Aquarius Drift over Antarctica and Rainforest Regions

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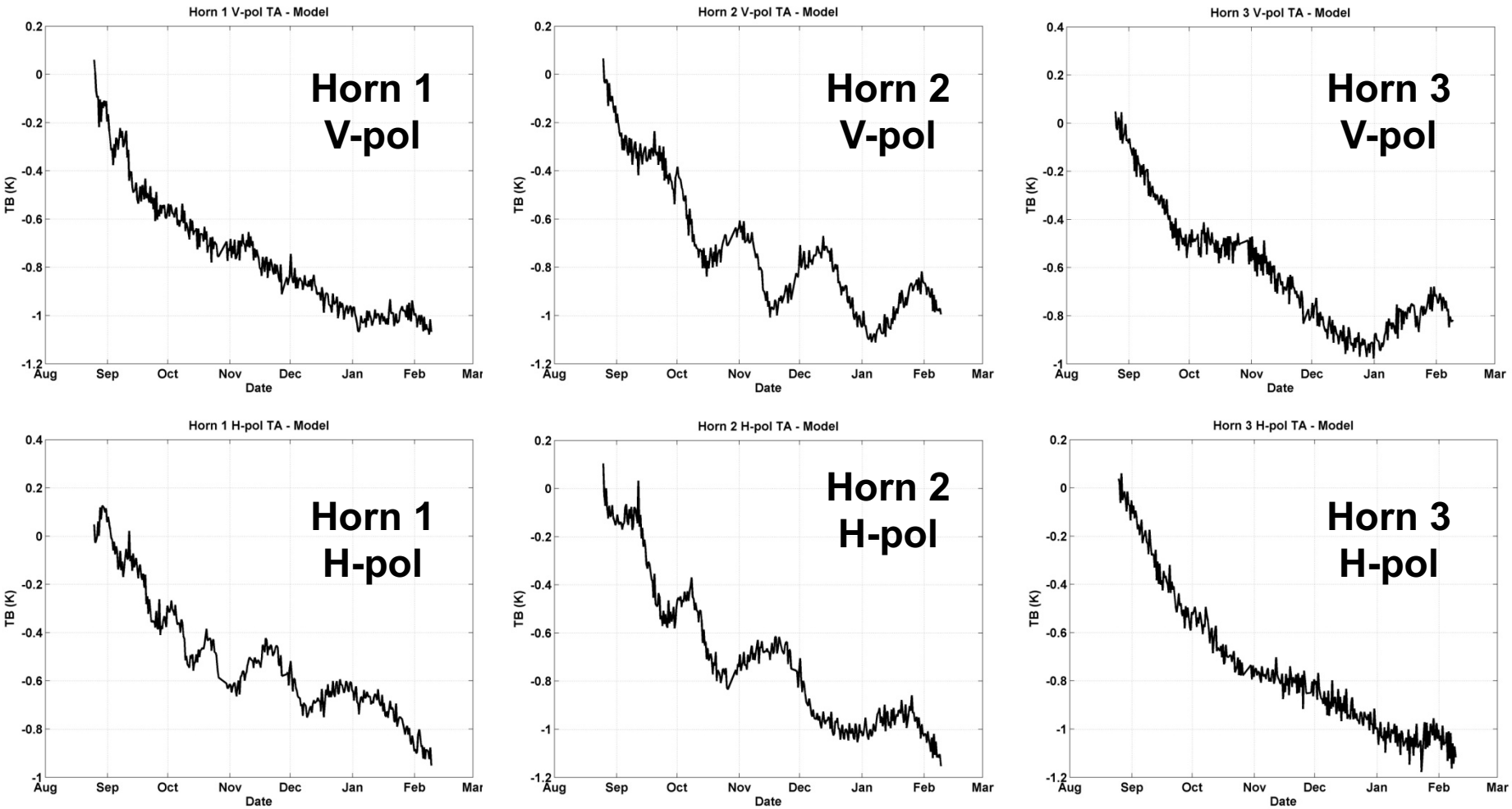
Aquarius Ocean Drift

- **Represents drift only at one TB – <u>need another reference to determine whether it is a gain or offset drift</u>**



Separation of Gain vs Offset Drift

- **Level of gain vs offset drift will depend on which components are changing**

$$\Delta T_B(T_B,t) = (T_B - T_{REF})\frac{\Delta T_{ND}(t,L,\Gamma)}{T_{ND}} + \Delta T_{Offset}(L,\Gamma)$$

- **Example: Drift in noise diode brightness creates gain drift**
  - **Largest drift for cold TBs, small drift at warmer TBs that are close to internal reference load temperature**

$$\Delta T_B(T_B,t) = (T_B - T_{REF})\frac{\Delta T_{ND}(t)}{T_{ND}}$$

ND drift will cause TB drift over Antarctica which is ~0.5 x ocean drift

$$\frac{\Delta T_B(T_B \approx 200K,t)}{\Delta T_B(T_B \approx 100K,t)} = \frac{(200-300)}{(100-300)} \approx 0.5$$

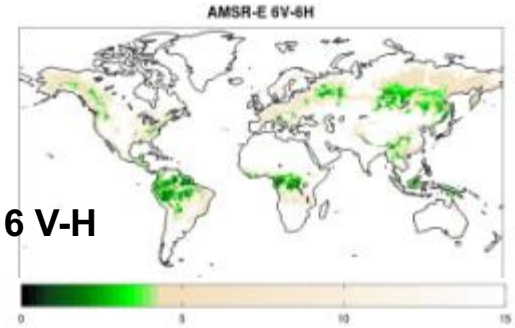
TB drift will approach zero over warm regions

$$\frac{\Delta T_B(T_B \approx 290K,t)}{\Delta T_B(T_B \approx 100K,t)} \approx 0.05$$

Natural On-Earth Calibration Targets for Stability Tracking

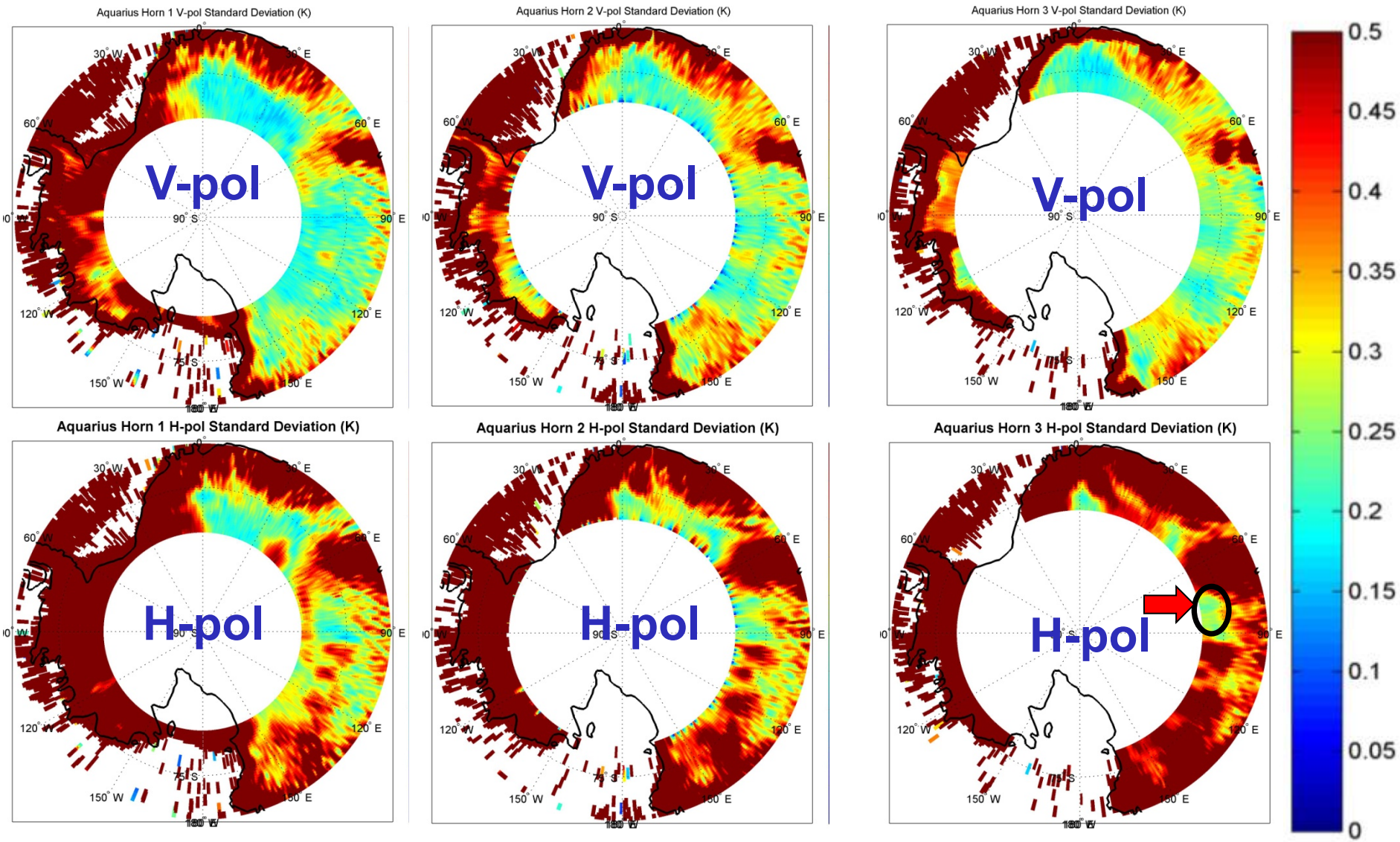
- **Antarctica**
  - Select areas with stable temperature (V-pol TB) and snow structure (H-pol TB)
  - Use in-situ temperature data coupled with a heat transport model to determine T(z,t)
  - Use AMSR-E 6.9-37 GHz observations to constrain ice structure
  - Radiative transfer model to determine L-band TB

- **Rainforest**
  - Select depolarized heavily vegetated areas within the Aquarius swath
  - Use TMI and WindSat to determine canopy temperature to track Aquarius calibration

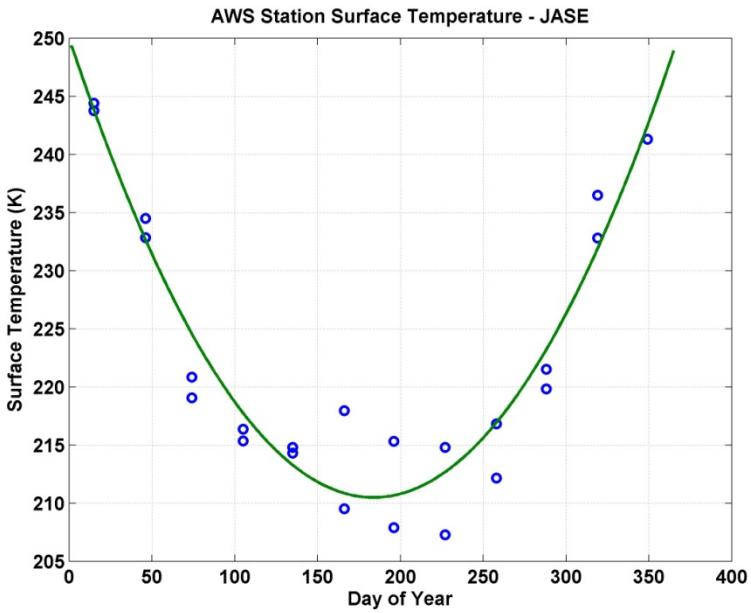


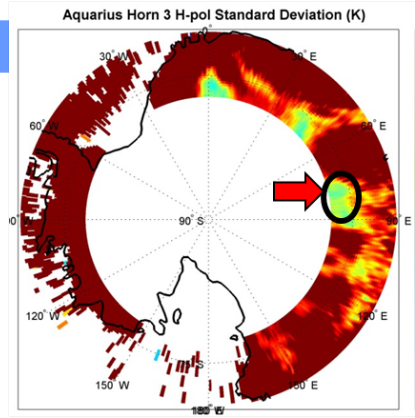
Aquarius L-band Temporal Stability (Sep'11-Feb'12)

θ= 28.7° θ= 37.8° θ= 45.6°



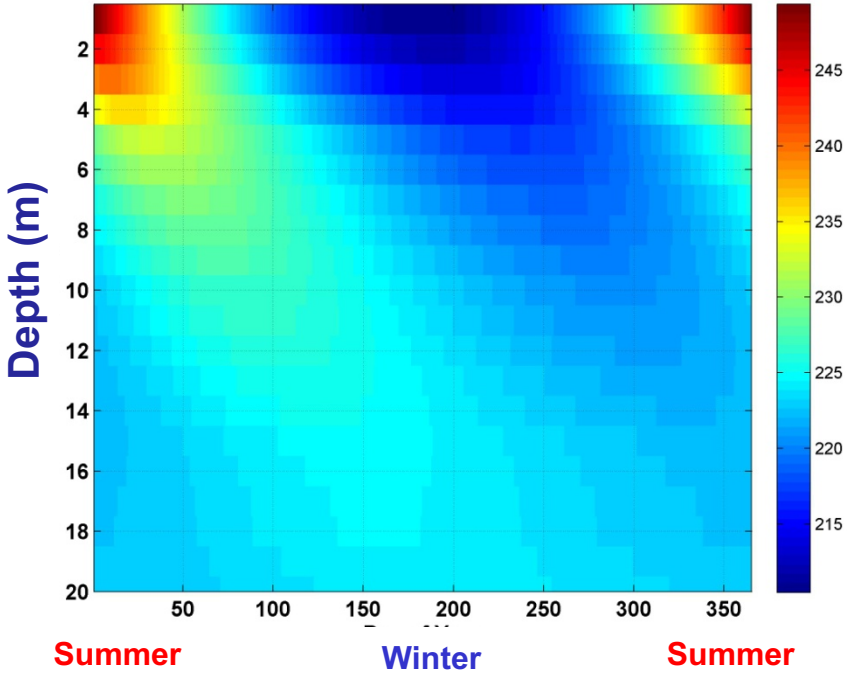
Thermal Profile





$$\frac{\partial T}{\partial t} = \alpha_T(\rho)\frac{\partial^2 T}{\partial z^2}$$

Ice Temperature

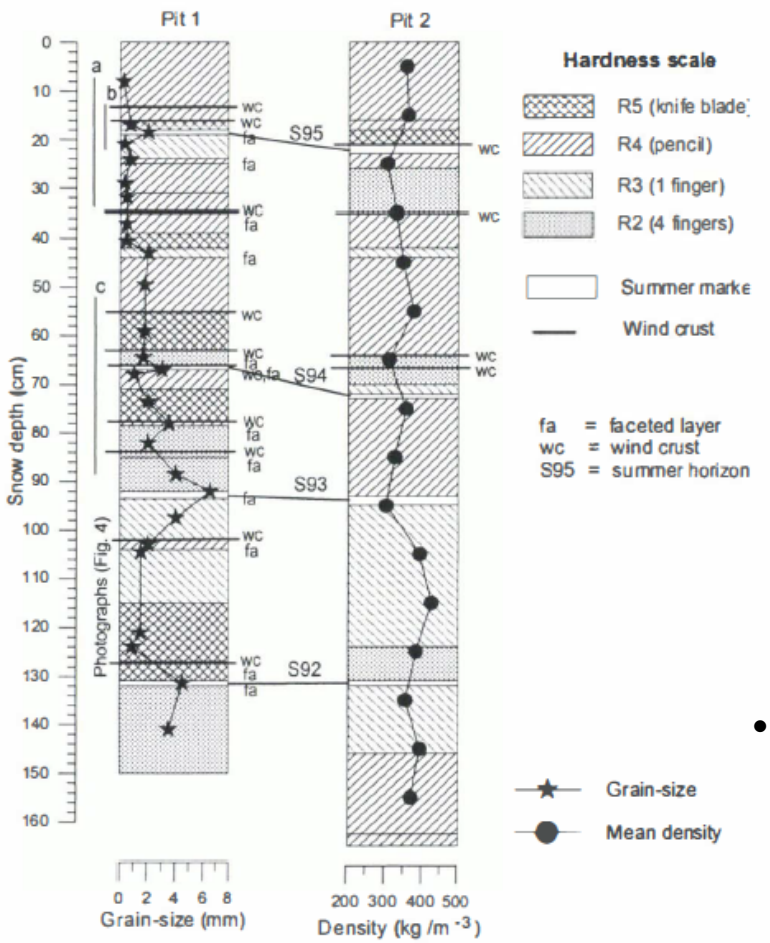


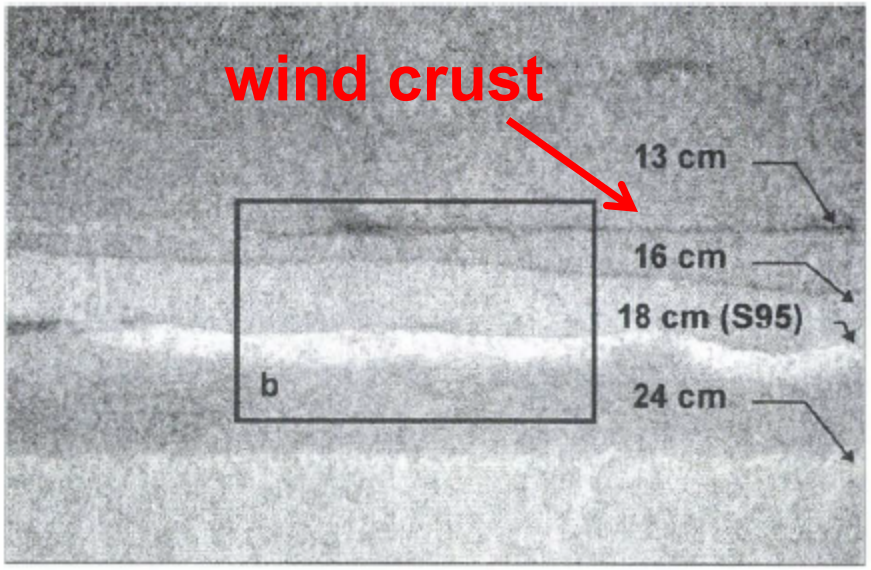
Surface temperature values obtained from near by AWS station (JASE) used as top boundary condition

Solved heat equation numerically to determine T(z,t) assuming only vertical heat transport

Thermal diffusivity increases as a function of density (Paterson, 2000)

Observed Snow Structure in Low Accumulation Regions



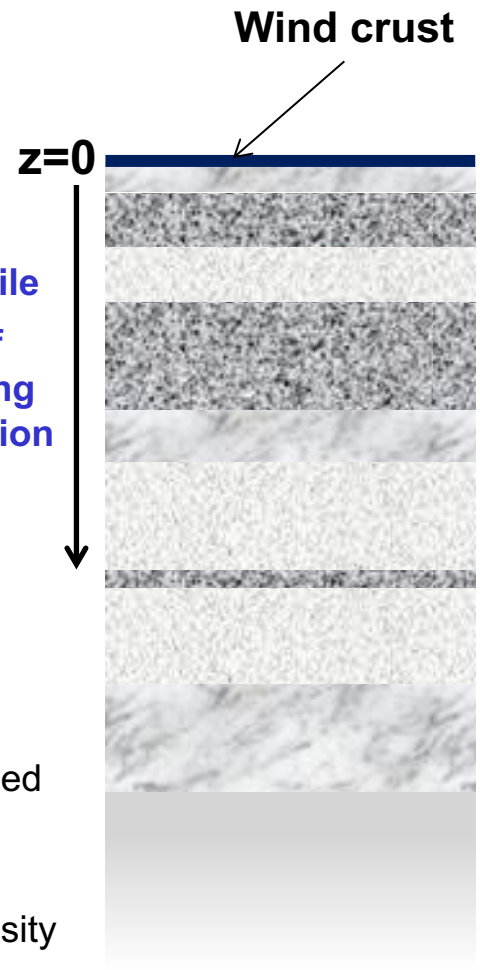


Steffen et al., 1999

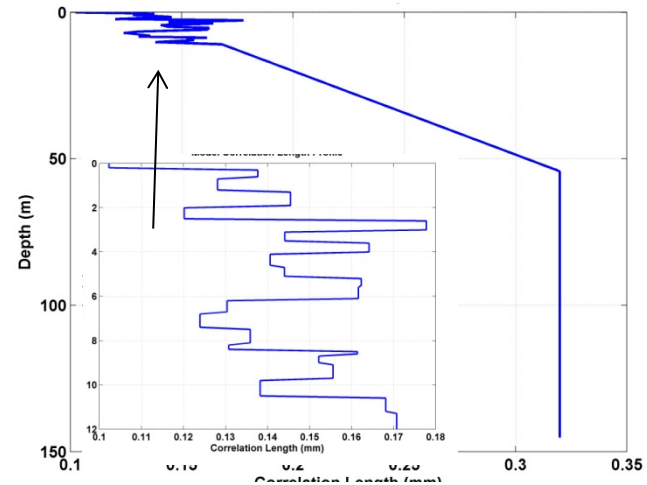
- **Snow structure near top surface contains layers with variable thickness, density and grain size (e.g. Steffen et al., 1999; Macelloni et al., 2007)**
- **Wind crusts (thin, high density) can be present (impact polarization difference)**

Snow Structure in TB Model

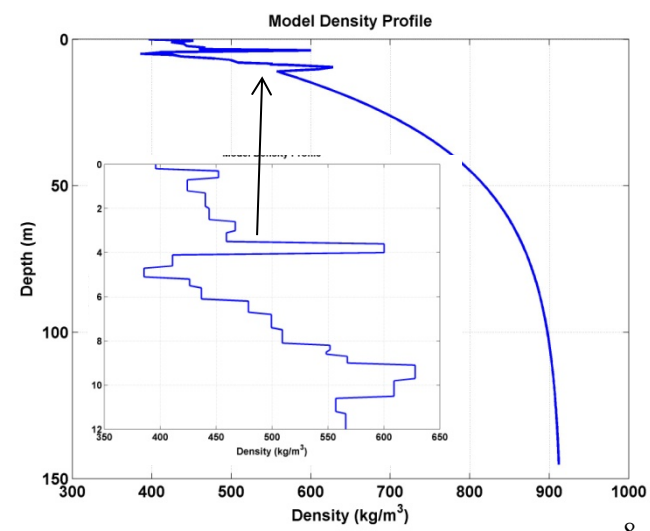
- **MEMLS model (Wiesmann and Matzler, 1999) used to compute upwelling TB**
  - **Started with exponentially increasing density profile and increasing correlation length profile**
  - **Generated multiple realizations of snow structure by randomly adding layers of varying density, correlation length and thickness to first 20 m**
    - Density variations based on measurements found in literature (e.g. Steffen et al., 1999; Paterson, 2000; Macelloni et al., 2007)
    - Correlation length profile based on Matzler (2002)
    - For each profile realization, found surface wind crust density and thickness to fit 6.9-36.5 GHz V&H-pol AMSR-E data
  - **Ice dielectric model from Tiuri et al., (1984) gave best fit AMSR-E 6 & 10 GHz temporal variability**

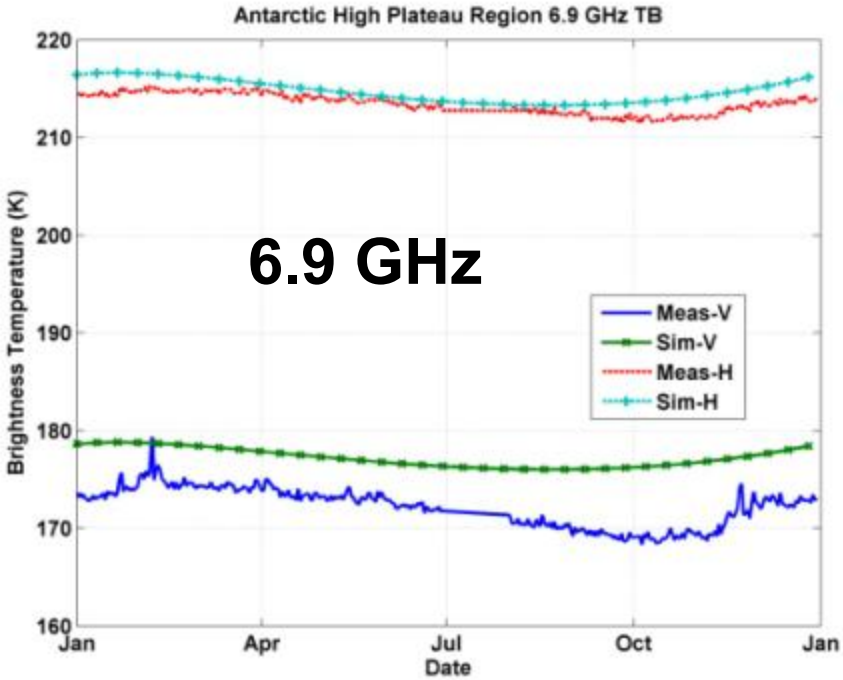


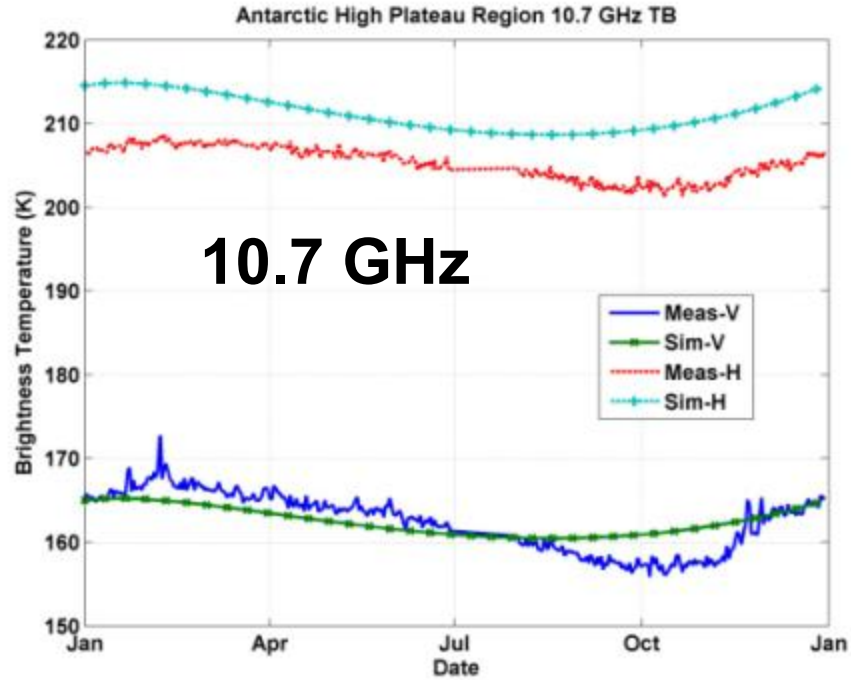
Correlation Length Profile

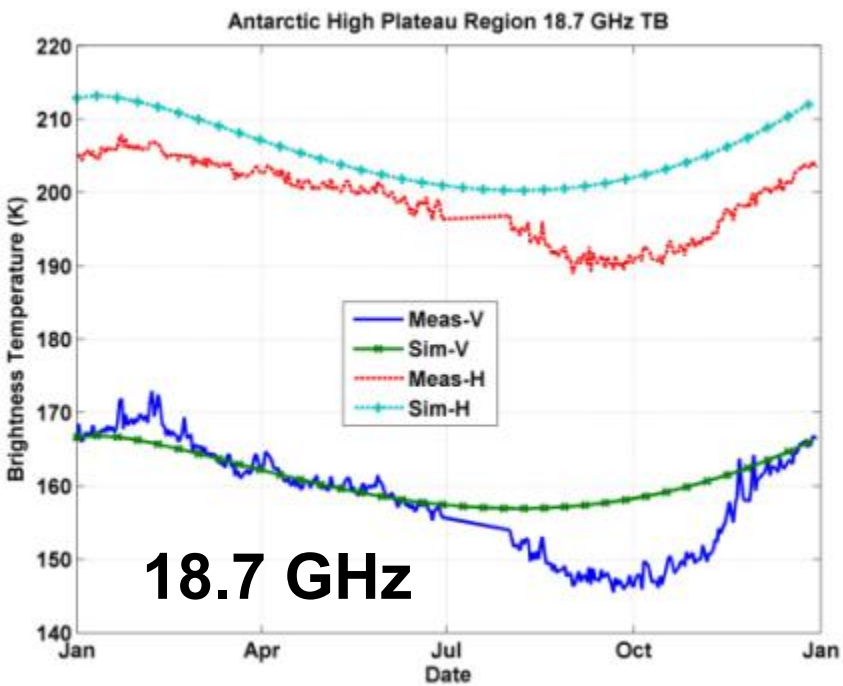


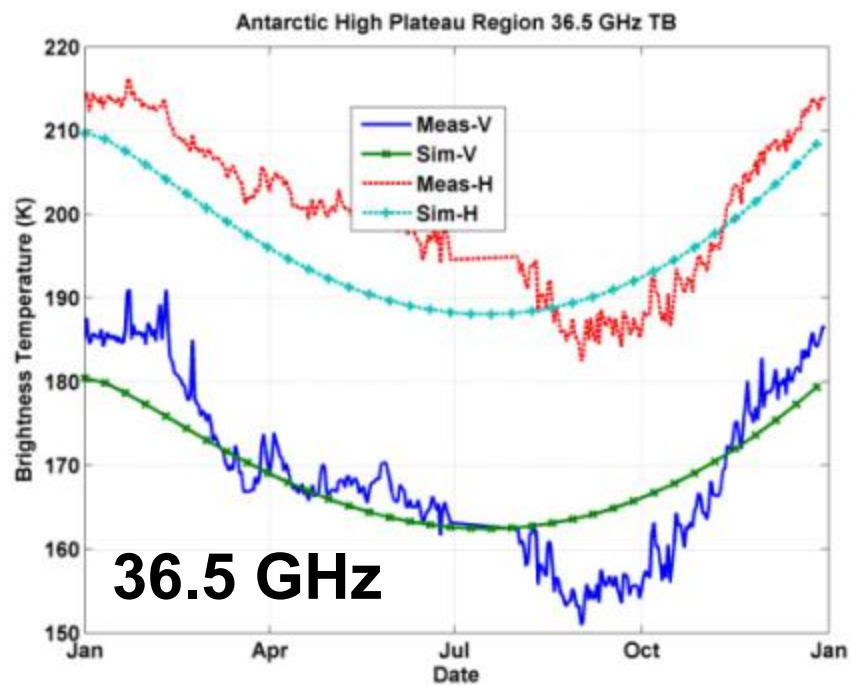
Density Profile




Antarctic High Plateau Region 6.9 GHz TB
6.9 GHz
Meas-V
Sim-V
Meas-H
Sim-H
Brightness Temperature (K)
Date
Jan
Apr
Jul
Oct
Jan


Antarctic High Plateau Region 10.7 GHz TB
10.7 GHz
Meas-V
Sim-V
Meas-H
Sim-H
Brightness Temperature (K)
Date
Jan
Apr
Jul
Oct
Jan

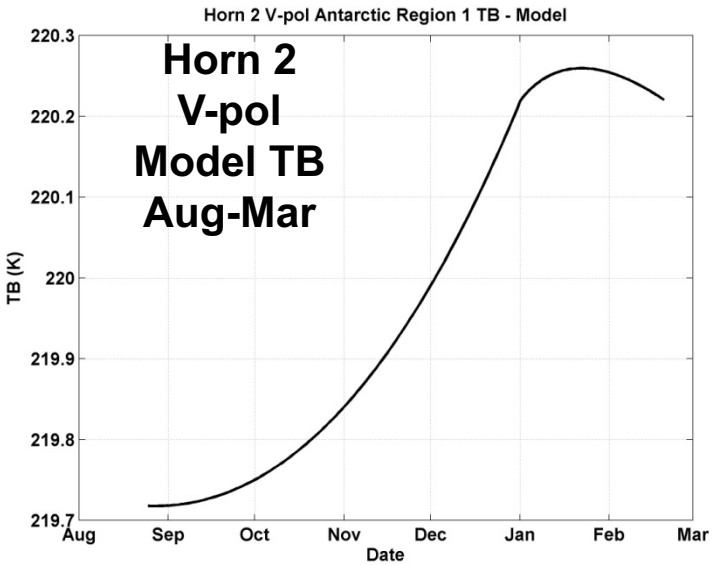

Antarctic High Plateau Region 18.7 GHz TB
18.7 GHz
Meas-V
Sim-V
Meas-H
Sim-H
Brightness Temperature (K)
Date
Jan
Apr
Jul
Oct
Jan

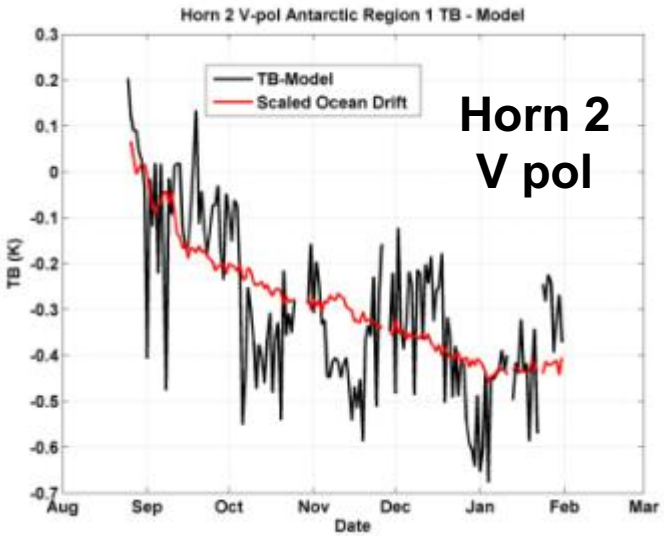

Antarctic High Plateau Region 36.5 GHz TB
36.5 GHz
Meas-V
Sim-V
Meas-H
Sim-H
Brightness Temperature (K)
Date
Jan
Apr
Jul
Oct
Jan

Drift over Antarctica

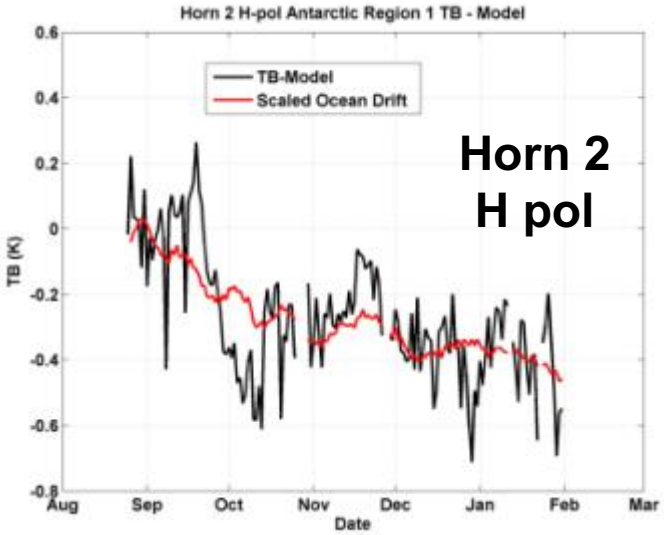
-Aquarius minus Model over Antarctica

- Scaled ocean drift



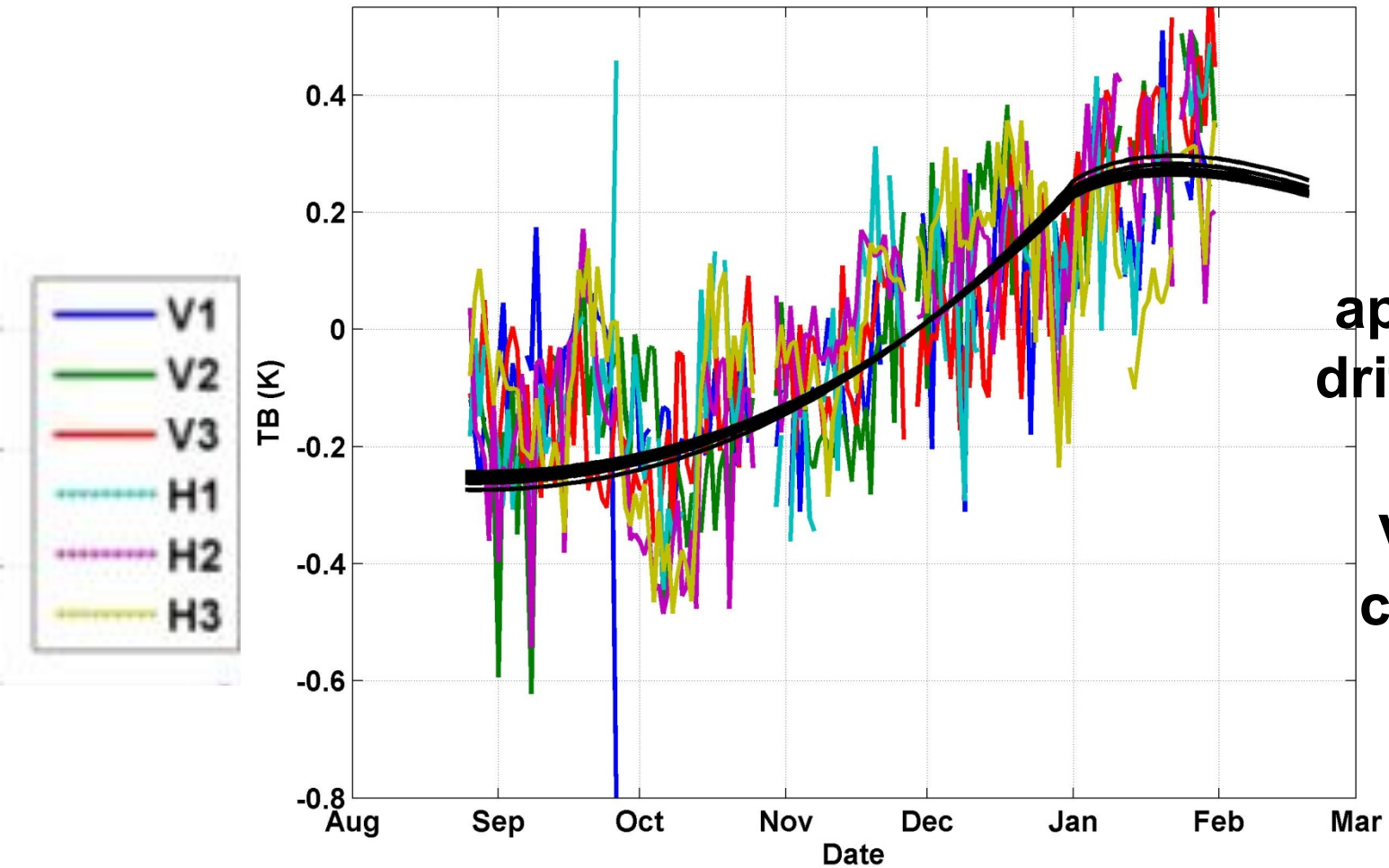


- Used model to compute Aquarius TB for each channel and polarization from Aug'11-Feb'12 and computed Aquarius-model difference
- Compared drift over ice to the scaled drift over the ocean (ice drift ~ 0.5 x ocean drift)
- Aquarius – model TB shows drift that is approximately half the ocean drift for all channels which is consistent with an instrument gain drift



TB with Model – All Channels

- All channels in good agreement with model after applying gain drift correction based on ocean TA drift estimates



TB after applying gain drift correction

V1.1 TB not corrected for drift

Warm Reference

- **Over warm regions (TB ~ 280K) we should see almost no drift in Aquarius TBs if it is a gain drift**
- **Heavily vegetated regions act like pseudo-blackbodies (Brown and Ruf, 2005)**
  - **Opaque canopy obscures the surface**
  - **Exhibit little polarization or incidence angle dependence**
  - **Brightness temperature closely tracks canopy physical temperature**
  - **TB near 280K**

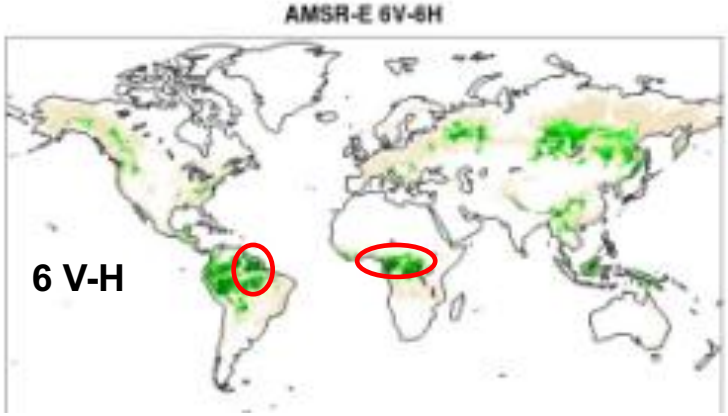
weakly scattering canopy

$$T_B = \left(1+\Gamma_S e^{-\tau_{canopy}\sec\theta}\right)\left(1-e^{-\tau_{canopy}\sec\theta}\right)(1-\omega)T_{canopy} + (1-\Gamma_s)e^{-\tau_{canopy}\sec\theta}T_{sfc}$$

$$\text{for} \quad \tau >> 1$$

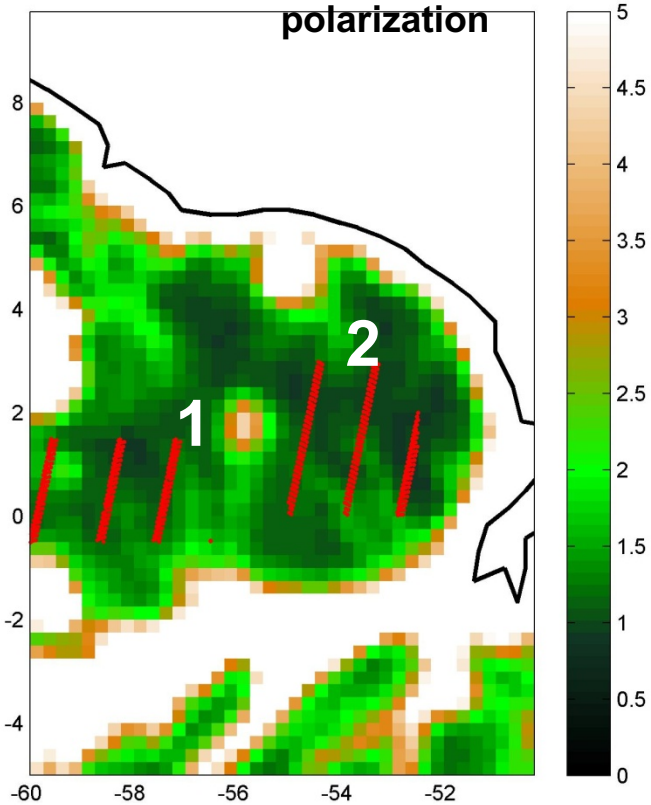
$$T_B(f) = (1-\omega(f))T_{canopy}$$

Regions

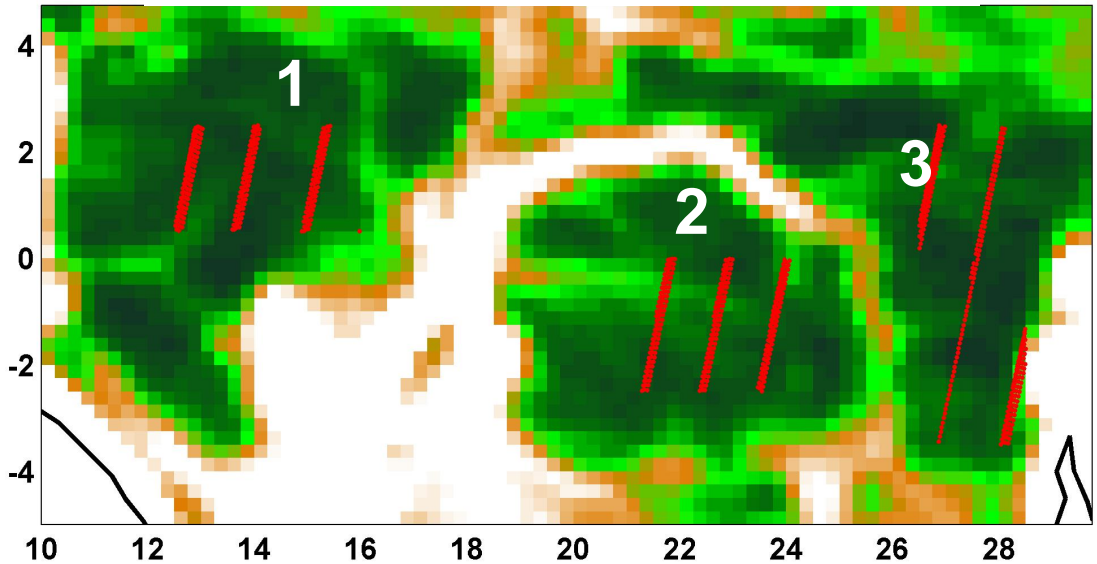


- Select regions in Amazon and Congo that exhibit small polarization signature at 6 and 10 GHz
- Regions also must be large enough to contain the Aquarius swath
- 5 regions identified

Amazon Region TMI 10 GHz De-polarization



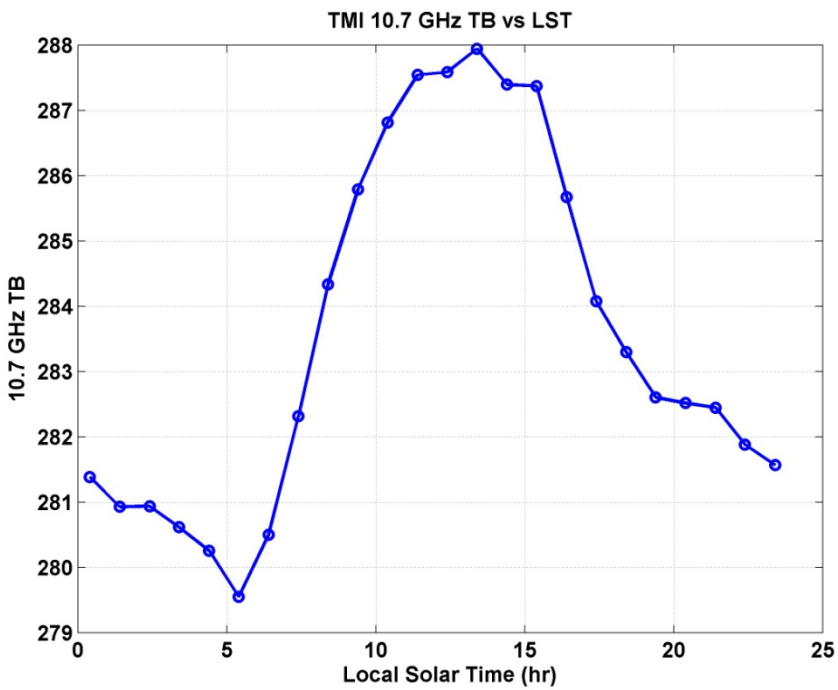
Congo Region TMI 10 GHz De-polarization



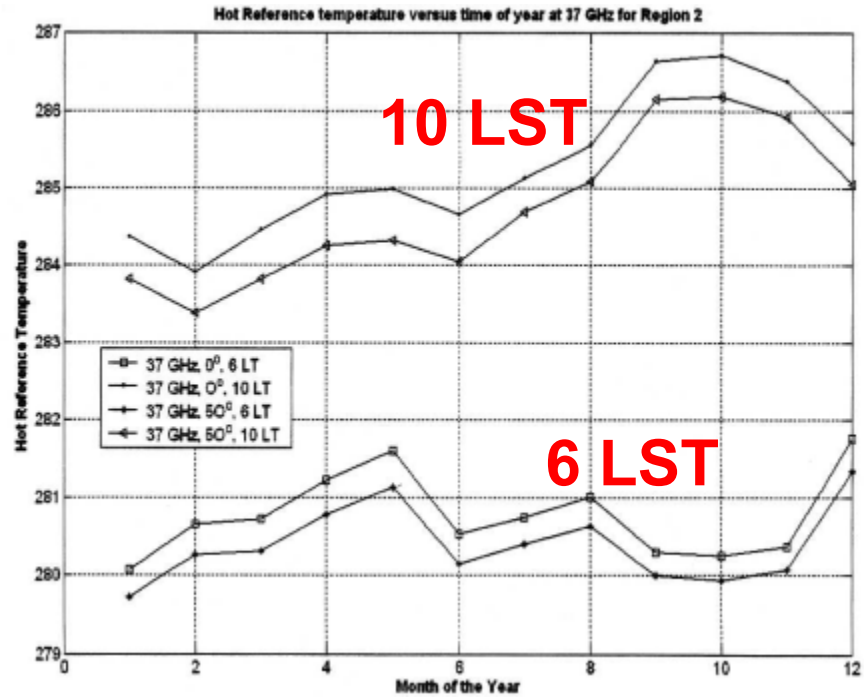
Rainforest Temperature Stability

- Diurnal signal typically ~6-9K and annual signal typically less than 2K
- Rainforest regions exhibit greatest stability in early morning hours

Diurnal Signal



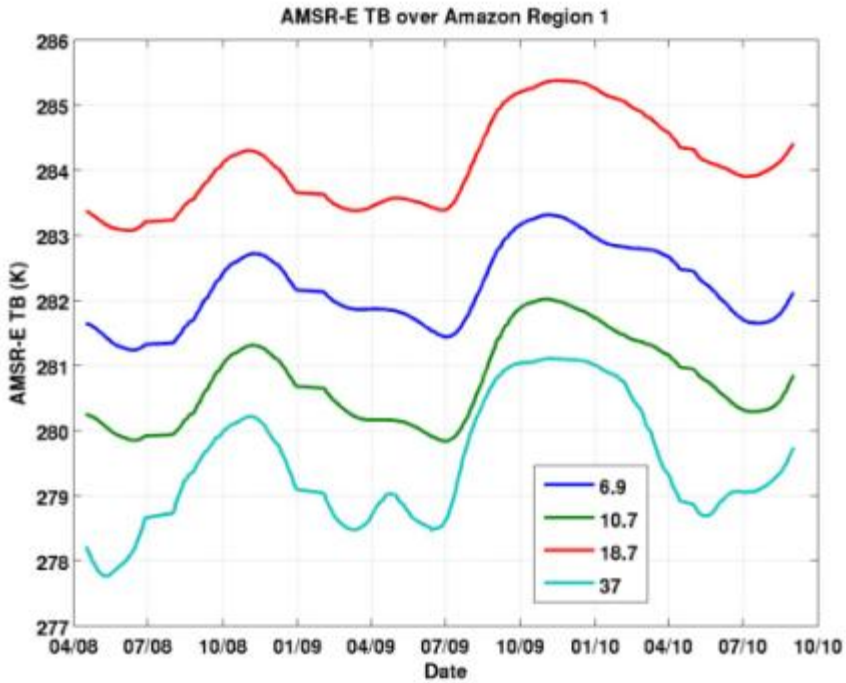
Annual Signal



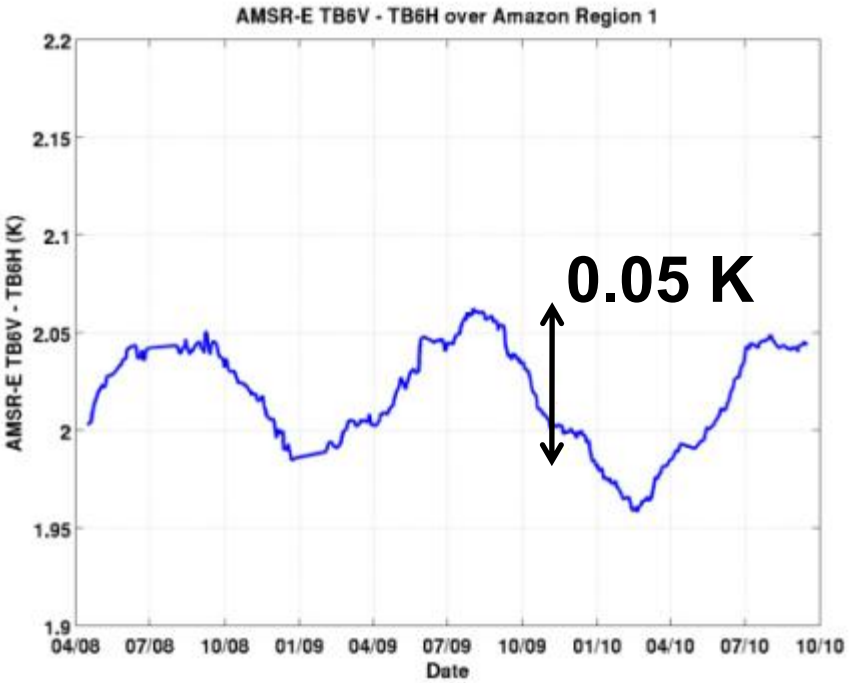
Stability of Regions

- TBs stable to ~2K over these regions over several years
  - C-band to Ka-band highly correlated
- 6.9 GHz polarization difference stable to 0.05K

AMSR-E TBs Amazon Region 1
April 2008 – October 2010

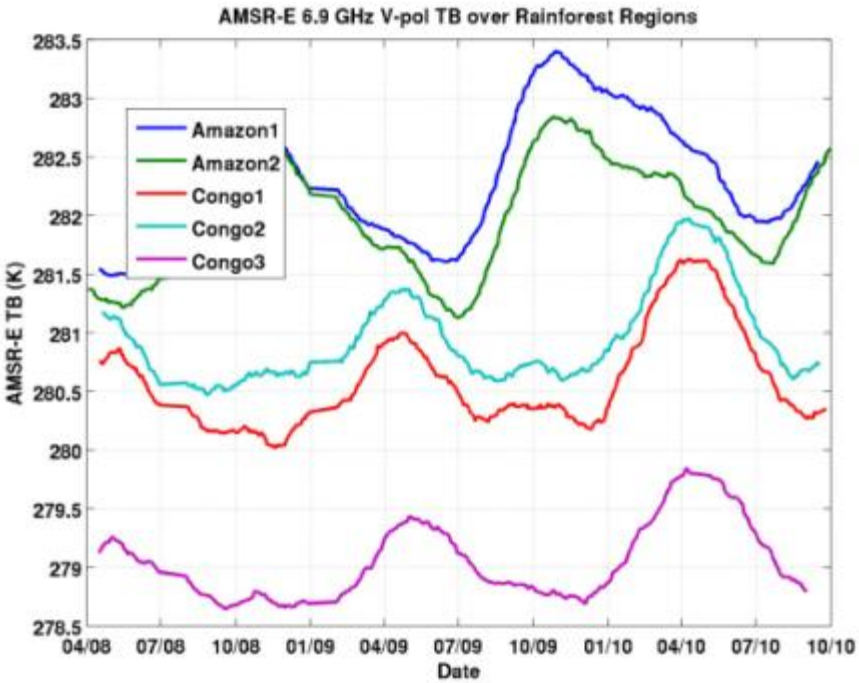


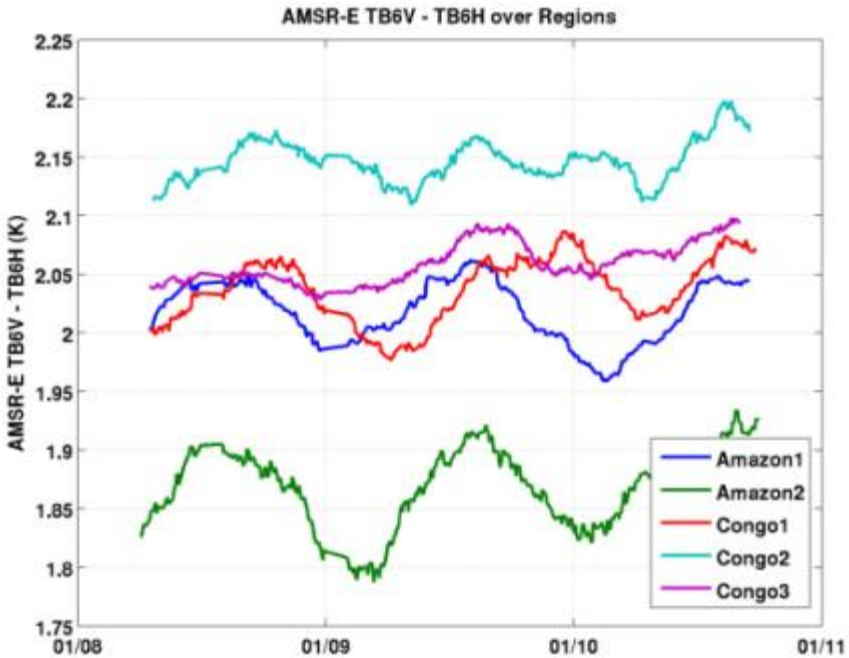
AMSR-E 6.9 GHz TBV-TBH
April 2008 – October 2010



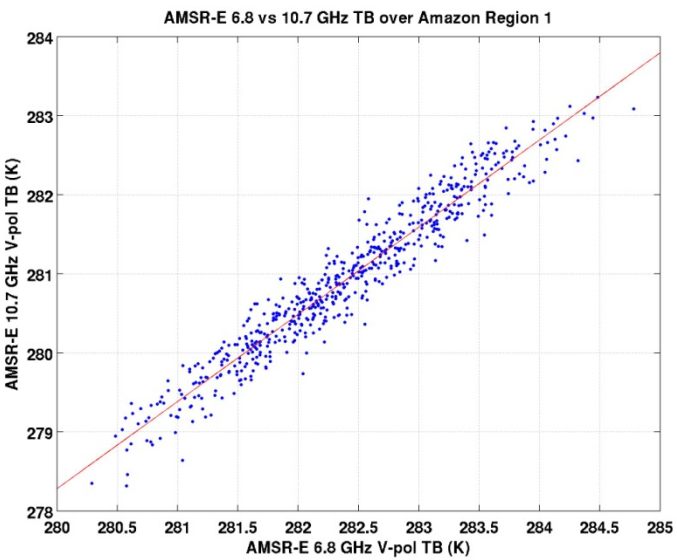
Stability of Regions

- **All regions exhibit similar stability in C-band TB and polarization signature**





Tracking Aquarius TB over Rainforest



$$T_B(f_2) = aT_B(f_1) + b$$

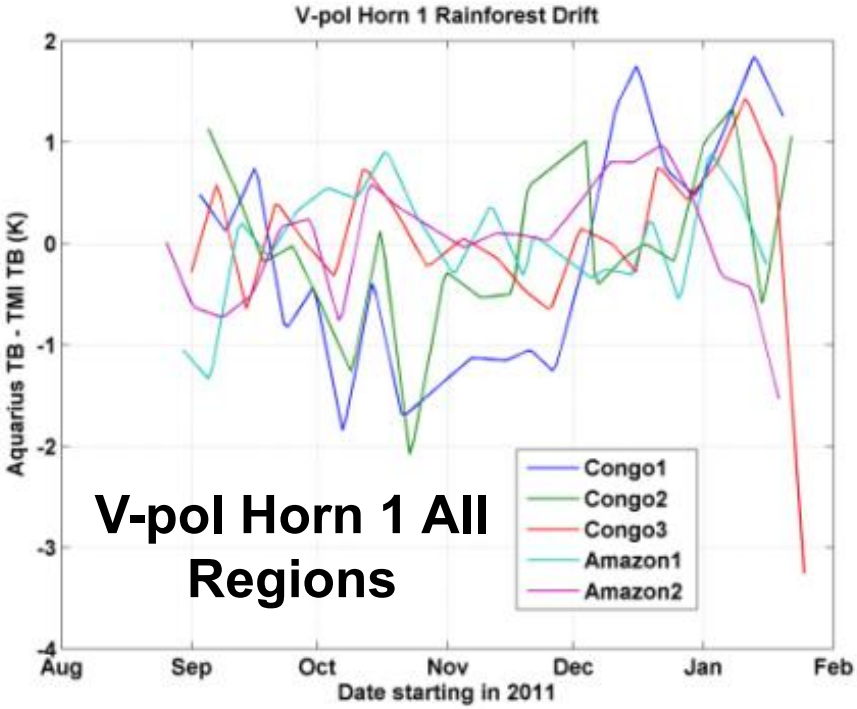
$$a \cong \frac{\varepsilon_2}{\varepsilon_1} \sim 1$$

- **Ferrazzoli and Guerriero (1999) and other modeling studies show that for high biomass, optical depth is >>1 and emissivities (defined by scattering from the forest) are within few %) between L-band , C-band and X-band**
- **Track variation of L-band TB as a function of time from TMI and WindSat 10.7 GHz observations for morning passes (4-7 LST)**
  - **Annual surface temperature variations less than 2K in the morning over these regions so a few percent uncertainty in scaling factor not critical for estimating temporal variability**

Tracking Aquarius at Warm TBs

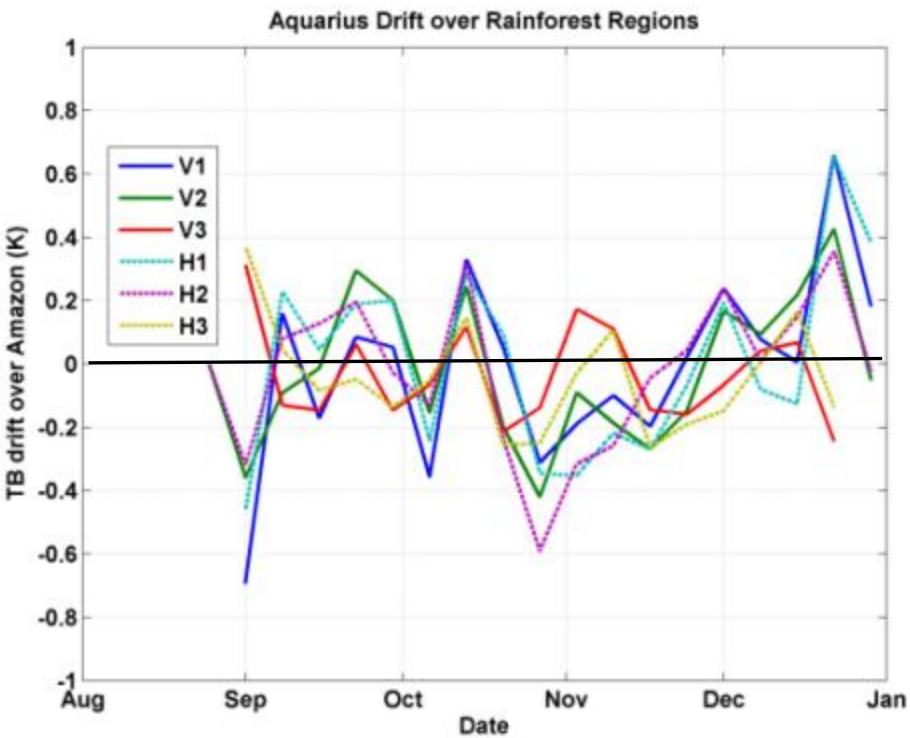
- **Differenced Aquarius TBs from TMI/WindSat 10.7 GHz TB time series to estimate residual drift over warm rainforest regions**
  - **TMI and WindSat data filtered for rain using flag based on 37-10 GHz TB difference**
  - **Applied 30-day smoothing**

- **Congo region 1 showed largest temporal variability (correlated in both TMI and Aquarius data)**



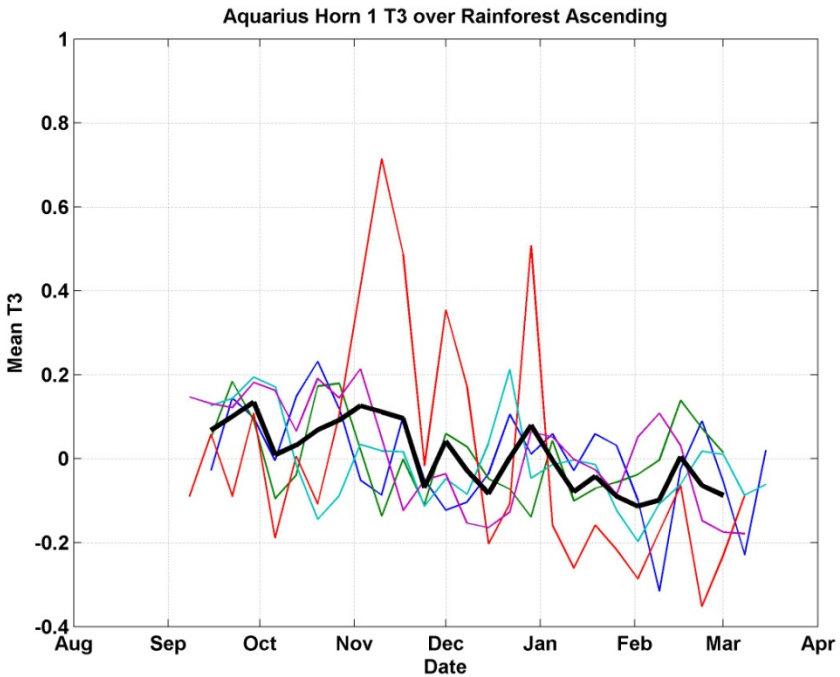
Average for All Channels

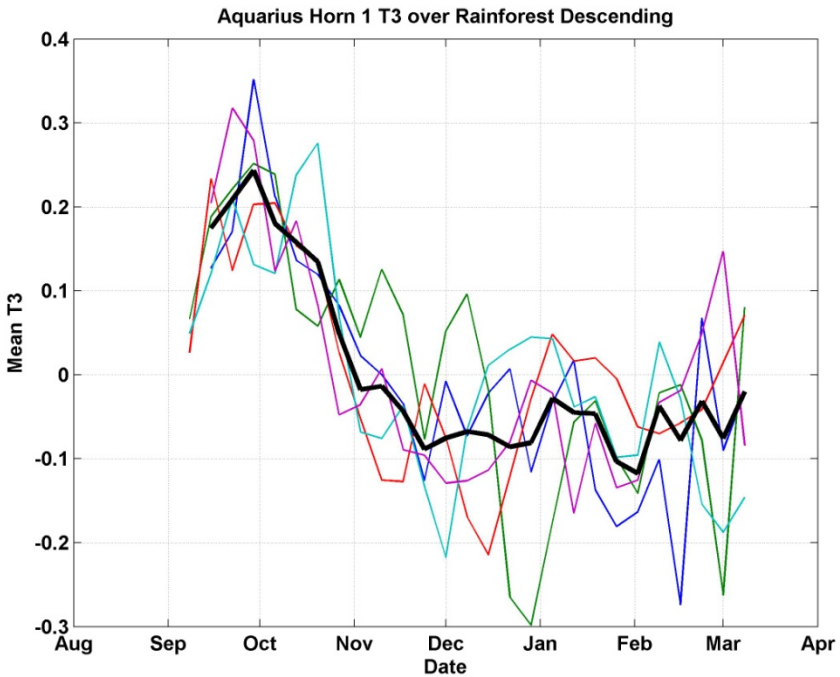
- Averaged all regions excluding Congo region 1 as a function of time for each channel and applied 30-day smoothing
- Negligible drift observed over warm regions – consistent with gain drift
- Rainforest regions show potential to monitor drift at the warm end to 0.1K level on > 60 day time scales

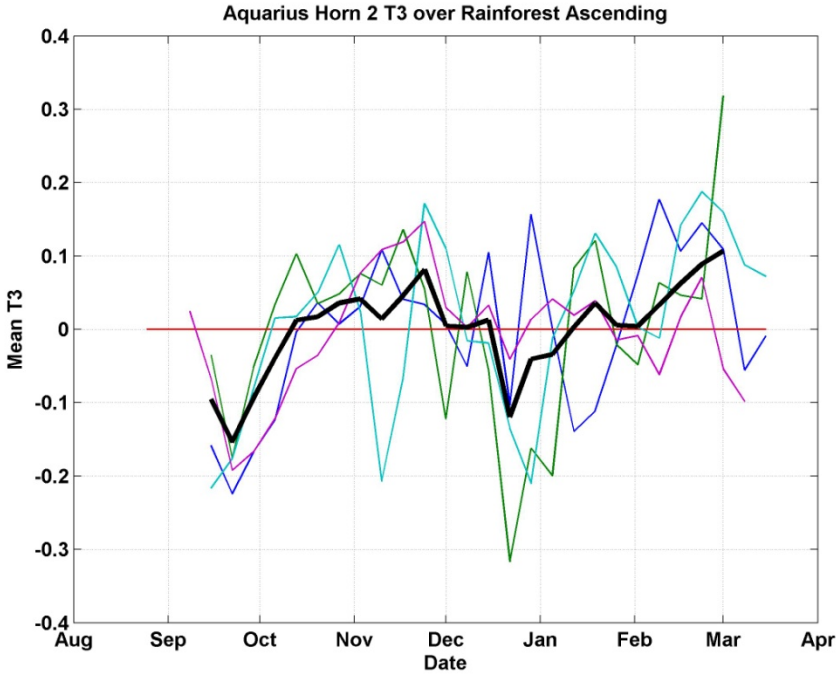


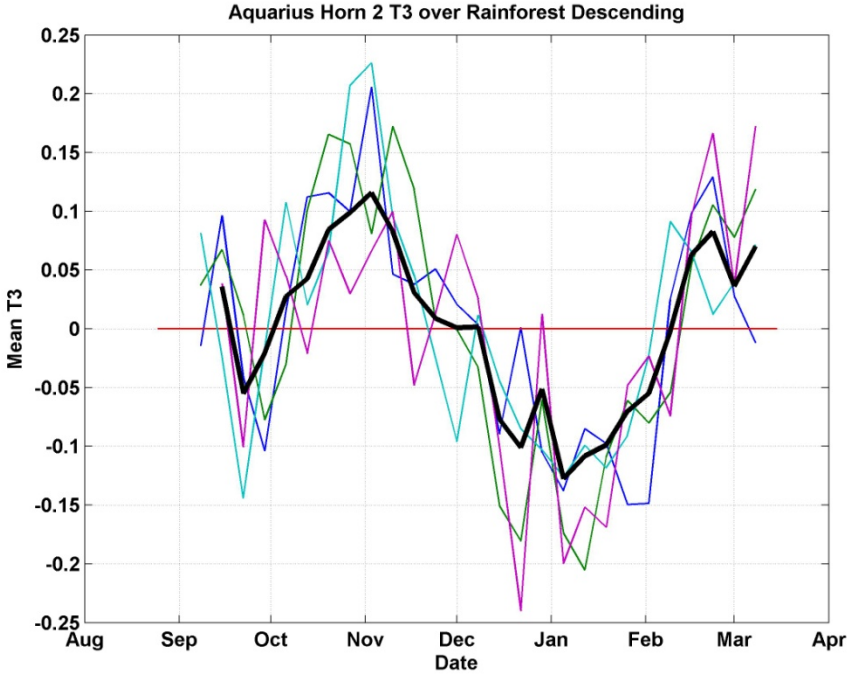
T3 Over Amazon

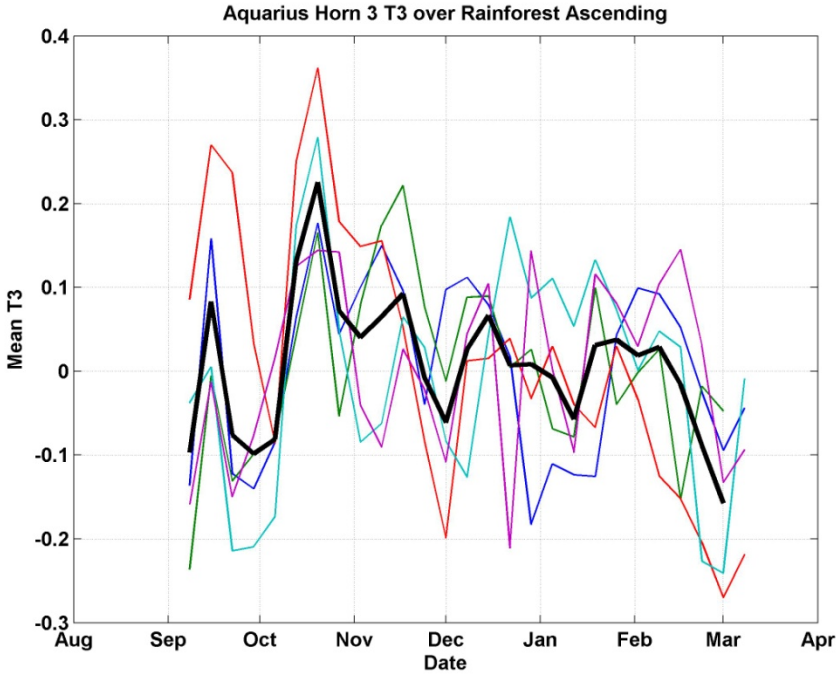
- T3 should be near zero over rainforest regions and generally stable in time
- 0.2-0.3K temporal changes observed in descending passes in horns 1 and 2 in all regions

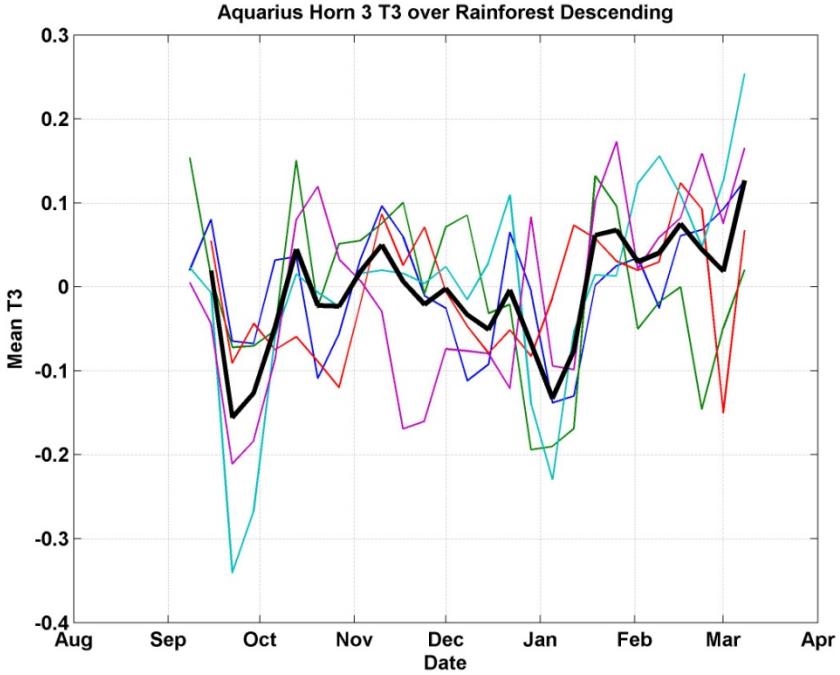





Aquarius Horn 2 T3 over Rainforest Ascending
Mean T3
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
Date


Aquarius Horn 2 T3 over Rainforest Descending
Mean T3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
Date

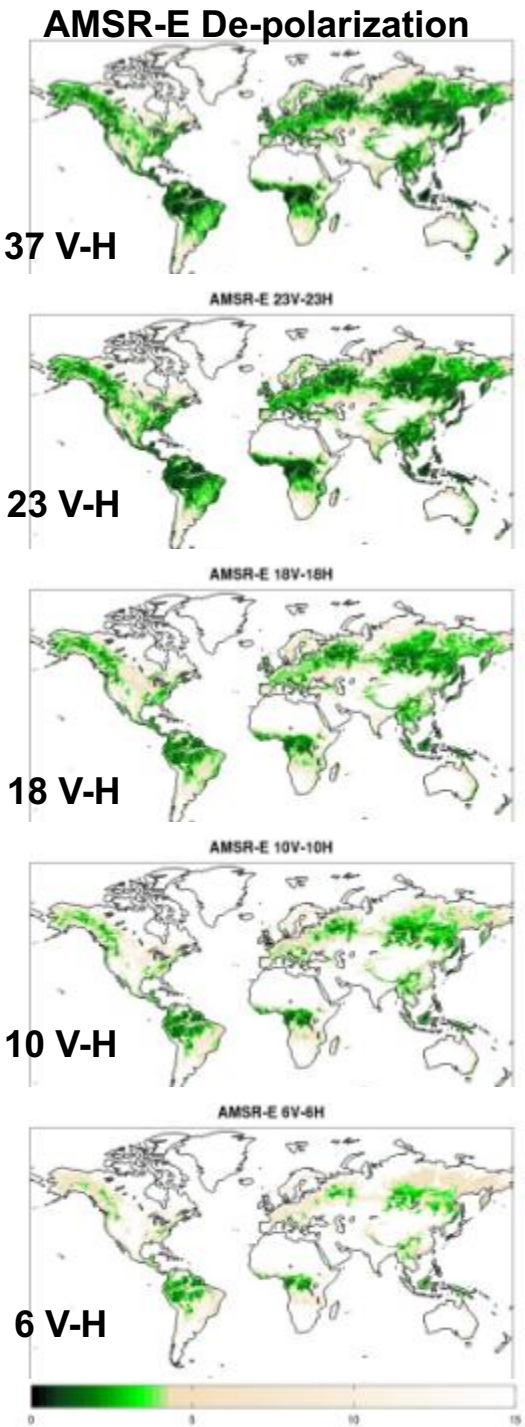

Aquarius Horn 3 T3 over Rainforest Ascending
Mean T3
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
Date


Aquarius Horn 3 T3 over Rainforest Descending
Mean T3
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
Date

Conclusions

- Aquarius data show there are small regions in the east Antarctic high plateau that exhibit both stable H-pol and V-pol TBs
  - Model developed for these regions constrained by AMSR-E and in-situ data used to track Aquarius TBs in the middle of the on-Earth dynamic range for TB
- Heavily vegetated rainforest regions appear optically thick at L-band and can be used to determine warm end TB trends to 0.1K level on >60 day time scales by cross-calibration with higher frequency radiometers (e.g. TMI/WindSat)
- Antarctic and Rainforest trend estimates consistent with a gain drift in the Aquarius radiometer (e.g. noise diode)
- Next steps are to continue model development for both regions to increase fidelity as well as continue tracking the Aquarius performance

Developing On-Earth T_B Calibration References at L-band



Natural targets for L-band radiometer calibration over on-Earth dynamic range

- **Calm, flat ocean scenes – Cold reference**
- **Ice sheets: Antarctica, Greenland – Mid-range reference**
- **Land areas: flat, dry deserts; homogeneous heavily vegetated regions – Hot reference**

Use to assess absolute calibration, monitor stability and assess residual instrument calibration errors

Aquarius TB – Model All Channels