Recent Updates in the SMAP Level-4 Soil Moisture Algorithm

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Outline

1. Overview and Climatology

2. Soil Moisture Validation

3. Assimilation Diagnostics

4. Summary

What's New in Version 4?

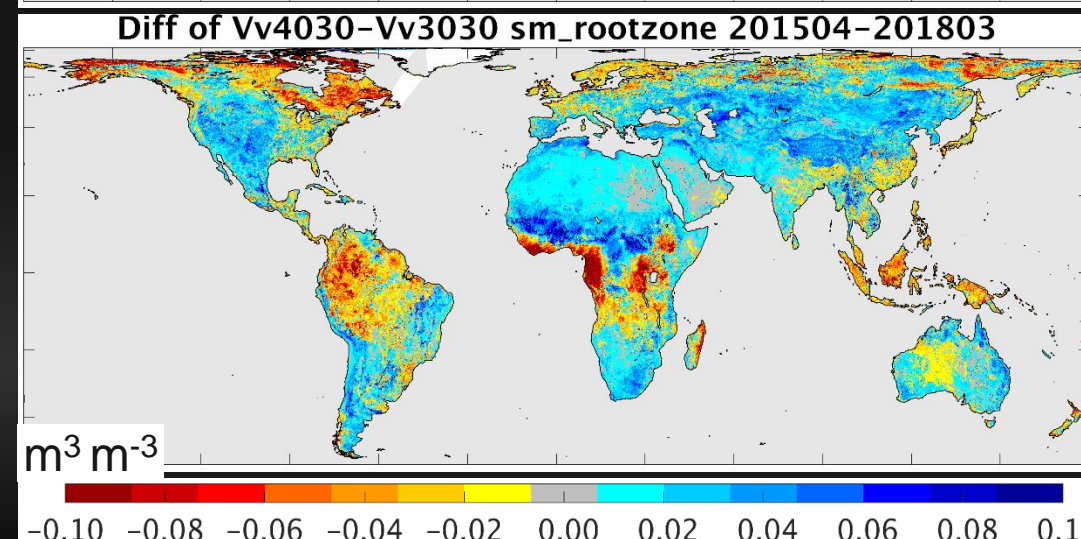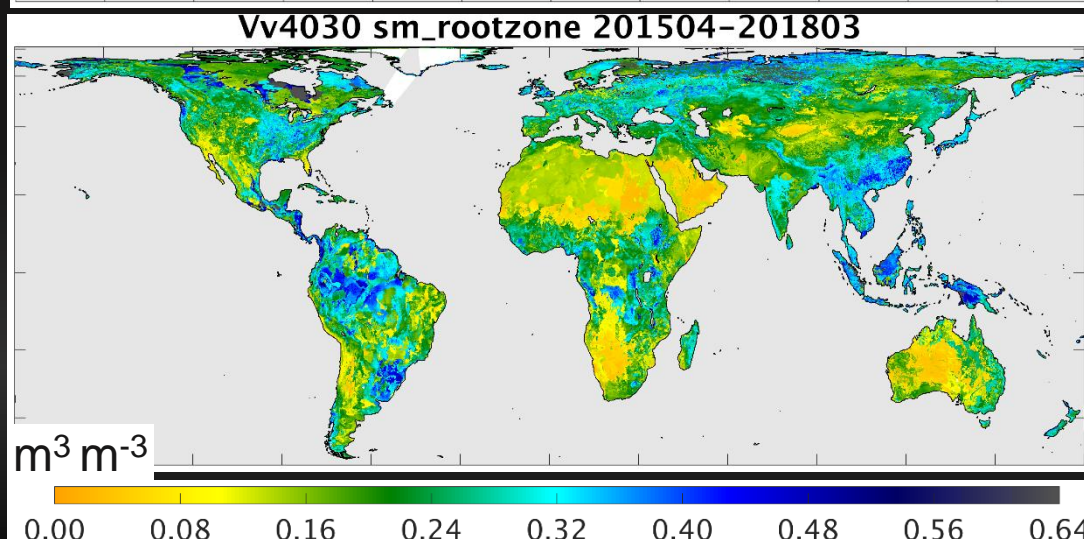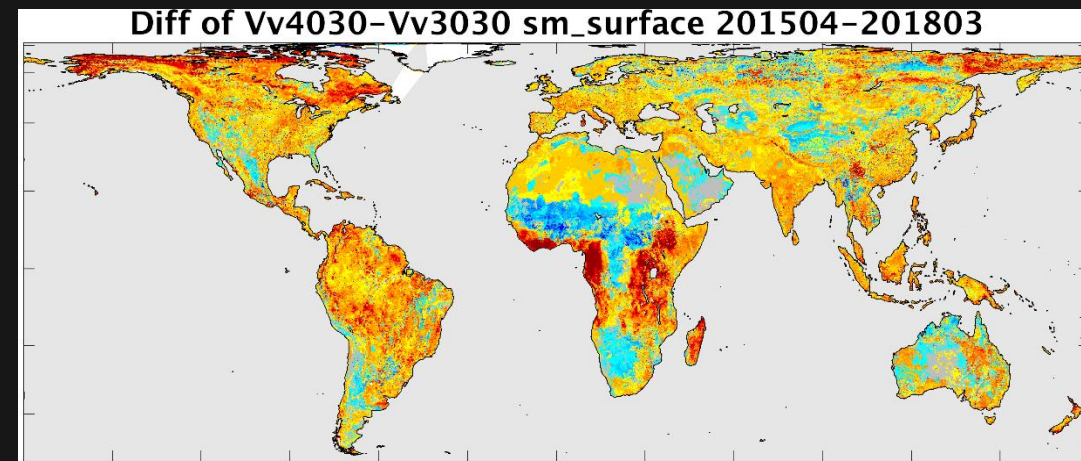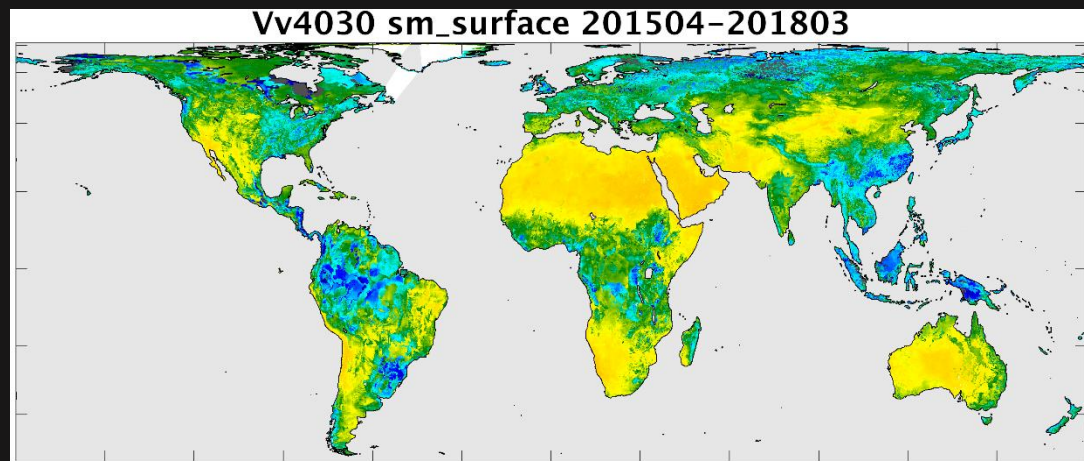**Key model changes in L4_SM Version 4 ("NRv7.2") w.r.t. Version 3 ("NRv4.1"):**

1. New parameters for topography (SRTM), land cover (Globcover), and tree height (Lidar).

2. Revised upward soil moisture recharge from root zone to surface excess reservoir.

3. Climatological rescaling of *background* precipitation to GPCPv2.2 (impacts L4_SM forcing where precipitation is not corrected with CPCU observations).

4. Retrospective forcing (for algorithm calibration and climatology) based on MERRA-2.

5. Minor revisions to surface energy balance and snow depletion curve.

Key Tb analysis changes in L4_SM Version 4 w.r.t. Version 3:

• Assimilated SMAP Tbs generally warmer by a few K owing to new L1 calibration.

• Removed "catdef" model prognostic variable from EnKF state vector.

• Tb scaling parameters based on longer data records (8 yrs of SMOS, filled with 3 yrs of SMAP).

New metadata ("projection coordinates") facilitate easier use with some applications (e.g., ArcGIS).

Soil Moisture Climatology

Vv4030 sm_surface 201504–201803

Diff of Vv4030–Vv3030 sm_surface 201504–201803

Vv4030 sm_rootzone 201504–201803

Diff of Vv4030–Vv3030 sm_rootzone 201504–201803

$m^3 m^{-3}$

0.00 0.08 0.16 0.24 0.32 0.40 0.48 0.56 0.64

$m^3 m^{-3}$

−0.10 −0.08 −0.06 −0.04 −0.02 0.00 0.02 0.04 0.06 0.08 0.10

Climatological surface & root zone s.m. are different in V4 (unlike in V3).

In V4, surface s.m. is generally drier and root zone s.m. wetter than in V3.

In Africa & high lats, V3 and V4 soil moisture different because of precipitation differences.

Do not mix V3 and V4!

Runoff and Evaporation Climatology
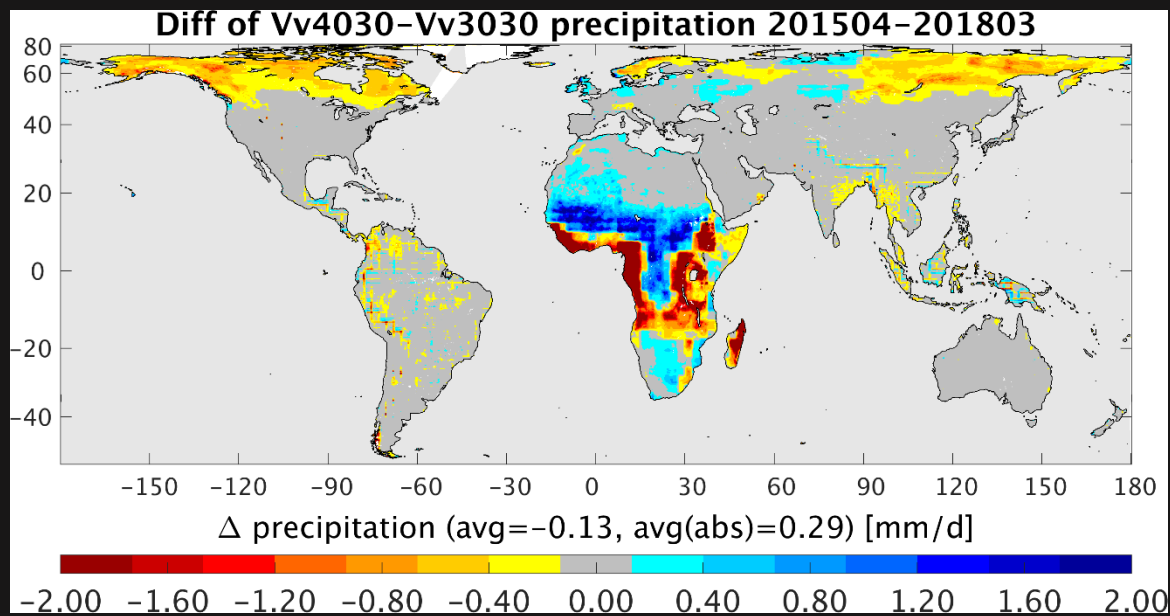
- In Version 4, GEOS model precipitation is rescaled to GPCPv2.2 climatology in Africa and high latitudes.

- In mid-latitudes, Version 4 has generally greater runoff ratio and smaller evaporative fraction than Version 3. ☺
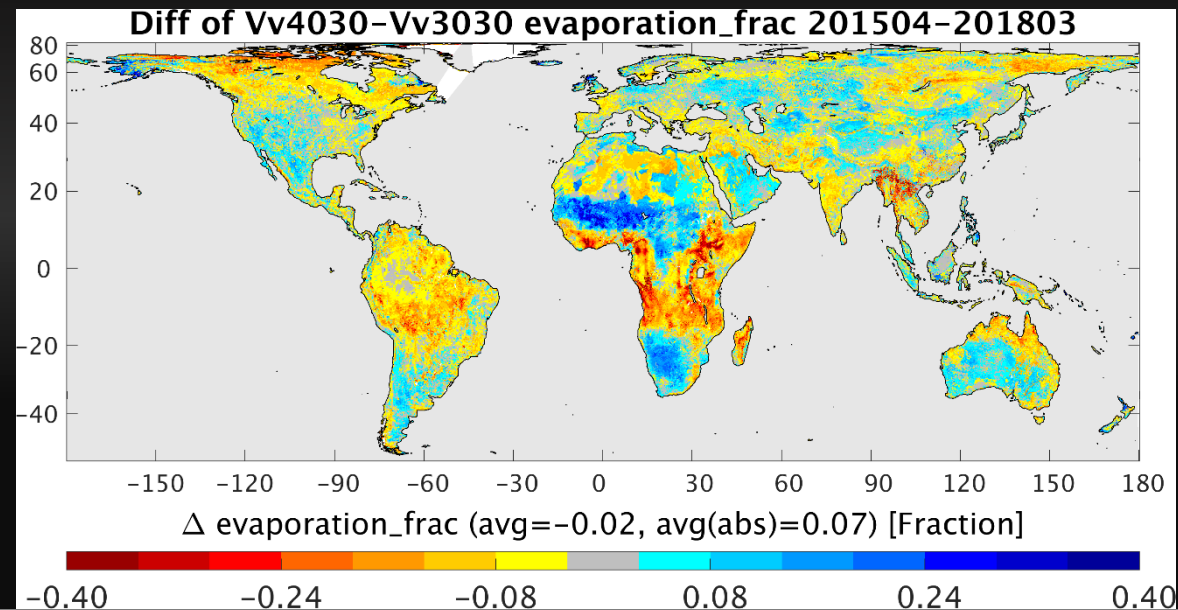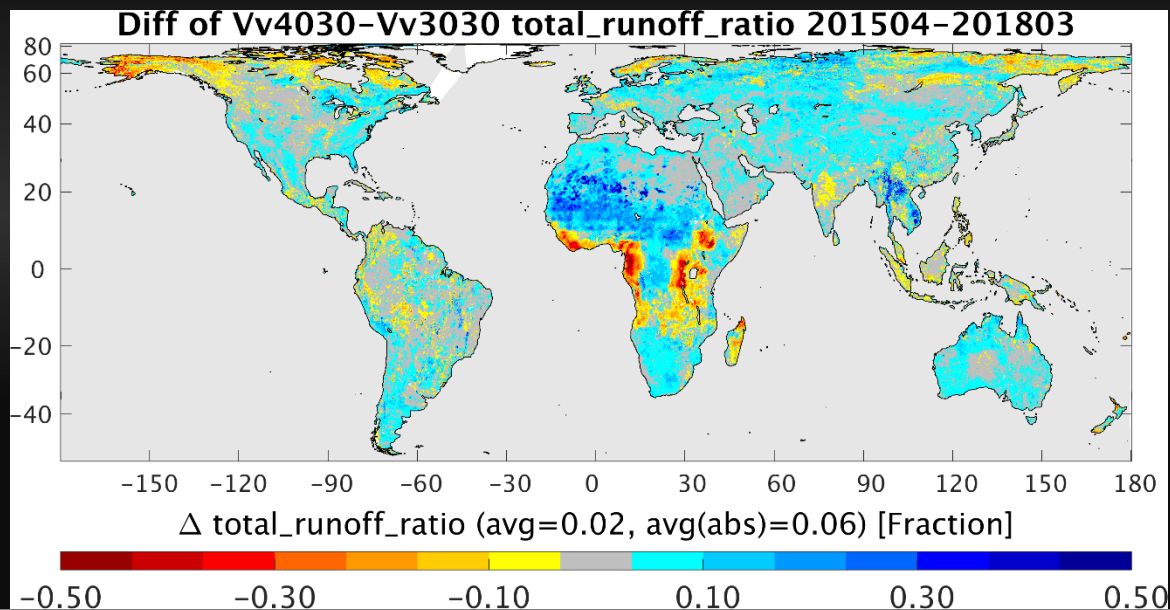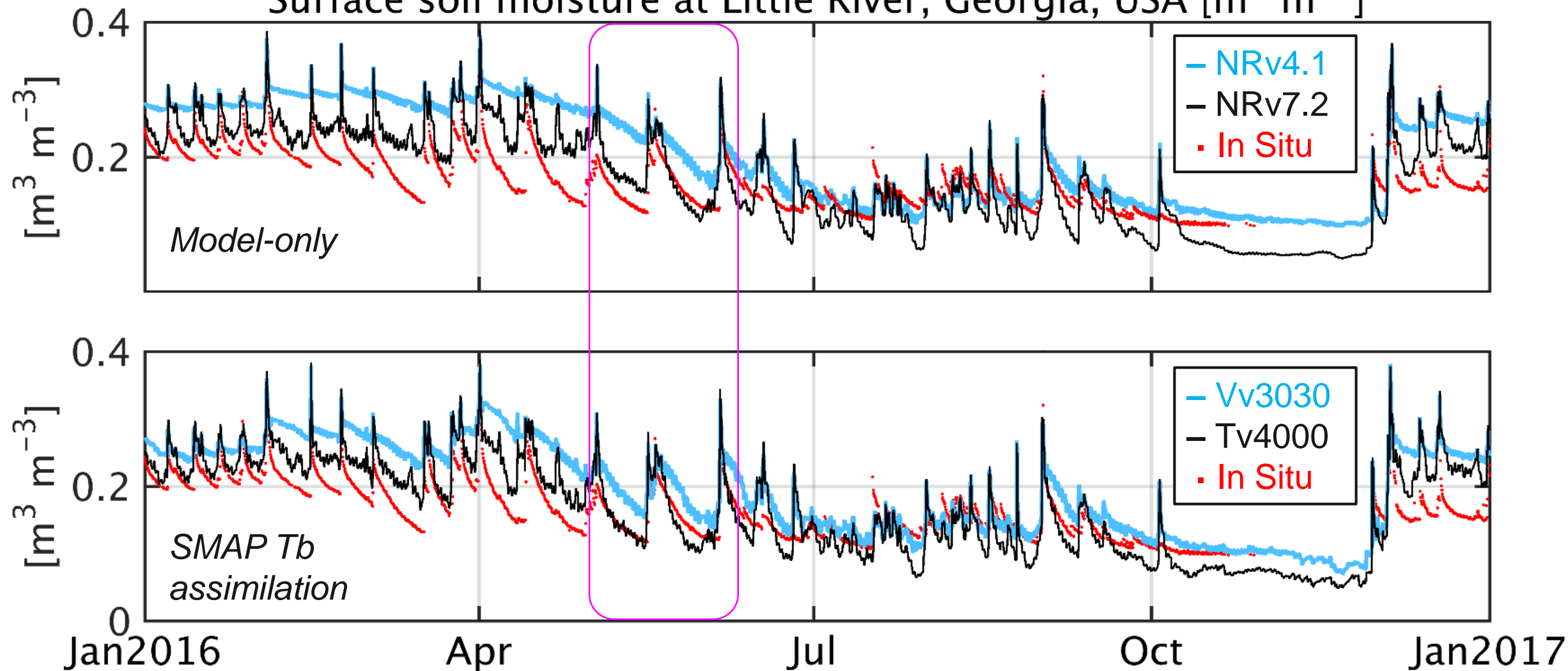
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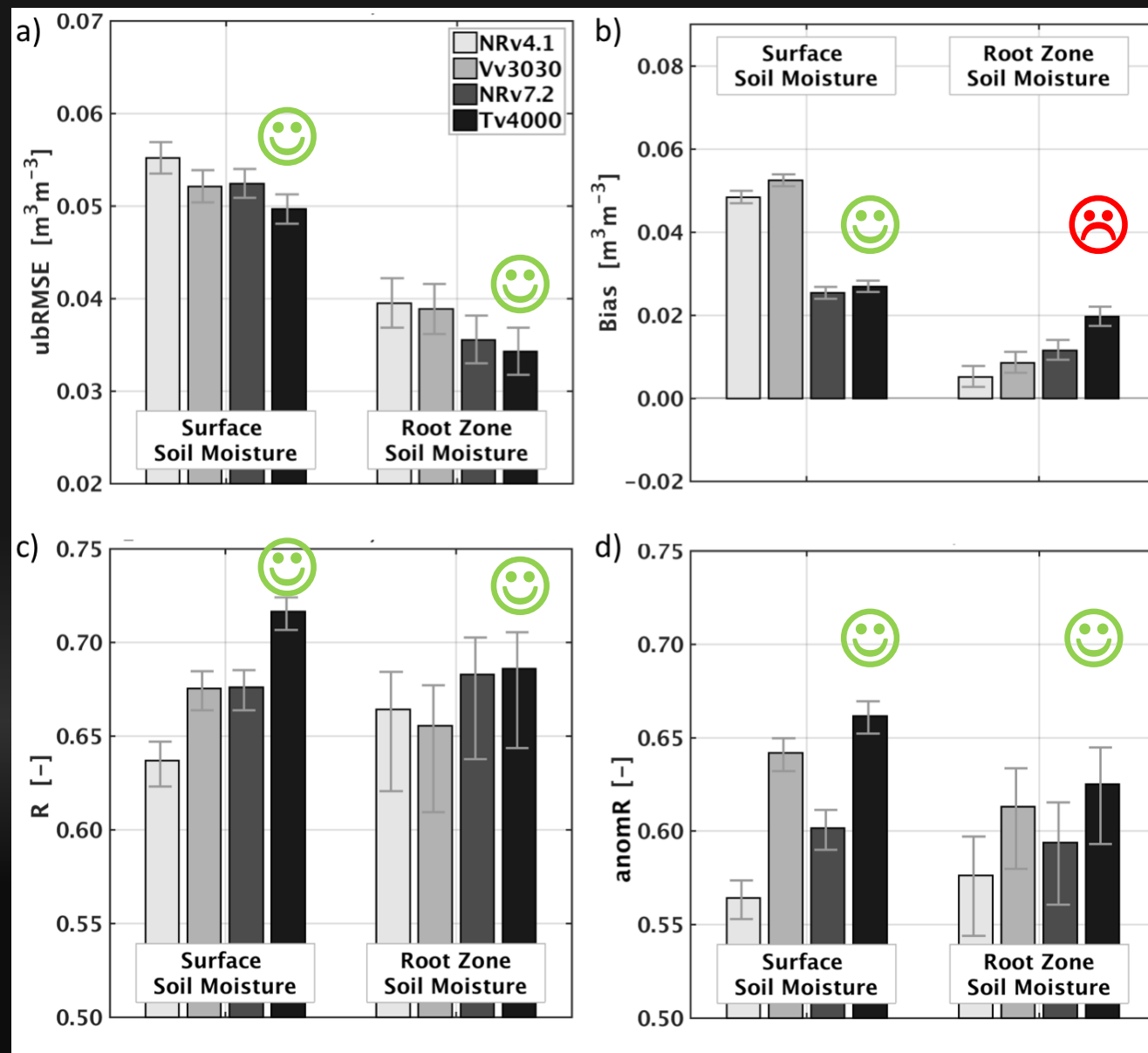# Calibration of Upward Soil Moisture Recharge

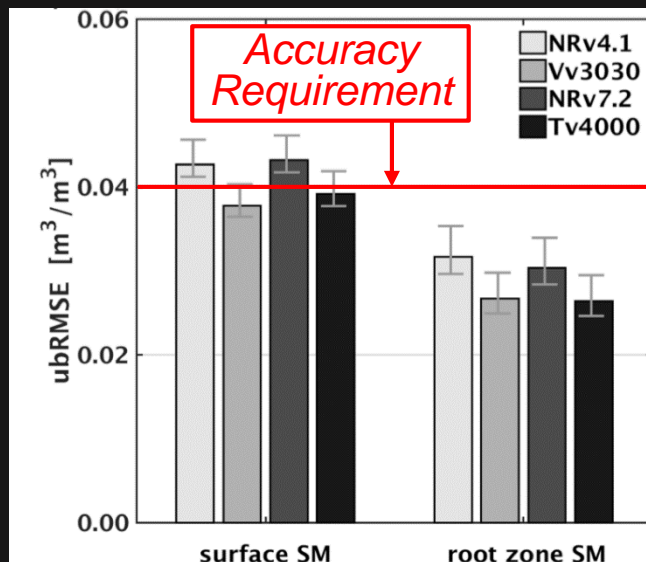Surface soil moisture at Little River, Georgia, USA [m³ m⁻³] (#16043302)

Sparse Network "Validation"

Improved skill vs. sparse network data…
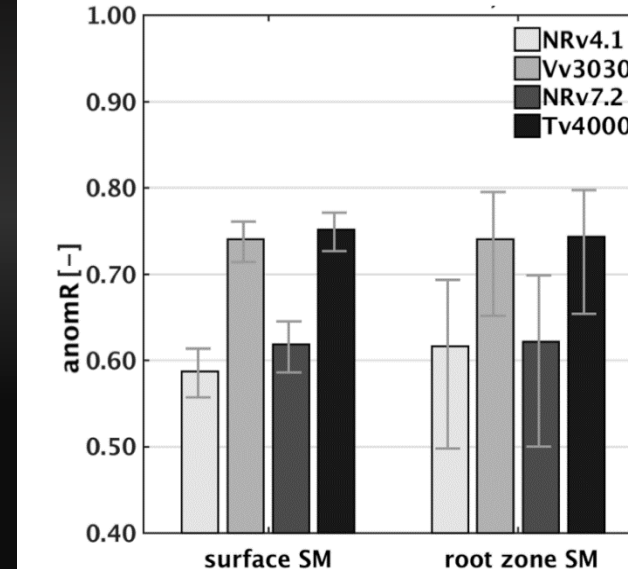
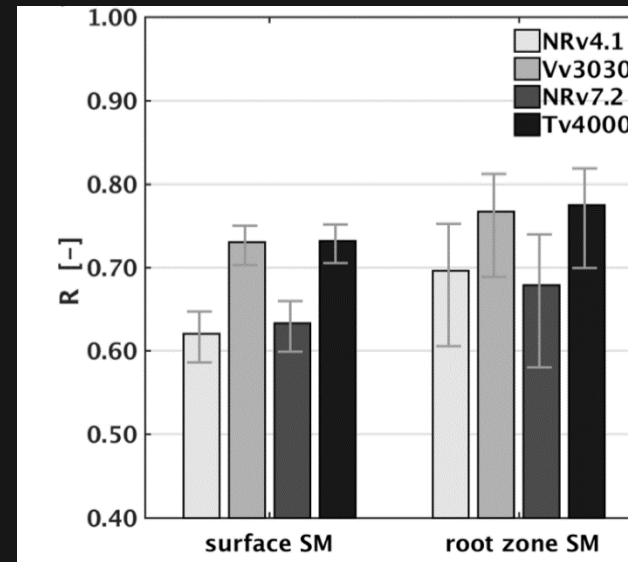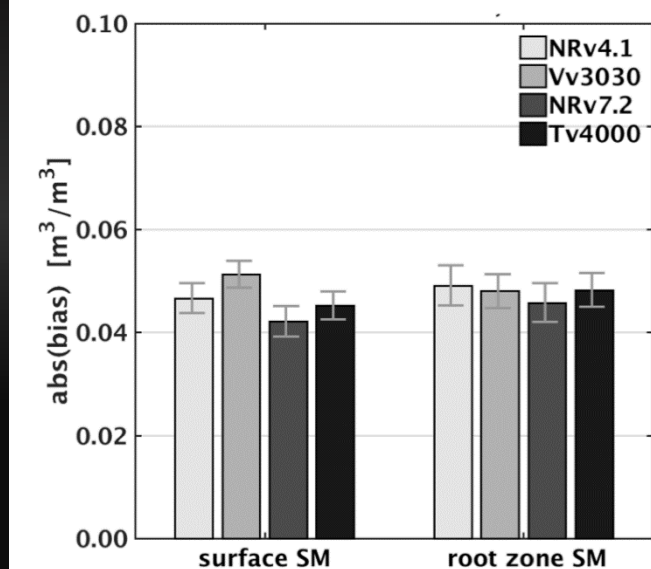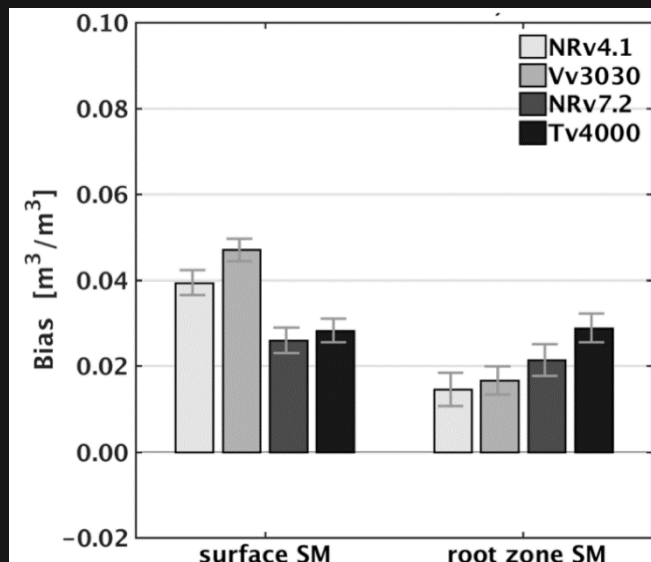… which were used to calibrate the model.

Core Site Validation (9-km reference pixels)

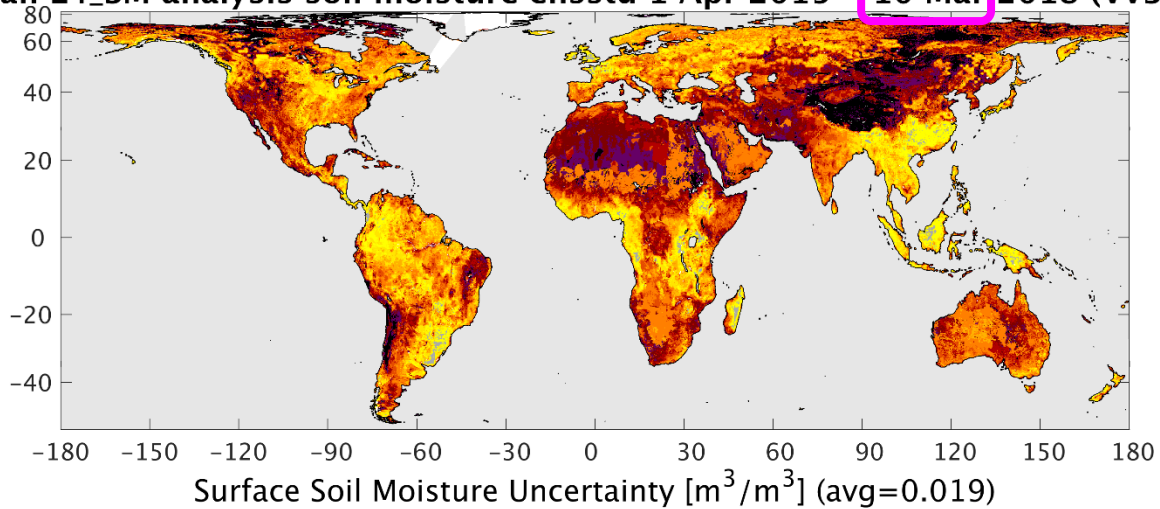Version 4 meets accuracy requirement.

On balance, V4 skill and improvements over model-only simulation are similar to those of V3.

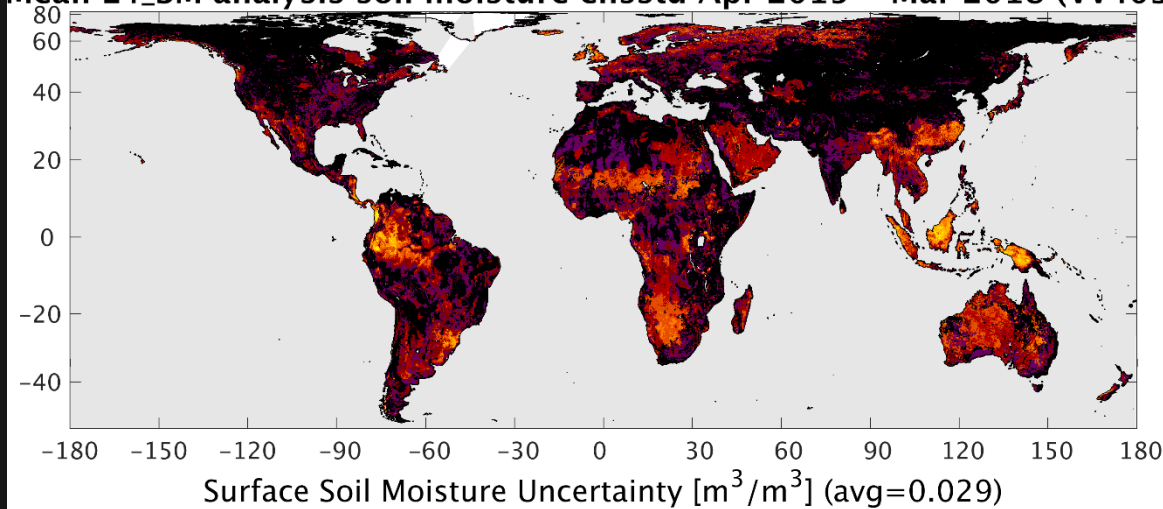Similar results for 33-km reference pixels.
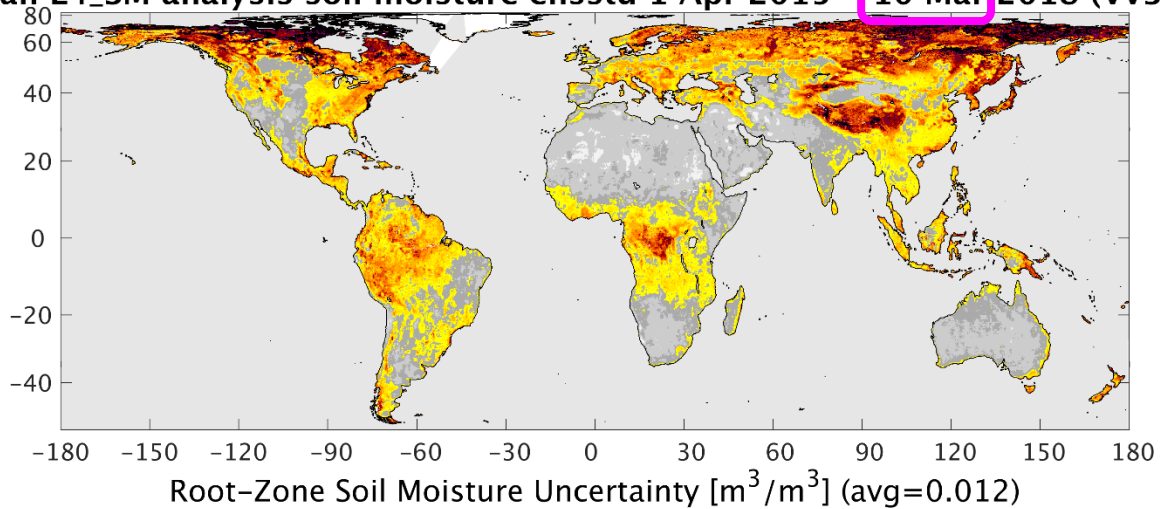
Uncertainty Estimates

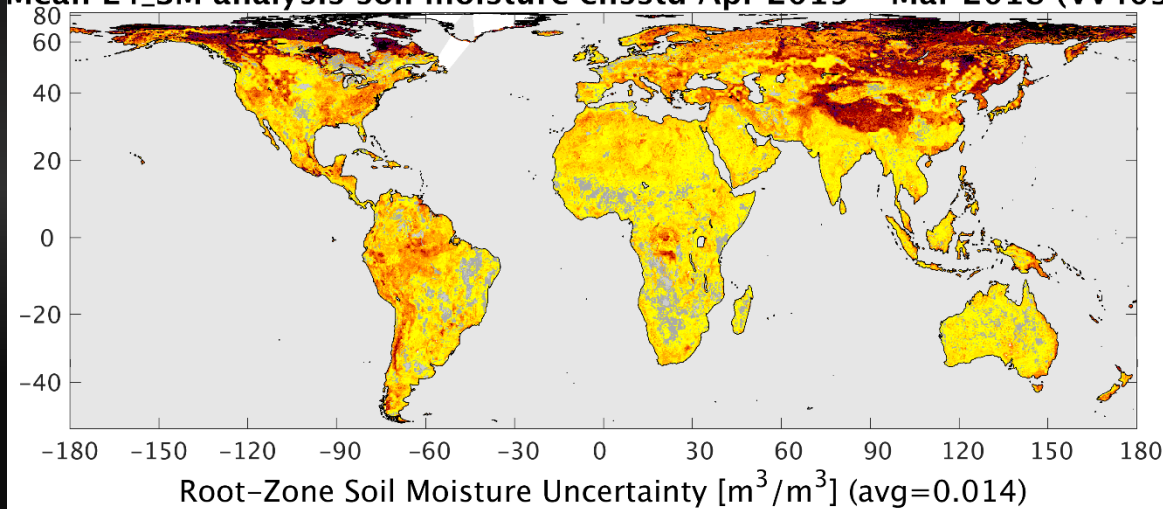Mean L4_SM analysis soil moisture ensstd 1 Apr 2015 – 10 Mar 2018 (Vv3030)

Surface Soil Moisture Uncertainty [m^3/m^3] (avg=0.019)

Mean L4_SM analysis soil moisture ensstd Apr 2015 – Mar 2018 (Vv4030)
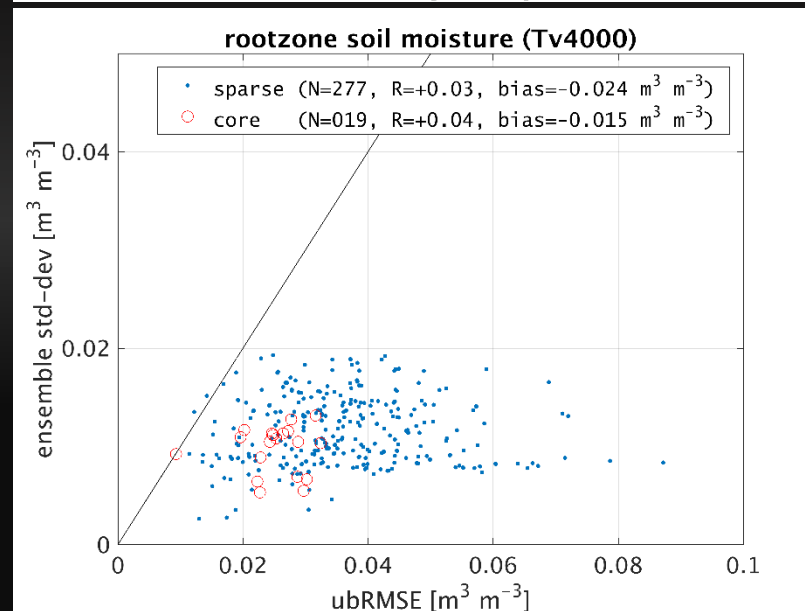
Surface Soil Moisture Uncertainty [m^3/m^3] (avg=0.029)

Mean L4_SM analysis soil moisture ensstd 1 Apr 2015 – 10 Mar 2018 (Vv3030)

Root–Zone Soil Moisture Uncertainty [m^3/m^3] (avg=0.012)

Mean L4_SM analysis soil moisture ensstd Apr 2015 – Mar 2018 (Vv4030)

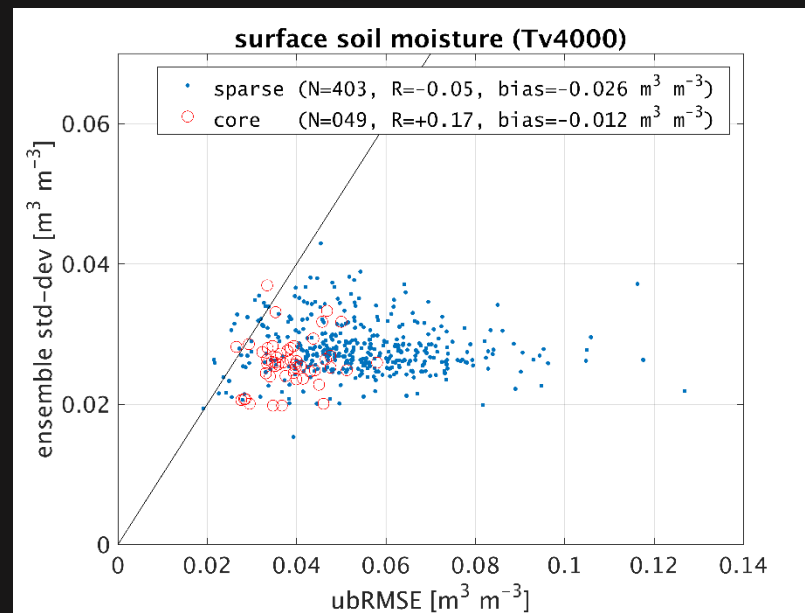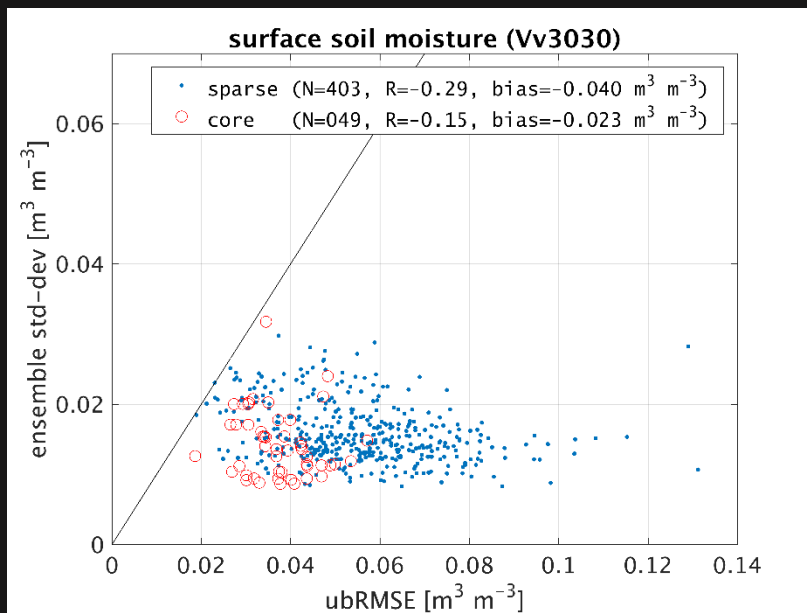Root–Zone Soil Moisture Uncertainty [m^3/m^3] (avg=0.014)

Uncertainty Estimates
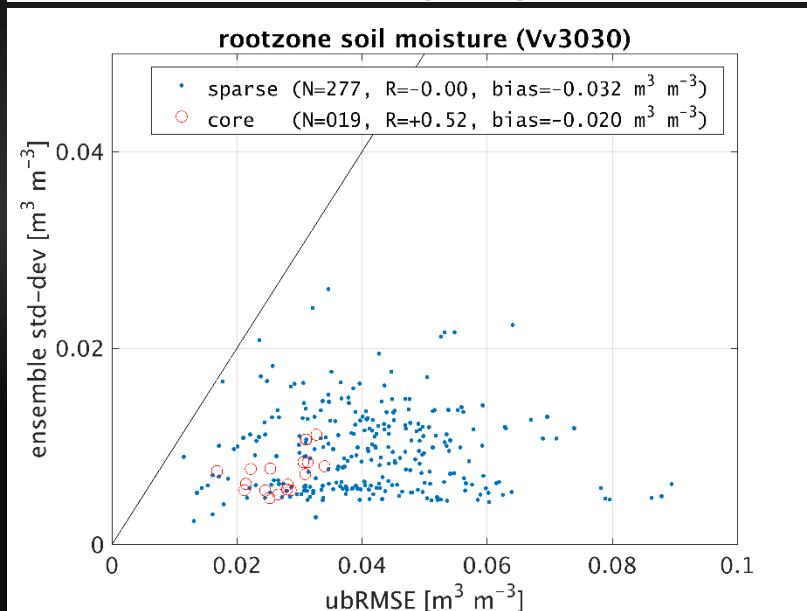
L4_SM provides uncertainty estimates ("ensemble std-dev") for surface and root-zone soil moisture.

These estimates should characterize the actual errors in the L4_SM product ("ubRMSE").
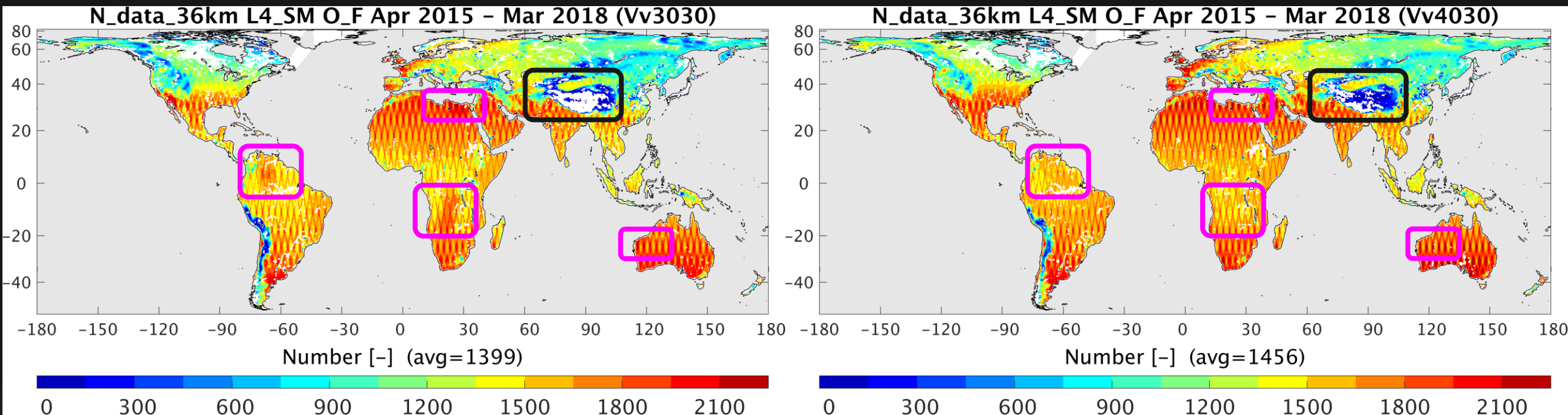
Uncertainty estimates in V4:

- better capture the average ubRMSE than in V3 but

- are still not (spatially) correlated with ubRMSE.

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O-F

N_data_36km L4_SM O_F Apr 2015 – Mar 2018 (Vv3030)

Number [–] (avg=1399)

N_data_36km L4_SM O_F Apr 2015 – Mar 2018 (Vv4030)

Number [–] (avg=1456)

- Bug fix: No longer assimilate fore & aft Tbs from same location and half-orbit at separate analysis times.

- Slightly improved coverage because Version 4 scaling parameters are based on a longer data record.
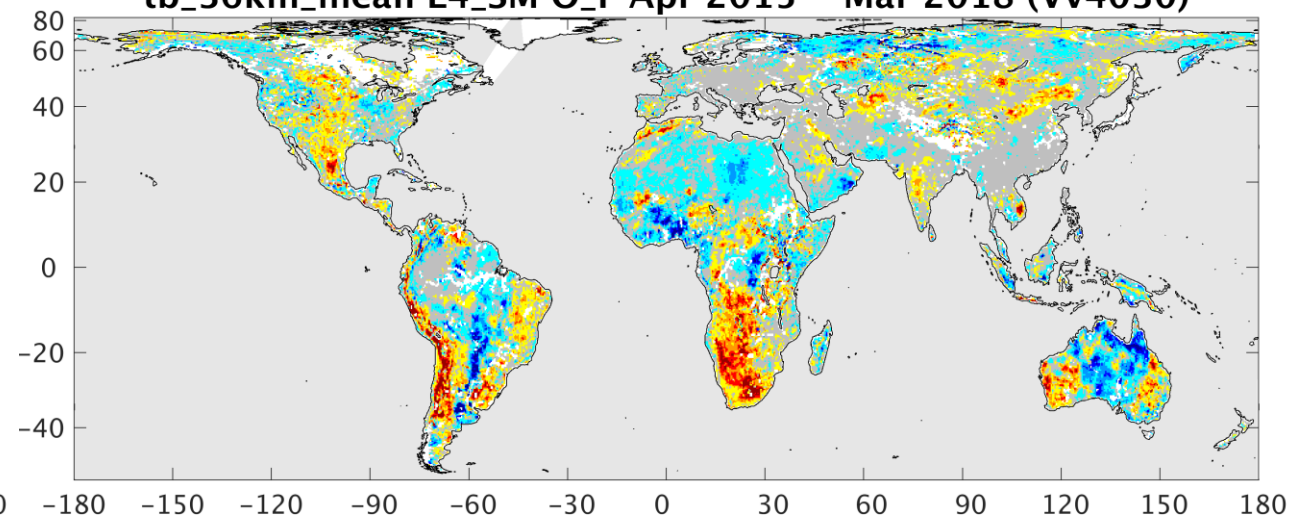
O-F

tb_36km_mean L4_SM O_F Apr 2015 – Mar 2018 (Vv3030)

tb_36km_mean L4_SM O_F Apr 2015 – Mar 2018 (Vv4030)
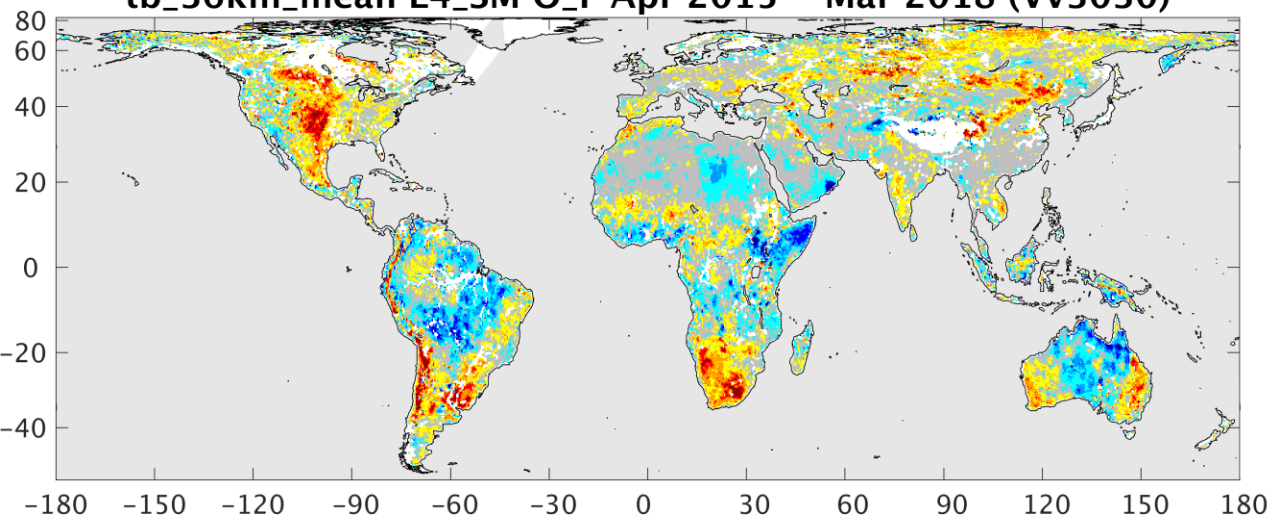
Brightness Temperature O-F [K] (avg=0.113, avg(abs)=0.584)
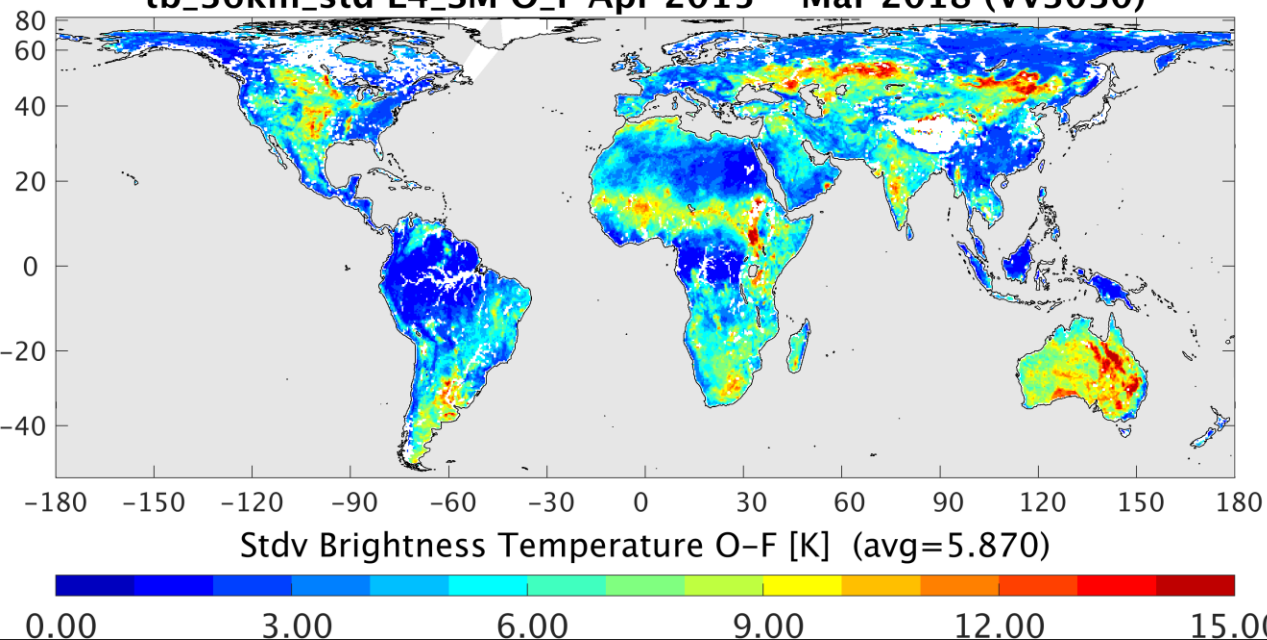
Brightness Temperature O-F [K] (avg=0.019, avg(abs)=0.557)

- Version 4 nearly bias-free in global average

- Slightly reduced typical magnitude of local bias.

O-F

tb_36km_std L4_SM O_F Apr 2015 – Mar 2018 (Vv3030)

Stdv Brightness Temperature O−F [K] (avg=5.870)

tb_36km_std L4_SM O_F Apr 2015 – Mar 2018 (Vv4030)

Stdv Brightness Temperature O−F [K] (avg=5.093)
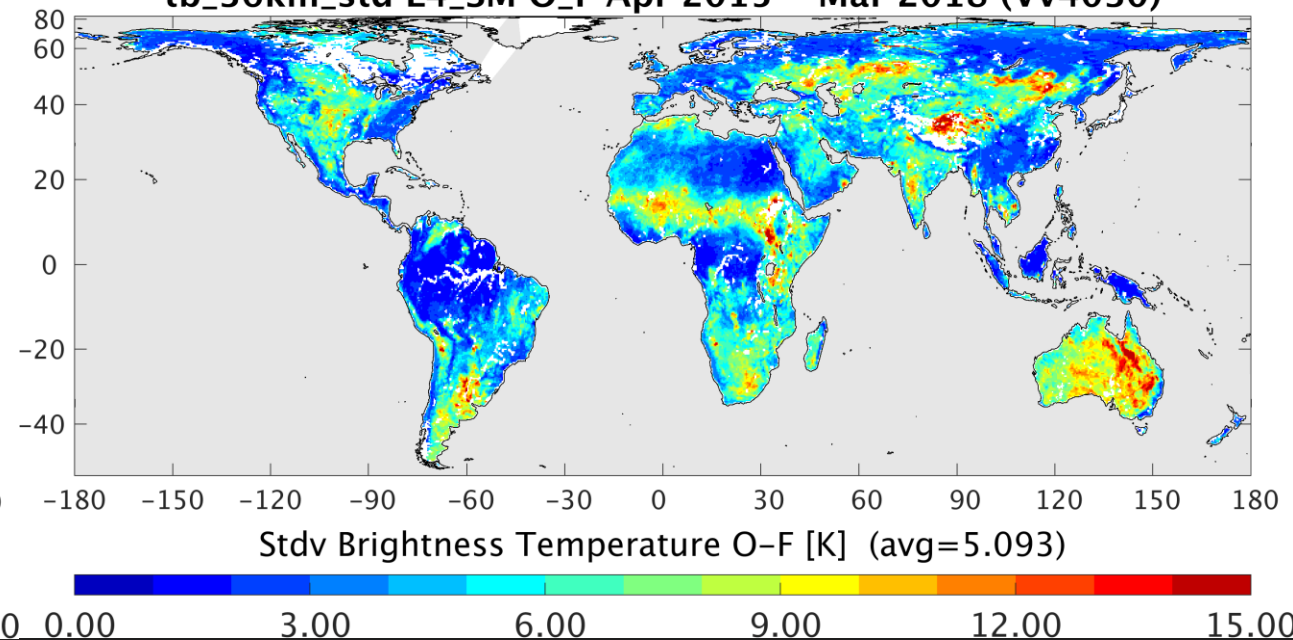
- Improved Tb model forecasts!   (Possibly helped by improved scaling parameters and improved obs.)

O-F

tb_36km_std L4_SM O_Fn Apr 2015 – Mar 2018 (Vv3030)

Stdv Normalized Brightness Temperature O–F [K/K] (avg=1.132)

tb_36km_std L4_SM O_Fn Apr 2015 – Mar 2018 (Vv4030)

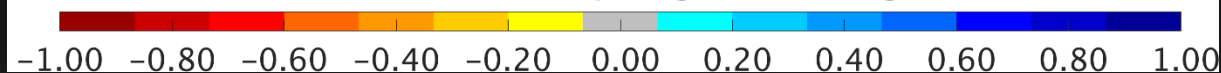Stdv Normalized Brightness Temperature O–F [K/K] (avg=1.015)
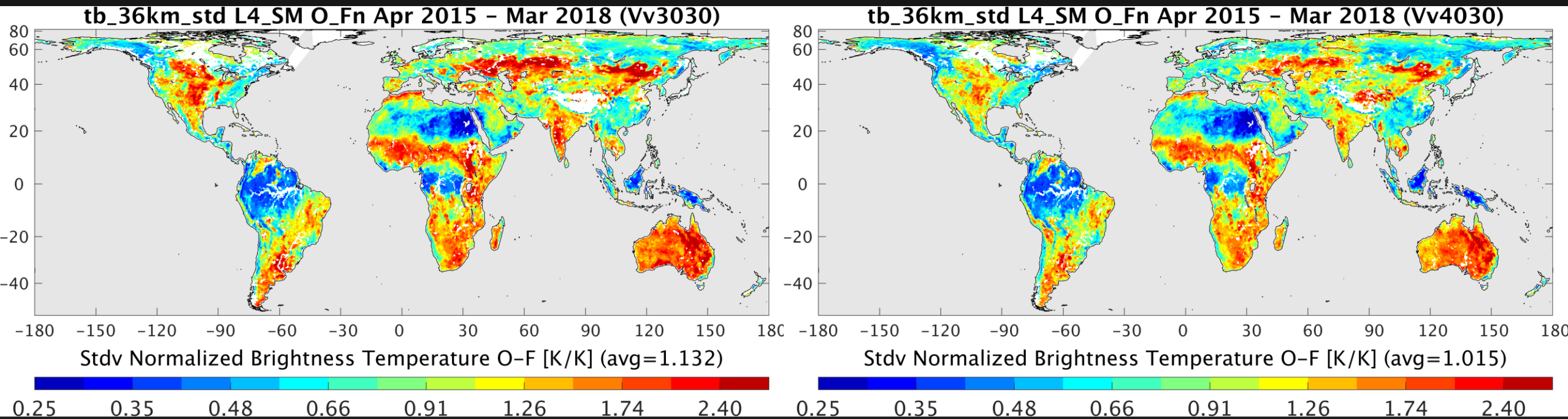
- Actual errors generally better represented, especially in N. American and Eurasian plains (crops & grasslands).
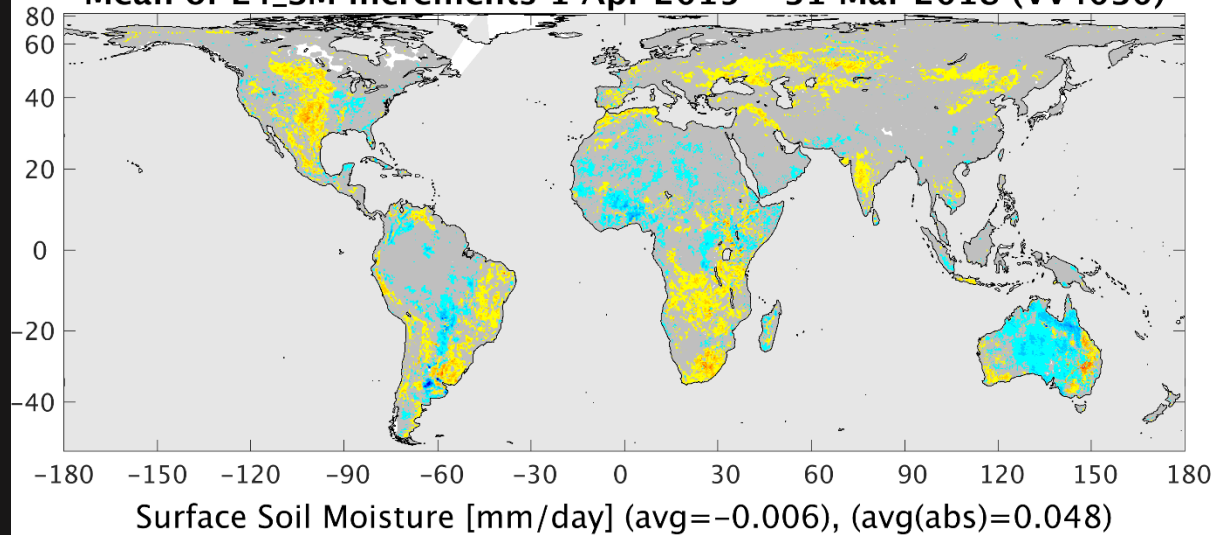
Increments

Mean of L4_SM increments 1 Apr 2015 – 31 Mar 2018 (Vv3030)
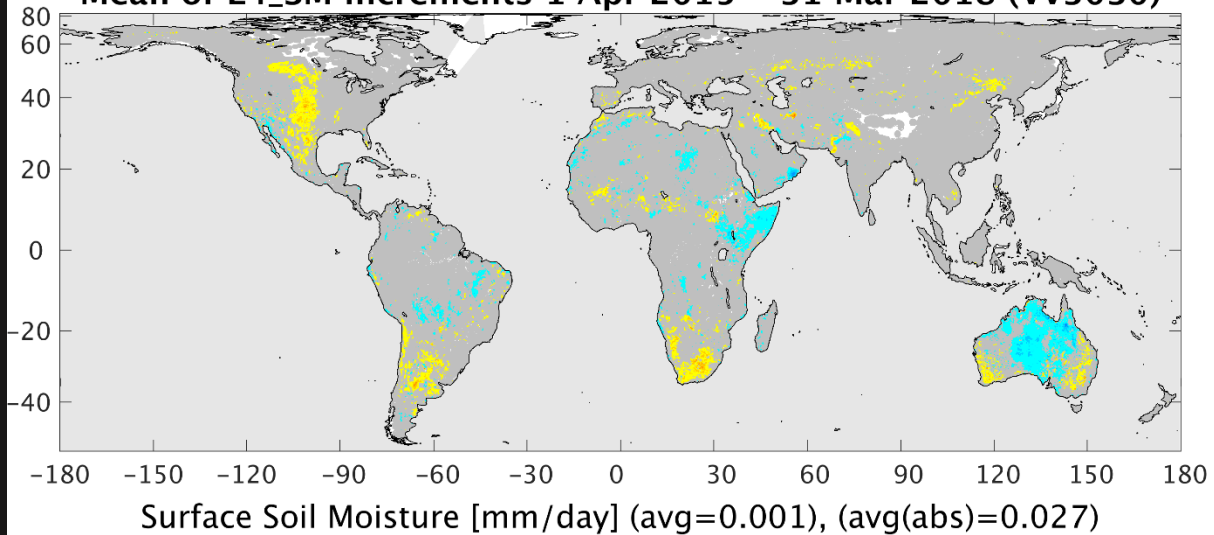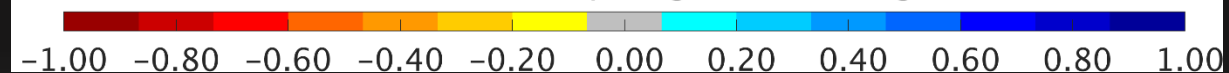

Surface Soil Moisture [mm/day] (avg=0.001), (avg(abs)=0.027)
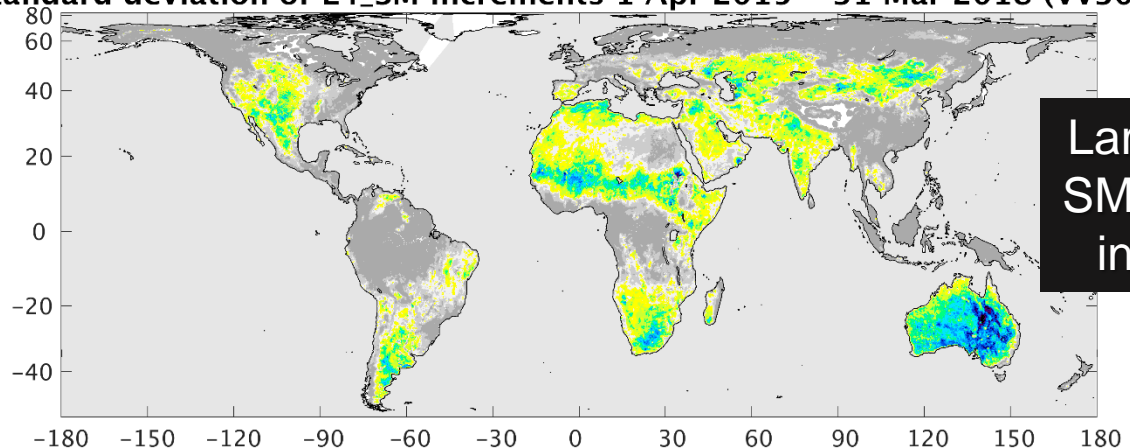
Mean of L4_SM increments 1 Apr 2015 – 31 Mar 2018 (Vv4030)

Surface Soil Moisture [mm/day] (avg=−0.006), (avg(abs)=0.048)

Standard deviation of L4_SM increments 1 Apr 2015 – 31 Mar 2018 (Vv3030)

Surface Soil Moisture [mm/day] (avg=0.073)

Standard deviation of L4_SM increments 1 Apr 2015 – 31 Mar 2018 (Vv4030)

Surface Soil Moisture [mm/day] (avg=0.091)

Larger surface SM increments in Version 4

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Increments

Mean of L4_SM increments 1 Apr 2015 – 31 Mar 2018 (Vv3030)

Root–Zone Soil Moisture [mm/day] (avg=0.069), (avg(abs)=0.152)

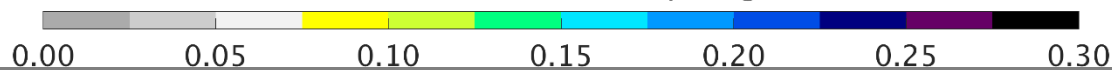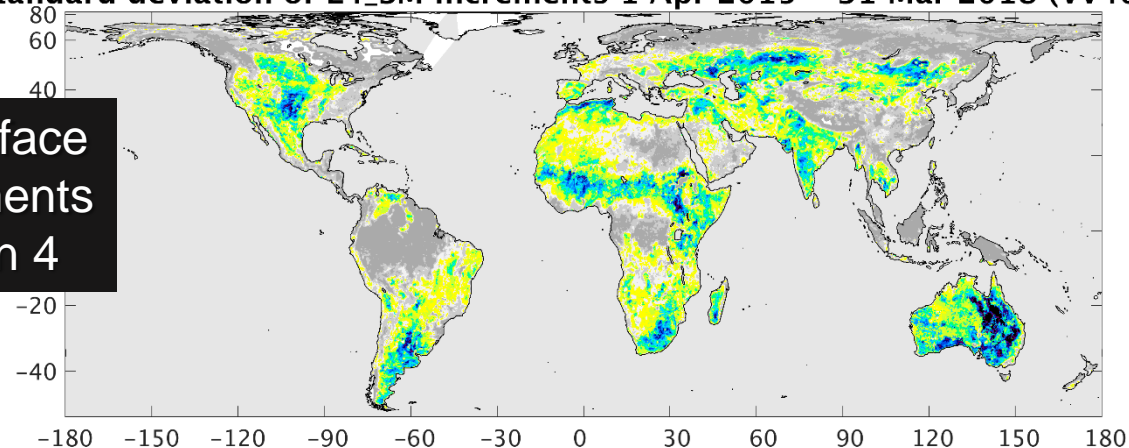**Mean of L4_SM increments 1 Apr 2015 – 31 Mar 2018 (Vv4030)**

Root–Zone Soil Moisture [mm/day] (avg=0.033), (avg(abs)=0.082)

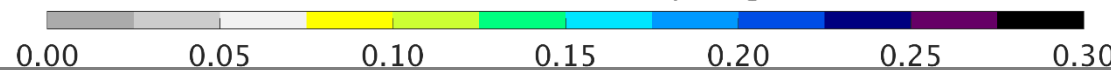**Standard deviation of L4_SM increments 1 Apr 2015 – 31 Mar 2018 (Vv3030)**

Root–Zone Soil Moisture [mm/day] (avg=0.103)

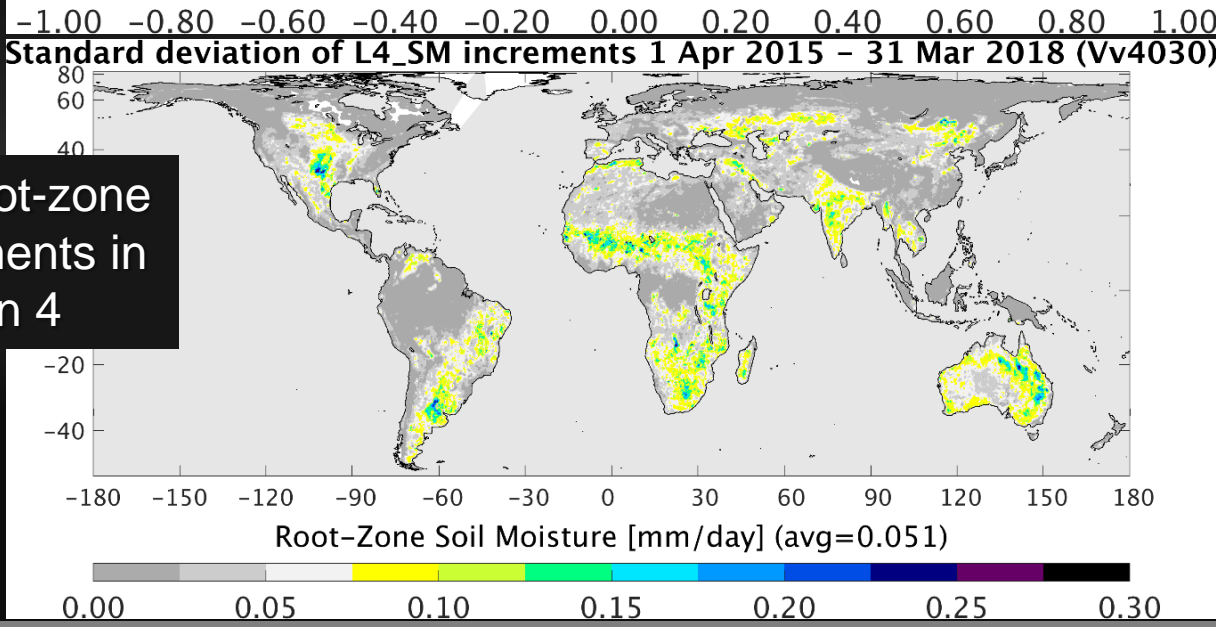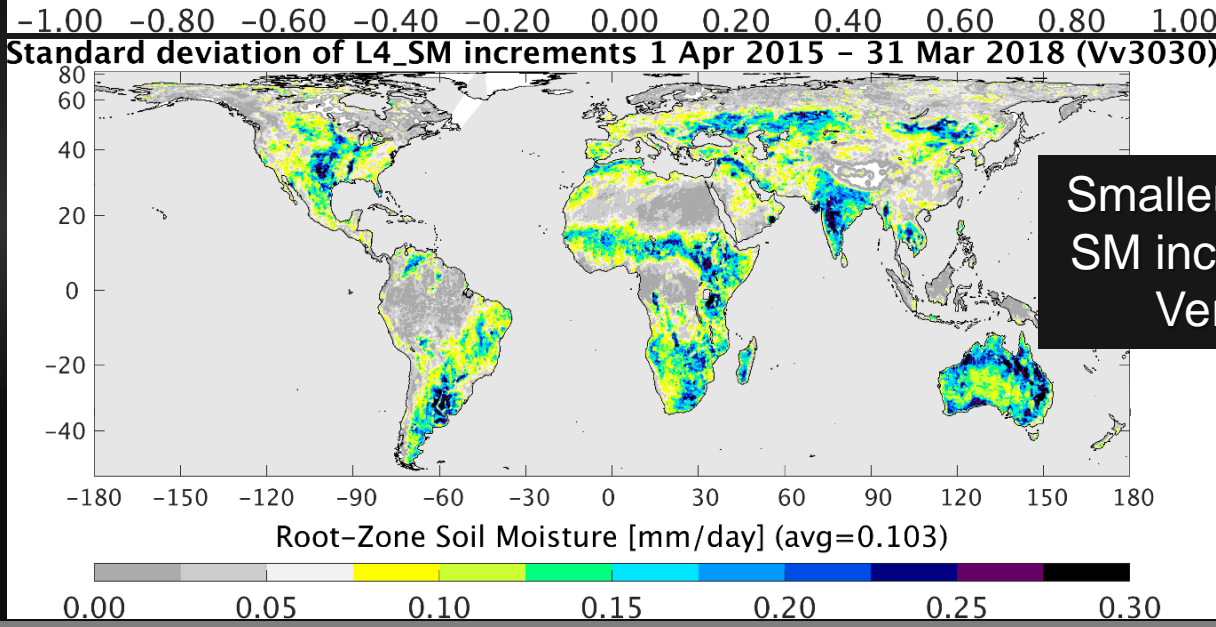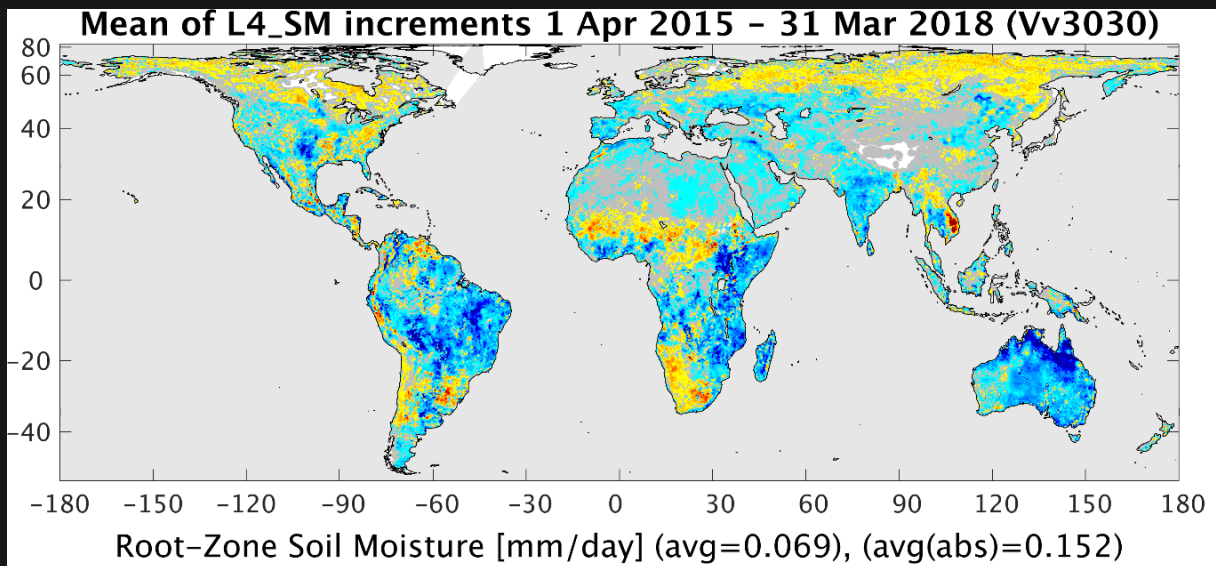**Standard deviation of L4_SM increments 1 Apr 2015 – 31 Mar 2018 (Vv4030)**

Root–Zone Soil Moisture [mm/day] (avg=0.051)

Smaller root-zone SM increments in Version 4

Summary

Version 4 meets requirements for new version:

- Soil moisture ubRMSE < 0.04 m^3 m^{-3} (vs. in situ measurements from 9-km core site reference pixels).
- Skill ~same as Vv3030 (on balance across all in situ metrics and assimilation diagnostics).

Compared to Version 3, Version 4 has slightly:

- drier surface and wetter root zone soil moisture,
- greater runoff ratio and smaller evaporative fraction,
- less biased uncertainty estimates,
- more assimilated SMAP Tb observations,
- smaller root zone soil moisture increments,
- smaller typical O-F values, and
- improved error representation.

Version 4 Validation Document

NASA/TM–2018-104606/Vol. 52

Technical Report Series on Global Modeling and Data Assimilation, Volume 52

Randal D. Koster, Editor

Soil Moisture Active Passive (SMAP) Project Assessment Report for Version 4 of the L4_SM Data Product

Rolf H. Reichle, Qing Liu, Randal D. Koster, Joseph V. Ardizzone, Andreas Colliander, Wade T. Crow, Gabrielle J. M. De Lannoy, and John S. Kimball

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

July 2018

Reichle et al. (2018),

SMAP Project Assessment

Report for Version 4 of the

L4_SM Data Product,

NASA Technical Report Series on

Global Modeling and Data

Assimilation, NASA/TM-2018-

104606, Vol. 52, NASA/GSFC,

Greenbelt, MD, 67pp.

https://gmao.gsfc.nasa.gov/pubs