Data assimilation of soil moisture for improved characterization of hydrological states and fluxes

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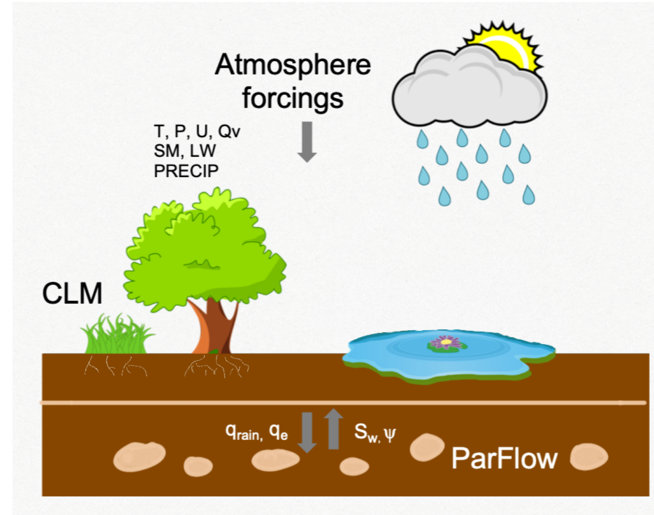
Introduction

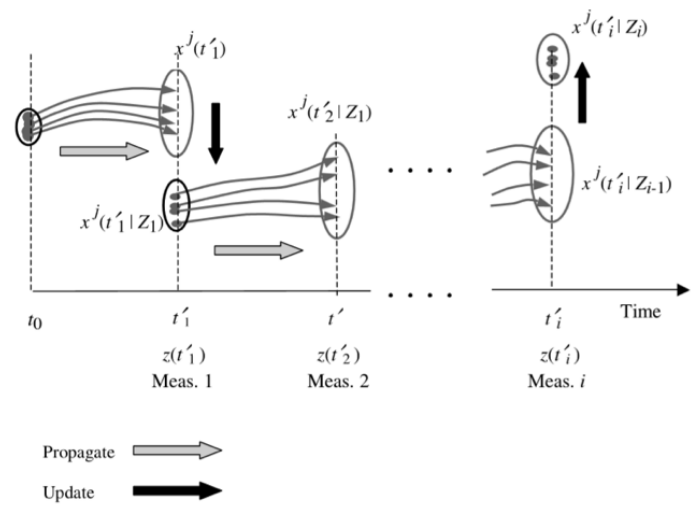
- Soil moisture influences partitioning of incoming net radiation and precipitation into energy and water fluxes. Improved characterization of soil moisture could improve weather prediction and crop yield prediction.

- Soil moisture can be obtained by predictions of land surface models, in situ observations and satellite products.

- TSMP is a terrestrial system modelling platform, with simulation of water and energy cycles from deep subsurface to atmosphere.

- Data assimilation (DA) is used to optimally merge observations and model simulations to improve model predictions. DA framework for TSMP : TSMP-PDAF (Kurtz et al., 2016)





Source: Mclaughlin et al, Advances in Water Resources, 2002.

❑ Model setup

Model: CLM-PDAF and CLM-ParFlow-PDAF

Domain and resolution:

so-called NRW domain: 150km x 150km

Grid size: 500m x 500m

Observations: SMAP L3_SM_P_E* Soil Moisture

Model inputs:

Soil texture: FAO dataset (Sulis, 2017)

Soil hydraulic parameters (Sulis, 2017)

Atmospheric forcings : COSMO-REA6

Simulation period: 1 March 2017 – 31 November 2017

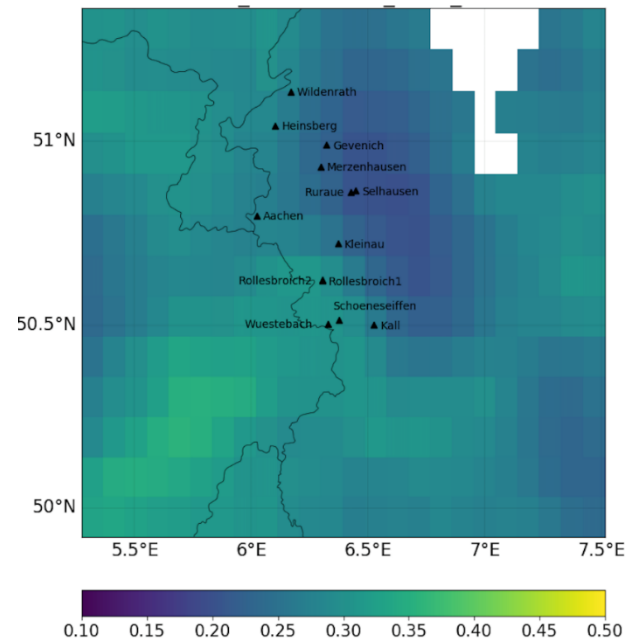
Ensembles:

32 realizations with

perturbed meteorological forcings and soil texture (% clay and % sand)

perturbed meteorological forcings and hydraulic conductivies

Validation data: Cosmic Ray Neutron Sensors (CRNS) and Eddy Covariance (EC)



Validation sites
CRNS and EC

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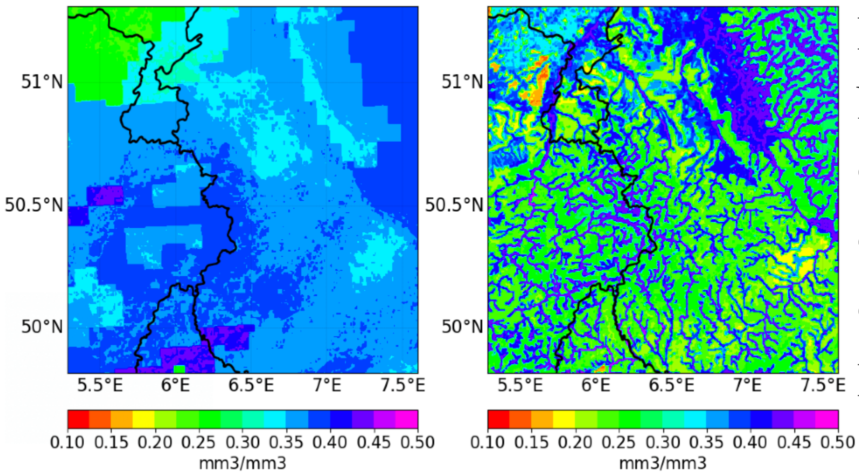
Results

Soil moisture



CLM CLM-ParFlow

Deterministic run

Period 1 Mar 2017 - 30 Nov 2017;

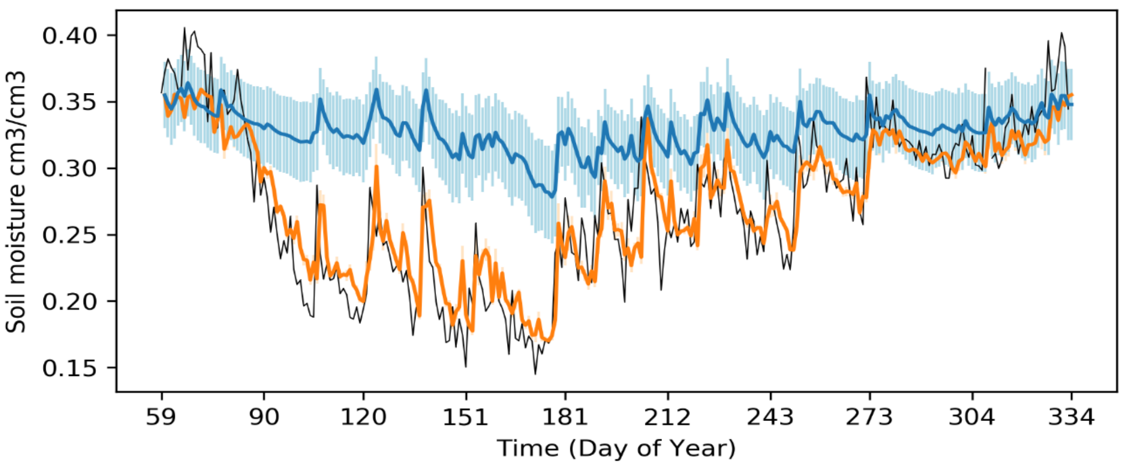
NRW domain

Compared with SMAP data

CLM: bias =0.0363 cm³/cm³ RMSE=0.0612 m³/cm³

CLM–ParPlow: bias=0.0046 cm³/cm³

RMSE = 0.0461 cm³/cm³



DA assimilation run with CLM-PDAF

Period 1 Mar 2017 - 30 Nov 2017

soil moisture (upper 5cm) from CLM open loop, EnKF and SMAP

❑ DA-results CLM-stand alone

Comparison of soil moisture (averaged over the upper 20cm) between CLM model and CRNS observations.

stations	ubRMSE m^3/m^3		r	
	OL	EnKF	OL	EnKF
Merzenhausen	0.038	0.047	0.80	0.70
Aachen	0.048	0.031	0.47	0.81
Selhausen	0.042	0.051	0.76	0.54
Heinsberg	0.038	0.030	0.89	0.91
Wuestebach	0.041	0.027	0.67	0.85
Gevenich	0.047	0.048	0.80	0.74
Rollesbroich1	0.059	0.043	0.49	0.76
Rollesbroich2	0.055	0.038	0.54	0.80
Ruraue	0.040	0.046	0.87	0.65
Wildenrath	0.029	0.033	0.79	0.85
Kall	0.071	0.053	0.48	0.76
Schoeneseiffen	0.054	0.035	0.69	0.83
Kleinau	0.047	0.054	0.31	0.26
Average	0.047	0.041	0.66	0.73

The ubRMSE decreased by 0.006. Meanwhile, the correlation coefficient increased from 0.66 to 0.73.

Verification with ET-data from EC

stations	ubRMSE mm/day		r	
	OL	EnKF	OL	EnKF
Rollesbroich	0.69	0.66	0.86	0.80
Selhausen	0.97	0.77	0.74	0.74
Wüestbach	0.79	0.81	0.69	0.69

Conclusions

- SMAP and CLM-PF do not show systematic differences, which is in contrast to most land surface models which are wetter than SMAP.
- Assimilating soil moisture data improves soil moisture estimates. Assimilation corrects overestimation of soil moisture, especially under drier conditions.
- Analysis regarding impact on ET and comparison with EC ongoing.
- Currently the assimilation of SMAP data into CLM and CLM-PF is under investigation.
- Experiments including parameter estimation and more ensemble members planned.

- **References:**
- Schrön, M., Köhli, M., Scheiffele, L., Iwema, J., Bogena, H. R., Lv, L., Martini, E., Baroni, G., Rosolem, R., Weimar, J., Mai, J., Cuntz, M., Rebmann, C., Oswald, S. E., Dietrich, P., Schmidt, U., and Zacharias, S. (2017). Improving calibration and validation of cosmic-ray neutron sensors in the light of spatial sensitivity, Hydrol. Earth Syst. Sci., 21, 5009-5030, https://doi.org/10.5194/hess-21-5009-2017.
- Sulis, M. et al. (2018) 'Quantifying the Impact of Subsurface-Land Surface Physical Processes on the Predictive Skill of Subseasonal Mesoscale Atmospheric Simulations', Journal of Geophysical Research: Atmospheres. John Wiley & Sons, Ltd, 123(17), pp. 9131–9151. doi: 10.1029/2017JD028187.