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

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Context of the study

70% of infrared hyperspectral 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 ....
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).

Motivations

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
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

For each class $j$ and each channel $i$:

- Mean Radiance : $L_{ij}$
- Mean standard deviation : $O_{ij}$
- Class coverage in the IASI FOV : $C_j$

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

\[ |BT_{Obs} - BT_{guess}| < 7 \text{ K} \]
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:
    - \( D_{\text{mean}} = \sum_{j=1}^{N} f_j D_j \)
    - 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: \( D_{\text{mean}} < 49 \text{ K}^2 \)
Bias and standard deviation (Stdv) of the differences between Background and the IASI observations

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

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

- Wavenumber [cm⁻¹]: «650-1000 cm⁻¹»
- Bias = 0.5
- Stdev = 7.45
- CC = 0.79

**Homogeneity Criteria derived from (Eresmaa, 2014)**

- Wavenumber [cm⁻¹]: «650-1000 cm⁻¹»
- Bias = 0.17
- Stdev = 1.36
- CC = 0.98
30 January 2017 the day on the sea

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

- 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 %

<table>
<thead>
<tr>
<th></th>
<th>Number of observations</th>
<th>Cloudy observations</th>
<th>Clear observations</th>
<th>Heterogeneous observations according AVHRR cloud cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>All observations</td>
<td>59040599</td>
<td>50.10%</td>
<td>12.61 %</td>
<td>37.29 %</td>
</tr>
<tr>
<td>Homogeneity Criteria</td>
<td>67.29 %</td>
<td>32.28 %</td>
<td>12.61 %</td>
<td>22.39 %</td>
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</tbody>
</table>
Identification of well simulated cloud situations with RTTOV-CLD

Selected homogeneity criteria

- **space modele**
  - Background departure check:

\[ D_{\text{mean}} < 49 \, \text{K}^2 \]
Identification of well simulated cloud situations with RTTOV-CLD

- Selected homogeneity criteria

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

  - Surface Channel
  - Tropospheric water vapor Channel
  - Humidity Channel

- Selected homogeneity criteria

  - Surface Channel
  - Tropospheric water vapor Channel
  - Humidity Channel
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!

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## Identification of well simulated cloud situations with RTTOV-CLD

### Overview

<table>
<thead>
<tr>
<th></th>
<th>Number of observations</th>
<th>Cloudy observations</th>
<th>Clair observations</th>
<th>heterogeneus observations</th>
<th>Correlation coefficient (surface channels)</th>
<th>Bias (Surface channels) «650-1000»</th>
<th>Stdev (Surface channels) «650-1000»</th>
</tr>
</thead>
<tbody>
<tr>
<td>All observations</td>
<td>59040599</td>
<td>50%</td>
<td>12%</td>
<td>38%</td>
<td>0.79</td>
<td>0.22</td>
<td>3.02</td>
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<tr>
<td>Homogeneity Criteria of Martinet</td>
<td>54 %</td>
<td>19%</td>
<td>11%</td>
<td>24%</td>
<td>0.97</td>
<td>0.07</td>
<td>0.87</td>
</tr>
<tr>
<td>Homogeneity Criteria of Eresmaa</td>
<td>15 %</td>
<td>4%</td>
<td>8%</td>
<td>3%</td>
<td>0.99</td>
<td>0.06</td>
<td>0.49</td>
</tr>
</tbody>
</table>
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 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 homogeneity 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:

90% of observations
Identification of well simulated cloud situations with RTTOV-CLD

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

![Graph showing selected homogeneity criteria](image)

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