FOR 2131

Ensemble experiments with a coupled atmosphere-land-surface-subsurface model

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Motivation and Objectives

- Ensemble simulations of the atmosphere – land surface – subsurface system are performed for a one year period.
- The Simulations allow to detect the coupling between compartments of the terrestrial system (e.g., how does uncertainty of land surface conditions affect weather prediction).
- The creation of an initial ensemble is a first important step towards a data assimilation framework for coupled models.

Questions addressed

- How do perturbations of the subsurface and land surface influence processes in the atmosphere?
- What makes an appropriate initial ensemble for a coupled data assimilation system?

General model setup

The model **TerrSysMP** (Shrestha et al 2014) consists of three component models:

COSMO (Consortium for Small-scale Modeling)
- Non-hydrostatic local area atmospheric model
- Deep convection is not parameterized and resolved directly
- 50 vertical levels (terrain following hybrid coordinate)
- 2.8km horizontal resolution
- 98 x 109 gridpoints (rotated lat/lon grid)

CLM (Community Land Model, NCAR)
- Land surface model including energy processes in the soil
- Fixed plant functional type (PFT) and leaf area index(LAI)
- 10 vertical levels with increasing spacing with depth
- 800m horizontal resolution
- 267 x 302 gridpoints (regular lat/lon grid)

ParFlow
- 3D hydrological model with overland flow (kinematic wave)
- 50 vertical layers (top 10 layers identical to CLM)

The three components are coupled together with a coupling frequency of 900 seconds by the external coupler **OASIS3** using bilinear interpolation or distance weighted averages.

TerrSysMP-PDAF (Kurtz et al. 2016) is used to realize the Ensemble setup.

Specific Ensemble Setup

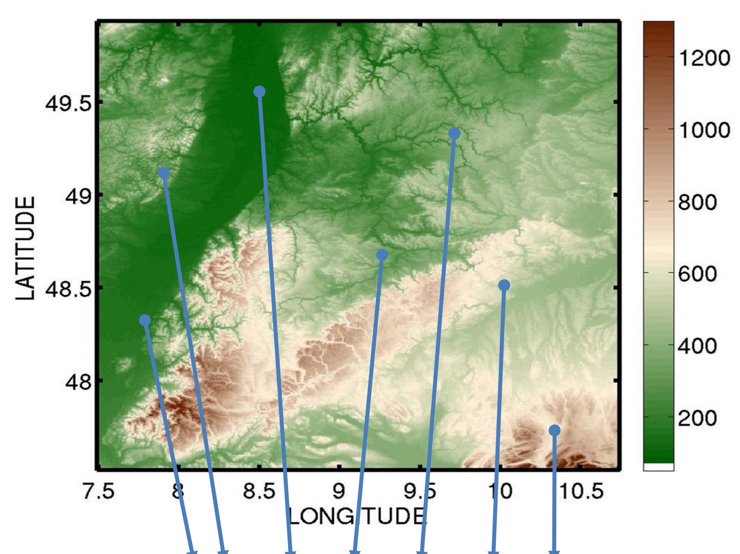
Basic setup: 32 ensemble members, 24 with only one parameter changed to investigate the sensitivity of the coupled system and 8 members with randomly combined changes to analyze the overall behavior and spread. In addition a reference simulation was performed with a setup identical to the high resolution virtual catchment simulation, from which observations will be taken for data assimilation.

COSMO: Variable lateral boundary forcing based on the COSMO-DE-EPS operational weather forecast ensemble of the German Weather Service (DWD). Parameterizations in COSMO follow the one of the driving EPS members (3,6,7,8,9,10,13 and 18).
CLM: Variation of the LAI values (-+ 25%) and yearly cycles (longer/shorter growing seasons) for the different PFTs, the land use map is not changed.
ParFlow: 8 different realizations of the soil map based on resampling of the soil map and parameters used for the high resolution catchment run.

The runs were performed on the IBM/BlueGeneQ system JUQUEEN at JSC. In total about 5M core-h have been used, 512 nodes (2x16 members per batch) at a time with a simulation time of 10 days per 8h of wallclock.

Project Overview

Virtual catchment simulation

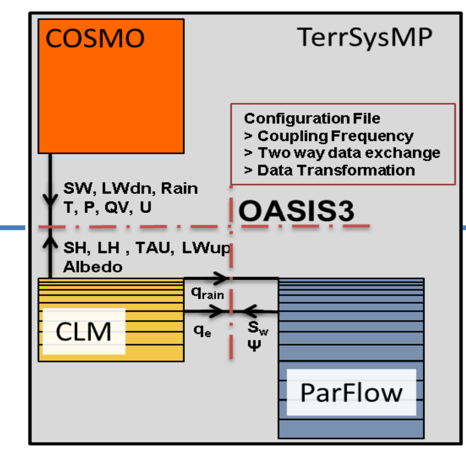


Observation Operators

$Y_{obs}=(y_1,y_2,\dots,y_k)$

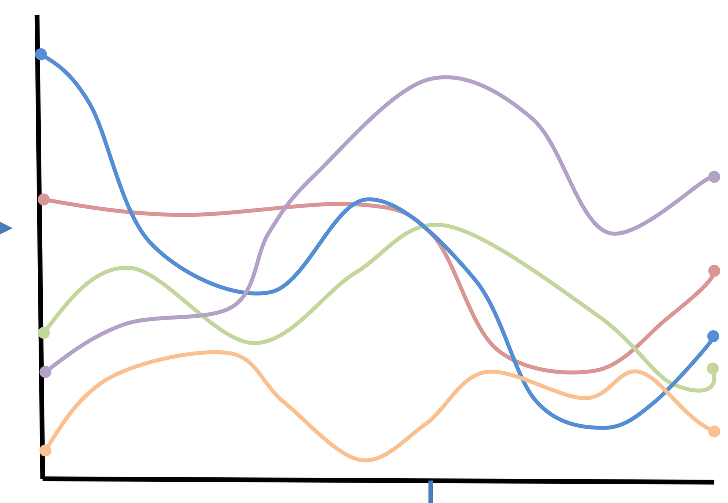
Observation operators are developed within the FOR2131 reseach unit. The developed DA methodology will be used in large joint experiments.

TerrSysMP



Shrestha et al. 2014

Free Ensemble



DA Experiments
- weakly coupled vs. strongly coupled
- assimilation of variables at different times/intervals according to their availability

DA Ensemble

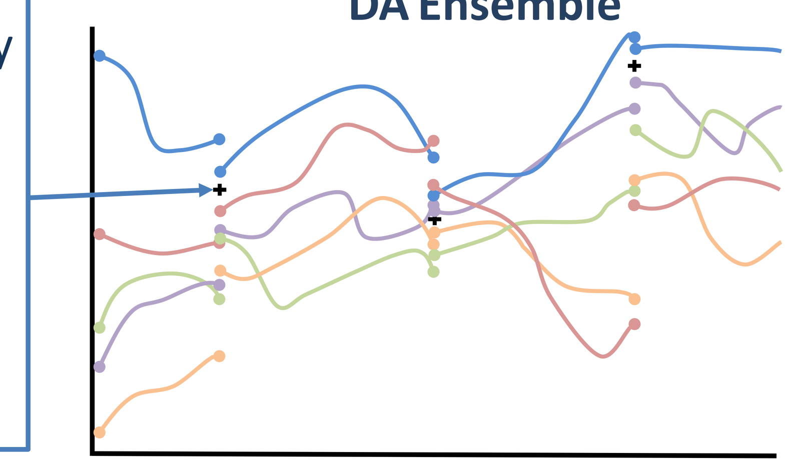
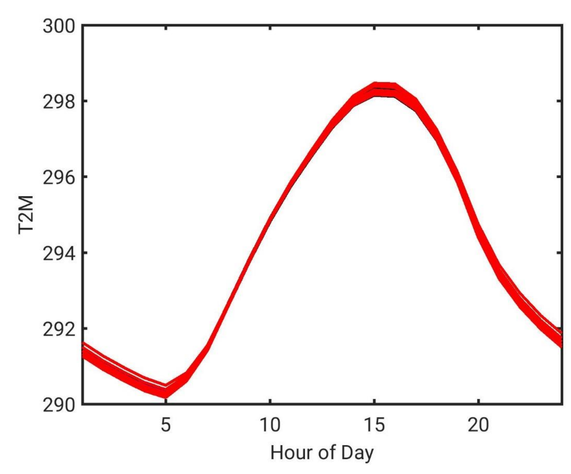


Figure 1: Methodology to develop a unified DA system for coupled terrestrial system models.

Here we focus on the red part – the free ensemble which is used to ensure the DA ensemble is of good quality.

Preliminary Results

Atmosphere:



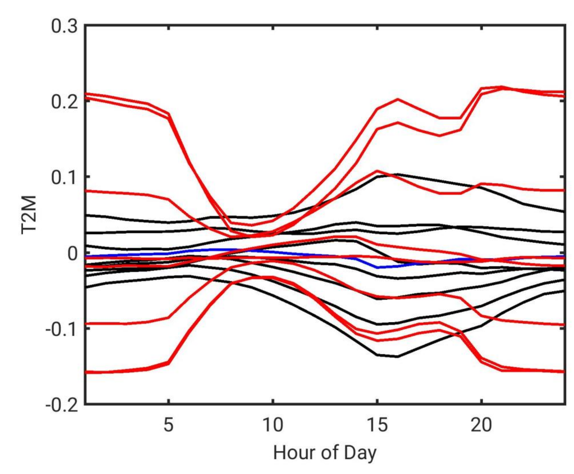
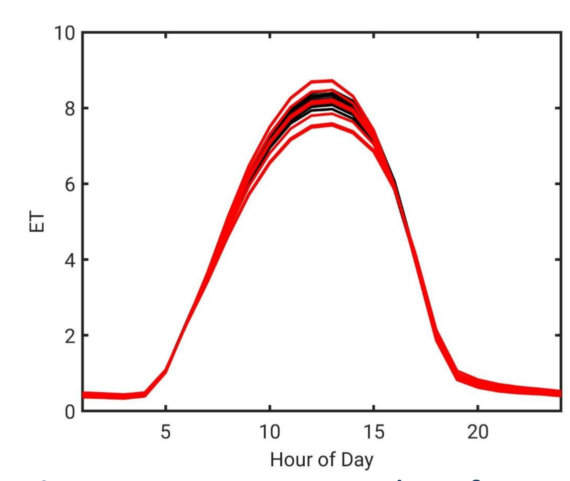


Figure 2: Average daily cycle of 2m Temperature [K] for July 2015 (left) and difference to the ensemble mean (right). Different land-covers are red, different soil setups black and the reference simulation is blue.

Land Surface:



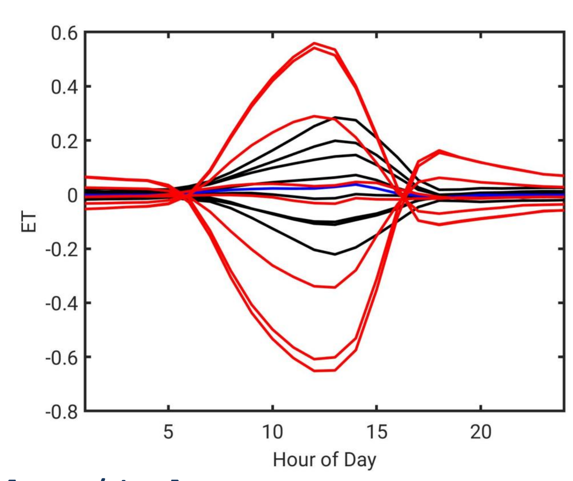
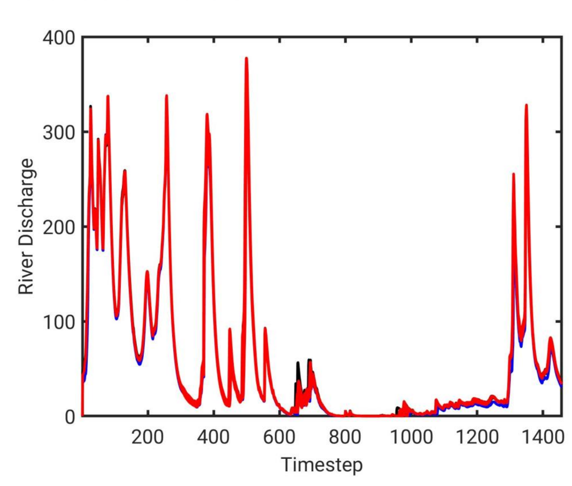


Figure 3: As Figure 1 but for Evapotranspiration [mm/day].

Subsurface:



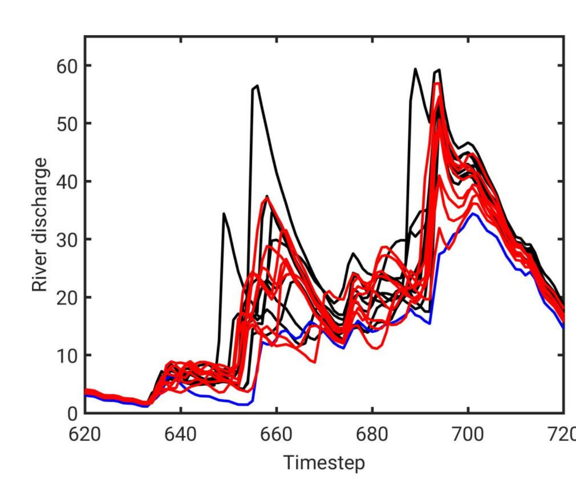


Figure 4: Time-series of river discharge at the Rockenau gauging station [m³/s] for the entire year 2015. The left figure shows a zoom into a time period where differences are particularly large.

- The spread of most variables is relatively low (< 0.4K for 2m Temperature for example), especially at night.
- Compartments directly affected by a change show a larger impact.
- River discharge mainly influenced by precipitation and therefore only occasionally showing spread.
- Overall encouraging results that need to be verified with the full ensemble.

References:
Jülich Supercomputing Centre. (2015). JUQUEEN: IBM Blue Gene/Q Supercomputer System at the Jülich Supercomputing Centre. Journal of large-scale research facilities, 1, A1. doi:10.17815/jlsrf-1-18
Kurtz, W., He, G., Kollet, S., Maxwell, R., Vereecken, H., and H.-J. Hendricks Franssen (2016), TerrSysMP-PDAF (version 1.0): a modular high-performance data assimilation framework for an integrated land surface–subsurface model, Geosci. Model Dev., 9(4), 1341-1360.
Shrestha, P., M. Sulis, M. Masbou, S. Kollet, and C. Simmer, 2014: A scale-consistent soil-vegetation-atmosphere modeling system based on COSMO, CLM and ParFlow. Mon. Wea. Rev. 142, 3466–3483, doi:10.1175/MWR-D-14-00029.1