



# Assimilation of simulated IRS data in a convective scale model

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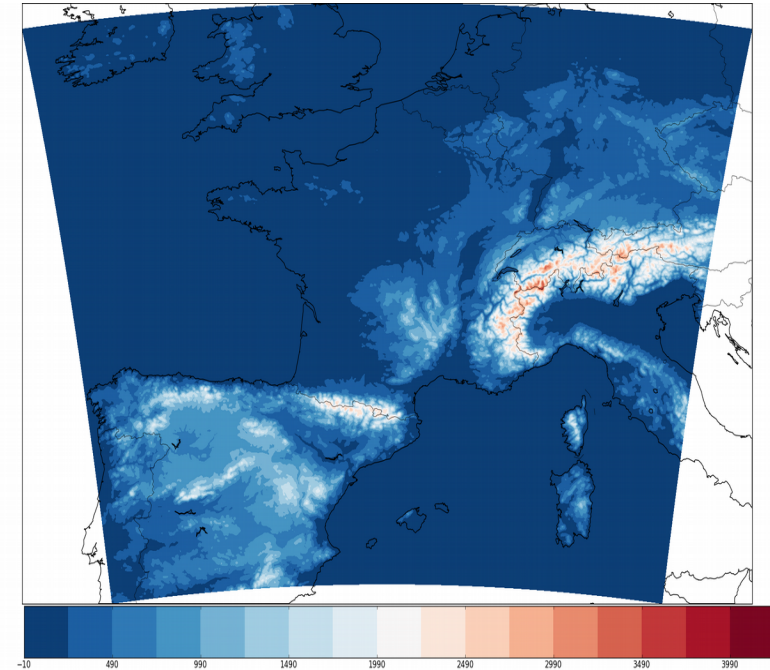
Nadia Fourrié, Fabrice Duruisseau, Philippe Chambon, Stéphanie Guedj, Vincent Guidard, Françoise Taillefer, Pierre Brousseau and Jean-François Mahfouf

Reading, 23 May 2017

# The meso-scale model AROME

- In operations since 2008
- Dedicated to the forecast of high impact weather : heavy precipitation, thunderstorm and fog.
- Forecast for the next day.  
Coupling files : hourly ARPEGE forecasts
- Spectral limited area non-hydrostatic model with explicit convection.
- 3D-Var assimilation, focus on the initialisation of convective clouds (low-level forcing + 3D humidity fields).

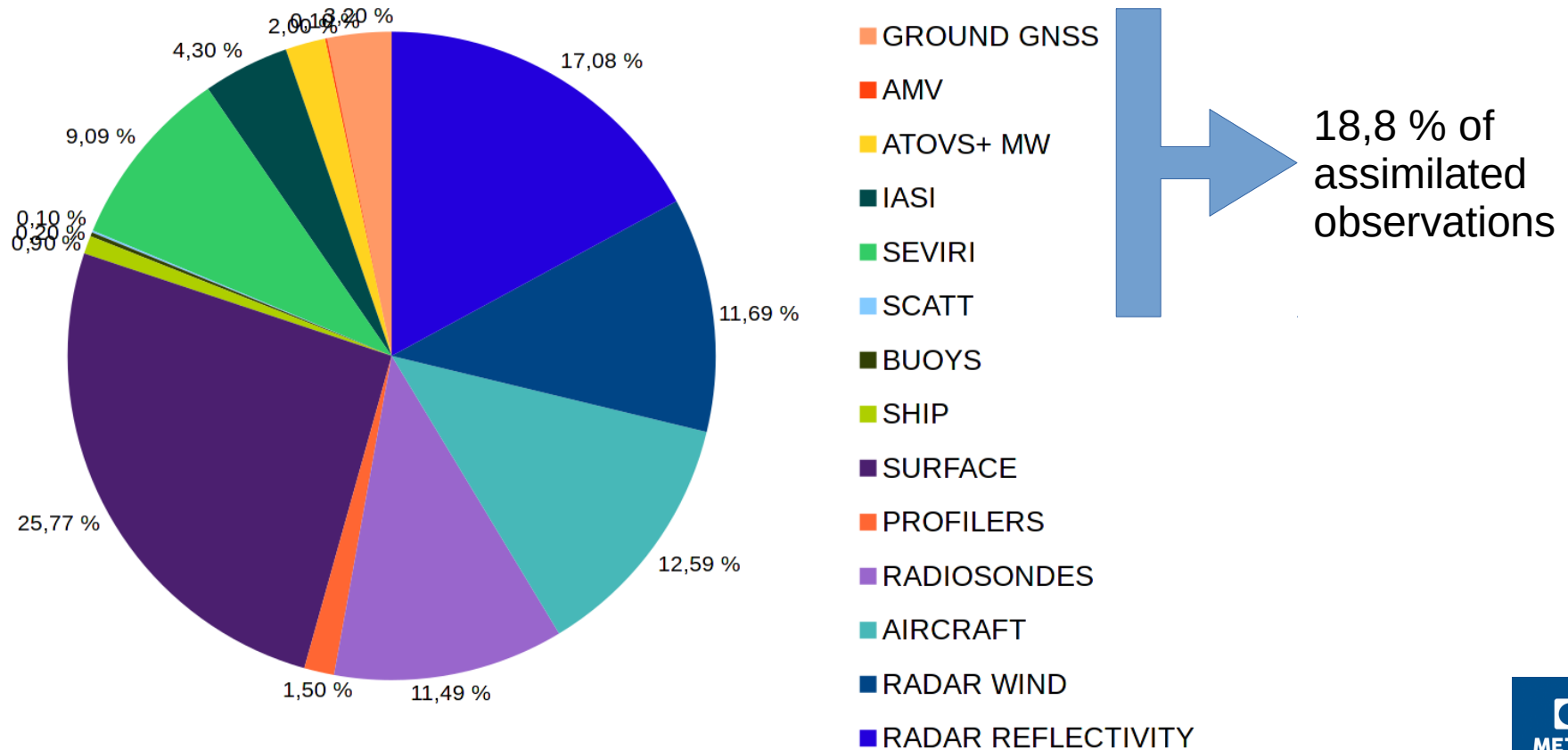
AROME-France domain



# AROME-France model

- Same assimilated data as global model plus radar radial winds and reflectivities (French network : 24 radars)
- Lack of information for AROME-France over sea

## Distribution of assimilated observations in AROME-France during April 2017



# Preparatory studies for IRS assimilation

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- MTG IRS :
  - observation every 30 minutes
  - Horizontal resolution 4 km
- Observing System Simulation Experiments : homogenous and harmonized approach to evaluate the synergy between instruments
- 2 projects :
  - Stephanie Guedj EUMETSAT fellowship
  - Potential benefit of a microwave geosounder in NWP (Duruiseau et al 2017, QJRMS).



# Outline

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## 1) OSSE framework

- Nature Run
- AROME Data Assimilation System
- Simulation of observations
- Selection of observations

## 2) Results

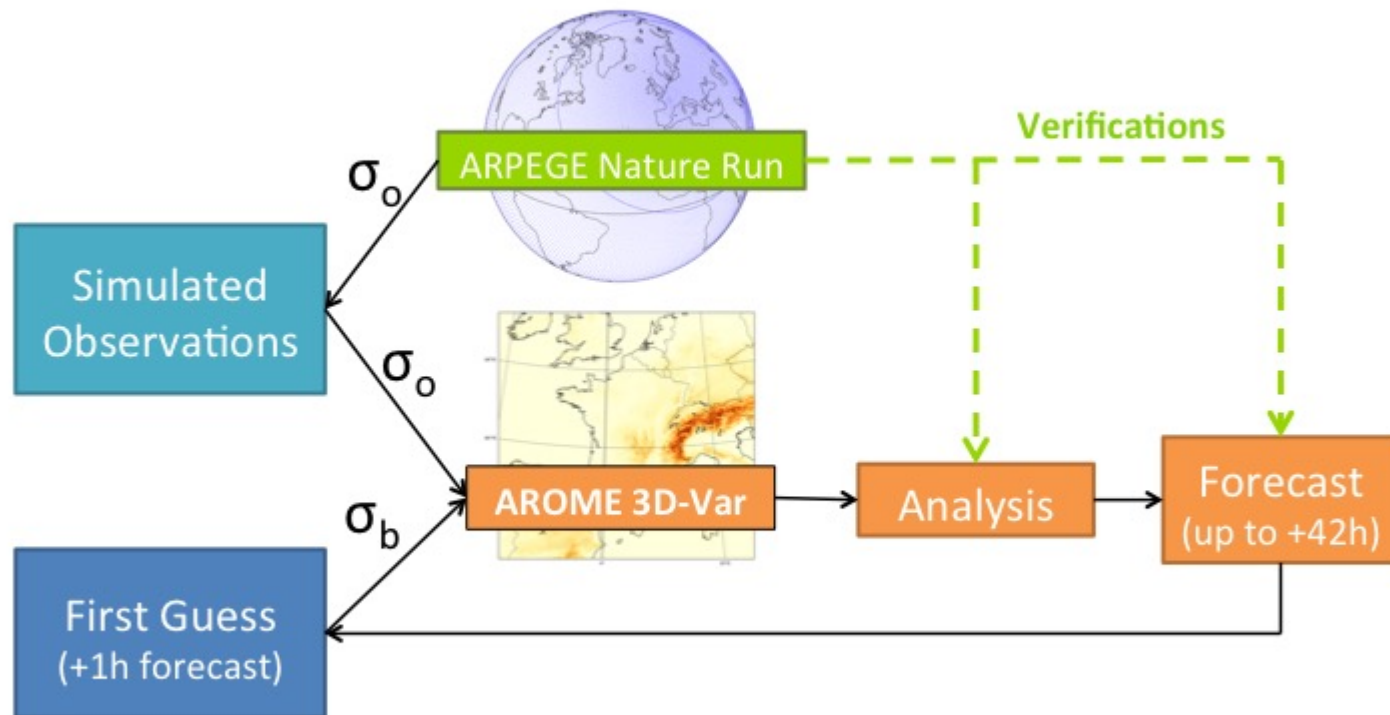
- Impact of IRS on the analysis and observation error correlation (Guedj et al 2014) .
- Impact of a cloud screening (Duruiseau et al, 2017,QJRMS).

## 3) Conclusions



# OSSE Framework

- At Météo-France, an OSSE framework has been built up since 2011, originally in order to assess the expected improvements from IRS into the AROME regional forecast model over Western Europe (EUMETSAT Fellowship of Stéphanie Guedj).

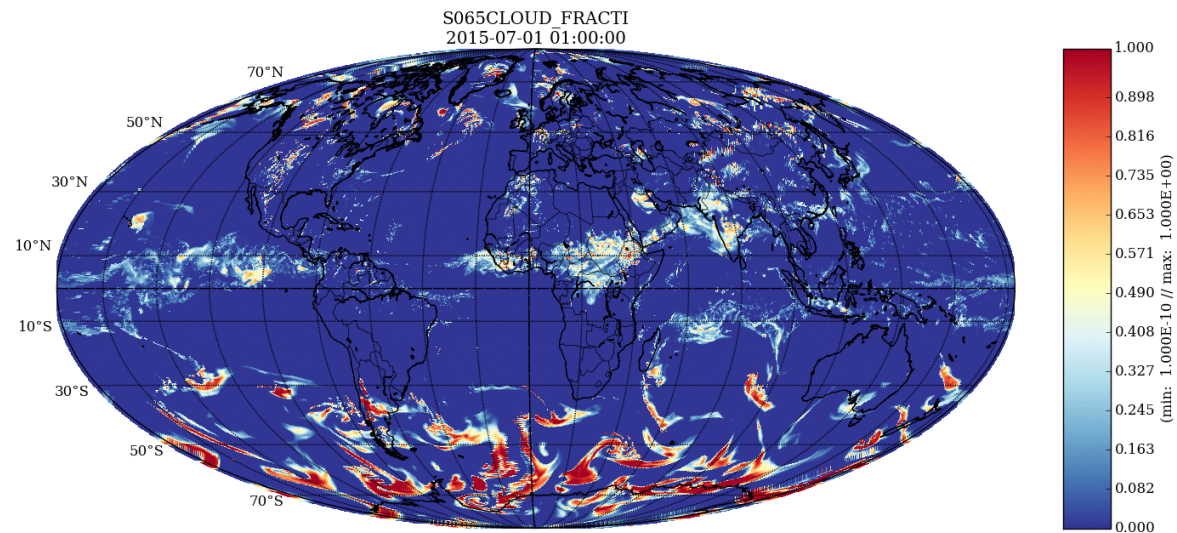


(Guedj et al., 2014)



# Nature Run

- The true atmospheric state is called the Nature Run (NR). It is a free-run, long and uninterrupted forecast performed with the global NWP ARPEGE model :



Main characteristics of Nature Run:

- Spectral resolution : T1200 (~7 km over Europe / 105 levels)
- Initial conditions :  
23/6/2013 0h  
01/06/2015 – 0h
- Forcing of SST using OSTIA analysis

# Data assimilation framework

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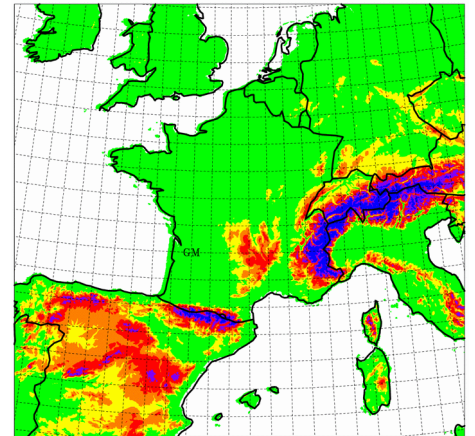
AROME is a non hydrostatic model, its DAS is a 3D-Var.

- In operations: 1.3 km res., with 90 vertical levels. Lateral boundary conditions from the ARPEGE global model
- Research version for the OSSE: 2.5 km res., with 60 vertical levels. . Lateral boundary conditions from the Nature Run.

Initial conditions : 15/07/2013 – 0h (NR)3H assimilation window

Initial conditions : 1/7/2015 0h 1h assimilation window

Assimilation of the **full simulated observing system (+ IRS)**



⇒ The impact of IRS is assessed on AROME analysis and forecasts



# Observations assimilated within AROME

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Within an OSSE framework, it is not only the new observations that need to be simulated, but the whole observing system to provide consistent observations of the atmosphere.

<b>Observation kinds</b>	<b>Observing systems</b>
Surface measurements	surface stations, ships and buoys ground GPS, wind profilers ground radar radial winds and reflectivities
Altitude measurements	Radiosondes (TEMP, PILOT) aircraft measurements (AIREP, AMDAR) AMVs
Infrared satellite data	HIRS, SEVIRI, IASI, AIRS, CRIS
Micro-wave satellite data	AMSU-A, AMSU-B, MHS, ATMS, SMIS

Radar data were not simulated within the OSSE as the observation operator used to simulate radar data was not adapted to the ARPEGE model and the NR.



# Observations assimilated within AROME

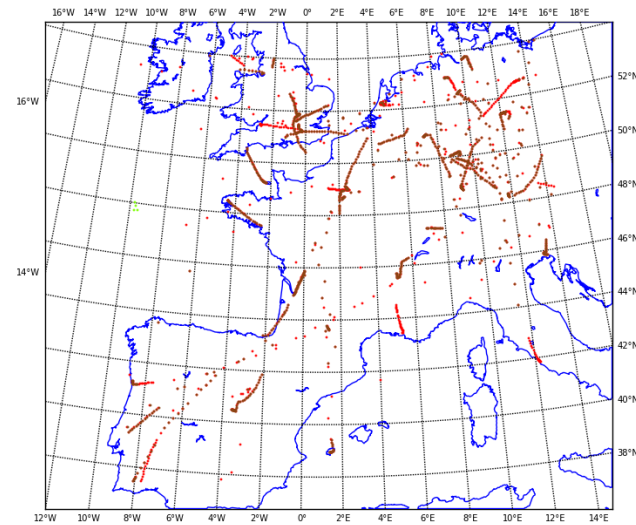
The observation values are simulated from the NR.

They are randomly perturbed to simulate instrumental errors.

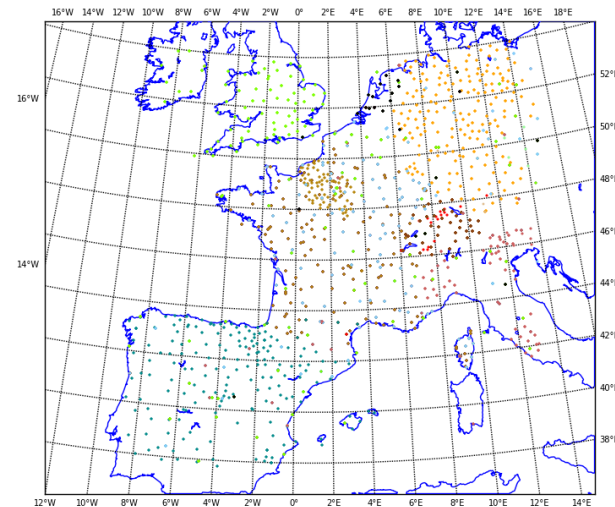
The observation locations used are the ones of the real observing system.

⇒ Realistic sampling of the atmosphere

Example of Aircraft Reports :



Example of zenithal total delay :

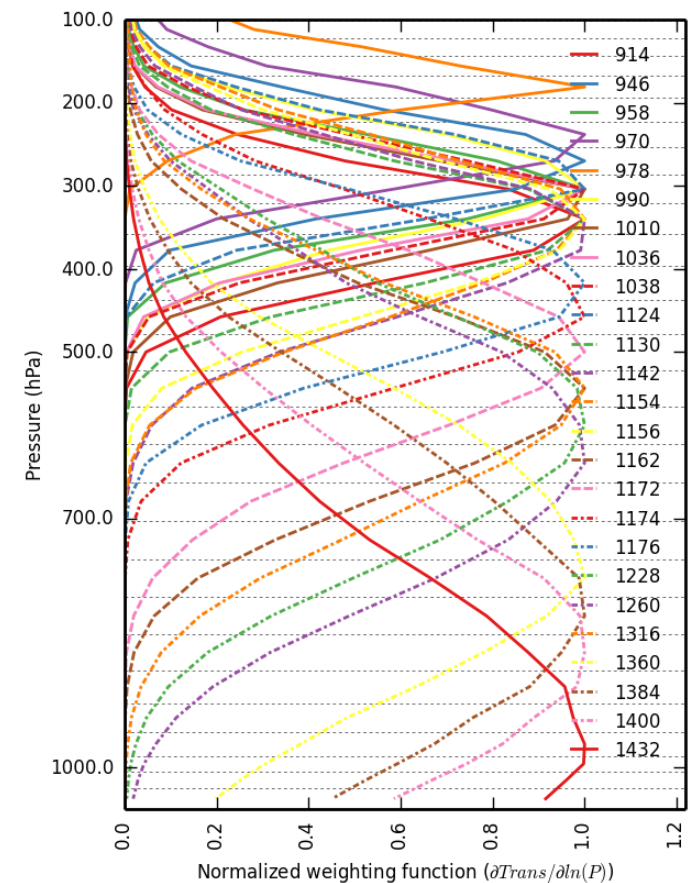


# Simulation of observations

## Future GEO satellite observation simulations

- Configuration for MTG IRS (Guedj et al., 2014) :
- Selection of 25 water vapour channels
- Horizontal thinning of 80km
- Observation errors consistent with IRS specifications.

**All observations are simulated and assimilated assuming uncorrelated errors**



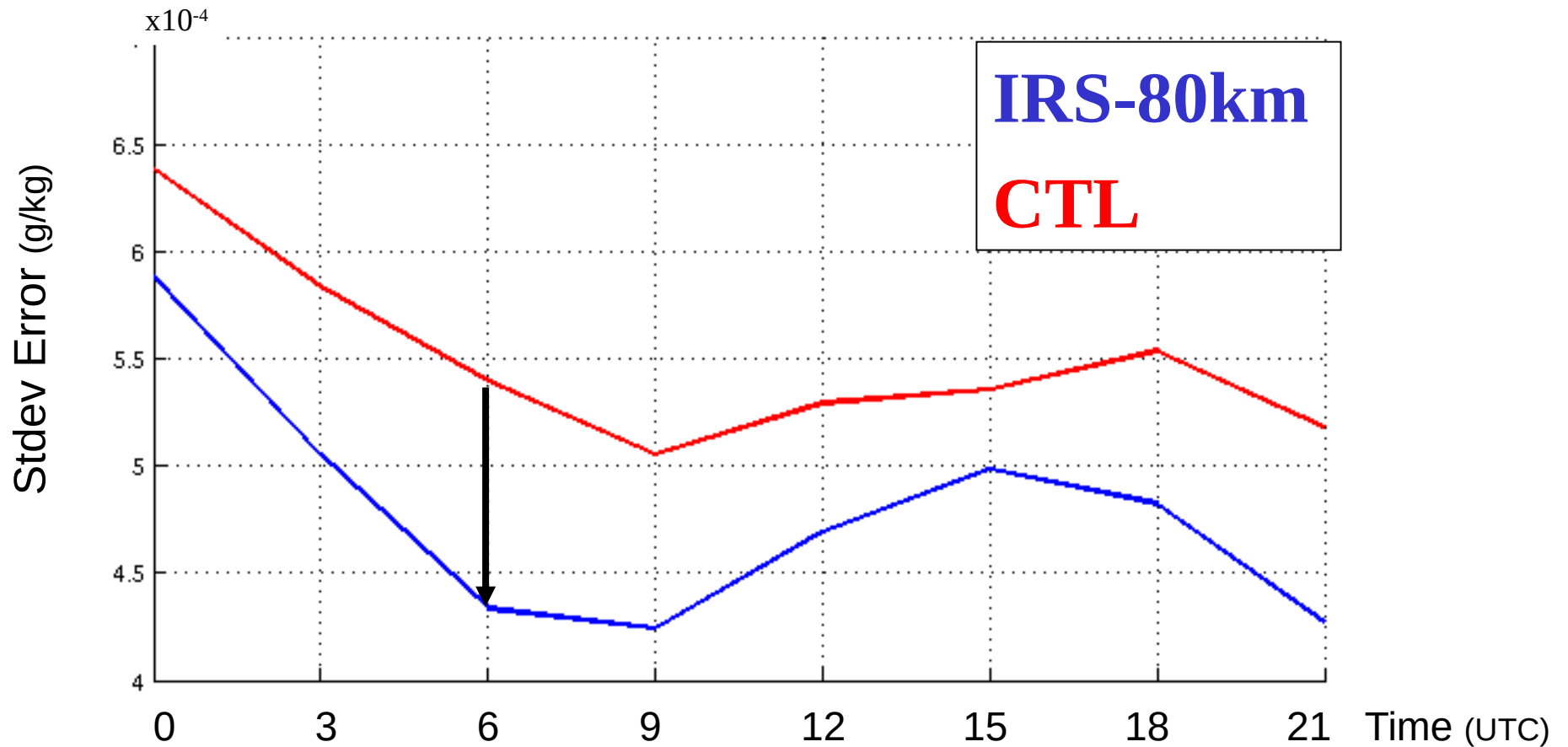
# Selection of observations for assimilation

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- In an OSSE framework, "quality control" procedures used with real observations may need to be adapted :
  - First guess departure controlled (observations too far from the model are discarded).
  - Observations are horizontally thinned to avoid correlation in observation errors which are not yet modelled in the observation error covariances in the data assimilation system.
  - Cloudy observations are rejected or not, considering the data assimilation system capability.
  - For infrared observations the data usage strongly depends on channel and their weighting function. A cloud detection method is used to assimilate observations sensitive to temperature and humidity above the cloud top (algorithm of McNally and Watts).

# Impacts on atmospheric analysis

Averaged analyse error stdev vs **REF** specific humidity at 700 hPa (g/kg)



% of change : -7.83   -13.44   **-19.64**   -15.97   -11.38   -6.87   -12.86   **-17.54**



# Impacts on atmospheric analysis

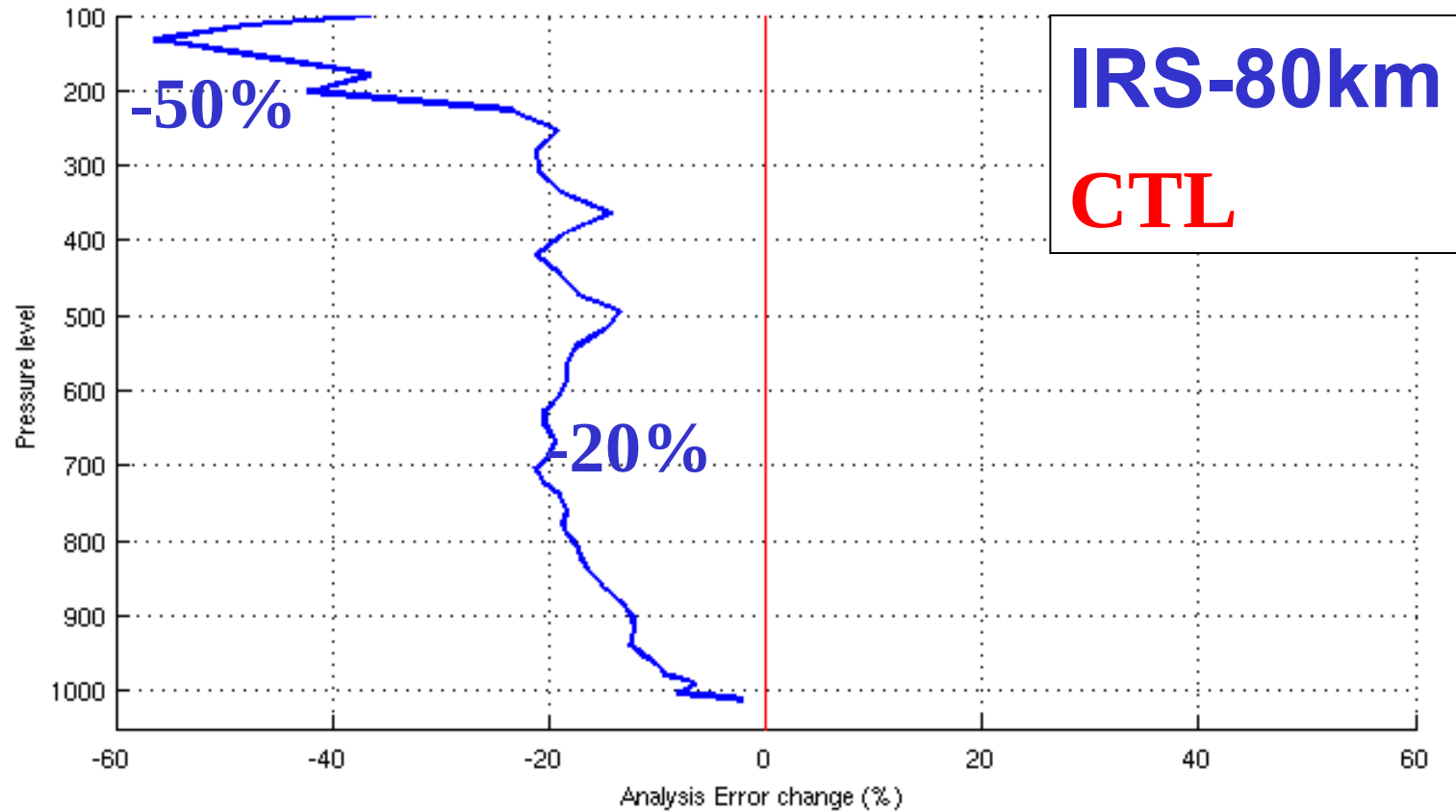
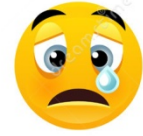


GOOD

## SPECIFIC HUMIDITY

Relative analyse error stdev changes (%)

BAD



**IRS-80km**  
**CTL**



# Impacts on atmospheric analysis

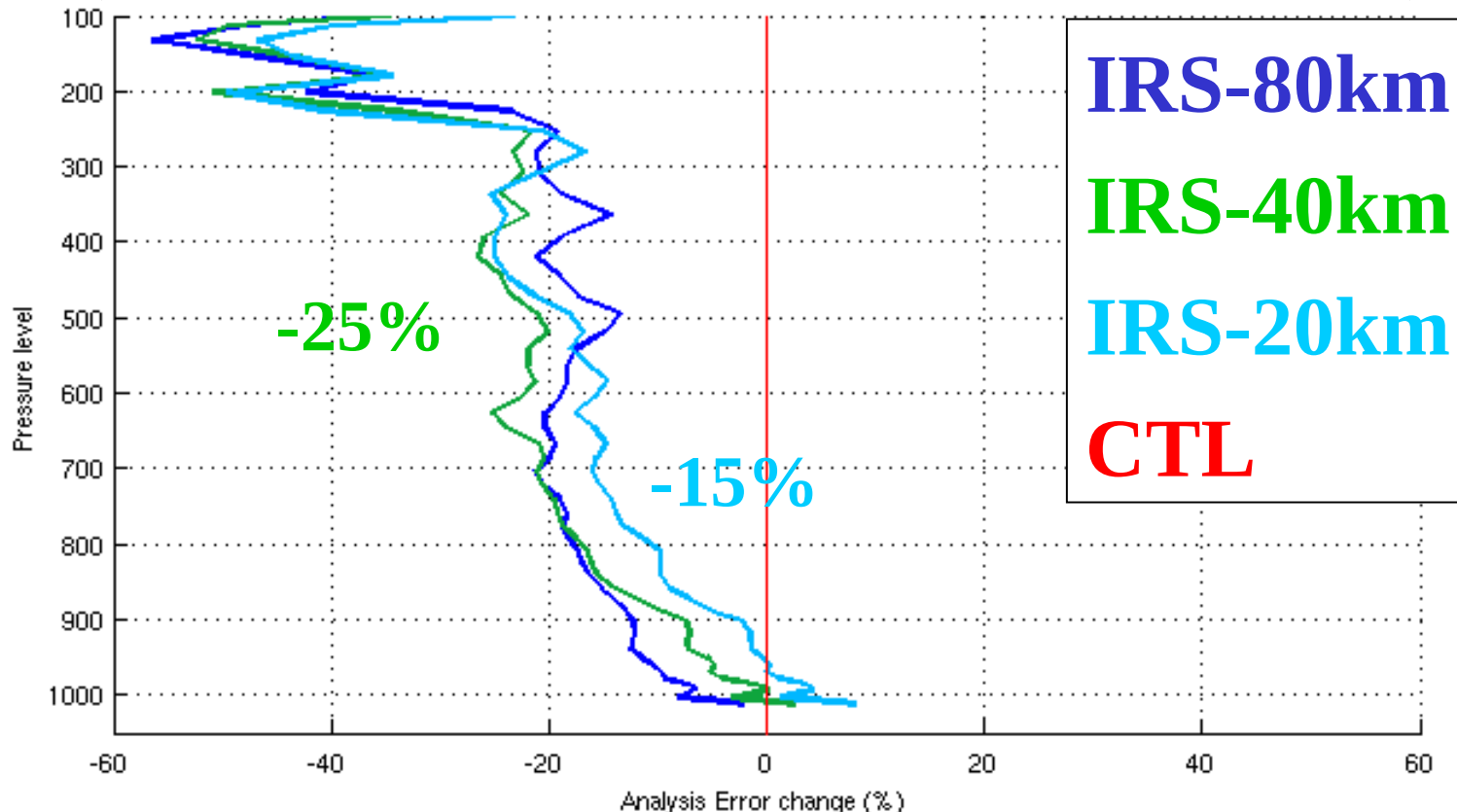


GOOD

## SPECIFIC HUMIDITY

Relative analyse error stdev changes (%)

BAD



⇒ Even if IRS observations are simulated assuming uncorrelated errors, there is a thinning distance threshold where background errors interact with obs. errors ...

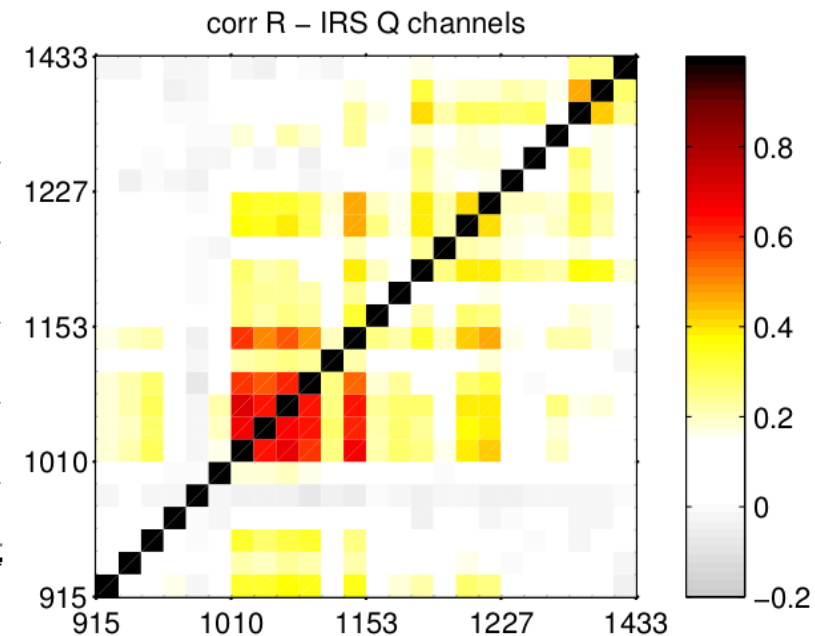
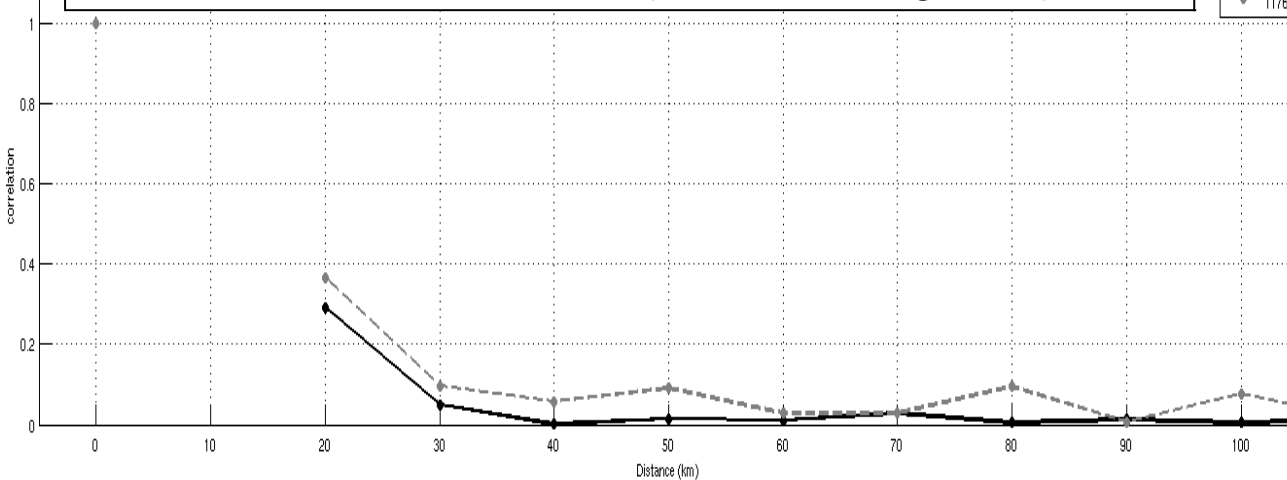
# IRS observation error correlation diagnosed in the OSSE

Perturbation added to radiance simulations was assumed to be uncorrelated. The a posteriori Desroziers diagnostic for horizontal and inter-channel error correlation was run on IRS simulated/assimilated WV data within the framework of this OSSE.

Result : Significant inter-channel error correlations were found even if the perturbation added to the observation was not correlated ...

40 days of IRS data assimilation (OSSE)  
25 IRS WV channels + Full obs. system

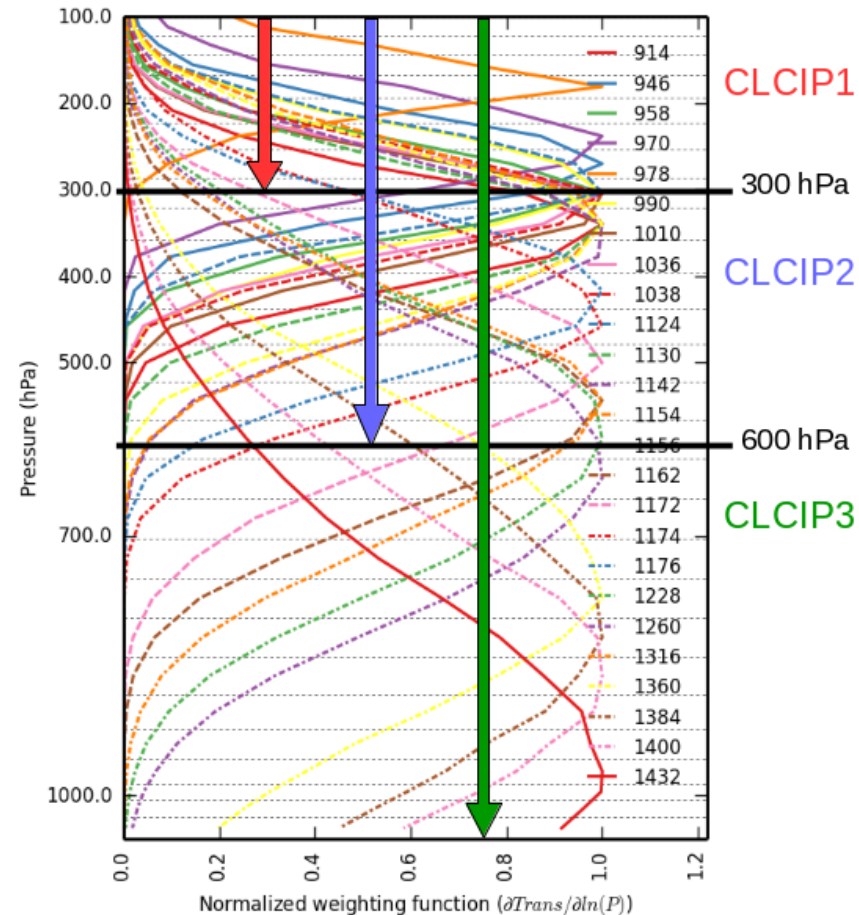
Estimate of **horizontal error correlation** using simulated IRS WV observations (Desroziers diagnostic)





# Impact of a simplified cloud screening for the OSSE

- Cloud screening techniques need to be modified (e.g. McNally and Watts algorithm for IASI), in particular when cloud contamination is not simulated with the DAS.
- Cloud Liquid Water and Cloud Ice Water are selected as predictors for the cloud screening implemented.
- IRS observations : piece-wise CIW+CLW paths are computed to mimick a simplified McNally and Watts algorithm.

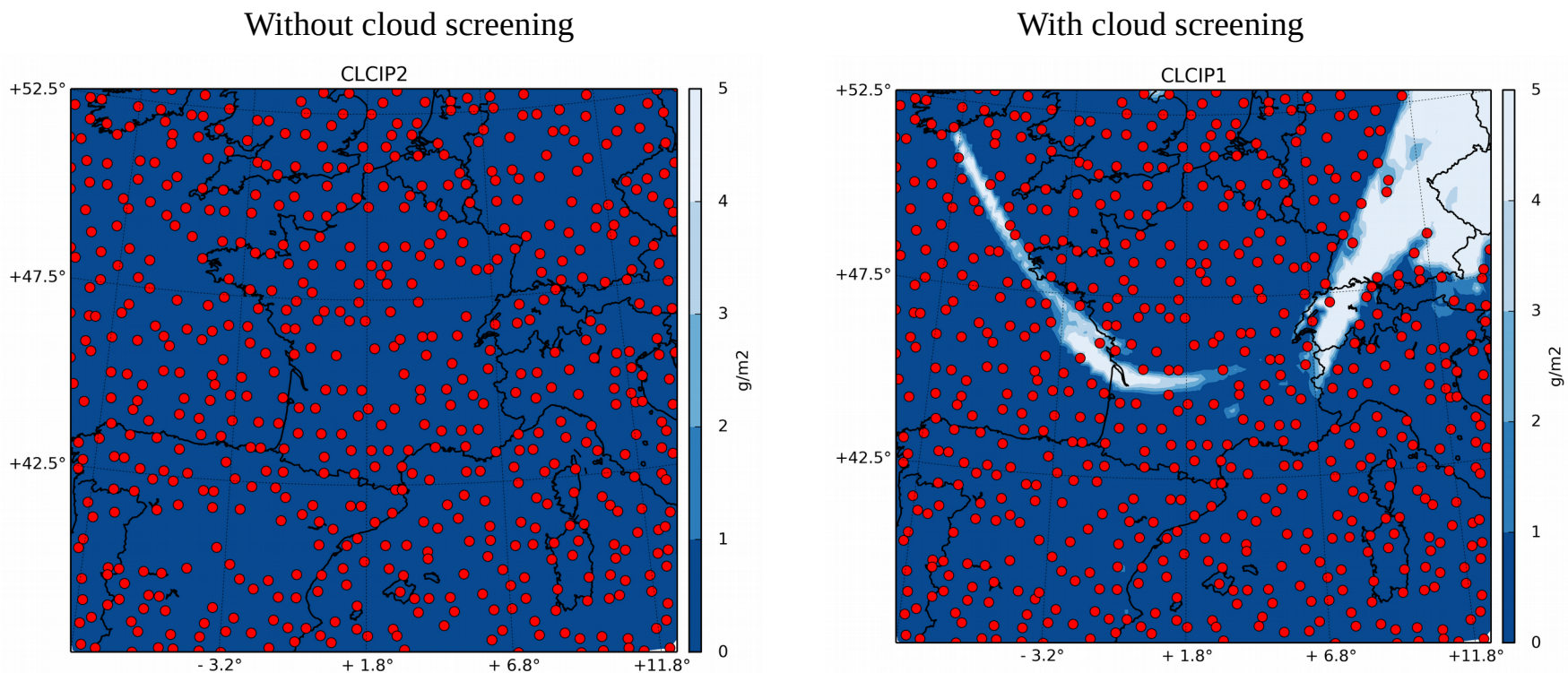


# A simplified cloud screening for the OSSE

Example of 2015/07/03 00h UTC

Location of IRS active observations, CLCIP1 threshold of 2 g/m<sup>2</sup>

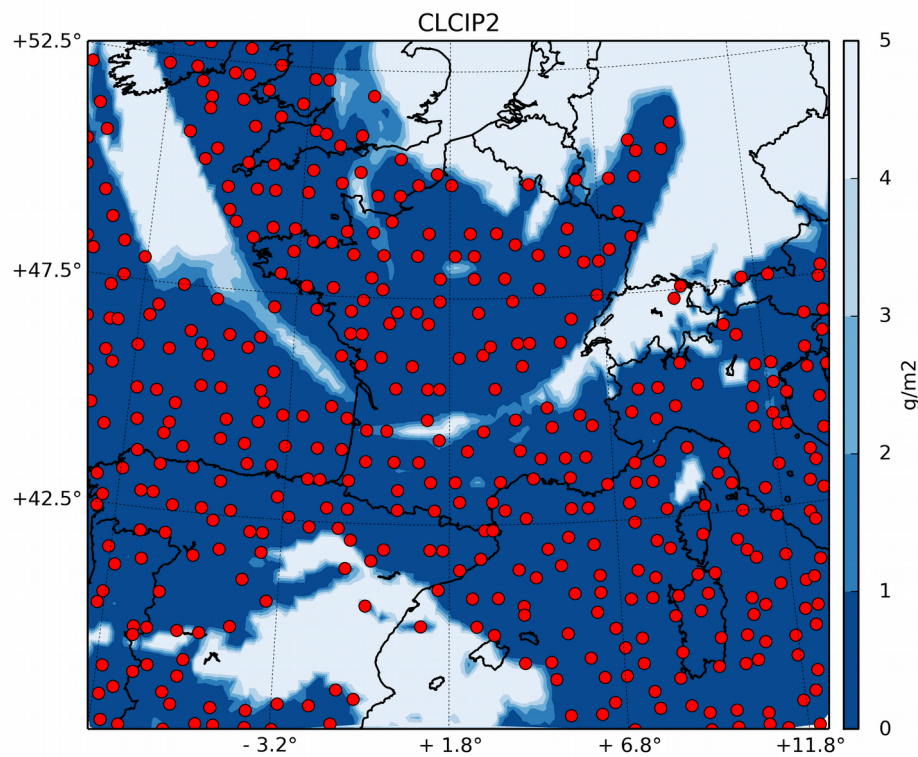
Channel 978 150 hPa



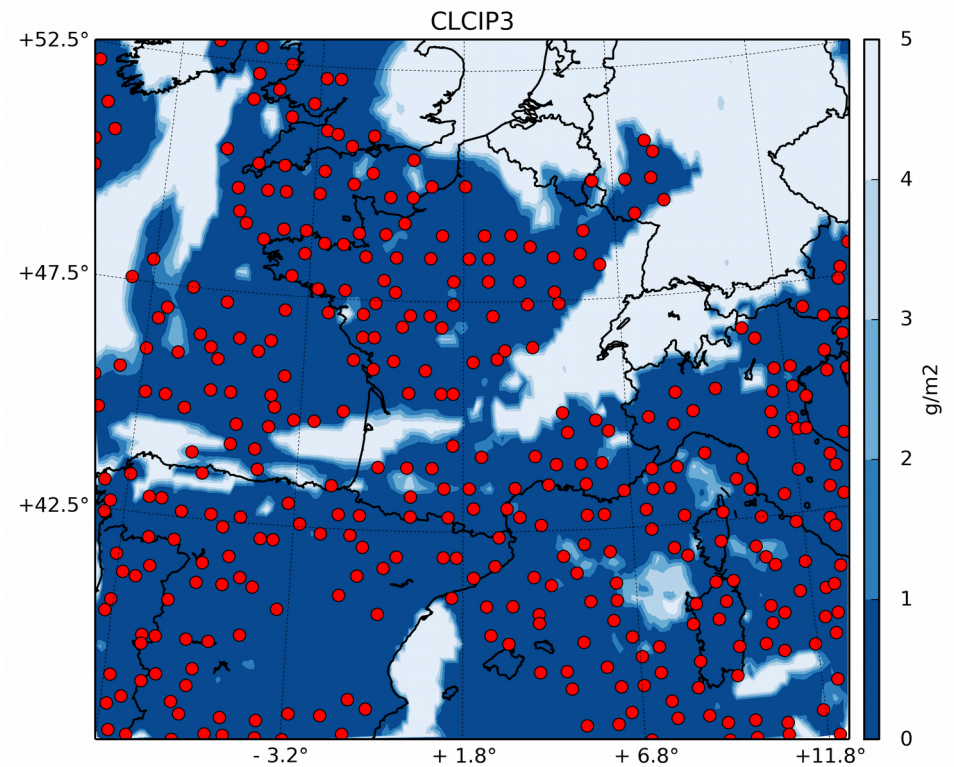
# A simplified cloud screening for the OSSE

Example of 2015/07/03 00h UTC  
Location of IRS active observations

Channel 1130 : 350 hPa



Channel 1260 : 600 hPa



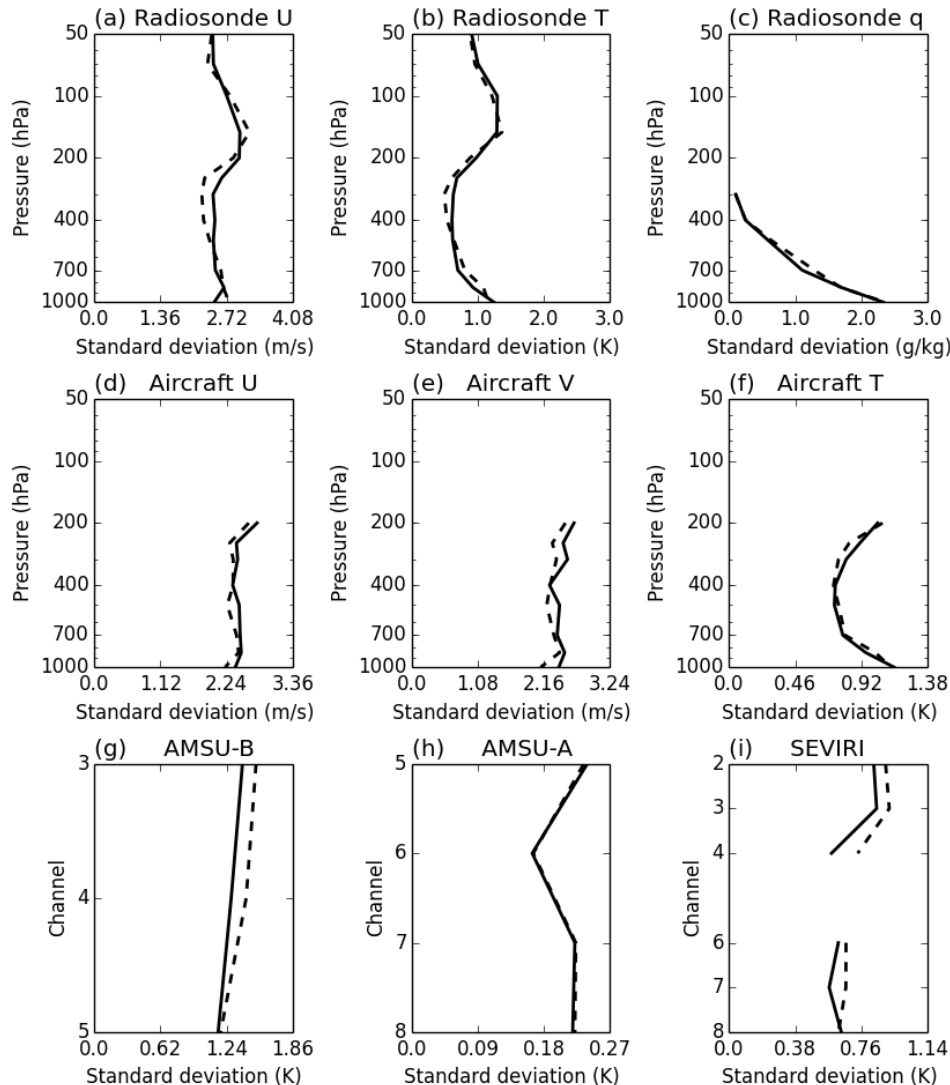
# Assimilation experiments

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- Two experiments were conducted over a 1-month period (July 1st to July 31st) with hourly cycles, and +42h forecast performed daily at 00h UTC. These forecasts are compared to the NR.
- Experiments :
  - CTRL
  - CTRL + IRS

# OSSE calibration

Standard deviation of FG departures for observations and computed from July 1st to July 10th



— Calibrated OSSE  
 - - - AROME in operations

Iterative process (15 iterations) to determine the perturbation which ensure that each observing system has a realistic impact on analyses and forecast.

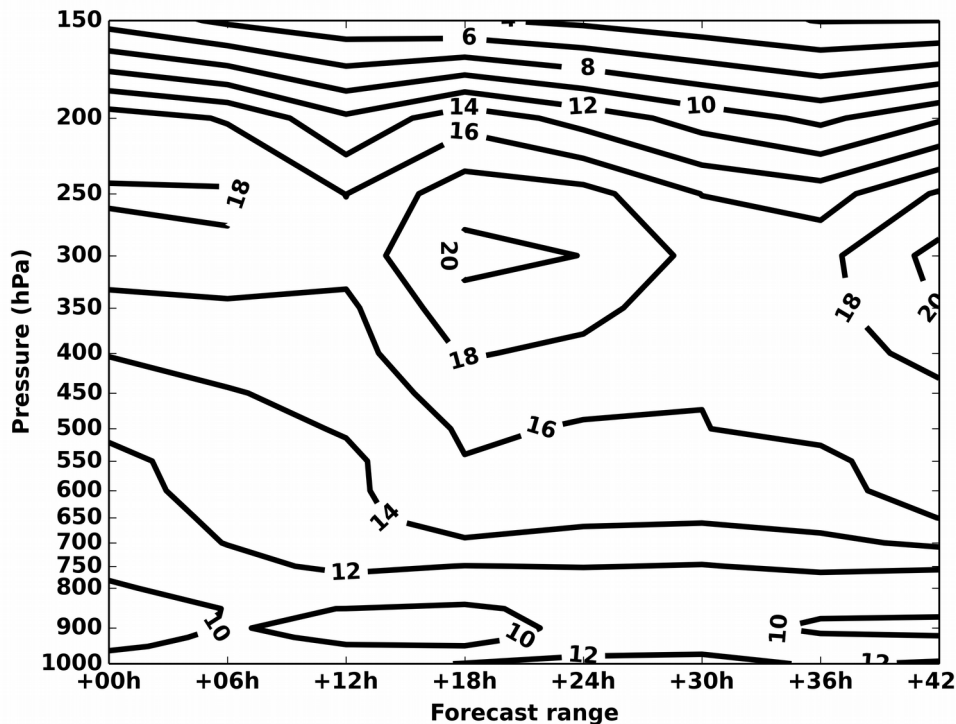
Very good agreement for wind, temperature humidity observed by Radiosondes and aircraft and for AMSU-A Bts.



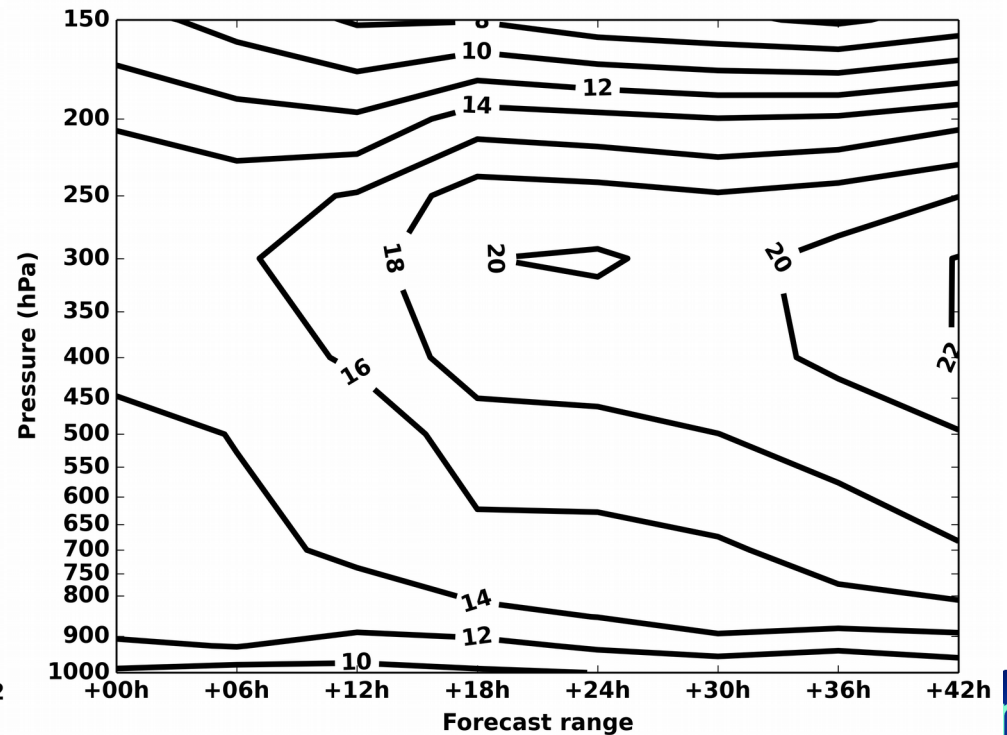
# Forecast errors on Relative Humidity in the CTRL

- Forecast errors being similar to the ones of the operational forecasts of AROME, it gives us confidence on the realism of the OSSE framework.

Relative humidity RMSE CTRL wrt NR

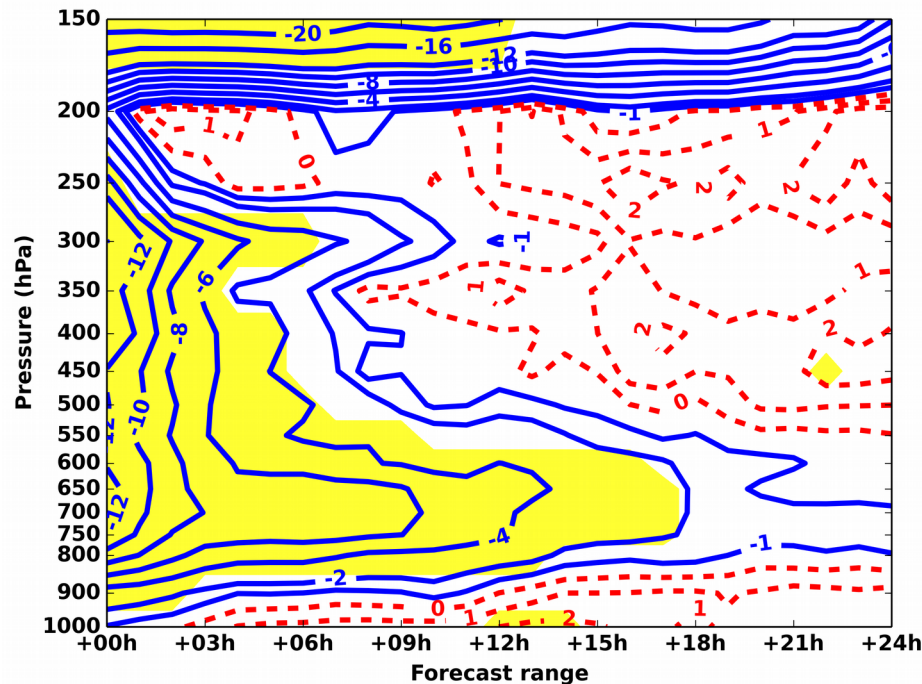


Relative humidity RMSE OPER wrt ECMWF analyses

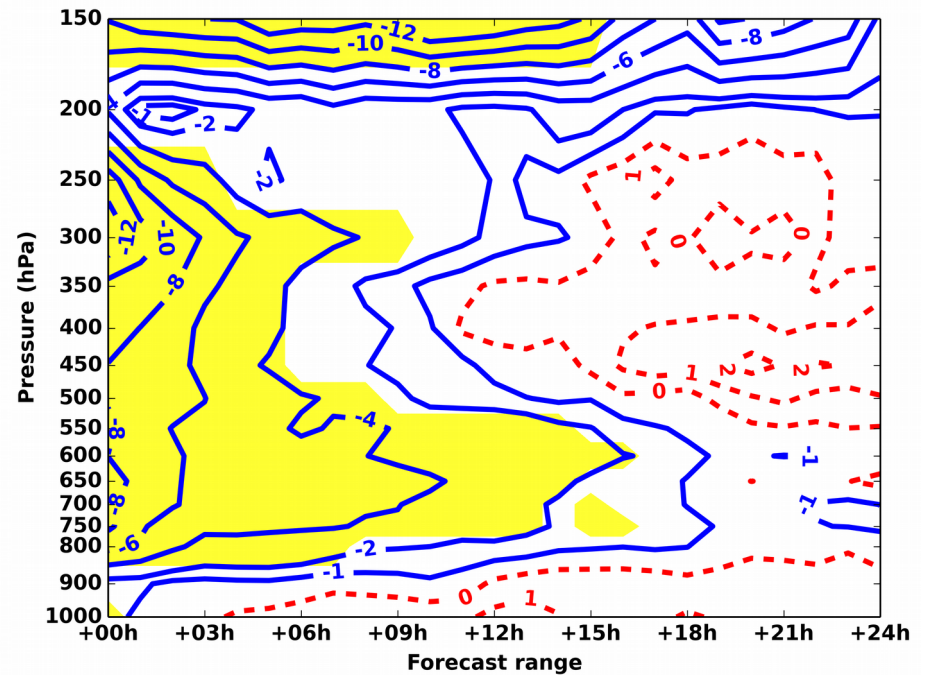


# Impact of cloud screening on IRS impact on top of the 2015 Observing System

Difference of the RH RMSE over the AROME domain  
(EXP IRS - CTRL)/CTRL



Without cloud screening



With cloud screening

Yellow areas correspond to differences that are significant at the 99% confidence level.

Positive impact in RH forecast between 800 and 600 hPa up to 18h.  
Forecast impact is decreased by 30 % when considering a cloud screening of IRS data.

# Conclusions

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- OSSEs have been run to estimate the impact of IRS observations in the meso-scale AROME system.
- Only 25 humidity channels have been assimilated.
- Even though simulated observations were not correlated, correlation in observation errors have been found in the OSSE.
- A large positive impact on the analysis of humidity is found with a 80 km thinning.
- A positive impact is observed up to the 15-h forecast range.
- The cloud screening method reduces the number of assimilated IRS radiances and the impact of IRS is reduced by a factor of 30 % compared to cloud free experiment.



# Perspectives

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- Improvement of the reference atmospheric and surface state (so called Nature Run) using higher resolutions and the latest developments of physics schemes now available at Meteo France.
- The reference observing system on top of which MTG IRS data will be assimilated should be as realistic as possible. In particular, ground radar data should therefore be added to future OSSEs to assess the potential impact of the IRS on high impact weather forecast.
- The IRS assimilation methodology need to be much more elaborated than in our past OSSEs :
  - The channel selection should be extended to the temperature channels of IRS as well as on surface channels and more water vapour channels.
  - To address inter-channel observation error correlations in the data assimilation system.



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# Thank you !

Duruissseau F, Chambon P, Guedj S, Guidard V, Fourrié N, Taillefer F, Brousseau P, Mahfouf JF and Roca R. (2017). Investigating the potential benefit of a Microwave sounder on-board a geostationary satellite on Numerical Weather Prediction with a meso-scale model. Accepted in Quart. J. Roy. Meteorol. Soc. *DOI: 10.1002/qj.3070*



# MW GEO<sub>1.25K</sub> on top of the 2023 observing system

Difference of the RH RMSE over the AROME domain

