The Update to L-Band Geophysical Model Function for SSS Retrieval Using SMAP Data with Improved Radiometric Calibration

Estimation of SMAP Mesh Antenna Emissivity or Loss

Simon Yueh¹, Wenqing Tang¹, Alexander Fore¹, Akiko Hayashi¹, Sidarth Misra¹, and Jinzheng Peng²

¹Jet Propulsion Laboratory, California Institute of Technology, CA
²Goddard Space Flight Center, MD

October 2018
How much radiation from the SMAP mesh antenna?

Pre-launch measurement and modeling (V3)
Emissivity 0.002  ~0.6K  ~1 psu

Or?

Post-launch analysis using ocean radiative transfer model (V4)
Emissivity 0.01  ~3K  ~5 psu
• Errors in the GMF and ancillary data can cause systematic errors (spatial and time varying)
• Potential Circular loop: Calibrated data will be used to build Geophysical Model Function
Daily average of dTA Observations from V3 calibration

- DTA reduced by about 0.3 K from non-eclipse to eclipse
- Asc-DEC bias was -0.2 K bias in June
Large orbital SMAP Reflector Temperature Changes During Eclipse (thermal model)

- Non-eclipse
  - Tant was near 380 K

Daily average

Descending

Ascending

Near North Pole

Near South Pole

Near North Pole

Eclipse
Regression of daily dTA against antenna temperature (Misra)

Regression slope is about 0.01

\[ \Delta T_A'' = \frac{\Delta L}{L} (T_A - T_{ant}) \]

SMAP Radiometer Brightness Temperature Calibration for L1B_TB and L1C_TB Version 3
Estimated SMAP Reflector Loss

- 1.0025 used for V3 processing and prior
- Regression analyses in 2017

<table>
<thead>
<tr>
<th></th>
<th>Pol</th>
<th>JPL</th>
<th>GSFC</th>
<th>RSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflector</td>
<td>H</td>
<td>1.014</td>
<td>1.016</td>
<td>1.01</td>
</tr>
<tr>
<td></td>
<td>V</td>
<td>1.012</td>
<td>1.012</td>
<td>1.01</td>
</tr>
<tr>
<td>Radome</td>
<td>H</td>
<td>NA</td>
<td>1.0023</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>V</td>
<td>NA</td>
<td>1.0017</td>
<td>NA</td>
</tr>
</tbody>
</table>

Significantly larger than 0.002, pre-launch data/model value, by a factor of 5 to 8

- JPL: **Daily average of dTA** (**ocean model**) vs daily average of antenna temperature
- GSFC: Minimization of peak-to-peak **daily dTA** during May-July
- RSS: Hovmueller diagram (doy, lat) of **daily dTA** with respect to **ocean model**
V3 and V4 dTBV Map on Doy 181

V3 shows ~
• Negative bias for ascending
• Positive bias for descending

V4 shows ~
• Positive bias for ascending
• Negative bias for descending

0.0025 for reflector emissivity
0.012-0.016 for reflector emissivity
JPL’s analysis for V3 dTB on June 22, 2016
JPL’s analysis for V4 dTB on June 22, 2016

Bias near the Antarctic for ascending pass has significantly increased

Negative bias for descending pass showed up
Critical V4 Calibration Impact on soil moisture retrieval

• V4 calibration raised the TB by ~3K.

• Impact on L2 soil moisture retrieval: effective land surface temperature, Teff, was raised by a factor of 1.02 (~5 deg C)), to reduce soil moisture bias (dry bias).
  • Can land surface model underestimate surface temperature by 5 deg C? This is unlikely.

• V4 calibration not preferred for SMAP L2 soil moisture retrieval
Additional fixes are needed

- Should the dynamic range of reflector temperature be adjusted?
  - RSS implemented reflector temperature adjustment to address this

Other solutions?
Revisit the regression analyses

Make the antenna colder for descending and warmer for ascending
Is this physical?

\[ \Delta T_A'' = \frac{\Delta L}{L} (T_A - T_{ant}) \]
Influence of Sun Glint
V3 and V4 DTB Comparison for DOY 1, 2016

Some large dTB caused by sea ice
Sun glint could be much more diffused than the 25 degree keep-out angular cone
Revisit the Regression Estimation

Perform regression using every data point (not daily average) to account for ascending and descending differences
SMAP V3 dTB vs. Antenna Temperature on June 22, 2016

\[ \Delta T_B'' = \frac{\Delta L}{L} \left( T_B - \frac{T_{\text{ant}}}{B_e} \right) \]
SMAP V4 dTB vs. Antenna Temperature on June 22, 2016

\[ \Delta T_B'' = \frac{\Delta L}{L} \left( T_B - \frac{T_{ant}}{B_e} \right) \]
## Estimated Delta Emissivity from SMAP V3 Data

<table>
<thead>
<tr>
<th>Date Range</th>
<th>Threshold of antenna azimuth angle from 90 degrees</th>
<th>Threshold of sun incidence</th>
<th>$dTBV/d(T_{ant}-TB)$</th>
<th>$dTBH/d(T_{ant}-TB)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/22/16</td>
<td>30</td>
<td>25</td>
<td>0.0022</td>
<td>0.0021</td>
</tr>
<tr>
<td>6/22/16</td>
<td>90</td>
<td>25</td>
<td>0.0029</td>
<td>0.0019</td>
</tr>
<tr>
<td>6/22/16</td>
<td>360</td>
<td>25</td>
<td>0.0027</td>
<td>0.0030</td>
</tr>
<tr>
<td>xx/22/16</td>
<td>30</td>
<td>25</td>
<td>0.0020</td>
<td>0.0016</td>
</tr>
<tr>
<td>xx/22/16</td>
<td>90</td>
<td>25</td>
<td>0.0024</td>
<td>0.0016</td>
</tr>
<tr>
<td>xx/22/16</td>
<td>360</td>
<td>25</td>
<td>0.0028</td>
<td>0.0033</td>
</tr>
<tr>
<td>xx/22/16</td>
<td>360</td>
<td>50</td>
<td>0.0026</td>
<td>0.0019</td>
</tr>
<tr>
<td>xx/22/16</td>
<td>360</td>
<td>0</td>
<td>0.0039</td>
<td>0.0047</td>
</tr>
<tr>
<td>xx/22/16</td>
<td>30</td>
<td>0</td>
<td>0.0020</td>
<td>0.0016</td>
</tr>
</tbody>
</table>

Residual sun glint can affect the estimate by about 0.001 ~50% of correction
# Estimated Delta Emissivity from SMAP V4 Data

<table>
<thead>
<tr>
<th>Date Range</th>
<th>Threshold of antenna azimuth angle from 90 degrees</th>
<th>Threshold of sun incidence</th>
<th>$dTBV/d(T_{ant-TB})$</th>
<th>$dTBH/d(T_{ant-TB})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/22/16</td>
<td>30</td>
<td>25</td>
<td>-0.0109</td>
<td>-0.0158</td>
</tr>
<tr>
<td>6/22/16</td>
<td>90</td>
<td>25</td>
<td>-0.0104</td>
<td>-0.0162</td>
</tr>
<tr>
<td>6/22/16</td>
<td>360</td>
<td>25</td>
<td>-0.0108</td>
<td>-0.0152</td>
</tr>
<tr>
<td>xx/22/16</td>
<td>30</td>
<td>25</td>
<td>-0.0097</td>
<td>-0.0142</td>
</tr>
<tr>
<td>xx/22/16</td>
<td>90</td>
<td>25</td>
<td>-0.0093</td>
<td>-0.0141</td>
</tr>
<tr>
<td>xx/22/16</td>
<td>360</td>
<td>25</td>
<td>-0.0089</td>
<td>-0.0123</td>
</tr>
<tr>
<td>xx/22/16</td>
<td>360</td>
<td>50</td>
<td>-0.0091</td>
<td>-0.0137</td>
</tr>
<tr>
<td>xx/22/16</td>
<td>360</td>
<td>0</td>
<td>-0.0079</td>
<td>-0.0110</td>
</tr>
<tr>
<td>xx/22/16</td>
<td>30</td>
<td>0</td>
<td>-0.0097</td>
<td>-0.0142</td>
</tr>
</tbody>
</table>
Delta Antenna Loss Estimated from dTB vs. Antenna Temperature

<table>
<thead>
<tr>
<th></th>
<th>V</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>V4*</td>
<td>0.0137</td>
<td>0.0183</td>
</tr>
<tr>
<td>dL (dTB - Tant)</td>
<td>-0.0097</td>
<td>-0.0142</td>
</tr>
<tr>
<td>Total loss</td>
<td>0.0040</td>
<td>0.0041</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>V</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>V3</td>
<td>0.0025</td>
<td>0.0025</td>
</tr>
<tr>
<td>dL (dTB - Tant)</td>
<td>0.0020</td>
<td>0.0016</td>
</tr>
<tr>
<td>Total loss</td>
<td>0.0045</td>
<td>0.0041</td>
</tr>
</tbody>
</table>

*Include reflector and radome lossess

Re-analyses of V3 and V4 reach essentially the same estimates ~0.004 (JPL V4.2). Probably within the uncertainties of pre-launch estimates
V3 and V4 dTBV Map on Doy 181

V3 shows ~
- Negative bias for ascending
- Positive bias for descending

V4 shows ~
- Positive bias for ascending
- Negative bias for descending

0.0025 for reflector emissivity
0.012-0.016 for reflector emissivity
V3 and V4 dTBV Map on Doy 151

V3 shows ~
• Negative bias for ascending
• Positive bias for descending

V4 shows ~
• Positive bias for ascending
• Negative bias for descending

0.0025 for reflector emissivity
0.012-0.016 for reflector emissivity
V3 and V4 dTBV Map on Doy 1

V3 shows ~
- About neutral

V4 shows ~
- Negative bias for descending

0.0045 for reflector emissivity
0.0025 for reflector emissivity
0.012-0.016 for reflector emissivity
Small loss adjustment can reduce ascending-descending bias

Then

• How about the seasonal drift during eclipse?

• DTQ Analysis (Double difference)
  • Polarization difference and temporal changes
Using Double Difference (Second Stokes= TBV-TBH)

\[ T_B'' = T_B + \frac{\Delta L}{L} \left( T_B - \frac{T_{ant}}{B_e} \right) - (L - 1 + \Delta L) \frac{\Delta T_{ant}}{B_e} \]

Assume L does not depend on polarization

\[ T_{BQ}'' = T_{BV}'' - T_{BH}'' = (1 + \frac{\Delta L}{L}) T_{BQ}'' \]

\[ dT_Q = < T_{BQ}'' - T_{BQmodel} > + dT_{Qbias} = \frac{\Delta L}{L} < T_{BQmodel} > \]

\[ \frac{\Delta L}{L} = \frac{dT_Q}{< T_{BQmodel} >} + \frac{dT_{Qbias}}{< T_{BQmodel} >} \]

- There could be a polarized bias in the model and data, resulting in the second term.
- This technique is a way to examine change of DL if the bias is fixed.
Estimated delta loss from V3 dTQ

Because of the possibility of a polarized bias between model and data, the delta loss estimated may have a bias.

Lower loss during eclipse when the reflector was on average colder.

Did the loss of reflector loss change with the average temperature of reflector?

The pre-launch loss estimate is 0.0025.
The delta loss changed from 0.002 to 0.004, except during eclipse.
Both ascending and descending dTA were lower than non-eclipse by 0.3 K in June.

\[
T_A'' = T_A + \frac{\Delta L}{L} (T_A - T_{ant}) - (L - 1 + \Delta L) \Delta T_{ant}
\]

If we change the loss by 0.0012, we can approximately re-produce the changes of dTA during eclipse.
Caution on the use of the DTA analysis

\[ d\text{SSS} \sim dT_A(asc \ or \ dec, \ lat, \ doy) = \frac{\Delta L}{L} (T_A - T_{ant}) \]

- We can zero out dTA (dSSS) vs time and latitude if both parameters (L and Tant) can be freely adjusted.
  - RSS Hovmueller
  - JPL dTB
  - SMOS Ocean Target Transformation
Summary

• Re-analyses of V3 and v4 data using JPL GMF led to small change (~0.002) of reflector loss from pre-launch measurements and model
  • This is the basis of JPL SMAP V4.2 SSS
• DTQ analysis suggested a small change of reflector loss (~0.001) over eclipse seasons – exact sources unknown.
• Be cautious in using dTB for radiometric calibration
  • We can over-calibrate the data to fit the model
• Absolute radiometric calibration requires constant attention
Plan - Community Based

- Collaboration with LOcean to develop consistent SMOS-SMAP-CCI products
  - JPL SMAP open source codes installed at LOcean
- Collaboration with NOAA (Bayler, Garrett), GSFC (Dinnat, Eric), Observatoire de Paris (Prigent) on Community Radiative Transfer Model (CRTM) and Community Surface Emissivity Model (CSEM)
- Initial discussions – Form the CRTM-L working group (open for volunteers)
  - Start from CRTM as the baseline and improve L-band CSEM
  - Coordinated inter-comparison effort among group members to select the best modules for regular updates
- Can leverage the JPL SMAP open source codes for SSS/wind processing to test the sensitivity to
  - ancillary data (ECMWF, NCEP)
  - dielectric model
  - Roughness model
- Leverage PI-MEP
SMAP orbit and sun geometry

Seasonal configuration of Earth and Sun

Earth’s orbit

North Pole

Equator

Sun

March

Dec

June

Summer solstice

Vernal equinox

Autumnal equinox

Winter solstice

© 2008 Encyclopædia Britannica, Inc.
Average SMAP Reflector Temperature on the 1\textsuperscript{st} of each Month between 50S and 50N
Antenna Model for Calibration

$$T_A'' = T_A + \frac{\Delta L}{L} (T_A - T_{ant}) - (L - 1 + \Delta L) \Delta T_{ant}$$

Loss correction is a slope correction

Tant correction is a bias correction

TA: True antenna brightness temperature
TA’’: Calibrated TA with error
L: true loss
ΔL: delta loss; L+ Δ L is the loss used for calibration
Tant: physical temperature of antenna
ΔTant: knowledge error of Tant; Tant+ Δ Tant is used for calibration
Alternate Expression for Antenna Model for Calibration

\[ T_B'' = T_B + \frac{\Delta L}{L} \left( T_B - \frac{T_{ant}}{B_e} \right) - (L - 1 + \Delta L) \frac{\Delta T_{ant}}{B_e} \]

TB: True brightness temperature
TB’’: Calibrated TB with error =TA”'/Be
Be: beam efficiency
TA”': Calibrated TA with error
L: true loss
\Delta L: delta loss; L+ \Delta L is the loss used for calibration
Tant: physical temperature of antenna
\Delta Tant: knowledge error of Tant; Tant+ \Delta Tant is used for calibration

Loss correction is a slope correction
Tant correction is a bias correction