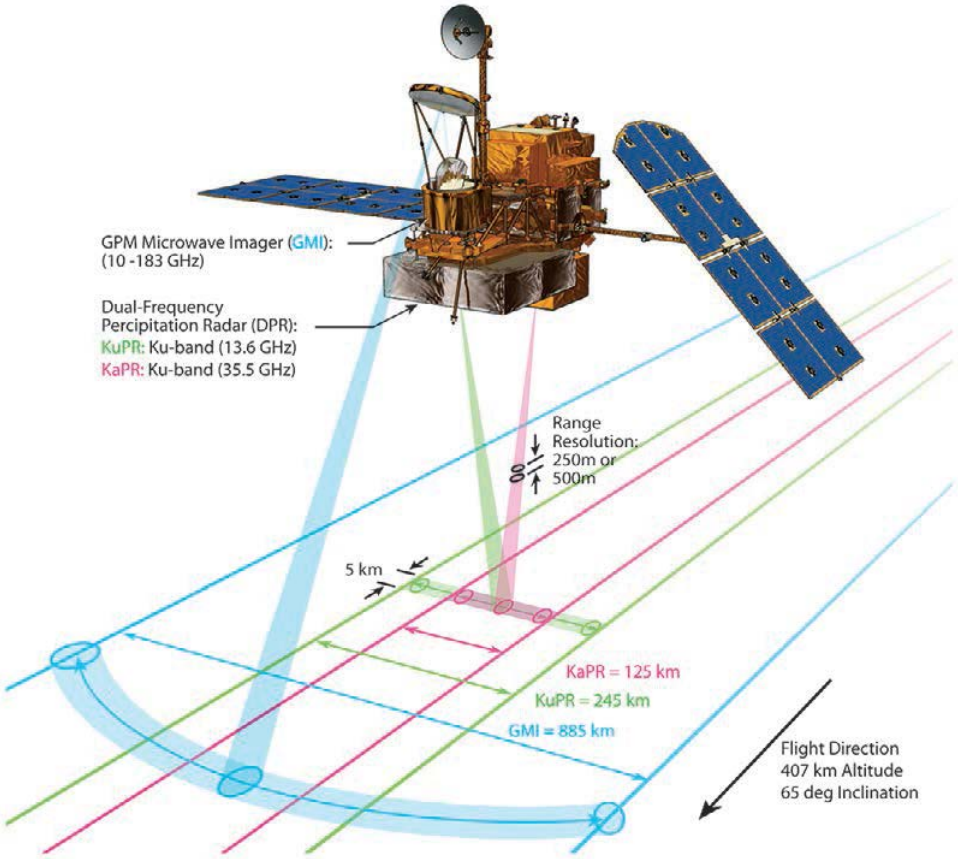
Intercalibration Activities for ATMS Window and Water Vapor Channels

Wesley Berg

Colorado State University

Global Precipitation Measurement (GPM) Mission



GPM Core Satellite
(Launched 27 Feb 2014)

Dual-Frequency radar (DPR)
- Ku-band (13.6 GHz)
- Ka-band (35.5 GHz)

Microwave Imager (GMI)
- 13 channels
- 10-183 GHz

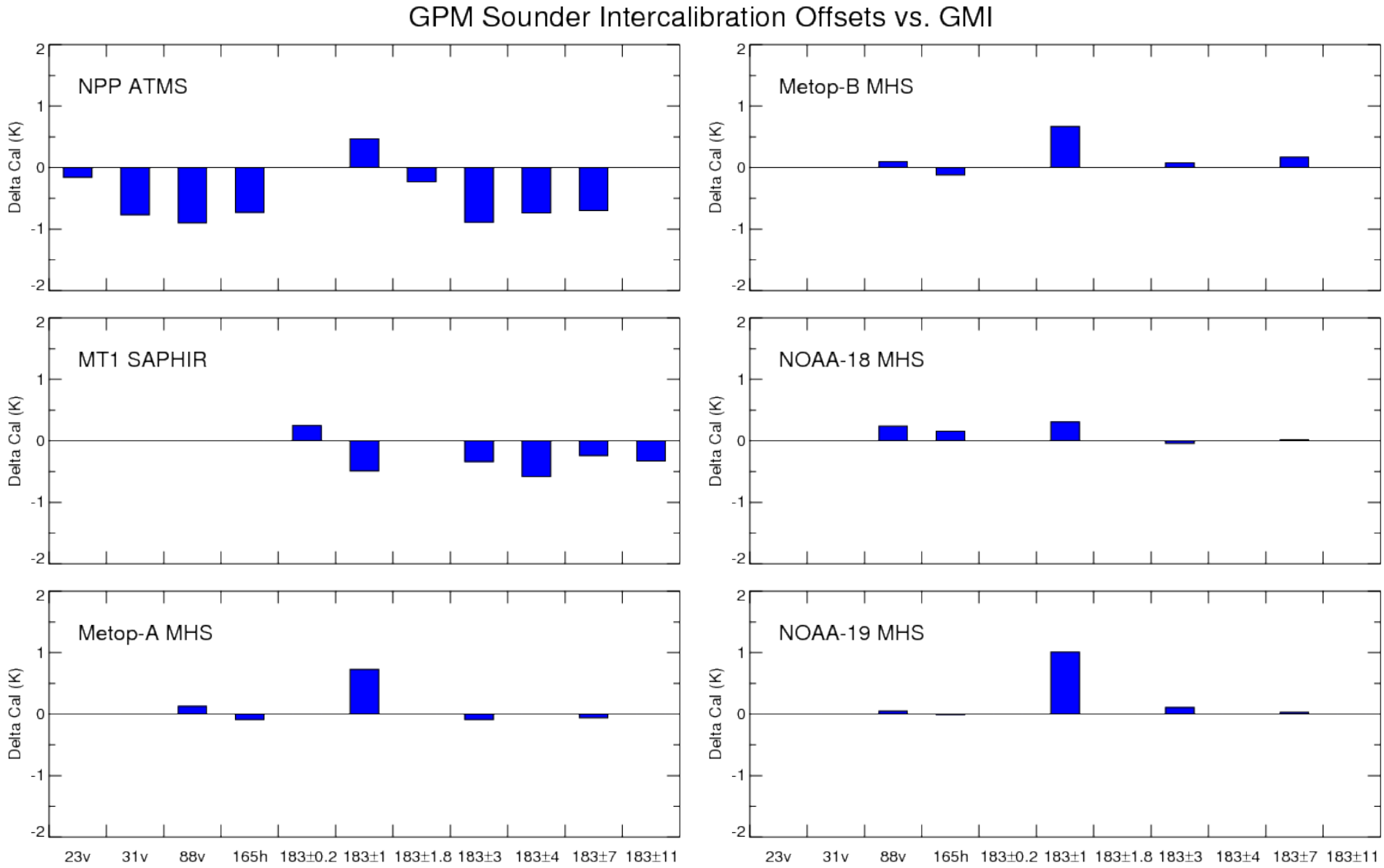
GPM Mission

Produce unified precipitation retrievals from a constellation of microwave radiometers through the use of intercalibrated brightness temperatures

GMI used as calibration reference for GPM radiometer Constellation
- Extremely well calibrated
- Low inclination orbit provides regular coincident observations with other satellites
- Has both window channels and water vapor sounding channels

GPM V05 Level 1C Intercalibration

Cross-Track Water Vapor Sounders



Intercalibration Considerations

Double Difference Technique

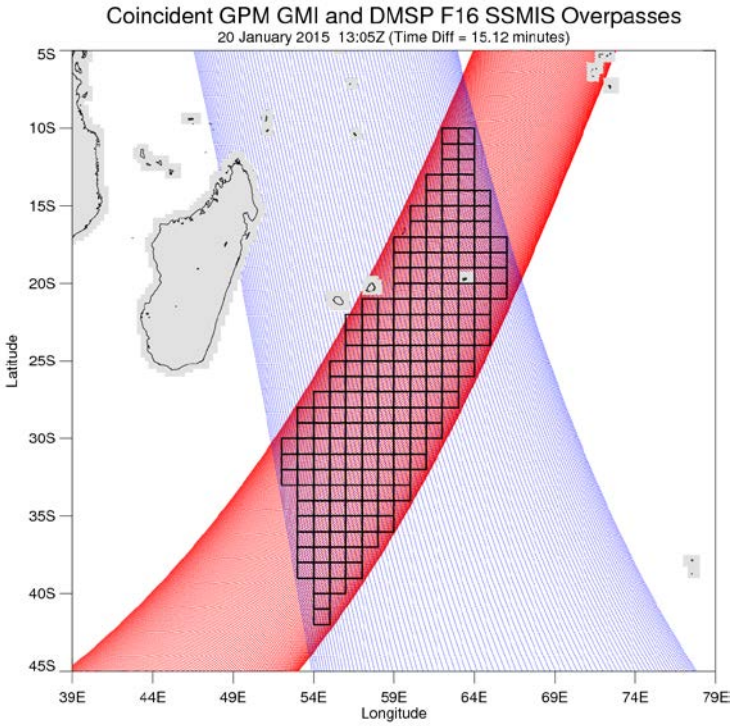
- Reference or comparison sensor
  - Availability (i.e. significant overlap period)
  - Frequent coincident observations (Ideally polar vs. low inclination orbit)
  - Similar channels (leads to cancelation of simulation errors)
  - Well calibrated and stable
- Radiative transfer models
  - Absorption models
  - Ocean emissivity model for channels seeing surface
  - Channel spectral response functions
- Geophysical parameters
  - Retrievals (CSU 1DVar using GPM GMI)
  - Model Analysis/Reanalysis (ERA-I, ERA5)

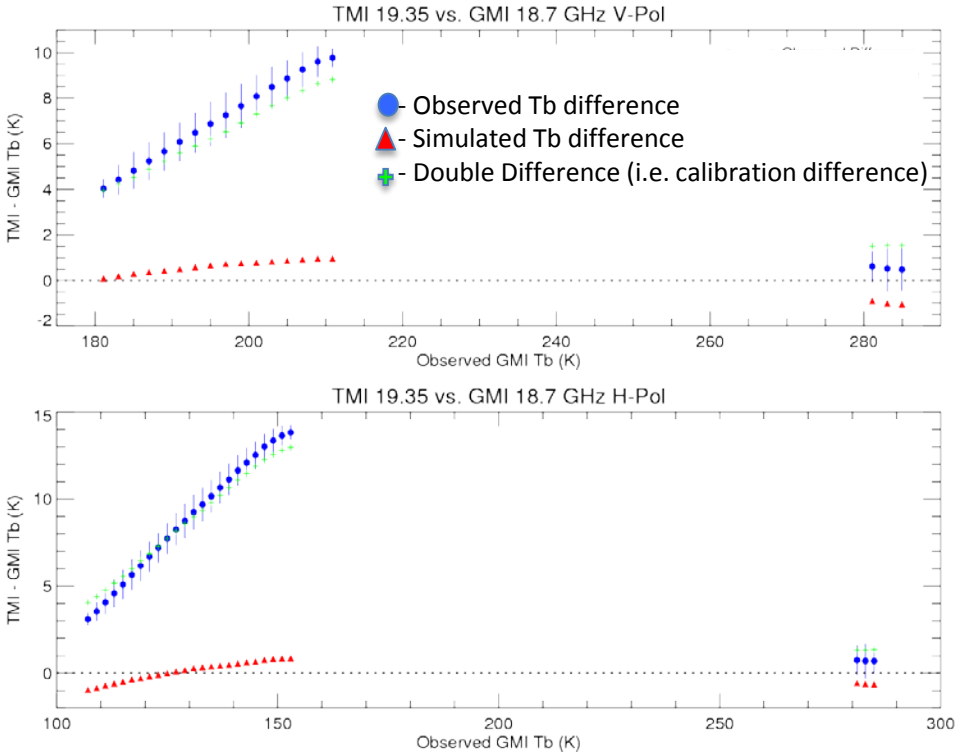
Intercalibration Considerations

Double Difference Technique

- Reference or comparison sensor
  - Availability (i.e. significant overlap period)
  - Frequent coincident observations (Ideally polar vs. low inclination orbit)
  - Similar channels (leads to cancelation of simulation errors)
  - Well calibrated and stable
- Radiative transfer models
  - Absorption models
  - Ocean emissivity model for channels seeing surface
  - Channel spectral response functions
- Geophysical parameters
  - Retrievals (CSU 1DVar using GPM GMI)
  - Model Analysis/Reanalysis (ERA-I, ERA5)
- Which is more important? Absolute calibration or consistency with radiative transfer models?

Double Difference Approach



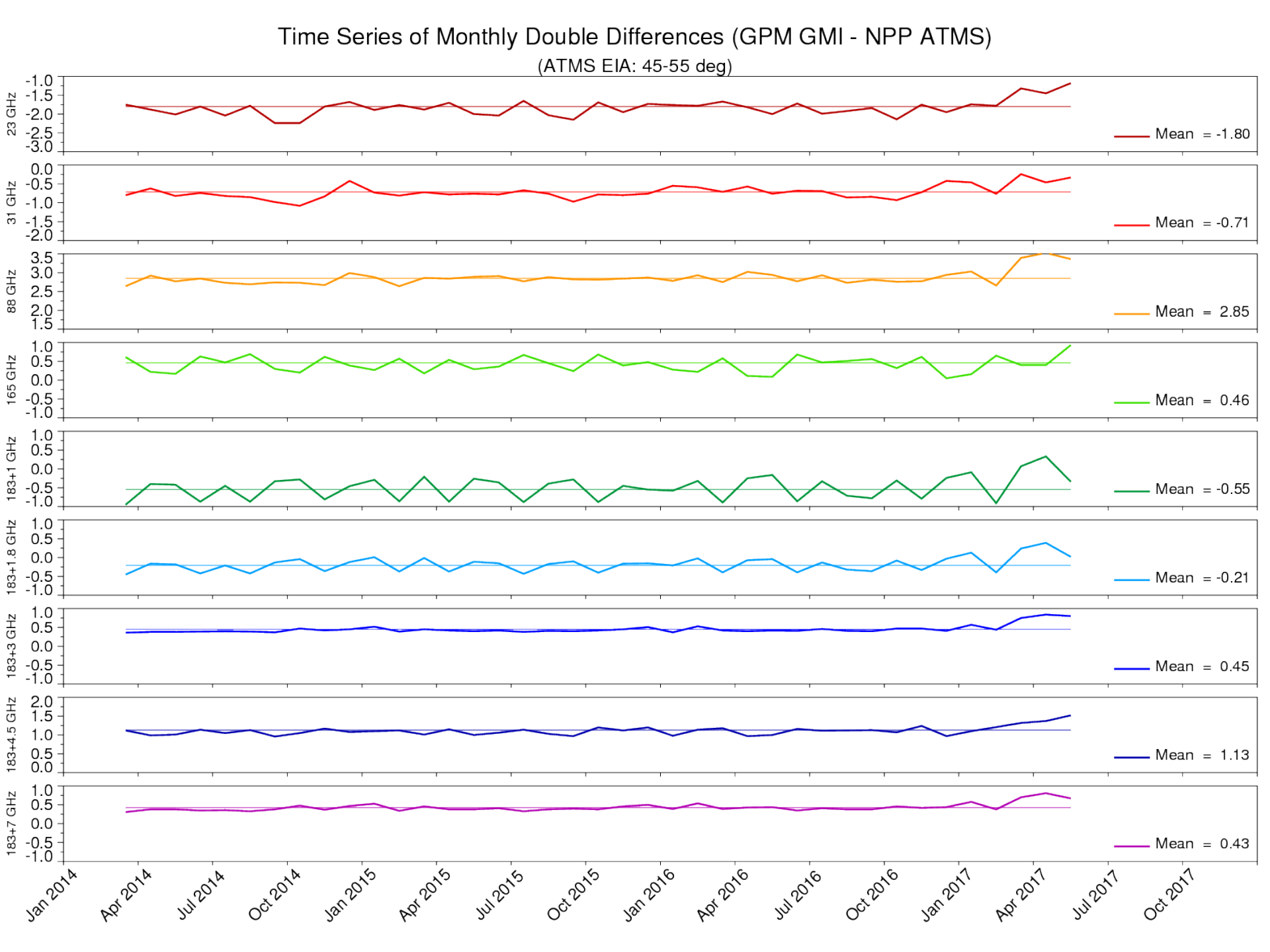


- Tb_obs(DIF) = Tb_obs(REF) – Tb_obs(TGT)
- Tb_sim(DIF) = Tb_sim(REF) – Tb_sim(TGT)
- Ddiff = Tb_obs(DIF) – Tb_sim(DIF)

GPM Constellation Radiometers

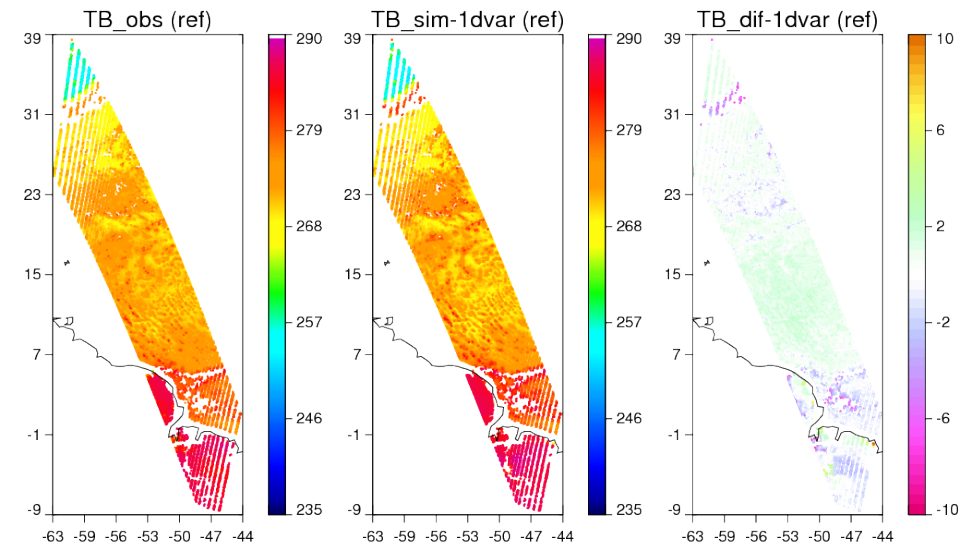
Variations in Channel Frequencies

Frequency	GMI	ATMS	MHS
10	10.65 v/h		
18	18.7 v/h		
23	23.8 v	23.8 qv	
31-37	36.64 v/h	31.4 qv	
88-89	89.0 v/h	88.2 qv	89qv
157-166	166.0 v/h	165.5 qh	157qv
	183.31±3.0v 183.31±7.0v	183.31±1.0 qh 183.31±1.8 qh 183.31±3.0 qh 183.31±4.5 qh 183.31±7.0 qh	183.31±1.0 qh 183.31±3.0 qh 190.31 qv

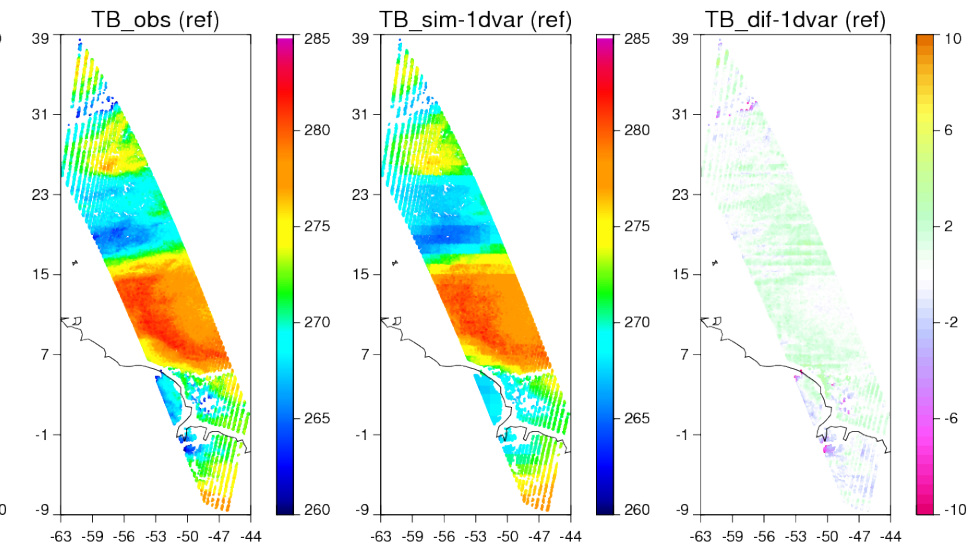

Time Series of Monthly Double Differences (GPM GMI - NPP ATMS)
(ATMS EIA: 45-55 deg)
23 GHz
Mean = -1.80
31 GHz
Mean = -0.71
88 GHz
Mean = 2.85
165 GHz
Mean = 0.46
183+1 GHz
Mean = -0.55
183+1.8 GHz
Mean = -0.21
183+3 GHz
Mean = 0.45
183+4.5 GHz
Mean = 1.13
183+7 GHz
Mean = 0.43
Jan 2014
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015
Jan 2016
Apr 2016
Jul 2016
Oct 2016
Jan 2017
Apr 2017
Jul 2017
Oct 2017

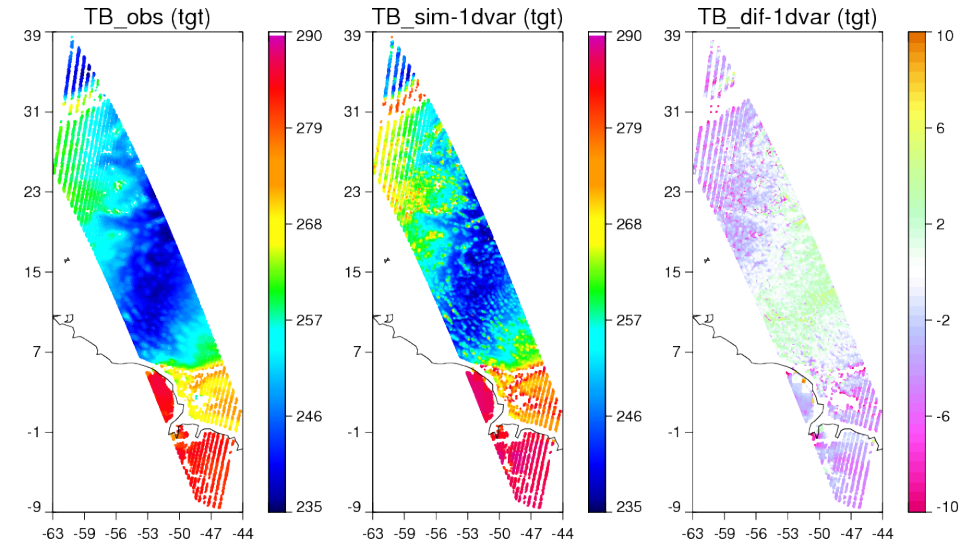
GPM GMI vs. NPP ATMS

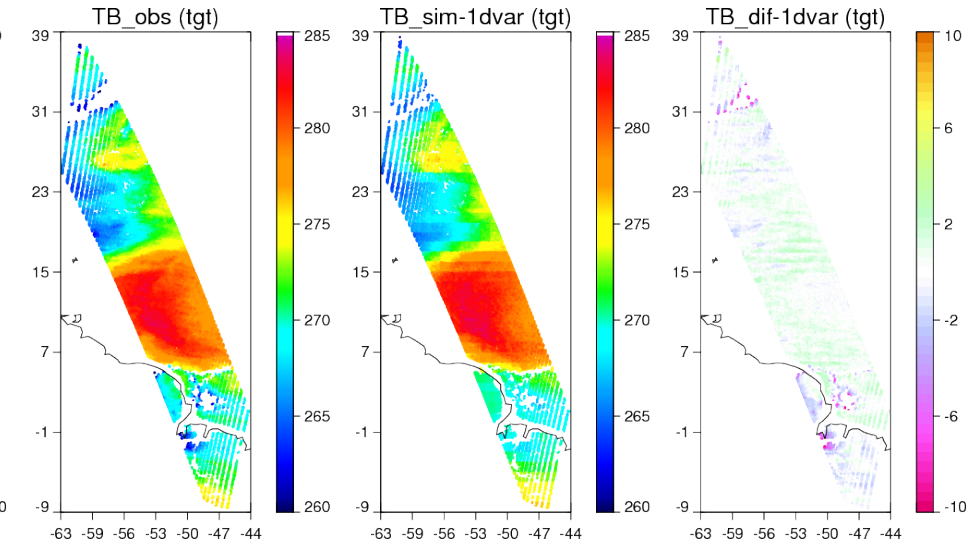
GPM-GMI 89.0v vs. NPP-ATMS 88.2qv

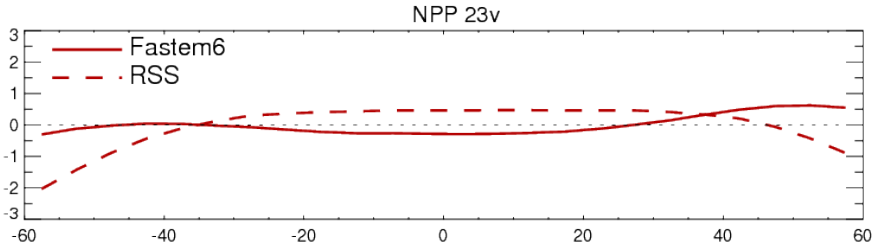


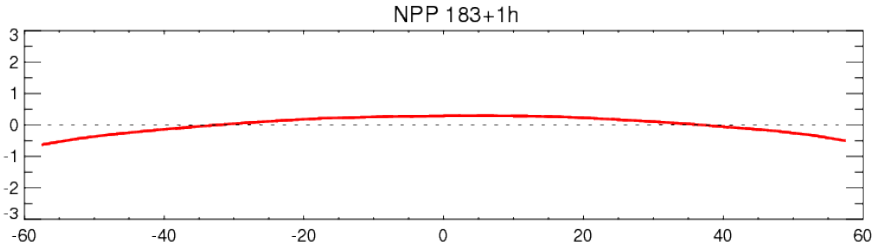
GPM-GMI 190.3v vs. NPP-ATMS 190.3qh

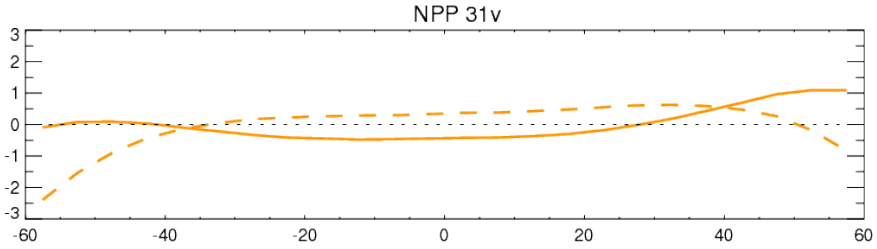


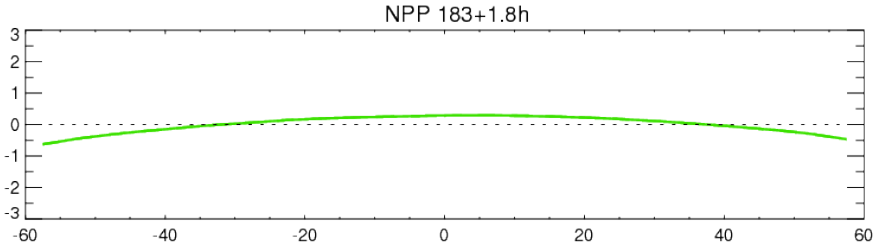


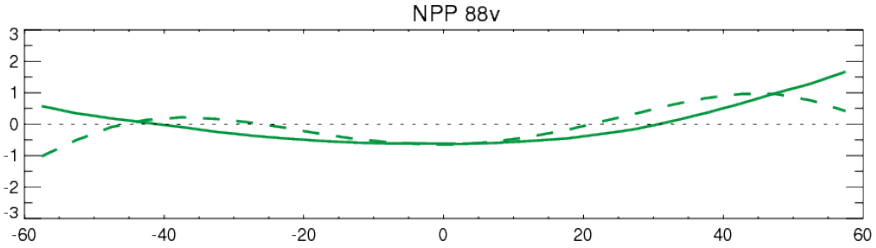


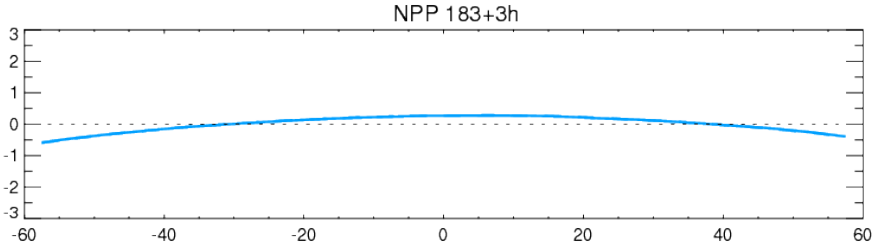

NPP 23v
Fastem6
RSS

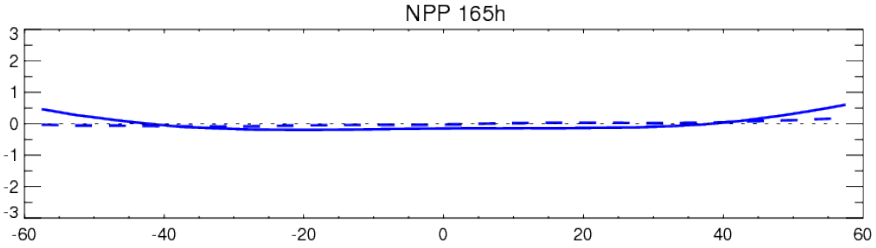

NPP 183+1h

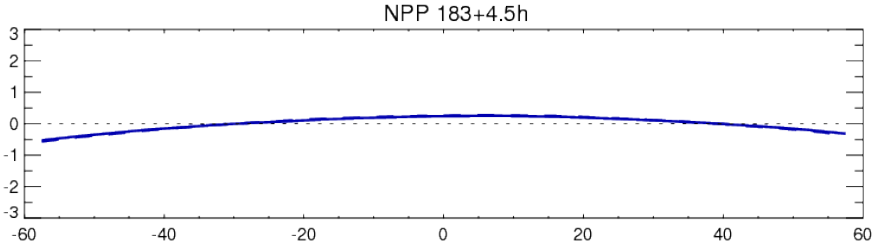

NPP 31v

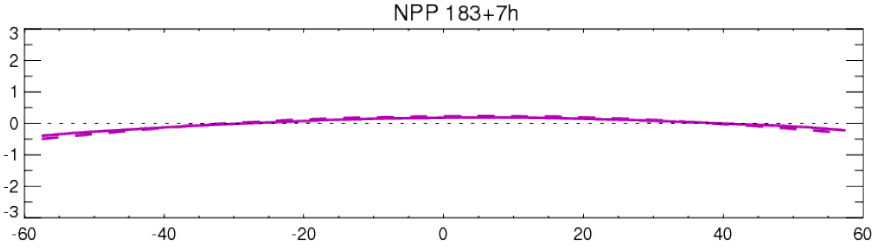

NPP 183+1.8h

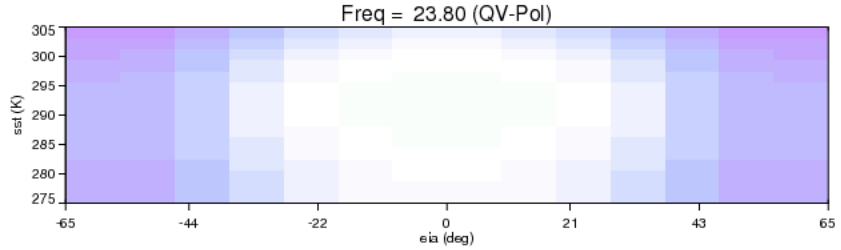

NPP 88v

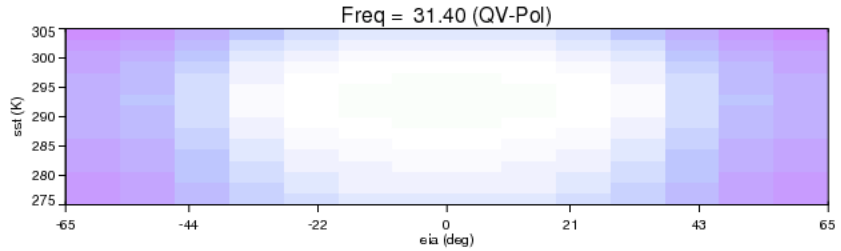

NPP 183+3h

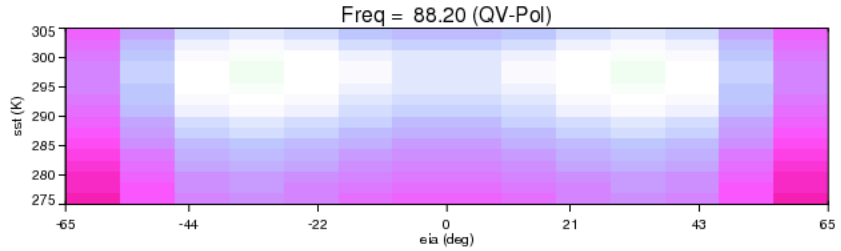

NPP 165h

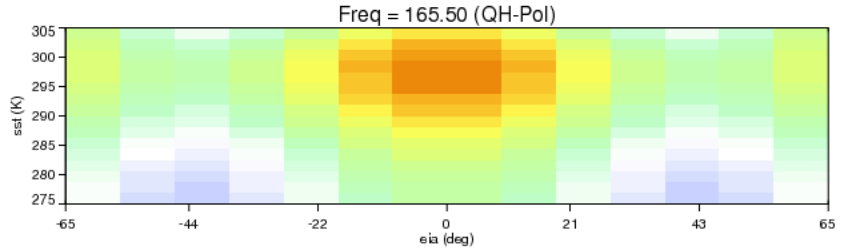

NPP 183+4.5h

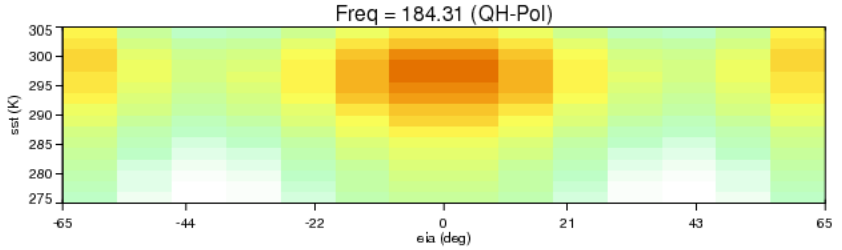

NPP 183+7h

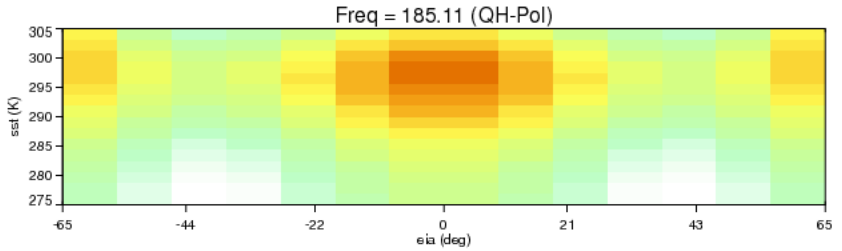

Freq = 23.80 (QV-Pol)
sst (K)
305
300
295
290
285
280
275
-65
-44
-22
0
21
43
65
eia (deg)
Ts Diff (K)
5
3
1
-1
-3
-5

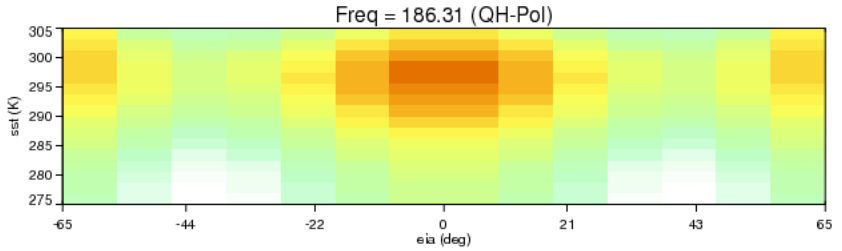

Freq = 31.40 (QV-Pol)
sst (K)
305
300
295
290
285
280
275
-65
-44
-22
0
21
43
65
eia (deg)
Ts Diff (K)
5
3
1
-1
-3
-5

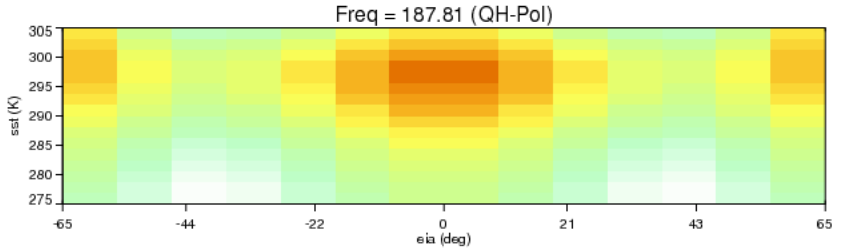

Freq = 88.20 (QV-Pol)
sst (K)
305
300
295
290
285
280
275
-65
-44
-22
0
21
43
65
eia (deg)
Ts Diff (K)
5
3
1
-1
-3
-5

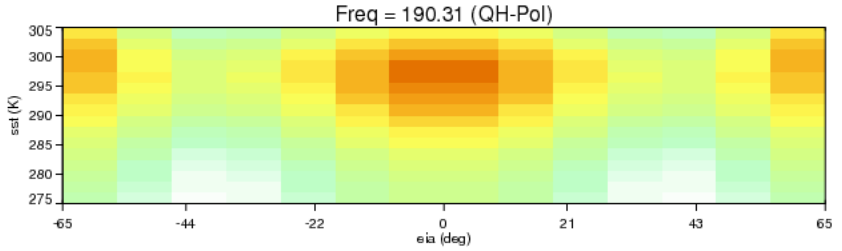

Freq = 165.50 (QH-Pol)
sst (K)
305
300
295
290
285
280
275
-65
-44
-22
0
21
43
65
eia (deg)
Ts Diff (K)
5
3
1
-1
-3
-5


Freq = 184.31 (QH-Pol)
sst (K)
305
300
295
290
285
280
275
-65
-44
-22
0
21
43
65
eia (deg)
Ts Diff (K)
5
3
1
-1
-3
-5


Freq = 185.11 (QH-Pol)
sst (K)
305
300
295
290
285
280
275
-65
-44
-22
0
21
43
65
eia (deg)
Ts Diff (K)
5
3
1
-1
-3
-5


Freq = 186.31 (QH-Pol)
sst (K)
305
300
295
290
285
280
275
-65
-44
-22
0
21
43
65
eia (deg)
Ts Diff (K)
5
3
1
-1
-3
-5

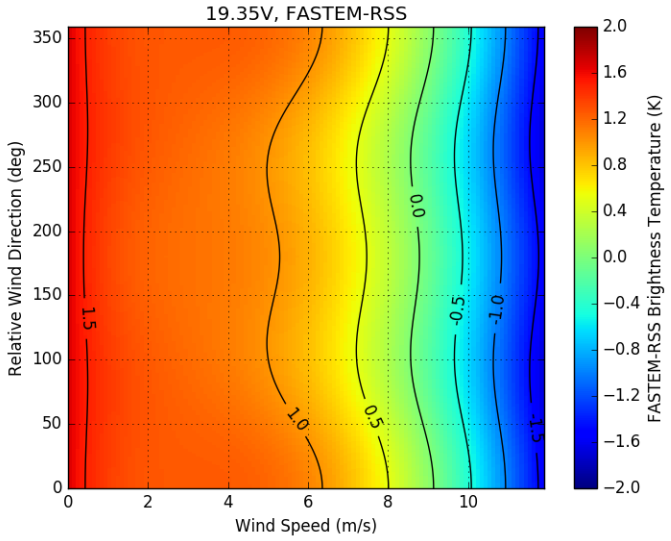

Freq = 187.81 (QH-Pol)
sst (K)
305
300
295
290
285
280
275
-65
-44
-22
0
21
43
65
eia (deg)
Ts Diff (K)
5
3
1
-1
-3
-5

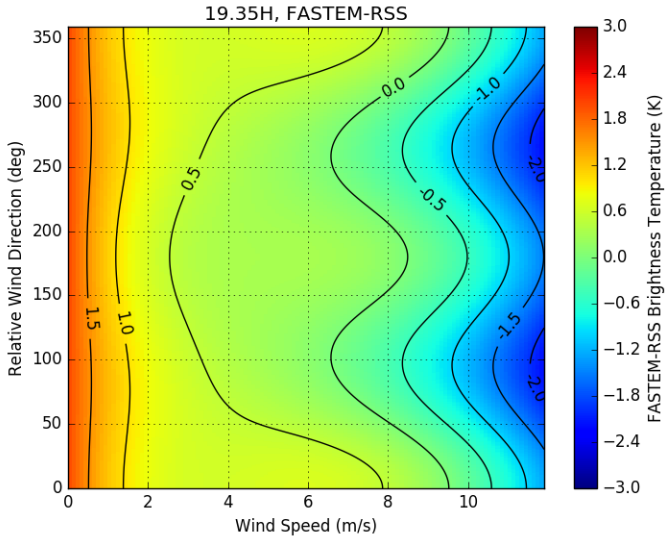

Freq = 190.31 (QH-Pol)
sst (K)
305
300
295
290
285
280
275
-65
-44
-22
0
21
43
65
eia (deg)
Ts Diff (K)
5
3
1
-1
-3
-5

RSS vs. FASTEM6 Emissivity Model Differences

Differences vs. Wind Speed and Direction

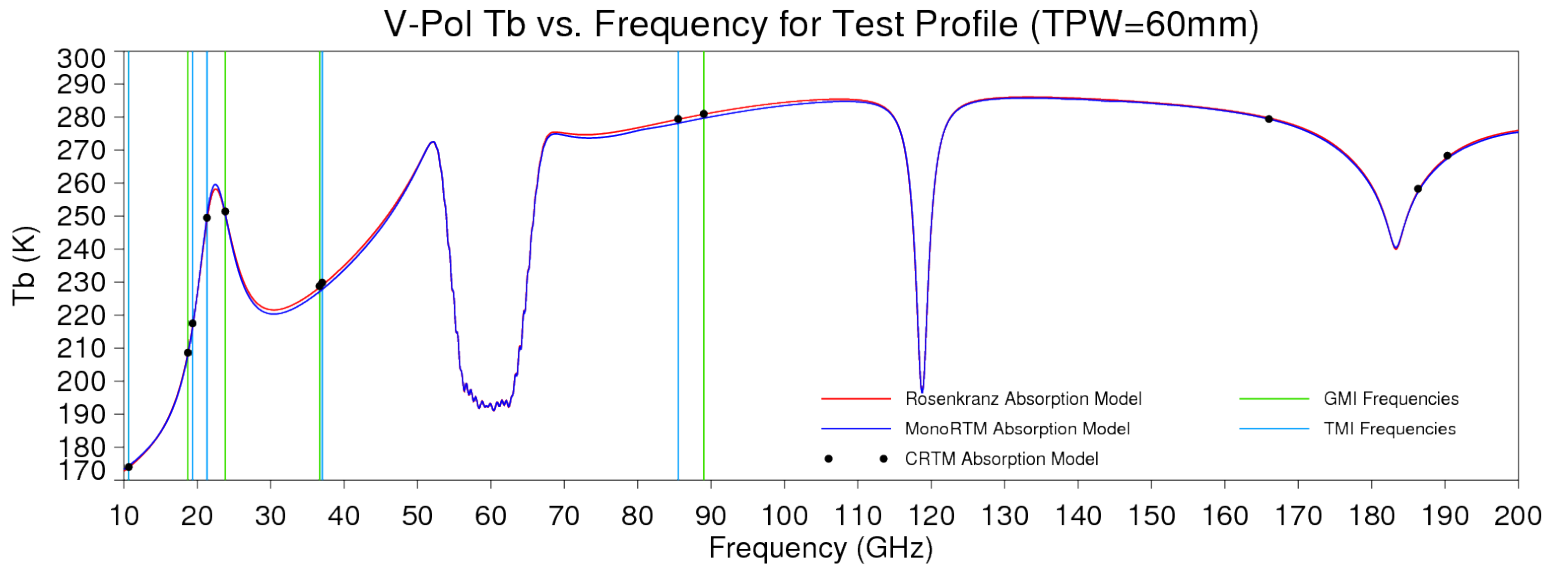
- The difference in large-scale wave spectrum leads to large differences between these models for low winds
- FASTEM is warmer at low winds
- RSS is warmer at high winds
- Models are in best agreement for 7-10 m/s, depending on frequency and incidence angle
- Figures specific to:
  - SST = 302 K
  - EIA = 53 deg

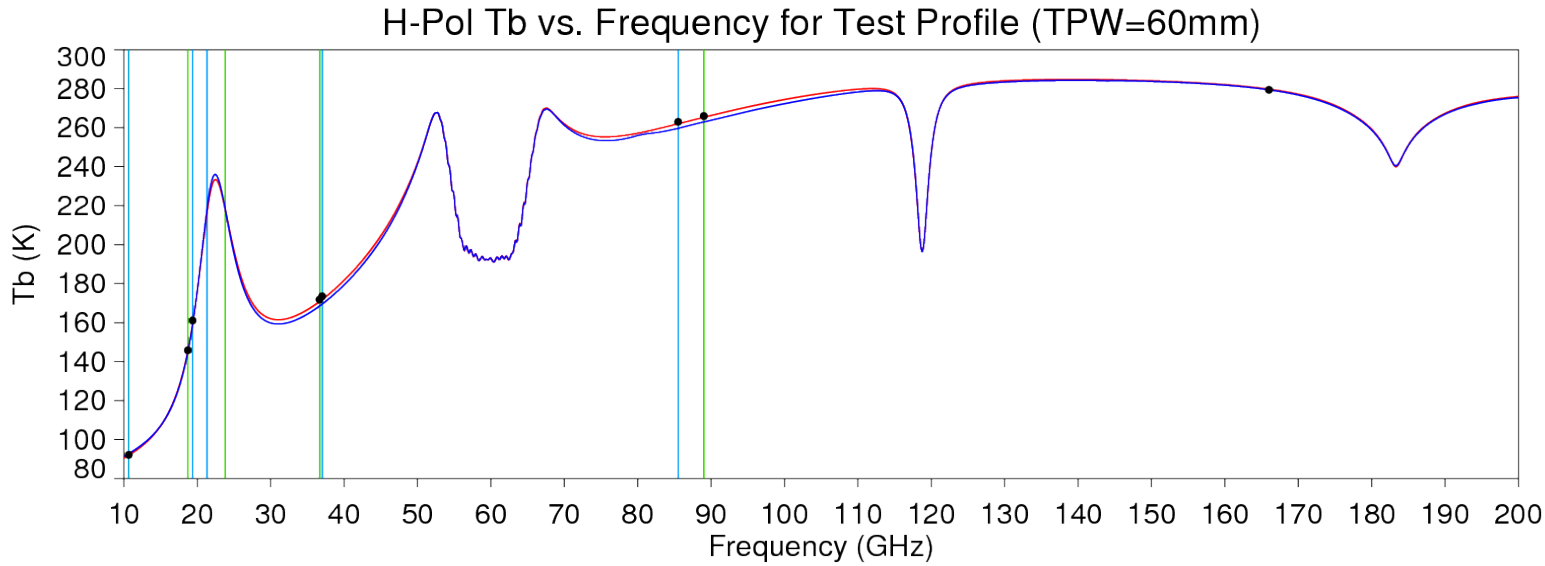




XCAL TMI/GMI Calibration Differences

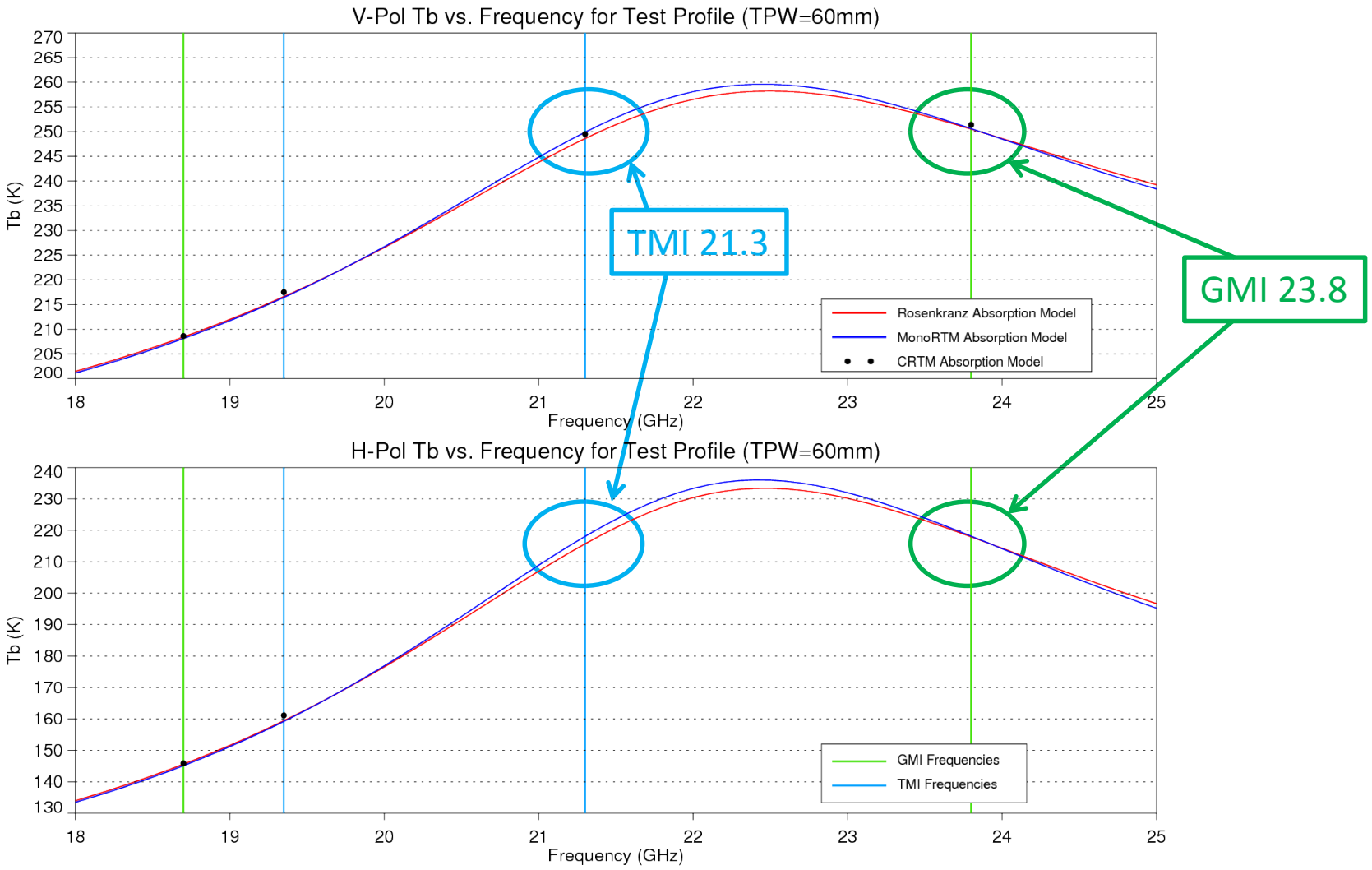
Radiative Transfer Model Dependency





XCAL TMI/GMI Calibration Differences

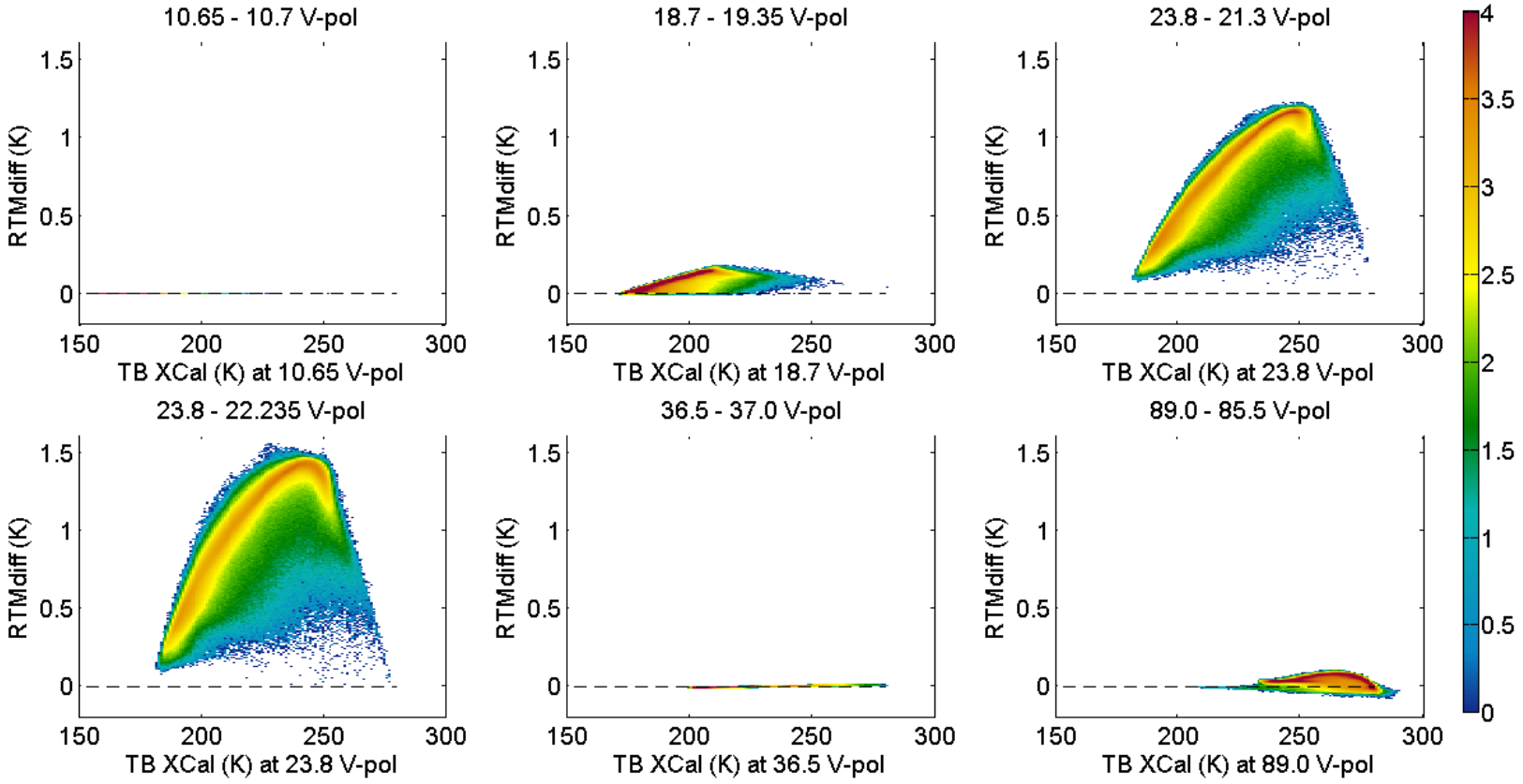
Radiative Transfer Model Dependency



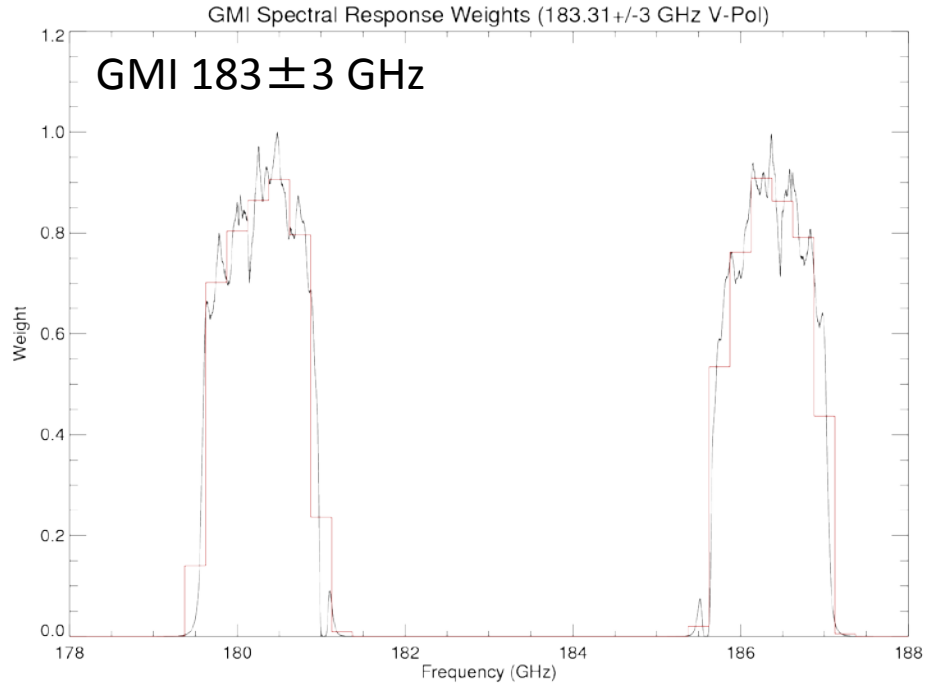
Atmospheric Absorption Models

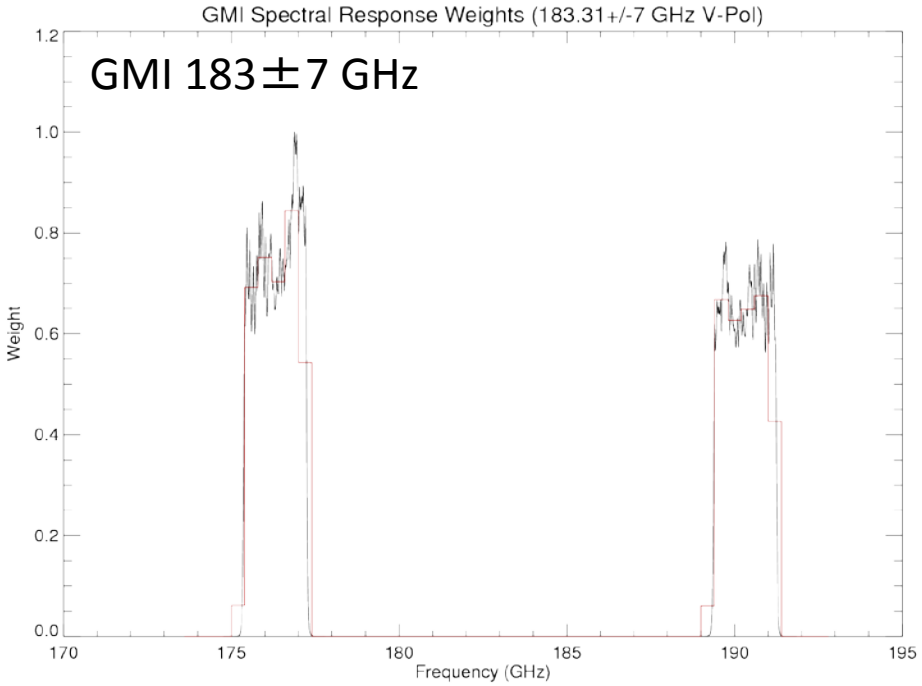
V-Pol Channels, Rosenkranz (XCAL) vs. MonoRTM

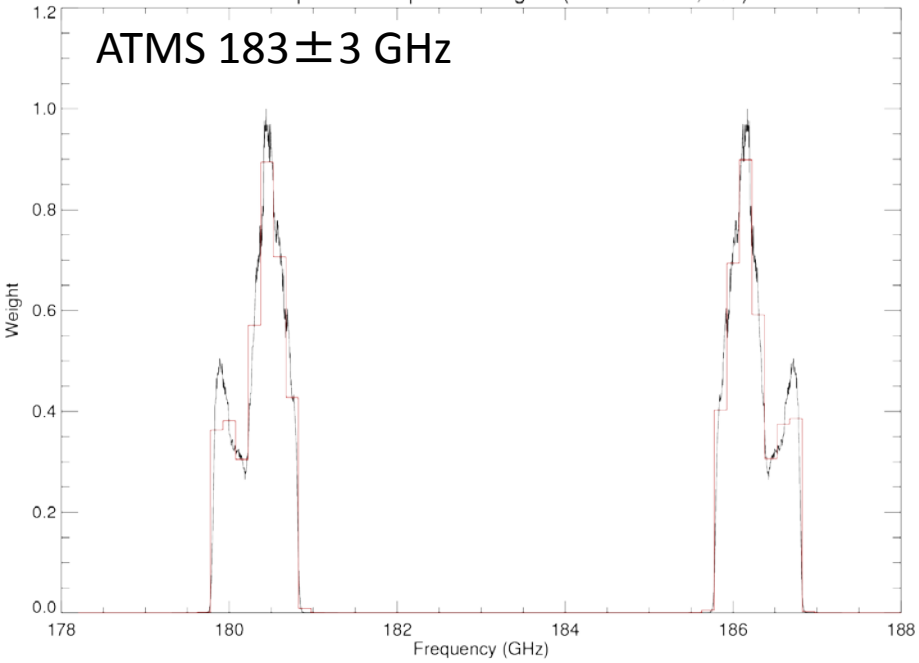
$$RTMdiff = \left(TB_X^{f_1} - TB_M^{f_1}\right) - \left(TB_X^{f_2} - TB_M^{f_2}\right)$$

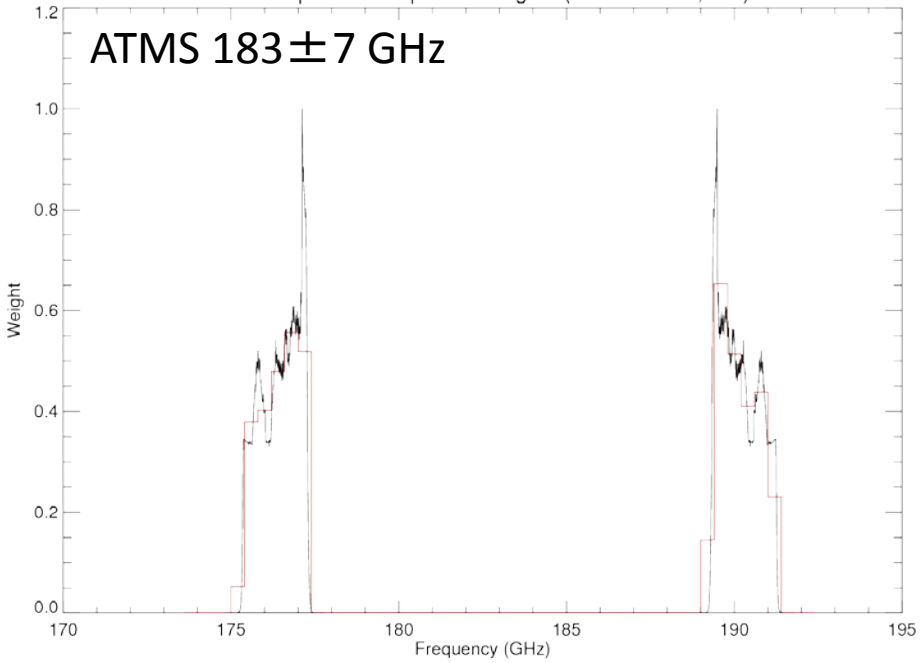


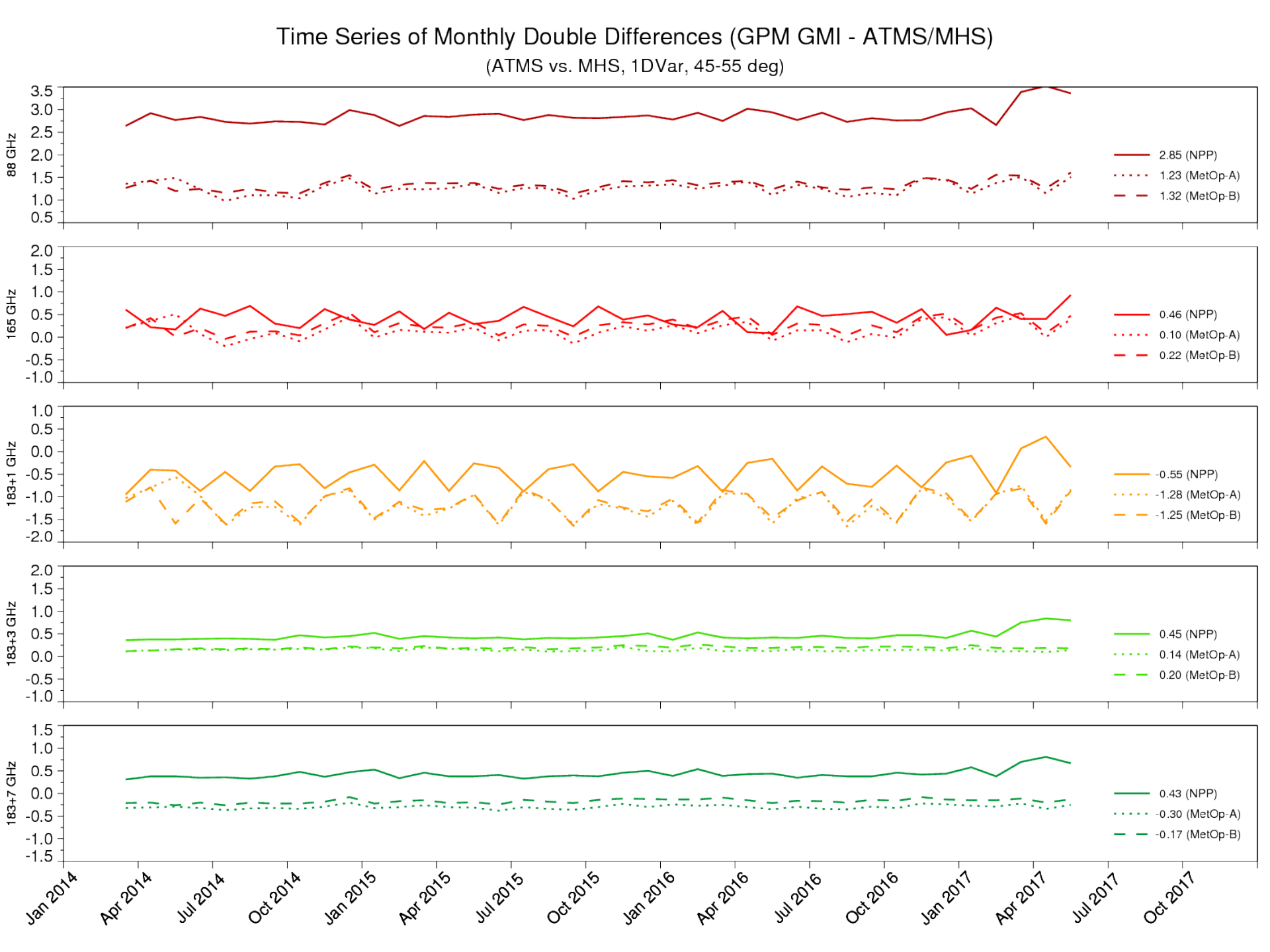
Courtesy Rachael Kroodsma at NASA Precipitation Processing System


GMI Spectral Response Weights (183.31+/-3 GHz V-Pol)
GMI 183±3 GHz
Weight
Frequency (GHz)


GMI Spectral Response Weights (183.31+/-7 GHz V-Pol)
GMI 183±7 GHz
Weight
Frequency (GHz)


ATMS Spectral Response Weights (183+/-3 GHz, QH)
ATMS 183±3 GHz
Weight
Frequency (GHz)


ATMS Spectral Response Weights (183+/-7 GHz, QH)
ATMS 183±7 GHz
Weight
Frequency (GHz)


Time Series of Monthly Double Differences (GPM GMI - ATMS/MHS)
(ATMS vs. MHS, 1DVar, 45-55 deg)
88 GHz
2.85 (NPP)
1.23 (MetOp-A)
1.32 (MetOp-B)
165 GHz
0.46 (NPP)
0.10 (MetOp-A)
0.22 (MetOp-B)
183+1 GHz
-0.55 (NPP)
-1.28 (MetOp-A)
-1.25 (MetOp-B)
183+3 GHz
0.45 (NPP)
0.14 (MetOp-A)
0.20 (MetOp-B)
183+7 GHz
0.43 (NPP)
-0.30 (MetOp-A)
-0.17 (MetOp-B)
Jan 2014
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015
Jan 2016
Apr 2016
Jul 2016
Oct 2016
Jan 2017
Apr 2017
Jul 2017
Oct 2017

Summary

- Multiple approaches/references sensors needed
  - GPM GMI
  - Megha-Tropiques SAPHIR
  - Direct SNO comparisons between polar-orbiters
- Understand/quantify residual intercalibration errors
  - Ocean emissivity models for window channels
  - Atmospheric absorption RTM models
  - Impact of spectral response functions
    - Availability?
    - What is used in RTM models (RTTOV, CRTM, etc.)?