Implementation of SMOS data monitoring in the ECMWF Integrated Forecast System.

- Preliminary results -

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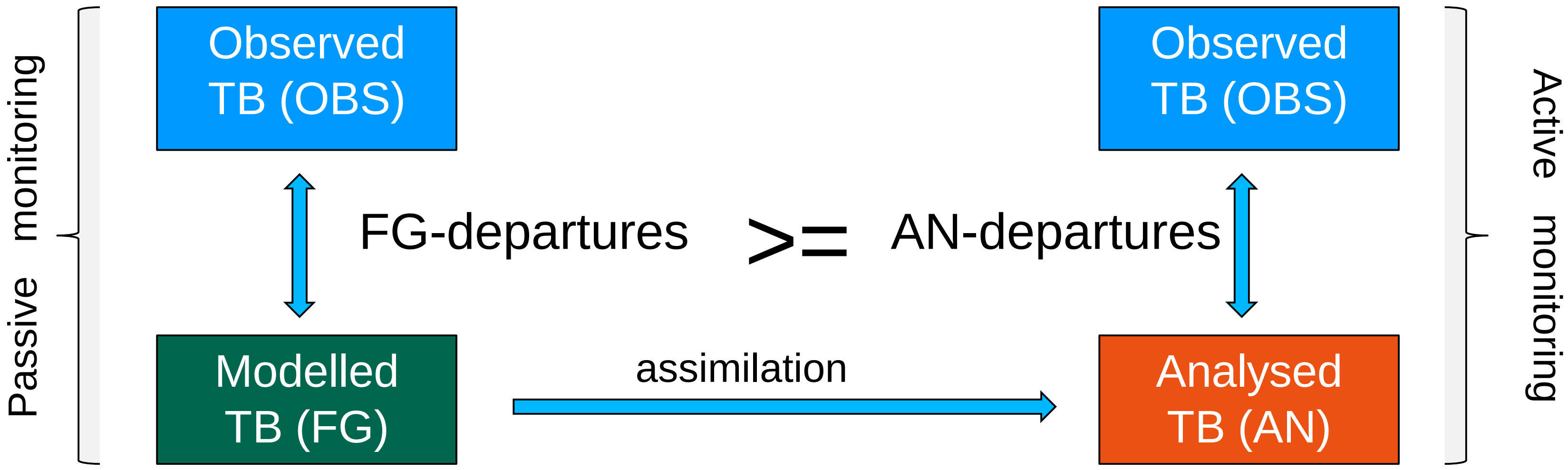
Outline

- ECMWF contribution to the SMOS mission,
- Implementation of SMOS data in the IFS
    - NRT product
    - Pre-processing,
    - Computations in model grid-point,
    - Main obstacles encountered in the implementation.
- Preliminary results
    - SMOS offline data monitoring webpage,
    - First-guess departures preliminary assessment,
    - Preliminary results using time series.

How does ECMWF contribute to the SMOS mission?

1. Global monitoring of Level-1C brightness temperatures at H and V polarisation and at several incidence angles.

- For NWP applications, monitoring compares forecast, or analysis, and observed data:



- Results will be available in NRT through the ECMWF satellite monitoring webpage.

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How does ECMWF contribute to the SMOS mission?

2. Assimilation of SMOS Level-1C brightness temperatures over land with an EKF scheme → the main objective is to investigate the meteorological impact caused by the assimilation of SMOS data.

- Optimal least-square estimator for soil moisture (w_a):

Background error matrix; a-priori knowledge of soil moisture variances

Observation error matrix → inputs given by monitoring statistics

$$w_{a,j} = w_{b,j} + \mathbf{B}\mathbf{H}^T(\mathbf{H}\mathbf{B}\mathbf{H}^T + \mathbf{R})^{-1}(TB_0 - H[w_{b,j}])$$

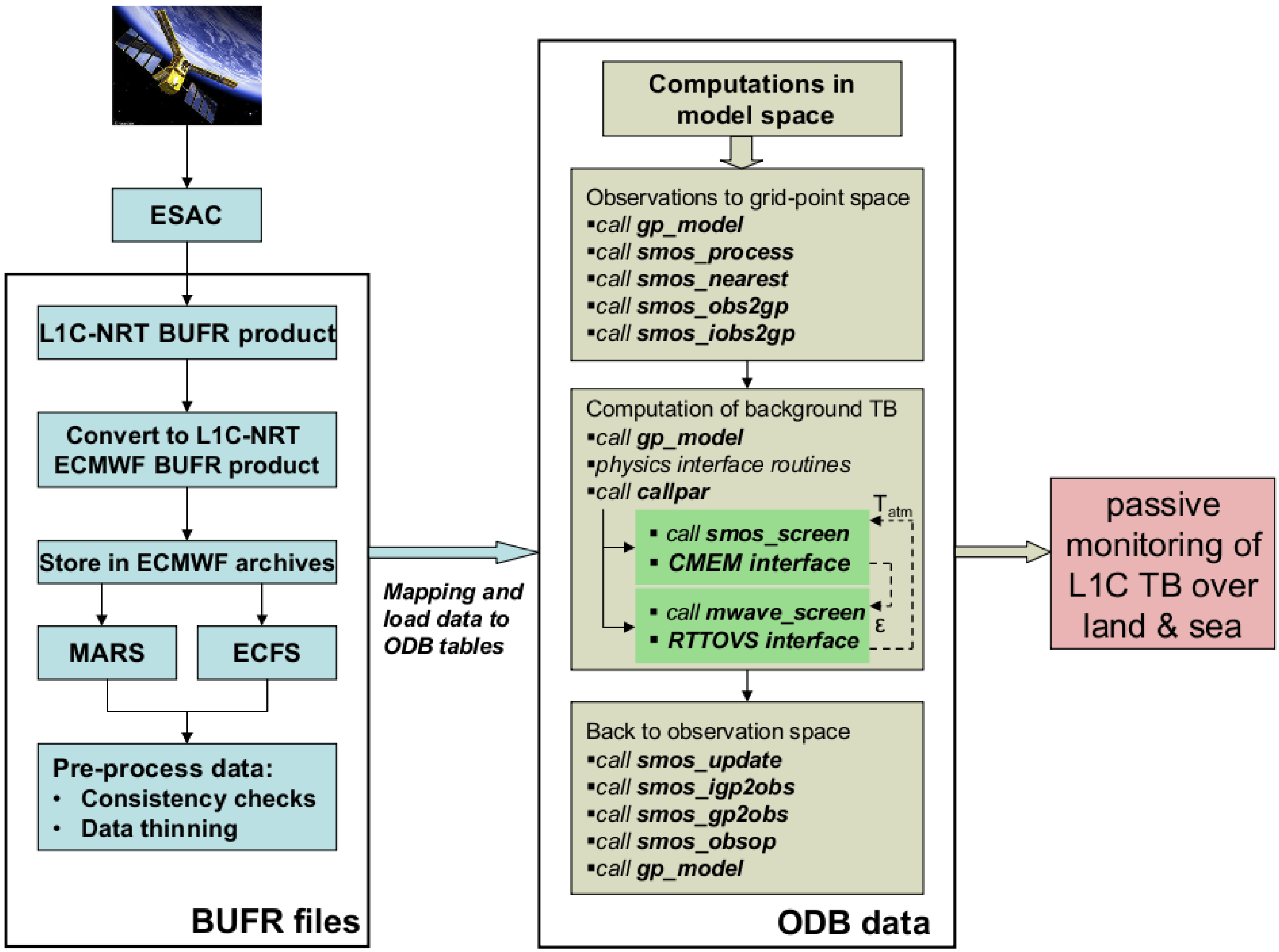
Soil moisture first-guess of j layer by ECMWF deterministic model

Multi-angular, multi-polarised SMOS TB observation

Linearised version of the observation operator CMEM by small perturbations of the initial moisture state

Soil layer defined in H-TESSEL

Implementation of SMOS data in the IFS. Overview



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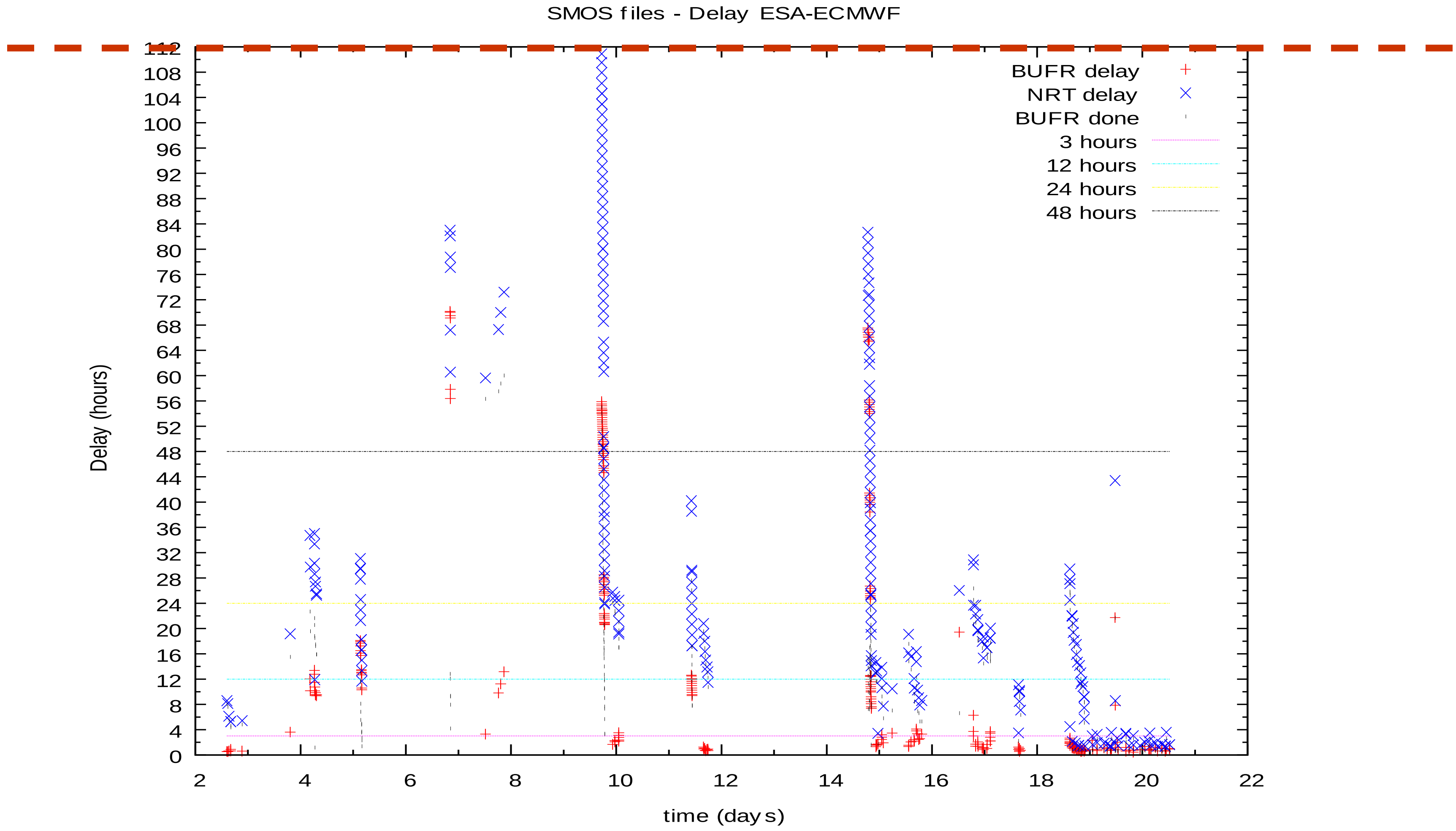
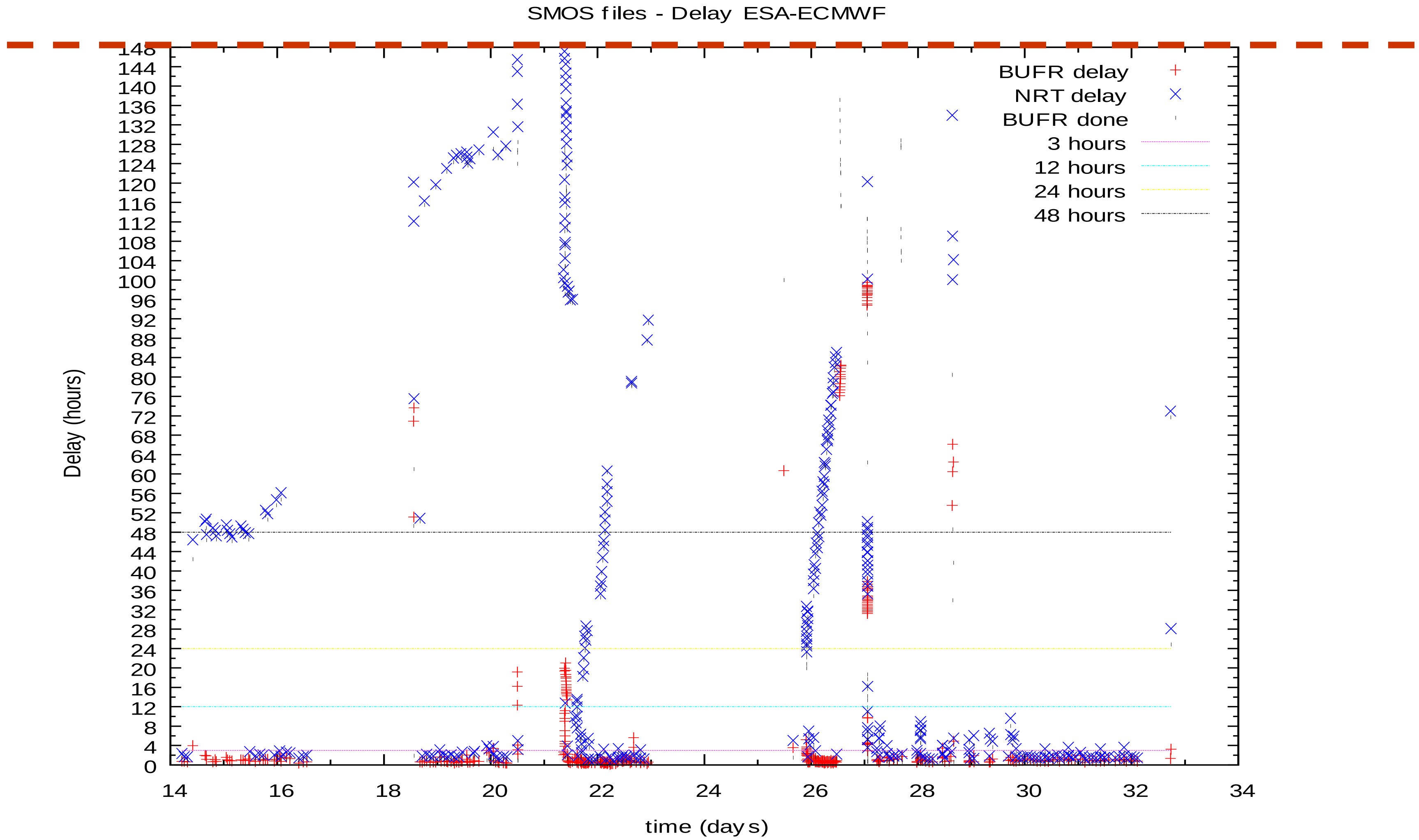
NRT latency – December 2009

$Instrument_$SensingTime1_$SensingTime2_$Satellite_$orbit_$datatype_$GeneratingTime_$datalevel.bufr



NRT latency – January 2010



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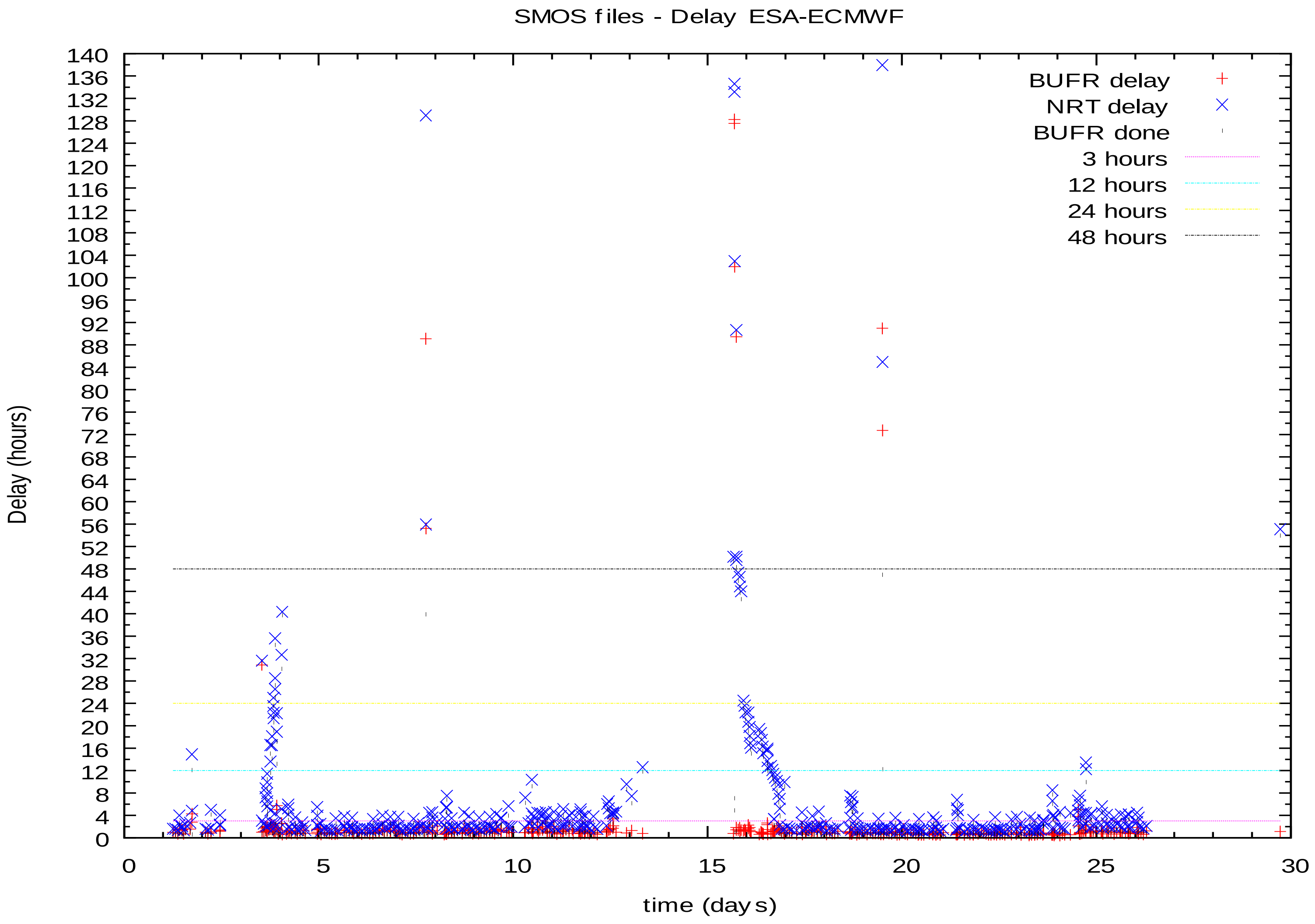
NRT latency – February 2010



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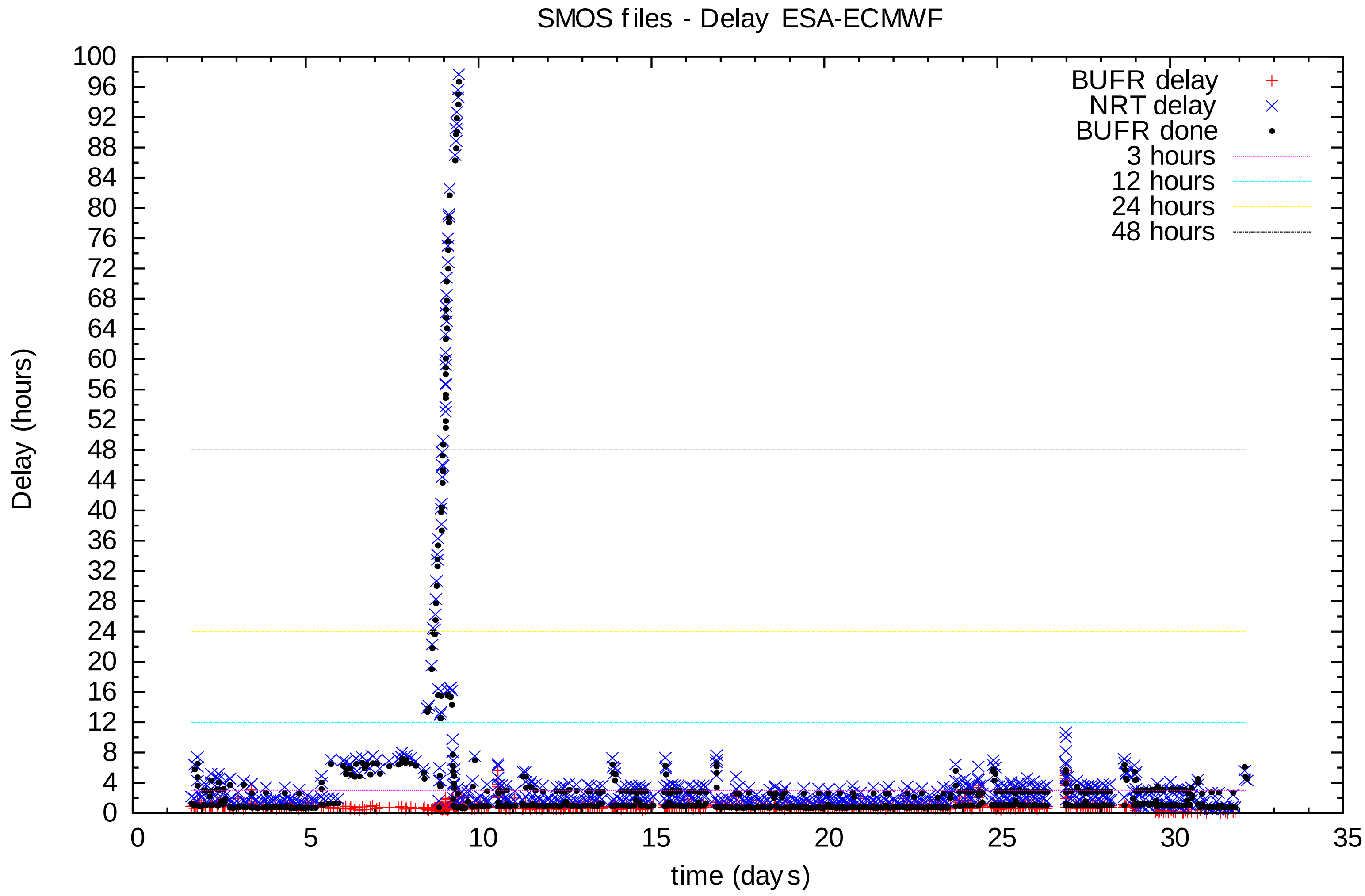
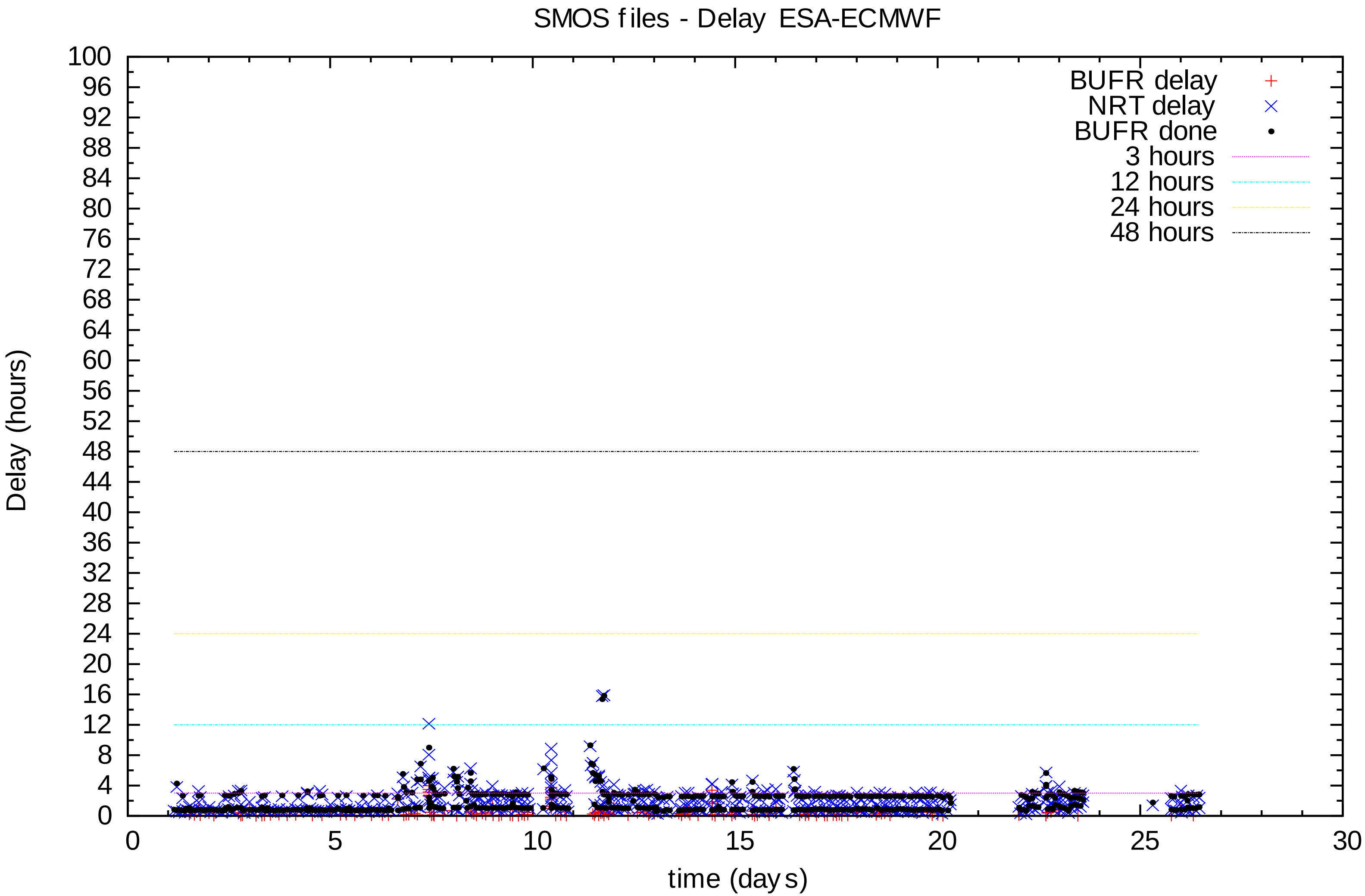
NRT latency – March 2010



NRT latency – April 2010



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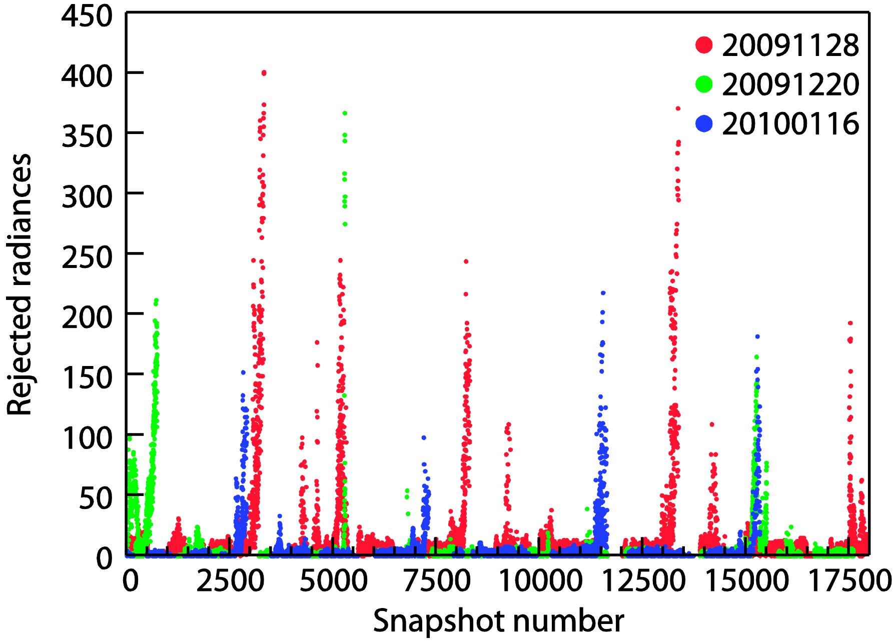
SMOS data pre-processing

► routinely checks:

- header corresponds to SMOS data,
- geographical coordinates not missing,
- date and time complete, etc.



► Validity of data checks:

- data has a correct position,
- TBs are within physically bounds, etc.

► Data thinning,

• Volume of SMOS daily data is very large (~4 Gby for dual-pol, ~8 Gby for full-pol), comparable to IASI data! → thinning is necessary to reduce amount of data and redundancy.

► Others checks, pre-tasks, can potentially be implemented here… (RFI filtering, data thinning based on angular criteria, etc.)

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Main tasks in model space

► Collocation of SMOS observations to a ECMWF model grid.

► Observations screening (flags are given for land, ocean, active observations, etc.)

► Forward computation is carried out at model grid-point with the IFS version of the Community Microwave Emission Model (CMEM),

► First-guess departures are computed at model grid-point, by comparing model background and the nearest SMOS observation to the grid-point.

► All the information (flags, forward computation, first-guess, etc.) is stored in an internal database for further use.

Main difficulties encountered

- Volume of SMOS data,
  - More computing resources and time is needed to process and test the data,
  - Some scripts show difficulties to cope with very large files and need re-adaptation,

- Particular measuring principle (observation of the same area under different illumination conditions at different time stamps) produces very large internal data bases which need special treatment,
  - Structure of SMOS database needs re-structuration to make it operational,
  - Independent multi-polarisation, multi-angular computations needed special treatment,
  - Statistics package needs to be adapted,

- The observation operator CMEM was not designed to run in a multi-thread environment and it was designed to be run just for a single incidence angle.
  - CMEM code and administrating routines needed to be adapted to make them compatible with the IFS structure,

Preliminary results

- Offline SMOS data monitoring webpage;
  - Available since November-2009,
  - Since January-2010 only NRT data is monitored and published,
  - Global maps of Level-1C NRT product,
  - Horizontal and vertical polarisations at 0°, 10°, 20°, 30°, 40°, 50° and 60°,

  http://www.ecmwf.int/research/ESA_projects/SMOS/monitoring/smos_monitor.html

- Global statistics of SMOS data and first-guess departures;
  - After CY36R4, statistics will be available in NRT, either in the o-suite or in an offline suite.
  - Preliminary detailed assessment of main sources of first-guess departures can be carried out with a few cycles of data,
  - Systematic bias or spurious errors can be identified through time series of global statistics.

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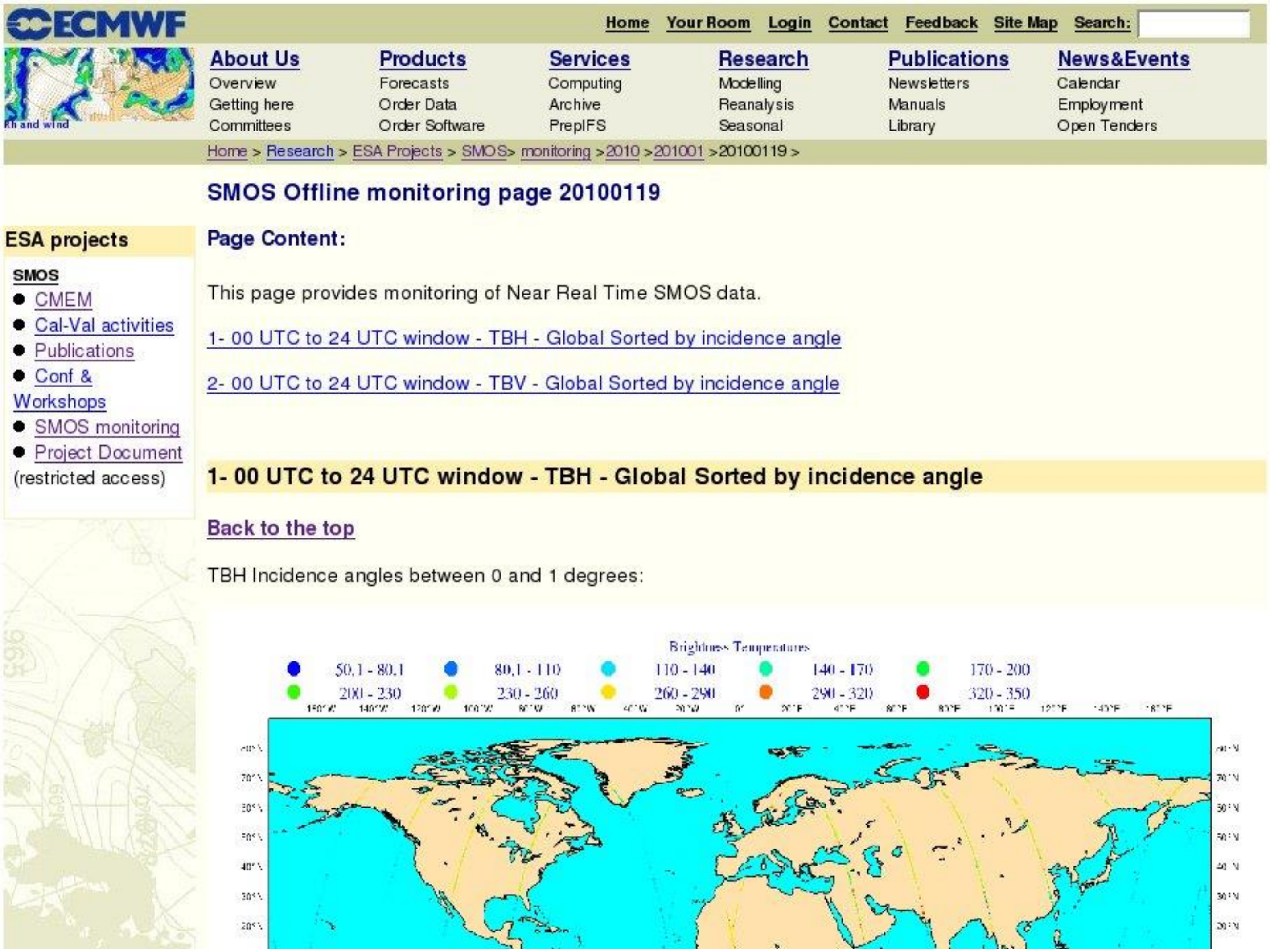
SMOS offline monitoring webpage



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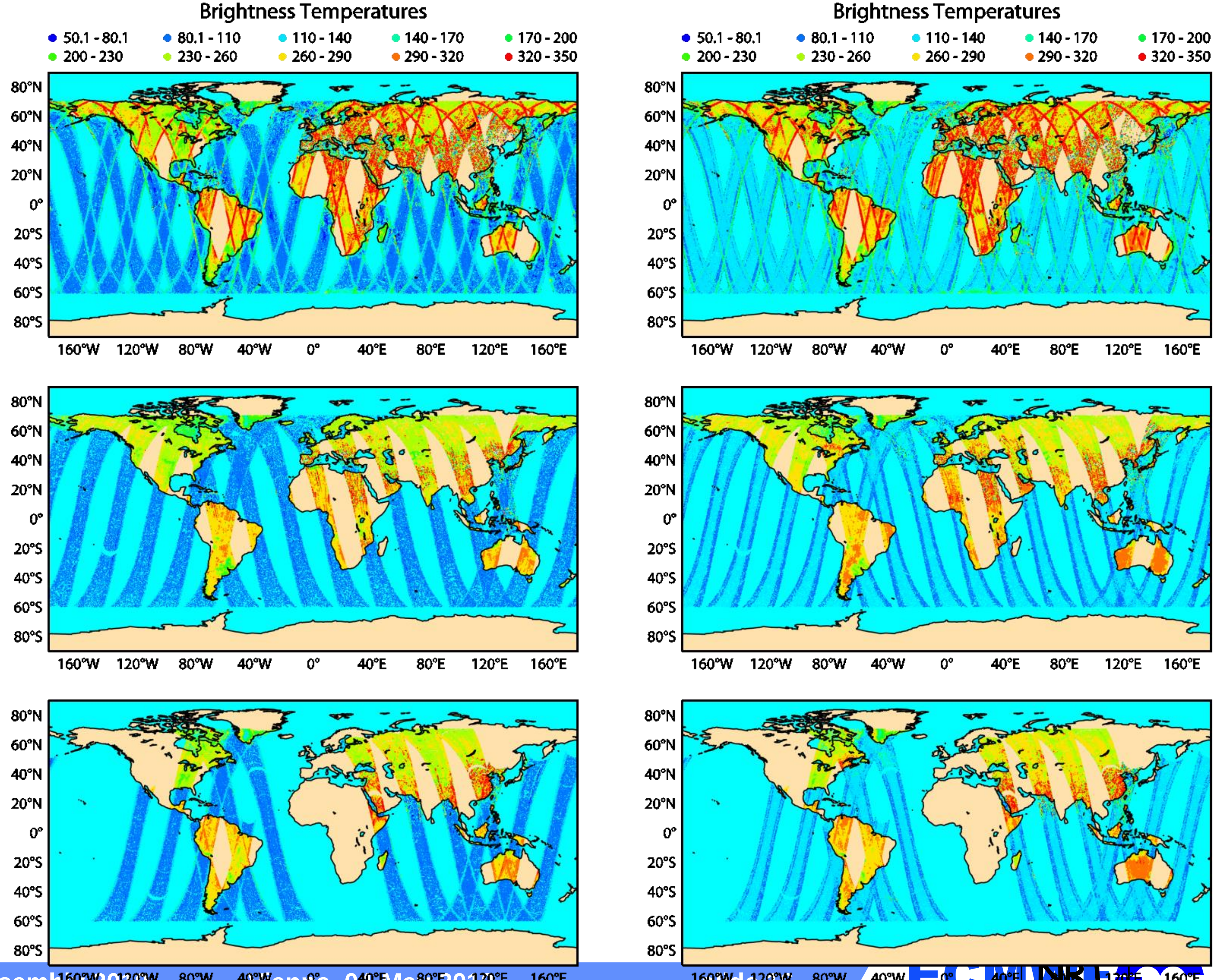
Θ = 40°

TBH | **TBV**

20-Nov-09

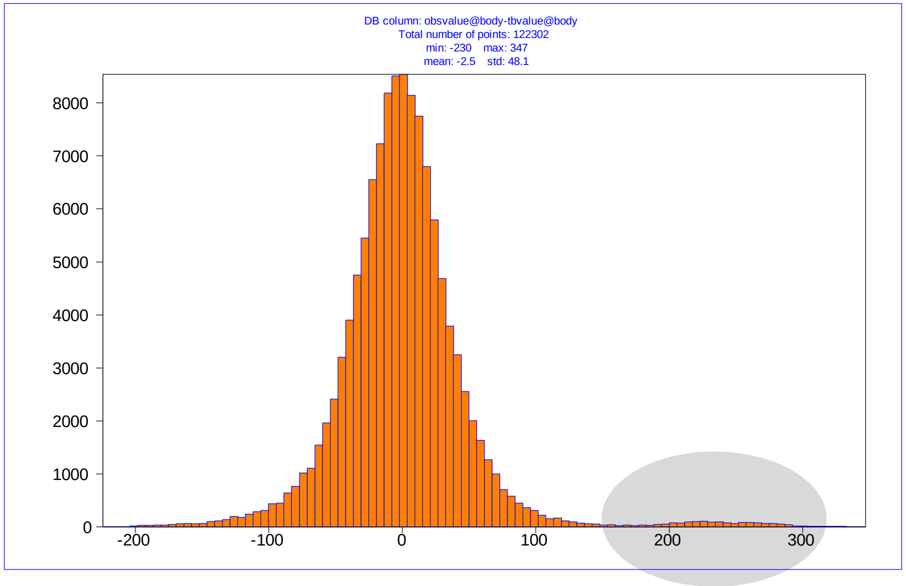
20-Dec-09
NRT

16-Jan-10
NRT

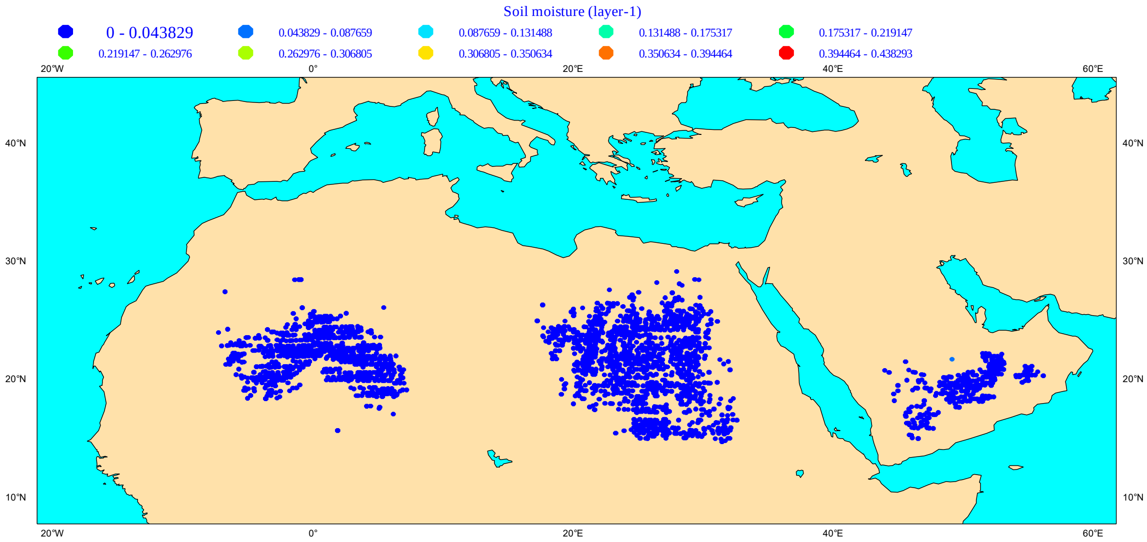


First-guess departures

- 22 January 2010,
- First 4DVAR 12h cycle,
- Global scale,
- all incidence angles included,
- no mask applied on vegetation or snow

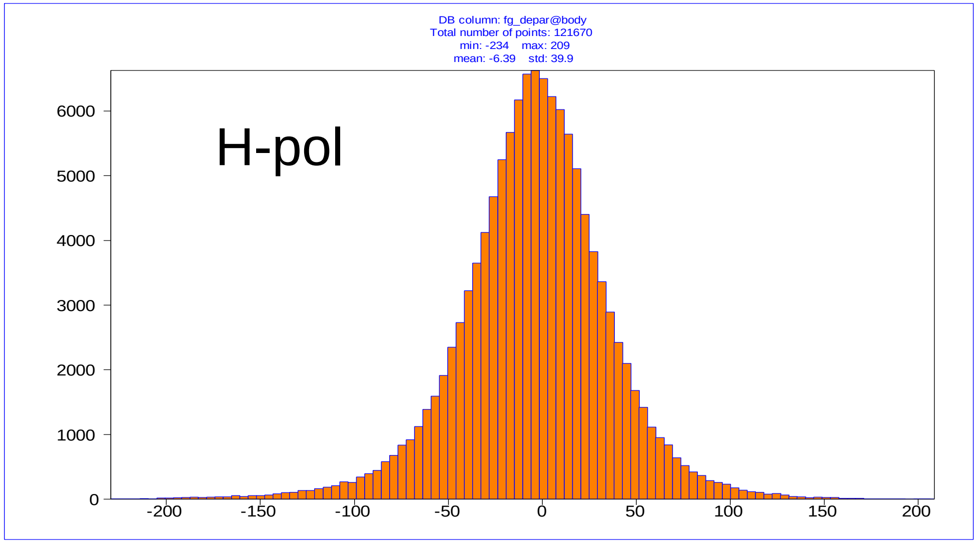


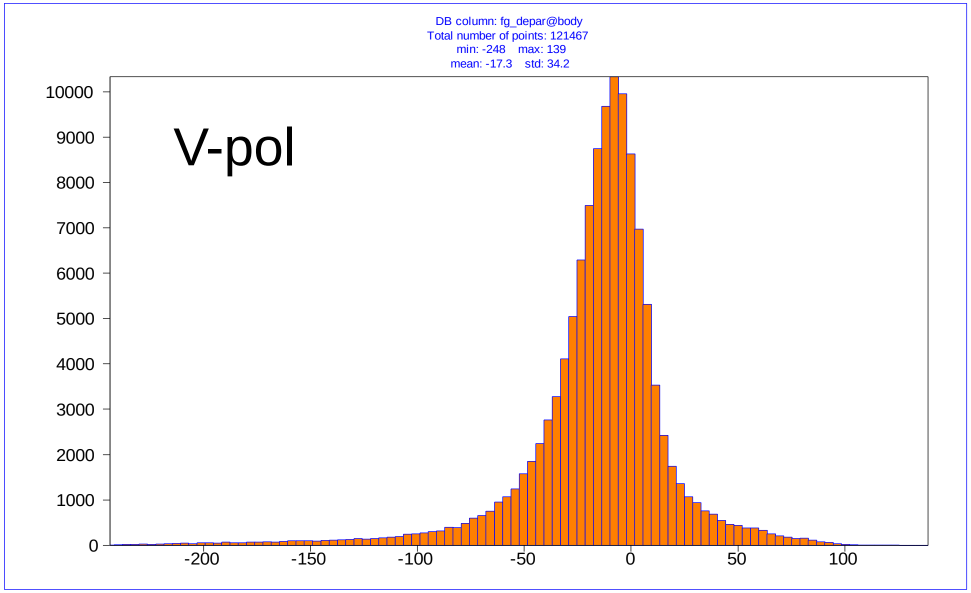
- If soil moisture is forecasted to be zero, a mask prevent of computing TB values. Therefore for these locations fg_depar=obsvalue !



First-guess departures

- **After bugs removal, still some departures are too cold or too warm.**





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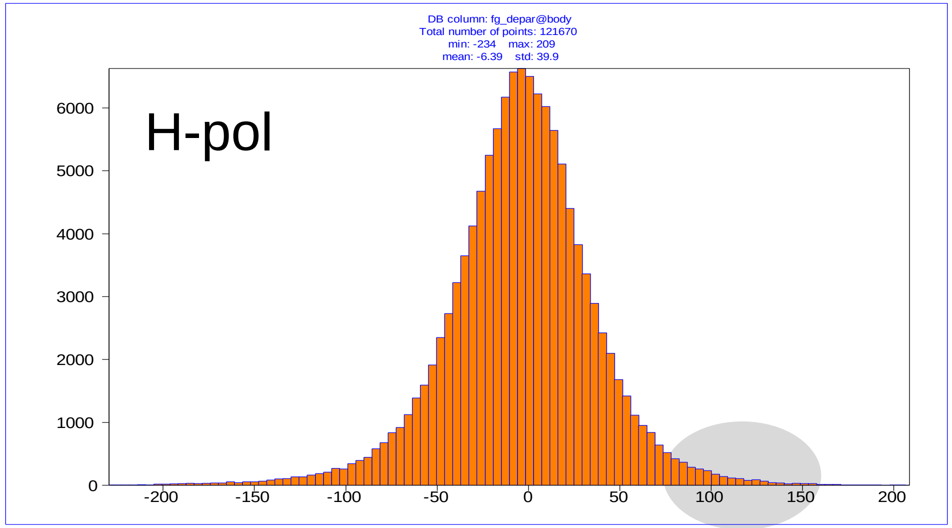
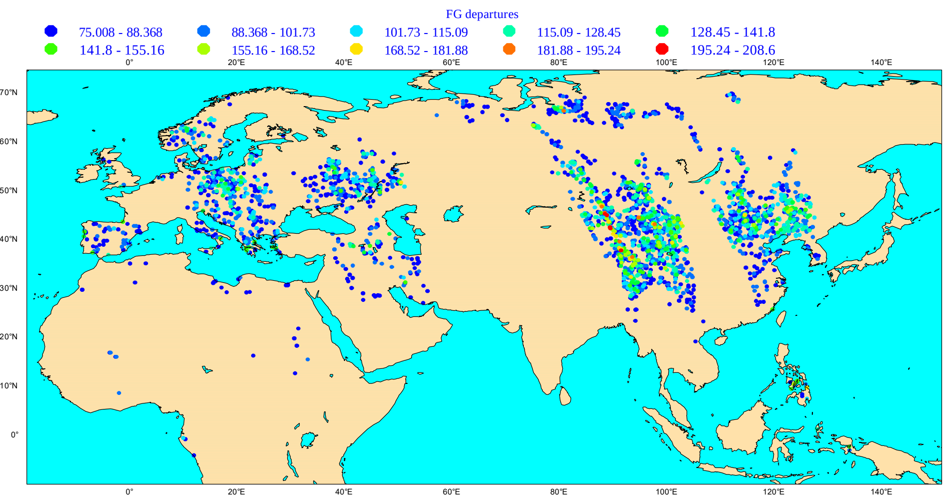
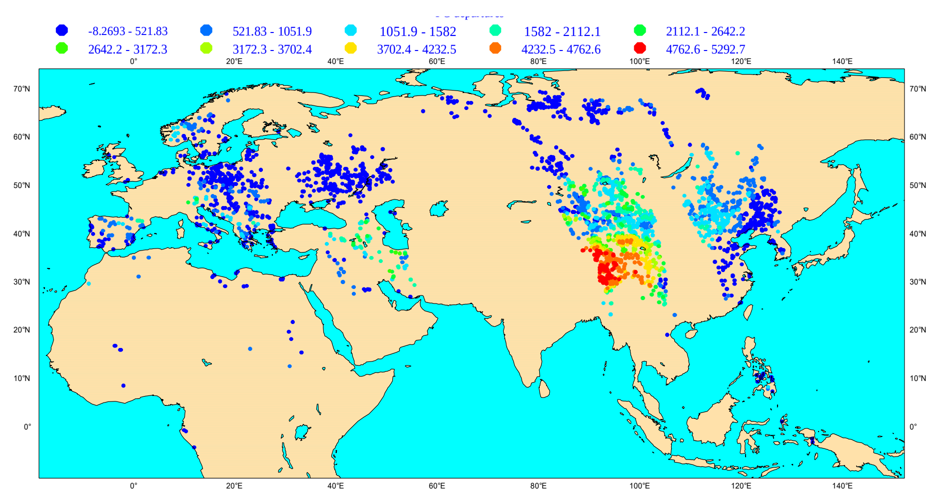
First-guess departures





FG departures



Orography

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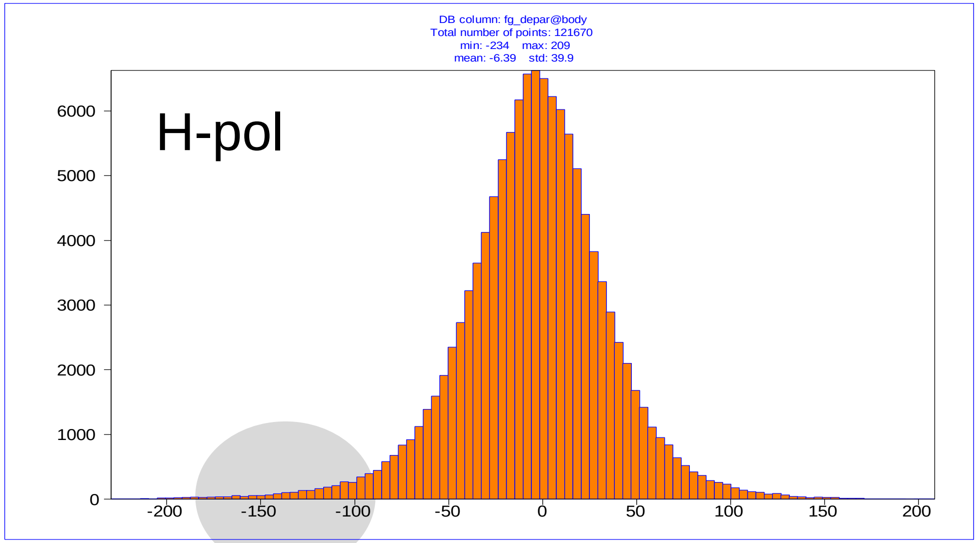
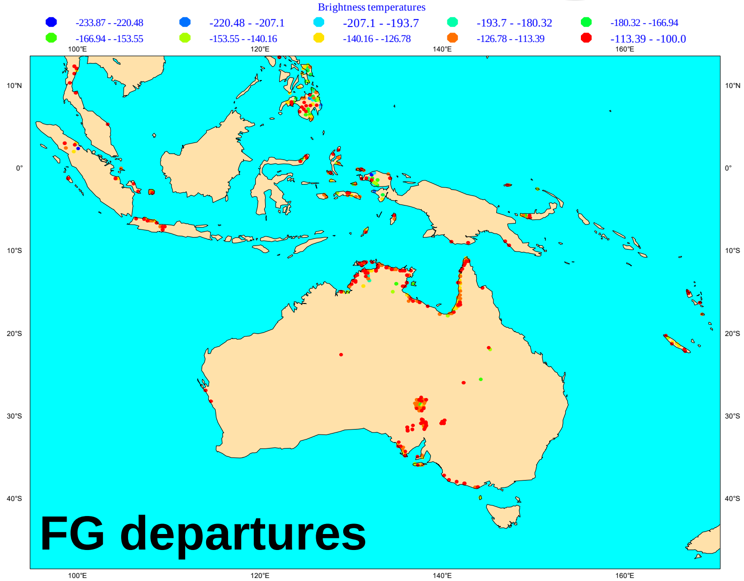
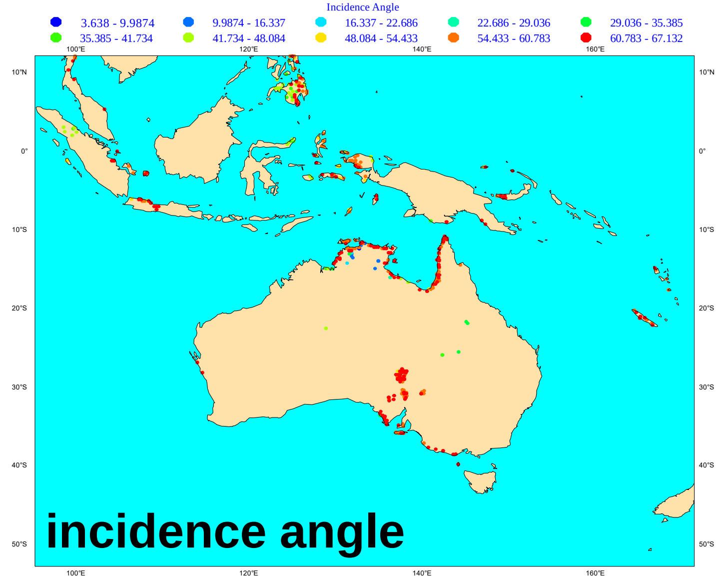
First-guess departures







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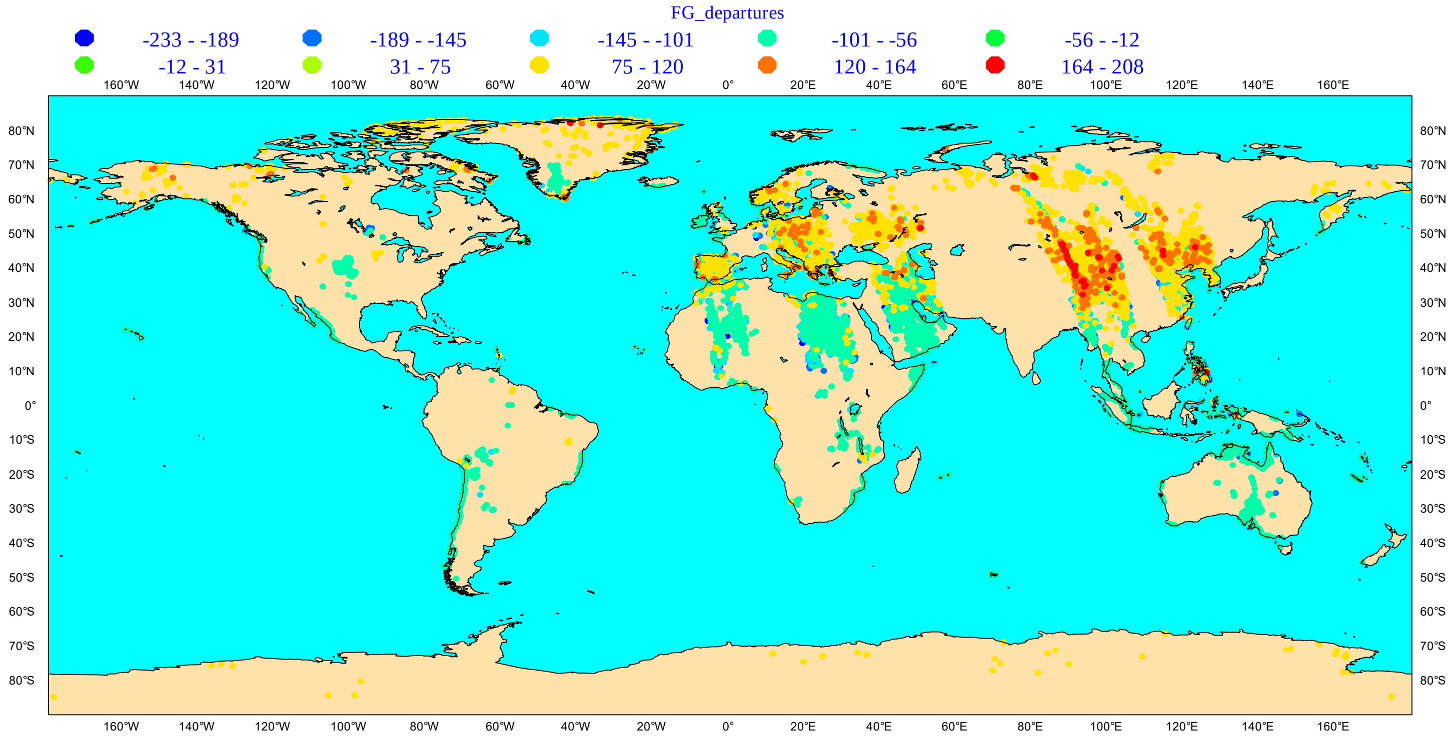
First-guess departures

Map of anomalous departures (> 75 K or < 75 K)



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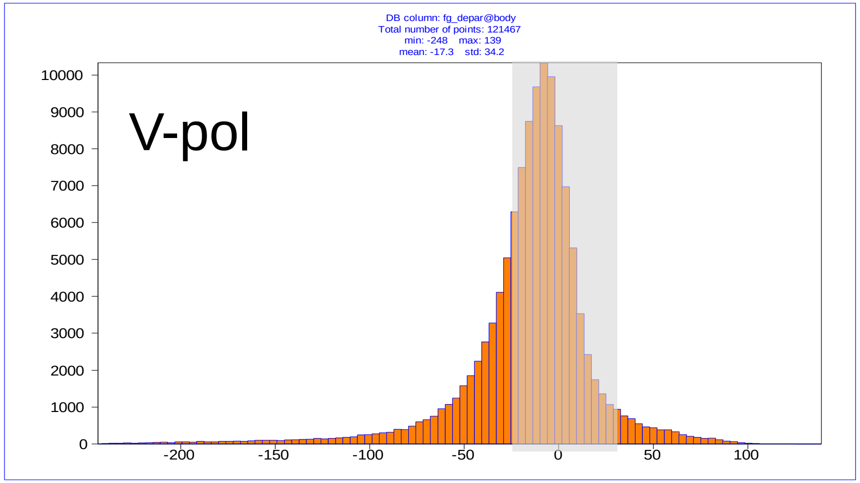
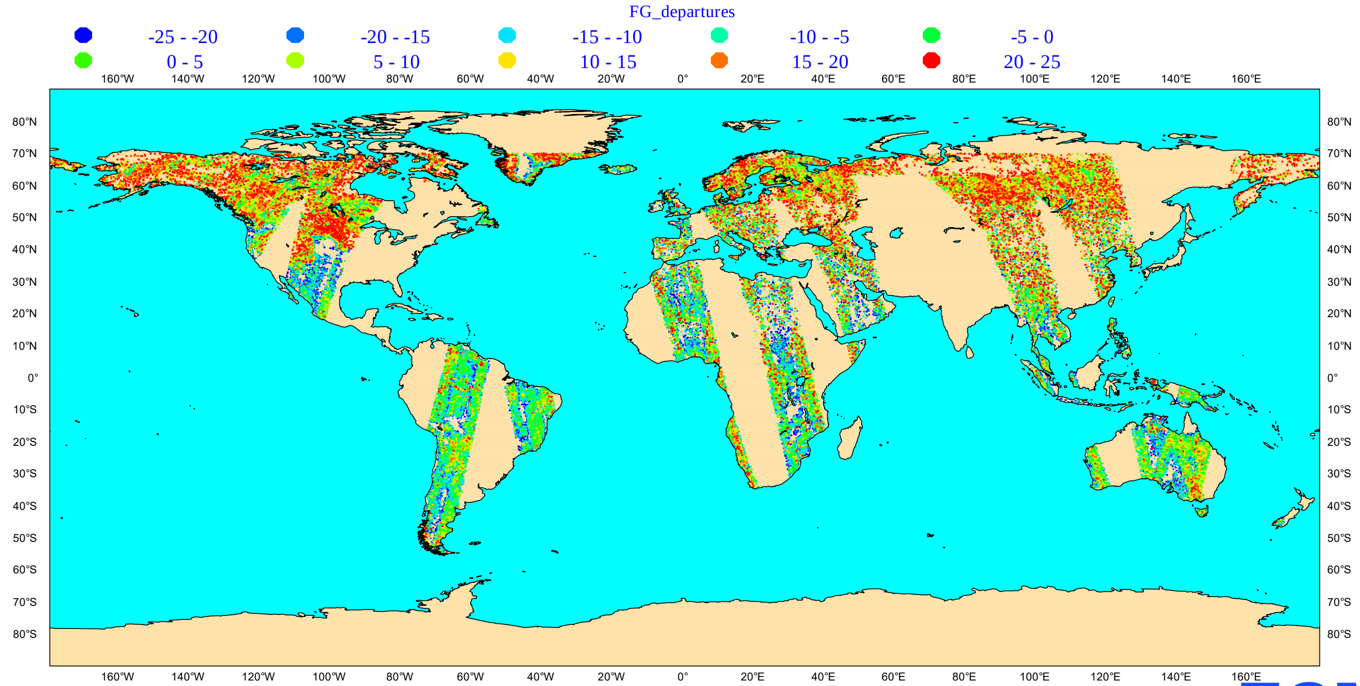
First-guess departures





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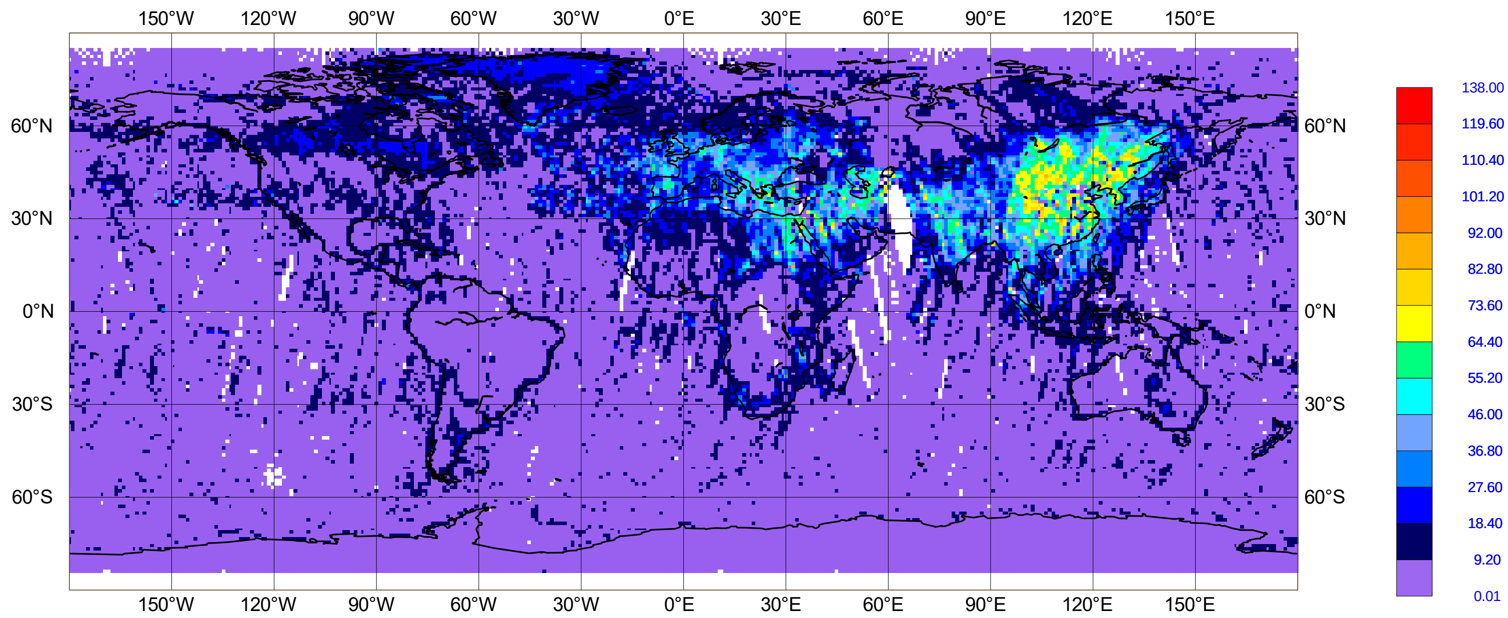
Preliminary assessment of fg-departures

- Departures too large → observations >> model :
  - Location: mainly in Europe and Central-West Asia,
  - Contributing causes:
    - mountainous areas,
    - areas contaminated by RFI.
- Departures too negative → model >> observations.
  - Location: South-Europe, North-Africa and some areas of China and Australia.
  - Contributing causes:
    - coastlines,
    - dry areas at large incidence angles.
- Snow-covered areas, boreal forest and desserts show departures around -20 K and +20 K. These effects are stronger in H-pol.
- These results need to be confirmed and further investigated with systematic statistics determined at global scale and at different incidence angles.

Global statistics

- Ex. 01-07 March-2010
  - Average of observations STD in bins of 0.5°.
  - Vertical polarisation; 55° < obs incidence_angle < 60°
  - RFI is clearly visible

STATISTICS FOR RADIANCES FROM SMOS
STDV OF OBSERVATIONS [ ] (ALL)
DATA PERIOD = 2010-03-01 12 - 2010-03-07 12 , HOUR= ALL
EXP = FC5I, CHANNEL =   2 (FOVS: 55-60)
Min: 0.132583   Max: 137.734   Mean: 11.4978



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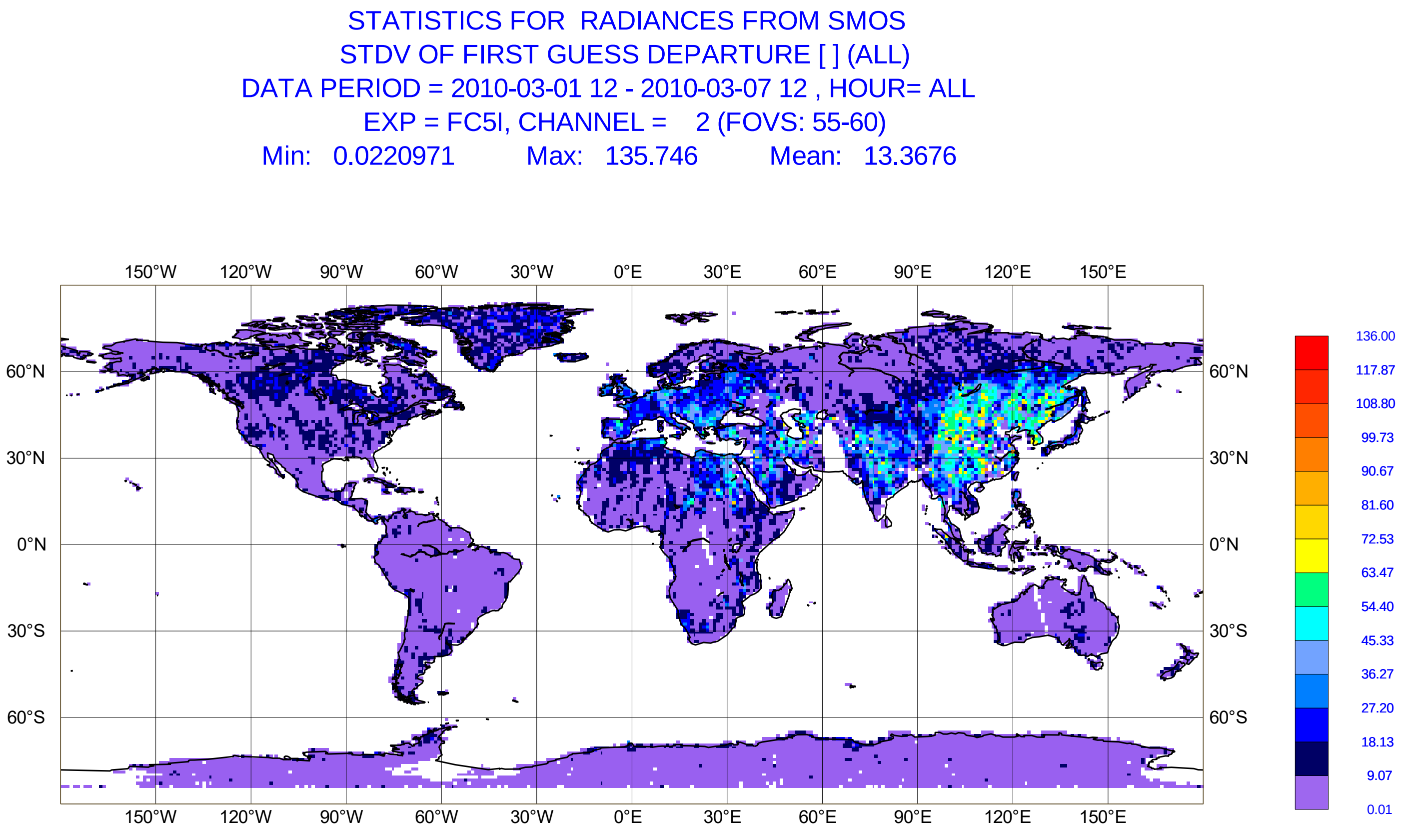
Global statistics

- **Ex. 01-07 March-2010**
  - **RFI impact on FG departures STD is large,**
  - **Excluding RFI contaminated aread, most of first-guess departures STD are below 9 K. Larger values found in boreal forests and dry areas.**



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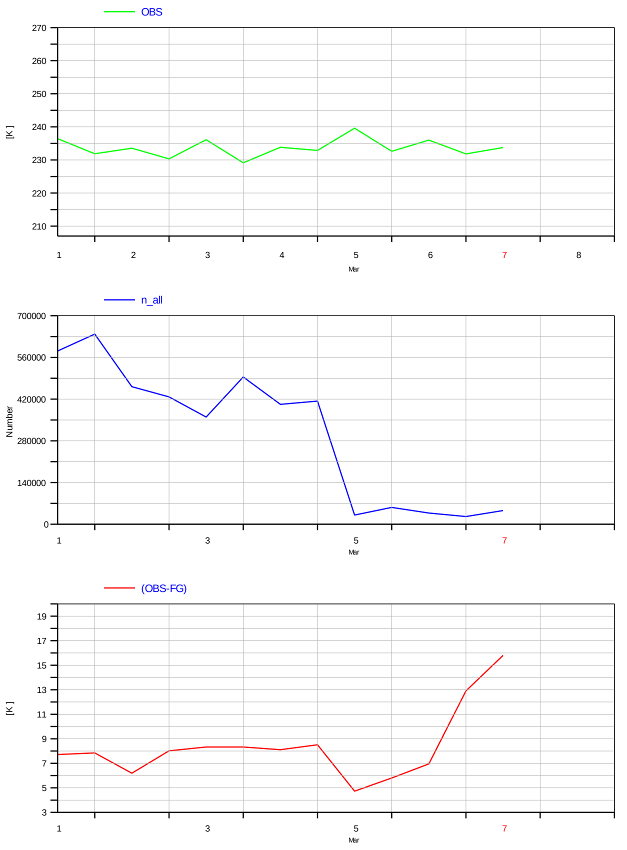
Global statistics

- **Ex. 01-07 March-2010 (H-pol)**

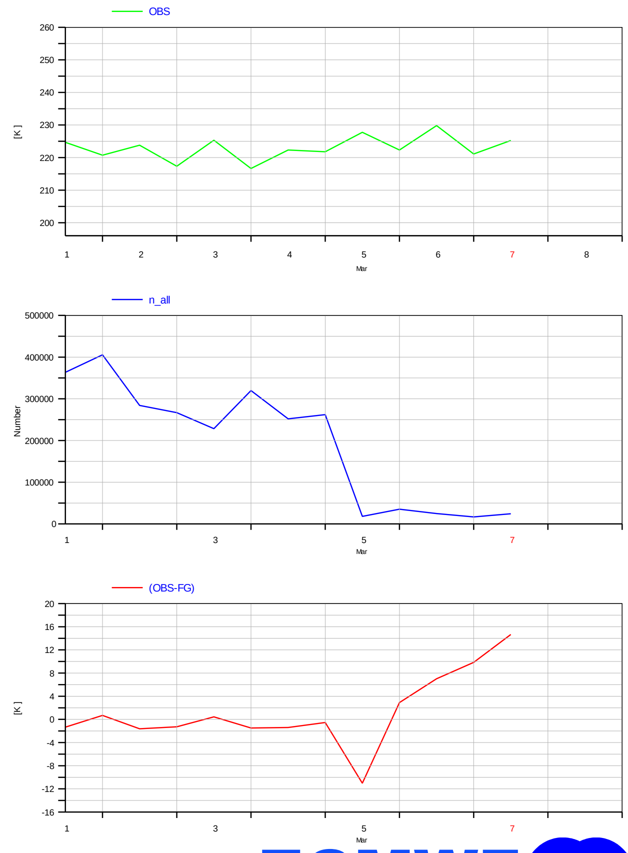
35-40

RADIANCES from SMOS
Channel = 1 (FOVS: 35-40), All data
Area: lon_w= 0.0, lon_e= 360.0, lat_n= -90.0, lat_s= 90.0 (over Land)
EXP = fc5i



45-50

RADIANCES from SMOS
Channel = 1 (FOVS: 45-50), All data
Area: lon_w= 0.0, lon_e= 360.0, lat_n= -90.0, lat_s= 90.0 (over Land)
EXP = fc5i



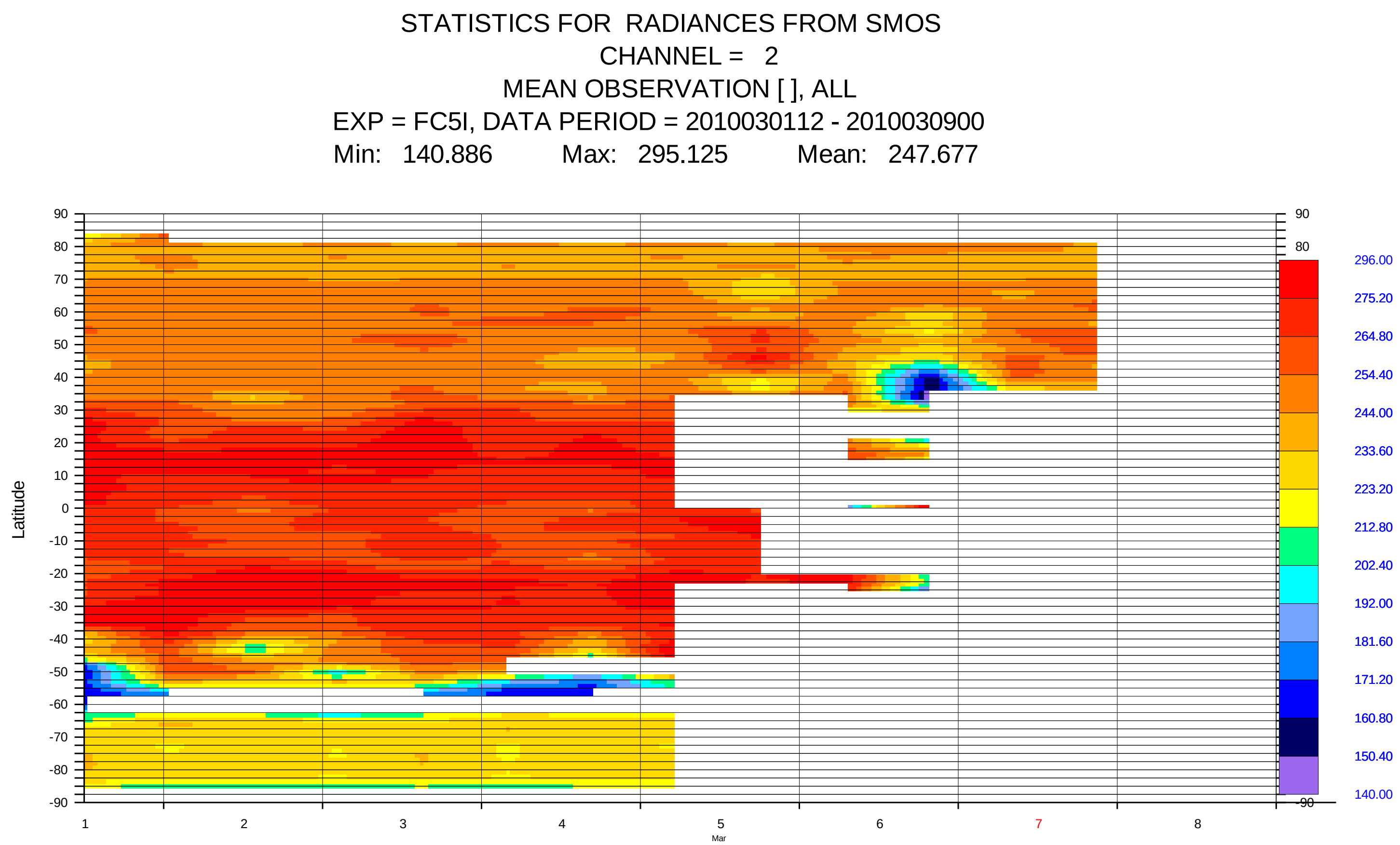
TB average

Nbr observations

First-guess departures

Global statistics

- **Ex. 01-07 March-2010 (V-pol)**
  - **Observations anomalies can be easily seen through Hovmoeller plots.**



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Summary

- ECMWF contribution to the SMOS mission includes two main components:
  - Global monitoring of Level-1C TB,
  - Data assimilation study.
- Implementation of SMOS data in the IFS was complex and challenging,
- The 'SMOS chain' depends critically on the NRT product latency,
- An offline data monitoring webpage is available since Dec.09 and regularly updated.
- Preliminary analyses on first-guess departures suggest that:
  - RFI is the most important source of positive bias,
  - Snow, ice, mountains, boreal forest and dry areas produce also a significant disagreement with the observations,
  - The implementation of SMOS passive monitoring permit to identify any source of systematic differences with observations.