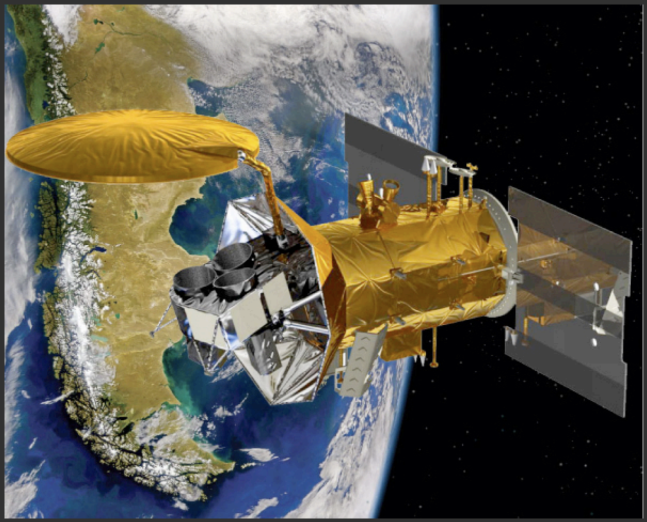
Mitigation of Large Scale Biases in the Aquarius Salinity Retrievals

T. Meissner and F. Wentz

Remote Sensing Systems

meissner@remss.com



2014 Aquarius / SAC-D Science Team Meeting

November 11- 14, 2014

Seattle. Washington, USA

Remote Sensing Systems
www.remss.com

Outline

1. **Current Status:**
   - **Observed Biases**
   - **Post-hoc SST correction**
2. **2-Dimensional Analysis: SST and Wind Speed**
3. **Low Wind Speed Limit**
   - **Dielectric Model**
   - **O_2 Absorption Model**
   - **SST Auxiliary Field**
4. **Moderate –High Wind Speeds**
   - **Wind Emissivity Model**
5. **Summary**
6. **Going Forward**

SST Dependent Biases

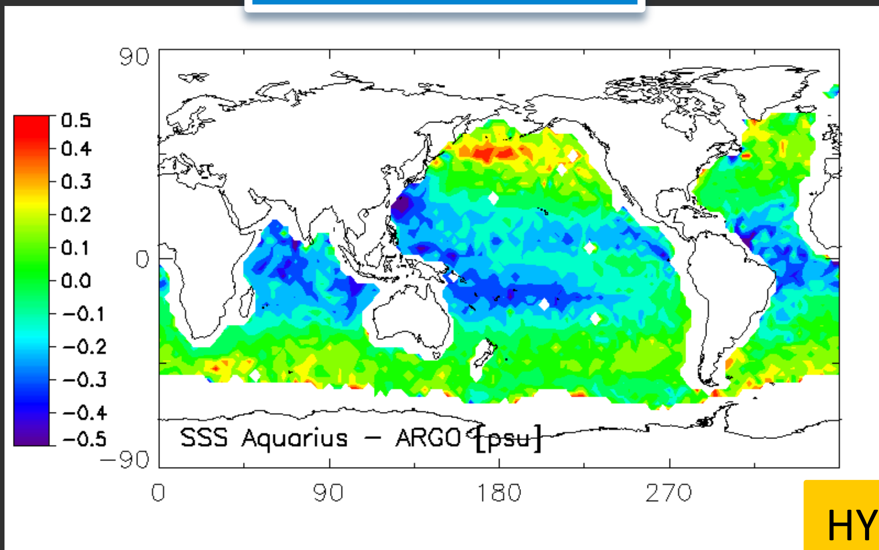
Post-hoc Correction (2)

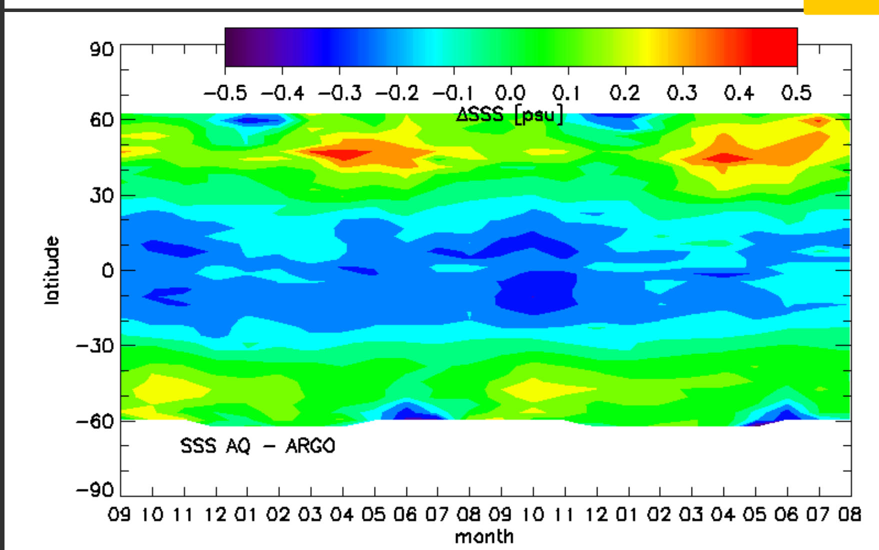
- The ADPS V3.0 standard SSS shows fresh biases in low latitudes and salty biases in high latitude compared to ARGO and HYCOM.
- These biases are a large part of the observed error
  - Global RMS of monthly 1 deg averages
  - Goal: 0.2 psu
- These biases are not caused by stratification/rain (see afternoon talk).
- These biases are caused by the geophysical model function and need to be removed.
- ADPS V3.0 contains a bias adjusted SSS product, which should be used for scientific studies.

Impact on Performance

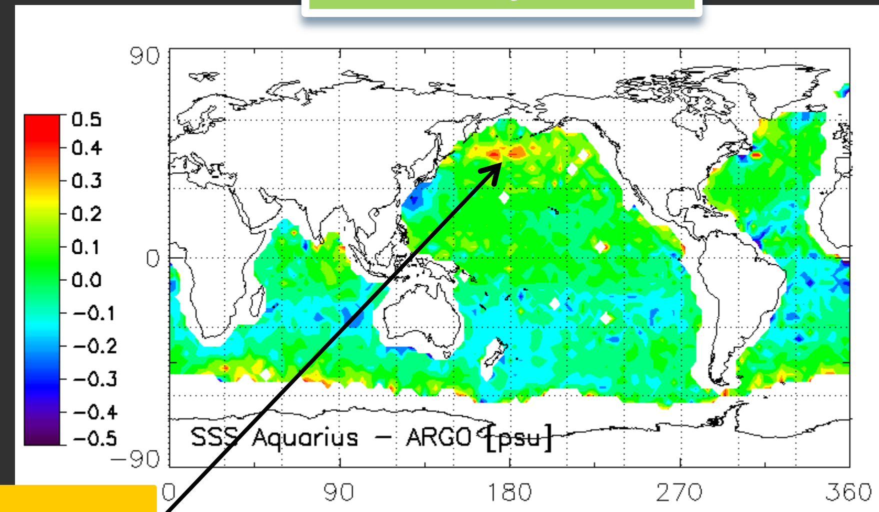
Local Biases

V3.0 no adjustment

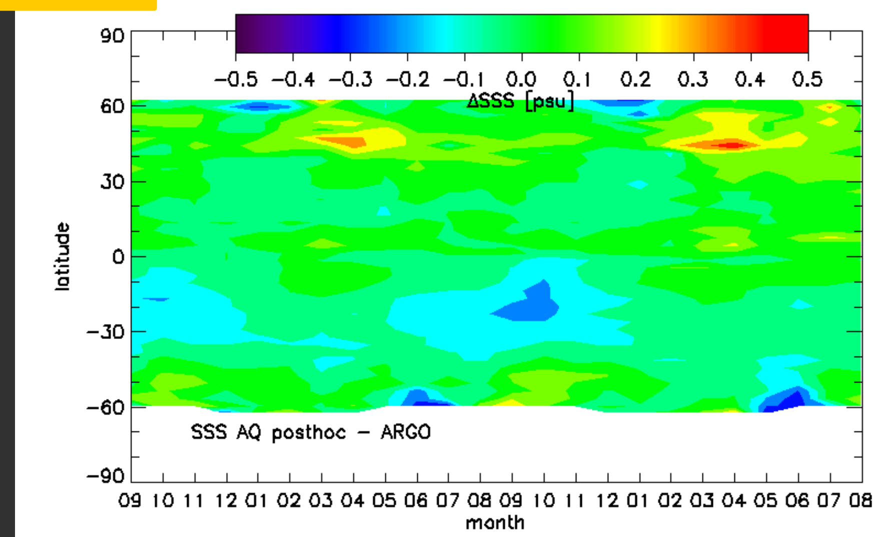




V3.0 bias adjusted

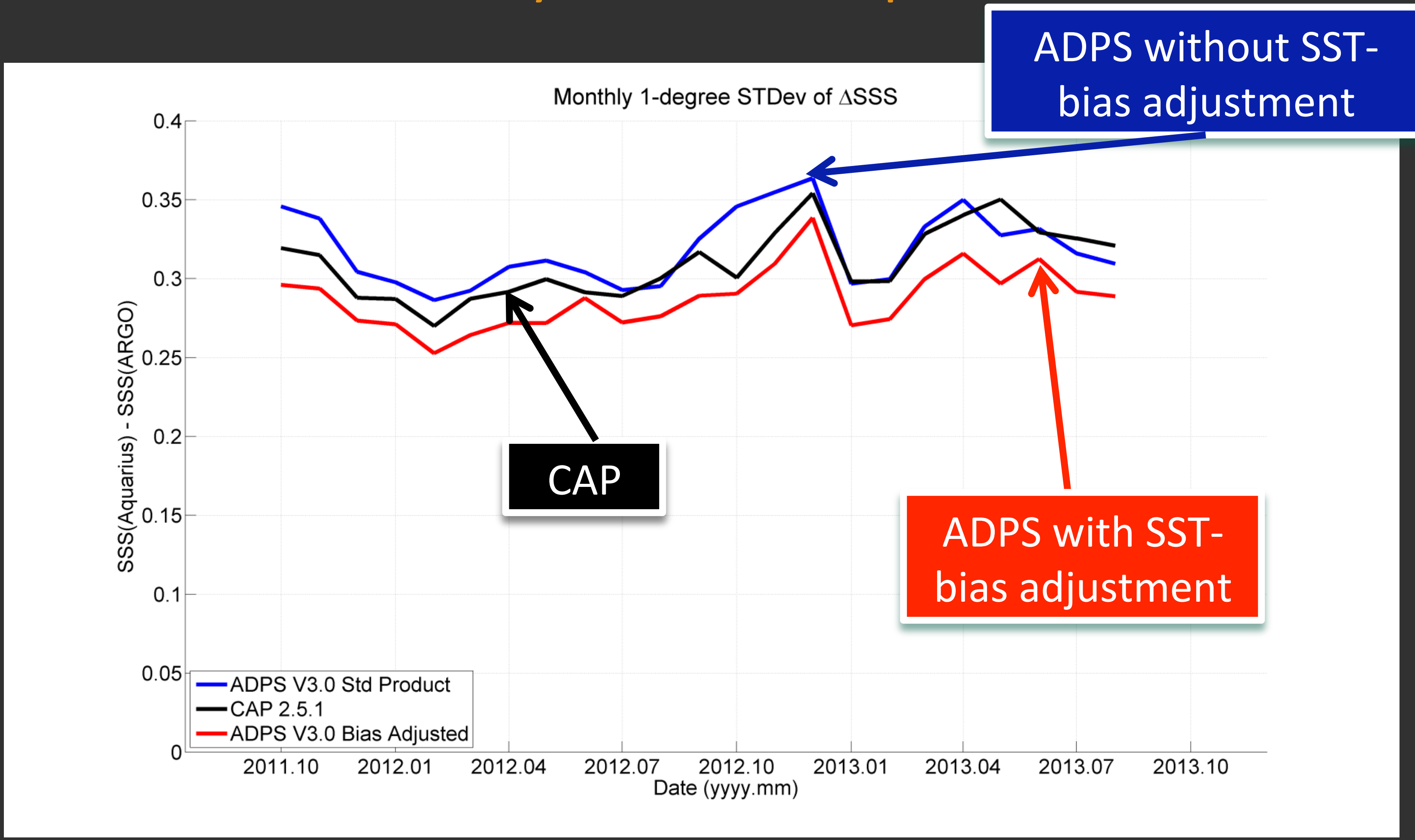


HYCOM ≠ ARGO



Std. Dev. of Monthly Averages vs. ARGO

Error dominated by local SST-dependent biases



CAP V3.0 has implemented an SST bias adjustment. So does SMOS. Need to compare ADPS SST-bias adjusted SSS with CAP V3.0.

Task and Challenge for L2 Algorithm

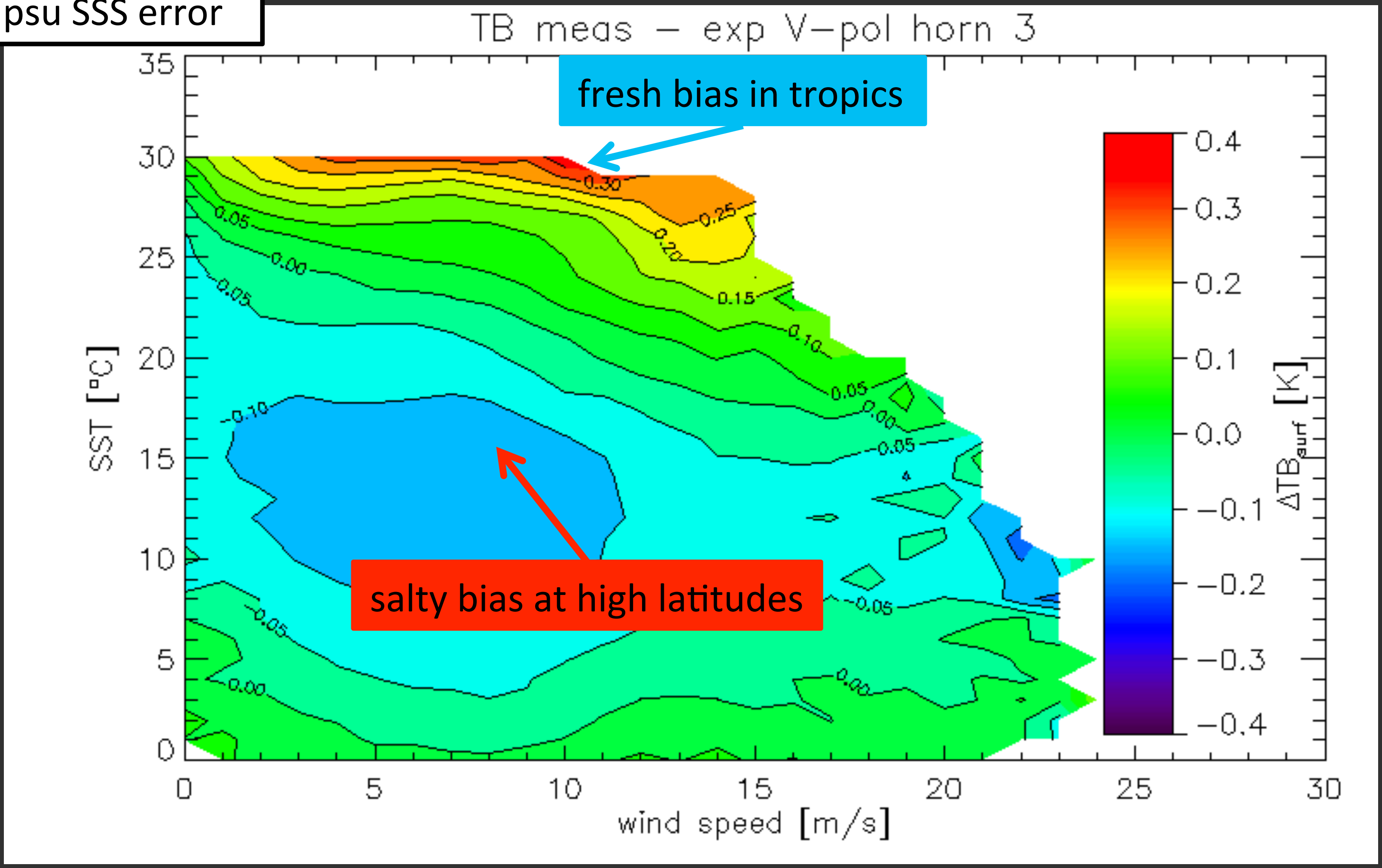
- The Aquarius salinity retrieval is a **physical algorithm**, which relates the measured TB to the emission of electromagnetic radiation from the ocean surface and its propagation through the atmosphere and ionosphere.
  - Geophysical Model (GM) based on Radiative Transfer Model (RTM)
- The goal is to try to identify the physical reason = component of the GM that cause the observed biases and correct for it.
- Should be done at the TB level and horn specific.
  - Integrated into calibration loop.

Remote Sensing Systems
www.remss.com

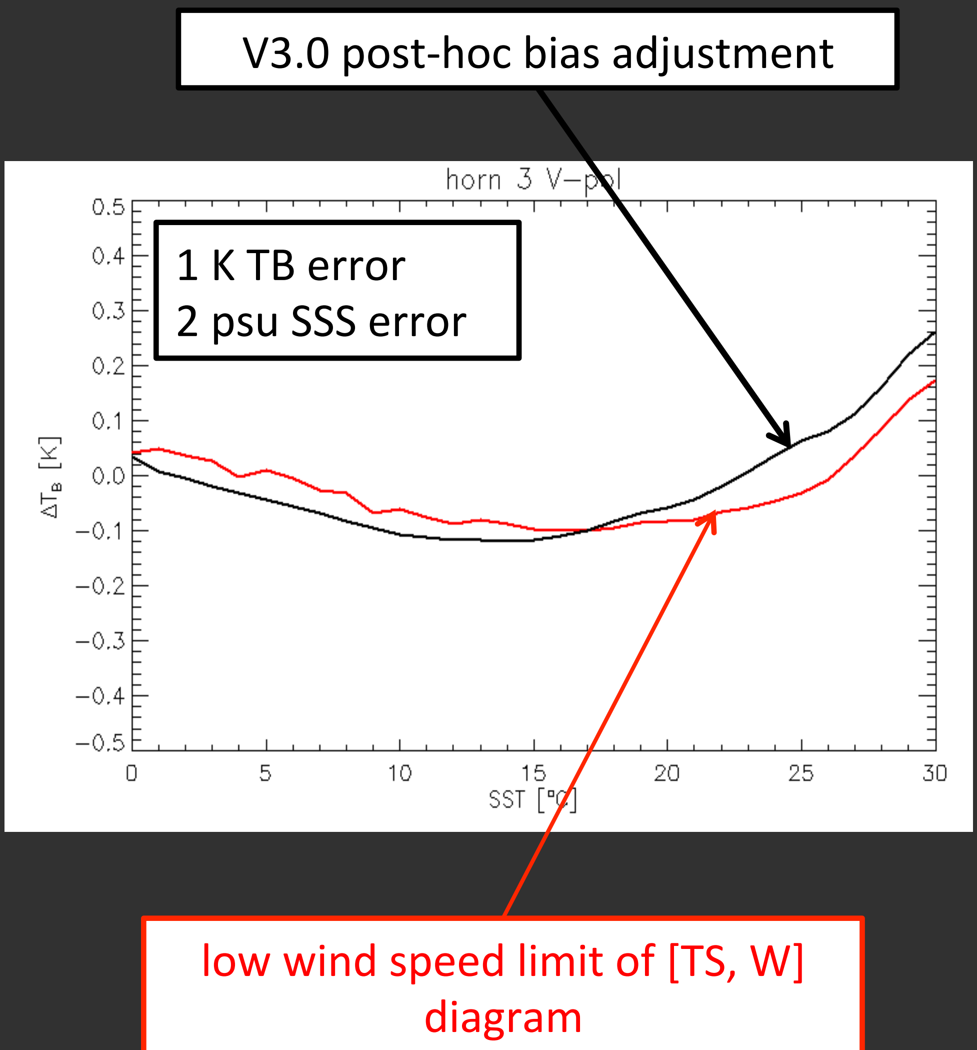
Key: 2-Dimensional Stratification

TB measured – RTM as function of SST and wind speed
Rain filtered

+ 1 K TB error
- 2 psu SSS error



Low Wind Speed Limit
Flat Surface

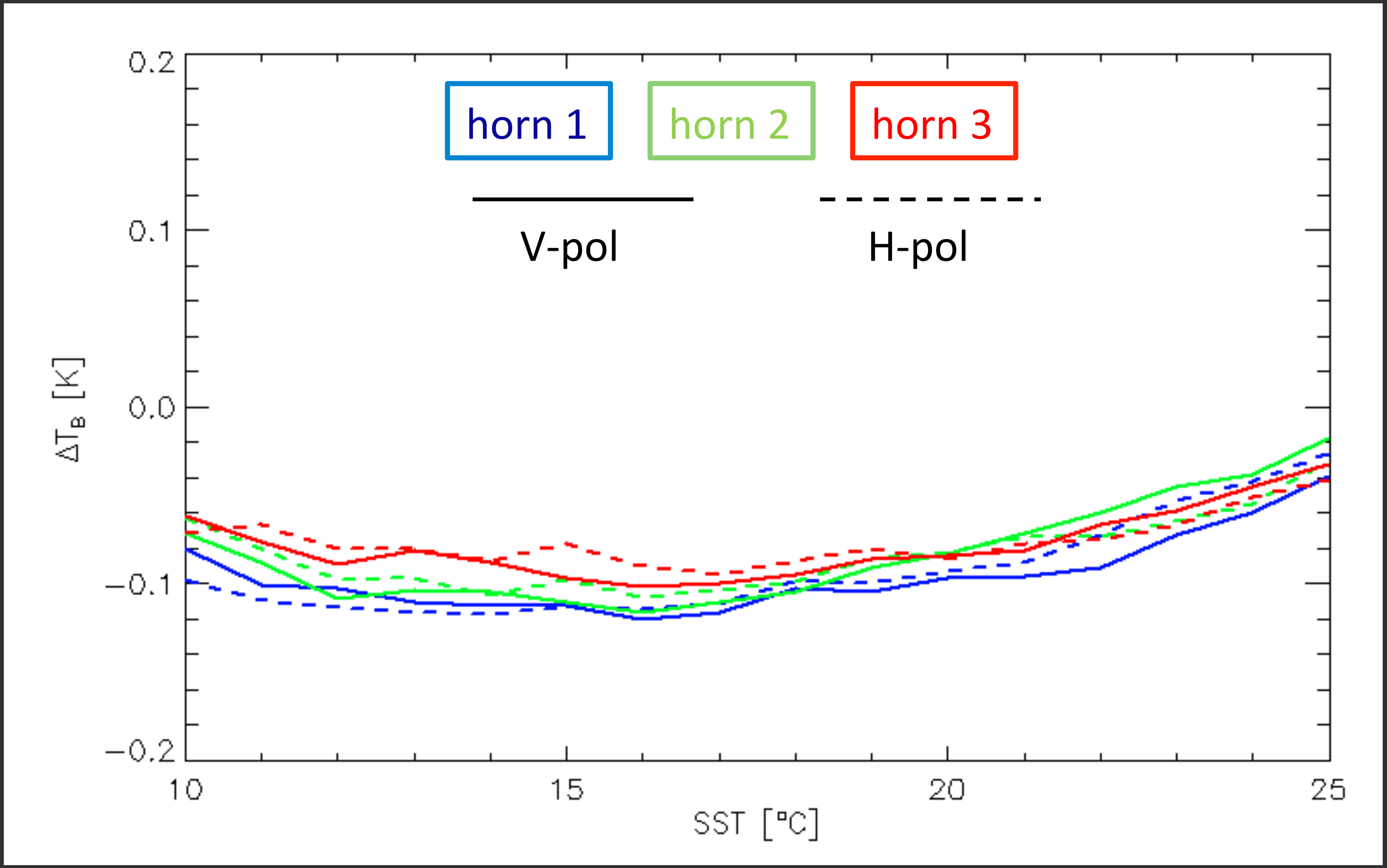


- Possible Causes:
  - Model for sea water permittivity (Meissner Wentz 2012)
  - Model for O_2 absorption in the atmosphere
  - Error in auxiliary SST input
  - NOT: Rain/Stratification
- **Small: 0.1 K level**
- Current post-hoc bias adjustment overcorrects in warm water and undercorrects in cold water (0.2 psu).

Remote Sensing Systems
www.remss.com

Low Wind Speed Limit

Channel Signature

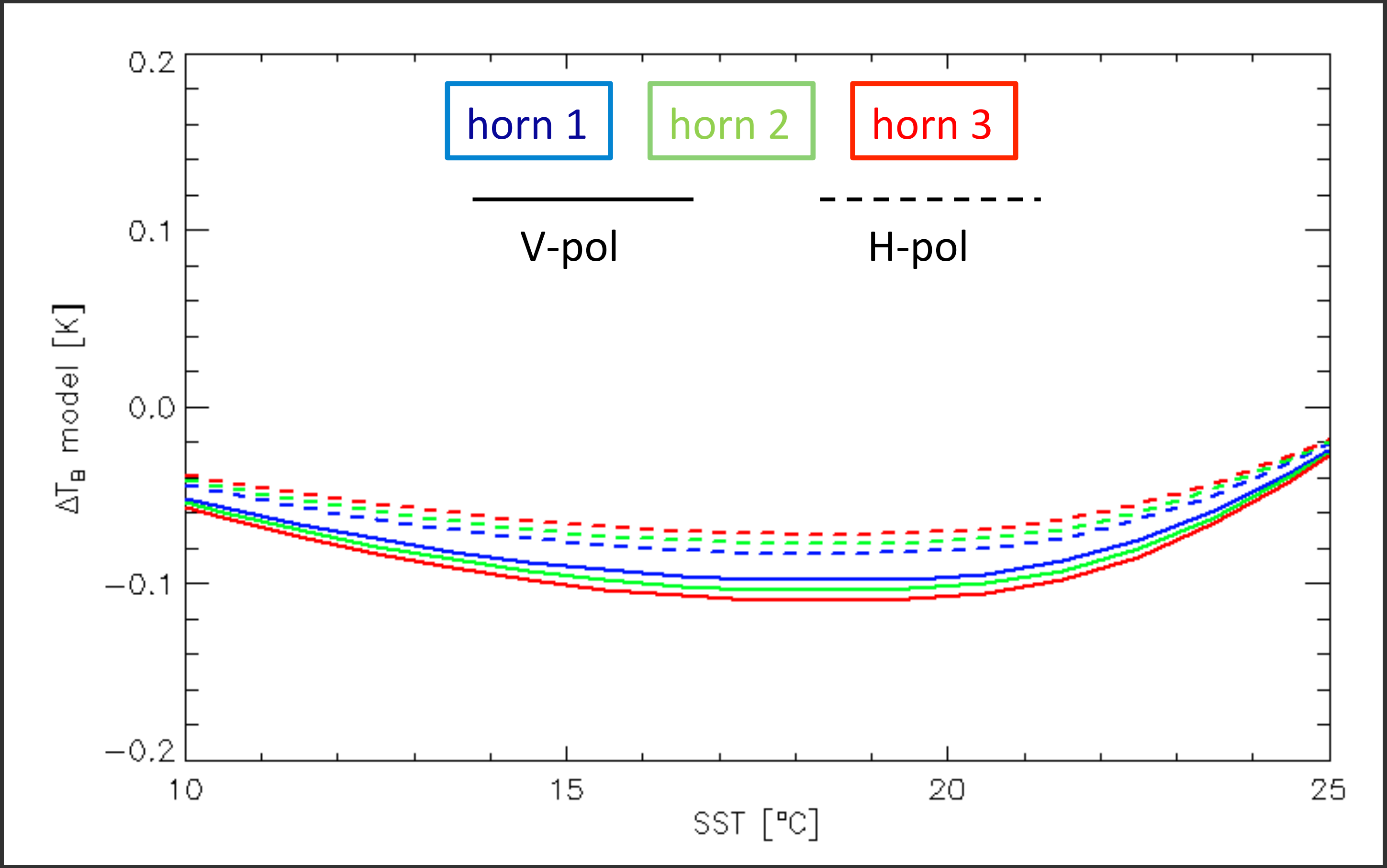


1 K TB error
2 psu SSS error

Very Small Inter-channel Differences

Small Error in Sea Water Permittivity Model

Im (ε) changed by 0.3%

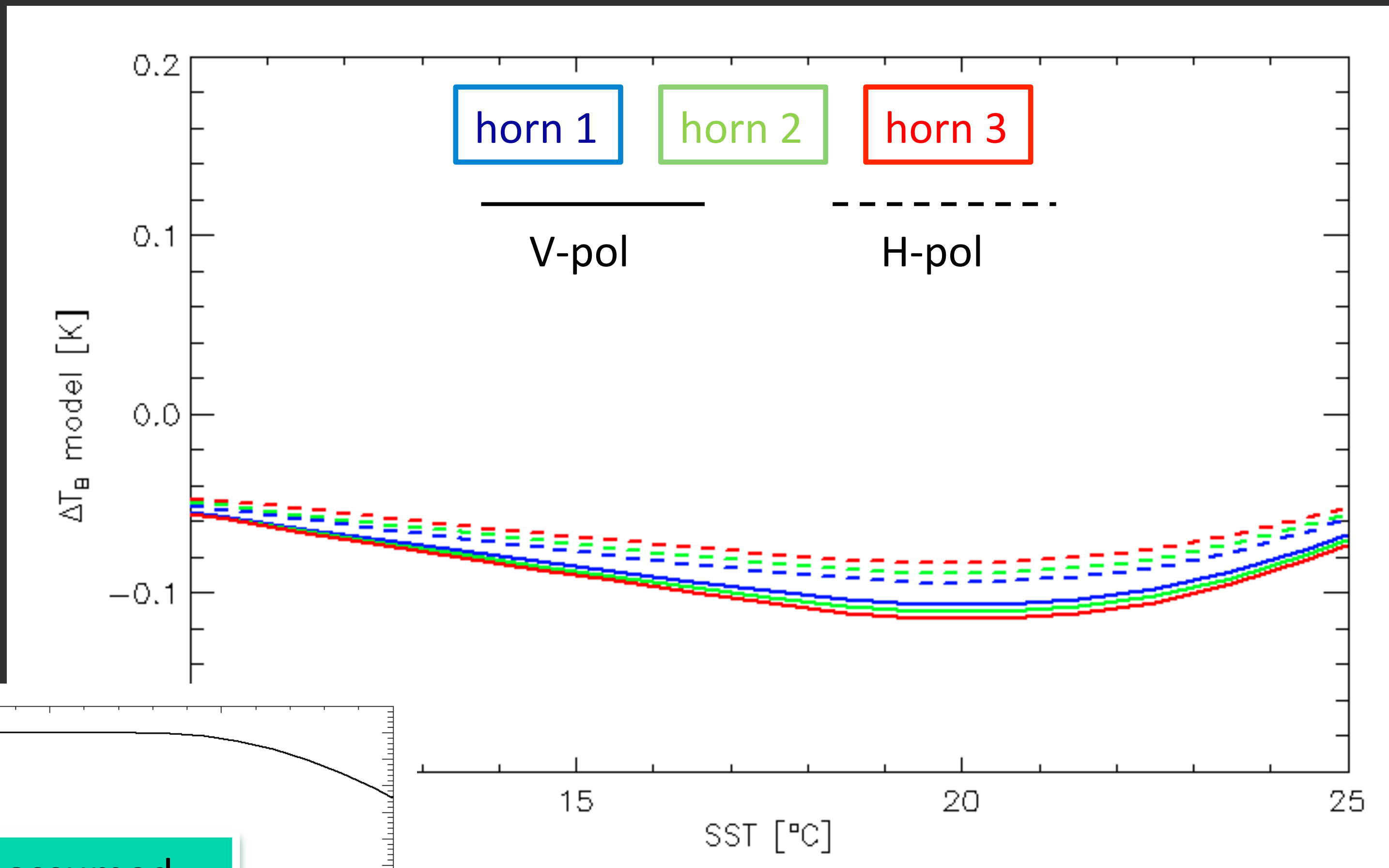


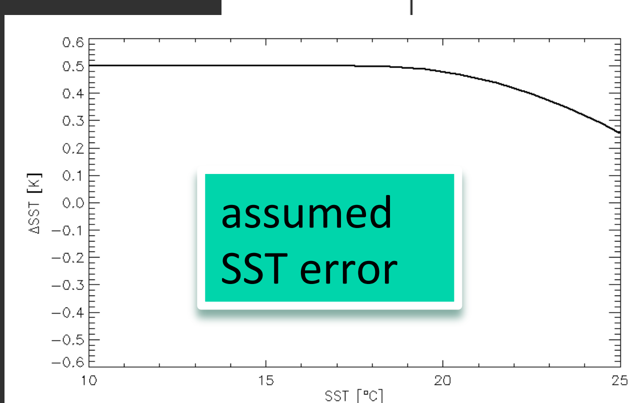
1 K TB error
2 psu SSS error

Remote Sensing Systems
www.remss.com

Small Error in Auxiliary SST Input

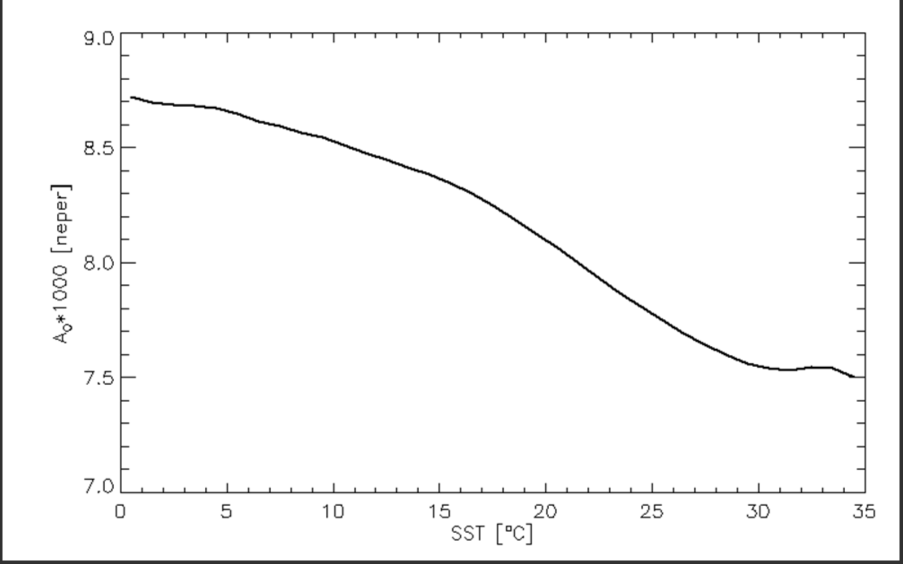
(Reynolds OI SST without MW Data)





Similar signature as error in dielectric model

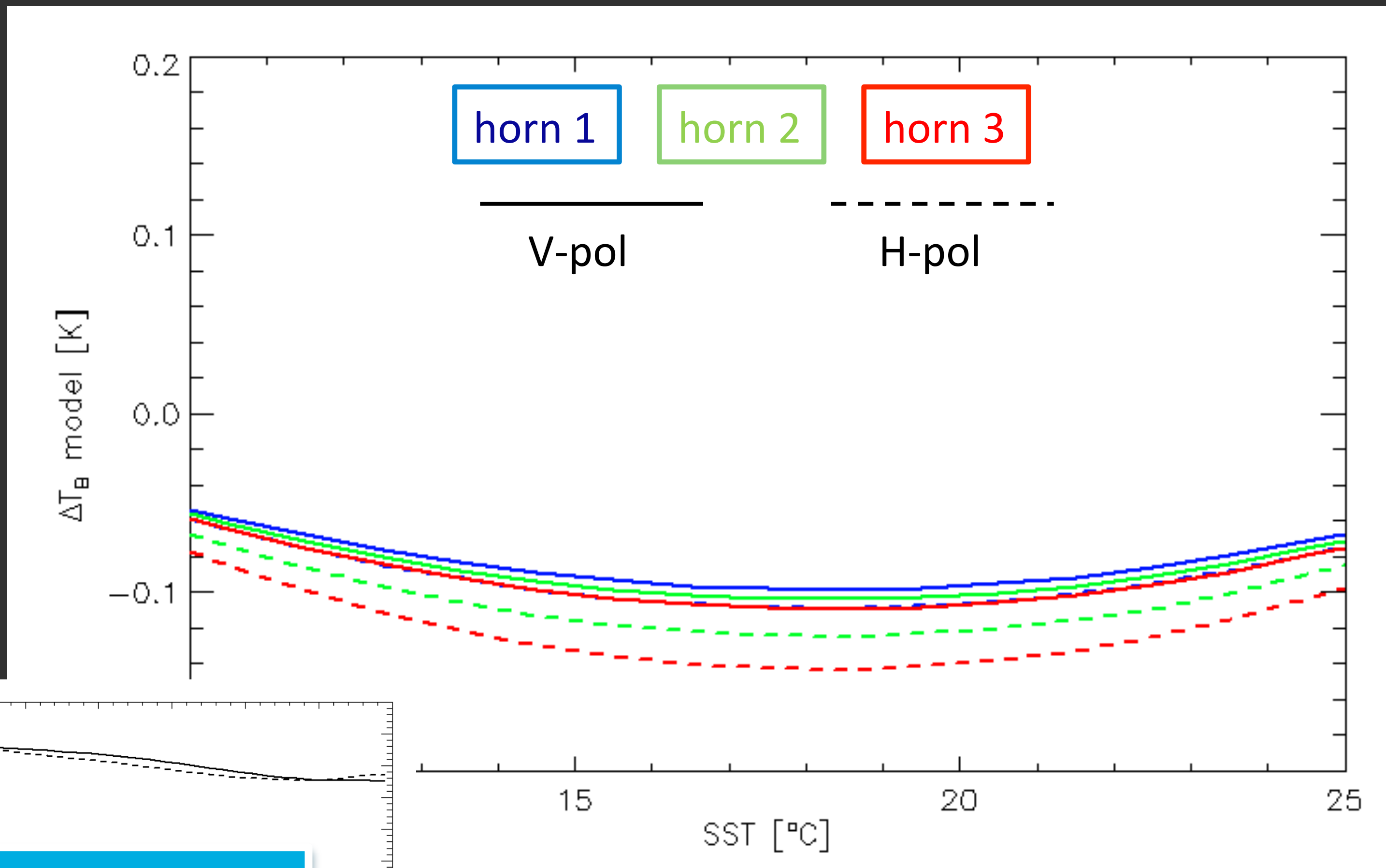
Oxygen Absorption

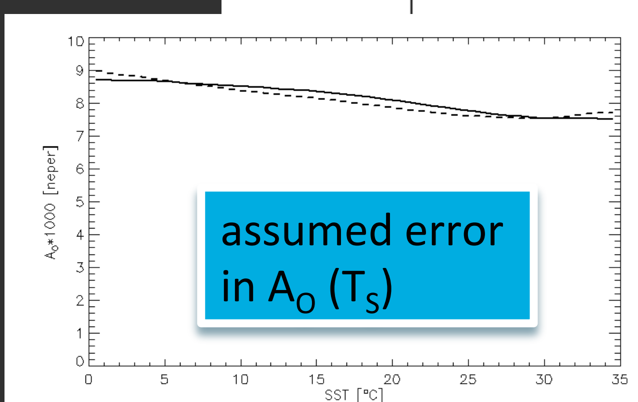


- O_2 absorption signal amounts to 3 – 5 K of TOA TB.
  It depends on atmospheric temperature, which correlates with SST.
- At L-band O_2 absorption is not caused by the 60 GHz O_2 band but due to non-resonant continuum, which is caused by transitions between degenerate (same energy) levels of the O_2 molecule. This is very difficult to measure in laboratory experiments.
- The O_2 absorption model used in V3.0 salinity retrievals is based on H. Liebe [1985], which itself quotes a paper by Mingelgrin [1974].
- We have made changes in the temperature dependence to match satellite TB with RTM TB in dry air at C-band and X-band.

Small Error in O2 Absorption

2% Change of A_O (T_S)

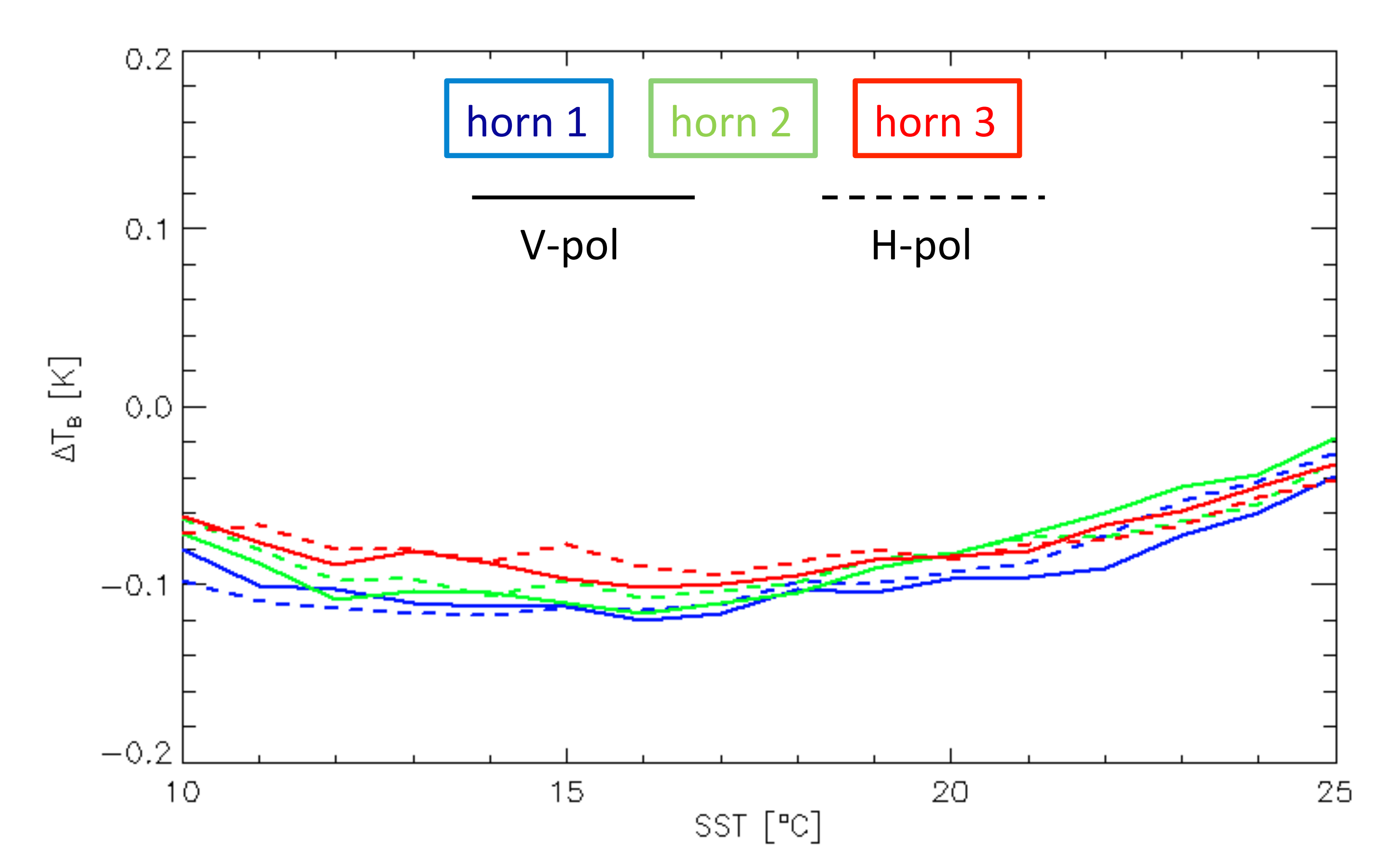




Remote Sensing Systems
www.remss.com

Low Wind Speed Limit

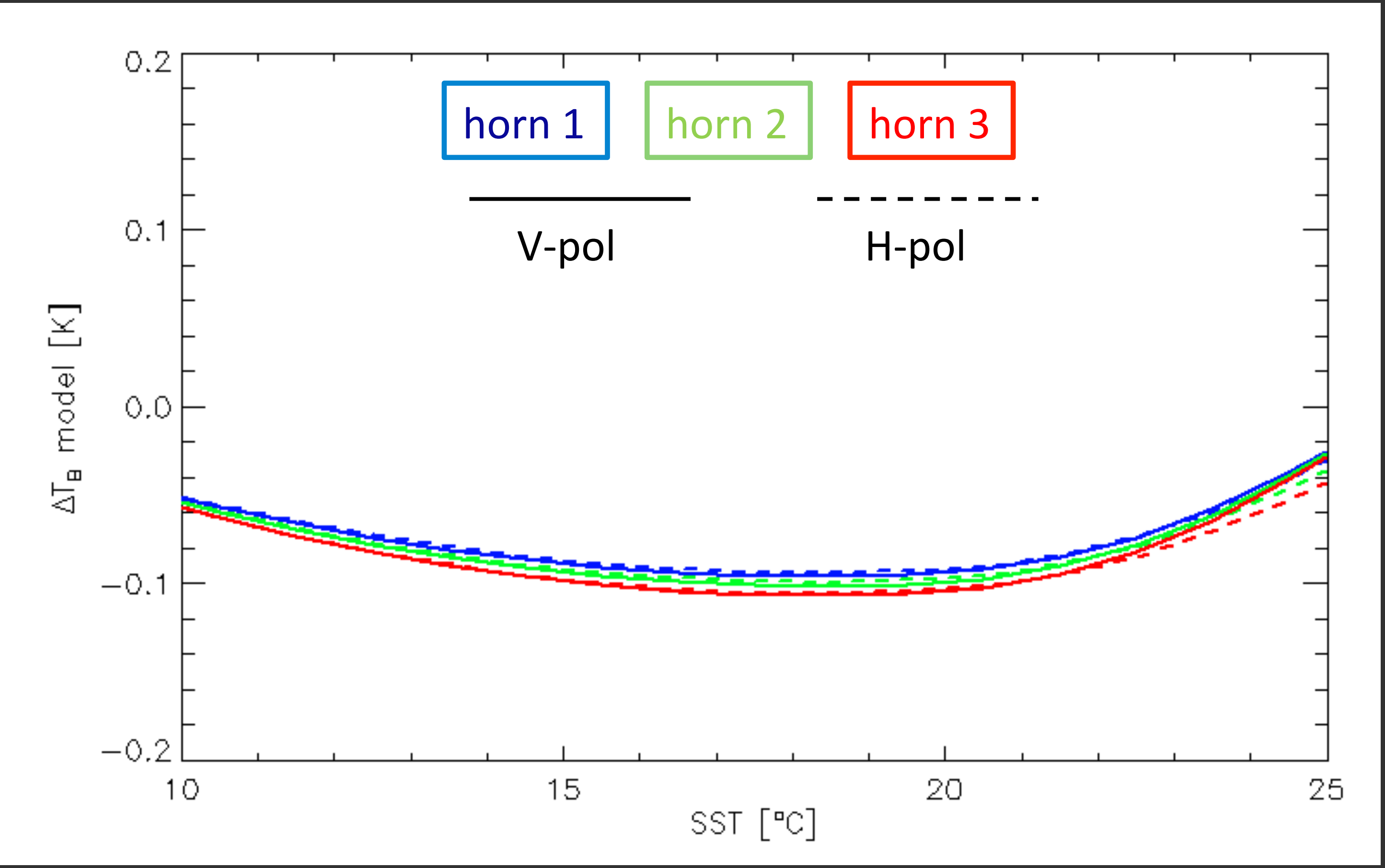
Channel Signature



Very Small Inter-channel Differences

Combined Error

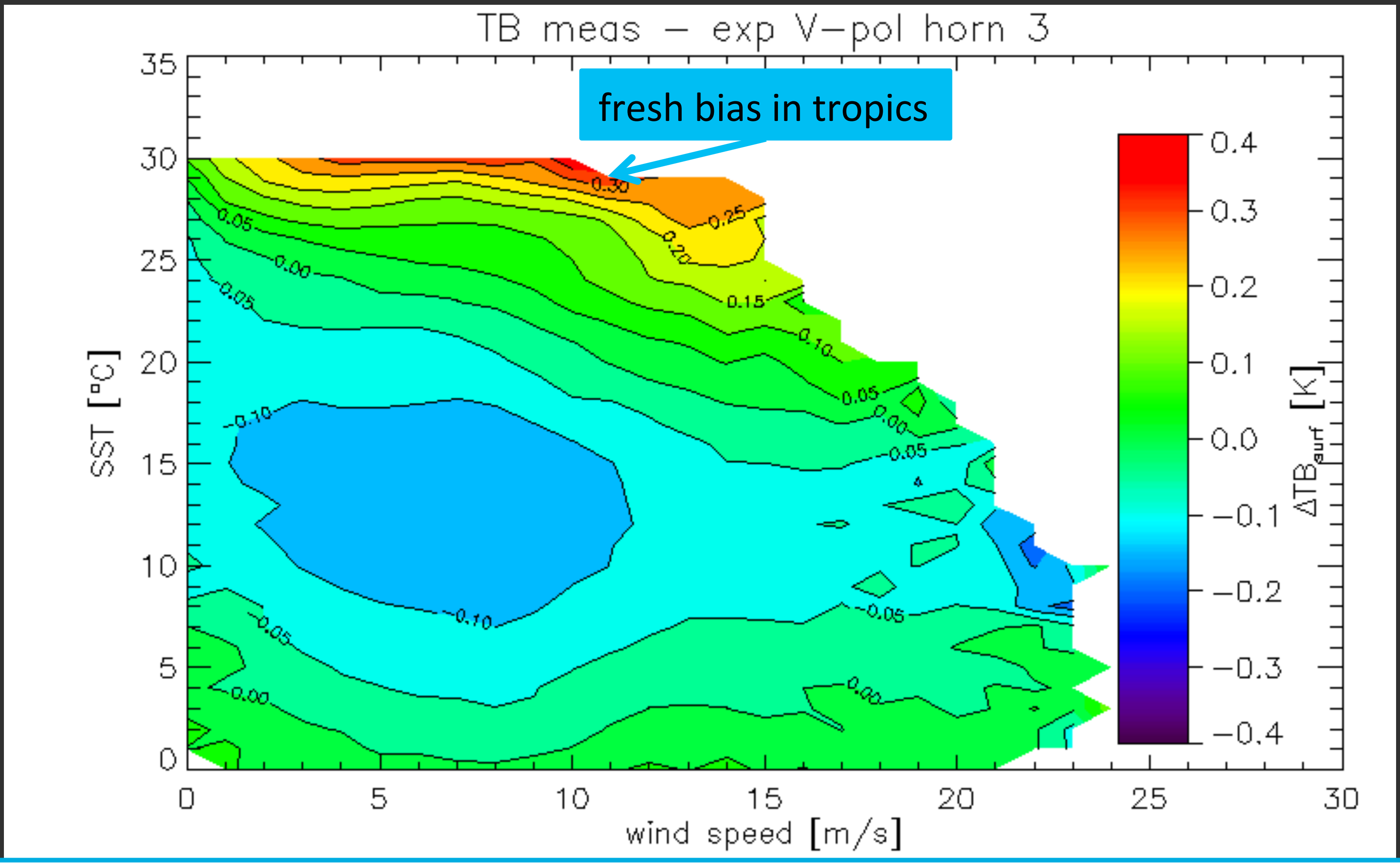
Dielectric Model + O_2 Absorption



1 K TB error
2 psu SSS error

2-Dimensional Stratification

Fresh Biases in Tropics: Increase with Wind Speed



Fresh biases in tropics are neither caused by dielectric model nor O_2 absorption, but by the modeled SST dependence in wind induced emissivity model.

Remote Sensing Systems
www.remss.com

SST Dependence of Wind Induced Emissivity

Meissner, Wentz + Ricciardulli, JGR Special Issue

$$\Delta E_W\left(W,T_S\right)=\delta\left(T_S\right)\cdot\alpha\left(W\right) \qquad \delta\left(T_S\right)=\frac{E_0\left(T_S\right)}{E_0\left(T_{ref}\right)} \qquad T_{ref}=20^{\circ}C$$

In V2.0 the wind induced emissivity ΔE_W had no SST dependence.

In V3.0 we have assumed that ΔE_W has the same SST dependence as the specular emissivity E_0.

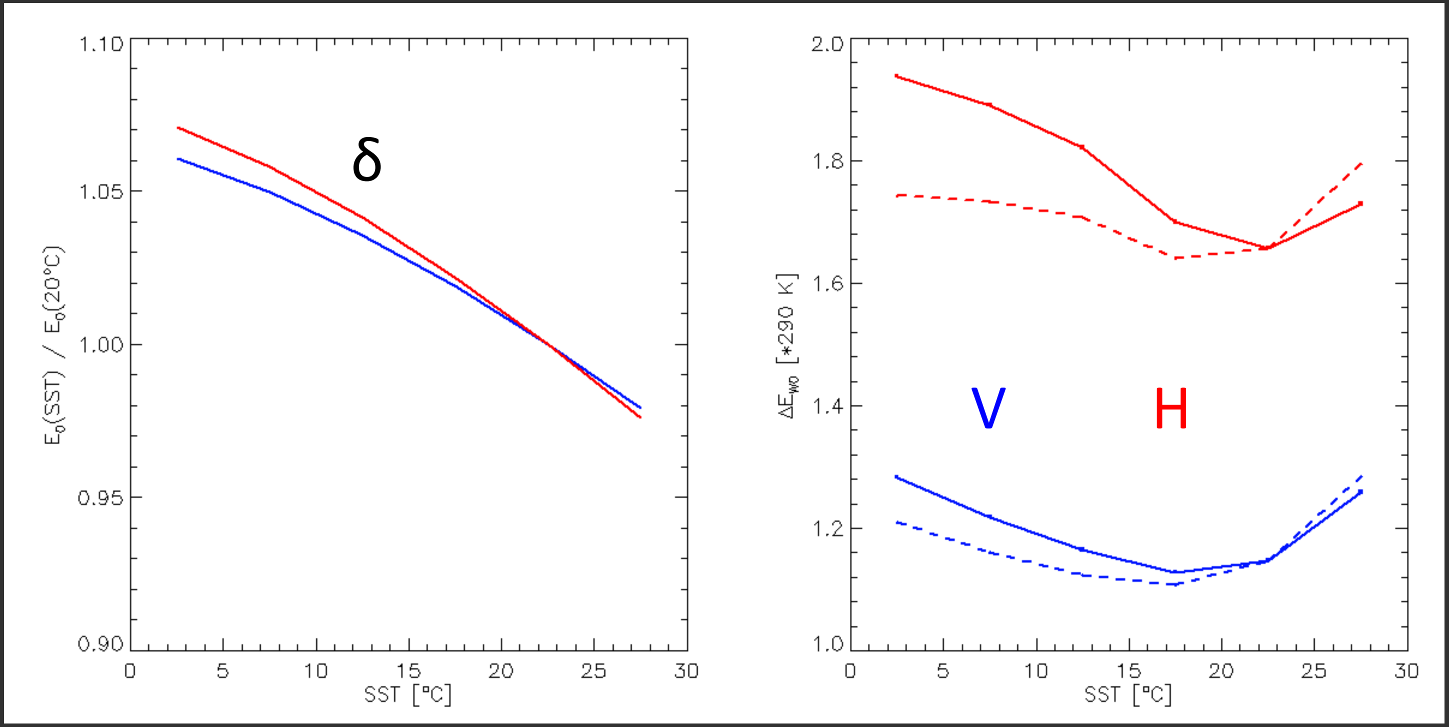
This is based on assuming geometric optics (tilted facets) and has been used in our RTM at higher frequencies.

It obviously breaks down at L-band in warm water. At L-band surface emission and scattering are different than at higher frequencies, as other physical mechanisms dominate.

Remote Sensing Systems
www.remss.com

SST Dependence of Wind Induced Emissivity

$$\Delta E_W\left(W,T_S\right) = \delta\left(T_S\right)\cdot\alpha\left(W\right) \qquad \delta\left(T_S\right) = \frac{E_0\left(T_S\right)}{E_0\left(T_{ref}\right)} \qquad T_{ref} = 20^oC$$



full: $\Delta E(T_S)$ for average wind speed.
dashed: divide by δ. ideally should be flat.

The assumed SST dependence **improves the model up to 20°C** but **makes it worse in very warm water**.

Summary

- SST dependent biases need to be stratified in **2 dimensions as function of SST and wind speed**.
- Low wind speed limit:
  - Reveals biases in dielectric model, oxygen absorption, auxiliary input SST
  - The observed biases are small (≈0.1 K)
  - The causes have similar signature and are thus hard to separate on that level
- Moderate - Higher wind speeds
  - Reveals biases in surface roughness model
  - Larger (up to 0.3K)
  - **Assumption that the T_S dependence of ΔE_W can be modeled by the specular emissivity E_0 breaks down at high T_S**

Going Forward

- Tweaking dielectric model ε or oxygen absorption model A_O
  - Likely futile.
  - Very small (0.1 K).
  - Ambiguous signature.
  - Physics of electromagnetic radiation has consequences at higher frequencies, which would need to be reanalyzed.
- Most important step in mitigating the large scale ST dependent biased is to adjust the SST dependence of ΔE_W

$$\Delta T_B(W,T_S) \approx \beta(T_S) + \delta'(T_S)\cdot\alpha(W)\cdot T_S$$

Small change in ε or A_O

adjust SST dependence of ΔE_W

Backup Slides

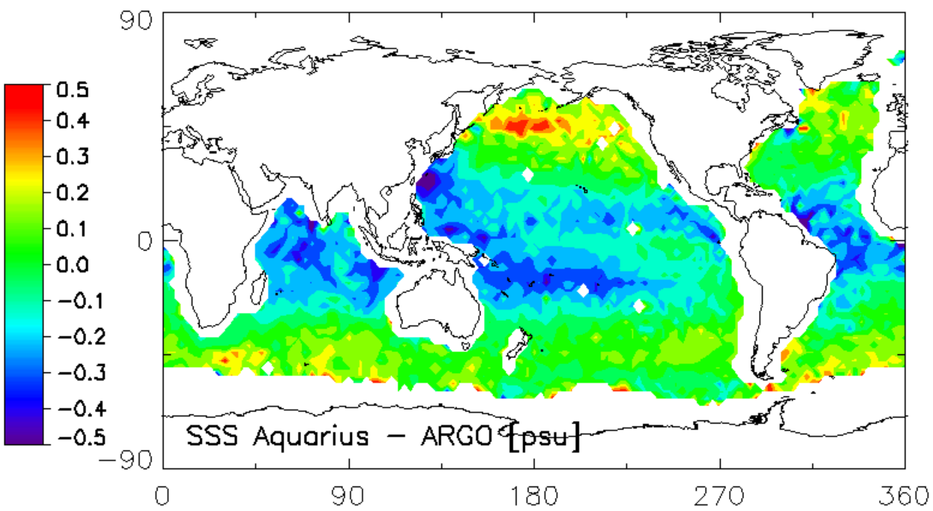
Performance: Local Biases

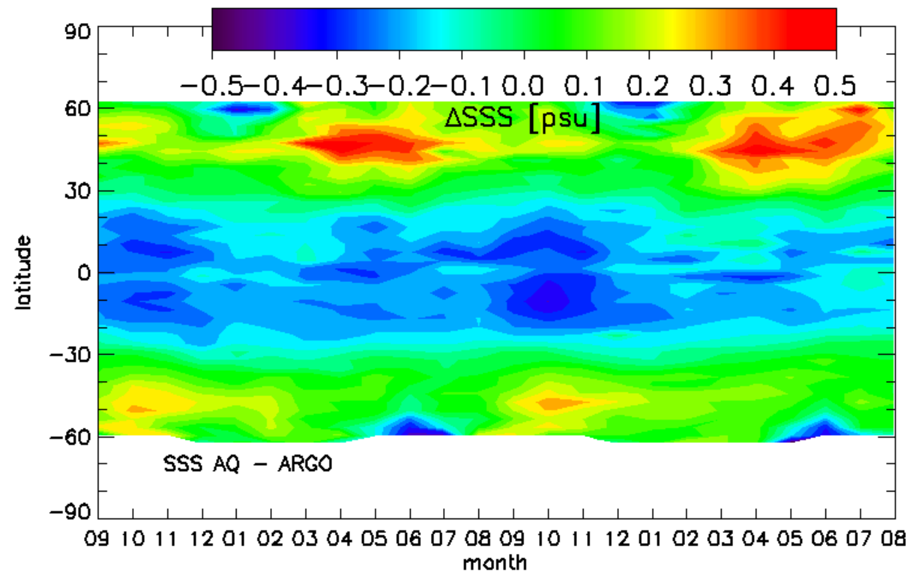
Aquarius - ARGO

Latitude

Month

2-year: 09/2011 – 08/2013

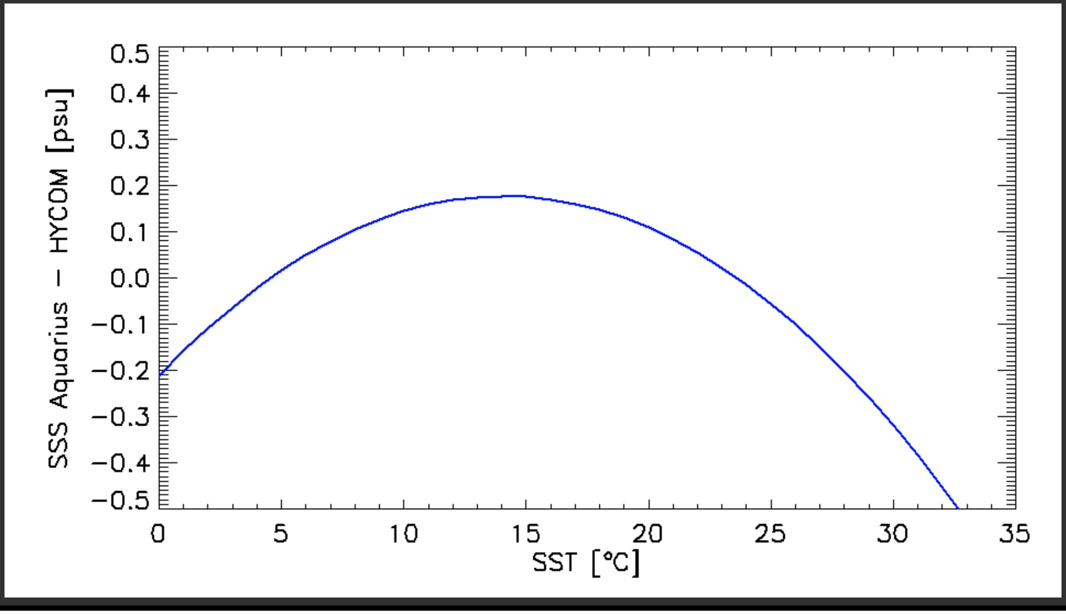




- **Fresh biases in tropics and subtropics.**
- **Salty biases at mid-high latitudes.**
  - **Biggest in N Pacific.**
- **Seasonal pattern.**

SST Dependent Biases

Post-hoc Correction (1)



- **Rain has been filtered out. Bias is not due to stratification.**
- **Sensor calibration: Aquarius is globally adjusted to HYCOM. Rain is not filtered when running calibration, which makes Aquarius too salty. But the effect is very small for global average: 0.04 psu.**
- Not caused by residual RFI contamination: Aggressive filtering for possible RFI (see S. Brown) does not change it significantly.

Impact on Performance

Triple Colocation Statistics

Global. Rain Filtered

AQ – HYCOM – ADPRC ARGO Differences σ [psu] 3^{o} monthly averages			
	AQUARIUS – HYCOM	AQUARIUS – ARGO	HYCOM – ARGO
V3.0	0.29	0.31	0.25
SST Bias adjusted	0.24	0.27	0.25

Estimated Individual Errors σ [psu] AQ – HYCOM – ADPRC ARGO σ [psu] 3^{o} monthly averages (1.5^{o} monthly averages)			
	AQUARIUS	HYCOM	ARGO
V3.0	0.24 (0.27)	0.16	0.19
SST bias adjusted	0.18 (0.22)	0.16	0.19