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

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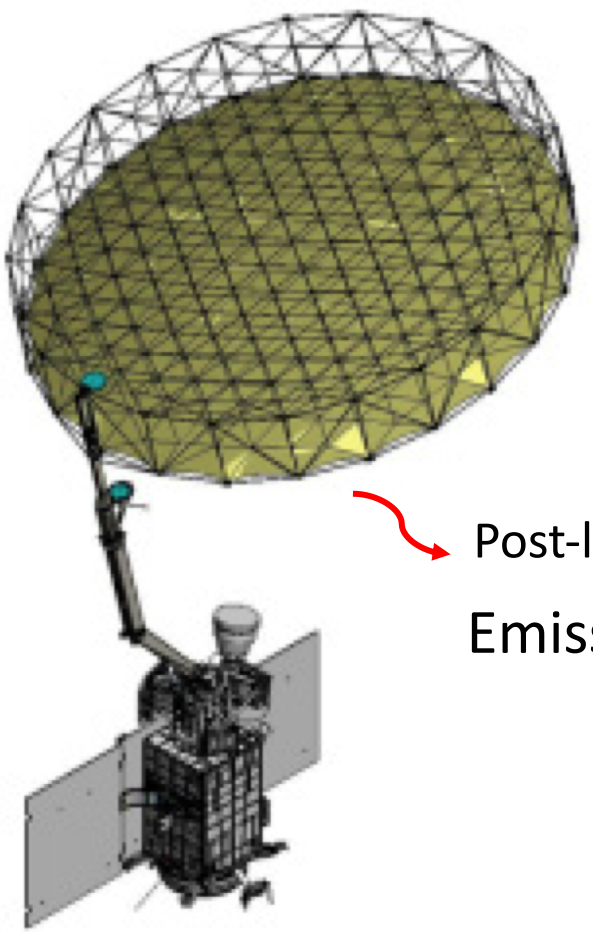
How much radiation from the SMAP mesh antenna?



Pre-launch measurement and modeling (V3)

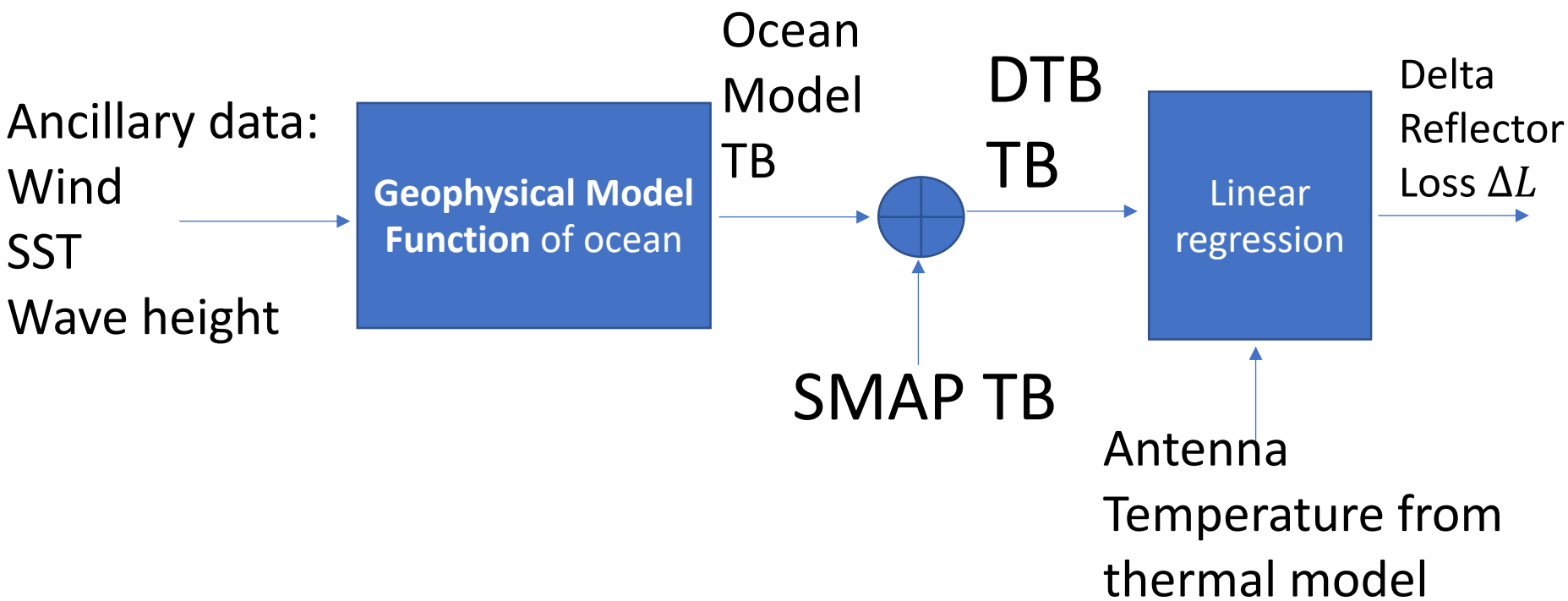
Emissivity 0.002 ~0.6K ~1 psu

Or ?

Post-launch analysis using ocean radiative transfer model (V4)

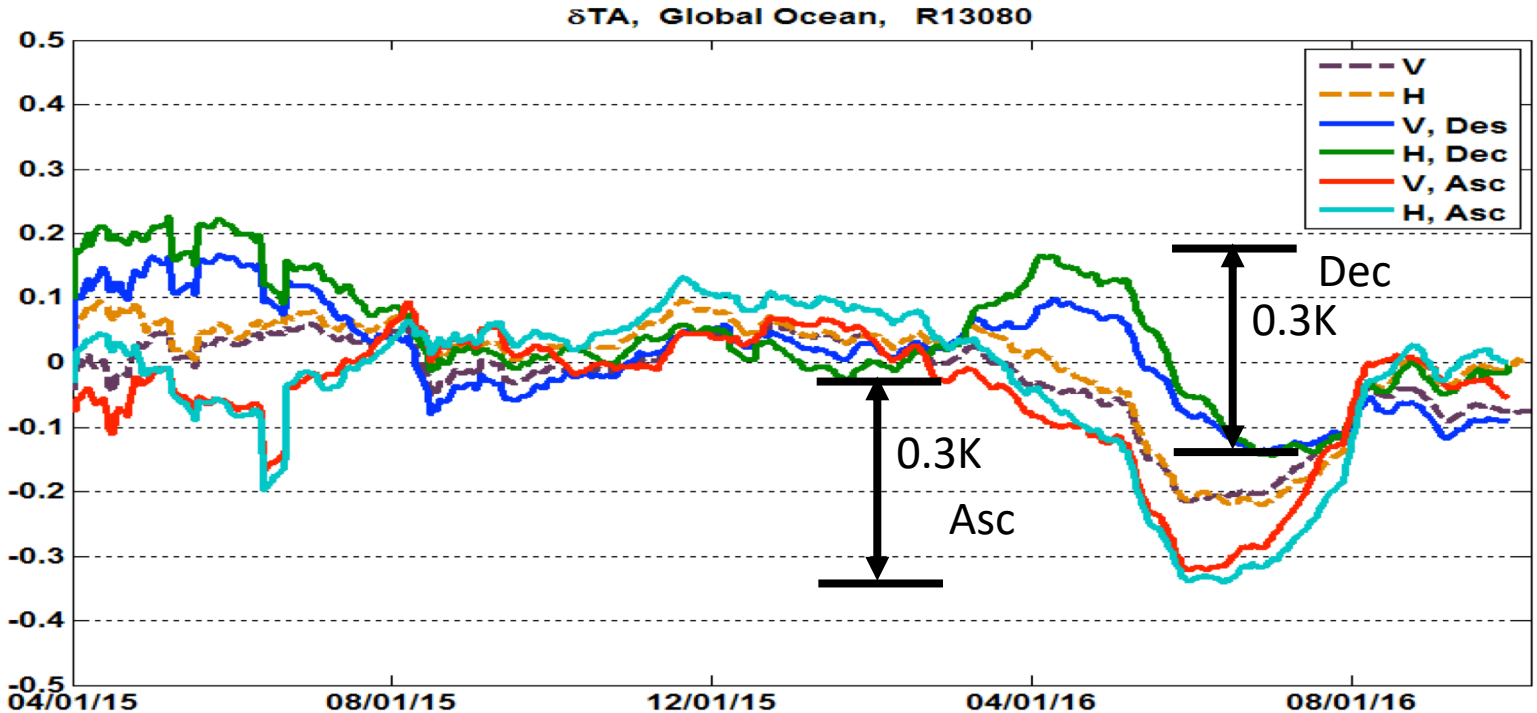
Emissivity 0.01 ~3K ~5 psu

Vicarious Antenna Emissivity Calibration Method



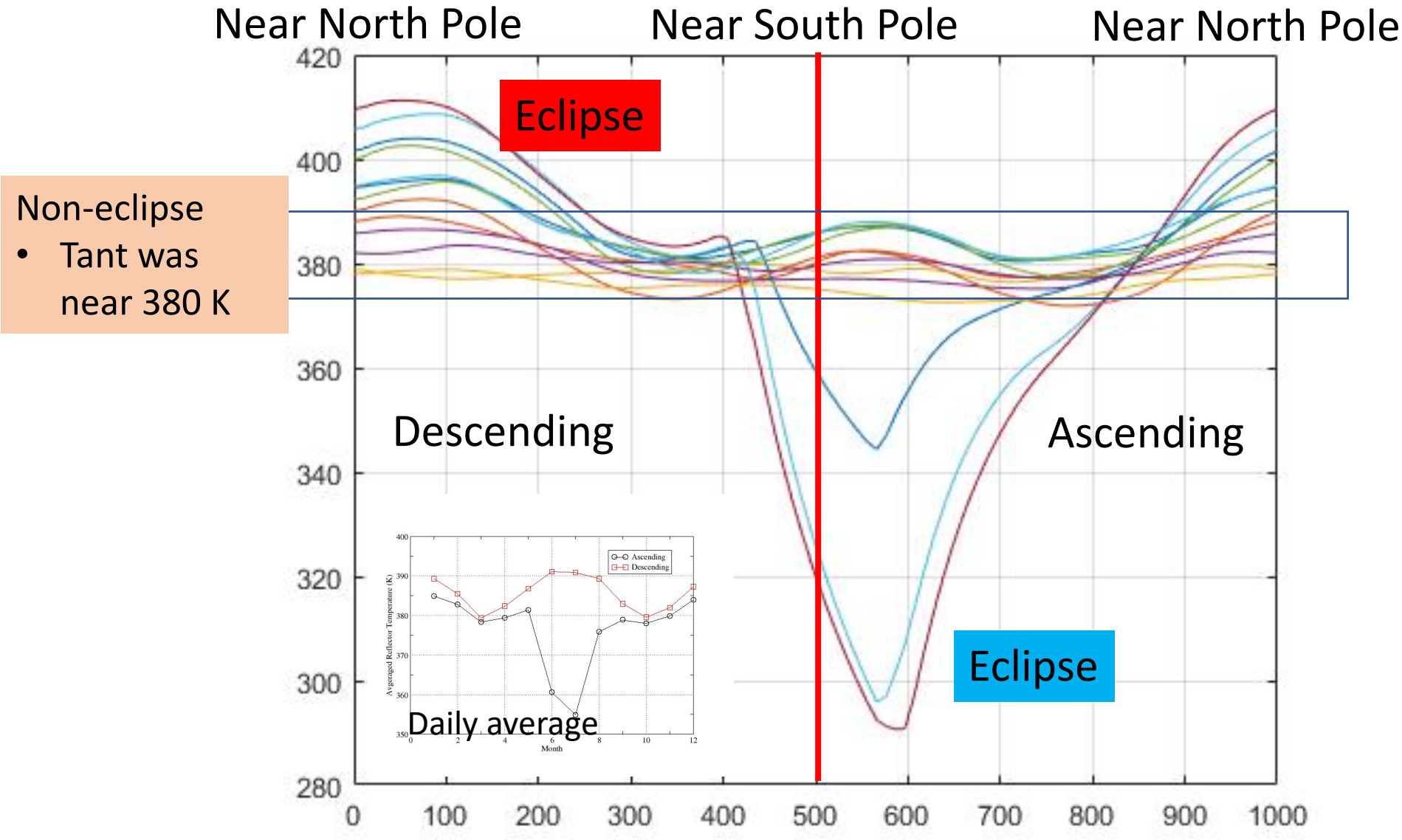
- Errors in the GMF and ancillary data can cause systematic errors (spatial and time varying)
- Potential Circular loop: Calibrated data will be used to build Geophysical Model Function

Daily average of dTA Observations from V3 calibration

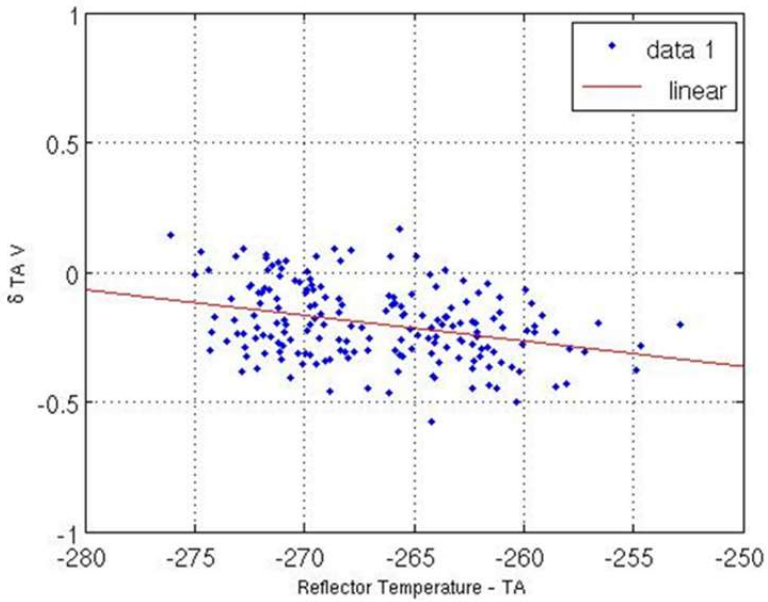


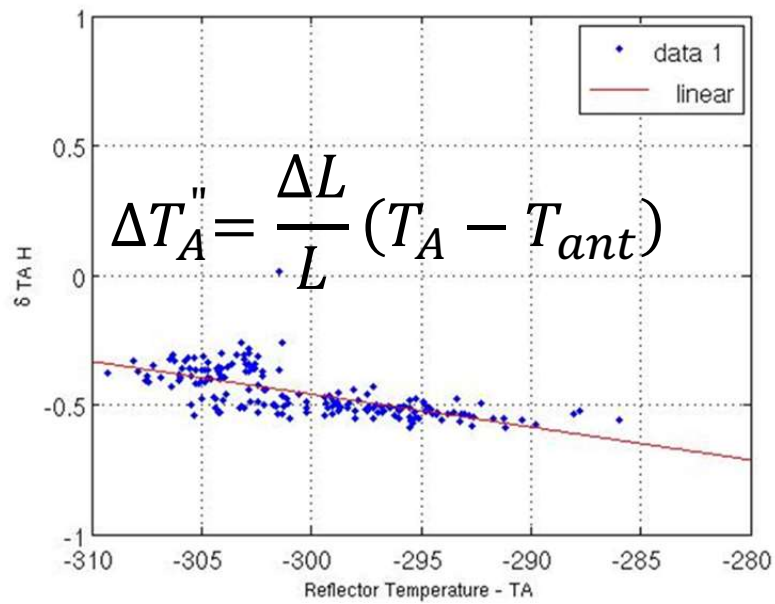
- **DTA reduced by about 0.3 K from non-eclipse to eclipse**
- **Asc-Dec bias was -0.2 K bias in June**

Large orbital SMAP Reflector Temperature Changes During Eclipse (thermal model)



Regression of daily dTA against antenna temperature (Misra)





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

Regression slope is about 0.01

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

	Pol	JPL	GSFC	RSS
Reflector	H	1.014	1.016	1.01
	V	1.012	1.012	1.01
Radome	H	NA	1.0023	NA
	V	NA	1.0017	NA

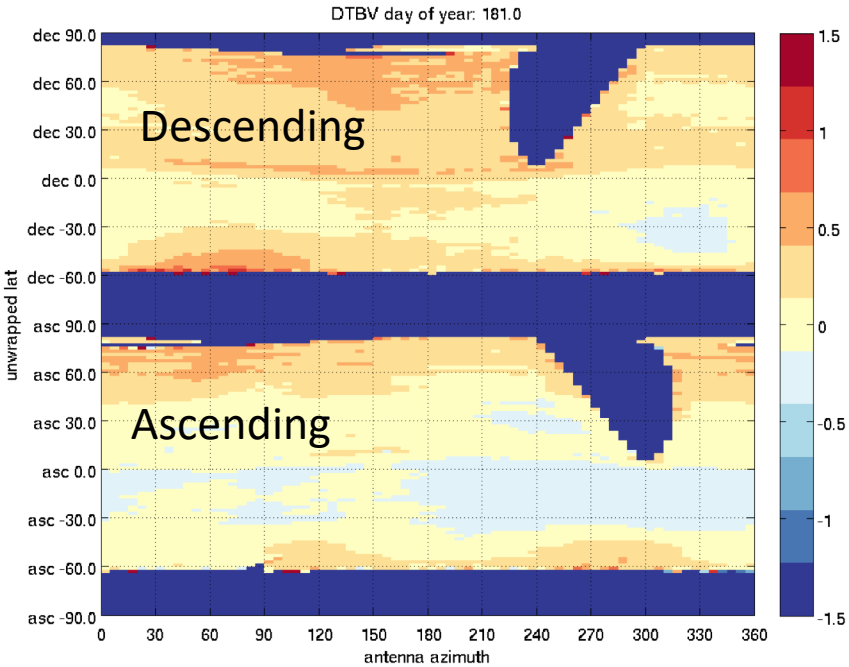
Significantly larger than 0.002, pre-launch data/model value, by a factor of 5 to 8

- 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

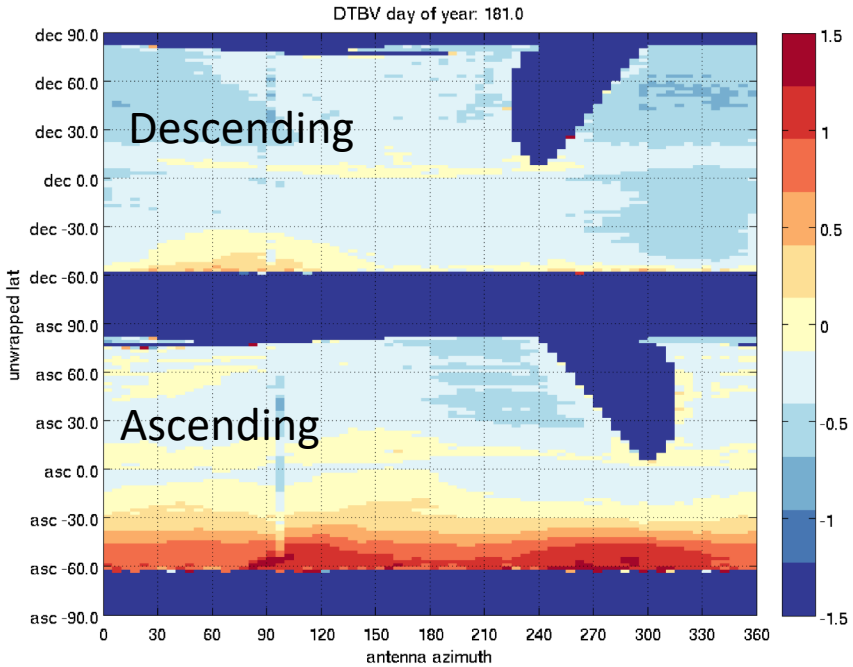


Antenna azimuth

0.0025 for reflector emissivity

V4 shows ~

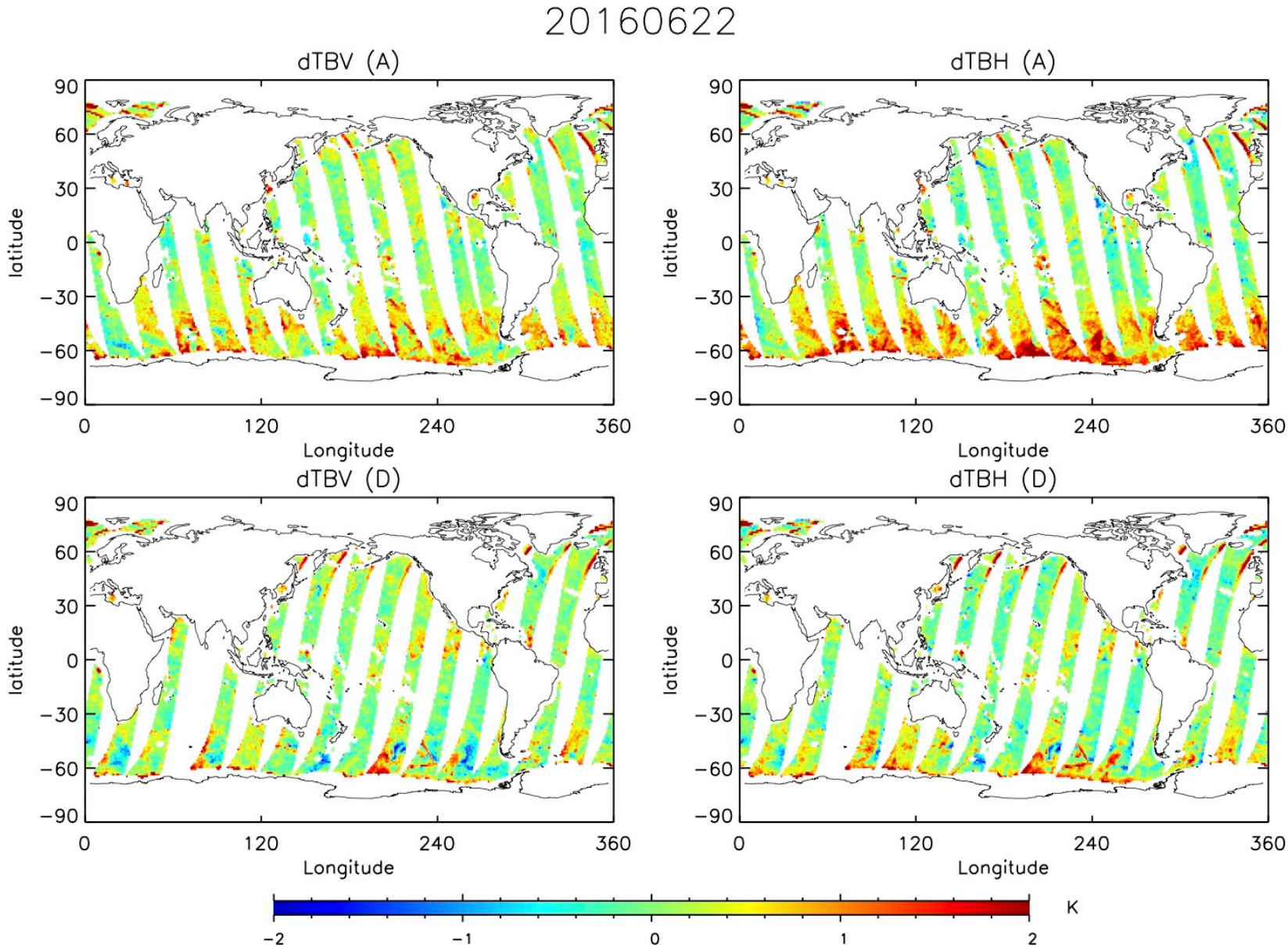
- Positive bias for ascending
- Negative bias for descending



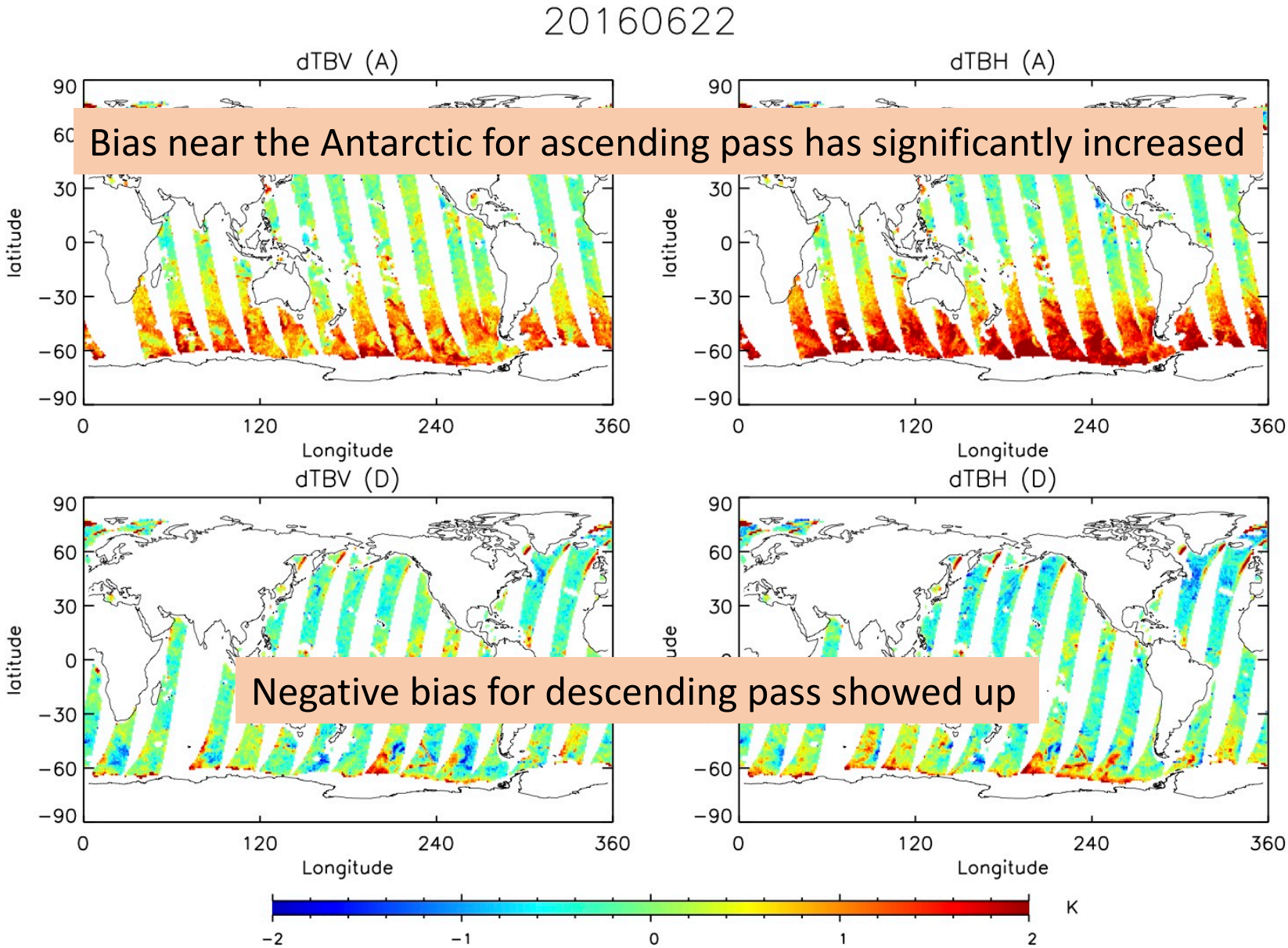
Antenna azimuth

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

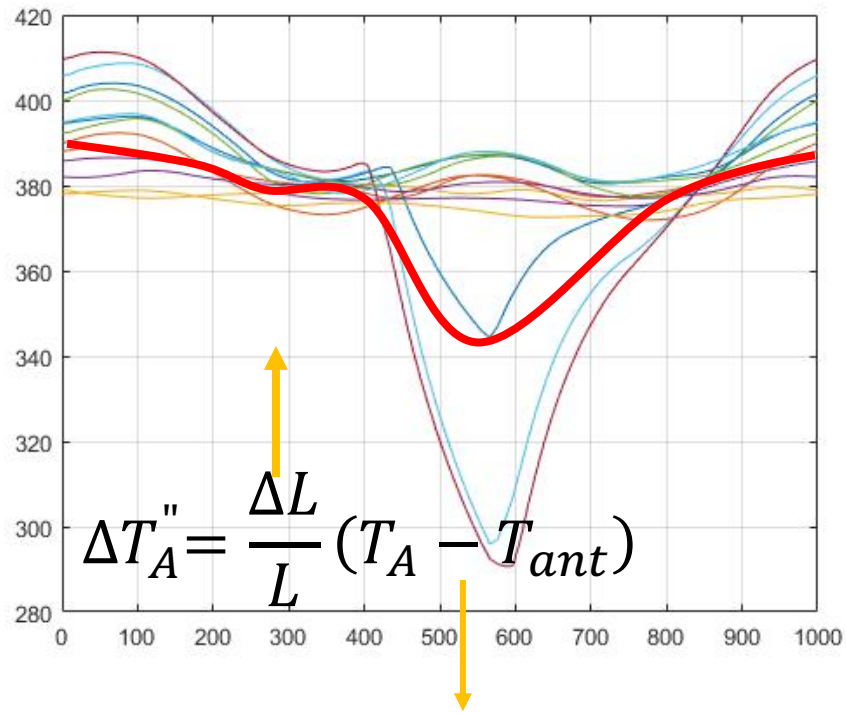
Additional fixes are needed

- 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?

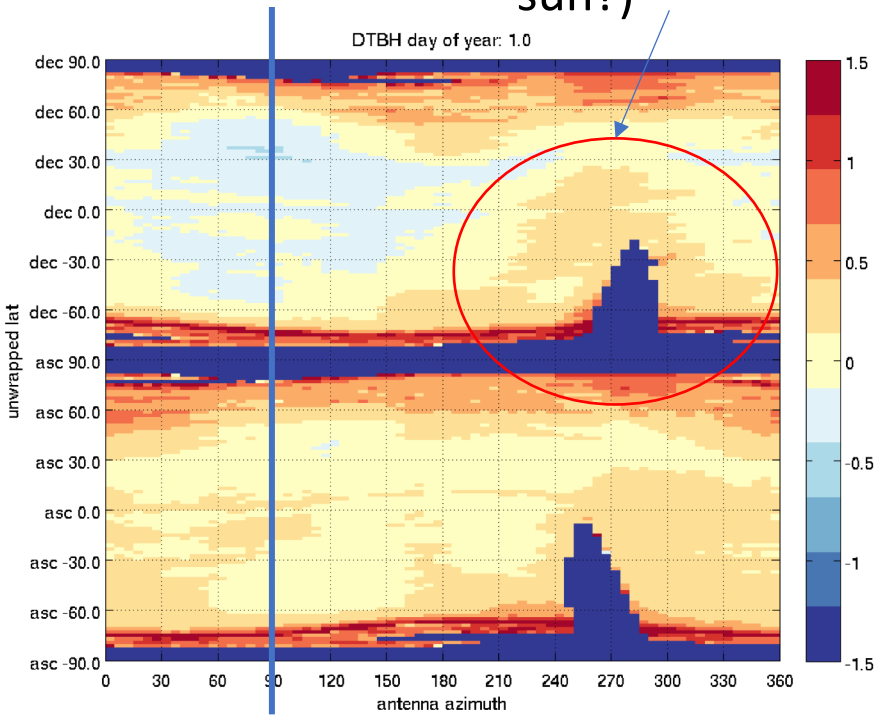


Influence of Sun Glint

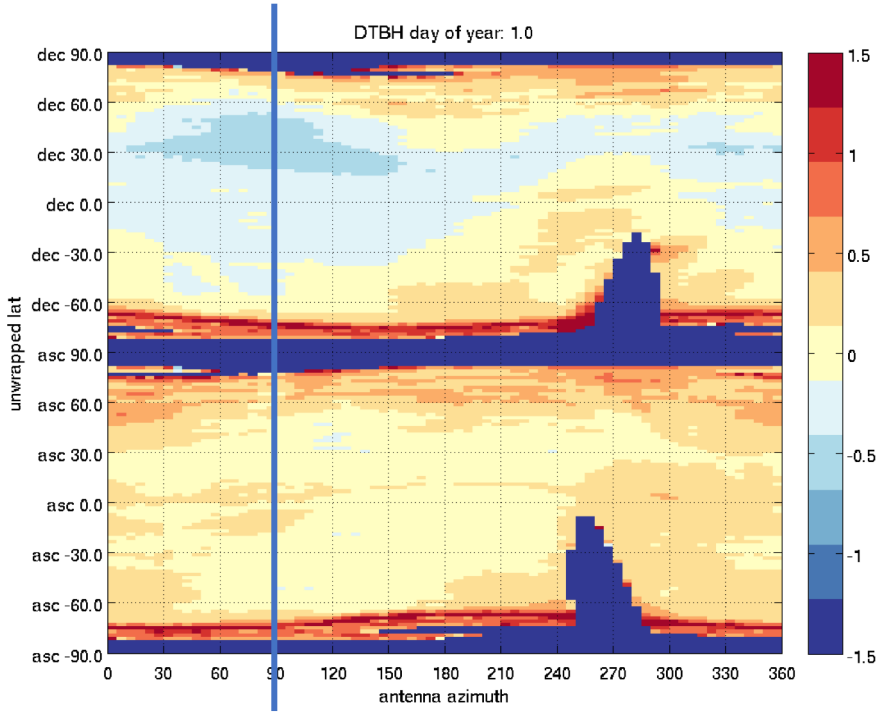
V3 and V4 DTB Comparison for DOY 1, 2016

Halo (diffused scattering by sun?)

V3



V4



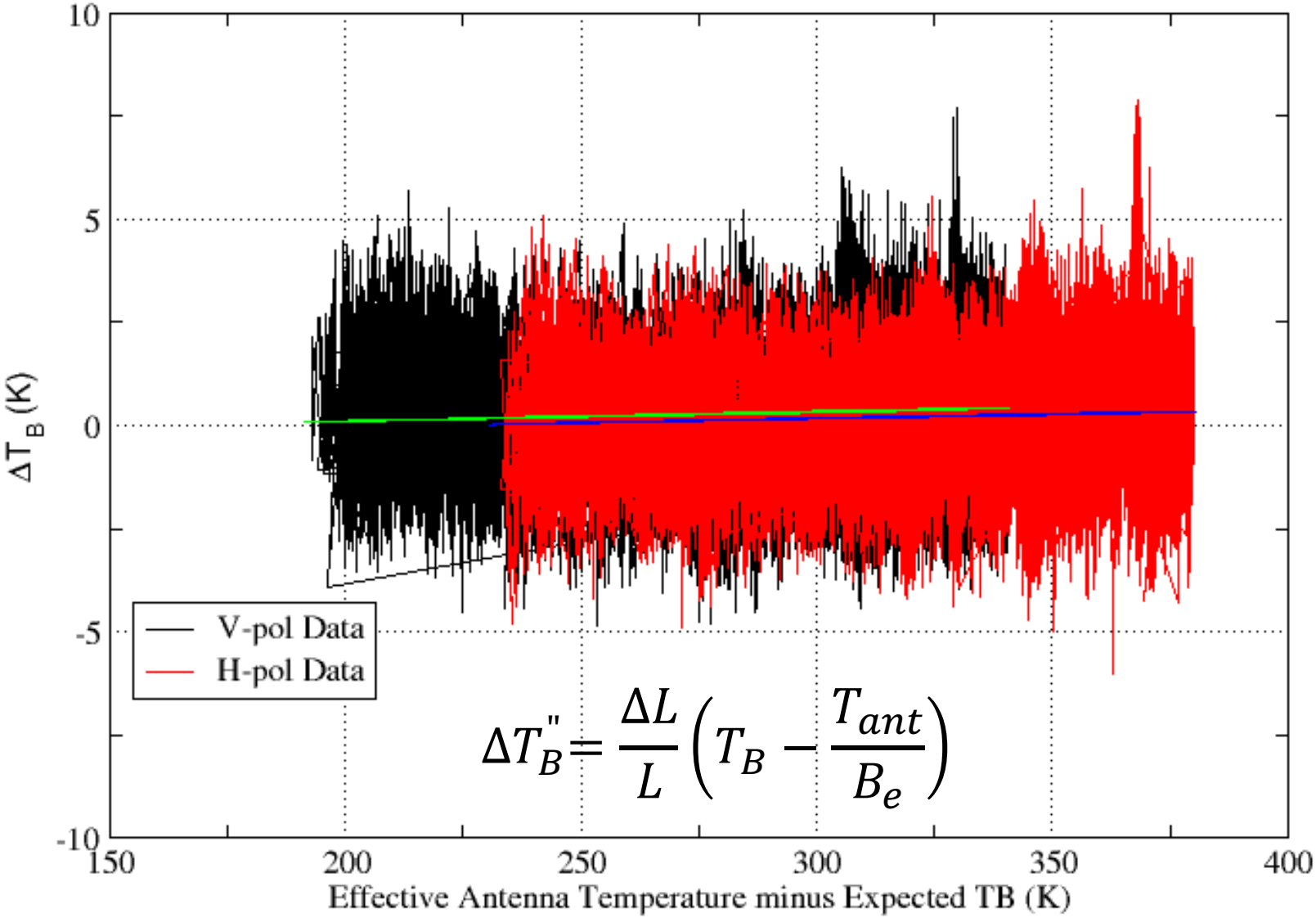
Some large dTB caused by sea ice

Sun glint could be much more diffused than the 25 degree keep-out angular cone

Revisit the Regression Estimation

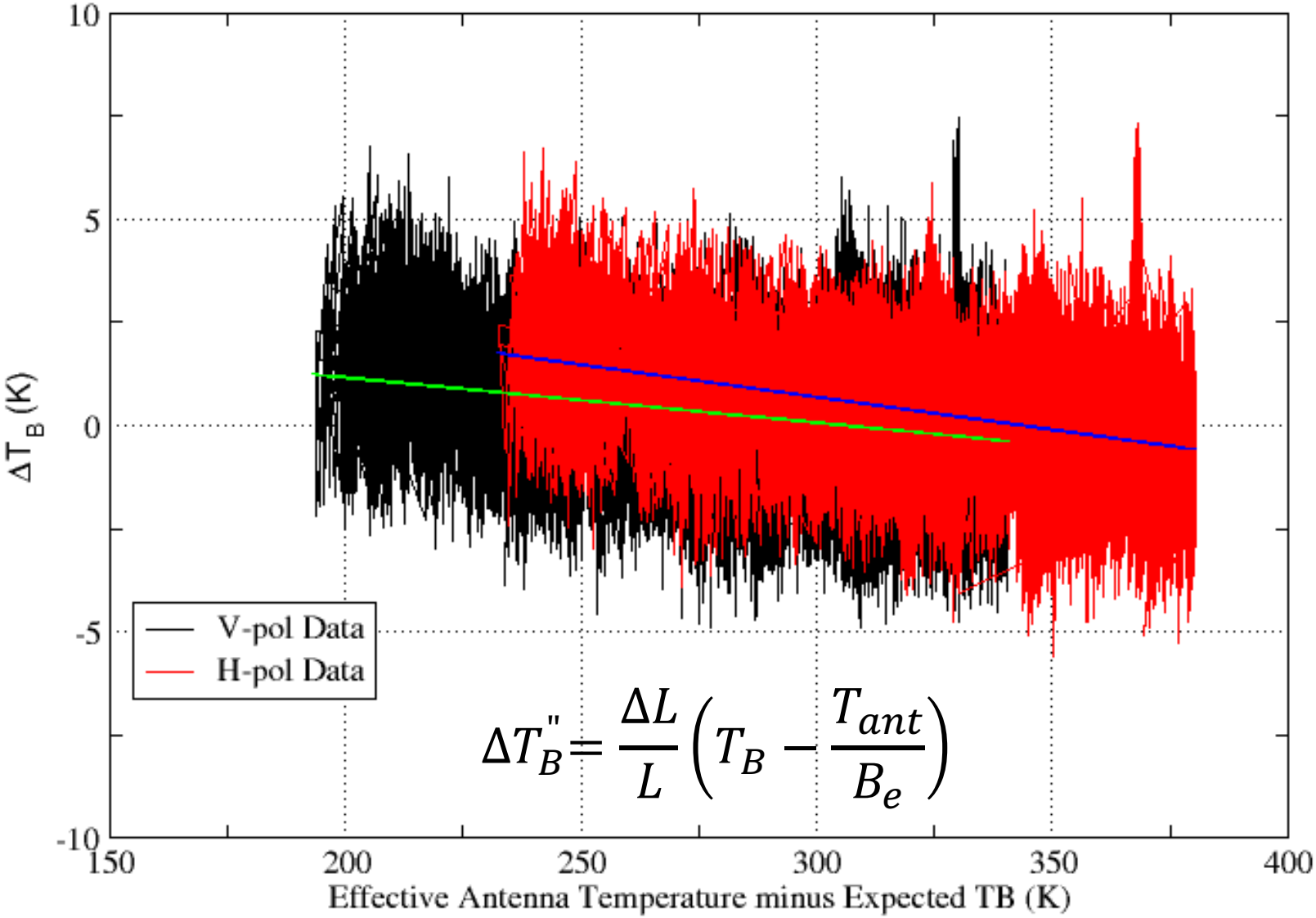
Perform regression using every data point (not daily average) to account for ascending and descending differences

SMAP V3 dTB vs. Antenna Temperature on June 22, 2016



$$\Delta T_B'' = \frac{\Delta L}{L}\left(T_B - \frac{T_{ant}}{B_e}\right)$$

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

Date Range	Threshold of antenna azimuth angle from 90 degrees	Threshold of sun incidence	dTBV/d(Tant-TB)	dTBH/d(Tant-TB)
6/22/16	30	25	0.0022	0.0021
6/22/16	90	25	0.0029	0.0019
6/22/16	360	25	0.0027	0.0030
xx/22/16	30	25	0.0020	0.0016
xx/22/16	90	25	0.0024	0.0016
xx/22/16	360	25	0.0028	0.0033
xx/22/16	360	50	0.0026	0.0019
xx/22/16	360	0	0.0039	0.0047
xx/22/16	30	0	0.0020	0.0016

Residual sun glint can affect the estimate by about 0.001 ~50% of correction

Estimated Delta Emissivity from SMAP V4 Data

Date Range	Threshold of antenna azimuth angle from 90 degrees	Threshold of sun incidence	dTBV/d(Tant-TB)	dTBH/d(Tant-TB)
6/22/16	30	25	-0.0109	-0.0158
6/22/16	90	25	-0.0104	-0.0162
6/22/16	360	25	-0.0108	-0.0152
xx/22/16	30	25	-0.0097	-0.0142
xx/22/16	90	25	-0.0093	-0.0141
xx/22/16	360	25	-0.0089	-0.0123
xx/22/16	360	50	-0.0091	-0.0137
xx/22/16	360	0	-0.0079	-0.0110
xx/22/16	30	0	-0.0097	-0.0142

Delta Antenna Loss Estimated from dTB vs. Antenna Temperature

	V	H
V4*	0.0137	0.0183
dL (dTB-Tant)	-0.0097	-0.0142
Total loss	0.0040	0.0041

	V	H
V3	0.0025	0.0025
dL (dTB-Tant)	0.0020	0.0016
Total loss	0.0045	0.0041

*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

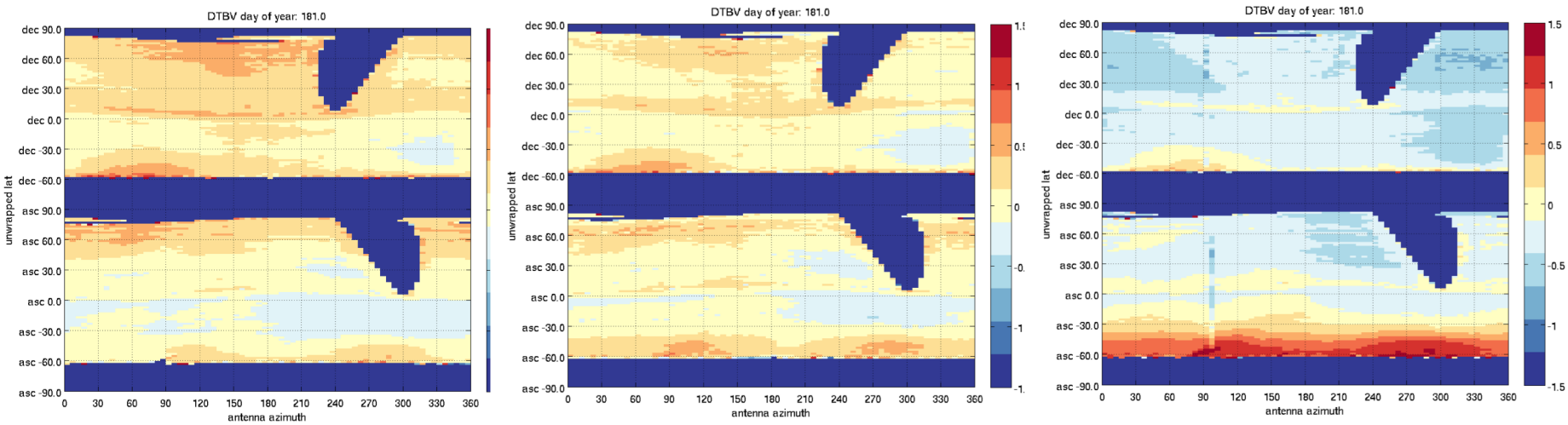
V4 shows ~

- Positive bias for ascending
- Negative bias for descending

V3

✓ V4.2

V4



0.0025 for reflector emissivity

0.012-0.016 for reflector emissivity

V3 and V4 dTBV Map on Doy 151

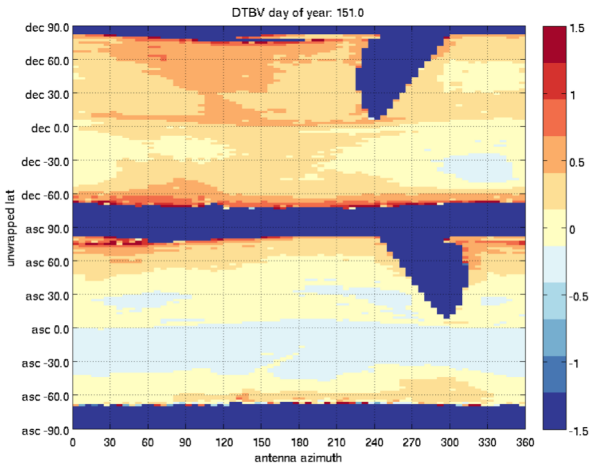
V3 shows ~
- Negative bias for ascending
- Positive bias for descending

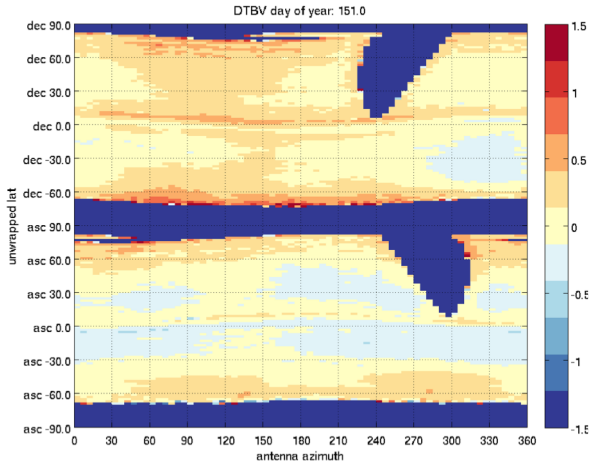
V4 shows ~
- Positive bias for ascending
- Negative bias for descending

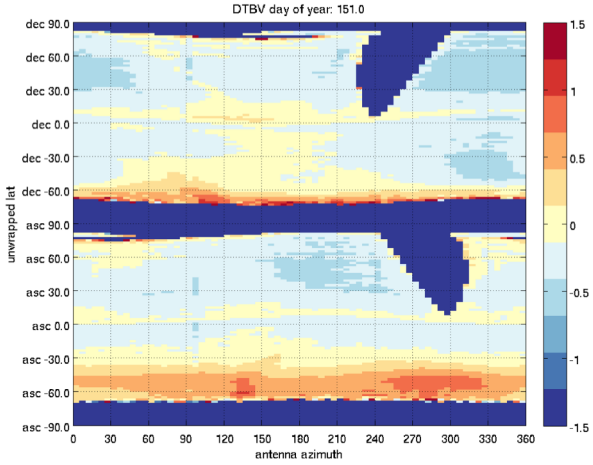
V3

✓ V4.2

V4







0.0025 for reflector emissivity

0.012-0.016 for reflector emissivity

V3 and V4 dTBV Map on Doy 1

V3 shows ~

- About neutral

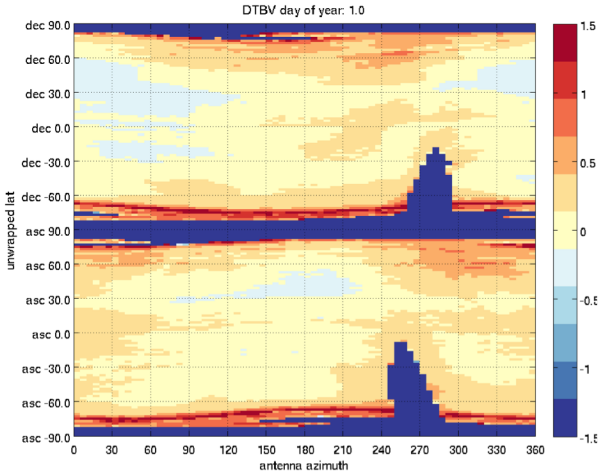
V4 shows ~

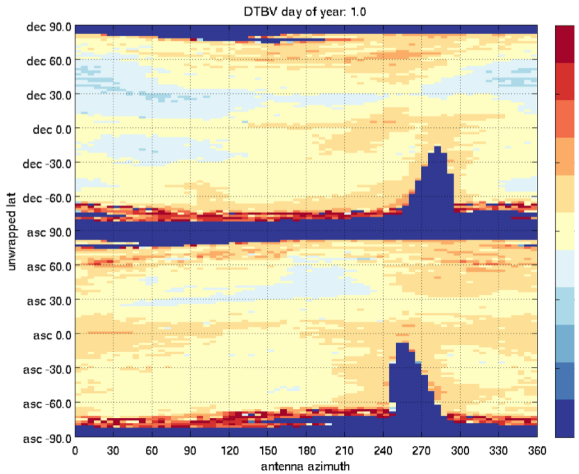
- Negative bias for descending

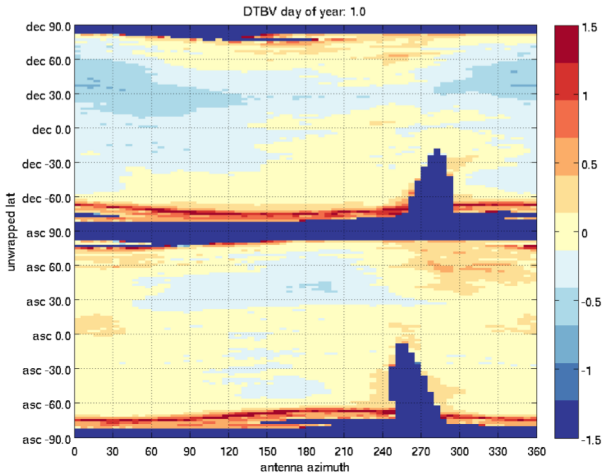
V3

✓ V4.2

V4







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

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

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

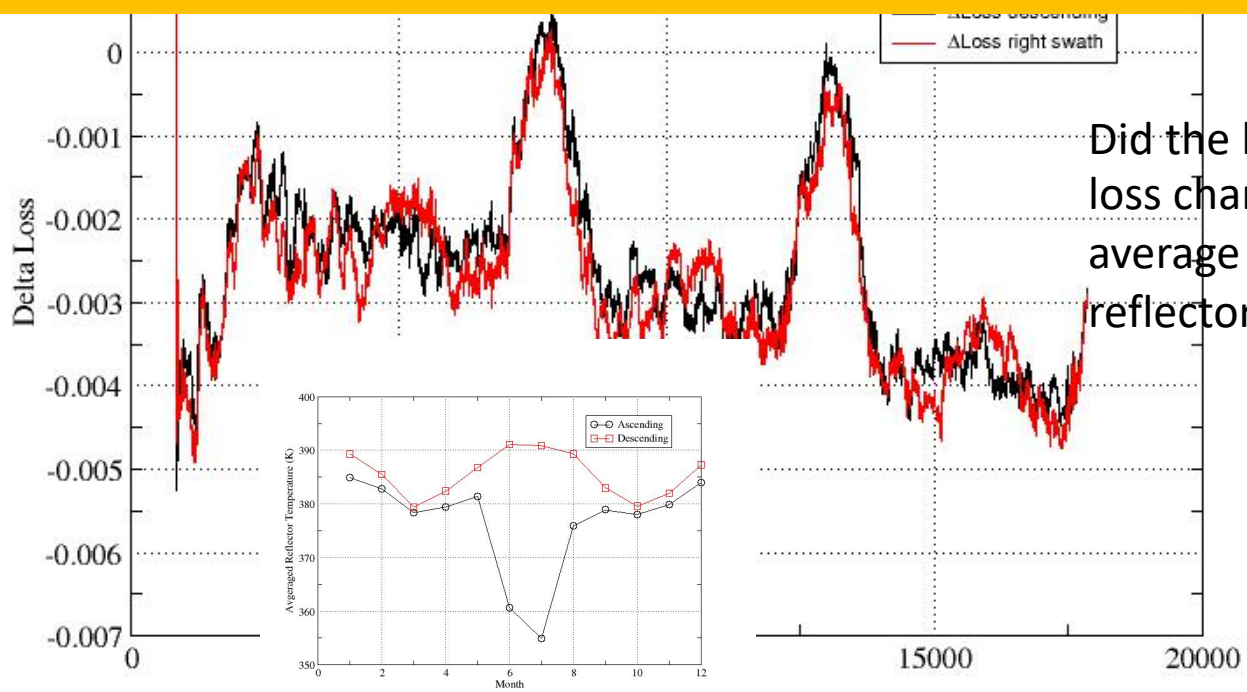
$$\boxed{\frac{\Delta L}{L} = \frac{dT_Q}{< T_{BQmodel} >}} + \frac{dT_{Qbias}}{< T_{BQmodel} >}$$

- **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.

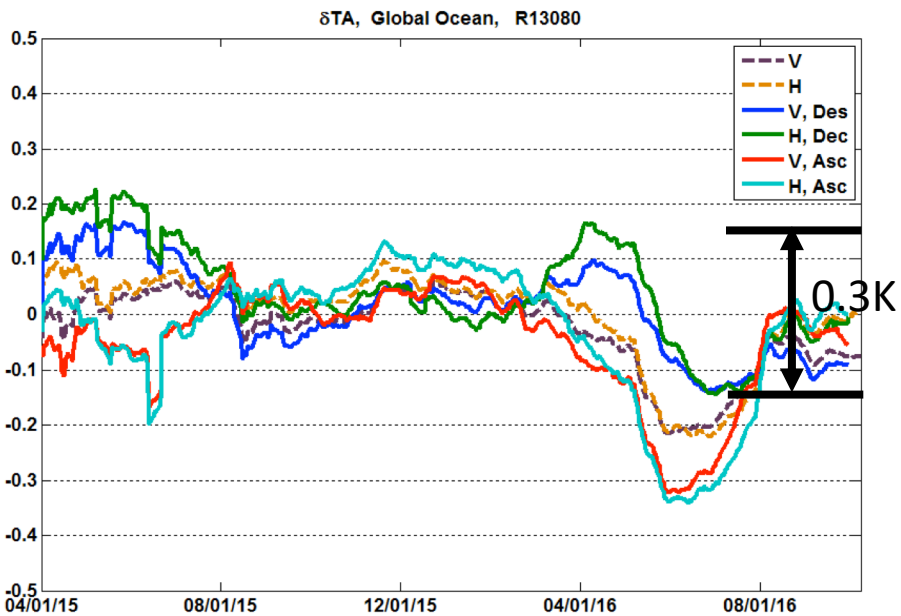
Lower loss during eclipse when the reflector was on average colder



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

dTA for Version 3



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.

	V		H	
	Asc	Dec	Asc	Dec
Tant	355	390	355	390
TA	120	120	70	70
L	1.005	1.005	1.005	1.005
DL	0.0012	0.0012	0.0012	0.0012
DTA	**-0.28**	**-0.32**	**-0.34**	**-0.38**

Caution on the use of the DTA analysis

$$\text{dSSS} \sim \text{d}T_A(asc\ or\ dec, lat, doy) = \boxed{\frac{\Delta L}{L}}\boxed{(T_A - T_{ant})}$$

- 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

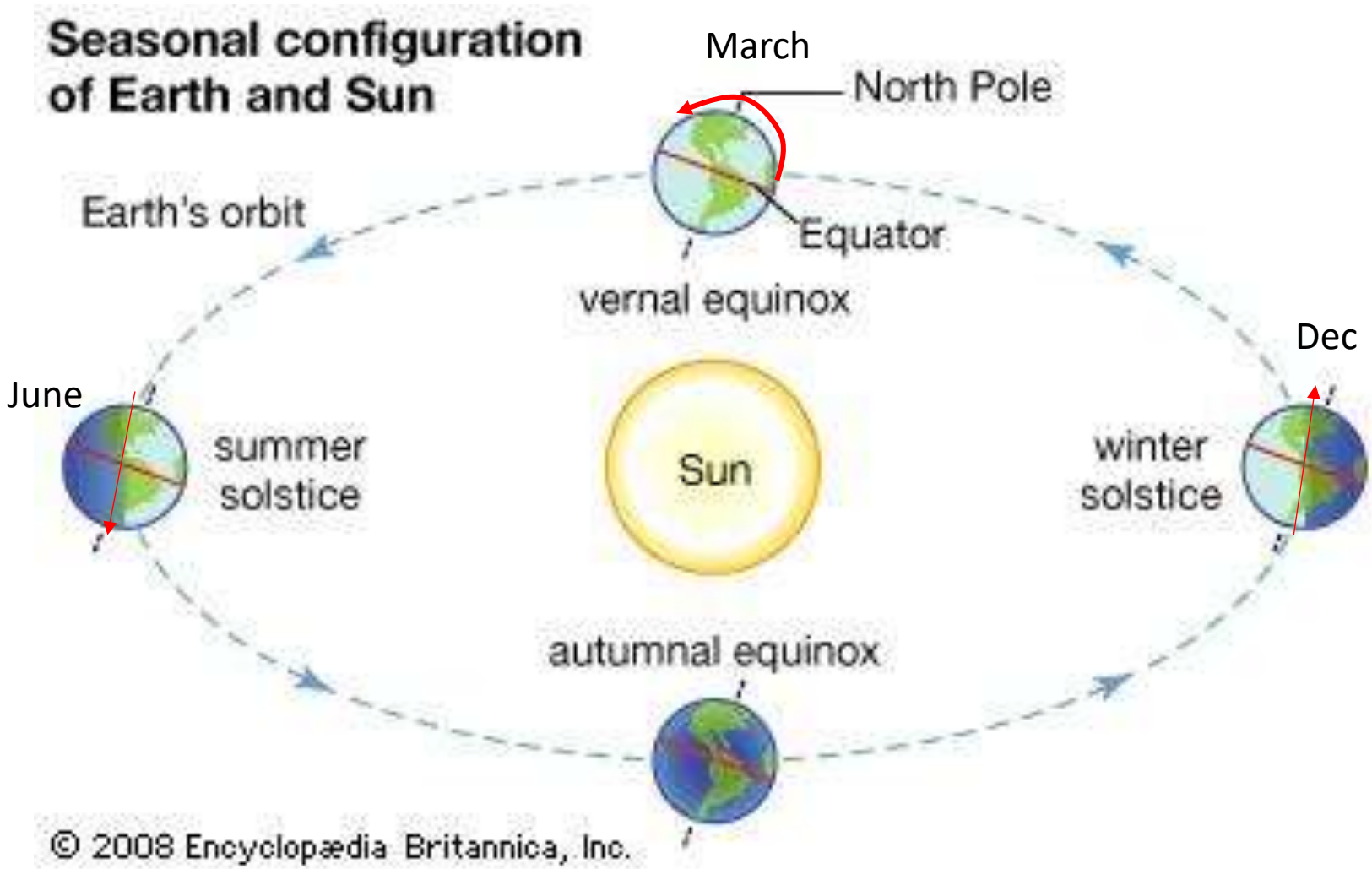
Summary

- 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**

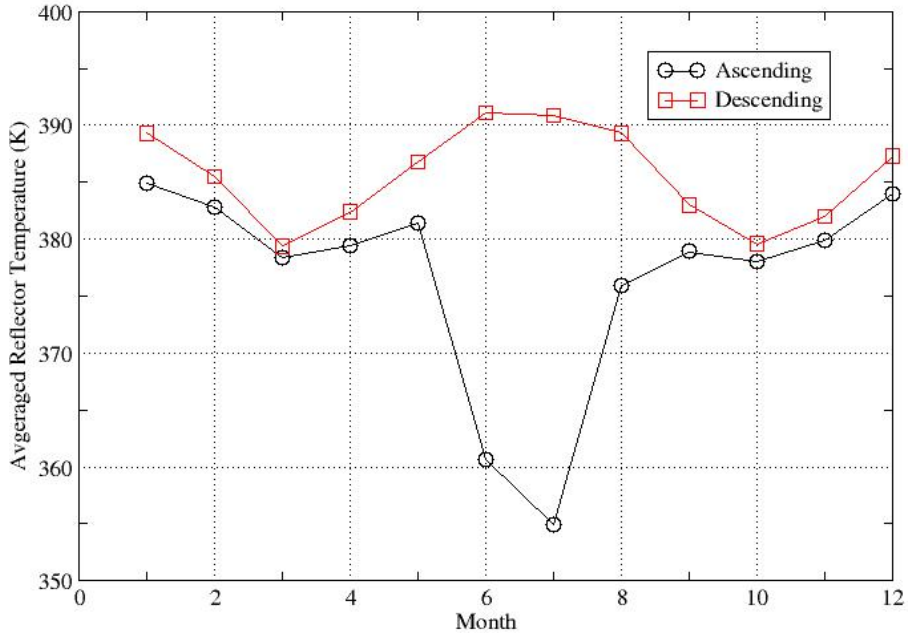
Plan - Community Based

- 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



Average SMAP Reflector Temperature on the 1st of each Month between 50S and 50N



Antenna Model for Calibration

Loss correction is a slope correction

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

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

Loss correction is a slope correction

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

Tant correction is a bias correction

TB: True brightness temperature

TB”: Calibrated TB with error =TA”/Be

Be: beam efficiency

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