First Results on the assimilation of radiances of the European instrument IASI

Internal seminar

Dorval, Qc

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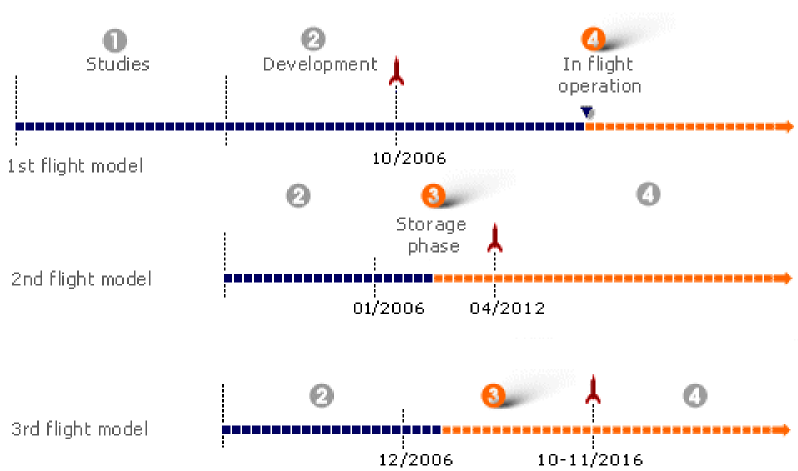
Jose Garcia , Pierre Koclas, Louis Grand, Nicolas Wagneur

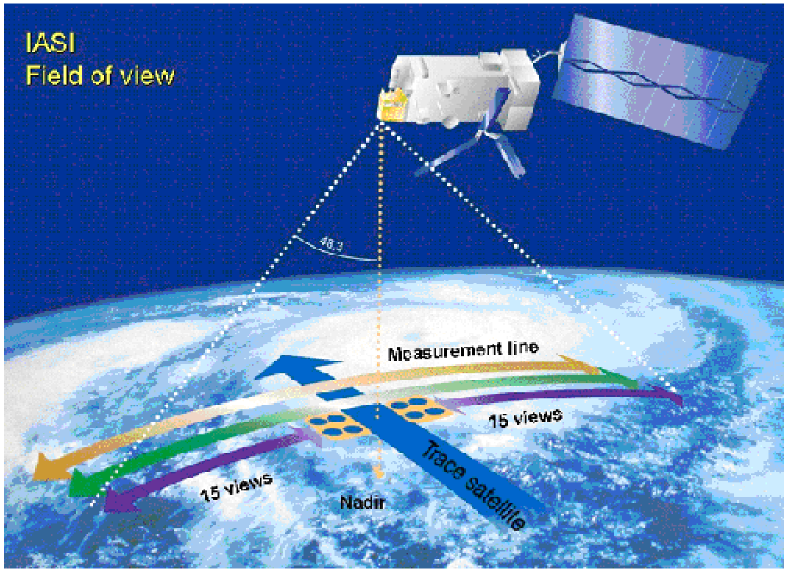
Outline

- Overview of the IASI instrument
- IASI versus AIRS
- Quality control
- Cloud detection: use of sub-pixel information provided by the AVHRR instrument
- Results of 4Dvar assimilation experiments:
  - Validation against radiosondes
  - Validation against analyses
- Conclusions, perspectives

The IASI Instrument 1/2

- **I**nfrared **A**tmospheric **S**ounding **I**nterferometer
- Flying onboard the METOP-A European **operational** satellite



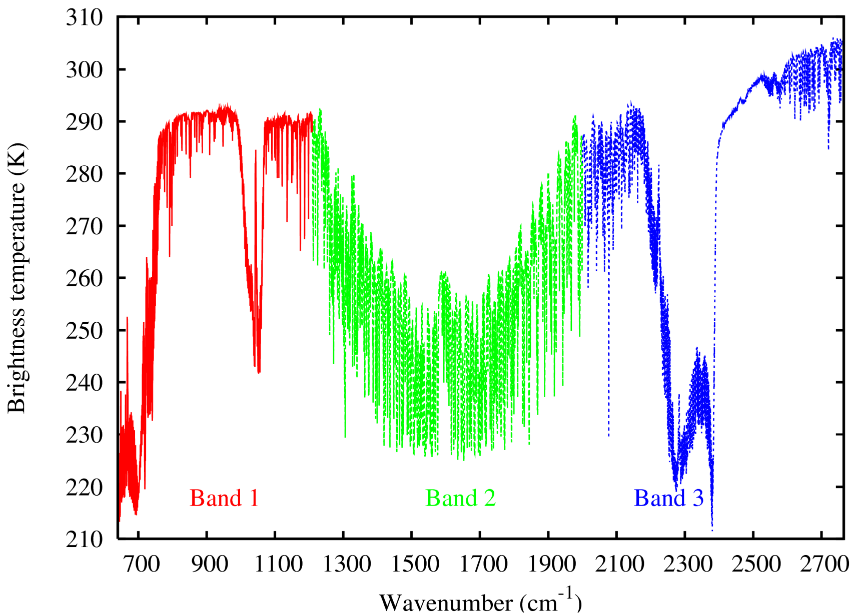


(Courtesy from CNES)

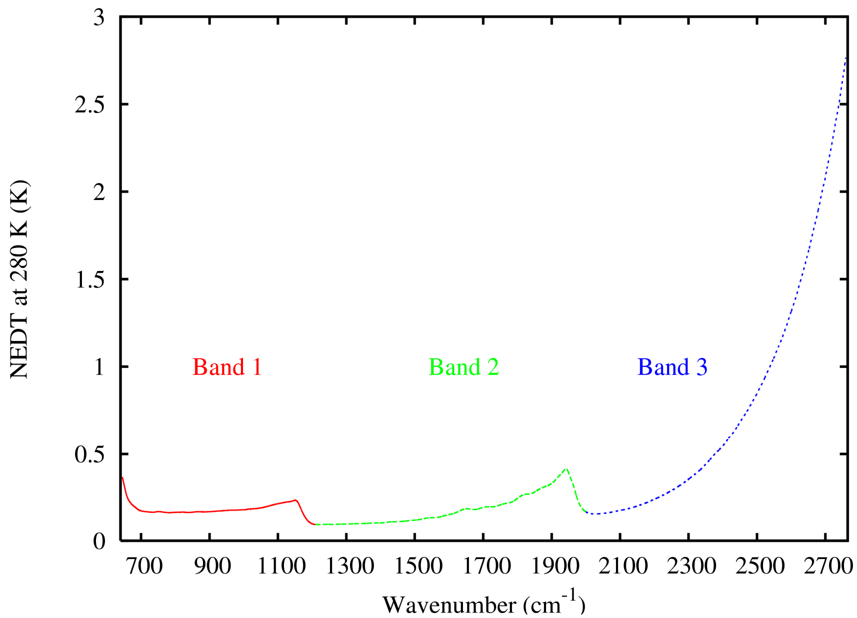
The IASI Instrument 2/2

- Provides high resolution spectra (apodised resolution of 0.5 cm^{-1}) of the infrared radiation emitted by earth/atmosphere between 645 cm^{-1} and 2760 cm^{-1} in 8461 spectral bands (channels)

Typical full resolution spectrum



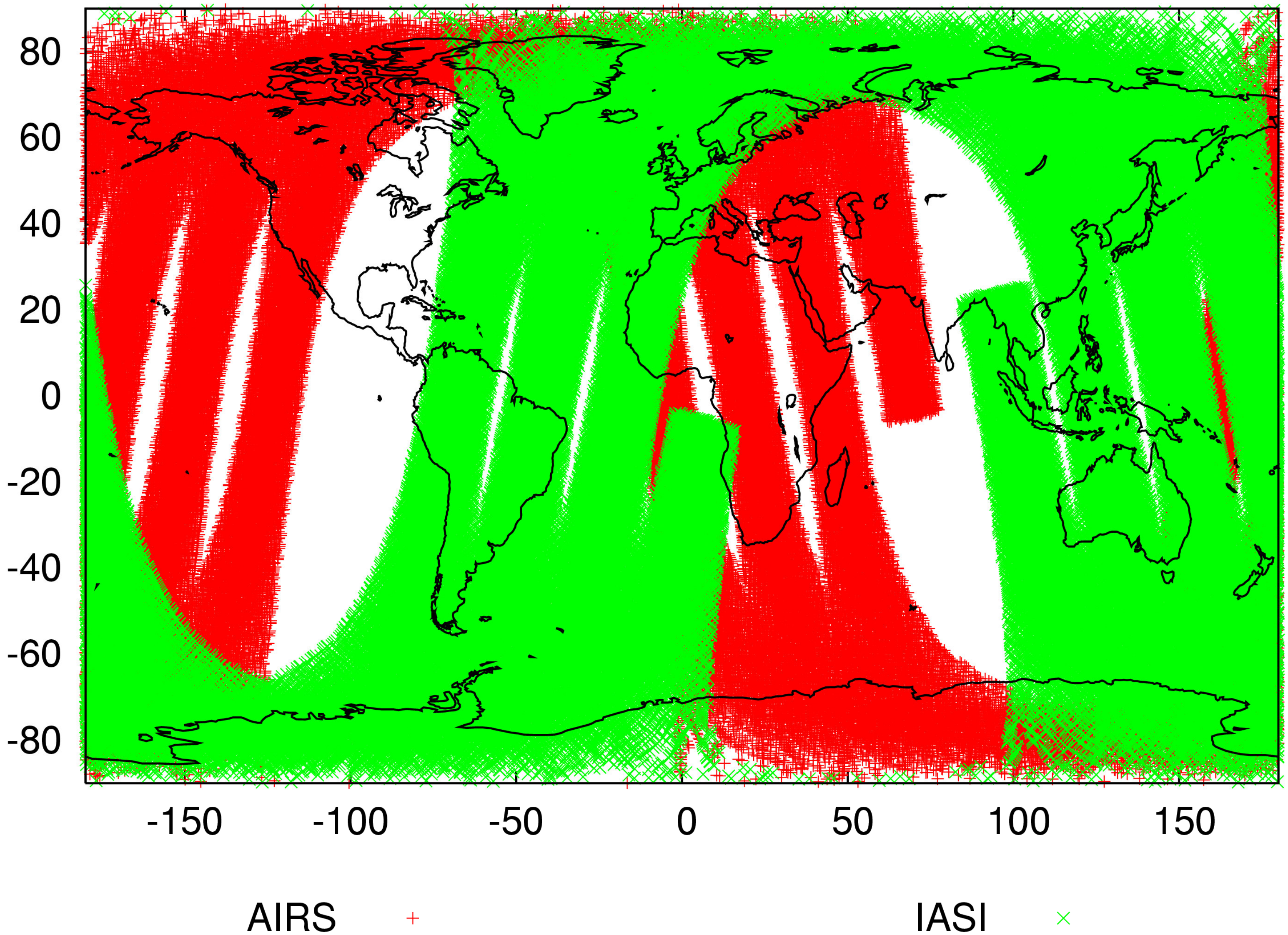
Radiometric noise characteristics



IASI versus AIRS

instrument	AIRS	IASI
# of channels	2378	8461
# of channels received at CMC	281 (324)	616 (314)
Spectral resolution	Resolving power λ/Δ λ =1300 (	0.5 cm^{-1} apodised
Spectral coverage	3 spectral bands: [650 cm^{-1};1137 cm^{-1}] [1217 cm^{-1};1614 cm^{-1}] [2181 cm^{-1};2665 cm^{-1}]	3 spectral bands: [645 cm^{-1};1210 cm^{-1}] [1210.25 cm^{-1};2000 cm^{-1}] [2000.25 cm^{-1};2760 cm^{-1}]
Technology	Grating Spectrometer	Michelson like interferometer
Platform	Research satellite AQUA	Operational satellite METOP-x
Orbit	sun-synchronous polar orbit, mean equator crossing time 09.30 am, descending node	sun-synchronous polar orbit, mean equator crossing time 1.30 pm, descending node

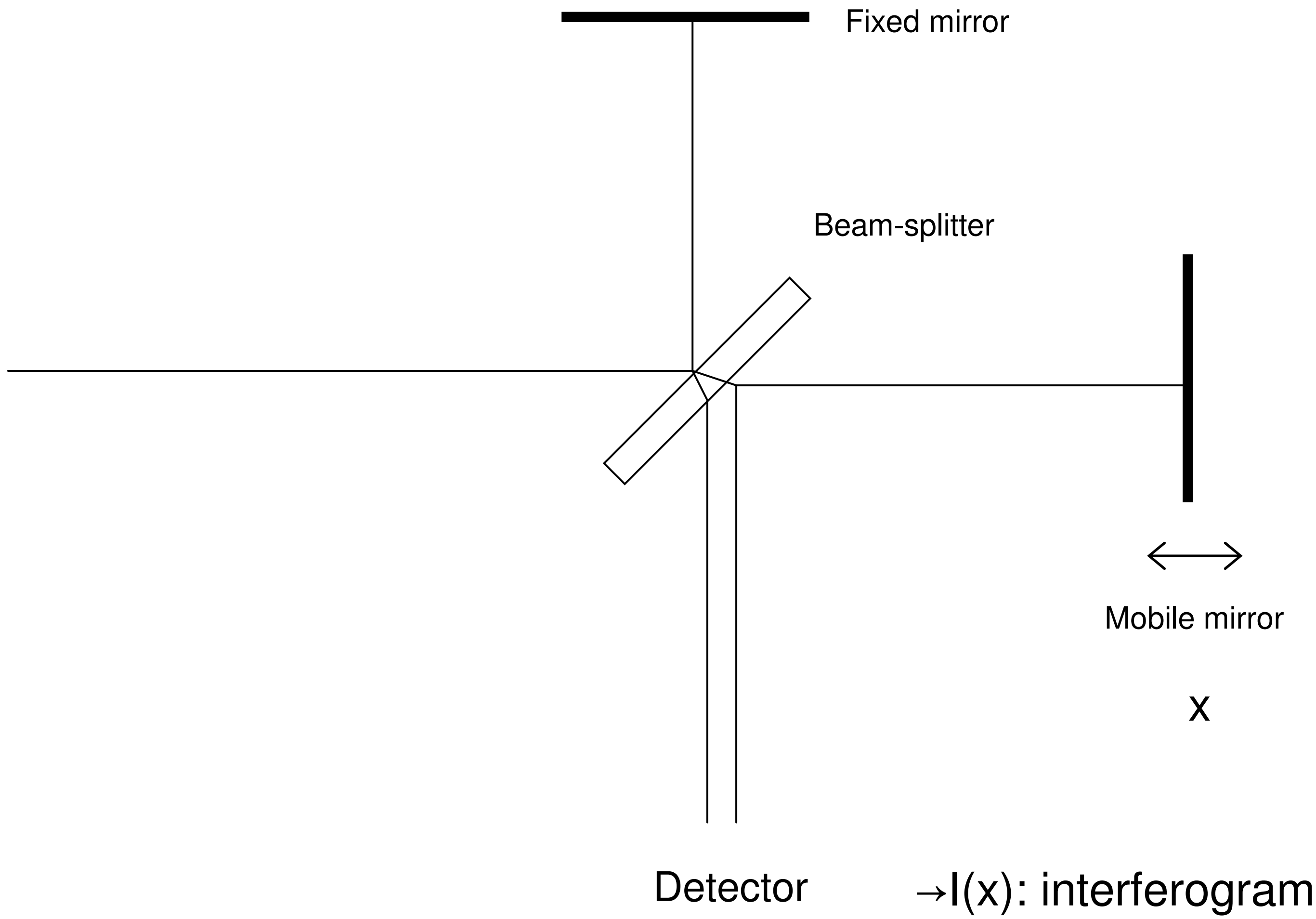
Spatial coverage



IASI Dataset Characteristics

- Level 1.c BUFR files containing 616 IASI channels and AVHRR cluster radiance analysis received from NOAA/NESDIS
- Warmest Field Of View (U3 files)
- Typically 81000 observations (i.e spectra) for a 6 h time windows

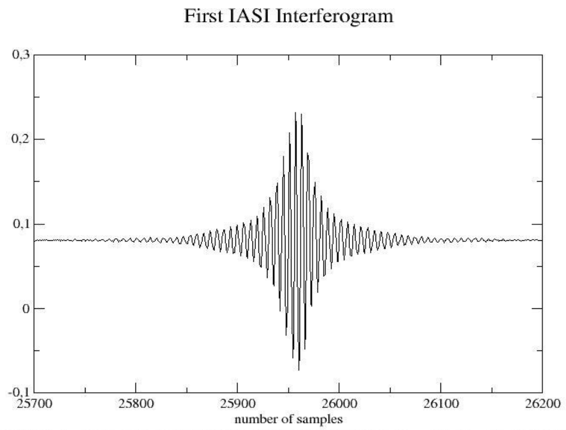
Principle of the measurement 1/3



→I(x): interferogram

Principle of the measurement 2/3

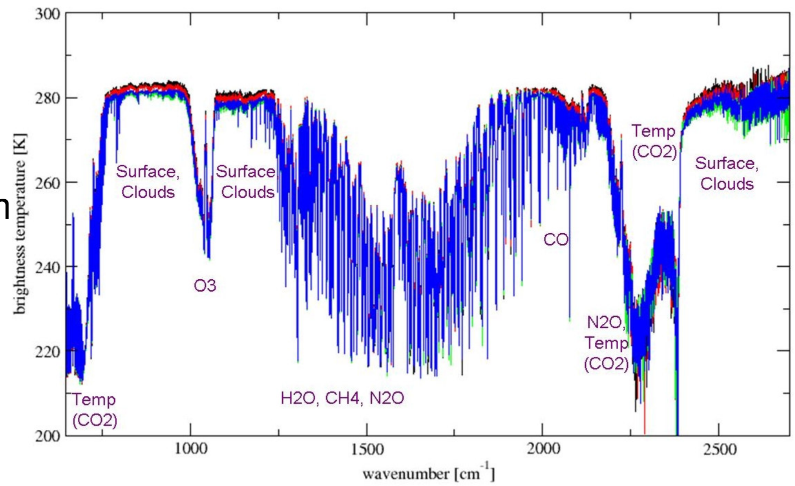
Interferogram space



METOP A: Orbit 552; 27/11/2006, 13:13:07.086 UTC; Band 3, Pixel 1, Cold Space View

Fourier transform

Spectral space



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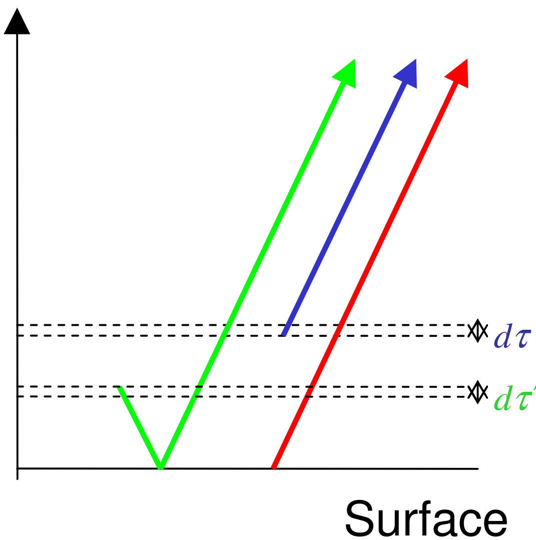
Canada

Principle of the measurement 3/3



$$I_{clear}(\nu) = \varepsilon_s \tau_s B(\nu, T_s) + \int_{\tau_s}^{1.0} B[\nu, T(\tau)]\, d\tau + (1-\varepsilon_s)\tau_s \int_{\tau_s}^{1.0} B[\nu, T(\tau')]\, d\tau'$$

$B(\nu, T)$ Planck function

τ transmission function between TOA and current level

τ' transmission function between surface and current level

$$\int_{\tau_s}^{1.0} B[\nu, T(\tau)]\, d\tau = \int_{\ln P_s}^{-\infty} \underbrace{B[\nu, T(\ln P)]} \underbrace{\left(\frac{\partial \tau(\nu)}{\partial \ln P}\right)} d\ln P$$

weighting function

Temperature

Atmospheric composition

IASI QUALITY CONTROL (QC) 1/6

1. Gross check: BT > 150 K, BT < 350 K
2. EUMETSAT flags GQisFlagQual and GQisQualIndexLoc
3. Cloudy or clear ? Based on window channel+ trial T profile

 * Garand-Nadon 1998 algorithm

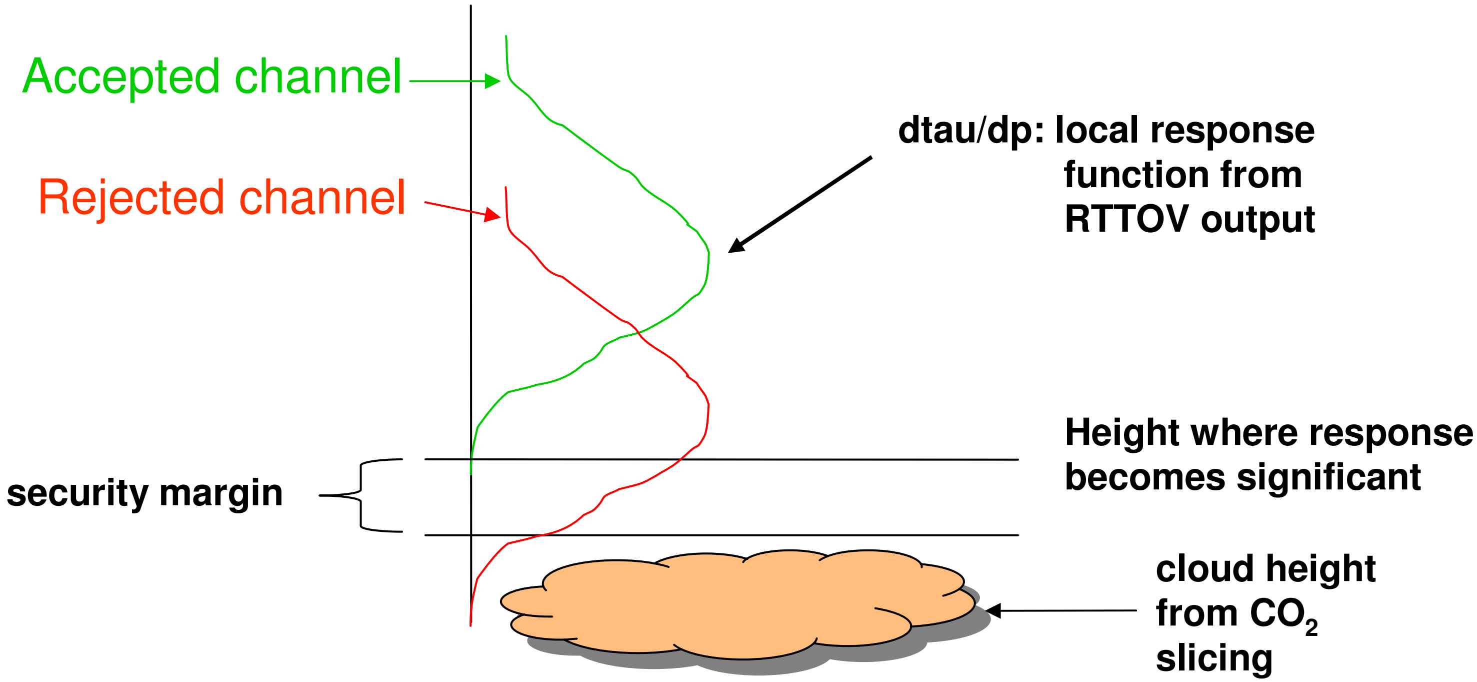
 * Invert RTE for TS using BT(window) assuming trial T,q profile perfect

 - if |TS(window) – TS(guess)| > 2K(ocean) or 4K(not ocean), cloudy

 * Use of AVHRR sub pixel information

IASI quality control 2/6

- IASI assimilation setup inspired from AIRS assimilation setup (assimilated operationally at CMC since June 2008)
- Assimilation of cloud unaffected radiances:

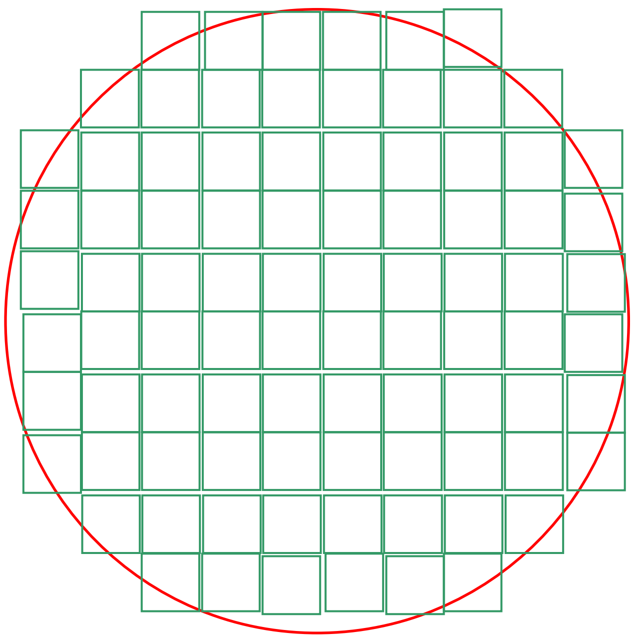


IASI QUALITY CONTROL 3/6

- The main difference between AIRS and IASI assimilation setup is related to cloud detection
- For IASI use is made of the cluster radiance analysis which gives AVHRR sub-pixel information

AVHRR/3: 5 channels :
1, 2, 3a (day only) : visible and near IR
3b (night only), 4 and 5 thermal IR;

Red disk: IASI field of view approximately
11.7 km in diameter at nadir
Green squares: AVHRR field of views
Approximately 1.08 km at nadir



IASI QUALITY CONTROL (QC) 4/6

An unsupervised classification algorithm (dynamic cluster method) is applied in radiance space to all the AVHRR pixels included in one IASI field of view.

As a result up to 6 classes are obtained. Each class **j** is characterized by

- the fraction $\boldsymbol{\alpha_j}$ (%) of the whole IASI pixel covered by the class **j**

- the mean $\boldsymbol{\mu_{ij}}$ and the standard deviation $\boldsymbol{\sigma_{ij}}$ of the radiance of each AVHRR channel **i**

IASI QUALITY CONTROL (QC) 5/6

- The 3 (1,2 and 3a) visible and near-IR AVHRR channels are used for **day time** cloud detection.

$$A_i = 100\pi \frac{I_i}{F_i \cos\theta_{sun}} > \text{Threshold} \Rightarrow \text{cloudy class}$$

Albedo

- Garand and Nadon algorithm (1998) and a comparison of Skin Surface Temperature estimated from the AVHRR IR radiances (channels 4 and 5) with SST from the model are used to detect cloudy classes.
- For each cloudy class, IR channels 4 and 5 (available day and night) are used to estimate an effective cloud top height. This height is used to complement cloud top pressure provided by CO_2 slicing.

IASI QUALITY CONTROL (QC) 6/6

- A **field of view homogeneity** criteria is added: S_i is the standard deviation of AVHRR channel i for the whole pixel

$$S_i^2 = \sum_{\text{classes j}} \alpha_j \left({\mu_{ij}}^2 + {\sigma_{ij}}^2 \right) - \left[\sum_{\text{classes j}} \alpha_j \mu_{ij} \right]^2$$

$$S_i > \text{Threshold} \Rightarrow \text{Cloudy IASI FOV}$$

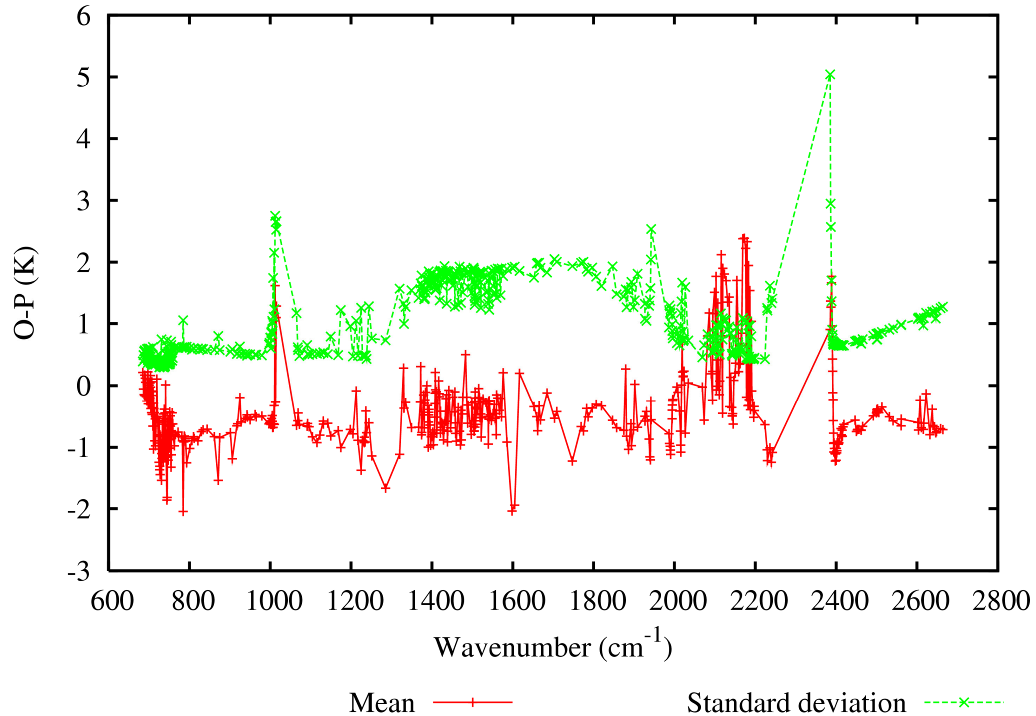
Model Setup

- Global GEM model
- Grid 800x600
- 58 vertical levels with model top at 10 hPa
- 128 IASI channels were selected for assimilation

A new version of the model with a 0.1 hPa top and 80 vertical levels will soon be operational and allow to assimilate more channels (GEM-strato 1)

Evaluation of O-F Statistics

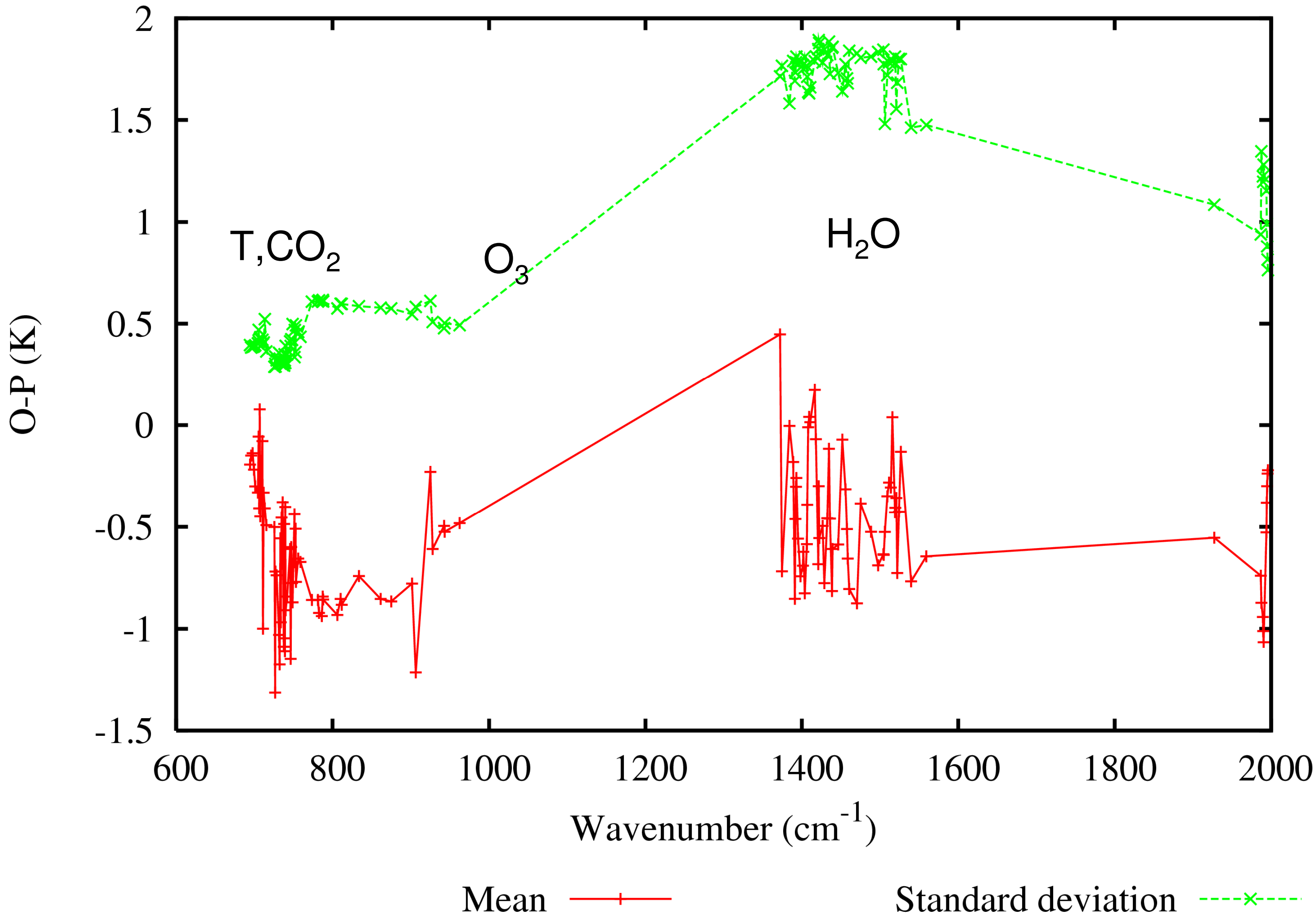
O-F statistics **before bias correction**. All channels. Clear radiances.



Standard deviation used as observation error

Bias correction: A*BT+B

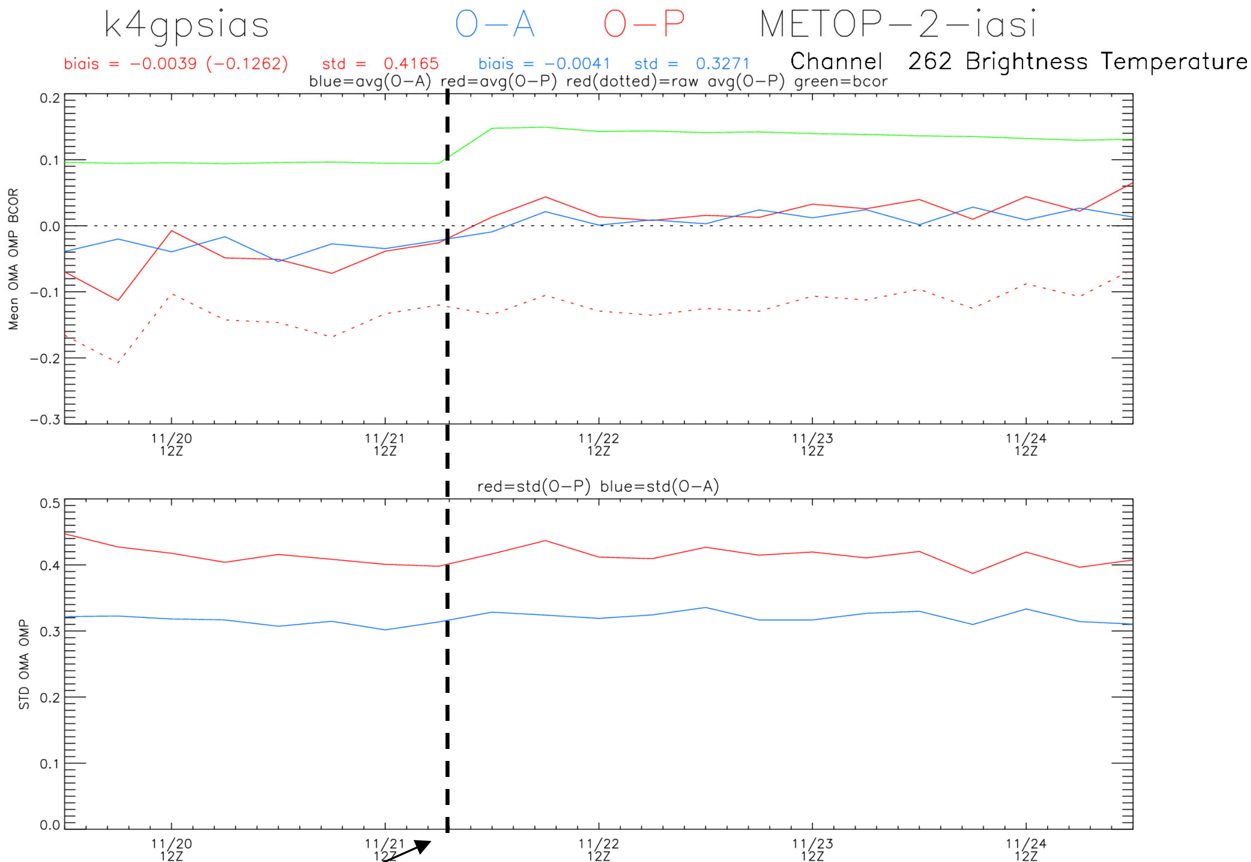
O-F statistics for the selected channels



Assimilation Experiments Setup

- 4Dvar assimilation experiments
- From 11/20/2008 to 12/17/2008
- **Control experiment** assimilation of:
  - Conventional data (radiosondes, etc…)
  - Quickscat winds
  - AMSU-A and AMSU-B microwave radiances from NOAAxx and AQUA platforms
  - SSM-I microwave radiances from DMSP-xx platforms
  - GOES infrared radiances
  - AIRS infrared radiances (87 channels)
  - GPS radio-occultation (refractivity profiles)
- **Test experiment**: all the above plus the assimilation of the 128 IASI selected channels

Assimilation Monitoring

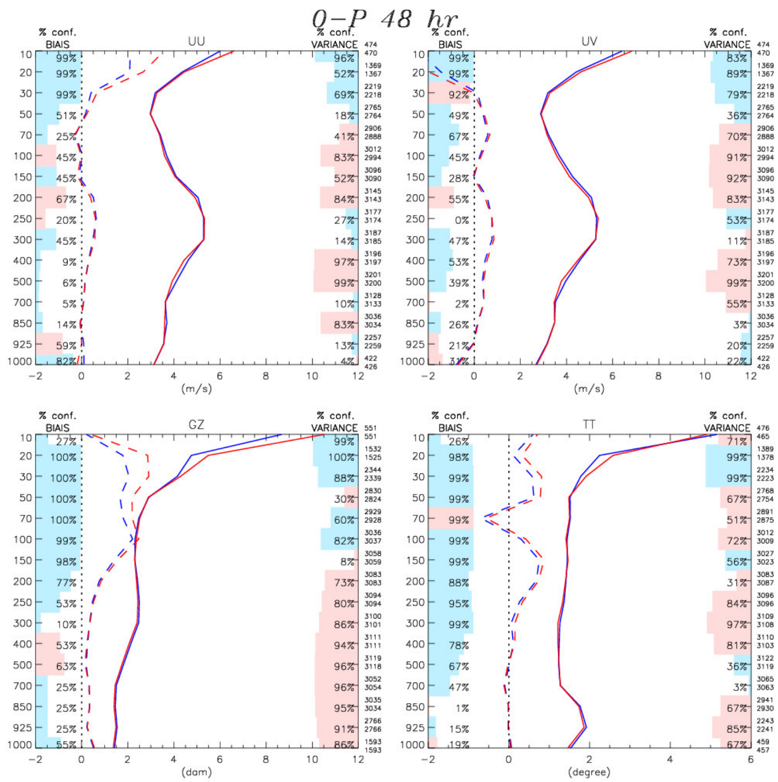


Activation of the dynamic bias correction

Result of 4dvar Assimilation Exp. 1/4

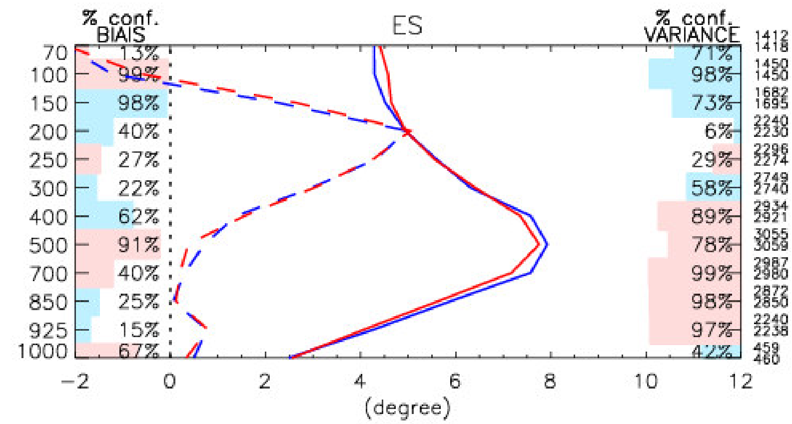
- Validation of forecasts against radiosondes: southern hemisphere 48 h

Wind



Geopotential height Temperature

Dew point depression



56 cases

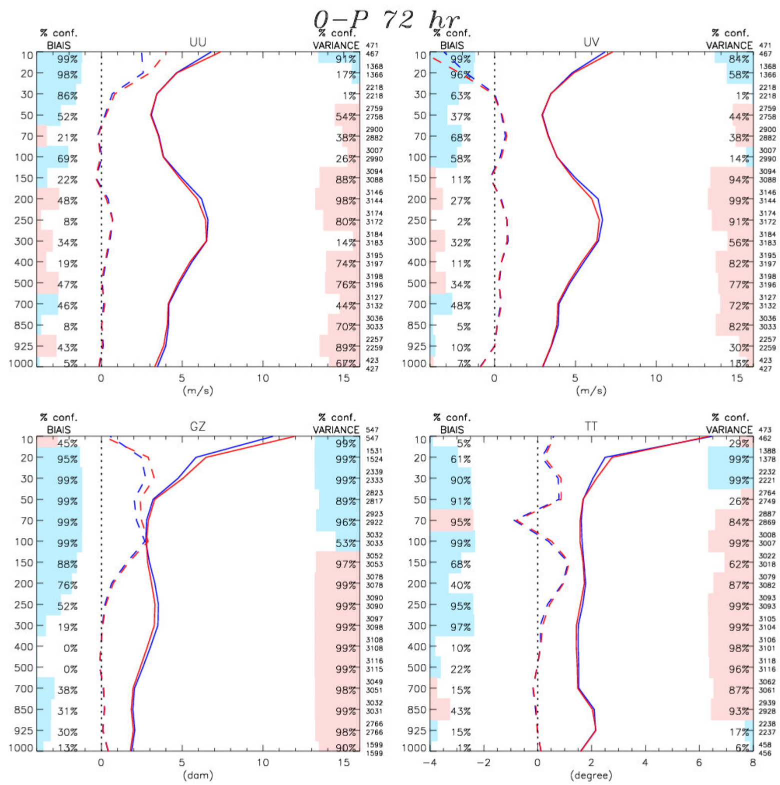
Legend:

- Control is better (blue)
- Test is better (red)

Result of 4dvar Assimilation Exp. 2/4

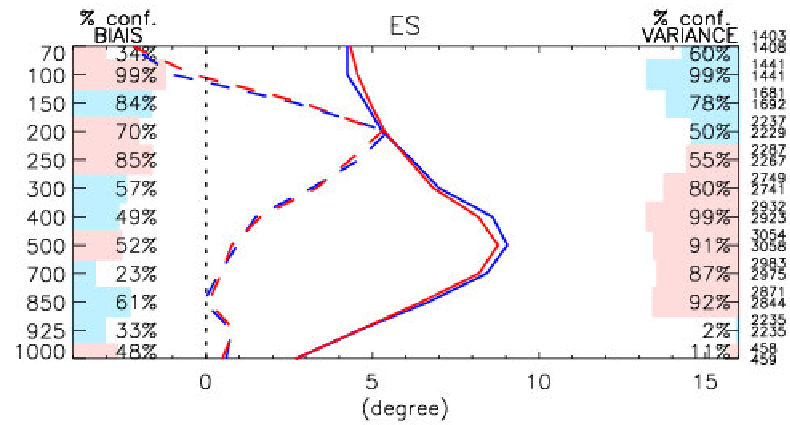
- Validation of forecasts against radiosondes: Southern hemisphere 72 h

Wind



Geopotential height Temperature

Dew point depression



56 cases

Legend:

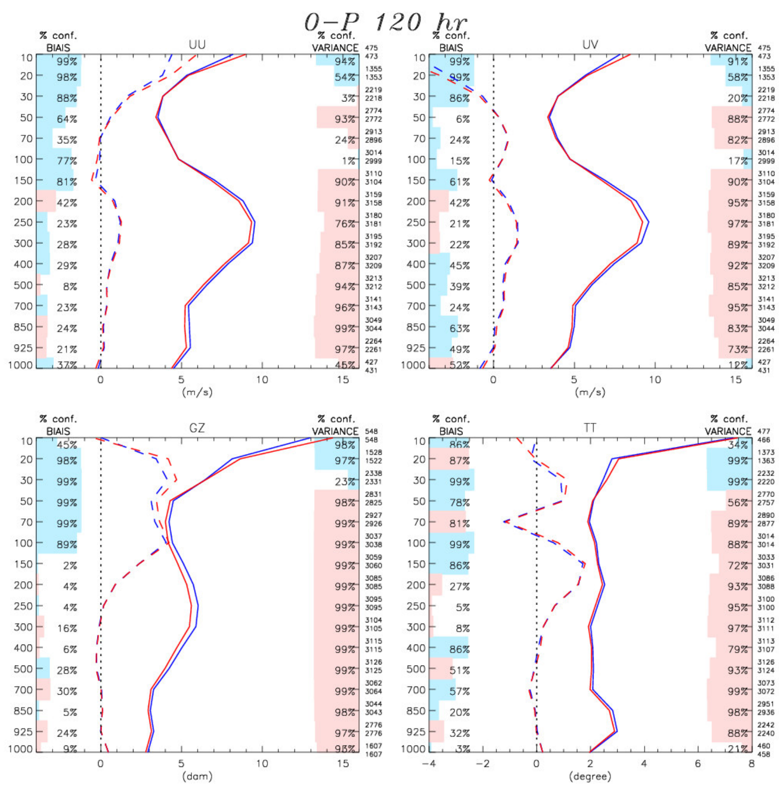
Control is better

Test is better

Result of 4Dvar assimilation exp. 3/4

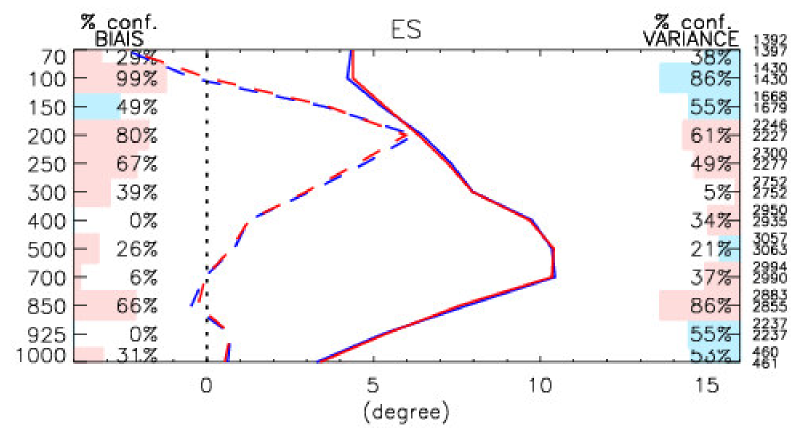
- Validation of forecasts against radiosondes: Southern hemisphere 120h

Wind



Geopotential height Temperature

Dew point depression



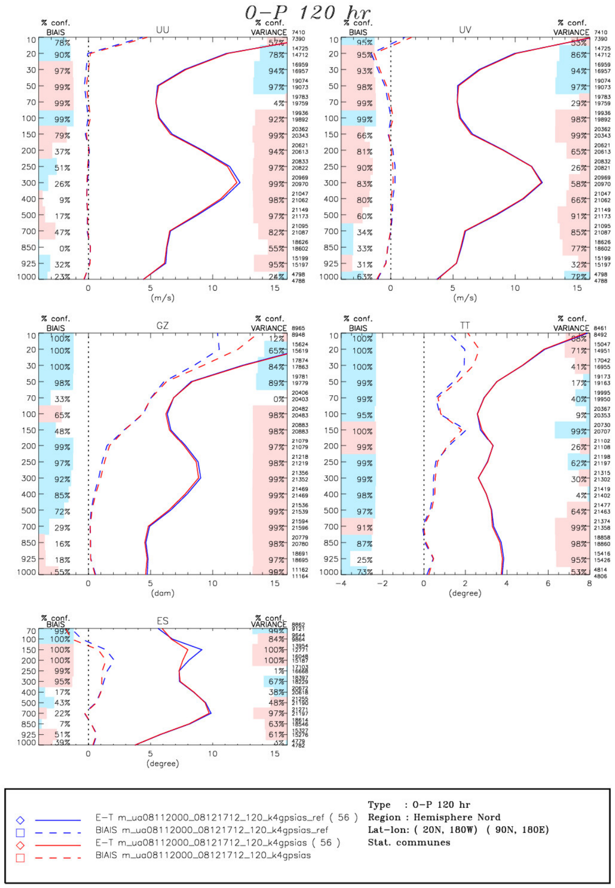
56 cases

Legend:

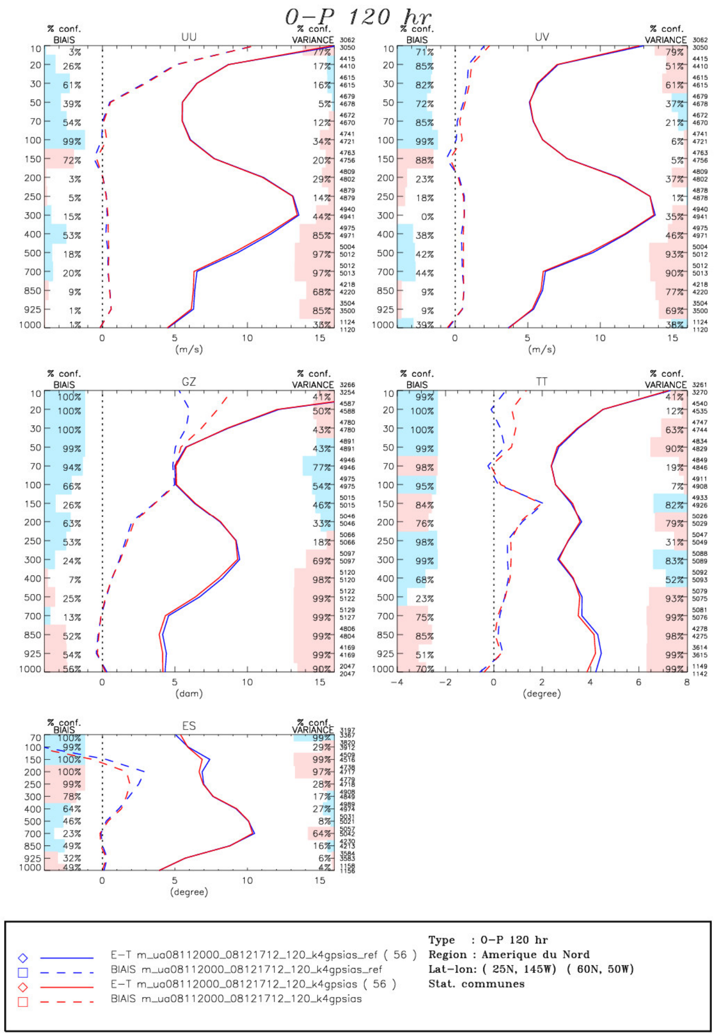
Control is better

Test is better

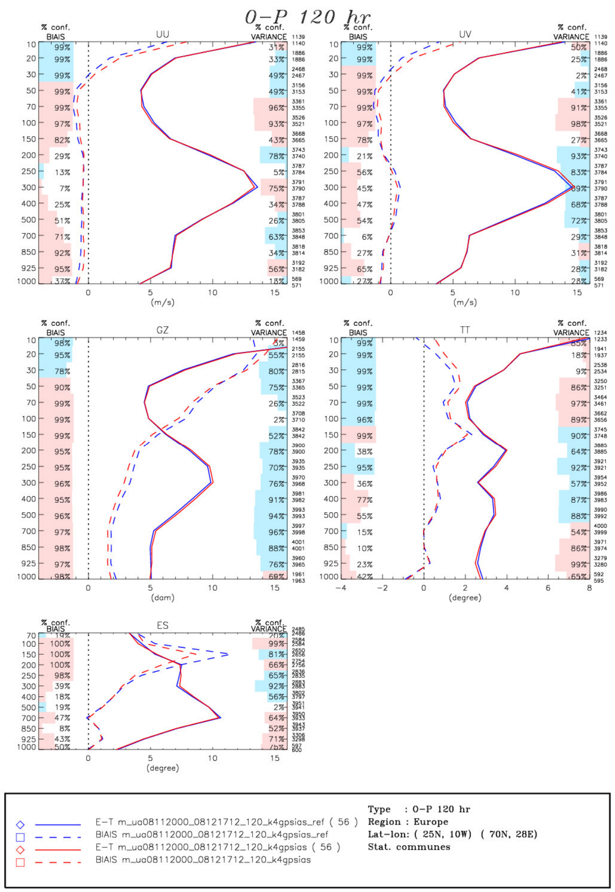
North hemisphere



North America



Europe



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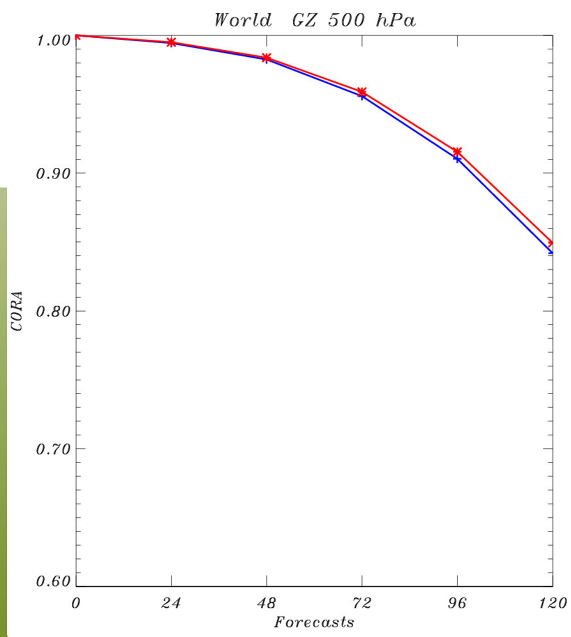
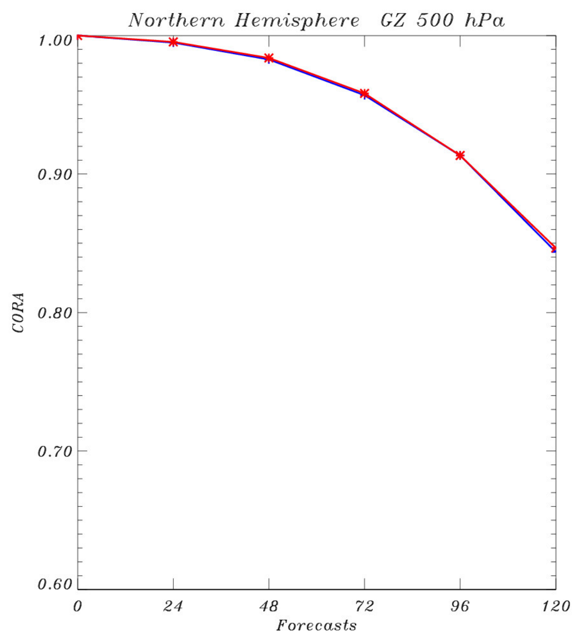
Result of 4dvar Assimilation Exp. 4/4

- Validation against analysis: Anomaly Correlation Coefficient for geopotential height at 500 hPa

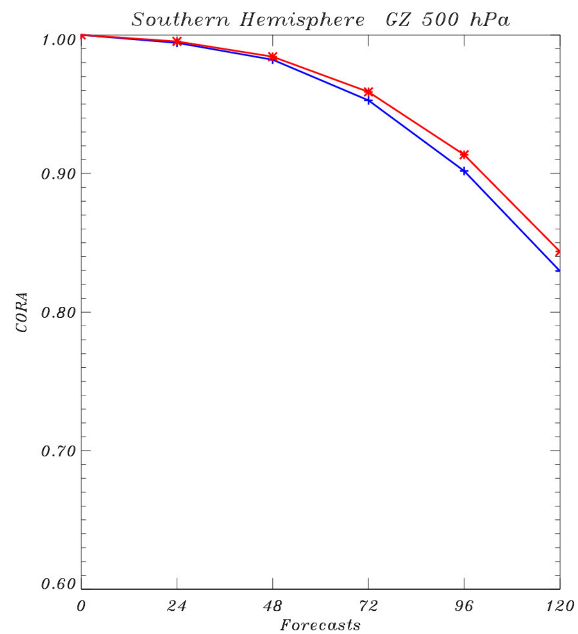
WORLD



NORTHERN H.

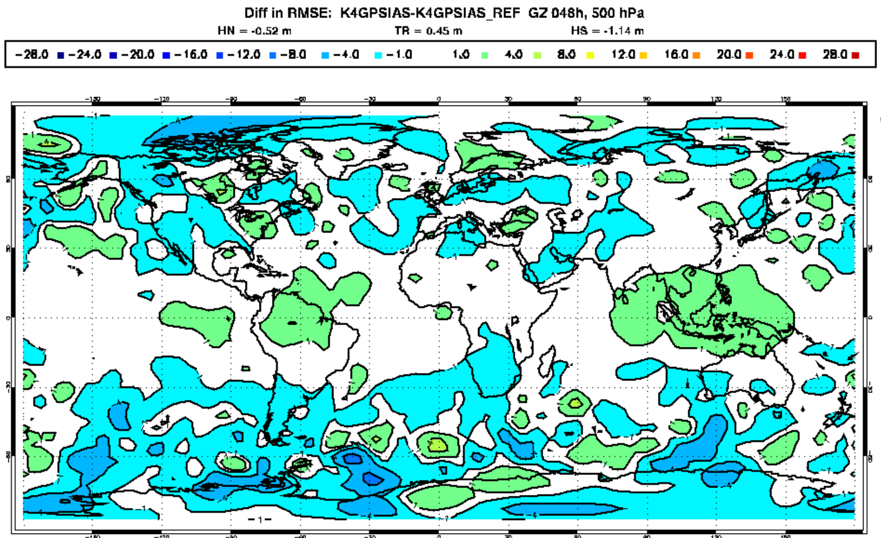


SOUTHERN H.

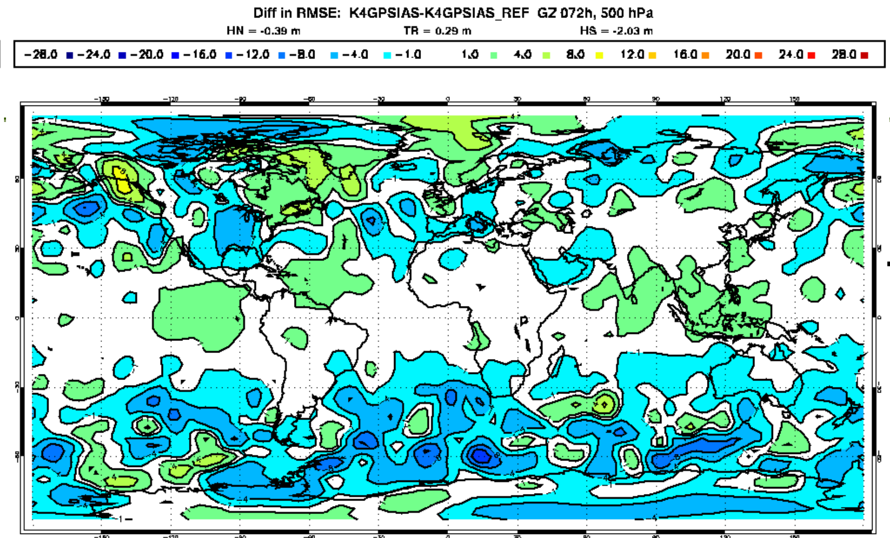


Difference of RMSe maps 500hPa GZ

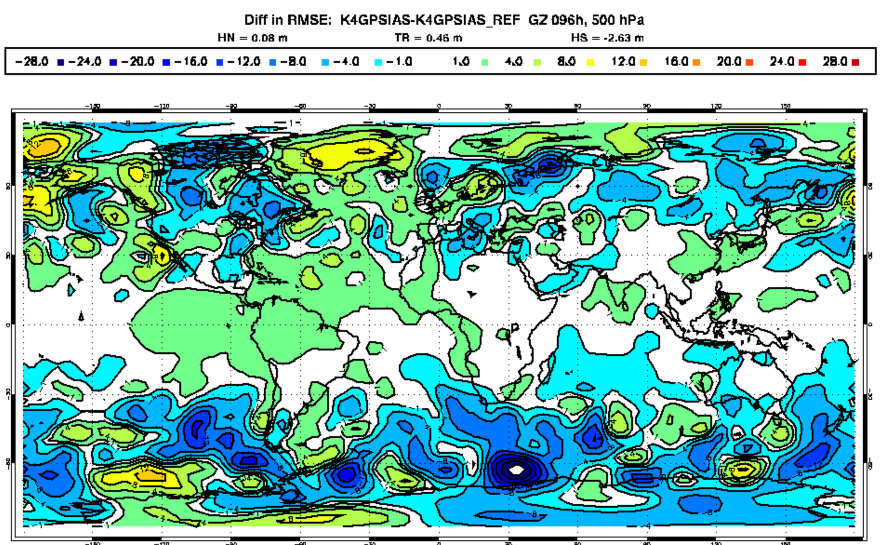
48



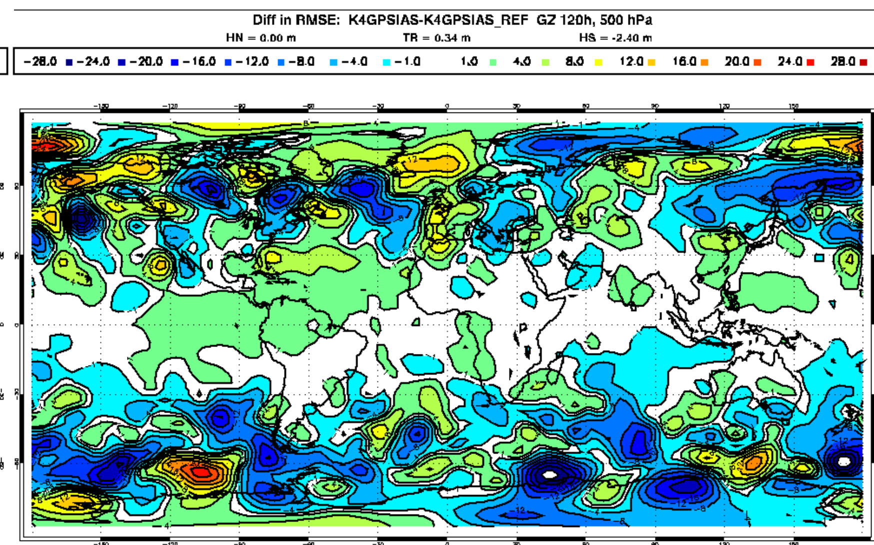
72



96



120



More…

- For those who want to see more, detailed statistics are available at:

http://iweb.cmc.ec.gc.ca/~armagr8/introduction_iasi/introduction_iasi.html

Computer time: background check

Instrument	AIRS	IASI
CPU time (maia 16 cpus)	13 minutes	35 minutes

$$\frac{13}{35} \approx 0.37 \qquad \frac{281}{616} \approx 0.45$$

Note: these results are preliminary. There is certainly room for optimization !

Computer time: 3Dvar analysis

	Without IASI	With IASI
time (maia 16 cpus) for 3Dvar (FGAT) analysis	19.7 minutes	25.6 minutes

In 3Dvar mode +30 %

Note: these results are preliminary. There is certainly room for optimization !

Strategies for operational implementation

- "Big package" strategy A (assuming Gem-Strato implementation in june 2009):
  - GEM Strato 1
  - IASI
  - AMSU-A and MHS from METOP-A
  - Georad
  - Humidity from planes
- Strategy B: in case of problem with A separate implementation of some components in GEM Strato1
- Strategy C: "On the fly" implementation in GEM Meso Global (not very likely)

Conclusions, Perspectives

- The results of these first 4Dvar assimilation experiments are very encouraging, notably in southern hemisphere
- Improved quality control using sub-pixel AVHRR information
- The assimilation experiments will be pursued with the new GEM meso-strato model (top at 0.1 hPa, 80 vertical levels) and possibly more IASI channels. This could improve the noted GZ bias at high levels
- Research is ongoing on the assimilation of cloud-affected radiances (in the case of IASI use of sub-pixel information should help). Restriction to quasi overcast situations
- Incorporation in AIRS/IASI quality control Work of Ovidiu Pancrati should improve our cloud characterization