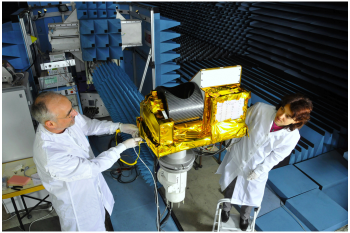
Data impact evaluation of a microwave sounder onboard a geostationary satellite through Observing System Simulation Experiments

Philippe Chambon[1], Fabrice Duruisseau[1], Stéphanie Guedj[2], Vincent Guidard[1], Nadia Fourrié[1], Françoise Taillefer[1], Pierre Brousseau[1], Jean-François Mahfouf[1], Rémy Roca[3]

(1) : CNRM, Météo-France and CNRS, Toulouse, France
(2) : JCSDA, Maryland, USA
(3) : LEGOS/OMP, CNRS, Toulouse, France

The idea of a radiometer observing the Earth in the microwave spectrum from a geostationary orbit has been put forth since a long time.

Such a mission would add the high observation rate offered by a geostationary orbit to the sounding capability of the current observing system.

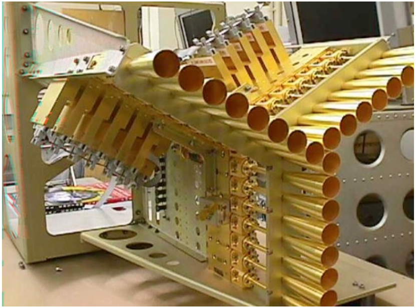


SAPHIR. Courtesy of CNES

Technologies used for sounders like AMSU/MHS/SAPHIR/MWHS2 are not well suited to the GEO orbit (very large antennas to obtain reasonably good horizontal resolutions).

Recent technical advances permit to revisit the trade-offs that were initially proposed in terms of scientific or operational objectives.

Different instrument concepts are emerging, mostly based on interferometry. This kind of technology may lead to reasonably good horizontal resolutions, but potentially at the cost of less accurate observations than technologies used for LEO orbit.



GEOSTAR at JPL, (Lambrigsten et al., 2000)

Recent technical advances permit to re-visit the trade-offs that were initially proposed in terms of scientific or ope-rational objectives.

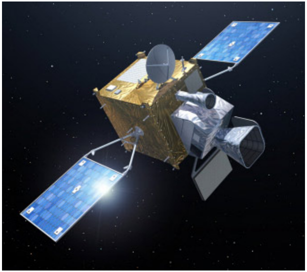
Different instrument concepts are emer-ging, mostly based on interferometry. This kind of technology may lead to reasonably good horizontal resolutions, but potentially at the cost of less ac-curate observations than technologies used for LEO orbit.

GIMS in China, (Zhang et al., 2012)

We can consider 2 baselines that a MW GEOsounder should either outperform or complete in order to find its place in the fleet of Earth Observing Systems :

- the GPM constellation of MW imagers and sounders
- the future IR hyperspectral instrument onboard Meteosat Third Generation, to be launched in 2021

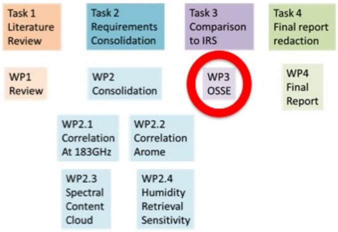
GPM constellation (http ://pmm.nasa.gov)



MTG-IRS (http ://www.esa.int)

The European Space Agency recently funded a *Geosounder Requirements Consolidation Study* which was conducted in 2015.

The study was led by CNRS and Météo-France and in partnership with the University of Hamburg.



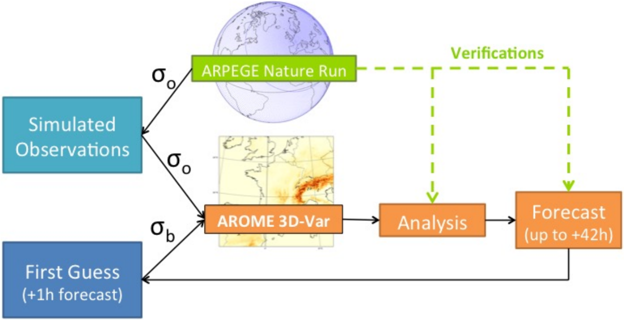
WP3 "Comparison to IRS"

Observing System Simulation Experiments $\Longrightarrow$ homogenous and harmonized approach to evaluate the synergy between instruments.

Question : would a MWGEO with observations that are less accurate than LEO MW sounders still bring some added value to the Observing System ?

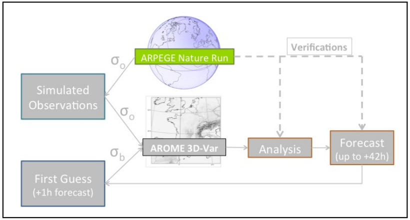
Outline

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)

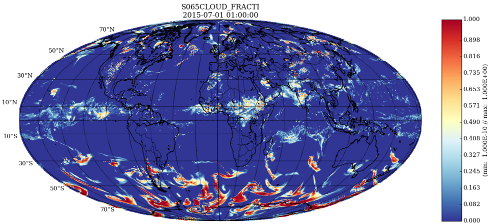
Nature Run



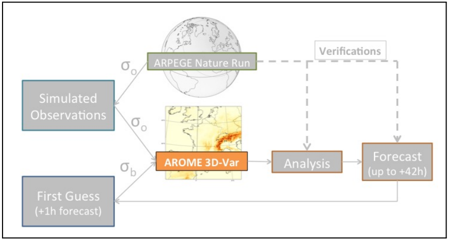
The true atmospheric state is called the **Nature Run (NR)**. It is a free-run, long and uninterrupted forecast performed with the global NWP ARPEGE model :

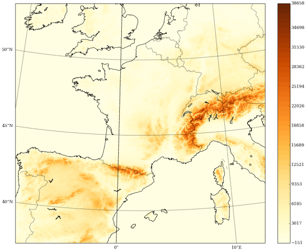
NR main characteristics :

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



Data assimilation framework





AROME is a non hydrostatic model, its DAS is a 3D-Var with 1h cycles.

In operations :

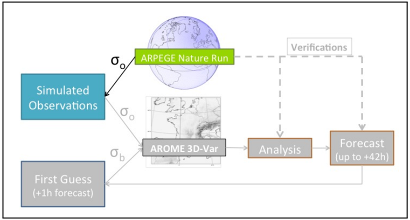
- 1.3km res., with 90 vertical levels
- Lateral boundary conditions from the ARPEGE global model

Research version for the OSSE :

- 2.5km res., with 60 vertical levels
- Lateral boundary conditions from the Nature Run

$\Longrightarrow$ The impact of the MWGEO is assessed on AROME analysis and forecasts

Observations assimilated within AROME



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

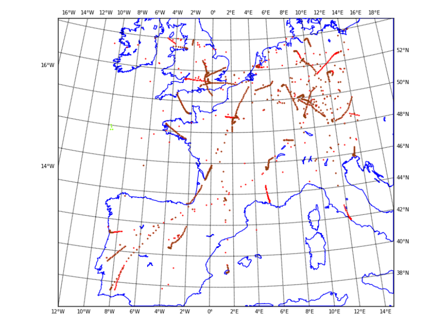
Observation kinds	Observing systems	Observation kinds	Observing systems
Land measurements	**surface stations, ships and buoys ground GPS, wind profilers ground radar radial winds and reflectivities***	Satellite data - IR	**HIRS, SEVIRI IASI, CRIS**
Altitude measurements	**radiosondes, (TEMP, PILOT) aircraft measurements, (AIREP, AMDAR)**	Satellite data - MW	**AMSU-A, AMSU-B MHS, ATMS SSMIS**

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

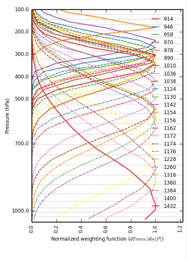
Example of Aircraft Reports :



Future GEO satellites observations simulations

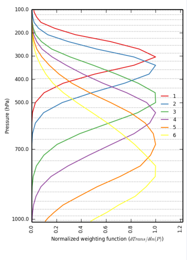
Configuration for MTG IRS (Guedj et al., 2014) :

- Selection of 25 water vapour channels
- Horizontal thinning of 80km
- Observation errors consistent with IRS spec.

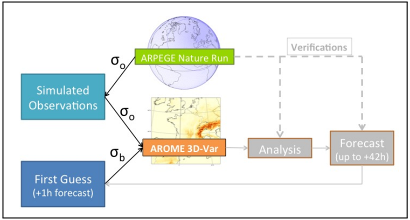


Configuration for the MW GEO :

- 6 SAPHIR-like channels at 183GHz
- Horizontal thinning of 80km
- Observation errors from 2 to 5K (MHS/AMSUB have a 2K error in Météo France DAS)



Selection of observations for assimilation



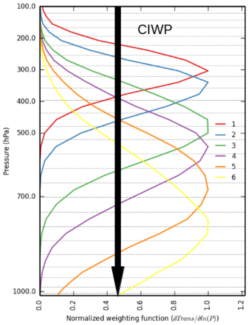
In an OSSE framework, "quality control" procedures used with real observations need to be adapted :

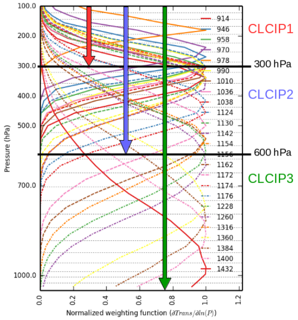
- Cloud screening techniques need to be modified (e.g. McNally and Watts algorithm for IASI), in particular when cloud contamination is not simulated with the DAS.

A simplified cloud screening for the OSSE

Cloud Liquid Water and Cloud Ice Water are selected as predictors for the cloud screening implemented.

- MWGEO observations : total column CIW path
- IRS observations : piece-wise CIW+CLW paths are computed to mimick a simplified McNally and Watts algorithm.



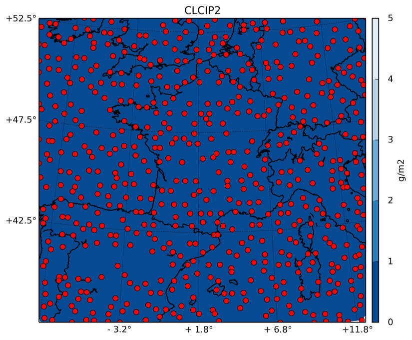


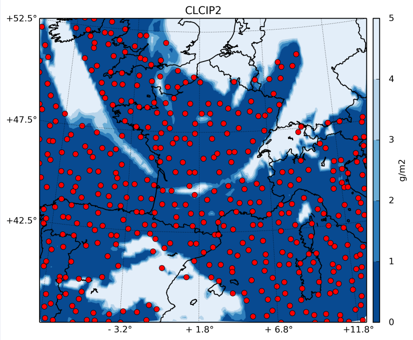
A simplified cloud screening for the OSSE

Example of 2015/07/03 00h UTC

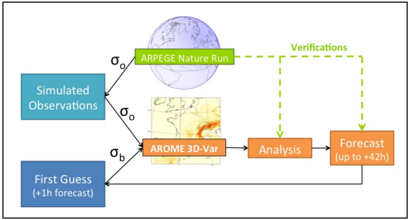
Location of IRS active observations, **CLCIP2** threshold of 2 g/m^2

without cloud screening | **with cloud screening**





Assimilation experiments

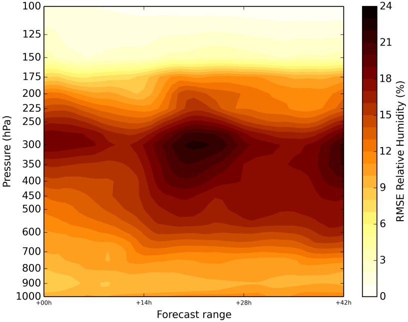


Several experiments are conducted over a 15-day period (July 1st to July 15th) with hourly cycles, and +42h forecast performed daily at 00h UTC. These forecasts are compared to the NR.

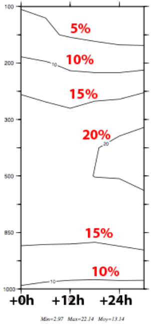
Experiments	Observing system in DAS
CTRL	obs of the real AROME DAS
CTRL + IRS	same as CTRL + IRS
CTRL + MWGEO$_{2K}$	same as CTRL + MWGEO with σ_o of 2K
CTRL + MWGEO$_{5K}$	same as CTRL + MWGEO with σ_o of 5K
CTRL + IRS + MWGEO$_{2K}$	same as CTRL + IRS + MWGEO with σ_o of 2K
CTRL + IRS + MWGEO$_{5K}$	same as CTRL + IRS + MWGEO with σ_o of 5K

Forecast errors on Relative Humidity in the CTRL

CTRL experiment vs NR

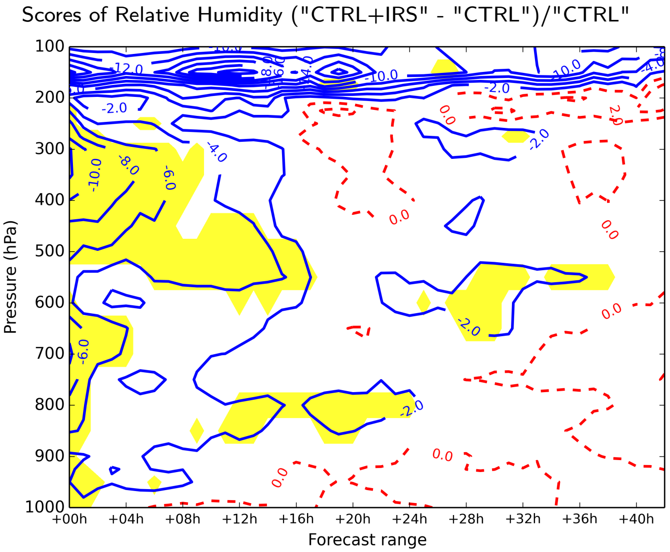


Oper vs ECMWF



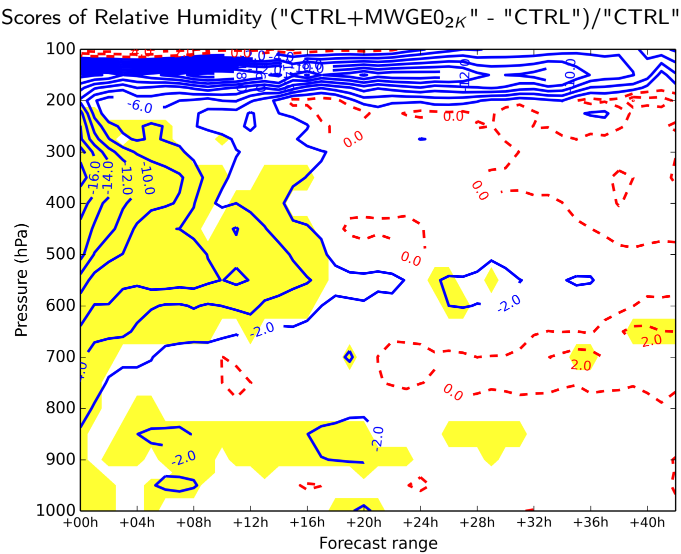
Forecast errors being similar to the ones of the operational forecasts of AROME, it gives us confidence on the realism of the OSSE framework.

IRS on top of the 2015 Observing System



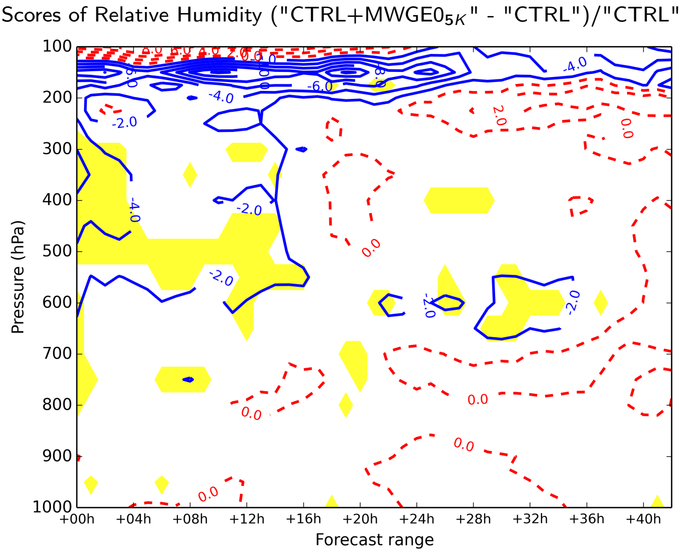
Yellow areas correspond to differences that are significant at the 99% confidence level.

$MWGE0_{2K}$ on top of the 2015 Observing System



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

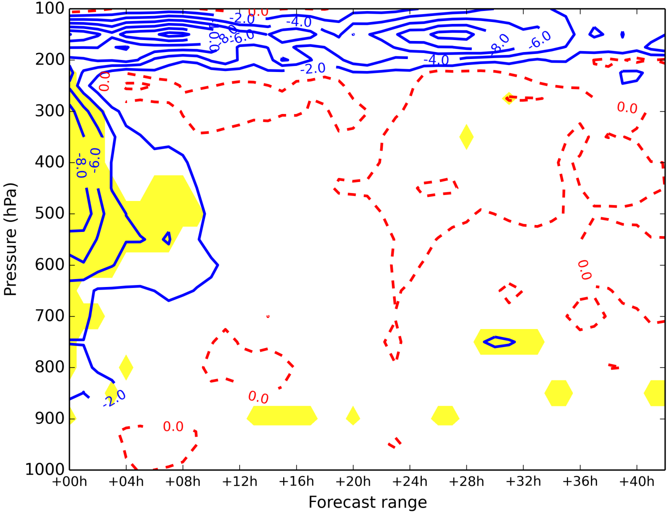
$MWGE0_{5K}$ on top of the 2015 Observing System



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

$MWGE0_{2K}$ on top of the 2021 Observing System

Score on Relative Humidity ("CTRL + IRS + $MWGEO_{2K}$" - "CTRL+IRS")/"CTRL+IRS"



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

Conclusions :

The main findings of these OSSEs are as follows :

- Improvements on Relative Humidity forecasts can be expected up to +15h when either an accurate MWGEO or an IRS-like instrument is assimilated.
- The results suggest that, when MTG will be operational, only an accurate MWGEO (e.g. σ_o of 2K) could bring some added value and for short forecasts ranges (up to +3h/+6h), due to the lowest cloud contamination of microwave observations.

Conclusions :

The main findings of these OSSEs are as follows :

- Improvements on Relative Humidity forecasts can be expected up to +15h when either an accurate MWGEO or an IRS-like instrument is assimilated.
- The results suggest that, when MTG will be operational, only an accurate MWGEO (e.g. σ_o of 2K) could bring some added value and for short forecasts ranges (up to +3h/+6h), due to the lowest cloud contamination of microwave observations.

Perspectives :

- Only 25 water vapour IRS channels have been used, assimilating more channels is likely to increase IRS impact.
- These results are based on 15 days long 1-hour cycle experiments, we are currently working on extending them to 1-month + performing the same analysis over 1-month in Winter.
- Plans are made to revisit these results with an all-sky assimilation framework.