Improving soil moisture prediction of a land surface model through data assimilation

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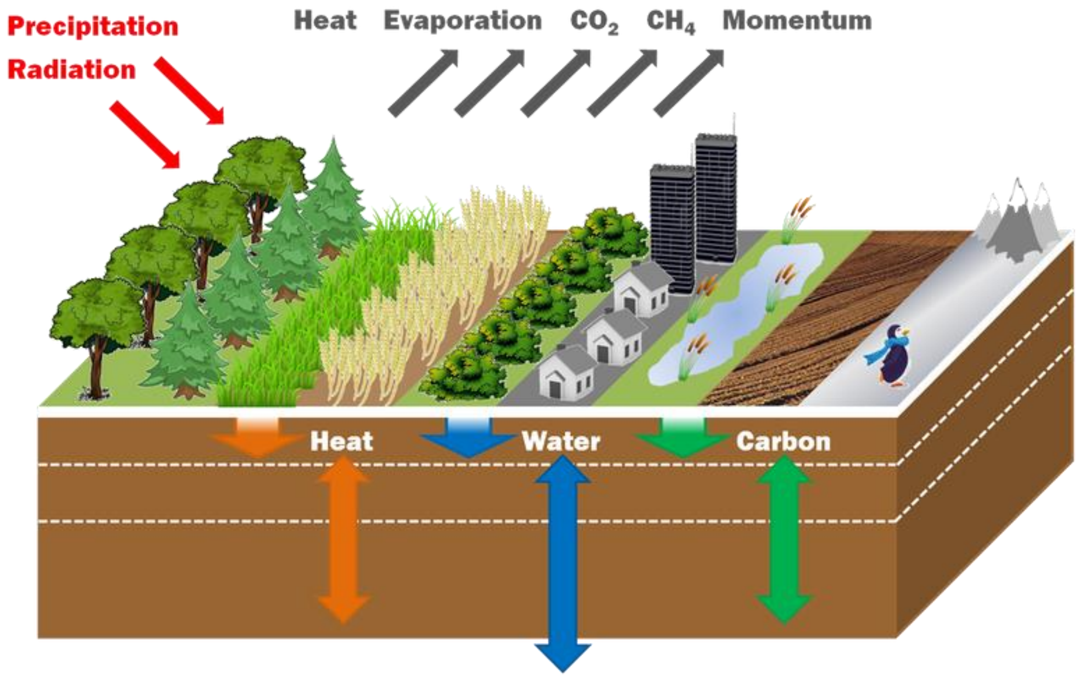
JULES land surface model

- The Joint UK Land Environment Simulator (JULES) made up of different tiles and soil layers.
- Combining JULES model predictions with physical observations to find improved estimates to model parameters and state variables using Data Assimilation (DA) techniques.



JULES model schematic

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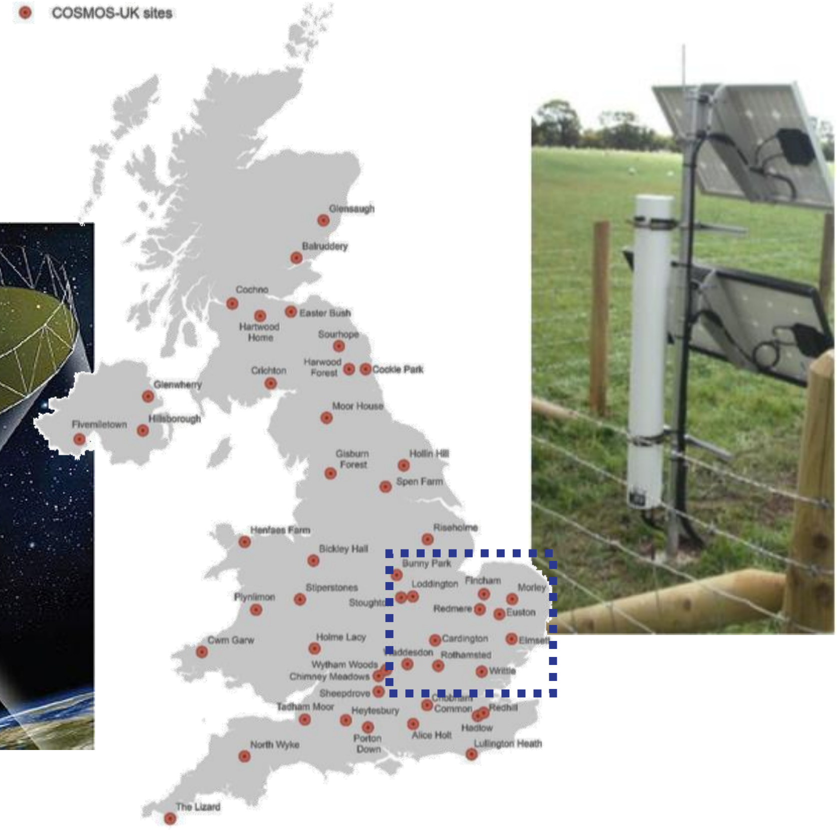
Satellite soil moisture Data Assimilation work

- Developing Data Assimilation (DA) techniques for soil model parameter estimation.
- Running JULES at 1 km resolution over the UK.
- Assimilating satellite observations from the NASA SMAP mission.
- Validate results using the cosmic-ray soil moisture monitoring network (COSMOS-UK) established by UKCEH.

Hydro-JULES



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LAVENDAR

- The Land Ensemble Variational Data Assimilation fRamework (LAVENDAR) implements Four-Dimensional Ensemble Variational (4DEnVar) DA for land surface models. Similarities with Iterative Ensemble Kalman Smooth (IEnKS).
  - https://github.com/pyearthsci/lavendar
  - Pinnington, E., Quaife, T., Lawless, A., Williams, K., Arkebauer, T., and Scoby, D.: The Land Variational Ensemble Data Assimilation Framework: LAVENDAR v1.0.0, Geosci. Model Dev., 13, 55–69, https://doi.org/10.5194/gmd-13-55-2020, 2020.
- Allows us to find improved parameters/state for models, informed by observations.
- Wrappers allow us to easily run ensemble of models with different parameters in parallel and perform the data assimilation.

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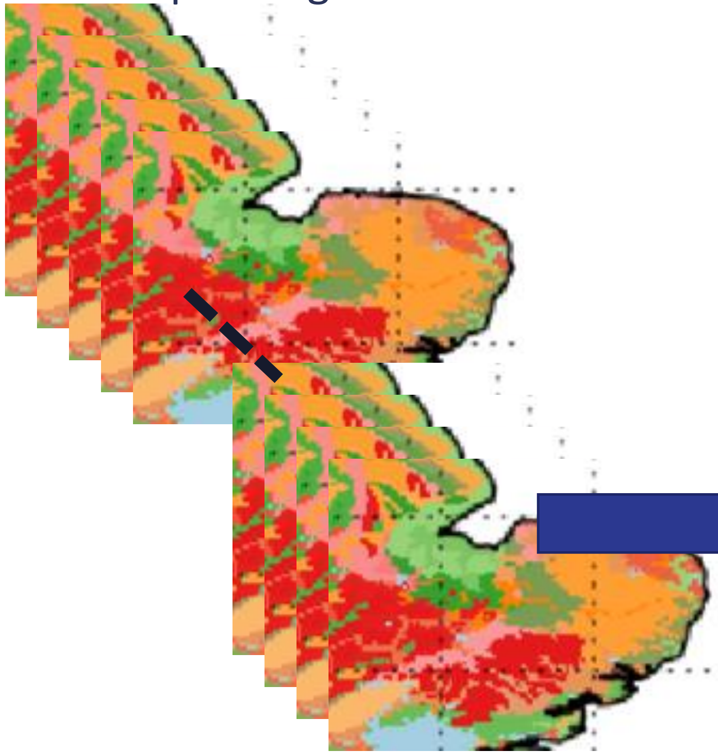
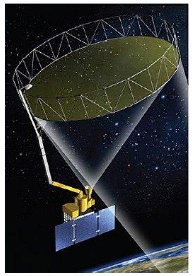
Assimilating SMAP over East Anglia

50 prior JULES soil parameter sets
& corresponding JULES runs

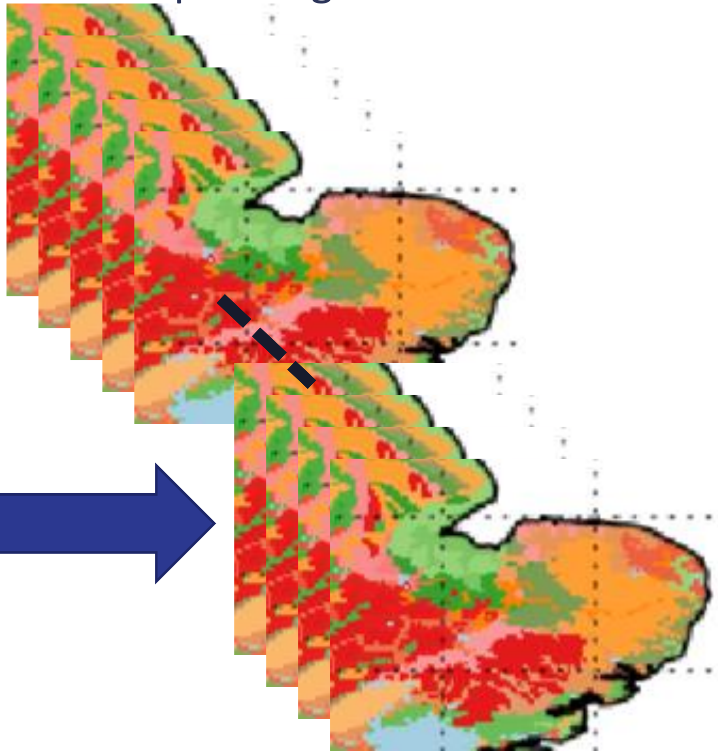


2016 SMAP obs.



LAVENDAR algorithm

50 posterior JULES parameter sets
& corresponding JULES runs



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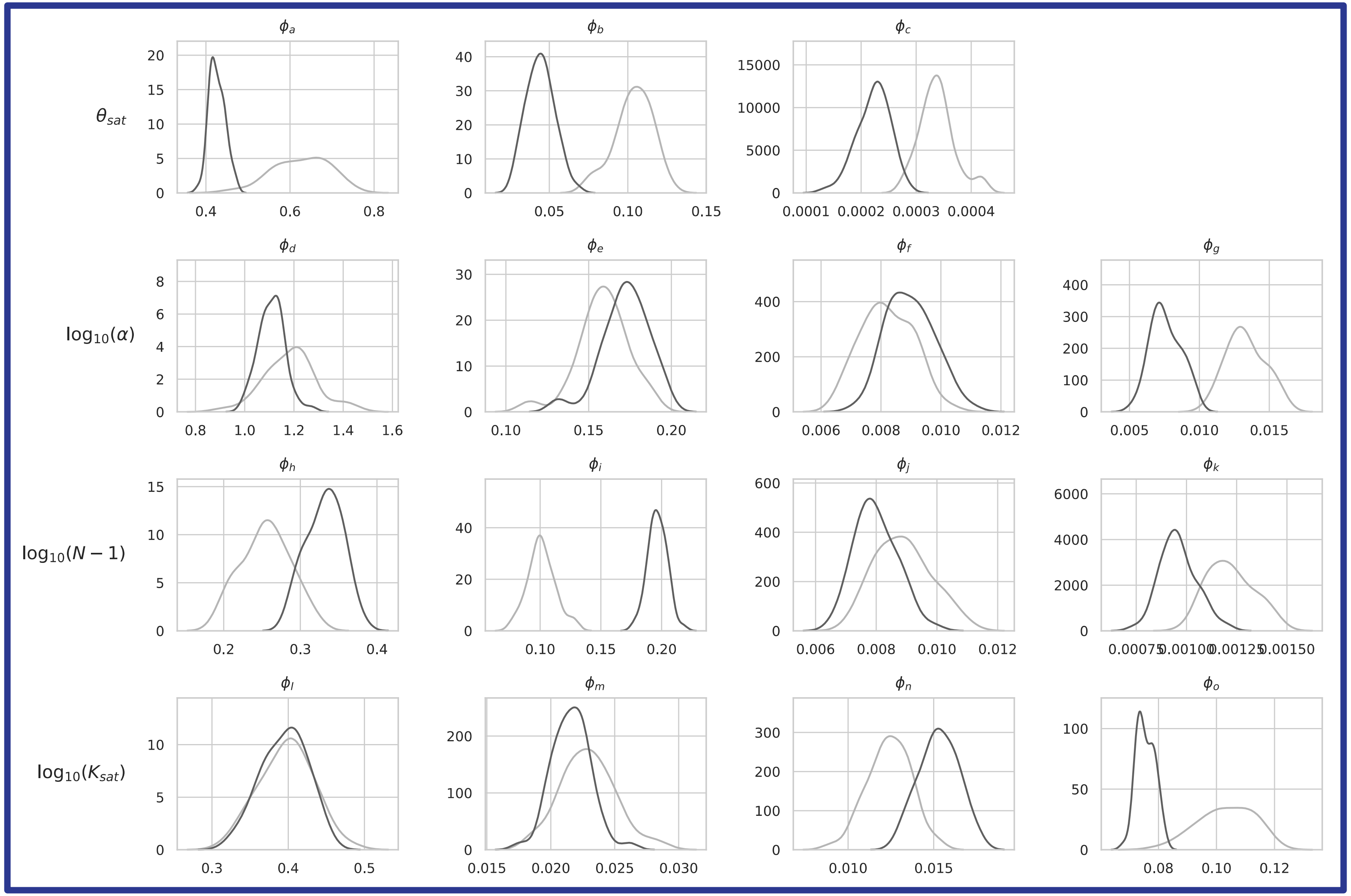
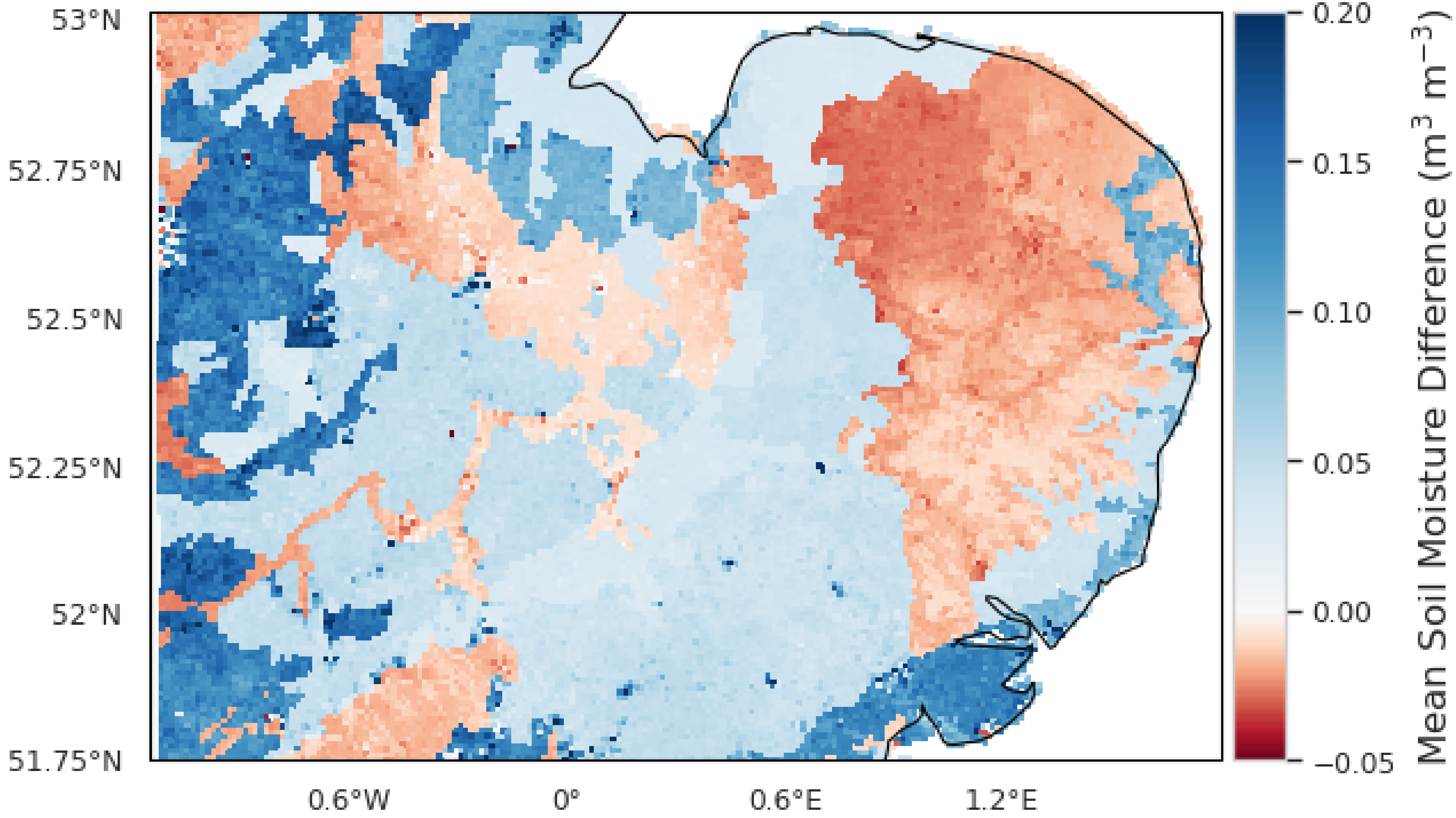
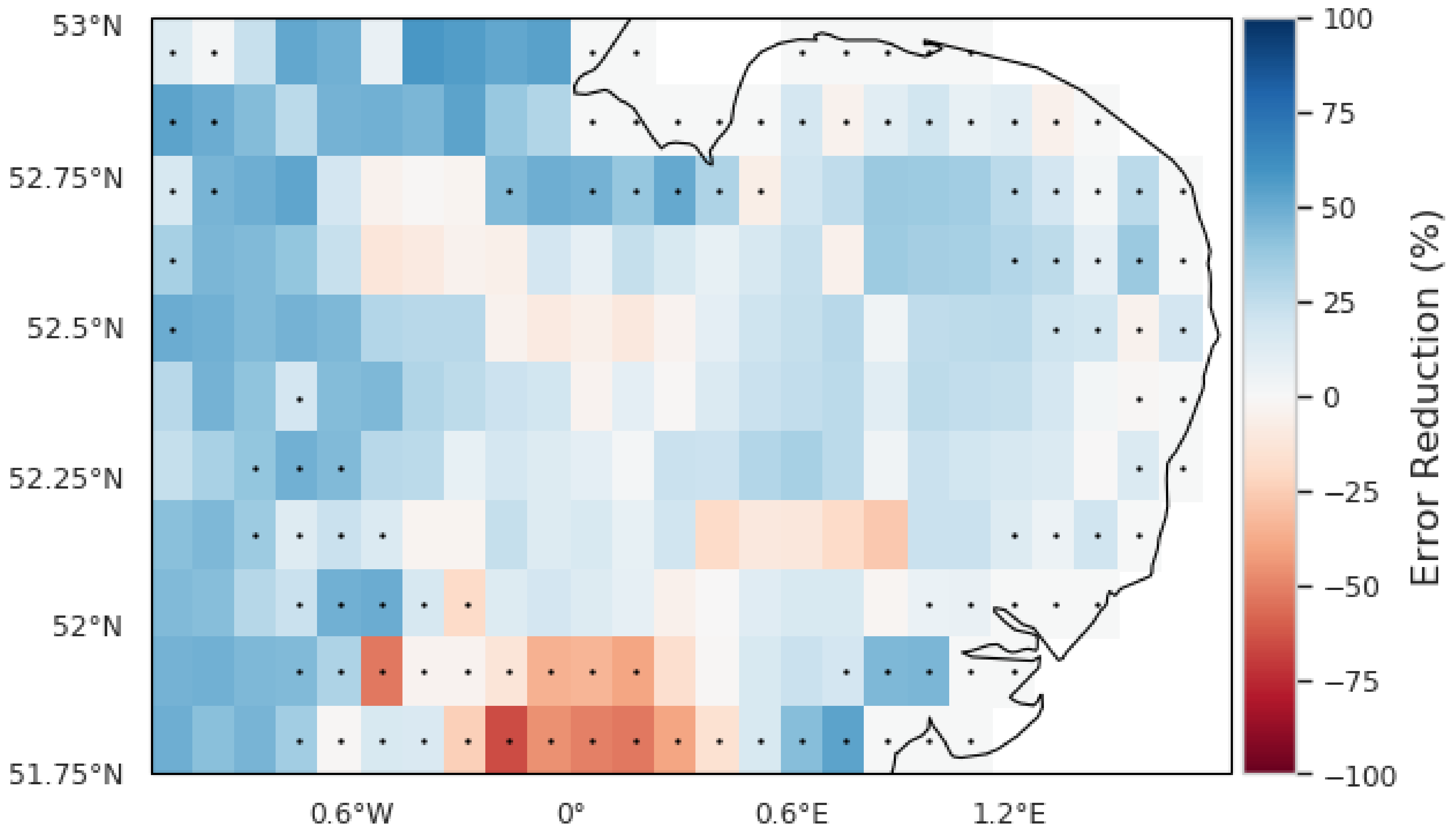
Assimilating SMAP over East Anglia



Impact on JULES soil moisture



JULES compared to 9km SMAP



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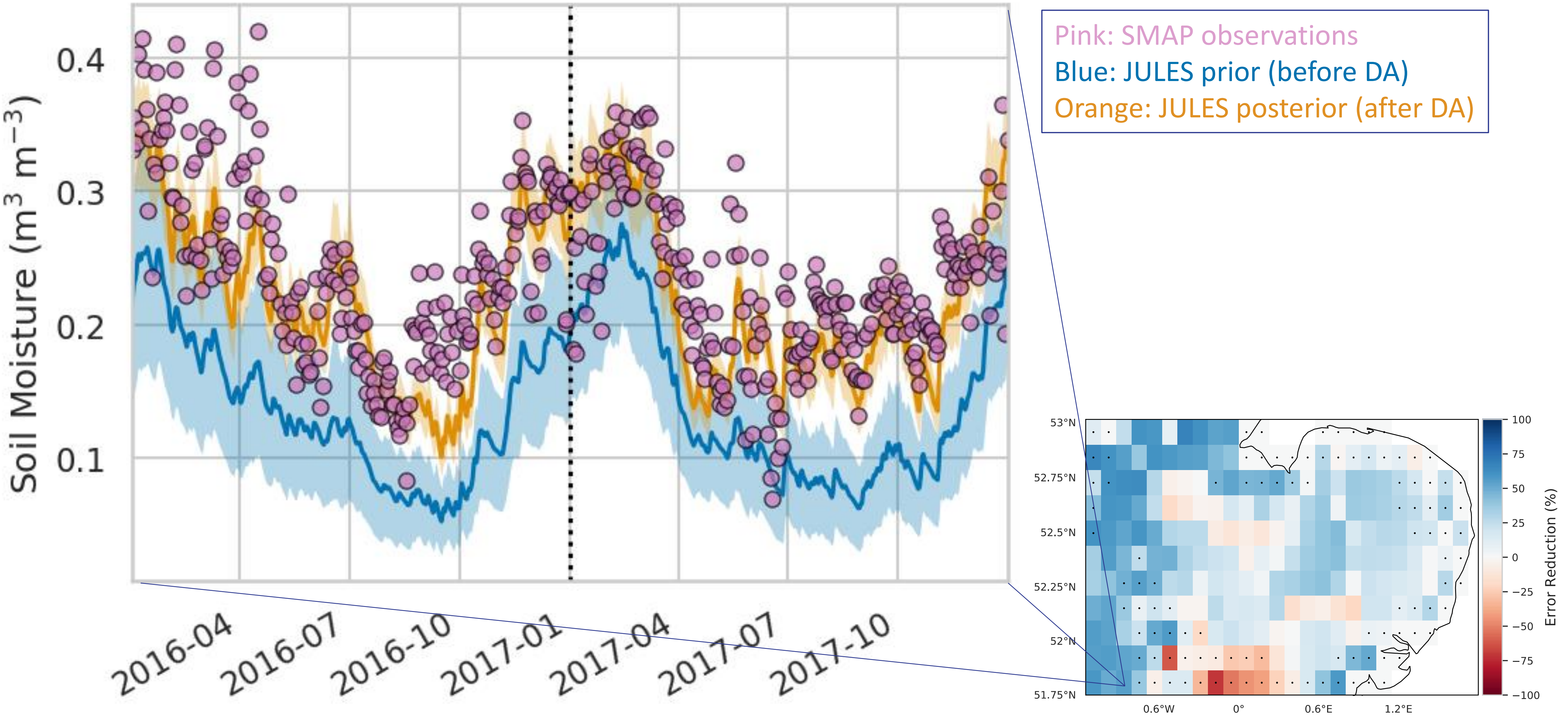
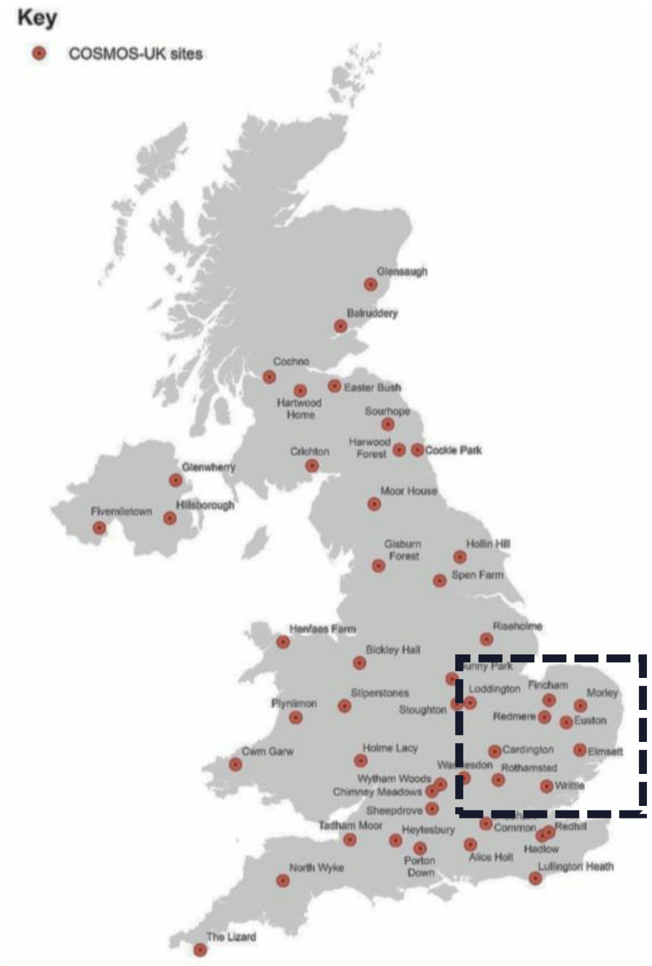


Pink: SMAP observations
Blue: JULES prior (before DA)
Orange: JULES posterior (after DA)

Do the new set of soil parameters perform better at COSMOS sites?



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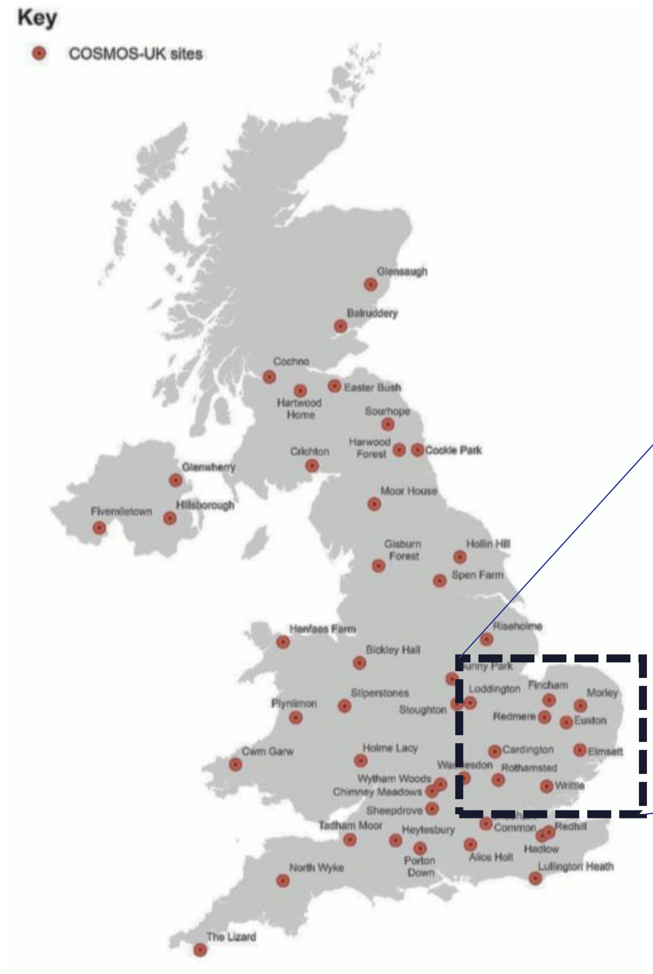

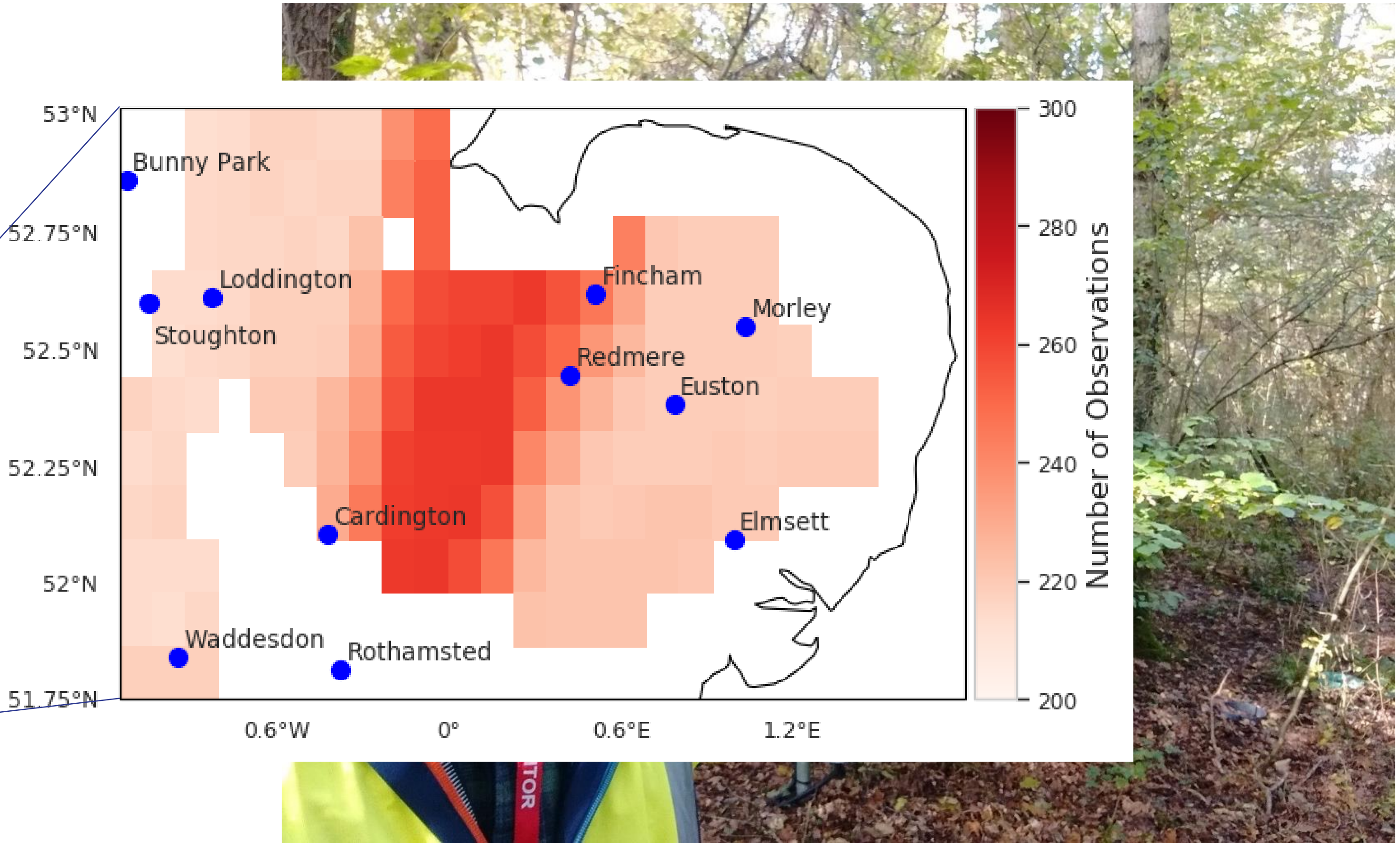

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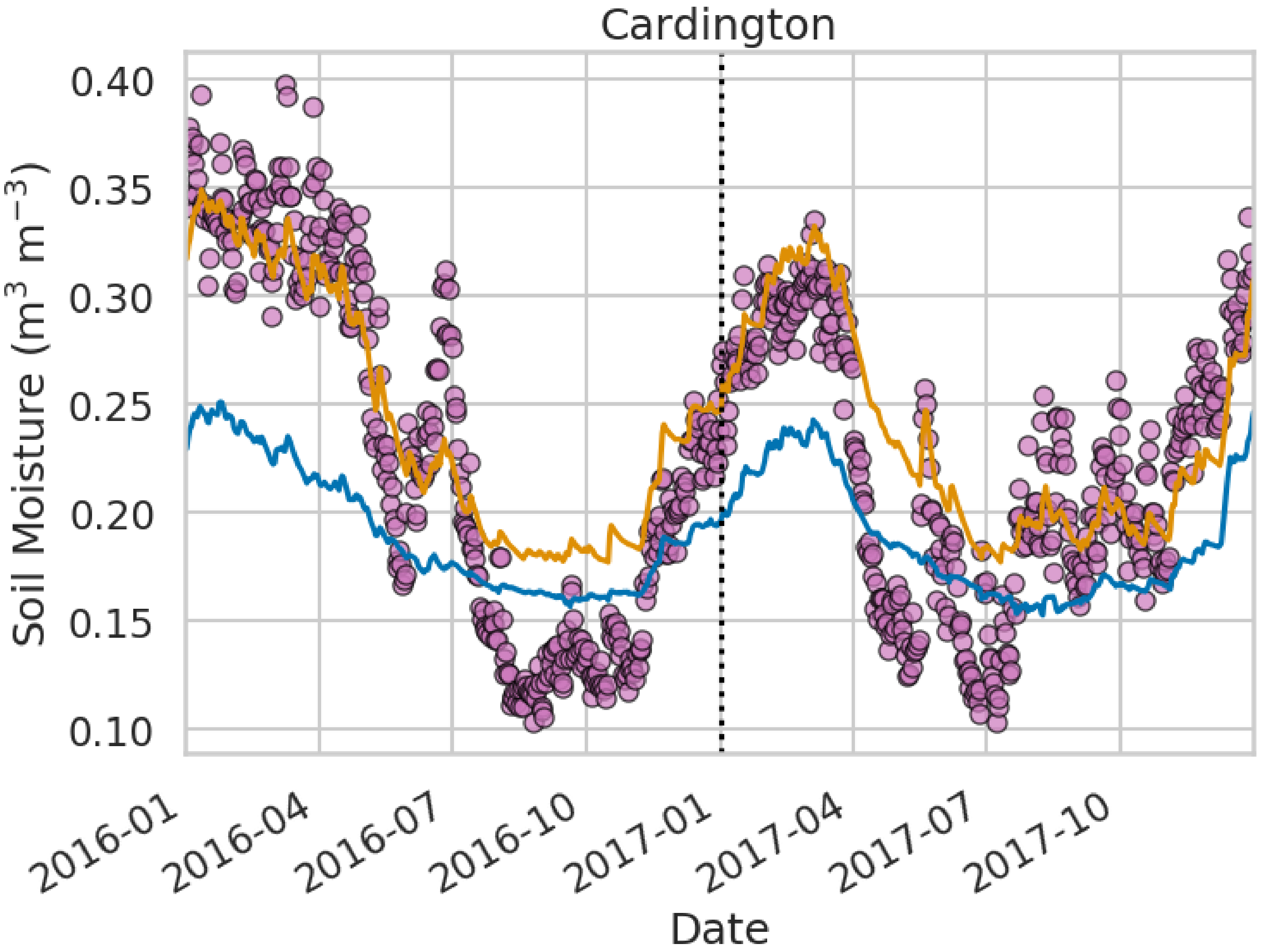

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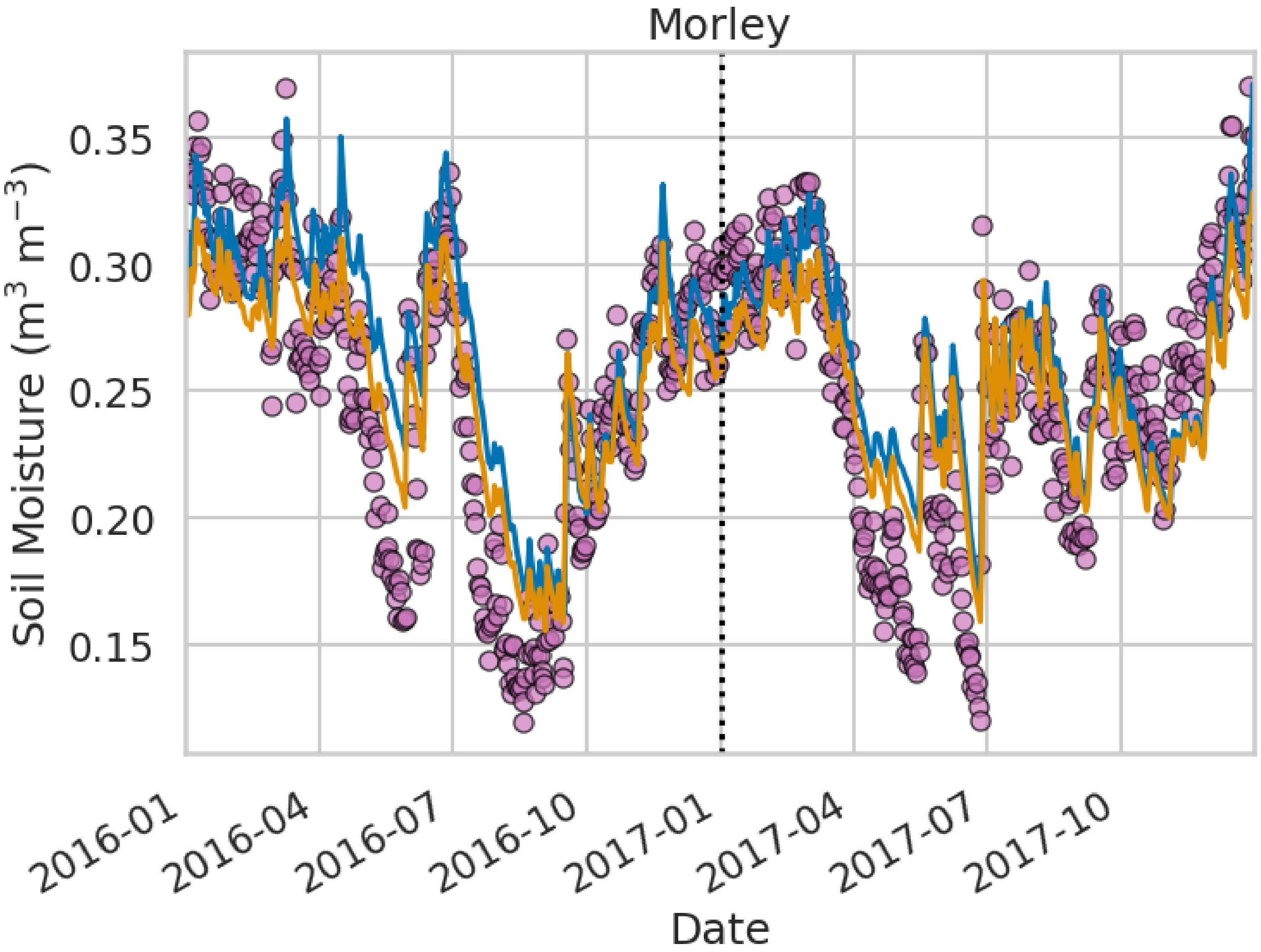

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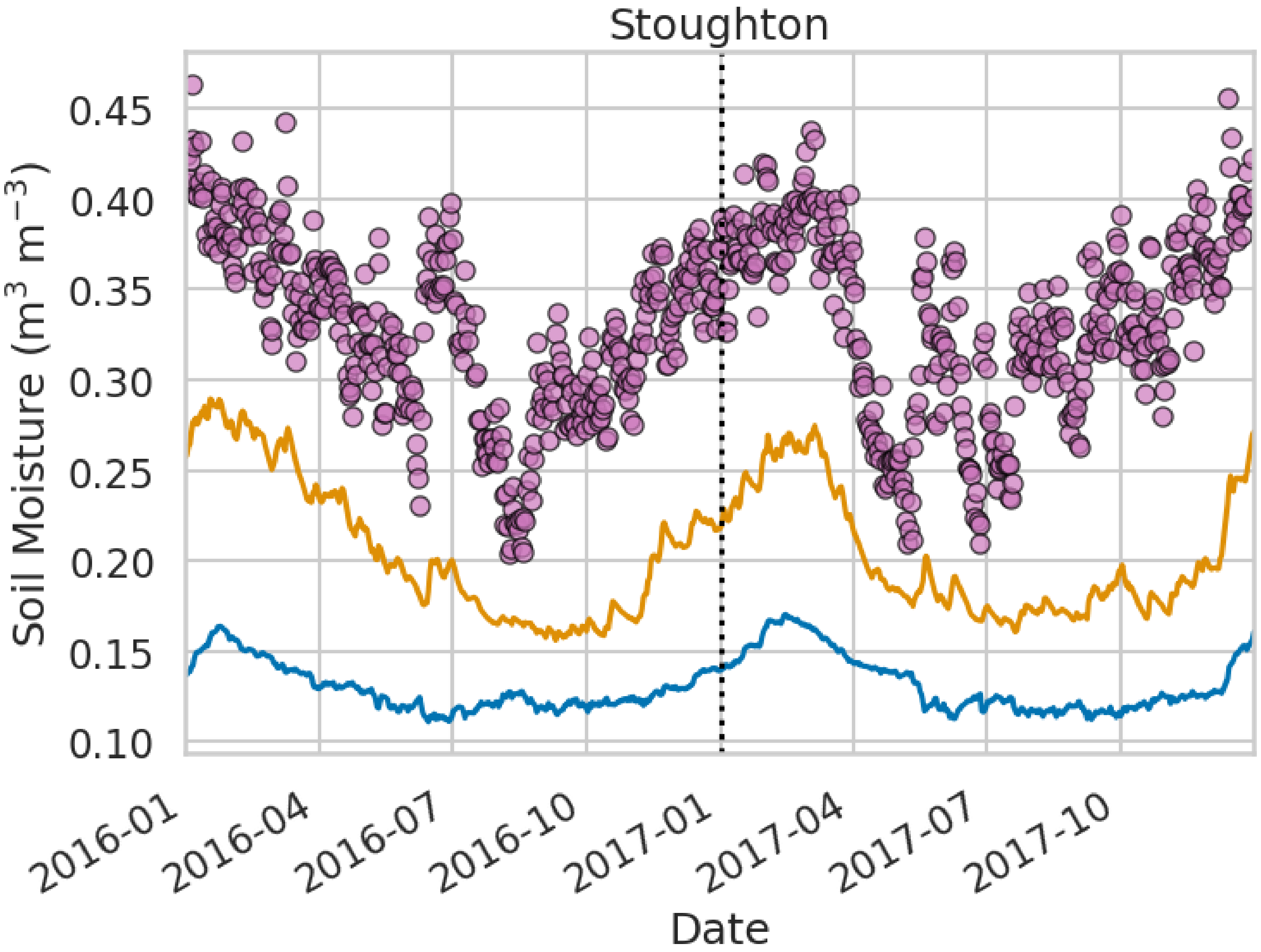

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Cosmos comparison summary

	Correlation		ubRMSE		RMSE	
Site	Prior	Posterior	Prior	Posterior	Prior	Posterior
Bunny Park	0.86	0.89	0.02	0.02	0.07	0.04
Cardington	0.85	0.91	0.05	0.03	0.06	0.03
Elmsett	0.81	0.82	0.04	0.04	0.16	0.17
Euston	0.90	0.92	0.04	0.04	0.05	0.04
Fincham	0.83	0.85	0.02	0.02	0.19	0.13
Loddington	0.45	0.79	0.06	0.04	0.39	0.31
Morley	0.86	0.89	0.03	0.03	0.03	0.03
Redmere	0.33	0.35	0.08	0.08	0.43	0.43
Rothamsted	0.85	0.89	0.03	0.03	0.05	0.07
Stoughton	0.30	0.76	0.05	0.04	0.24	0.13
Waddesdon	0.63	0.87	0.07	0.05	0.27	0.19
All Sites	0.70	0.81	0.045	0.038	0.18	0.14

Over all sites we find an average 16% increase in correlation, 16% reduction in ubRMSE and 22% reduction in RMSE.

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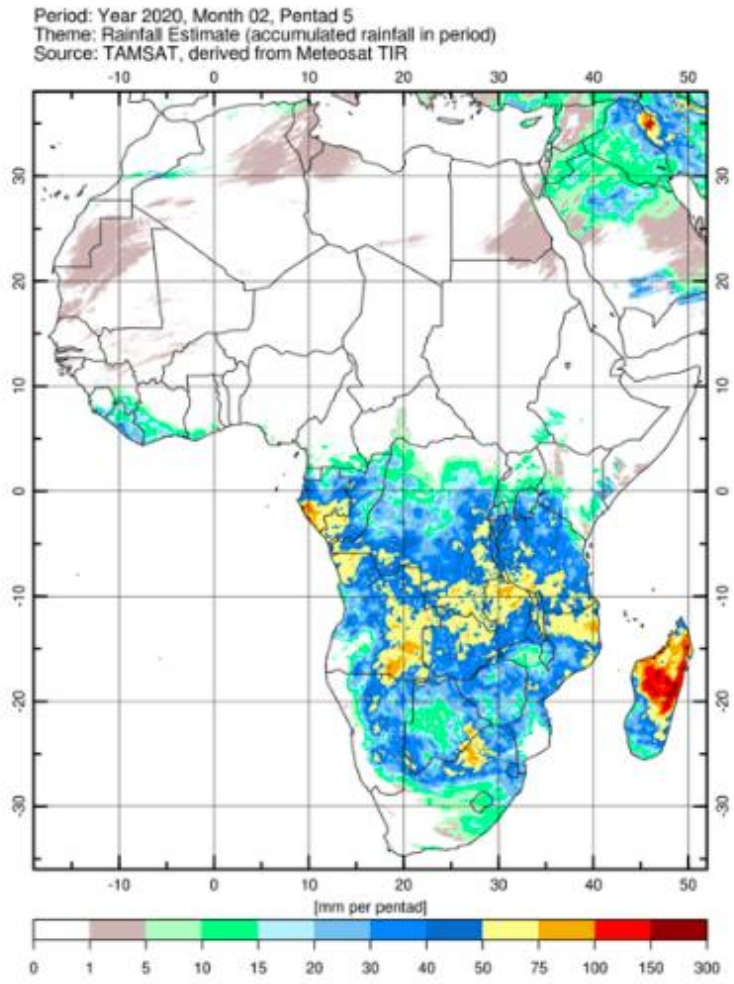
Conclusions

- We find large reduction in RMSE for JULES CHESS compared to SMAP SM after data assimilation.
- Certain areas cannot be improved due to the strong constraint of the underlying soil texture map and the fact that we do not include urban tiles.
- As independent validation we also find good improvements in soil moisture estimates at COSMOS-UK stations.

Hydro-JULES

Other ongoing activities

- As part of the TAMSAT group (tamsat.org.uk) working towards producing near real-time estimates of soil moisture with JULES over Africa.
- TAMSAT is a satellite rainfall product over Africa produced by the University of Reading.
- Running JULES with daily TAMSAT rainfall data and using LAVENDAR again to combine model output with SMAP satellite observations.



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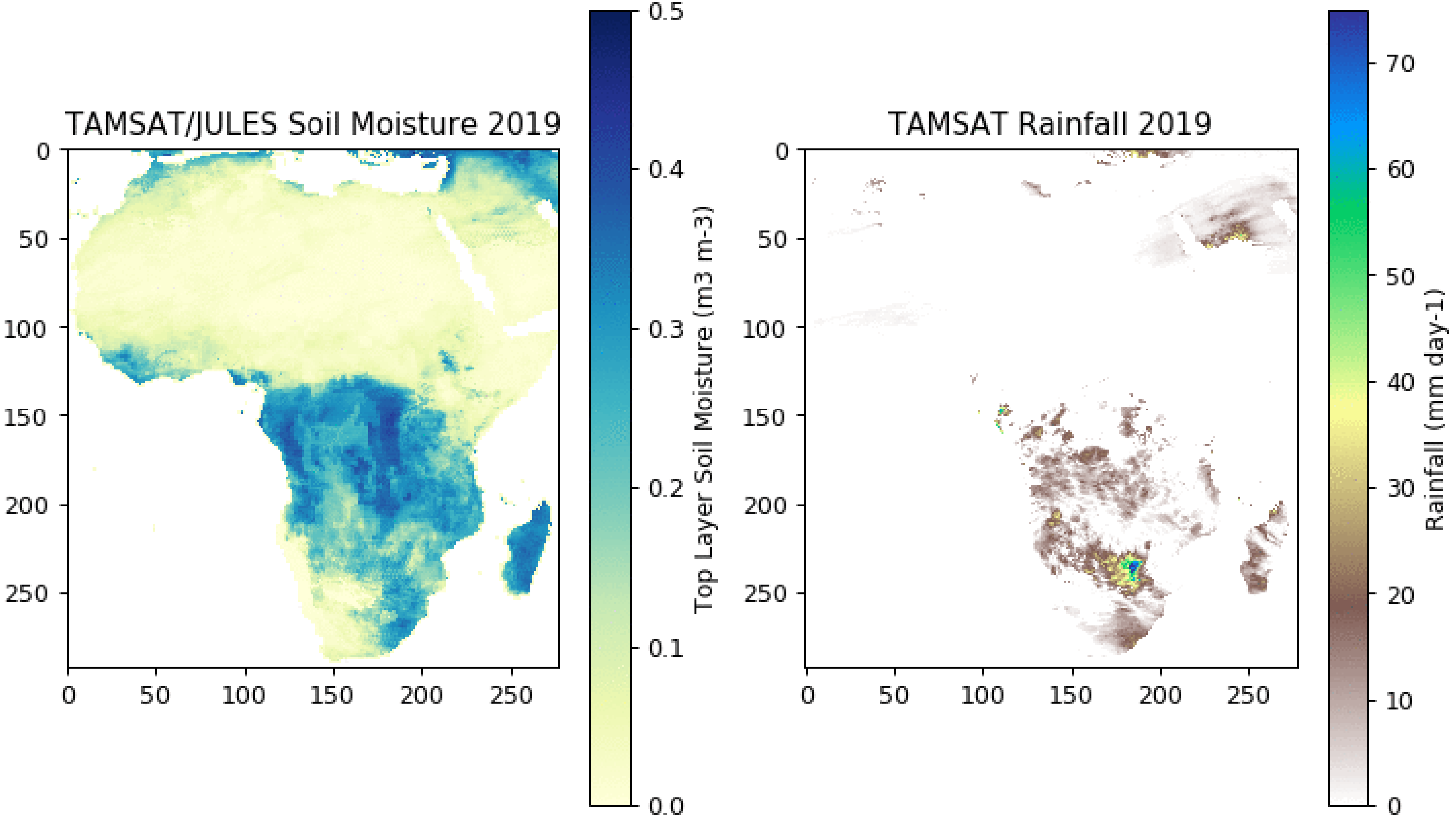


TAMSAT/JULES Soil Moisture 2019
Top Layer Soil Moisture (m3 m-3)
0.0
0.1
0.2
0.3
0.4
0.5
TAMSAT Rainfall 2019
Rainfall (mm day-1)
0
10
20
30
40
50
60
70

http://gws-access.jasmin.ac.uk/public/odanceo/soil_moisture/

TAMSAT Soil Moisture

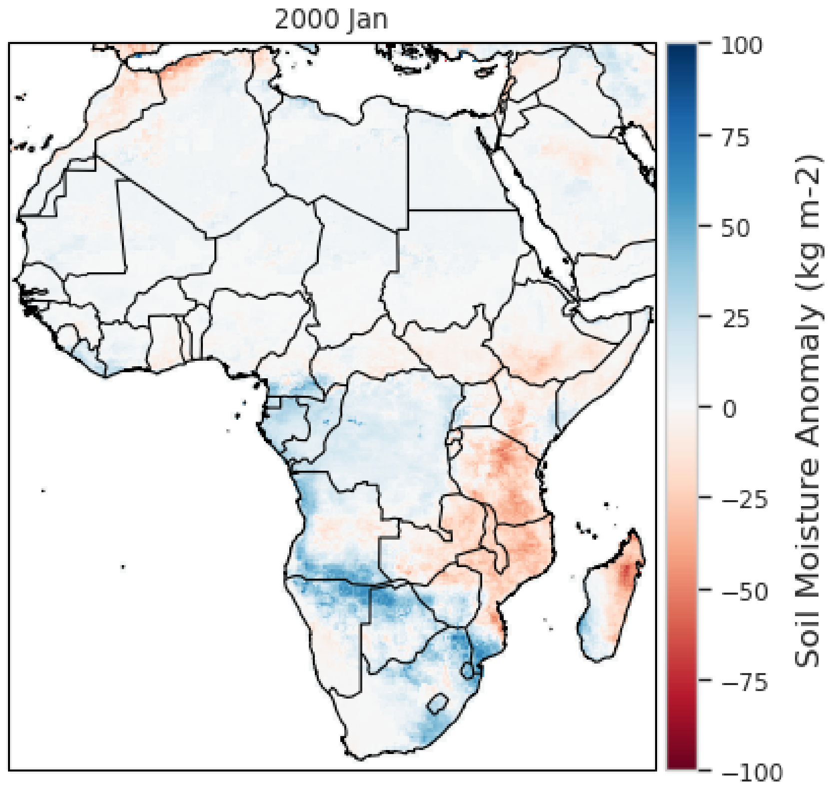
Data   About   Team

Disclaimer: the data currently available on this page are for testing purposes only. Although you are welcome to download them we do not recommend using them for any application. We anticipate the first full release of the data in June or July of 2020. For more information see the about tab.

Select year:
2000
Select month:
Jan

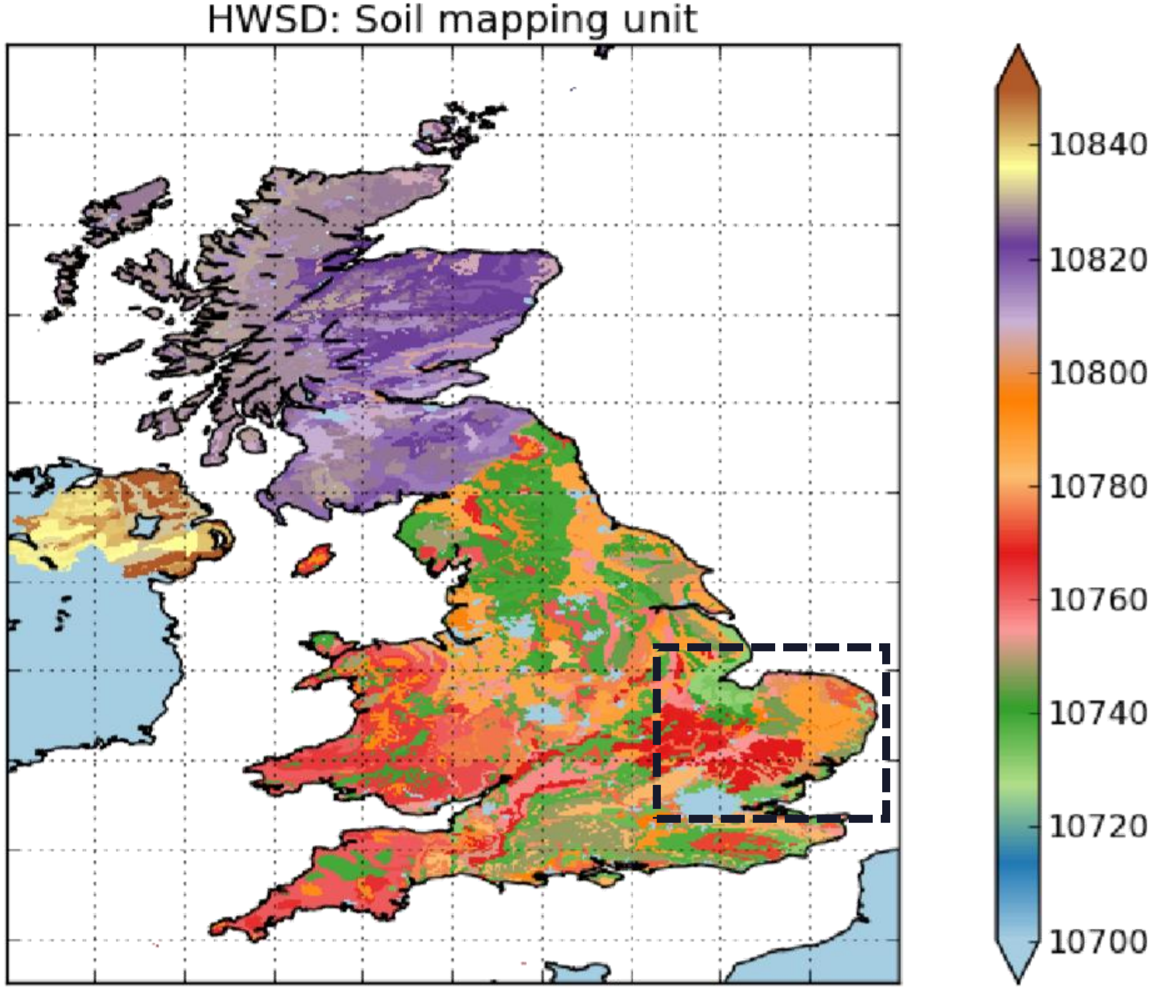
Select variable for display:

- (●) Soil moisture, root zone, anomaly
- ( ) Soil mositure, root zone, mean



Assimilating SMAP over East Anglia

- Using Harmonized World Soil Database (HWSD) soil information in creation of JULES soil parameter ancillaries.
- Optimising 15 parameters in Toth et al. 2015 pedo-transfer functions for Van Genuchten JULES soil model.
- Running 50 JULES ensemble members with varied parameter values.



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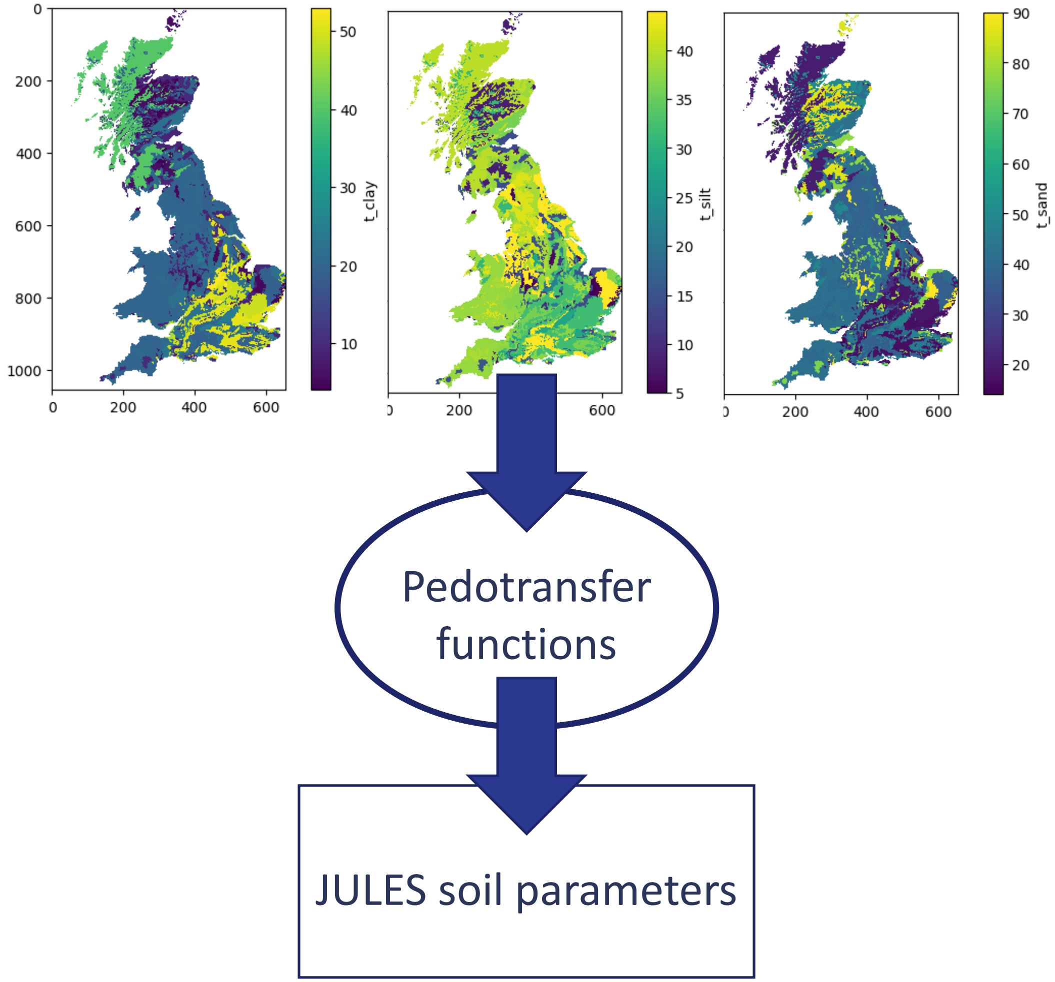

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European Journal of **Soil Science**

European Journal of Soil Science, January 2015, **66**, 226–238 doi: 10.1111/ejss.12192

New generation of hydraulic pedotransfer functions for Europe

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Rule 1
IF Sa >= 2.00
$\theta_r = 0.041$

Rule 2
IF Sa < 2.00
$\theta_r = 0.179$

$$\theta_s = 0.63052 - 0.10262 * BD^2 + 0.0002904 * pH^2 + 0.0003335 * Cl$$

$$\log_{10}(\alpha) = -1.16518 + 0.40515 * (1/(OC+1)) - 0.16063 * BD^2 - 0.008372 * Cl - 0.01300 * Si + 0.002166 * pH^2 + 0.08233 * T/S$$

$$\log_{10}(n-1) = -0.25929 + 0.25680 * (1/(OC+1)) - 0.10590 * BD^2 - 0.009004 * Cl - 0.001223 * Si$$

$$\log_{10}K_S = 0.40220 + 0.26122 * pH + 0.44565 * T/S - 0.02329 * Cl - 0.01265 * Si - 0.01038 * CEC$$