Investigating the impact of the SAPHIR microwave rainy and cloudy observations within the AROME regional model

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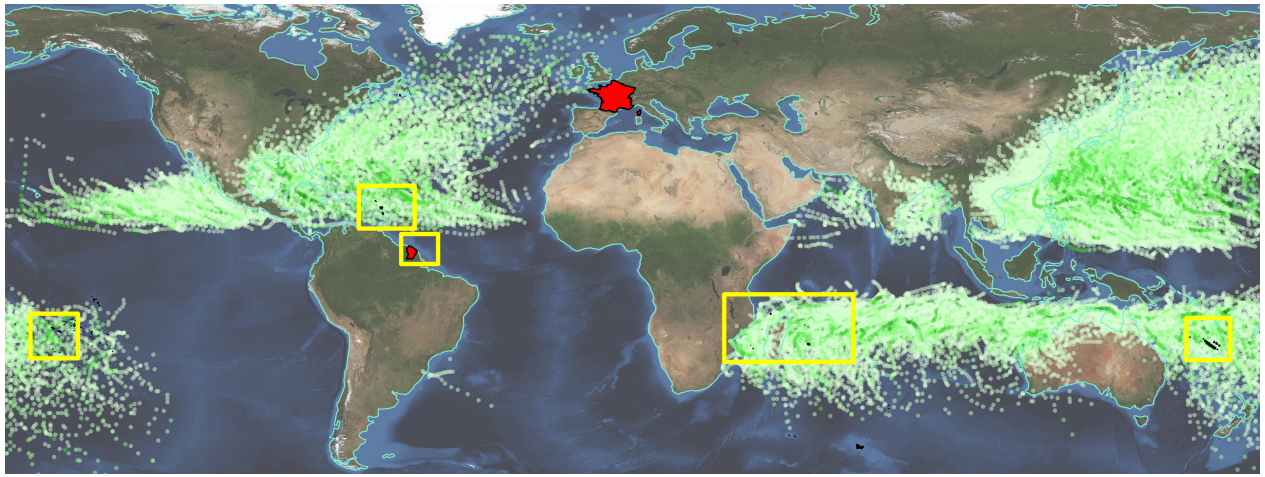
Introduction



AROME characteristics

Over Western Europe :

- In operations since 2008, now running at 1.3km res., with 90 vertical levels
- 3D-Var with 1h assimilation cycles

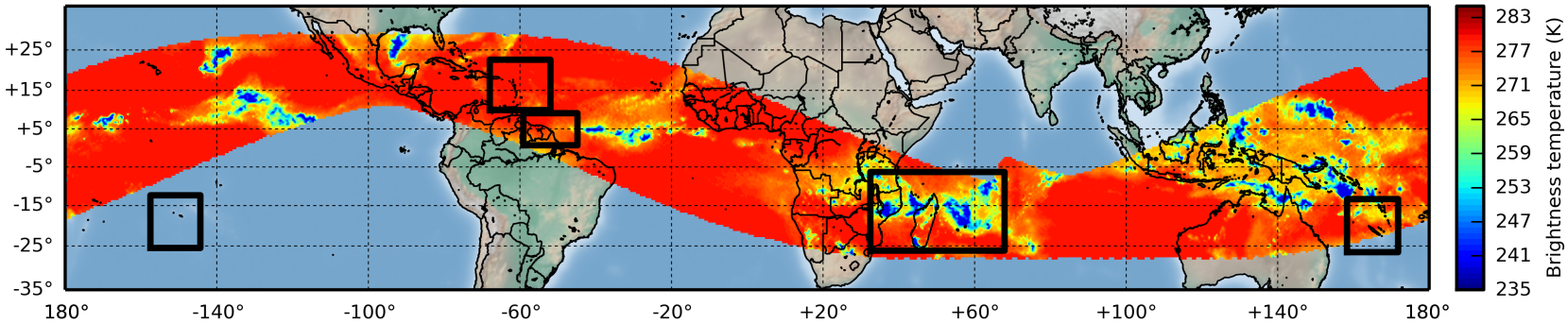
In the Tropics :

- In replacement of ALADIN models
- Soon in operations over 5 domains, at 2.5km res., with 90 vertical levels
- No 3D-Var yet, cold start from IFS

$\Rightarrow$ **Work on data assimilation in research mode for the Tropical version of AROME, focus on microwave cloudy and rainy observations**

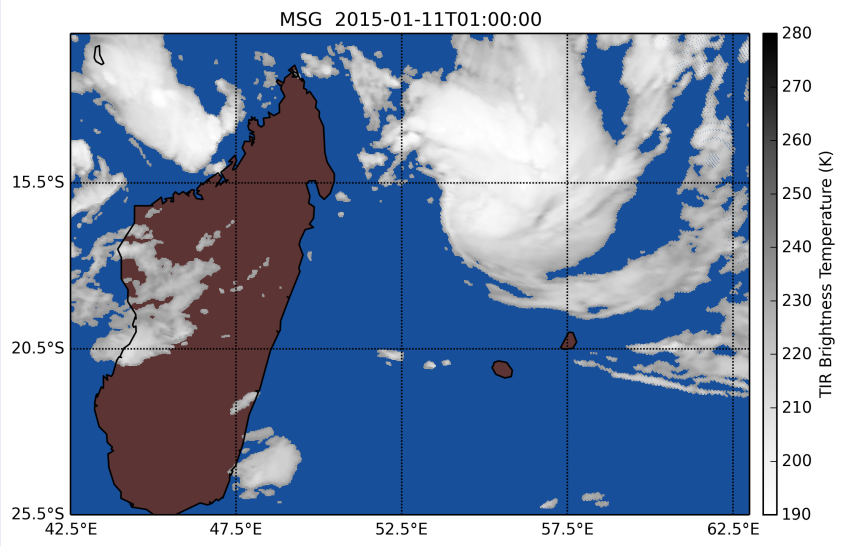
Introduction

The low inclined orbit of the Megha-Tropiques satellite provides a good coverage of the AROME domains. It's sounder SAPHIR (6 channels around 183.31GHz) is already assimilated operationally in MF global and regional models, in clear sky only.

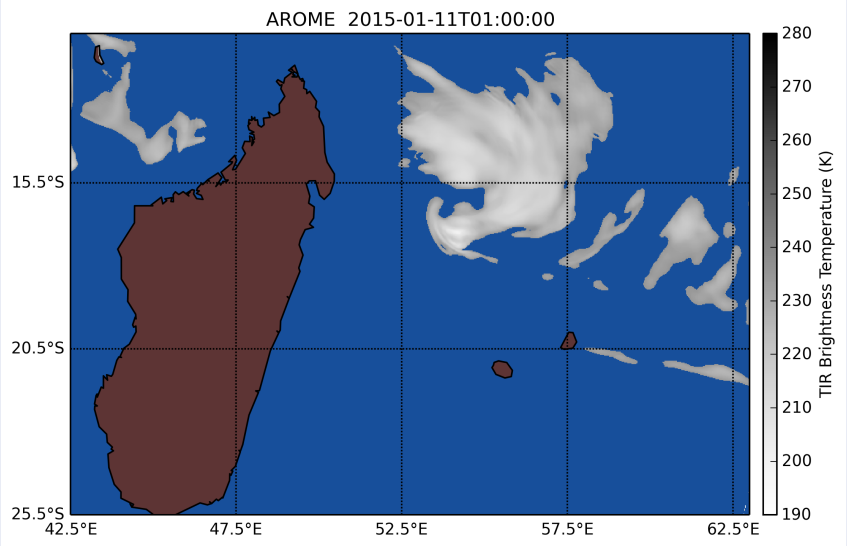


Period of interest : cyclonic period January/February 2015

MSG (10.8μm channel)



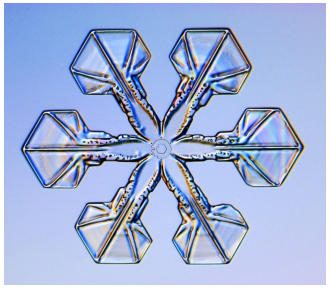
AROME (10.8μm simulations)



Outline

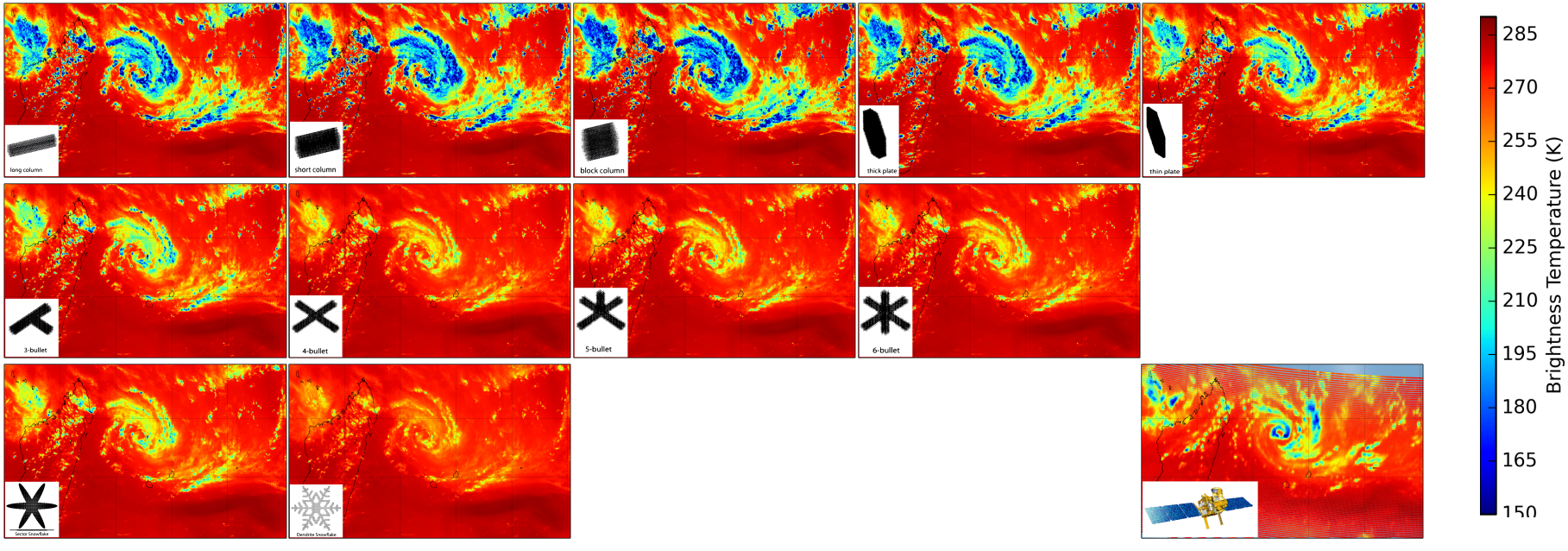
1. Introduction
2. Radiative transfer model
   - RTTOV-SCATT
   - Principal component analysis
3. 1D framework
   - Definition
   - Example
4. Verification
   - At 183.31 GHz
   - With radar observations
5. Conclusion and perspectives

Simulations at 183.31 GHz using RTTOV 11 - SCATT



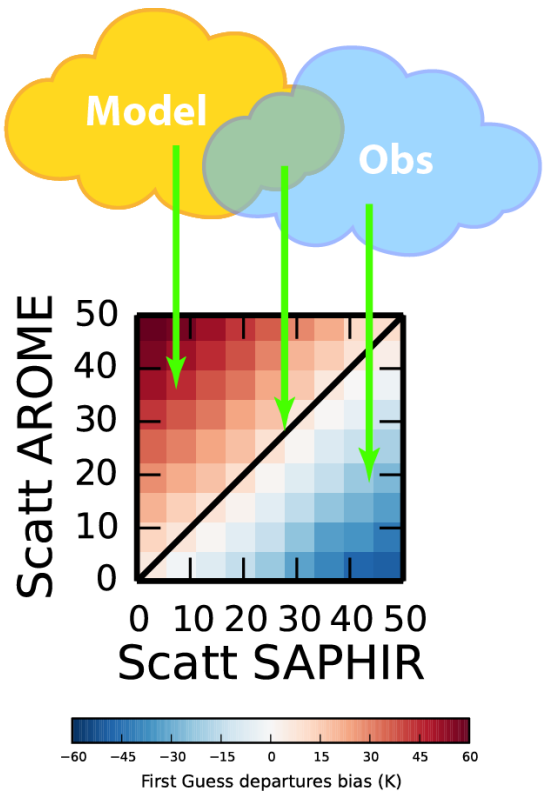
- Mie tables computed using Liu (2008) DDA database.
- PSD for snow : tropical version of Field et al. (2007)
- Sensitivity study to the particle shapes available within RTTOV SCATT (Geer and Baordo, 2014)

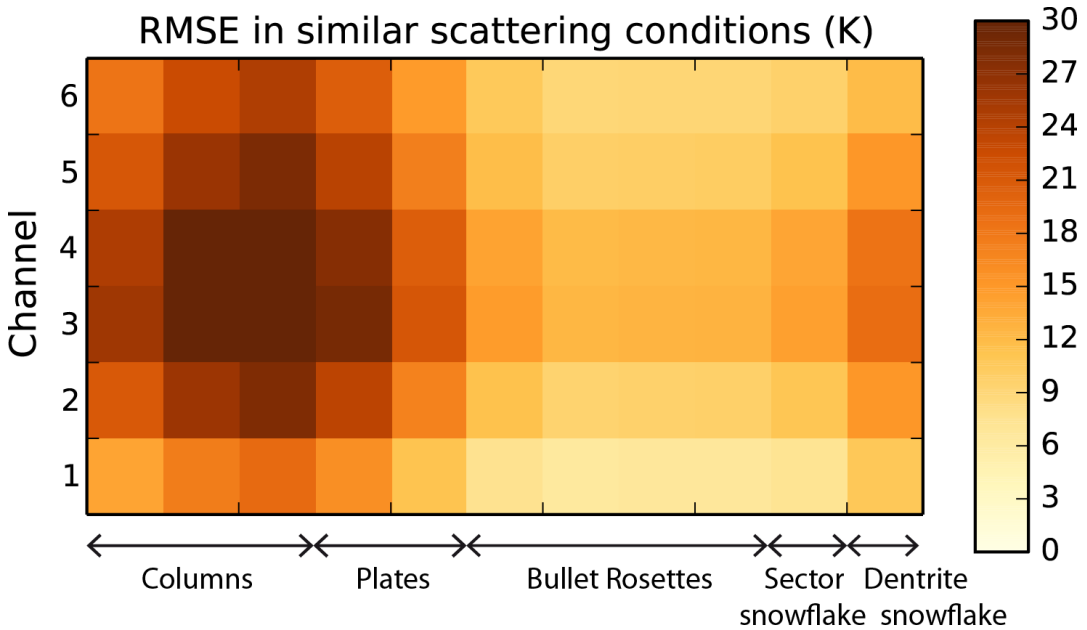
Example of simulations for SAPHIR channel 6 (183.31 ± 11GHz) :



RTTOV-SCATT

A simple scattering index can be used to categorize meteorological scenes and extract bias information in similar scattering conditions for both the model and the observations

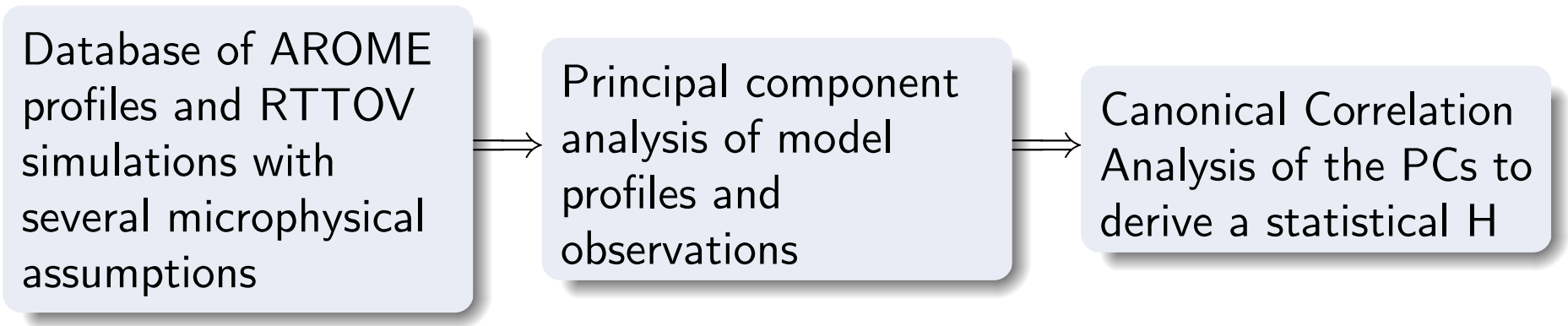




"Best candidate particles" for AROME snow

Bullet rosettes seem to have microphysical properties that provide the best fit between AROME and SAPHIR. Nonetheless, a large spread exists among bullet rosettes simulations (up to 60K).

Development of a statistical observation operator :
A statistical observation operator is currently developed, it aims at taking into account various microphysical assumptions to derive a brightness temperature mean. This approach is based on a principal component analysis (Haddad et al., 2015).



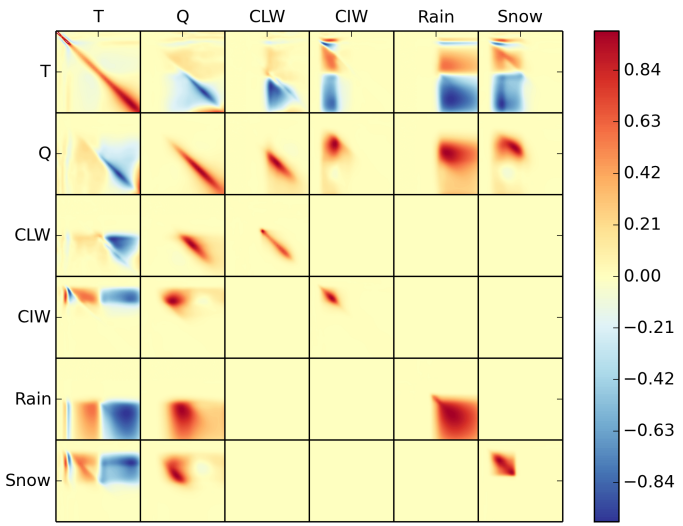
Tests of the statistical H in a 1D framework :

$x_a = x_b + K.(y - H[x_b])$
with $K = B.H^T.(H.B.H^T + R)^{-1}$

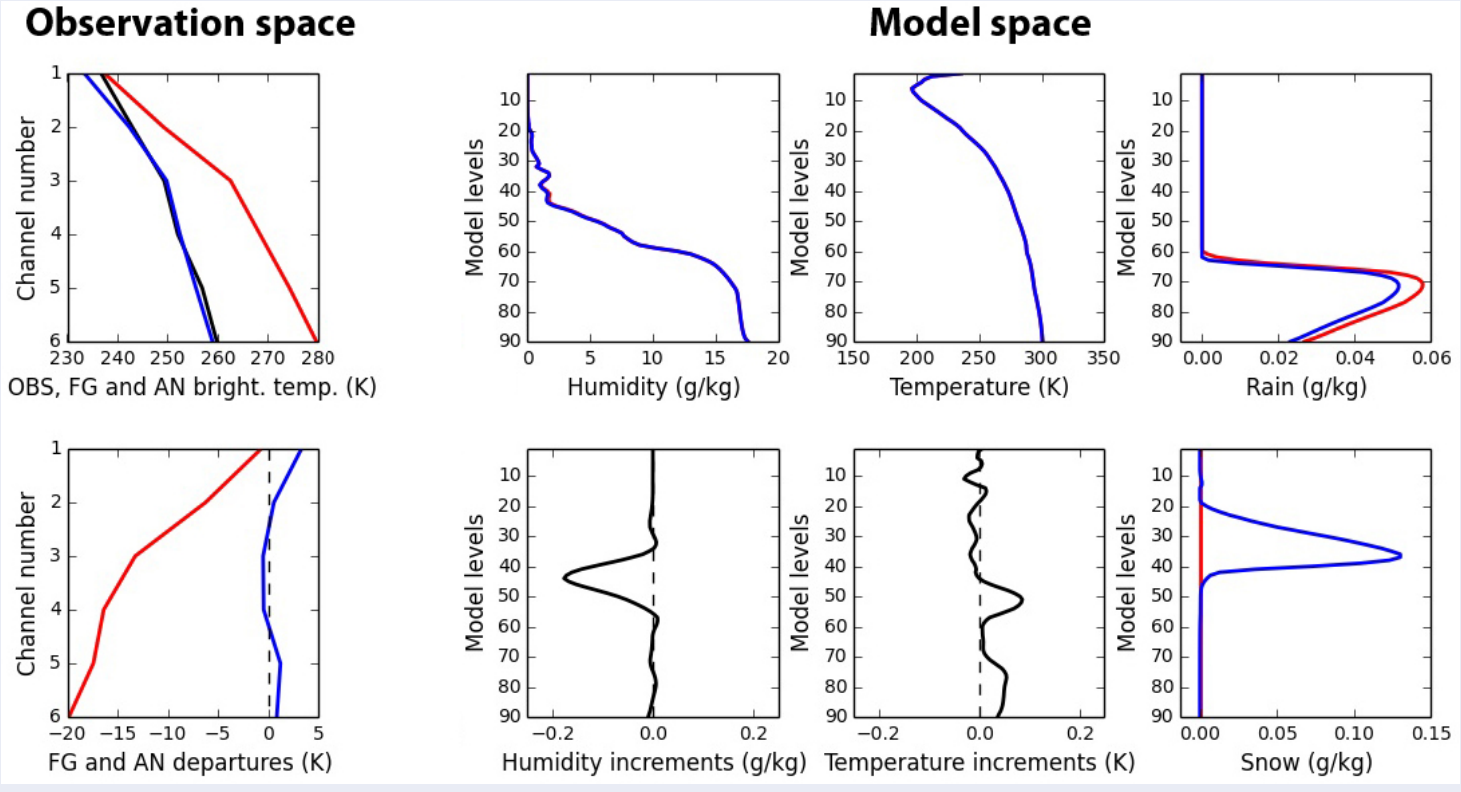
- R : diagonal matrix with a first set of σ_o derived from an iterative a-posteriori diagnostic

$$\begin{pmatrix} (6.5K)^2 & 0 & \cdots & \cdots & \cdots & 0 \\ 0 & (6.5K)^2 & \ddots & \ddots & \ddots & \vdots \\ \vdots & \ddots & (6.5K)^2 & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & (7.5K)^2 & \ddots & \vdots \\ \vdots & \ddots & \ddots & \ddots & (10K)^2 & 0 \\ 0 & \cdots & \cdots & \cdots & 0 & (14K)^2 \end{pmatrix}$$

- B : multivariate background errors vertical covariances modeled over the Indian Ocean for T, Q and hydrometeors



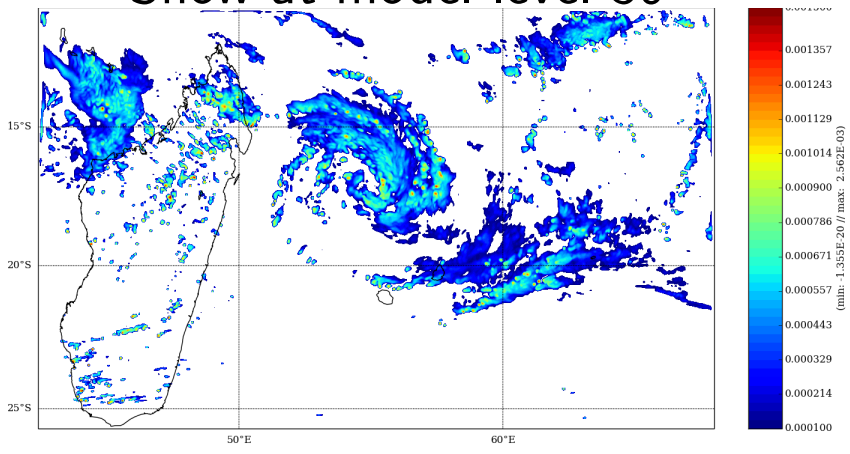
Example :



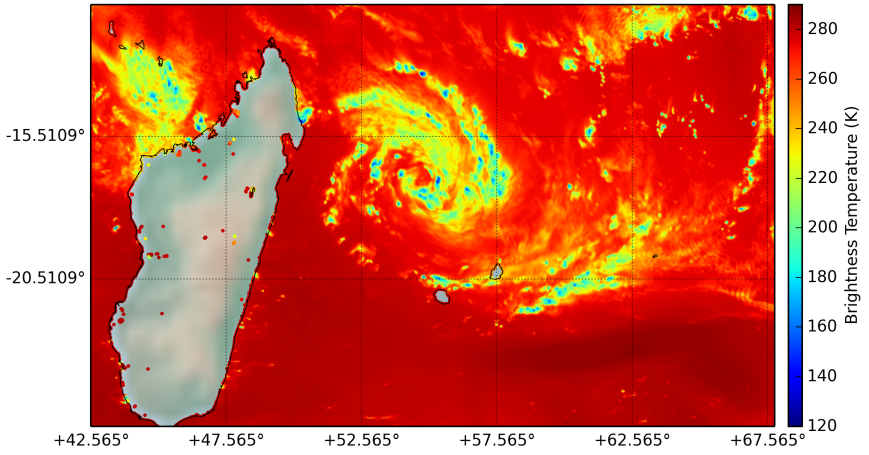
First Guess, Observations, Analysis

In this example, the first guess is too warm with respect to SAPHIR observations. The analysis increments lead to simulated brightness temperatures more consistent with the observations (using the statistical H).

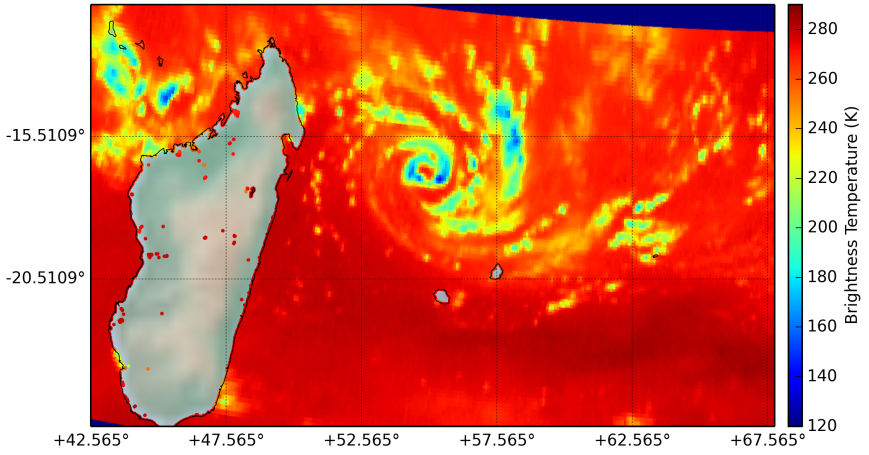
Snow at model level 30



AROME Channel 6



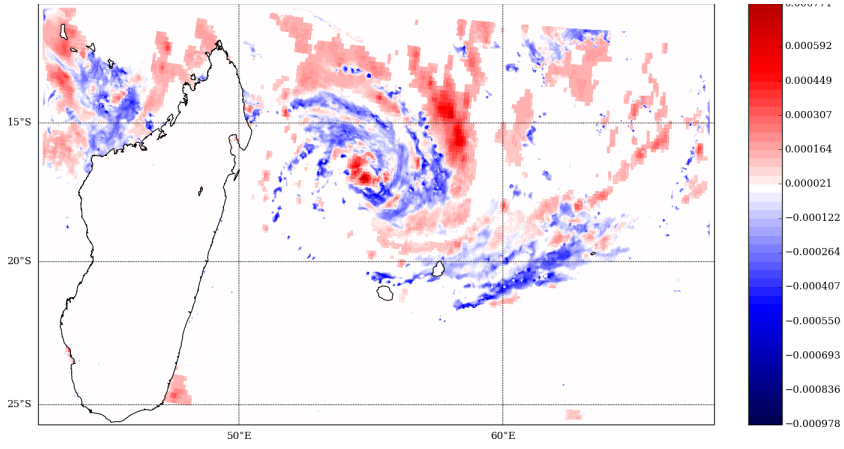
SAPHIR Channel 6



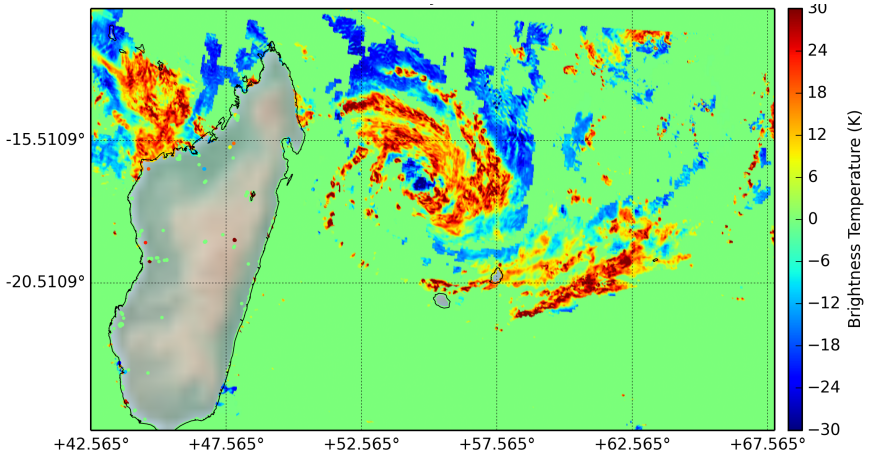
Verification of consistency between the statistical H and RTTOV-SCATT :

- The 1D framework was applied to Cyclone Bansi (Jan. 2015)
- RTTOV-SCATT simulations are computed with both first guess and analyzed profiles.

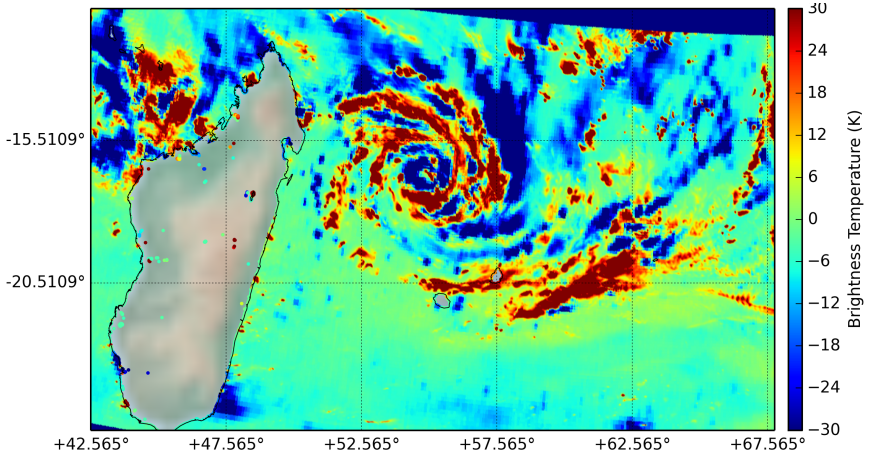
Snow increments at model level 30



(Analysis - First Guess) Channel 6



(Obs - First Guess) Channel 6



Results :

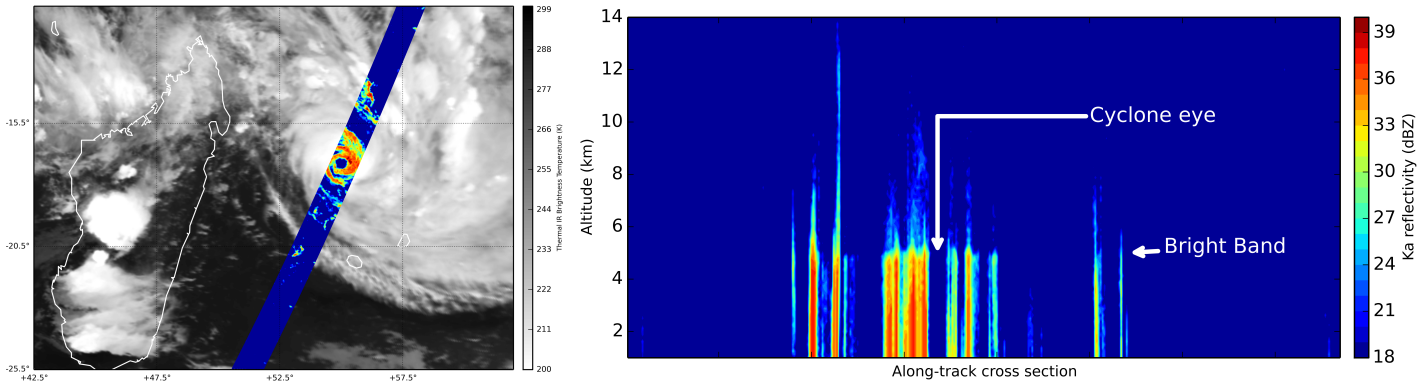
- Reduction of departures up to 20%
⇒consistent behavior of the statistical H
- Larger improvements when obs. are warmer than the model.

	S6	S5	S4	S3	S2
Cold Guess	23%	21%	18%	14%	6%
Cold OBS	15%	14%	11%	9%	5%
All OBS	20%	19%	16%	13%	6%

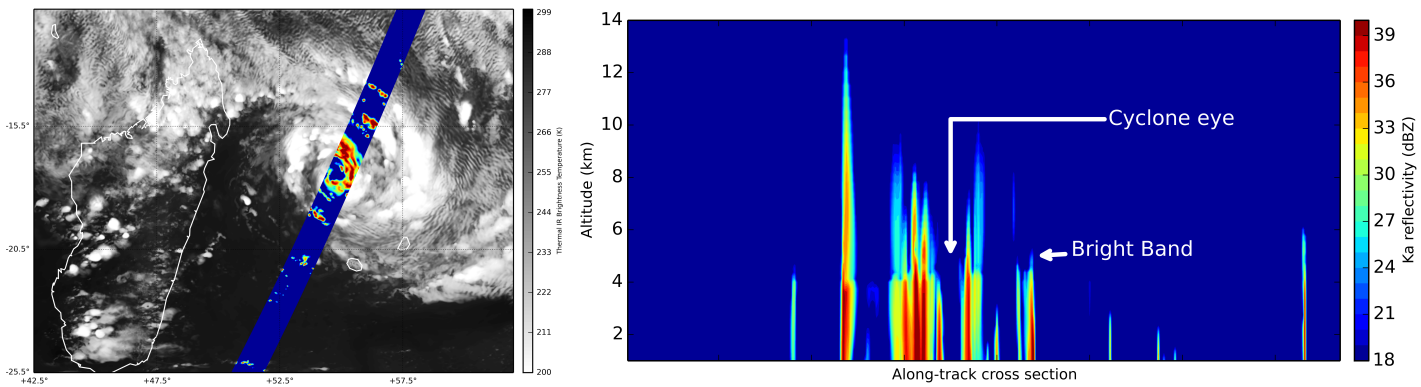
Verification of analyzed profiles with independent radar data :

- Comparison between reflectivity profiles from the GPM Dual frequency Precipitation Radar, first guess and analyzed profiles over 1.5 months
- SDSU observation operator for simulating reflectivities (Matsui et al. 2014)

DPR



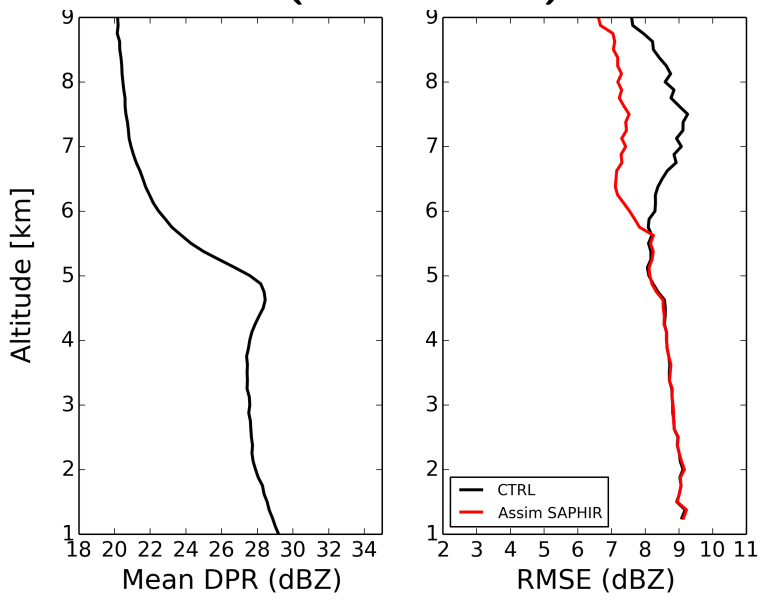
AROME



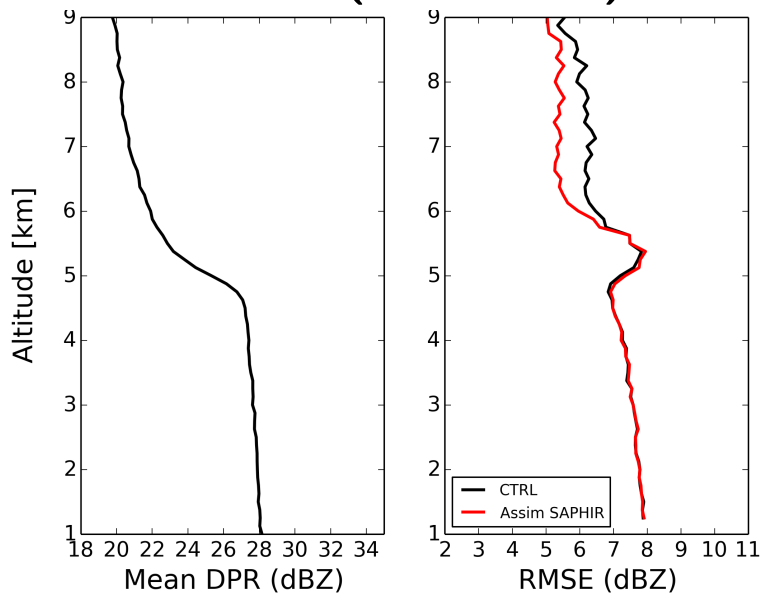
Verification of analyzed profiles with independent radar data :

- RMS Error between observations and simulations for the **FIRST GUESS** and the ANALYZED profiles over the 1.5 months of collocated data.

Ku (13.6 GHz)



Ka (35.5 GHz)



Results :

- improvement of simulated reflectivities above the bright band (snow analysis)
- consistent with SAPHIR weighting functions in cloudy and rainy sky

Conclusions

- RTTOV-SCATT simulations of SAPHIR channels have been performed with the AROME model over the Indian ocean.
- Several particle shapes seem to provide similar fits to SAPHIR observations (3-4-5-6 bullet rosettes, sector snowflake)
- The statistical observation operator behaves consistently with RTTOV-SCATT
- The 1D framework have been used over several thousands of profiles and seem to lead to positive impacts with respect to independent data like the GPM Core Dual frequency Precipitation Radar.

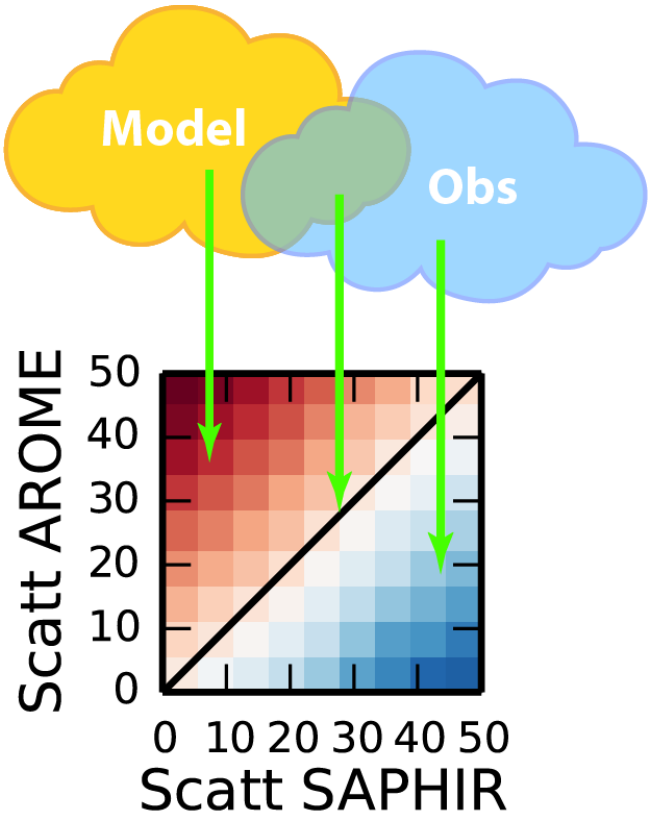
Perspectives

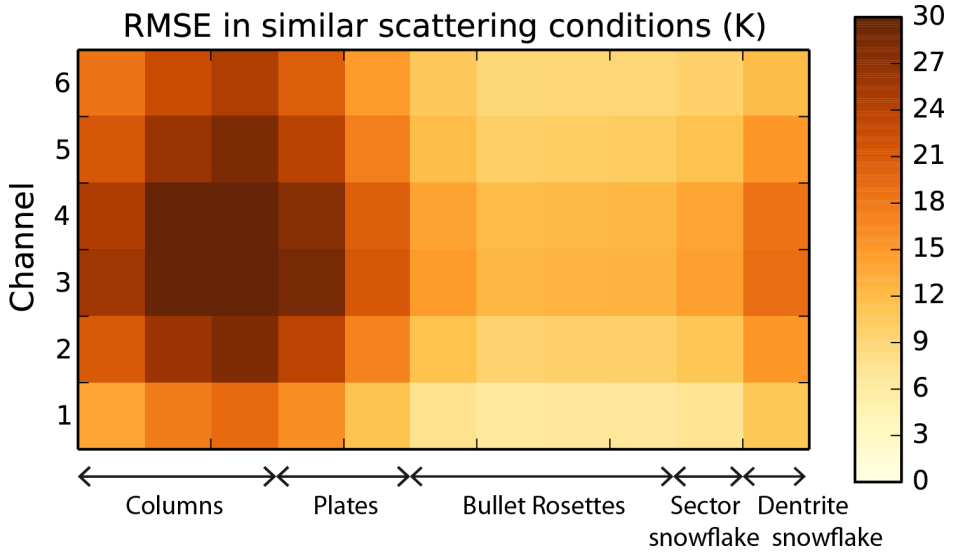
- Continue the development of the statistical H, exploring the use of several microphysical assumptions within the database.
- Performing analyses and forecasts with a 3D-Var once set up for AROME Indian Ocean.

Thank you !

(Courtesy of CNES)

A simple scattering index can be used to categorize meteorological scenes and extract bias information in similar scattering conditions for both the model and the observations





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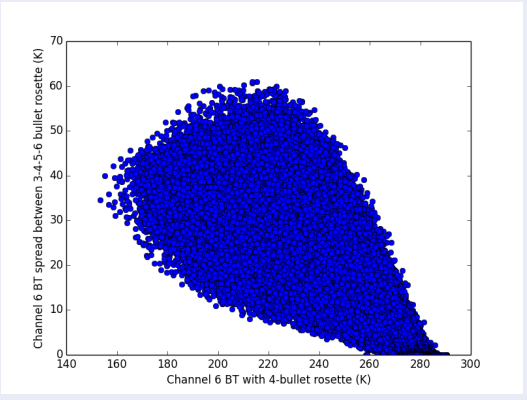


A principal component-based observation operator is currently developed, based on Haddad et al. (2015). It aims at taking into account various microphysical assumptions to derive a brightness temperature mean.

Database of AROME profiles and RTTOV simulations with several microphysical assumptions

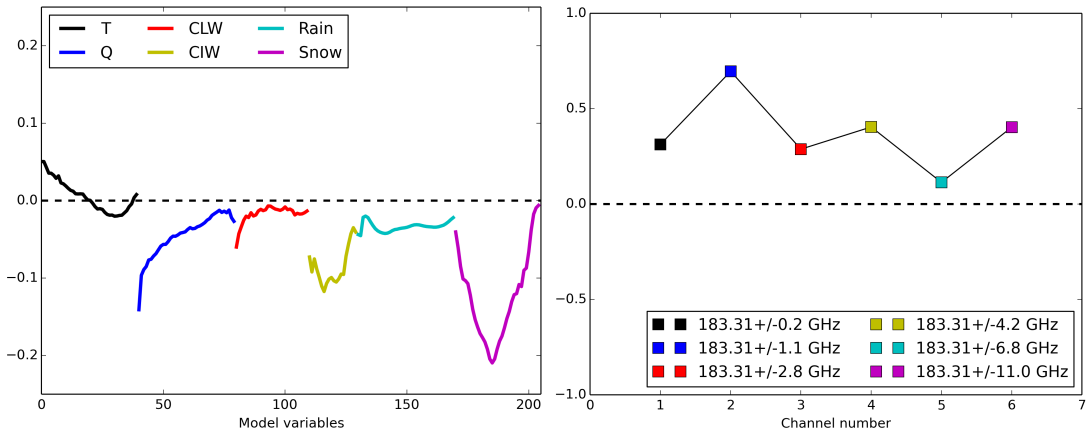
⟹

Principal component analysis of model profiles and observations

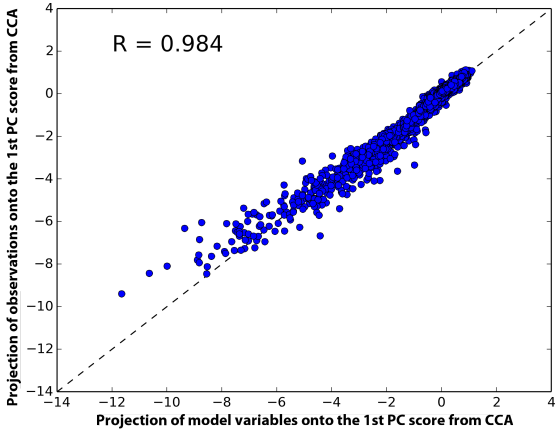
⟹

Canonical Correlation Analysis of the PCs to derive a statistical H

Example of PC scores :

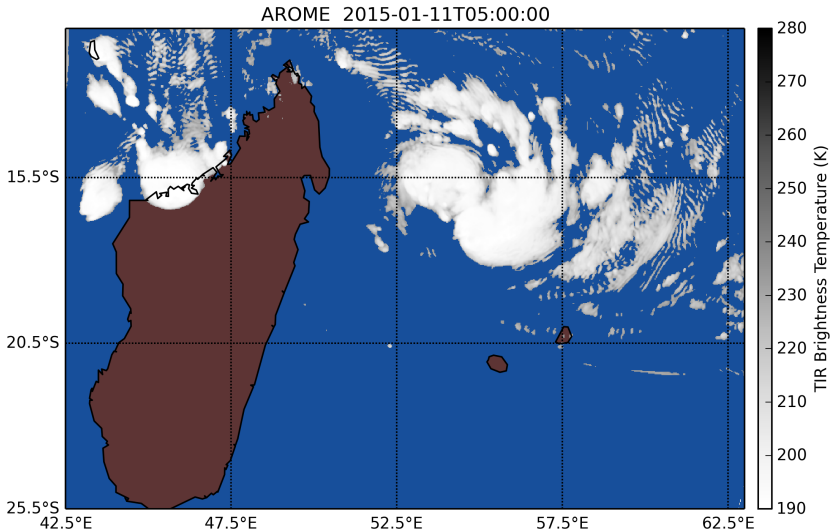


CCA : link between the 2 PC scores



Forecast verification in the observation space :

A first forecast have been produced for cyclone Bansi. Results of the forecast are then compared with Meteosat data.



Results

A slight improvement of the departures standard deviation, up to 2.5%, was found during the first 5 hours of the forecast.

Reduction of Standard deviation between a CTRL and the SAPHIR assimilation experiments, with respect to Meteosat 10.8μm observations