Aquarius Drift over Antarctica and Rainforest Regions

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Aquarius Ocean Drift

- Represents drift only at one TB – need another reference to determine whether it is a gain or offset drift
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 \( \approx 0.5 \times \) 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°
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

- 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)

Steffen et al., 1999
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
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.
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

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

for \( \tau >> 1 \)

\[ T_B (f) = \left( 1 - \omega(f) \right) T_{\text{canopy}} \]
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
Rainforest Temperature Stability

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

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

\[
T_B(f_2) = a T_B(f_1) + b
\]

\[
a \approx \frac{\varepsilon_2}{\varepsilon_1} \sim 1
\]
• 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)
• 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
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