Toward assimilation of IASI All-sky radiances for Numerical Weather Prediction.

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1. Introduction

On a global scale, 80% of infrared (IR) observations are impacted by clouds (McNally., 2002). Research at JMA (Okamoto et al., 2024) and ECMWF (Geer et al., 2019) has shown the potential of all-sky assimilation of IR instruments in their global forecasting model.

At Météo-France, IR instruments are only assimilated in clear-sky areas in operations. Only a few microwave instruments are all-sky assimilated (Geer et Bauer, 2011) in Météo-France's global ARPEGE model (Bouyssel et al., 2022).

In this model, the IASI sounder represents around 49% (03/01/2025) of assimilated observations. All-sky assimilation of IASI could provide a better initial state and improve the quality of numerical weather forecasts in major challenges situations (often cloudy) (Fourrie et Rabier., 2004).

Objective to my thesis :

Implement and assess the impact of IASI all-sky assimilation in Météo-France's ARPEGE model.

Key points of my thesis :

➔ Obtain a functional all-sky assimilation framework.

➔ Set up and use the observation error model according to the cloud situation, for near-clear observations.

➔ Study IASI's single-channel cloud assimilation before extending to the whole channel set.

2. Calculation of the error model

In clear sky assimilation, the observation error is assumed to be constant and is estimated using a Desroziers diagnostic. In the case of an all-sky assimilation, the observation error can't be constant and should depend on the cloud scene. We follow the work of Geer et Bauer (2011) to estimate an error model which computes the observation error depending on a cloud proxy (Figure 1) and standard deviation of observation minus guess. For this proxy we use the cloud amount C_A (Okamoto et al., 2014). This proxy is used to calculate the radiative influence of clouds (Eq 1).

$$C_A = \frac{|B_{cloud} - B_{clear}| + |O - B_{clear}|}{2}$$

Eq 1 : Cloud amount equation (Okamoto et al., 2014). B_{cloud} : All sky simulation ; B_{clear} : Clear simulation ; O : Observation.

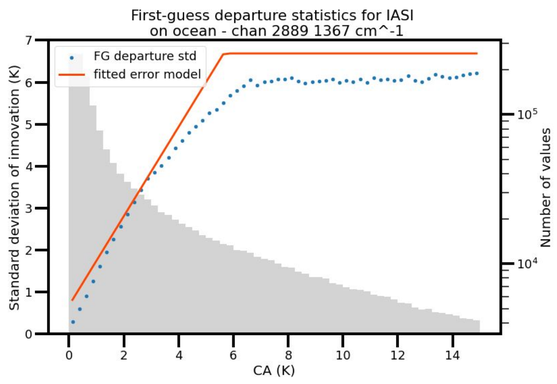


Figure 1 : Observation error model for humidity channel number 2889 of IASI calculated from Geer and Bauer, 2011.

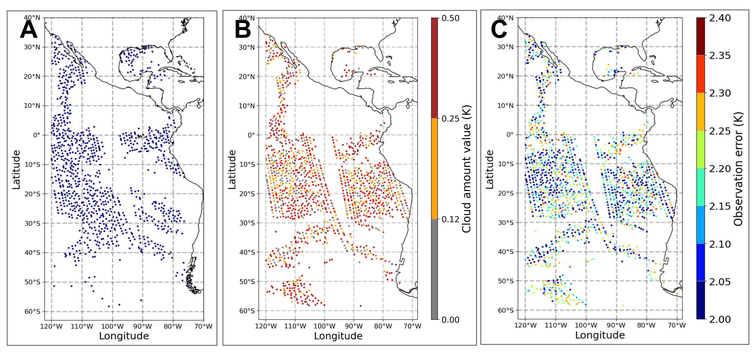
3. experimental setup for all-sky assimilation

Experimental setup :

- Assimilation of IASI humidity channel n°2889 (maximum weight function : 600 hPa).
- Only points over sea considered.
- Without sea ice points.
- No observations below 230 K for an IASI surface channel (channel 1191). Because cloud simulation doesn't work well below 230K.
- With a filter on CA, which must be less than 0.5 K to be close to clear assimilation. This threshold will be increased gradually.

4. Validation of all-sky assimilation with “clear” situations

To validate this experimental setup, we will assimilate IASI channel 2889 in all-sky. Its observational error model will be inflated to start at 2K, as for clear-sky errors.



The all-sky experiment assimilates more points (+314 points) than the clear-sky assimilation (Figure 2.A and B) on 15/08/2023 at 00 UTC. Figure 2.B shows the distribution of assimilated C_A. Most C_A are between 0.25 and 0.5 K. The associated observation errors are therefore greater than 2K, with an average observation error of 2.12 K in Figure 2.C.

Figure 2 : Map of 15/08/2023 at 00 UTC showing **A** : observation points assimilated in the reference; **B** : the assimilated CAs of the all-sky experiment and **C** : the associated observation errors of the all-sky experiment.

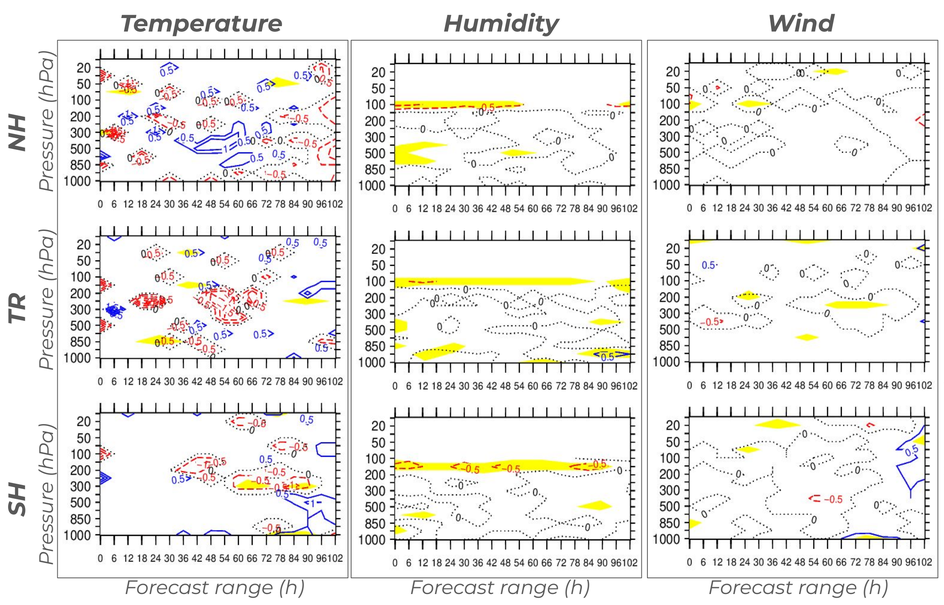


Figure 3 : Relative impact of the IASI all-sky assimilation (CA < 0.5K) on forecast error (%) - 1 months (08/15/2023 - 09/15/2023) - for temperature, humidity and wind in the Northern Hemisphere (NH), Tropics (TR) and Southern Hemisphere (NH) according to the forecast deadline (102 hours) - Areas highlighted in yellow are significant at 95%.

Figure 3 shows the prediction scores of this all-sky assimilation compared with a clear-sky assimilation of this channel with an observation error of 2K (as in operational use).
All-sky assimilation of IASI channel 2889 under near-clear sky conditions produces neutral to positive forecast scores.

5. Impact of IASI's single-channel all-sky assimilation

We will now evaluate the all-sky assimilation of IASI channel 2889 with the true observational error model of Geer and Bauer, 2011 (Figure 1) against the clear assimilation of this channel with the operational observational error (2K). The same quality controls as in section 3 are applied.

Figure 4.A shows that the all-sky assimilation of the IASI 2889 channel recovers more points in the southern hemisphere and on the eastern edges of the oceans than a clear-sky assimilation (figure 4.B). This represents around **+5%** of observations.

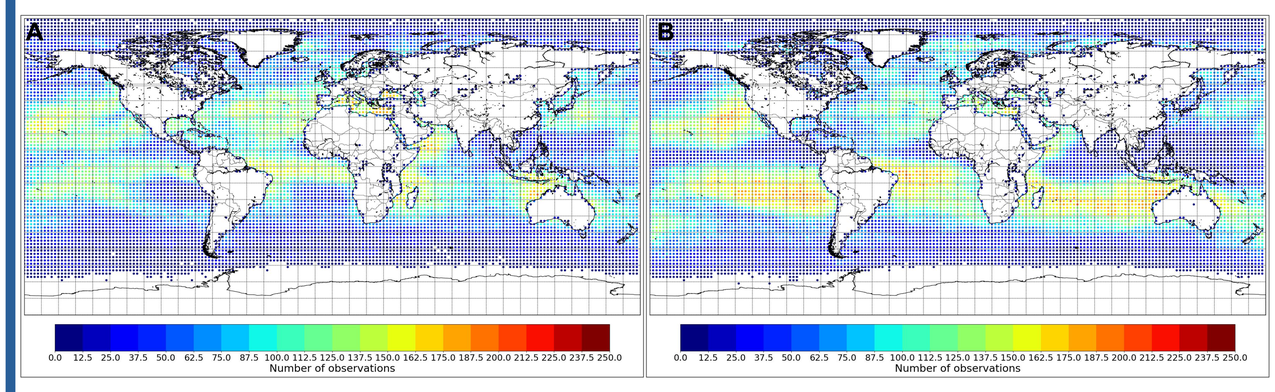


Figure 4 : Number of observations per 1° box for **A** a clear assimilation ; **B** all-sky assimilation of IASI channel 2889 over 31 days.

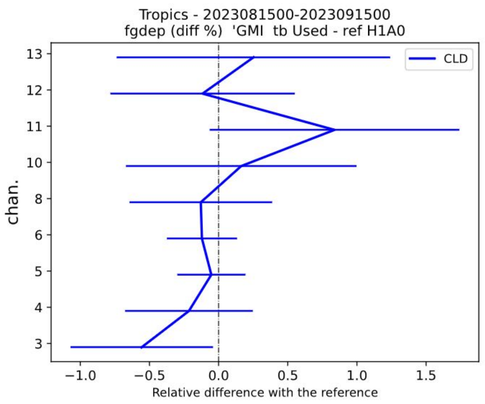


Figure 5 : Relative GMI fg_departure STD difference with the reference 08/15/2023 - 09/15/2023 - Tropics.

Overall, the fg_depar (observation - guess) of the satellite instruments are neutral when switching to all-sky assimilation.
In this figure, we can see that the fg_depar of the GMI microwave instrument channels are neutral overall, assimilating IASI's all-sky channel 2889. Channel 3, which is sensitive to rain, is slightly improved.

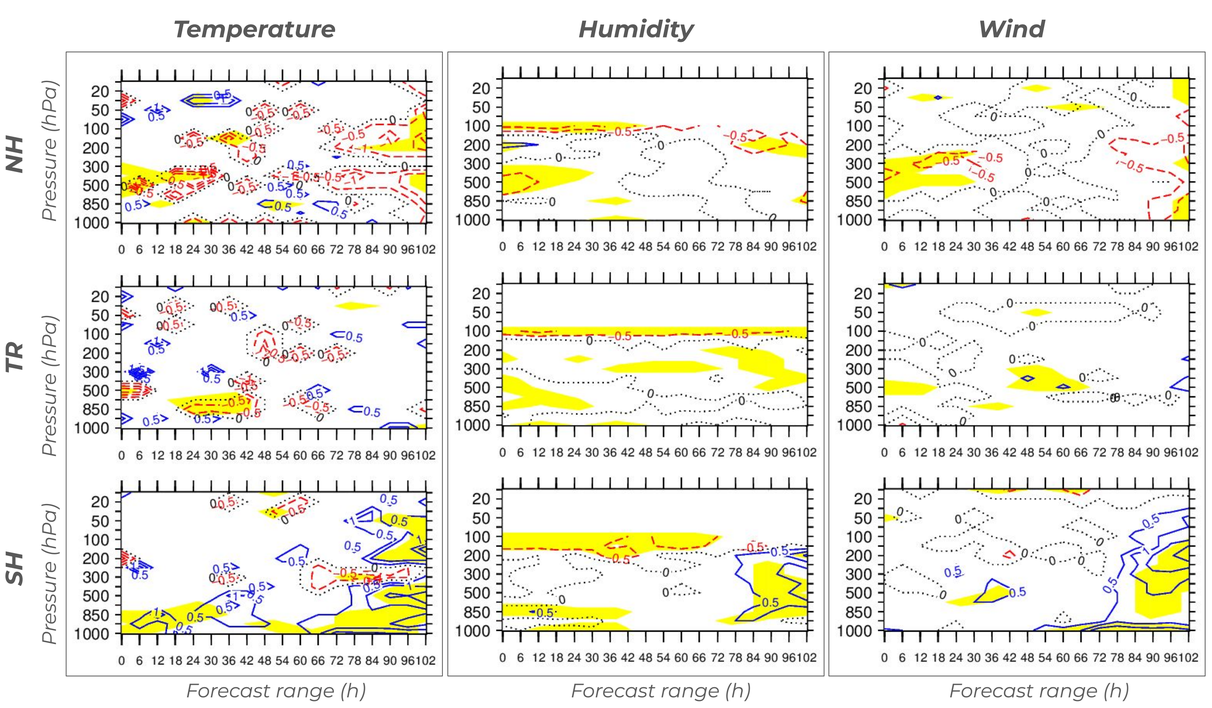


Figure 6 : As in figure 3 but for an experiment with the observation error model for observations with CA < 0.5 K

The all-sky assimilation of IASI channel 2889 now directly uses the observation error model from the work by Geer and Bauer, 2011 (Figure 6). The prediction scores for all-sky assimilation are much more significant and positive, especially in the southern hemisphere.

6. Conclusions and next steps

Conclusions :

- *The assimilation of IASI channel 2889 is producing promising results, particularly in the southern hemisphere. This can be explained by the increase in the number of observations assimilated in the southern hemisphere compared with the reference.*

Prospects :

- *Extended to other single-channel assimilation of other humidity channels.*
- *Test multi-channel assimilation with a cloud-dependent correlation matrix.*
- *Towards the assimilation of all assimilated humidity channels into operations.*

7. References

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