentation will address the operational adjustments necessary for optimising the active utilisation of these channels, including a bespoke dust screening and a tighter cloud screening, as well as the need for quality control due to its sensitivity to surface conditions. These measures help ensuring the reliability of data derived from this channel. Additionally, the window channels significantly improve the accuracy of sea surface temperature (SST) assessments, which is a key factor in coupled ocean-atmosphere models. Experiments using skin temperature information derived from the window channels, into the coupled ocean-atmosphere data assimilation system in the latest version of IFS will be discussed. Preliminary analyses of the new instrument MTG-FCI, which is expected to provide improved data quality and availability, will also be presented.

9.03 Developing a SWIR/MWIR-based Cloud Detection for CrIS in CADS

Presenter: Erin Jones, UMD ESSIC @ NASA GMAO
Co-authors: Bryan Karpowicz, Chris Burrows

Historically, the assimilation of radiances from hyperspectral infrared (IR) instruments has focused primarily on the use of observations from the longwave (LWIR) part of the spectrum, and the use of shortwave (SWIR) observations has typically been avoided because of, for instance, difficulties in simulating these observations (primarily during the daytime) and characterizing their errors. Recent advances in radiative transfer models and data assimilation systems have sought to address these issues, but the challenge remains that the cloud detection schemes used for the clear-sky assimilation of radiances from hyperspectral IR sensors rely heavily on the use of LWIR channels. A downside of this dependence on one portion of the spectrum for quality control is the lack of ability to effectively assimilate observations from hyperspectral IR sensors when their LWIR bands fail (as occurred with S-NPP CrIS), or when they are built without LWIR bands to begin with - something that could occur in the future, considering that the lower power needs of SWIR instrumentation make the production of SWIR, or SWIR + midwave (MWIR), sensors for use on future smallsats an attractive prospect.To investigate the feasibility of a cloud detection scheme for the clear-sky assimilation of hyperspectral IR observations based on only SWIR and MWIR channels, a collaborative effort was undertaken between ECMWF, NASA GMAO, and UMD CISESS to develop and test a SWIR-based cloud detection for CrIS. This cloud detection scheme employed the NWP SAF Cloud and Aerosol Detection Software (CADS) and omitted the use of any channels from CrIS's LWIR band. During the process of tuning/optimization, results from SWIR and MWIR-based cloud detection were compared to results from the LWIR-based cloud detection implemented in CADS at ECMWF as a way to assess the scheme's performance. To test the performance of the cloud detection in data assimilation, a series of OSEs was performed using ECMWF's Integrated Forecasting System. To be discussed here are the particulars of the SWIR and MWIR-based cloud detection for CrIS, some results from the use of this cloud detection in the IFS, and some thoughts what work should still be done to optimize the assimilation of a hyperspectral IR sensor that does not provide any LWIR observations.

9.04 Vertical localization for the microwave humidity sounder in the ensemble Kalman filter

Presenter: Young-Chan Noh, Korea Polar Research Institute
Co-authors: Eui-Seok Chung, Yonghan Choi, Hyo-Jong Song, Kevin Raeder, and Joo-Hong Kim

Localization is an essential technique to mitigate the sampling error in the ensemble Kalman filter (EnKF). To effectively apply the localization function within the EnKF, the specific location information of observations being assimilated is essential to measure the distance between the model state variables and the observations. However, as the satellite-observed radiance represents integrated quantities across the entire vertical profile of an atmospheric column, it is a challenging issue to define the vertical location, especially for the satellite radiances sensitive to the variable atmospheric constituents (e.g., water vapor). In this study, we aim to estimate the vertical location for observations of microwave humidity sounders onboard low-earth-orbiting satellites, using the spectral characteristics of the microwave instrument channels. As the radiance departures between the channels are solely used to estimate the vertical location within the regression method, there is no need for additional computational costs such as the radiative transfer modeling. The estimated vertical locations are employed for the vertical localization function within the Data Assimilation Research Testbed (DART) based on the EnKF. The verification results show that applying vertical localization to observations from microwave humidity sounders significantly improves the water vapor analysis derived by the DART system, particularly in the lower troposphere.

9.05 Graph Theoretic Observation Thinning for Satellite Radiances

Presenter: William Campbell, U.S. Naval Research Laboratory
Co-authors: Christopher Hartman, Hui Christophersen

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, but large data volumes can also be problematic for a real-time NWP system. Most global NWP centers average (superob) observations, or discard (thin) a large percentage of them, or both. The reasons are not simply about data volume. Spatially correlated error is very difficult to account for properly, and ensuring that two profiles from the same satellite and instrument have a certain minimum horizontal spacing can mitigate the effect of that error. Another reason to thin is to choose good data, which is generally more about avoiding bad data. QC procedures can be expensive to run on full, raw radiance datasets, so often there is a thinning step first, which could potentially throw out all of the good data in a small area, leaving only bad data. We will present an adaptable methodology to address all of these concerns in a timely fashion, and show experiments comparing the performance of traditional data thinning versus the new approach. Note that this method is not restricted to satellite radiances, and is equally applicable to legacy instruments and newer microsats.Specifically, we perform a static thinning in an observation-blind way, retaining, for a particular satellite and instrument, approximately five times more data than we do routinely in our operational NWP system (NAVGEM). These data are chosen to fall near the centers of an approximately equal area latlon grid. The next steps are the new graph-theoretic approach to retain as many observation locations as possible while respecting an observation density function both globally and locally. This is done by first choosing a normalized observation density function whose maximum is determined by the minimum safe horizontal distance needed to mitigate spatially correlated error, chosen by the user. Other aspects of the density function can be set by the user as well. For instance, one might want the maximum density of observations over the SH and tropical oceans, less dense observations over NH oceans, and even less dense observations over land. Once the density function is set, each observation location is assigned a radius inversely proportional to the square root of the density function. At that point other metadata, such as QC flags, can be considered, possibly inflating the assigned radius for suspect obs. Because large radius observations are less likely to be chosen (see algorithm description below), QC inflation of observation radii downweights their selection, unless they are the only available observation, which is the behavior that we desire.Once the radii are assigned, we can solve the maximum disjoint set problem on the sphere. If one were to plot circles of the assigned radius at each observation location, there will be many circles that overlap, indicating that the observations are too close to one another relative to the assigned density function. The maximal disjoint set problem solution is to retain as many observations as possible with no circle overlapping any other circle. In general, this is an NP-hard problem, but fast, approximate methods work very well. We construct a graph representation of the observations, where each observation location is a node, and each overlapping circle is an edge between two nodes. Then we apply the algorithm to judiciously eliminate nodes until we are left with a completely disjoint set of nodes, (nearly) the maximum number of observations. These observations will directly reflect the chosen density function both locally and globally.We plan to present results from cycling DA runs of NAVGEM for satellite radiances using our standard thinning at baseline resolution, graph thinning at that same (uniform) resolution, and graph thinning at the same average resolution, but distributed according to density functions of interest.

9.06 Effect of bias correction sample selection on FY-3D satellite microwave humidity data assimilation in CMA_GFS model

Presenter: Xi Shuang, Center for Earth System Modelling and Prediction of China Meteorological Administration
Co-authors: Han Wei, Hu Hao

Because of the systematic bias between satellite observation and simulated observation, bias correction (BC) is necessary in satellite data assimilation. As the coefficient of initial bias correction derived from the statistical samples, what is the appropriate background field for statistical sample production? Is it a background field closer to the real atmosphere and correcting the observation with instrument error better, such as analysis filed NCEP FNL in numerical weather prediction (NWP)? Or is it a background field equivalent to the numerical weather model error, such as forecast filed of the same NWP model? In this paper, these two kinds of background field samples were used, for the humidity and temperature channels of the FY-3D microwave humidity sounder MWHS-2, in a global numerical weather forecast model CMA_GFS of China Meteorological Administration. The static bias correction and dynamic bias correction were taken successively in the 40-d cycling assimilation and prediction experiment. Result of bias correction, assimilation and 10-d prediction were evaluated. The results of bias correction show more stable and better, with the initial BC coefficients derived from BC samples using CMA_GFS background field, and with better results of assimilation and prediction. It shows that in long-time bias correction, especially in the dynamic bias correction, using background field samples that are closer to the numerical prediction model as the initial coefficient of regression statistics is conducive to the continuous reduction of model errors after variational assimilation.

9.07 Introducing horizontal correlations of satellite observation errors into the data assimilation system of the AROME model

Presenter: Thomas Buey, Meteo France
Co-authors: Oliver Guillet, Nadia Fourrié, Olivier Audouin

In variational data assimilation, high-resolution satellite observation errors exhibit significant inter-channel, temporal, and spatial correlations. The vast number of observations and their uneven distribution complicate the modeling of the horizontal correlation matrix of observation errors. Consequently, strategies like thinning, variance inflation, and superobbing are commonly employed to mitigate these spatial correlations. This leads to a sharp decrease in the number of observations assimilated into operational systems, causing the non-diagonal terms of the correlation matrix to approach zero.

However, discarding observations that could hold valuable information results in a sub-optimal analysis. To support high spatial density operational assimilation, we propose an implementation of a non-diagonal observation error covariance matrix within the OOPS (Object-Oriented Prediction System) framework. To address this issue we consider infrared spectrum observations from the Spinning Enhanced Visible and InfraRed Imager (SEVIRI) and we run experiments using the AROME data assimilation system. The introduction of horizontal observation error correlations is evaluated for its impact on both analysis quality and computational performance.

9.08 Enhancing Numerical Weather Prediction Accuracy through EN4DVAR and Novel Satellite Data Assimilation

Presenter: Qifeng Lu, CMA Earth System Modeling and Prediction Centre (CEMC)

This report focuses on advancements in the China Meteorological Administration Global Forecast System (CMA-GFS) by upgrading its data assimilation method from traditional four-dimensional variational data assimilation (4DVAR) to ensemble-based 4DVAR (EN4DVAR). The EN4DVAR approach integrates ensemble forecasting into the variational framework, thus enhancing the system's ability to capture atmospheric uncertainty and improve forecast accuracy. The key of EN4DVAR is to capture more accurate initial conditions of the atmosphere through an ensemble-based approach, which better represents flow-dependent background errors. An essential development in the CMA-GFS system is the introduction of a constrained bias correction technique for assimilating microwave observation data. Microwave remote sensing offers valuable atmospheric information, particularly for temperature and humidity profiling. However, these measurements are prone to systematic biases due to variations in satellite sensor characteristics, environmental conditions, and data processing methods, especially at the high-level of NWP model. The newly developed bias correction methodology addresses these biases by implementing constraints within the assimilation process, improving the reliability of microwave data and thus contributing to more accurate numerical weather forecasts. Additionally, the study explores the role of commercial small satellite constellations in numerical weather prediction, with a particular emphasis on radio occultation (RO) data. Radio occultation from small satellite constellations provides high-precision atmospheric profiles, especially valuable in sparsely observed regions. This data, while beneficial, requires specific processing techniques such as vertical thinning to mitigate oversampling and data redundancy. Vertical thinning addresses the issue of data sparseness by reducing the vertical resolution to match the model's representation, thereby optimizing the assimilation of RO data within the CMA-GFS system. The results suggest that small satellite constellations can offer significant potential in enhancing global observational coverage and resolution, promising to play a larger role in future atmospheric modeling and prediction. The research also introduces new quality control and all-sky assimilation techniques for the Fengyun satellite series. The study presents customized quality control algorithms that effectively address instrument biases, calibration discrepancies, and observation noise. Additionally, specialized assimilation methods are designed to optimize the use of Fengyun data, enhancing its integration into the CMA-GFS system. These refinements allow for more precise observations of atmospheric parameters, further improving forecast accuracy.

9p.01 Assimilating FCI data within the Météo-France models

Presenter: Olivier Audouin, Meteo France
Co-authors: Nadia Fourrié

The majority of data used in numerical weather prediction models comes from radiance measurements captured by satellite instruments in Low Earth Orbit (LEO) and geostationary (GEO) orbits. Infrared imagers on GEO satellites, covering mid-latitudes and the tropics, provide essential atmospheric temperature and humidity profile information with high temporal and spatial resolution. In late 2022, EUMETSAT launched the first satellite in the Meteosat Third Generation (MTG) series, equipped with the innovative Flexible Combined Imager (FCI). This instrument offers advanced infrared data over Europe and Africa and will succeed the Spinning Enhanced Visible and Infrared Imager (SEVIRI) on the Meteosat Second Generation satellites. Compared to SEVIRI, FCI covers the infrared spectral range in slightly adjusted bands, with a twofold improvement in spatial resolution and signal-to-noise ratio. FCI delivers visible and infrared Earth imagery every 10 to 2.5 minutes with a spatial resolution between 0.5 and 2 km across 16 spectral channels, including eight in the infrared range from 3.80 to 13.3 μm and spectral resolutions between 0.40 and 1.00 μm.This study presents initial experiments on assimilating FCI data into Météo-France models. For the limited-area convection-permitting AROME model, the FCI assimilation strategy will mirror that used for the SEVIRI instrument, namely the assimilation of raw radiances. For the global ARPEGE model, the introduction of FCI allows a shift from assimilating SEVIRI-based clear-sky radiances (CSRs) to raw radiances, similar to the approach used for the ABI imager on GOES satellites. In both models, cloud scene conditions for assimilation, based on NWCSAF's cloud-type classification, will be detailed. Finally, the study will present assimilation experiment results to assess the impact of FCI compared to SEVIRI, with analyses on innovation statistics and long-term forecast quality. For the AROME model, evaluations of forecast quality in terms of sensible weather will also be presented. If relevant, for both models, case studies may also be included.

9p.03 Usage of L2 soundings in the data assimilation and numerical weather prediction system at the Argentinian NMS: present implementation and experiments.

Presenter: Maria Eugenia Dillon, Consejo Nacional de Investigaciones Científicas y Técnicas; Servicio Meteorológico Nacional

Co-authors: Paula Maldonado, Gimena Casaretto, Federico Cutraro, Yanina García Skabar, Cynthia Matsudo, Maximiliano Sacco, Silvina Righetti, Milagros Alvarez Imaz, Juan Ruiz, Soledad Osores, Paula Hobouchian

This work aims to provide an overview of the current usage of L2 soundings in the data assimilation and numerical weather prediction system at the National Meteorological Service of Argentina (SAP.SMN) and the future perspectives of including more products. Since 2020, the SMN has been running a 4-km horizontal resolution probabilistic forecast for the southern region of South America, using the Weather Research and Forecasting (WRF) regional model with the GEFS global model as initial and boundary conditions. After many years of regional data assimilation (DA) research, by the end of 2024 the SAP.SMN is transitioning to a high-resolution Local Ensemble Transform Kalman Filter (LETKF) DA system, adding value by using conventional, satellite and radar observations and producing hourly analyses. Particularly, L2 temperature and humidity profiles from AIRS are assimilated in this system, as their positive impact in both analyses and forecasts has been demonstrated in previous studies over our region. Moving forward in the necessity of including more observations in future updates to the DA system, some experiments were carried out assimilating L2 soundings from NUCAPS and IASI. Through the application of the Ensemble Forecast Sensitivity to Observations Impact (EFSOI) methodology it was found that, in general, the assimilation of these thermodynamic retrievals has a beneficial impact. This work emphasizes the importance of L2 soundings for regional DA systems which are not able to include radiances directly due to computational restrictions.

9p.04 Diagnostics of CrIS Preprocessing System in Korean Integrated Model (KIM)

Presenter: Na-Mi Lee, Korea Meteorological Administration

Co-authors: Jiyoung Son, Hyoung-Wook Chun, Yong Hee Lee

Since April 2020, the Korea Meteorological Administration (KMA) has been operationally running the Korean Integrated Model (KIM), which preprocesses observational data used for background fields and forecasts through the KIM Package for Observation Processing (KPOP). Among the various types of data, Cross-track Infrared Sounder (CrIS) data undergo preprocessing steps such as bias correction, cloud detection, outlier removal, and thinning. This study analyzed the impact of CrIS data on KIM and examined the preprocessing procedures. Impact assessment experiments were conducted using KIM3.9 at low resolution (25 km) from June 20, 2022, to August 6, 2022, and verification was performed for July 2022 using the analysis fields from the European Centre for Medium-Range Weather Forecasts (ECMWF) Integrated Forecasting System (IFS) as a reference. The experiment consisted of two configurations: the CTL experiment without CrIS data and the EXP experiment with CrIS data. Analysis of RMSE when compared with IFS analysis fields showed that EXP, relative to CTL, resulted in performance degradation of 4.08% in analysis and 0.64% in 3-day forecasts for temperature in the equatorial upper-middle layers (150~350 hPa). Furthermore, KIM analysis fields showed negative bias compared to IFS analysis fields in this region, and increment (A-B) analysis of CTL and EXP confirmed that CrIS data reinforced this negative bias. Innovation (C-B) statistical analysis revealed that the standard deviation in the equatorial region was higher for channels 80~93 (100~350 hPa) compared to other channels, indicating the need for improvements in cloud screening. Additionally, the innovation mean in these channels was closer to zero, and the relatively smaller standard deviation indicated a need for improvements in bias correction. Based on these results, improvements to cloud screening and bias correction are planned to enhance analysis field performance for equatorial upper-middle layer temperatures.

9p.05 Assimilation of data from the FCI onboard MTG-I1 into the ECMWF system

Presenter: Cristina Lupu, ECMWF

Co-authors: Ethel Villeneuve, Angela Benedetti, Samuel Quesada-Ruiz, Tobias Necker, Volkan Firat

The Flexible Combined Imager (FCI) onboard Meteosat Third Generation (MTG-I1) satellites offer several improvements compared to its predecessor, SEVIRI on board Meteosat Second Generation satellites, including a higher spatial resolution and an enhanced temporal coverage. Similarly to SEVIRI, the initial focus will be to actively use clear-sky radiances (from the Level 2 ASR product) in the water vapour channels (6.3 μm and 7.35 μm). Additionally, investigations will be carried out to also activate the window channel, which play a key role in surface and sea surface temperature (SST) monitoring. It is worth noting that FCI window channel slightly differs from SEVIRI, being narrower (1.4 μm bandwidth instead of 2 μm for SEVIRI) and its central wavelength being shifted from 10.8 μm to 10.5 μm. This change is expected to influence the channel's sensitivity to atmospheric moisture resulting in less interaction with the atmosphere and consequently enhanced and more precise sensitivity to the surface. This should lead to an improved quality of SST observation.In this poster, we will discuss FCI’s impact on analysis and forecast quality and show initial results from the integration of FCI data into the ECMWF IFS. We will also review the operational setup, including spatial and temporal thinning, and the specification of observation errors. Progress has been made at ECMWF towards developing capabilities for real time monitoring and assimilation of Level 1 visible reflectances from geostationary satellites. The poster will cover recent developments made to facilitate the direct assimilation of visible observations into the 4D-Var system, including data handling aspects, such as screening, quality control, superobbing, error characterization and bias-correction. ECMWF is currently performing monitoring experiments of cloudy visible geostationary radiances, as a first step towards their possible future implementation in operational data assimilation. An initial assessment of the impact of the FCI 0.64 μm visible observations is achieved through single-cycle tests with an evaluation of impact on analysis increments and background fits to the observations. All the above developments allow for the start of impact studies of direct 4D-Var assimilation of FCI visible observations.

9p.06 Development for better utilization of AMSR3 humidity sounding channels in JMA's global NWP system

Presenter: Hiroyuki Shimizu, Japan Meteorological Agency
Co-authors: Hidehiko Murata, Misako Kachi

Microwave radiance data including JAXA's Advanced Microwave Scanning Radiometer 2 (AMSR2) have been assimilated in the JMA's numerical weather prediction (NWP) systems. The assimilation of those data has significantly improved NWP skills. As a successor of AMSR2, JAXA plans to operate AMSR3 carried by the Global Observing SATellite for Greenhouse gases and Water cycle (GOSAT-GW) in Japanese fiscal year of 2024. AMSR3 will have three additional high-frequency channels (165.5 GHz, 183±3 GHz and 183±7 GHz, V-pol) to measure solid particles and humidity profile in the atmosphere. JMA is preparing to assimilate these channels more effectively. We investigated the impact of assimilating surface-sensitive data using dynamic emissivity retrieval (DE) method (Karbou et al., 2005; Baordo and Geer, 2016) and the impact of assimilating superobbed humidity sounder radiances (Duncan et al., 2023) in JMA's global NWP system. Our previous research indicated that the DE method reduced the biases and standard deviations of the FG departure for humidity sounder data especially over sea ice and the Eurasian continent during boreal winter, contributing to a positive impact on water vapor field in the analysis. The Superobservation of humidity sounder radiances decreased the standard deviation of FG departure (approximately 6 ~ 20 %) and increased the number of involved data (6 times more than without superobbing), leading to an improvement in the water vapor field in the analysis. In addition, shortening the thinning distance based on the horizontal correlation of the observation error derived by the method of Desroziers et al. (2005) also had a positive impact on the water vapor field in the analysis. We are now investigating the combined impact of these developments, and the results will be presented at the conference. If the AMSR3 data became available, an initial assessment of data quality using FG departure statistics will also be presented.

9p.07 Assessing the thinning scale for humidity sounding observations at ECMWF

Presenter: Niels Bormann, ECMWF
Co-authors: Liam Steele and David Duncan

Observations from microwave humidity sounders are thinned prior to assimilation for two reasons. Firstly, thinning helps to reduce the impact of spatially-correlated observation errors, which are not explicitly accounted for in 4D-Var. Secondly, thinning reduces the computing cost associated with large numbers of observations. The thinning scale for microwave humidity sounders has remained constant for many years, but with increased computing power, and the increasing resolution of ECMWF's forecasting model and 4D-Var scheme, there is the potential to use data more densely. A balance must be made though, as using observations too densely while neglecting spatial error correlations can result in a degraded analysis.In this presentation we primarily investigate the optimal thinning scales for the all-sky microwave humidity sounders MHS and MWHS-2, with thinning scales for other temperature and humidity sounding instruments also considered. This is to enable us to obtain the most benefit from the observations we currently assimilate, as well as informing on the use of future observations, such as those from the Microwave Sounder on EUMETSATs Metop second generation satellites and the microwave radiometer on the EPS-Sterna constellation.Experiments were performed with thinning scales ranging from the current operational value of ~110 km down to ~16 km, which corresponds to all the observations being used. Benefits out to forecast day 4 are observed when the thinning scale is reduced to ~55-80 km. For the smallest thinning scales in our experiments there are still benefits observed in the model humidity field, but degradations appear in the temperature and wind fields, likely due to neglected spatial observation error correlations. The results highlight the need for revisiting thinning choices as the resolution of assimilation systems increases.

Session 10: All-sky assimilation

10.01 Perturbations of all-sky microwave radiances forward operator specifications within the Ensemble of Data Assimilation system of Météo-France

Presenter: Mary Borderies,
Météo-France/cnrm
Co-authors: Hélène Dumas, Philippe Chambon, Loïk Berre, Nicole Girardot

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 this context, since October 2024, the operational suite of Météo-France makes use of the allsky assimilation route of ECMWF (Geer et al. 2014) for a part of the microwave constellation (GMI, AMSR-2, MWHS-2 and MHS). Despite of the high dependency of single scattering properties to the meteorological situation, this first operational version makes use of the same options used at ECMWF for the radiative properties' specification of the observation operator, RTTOV-SCATT, and of observation errors. This means using a single set of radiative properties for the full globe and all cloud types, which is a 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 scattering properties within the ARPEGE Ensemble Data Assimilation system AEARP as a way of propagating errors of the observation operator and to increase the ensemble spread of the AEARP. In this presentation, the impact of this multiple particle shapes approach onto the spread of the AEARP will be studied in synergy with an experiment in which the ARPEGE EDA is only perturbed through different choices of physic parameters. We will also show the resulting impact onto the forecast scores of a fully-coupled deterministic ARPEGE forecasts using the modified EDA as source for the background error covariances.

10.02 Operational all-sky assimilation of geostationary water vapour channels in a regional ensemble Kalman filter NWP system

Presenter: Christina Köpken-Watts, DWD
Co-authors: Annika Schomburg, Christoph Schraff, Lieselotte Bach, Klaus Stephan

In November 2023 we introduced the all-sky assimilation of the infrared water-vapour sensitive channels from SEVIRI/METEOSAT into operations for the regional ICON-D2 model at DWD as well as into the rapid-update-cycle system for very short range forecasts. The regional model has a horizontal resolution of ~2km, and the data assimilation system is based on a Local Ensemble Transform Kalman Filter (LETKF) with 40 members. The two water-vapour channels at 6.2 and 7.3 µm are assimilated in addition to the visible channel at 0.6 µm, which is assimilated routinely since March 2023. For the water vapour channels, an observation error model based on cloud impact, i.e. the symmetric difference between all-sky and clear-sky first guess and observations, has been implemented. For clear-sky situations the observations errors are fixed to a minimum value of 2K but increase if either model or observations or both are cloudy. A data thinning to a scale of ~12km is applied, and it was found that the best results were achieved when localizing the observations horizontally with a radius of 25 km applying a Gaspari-Cohn type localization. For vertical height assignment the level where the transmission has a value of 0.5 is chosen, around which we localize quite broadly with a radius of 0.5 in ln(p). Further experimentation explored different control vector setups leading to the inclusion not only of cloud water but also cloud ice contents in the operationally used control vector.The all-sky water-vapour channel assimilation leads to strongly improved profiles of humidity in the upper and mid-level troposphere, improved cloud cover for mainly high-level clouds but also mid-level clouds, improved radiative surface fluxes and improved boundary-layer temperature. The presentation will describe these operational setup aspects, an additional use of a bias correction scheme as well as the forecast impact and ongoing work to transition to the new FCI instrument.

10.03 Global all-sky radiance assimilation for geostationary satellite imagers

Presenter: Izumi Okabe, MRI / Japan Meteorological Agency
Co-authors: Kozo Okamoto (JMA/MRI), Toshiyuki Ishibashi (JMA/MRI)

Assimilation of all-sky radiance (ASR) is expected to offer additional advantages over clear-sky radiance (CSR). For instance, it can increase data coverage and the number of assimilated observations, while also avoiding the sampling bias issue inherent in CSR, which relies solely on clear-sky data. In this study, we modified and extended the method from a previous study (Okamoto et al. 2023), which assimilated all-sky infrared radiances from the geostationary (GEO) satellite Himawari-8, to include other GEO satellites: GOES-16, Meteosat Second Generation (MSG) -1, and -4. The result of a preliminary experiment in which Okamoto et al. (2023) was applied to assimilate ASRs from GOES-16 and MSGs demonstrated the problems with the method. The accuracies of analysis and prediction significantly worsened over the Sahara Desert and the Arabian Peninsula. This degradation was observed where cloud effects between the model and observations are discrepant. To address this issue, we developed a method to inflate the observation error based on the magnitude of the difference in cloud effects between the model and observations. This difference was also used in a new quality control procedure to discard the data when the discrepancy exceeded a threshold. Additionally, we incorporated the sun zenith angle as a predictor for bias correction, addressing the heightened impact of diurnal variation in model bias as GEO satellite data usage increases. The bias correction method applied in Okamoto et al. (2023) assumes minimal model bias, however, the limited coverage of GEO satellites and the presence of regional diurnal variations in model bias invalidate this assumption. Thus, using a predictor that reflects local time variation was effective in maintaining the Gaussian distribution of first-guess departures, and the assimilation experiment results indicated that it improved prediction accuracy in the later forecast period. These improvements allowed us to achieve a positive impact of ASR assimilation that exceeds the performance of CSR assimilation in the tropics, while also mitigating regional degradations.

10.04 Global all-sky radiance assimilation for IASI

Presenter: Kozo Okamoto, JMA/MRI
Co-authors: Toshiyuki Ishibashi, Izumi Okabe, Hiroyuki Shimizu

Infrared all-sky radiance assimilation is more beneficial than traditional clear-sky radiance assimilation because it enhances the observation coverage. Nevertheless, infrared all-sky assimilation has received less attention than micro-wave all-sky assimilation. We successfully developed the infrared all-sky assimilation for water vapor channels of the hyperspectral infrared sounder of Metop/IASI in a global data assimilation system. This development was extended from the all-sky assimilation of infrared imager of Himawari-8/AHI in Okamoto et al. (2023). Essential assimilation procedures of this infrared all-sky assimilation are cloud-dependent quality control, bias correction, and observation error models including inter-band error correlation. Because of the limited capability to reproduce cloud-affected radiances in current forecasting models and radiative transfer models, we still remove, correct, or underweight radiances strongly affected by the cloud. Nonetheless, the all-sky approach increased the available data by more than a factor of two over the clear-sky approach. This mitigated drying bias better than the clear-sky assimilation, and significantly improved forecasting skills of temperature, humidity, and winds. These impacts were greater than those from AHI all-sky assimilation due to the global observation coverage of IASI.

10.05 Enhancing the exploitation of all-sky microwave sensors at ECMWF using inter-channel error correlations

Presenter: Liam Steele, ECMWF
Co-authors: Niels Bormann, Alan Geer and Marcin Chrust

Microwave temperature and humidity sounding is a key component of the global observing system, and is vital for improving numerical weather prediction skill. In this presentation we will cover some key developments to prepare for the advanced use of upcoming European microwave sensors, such as the Arctic Weather Satellite (AWS), the Micro-Wave Sounder (MWS), the Micro-Wave Imager (MWI), and the Ice Cloud Imager (ICI). Using heritage instruments, we evaluate the benefit of accounting for the presence of inter-channel observational error correlations in the all-sky assimilation of these sensors. This is expected to be particularly important for the upcoming new sensors given the wider range of humidity-sensitive channels available.At present, the assimilation of temperature- and humidity-sounding channels around 50, 118 and 183 GHz is performed operationally at ECMWF. The observation errors are assumed to be uncorrelated, but previous studies have shown that inter-channel error correlations exist, particularly for channels that are sensitive to water vapour. Accounting for these inter-channel error correlations has led to improvements in the assimilation of hyperspectral infrared sounder radiances in clear-sky conditions, where observations affected by cloud and precipitation are screened out.We will present our latest developments in the use of inter-channel error correlations for all-sky microwave sensors, where clear, cloudy or precipitating observations are assimilated using the same scattering-capable radiative transfer model. Moving from clear-sky to all-sky requires an error model that can handle situation dependence (where representation errors are larger in the presence of cloud and precipitation) as well as inter-channel error correlations. We will describe the development of the error model and covariance matrices, and show the impact on short- to medium-range forecasts.

10p.01 Assimilation of IASI all-sky radiances for Numerical Weather Prediction

Presenter: Antoine Chemouny, CNRM/CNES
Co-authors: Nadia Fourriè, Olivier Audouin

Infrared (IR) observations accounts for a significant proportion (80%) of the observations assimilated in numerical weather prediction (NWP) systems at Météo-France. These observations are sensitive to various variables, such as non-precipitating hydrometeors in cloud tops.At Météo-France, the global NWP system is based on the model ARPEGE which provides forecasts up to 5 days. The IASI instrument provides the majority of IR observations assimilated in the globalNWP model ARPEGE. With its 8461 channels, IASI measures the radiation emitted by the top of the atmosphere in the thermal infrared (3.6 µm-15.5 µm) and is sensitive to temperature, water vapour and cloud.Currently, IASI observations are only assimilated in clear-sky conditions. Given that 80% of IRmeasurements are impacted by clouds, these cloudy data represent an important amount of new observations to be used in NWP models. Their assimilation in the systems could significantly improve the forecasts.As IASI infrared data are currently assimilated into ARPEGE in clear-sky conditions, the all-sky approach would enable to improve the initial state of cloud zones. Different research projects are currently underway on this subject at various/different meteorological centers.Kozo Okamoto et al. (2017, 2023) have tested all-sky assimilation for 3 water vapor channels of the AHI instrument in the Japanese regional and global models. At the European Centre forMedium-Range Weather Forecasts

(ECMWF), all-sky assimilation has been tested for 7 IASI water vapor channels (Geer, 2019).The aim of this work is to develop and implement the all-sky assimilation of IASI observations into the ARPEGE model. Several key steps are required to achieve this, starting with setting up and evaluating the cloud simulation of IASI observations with the radiative transfer model RTTOV and the ARPEGE profiles. Another key point for the all-sky assimilation is to correctly estimate the observation-error matrix with respect to the cloudiness conditions. These errors are larger in cloudy situations than for clear sky and inter-channel correlations are increased for cloudy observations.This presentation focuses first on the diagnostics of the IASI cloud simulation implementation. The preliminary results of the observation-error matrix that will be used to assimilate in all-sky condition will be also presented. Finally, the third part is dedicated to the initial tests of IASI assimilation.

10p.02 ICON and IFS model cloud evaluation using visible imagers on geostationary satellites

Presenter: Christina Köpken-Watts, DWD
Co-authors: Christina Stumpf, Robin Faulwetter, Florian Baur, Leonhard Scheck, Cristina Lupu, Samuel Quesada Ruiz, Angela Benedetti, Tobias Necker, Volkan Firat

Visible channels offer valuable information on the presence, location and nature of clouds and are complementary to the widely assimilated IR and MW data. Additionally, these channels are widely available both on geostationary and polar orbiting satellites. Their use promises improved cloud and near-surface analyses and forecasts, particularly in conjunction with all-sky assimilation of corresponding infrared channels. Here, the visible channel information is complementary especially for the analysis of the representation of low clouds and has a higher sensitivity with respect to some model physics aspects like sub-grid scale cloud representation. In preparation of an assimilation of visible satellite images in the global NWP systems of DWD and ECMWF, we perform a joint evaluation and intercomparison of global ICON and IFS model cloud fields using one month of visible reflectance observations by SEVIRI, ABI and AHI on board the geostationary satellites Meteosat-9, Meteosat-10, Goes-16, Goes-18 and Himawari-9. These data offer a unique test bed as they cover a wealth of atmospheric situations and different local times. Model equivalents are computed using the Neural Network based forward operator MFASIS available in RTTOV-13.2 and we analyze the difference to the observed values. For an optimal comparability of the ICON and IFS evaluations, we ensure that the setup in both NWP systems is as consistent as possible, particularly in terms of model resolution, superobbing and quality control. The possibility to use two global models in the evaluations is ideally suited to disentangle model and observation errors. Furthermore, we take advantage of our evaluation setup to study the results in view of different parameterizations of the effective cloud water and cloud ice particle radii from RTTOV or derived within the NWP models to provide feedback on the model cloud physics and also to compare the performance of the two models in predicting cloud cover and liquid water and ice water contents. These evaluations help understand the cloud-related biases and are important steps for developing an all-sky assimilation of visible satellite channels in the global systems of DWD and ECMWF, and is also being extended to the newly available FCI instrument onboard MTG.

Session 11: Calibration of sensors

11.01 IASI-NG : Overview of L1 processing and performances

Presenter: Quentin Cebe, CNES
Co-authors: Pierre RIEU, Antoine PENQUER, Clemence LE FEVRE, Jérémie ANSART, François BERMUDO

Developed by Airbus Defense and Space under CNES overall responsibility in partnership with EUMETSAT, the Infrared Atmospheric Sounding Interferometer New Generation (IASI-NG) is a key payload element of the second generation of European meteorological polar-orbit satellites (METOP-SG). IASI-NG instrument has been designed to ensure continuity the IASI acquisitions, while improving by a factor two compared to IASI with regards to spectral resolution and radiometric accuracy. To achieve the targeted performance enhancement, the IASI-NG instrument design differs significantly from IASI. It is based on an innovative Mertz interferometer concept that allows partial compensation of the so-called self-apodization effect. The complexity of the instrument makes it necessary to perform a dynamical estimation of the Instrument Spectral Response Function (ISRF). This estimation and the subsequent correction are performed by the ground processing using metrology laser measurements and a model of the interferometer. The best evaluation of the complete performance budget pre-launch is done using a mix of measurements acquired during the Thermal Vacuum tests and simulations of atmospheric scenes. The objective of this presentation is to give insights into the L1 processing, and the performances evaluation on L1 products for the IASI-NG sounder.

11.02 Spectral Response Function Retrieval of spaceborne Fourier Transform Spectrometers – Application to Metop IASI
Presenter: Guillaume Deschamps, EUMETSAT
Co-authors: Pierre Dussarrat, Dorothee Coppens

Satellite hyperspectral remote sensing instruments are crucial for environmental monitoring, such as the analysis of water and air quality, weather forecasting or climate change. Their effectiveness depends on the knowledge of the instruments' Spectral Response Functions (SRFs). Traditionally, SRFs are assessed on-ground and monitored in-flight, but complete retrievals remain challenging. To address this, EUMETSAT has developed a novel methodology for retrieving SRFs using spatio-temporal colocations of different detectors, requiring no prior knowledge. This approach is particularly suited for Fourier Transform Spectrometers (FTS) operating in the thermal infrared. While this talk is focusing on the IASI instruments aboard the Metop satellites, the method is believed to be extendable to other instruments and technologies. The article discusses simulations and applications of the SRF retrieval for the Metop IASI instruments, analysing both IASI sensors aboard Metop-B and C, and the evolution of Metop-A IASI over 13 years of operation.

11.03 An energy-conservation system developed for calibrating satellite microwave instruments
Presenter: Fuzhong Weng, CMA Earth System Modeling and Prediction Centre
Co-authors: Zhenzhan Wang and Yang Han

A factor of 2 difference is found between microwave brightness temperature (TB) observations and simulations from vector radiative transfer models. A physical explanation of this difference is related to the calibration process. In principle, for the calibration of polarimetric instruments of a total power radiometer, the radiation should be only half of the values derived from Planck function but in the actual calibration process, a full value is used. When this full value is converted to a TB it is approximately, but not exactly, twice the TB simulated by a vector radiative transfer model. This inconsistency is verified by simulations of three conically scanning microwave imagers and one cross-track scanning microwave sounder. This difference cannot be compensated simply by dividing a factor of 2 to the processed TBs, especially at high frequencies or at low physical temperatures due to the nonlinear property of Planck function.Thus, an energy-conservation system is developed for calibrating the microwave radiometer sensitive to polarization and tested for a cross-track scanning radiometer. The results show the new calibration reduces the magnitude of the measurements to nearly half of the data obtained from the operational calibration. The radiances from the new calibration system agree well with the simulation from the vector radiative transfer models. The new calibration has a significant implication when the past and current satellites are used for monitoring of weather and climate. It is recommended that the future satellite data records from the microwave instruments be calibrated in radiance and also meet the energy conservation as defined from Stokes vector.

11p.01 EUMETSAT's IRS L2 Cal/Val and monitoring activities

Presenter: Harshitha Bhat, CLC Space GmbH
Co-authors: C. Goukenleuque, S. Stapelberg, M. Crapeau, T. Hultberg, D. Coppens

The upcoming Infrared Sounder (IRS) on the Meteosat Third Generation sounding satellite (MTG-S) is designed to significantly improve weather forecasting capabilities. It will provide high-resolution, four-dimensional data on atmospheric temperature, water vapor, and ozone profiles, along with cloud information, surface emissivity, and instability indices. The IRS will operate with high vertical, horizontal, and temporal resolution (every 30 minutes over Europe) and aims to enhance the accuracy of numerical weather prediction models, leading to more reliable forecasts. To ensure the effectiveness of IRS measurements, rigorous validation and continuous monitoring of the L2 products are required. EUMETSAT has developed dedicated offline monitoring toolkits — MOVIT (MOnitoring & Validation Integrated Tool) and MONALiSA (MONitoring of Atmospheric Level2 SAtellite products) — for this purpose. MOVIT will conduct thorough validation during the commissioning phase of IRS and will continue to serve as a routine monitoring tool, along with MONALiSA, an offline tool dedicated to validating L2 products with in-situ measurements. We present an overview of MOVIT's capabilities, including cross-validation with other sounding instruments such as IASI, comparisons against climate models, and rigorous quality control measures.

11p.02 EUMETSAT Polar System - Second Generation: pre-launch characterization of the microwave sounder (MWS) onboard Metop-SGA1

Presenter: Vinia Mattioli, EUMETSAT
Co-authors: J. Ackermann, I. Krizek, S. Di Michele, M. Labriola, D. Schobert

EUMETSAT Polar System Second Generation (EPS-SG) is EUMETSAT contribution to the Joint Polar System (JPS) shared with NOAA, to provide continuation and enhancement of service from the mid-morning polar orbit in the 2025 – 2046 timeframe. The programme features a two-satellite configuration in a sun-synchronous orbit, Metop-SGA and Metop-SGB, with the first satellite (Metop-SGA1) to be launched during 2025. Three microwave radiometers will be part of EPS-SG: the Microwave Sounder (MWS) on satellite Metop-SGA, and the Microwave Imager (MWI) and the Ice Cloud Imager (ICI) on Metop-SGB. In particular, MWS is a cross-track scanning radiometer, equipped with 24 channels ranging from 23.8 to 229 GHz designed to provide comprehensive temperature and water vapor soundings in all sky conditions. MWS builds on the legacy of previous instruments from the current EUMETSAT EPS mission, such as the Advanced Microwave Sounding Unit (AMSU) and the Microwave Humidity Sounder (MHS), with improved sensitivity and broader spectral coverage. Notably, it includes a new channel at 229 GHz for improved sensitivity to cloud ice with respect to the 183 GHz measurements. The poster will focus on the Metop-SGA1 MWS radiometric performance based on pre-launch RadCal and Antenna campaigns, showing the main calibration parameters that have been derived, to be included in the L1B operational processing.

11p.03 High Spatial and Spectral Resolution Infrared Observations from the Scanning High-resolution Interferometer Sounder (S-HIS): Recent Datasets and Next-Gen Sensor Development

Presenter: Joe Taylor, SSEC, University of Wisconsin-Madison
Co-authors: S-HIS Team

The University of Wisconsin-Madison Space Science and Engineering Center (UW-SSEC) Scanning High-resolution Interferometer Sounder (S-HIS) measures emitted thermal radiation at high spectral resolution (0.5 cm-1) between 3.5 and 17.3 microns (580 - 2850 cm-1) with 0.1 radians angular field of view (e.g., 2km footprint at nadir from a 20km observing altitude, 500m footprint at nadir from a 5km observing altitude) and scene imaging accomplished via cross-track scanning. Since 1998, the S-HIS has completed 37 field campaigns on the NASA ER-2, DC-8, Proteus, WB-57, and Global Hawk aircraft. The S-HIS has proven to be extremely dependable, with high calibration accuracy and consistent performance on all platforms, with quality-controlled data yields typically above 99% for flight science data collection. This extensive collection of highly accurate, traceable, high spatial and high spectral resolution infrared radiance datasets is highly valuable for next-generation geosynchronous infrared sounder, and Planetary Boundary Layer (PBL) studies that will support maturation of measurement concepts, retrieval algorithms, models, data assimilation, and integrated observing system approaches. We have completed an engineering design study to identify and outline a modular modernization and upgrade approach for the S-HIS and are currently funded to conduct early breadboard development and testing of core next-generation subsystems including an Imaging Fourier Transform Spectrometer (IFTS) to provide significantly better spatial resolution. The breadboard development and testing activities will reduce programmatic and technical risk for the eventual replacement instrument development program and will use components and a design based on small-sat technology.

Session 12: Space agency reports

12.01 Overview of the EUMETSAT operated missions missions and their applications

Presenter: Bojan Bojkov, EUMETSAT
Co-authors: C. Accadia, D. Coppens, B. Fougnie, G. Grandell, S. Joro, R. Lang, R. Lindstrot, M. Lekouara, E. Obligis, R. Munro

The European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), together with the European Commission's Copernicus delegated missions, and its international partners (e.g. CMA, ISRO, IMD, JMA, NASA, NOAA, etc.) provide the backbone of the global meteorological, marine, and environmental space based observing system. Starting with the successful launch of the first Meteosat Third Generation (MTG) geostationary system on 13 December 2022, EUMETSAT has embarked in a decadal renewal of its geostationary and polar systems meeting the needs and requirements of a diverse set of earth observation derived products and applications, including for global and regional numerical weather prediction, for nowcasting, for ocean monitoring, for atmospheric composition, and for climate monitoring. These core EUMETSAT systems are complimented by a series of EUMETSAT operated Copernicus Sentinel missions for ocean and atmospheric composition and greenhouse gas monitoring, including the Sentinel-3 and Sentinel-6 series missions, and the soon to be launched Sentinel-4, Sentinel-5, CO2M, CIMR and CRISTAL missions. Furthermore, two new meteorological programme proposals are being prepared, namely the dial wind lidar system EPS-AEOLUS, and the constellation of passive microwave sounders EPS-STERNA, with launches planned starting in the early 2030s.Here an overview of the current and up-and-coming missions from EUMETSAT with their key products and applications will be presented.

12.02 Status report of space agency: JMA and JAXA

Presenter: Kozo Okamoto, JMA/MRI
Co-authors: Misako Kachi, Kotaro Bessho

JMA operates Himawari-9 carrying AHI imager. It aims to operate a hyperspectral infrared sounder (GHMS: Geostationary HiMawari Sounder) in addition to a visible and infrared imager (GHMI: Geostationary HiMawari Imager) for Himawari-10. JMA completed a contract of Himawari-10 in March 2023 and began manufacturing it with the view to launch in 2028.JAXA operates eight LEO mission/sensors, including CPR for Europe-Japan joint EarthCARE launched in May 2024, GCOM-W/AMSR2, GCOM-C/SGLI, DPR for US-Japan joint GPM, GOSAT & GOSAT-2, and ALOS-2 and -4 launched in July 2024. It plans to launch the GOSAT-GW satellite with payloads of AMSR3 (follow-on of GCOM-W) and TANSO-3 (follow-on of GOSAT-2) by the end of March 2025.The status and plans of these satellite observations will be overviewed in the conference.

12.03 ISRO Agency Report: Present and future satellite instruments in support of Met-Ocean applications

Presenter: Pradeep Thapliyal, Space Applications Centre (ISRO)

ISRO has developed several space-based instruments for Met-Ocean applications, that were flown onboard Geostationary Earth Orbiting (GEO) as well as Low Earth Orbiting (LEO) satellites. In the GEO platform, INSAT-3D/3DR/3DS series of satellites (launched in 2013/2016/2024) are providing observations from 6-channel Imager at 30-minute interval and 18-channel IR Sounder at hourly interval. In this series, presently INSAT-3DR and INSAT-3DS are operational at 74°E and 82°E, respectively. Recently, INSAT-3D has been replaced with INSAT-3DS, that was launched on 17 Feb 2024. INSAT-3DS has undergone many improvements to mitigate the issues related to the blackbody calibration, mid-night sun intrusion and geolocation errors that were experienced in INSAT-3D/3DR. Under LEO satellites, the Oceansat series started with the launch of Oceansat-1 in 1999 with 8-band Ocean Color Monitor (OCM), and a 4-channel dual polarisation Multi-frequency Scanning Microwave Radiometer (MSMR). The Oceansat-2, launched in 2009, carried OCM, Ku-band Scatterometer, and Radio Occultation Sounder for Atmosphere (ROSA). This was followed by SCATSAT-1 with Ku-band Scatterometer in 2016, and Oceansat-3 (EOS-06) in 2022 with a Ku-band scatterometer, 13-band Ocean Color Monitor (OCM-3), and 2-channel Sea Surface Temperature Monitor (SSTM). The SSTM operations have been stopped due to in orbit anomaly. In the Microsat series of satellites, a few experimental payloads were flown to demonstrate the technology development towards new payloads. In this series, the Microsat-2B (EOS-07) was launched in 2023 in the low inclination orbit with a 6-channel Millimeter-wave Humidity Sounder (MHS), and Microsat-2C (EOS-08) with a GNSS-R and high spatial resolution thermal infrared EOIR instruments. ISRO also collaborates with various international space agencies in developing and launching several joint satellite missions, e.g., MeghaTropiques (MADRAS, SAPHIR, ScaRaB, ROSA), and SARAL (AltiKa), and presently working for upcoming missions, NISAR and TRISHNA. Indian satellite data are available freely through MOSDAC and BHUVAN web-portals of ISRO.

12.04 An Update of NOAA Satellite Missions for ITWG

Presenter: Lihang Zhou, NOAA

NOAA National Environmental Satellite, Data and Information Service (NESDIS) is leading future LEO/GEO/Space Weather satellite programs aimed at a comprehensive understanding of Earth's environment. NESDIS strives to deliver cutting-edge products, services, and data management that can adapt swiftly to meet evolving user expectations. This presentation will provide the ITWG community an update of NOAA's current satellite programs and information services, as well as the future plans for NOAA’s satellite programs and missions.

12.05 Overview of CNES Earth Observation programs

Presenter: Francisco Bermudo, CNES - Centre National d'Etudes Spatiales
Co-authors: Clémence Lefèvre, Antoine Penquer, Jérémie Ansart, Quentin Cebe

CNES is developing the Infrared Atmospheric Sounding Interferometer New Generation (IASI-NG), a key payload element of the second generation of EUMETSAT meteorological polar-orbit satellites (METOP-SG), 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.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 and the IASI NG Technical Expertise Centre in charge of the in-flight calibration, validation and performance monitoring. The instrument measurement (operating in the 3.5 - 15.5 µm spectral range) concept is based on an innovative Mertz Fourier Transform interferometer compensating the so-called self-apodisation effect and the associated spectral resolution degradation. The first Instrument Proto Flight Model has been mounted on MetOp SG A1 Satellite and passed successfully the mechanical and TVAC (Thermal Vacuum) Satellite campaign in 2023. It was then dismounted for open work completion and anomaly investigation. In parallel, FM2 instrument has been fully integrated, tested, and mounted on MetOp SG A1 in September 2024 to participate to the remaining Satellite Qualification tests campaign. Further to a launch campaign mid-2025, MetOp SG A1 launch is planned in fall 2025 from CNES Guyana Space Canter with an Ariane 6 launcher. The status of the most recent CNES activities related to the system and ground segment progress will be also provided. In 2024, CNES achieved the development of a first version of Level 1 C data Processor encompassing the full perimeter of data processing algorithms. This processor has been used for the integration and validation tests of EPS SG mission data processing centre. A final version of the processor to perform the in Orbit Verification and Cal/Val activities is under development with delivery planned early 2025. The development of the IASI-NG Technical Expertise Centre also started in an incremental approach with the objective to release a final version to support IASI-NG Cal/Val activities early 2025. These Cal/Val activities will be done in 3 phases, starting by the low level instrument tuning and finishing by the fine characterization of L1 products.

Tuesday, 13 May 2025

Session 13: NWP centre status reports

13.01 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, Azadeh Gholoubi, Jianjun Jin, Russ Treadon, Xiaoyan Zhang, Jim Jung, and Daryl Kleist

Since the last International TOVS Study Conference in March 2023, there have been a number of minor operational upgrades to the data assimilation system at NCEP. The main data upgrade was in December 2023 and included the active assimilation of NOAA-21 ATMS and CrIS as well as GOES-18 clear sky radiances.A further minor implementation in May 2025 will focus on preparation for data from MetOp-SG and modifications to the infrared cloud detection algorithm.The next major upgrade to the Global Forecasting System (GFS) will be version 17 in 2026. GFSv17 will be a coupled system and will necessitate a greater focus on the assimilation of surface channels. We also expect to transition to CRTMv3 at this time.While the non-atmospheric components of GFSv17 will use the Joint Effort for Data Assimilation (JEDI) framework, the atmospheric part will be upgraded to JEDI in a later implementation.

13p.01 Ongoing developments on satellite radiance assimilation at Météo-France
Presenter: Olivier Audouin, Meteo France
Co-authors: Philippe Chambon, Mary Borderies, Thomas Carrel-Billiard, Alexis Doerenbecher, Hélène Dumas, Nadia Fourrié, Dominique Raspaud, Thomas Buey, Elisa Chardon—Legrand, Antoine Chemouny, Keyi Chen, Nicolas Sasso

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 poster 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 2024 operational suite will be presented. Among the various developments, highlights will be given on the updates made regarding the use of infrared and microwave data within ARPEGE, as well as the all-sky assimilation of several microwave sensors (MHS, MWHS2, GMI and AMSR2) within AROME. The status of the ongoing research will be shown on allsky IR data and horizontal observation error correlations handling within AROME. Other highlights will be made on the preparation to the assimilation of MTG/IRS as well as on the current impact study performed at MF on the combined impact of ESA WIVERN HLOS winds and brightness temperatures.

13p.02 Satellite Radiance Data Assimilation at Korea Meteorological Administration
Presenter: Hyoung-Wook Chun, KMA
Co-authors: Na-Mi Lee, Jiyoung Son, Young-Jun Cho, Chang-Hwan Kim, Eun-Hee Kim, and Yong Hee Lee

The Korea Meteorological Administration (KMA) has been enhancing its satellite radiance data assimilation capabilities to improve weather forecasting accuracy. This study focuses on the current satellite radiance data assimilation system of the Korean Integrated Model (KIM), operational since April 2020. KIM incorporates various satellite radiance observations, including AMSU-A, MHS, ATMS, AMSR2, MWHS-2, IASI, CrIS, AHI-CSR, AMI-CSR, and SEVIRI-ASR. In May 2023, FY-3D/MWHS-2 was integrated into the system, while CrIS/NPP was blacklisted due to issues with long-wave observations. The impact of microwave and infrared radiance observations was evaluated through denial experiments within the KIM operational system. Microwave observations demonstrated significant overall improvements, leading to a 20% enhancement in 500 hPa geopotential height analysis globally and a 10% improvement in 3-day forecast accuracy. However, some performance degradation was observed in the upper levels of the tropics and in the Arctic. Infrared observations showed more modest improvements, resulting in a 3% enhancement in 500 hPa geopotential height analysis and a 2% improvement in 3-day forecast accuracy. Notably, infrared observations helped offset the negative impacts of microwave data, particularly by improving upper-level conditions in the tropics. Ongoing research aims to optimize satellite data utilization by improving bias correction methods to address performance issues at higher altitudes, expanding ATMS observations over sea ice regions to enhance Arctic performance, refining the use of infrared hyperspectral data through better channel selection, cloud removal, and observation error adjustment, and evaluating new satellite data sources, such as ATMS/NOAA-21, CrIS/NOAA-21 and GIIRS/FY-4B. These efforts underscore KMA's commitment to continually advancing its weather forecasting capabilities through improved satellite data assimilation techniques.

13p.03 ECMWF NWP changes
Presenter: Mohamed Dahoui, ECMWF
Co-authors: Angela Benedetti, Niels Bormann, Chris Burrows, David Duncan, Alan Geer,

Cristina Lupu, Anthony McNally, Samuel Quesada Ruiz, Tracy Scanlon, Josef Schröttle, Bill Bell, Naoto Kuzano, Katie Lean, Zaizhong Ma, Kirsti Salonen, Liam Steele, Emma Turner, Ethel Villeneuve

The poster gives an overview of the assimilation of passive sounding data and highlights the main changes implemented in the operational ECMWF NWP forecasting system since ITSC-24. At the time of writing, ECMWF assimilates data from 19 microwave instruments, 5 high spectral infrared sounders and 5 geostationary satellites. Additions since ITSC-24 have been ATMS and CrIS from NOAA-21. The detailed structure and status of the observing system used at ECMWF is available from the recently deployed observations dashboard (https://obsstatus.ecmwf.int) Since ITSC-24, ECMWF implemented two major system upgrade 48r1 (27 June 2023) and 49r1 (12 Nov 2024). Both cycles brought significant changes to the assimilation of passive radiances: •Upgrade to RTTOV to V13 (48r1) and V13.2, including used of SURFEM (49r1), •Assimilation of microwave imagers over land surfaces and polar ocean (48r1)•Improved treatment of mixed land-water and water-sea-ice scenes for MW instruments (48r1)•Extended use of lowest humidity-sounding channels over snow-free land at high latitudes (48r1)•Activate ATMS humidity channels over snow (48r1), •ATMS Lambertian surface reflection over snow and sea-ice (48r1), •Slant-path interpolation for MW humidity sounders assimilated in the all-sky system (48r1),•Unified VarBC setup for IR sounders (48r1), •Allow usage of all pixels from IASI (48r1), •Aerosol type classification in IR data (48r1), •Update on the IR trace gas detection (48r1), •Scene dependent observation errors for CrIS (NPP and NOAA-20) (49r1)•Increased density of SEVIRI data (49r1).•Superobbing and increased density for cross-track MW humidity sounders (49r1) •Increased resolution of MW imager suberobs (49r1)•Activation of AMSU-A channels 1 and 2 (49r1)•Activation of imager channels from F-18 SSMIS (49r1)•Hybrid machine-learning/physical sea-ice emissivity scheme, allowing retrieval of sea-ice concentration and assimilation of MW imagers in sea-ice areas (49r1)•Revised convective precipitation fraction assumption for all-sky MW assimilation (49r1)Cycle 48r1 brought other significant beneficial changes to the model, major resolution increase of the ensemble forecasting system and major upgrade to the configuration of the extended-range ensemble forecasting system. Cy49r1 included changes allowing the assimilation of T2m in the atmospheric 4DVAR, Activation of Variational Quality Control (VarQC) in the first 4D-Var minimization, Increased resolution of the Ensemble data assimilation (EDA) and Activation of the Stochastically Perturbed Parametrisations (SPP) in the Ensemble forecasting system.

13p.04 Overview of recent developments in satellite radiance data assimilation at DWD

Presenter: Christina Köpken-Watts, DWD
Co-authors: Ch. Köpken-Watts, R. Faulwetter, O. Stiller, A. Rojahn, C. Stumpf, A. Schomburg, M. Mousavi

This poster gives an overview of recent developments in radiance assimilation in DWD’s operational global and regional forecasting systems. The global forecasts are based on the ICON model and a hybrid EnVar data assimilation with 40 members, while the regional convection resolving limited area version of ICON uses a purely ensemble based LETKF approach. Additionally, since summer 2024, a new rapid update cycle system became fully operational supporting the seamless SINFONY system for nowcasting to very short forecast range. In the global ICON/EnVar system, one focus is on keeping the operationally used RTTOV version up to date as well as updating data usage to new satellites and we were able to introduce RTTOV v13.2 as well as ATMS data from NOAA-21. Additionally, MW usage over land has been enhanced by adding channel 6 (7) from AMSU-A (ATMS) and updating reflection assumptions over snow/ice along with introducing a more precise emissivity calculation over land taking fractional surface types into account. A second focus is the ongoing preparation of an all-sky assimilation capability in the global system along with preparatory evaluation work on model clouds using also visible channel information from geostationary satellites. In the regional systems including the RUC setup, the assimilation of geostationary imager radiances from MSG/SEVIRI was further enhanced with the operational introduction of water vapour channels in an all-sky setup to complement the already operational use of the visible 0.6 micron channel. This results in a positive impact especially on upper level humidity.Ongoing work focuses also on preparation for MTG IRS with key technical implementations having been completed both in the global and regional systems ranging from data processing to cloud detection and observation error setups. In this context a skin temperature retrieval based on selected window channel information was made operational for both geostationary imager WV channel assimilation and IR hyperspectral sounders to improve the model first guess values. This also allowed to successfully introduce the operational assimilation of IR hyperspectral data over land in the lobal ICON.

13p.06 Present and future use of satellite atmospheric sounding data in United Weather Centres West

Presenter: Isabel Monteiro, KNMI
Co-authors: Eoin Whelan, Fabrizio Baordo, and Mats Dahlbom

The 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. UWC-W is operating the HARMONIE-AROME limited-area model in two common domains, called DINI (Western Europe) and IG (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 is 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 is using the superset of observations previously assimilated by each NMHS. The following satellite data types are used: (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 occultations, using retrieved refractivity. Passive infrared sounders include, IASI on board Metop-B and Metop-C, and, CrIS on board NOAA-21 satellites. The Microwave sounders employed are AMSU-A, on Metop-B, Metop-C, NOAA-19, and NOAA-20; MHS, on board Metop-B and Metop-C; ATMS on NOAA-20 and NOAA-21; and MWHS2 on board FY-3D. Channel selection, thinning strategies, variational bias correction schemes and blacklisting are similar to the previous local implementations. In addition to the consortium member operations, UWC-W is actively preparing the assimilation system for the uptake of data from next generation satellites. For the novel hyperspectral sounder MTG-IRS with an unprecedented volume of information, priority is being given to the configuration of UWC-W data acquisition system. For Metop-SG, flying instruments with major capabilities to detect clouds and precipitation, UWC-W preparation is being carried out in cooperation with Météo-France and MET Norway, focusing on the implementation of the all-sky configuration in HARMONIE-AROME.

13p.07 Recent upgrades and progresses of satellite radiance data assimilation at JMA

Presenter: Hidehiko Murata, Japan Meteorological Agency
Co-authors: HAYASHI Masahiro, AKIMOTO Ginga, TOYOKAWA Masakazu, TOMA Tsuguyoshi, URATA Tomoya, NISHIZAWA Keisuke, SHIMIZU Hiroyuki

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 have been implemented into the operational systems 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-24 in March 2023. Main topics are listed as follows.- Assimilation of hyperspectral infrared sounders (IASI and CrIS) in MA and LA, and additional use of humidity sensitive channels in GA have started in March 2023. - Assimilation of GOES-18/CSR replacing GOES-17 in GA has started in May 2023.- Assimilation of Meteosat-10/CSR replacing Meteosat-11 in GA has resumed in May 2023.- The supercomputer systems at JMA have been upgraded to the 11th generation in March 2024. All the subsystems, including NWP systems, have been migrated to the new supercomputers.- Assimilation of NOAA-21/ATMS and CrIS in GA, MA and LA has started in March 2024, concurrent with the start of the new supercomputer operations. In addition, main topics that JMA is currently working on are as follows. - Additional use of CO2 band of the geostationary satellites' CSR in GA- All-sky infrared radiance assimilation in GA.- Upgrading the coefficients and sea surface emissivity models used in RTTOV-13.0 in GA, MA and LA.- Additional use of microwave sounders' window channels (23.8 and 31.4GHz) in GA, MA and LA.- Improvement of assimilation schemes for all-sky assimilation of microwave water vapor sounder in GA.- Preparation for the assimilation of Himawari-10/GHMS.

13p.08 Satellite radiance assimilation at the Met Office

Presenter: Stefano Migliorini, Met Office
Co-authors: Brett Candy, Fabien Carminati, Michael Cooke, Mhari Dell, Chawn Harlow, Nina Kristiansen, Peter Levens, Rowan McLaughlin, Stuart Newman, David Rundle, Ruth Taylor

The Met Office is upgrading its infrastructure for assimilating observations. In collaboration with the Joint Center for Satellite Data Assimilation (JCSDA), the Joint Effort for Data Assimilation Integration (JEDI) framework has been adopted (i) to perform pre-processing and quality control, and (ii) as an eventual replacement for the current 4D-Var data assimilation. The initial JEDI-based Observation Processing Application (JOPA) is planned to become operational during 2025. A prototype for the new JEDI Application for Data Assimilation (JADA) is being tested with key observations including satellite microwave and infrared sounders. This poster summarises these technical developments as well as highlighting work towards the assimilation of current and future satellite sounders: NOAA-21 ATMS and CrIS, Arctic Weather Satellite Sterna radiometer, Meteosat Third Generation InfraRed Sounder and IASI-NG. The Met Office is also initiating studies for the hyperspectral microwave (HYMS) demonstrator mission.

13p.09 NCMRWF NWP status since ITSC-24

Presenter: John P George, NCMRWF, Ministry of Earth Sciences (Government of India)
Co-authors: V. S. Prasad

This presentation will give an update on the Observation usage & Data Assimilation, Global & regional NWP Models and HPC facility.

13p.10 Status and ongoing developments of satellite data assimilation in NASA GMAO's GEOS

Presenter: Ahreum Lee, UMBC, GMAO NASA/GSFC
Co-authors: Yanqiu Zhu, Jianjun Jin, Wei Gu, Bryan Karpowicz, Min-Jeong Kim, Krzysztof Wargan, Michael Murphy, Meta Sienkiewicz, Ricardo Todling, Amal El Akkraoui, Robert Lucchesi, Austin Conaty, Gary Partyka, Ron Gelaro, Steven Pawson

The Goddard Earth Observing System (GEOS) developed at NASA Global Modeling and Assimilation Office (GMAO) produces operational-quality products to support NASA's

Earth Science missions and diverse user communities, by combining advanced GEOS atmospheric model with a wide range of observations from various observing systems. While progress has been made in increasing model resolution and improved physics, the GMAO continuously enhances observation usage and develops new methods to advance the GEOS capabilities and performance. The GEOS Forward Processing (FP) system for real-time NWP is routinely upgraded, and efforts are also underway to assimilate new observations with near-future data. The latest advancements in satellite data assimilation have also been incorporated into the GMAO's newly implemented MERRA-21C reanalysis. Meanwhile, GMAO has focused on the development of a JEDI-based GEOS system to replace the GSI-based GEOS. So far, the transition, testing and validation of all operational observations used in the GEOS-FP to the JEDI-based GEOS have been completed. Efforts will be focused on supporting the integration of the JEDI-based GEOS system.

13p.11 Advances in Data Assimilation at CPTEC/INPE

Presenter: Dirceu Herdies, CPTEC/INPE
Co-authors: Eder P. Vendrasco, João Gerd Z. de Mattos, Luiz F. Sapucci, Liviany Viana, Sergio H. Ferreira, Carlos F. Bastarz

Data assimilation is key to numerical weather prediction (NWP), especially in tropical regions where deep convection and land-atmosphere interactions exhibit high spatiotemporal variability. At the National Institute for Space Research (INPE), the Data Assimilation Development Group (GDAD) is leading a strategic transition from the legacy NMDAS (Numerical Modeling and Data Assimilation System), which integrates the GSI (Gridpoint Statistical Interpolation) and BAM (Brazilian Atmospheric Model), to a modern platform based on JEDI (Joint Effort for Data assimilation Integration) and MONAN (Model for Ocean, Land, and Atmosphere Prediction). Within MONAN, MPAS-A (Model for Prediction Across Scales – Atmosphere) serves as the atmospheric component, introducing unstructured grids and allowing seamless resolution variation across domains.The transition begins with implementing the 3DVar scheme, replicating the basic functionality of NMDAS, and aims to evolve toward the more advanced 3DEnVar. Additionally, hybrid methodologies that combine machine learning and traditional techniques (3DVar, 4DVar, EnKF) are being developed to enhance the representation of tropical phenomena, optimize initial conditions, and improve computational efficiency. These methodologies are validated using data from modern observation systems, focusing on extreme meteorological events like South Atlantic Convergence Zone (SACZ) rainfall and tropical cyclones.The CPTEC/INPE's next operational NWP systems (MONAN/JEDI) will be deployed on the new upgraded HPC (HPE Cray XD) system 2024/2025. This system will also include the latest satellite data. Preliminary results highlight the potential of these approaches to improve analysis quality and predictive skill in resource-constrained environments. Integrating JEDI and MONAN aligns with MONAN's objectives to enable high-resolution and multiscale predictions. This work demonstrates how adopting advanced tools and methods can address long-standing challenges in tropical data assimilation and deliver more accurate and reliable forecasts.

13p.12 Latest upgrades and developments in the use of satellite radiances at ECCC

Presenter: Zheng Qi Wang, McGill University / Environment and Climate Change Canada
Co-authors: Josep Aparicio, Seung-Jong Baek, Maziar Bani Shahabadi, Patrice Beaudoin, Joel Bedard, Mark Buehner, Jean-Francois Caron, Chantal Cote, Ping Du, Normand Gagnon, Alain Beaulne, Gabriel Gobeil, Sylvain Heilliette, Ervig Lapalme, Thomas Milewski, Aleksandra Tatarevic

Environment and Climate Change Canada (ECCC) implemented major upgrades to its numerical weather and environmental prediction (NWEP) systems on June 11, 2024, bringing over 100 scientific innovations in more than 30 atmospheric, oceanic, hydrological and surface operational forecasting systems. Refinements to radiance data assimilation methodologies were done in two deterministic (global domain and Canadian limited-area) systems using a 4D-EnVAR analysis scheme, as well as one ensemble (global) system using a LETKF analysis scheme. They include updating the RTTOV observation operator to version 13, as well as the use of RTTOV-SCATT, extending all-sky assimilation to ATMS temperature channels 5 and 6 and MHS humidity channels, the use of purely flow-dependent background error covariances and, for the ensembles, their own separate and stand-alone filtering of observations. Moreover, the FSOI system was upgraded to use a wet norm, and a new norm was added between 100hPa and 1hPa for the Global domain, while an automatic data checking using soft limits was added to our observation monitoring system. This poster will also display the status on the use of assimilated observations and present some project proposals in Artificial Intelligence.

Session 14: Future microwave technologies

14.01 Deep Learning-Based Retrievals from Spire's Hyperspectral Microwave Sounder

Presenter: Kristen Bathmann, Spire Global
Co-authors: Manju Henry, Richard Whitehead, Mo Belal

Spire Global is planning to launch a Hyperspectral Microwave Sounder (HyMS) within the next year. This new instrument is 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 well over 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. In this presentation, we introduce a machine learning approach for retrieving atmospheric profiles from HyMS observations using a deep neural network (DNN) model. The retrievals were performed by training the DNN on Community Radiative Transfer Model (CRTM) simulated radiances and co-located European Centre for Medium-Range Weather Forecasts (ECMWF) analyses. Preliminary results in clear sky conditions over ocean have been promising, showing accurate temperature and humidity profile retrievals at the vertical resolution of ECMWF analyses. In this presentation we will discuss the training process, validation against independent datasets, and the model's performance in all-sky conditions and over ocean and non-ocean surfaces. These results highlight the potential of deep learning techniques in advancing the retrieval capabilities from hyperspectral microwave observations.

14.02 Recent Advances in Microwave Sounding: Smallsat Constellations, Beam-steering Arrays, and Cognitive Sensing

Presenter: Bill Blackwell, MIT Lincoln Laboratory
Co-authors: R. Leslie, C. Kataria, W. Moulder, S. Reising, Z. Li

New Earth atmospheric sounding systems are needed that offer lower noise, finer resolution, broader coverage, and better revisit rates relative to current state-of-the-art to improve numerical weather prediction capabilities and inform detailed scientific studies of weather and climate. These new systems increasingly must be lower-cost, accommodatable on a wide range of launch vehicles and hosted payload platforms, and provide flexibility in how they are deployed and used. Here we discuss three new microwave sounding technologies that are leading to significant improvements in both the performance benefits and the development and operating costs of new observing systems. First, small satellite constellations, such as the NASA TROPICS mission, have demonstrated new capabilities for high-revisit sampling of tropical cyclones with observing quality that approaches (and exceeds in some cases) the current state-of-the-art sensors, and commercial follow-ons to TROPICS are now being launched that offer improved performance and reliability and utilize high-speed digital spectrometers necessary for hyperspectral microwave operation and RFI detection and mitigation. Second, large-format planar arrays, such as the Configurable Reflectarray Wideband Scanning Radiometer (CREWSR), can provide high-resolution (up to 10X better than ATMS), light weight, low power, and multiband (23, 31, and 50-58 GHz) hyperspectral operation with electronically steerable beams that can operate independently in each band. CREWSR is designed to be fielded on an ESPA-class small satellite platform, and once in orbit, the platform will deploy a large Reconfigurable Reflective Surface (RRS), as well as a multi-feed antenna connected to a multiband radiometer. Third, we consider the observing system as comprising not only the sensor but also the concept of operations, processing, and potential for collaborative and synergistic observations. Highly configurable sensors such as CREWSR enable the utilization of new “cognitive sensing” concepts, where the sensor is aware of the characteristics of the scene to be viewed and can reconfigure itself in real time to adjust where it is looking, the dwell time, the spatial resolution, and depending on the platform, the geometrical vantage point. Observing System Simulation Experiments (OSSEs) have shown forecasting benefits of cognitive sensors in regional simulations, and new laboratory testbeds are now being developed to characterize end-to-end performance in a realistic, test-as-you-fly environment.

14.03 The Advanced Ultra-high Resolution Optical RAdiometer (AURORA) Pathfinder

Presenter: Antonia Gambacorta, NASA Goddard Space Flight Center
Co-authors: Omkar Pradhan, Mark Stephen, Fabrizio Gambini, Sidharth Misra, Mehmet Ogut, Manuel Vega, Priscilla Mohammed, Narges Shahroudi, Patrick Stegmann, Jared Lucey, Pekka Kangaslahti, Shannon Brown, and Jeffrey Piepmeier

This presentation introduces the design, science objectives and project plan of the Advanced Ultra-high Resolution Optical RAdiometer (AURORA) Pathfinder.Hyperspectral microwave sensors, which offer a few hundred to a few thousand channels, are strongly advocated by space and meteorological agencies worldwide. These sensors are critical for enhancing the capability of Earth atmospheric sounding, particularly for measuring temperature and water vapor from space. Despite their significance, current microwave sensors in the Program of Record are limited to only a couple dozen sparsely sampled channels, which constrains the vertical resolution and accuracy of the sounding profiles. The primary challenge lies in traditional radio-frequency technology's inability to process ultra-wide bandwidths (20-200 GHz) at hyperspectral resolutions (<1 GHz) simultaneously, while keeping the instrument size, weight, power consumption, and cost (SWaP-C) feasible.These challenges are now being effectively addressed. The NASA Earth Science Technology Office (ESTO) and the Small Business Innovation Research (SBIR) program have made significant investments in hyperspectral microwave technology by funding research and development in Photonic Integrated Circuit (PIC) and Application Specific Integrated Circuit (ASIC) technologies. These efforts have ultimately led to the award of the AURORA Pathfinder. This project is a collaborative NASA project bringing together a team from the Goddard Space Flight Center, Jet Propulsion Laboratory and private industry to demonstrate this new sensor technology.AURORA Pathfinder will offer accurate measurements of the Earth’s thermal microwave radiation, with unprecedented spectral and spatial resolution, unveiling critical and unexplored information about the PBL, as well as the free atmosphere's temperature, water vapor, and hydrometeors. Concurrent efforts have matured hyperspectral microwave radiative transfer and inverse techniques to conduct trade studies aimed at maximizing information content, stability and SWaP-C efficiency. AURORA Pathfinder will demonstrate readiness for a future NASA Planetary Boundary Layer mission. Findings from AURORA will also inform the NOAA Near Earth Orbit Network program.

14.04 The Tomorrow Microwave Sounder program: an assessment of the observations and observing system impacts
Presenter: Ryan Honeyager, The Tomorrow Companies, Inc.
Co-authors: Jonathan Guerrette, S. Joseph Munchak, Stylianos Flampouris

Tomorrow.io is a technology company that aims to revolutionize the commercial/private weather partnership by launching a low-Earth-orbit, rapid refresh satellite constellation consisting of microwave sounders. The first Tomorrow Microwave Sounders (TMS) began launching in August 2024, and we anticipate fourteen satellites by early 2026. Their onboard sensors represent the latest generation of the TROPICS (Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats) instrument design, featuring an operationalized payload with improved onboard calibration and digital signal processing capabilities. When fully deployed, the constellation will provide global sub-hourly revisit rates with low data latencies, and it will support both nowcasting and numerical weather prediction applications.We provide an overview of instrument capabilities and L1/L2 products, with comparisons to TROPICS where appropriate. We present results from an observing system experiment that combines the Unified Forecasting System standalone atmospheric model (UFS-ATM) and the Joint Effort for Data assimilation Integration (JEDI) codes. While we closely follow ongoing developments of NOAA's Global Data Assimilation System (GDAS), this experiment is aimed at producing an instrument configuration that is compatible with any JEDI-based system. We assess our quality control and observation error models for TMS globally, and we gauge the growing impact of our satellite constellation as it is deployed.

14.05 Experiments in Support of Next Generation Low Earth Orbit Microwave Sounder Formulation at NOAA
Presenter: Satya Kalluri, NOAA
Co-authors: Isaac Moradi, Nikki Prive

Microwave and infrared soundings from Low Earth Orbiting (LEO) satellites have been proven to be of high impact to Numerical Weather Predication (NWP) models with most current operational LEO sounders developed by NOAA. The US Joint Polar Satellite System (JPSS) and NOAA's legacy Polar Operational Environmental Satellites (POES) satellite system together with Metop satellites operated by EUMETSAT provide almost 4-hour global refresh of microwave (MW) soundings and are considered as the backbone of NWP. However, the legacy POES satellites are operating beyond their planned mission life and their loss would lead to reduction in global refresh of soundings. Because of the critical importance of MW soundings to NWP, NOAA's Near-Earth Orbit Network (NEON) program identified the anticipated disruption of sounding data in the early-morning as a first priority to address as the risk to the LEO constellation. To mitigate this coverage gap and to serve as a pathfinder for future acquisitions, NESDIS authorized the QuickSounder mission that will fly an existing Advanced Technology Microwave Sounder (ATMS) engineering development unit (EDU) in the early morning orbit. At the same time, the LEO program also awarded four Phase-A study contracts for NOAA's next generation of MW sounder, “Sounder for Microwave-Based Applications (SMBA)”, which is a follow on to the highly successful ATMS sensor. SMBA would fly on NOAA's NEON program series of LEO satellites with the first launch planned in 2030. In support of future LEO planning and to develop a mission/system architecture that is credible and responsive to program expectations, requirements, and constraints on the project, including resources, the LEO program sponsored several Observing System Experiments (OSEs). The OSEs are used to evaluate the impact of microwave and infrared observations on the prediction of tropical cyclone track and intensity. These experiments involve conducting a series of data assimilation experiments using the Gridpoint Statistical Interpolation (GSI) system. In these experiments, microwave and infrared observations from various spaceborne platforms are alternately assimilated alongside conventional and GPS-RO observations. The outcomes are assessed using diverse metrics, including hurricane track and intensity, as well as the influence on the vertical structure of tropical cyclones across the different experiments. Additionally, Observing System Simulation Experiments (OSSEs) were also conducted to study the complementarity of the current satellite observations with a future architecture that would include potential infrared sounders in a “geostationary ring”. This presentation will highlight NOAA’s strategic plan for supporting NWP and Earth system prediction as well as results from these experiments.

14.06 Simulation and Evaluation of NOAA Next-gen Microwave Satellite Observation System with the ECMWF EDA method

Presenter: Zaizhong Ma, UMD/CISESS
Co-authors: Niels Bormann, Katie Lean, David Duncan, Ernesto Hugo Berbery and Satya Kalluri

This study evaluates the impact of hypothetical future MW-sounding instruments, in order to provide input to the design of NOAA’s next generation MW sounding missions. As an international collaborative effort between the University of Maryland Cooperative Institute for Satellite Earth System Studies (UMD/CISESS) and the European Centre for Medium-Range Weather Forecasts (ECMWF), the potential NWP benefits of these future microwave sounders are being evaluated using an Ensemble of Data Assimilations (EDA) approach. The EDA method for assessing new observations provides a theoretical estimate of the expected reduction in analysis and short-range forecast uncertainty, as a result of assimilating the new data. A reduction of the spread resulting from additional observations used is hence an indication of beneficial impact from these observations. This study considers the impact of such instruments at both 13:30 and 17:30 Local Time of Ascending Node (LTAN) orbits, and relate this impact to that of the microwave sounders on the current heritage Polar Operational Environmental Satellites (POES) as well as that of ATMS.EDA experiments were performed to assess the expected benefit of an ATMS instrument in a 17:30 LTAN orbit, assuming a noise performance similar to that of the S-NPP instrument. Our analysis shows that such an instrument significantly reduces forecast uncertainty when added on top of an observing system that otherwise uses MW-sounding from Metop and JPSS satellites only. Impacts are comparable to or slightly larger than those of the current POES satellites (NOAA-15, 18, and 19). The greatest improvements were observed when combining data from 1730_LTAN and POES satellites. Sensitivity experiments were also conducted to evaluate the effect of the noise performance of the instrument in the 17:30 orbit. While an instrument with degraded noise still provides a positive impact, its benefit is significantly reduced compared to assuming S-NPP ATMS-like noise levels. These findings highlight the critical role of instrument noise characteristics in determining the effectiveness of microwave observations in Numerical Weather Prediction (NWP) systems.In addition, the consistency of the impact in the EDA between real and simulated microwave radiance observations was assessed. An additional experiment was conducted to compare the impact of simulated ATMS data with real ATMS observations from S-NPP and NOAA-20 satellites. The results show that the simulated and real ATMS data have a similar impact on EDA spread, providing further confidence in the simulation results. Lastly, we evaluate selected new capabilities that are being considered for NOAA’s future Sounder for Microwave Brightness and Analysis (SMBA) using the EDA method, including the impact of measuring radiation at frequencies not previously covered by heritage instruments.

14.07 Development and pre-launch characterisation of a Hyperspectral Microwave sounder In Orbit Demonstrator

Presenter: Manju Henry, Spire Global UK Ltd.
Co-authors: Kai Parow Souchon, Jacobus Vander Merwe, Mohammed Belal, Richard Whitehead, Vladmir Irisov, Kristen Bathmann, Simon Rea, Steve Parkes, Mark Jarrett, Soe Min Tun, and Janet Charlton

Spire Global is set to launch a Hyperspectral Microwave Sounder as an orbital demonstration (HYMS IOD) in 2025, following funding from NOAA/NESDIS. The instrument is currently in the integration phase with Spire's 16U LEMUR satellite platform and is undergoing comprehensive pre-launch characterisation. HYMS is a next generation remote sensing instrument capable of sampling the microwave spectrum near the 60 GHz, and 183 GHz absorption lines at very high resolution as well as 89GHz. Current state of the art microwave sounders have a limited number of sampling channels, typically less than 24 channels, but HyMS significantly increases the number of observation channels (>100 channels). This enhancement offers several potential benefits including improved retrieval accuracy for water vapour and temperature measurements, the more detailed profiling of the vertical structure of atmospheric temperature and humidity, and enhanced hydrometeor profiling. HyMS can also provide mitigation against radio frequency interference, which is a growing concern in the community with the expansion of 5G/6G communication networks.This presentation will detail the development of the HyMS In-orbit demonstrator instrument, its performance, and calibration & verification efforts on ground prior to its launch.

14p.01 Impact of WIVERN 94GHz brightness temperature observations on global NWP model forecasts using an OSSE framework

Presenter: Mary Borderies, Météo-France/cnrm
Co-authors: Nicolas Sasso, Philippe Chambon, Alessandro Battaglia, Anthony Illingworth, Louis Rivoire, Thomas Carrel-Billiard, Nadia Fourrié

As part of the Earth Explorer 11 programme, ESA has selected the WIVERN1 (Illingworth et al. 2018) satellite mission concept to move into phase A in October 2023 and is now under study to enter phase B in July 2025. WIVERN will be the first spaceborne dual-polarisation Doppler W-band radar to provide 94GHz brightness temperature observations colocated with in-cloud reflectivity and Horizontal Line-Of-Sight (HLoS) wind profiles. This unique coincident dataset of the dynamical and mass fields within the clouds will be collected at an unprecedented horizontal resolution of 1km over a large 800~km wide conical swath. Recent studies have already shown the benefits of assimilating WIVERN in-cloud HLoS wind profiles to improve global NWP forecasts (Sasso et al. To be submitted). Here, the focus is made on WIVERN 94GHz brightness temperature observations at both polarisations. In particular, the impact is investigated using the Observing System Simulation Experiment (OSSE) approach which has been developed in previous studies to evaluate the impact of the EPS-Sterna constellation (Rivoire et al. 2024), and WIVERN HloS winds in the global NWP model of Météo-France, called ARPEGE, with its state-of-the-art 4DVar data assimilation system. Here, WIVERN brightness temperature observations are assimilated using the Allsky assimilation route developed at ECMWF, which is also operational in ARPEGE for a part of the microwave constellation. In this presentation, the impact of WIVERN brightness temperature observations will be assessed through its ability to improve different metrics (e.g. forecast error, rainfall accumulated rainfall forecast, FsoI, time gained) over two 3-month periods. The impact of WIVERN brightness temperature observations will also be studied alone or jointly with WIVERN wind profiles to investigate if the corrections induced by the WIVERN brightness temperature assimilation act in synergy with those obtained by the direct assimilation of the WIVERN HloS wind profiles.

14p.02 Developing the use of hyperspectral MW observations for global NWP in an Ensemble of Data Assimilations (EDA)

Presenter: Niels Bormann, ECMWF
Co-authors: Katie Lean

Recent technology enhancements make hyperspectral MW sounding from space a possibility. The Hyperspectral Microwave Sensor (HyMS) to be launched by Spire, for instance, provides configurable spectral sampling of the 50-58-GHz oxygen band at up 5 MHz and of the 175-192 GHz water vapour band at up to 40 MHz, together with a window channel at 89 GHz. Several space agencies are also considering hyperspectral MW concepts. Compared to heritage MW sounders, the advantage of these sensors is expected to arise from a combination of providing a greater diversity of weighting functions as well as sampling in spectral parts that have previously not been covered. Given that the spectral features in the MW are relatively broad, the case for hyperspectral MW instruments is however not as clear as for the IR. With the advent of hyperspectral MW sounders comes the need to develop approaches to use such data in an NWP system most effectively, to evaluate expected benefits compared to traditional MW sounders, and to specify requirements. To achieve this requires not only the development of approaches to deal with the large increase in the number of channels (100s-1000s compared to around 20-30), but also the specifics of the strengths of the MW region for atmospheric sounding. While experience with hyperspectral IR instruments gives some basis, the all-sky approach adopted for MW instruments as well as the specific noise performance of such instruments require careful attention. These aspects are being studied at ECMWF by adopting an Ensemble of Data Assimilations (EDA) approach in an ESA-funded study. The poster gives an overview of the study, the approaches considered, and outlines recent progress.

14p.03 The Global Environment Monitoring System (GEMS) suite of novel passive microwave instrumentation

Presenter: Allen Huang, University of Wisconsin Madison
Co-authors: Richard Delf, Michael Hurowitz, Roger Carter, Robert Belter, Michael Marques, Albin Gasiewski

Weather Stream design, build, and operate innovative passive microwave radiometers to support the global weather monitoring system and the research and commercial communities. Collectively, we refer to this as the Global Environment Monitoring System (GEMS). GEMS1 was an 8-channel radiometer centered on the 118.75 GHz O2 absorption line operating on a 3U CubeSat, and successfully demonstrated operations on-orbit from 2019-2021. Here we present details of our upcoming launch of GEMS2-Amethyst and GEMS2-Beryl dual-band (118.75/183.3 GHz) radiometers which will support global stratospheric sounding and precipitation observations and support evaluation of NWP impact from commercial CubeSat platforms. We also present a summary of the range of passive microwave mission payloads developed by Weather Stream, including hyperspectral and soil moisture sensors, aiming to improve global observations atmospheric profiles, cloud ice, and soil moisture from satellite and drone platforms.

Session 15: Impacts in Indian regional applications

15.01 Radiance assimilation over the extra-tropics and polar regions: Impact on the simulation of Indian Monsoon

Presenter: Indira Rani S, NCMRWF, Ministry of Earth Sciences
Co-authors: Srinivas Desamsetti, Nuncio Murukesh, John P. George and V. S. Prasad

Indian Summer monsoon (ISM), typically lasts from June to September, brings 70- 90% of the total annual precipitation. The ISM significantly impacts India's economy, including the GDP and livelihoods of millions of farmers. The ISM is affected by many global (El Lino, La-Nina, IOD, etc.) and local (dust storms, irrigation patterns, etc) effects and destructive monsoon-related events due to climate change. Recent studies have reported that the Polar Vortex indirectly affects the ISM. Polar Vortex is a large area of cold air and low pressure around the Earth's poles. A weaker or disrupted polar vortex can cause unusual cold air outbreaks in the lower latitudes, extending south to the Indian subcontinent. This change in wind pattern can delay the ISM onset and weaken the monsoonal winds and, hence, the annual precipitation amount. Assimilation of wind observation can significantly improve the upper troposphere, lower stratosphere, and in the Tropics. In contrast, mass data are more valuable in the extra-tropics, particularly in the lower part of the atmosphere. The mass field can be used to derive the wind field over the extra-tropics; however, the same is not suitable for the small scale features in the Tropics. This study will try to address some of the following research objectives: (i) investigate the impact of satellite radiance assimilation over the extra-tropics and polar regions, (ii) whether the satellite radiance assimilation modulates the polar Vortex, (iii) how the radiance assimilation over the polar region influence the Indian summer monsoon circulation features and the precipitation pattern, etc.

15.02 DBNet data assimilation during cyclone events- Advantage of timeliness

Presenter: Srinivas Desamsetti, National Centre for Medium Range Weather Forecasting (NCMRWF), MoES
Co-authors: Srinivas Desamsetti, Upal Saha, Indira Rani S, John P George, and V.S.Prasad

NCMRWF receives the Direct Broadcast Network (DBNet) data near real-time from global stations (Japan, Europe, Australia etc.). NCMRWF initiated receiving the DBNet data from Central India (Hyderabad) from low earth orbit (LEO) satellites in near real-time. NCMRWF has been receiving the level-0 data from Indian National Centre for Ocean Information Services (INCOIS) and the other at National Remote Sensing Centre (NRSC) located at Hyderabad. Mainly NCMRWF receives the multispectral (ATMS, ATOVS) and hyper-spectral sounder radiances (IASI, CrIS) radiances from NOAA-18, NOAA-19, MetOp-B, JPSS-1, and SNPP satellites. The raw data has been processed at NCMRWF and converted to level-1b/1c/1d. The same is also shared in BUFR format with the global community through Global Telecommunication System (GTS) via Regional Telecommunication Hubs (RTH) New Delhi. The present study assesses the impact of data reception timelines in the assimilation system. The Observing System Experiments (OSEs) are designed to study the impact of these datasets and their time of reception. The case study is taken up during the cyclone season (Mocha (9-15 May) and Biparjoy (6-19 June)) of 2023. The NCMRWF operational global modelling system is used with state-of-art 4DVAR assimilation system in this study. Two types of numerical experiments were designed one with control (CNT) with conventional data, and the other by adding ATOVS (AMSU-A and MHS) along with ATMS (DBN). The DBN numerical experiments have been designed with Indian DBNet data received with 1-hour intervals. Over Indian region, the DBNet data reception is for 06 and 18 UTC assimilation cycles. The impact of these DBNet data is presented for case studies of cyclone movement and intensification. These findings will be presented at the conference.

15.03 Seasonal Impact of INSAT-3DR Satellite Radiance in NCMRWF Global Forecast System

Presenter: Sujata Pattanayak, National Centre for Medium Range Weather Forecasting, MoES
Co-authors: Ashish Routray, S. Indira Rani, Suryakanti Dutta, and V S Prasad

This study demonstrates the impact of Indian geostationary meteorological satellite INSAT-3DR sounder radiance observations in the NCMRWF Global Forecast System (NGFS). This advanced meteorological satellite carries 19-channel multi-spectral sounder payload. The sounder has 18 narrow spectral channels in the shortwave, middle, and longwave infrared regions and one channel in the visible region. In the present study, the assimilation experiment will be carried out for the whole year 2024 to assess the impact of INSAT-3DR satellite data in different seasons of the year. The mid-wave water vapour channels are considered in the assimilation experiment. The statistical analysis in terms of frequency of assimilated observation, bias, root mean square error (RMSE), standard deviation, scatter plot, etc., are calculated based on the results obtained to date. These RMSEs are calculated based on the bias-corrected analysis with respect to the bias-corrected background. The bias-corrected radiances show RMSE reduction of about 20%, 62%, and 54%, respectively, for low-level, mid-level, and upper-level moisture channels. The daily, monthly, and seasonal statistics also suggest that the analysis field with bias correction improved significantly over the background for all the assimilated channels. This initial analysis suggests that the assimilation of INSAT-3DR observation provides a positive impact on the analysis field and, consequently, the model forecast. It is also noticed that the analysis field gives lesser error i.e varies from -2 to + 2° K. Additionally, it has been proposed to analyse the INSAT-3DS data in a similar way as soon as NCMRWF receives the data.Keywords: INSAT-3DR; Radiance; Global Forecast System; Assimilation; Statistical Skill Score

15.04 All-sky radiance assimilation of INSAT-3DS Sounder Radiance in the WRF Model

Presenter: Prashant Kumar, Space Applications Centre, ISRO
Co-authors: P. K. Thapliyal, V. S. Prasad

This study aims to develop and present a methodology for assimilating all-sky water vapor (WV) radiance data from the recently launched geostationary sounder onboard INSAT-3DS satellite into the Weather Research and Forecasting (WRF) model. In the all-sky assimilation approach, hydrometeors are included as control variables by incorporating them into the background error covariance. To achieve this, three sets of experiments were conducted for July 2024 over the South Asia region, both with and without WV radiance assimilation. The impact of assimilation was evaluated by comparing the radiative transfer (RT) model's simulated analyzed and predicted brightness temperatures with independent satellite observations. The findings reveal a significant increase in the number of assimilated observations in the all-sky approach compared to clear-sky assimilation. Additionally, the all-sky analyses were found to align more closely with actual satellite observations. Due to the multivariate nature of variational data assimilation, notable changes were also observed in the hydrometeor analyses with all-sky assimilation. Short-range forecasts further confirmed the positive impact of all-sky assimilation over the clear-sky approach.

15p.01 Atmospheric Temperature and Moisture Profiles from Recently Launched INSAT-3DS Sounder

Presenter: Rishi Kumar Gangwar, Space Applications Centre (Indian Space Research Organisation)
Co-authors: Tapan K. Patel, M. V. Shukla, P. K. Thapliyal

With the launch of its improved multi-spectral infrared Sounder onboard Geostationary satellite INSAT-3DS on 17th February 2024, India aims to provide three dimensional structure of atmospheric temperature and moisture over the Indian subcontinent more accurately. INSAT-3DS, like its predecessors-INSAT-3D & 3DR, has 6-channels Imager and 19-channels Sounder but with improved onboard black-body calibration and thermal management to mitigate mid-night solar intrusion. The present work demonstrates the development of the algorithm for the retrieval of the atmospheric temperature and moisture profiles from INSAT-3DS Sounder observations. Herein, the optimal estimation (OE) or 1-dimensional Variational (1DVAR) method is exploited to retrieve the desired atmospheric profiles from INSAT-3DS Sounder observations. The first guess atmospheric profiles required by the developed OE based retrieval algorithm are acquired from the closest forecast fields available from Global Forecast System (GFS), which is a numerical weather prediction (NWP) model of National Centers for Environmental Prediction (NCEP), National Oceanic and Atmospheric Administration (NOAA), the United States of America (USA). The algorithm is assessed on both the simulated and the actual observations of INSAT-3DS Sounder for a limited period. The preliminary evaluation shows that the developed algorithm performs well on both simulated and actual observations and appropriately adjusts the first guess profiles to estimate the optimum atmospheric profiles of temperature and moisture. The improved atmospheric profiles may further be utilised for various important atmospheric applications like now-casting of extreme weather events such as thunder storms, etc.

15p.02 Analysis of diurnal nature of spatial variability of Land Surface Temperature in Delhi NCR using Sentinel 3 and INSAT-3D/R satellite data

Presenter: Ashim Kumar Mitra, India Meteorological Department
Co-authors: Anusuya Datta and Pratiksha Dubey

Urbanization in India is happening over a breakneck pace in last few years. The capital city, Delhi and NCR region is undergoing the aftermaths of increased urban density and resulting escalation in pollution. This study accounts the presence of nocturnal Urban Heat Island (UHI) effect of about 5-7°C during May, 2018.Also, the Urban Cool Island (UCI) effect is very prominent with presence of urban “cool-spots” with negative UHI of 5-10°C in central Delhi and surrounding urban clusters like Meerut, Greater Noida, Gurgaon, Bahadurgarh etc. during the daytime. We have also deduced that the UHI and UCI effects are not restricted to an overall city span or only urban settlements but can be prominent over micro regions such as major transport route intersections also. The dependence of the LST parameter over Normalized Difference Vegetation Index (NDVI) (from Sentinel 3 satellite) and Aerosol loading (from MODIS Terra satellite) has been assessed to justify the spatial changes of LST diurnally. A negative dependence of both parameters has been established and the formation of UCI due to increased loading of aerosols over urban dense areas and highway intersections during the day time ultimately affecting the short wave incoming radiation is observed. The areas of Central Delhi, Hapur and northern part of area of interest especially show the high aerosol loading and corresponding comparatively lesser temperature during daytime. The average range of aerosol optical depth over Delhi is between 0.4-0.8. Understanding the feasibility of using high temporal resolution (half hourly) Indian INSAT 3D LST data at 4000m spatial resolution for carrying out such studies has been also attempted. The algorithmic differences between the retrieval of LST from the two satellites has been studied and the difference in the LST values has been owed to the basic retrieval algorithms.

15p.03 Assimilating NOAA-21 Data for Enhanced Forecasting of Deep Depressions in India

Presenter: Devanil Choudhury, National Centre for Medium Range Weather Forecasting, Ministry of Earth Sciences, India
Co-authors: Upal Saha, S. Indira Rani, Devajyoti Dutta, Ankur Gupta, Sumit Kumar and J. P. George

NCMRWF receives NOAA-21 ATMS and CrIS data through EumetCast. Necessary modifications have been made to the NCMRWF Unified Model (NCUM) assimilation and forecast system to assimilate NOAA-21 data, as well as similar data from S-NPP and NOAA-20. As an initial step, prior to operationalizing NOAA-21 data, background and analysis innovations from ATMS and CrIS observations were computed and compared with those from S-NPP and NOAA-20. It was noticed that the NOAA-21 ATMS and CrIS innovations are of similar magnitudes to those of the corresponding observations from S-NPP and NOAA-20. After confirming the quality of NOAA-21 data, its impact on the simulation of deep depressions over India during September 2024 was examined by conducting Observing System Experiments (OSEs). The

OSEs analyzed the importance of the multispectral microwave and hyperspectral infrared instruments onboard NOAA-21 satellite, analyzing different channel/band combinations from these instruments. Two additional OSEs were performed with a combination of conventional observations along with ATMS and CrIS onboard (i) NOAA-20 and (ii) NOAA-20 and NOAA-21 to assess the additional impact of NOAA-21 data during two recently occurred deep depressions over India (7th to 11th September & 14th to 20th September, 2024).

15p.04 Assimilation of Microwave Imager Radiance Data in NCUM-R-4DVAR System and Its Impact on Simulation of TCs over Bay of Bengal

Presenter: Ashish Routray, NCMRWF, MoES
Co-authors: Shivaji Singh Patel, Devajyoti Dutta, K. B. R. R. Hari Prasad, Rajeev Bhatla and V. S. Prasad

An effort was made to investigate the impact of assimilation of Microwave Imager (MI) radiance observations on simulation of Tropical Cyclones (TCs) using high resolution NCUM-4DVAR assimilation method. Two sets of numerical experiments were performed: CTL (assimilated GTS observations) and SAT (assimilated GTS plus GMI and SSMIS satellite MI radiance). It is observed that assimilation of MI radiance is capable to depict the structure, track and intensity of storms. The analysis increments of temperature and geopotential height suggested that SAT experiment effectively adjust the core region of TCs and systematically correct the position in the first-guess of the model. The strength of large-scale transport of moisture from underlying oceanic surface and helicity around the storms are well simulated by the SAT with axisymmetric eye of TCs. The premature intensification of TCs is simulated by CTL, whereas the progression of the intensity of storms is relatively well captured in SAT experiment. It is seen, dry air invading into the inner-core of TC can disrupt the energy cycle, reducing storm intensity, which clearly seen in the CTL simulations. Similarly, the –ve value of diabatic heating is appeared around the centre of the storm with increase of altitudes in CTL simulations, which impede the intensity of TC. This feature clearly suggested that the intensity and vertical structure of the TCs are not properly brought out by CTL simulations. The track forecast of storms is considerably improved in SAT simulations than CTL. The forecast skill of rainfall is also fairly improved in SAT simulations. Overall assimilation of MI radiances enhanced model’s forecast skill to simulate structure, movement, intensity and precipitation associated with the storms.Key Words: Microwave Imager; Tropical Storm; NCUM-R model; Helicity; Moist-static

Session 16: The use of surface-sensitive data

16.01 Significance and Impact of High-Resolution Variational Assimilation of Satellite Microwave Radiances over Difference Surfaces

Presenter: Swapan Mallick, Swedish Meteorological and Hydrological Institute (SMHI)
Co-authors: Magnus Lindskog and Stéphanie Guedj

Assimilation of microwave radiances plays a crucial role in improving weather forecasts. Despite uncertainties in usage over land and sea-ice area, recent progress has been made. High-resolution variational data assimilation of microwave satellite observations from polar-orbiting platforms is a key area of research. This study examines the impact of radiances from the Microwave Humidity Sounder (MHS) and Advanced Microwave Sounding Unit-A (AMSU-A) instruments aboard NOAA and METOP satellites within the regional Nordic MetCoOp domain. Additionally, this study evaluates analysis and simulation results across different weather seasons to capture a broad range of conditions. Surface emissivity over land and sea-ice is retrieved using a dynamical emissivity approach with window channels and various modules of the RTTOV (Radiative Transfer for TOVS) model. We also aim to improve the use of surface-sensitive microwave radiances by exploring Lambertian and specular reflection assumptions in radiative transfer modeling over snow and sea-ice surfaces. A series of experiments has been conducted using the high-resolution (~2.5 km) HARMONIE-AROME model, run within a 3-hour assimilation cycle. The results will be analyzed using comprehensive statistical methods, assessing analysis increments, the number of assimilated observations, variational bias correction, rejection rates, and the error probability distribution across the observation space.

16.02 An Observing System Simulation Experiment for satellite observations: Uncertainty estimation of emissivity retrieval over sea-ice and land

Presenter: Roger Randriamampianina, Norwegian Meteorological Institute
Co-authors: Máté Mile, Stephanie Guedj, Roohollah Azad, Harald Schyberg

The relative importance of present observing system component contributions in this Arctic Numerical Weather Prediction model system is already well documented through data denial studies. For future enhancements in observations usage, Observing System Simulation Experiments (OSSEs) can assess the expected impact. In the frame of the Arctic-PASSION EU-funded project, we aim at configuring an Arctic OSSE to assess the capabilities of the current and future observing systems with special attention to microwave sounding instruments and the related surface emissivity retrieval approach in data assimilation. The goal is to demonstrate the impact of assuming a “perfect surface description” for the simulation and the assimilation of microwave low-peaking channels (for instance instruments onboard EUMETSAT Polar system and NOAA satellites). This will provide information on the value of the improvement of modeling the surface contribution to the observation. Technically, the Nature Run of the Arctic OSSE (provided by Météo-France) is used first, to simulate perfect observations, then 2) produce the perfect surface conditions with related perturbations. In this preliminary study, we will show how much uncertainty is associated with emissivity retrieval over mixed and complex surface scenes (sea-ice and land) and quantify how much we can expect to gain in forecast quality by reducing this uncertainty.

16.03 Simultaneous Estimation of Atmospheric Temperature, Surface Emissivity and Skin Temperature by Assimilating Surface-Sensitive Microwave Observations Over Land in a 1D-EnVar System

Presenter: Zheng Qi Wang, McGill University / Environment and Climate Change Canada
Co-authors: Dr. Mark Buehner and Prof. Yi Huang

Accurate information on surface emissivity and skin temperature is essential for effectively assimilating surface-sensitive microwave radiance observations over land in a way that enhances the accuracy of numerical weather prediction forecasts. A prior idealized assimilation study demonstrated that the error contribution of surface emissivity associated with each individual surface-sensitive microwave radiance observation can vary significantly due to spatial and temporal variations in surface emissivity Jacobians. Most assimilation systems fail to account for this variability, instead using a single prescribed observation error covariance matrix that averages the error contribution of surface emissivity. The previous idealized study addressed this issue by including surface emissivity as an analysis variable and representing its errors in the ensemble-based background-error covariance matrix within a 1D ensemble-variational data assimilation system. This approach resulted in up to a 20% reduction in air temperature error in the lower troposphere and a 35% reduction in skin temperature error. This study aims to implement the same approach in an experimental setup using real observations and background data, while also evaluating observation quality control and bias correction methods for surface-sensitive microwave channels.

16.04 Toward the all-surface assimilation of surface-sensitive satellite data from microwave temperature- and humidity-sounding channels in CMA-GFS 4D-Var system

Presenter: Hongyi Xiao, CMA Earth System Modeling and Prediction Center
Co-authors: Wei Han, Yining Shi, Yihong Bai

The assimilation of both temperature-sounding and humidity-sounding surface-sensitive channels from satellite microwave instruments are promoted over four main kinds of underlying surface type (snow-free land, snow, sea ice, coast) in CMA-GFS four-dimensional variational (4D-Var) system. The usage of microwave temperature-sounding channels on ATMS, MWTS(-II/III) and new-added AMSU-A over land (both snow-free and snow-covering land) is harmonized on basic of our previous work about the AMSU-A surface-sensitive channels assimilation by dynamic emissivity scheme. The same method is extended to the case of sea ice for above microwave temperature sounders. The capacity for assimilation of low-peak humidity-sounding channels from MHS and MWHS-2 over complicated underlying surface of CMA-GFS is also enhanced greatly. Over snow or sea ice, the different choices of window channels for the surface emissivity retrieval are compared. Over sea ice, the different correction schemes for extrapolating the emissivity retrieved from window channel to that of humidity-sounding channels are evaluated and assessed, and the semi-empirical linear extrapolation relations are obtained for different microwave humidity sounders. The data from microwave humidity-sounding channels are also activated over mixture surface type, such as coast. Till now, the all-surface assimilation framework of microwave channels within various frequency is constructed in CMA-GFS. These progresses are expected to bring benefits to the low-layer analysis, especially the depiction of atmospheric situation in the high-latitude region, where the accuracy of CMA-GFS is constrained. In consideration of the deeply coupling between CMA-GFS 4D-Var and radiative transfer model ARMS, in which the scheme for simulated brightness temperature of pixels over complicated underlying surface is continuous evolving, the future plan about the all-surface assimilation of microwave radiances in CMA-GFS will also be prospected.

16p.01 Study on extending the use of satellite microwave sounder data over the land

Presenter: Hyeyoung Kim, Korea Institute of Atmospheric Prediction System
Co-authors: Jeon-Ho Kang

The Advanced Technology Microwave Sounder(ATMS) data have, until now, only been assimilated over sea in Korea Integrate Model(KIM). To extend the coverage of the ATMS over land and sea-ice, we firstly assimilated only the high peaking, non-sensitive surface, channels (ch8~15 over land and ch22~23 over sea-ice). To extend the use of ATMS high peaking channel over land, bias correction and observation error covariance were adjusted. As a result, the analysis field error of stratosphere was reduced especially and the forecast skill improved (GPH NH: 0.48~2.65%, Asia: 1.35~ 2.35%).In order to assimilate more surface-sensitive microwave observation, the contribution of the atmosphere must be separated by removing the effect of surface radiance from the observed brightness temperature. Compared to the ocean, the land skin temperature has higher uncertainties, and surface emissivity is larger at around 0.8-0.95 with higher heterogeneities due to the complex surface condition, making it harder to model. So, estimating the land emissivity/surface temperature directly from satellite is tested. Using the radiation transfer equation and observation, the observation-dependent surface emissivity estimation method was introduced. Preprocessing was performed to remove the contaminated area and scattered data that cause errors in emissivity retrieval, and remove the data that differed significantly from the emissivity climate value. It was diagnosed that the model surface temperature is about 3K higher than the value calculated based on ATMS observation, which cause 20% difference in the observation increment of channel 6. It is necessary to use a more appropriate surface temperature for microwave surface radiance and correct the resulting bias. The number of observation available on land increased by 200% when an observation-dependent emissivity is applied compared to the default emissivity model. As a result of conducting the model impact test, it shows improvements in the lower-level temperature and the water vapor field of the analysis field.

16p.02 Assimilation of IASI Observations Over Land: Impact of Improved Surface Emissivity and Skin Temperature
Presenter: Christina Köpken-Watts, DWD
Co-authors: Mahdiyeh Mousavi, Robin Faulwetter

The assimilation of infrared satellite observations over land poses unique challenges due to the complex and variable nature of surface properties, such as emissivity and skin temperature (Ts), which can change significantly across different terrains, seasons, and local conditions. If not properly accounted for, these variations can introduce errors in the radiative transfer calculations used to represent the observations in data assimilation. Therefore, accurately representing land surface properties is essential, particularly for the effective assimilation of surface sensitive observations from the various existing and upcoming hyperspectral IR sounders into NWP systems.To address this, we use a climatology-based infrared emissivity atlas for improved emissivity estimates (provided as part of RTTOV, CAMEL V002) and invert the radiative transfer equation using clear-sky radiance of window channels to derive more accurate skin temperature values. The results show that the retrieved Ts aligns more closely with reference datasets, such as the IASI Level 2 LST product from EUMETSAT, compared to the forecast model's skin temperature. The retrieved values are therefore used as first guess instead of the model values. In our data assimilation framework, skin temperature is additionally treated as a sink variable within the variational analysis, controlled via the Ts-background error value. These improvements suggest a reduction in the specified background error for points with Ts retrievals.A similar approach is also used to enhance the assimilation of infrared water vapor sensitive channel on the geostationary imagers from Meteosat GOES and Himawari satellites.Assimilation experiments for IASI indicate that, with these enhanced representations of land surface properties, we can utilize approximately 15-35% more data from various IASI channels by including the observations over land. The impact on forecast scores has been consistently positive in the Northern Hemisphere, while generally neutral in the Southern Hemisphere. As of this abstract's preparation, the system is in a pre-operational stage and is expected to become fully operational soon.Additionally, we are investigating the potential of implementing spatially varying Ts background errors based on more extensive diagnostics, as opposed to the current approach of using constant error values for points with Ts retrievals and larger values where model Ts is used as first guess.

Session 17: Regional studies

17.01 Taking Advantage of Vertical Temperature and Dew Point Profiles Derived from HEAP and MIRS Software: Validation Products over Poland and Case Study Analysis
Presenter: Tobiasz Górecki, Institute of Meteorology and Water Management – National Research Institute
Co-authors: Bożena Łapeta, Artur Rutkowski

In Poland, the Institute of Meteorology and Water Management (IMGW) operates a station dedicated to the direct reception and processing of data from polar-orbiting satellites. In its operational mode, data from sensors such as IASI, MHS, AMSU-A (on Metop-B and Metop-C), and CrIS, ATMS (on NOAA-20) are processed using the Community Satellite Processing Package (CSPP). Specifically, HEAP and MIRS software are used, both of which are commonly employed to retrieve atmospheric profiles of temperature (VTP), moisture, and trace gases.One key advantage of HEAP is its ability to simultaneously use data from both hyperspectral and microwave instruments, resulting in more accurate VTPs. However, HEAP requires at least partially clear conditions, which are often limited, especially over Central Europe. In such cases, VTPs derived from microwave instruments are used instead.In my talk, I will present statistical validation results comparing VTPs and dew point temperatures (DPTs) obtained from HEAP and MIRS software with radiosonde data. Additionally, I will demonstrate the application of VTPs and DPTs in specific forecasting cases to address the question: In which weather situations do satellite data provide added value in understanding atmospheric conditions compared to numerical weather prediction?

17.02 Optimizing the assimilation of radiances in the operational AROME-Arctic NWP system

Presenter: Stephanie Guedj, The Norwegian Meteorological Institute
Co-authors: Máté Mile, Per Dahlgren, Åsmund Bakketun, Jostein Blyverket, Benjamin Ménétrier, Jana Sanchez and Magnus Lindskog

The AROME-Arctic forecast system has been running operationally at MET Norway since November 2015. To compensate for the lack of conventional/radiosondes observations in the Arctic, an optimal use of satellite observations from polar-orbiting satellite instruments is crucial. Currently, the operational suite is assimilating level 1 radiances from AMSU-A, MHS, IASI, ATMS and MWHS-2. Radiances from CrIS are presently monitored and some preparatory work is ongoing for the assimilation of Arctic Weather Satellite. This work aims at optimizing the use and documenting the impact of radiances in these complex polar regions, focusing on low-peaking channels. To carefully tune the system, the Desroziers diagnostic has been used to estimate the optimal observation errors and their correlations for each instrument. Then, extensive Observing System Experiments (OSE) have been run in which each instrument separately has been denied from the 3D-Var data assimilation system over both winter and summer periods. Objective forecast scores against conventional and radiances (AllObs) together with diagnostics such as Degree of Freedom for Signal (DFS) and Moist Total Energy Norm (MTEN) are used to tune once again the system and document the impact of each instrument over the AROME Arctic domain. A case study of an extreme event will be presented.

17p.01 Towards a full exploitation of satellite radiance information using transformed retrievals in HARMONIE-AROME 4D-Var

Presenter: Erik Dedding, KNMI
Co-authors: Stefano Migliorini, Isabel Monteiro, Siebren de Haan, Gert-Jan Marseille, Fabien Carminati

Numerical weather prediction (NWP) models commonly employ direct radiances for data assimilation. This approach has avoided difficulties that were encountered when assimilating retrievals, due to the presence of biases in observation errors, retrieval errors depending on background fields and limited vertical resolutions of retrievals. However, assimilation of radiances comes with a high computational cost and complex modelling of the measurement instruments. Additionally, the current implementation leaves operational NWP centres unable to exploit all observation information and only a fraction of the available channels from hyperspectral instruments are selected. With forthcoming satellites expected to add thousands of channels of infrared and microwave sounder data, assimilation of Transformed Retrievals (TRs) can attain equivalent results compared to direct assimilation of radiances, while also offering compression of the information content from thousands of radiance channels. Earlier work has provided support for the equivalence between direct radiances and TRs, condensing information content from thousands of radiance channels to tenths of TR components. A collaborative effort between the Met Office and KNMI is initiated to implement TRs into HARMONIE-AROME 4D-Var, corroborating the benefits in a different NWP-system and validating their equivalence. During the first part TRs from Infrared Atmospheric Sounding Interferometer (IASI) radiances over a wide selection of channels sensitive to atmospheric temperature and humidity are generated using existing software at the Met Office and subsequently assimilated into HARMONIE-AROME 4D-Var. Case studies are performed over two domains covering the Netherlands and DINI (Denmark, Iceland, Netherlands, Ireland) for validation. The second part focuses on implementing the 1D-Var algorithm into a software package for in-situ generation of TRs. This allows estimation of TRs and observation operators along with atmospheric profiles, surface fields, cloud top pressure and cloud fractions to be deployed by NWP-SAF users.

17p.02 Variational Bias Correction of Polar-Orbiting Satellite Radiances in Convective-scale Data Assimilation

Presenter: Reima Eresmaa, Finnish Meteorological Institute

Maintenance of robust bias correction is a major challenge in the assimilation of meteorological polar-orbiting satellite data into limited-area Numerical Weather Prediction (NWP) systems. I present a variant of the variational bias correction algorithm suitable for use in convection-resolving systems. Stable bias correction requires continuous and representative sampling of predictor variables such as satellite view angles and air-mass properties. In convection-resolving NWP systems, the sampling is often compromised because of small computing domains, short assimilation time windows, and large diurnal variation in data availability.The proposed variant is designed around the assumption of one recurring daily analysis hour at which a given satellite provides comprehensive data coverage inside the computing domain. The idea is to allow the variational algorithm to adjust the bias correction coefficients at that analysis hour only, and otherwise keep the updated coefficients constant during the analysis. The time of the daily coefficient update is to be specified separately for each satellite, taking account of the satellite orbit parameters. The proposal is an alternative to the widely-adopted operational practice where independent streams of coefficients are maintained and updated separately at each analysis hour.The proposal is evaluated by data assimilation experiments in the context of a state-of-the-art Northern-European limited-area NWP system. In comparison with the operational setup, the proposed method is found to slightly improve the satellite radiance data fit to the NWP model background. Nevertheless, verification against independent data sources indicates no solid and statistically significant impact on forecast system performance.

17p.03 Himawari Radiance Integration in the Bureau Limited-Area Assimilation System: Impact of Assimilation, Error Diagnostics and Treatment

Presenter: Nahidul Samrat, Bureau of Meteorology
Co-authors: Andy Smith, Fiona Smith, Jin Lee

This study investigates the integration of Himawari radiance data into our limited-area assimilation system, known as the Australian Community Climate and Earth System Simulator (ACCESS-C), emphasising the impact of assimilation, data processing treatment, and error diagnostics on the accuracy of the forecast. First, we evaluate the impact of integrating Himawari clear-sky radiance data in our system; the trials run for a 2.5-month period. Then, we run a series of experiments to find the optimal spatial distance to thin the dense observations, especially Himawari radiance in the DA system, to improve the accuracy of the analysis. The results from the thinning experiments show improvement in the short-range forecasts (up to T+18 hours) when using a uniform 70 km spatial distance for all satellites compared to the current setting of 12 km for Himawari AHI radiances, 24 km for ATMS and ATOVS and 60 km for IASI and CrIS (i.e., when using less data compared to current assimilation settings). After that, we performed an observation error diagnostics test to estimate horizontal and inter-channel observation error correlations for Himawari data. Overall, our results show that Himawari radiance assimilation contributes to ACCESS-C's forecast performance and highlights the critical role of effective error diagnostics and treatment in optimising its benefits.

17p.04 Characterisation and Handling of Errors of Satellite Radiances for km-scale Data Assimilation over Three Operational Domains

Presenter: Magnus Lindskog, Swedish Meteorological and Hydrological Institute
Co-authors: Jana Sánchez-Arriola, Benjamin Menetrier, Stéphanie Guedj, Per Dahlgren

Assimilation of satellite radiances plays a crucial role in improving weather forecasts. In recent years significant progress has been made for use of microwave and infrared radiances from polar-orbiting and geostationary satellites in km-scale regional models. Here we use the variational data assimilation procedure applied in the HARMONIE-AROME modelling system and containing the RTTOV (Radiative Transfer for TOVS) model. This modelling system is applied to derive statistics for the three operational domains of MetCoOp, AEMET and UWC-W. But an optimal use of satellite observations requires knowledge about the error characteristics of the data and how it compares with the corresponding errors of a short-range forecast, the so-called background state. Here we utilise a randomization technique to obtain background errors in observation space (BGOS) to enable comparison of observation errors with background equivalents. Observation errors characteristics are explored utilising various techniques. Then the observation and background errors utilised have been compared with the ones diagnosed by Desroziers (2012) technique. Apart from this, the optimal thinning distances for every instrument have been calculated throughout the background and observation error correlations with the method called Obstool (based on Desroziers 2012 too). In addition, the First Guess quality control values most adequate to avoid gross errors but to not to be too restrictive when assimilating radiances, have been obtained. Observation diagnostics tools that has been used are shared with the ACCORD modelling Community. The obtained characteristics are then used to optimise the satellite radiance handling with respect to error specification, thinning and quality control. Data assimilation studies are carried out to evaluate the functionality and meteorological impact of the enhancements.

17p.05 Use of Radar and Lightning Data Assimilation in Short-term Forecast over Brazil

Presenter: Dirceu Herdies, CPTEC/INPE
Co-authors: Vanderlei Vargas, Rute Costa Ferreira and Eder Vendrasco

The storms observed in the South and Southeast of Brazil caused several economic and social damages. These storms are often associated with severe weather conditions, with wind gusts, hail, lightning, and even tornadoes. Using numerical modeling and observed data is fundamental to increasing the knowledge of the environment in which storms are formed and improving their predictability. The main goal was to implement and enhance a data assimilation algorithm integrating radar and lightning data into the WRF model, assessing its impact on forecast accuracy. Focusing on South/Southern Brazil, a region with extensive observational infrastructure and frequent meteorological activity, this research utilized several data sources: precipitation data from the National Institute of Meteorology (INMET), lightning data from the Brazilian Lightning Detection Network (BrasilDAT) and GLM (Geostationary Lightning Mapper) instrument of the geostationary satellite GOES-16, reflectivity and radial velocity from the radars of the Brazilian Air Force, synoptic weather charts from the National Institute for Space Research (INPE), and initial conditions from the GFS model. The Weather Research and Forecasting (WRF) model with 3DVAR methodology was used in the study to evaluate the assimilation algorithm. The results were analyzed according to the impact

of assimilation in the atmospheric fields and evolution in the forecast of studied cases. The experiments with data assimilation from BrasilDAT or GLM indicated increased hydrometeors distributed throughout the troposphere and, consequently, in precipitation. The rapid rate of microphysical conversion was noticed mainly in the first hour of the forecast. The lightning and radar data assimilation methodology significantly contributes to the field, indicating that using such alternative data can improve short-term forecasts, benefiting various societal sectors.