Improving soil moisture prediction of JULES using data assimilation with SMAP satellite observations

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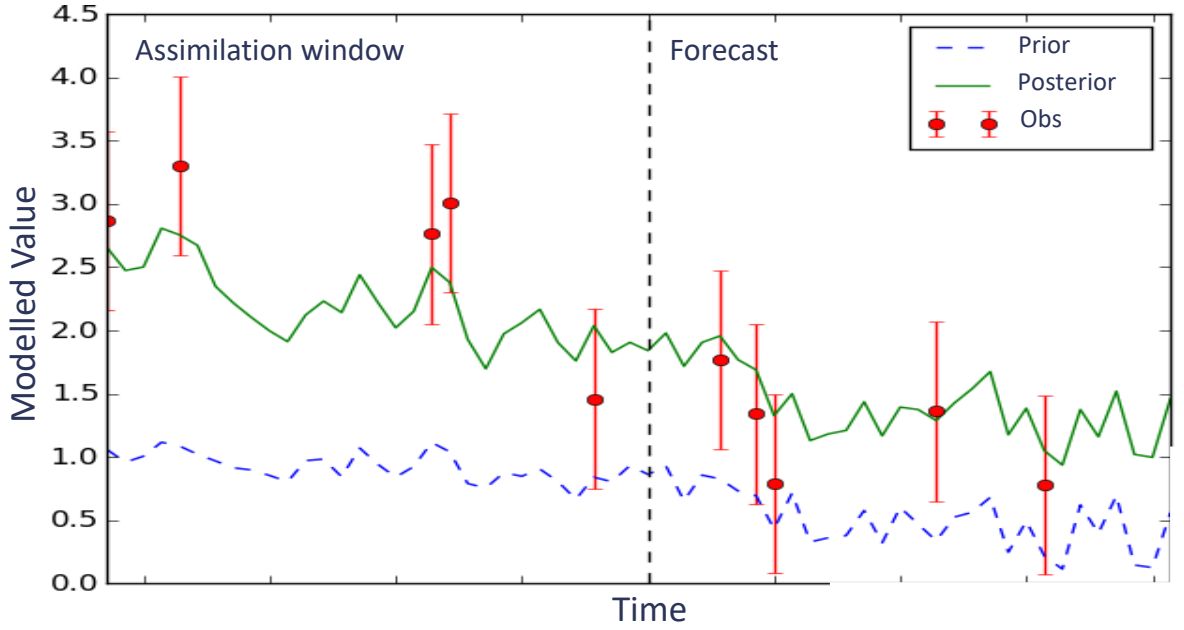
What is Data Assimilation (DA)?

- Many related terms and techniques, *e.g.* Model-Data Integration/Fusion, Bayesian inference, Inverse modelling.
- Methods to combine Models + uncertainties with Observations + uncertainties to find maximum likelihood estimates.
- Here we are focused on finding improved estimates to model parameter/state values.



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LAVENDAR

- The Land Ensemble Variational Data Assimilation fRamework (LAVENDAR) implements Hybrid DA technique for land surface models.
  - 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 model instances while varying parameters in parallel and perform the DA (now in Rose/Cylc).
- Avoids need to find model derivative or adjoint.

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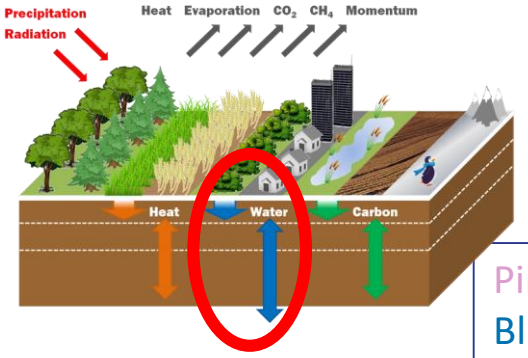
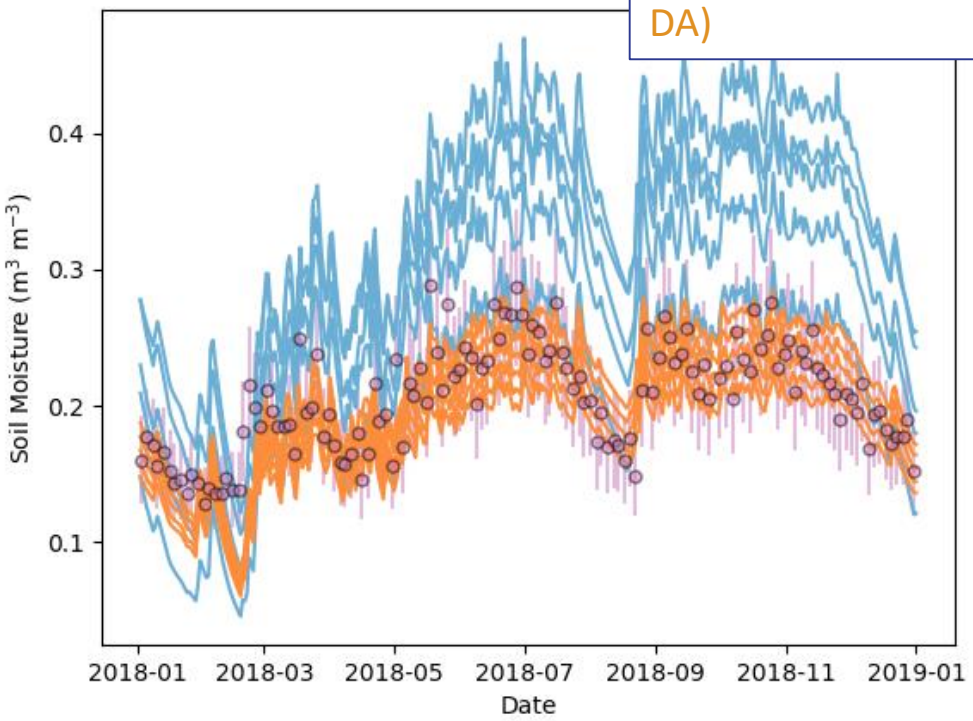
LAVENDAR for soil moisture with JULES

- Majority of DA efforts focus on updating model state values.
- However, land surface model parameters can be highly uncertain meaning that DA for state estimation can become futile!
- In this work we instead use DA to learn about model physics and update model parameters. Improving predictions into the future.
- Using LAVENDAR to combine JULES model predictions with observations to find improved soil parameter ancillaries.



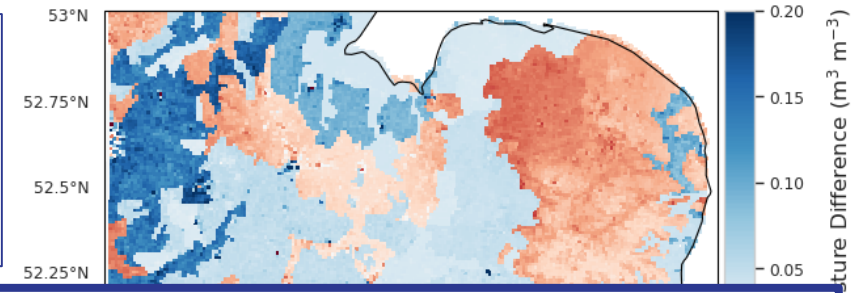
JULES model schematic

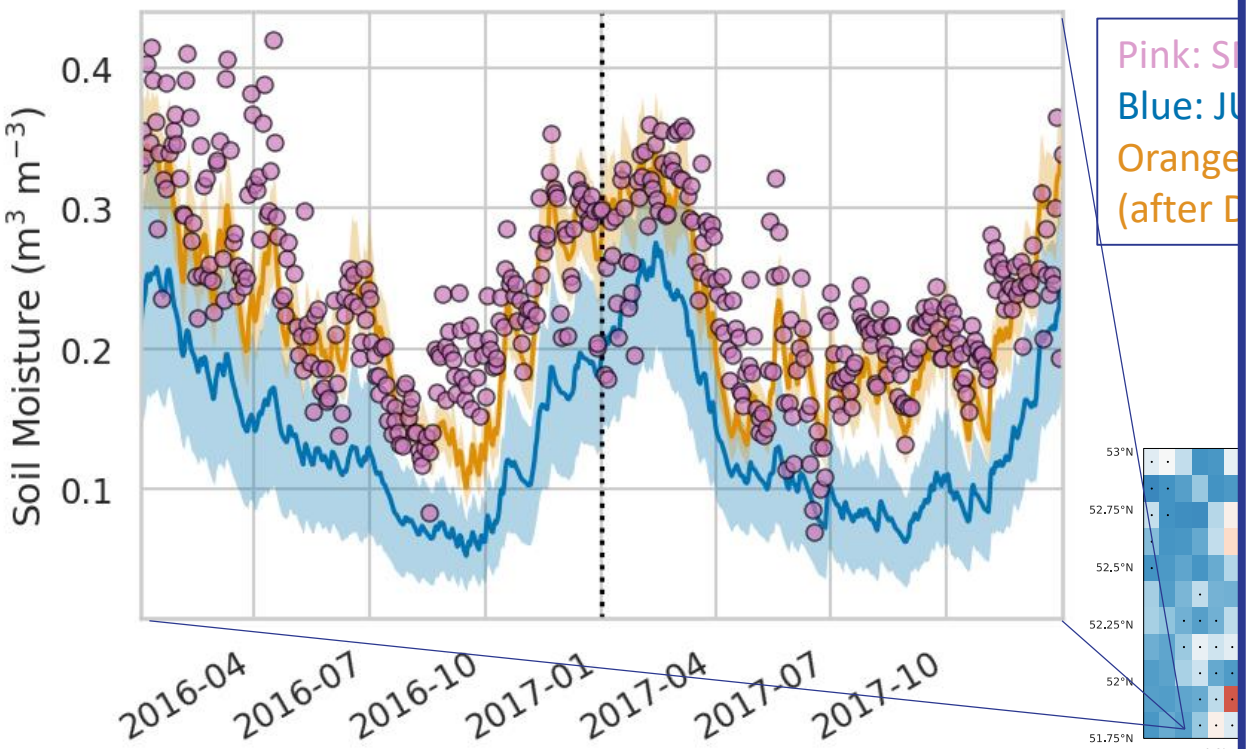
Pink: Observations
Blue: Prior (before DA)
Orange: Posterior (after DA)



Assimilating SMAP over East Anglia

Pinnington, E., et. al: Improving Soil Moisture Prediction of a High–Resolution Land Surface Model by Parameterising Pedotransfer Functions through Assimilation of SMAP Satellite Data, Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2020-303, in review, 2020.





Pink: SI
Blue: JU
Orange
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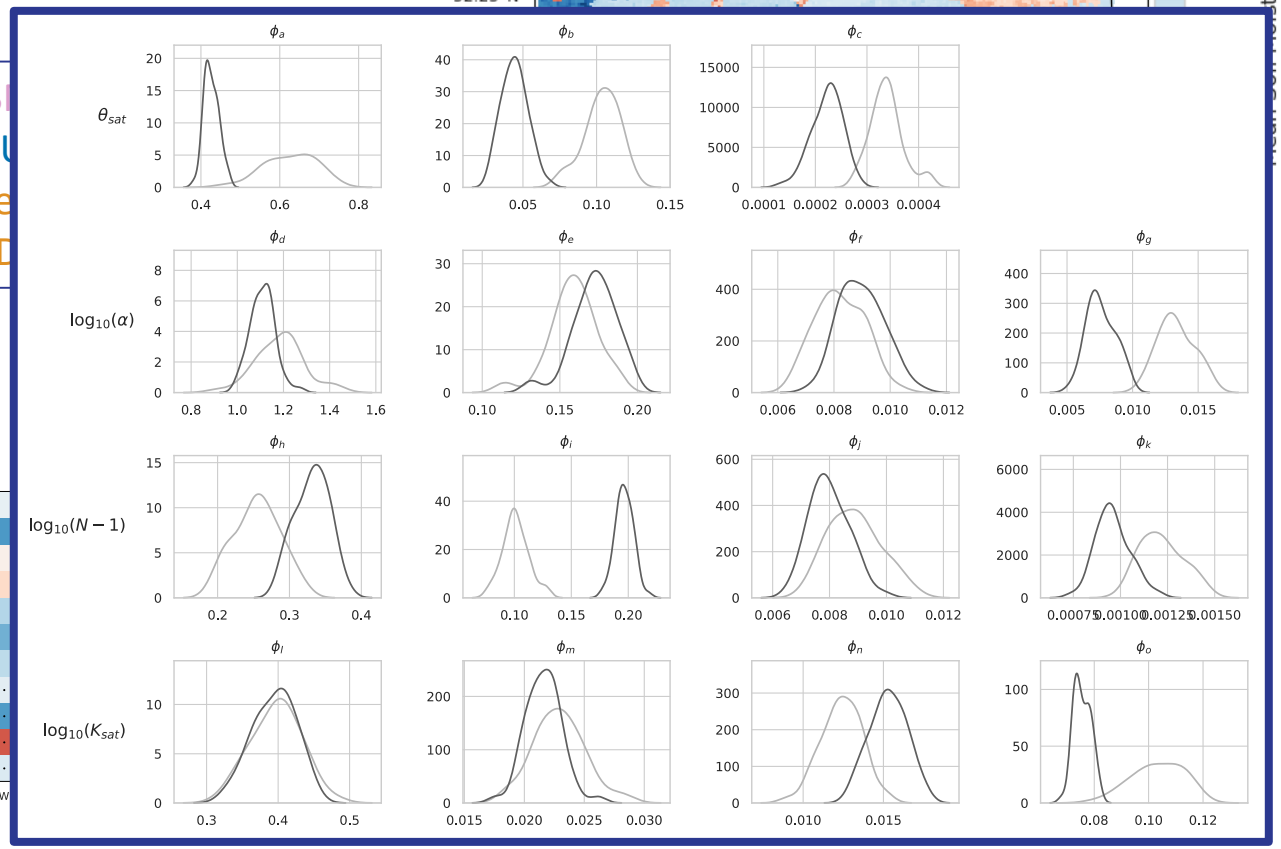

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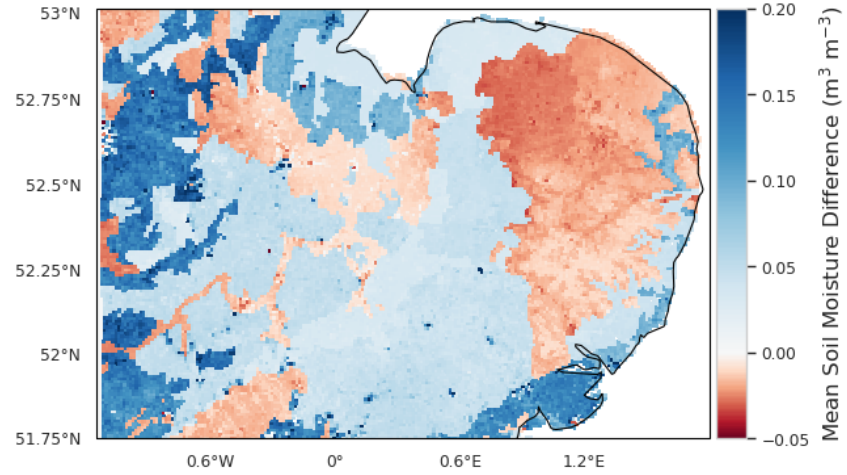
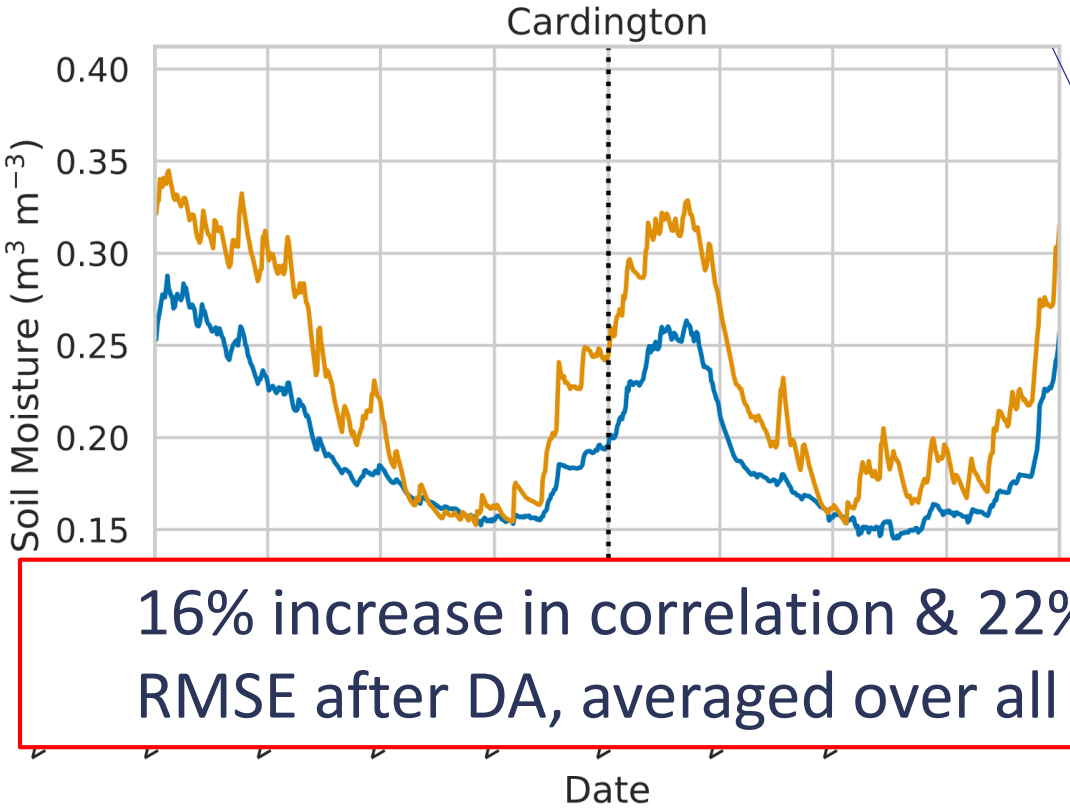
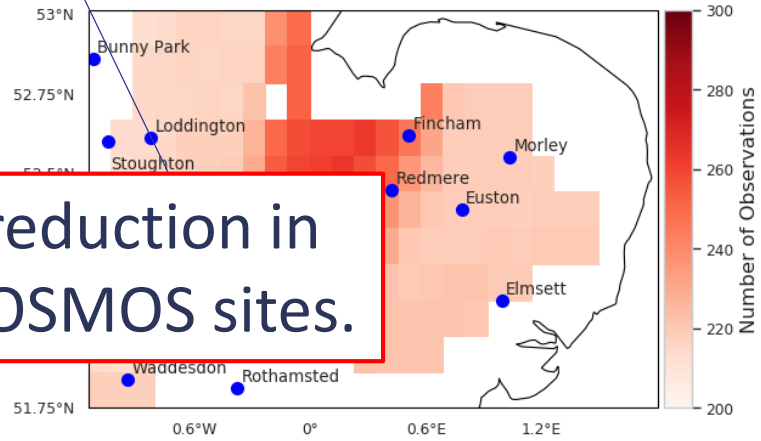




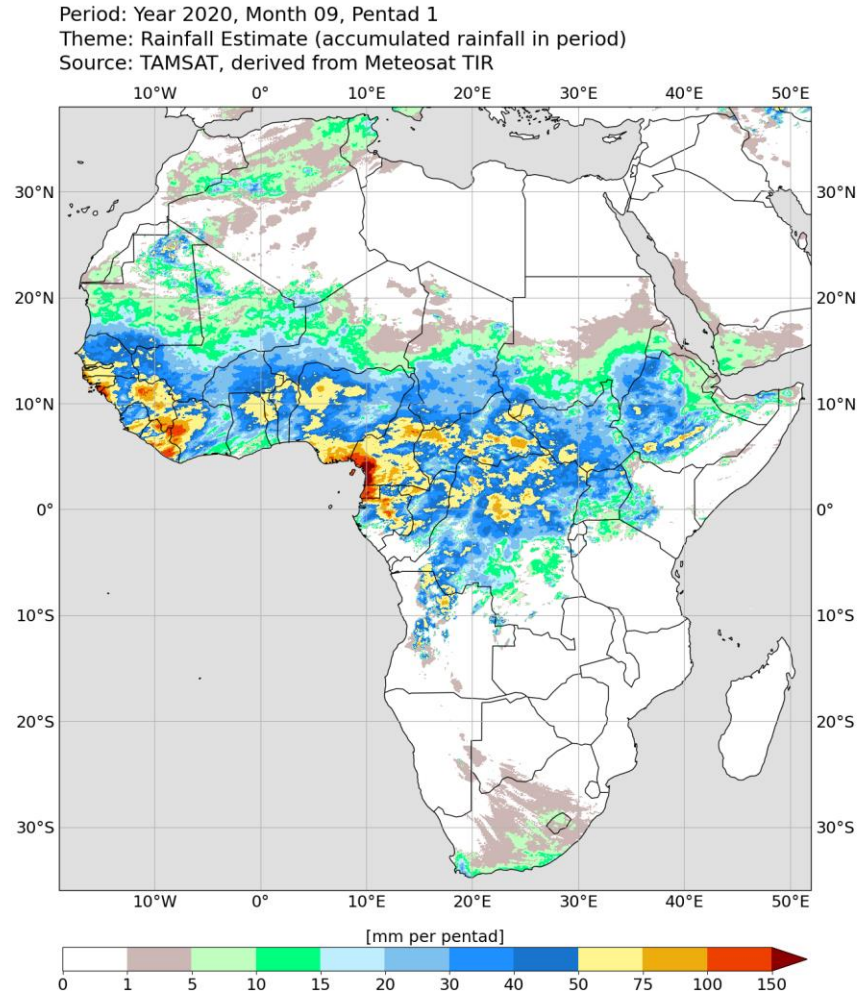
Pink: COSMOS observations
Blue: JULES prior (before DA)
Orange: JULES posterior (after DA)



16% increase in correlation & 22% reduction in RMSE after DA, averaged over all COSMOS sites.

TAMSAT Soil Moisture Africa

- 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.
- Many more observations now (1.5 – 2 million)



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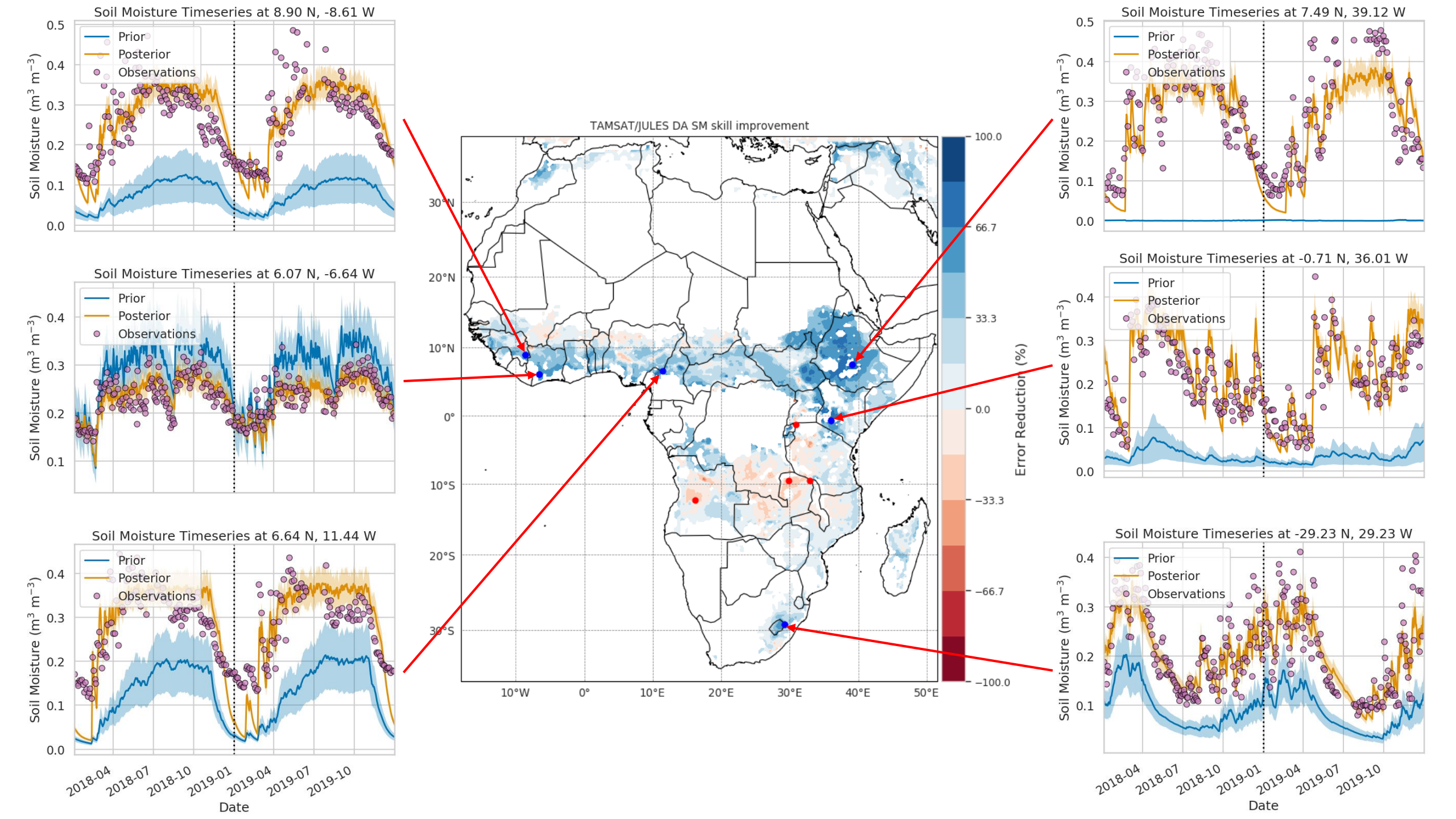
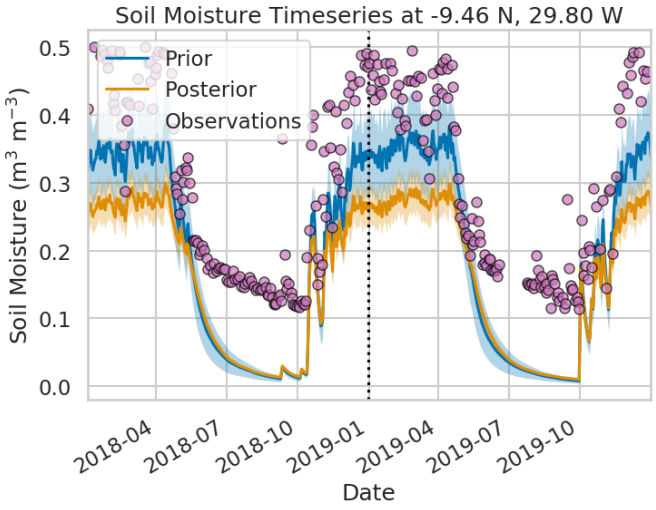
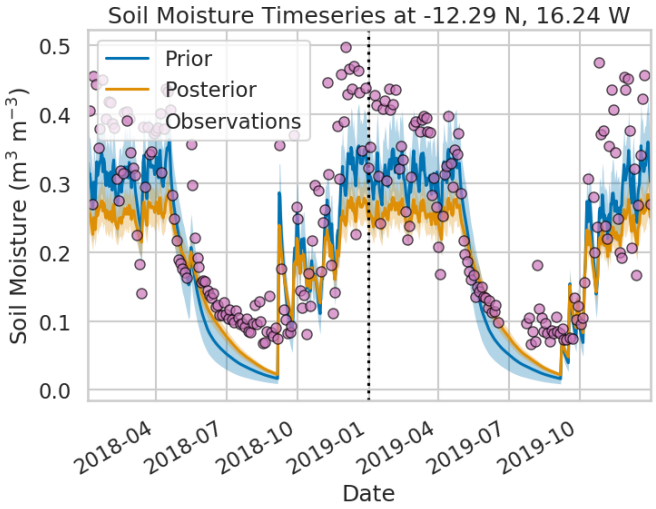
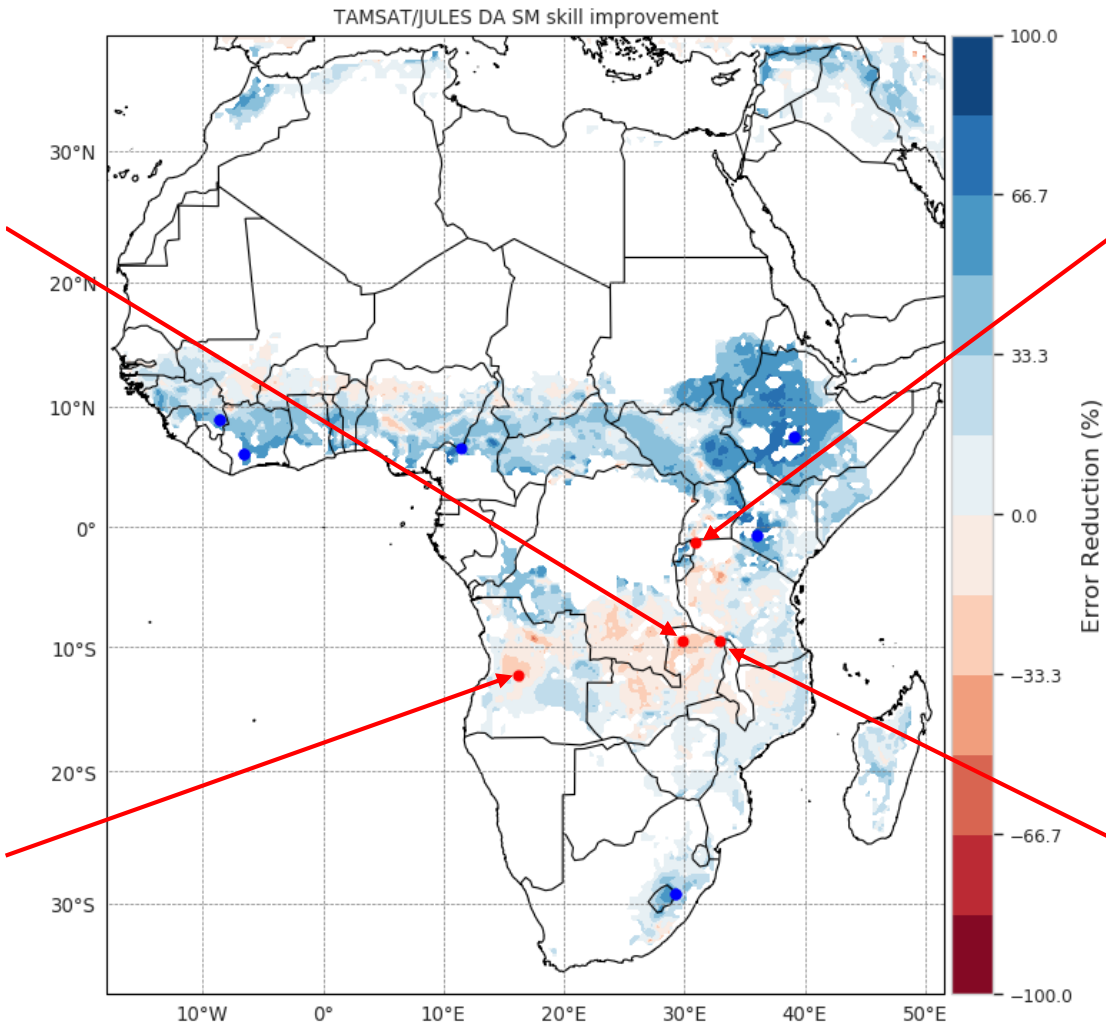
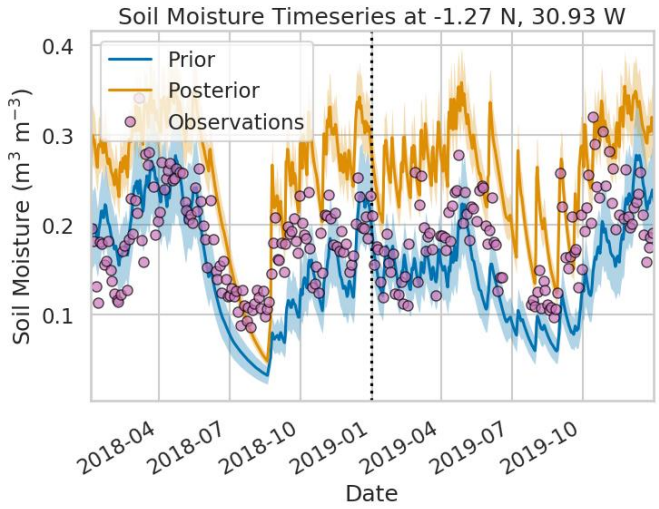
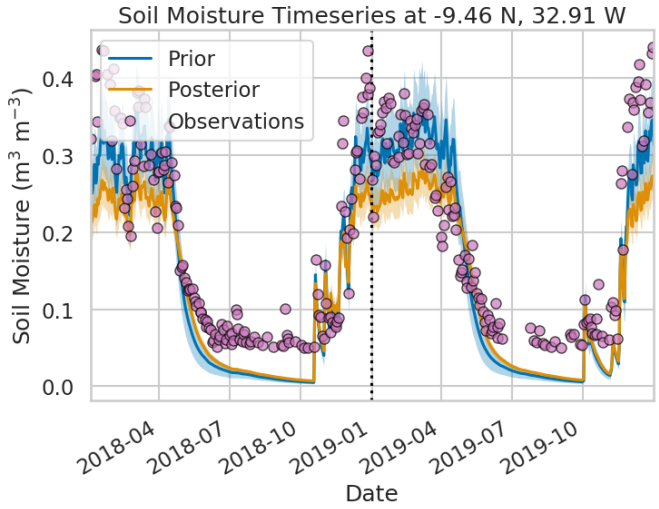

Soil Moisture Timeseries at 8.90 N, -8.61 W
Soil Moisture Timeseries at 6.07 N, -6.64 W
Soil Moisture Timeseries at 6.64 N, 11.44 W
Soil Moisture Timeseries at 7.49 N, 39.12 W
Soil Moisture Timeseries at -0.71 N, 36.01 W
Soil Moisture Timeseries at -29.23 N, 29.23 W
Prior
Posterior
Observations
Soil Moisture (m^3 m^{-3})
Date
2018-04
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10
TAMSAT/JULES DA SM skill improvement
Error Reduction (%)
100.0
66.7
33.3
0.0
−33.3
−66.7
−100.0
30°N
20°N
10°N
0°
10°S
20°S
30°S
10°W
0°
10°E
20°E
30°E
40°E
50°E

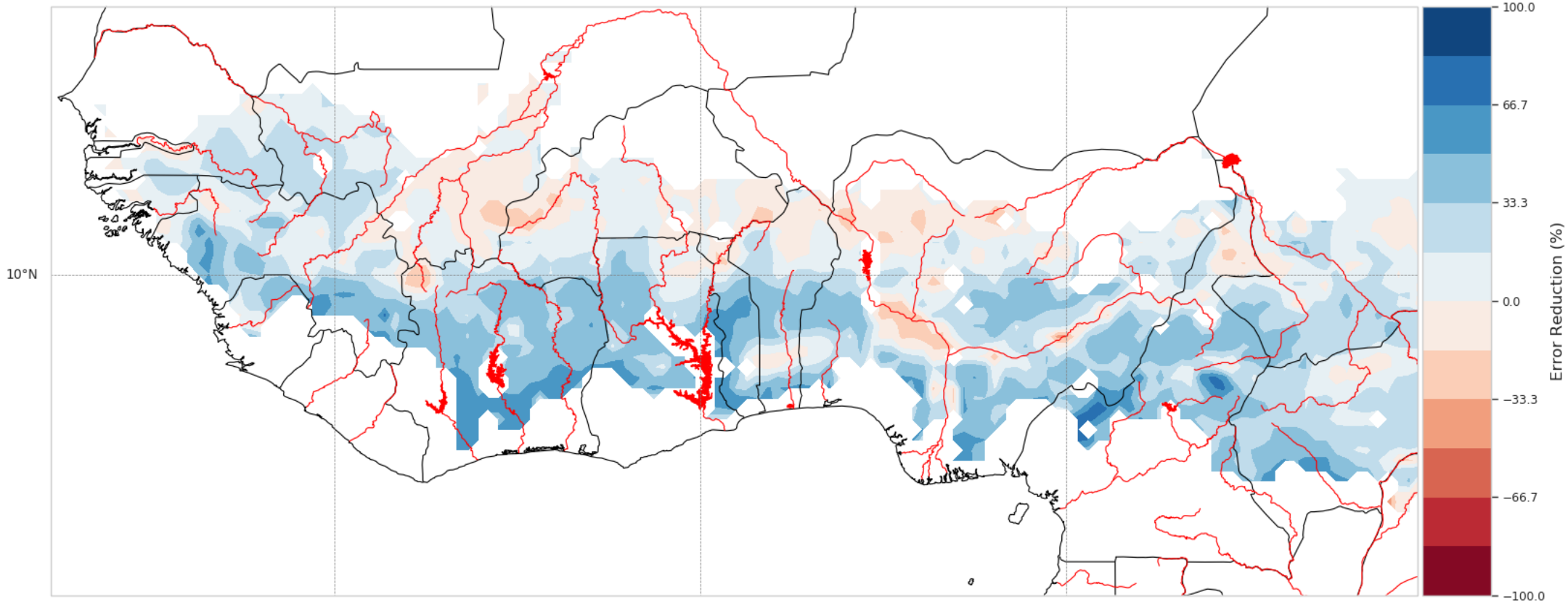

Soil Moisture Timeseries at -9.46 N, 29.80 W
Prior
Posterior
Observations
Soil Moisture (m³ m⁻³)
Date


Soil Moisture Timeseries at -12.29 N, 16.24 W
Prior
Posterior
Observations
Soil Moisture (m³ m⁻³)
Date


TAMSAT/JULES DA SM skill improvement
Error Reduction (%)


Soil Moisture Timeseries at -1.27 N, 30.93 W
Prior
Posterior
Observations
Soil Moisture (m³ m⁻³)
Date


Soil Moisture Timeseries at -9.46 N, 32.91 W
Prior
Posterior
Observations
Soil Moisture (m³ m⁻³)
Date



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

TAMSAT|NCEO Soil Moisture

Data About Team

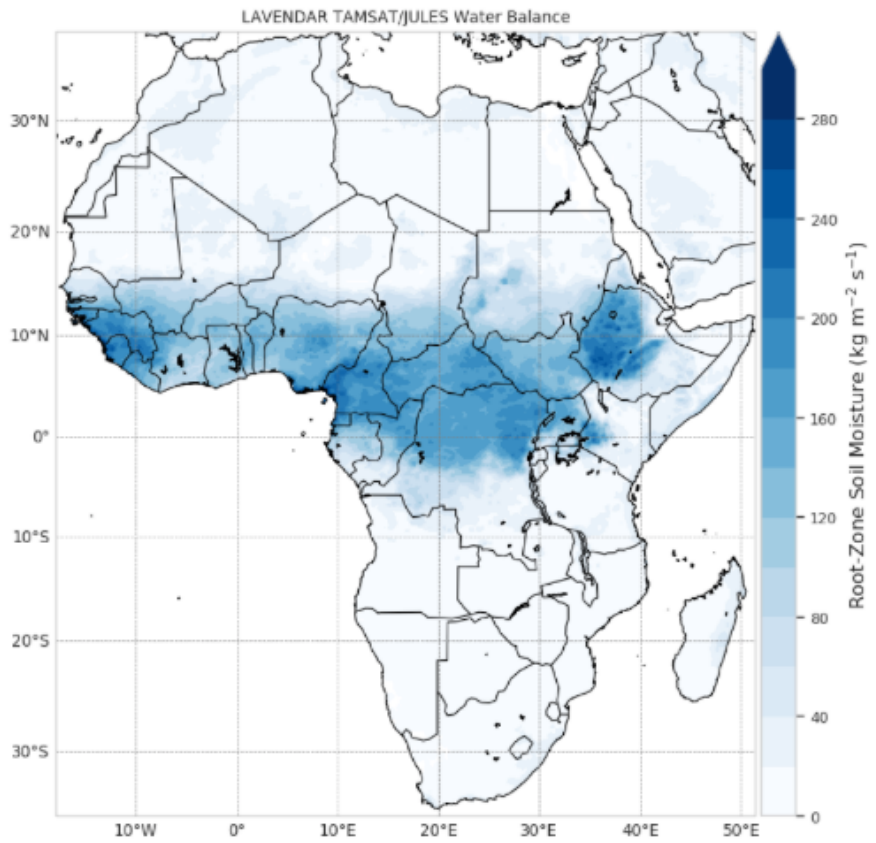
These data are the first full release (v1.0.0) of our Africa soil mositure generated data by assimilating NASA SMAP data into the JULES land surface model. We are currently in the process of evaulating the data and we will include the results of that here in due course. For more information see the about tab.

Select year:
2020
Select month:
Aug
Select day:
29

Select variable for display:

- Soil moisture, root zone, anomally
- Soil mositure, root zone, mean
- Evapotranspiration mean
- P-ET mean

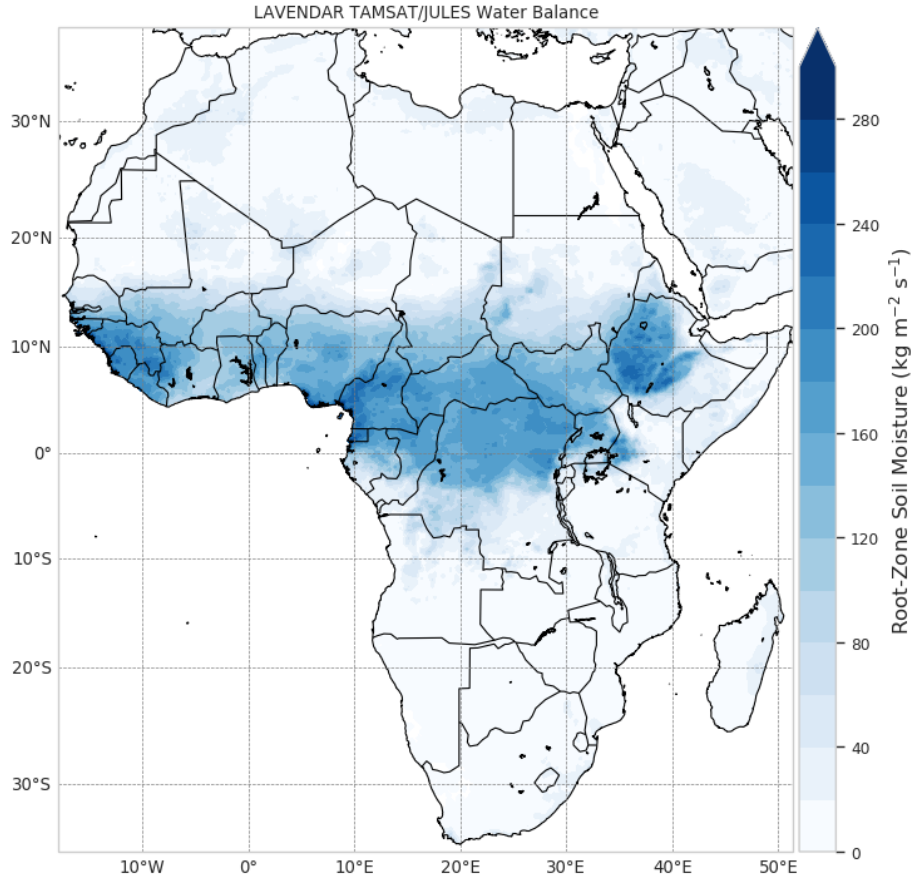
Download netCDF
Note: netCDF file contains all variables for one day



Africa Soil Moisture Summary

- Able to scale UK technique to continent of Africa and find good improvements.
- Need to look at additional validation (*e.g.* river flow, flux sites, SM probes) but difficult over Africa and at coarser resolution.
- Feeding into work with University of Reading TAMSAT group for near real-time soil moisture dataset:
  - http://gws-access.jasmin.ac.uk/public/odanceo/soil_moisture/

Hydro-JULES



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