Ongoing developments on satellite radiance assimilation at Météo-France

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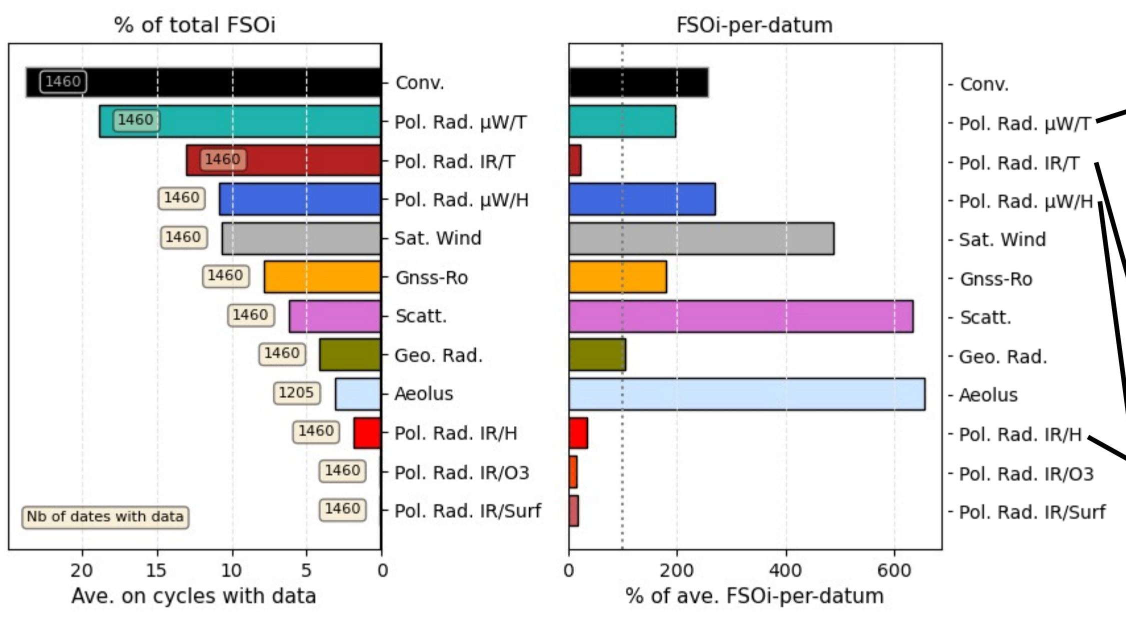
1. Introduction

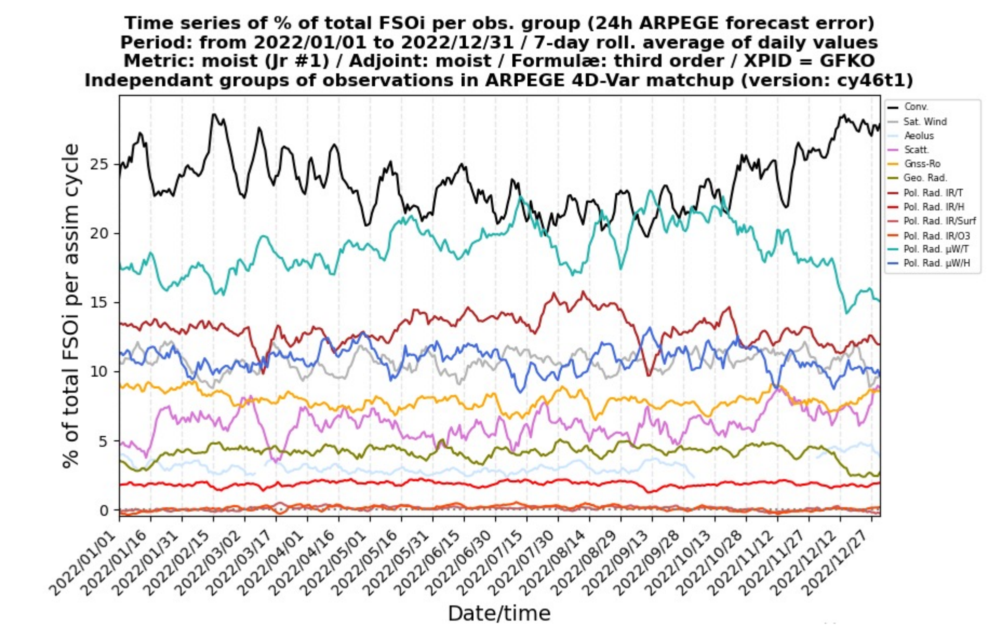
A large part of assimilated observations in the global model of Météo-France ARPEGE come from satellites radiances (mostly on polar orbiting satellites). Satellite radiances are also assimilated in the meso-scale model AROME-France but represent a smaller fraction of observations with a dominance of 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.

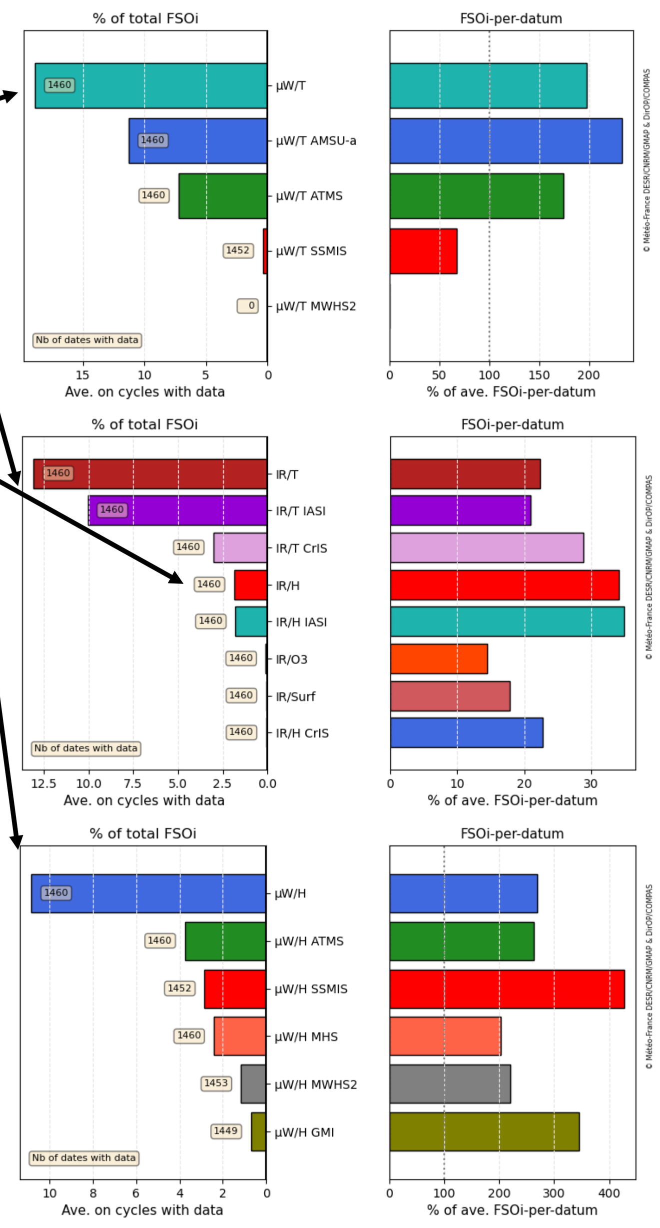
The summary of recent changes in data usage in the future 2023 operational suite will be presented. Among the various developments, highlights will be given on the updates made regarding the use of infrared geostationary data and the observation error cross-correlations for infrared hyperspectral radiances from IASI and CrIS, as well as the all-sky assimilation of several microwave sensors (MHS, MWHS2, GMI and AMSR2). Another highlight will be made on one growing activity of the OBS team related to the assessment of the impact of future sensors with five ongoing projects: OSSE for IRS within AROME, OSSE for IASI-NG within ARPEGE, OSSE for EPS-Sterna with ARPEGE, OSSE for CMIM within ARPEGE, EDA for WIVERN with the ARPEGE EDA.

2. Status of the operational framework regarding radiance assimilation

The figures below shows the FSOi metrics (total and per-datum) for the **full year of 2022 for the ARPEGE global model**, with a new channel splitting which was recently implemented, separating Temperature and Humidity sensitive channels for IR and MW sounders. It can be seen that the top 3 contributors are conventional data and the MW and IR temperature sounding channels. On the time series of FSOi (bottom left figure), the seasonal cycle of FSOi can also be seen with the MW temperature sounding reaching the same level of conventional data during summertime in the Northern Hemisphere.

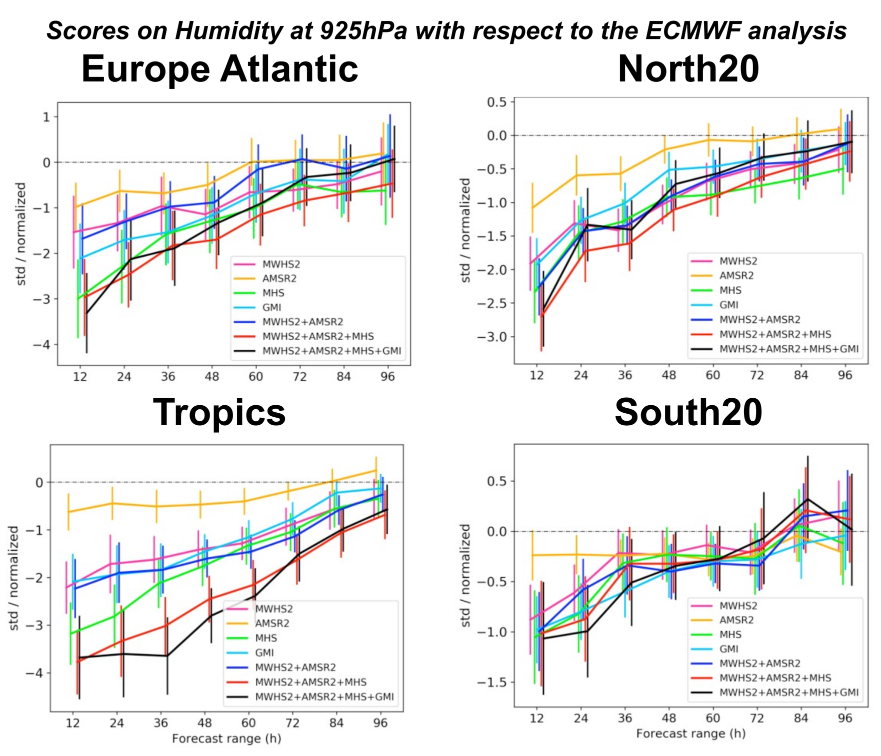






3. Evolutions in the 2022 parallel suite for the ARPEGE global model

- **Direct all-sky assimilation of microwave radiances from 4 sensors: MHS, MWHS2, AMSR-2, GMI using the ECMWF allsky route within the IFS/ARPEGE code.**

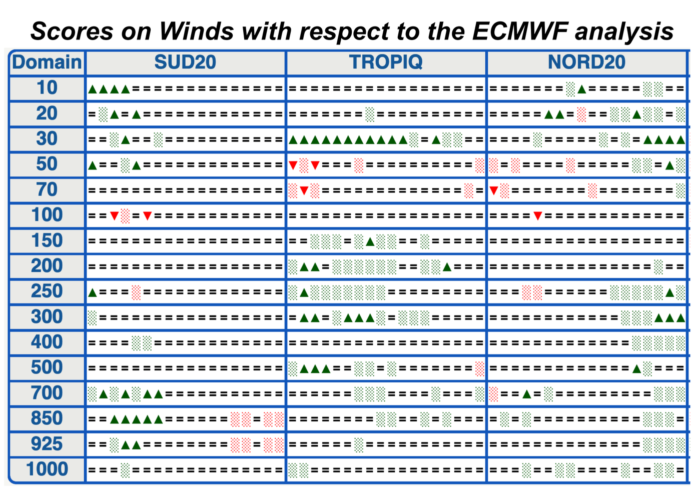


The figure on the left shows the reduction of ARPEGE forecast errors on ***Relative Humidity at 925 hPa*** *with respect to the ECMWF analysis over a two-month period in 2021, for four geographical zones, for single sensor experiments as well as incremental combinations of sensors.*

=> See Presentation 9.03 on Friday

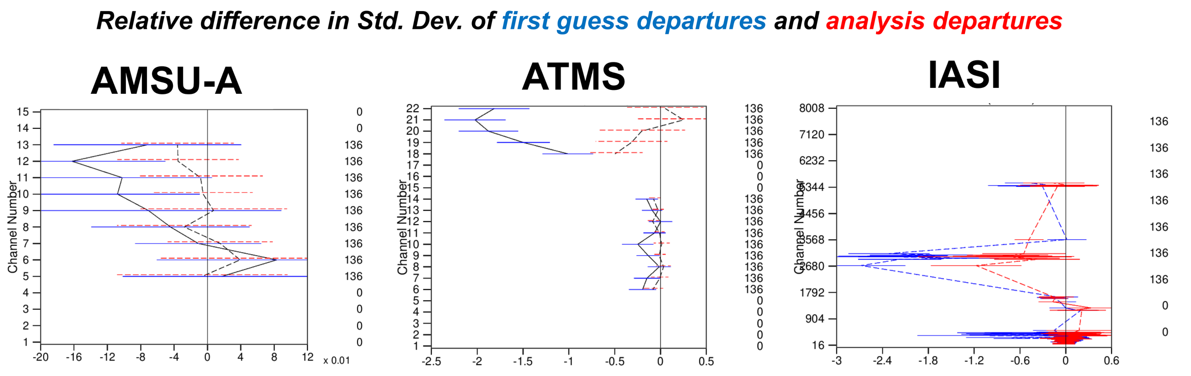
- **Update of the inter-channel correlation matrix for IASI.**

The IASI inter-channel observation error correlation matrix had not been recomputed since several cycles within ARPEGE. However, several major changes had been performed in the model physics (e.g. change of convection scheme), therefore, the impact of revisiting the R matrix for IASI was investigated. This update led to positive impact on most regions of the globe as can be seen on the score card on the right, showing the reduction of ARPEGE forecast error on ***Winds with respect to the ECMWF analysis over a two-month period in 2022.***



=> See Poster 15p.04 on Tuesday

- **Use of the most recent geostationary infrared sensors: assimilation of AHI/Himawari-9, monitoring of ABI/GOSE-18**



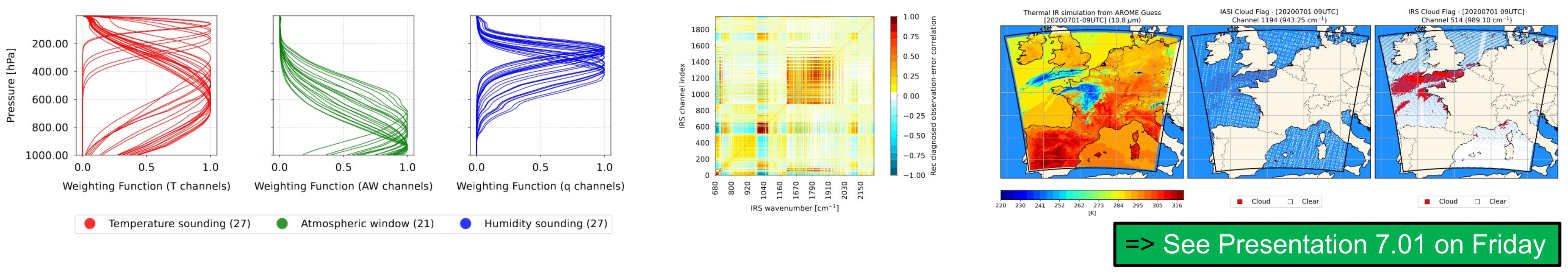
The figures on the left shows the impact of ***assimilating AHI/H9*** *on ARPEGE short range forecasts, highlighting a positive synergy with other sensors, over a one-month period in 2022.*

=> See Presentation 15p.04 on Thursday

4. Ongoing research for future evolutions

- **Preparation to the assimilation of the IRS instrument onboard MTG**

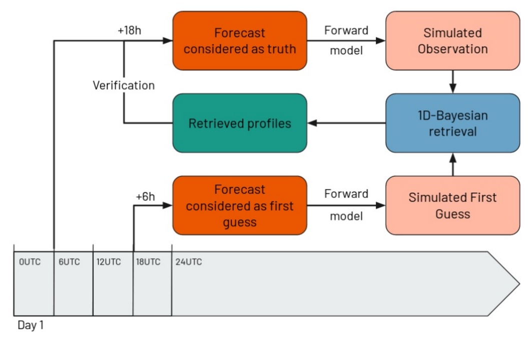
The preparation to the MTG/IRS assimilation within the AROME 3D-Var system has been undertaken using an OSSE approach (Coopmann et al., 2023) which allowed to make a first channel selection (left figure), to estimate a first R matrix from reconstructed radiances (middle figure), and to also set-up the cloud detection algorithm (right figure) as well as estimating first impacts on forecasts errors.



=> See Presentation 7.01 on Friday

- **Preparation to the assimilation of IR data affected by clouds (MTG/FCI) and the synergy with MW data (MWI and ICI/EPS-SG):**

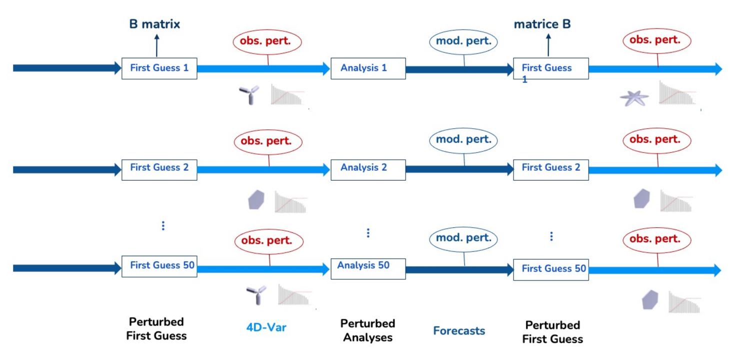
A simulated framework was built to assess the relative importance of cloudy IR radiative transfer uncertainties and inconsistencies with MW cloudy radiative transfer, compared to other sources of uncertainties like NWP model microphysical assumptions (Villeneuve et al., 2023). The main outcome of the study is that inconsistencies between IR and MW RT affects the synergistic use of IR and MW data within clouds much less than NWP model errors



=> See Presentation 1.05 on Thursday

- **Toward the use of multiple microphysical assumptions for the all-sky assimilation of MW data**

Building on the experience on the use of multiple microphysical assumptions with the 1D-Bayesian technique used in ARPEGE operationally for MW cloudy observations (Barreyat et al., 2022), a new set up has been explored to make a random use of several microphysical assumptions within the ARPEGE EDA system. This experiment was conducted with a direct assimilation method instead of the Bayesian scheme and led to a reduction of the EDA spread, in particular for humidity in the Tropics.



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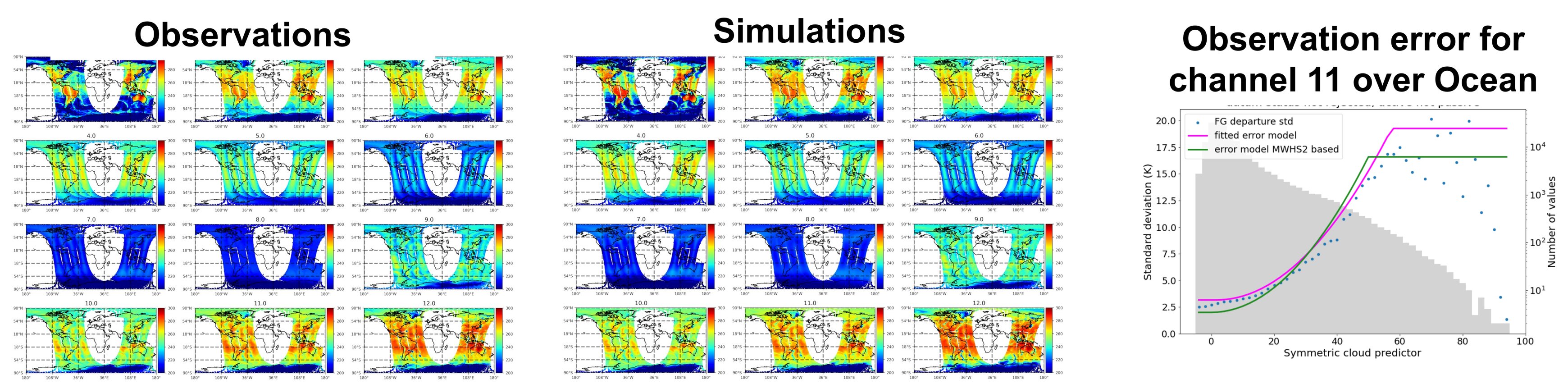
- **Preparation to the assimilation of TROPICS data**

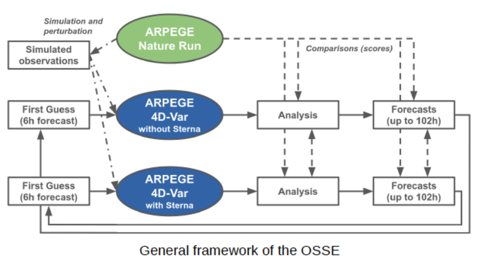
Using the data of the TROPICS pathfinder, preparatory activities have been conducted to make the ARPEGE 4D-Var system capable of assimilating TROPICS data when they will be available later this year. This included the adaptation of our software to ingest the observations (left panel), their forward simulation with RTTOV-SCATT (middle figure) as well as setting up observation errors in allsky conditions (right figure).



5. Impact assessment studies

- Using an **Observing System Simulation Experiment** framework to assess the potential impacts of the **EPS-Sterna MW** constellation, of the **CMIM** IR/MW constellation and of the **IASI-NG** instrument.

Parameters	Nature run	Data assimilation and forecasting system
Model	ARPEGE (version 46t1)	ARPEGE (version 46t1)
Truncation / nb of levels	TL1798 / 105 levels	TL798 / 105 levels
Resolution over Europe	About 5 km	About 10 km
Resolution over New-Zealand	About 24 km	About 61 km
DAS	None	4D-Var 6h cycle
Forecasts	None	102h
Physics package	Tiedtke convection scheme	Bougeault convection scheme
Period of study	July to October and November to February (one month of spin-up)	August to October and December to February

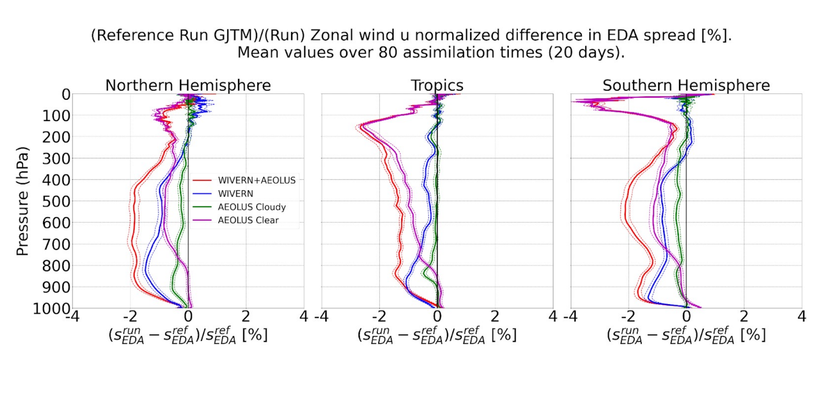


General framework of the OSSE

=> See Posters 15p.05, 8p.02, 8p.06

- Using an **Ensemble Data Assimilation** framework to assess the potential impact of the **WIVERN HLOS wind observations** and it's added value compared to the **AEOLUS mission**.

Following the method developed at ECMWF for assessing the impact of future observations, an EDA experiment was set up to assess the potential impacts of the wind observations from the WIVERN mission (candidate for ESA Earth Explorer 11), and its complementarity with AEOLUS data. The figure on the right shows the reduction of the EDA spread for zonal winds with either WIVERN, AEOLUS or both datasets assimilated. One of the main finding is the complementarity of impact in altitude between the WIVERN Doppler radar and AEOLUS.



6. Perspectives

- In the coming years, the **transition to MTG and EPS-SG instruments** will be a major activity of the team. Other new sensors will also be added to our systems, this includes the observations from **JPSS-2**, **FY3-E, AWS and of the TROPICS** constellation.
- A number of other research activities will also be conducted on several subjects. This will include the use of **IASI surface temperature retrievals within the surface analysis**, the use of **Full Spectral Resolution CrIS data**, as well as the use of **allsky MW** observations in the **AROME 3D-EnVar** using **hydrometeors in the control vector**.
- Activities related to **impact assessment studies** will also be pursued both with **the OSSE and the EDA frameworks**.

7. References

- P. Chambon, J.-F. Mahfouf, O. Audouin, C. Birman, N. Fourrié, C. Loo, M. Martet, P. Moll, C. Payan, V. Pourret, D. Raspaud. Global Observing System Experiments within the Météo-France 4D-Var Data Assimilation System. Monthly Weather Review, 2022, ⟨10.1175/MWR-D-22-0087.1⟩
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- Marylis Barreyat, Philippe Chambon, Jean-François Mahfouf, Ghislain Faure. A 1D Bayesian inversion of microwave radiances using several radiative properties of solid hydrometeors. ASL. 2023 (10.1002/asl.1142)

8. Acknowledgements

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