A sensitivity analysis of hydrological states and fluxes to groundwater representation in pan-European multimodel simulations

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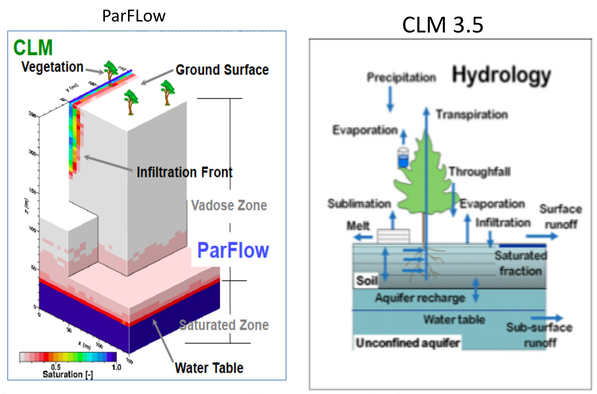
1. Motivation

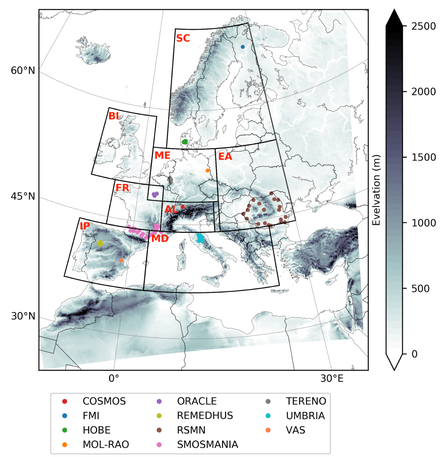
High-resolution large-scale predictions of hydrologic states and fluxes are important for many regional-scale applications and water resource management. However, because of uncertainties related to forcing data, model structural errors arising from simplified representations of hydrological processes or uncertain model parameters, model simulations remain uncertain. To quantify this uncertainty, multi-model simulations were performed at 3km resolution over the European continent using the Community Land Model (CLM3.5) (Naz et al., 2019, 2020) and the ParFlow hydrologic model.

2. Study domain and modeling setup

- ParFlow simulates three-dimensional variably saturated groundwater flow solving Richards equation and overland flow with a two-dimensional kinematic wave approximation.
- In ParFlow the soil column is divided into 15 soil layers (0–60 m), while in CLM 3.5, the soil profile is divided into 10 soil layers (0–3.8 m).



- CLM3.5 simulates movement of moisture between 10 soil layers is calculated using Richard's equation. The bottom soil layer is also coupled with an unconfined aquifer to account for groundwater recharge and discharge processes. There is no representation of the confined aquifer in the model.



Model Inputs:
Various key hydrologic model inputs were organized at 1/36 degree (~3 km) grid for the EU–CORDEX domain:

- Topography (GMTED2000 elevation) (Figure 2).
- Soil characteristics (FAO global dataset)
- In ParFlow, alluvial aquifers were represented using BGR Europe dataset plus CCMR global dataset.
- Vegetation LAI (MODIS LAI)
- Land surface classification (MODIS)
- Meteorological forcing (6km COSMO-REA6 reanalysis)
- Simulation period: 1 January 2000 – 31 December 2006.

Model validation datasets:

- *In-situ* Water Table Depth, FLUXNET ET, GRDC discharge data and remotely sensed (RS) ESA CCI for SM, comparison over PRUDENCE regions were used.

Acknowledgements

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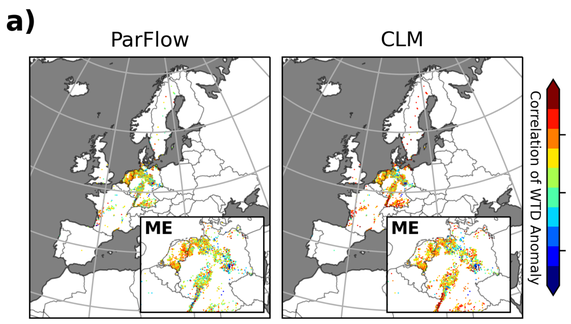
3. Validation of models simulations

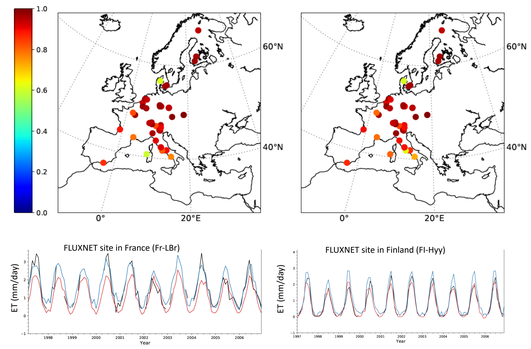
Water Table Depth



Correlation of ParFlov and CLM simulated monthly water table depth anomaly (1997 – 2006) with in-situ observations form WTD wells

CDF of the Pearson correlation between models simulated water table depth anomaly and in-situ WTD anomalies for different seasons (1997 – 2006).

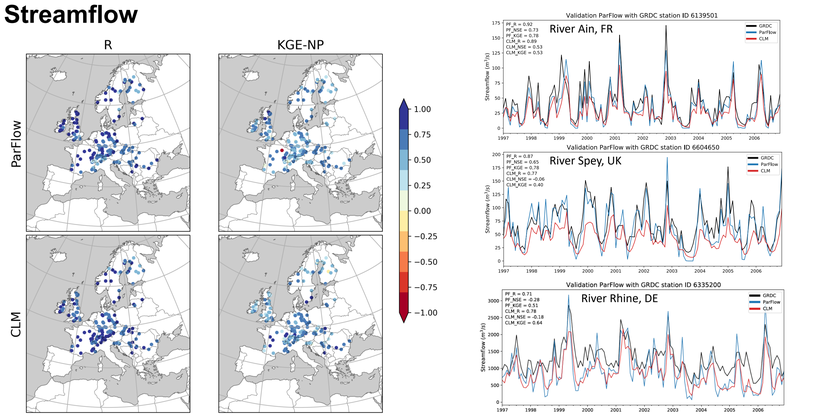
Evapotranspiration



Pearson correlations between ParFlow and CLM simulated monthly ET and 65 FLUXNET sites.

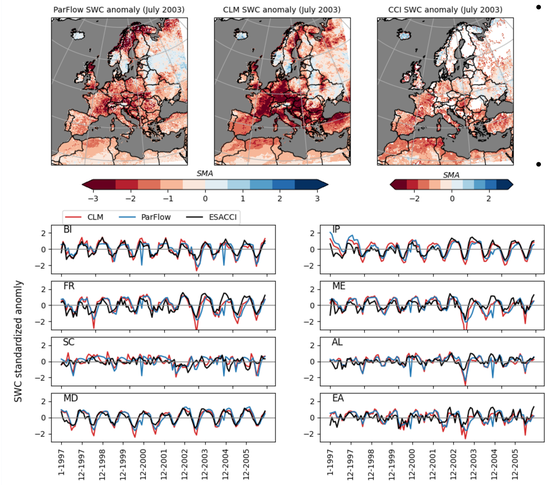
Example of of observed and simulated monthly ET at two FLUXNET sites with complete observation period (1997 – 2007).

Streamflow



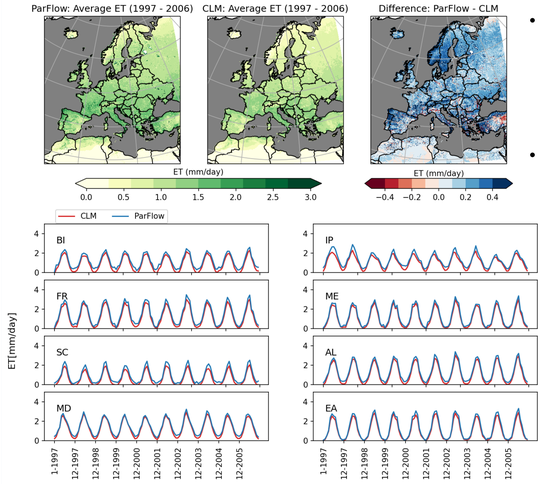
4. Regional comparisons

Surface Soil Moisture



- Regionally, SWC anomalies from both ParFlow and CLM compare well with the ESA CCI anomalies.
- Overall, CLM estimates much stronger dry anomalies than both ParFlow and ESACCI, particularly in drought years.

Evapotranspiration



- On average, ET in ParFlow is 25% higher than CLM3.5 for time period of (1997 – 2006).
- Regional comparison shows that maximum ET increase occurs mostly in summer. Winter ET is slightly higher in ParFlow than CLM model.

5. Summary

- Our results show that both models capture the interannual variability in the hydrologic states and fluxes well when compared with observational data of water table depth, ET and surface soil moisture.
- Our results show significantly wetter soil and enhanced ET in ParFlow when compared to CLM model over all regions.
- ParFlow simulates more realistic water table distribution, where local drainage is better resolved with shallow groundwater in valleys and deeper under hilltops.
- In future, these simulation would be extended to longer time periods (30 years, and for climate projections) and plan to perform global simulations at sub-km spatial resolution.