Impact of the future IASI-NG hyperspectral infrared sounder in the ARPEGE Numerical Weather Prediction model

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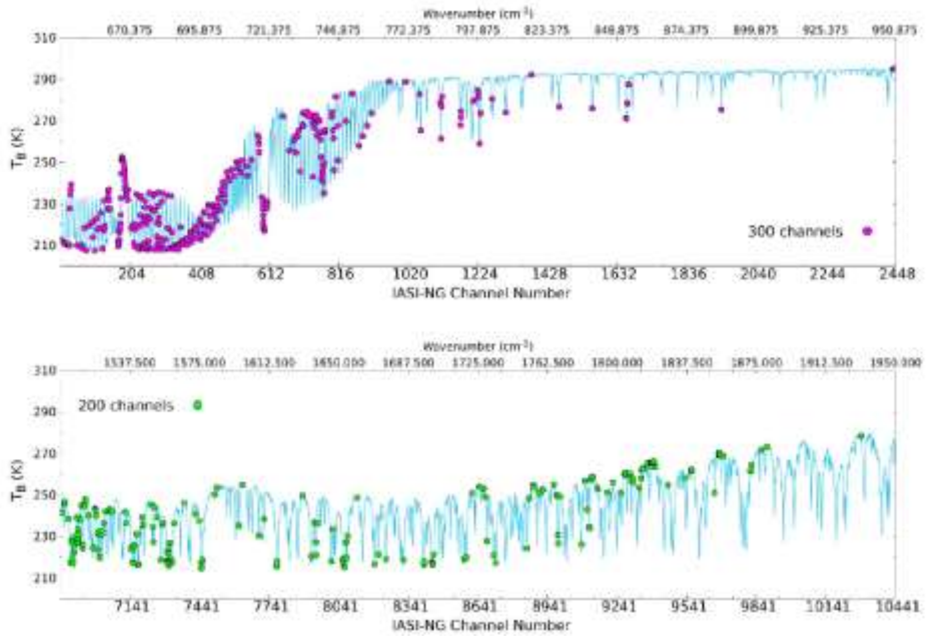
Introduction

- Positive impact of IASI-NG compared to IASI (1D study, Andrey-Andres et al, 2018)
- Channel selection proposed by Vittorioso et al (2021)
  — Bands chosen in conjuction with IRS
- Next step → assimilation in ARPEGE
  to evaluate the impact of IASI-NG



500 selected channels by Vittorioso et al (2021)

<u>Plan :</u>

- What is an OSSE ?
- OSSE framework for IASI-NG study
  and simulation of the observations
- IASI-NG data assimilation
- Impact of adding IASI-NG or replacing IASI
  with IASI-NG
- Conclusions

What is an Observing System Simulation Experiment (OSSE) ?

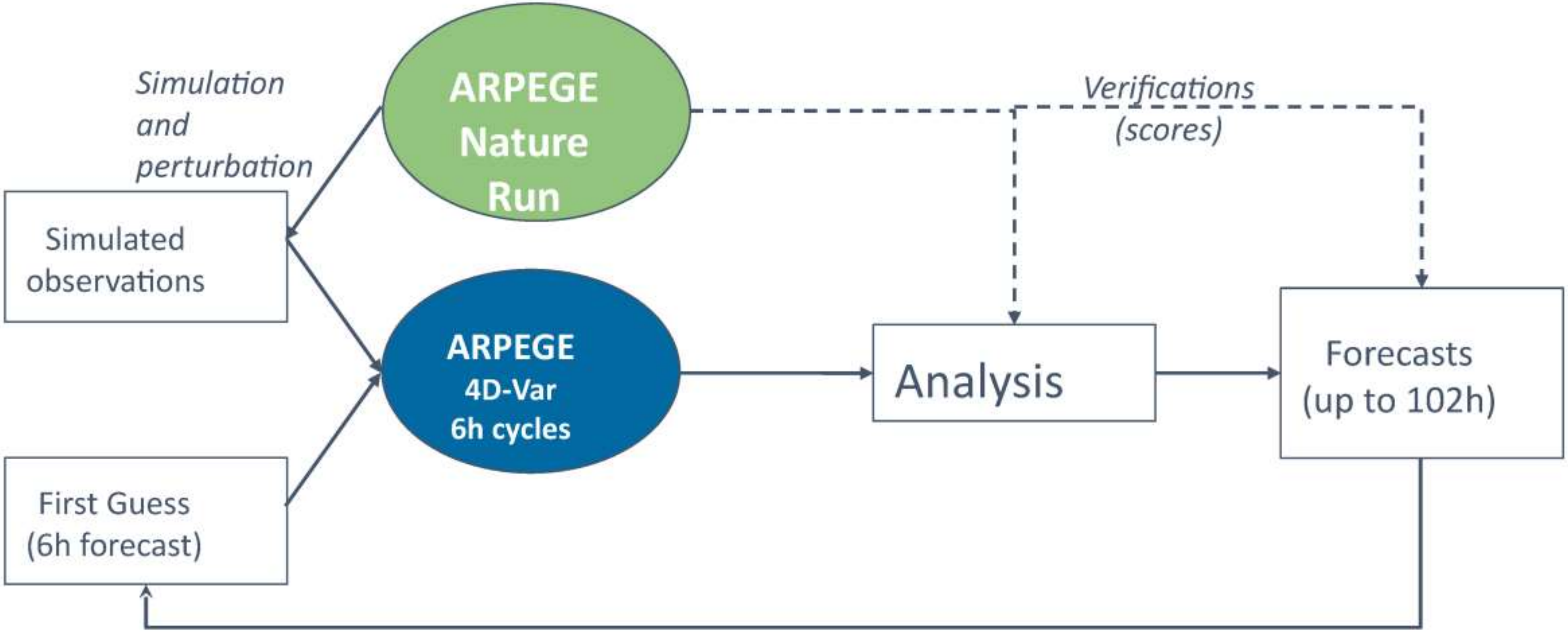
- An OSSE mimics a real numerical weather prediction system with simulated data, by providing forecasts with realistic errors, compared to a known truth.
- An OSSE system can be used for two purposes :
  - (i) to estimate the impact of a future observing system,
  - (ii) to prepare an assimilation framework with simulated data to increase the readiness level before the availability of a new dataset.

What is an Observing System Simulation Experiment (OSSE) ?

Several OSSEs have already been conducted at CNRM before :

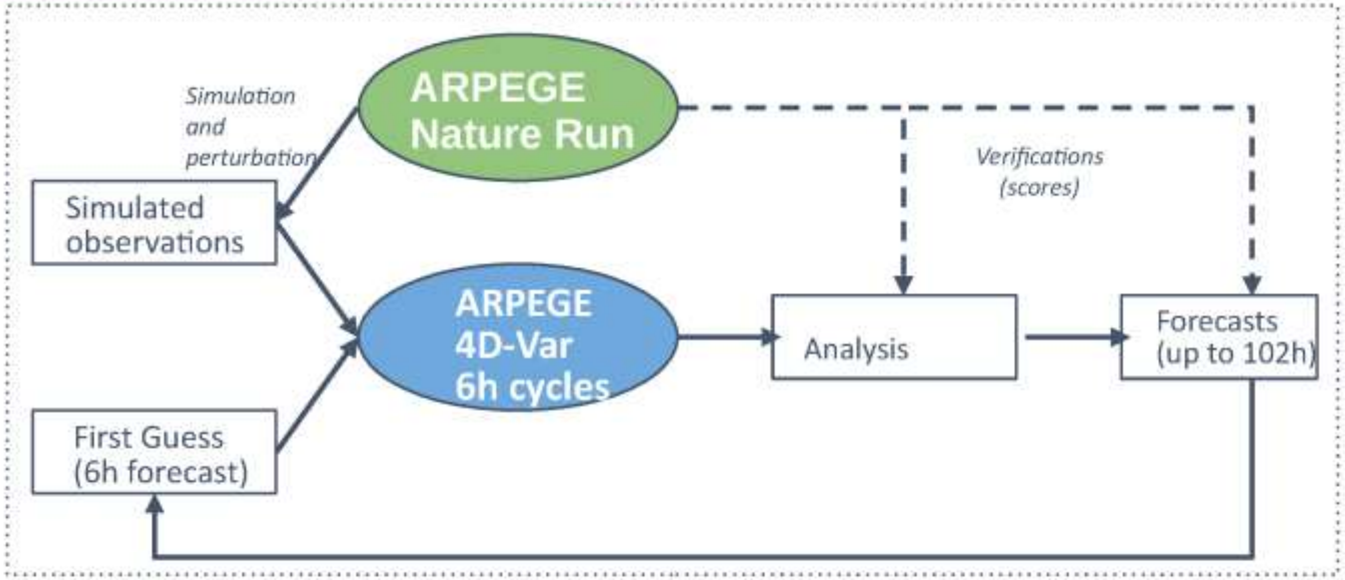
- in the mesoscale model AROME :
  - for MTG/IRS in 2013 (EUMETSAT Fellowships, S Guedj, and O. Coopmann et al, 2023),
  - for a potential Microwave GEOsounder (Duruisseau et al, 2017),
- in the global model ARPEGE :
  - for the design of a potential constellation of hyperspectral IR and/or MW sounders (CMIM, CNES project, see Thomas Carrel-Billiard's presentation),
  - for the design of the EPS-Sterna constellation (Rivoire, et al., 2024)
  - For the evaluation of the IASI-NG
  - These 3 studies benefited from the same OSSE framework.

General framework of the OSSE



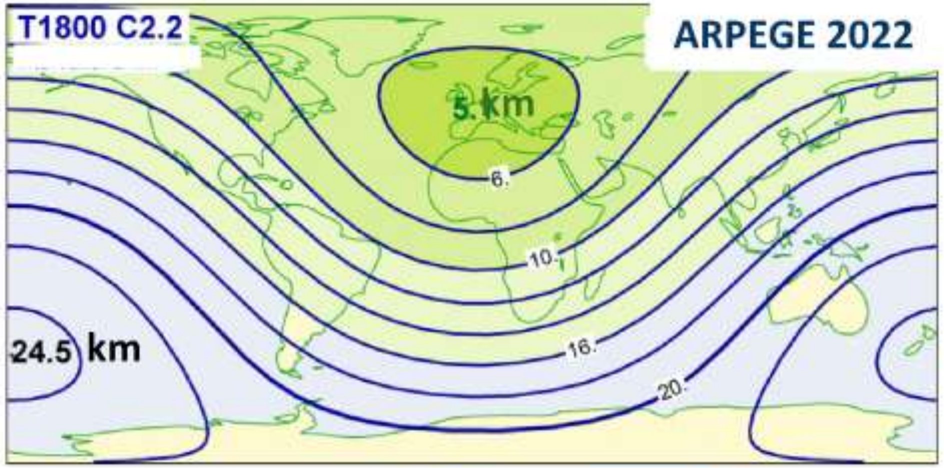
General framework of the OSSE

ARPEGE Nature Run



Main characteristics of the Nature Run:

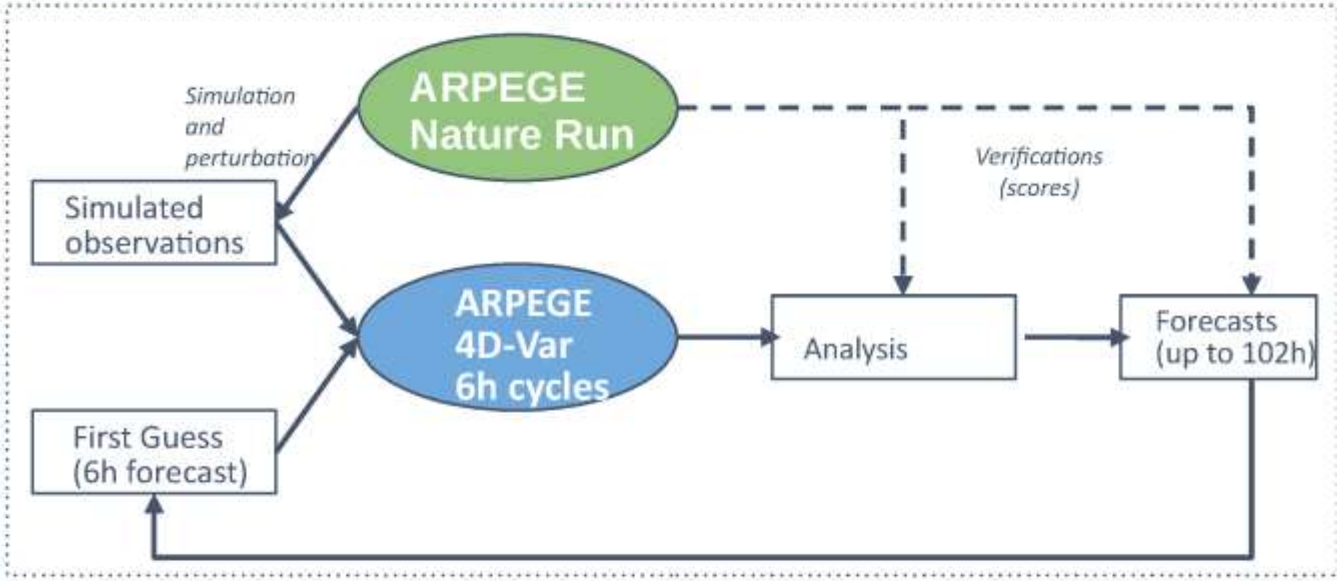
- Two periods:
  - Summer 2021 (July – October, July used for spin up)
  - Winter 2021/2022 (November – February, Nov. used for spin up)
- Operational horizontal and vertical resolution : T1798c2.2, 105 levels
- Operational physics packages (e.g. Tiedtke convection scheme)

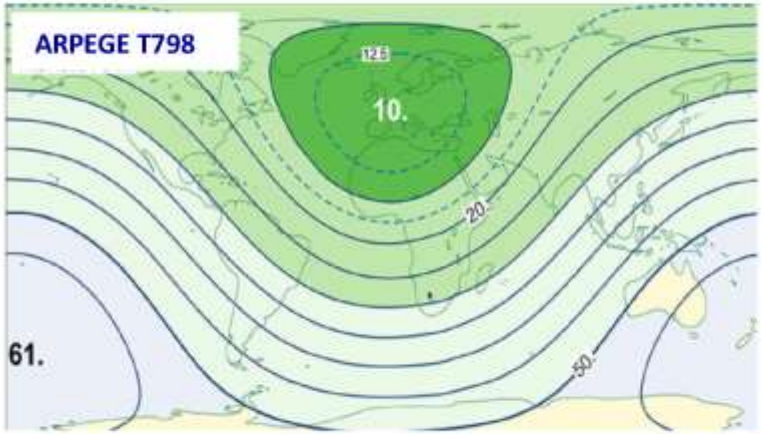


General framework of the OSSE

ARPEGE 4D-Var

Parameters of the model	ARPEGE Nature Run	ARPEGE 4D-VAR
Truncation	TL1798	TL798
Resolution over Europe	About 5 km	About 10 km
Resolution over New-Zealand	About 24 km	About 61 km
Physics	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



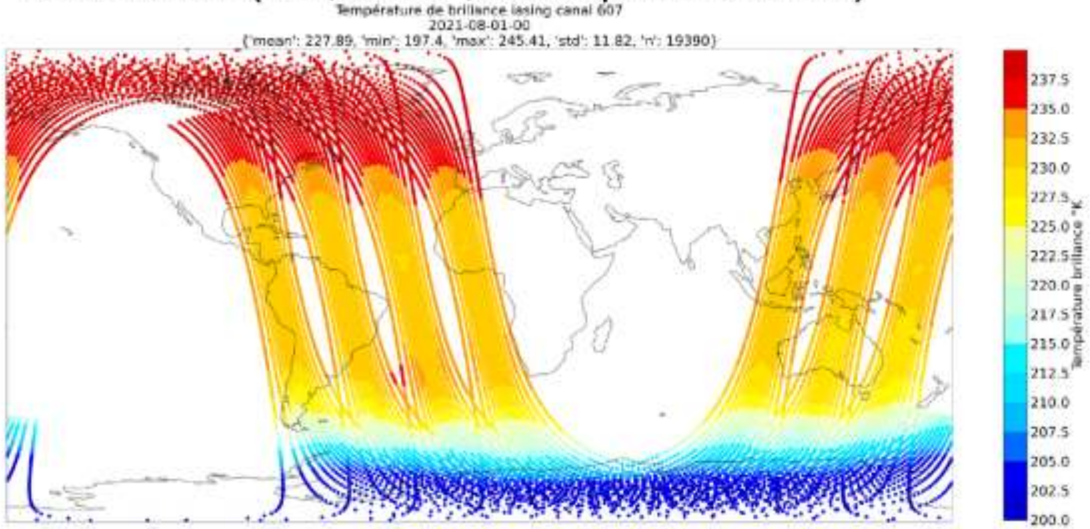


IASI-NG data assimilation framework

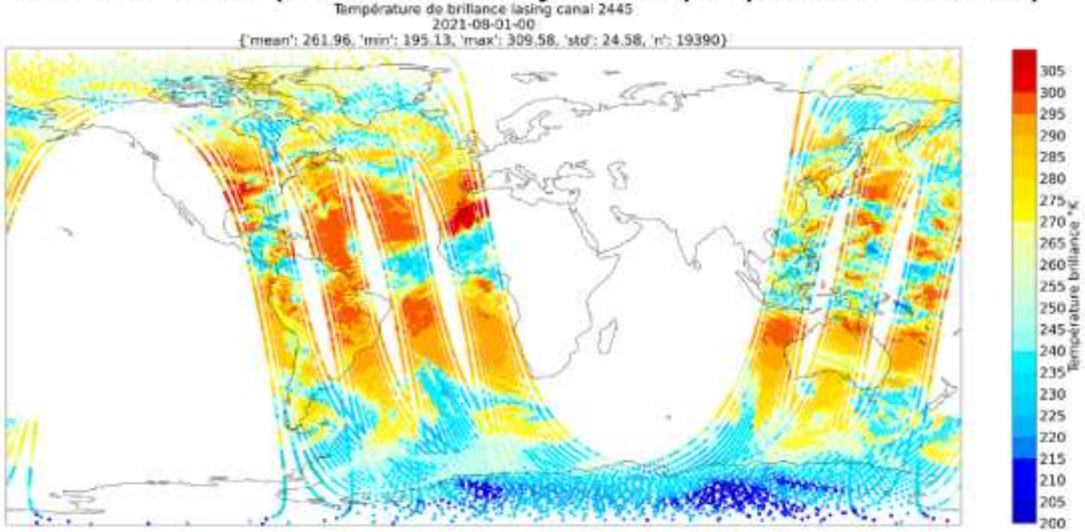
- Experimental setting : data assimilation experiments with/without the assimilation of IASI-NG on top of the full observing system used in ARPEGE (conventional and satellitte data)
- Study period : 4 months (summer and winter)
- IASI-NG data assimilation parameters based in those used for IASI data assimilation
  - Channel selection (~120 channels for the assimilation)
  - Cloud detection adapted from McNally and Watts (2003)
  - Setting the observations errors (for simulation and assimilation).
  - Horizontal thinning : 95 km

Simulation of IASI-NG observations

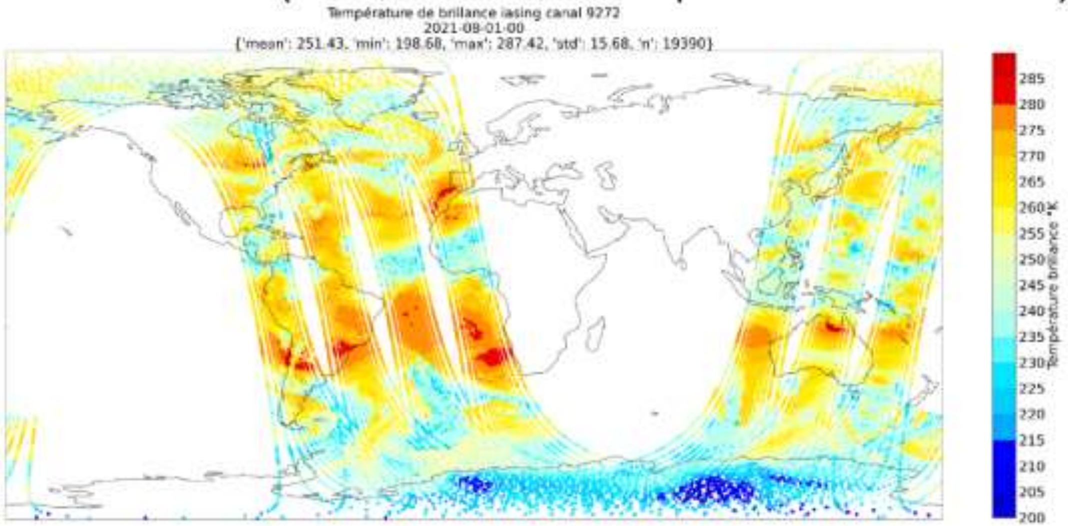
Channel 607 (720,75 cm^{-1}, stratospheric channel)



Channel 2445 (950,5 cm^{-1}, very low tropospheric T channel)



Channel 9772 (1866,375 cm^{-1}, mid troposheric WV channel)

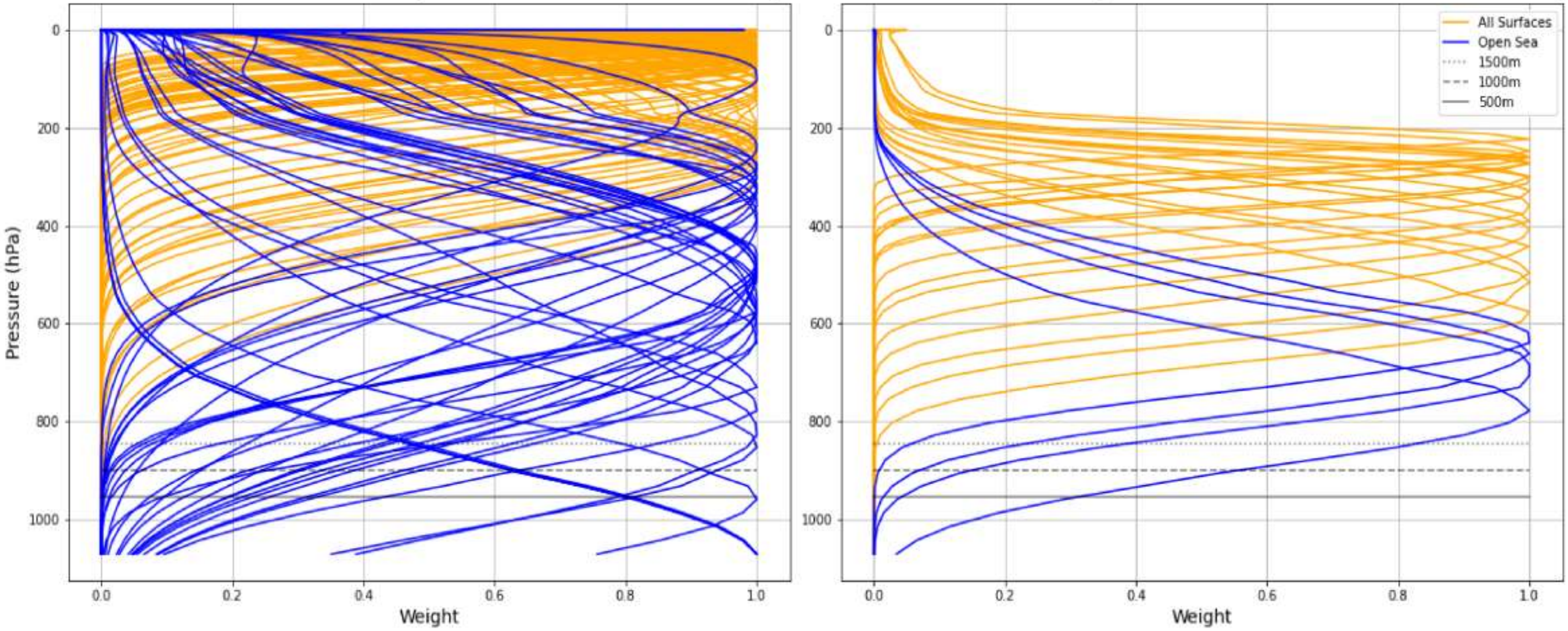


All-sky radiance simulation with RTTOV-cloud **(+ random perturbations added)**.

Orbit location provided by CNES

Selection of IASI-NG channels for data assimilation

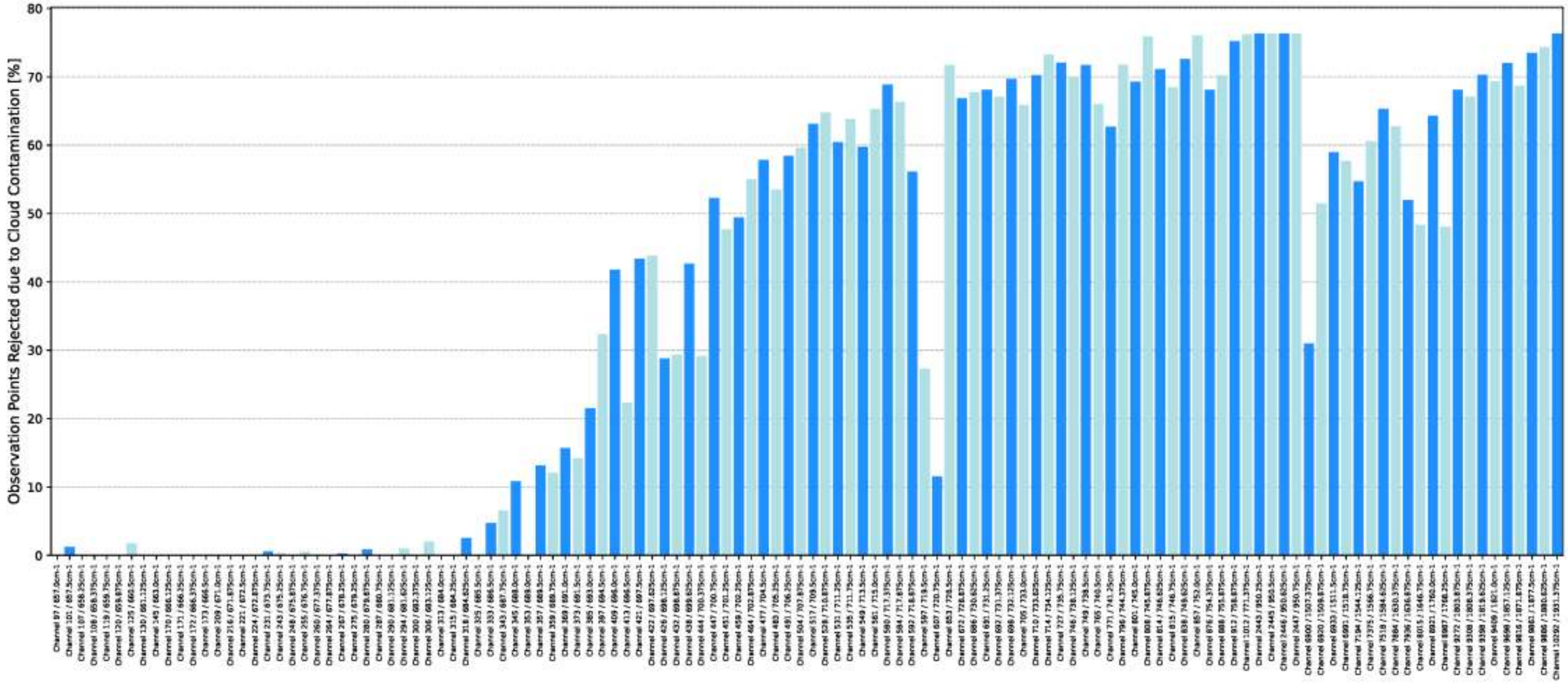
101 from CO_2 band 1 (657 cm^{-1} – 950,750 cm^{-1}) 21 in WV band (1507,375 cm^{-1} – 1931,375 cm^{-1})



122 channels selected for data assimilation (129 for IASI)

Distribution of the cloud flags wrt channel number

Percentage of cloudy observations for the 122 assimulated IASI-NG channels.



~75 % of IASI-NG channels sensitive to the surface are cloudy, similar to what is obtained with IASI.

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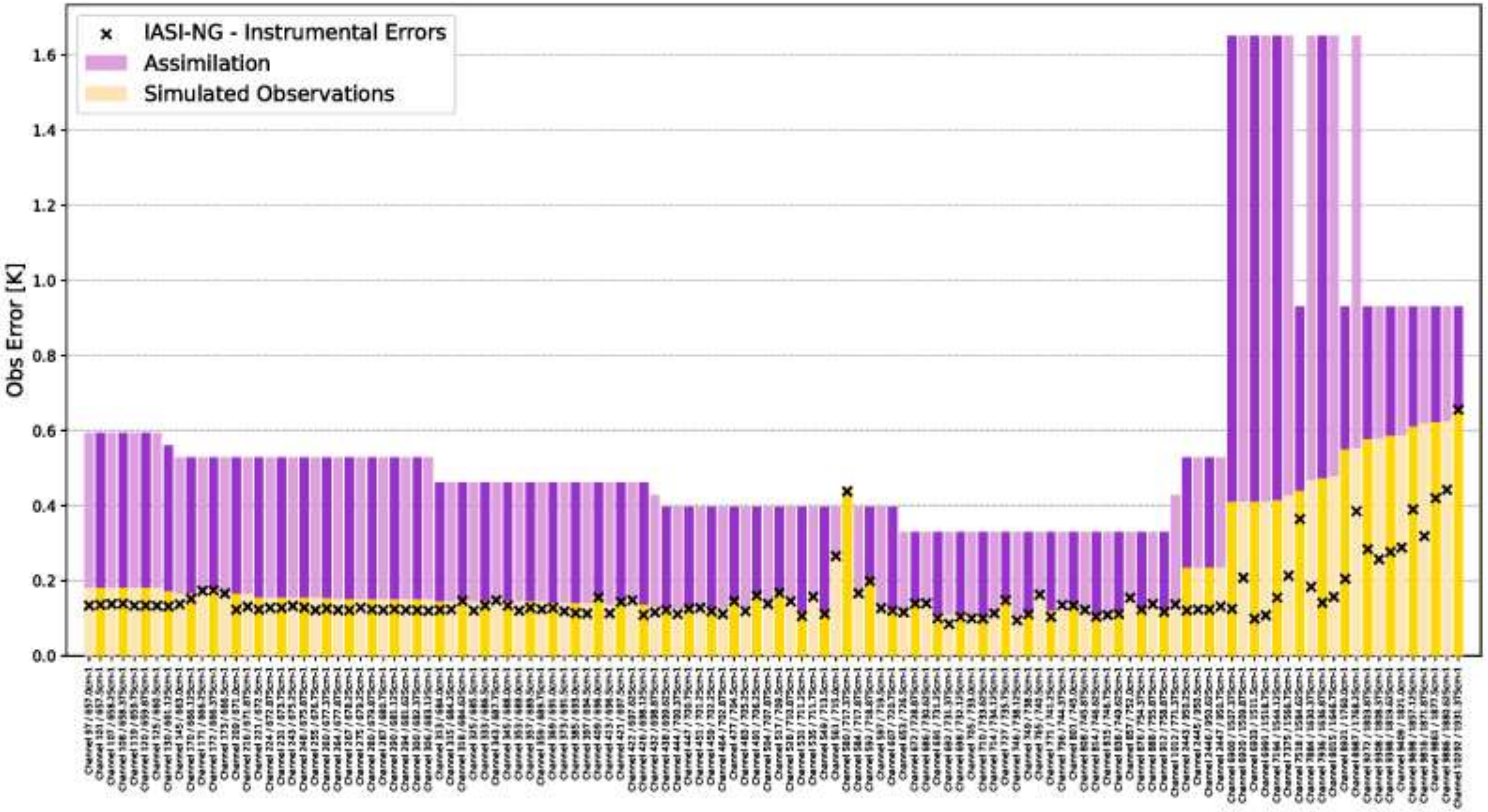
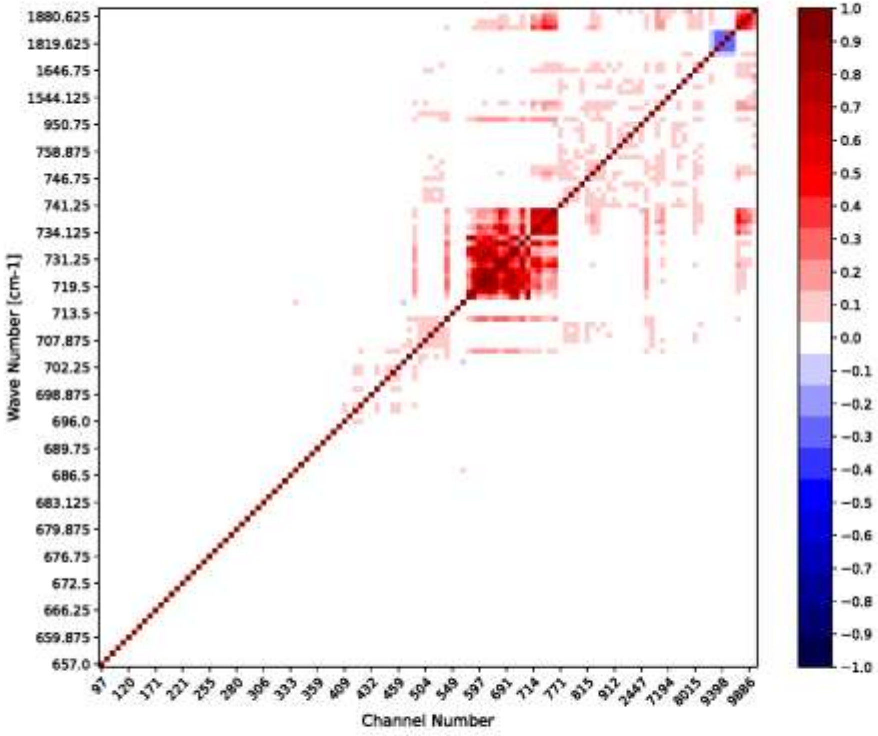
Observations Errors

Observation errors for the 122 assimilated IASI-NG channels.



Correlation matrix of observation errors

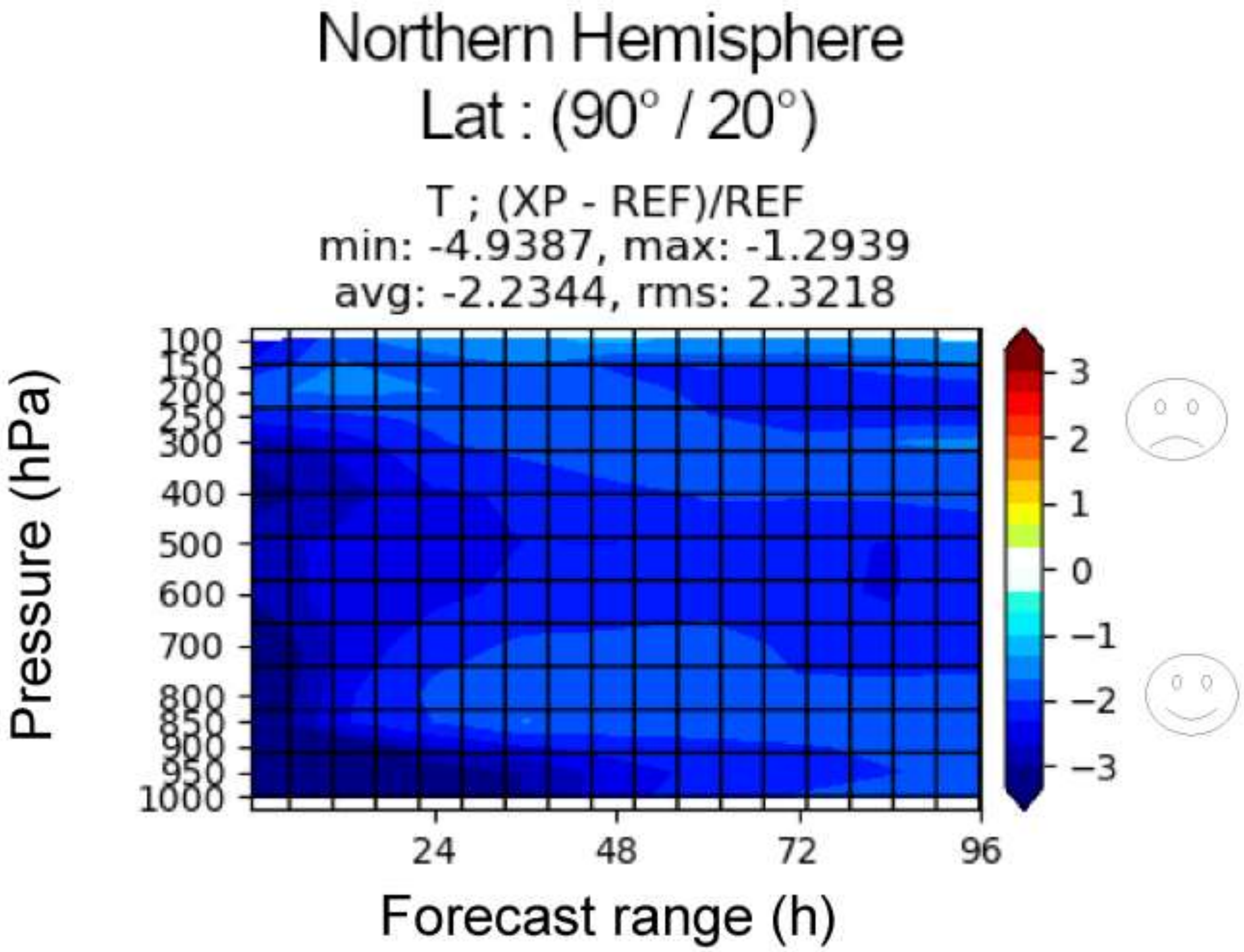


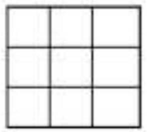
Not enough correlations !
First iteration without correlation (as they are not yet known)

Perturbations for the simulation correspond to the perturbations applied to IASI and divided per two.

Impact of adding IASI-NG on the forecast

Reduction (%) of the forecast error with the IASI-NG assimilation



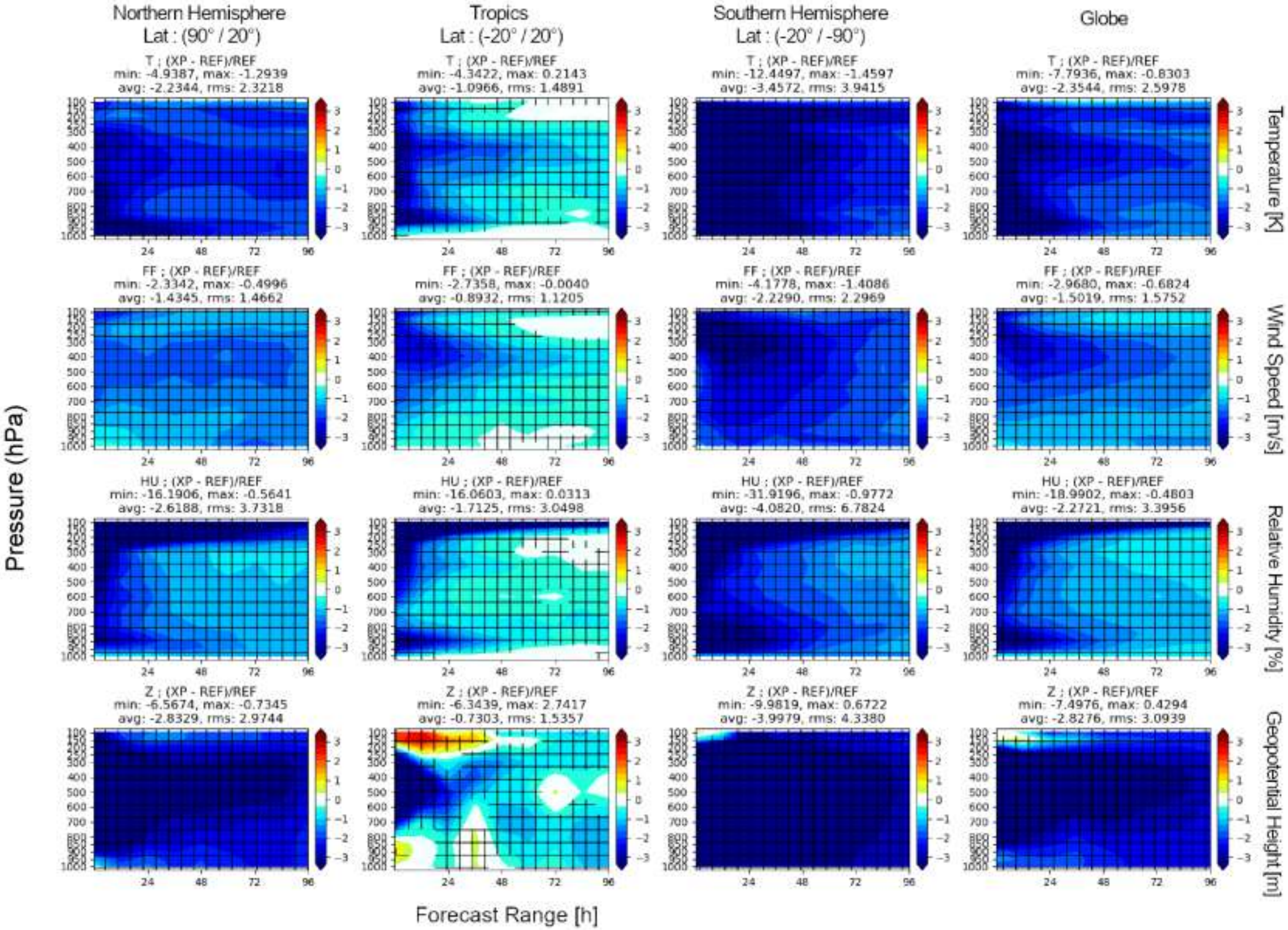


Difference statistically significant WITH-WITHOUT

Forecast scores computed :
- over different geopgraphical areas (Globe NH, SH and Tropics)
- for various parameters : temperature, humidity wind and geopotential

Impact of adding IASI-NG on the forecast

Reduction (%) of the forecast error with the IASI-NG assimilation



REF with 1 IASI instrument
EXP=REF+IASI-NG

Positive impacts (T and humidity) of the assimilation of IASI-NG over the globe, especially in the Southern and Northern hemispheres in the lower troposphere and at the tropopause.
Positive impact in the Tropics in the upper troposphere and above.

More than 2 % of reduction on average over the globe for T and Hu.

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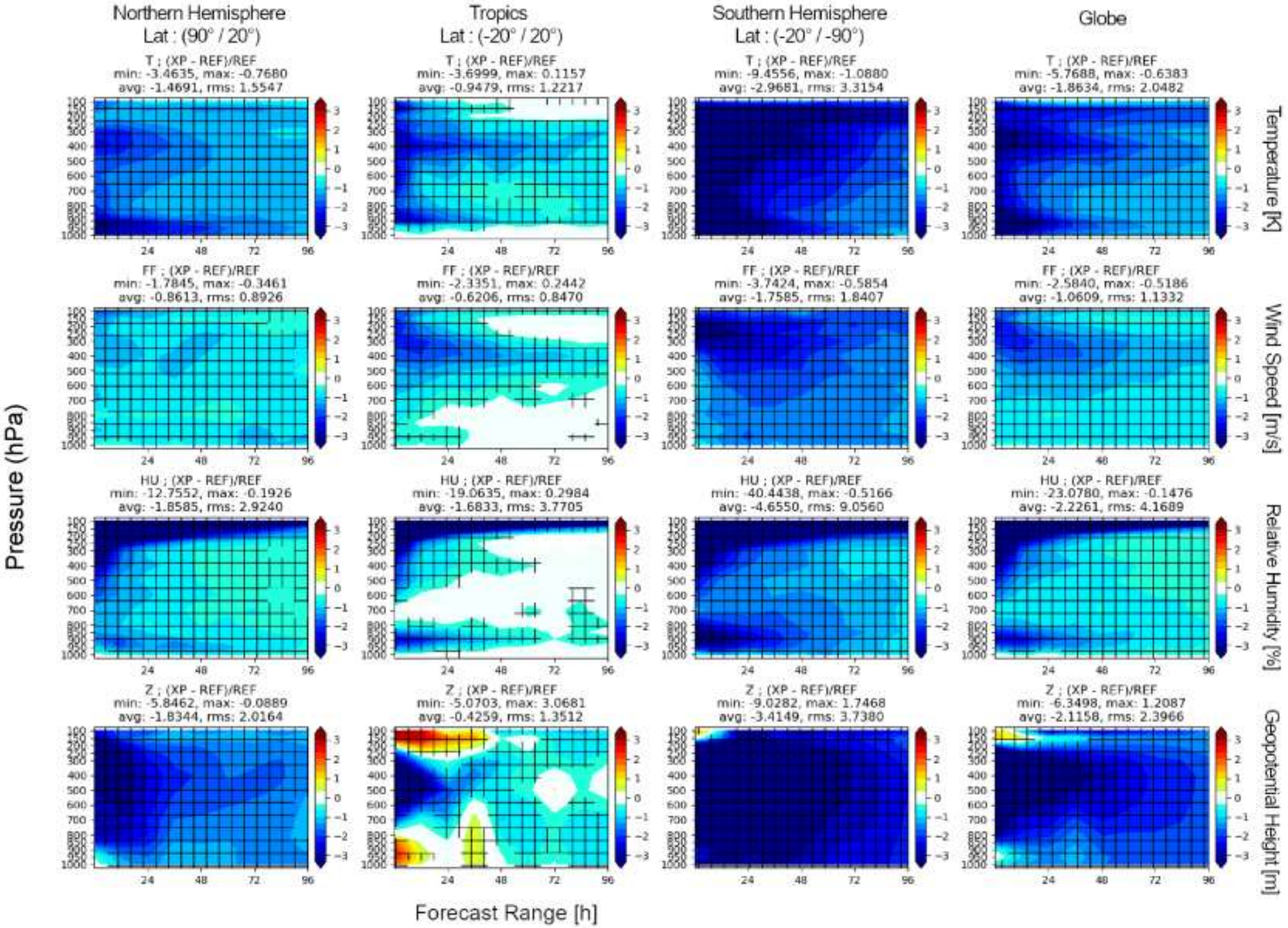
Impact of replacing IASI with IASI-NG on the forecast

Reduction (%) of the forecast error with the IASI-NG assimilation



REF1 with 2 IASI instrument
EXP=REF+IASI-NG

Positive impact but slightly weaker over the globe and especially in the Southern hemisphere.
Positive impact in the tropics in the upper troposphere and above.

Temperature, relative humidity and winds (upper troposphere).

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Conclusion

- Ready for the assimilation of IASI-NG radiances in the global model ARPÉGÈ, even if work still remains for the operational data assimilation.

- Evaluation over a 5-month period
- Positive impact of the IASI-NG assimilation obtained:
  - In the high troposphere and in the lower troposphere (both for temperature and humidity)
  - In the upper troposphere for the wind
  - Impact on the forecast scores lasts up to 96h
- LIMITATION : Impact is overestimated due to uncorrelated errors used in the simulation and in the assimilation.