

High resolution soil moisture analysis based on the water budget model TERRA multi-layer

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Langen, 6 March 2006

1 Motivation

2 Methodology

3 Potential of Method – Lindenberg Simulations

4 Development and Evaluation of Pre-Operational Scheme

5 Sensitivity Analysis

6 Conclusions

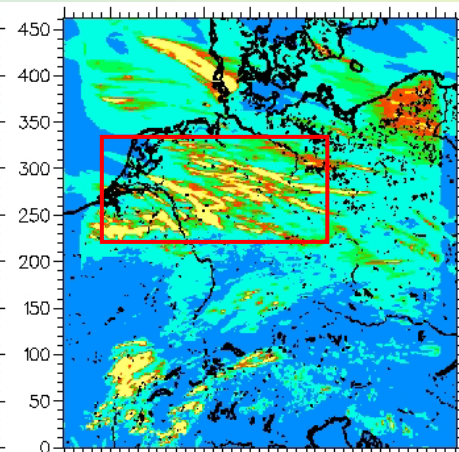
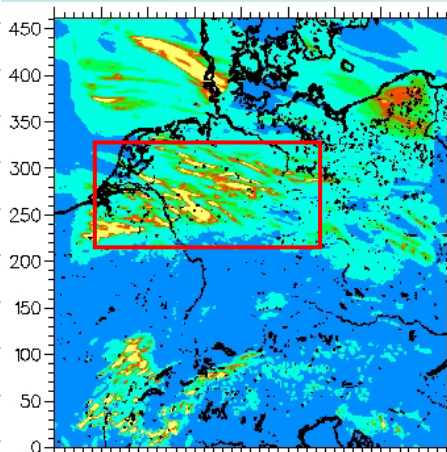
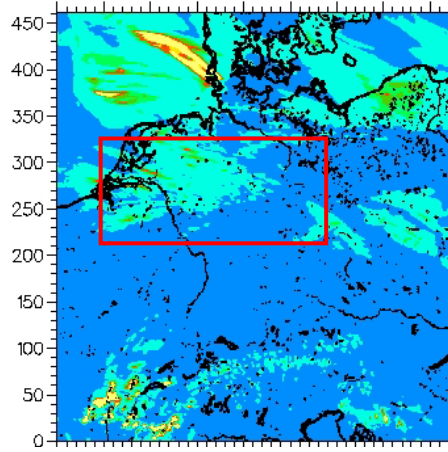
Motivation 1: Impact of soil moisture (SM) on clouds and precipitation

daily sum of
precipitation

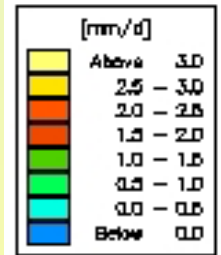
10% SM

reference SM

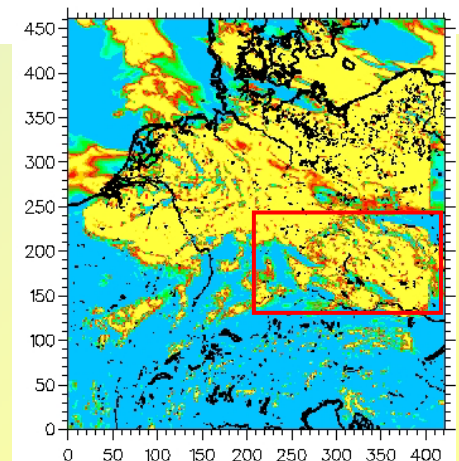
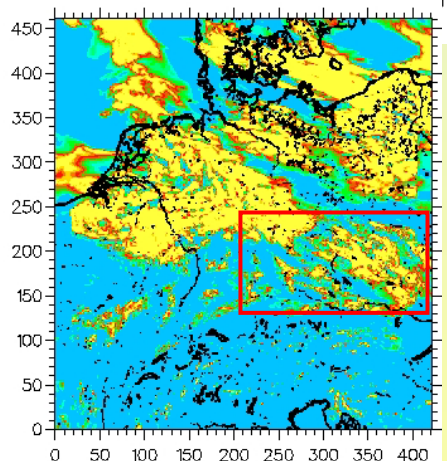
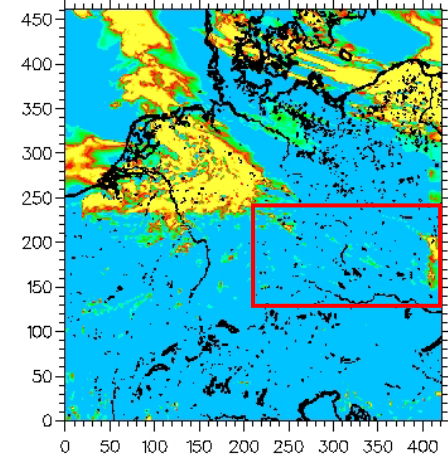
2x SM



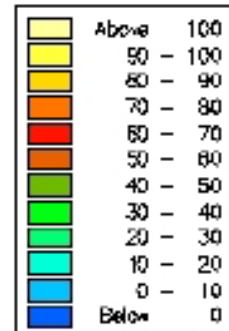
20 May
2004



total cloud cover

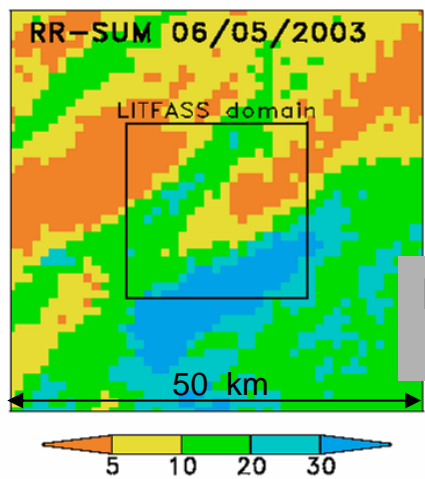


12 UTC

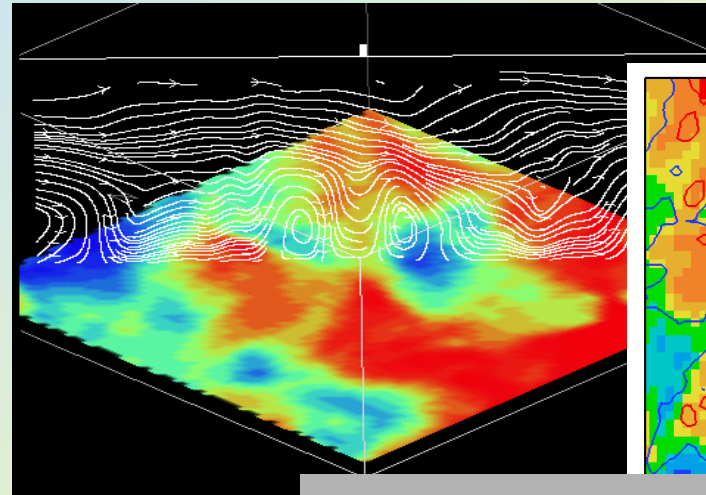


(G.Vogel)

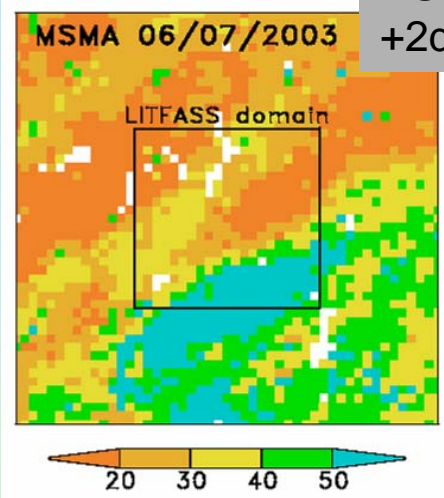
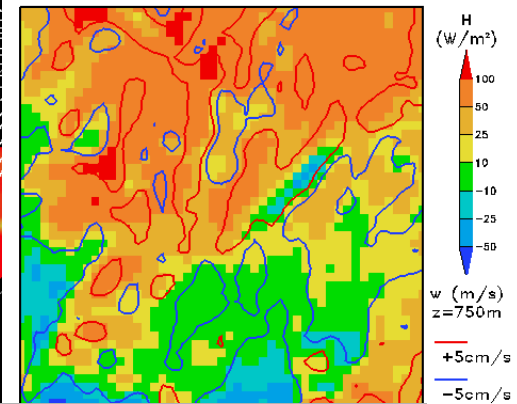
Motivation 2: Impact of small scale soil moisture structures



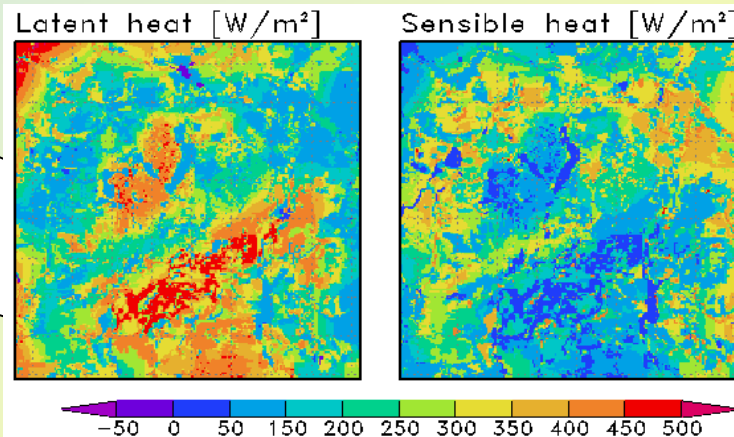
Precipitation
(Radar)



ABL circulation, (LM)

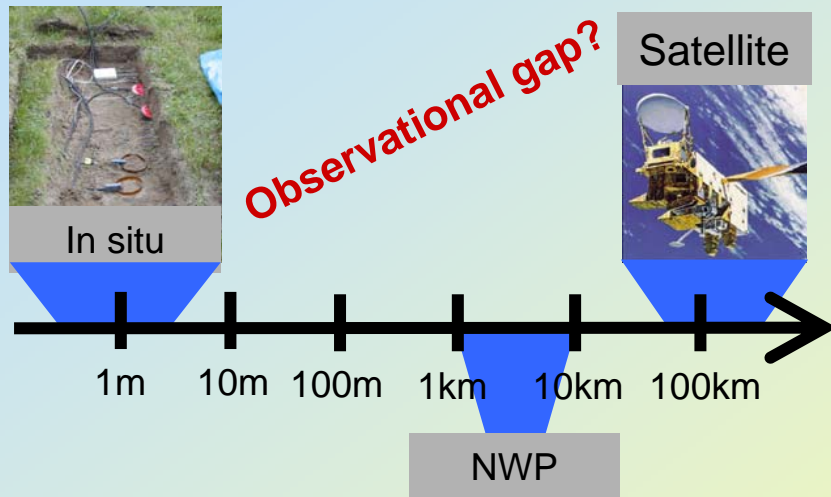


Soil moisture
+2days (MSMA)



Fluxes, +2days (LM)

Motivation 3: SM-Assimilation Problem for NWP



“Operationally,
no SM observations are
available for numerical weather
prediction (NWP)!”

Methodology 1: Soil Moisture Analysis Methods

Variational SM Analysis:

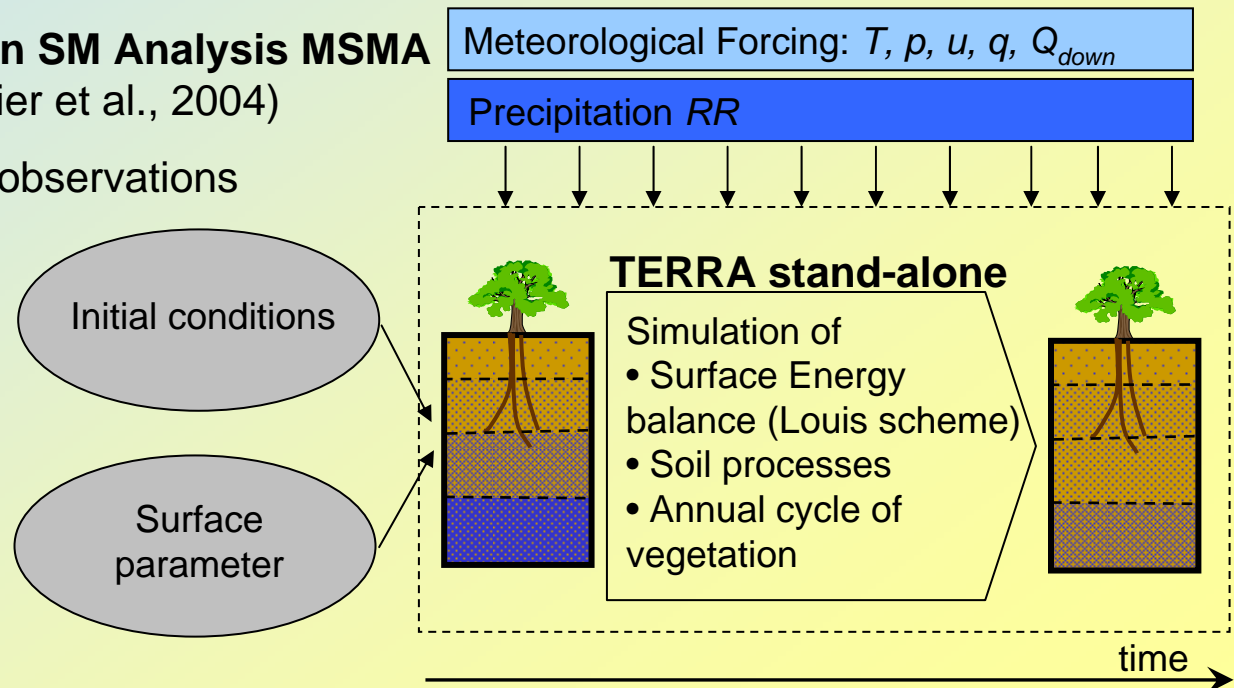
(e.g. Hess, 2001)

Correct SM to minimize prediction error of near surface temperature and humidity (see talk by M. Lange)

(RR-) Measurement-driven SM Analysis MSMA

("LDAS approach", e.g. Trier et al., 2004)

Model predicted SM using observations as forcing data.



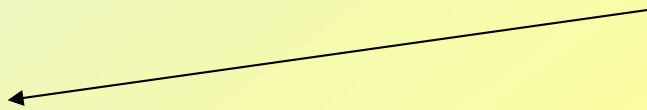
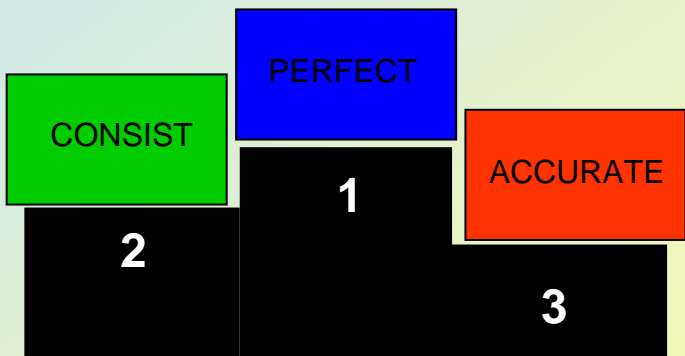
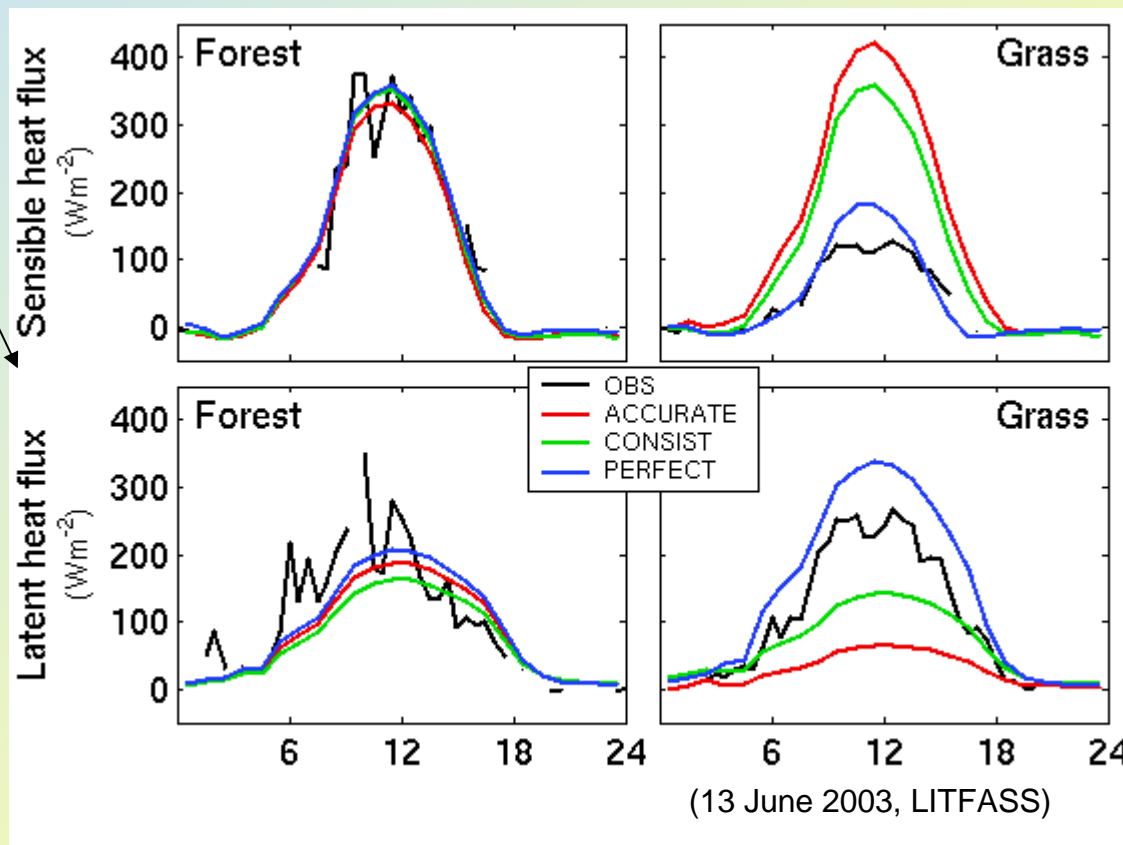
Methodology 2: Variational Method versus MSMA

	Variational	MSMA
PRO	<ul style="list-style-type: none"> assimilates additional information (T2m, RH2m) prevents drifts (extremely dry or wet SM conditions) 	<ul style="list-style-type: none"> captures response of SM to rainfall precisely in space and time. ensures a hydrologically consistent SM analysis in balance with model parameterizations fast
CONTRA	<ul style="list-style-type: none"> projects all model errors on SM first guess based on model forcings 	<ul style="list-style-type: none"> assumes a perfect SVAT model assumes perfect observations

Methodology 3: Accuracy versus model balance

We encountered a bug in the operational TERRA-2L (“poor model”) and corrected it (“good model”).

		Model integration	
		Poor model	Good model
MSMA	Poor model	CONSIST	
	Good model	ACCURATE	PERFECT

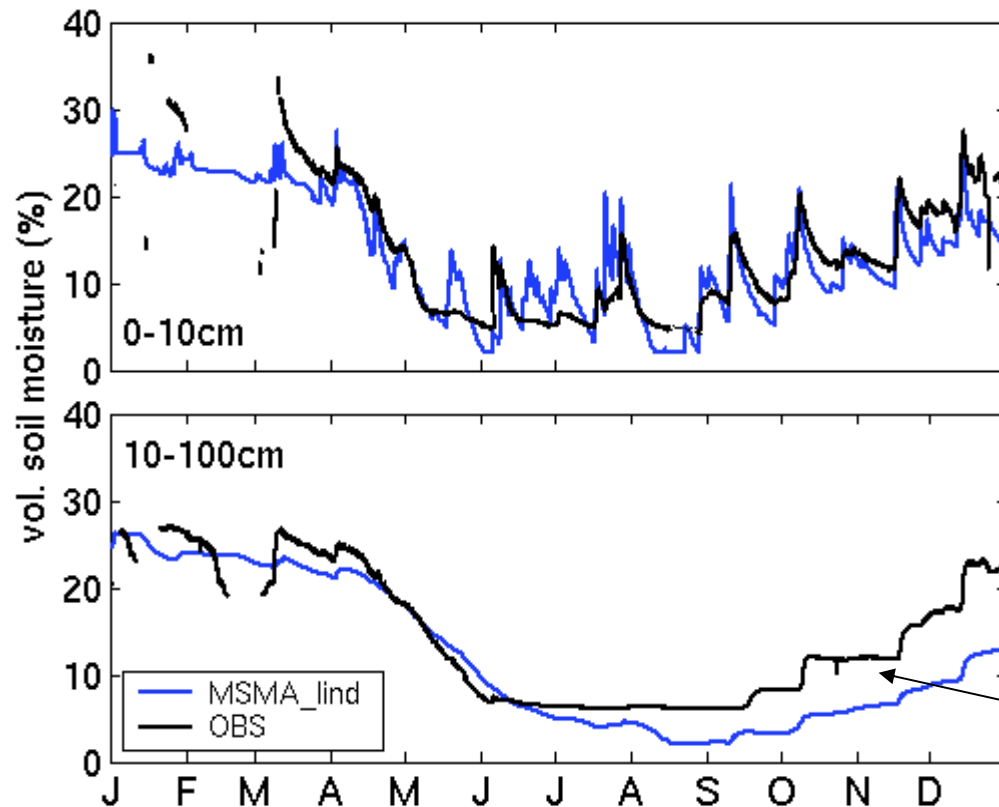


Potential of MSMA I

1d-integration at MOL Lindenberg

TERRA-2L driven by observations at the location of the SM measurements.

→ (almost) no uncertainties due to the forcing data



2003

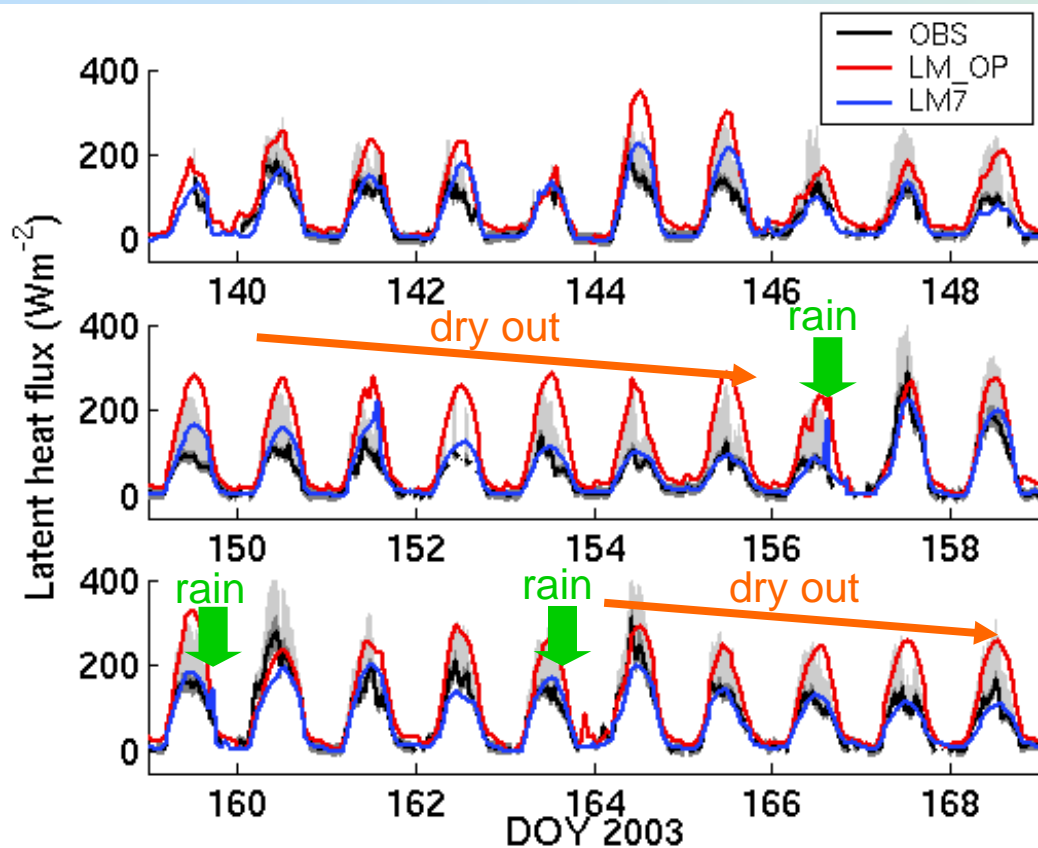
- good agreement between MSMA and OBS

Free drainage lower boundary condition

→ no ground water uptake

Potential of MSMA II

Effect on surface fluxes



Example:

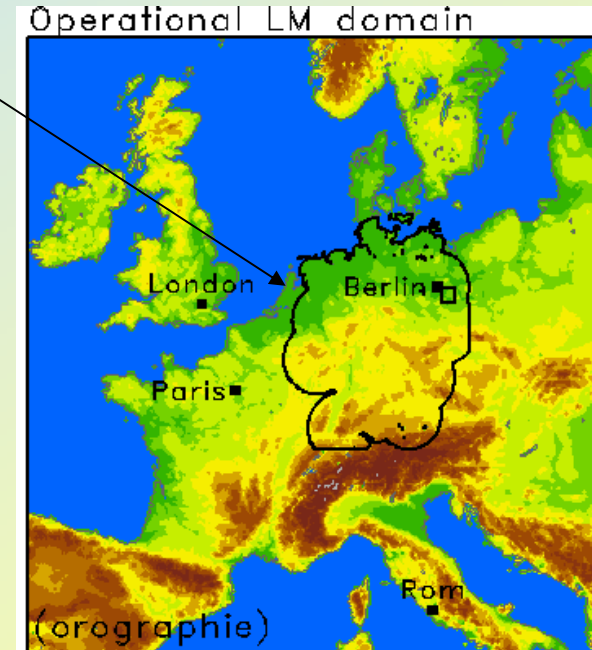
30 day period at 20x20km²
domain close to Lindenberg
(southeast of Berlin)

LM with operational SM analysis

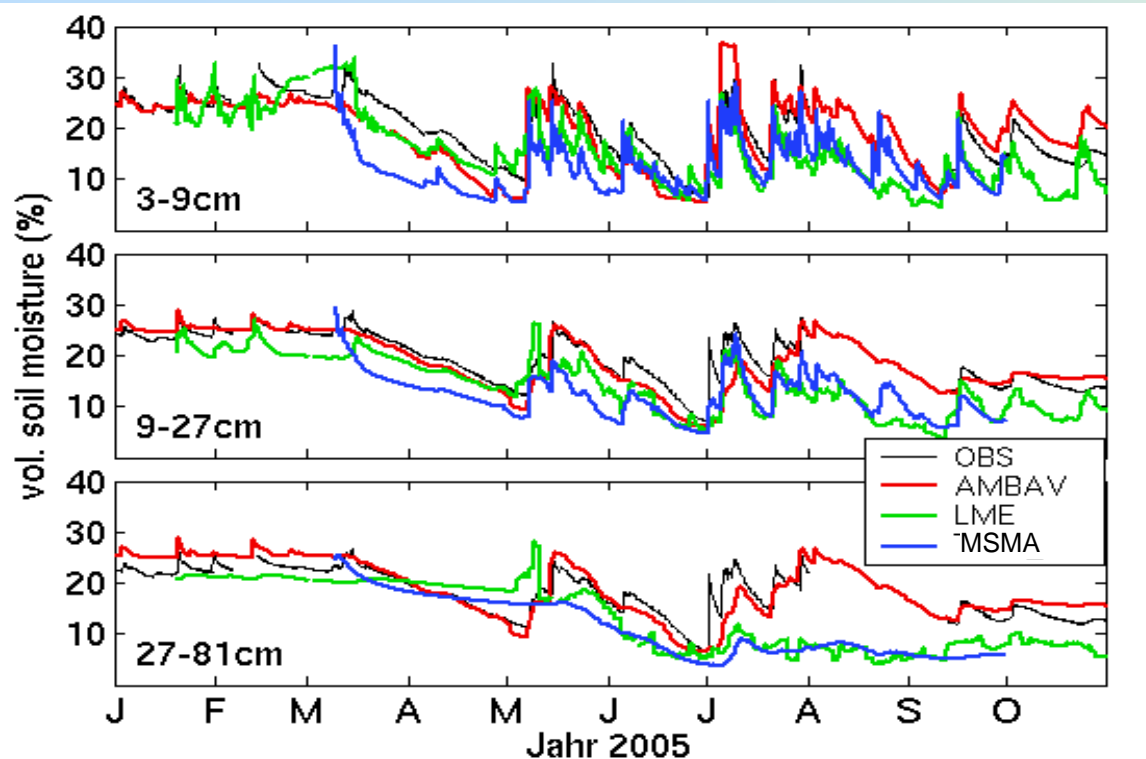
LM with MSMA
(and some other minor modifications)

Pre-Operational Method 1: Towards operational application of MSMA

domain	RADOLAN domain
model	Multi-layer TERRA
period	10 Mar 2005 – 30 Sep 2005
resolution	2.8 km
T_2m, rh_2m, v	DWD analysis based on SYNOP
radiation	LM analysis
precipitation	RADOLAN (Bartels et al., 2004) Radar based precipitation estimates calibrated by rain gauges



Pre-Operational Method 2: Evaluation at Lindenberg (a)

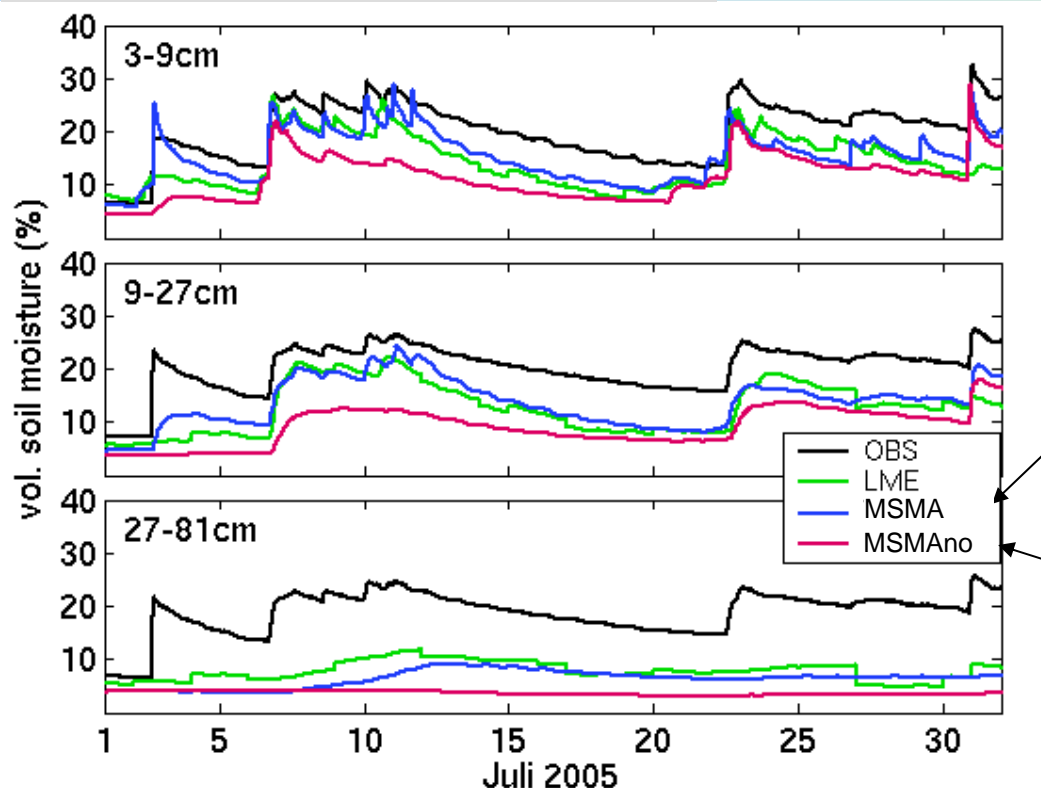


- deep soil moisture dries out too much
- but, variational method (LME) is not better
- AMBAV (“better” SVAT) gives very good results
- MSMA captures the response to rainfall very well.

	AMBAV			LME			MSMA		
	3-9cm	9-27cm	27-81cm	3-9cm	9-27cm	27-81cm	3-9cm	9-27cm	27-81cm
BIAS	-2.0	-2.2	-0.8	-3.3	-4.3	-3.4	-6.8	-6.3	-5.0
STD	4.5	2.3	2.3	3.4	2.9	5.8	3.8	1.9	5.2
CORR	0.79	0.88	0.88	0.81	0.80	0.40	0.75	0.91	0.5

Pre-Operational Method 3: Evaluation at Lindenberg (b)

Grid point Lindenberg, July 2005



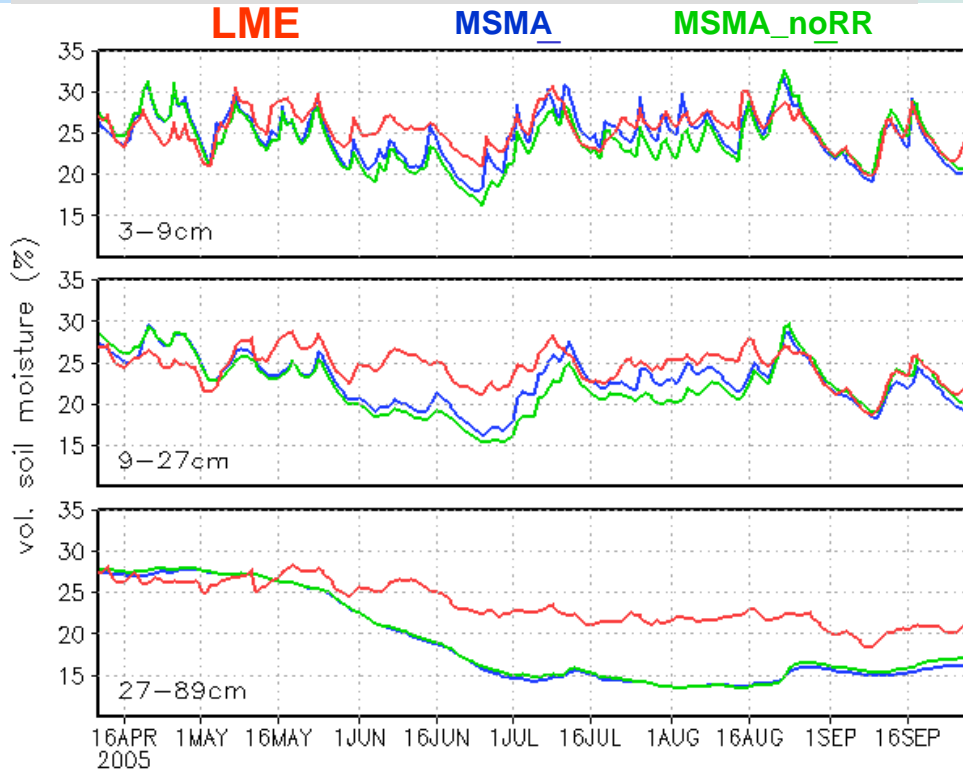
MSMA with observed
precipitation

MSMA with predicted
precipitation

- using **observed** precipitation observation leads to better results
- (response to rain events at deep soil layers is dampened too much - but, measurements have to be reconsidered.)

Pre-Operational Method 4: RADOLAN domain average

Radolan domain average SM



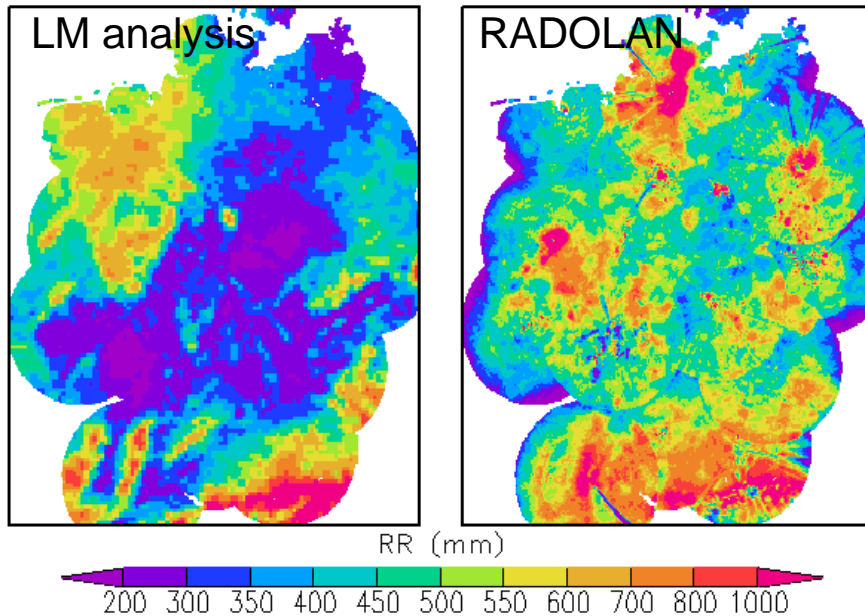
- dry out of deeper layer in **MSMA** occurs within the whole domain
- variational method (**LME**) partly corrects for this effect
- using observed precipitation tends to be beneficial (?)

Reasons for dry BIAS of MSMA:

- a) poor forcing data?
- b) model deficiency of TERRA-ML?

Pre-Operational Method 5: Precipitation data

Accumulated precip., Mar.-Sep. 2005

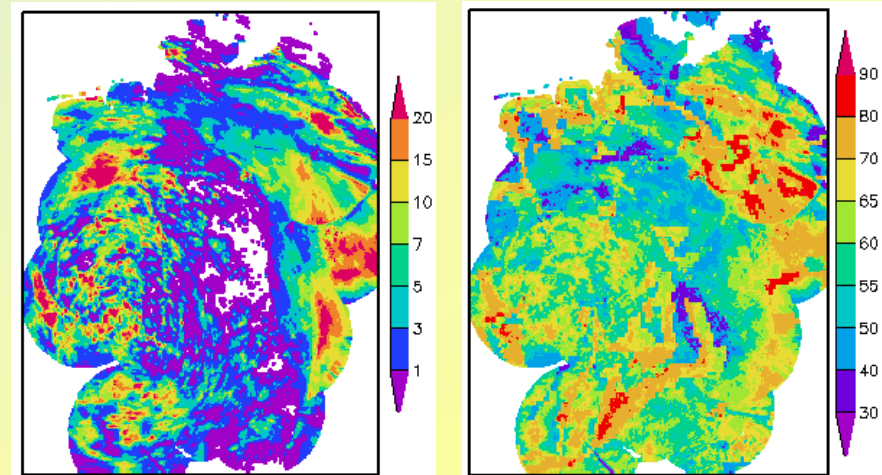


→ These artefacts affect SM analysis.

Example: 8 July 2005

RADOLAN RR,
8 July 2005

SM,
9 July 2005



Problems of RADOLAN product:

1. Overestimation close to radar sites
2. Compositing (radar circles are visible)
3. Too little rain at the boundaries of the domains

Dry-out not explained!

Pre-Operational Method 6: Model deficiencies (dry-out)

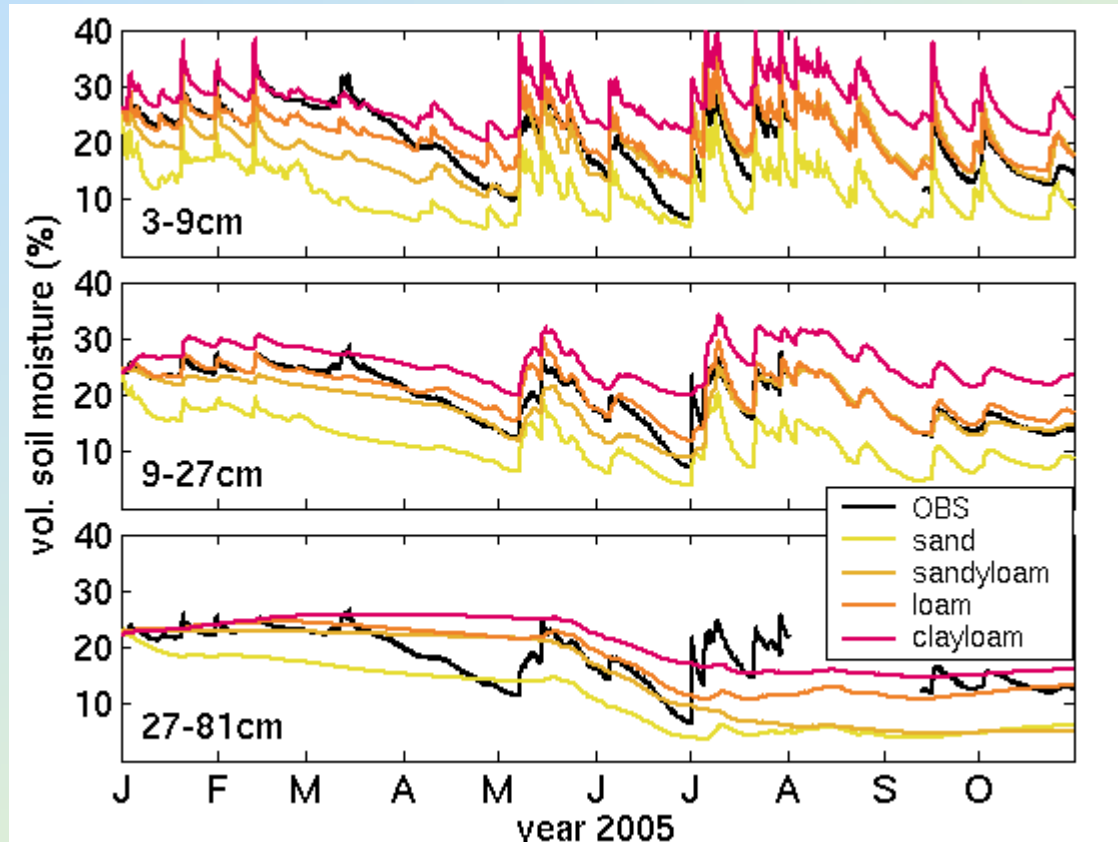
Hypotheses

- wrong parameterizations of soil water dynamics
- numerical problems
- too deep roots (~doubling in LMK)
- lower boundary condition (free drainage; no ground-water take-up)
- too much runoff (because the thin upper soil layer saturates too fast (© MeteoSwiss))
- Interception store bug (© DWD)

Sensitivity studies with TERRA
stand-alone in 1d-mode at Lindenberg
with locally measured forcings

Sensitivity Analysis 1: Changing the soil type

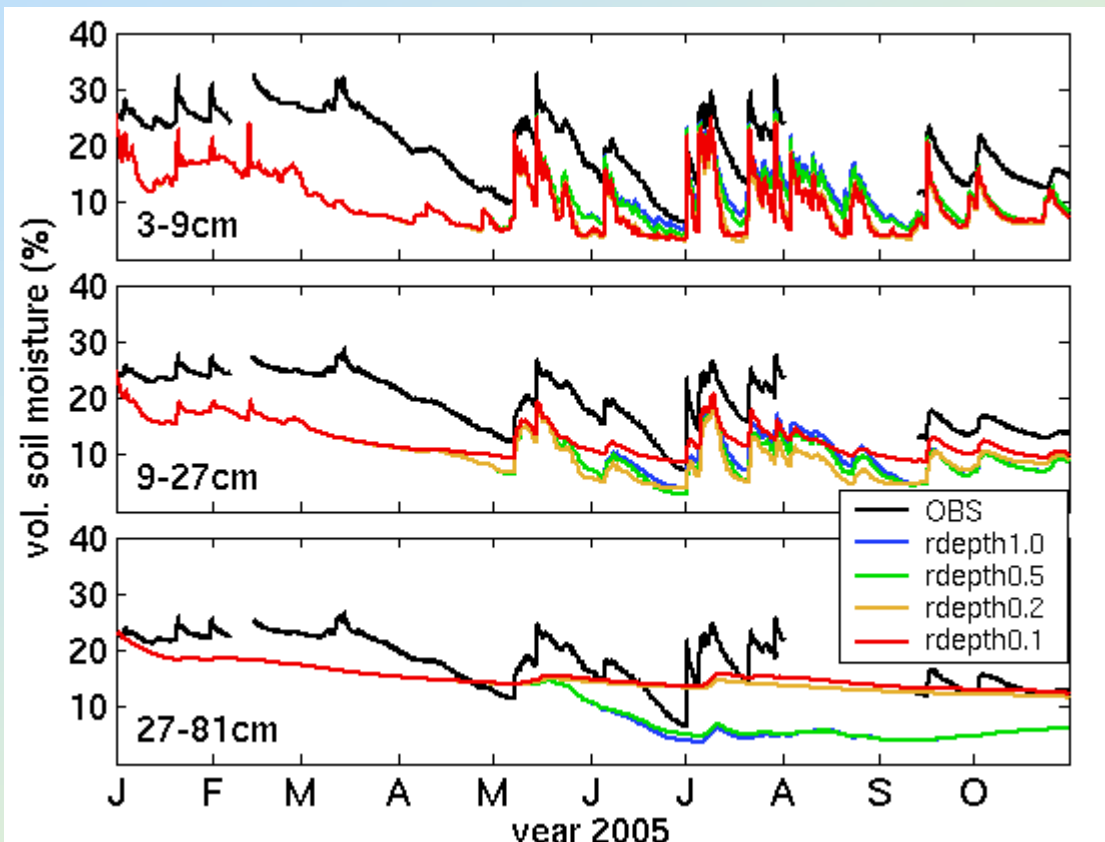
Poor mans method to asses the impact of soil parameters



- **Strong sensitivity**
 - adapting the soil parameters (as recommended by LM documentation!)
 - Testing of other parameterizations (e.g. according to Brooks and Corey)

Sensitivity Analysis 2: Changing the root depth

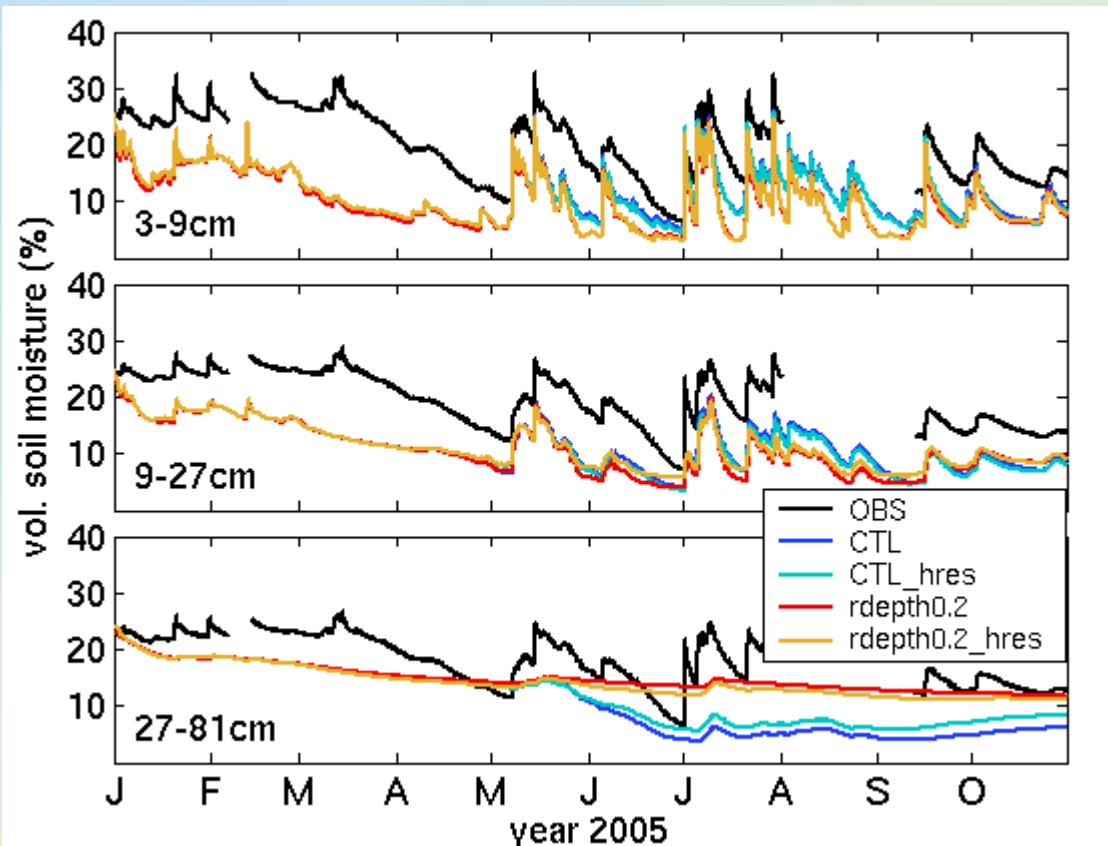
Operational root depth (LMK) are very large (1 m at Lindenberg).



- Large variations depending on whether a layer is penetrated by roots or not
- Fraction of penetration is almost irrelevant
- revision of the all-or-nothing formulation; implementation of a root depth PDF

Sensitivity Analysis 3: Changing the vertical discretization

Increasing the number of layers from 7 to 27 ($\Delta z \leq 6\text{cm}$ down to 1m depth)



- Small effects
→ no great impact of numerics

Conclusions

- **Assimilating standard observations in a SVAT model (MSMA)** has the potential to give good SM analysis. Nonetheless, it can be combined with other methods!
- Using MSMA it is possible to model the **soil moisture feedback processes** correctly (no timing or positioning errors).
- From a model perspective, **consistency** of SM data might be more important than **accuracy**.
- Work towards **operational applications** is currently done. Model as well as data problems have to be solved.
- Solving the “**dry-out**” **problem** is a essential task - not only for MSMA! **TERRA stand-alone** might be a useful **tool**.

Work plan 2006

(hopefully with support by MeteoSwiss/DWD)

1d simulations at the grid point Lindenberg

- Sensitivity studies to figure out the dry out problem
- Analysis of water budget

Model intercomparison with AMBAV

- comparison/exchange of parameters and parameterizations
- comparison of “intermediate” quantities (e.g. fluxes)

Improvement of RADOLAN data

- quality control
- efforts by DWD?

Using satellite derived radiative fluxes

- using MSG data from Climate SAF (COSMO cooperation with Poland)

Soil moisture validation at more site

- more measurement sites (e.g. Uni Bonn, MeteoSwiss)

Impact studies

- comparison of LM model runs with and without MSMA data at appropriate cases