

# 4<sup>th</sup> Satellite Soil Moisture Validation and Application Workshop

19-20 Sep 2017, Vienna, Austria

## *Version 3 of the SMAP Level 4 Soil Moisture Product*

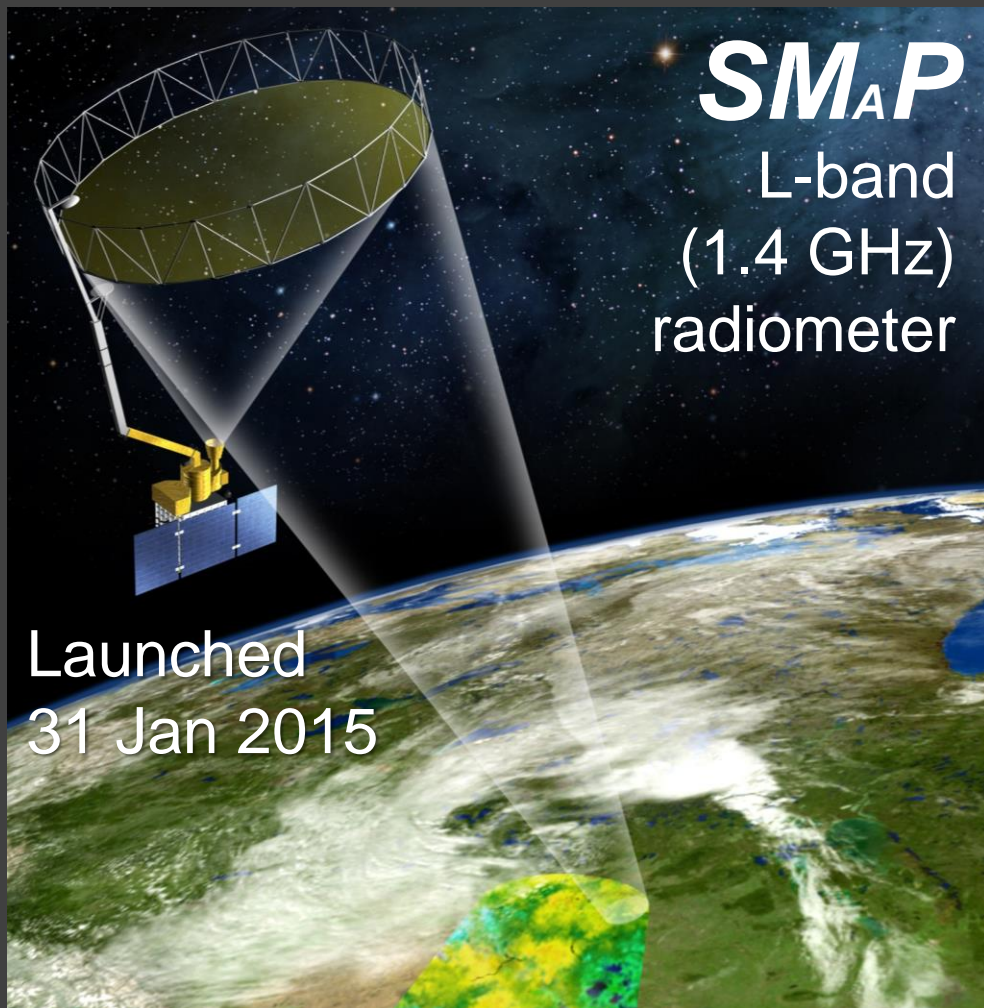
**Rolf Reichle\***

Qing Liu, Joe Ardizzone, Wade Crow, Gabrielle De Lannoy,  
Jana Kolassa, John Kimball, and Randy Koster

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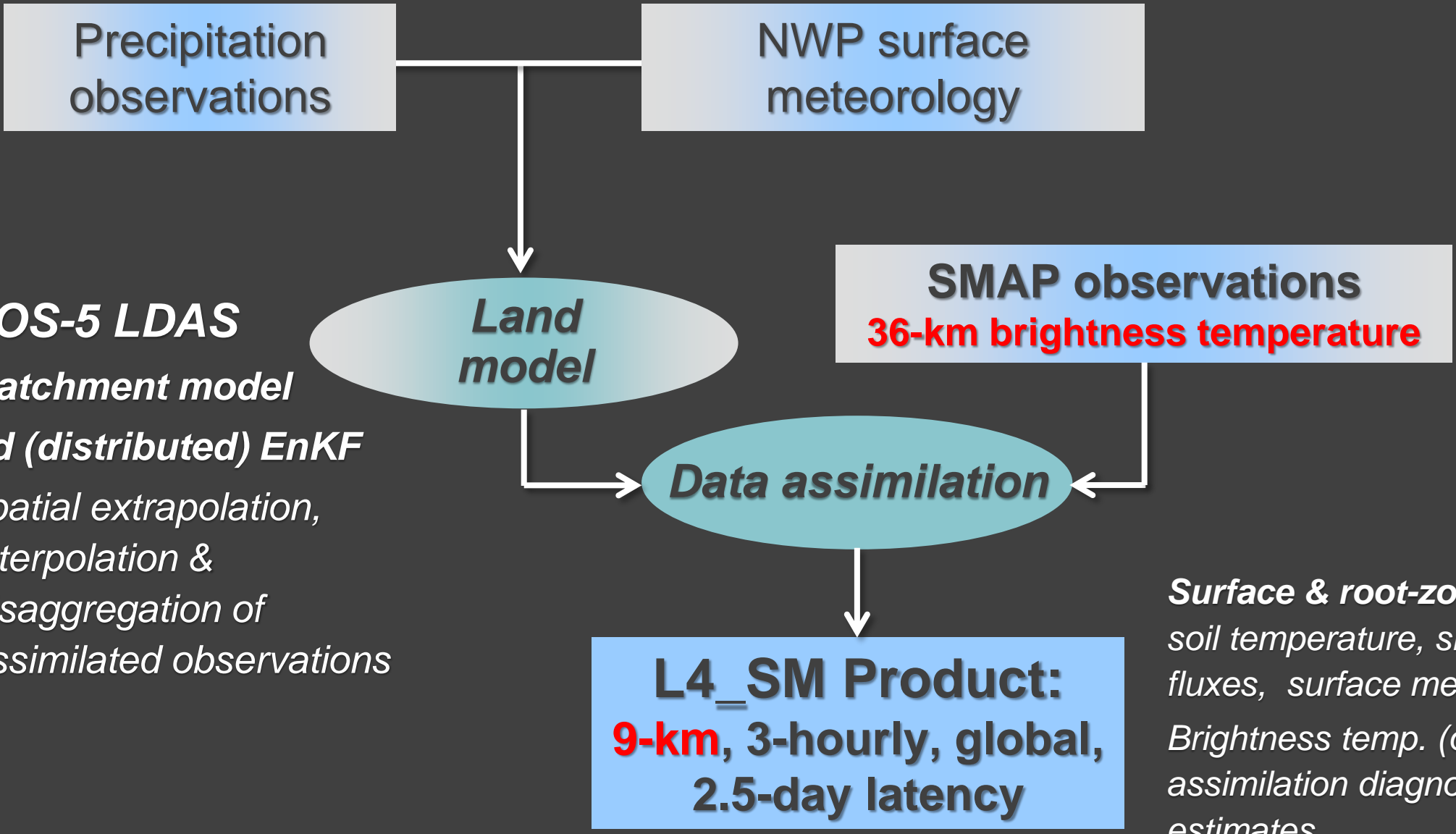
**SMAP**  
L-band  
(1.4 GHz)  
radiometer

Launched  
31 Jan 2015

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

*Key Objectives of the*  
*Level 4 Surface & Root-Zone Soil Moisture*  
*(L4\_SM) product:*

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



**GEOS-5 LDAS**  
– Catchment model  
– 3d (distributed) EnKF  
spatial extrapolation,  
interpolation &  
disaggregation of  
assimilated observations

*Surface & root-zone soil moisture,  
soil temperature, snow, surface  
fluxes, surface met. forcing.  
Brightness temp. (obs & modeled),  
assimilation diagnostics, uncertainty  
estimates.  
Land model constants.*

*Data available publicly from NSIDC for 3/31/2015-present.*

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

### **New in Version 3:**

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

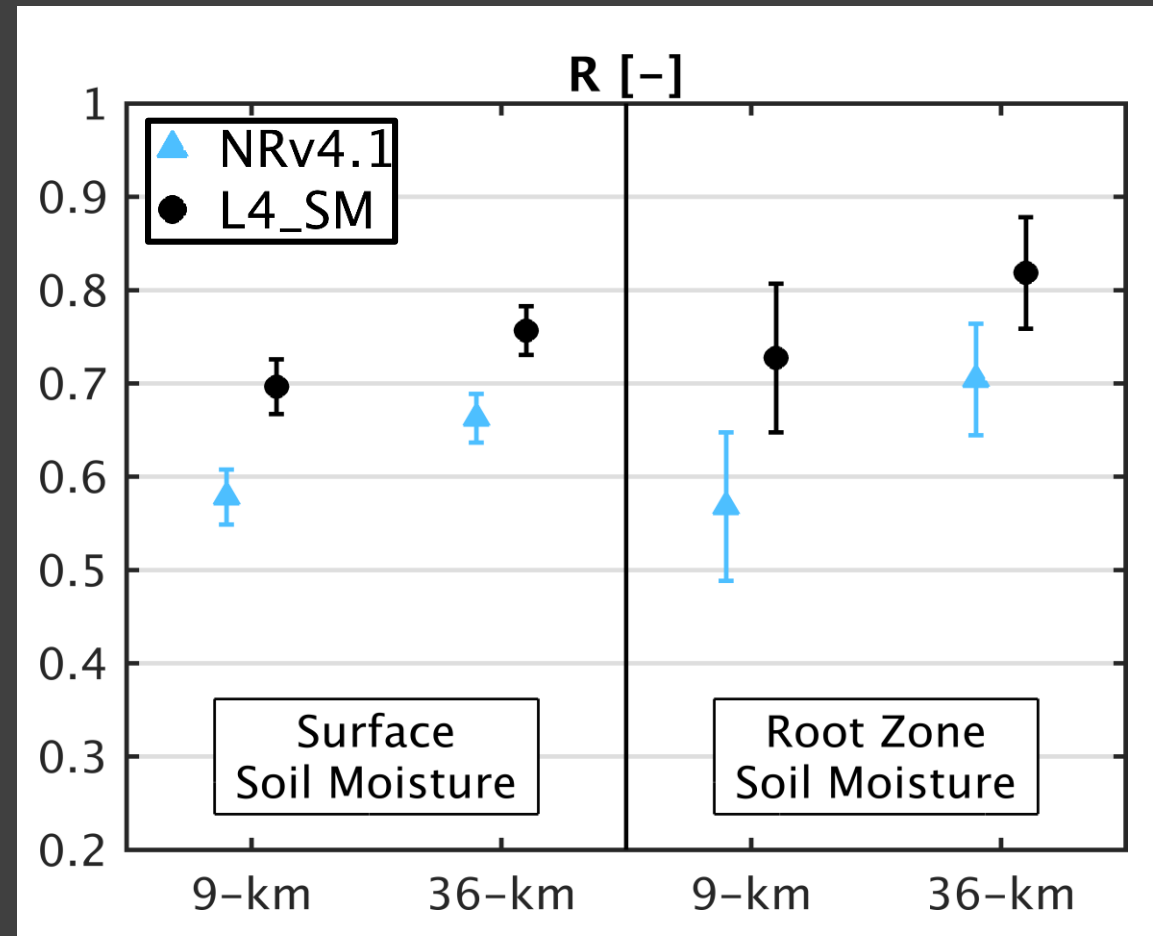
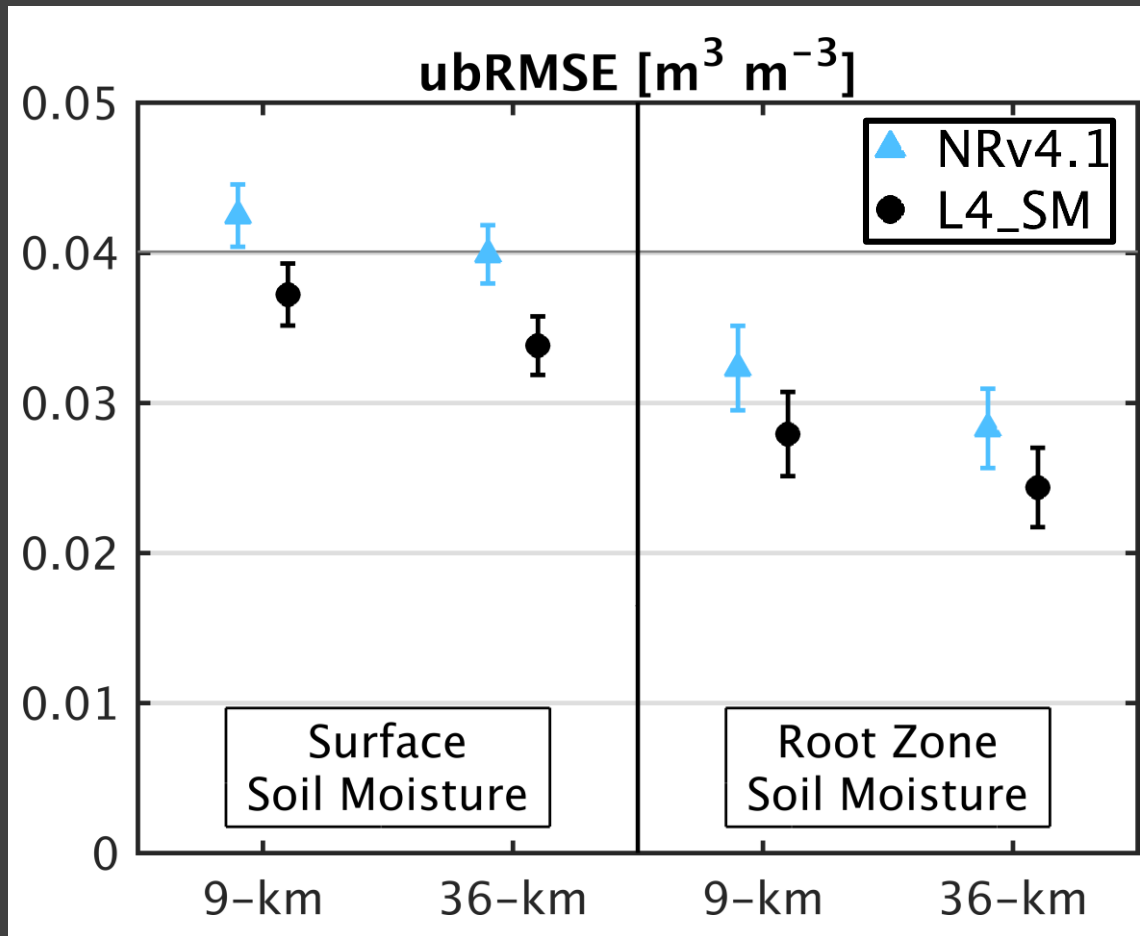
- Newer & more SMOS Tbs where available (6 years of v6, rescaled to v5)*
- SMAP Tbs elsewhere (2 years of Version 3)*
- Model Tbs from updated “Nature Run” (NRv4.1)*

*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.*

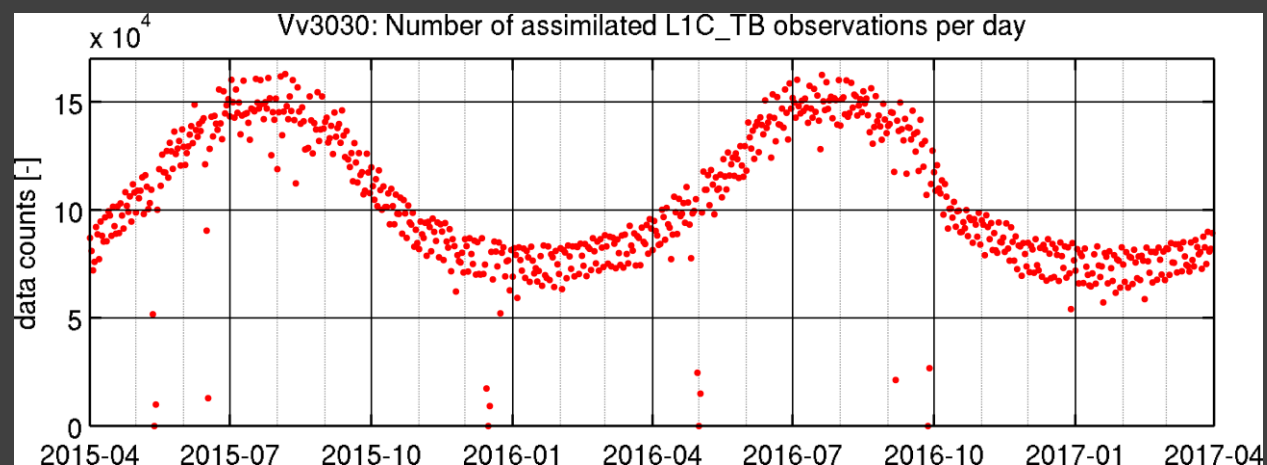
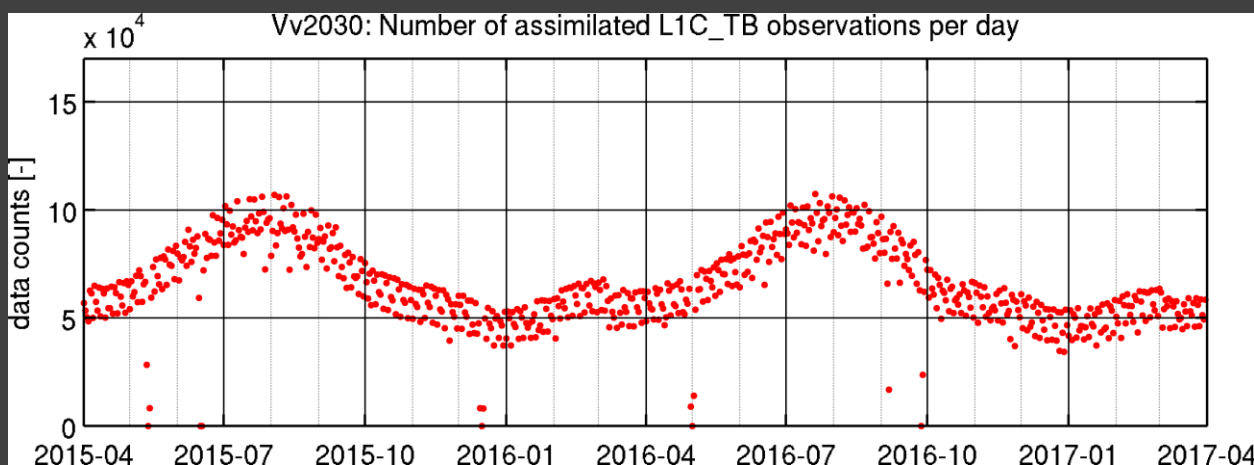
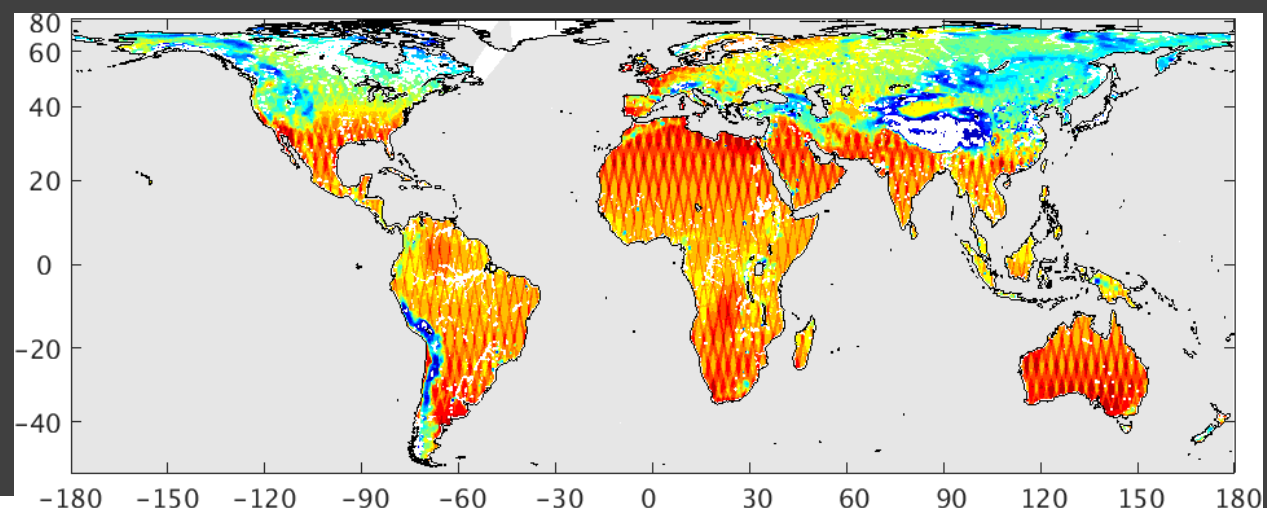
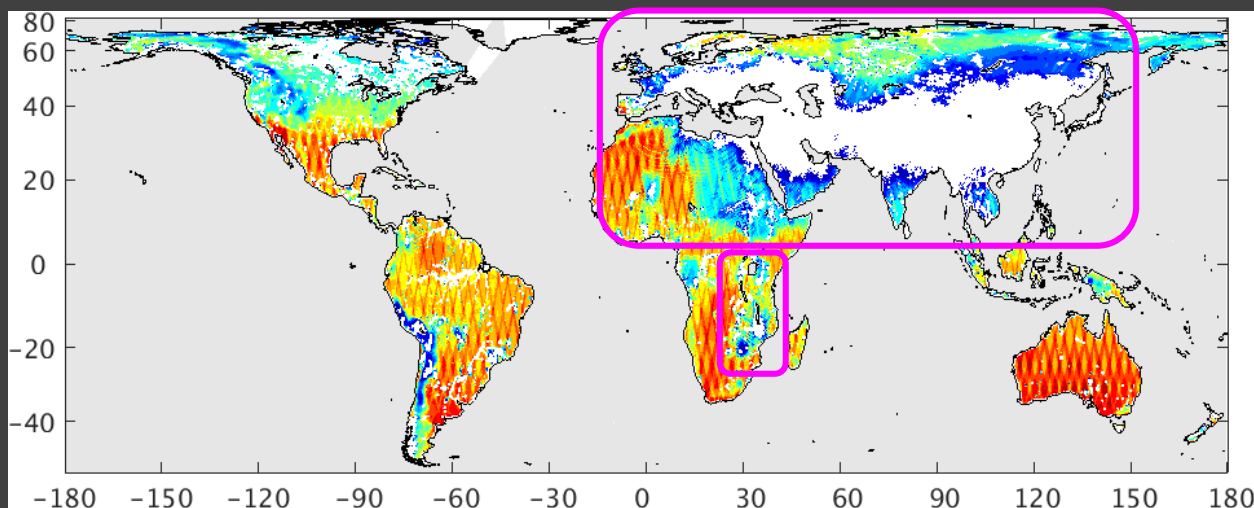


L4\_SM shows small but consistent improvements over model-only data (NRv4.1).  
 L4\_SM meets ubRMSE accuracy requirement of  $0.04 m^3 m^{-3}$ .  
 Results nearly identical for Version 2 (Reichle et al. 2017; doi:10.1175/JHM-D-17-0063.1).

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

Version 2

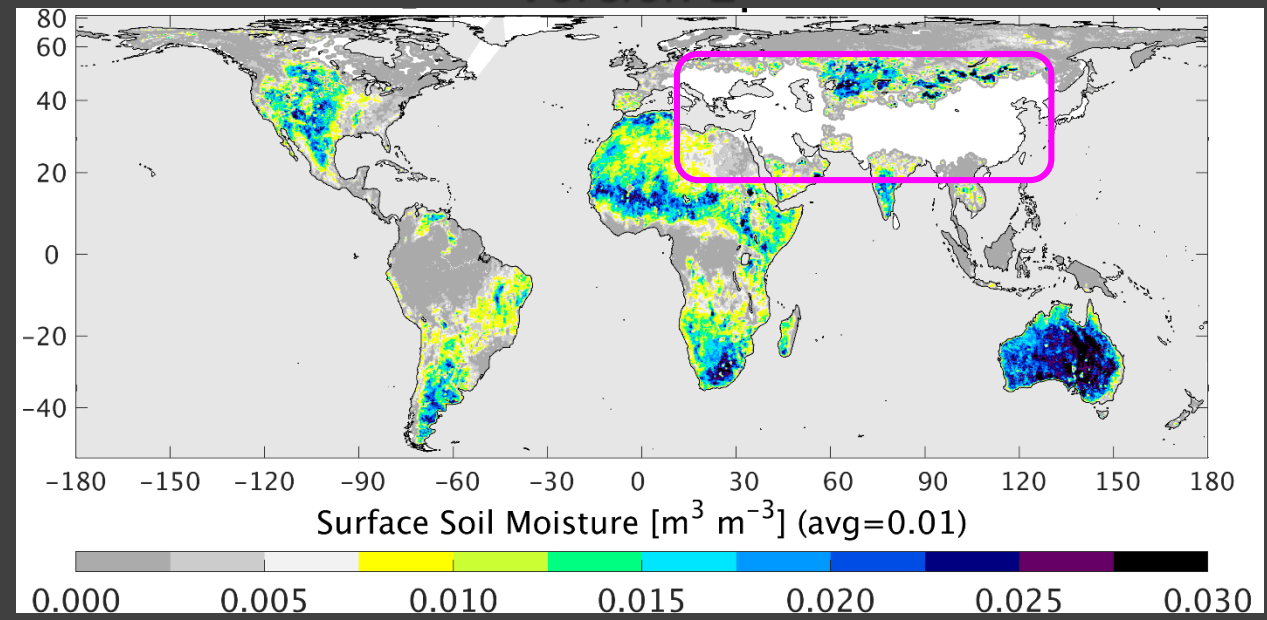
Version 3



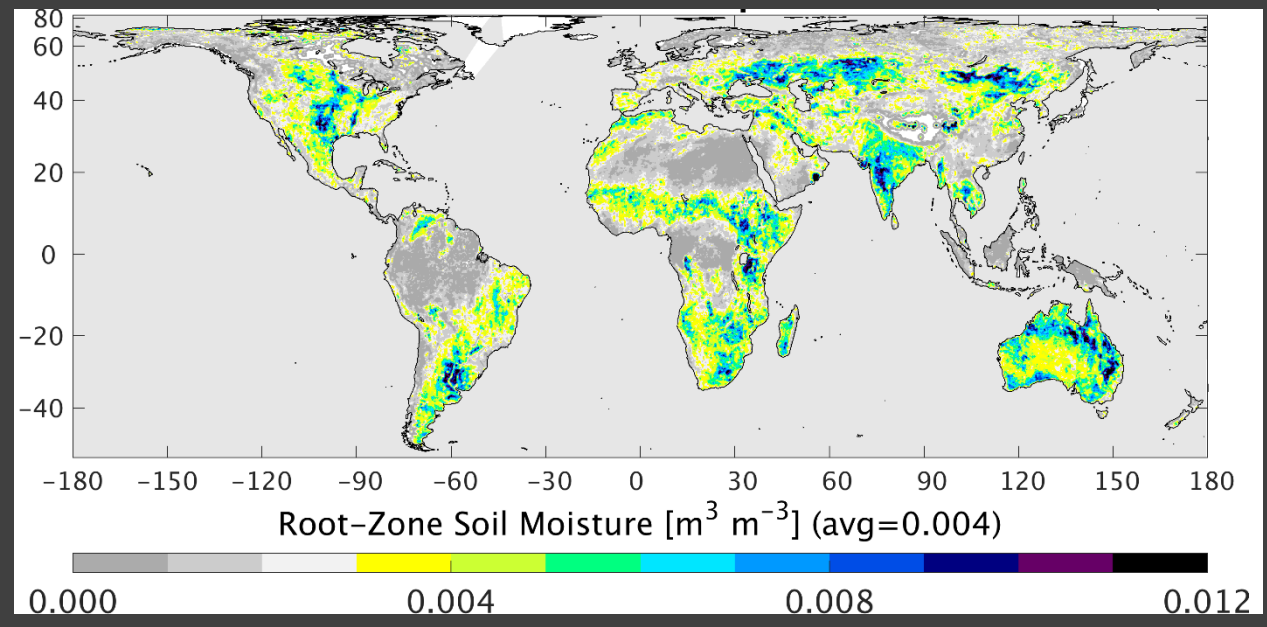
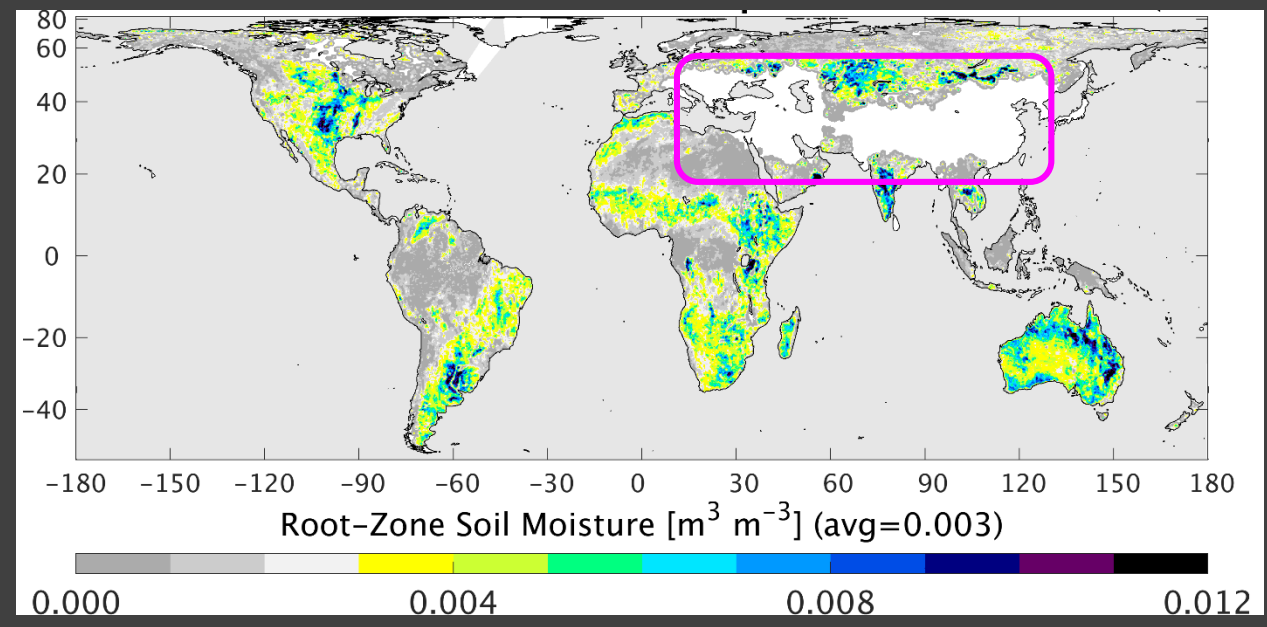
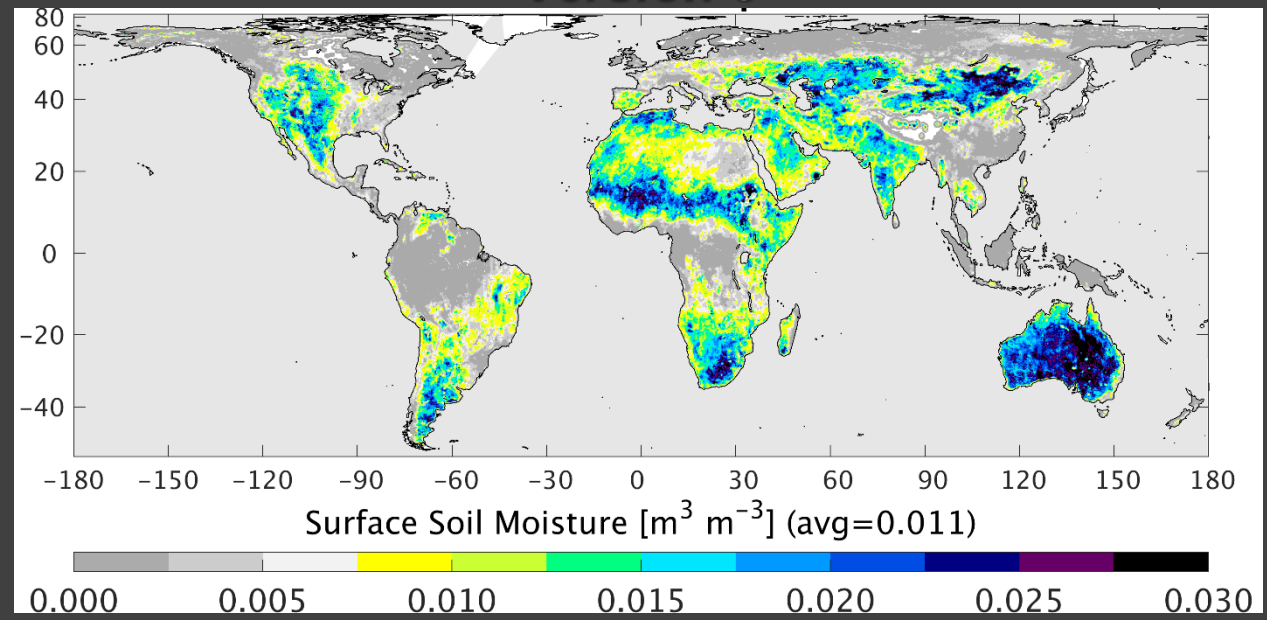
Average: 65,000 / day

Average: 104,000 / day

Version 2

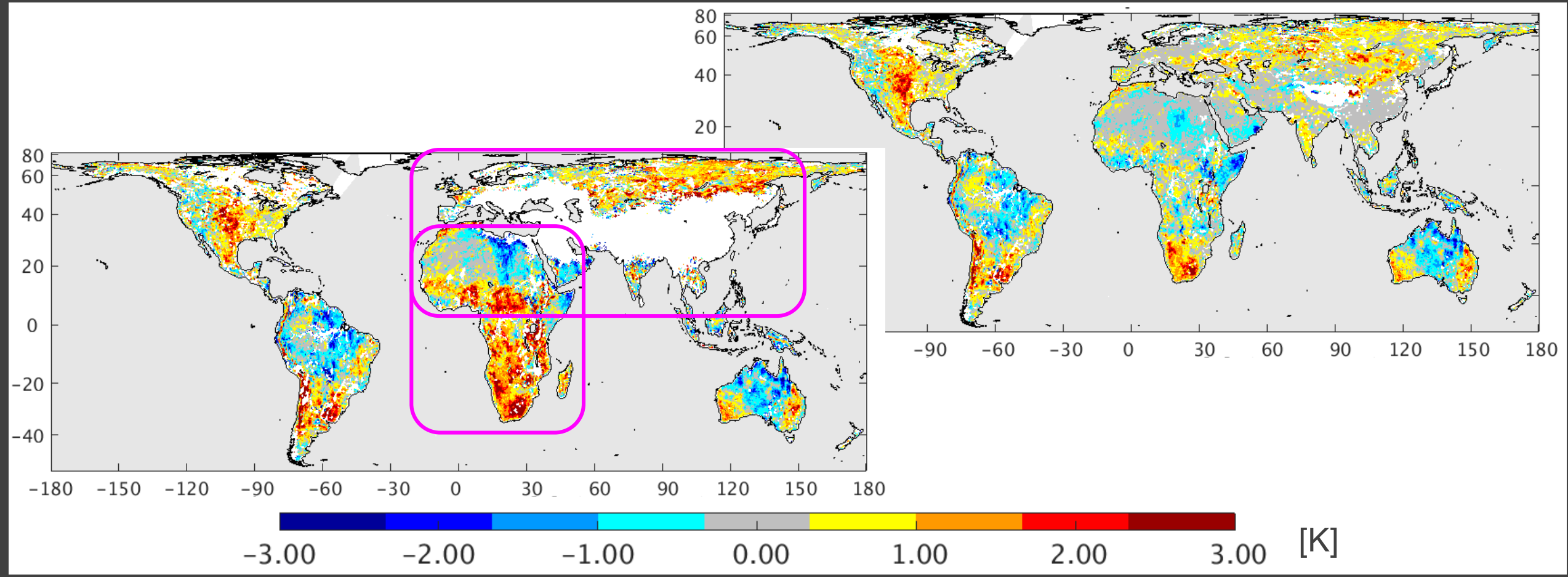


Version 3



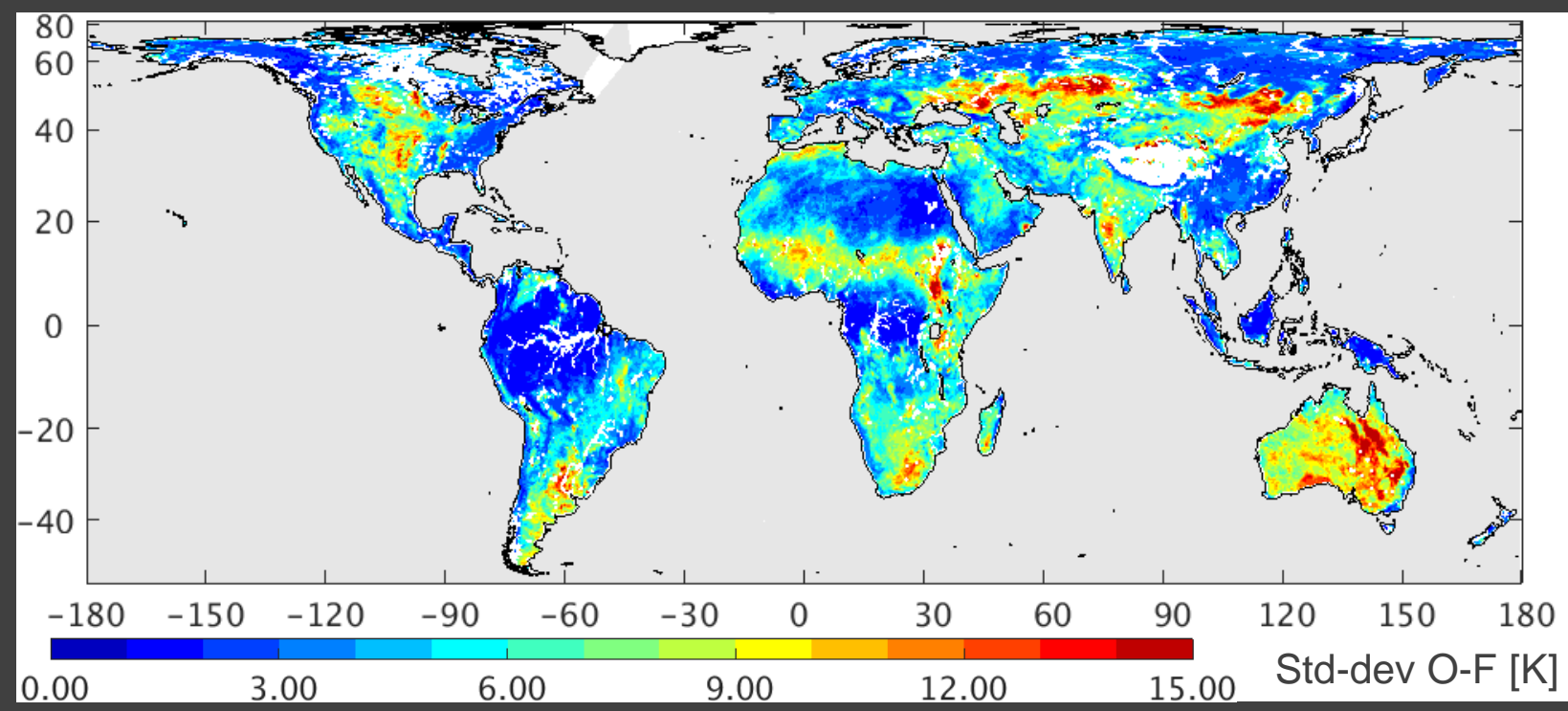
Version 2

Version 3





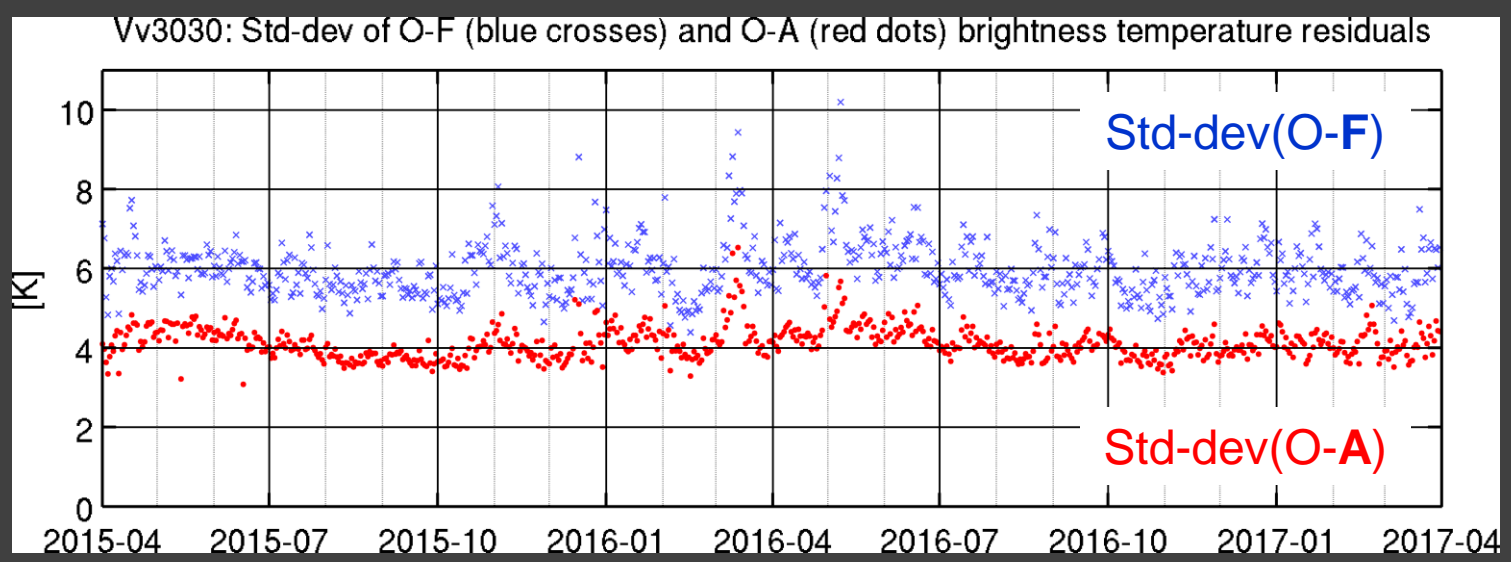
# Std-dev O-F



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

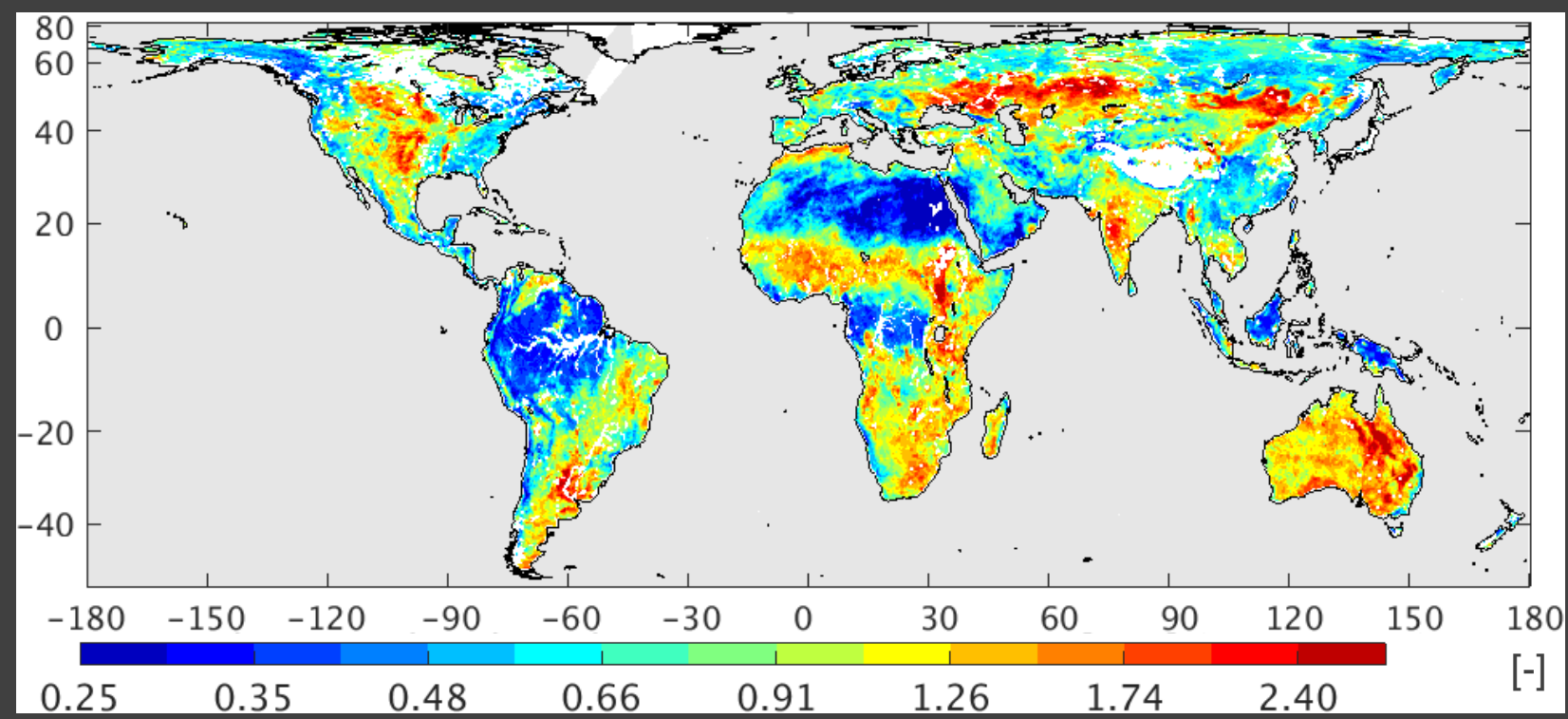
Cf. Tb obs error  
= 4 K

includes



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

# Std-dev Normalized O-F

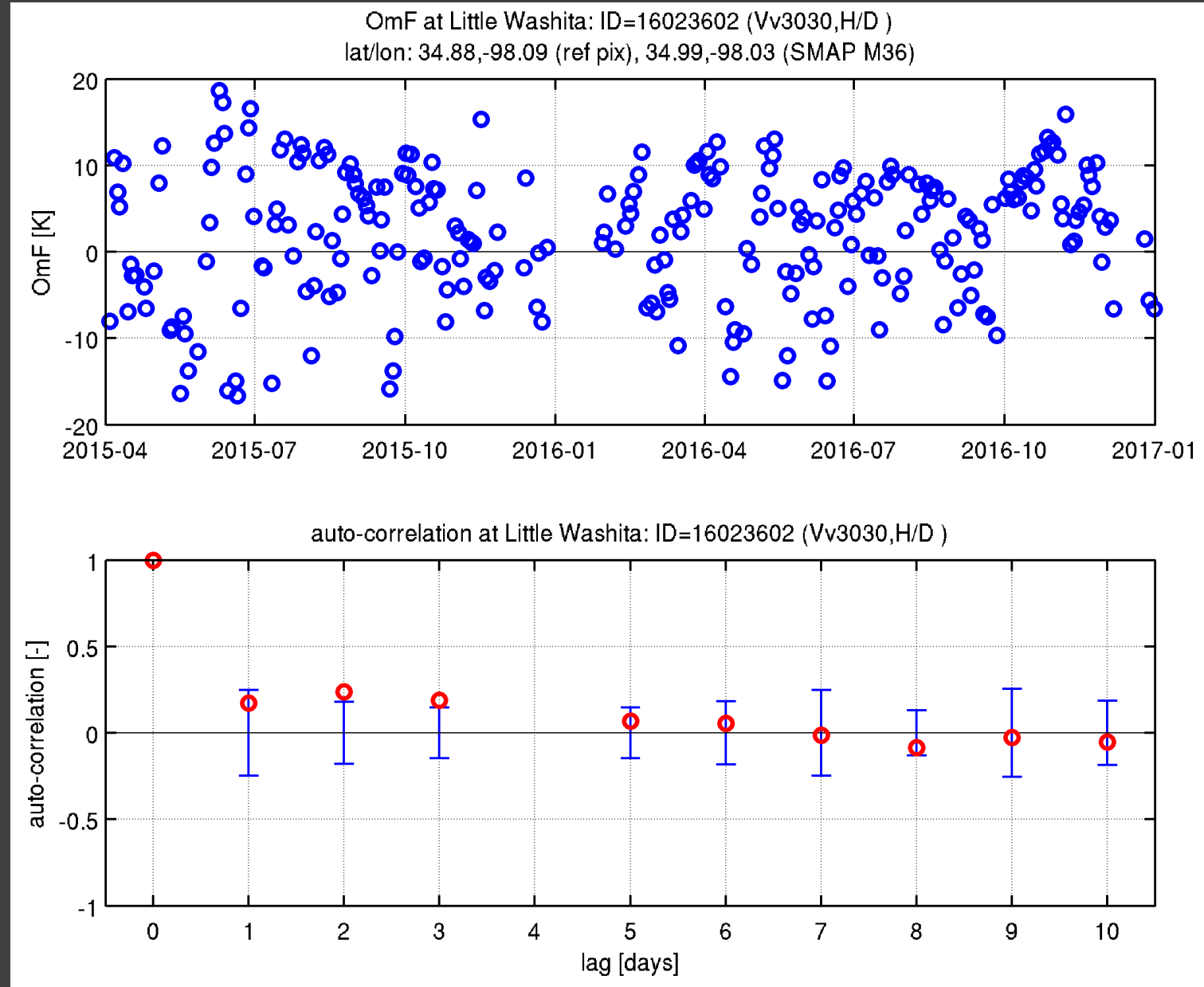


Average:  
1.0



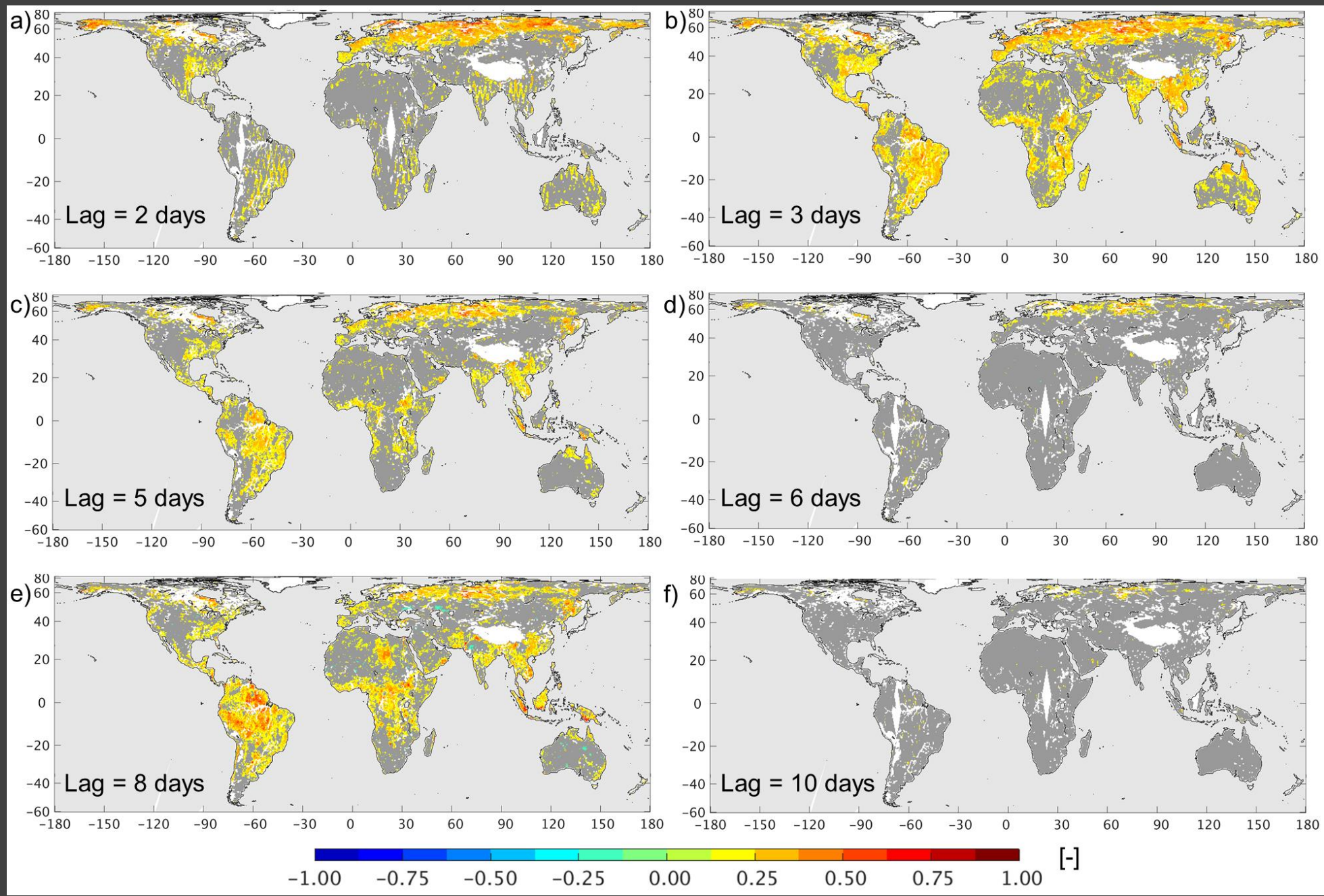
**over-estimation**                      **under-estimation**  
of actual O-F errors

# O-F at Little Washita (Oklahoma)

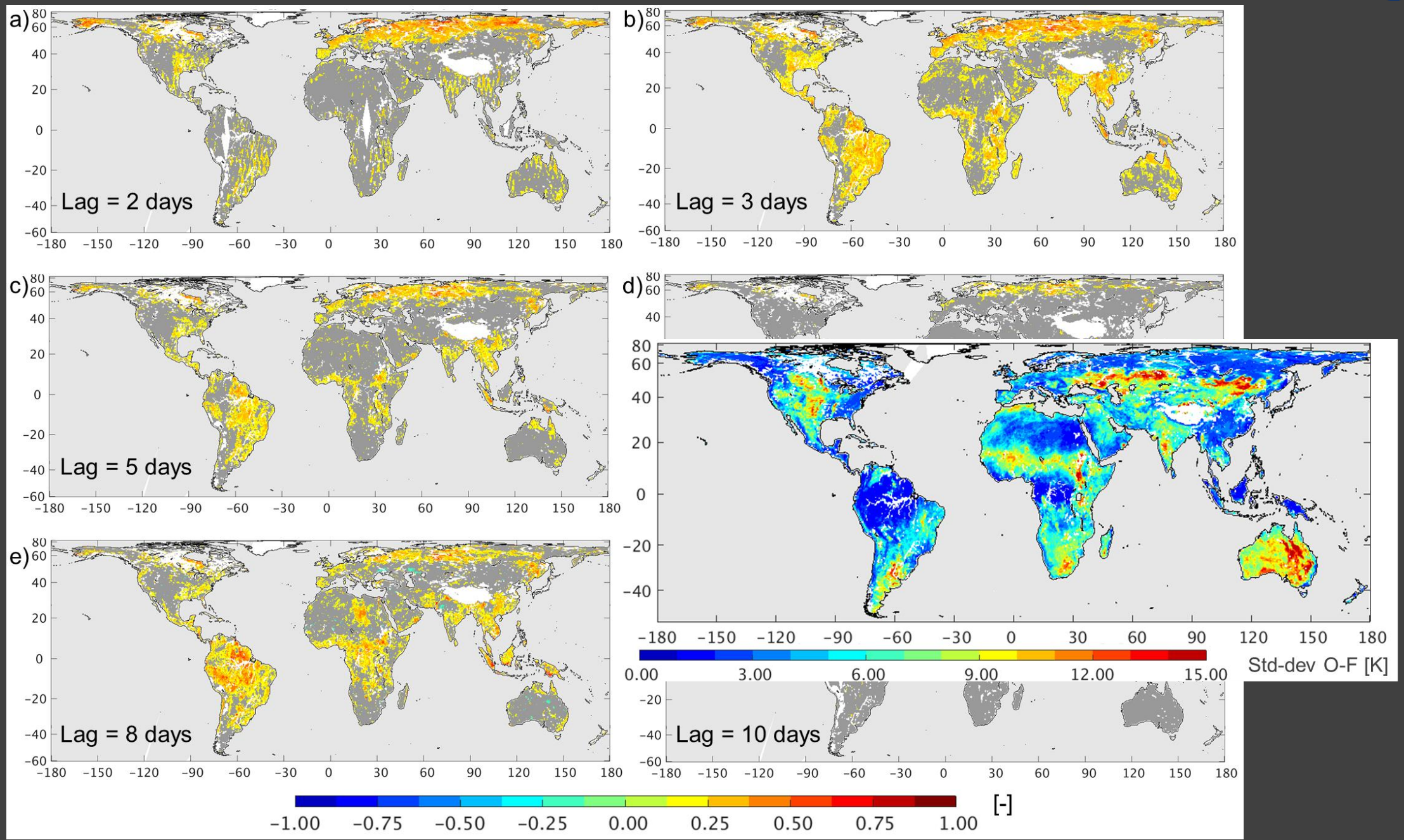


O-F auto-correlation measures “efficiency” of assimilation system.

# O-F Auto-correlation



# O-F Auto-correlation



- *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<sup>3</sup> m<sup>-3</sup> for surface (root-zone) soil moisture increments.*
- *Actual errors are overestimated in deserts and densely vegetated regions and underestimated 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.*



**Data Archive & HTML Doc**  
<http://nsidc.org/data/smap>

**Global Assimilation of Multiscale and Multipurpose Temperature Observations Into the GFDL-ES-CM3 Model for Soil Moisture Estimation**  
 GABRIELLE J. M. DE LANNY<sup>1</sup>, ROSE H. REICHEL<sup>2</sup>  
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 Manuscript received 18 March 2015, in final form 16 June 2015

**ABSTRACT**  
 Multiscale and multipurpose L-band microwave observations from the SMOS mission are assimilated into the Goddard Earth Observing System using a variational data assimilation ensemble Kalman filter. A subset of the assimilated data is used to evaluate the SMAP Level 4 soil moisture product. The assimilation uses brightness temperatures (TB) for various incidence angles and polarizations, as well as vertical soil temperatures. With SMOS TB assimilation, the assimilated brightness temperatures and soil moisture estimates are more accurate and smoother than those from the SMAP Level 4 soil moisture product. The assimilation improves both soil moisture and soil temperature estimates, with the soil moisture improvements being most significant over the high-latitude regions. The soil moisture estimates are more accurate and smoother than those from the SMAP Level 4 soil moisture product. The assimilation improves both soil moisture and soil temperature estimates, with the soil moisture improvements being most significant over the high-latitude regions. The soil moisture estimates are more accurate and smoother than those from the SMAP Level 4 soil moisture product.

**Assimilation of SMOS brightness temperatures retrievals into a land surface model**  
 GABRIELLE J. M. DE LANNY<sup>1</sup> and ROSE H. REICHEL<sup>2</sup>  
<sup>1</sup>KU Leuven, Department of Earth and Environmental Sciences, Herestraat, Belgium  
<sup>2</sup>NASA Goddard Space Flight Center, Global Modeling and Assimilation Office, Greenbelt, Maryland

**ABSTRACT**  
 Three different data products from the Soil Moisture Ocean Salinity (SMOS) mission are assimilated separately into the Goddard Earth Observing System Model, version 5 (GEOS-5), to improve estimates of surface and root zone soil moisture. The first product consists of multi-angle, dual-polarization brightness temperatures (TB) observations at the bottom of the atmosphere extracted from Level 1 data. The second product is a derived SMOS TB product that removes the effect of a 40° incidence angle from the Soil Moisture Ocean Salinity (SMOS) mission. The third product is the operational SMOS Level 2 surface soil moisture (SM) retrieval product. The assimilation system uses a spatially distributed ensemble Kalman filter (EnKF) with regularly varying the retrieval parameters for TB assimilation, whereas a time-invariant covariance density function resulting in a soil for SM retrieval assimilation. All assimilation experiments improve the soil moisture estimates compared to model-only simulations in terms of unbiased root-mean-square difference and monthly correlation during the period from 1 July 2010 to 1 May 2015 and for 187 sites across the US. Especially in areas where the satellite data are most sensitive to surface soil moisture, large skill improvements (e.g., an increase in the monthly correlation by 0.11) are observed. The assimilation improves the domain-average surface and root zone soil moisture, as well as the vertical soil moisture estimates, but large differences in skill are found locally. The observation-minus-forecast residuals and analysis increments reveal large differences in how the observations add value in the TB and SM retrieval assimilation systems. The distinct patterns of these diagnostics in the two systems reflect observation and model errors patterns that are not well captured by the assimilation.

**Assessment of the SMAP Level 4 Surface and Root-Zone Soil Moisture in Situ Measurements**  
 ROSE H. REICHEL<sup>1</sup>, GABRIELLE J. M. DE LANNY<sup>2</sup>, QING LIU<sup>3</sup>, JOSEPH ANDREA COLLANONNE<sup>4</sup>, ADRIAN CONANTY<sup>5</sup>, WAGE CROW<sup>6</sup>, THOMAS LUCIA A. JONKE<sup>7</sup>, JESSIE S. KIRKALL<sup>8</sup>, RANDI D. KOTIKU<sup>9</sup>, SORLEY E. EDMOND B. SMITH<sup>10</sup>, AARON BERG<sup>11</sup>, SHONNE BROCKIE<sup>12</sup>, DAVID BOSCH<sup>13</sup>, MICHAEL CONIG<sup>14</sup>, ANGELO FERRARESE<sup>15</sup>, CHRISTOPHER D. HUBER<sup>16</sup>, KATHLEEN H. JENSEN<sup>17</sup>, SYLVIA LIVINGSTON<sup>18</sup>, ERNESTO LOPEZ-BAEZA<sup>19</sup>, JOSE MA HEATHER MENAQUIE<sup>20</sup>, MAHMOUD MANSOURI<sup>21</sup>, ANNA PACHYRETT<sup>22</sup>, THOMAS JOHN PRUEGER<sup>23</sup>, TRACY ROWLANDSON<sup>24</sup>, MARK SEVRYN<sup>25</sup>, PATRICK STARR<sup>26</sup>, MARC THIEBAULT<sup>27</sup>, ROGER VAN DER VELDE<sup>28</sup>, JEFFREY WALKER<sup>29</sup>, XIANGJUN YU<sup>30</sup>  
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**Global Assessment of the SMAP Level 4 Surface and Root-Zone Soil Moisture Product Using Assimilation Diagnostics**  
 ROSE H. REICHEL<sup>1</sup>, GABRIELLE J. M. DE LANNY<sup>2</sup>, QING LIU<sup>3</sup>, RANDI D. KOTIKU<sup>4</sup>, JOHN S. KIMBALL<sup>5</sup>, WAGE CROW<sup>6</sup>, JOSEPH V. ARIZONA<sup>7</sup>, PARNESH CHAKRABORTY<sup>8</sup>, DOUGLAS W. COLLINS<sup>9</sup>, ANTON L. COONEY<sup>10</sup>, MANUELA GAZOTTO<sup>11</sup>, LUCAS A. JONES<sup>12</sup>, JANA KOLASNA<sup>13</sup>, HANS LAURVENS<sup>14</sup>, ROBERT A. LUCCHESI<sup>15</sup>, EDMOND B. SMITH<sup>16</sup>  
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**Global Modeling and Assimilation Office**  
 GMAO Office Note No. 10 (Version 1.4)

**Soil Moisture Active Passive (SMAP) Mission Level 4 Surface and Root Zone Soil Moisture (L4\_SM) Product Specification Document**

Release Date: 10/31/2015

**Global Modeling and Assimilation Office**  
 GMAO Office Note No. 12 (Version 1.0)

**Soil Moisture Active Passive (SMAP) Algorithm Theoretical Basis Document Level 4 Surface and Root Zone Soil Moisture (L4\_SM) Data Product**

Revision A  
 December 9, 2014

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**Global Modeling and Assimilation Office**  
 GMAO Office Note No. 12 (Version 1.0)

**Soil Moisture Active Passive Mission L4\_SM Data Product Assessment (Version 2 Validated Release)**

Release Date: 04/29/2016

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 Greenbelt, Maryland 20771

**Product Specification Document**  
**Algorithm Document**  
**Data Assessment Reports**

[http://gmao.gsfc.nasa.gov/GMAO\\_products/SMAP\\_L4](http://gmao.gsfc.nasa.gov/GMAO_products/SMAP_L4)

10.5194/hess-20-4895-2016  
 10.1175/JHM-D-15-0037.1  
 In Review  
 10.1175/JHM-D-15-0063.1

**Peer-reviewed SMOS and SMAP Papers**