

SMAP L4_SM Version 5

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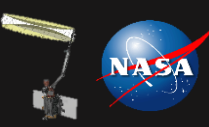
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³Division of Soil and Water Management, KULeuven, Leuven, Belgium

⁴College of Forestry & Conservation, University of Montana, Missoula, MT

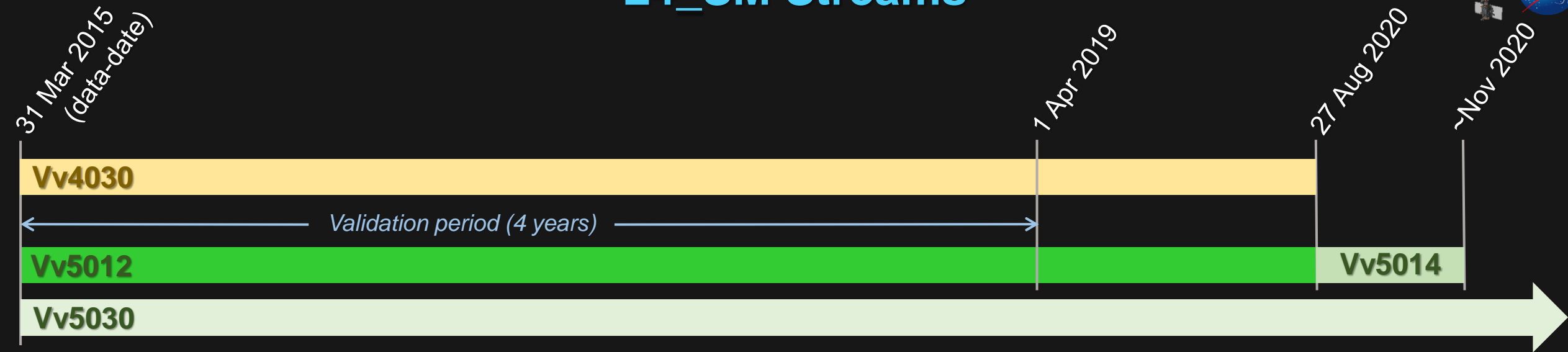
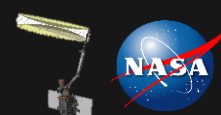
*Rolf.Reichle@nasa.gov

Outline



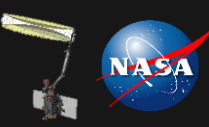
1. Overview and Status
2. Model and Analysis Changes
3. Climatology
4. In Situ Validation
5. Assimilation Diagnostics
6. Summary

L4_SM Streams



| L4_SM Stream | Data Period | Production Status | Description |
|--------------|---------------------------|------------------------------|---|
| Vv4030 | 31 Mar 2015 – 26 Aug 2020 | Complete | Version 4 ops |
| Vv5012 | 31 Mar 2015 – 26 Aug 2020 | Complete | Version 5 ops (“preliminary” reprocessing) using L1C_TB inputs from “OASIS” R17 test data (T16[516,518,700]) |
| Vv5014 | 27 Aug 2020 – ... | On-going | Version 5 ops (initial forward processing stream) |
| Vv5030 | 31 Mar 2015 – ... | Planned, starting ~Sep 2020* | Version 5 ops (“official” reprocessing) using R17 ops Tb; once caught up to present (~Nov 2020*), Vv5030 replaces Vv5012 & Vv5014 |

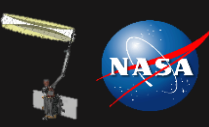
*TBD, pending decision on updates in scaling parameters or mwRTM parameter calibration.



L4_SM Documentation

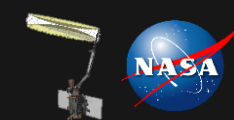
- Product Specs *(unchanged)*
- User Guide *(delivered to NSIDC)*
- ATBD *(unchanged)*
- Validation Report
 - Slides *(complete; this presentation)*
 - Written Report *(in progress)*

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Changes in L4_SM Modeling System (“NRv[x]”)



Only minor science changes in land model between Versions 4 and 5.

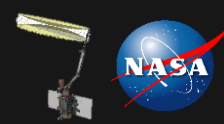
| Experiment | NRv7.2 | Vv4030 | NRv8.3, Vv5012 |
|-------------------------------------|-----------------------|--------------------------|--|
| L4_SM Version | 4 | | 5 |
| Software Version | LDASsa m3-16_6 | | GEOSIdas v17.9.0 |
| Boundary conditions | Icarus NL ("v003") | Icarus NLv2 ("v003a") | Icarus NLv4 |
| Greenness, NIRDF, & VISDF fix | No | Yes | |
| “Mali” bug fix | No | | Yes |
| <u>z0 formulation</u> | <u>3</u> | | <u>4 (increased z0_{min}, stem area index)</u> |
| Zenith angle revision | No | | Yes |
| Climatology (for percentile output) | 2001-2017 | | 2001-2019 |

Revised aerodynamic roughness length (z0) formulation represents minor science change.

Rejected change in vegetation height (explored to achieve consistency with recent GEOS FP upgrade).

Greenness and “Mali” bug fixes, zenith angle revision, and s/w version have minimal impact on science.

(Small everywhere and/or limited to a small fraction of grid cells.)



Changes in L4_SM Tb Analysis

Re-calibrated Tb analysis in Version 5.

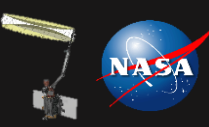
- Assimilate R17 L1C_TB Tbs.
(Different from R16 Tbs by a couple of K owing to revised L1 calibration.)
- Reinstated check for excessive std-dev in fore-minus-aft Tbs. (After problems in L1 processing resurfaced.)
- RTM parameters calibrated using NRv7.2 modeling system based on 7 yrs of multi-angular SMOS v620 data.
(New calibration using NRv8.3 has been completed; testing in progress for future version upgrade.)
- Tb scaling parameters based on SMAP only:

| L4_SM Stream | SMOSv620 Period | SMAP Period and Version |
|----------------|-----------------------------|--|
| Vv4030 | Jul 2010 – Jun 2018 (8 yrs) | Apr 2015 – Mar 2018 (3 yrs; R16 ops) |
| Vv5012, Vv5014 | n/a | Apr 2015 – Mar 2020 (5 yrs; T16[516,518] OASIS) (1-yr, discontinuous streams) |
| Vv5030 | n/a | Apr 2015 – Mar 2020 (5 yrs; R17 ops) [TBD*] (continuous integration) |

*Requires completion of R17 L1C_TB reprocessing and Version 5 Open-Loop before Vv5030 production can start.

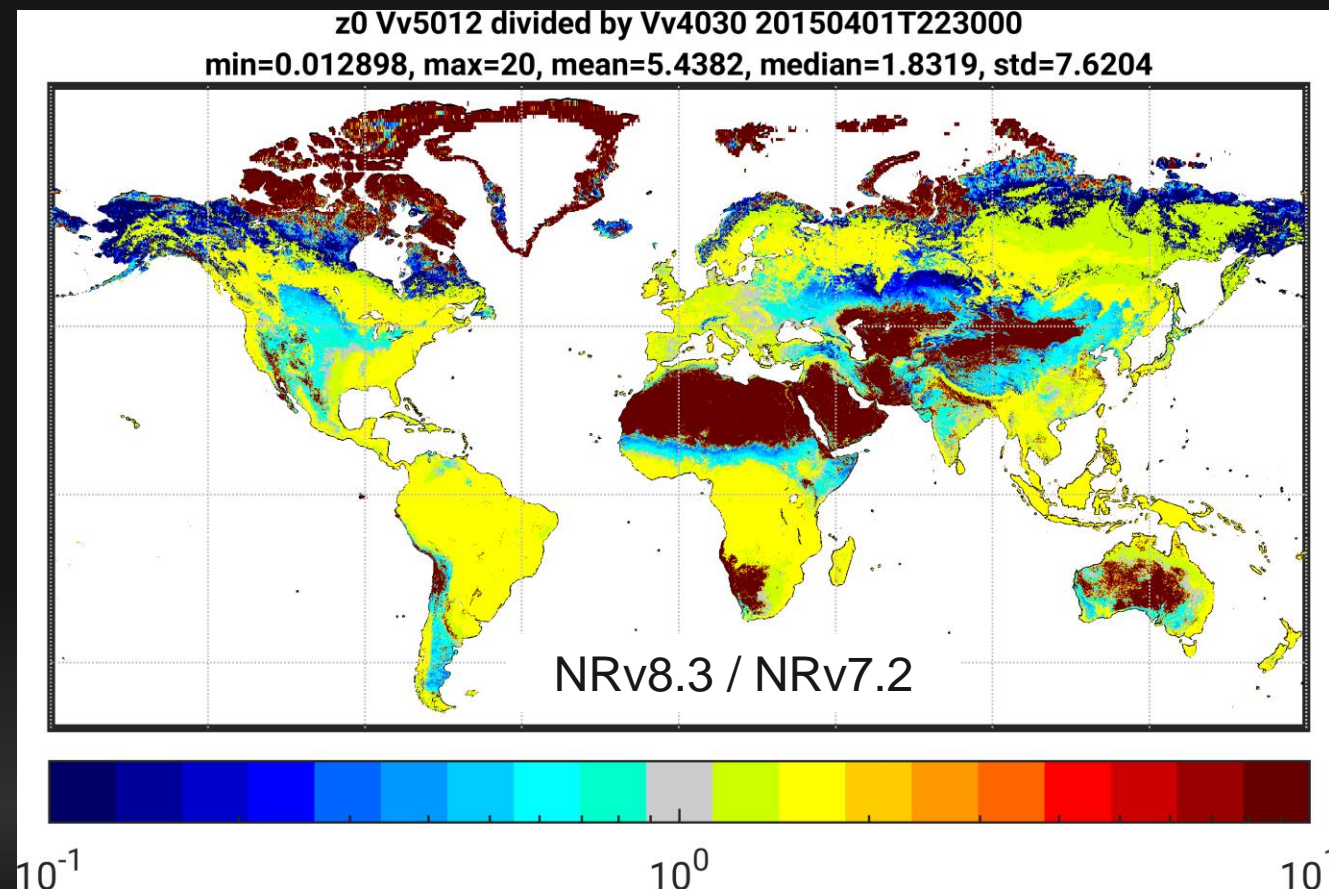
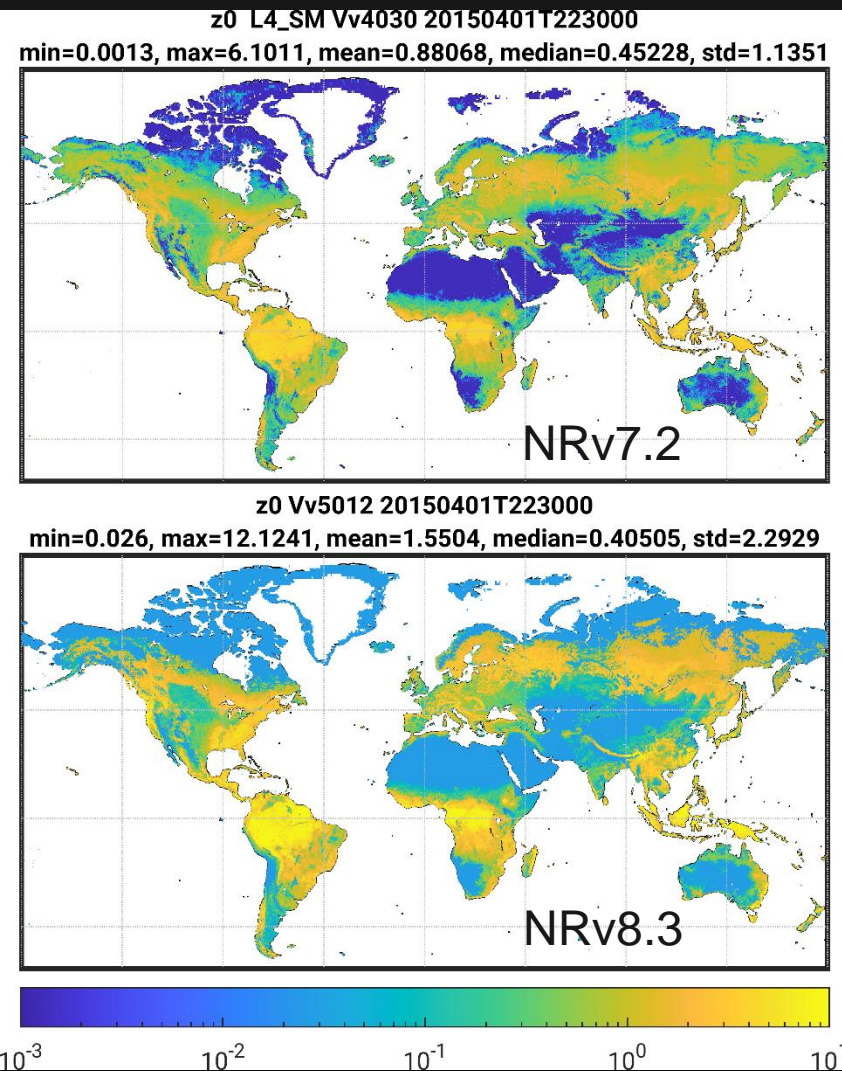
- PAR perturbations bug fix (removes inconsistency in latent & sensible heat flux between NR and L4_SM).
(PAR = Photosynthetically Active Radiation)

Outline



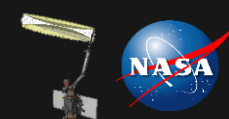
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Aerodynamic Roughness Length z_0 (Apr 1)

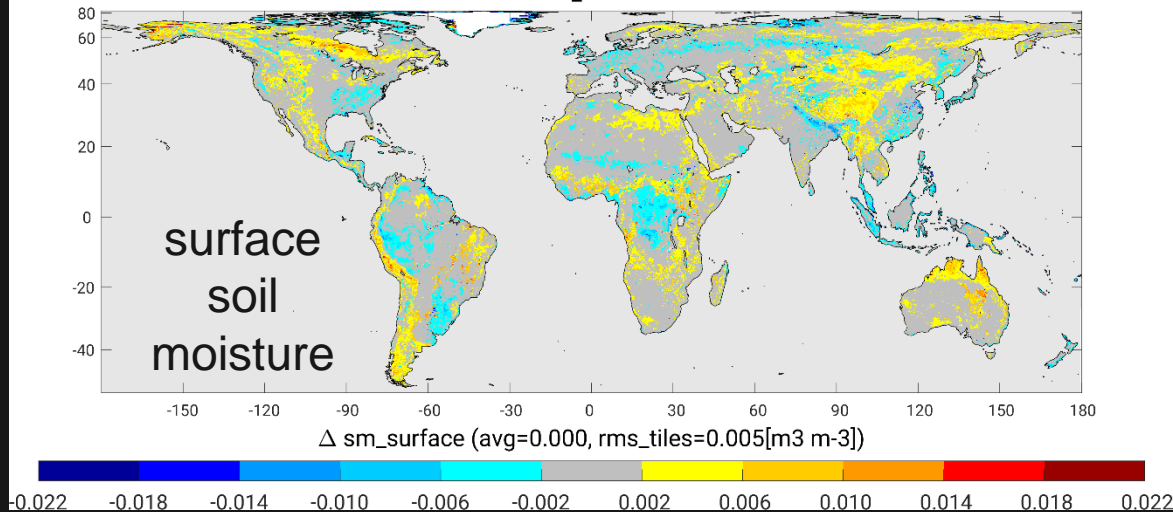


Revised z_0 formulation for consistency with Jan 2020 GEOS FP upgrade. Roughness increased by factor of 10 in deserts (increased minimum z_0). New dependency on stem area index and revised equation result in minor changes elsewhere.

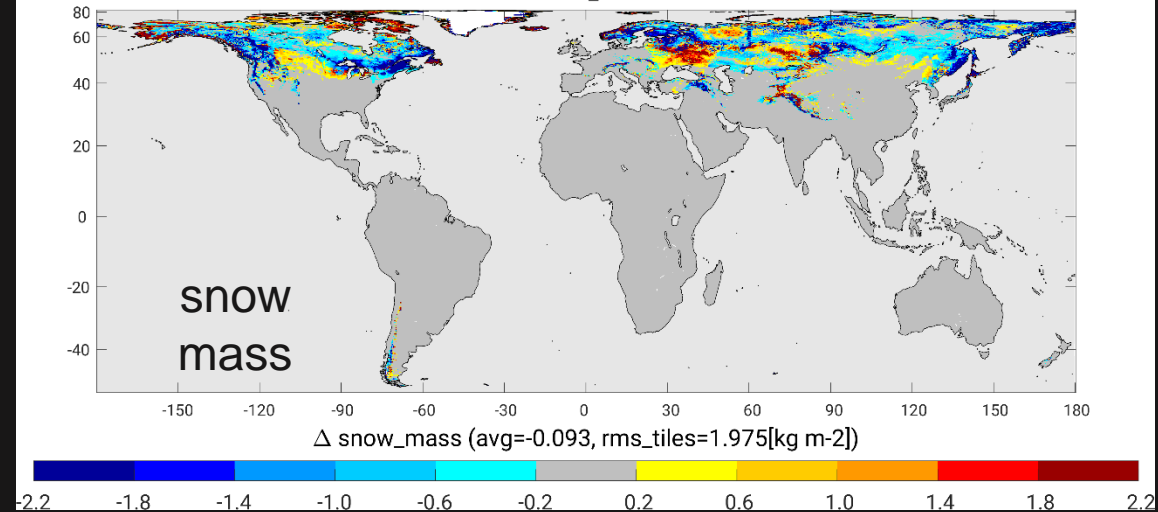
NRv8.3 minus NRv7.2 (Water Variables)



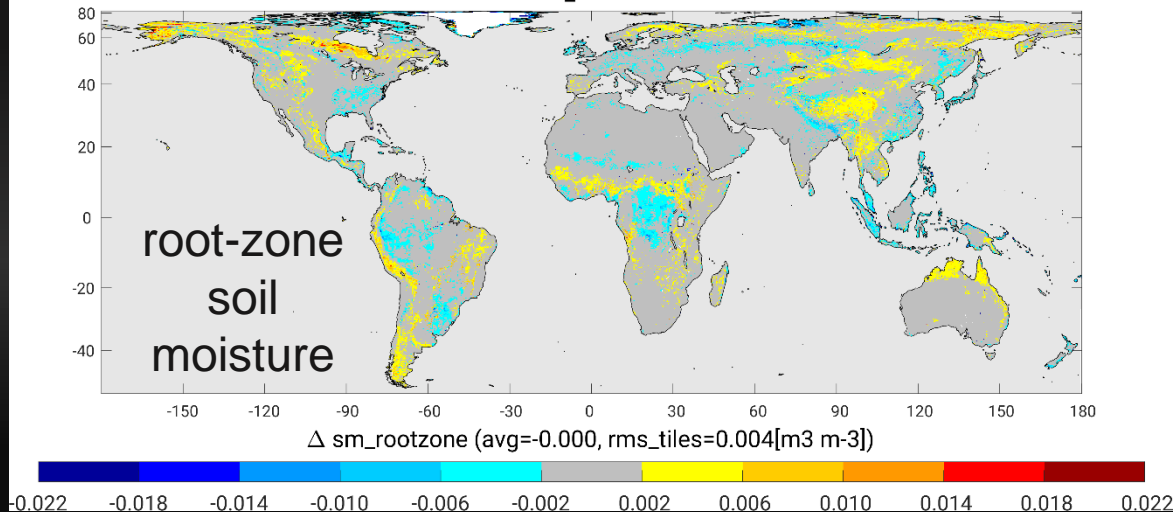
Diff of NRv8.3-NRv7.2 sm_surface 201504-201903 ALL



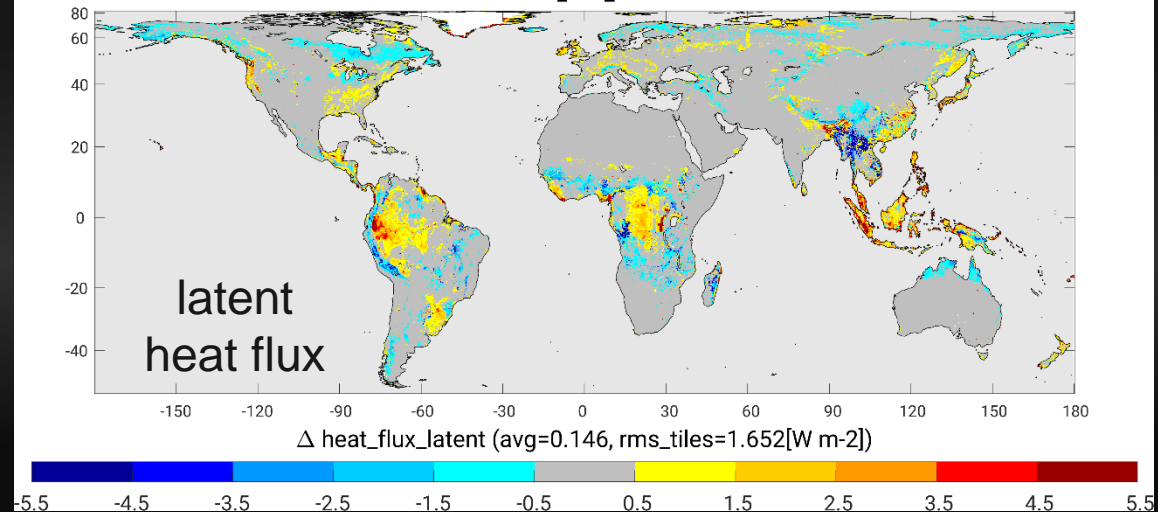
Diff of NRv8.3-NRv7.2 snow_mass 201504-201903 ALL



Diff of NRv8.3-NRv7.2 sm_rootzone 201504-201903 ALL

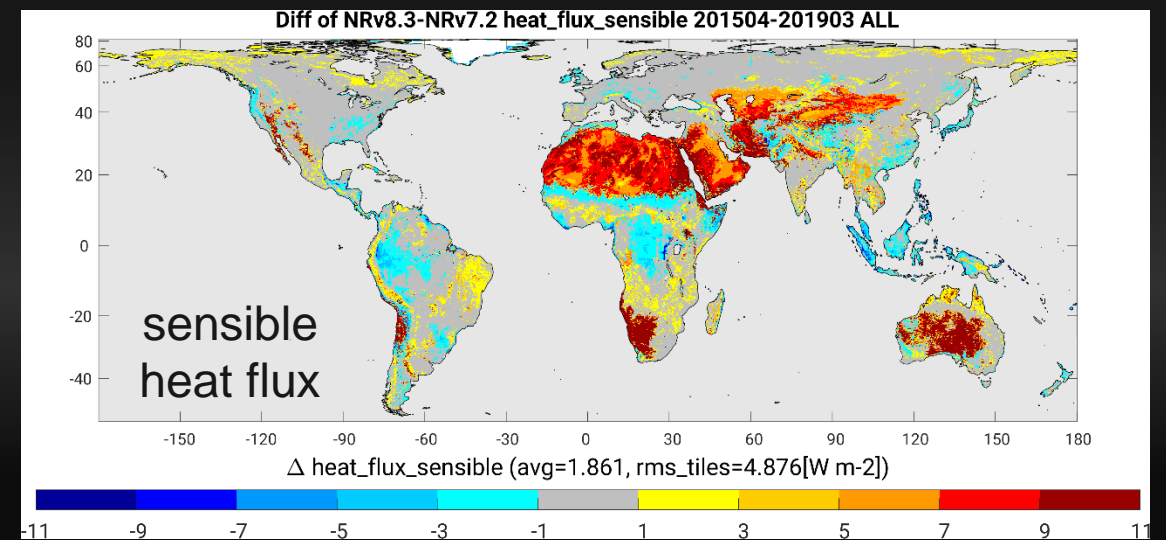
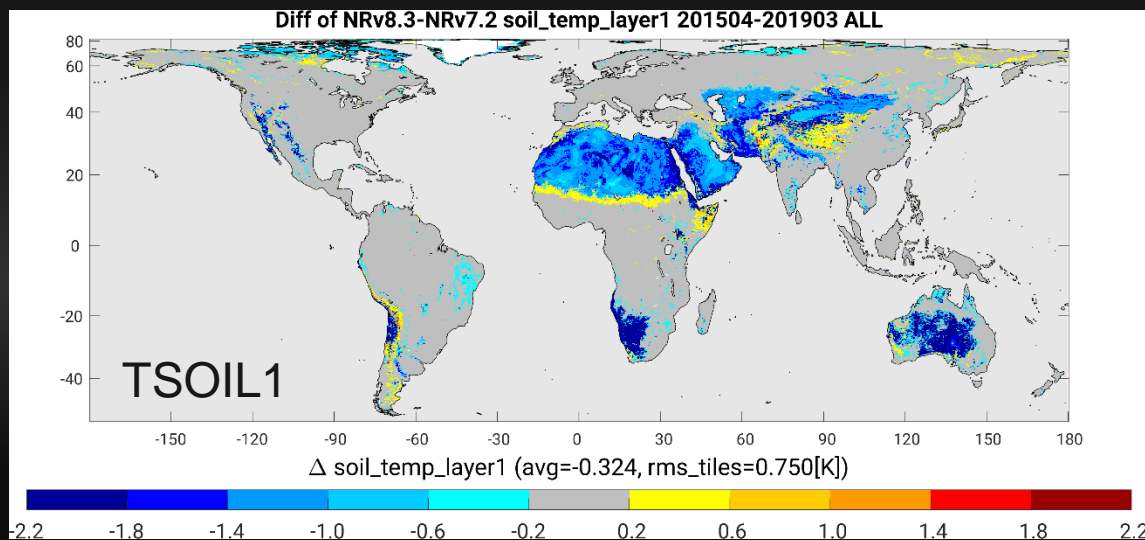
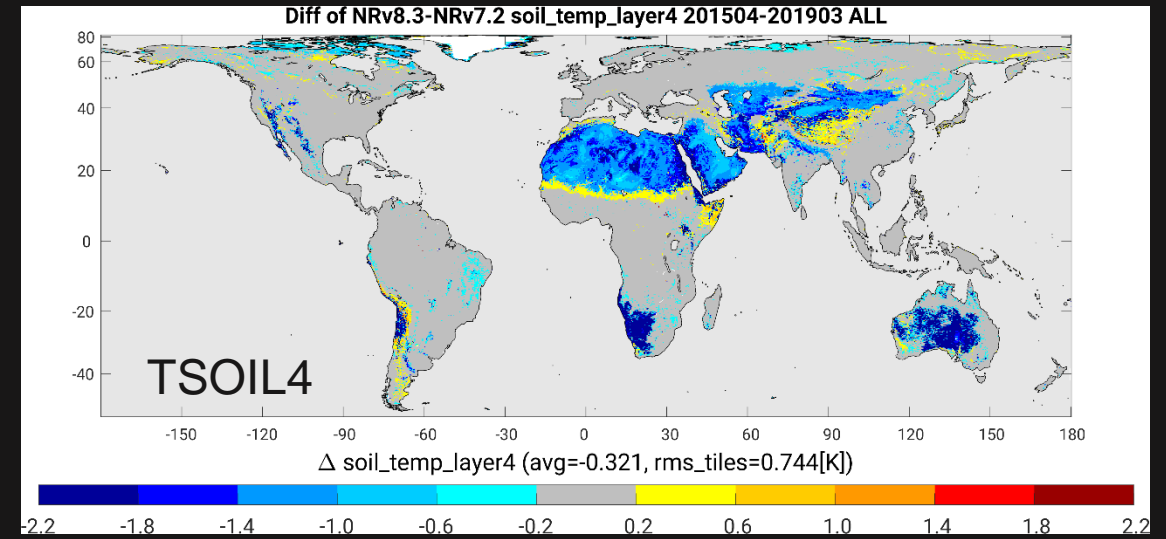
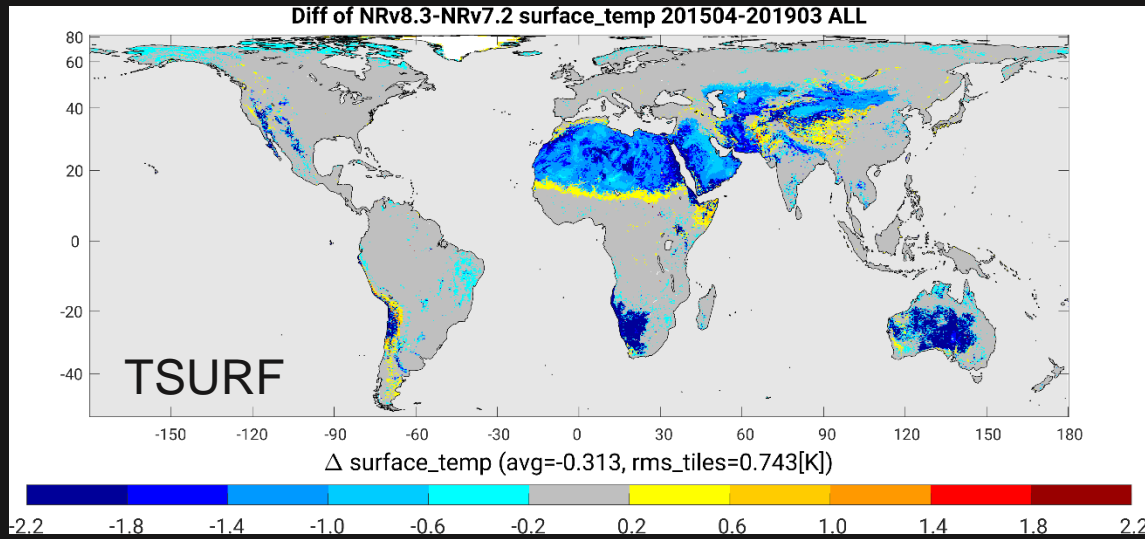


Diff of NRv8.3-NRv7.2 heat_flux_latent 201504-201903 ALL



Only minimal climatology changes in surface and root-zone soil moisture, snow, and latent heat flux.

NRv8.3 minus NRv7.2 (Energy Variables)

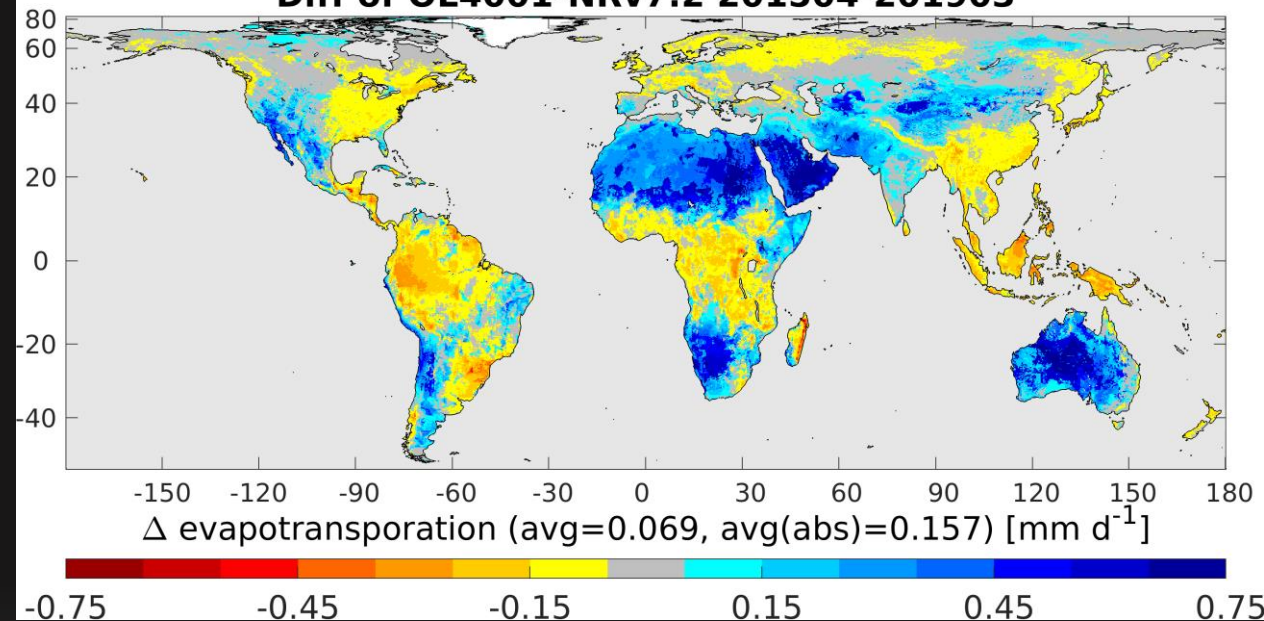


Soil temperature climatology changes by ~1-2 K in deserts, with corresponding changes in sensible heat flux.

PAR Perturbations Bug Fix



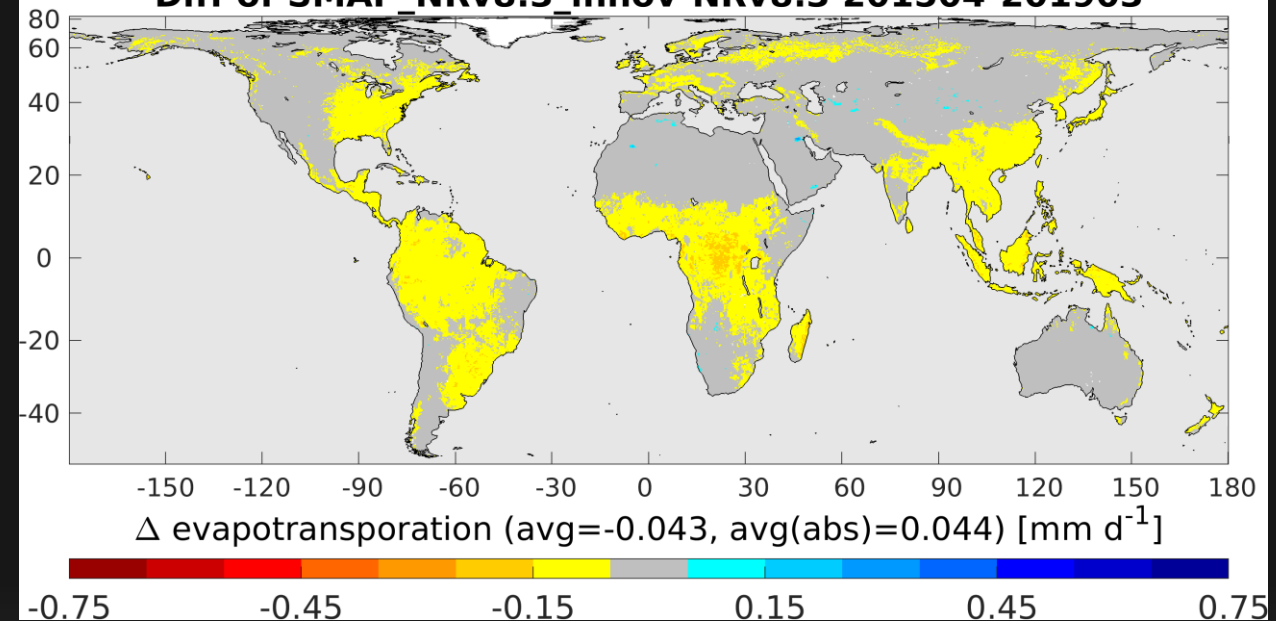
Diff of OL4001-NRv7.2 201504-201903



Version 4 OL minus NRv7.2

Bug resulted in larger differences between Open-Loop (OL) ensemble simulation (with perturbations) and single-member, unperturbed simulation.

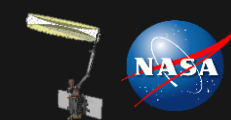
Diff of SMAP NRv8.3 innov-NRv8.3 201504-201903



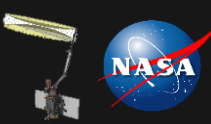
Version 5 OL minus NRv8.3

Version 5 has improved consistency between single-member, unperturbed model and ensemble simulations.

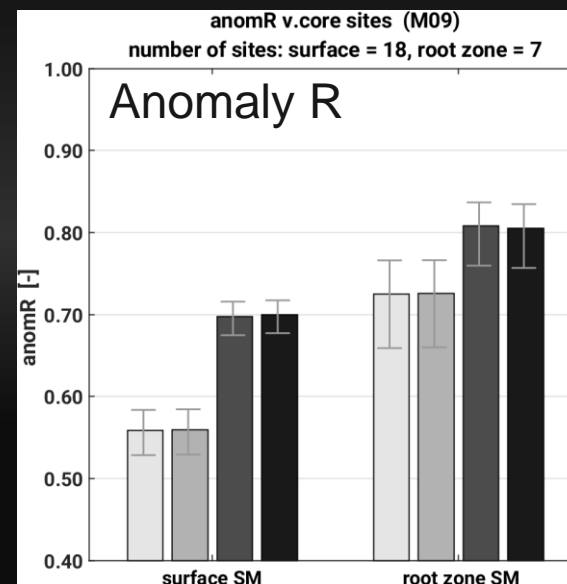
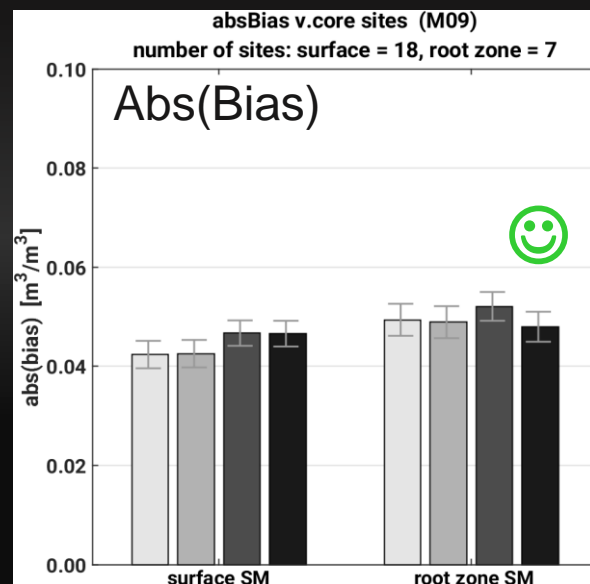
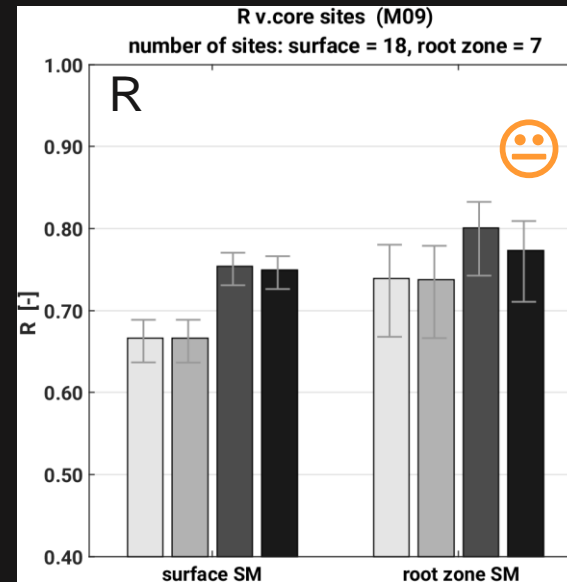
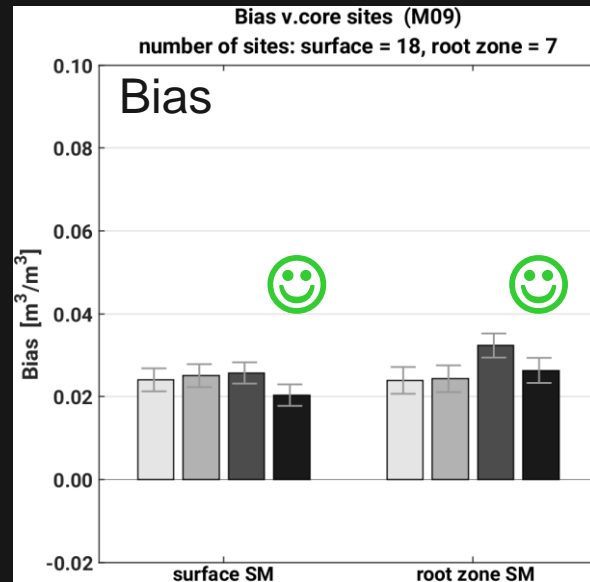
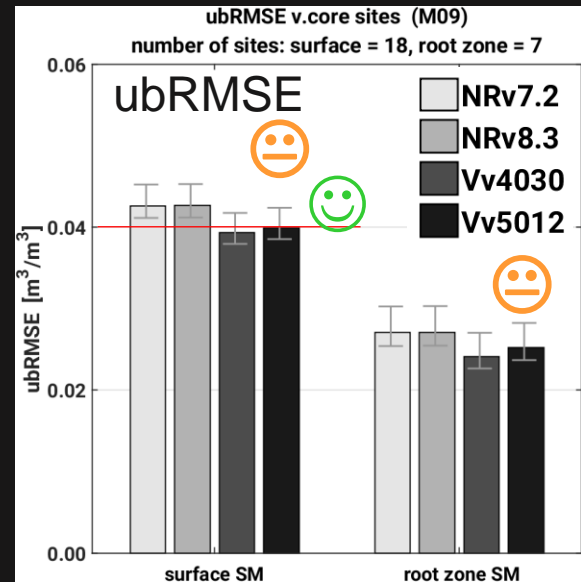
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Core Validation Sites (9 km)



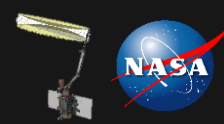
Version 5 meets requirement:

$$\text{ubRMSE} \leq 0.04 \text{ m}^3/\text{m}^3$$

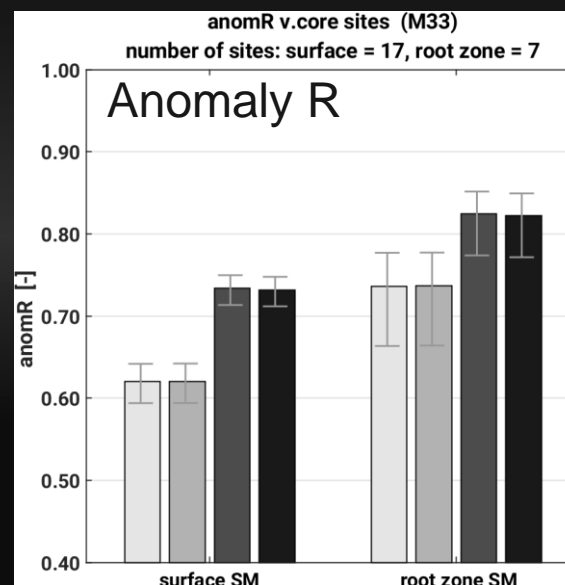
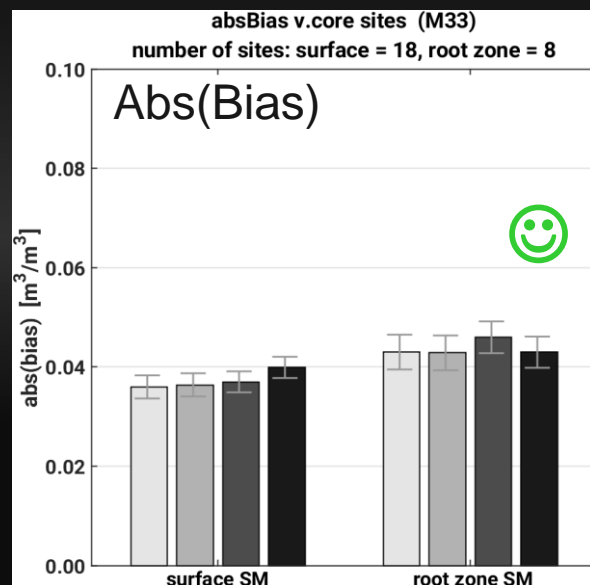
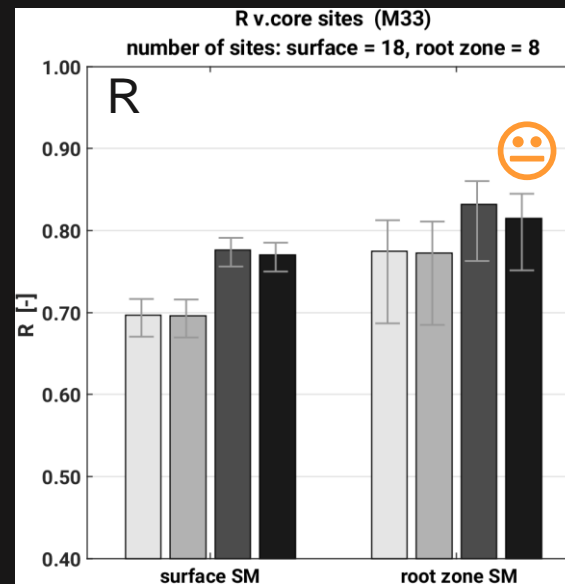
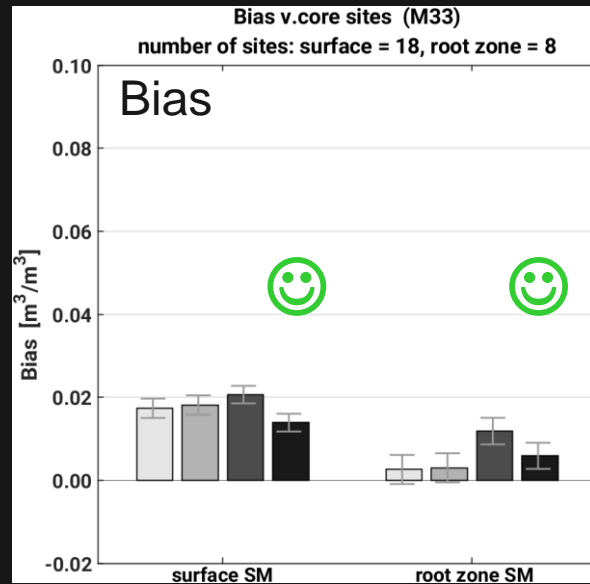
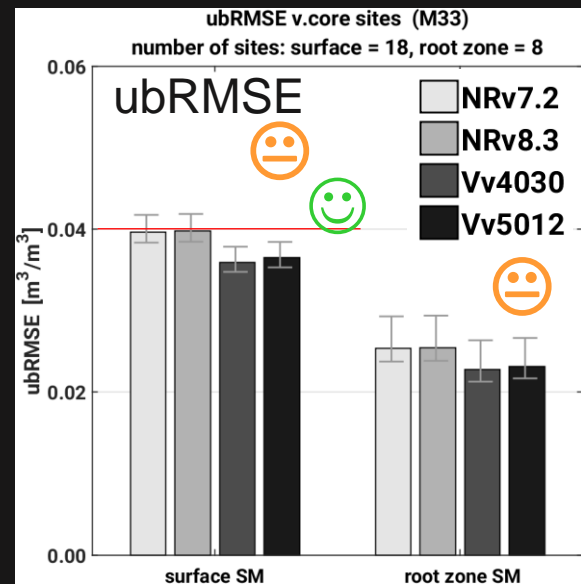
ubRMSE and root-zone R slightly worse in Version 5. (Within 95% conf. interval.)

Bias better in Version 5.

On balance, the performance of Version 5 is the same as that of Version 4.



Core Validation Sites (33 km)

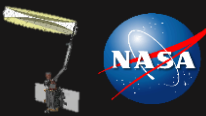


At 33-km core sites:

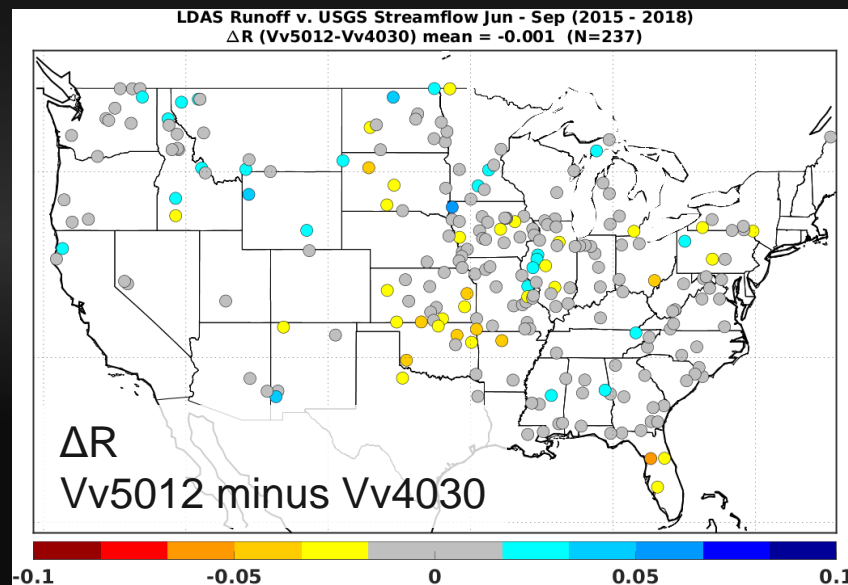
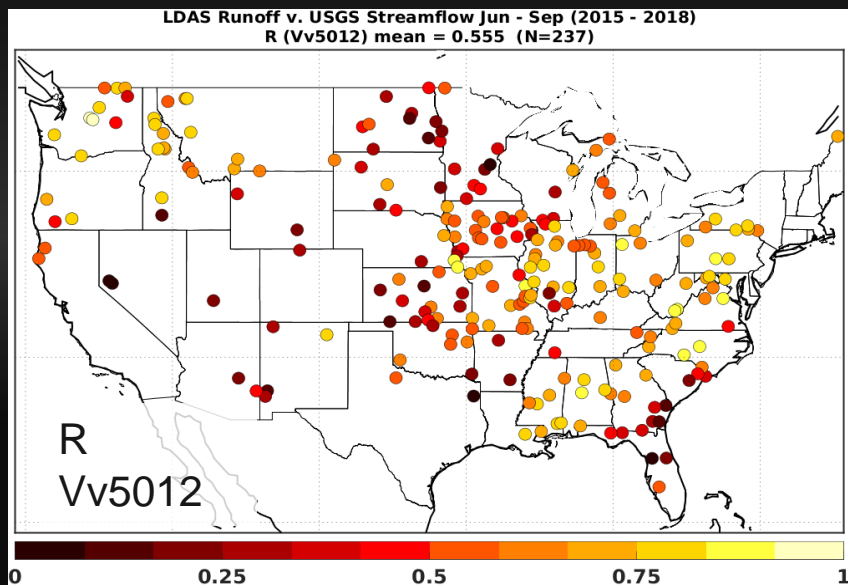
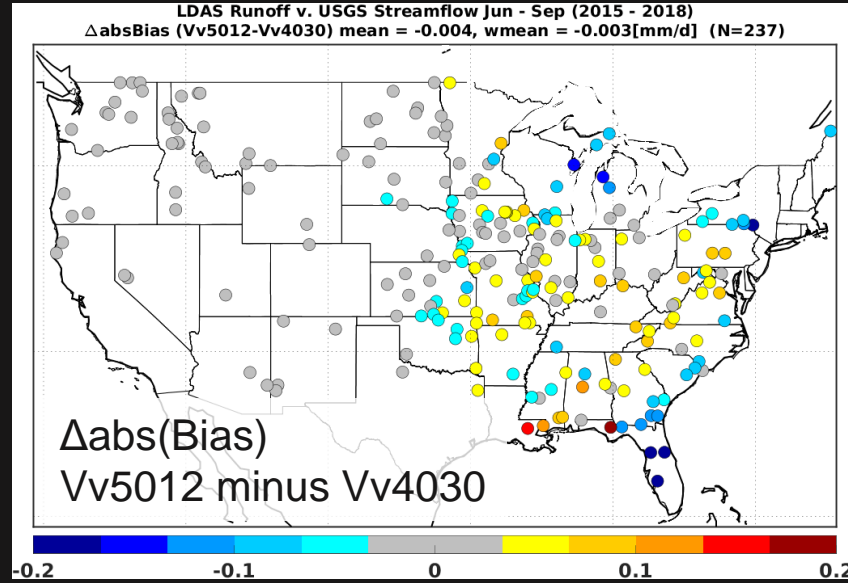
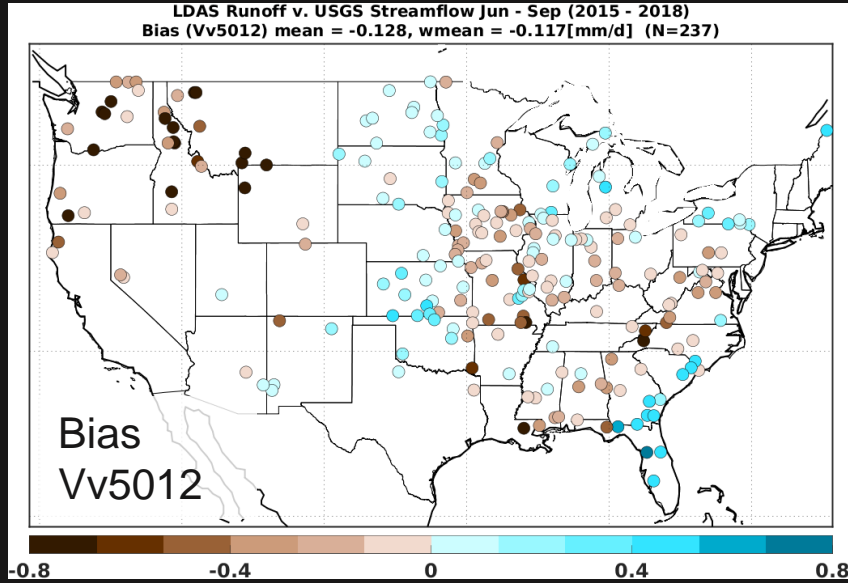
Same *relative* performance of Versions 4 and 5.

Metrics generally better.

(W.r.t. metrics at 9-km sites.)



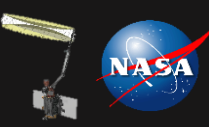
Runoff Validation



No meaningful change in performance between Versions 4 and 5.

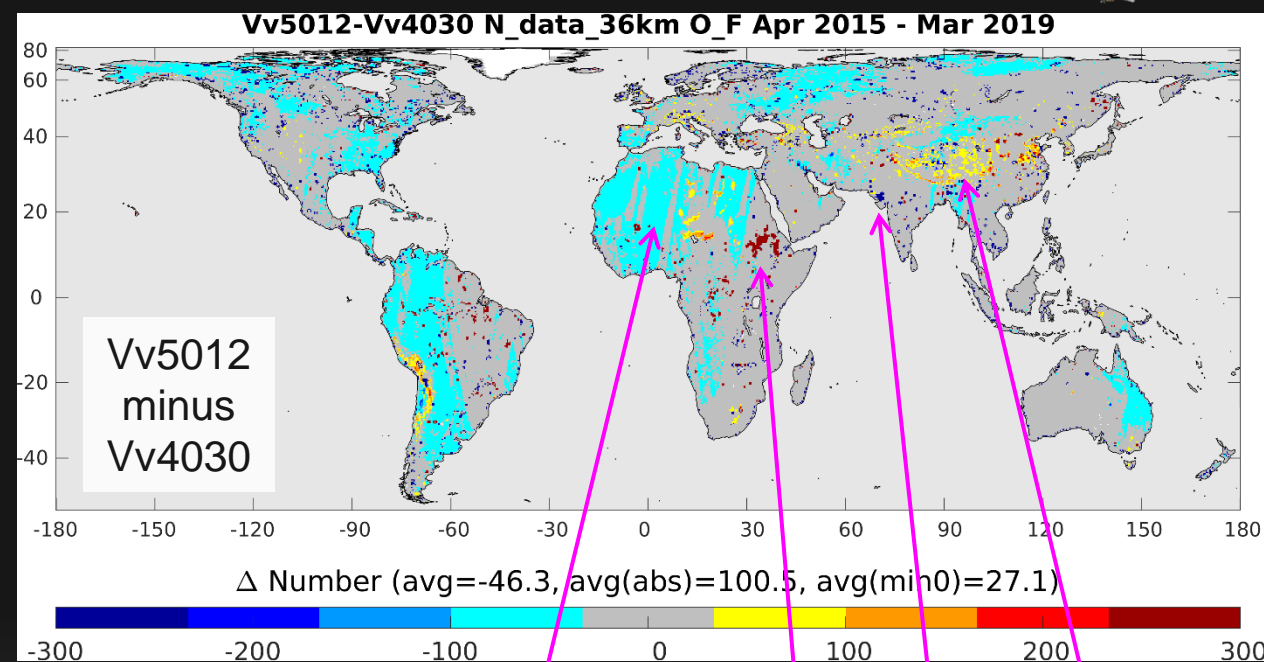
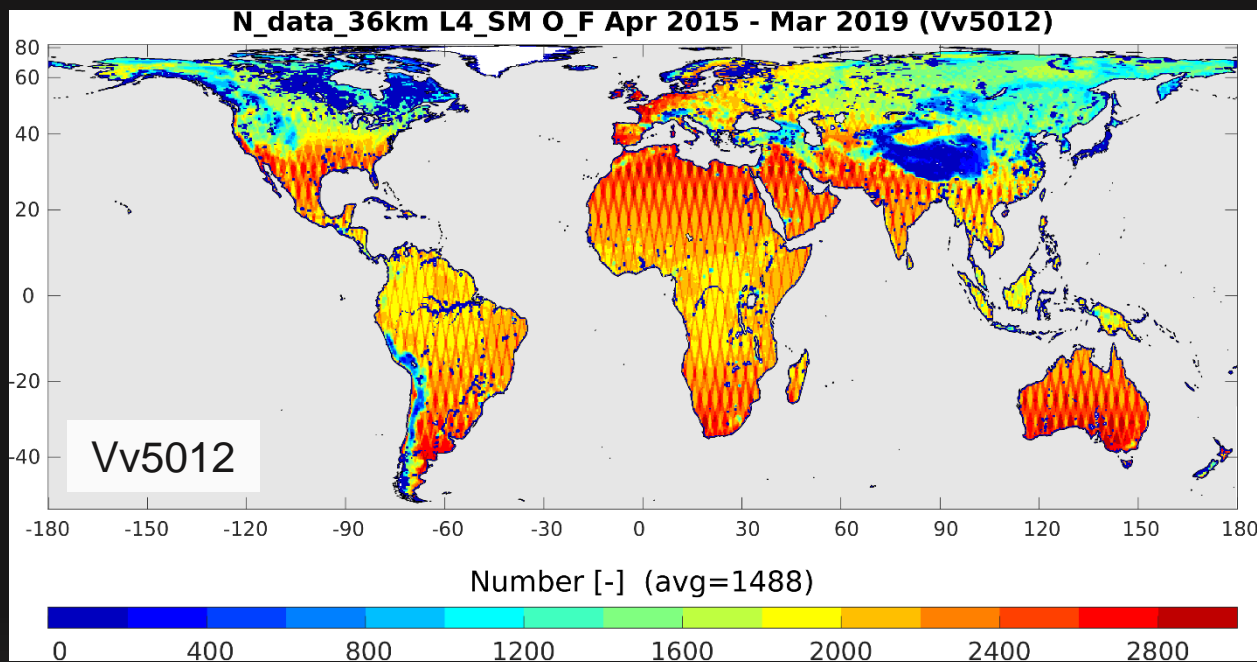
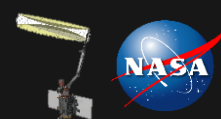
(Same for NRv7.2 and NRv8.3; not shown.)

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Number of Assimilated SMAP L1C_TB Observations



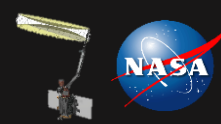
Light blue shading: Incomplete OASIS Tb processing. Will be fixed w/ R17 ops (Vv5030).

Dark red "filling": Calibration of mwRTM parameters in Vv5012 based on simulation with newer land mask.

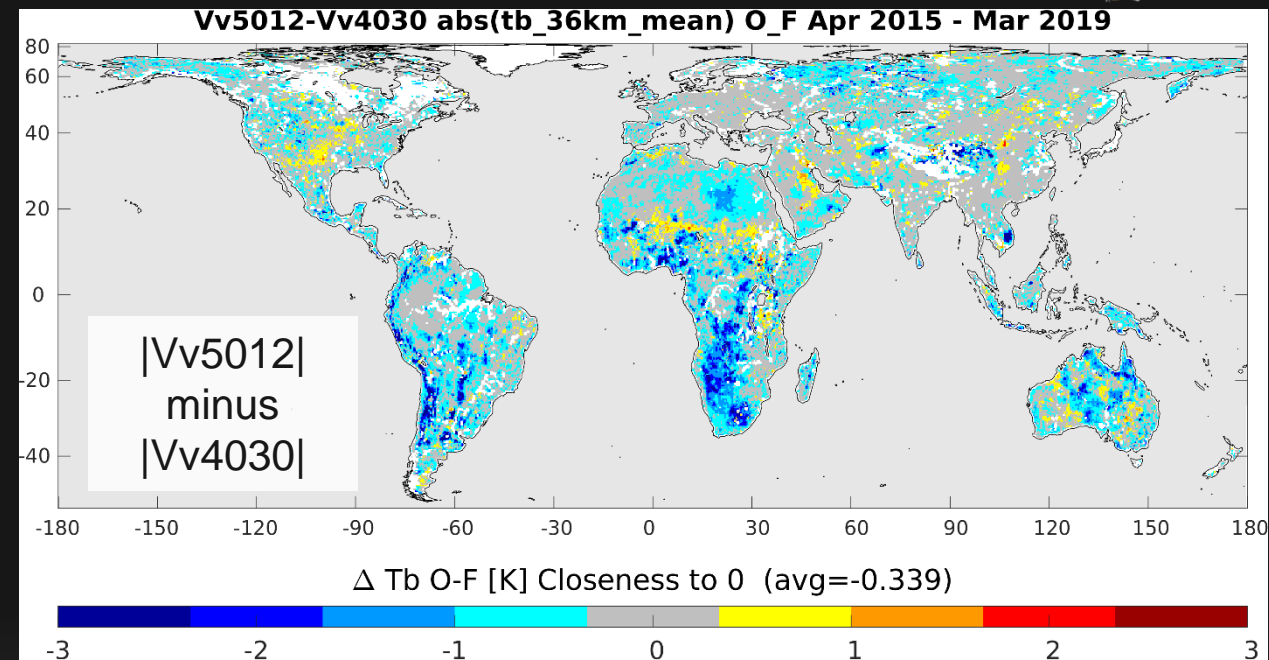
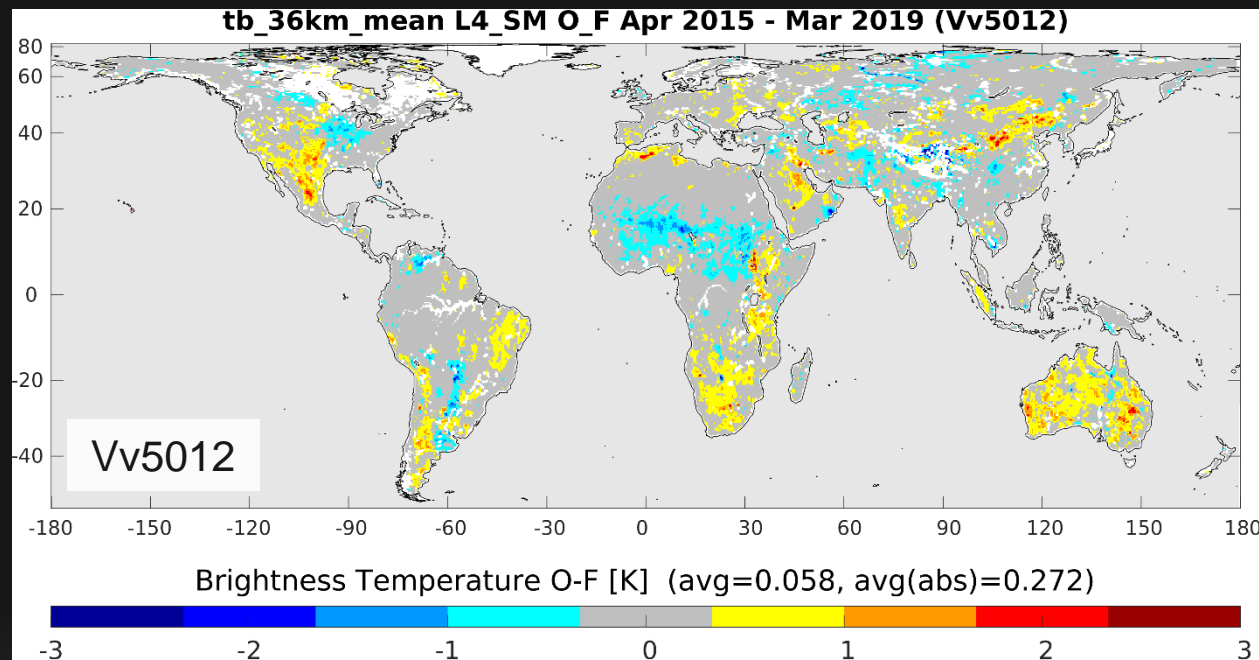
Dark blue "holes": Minor processing issue during mwRTM parameter calibration (some ancillary data on old land mask).

Light yellow shading: Better coverage of Tb scaling parameters.

On average, Vv5012 assimilates slightly fewer L1C Tb obs. Performance may change slightly for Version 5 ops and (possibly) with revised mwRTM calibration.



O-F Tb Residuals (Mean)

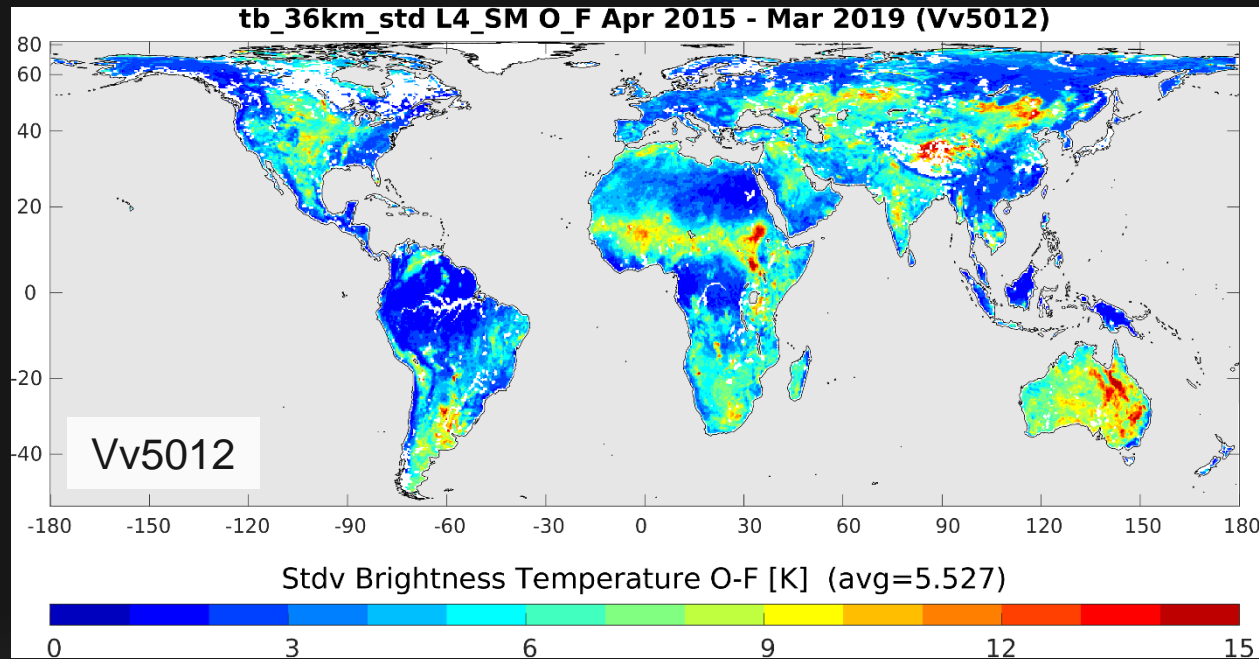


Mean of observation-minus-forecast (O-F) Tb residuals.

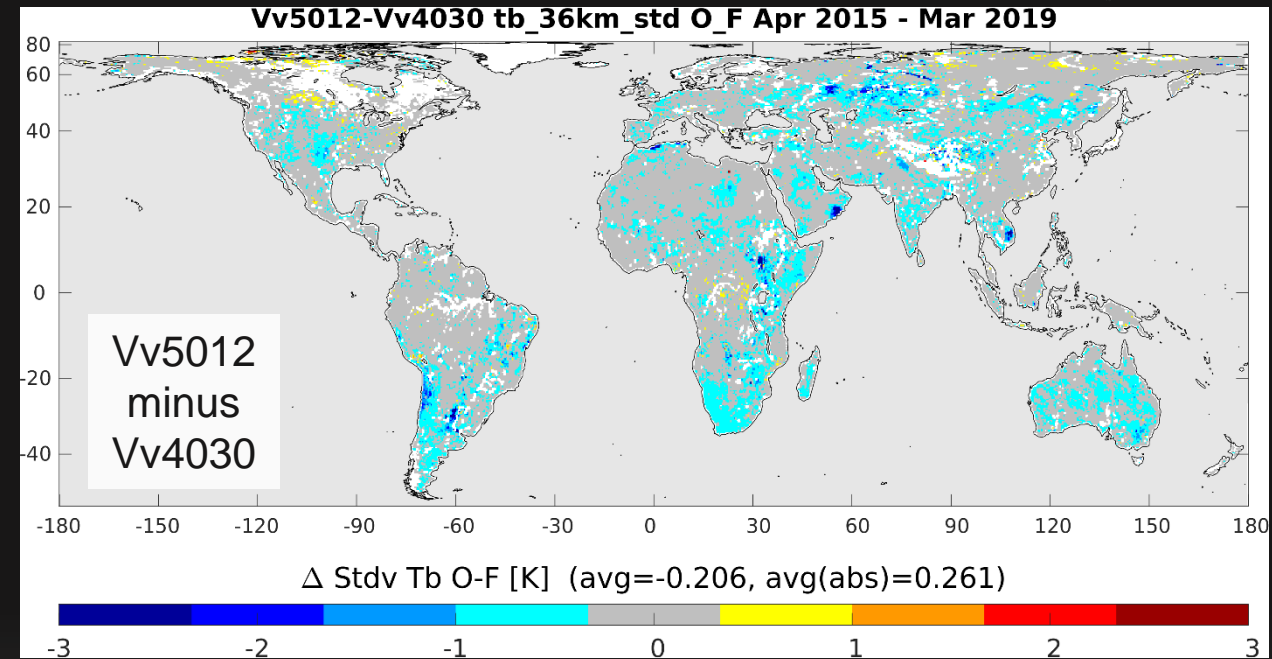
Version 5 has better calibration of the Tb analysis, likely because only SMAP data are used to derive Tb scaling parameters.



O-F Tb Residuals (Std-Dev)

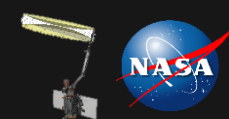


Typical magnitude of O-F Tb residuals.

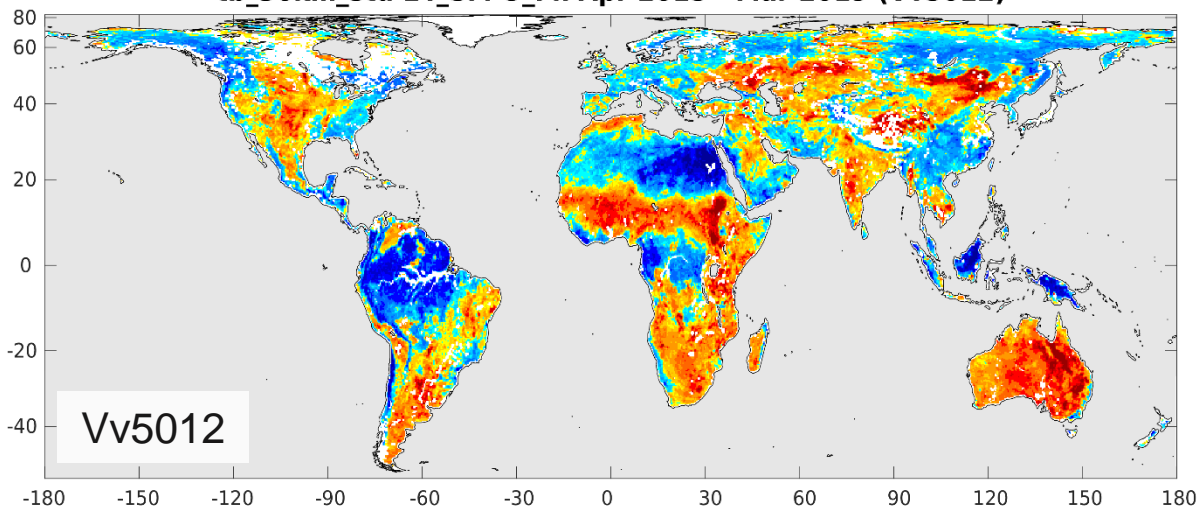


Version 5 has slightly better model forecasts of SMAP Tb observations that are about to be assimilated.

O-F Tb Residuals (Std-dev of Normalized)



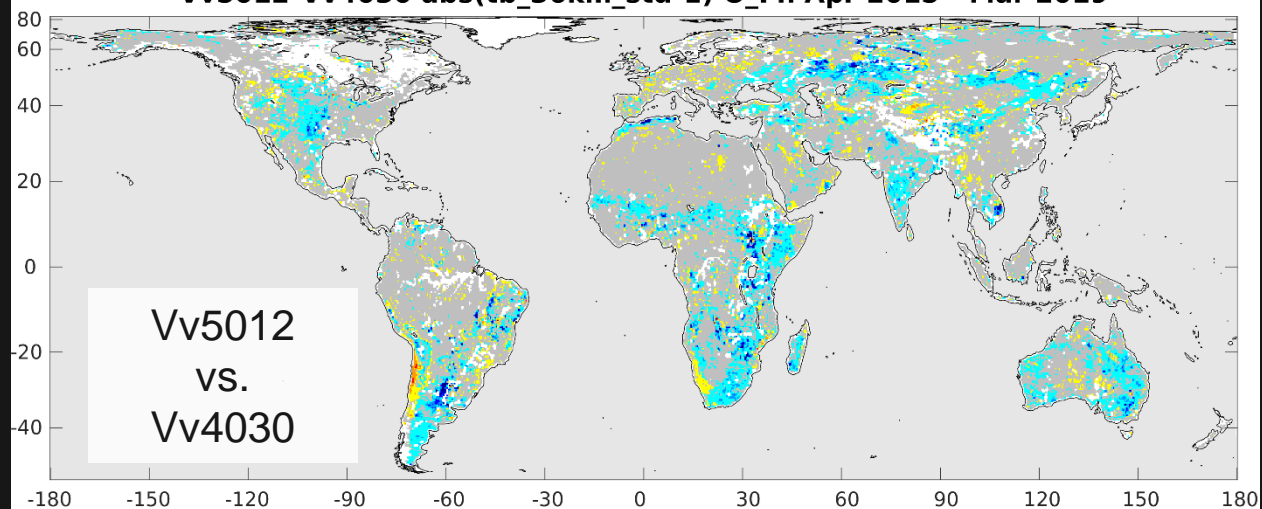
tb_36km_std L4_SM O_Fn Apr 2015 - Mar 2019 (Vv5012)



Stdv Normalized Brightness Temperature O-F [K/K] (avg=1.082) (avg(abs(nstdv-1))=0.372)

0.25 0.35 0.48 0.66 0.91 1.26 1.74 2.40

Vv5012-Vv4030 abs(tb_36km_std-1) O_Fn Apr 2015 - Mar 2019



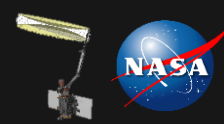
Vv5012
vs.
Vv4030

Δ (Stdv normalized Tb O-F [K/K] Closeness to 1) (avg=-0.023)

-0.6 -0.4 -0.2 0.0 0.2 0.4 0.6

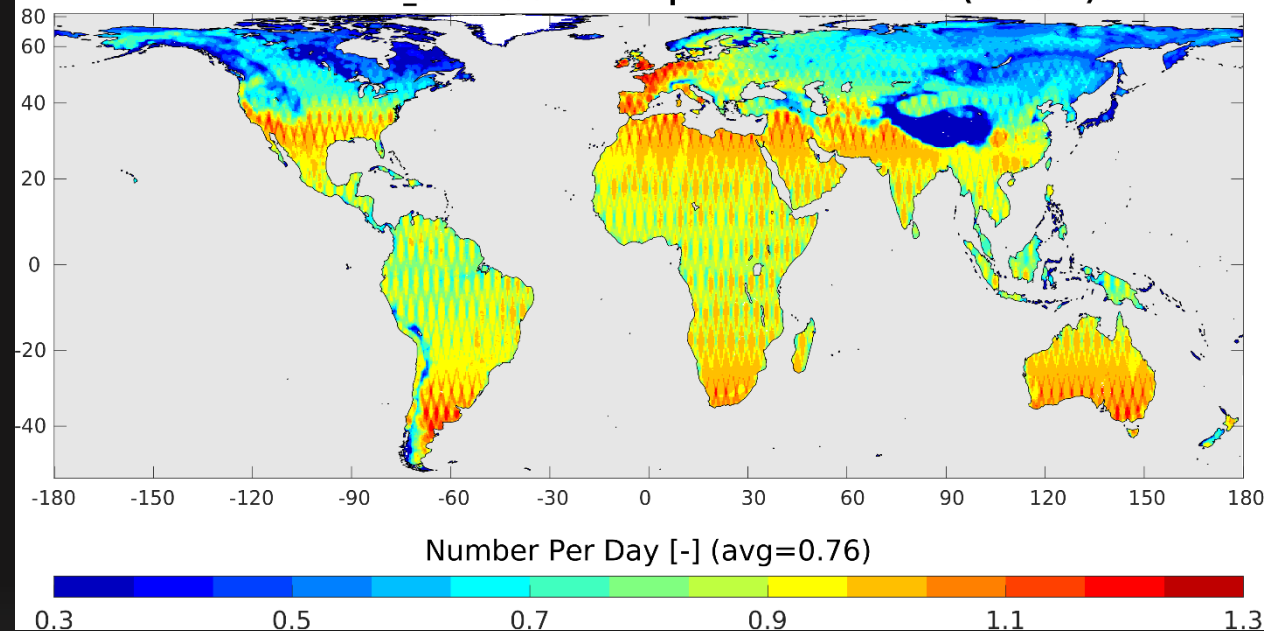
Std-dev of normalized O-F Tb residuals.

Version 5 has slightly better consistency between actual and assumed errors.

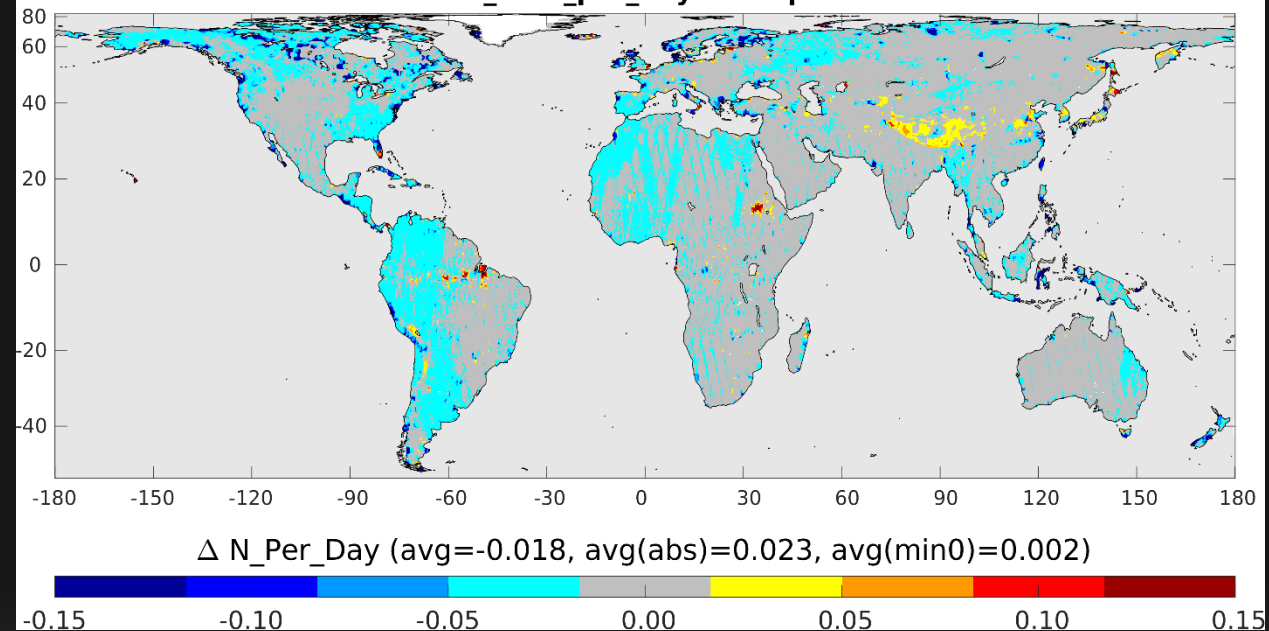


Analysis Increments (Number)

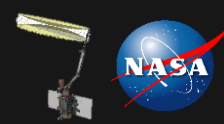
Number of L4_SM increments Apr 2015 - Mar 2019 (Vv5012)



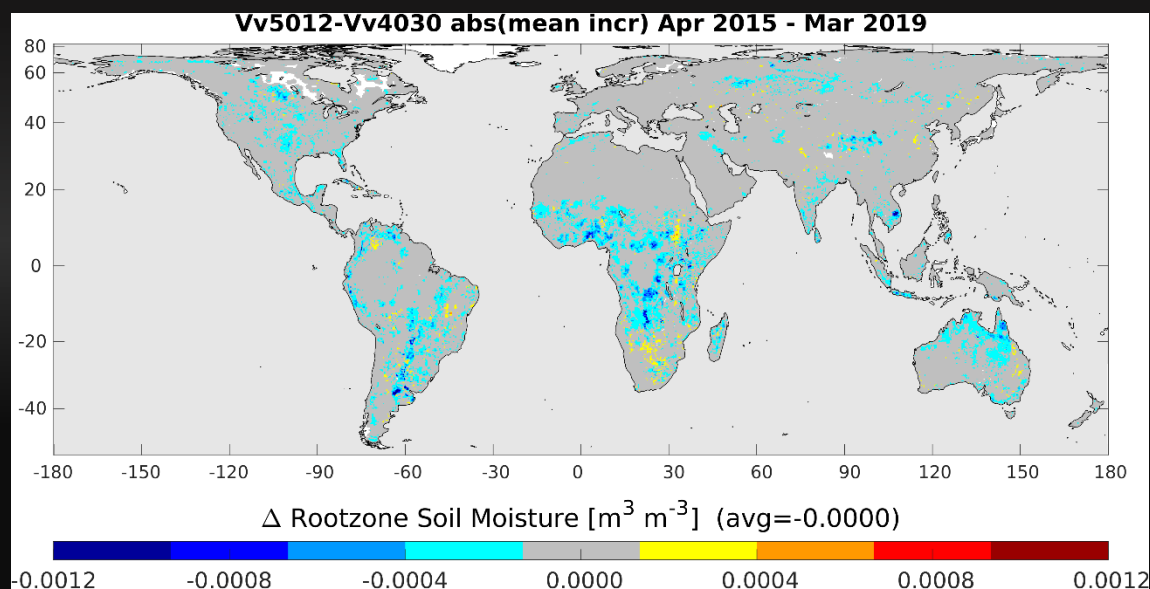
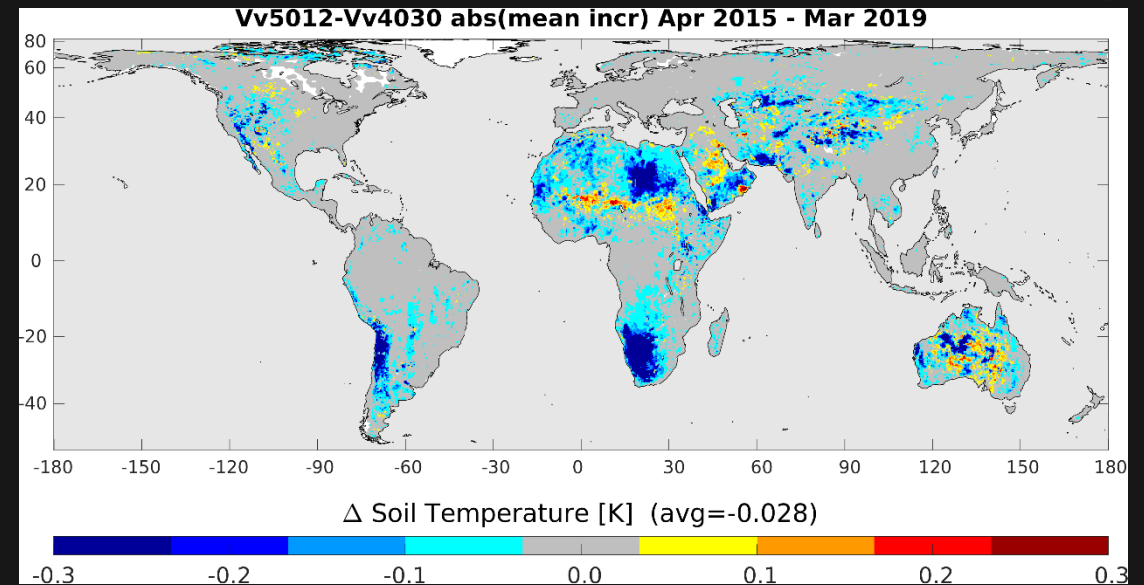
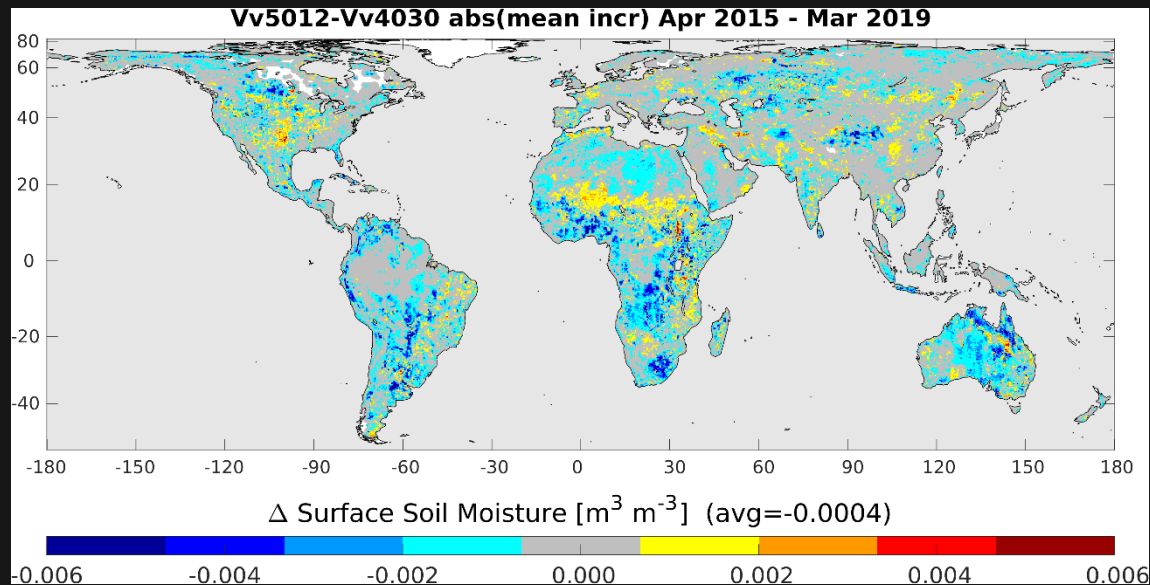
Vv5012-Vv4030 N_data_per_day incr Apr 2015 - Mar 2019



Changes in number of increments reflect changes in number of assimilated Tb observations.

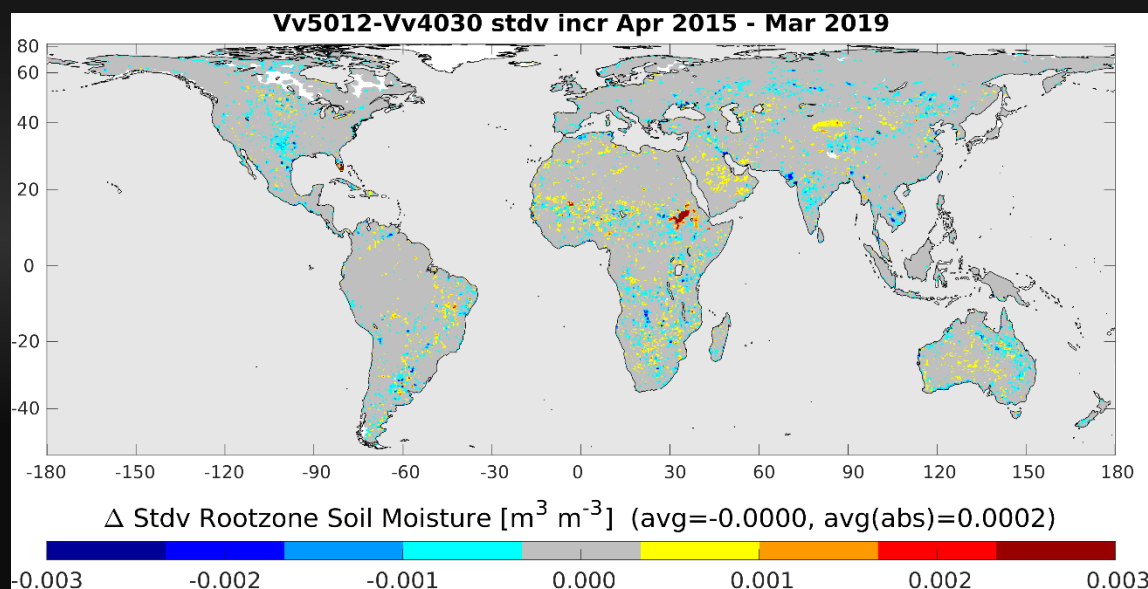
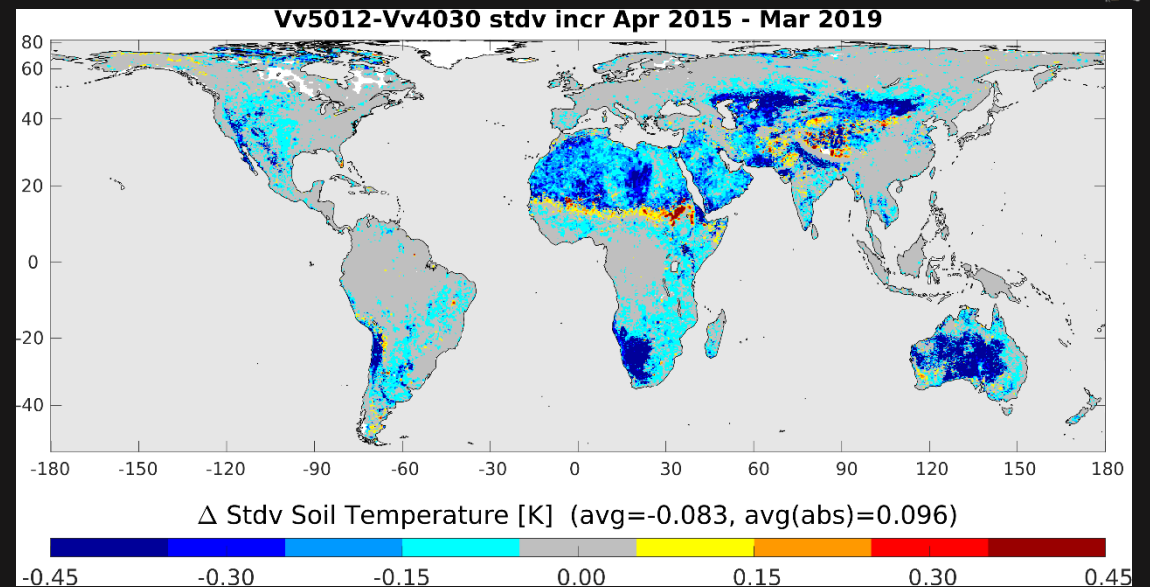
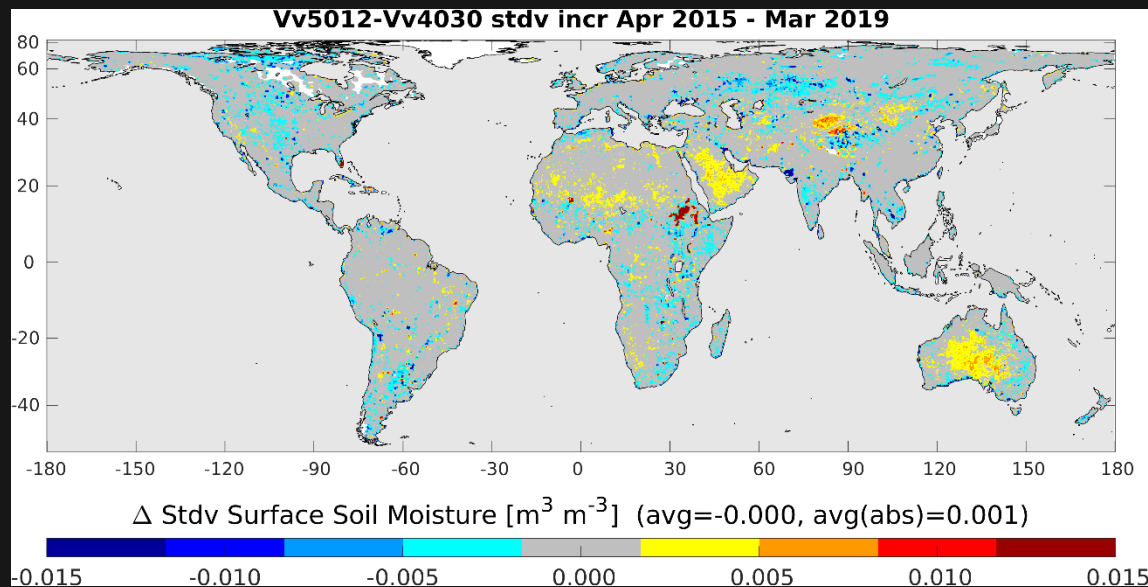


Analysis Increments (Mean)



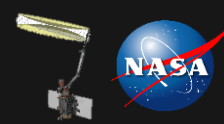
Version 5 has slightly smaller mean absolute increments than Version 4, likely because only SMAP data are used to derive Tb scaling parameters.

Analysis Increments (Std-Dev)

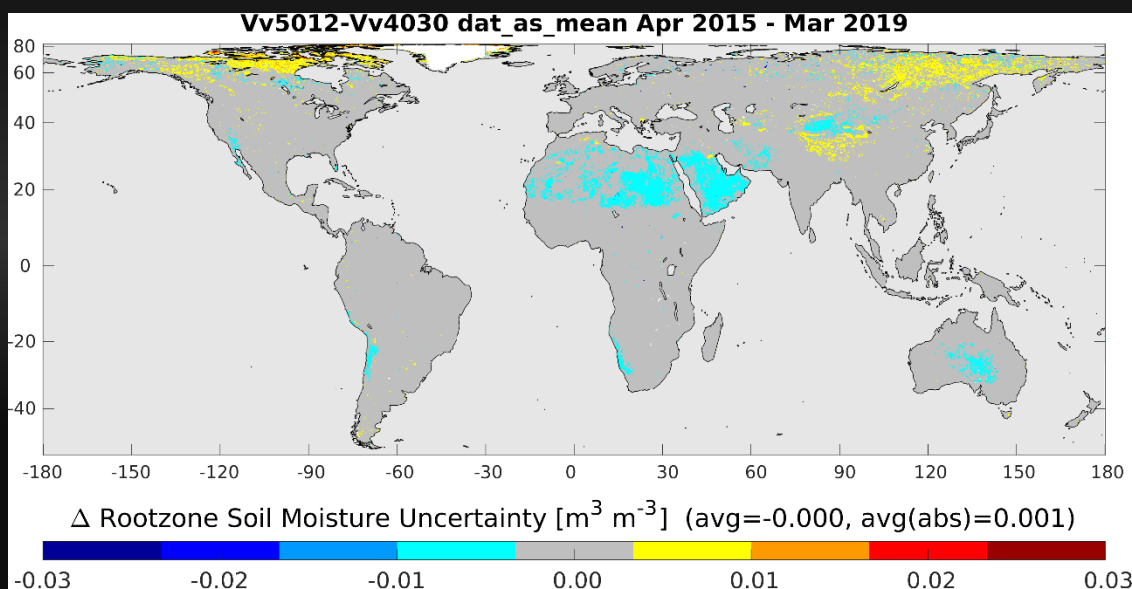
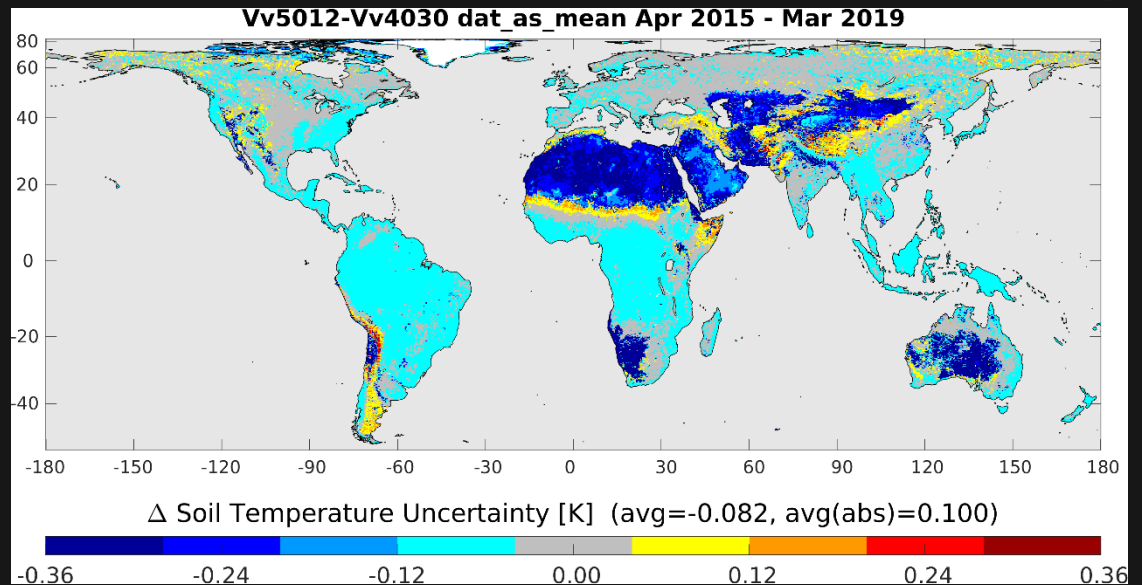
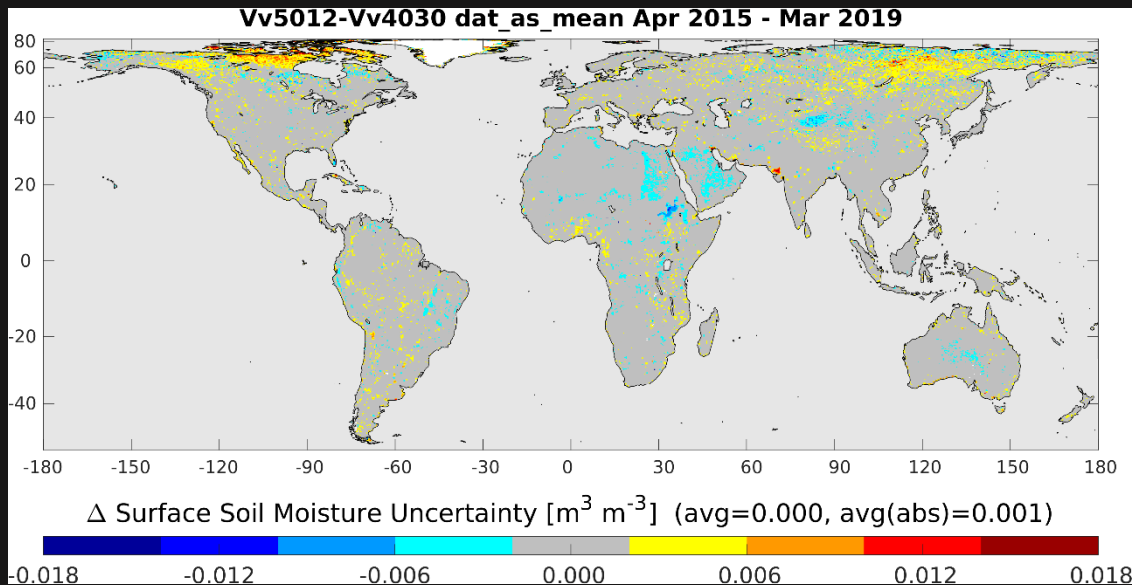


Minimal differences in typical magnitude of soil moisture increments.

Typical surface soil temperature increments in deserts are smaller by ~ 0.3 K in Version 5 than in Version 4.

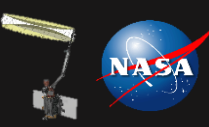


Uncertainty Estimates

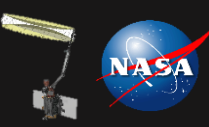


Minimal differences in uncertainty estimates (analysis ensemble spread) for soil moisture. Surface soil temperature uncertainty estimates in deserts are smaller by ~ 0.3 K in Version 5 than in Version 4.

Outline



1. Overview and Status
2. Model and Analysis Changes
3. Climatology
4. In Situ Validation
5. Assimilation Diagnostics
6. Summary



Summary

Vv5012 meets minimum requirements for new Version:

- Soil moisture ubRMSE $\leq 0.04 \text{ m}^3 \text{ m}^{-3}$ (vs. in situ measurements from 9-km core site reference pixels).
- Vv5012 is at least as good as Vv4030 (on balance across in situ metrics & assimilation diagnostics).

Compared to Vv4030, Vv5012 has:

- Revised aerodynamic roughness length calculations;
- Catchment model bug fixes;
- Better calibration of the Tb analysis based only on SMAP observations;
- Improved software framework to support future science development;
- Slightly worse ubRMSE and but better bias metrics;
- Slightly smaller O-F Tb residuals and soil temperature increments;
- Slightly better consistency between actual and assumed errors.

Official reprocessing (Vv5030):

- Considering using NRv8.3-based mwRTM calibration (improved spatial coverage).