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

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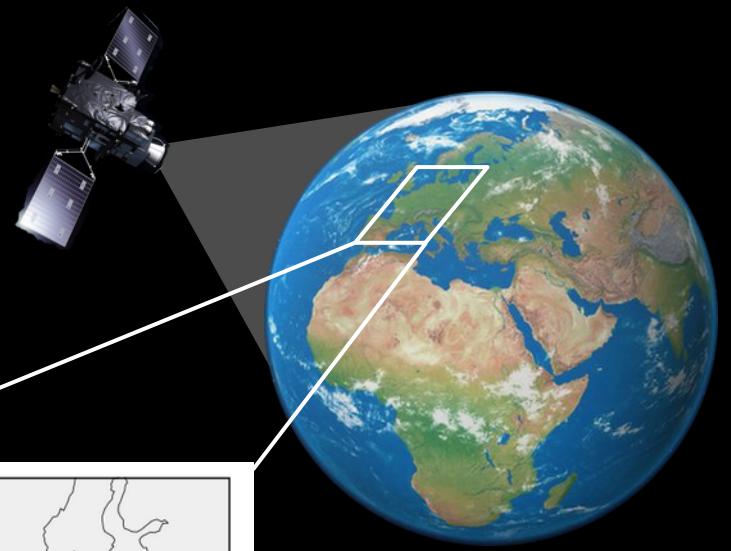
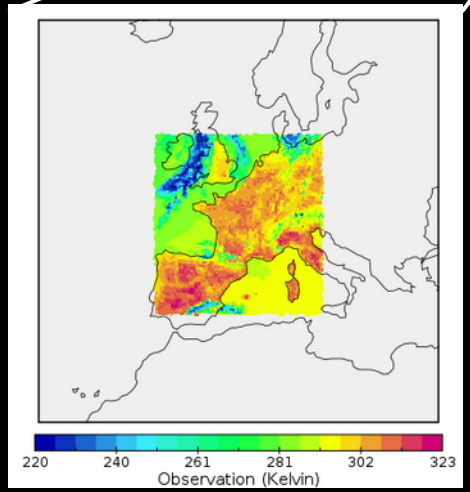
## The future infrared sounder (IRS)

- 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

# Interest of IRS in the AROME model



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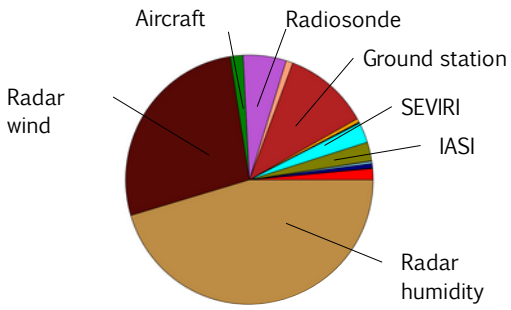
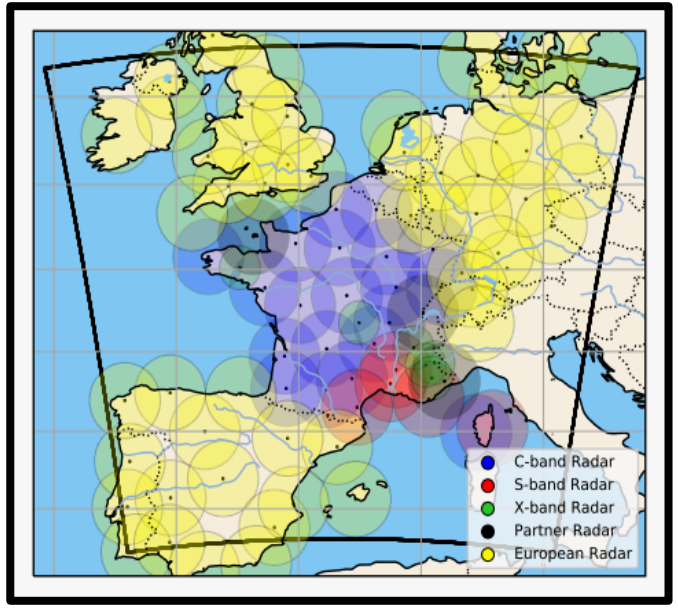
**Ratio of the number of observations used in AROME (January 2021)**




- 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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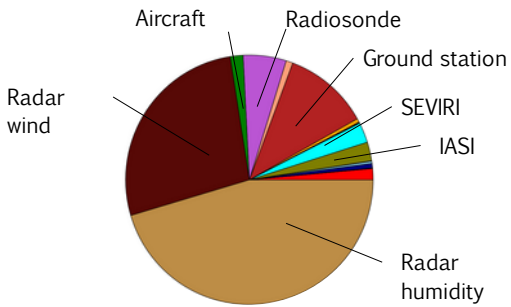


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**IRS will fill in this gap of observations**

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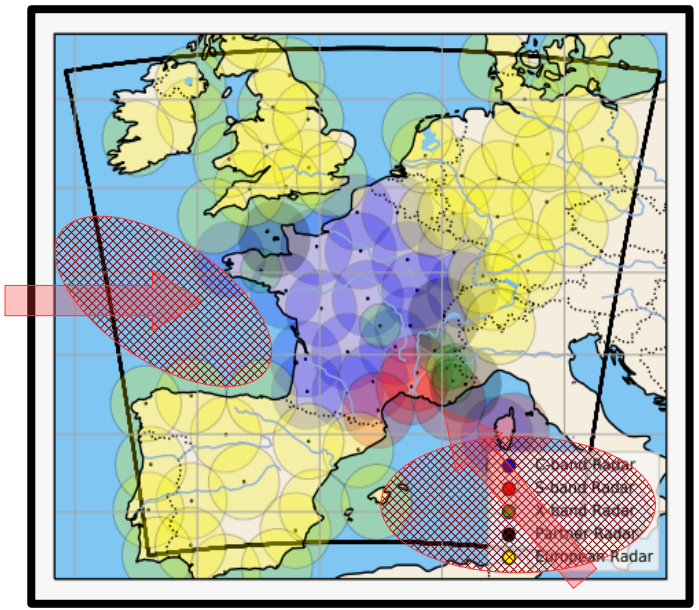


Heavy precipitations from the Mediterranean Sea

# Completed work

## 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

→ 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

## 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)
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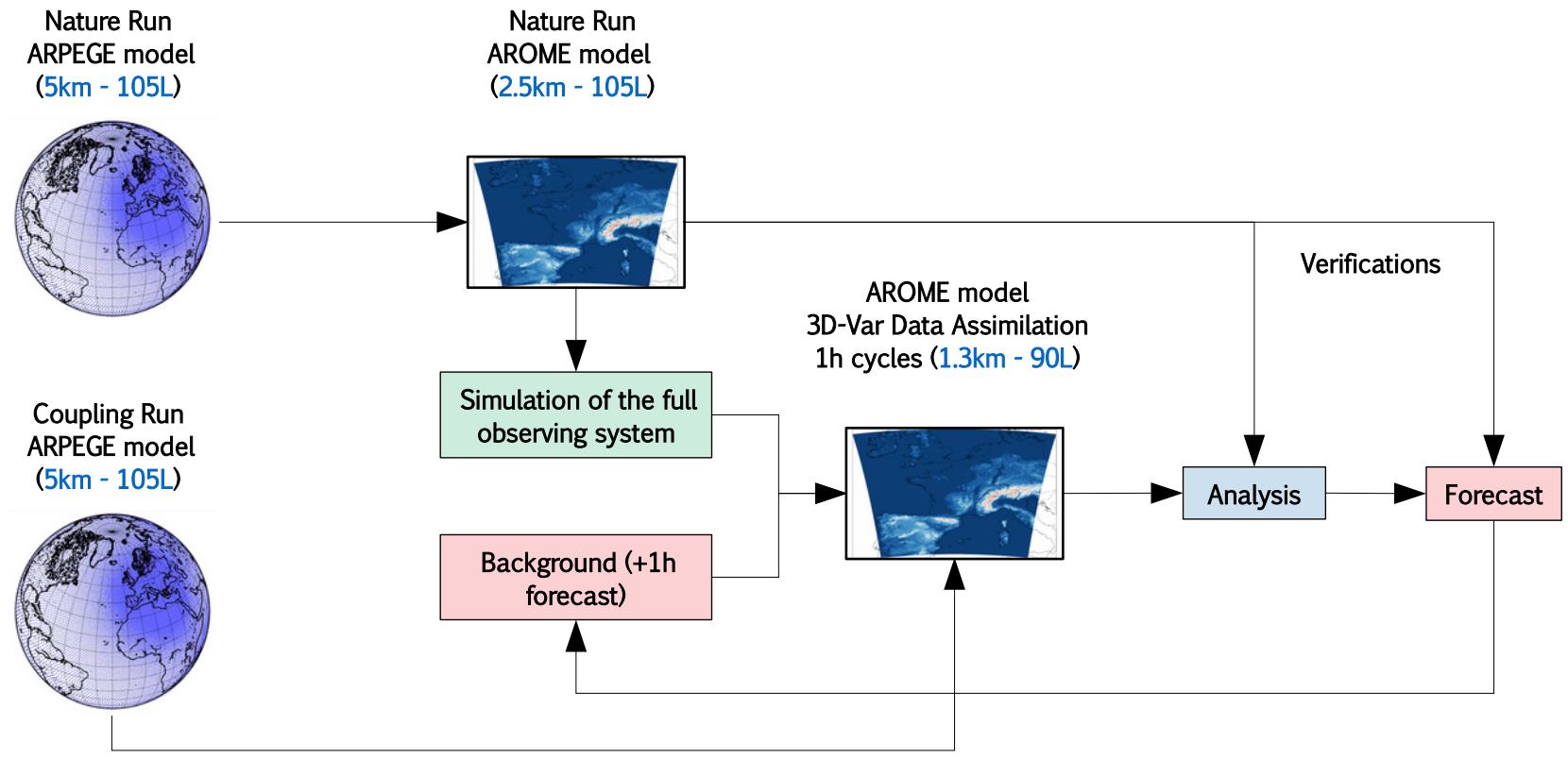
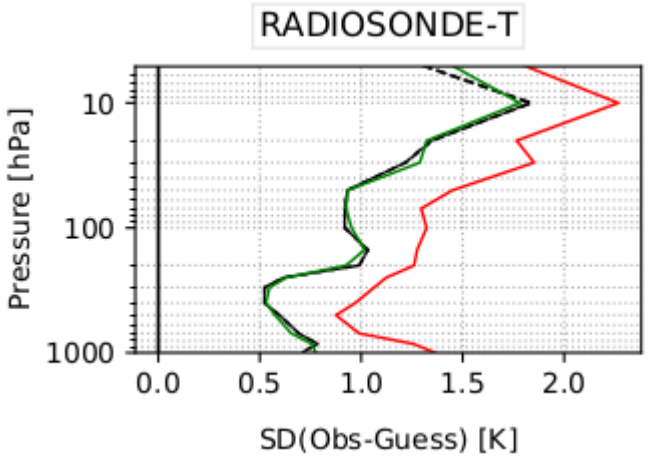
# Observing System Simulation Experiment for 3D-Var AROME

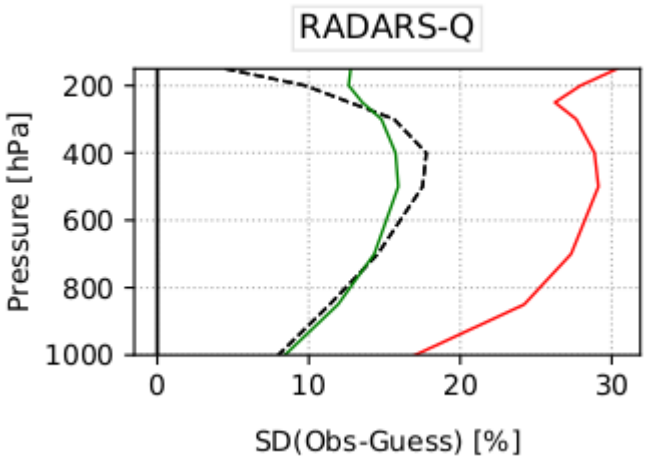


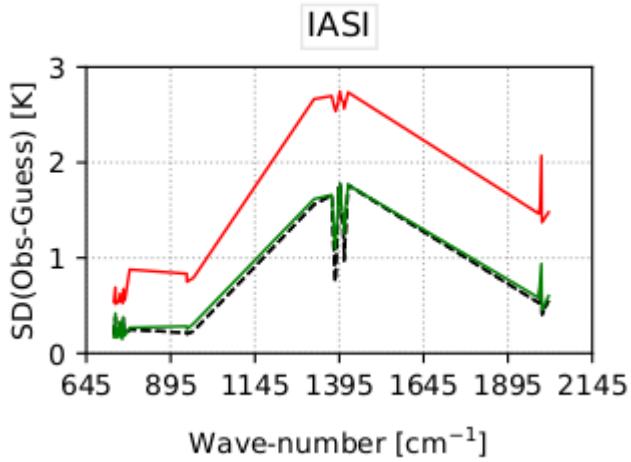

Scheme of OSSE framework for AROME 3D-Var data assimilation system

# AROME Observing System Simulation calibration

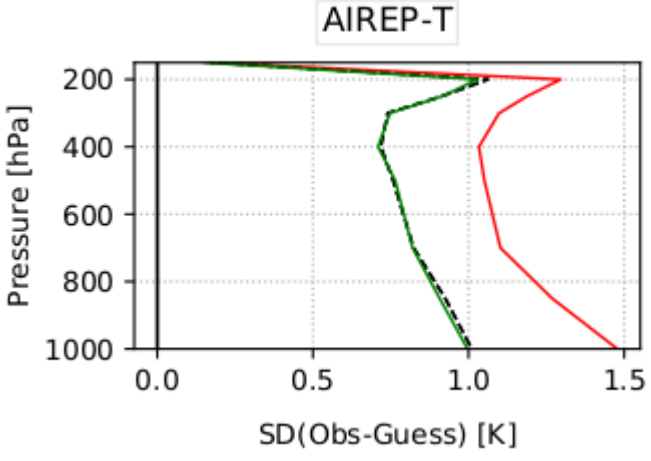
Standard deviation of first-guess departure for 44 days (22 days Summer + 22 days Winter)

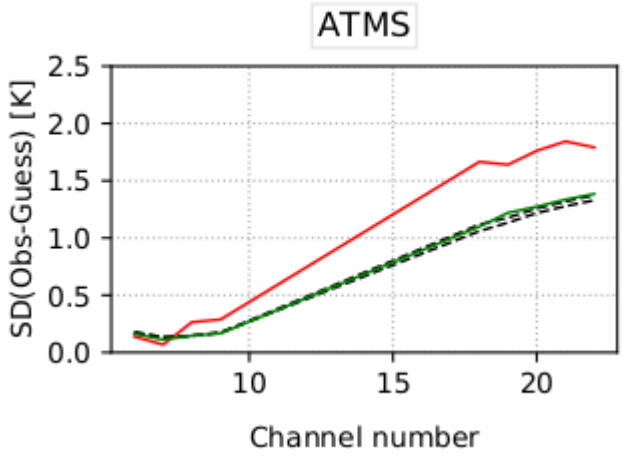


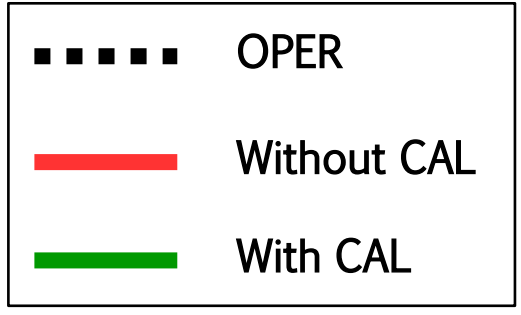




**The oper is well reproduced in terms of analysis**



# OSSE validation

## 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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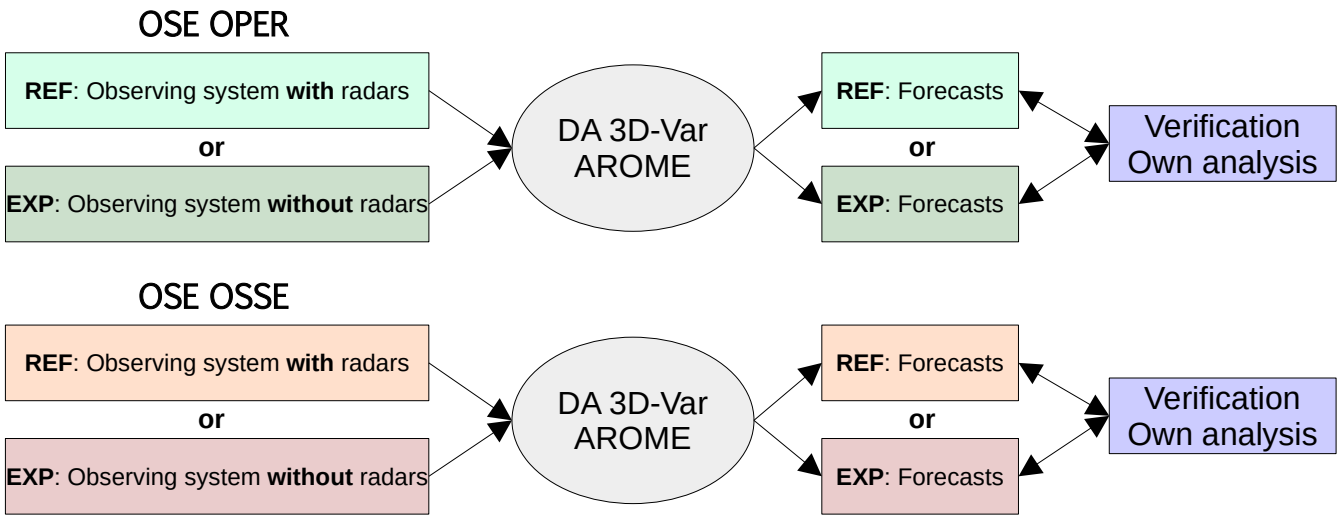

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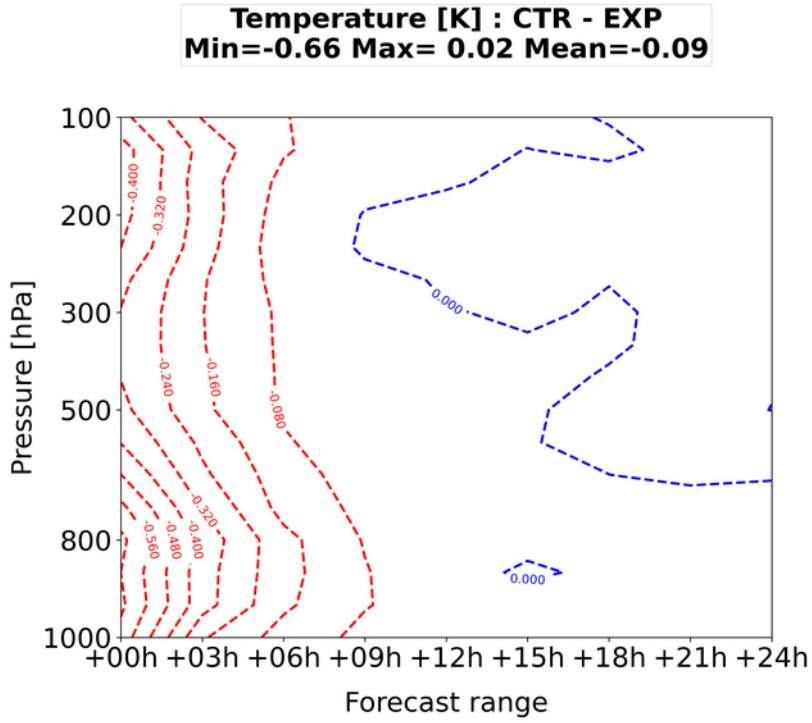


- To validate … evaluate th … system on t … ich allows us to … f the observing …
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OSE (…)
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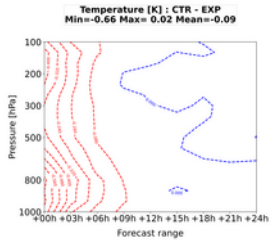
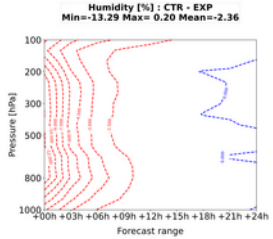
- Co… … … …
- Slight overestimation of impact in OSSE

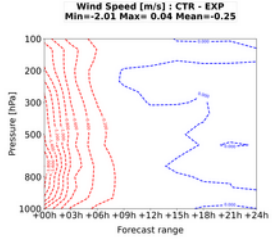
**Removing radar data implies a degradation of forecasts (red lines)**

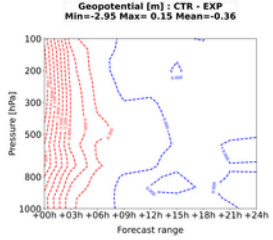
RMS of REF – EXP with against its own analysis

OSE OPER

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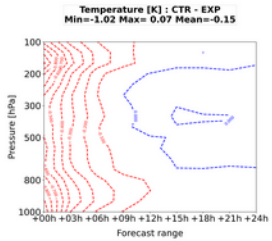


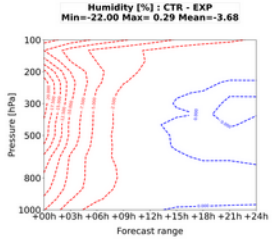


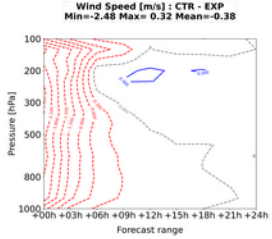


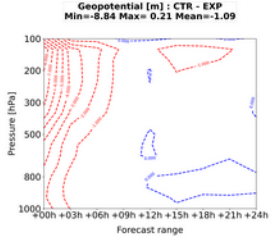

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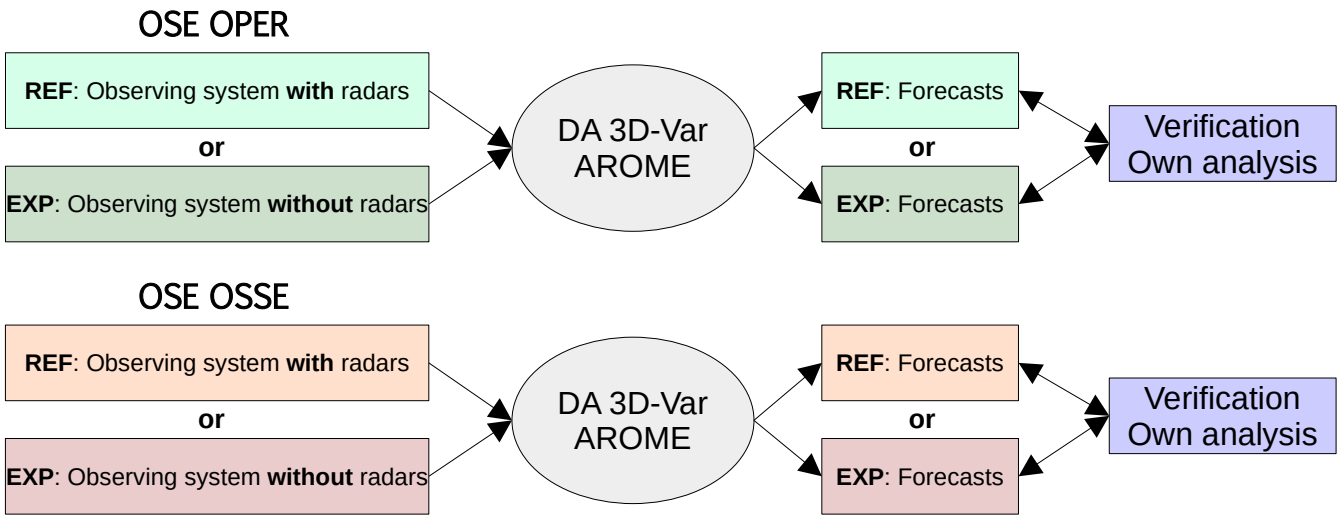
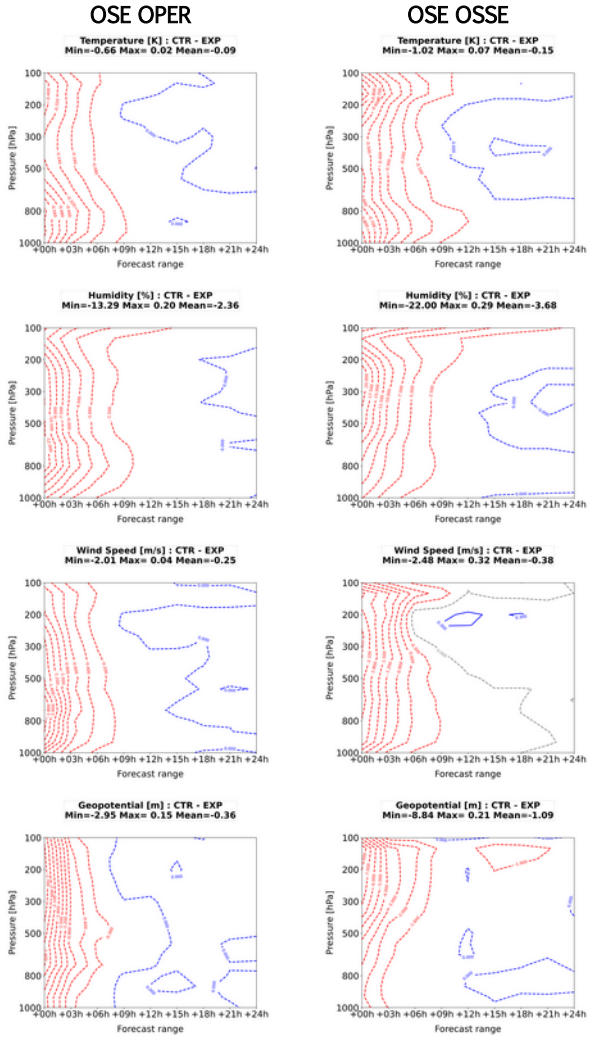


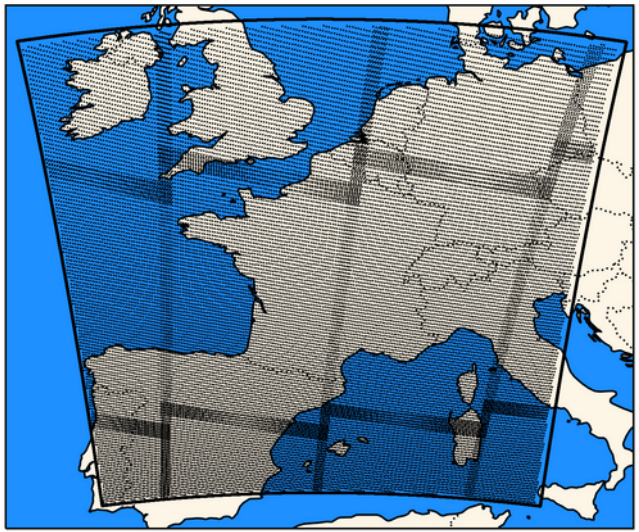

- Consistent behaviour between OPER and OSSE
- Slight overestimation of impact in OSSE

RMS of REF – EXP with against its own analysis



# Creation of IRS synthetic observations





- Simulation of the 1960 channels (pseudo-hamming apodization)
- Simulation over 4 months (July-August & January-February)
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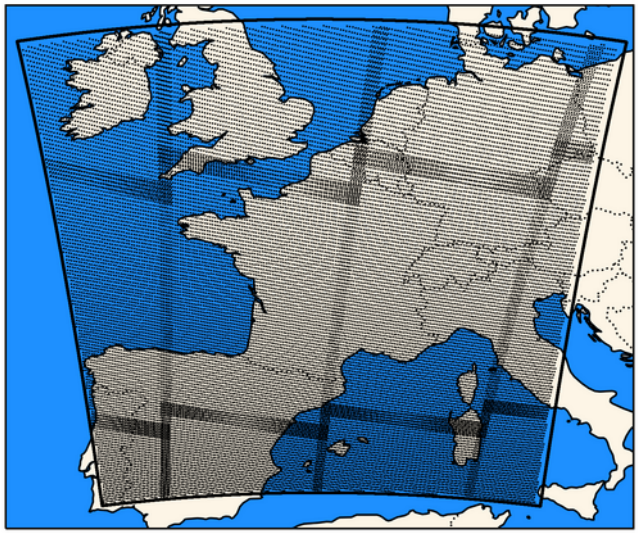

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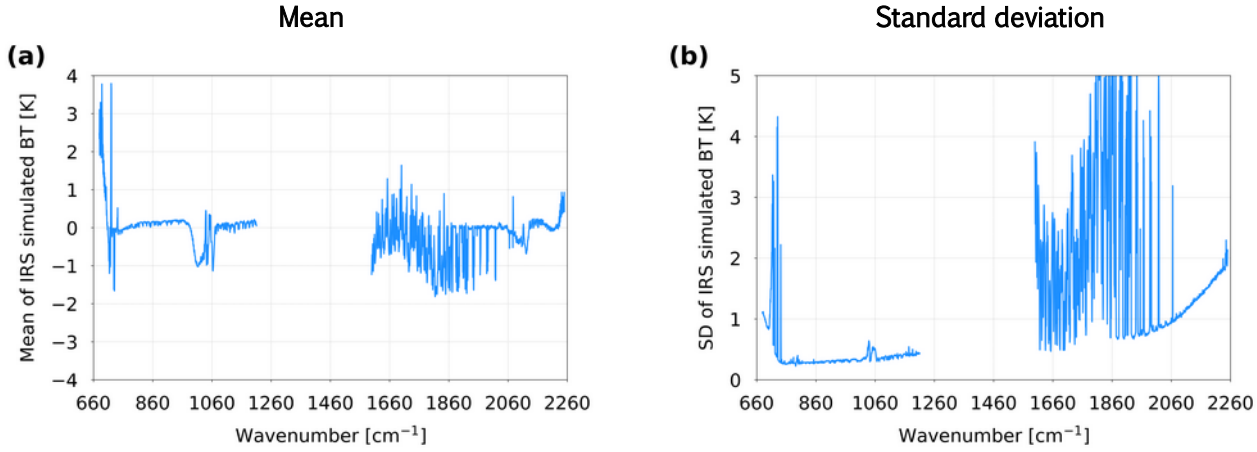

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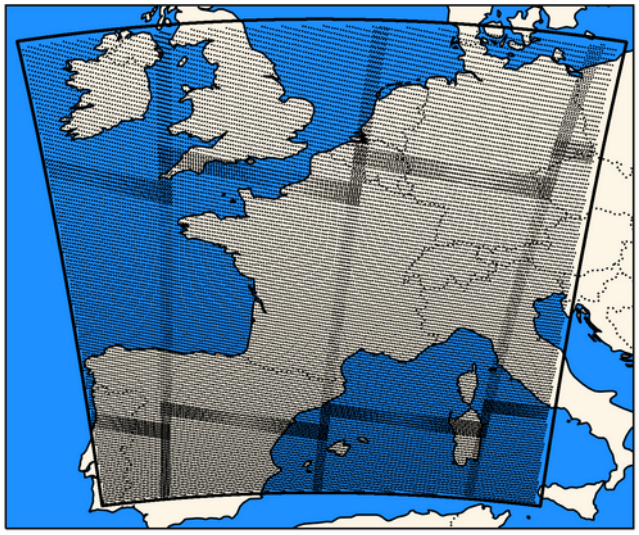

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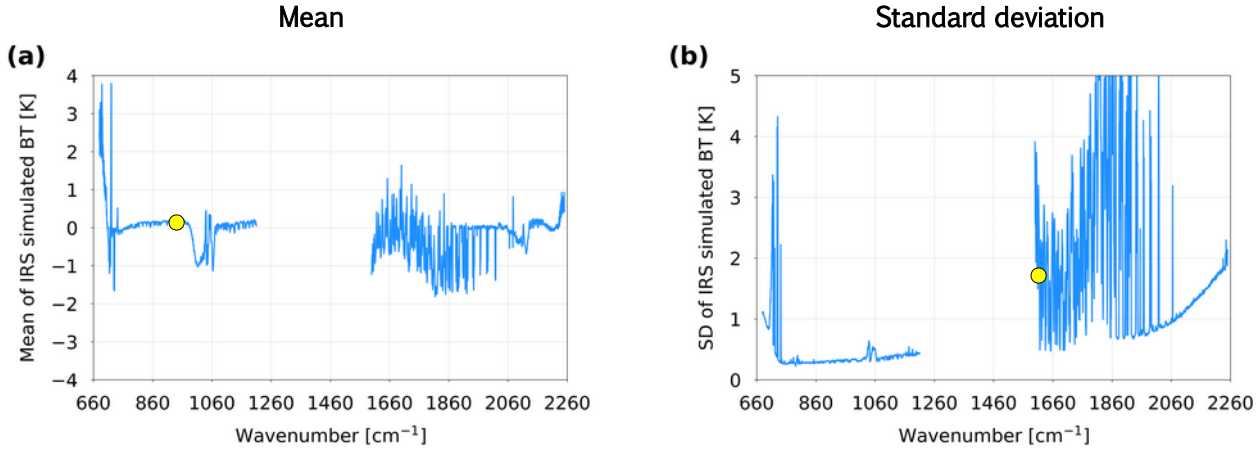
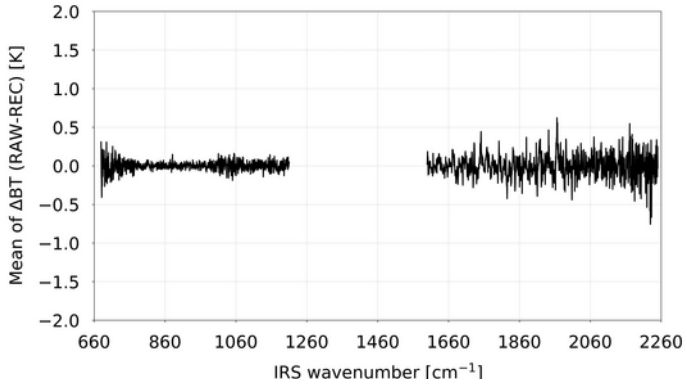


# Tools for IRS Assimilation

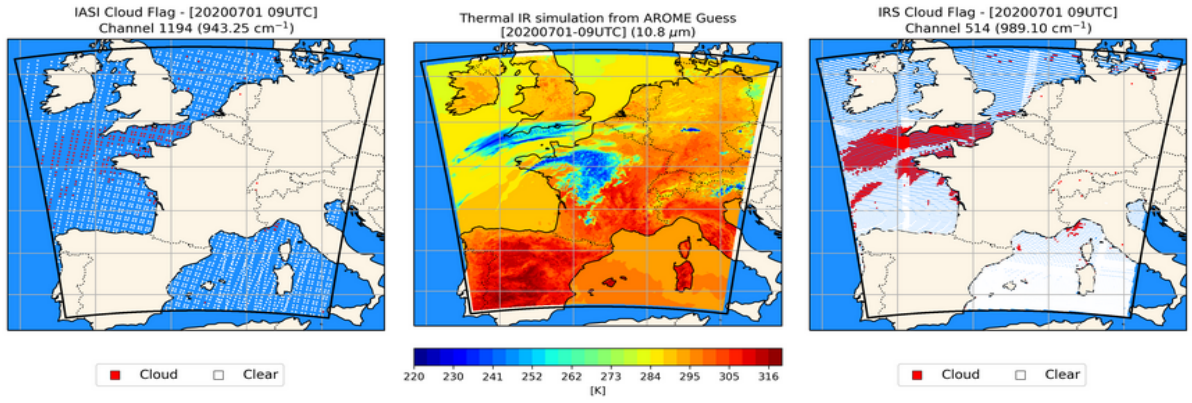
## Reconstructed Brightness Temperature

BT raw simulation → BT + R(NEDT) x Zpert → **BT raw** synthetic obs
BT raw simulation → PC scores → BT rec
& BT rec → BT rec + R(NEDT) x Zpert → BT rec synthetic obs



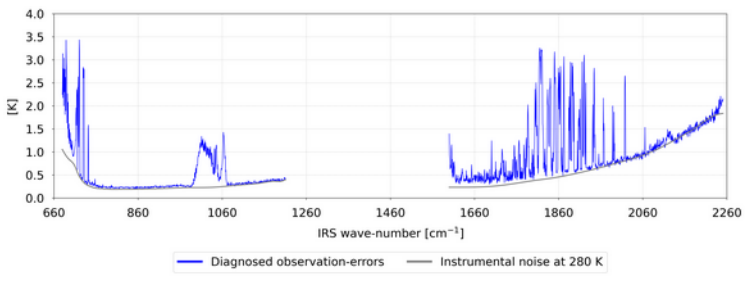

## Cloud detection configuration for IRS

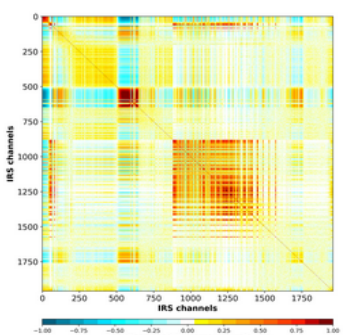
Setting up the cloud detection scheme (McNally & Watts) to be adapted to IRS
Comparison between a thermal IR image, the cloud detection for IASI pixels and for IRS




## IRS observation-error estimation

Observation error diagnosed with reconstructed BT



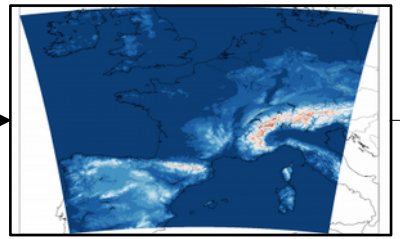



# First impact of IRS assimilation

Observations | 3D-VAR AROME | Forecast +P24

AROME observing system

Conv, radars, IR, MW...



CTL

AROME observing system

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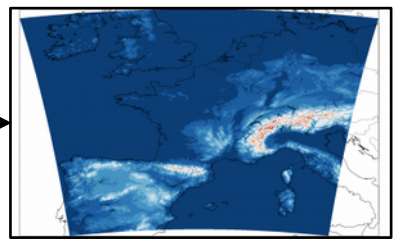
+

**IRS observations**

(reconstructed BT)



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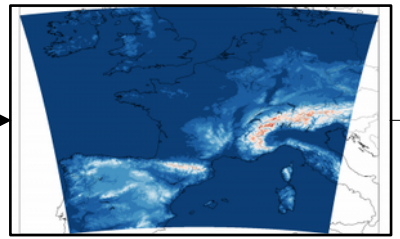

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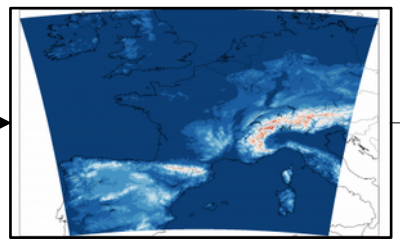


EXP

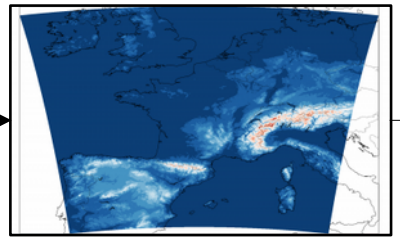
- 75 IRS channels selected (27 T, 27q, 21 AW)
- Thinning : 70 km
- Assim only over sea
- R diagnosed (with correlation)
- Appropriate Cloud detection

# First impact of IRS assimilation

Observations | 3D-VAR AROME | Forecast +P24 | Scores

AROME observing system

Conv, radars, IR, MW, ...



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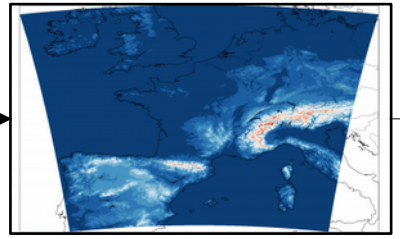

EXP

Relative differences / NR

Over **July & August**

Over **January & February**

Temperature

Humidity

Wind

Geopotential

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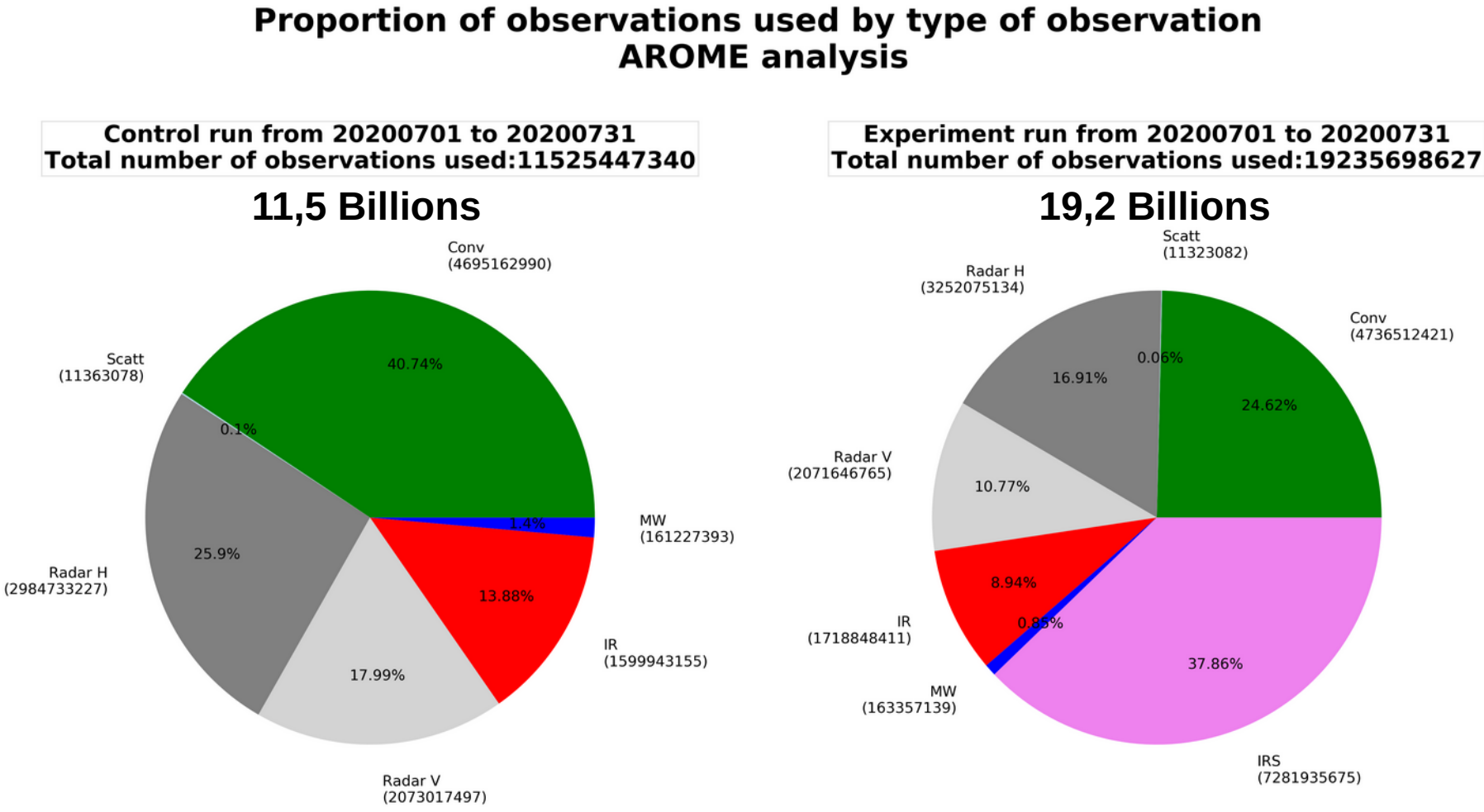
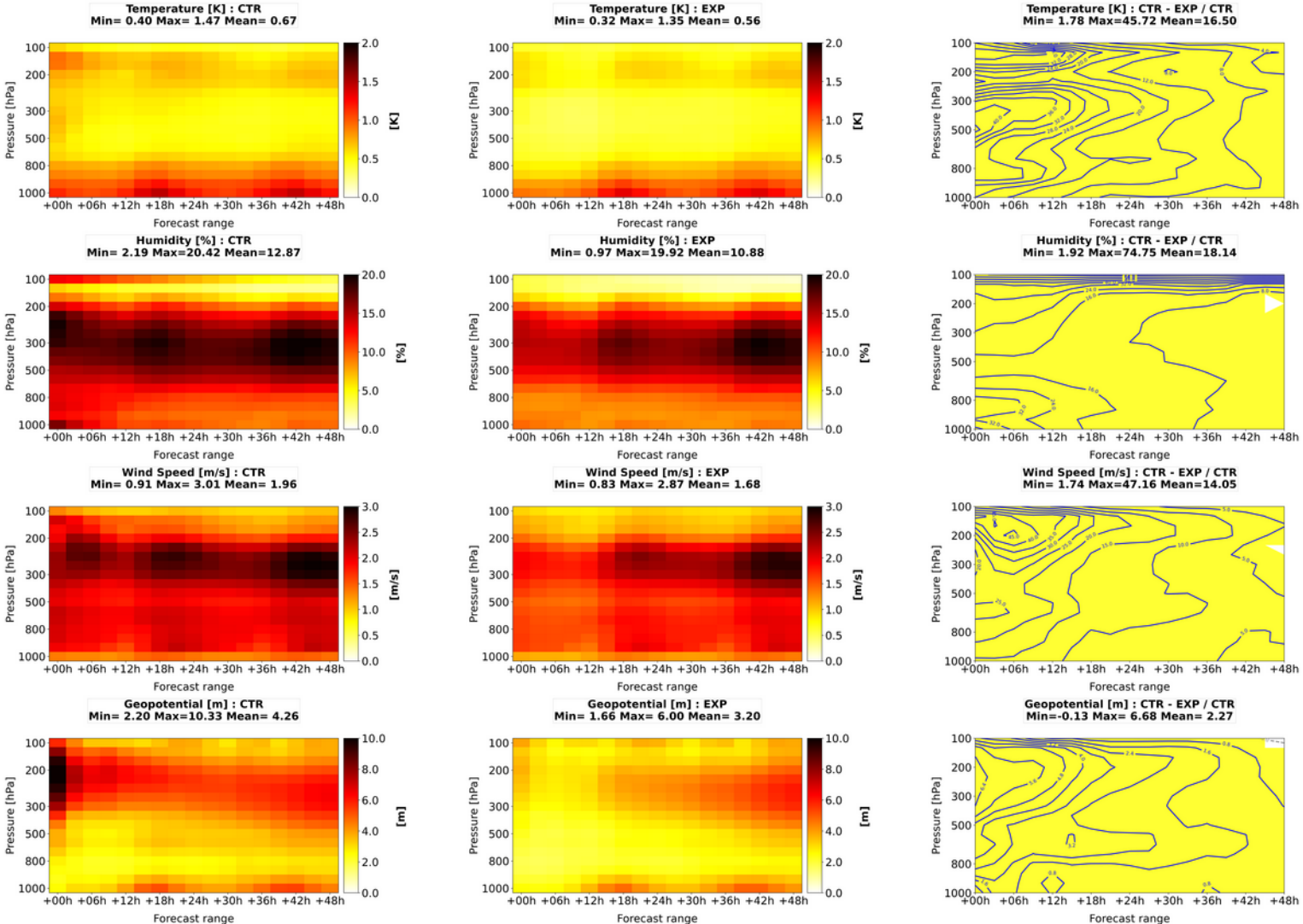
# Percentage of assimilated observations (Summer – 1 month)

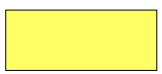


# Relative Forecast scores (RMS – Summer – 2 month)






Significativity at 95 %

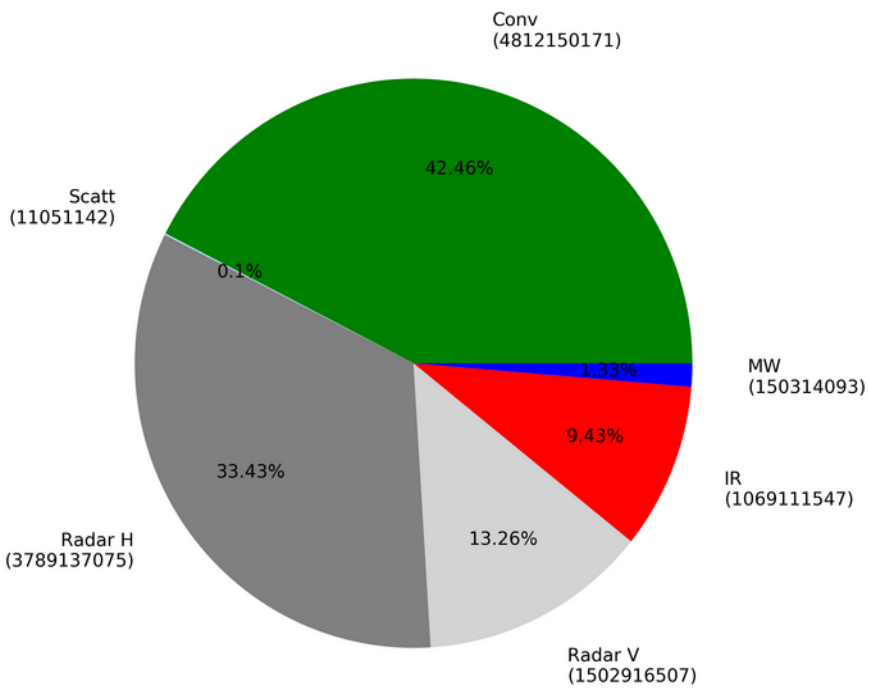


# Percentage of assimilated observations (Winter – 1 month)

**Proportion of observations used by type of observation**
**AROME analysis**

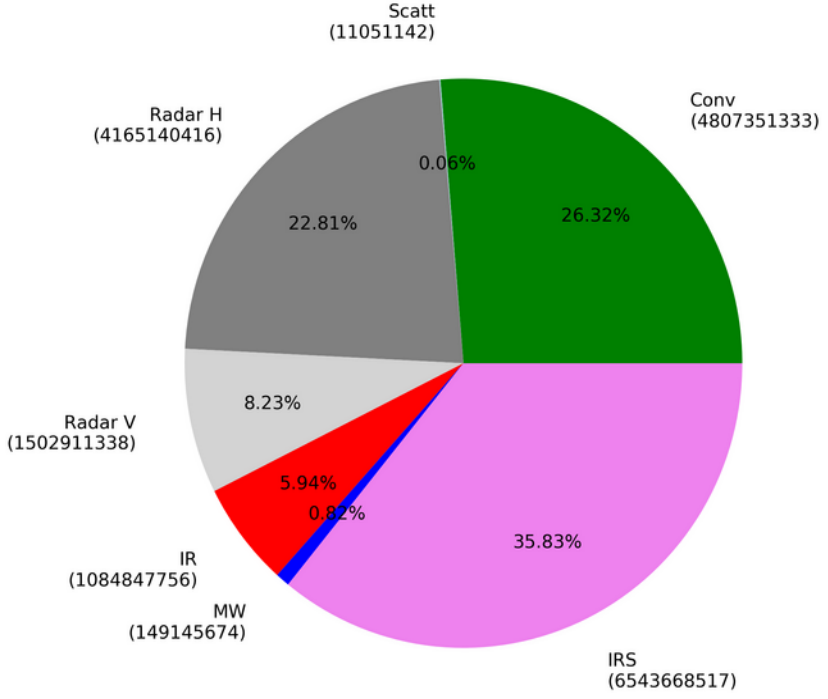
**Control run from 20200101 to 20200131**
**Total number of observations used:11334680535**

**11,3 Billions**



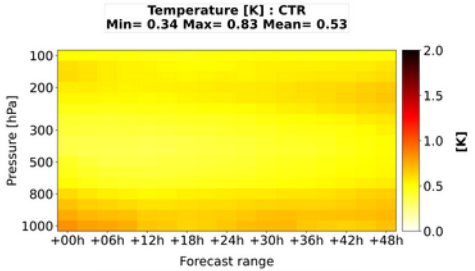

**Experiment run from 20200101 to 20200131**
**Total number of observations used:18264116176**

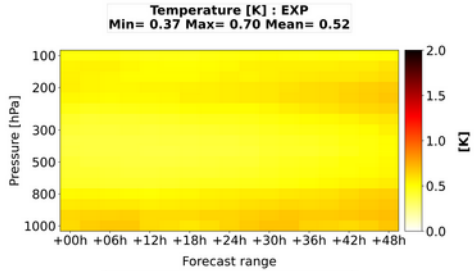
**18,2 Billions**

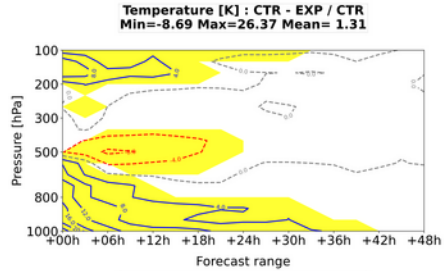


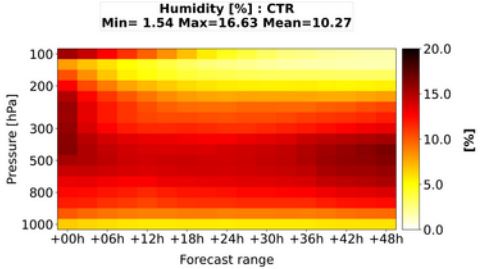
# Relative Forecast scores (RMS – Winter – 2 month)

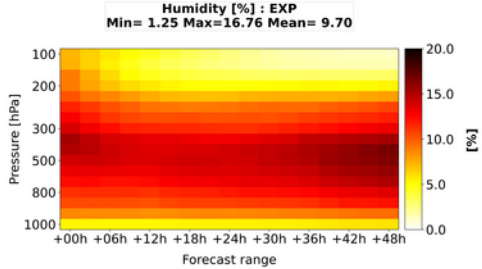


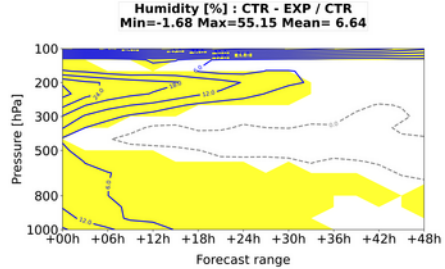


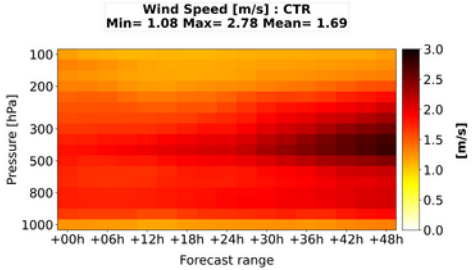



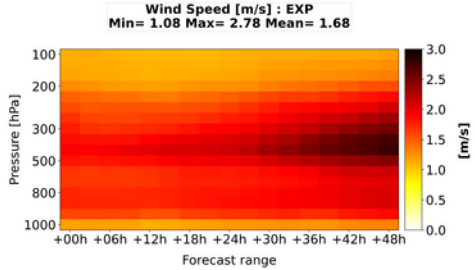



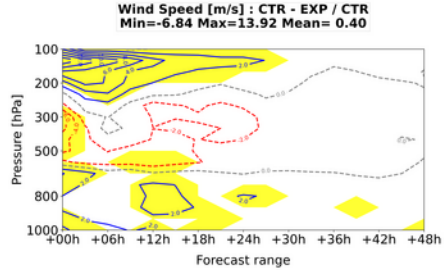



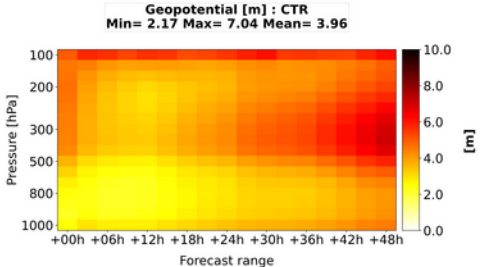



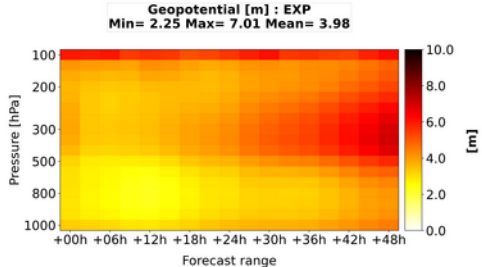



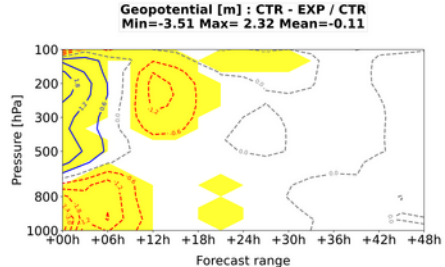




Significativity at 95 %

# Conclusion

- 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 :** Project to assimilate the future MTG-IRS sounder into the mesoscale NWP model

  (submission at end of month 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.

# Discussion

- **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

# Current & Future works



- Precipitation scores → next work
- Assimilation with channel selection over sea **+ land** → next work
- Diagnostic of IRS horizontal correlation lengths and thinning adaptation → next work
- A specific case study on the impact of IRS for forecasting and monitoring heavy rainfall from the Mediterranean sea → next work