Updates of Aquarius' CAP Ocean Surface Salinity and Wind Retrieval Algorithm

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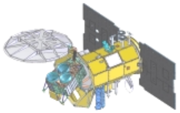
November 14, 2013

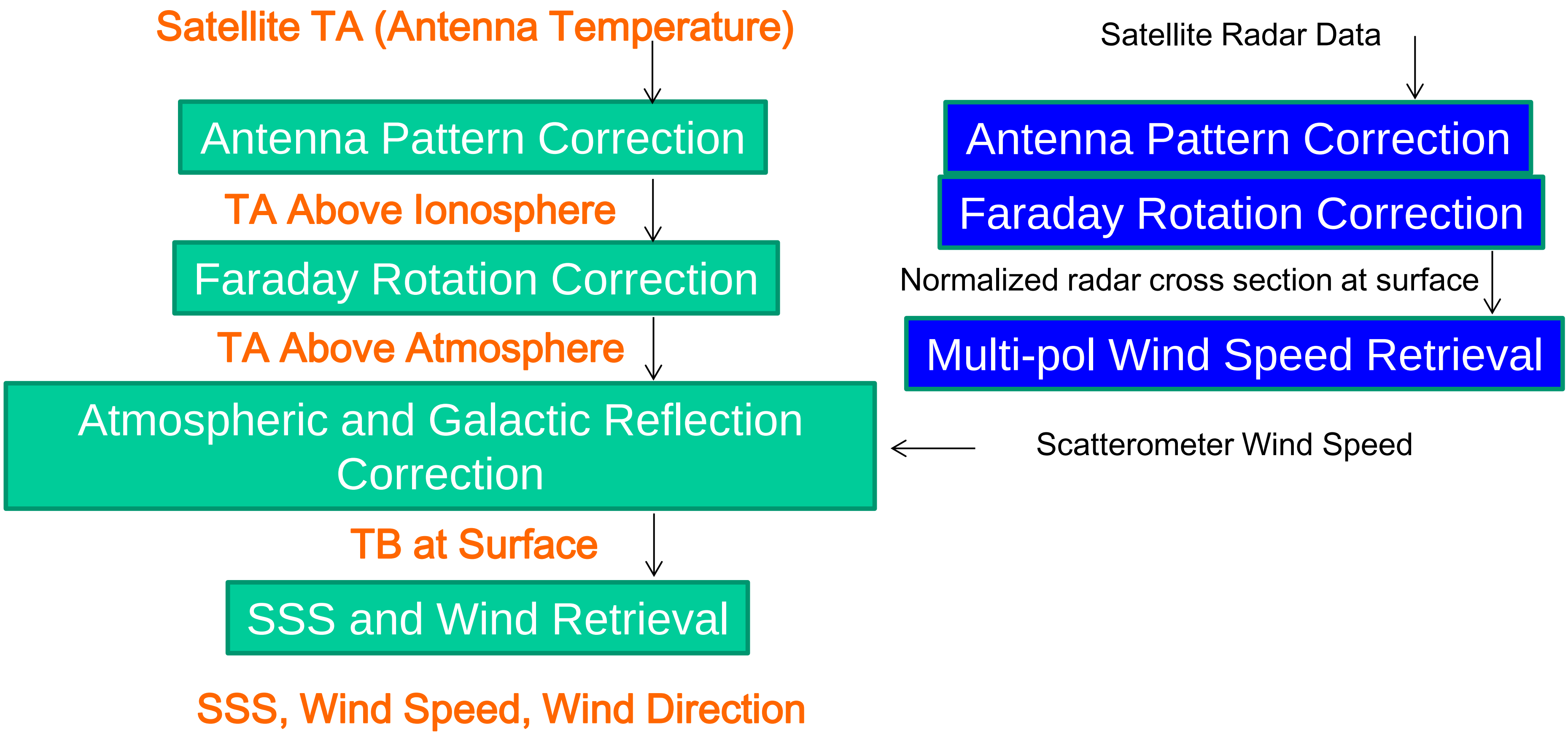
Outline

- Introduction
- CAP V3.0 Flow
- Antenna Pattern and Faraday Rotation Corrections – Optimized
- Galactic Reflection Correction
- SSS and Wind Retrieval
- Summary



Aquarius Combined Active-Passive (CAP) Algorithm

- Use combined active and passive data to correct the surface roughness effects – galactic radiation reflection, wind/wave effects on surface emissivity, and rain-induced roughness

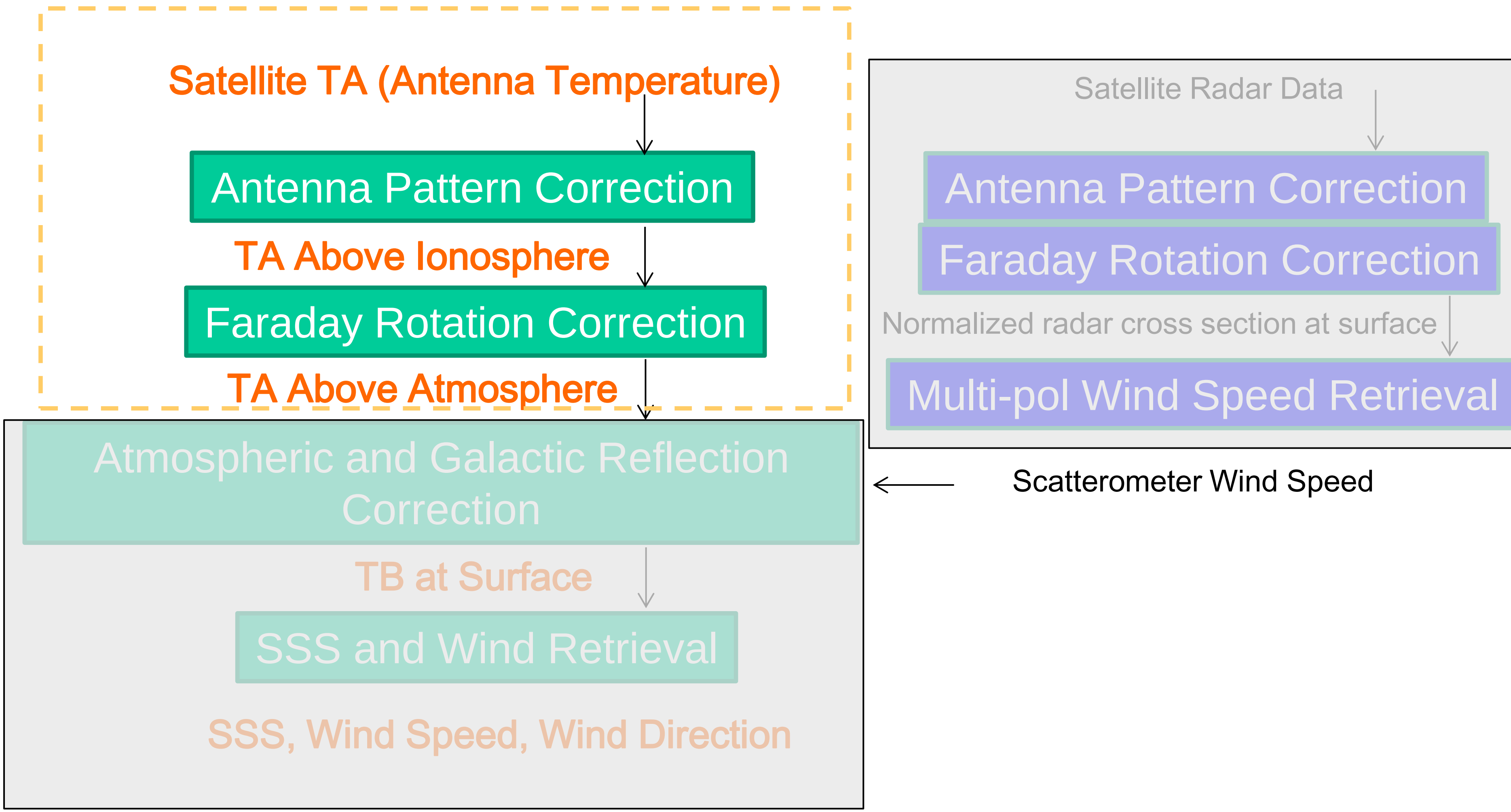


Major Differences Between CAP and RSS Algorithms

- Aquarius CAP algorithm is implemented at JPL – products distributed through PO.DAAC

	Aquarius RSS (Project Baseline)	Aquarius CAP (JPL)
Antenna Pattern Correction	APC matrix elements manually adjusted	APC matrix optimized using ocean data
Galactic Reflection Correction	· Geometric Optics · Ascending and Descending TA symmetrization	Non-Gaussian Scattering
Wind and Wave correction	· Two steps · Require ancillary SSS monthly climatology maps – **equivalent to low-pass filtering**	One step optimization

Aquarius Combined Active-Passive (CAP) Algorithm



Antenna Pattern Correction (APC) matrix Optimization

Satellite T_A (Antenna Temperature)

↓

Antenna Pattern Matrix (A) Optimization

↑

T_{AI} (TAV, TAH and 3rd Stokes Above Ionosphere)

↑

Faraday Rotation Using IGS TEC and GSFC Scaling Maps (E. Dinnat)

↑

TA Above Atmosphere

↑

Atmospheric Radiation and Galactic Reflection (non-Gaussian model)

↑

TBV, TBH, and 3rd Stokes at Surface

↑

TB Simulation Using JPL Polarimetric GMF

↑

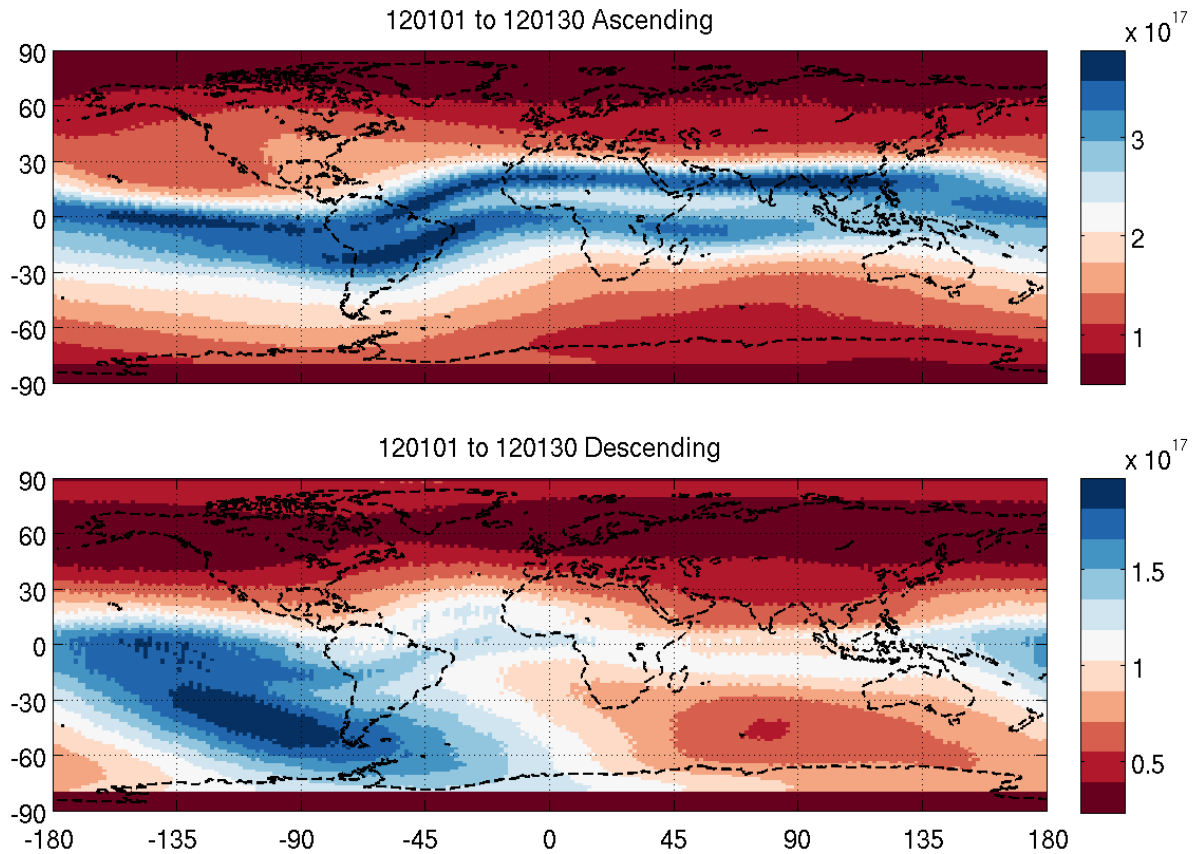
SSS, Wind Speed, Wind Direction

$$Min(AT_A - T_{AI})$$

- A is a 3x3 matrix

TEC and Scale Factors

- TEC Scale factors provided by E. Dinnat, and were from NeQuick model
- We do not use this model in the operational processing because it is a monthly climatology, and has discontinuities at monthly boundaries

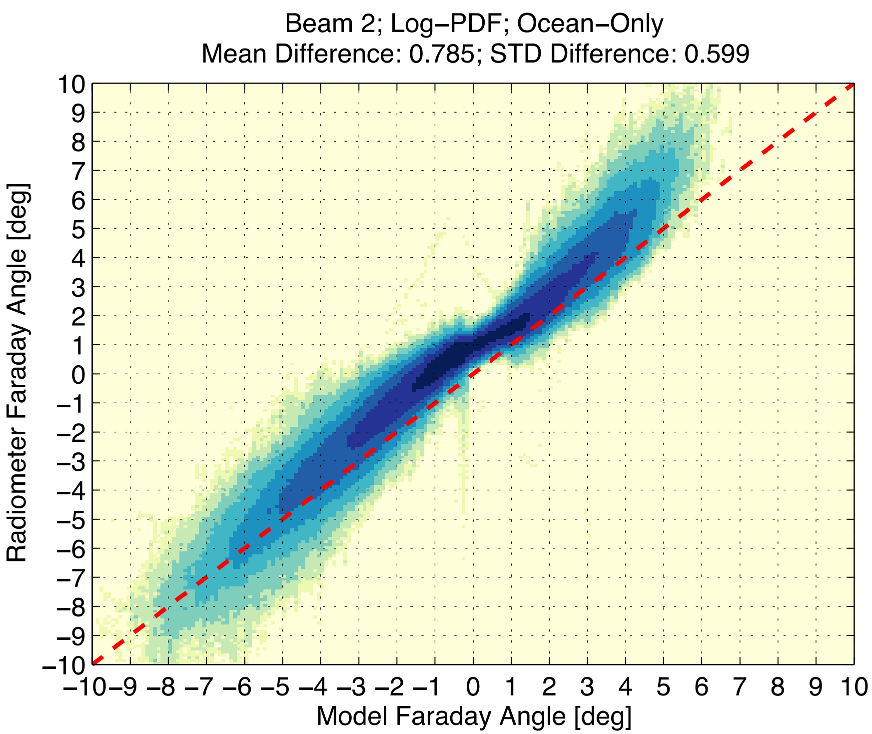


Validation of APC Matrix Optimization Using Ocean Data

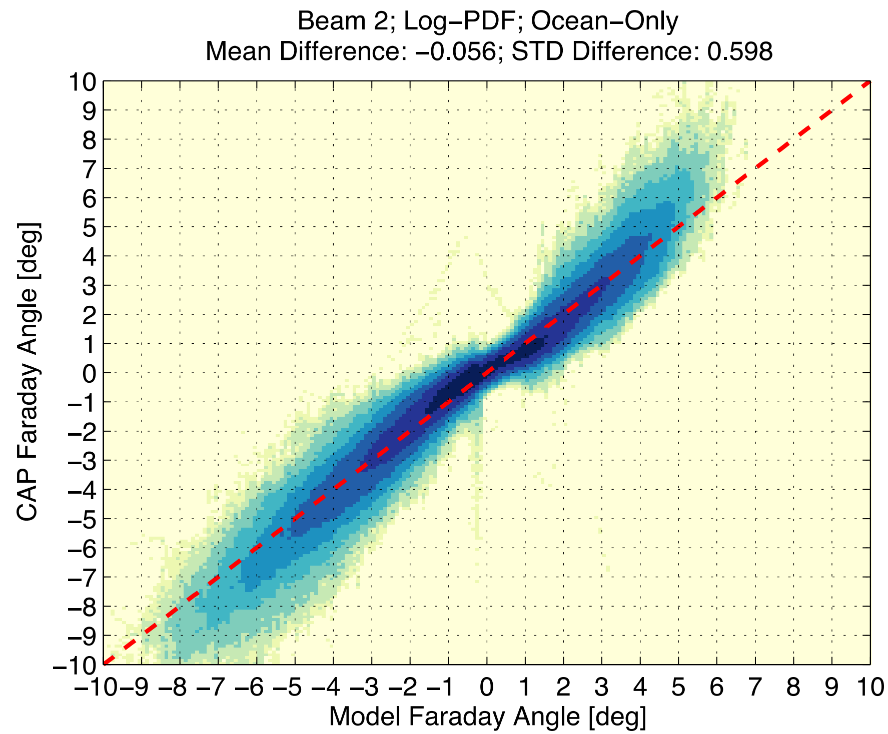
- Use the corrected TA to derive the Faraday Rotation Angle
- Make comparison with the FR from the IGS/Scaling model

$$W = 0.5 \tan\left(\frac{U}{Tv - Th}\right)$$

Aquarius V2.5.1



Aq CAP 2.5.1 (Optimized)

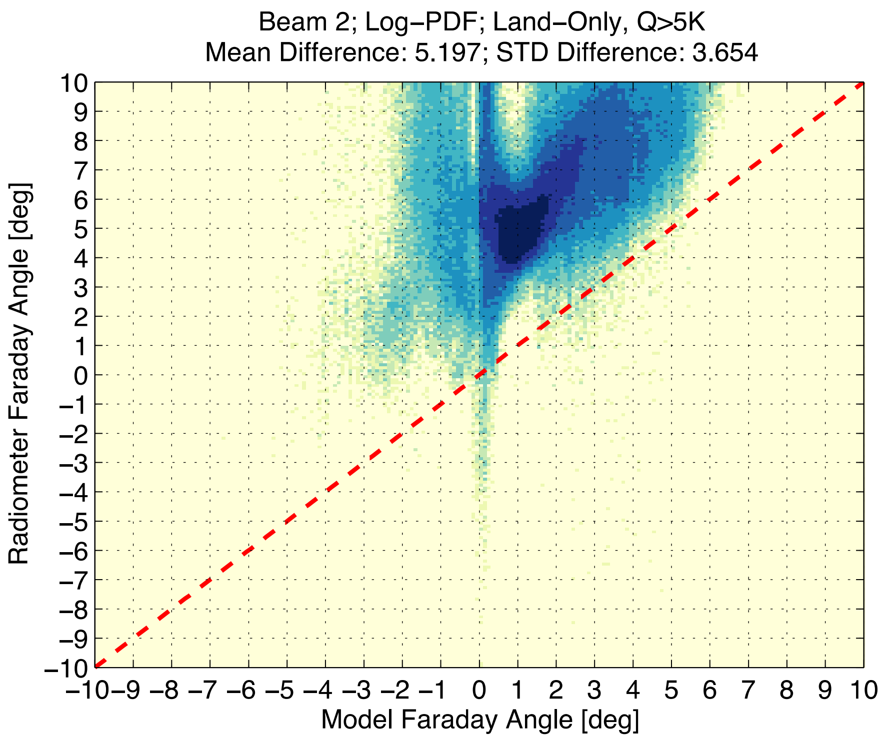


Validation of APC Matrix Optimization Using Land Data

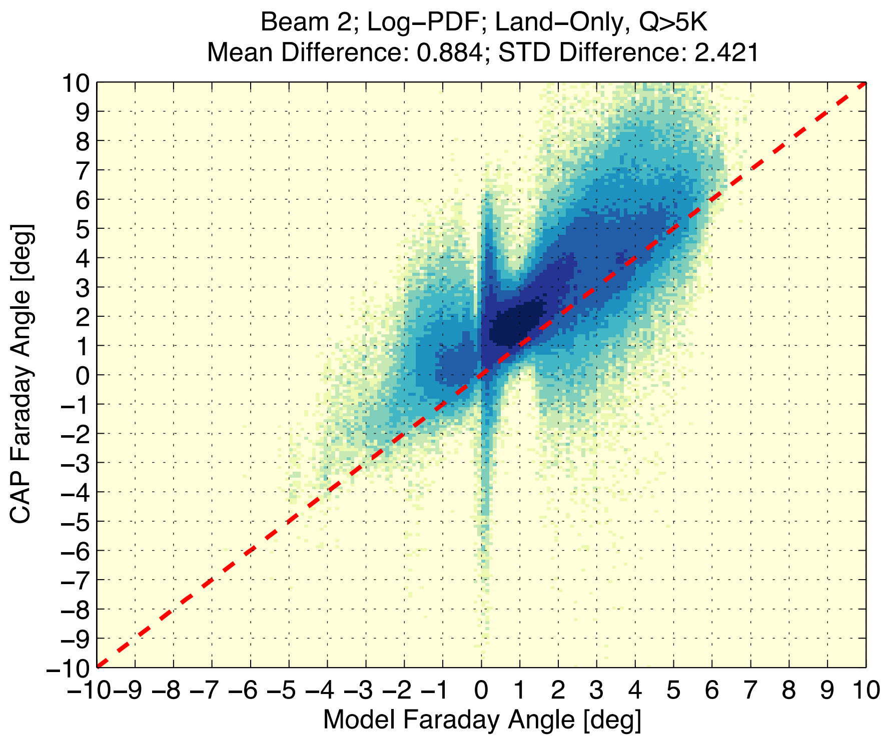
- Use the corrected TA to derive the Faraday Rotation Angle
- Make comparison with the FR from the IGS/Scaling model
- Baseline APC has bias over land for beam 2

$$W = 0.5 \tan\left(\frac{U}{Tv - Th}\right)$$

Aquarius V2.5.1



CAP 2.5.1 (Optimized)



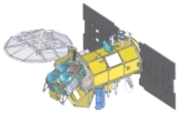
APC and FR Comparison

- Ocean, Beam 2

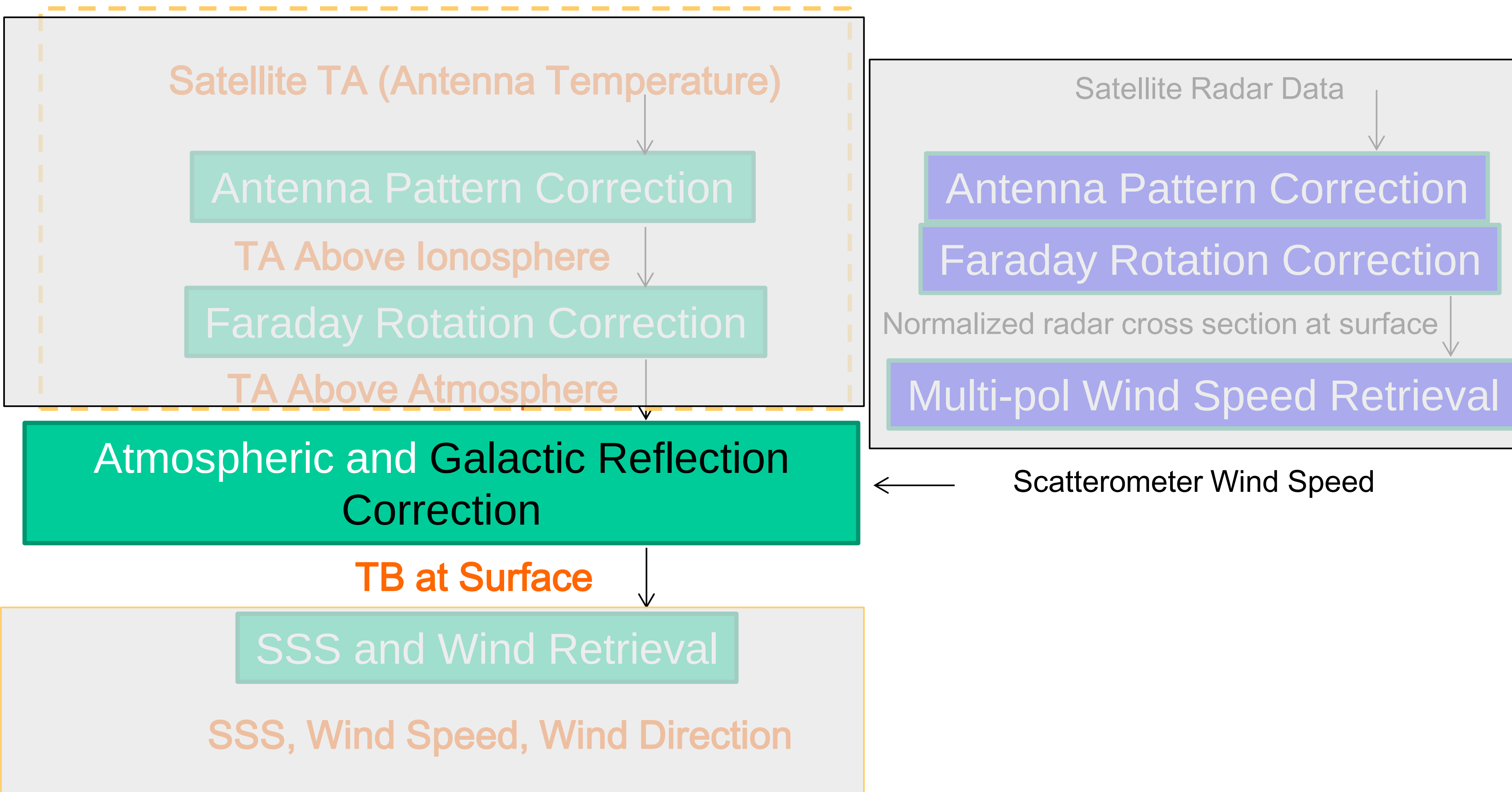
	V2.5.1	CAP V2.5.1
Faraday Rotation Bias	0.785	-0.056
Faraday Rotation Std	0.599	0.596

- Land, Beam 2

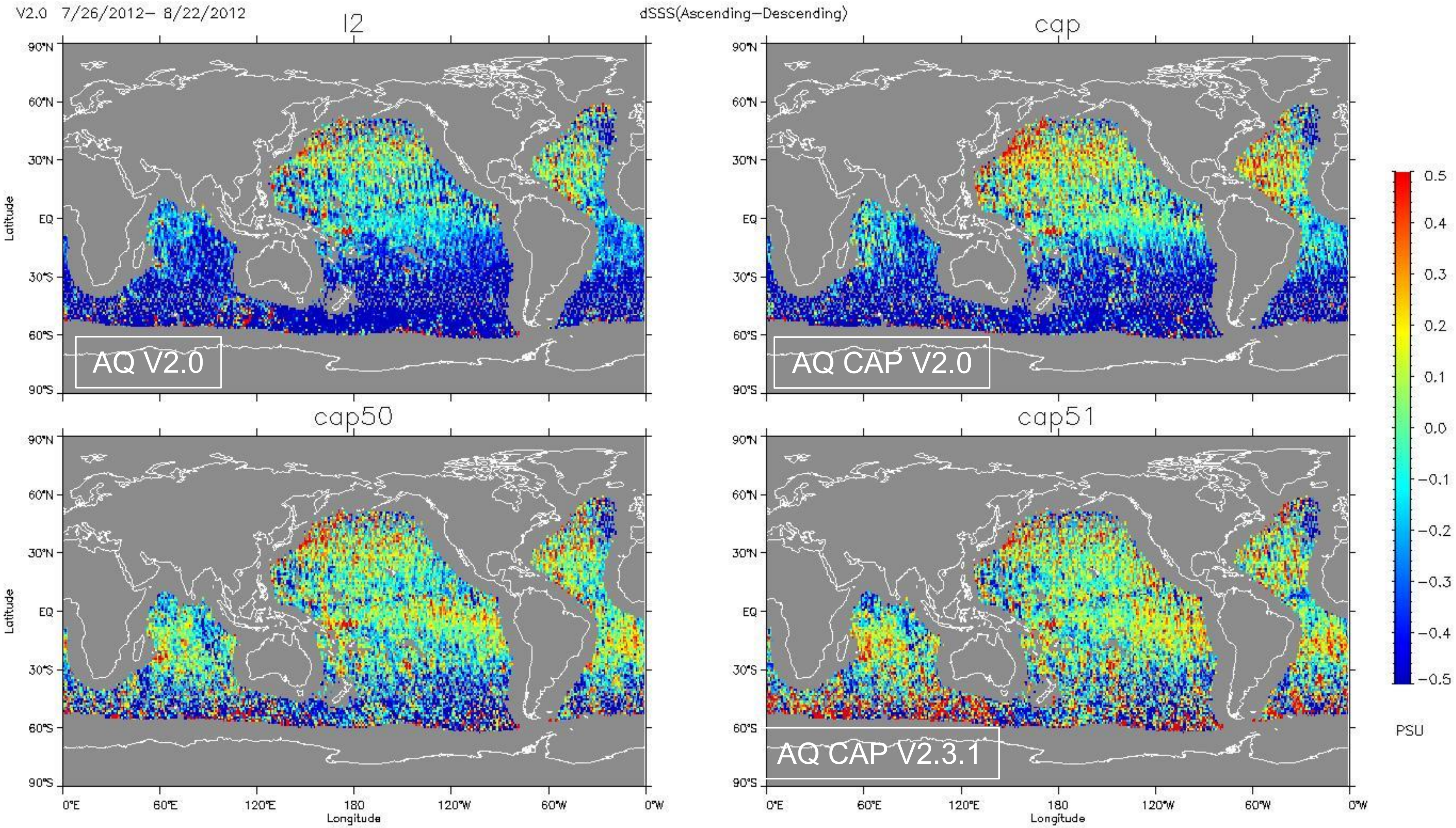
	V2.5.1	CAP V2.5.1
Faraday Rotation Bias	5.197	0.884
Faraday Rotation Std	3.654	2.421



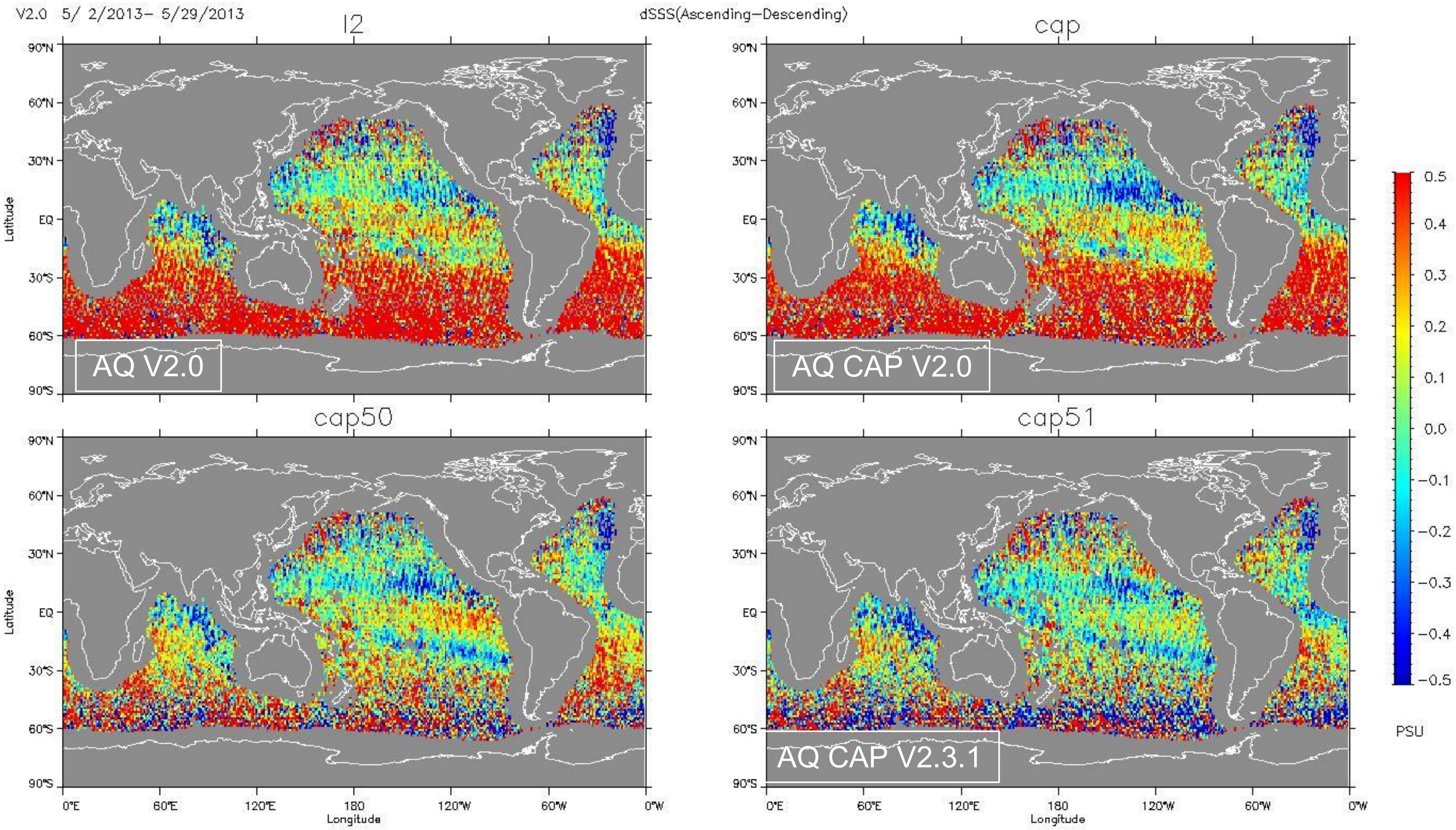
Aquarius Combined Active-Passive (CAP) Algorithm



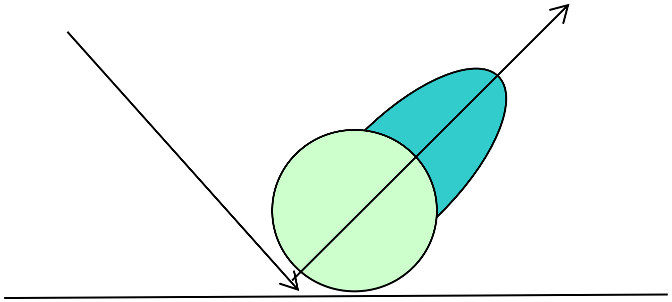
Ascending-Descending Bias
7/26/2012-8/26/2012



Ascending-Descending Bias
5/2/2013-5/29/2013



- Gaussian Geometric Optics model appears fairly reasonable, but not accurate enough
  - Tuning the Gaussian slope allows some improvement
- Why? Total scattering= Geometric Optics + Diffused Scattering (Bragg and so on)
- K is non-Gaussian



$$DT_{Bg} = R\int K(q_x, q_y) T_{sky}(q_x, q_y)\, dq_x\, dq_y$$

- How to determine the Kernel?

- Series Expansion of the Kernel

$$K = \sum_{i=1}^{N} a_i(w) g_i(q_x, q_y)$$

- g_i is a circular Gaussian function with s.d.=i*B; B=5 degrees.
- We can pre-integrate Gi and Tsky

$$DT_{Bg} = R \sum_{i=1}^{N} a_i(w) T_{bgi}$$

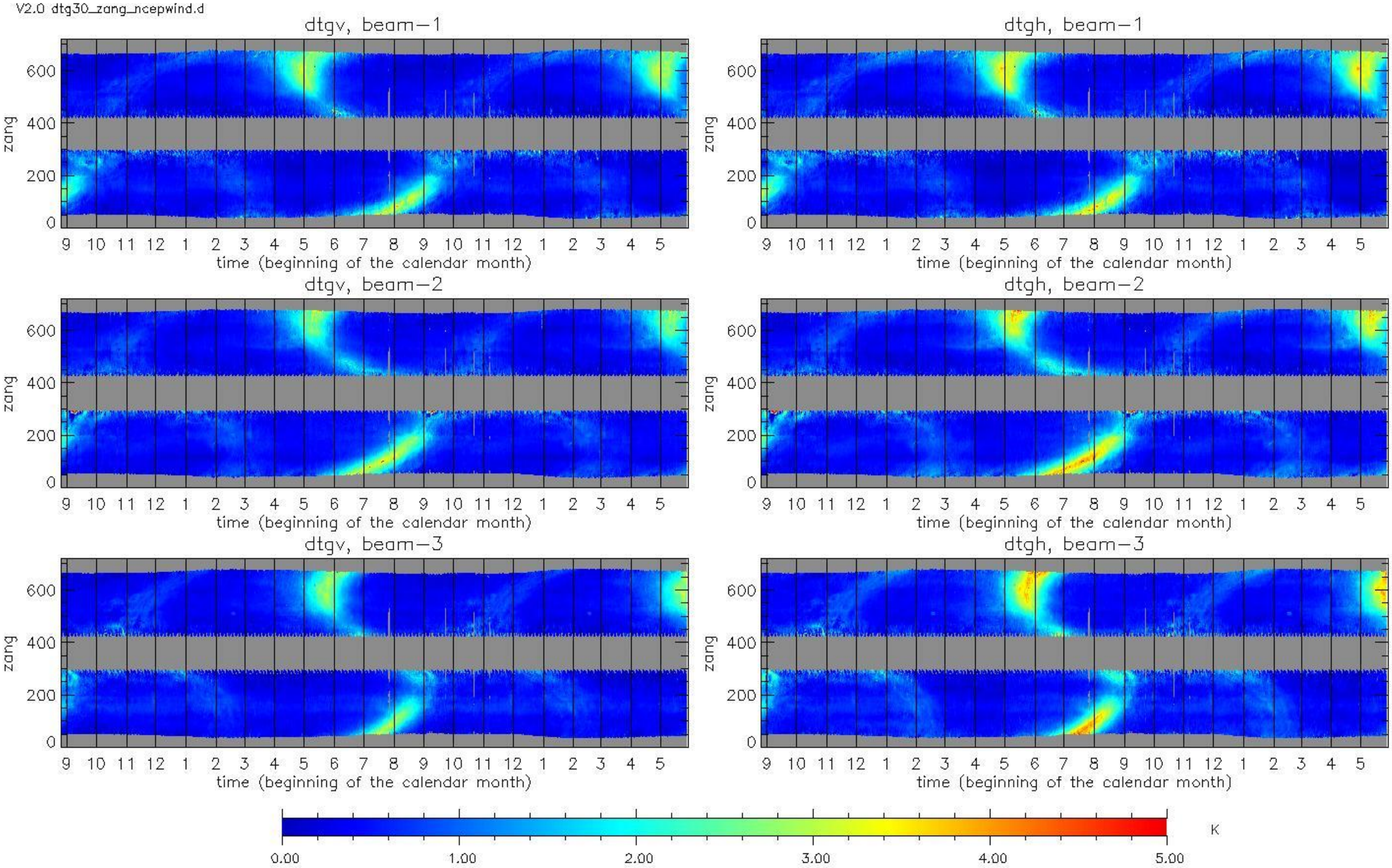
$$T_{bgi} = \int g_i(q_x, q_y) T_{sky}(q_x, q_y)\, dq_x\, dq_y$$

- How to solve a_i?

Network structure & training

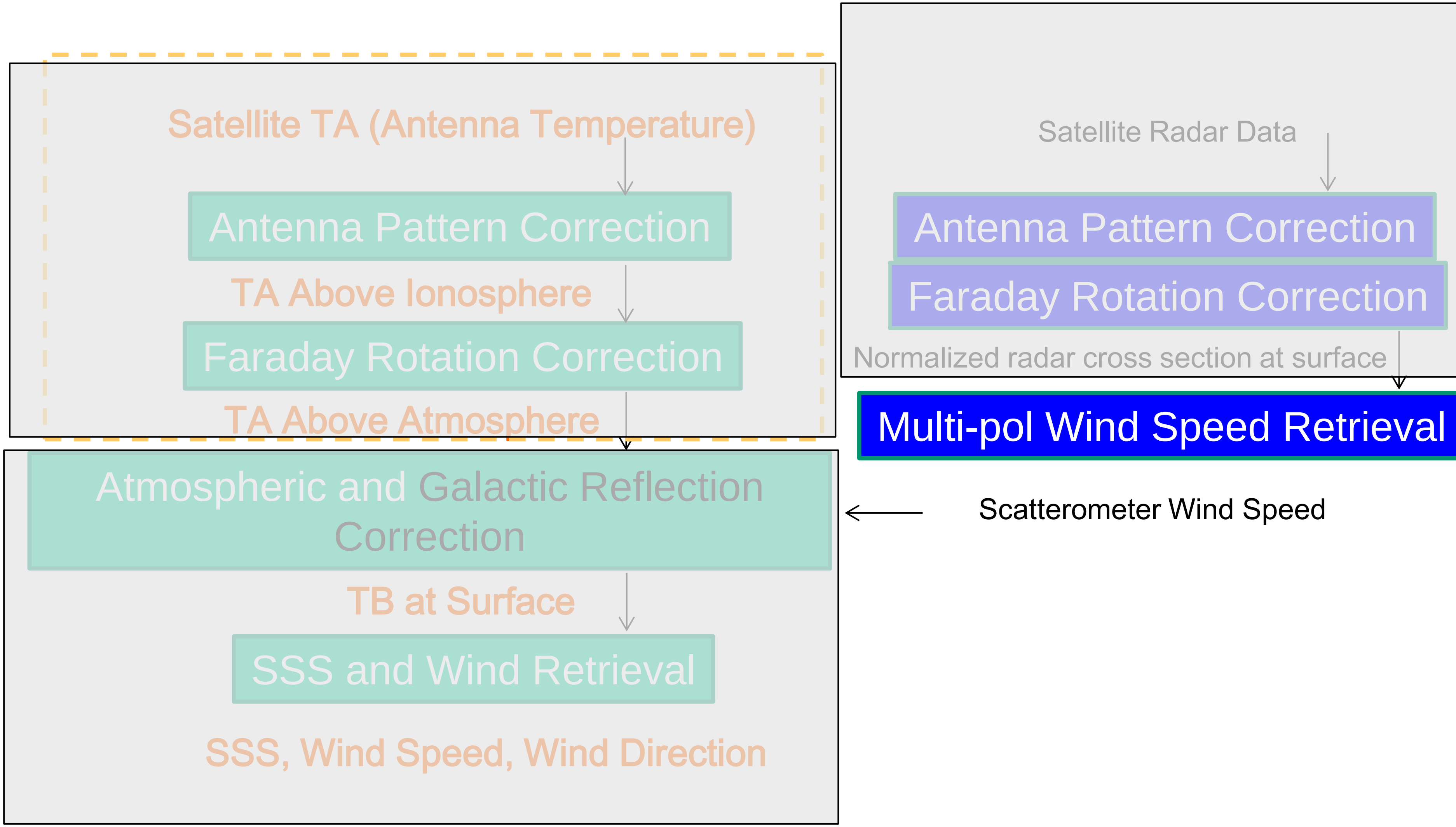
- 3 Layers: 14 x 25 x 2 (for each of 3 beams and each of calendar month)
- Inputs:
  - scat_wind_speed, ww3swh, rel_wind_dir,
  - xanc_trans, rv, rh,
  - tbg, tbg05, tbg10, tbg15, tbg20, tbg25, tbg30,
  - celtht
- Targets: dtbv, dtbh (calculated with scat_wind_speed for roughness correction; with wave correction)
- Training data for NN50:
  - All training data from 2012
  - one day/week, starts from 1st of the month (5 weeks);
  - averaged over five 1.44 sec. pixels
- Training data for NN51:
  - One NN per month for each month in 2012
  - one day/week, starts from 1st of the month (5 weeks);
  - averaged over five 1.44 sec. pixels

NN retrieved dtgv & dtgh (anc_wind_speed for roughness) (used for CAP retrieval)



averaged for doy and zang bins (0.5 deg)

Aquarius Combined Active-Passive (CAP) Algorithm



Wind Retrieval Algorithms

- Scatterometer Only Speed Retrieval
  - Dual polarization retrieval will be implemented in V3.0 data.
  - Have considered HH only and VV only retrieval as well as a tri-polarization retrieval.
- Combined Active Passive (CAP) Speed, Direction and SSS Retrieval

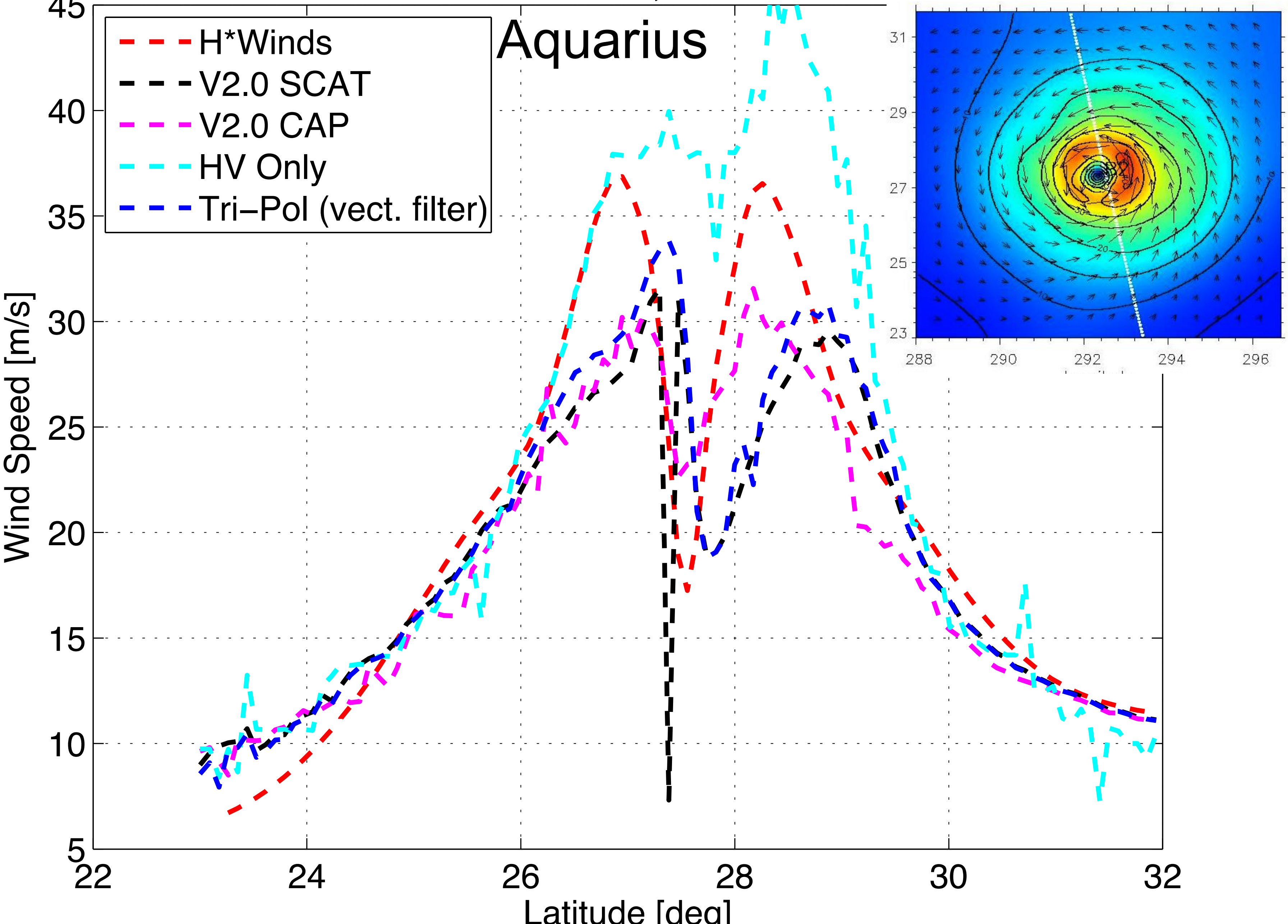
VV+HH Dual-pol Scat. Wind Ret Cost Function:

$$J = -\left[\frac{\left(\sigma_{0,HH}^{gmf} - \sigma_{0,HH}^{obs}\right)}{kp_{HH}\sigma_{0,HH}^{obs}}\right]^2 - \left[\frac{\left(\sigma_{0,VV}^{gmf} - \sigma_{0,VV}^{obs}\right)}{kp_{VV}\sigma_{0,VV}^{obs}}\right]^2$$

VV+HH+HV Tri-Pol Cost Function:

$$J = -\left[\frac{\left(\sigma_{0,HH}^{gmf} - \sigma_{0,HH}^{obs}\right)}{kp_{HH}\sigma_{0,HH}^{obs}}\right]^2 - \left[\frac{\left(\sigma_{0,VV}^{gmf} - \sigma_{0,VV}^{obs}\right)}{kp_{VV}\sigma_{0,VV}^{obs}}\right]^2 - \alpha(w_{NCEP})\left[\frac{\left(\sigma_{0,HV}^{gmf} - \sigma_{0,HV}^{obs}\right)}{kp_{HV}\sigma_{0,HV}^{obs}}\right]^2$$

Hurricane Katia; Beam 2 of Aquarius



Scatterometer Only Wind Speed Performance

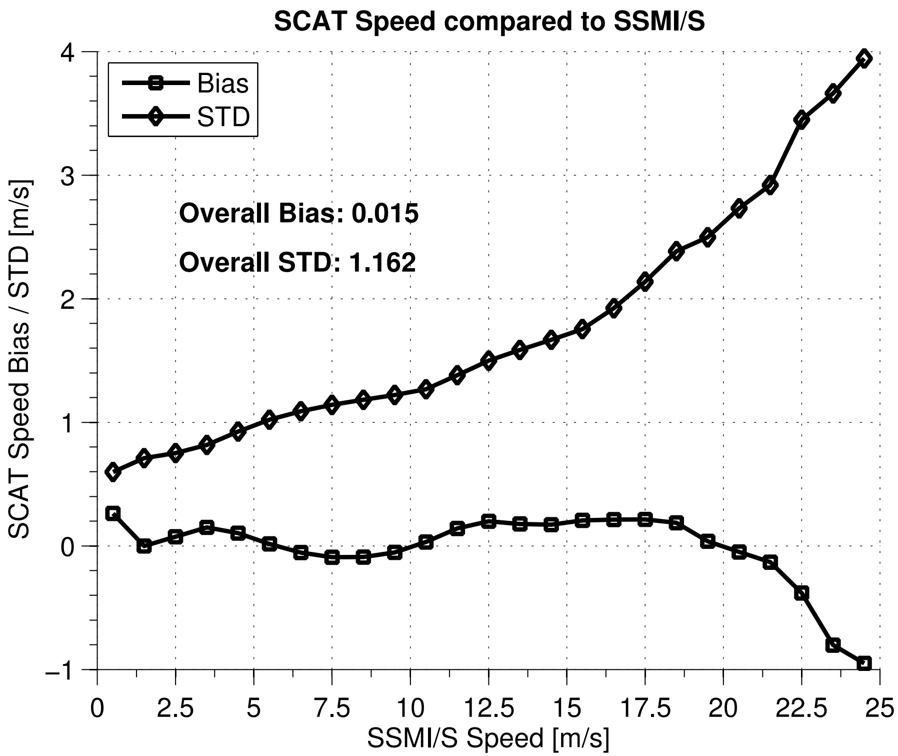


TABLE II
SCAT TRIPLE-COLLOCATION RESULTS

	SSMI/S	ECMWF	SCAT
Bias	0	0.2461	-0.3250
Slope	1	0.9599	1.0454
RMS Error	0.6801	0.8544	0.9357
	SSMI/S	**QuikSCAT**	**SCAT**
Bias	0	0.4901	0.0247
Slope	1	0.9475	1.0174
RMS Error	0.6374	0.9553	0.9833

Fore, A.G.; Yueh, S.H.; Tang, W.; Hayashi, A.K.; Lagerloef, G.S.E., "Aquarius Wind Speed Products: Algorithms and Validation," Geoscience and Remote Sensing, IEEE Transactions on , vol.PP, no.99, pp.1,8, 0. doi: 10.1109/TGRS.2013.2267616

CAP Wind Speed Performance

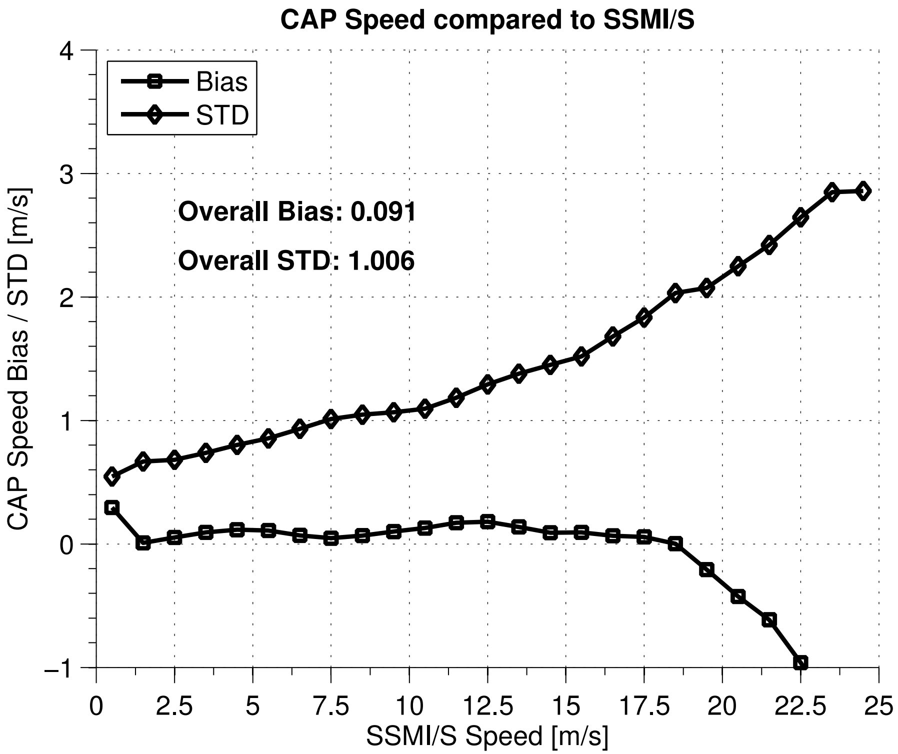


TABLE III
CAP TRIPLE-COLLOCATION RESULTS

	SSMI/S	ECMWF	CAP
Bias	0	0.2126	-0.2679
Slope	1	0.9644	1.0465
RMS Error	0.7133	0.8290	0.6967
	SSMI/S	**QuikSCAT**	**CAP**
Bias	0	0.4819	-0.0071
Slope	1	0.9487	1.0219
RMS Error	0.6466	0.9497	0.7072

Fore, A.G.; Yueh, S.H.; Tang, W.; Hayashi, A.K.; Lagerloef, G.S.E., "Aquarius Wind Speed Products: Algorithms and Validation," Geoscience and Remote Sensing, IEEE Transactions on , vol.PP, no.99, pp.1,8, 0. doi: 10.1109/TGRS.2013.2267616

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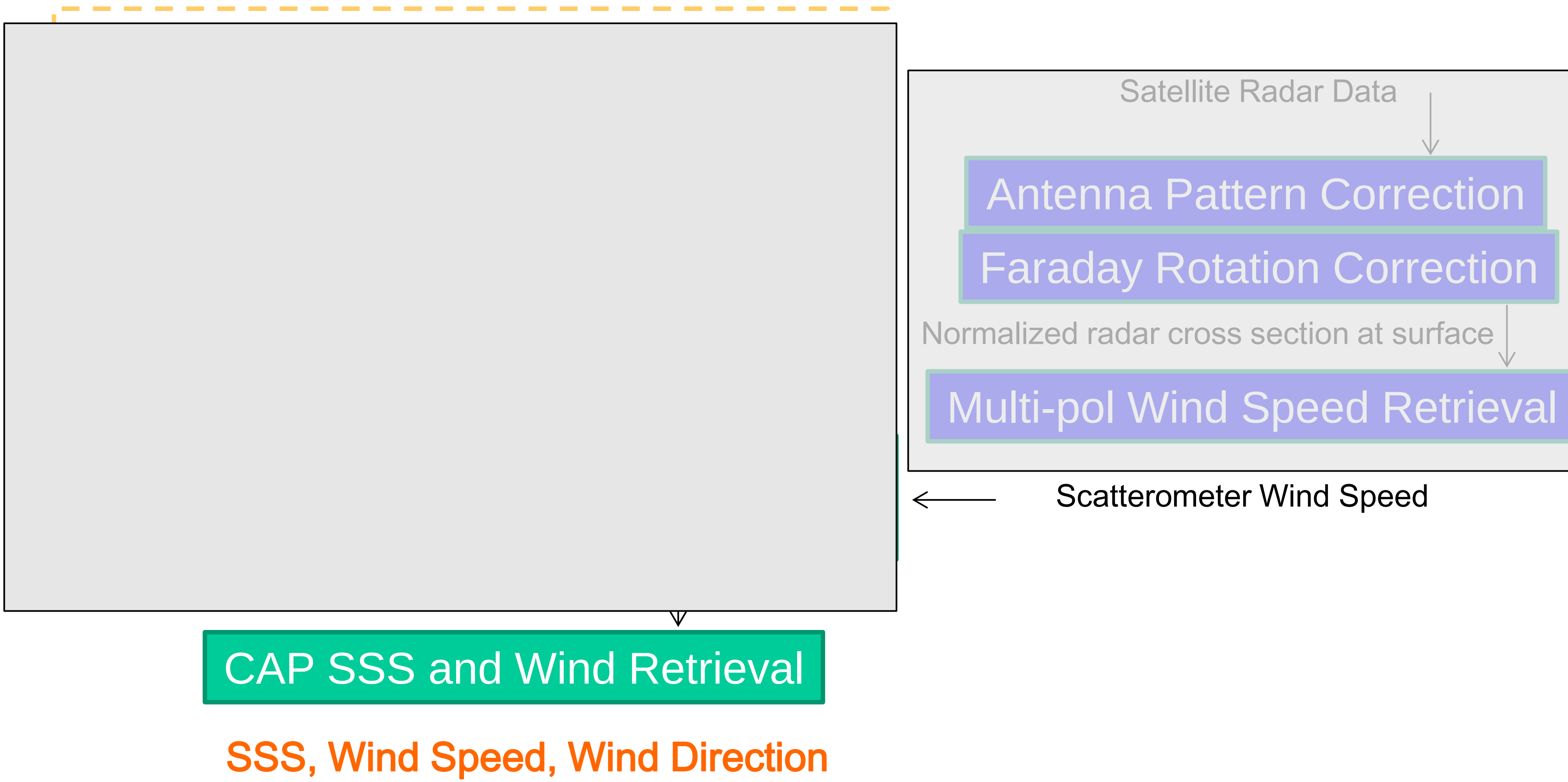


Aquarius GMF for Roughness Effects

- 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

- Combined Active-Passive (CAP) Algorithm
  - Retrieve SSS, Wind Speed and Direction Using Combined Passive and Active Data
  - Use NCEP winds only near cross-wind
  - Can be easily updated to account for additional corrections
  - Don't need monthly SSS climatology constraint

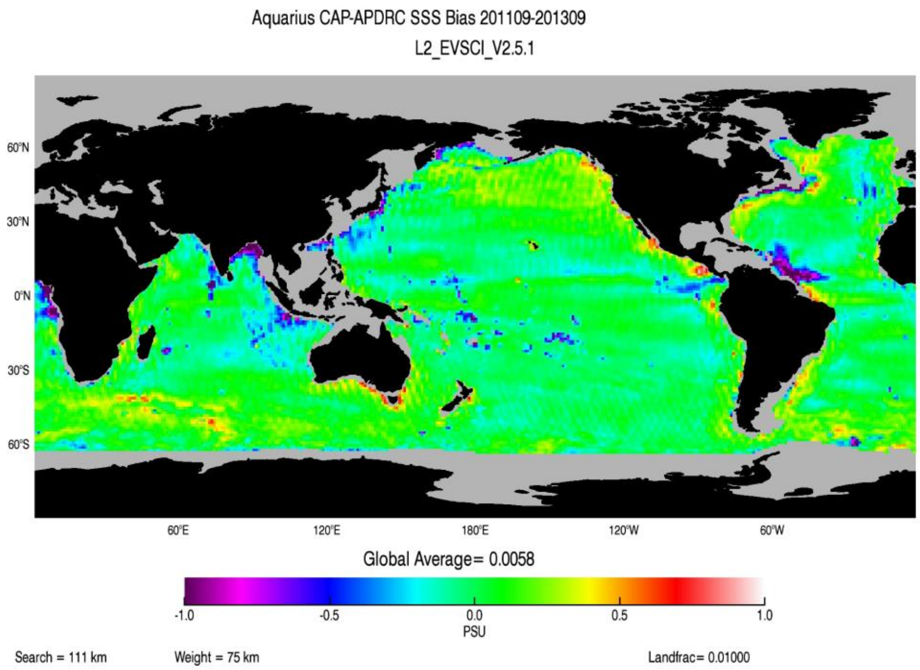
$$F_{ap}(SSS, w, \phi) = \frac{(T_{BV} - T_{BVm})^2}{\Delta T^2} + \frac{(T_{BH} - T_{BHm})^2}{\Delta T^2} + \frac{(\sigma_{VV} - \sigma_{VVm})^2}{k_p^2 \sigma_{VV}^2} + \frac{(\sigma_{HH} - \sigma_{HHm})^2}{k_p^2 \sigma_{HH}^2} + \frac{(w - w_{NCEP})^2}{\Delta w^2} + \frac{\sin^2((\phi - \phi_{NCEP})/2)}{\delta^2}$$

- CAP V3.0 includes two SSS outputs
  - SSS with no rain correction
  - SSS_rc with rain correction

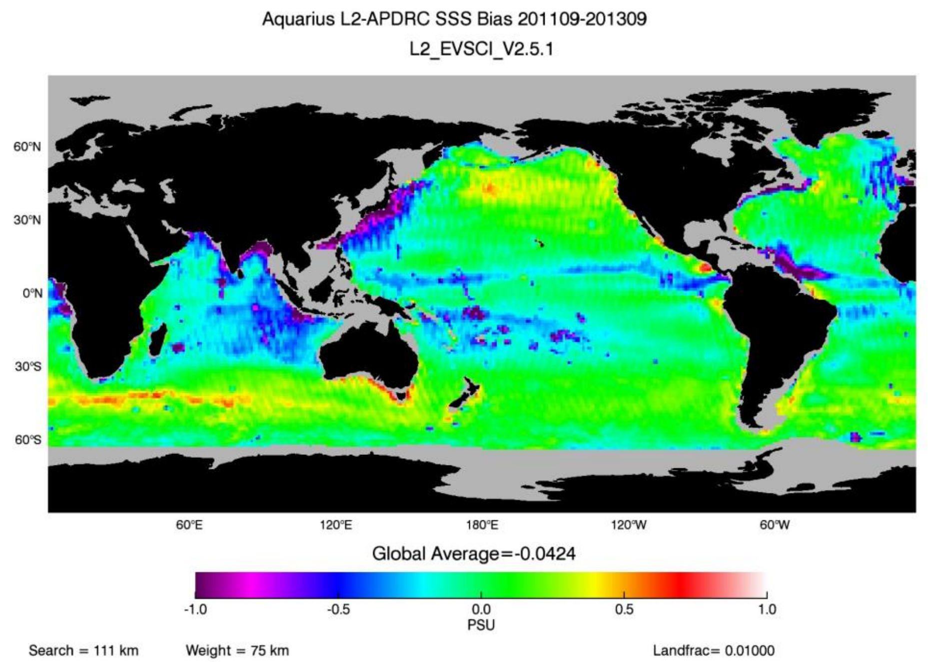
Original formulation in Yueh and Chaubell, IEEE TGRS, April 2012

Monthly Bias - Averaged Differences (AQ-APDRC)

CAP V2.5.1-APDRC

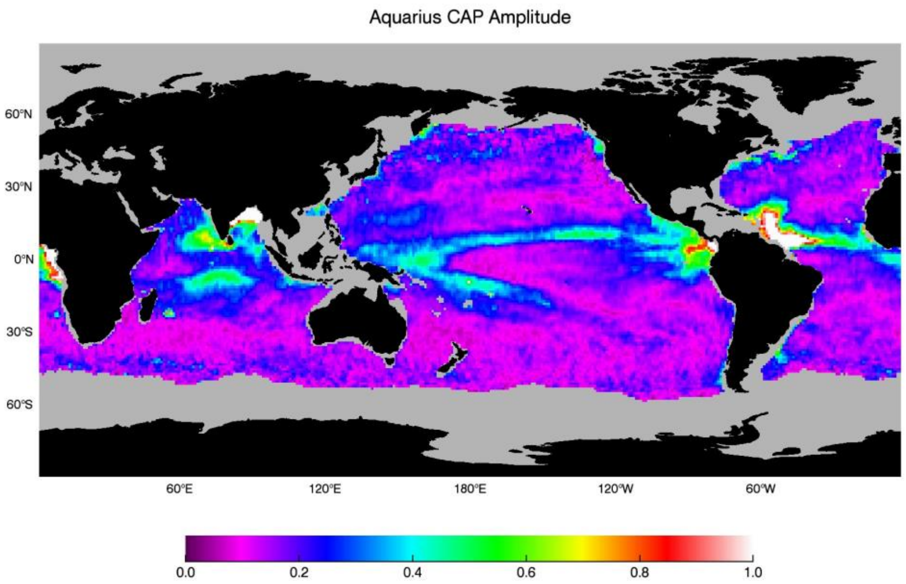


RSS V2.5.1-APDRC

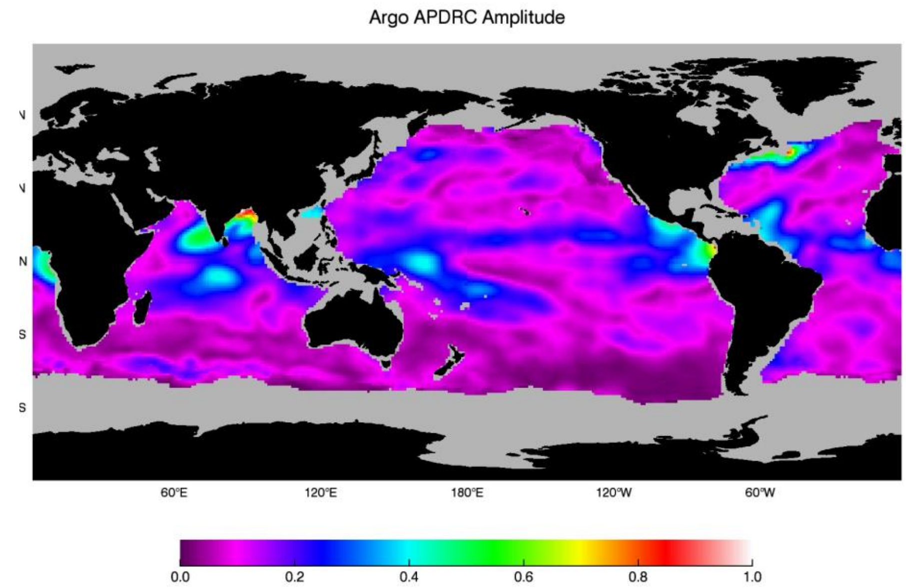


Amplitude of CAP vs APDRC Anomaly

Amplitude of CAP 2.5.1 Anomaly



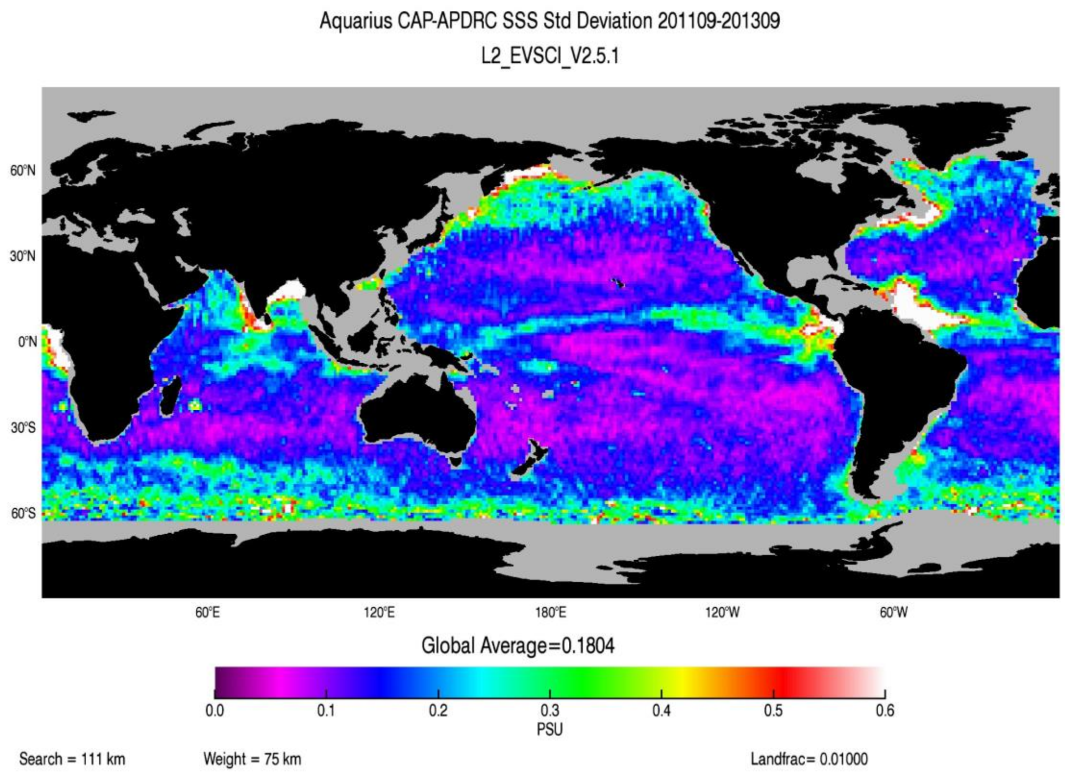
ARGO



Standard Deviation of Monthly Averaged Differences of Anomalies (AQ-APDRC)

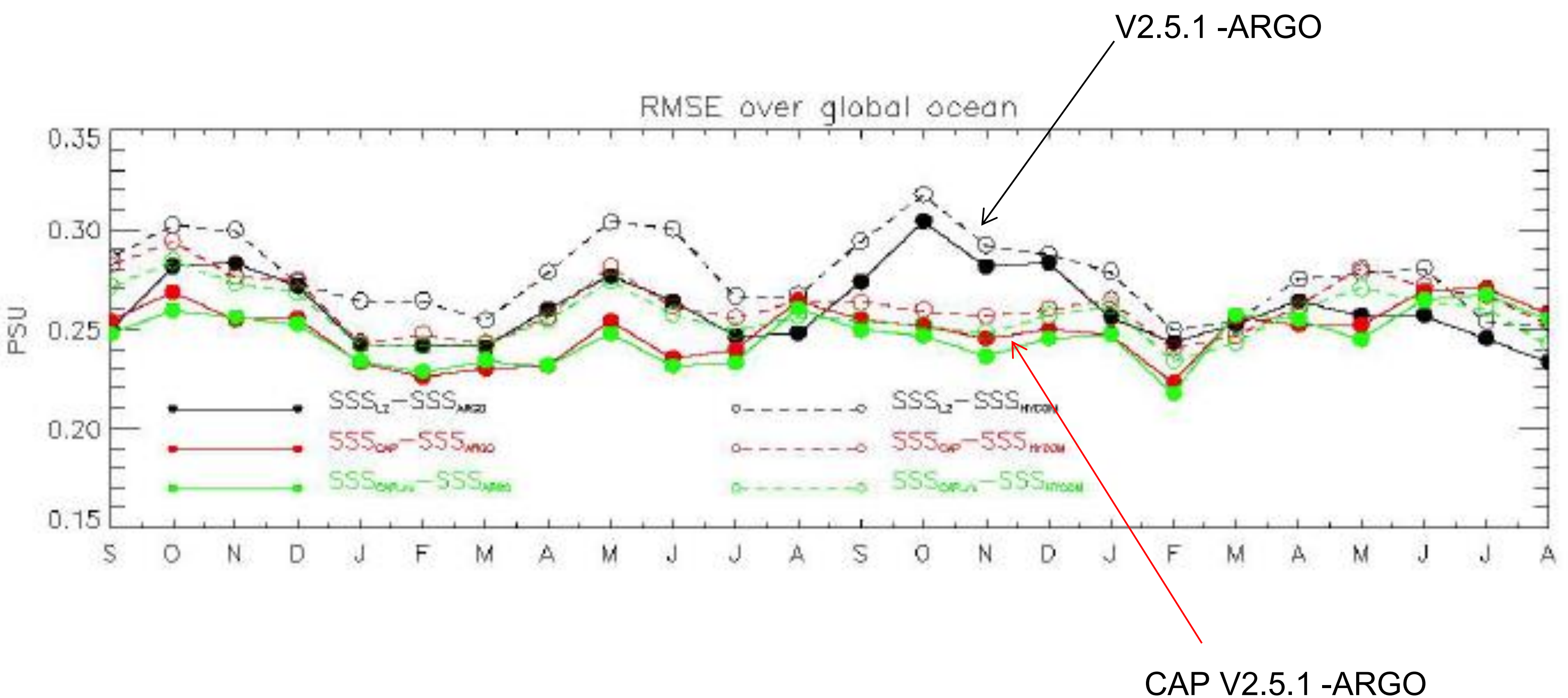
- Global mean is 0.18 psu
- Mostly (>80%) between 0.1 to 0.2 psu
- Reaching 0.3 to 0.4 psu for cold waters (high latitudes) and Amazon outflow

$$s.d. = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(x_i - \langle x_m \rangle - y_i + \langle y_m \rangle\right)^2}$$



RMSE of Monthly Averaged Differences (AQ-APDRC)

- In general, RMSE of CAP's V2.5.1 is smaller than V2.5.1's by as much as 20%



Comparison of CAP and RSS Solutions

- Puzzle: σ(CAP L2)>σ(RSS L2). However E(CAP L3)>E(CAP L3). Why?
- RSS v2.3.1 or v2.5.1 of future v3.0 uses a priori monthly climatology (Sc) to constrain the solution through a two-step cost function optimization. Effectively a weighted average (or a low-pass filtering.)

$$S(t) = aS_{aq}(t) + (1 - a)S_c$$

- ➢ The standard deviation of S(t)=a Std(S_{aq})
- Question: Smaller std=better accuracy?
- CAP L2 and RSS L2 are “Orange” and “Apple”
- ➢ Monthly average of S(t) on the latitude and longitude grid does not improve the accuracy of monthly product

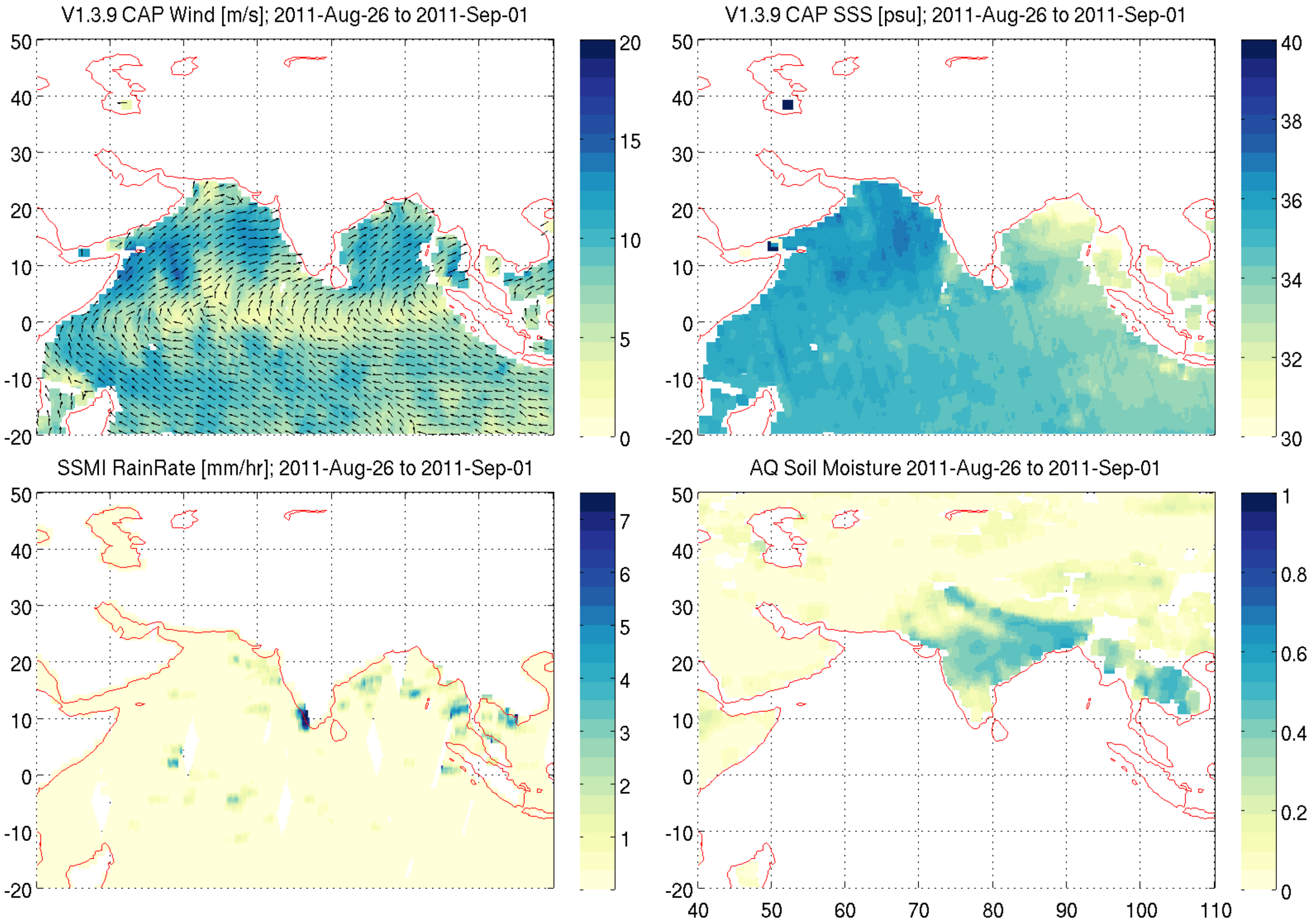
Interannual variation: $DS(t) = aDS_{aq}(t)$

- ➢ Caution: Using the RSS v3.0 or AQ V2.3.1 and V2.5.1 to study the interannual variability requires 1/a calibration
- ➢ Not a constant adjustment: a=a(SSS,SST,W)

Summary

- CAP V2.5.1 (pre V3.0)
  - Improved APC and Faraday rotation correction
  - Improved galactic reflection correction
  - Updated geophysical model function
  - SSS and Wind speed retrieval:
    - Using the CAP method we obtain about 0.7 m/s RMS wind speed performance – accuracy the same as rain-free SSM/I
    - Accuracy superior to RSS V2.5.1
- CAP V2.5.1 (the same as V2.3.1) can be made available through PO.DAAC
- CAP 3.0 will be distributed through PO.DAAC

Aquarius CAP Wind as well as SSS in the Data Files



Aquarius soil moisture from Jackson and Bindlish

SSMIS rain from RSS