

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

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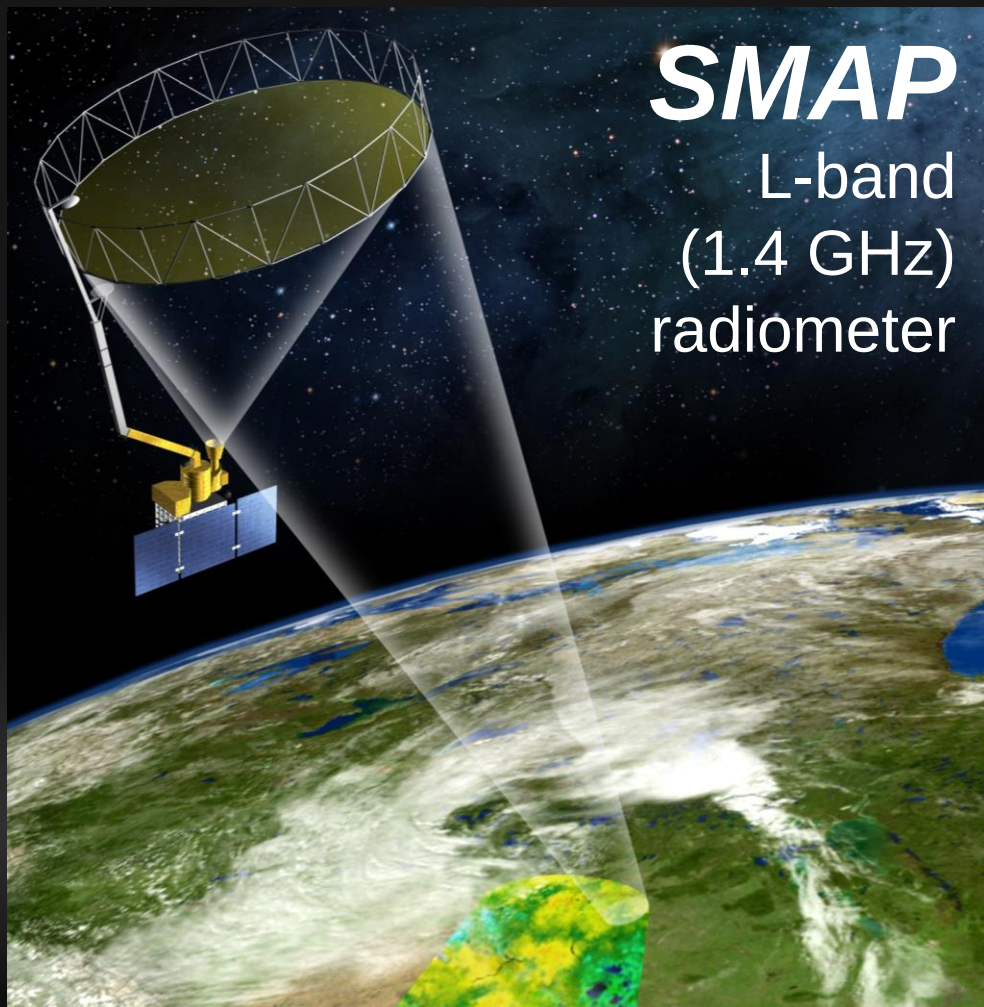
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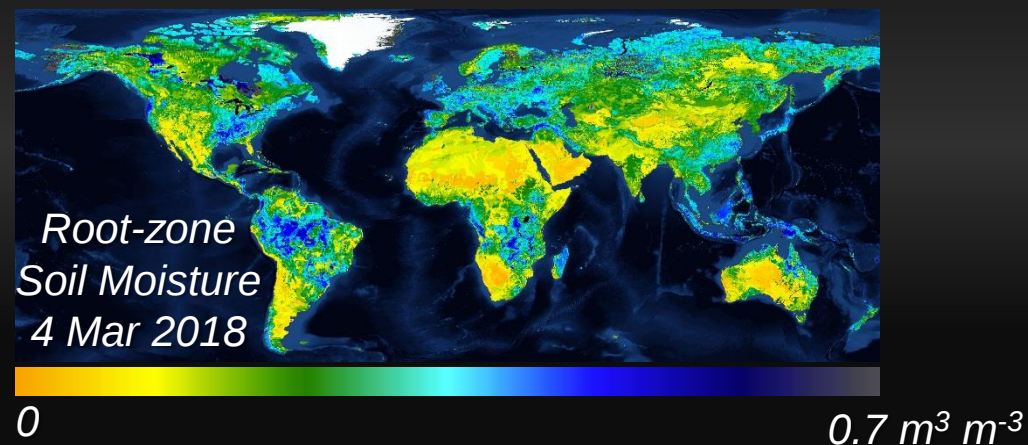
Motivation



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



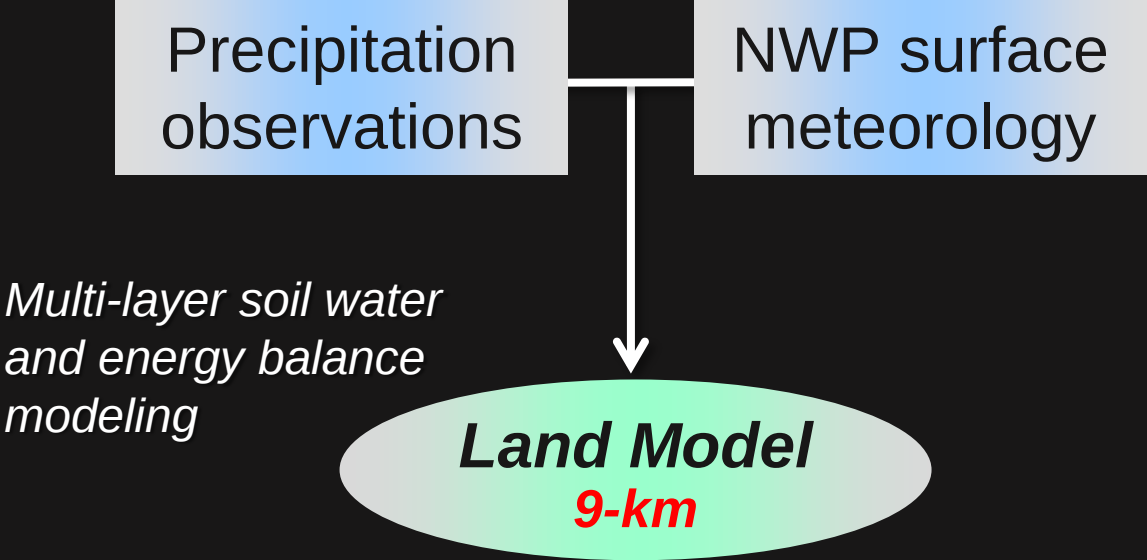
Outline



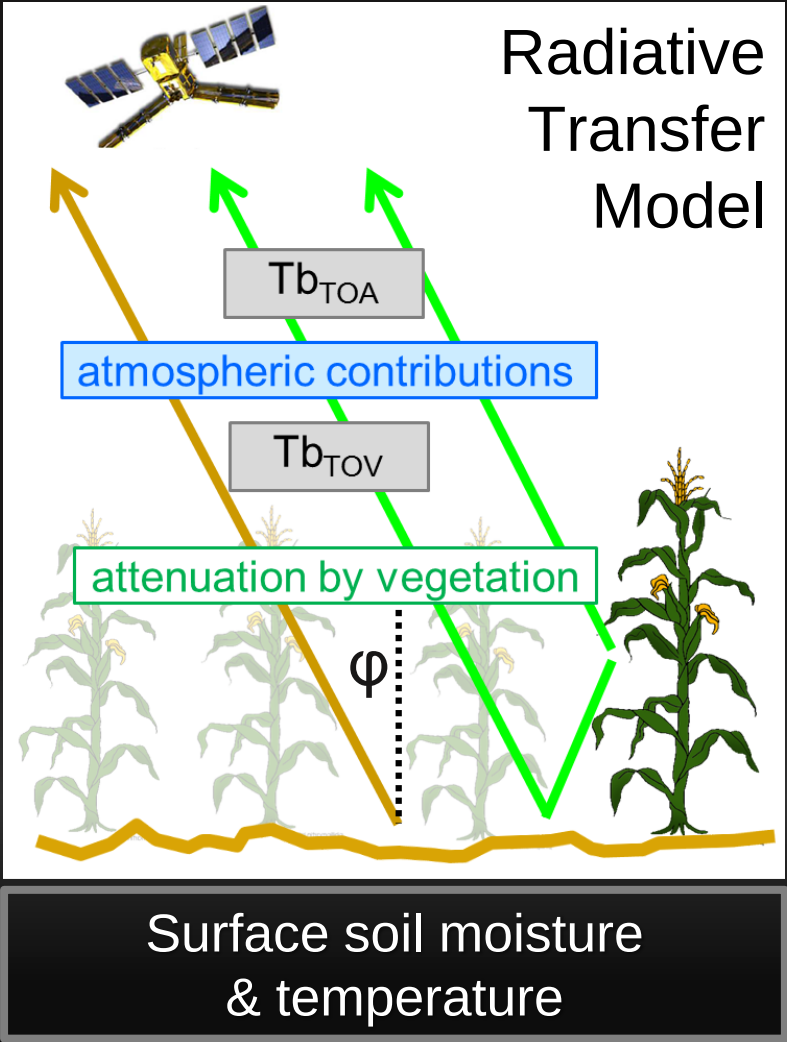
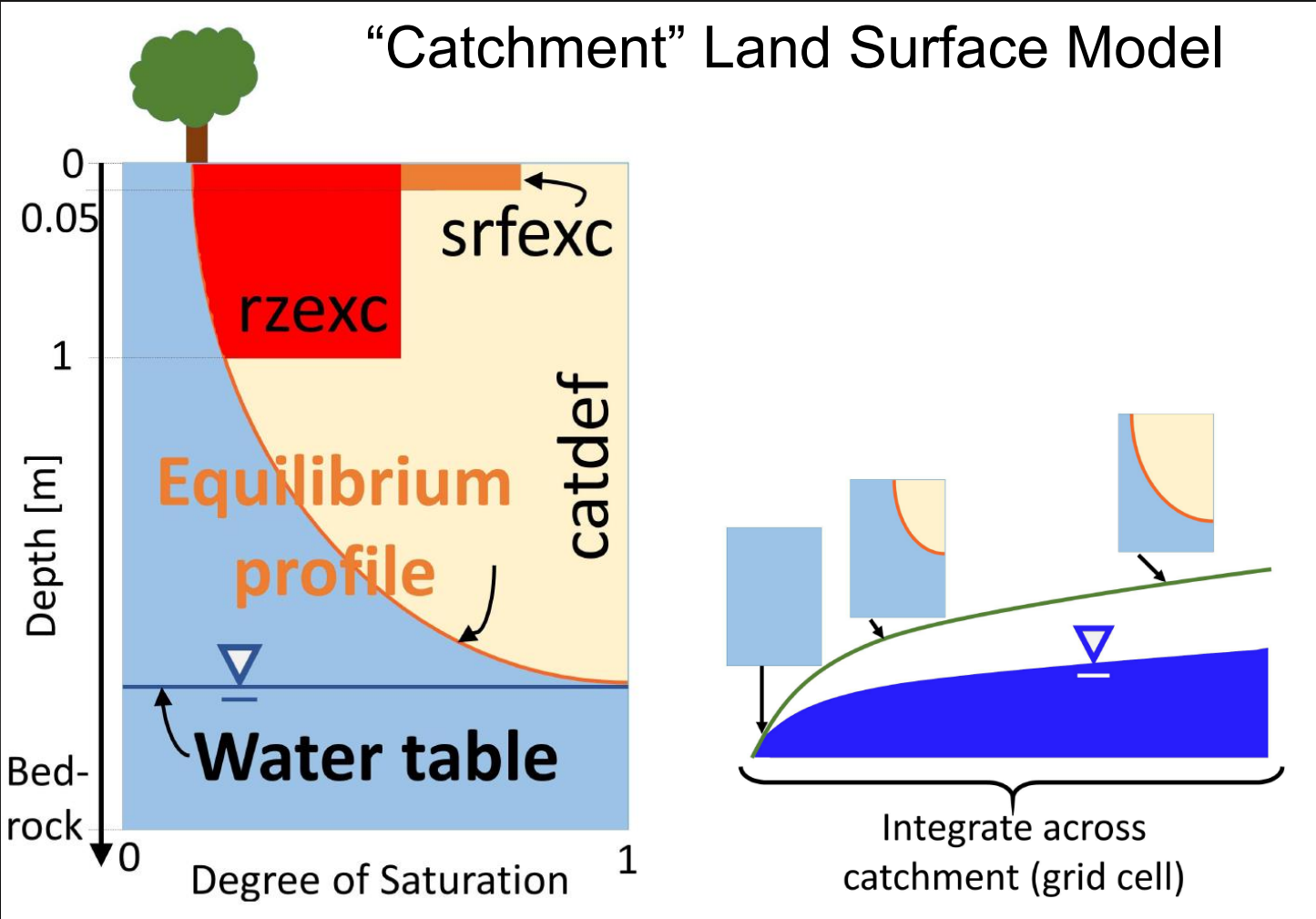
1. Algorithm Overview
2. Validation vs. In Situ Measurements
3. Assimilation diagnostics
 - a) Data Counts
 - b) Observation-Minus-Forecast Residuals
 - c) Assimilation Increments
4. Summary and Conclusions



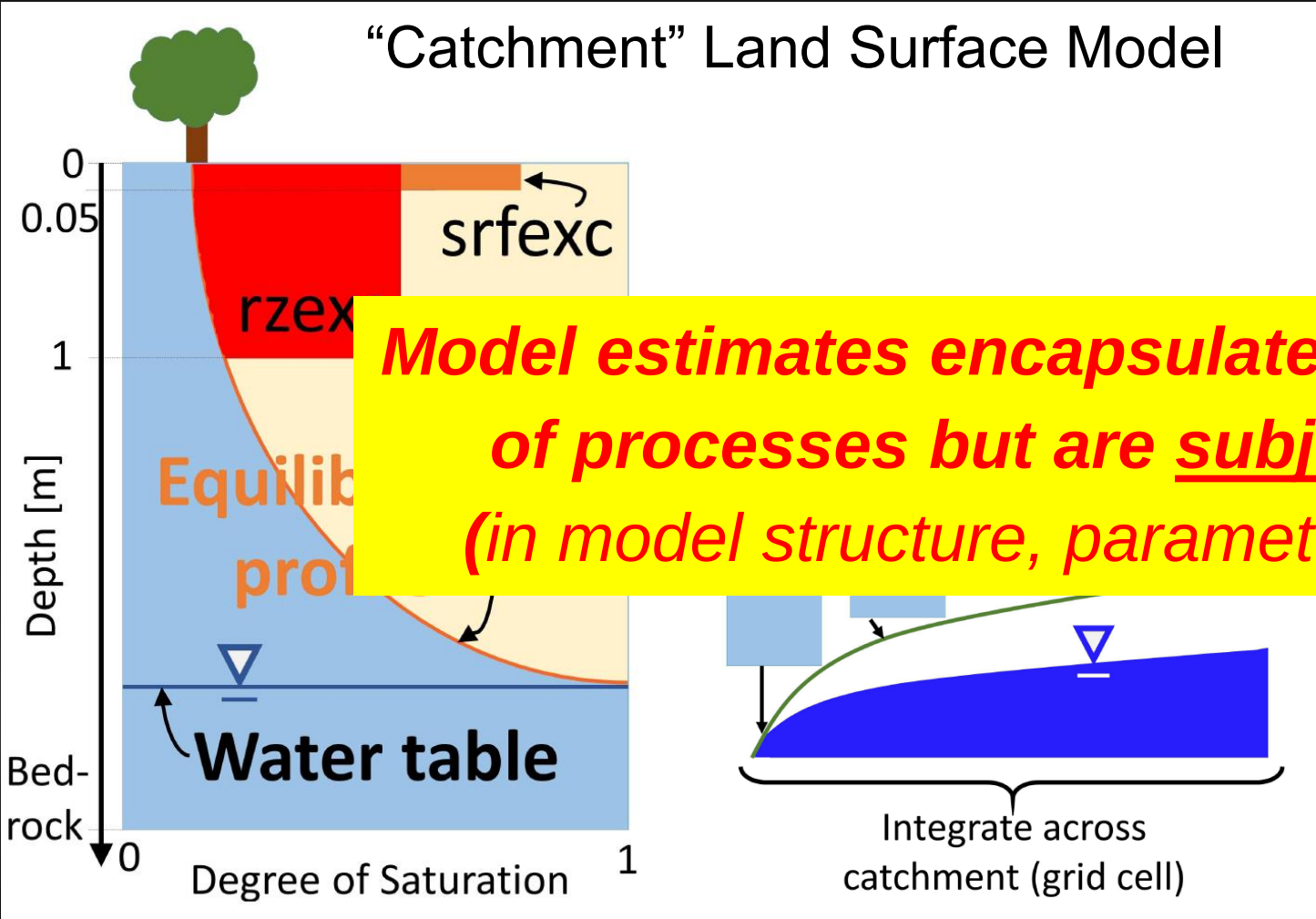
Algorithm Overview



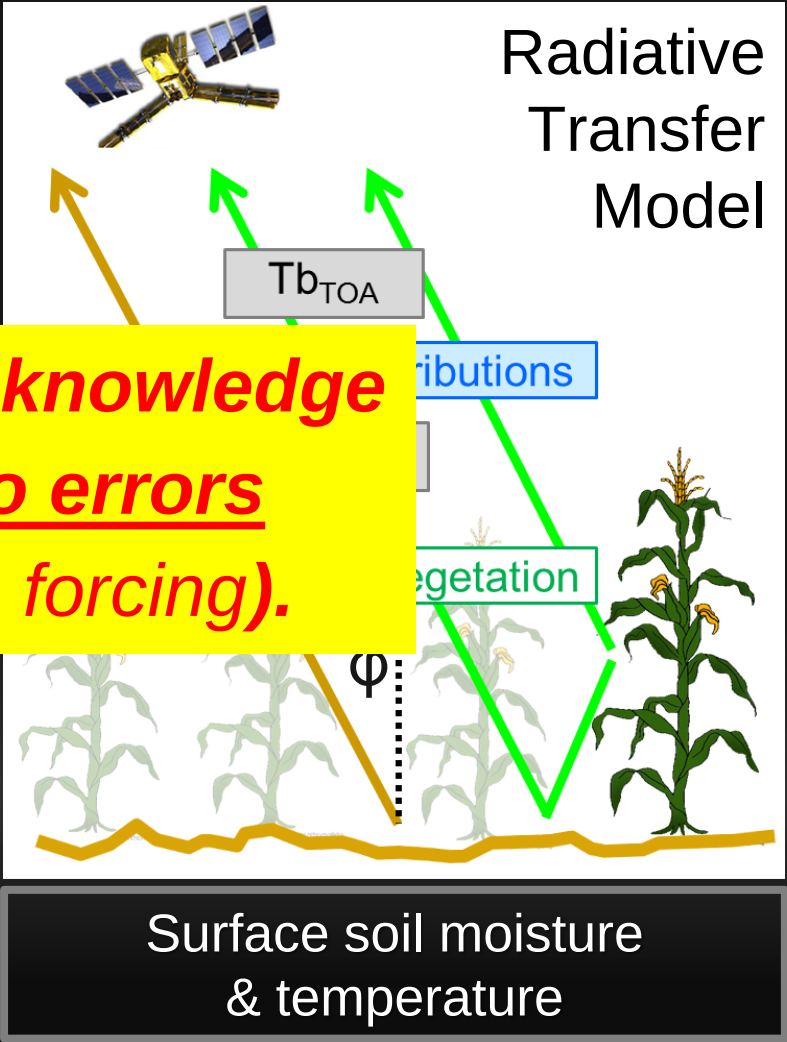
Land Modeling System



Land Modeling System

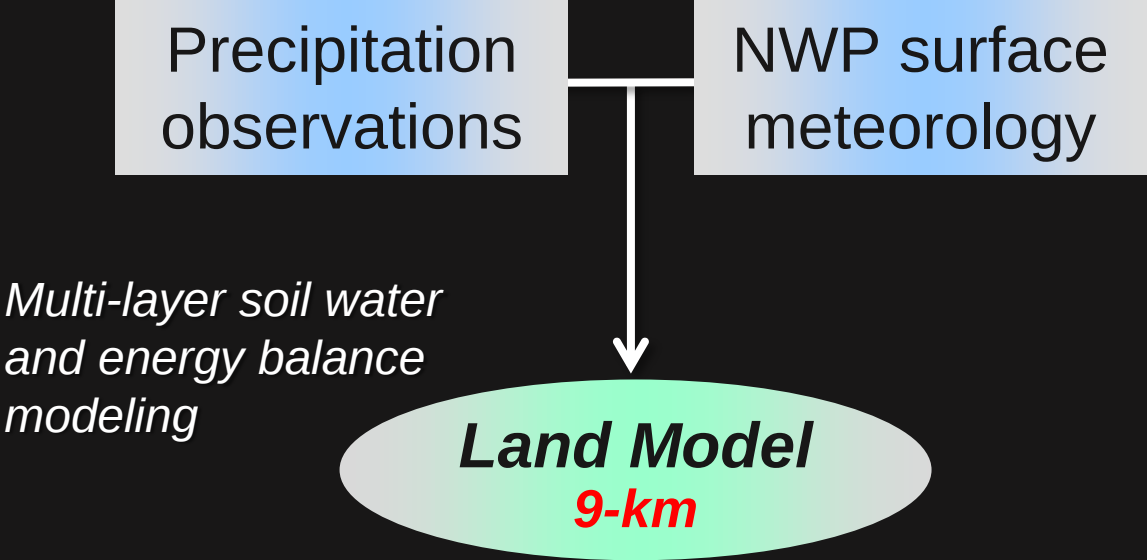


Model estimates encapsulate our knowledge of processes but are subject to errors (in model structure, parameters & forcing).

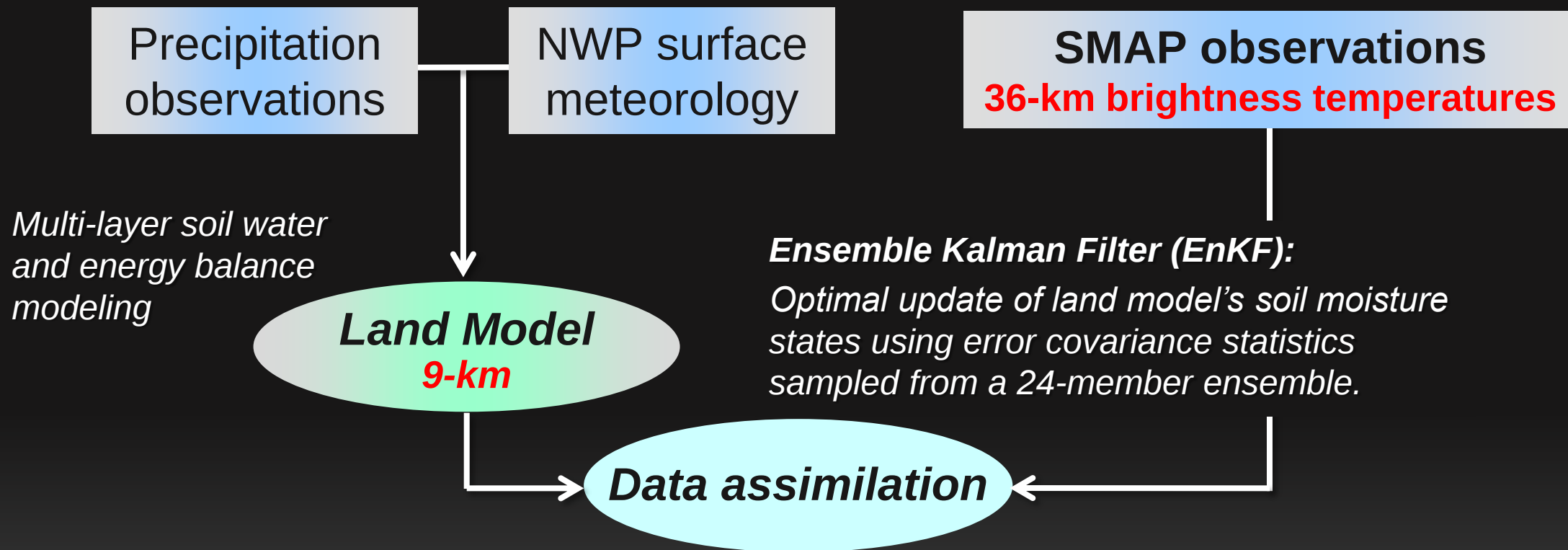




Algorithm Overview

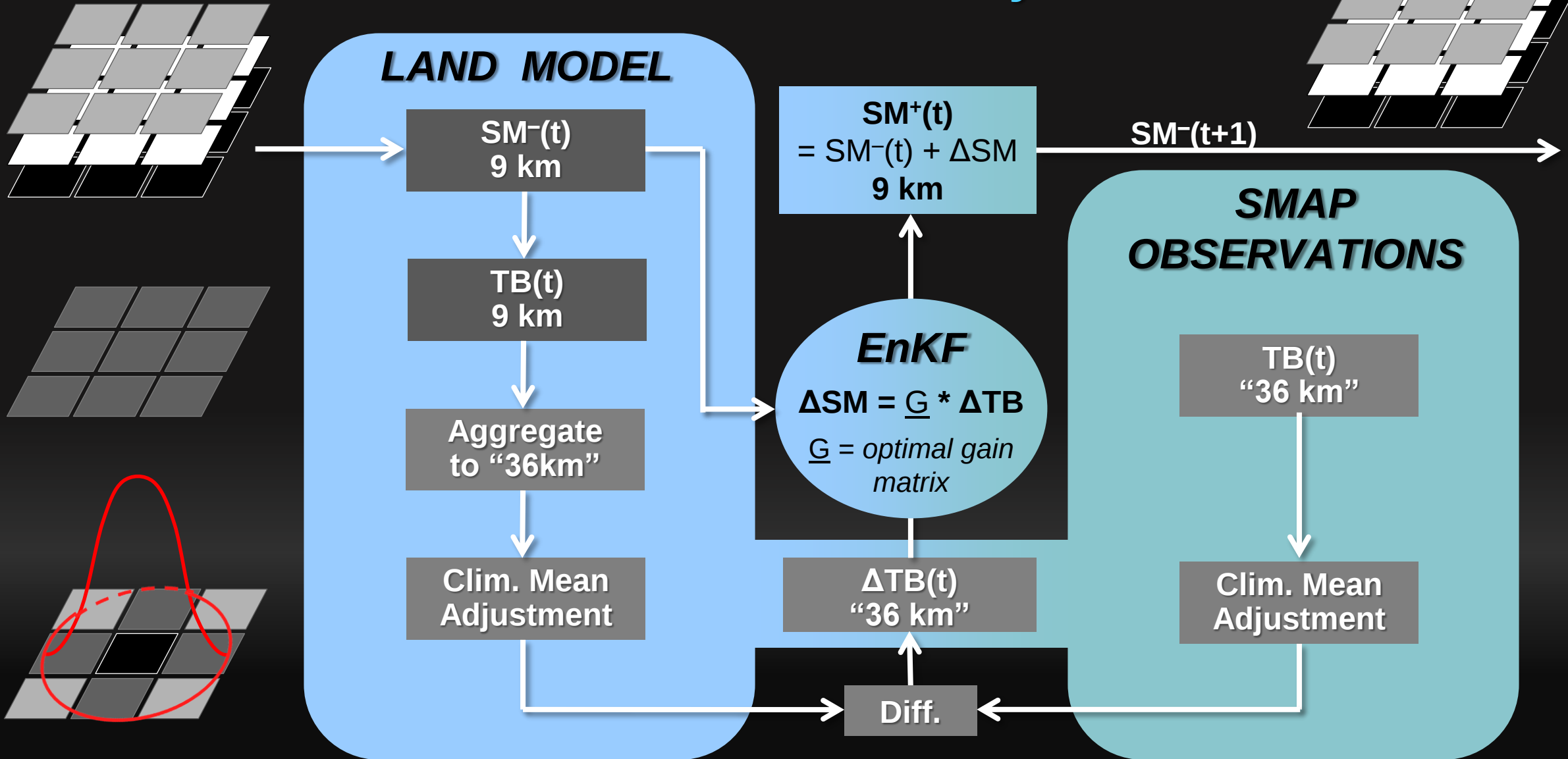


Algorithm Overview





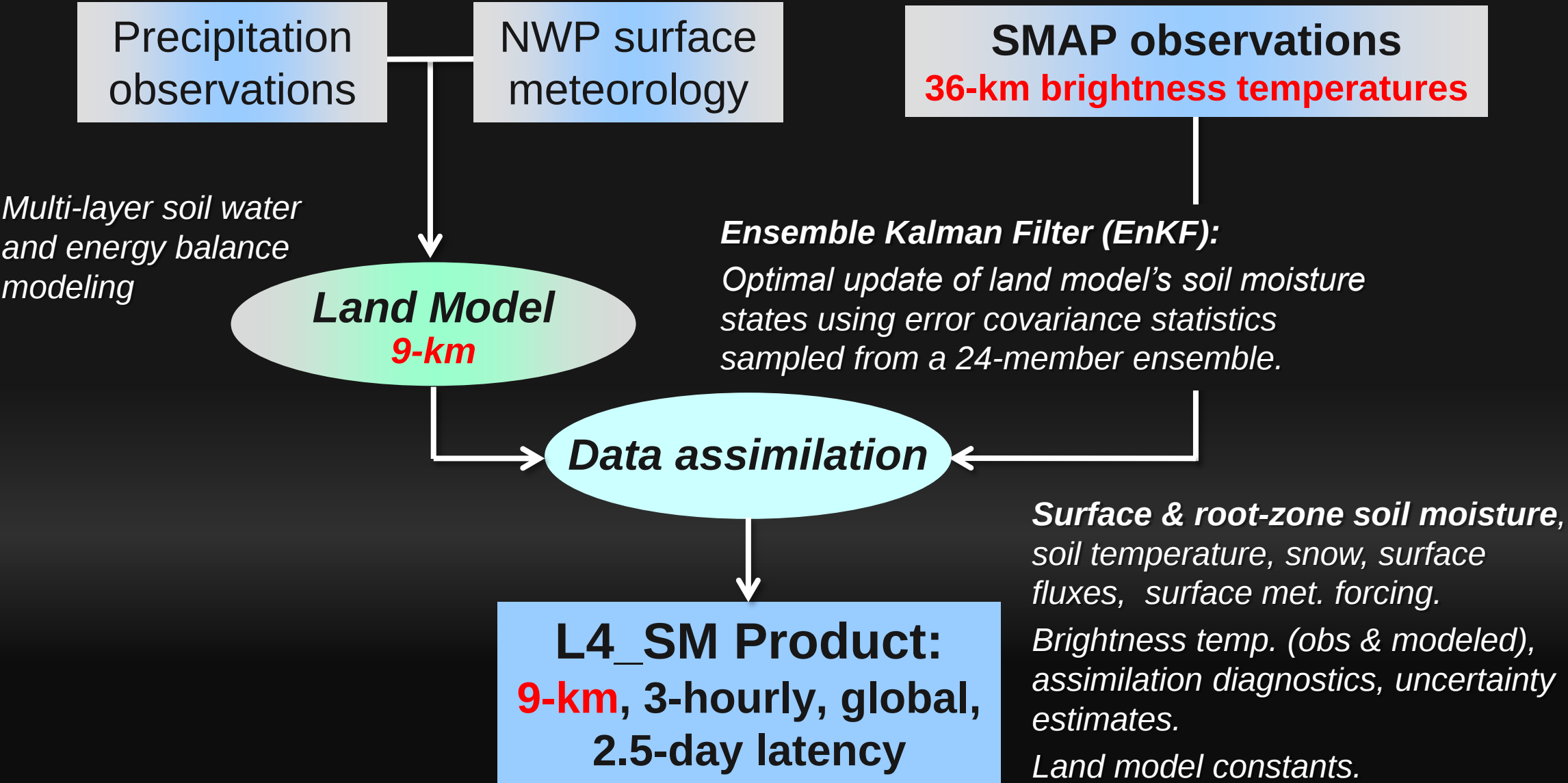
Soil Moisture Analysis



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



Algorithm Overview



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

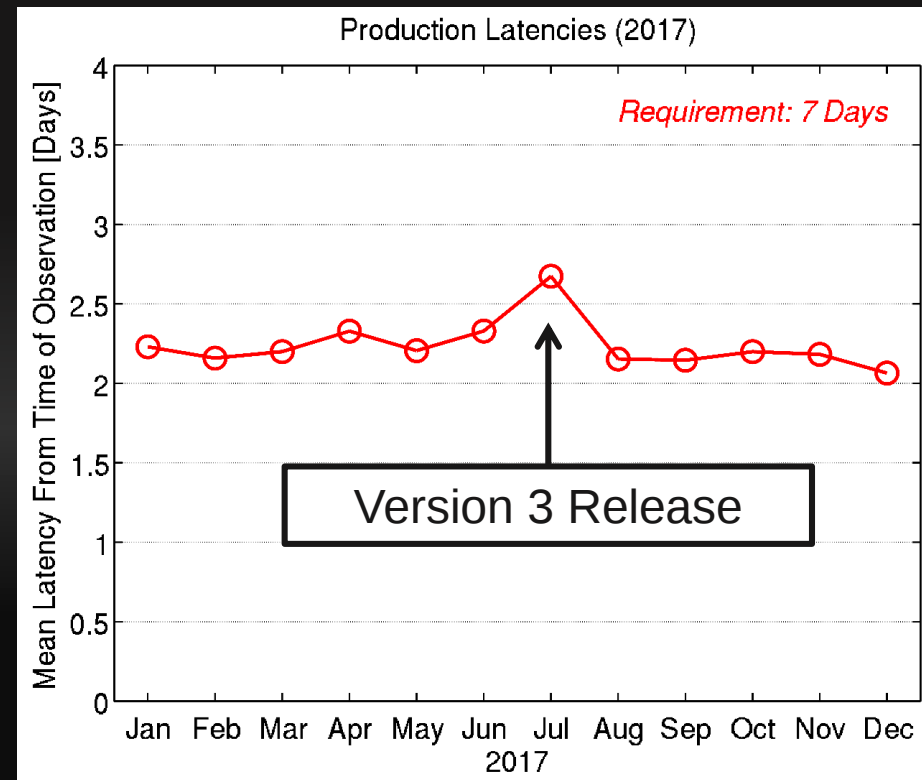
Used here (unless indicated otherwise):

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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a) Data Counts

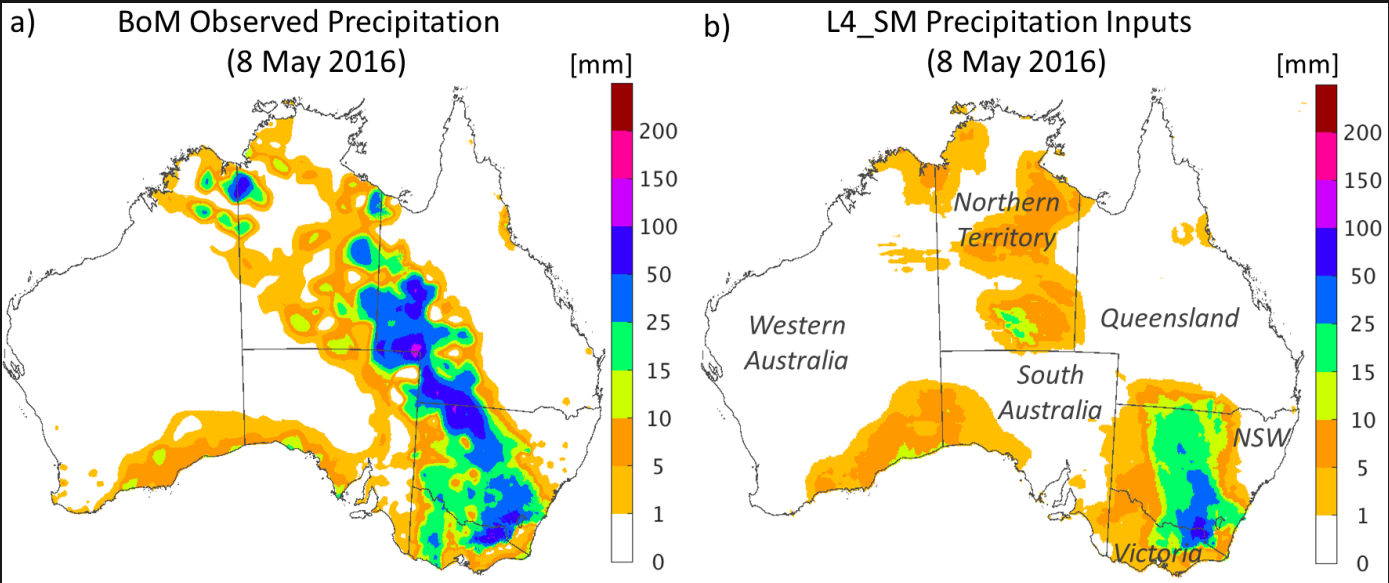
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4. Summary and Conclusions

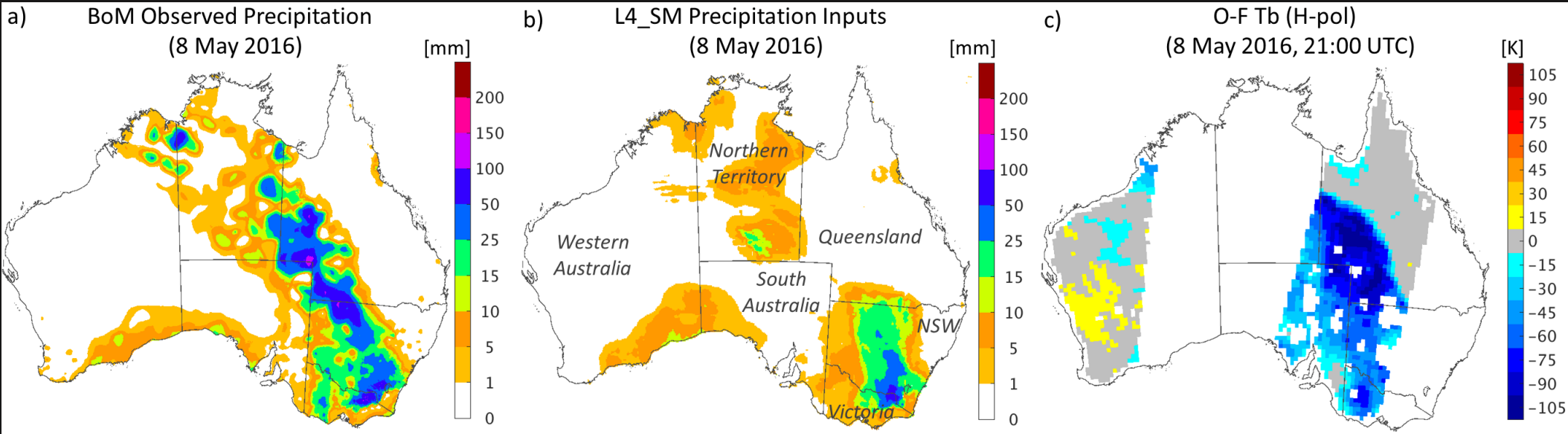


L4_SM Analysis – 2100 UTC 8 May 2016

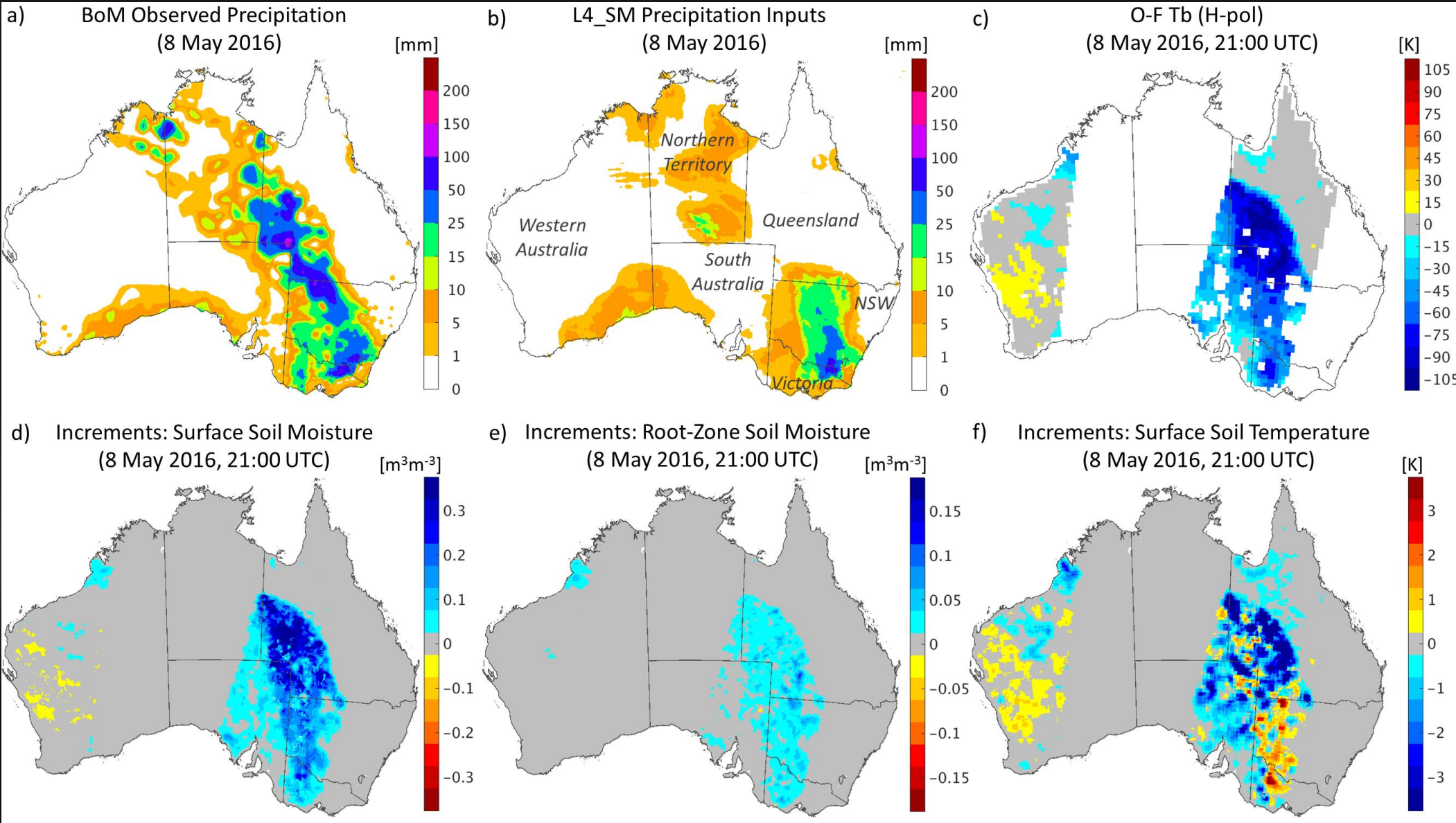




L4_SM Analysis – 2100 UTC 8 May 2016

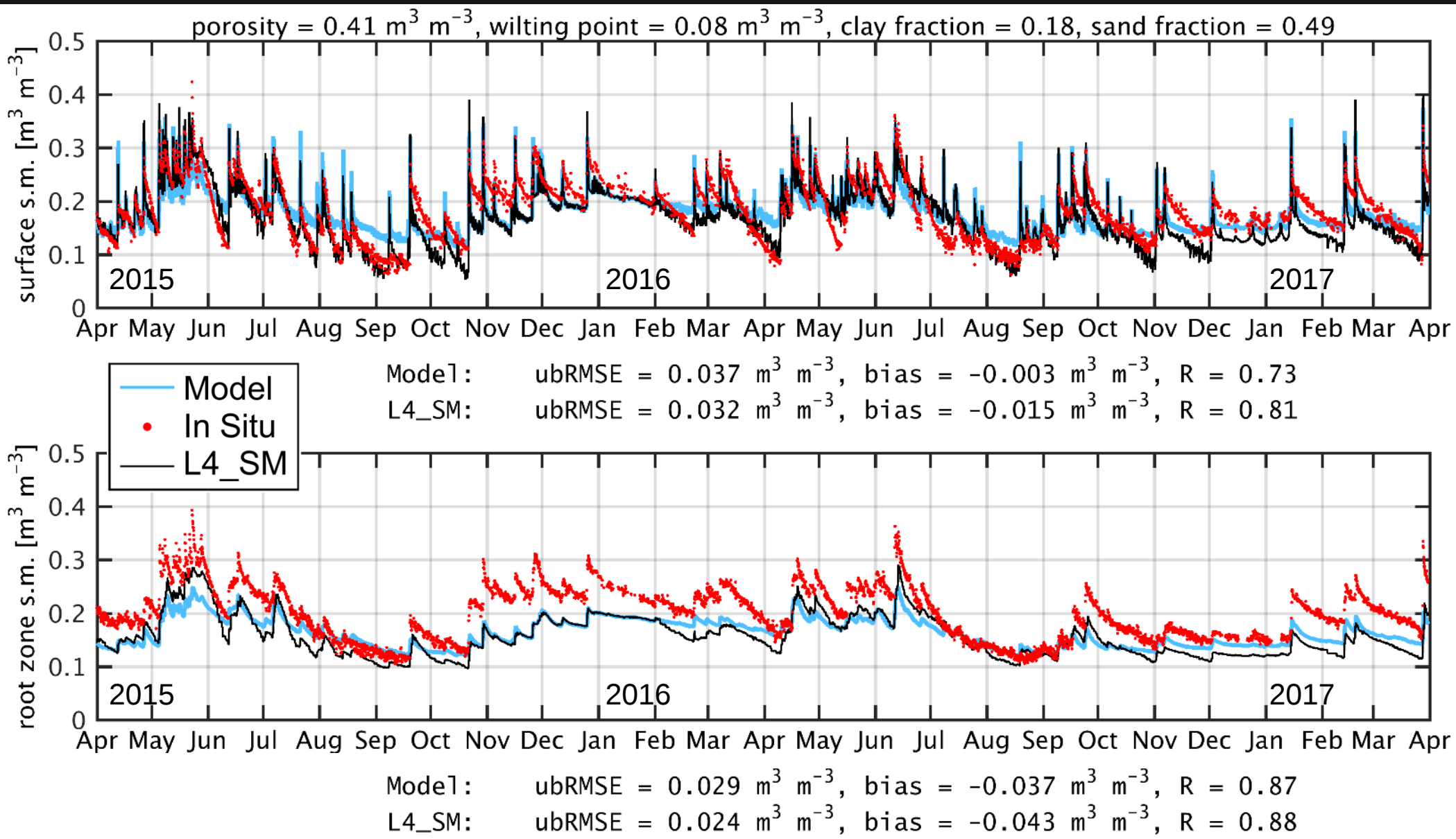


L4_SM Analysis – 2100 UTC 8 May 2016



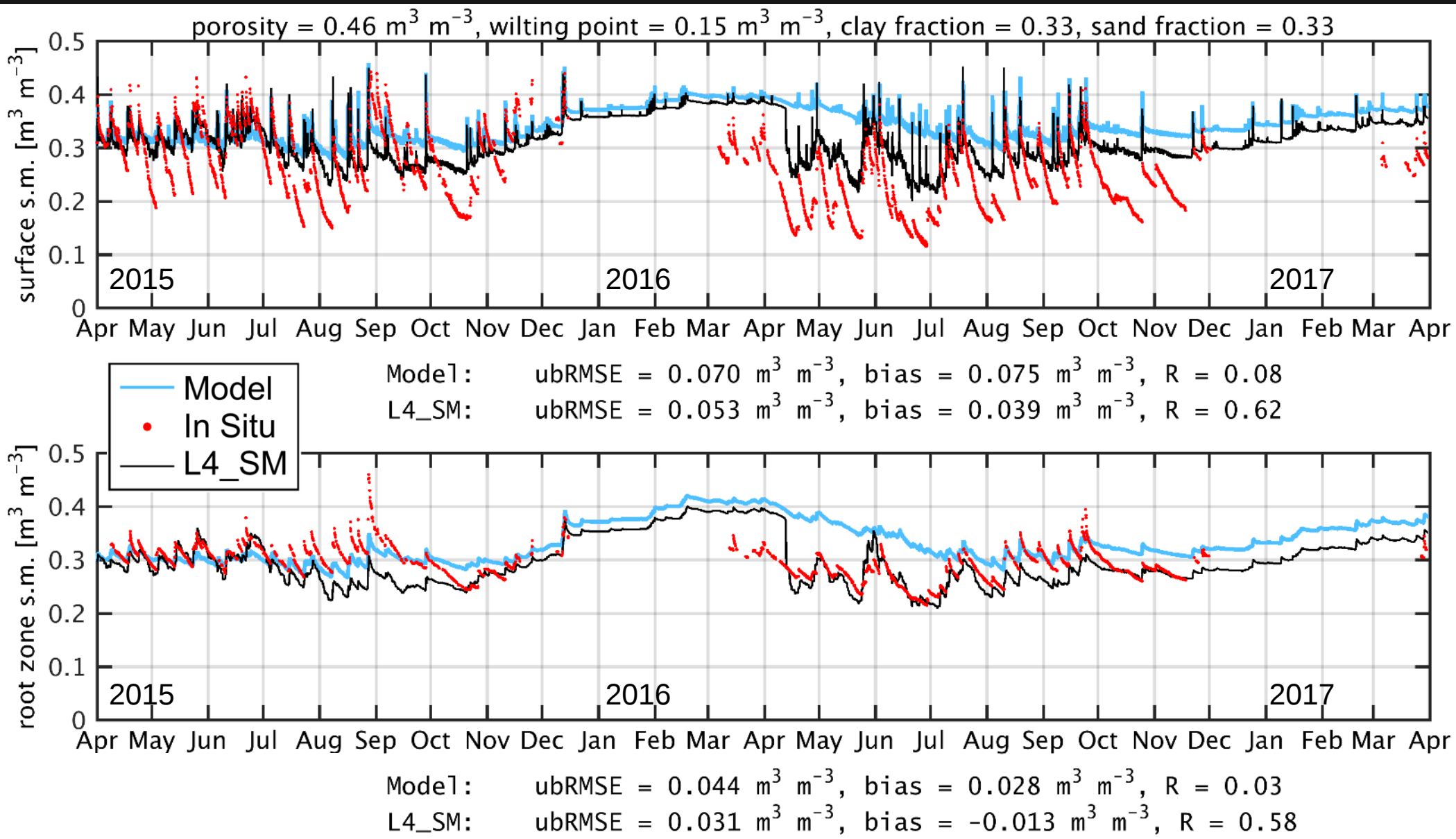


Soil Moisture at Little Washita (Oklahoma)

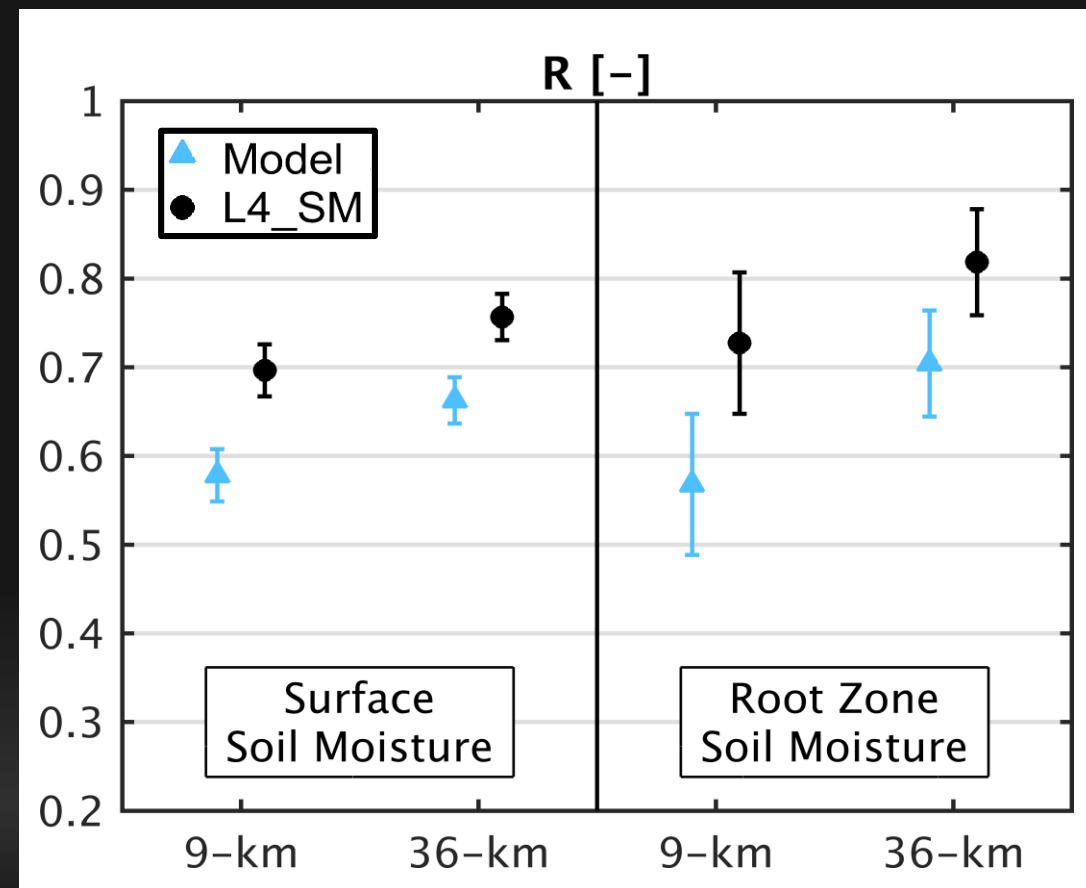
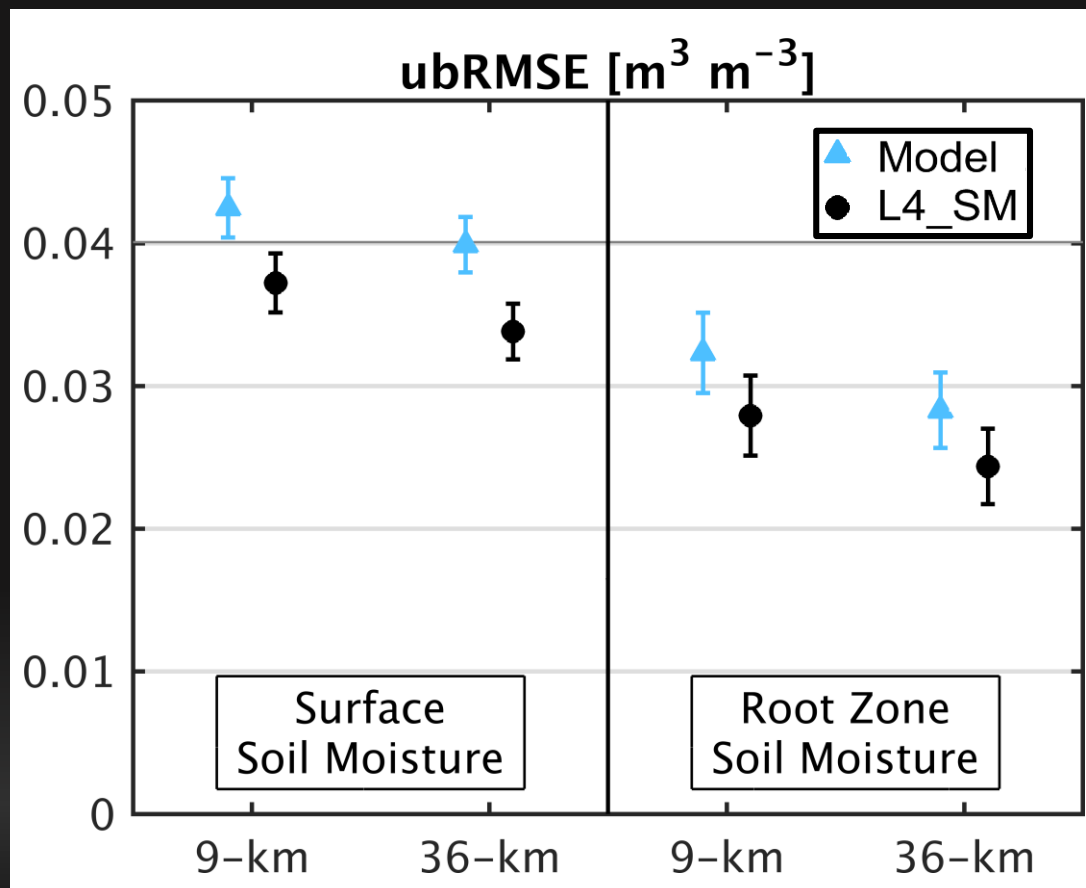




Soil Moisture at South Fork (Iowa)



Validation vs. Core Site In Situ Measurements

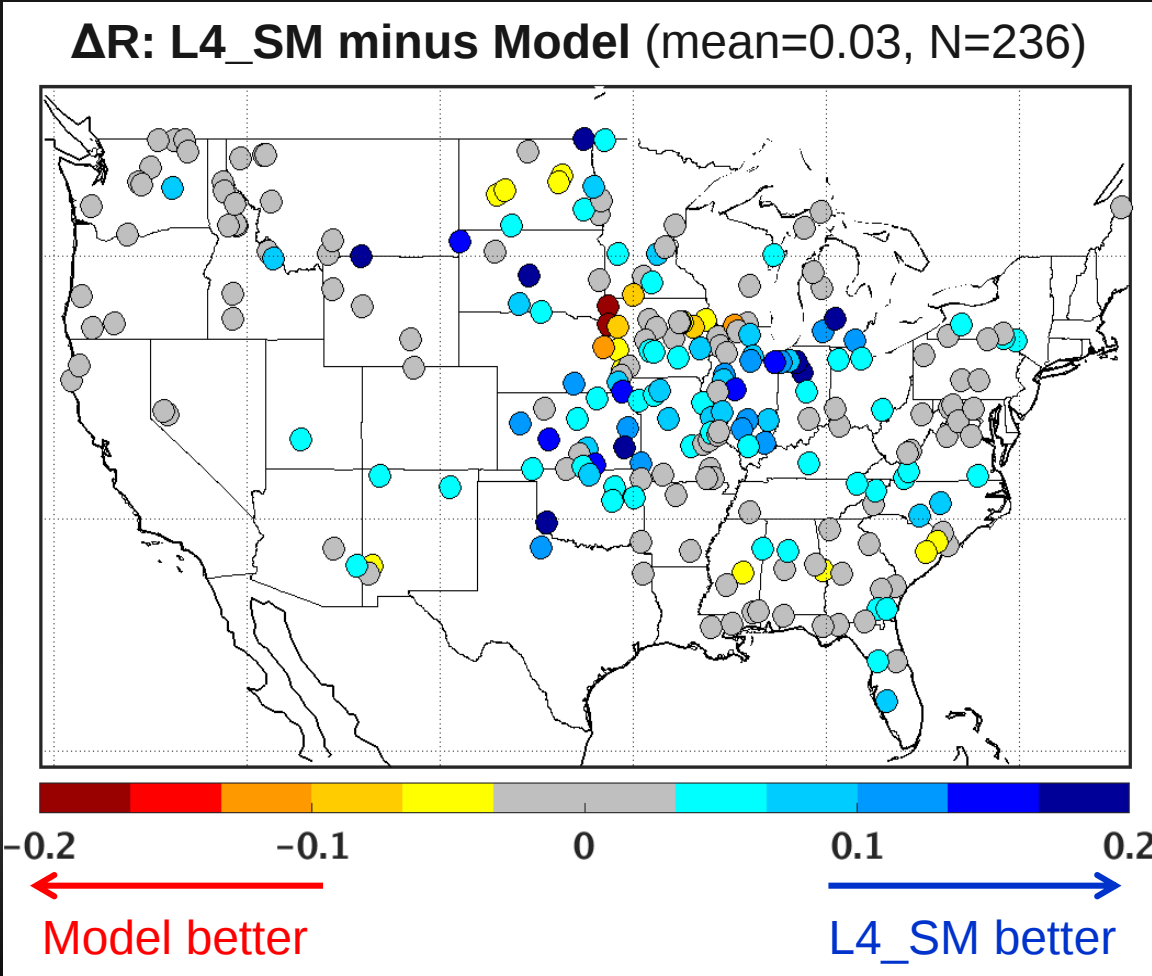
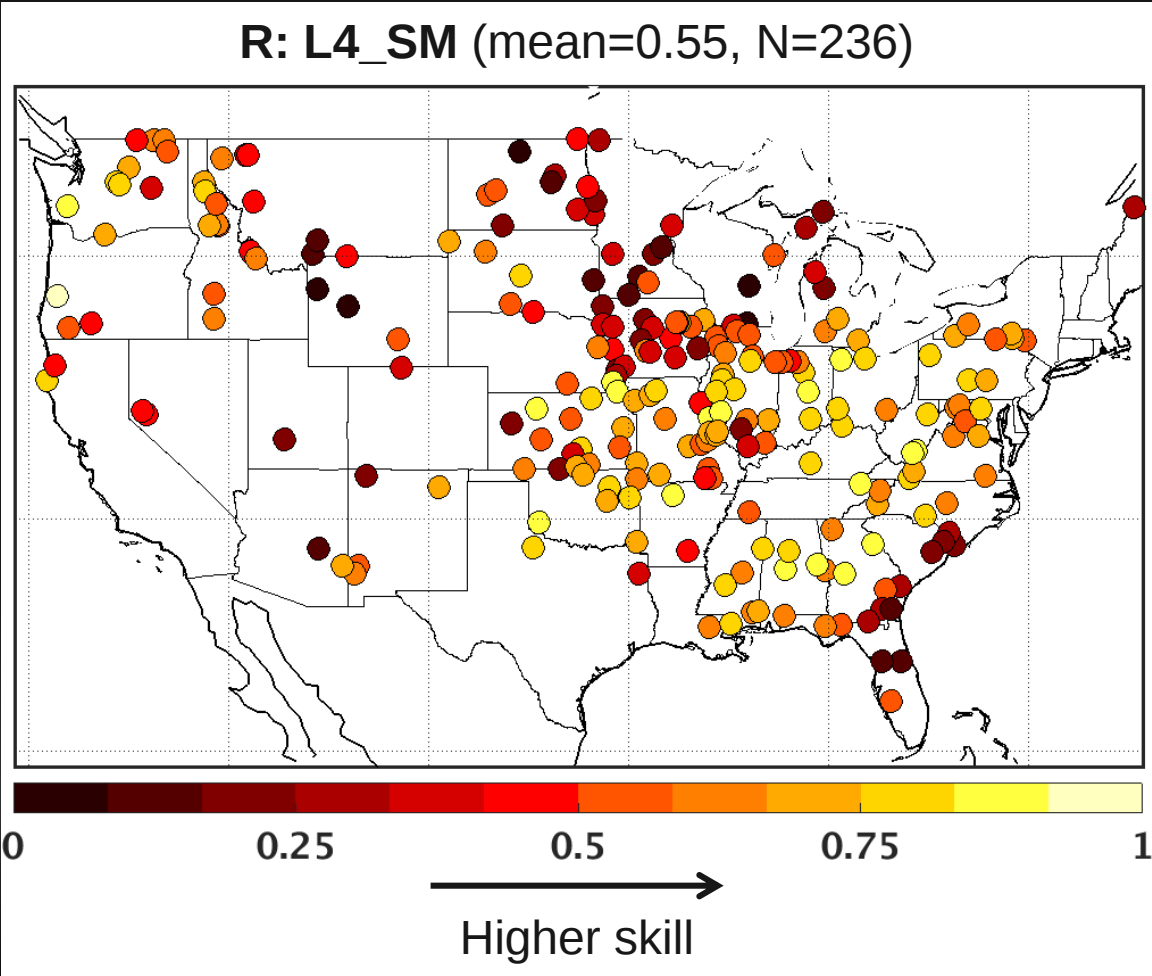


- L4_SM shows small but consistent improvements over model-only data.
- L4_SM meets ubRMSE accuracy requirement of $0.04 \text{ m}^3 \text{m}^{-3}$.

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



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.

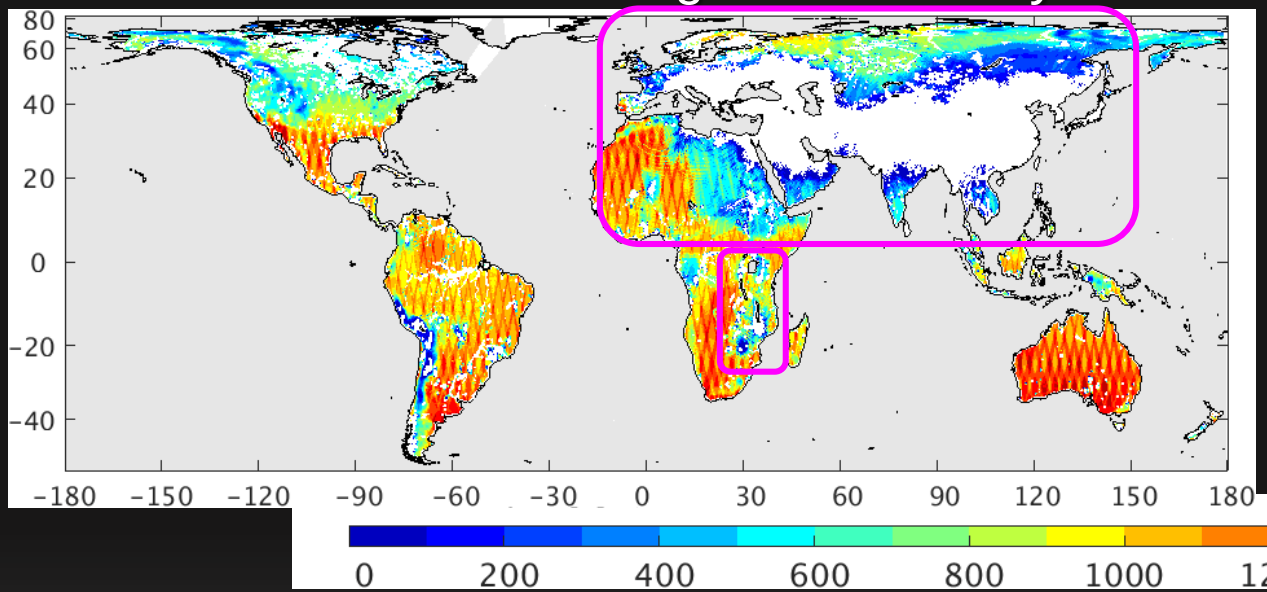
→ More SMAP observations assimilated.

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

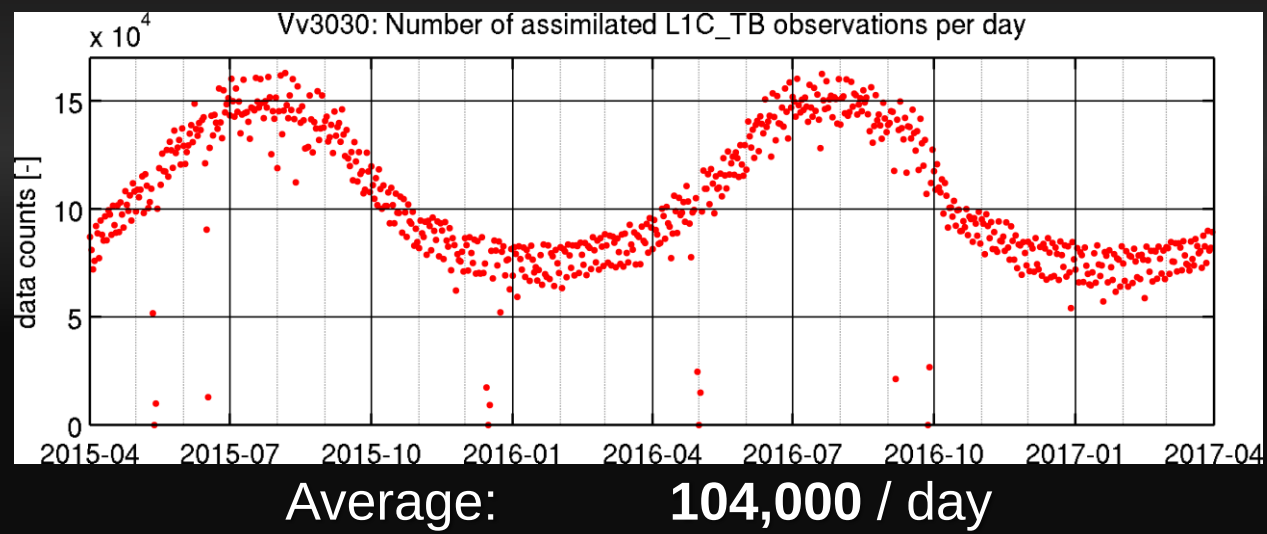
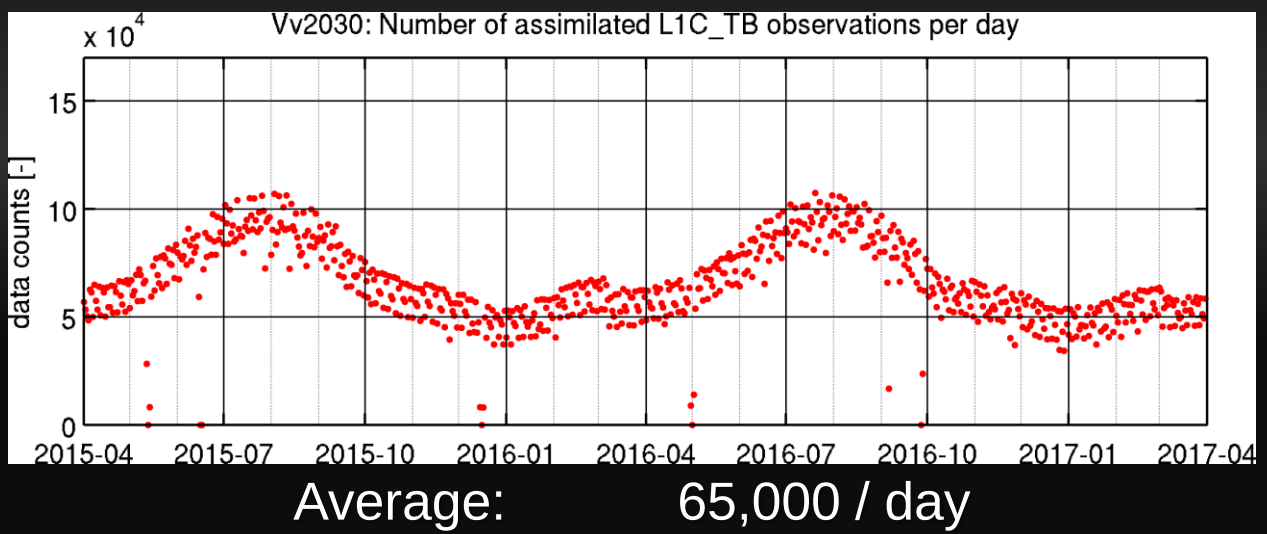
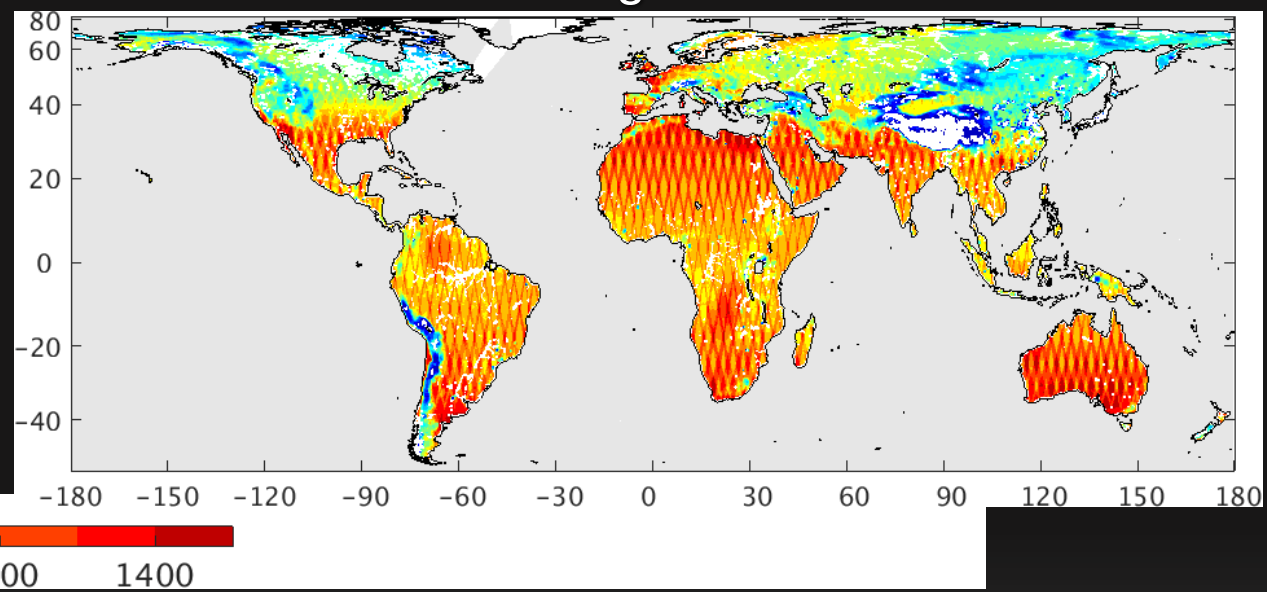
Objective was to avoid recalibration of L4_C algorithm.

Number of Assimilated SMAP L1C_TB Observations

Version 2 – rescaling w/ SMOS only



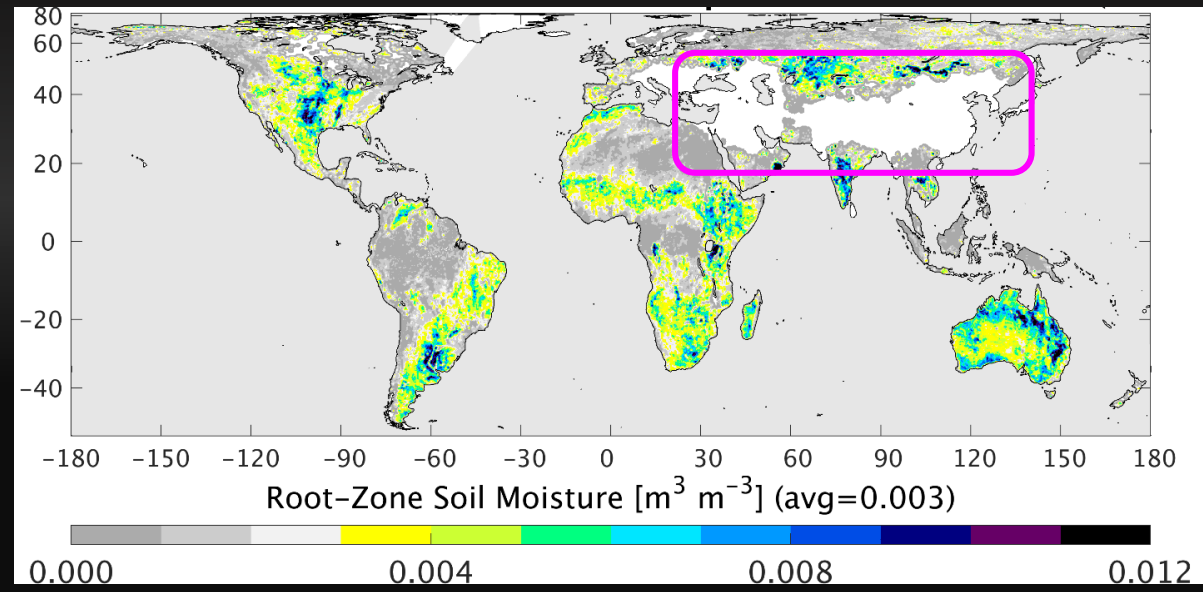
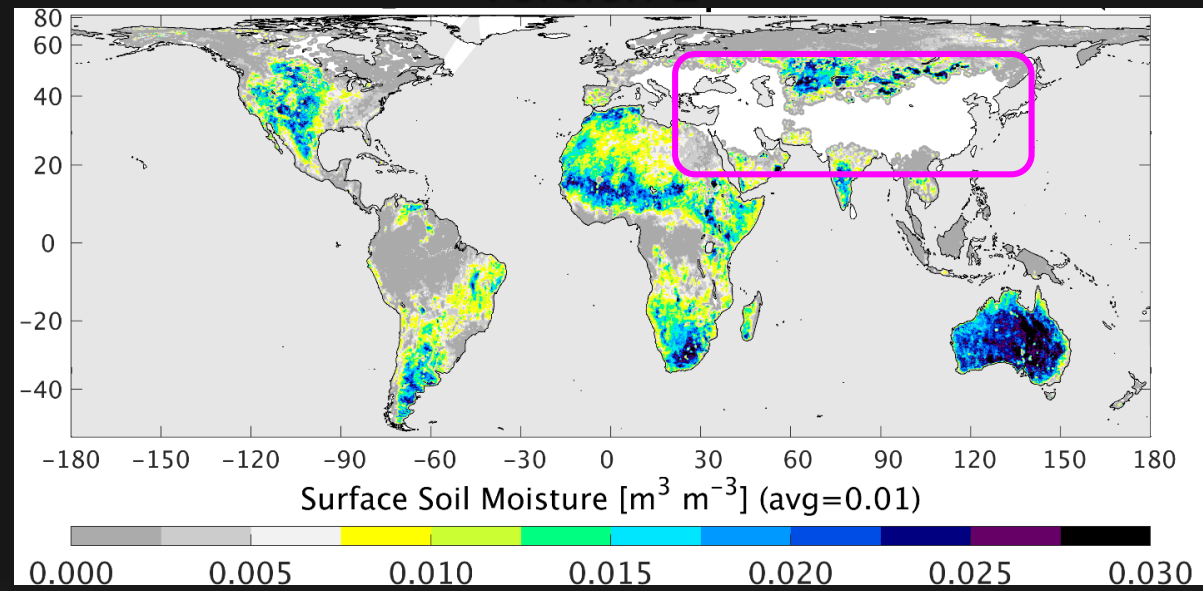
Version 3 – rescaling with SMOS & SMAP



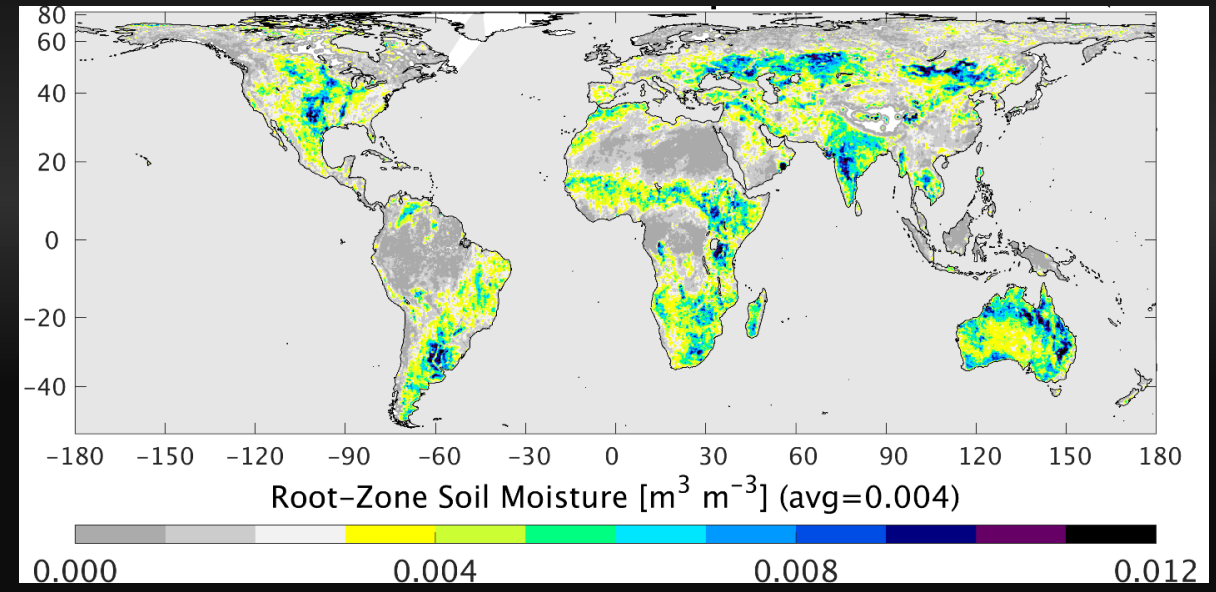
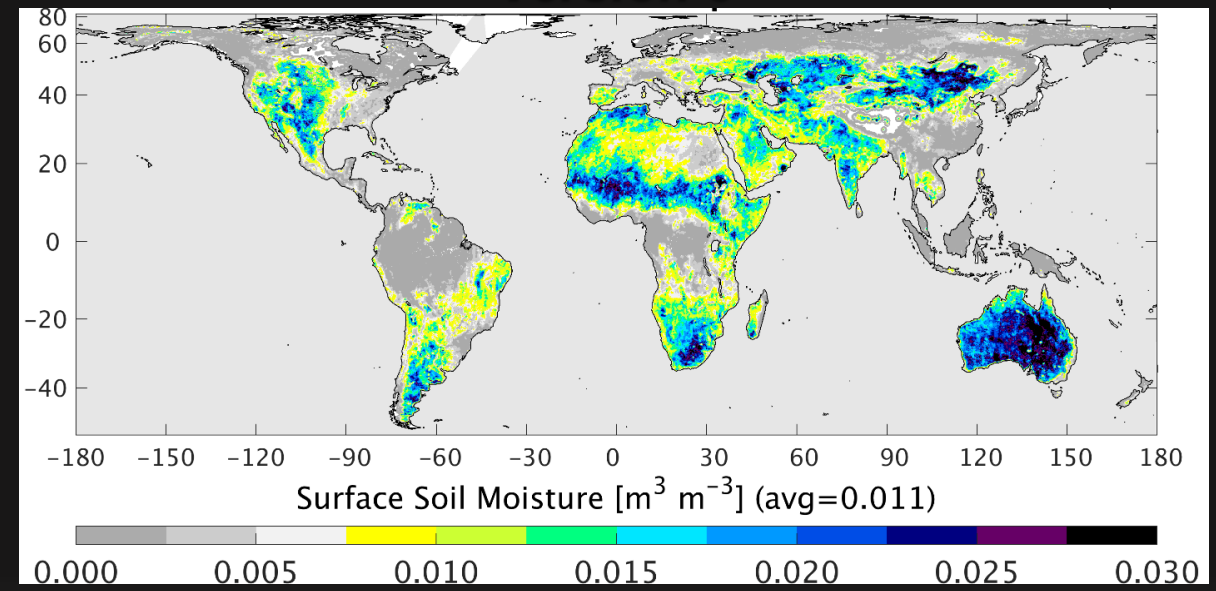


Std-dev Increments

Version 2



Version 3

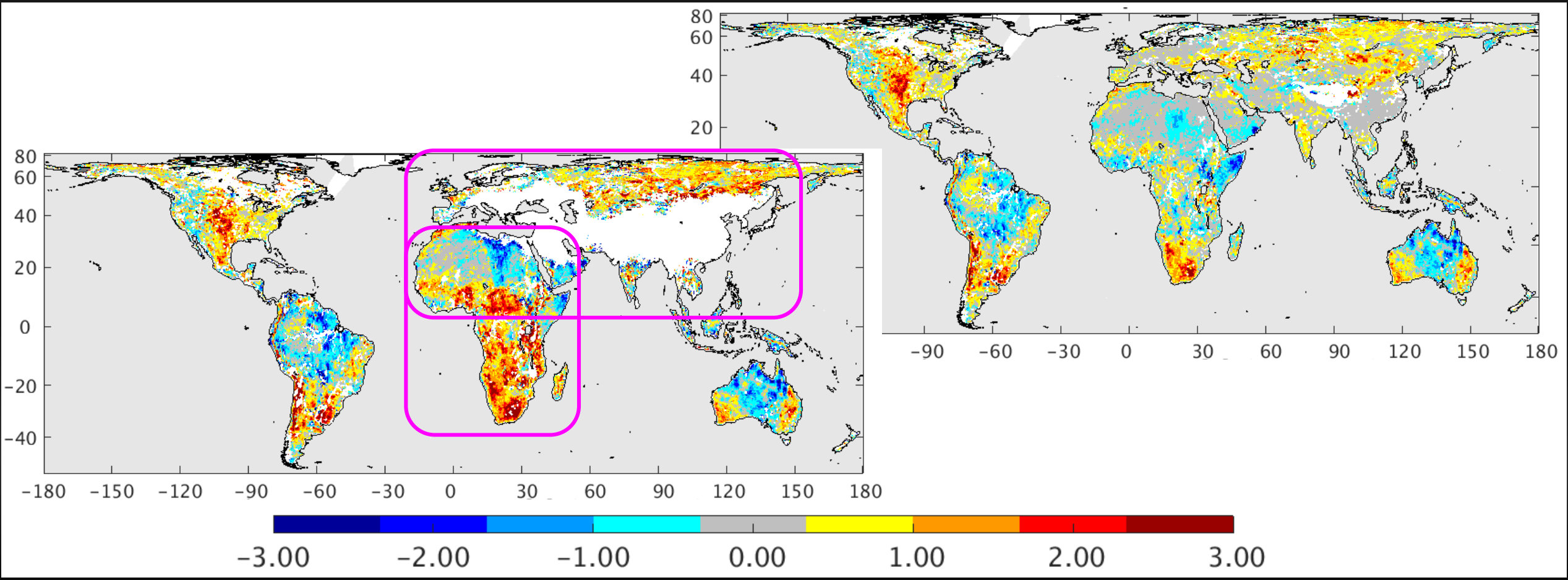




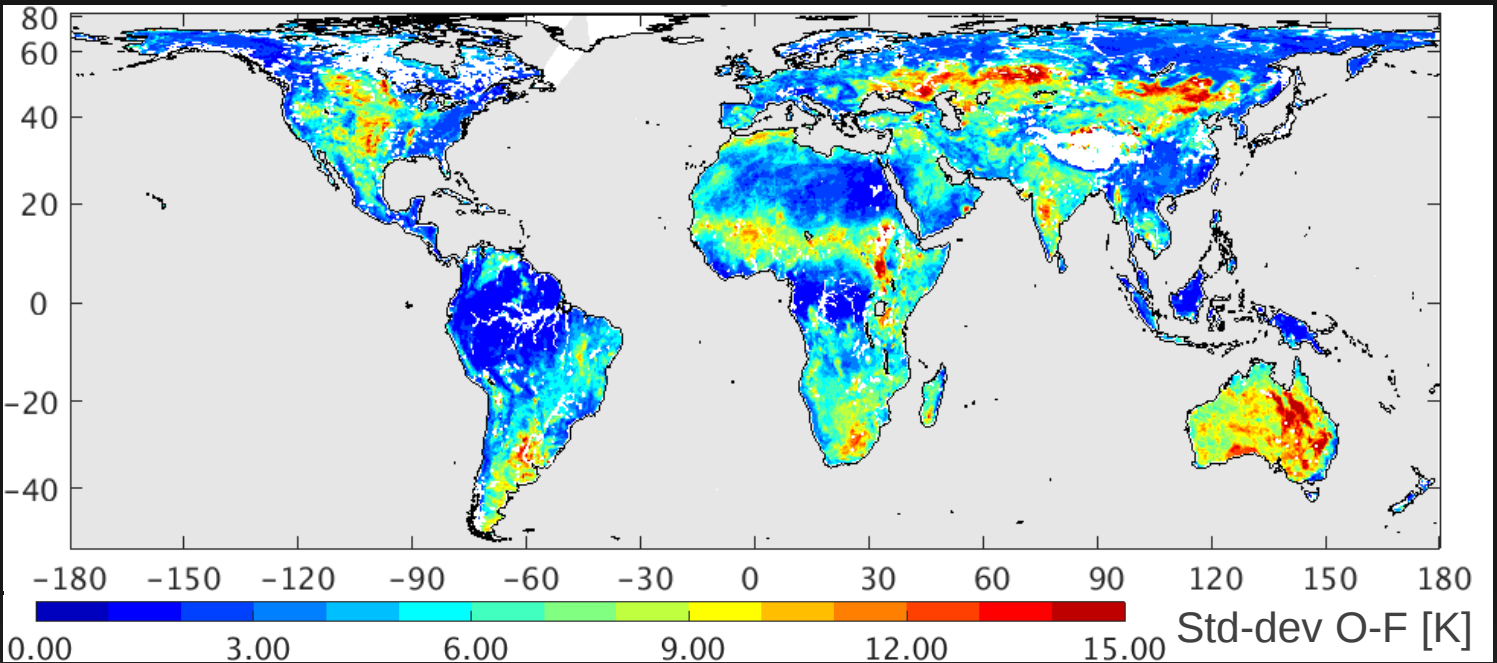
Mean O-F

Version 2

Version 3



Std-dev O-F

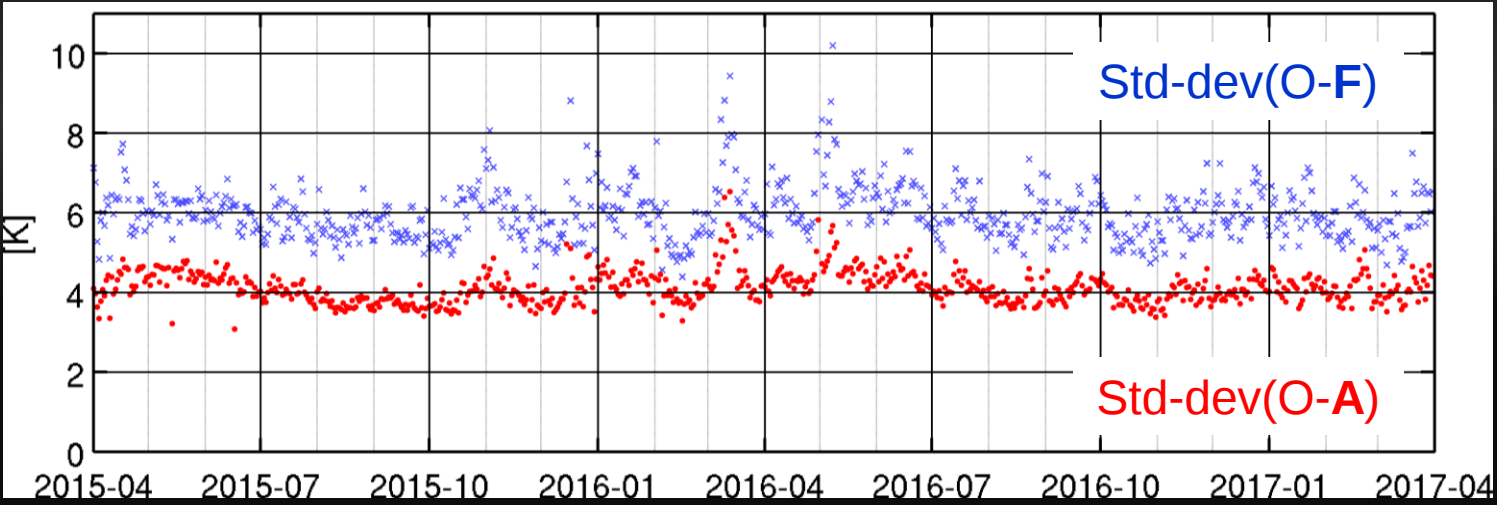


Average:
O-F: 6 K
O-A: 4 K

cf. Tb obs error
= 4 K

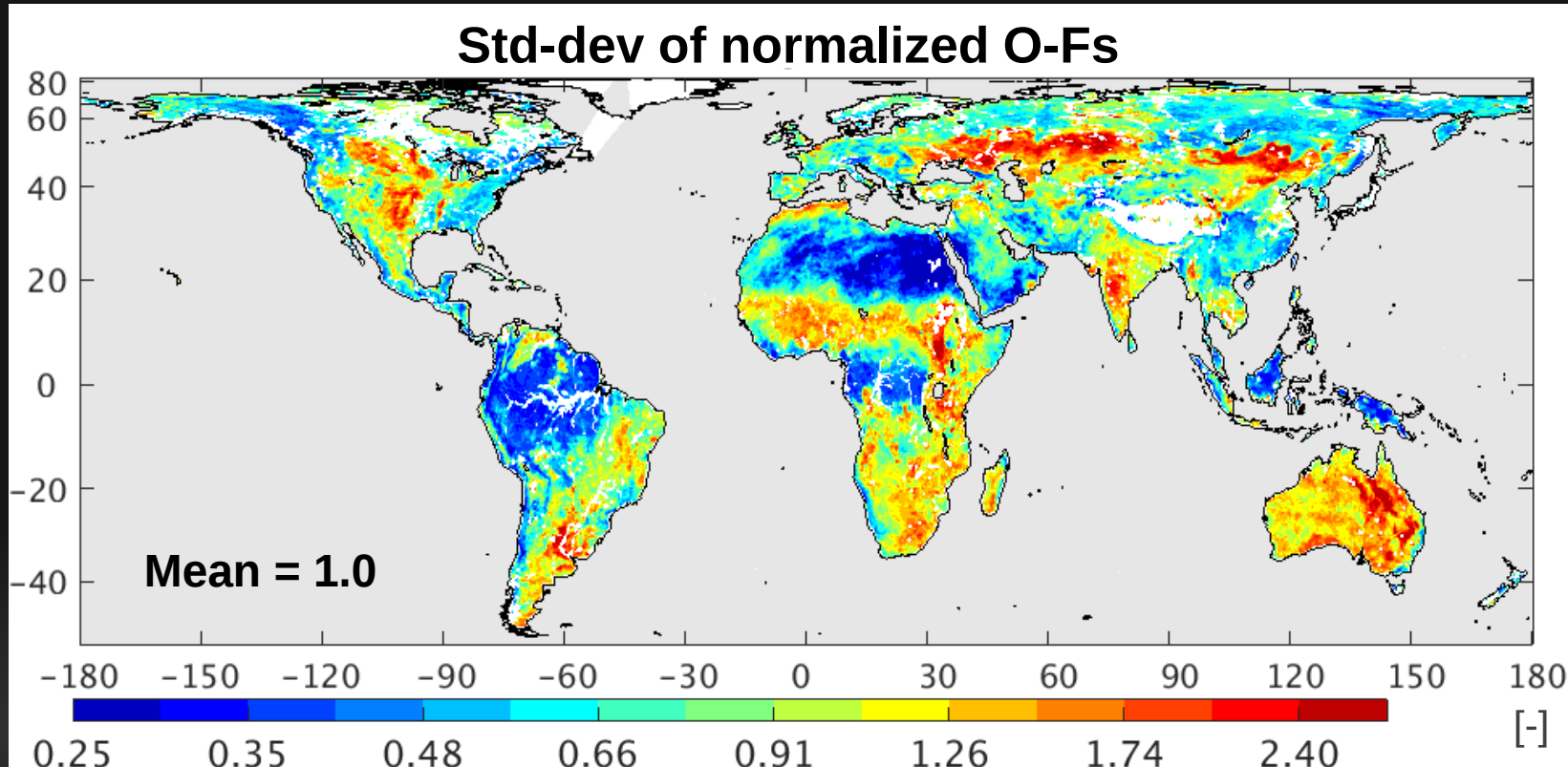
includes

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.

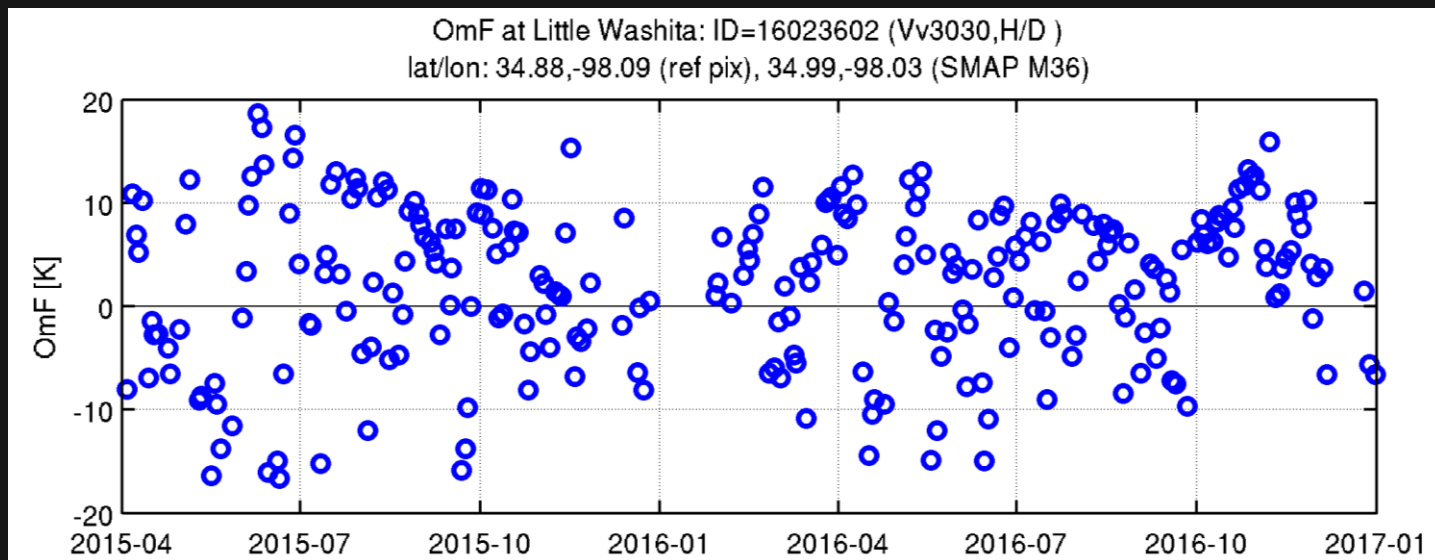


over-estimation

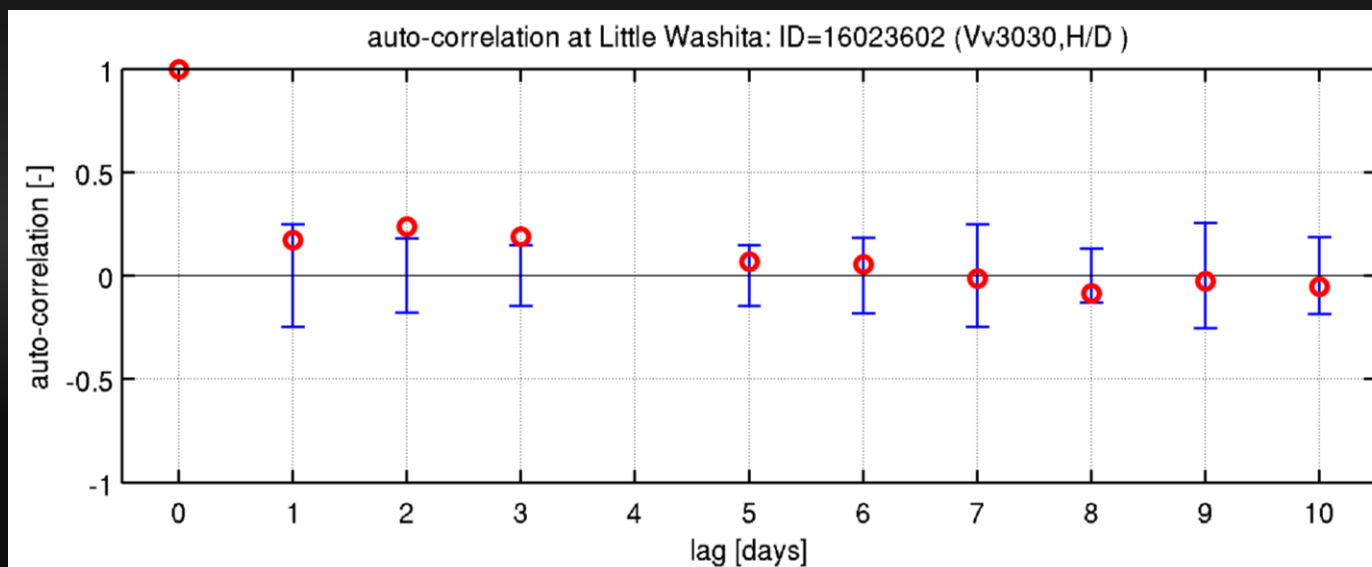
under-estimation

of actual O-F errors

How Efficiently do we Use the Observations?

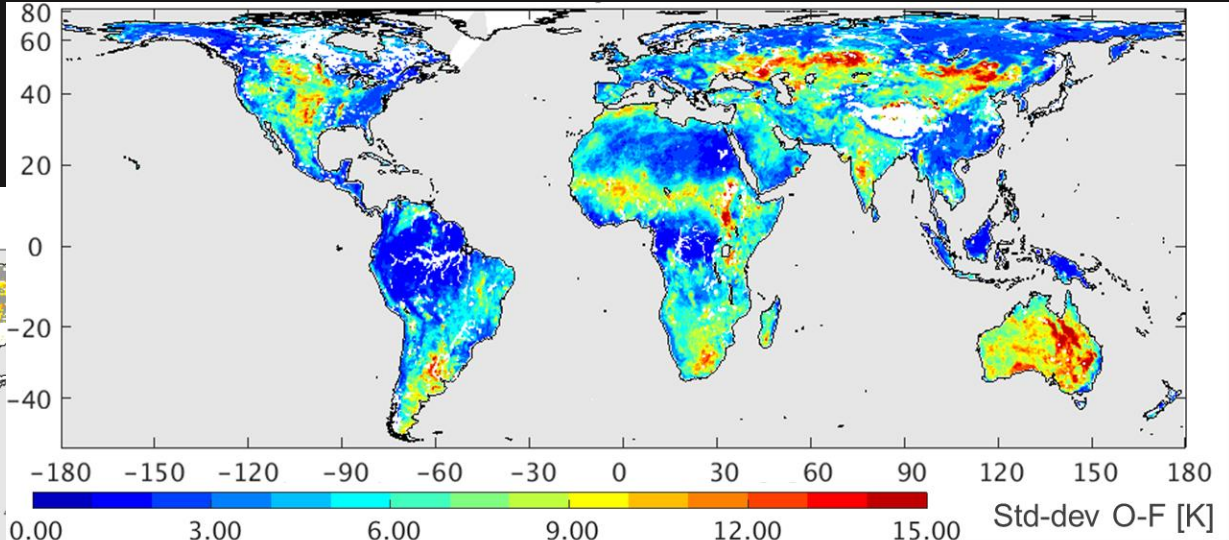
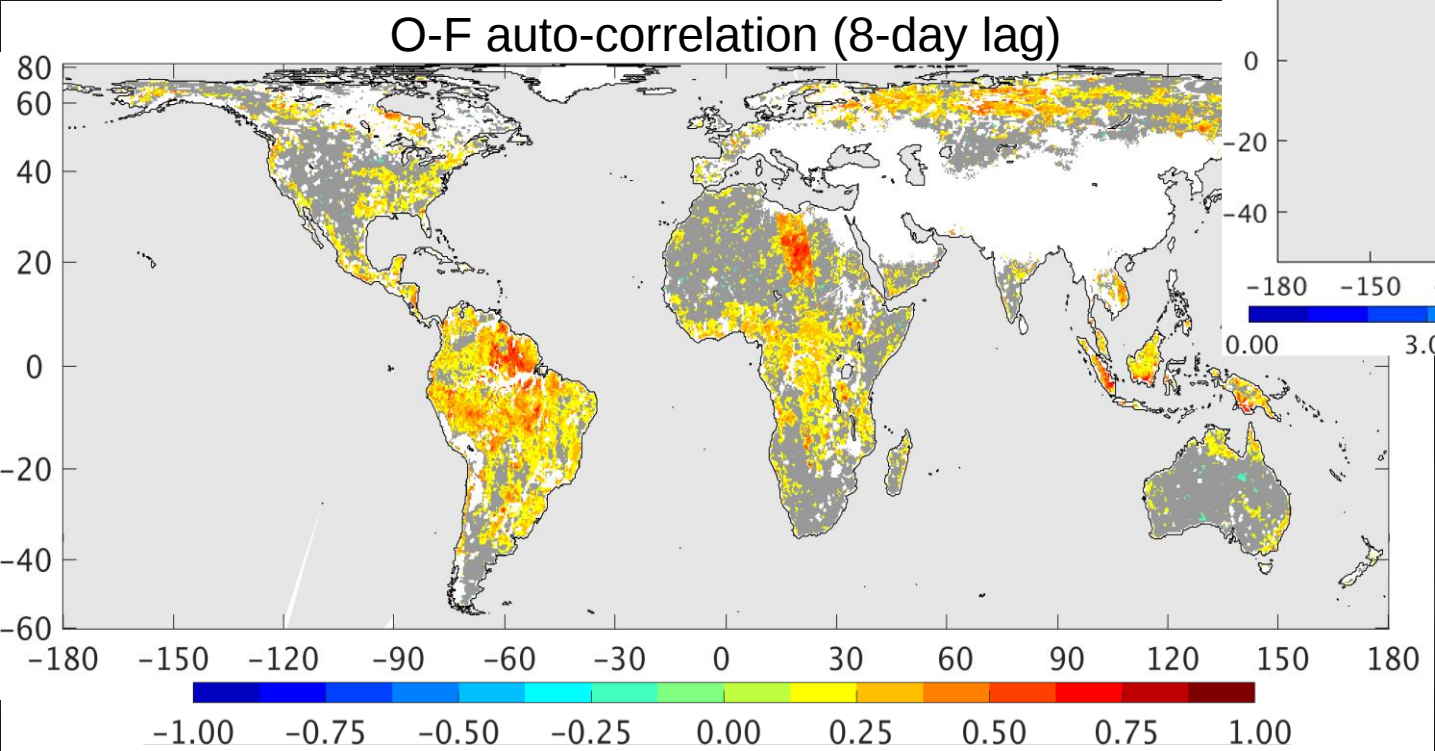


O-F time series at Little Washita, Oklahoma.



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
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) m³ 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!