SMOS Data Assimilation Study:

Introduction and Preparatory Work

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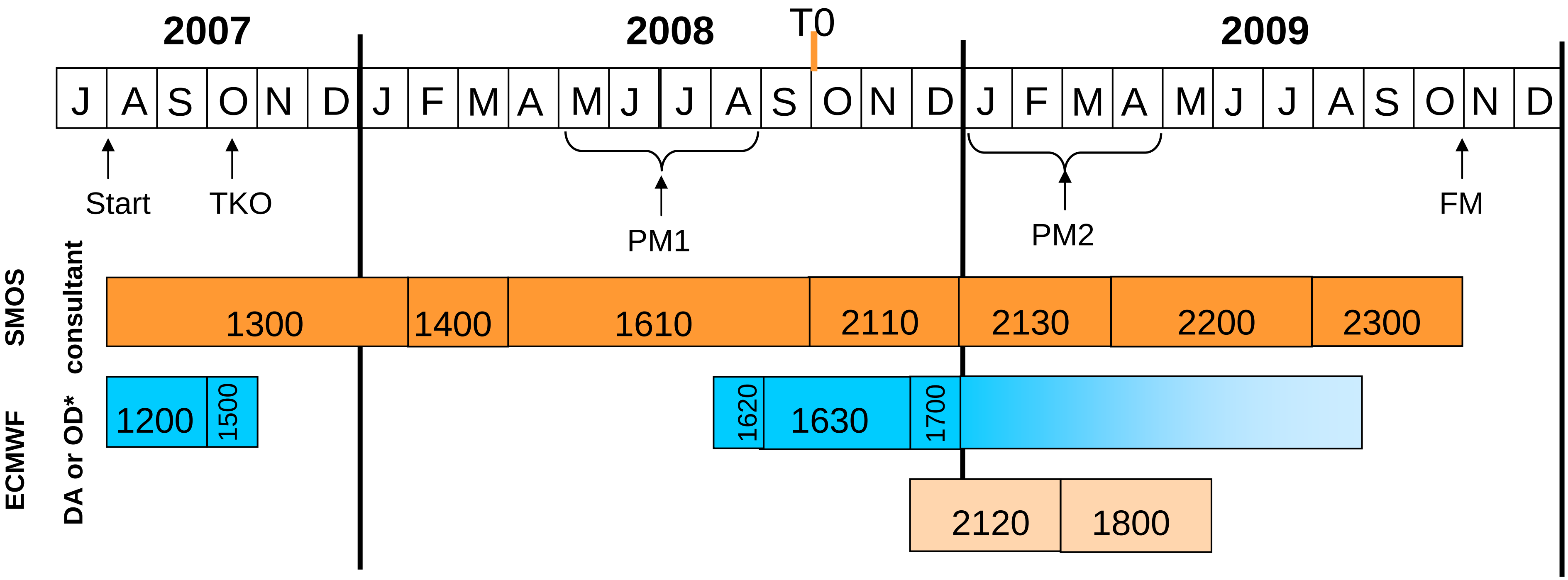
Phase I to III

- **Monitoring of Level 1c brightness temperatures and assimilation of brightness temperatures over land**

  - 27 months, August 2007 - October 2009
  - 15 WPs: 7 WPs (ESA, 27 woman months) + 8 WPs (ECMWF, 14 man months)
  - Part I: NRT monitoring of global brightness temperatures.
  - Part II: Evaluation of the possible impact of SMOS measurements on the weather forecast quality.

- **Assimilation of SMOS derived surface soil moisture**
- **Assimilation of SMOS derived surface salinity**

Schedule Phase I



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Part I: Monitoring -
Comparing the Model Against Observations

General idea:

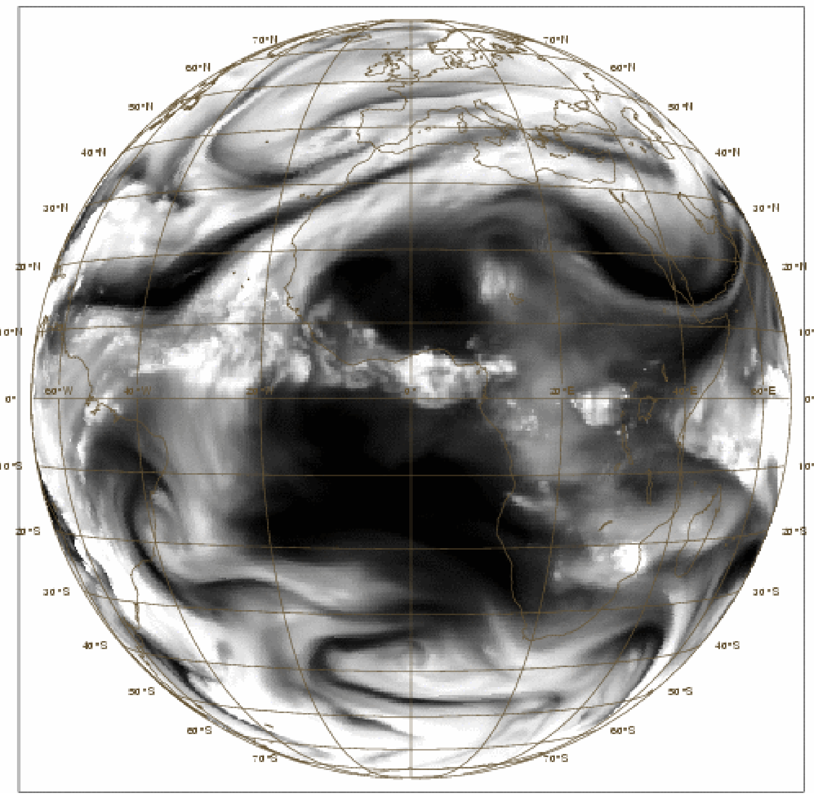
- Observations are not generally available at model grid points and do not support the same spatial scale.
- Satellites measure radiances/brightness temperatures/reflectivities, etc., NOT directly temperature, soil moisture, or ozone.
- A model equivalent of the observation is calculated to enable comparison.
- This is done with the ‘observation operator’ *H*:

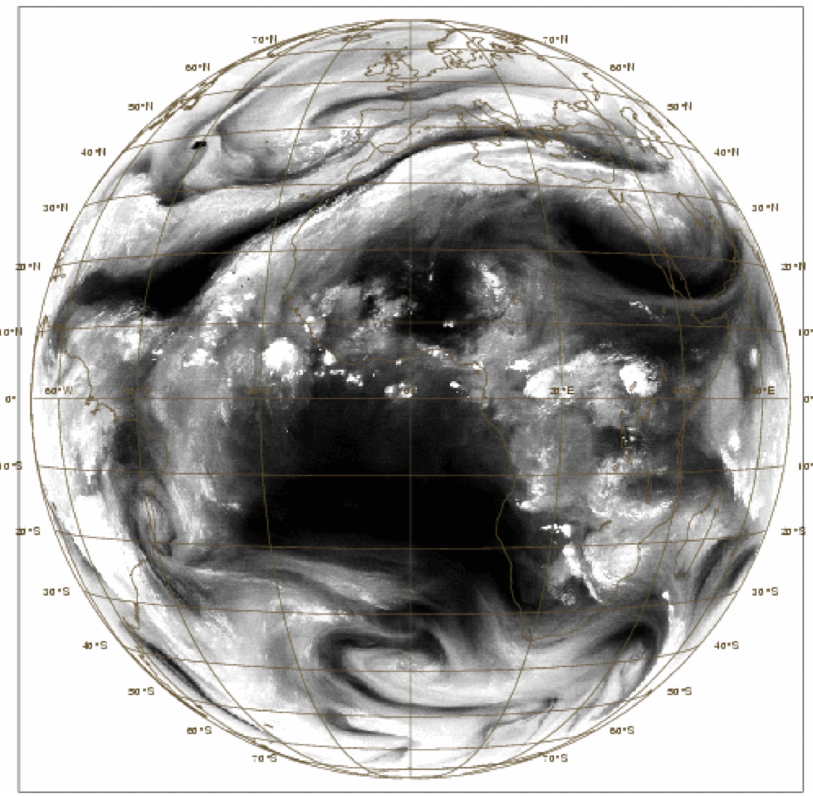
  H may be a simple interpolation from model grid to observation location for direct observations, for example, of winds or temperature from radiosondes

  H may possibly perform additional complex transformations of model variables to, for example, satellite radiances.

A Monitoring Example

Model T and q → H → Model radiance ⟷ J_o compare ⟷ Observed satellite radiance





Meteosat imagery

The SMOS Observation Operator

WP 1100: Sensitivity study on auxiliary data sets

WP 1200: Ocean Salinity in the Integrated Forecast System

WP 1300: Global Surface Emission Model

WP 1400: IFS Interface

WP 1500: RTTOVS Update

WP 1600: IFS Suite Development

WP 1610: Collocation Software Development

WP 1100 / 1300: SMOS Community Microwave Emission Model

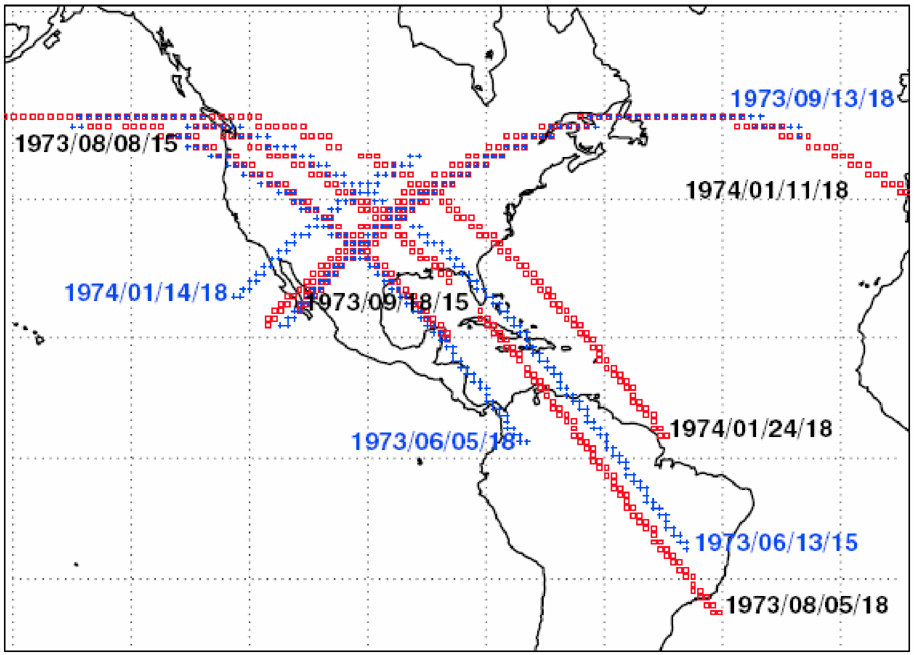
TABLE II

DEFAULT MODEL CONFIGURATION FOR L-BAND AND OPTIONAL MODULES. ALL MODULES ARE DESCRIBED IN SECTION II. VEGETATION PARAMETERS INCLUDE VALUES FOR LOW AND HIGH VEGETATION.

Components	*Default Module*	*Optional Modules*		
T_{eff}	Wigneron [22]	Holmes [23]	Choudhury [21]	
ϵ_{soil}	Dobson [25]	Wang-Schmugge [24]		
r_s	Fresnel law	Wilheit [18]		
r_r	Wigneron I [22]	Wegmüller [32]	Wigneron II [22]	Choudhury [30]
vegetation	Kirdyashev [33]	Wigneron [47]	Wegmüller [32]	
snow	Pulliainen [36]			
atmosphere	Pellarin [48]	Liebe [39]		

Parameters	*Default*	*L-MEB Setup*	*LSMEM Setup*
$sal_{soil}[psu]$	0	0	0.65
$sal_{veg}[psu]$	6	6	6
$sal_{sea}[psu]$	32.5	32.5	–
r_r- module	Wigneron I [22]	Wigneron II [22]	Wegmüller [32]
L_c/s or $\sigma[cm]$	$L_c/s = 6.0/2.2$	$L_c/s = 6.0/0.15$	$\sigma = 0.5$
$Q[-]$	0	0	$f(\sigma)$
Nrp	0	0	2
$VWC[kgm^{-2}]$ (L,H)	$f(vegtype)$	$f(vegtype)$	$(1.0, 4.0)$
$\omega[-]$ (L,H)	$(0.05, 0.05)$	$(0.\ to\ 0.05, 0.15)$	$(0.05, 0.05)$
vegetation module	Kirdyashev [33]	Wigneron [47]	Wegmüller [32]
a_{geo} or $b[m^2kg^{-1}]$ (L,H)	$a_{geo} = (0.33, 0.66)$	$b = (0.2, 0.33)$	$b = (0.33, 0.33)$

WP 1100 / 1300: Initial Calibration Using ERA-40 and Skylab



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
- most measurements were lost, 9 overpasses could be recovered from print-outs …

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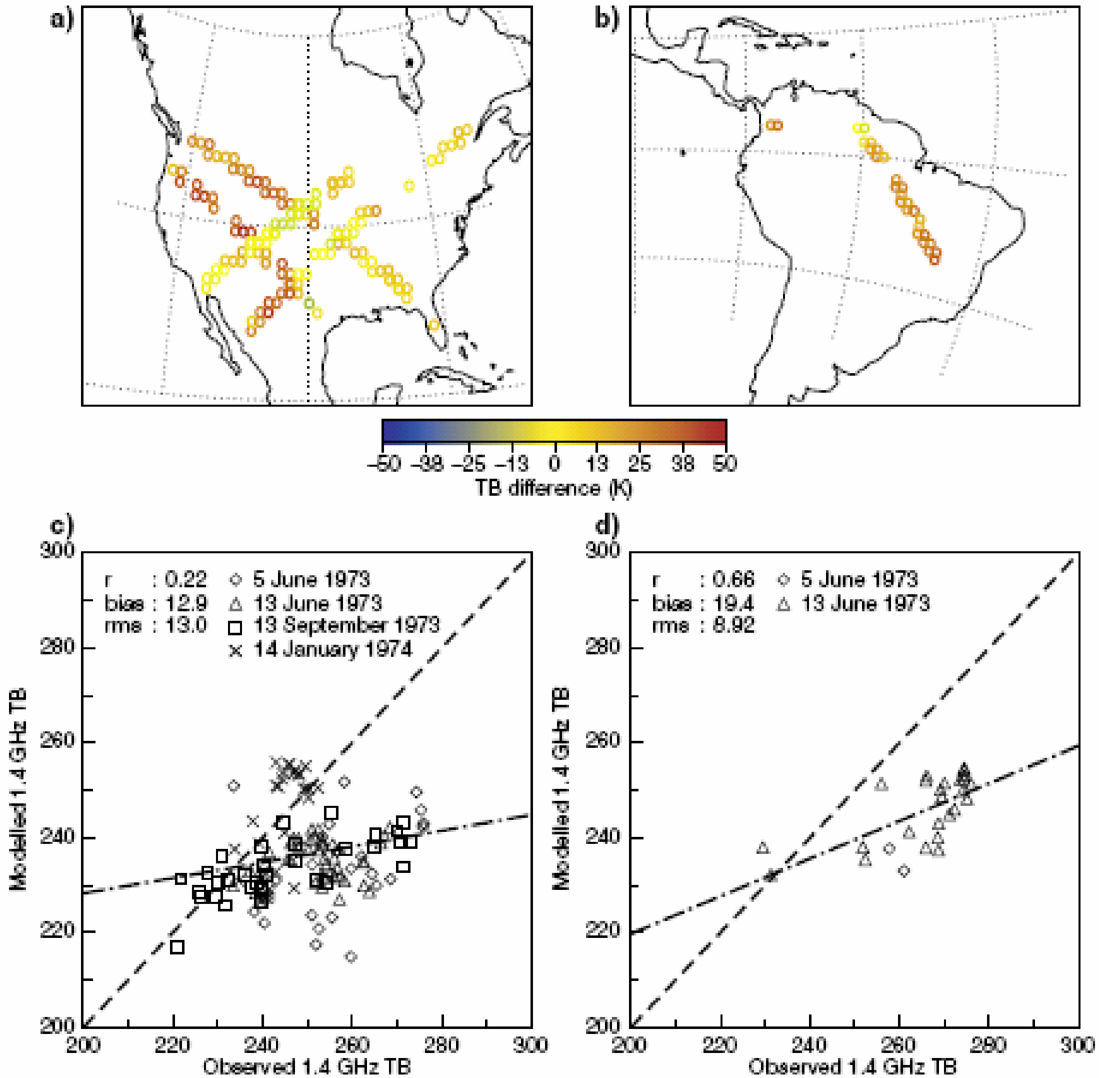
WP 1100 / 1300: Initial Calibration Continued



Data:

- S-194 L-band TB

- ECOCLIMAP LAI
- (C-TESSEL)
- ERA soil moisture
- ERA soil temperature
- ERA 2 m temperature
- ERA snow depth
- FAO soil types
- (H-TESSEL)

Calibrating:

- surface roughness,
- vegetation structure coef.
- single scattering albedo

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WP 1100 / 1300: Initial Calibration Continued

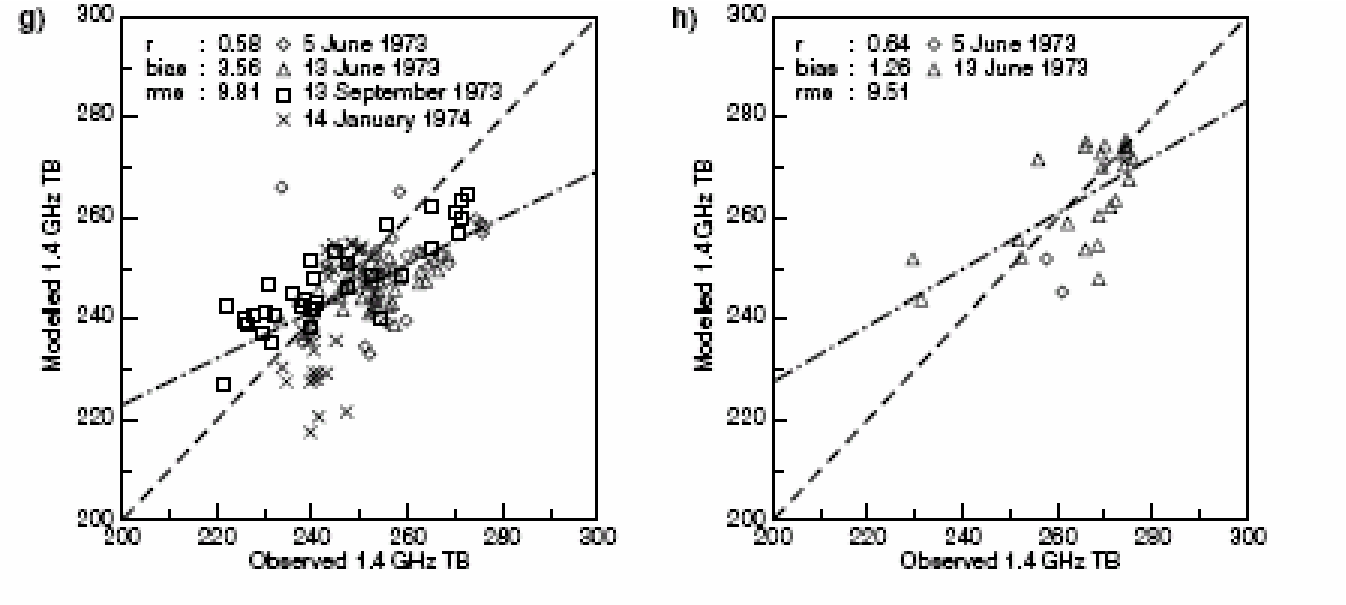
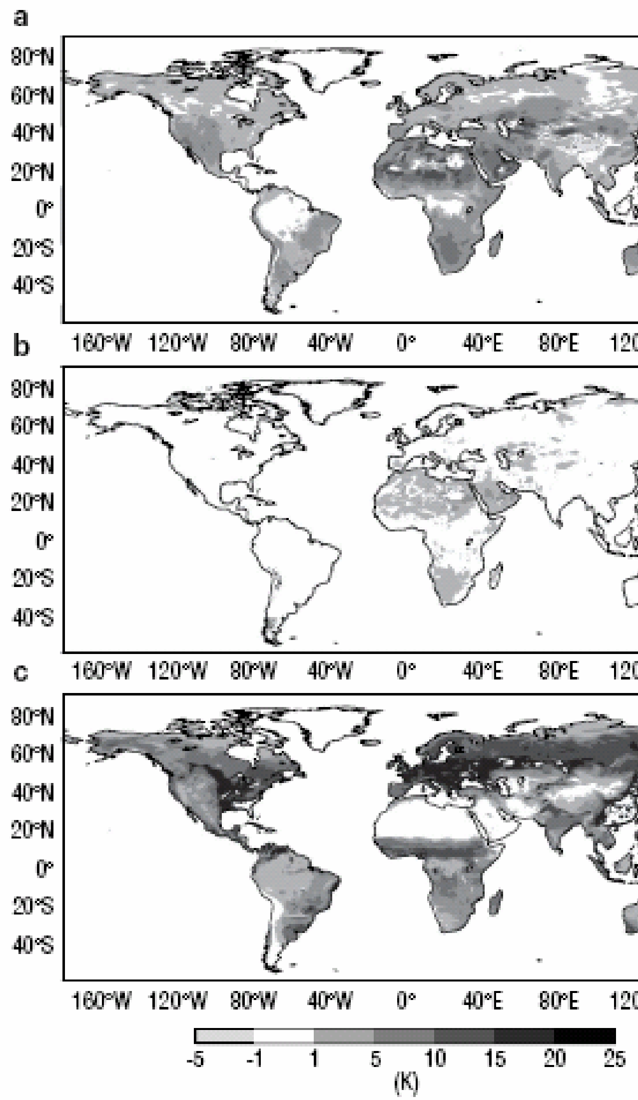


Table 1: CMEM model setup for the calibration and validation computations.

SetUp	Roughness	Vegetation	σ	$\omega(L,H)$	b (L,H)	$a_{geo}(L,H)$	$VWC_{trop.}$
A	Wigneron (Eq.4)	Wigneron	0.15	$(0.05, 0.15)$	(0.2, 0.33)		6
B	Wigneron (Eq.4)	Wigneron	2.2	$(0.05, 0.05)$	(0.2, 0.33)		6
C	Wigneron (Eq.5)	Wigneron	2.2	(0.05, 0.05)	(0.2, 0.33)		6
D	Wigneron (Eq.5)	Kirdyashev	2.2	(0.05, 0.05)		(0.33, 0.33)	6
E	Wigneron (Eq.5)	Kirdyashev	2.2	(0.05, 0.05)		(0.33, 0.66)	10

WP 1100 / 1300: Sensitivity



L-band (1.4 GHz)

- brightness temperature differences
- h-polarization, 50° incidence angle
- 1 July 2005, 12:00 UTC, DA stream
- dielectric model for the wet soil

  ([Wang and Schmugge, 1980]-[Dobson et al. 1985])

  global mean: 4 K
- effective soil temperature

  ([Wigneron et al. 2001] – [Wilheit 1978])

  maximum < 5 K
- vegetation model

  ([Wigneron et al. 1995] – [Kirdyashev et al. 1979])

  global mean: 8 K

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Part I: Monitoring SMOS Brightness Temperatures

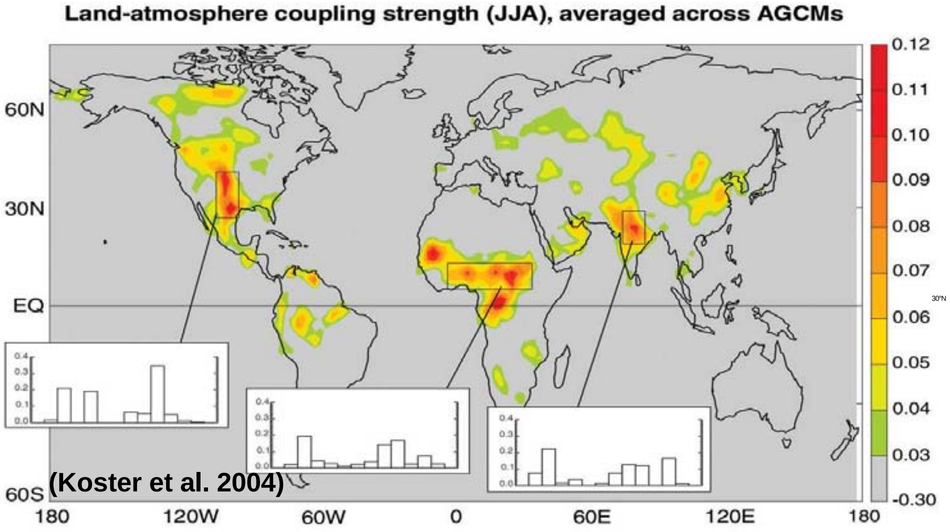
WP 1620: Operational Pre-processing Chain

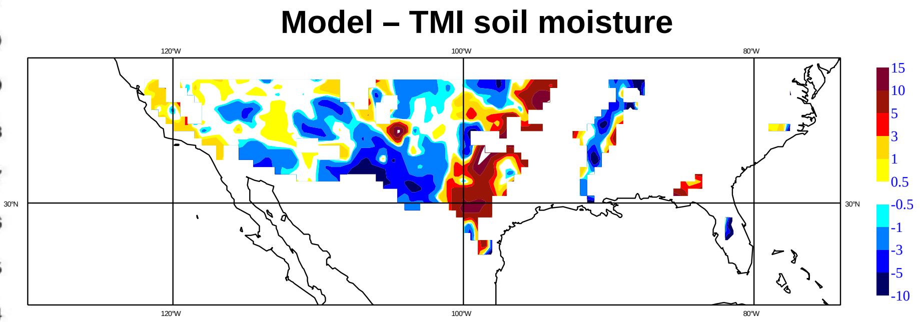
WP 1630: ‘Offline’ Monitoring Suite

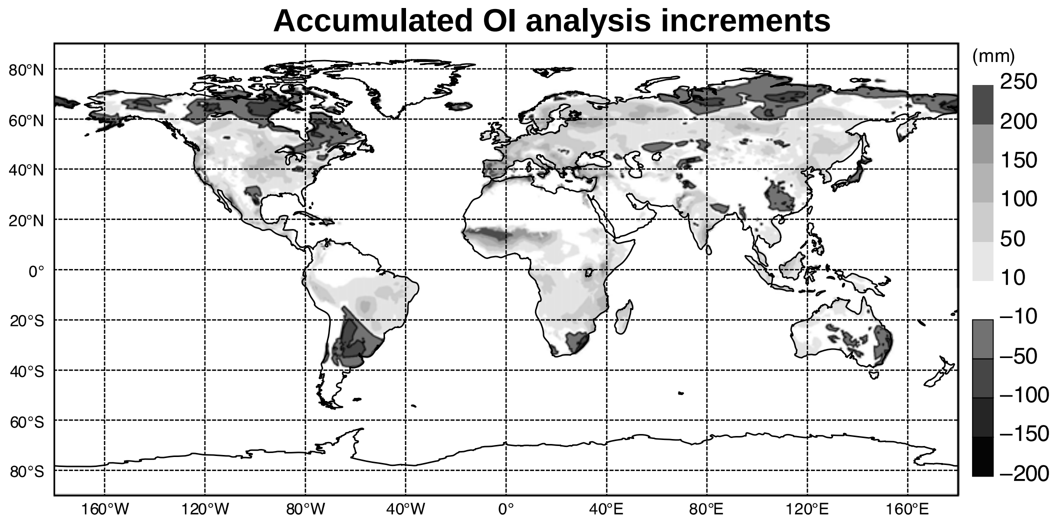
WP 1700: Continuous Monitoring

WP 1800: Hot Spot Analysis

Hot Spot Analysis (Land - Atmosphere Coupling)







Part II: DA Study

WP 2110: Modifying the Extended Kalman Filter

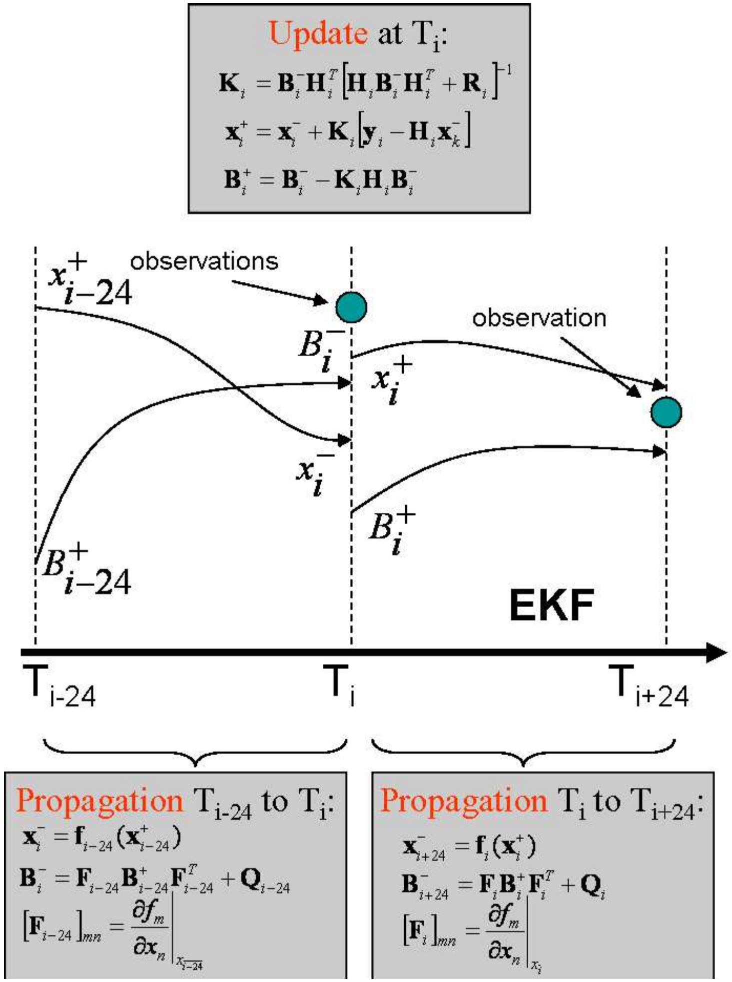
WP 2120: Adjusting the Surface Data Assimilation System

WP 2130: Bias Correction

WP 2200: Assimilation Experiments

WP 2300: Soil Moisture Monitoring

WP 2110: EKF Modifications



y: observation vector

x: model state vector

H: observation operator

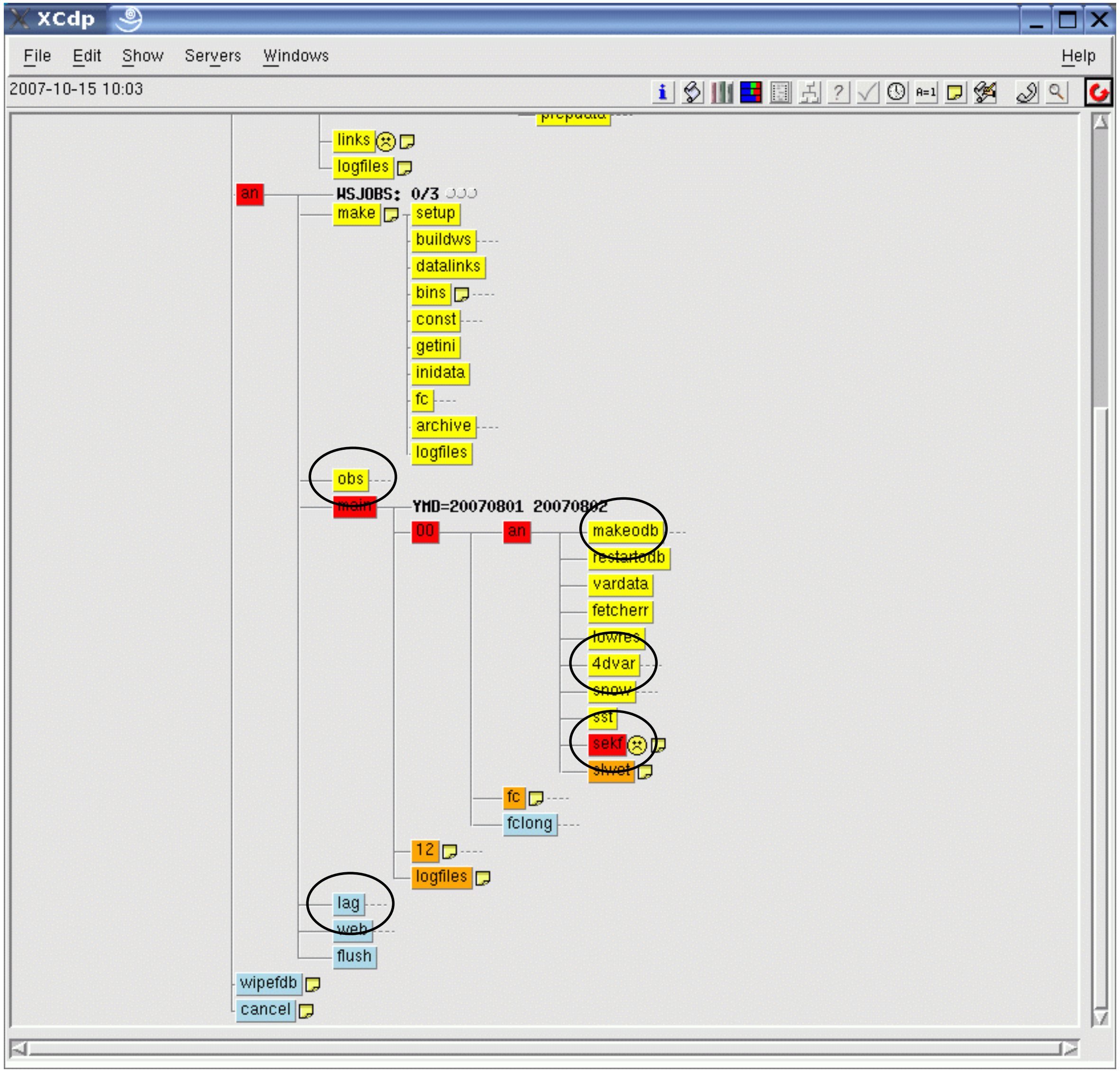
B: background error covariance matrix

Q: model error covariance matrix

R: observation error covariance matrix

F: state transition matrix

WP 1630 & 2120: SDAS Adjustment



Supervisor Monitor Scheduler

Modifications to:

- **the observation retrieval**
- **the observation data base**
- **the observation handling in the atmospheric 4DVar**
- **the observation handling in the extended Kalman Filter**
- **the archiving task**

WP 2130: Bias Correction

Systematic errors (or biases) must be removed before the assimilation otherwise biases will propagate in to the analysis (causing global damage in the case of satellites!).

$$\textit{Bias} = \textit{mean}\,[\,Y_{obs} - H(X_b)\,]$$

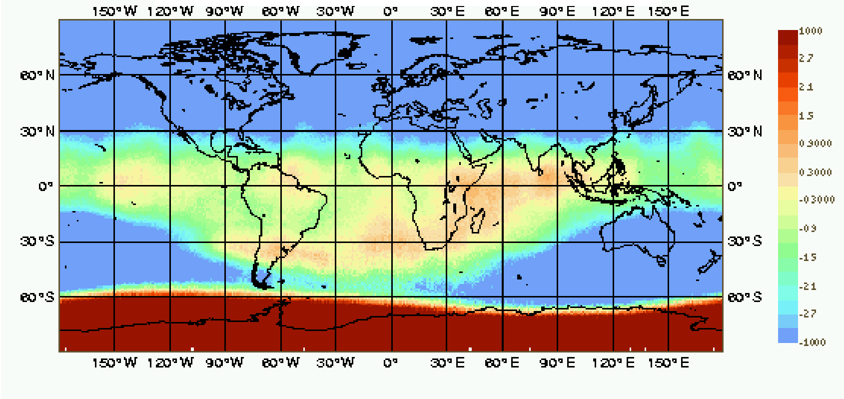
Observed radiance

RT model

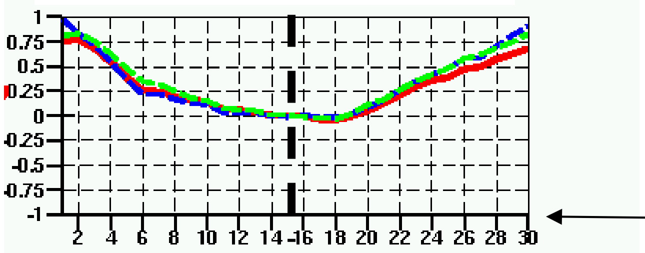
Background Atmospheric state

biases that vary depending on location or air-mass

AMSU-A channel 14



AMSU-A channel 7



limb

nadir

limb

biases that vary depending on the Scan position of the satellite instrument

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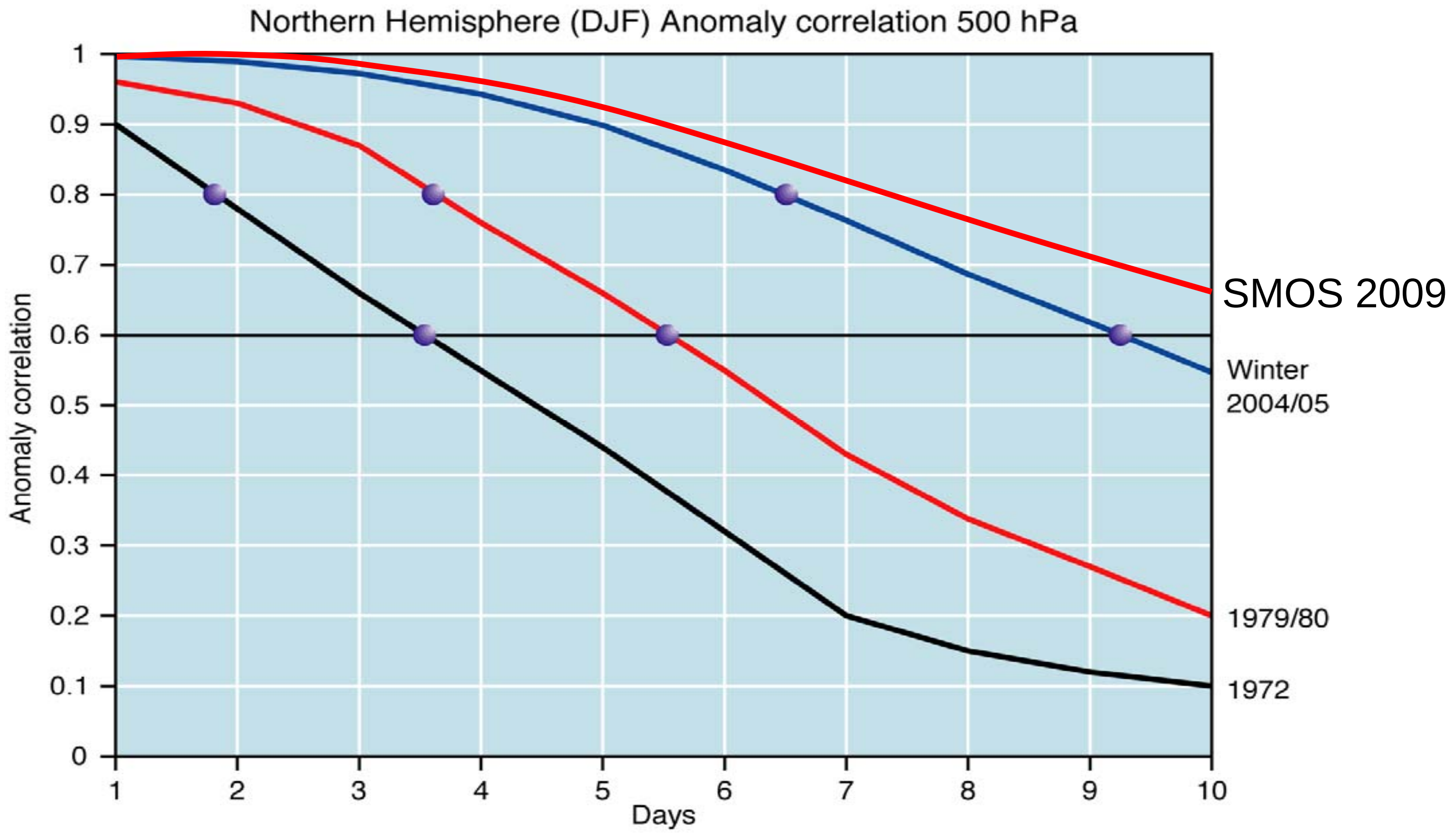
WP 2200: Assimilation Experiments



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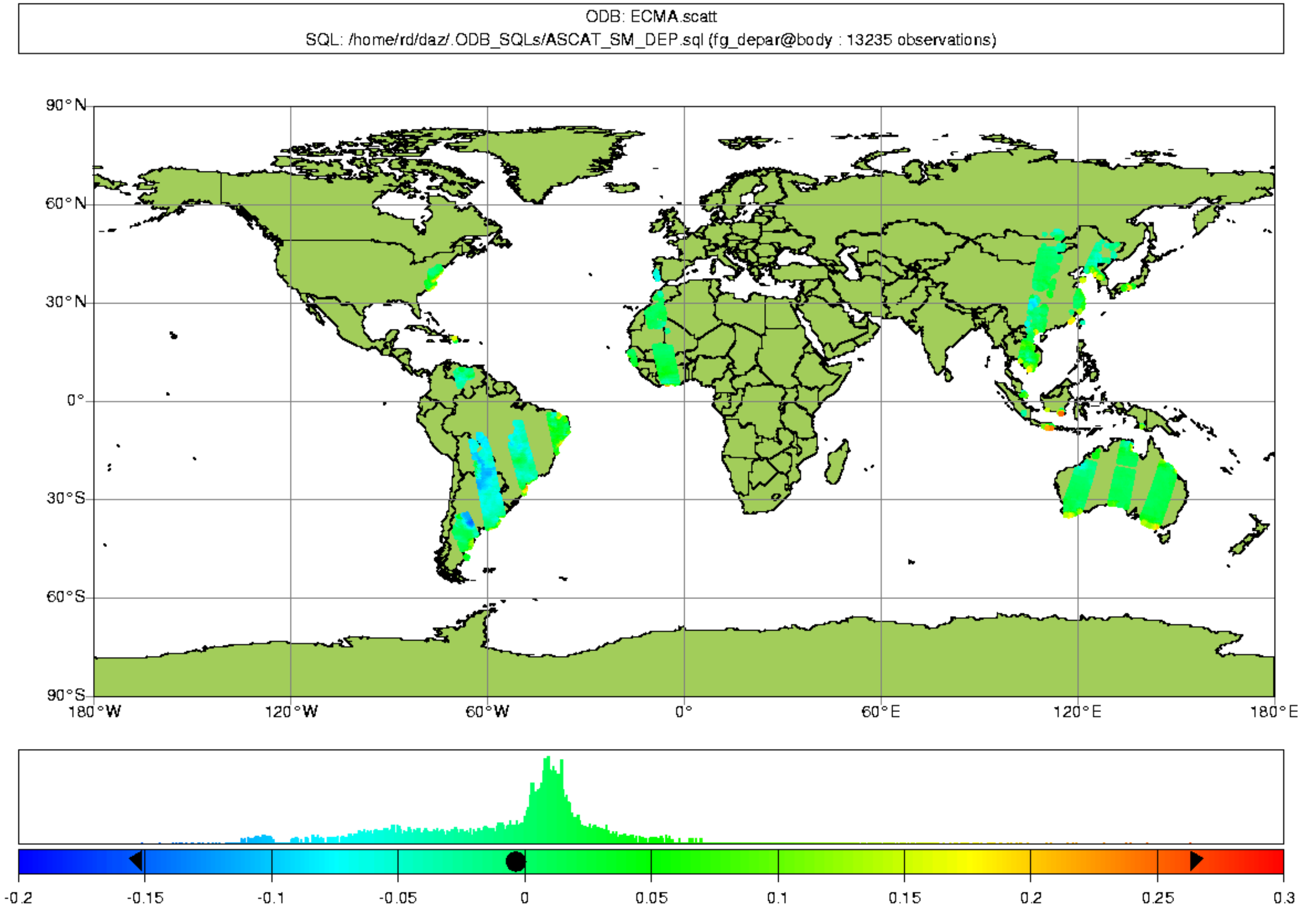
WP 2300: Soil Moisture Monitoring

first guess departures 01/04/2007



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