



Nadia Fourrié¹, Olivier Audouin¹, Philippe Chambon¹, Vincent Guidard¹
¹ CNRM, Université de Toulouse, Météo-France, CNRS, Toulouse, France

Correspondence to nadia.fourrie@meteo.fr

1. Introduction

Instruments (imagers, sounders, or radar) on board satellites are nowadays the most important data providers to build the initial conditions of NWP models. Among these, infrared hyperspectral sounders on board polar orbiting satellites, such as IASI or CrIS, provide information on temperature and moisture profiles with good precision and good vertical resolution. Among many channels available on this type of instruments, those assimilated for NWP are channels sensitive to different parameters, such as temperature, water vapour or ozone.

For IASI up to 129 channels (Figure 1) are assimilated over sea in clear sky conditions from Metop B and C (Figure 2). They consist of 99 temperature channels, 4 ozone and 21 WV channels. Over land the surface temperature is retrieved by inverting the radiative transfer equation with channel 1194 (945 cm⁻¹). Only clear channels are assimilated and they are detected with the McNally and Watts (2003) cloud detection scheme. They are bias corrected with the variational bias correction (Aulignier et al., 2007). The inter-channel correlation of the observation errors are taken into account using a Desroziers diagnostic (Desroziers 2005).

In this poster, we present the results of an OSE concerning the observation system used at Météo-France and the results are focussed on the IASI interferometer. The second point is the impact of changing the correlated R matrix for IASI and CrIS in the assimilation.

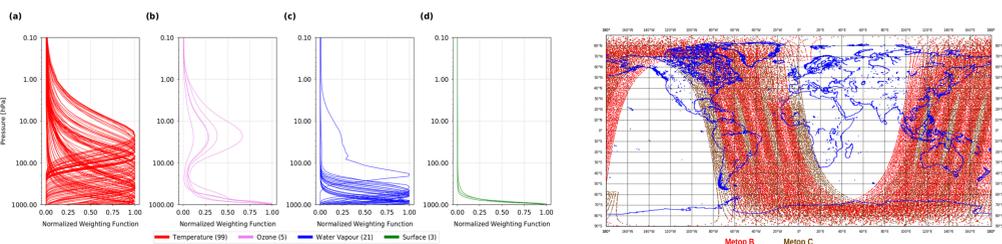


Figure 1: Weighting functions of assimilated IAS channels. In red CO₂-sensitive channels, in pink ozone sensitive channels, in blue water vapour sensitive channels and in green channels located in the surface window.

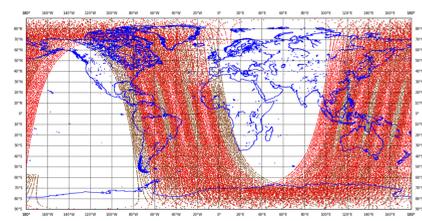


Figure 2: Location of IASI observations from Metop B and Metop C assimilated in the operational ARPEGE analysis of 2022/06/30 00 UTC.

2. Observing System Experiments

An OSE (Observing System Experiment) type study (Chambon et al. 2022) has been conducted to determine the relative importance of each observing system used at Météo-France and of the IASI instrument (among other observations) in the quality of the forecast for the global model ARPEGE, measured by objective scores.

- Denial experiments in which an observation system is removed from the data assimilation.
- All experiments conducted with lower resolution (T798) than operational one
- 6 months 1 October 2019 – 31 March 2020
- Experiments:
 - NO IR (no IASI, CRIS, AIRS and GEO radiances)
 - NO MW (No AMSUA MHS ATMS SSMIS GMI SAPHIR MWHS2)
 - NO CONV (no radiosonde, aircraft, wind profilers and surface observation)
 - NO SCATT (no observation from scatterometers)
 - NO GNSS (no GNSS Radio Occultation data)
 - NO AMV (no Atmospheric Motion vectors)
 - NO IASI
- Verification Analysis of IFS and comparison of the different experiments forecast scores to the reference ones.

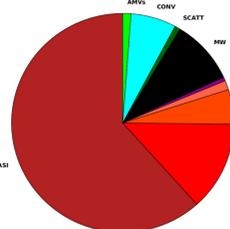


Figure 3: Main observation types assimilated in the ARPEGE 4D-Var assimilation system over October 2019 to March 2020. AMVs are shown in green, in-situ observations (CONV) in cyan, oceanic surface winds from scatterometers (SCATT) in olive, microwave radiances (MW) in black, GNSS-RO bending angles (GNSS) in purple, infrared radiances from geostationary satellites (GEORAD) in orange and those from polar orbiting satellites are shown in red (IASI, CrIS, AIRS).

The NO IASI experiment has been extended in three other denial experiments: the NO IASI T (in which the "temperature channels" were removed from the assimilation), the NO IASI WV (for which the "water vapour channels" were removed from the assimilation) and the NO IASI O3 where the 5 "ozone channels" were removed.

3. Impact of Infrared Sounders and IASI

First the impact of each large observation group was evaluated (Figure 3). In the Northern Extra-tropics, the main contributor is the conventional observation for the three parameters (i.e. geopotential, temperature and humidity). For the two other regions, micro-wave and infrared data denial leads to the largest impact. For temperature at 850 hPa especially, the Infrared Sounders is the second contributor (in Northern Hemisphere) or the first one in Tropics and the southern Hemisphere. For the humidity, removing micro-wave data degrades the forecast the most in the southern hemisphere and in the tropics.

In tropical regions, the lack of IR radiances significantly degrades the temperature at 850 hPa with values slightly above 6% during the first 24 hours. Conventional observations and infra-red sounders contribute similarly but to a lesser extent to forecast skill score reduction, except in the short-range at 12-h for temperature with a larger loss of around 9% from NO IR.

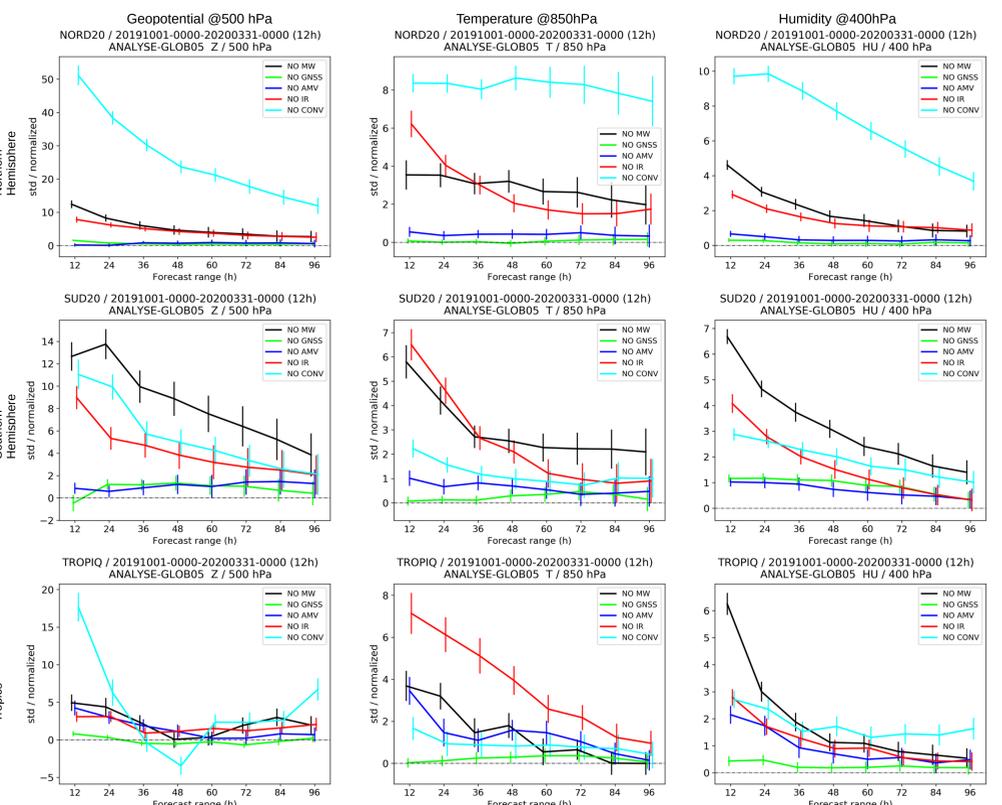


Figure 4: Normalized difference in the standard deviation of the forecast error (against ECMWF analyses) in geopotential @ 500hPa (first column), temperature @ 850 hPa (second column) and relative humidity (third column) versus the reference experiment REF, as a function of forecast range for five OSEs. The first row corresponds to the Northern Hemisphere extra-tropics, whereas the second row shows the Southern Hemisphere extra-tropics and the third one the Tropics. The period extends from October 2019 to March 2020 (6 months). The vertical bars indicate 99% confidence intervals.

4. Impact of the IASI Channels on the forecast skill

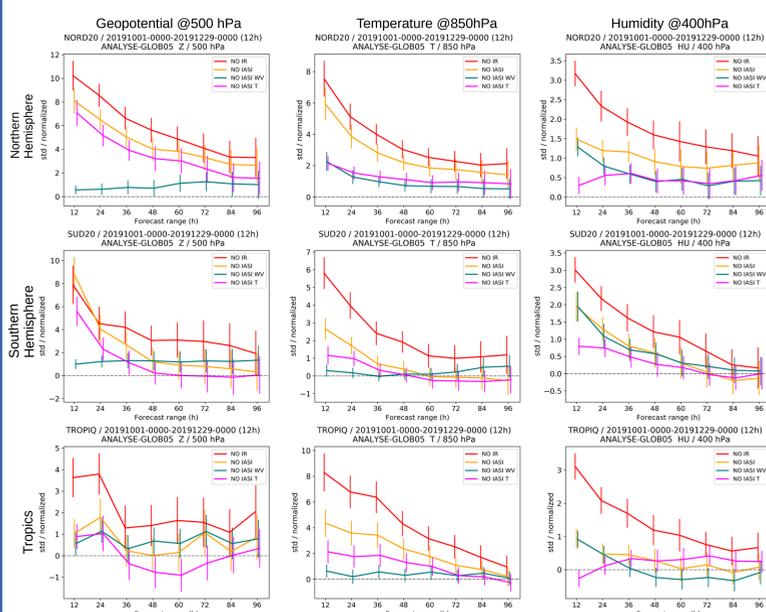


Figure 5: Normalized difference in the standard deviation of the forecast error (against ECMWF analyses) in geopotential @ 500hPa (first column), temperature @ 850 hPa (second column) and relative humidity (third column) versus the reference experiment, as a function of forecast range for the IR OSE, the NO IASI, the NO IASI T in which temperature channels were removed and NO IASI WV (in which the water vapour channels were removed). The first row corresponds to the Northern Hemisphere extra-tropics, whereas the second row shows the Southern Hemisphere extra-tropics and the third one the Tropics. The period extends from October 2019 to December 2019 (3 months). The vertical bars indicate 99% confidence intervals.

IASI brings more than half of the impact of the IR sounders. Due to the presence of clouds, the impact is reduced in the low troposphere (Figure 5). Temperature channels are beneficial for temperature up to 84 h forecast range and Water vapour channels for humidity even if the impact lasts less time (up 60 h).

The denial experiments with respect to channels show that removing temperature channels is detrimental, removing water vapour channels is in general detrimental, removing ozone channels is detrimental for temperature but positive for the humidity (Figure 6).

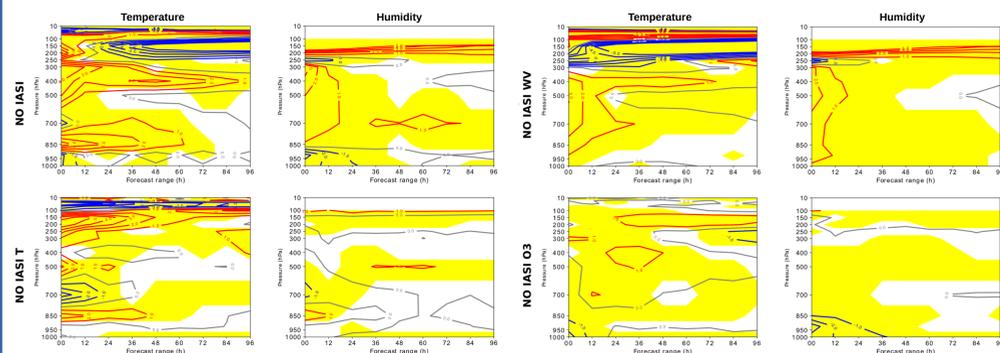


Figure 6: Normalized RMSE values (in percent) for tropical temperature (first and third columns) and relative humidity (second and fourth columns) against ECMWF analyses for denial experiments NO IASI T, NO IASI WV and NO IASI O3 against a reference experiment for forecast ranges up to 102 hours. Negative (red) values indicate a positive impact of the observing system (degradation of the forecast skill scores). Positive (blue) values indicate a negative impact of the observing system (improvement of the forecast skill scores). Yellow areas indicate where the differences are significant up to 99% confidence. The period ranges from October 2019 to March 2020.

5. Impact of an updated R matrix for IASI and CrIS

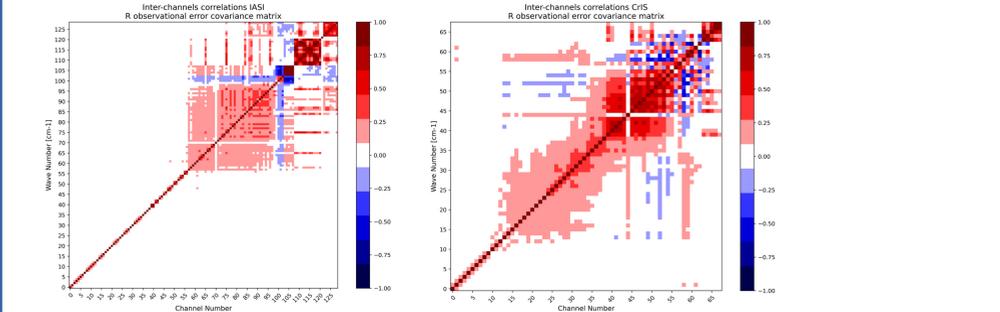


Figure 7: Interchannel correlation for IASI and CrIS. 129 channels of IASI are assimilated and 68 CrIS channels are assimilated.

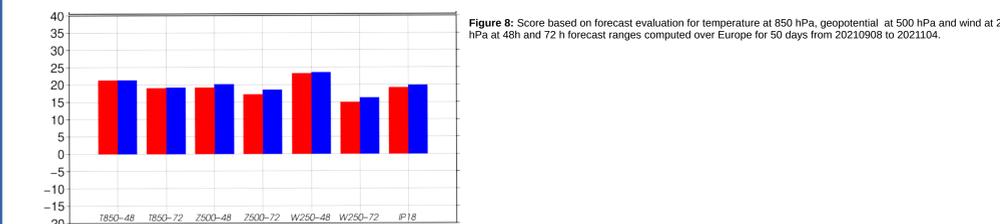


Figure 8: Score based on forecast evaluation for temperature at 850 hPa, geopotential at 500 hPa and wind at 250 hPa at 48h and 72h forecast ranges computed over Europe for 50 days from 20210908 to 2021104.

The inter-channel correlation matrix for the observation errors have been updated for cycle 48 according to the Desroziers et al (2005) method. The new correlation matrices are plotted in Figure 7 the impact of this modification on the forecast skill is weak but positive as shown by Figure 8 over Europe. It seems to impact mostly geopotential and wind. Positive impact on most regions of the globe are also found.

6. Conclusions and perspectives

- The OSE conducted at Météo-France show that Infra-red radiances also have a positive impact but which is less pronounced at longer ranges. Since they represent 80% in terms of the number of observations, each individual radiance has a rather low information content compared to NO CONV and NO MW. IR data are dominated by the 3 IASI sounders in terms of observation quantity and observation impact.
- IASI has a large impact on the forecast, especially in the troposphere for temperature around 400 hPa and 800 hPa.
- Temperature channels from CO₂ band are beneficial mostly for temperature forecast.
- Water vapour channels appear to be detrimental for the temperature forecast in the UTLS, requiring further investigation.
- Ozone channels seem to be detrimental for humidity near the surface.
- For more details, please refer to Chambon et al (2022)

Other experiments will be conducted to further understand the impact of the various IASI channel data sets.

The update of IASI and CrIS observations error correlation matrices slightly improve the forecast quality.

References

Chambon, P., Maifouf, J.-F., Audouin, O., Birman, C., Fourrié, N., Loo, C., Martet, M., Moll, P., Payan, C., Pourret, V., & Raspaud, D. (2022). Global Observing System Experiments within the Météo-France 4D-Var Data Assimilation System. *Monthly Weather Review* (published online ahead of print 2022).

Desroziers, G., Berre, L., Chapnik, B. and Poli, P. (2005). Diagnosis of observation, background and analysis-error statistics in observation space. *Q. J. R. Meteorol. Soc.*, 131: 3385-3396.