Assessment of Rain Impact on the Aquarius Salinity Retrievals

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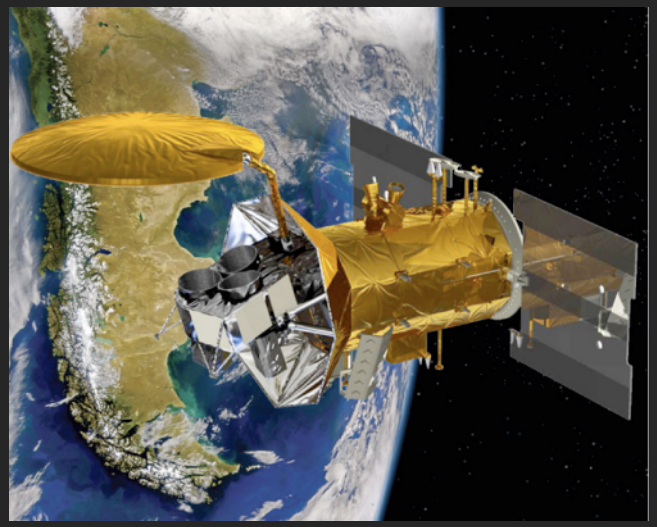

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Met Office, Exeter, UK

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NASA

Outline

1. Aquarius ADPS Version 3.0
   - Major Updates from V2.0
2. Local Biases
   - Rain Effects versus Geophysical Model Function
3. Rain Impact: Atmosphere
4. Rain Impact: Surface Splashing
5. Rain Impact: Freshening
6. Freshwater Lensing
7. Summary

Aquarius ADPS Version 3.0

Official Aquarius Product. Released June 2014.

ADPS V2.0

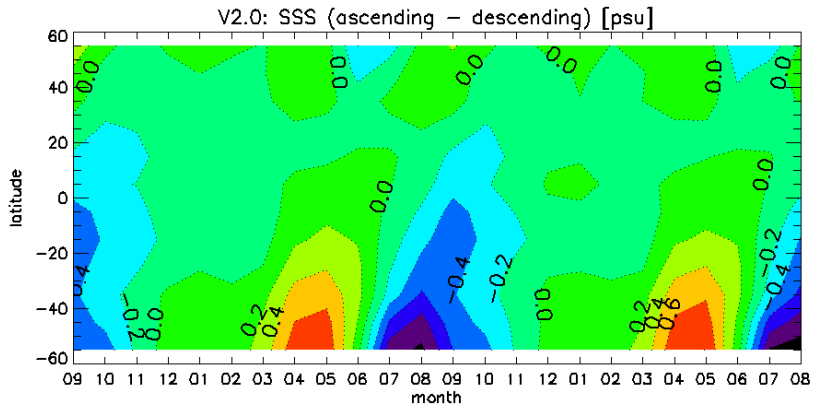
- Surface Roughness Correction
  - Based on NCEP wind speeds
- Reflected Galaxy
  - Physical model:
    Ocean surface modelled as ensemble of tilted facets: Geometric Optics

ADPS V3.0

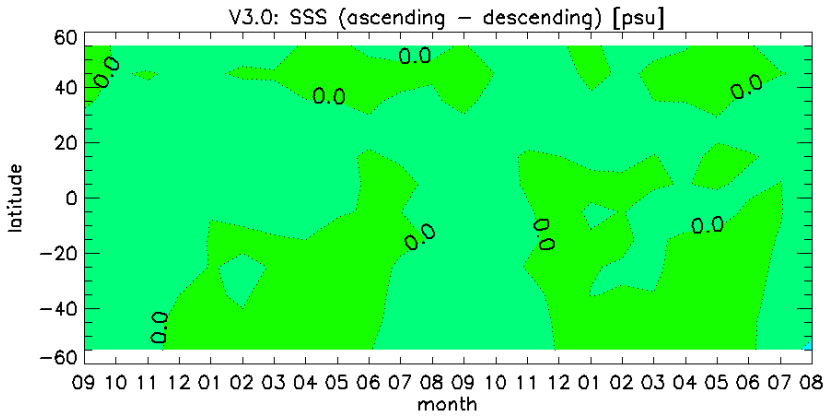
- Surface Roughness Correction
  - Based on Aquarius wind speeds
  - HH-pol active and H-pol passive
- Reflected Galaxy
  - Geometric Optics (about 90%)
  - Empirical correction: Symmetrization between ascending and descending swaths
- Q/C Flagging
  - degraded conditions
  - undetected RFI
- Antenna Pattern Correction
  - Reduced biases over land + ice
  - Reduced biases in 3rd Stokes
- ΔSSS (SST) bias adjustment
  - mitigates large scale biases

Ascending (PM) – Descending (AM) Biases

GO (V2.0)

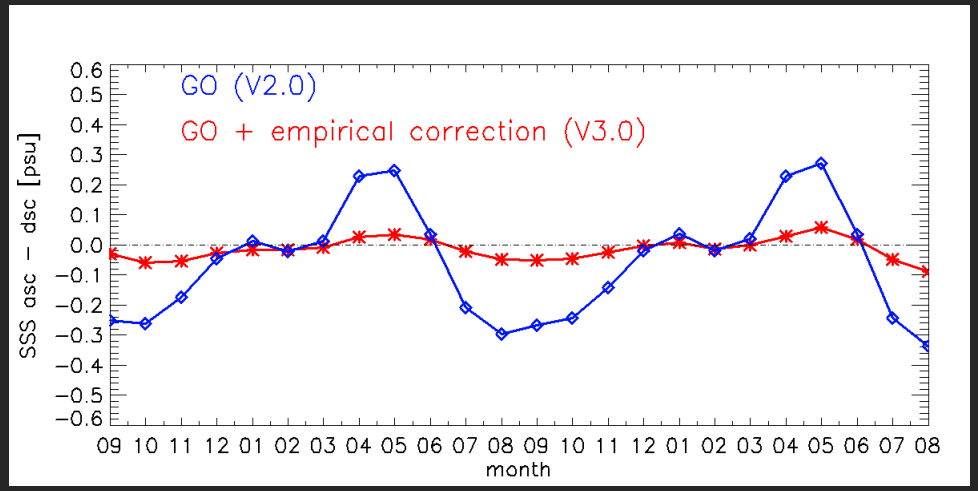


GO + empirical adjustment (V3.0)



Latitude

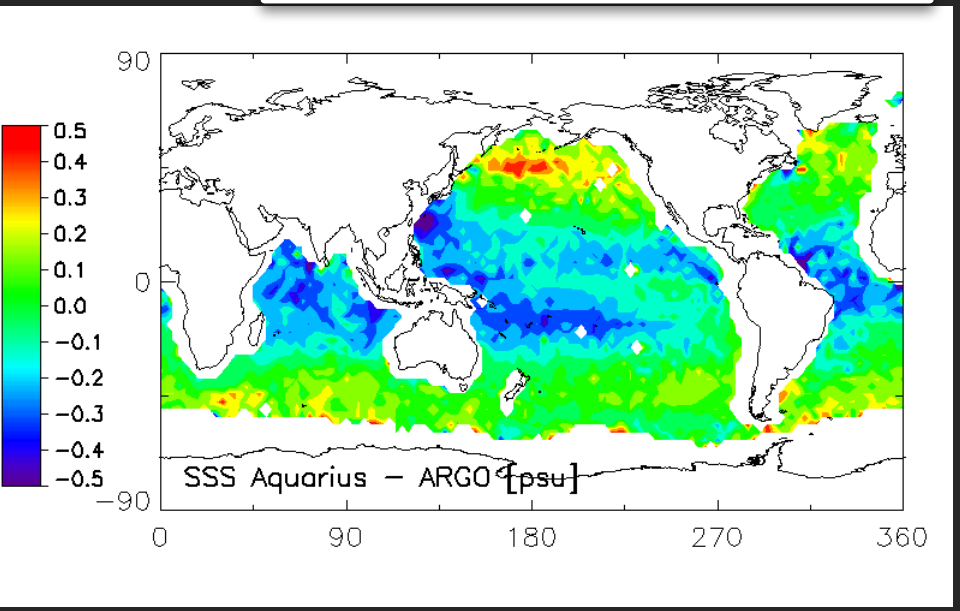
Month

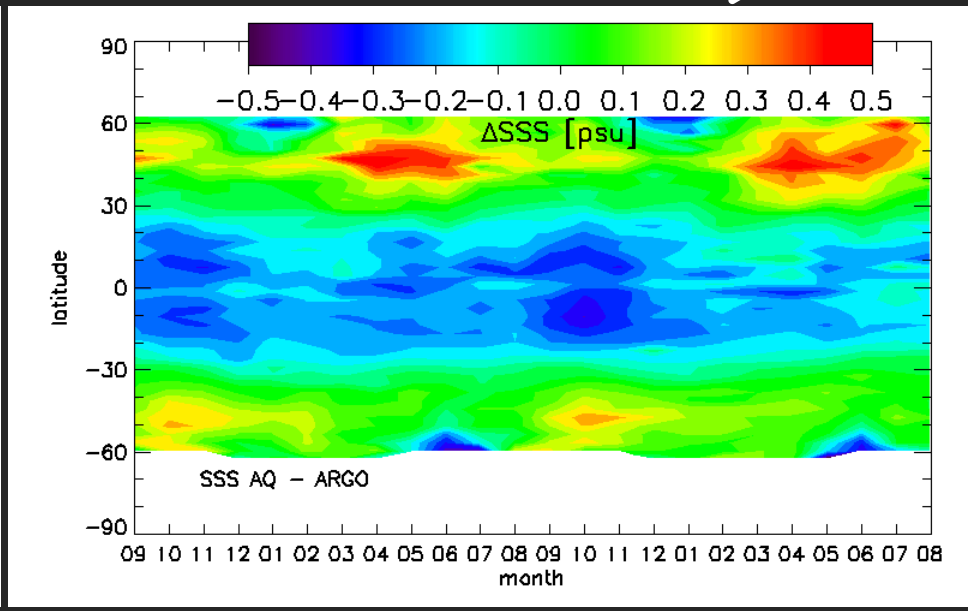


Performance: Local Biases

Aquarius - ARGO

2-year: 09/2011 – 08/2013





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

Causes of Regional Biases and Mitigation

"Real"

Aquarius is correct

should not be corrected

- Rain induced freshening
  - Mainly tropics (ITCZ)
  - Stratification of upper ocean layer.
  - Aquarius measures within few cm of surface.
  - In situ measurements at various depth:
    - ARGO: 5 m
    - HYCOM: upper layer ?
    - moored buoys: 1m

"Fake"

should be corrected/mitigated

- Errors in the geophysical model function that is used in the SSS retrieval and that has a zonal signature.
- Rain
  - splashing effect on surface
  - atmosphere
- Undetected RFI
  - entering through sidelobes
  - makes SSS artificially low
  - issue in certain areas (China, Japan, Indonesia, …)

It is essential to separate the effects.

Rain Measurement and Filtering

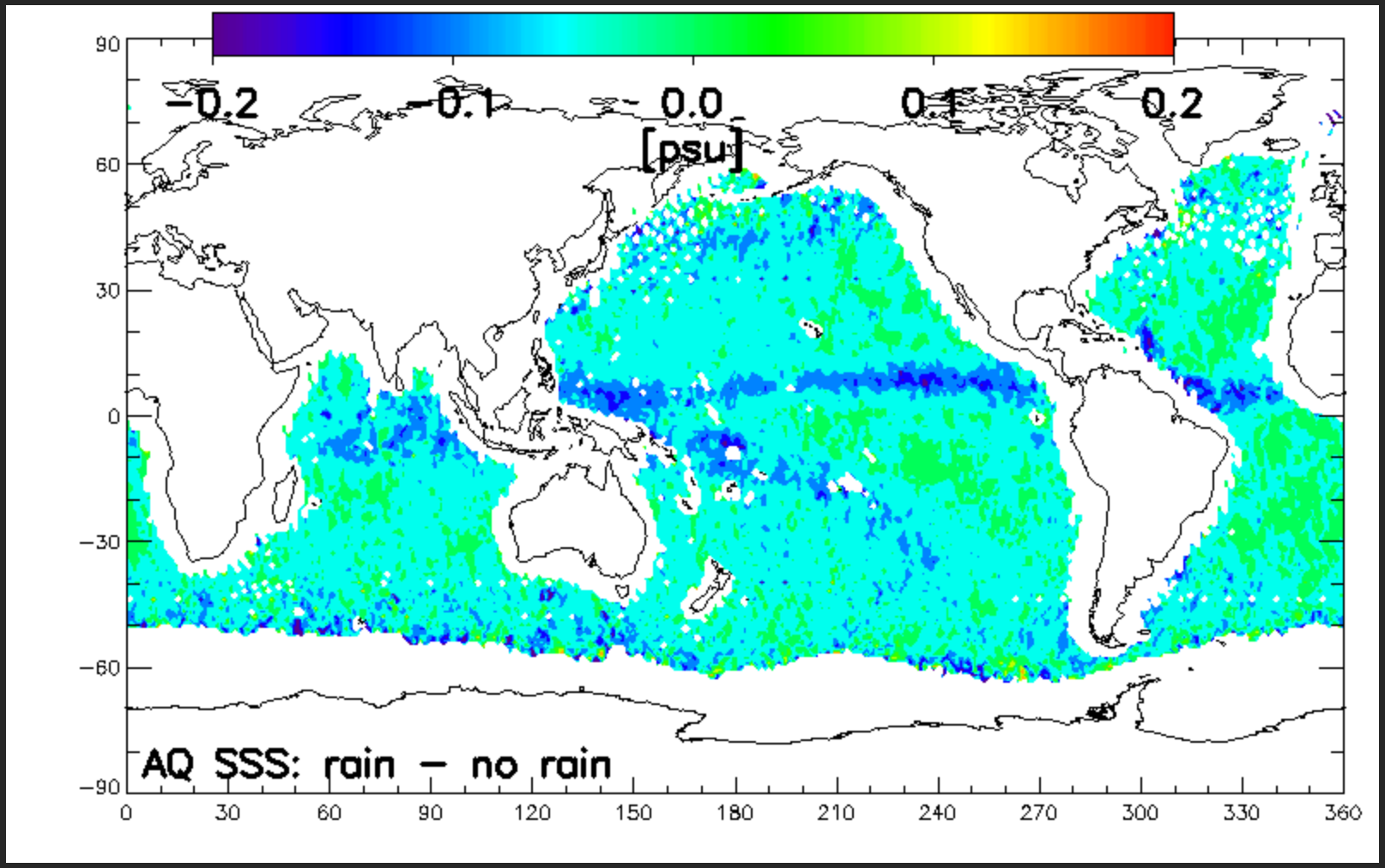
- **Approach:**

1. **Filter out rain at or close to Aquarius observation .**
2. **Choose observations that are not impacted by undetected RFI.**
3. **Deal with the model function dependent biases.**
4. **Estimate atmospheric effects and surface splashing.**
5. **Left with the real freshening.**

- **CONAE Microwave Radiometer (MWR): K and Ka –band**
  - On Aquarius platform
  - Was operating until April 2014
  - Allows rain measurement at the location and time of Aquarius observation
  - Rain rates are not very good (no 18 GHz channel)
  - Allows rain flagging: Aquarius observation rain free
  - Available at RSS ftp server ftp://Aquarius_mwr:mar23vista36@ftp.remss.com/aquarius_mwr/rss_l2c_h5/
  - Will be available at PO.DAAC

- **Microwave Imagers**
  - SSMIS (F17), WindSat: 1 hour within Aquarius (same equatorial crossing time)
  - TMI: crossing time shifting relative to Aquarius
  - Can detect rain within time window of Aquarius observation

Aquarius SSS: All Events – Rain Filtered

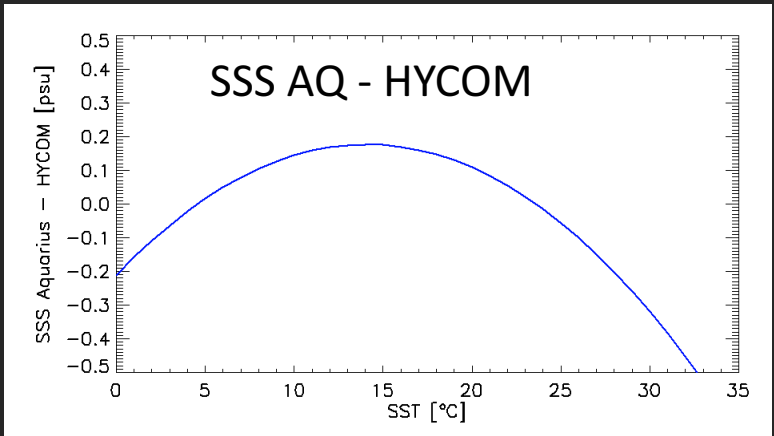


About 30% of the fresh biases at low latitudes are due to rain.
The salty biases at high latitudes are not due to rain.

Causes of SST Dependent Biases

- Geophysical Model Function GMF that is used in the retrievals
  - 0.1 K uncertainty in GMF is 0.2 psu uncertainty in SSS
  - Dielectric constant of seawater
  - Oxygen absorption model used for atmosphere (non-resonant continuum)
  - **Surface roughness model**
  - Error in auxiliary SST field that is used in the retrievals (cold water)
  - Undetected RFI
  - A combination of such
  - We are currently tracking that down. Improvement planned for V4.0.

- "Bias adjusted" SSS product
  - provided in V3.0 in addition to standard product



Impact on Performance

Local Biases

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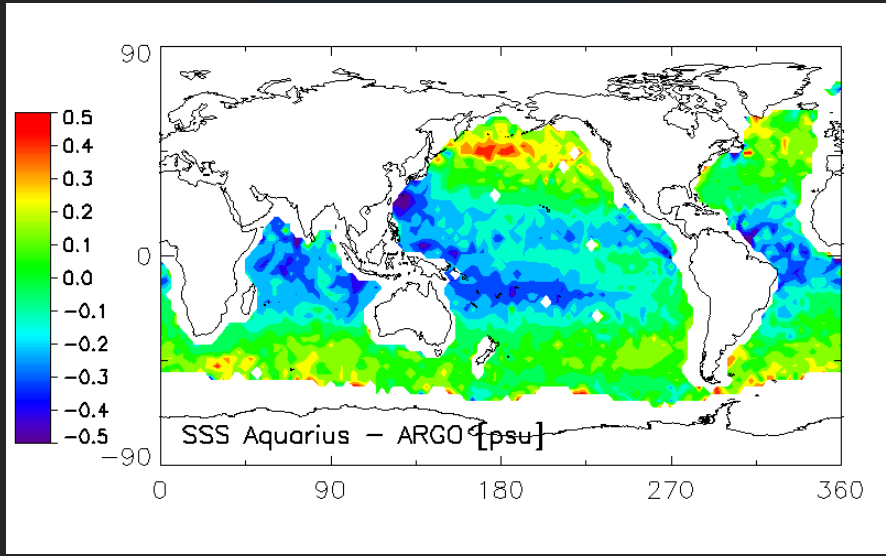
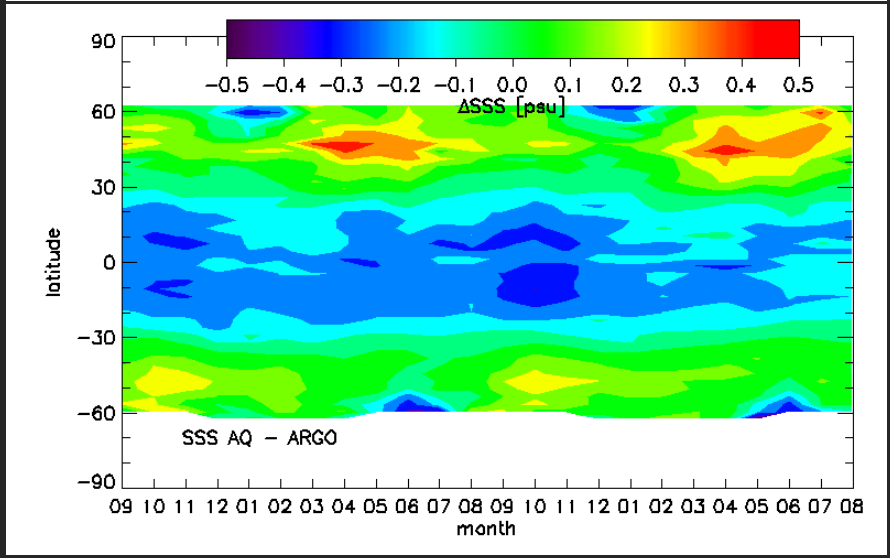
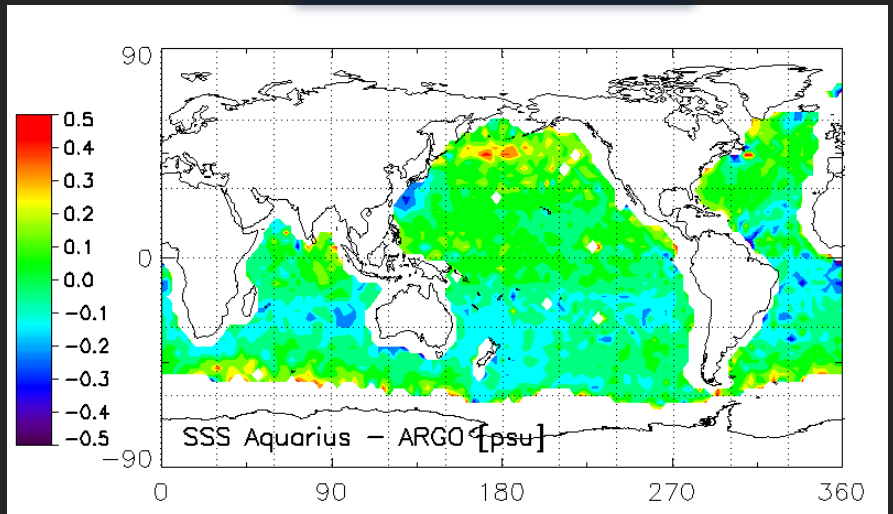
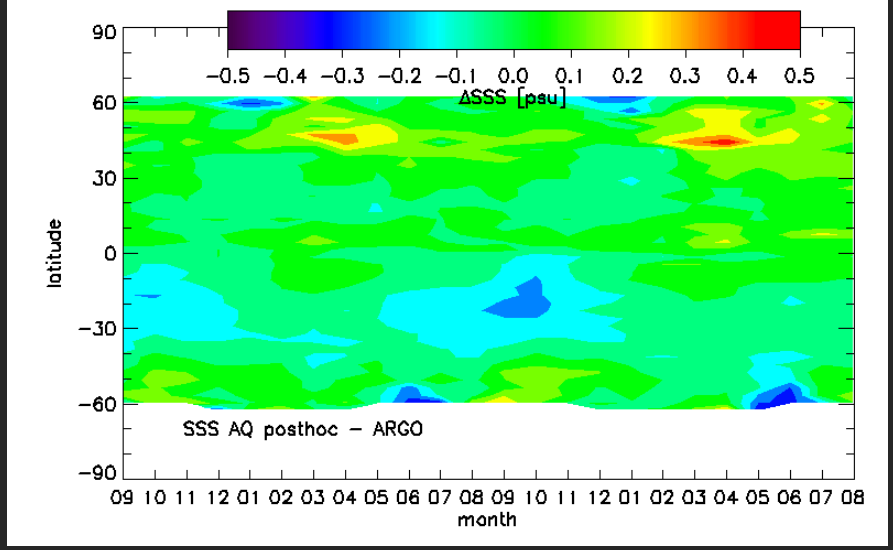
V3.0
no rain filter





bias adjusted
rain filter





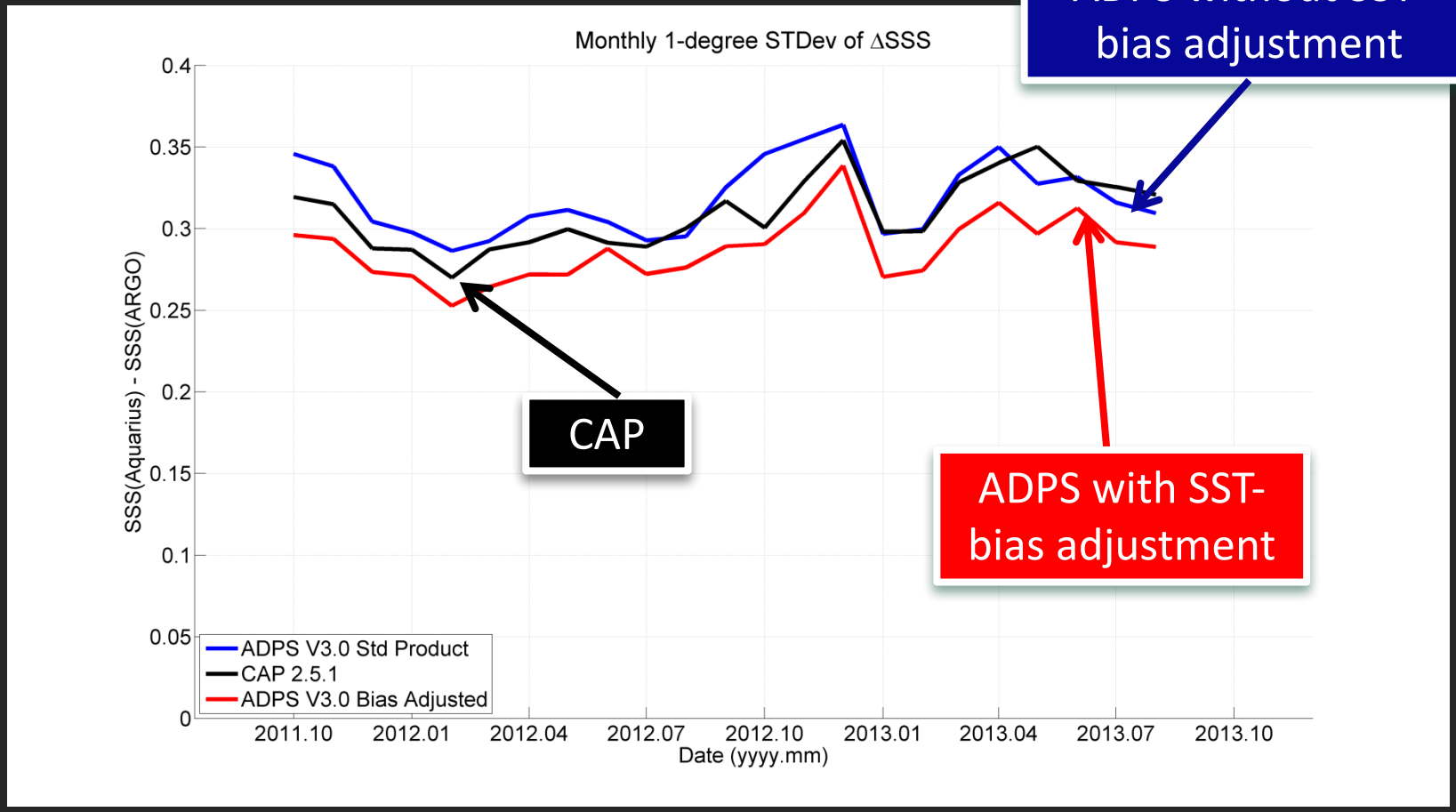
Impact on Performance

Triple Colocation Statistics
Global. Rain Filtered

Estimated Individual Errors σ [psu]
AQ – HYCOM – ADPRC ARGO σ [psu]
Triple Collocation: Assume that errors in the 3 products are independent
3° monthly averages
1.5° monthly averages
***"Errors"* in HYCOM/ARGO due to sampling**

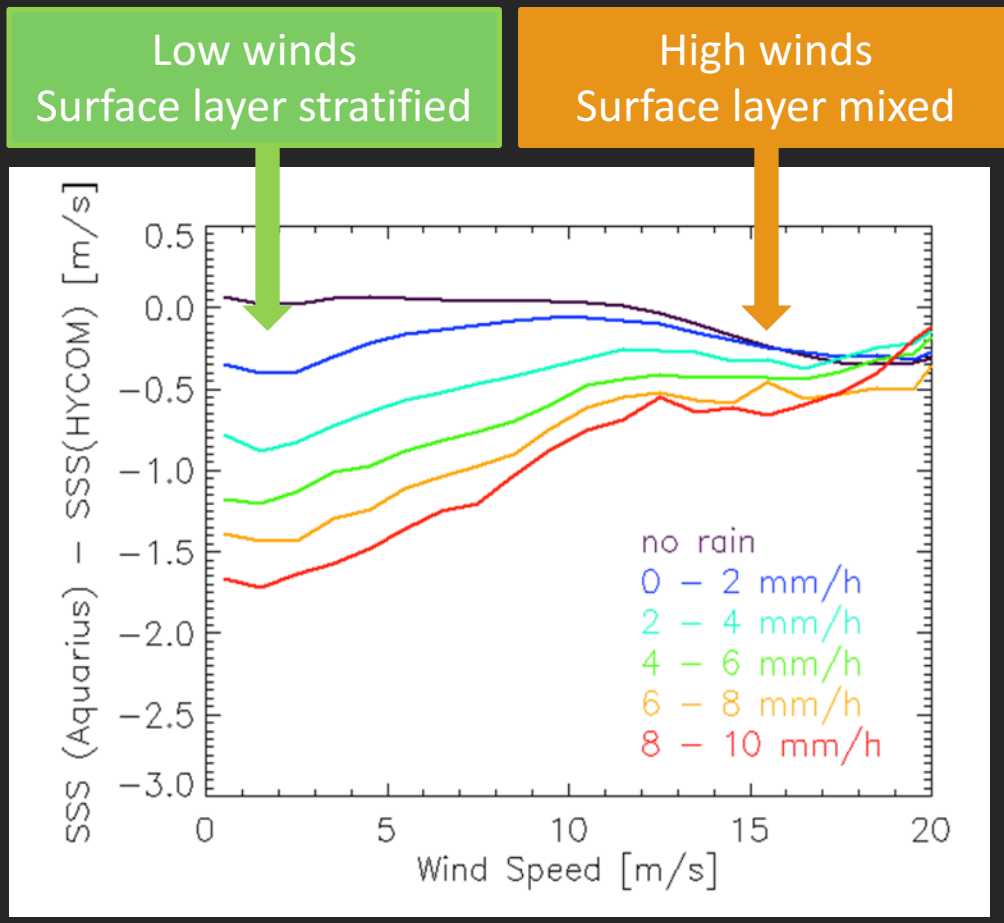
	AQUARIUS		HYCOM	ARGO
V3.0	0.24	0.27	0.16	0.19
SST bias adjusted	0.18	0.22	0.16	0.19

Std. Dev. of Monthly Averages vs. ARGO



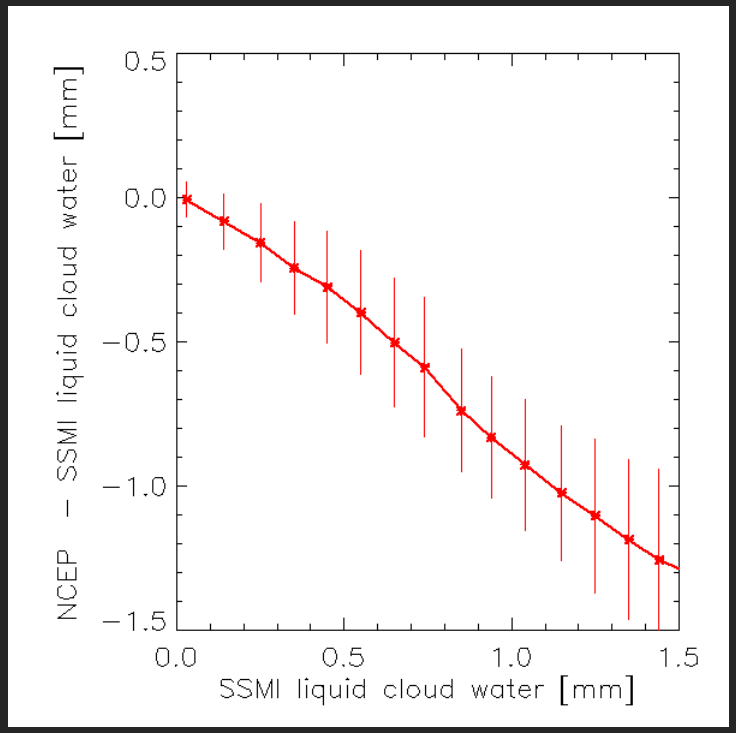
Rain Induced Effects (1)

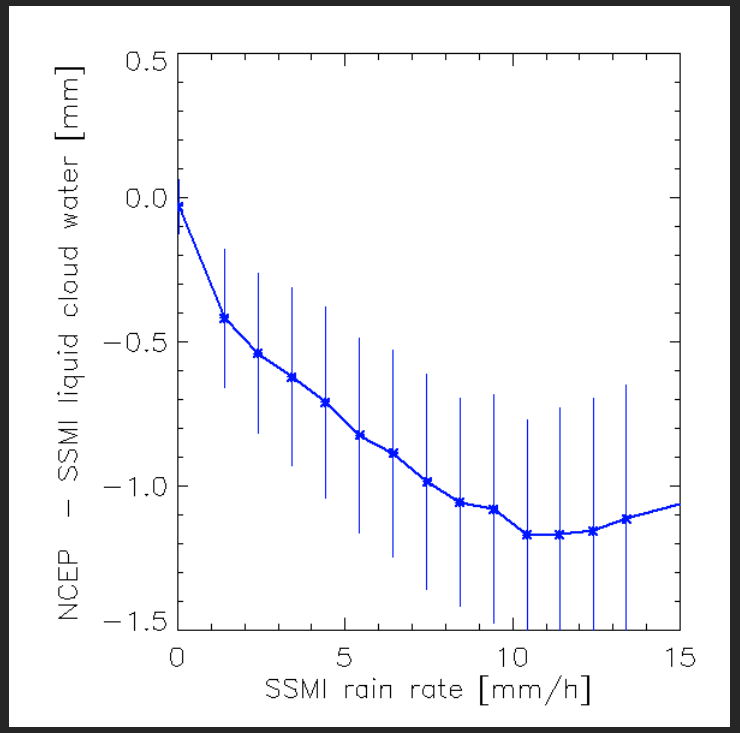
1. Real freshening
   - Aquarius (few cm of surface) versus ARGO or HYCOM (5 m depth)
2. Atmospheric absorption
   - Aquarius L2 SSS retrieval uses cloud water from NCEP for atmospheric correction.
3. Surface splashing?



We will now show that about 80-90% of the observed effect is mostly due to rain freshening.

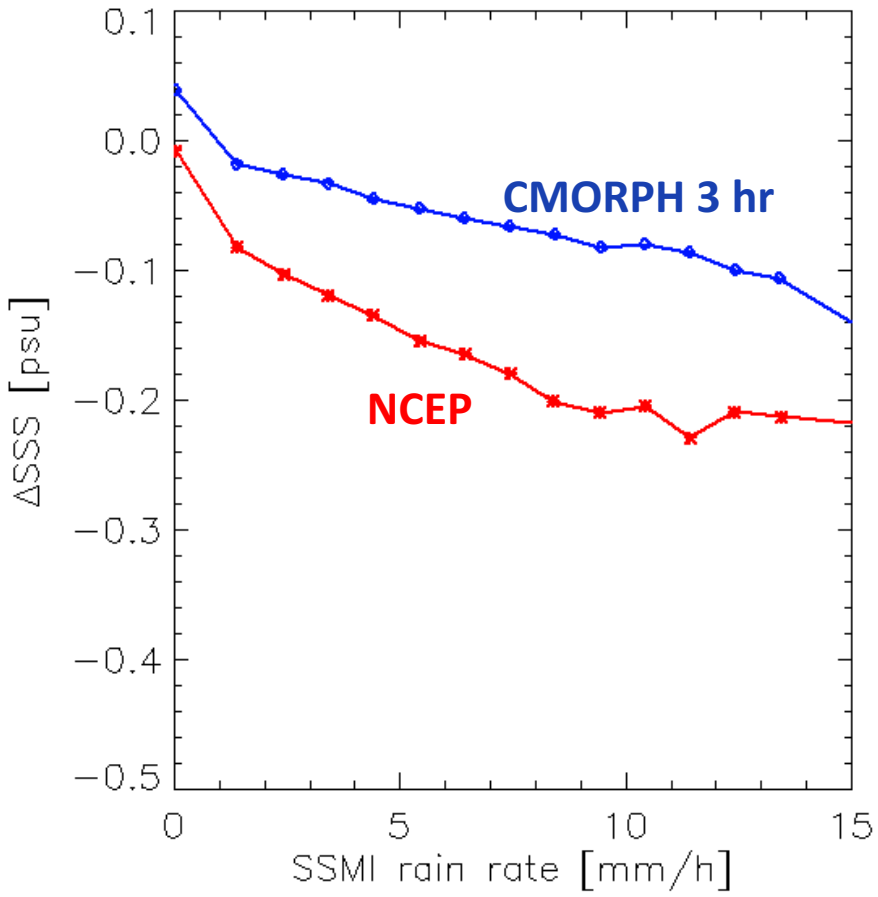
Atmospheric Correction





- Aquarius uses NCEP liquid cloud water for atmospheric rain correction.
- NCEP misses most of the rain. It underestimates the cloud water by close to 100% and thus it is basically useless in rain.
- Future version will use CMORPH accumulated rain product.

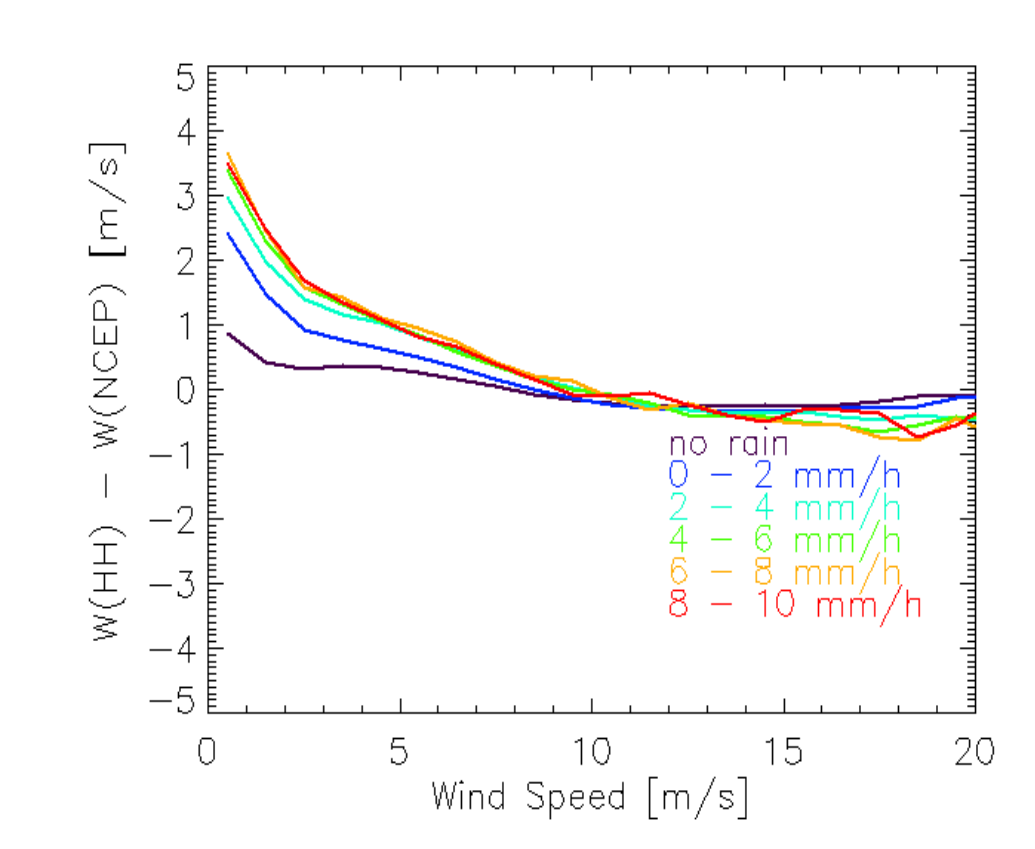
Impact on Salinity Retrieval



- Assume that SSM/I gives correct cloud water.
- Atmospheric absorption increases TB and thus gives a SSS that is too low.
- The atmospheric rain correction algorithm is supposed to correct that.
- NCEP underestimates the cloud water content and therefore undercorrects the atmospheric effect.
- **Our current Aquarius V3.0 SSS is too low/fresh in rain.**
  - 0.2 psu in high rain.
- Future releases will use CMORPH

Rain Splashing: Wind Speed

- When compared to NCEP the scatterometer (HH- pol) wind speed shows an increase at low wind speeds and high rain rates.
- Likely due to surface splashing.
- NCEP wind speed best ground truth in rain?
- **How does that effect the salinity retrievals in rain?**



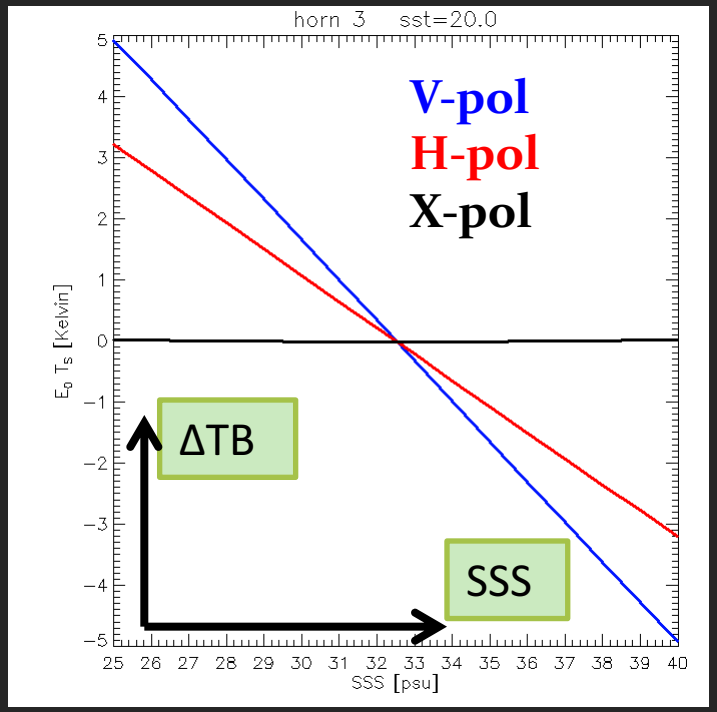
Rain splashing: Surface emissivity

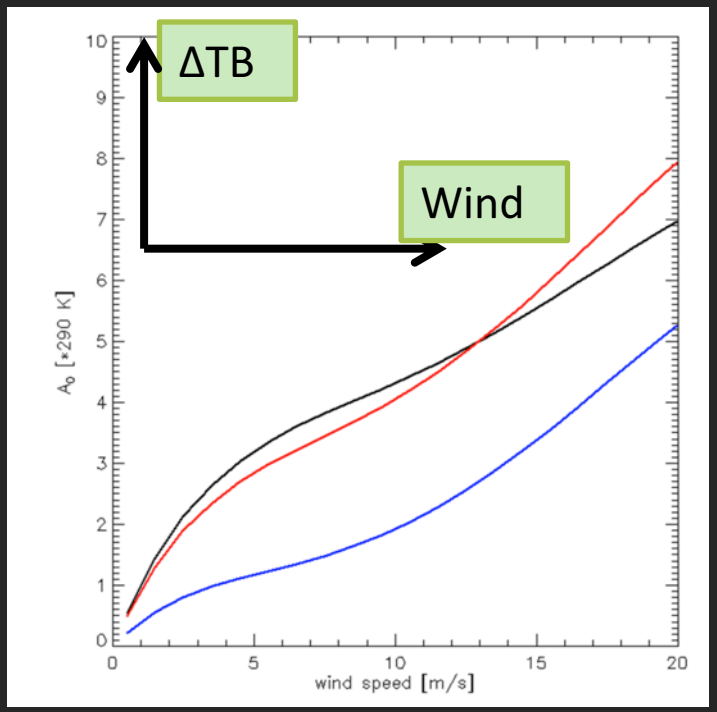
Analyze X-pol: **X = β·H - V**

Combination of V-pol and H-pol that is insensitive to SSS

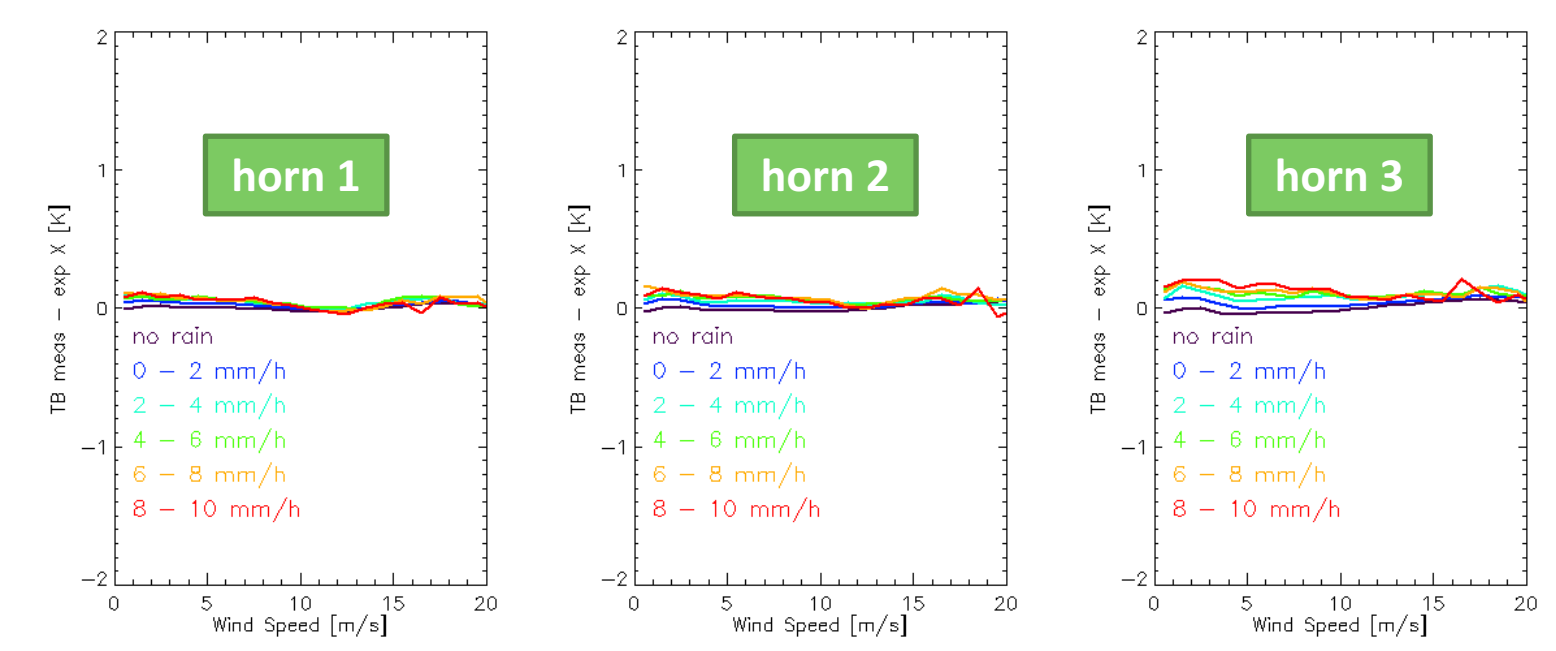
β = 1.18 (inner horn), 1.33 (middle horn), 1.54 (outer horn)

It is however, very sensitive to roughness





Rain Effect on X-pol TB measured- model

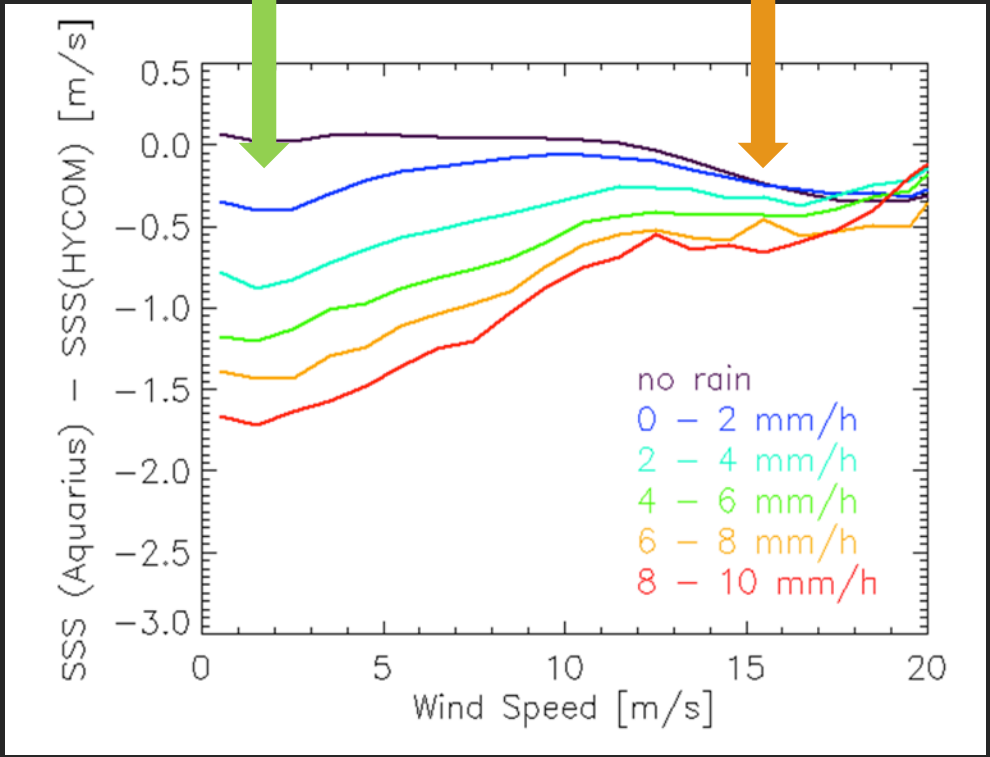


- There is very little rain induced excess emissivity on X-pol.
- Part of the little effect we are seeing could be actually due to undercorrecting the atmospheric effect.
- **Scatterometer wind is used in roughness correction.**
  Scatterometer wind is proxy for roughness.
- The results indicate that it is NOT warranted to perform a "rain splash correction" in the ADPS algorithm by forcing the Aquarius SSS to HYCOM.

Rain Induced Effects (2)

Low winds
Surface layer stratified

High winds
Surface layer mixed

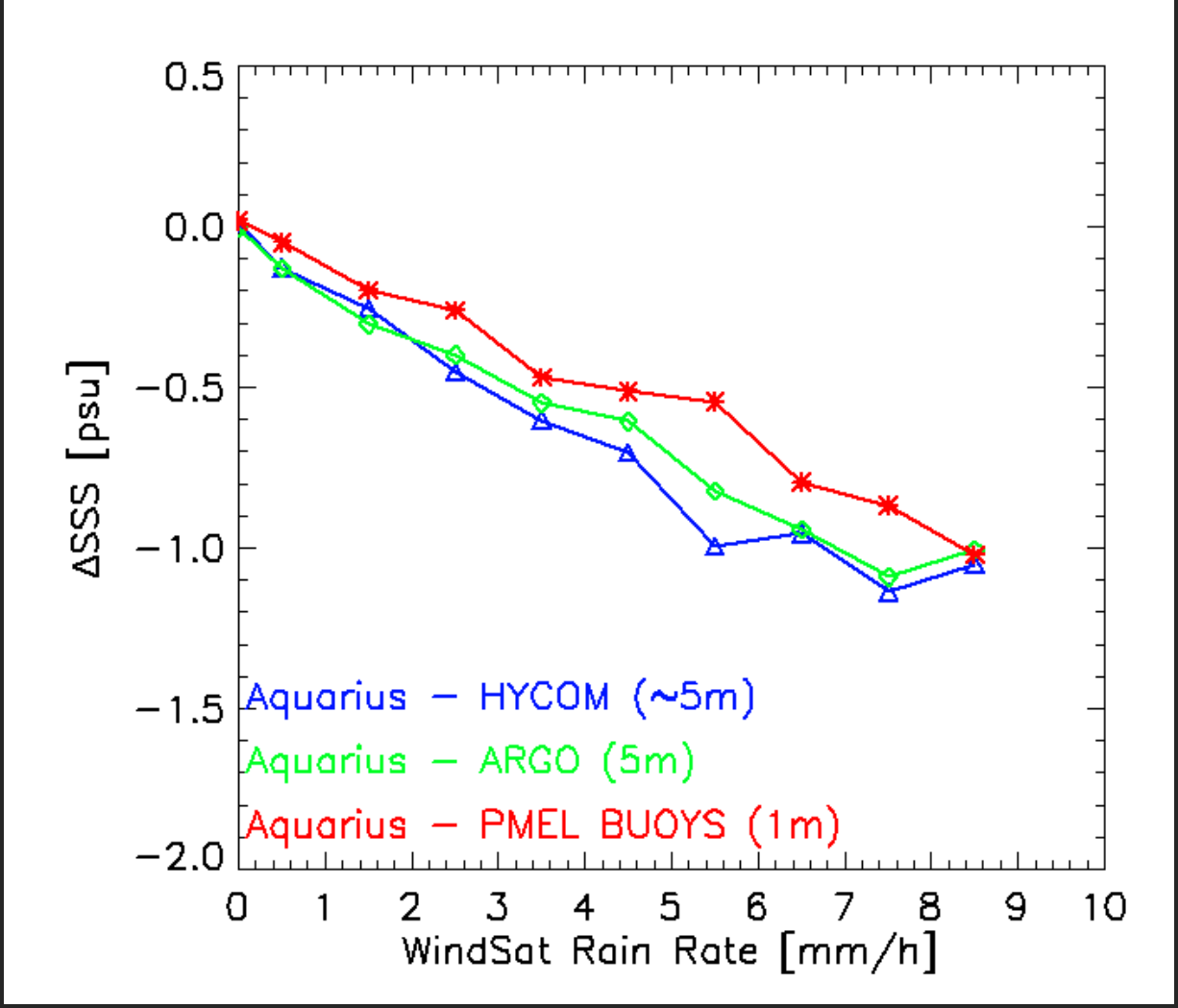


About 80-90% of the observed effect is due to rain freshening.
The rest is due to atmosphere + surface splashing.

Low winds: freshening is about - 0.13 to - 0.15 psu/(mm/h)

Rain Freshening in Tropics

Aquarius versus HYCOM, ARGO, moored Buoys



Freshwater Lensing

Rain Rates from Microwave imager

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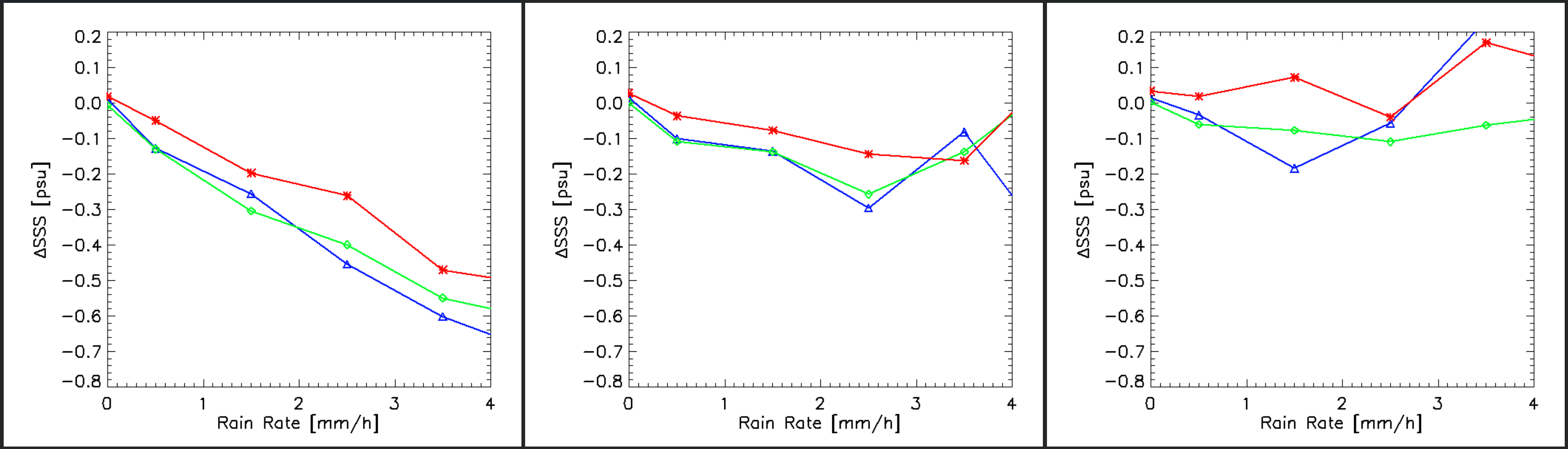
Rain within 1 hour of Aquarius Freshening at surface compared with 1m/5m	**No rain at Aquarius Rain 0 - 1 hour before AQ** Freshwater lensing visible	**No rain within 1 hour before Aquarius Rain 1 - 12 hours before AQ** upper layer has mixed



Aquarius – PMEL (1m)

Aquarius – ARGO (5m)

Aquarius – HYCOM (5 m?)

Summary and Conclusions

- When comparing satellite salinity with ground truth we need to carefully separate biases that are due to inaccuracies in the GMF from biases that are due to stratification within the upper layer.

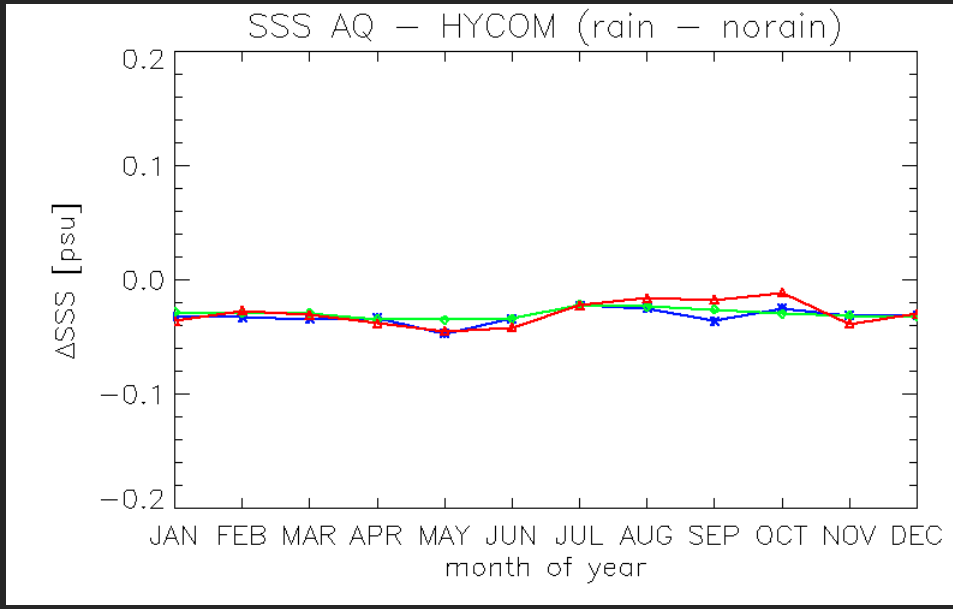
- **Aquarius ADPS V3.0 mitigates the GMF biases but keeps the stratification.**
  - Estimated accuracy:
    0.22 psu (1.5 deg monthly).
    0.18 psu (3.0 deg monthly).

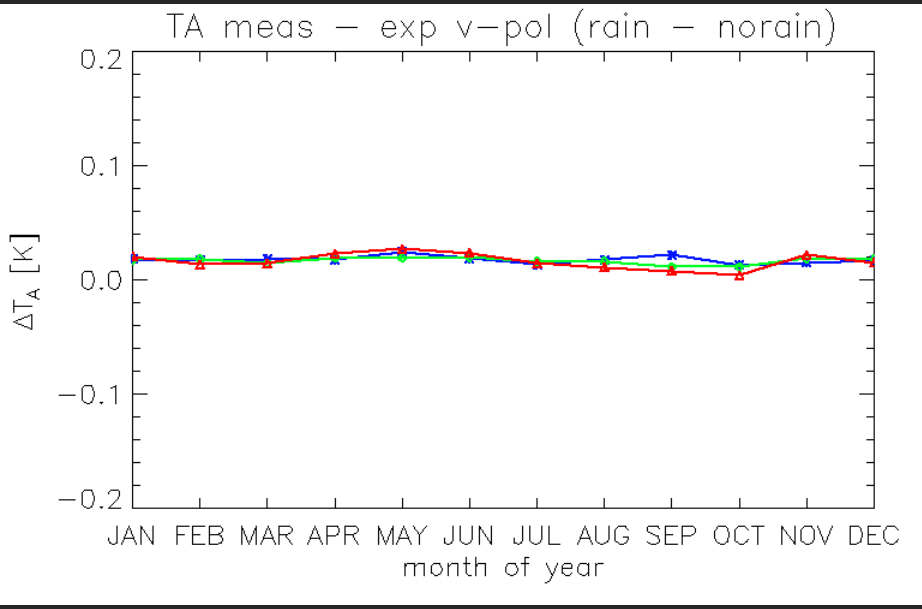
- **Rain freshening from Aquarius**
  - Observed difference between surface and 5 m layer: 0.17 psu / (mm/h) at low wind speeds.
  - Small error due to inadequate atmospheric correction and surface splash effects .
  - The scatterometer wind speed is a good proxy for surface roughness including rain splashing. No or only very small correction for rain splashing effects is warranted, if scatterometer wind speeds are used in the surface roughness correction.
  - Instantaneous freshening estimated to about 0.13 to 0.15 psu /(mm/h) at low wind speeds.
  - Consistent with SMOS results.
  - Surface freshwater lensing is visible in Aquarius data 1 – 3 hours after rain event.

Backup Slides

Aquarius SSS: All Events – Rain Filtered

Global Average as Time Series





- Global difference rain – no-rain is small
  - 0.04 psu / 0.02 K.
  - Time dependence (month) very weak.
- **Globally it does not rain that much!**
- Compensation to account of the fact that we do not rain filter in calibration can be done
  - Add one-time small TA number for each of the 6 channels in calibration.

Rain Impact on Sensor Calibration

- V3.0 senor calibration:
  - Matches global 7-day average of Aquarius with HYCOM
  - Does not do rain filtering.
- Consequence: The V3.0 Aquarius SSS are too salty
  - Global bias.
  - Stratification in tropics:
    Aquarius sees rain freshening, which is real, but HYCOM does not. It therefore blames the mismatch to the sensor calibration.
  - The correct way would be to filter Aquarius observations for rain before matching them to HYCOM (or ARGO).
- How much does that amount to?
- Study: Computed monthly climatology of non-rain filtered minus rain filtered Aquarius observations.
  - Time frame where MWR is available for rain flagging.
  - In addition use MW imagers (SSMIS, WindSat, TMI) to filter out rain within 1 hour before Aquarius observation.

MWR Rain Rates

- Available at RSS FTP site
  - ftp://Aquarius_mwr:mar23vista36@ftp.remss.com/aquarius_mwr/rss_l2c_h5/
- Space and time collocated to Aquarius L2 swath.
- Format:
  - HDF5
  - same structure as Aquarius ADPS L2 files
  - same name convention for granules
- Variables
  - time, latitude, longitude (matches ADPS L2)
  - cloud water, rain rate, liquid water attenuation at L-band
  - wind speed, water vapor
- Documentation on processing algorithm and file content
- PO.DAAC ?
- Use in Aquarius
  - For analysis only. Not part of L2 processing.
  - Rain Flagging
  - Rain Rates: not very good (37 GHz channel saturates)

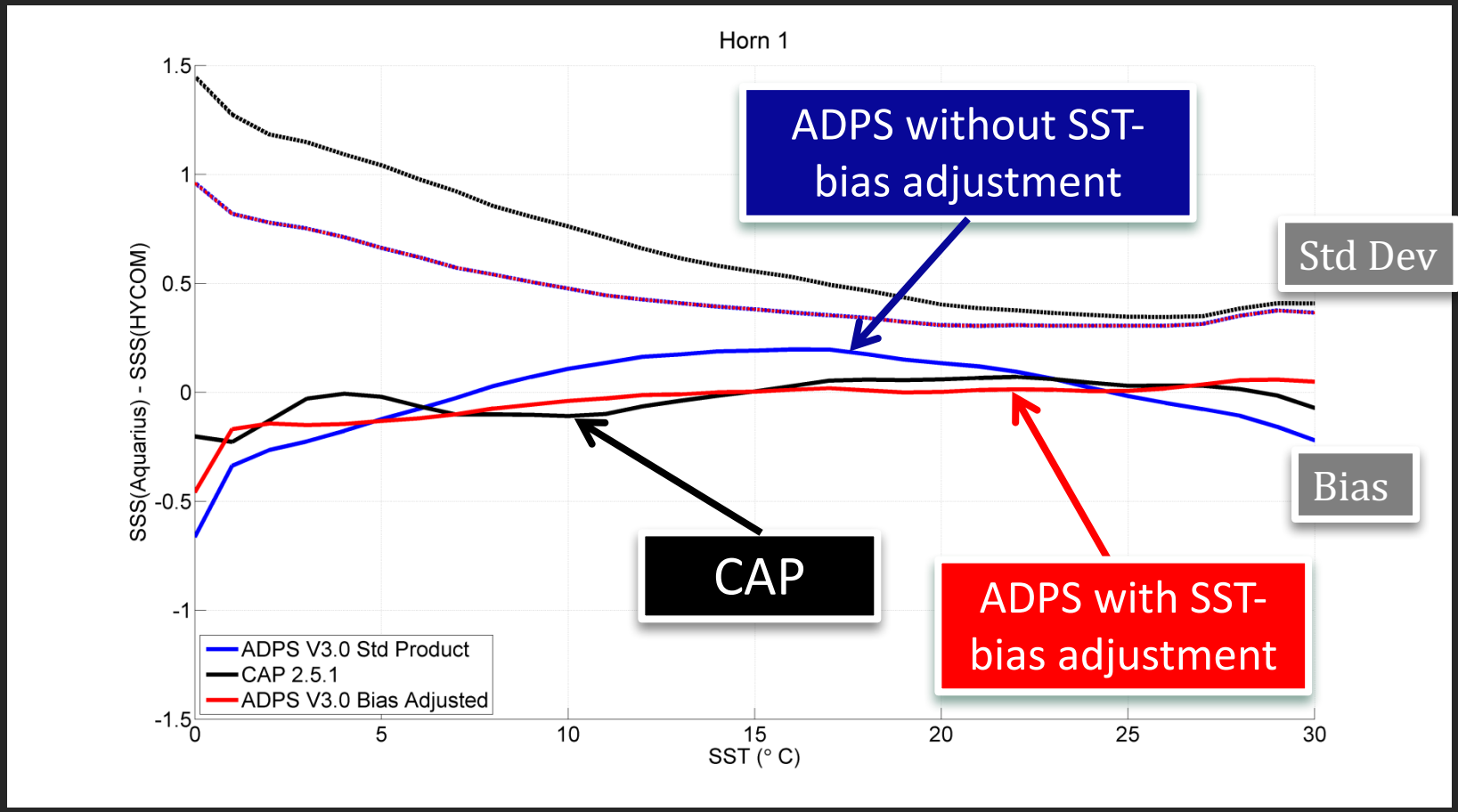
Aquarius ADPS versus CAP

Performance Analysis

- Exactly the same ensemble of samples used for all comparisons
  - Same Q/C
- Two-types of Standard Deviations
  - 1.44 Sec single retrievals
  - Retrievals first averaged over a month
- CAP is Version 2.5.1
- ADPS
  - without and with SST-bias adjustment

Mean and Std. Dev. (1.44 sec) vs. SST

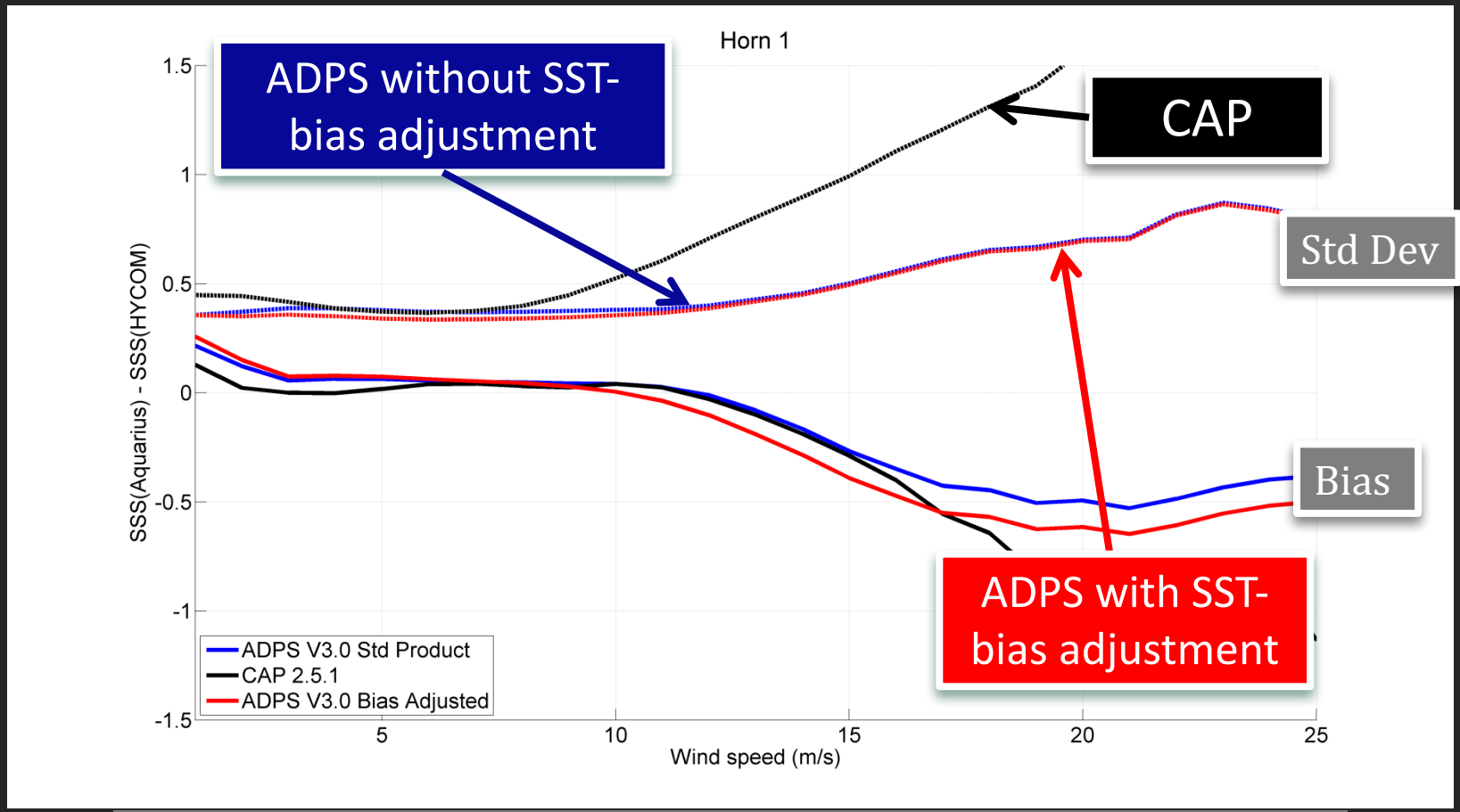
Error dominated by roughness



1. CAP is noisier at ADPS on 1.44 sec cycle.
2. CAP has applied an SST flattening by making an adjustment of the dielectric constant. This one of many ways to do that.

Mean and Std. Dev. (1.44 sec) vs. Wind

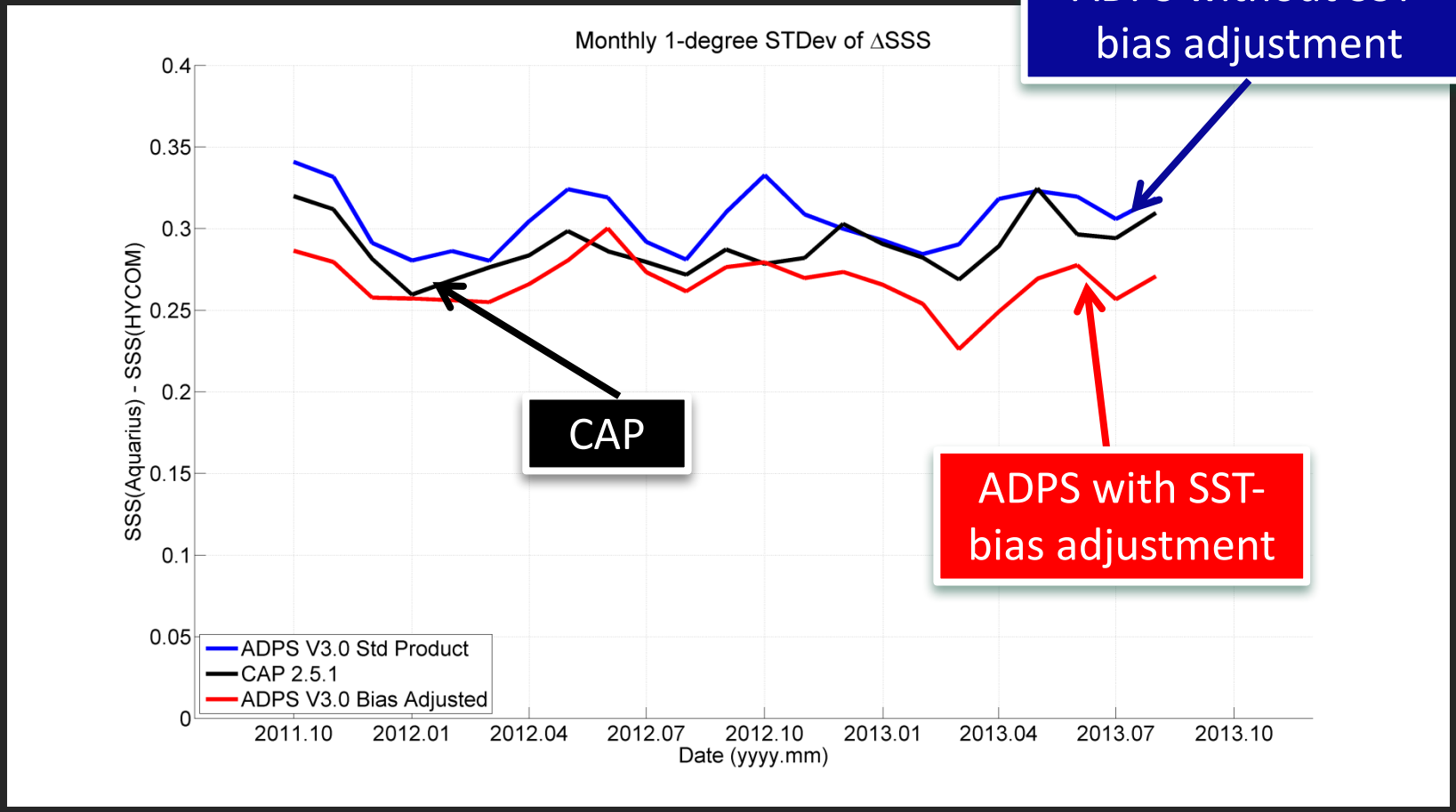
Error dominated by roughness



- CAP is noisier at ADPS on 1.44 sec cycle.
- Noise is increasing with increasing wind speed.

Std. Dev. of Monthly Averages vs. HYCOM

Error dominated by local SST-dependent biases



Std. Dev. of Monthly Averages vs. ARGO