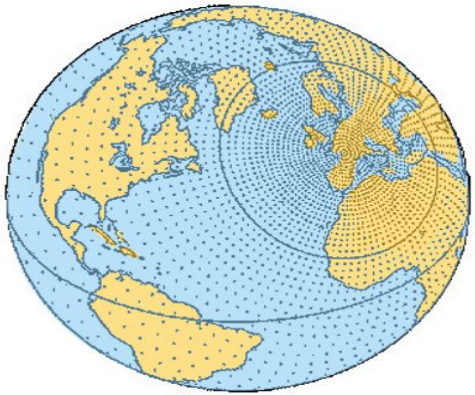
Towards the improvement of the assimilation of cloudy IASI observations in Numerical Weather Prediction.

Imane Farouk, Nadia Fourrié and Vincent Guidard
CNRM/ Météo-France & CNRS
Imane.farouk@meteo.fr

ITSC-XXI: Darmstadtium, Darmstadt,
Germany 29 November - 5 December 2017

Context of the study

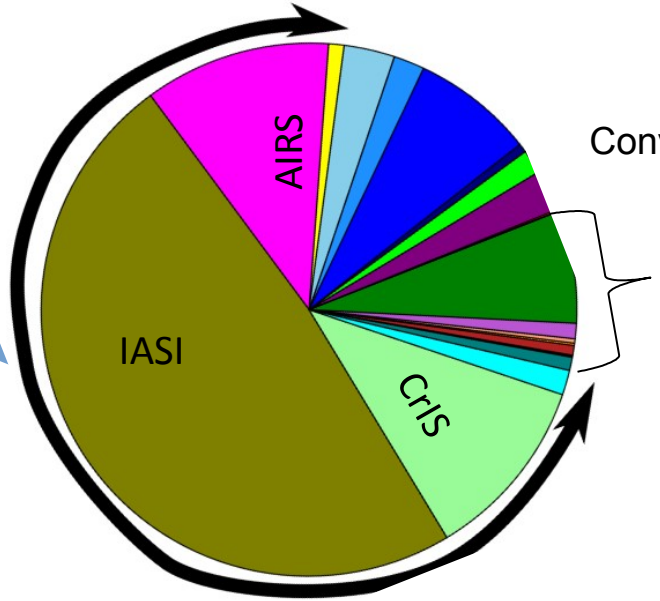
ARPEGE



70% of infrared hyperspectral observations

Initialization

Observation system

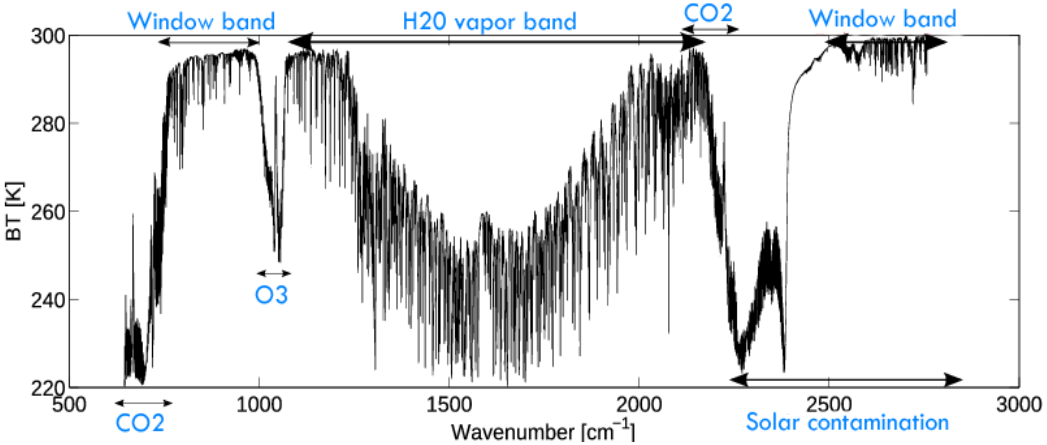


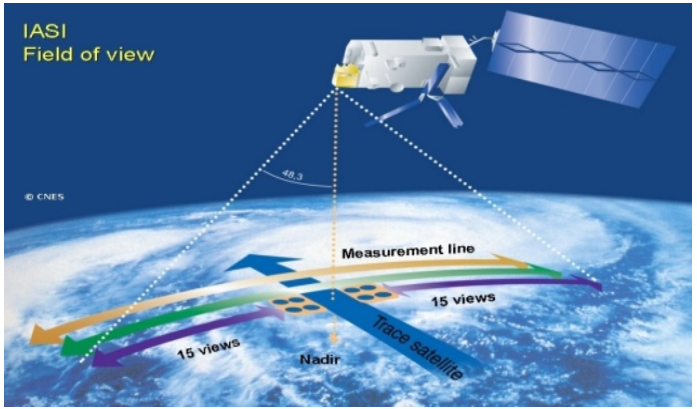
Conventional observations

Context of the study

Observation system : IASI/MetOp

- Very high spectral resolution (0.25 cm-1),
- Measures infrared radiation in 8461 channels,
- Daily coverage,
- Pixel = 12 km diameter at the nadir.





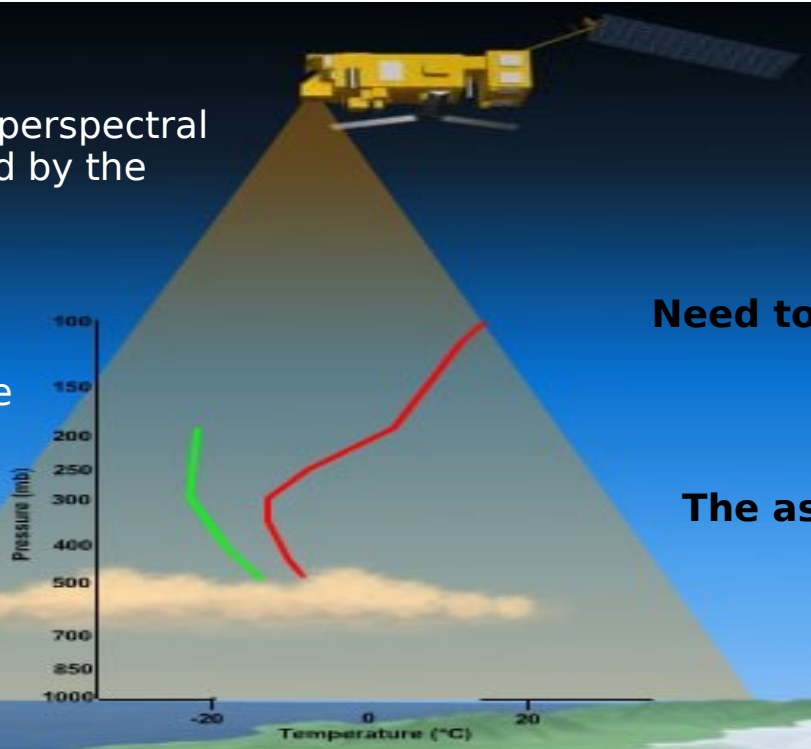
➢ **Informations:**

Temperature, moisture, ozone, trace gases ....

Motivations

Why assimilate cloudy IASI radiances?

- 80% of the pixels of the hyperspectral sounders (IASI) are affected by the presence of clouds
- **Sensitive meteorologically zones** strongly correlated with the presence of clouds (McNally 2002, Fourrié and Rabier 2004).



Need to constrain analysis in cloudy areas

The assimilation of cloudy radiances

Objectives

- **Increase the amount of infrared data assimilated in the global ARPEGE forecast model.**

- New developments to better assimilate the IASI cloudy radiances in the model: use of **cloud microphysics** to simulate and assimilate the data;

- The identification of **homogeneous situations** in cloudy sky potentially usable in the data assimilation.

Methodology

Cloudy sky radiative transfer model

From the model

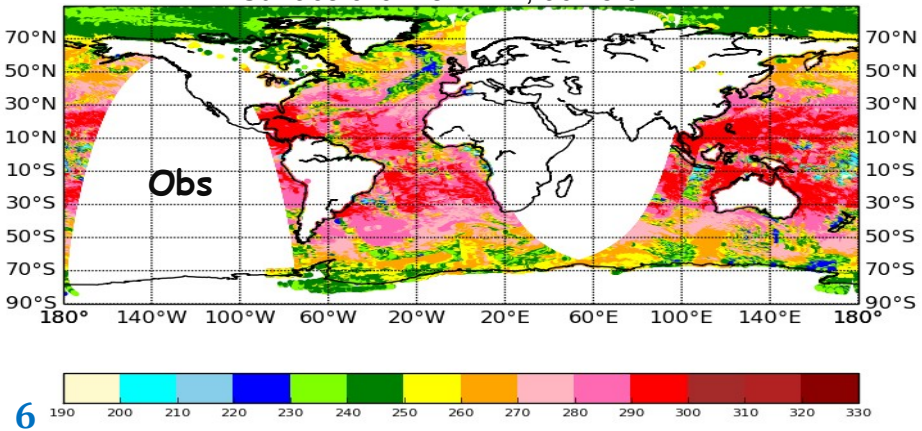
- Temperature profiles
- Moisture profiles
- Surface data

Radiative Transfer Model in cloudy sky RTTOV-CLD (Hocking 2010)

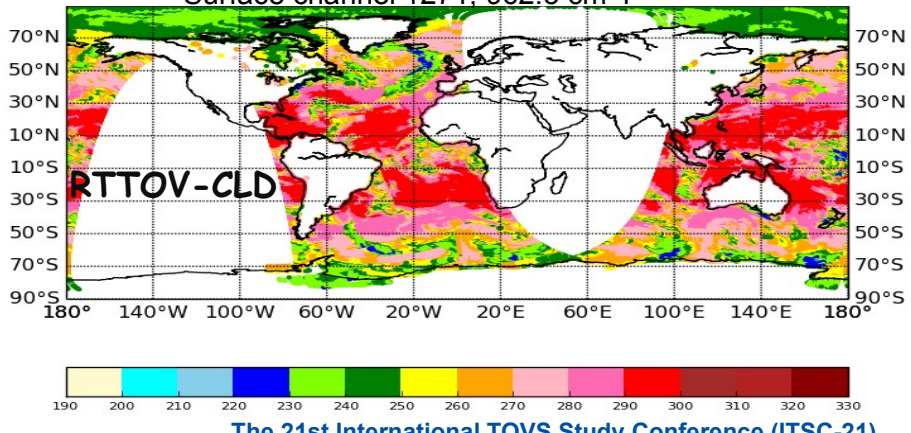
→ **Simulated cloudy radiance**

Microphysical cloud parameters
- Liquid water content (ql)
- Ice content (qi)
- Cloud Fraction

Surface channel 1271; 962.5 cm-1



Surface channel 1271; 962.5 cm-1

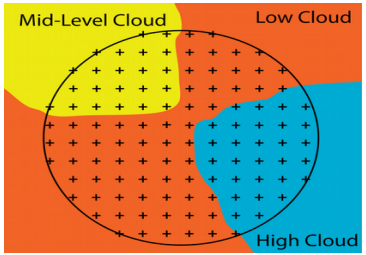


Methodology

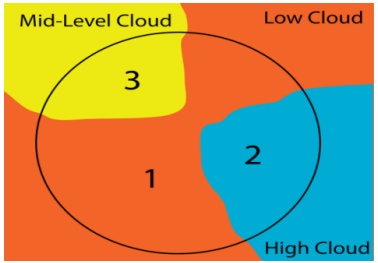
Selection of homogeneous scenes with AVHRR data

- The **AVHRR sensor** onboard MetopA and MetopB satellites
- Measures in 5 channels(visible, near-, middle, and thermal infrared spectrum)
- Pixel = 1 km diameter at the nadir
- Pixels homogeneity, CldCover

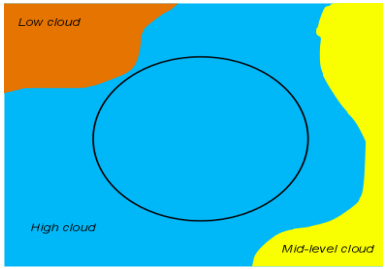
Aggregation of AVHRR pixels (1km resolution) within the IASI FOV in homogeneous classes



AVHRR pixels within the IASI FOV (Pauline Martinet, 2013)



Aggregation of pixels in homogeneous classes (Pauline Martinet, 2013)



Homogeneous IASI Pixel

For each class j and each channel i :

- Mean Radiance : Lij
- Mean standard deviation : Oij
- Class coverage in the IASI FOV : Cj

The application of homogeneity criteria for the selection of homogeneous scenes

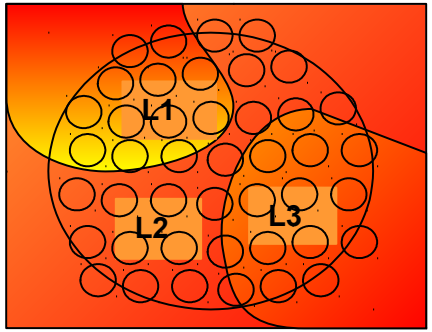
Identification of well simulated cloud situations with RTTOV-CLD

➢ **Homogeneity Criteria derived from (Martinet et al., 2013)**

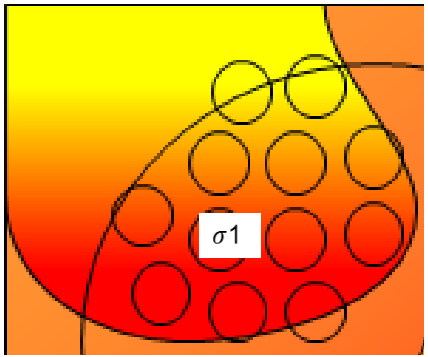
space observations

Use of a single infrared channel of AVHRR (11.5 μm), and definition of two homogeneity criteria, in the radiance space: **inter-class homogeneity** and **intra-class homogeneity**

- Relationship between inter-class homogeneity and mean radiance<8%



- Relationship between intra-class homogeneity and mean radiance<4%



Space model

- Background departure check

$$|BT_{Obs} - BT_{guess}| < 7\ K$$

Identification of well simulated cloud situations with RTTOV-CLD

- **Homogeneity Criteria for cloudy sky derived from (Eresmaa , 2014)**

  - space observations

    Use of two infrared channels 10.5 μm and 11.5 μm and definition of two criteria homogeneity in the brightness temperature space.

    $\sigma_4 < 0.75$ $\sigma_5 < 0.8$

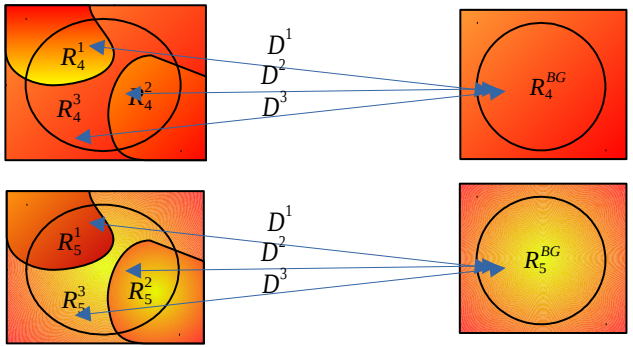
  - Space model

    - Background departure check :

$$D_{mean} = \sum_{j=1}^{N} f^j D^j$$

where f^j is the fractional coverage of class j.

D^j is the distance between each class j and the background, is computed as : $D_{mean} < 49\ K^2$



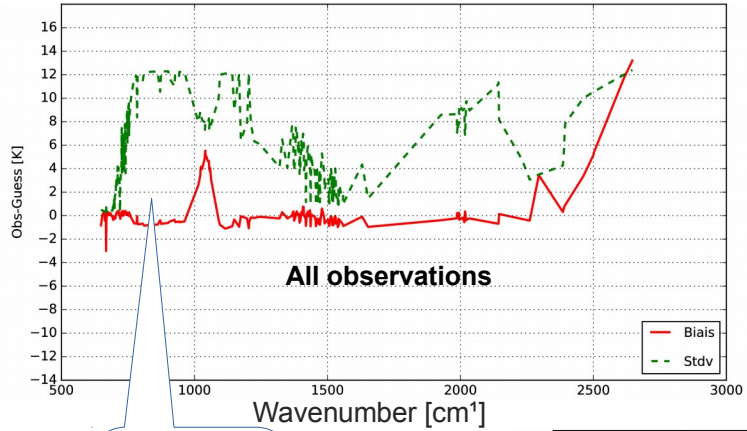
$$D^j = \sum_{i=4}^{5} \left(R_i^j - R_i^{BG}\right)^2$$

$$D^1 = \left(R_4^1 - R_4^{BG}\right)^2 + \left(R_5^1 - R_5^{BG}\right)^2$$

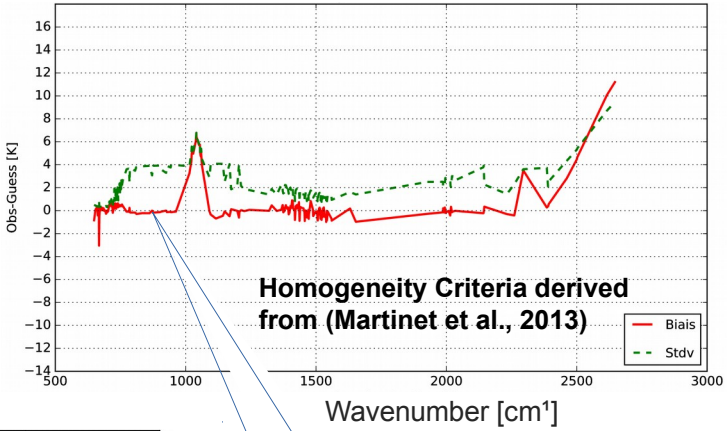
$$D_{mean} = \left(f^1 \times D^1\right) + \left(f^2 \times D^2\right) + \left(f^3 \times D^3\right)$$

Identification of well simulated cloud situations with RTTOV-CLD

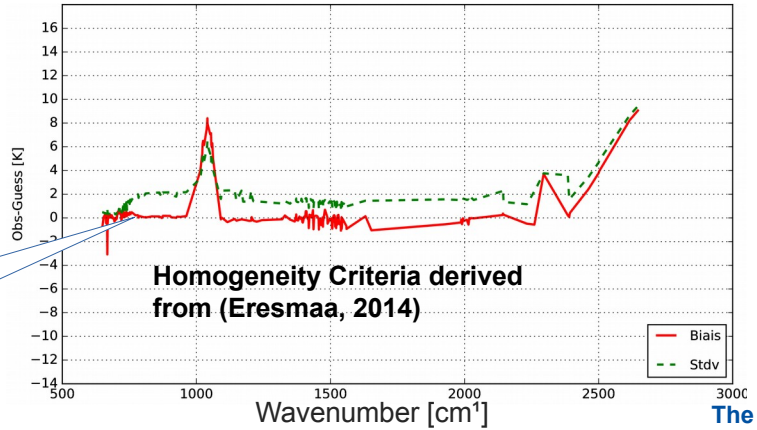
Bias and standard deviation (Stdv) of the differences between Background and the IASI observations



(BT channels)
«650-1000 cm^{-1}»
Bais = 0.5
Stdev = 7.45
CC = 0.79



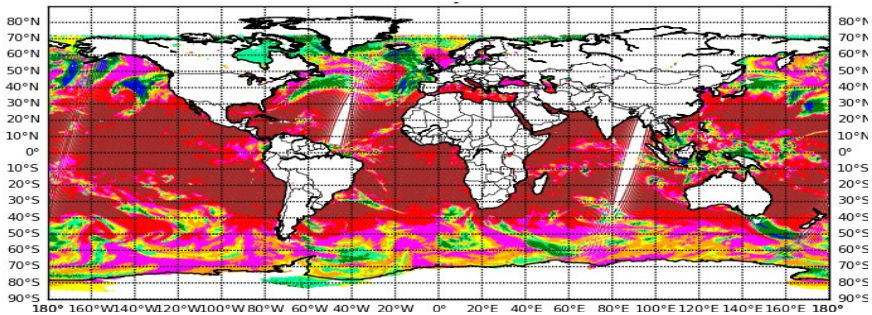
(BT channels)
«650-1000 cm^{-1}»
Bais = 0.21
Stdev = 2.33
CC = 0.98



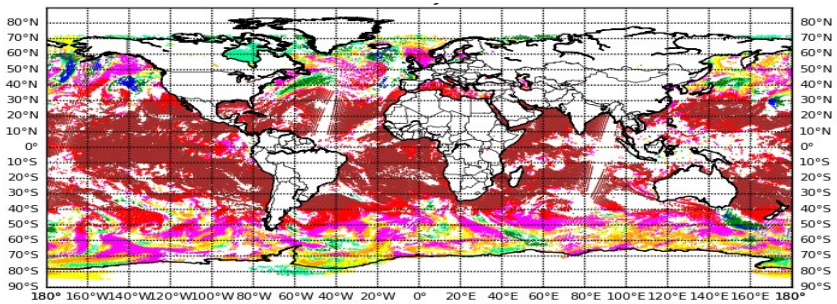
(BT channels)
«650-1000 cm^{-1}»
Bais = 0.17
Stdev = 1.36
CC = 0.98

Identification of well simulated cloud situations with RTTOV-CLD

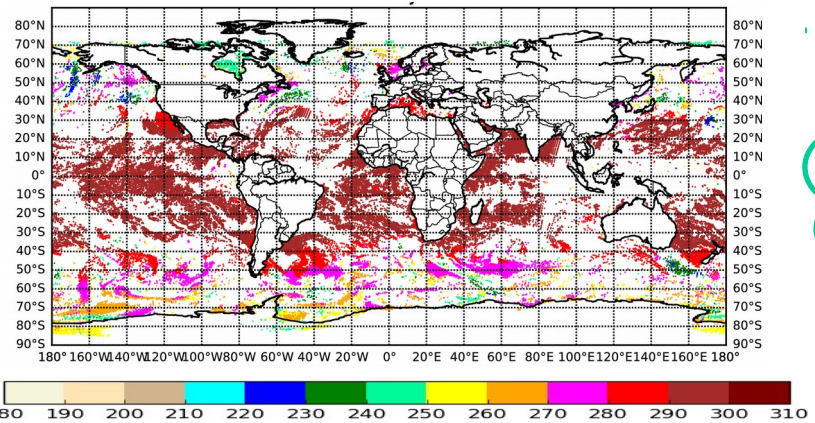
All observations



Homogeneity Criteria derived from (Martinet et al., 2013)



Homogeneity Criteria derived from (Eresmaa, 2014)



22% of observations (10% are totally clear and 6% are totally covered by clouds)

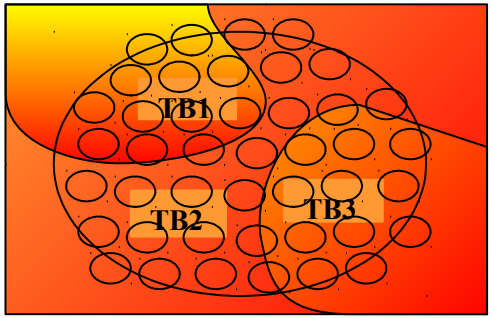
54 % of observations (19% are totally covered by clouds and 10% are clear)

Identification of well simulated cloud situations with RTTOV-CLD

- **Selected homogeneity criteria**

  - space observations

    Using two infrared channels of AVHRR and definition of the **inter-class homogeneity** in the brightness temperature space

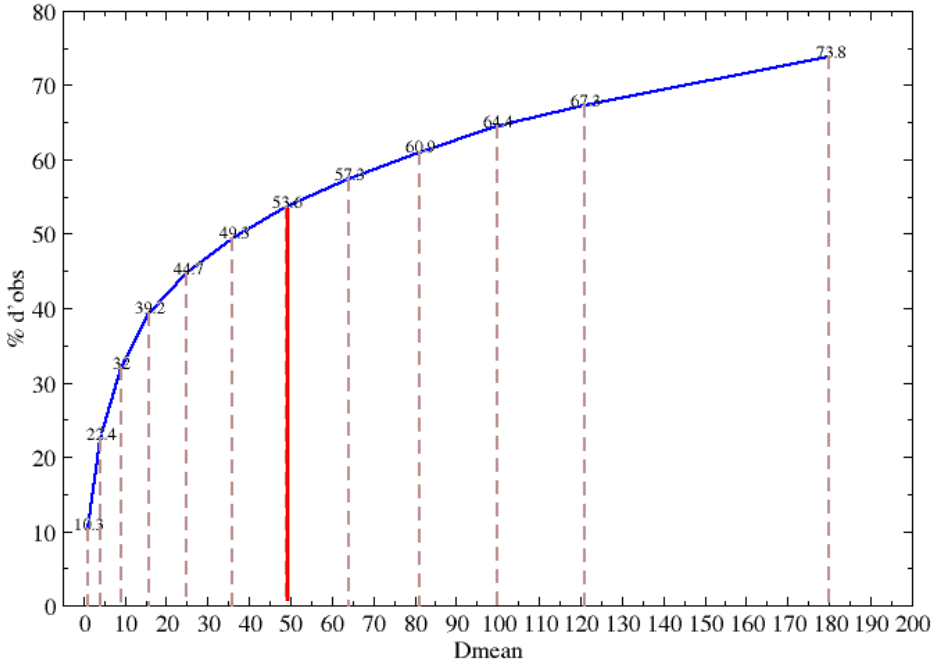


- Relationship between inter-class homogeneity and mean BT < 0.8 %

	Number of observations	Cloudy observations	Clear observations	heterogeneous observations according AVHRR cloud cover
All observations	59040599	50.10%	12.61 %	37.29 %
Homogeneity Criteria	67.29 %	32.28 %	12.61 %	22.39 %

Identification of well simulated cloud situations with RTTOV-CLD

- **Selected homogeneity criteria**
  - space modele
    - Background departure check :



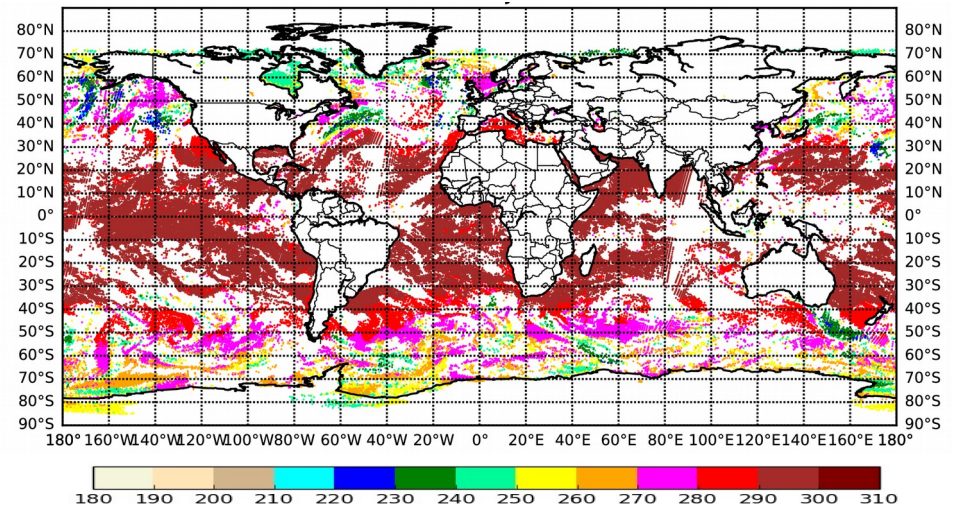
$D_{mean} < 49\ K^2$

Identification of well simulated cloud situations with RTTOV-CLD

- **Selected homogeneity criteria**

(BT channels)
«650-1000 cm^{-1}»

Bais = 0.18
Stdev = 1.46
CC = 0.99



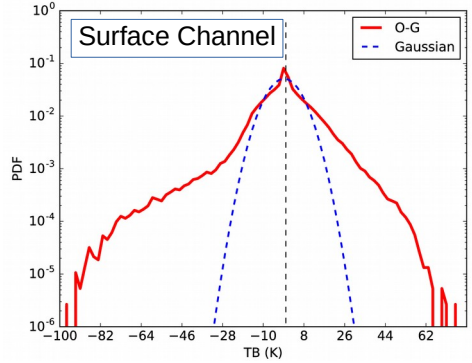
- 36 % of observations (10% are totally clear and 11% are totally covered by clouds).

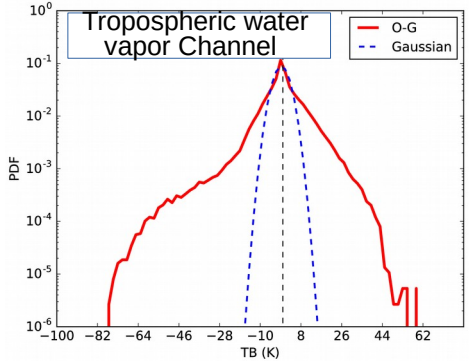
Identification of well simulated cloud situations with RTTOV-CLD

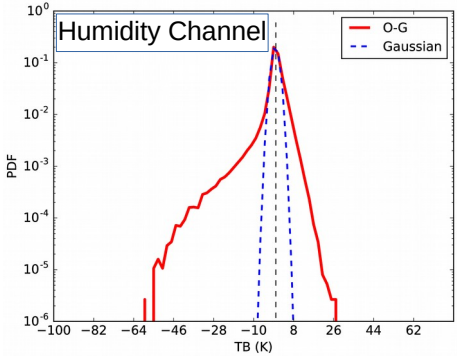
- **Selected homogeneity criteria**

  Frequency distribution of the IASI observations and the Background difference

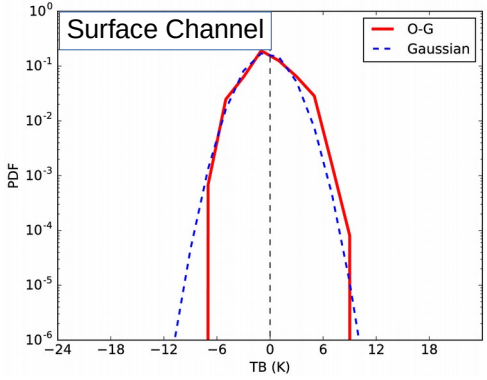
  - **All observations**

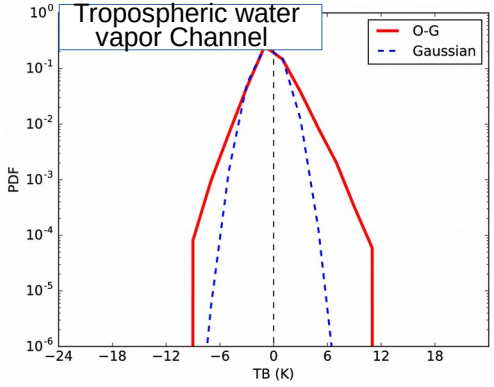


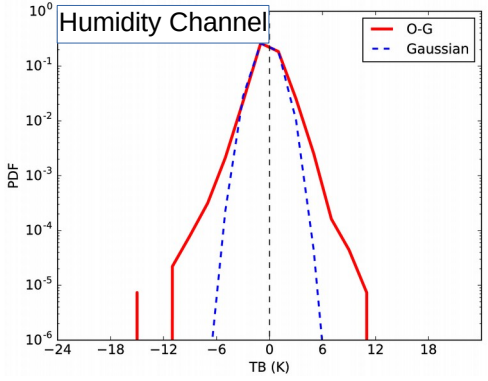




  - **Selected homogeneity criteria**







Conclusions and perspectives

Identification of well simulated cloud situations with a model of radiative transfer in cloudy sky potentially usable in the assimilation of data

The comparison of two methods for selecting homogeneous scenes of Martinet et al (2013) and Eresmaa (2014) shows that:

- The method of Martinet et al.(2013), improves our background departure statistics but it keeps more heterogeneous observations.
- The method from Eresmaa(2014), greatly improves our statistics, and favors more clear observations but we keep only 22% of the observations.

By applying our third selection method that is based on the homogeneous observations and the model space we obtained a good compromise between the two previous methods, selecting fewer heterogeneous observations with a bias and a standard deviation close to 0 during day and night, with a distribution of observations minus simulations very close to the Gaussian shape, by keeping 36% of observations.

Definition of observation errors for all-sky observations

Test different assimilation methods to initialize the ARPEGE model

Thank you !

Imane.farouk@meteo.fr

www.meteofrance | @meteofrance

ITSC-XXI: Darmstadtium, Darmstadt,
Germany 29 November - 5 December 2017

Identification of well simulated cloud situations with RTTOV-CLD

overview

	Number of observations	Cloudy observations	Clair observations	heterogeneo-us observations	Correlation coefficient (surface channels	Bias (Surface channels) «650-1000»	Stdev (Surface channels) «650-1000»
All observations	59040599	50%	12 %	38 %	0.79	0.22	3.02
Homogeneity Criteria of Martinet	54 %	19 %	11 %	24 %	0.97	0.07	0.87
Homogeneity Criteria of Eresmaa	15 %	4 %	8 %	3 %	0.99	0.06	0.49

Identification of well simulated cloud situations with RTTOV-CLD

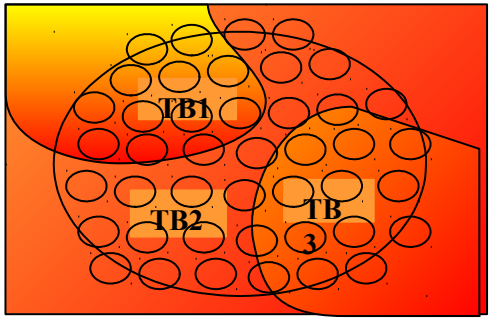
- **Selected homogeneity criteria**

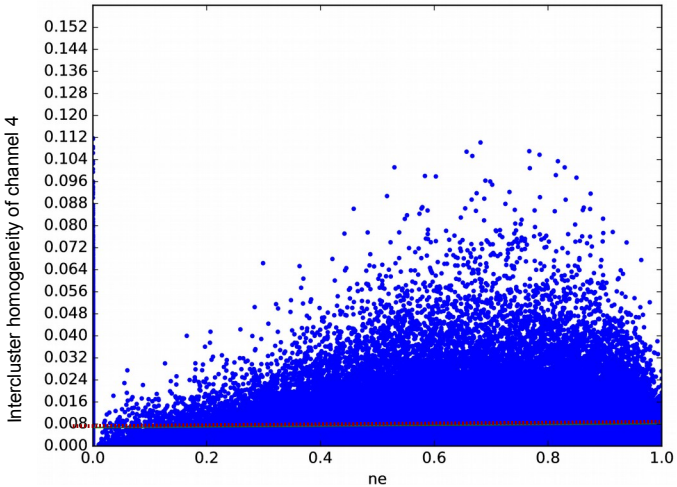
  - space observations

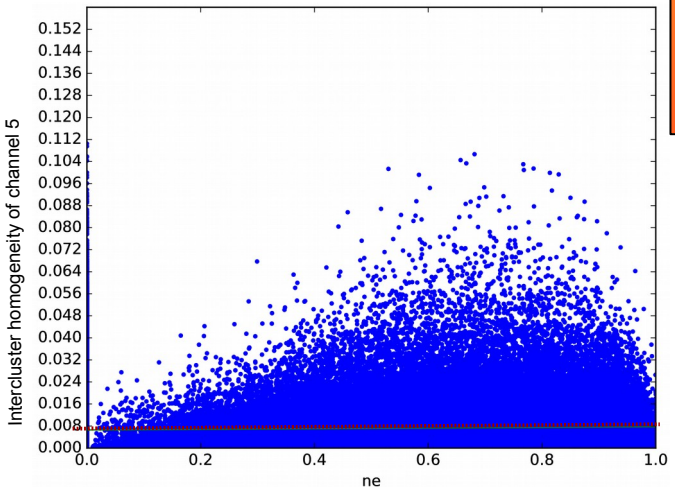
    Using two infrared channel of AVHRR and definition of the **inter-class homogeneity** in the the Brilliance temperature space

    - Relationship between inter-class homogeneity and mean BT < 0.8 %

  - The choice of threshold for both channels by **polynomial smoothing**



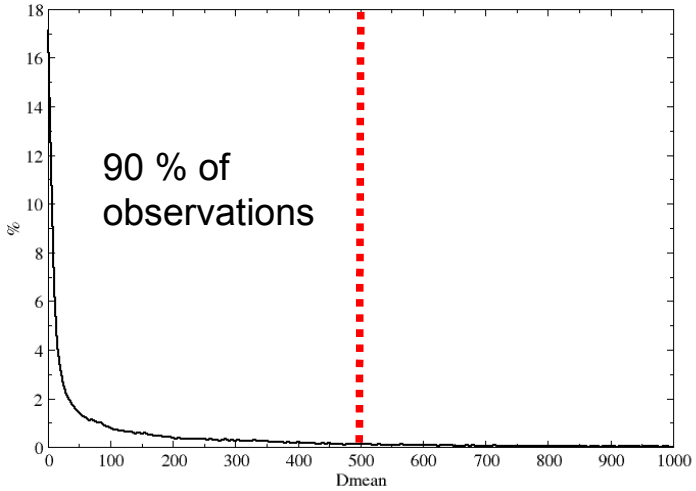


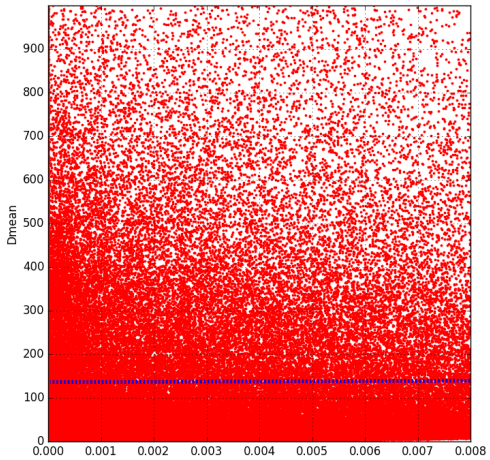


68% of observations have an intercluster homogenity less than 0.8% for channel 4 and 70% for channel 5

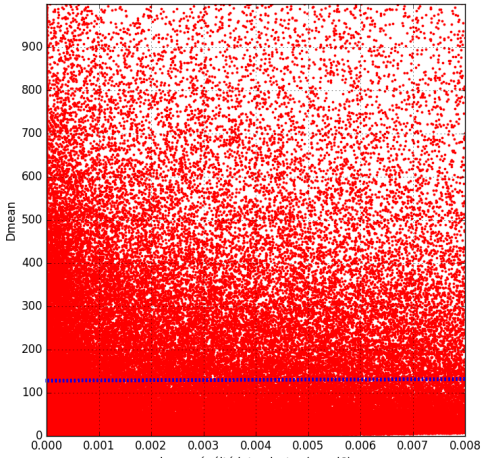
Identification of well simulated cloud situations with RTTOV-CLD

- **Selected homogeneity criteria**
  - space modele
    - Background departure check :





Intercluster homogeneity of channel 4



Intercluster homogeneity of channel5

Identification of well simulated cloud situations with RTTOV-CLD

- **Selected homogeneity criteria**
  - space modele
    - Background departure check :