

# Groundwater-landsurface-atmosphere simulations: An overview of experiences and results using TerrSysMP

M. Sulis<sup>1\*</sup>, P. Shrestha<sup>1</sup>, J. Keune<sup>1</sup>, F. Gaspar<sup>2</sup>  
K. Goergen<sup>2,3</sup>, C. Simmer<sup>1,3</sup>, and S. J. Kollet<sup>2,3</sup>

<sup>1</sup>Meteorological Institute, University of Bonn

<sup>2</sup>Institute for Bio- and Geosciences (Agrosphere, IBG-3), Research Centre Jülich

<sup>3</sup>Centre for High-Performance Scientific Computing in Terrestrial Systems (HPSC TerrSys), Geoverbund ABC/J, Jülich

Impact of Groundwater in Earth system Models

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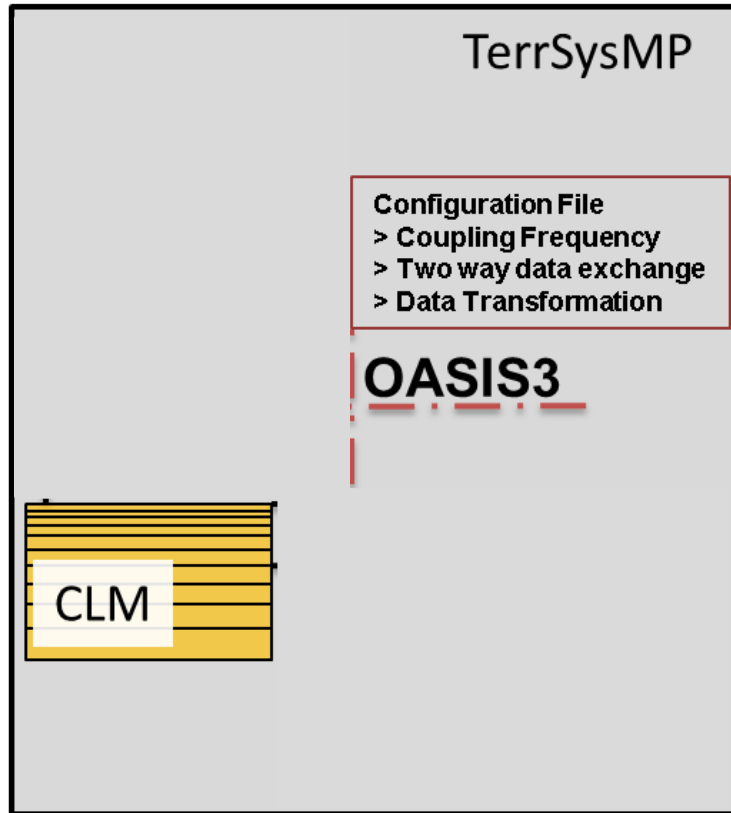
# Outline

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# Terrestrial Systems Modeling Platform (TerrSysMP)<sup>1</sup>

## ■ Model components



TerrSysMP schematic

### COSMO

Convection permitting configuration (COSMO-DE) (Baldauf et al. 2011).

### CLM

Land surface scheme (Oleson et al. 2008).

### ParFlow

Integrated surface-subsurface flow model with terrain following coordinates (Kollet and Maxwell, 2006; Maxwell, 2012).

### OASIS3

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### OASIS-MCT

External coupler with multiple executable approach (Valcke 2013).

<sup>1</sup>P. Shrestha, M. Sulis, M. Masbou, S. Kollet, and C. Simmer, MWR, 2014

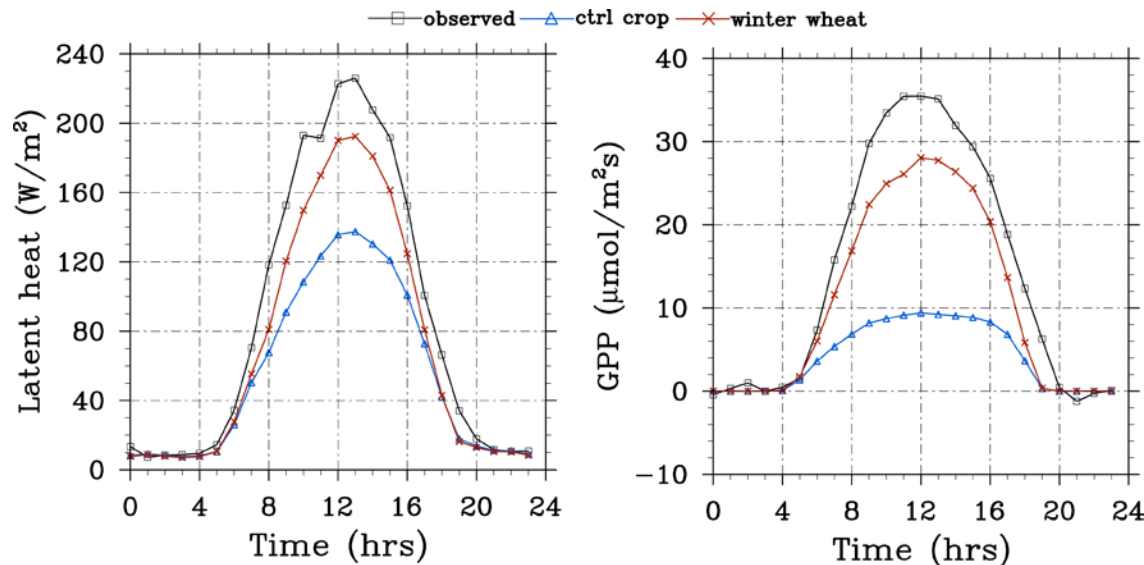
# Terrestrial Systems Modeling Platform (TerrSysMP)

## ■ Improved scientific parameterizations<sup>1</sup>

Comprehensive field measurements of optical properties, photosynthesis characteristics, and nutrient balances →



Estimation of key physiological parameters for the PFTs



Monthly averaged diurnal cycle (June 2011) of LE and GPP at Selhausen site.



Examples of leaf-gas exchange (top) and canopy chamber measurements (bottom) for the sugar beet (top) and winter wheat crop (bottom).

<sup>1</sup>M. Sulis, M. Langensiepen, P. Shrestha, A. Schickling, C. Simmer, and S. J. Kollet, JHM, 2015

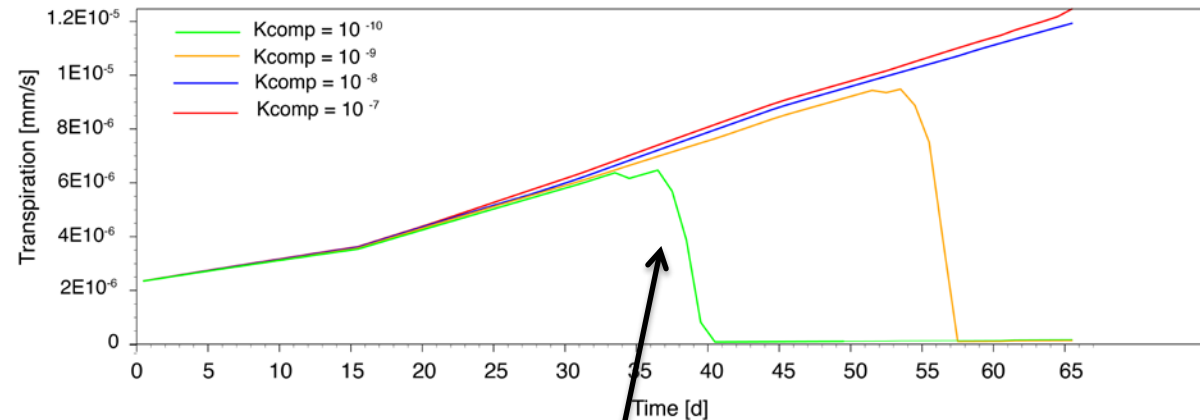
# Terrestrial Systems Modeling Platform (TerrSysMP)

## ■ Improved scientific parameterizations

Compensatory RWU model based on the upscaling of the root system hydraulic architecture



Development of a field rhizotron facility that allows a quasi-non-invasive monitoring of root growth and root zone processes.



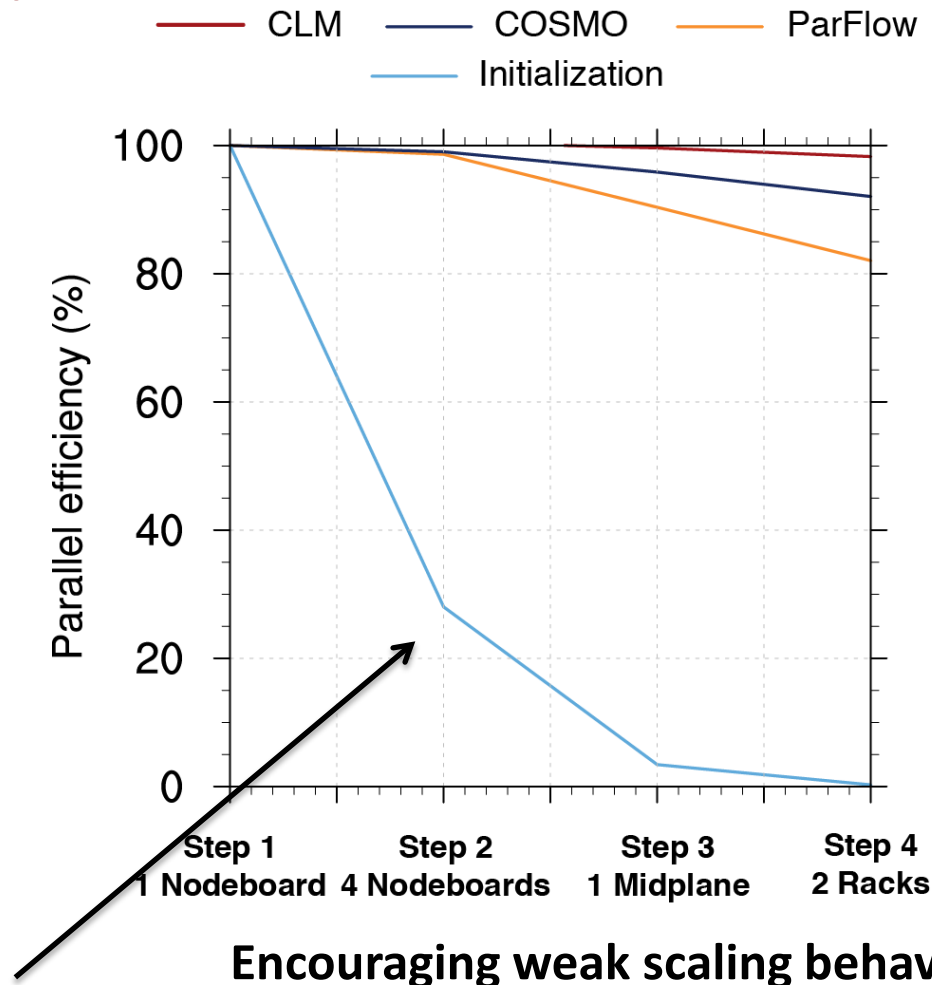
**Decreasing the compensatory effect the plant stress starts earlier**



Rhizotron facility in Selhausen developed and maintained by IBG3-Research Centre Juelich.

# Terrestrial Systems Modeling Platform (TerrSysMP)

## ■ HPC applications<sup>1</sup>



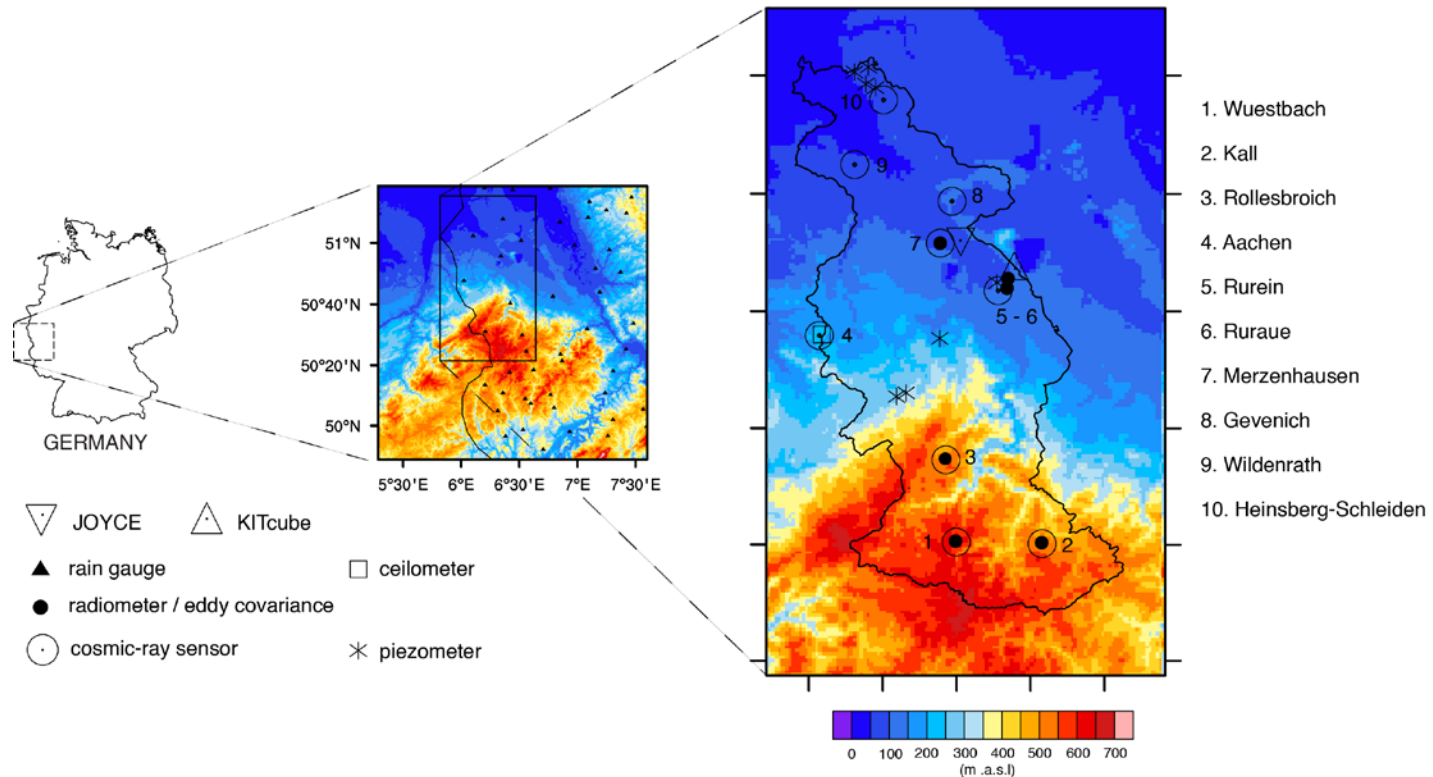
- Idealized test case
- 3 h simulation time
- 1 km COS
- 0.5 km CLM, PFL
- Weak scaling
- Optimally balanced
- Increase of domain size by factor of 4 (64x overall wrt our unit size)
- No I/O for largest runs

**Initialization bottleneck removed updating the CLM version**

<sup>1</sup>F. Gaspar, K. Goergen, P. Shrestha, M. Sulis, J. Rihani, M. Geimer, and S. J. Kollet, GMD, 2014.

# Research topics

- Assessing seasonal diagnostic improvements of atmospheric simulations with detailed subsurface representation<sup>1</sup>

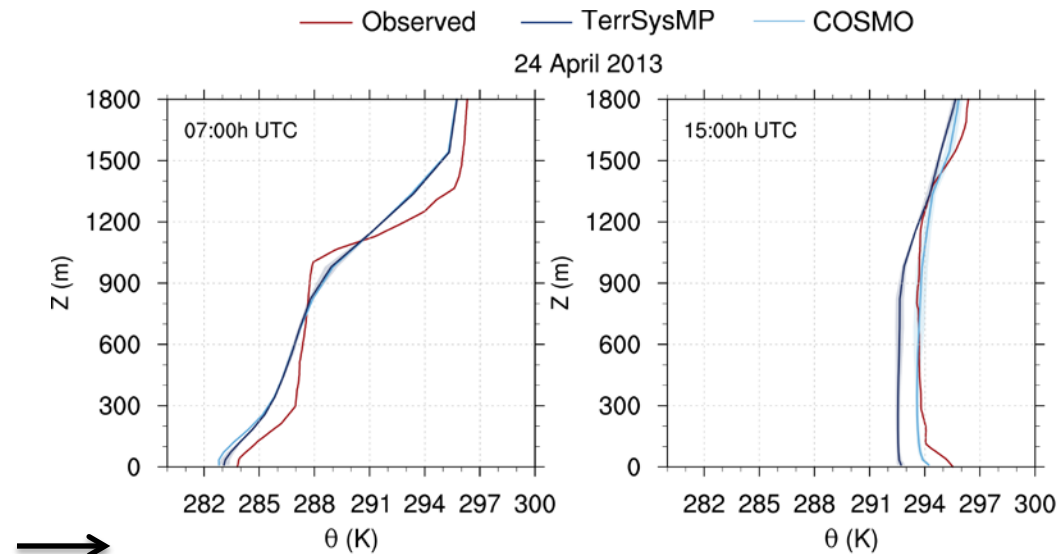


Observed states (e.g., vertical profiles of atmospheric temperature and humidity), fluxes (e.g., eddy covariance), and diagnostics (e.g., ABL height) across the subsurface, land surface, and atmosphere compartments of the terrestrial system.

<sup>1</sup>M. Sulis, P. Shrestha, J. Keune, C. Simmer, and S. J. Kollet, manuscript in preparation.

# Research topics

Analysis of vertical profiles of potential temperature at two “contrasting” days



“DRY”

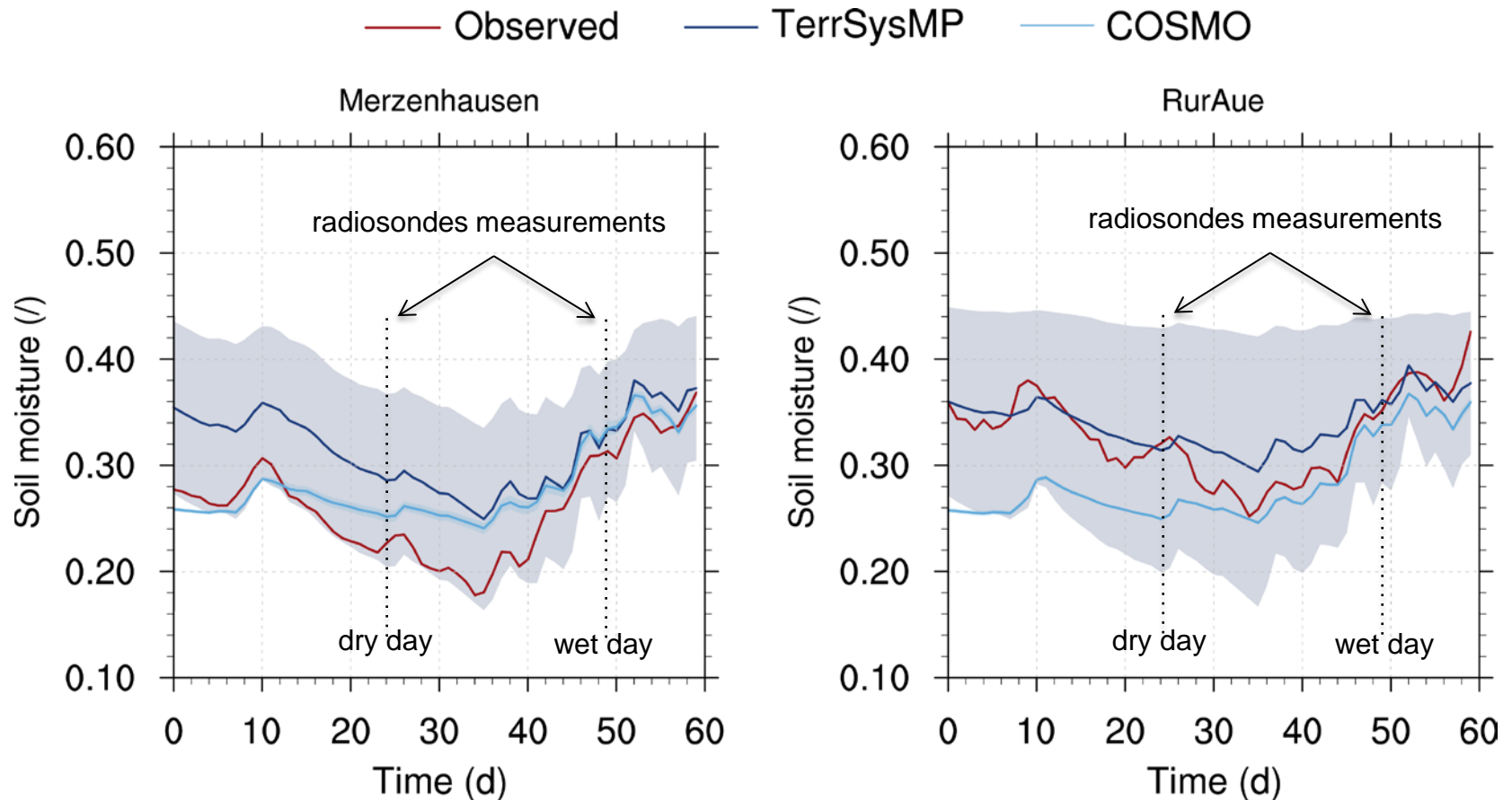
“DECOUPLED”

“COUPLED”



# Research topics

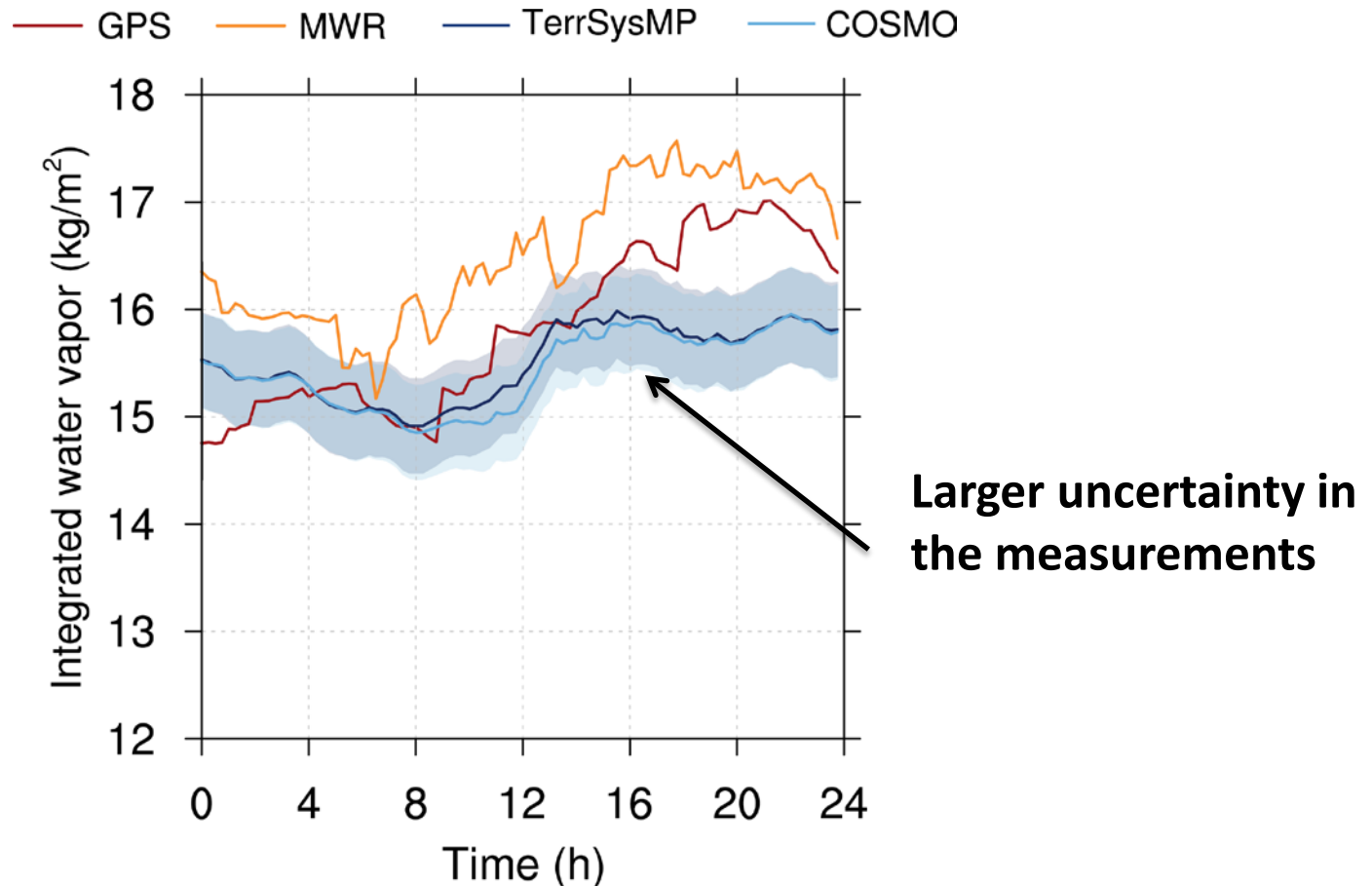
Analysis of soil moisture temporal evolution:



**Larger spatial variability introduced by coarse resolution of the river network in TerrSysMP is reflected in the cold bias in the atmosphere**

# Research topics

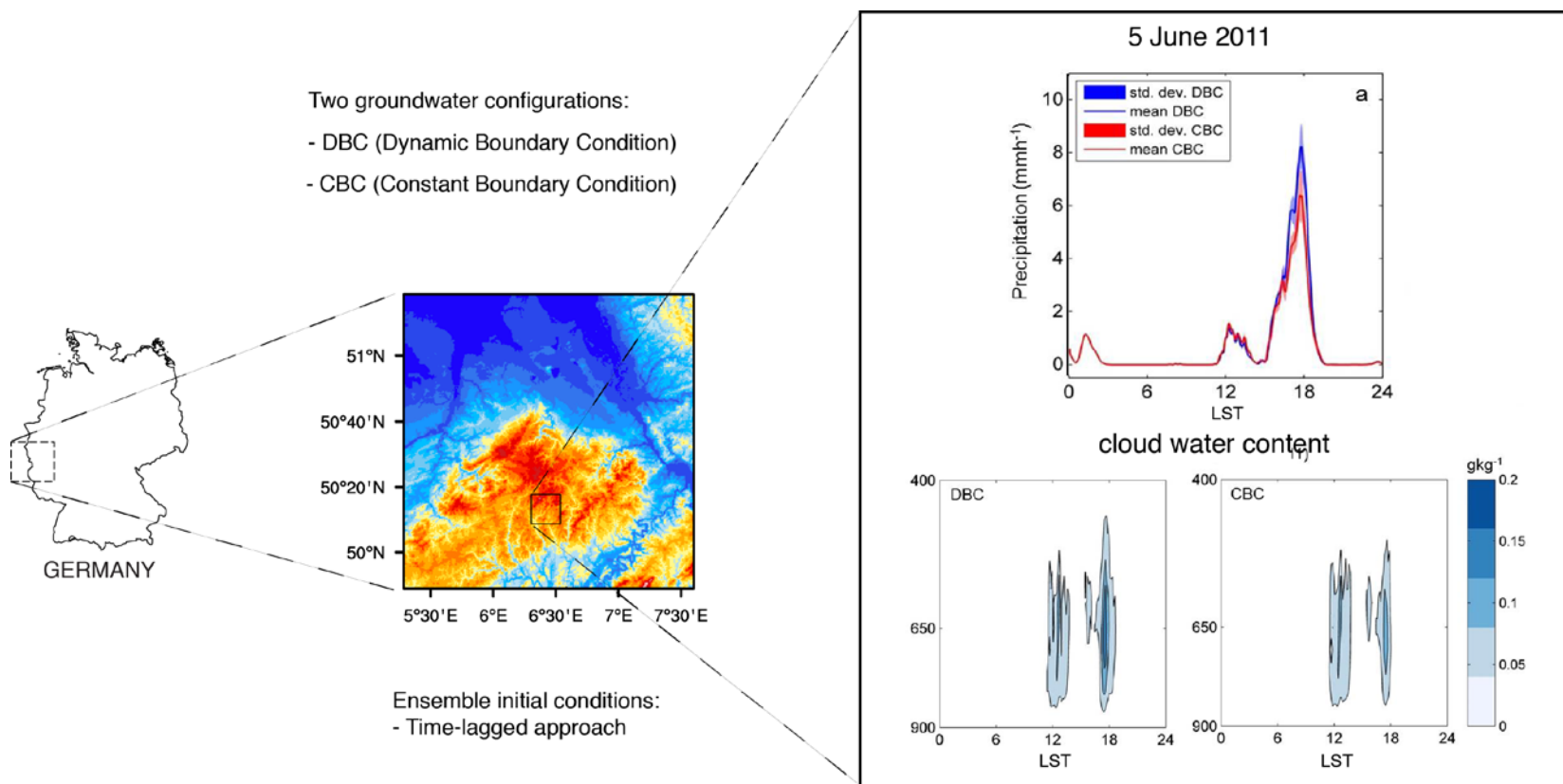
## Analysis of integrated water vapor:



**Response is consistent with the lateral boundary conditions**

# Research topics

- Investigating the groundwater-atmosphere connection under convective conditions<sup>1</sup>

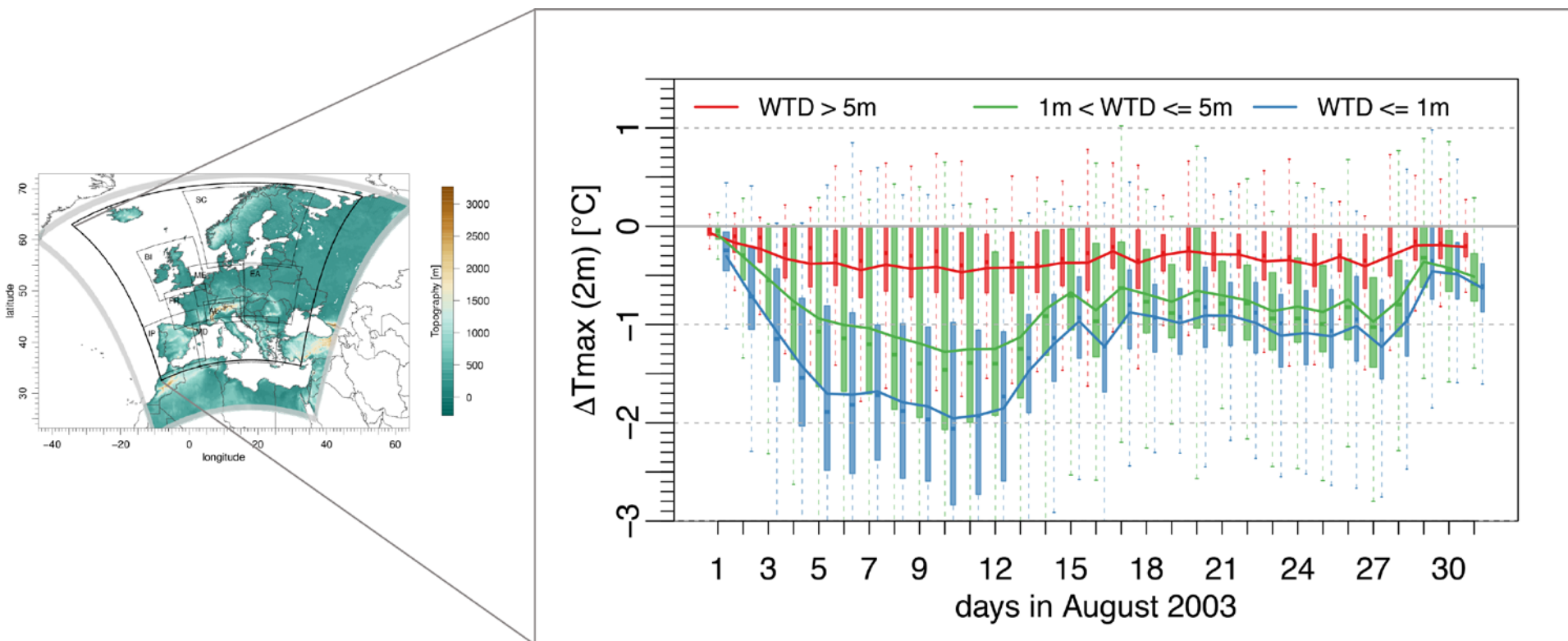


**Differences in the lower boundary conditions (i.e., groundwater representation) propagate into the atmosphere producing different precipitation**

<sup>1</sup>M. Rahman, M. Sulis, and S. J. Kollet, AWR, 2015.

# Research topics

- Investigating the groundwater-atmosphere feedback during the European heat wave in 2003<sup>1</sup>

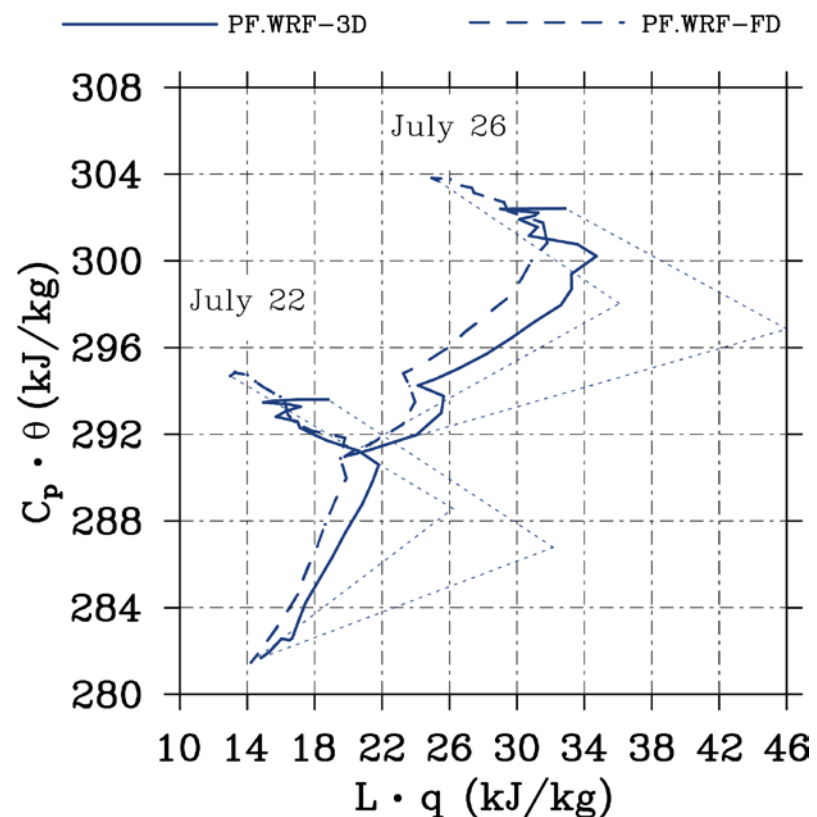
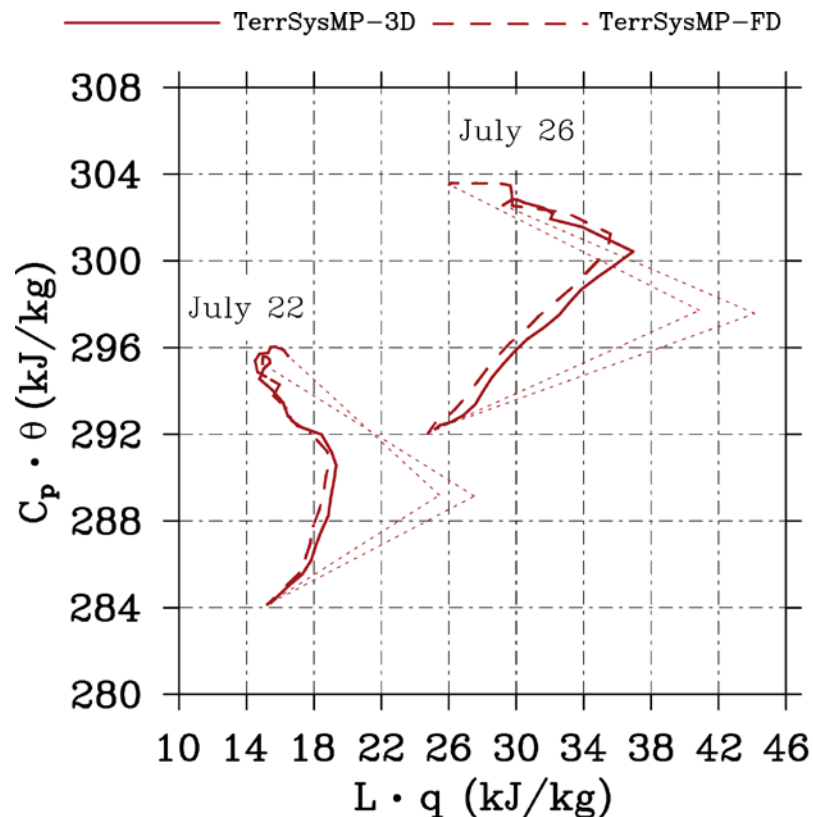


**Impact of groundwater configuration (3D - FD) is reflected on the maximum T2m especially for shallow water table conditions**

<sup>1</sup>J. Keune, F. Gaspar, K. Goergen, A. Hense, P. Shrestha, M. Sulis, and S. J. Kollet, JGR, under review.

# Research topics

- Influence of groundwater dynamics on the ABL heat and moisture budgets using the mixing diagram approach<sup>1</sup>



**Soil moisture differences induced by two LBCs evolve differently according to different land surface-atmosphere parameterizations**

<sup>1</sup>M. Sulis, J. Williams, P. Shrestha, M. Diederich, C. Simmer, S. J. Kollet, and R. M. Maxwell, JHM, under review

# Outlook

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***Subsurface-land surface-atmosphere simulations provide a holistic and physically-based view of the energy, water, and matter cycle across a range of spatial and temporal scales.***

New opportunities:

- Powerful tools to test scientific hypothesis.
- Integrated assessment of the water cycle for long-term climate projections and short- and medium-term weather/hydrological forecasts.
- Synergies in the development of monitoring networks (e.g., multiple co-located measurements) that cover the SVA continuum.

Grand challenges:

- Improved treatment of uncertainty in characterizing the multiple compartments of the terrestrial systems.
  - Routinely consideration of anthropogenic forces.
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# Acknowledgments

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SFB/TR32 Patterns in Soil-Vegetation-Atmosphere Systems: Monitoring, Modeling and Data Assimilation project ([www.tr32.de](http://www.tr32.de)) funded by the Deutsche Forschungsgemeinschaft (DFG).

The observational dataset is a synthesis of intensive field campaigns and continuous monitoring operated by TR32, the Terrestrial Environmental Observatories (TERENO), the Jülich Observatory for Cloud Evolution (JOYCE), and the High Definition Clouds and Precipitation for advancing Climate Prediction (HD(CP)<sup>2</sup>) project.

Computing time (project HBN33) granted by the John von Neumann Institute for Computing (NIC) and provided on the supercomputer JURECA at Jülich Supercomputing Centre (JSC).

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