Assimilation of in-situ soil water content and leaf area index to improve evapotranspiration prediction for European forest sites

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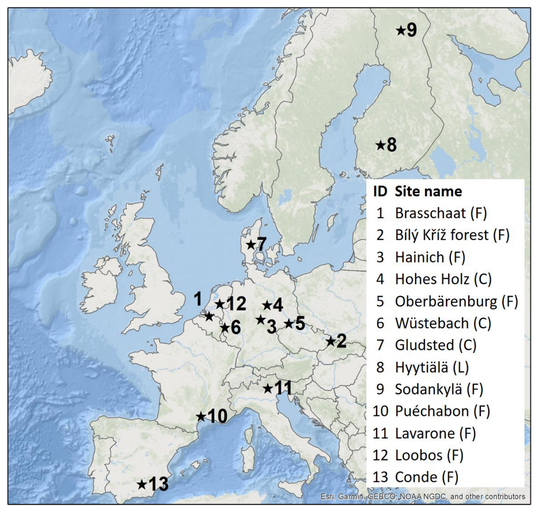
Introduction

- Land surface models (LSM) are important tools to improve our understanding of interacting ecosystem processes and for the prediction of future risk of droughts and fires.
- LSM predictions are associated with uncertainties related to model forcings, parameters and process simplifications.
- The increasing availability of high-quality observations can be used to improve the accuracy of land surface model predictions.
- The combination of LSM simulations and observations can be used to work towards an ecosystem reanalysis, not existing until now. In this work, we test in this context the assimilation of SWC data and its value to improve characterization of ecosystem variables.

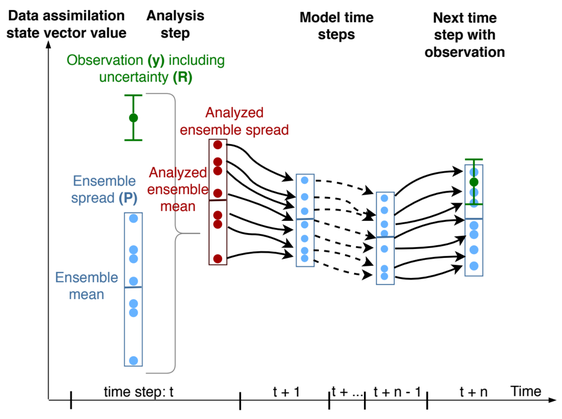
The study sites



Map of the distribution of the study sites.

- Forested sites throughout Europe with long measured time series of SWC and ET (between 2009 and 2019).
- Different climate zones and dominant tree species (represented as plant functional types (PFT) in CLM5).
- Data from different observation networks / data products:
  - FLUXNET (F)
  - COSMOS (C) (includes data from TERENO)
  - eLTER (L)

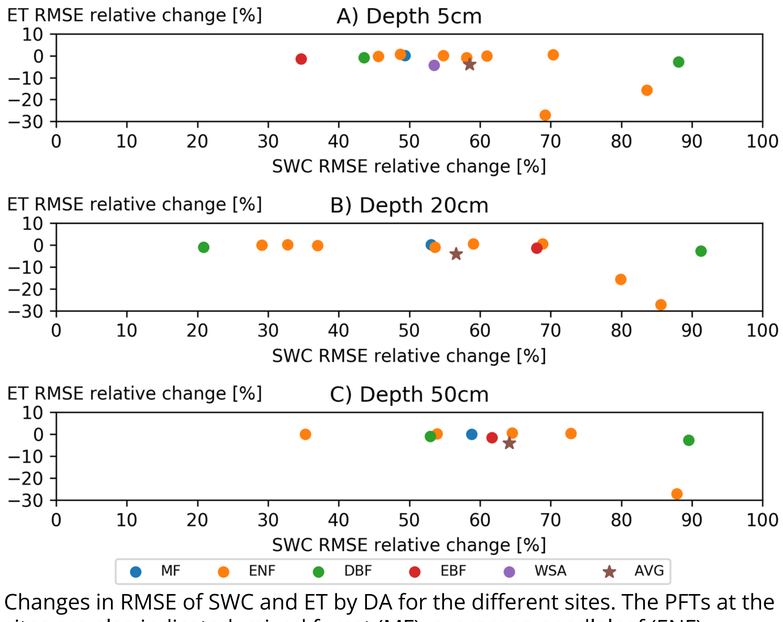
Data Assimilation (DA) - Ensemble Kalman Filter



Visualization of the Ensemble Kalman Filter process.

- We use the Ensemble Kalman Filter (EnKF) (*Evensen 1994*) to perform DA.
- The EnKF fuses data and model states based on observation uncertainty and model uncertainty.
- Model uncertainty is approximated using an ensemble of model simulations.
- In a previous study, we coupled CLM5-PDAF *(Strebel et al. 2022).*

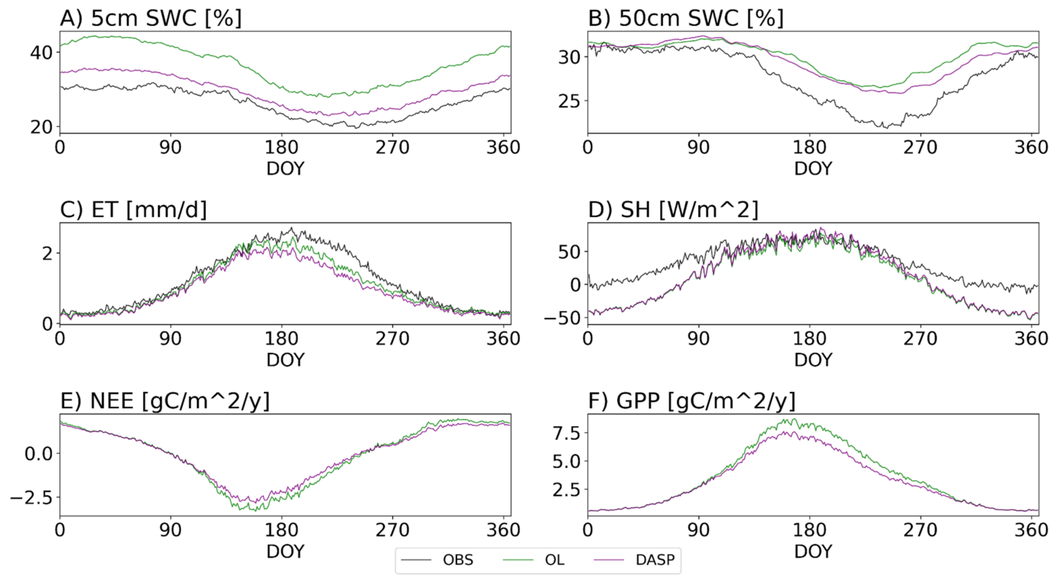
Assimilation of SWC observations



Changes in RMSE of SWC and ET by DA for the different sites. The PFTs at the sites are also indicated: mixed forest (MF), evergreen needleleaf (ENF), deciduous broadleaf (DBF), evergreen broadleaf (EBF), woody savannah (WSA)

- Results from SWC assimilation study (*Strebel et al. 2023 preprint*).
- SWC RMSE reduction between 20% to 90% (in terms of comparing observation and model).
- No improvement or detriment in ET RMSE.
- No clear trend for different PFTs.

Impact of SWC DA



Yearly average cycles of water, energy and carbon fluxes, averaged over all sites: observations (OBS) where available, open loop (OL, and data assimilation including parameter estimation (DASP).

- Impact of SWC DA limited for ET, SH, NEE and GPP characterization.
- ET difference between simulations and observations largest in summer.
- SH difference between simulations and observations largest in winter.
- DA results in less simulated GPP in summer.
- Only limited impact of DA on net ecosystem exchange (NEE).

Assimilation of LAI observations

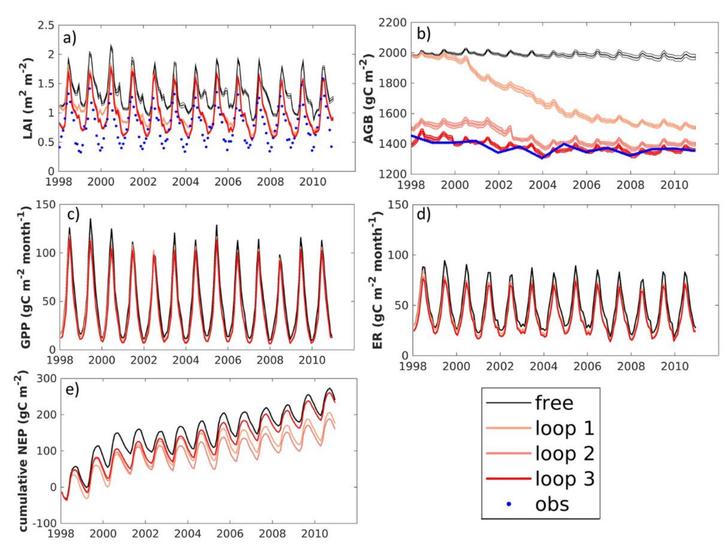


Figure 2 from *Raczka et al. (2021)* "Improving CLM5.0 biomass and carbon exchange across the Western United States using a data assimilation system." Comparison across western United States. The loop 1-3 lines represent the DA used in the study, free is the open loop simulation, and obs are the observed data points.

- Modeled LAI has a stronger effect on modeled ET than SWC.
- *Raczka et al. (2021)* assimilated LAI and above ground biomass in CLM5 and analyzed the improvement to carbon fluxes but did not include analysis of the impact on energy fluxes.
- The large difference between open loop (free) model LAI and observed LAI suggests that modelled LAI can be improved with DA (Figure a).
- Implementation of the LAI DA for CLM5-PDAF ongoing.

Challenges

- Relatively few sites across Europe with availability of long term high quality data for forest sites with both SWC and ET measurements.
- Assimilation of SWC improves SWC characterization, but not ET estimations by CLM5.
- ET estimation should improve with improved LAI representation / assimilation.
- LAI in CLM5-BGC is a diagnostic variable for DA adding complexity to the observation operator used in DA to assimilate LAI observations (e.g. leaf carbon needs to be updated as it is strongly correlated to LAI).
- Modelled leaf carbon has to be kept in balance with leaf nitrogen as well as other carbon and nitrogen pools of CLM5-BGC.
- Availability of long term in-situ LAI measurements at high enough temporal frequency is limited:

→ Need to use satellite products with coarser resolution.

→ As LAI is strongly dependent on the captured land-use / PFTs, the scale difference can cause misalignment between the modelled and observed PFTs.

References:

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Acknowledgements

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