Using Data Assimilation Diagnostics to Assess the SMAP Level-4 Soil Moisture Product

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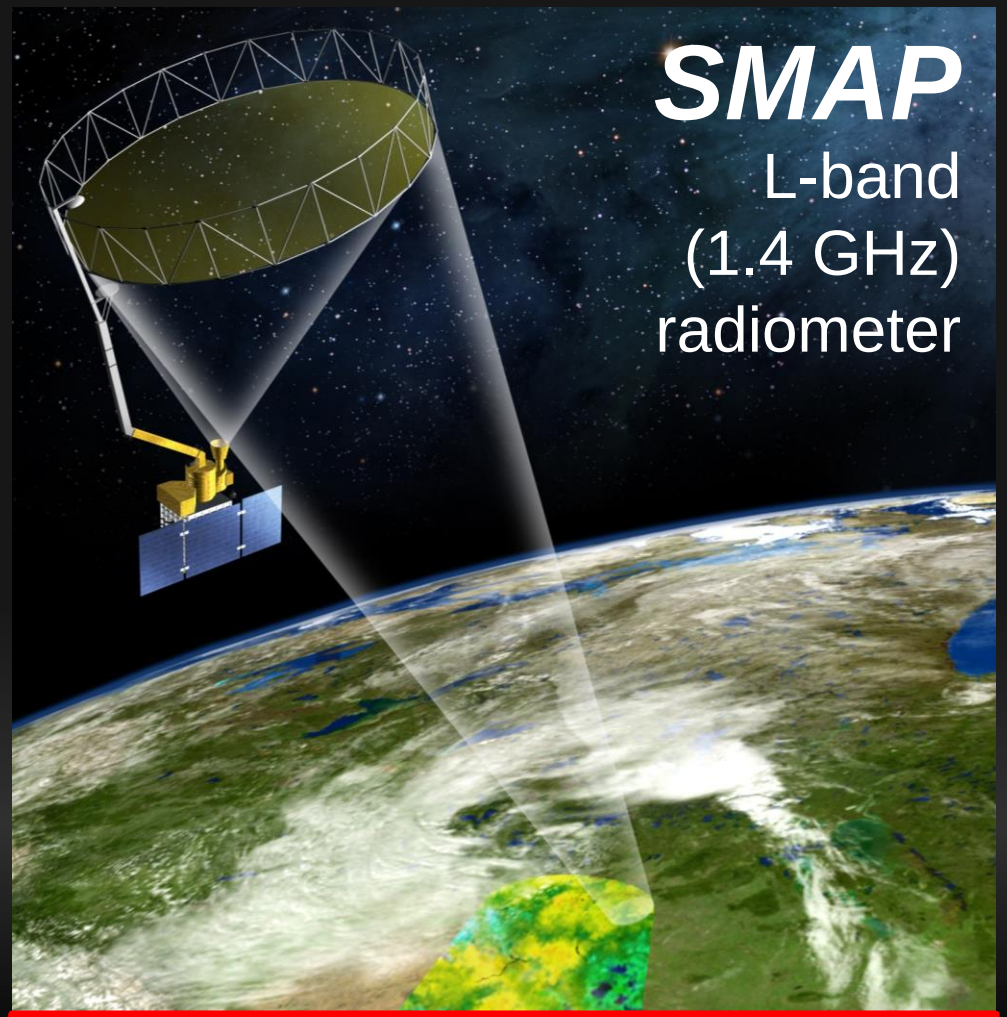
Motivation

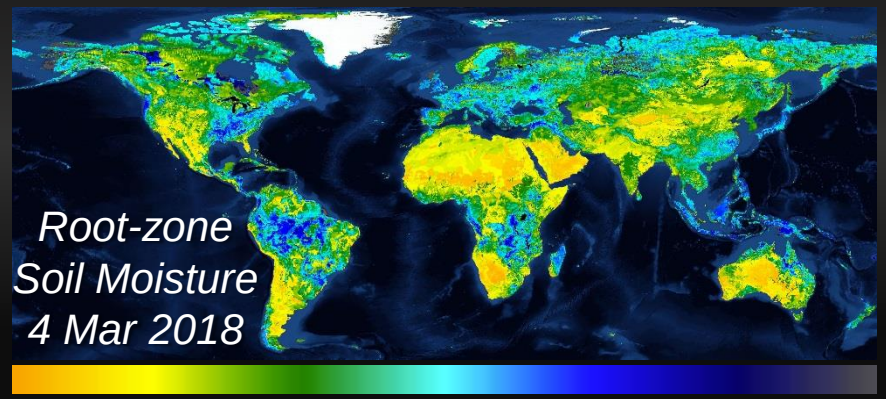


Sensitive only to surface soil moisture (~0-5 cm)

Key Objectives of the

Level-4 Soil Moisture (L4_SM) product:

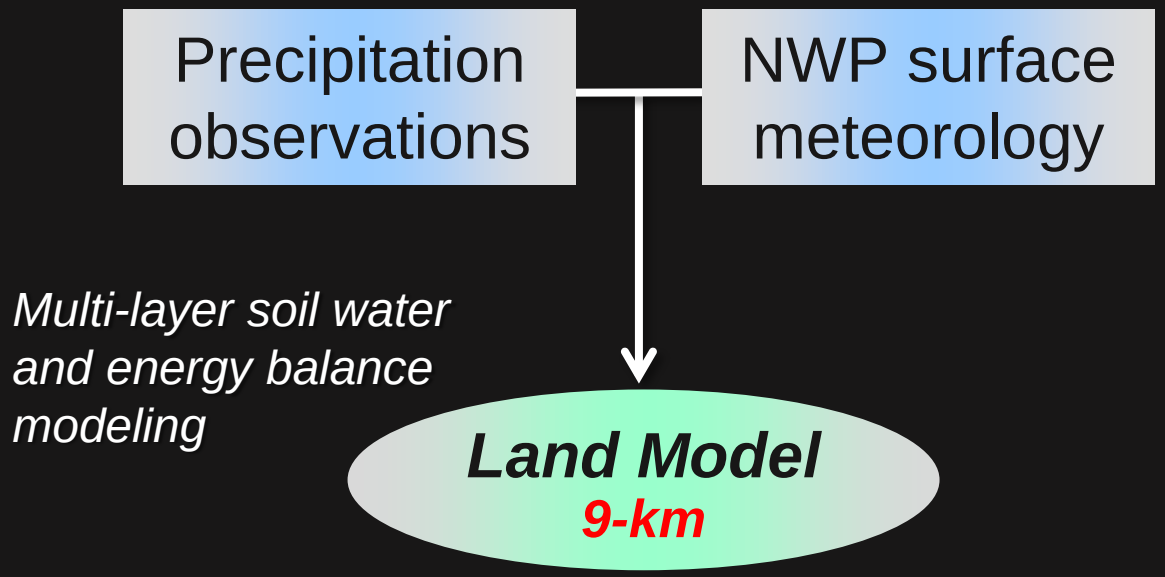
1. **"Root-zone" soil moisture (0-100 cm)**
2. **Spatially & temporally complete**



Outline

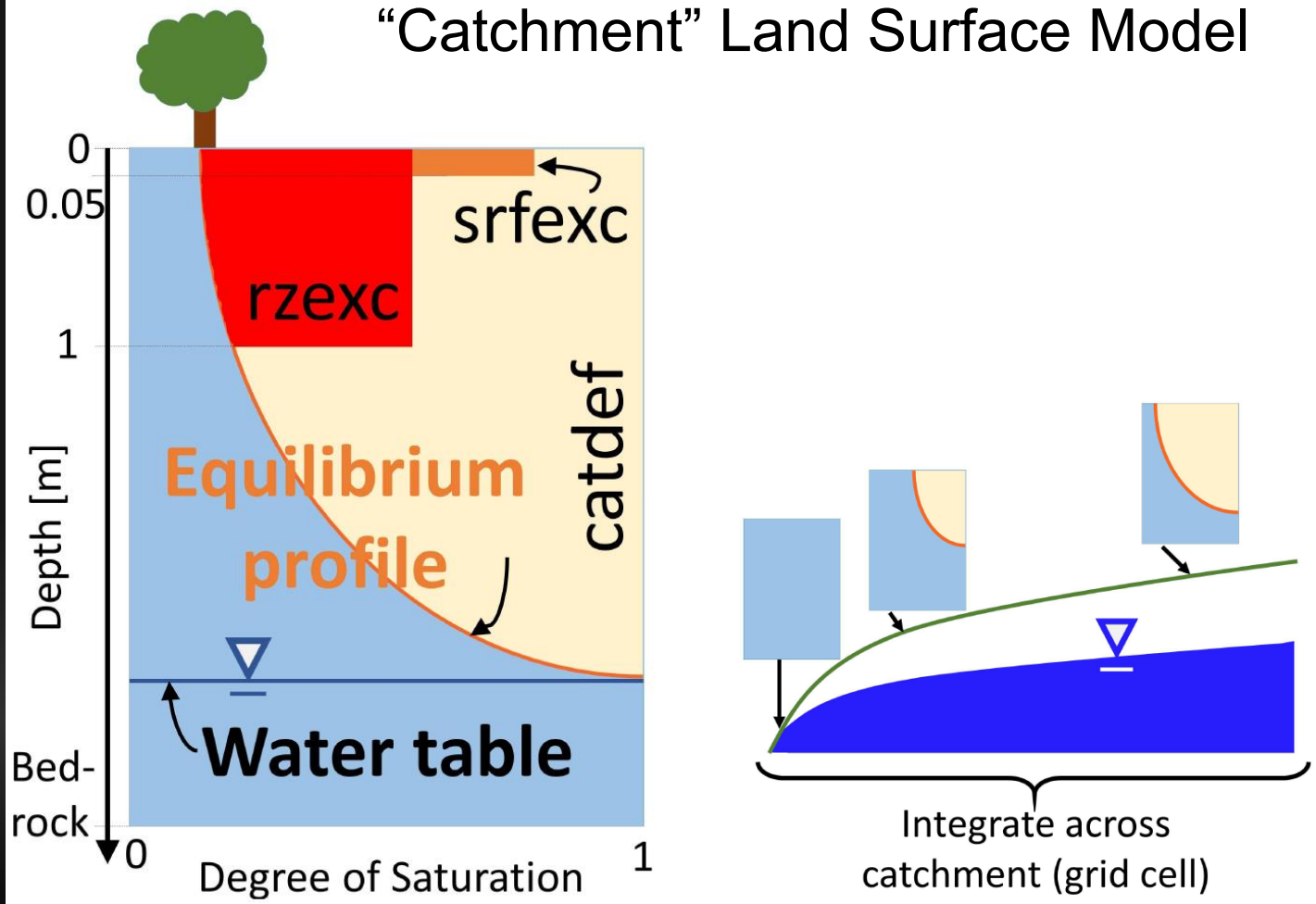
1. Algorithm Overview
2. Validation vs. In Situ Measurements
3. Assimilation diagnostics
   a) Data Counts
   b) Observation-Minus-Forecast Residuals
   c) Assimilation Increments
4. Summary and Conclusions

Algorithm Overview

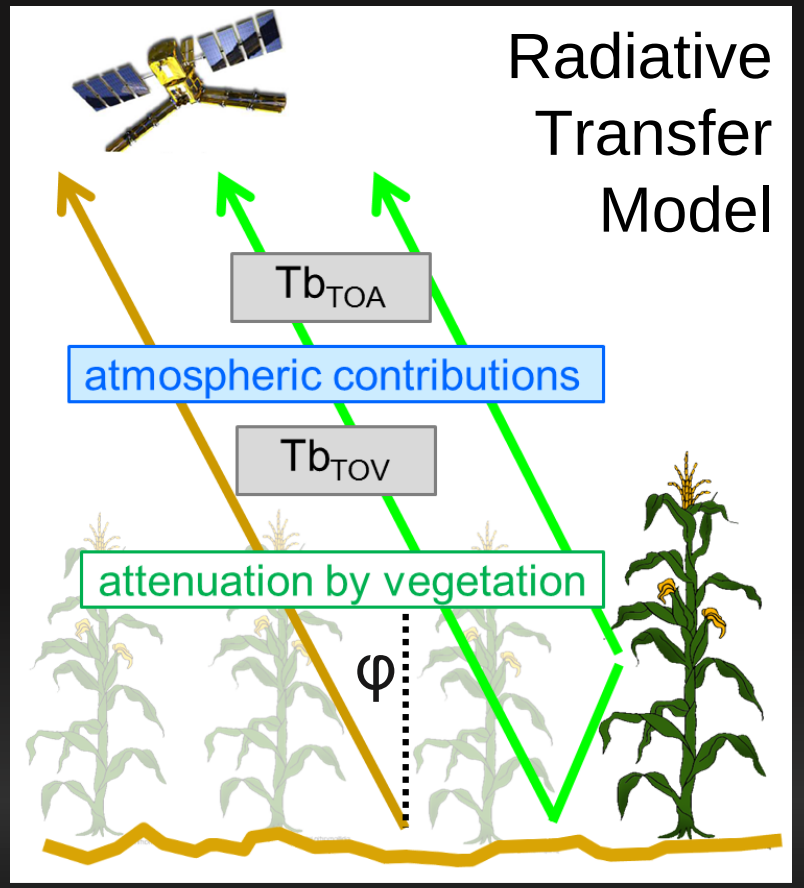


Land Modeling System

"Catchment" Land Surface Model



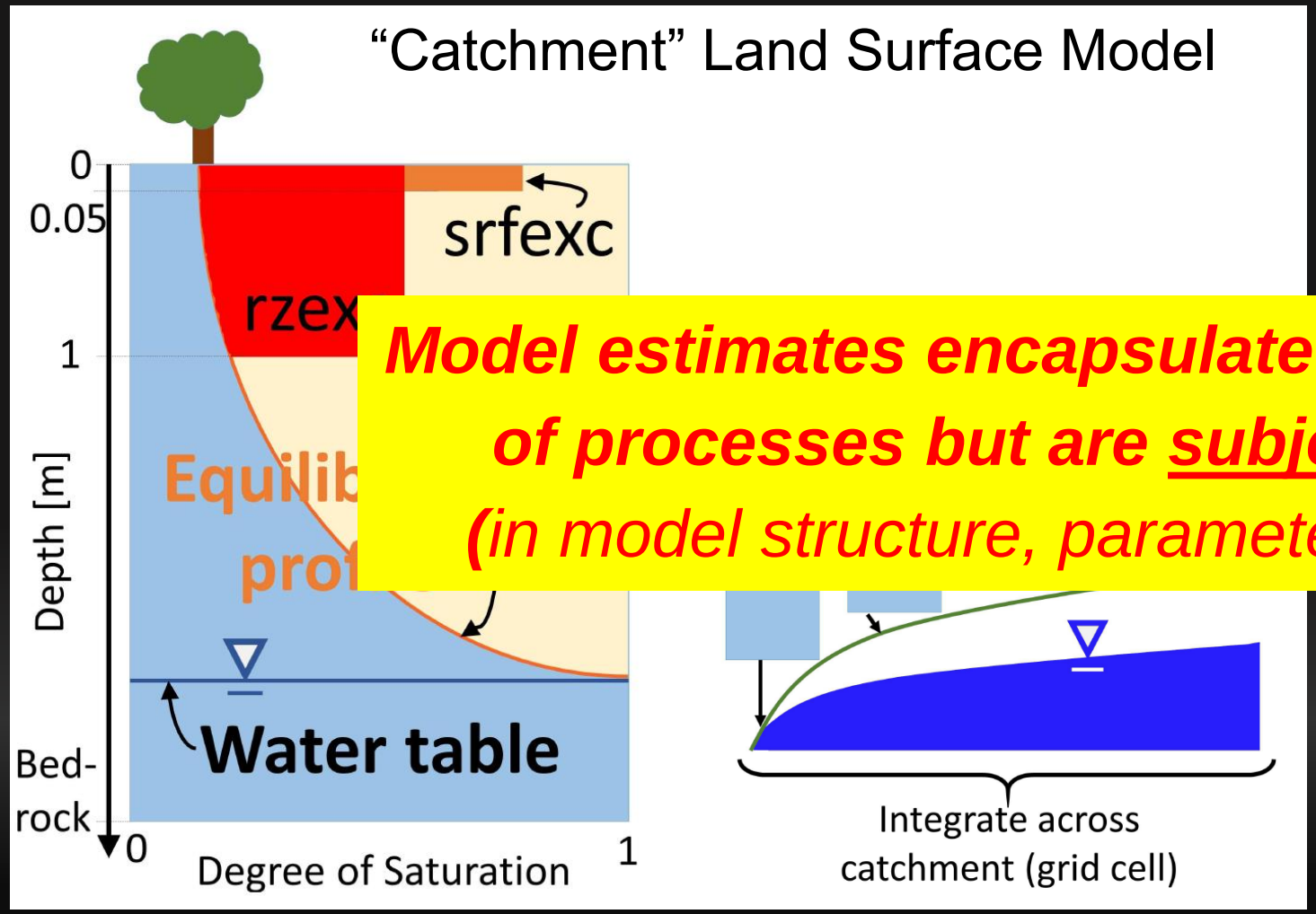
Radiative Transfer Model



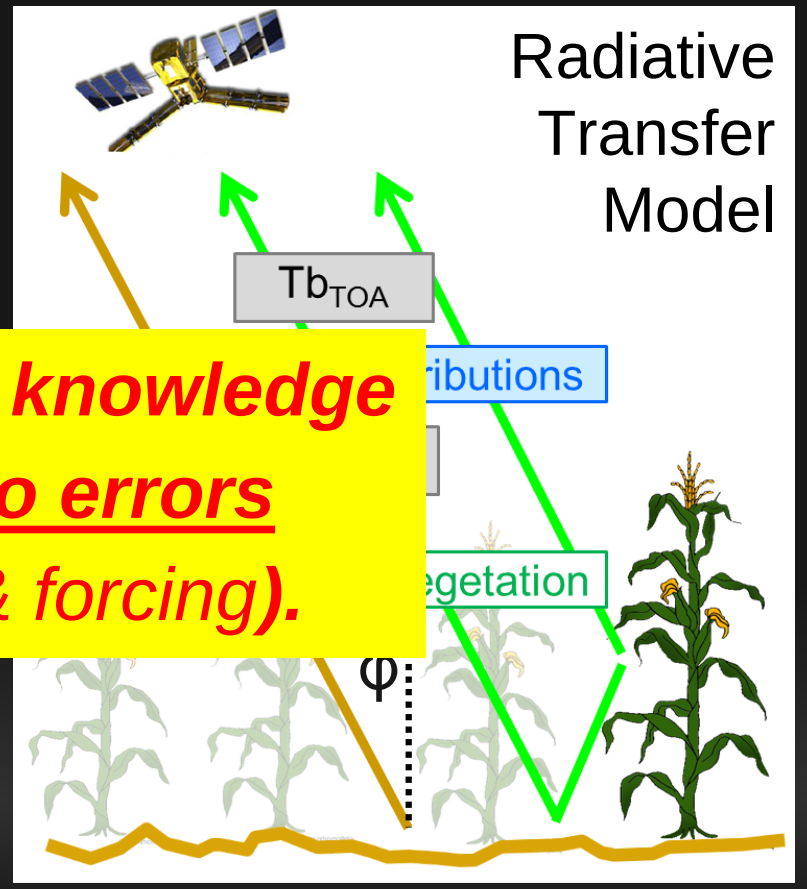
Surface soil moisture & temperature

Koster et al. (2000), *JGR*, doi:10.1029/2000JD900327.
De Lannoy et al. (2013), *JHM*, doi:10.1175/JHM-D-12-092.1.

Land Modeling System



Model estimates encapsulate our knowledge of processes but are <u>subject to errors</u> (in model structure, parameters & forcing).



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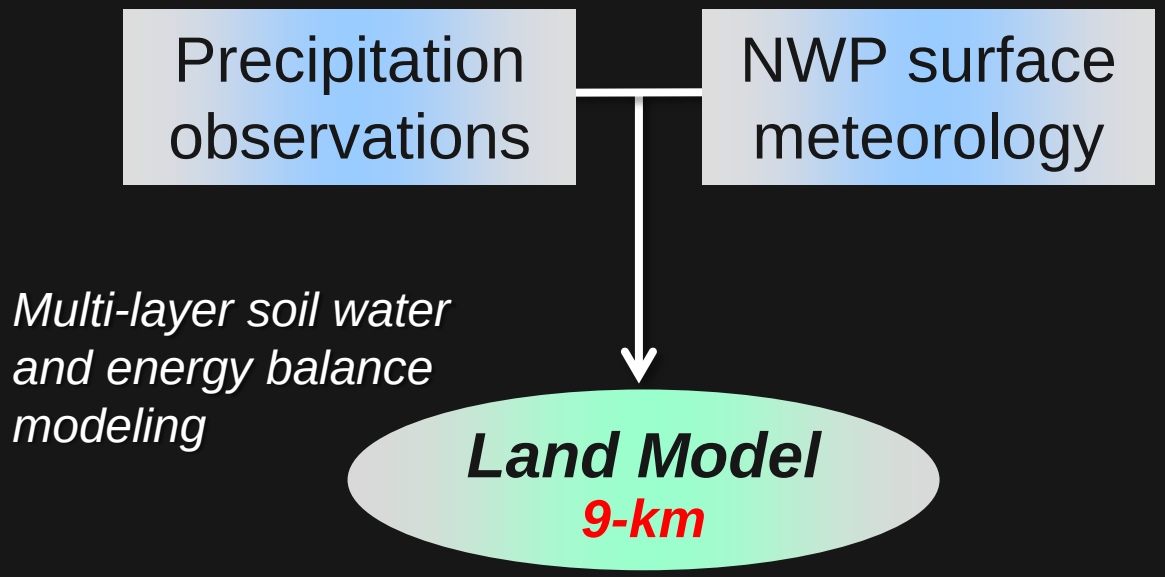

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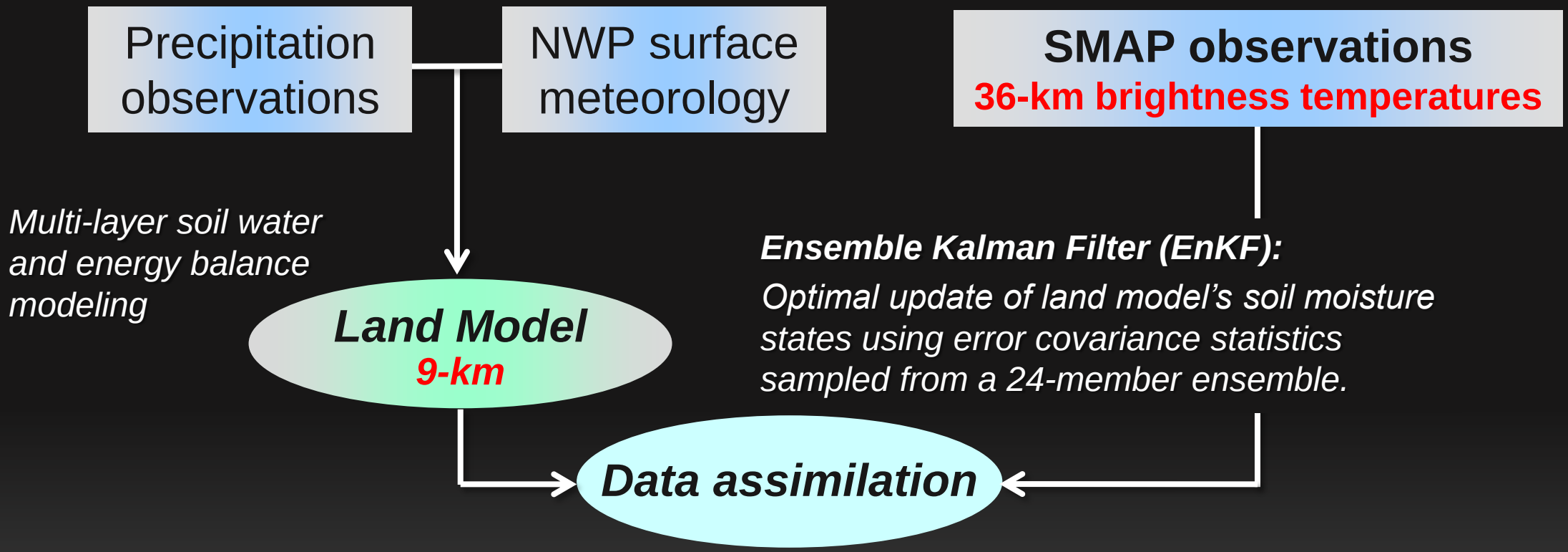
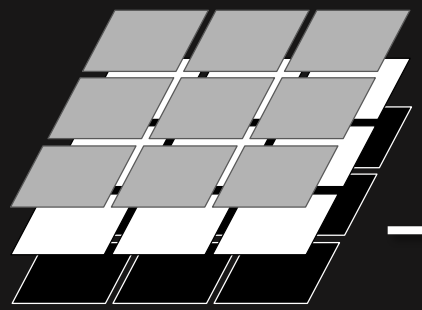
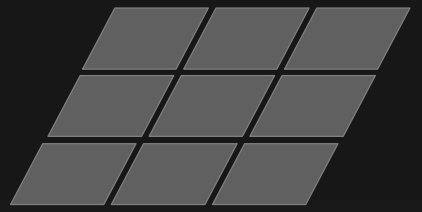
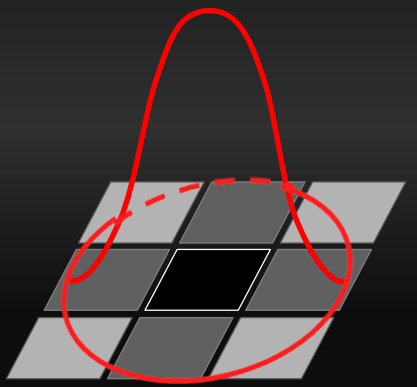
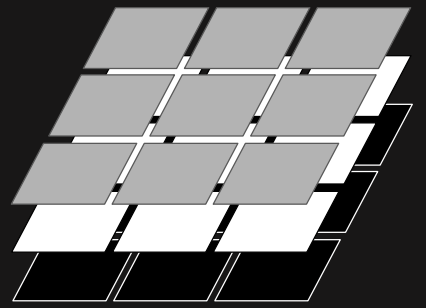


Soil Moisture Analysis









LAND MODEL

$SM^{-}(t)$
9 km

TB(t)
9 km

Aggregate
to "36km"

Clim. Mean
Adjustment

$SM^{+}(t)$
$= SM^{-}(t) + \Delta SM$
9 km

$SM^{-}(t+1)$

EnKF

$\Delta SM = \underline{G} * \Delta TB$

$\underline{G}$ = *optimal gain matrix*

$\Delta TB(t)$
"36 km"

Diff.

SMAP OBSERVATIONS

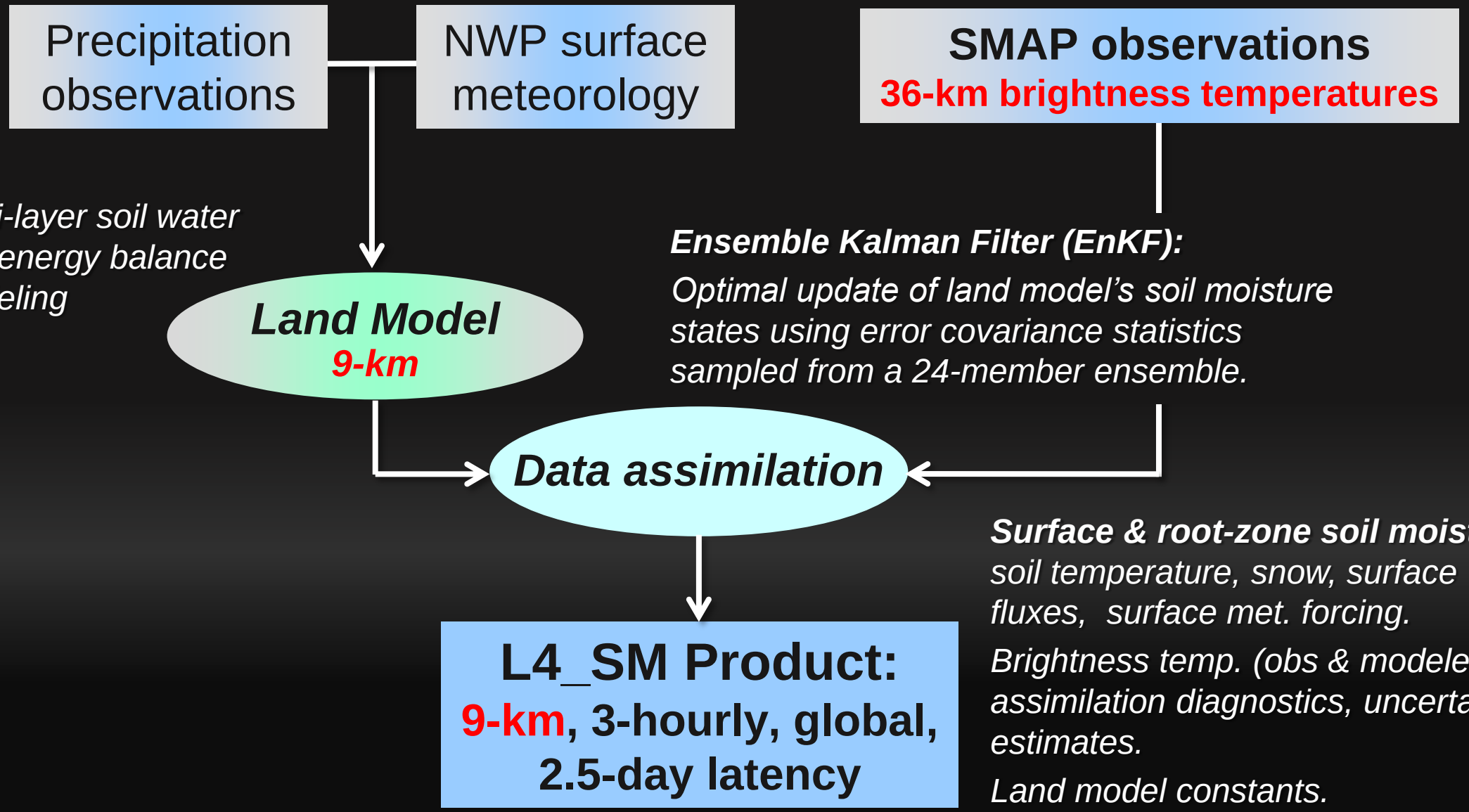
TB(t)
"36 km"

Clim. Mean
Adjustment

$$\underline{G} = Cov(SM_{ens}, Tb_{ens})\,[\,Cov(Tb_{ens}) + Cov(Tb_{obs})]^{-1}$$

Reichle et al. (2017), *JHM*, doi:10.1175/JHM-D-17-0130.1.

Algorithm Overview



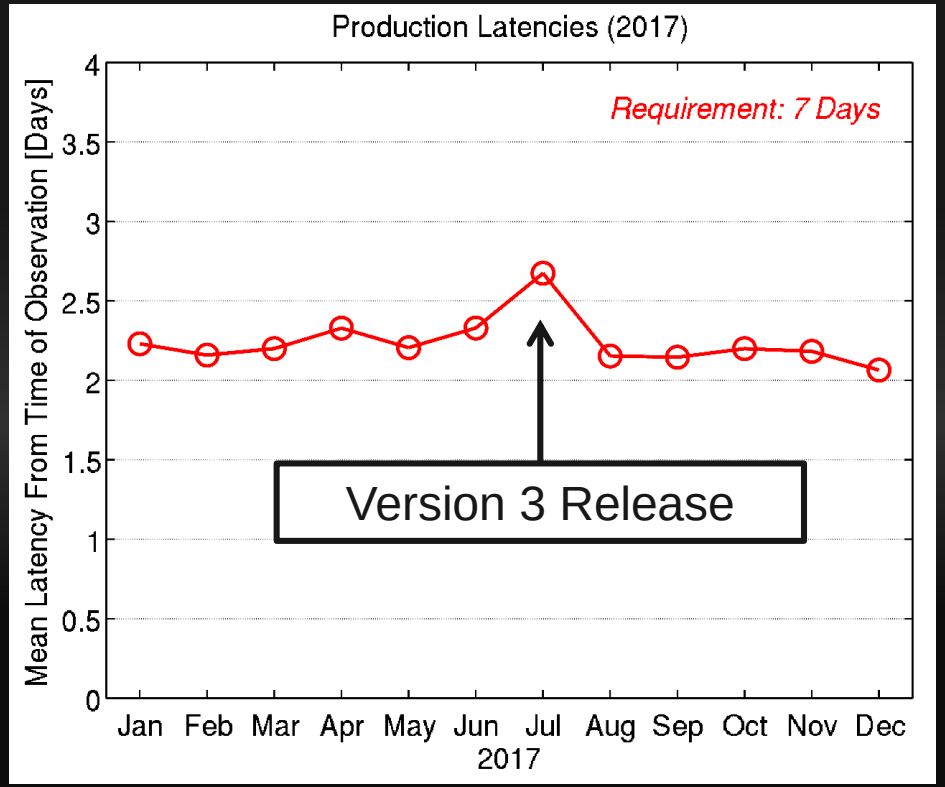
L4_SM

Data available publicly for 3/31/2015-present from `http://nsidc.org`.

Used here (unless indicated otherwise): ***Version 3***
April 2015 – March 2017

Since 2015, L4_SM data have been produced and published once daily about ~2.5 days behind real-time.

Main driver for L4_SM latency is the wait for precipitation observations.



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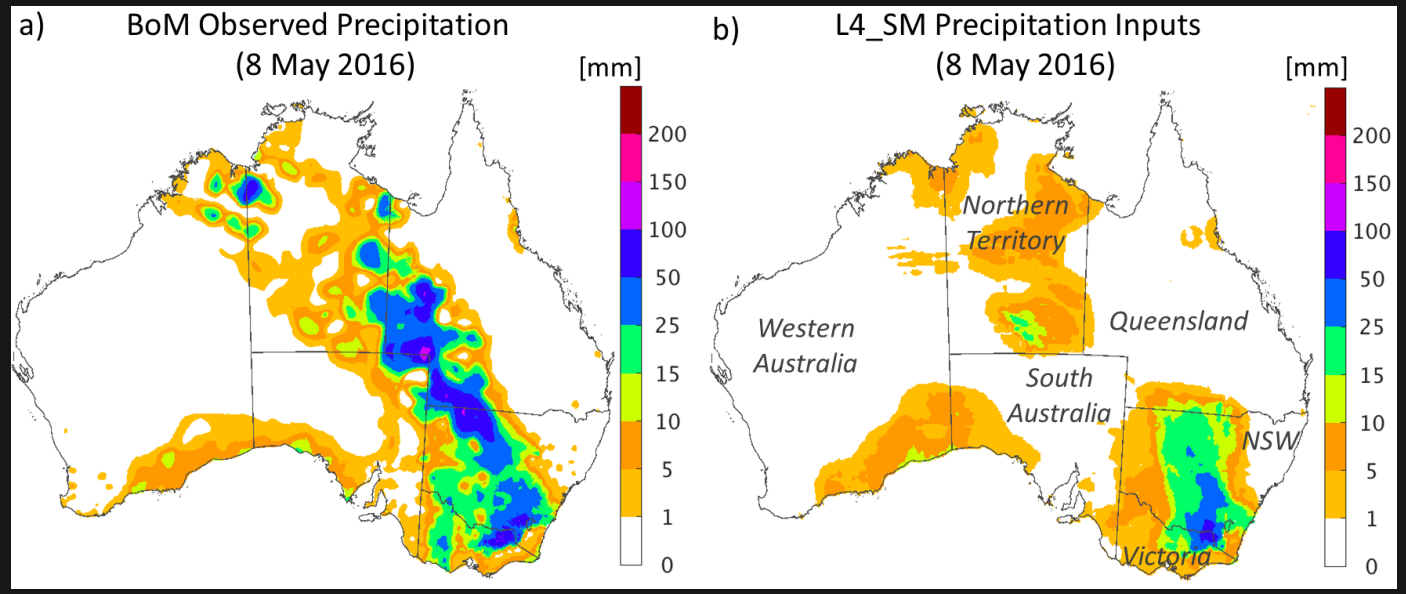
L4_SM Analysis – 2100 UTC 8 May 2016



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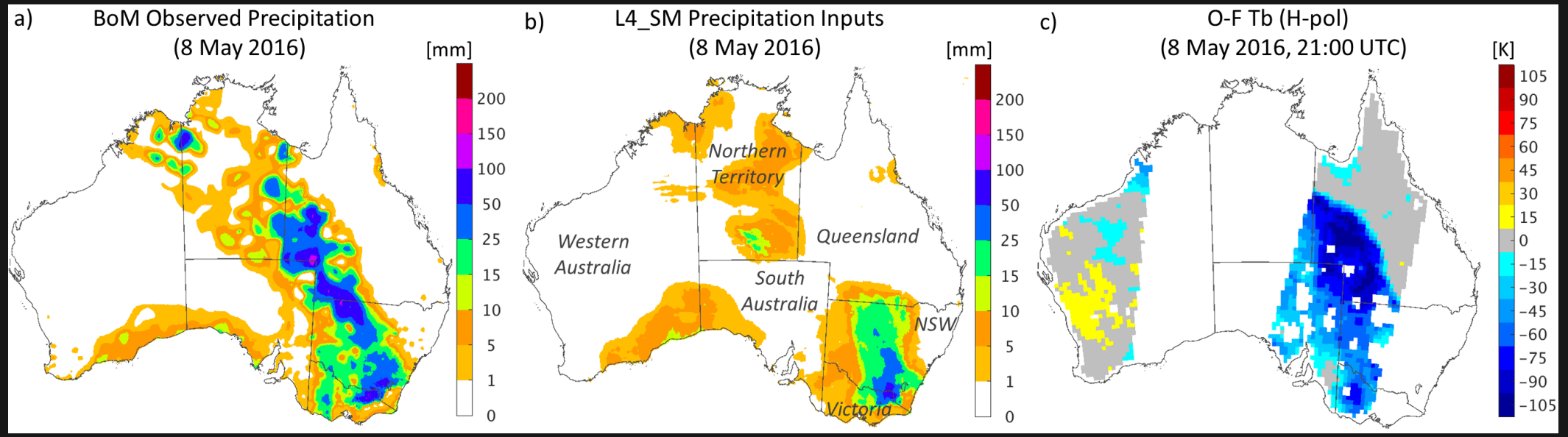

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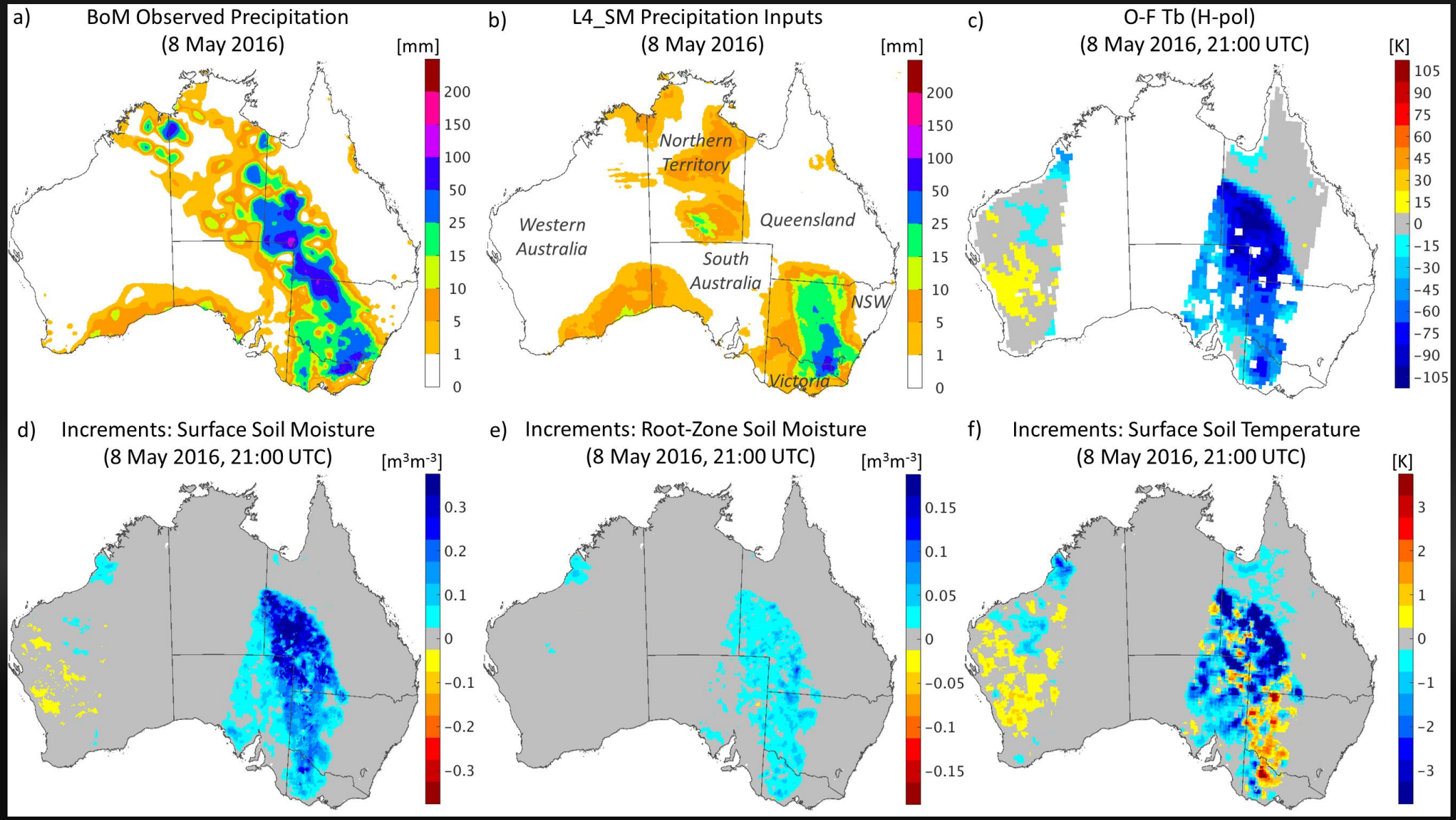
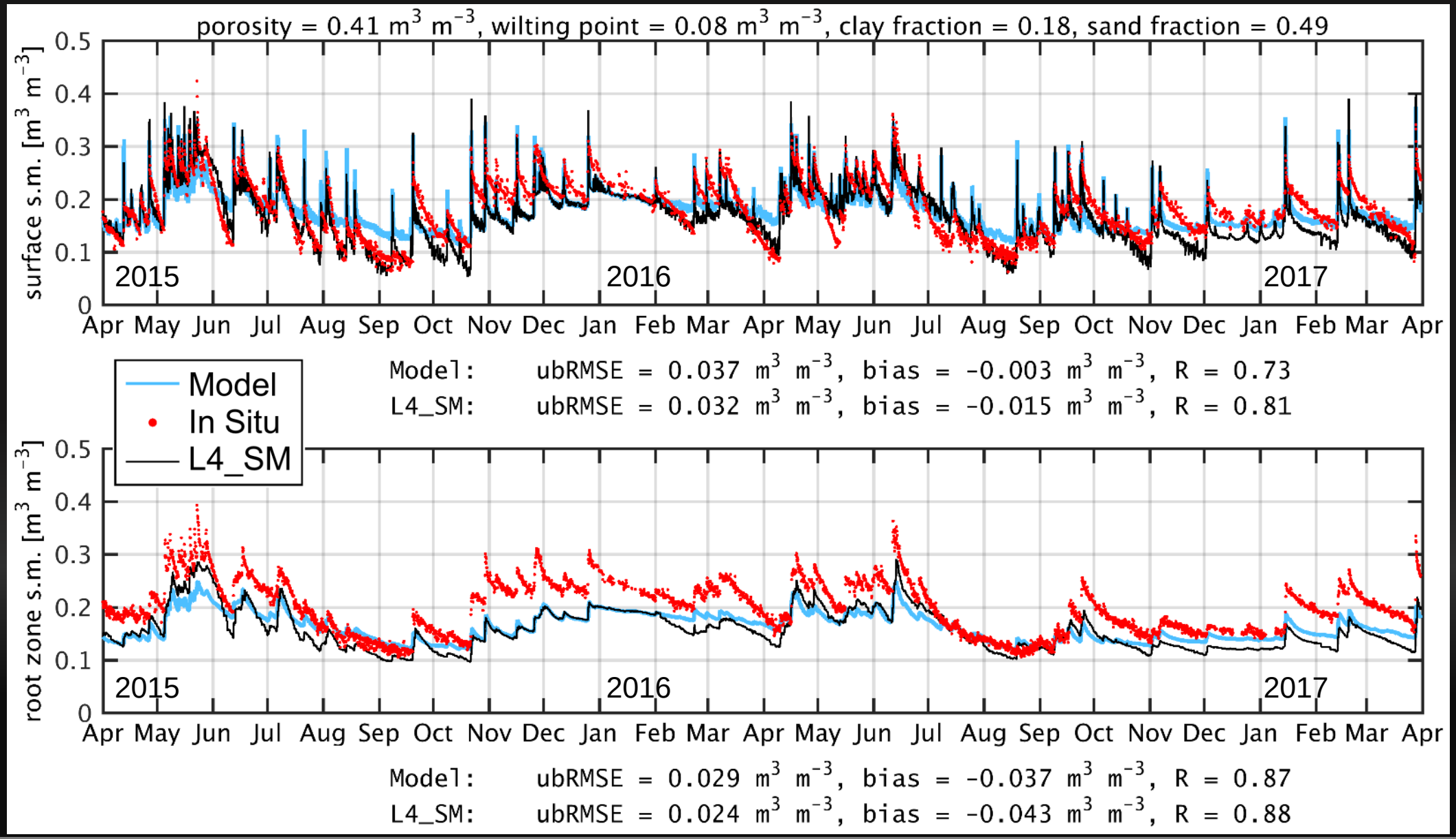


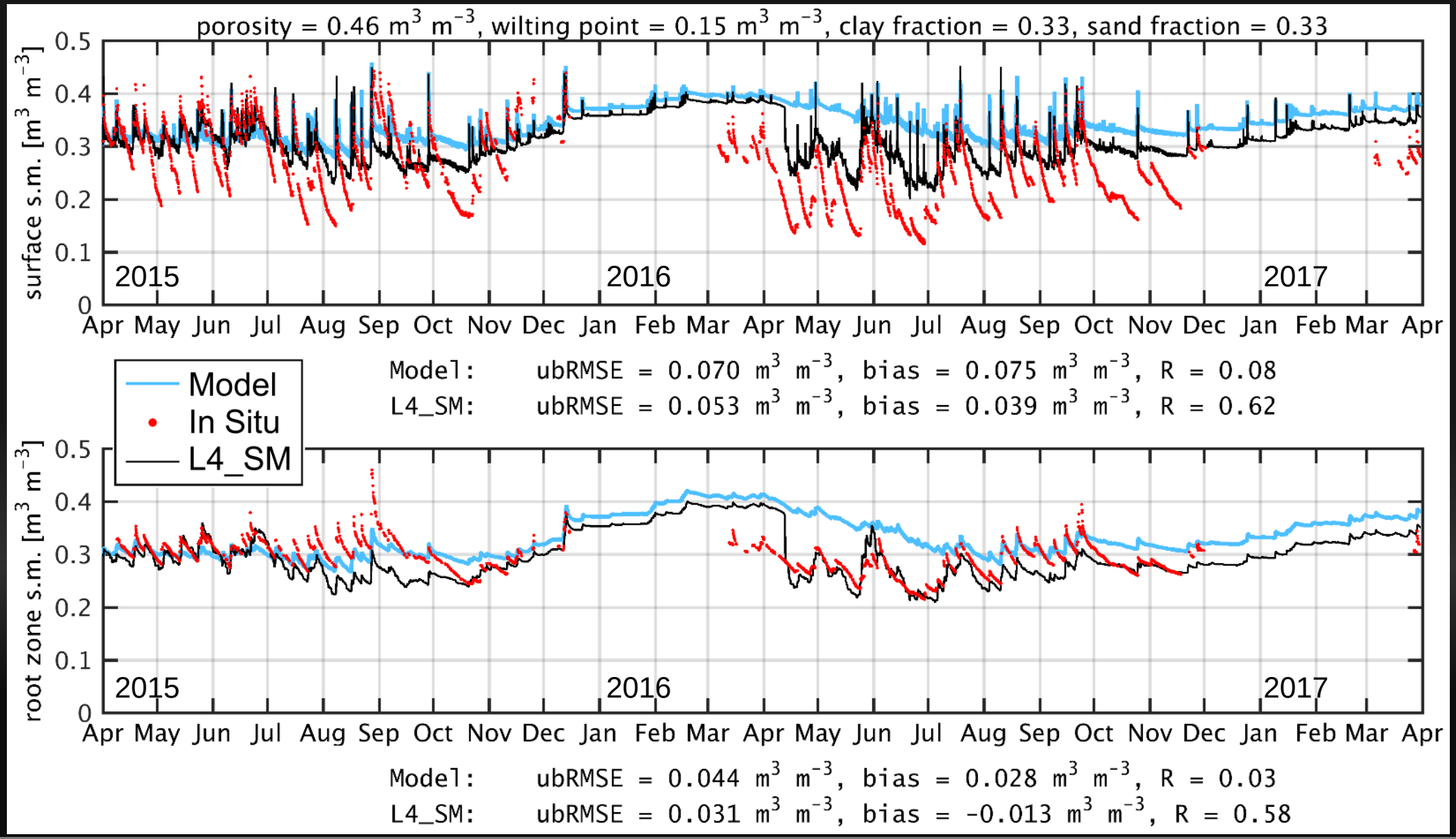
Reichle et al. (2017), *JHM*, doi:10.1175/JHM-D-17-0130.1.

Soil Moisture at Little Washita (Oklahoma)

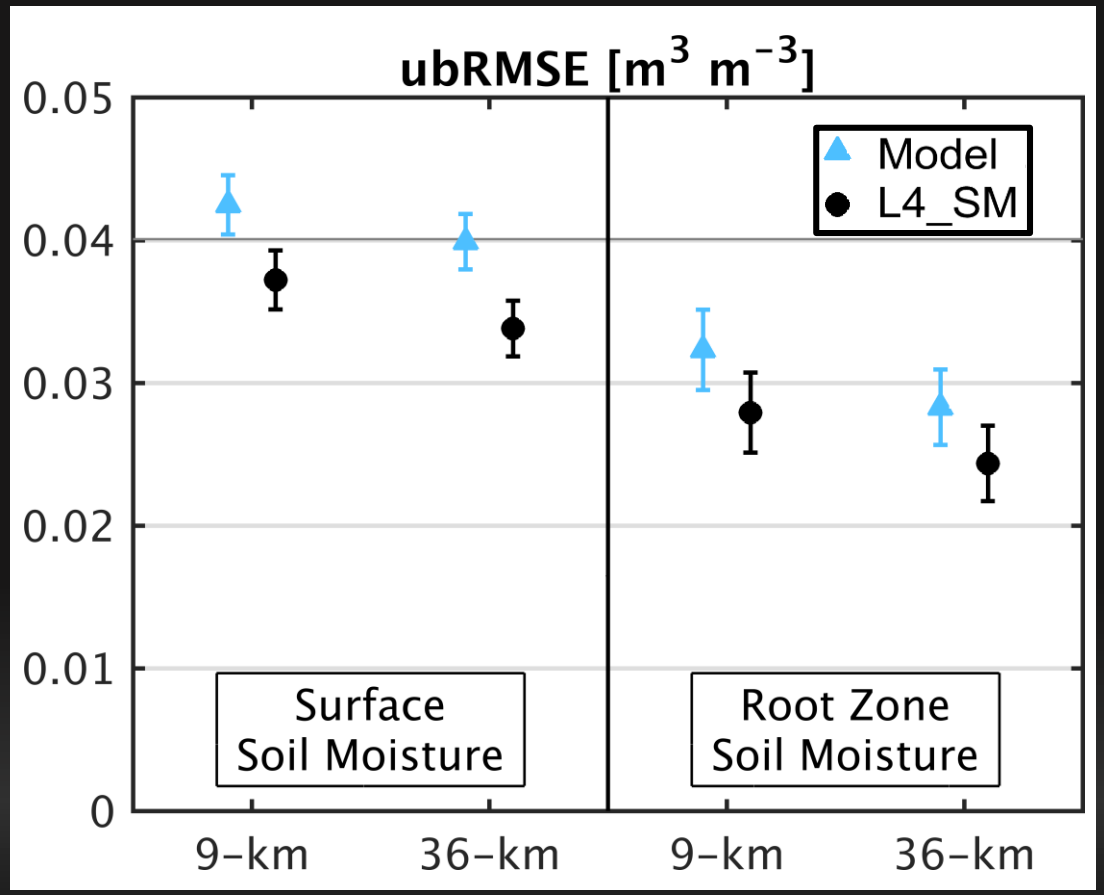


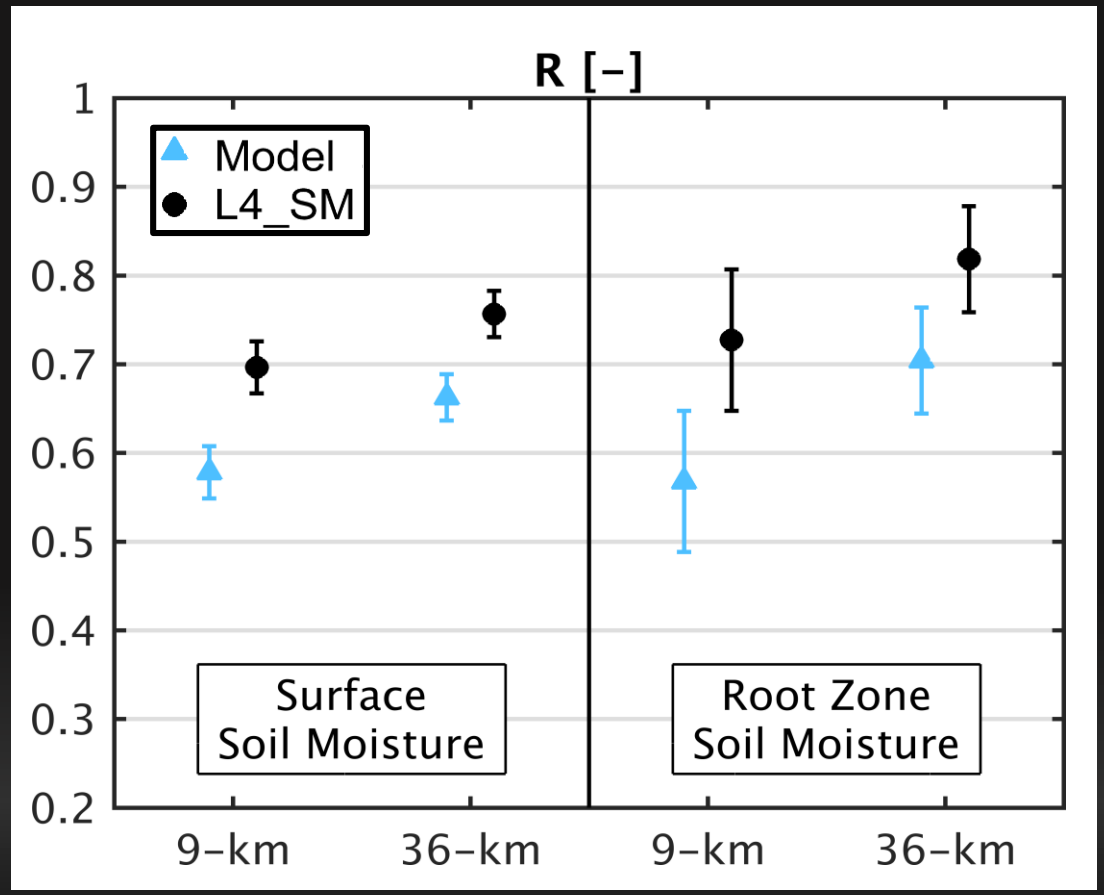
= RMSE after removing bias

Soil Moisture at South Fork (Iowa)



Validation vs. Core Site In Situ Measurements



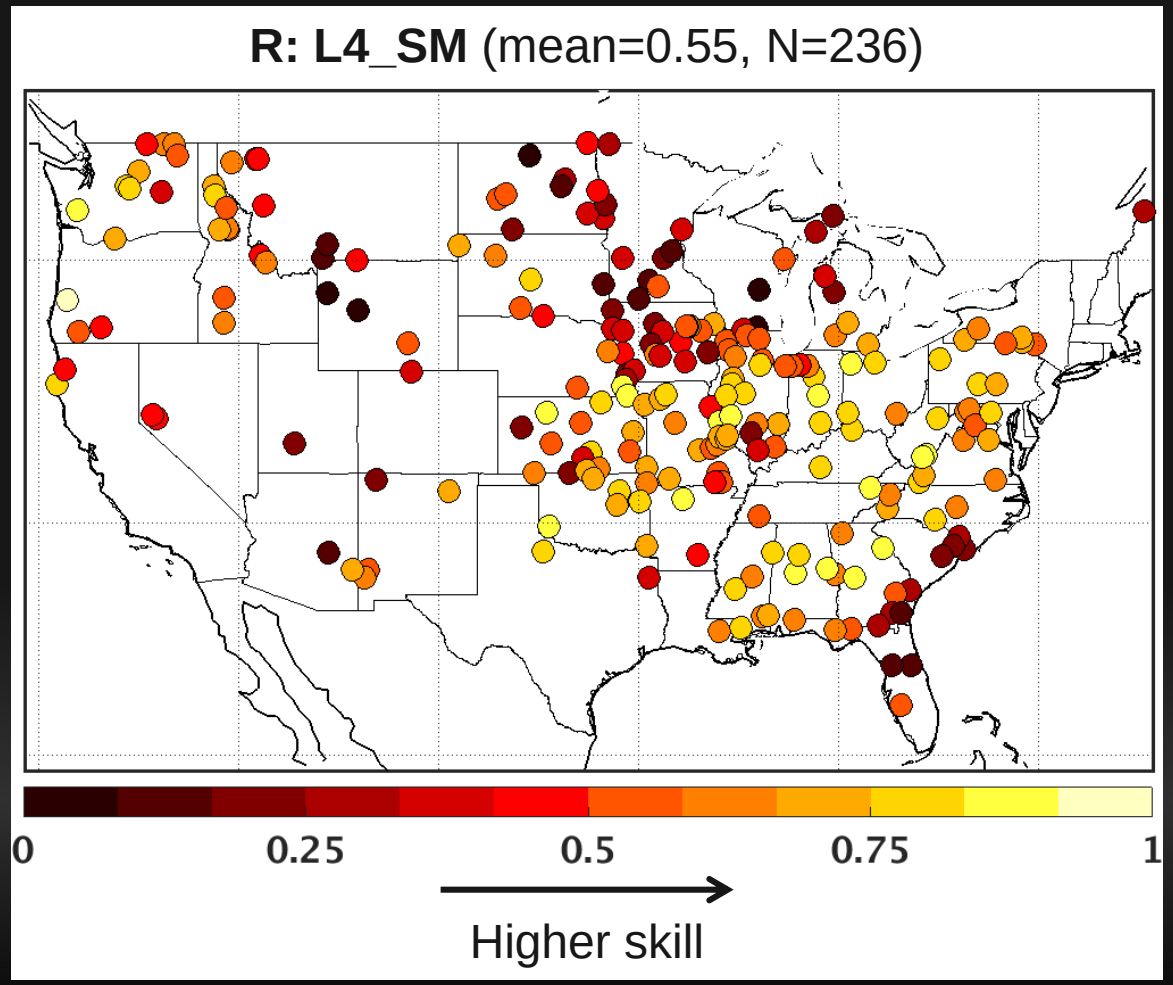


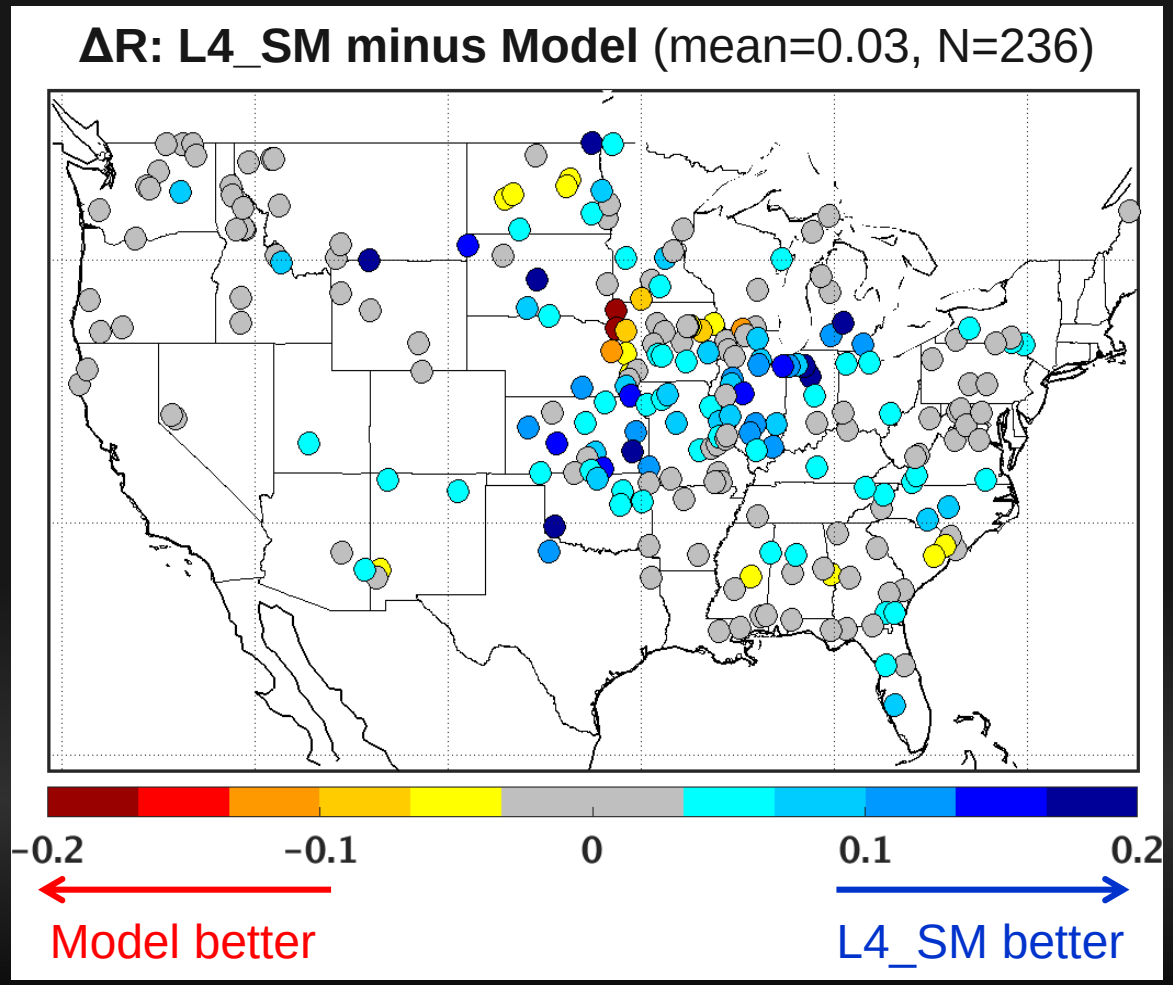
- L4_SM shows small but consistent improvements over model-only data.
- L4_SM meets ubRMSE accuracy requirement of 0.04 $m^3\ m^{-3}$.

	# Ref. Pixels
SFSM 9 km	26
SFSM 36 km	17
RZSM 9 km	9
RZSM 36 km	7

Reichle et al. (2017), *JHM*, doi:10.1175/JHM-D-17-0063.1.

Validation vs. USGS Streamflow





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New in L4_SM Version 3

Updated brightness temperature (Tb) scaling factors *based on:*

- *Newer & more SMOS Tbs where available (6 years of v6, rescaled to v5)*
- *SMAP Tbs elsewhere (2 years of Version 3)*
- *Model Tbs from updated "Nature Run" (NRv4.1)*

  Retrospective forcing is better and more consistent w/ 2015-present data.

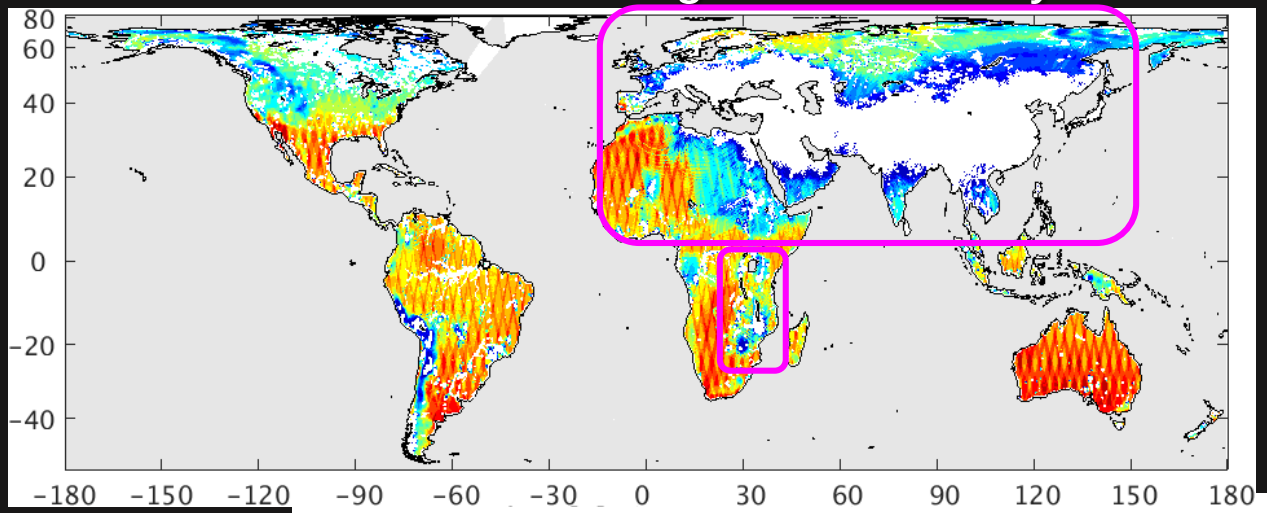
→ More SMAP observations assimilated.

Unchanged *Catchment model version & 2015-present forcing (w/ minimal exceptions).*

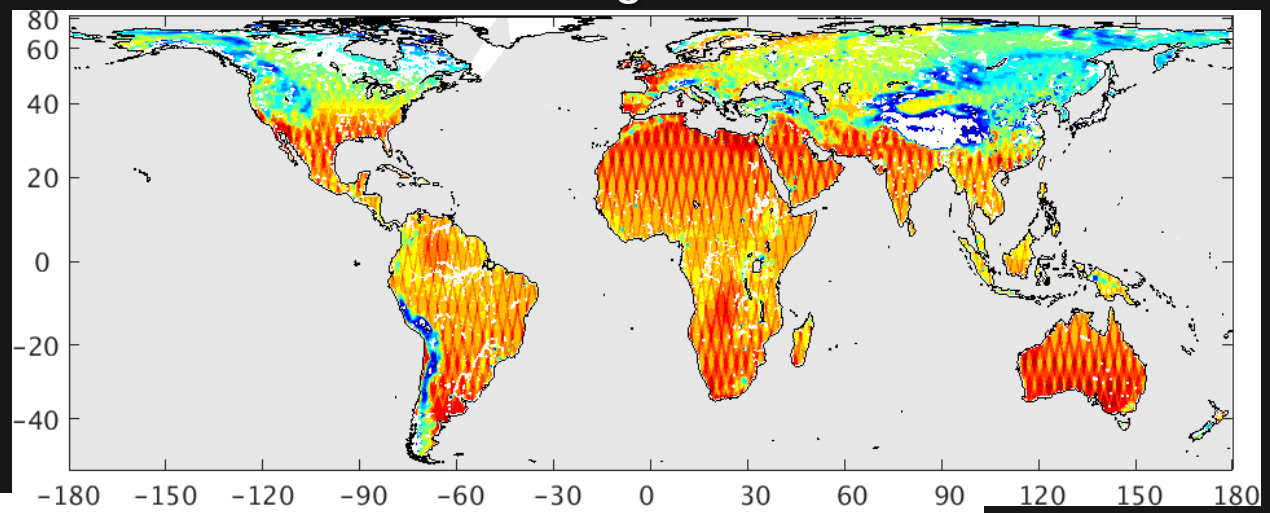
Objective was to avoid recalibration of L4_C algorithm.

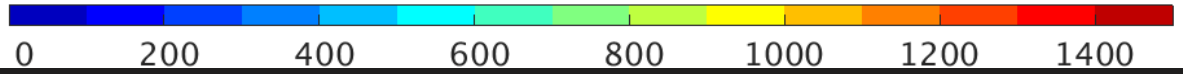
Number of Assimilated SMAP L1C_TB Observations

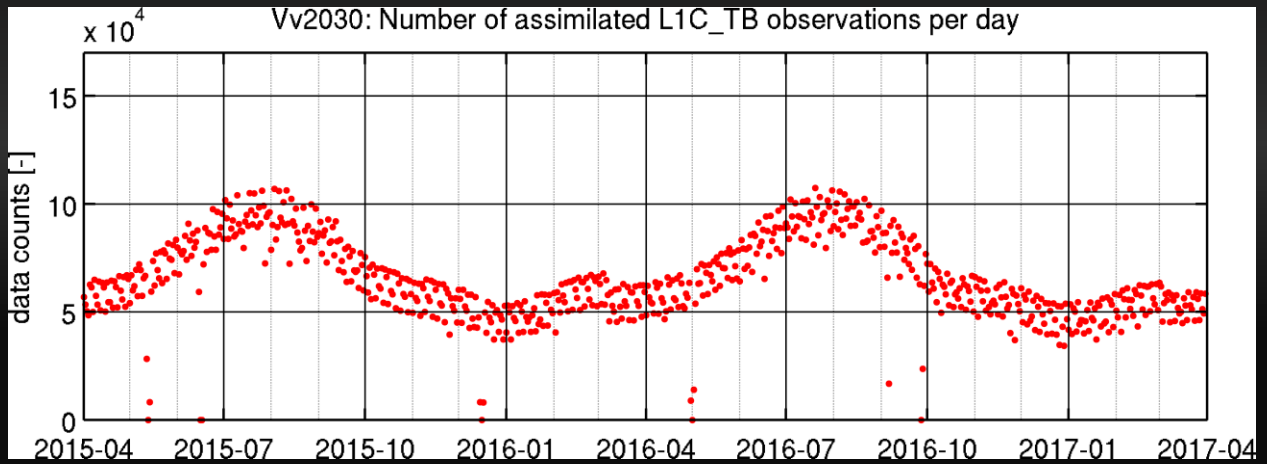
Version 2 – rescaling w/ SMOS only



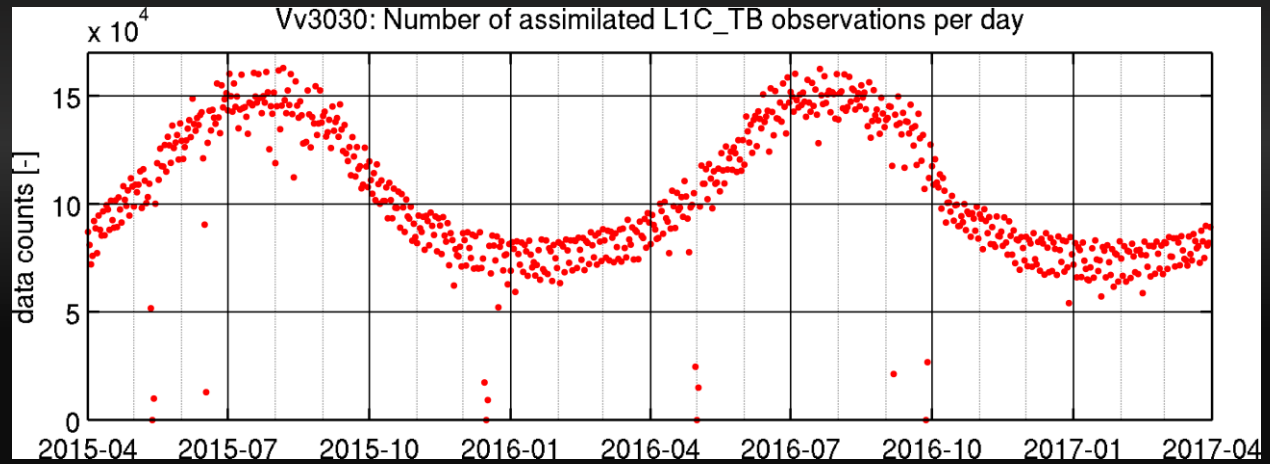
Version 3 – rescaling with SMOS & SMAP







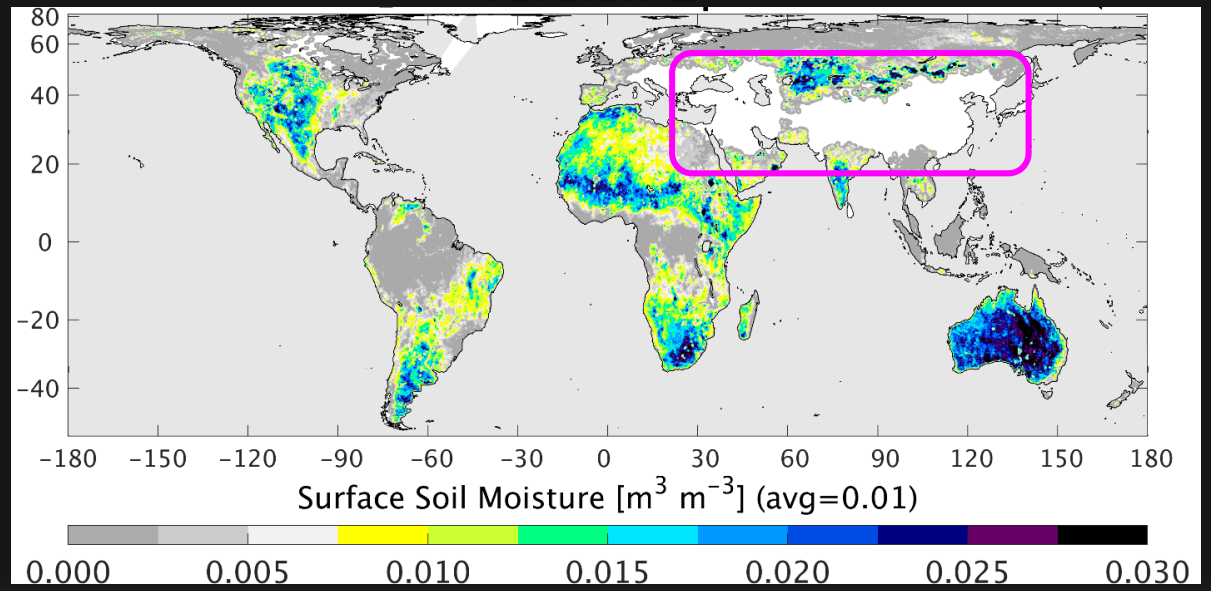
Average: 65,000 / day

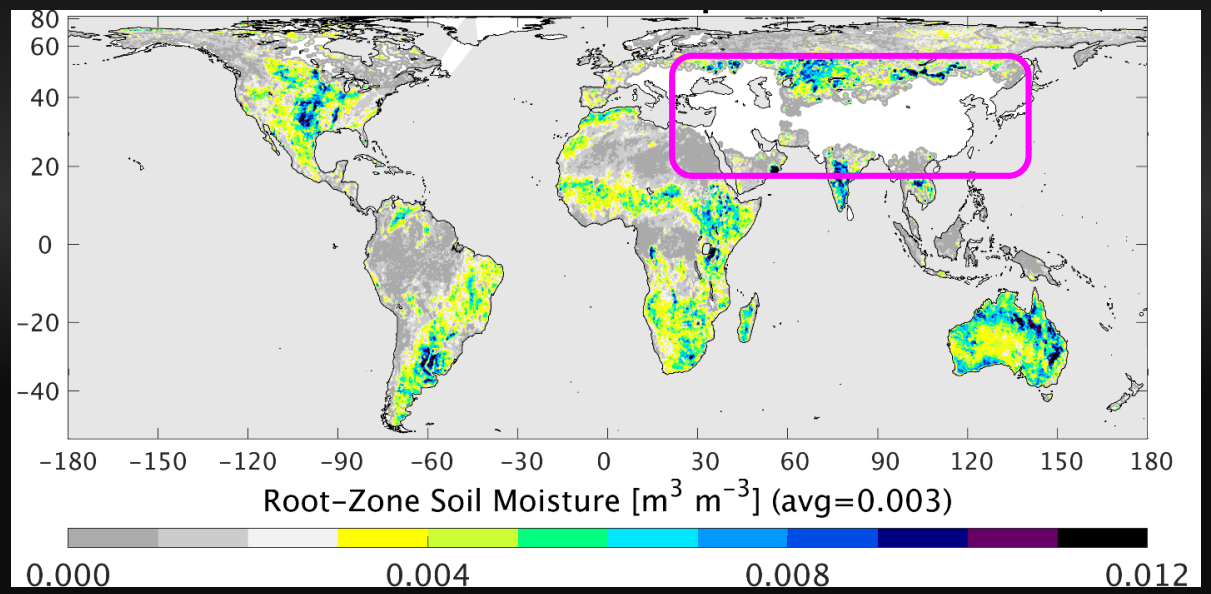


Average: **104,000** / day

Std-dev Increments

Version 2





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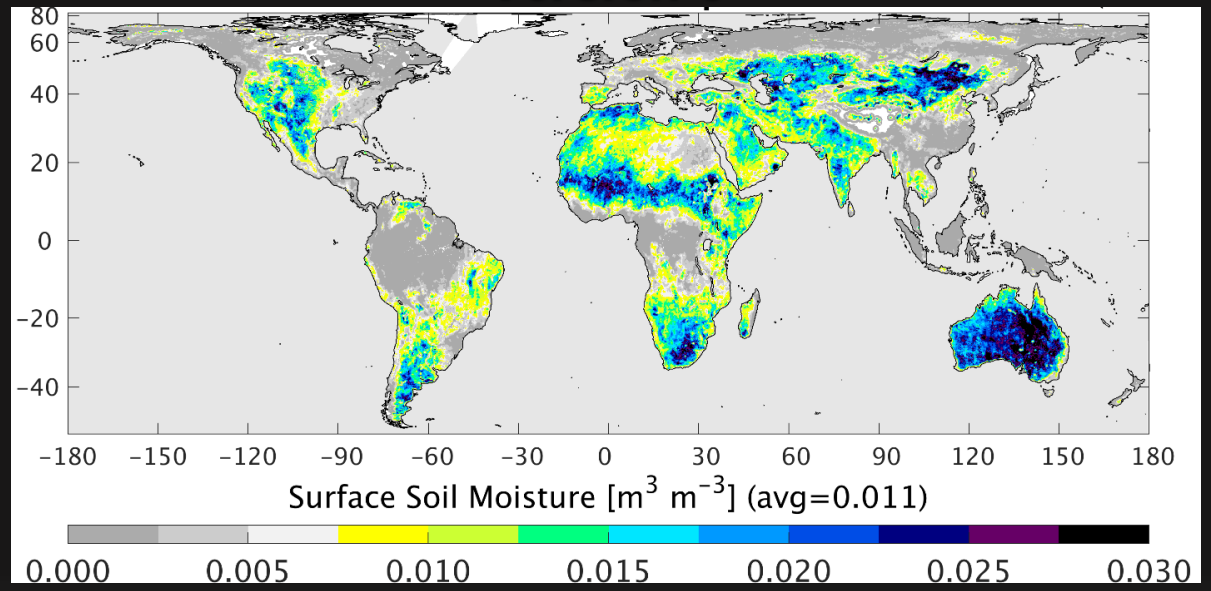
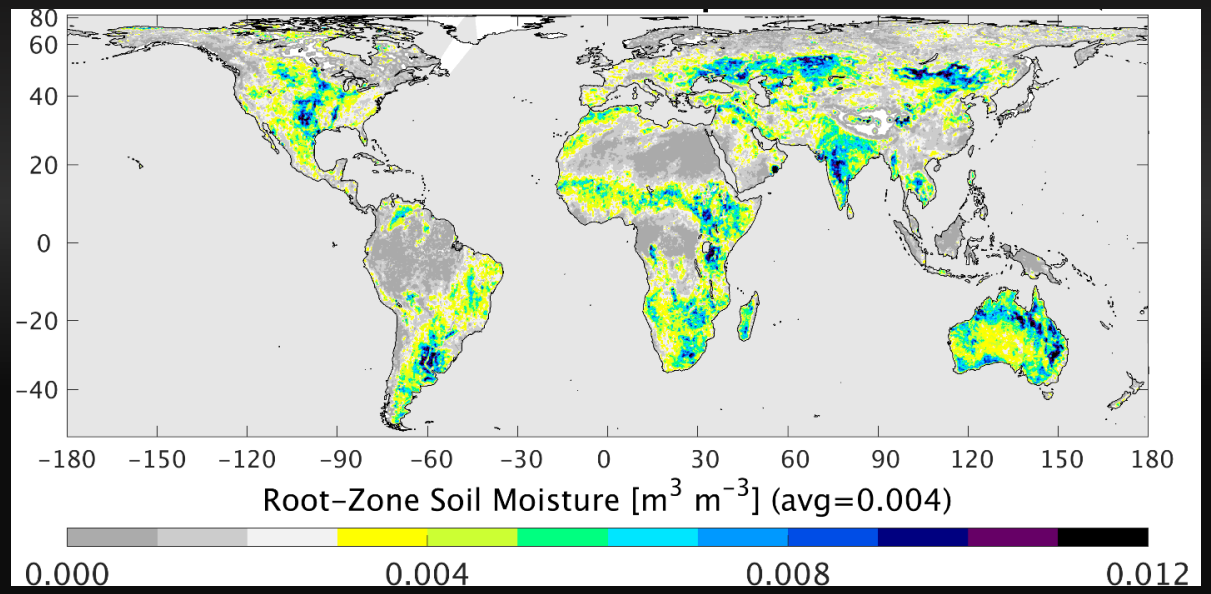
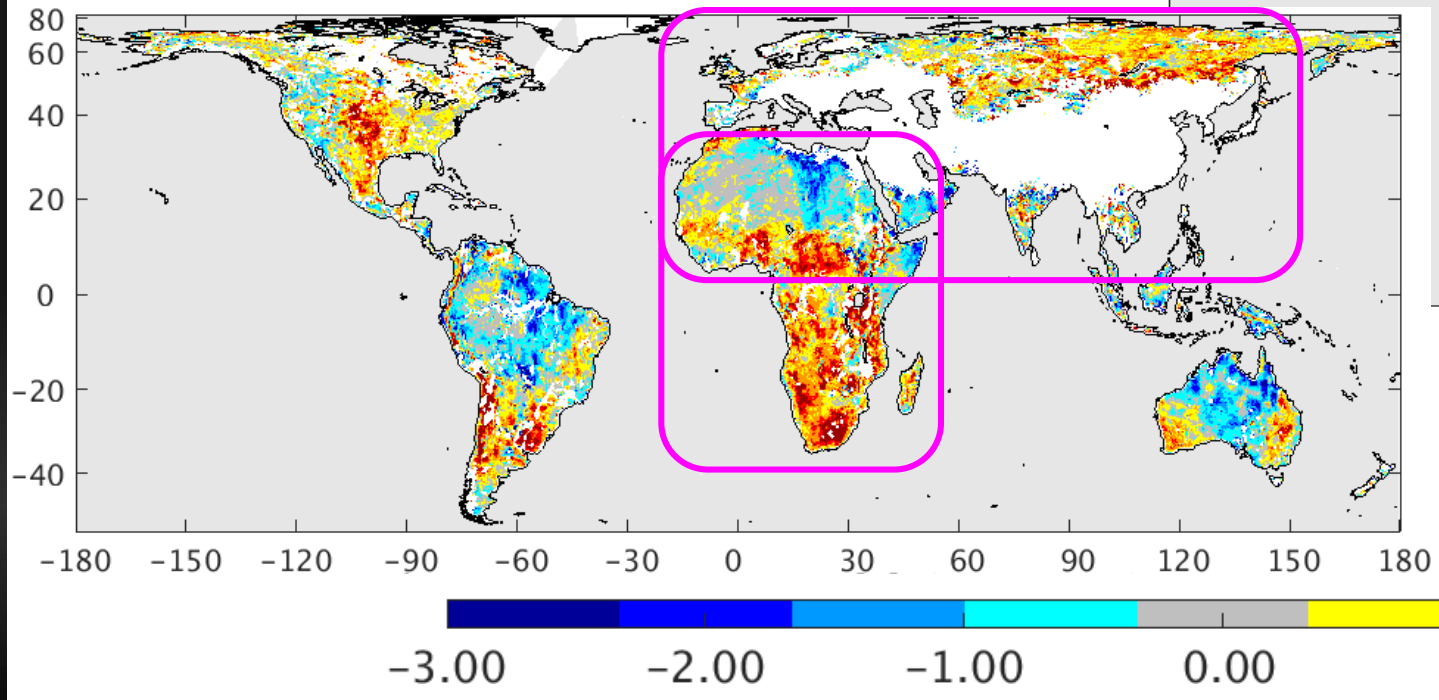


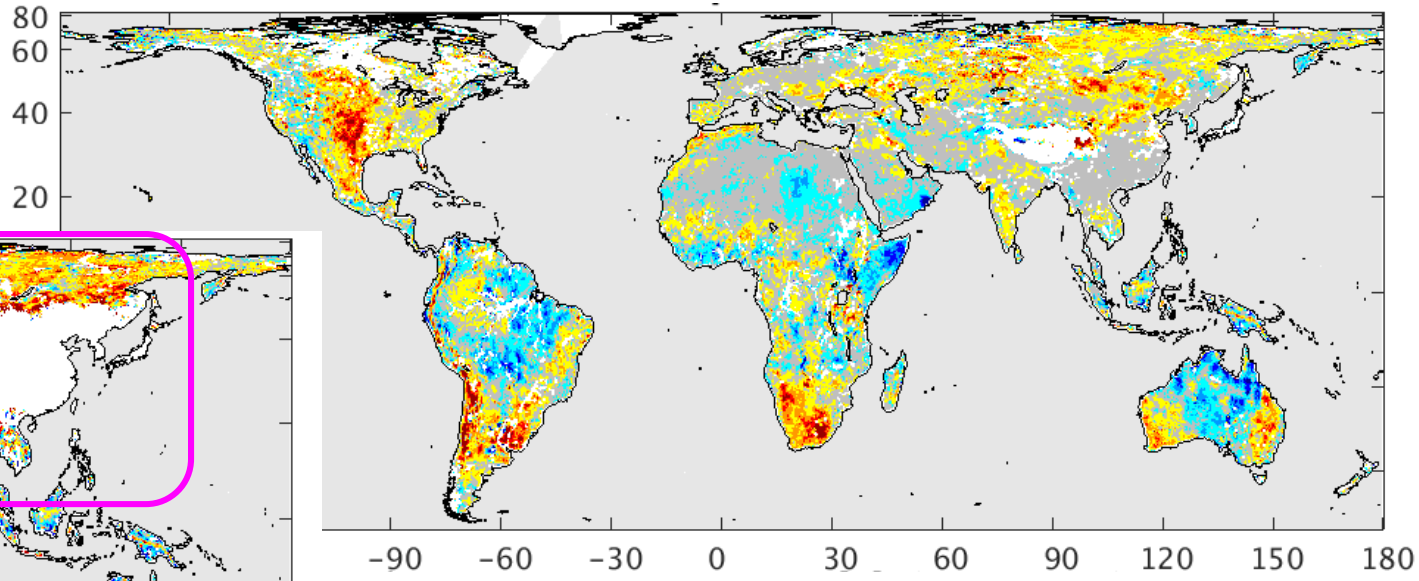


Mean O-F

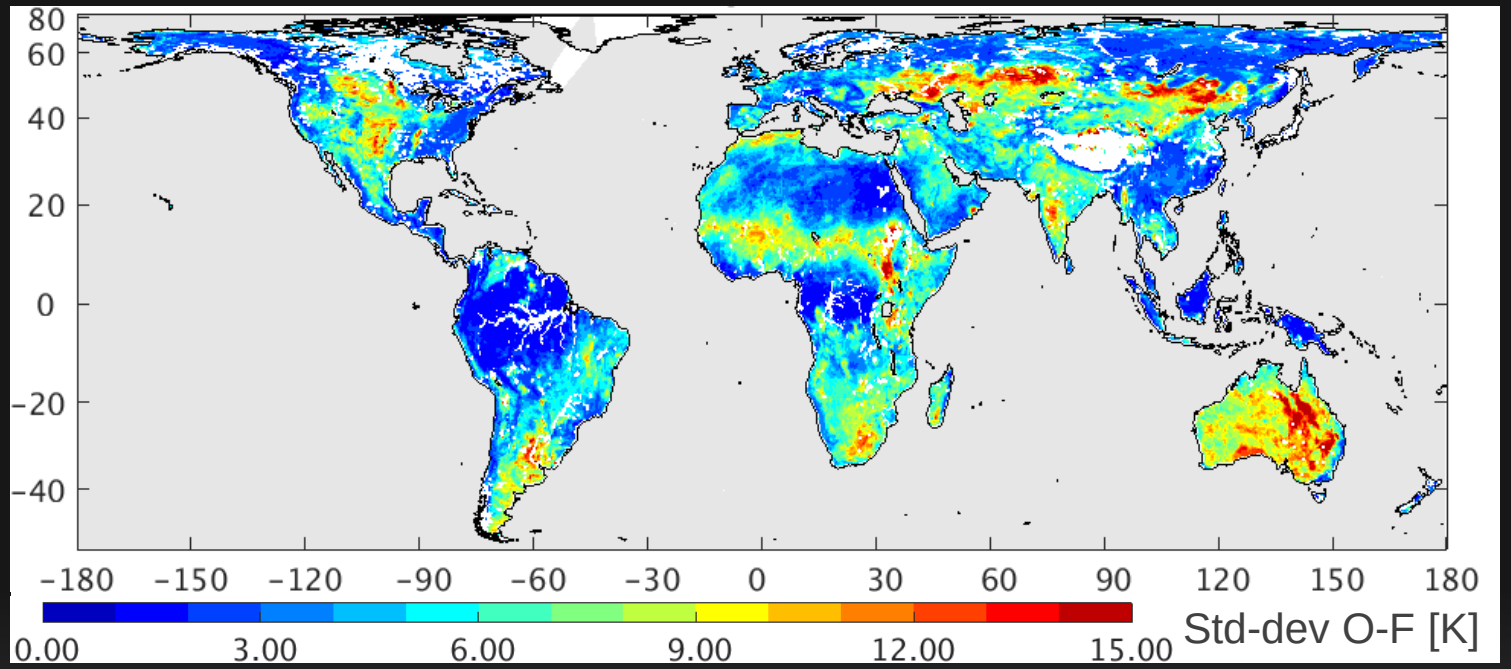
Version 2

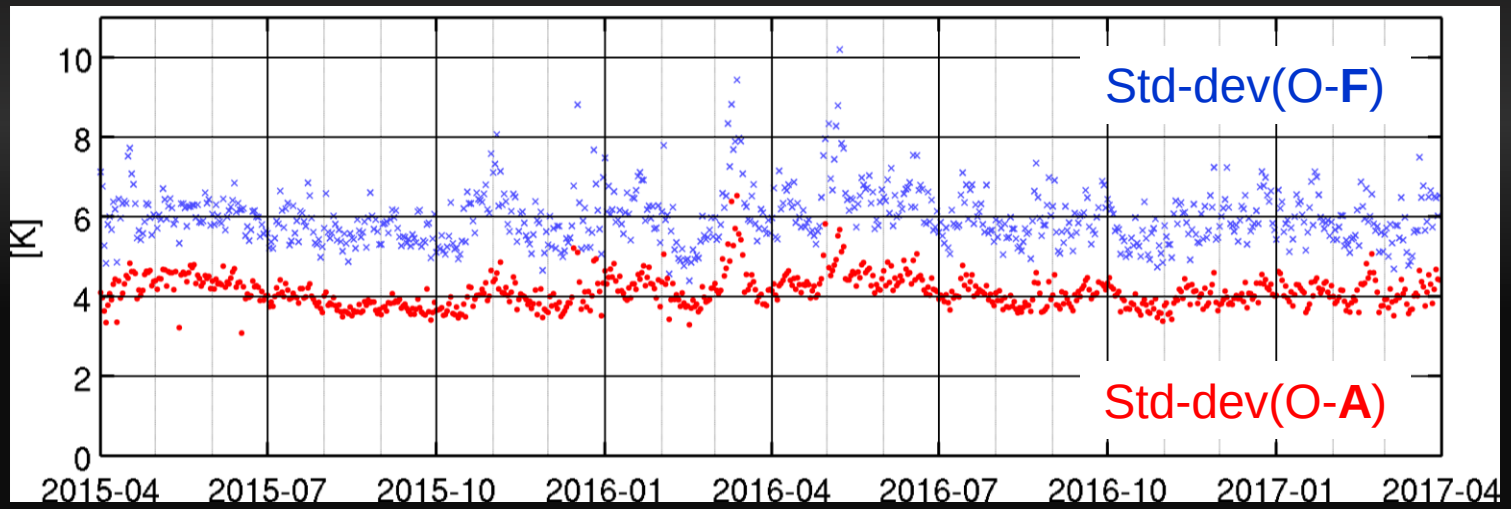


Version 3



Std-dev O-F





Average:
O-F: 6 K
O-A: 4 K

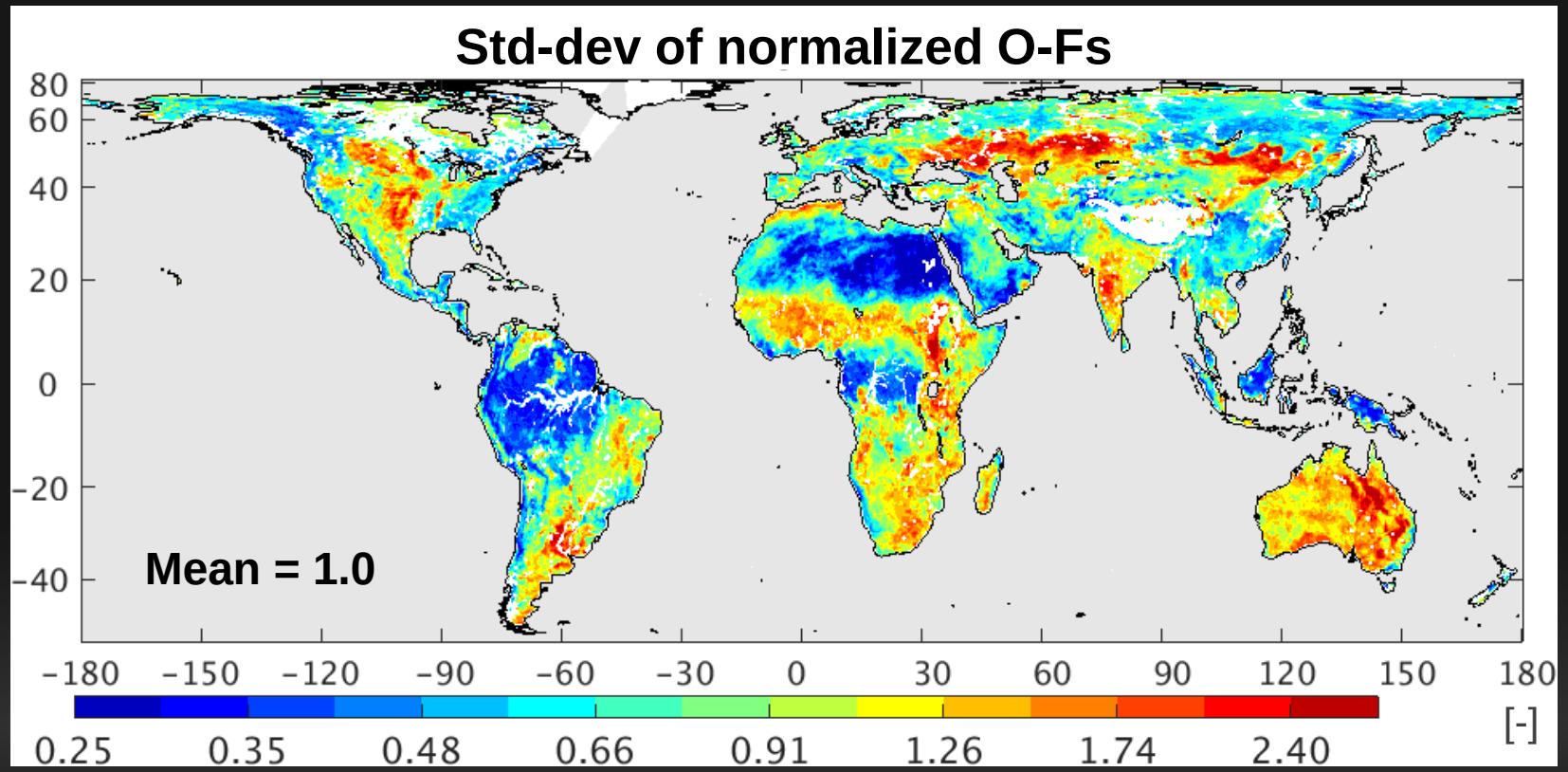
cf. Tb obs error
= 4 K

includes

instrument error
= 1.3 K
&
representative-
ness error
= 3.8 K

What is the Quality of the Error Estimates?

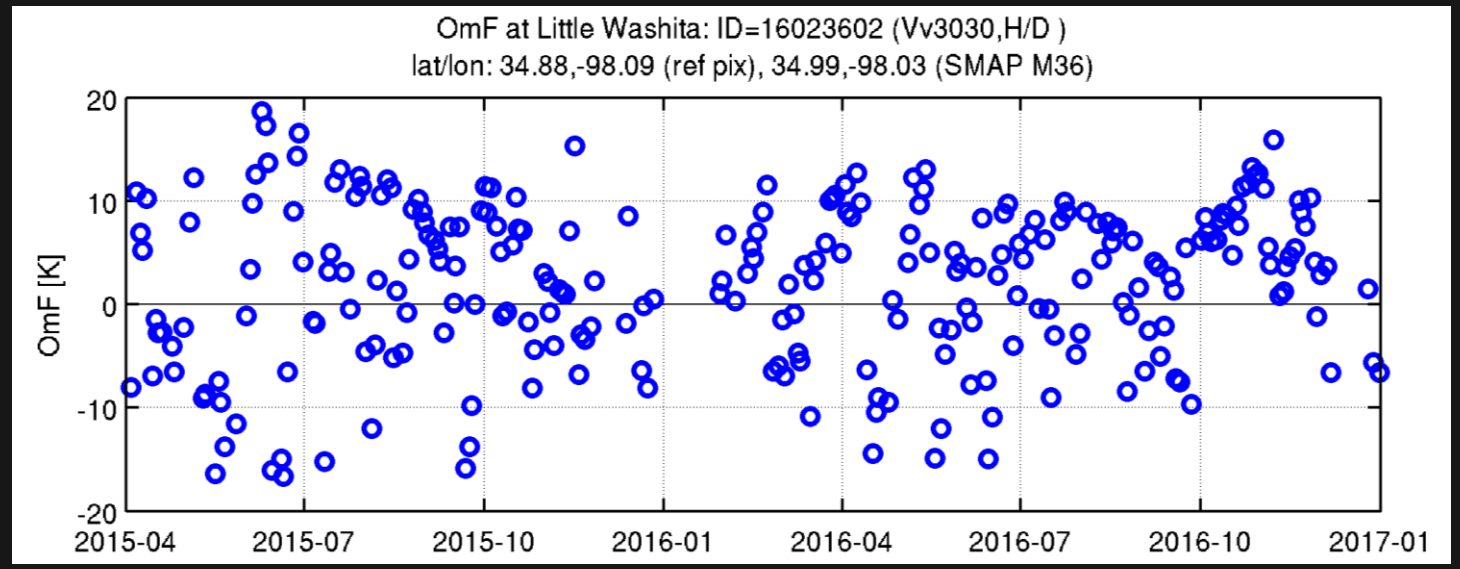
Normalize O-Fs with (assumed) error std-devs supplied to the analysis.



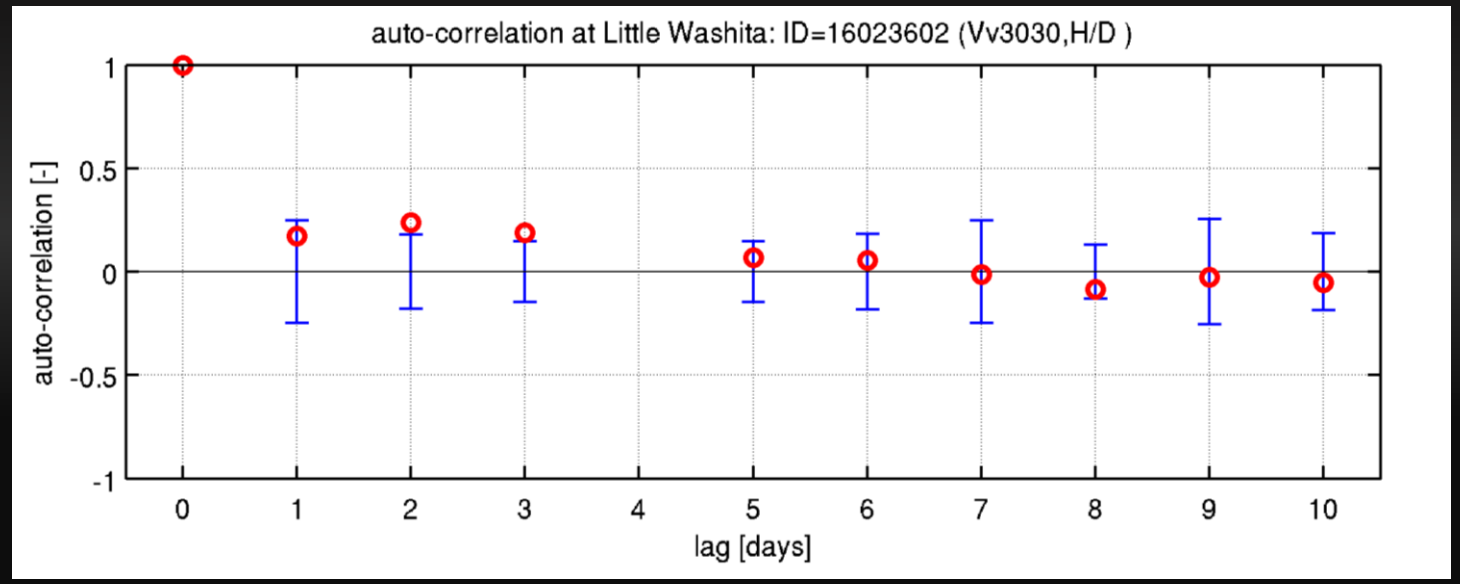
over-estimation **under-estimation**

of actual O-F errors

How Efficiently do we Use the Observations?

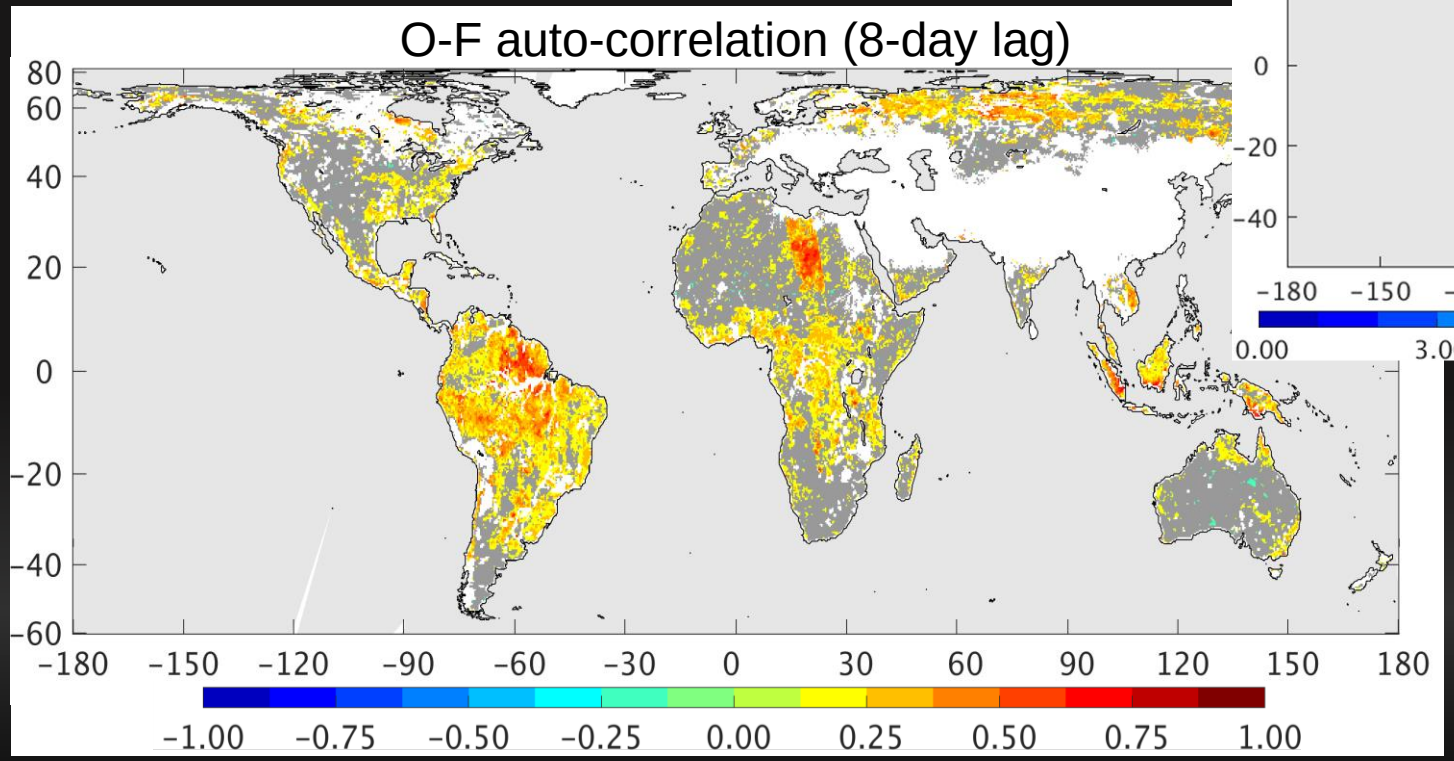


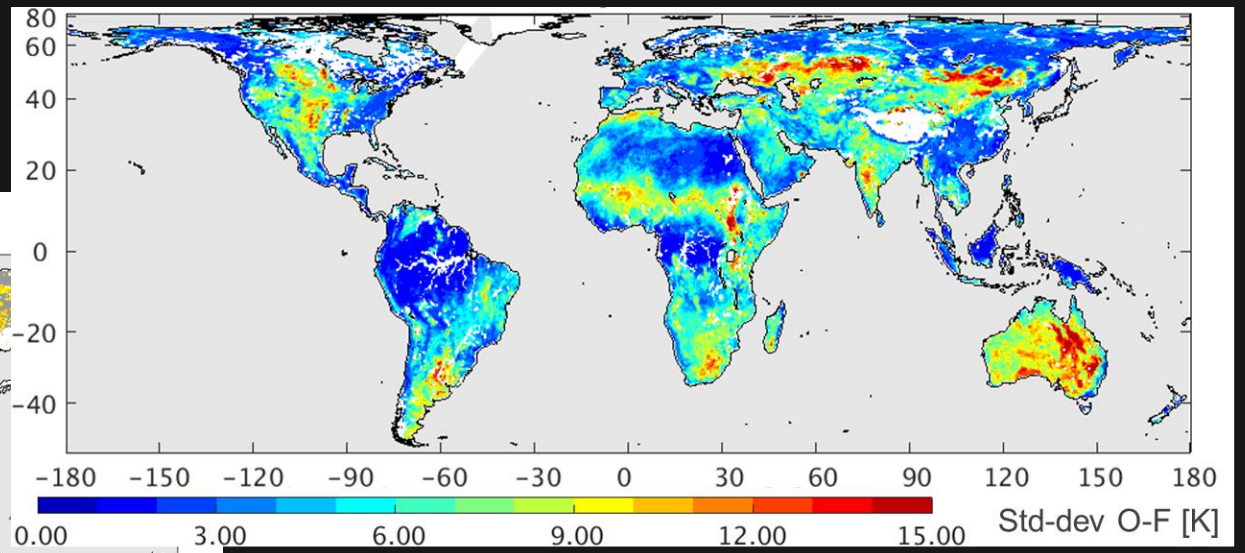
O-F time series at Little Washita, Oklahoma.



O-F auto-correlation measures “efficiency” of assimilation system.

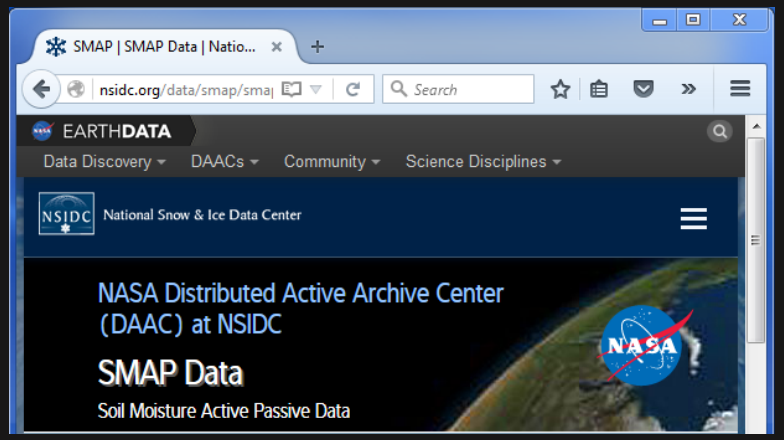
How Efficiently do we Use the Observations?





Observations *are* used efficiently where it matters.

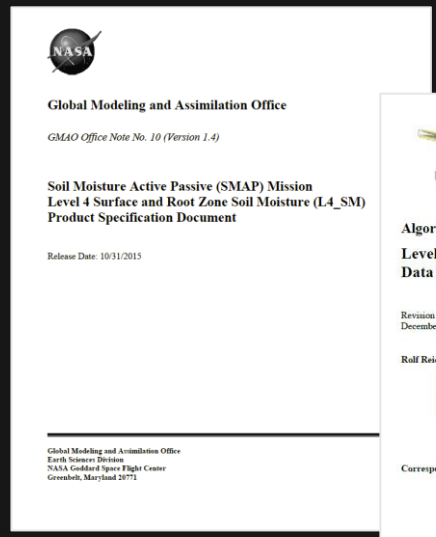
SMAP L4_SM Documentation



***Data Archive** & HTML Doc*

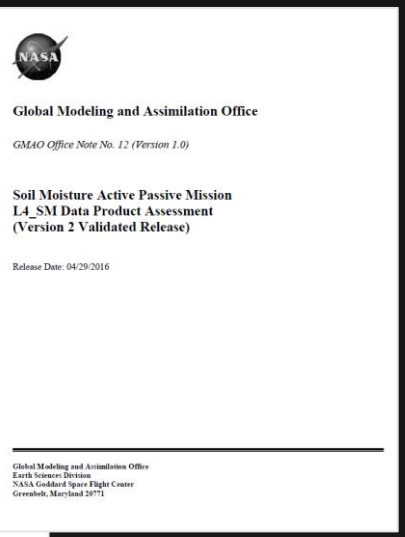
`http://nsidc.org/data/smap`

Peer-Reviewed Papers (J. Hydromet.)



Product Specification Document

Algorithm Document



Data Assessment Reports

`http://gmao.gsfc.nasa.gov/GMAO_products/SMAP_L4`

Summary

- *The L4_SM algorithm assimilates SMAP brightness temperature (Tb) observations into the NASA Catchment model using a distributed (3d) EnKF.*
- *The L4_SM product provides global, 9-km, 3-hourly estimates with ~2.5-day latency.*
- *Version 3 of the L4_SM algorithm also assimilates SMAP Tbs in RFI-prone regions.*
- *The L4_SM analysis is largely unbiased, but there are modest regional biases in the O-F Tb residuals (<3 K).*
- *Typical instantaneous values are ~6 K for O-F Tb residuals and ~0.01 (~0.004) m^3 m^{-3} for surface (root-zone) soil moisture increments.*
- *Actual errors are over-estimated in deserts and densely vegetated regions and under-estimated in agricultural regions and wet-dry transition zones.*
- *SMAP observations are assimilated efficiently in western North America, the Sahel, and Australia, but not in many forested regions and the northern high latitudes.*

Thanks for listening!