

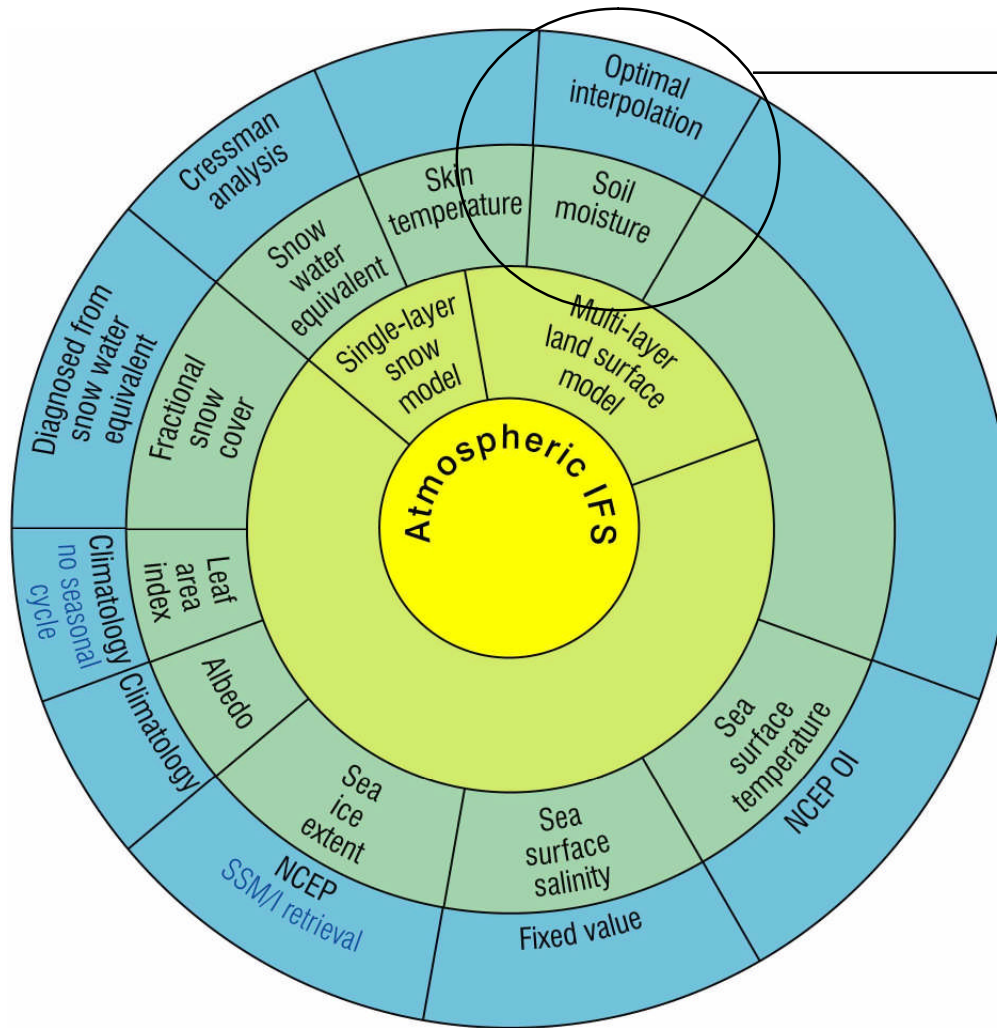
# **Analysing surface soil moisture for NWP applications: Developments at ECMWF**

**M. Drusch, P. de Rosnay, K. Scipal, G. Balsamo and E. Andersson**

**European Centre for Medium-range Weather Forecasts**

**Reading, UK**

# Surface Analyses at ECMWF



## 1. The OI System

## 2. Developments for using SMOS

- CMEM / Observation Operator
- Application to AMMA / AMSR-E

## 3. Developments for using ASCAT

- Observation Operator / Monitoring
- Results from ERS DA experiments

## 4. Summary

## The Optimal Interpolation Scheme

The analysis increments from the screen level analysis are used to produce increments for the water content in the first three soil layers (root zone):

$$\Delta\Theta_i = A_i(T^a - T^b) + B_i(rH^a - rH^b)$$

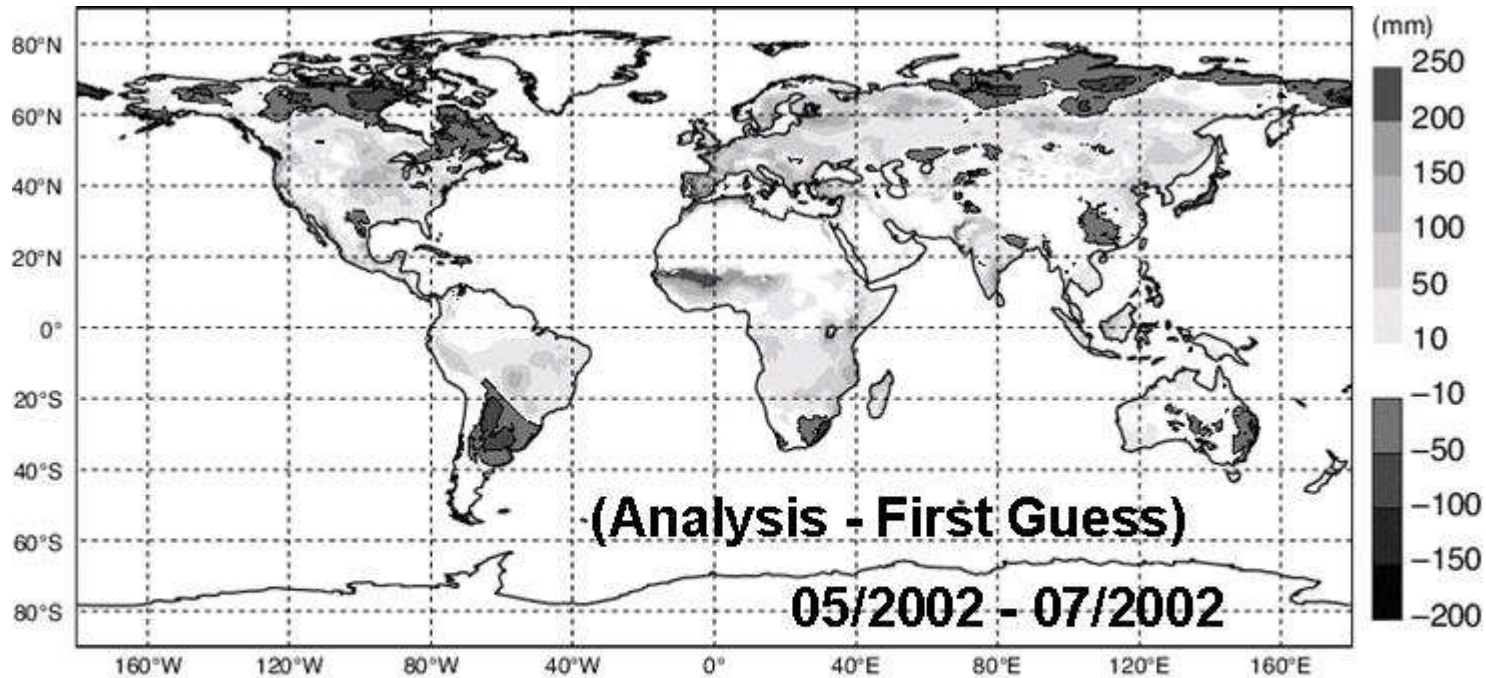
Superscripts a and b denote analysis and background (= forecast), respectively, i denotes the soil layer. Coefficients  $A_i$  and  $B_i$  are defined as the product of optimum coefficients  $\alpha$  and  $\beta$  minimizing the variance of analysis error (e.g. Daley 1991) and of empirical functions  $F_1, F_2, F_3$ .

Coefficients A and B can be written as:

$$A = C_v \times \alpha \times F_1 F_2 F_3$$
$$B = C_v \times \beta \times F_1 F_2 F_3$$

with:  $C_v$  vegetation fraction ( $c_{low} + c_{high}$ ),

# Soil Moisture Analysis Increments



- ❑ Analysed screen level parameters are used as proxy 'observations' for the root zone soil moisture analysis.
- ❑ In general, the analysis tends to add water. The amount of water is non-negligible and represents a sizeable part of the terrestrial water budget.
- ❑ The soil moisture analysis is designed to provide 'good' fluxes. Soil moisture is weakly constrained and acts as a 'sink' variable.
- ❑ Satellite derived surface soil moisture is a strong constraint!

# SMOS: The Observation Operator

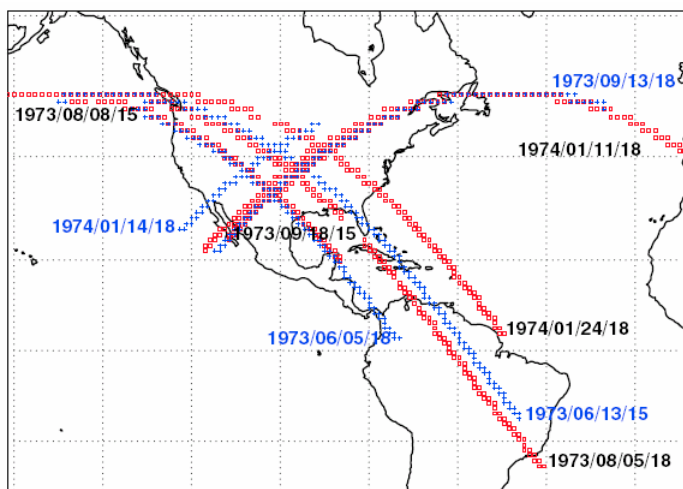
- ❑ Near real time applications have to be based on brightness temperatures.
- ❑ The Community Microwave Emission Model (CMEM) is the observation operator transforming NWP model state variables into observation space.

- **Parameterizations from L-MEB, ESA's SMOS Retrieval Algorithm and LSMEM**
- **Input / Output file format:**
  - Grib, Ascii, Netcdf
- **Input / output file size and variable dimensions**
  - Automatic detection of input size and variable allocations.
- **Portable code for Linux and Unix systems**
  - Requirements: Grib and Netcdf both compiled with Fortran 90
  - CMEM code: 8300 lines of Fortran 90 (43 subroutines)

**Last tagged version of CMEM version 1.2, March 2008**

[http://www.ecmwf.int/research/ESA\\_projects/SMOS/cmem/cmem\\_index.html](http://www.ecmwf.int/research/ESA_projects/SMOS/cmem/cmem_index.html)

# CMEM Calibration using Skylab Data and ERA-40



## SKYLAB facts:

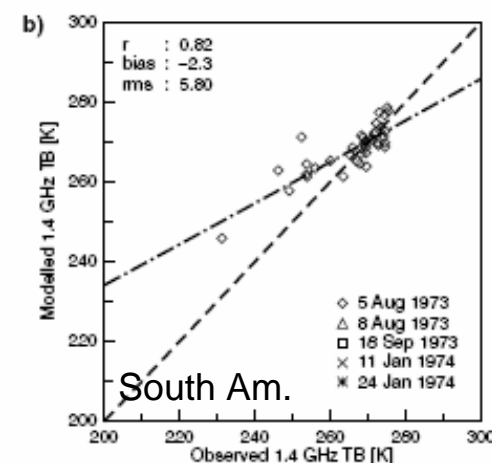
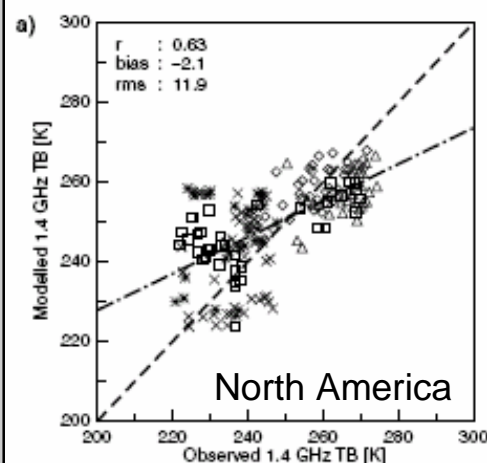
- launch 14 May 1973
- nominal altitude 435 km
- back on earth 11 July 1977
- data collection required astronaut

## S-194 facts:

- L-band radiometer
- nadir looking
- 110 km resolution
- 2.5 km sampling

## Cal / Val results:

- ❑ rms error due to model soil moisture
- ❑ dynamic range of modeled TB too small => need for 'bias correction'
- ❑ best results for: Wigneron et al. 2001 (roughness) Kirdyashev et al. 1979 (vegetation)



# CMEM - Application to AMMA / AMSR

## ALMIP-MEM experiment set up:

- 2 ALMIP Experiments with different precipitation forcing (exp1, exp2)
- 6 LSMs (HTESSEL, CTESSEL, TESSEL, JULES, ISBA, ORCHIDEE)
- 2 observing configurations: C-band and X-band
- 2 orbits per day: desc. Orbit (night) and asc. Orbit (day)
- 12 configurations of the forward model:
  - 3 dielectric models (Dobson, Mironov, Wang)
  - 4 Vegetation models (Kirdyashev, Wigneron, Wegmueller, Jackson)

-> 96 simulations per LSMs

Total of 576 simulations

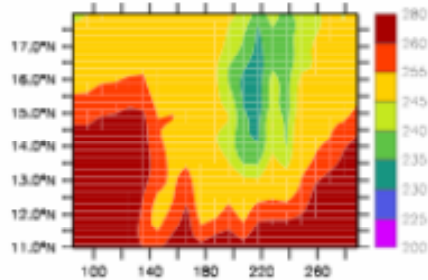
Each on 101x51x365 grid-cells (lon \* lat \* day) ( $1.9 \cdot 10^6$ )

For the comparison and to compute background errors:  
AMSR-E TB interpolated on the ALMIP grid (0.5 degree)

-> CMEM allows evaluating radiative transfer modelling for future SMOS validation

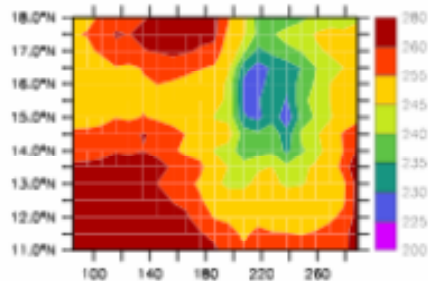
# CMEM - Application to AMMA / AMSR

## Latitude-Time diagram of TBH for 2006 (10W-10E)

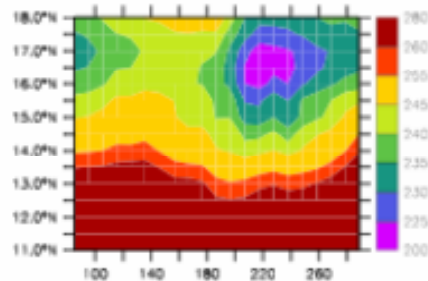


- Best configuration for **all** land surface models: Wang or Mironov (soil dielectric constant) and Kirdyashev et al. (vegetation).
- Consistent with Skylab study (Drusch et al. 2008).

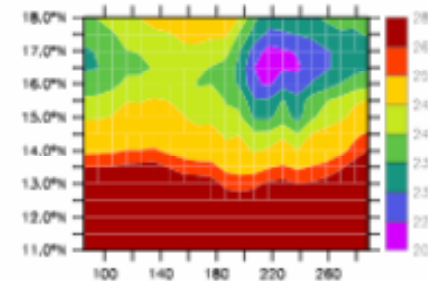
AMSR-E 6.9 GHz TBH (desc)



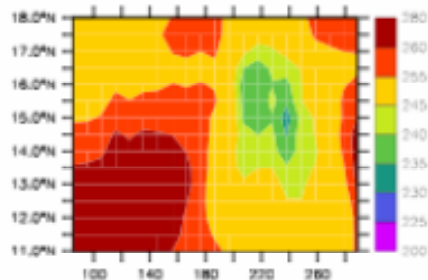
H-TESSEL



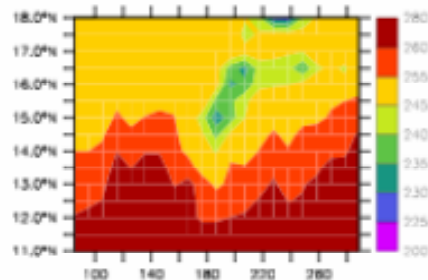
TESSEL



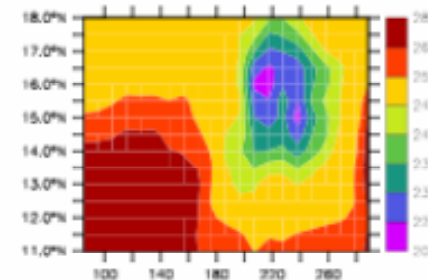
C-TESSEL



JULES



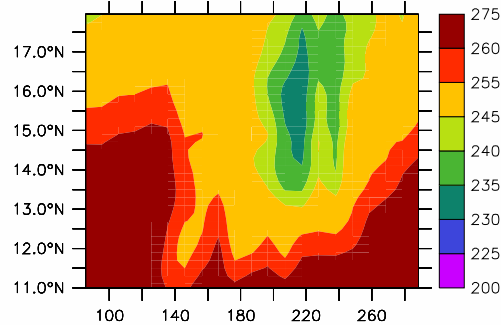
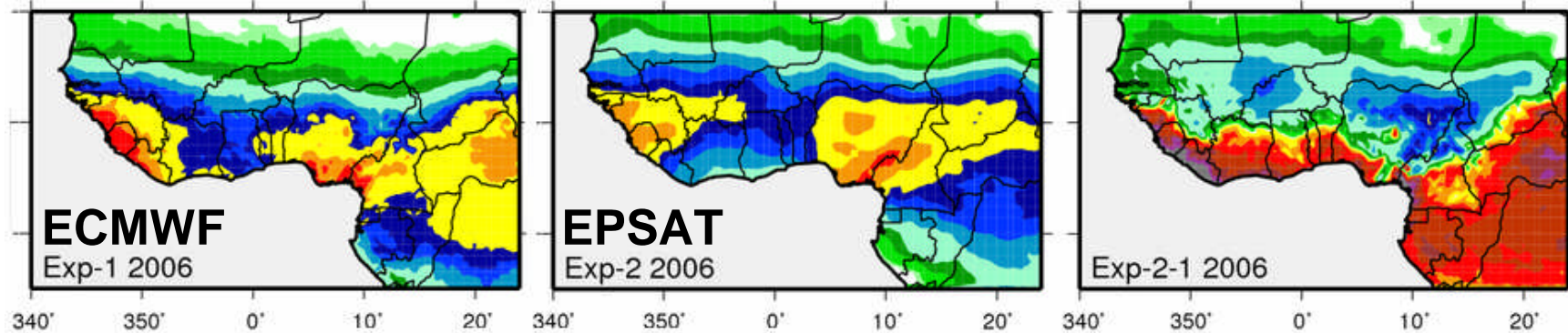
ISBA



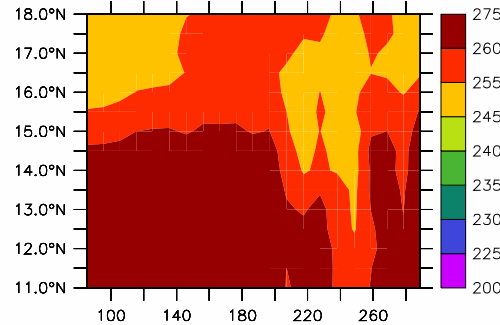
ORCHIDEE

# CMEM - Application to AMMA / AMSR

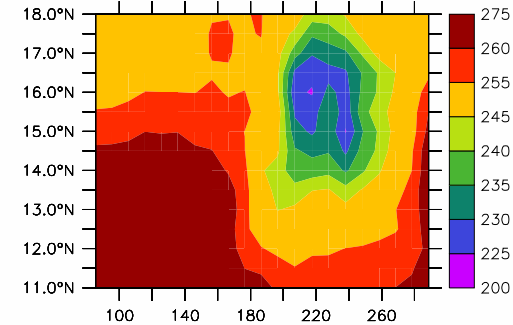
Rainf (mm day-1) JJAS



**AMSR 6.9 GHz desc.**



**ORCH+CMEM+ECMWF**

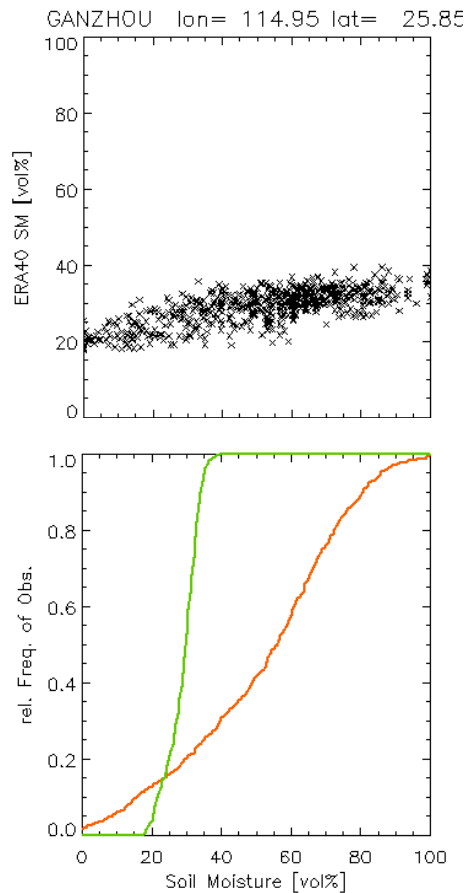


**ORCH+CMEM+EPSAT**

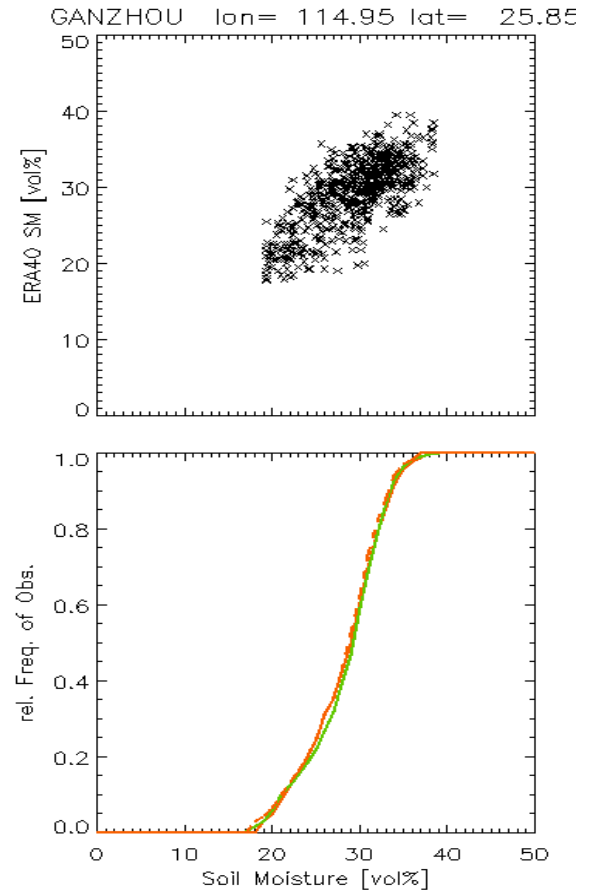
- Good agreement between modeled and observed TB when EPSAT forcing is used.
- Using AMSR data in the soil moisture analysis has the potential to correct for erroneous precipitation forcings.

# ERS/ASCAT: Observation Operator

- ERS / ASCAT soil moisture from TU Vienna is an index, which needs to be transformed to volumetric soil moisture prior to DA.
- Systematic differences between model and observation have to be minimized.



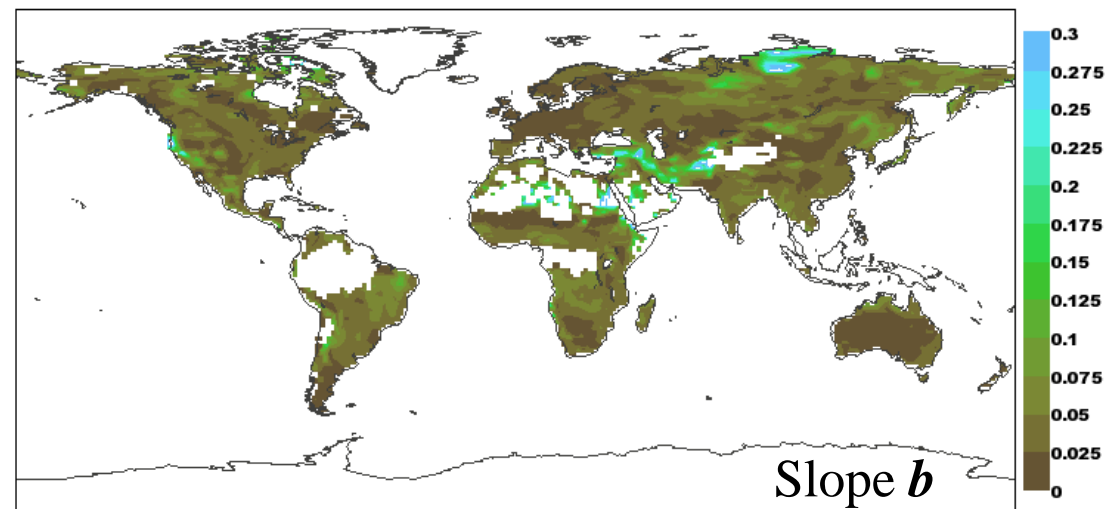
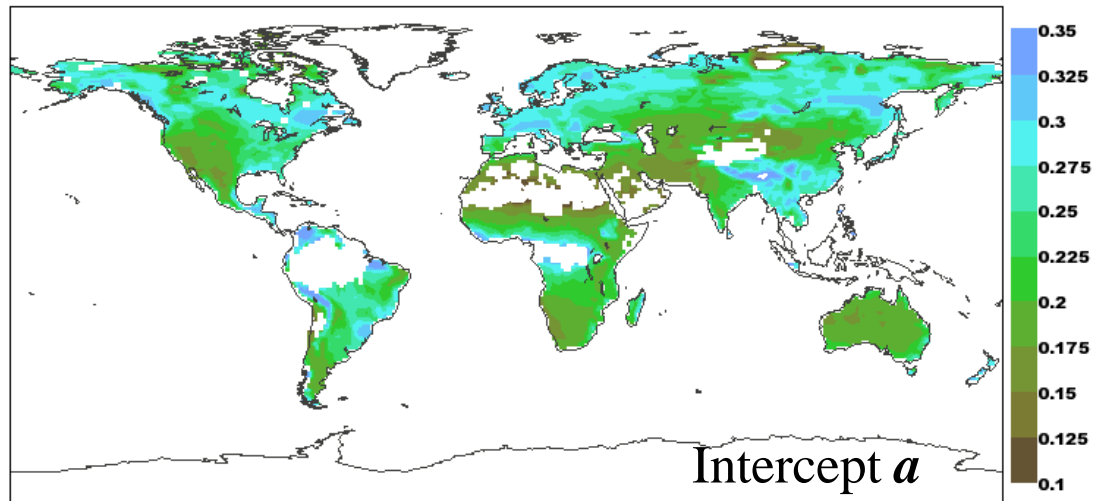
$$\Theta_{adj} = a + b \times \Theta_{Sat}$$



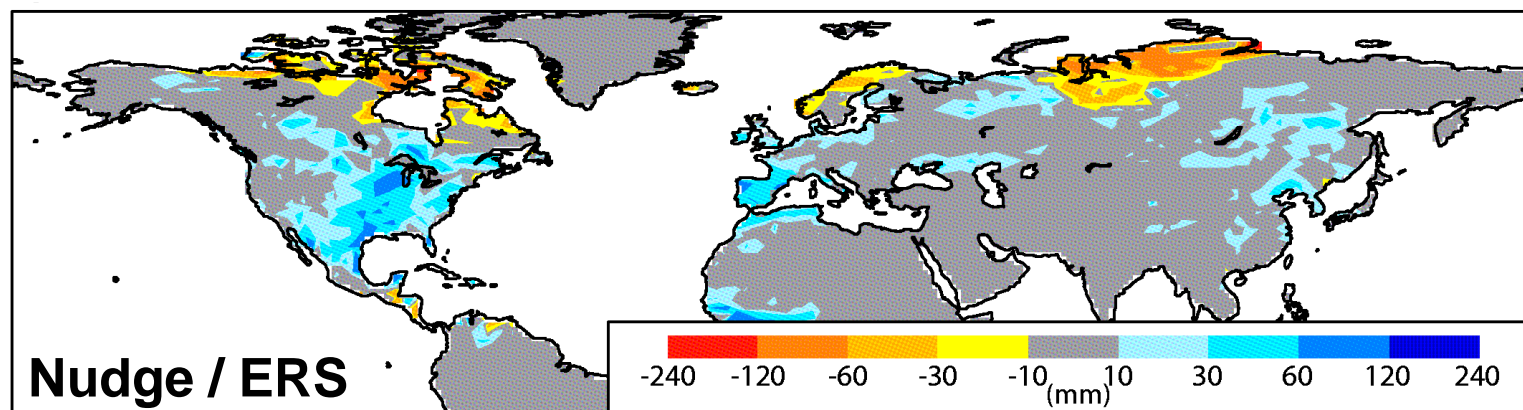
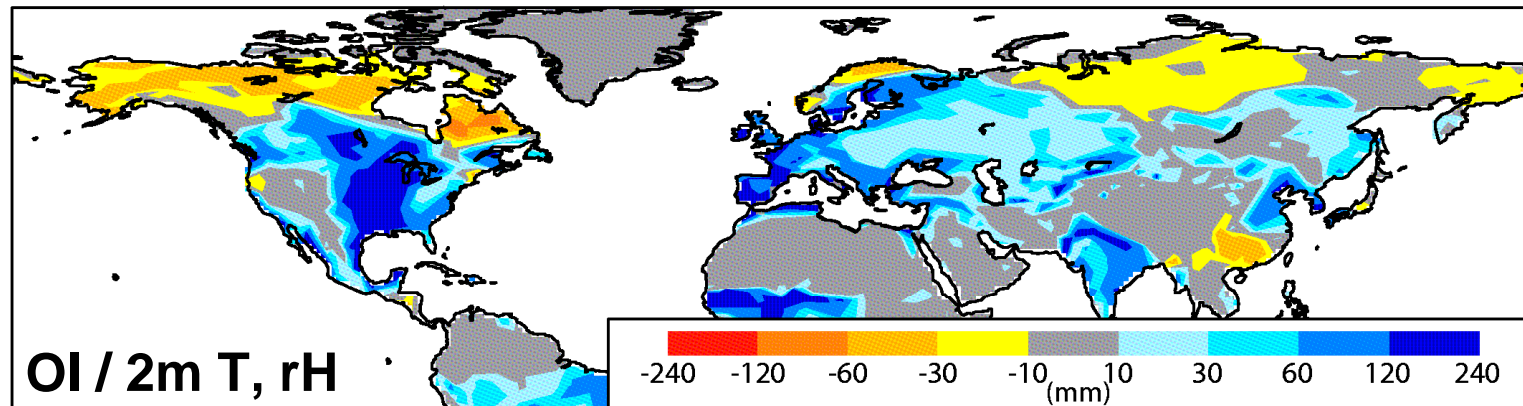
$$a = \overline{\Theta}_M - \overline{\Theta}_{Sat} \times \frac{\sigma_{\Theta_M}}{\sigma_{\Theta_{Sat}}}$$

$$b = \frac{\sigma_{\Theta_M}}{\sigma_{\Theta_{Sat}}}$$

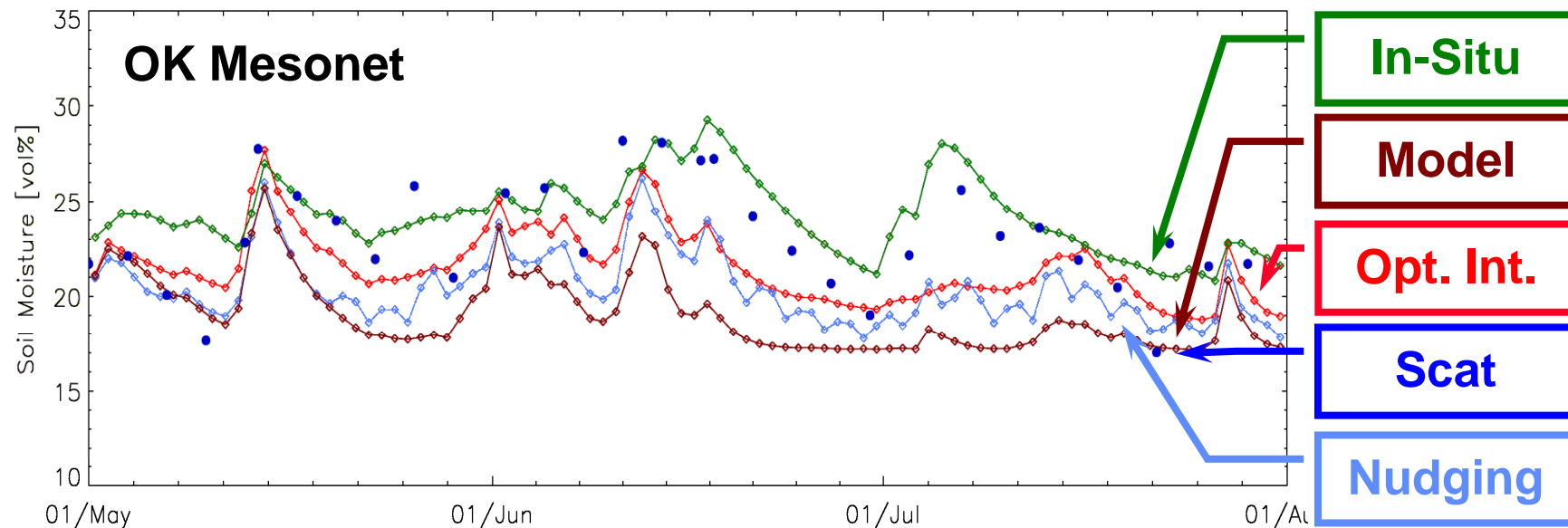
# ERS/ASCAT: Observation Operator



# ERS/ASCAT: Experimental Results from a Nudging Experiment - Analysis Increments



# ERS/ASCAT: Experimental Results from a Nudging Experiment - Verification



- The Nudge / ERS experiment is better than the model without DA!
- The operational OI gives the best results.
- Nudge / ERS is not 'optimal':
  - Model and observation errors have not been taken into account.
  - Higher temporal sampling rate is needed.

# Summary

## SMOS:

- Calibrating CMEM results in a 'bias-free' TB estimate.  
*A statistical correction scheme is needed to reduce other systematic differences, e.g. in the dynamic range.*
- Field experiments and campaigns are very useful to develop parameterizations.  
*DA and Level 2 processing are based on operational data, which should be explored as well.*
- ESA's Cal / Val study provides the framework; CMEM could be the tool since it provides a common benchmark.

## ASCAT / ERS:

- First DA experiments have been successful in outperforming the OL experiment.  
*To beat the Ol an advanced DA system should be used. Currently, an EKF is being optimized.*
- Operational monitoring, i.e. continuous comparisons between the model first guess and the ASCAT observations, is in place.  
*At least 6 months of data are needed to adjust the observation operator.*

# Implementation Plan

- ❑ Monitoring ASCAT: mid 2008
- ❑ Replace the operational OI by an EKF: *late 2008 / early 2009*.
- ❑ Adjusted observation operator for ASCAT: *end 2008*.
- ❑ Impact study for combined assimilation of ASCAT and 2m T / rH: *spring 2009*.
- ❑ Operational processing chain and monitoring for SMOS: *spring / summer 2009*.
- ❑ Impact study for combined assimilation of ASCAT, SMOS and 2m T / rH: *end 2009*.
- ❑ In parallel: RD activities on combined analysis of LAI and soil moisture (GEOLAND 2).