Combining JULES with observations to improve soil moisture estimates

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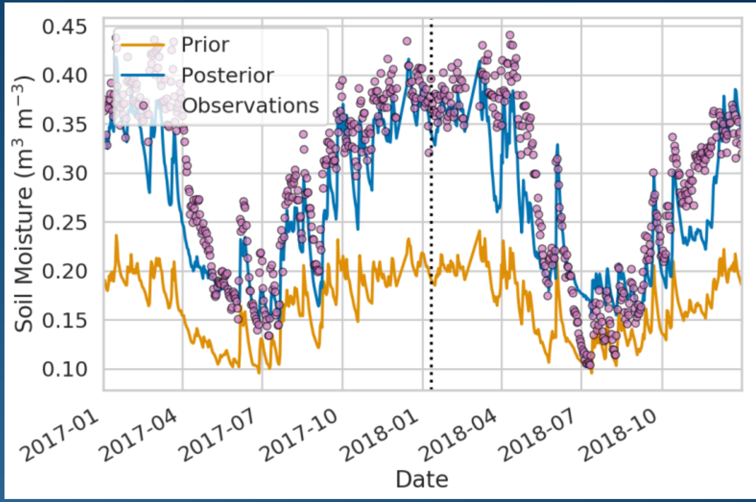

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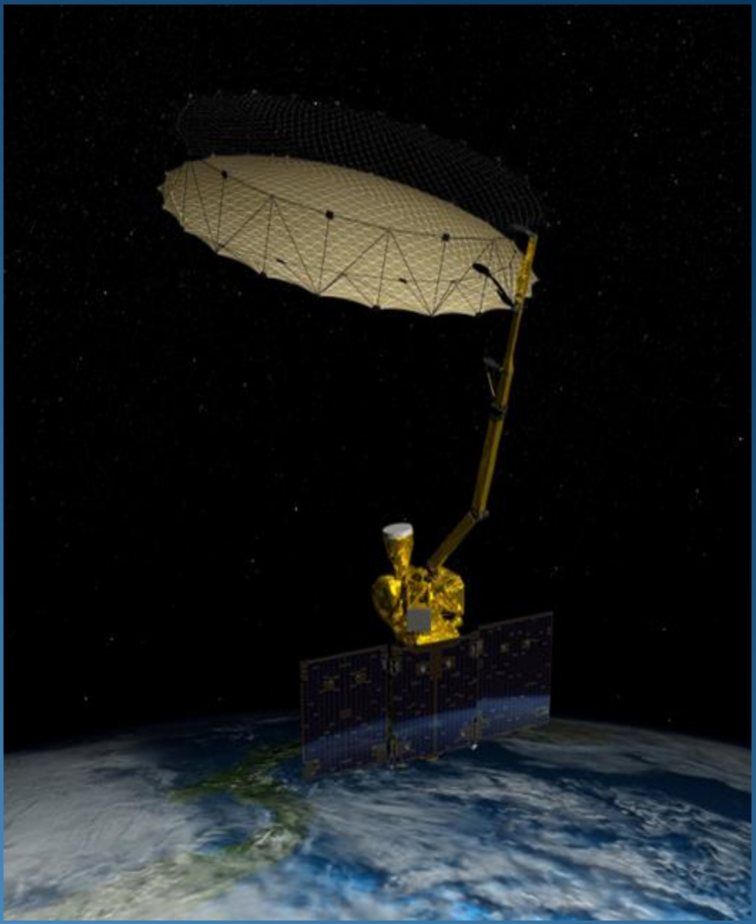
Data assimilation is……

A group of sophisticated mathematical methods which combine models and observations, *taking into account uncertainties in each*

Two studies in hydroJULES have used data assimilation techniques

- Both use JULES model
- Different sets of observations
  - Study 1: in situ field scale soil moisture observations
    Cooper et al. https://doi.org/10.5194/hess-25-2445-2021
  - Study 2: satellite-derived large scale soil moisture observations
    Pinnington et al. https://doi.org/10.5194/hess-25-1617-2021
- Both use same data assimilation technique
  Pinnington et al. https://doi.org/10.5194/gmd-13-55-2020
- Both improve model soil moisture output by updating the way we map between soil texture and parameters in JULES



Two instruments for measuring soil moisture.

L: Cosmic-Ray Neutron Sensor (CRNS) at one of UKCEH's COSMOS-UK sites. Photo taken from COSMOS-UK User Guide: https://cosmos.ceh.ac.uk/

R: artist rendering of the Soil Moisture Active Passive spacecraft, taken from https://www.nasa.gov/press-release/nasa-soil-moisture-radar-ends-operations-mission-science-continues, credit NASA.

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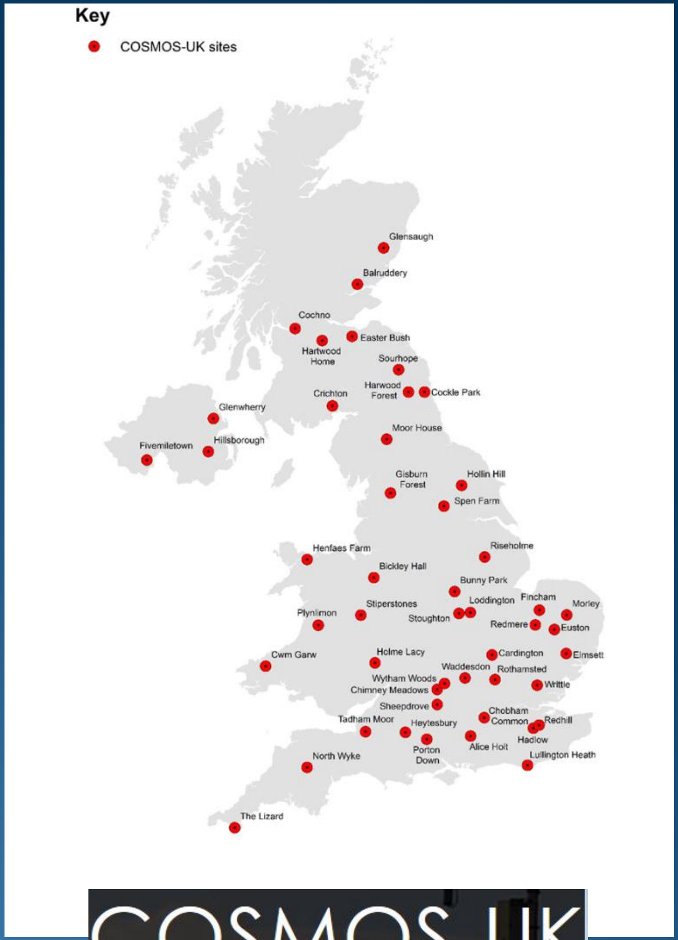
Observations: COSMOS-UK

- Network of ~50 sites
- Measurements of soil moisture from Cosmic Ray Neutron Sensors over ~200m radius
- AND measurements of meteorological variables we can use to drive JULES (Joint UK Land Environment Simulator)



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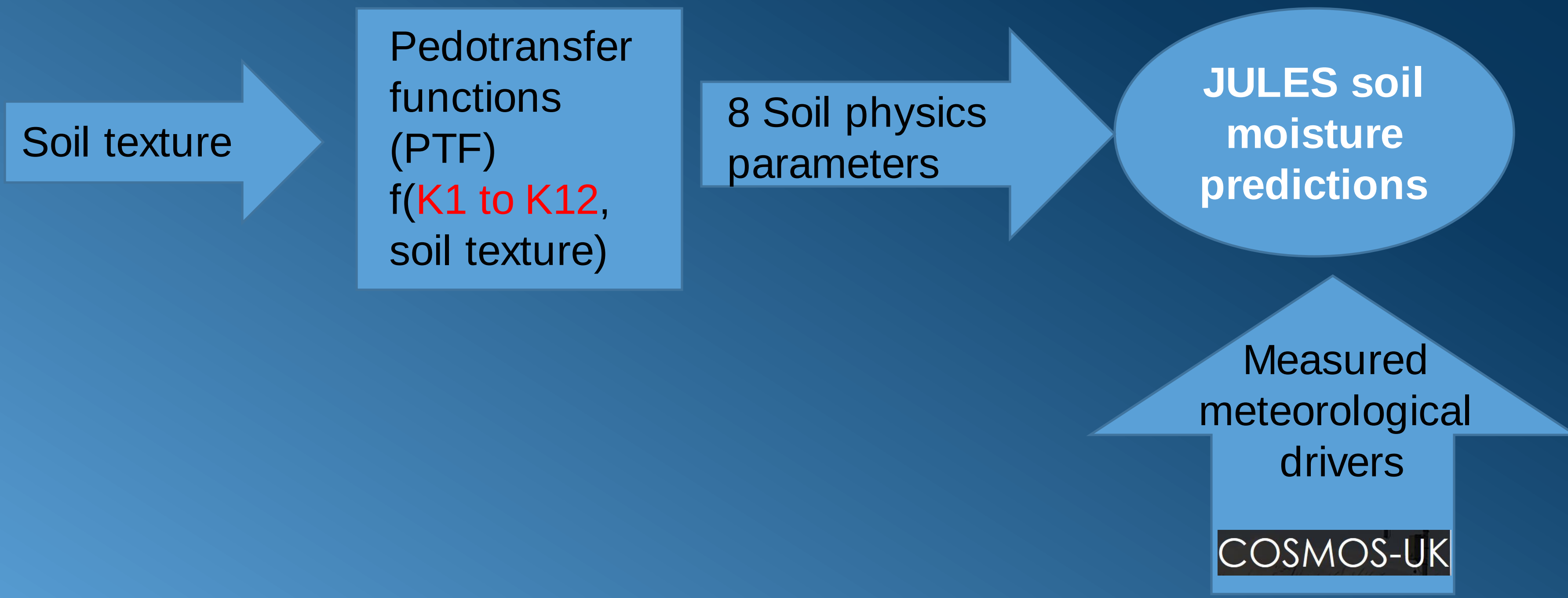
Model: JULES soil physics

Driving JULES with local observed meteorology produces soil moisture estimates that can be compared with measured values



Cosby(ish) pedotransfer functions

Cosby et al. doi:10.1029/WR020i006p00682

$$b = \kappa_1 + \kappa_2 f_{clay} - \kappa_3 f_{sand}$$

$$vsat = \kappa_4 - \kappa_5 f_{clay} - \kappa_6 f_{sand}$$

How wet can the soil get?

$$sathh = 0.01 \text{ x } 10\text{^} (\kappa_7 - \kappa_8 f_{clay} - \kappa_9 f_{sand})$$

How tightly is water held?

$$satcon = 10\text{^} (-\kappa_{10} - \kappa_{11} f_{clay} + \kappa_{12} f_{sand})$$

How fast can water move?

$$vcrit = vsat \left(\frac{sat\,hh}{3.364}\right)^{\frac{1}{b}}$$

When does vegetation get water stressed?

$$vwilt = vsat \left(\frac{sat\,hh}{152.9}\right)^{\frac{1}{b}}$$

When does vegetation start to die?

$$hcap = (1 - vsat)(2.376 \times 10^6 f_{clay} + 2.133 \times 10^6 f_{silt}$$

$$hcon = 0.025^{vsat} (1.16^{f_{clay}\ (1-vsat)} \times 1.57^{f_{sand}\ (1-vsat)} \times 1.57^{f_{silt}\ (1-vsat)})$$

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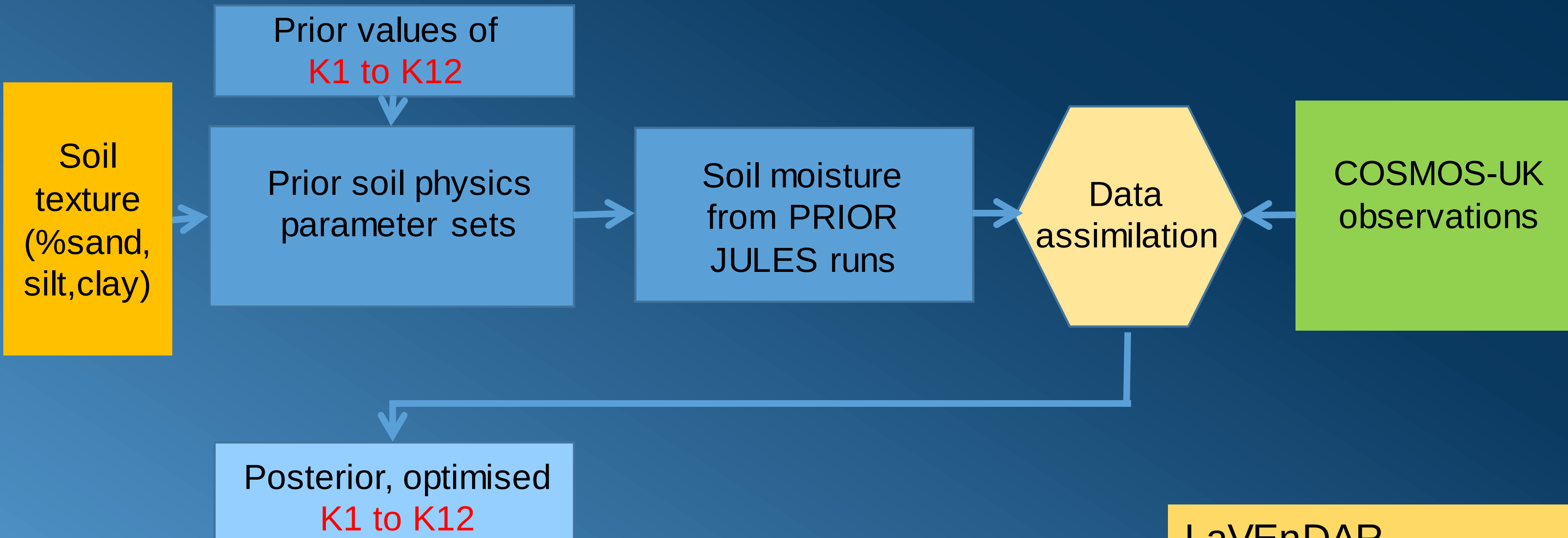
Experimental schematic



LaVEnDAR framework:

4D ensemble variational method by Ewan Pinnington doi: 10.5194/gmd-13-55-2020

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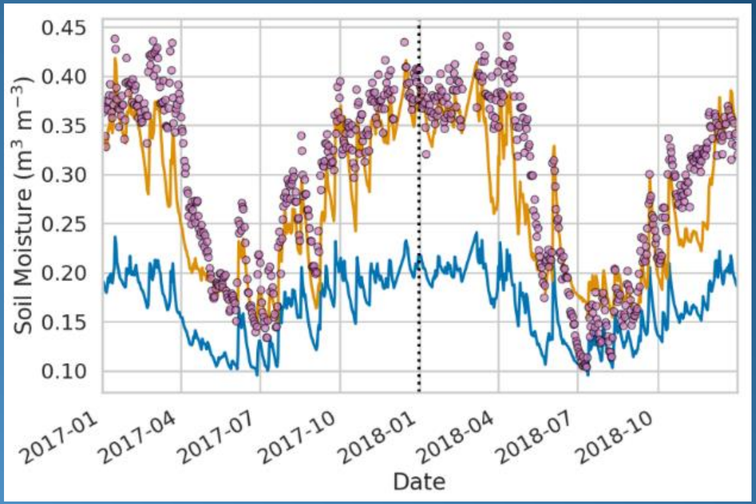
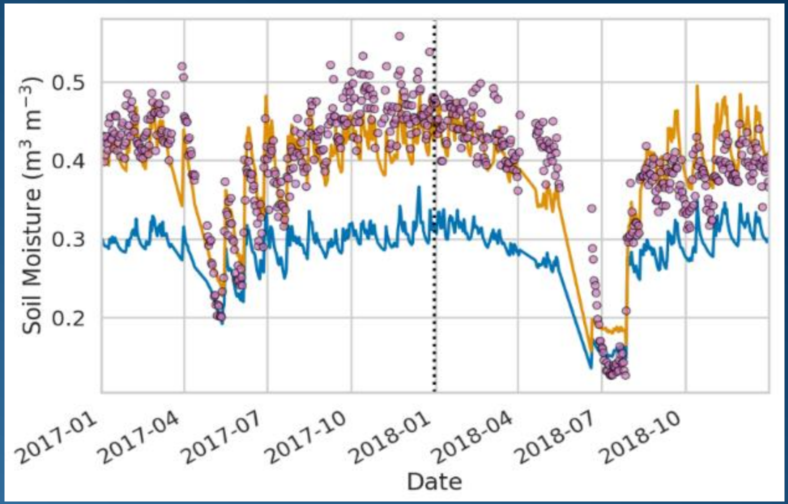
Example soil moisture results: study 1



BICKL



CRICH

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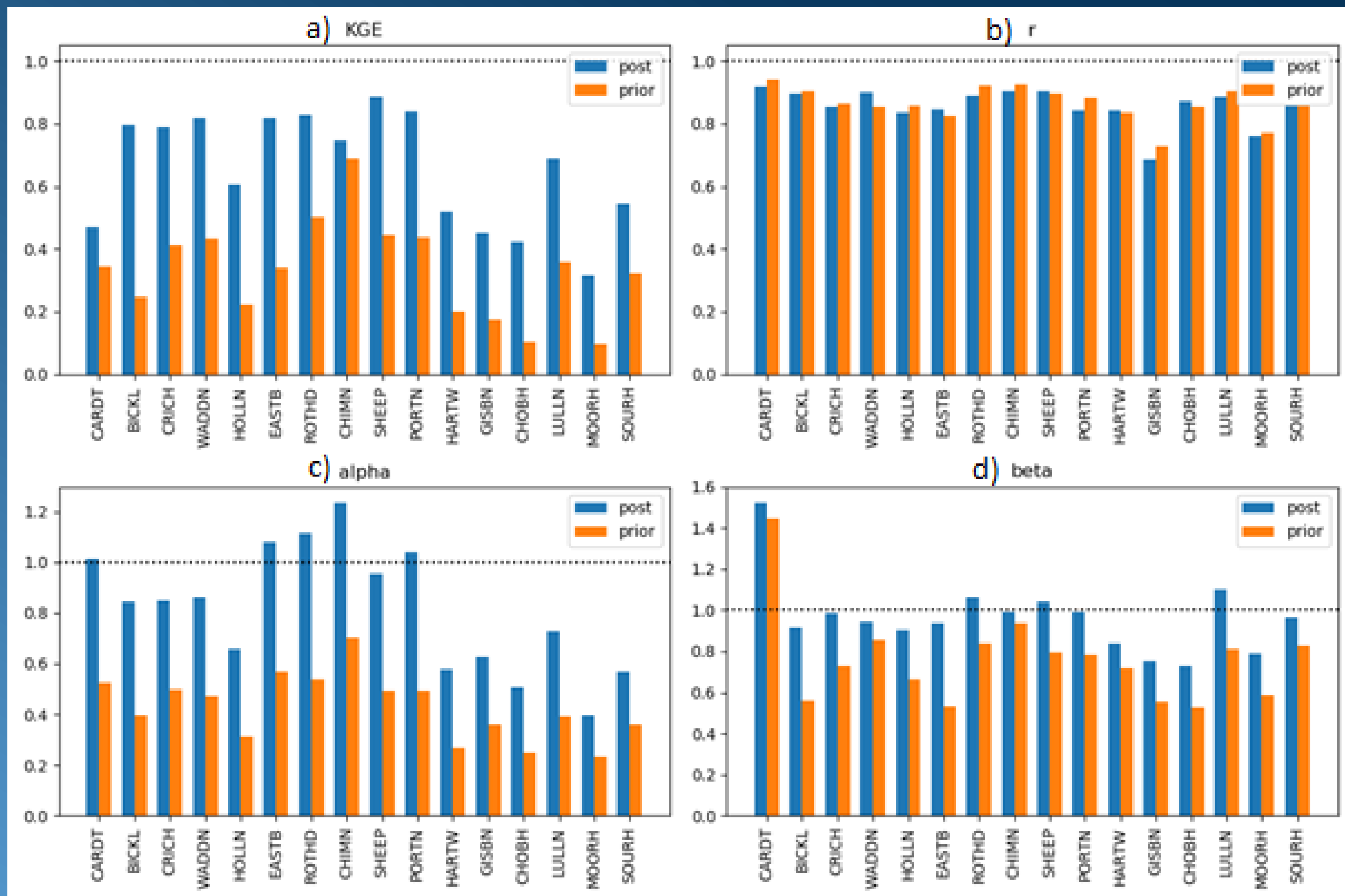
Better fit at all sites: study 1



Alpha =
Model spread/
obs spread

Bets =
Model mean/
obs mean

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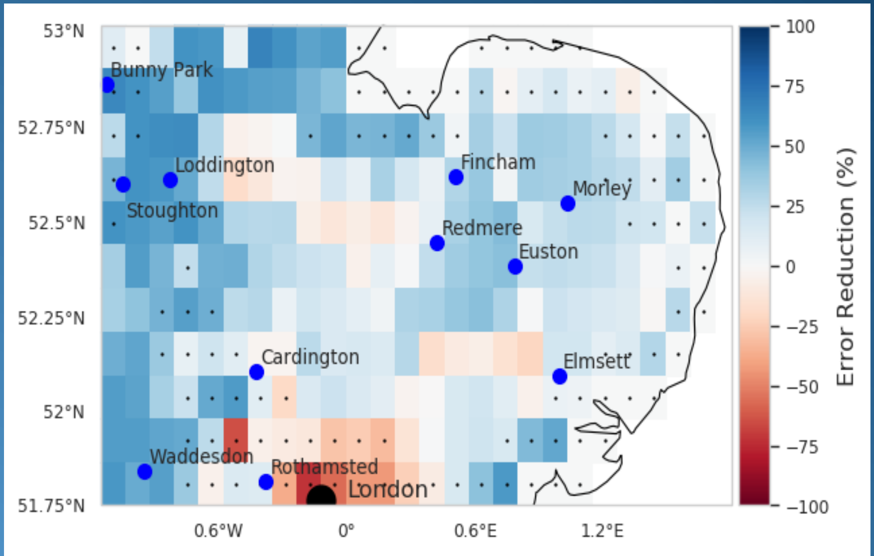
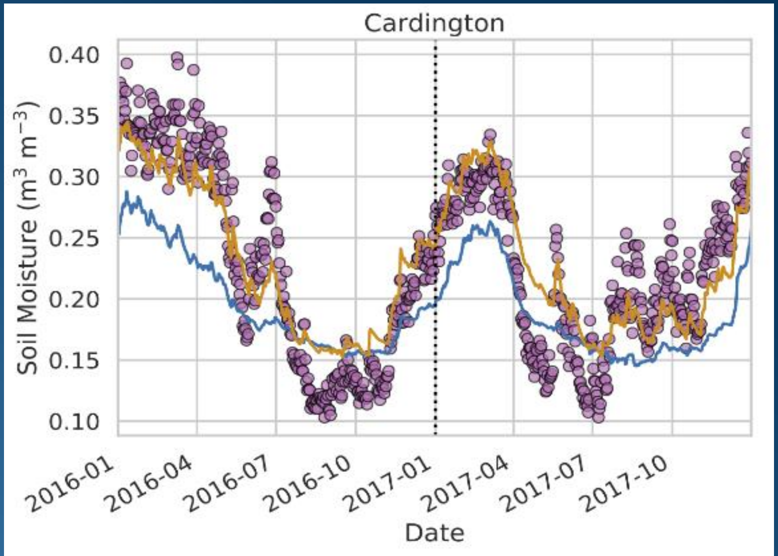
Example soil moisture results: study 2





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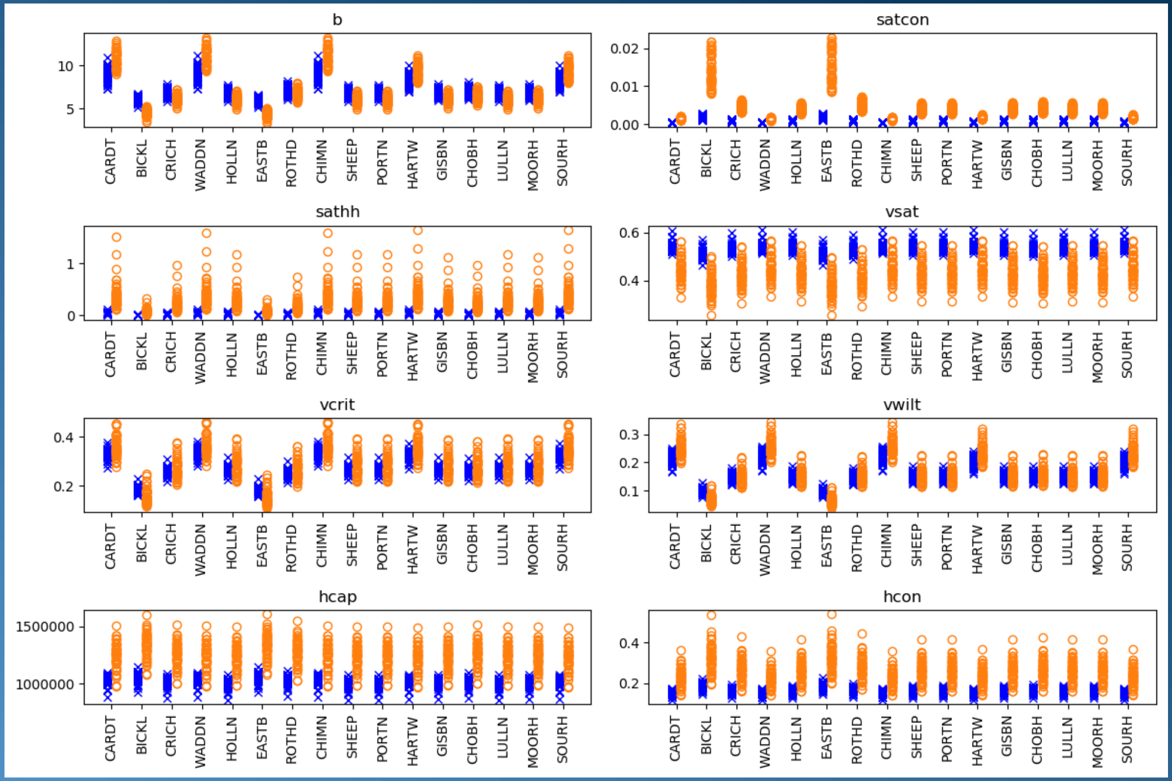
What happens to the soil physics parameters?



How fast can the water move?

How tightly is water held?

How wet can the soil get?

When do plants start to die?

When do plants get water stressed?

Orange is PRIOR, blue POSTERIOR

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Discussion:

We have successfully improved fit between JULES and observed soil moisture by optimizing constants in a pedotransfer function! ☺

Resultant changes to the soil physics parameters can tell us something about…

- scale of measurements?
- global location of measurements?
- missing processes in JULES?
- process representation in JULES?
- all of the above?!

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