



# Regional Time Dependent Biases in the Aquarius Salinity Product and Options for Correction

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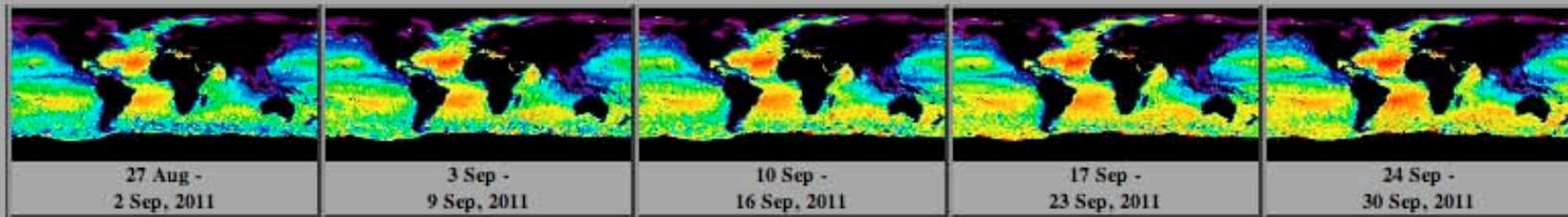
9/18/2017

OSST – Crystal City, VA

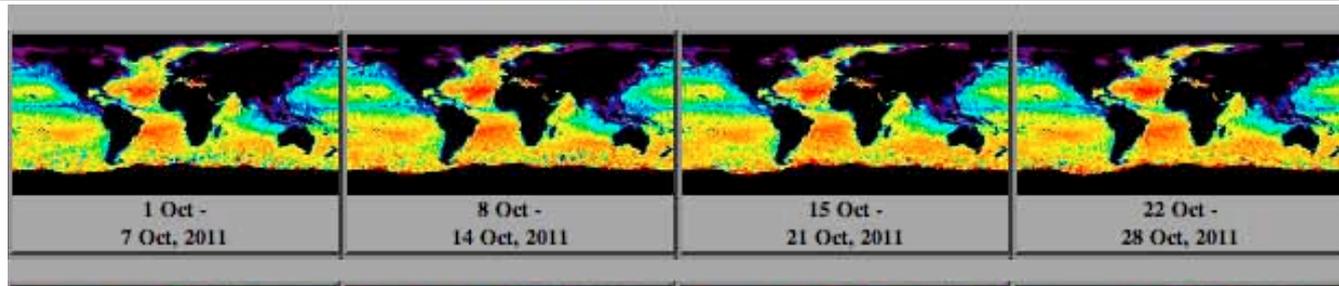
# Need for Stability

- A main mission objective is for Aquarius to provide monthly global salinity maps for climate studies
  - Critical that any spatial or temporal systematic biases be characterized and corrected to  $< 0.2$  psu
  - Requires TB stability of about  $0.1K$ , which is a challenging requirement for the radiometer

Weekly  
Version 1.1



- Initially, Aquarius revealed increasingly more saline oceans with time
- Significant Aquarius drift became evident within the first few weeks

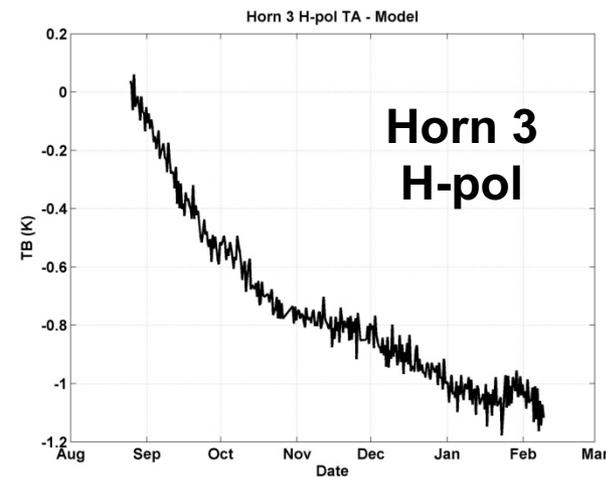
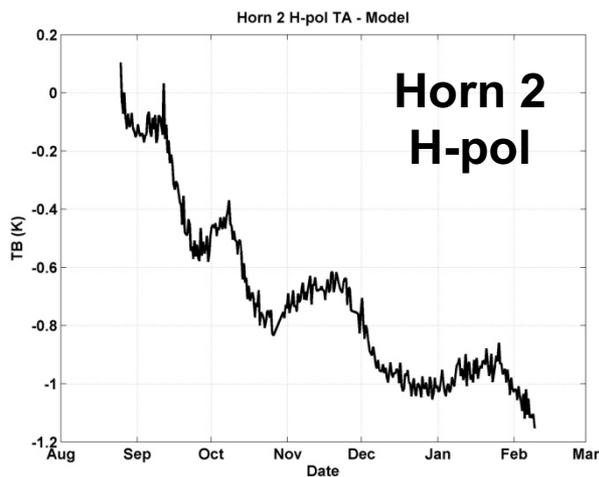
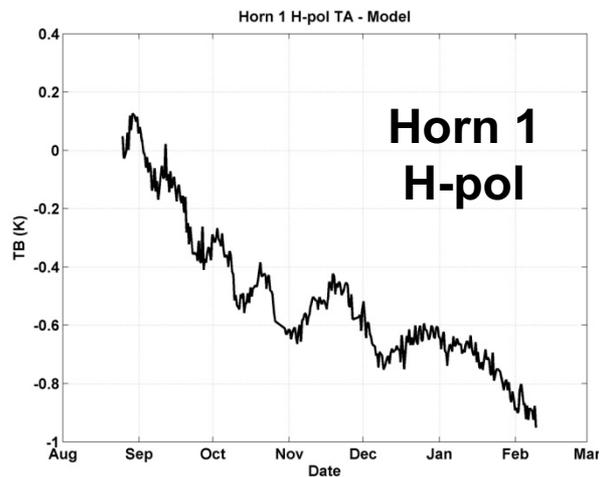
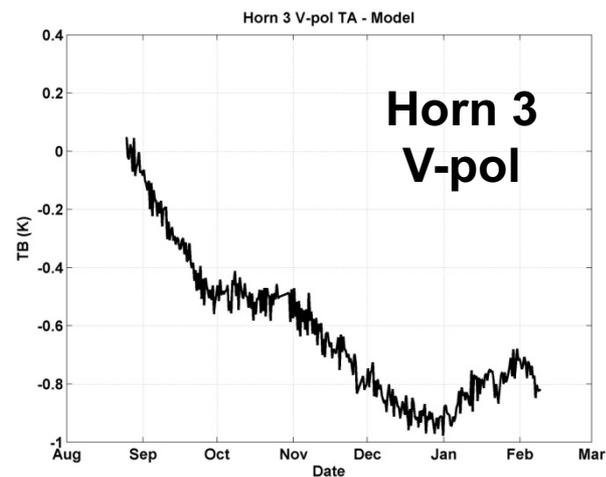
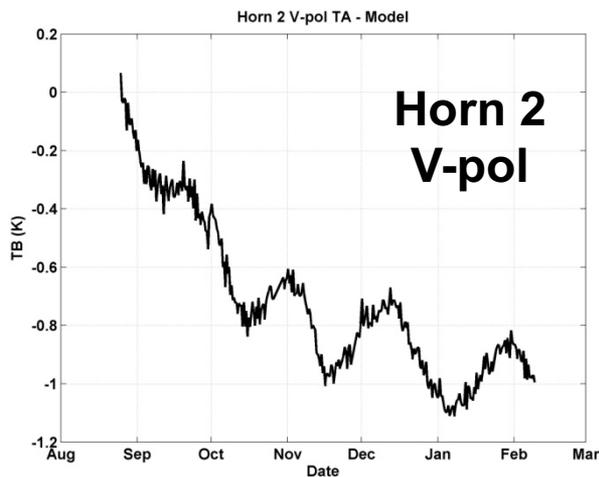
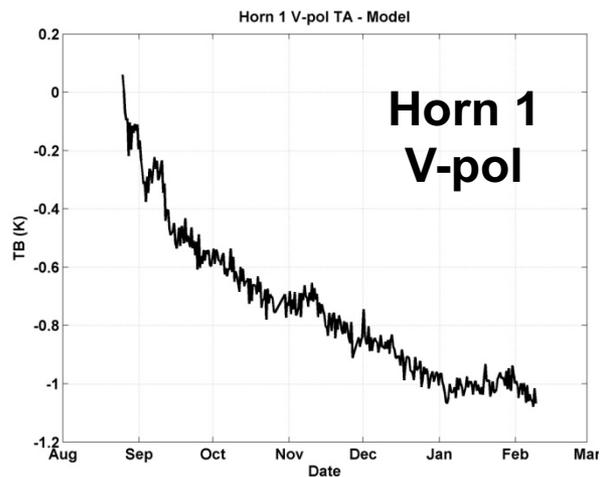


Sea Surface Salinity (psu)



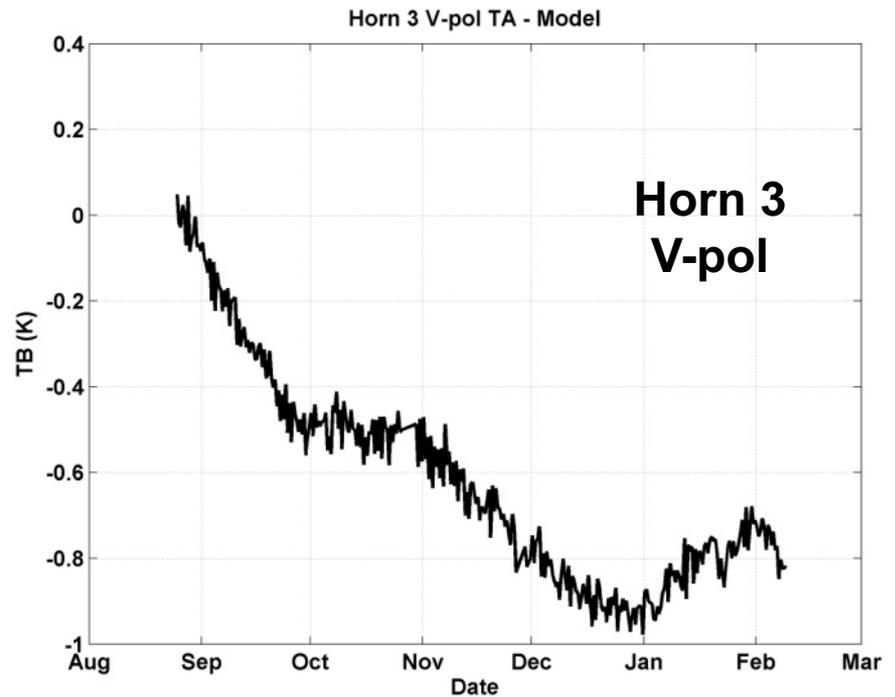
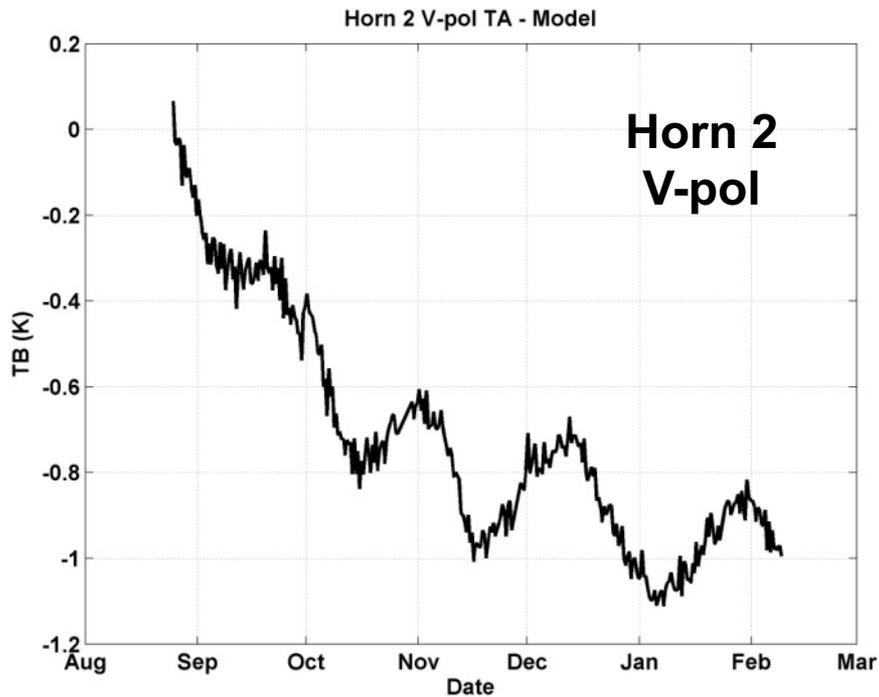
# Aquarius Drift Relative to Ocean Model

- Global average difference between observed and modeled TBs using HYCOM salinity revealed drift in all channels early in the mission
  - Data filtered for low wind conditions, negligible galactic contribution and weak faraday rotation



# Nature of the Drift

- Long period exponential trend ( $\sim 1\text{K}$  level)
- Shorter period oscillations ( $\sim 0.2\text{ K}$  level)





- **Extended a technique originally developed to stabilize the climate calibration of the water vapor radiometers on the NASA altimeter missions**
  - **Use known reference targets at several brightness temperature levels to track both the gain and offset stability of the radiometer**
  - **Look for consistency between references to isolate instrument contribution from systematic model errors**
  
- **Antarctic and Amazon reference models developed**

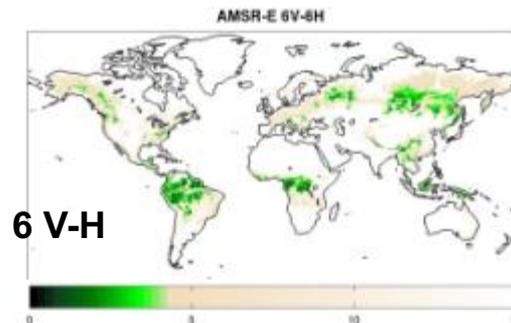
- Antarctica (**mid-range TB ~200K**)

- Selected areas with stable temperature (V-pol TB) and snow structure (H-pol TB)
- Radiative transfer model used to determine L-band TB over time using in-situ temperature and higher frequency microwave observations as input



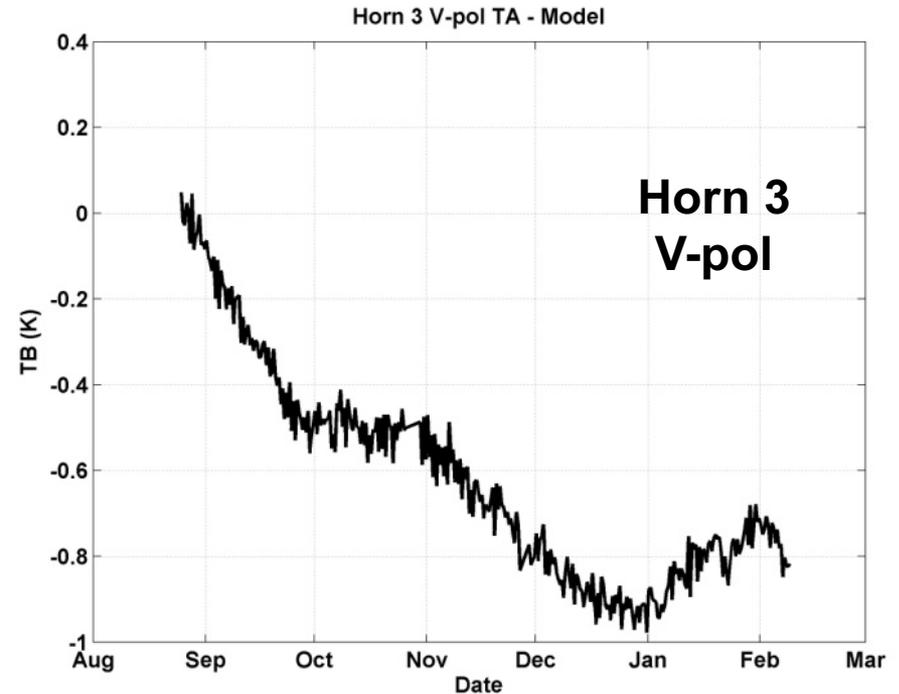
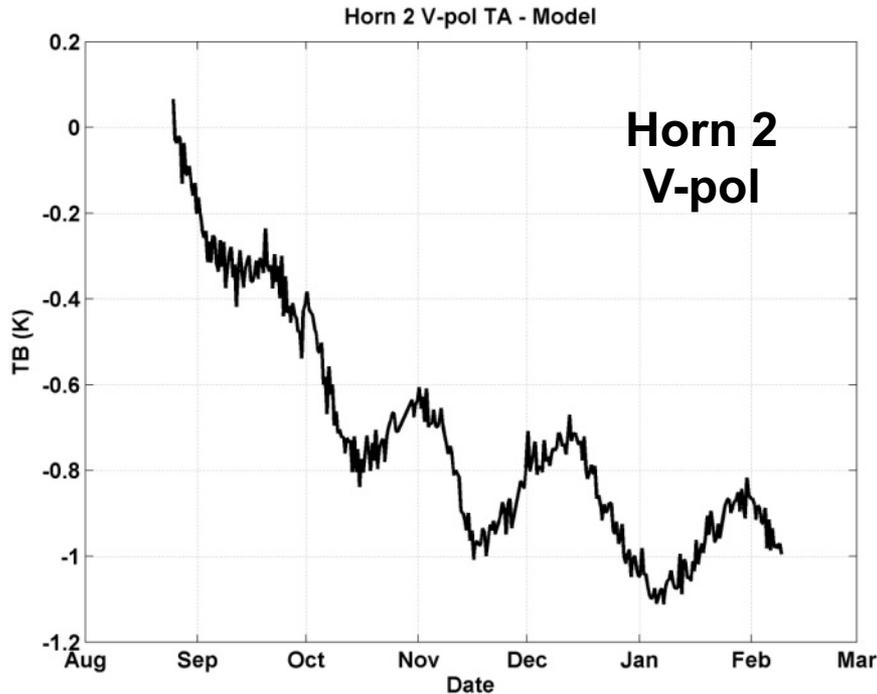
- Rainforest (**warm end TB ~280K**)

- Select depolarized heavily vegetated areas within the Aquarius swath
- Use ancillary data to determine canopy temperature to track Aquarius calibration



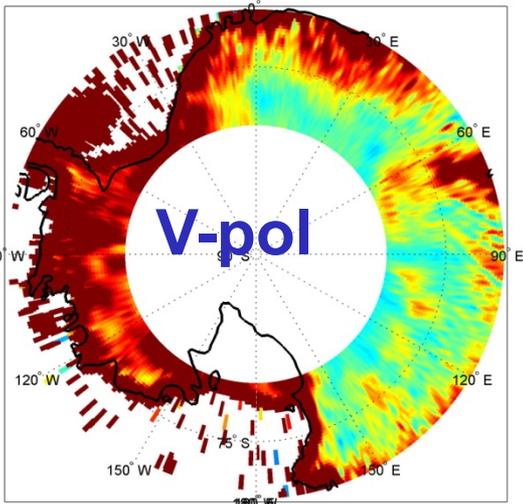
# Nature of the Drift

- Antarctic and rainforest comparisons used to confirm trends and isolate instrument contributions to drift
  - Gain drift would be 0.5x over ice and 0.05x over Amazon
  - Offset variation would be the same over ocean, ice and Amazon



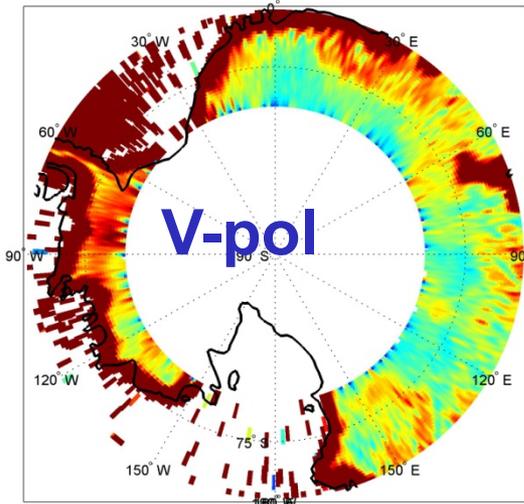
$\theta = 28.7^\circ$

Aquarius Horn 1 V-pol Stability (K)



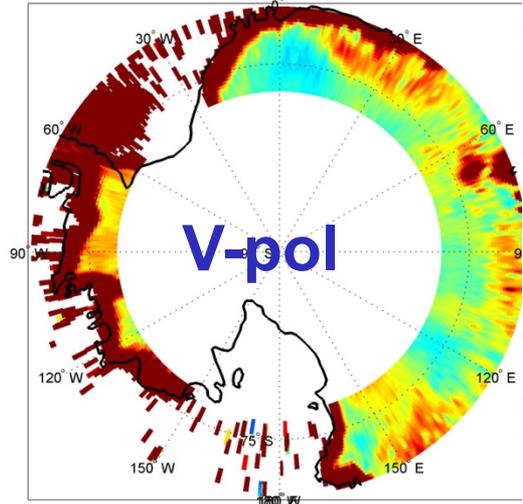
$\theta = 37.8^\circ$

Aquarius Horn 2 V-pol Stability (K)

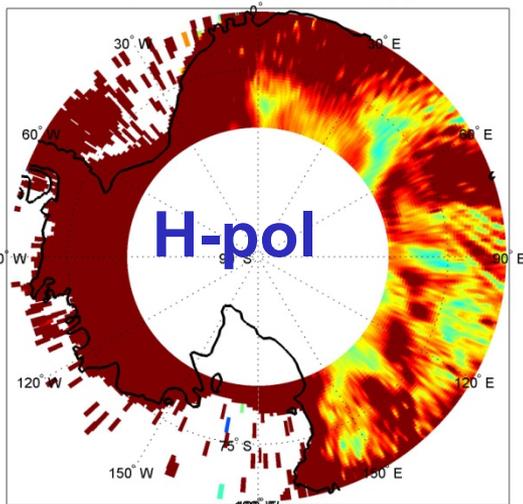


$\theta = 45.6^\circ$

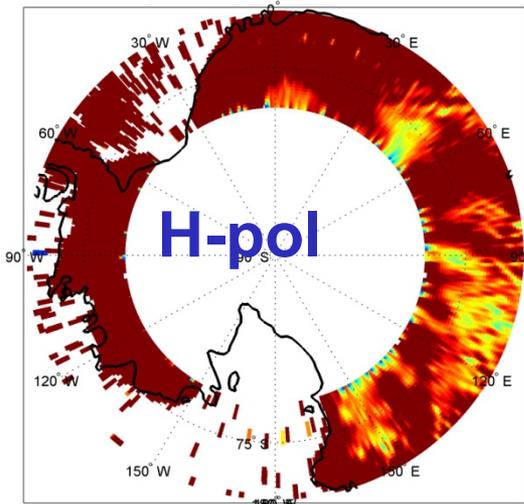
Aquarius Horn 3 V-pol Stability (K)



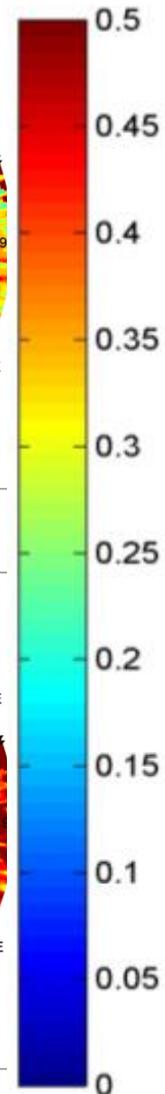
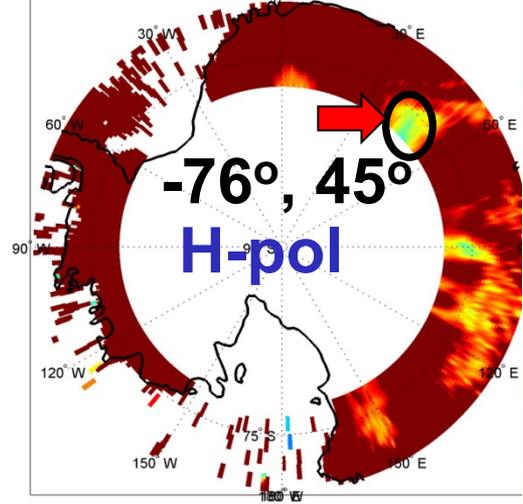
Aquarius Horn 1 H-pol Stability (K)



Aquarius Horn 2 H-pol Stability (K)

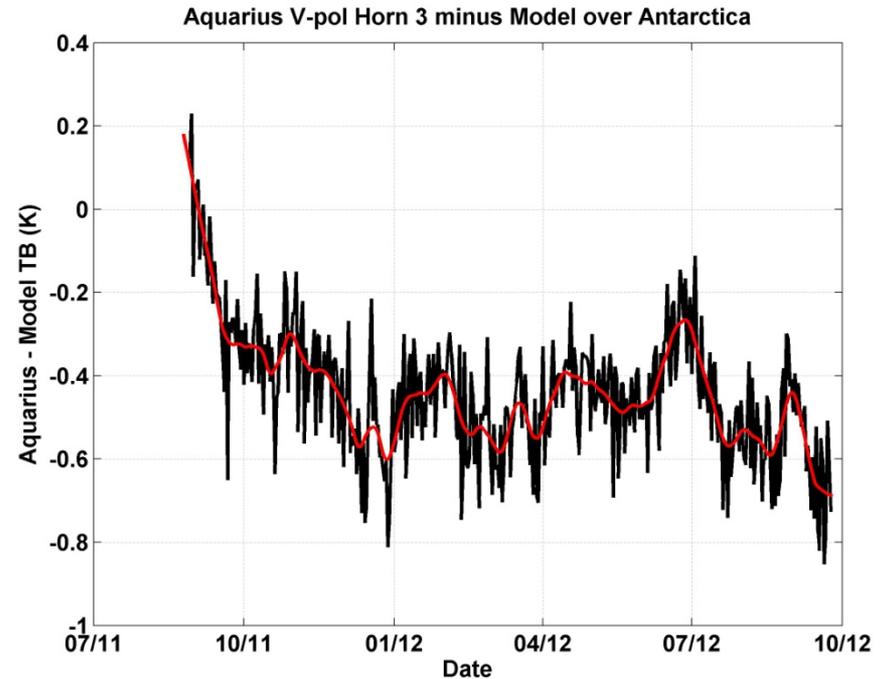
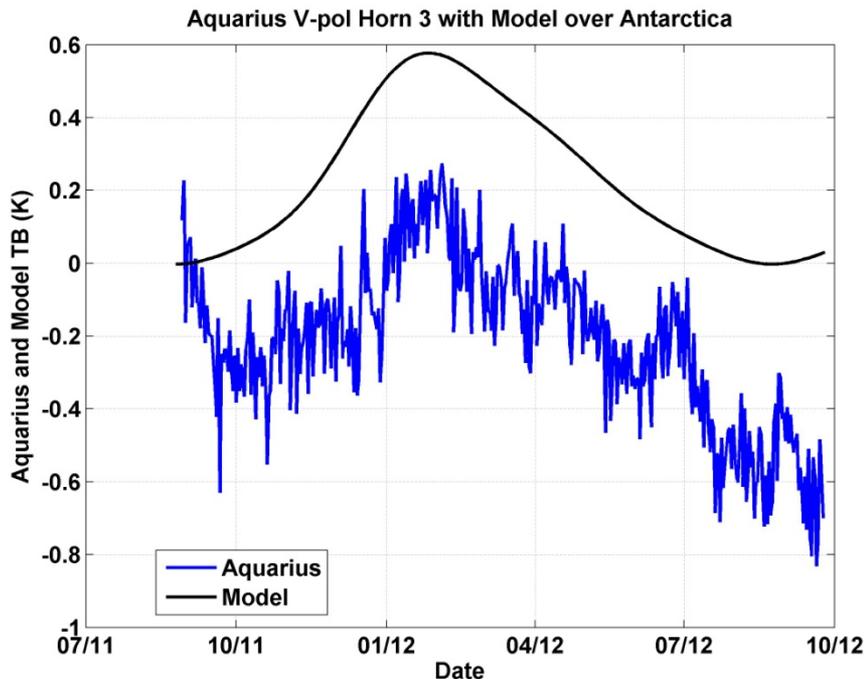


Aquarius Horn 3 H-pol Stability (K)



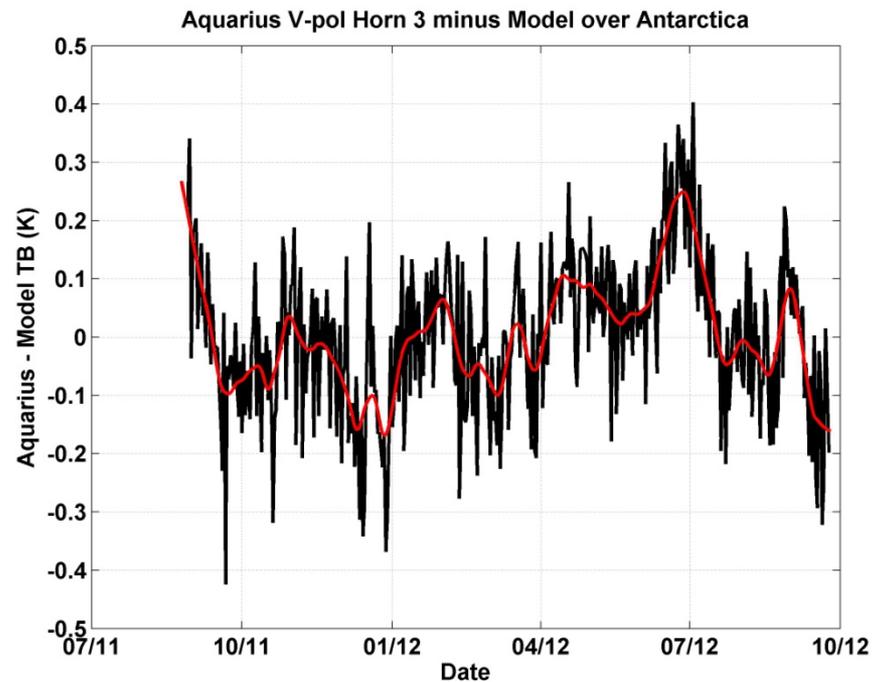
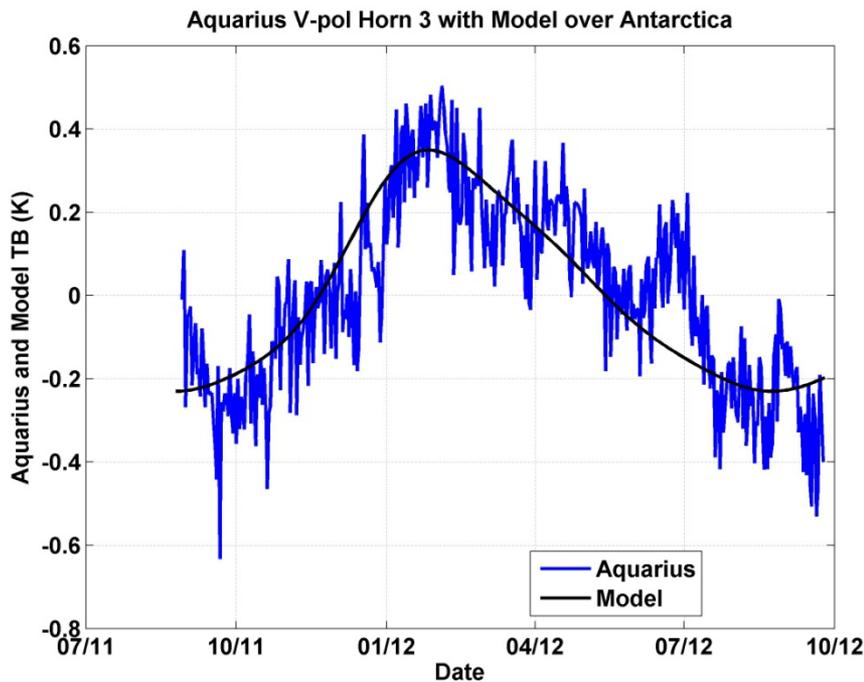
# Aquarius – Antarctica TB Model

- Difference between Aquarius and Antarctica TB model showed  $\sim 0.5\text{K}$  long term drift, but similar magnitude short term oscillations
- Long term drift consistent with a gain drift (e.g. half the magnitude of ocean drift)
- Quasi-monthly oscillations consistent with offset modulation

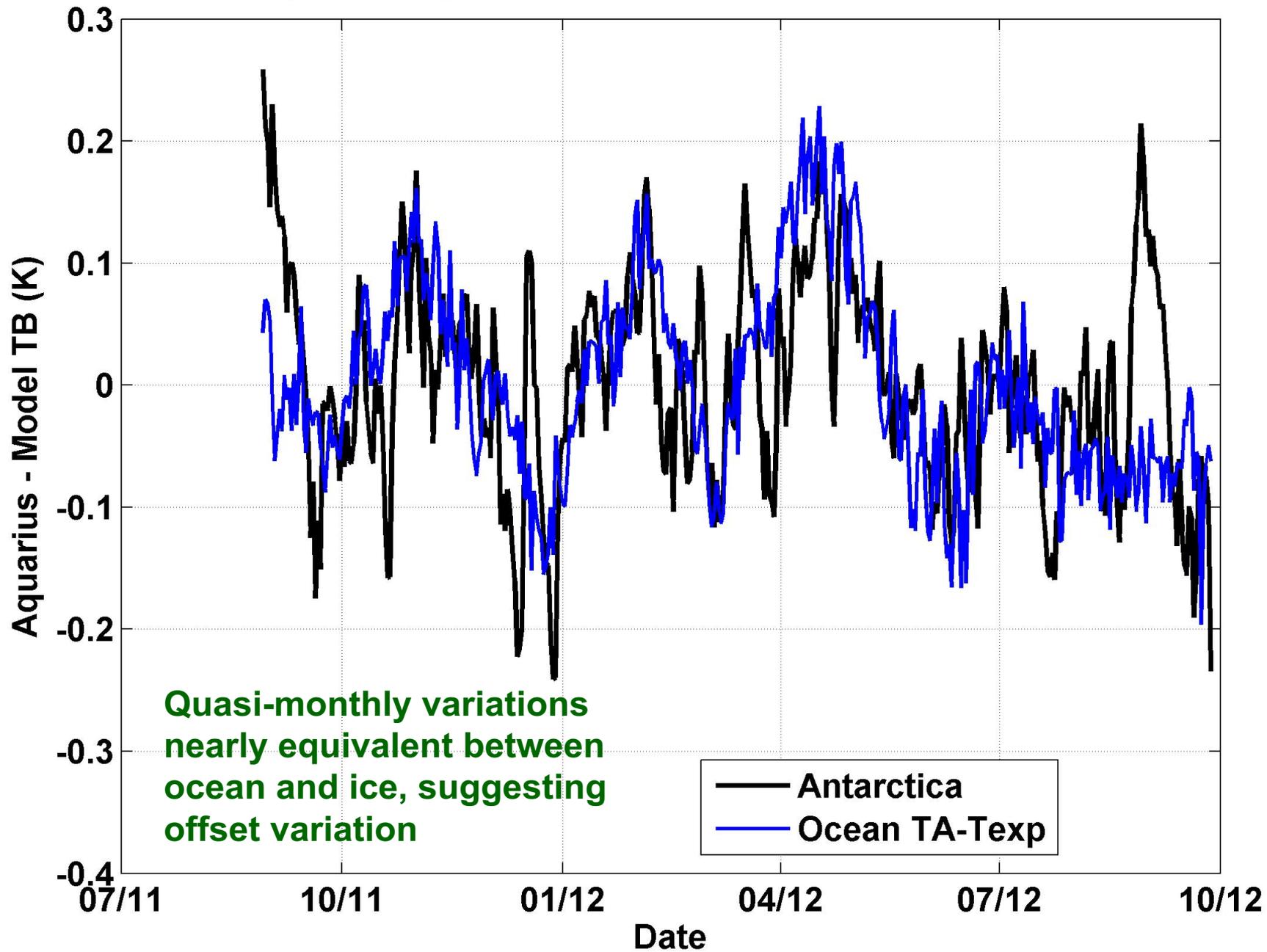


# With Exponential Gain Correction

- Exponential TND correction based on fit to ocean model removes long term drift over Antarctica
- Quasi-monthly oscillations remain after gain drift correction



# Aquarius V-pol Horn 3 minus Model over Antarctica

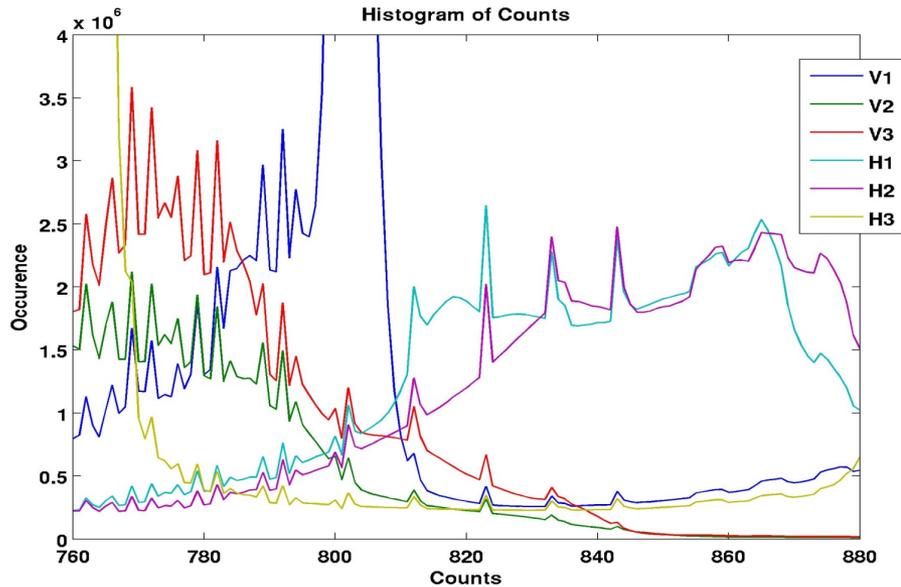




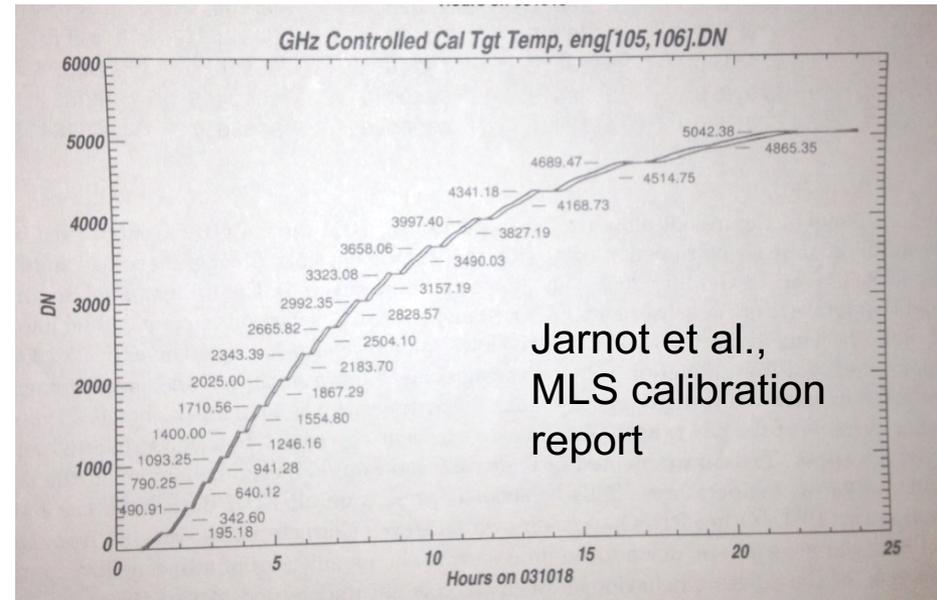
# VFC Locking Issue



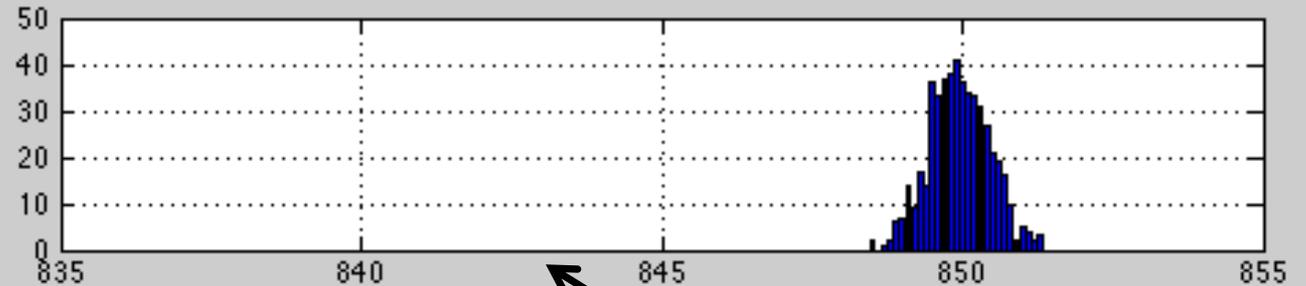
- **Investigation into cause of offset variations led to the discovery of a counts “locking” issue**
- **Radiometer output stays constant while input changes**
- **Instrument temperature is so stable, that reference load counts slowly pass through locking regions as gain changes with aging**
- **Manifests as a periodic offset oscillation in reference load measurement**
- **Hardware-only correction model developed by characterizing locking phenomenon**



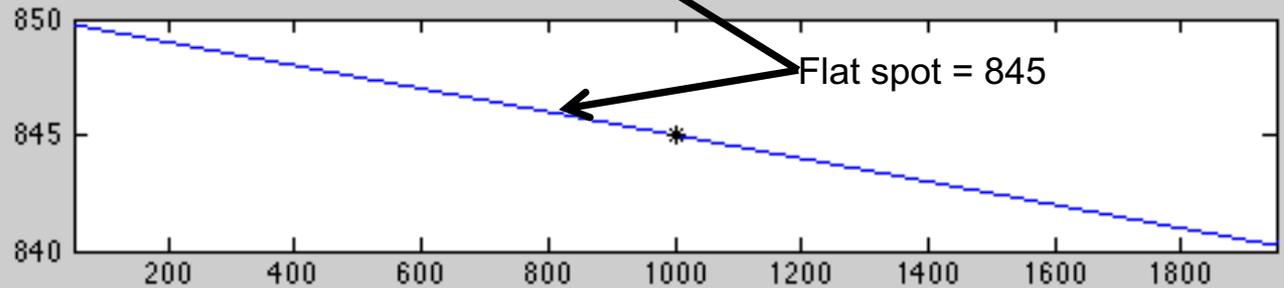
- Plot shows histogram of counts for the entire mission
- Some values show anomalously high probability of occurrence which occurs from “locking”



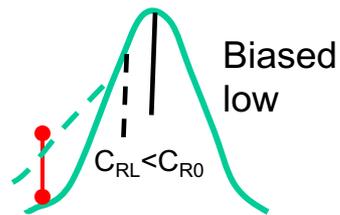
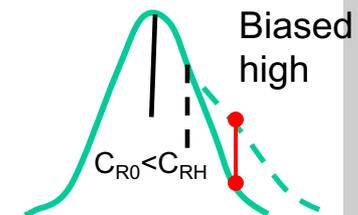
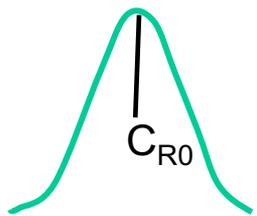
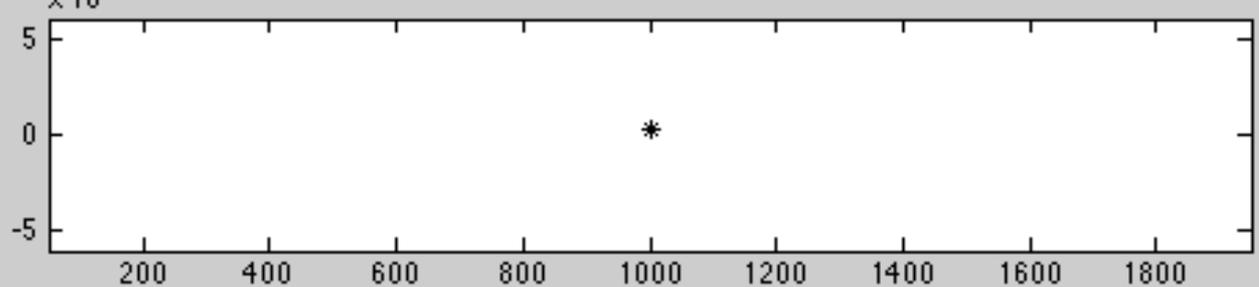
### Slow-drifting reference load



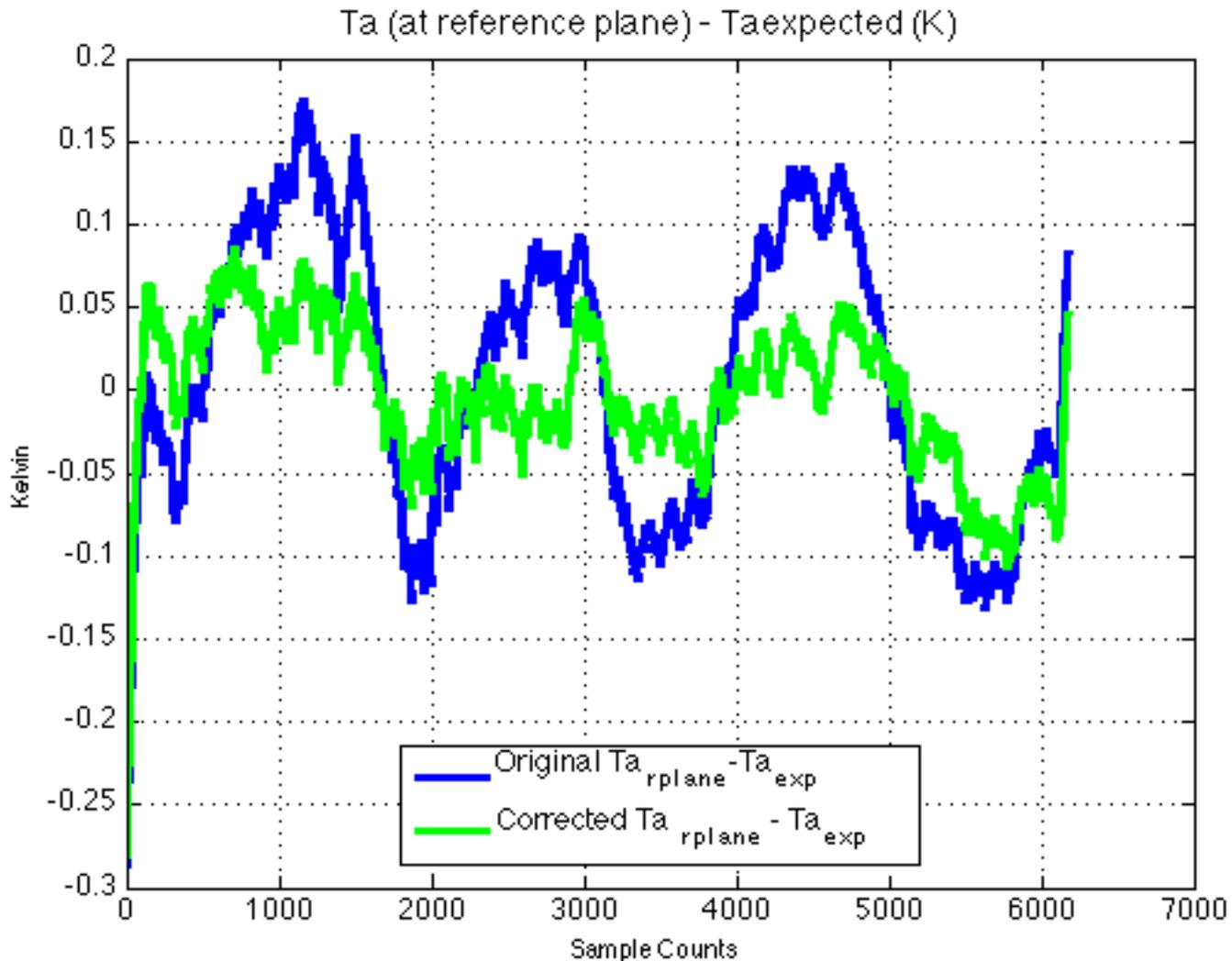
### Apparent reference load mean



### Mean-Bias introduced



Based on a hardware model for the locking, a correction is derived that is independent of any ancillary information



# Corrections Summary

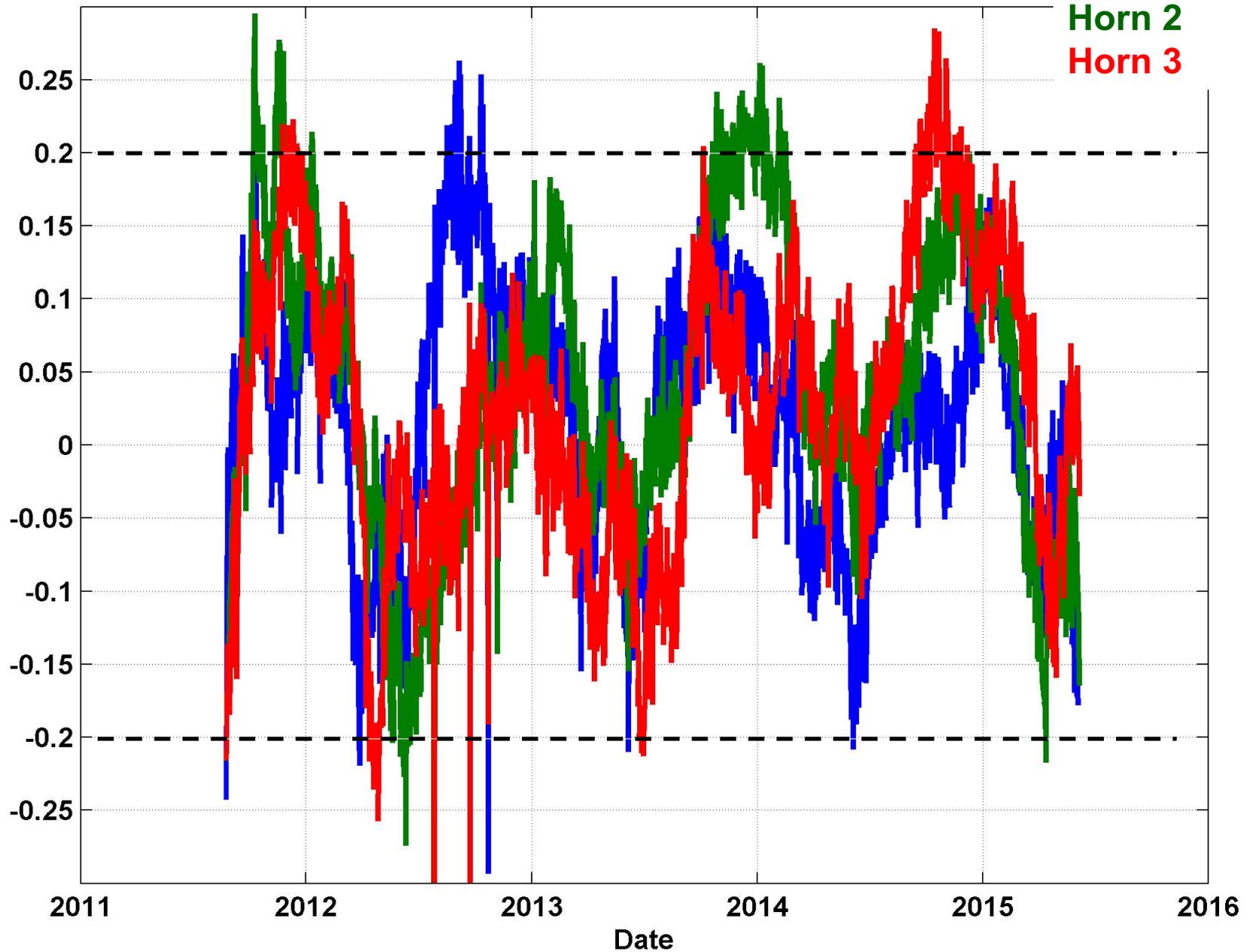
1. Long term exponential drift correction fit to ocean comparisons
    - Based on understanding of noise diode drift behavior (e.g. outgassing)
  
  2. Reference load counts correction to account for quasi-monthly offset variations
    - Based on understanding of locking anomaly
- 
3. V4 included a final de-biasing relative to 7-day running mean from HYCOM
    - Empirical correction without physical basis

***Given algorithm improvements, what is necessity of final step for V5?***

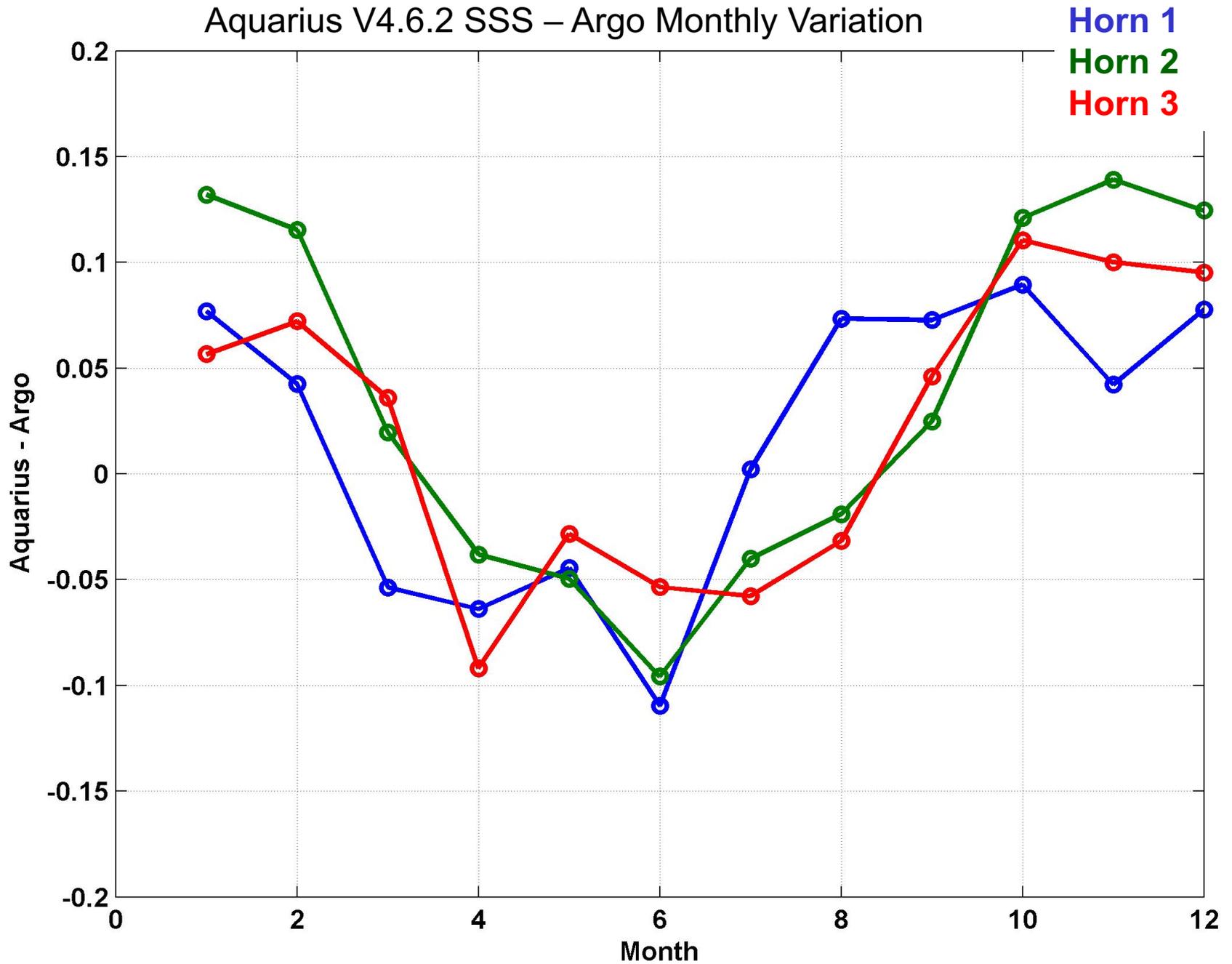
- *evaluate temporal biases prior to final de-biasing step*

# Aquarius V4.6.2 SSS – Argo

Horn 1  
Horn 2  
Horn 3

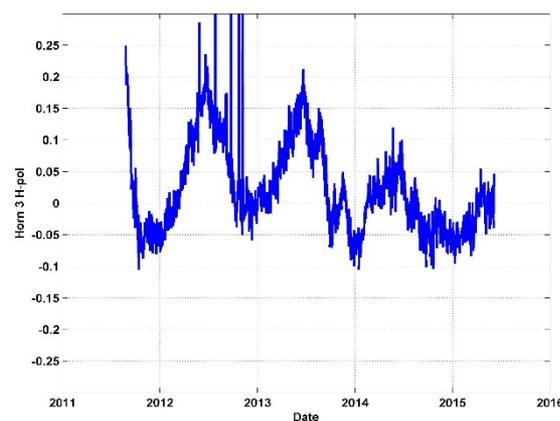
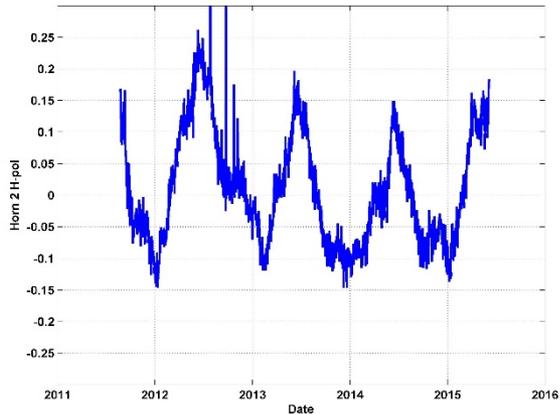
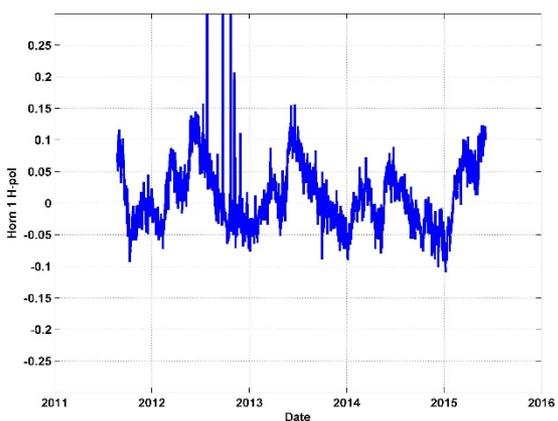
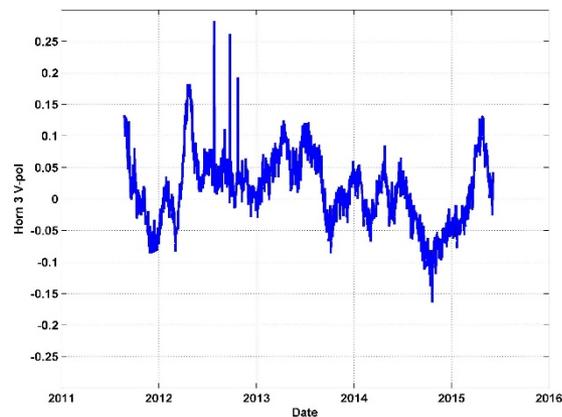
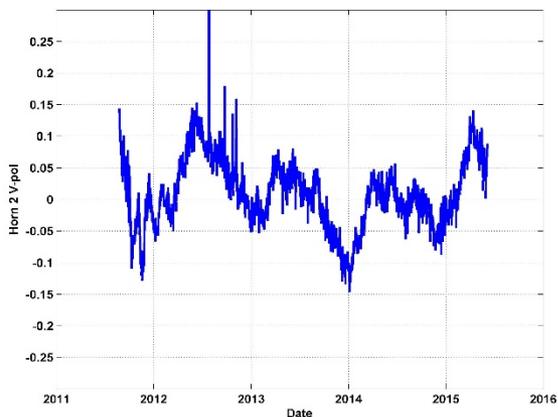
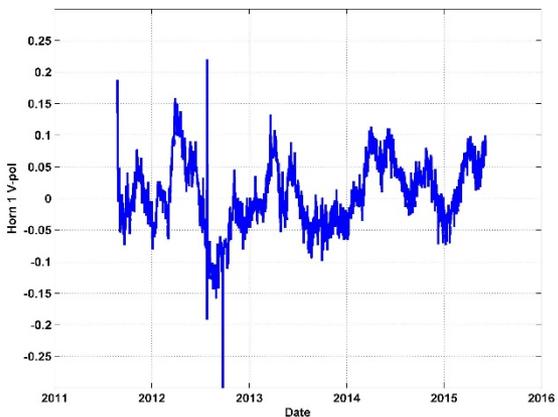


Aquarius V4.6.2 SSS – Argo Monthly Variation



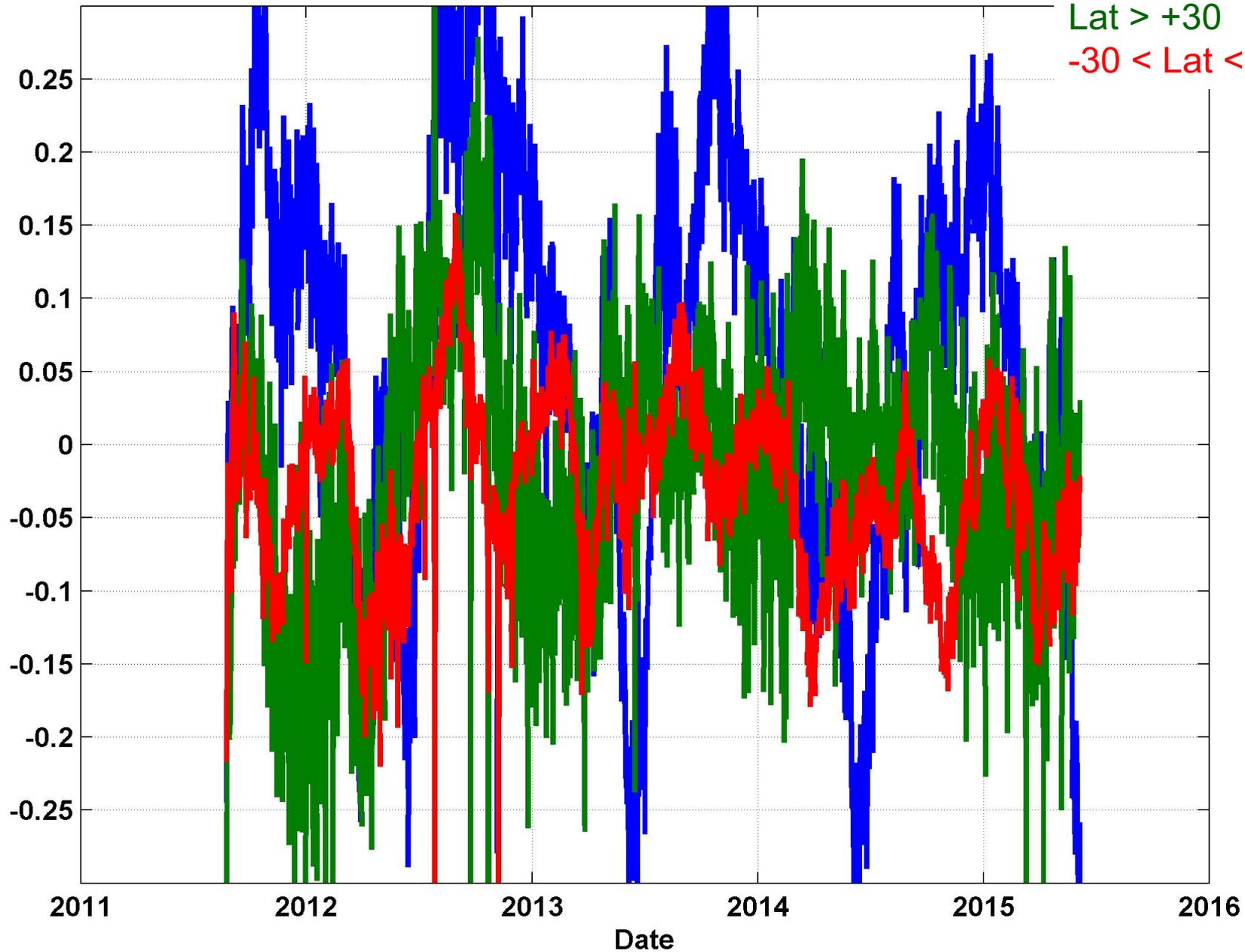
# V4.6.2 TA Variability over Ocean

- H-pol has more annual variability, particularly for higher incidence angle horns
  - Most channels within 0.1K with hardware only correction



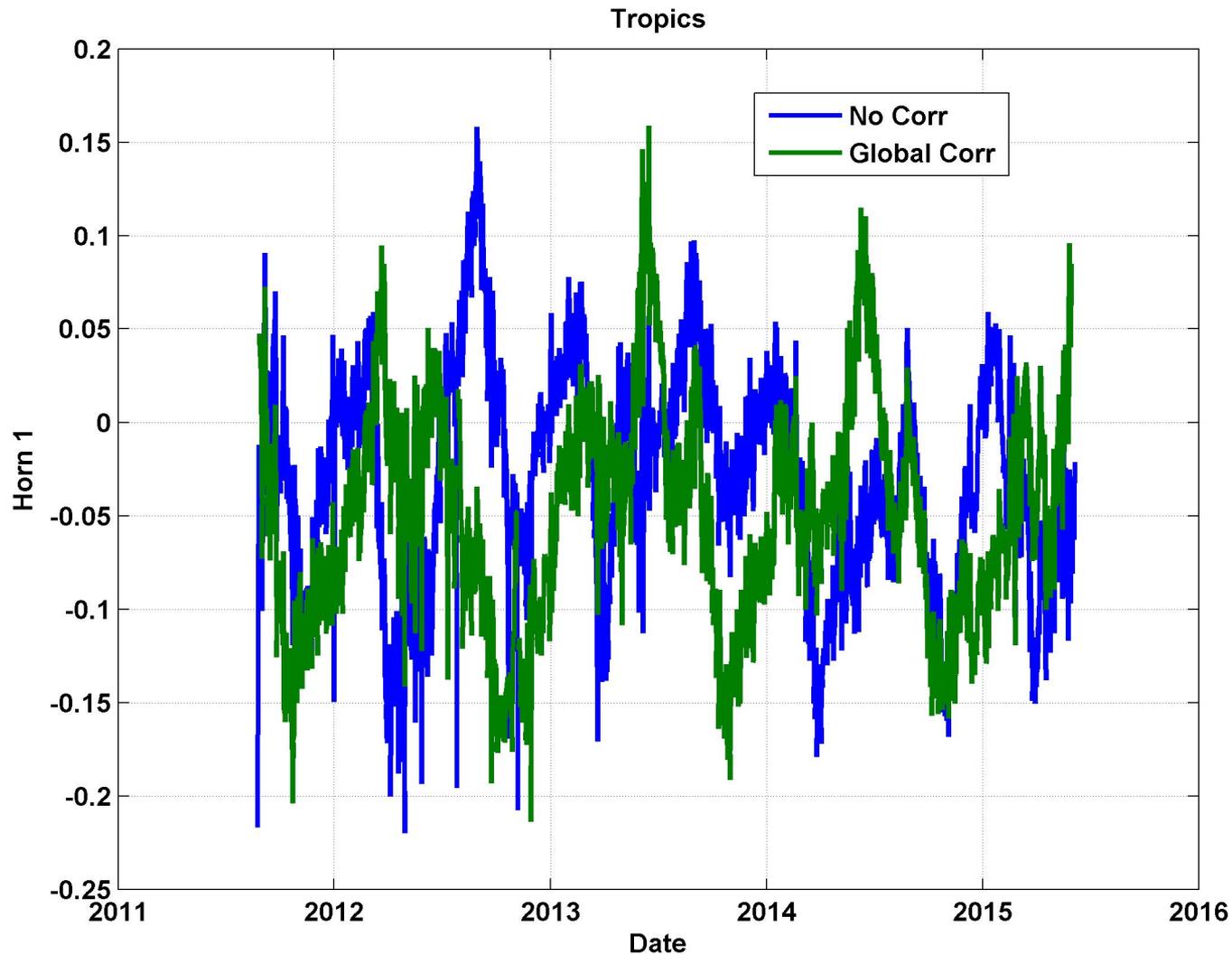
# Horn 1 Aquarius SSS – Argo Zonal

Lat < -30  
Lat > +30  
-30 < Lat < +30



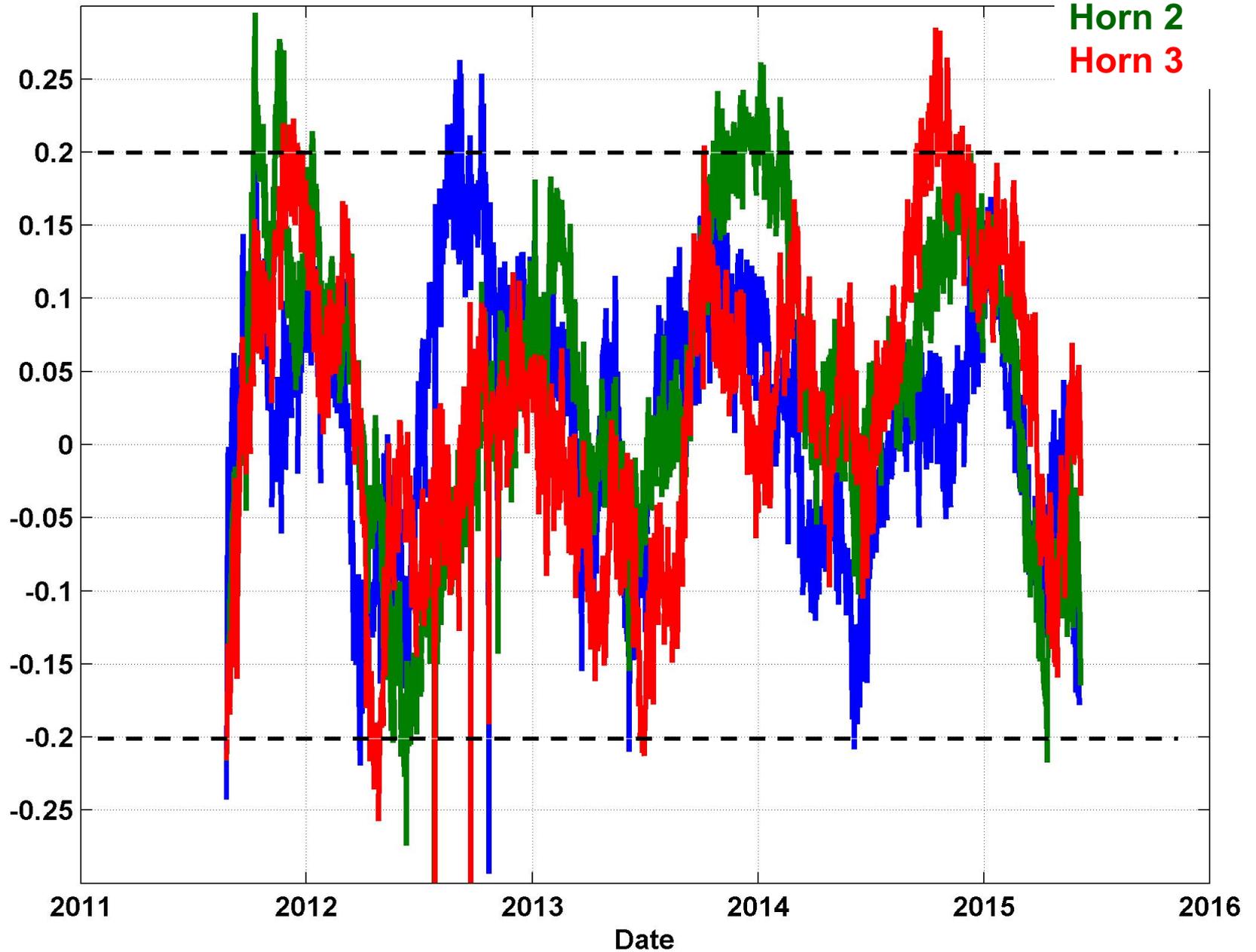
-30 < Lat < 30

- Global empirical correction modifies regional variability



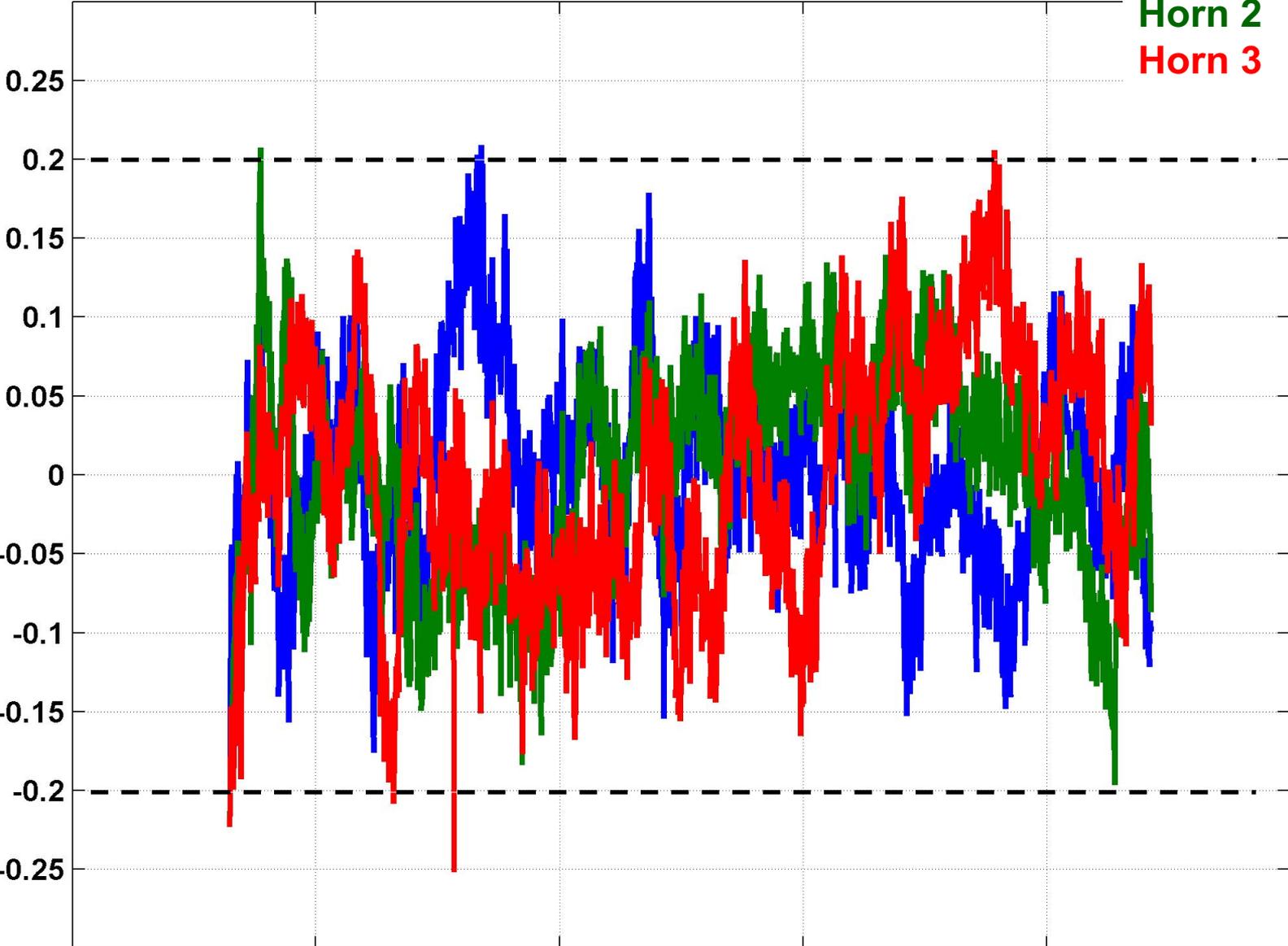
# Aquarius V4.6.2 SSS – Argo

Horn 1  
Horn 2  
Horn 3



Aquarius V4.6.2 SSS – Argo : Annual Harmonic Removed

Horn 1  
Horn 2  
Horn 3



2011

2012

2013

2014

2015

2016

# Summary and Recommendation

- **Hardware based correction reduces global residuals relative to Argo to within 0.2 psu mission objective**
- **Remaining biases between Aquarius and Argo have a strong seasonal component, but root cause of differences not known**
- **Removal of annual signal reduces variability from Argo to  $< 0.1$  psu**

## Recommendation:

- **V5 should NOT be de-bias relative to Argo or HYCOM with a 7-day running window**
- **At most, an annual harmonic can be removed if better consistency with Argo is desired**