

Preparation for the assimilation of the future IRS sounder in NWP models

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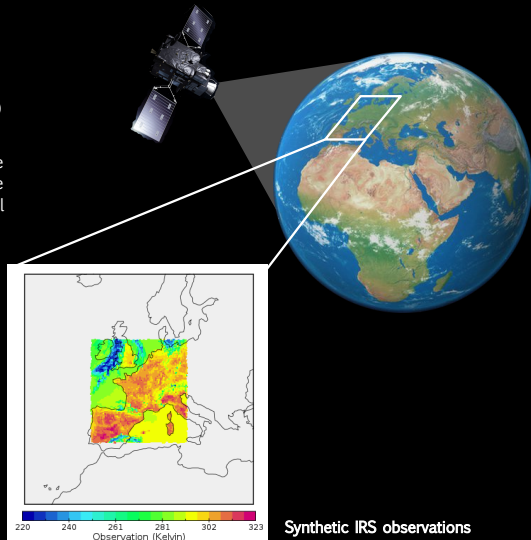


The future infrared sounder (IRS)

- Will be on board the future European geostationary satellite MTG (2024)
- Will be able to measure radiance at the top of the atmosphere using **1960** channels in the infrared between **680-1210 cm^{-1}** and **1600-2250 cm^{-1}**
- The IRS observations will provide information on atmospheric temperature and humidity, surfaces, winds, chemical composition of the atmosphere over Europe with high temporal frequency (**30 minutes**) and fine horizontal resolution (**4x7 km**)

Objectives

- Preparation of the assimilation of IRS for AROME
- Assessing the impact of IRS in the full system
- To be ready to assimilate real IRS data from day one!



Synthetic IRS observations

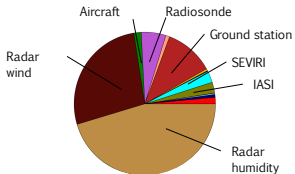
AROME model:

- Horizontal resolution of 1.3 km & 90 vertical levels (5 m to 10 hPa)
- High skill short range forecasts of severe events such as intense Mediterranean precipitation, severe storms...
- AROME forecasts are initialized using analyses from a 3D-Var data assimilation system with 1h cycling

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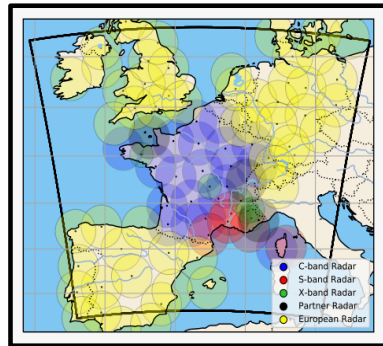
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Ratio of the number of observations used in AROME (January 2021)



- Radar data represent 75% (France + Europe) of the observations assimilated mainly on land
- Infrared observations represent only 5% of the assimilated data for a rainy day

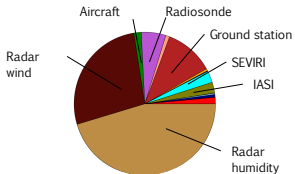
The Météo-France radar network



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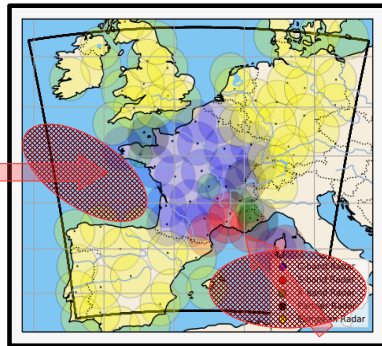
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IRS will fill in this gap of observations

The Météo-France radar network



Synoptic perturbations

Heavy precipitations from the Mediterranean Sea

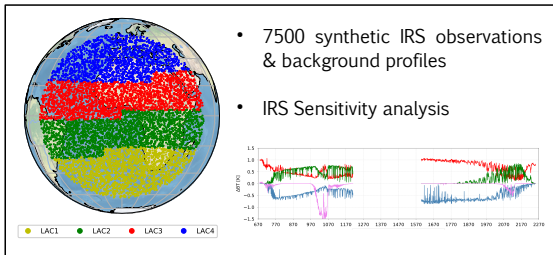
Part 1: IRS analysis and selection of information

- Synthetic database (IRS observations & ARPEGE background profiles)
- Sensitivity analysis (BT differences, Weighting function & Jacobians)
- Observation-errors (Desroziers diagnostic)
- General Channel selection

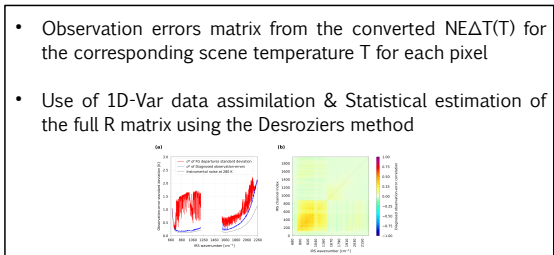
Part 2: First step of OSSE to assimilate IRS in AROME model

- Nature Run, Coupling Run (ARPEGE) & Nature Run (AROME)
- Calibration → AROME observing system processing
- IRS simulation (pseudo-hamming apodization, thinning & all-sky)
- IRS assimilation (adaptation of the cloud detection code (McNally & Watts))

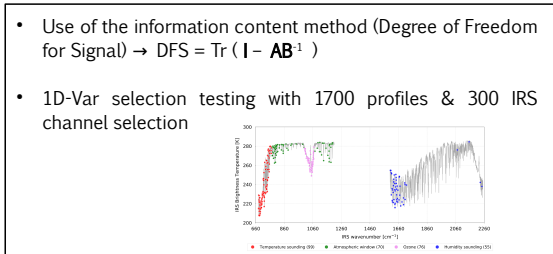
Creation of 1D database & sensitivity analysis



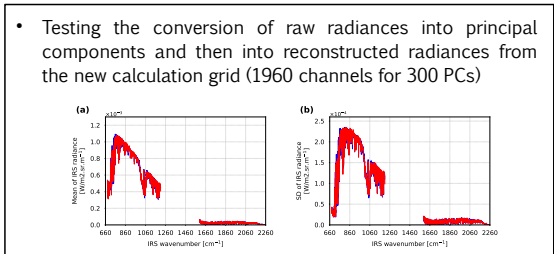
IRS Observation-errors



General IRS channel selection for NWP



Principal component study



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→ Coopmann et al. 2022 « **Analysis of MTG-IRS observations and general channel selection for Numerical Weather Prediction models** » published in QJRMS → <https://doi.org/10.1002/qj.4282>

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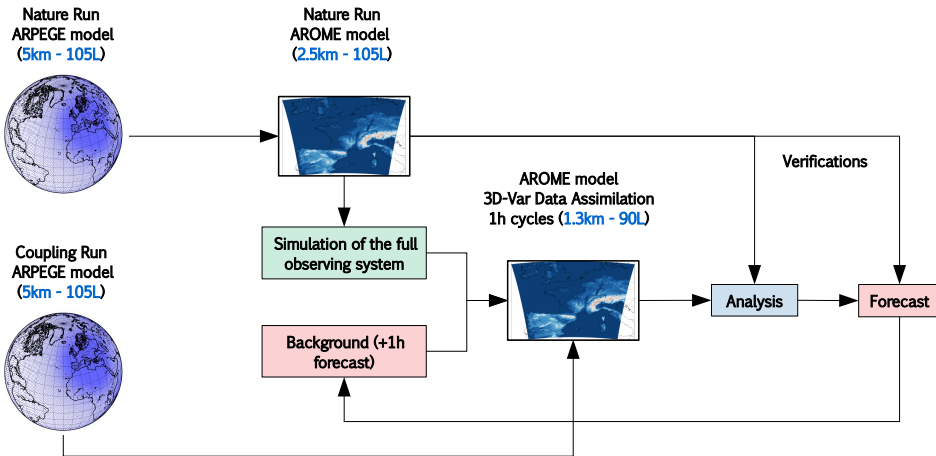
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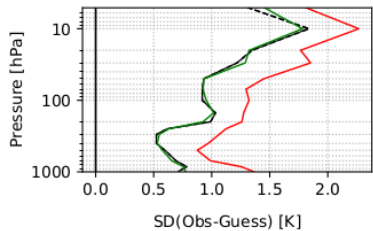
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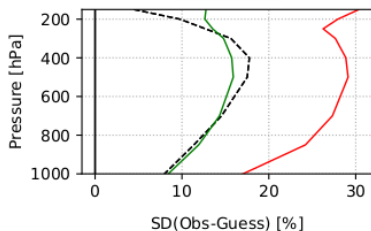
Scheme of OSSE framework for AROME 3D-Var data assimilation system

Standard deviation of first-guess departure for 44 days (22 days Summer + 22 days Winter)

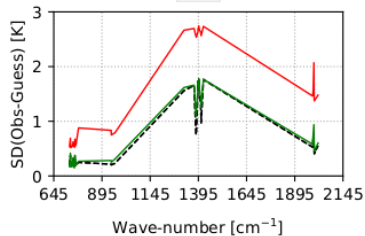
RADIOSONDE-T



RADARS-Q

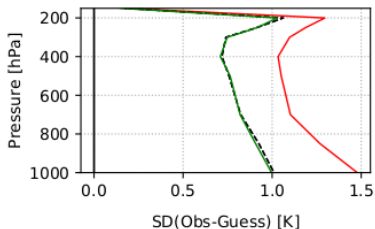


IASI

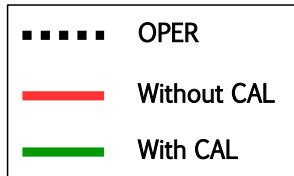
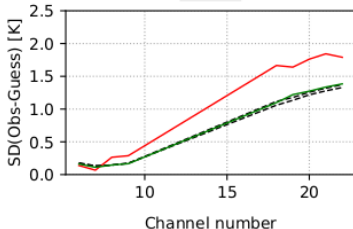


The oper is well reproduced in terms of analysis

AIREP-T



ATMS



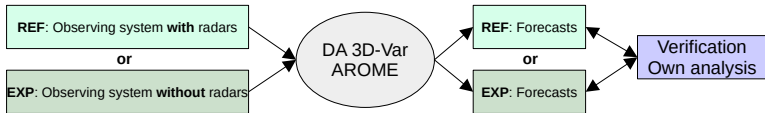
Observing System Experiment:

- To validate the quality of our OSSE we have chosen the **OSE** method which allows us to evaluate the effect of adding or removing an individual component of the observing system on the quality of the analyses and forecasts
- In operations, radar has the major impact in AROME → OSE experiments with and without radar data in the operational (**OPER**) and **OSSE** setting (1 month - Summer)

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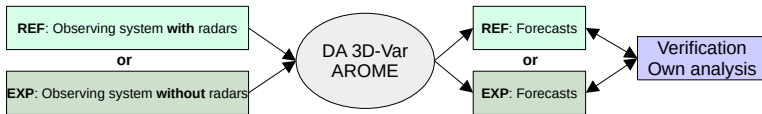
OSE OPER



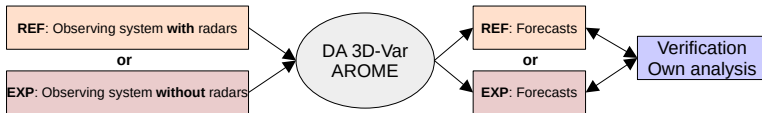
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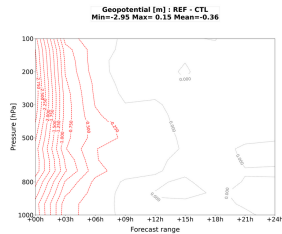
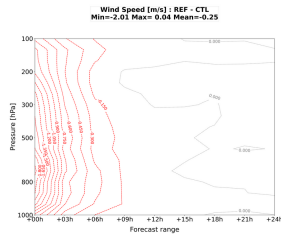
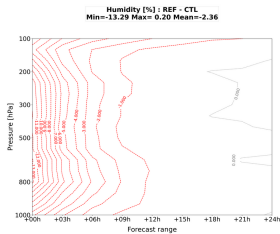
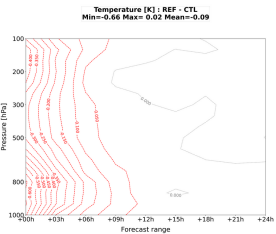


OSE OSSE

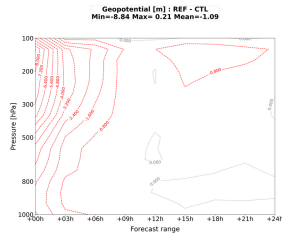
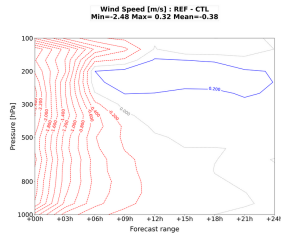
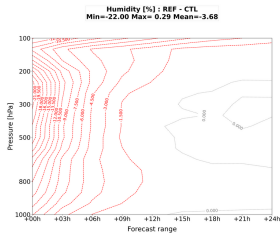
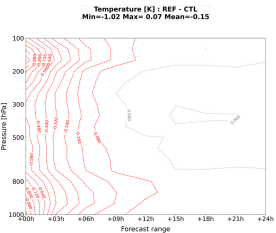


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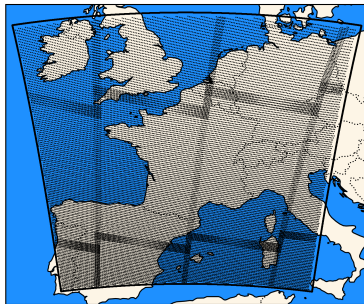
RMSE forecast scores over AROME domain for OPER Observing System Experiment over 1 month



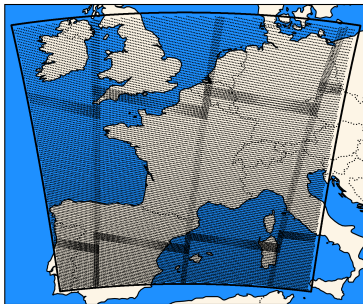
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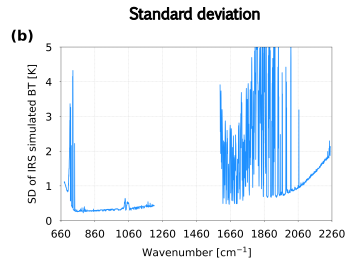
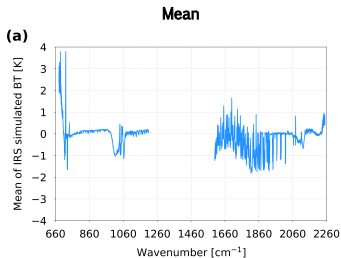
--- Negative impact without radar --- Positive impact without radar --- Neutral impact



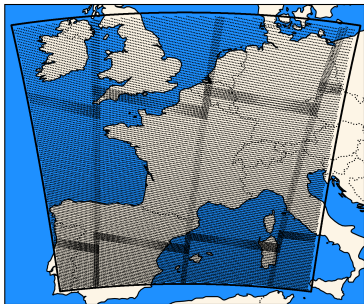
- Simulation of the 1960 channels (pseudo-hamming apodization)
- Simulation over 4 months (July-August & January-February)
- Thinning of 1 in 2 pixels in longitude and latitude
- Using perturbed instrumental noise to process IRS synthetic obs
- All-Sky simulation with cloud coefficients



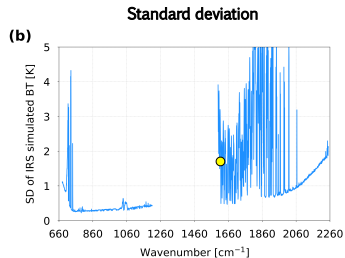
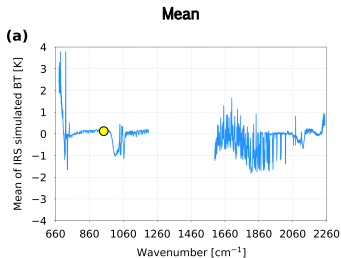
Statistics of First-Guess Departure over 1 Day



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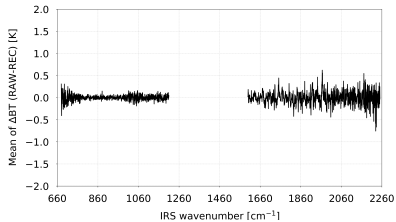
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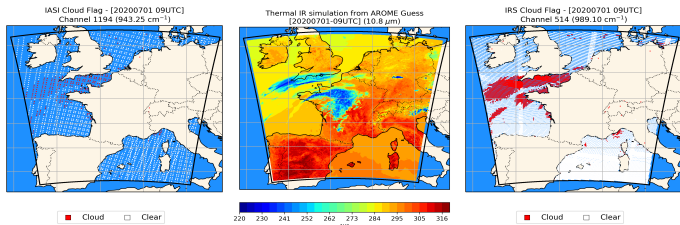
Reconstructed Brightness Temperature

BT raw simulation \rightarrow $BT + R(NEDT) \times Z_{pert} \rightarrow$ **BT raw** synthetic obs
 BT raw simulation \rightarrow **PC scores** \rightarrow **BT rec**
 & **BT rec** \rightarrow **BT rec** + $R(NEDT) \times Z_{pert} \rightarrow$ **BT rec** synthetic obs



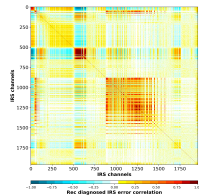
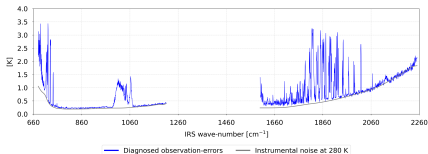
Cloud detection configuration for IRS

Setting up the cloud detection scheme (McNally & Watts) to be adapted to IRS
 Comparison between a thermal IR image, the cloud detection for IASI pixels and for IRS



IRS observation-error estimation

Observation error diagnosed with reconstructed BT

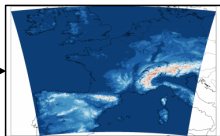


Observations

3D-VAR AROME

Forecast +P48

AROME observing system
Conv, radars, IR, MW...



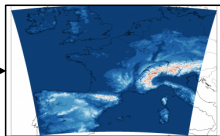
CTL

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+

IRS observations

(reconstructed BT)

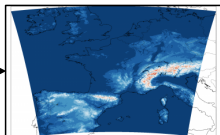


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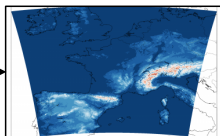


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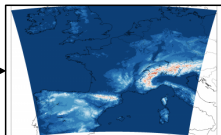
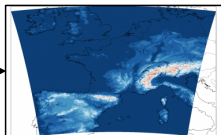
- 75 IRS channels selected (27 T, 27q, 21 AW)
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- Assim only over sea
- R diagnosed (with correlation)
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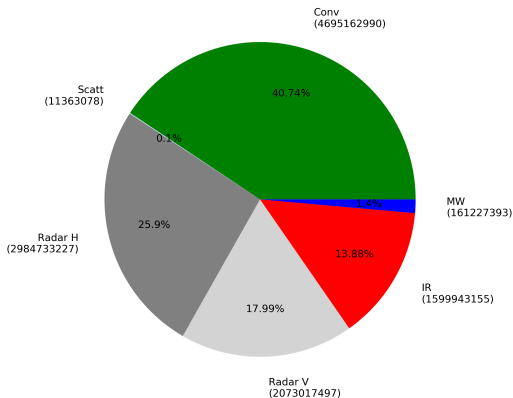
Scores

Relative differences / NR
Over **July & August**
Over **January & February**
Temperature
Humidity
Wind
Geopotential

Proportion of observations used by type of observation AROME analysis

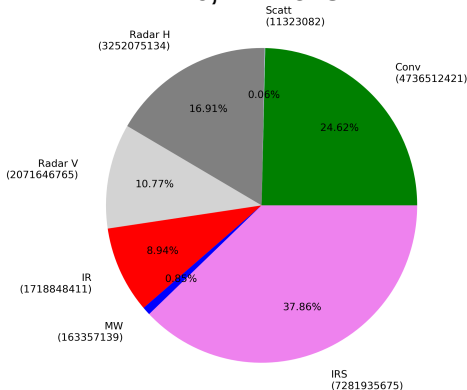
Control run from 20200701 to 20200731
Total number of observations used: 11525447340

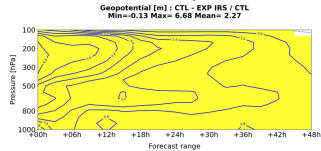
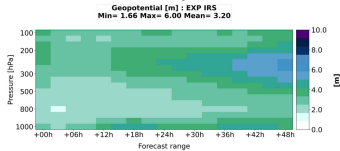
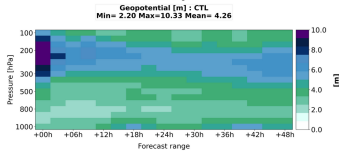
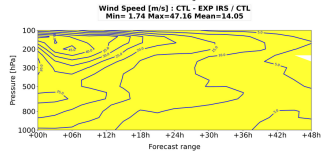
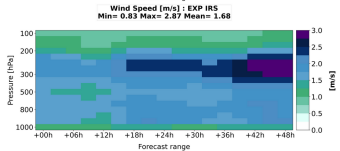
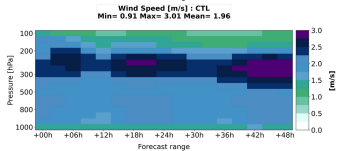
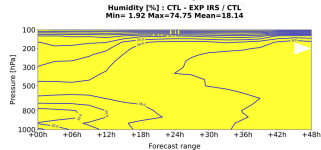
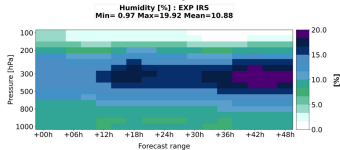
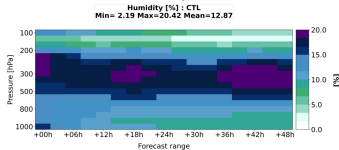
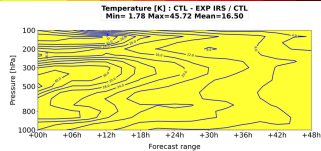
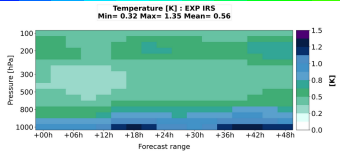
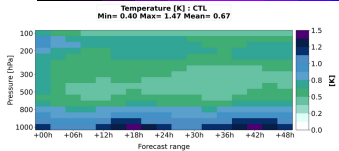
11,5 Billions



Experiment run from 20200701 to 20200731
Total number of observations used: 19235698627

19,2 Billions



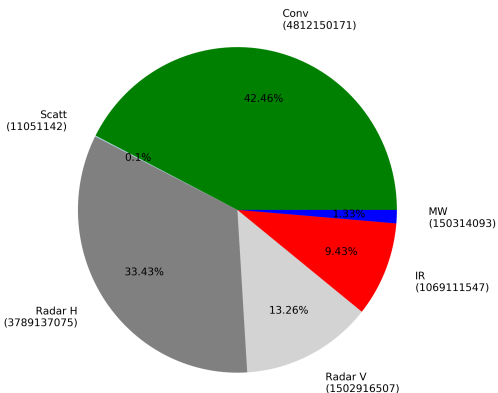


--- Negative impact
 --- Positive impact
 --- Neutral impact
 Statistical significance at 95% (Bootstrap)

Proportion of observations used by type of observation AROME analysis

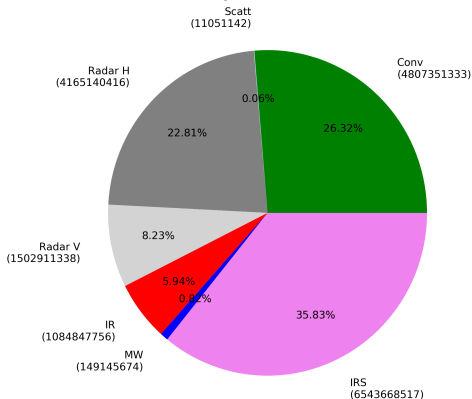
Control run from 20200101 to 20200131
Total number of observations used: 11334680535

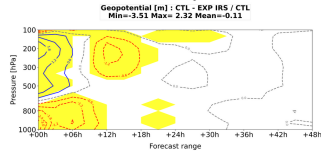
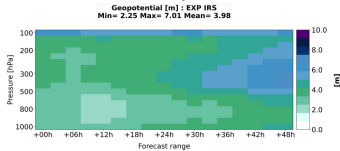
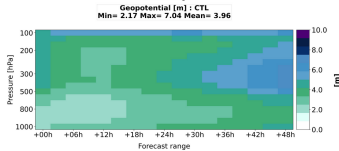
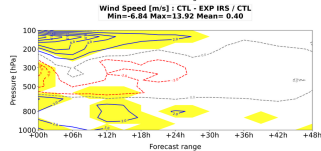
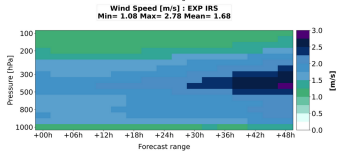
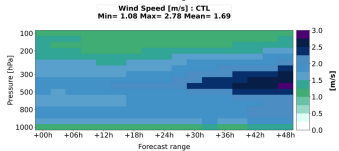
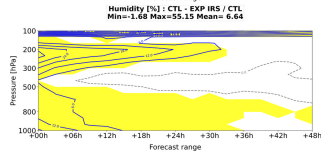
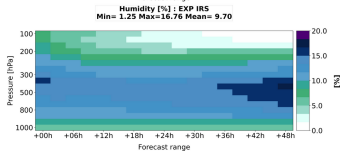
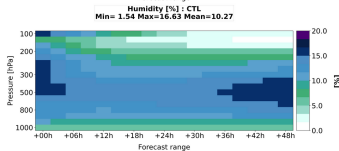
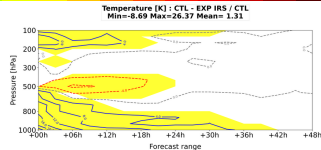
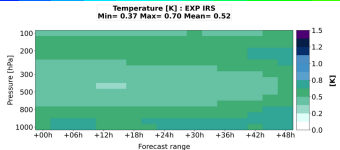
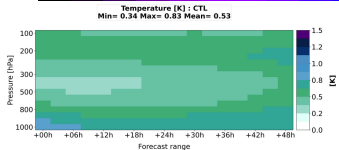
11,3 Billions



Experiment run from 20200101 to 20200131
Total number of observations used: 18264116176

18,2 Billions





--- Negative impact
 --- Positive impact
 --- Neutral impact
 Statistical significance at 95% (Bootstrap)

- First assimilation of IRS brightness temperatures (**raw & reconstructed**) in a realistic AROME framework
- **Very promising impact of IRS assimilation in AROME** even though a very simple channel selection (only over sea and a thinning of 70 km)
 - **Future paper : Preparing the assimilation of the future MTG-IRS sounder into the mesoscale NWP AROME model (in review for the QJRMS)**
- Obviously, many questions raised about the high impact of the IRS for the summer period and many discussions and verification tests were carried out.

- **Why such an impact on the summer period?**
 - Higher impact expected on the summer period:
 - less clouds: **more IRS observations to assimilate down to the surface**
 - less precipitations: **less impact from radar data**
 - More observations assimilated over the summer period with a rapid impact on the analyses:
 - **10% more assimilated IRS observations for the summer period**
 - **direct impact on improving the assimilation of other observations**
- Being in an idealized case, it was expected that the impact of IRS would be overestimated in the OSSE framework. However, the results show a **clear contribution** of these new observations to the improvement of AROME forecasts
- Various diagnostics were performed to evaluate the reliability of our OSSE: **radar OSE, statistics on observations, evaluation of the minimisation of the cost function**. Consistent results were observed between all experiments and study periods

- Precipitation scores → **Work performed**
- Assimilation of a pragmatic channel selection (82) → **Work performed**
- Assimilation with channel selection over sea + **land** → **Work performed**
- Diagnostic of IRS horizontal correlation lengths and thinning adaptation → **Work performed**
- Assimilation experiments and forecast scores with specific calibrations for summer and winter periods → **Work performed**
- Transfer of work for the assimilation of IRS to the future cycle of NWP 48t1 → **Work performed**

Thank you for your attention

