Aquarius' CAP Ocean Surface Salinity and Wind Products and Their Applications to Water Cycle Research

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Outline

- Introduction
- CAP V2.0 Algorithm Validation
  - Triple Collocations
  - Validation Using ARGO
- An example for application to water cycle research
- Summary

Aquarius GMF for Roughness Effects

- Radiometer Model Function

$$T_{Bp}(SSS, SST, w, \phi) = T_{Bp0}(SSS, SST) + SST \cdot [e_{p0}(w, SWH) + e_{p1}(w)\cos\phi + e_{p2}(w)\cos 2\phi]$$

- Scatterometer Model Function

$$\sigma_p(w, SWH, \phi) = A_{0p}(w, SWH)[1 + A_{1p}(w)\cos\phi + A_{2p}(w)\cos 2\phi]$$

- Two versions of GMFs are built
  - AQ data, SSM/I wind speed, NCEP wind direction, NOAA WW3 SWH
  - AQ data, NCEP wind speed, NCEP wind direction, NOAA WW3 SWH

Aquarius Combined Active-Passive (CAP) Retreival

- Combined Active-Passive (CAP) Algorithm
  - Retrieve SSS, Wind Speed and Direction Using Combined Passive and Active Data
  - Do not use NCEP winds for TB correction
  - Can be easily updated to account for additional corrections

$$F_{pol}(SSS,W,\phi)=\frac{(I-I_m)^2}{2\Delta T^2}+\frac{(\sqrt{Q^2+U^2}-\sqrt{Q_m^2+U_m^2})^2}{2\Delta T^2}+\frac{(\sigma_{0VV}-\sigma_{0VVm})^2}{(k_p\sigma_{0VV})^2}+\frac{(\sigma_{0HH}-\sigma_{0HHm})^2}{(k_p\sigma_{0HH})^2}$$

$$Q=T_{BV}-T_{BH}$$
$$I=T_{BV}+T_{BH}$$

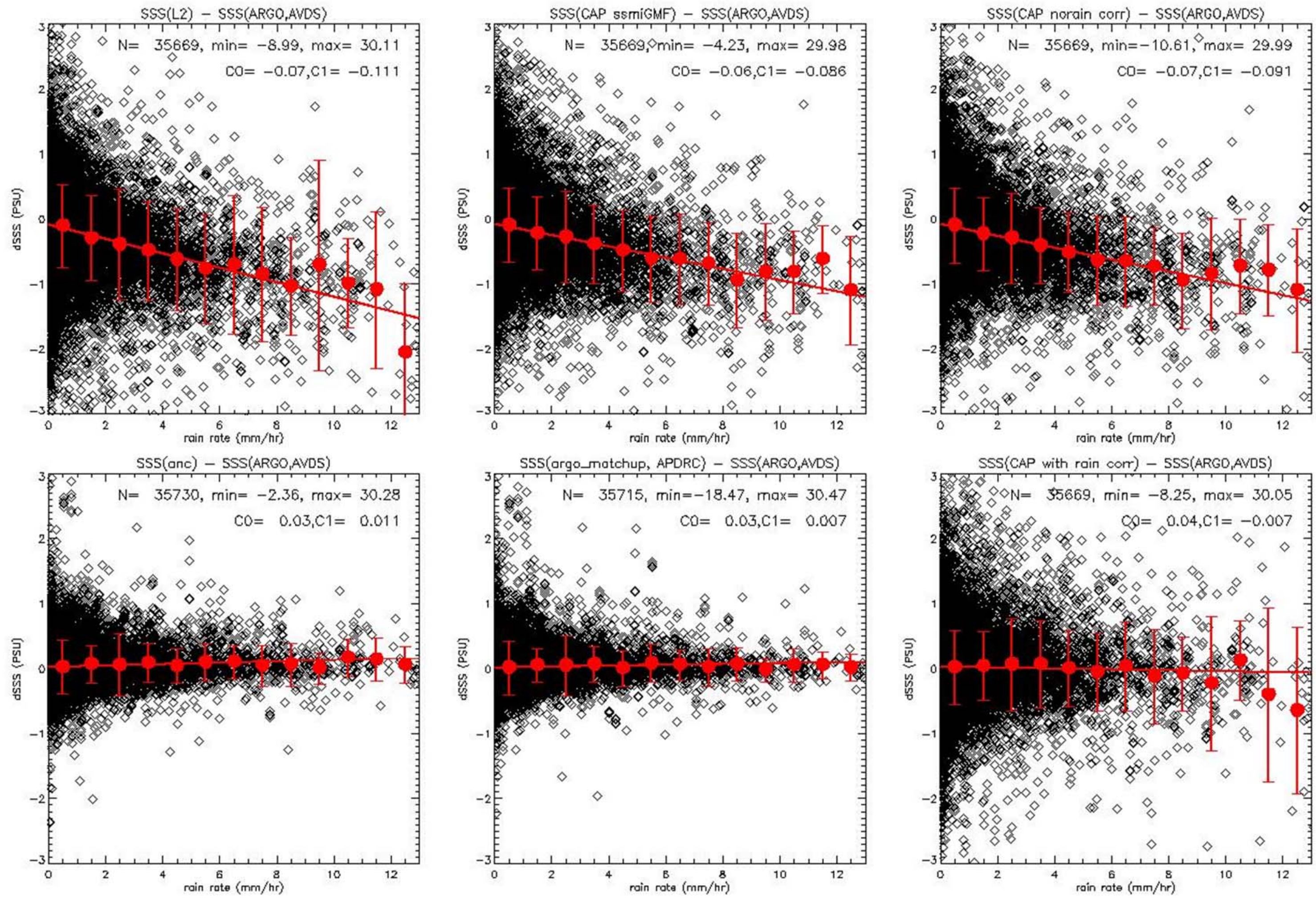
Yueh and Chaubell, IEEE TGRS, April 2012

- V2.0 modification to constrain wind speed retrieval at crosswind and direction retrieval for light-mid winds

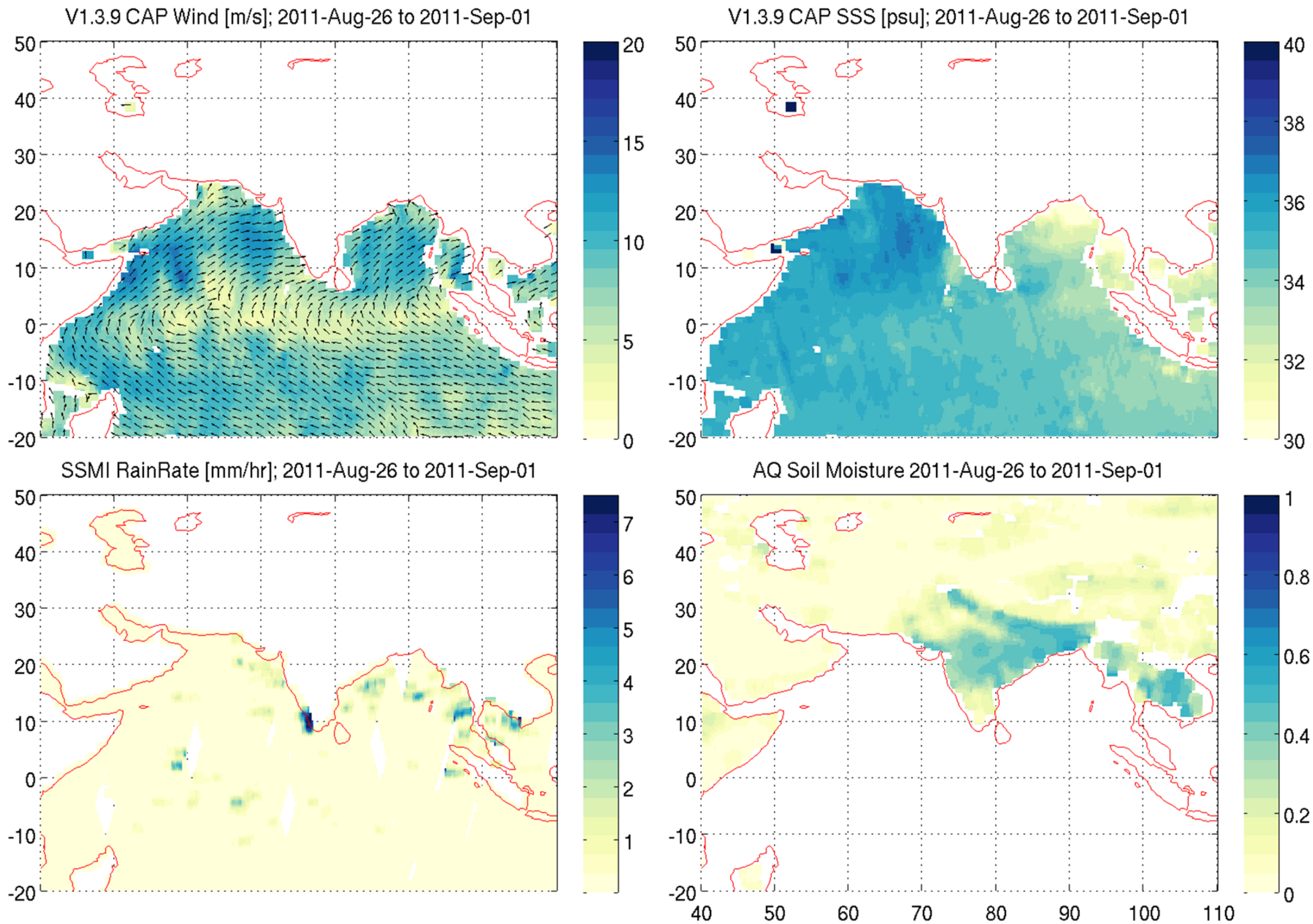
$$F_{ap}(SSS,w,\phi)=\frac{(T_{BV}-T_{BVm})^2}{\Delta T^2}+\frac{(T_{BH}-T_{BHm})^2}{\Delta T^2}+\frac{(\sigma_{VV}-\sigma_{VVm})^2}{k_{pc}{}^2\sigma_{VV}{}^2}+\frac{(\sigma_{HH}-\sigma_{HHm})^2}{k_{pc}{}^2\sigma_{HH}{}^2}+\frac{(w-w_{NCEP})^2}{\Delta w^2}+\frac{\sin^2((\phi-\phi_{NCEP})/2)}{\delta^2}$$

Rain Correction

- Please check out Wendy's poster on rain effects and correction, which removes the bias with respect to ARGO

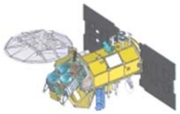


Aquarius SSS, Wind and Soil Moisture Products



Aquarius soil moisture from Jackson and Bindlish

SSMIS rain from RSS



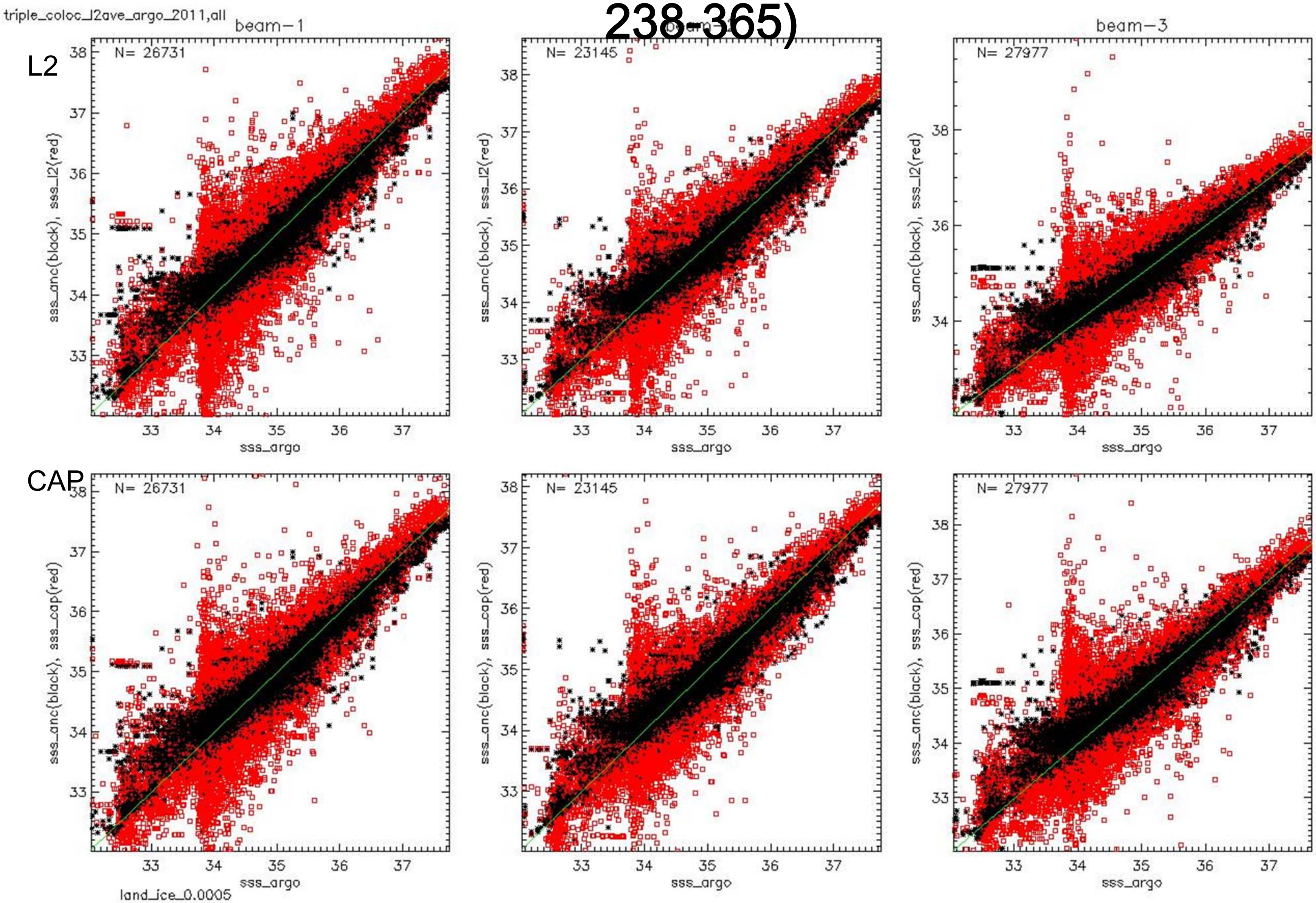
Error Analysis of CAP Wind Speed

- Two sets of triple collocation analyses indicate that CAP's wind speed accuracy is comparable to those of SSMIS and QuikSCAT.

	Bias	Slope	RMS Error
SSMI	0	1	0.6516
QuikSCAT	0.4154	0.9714	0.8639
CAP 2.0	-0.1615	1.0452	0.7616

	Bias	Slope	RMS Error
SSMI	0	1	0.7133
ECMWF	0.213	0.9644	0.8290
CAP 2.0	-0.270	1.0465	0.6967

Triple Collocated SSS: ARGO, HYCOM, L2/CAP (2011 238-365)



Excluding record if any SSS<=32 or >= 40 PSU

Land & ice_frac <= 0.0005

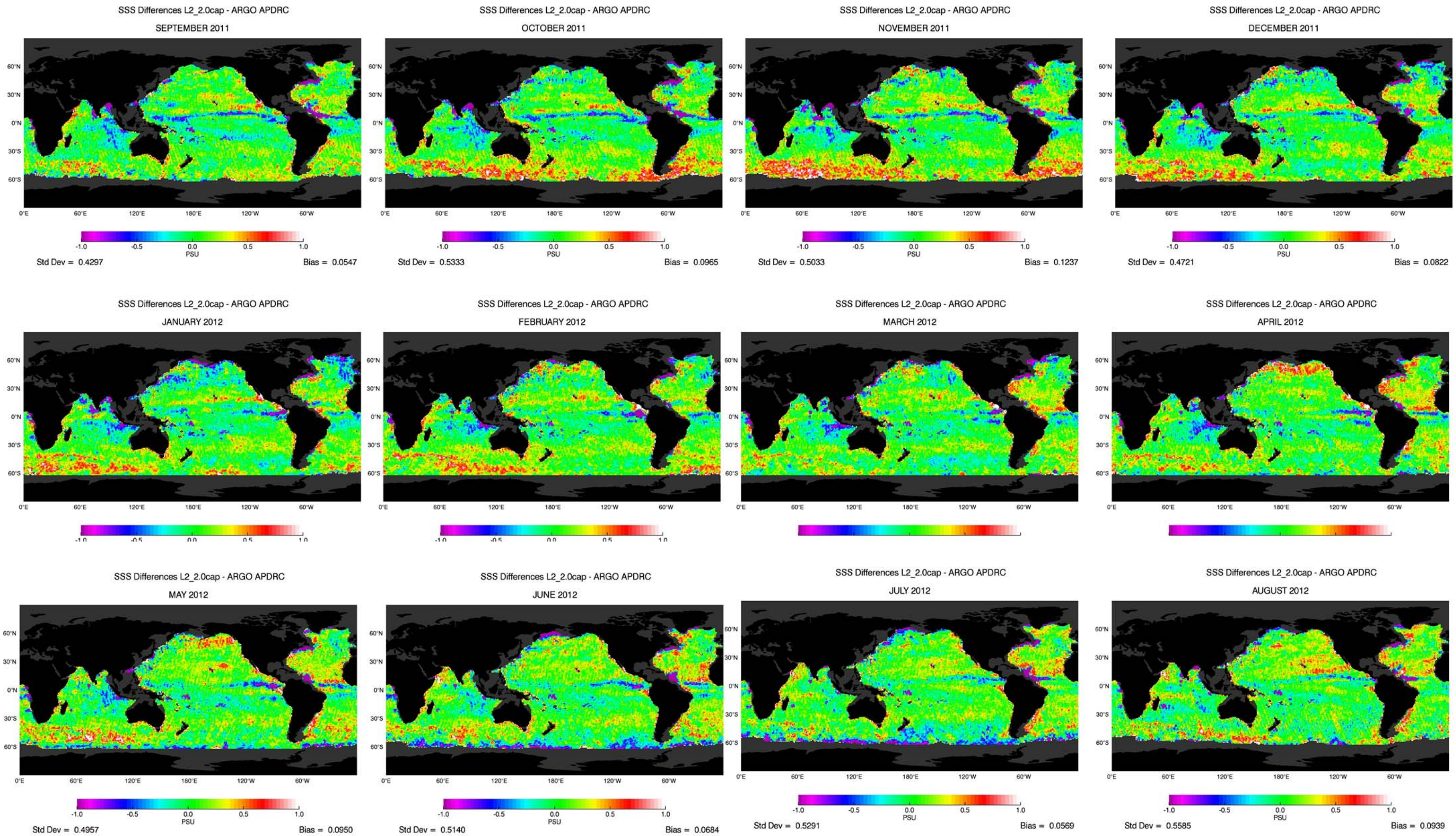
Triple Collocated SSS: ARGO, HYCOM, L2/CAP (2011), $<r_1r_2>=<r_1r_3>=<r_1r_3>=0$

	ARGO	HYCOM	L2
Beam 1; Bias	0	4.4533	0.6572
Beam 2; Bias	0	4.4759	0.8506
Beam 3; Bias	0	4.5999	2.5117
Beam 1; Slope	**1**	**0.8724**	**0.9825**
Beam 2; Slope	**1**	**0.8719**	**0.9771**
Beam 3; Slope	**1**	**0.8684**	**0.9307**
Beam 1; Error	**0.1708**	**0.1585**	**0.4382**
Beam 2; Error	**0.1656**	**0.1734**	**0.4049**
Beam 3; Error	**0.1549**	**0.1780**	**0.4457**

	ARGO	HYCOM	CAP
Beam 1; Bias	0	4.4357	1.3685
Beam 2; Bias	0	4.4863	1.8644
Beam 3; Bias	0	4.5756	3.2516
Beam 1; Slope	**1**	**0.8729**	**0.9607**
Beam 2; Slope	**1**	**0.8716**	**0.9461**
Beam 3; Slope	**1**	**0.8690**	**0.9068**
Beam 1; Error	**0.1722**	**0.1573**	**0.4291**
Beam 2; Error	**0.1648**	**0.1740**	**0.3846**
Beam 3; Error	**0.1570**	**0.1766**	**0.4398**

Land & ice_frac <= 0.0005

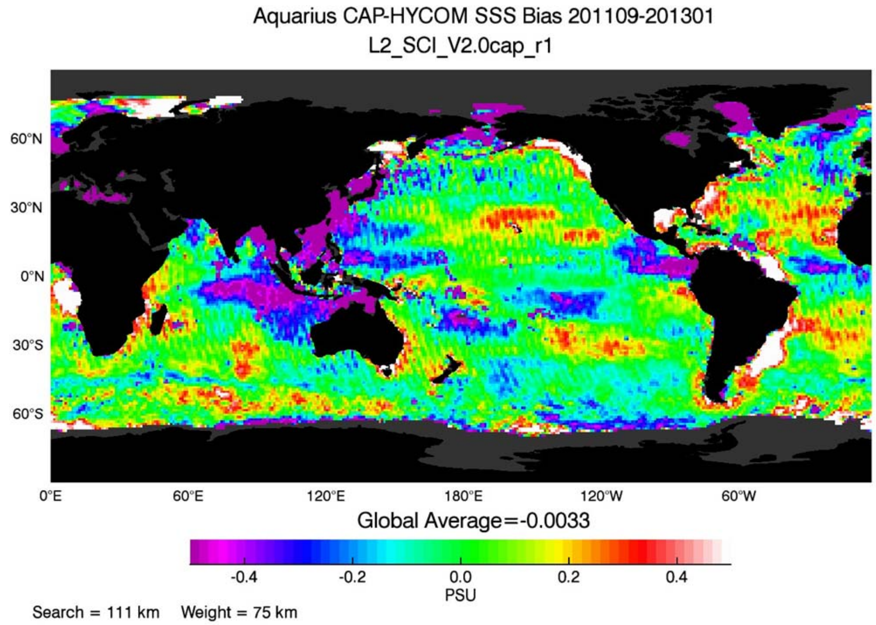
Monthly Averaged CAP-APDRC



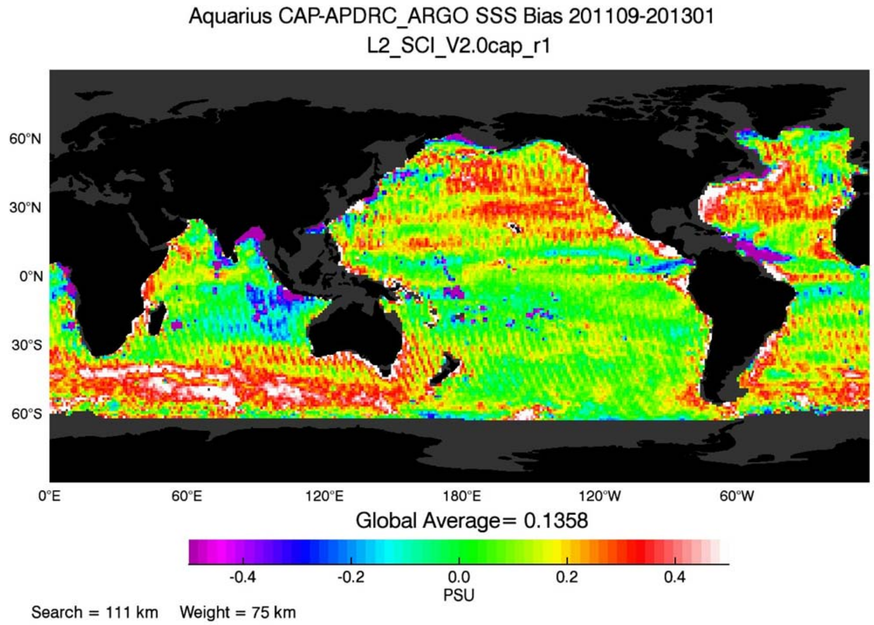
Aquarius CAP Retrieval Bias

- There are differing systematic biases with respect to HYCOM and APDRC
- CAP GMF was trained using Aquarius-HYCOM matchups
  - Need to be retrained to take out the bias

CAP-HYCOM

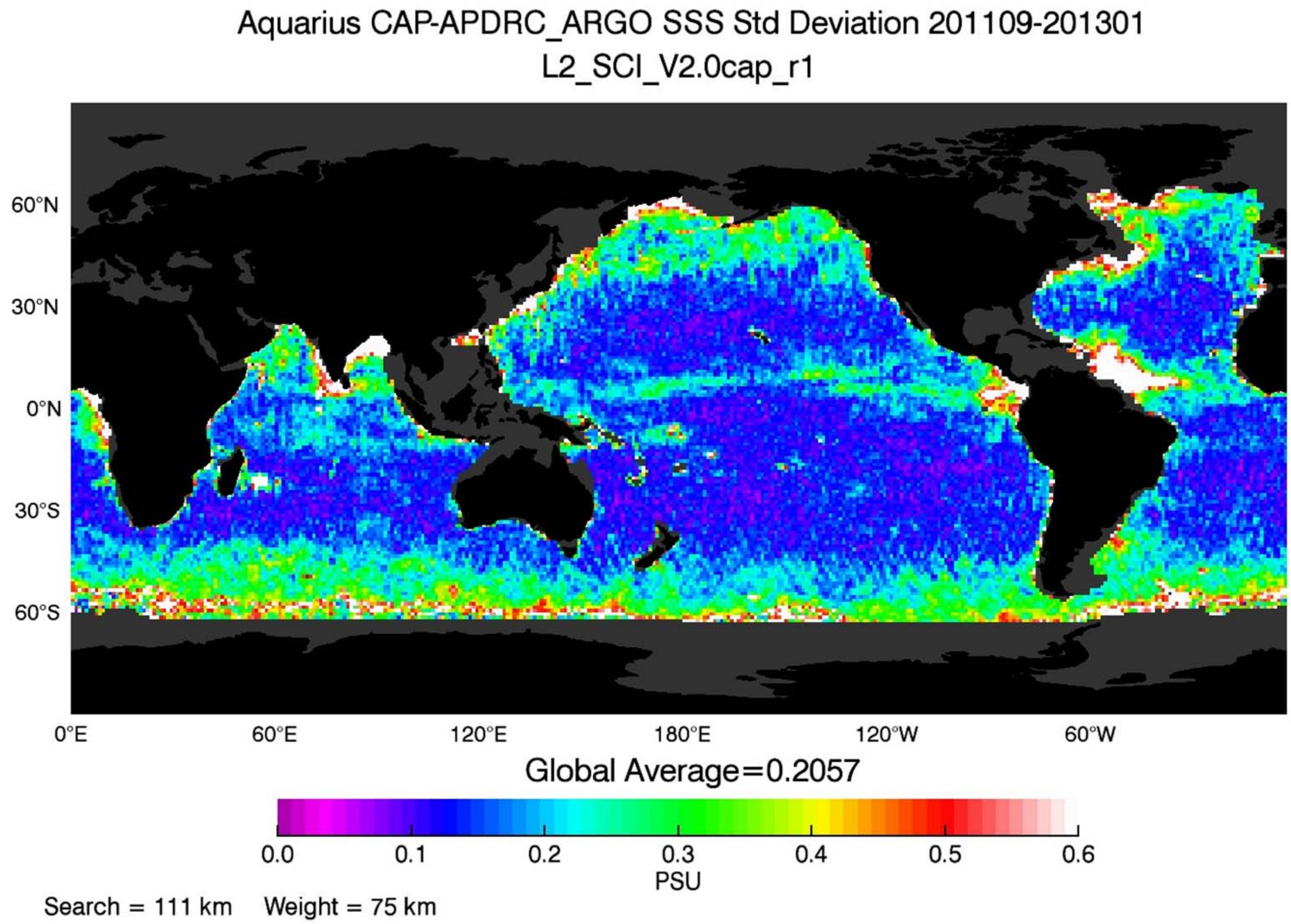


CAP-APDRC



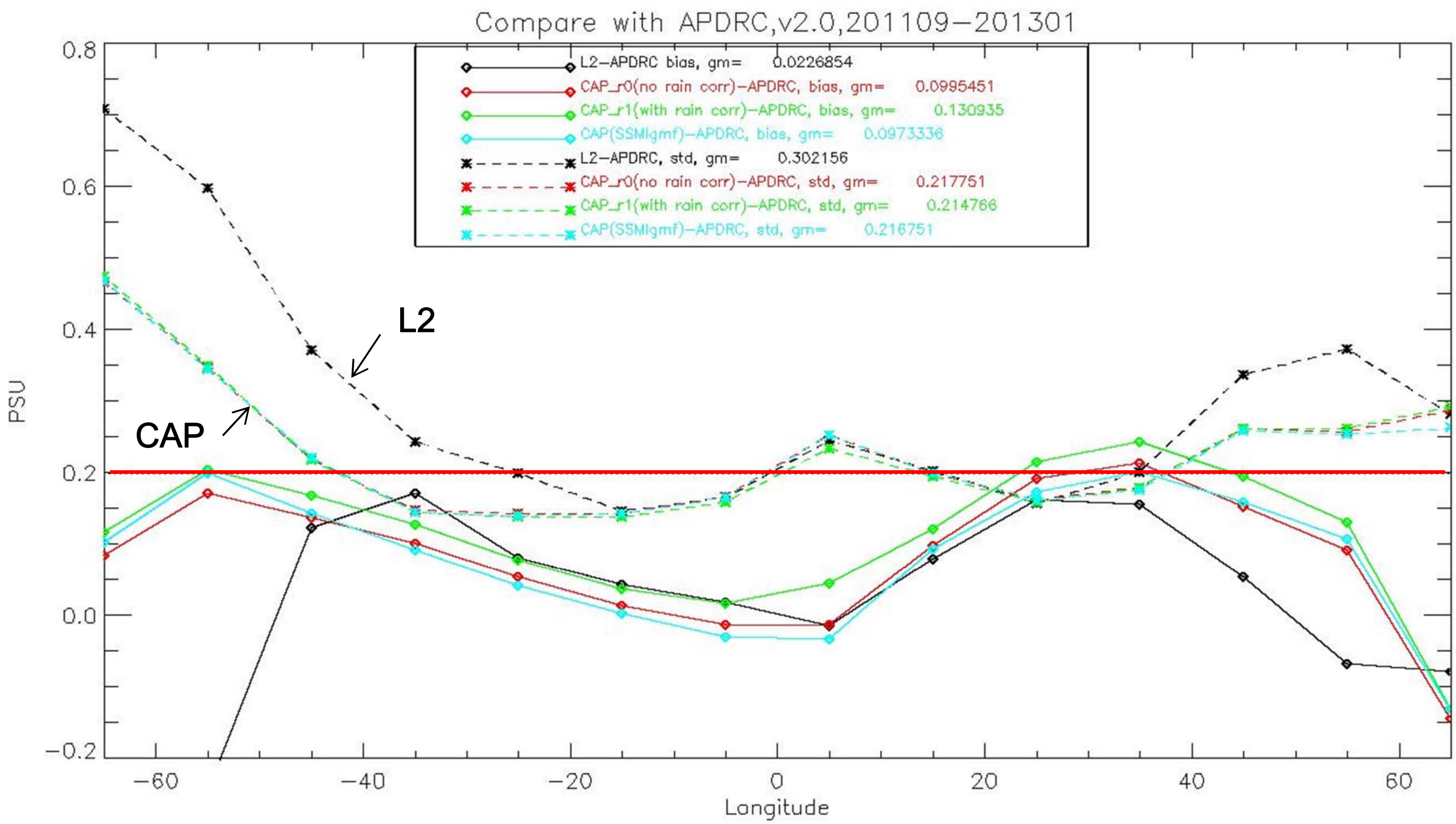
Standard Deviation of Monthly Averaged Differences (AQ-APDRC)

- Mostly between 0.1 to 0.2 psu
- Reaching 0.3 to 0.5 psu for cold waters (high latitudes)



Zonal Averaged Errors Comparison with APDRC

- There is about 0.1 psu mean bias globally – CAP model was trained using HYCOM matchup
- Global average of s.d. for various CAP versions is about 0.21 psu

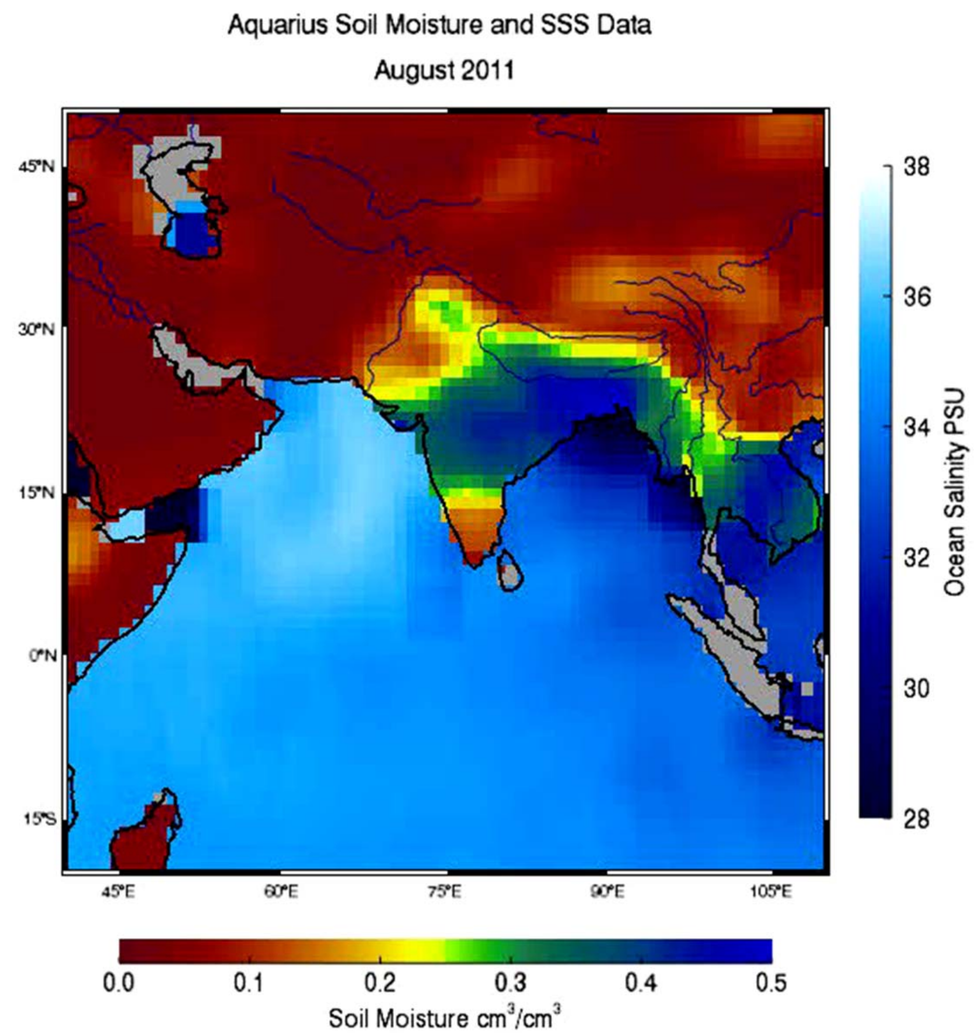


Summary of Aquarius-APDRC

- Land fraction < 0.0005
- The CAP with rain correction retrieval has the smallest standard deviation (best accuracy).

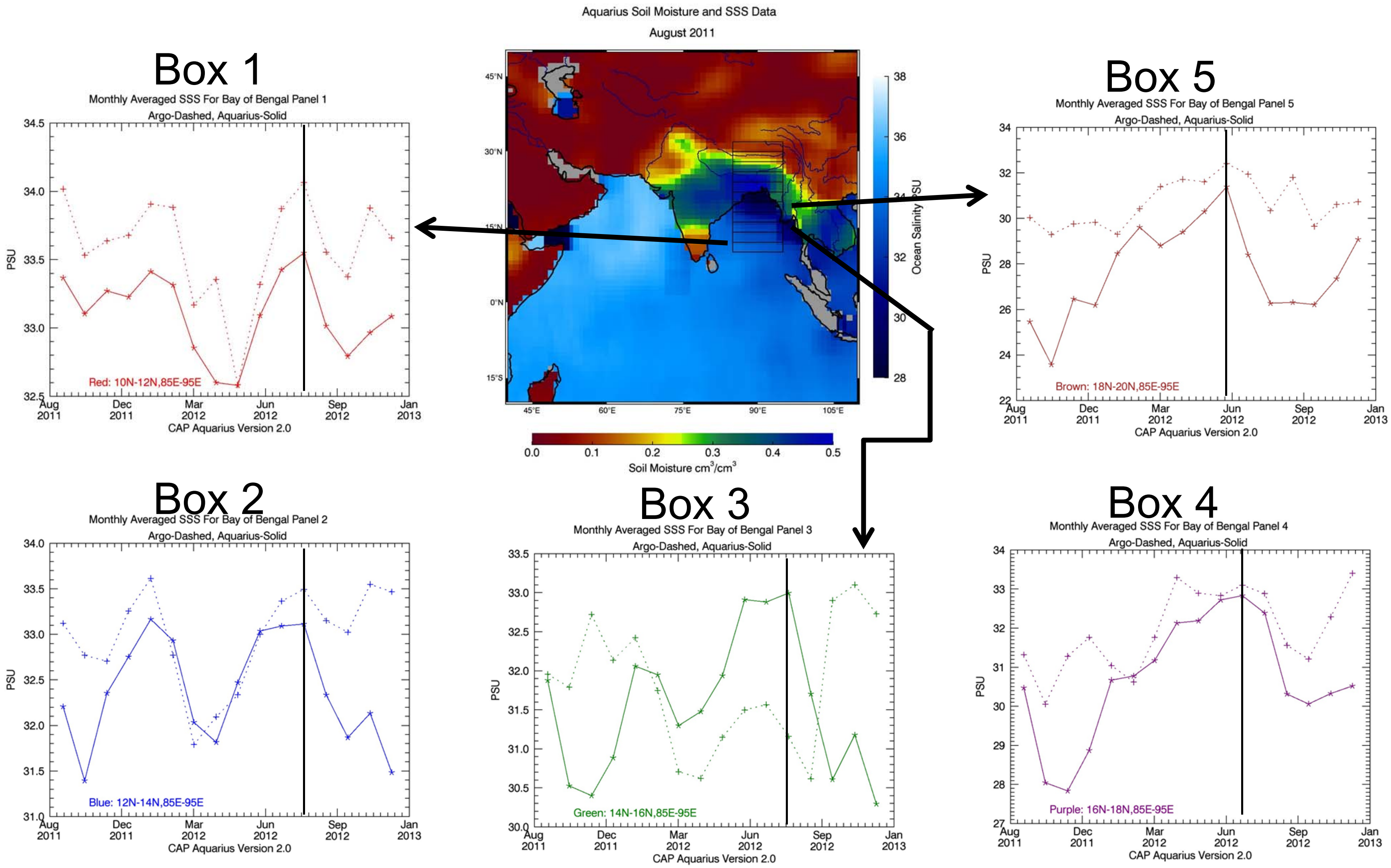
Products	**Global mean of standard deviation of differences of monthly averages (psu)**
L2-APDRC	0.302
CAP-APDRC (SSMIS, no rain correction)	0.217
CAP-APDRC (NCEP, no rain correction)	0.218
CAP-APDRC (NCEP, rain correction)	**0.215**

Application of Aquarius data to Water Cycle Observations
Salinity and Soil Moisture



- Changes of SSS and soil moisture illustrate the water cycle in the Bay of Bengal and the Indian subcontinent.

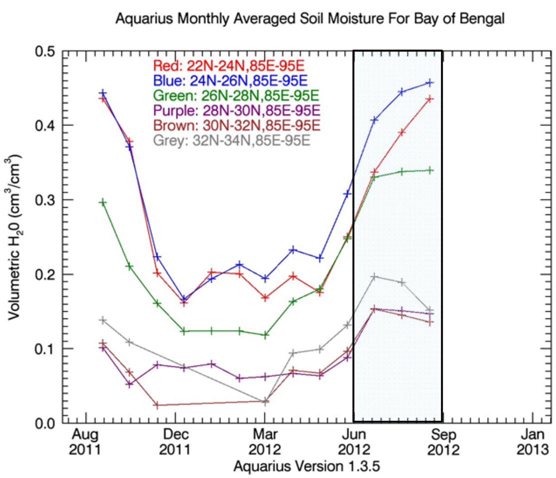
Good Temporal Correlation with ARGO



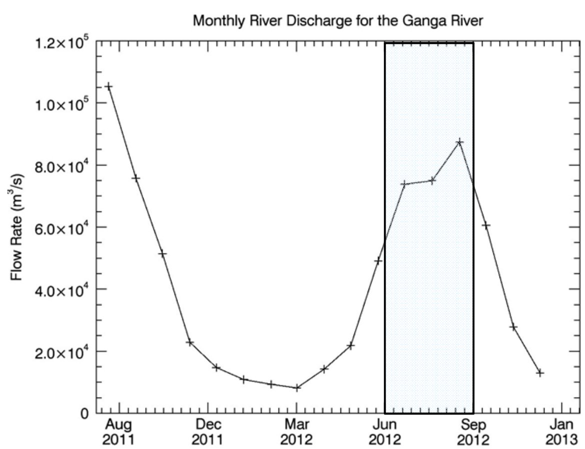
Comparison of SSS, Soil Moisture and River Discharge

- The time series of river discharge reflects the change of soil moisture – rain starting in March
- The drop of salinity in box 5 lags the change of river discharge by about 3 months (March to June)
  - Box 5 is about 200 km from the mouth of Ganga river
- The increase of salinity in box 5 corresponds well with the drop of river discharge

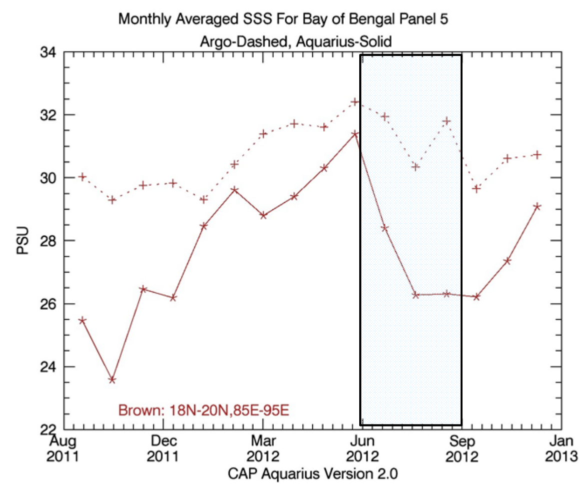
Soil moisture



River discharge



SSS



Summary

- The Aquarius CAP monthly averaged salinity product
  - About 0.24* psu RMS difference wrt ARGO (ADPRC)
    - *after debiasing 0.1 psu (Hycom's artifacts?)
    - CAP's RMS error is estimated to be

$$0.17 = \sqrt{0.24^2 - 0.17^2}$$

  - Assume 0.17 psu error in ARGO based on triple collocation analysis
- Aquarius SSS, wind and soil moisture together with the altimeter river discharge provide a rich picture of water cycle
- HYCOM is probably inadequate for calibration drift correction and algorithm development for Aquarius any more.

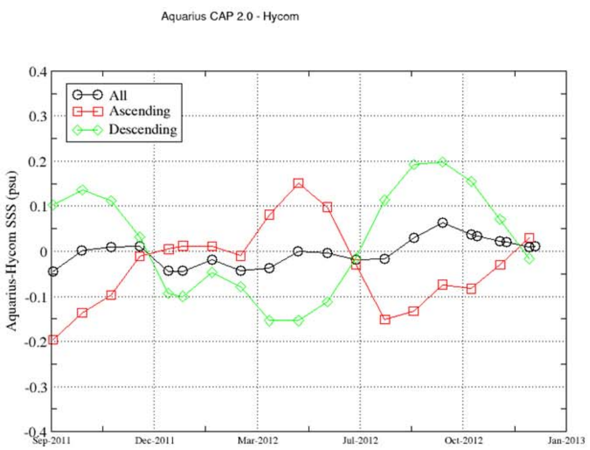
Plan Towards CAP V3.0

- Incorporate rain correction
- Improve galactic reflection correction -> Ascending-descending bias
- Improve Faraday rotation correction -> regional and global bias
- Include X-pol scatterometer sigma0 for roughness correction -> high latitudes
- Improve land contamination correction

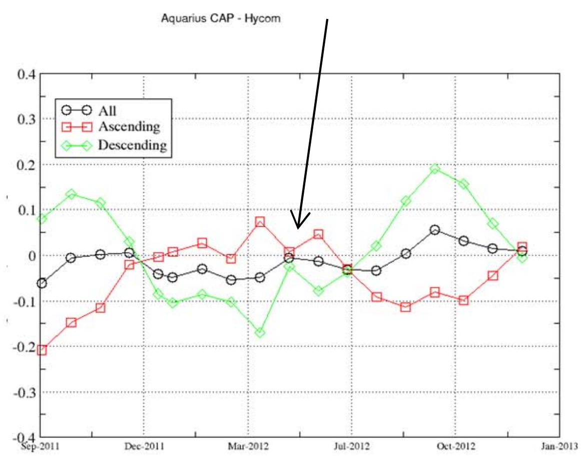
CAP 2.0 (Developmental) Retrieval Bias

- After effective beamwidth adjustment
- Retrieval biases (28 day average) vary over time
- Improvement: Asc-Des biases are reduced in May-August 2012
- Not much change in Sept-Oct 2011

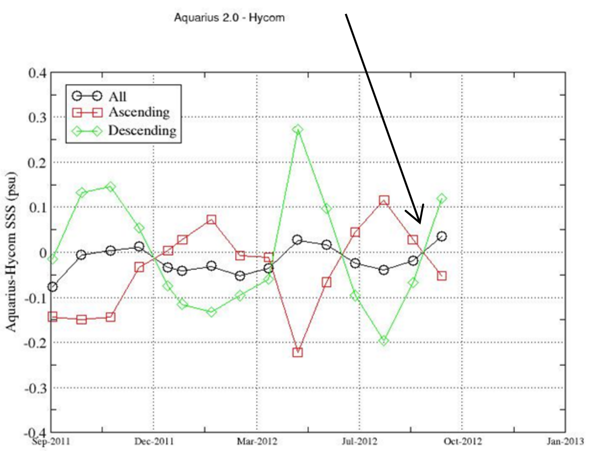
CAP 2.0



After effective beamwidth and scaling adjustment using May-June 2012 data



After effective beamwidth and scaling adjustment using Sept 2012 data



Aquarius CAP Products distributed through PO.DAAC

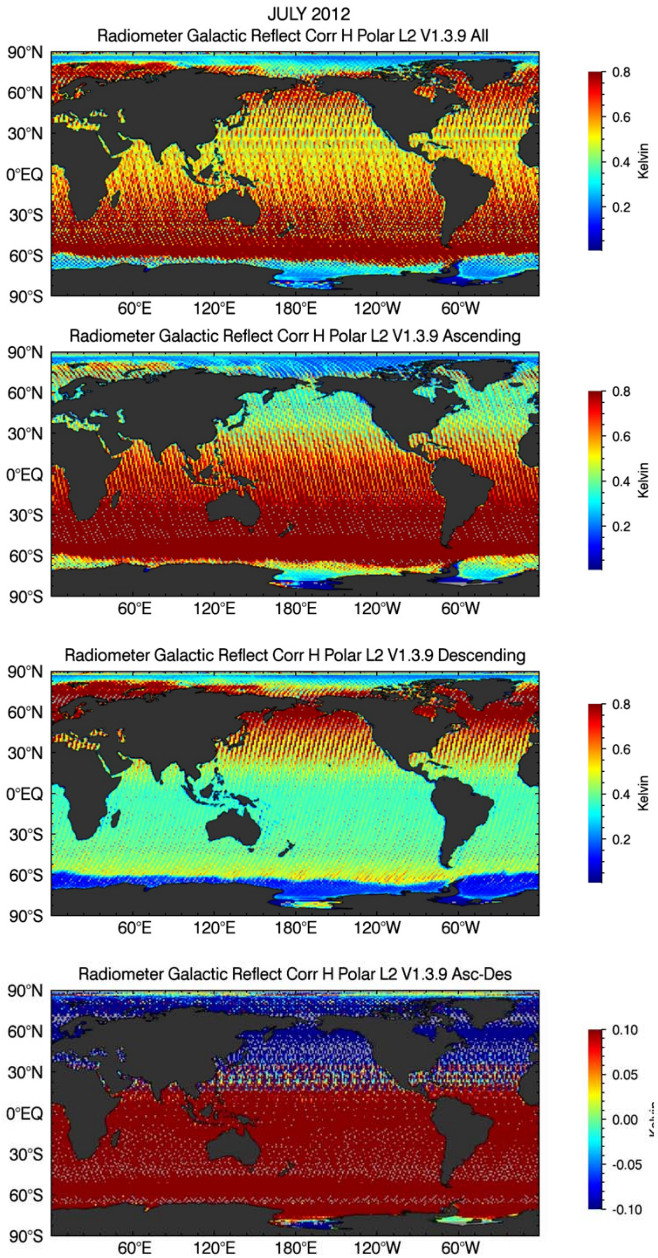
- Aquarius CAP (combined active-passive) product processed at JPL:
  - SSS
  - Wind speed
  - Wind direction
- **CAP V2.0 L2 and L3 products available at PO.DAAC**
  - **http://podaac.jpl.nasa.gov/SeaSurfaceSalinity**
  - **Follow the FTP Data Access link for Aquarius data**

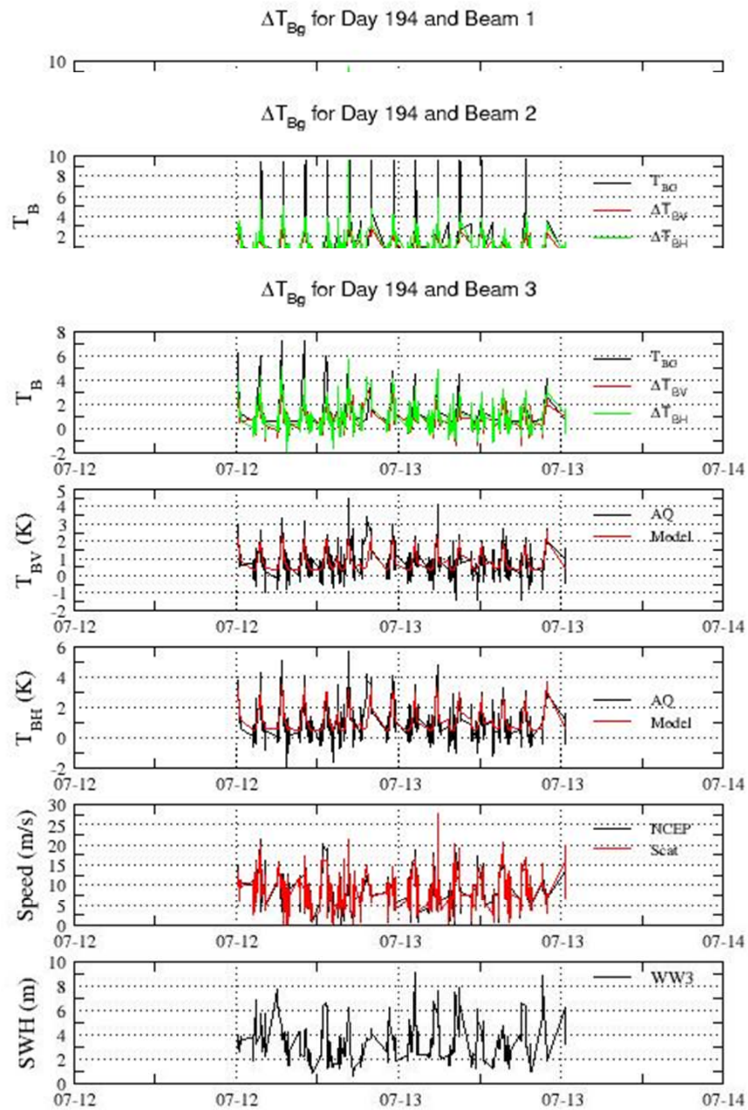
Summary

- Gaussian Geometric Optics model appears fairly reasonable
- Tuning in the Gaussian slope allows some improvement
- The residual may have small dependence on SWH and wind speed
- The residual appears to depend on antenna beam (incidence angle) and polarization
  - Diffuse scattering effects?
- Will start to explore non-Gaussian angular distribution (K) for bistatic scattering coefficients

$$\Delta T_{Bg} = R\int K(\theta_x,\theta_y)T_{sky}(\theta_x,\theta_y)d\theta_x d\theta_y$$

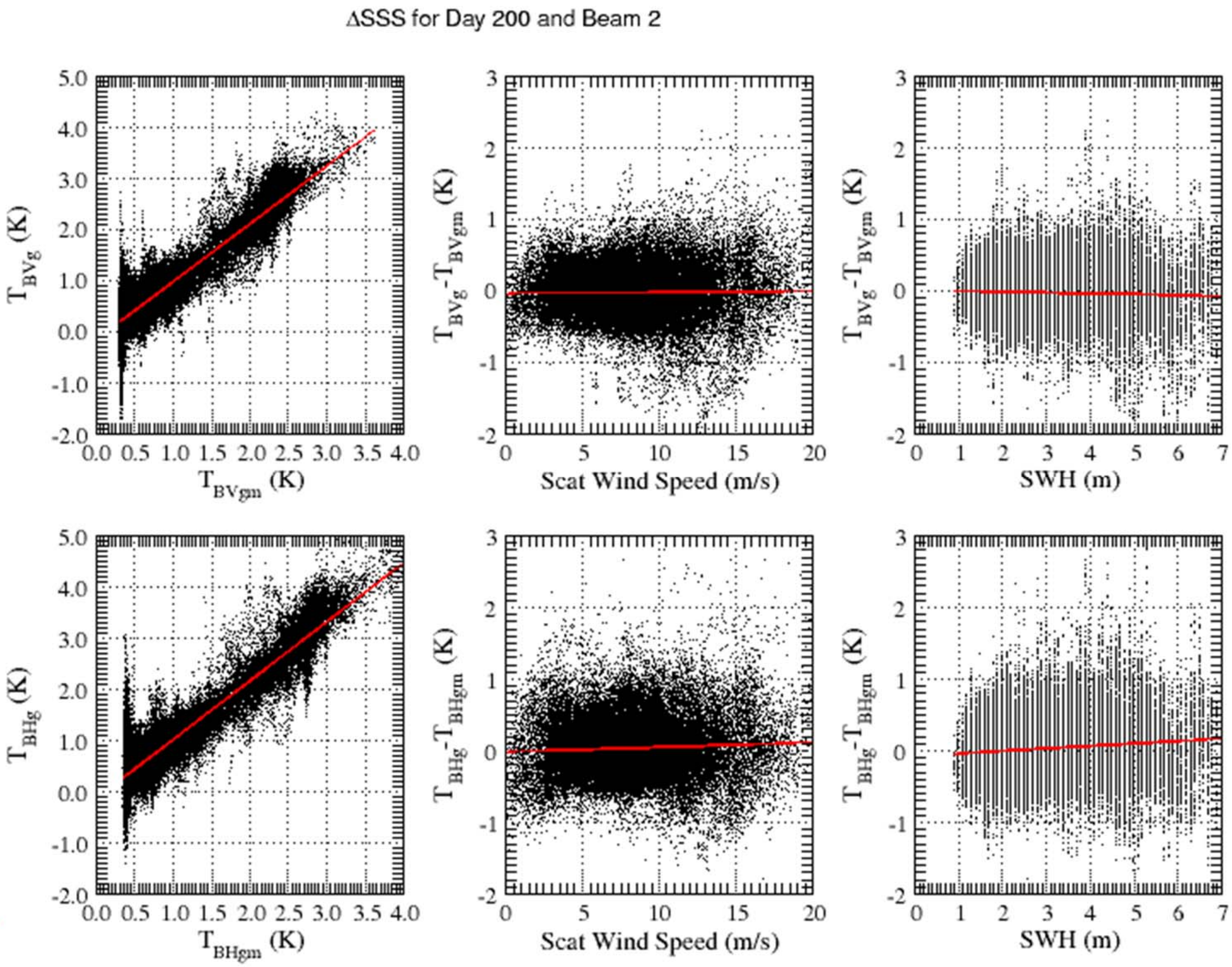
Galactic Reflection and Gaussian GO Model (July 2012)





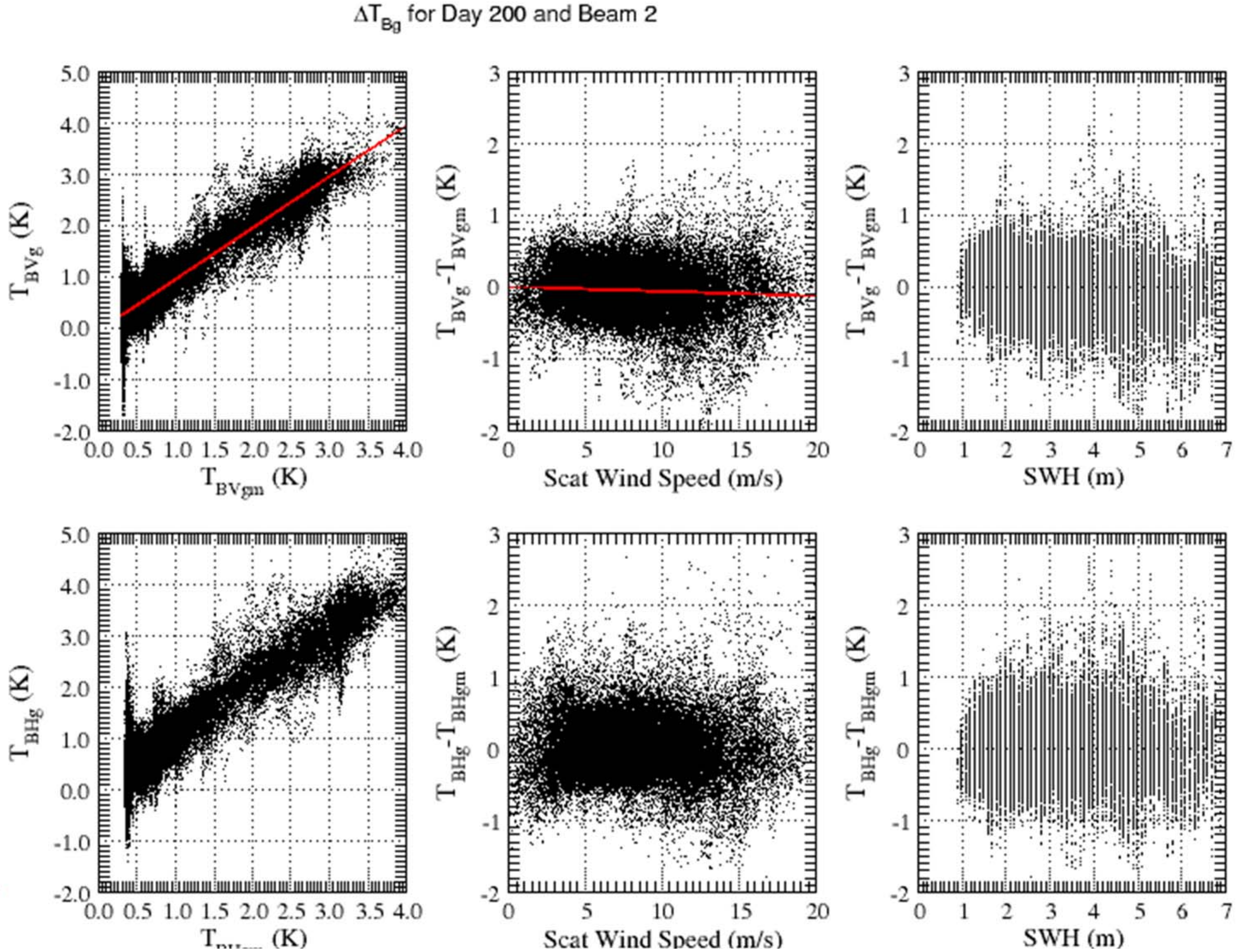
Galactic TB Reflection Scatter
Doy 194-200, 2012

- There is a small departure from linear
- H-pol residual has a small dependence on wind speed and SWH



Galactic TB Reflection Scatter
Doy 194-200, 2012

- Readjusted the effective beamwidth to remove the small departure from linear
- V- and H-pol residuals have a small dependence on wind speed and SWH



Galactic Reflection and Ascending-Descending Bias

- The Geometry Optics model for galactic reflection does not seem to behave consistently throughout the year
- The following charts illustrate the difference between data and model for v and h polarizations. Model appears to overestimate for descending passes