ADDITIONAL VALUE OF CONSIDERING LATERAL FLOW PROCESSES FOR ASSIMILATING SMAP DATA INTO A LAND SURFACE MODEL

Haojin Zhao[1,2] , Carsten Montzka[1] , Harry Vereecken[1,2] and Harrie-Jan Hendricks Franssen[1,2]

[1] Agrosphere (IBG-3), Institute of Bio- and Geosciences, Forschungszentrum Jülich GmbH, Jülich, Germany
[2] Centre for High-Performance Scientific Computing in Terrestrial Systems, HPSC TerrSys, Geoverbund ABC/J Email: h.zhao@fz-juelich.de

JÜLICH Forschungszentrum

ABSTRACT

Soil moisture plays an important role in controlling water and energy exchange between the land and the atmosphere. Characterizing large scale soil moisture is important for many applications, e.g, agricultural and water resources management, drought and flood forecasting. Assimilation (DA) of remotely sensed soil moisture observations into land surface models (LSMs) can improve soil moisture estimation, however, in many studies assimilation of remotely sensed soil moisture improves evapotranspiration prediction hardly. Most LSMs have an over-simplified representation of groundwater dynamics, and the propagation of remote sensing information into neighboring and deeper soil zones depends on the lateral flow and subsurface physical processes represented in the model. In this study, we assimilated soil moisture information into the stand-alone Community Land model (CLM) and the land surface-subsurface model CLM-ParFlow, components of the Terrestrial Systems Modeling Platform (TSMP). The CLM-ParFlow uses Richard's equation to simulate variably saturated three-dimensional flow in the subsurface and uses a two-dimensional kinematic wave approximation for overland flow and river routing. The experiment is conducted for a temperate region (150 km × 150 km) in Western Germany, with a horizontal grid resolution of 500 m, for the period from Mar 2018 to Nov 2018. The SMAP soil moisture data are assimilated with the Ensemble Kalman Filter (EnKF) on a daily basis. We compared the simulated soil moisture content with in situ soil moisture measurements derived from Cosmic Ray Neutron Sensors (CRNS), and simulated ET with observations by Eddy Covariance (EC) stations. It is found that soil moisture characterization improved by DA, but metrics are not better for CLM-ParFlow than CLM stand-alone. Nevertheless, spatial soil moisture patterns by CLM-ParFlow look more realistic than the ones simulated by CLM. DA was able to further improve the characterization of soil moisture contents and improves ET estimation under drought conditions. In addition, with coupled land surface-subsurface models the impact of soil moisture assimilation on simulated groundwater levels and river discharge, which are not represented well by classical land surface models, could also be evaluated.

INTRODUCTION

- Soil moisture exerts an important role in the water and energy cycles, and strongly influences ecosystem water stress and agricultural production.
- Studies indicate that data assimilation (DA) of remotely sensed soil moisture into land surface models (LSMs) can improve soil moisture characterization, however, evapotranspiration (ET) estimates are often hardly improved.
- Most LSMs have an over-simplified representation of groundwater dynamics.
- We assimilate soil moisture from SMAP into the CLM stand alone LSM and the coupled land surface-subsurface model CLM-ParFlow, components of the Terrestrial Systems Modelling Platform (TSMP), and quantified the added value of assimilating remotely sensed soil moisture for predicting soil moisture and other states and fluxes and assessed the potential of considering lateral flow in LSMs.

METHODS

- **Study area.**

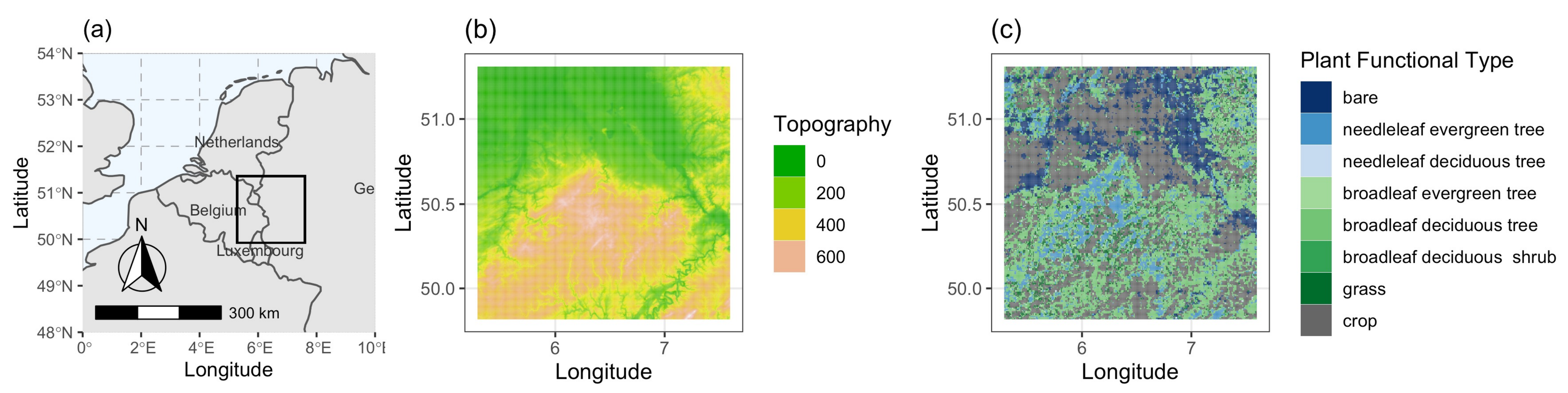

Figure 1 a) Location of the study area in Europe; b) altitude over the study area; c) plant functional types

- **The integrated terrestrial systems model CLM-ParFlow in TSMP (see Figure 2) .**
- **Model configuration, parameters and inputs.**

Domain size: 150 km × 150 km; Spatial resolution: 500 m × 500 m (Figure 1).
Subsurface in CLM-ParFlow: 0 – 30 m below the ground, with 10 near-surface layers with increasing thicknesses from 0.02 m to 1 m and 20 vertical layers with a thickness of 1.35 m each.
Meteorological forcing dataset: COSMO-REA6 (resolution: 6 km)
Simulation period: April 2018 -- November 2018.
Quality control of the SMAP L3_SM_P_E product: considering the flags for retrieval, dense vegetation, frozen soil, snow cover and radio frequency interference.

- **Datasets for evaluation.**

Cross-validation with in-situ measurement data, calculating Root Mean Square Error (RMSE), Pearson correlation coefficient (r), and unbiased Root Mean Square Error (ubRMSE).
To calculate the relative weights for simulated soil moisture content for different layers in the model, the CRNS penetration depth z* is calculated and given by (Franz et al., 2012):

$$z^* = \frac{5.8}{\theta + 0.0829}$$

where θ is the total soil water content.

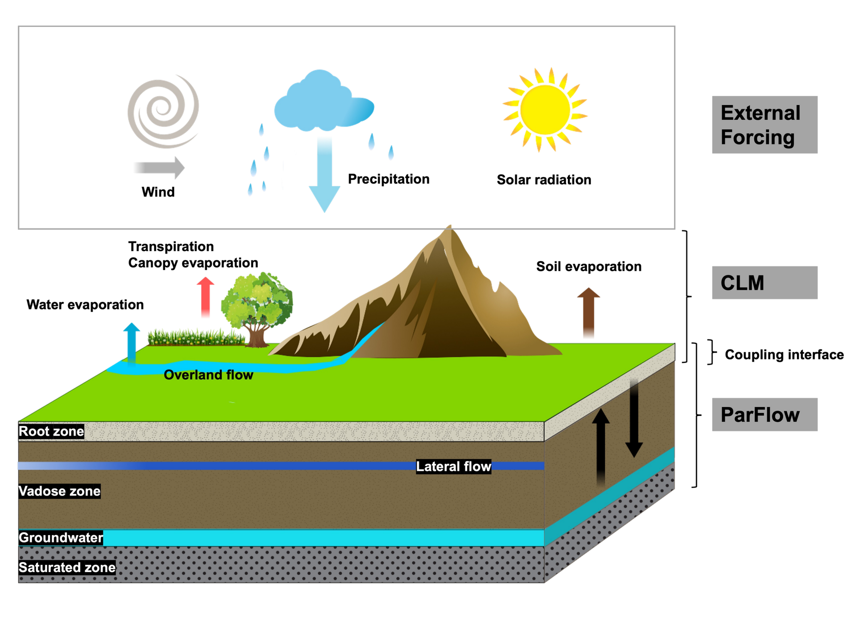

Figure 2 Schematic diagram of CLM-ParFlow in TSMP

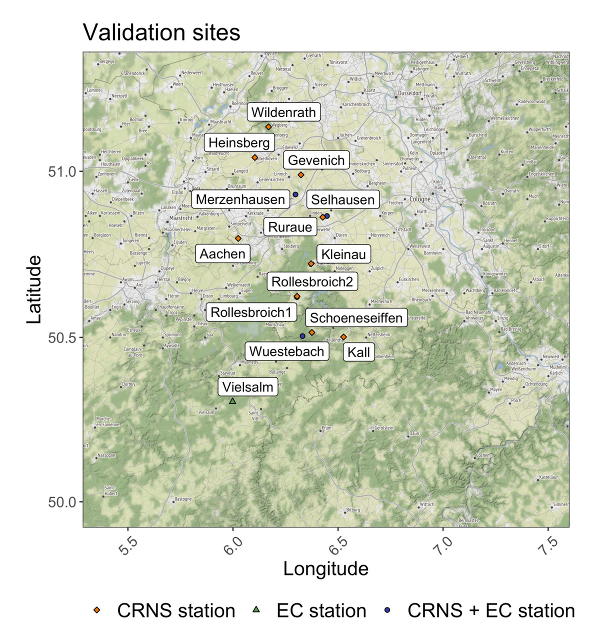

Figure 3 Location of 13 CRNS stations and 4 EC sites for evaluation of simulation results

RESULTS

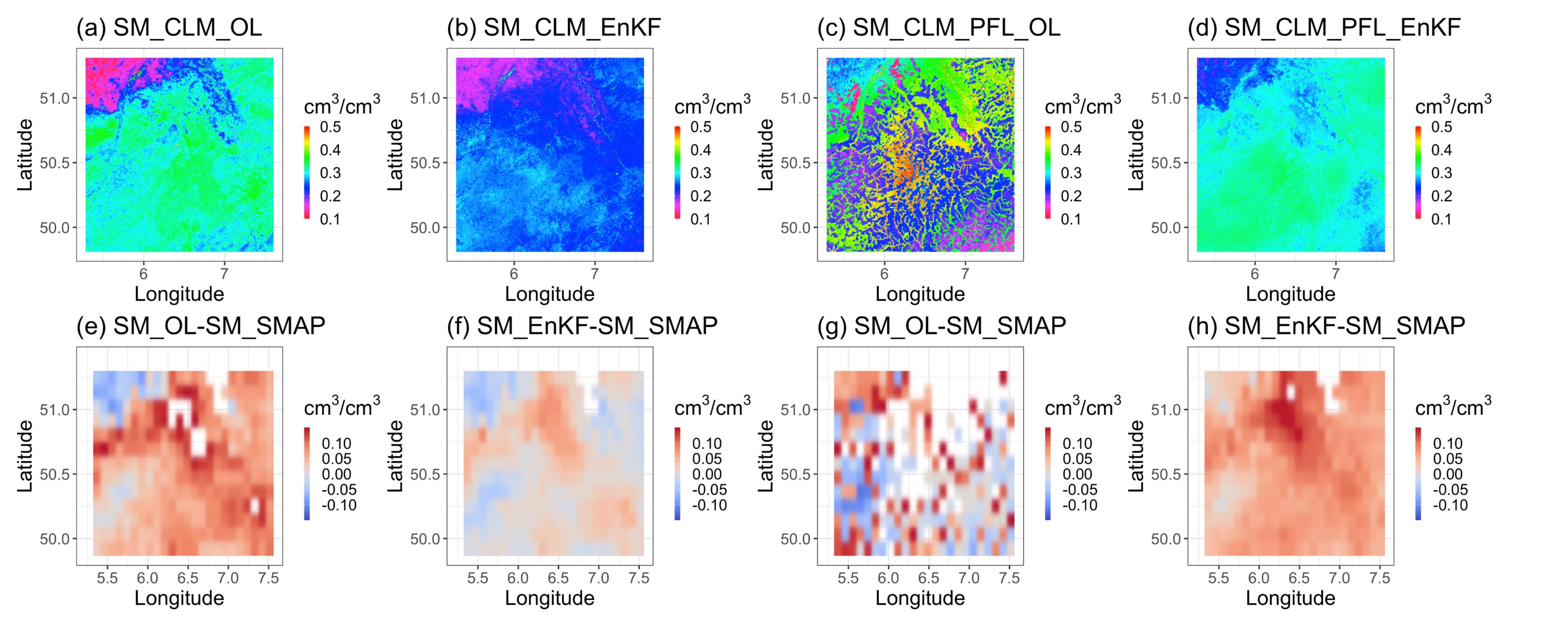

Figure 4 Temporally averaged soil moisture (SM) over 2018.04 – 2018.11 for OL (open loop) and EnKF (DA) with CLM and CLM-ParFlow (CLM_PFL) (a-d) , and differences between (e) (g) SM-OL and SM-SMAP and (f) (h) SM-EnKF and SM-SMAP

- The simulated SM was regridded and compared with SMAP soil moisture dataset.
- The difference between simulated SM and SMAP SM is reduced by DA.
- The CLM-PFL model captures the spatial variability of SM and the river network.

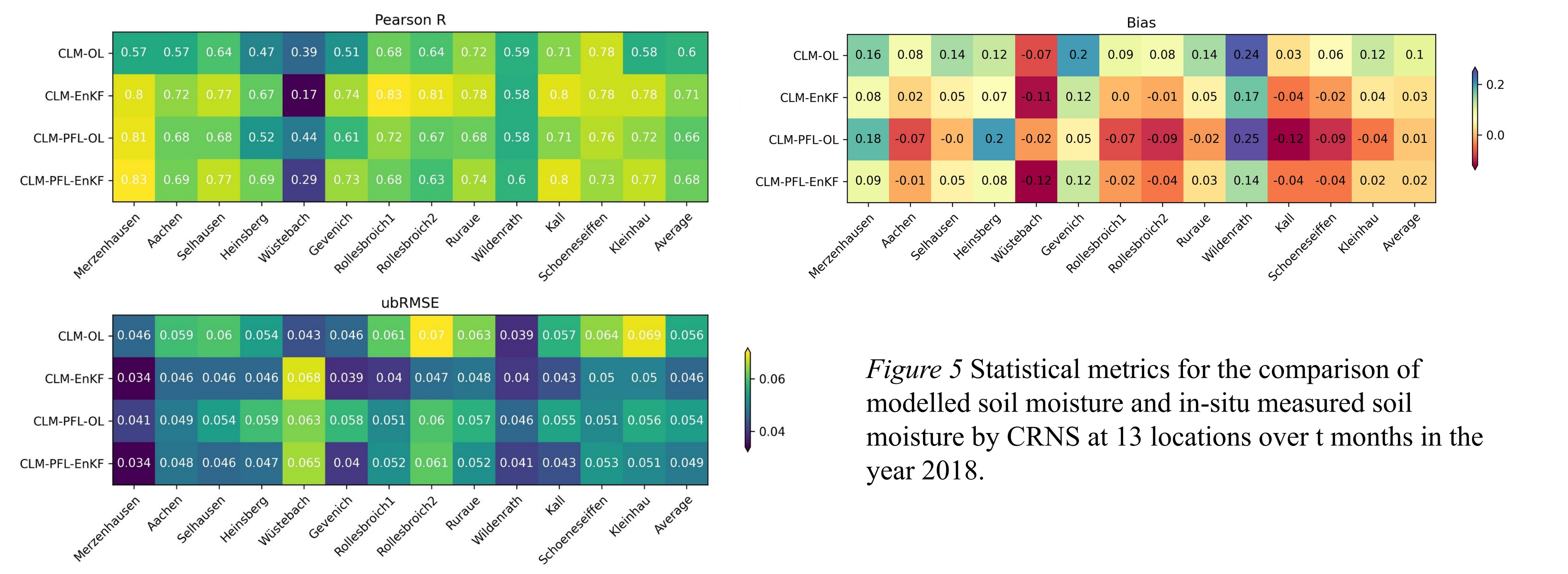

Figure 5 Statistical metrics for the comparison of modelled soil moisture and in-situ measured soil moisture by CRNS at 13 locations over t months in the year 2018.

- Assimilation with CLM and CLM-PFL reduces bias and ubRMSE, increases the Pearson R, with strong variations among sites.
- There is no systematic bias between CLM-PFL OL and CRNS measurements.
- The CLM OL shows a slight overestimation of SM.

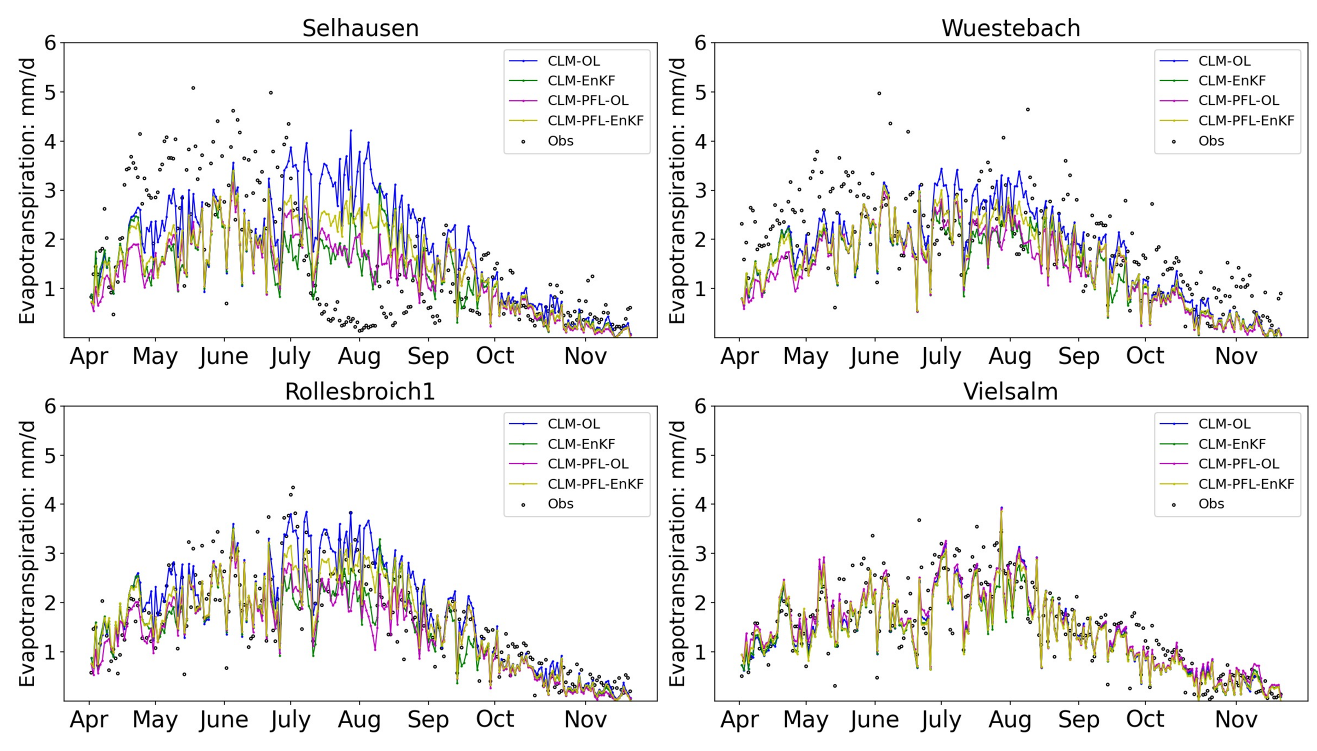

Figure 6 ET for the OL simulation and DA experiments with CLM and CLM-PFL, compared with EC measurements at four sites. The PFT is crop (Selhausen), spruce (Wuestebach), grassland (Rollesbroich1) and mixed forest (Vielsalm.)

- The overestimation of ET at the Selhausen site in summer is reduced as soil moisture content decreases by the assimilation of SMAP data.
- The other three EC-sites experienced in 2018 only limited drought stress and improvements in flux estimation were not observed.
- The modelled ET by CLM and CLM-PFL provide a good fit to the seasonal patterns with rises and falls.

CONCLUSIONS

- Soil moisture characterization improved by DA, but metrics are not better for CLM-ParFlow than CLM stand-alone. Nevertheless, spatial SM patterns by CLM-ParFlow look more realistic.
- Assimilation of soil moisture reduces ET (towards observed ET) at EC-sites and gives little improvement.
- Simulations with larger perturbations and parameter updating are ongoing.

REFERENCES

1. Shrestha, P., Sulis, M., Masbou, M., Kollet, S., Simmer, C. (2014). A Scale-Consistent Terrestrial Systems Modeling Platform Based on COSMO, CLM, and ParFlow. Monthly Weather Review, 142(9), 3466–3483. https://doi.org/10.1175/MWR-D-14-00029.1
2. Franz, T.E. et al. (2012) "Measurement depth of the cosmic ray soil moisture probe affected by hydrogen from various sources," Water Resources Research, 48(8). https://doi:10.1029/2012WR011871.