

The background of the slide is an aerial photograph of the ocean. The water is a deep blue-grey color, and the surface is covered in small, white-capped waves that create a textured, shimmering effect. The perspective is from directly above, looking down at the sea.

# **Impact of Atmospheric Boundary Layer Stability on Aquarius Regional and Seasonal Salinity Biases**

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**Aquarius/SAC-D Science Team Meeting**

**Buenos Aires, AR**

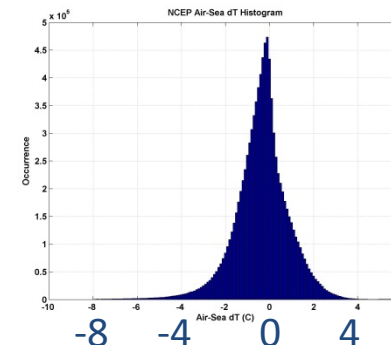
# Roughness Correction

- The correction for the excess emission generated by the rough ocean surface is one of the largest corrections required in the SSS retrieval algorithm
- Current implementation use an MLE solution given the measured H-pol backscatter, H-pol surface brightness temperature and NCEP model wind speed
- Model function relating backscatter/emission is a function of wind speed, wind direction, SST, SWH, polarization and incidence angle
- This study assesses the dependence of atmospheric boundary layer stability on the excess emission

# Boundary Layer Stability: Air-Sea Temperature Difference



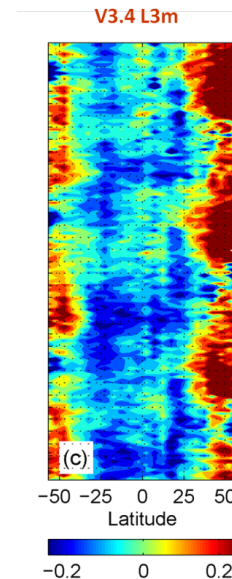
- Air-Sea temperature difference is a measure of boundary layer stability
  - $T_a - T_s < 0$  : unstable
  - $T_a - T_s > 0$  : stable
  - Strong seasonal and latitudinal dependence



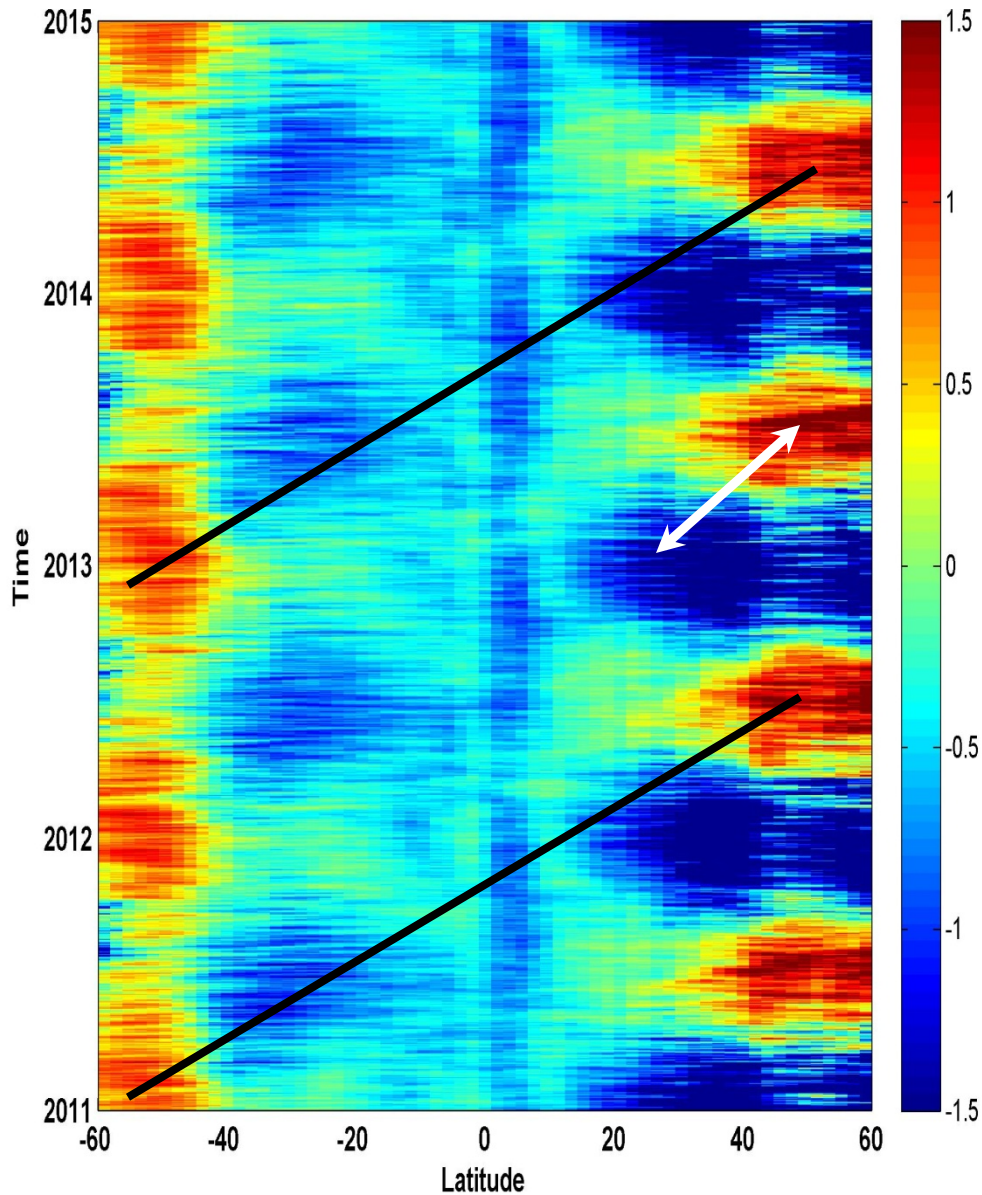
- Previous studies have shown boundary layer stability is a key factor in air-sea interaction, including wave and foam formation
  - Monahan and O’Muircheartaigh (1986) show that **foam fraction increases by about 10% per degree of air-sea temperature difference at a fixed wind speed**
  - Salisbury et al. (2013), show a decrease in foam fraction for warm SSTs (> 15C)
  - Foam development also suppressed for developing seas versus fully developed wave fields (Salisbury et al, 2013)

- Microwave sea surface excess emissivity has been shown to have a significant dependence on air-sea temperature difference at C-band and higher (Giampaolo and Ruf, 2001; Shibata 2007)
  - -0.4 K/C observed at C-band

- **Could this be the cause of the observed seasonal biases at high latitudes?**

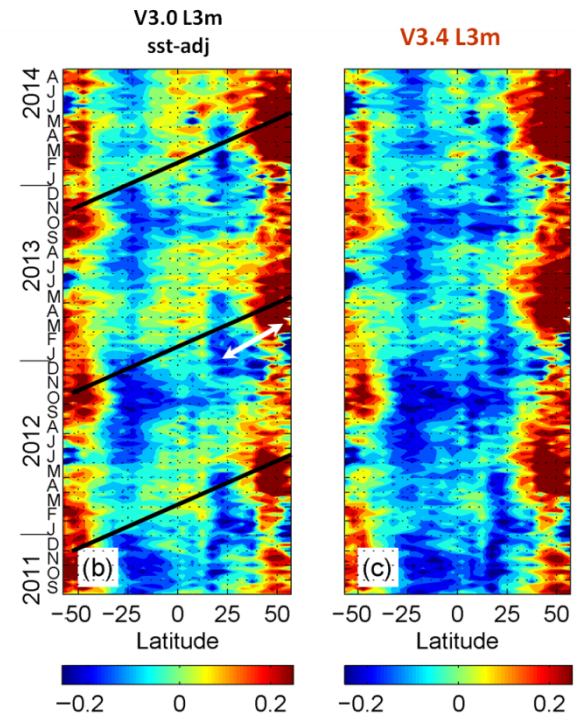


# Air-Sea $\Delta T$ from NCEP

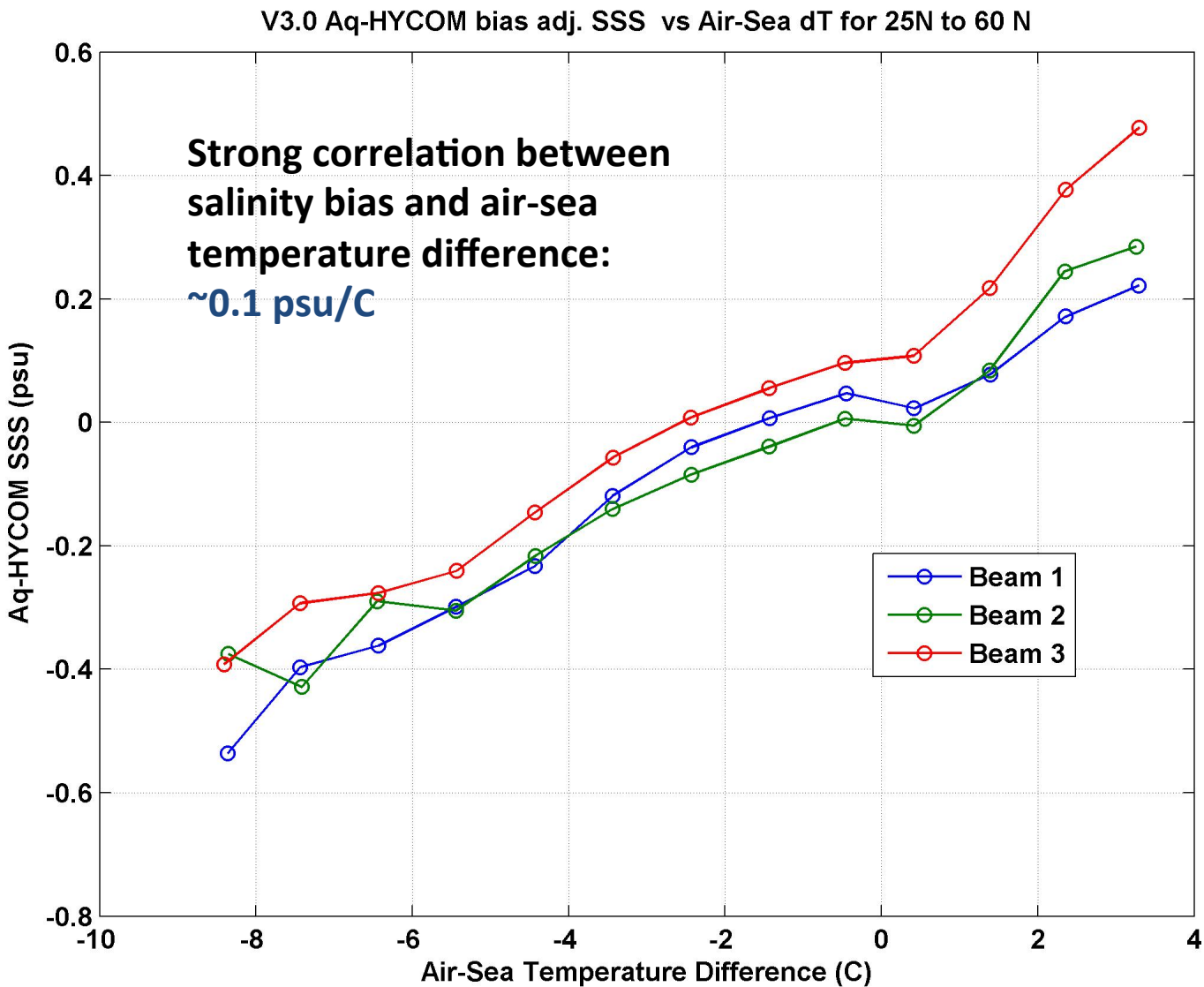


In winter months at high latitudes, air is on average cooler than the water temperature

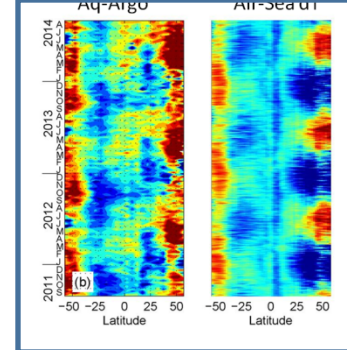
Air is warmer than the water on average in the summer months



# V3 Aq(bias adj) – HYCOM vs NCEP Air-Sea $\Delta T$

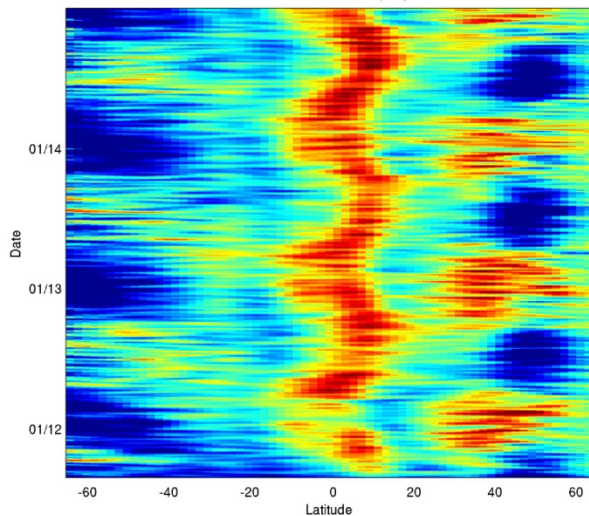


- All L2 wind products show regional biases similar to SSS biases
- Strong correlation with Air-Sea temperature difference
  - Scatterometer WS exhibits inter-beam variation in bias



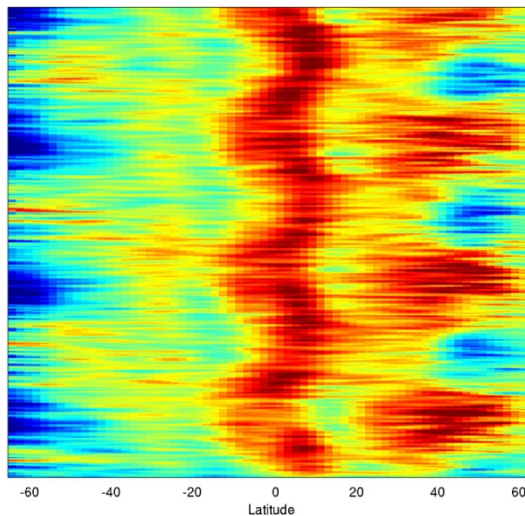
## Scatterometer WS - NCEP

Scat WS - NCEP WS (m/s)



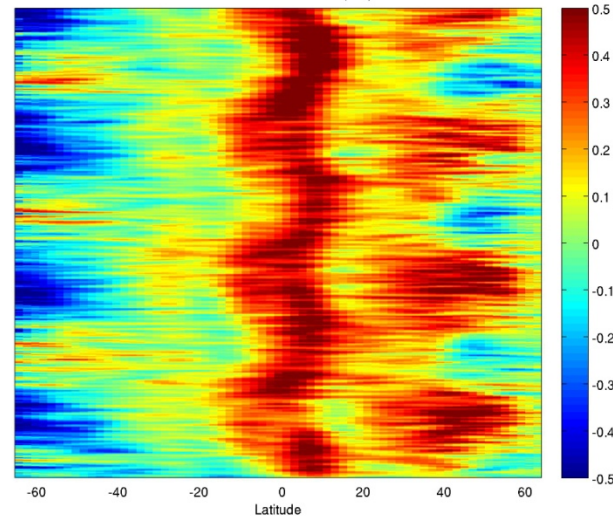
## HH WS - NCEP

Rad HH WS - NCEP WS (m/s)

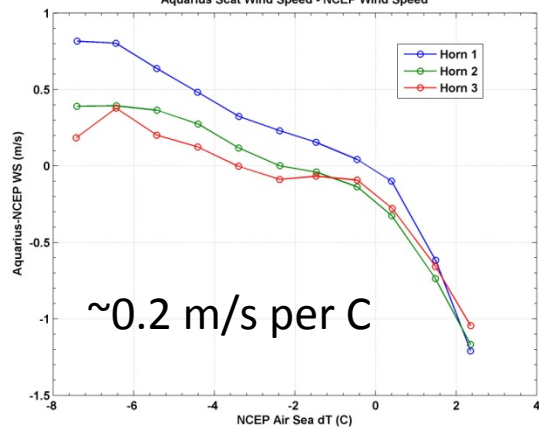


## HHH - NCEP

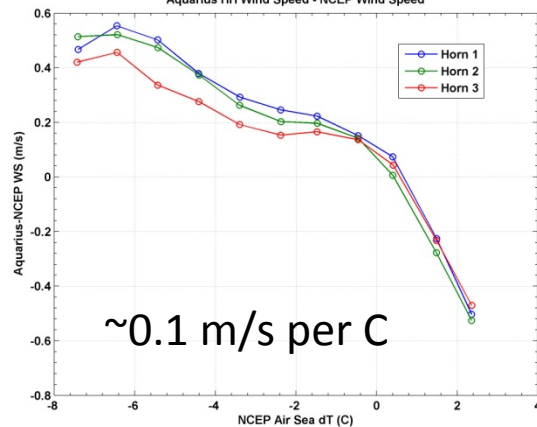
Rad HHH WS - NCEP WS (m/s)



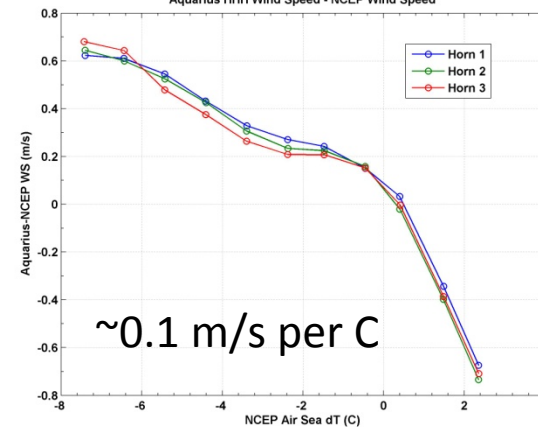
Aquarius Scat Wind Speed - NCEP Wind Speed



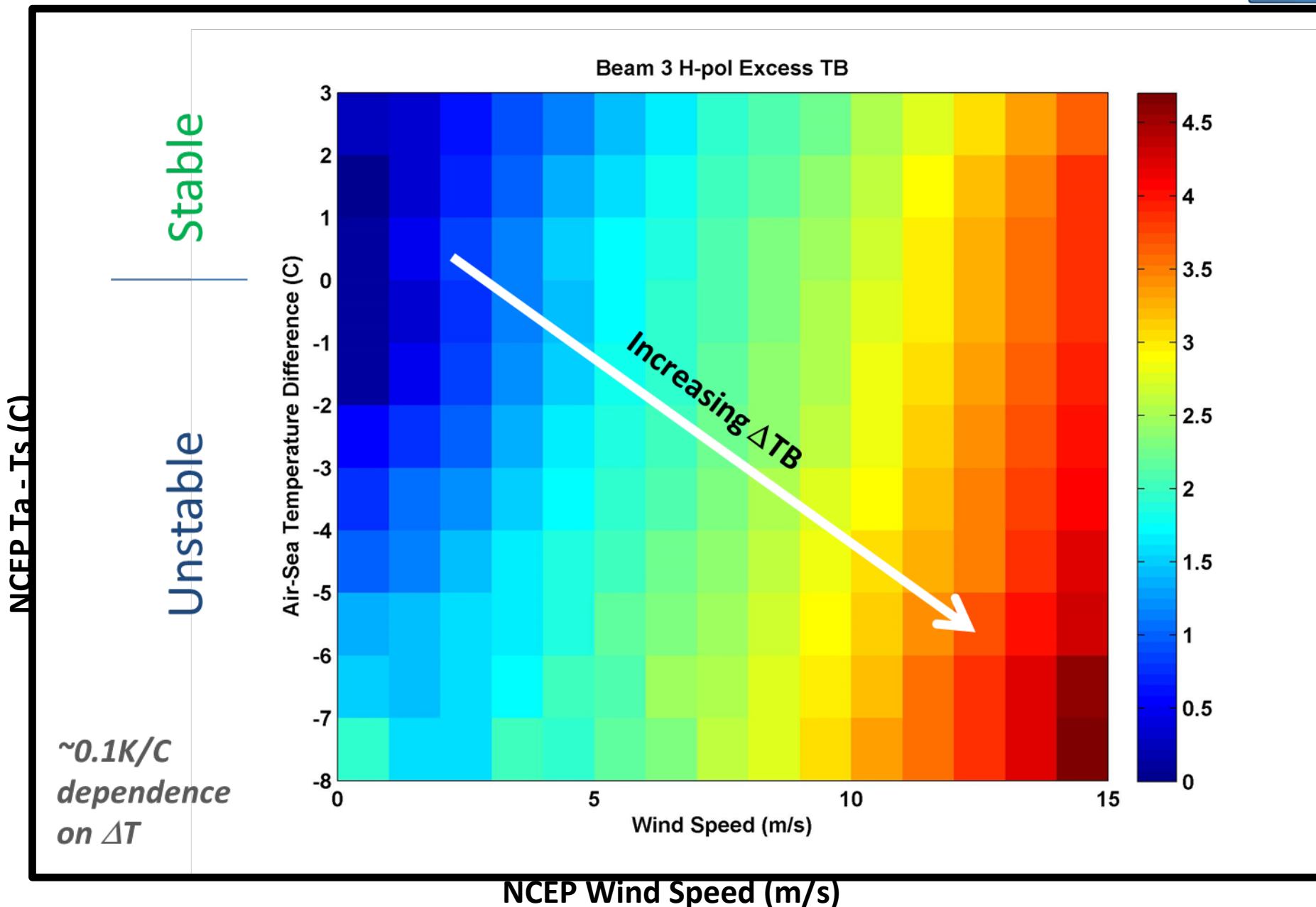
Aquarius HH Wind Speed - NCEP Wind Speed



Aquarius HHH Wind Speed - NCEP Wind Speed



# Isotropic Excess Emission vs WS and Air-Sea $\Delta T$



# Isotropic Backscatter vs WS and Air-Sea $\Delta T$

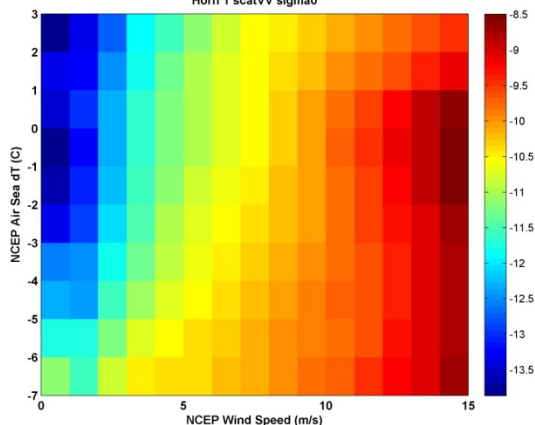


- Scatterometer also sensitive to air-sea temperature difference, suggesting wind/wave interactions may be a significant contributor to the observed radiometer excess TB dependence with air-sea  $\Delta T$

NCEP  $T_a - T_s$  (C)

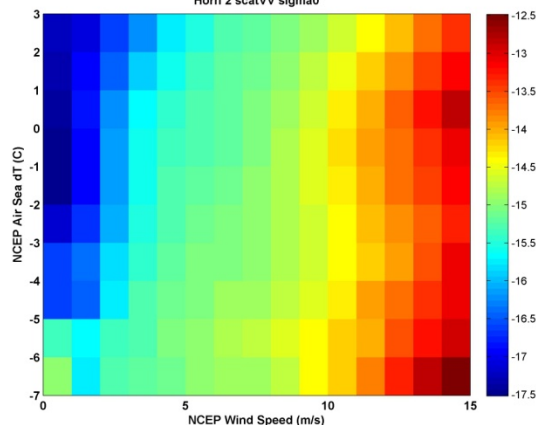
### Horn 1 V-pol

Horn 1 scatVV sigma0



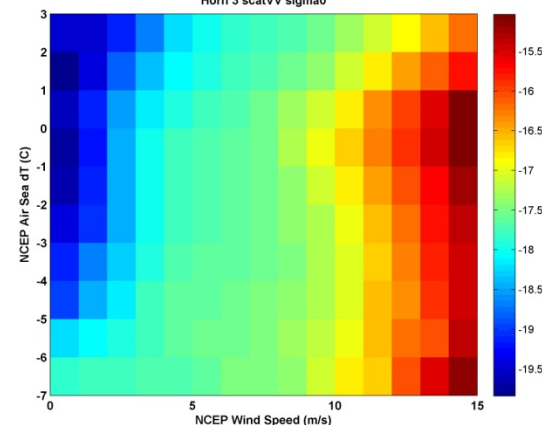
### Horn 2 V-pol

Horn 2 scatVV sigma0



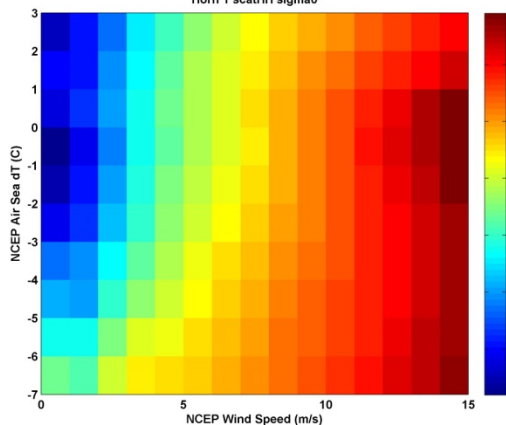
### Horn 3 V-pol

Horn 3 scatVV sigma0



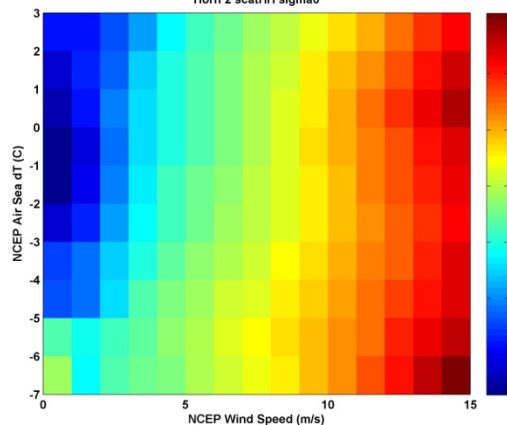
### Horn 1 H-pol

Horn 1 scatHH sigma0



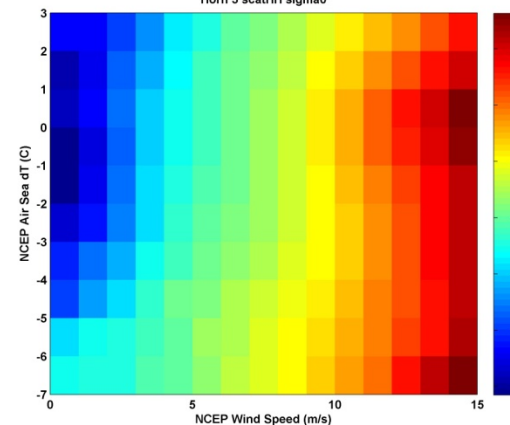
### Horn 2 H-pol

Horn 2 scatHH sigma0



### Horn 3 H-pol

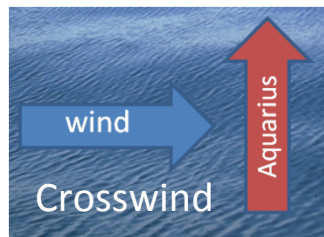
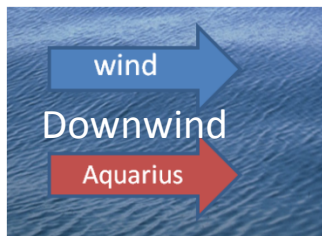
Horn 3 scatHH sigma0



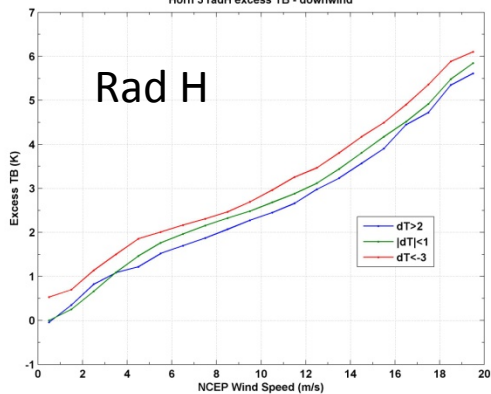
NCEP Wind Speed (m/s)



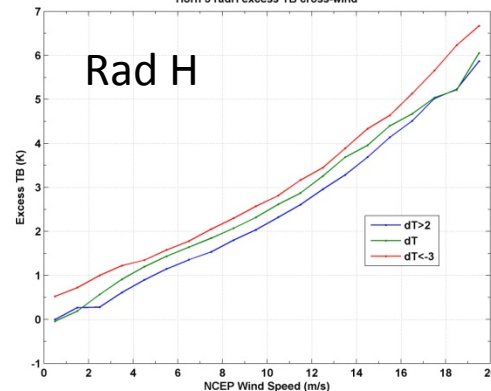
- Sensitivity to air-sea  $dT$  most prominent in downwind and cross-wind look directions for radiometer
- Scatterometer shows most sensitivity in cross-wind direction at low winds
- Less sensitivity in upwind direction for both
- Scatterometer loses sensitivity to  $\Delta T$  at high winds while radiometer does not (likely foam dependence)



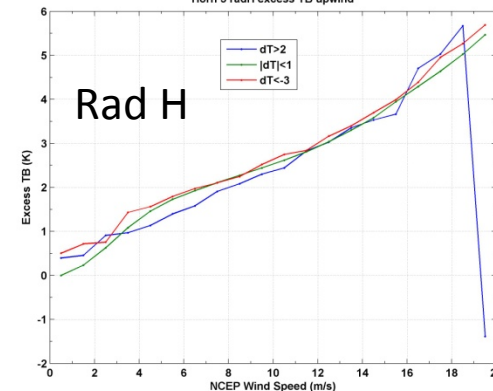
Horn 3 radH excess TB - downwind



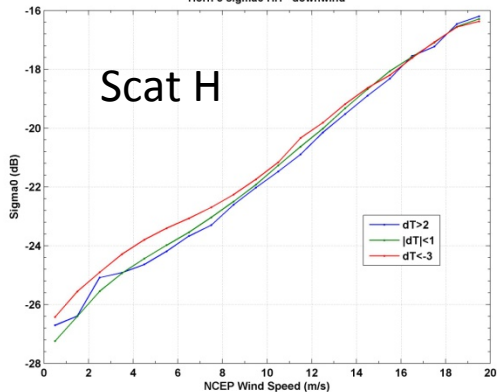
Horn 3 radH excess TB cross-wind



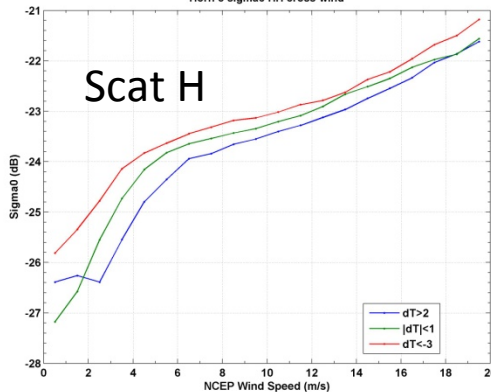
Horn 3 radH excess TB upwind



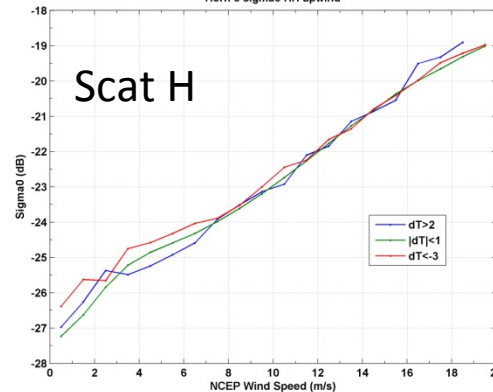
Horn 3 sigma0 HH - downwind



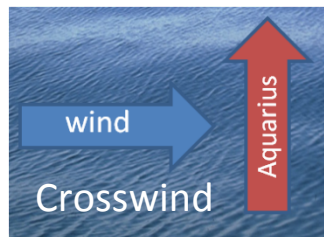
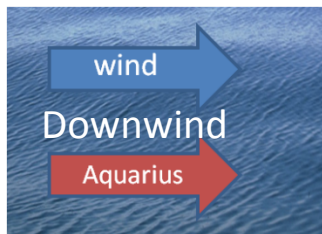
Horn 3 sigma0 HH cross-wind



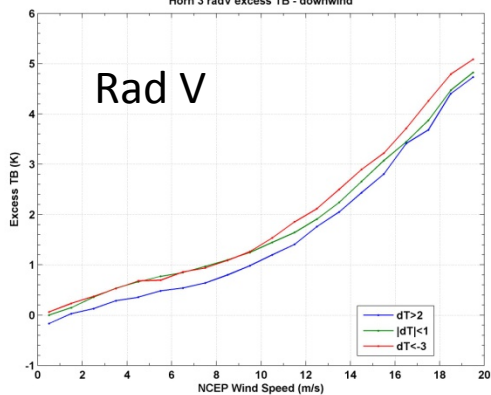
Horn 3 sigma0 HH upwind



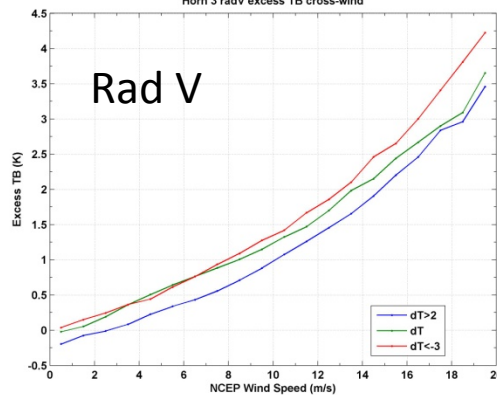
- V-pol shows similar results to H-pol, but less sensitivity observed



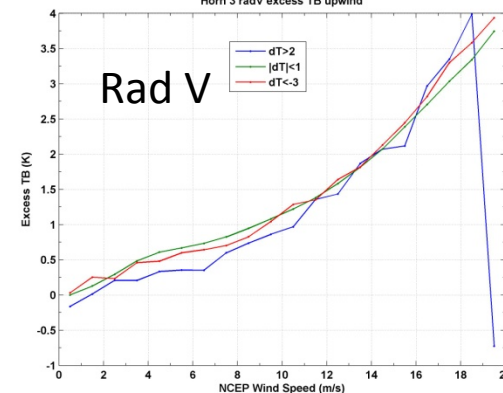
Horn 3 radV excess TB - downwind



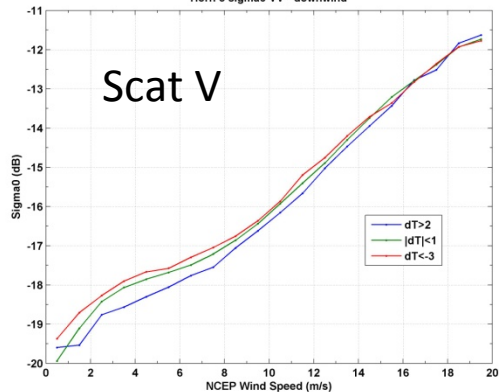
Horn 3 radV excess TB cross-wind



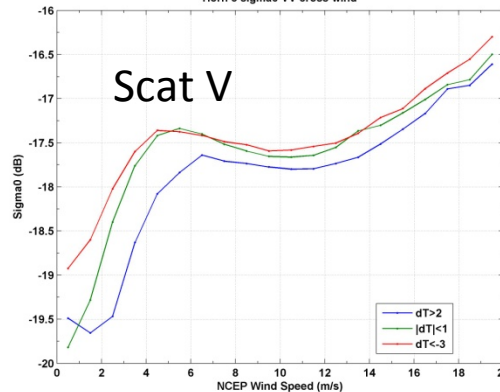
Horn 3 radV excess TB upwind



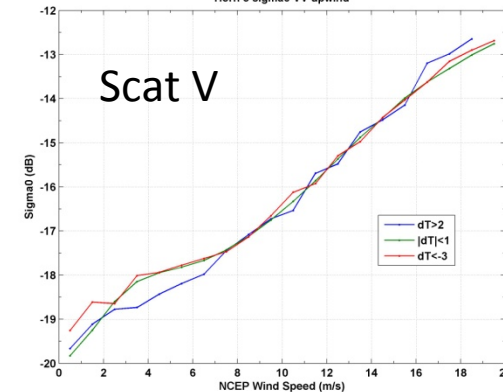
Horn 3 sigma0 VV - downwind



Horn 3 sigma0 VV cross-wind



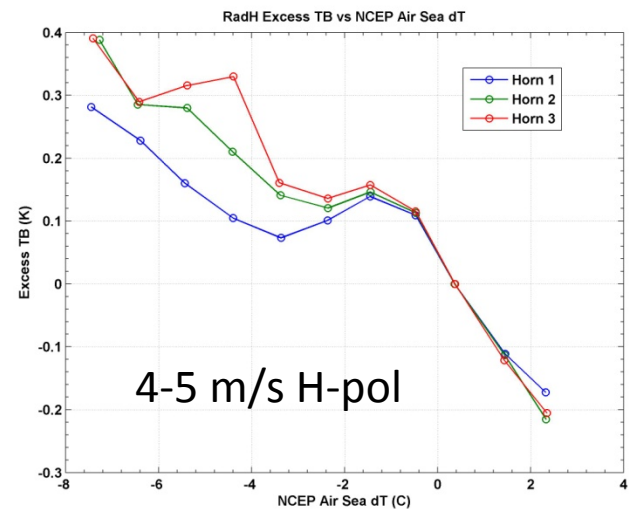
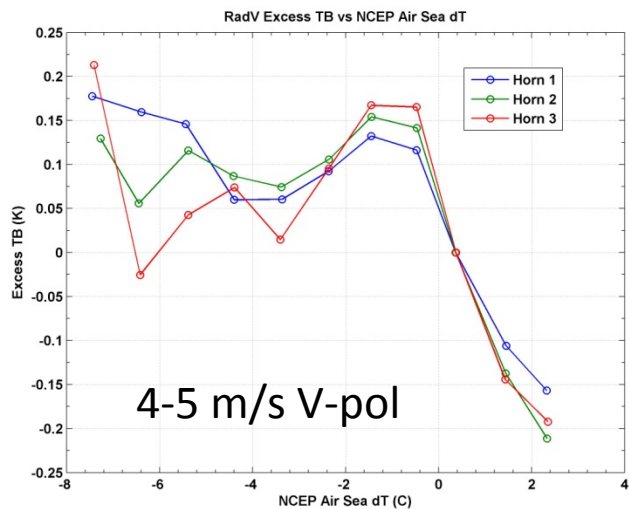
Horn 3 sigma0 VV upwind



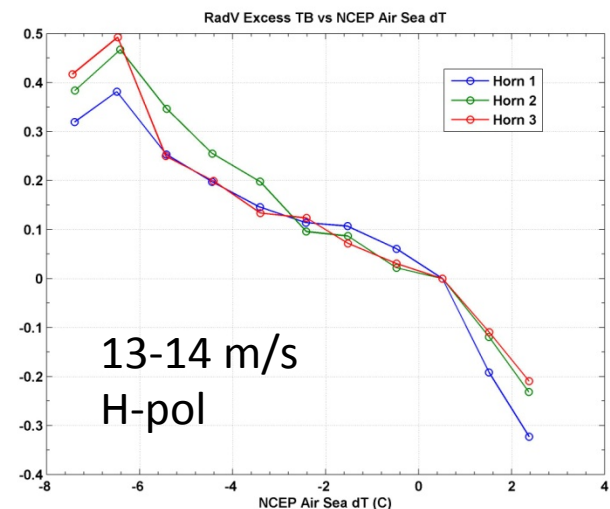
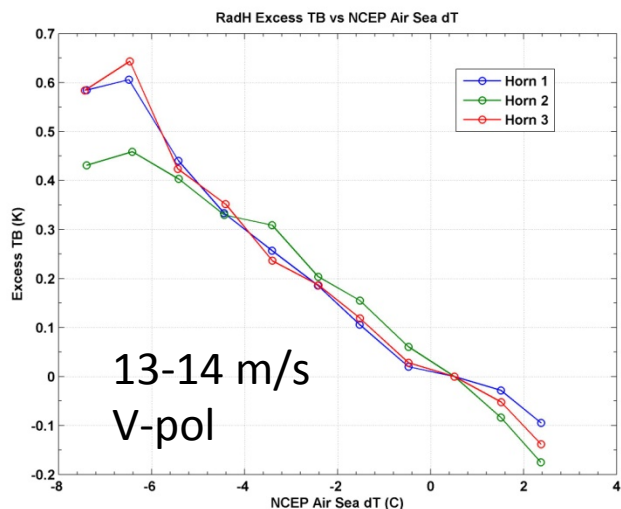
# Air-Sea $\Delta T$ Sensitivity with Incidence Angle



- Some variation of excess emission with incidence angle at lower winds



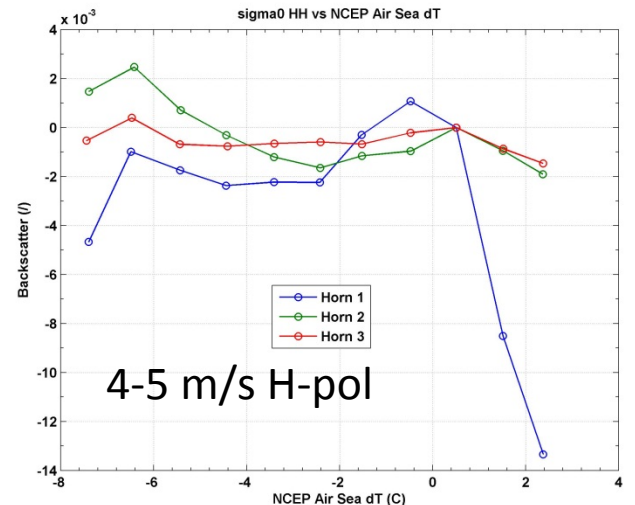
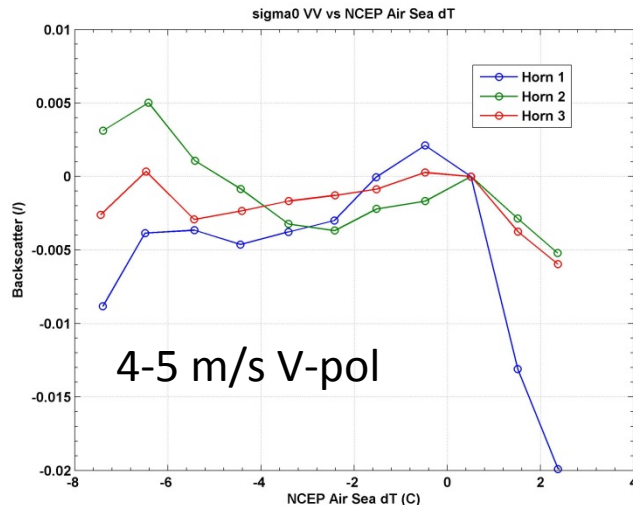
- At higher winds, less variation with incidence angle, stronger sensitivity in both polarizations



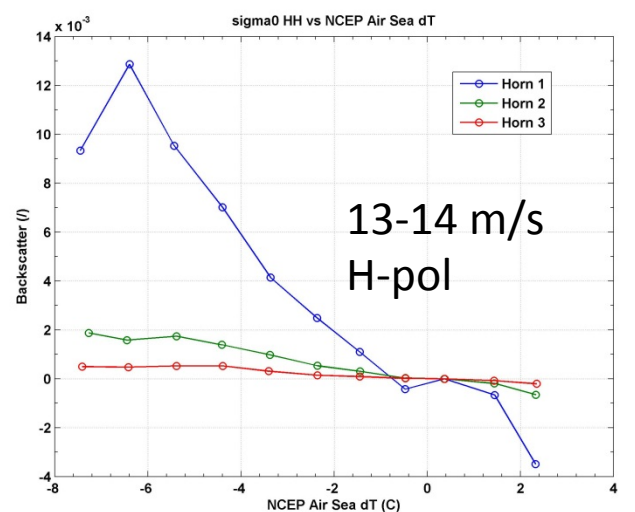
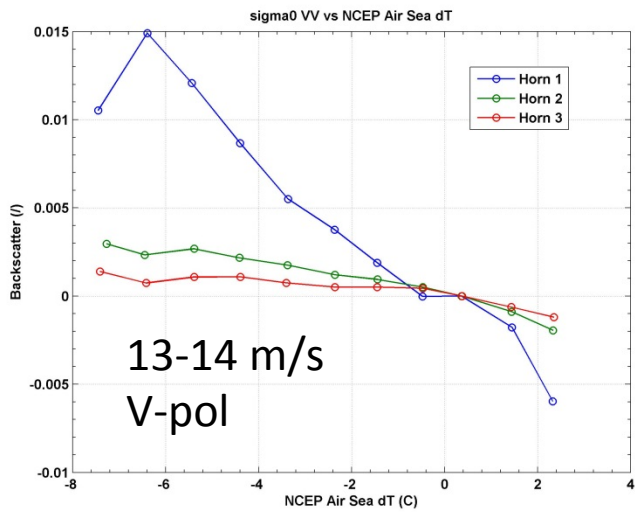
# Air-Sea $\sigma_0$ Sensitivity with Incidence Angle



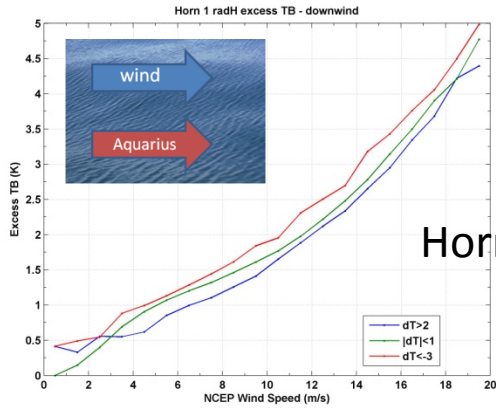
- Scatterometer shows distinct variation in sensitivity with incidence angle at high winds, less at low winds



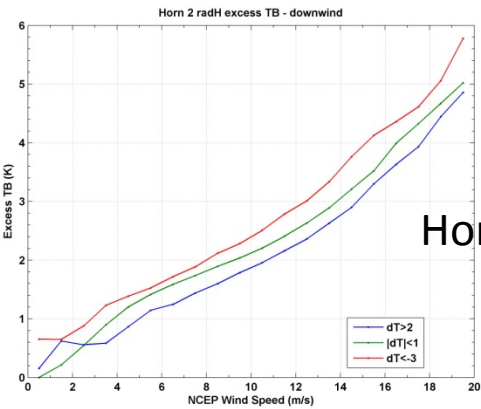
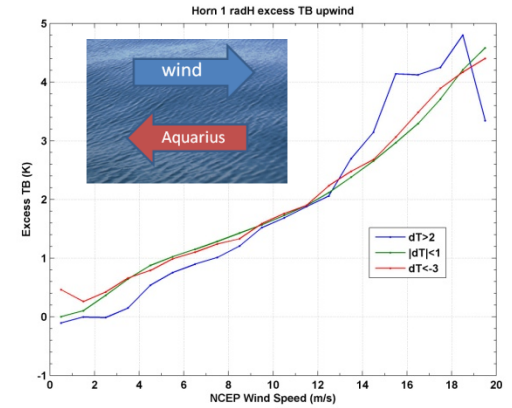
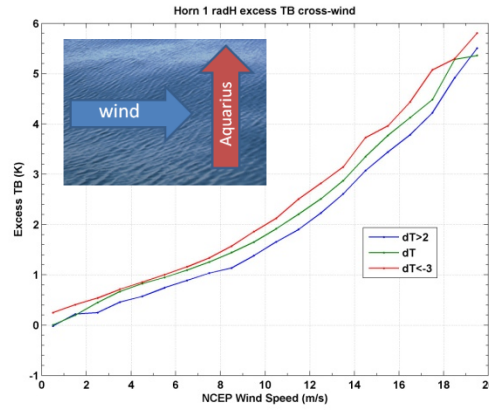
- Consistent with observation that scatterometer wind speed bias is channel dependent



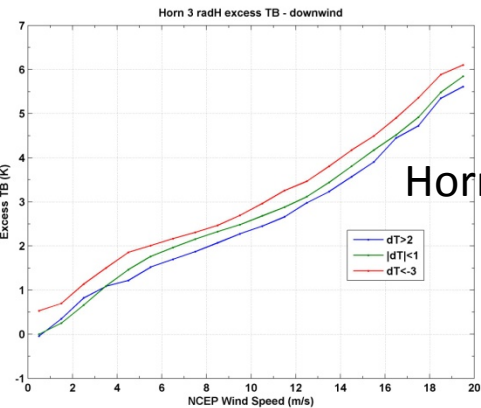
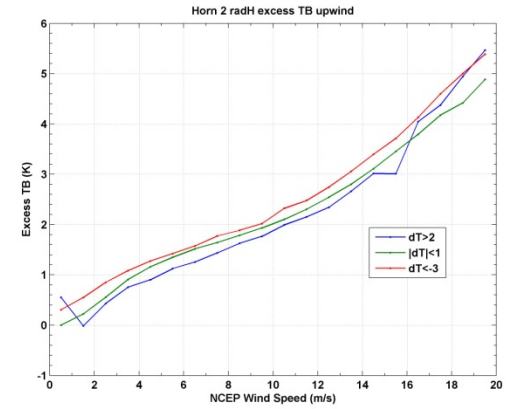
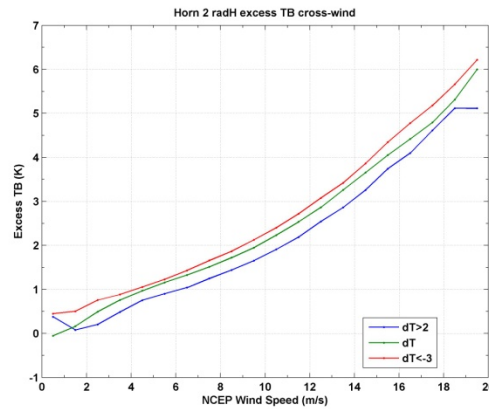
# Rad Air-Sea $\Delta T$ Sensitivity to Direction H-pol All Horns



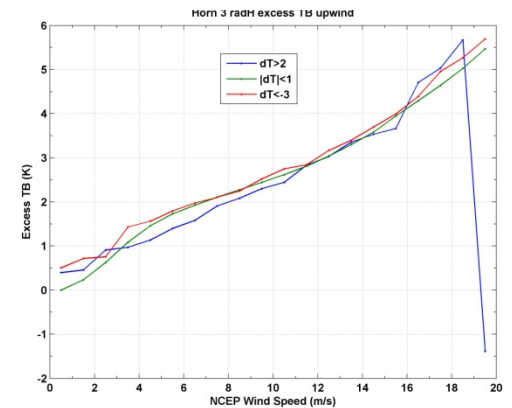
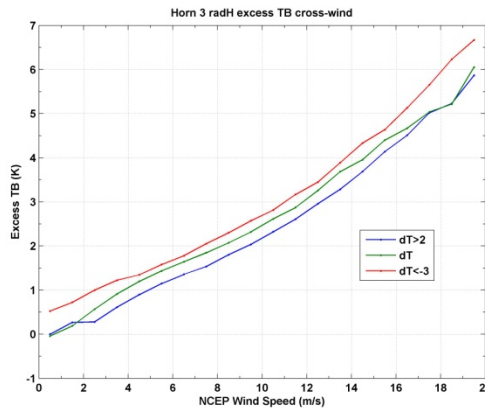
Horn 1

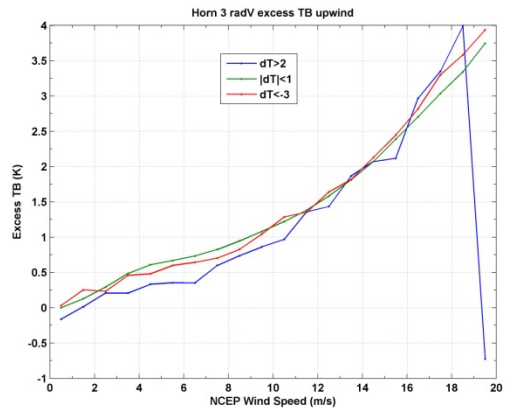
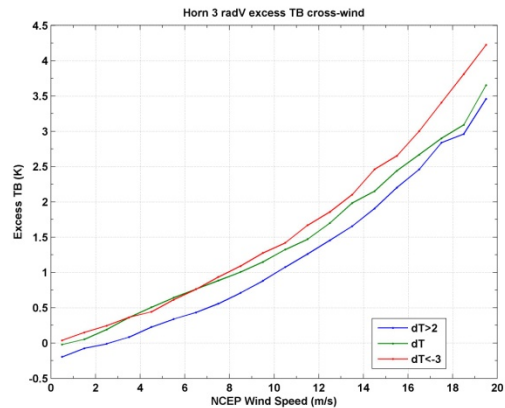
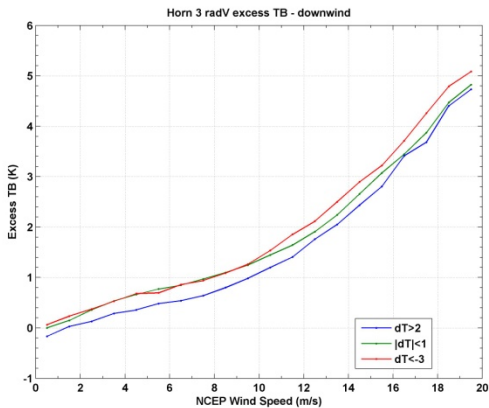
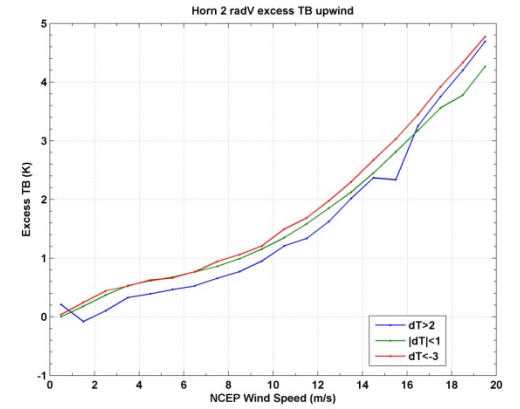
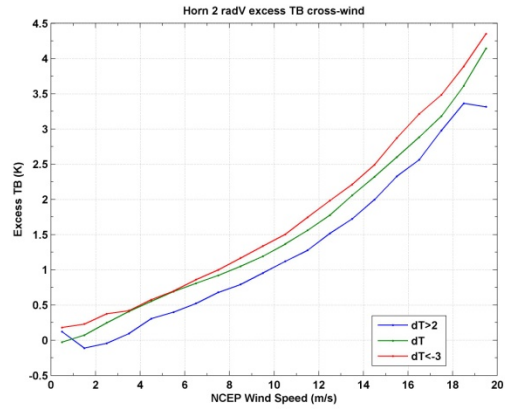
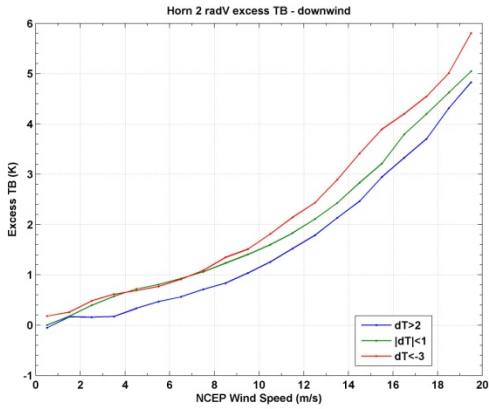
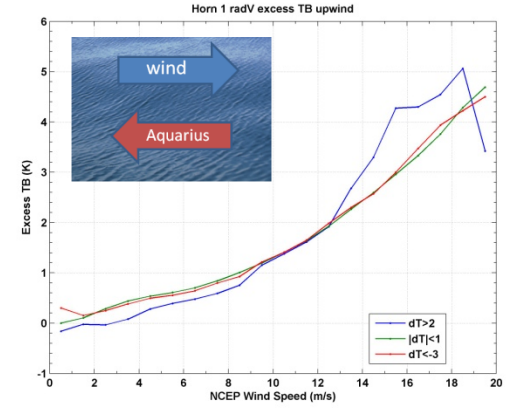
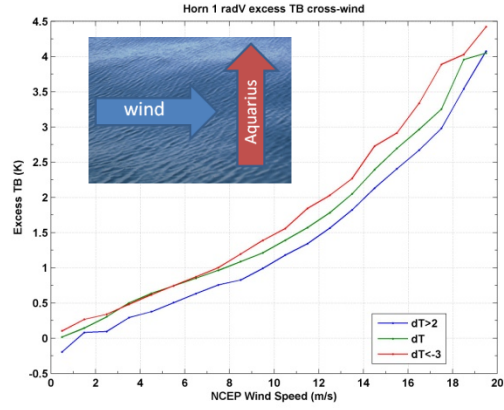
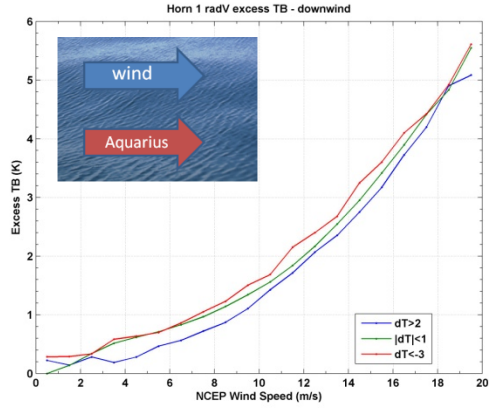


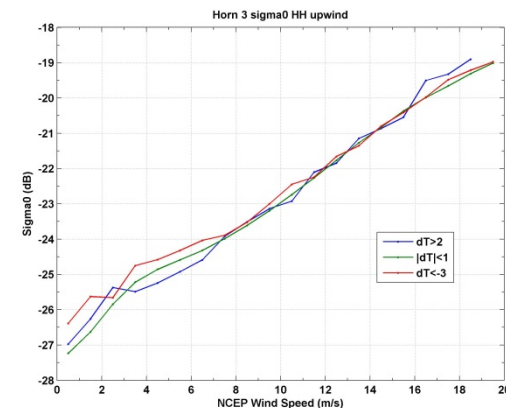
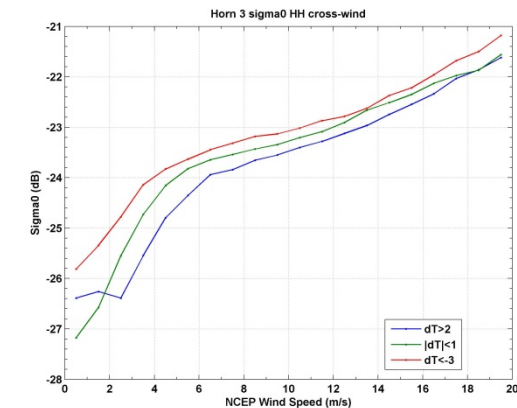
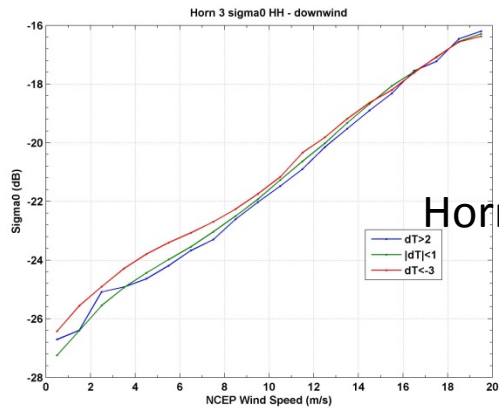
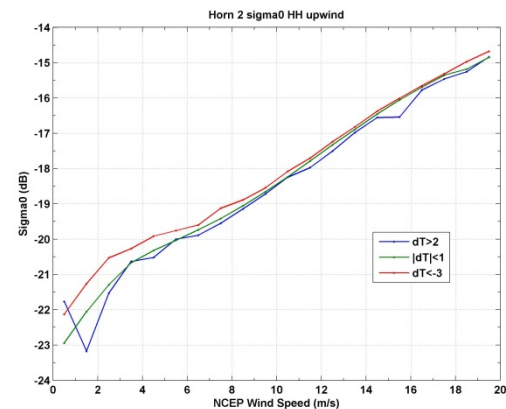
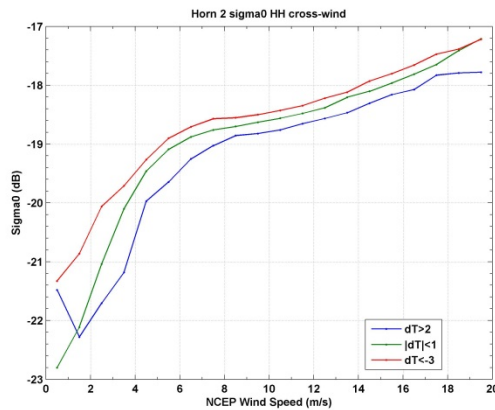
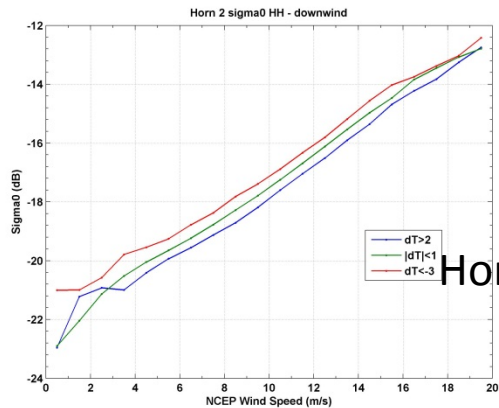
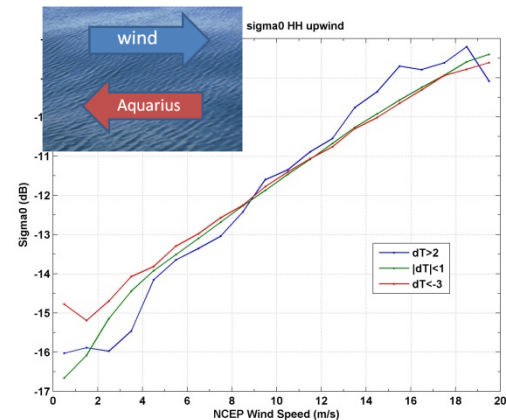
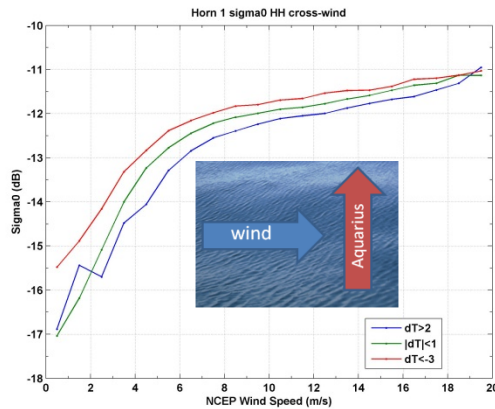
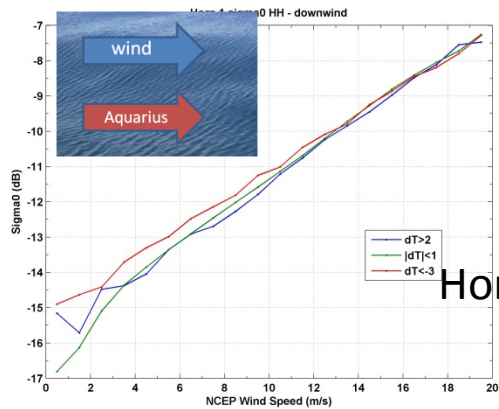
Horn 2

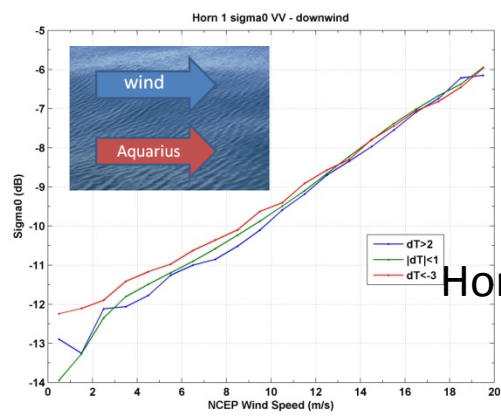


Horn 3

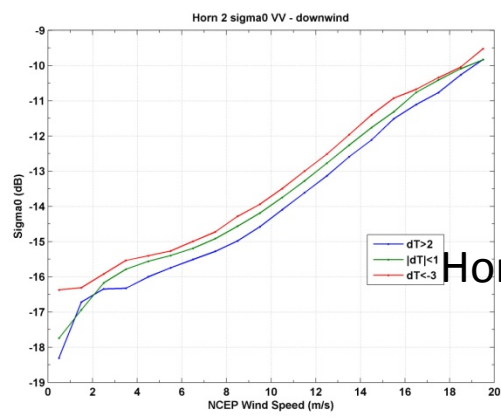
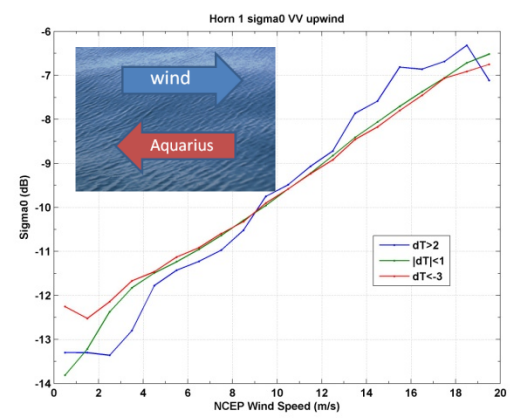
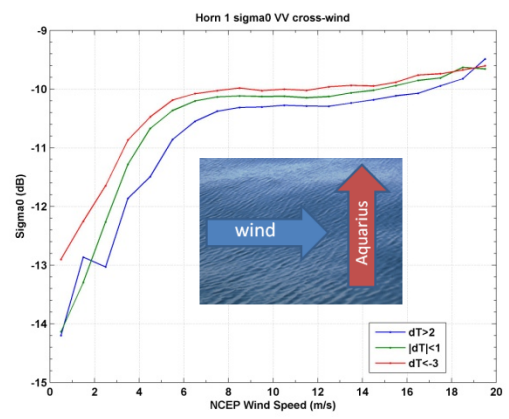




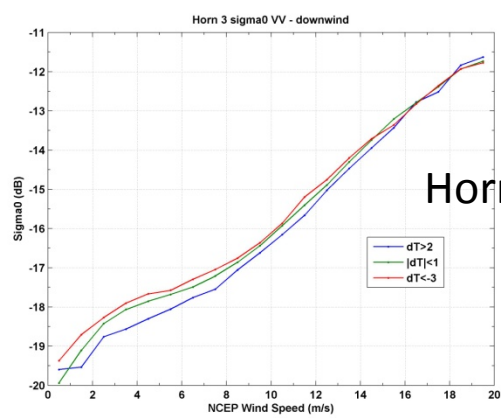
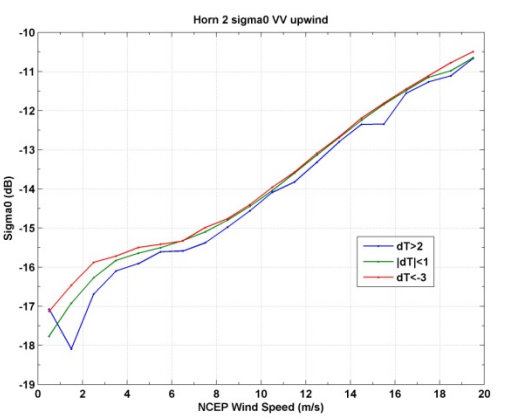
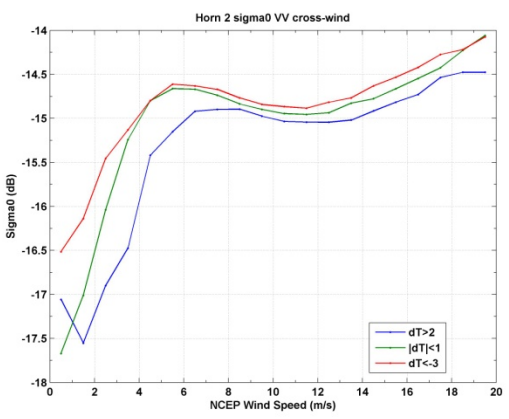




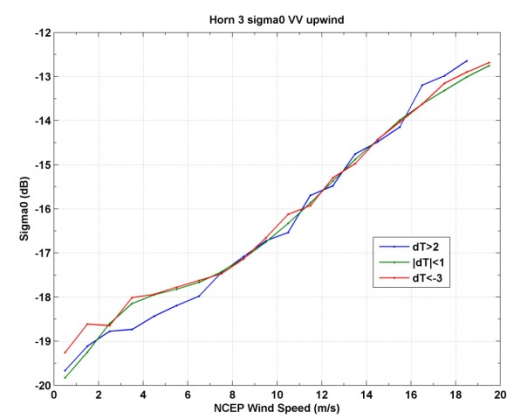
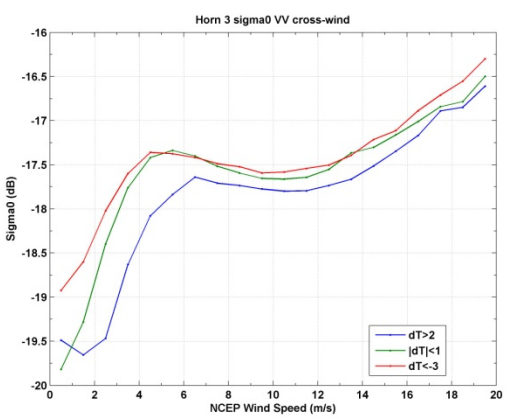
Horn 1



Horn 2



Horn 3





- Current model function is of the form:

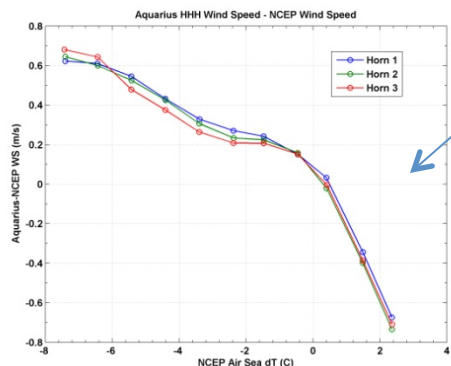
$$\Delta E_{rough} = \Delta E_{w0}(W_{HHH}, \varphi_r, T_S) + \Delta E_{w1}(W_{HHH}, \sigma_{0,VV}) + \Delta E_{w2}(W_{HHH}, SWH)$$

- Harmonic coefficients in E0 term could be modified as one approach
- Another approach which may be easier from a processing perspective is to add a term to incorporate a look-up table for the delta impact from the air-sea temperature difference dependence

$$\Delta E_{rough} = \Delta E_{w0}(W_{HHH}, \varphi_r, T_S) + \Delta E_{w1}(W_{HHH}, \sigma_{0,VV}) + \Delta E_{w2}(W_{HHH}, SWH) + \Delta E_{w3}(W_{HHH}, \varphi_r, \Delta T_{a-s})$$


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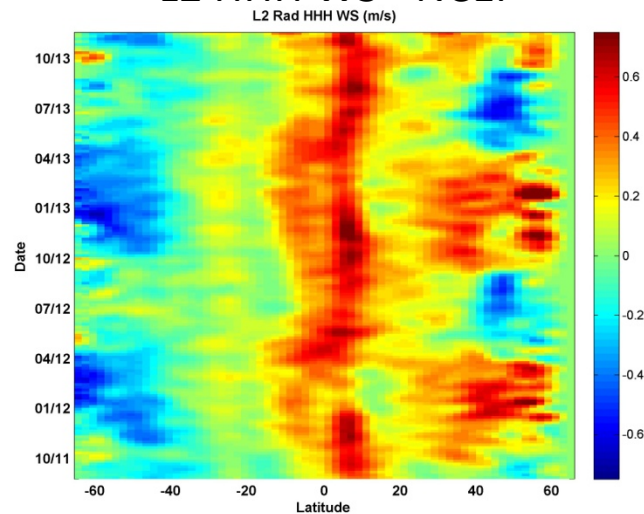
# Testing Simple Post-hoc Correction



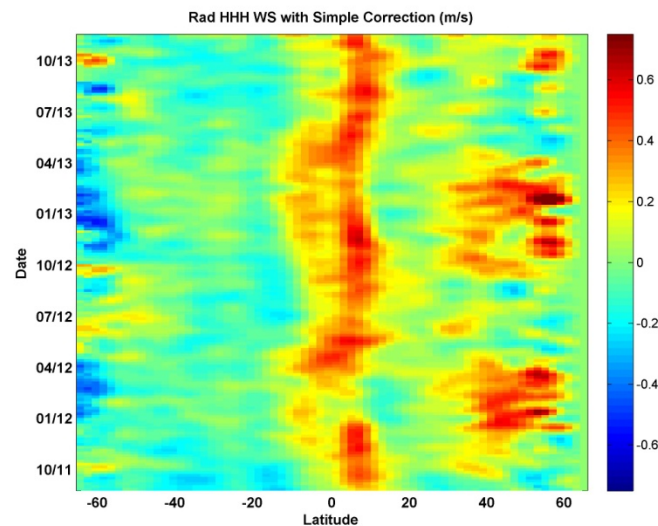
Subtracted WS bias with respect to Air-Sea  $\Delta T$  and re-computed hovmoller diagram neglecting wind direction dependence

- Indicates that incorporation of air-sea temperature dependence in GMF should significantly reduce regional biases in SSS product and WS product

L2 HHH WS - NCEP



After simple post-hoc correction



# Summary

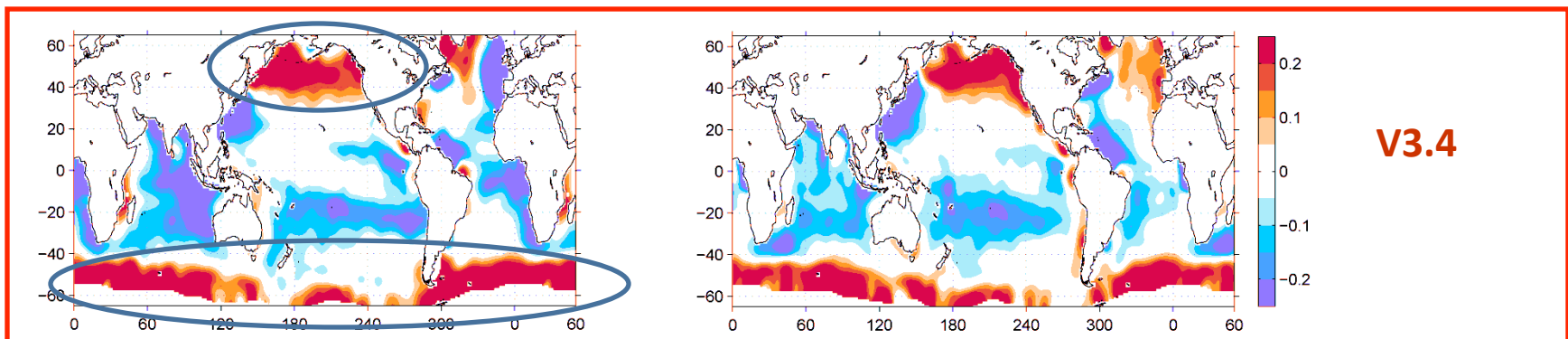
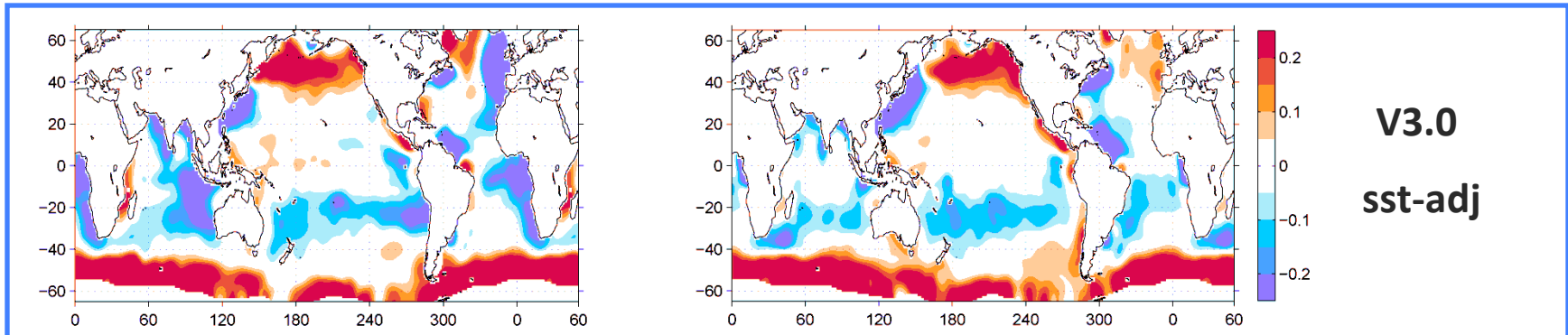
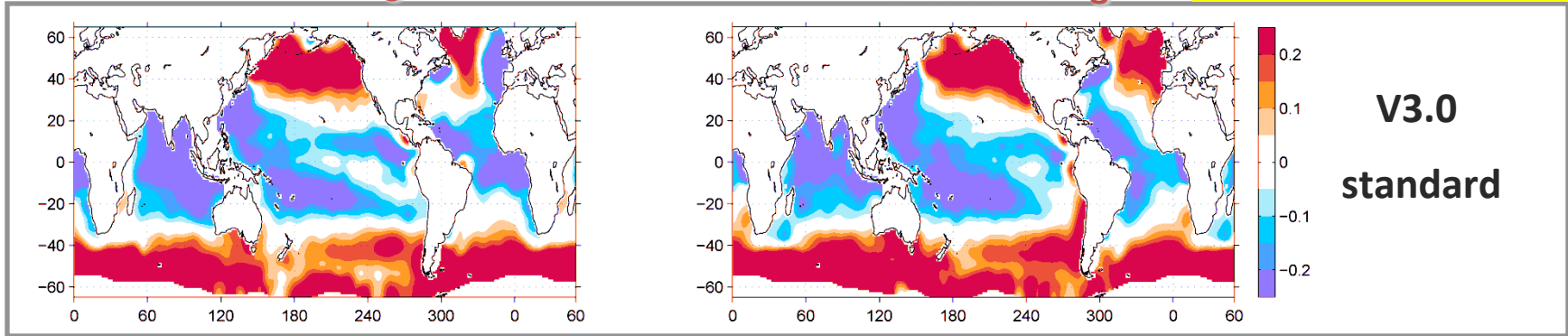
- Backscatter and excess rough surface emission found to have significant dependence on air-sea temperature difference
  - Scatterometer shows largest sensitivity at low winds ( $< 7\text{m/s}$ ) while radiometer shows sensitivity over all wind speeds
  - Suggests wave influence at low winds with foam influence more important at high winds
  - Sensitivity strongest in downwind and cross-wind look directions with much less sensitivity when looking into the wind
- The bias is clear and is robust - suitable for an empirical correction (same dependence found between two different years), but more work needed to completely understand the physics
  - It's possible that we're seeing a correlation with some other physical mechanism influencing the sea surface
  - Plan to bring wave model information into analysis to help physical understanding

# Backup

# Static bias (3-year mean) with respect to Argo (APDRC)

Ascending

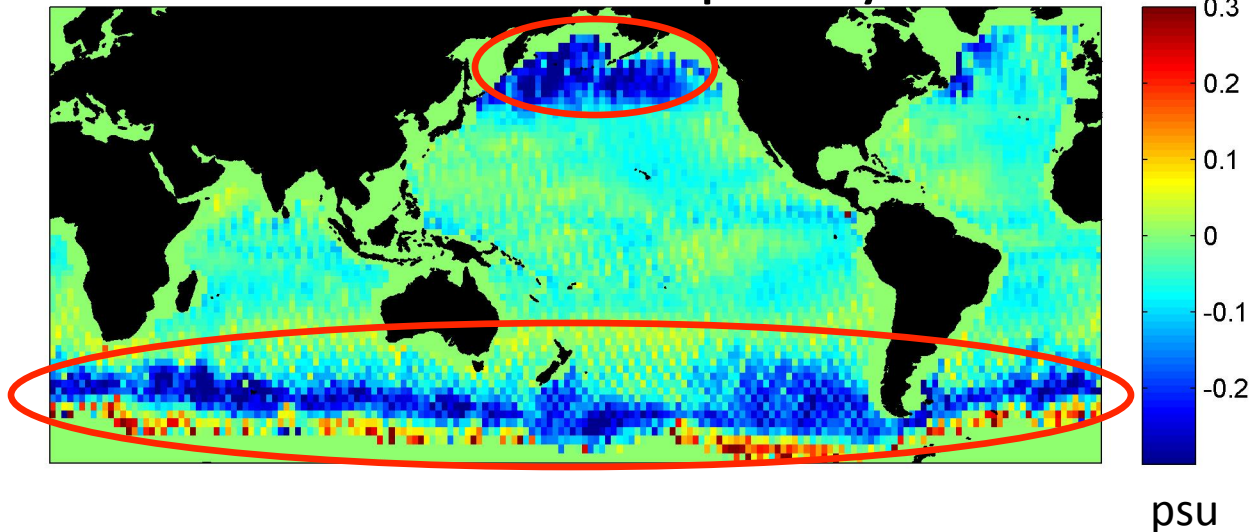
Descending



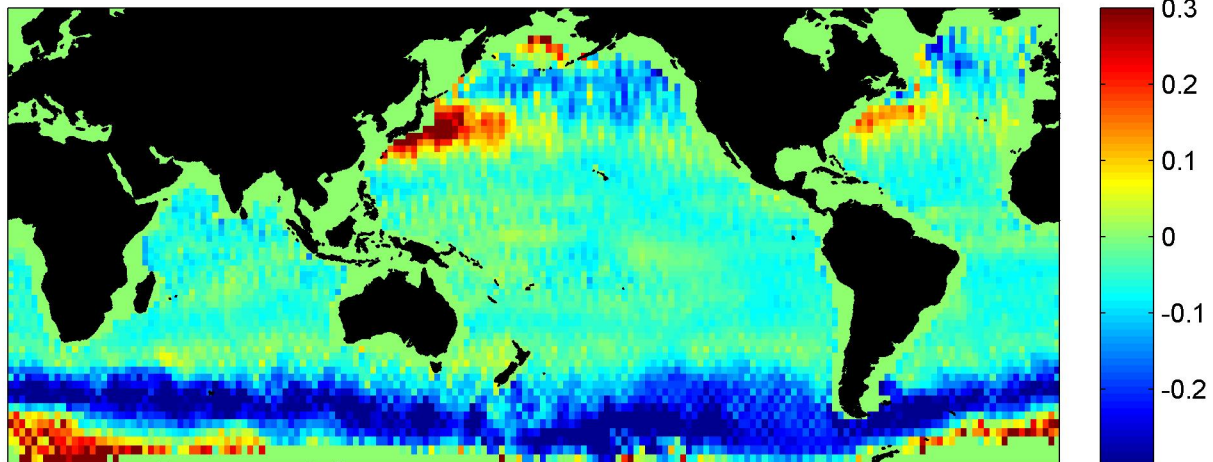
Bias maps are computed from monthly fields using 6x6 degree boxes on a 3-degree grid.

# Mitigating Regional Biases

## SSS Correction Map: July 2012



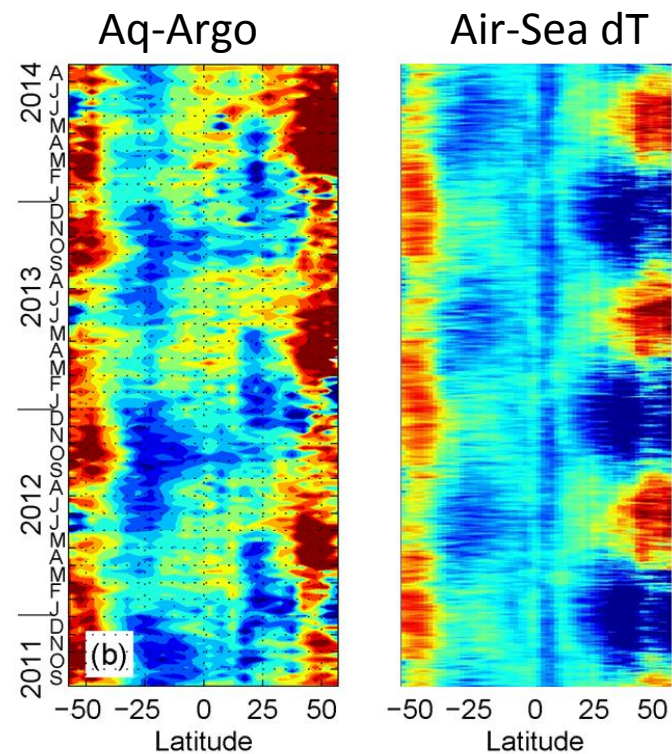
## SSS Correction Map: January 2012



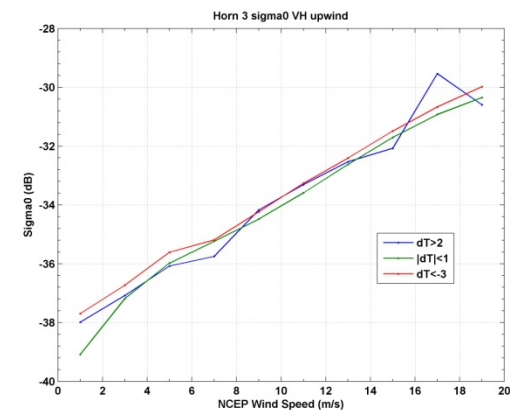
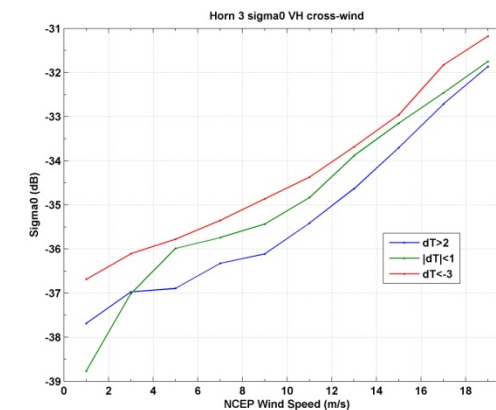
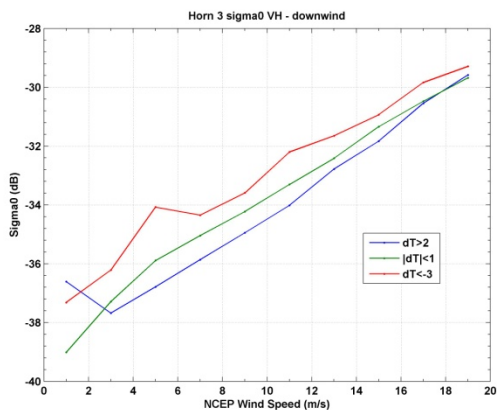
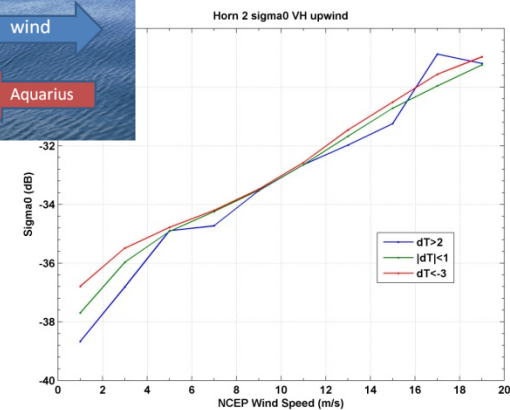
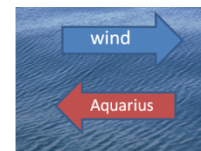
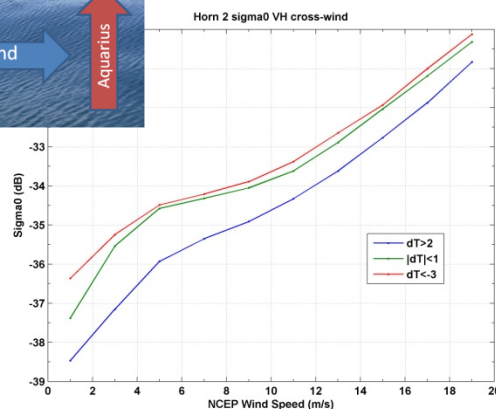
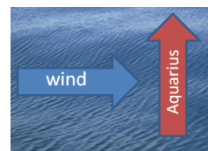
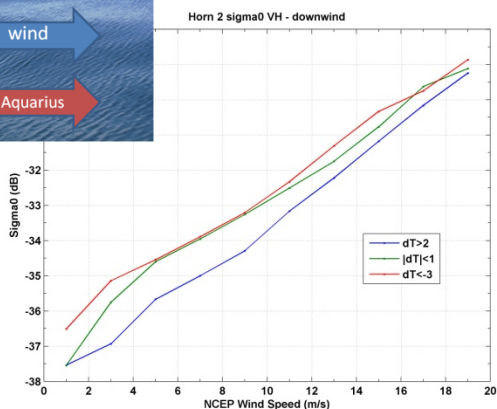
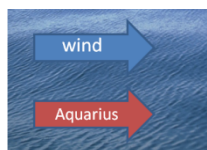
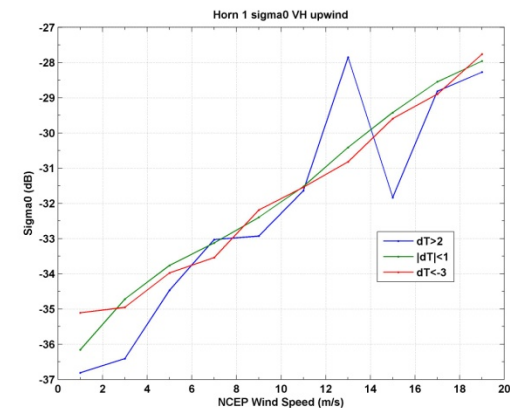
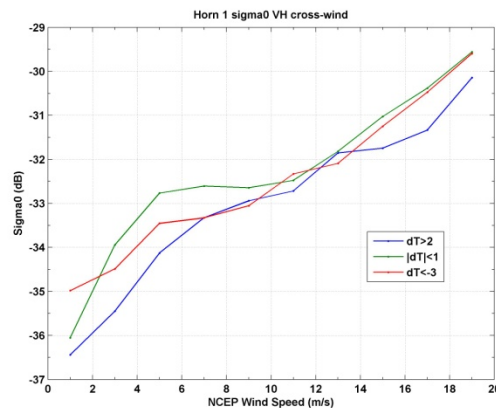
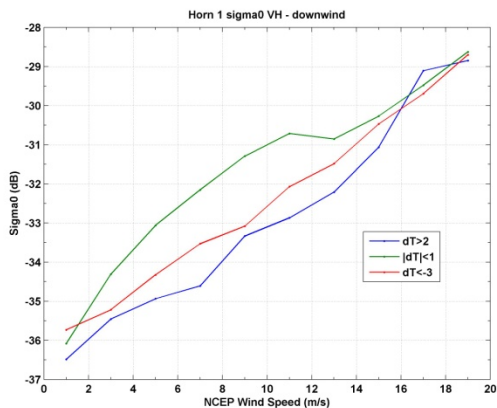
- Derived empirical Air-Sea dT correction based on HYCOM
- Maps show regional and seasonal dependence of correction
- Largest impact of accounting for Air-Sea temperature difference will be in high latitudes

# Summary

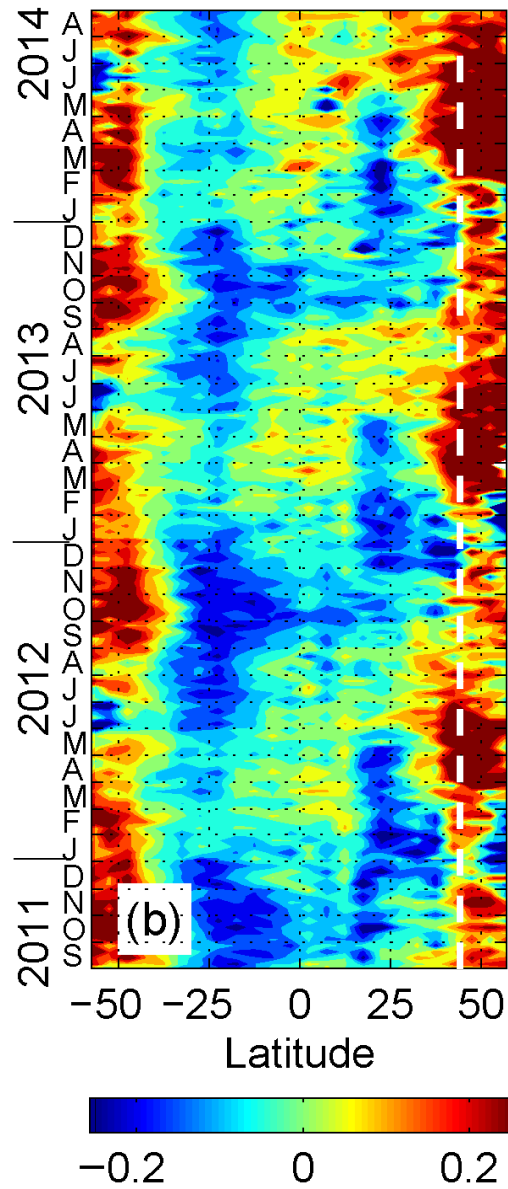
- Air-sea temperature difference appears to be a significant contributor to the regionally dependent seasonal errors observed in Aquarius SSS
- Correction can be implemented by updating the GMF to include an explicit parameterization for foam
- Future work required to develop this parameterization



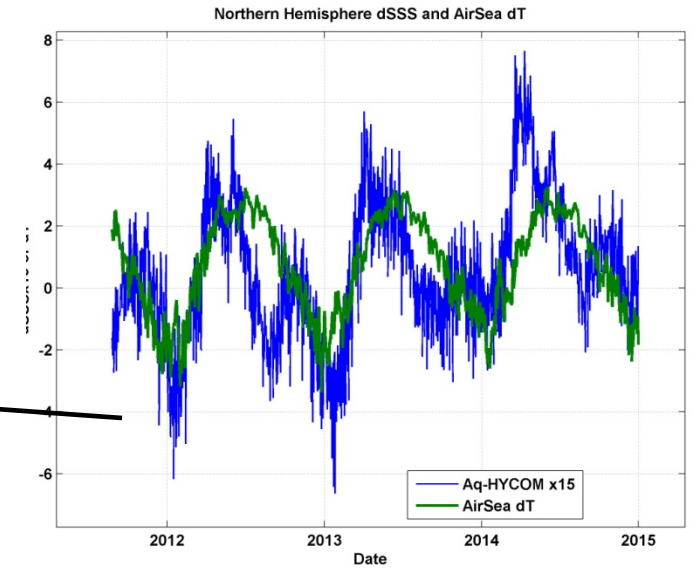
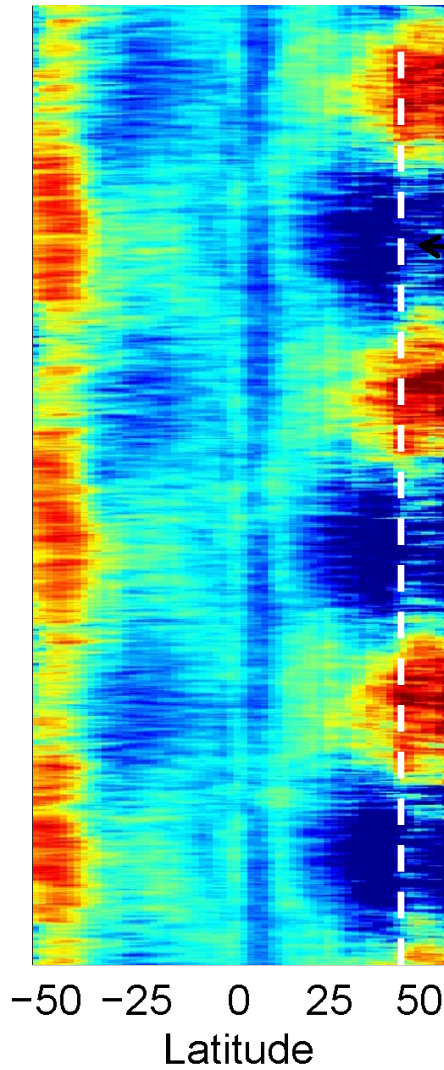
# Scatterometer VH







Air-Sea dT



Good correlation between seasonal salinity bias and air-sea dT variation

