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National Aeronautics and Space Administration

Improved Peatland Hydrology and L-Band Microwave Radiative Transfer Modeling in Version 7 of the SMAP Level-4 Soil Moisture Data Assimilation Product

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[3]USDA ARS, Beltsville, MD, USA
[4]U. Montana, Missoula, Montana

SMAP Level-4 Soil Moisture (L4_SM)

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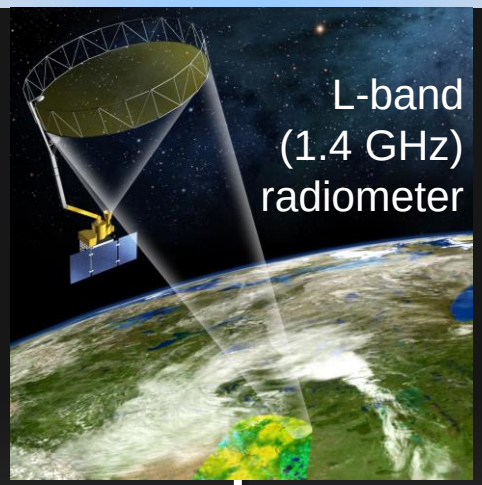
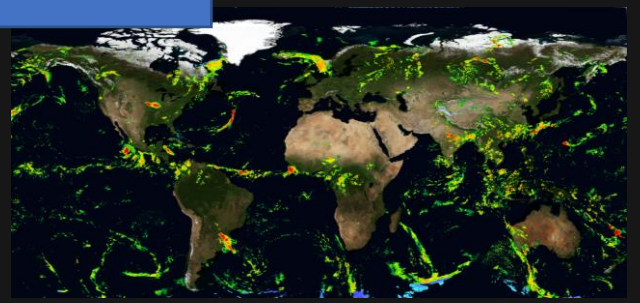
SMAP observations
36-km brightness temperatures



NWP surface meteorology

Precipitation observations

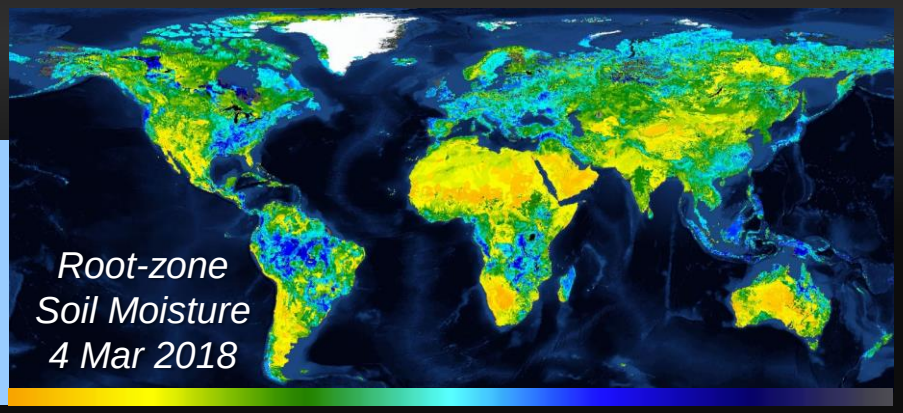
← Brief detour.



Land Model
(9 km)

Data assimilation

L4_SM Product
9-km, 3-hourly, global,
2.5-day latency



Reichle et al. (2019) doi:10.1029/2019MS001729
Reichle et al. (2017a) doi:10.1175/JHM-D-17-0130.1
Reichle et al. (2017b) doi:10.1175/JHM-D-17-0063.1

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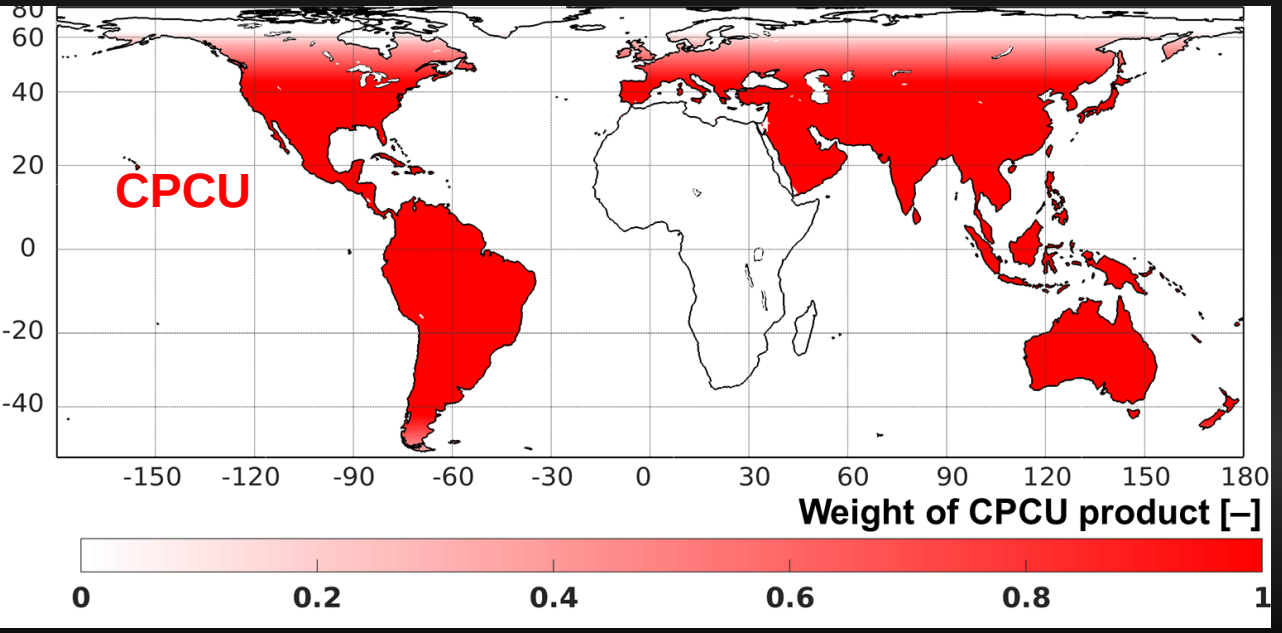
Precipitation Forcing

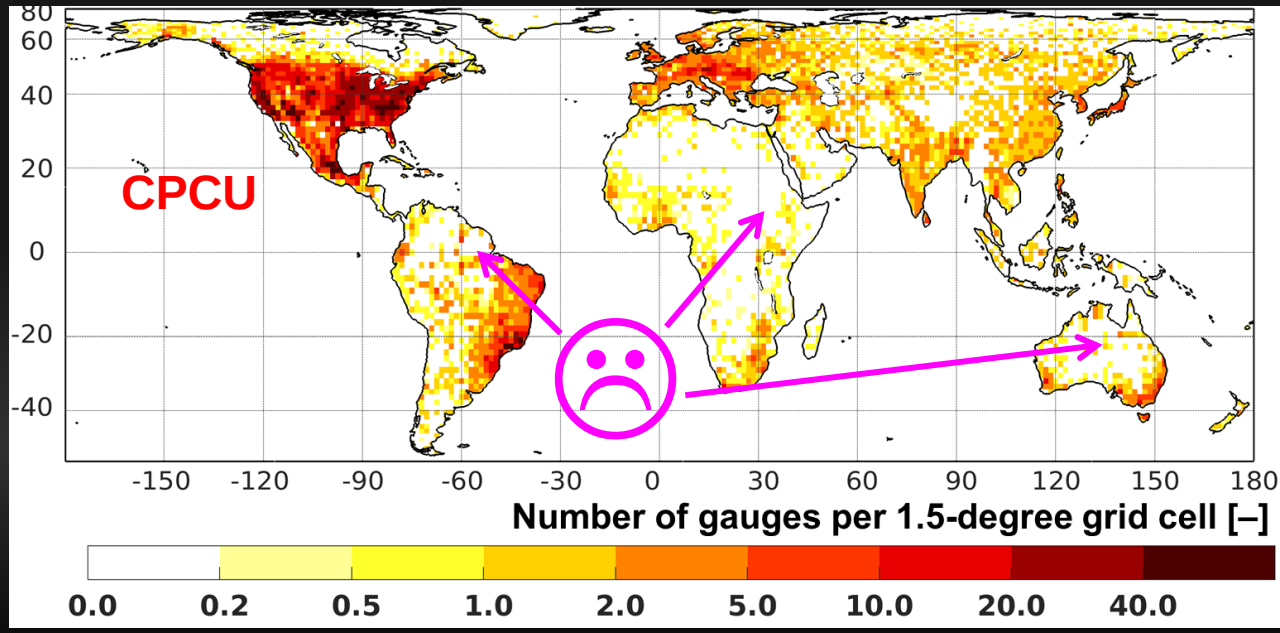
National Aeronautics and Space Administration

Until **Version 5**:

- Use precip. obs. from CPCU gauge product

  … except in Africa and high lats (few gauges).





Reichle & Liu (2021), NASA Tech Report TM-2022-104606, Vol. 59
Reichle et al. (2022), NASA Tech Report TM-2022-104606, Vol. 60
Available at: https://gmao.gsfc.nasa.gov/pubs/

Precipitation Forcing

National Aeronautics and Space Administration

Until **Version 5**:

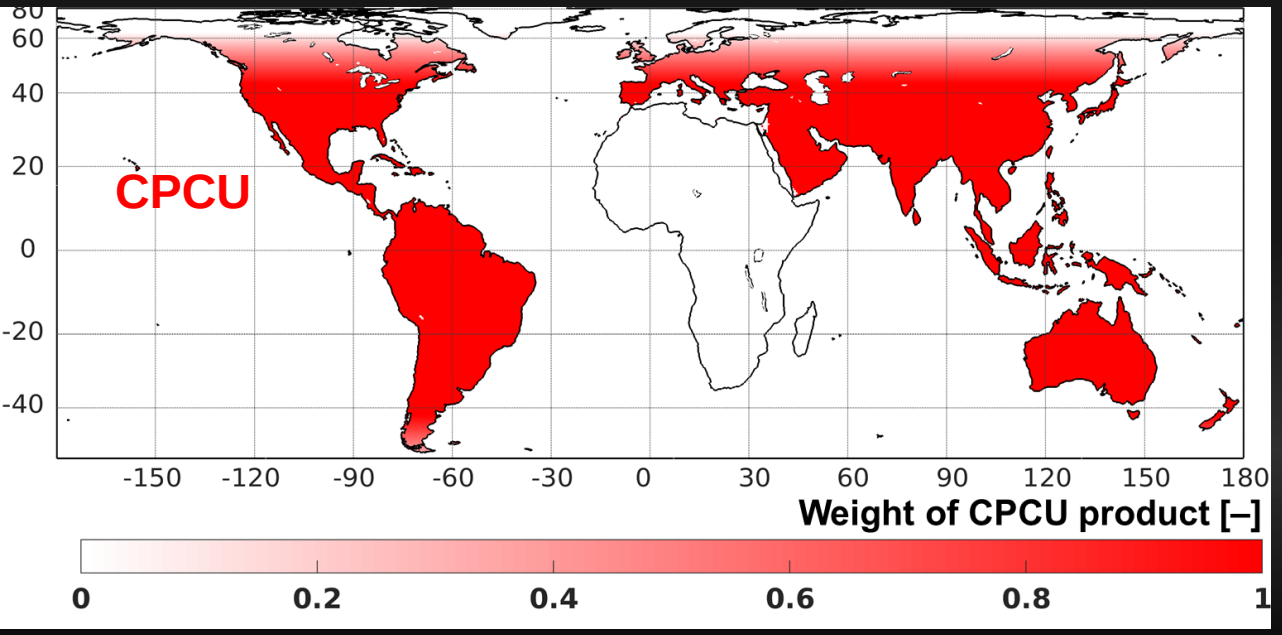
- Use precip. obs. from CPCU gauge product

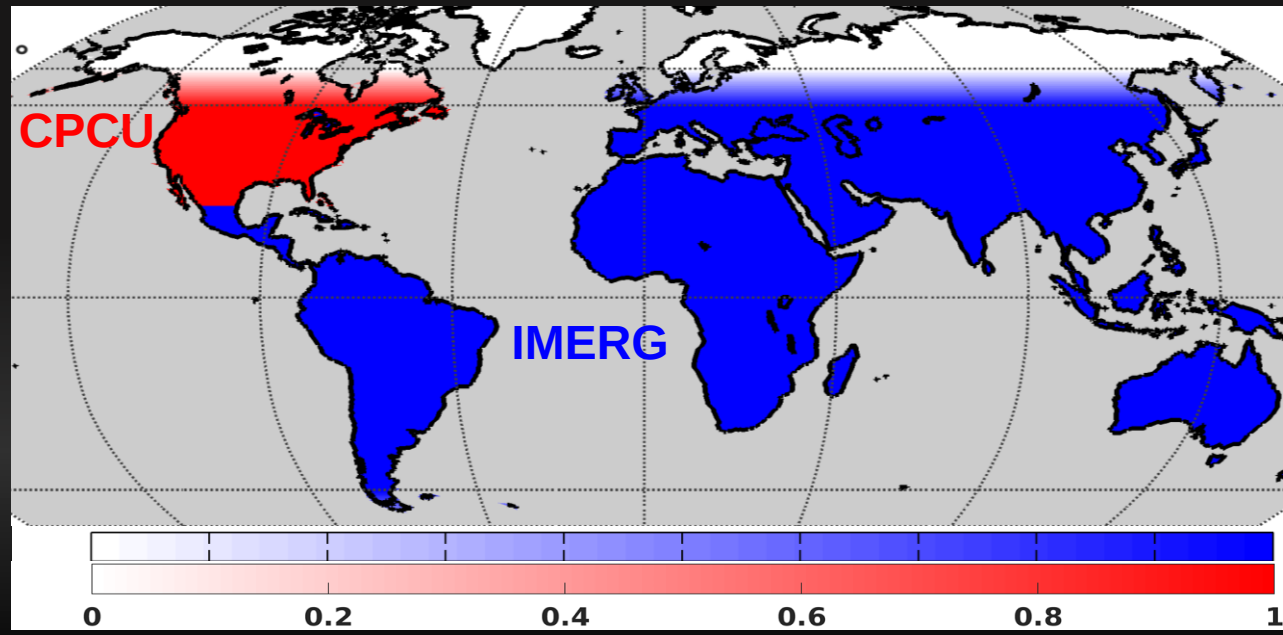
  … except in Africa and high lats (few gauges).

Since **Version 6** (released Nov 2021):

- Use IMERG satellite+gauge product

  …except N. America but incl. Africa.





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Impact of IMERG Precipitation

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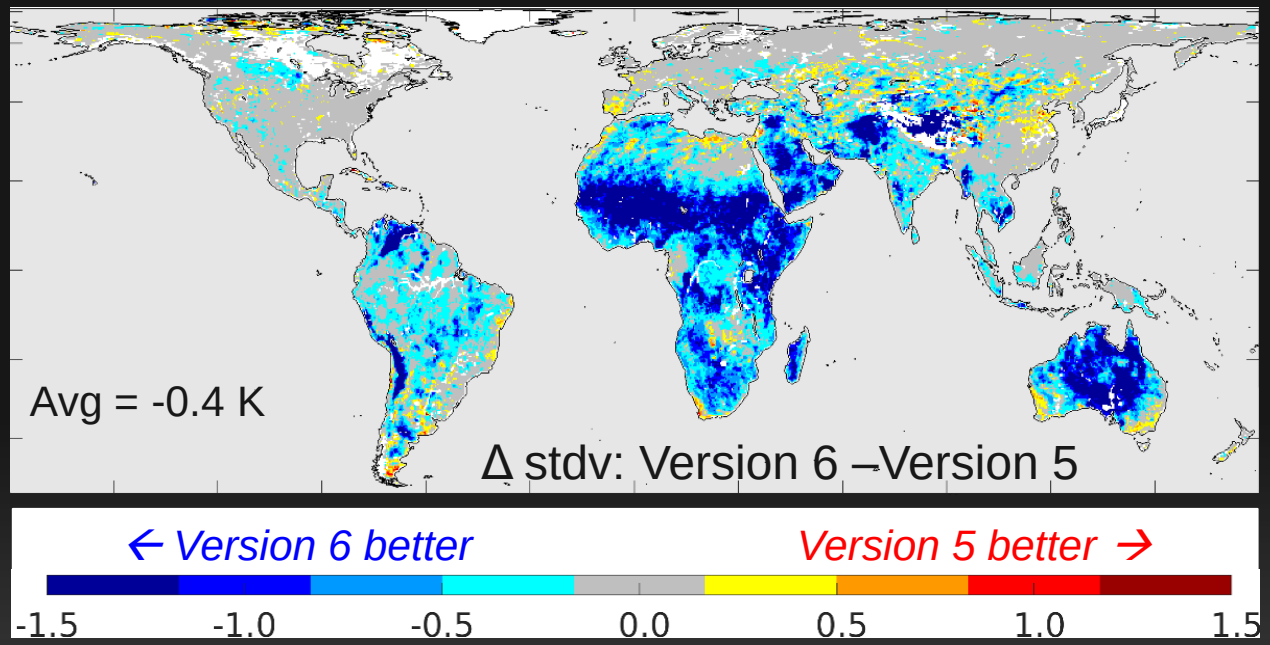
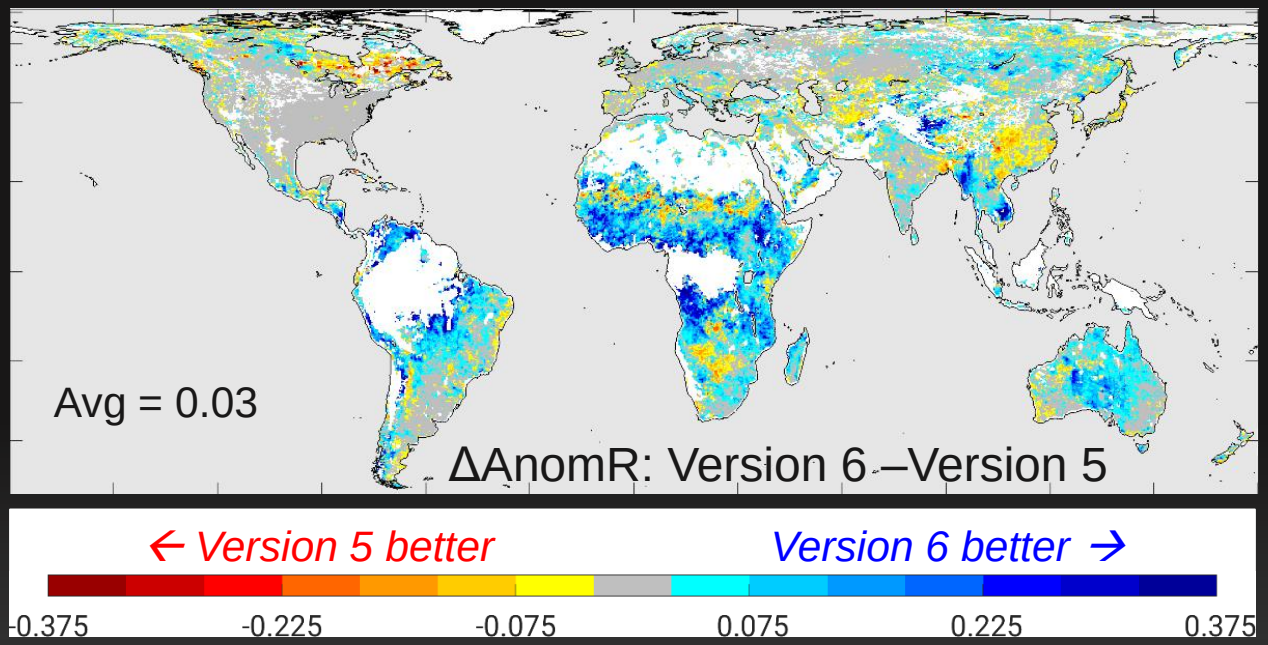
Δ stdv of Tb observation-minus-forecast residuals:

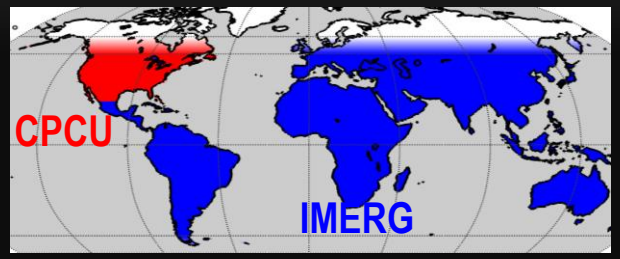


→ IMERG improves simulated Tb.

Δ anomaly correlation skill of surface soil moisture (ASCAT retrievals used as "instrumental variable"):



→ IMERG improves surface soil moisture anomaly skill.



Largest improvements across S. Hemishere.

Reichle & Liu (2021), NASA Tech Report TM-2022-104606, Vol. 59
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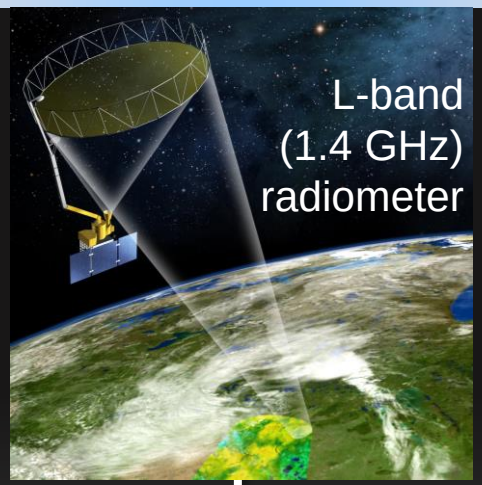
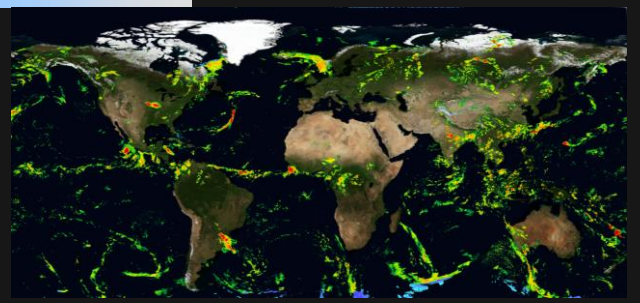
36-km brightness temperatures



NWP surface meteorology

Precipitation observations

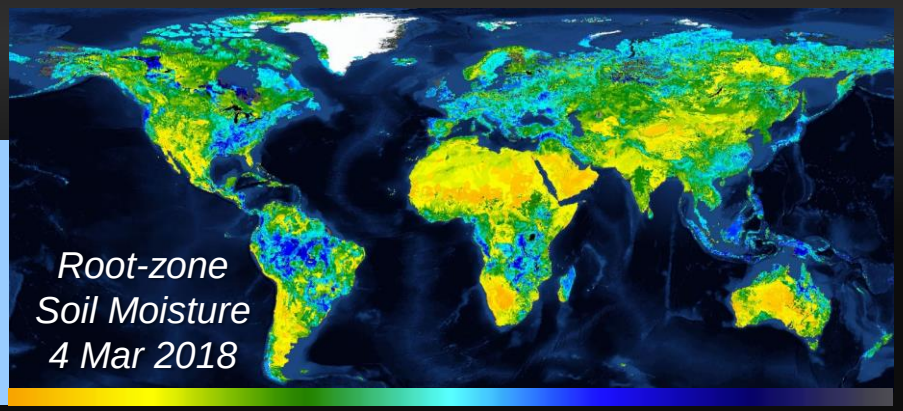


Land Model
(9 km)

Data assimilation

Revised parameters in microwave radiative transfer model.

L4_SM Product
9-km, 3-hourly, global,
2.5-day latency



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L-band Radiative Transfer Model (RTM) Parameters

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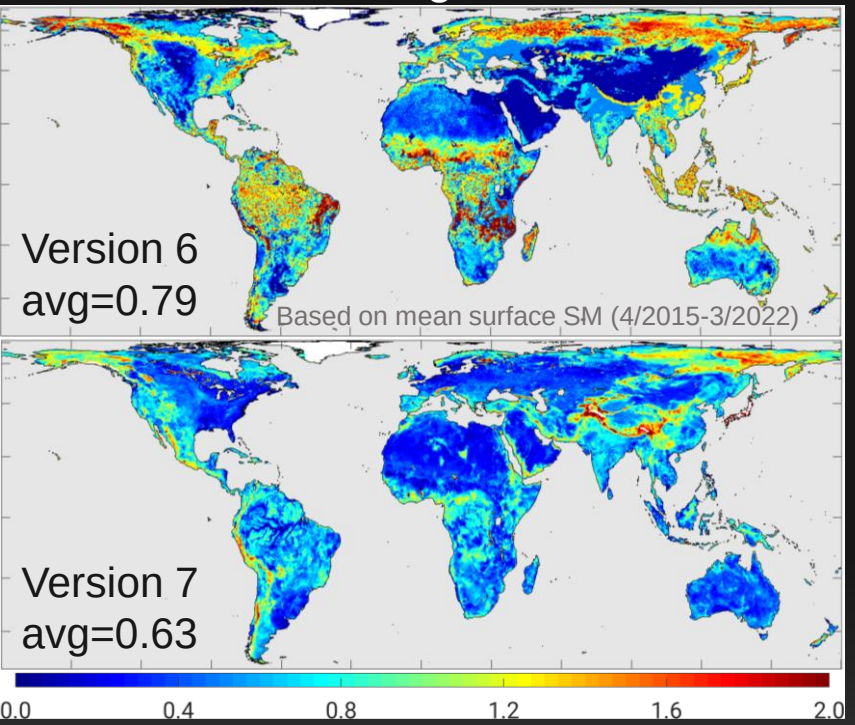
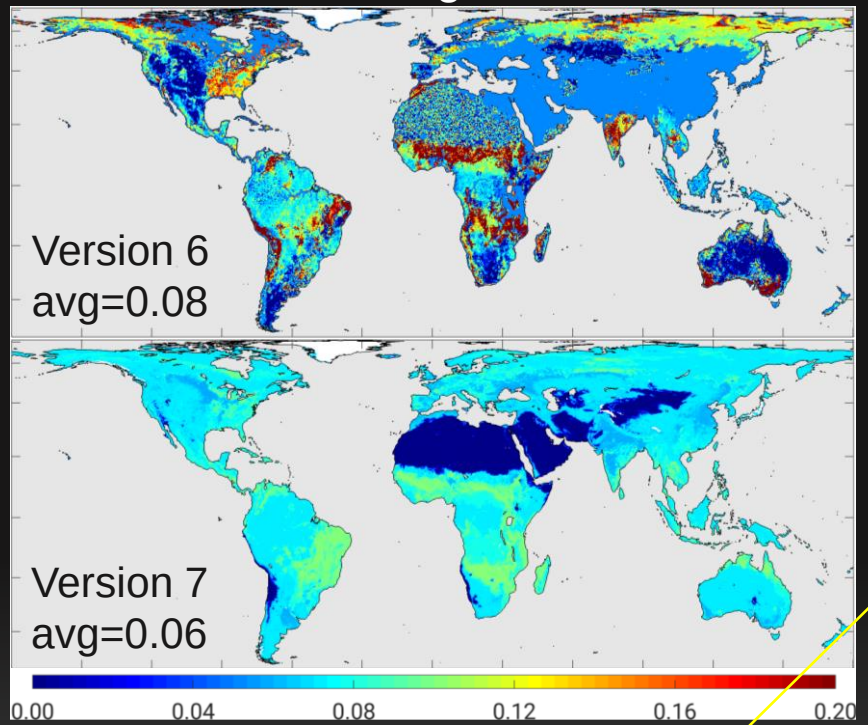
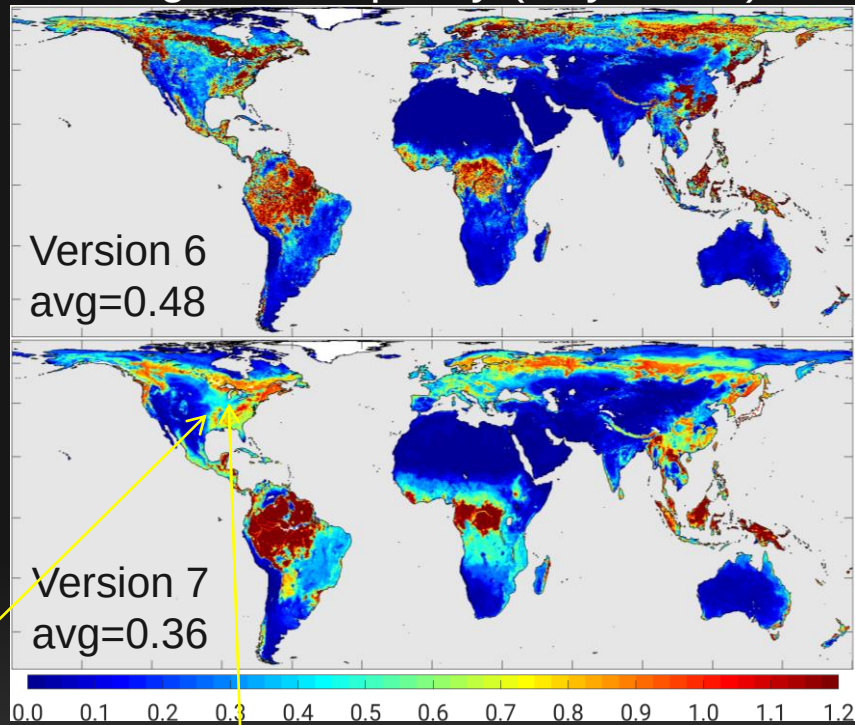
Soil roughness



Scattering albalbedo

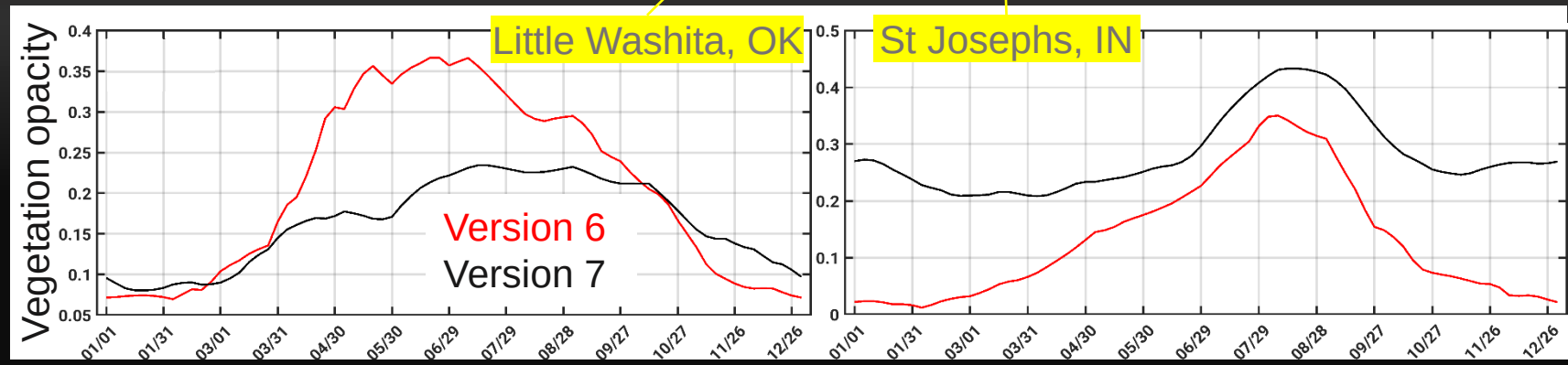


Vegetation opacity (July 20-27)



Version 6: Calibrated using multi-angular SMOS Tb. Climatology of vegetation opacity based on NDVI.

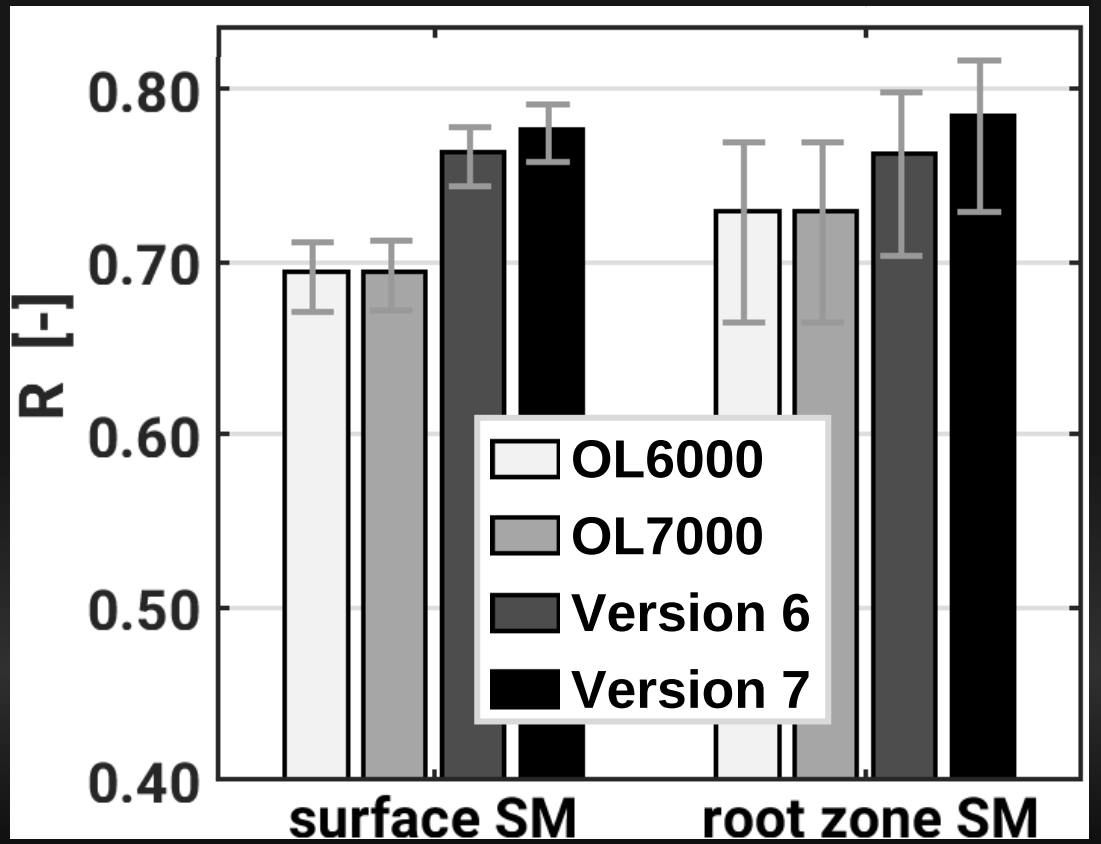
Version 7: Climatology from SMAP L2 dual-channel retrievals.



Validation vs. In Situ Measurements

L2-based RTM parameters slightly improve time series correlation of…

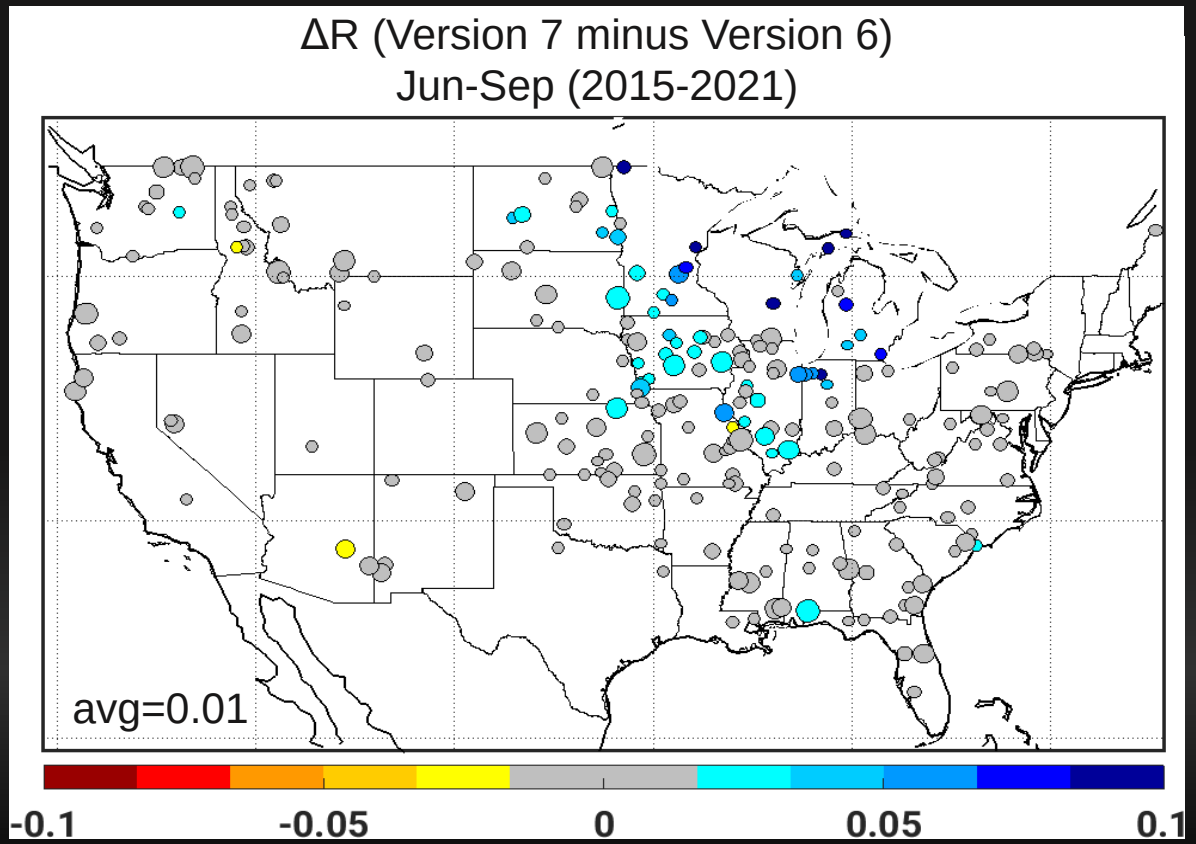
soil moisture



Average R across 18 SMAP core site 9-km ref. pixels.

Result corroborated with measurements from 36-km reference pixels and 428 sparse network sites.

and runoff.



R vs. USGS gauge measurements of streamflow in 238 small basins.

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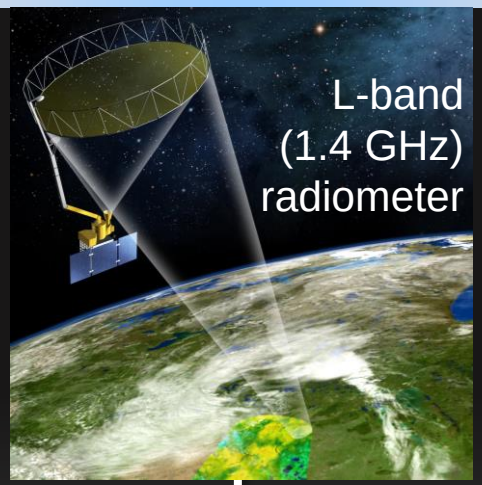

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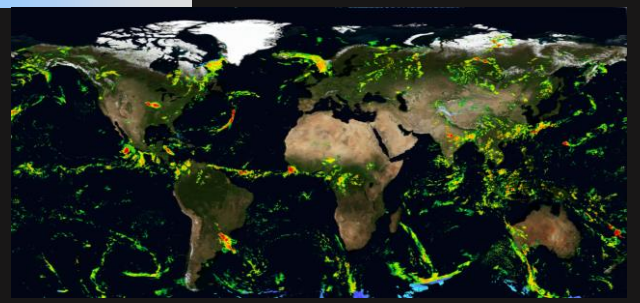
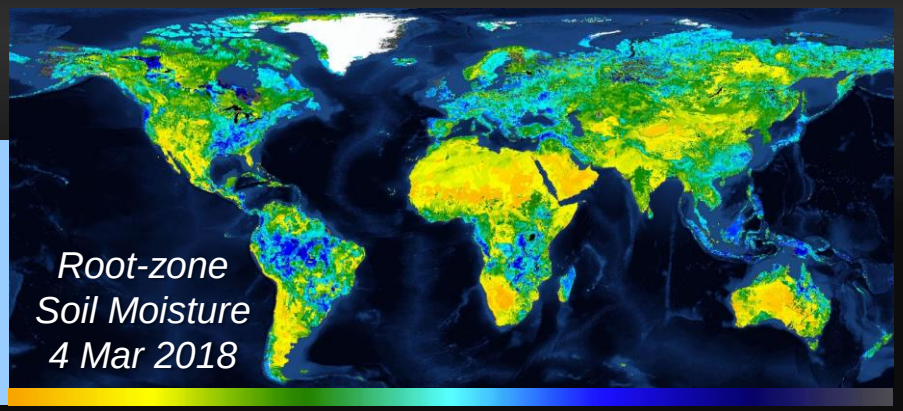


Land Model
(9 km)

Revised peatland hydrology & distribution.

Data assimilation

L4_SM Product
9-km, 3-hourly, global,
2.5-day latency



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

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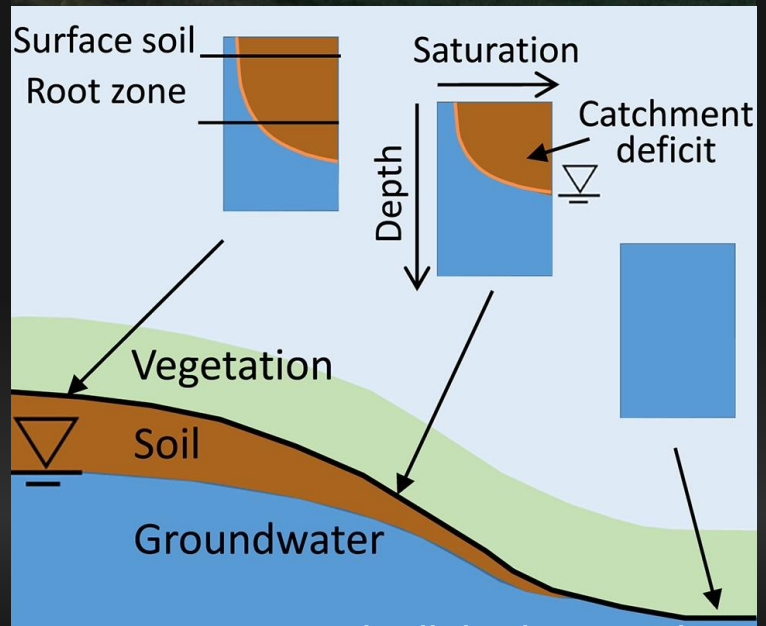
Catchment Land Surface Model (CLSM)

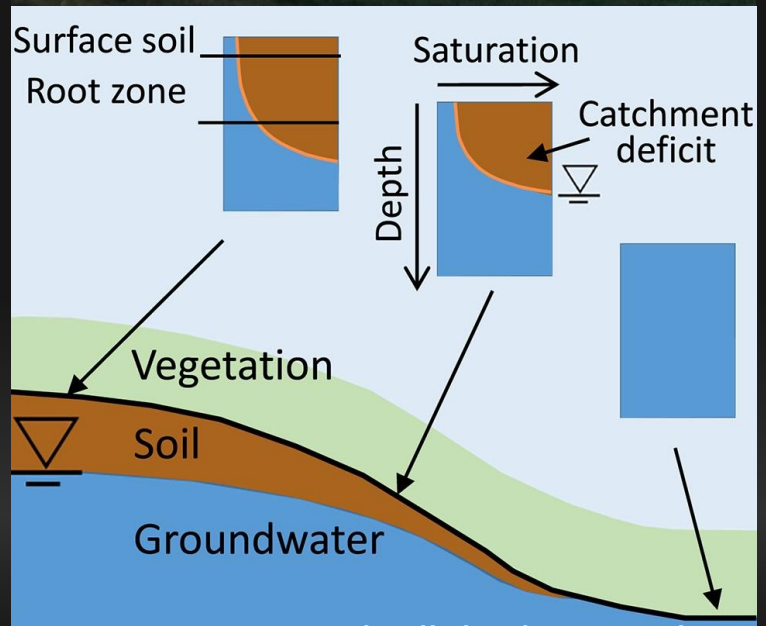


- Wetness at a point linked to terrain slope and upstream area.
- Spatial integration across catchment (characterized by distribution of slope and upstream area).

Koster et al. (2000) doi:10.1029/2000JD900327
Bechtold et al. (2019) doi:10.1029/2018MS001574
Bechtold et al. (2020) doi:10.1016/j.rse.2020.111805

Peatland-specific Hydrology Module (PEATCLSM)

Catchment Land Surface Model



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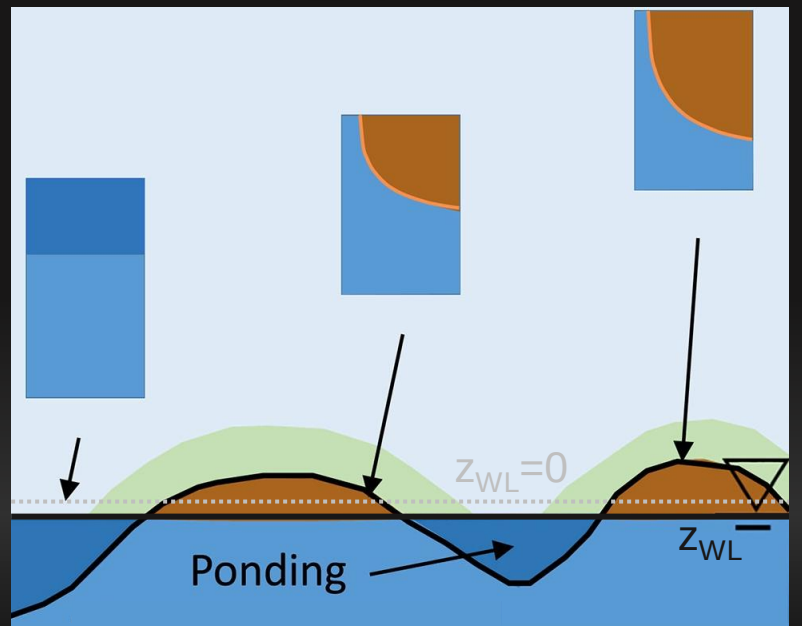
PEATCLSM



- Spatial integration across micro-topography.
- Peatland-specific hydraulic properties, macropore infiltration, discharge function, and water limitation of ET.

Koster et al. (2000) doi:10.1029/2000JD900327
Bechtold et al. (2019) doi:10.1029/2018MS001574
Bechtold et al. (2020) doi:10.1016/j.rse.2020.111805

Peatland Distribution

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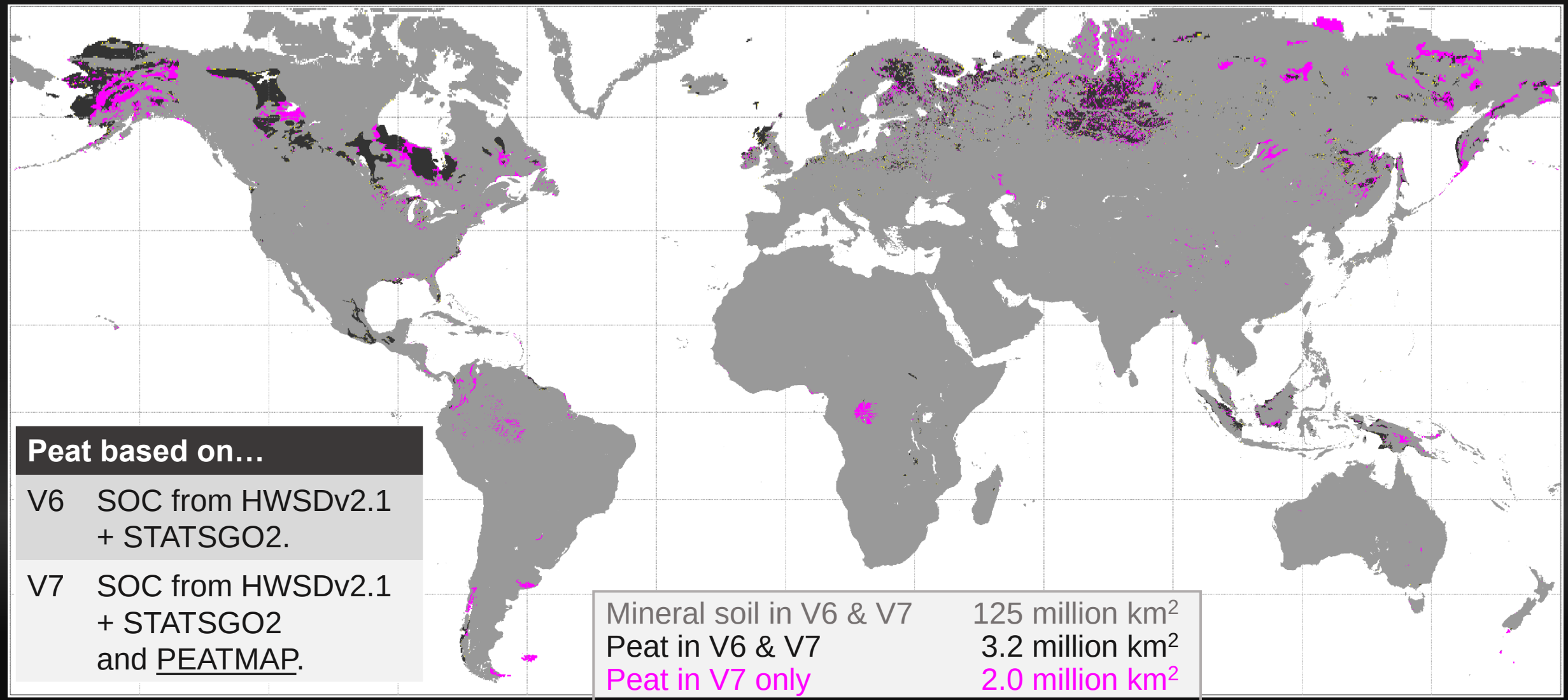

Peat based on…	
V6	SOC from HWSDv2.1 + STATSGO2.
V7	SOC from HWSDv2.1 + STATSGO2 and PEATMAP.

Mineral soil in V6 & V7	125 million km^2
Peat in V6 & V7	3.2 million km^2
Peat in V7 only	2.0 million km^2
Peat in V6 only	0.2 million km^2

Peatland Soil Moisture Climatology

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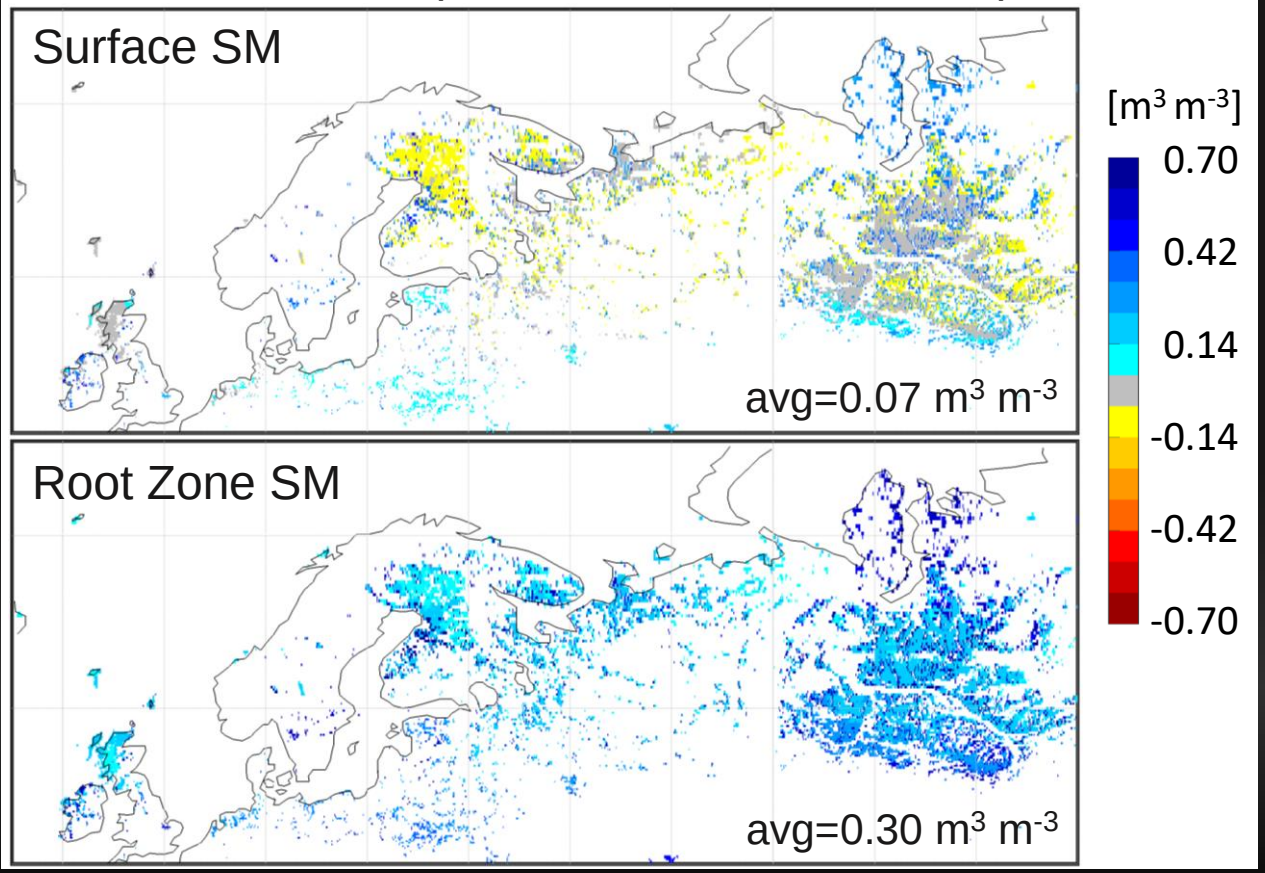
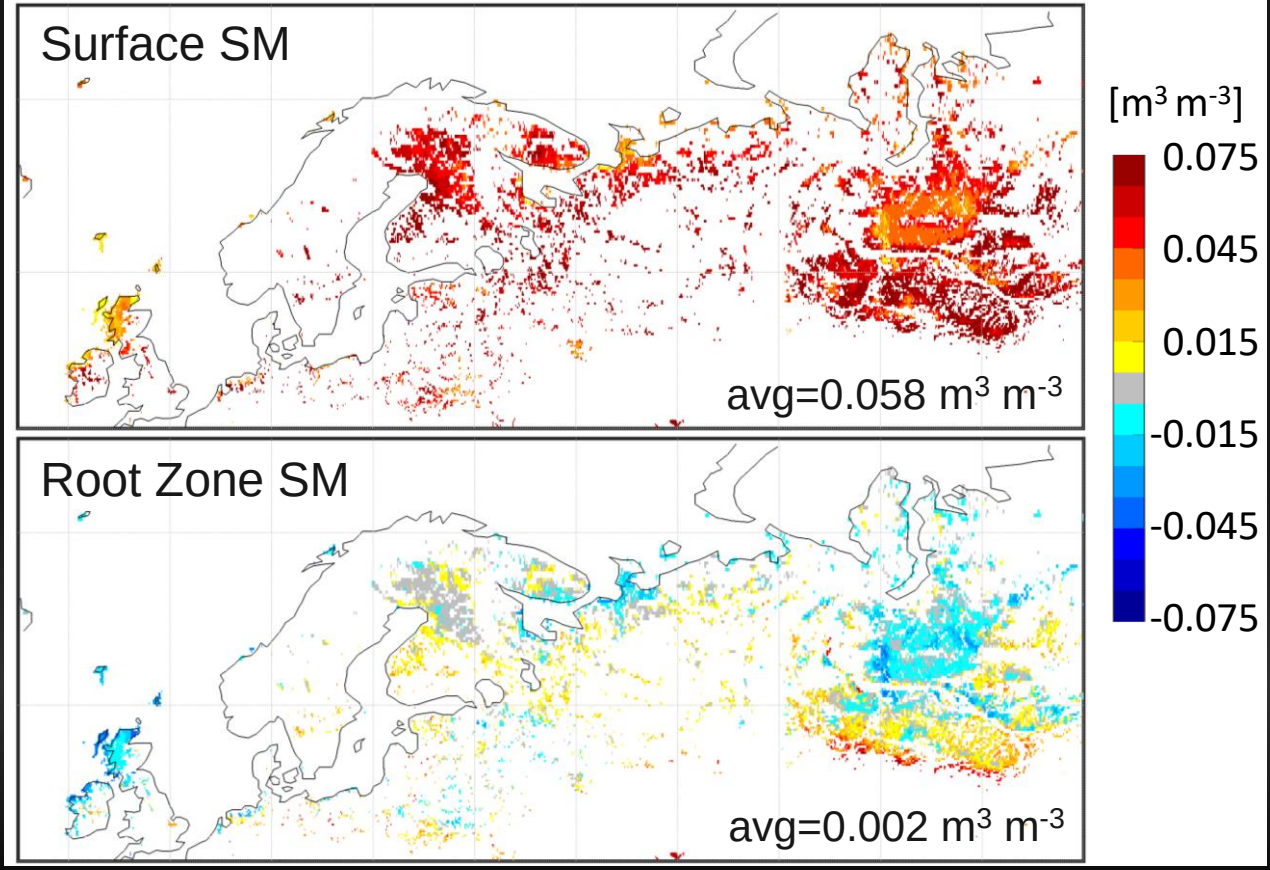
Δ Mean (Version 7 minus Version 6)



Δ Std-dev (Version 7 minus Version 6)



Version 7 has much wetter root zone soil moisture

and much more variable surface soil moisture.

Peatland Water Level* Climatology

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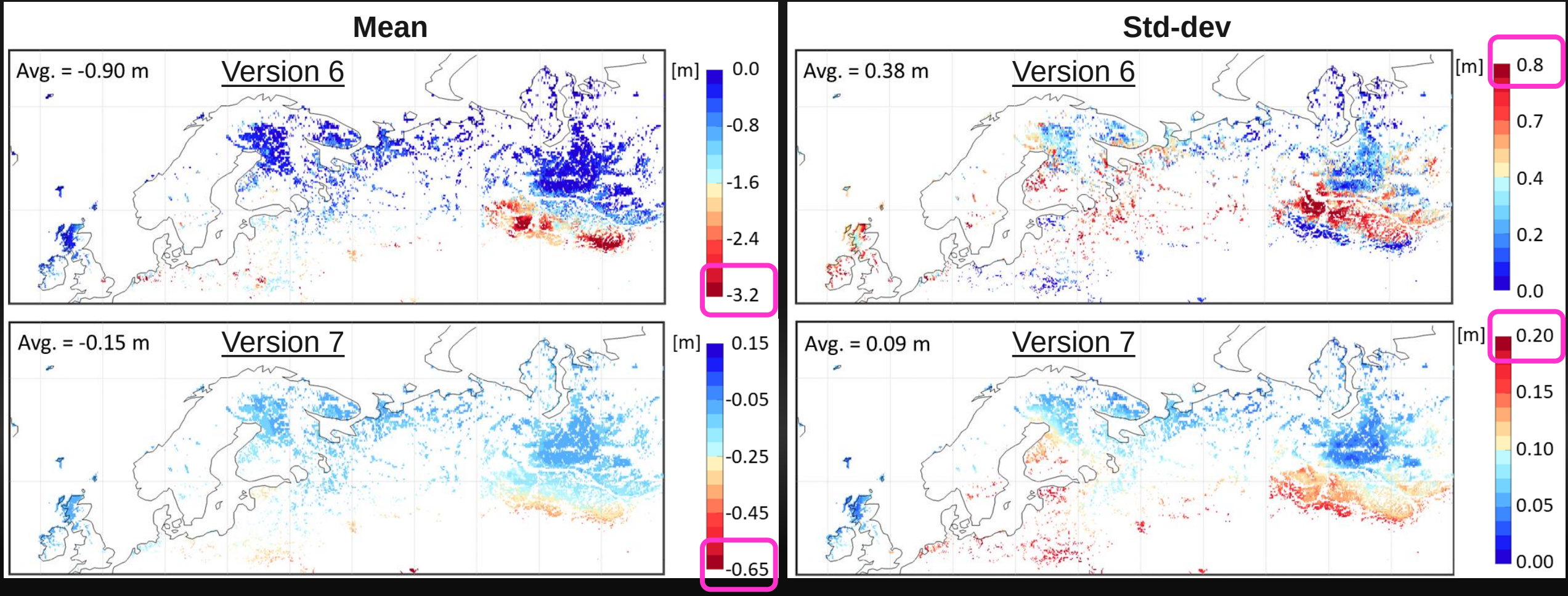
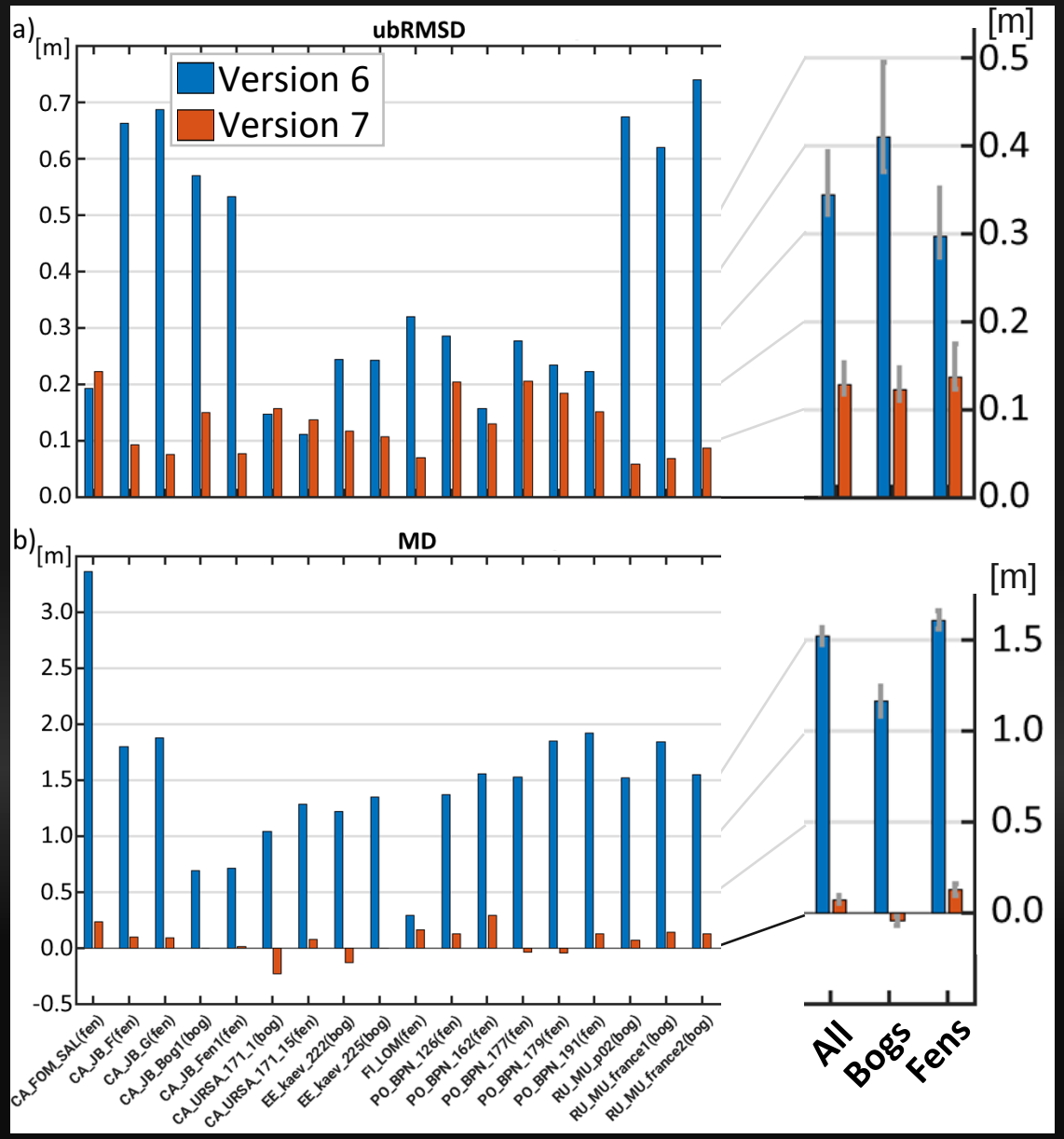
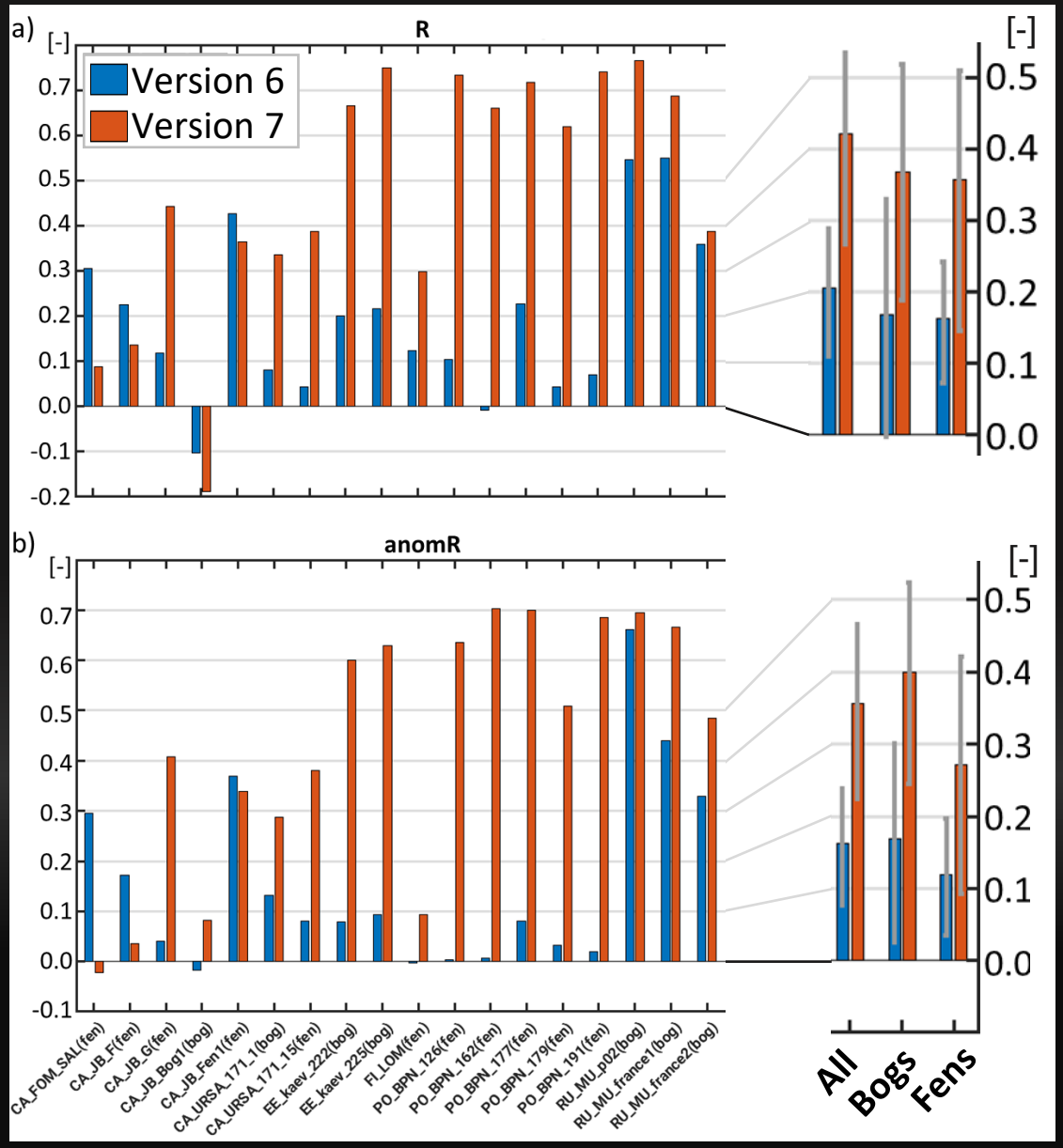
Version 7 has far more realistic peatland water level mean and variations.



*Water level not reported in L4_SM Version 6 output because of shortcomings in the CLSM water level diagnostic. Climatology shown above computed from single-member, model-only ("Nature Run") simulations of the Version 6 and Version 7 modeling systems (4/2015-3/2022).

Peatland Water Level* vs. In Situ Measurements





Version 7 far better simulates peatland water levels for bogs and fens.

*Metrics computed from Nature Run simulations (2008-2018).

Δ Stdv Tb O-F Residuals* (Version 7 minus Version 6)

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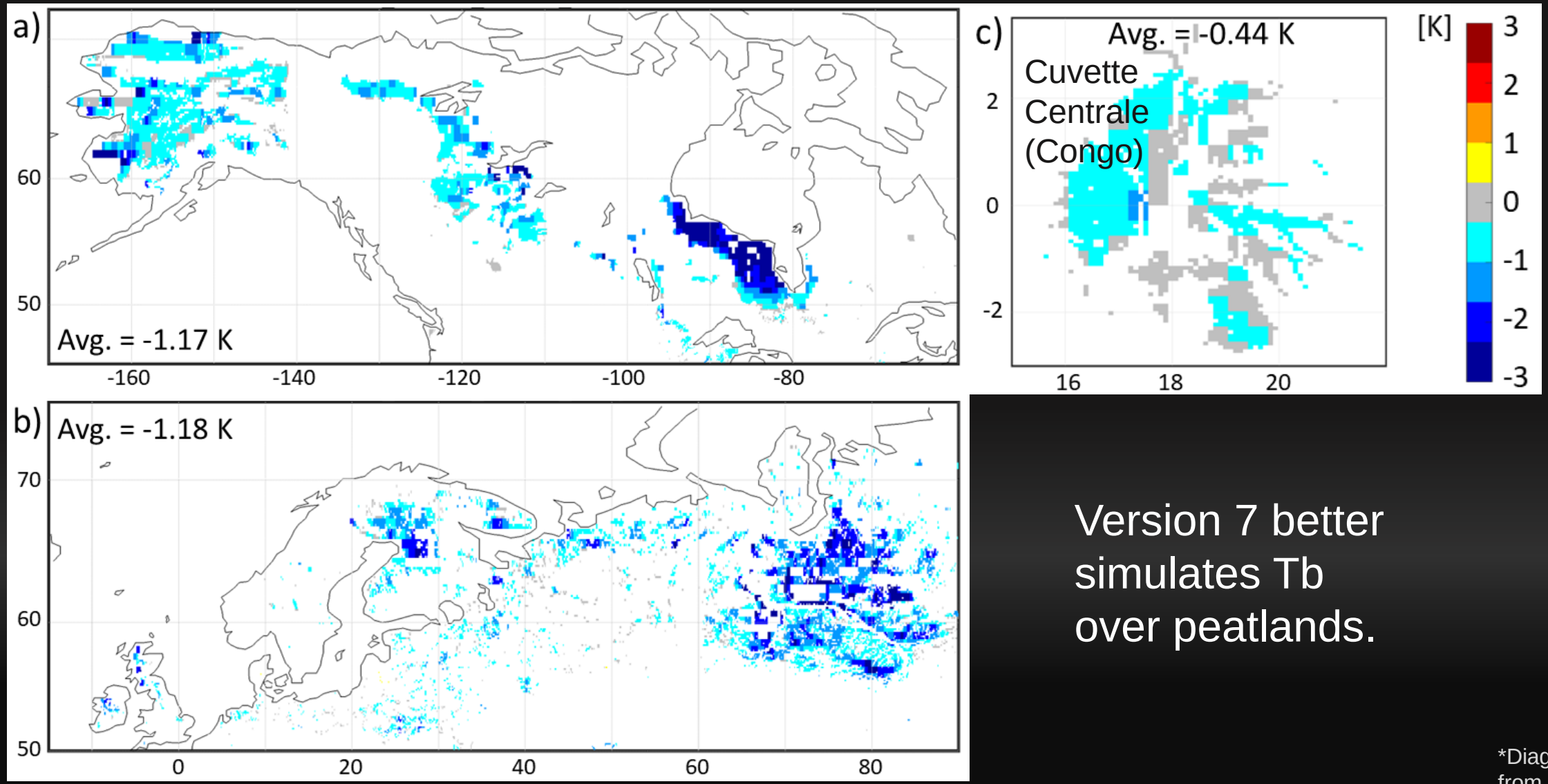
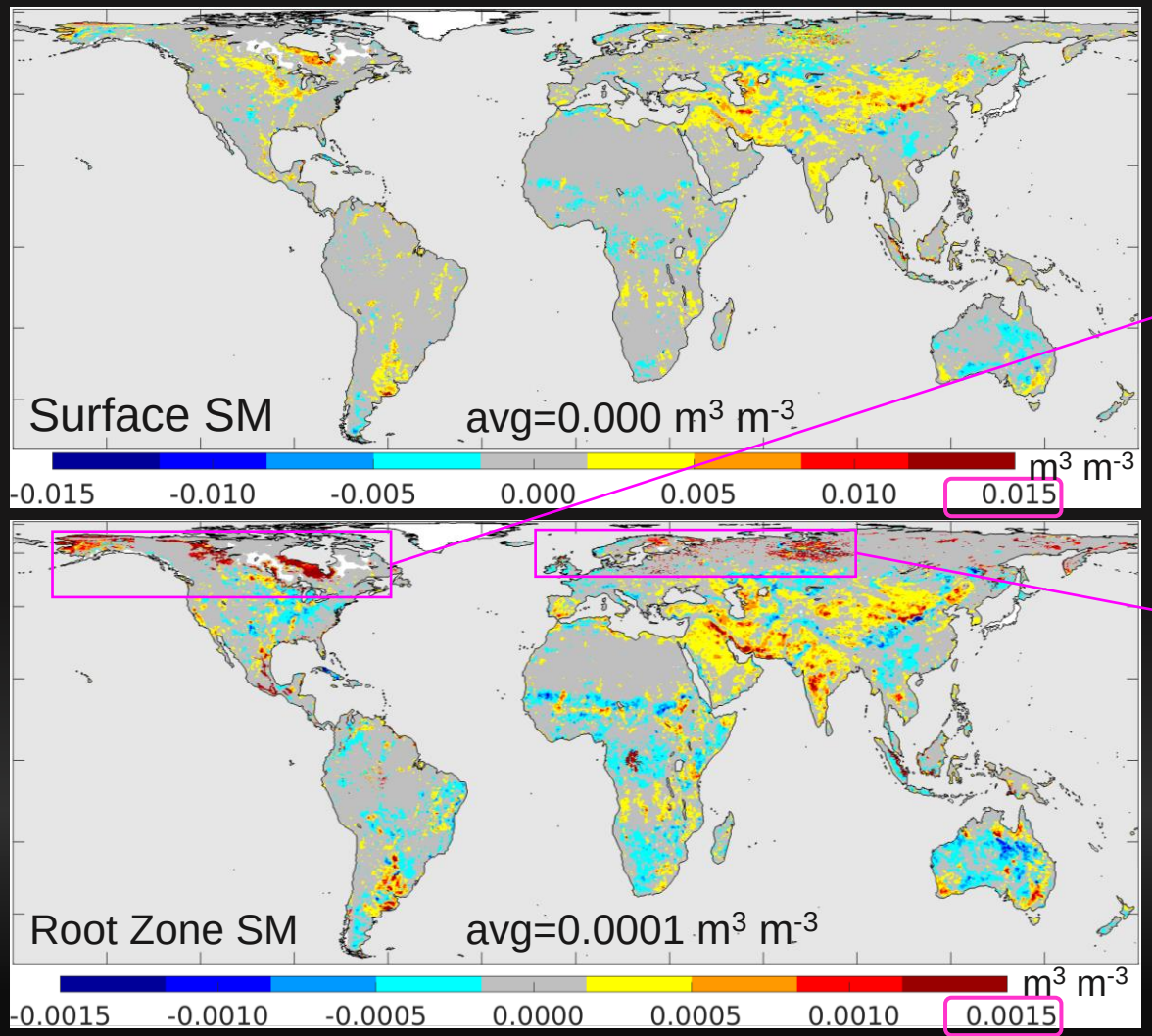
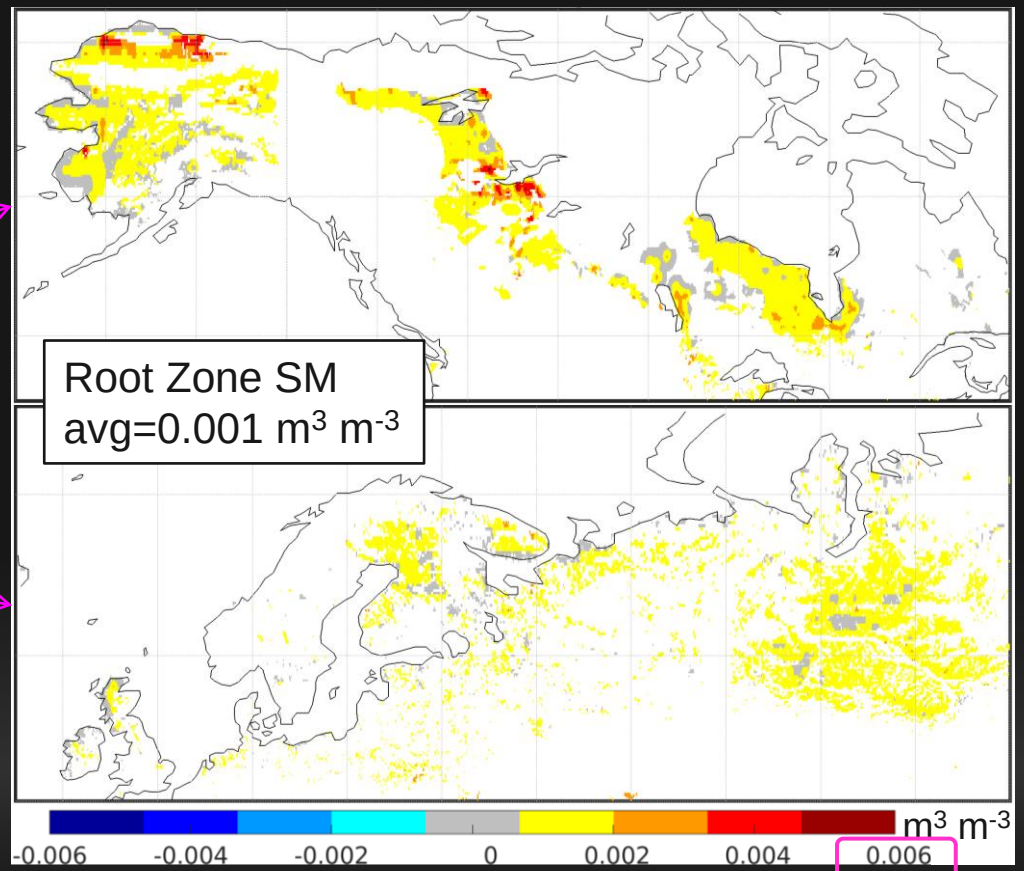


Version 7 better simulates Tb over peatlands.

*Diagnostics computed from L4_SM products (4/2015-3/2022).

Soil Moisture Increments: Δ Stdv





In Version 7, “catdef” model prognostic variable added to EnKF state vector in peatlands.

→ Larger root zone soil moisture increments.

Summary and Conclusion

IMERG precipitation considerably improves soil moisture, particularly in S. Hemisphere:

- Improved time series anomaly correlation for surface soil moisture (global avg = +0.03).
- Reduced Tb O-F std-dev (global avg = -0.4 K).

Climatological L-band soil roughness, scattering albedo, and (seasonally varying) vegetation opacity from SMAP L2 retrievals:

- Improved soil moisture time series correlation vs. in situ measurements.

Revised peatland hydrology and distribution:

- Greatly improves water level simulation in peatlands.
- Reduced Tb O-F std-dev in peatlands (typically -1 K).

Version 7 Validation Report in preparation.

Thanks for listening!