Propagating non linearities of the observation operator for microwave radiances within an all-sky data assimilation system

Mary Borderies[1], *Marylis Barreyat*[1], *Philippe Chambon*[1], *Loïk Berre*[1], *Patrick Moll*[1], *Nicolas Sasso*[1]

[1] CNRM, Météo-France/CNRS, Toulouse, France

mary.borderies@meteo.fr

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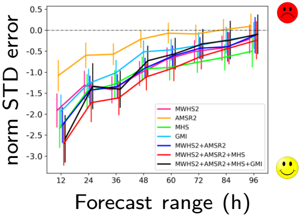
Assimilation of passive microwave observations in the global NWP model ARPEGE for the 2023 parallel suite (cy48 t1)

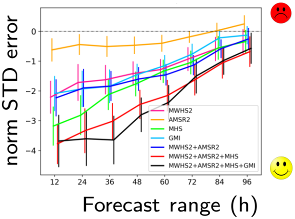
Transition from the (1D-Bayesian + 4DVar) route to the direct allsky assimilation route of ECMWF (Geer et al. 2014) for MHS, MWHS-2, GMI and AMSR-2 :

- Standard deviation on forecast errors (forecasts - ECMWF analyses) for a 2-month period (20210801 - 20210931) at 925 hPa for relative humidity :

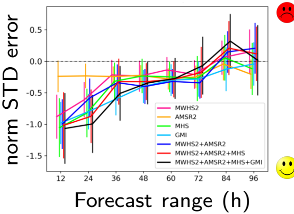
NORTH20



TROPICS



SOUTH20



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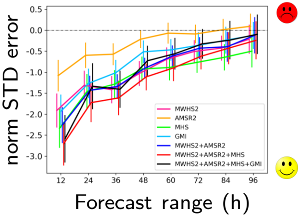

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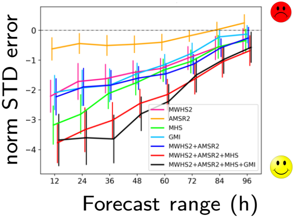

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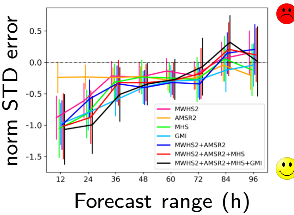


Significant positive impact on the deterministic model.

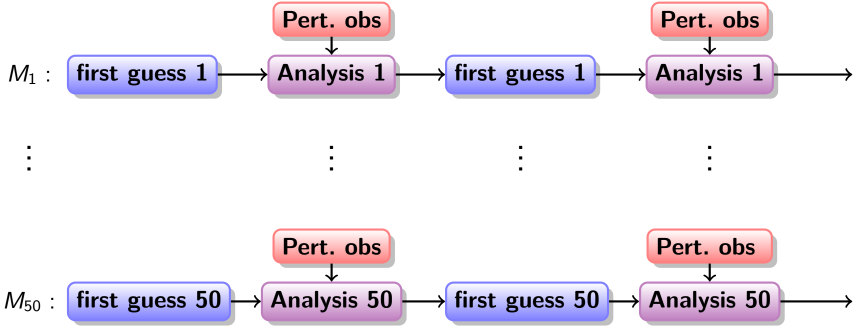
What is the impact on our EDA system ?

What is the impact of cloudy passive microwave observations in the Ensemble Data Assimilation system of ARPEGE ?

1. The experimental setup
2. Impact of cloudy observations on the ensemble spread
3. Experiments to take into account radiative transfert uncertainties within the EDA

The Ensemble Data Assimilation system of Météo-France (AEARP)

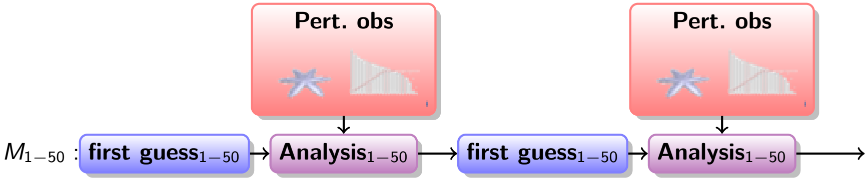
- Operational at MF since July 2008.
- Ensemble of **50 members** with perturbed **observations** running a 4D-Var at 100 km.
- Lower horizontal resolution (40 km) than the deterministic (5 to 25 km), 6h cycling.



Experimental setup

Use of RTTOV-SCATT v12 to simulate the brightness temperatures

- Single Scattering Properties specified using the Sector Snowflake shape of the Liu (2008) database.



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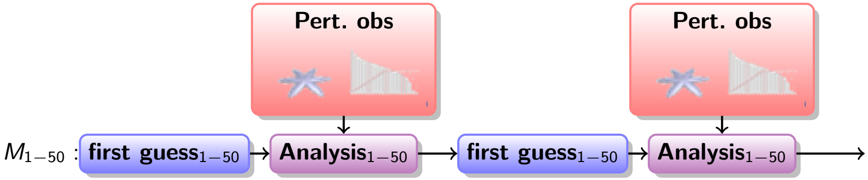

Experiments for a 1-month period (27 July to 31 August 2022) :

- REF : Operational observing system without MHS, MWHS-2, GMI and AMSR-2 ;
- clearsky : REF + MHS, MWHS-2, GMI and AMSR-2 in clearsky conditions within the allsky route ;
- allsky : REF + MHS, MWHS-2, GMI and AMSR-2 in clear and cloudy situations.

Impact of allsky observations on the ensemble spread ratio

$$I = \frac{\sigma_{ens}^{xp} - \sigma_{ens}^{REF}}{\sigma_{ens}^{REF}}$$

Expectation : If $I < 0 \Rightarrow$ the EDA spread is reduced $\Rightarrow$ positive impact (Tan et al. 2007, Harnisch et al. 2013, Lean et al. 2022)

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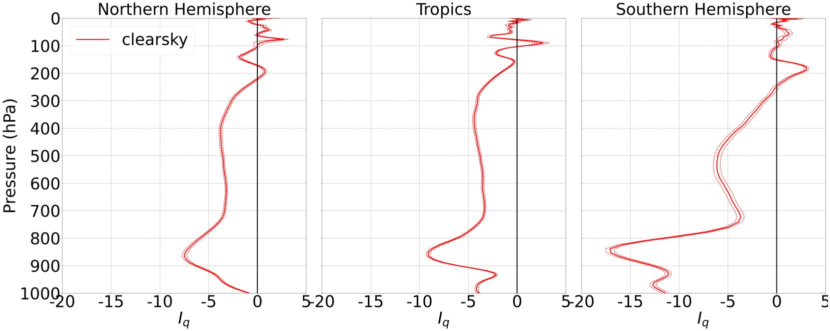

- Clearsky MW observations reduce the spread.

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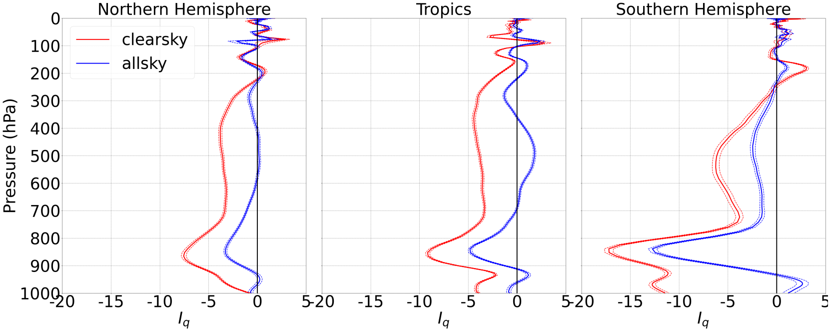

- Clearsky MW observations reduce the spread.
- *Adding the clouds attenuates this spread reduction $\Rightarrow$ Is this a good thing ?*

New metric using a reference spread : $\beta_{clearsky} = \frac{\sigma_{ens}^{clearsky}}{\sigma_{clim}^{clearsky}}$

- The reference spread $\sigma_{clim}^{clearsky}$ is calculated using monthly optimally diagnostics (Desroziers et al. 2005, Rabier et al. 2005) and can be seen as a target to reach.
- $\beta_{clearsky} > 1 \Rightarrow$ we would like to $\searrow$ the ensemble spread
- $\beta_{clearsky} < 1 \Rightarrow$ we would like to $\nearrow$ the ensemble spread

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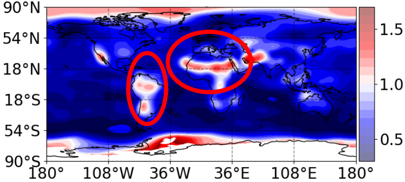
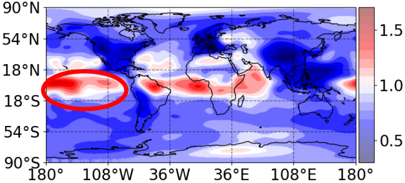
$\beta_{clearsky}$ at 950 hPa for q



$\beta_{clearsky}$ at 450 hPa for u



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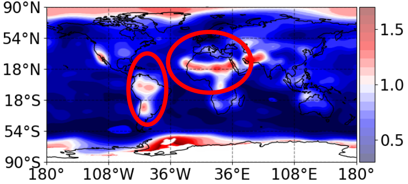

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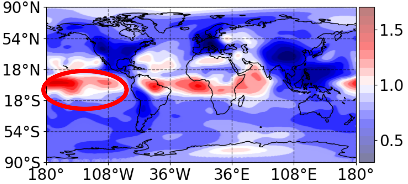
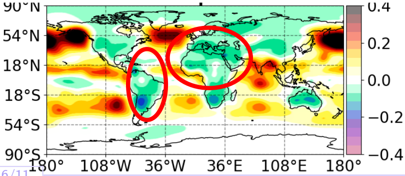
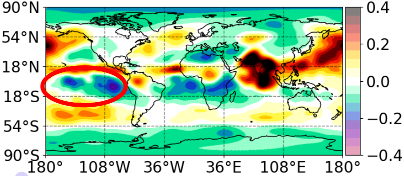


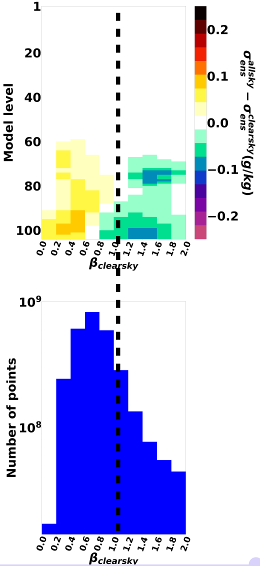
$\sigma_{ens}^{allsky} - \sigma_{ens}^{clearsky}$ at 950 hPa for q



$\sigma_{ens}^{allsky} - \sigma_{ens}^{clearsky}$ at 450 hPa for u



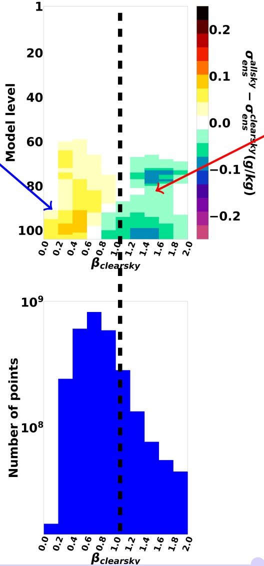
Comparison between the ensemble spread difference $\sigma_{ens}^{allsky} - \sigma_{ens}^{clearsky}$ and a reference spread $\beta_{clearsky}$ at a global scale



Comparison between the ensemble spread difference $\sigma_{ens}^{allsky} - \sigma_{ens}^{clearsky}$ and a reference spread $\beta_{clearsky}$ at a global scale

$\beta_{Clearsky} < 1$:

- the clearsky EDA is under-dispersive ;
- Cloudy observations $\nearrow \sigma^{ens}$



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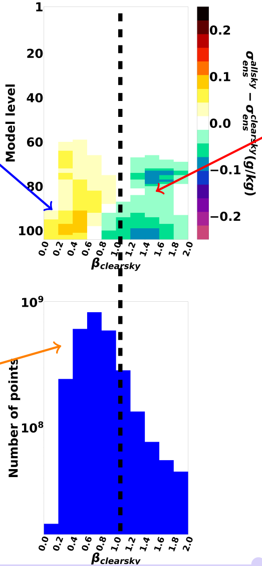


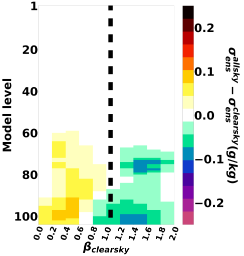
$\beta_{Clearsky} > 1$:

- the clearsky EDA is over-dispersive ;
- Cloudy observations $\searrow \sigma^{ens}$

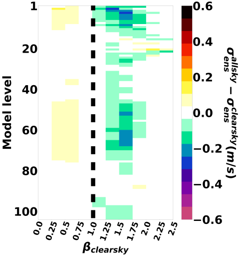
- The AEARP is mostly under-dispersive.

Comparison between the ensemble spread difference $\sigma_{ens}^{allsky} - \sigma_{ens}^{clearsky}$ and a reference spread $\beta_{clearsky}$ at a global scale

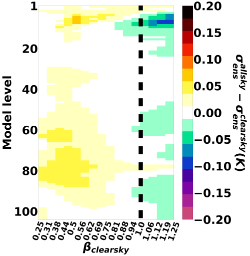
Specific humidity (g/kg)



Zonal wind (m/s)



Temperature (K)



The assimilation of cloudy microwave observations :

- increases the spread in areas in which the ensemble spread was under-dispersive ;
- decreases the spread in areas in which the ensemble spread was over-dispersive.

Experiments to take into account radiative transfert uncertainties within the EDA

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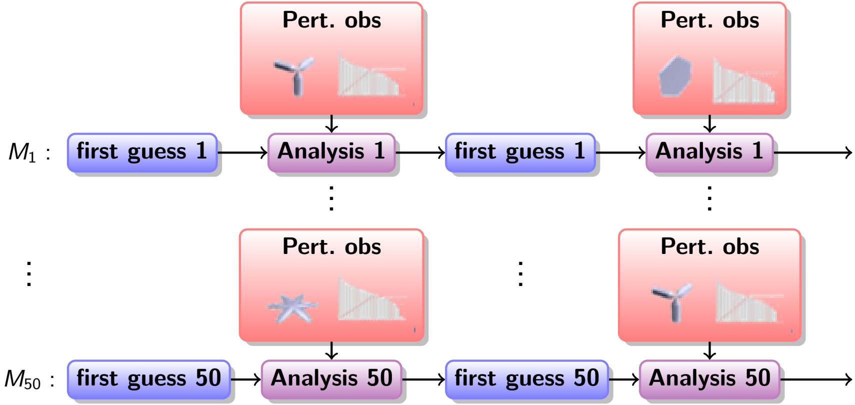
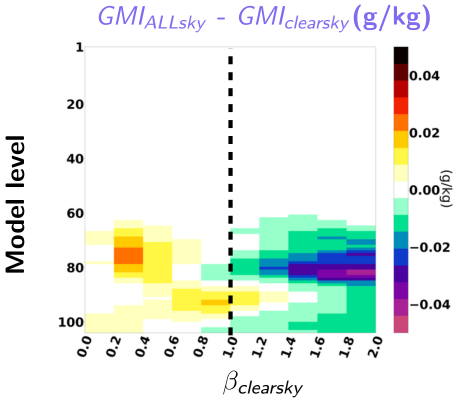
The allsky-multi experiment : Random selection (1 out of 3) of the Single Scattering Properties for each member at each assimilation time.



Impact of the assimilation of GMI using the allsky-multi framework for 3-month period (August 2021 - October 2021)



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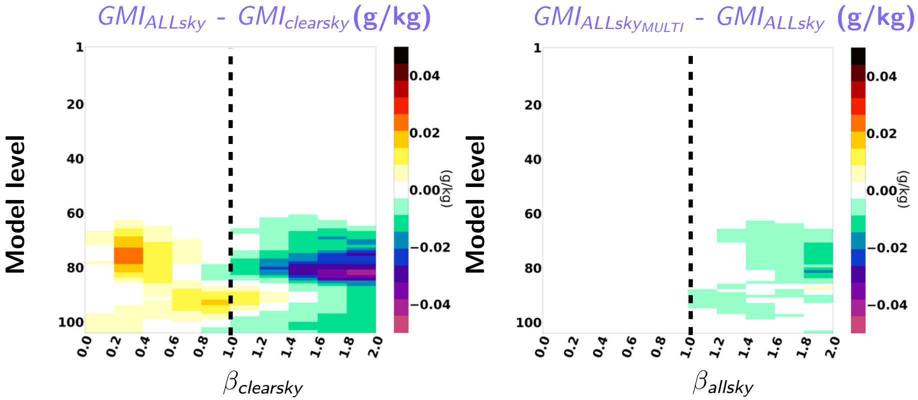

- The impact of the random selection of several SSPs is 5 to 10 times smaller than when adding cloudy observations ;
- The $GMI_{ALLsky_{MULTI}}$ ensemble spread was reduced in areas where the GMI_{ALLsky} experiment was over-dispersive.

Summary

The transition to the allsky assimilation route improves the deterministic global model

The impact of cloudy observations on the EDA spread :

- They have a combined effect of increasing and decreasing the spread in areas where it is needed ;
- The use of multiple SSP assumptions in the EDA seems to further reduce the spread ;
- The use of a B-matrix built using multiple scattering assumptions improves the deterministic model ARPEGE (not shown here).

Perspective :

- Test the EDA-MULTI experiment using multiple SSP assumptions for the 4 sensors (MWHS-2, GMI, AMSR-2, MHS).

Thank you for your attention

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