Using data assimilation to improve JULES soil moisture outputs and better understand soil physics processes

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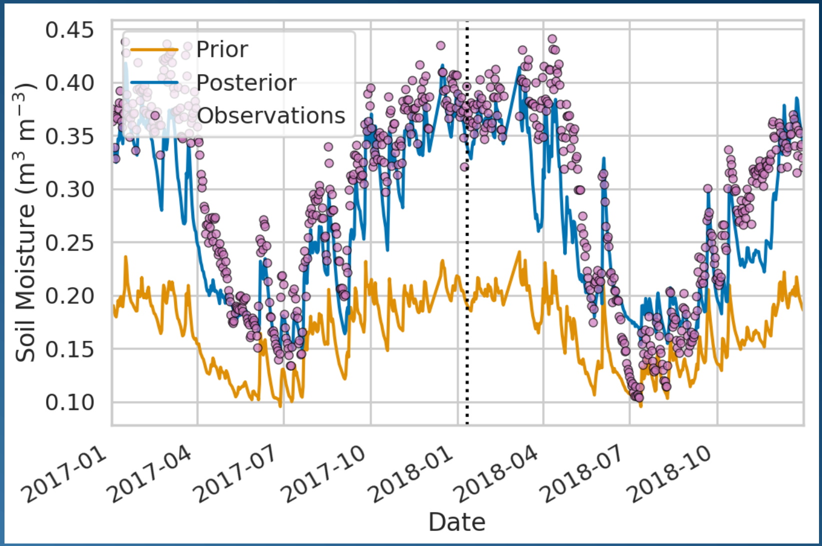
COSMOS-UK



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Data assimilation is……

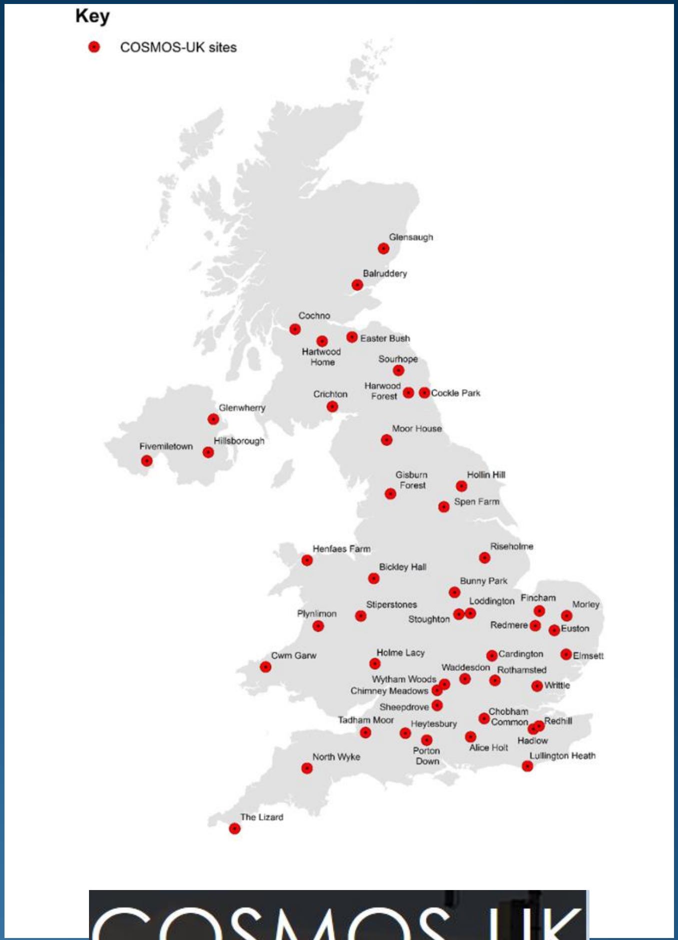
The art of combining information from models and observations in order to find out something we want to know

I'm going to tell you about

- **Our observations**
- **Our model**
- **The experiments we ran using LaVEnDAR**
- **How this can help us unravel *some* information about infiltration excess runoff, leading to…..**
- **…. more questions!**

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

Soil texture

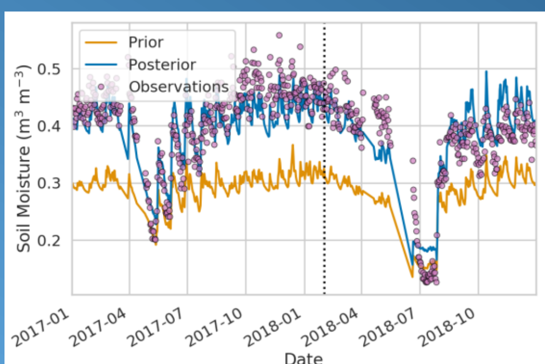
Pedotransfer functions (PTF) f(K1 to K12, soil texture)

8 Soil physics parameters

JULES soil moisture predictions

Measured meteorological drivers

COSMOS-UK



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Cosby (ish) pedotransfer functions give params with physical meanings

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

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

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

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

$$\theta_{crit} = \theta_s \left(\frac{\psi_s}{3.364}\right)^{\frac{1}{b}}$$

$$\theta_{wilt} = \theta_s \left(\frac{\psi_s}{152.9}\right)^{\frac{1}{b}}$$

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

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

How wet can the soil get?

How tightly is water held?

How fast can water move?

We optimise the constants in red

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

$\theta_s = \kappa_4 - \kappa_5 f_{clay} - \kappa_6 f_{sand}$ — How wet can the soil get?

$\psi_s = 0.01 \text{ x } 10\text{\^{}} (\kappa_7 - \kappa_8 f_{clay} - \kappa_9 f_{sand})$ — How tightly is water held?

$K_s = 10\text{\^{}} (-\kappa_{10} - \kappa_{11} f_{clay} + \kappa_{12} f_{sand})$ — How fast can water move?

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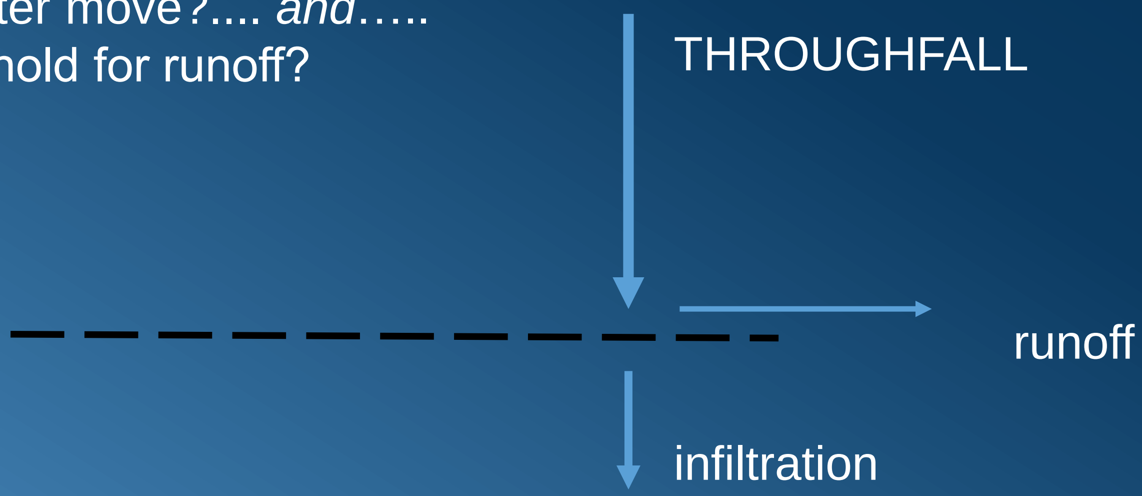
Two jobs of Ks (Ksat)

- How fast can water move?.... *and*…..
- What’s the threshold for runoff?



Smaller Ks means:

- Water moves more slowly through soil
- Less infiltration (more runoff, more often)

To separate Ks' jobs, we add an extra equation to pedotransfer functions

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

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

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

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

How wet can the soil get?

How tightly is water held?

How fast can water move?

$$\theta_{crit} = \theta_s \left(\frac{\psi_s}{3.364}\right)^{\frac{1}{b}}$$

$$\theta_{wilt} = \theta_s \left(\frac{\psi_s}{152.9}\right)^{\frac{1}{b}}$$

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

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

$max\_inf = 10\text{\^{}}(-\kappa_{13} - \kappa_{14} f_{clay} + \kappa_{15} f_{sand})$

When does runoff start?

++ ++

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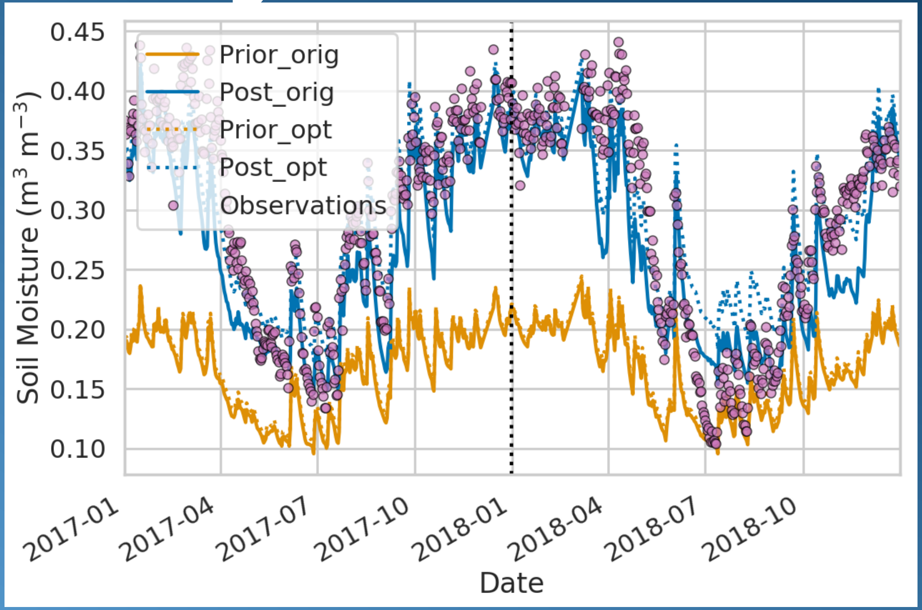
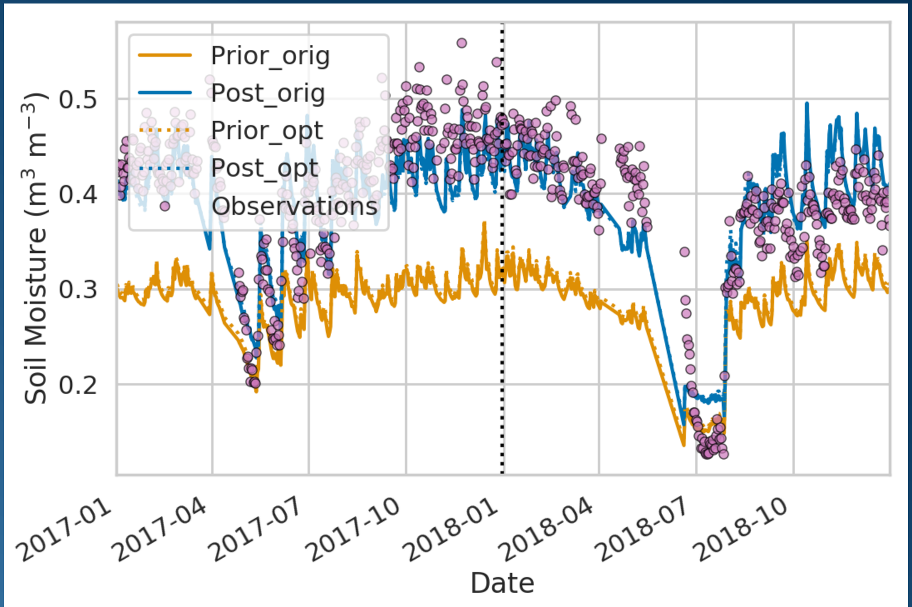
Soil moisture results stay very similar



BICKL



CRICH

+ less runoff at all sites

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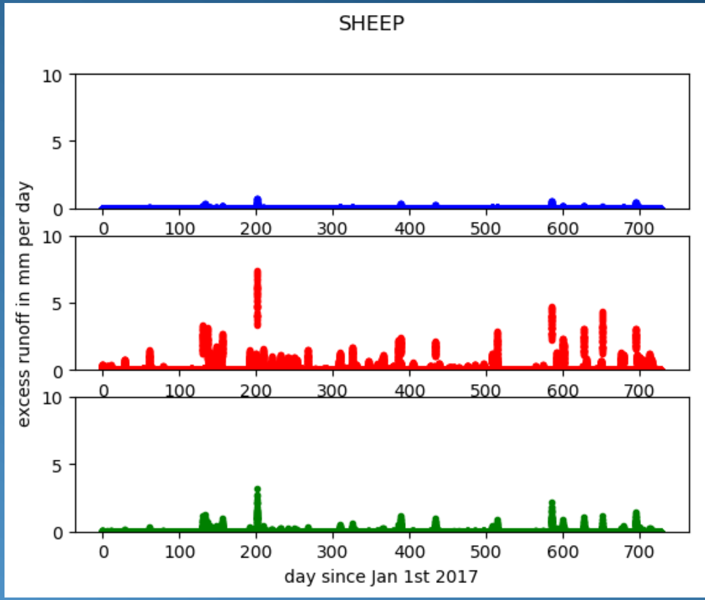
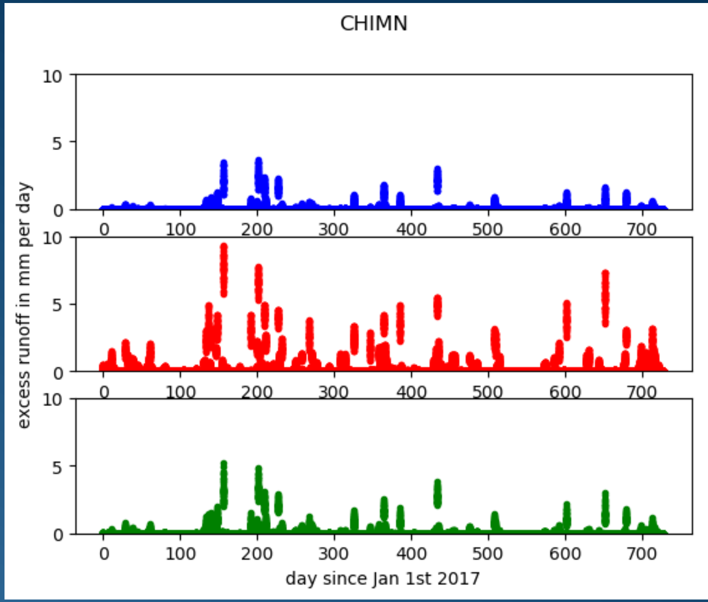
Runoff looks different



Before DA

Ksat two jobs

Ksat and max_inf



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PTF params

clay sand

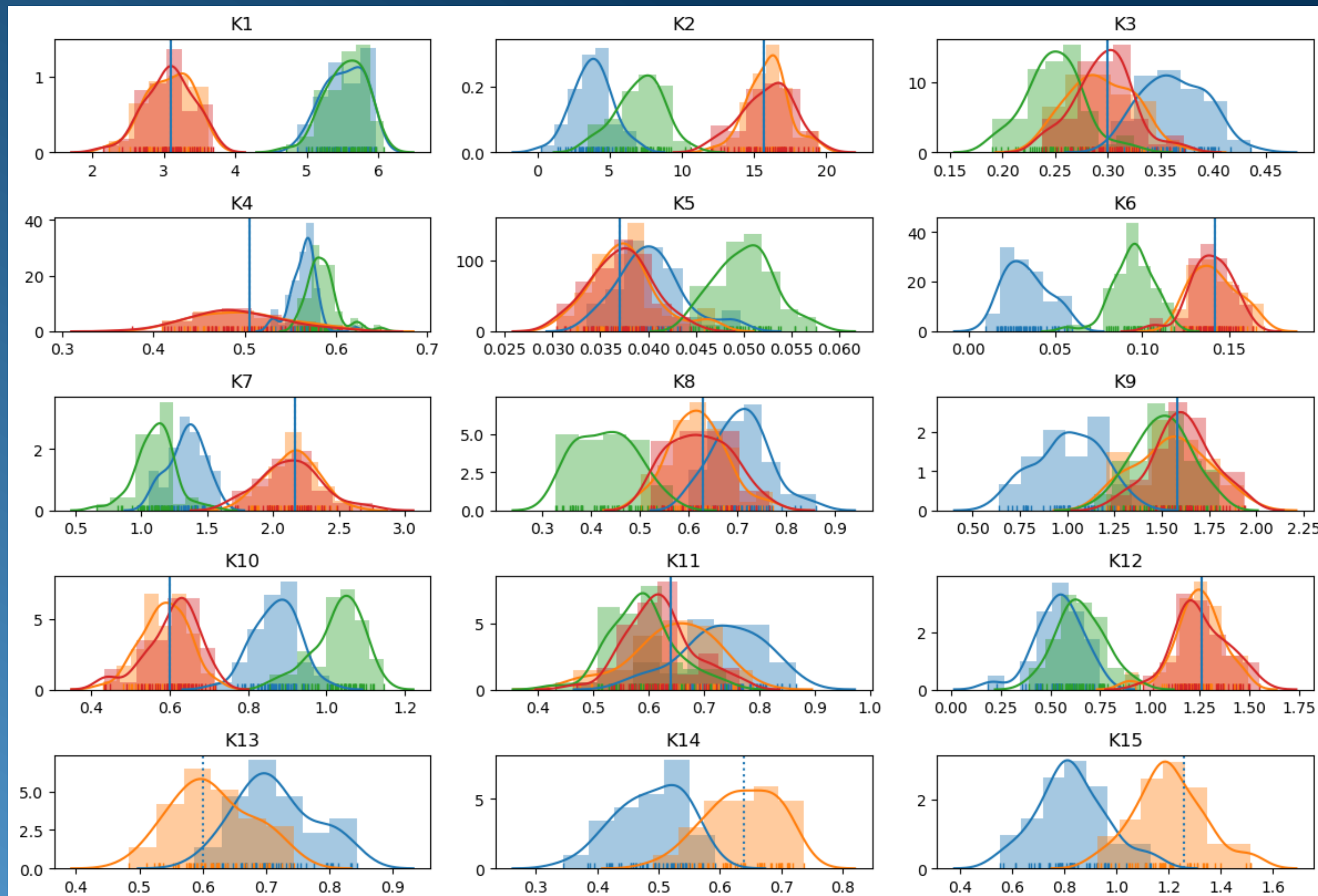
b

vsat

sathh

Ksat

max_inf



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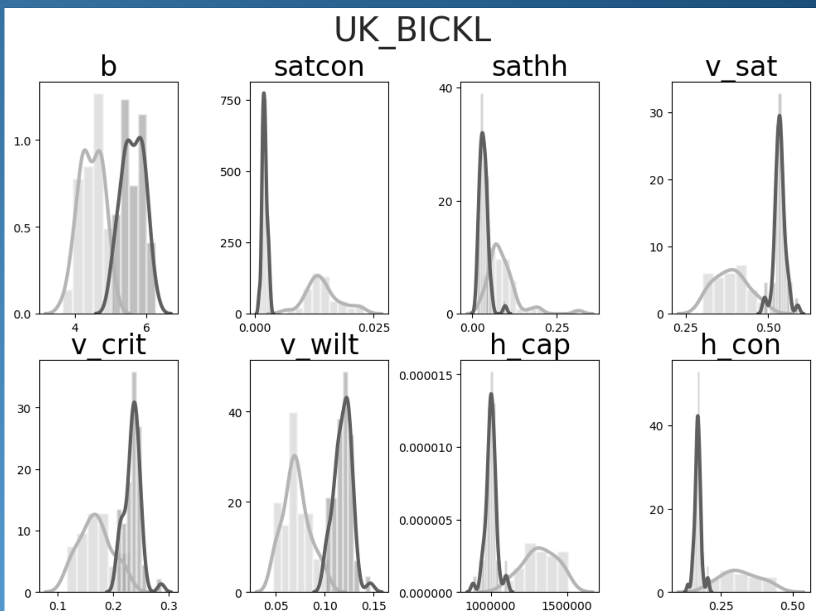
Soil physics parameter values

with optimised max_inf



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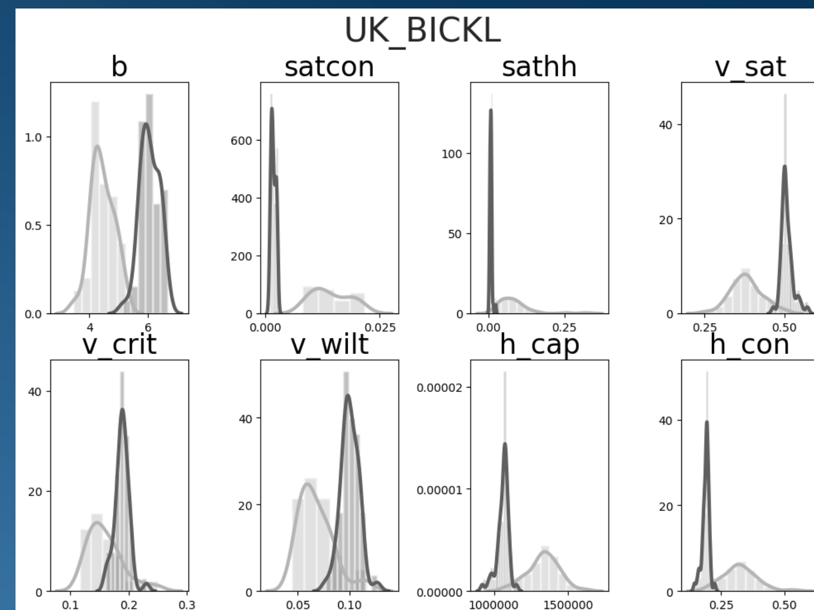

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Discussion:

Improved JULES soil moisture outputs

Introduced a new parameter to control infiltration excess runoff

- **Still see improved JULES soil moisture**
- **Runoff reduced**

New questions

- **What should max_inf really look like?**
    - **River flow data?**
    - **Dependence on rain input timestep?**
- **Weather/climate forecasts?**
- **What does all this mean for process representation?**

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