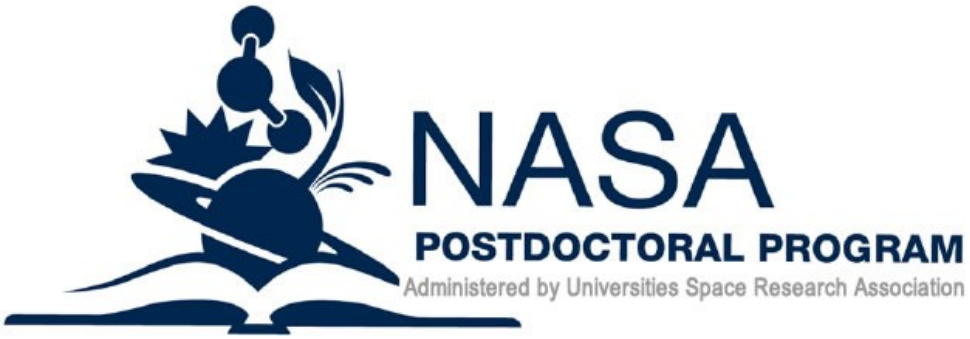


Land Surface Properties and Emissivity in Passive Microwave Precipitation Retrievals for GPM

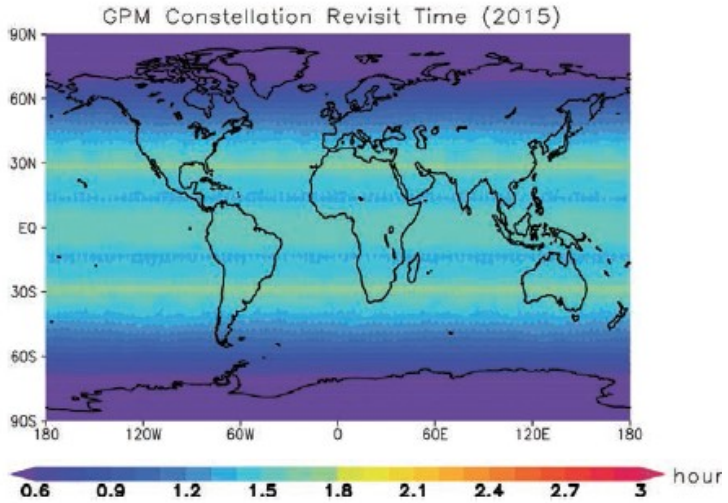
Sarah Ringerud[1], C.D. Kummerow[2] , S. J. Munchak[3]

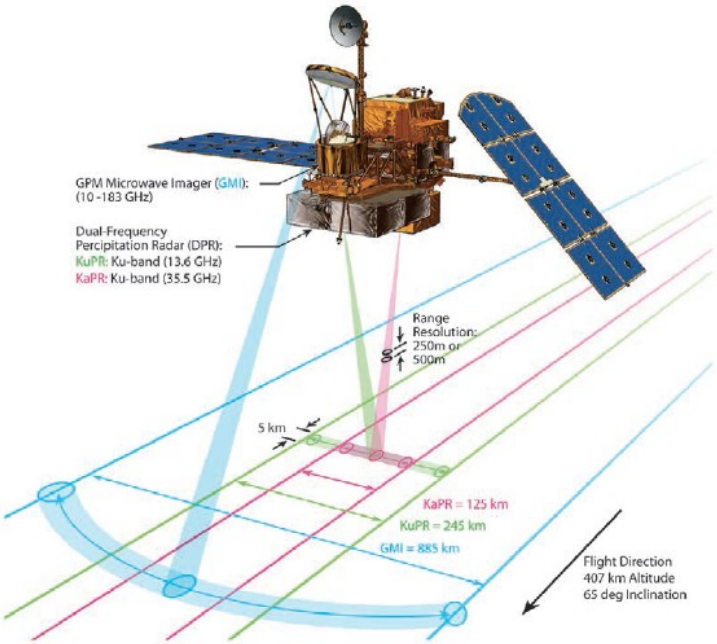
[1]NASA GSFC NPP/USRA Greenbelt, MD

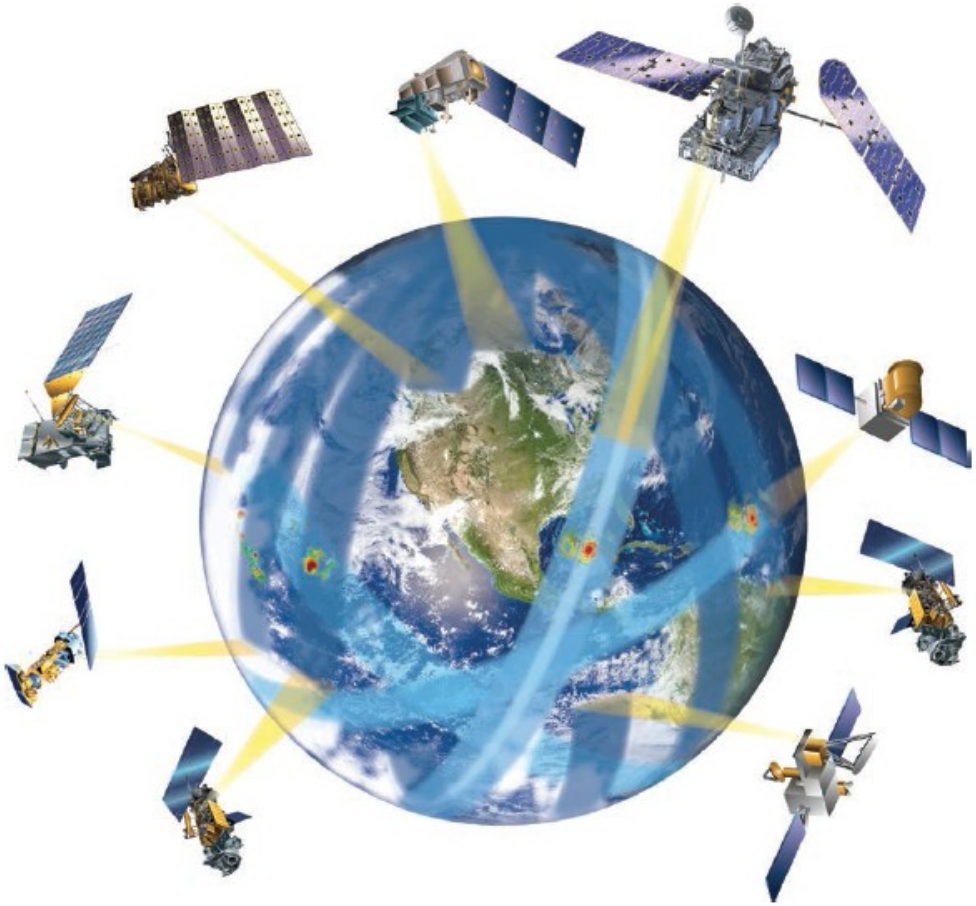
[2]Colorado State University, Fort Collins, CO

[3]NASA GSFC Greenbelt, MD

Introduction: GPM Constellation





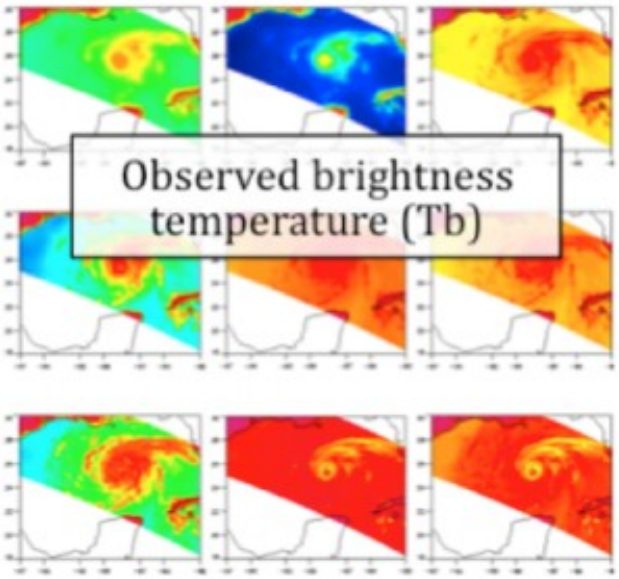


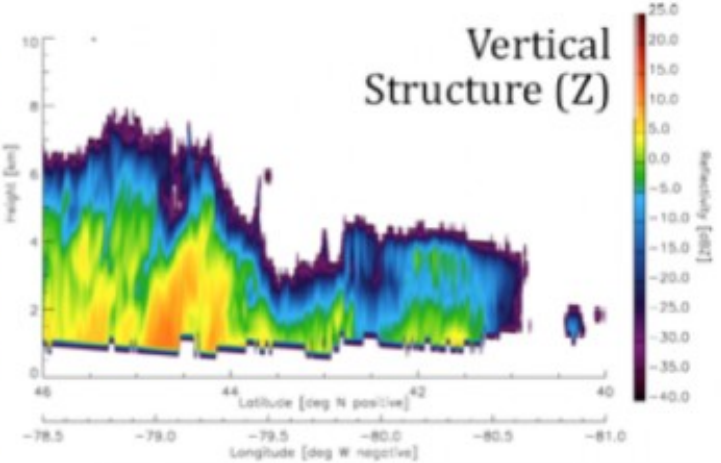
Hou et al. 2014 BAMS

Introduction

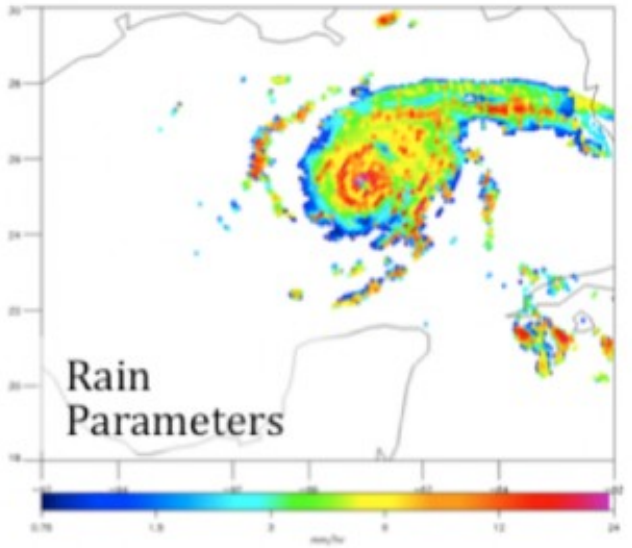
GPM's database from DPR+GMI obs.

Observed T_b, Z, & combined retrievals





GPM: GPM Core observations provide database T_b and RR, this transfer standard allows for unified precipitation retrievals.



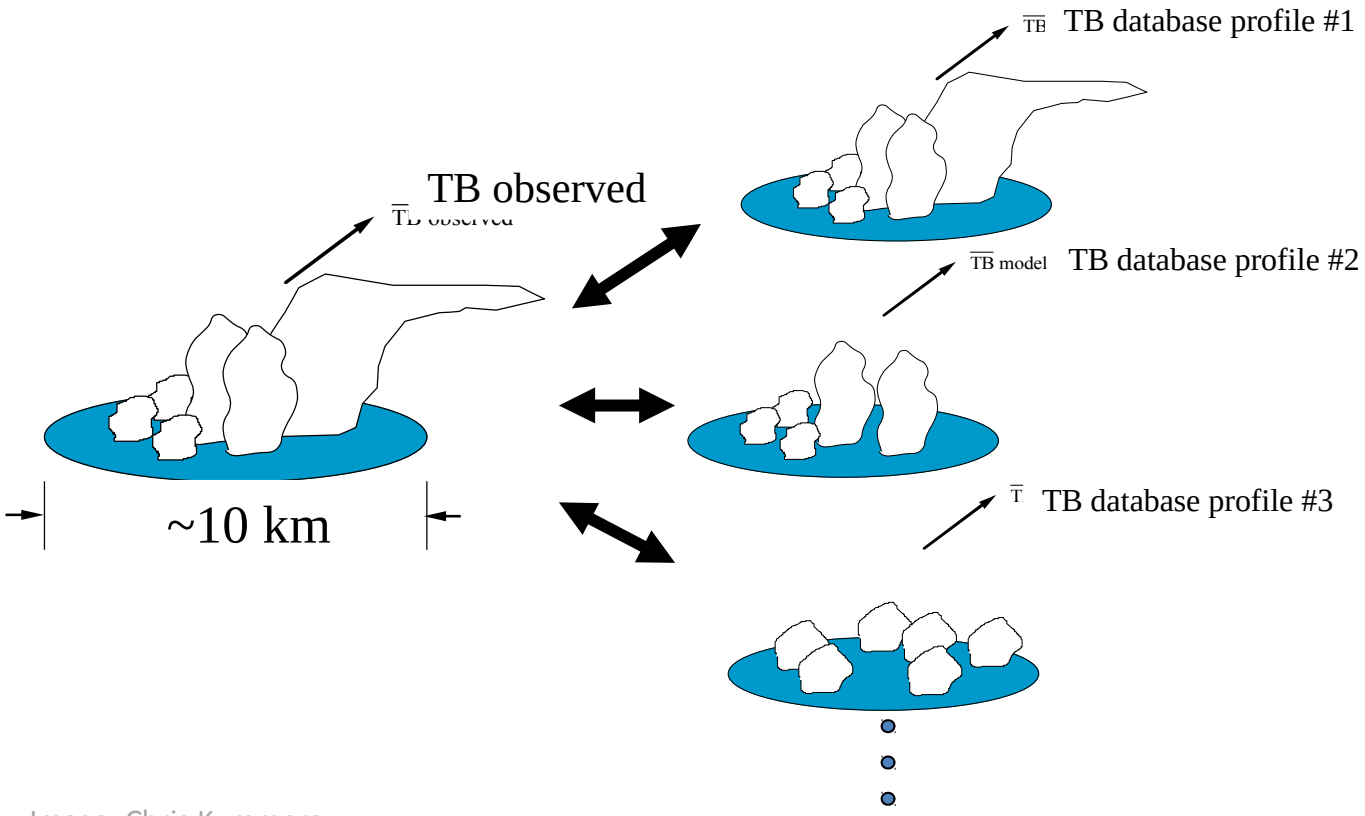
pmm.nasa.gov/multimedia/images/GPM

Introduction

Bayesian Inversion: $$P(\mathbf{x}\,|\,\mathbf{y}) = \frac{P(\mathbf{y}\,|\,\mathbf{x})P(\mathbf{x})}{P(\mathbf{y})}$$

P(x), P(y): global statistics

P(y|x): Radiative transfer modeling



Organize/Constrain database for search:

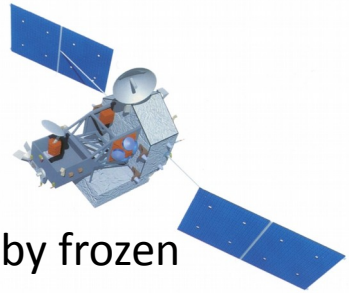
TPW
SST/Tsfc/T2m
Surface type

Image: Chris Kummerow

Introduction

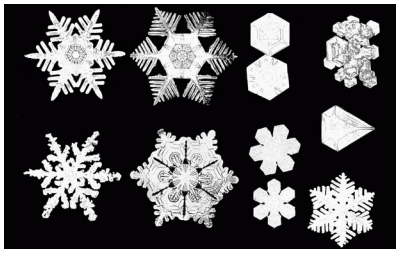
- Construct **physically based** profile database using combined retrievals
  - A physically consistent system – calculate Tb for any frequency, angle, etc.
  - Feeds back to modeling community
- Apply to all constellation radiometers
  - Core satellite acts as **transfer standard** for consistent constellation retrievals
  - Quality, robustness of database are key
- Land Surface Representation:
  - Database simulations (emissivity)
  - Retrieval stratification (constrain search)

Part I: Database Construction



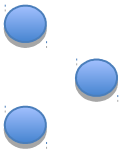
Mie scattering by frozen hydrometeors

Melting layer

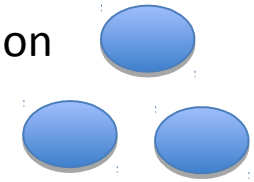


Atmospheric absorption by oxygen and water vapor

Absorption by cloud water



Mie scattering and absorption by liquid hydrometeors



Surface emissivity:

Database Emissivity: Ocean

- Remote Sensing Systems (RSS) 2012 Radiative Transfer Model emissivity – Meissner and Wentz 2012
- Function of f, pol, EIA
- Inputs: SST (COMB), wind speed (OE)

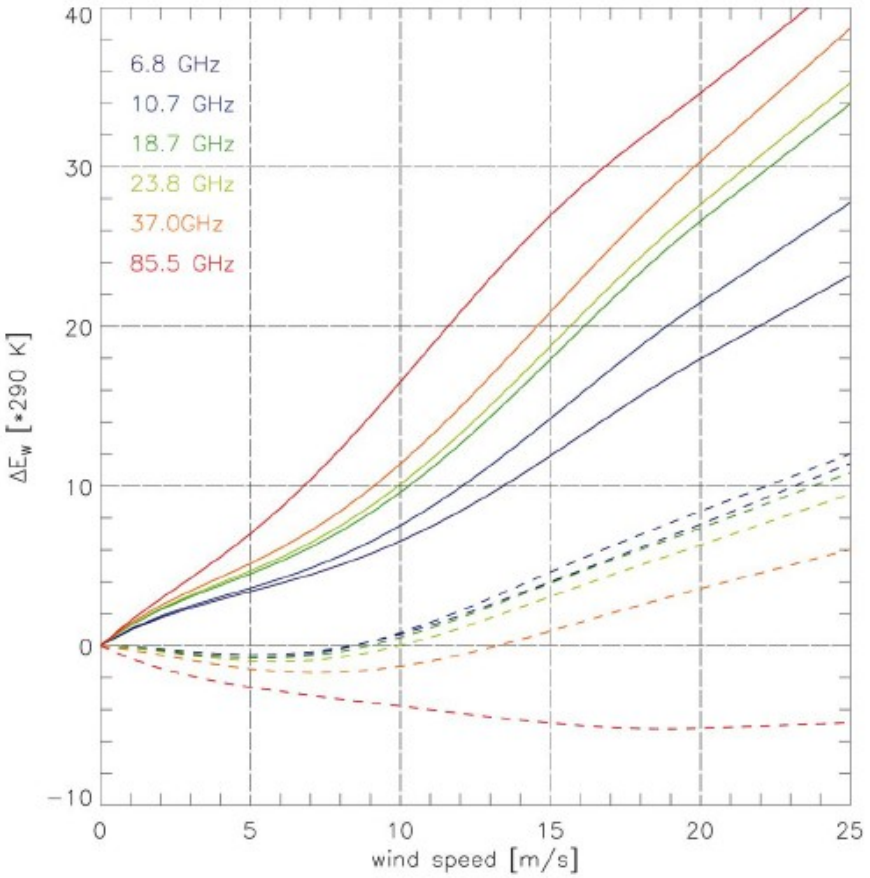


Fig. 8. Model functions from Section IV of this paper for the wind-induced ocean surface emissivity at six different frequencies as function of wind speed. The curves are displayed for the reference surface temperature $T_{ref} = 20\ ^{\circ}\mathrm{C}$ and the reference EIA $\theta_{ref} = 55.2^{\circ}$. Dashed lines show the v-pol, and solid lines show the h-pol. The emissivities have been multiplied by a typical surface temperature of 290 K.

Database Emissivity: Land

Emissivity Retrieval at GMI Microwave Frequencies

$$B_\lambda \cong \frac{2ck_BT}{\lambda^4}$$

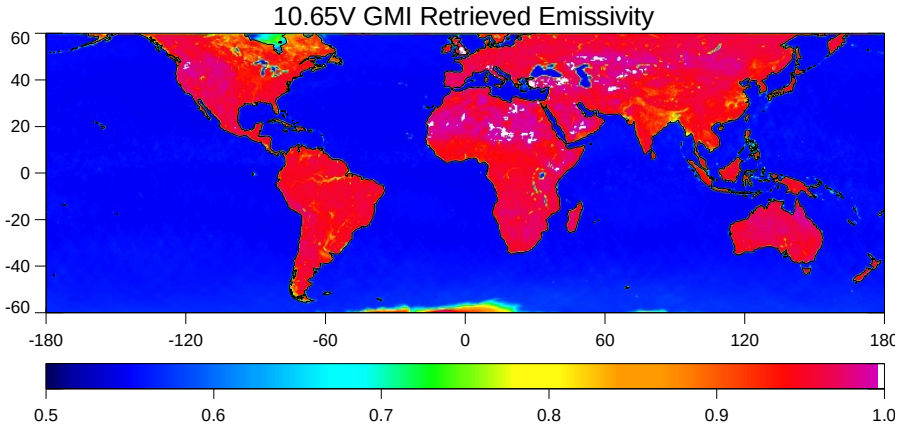
Rayleigh-Jeans Approximation – Planck radiance proportional to T

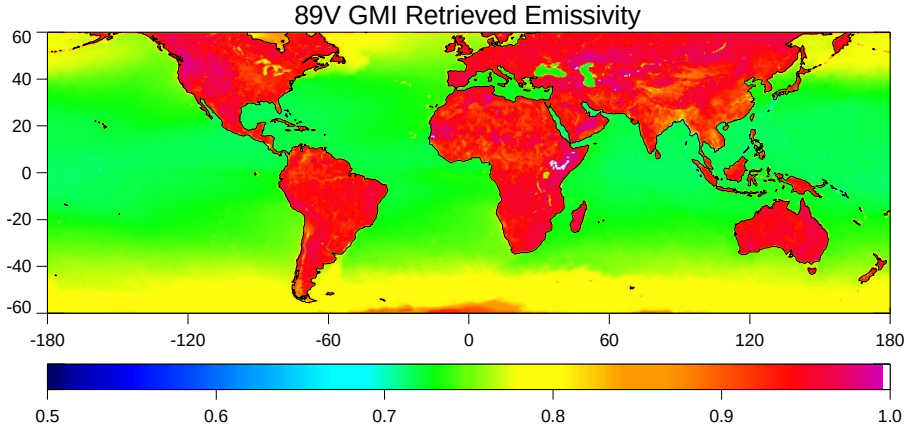
Plane parallel, non-scattering atmosphere at TOA:

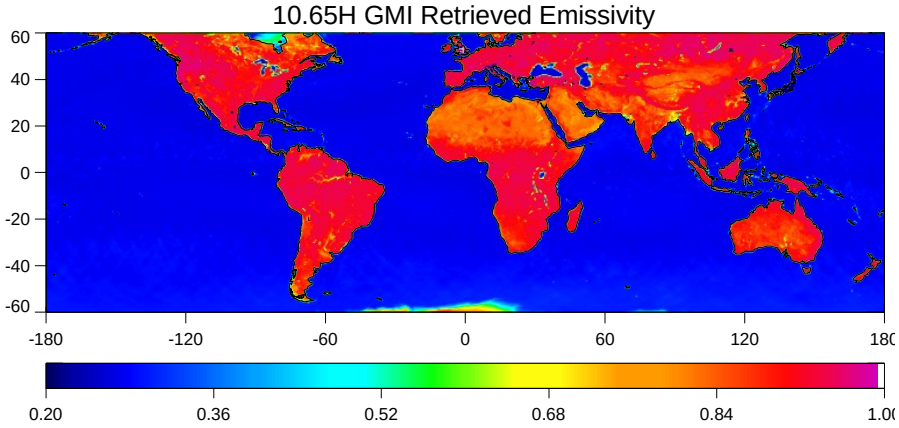
$$Tb = \varepsilon T_{sfc} e^{-\tau(0,z^*)/\mu} + (1-\varepsilon)\int_{z^*}^{0} T_{atm}(z) e^{-\tau(z,0)} d\tau/\mu + \int_{0}^{z^*} T_{atm}(z) e^{-\tau(z,z^*)} d\tau/\mu$$

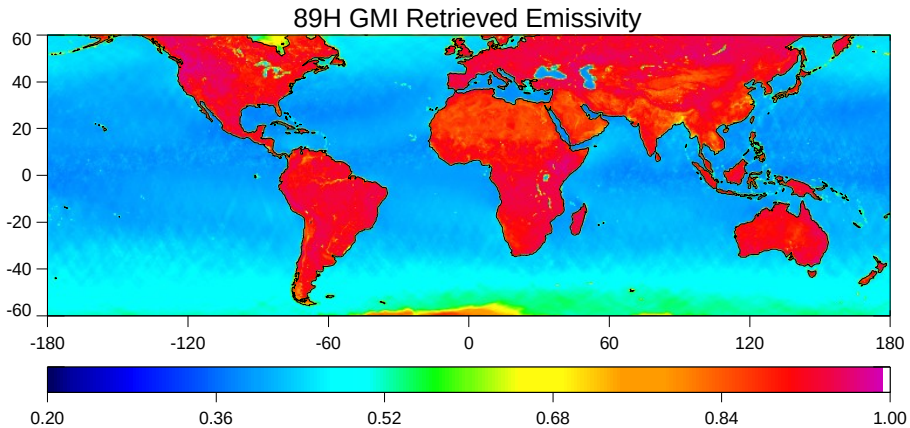
If atmosphere and T_{sfc} are known, can use measured Tb to solve for ε

Database Emissivity









S.J. Munchak

Constructing the Profile Database

- Take precipitation profiles from GPM Combined Algorithm as “truth”
- Add necessary geophysical information in non-raining areas
  - Ocean: OE Retrieval, emissivity model
  - Land: Model Reanalysis, retrieved emissivity
- Compute Tb and compare to obs
  - 1D slant path Eddington
- Add/optimize graupel for convective profiles
- Add/optimize cloud ice for improved agreement in high frequency channels

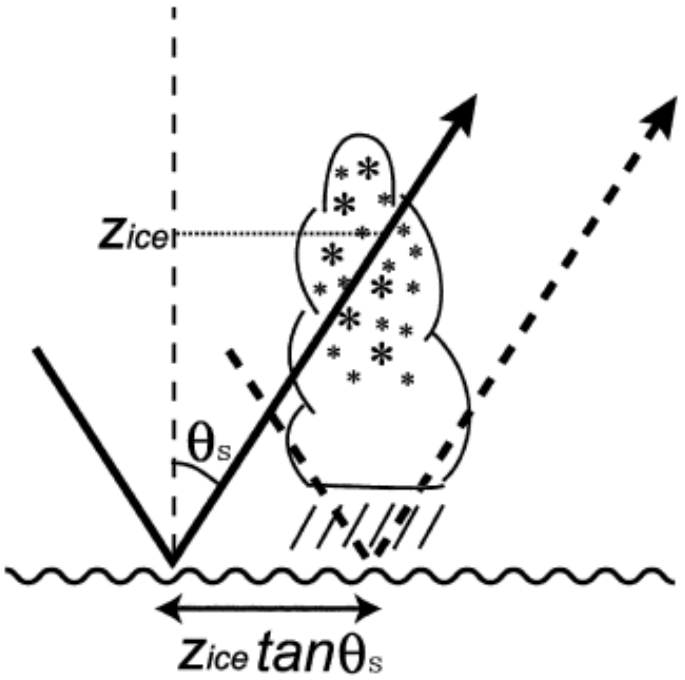
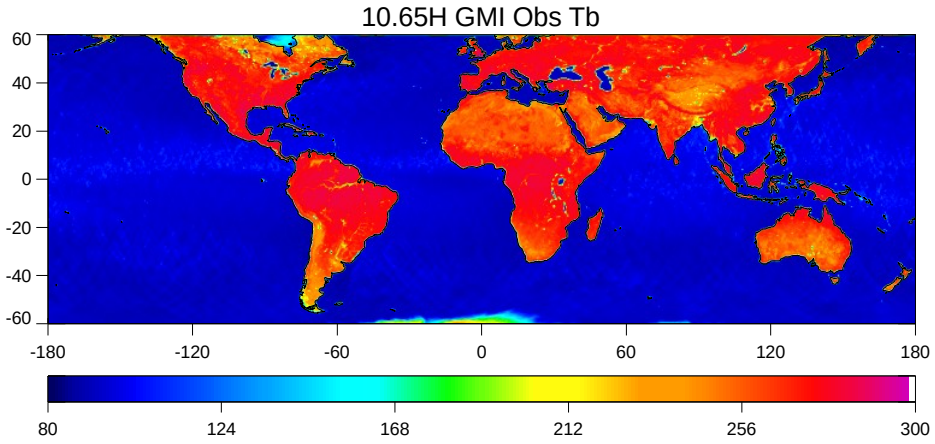
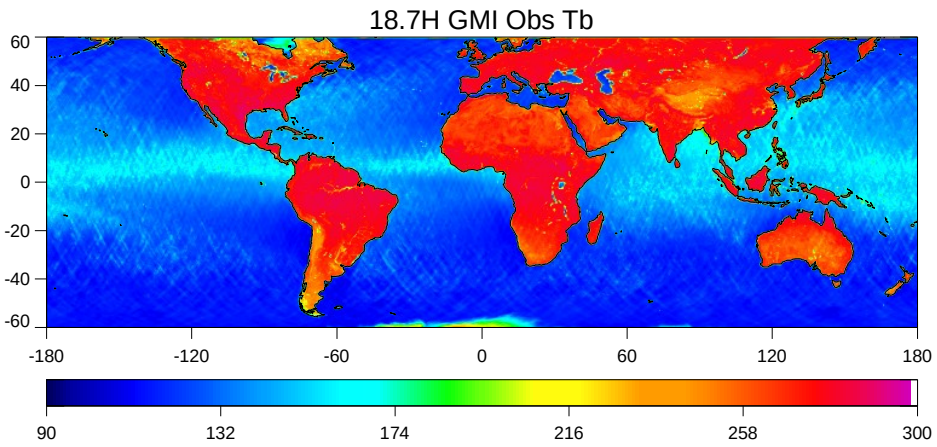


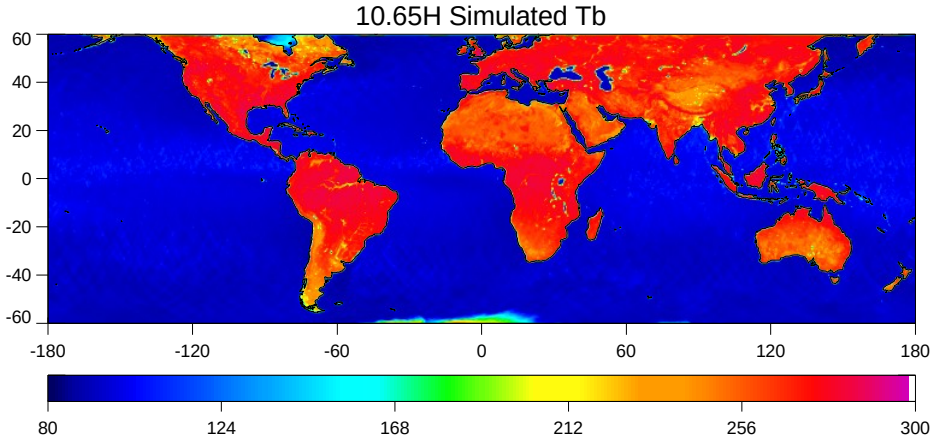
FIG. 4. A schematic of the TMI scan geometry to demonstrate the slant-intersection effect.

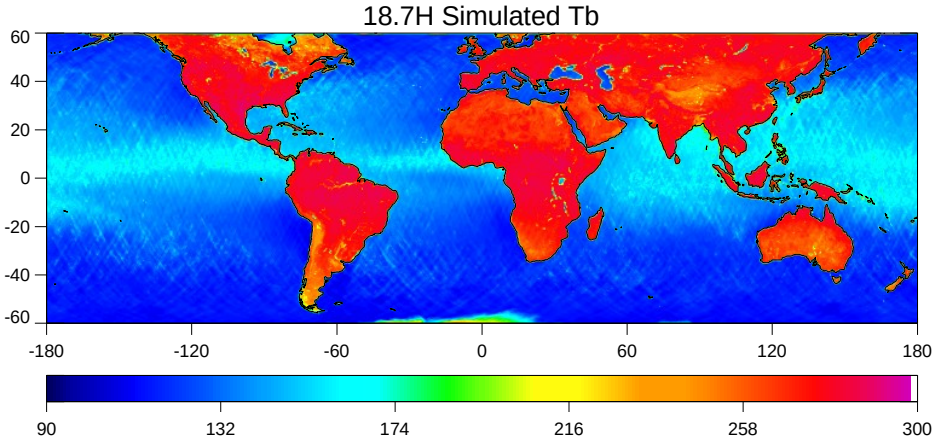
Masunaga and Kummerow 2005

Database: Simulate Tb



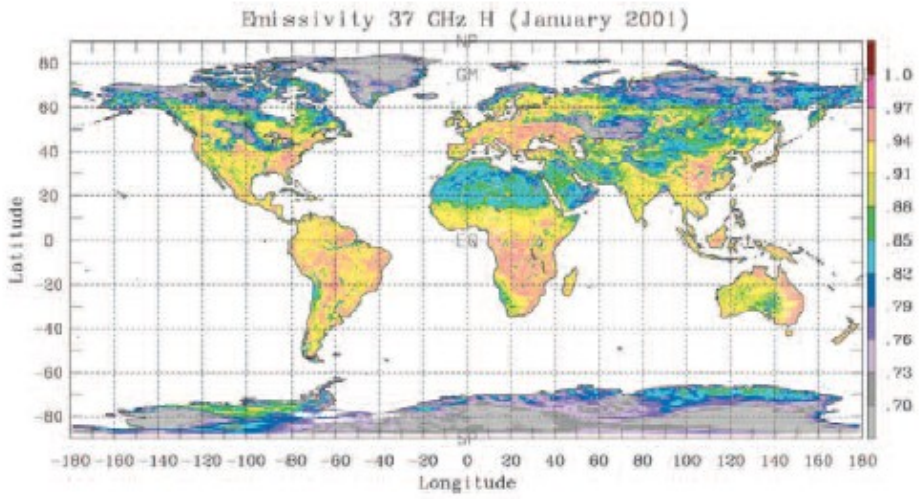


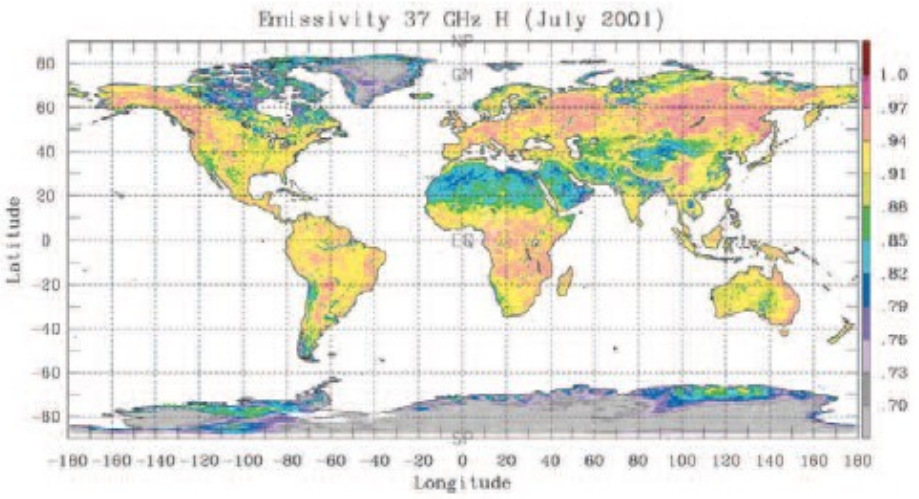




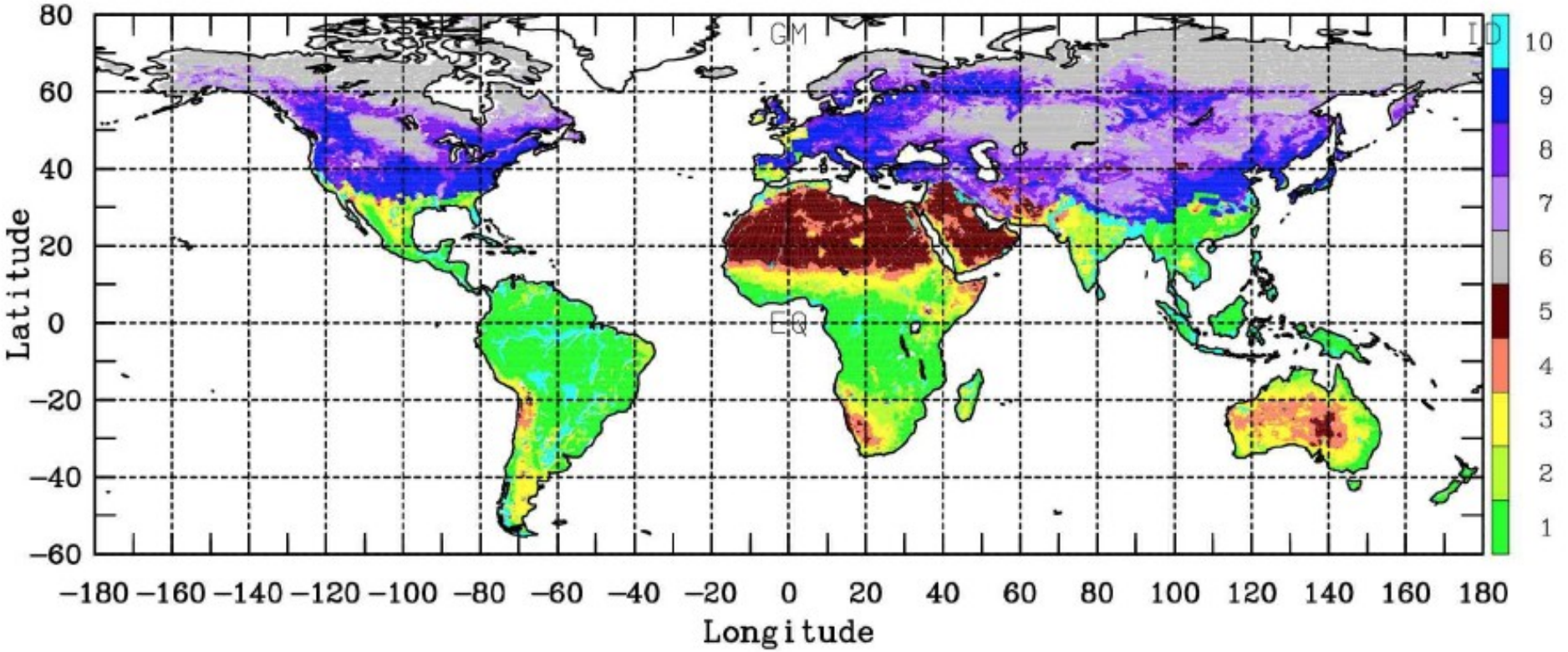
Part II: Land Surface Representation in the Precipitation Retrieval

- Indexing, database stratification for retrieval search
- Define 14 surface classes
  - SSM/I observations 1993-2008 (climatology described in Prigent et al. 2006) clustered into self-similar classes, correlations analyzed using Tool to Estimate Land-Surface Emissivities at Microwave frequencies (TELSEM: Aires et al. 2011)



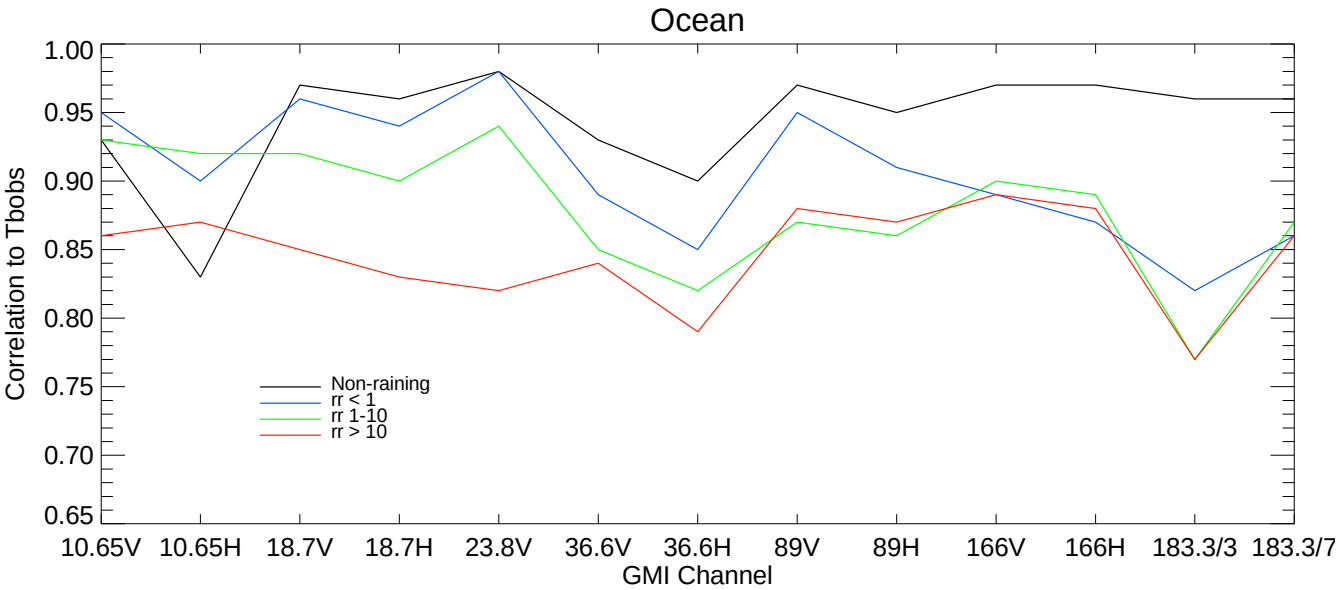


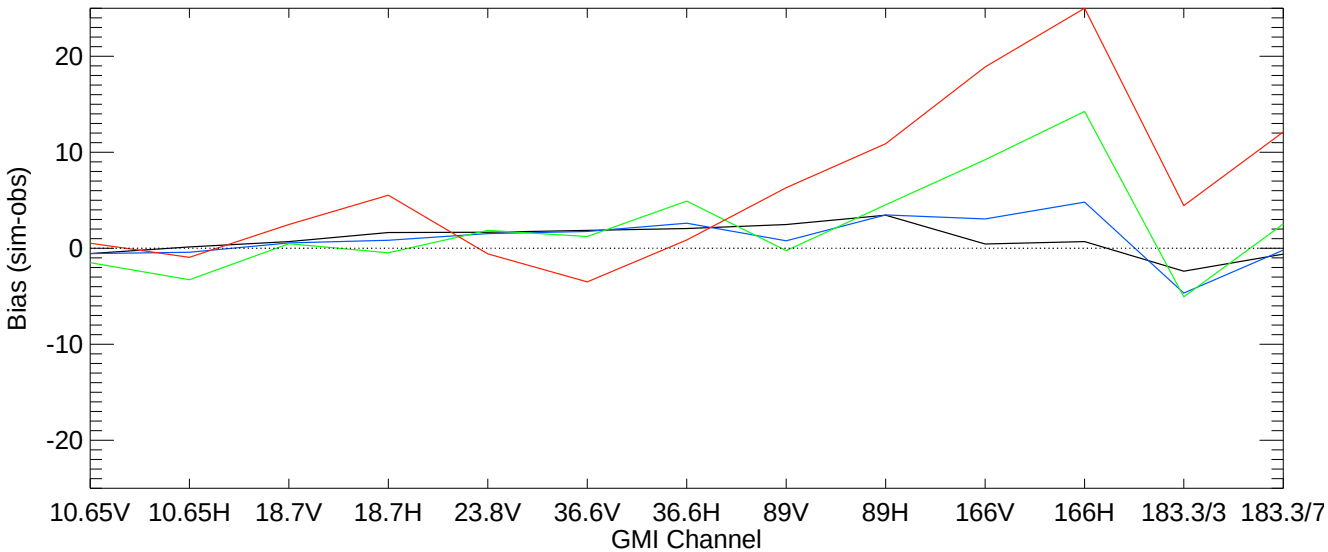
Land Surface Classes



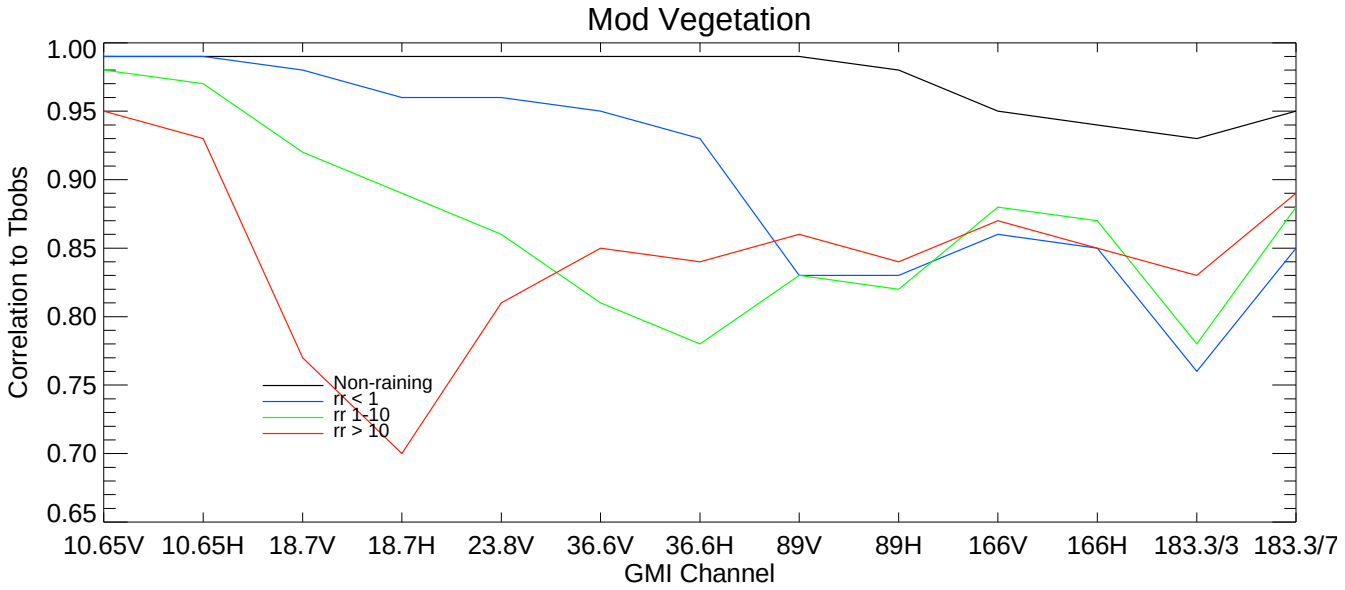
GPROF ATBD, Nov. 2014

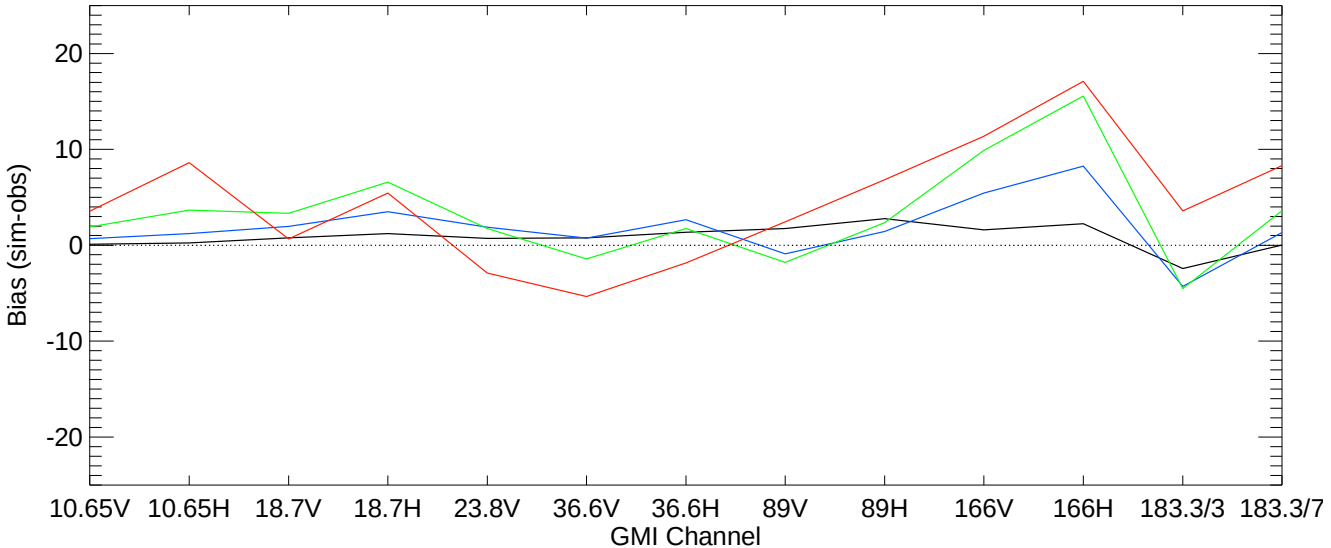
Ocean


Ocean
Correlation to Tbobs
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
Non-raining
rr < 1
rr 1-10
rr > 10
10.65V
10.65H
18.7V
18.7H
23.8V
36.6V
36.6H
89V
89H
166V
166H
183.3/3
183.3/7
GMI Channel

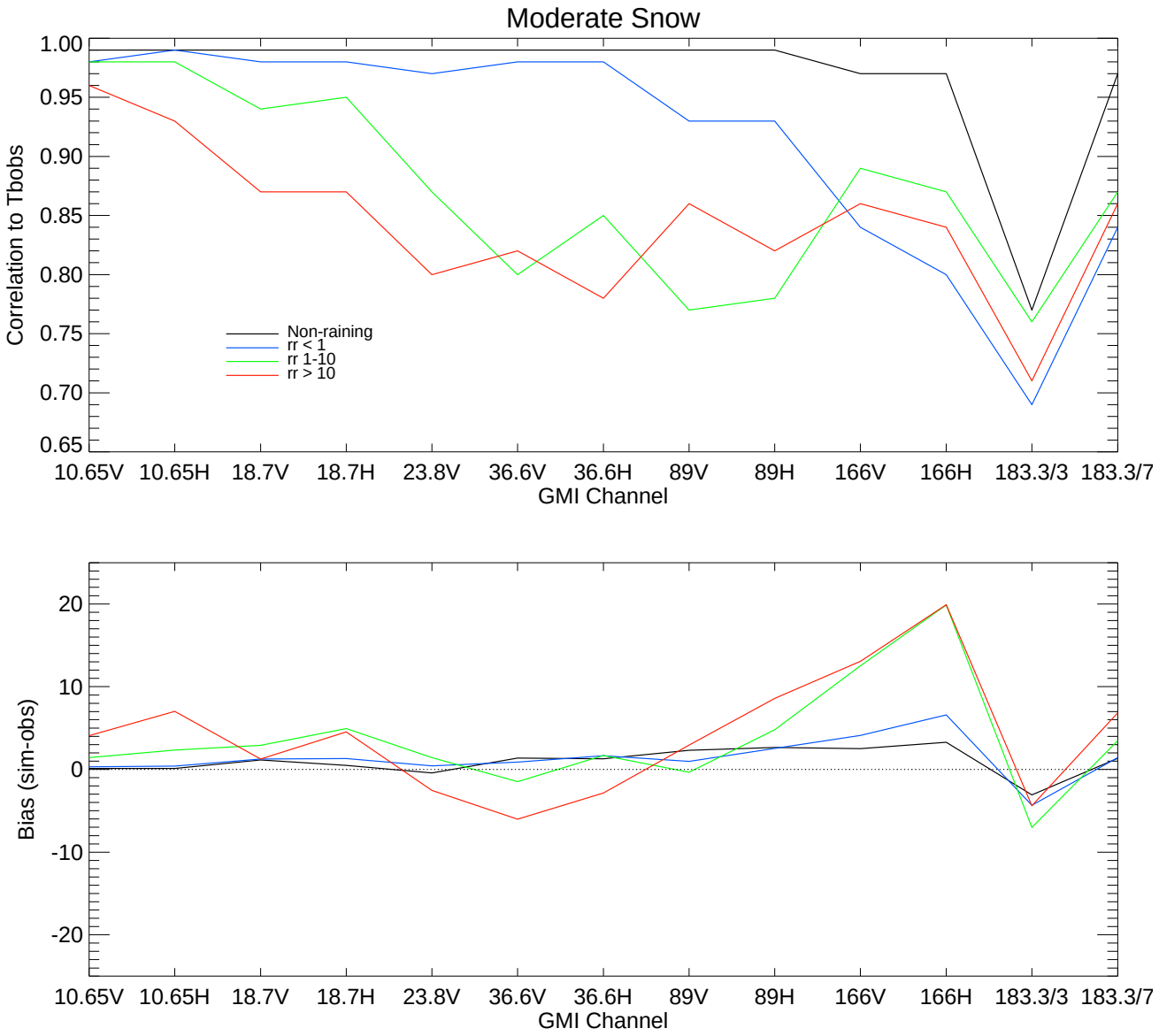

Bias (sim-obs)
20
10
0
-10
-20
10.65V
10.65H
18.7V
18.7H
23.8V
36.6V
36.6H
89V
89H
166V
166H
183.3/3
183.3/7
GMI Channel

Moderate Vegetation

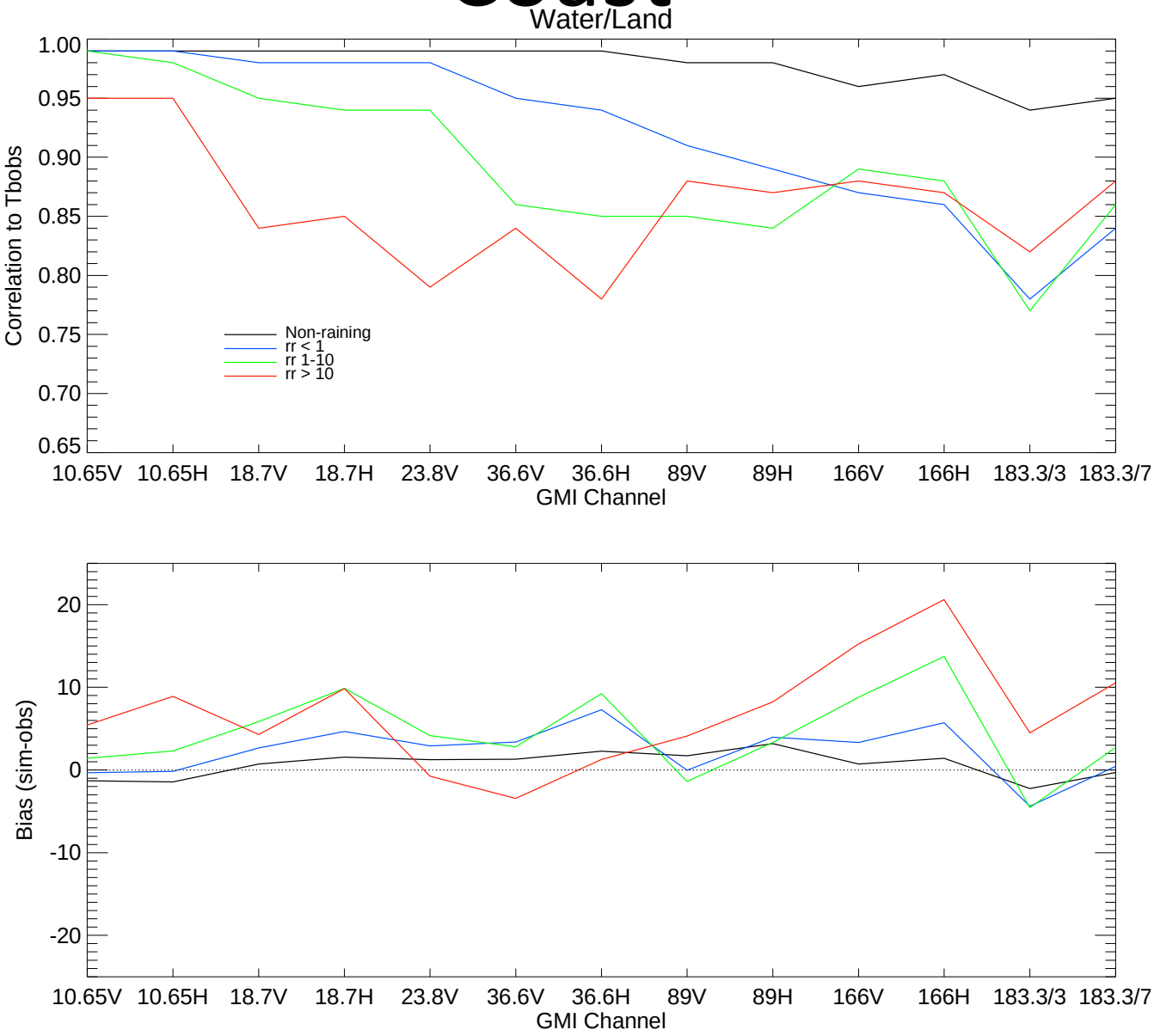


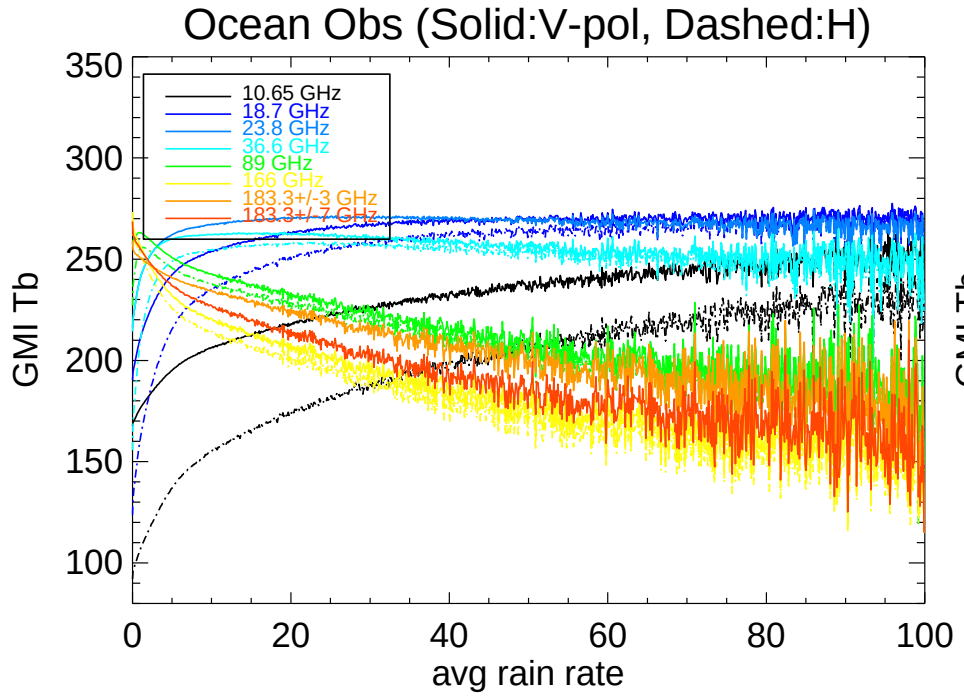


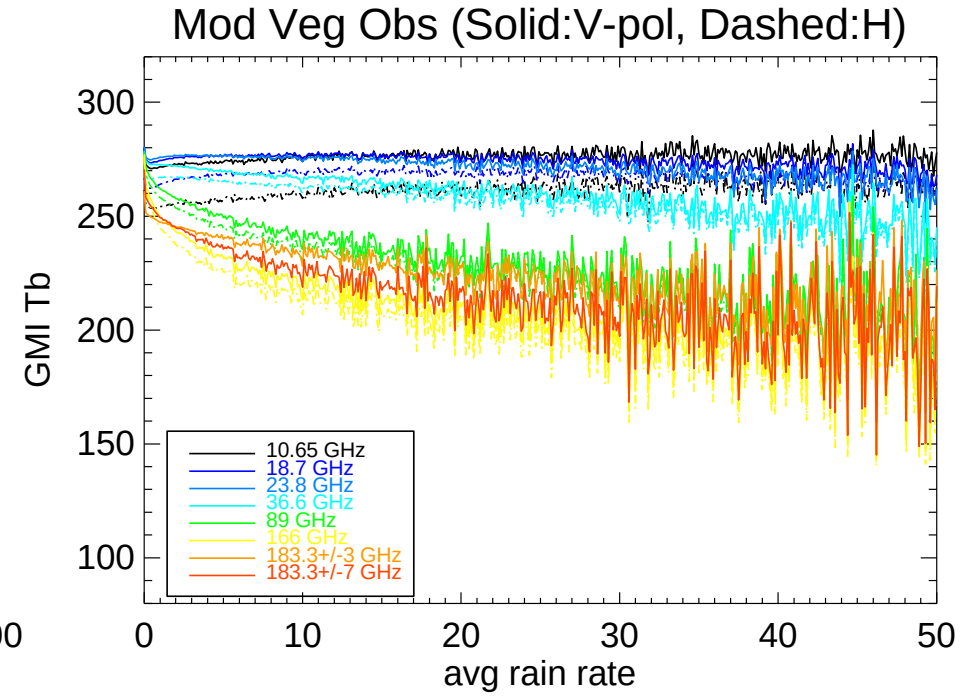
Moderate Snow

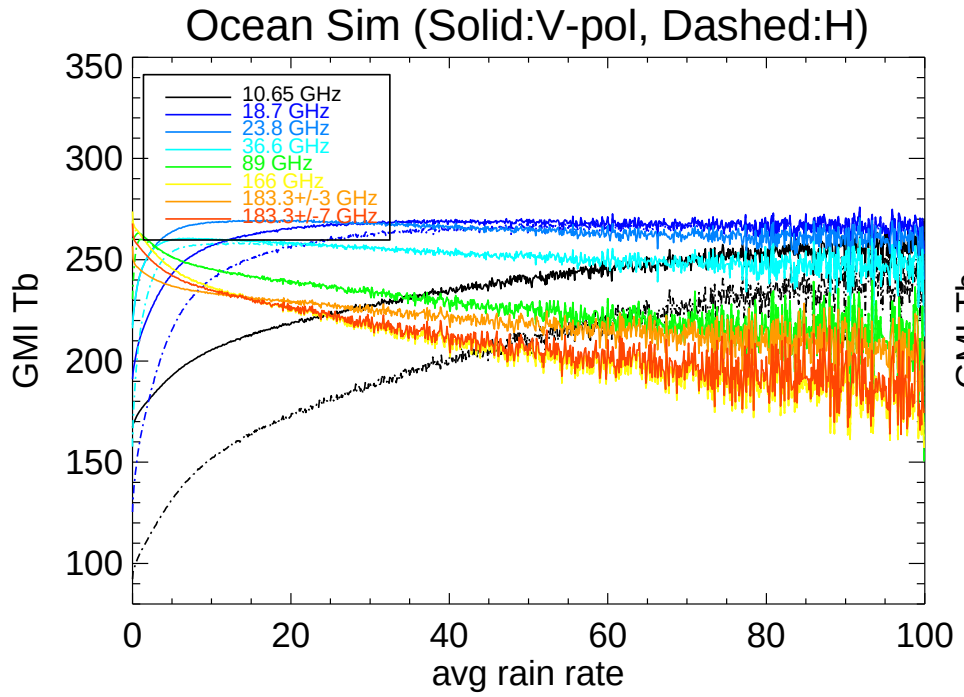


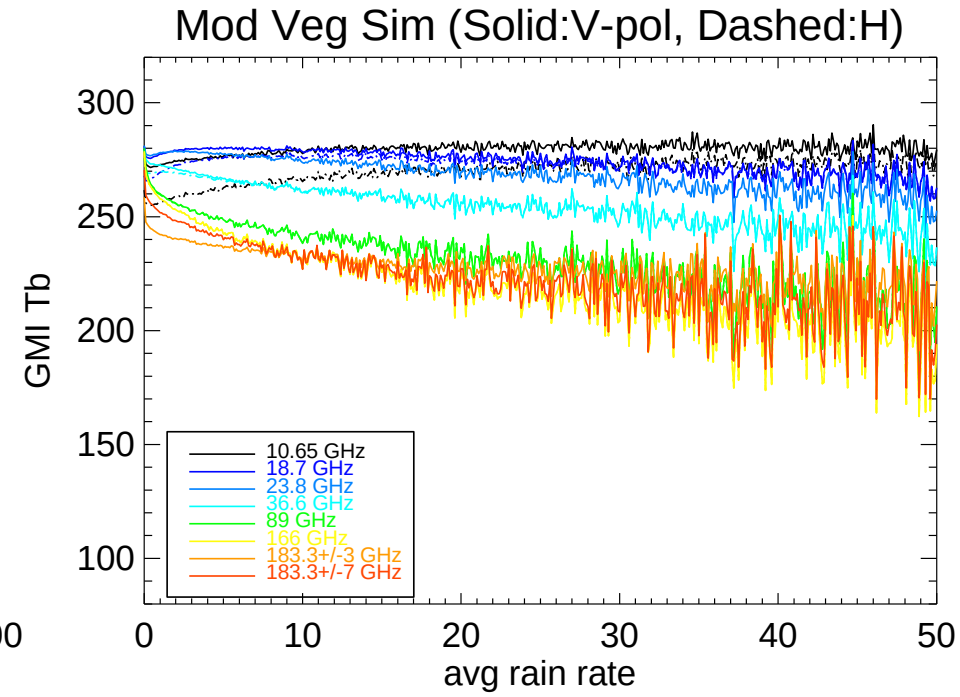
Coast

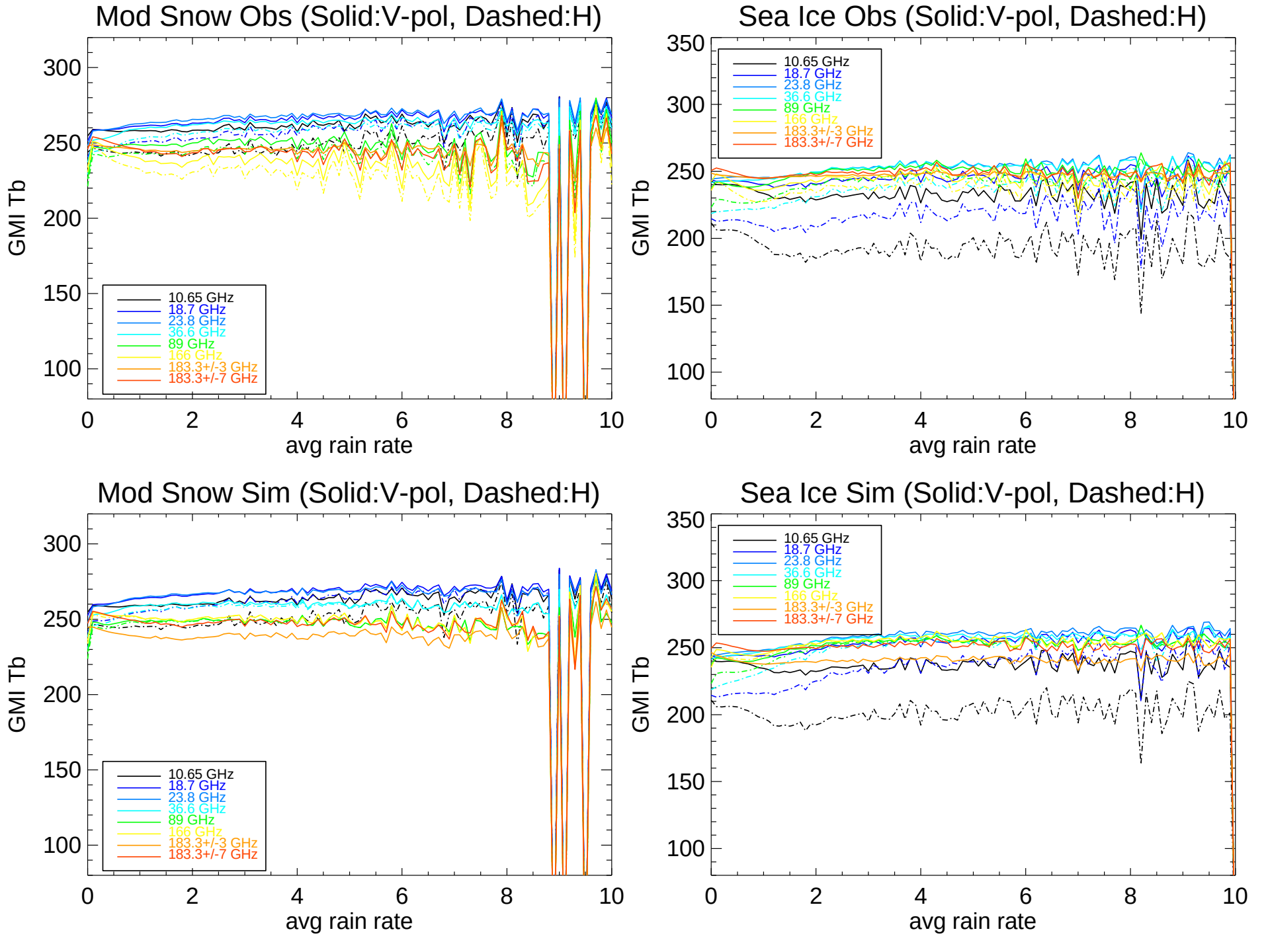

Water/Land
Correlation to Tbobs
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
Non-raining
rr < 1
rr 1-10
rr > 10
10.65V
10.65H
18.7V
18.7H
23.8V
36.6V
36.6H
89V
89H
166V
166H
183.3/3
183.3/7
GMI Channel
Bias (sim-obs)
20
10
0
-10
-20
10.65V
10.65H
18.7V
18.7H
23.8V
36.6V
36.6H
89V
89H
166V
166H
183.3/3
183.3/7
GMI Channel


Ocean Obs (Solid:V-pol, Dashed:H)
GMI Tb
avg rain rate
10.65 GHz
18.7 GHz
23.8 GHz
36.6 GHz
89 GHz
166 GHz
183.3+/-3 GHz
183.3+/-7 GHz


Mod Veg Obs (Solid:V-pol, Dashed:H)
GMI Tb
avg rain rate
10.65 GHz
18.7 GHz
23.8 GHz
36.6 GHz
89 GHz
166 GHz
183.3+/-3 GHz
183.3+/-7 GHz


Ocean Sim (Solid:V-pol, Dashed:H)
GMI Tb
avg rain rate
10.65 GHz
18.7 GHz
23.8 GHz
36.6 GHz
89 GHz
166 GHz
183.3+/-3 GHz
183.3+/-7 GHz

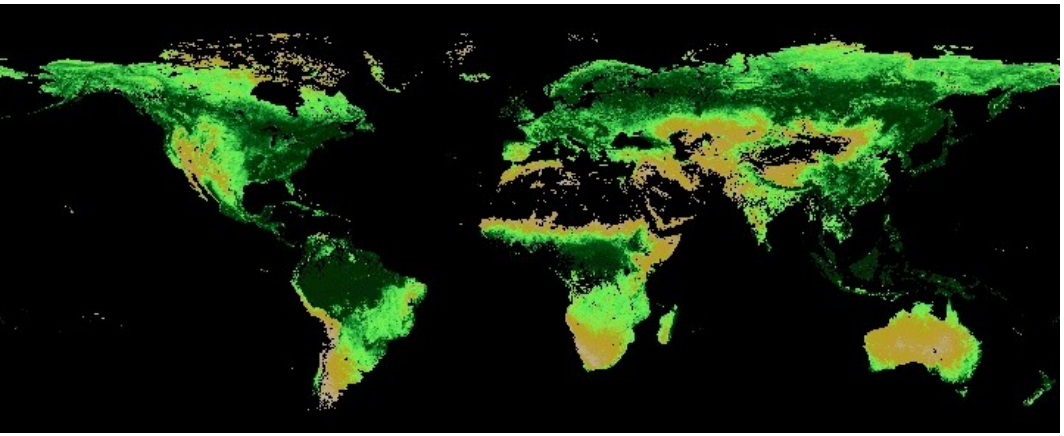

Mod Veg Sim (Solid:V-pol, Dashed:H)
GMI Tb
avg rain rate
10.65 GHz
18.7 GHz
23.8 GHz
36.6 GHz
89 GHz
166 GHz
183.3+/-3 GHz
183.3+/-7 GHz

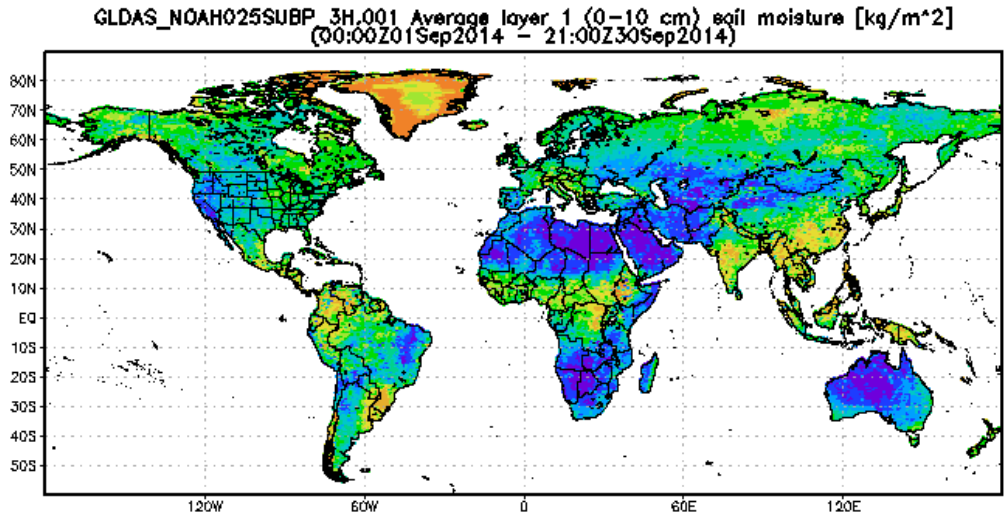

Mod Snow Obs (Solid:V-pol, Dashed:H)
Sea Ice Obs (Solid:V-pol, Dashed:H)
Mod Snow Sim (Solid:V-pol, Dashed:H)
Sea Ice Sim (Solid:V-pol, Dashed:H)
GMI Tb
avg rain rate
10.65 GHz
18.7 GHz
23.8 GHz
36.6 GHz
89 GHz
166 GHz
183.3+/-3 GHz
183.3+/-7 GHz

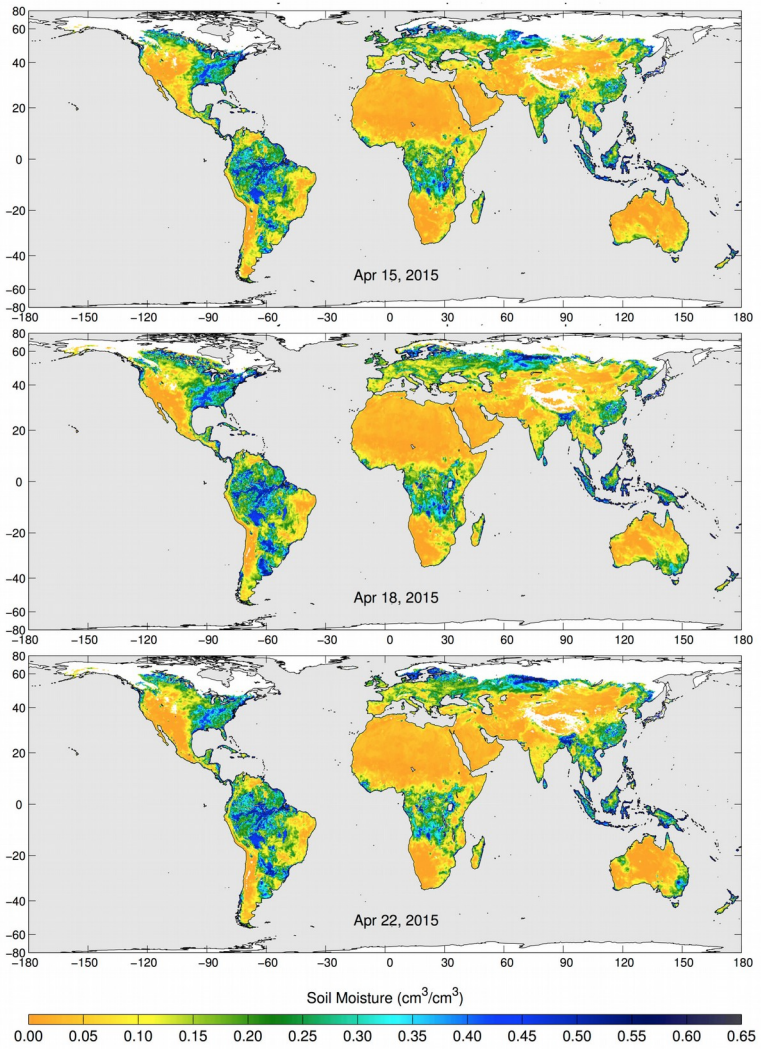
Retrieval

- Constellation retrieval scheme is still being finalized and tested
- When product is available, will be validated as a function of surface type
- Assessment: what is best way to do this? Is the answer the same for each constellation member?
  - Cross-track sounders: broaden or eliminate?
- Test additional stratification strategies
  - You et al. 2015: land elevation, ice thickness
  - Soil moisture/LAI (Ringerud et al. 2014)
  - Emissivity itself
    - empirical model, physical model (Tian et al. 2015), combination

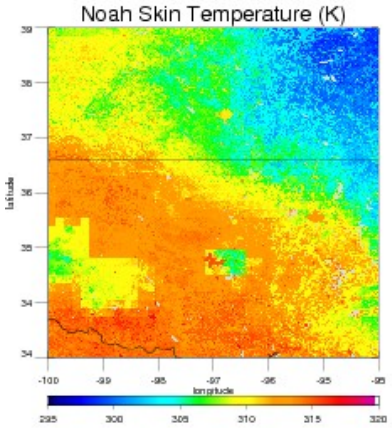
Many Possibilities…

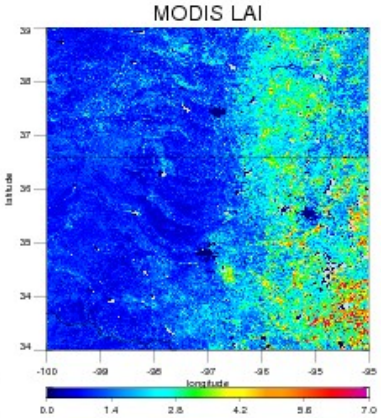


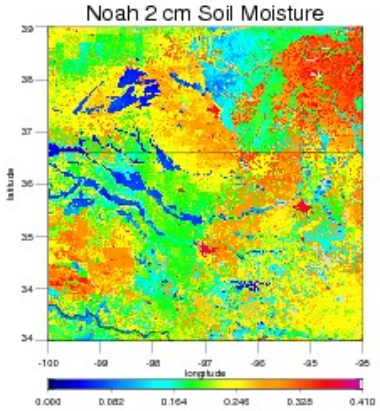


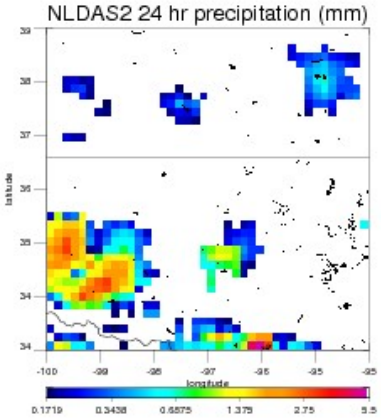


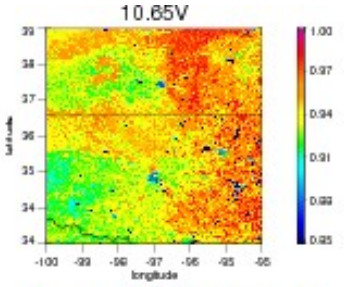
Emissivity Example
July 1, 2009

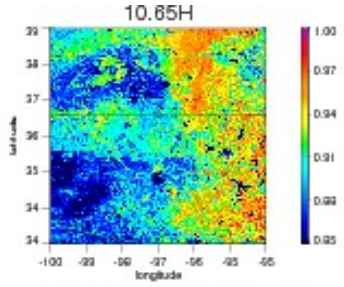


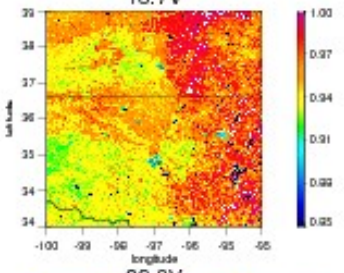


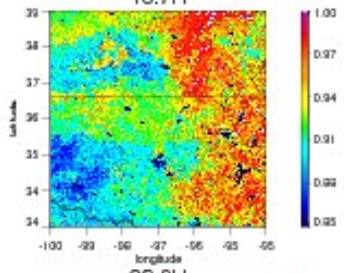


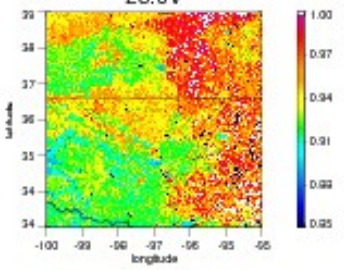


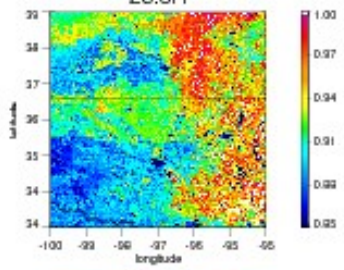


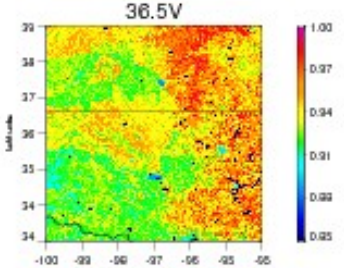


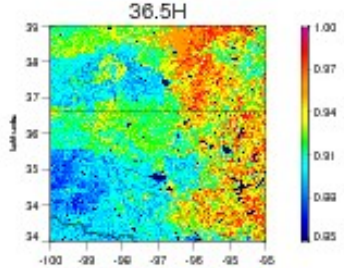


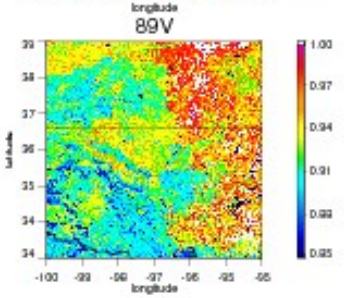


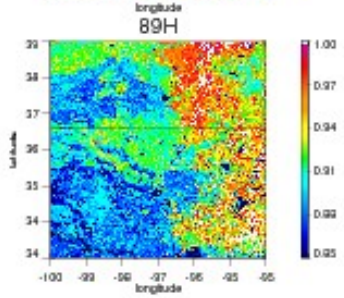












Conclusions

- Use of retrieved emissivity (land) + RSS ocean emissivity model performing well in development of physically-based database for GMI
  - Database simulated- observed Tb biases small, correlations high at low frequencies, non-raining and low rain rates
- Issues remain
  - Ocean model not valid at highest frequencies
  - GMI retrieved emissivities not ideal choice for extension of database to other constellation members – need to explore extension to any frequency, viewing geometry
- Ideally would like physical model and fully physical retrieval scheme for use across constellation and backward to TRMM era, etc. – not there yet
- Validation of GPROF retrievals following April 1 release will involve validating utility of surface classes and testing of other methods of stratification (or lack thereof)