Terrestrial systems numerical simulations in the framework of Jülich Research on Exascale Cluster Architectures (JURECA)

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1 Introduction

The Terrestrial Systems Modeling Platform [Shrestha et al. 2014] with upgrade to OASIS3-MCT coupler for continental scale hyper-resolution simulations at massively parallel supercomputing environments (Gasper et al. 2014) has aided in advancing our understanding of groundwater-atmosphere connections [Rahman et al. 2015; Keune et al. 2016; Sulis et al. 2017; Poll et al. 2017; Uebel and Bott 2018; Shrestha et al. 2018]. In addition, the development of TerrSysMP interface with data assimilation (DA) tools which maintains the modularity of the platform has further opened doors to improve model predictions, investigate joint state parameter updates and model structural errors.

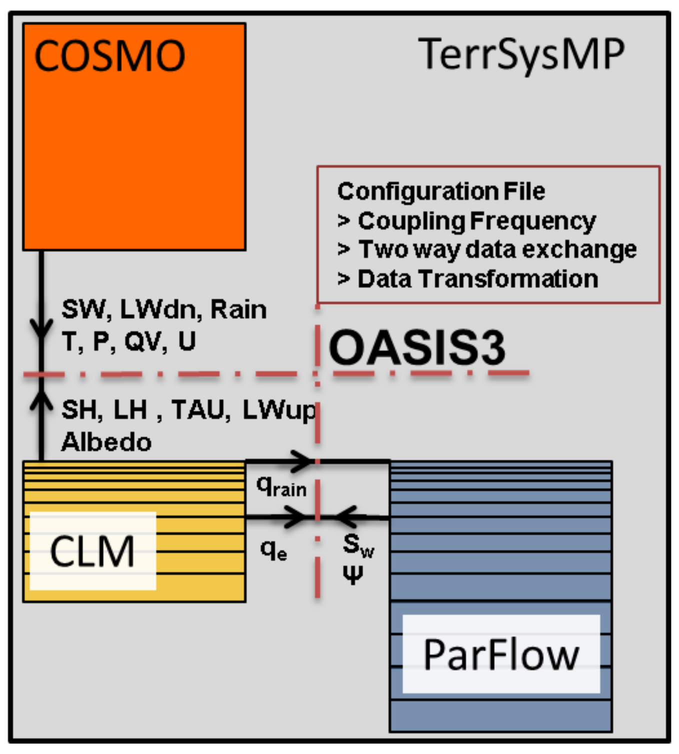


Figure 1: Schematic of TerrSysMP (*Source: Shrestha et al. 2014*)

In this work, we briefly report on simulations with TerrSysMP performed in the JURECA machine over the NRW domain (Figure 2) to investigate:

- Groundwater modulation of atmosphere under seasonal scales
- Effect of grid resolution on pathways of evapotranspiration
- Atmospheric boundary layer (ABL) schemes for hyper-resolution runs
- Weakly coupled data assimilation with TerrSysMP-DART interface

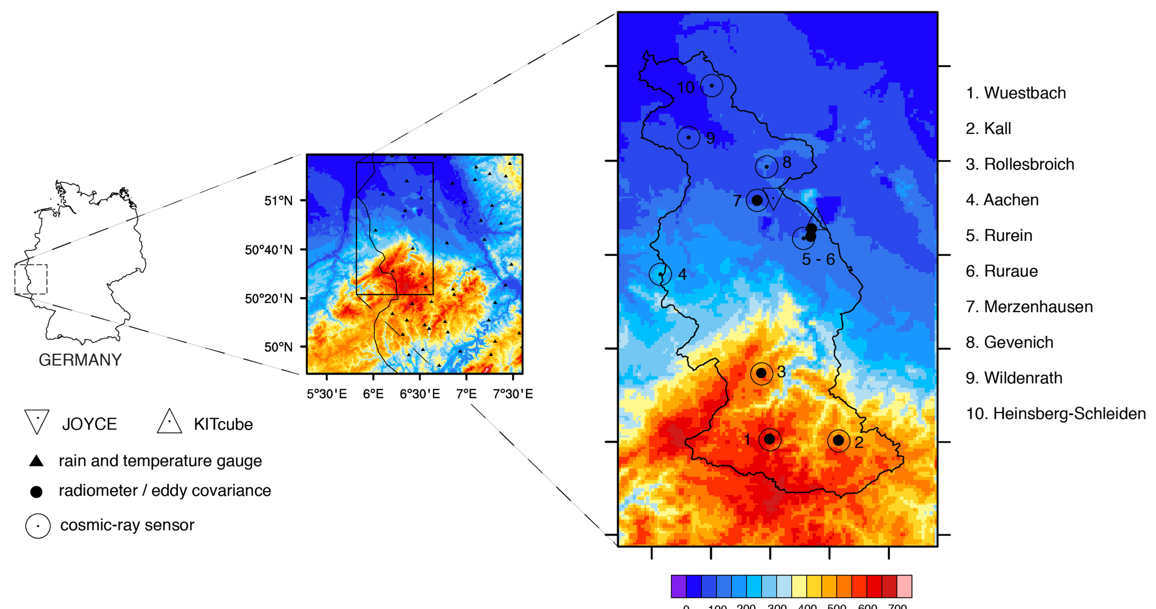


Figure 2 : Topographic map of the study area showing the Rur catchment including measurement sites.

2 Groundwater Modulation of Atmosphere under Seasonal Scales

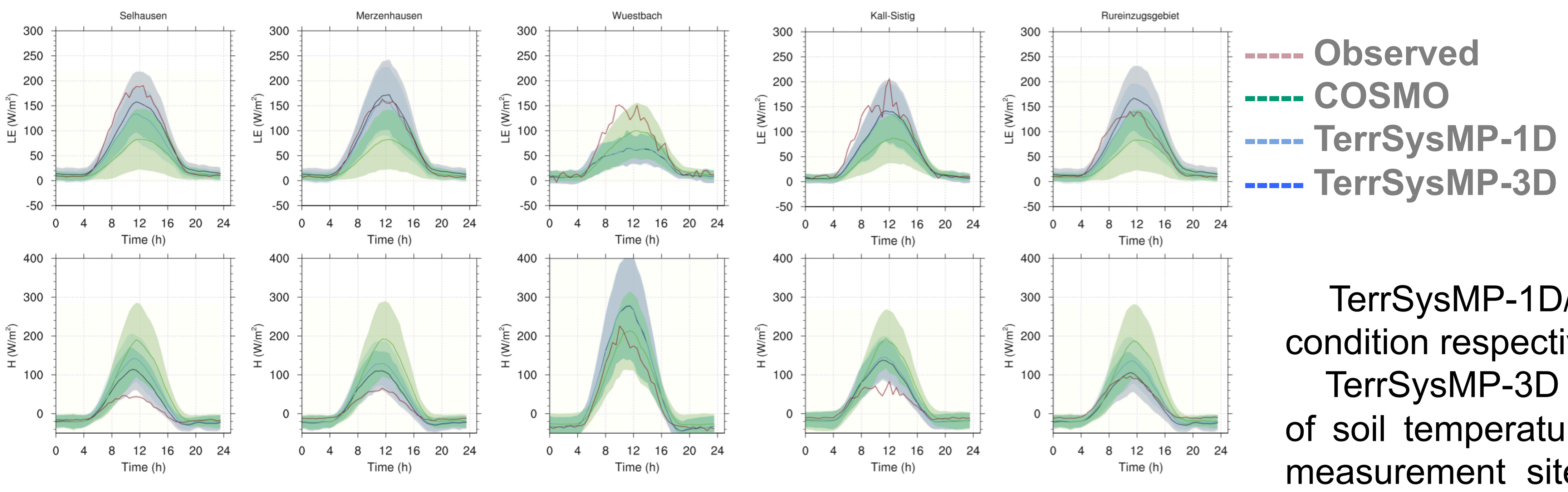


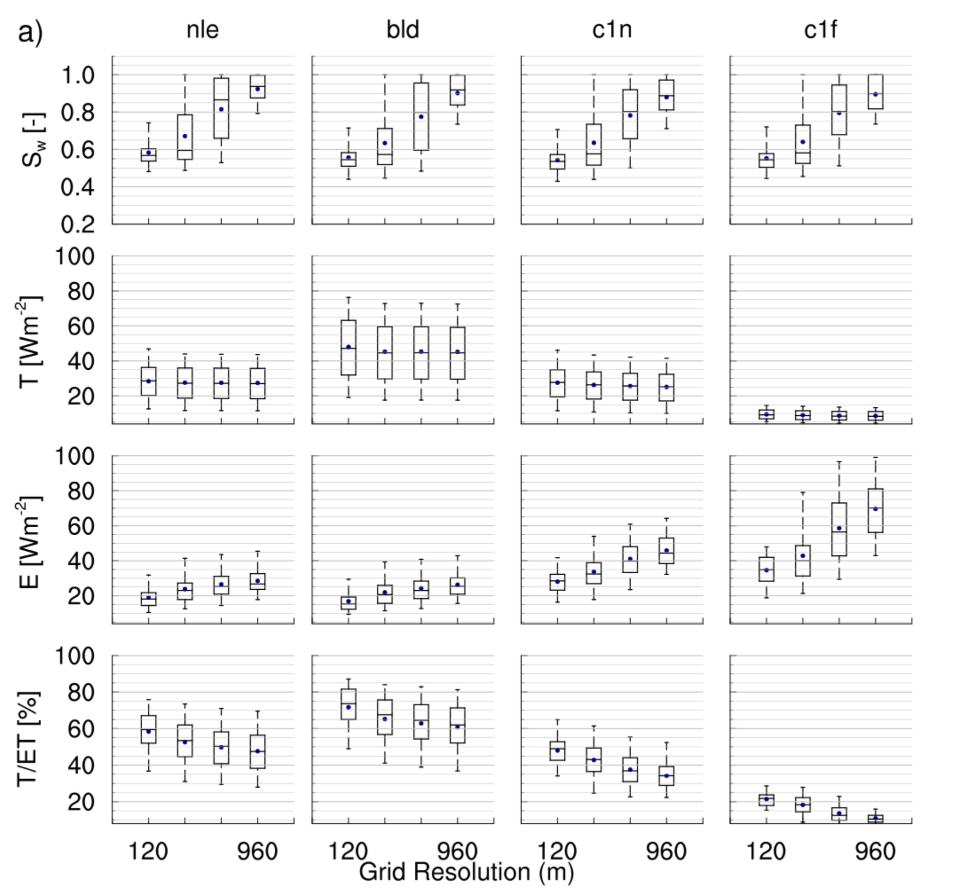
Figure 3: Average diurnal cycle of the latent (LE) and sensible (H) heat fluxes. Shaded areas indicate the temporal variability (±σ) of models simulations while the solid lines indicate the spatial average around (± 1 km) the measurement point. (*Source Sulis et al. 2018*, in review JGR-A)

3 sets of seasonal scale simulations were conducted using COSMO, TerrSysMP-1D and TerrSysMP-3D over the NRW domain (Fig. 2). Additionally, the hydrological model was initialized using the soil-vegetation states from a spinup run (2008 to 2015).

TerrSysMP-1D/3D uses free gravity drainage and no-flow bottom boundary condition respectively for the groundwater model.

TerrSysMP-3D was generally found to better match the average diurnal cycle of soil temperature, soil moisture and surface fluxes (Fig. 3) in most of the measurement sites. However, no clear improvements (or deteriorations) in predicted daily cumulative precipitation and minimum/maximum temperature were found for TerrSysMP(1D/3D) compared to COSMO for this particular study.

3 Grid Resolution Effects on Pathways of Evapotranspiration



Hyrological component of TerrSysMP was used in 16 sets of simulation for 6 year period. The setup included dry and wet year with/without accounting antecedent conditions at 4 different grid resolutions. Coarsening of the grid resolution decreased T/ET ratio by about 5 % and 8 % for dry and wet year respectively.

Figure 4: Scaling behavior of relative soil moisture (Sw), canopy transpiration (T), evaporation (E) and the ratio of transpiration to total evapotranspiration (T/ET) with grid resolution for wet year (2009). (*Source : Shrestha et al. 2018*)

4 ABL schemes for Hyper-resolution Runs

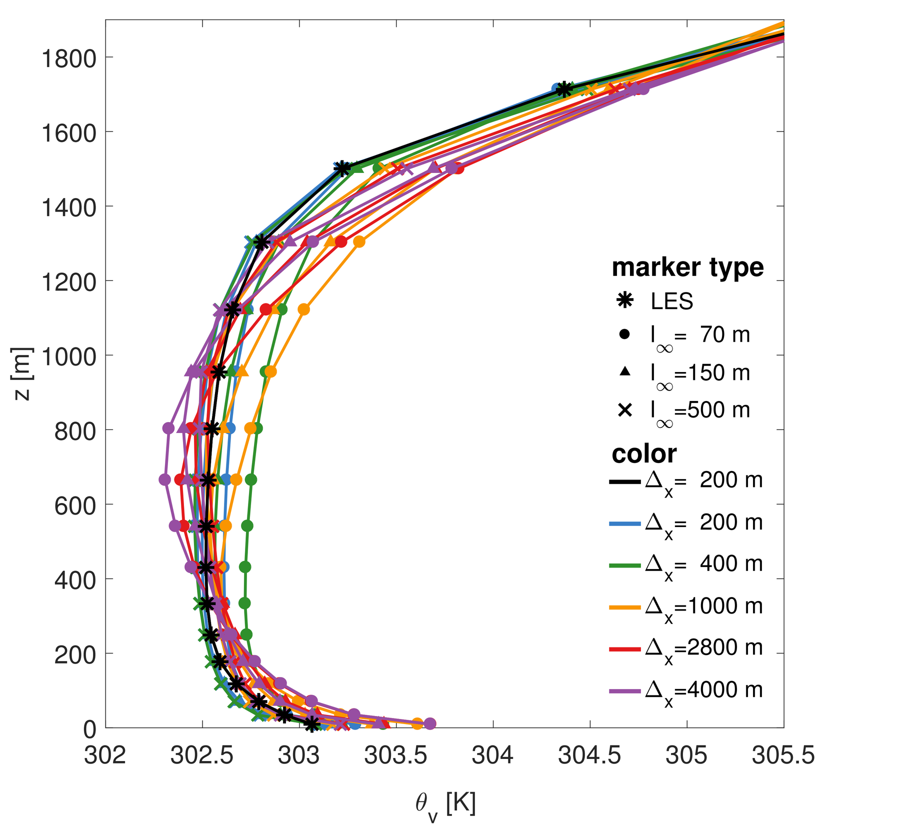


Figure 5: Domain averaged vertical profile of virtual potential temperature on 25th of July 2012 at 13: 00 UTC. (*Source : Poll et al. 2017*)

32 sets of idealized and 17 sets of real data runs were conducted with TerrSysMP over diurnal scales. The setup used large eddy simulation (benchmark runs) and other simulations (1D ABL scheme) with varying grid resolution and turbulent mixing length scale. Turbulent mixing length scale used in the ABL scheme can be tuned to suppress model generated convectively induced secondary circulations while the non-resolved turbulence dealt with by the ABL scheme effectively propagates the surface fluxes into the ABL and sustains reasonable ABL profiles.

5 Weakly coupled data assimilation (WCDA) with TerrSysMP-DART interface

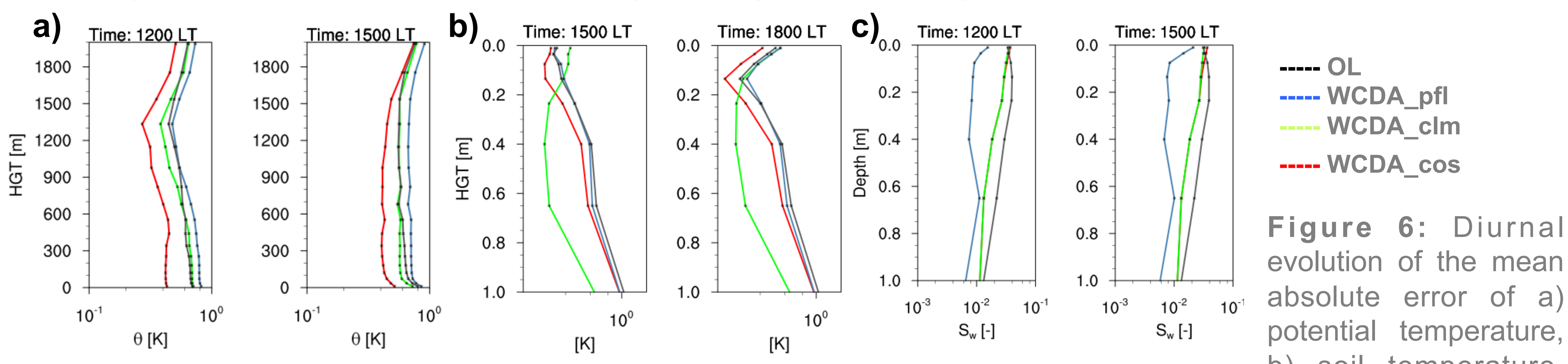


Figure 6: Diurnal evolution of the mean absolute error of a) potential temperature, b) soil temperature, and c) soil moisture for the ensemble means. The vertical profiles are temporally averaged for the entire period of simulation.

WCDA experiment is conducted with a semi-idealized setup with 48 ensemble members. Model uncertainty is generated using random error method, prescribed variability and spatially correlated method. Using perfect model observations, DA for respective component models was conducted at 0000 UTC everyday for 10 different locations .These runs show that the assimilation of model states only improve the specific model components.

6 Outlook

New TerrSysMP simulations at JSC will focus on exploitation of polarimetric radar retrievals for validation and extension of the WCDA experiment for idealized and real data runs.

Publications:

Poll, S., Shrestha, P., & Simmer, C. (2017). Modelling convectively induced secondary circulations in the terra incognita with TerrSysMP, QJRMS.

Shrestha, P., Sulis, M., Simmer, C., & Kollet, S. (2018). Effects of horizontal grid resolution on evapotranspiration partitioning using TerrSysMP, J. Hydro.

Sulis, M., J. Keune, P. Shrestha, C. Simmer and S. Kollet (2018). Quantifying the impact of subsurface-land surface physical processes on the predictive skill of subseasonal mesoscale atmospheric simulations (*submitted to JGR-A*)

Acknowledgements:

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