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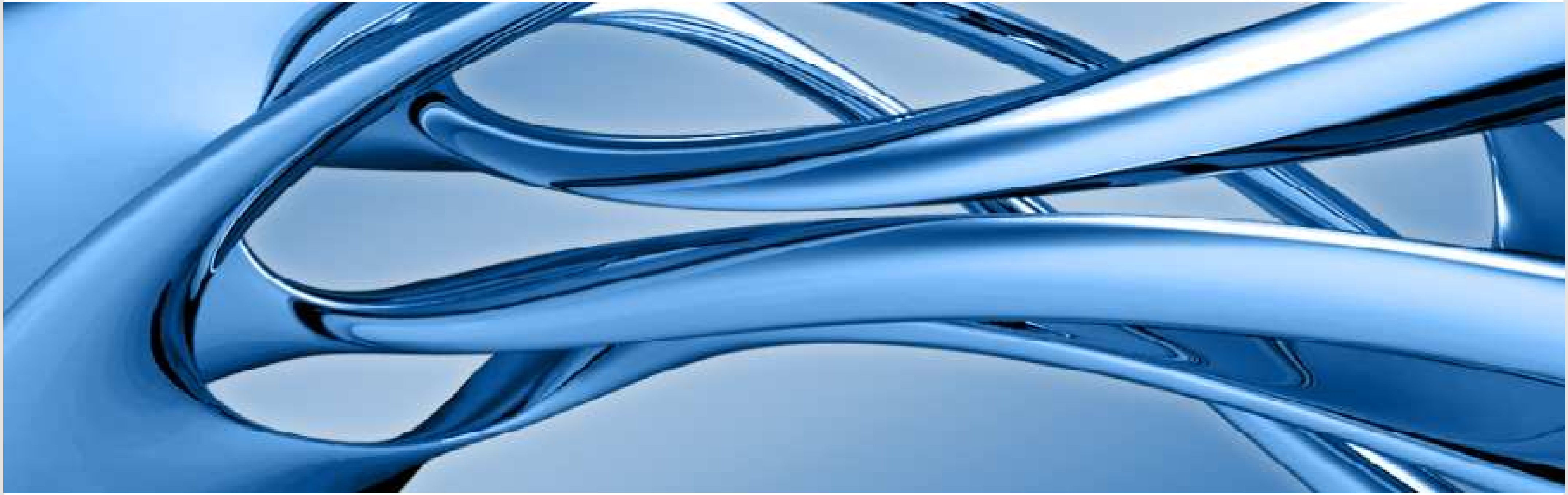
Soil moisture network during COPS: Comparison to model values and impact on convective indices

Ch. Barthlott, L. Krauss, Ch. Hauck,
G. Schädler, N. Kalthoff, and Ch. Kottmeier

7th COPS Workshop Strasbourg



DFG-project SOMONET

Karlsruhe Institute of Technology

- **Title:**
  Multi-scale Analysis of the Impact of Soil Moisture and Boundary Layer Processes on Convective Precipitation
  (Applicants: Ch. Hauck, G. Schädler, N. Kalthoff, Ch. Kottmeier)
- Goal:
  identify the dependence of convective and orographically induced precipitation on the variability of the soil moisture field and the corresponding processes in the PBL
- How?
  $\Longrightarrow$ unique data set realised during COPS with a very high number of soil moisture sensors
  $\Longrightarrow$ model simulations

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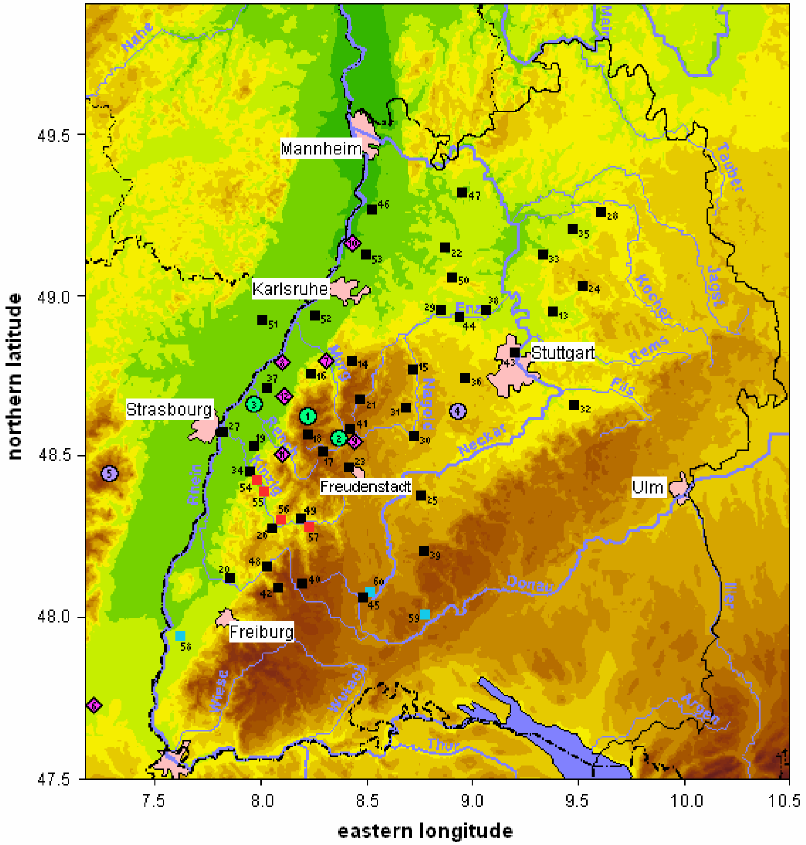
Soil Moisture Network

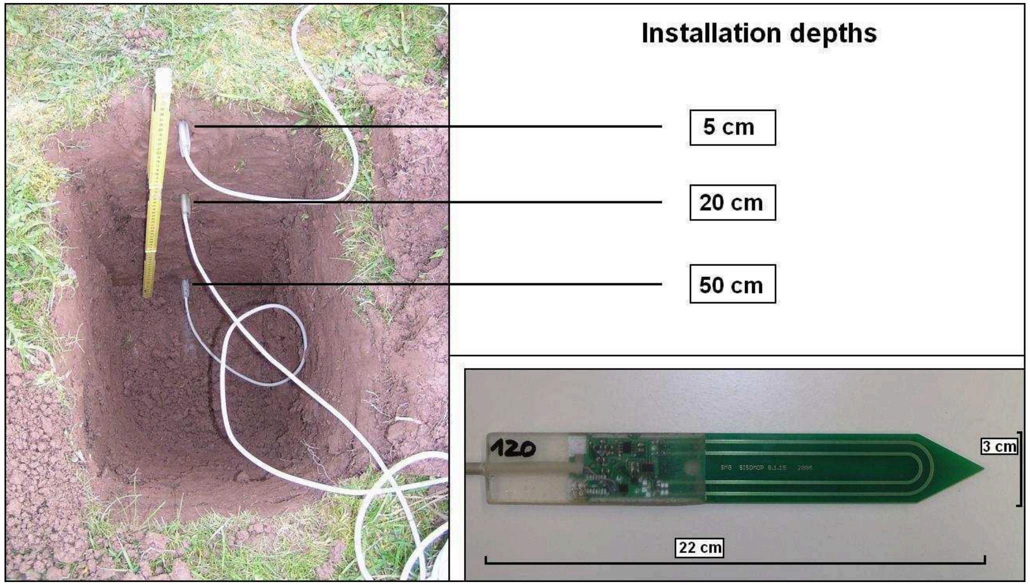


1. COPS specific Sites

- Supersites with Energy Balance Station and IMK Soil Moisture Station
- Supersites with Energy Balance Station and Soil Moisture Station run by collaborating Institutes
- Sites with IMK Energy Balance Station and IMK Soil Moisture Station
- Sites with Energy Balance Station and Soil Moisture Station run by collaborating Institutes

2. Soil Moisture Station only

- IMK Soil Moisture Stations
- Soil Moisture Station run by collaborating Institutes



- 60 stations (IMK: 43 + 8 (COPS), collaborating institutes: 9)
- measurements over 2 years intended
- more information? ⟹ see poster of Liane Krauss (session Surface Processes A10)

Long-term comparison: Global model GME

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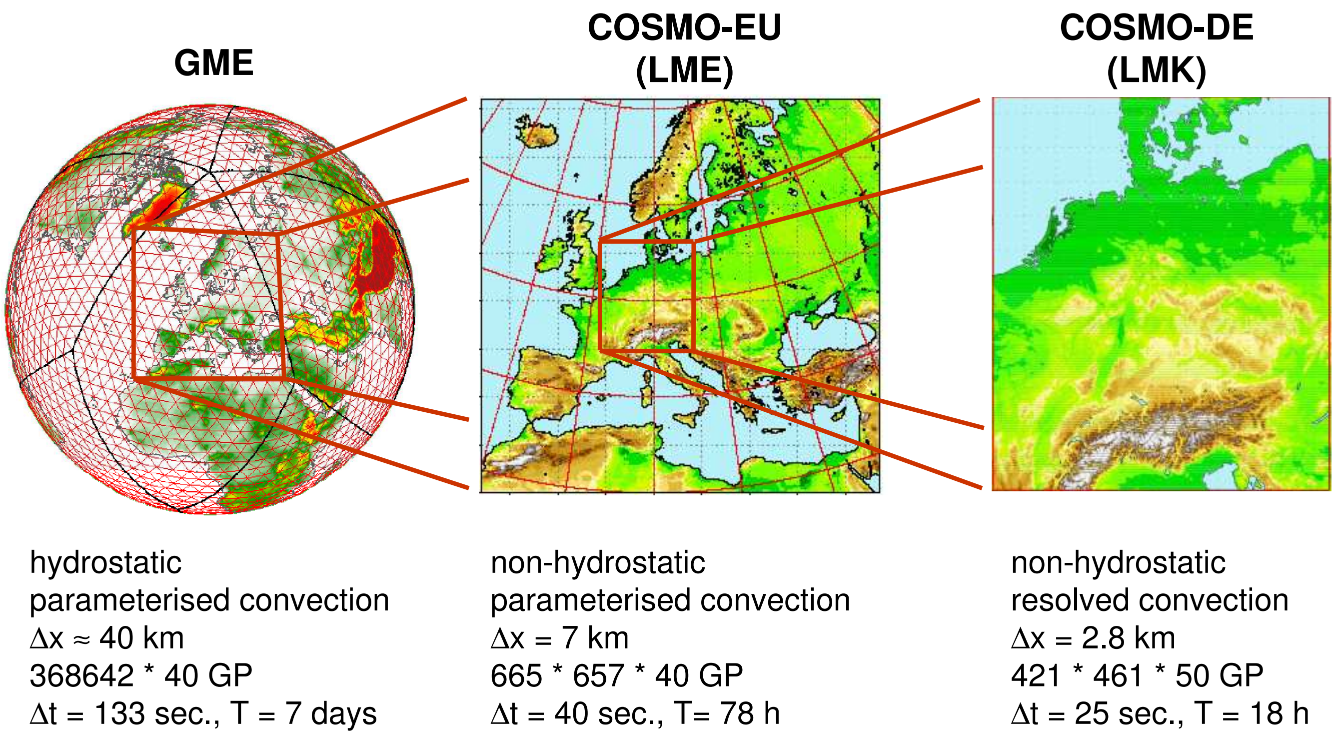
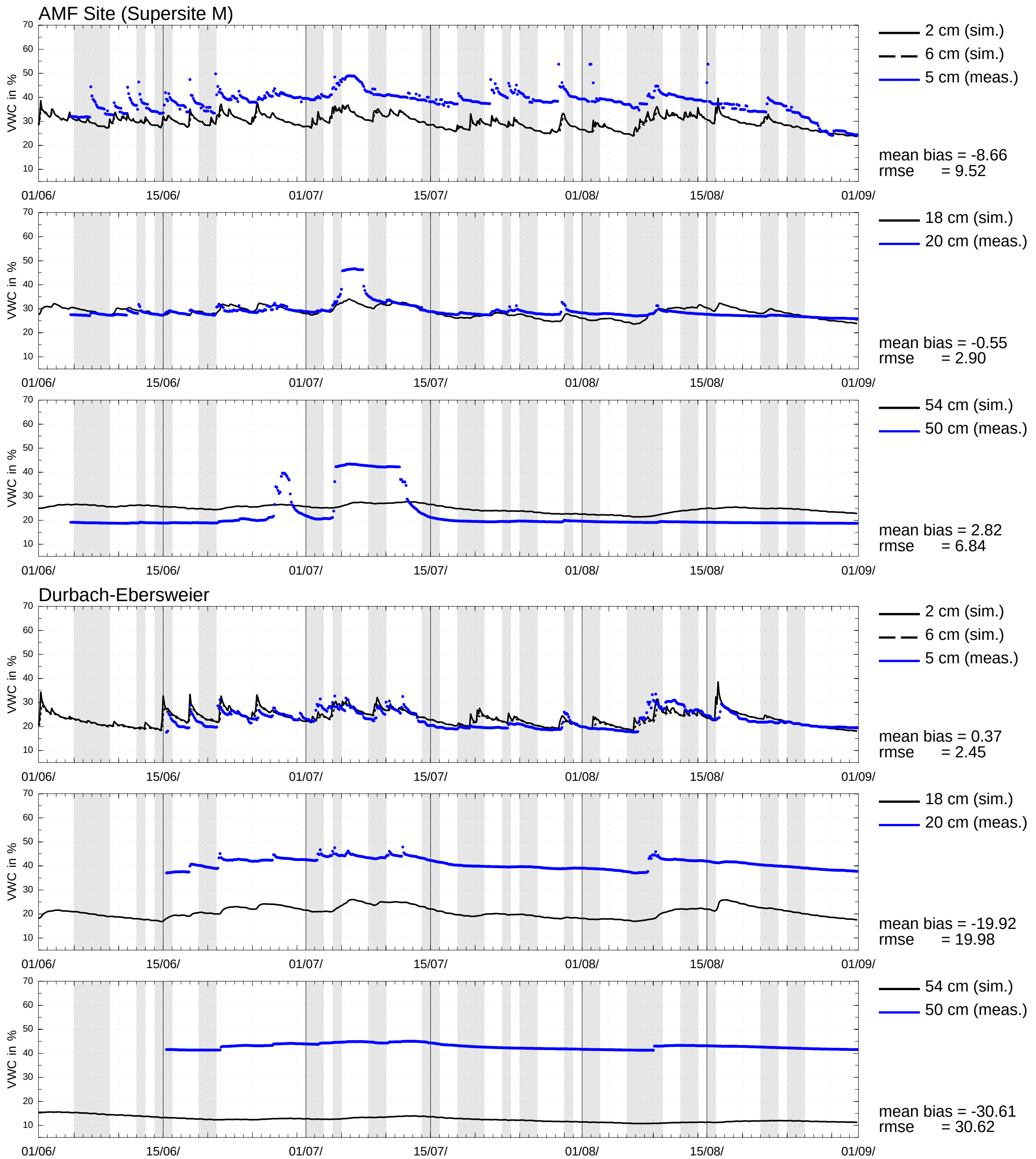
GME: hydrostatic numerical weather prediction model; triangular grid with a mesh size of 40 km; 40 layers; 7-layer soil model including freezing and melting of soil water and a sea ice

3-hourly GME analysis $\Longrightarrow$ interpolation on COSMO-DE grid (2.8 km) with int2lm



Baldauf (2007)



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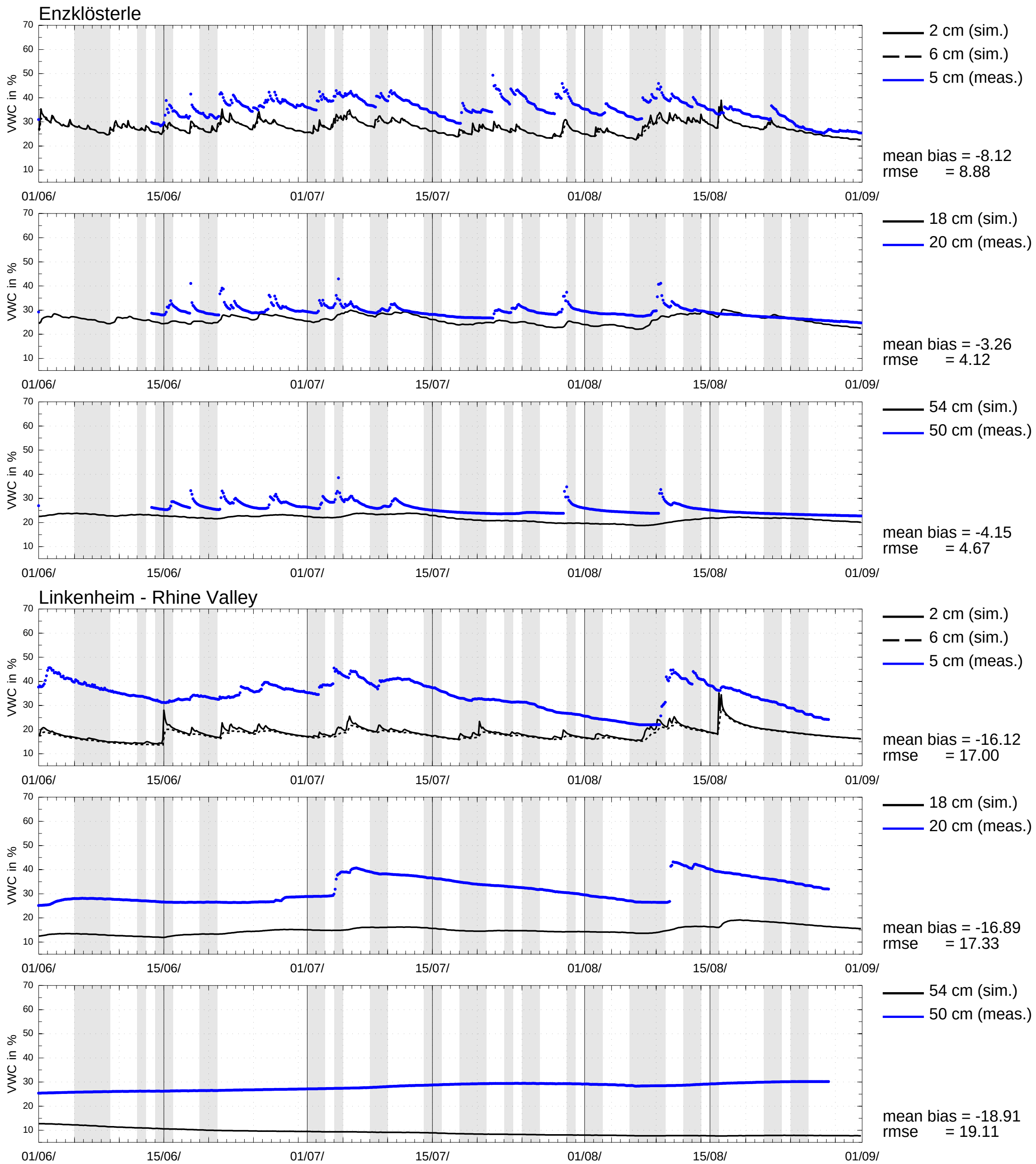
AMF:

- good qualitative agreement for uppermost sensor, deviations of 5-15 Vol.%
- good agreement at 20 and 50 cm depth, exception: beginning of July (raised ground water level? close vicinity to Murg)

Durbach:

- almost perfect match at 5 cm
- large discrepancies at greater depths



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Enzklösterle:

- variance of the measurements in 20 and 50 cm significantly higher as variance of simulations

Linkenheim:

- poor result: large differences for absolute values and trends

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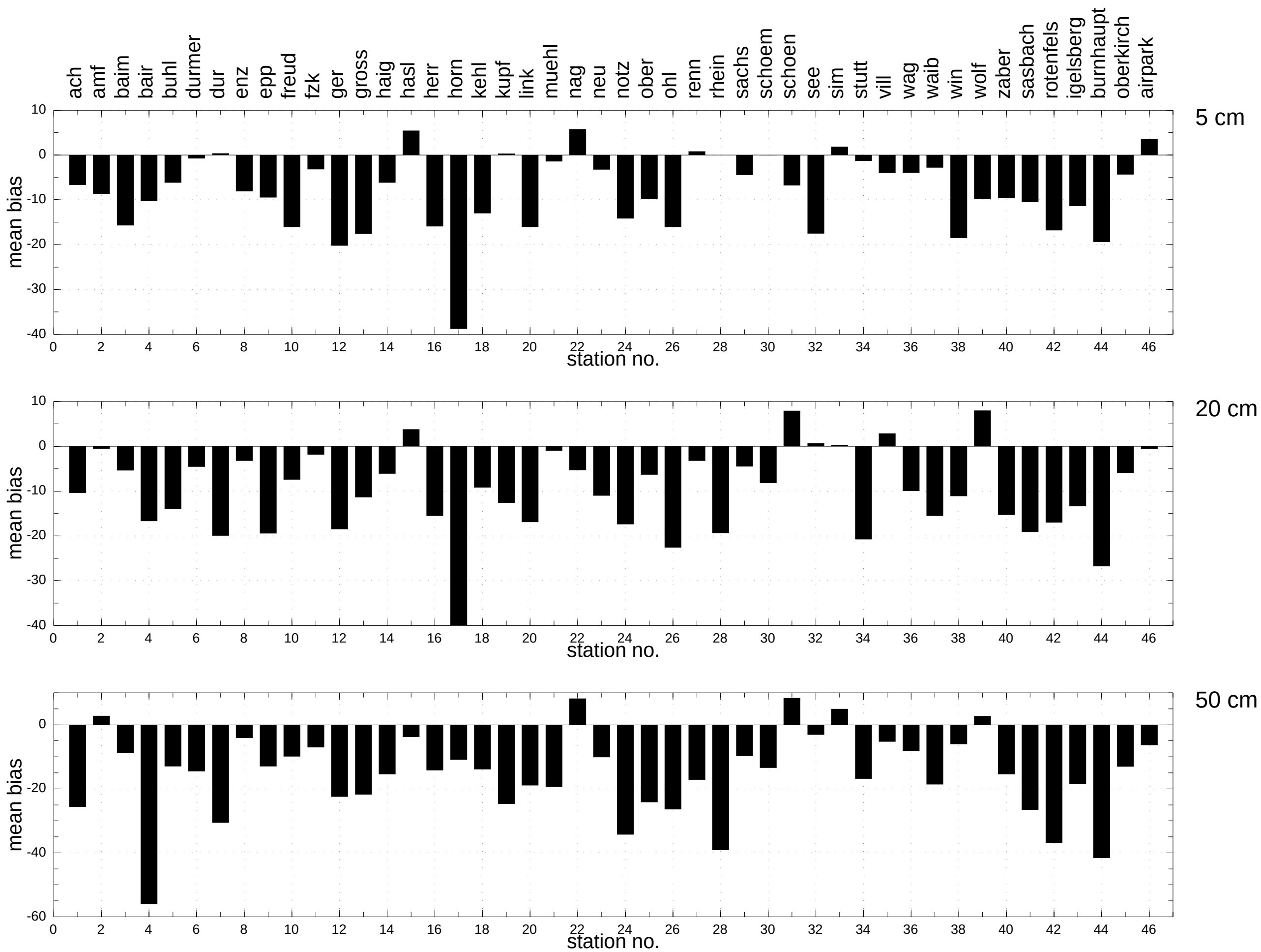


$$MB = \frac{1}{N}\sum_{i=1}^{N}(SIM_i - MEAS_i)$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(SIM_i - MEAS_i)^2}$$

- GME is generally too dry with tendency of amplification of this effect with depth (rmse increases with depth)
- lowest correl. at 50 cm
- variance decreases with depth
- variance of measurements $>$ variance of GME-values

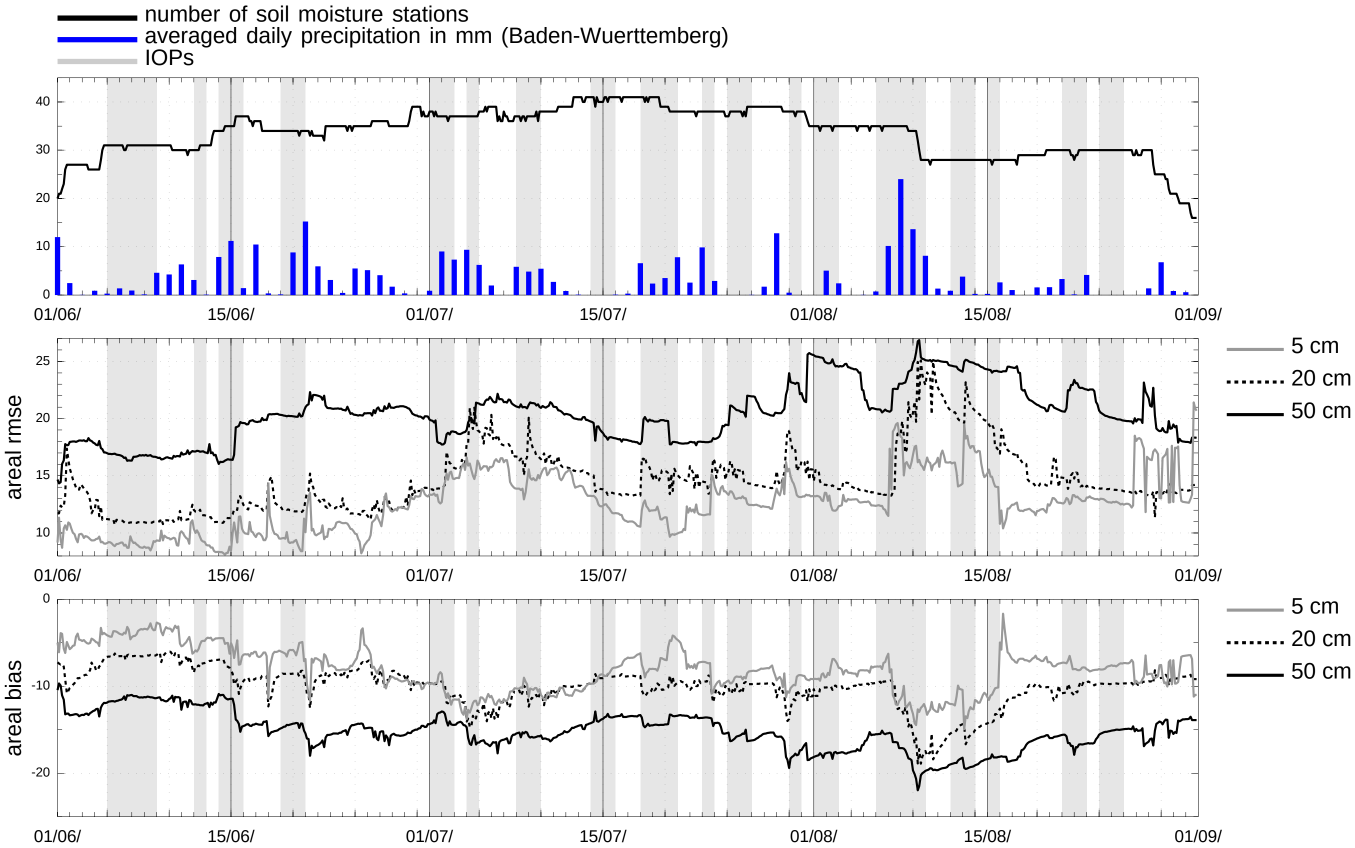
depth	rmse	correl.	σ^2_{meas}	σ^2_{sim}
5 cm	10.8	0.52	23.3	6.2
20 cm	12.2	0.56	11.7	4.1
50 cm	17.4	0.38	7.9	1.8

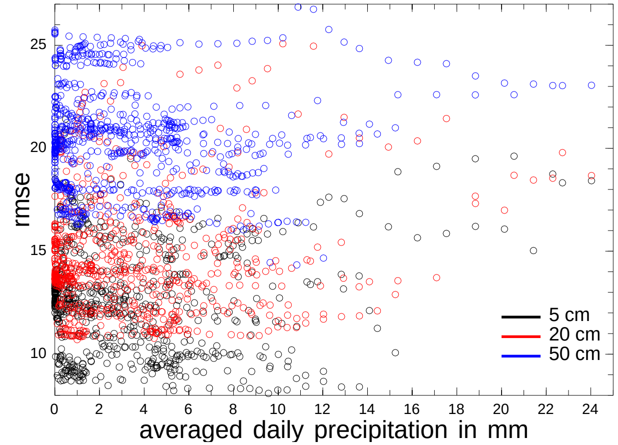
Areal Bias + RMSE

$$MB = \frac{1}{N}\sum_{i=1}^{N}(SIM_i - MEAS_i) \qquad RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(SIM_i - MEAS_i)^2}$$

N: number of available stations for each time step

$\Longrightarrow$ time series for COPS-period:





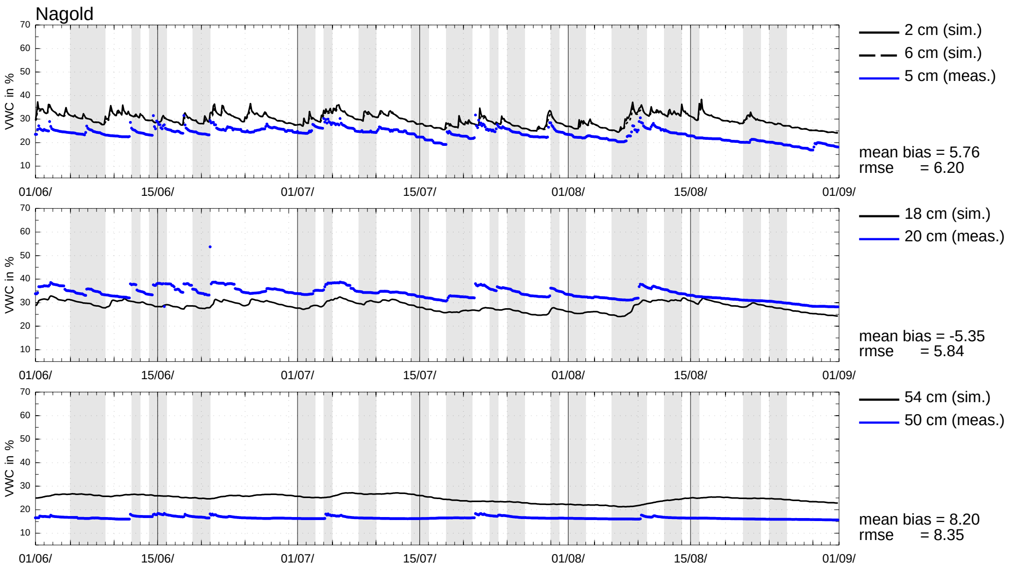
- **long periods with smaller and larger errors**
- **rmse not dependent on averaged daily precipitation; precip. $>$ 15 mm $\Longrightarrow$ rmse always high**
- **ind. error for each station = fct(precip)?**

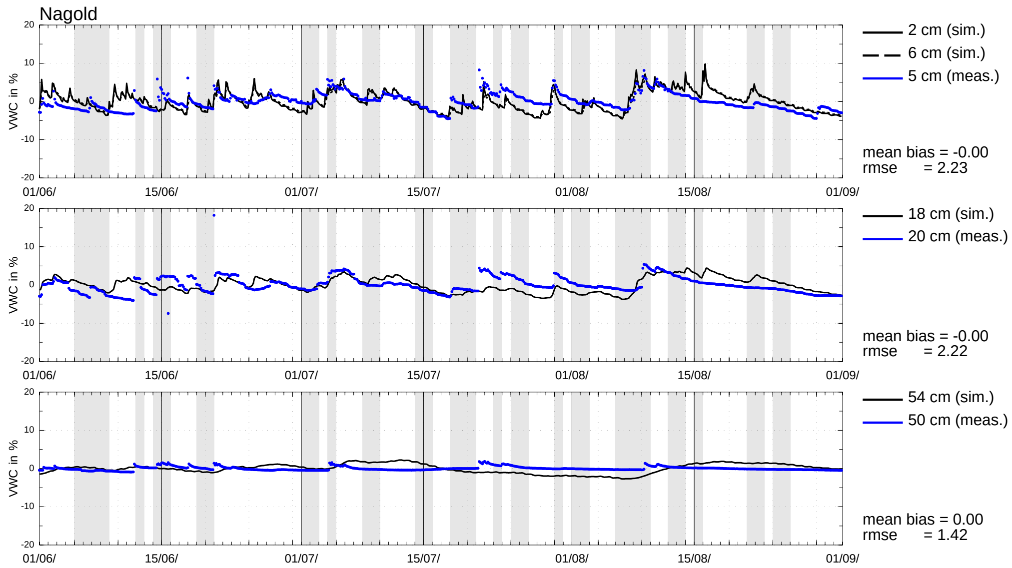
Problem: Calibration

Current status: 1 calibration for all soil moisture sensors

In preparation: individ. calibration for each sensor dependent on soil type

Current uncertainty: ±10 Vol.%





	original	detrended
rmse 5 cm	6.2	2.2
rmse 20 cm	5.8	2.2
rmse 50 cm	8.4	1.4

Comparison with COSMO-DE

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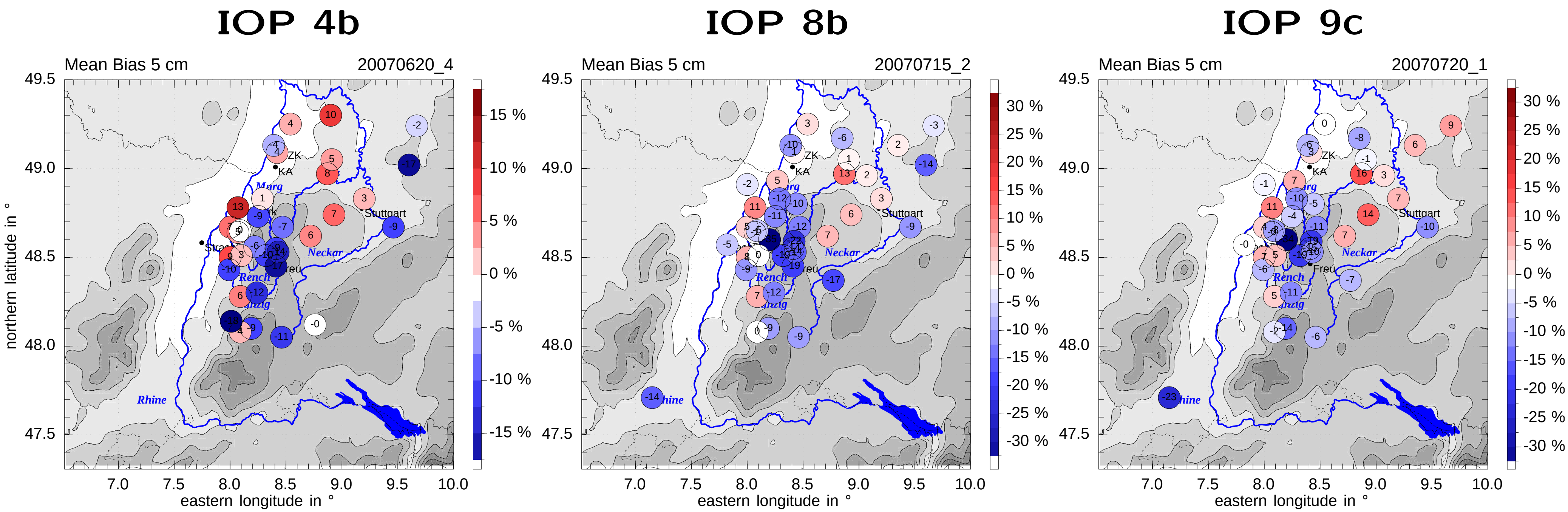

- large differences between measured and simulated soil moisture
- simulated soil moisture in Northern Black Forest systematically too low

What is the impact of reduced/increased soil moisture on convective processes in the model?

Sensitivity studies with reduced and increased soil moisture (± 25/50%)

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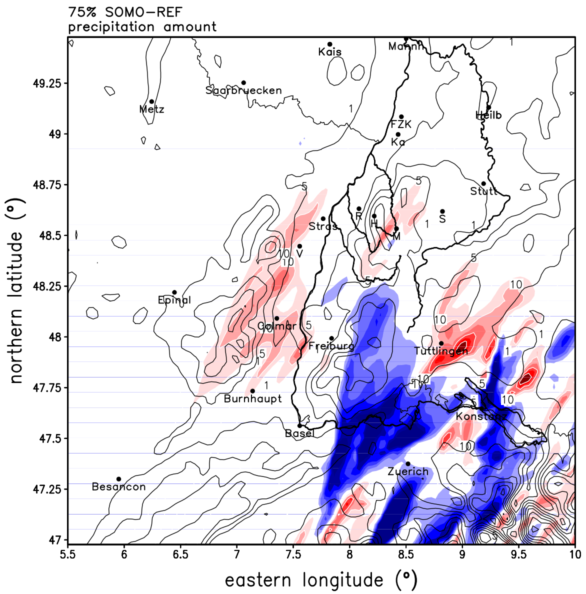
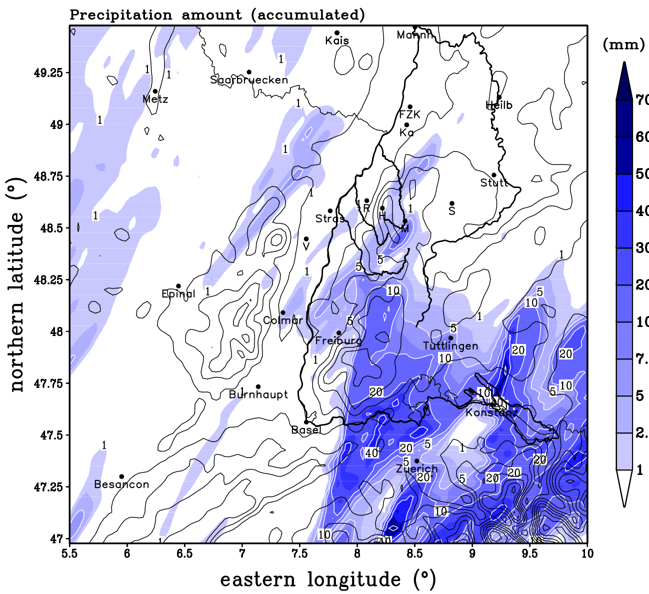
IOP 4b: June 20th



75% SOMO - REF



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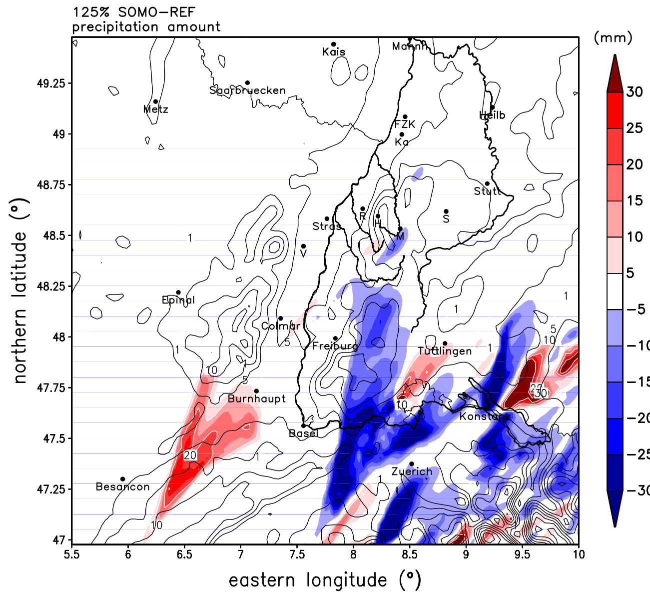

125% SOMO - REF

- RED: more precip. in Vosges, Northern Black F., Swabian Jura (+15 mm)
- INC: +25 mm in Jura mountains
- Basel-Constance: -25 mm

⟹ Soil moisture can have a significant influence on convective precipitation.

Energy Balance and Convective Indices (IOP 8b, average over COPS domain)

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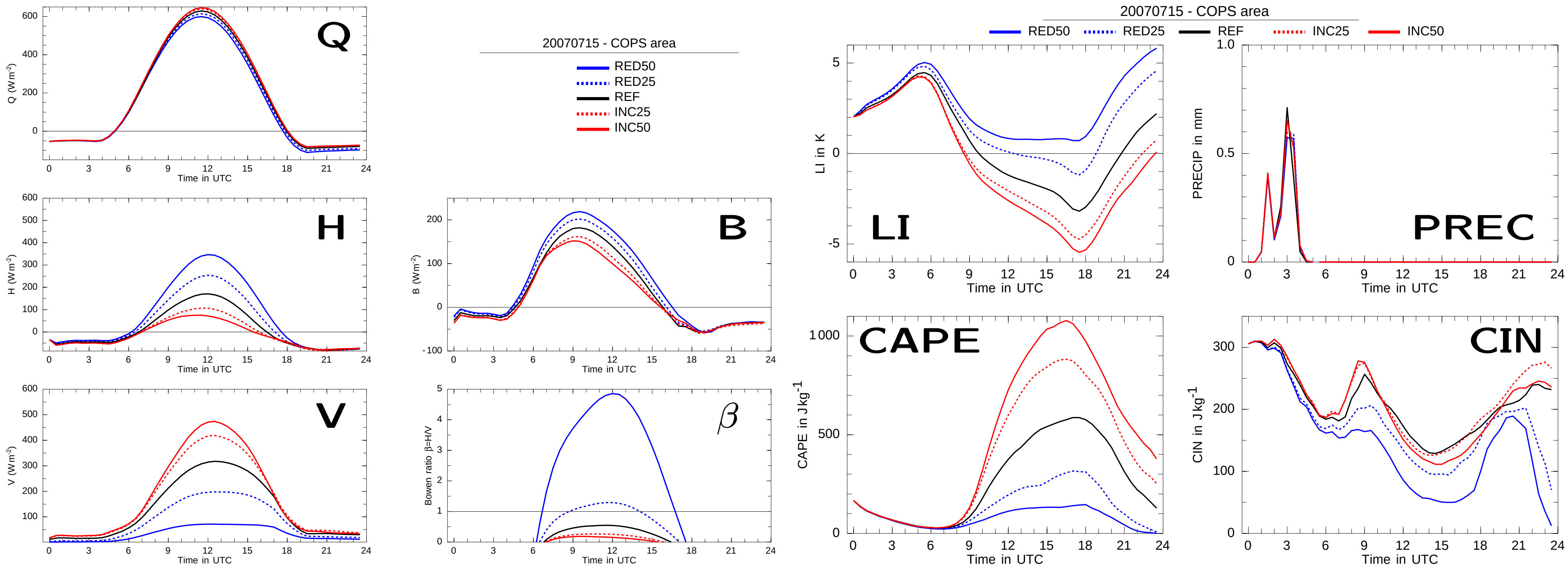
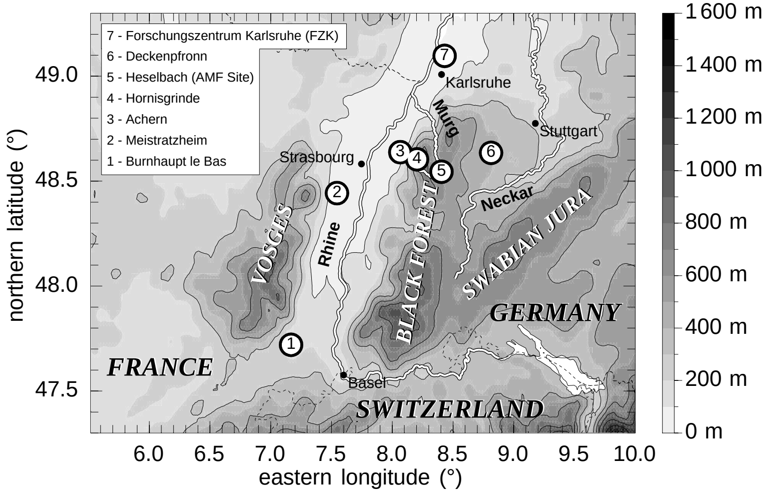


- low impact on net radiation
- increase of soil moisture:
  - → increase V, decrease H + Bowen-ratio β
  - → increase CAPE (doubled)
  - → CIN remains more or less constant
  - → decrease LI
- reduction of soil moisture:
  - → decrease CAPE
  - → decrease CIN
- no deep convection

Analysis of model grid points of COPS radiosondes

- Version 4.0
- hor. grid resolution 2.8 km (deep convection not parameterized)
- 6-class graupel scheme for microphysics
- 2-time level Runge-Kutta method for dynamics
- Initial and hourly boundary data: COSMO-EU forecast, initial time 0 UTC
- 5 IOPs: 4b, 8b, 9c, 14a, 15a with mid-tropospheric and PBL-forcing (SOMO $\pm$ 25/50%)

$\Longrightarrow$ analysis of near-surface variables, condensation levels, and convective indices



Deviation of 24 h-mean values of wet/dry sensitivity exp. from reference run

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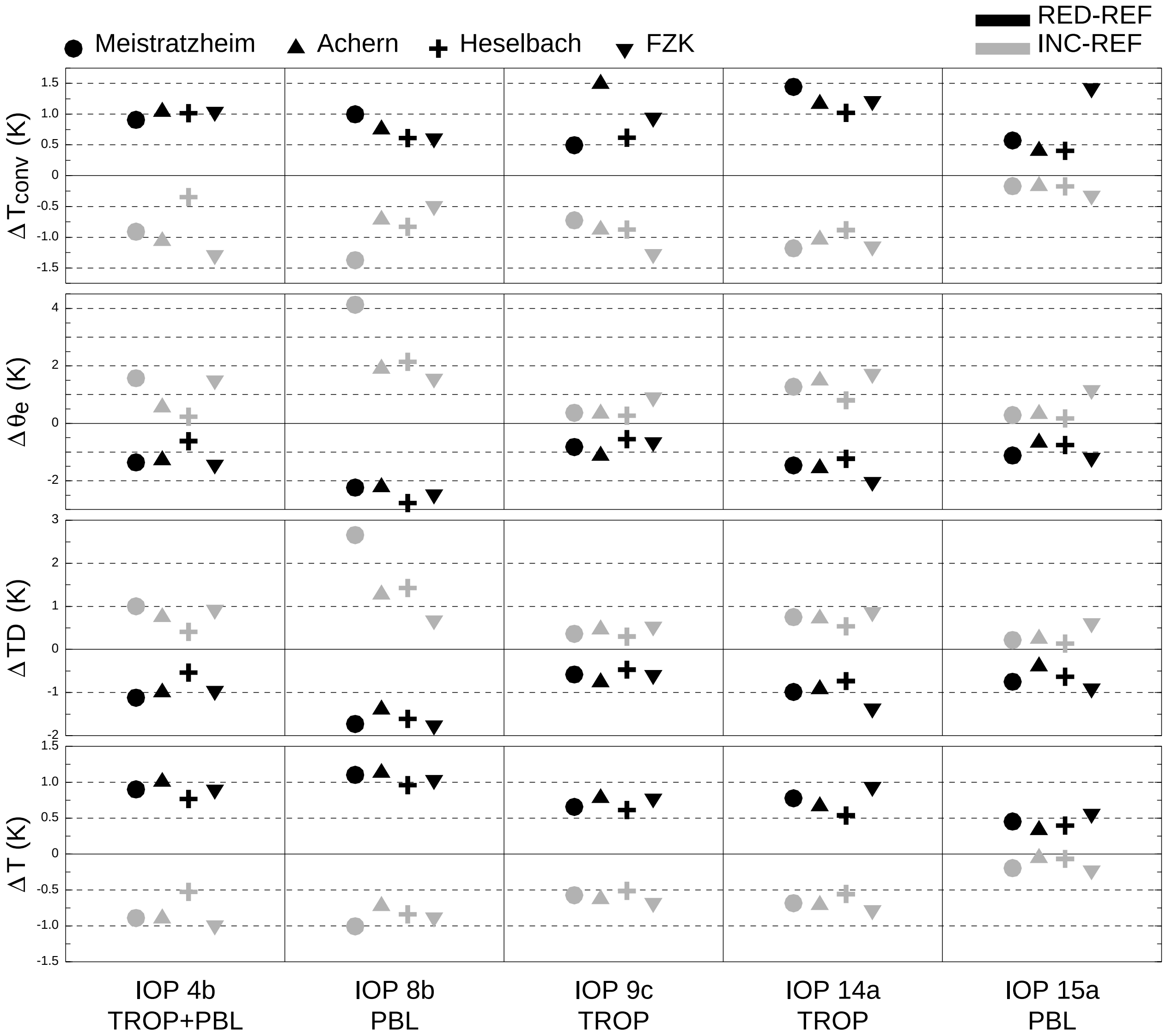

Soil moisture shows

- negative relationship with near-surface temperature and convective temperature
- positive relationship with near-surface dewpoint temperature and equiv. pot. temperature

Deviation of 24 h-mean values of wet/dry sensitivity exp. from reference run

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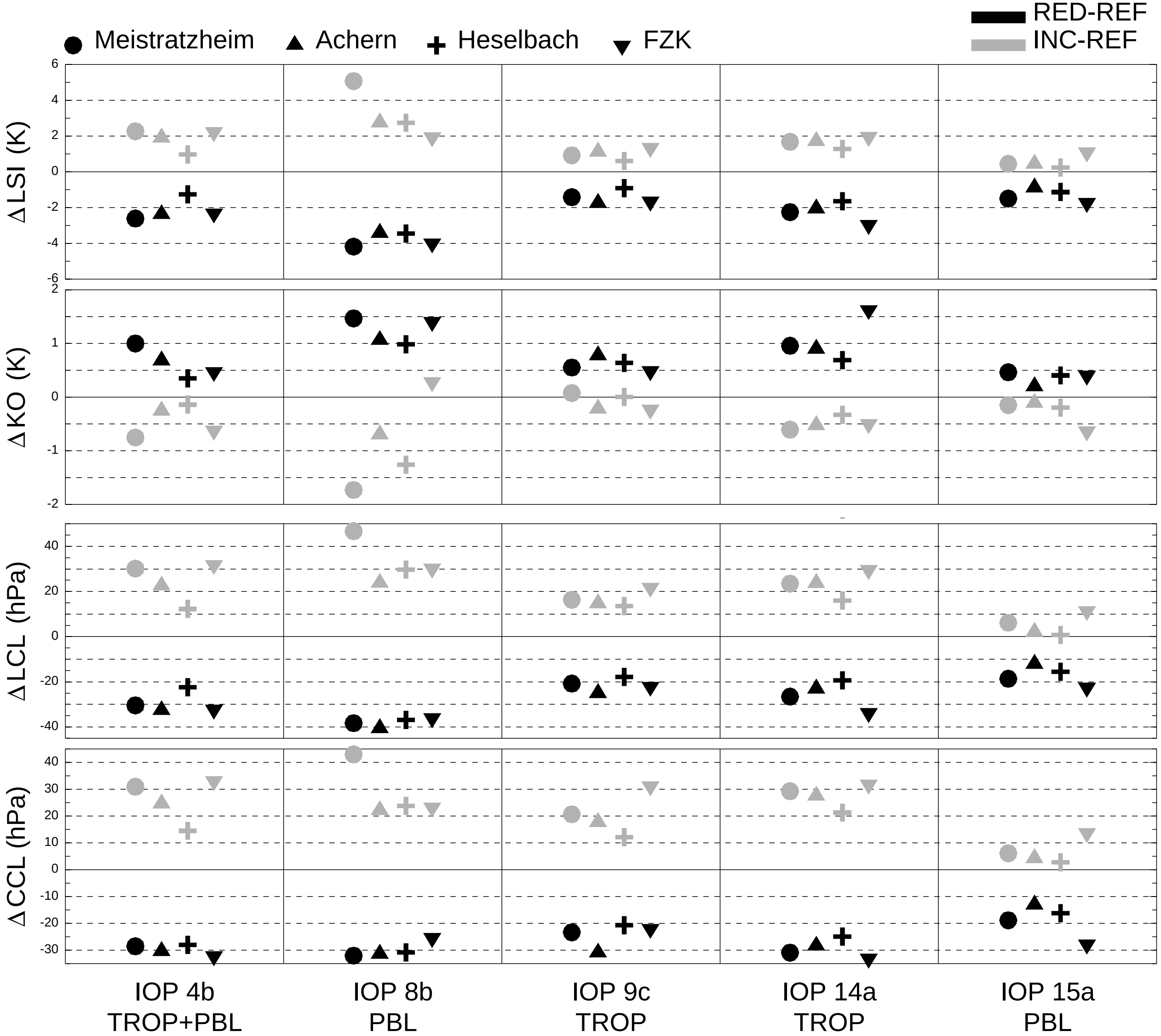

Soil moisture shows

- positive relationship with CCL and LCL (i.e. they are lower in the wet exp.)
- larger LSI-values and lower KO-index for inc. SoMo $\Longrightarrow$ potential for thunderstorms is higher in the wet experiment
- findings independent on site location and forcing mechanism

Summary

- GME comparison (COPS-period)
  - astonishing good agreement for a number of stations
  - for most of the stations, site specific characteristics not resolved
  - generally too dry, tendency of amplification of this effect with depth
  - areal bias not dependent on averaged precipitation
- COSMO-DE comparison (3 IOPs)
  - large differences exist
  - Northern Black Forest systematically too dry
- individual calibration of soil moisture sensors still in preparation
- sensitivity studies with increased/reduced soil moisture:

  $\Longrightarrow$ large impact on convective indices and conv. precipitation
- results demonstrate the particular importance of accurate initial soil moisture fields in numerical weather prediction models
- Outlook? PhD/Post-Doc position still open!