A COUPLED REANALYSIS FOR THE LAND SURFACE AND SUBSURFACE OVER EUROCORDEX

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Research questions

1. Can we use **iterative Ensemble Smoothers (iES)** to reduce model biases in terrestrial system modelling (land surface and subsurface)?
2. Compared to reanalyses based on atmosphere only Data Assimilation (DA), does a **weakly coupled reanalysis** enhance the representation of the terrestrial water cycle?

Introduction

Reanalyses play an important role in the monitoring of our changing climate.
By using **Data Assimilation**, we optimally combine knowledge from models & observations, to produce a dataset that is as accurate as possible, without gaps.

A comprehensive reanalysis of the full hydrological cycle, including the subsurface, is lacking. We aim to produce this reanalysis for the European domain.

Some sources of uncertainties:
- Poorly known parameters (e.g. subsurface) → model bias
- Sensitivity to Initial Conditions

iES's have proven to be very effective to infer subsurface parameters that are related **non-linearly** to the model state in e.g. seismic inversion.[3]

Objective

- Develop iES for the Terrestrial Systems Modelling Platform (**TSMP**), compare to EnKF
- Select the best option for the production of a reanalysis over **EUROCORDEX** (11-km, 3-km res.)

Methods

- Land surface processes: Community Land Model, CLM3.5 → CLM5.0
- Surface runoff and subsurface hydrology: ParFlow
- Atmosphere: ERA5 → ICON
- DA done on the JUWELS supercomputer in Jülich, Germany
- SMAP soil moisture observations

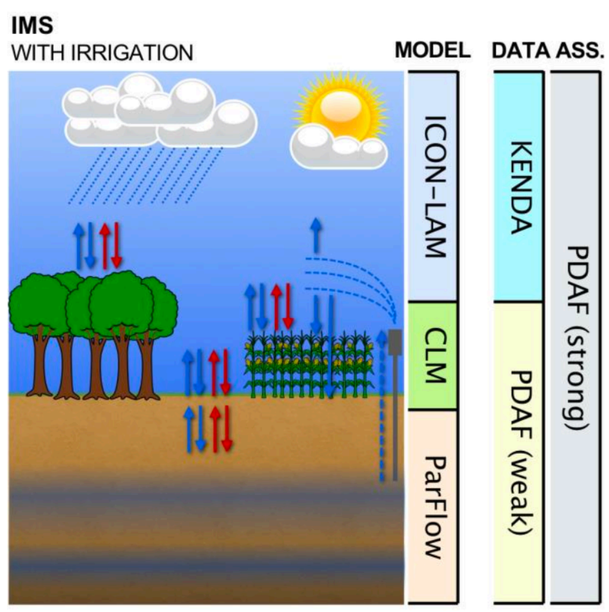

***Fig. 1**: Illustration of the coupled data assimilation framework[1]*

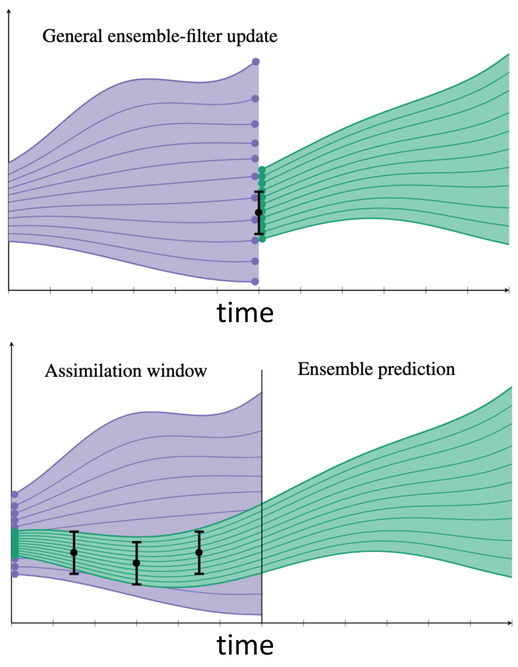

***Fig. 2**: Illustration of [2]*
*1) Ensemble Kalman **Filter** (**EnKF**, upper)*
*2) Ensemble Kalman **Smoother** (**ES**, lower)*

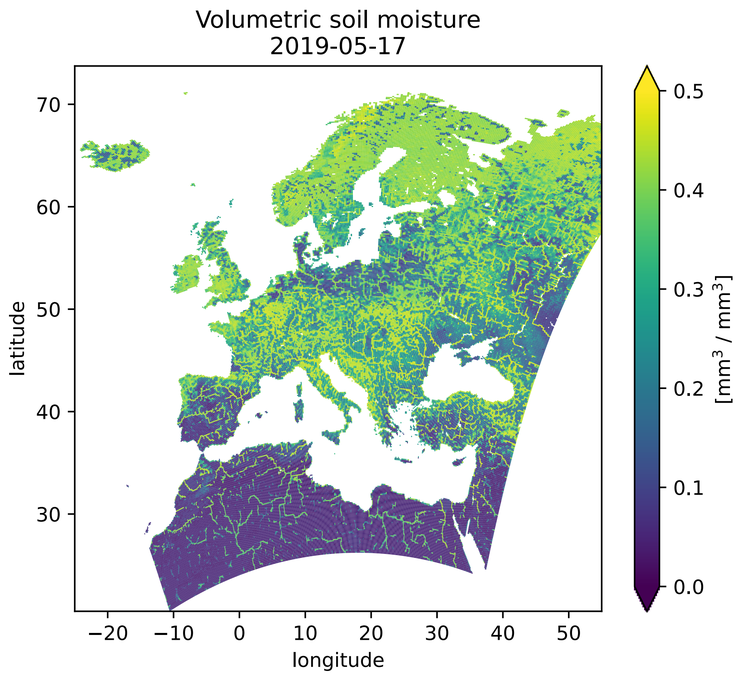

***Fig. 3**: Open loop soil moisture prediction over EUROCORDEX (11-km res.)*

Preliminary results

- Parameters such as subsurface permeability (K), porosity (θ) varied
- Low resolution investigations show improvements in soil moisture, mainly in the south (*Fig. 4* and *Fig. 5*)

Discussion

- TSMP **too dry** in the Nordics (**red**), **too wet** in central EU (**blue**)
- Ensemble spread low in areas with highest mismatch
- Spinup (1 year) after parameter update recommended
- iES under development: e.g. localisation still to be done

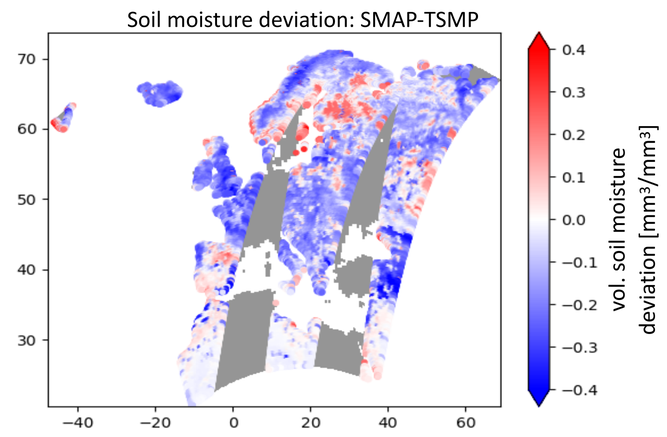

***Fig. 4**: Open loop deviation (2019-05-17, R=0.69)*

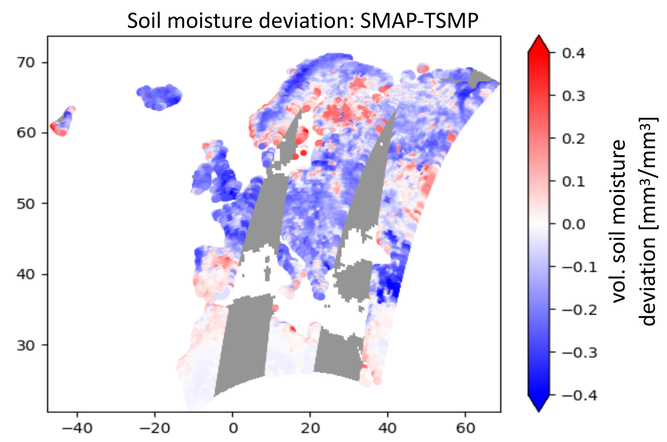

***Fig. 5**: After 2 iES steps (2019-05-17, R=0.72)*

- Next steps: consider other parameters, e.g. Leaf Area Index, root depth
- Validate with evapotranspiration estimates (FLUXNET), groundwater table measurements

Conclusions

- iES proven to be effective for inversion problems, currently investigating the usage for terrestrial systems modelling
- Possible application: minimise model bias using 1 year of training data, use inferred parameters for the production of a high-quality reanalysis product for multiple years

References

1. Keller J., Hendricks-Franssen H., Valmassoi A. *D03 - DETECT funding proposal* (2020)
2. Evensen G., Vossepoel F., van Leeuwen P. *Data Assimilation Fundamentals* (2022)
3. Emerick A. *History matching time-lapse seismic data using the ensemble Kalman filter with multiple data assimilations* (2012)