Advances in land data assimilation at ECMWF

P. de Rosnay, M. Drusch, J. Muñoz Sabater
G. Balsamo, A. Beljaars, K Scipal

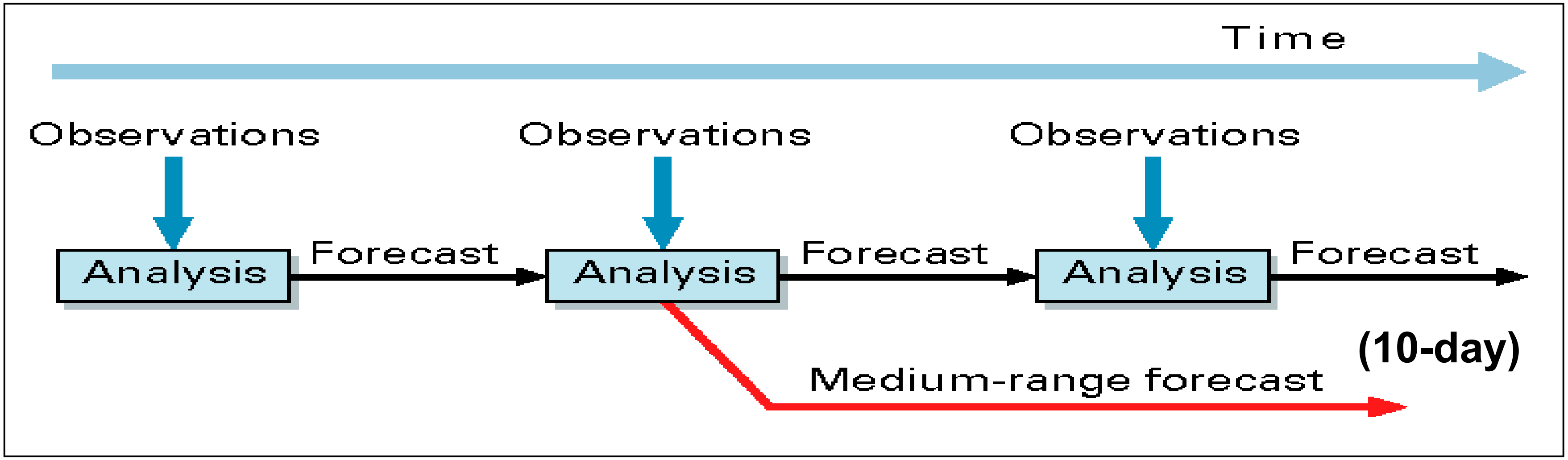
Thanks to: A. Boone, S. Boussetta, J.-C. Calvet, M. Dahoui, M. Dragosavac, A. Fouilloux, A. Geer, J. Haseler, H. Hersbach, A. Hofstadler, L. Isaksen, I. Mallas, F. Pappenberger, D. Salmond J. Urban, D. Vasiljevic

- **Introduction**
- EKF soil moisture analysis
- Use of satellite data for soil moisture monitoring and analysis
    - Active microwave: MetOp/ASCAT (H-SAF)
    - Passive microwave: SMOS (ESA)

The ECMWF Integrated Forecasting System (IFS) data assimilation system

From L. Isaksen's training courses

http://www.ecmwf.int/newsevents/training/meteorological_presentations/MET_DA.html



Data Assimilation System:
Provides best possible accuracy of initial conditions to the forecast model

Analysis:
- 4D-VAR for atmosphere
- Surface analysis

- The observations are used to correct errors in the short forecast from the previous analysis time.
- Every 12 hours we assimilate 7 – 9,000,000 observations to correct the 80,000,000 variables that define the model's virtual atmosphere.
- This is done by a careful 4-dimensional interpolation in space and time of the available observations; this operation takes as much computer power as the 10-day forecast.

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Surface analysis

Ocean surface analysis:

• Sea Surface Temperature: SST (2D interpolation, based on OSTIA)

• Sea Ice concentration: CI (2D interpolation, based on OSTIA)

• Sea surface salinity (global constant) ;
for seasonal forecast, analysed from Argofloat (Optimum Interpolation)

Land surface analysis:

• **Snow** Water Equivalent (Cressman analysis, SYNOP Snow depth corrected according to NOAA/NESDIS snow extend information)

• **Screen level parameters** analysis: 2m air Relative humidity and air Temperature (SYNOP, Optimum Interpolation)

• **Soil moisture and soil temperature**:

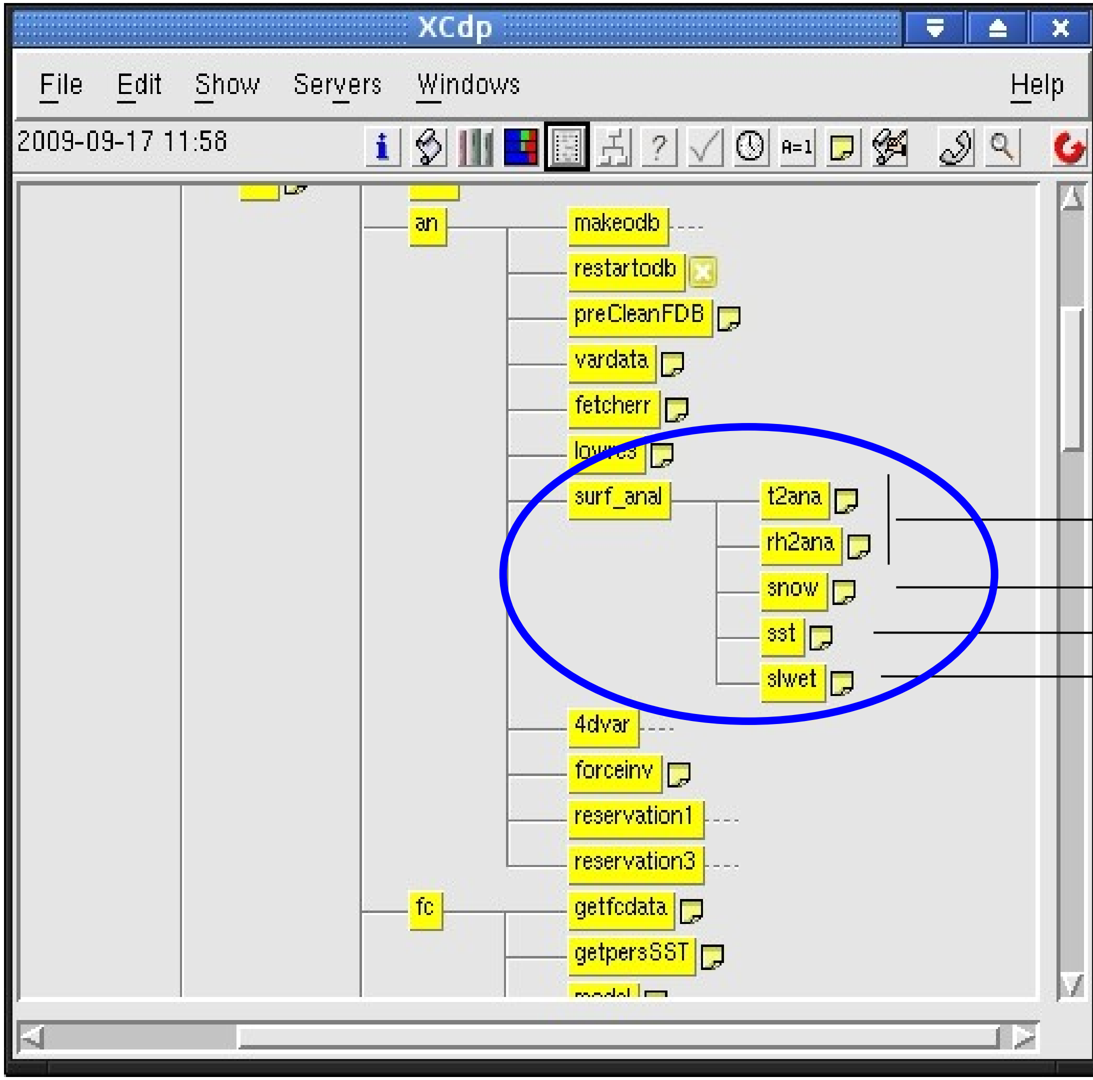
- Optimum Interpolation (OI) using 2m air Relative humidity and air Temperature (1999)
- Extended Kalman Filter (EKF) (activated in operation early 2010)

Recent advances at ECMWF focus on:

• Soil moisture analysis improvements and use of satellite data (ASCAT and SMOS)

Surface analysis

IFS cycle 35r3 is the current operational cycle since 8 September 2009



SMS: Supervisor Monitor Scheduler

Different tasks performed

Colour code:
-Yellow: task completed
- Green: running
- Blue: in queue
- Red: failed

Screen level parameters

Snow

SST and CI

Soil Moisture and Temperature

Surface analysis tasks and 4DVAR are decoupled. They are running in parallel.

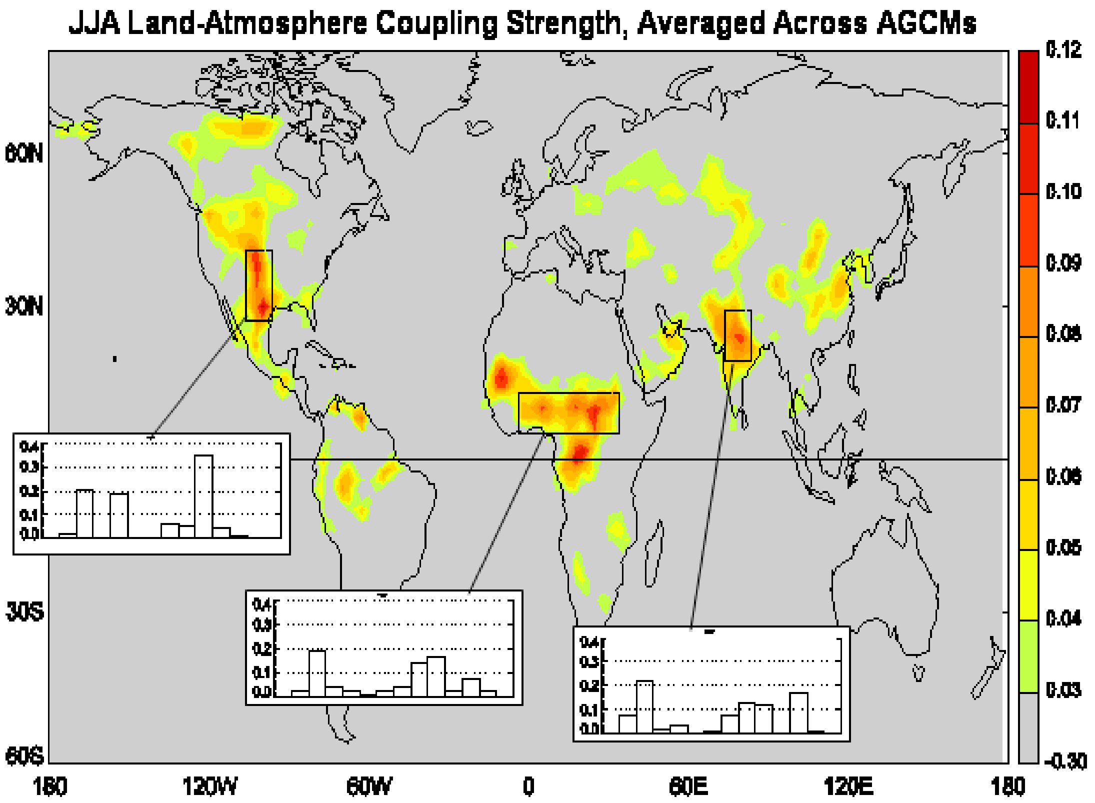
Contribution of land surface to predictability

(Session 4 Wednesday Morning)

GLACE: Koster et al, Science 2004): characterization of the strength of the coupling between surface and atmosphere.

→ Role of soil moisture

Further investigated in the current GLACE-2 (see Koster et al., session 4)



Importance of SM → Motivation

to improve Soil Moisture initialization

for NWP → Soil Moisture analysis

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Operational soil moisture analysis

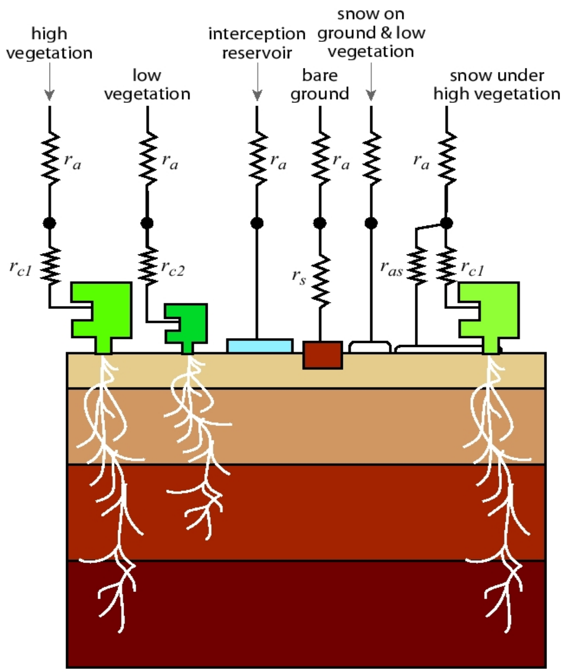
IFS cy35r3, Optimum interpolation (OI)

Relies on the link between soil variables and the lowest atmospheric level:

- **Too dry soil → 2m air too dry & too warm**
- **Too wet soil → 2m air too moist & too cold**

HTESSEL Land Surface Model
Session 1 → Balsamo et al.

Schematics of the land surface



→ Soil Moisture increments based on the analysis increments for the T2m and RH2m:

$$\Delta\Theta_i = a_i \left(T^a - T^b\right) + b_i \left(rH^a - rH^b\right)$$

a and b: analysis and background, i: soil layer.
ai and bi computed from product of optimum coefficients αi and βi minimizing the variance of analysis error, and of empirical functions.

References HTESSEL:
Viterbo et al., 1995
Van den Hurk et al., 2000
Balsamo et al., 2009

References OI:
Douville et al., 2000
Mahfouf et al., 2000
Mahfouf, 1991

OI is used operationally since 1999 for the soil moisture & temperature analysis

Some limitations:

The OI SM analysis efficiently improves the turbulent surface fluxes and the weather forecast on large domains.

• However, root zone soil moisture is the variable in which errors accumulate while we are looking for improving consistency between fluxes and reservoirs (SM).

• OI switched off in particular conditions: wind, freezing, snow, precipitation
→ no SM analysis in these conditions.

• **OI does not follow the evolution of the Land Surface Model (HTESSEL)**

• **Not flexible to include new generation of satellite data linked to soil moisture or vegetation:**

- **SM form active microwave (C-band ERS, MetOp/ASCAT, L-band SMAP)**
- **SM from passive microwave (L-band SMOS, SMAP, C-band AMSR-E)**
- **Leaf Area Index/ NDVI (MODIS, MetOp/AVHRR)**
- **Snow (H-SAF, Land-SAF, ..., coreH2O ?)**

→ Motivations to develop and implement and EKF surface analysis

- Introduction
- **EKF soil moisture analysis**
- Use of satellite data for soil moisture monitoring and analysis
    - Active microwave: MetOp/ASCAT (H-SAF)
    - Passive microwave: SMOS (ESA)

Extended Kalman Filter soil moisture analysis

The analysis is obtained by an optimal combination of the observations and the background (short-range forecast):

$$\mathbf{x_a}(t) = \mathbf{x_b}(t) + \mathbf{K}\left(\mathbf{y}(t) - \mathbf{H}\mathbf{x_b}(t)\right)$$

where $\mathbf{K}$ is the gain matrix:

$$\mathbf{K} = \left(\mathbf{B}^{-1}(t) + \mathbf{H}^T(t)\mathbf{R}^{-1}\mathbf{H}(t)\right)^{-1}\mathbf{H}^T(t)\mathbf{R}^{-1}$$

The observation operator $\mathbf{H}$ is the Jacobian matrix of:

$$H_{ij} = \frac{\delta y_i}{\delta x_j} \simeq \frac{y_i\left(x + \delta x_j\right) - y_i\left(x\right)}{\delta x_j}$$

In finite differences, the elements of the Jacobian matrix are estimated by perturbing individually each component x_j of the control vector $\mathbf{x}$ by a small amount δx_j.

Drusch et al., GRL 2009, also TM 576
Seuffert et al., GRL 2004, also TM 421

Comparison between the OI and the EKF soil moisture analysis

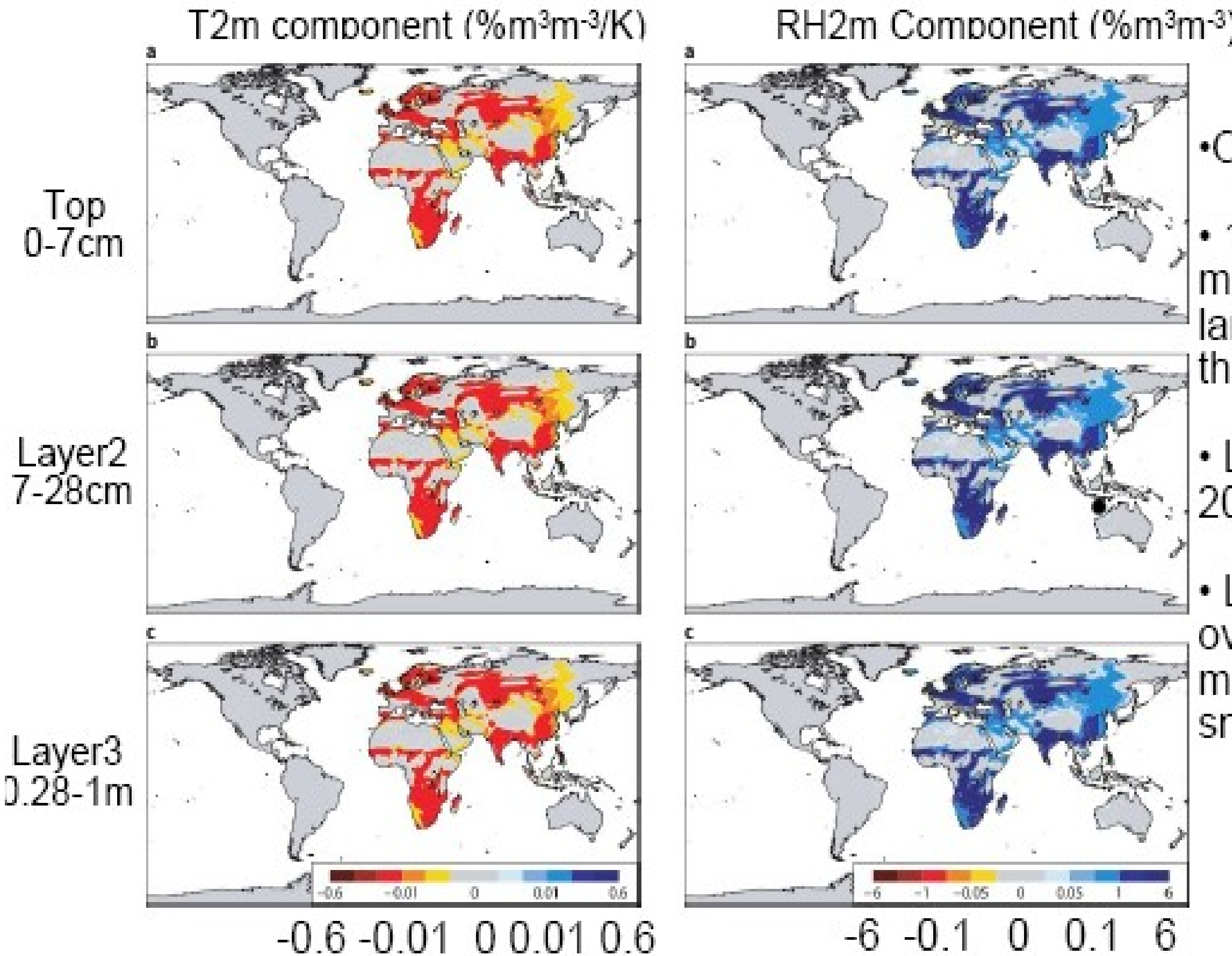
- EKF relevant to be used with screen level parameters and/or satellite data (ASCAT and SMOS).

- Preliminary tests of the EKF approach at T159 (~125km):
Comparison OI vs EKF when the two assimilation systems are used in the same conditions.

- Experiments using the Integrated Forecasting System (IFS)
  May 2007, 6h assimilation window, using T2m and Rh2m observations
- Observation errors: σ_{T2m} =2K; σ_{RH2m}=10% ; σ_B=0.01m^3m^{-3} (B not cycled)
- Two experiments:
  - OI experiment (SM and ST)
  - EKF experiment (SM)

Comparison between OI and EKF

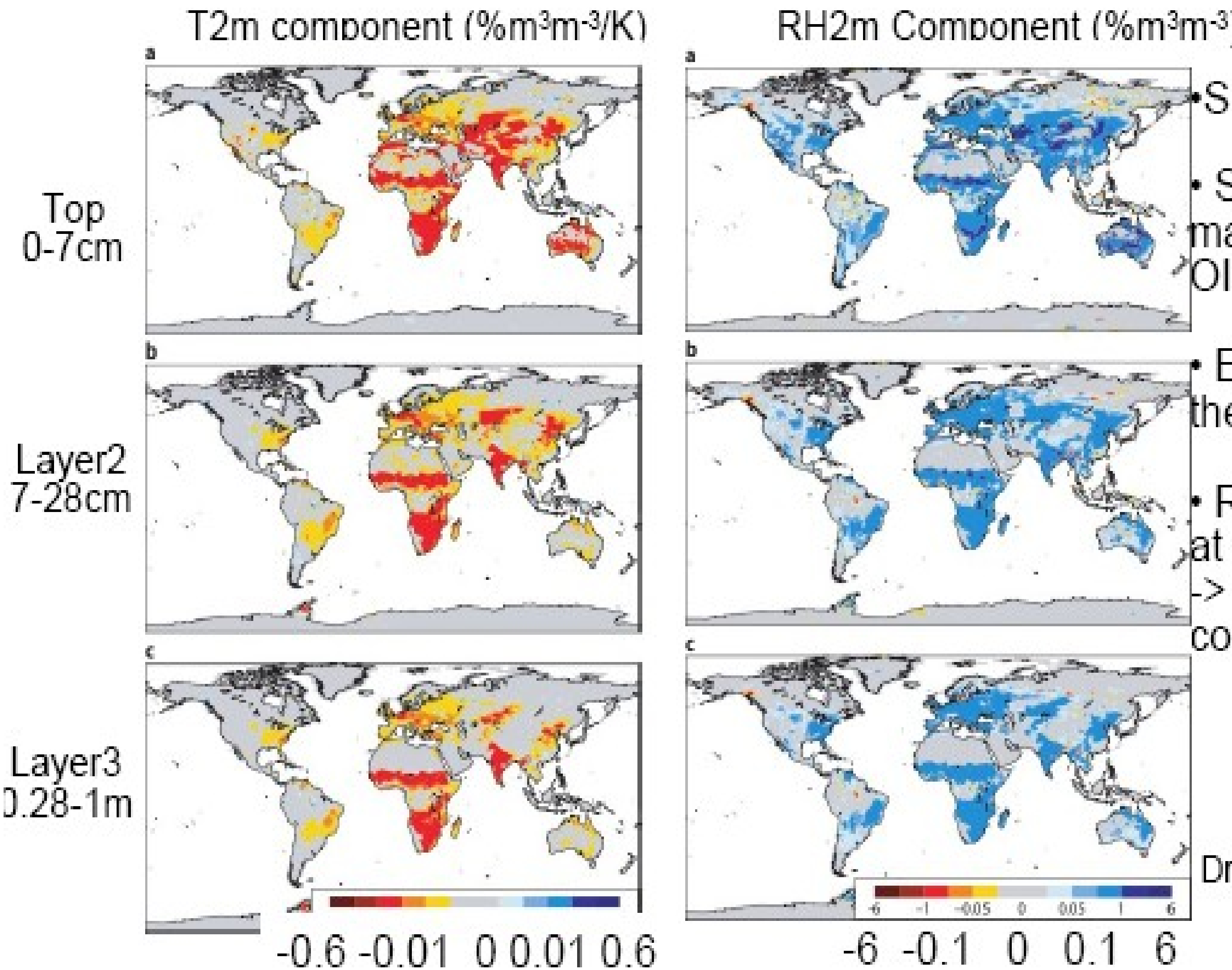
1- OI Gain matrix coefficients 01 May 2007 12UTC



- Opposite sign
- 1 order of magnitude larger for RH than T2m
- Limited to 20W-130E
- Low values over mountains, snow, deserts

Comparison between OI and EKF

2- EKF Gain matrix coefficients 01 May 2007 12UTC



- Similar pattern
- Same order of magnitude than OI gain
- Extended to the global scale
- Reduced gain at depth -> hydrological consistency

Drusch et al., 2009

EKF surface analysis system

Operational implementation in two steps:

The EKF surface analysis is far more expansive than the OI in CPU, which is normal since the OI cost was almost none (a few seconds).

Still, in order to enable the use of the EKF in operation we needed to develop:

- **A new structure of the analysis:** From cycle 35R3. Allows more time for the surface analysis.

Part of the costs is due to the perturbed coupled simulations required to estimate the Jacobian matrix (1 simulation per analysed layer).

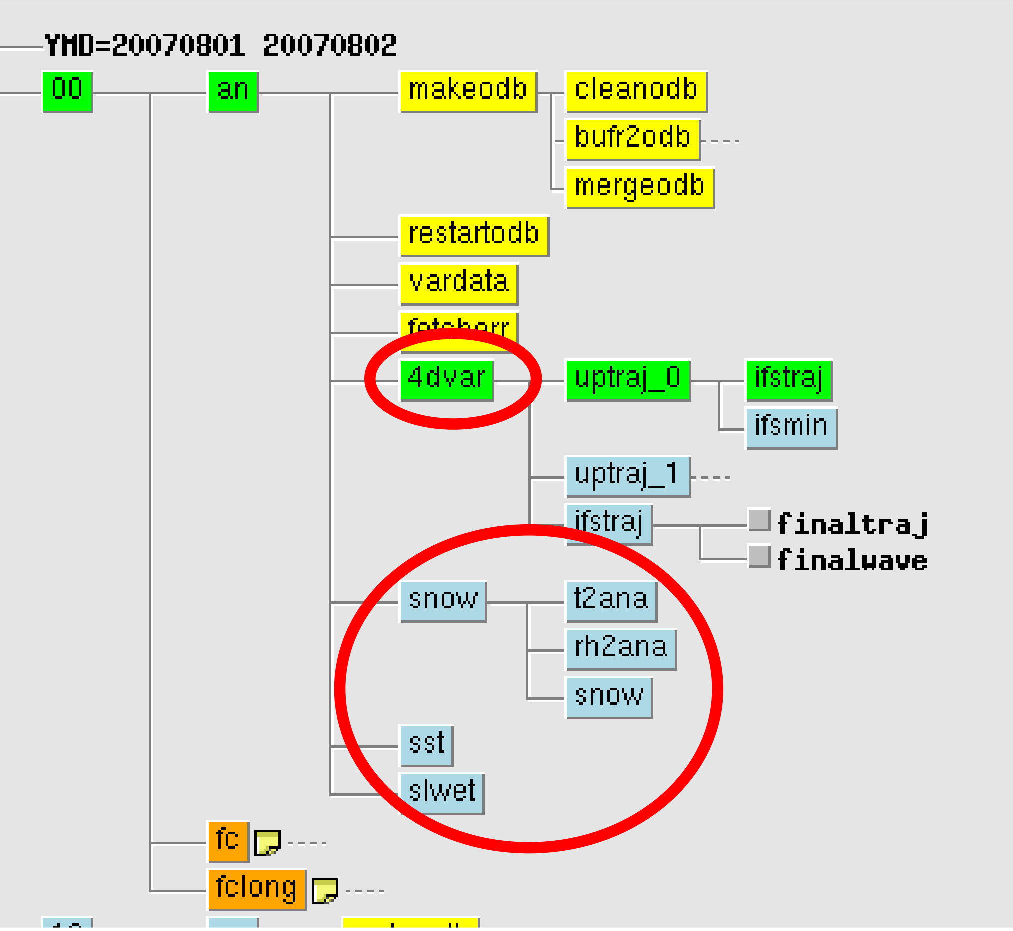
For the use of satellite data cost reduction needed → decoupling the Jacobian computation from the atmosphere. Done by reorganizing the EKF perturbing loops at low level in the model (under test).

- **Offline Jacobians: developed** in cycle 36R1 --> to be in the next cycle
  Reduces the cost of the EKF surface analysis to that of a simple 12h forecast
  (de Rosnay, Balsamo, Beljaars and Drusch, in prep 2009)

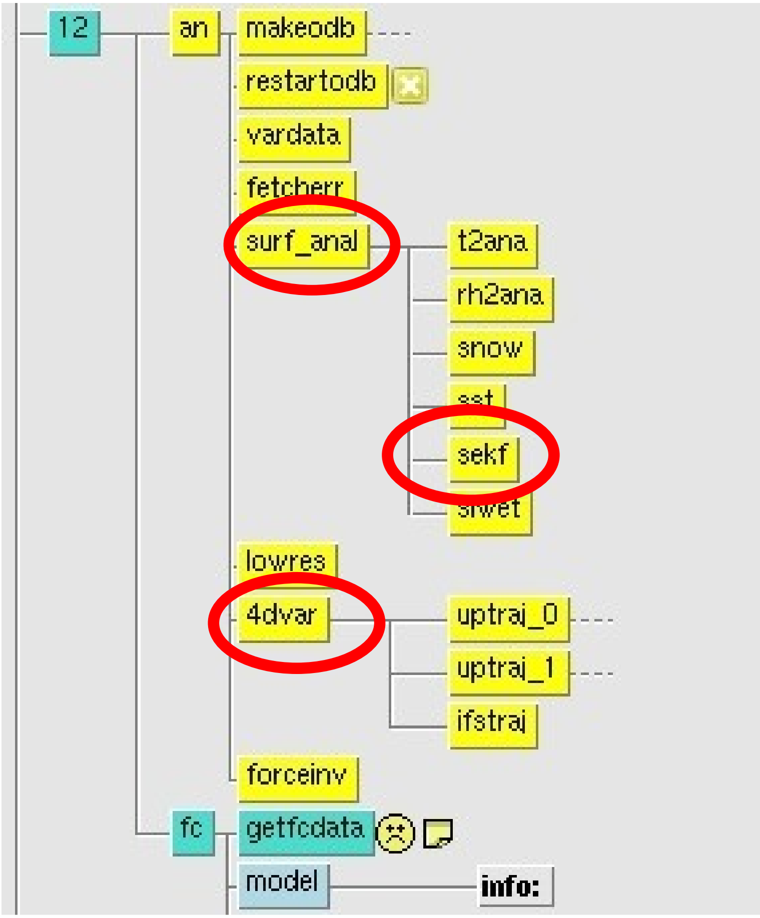
Surface Analysis structure

organisation within the ECMWF Integrated Forecasting System (IFS)

35r2:
- Surface analysis after 4D-VAR



From 35r3:
- Surface analysis before 4D-VAR (run in parallel)
Vasiljevic, de Rosnay, Haseler: Res M. 0920



From cycle 35r3, the surface analysis is completely independent from the 4D-VAR

EKF surface analysis system

• The EKF within the new structure of the surface analysis is ready for operational implementation in 36r3 (after the resolution cycles T799 → T1279 in 36r1 and EPS in 36r2).

• Accounts for the complex and non-linear link between screen parameters (T2m RH2m).

With screen level parameters scores are rather neutral compared to the OI.

• Flexible to include new type of observations that are more directly linked to soil moisture or vegetation:

- → Active microwave (C-band ASCAT on MetOp, L-band SMAP)
- → Passive microwave (L-band SMOS, SMAP)

• → Opens the possibility to perform multi-variate land surface data assimilation.

• Perspectives: possibilities to extend the EKF for snow analysis (H-SAF, Land-SAF) and vegetation characteristics/NDVI analysis (→ link G. Balsamo & S. Boussetta).

• On going Technical development of a 'surface analysis only' suite (without 4DVAR)

→ Suitable for possible near future inter-comparison experiment of LDAS.

LDAS-IP ? to be discussed in the Data Assimilation working group

- Introduction
- EKF soil moisture analysis
- **Use of satellite data for soil moisture monitoring and analysis**
    - **Active microwave: MetOp/ASCAT (H-SAF)**
        - **Monitoring**
        - **Data assimilation**
    - Passive microwave: SMOS (ESA)

Active microwave remote sensing

Long time series of soil moisture data

ERS-1/2 scatterometer data and MetOp ASCAT:

- Active microwave instruments operating at C-band (5.6GHz)
- ERS-1: 1991 – 1996
- ERS-2: 1996 – 2001 and 2004 – now
- MetOp ASCAT: since 2006

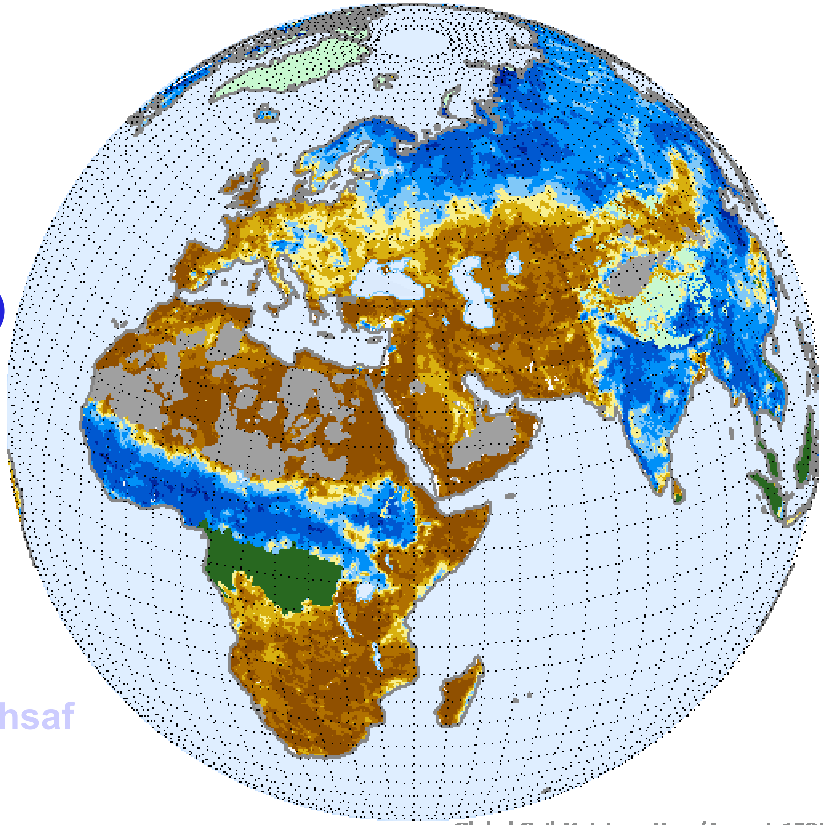
Near Real Time (NRT) ASCAT data available

Surface soil moisture index (ws) based on the TUWien retrieval scheme (Wagner et al. 1999)

ECMWF observation operator (**Scipal et al., 2008**)

Cumulative Distribution Function (CDF) of ws (ASCAT or ERS SM index) and ECMWF soil moisture

EUMETSAT H-SAF project:



Global Soil Moisture Map (August 1995)

H-SAF Project: http://www.meteoam.it/modules.php?name=hsaf

ECMWF H-SAF web page:

http://www.ecmwf.int/research/EUMETSAT_projects/SAF/HSAF/

Active microwave remote sensing

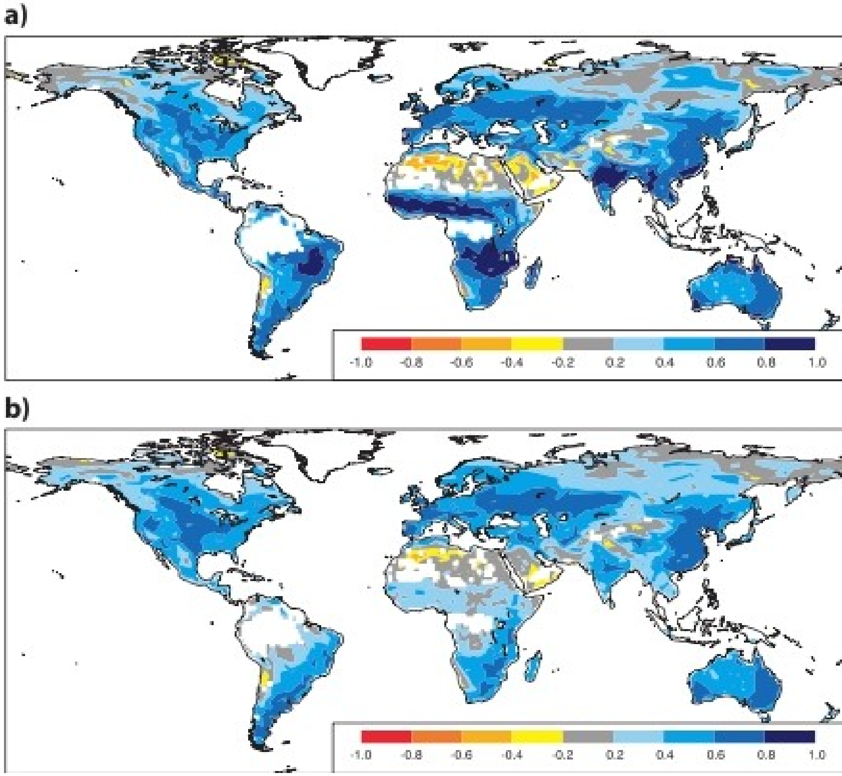
Correlation of ERS and ERA-40 SM abs. values and anomalies

General good agreement between ERS and ERA-40 soil moisture products.

For 85% of the land points, correlation is significant at the 0.05 level.

High correlation where strong SM seasonal cycle (e.g. monsoon regions).

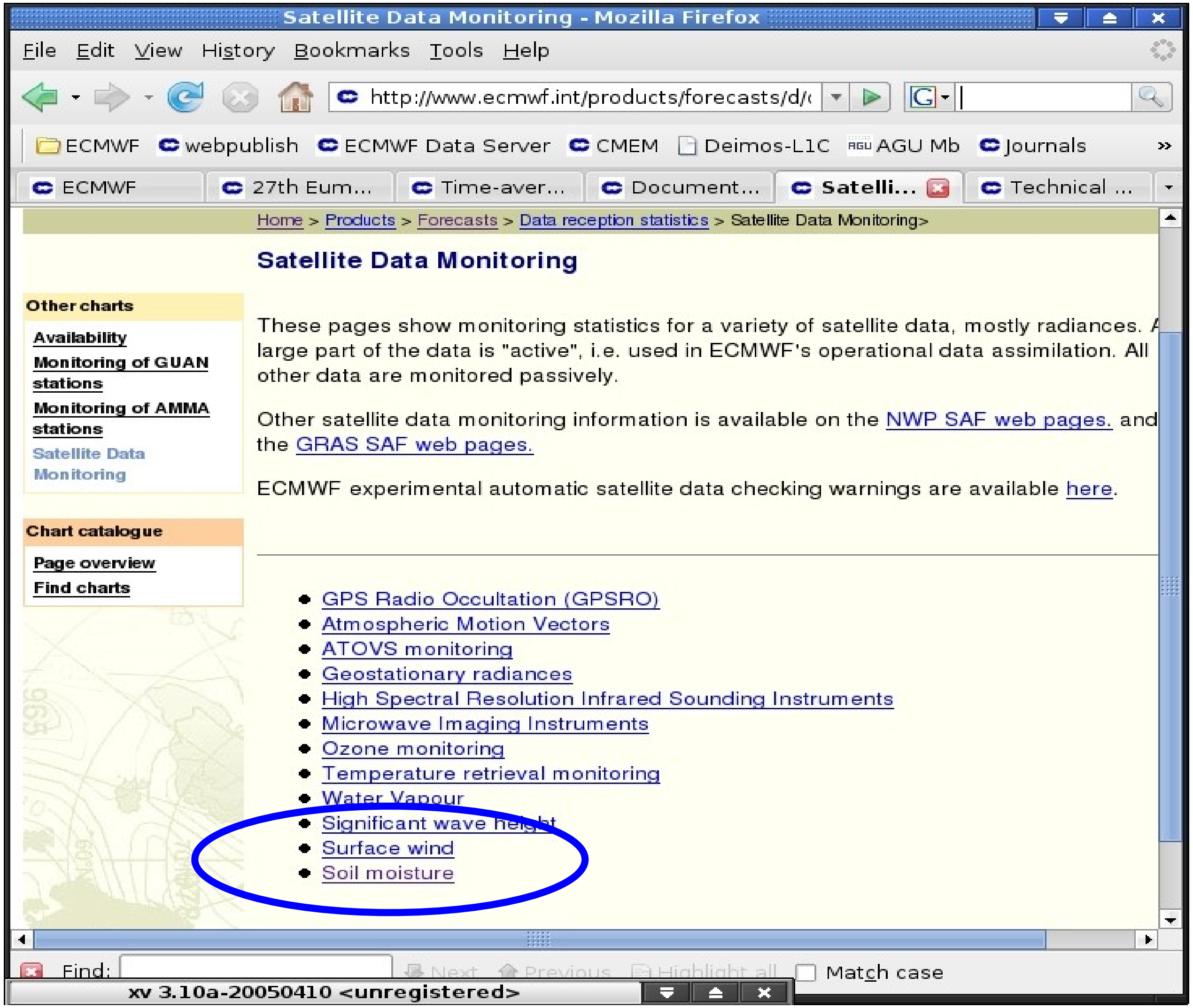
Relatively low correlation in the eastern part of the North America (high amount of biomass).



Scipal et al., 2008

ASCAT provides good SM information in semi-arid and moderately vegetated area.

ASCAT monitoring in IFS cycle 35r3



New Soil Moisture item on the ECMWF monitoring page

E-suite: July 2009

Operation:
since 8 September 2009

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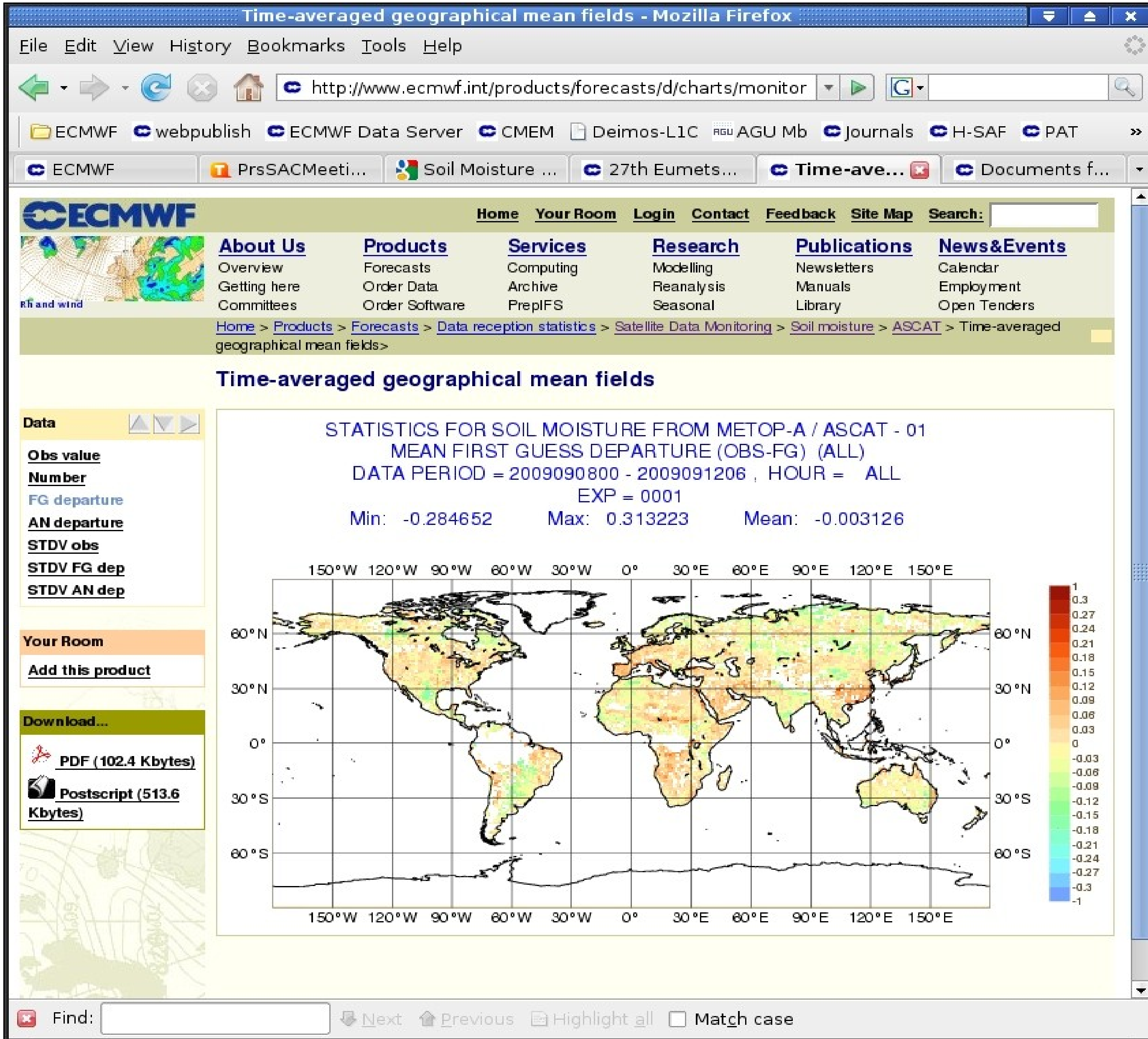
ASCAT monitoring in IFS cycle 35r3



ASCAT monitoring: FG departure in m3/m3

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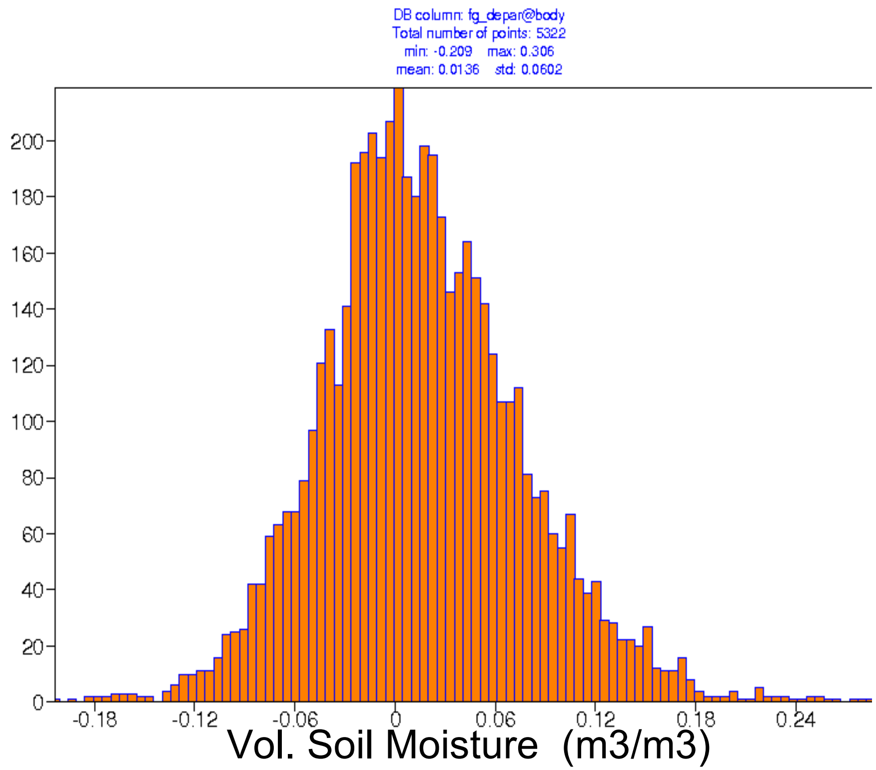
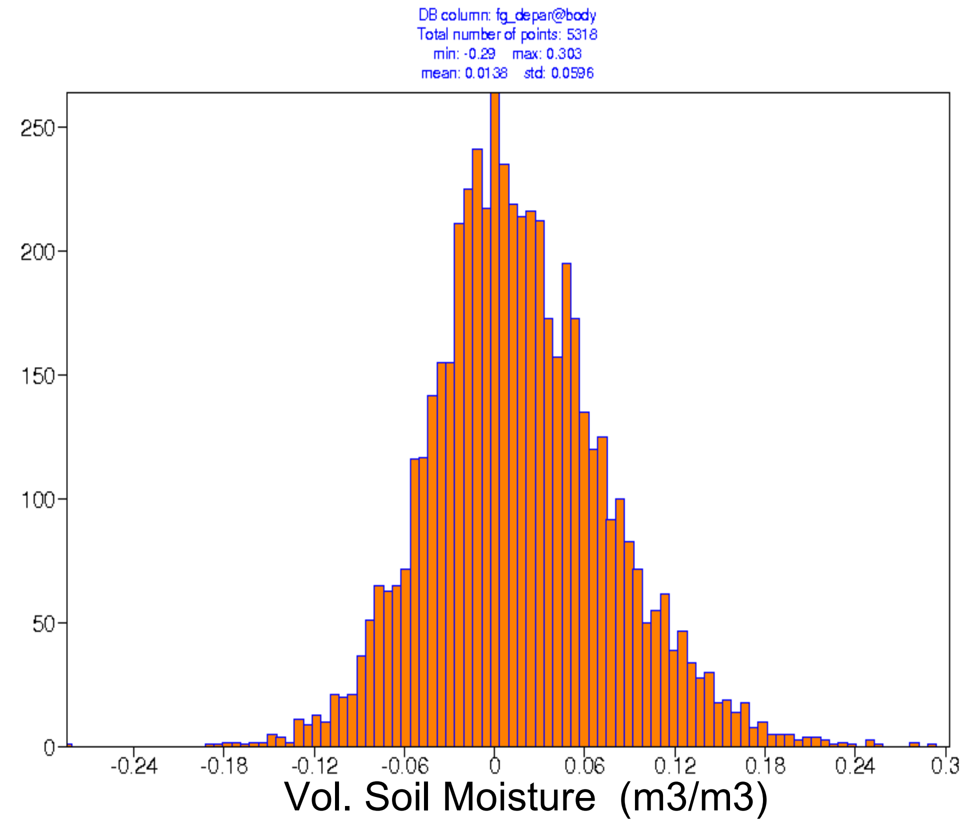
ASCAT monitoring at different resolutions: Distribution function of FG departure (OBS- first guess)

cycle 35r3:
At T799 (~25 km)



cycle 36r1
At T1279 (~16km)



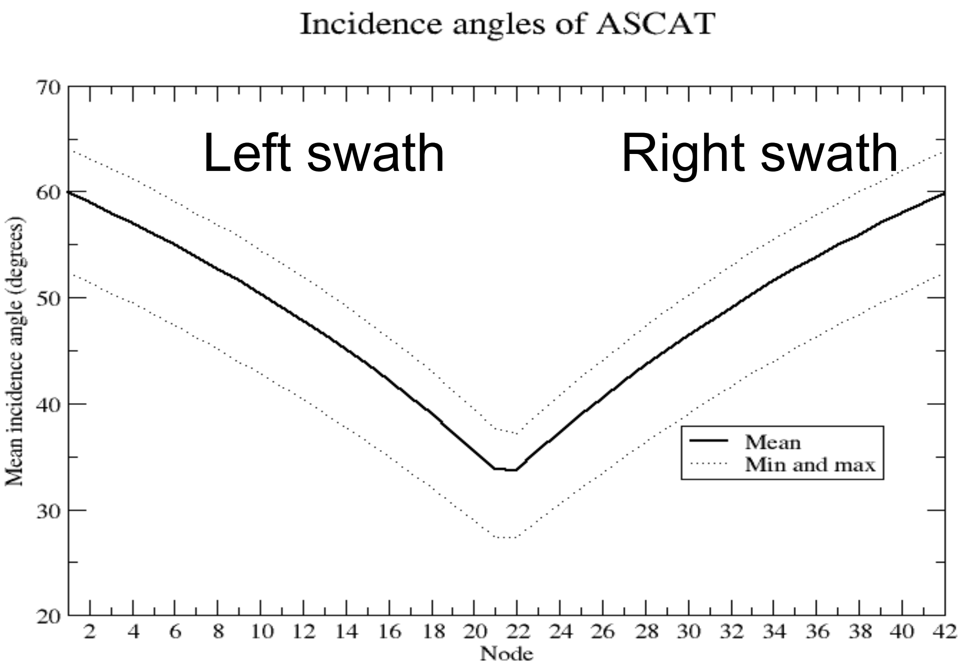
Bias free CDFmatched ASCAT soil moisture (based on ERS-ERA-Interim)
Validation of the CDF matching parameters at T799 and T1279
No sensitivity of ASCAT monitoring to resolution T799 and T1279

Sensitivity of ASCAT soil moisture first guess departure to incidence angle

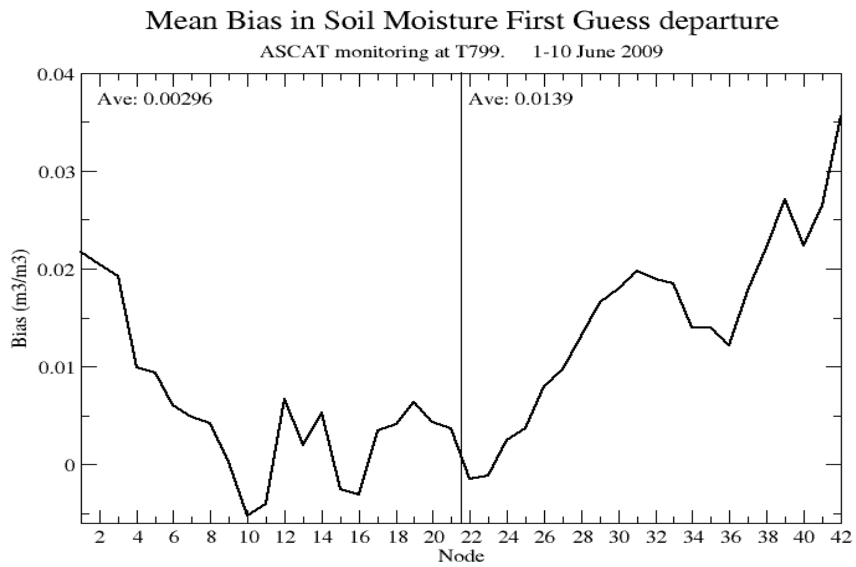
- In contrast to ERS, ASCAT covers two swaths gridded into nodes (incidence angles from 25 to 65 degrees).

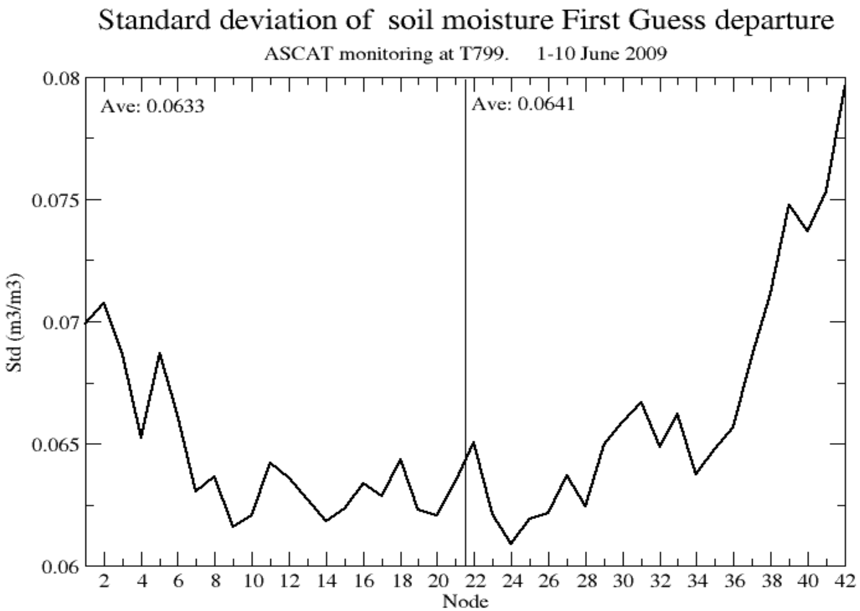
- Since May 2009, EUMETSAT deliver a re-processed soil moisture product, based on corrected inter-calibration ASCAT/ERS.

- Use of ASCAT soil moisture at ECMWF relies on a CDF matching between ERA-Interim and ERS data
- -> need to evaluate the consistency between ASCAT and ERS and possible angular effect.



Sensitivity of ASCAT soil moisture first guess departure to incidence angle





- Bias and STD increase with incidence (consistency with IPF study 2009)

- Larger errors for right swath

- Clearly show that the ERS/ASCAT inter-calibration still needs improvements

(de Rosnay Res.Mem. 0953, July 2009)

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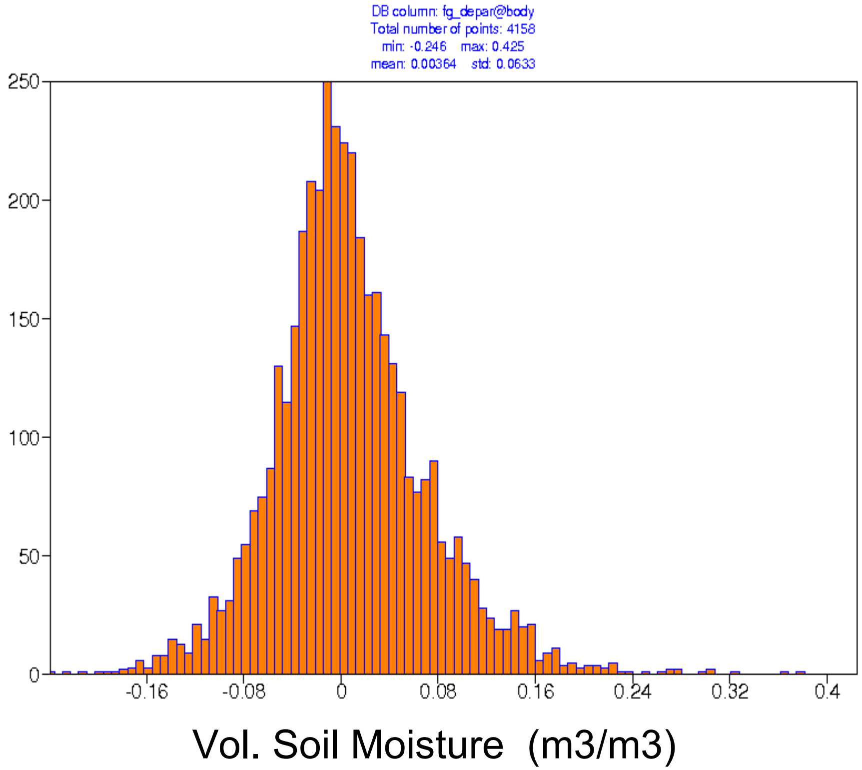
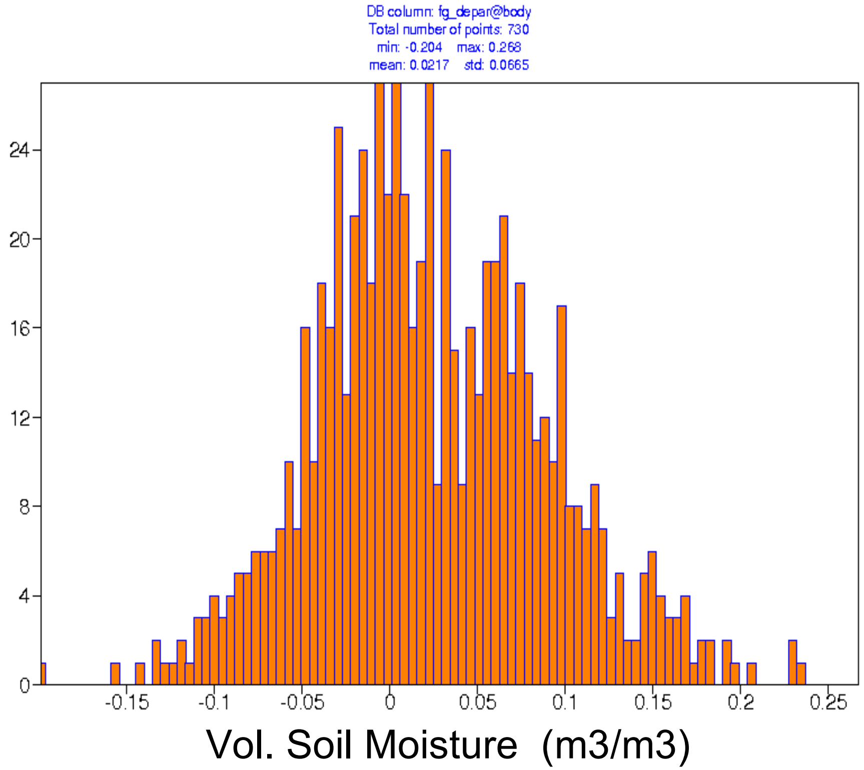
Sensitivity of ASCAT soil moisture first guess departure to incidence angle

Node 21 (low incidence)
bias: 0.0036 m3/m3



Node 1 (high incidence)
bias: 0.0217 m3/m3



Large scatter of FG_depar at high incidence angles

→ USE of ASCAT data: blacklisting of high incidence angles data

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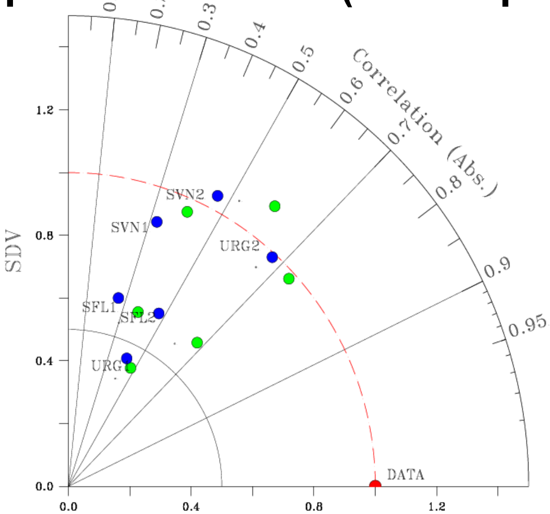
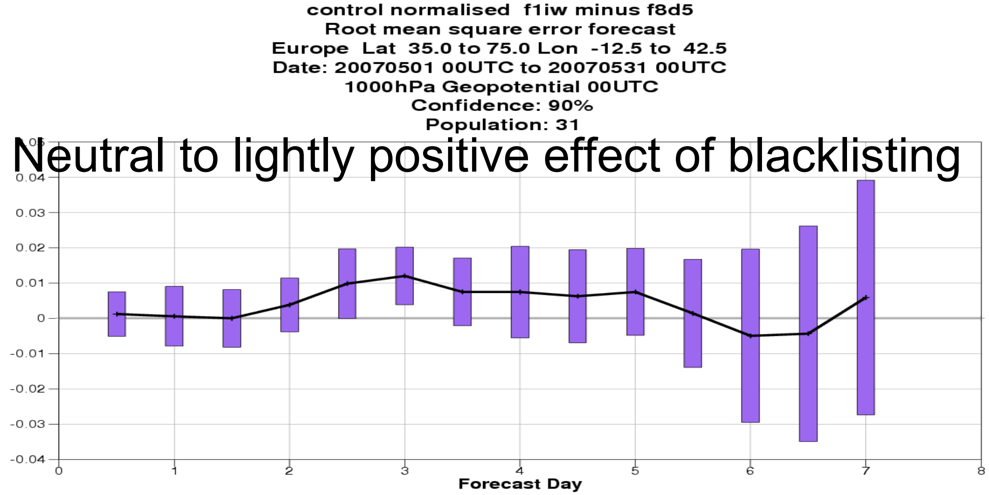
ASCAT data assimilation – interest of blacklisting

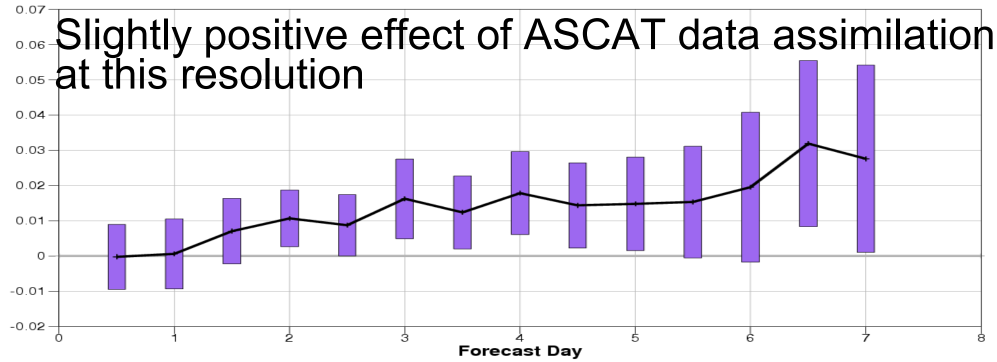
Preliminary results at T799:
ASCAT data assimilation (green)
→ Improved soil moisture representation in terms of correlation for all the SMOSMANIA stations (Calvet et al.) compared to control (blue: Operation)



Forecast Scores



Neutral to lightly positive effect of blacklisting



Slightly positive effect of ASCAT data assimilation at this resolution

USE of ASCAT data:
- neutral scores – still needs more investigation
- improves soil moisture over SMOSMANIA
→ toward a better consistency between fluxes and reservoirs

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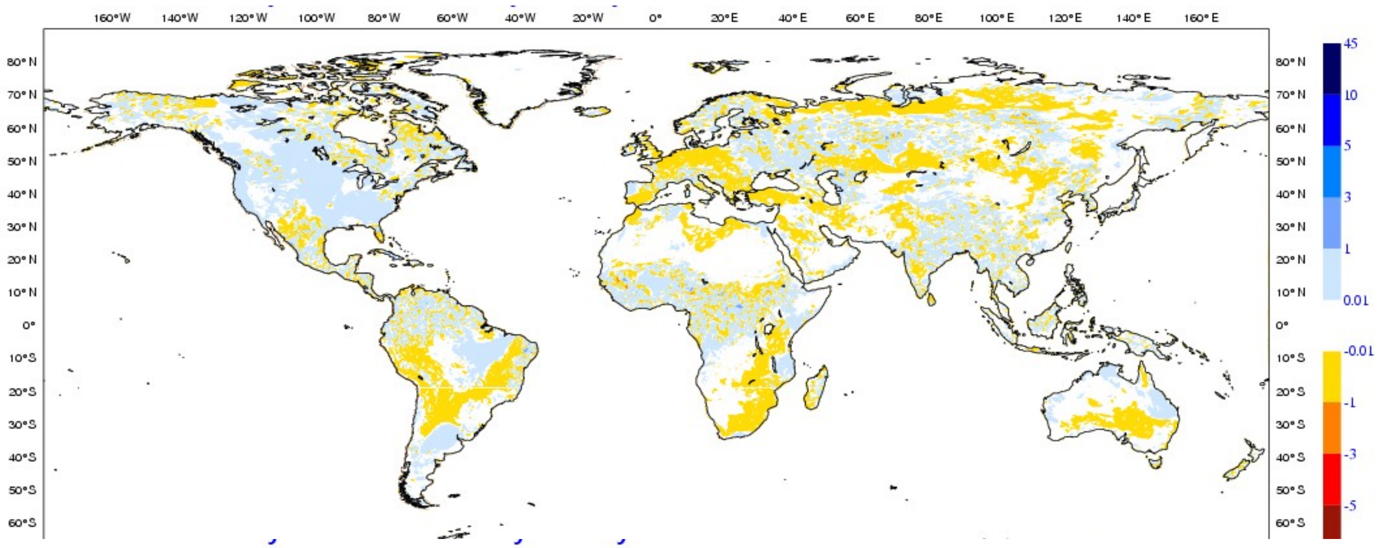
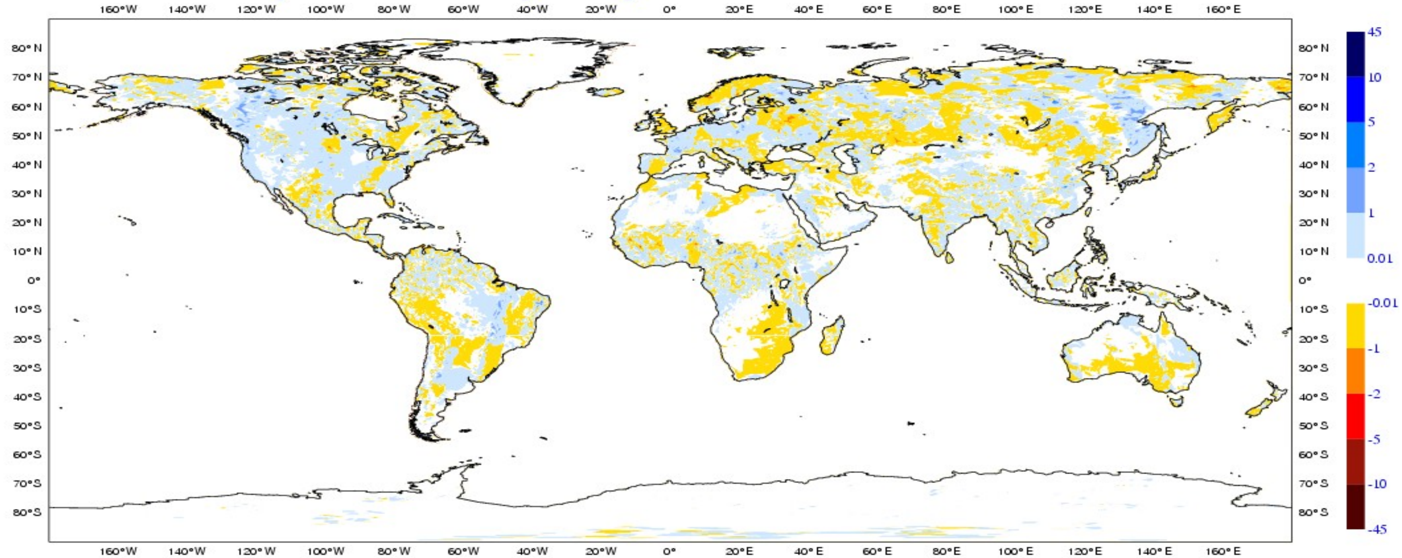
ASCAT data assimilation in cycle 35r3, T799

Surface SM increments (mm)



EKF with Screen level parameters

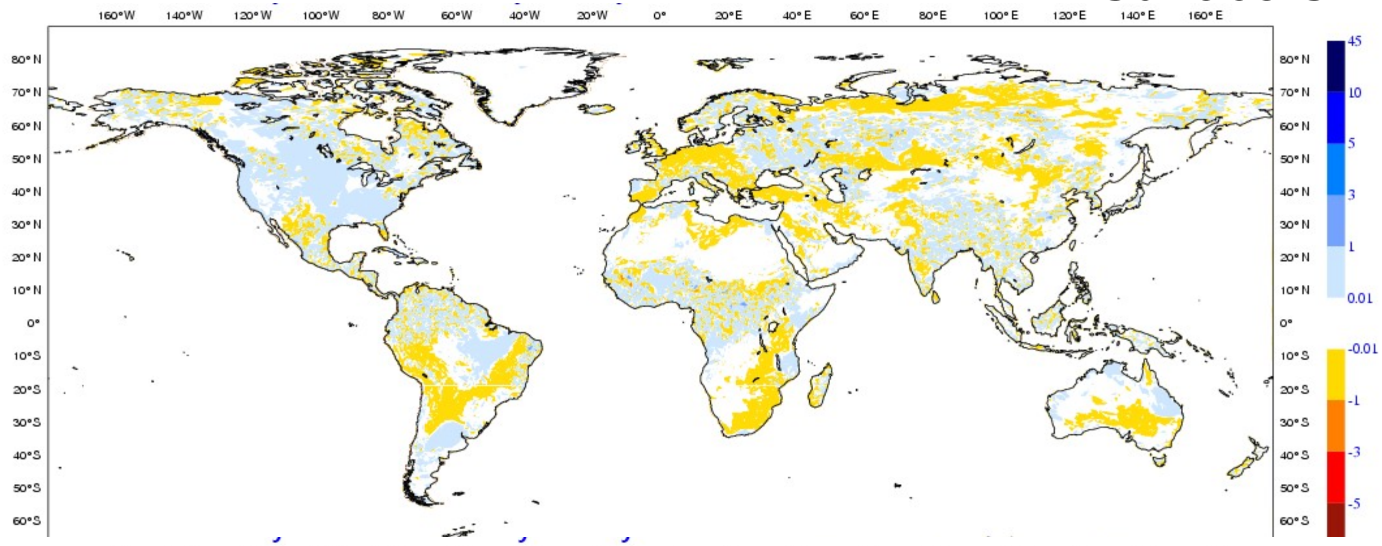


EKF with Screen level parameters + ASCAT SM

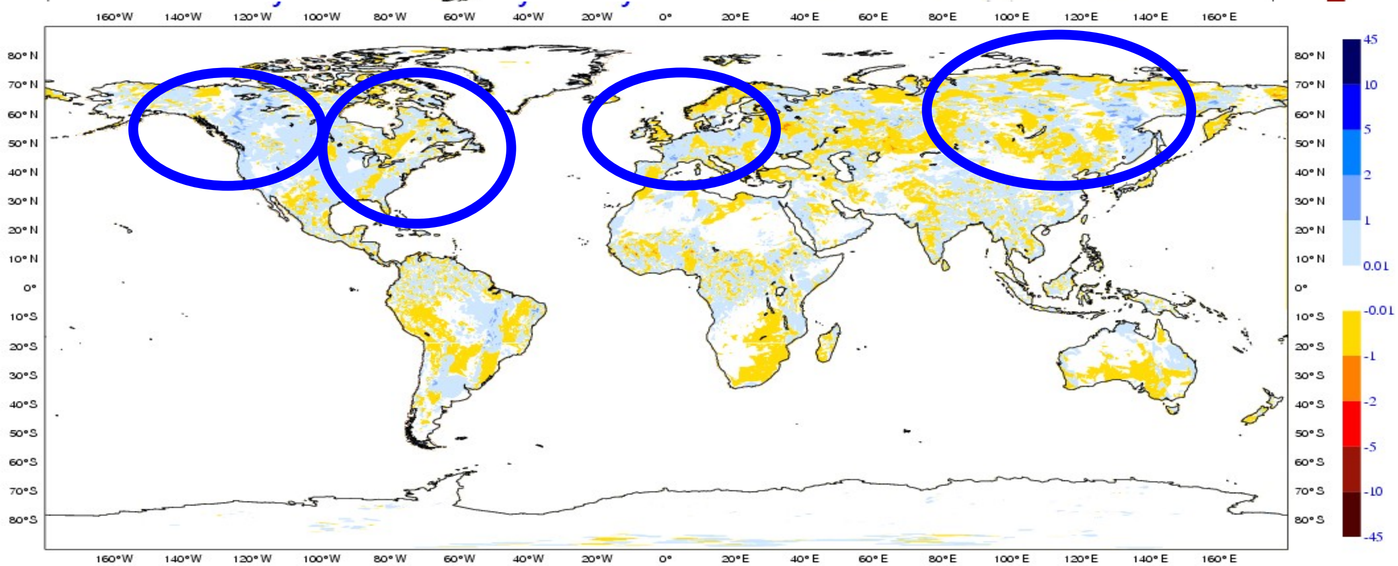
01.07.2008 9-21 UTC

ASCAT data assimilation in cycle 35r3, T799
-> production of root zone SM for H-SAF

Surface SM increments (mm)



EKF with
Screen level
parameters



EKF with
Screen level
parameters
+ ASCAT SM

01.07.2008 9-21 UTC

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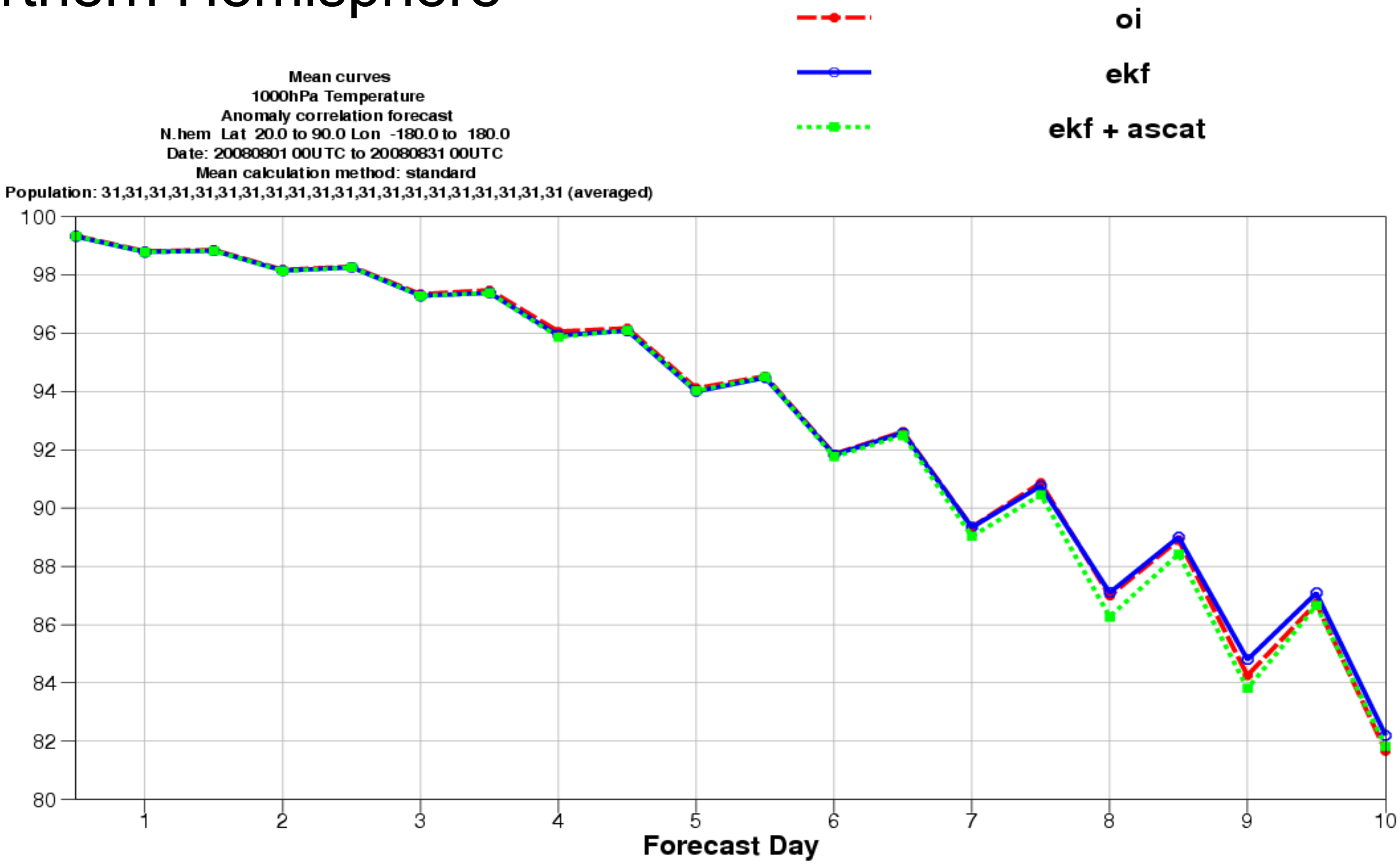
Scores of OI/EKF/EKF+ASCAT -
Cycle 36r1 validation runs for operational EKF implementation
2 months (December 2008 -January 2009), at T255
Scores after 1 month of spin-up: January 2009

Northern Hemisphere



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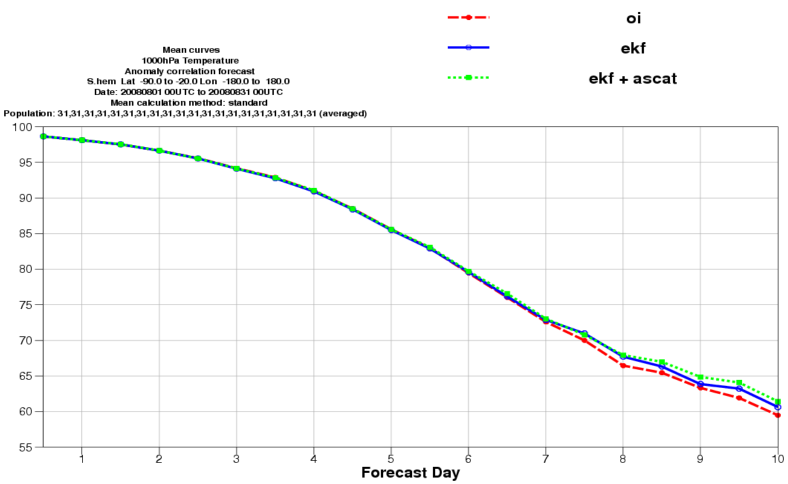
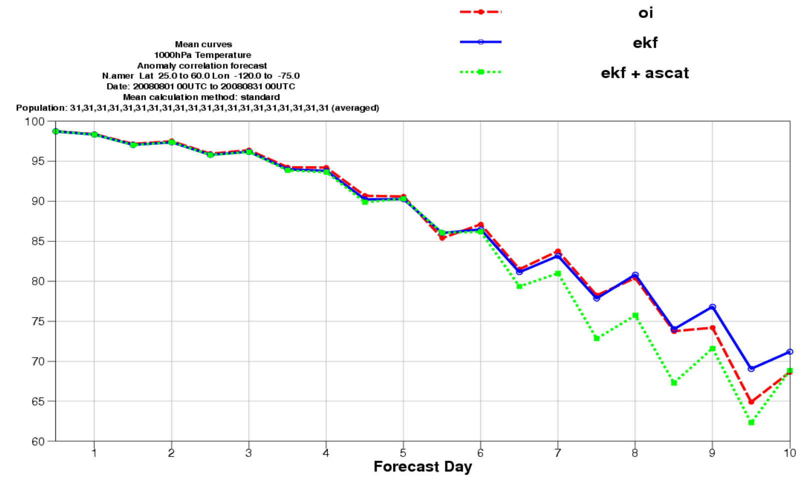
Scores of OI/EKF/EKF+ASCAT - 36r1 – January 2009

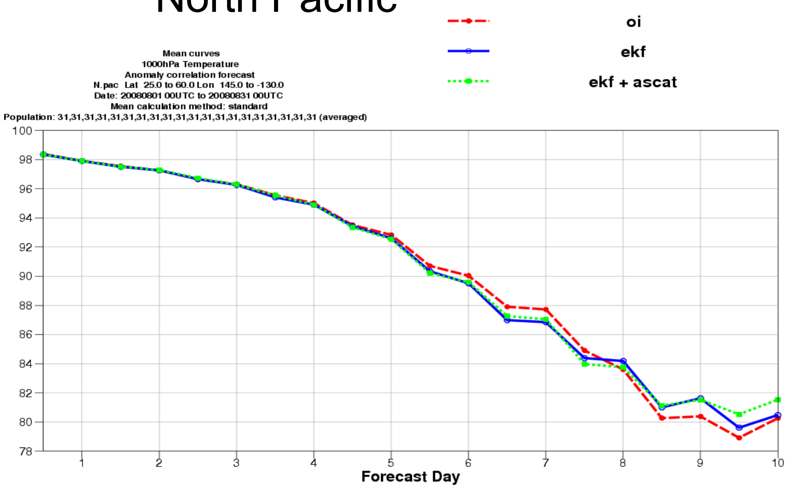
Southern Hemisphere



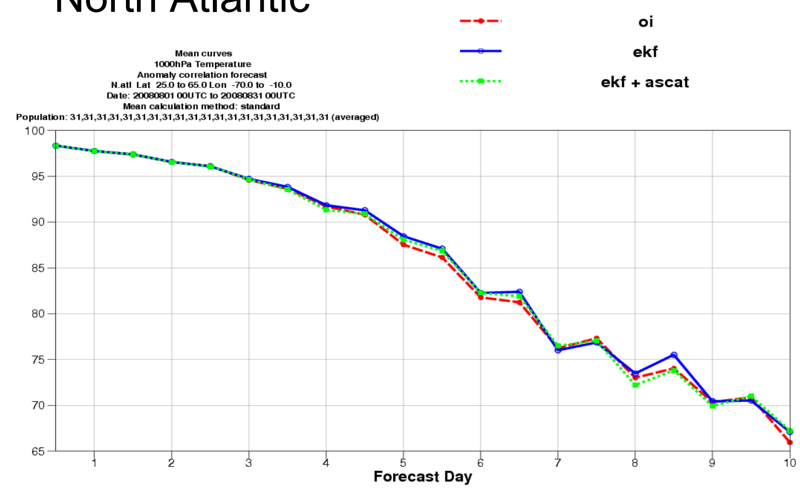
North America



North Pacific

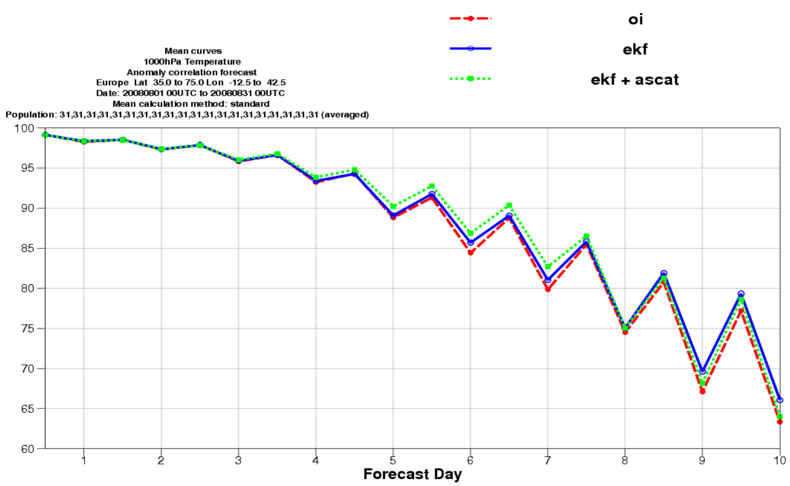


North Atlantic

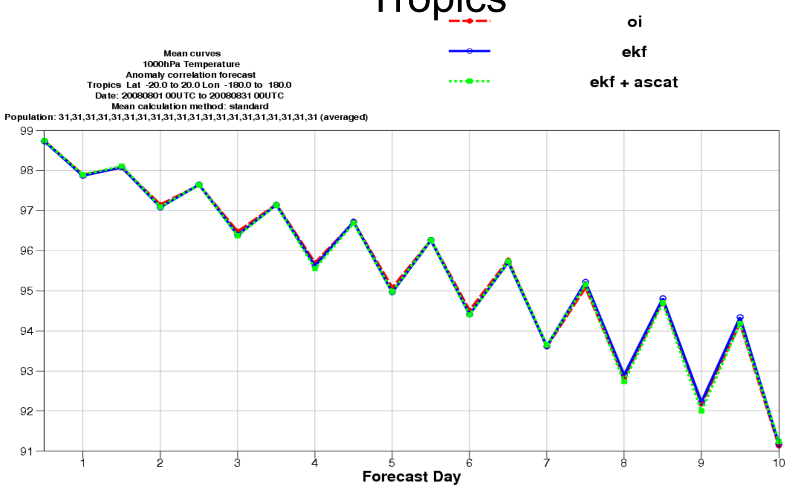


Scores of OI/EKF/EKF+ASCAT - 36r1 – January 2009

Europe



Tropics



Neutral impact of the EKF when using screen level parameters

Using ASCAT data improves soil moisture and generally neutral (but variable) impact.

- Introduction
- EKF soil moisture analysis
- **Use of satellite data for soil moisture monitoring and analysis**
  - EUMETSAT H-SAF: MetOp/ASCAT
  - **ESA: SMOS**

Soil Moisture and Ocean Salinity mission

ESA SMOS launched on 2nd of November 2009

ECMWF contribution:

Global monitoring and
Data assimilation
of brightness temperatures (TB).

A Key component of TB monitoring and assimilation is the **forward operator** that transforms model variables (eg soil moisture and temperature) into observed variable (SMOS TB)

Community Microwave Emission Model (CMEM)

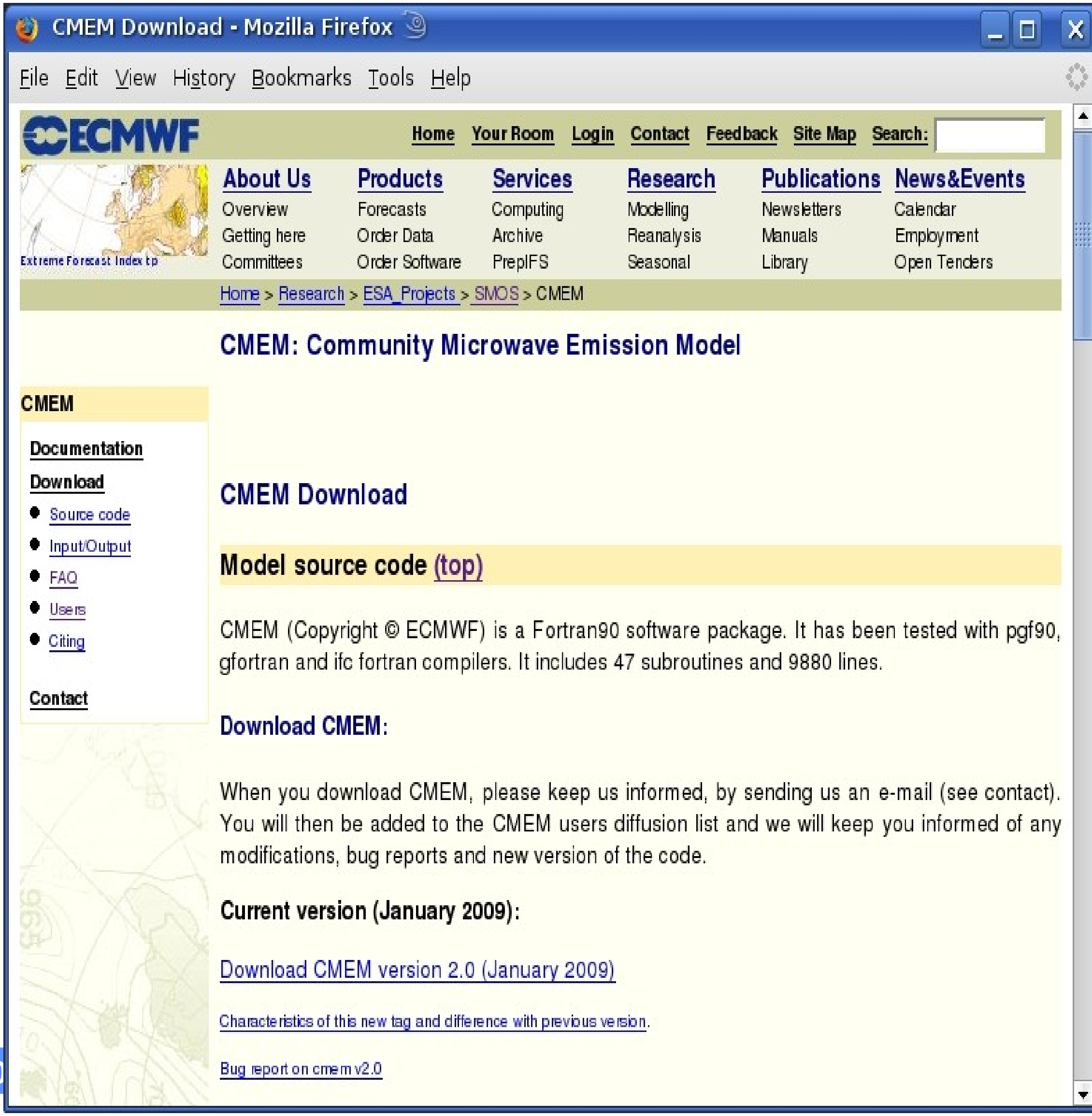
http://www.ecmwf.int/research/ESA_projects/SMOS/cmem/cmem_index.html

Land surface MW emission model developed at ECMWF for NWP.

SMOS forward operator
Also suitable at higher frequencies (C-Band and X-Band).

- Code source available on the ECMWFSMOS web page
- Modular in terms of
- parametrisations
- input/output
- Tiled emission model. Takes advantage of recent lake param in HTESSEL in 35r3

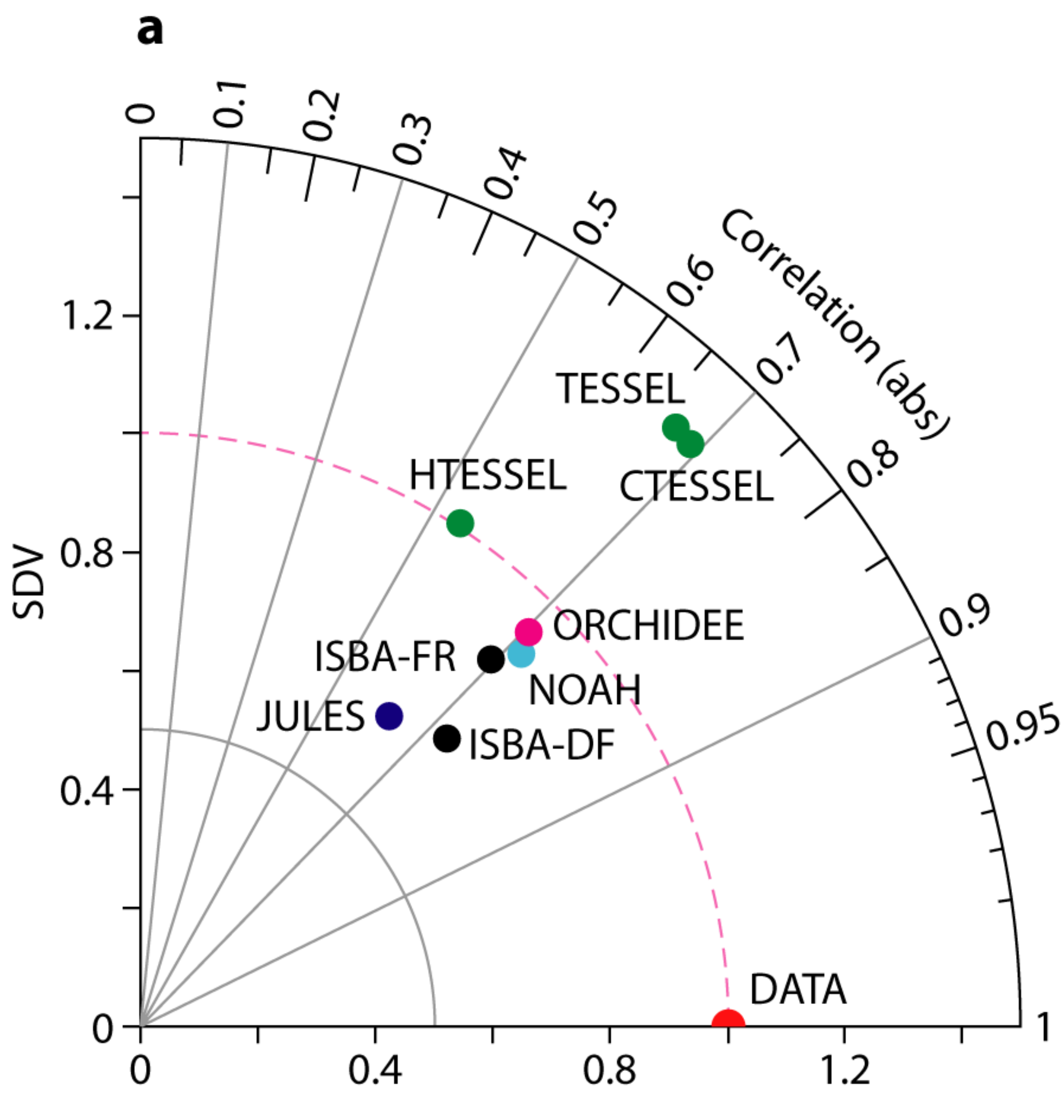
- Calibrated, evaluate,d inter-compared (modular multi-parametrisations)
de Rosnay et al., JGR 2009
Drusch et al., JHM 2009



Impact of soil texture on TB errors with HTESSEL

(de Rosnay, Balsamo and Dharssi)

Following the ALMIP-MEM study (de Rosnay et al., 2009, cf A. Boone's talk)
Need to investigate the sensitivity of the coupled HTESSEL-CMEM to the use of different soil texture maps.



Impact of soil texture on TB errors with HTESSEL

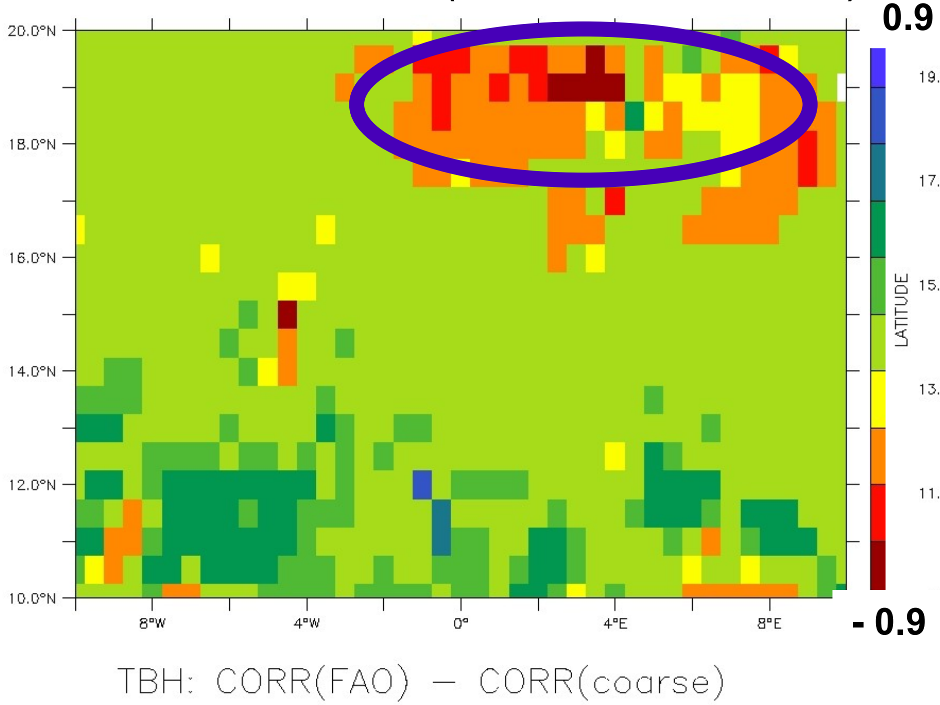
(de Rosnay, Balsamo and Dharssi)

Following the ALMIP-MEM study (de Rosnay et al., 2009, cf A. Boone's talk)
Need to investigate the sensitivity of the coupled HTESSEL-CMEM to the use of different soil texture maps.
→ HTESSEL run with different soil texture maps and TB compared with AMSR-E.

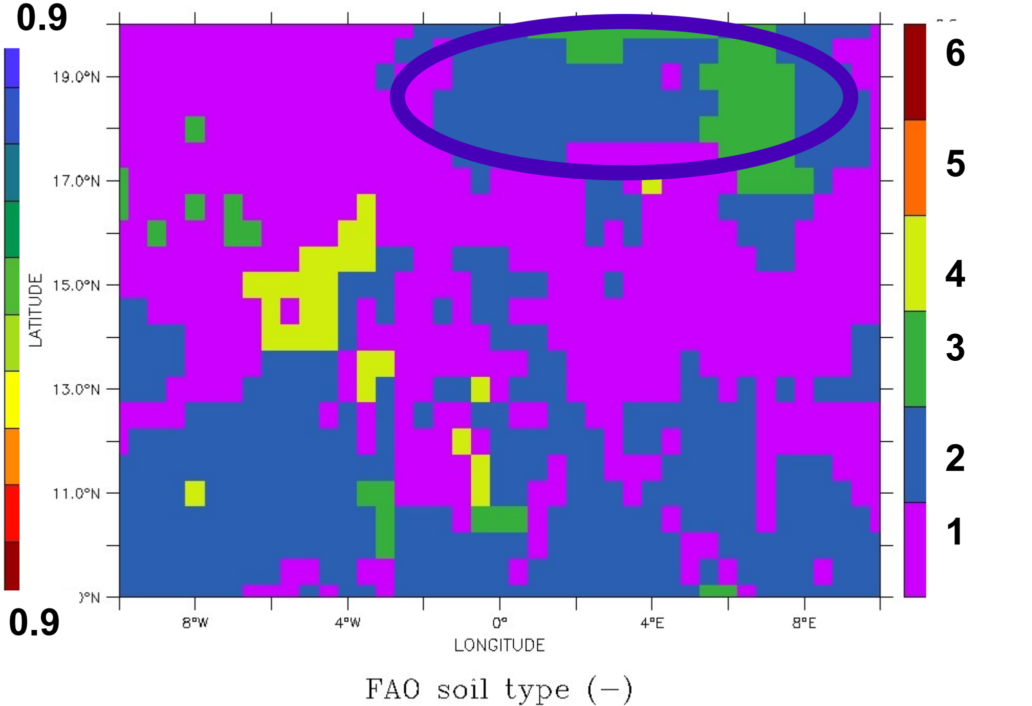
Using coarse textured soil over the entire Sahel window leads to better agreement between simulated and observed TB than when using the ECMWF soil texture map.

Soil Texture → affects SM dynamics → influences simulated TB and agreement with AMSR-E
(also a direct, but much smaller, effect of texture on emissivity)
→ High potential of passive microwave evaluate soil texture maps

Diff of TBH Corr (ECMWF – Coarse)



Soil texture ECMWF (1 coarse, 2 med, 3 fine)



Impact of soil texture on TB errors with HTESSEL

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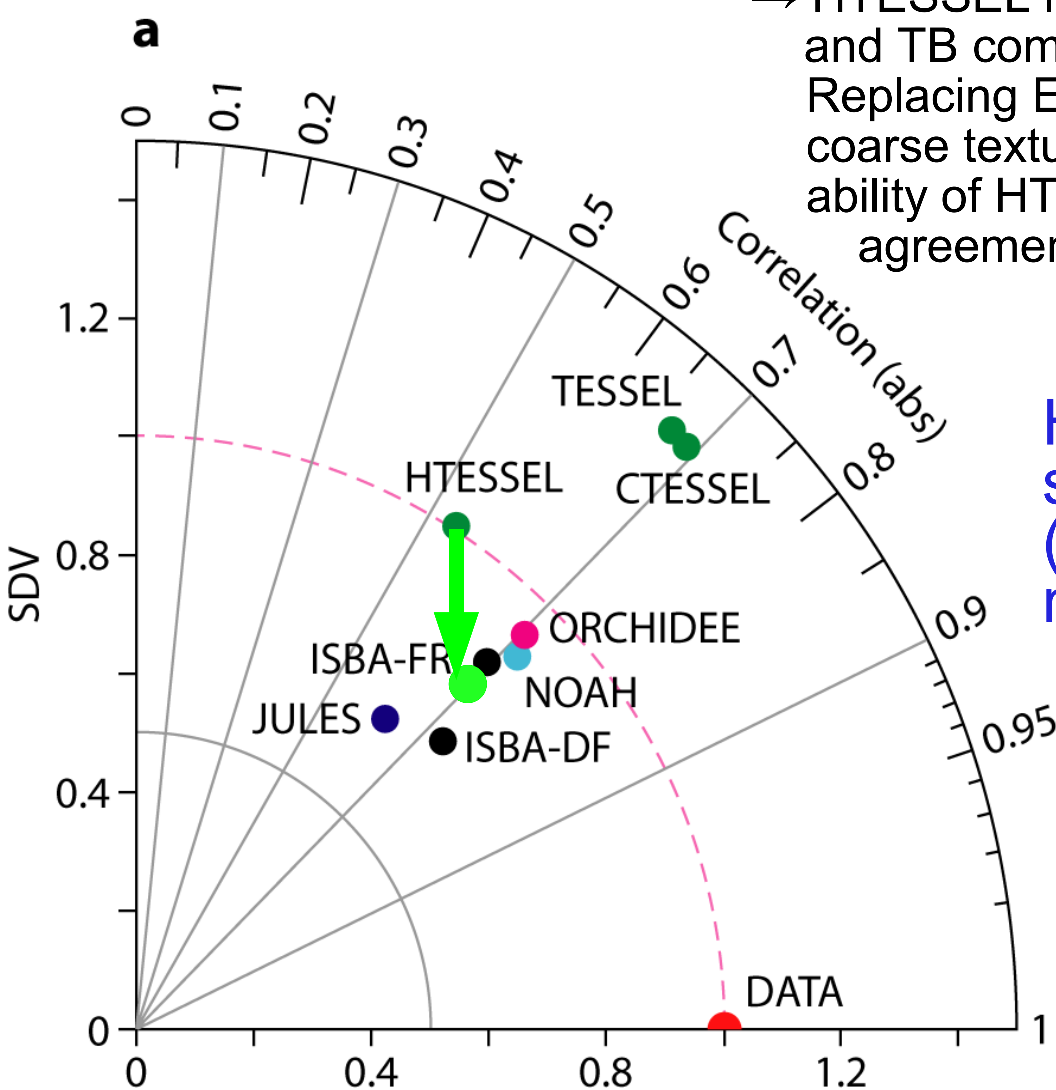
Need to investigate the sensitivity of the coupled HTESSEL-CMEM to the use of different soil texture maps.

→ HTESSEL run with different soil texture maps and TB compared with AMSR-E.
Replacing ECMWF soil texture map by a coarse textured soil over Shale improves the ability of HTESSEL-CMEM to simulate TB in agreement with AMSR-E data

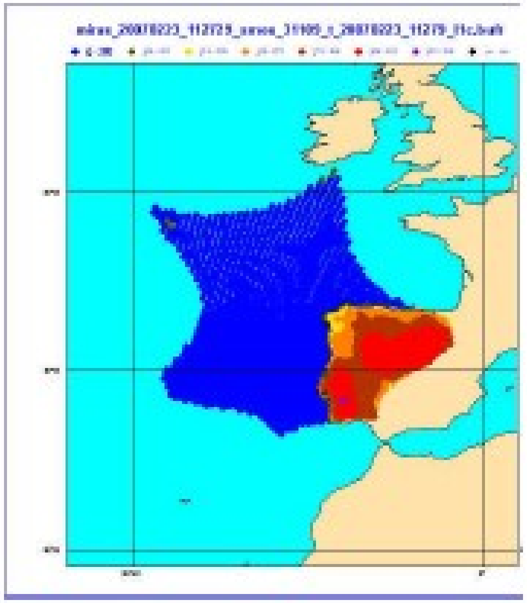


High potential of microwave satellite data to validate (and correct ?) model parameters

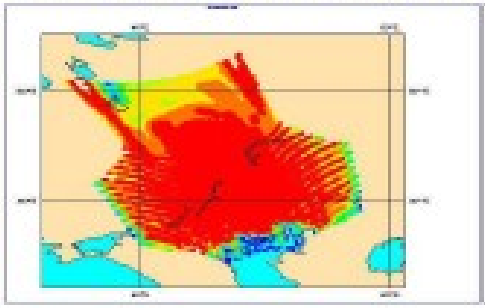
Implementation of SMOS data in IFS

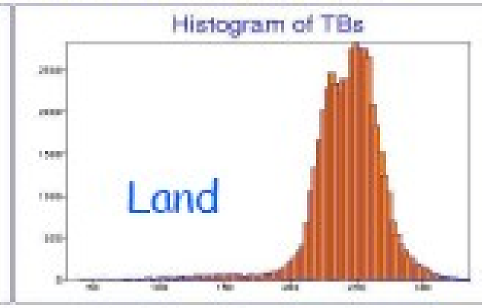
- Technical implementation to transform raw SMOS bufr data in IFS internal format + filtering jobs.
- Testing data:

2 demonstration files (19 bufr messages, 54 sec.)

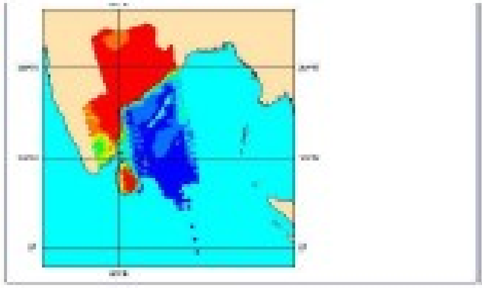


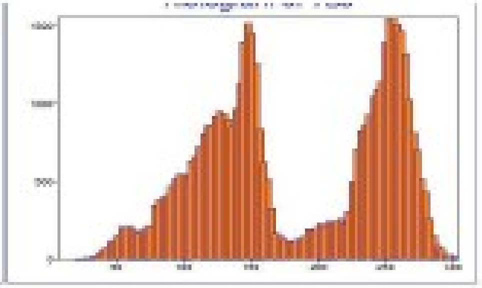
24h of pre-processed (simulated) bufr data for 2010





Land and sea





→ See poster Muñoz Sabater et al.

ECMWF

Summary (1/2)

• New EKF soil moisture analysis has been developed and tested in research mode.

• EKF will replace the OI in the operational cycle 36r3. Operational implementation has been done in two steps:

  - New structure of the surface analysis operational (35r3) since September 2009
  - Offline Jacobians used to reduce the cost of the EKF surface analysis to the cost of a 12h FC. (cycle 36r3)

• Open the possibility of multi-variate land surface data assimilation

• Offline surface analysis suite under development. Of high interest for research activities and for seasonal forecast.

Structure for land data assimilation intercomparison experiment (LDAS-IP ?)

Summary (2/2)

Use of satellite data for land surface analysis: recent advances

- ASCAT (active microwave):
  - EUMETSAT H-SAF
  - Monitoring of SM data
  - Assimilation of soil moisture data → scores neutral to positive (needs more investigation) and improve soil moisture (SMOSMANIA) → better consistency between SM and fluxes.
  - First step toward consistent NWP and operational hydrology (link with F. Pappenberger activities)
- SMOS (passive microwave):
  - CMEM forward operator ;
  - Implementation of SMOS data in the IFS → Poster Muñoz Sabater et al.
  - Potential for soil parameter evaluation.
- Future extension of the EKF surface analysis to:
  - Snow analysis (H-SAF CDOP 2010-2017) – Continuity of current HTESSEL developments (Dutra et al. and Balsamo et al.)
  - Vegetation LAI analysis (following current vegetation seasonality dvpts within GEOLAND: G. Balsamo, S. Boussetta)

More information on the surface analysis:

Data Assimilation training courses:

http://www.ecmwf.int/newsevents/training/meteorological_presentations/MET_DA.html

ECMWF SMOS page:
http://www.ecmwf.int/research/ESA_projects/SMOS/index.html

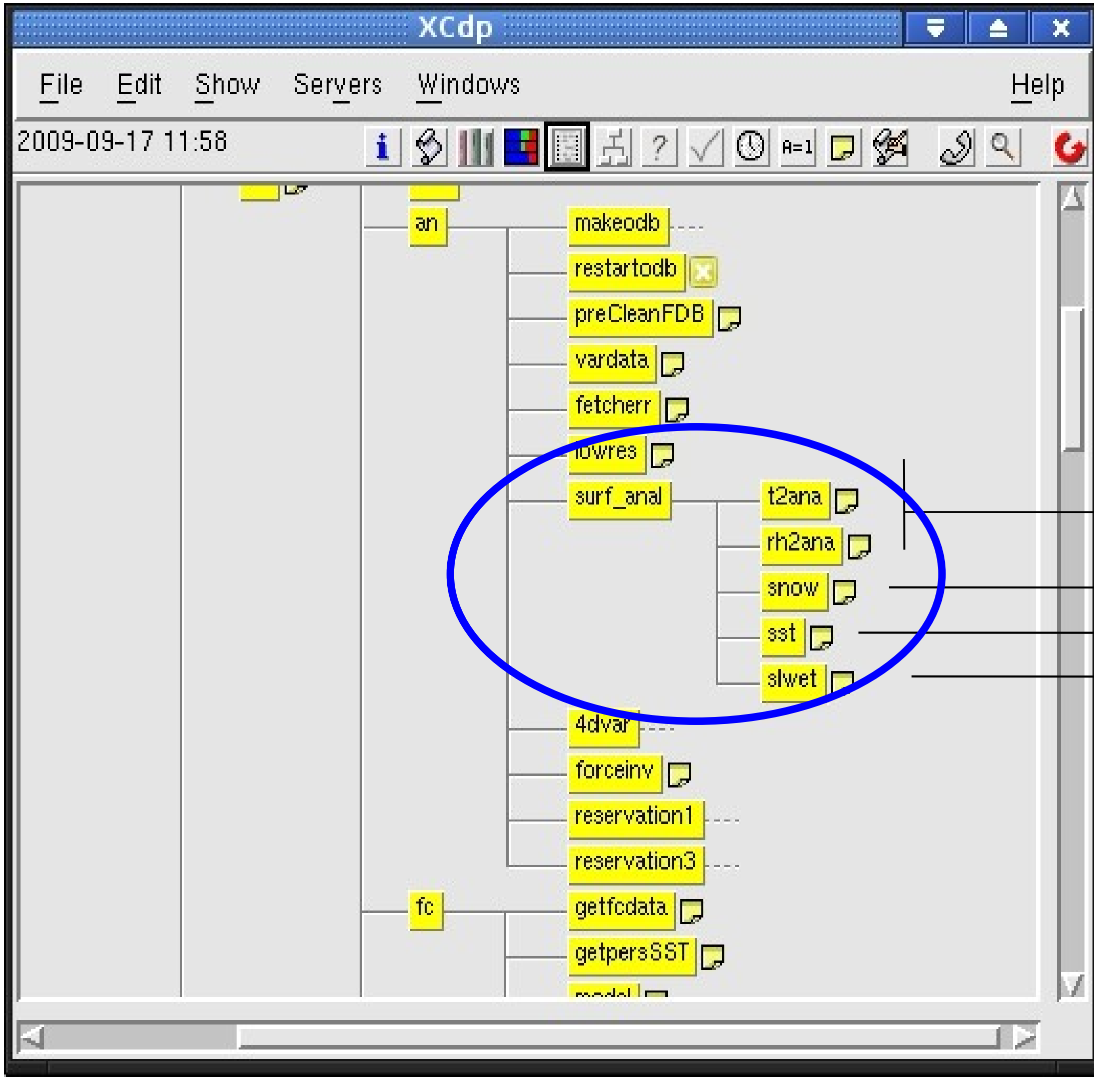
ECMWF H-SAF page:
http://www.ecmwf.int/research/EUMETSAT_projects/SAF/HSAF/

ECMWF's SMOS cake prototype

Surface analysis

CY35R3 surface analysis:

Different tasks performed for the analysis.



Screen level parameters

Snow

SST and CI

Soil Moisture and Temperature

ECMWF

SST and Sea Ice analysis

- Information on SST and sea ice concentration (CI) is imported and simply re-sampled to the model grid.

- Information used:

  - OSTIA analysis product at 0.05x0.05 degrees from the UK MetOffice. Used for oceans and Caspian Sea.
  - NCEP Used for Great Lakes.

→ Fields used to replace the model value

(Hersbach, TR 08105, Nov 2008)

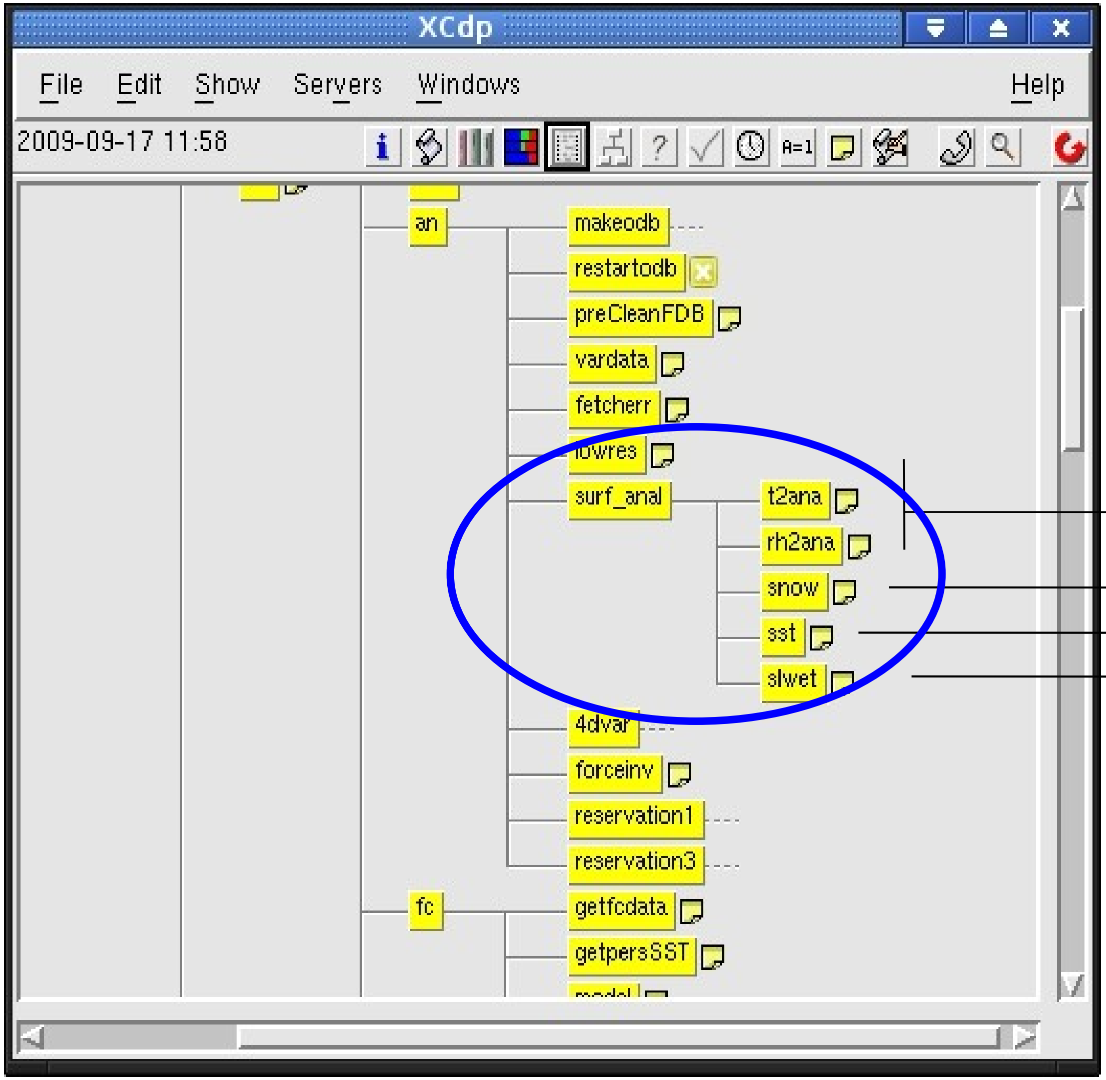
OSTIA: Operational Sea Surface Temperature and Sea Ice Analysis.
SST: Uses Infra-red (AVHRR, AATSR, SEVIRI); microwave (AMSR-E, TMI); In situ (Ships, drifting and moored buoys)
CI: Uses SSMI, AVHRR, AMSR-E, T2M fro, ECMWF for Quality Control
http://ghrsst-pp.metoffice.com/pages/latest_analysis/ostia.html

NCEP SST: product uses Infra-red (AVHRR) and in situ data.
CI: uses SSMI data.

Surface analysis

CY35R3 surface analysis:

Different tasks performed for the analysis.



Screen level parameters

Snow

SST and CI

Soil Moisture and Temperature

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Snow Analysis - Definitions

Observation types

- Snow Depth observed snow depth from in situ measurements (SYNOP)
- Snow extent product (NOAA/NESDIS)

Background

- Snow depth estimated from the short- range forecast of Snow Water Equivalent

Fractional snow cover is not analysed but calculated from SWE

Snow depth analysis in two steps:

1- Use SYNOP and satellite data to update the snow depth information:

- Compare FG (depth) vs NOAA/NESDIS (extend):

If FG is snow free but NOAA/NESDIS has snow, then snow depth is updated to 10cm.

- Snow free NOAA/NESDIS pixels used as an observation of 0cm of observed snow depth.
- Otherwise use SYNOP data as snow depth observation

2- Cressman analysis uses Snow depth information

Where S is snow depth, superscripts a, b, o refer to analysis, background and observation, N is the number of observations, w is a weight factor function of horizontal and vertical distances between observation location and model grid point.

$$S^a = S^b + \frac{\sum_{n=1}^{N} wn\left(S_n^O - S^{b'}\right)}{\sum_{n=1}^{N} wn}$$

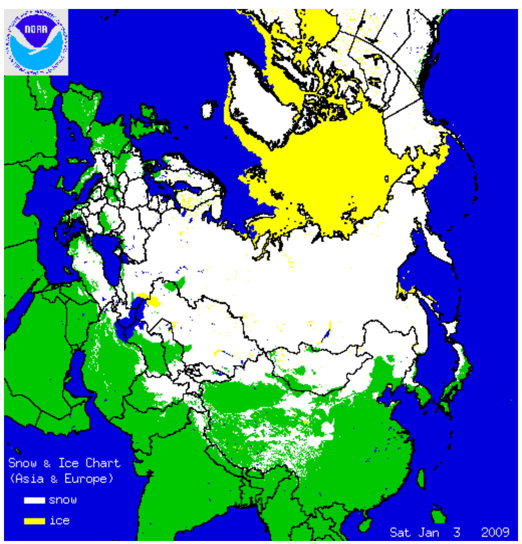
Reference on snow analysis: Drusch et al., 2004

Some problems and limitations

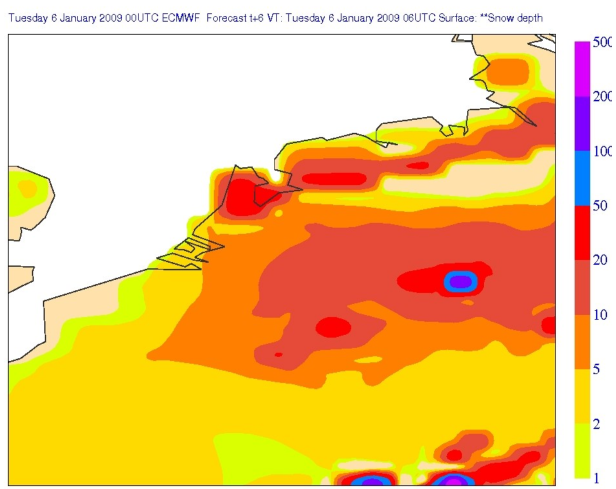
Snow analysis is very simple (Cressman analysis) and the use of satellite data is limited to a switch correction of snow depth in case of disagreement on snow presence between satellite data and model or SYNOP.

Daily report 06.01.2009:
- 15cm of snow over the Netherlands in the ECMWF analysis
- SYNOP do not confirm this presence of snow
- Very low temperature in the ECMWF FC
- Problem due to an error in the NESDIS product (frozen soil interpreted as snow ?)
- Persistence of error for several days: snow melt is slow due to cold conditions.

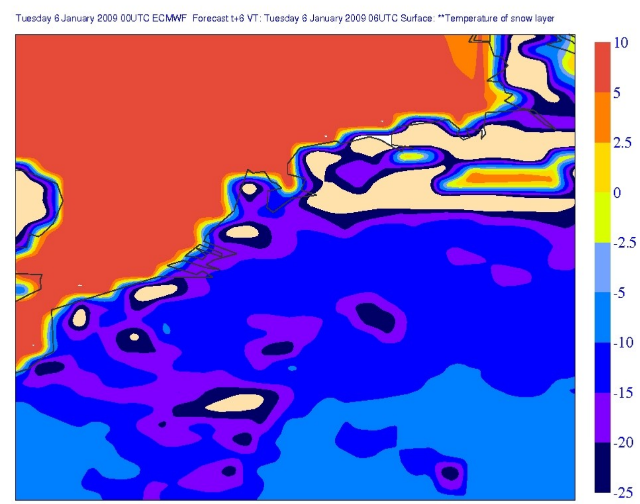
NOAA/NESDIS Snow extent on 04.01.2009



ECMWF FC on 06.01.2009



Snow depth (cm)



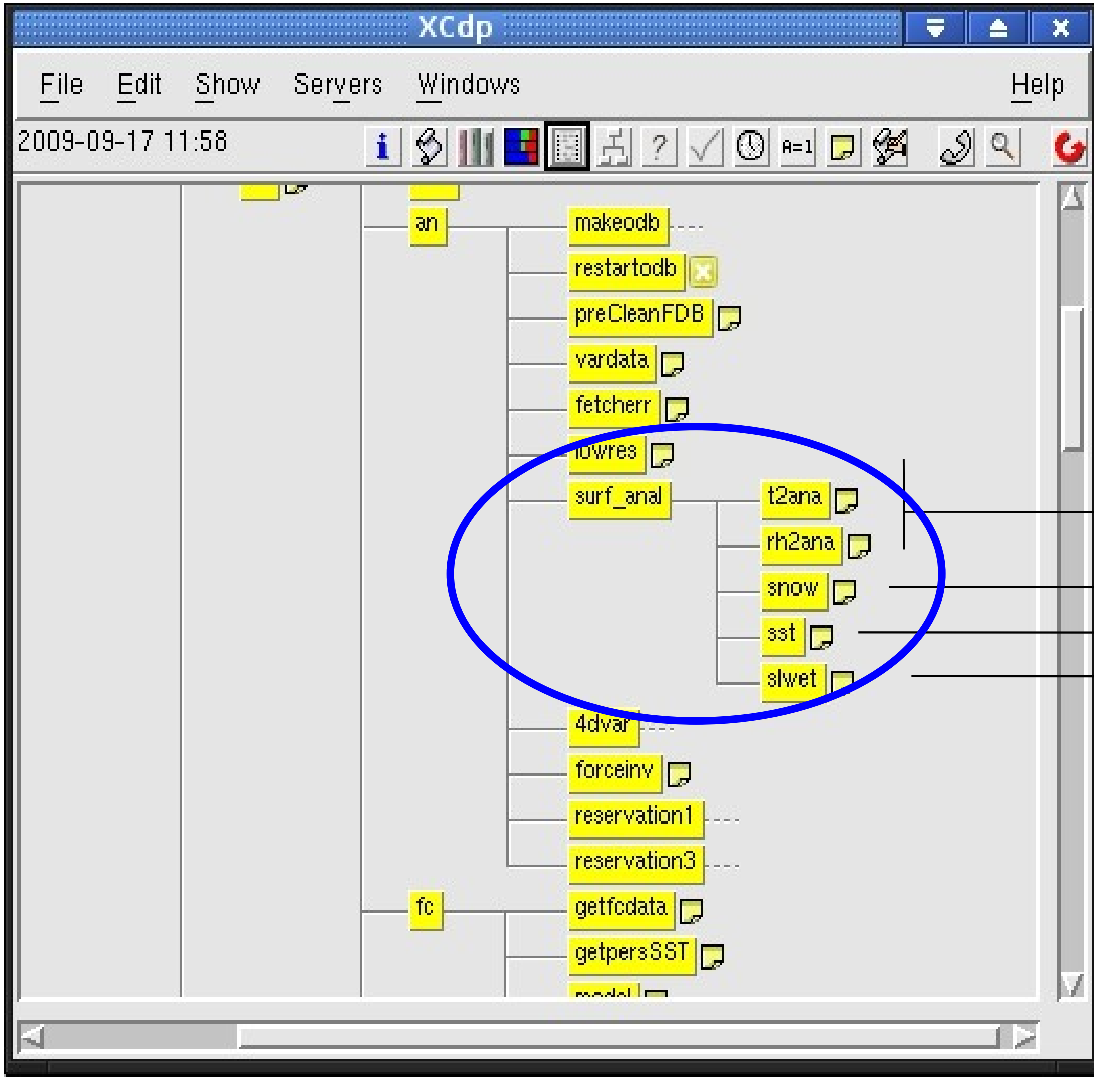
Snow Temp (C)

ECMWF

Surface analysis

CY35R3 surface analysis:

Different tasks performed for the analysis.



Screen level parameters

Snow

SST and CI

Soil Moisture and Temperature

ECMWF

Screen level analysis

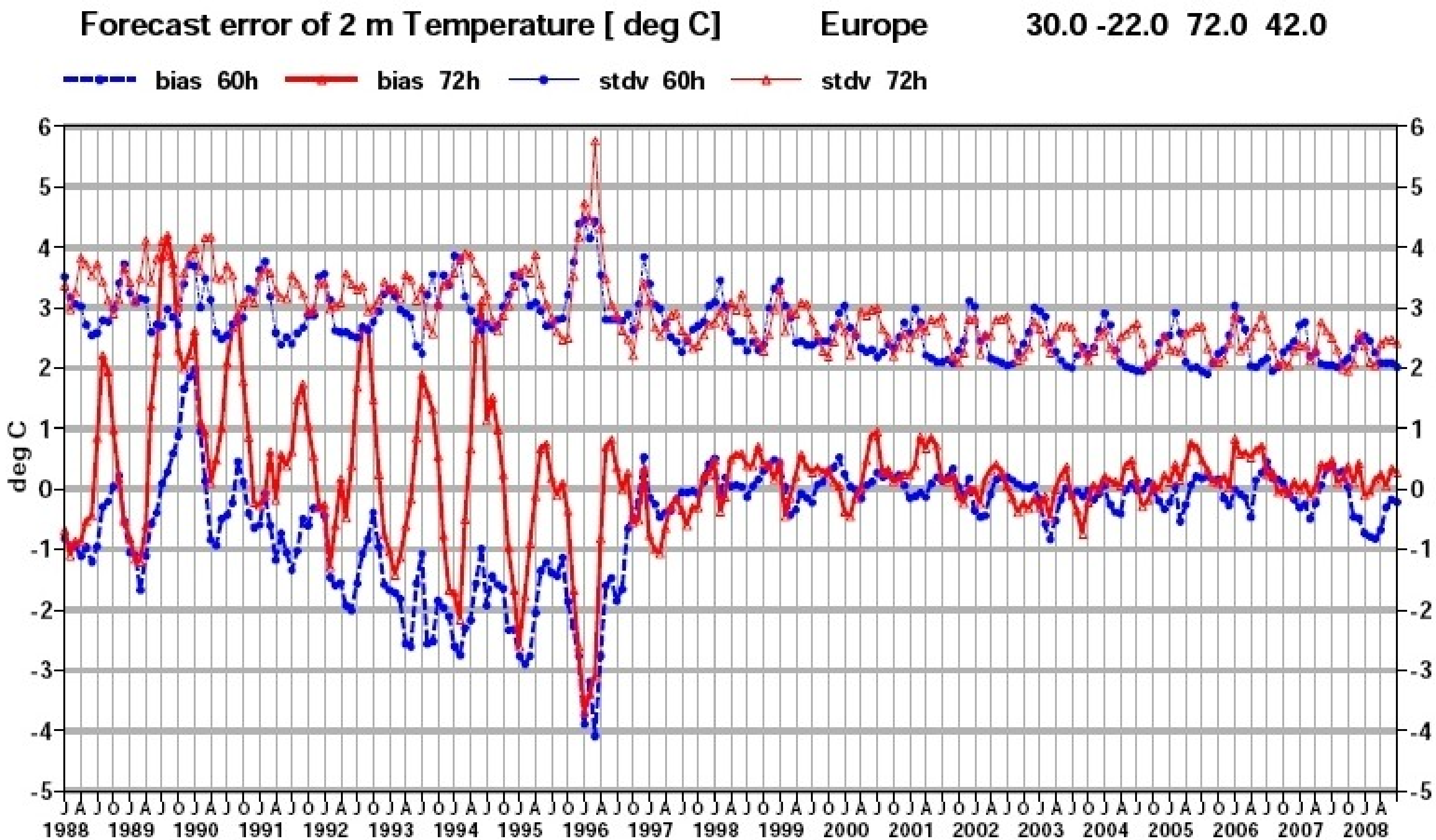
Analysed screen level (2m above ground) variables:
→ air temperature (T) and air relative humidity (rH).

Method based on a two-dimensional statistical interpolation.

It is applied over land and ocean surfaces.

Background fields (6h or 12h forecasts) is interpolated horizontally to the observation locations using a bi-linear interpolation and background increments are estimated at each observation location.

2m temperature forecast verification



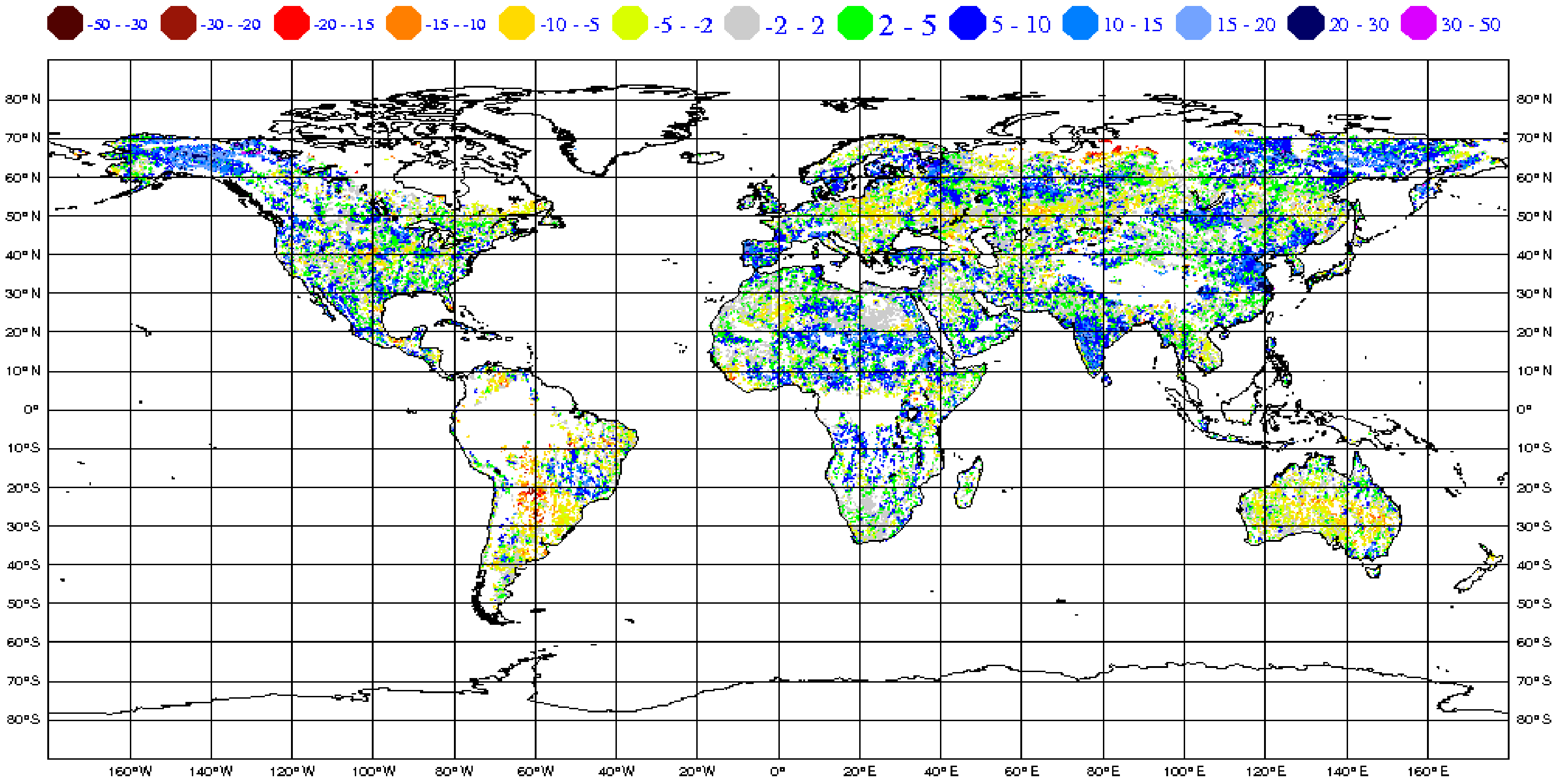
Verification for 60h (2.5 d; night time) and 72h (3 d; day time)

From Richardson et al., 2008, ECMWF Tech. Memo 578

ASCAT monitoring in CY35R3

Experiment f7ui at T799 in early delivery mode, 01-06 June 2009

ASCAT Soil Moisture (% m3/m3) FG_DEPAR 01-06 June 2009



ECMWF

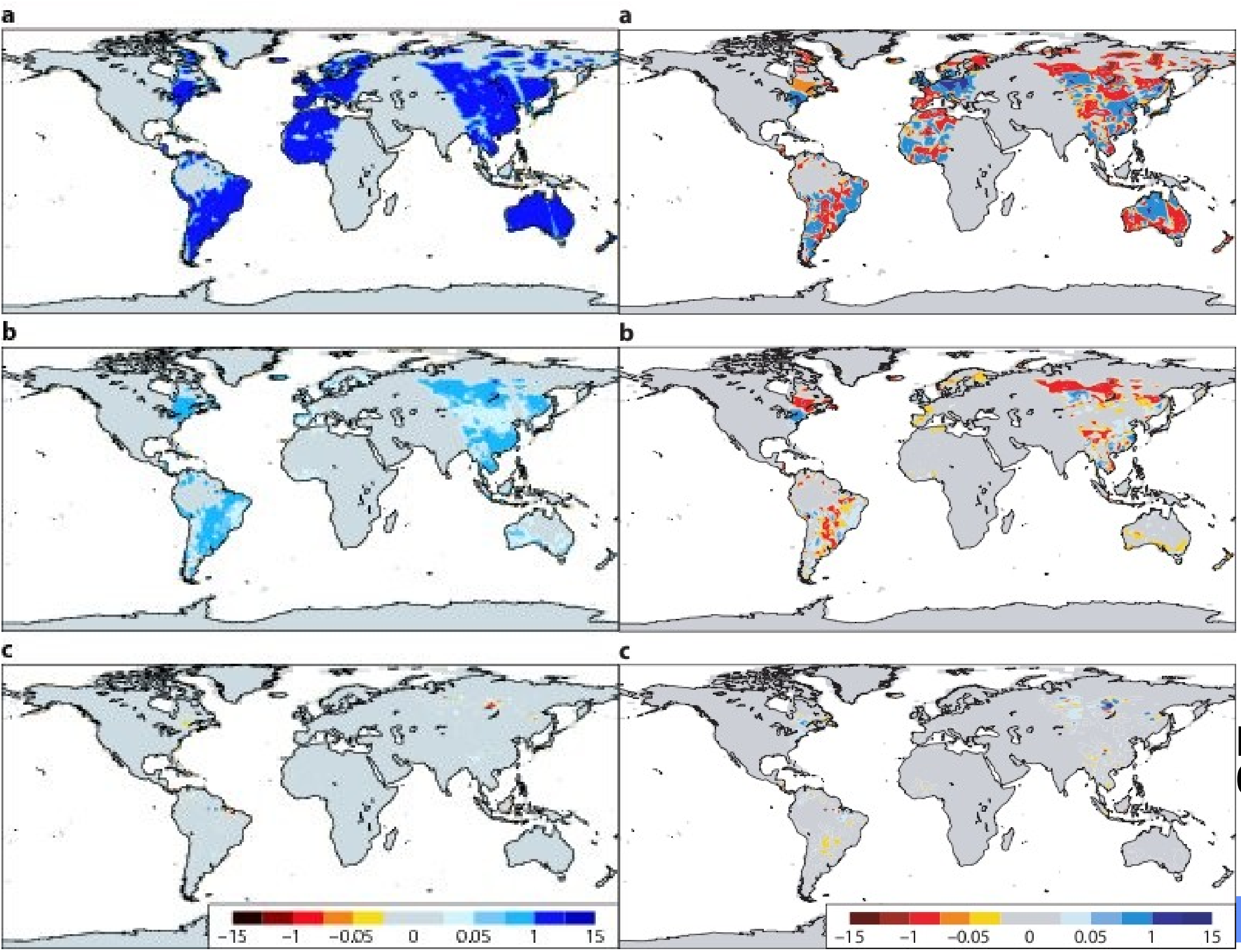
Active microwave remote sensing

ASCAT assimilation in the EKF: 1-3 May 2007, T159

IFS cycle 33R1 at T159 – no screen level parameters

Gain 10 x (m3/m3)/(m3/m3)

Increment (mm)



Top layer
0-7cm

- Low values at high latitudes
- No gain over tropical Forest, desert

Layer 2
7-28 cm

-Similar amplitude at night (US) and day (Europe)
- Low gain at depth

Layer 3
0.28-1m

ECMWF