Applications of L-Band Scatterometry and Radiometry to Aquarius and SMAP

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Time Series of L-band Scatterometry and Radiometry Missions

SMOS, Aquarius*, SMAP*, PALSAR-2, DESDYNI, …

Aquarius (Sea Surface Salinity)

L-band radiometer and scatteroemter

Push-broom (single look) with three feeds

~100 km resolution

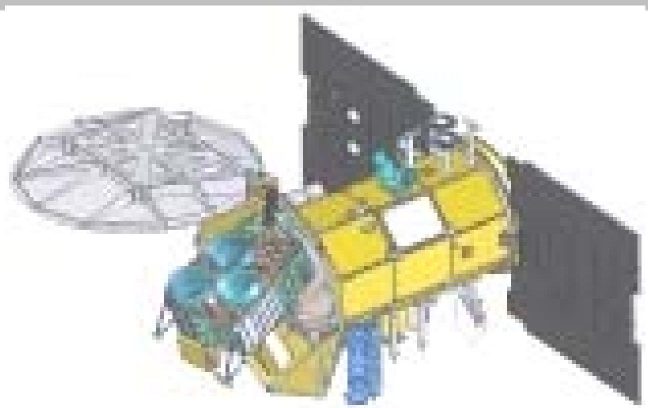
~ 350 km swath

<0.1 K for radiometer

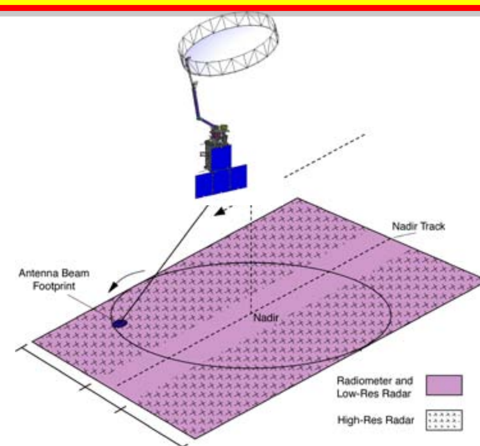
<0.1 dB for scatterometer

SMAP

- L-band (1.26 GHz) Radar (JPL)
- L-band (1.41 GHz) Radiometer (GSFC)
- Shared Antenna (6m diameter)
  - Conical scan with 2 azimuth looks
  - Contiguous 1,000 km swath width
  - 0.9 K NEDT on 30 km grid

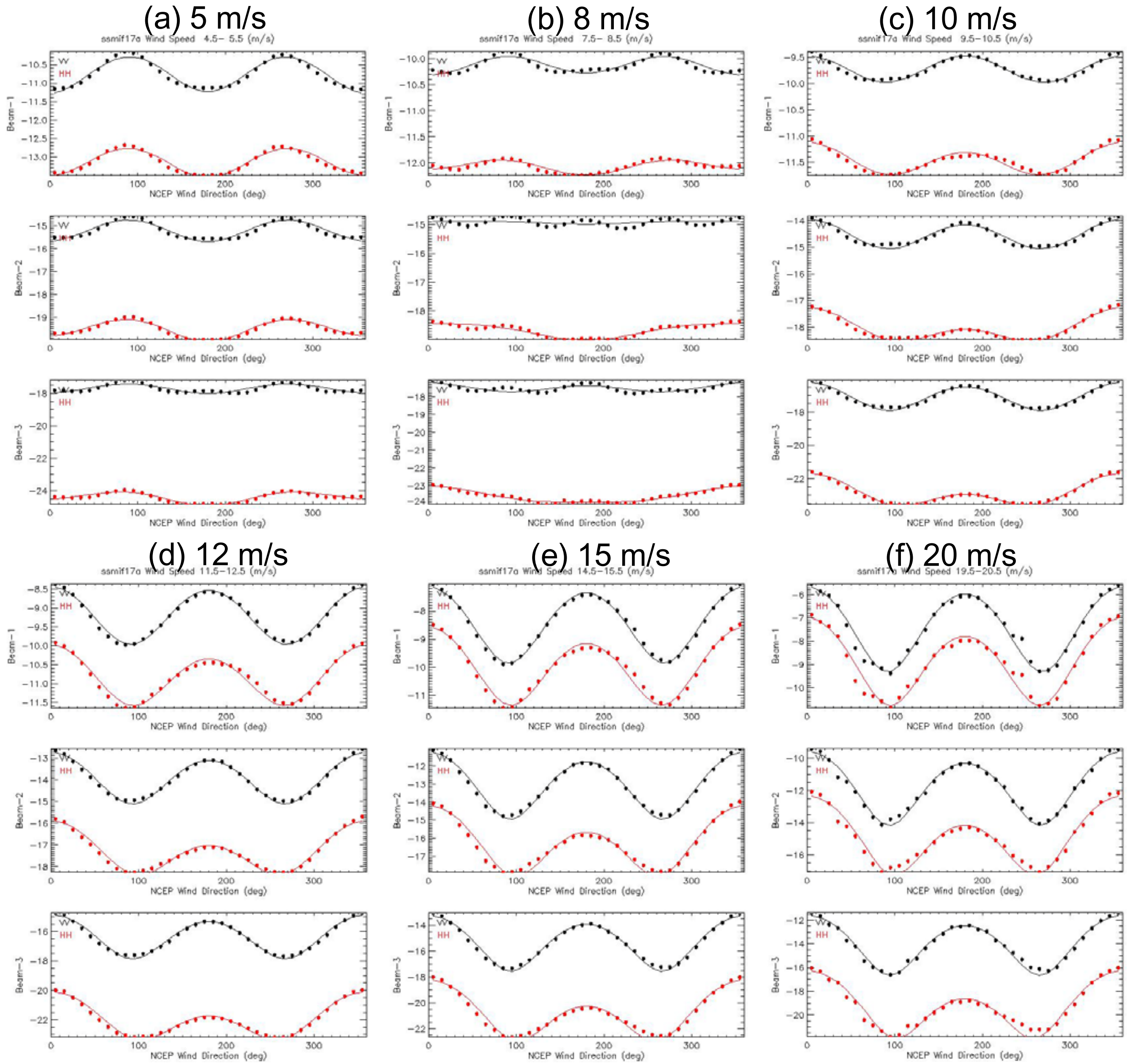


Launched on June 11, 2011



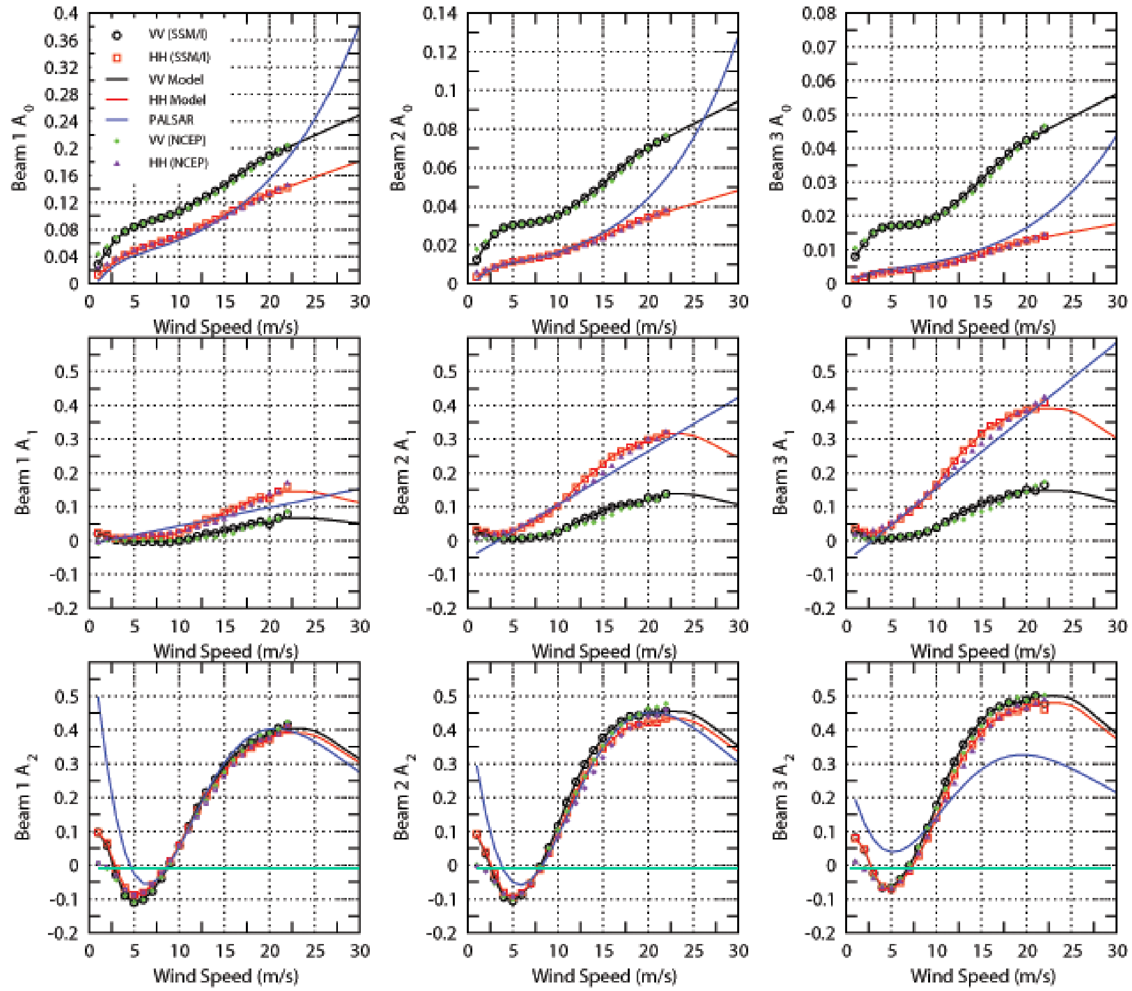
To be launched in late 2014

Aquarius L-Band Scatterometer Sigma0 vs. Wind



Aquarius Scatterometer An vs. SSM/I Wind Speed

- Sigma0 model $\sigma_0(w,\phi) = A_0(w)[1 + A_1(w)\cos\phi + A_2(w)\cos 2\phi]$

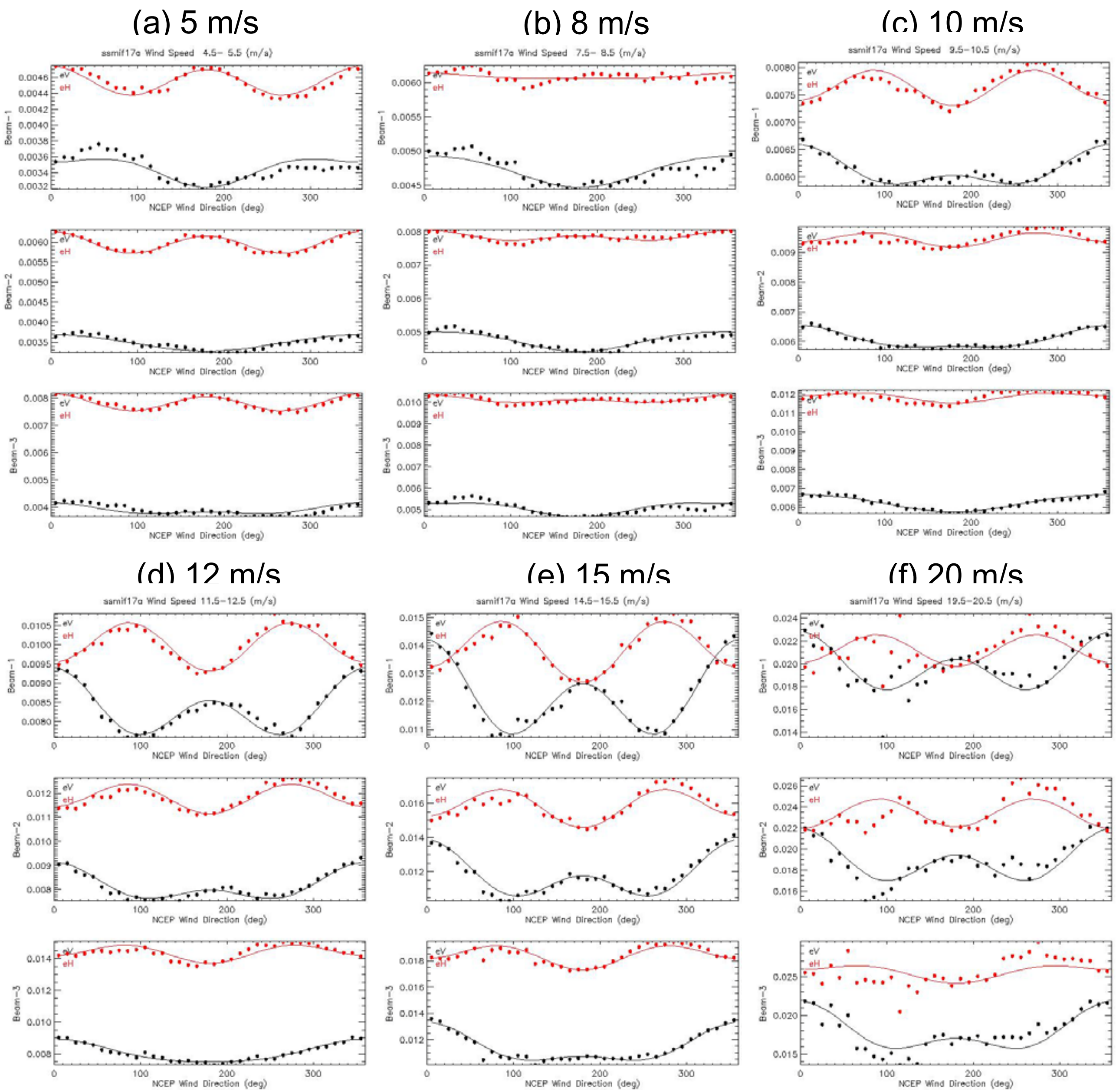


Negative A2 from 3 to 8 m/s

Non-Bragg?

- Aquarius GMF for HH agrees well with the Japanese PALSAR GMF (Osamu Isoguchi and Masanobu Shimada, IEEE TGRS, 2009.

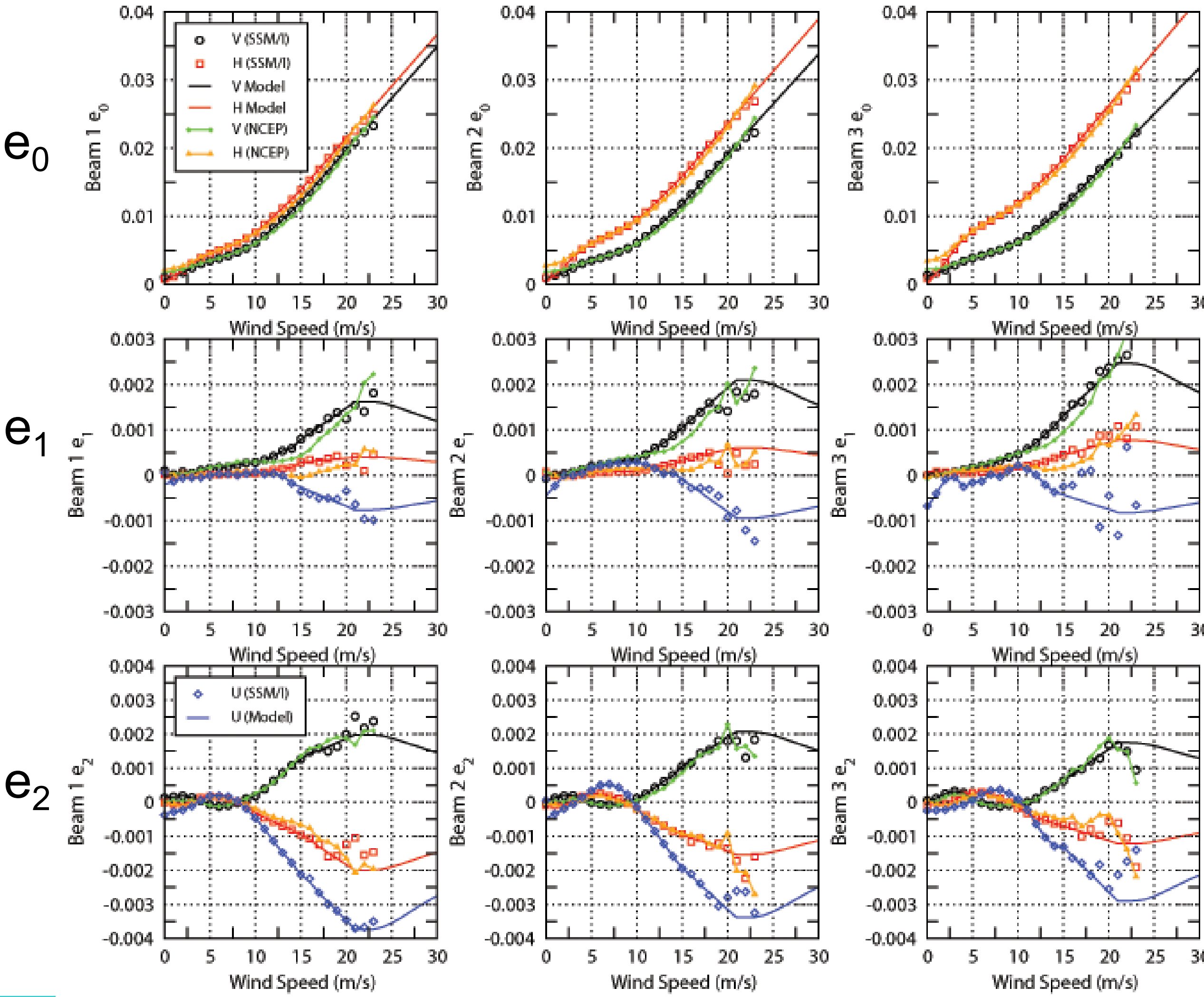
L-band Passive Microwave TB vs. Wind



L-band Passive En vs. SSM/I Wind Speed

- Match up with SSM/I wind speed

$$\Delta e(w,\phi) = e_0(w) + e_1(w)\cos\phi + e_2(w)\cos 2\phi$$



e2 changes phase at about 3 and 8 m/s

Similar to active

Non-Bragg?

- 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

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

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

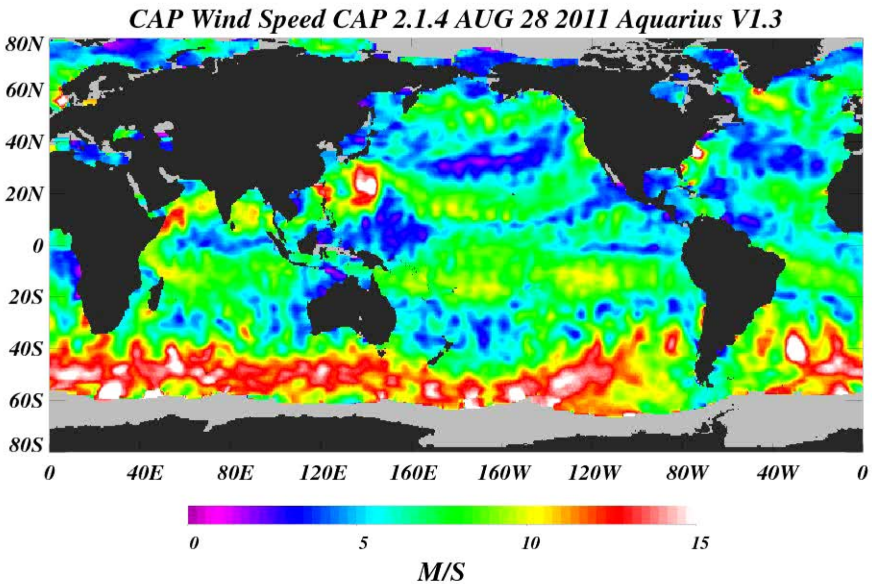
$$Q=T_{BV}-T_{BH}$$

Yueh and Chaubell, IEEE TGRS, April 2012

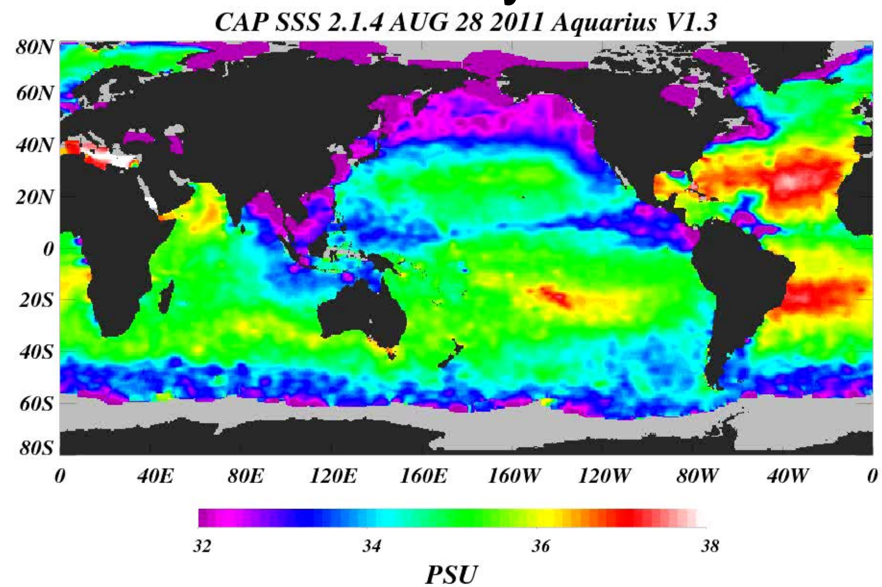
Aquarius CAP Wind and SSS Animation

- Global 7-day moving window at 1 day step

Wind



Salinity

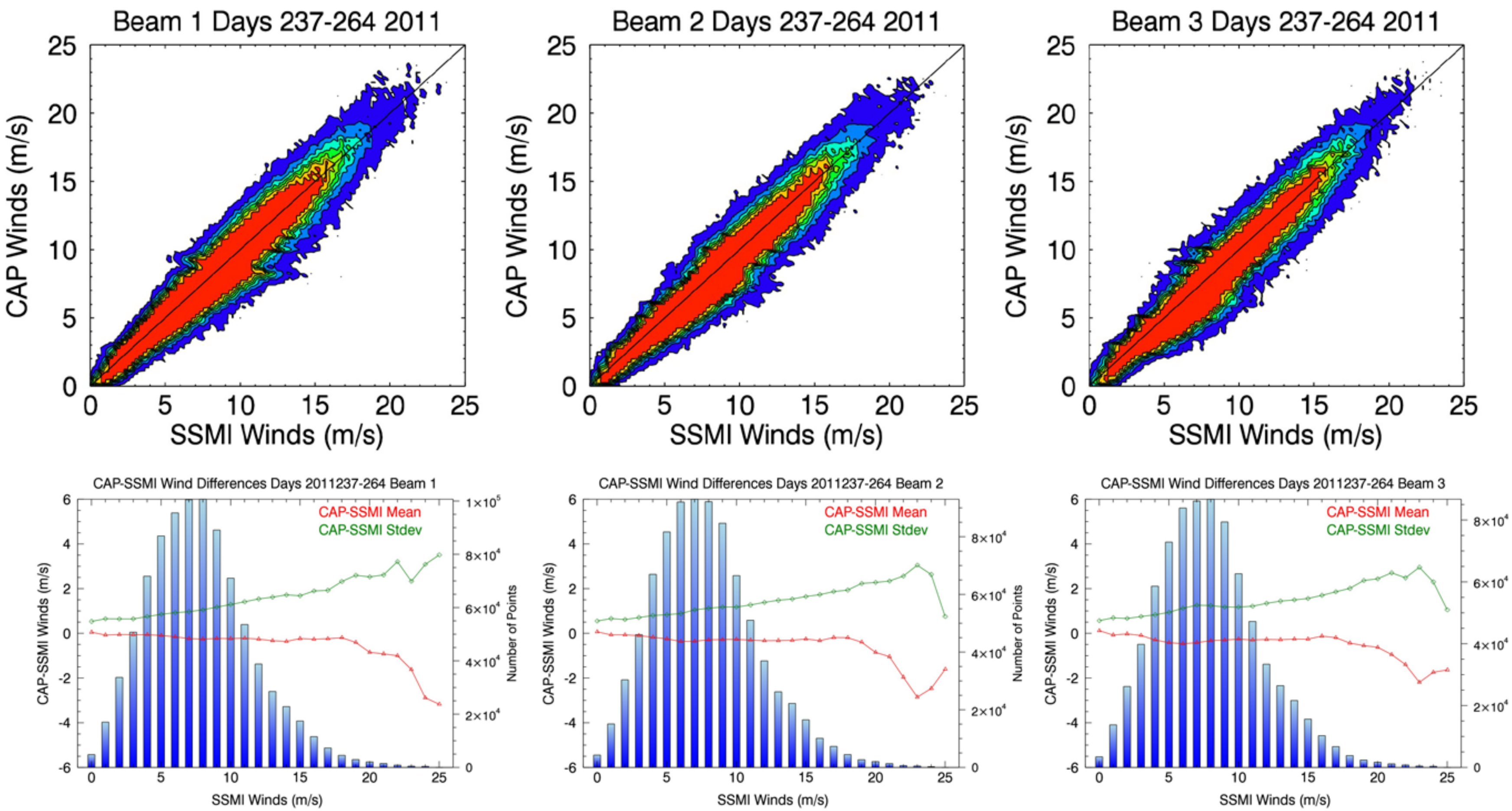


AQ CAP wind and SSS products available on

ftp://oceans-ftp.jpl.nasa.gov/pub/akh/aquarius/L2_1.3cap

CAP Wind Speed comparison with SSM/I

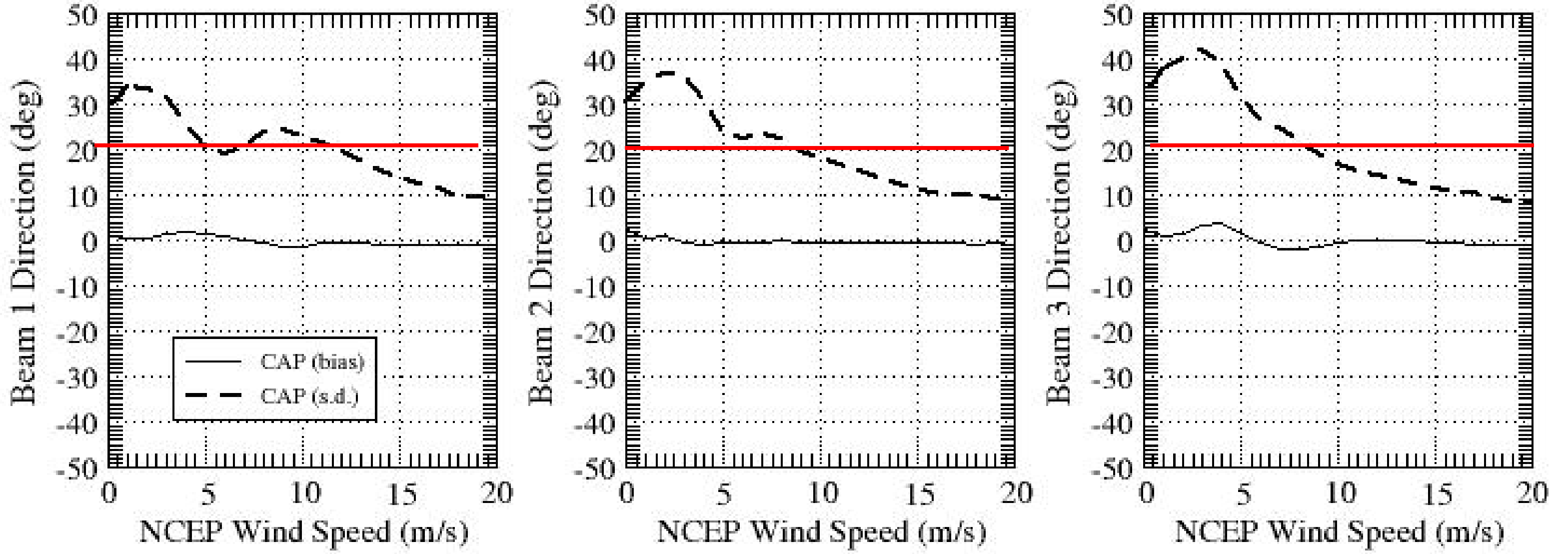
- Aquarius CAP winds agree well with SSM/I
  - standard deviation of speed difference < 1.5 m/s for 0-15 m/s



Wind Direction Difference with Respect to NCEP

- RMS wind direction difference smaller than 20 degrees for mid to high winds

Day 240 2011 to Day 91 in 2012



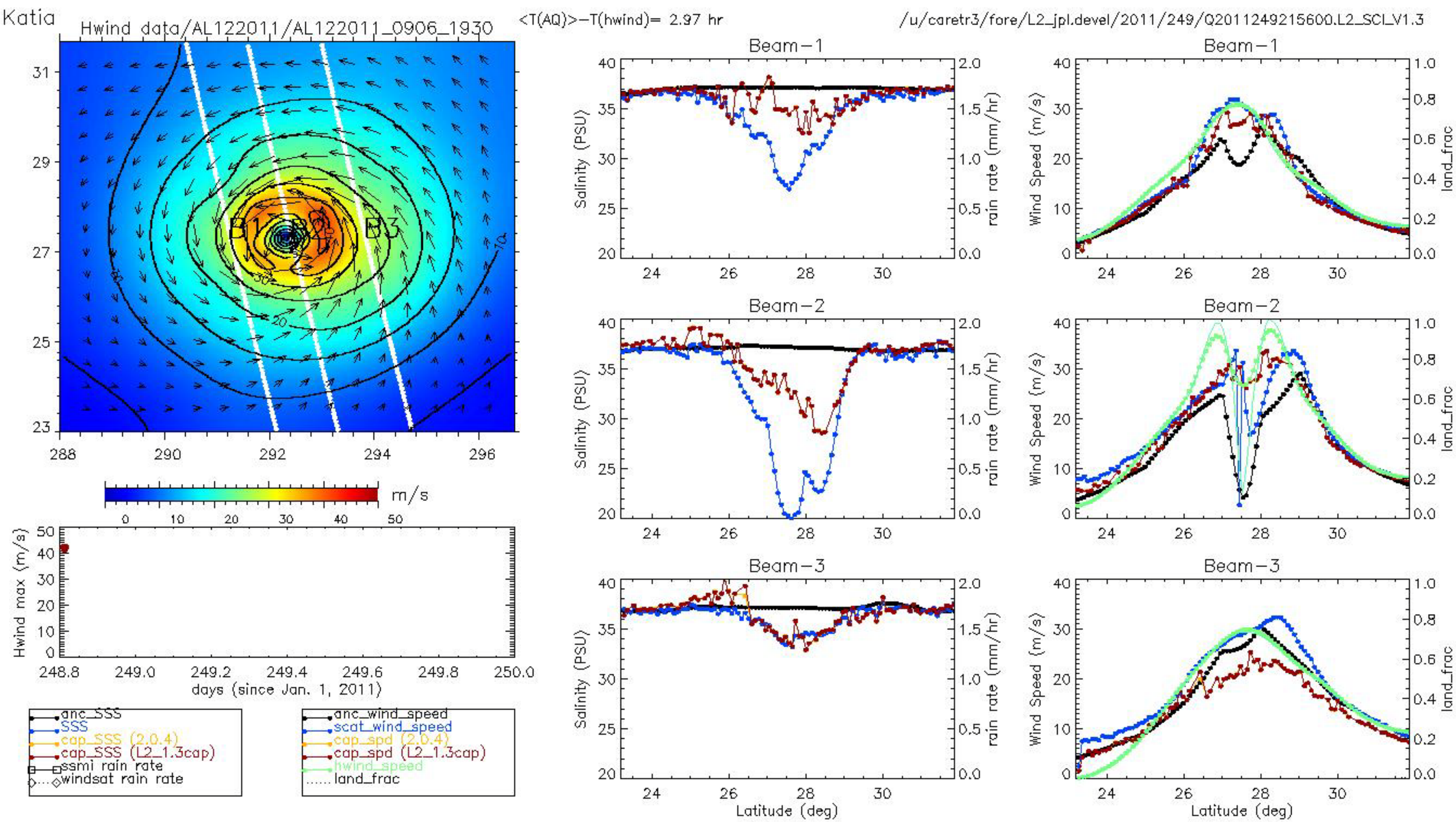
Results of Triple Collocation Analysis

- Apply triple collocation method (Stoffelen, 1998)
- RMS AQ-CAP wind speed error about 0.76 m/s
  - Superior to NCEP by about 30 percent
  - Comparable to SSM/I

	SSM/I	NCEP	AQ-CAP
Beam 1 Random Error (m/s)	0.77	1.08	0.77
Beam 2 Random Error (m/s)	0.75	1.07	0.73
Beam 3 Random Error (m/s)	0.80	1.03	0.78

Wind and SSS Retrieval for Katia and Comparison with HWnd
In collaboration with Y. Chao of RS Solutions

AQ-CAP Maximum Wind Speed within the Hwind by about 2-3 m/s.



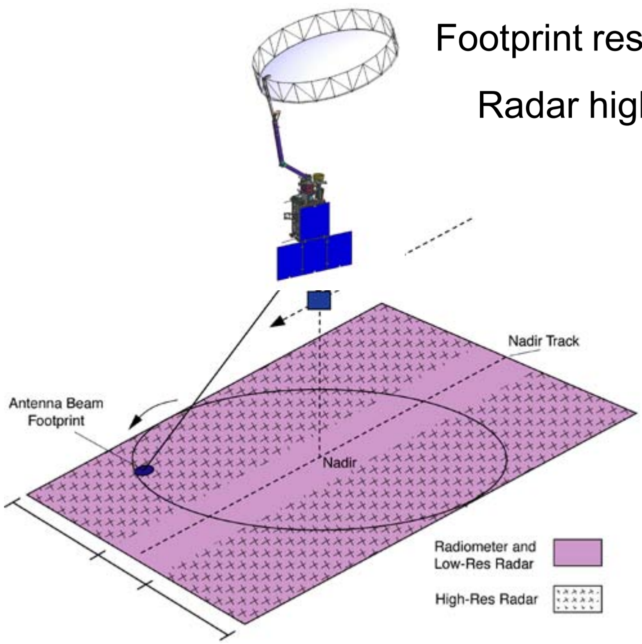
Retrieval Simulation SMAP (2 Azimuth Looks)

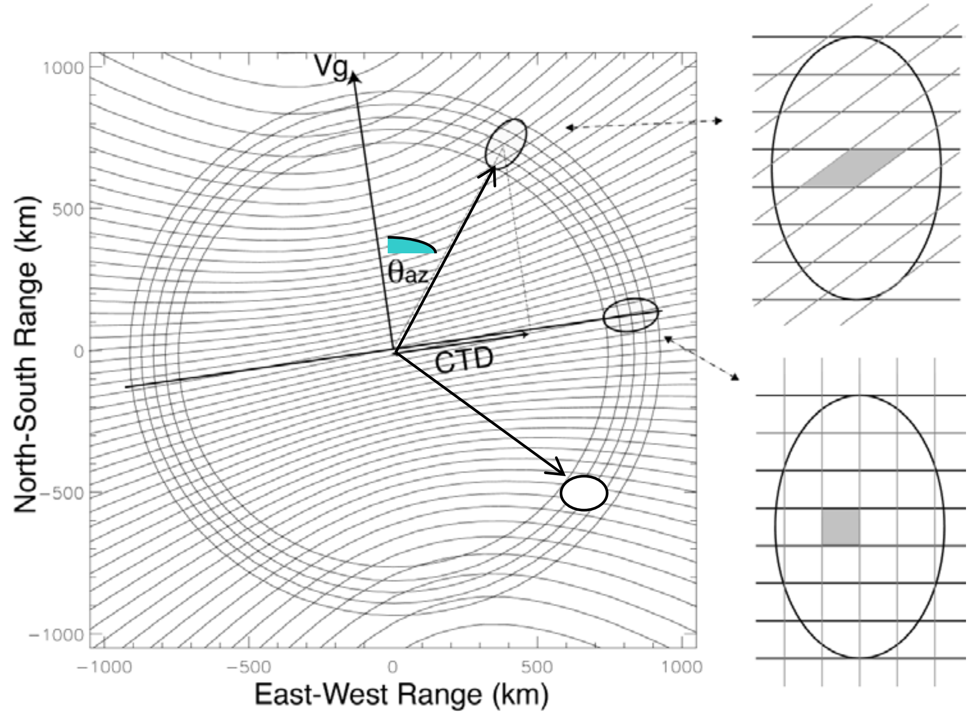
- Simulate data for SMAP Scanning Geometry
- Use Fpol with two looks
  - Ideal correction of galactic reflection and other geophysical parameters

$$F_{pol}(SSS,W,\phi)=\sum_{i=1}^{2}\frac{(I_i-I_{mi})^2}{2\Delta T^2}+\frac{\left(\sqrt{Q_i^2+U_i^2}-\sqrt{Q_{mi}^2+U_{mi}^2}\right)^2}{2\Delta T^2}+\frac{(\sigma_{0i}-\sigma_{0mi})^2}{k_p\sigma_0^2}$$

Footprint resolution ~ 40km

Radar high res 1-3 km

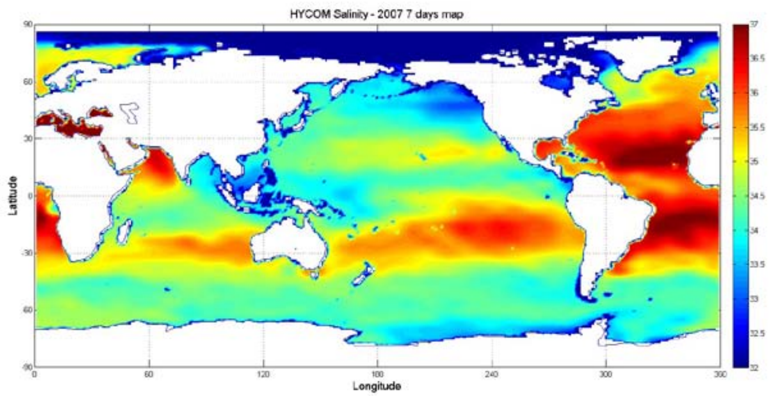


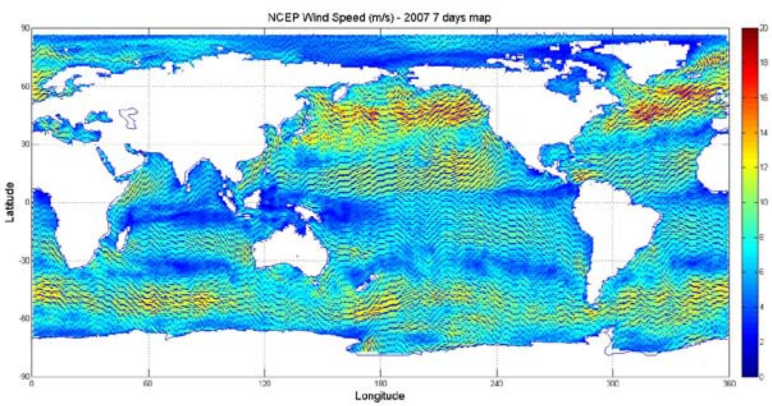


SMAP Salinity and Wind Retrieval Simulation

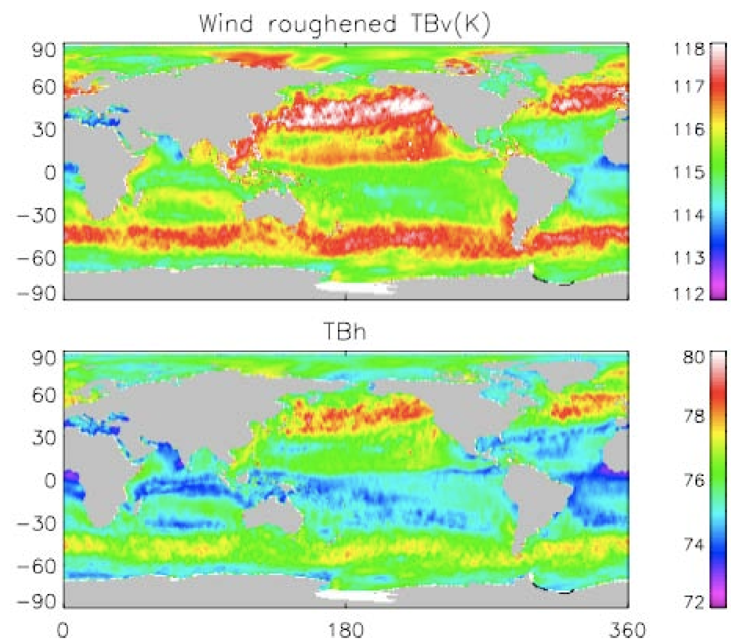
- Simulate SMAP TB and Sigma0 data at 14 ms sampling resolution
- Pencil beam – no antenna pattern average
- Retrieve the salinity and wind using the fpol algorithm

HYCOM salinity and NCEP wind





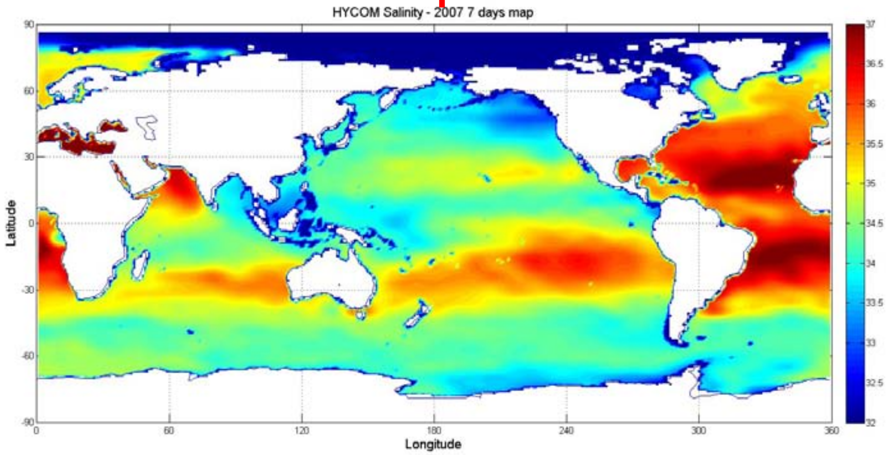
Simulated TB



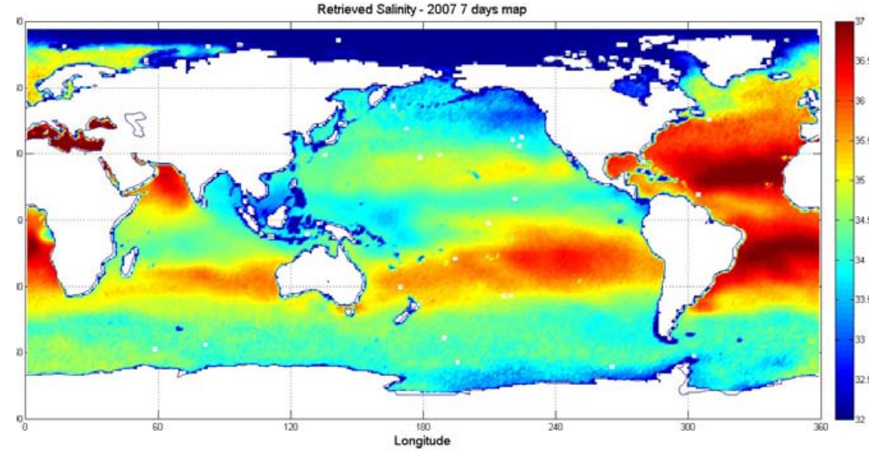
Simulated Salinity Retrieval

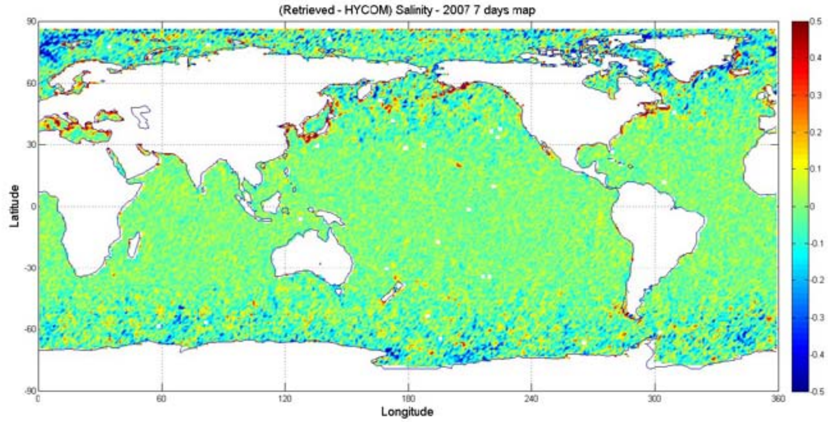
- Weekly average of simulated salinity retrieval using fpol with the closest to the input wind field.

Input



Retrieved



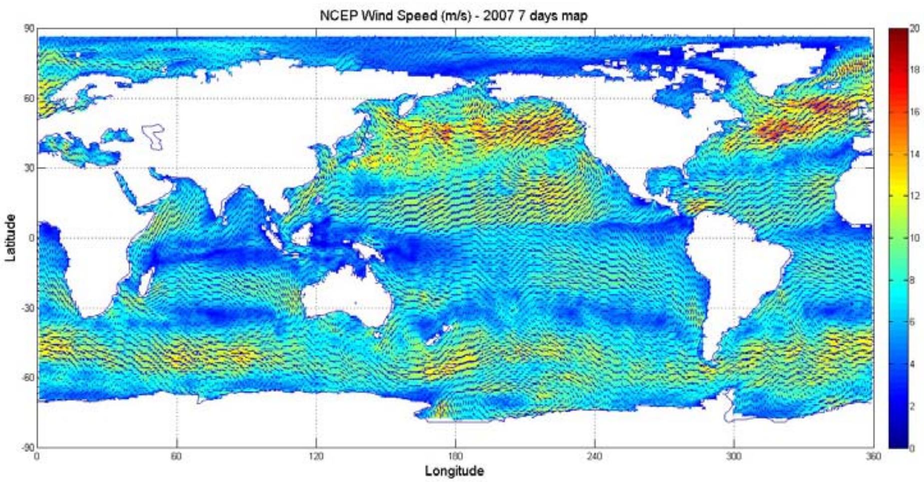


Retrieved-Input

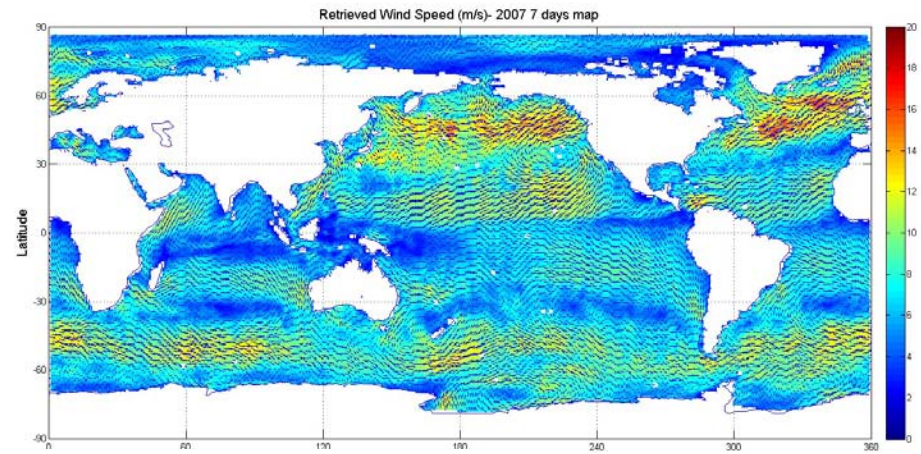
Simulated Wind Retrieval

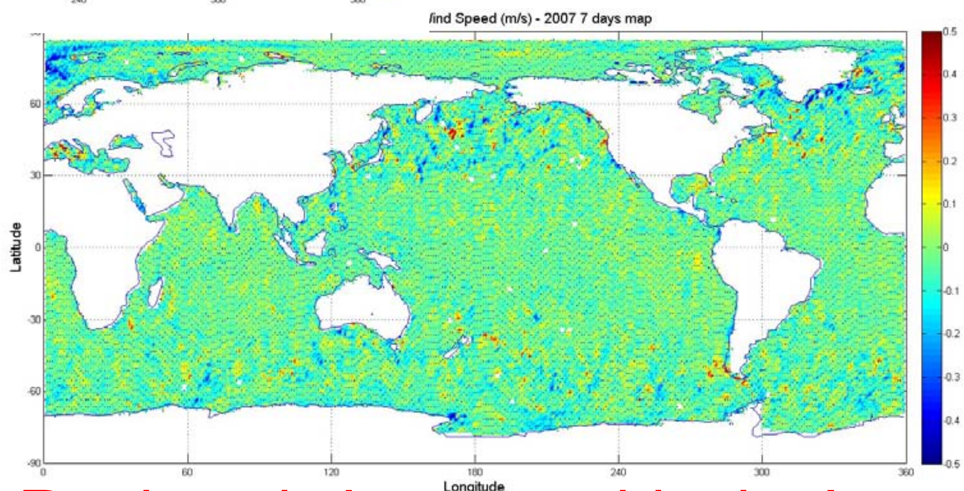
- Weekly average of simulated retrieved wind is close to the input wind field.

Input



Retrieved closest ambiguity

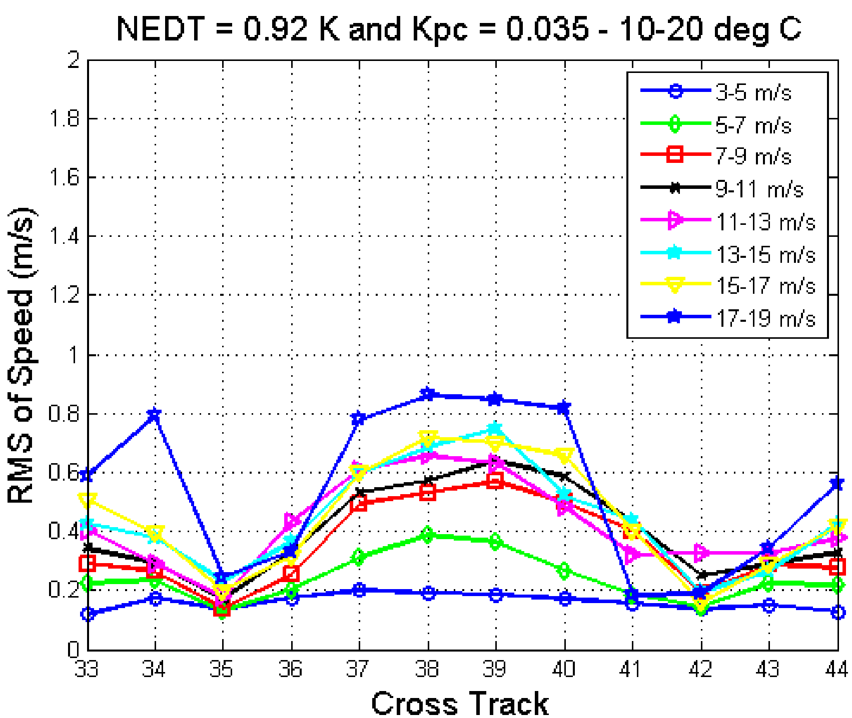


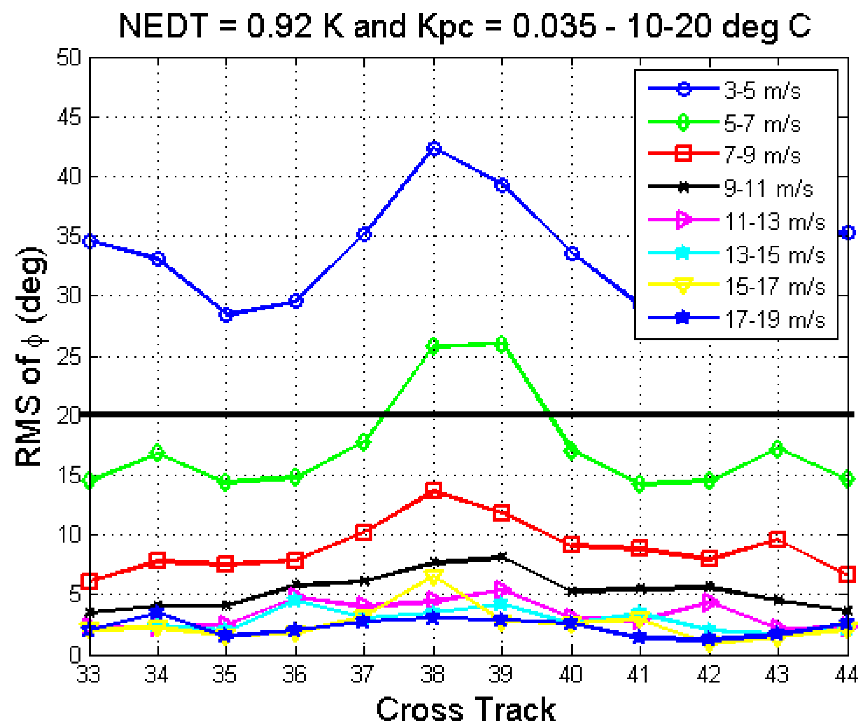


Retrieved closest ambiguity-Input

Simulated SMAP Wind Retrieval Error

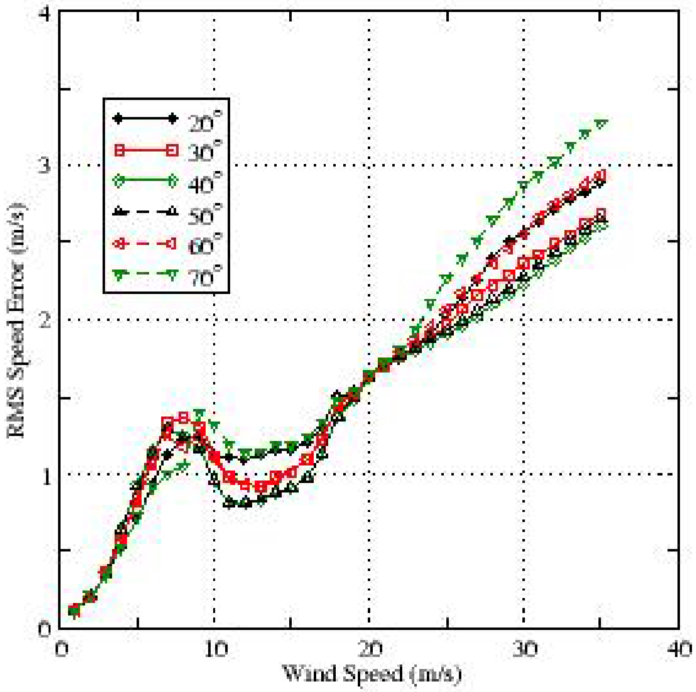
- Case Study - One week only
  - 100 km gridded resolution
- Excellent Wind Speed Accuracy
- Excellent wind direction accuracy for above 9 m/s

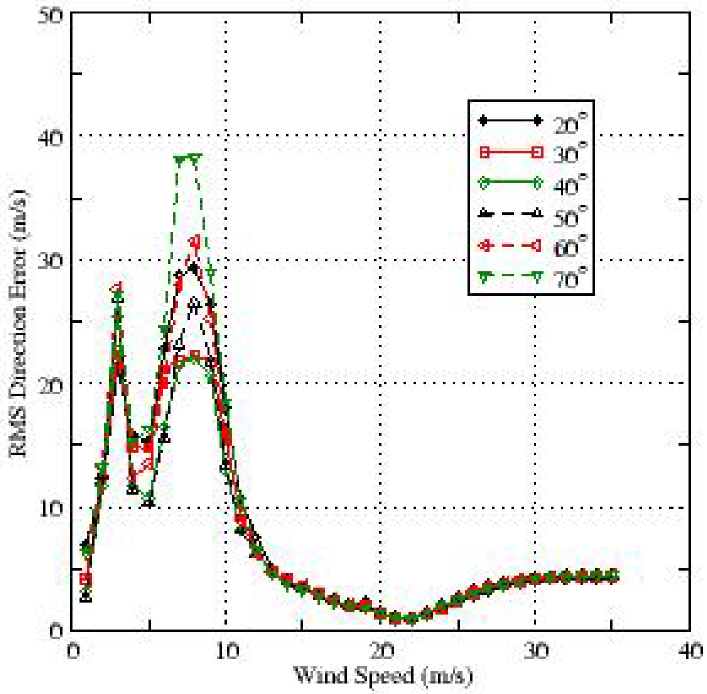




15 km Grid – kpc=0.07

- Use VV and HH
- Available high res swath width ~500km
- Error for closest ambiguity
  - Error will increase for selected ambiguity
  - Combined active-passive will help ambiguity selection
- Kpc error only – no other errors; not yet accounting for SNR
- Not accounting for SMAP spatial sampling pattern





Summary

- L-Band active and passive microwave show good wind response
  - Not a replacement of C- and Ku-band Scatterometers
  - Negative Upwind-Crosswind Asymmetry from 3 to 8 m/s. Why?
- The accuracy of Aquarius CAP wind speed is excellent - essentially the same as SSM/I ~ 0.76 m/s
- Aquarius CAP wind speed agrees well with the Hwind analysis for Hurricane Katia
- SMAP predicted to provide high quality vector winds for mid to high winds
- SMAP predicted to provide accurate high res (<10 km) wind speed retrievals for up to 20 m/s wind speed.

Error Analysis - Triple Collocation Method

- 3 wind speed datasets: SSMI, NCEP, Aquarius retrieval.
  - $w_{ssmi} = w + r_{ssmi}$
  - $w_{ncep} = a_{ncep} + b_{ncep} w + r_{ncep}$
  - $w_{scat} = a_{scat} + b_{scat} w + r_{scat}$
- a, b are bias and scale factors, r is random error, w is true wind speed.
- Apply triple collocation method (Stoffelen, 1998) to determine a, b, and r for each.
- Assumptions:
  - $<r_{ssmi} r_{ncep}> = <r_{ssmi} r_{scat}> = <r_{ncep} r_{scat}> = 0$ (all errors uncorrelated)
  - SSMI has no bias and no scale offset from true winds.
  - $<r_{ssmi} w> = <r_{ncep} w> = <r_{scat} w> = 0$ (errors not correlated with true winds).

Results of Triple Collocation Analysis

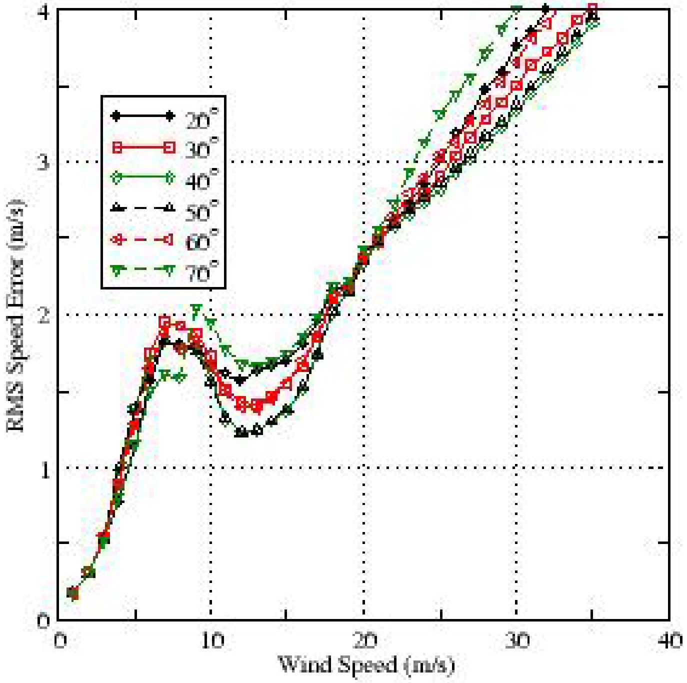
- Apply triple collocation method (Stoffelen, 1998)
- RMS AQ-CAP wind speed error about 0.76 m/s – superior to NCEP

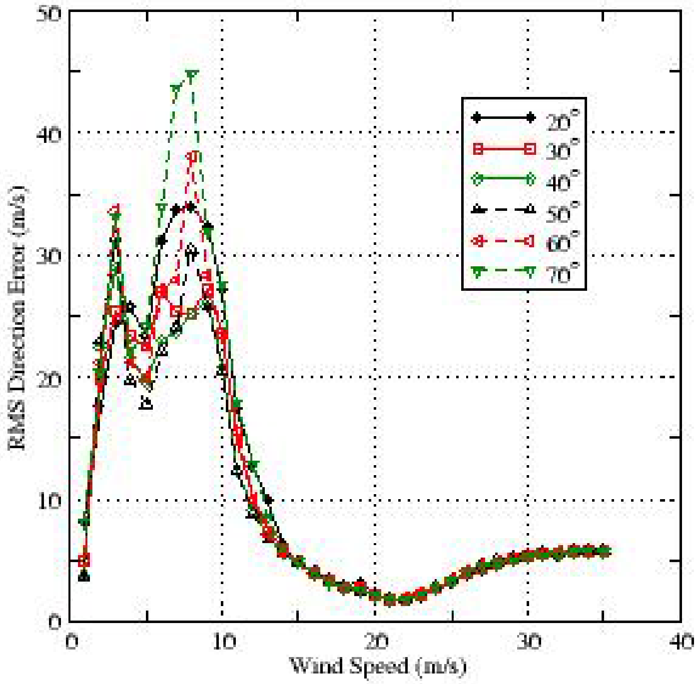
	SSM/I	NCEP	AQ-CAP
Beam 1 Random Error (m/s)	0.77	1.08	0.77
Beam 2 Random Error (m/s)	0.75	1.07	0.73
Beam 3 Random Error (m/s)	0.80	1.03	0.78

	SSM/I	NCEP	AQ-CAP
Beam 1 Slope A	1	1.020	1.043
Beam 2 Slope A	1	1.021	1.042
Beam 3 Slope A	1	1.032	1.052
Beam 1 bias B ($m \cdot s^{-1}$)	0	-0.19	-0.31
Beam 2 bias B ($m \cdot s^{-1}$)	0	-0.19	-0.33
Beam 3 bias B ($m \cdot s^{-1}$)	0	-0.27	-0.43

Wind Retrieval Using Radar Data
10 km – kpc=0.10

- Use VV and HH
- Available high res swath ~500km
- Error for closest ambiguity
  - Error will increase for selected ambiguity
  - Combined active-passive will help ambiguity selection
- Kpc error only – no other errors; not yet accounting for SNR
- Not accounting for SMAP spatial sampling pattern





Wind Retrieval Using Radar Data on 30 km Grids – kpc=0.035

- Use VV and HH
- 1000 km swath
- Error for closest ambiguity
  - Error will increase for selected ambiguity
  - Combined active-passive will help ambiguity selection
- Kpc error only – no other errors; not yet accounting for SNR
- Not accounting for SMAP spatial sampling pattern