Assessment of Rain Impact on the Aquarius Salinity Retrievals

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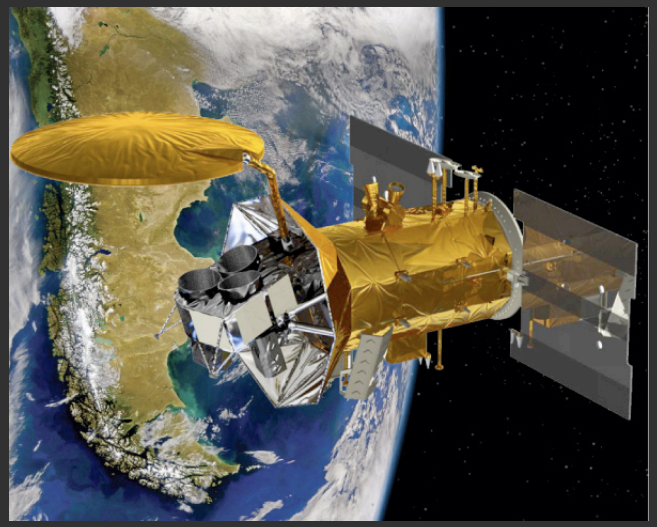

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Outline

1. MWR
2. Atmospheric Effects
3. Rain Splashing Effects
4. Rain Induced Freshening
5. Freshwater Lensing
6. Rain Impact on Calibration Loop
7. Summary

MWR Rain Rates

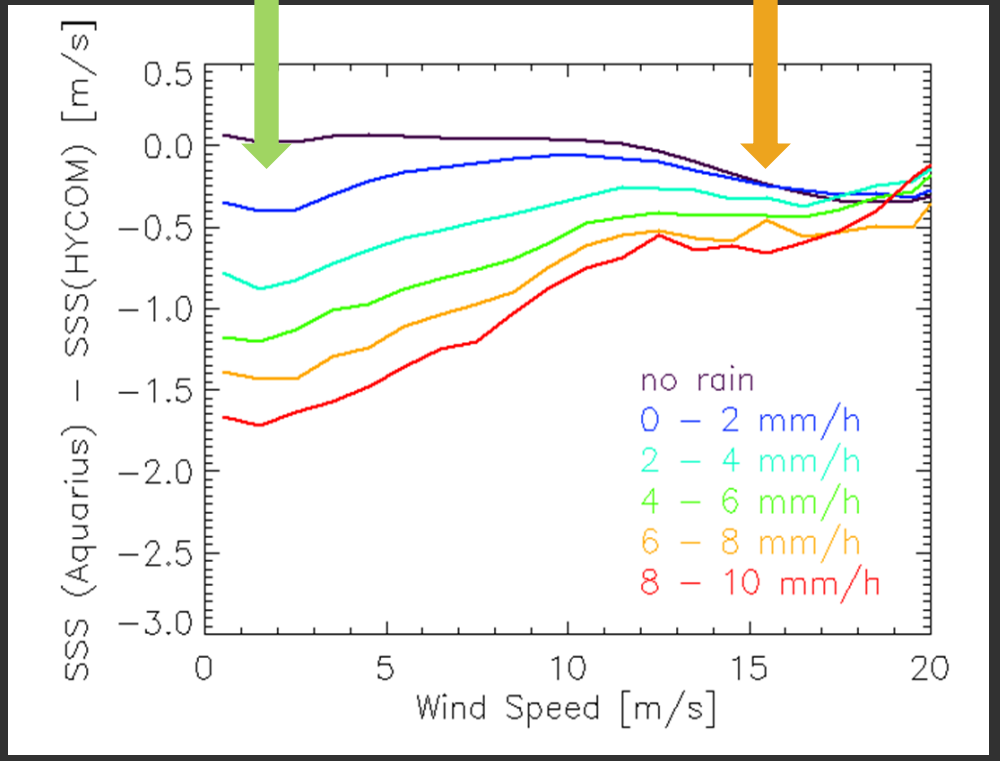
- Available at RSS FTP site
  - ftp://Aquarius_mwr:mar23vista36@ftp.remss.com/aquarius_mwr/rss_l2c_h5/
- Space and time collocated to Aquarius L2 swath.
- Format:
  - HDF5
  - same structure as Aquarius ADPS L2 files
  - same name convention for granules
- Variables
  - time, latitude, longitude (matches 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)

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?
4. SST bias correction
   - Has been applied

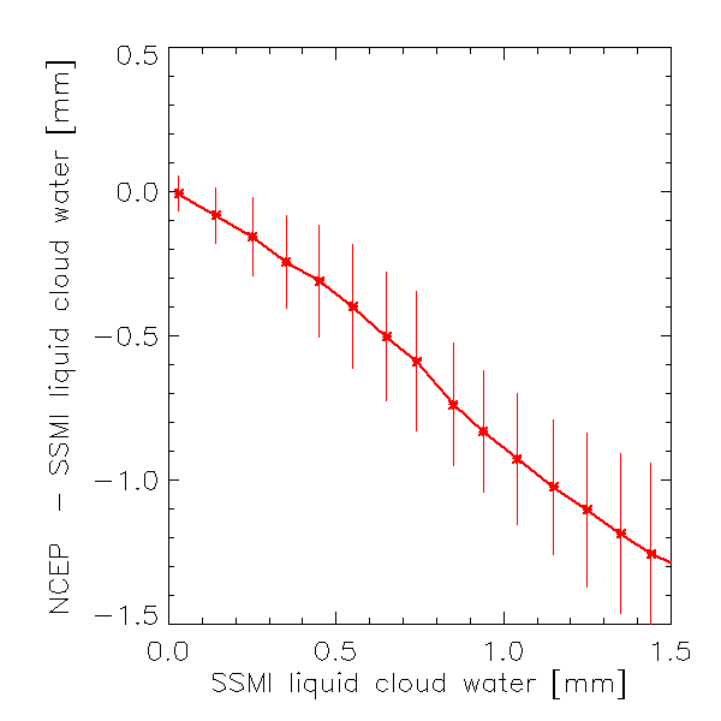
Low winds
Surface layer stratified

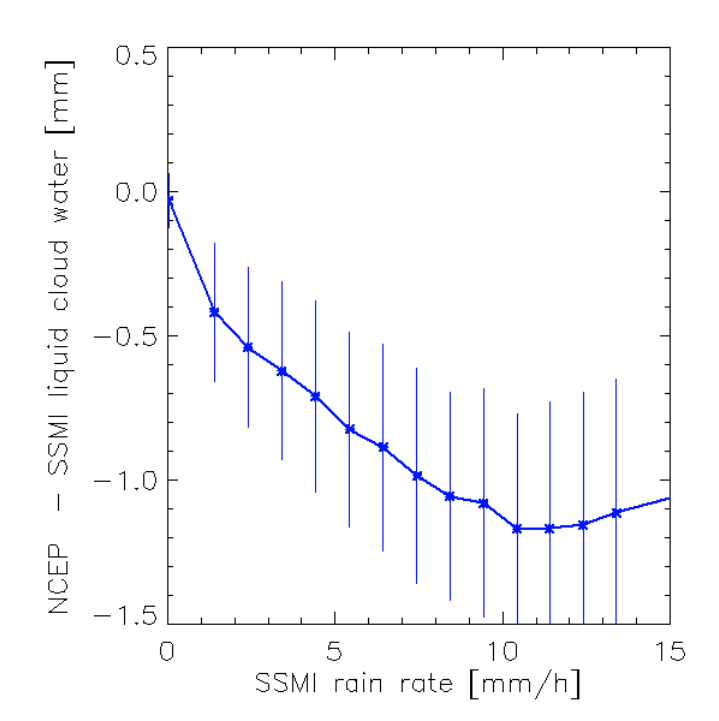
High winds
Surface layer mixed



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

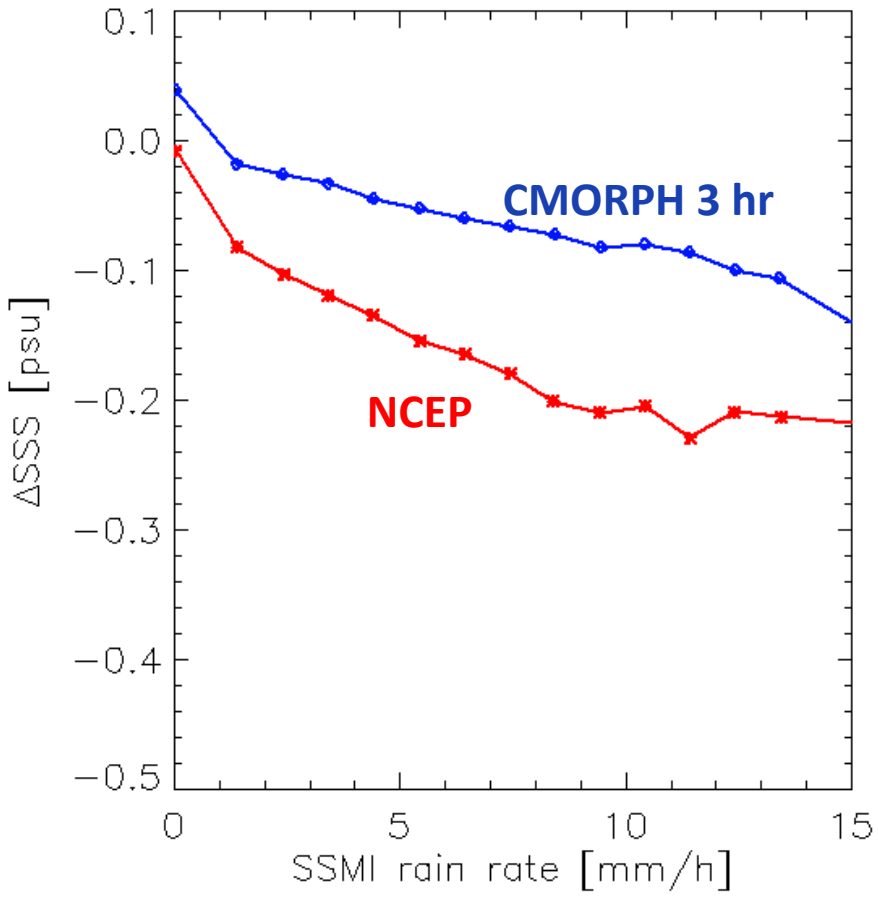
Atmospheric Correction





- Aquarius uses NCEP liquid cloud water for atmospheric rain correction.
- How good is NCEP?
- NCEP misses most of the rain.
- It underestimates the cloud water by close to 100% and thus it is basically useless in rain.

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.
- Conclusion:
  Our current Aquarius V3.0 SSS is too low/fresh in rain.
- 0.2 psu in high rain.

What to do about it?

- Consider using different cloud water auxiliary field for atmospheric rain correction.

- MWR
  - this was the original plan
  - dead
  - MWR rain rates are not very good (no 18 GHz channel, saturation)

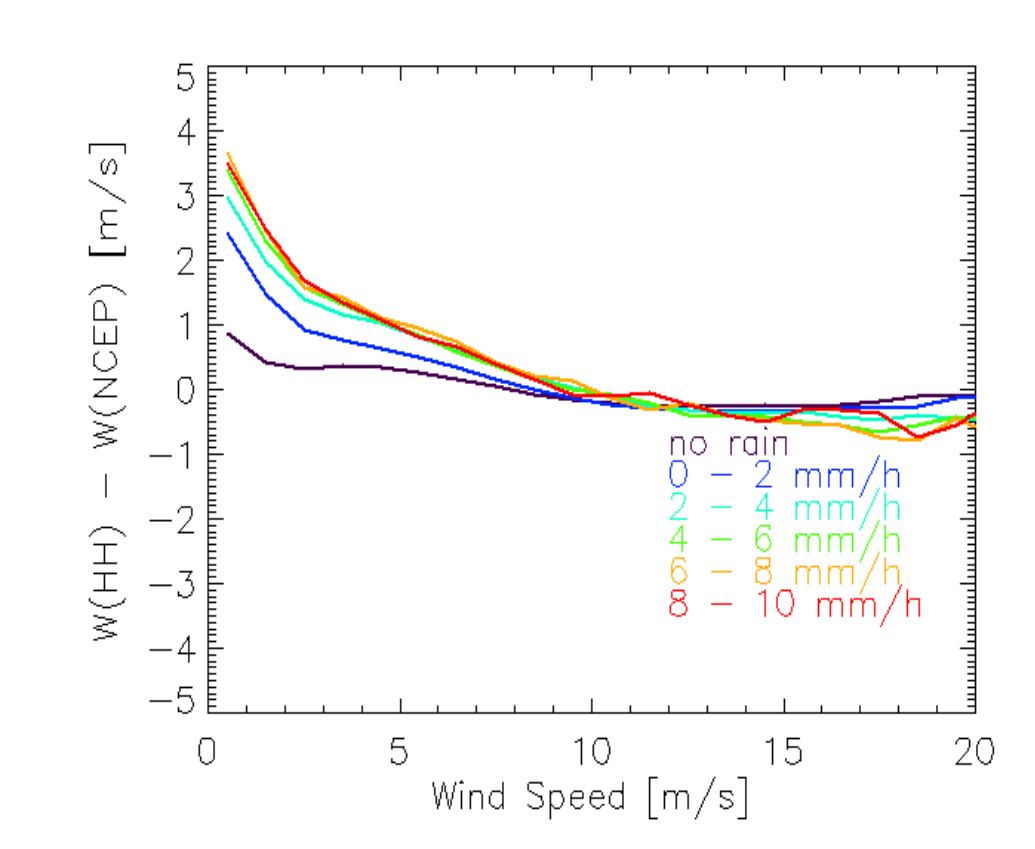
- RSS V7 products: SSMIS F17, WindSat, TMI, GMI
  - collocates well with Aquarius (1 hour)
  - but not completely
  - leaves small holes

- **CMORPH**
  - **almost global (lat<60^{o})**
  - **gives rain accumulation not cloud water**
  - **need to transform into cloud water absorption**

- Match resolution to Aquarius?

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?**



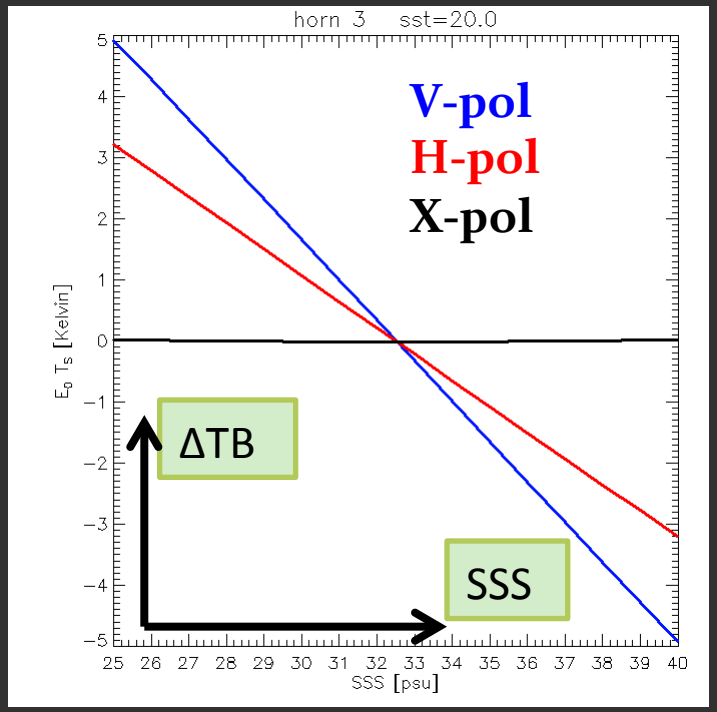
Rain splashing: Surface emissivity

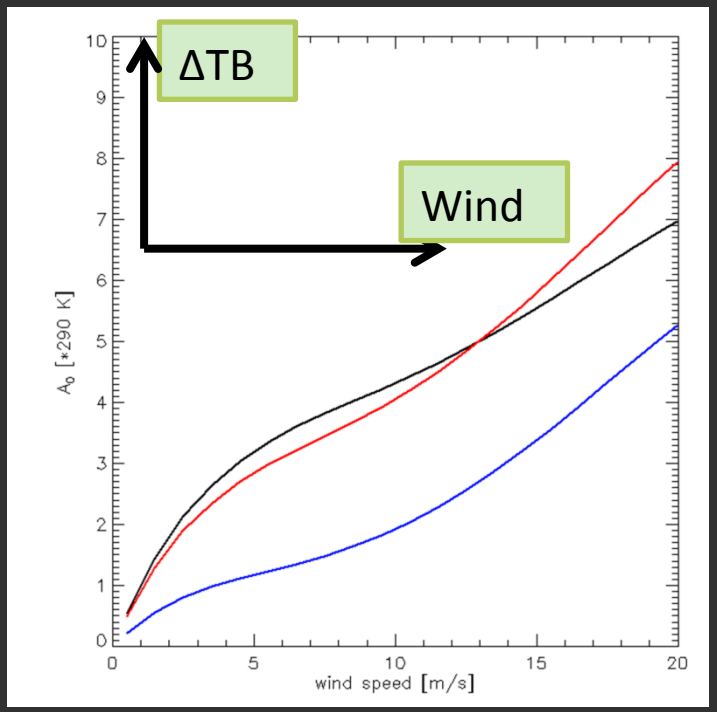
Analyze X-pol: **X = β·H - V**

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)

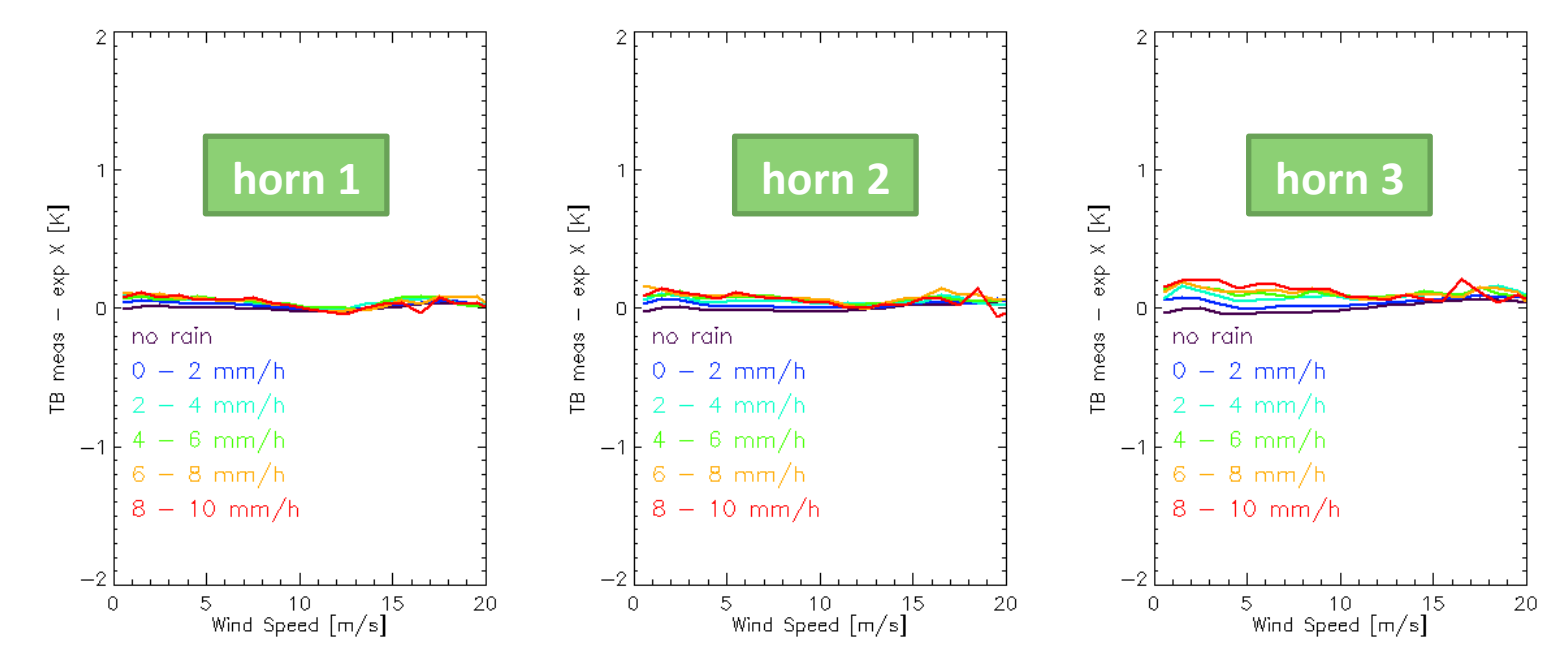
It is however, very sensitive to roughness





Rain Effect on X-pol TB meas - model

after removing wind induced (no-rain) emissivity using scatterometer wind speed

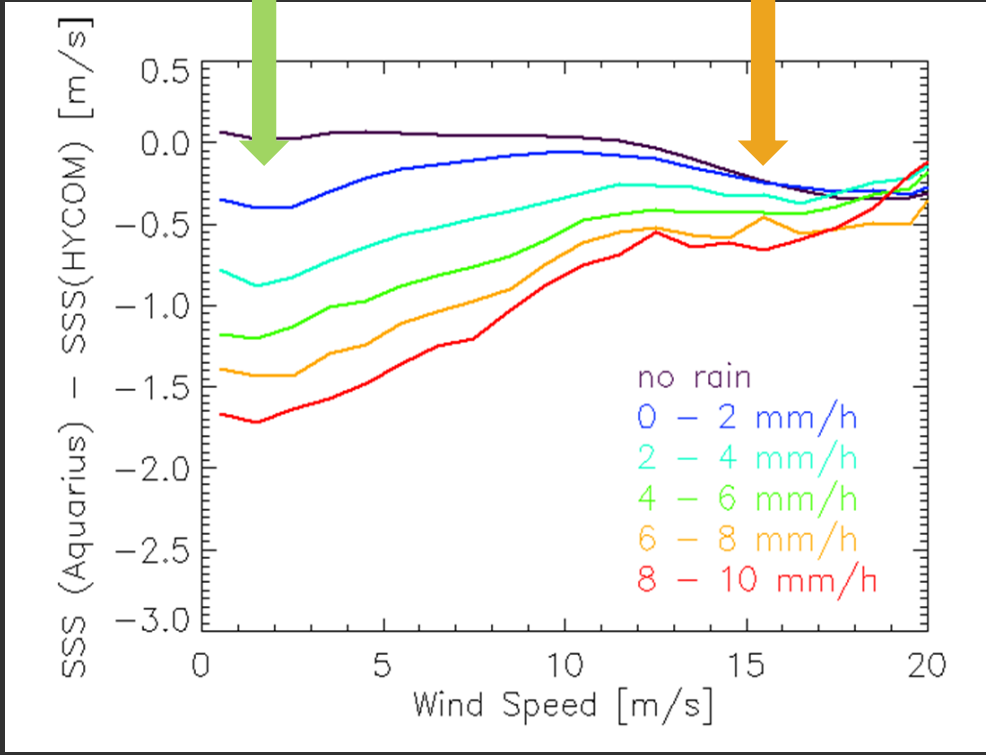


- Very little rain induced excess emissivity on X-pol.
- Part of the little effect we are seeing could be actually due to undercorrecting the atmospheric effect.
- **Scatterometer wind is used in roughness correction. Scatterometer wind is proxy for roughness.**
- The results indicate that it is NOT 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



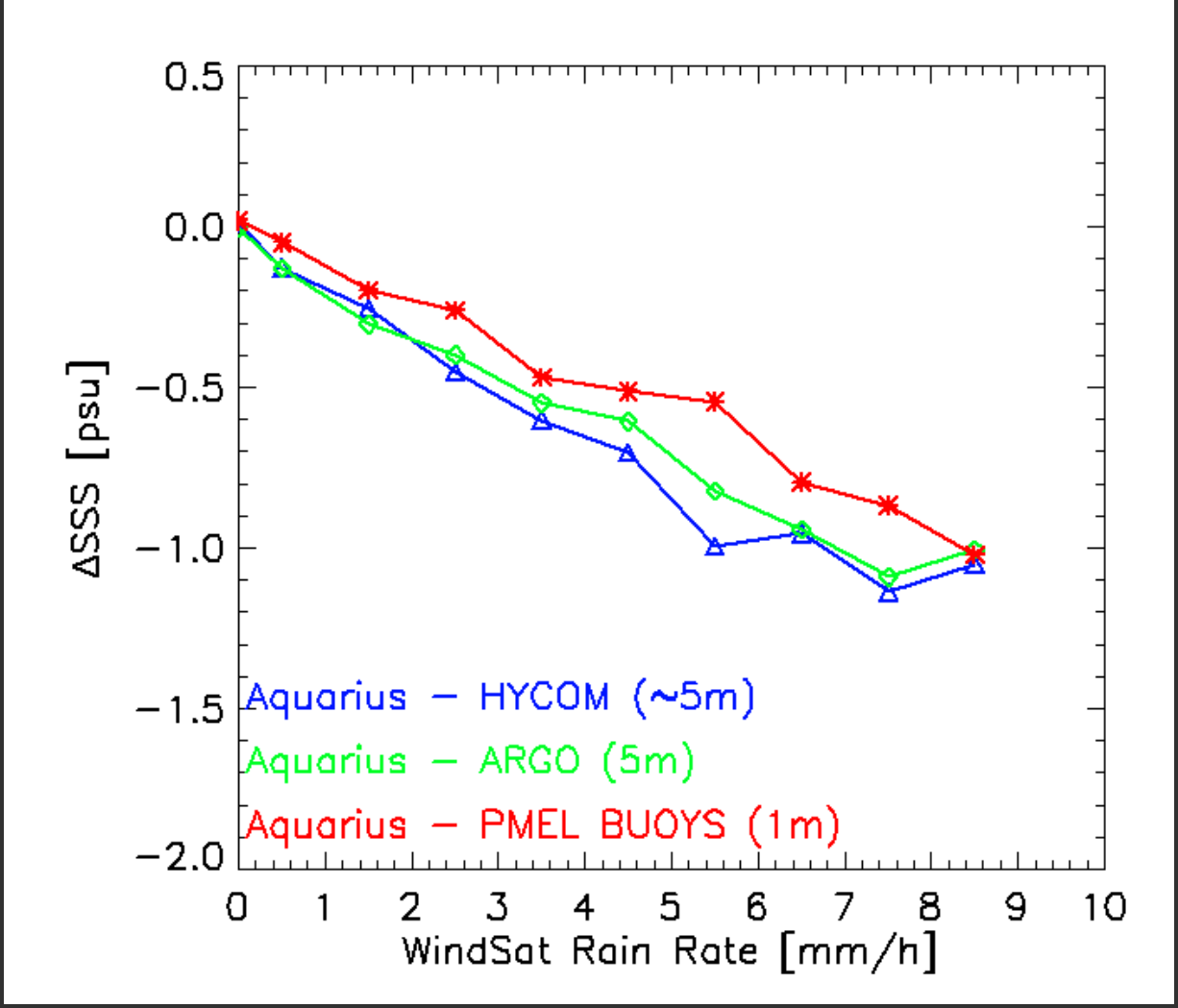
About 80-90% of the observed effect is due to rain freshening.
Consistent with SMOS finding (J. Boutin et al.)

Rain Measurement and Filtering

- **CONAE Microwave Radiometer (MWR): K and Ka –band**
  - On Aquarius platform
  - Allows rain measurement at the location and time of Aquarius observation
  - Allows rain flagging: Aquarius observation rain free
- **Microwave Imager**
  - 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

Rain Freshening in Tropics

Aquarius versus HYCOM, ARGO, moored Buoys



Freshwater Lensing

Rain Rates from Microwave imager

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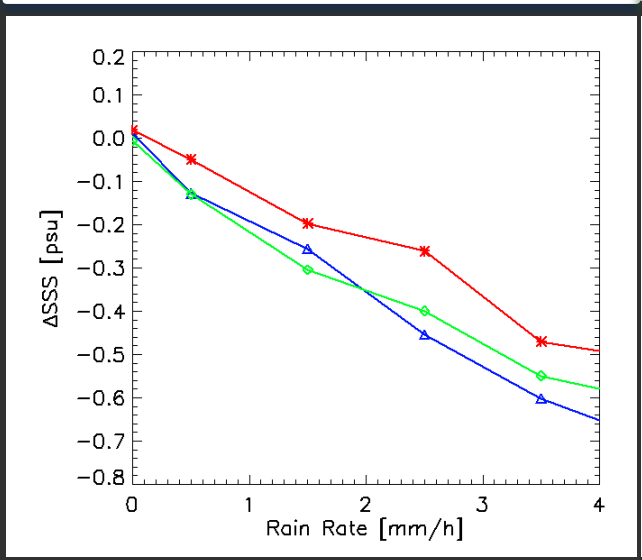
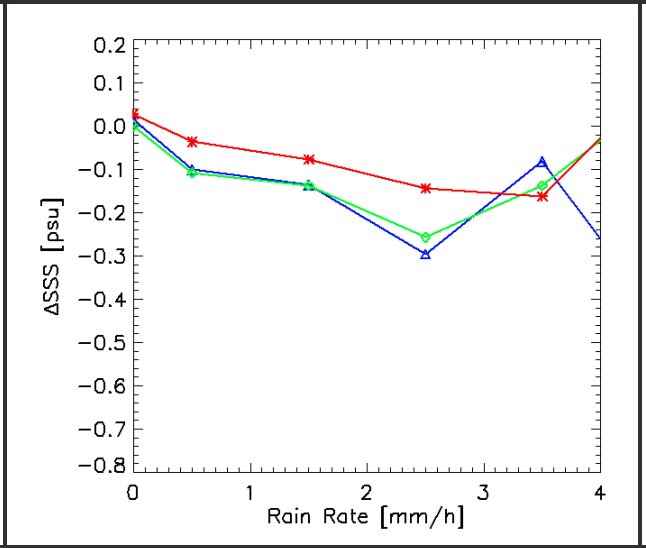
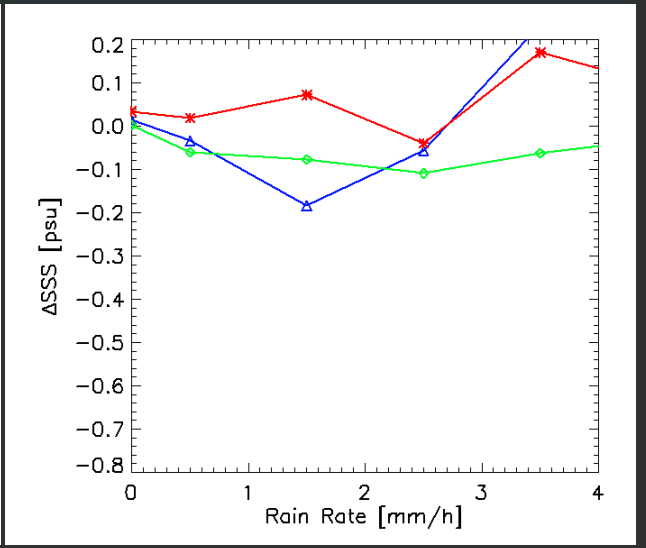
Rain within 1 hour of Aquarius Freshening at surface compared with 1m/5m	No rain at Aquarius Rain 0 - 1 hour before AQ Freshwater lensing visible	No rain within 1 hour before Aquarius Rain 1 - 12 hours before AQ upper layer has mixed







Aquarius – PMEL (1m)

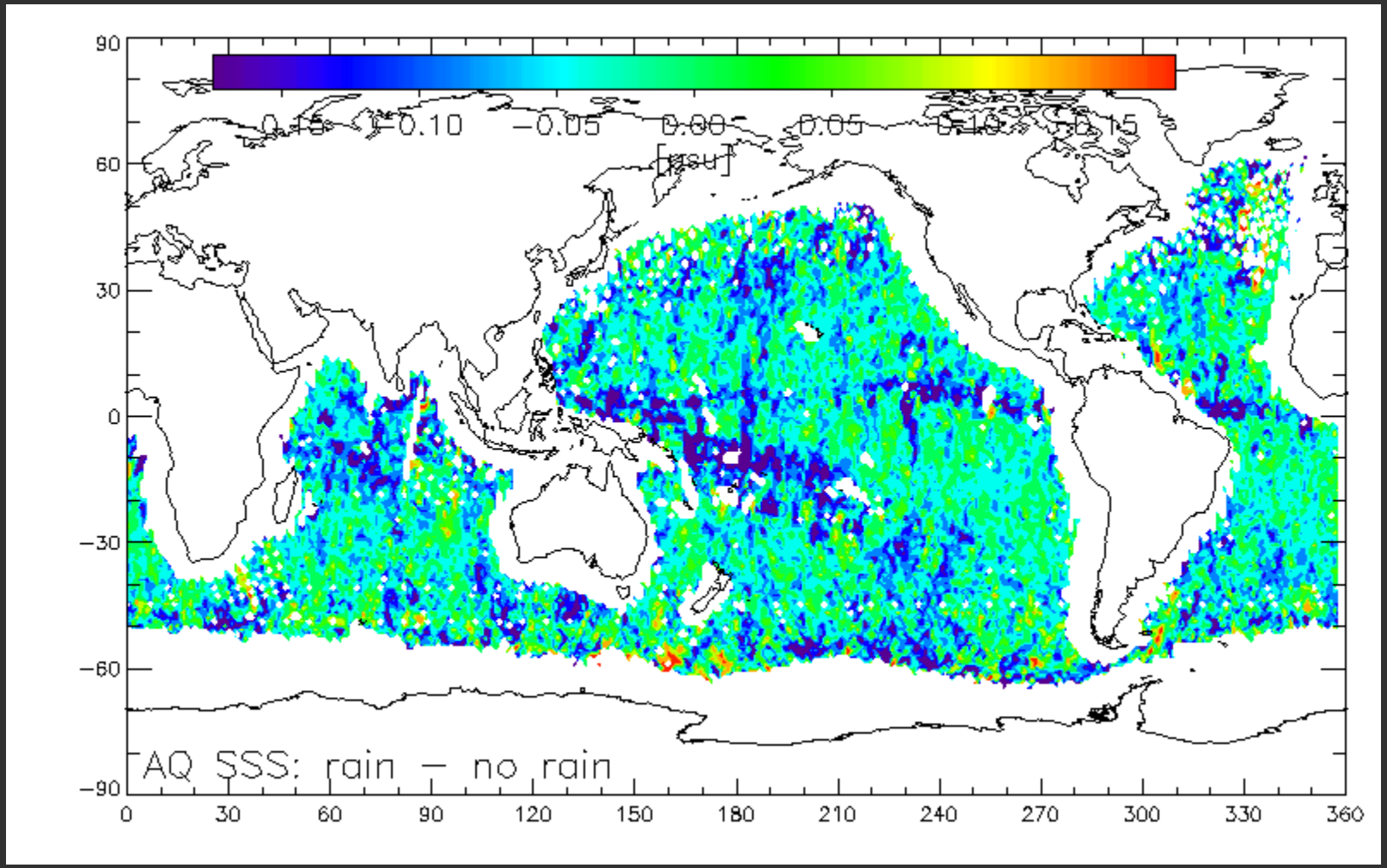
Aquarius – ARGO (5m)

Aquarius – HYCOM (5 m?)

Rain Impact on Sensor Calibration

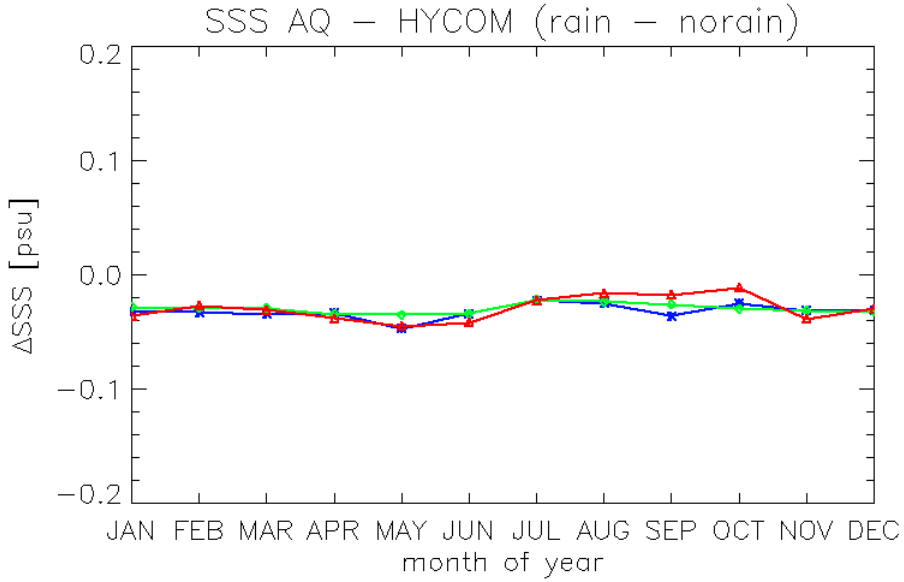
- V3.0 senor calibration:
  - Matches global 7-day average of Aquarius with HYCOM
  - Does not do rain filtering.
- Consequence: The V3.0 Aquarius SSS are too salty
  - Global bias.
  - Stratification in tropics:
    Aquarius sees rain freshening, which is real, but HYCOM does not. It therefore blames 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.

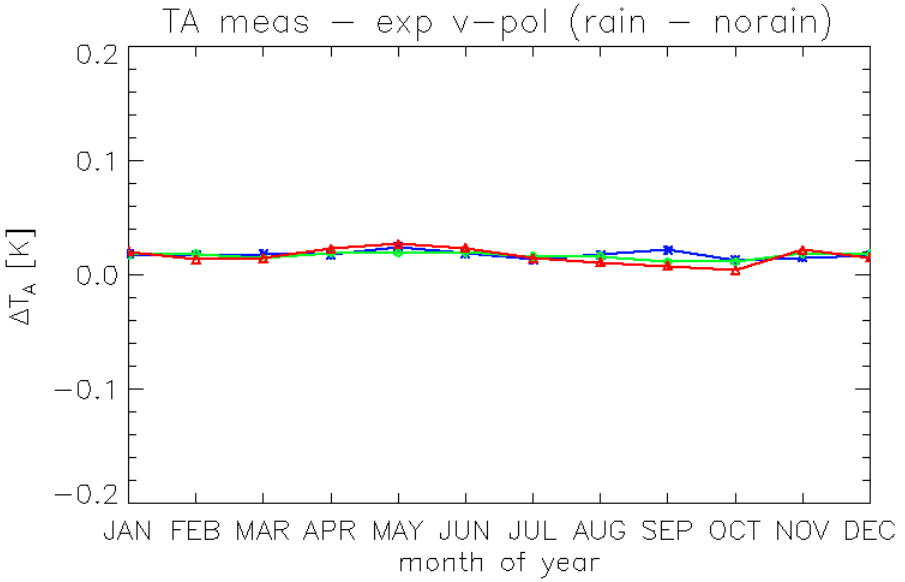
Aquarius SSS: All Events – Rain Filtered



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.

Summary and Conclusions

- MWR rain rates matched to Aquarius are available.
- Atmospheric rain correction has room for improvement.
  - NCEP cloud water auxiliary fields are insufficient for atmospheric correction.
  - Plan: CMORPH
- No or only very small correction for rain splashing effects is warranted, if scatterometer wind speeds are used in the surface roughness correction.
  - The scatterometer wind speed is a good proxy for surface roughness including rain splashing.
- Rain freshening and stratification in upper layer (5 m) visible in data.
- Rain induced freshwater lensing visible in data.
  - Freshening stays on average for 1 - 3 hour.
- Rain impact on calibration loop very small
  - V3.0 does not rain filter in calibration loop.
  - V3.0 SSS are about 0.04 psu too salty.