Terrestrial simulations from groundwater into the atmosphere over Europe and North Rhine Westphalia, Germany

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Regional Earth system modeling with *Terrestrial Systems Modeling Platform* (TerrSysMP)

Challenges:
- Complex interactions and feedbacks between various compartments of the geo-eco-system (e.g., pedo-, bio-, hydro- or atmosphere) across multiple spatio-temporal scales
- Linkages through energy, mass and momentum transfers
- (Anthropogenic) physical (climate) system changes modify land surface and ecosystem processes and services with multiple (socioeconomic) impacts on many sectors (e.g., water management, farming, energy production, transport, etc.)

TerrSysMP:
- A scale-consistent fully integrated soil-vegetation-atmosphere modelling system
- Full representation of terrestrial hydrological cycle including groundwater dynamics
- Massively parallel multi-physics application across scales down to sub-km resolutions
- Explicit feedbacks between compartments
- Overall goal: Towards a holistic representation of complex interactions among the compartments in the geo-ecosystem

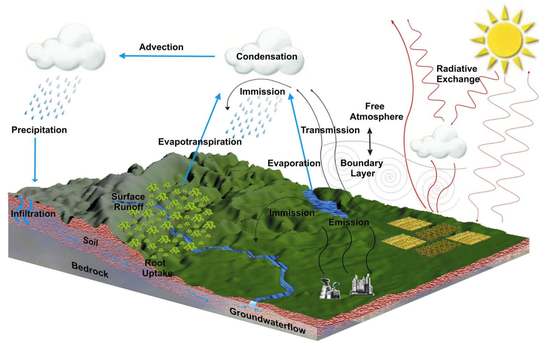
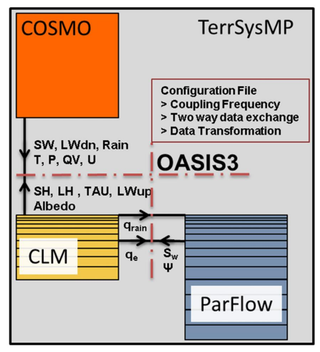


Fig. 1: Schematic of coupled geo-ecosystem components; shown here: NRW model domain in western Germany

Research focus is on the hydrological cycle, e.g.:
- Process representation and understanding
- Subsurface-land-atmosphere coupling
- Resolution effects
- Improvement of parametrisations
- Experiments, e.g.:
  - Idealized and real data
  - Data assimilation
  - Forecasts
  - Convection permitting
  - Towards regional climate change projections



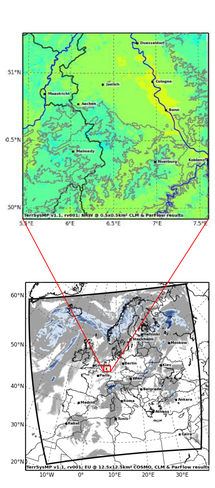
Some features:
- Externally coupled via OASIS3(-MCT)
- Component models can have different spatio-temporal resolution
- Sub-cycling, temporal averaging, grid interpolation possible
- Downscaling option also implemented
- Production use on various HPC systems and architectures
- Main model e.g., in DFG CRC/TR32 (Simmer et al., 2015), DFG Research Group FOR2131

Fig. 2: Schematic overview of TerrSysMP and its coupling scheme. Different configuration options (standalone/coupled). Three component models in different versions:
COSMO (v4.11, 4.21, 5.1) ; Community Land Model (CLM) (3.5, 4.0 with CESM) ; ParFlow (v3.1, r693, r711)
Coupling interface: OASIS3 and OASIS3-MCT
For an overview on TerrSysMP see Shrestha et al. (2014) and Gasper et al. (2014) for HPC aspects

Setups and results

North Rhine-Westphalia domain (NRW):
- Boundary conditions provided by German Weather Service (DWD)
- Grid dimension: 150x150 / 300x300
- Spatial resolution: 1km / 0.5km
- Temporal resolution: 10s / 15min
- Coupling frequency: 15min

EURO-CORDEX EUR-11 domain:
- Boundary conditions provided by ECMWF
- Grid dimension: 444x432
- Spatial resolution: 12.5km
- Temporal resolution: 1min / 1h
- Coupling frequency:1h



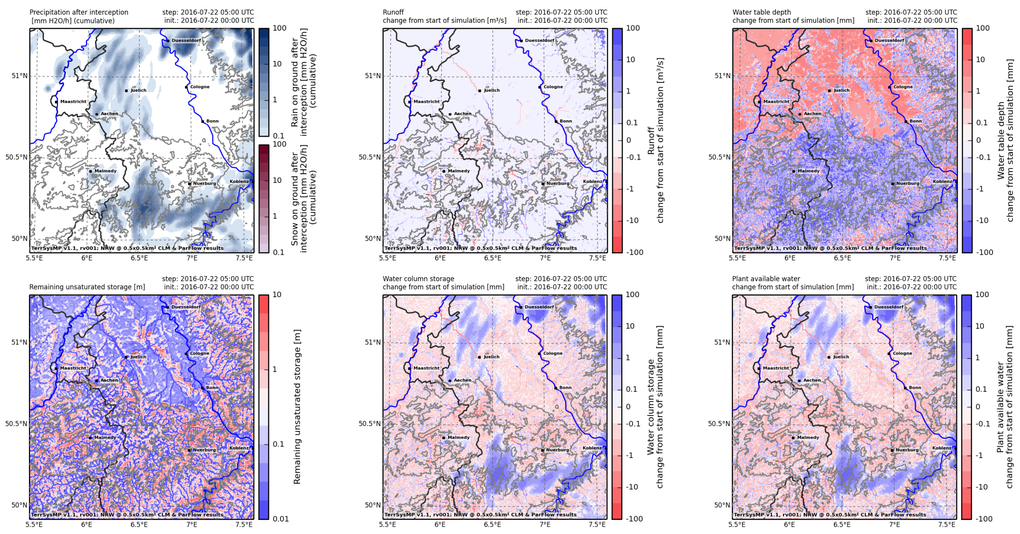


Fig. 3: Real-time monitoring output of some hydraulic metrics for the NRW domain. Calculated from the output of the subsurface model ParFlow in the fully coupled TerrSysMP.

Ensemble runs and data assimilation with TerrSysMP-PDAF

Development:
- Ensemble runs are performed for uncertainty quantification
- Data assimilation is used to improve the prediction of state variables and the estimation of model parameters with available observation data
- Both: fully coupled for real-time monitoring.

TerrSysMP-PDAF:
- TerrSysMP + Parallel DA Framework (PDAF) from AWI
- Currently assimilates land-surface and subsurface data
- Fully parallel, tested up to 128 ensemble members (JUQUEEN)
- Using Ensemble Kalman Filter DA algorithm

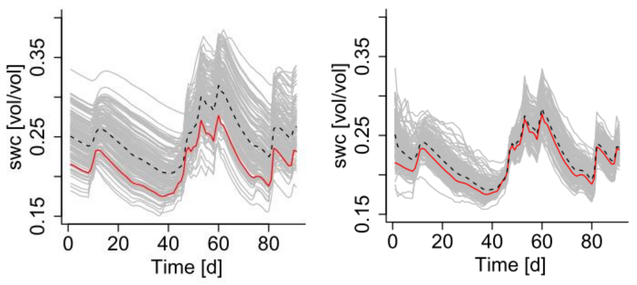


Fig. 4: Validation experiment: without (left), with (right) DA, soil water content, Apr-Jun '13. Kurtz et al. (2016)

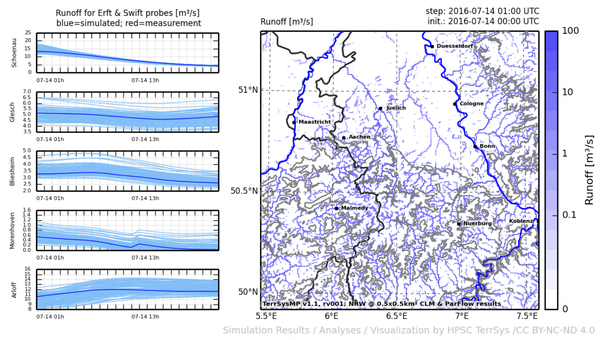
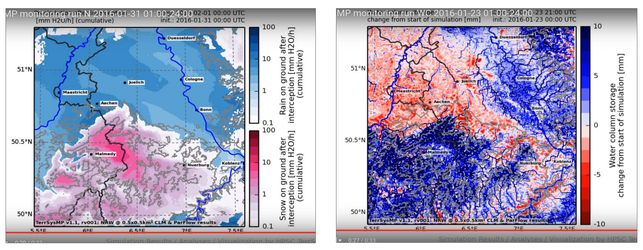
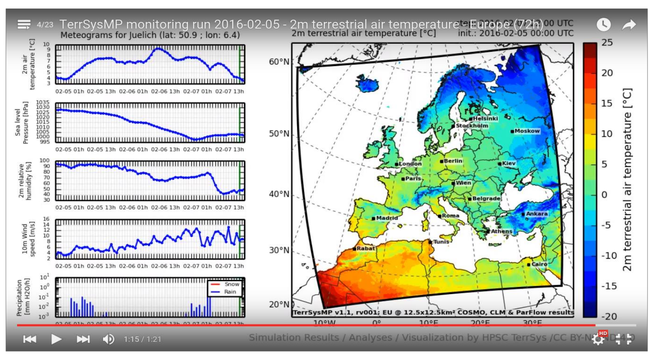


Fig. 5: Ensemble setup with 81 different configurations of subsurface hydraulic properties.

Real-time TerrSysMP monitoring runs

- Fully coupled TerrSysMP on JSC/JURECA
- Nightly: pan-EU 12km (72h), NRW 1km / 0.5km (24h)
- Automatic processing, modelling, visualisation chains
- Public dissemination: HPSC TerrSys YouTube Channel





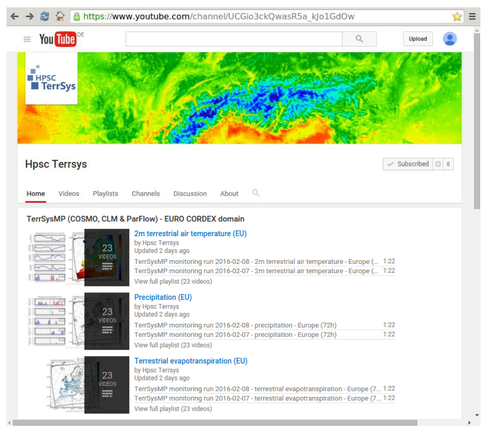


Fig. 7: Screenshot of the YouTube Channel front page. Data upload into separate playlists for pan-EU and NRW Per playlist: one forecast movie per variable and day.

HPSC TerrSys YouTube Channel

Fig. 6: Screenshots of the YouTube Channel: Some examples on TerrSysMP monitoring run results movies. Specific analyses (left): only possible with coupled model system. “Standard” forecasting products including meteograms (right).

Acknowledgements

TerrSysMP development:
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Poster: GEWEX Convection-Permitting Climate Modeling Workshop, Boulder, Co., USA, September 6-8, 2016

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