Cloud detection for IASI/AIRS using imagery

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Purpose and methodology

prepare assimilation of AIRS cloudy radiances at Météo-France

- selection of a robust and efficient cloud detection and characterisation scheme
- first investigations for cloudy radiances assimilation

1. MODIS cloud mask:
   -> cloud status to AIRS ifov from collocation of MODIS and AIRS granules
2. AIRS cloud detection/ characterisation on the same data:
   - NESDIS, ECMWF, CO_2-slicing, MLEV schemes
   - same bias correction and set of channels applied to ECMWF, CO2-slicing, MLEV
3. CO_2-slicing cloud information:
   - Errors characterization
   - Impact of reconstructed radiances
4. First investigations for cloudy radiances assimilation
5. Conclusion and perspectives

Data set

- Area : North East Atlantic
- 2 test periods :

  10 to 20 April 2003 -> 35 granules

  15 to 28 March 2004 -> 52 granules

- 10 ->15 April and 15 ->21 March used as training period for thresholds, bias coefficients …
- Data : MODIS , AIRS and AMSU
- collocated NWP Arpège T,Q
- Sea situations

MODIS cloud mask (MF/CMS , LeGléau, Derrien)

Adaptation to MODIS of the NWC SAF SEVIRI cloud mask

For each MODIS pixel, gives:

- Clear/cloudy flag
- Cloud type
- Cloud top temperature and pressure
- Snow/ sea ice (clear pixels)

Thresholds tests series of various channels combinations to each fov:

- test series depend on surface type, solar zenith angle, specular reflection (daytime)
- thresholds depend on :
  - measurement conditions (solar and local zenith angles)
  - environmental conditions from external information (atlas, forecast)
  - satellite through off-line tables (with RTTOV) depending on channels filters

Cloud level: radiance ratioing + H_2O/IRW intercept methods

MODIS and AIRS mapping

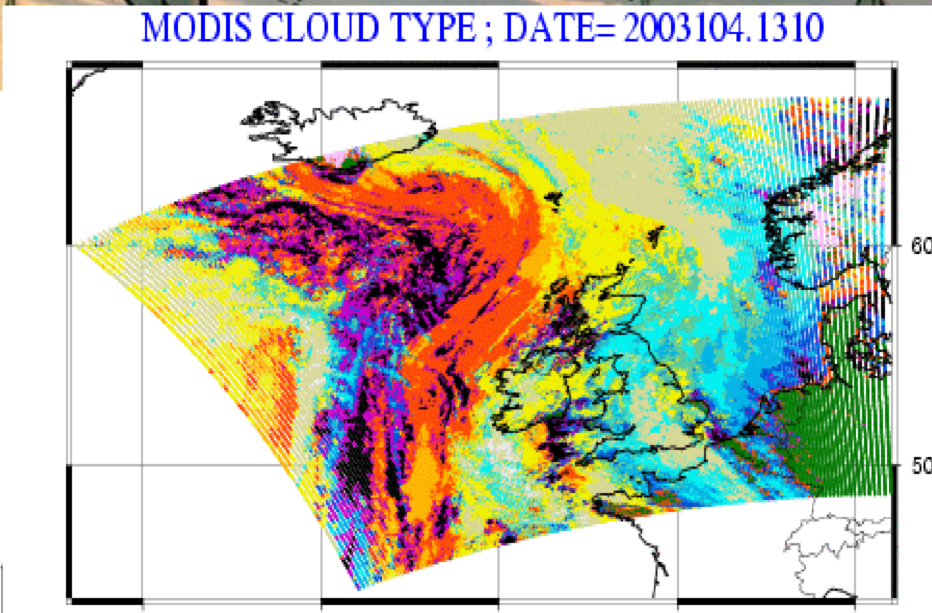
Objectives :

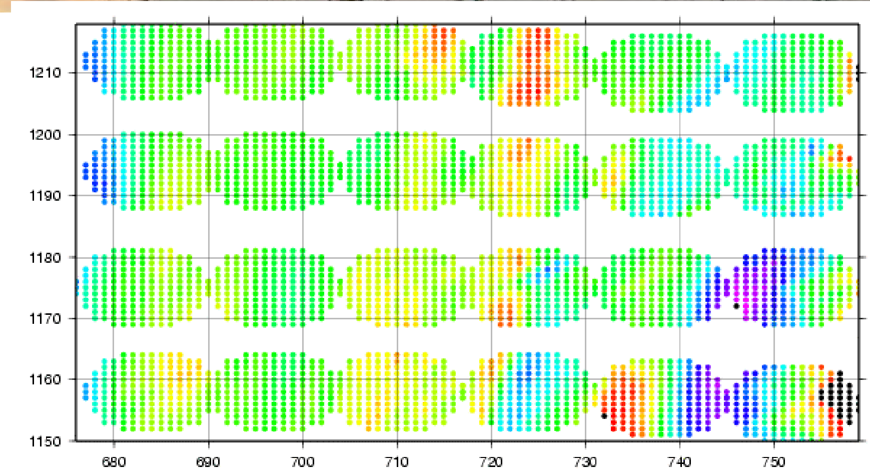
Determine the number of cloud layers, their cloud type, coverage and top temperature in AIRS ifov using the MODIS cloud mask mapped in AIRS ifov

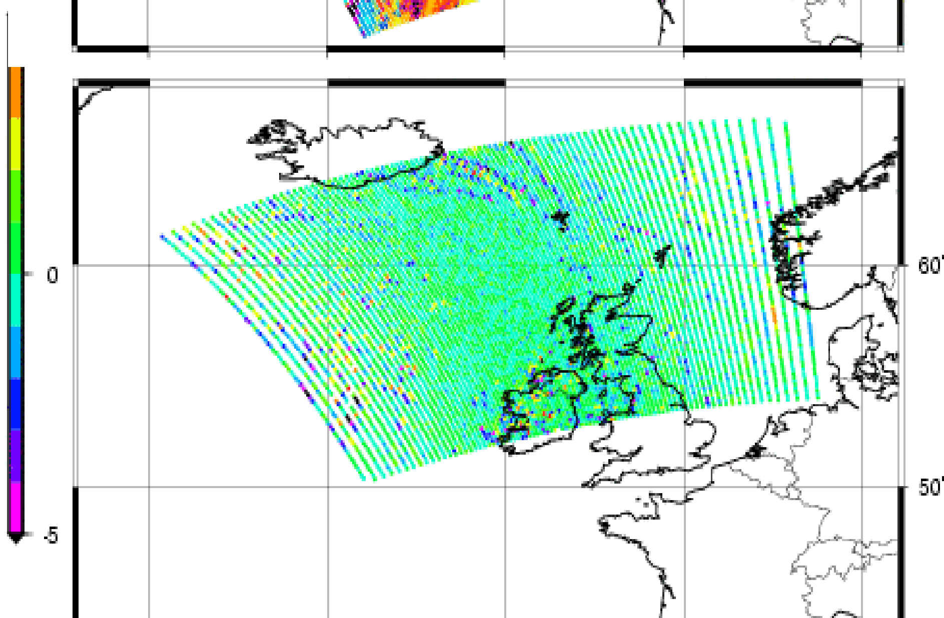
Principe :

- based on MODIS and AIRS navigation data and scan geometry
- adjustment in line and pixel of MODIS and AIRS through statistics on differences between AIRS simulated radiances for MODIS 32 filter
- from pixel MODIS cloud type + temperature characteristics, determine the number of cloud layers (3 max)
- situation = clear if < 5% MODIS pixels are cloudy

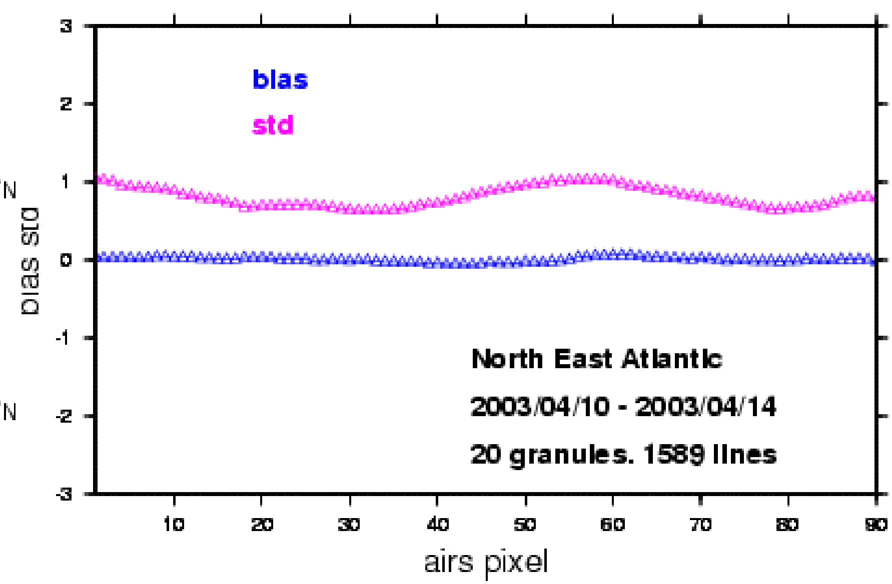
MODIS and AIRS mapping







MODIS 32 - AIRS collocation



AIRS cloud masks

NESDIS: detection of clear situations

based on a combination of 3 tests on AIRS channels.
SST thresholds adapted to our test data
very fast model. no need of previous bias correction

ECMWF: selection of clear channels above the clouds

RTTOV-7 and NWP background used for simulating the AIRS clear radiances
15 µm band used (130 channels)

CO_2 Slicing: determination of cloud top pressures and emissivities

RTTOV-7 and same NWP background used
15 µm band used (124 channels on first time period ; 20 channels on second period)
cloud pressure: weighted mean of individual pressures with function sensitivity
allows 1D-Var cloudy retrievals

MLEV: determination of cloud parameters

RTTOV-7 and same NWP background used
minimization of the local emissivity variation in 5cm-1 spectral windows
all channels in [750-900 cm-1]

AIRS bias correction

Systematic errors between observed and simulated radiances from :

- errors in the radiative transfer model
- instrument measurement/calibration problems
- errors in NWP fields

Model used for bias correction for channel j:

$$A_0(j) + \sum_{i=1,8} (A_i(j) * (y_i - \overline{y_i})) + A_9 * (TWVC - \overline{TWVC}) + A_{10} * (T_s - \overline{T_s}) + A_{11} * \sec$$

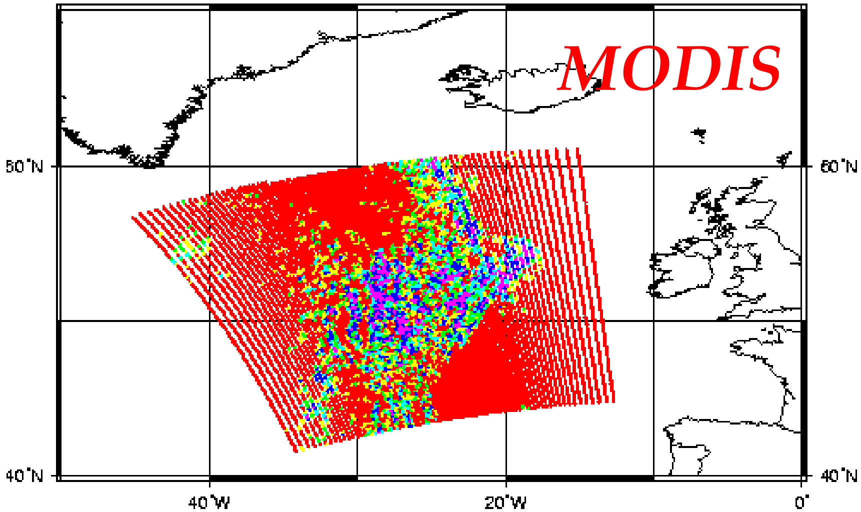
Y= AMSU 6, 8,9,10,11,12,13,14

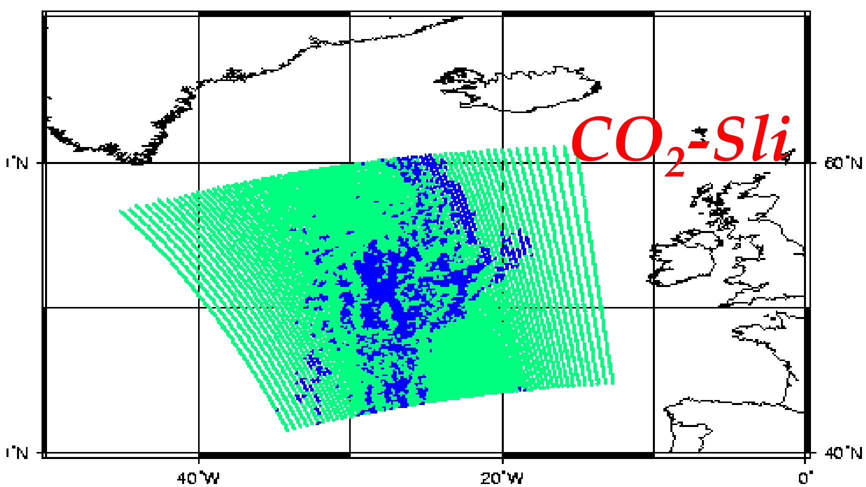
coefficients computed from MODIS clear detected situations on training periods

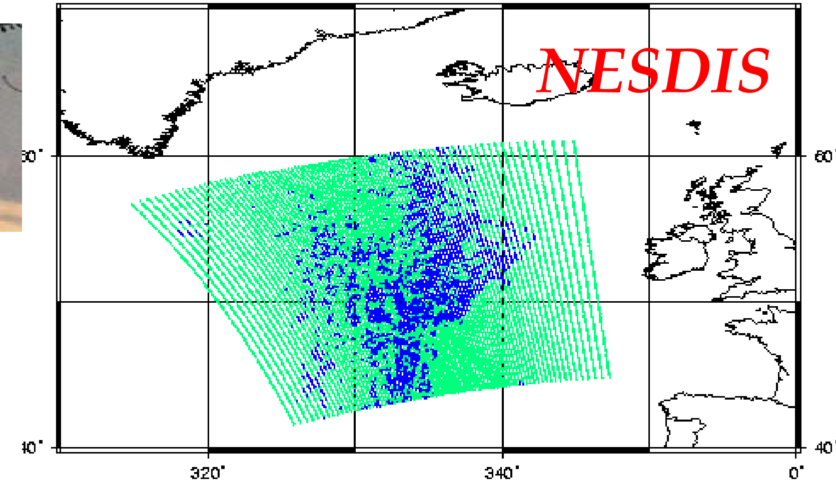
applied on each AIRS situations before AIRS cloud detection

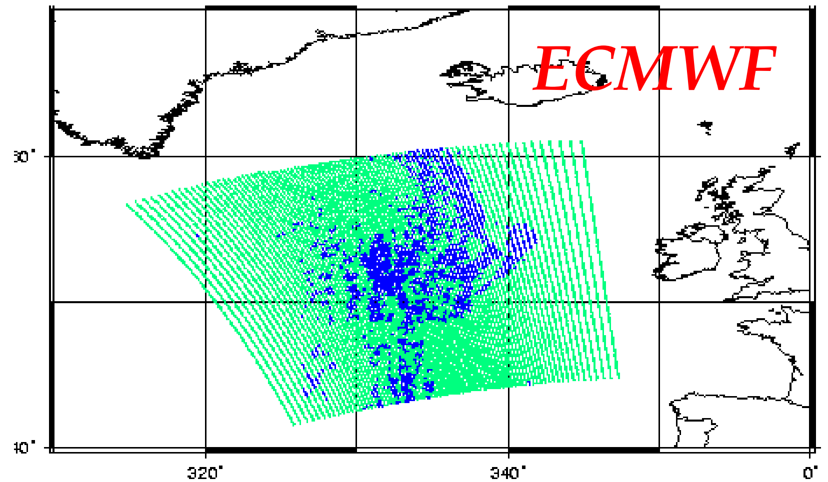
Cloud detection

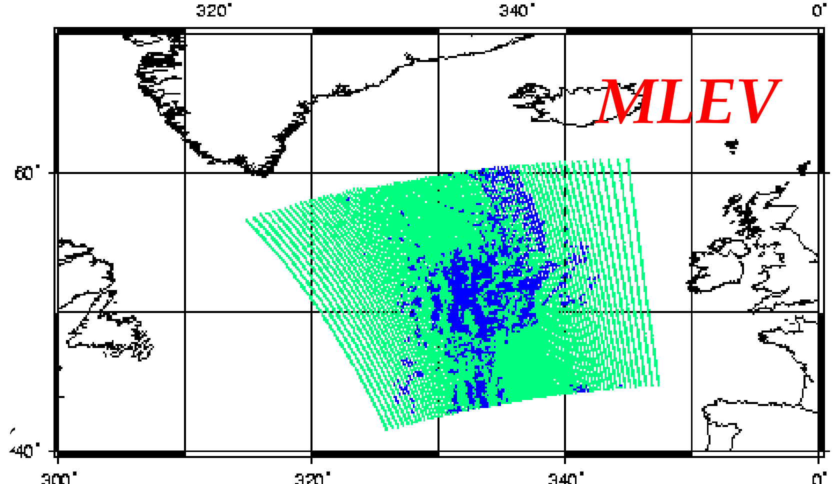
Ex: 16/04/2003, granule 146











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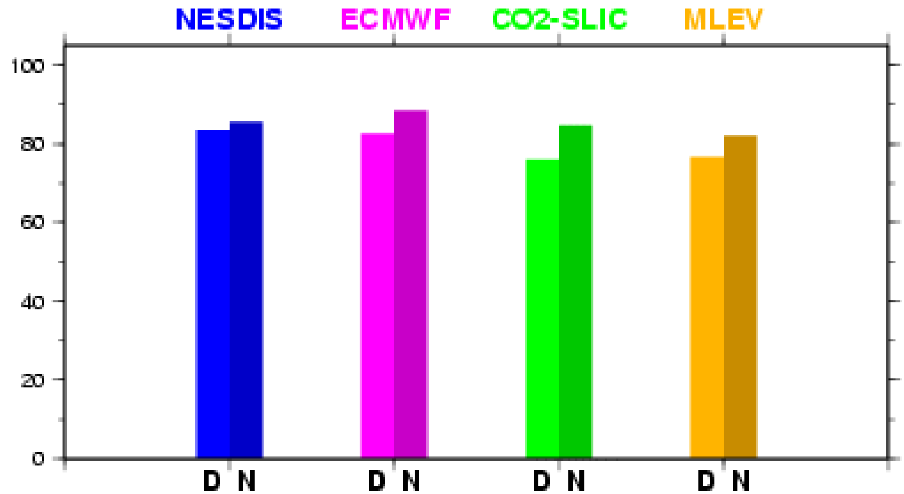
Validation: clear/cloudy AIRS ifov detection

Statistics from 16 – 19 April, 2003

Clear AIRS ifov detection

Day: 2799 sit.

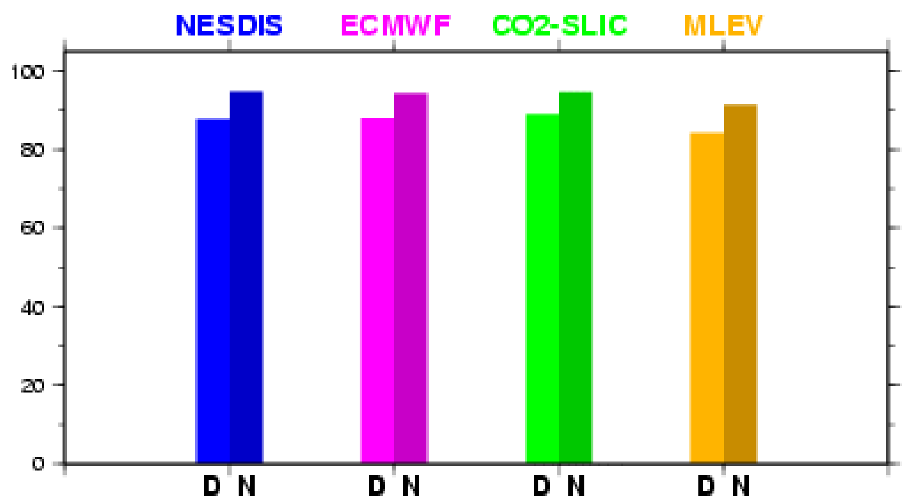
Night: 5470 sit.



Cloudy AIRS ifov detection

Day: 28510 sit.

Night: 57719 sit.



Channels used in CO_2 slicing on march 2004 dataset

selection of 20 channels among the 124

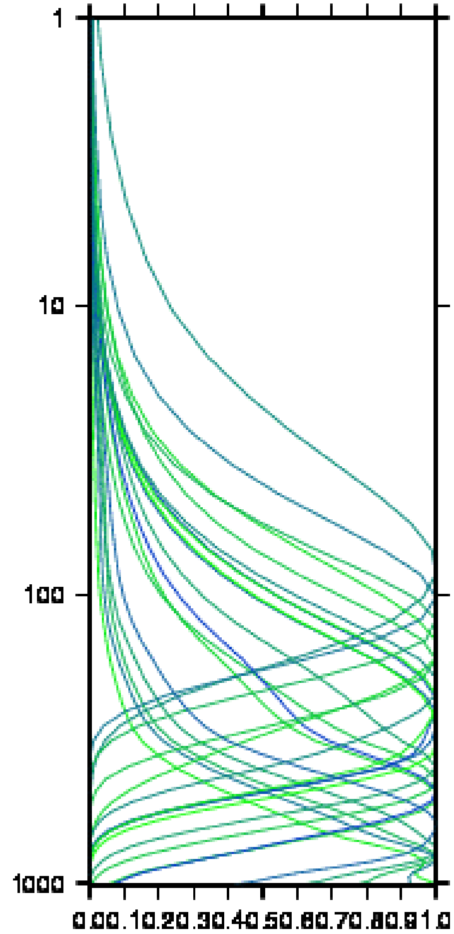
- less noisy from monitoring
- max of weighting function < 85hPa
- no overlapping of max weighting function

channels:

7, 139, 150, 165, 172, 175, 179, 180, 185, 186, 192, 198,210, 216, 221, 232, 252, 262, 305, 950

R rms:

1.09, .60, .66, .58, .49, .47, .42, .43, .45, .44, .44, .39, .39, .36, .32, .33, .32, .34, .44, .57



cloud detection applied before CO_2-Slicing

Follows G. Auman work: based on
$\Delta SST = SST\_nwp - SST\_2616$

Cloudy if:

- $\Delta SST > 2.5K$

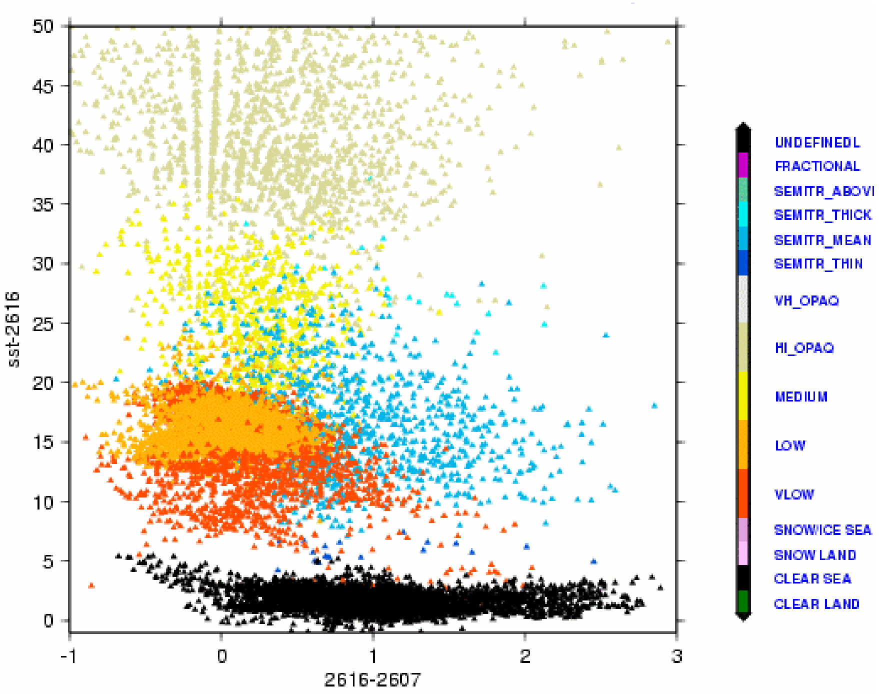
or

- Local max $\Delta SST > 0.8K$ (4 nearest neighbours)

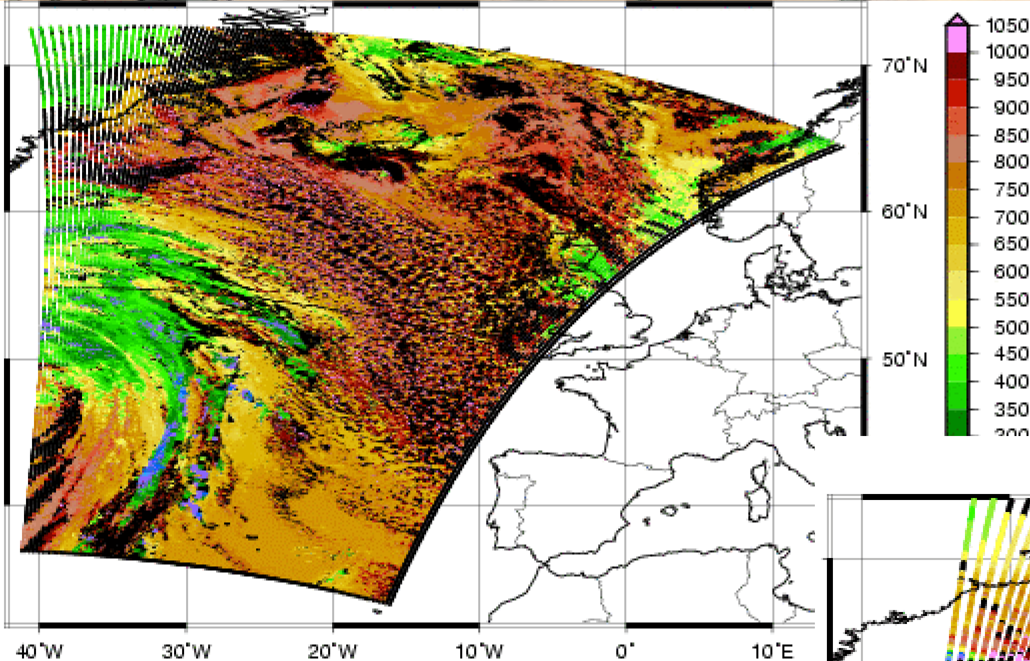
or

- for one channel

[Tb_rttov - TbObs] < 1.5*sig (from clear monitoring)



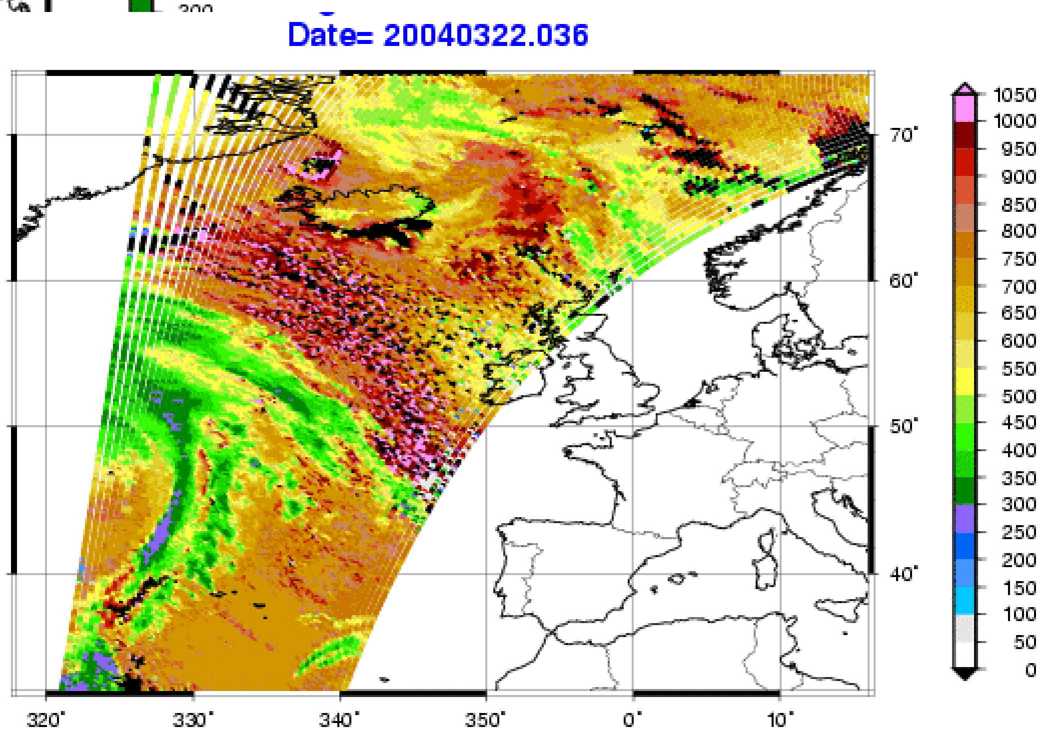
Cloud characterization



Modis

CO_2-Slicing

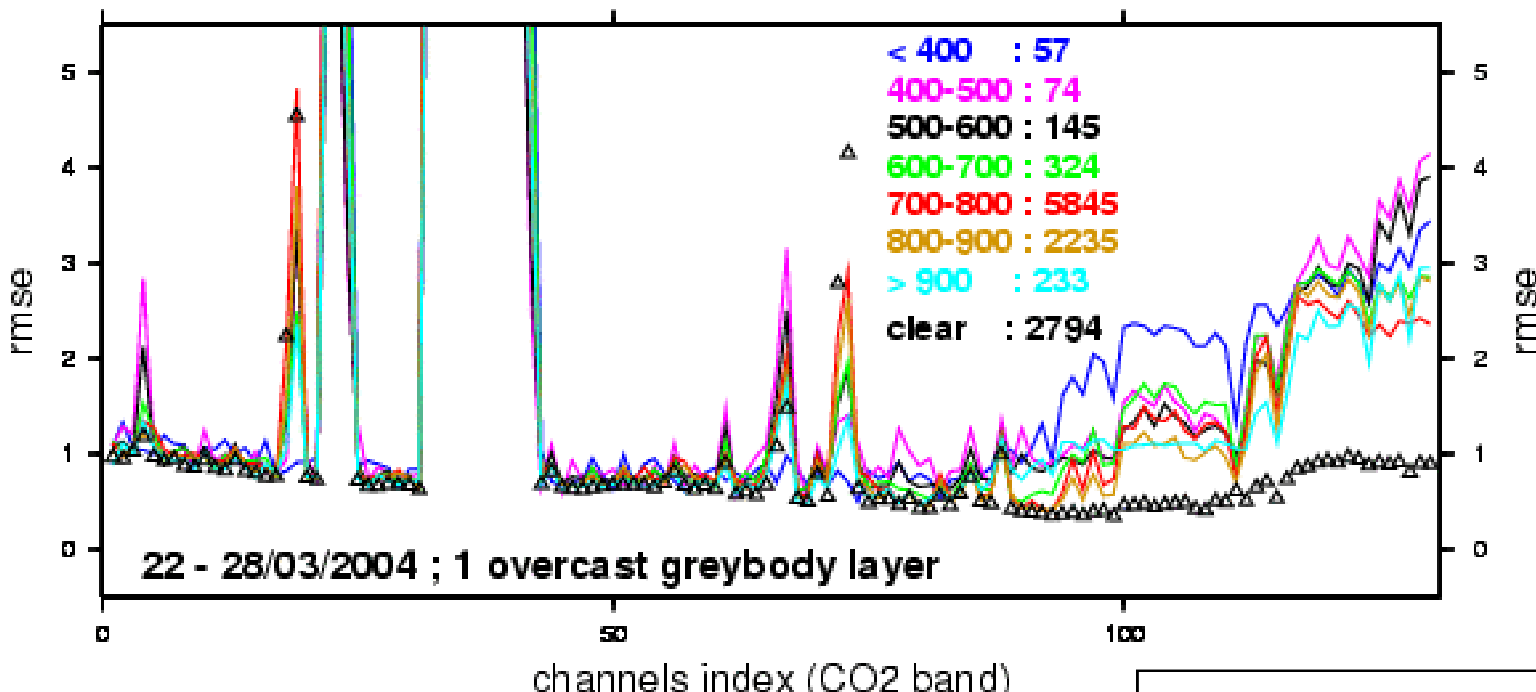
30 PCA



Cloudy radiances monitoring

Rms of the differences between RTTOV Tbs and observations using MODIS CO_2-Slicing cloud parameters

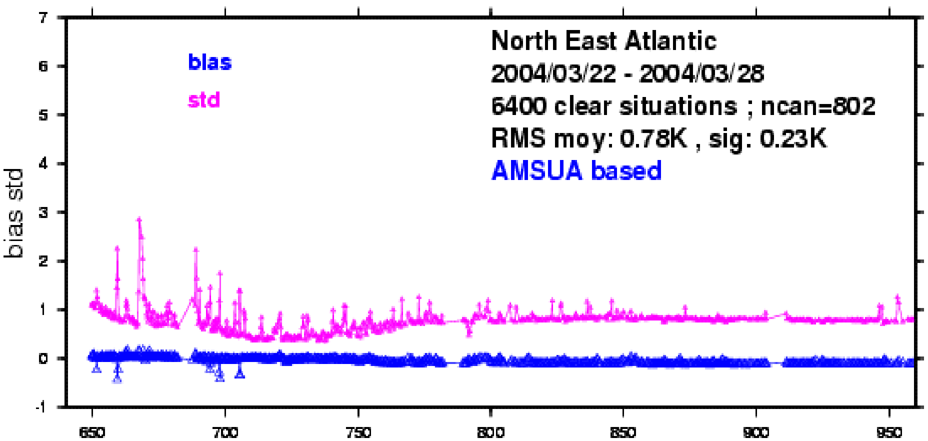
function of cloud height



No bias correction

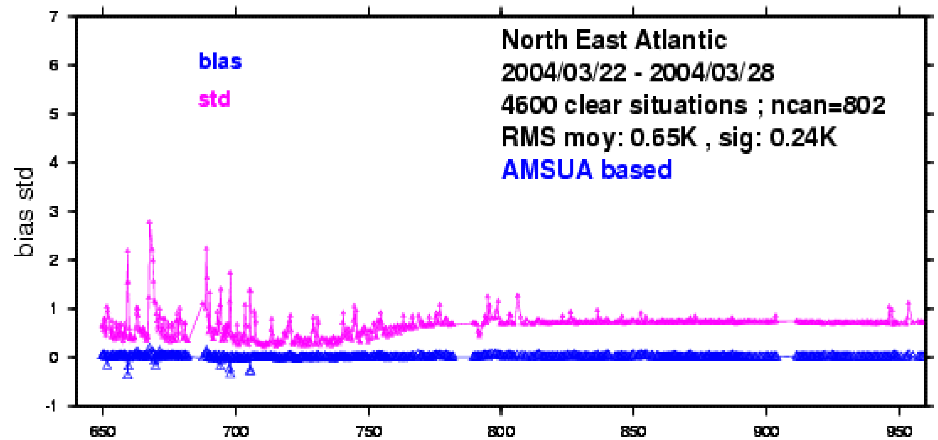
Reconstructed radiances: impact on residual biases

residual bias

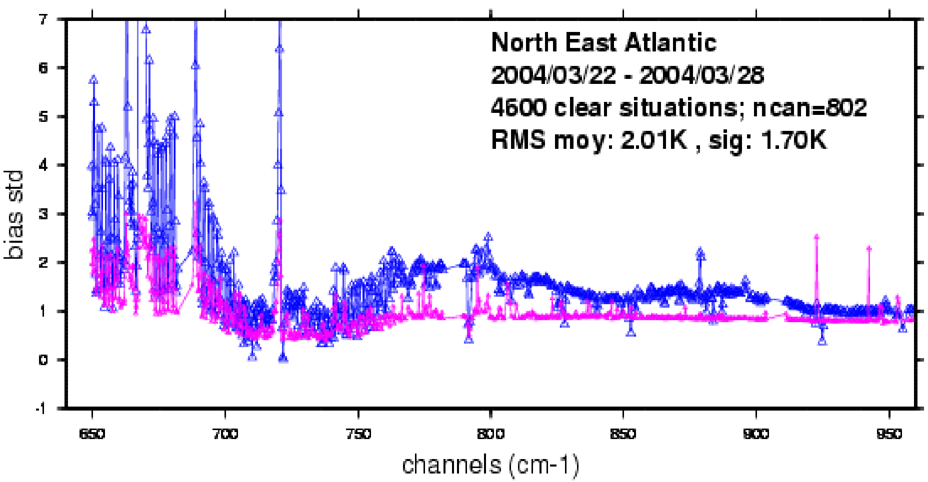


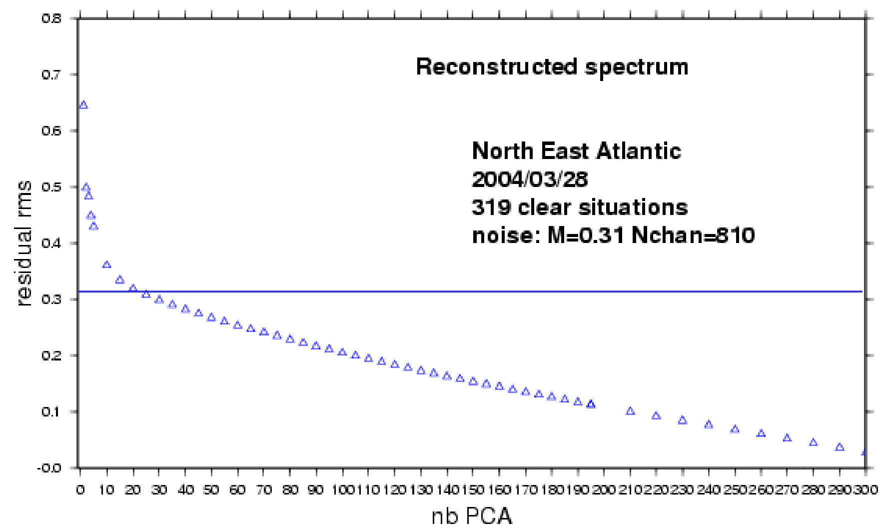
reconstructed channels ; nb PCA=30

residual bias

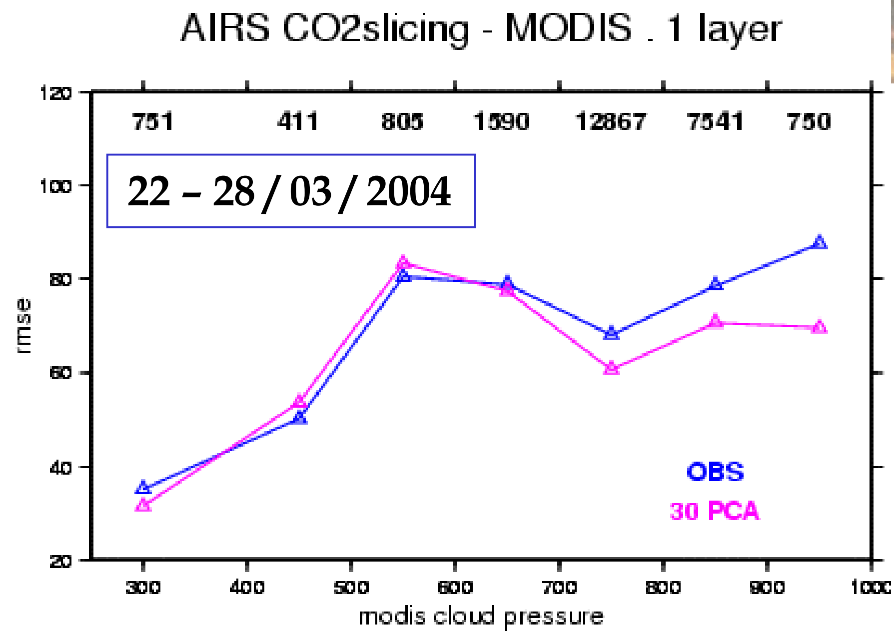


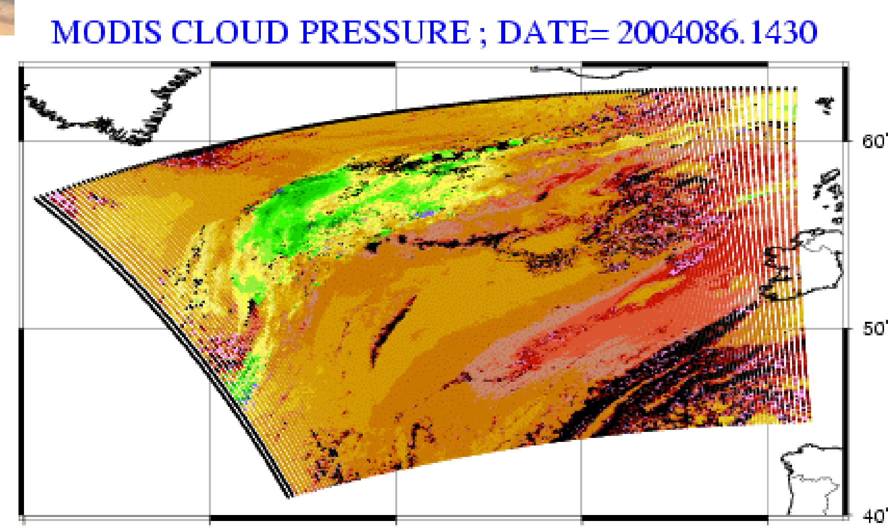
before bias correction

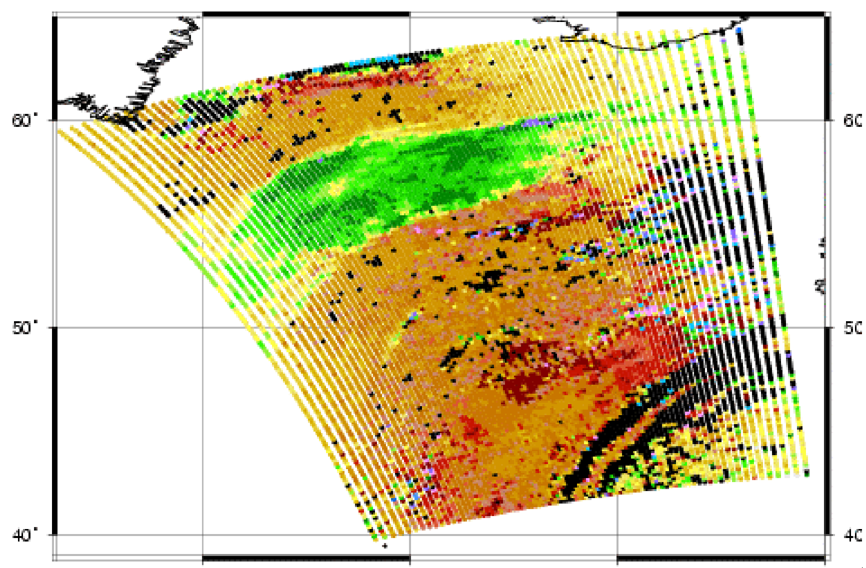


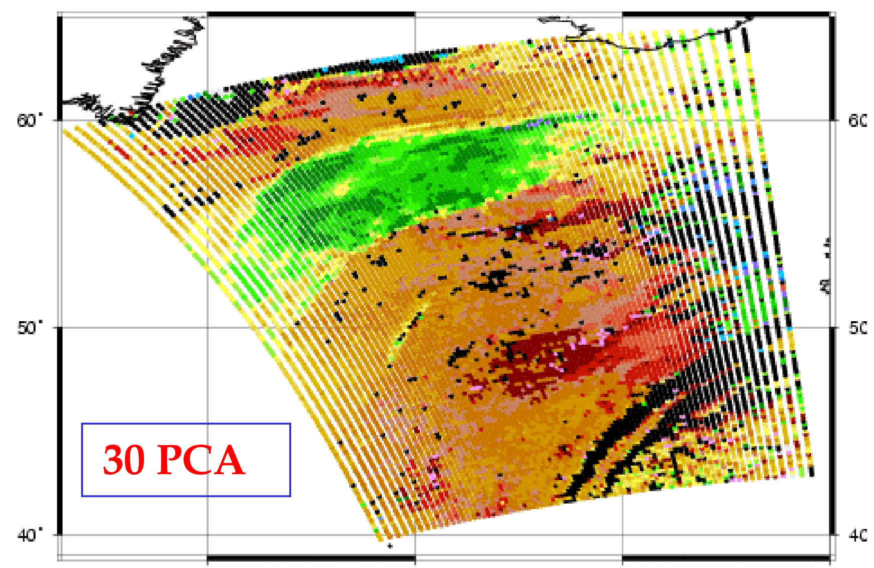


Impact of noise reduction on cloud pressure









Summary of AIRS cloud characterisations (1)

Cloud and clear detection (more details in QJRMS or ITSC-13) :

- For all schemes, synoptic cloud patterns are well detected.
- For all schemes, general good agreement with MODIS mask above 900hPa
- For all schemes, poor sensitivity to clouds near the surface and for fractional and unclassified clouds
- ECMWF and CO_2-slicing give similar results (confirmed on second period)
- NESDIS is very efficient (slightly less for thin semi-transparent and fractional clouds)
- MLEV is more sensitive to the measurement noise: results improved with PCA

Collocated or associated imager is still necessary to determine the number of cloud layers and for detecting small cloud fractions

IASI pre-processed data (level 1c): Collocation is done with AVHRR imager -> gives 6 clusters with for each:

- % coverage
- Mean and std AVHRR radiances for all channels
- Position of the centre of gravity

Should allow to run a cloud mask on clusters to help IASI processing decision

Summary of AIRS cloud characterisations (2)

Cloud top pressure:

- Good coherence between AIRS and MODIS for one cloud layer
- For multi layers situations, AIRS methods are more sensitive to the highest layer
- Improvement of CO_2-slicing cloud retrievals near the surface with PCA
- MLEV: good coherence with MODIS even for small fraction

First investigations for cloudy radiances assimilation

➔ CO_2slicing method in test inside Arpège NWP model

➔ Diagnostic cloud scheme:

- determine cloud cover, cloud liquid & ice water vapor contents from T,Q profile
- cloud parameters input of RTTOV-CLD
- test of the linerarity of observation operator, necessary for NWP assimilation
- CO_2slicing clouds used for visual selection of situations of large-scale low, medium, high layers

➔ Direct use of CO_2slicing parameters:

- selection of cloud affected channels
- CO_2slicing parameters input of RTTOV « standard »

➔ both methods tested in a 1d-Var scheme

Diagnostic cloud scheme: observation operator linearity

Correlation between:

$H(x_{an}-x_g)$ and $H(x_{an}) - H(x_g)$

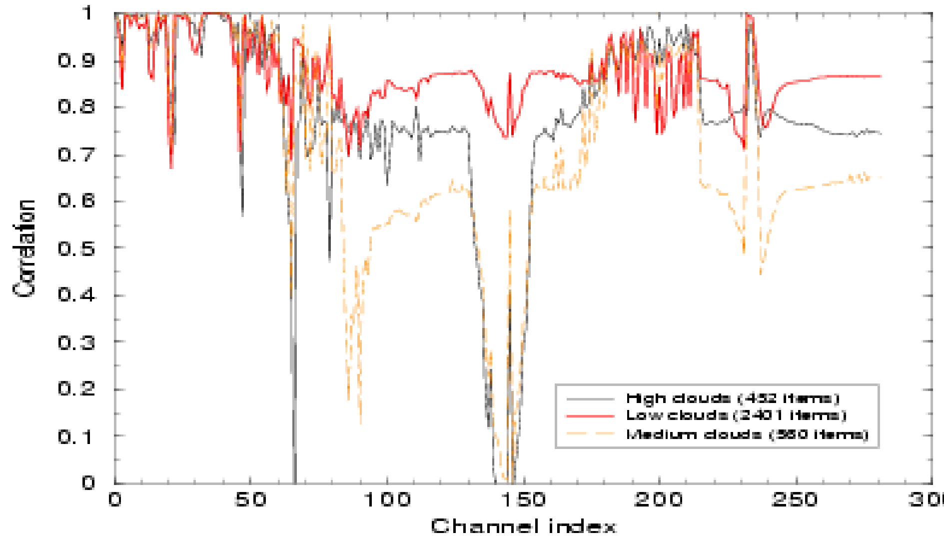
✓ good linearity in stratosphere and upper troposphere [649-700 / 1267-1604cm^{-1}]

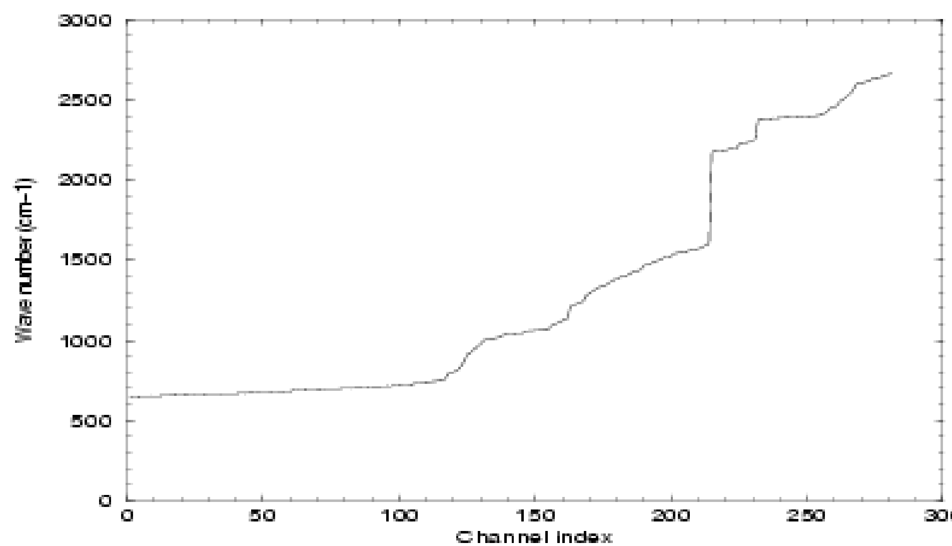
✓ linerarity significantly depends on cloud type in mid-atmosphere [700-1000cm^{-1}]

- low clouds: acceptable
- medium clouds: highly non-linear
- high clouds : case to case

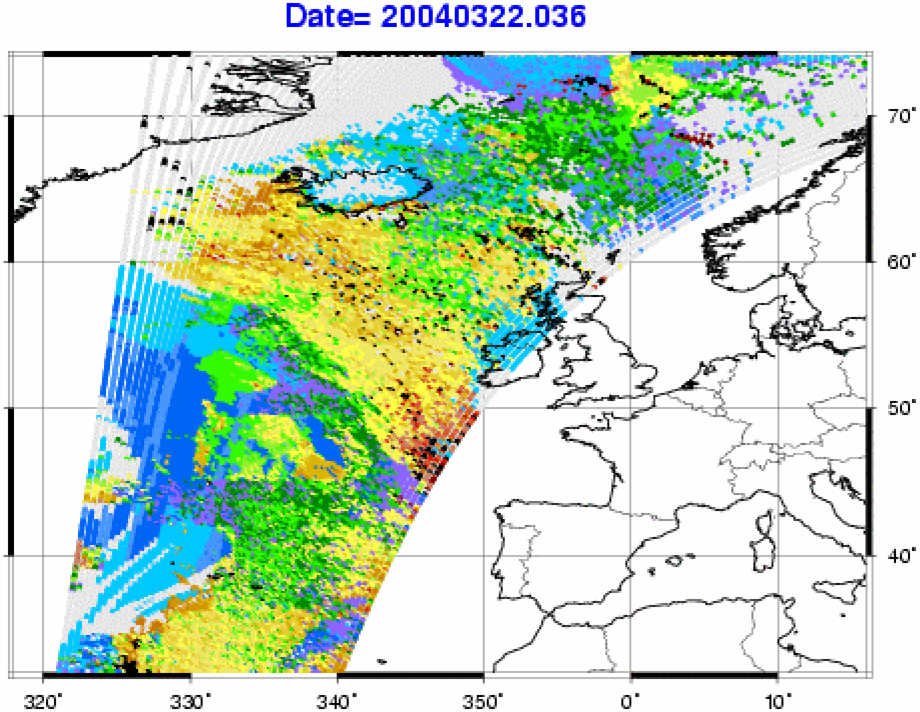
✓~ 1000cm^{-1}: highly non-linear

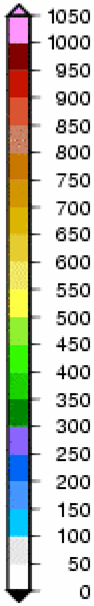
Only few AIRS channels shows enough linearity for assimilation





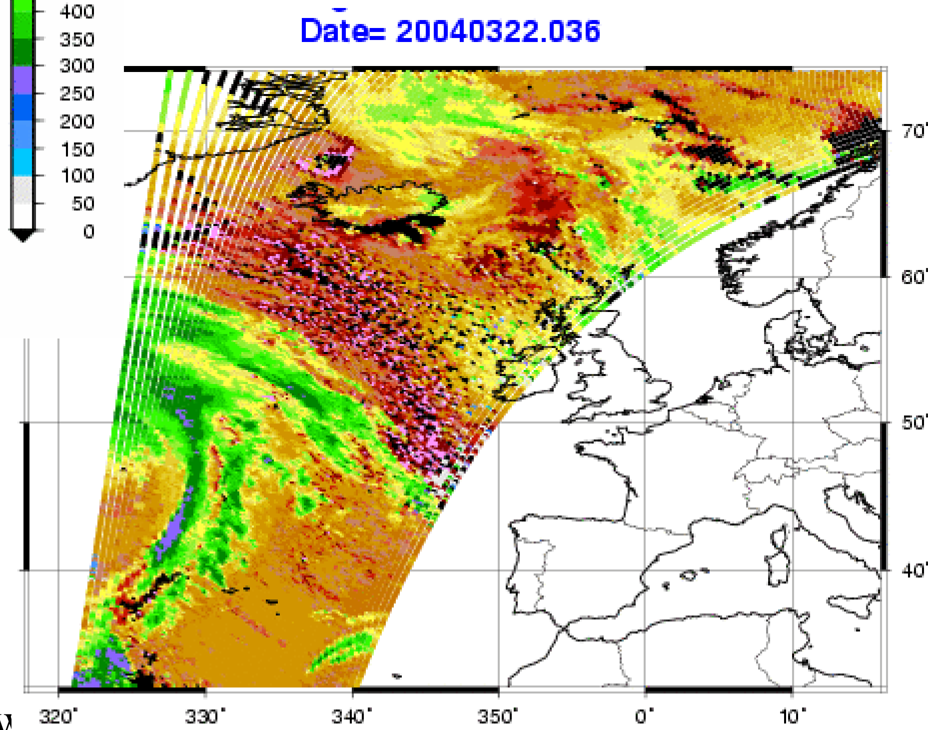
ECMWF first cloud affected pressure





CO_2-Slicing

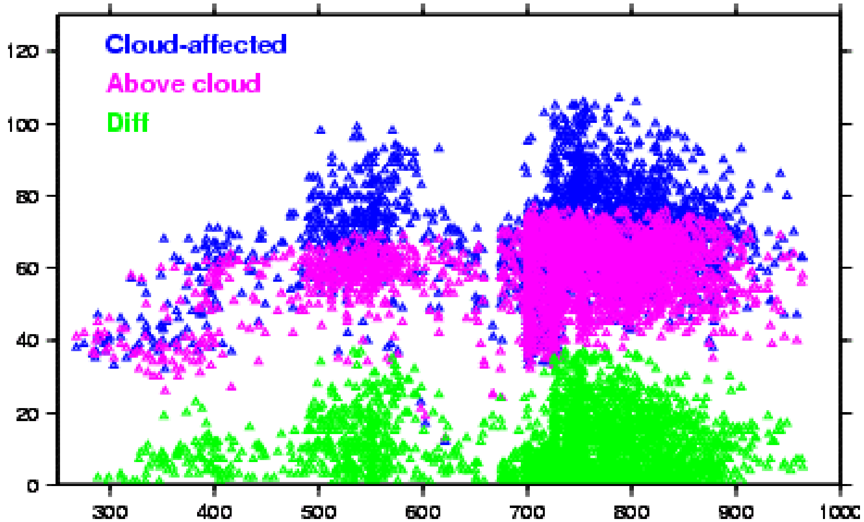
30 PCA



ECMWF

Max highest pressure level authorized: 16 (83hPa)

1D-Var minimization: channels selection



Corr [Hδx ; H(x_g +δx)–H(x_g)] > 0.85

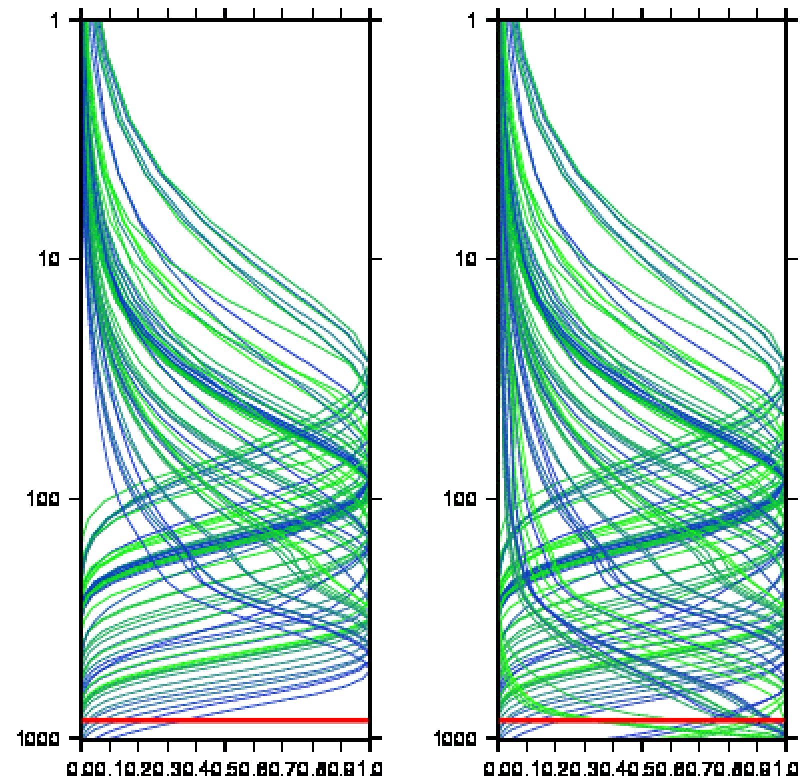
Cloud-affected:

|Tbsynt-Tbobs| < 1.5*std (cloudy monitoring)

Above cloud:

|Tbsynt-Tbobs| < 1.5*std (clear situations)

Example for P_cld=843hPa



Above cloud: 59

Cloud-affected: 79

Conclusions and perspectives

Future :

Assimilation experiments tests and comparison:

1. diagnostic cloud-scheme : perform a more extensive evaluation with systematic selection of situations
2. direct assimilation of cloud parameters from CO_2-slicing:

   Improved selection of cloud affected channels

   Cloud error characteristics

   - ✓ Clouds parameters keep constant during 4D-Var minimisation
   - ✓ Prior 4D-Var, perform a cloud parameter minimisation with a 1D-Var using CO_2-slicing clouds as guess

   IASI 1D-Var simulations (see ITSC-12) show improved retrieved profiles just above the cloud, using cloud-affected radiances + co_2slicing clouds as guess

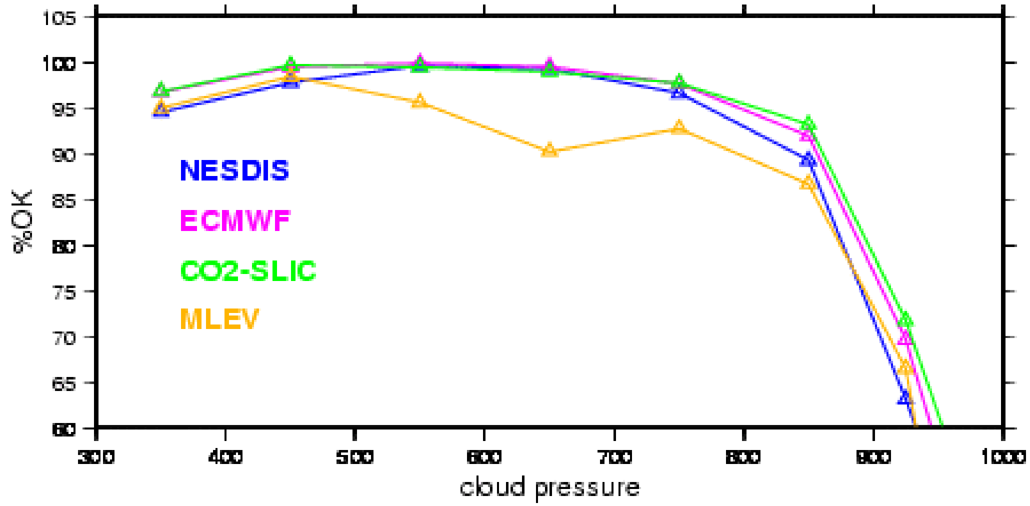
Impact of reconstructed cloudy radiances on T,Q retrievals

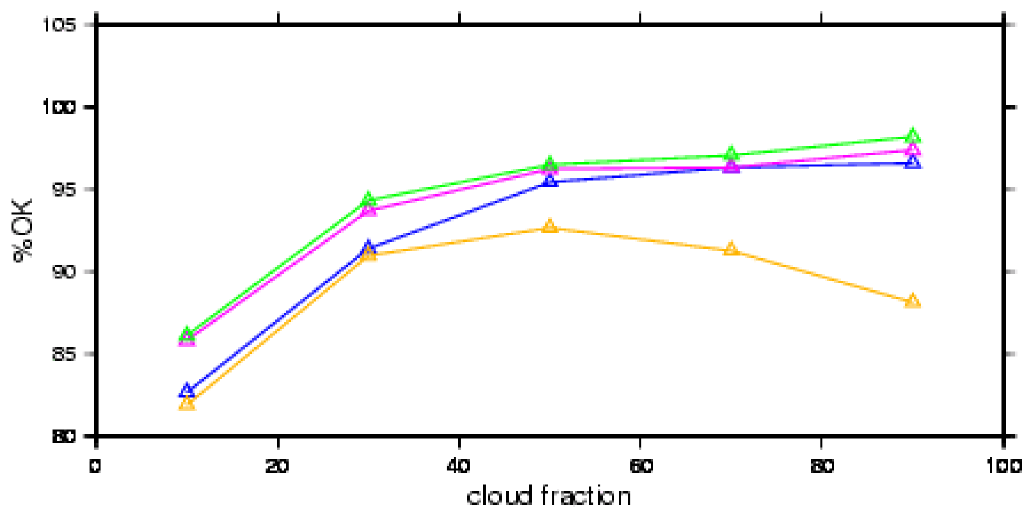
Thanks for your attention

Validation: cloudy AIRS ifov detection

Statistics from

16 – 19 April, 2003





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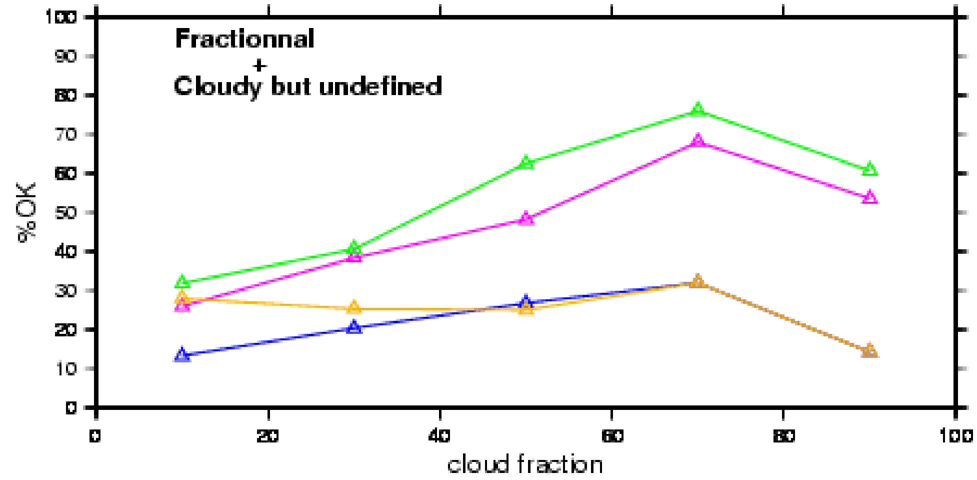
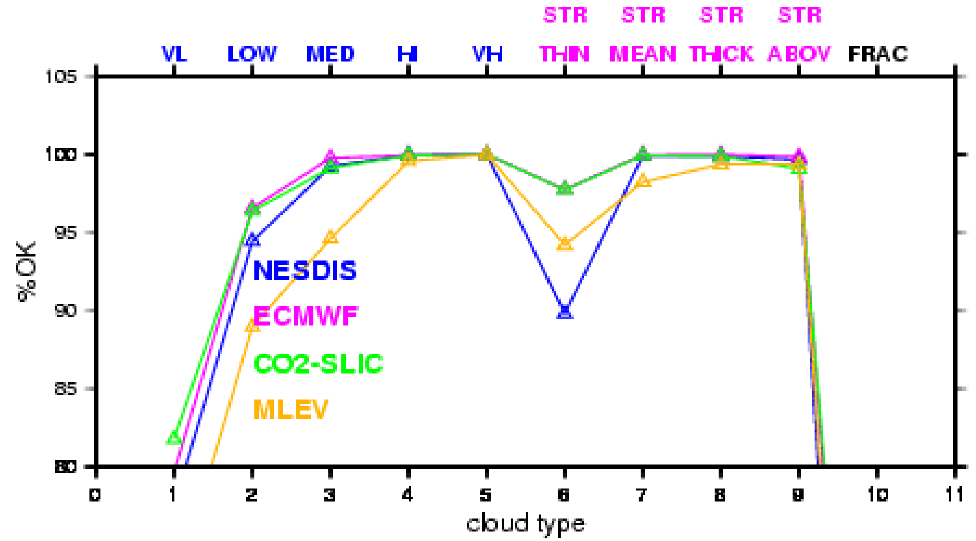
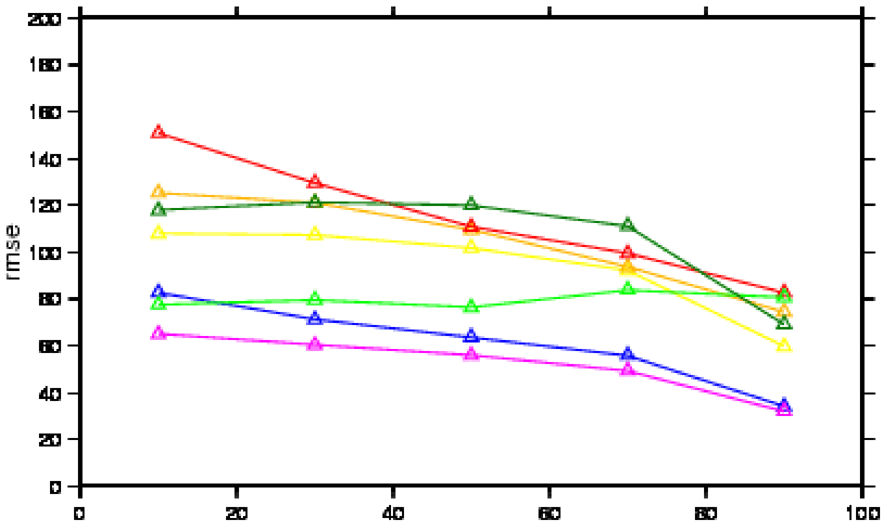




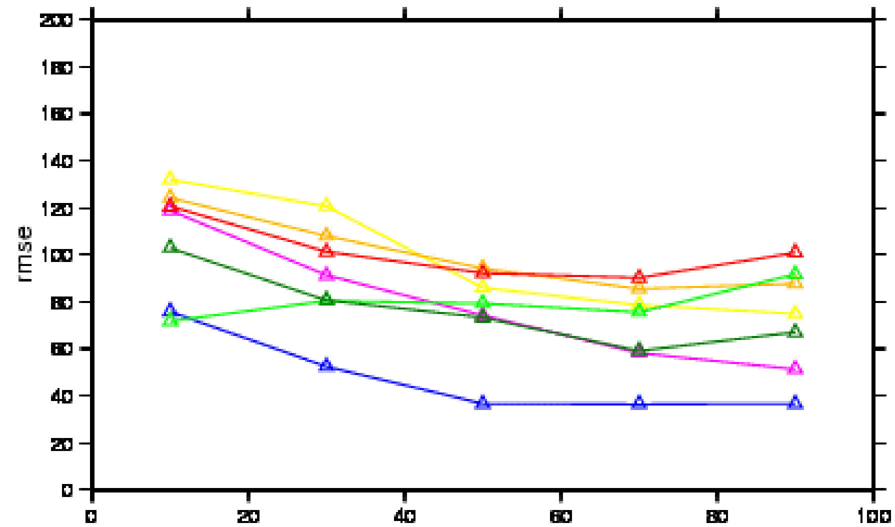
Validation: cloud top pressure

Statistics from 16 – 19 April, 2003

AIRS CO2-slicing - highest MODIS layer



AIRS MLEV - highest MODIS layer



	0-20	20-40	40-60	60-80	80-100
< 400	1984	2703	1780	1395	5264
400-500	339	497	448	352	979
500-600	145	214	273	434	1641
600-700	1001	1323	911	598	944
700-800	1143	1486	930	767	2067
800-900	144	246	287	180	245
> 900	240	588	844	838	2319

simulation IASI: sondage en conditions nuageuses

Guess: forecast + CO_2 p_cld and ε_cld
Control variables: T, ln(p_cld), ε_cld
up to 3 iterations
selected channels: Tbobs – Tbgucld < 0.5K
-> more than 60% channels selected

all P_cld > 800hPa
1807 situations