Use of MODIS imager data to help dealing with AIRS cloudy radiances

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Purpose and methodology

➔prepare AIRS day1 assimilation of clear radiances at Météo-France

- need of a robust and efficient clear detection scheme
- low computer cost

➔start the study of a high spectral resolution cloud mask model

1. MODIS cloud mask
2. collocation of MODIS and AIRS granules
3. cloud status of all AIRS ifov with MODIS cloud info.
4. Bias correction of AIRS measurements
5. AIRS cloud detection with NESDIS, ECMWF, CO2-slicing, MLEV
6. AIRS cloud top pressure with CO2-slicing, MLEV models
7. Visual comparison and statistics
8. Cost execution time
9. Conclusion and perspectives

Data set

- Area : North East Atlantic
- Périod : 10 to 20 April 2003 -> 35 granules
- 10 -> 15 April used as training period for thresholds, bias coefficients …
- Data : MODIS , AIRS and AMSU
- Sea situations

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

Adaptation to MODIS of NWC SAF cloud mask for SEVIRI

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 (land, sea), solar zenith angle (day, twilight, night), specular reflection during the daytime
- thresholds depend on :
    - measurement conditions (solar and local zenith angles)
    - environmental conditions from external information (atlas, forecast)
    - satellite through off-line tables depending on channels filters

Cloud level: radiance ratioing + H2O/IRW intercept methods

MODIS and AIRS mapping

Objectives :

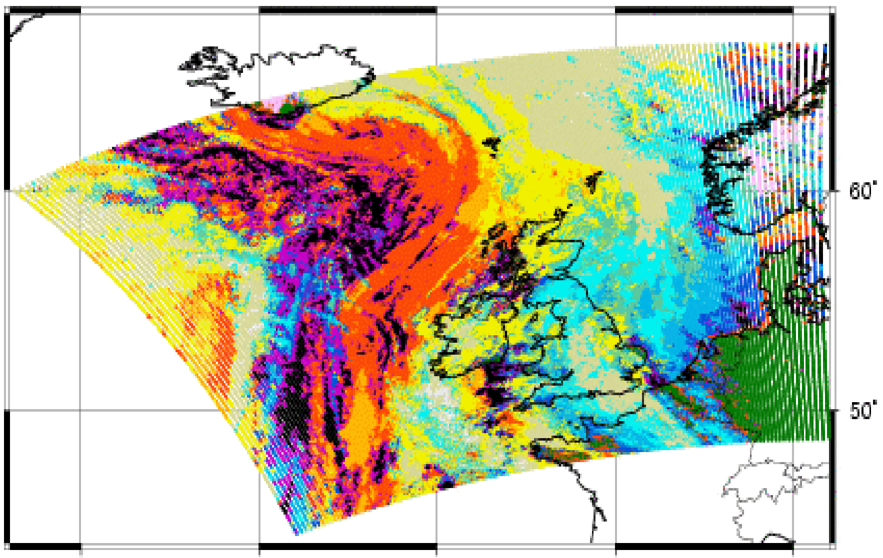
Determine the number of cloud layers, their cloud type, coverage and top temperature in AIRS ifov using the MODIS cloud mask mapped in AIRS ifov

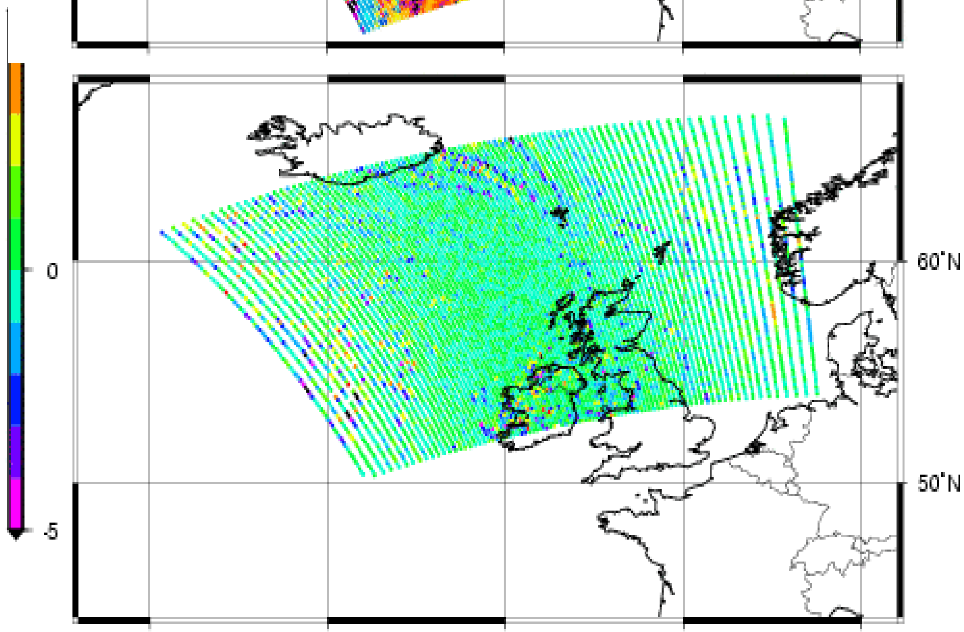
Principe :

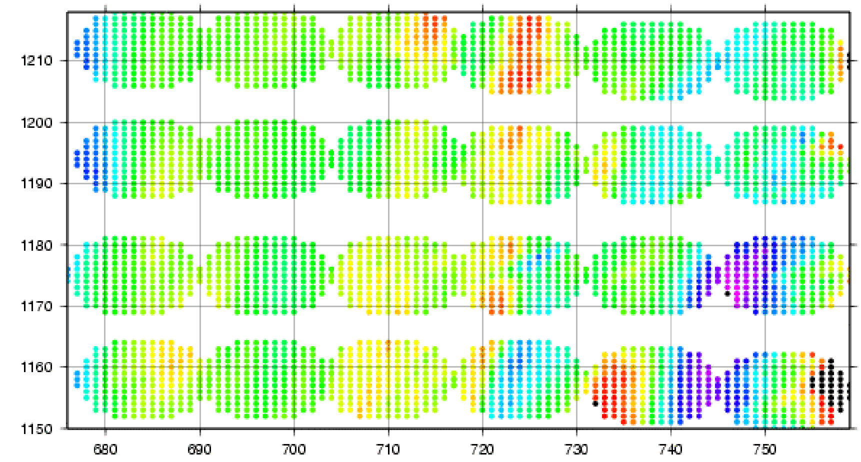
- Based on MODIS and AIRS navigation data and scan geometry
- adjustment in line and pixel of MODIS and AIRS through statistics on differences between AIRS simulated radiances for MODIS 32 filter
- Precise ifov adjustment also tested with VIS/NIR AIRS imager
- From pixel MODIS cloud type + temperature characteristics, determine the number of cloud layers (3 max)
- Situation = clear if < 5% MODIS pixels are cloudy

MODIS and AIRS mapping

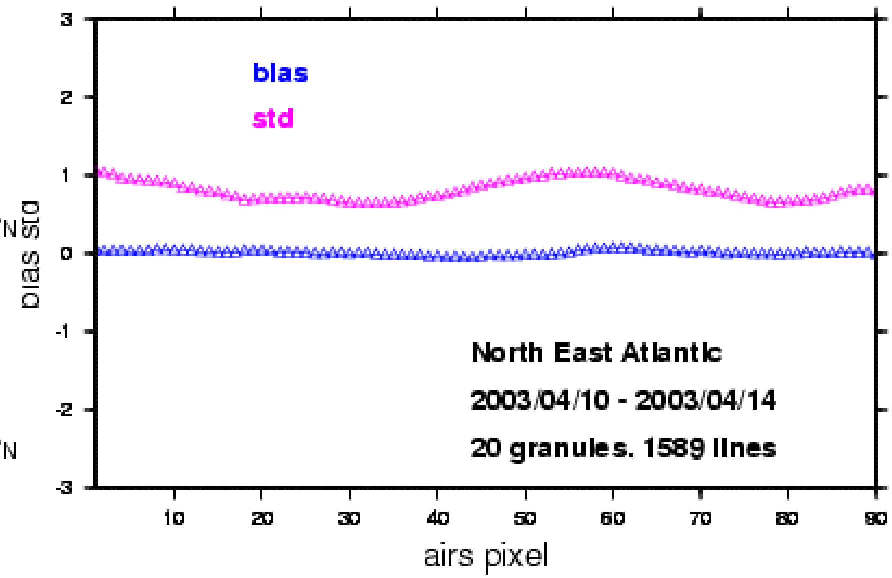
MODIS CLOUD TYPE ; DATE= 2003104.1310







MODIS 32 - AIRS collocation



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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 period

Applied on each AIRS situations before AIRS cloud detection

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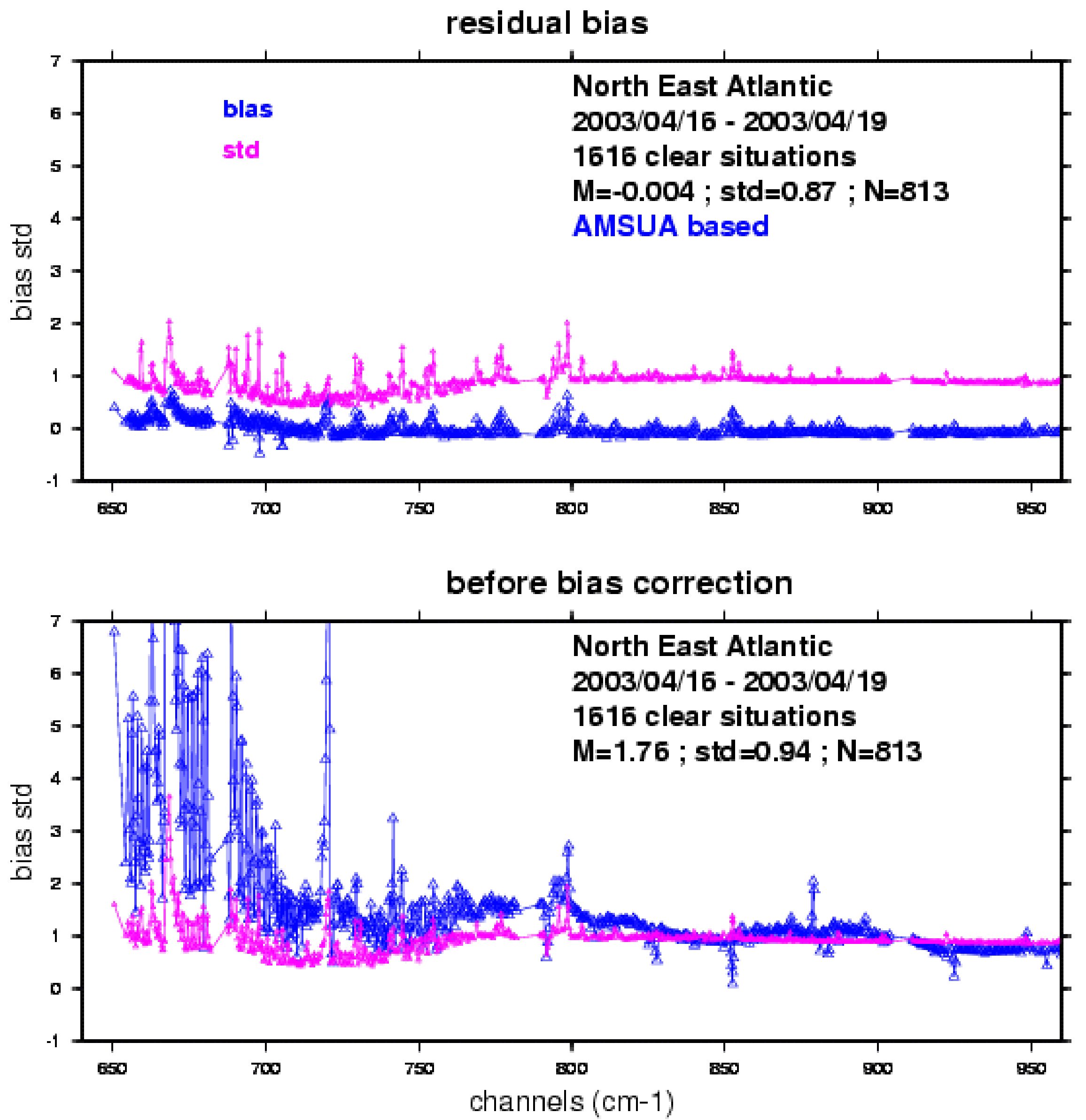
AIRS bias correction



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NESDIS AIRS cloud detection (Goldberg and Zhou, 2002)

Purpose: detection of clear situations
very fast model

Based on a combination of 3 tests on AIRS channels:

pre-launch coefficients

1. **AIRS_2112_sim – AIRS_2112** (2391 cm-1) < **Thres1 (2K)**

   AIRS_2112_sim= fct(AMSU4, AMSU5, AMSU6, secant)

   and

2. **AIRS_2226** (2532cm-1) – **AIRS_843** (937.92cm-1) < **Thres2 (10K)** (night)

3. **Thres3** < **SST_guess - SST_sim** < **Thres4**

   SST_sim=fct(AIR_791, AIRS_914 ,AIRS_1285, AIRS_1301)

   791=918.747cm-1 ; 914=927.122cm-1 ; 1285=1228.225cm-1 ; 1301=1236cm-1

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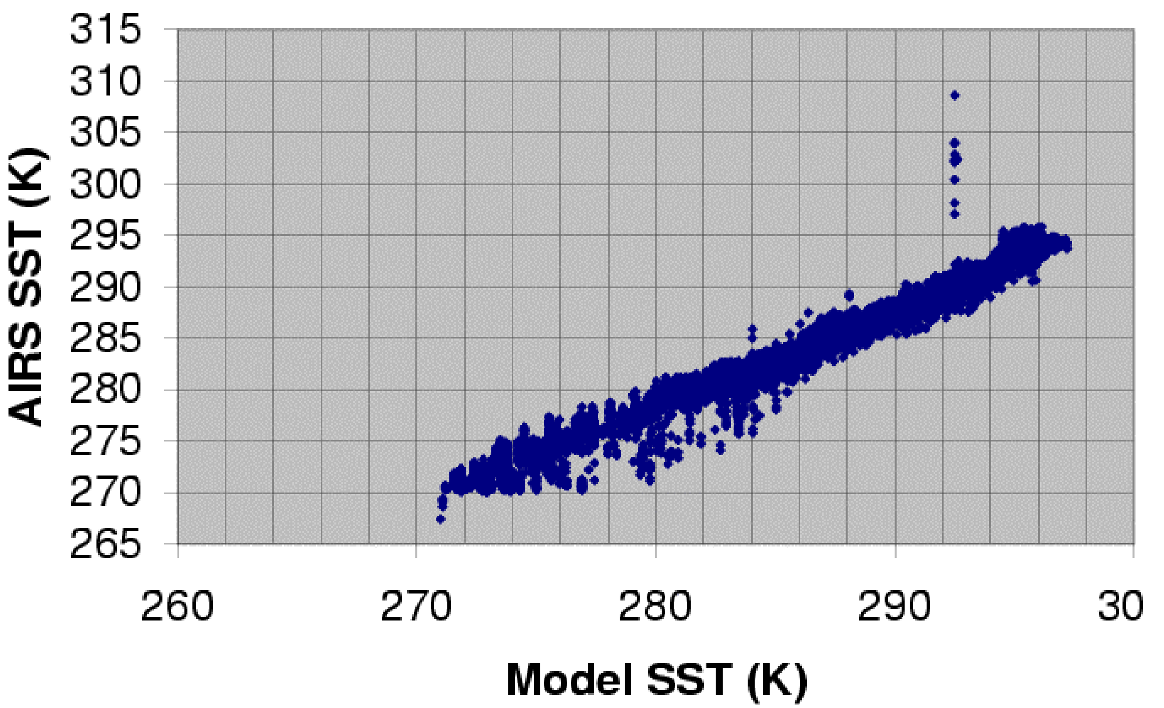
NESDIS cloud detection: Test3 thresholds values

Period: 10 - 20/04/2003 - 14700 collocations

MODIS clear data:
86% -> -0.6K < ΔSST< 3K
97% -> -0.6K < ΔSST< 4K
99% -> -0.6K < ΔSST< 5K

MODIS cloudy data:
89% -> ΔSST> 6K
93% -> ΔSST> 5K
98% -> ΔSST> 3K

Thresholds used:
Thres3= -0.6K
Thres4= 3.3 K



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ECMWF AIRS cloud detection (McNally andWatts, 2003)

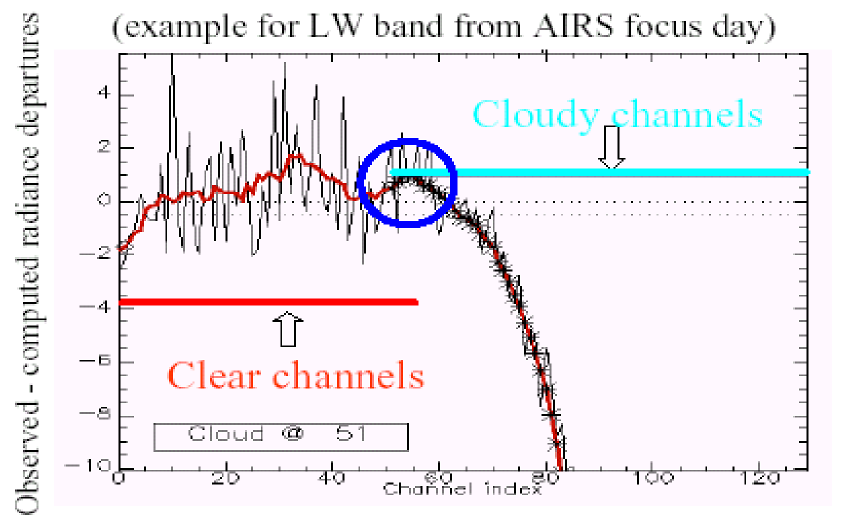
Purpose: Detection of clear channels above the cloud layer

RTTOV-7 and NWP background used for simulating the AIRS clear radiances for each level, each situation, 281 selected channels

steps:

1. Each channel is associated to the first pressure level p for which:

   |Rcld(p)-Rclr|/Rclr > 0.01
2. Channels are ranked according to the assigned pressure level- > channel index
3. 5 spectral bands (15, 9, 6, 4.5, 4.2 μm)
4. O-G function of channel index
5. low-pass filter applied on O-G - > channels with O-G < noise are discarded
5. In each band, a threshold is applied on the gradient of the filtered O-G.



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CO_2-Slicing method (Menzel and Stewart, 1983)

Purpose: Detection of clear situations and determination of cloud top pressure

RTTOV-7 and NWP background used for simulating the AIRS clear radiances for each level, each situation, 124 selected channels (among the 281) in CO_2 band [649.61 – 843.91cm-1]

$$F\nu,p=[(Rclr - Robs)_\nu / (Rclr - Robs)_{ref}] - [N\varepsilon_k\,(Rclr - Rcld(p))_\nu \,/\, N\varepsilon_{ref}(Rclr - Rcld(p))_{ref}]$$

Robs: measured radiance
Rclr, Rcld(p): computed clear radiance and black-body radiance at level p
ν= AIRS channels in CO_2 band   Ref= reference channel = 979.128 cm-1

- For each channel ν: $Pc(\nu)$ = pressure which minimises $F\nu,p$
  $Pc = \Sigma\,(pc(\nu) * W(\nu)^2) / \Sigma\, W(\nu)^2$ with $W(\nu) = \delta F\nu,p / \delta \ln p$
- effective emissivity : $N\varepsilon = (Rclr - Robs)_{ref} / (Rclr - Rcld)_{ref}$
- rejection if $(Rclr - Robs)$ < radiometric noise or $N\varepsilon < 0$ or $N\varepsilon > 1.1$

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Minimum Local Emissivity Variation method

From: Huang and al

Purpose: Detection of clear situations and determination of cloud pressure

RTTOV-7 and NWP background used for simulating the AIRS clear radiances for each level, each situation, all channels in CO_2 band

Assumption: low spectral variation of the cloud emissivity in CO_2 band.

Local variance: $Var_{loc}(\nu) = \Sigma\, [N\varepsilon(\nu) - moy(N\varepsilon(\nu))]^2$ in $[\nu - \Delta\nu/2, \nu + \Delta\nu/2]$ with $\Delta\nu$=5cm-1

$N\varepsilon(\nu) = (R_{obs}(\nu) - R_{cl}(\nu)) / (R_{cld}(\nu) - R_{cl}(\nu))$

R_{obs}, R_{cl} : observed and RTTOV-7 synthetic clear radiances
R_{cld}: black-body radiance at pressure level p
ν in [750 - 900 cm-1] ; best sensitivity to variations of Pc and $N\varepsilon(\nu)$

Pc pressure that minimizes the mean value $\Sigma[Var_{loc}(\nu)]$

Remark: no use of $W(\nu) = \delta F\nu,p / \delta \ln p$ channel sensitivity to pressure

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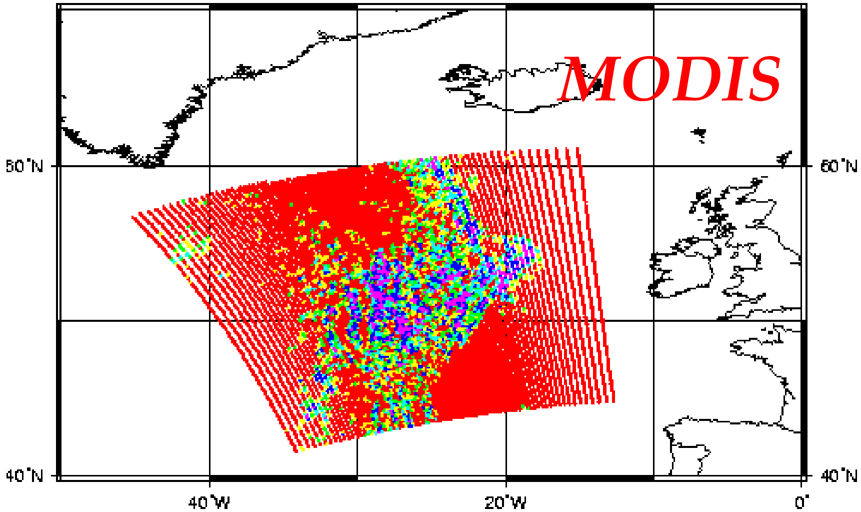
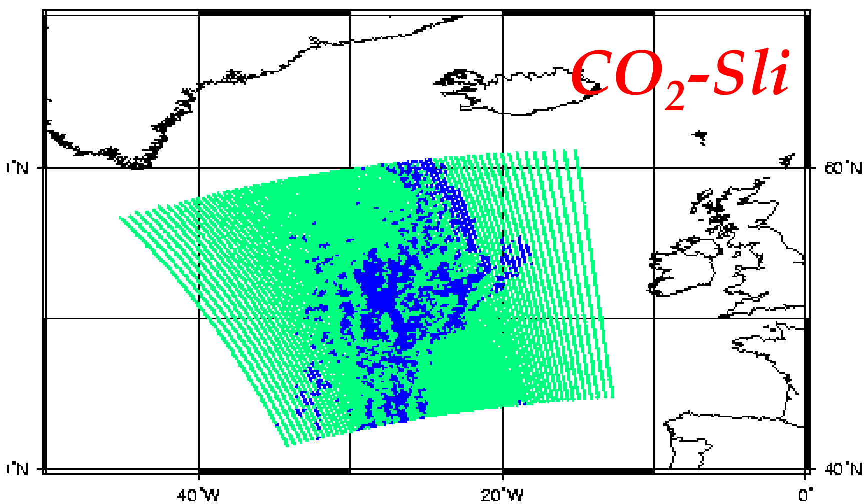
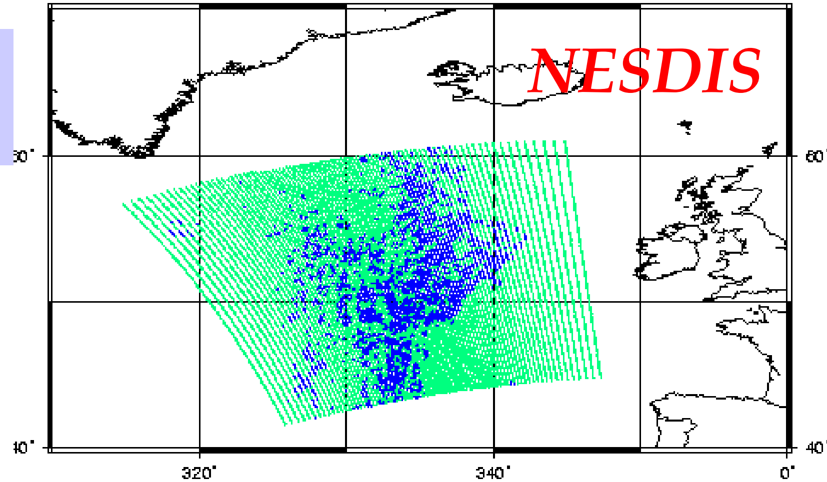
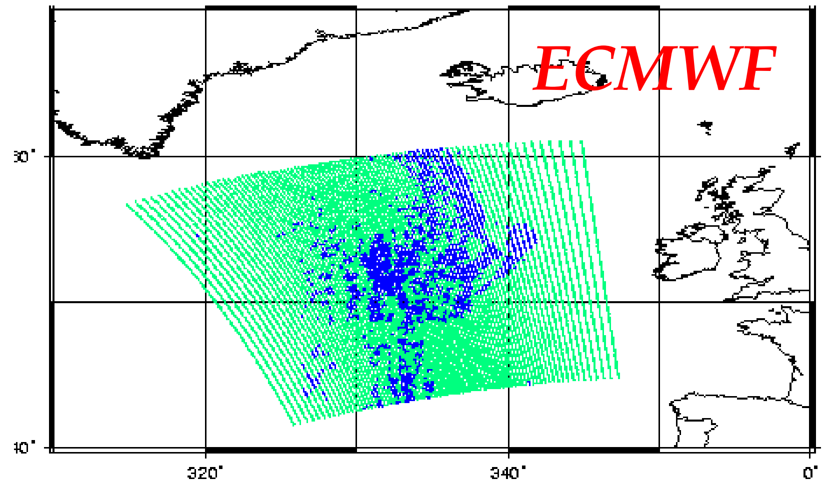
Cloud detection

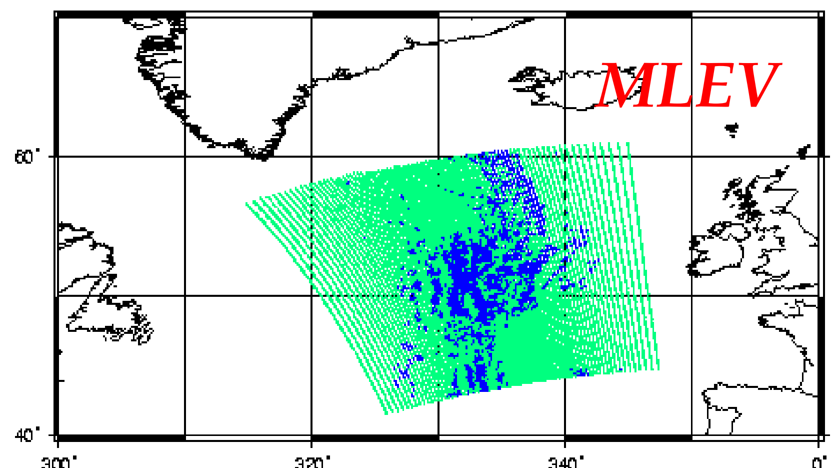
Ex: 16/04/2003, granule 146



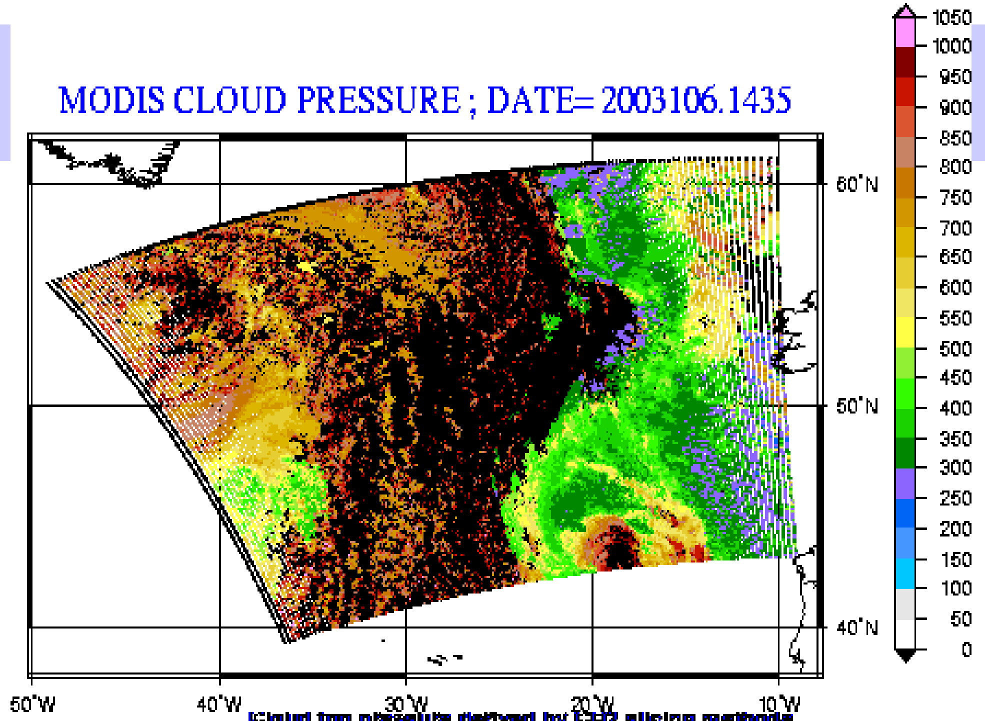




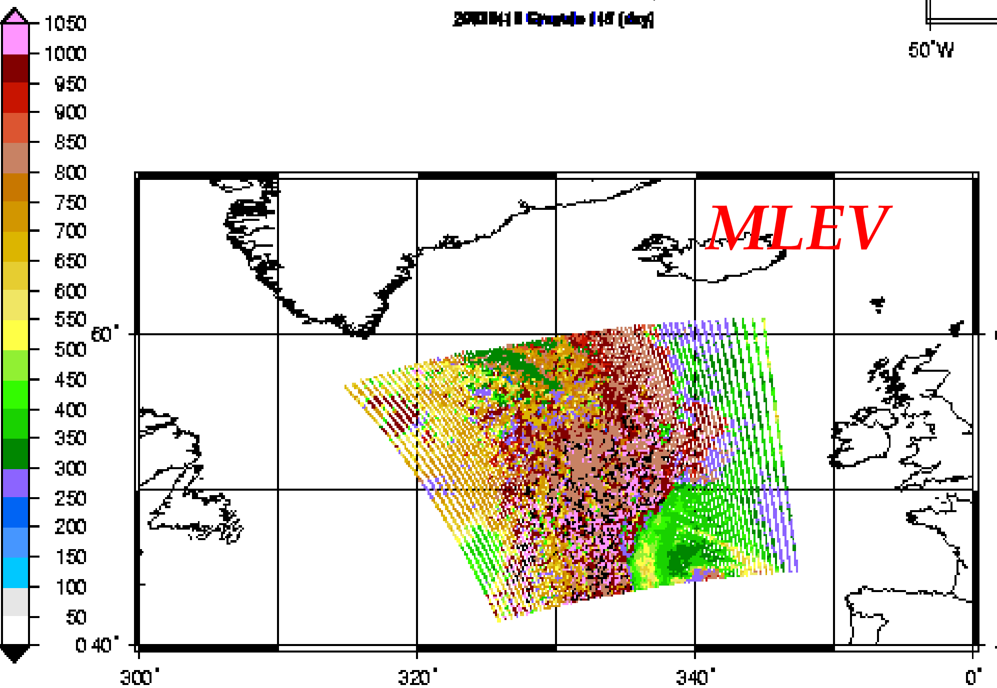




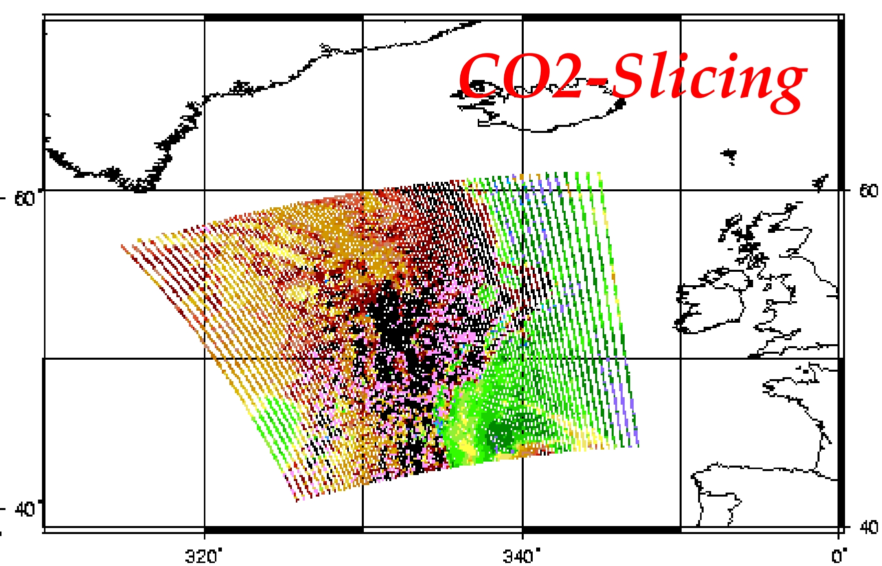
Cloud characterization



AIRS Cloud top pressure derived by MLEV methods



Cloud top pressure derived by CO2 slicing methods



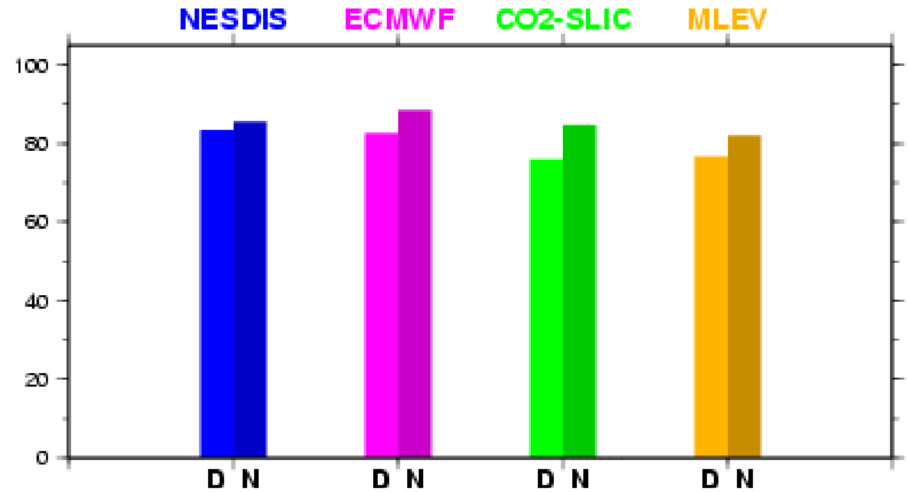
Validation: Clear/cloudy AIRS ifov detection

Statistics from 16 – 19 April, 2003

Clear AIRS ifov detection

Day: 2799 sit.

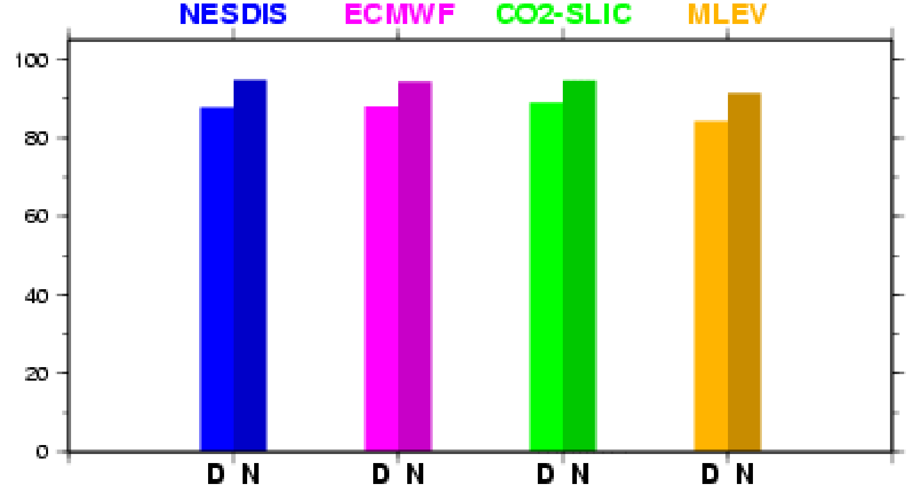
Night: 5470 sit.



Cloudy AIRS ifov detection

Day: 28510 sit.

Night: 57719 sit.



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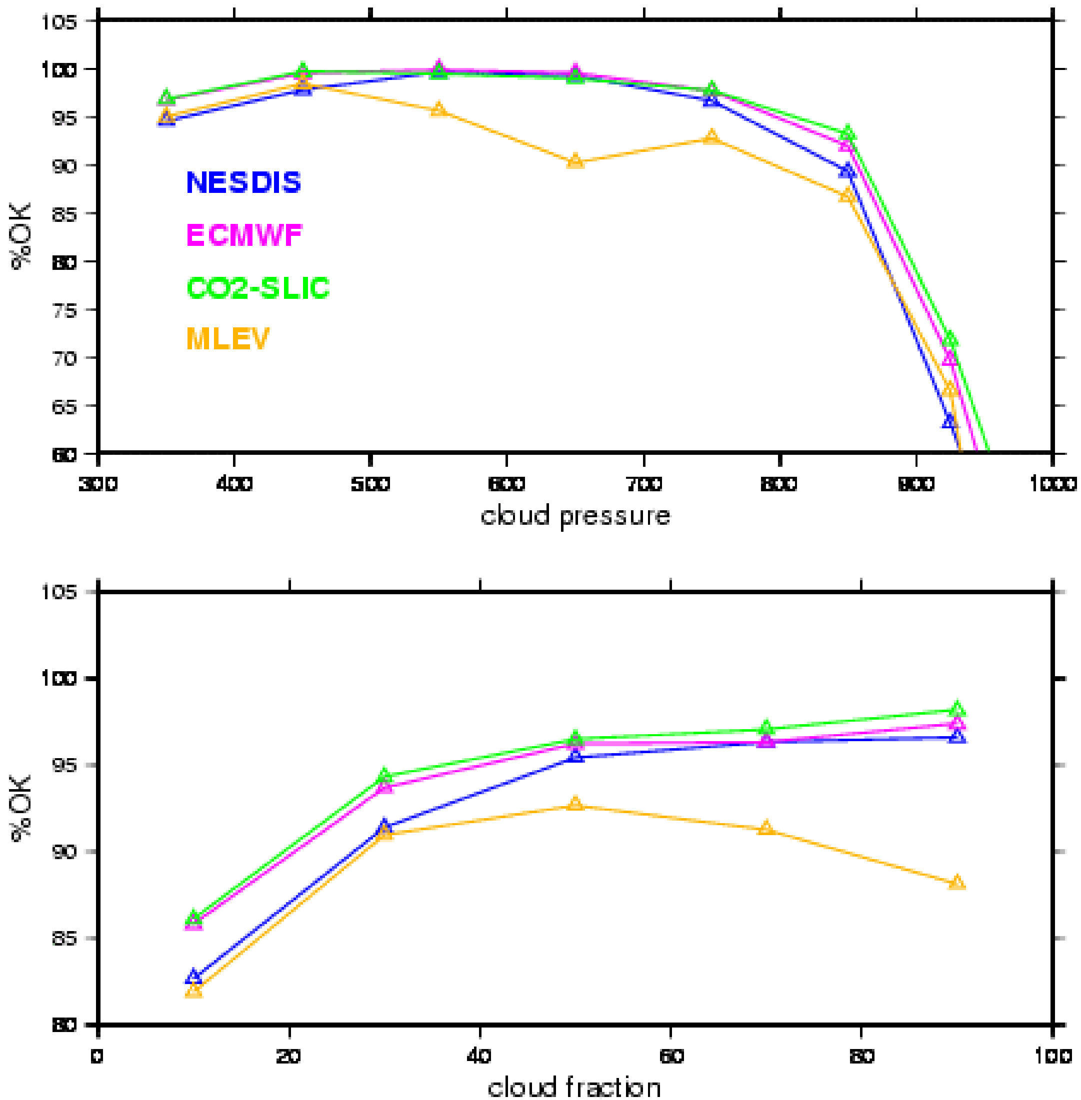
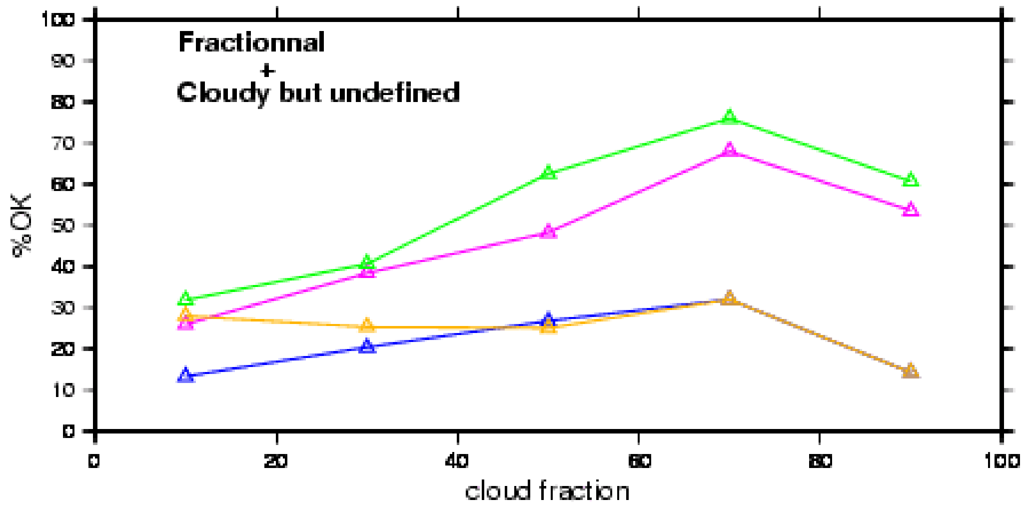
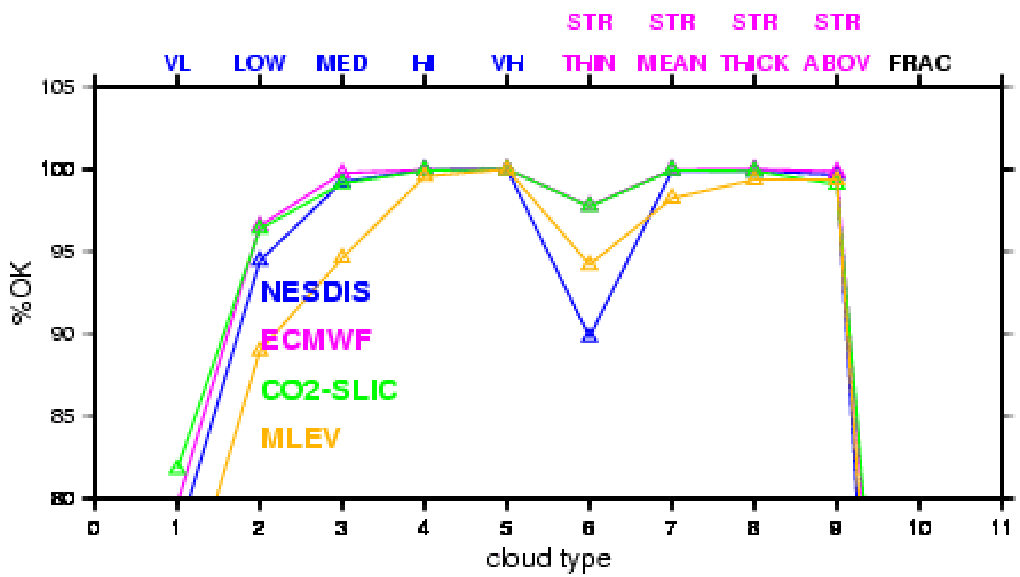
Validation: Cloudy AIRS ifov detection



Validation: Cloudy AIRS ifov detection

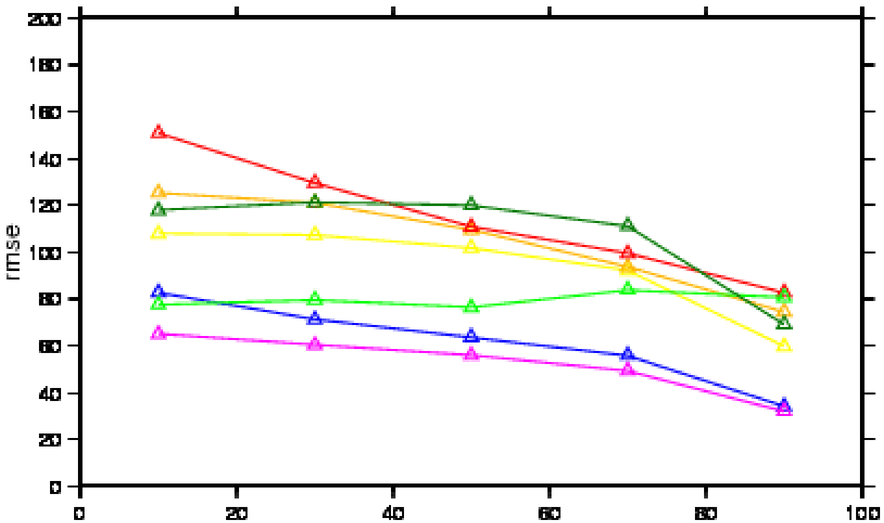




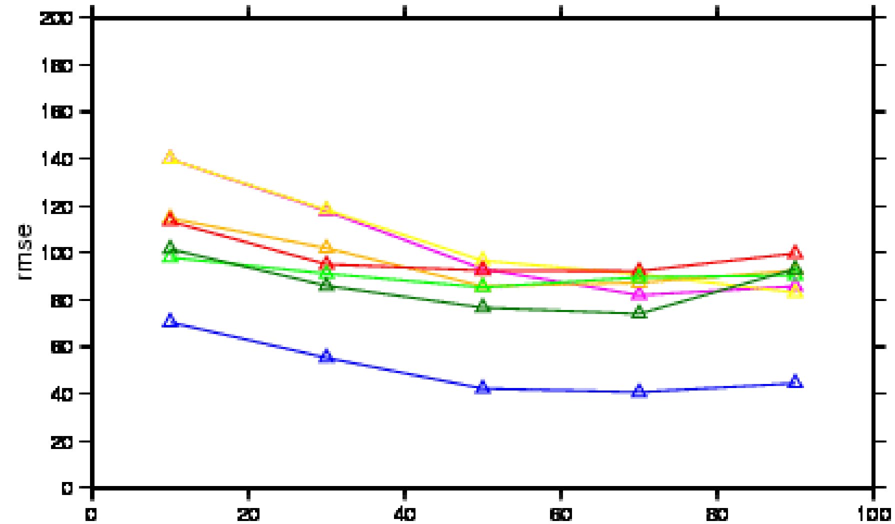
Validation: Cloud top pressure

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

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Conclusions and perspectives

1. For all schemes, synoptic cloud patterns are detected.
2. Cloud and Clear detection:
   - For all schemes, general good agreement with MODIS cloud mask above 900hPa
   - For all schemes, poor sensitivity to clouds near the surface and for fractional and unclassified clouds
   - ECMWF and CO2-slicing give similar results.
   - NESDIS *pre-launch* model is less efficient for thin semi-tranparent and fractional clouds -> thresholds depending on location (atlas, forecast) could help
   - MLEV is more sensitive to the measurement noise -> less efficient for detecting low level and fractional clouds
3. Cloud top pressure:
   - For multi layers situations, both methods see the highest layer
   - MLEV: good coherence with MODIS even for small fraction

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