Soil Moisture
Active Passive Mission
SMAP

Cal/Val Workshop #6
Sep 1-3, 2015
Columbia, MD

L4_SM


*NASA/GMAO, +JPL Caltech, #USDA, &Univ. MT

L4_SM Product Specifications

- **Global**
- **3-hourly**
- **9-km**
- **~3-day latency**

### Geophysical Data ("gph")

- 3-hour time averages

  Surface and **root zone** soil moisture, soil temperature, snow, land surface fluxes, surface meteorological forcing data.

### Analysis Update Data ("aup")

- 3-hour instantaneous (snapshots)

  Brightness temperatures (observed and modeled), soil moisture and soil temperature (model forecast and analysis), **uncertainty estimates**.
SMAP L4_SM Algorithm

GEOS-5 LDAS
- Catchment model
- 3d EnKF
  spatial extrapolation, interpolation & disaggregation of assimilated obs

Precipitation observations

GEOS-5 surface meteorology

SMAP observations (L1C_TB)

Land surface model

Data Assimilation

L4_SM Product
## Current Operational Product Status

GSFC local time: 20150831 12:02:19 ET    UTC: 20150831 16:02:19 Z

<table>
<thead>
<tr>
<th>JOB NAME</th>
<th>STATUS</th>
<th>RUNNING</th>
<th>COMPLETED</th>
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<tbody>
<tr>
<td>SPL4SM V10002 001</td>
<td>Nominal</td>
<td>20150829</td>
<td>08/28/2015</td>
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</tbody>
</table>

http://gmao.gsfc.nasa.gov/operations/status.php
Pre-beta data (V10002) available for 3/31/2015-present from

- JPL (smap-tb.jpl.nasa.gov) and
- NSIDC (for restricted distribution).

V10002 algorithm very close to beta-release version, but operational V10002 stream used pre-beta L1 and L2 inputs.

Reprocessing for L4_SM beta-release will fix many of the issues encountered in V10002.
L4_SM Observed Latencies

Performance Period: 2015/06/01 to 2015/08/23

Max latency driven by L1C_TB inputs.

Lower limit for mean latency given by Corrected Precipitation inputs.

*Excl. back-processed granules.
L4_SM Movie

Surface soil moist.

Root zone soil moist.

Surface soil moist. uncertainty

Root zone soil moist. uncertainty
L4_SM as Cal/Val Tool

L4_SM algorithm routinely confronts SMAP Tbs with model forecasts:

- Data coverage
- Data counts
- Observation-minus-forecast residuals (O-F; a.k.a. “innovations”)
- Observation-minus-analysis residuals (O-A)
Coverage of Assimilated Tb Observations

Gaps in SMOS-based rescaling files (because of RFI in SMOS)
Number of Assimilated Tb Observations

April

May

June

SPL4SM_V10002
Obs: L1C, L2AP
Global
March 31 – May 15:
L1C Tbs only (no L2AP) because of inconsistent treatment of flags in L1C and L2AP.
Number of Assimilated Tb Observations

May 12 – 14: No L1-2 data (safe mode event)

Data counts: Used (p) Passive Not used
May 16 – 17: New CRID in L2AP only resulted in some unflagged disaggregated Tbs.
Number of Assimilated Tb Observations

May 18 – 26:
Bad L1-2 build resulted in bad data.
May 27 – 29: Bad build fixed.
May 30 - present:
Turned off L2AP ingest because of faulty (NaN) values in OPS granules. Stable data counts through present (Jul-Aug not shown).
Data Residuals

May 18 – 26:
Bad L1-2 build resulted in bad L1-2 data.

Occasional outliers:
Half-orbits with bad data.
Occasional outliers: Half-orbits with bad data.
Data Residuals

“Good” spike: 15 July 2015, 6z.

Radar HPA anomaly shifts mean O-F values.

Half-orbits with bad data.

??
Data Residuals

L4_SM O-F [K], 15 July 2015, 6z

Precip Forcing (GEOS-5) [mm d⁻¹]

NRL 3-hr satellite precip

CPCU Gauge Precip

NOT used in L4_SM over Africa!
15 Jul 2015
Soil Moisture and Temperature Analysis
29 May 2015, 0z

tb_h_obs_assim-tb_h_forecast

sm_surface_analysis-sm_surface_forecast

soil_temp_layer1_analysis-soil_temp_layer1_forecast

sm_rootzone_analysis-sm_rootzone_forecast

[K]

[K]

[m³m⁻³]

[m³m⁻³]
Number of Assimilated Data (L1C_TB)

Number of assimilated L1C_TB obs per day (avg=0.49)
H- & V-pol, ascending & descending, 3/31-8/23/2015
Observation Minus Forecast Residuals (L1C_TB)
31 Mar – 23 Aug 2015

Mean O-F (avg=1.3 K)

Std-dev O-F (avg=6.0 K)

H- & V-pol, ascending & descending
Observation Minus Forecast Residuals (L1C_TB)
31 Mar – 23 Aug 2015

Std-dev normalized O-F ~ Actual Uncertainty
Assumed Uncertainty

H- & V-pol
Asc & Desc

[dim.-less]

Target value = 1

DA system

overestimates
underestimates
actual uncertainty

0.5 1 1.5
Mean Increments (Analysis Minus Forecast)
31 Mar – 6 Jun 2015

mean $\Delta$sm_surface; m=-0.002 [m$^3$/m$^3$]

mean $\Delta$soil_temp_layer1; m=0.093 [K]
Std-dev Increments (Analysis Minus Forecast)
31 Mar – 6 Jun 2015

stdv \( \Delta \text{sm\_surface} \); \( m = 0.014 \) [m\(^3\)/m\(^3\)]

stdv \( \Delta \text{sm\_rootzone} \); \( m = 0.006 \) [m\(^3\)/m\(^3\)]

stdv \( \Delta \text{soil\_temp\_layer1} \); \( m = 0.596 \) [K]
Core Site Validation – Sample Time Series

48010902 (TxSON)

- In situ
- NRv04
- L4_SM (V10002)

**Surface**

- $ubRMSE_v4 = 0.042$; $R_v4 = 0.745$, Bias$_v4 = 0.150$
- $ubRMSE_L4 = 0.047$; $R_L4 = 0.729$, Bias$_L4 = 0.155$

**Rootzone**

- $ubRMSE_v4 = 0.028$; $R_v4 = 0.884$, Bias$_v4 = 0.092$
- $ubRMSE_L4 = 0.022$; $R_L4 = 0.906$, Bias$_L4 = 0.102$
Core Site Validation – Sample Time Series

16030911 (Ft Cobb)  ● In situ  ● NRv04  ● L4_SM (V10002)

Surface

ubRMSE_v4 = 0.042; R_v4 = 0.696, Bias_v4 = 0.019
ubRMSE_L4 = 0.032; R_L4 = 0.846, Bias_L4 = 0.039

Rootzone

ubRMSE_v4 = 0.025; R_v4 = 0.790, Bias_v4 = 0.012
ubRMSE_L4 = 0.031; R_L4 = 0.896, Bias_L4 = 0.035
Core Site Validation – Sample Time Series

07010903 (Yanco)  |  In situ  |  NRv04  |  L4_SM (V10002)

ubRMSE_v4 = 0.067; R_v4 = 0.851, Bias_v4 = 0.004
ubRMSE_L4 = 0.047; R_L4 = 0.877, Bias_L4 = 0.028
Core Site Validation – ubRMSE

Surface

Root Zone

<table>
<thead>
<tr>
<th>Product</th>
<th>CVS Scale</th>
<th>ubRMSE [m³/m³]</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRv04</td>
<td>36 km</td>
<td>.034 .020</td>
</tr>
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<td>L4_SM</td>
<td>36 km</td>
<td>.029 .023</td>
</tr>
<tr>
<td>NRv04</td>
<td>9 km</td>
<td>.034 .014</td>
</tr>
<tr>
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<td>9 km</td>
<td>.031 .021</td>
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Average metrics are for core sites only (excl candidate sites).
Core Site Validation – **Bias** (model minus in situ)

### Surface Root Zone

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<td>.034 .020</td>
<td>.062 .042</td>
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<td>.029 .023</td>
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<td>.065 .040</td>
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*Average metrics are for core sites only (excl candidate sites).*
Core Site Validation – Time Series Correlation (R)

Surface

Root Zone

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<th>Bias [m³/m³]</th>
<th>R [-]</th>
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Average metrics are for core sites only (excl candidate sites).
L4_SM V10002 surface and root zone soil moisture estimates meet the validation requirement at 9 km:

\[
\text{ubRMSE} = 0.031 \text{ m}^3\text{m}^{-3} \quad \text{(surface)}
\]
\[
\text{ubRMSE} = 0.021 \text{ m}^3\text{m}^{-3} \quad \text{(root zone)}
\]

Comparison with skill of Nature Run v04 estimates suggests mixed impact of assimilated SMAP Tbs.

Reprocessing against beta version of L1 observations should further improve L4_SM.

On schedule for L4_SM beta-release (~1 Nov 2015).
L4_SM Science Issues (Beyond Beta-Release)

- **L4_SM calibration**
  - Forcing climatology (*MERRA-2; revised precipitation corrections*)
  - RTM parameters (*recalibrate to SMOS v620*)

- **Refined assessment of SMAP impact in assimilation system**
  - Single-member (no perturbations) with precip. corr. (Nature Run)
  - Ensemble open-loop with precipitation corrections (*new*).
  - Ensemble open-loop without precipitation correction (*new*).

- **Improved precipitation corrections during reprocessing?**
  - Forward-processing (OPS) data trade quality vs. latency.
  - Reprocessing could use GPCP, GPM, and/or CMAP data, but
    - Requires re-calibration of the system
    - Difficult to transition into forward-processing (OPS)

- **Other algorithm enhancements**
  - Waterbody correction (not just screening)
  - Freeze-thaw analysis
  - Improved utilization of flags in L1C.
Thanks for listening.
EXTRA SLIDES
Assimilated Data (L1C_TB, H&V-pol)

**Number of data per day**

<table>
<thead>
<tr>
<th>Month</th>
<th>N_data_per_day ΔTbL1C</th>
<th>m</th>
<th>s</th>
</tr>
</thead>
<tbody>
<tr>
<td>April</td>
<td>0.66</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>0.43</td>
<td>0.16</td>
<td></td>
</tr>
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</table>

**Mean O-F**

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean ΔTbL1C</th>
<th>m</th>
<th>s</th>
</tr>
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<tbody>
<tr>
<td>April</td>
<td>1.85</td>
<td>3.10 [K]</td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>1.41</td>
<td>3.46 [K]</td>
<td></td>
</tr>
</tbody>
</table>
Assimilated Data (L1C_TB, H&V-pol)

**Std-dev O-F**

- April: stdv $\Delta T_{b1C}$; $m=33.31$, $s=3.43$ [K]
- May: stdv $\Delta T_{b1C}$; $m=6.34$, $s=4.39$ [K]

**Std-dev normalized O-F**

- April: stdv $\Delta T_{b1C}$; $m=1.20$, $s=0.71$ [K]
- May: stdv $\Delta T_{b1C}$; $m=1.35$, $s=0.93$ [K]
Coverage of Assimilated Tb Observations

24May2015, 00Z All SMAP data: 24 observations
all lat, all lon, all lev, k=40, bx=640,641,642,643,644,645,646,647, all qcc, all qch
SPL4SM_V10002Tb20150524_0000Z.ods

Observation Locations

Bad L1-2 build: Just 24 Tb observations assimilated…
Compare L4_SM to science experiment using SMOS:

• Assimilate SMOS v5 Tb interpolated to 40° inc angle.
• Otherwise configuration identical to L4_SM V10002.
• April 2015 only.
Mean innovations (observations minus forecast)

mean $\Delta T_{bL1C}$; $m=1.87$, $s=2.88$ [K]

mean $\Delta T_{bf}$; $m=0.26$, $s=3.97$ [K]

SMAP warmer on average than SMOS? Not expected.
Total profile soil moisture increments (mean)

mean $\Delta w_{\text{totvol}}; m=-0.4255$, $s=1.552 \left[10^{-3} \text{ m}^3/\text{m}^3\right]$

Mean increments larger for SMAP (but still small.)
**Total profile soil moisture increments (std-dev)**

Increments from SMAP and SMOS are of similar size on average.

(As measured by the time series std-dev of the increments.)