Evaluating the impact of ocean gravity wave variability on Aquarius satellite measurements

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within **Aq. Cal/Val team efforts**

OSST Meeting 2012

Overview

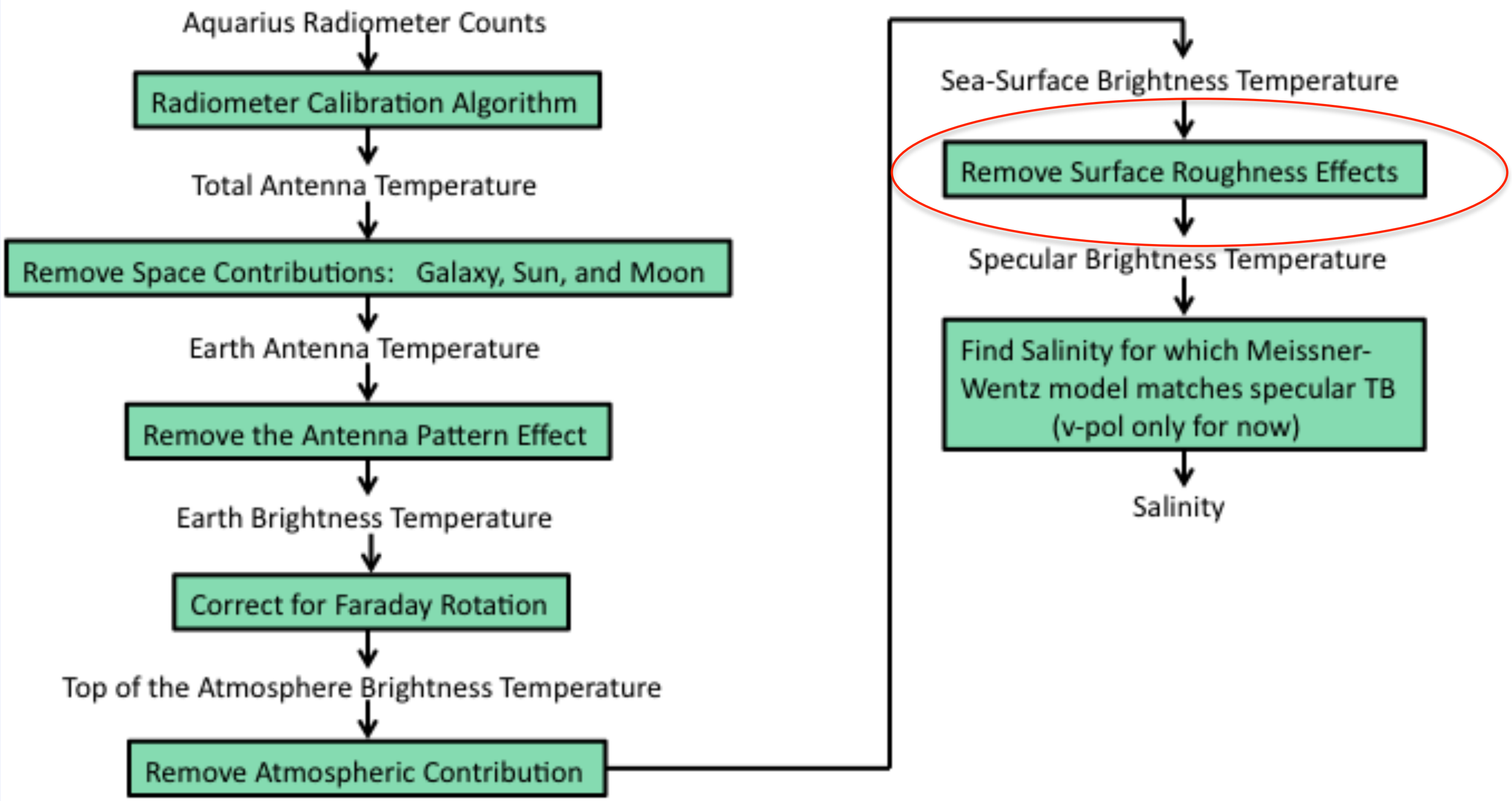
Goal

Develop and refine an empirical satellite salinity correction for long wave impacts that augments the 1st order roughness corrections made using NCEP winds, Aquarius scatterometer, or other ocean roughness information

Approach

- Geolocate ancillary ocean wave data with each satellite data point
- Detect, characterize, and quantify long-wave impacts seen in the scatterometer, radiometer, and ultimately salinity
- Help implement a point-by-point correction using operational wave model data

Salinity Retrieval Algorithm



The general geophysical problem

To obtain accurate salinity we need to accurately remove the signal due to rough surface emission

Specifically for Aquarius

1) A three beam **radiometer** at L band -

Tb_ocean (2 polarizations, 3 incidence angles, look angle) =
F (variable sea surface waves, **S(k)**) ~= rms slopes = $\int_{0.001}^{10} k^3 S(k) dk$

2) A three beam **radar** scatterometer at L-band (Bragg waves ~ 18 cm)

NRCS_ocean (2 polarizations, 3 incidence angles, look angle) =
F (variable sea surface waves) ~= $\boldsymbol{S(k_{Bragg})}$ + tilting effects

3) The portion of the wave spectrum and EM interaction differs for the radar and radiometer and for each beam's incidence angle – **how well correlated are 1) and 2)?**

4) Usual surrogate for sea surface wave information is wind – unlikely to provide sufficient precision to correct for the true ocean wave field.

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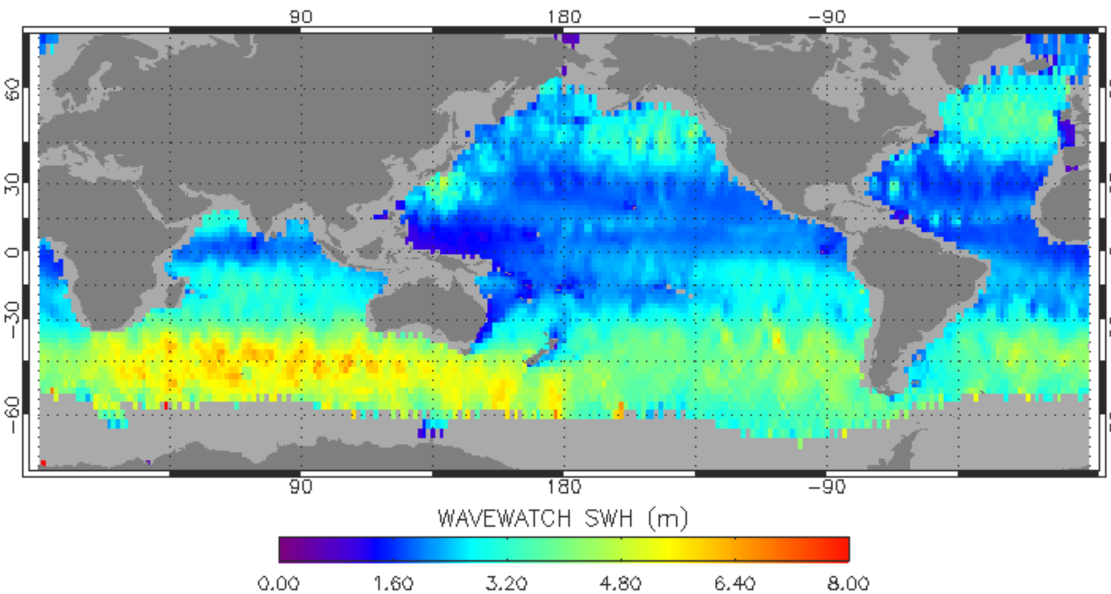
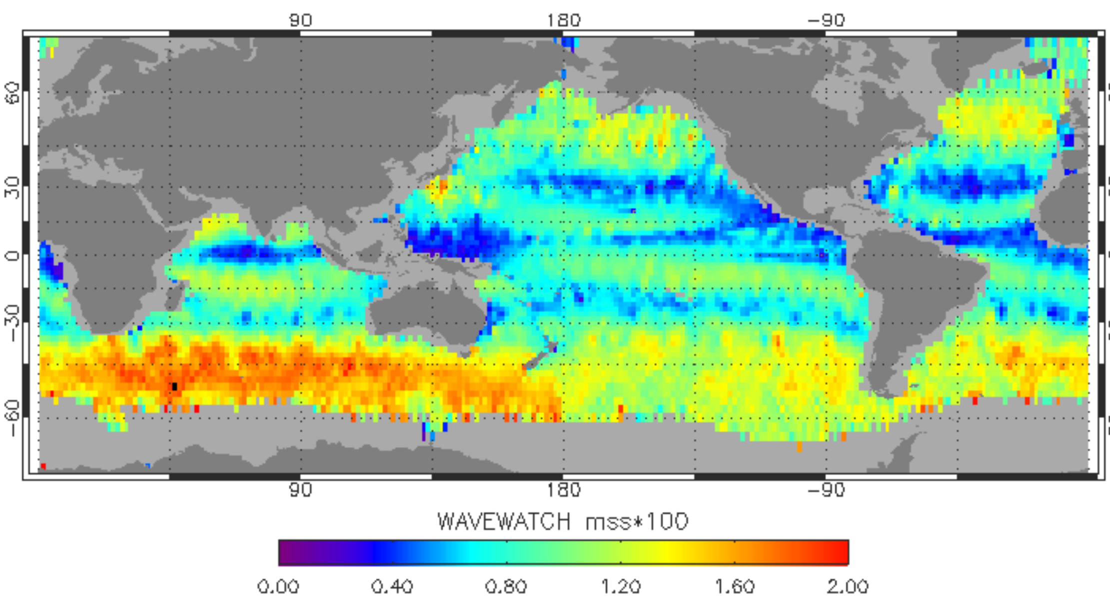
Global Wave model fields, Aquarius L2_wwav files, Day 240-271 2011

Aquarius *L2_wwav files are assembled daily at UNH for the Aq. cal/val team

available at PO.DAAC





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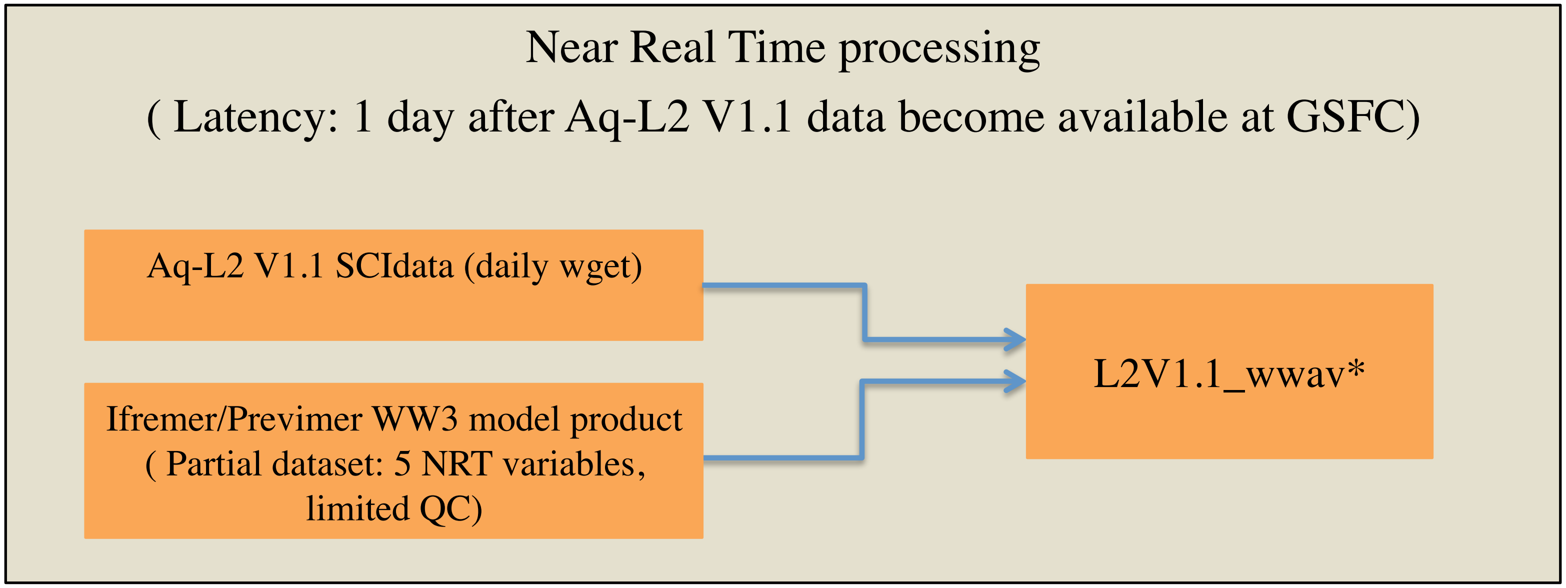
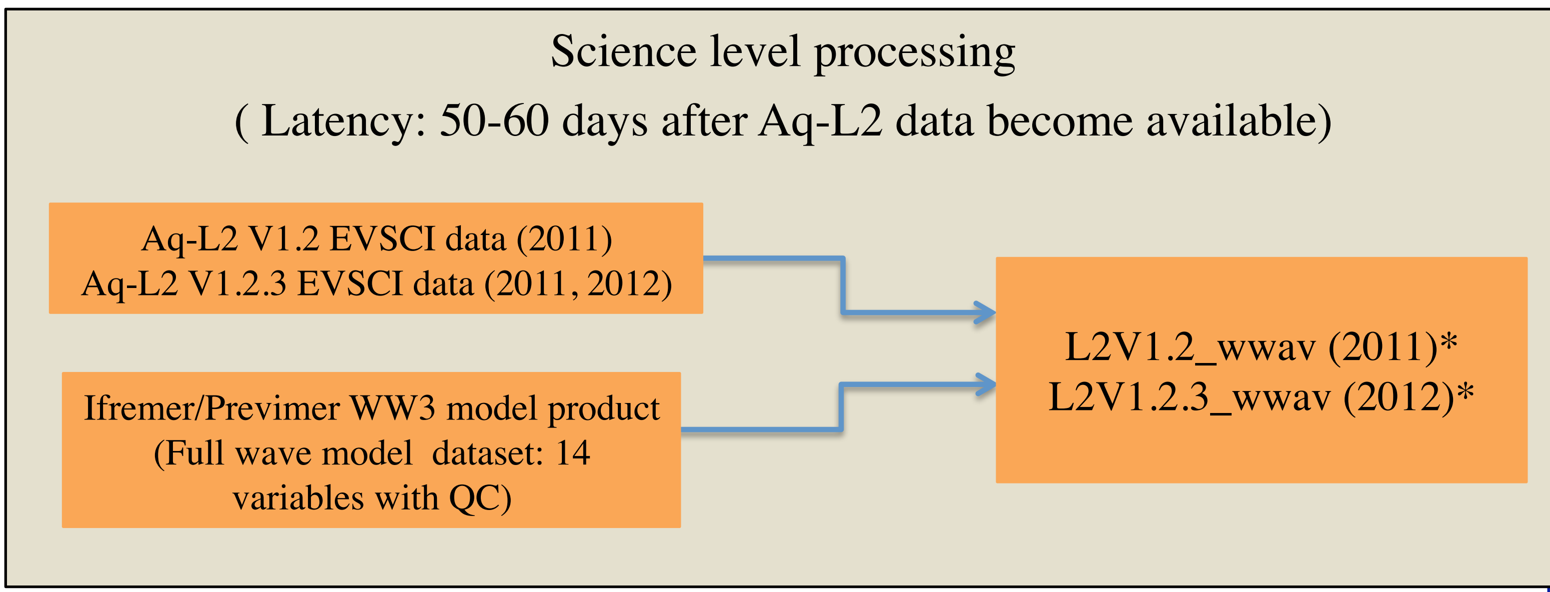
Aquarius Level 2 wave model collocation products: Processing status (March 2012)



* ftp access via PODAAC for Aq. Cal/Val team members



Diagnosis using Significant Wave Height (SWH)

Evaluate Aquarius L2 scatterometer and SSS data

Expectations:

1) For fixed wind speed we'll see long wave impacts in the scatterometer roughness and derived wind speeds

2) For fixed wind speed we'll see long wave impacts in the radiometer-derived salinity

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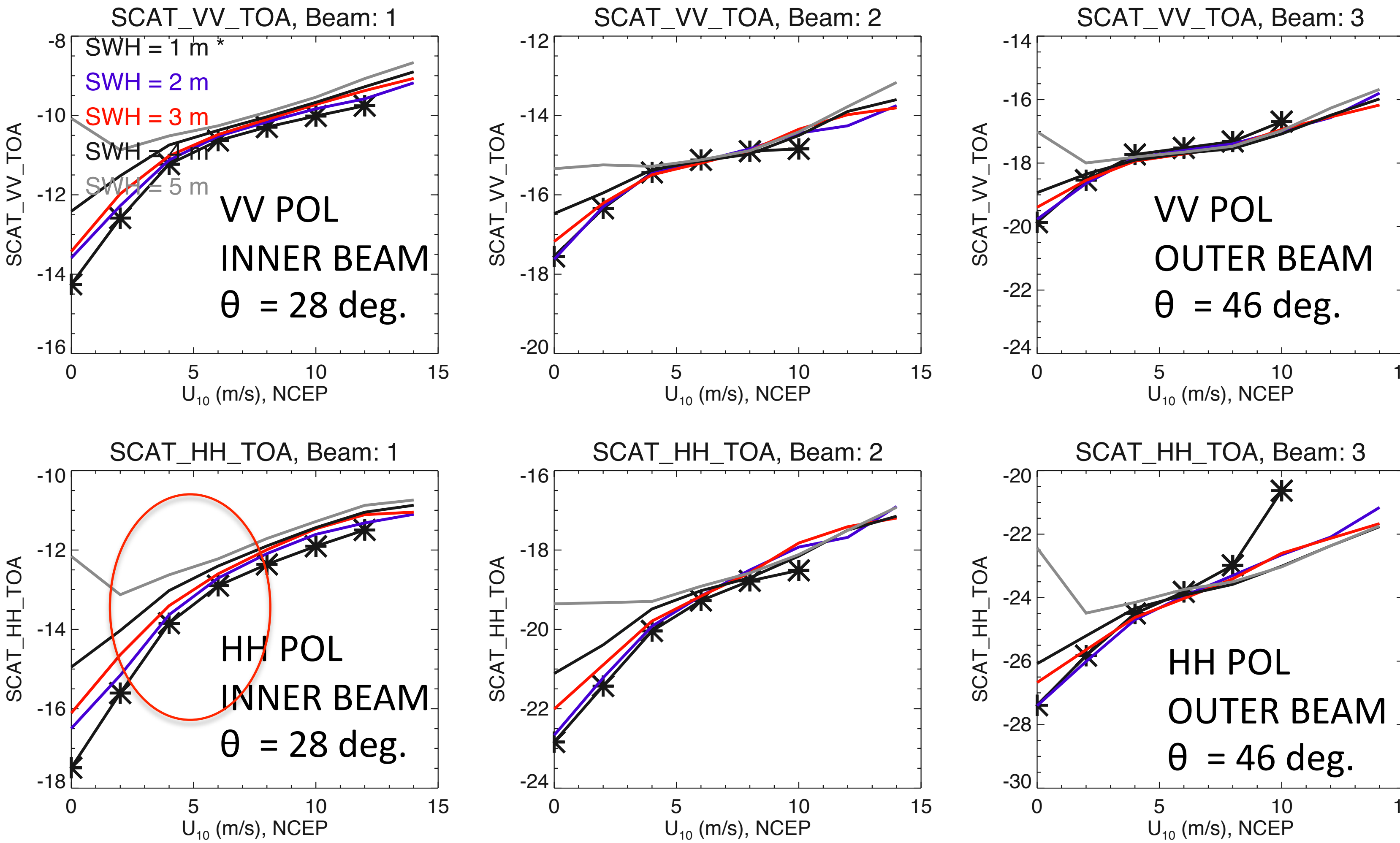
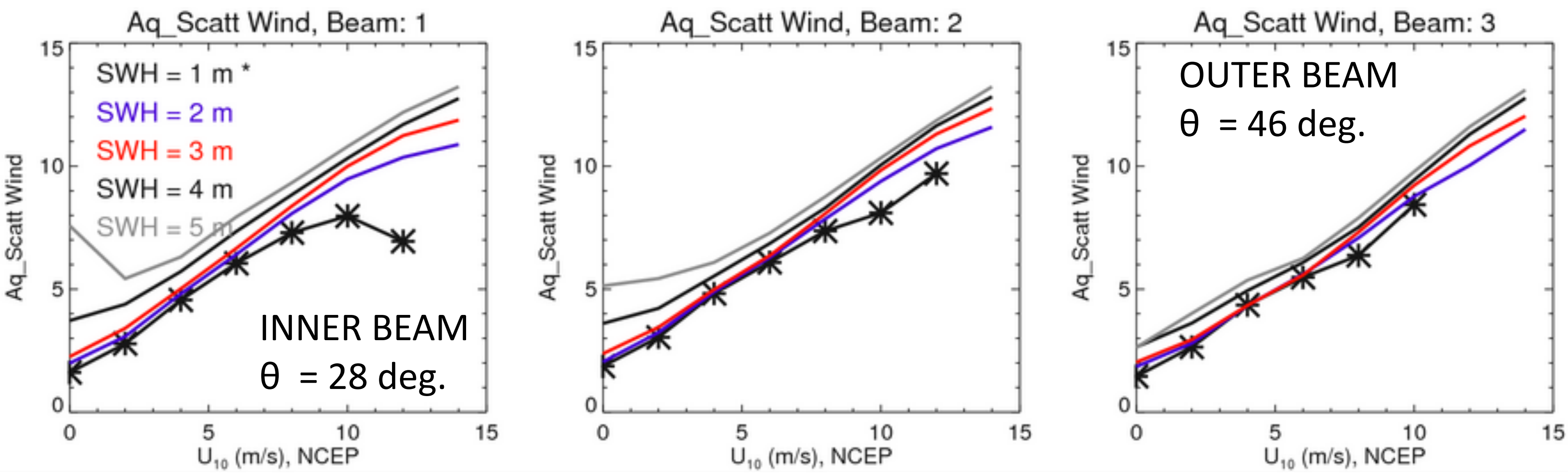
Aquarius Scatterometer sigma0 vs. significant wave height (17 weeks; Day 240-362) ; X-axis=NCEP wind



LARGEST IMPACT

LEAST IMPACT

Aquarius Scatterometer Wind vs. significant wave height (17 weeks; Day 240-362) ; X-axis=NCEP wind



LARGEST IMPACT **WEAKER IMPACT**

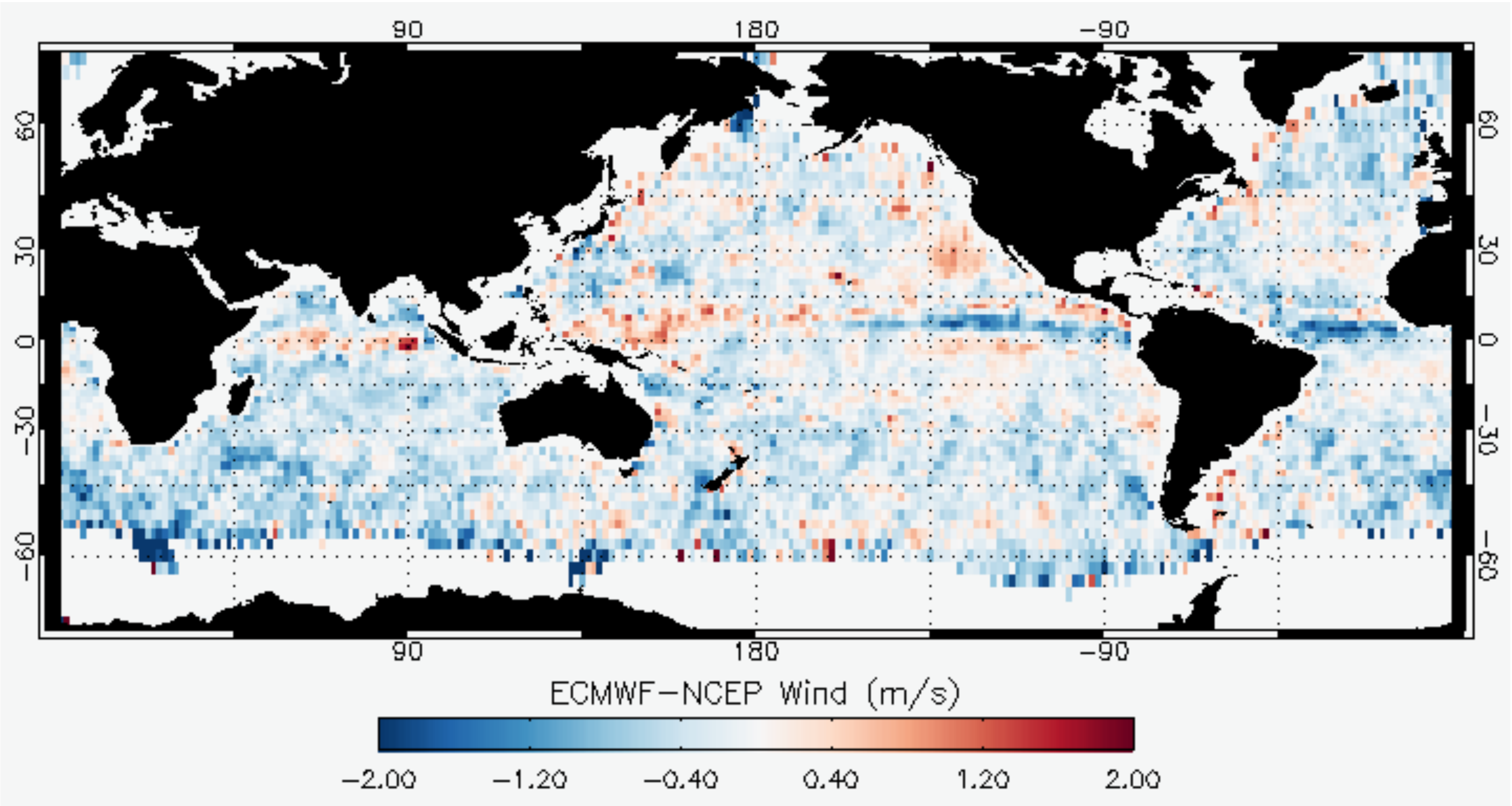
- **Long-waves lead to wind speed error when seas are exceedingly high**
- **This is a good thing – indicates that the scatterometer is sensitive to longer waves that likely impact the radiometer**

Getting sidetracked

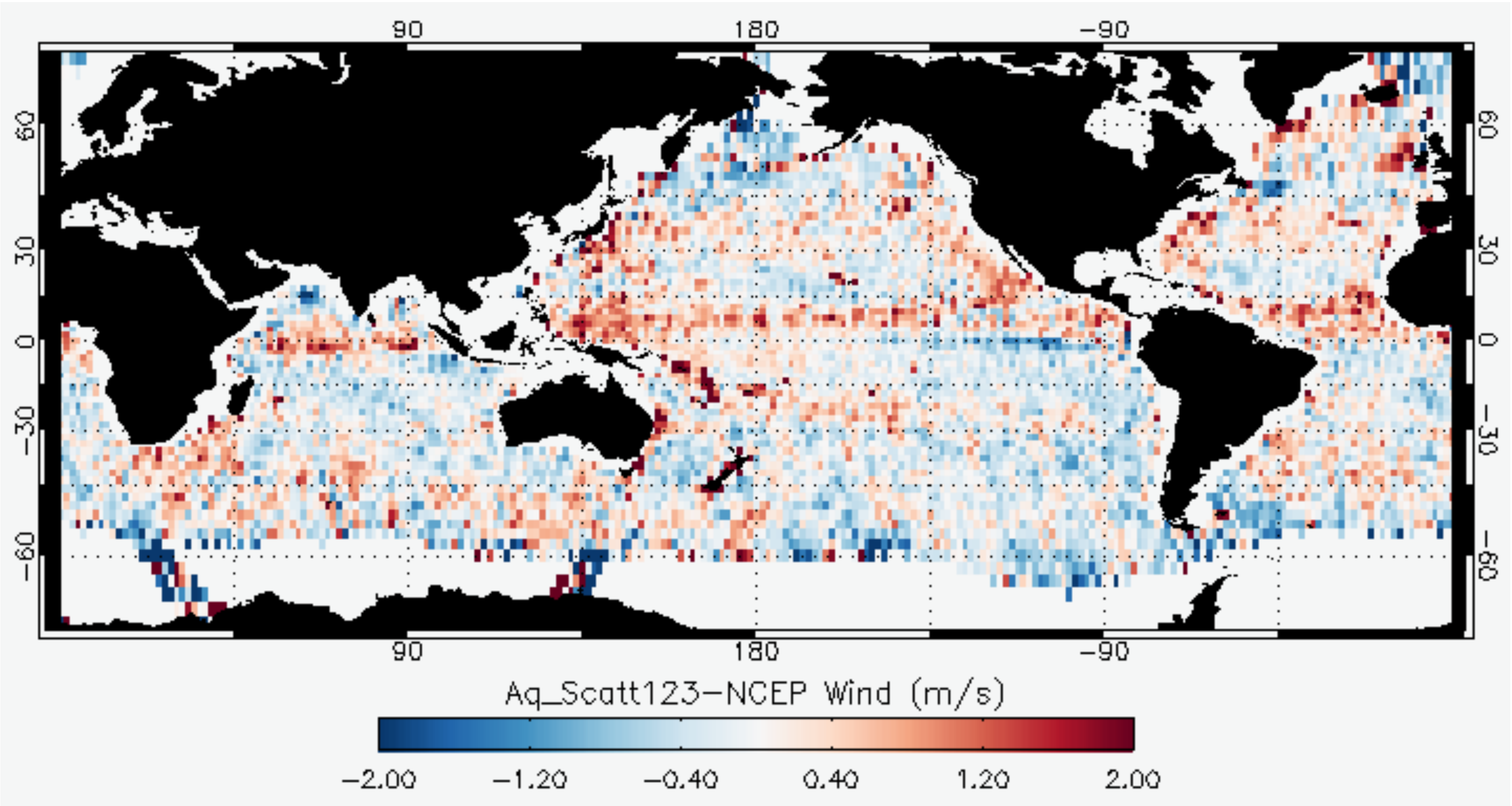
All wind products show significant systematic differences – likely associated with ocean currents. wind waves, and atmospheric stability (SST) impacts.

NCEP, ECMWF, SSM/I, Aquarius Scatterometer

Wind products and spatial differences
Day 240-270



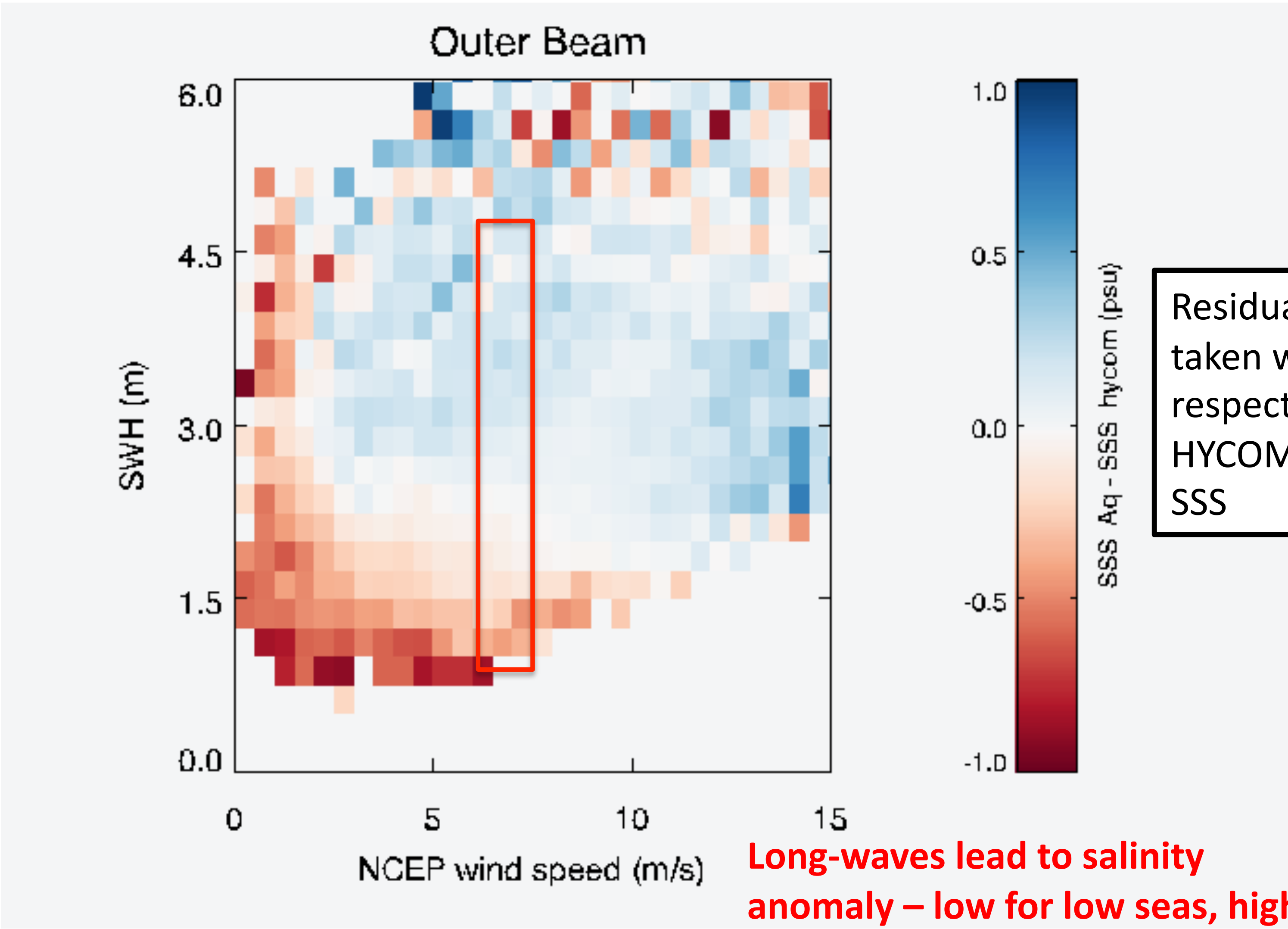
Wind products and spatial differences
Day 240-270



Onto radiometer derived SSS

Some substantial improvement already L2 V1.2 -> 1.3

Aquarius Radiometer Salinity error vs. SWH
(17 weeks; Day 240-362) ; X-axis=NCEP wind, V`1.2; DESC



Residual Salinity taken with respect to HYCOM model SSS

Long-waves lead to salinity anomaly – low for low seas, high for high seas

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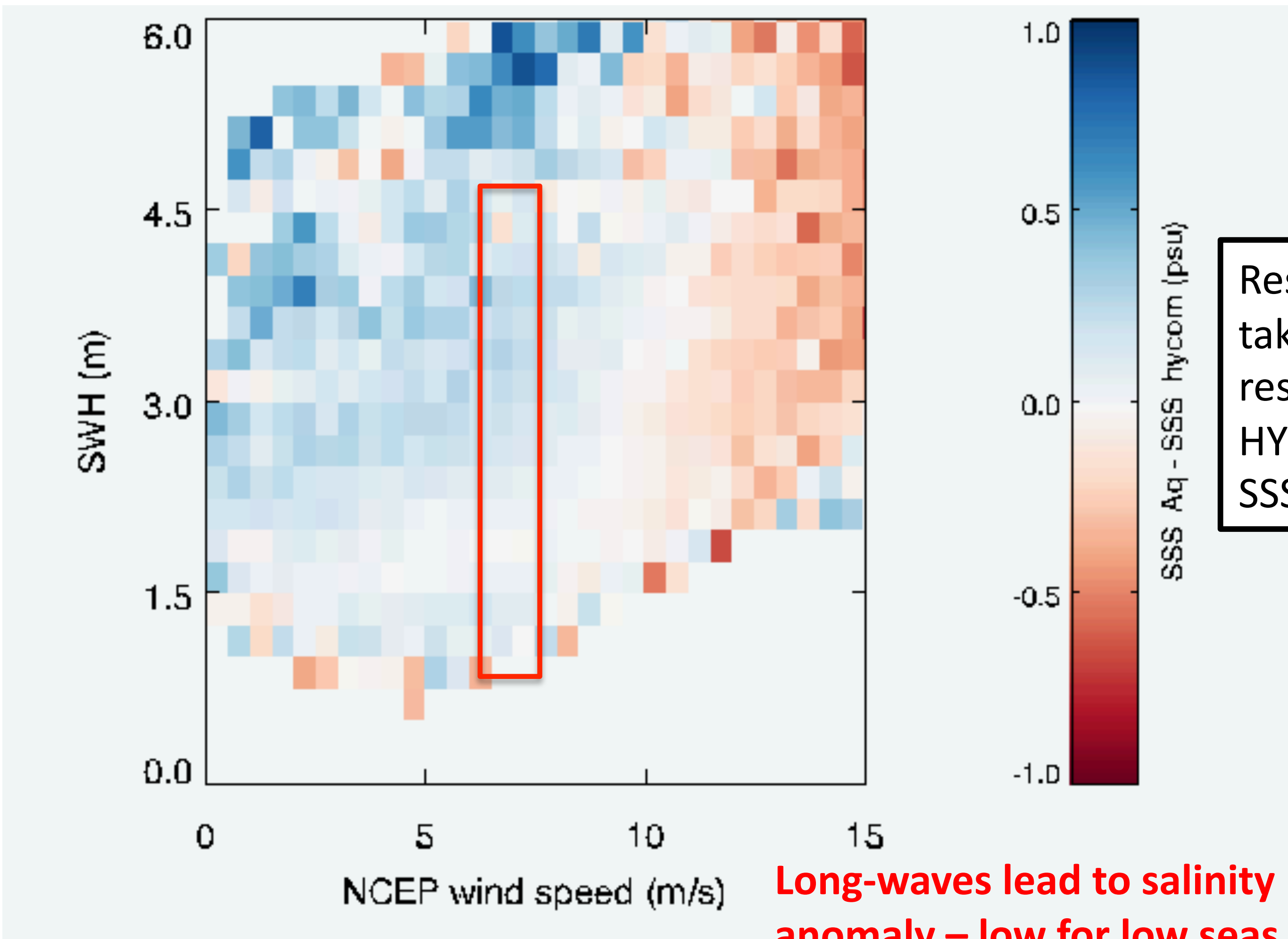
Aquarius Radiometer Salinity error vs. SWH
(17 weeks; Day 240-362) ; X-axis=NCEP wind; Ver 1.2.3; DESC; OUTER BEAM



Residual Salinity taken with respect to HYCOM model SSS

Long-waves lead to salinity anomaly – low for low seas, high for high seas

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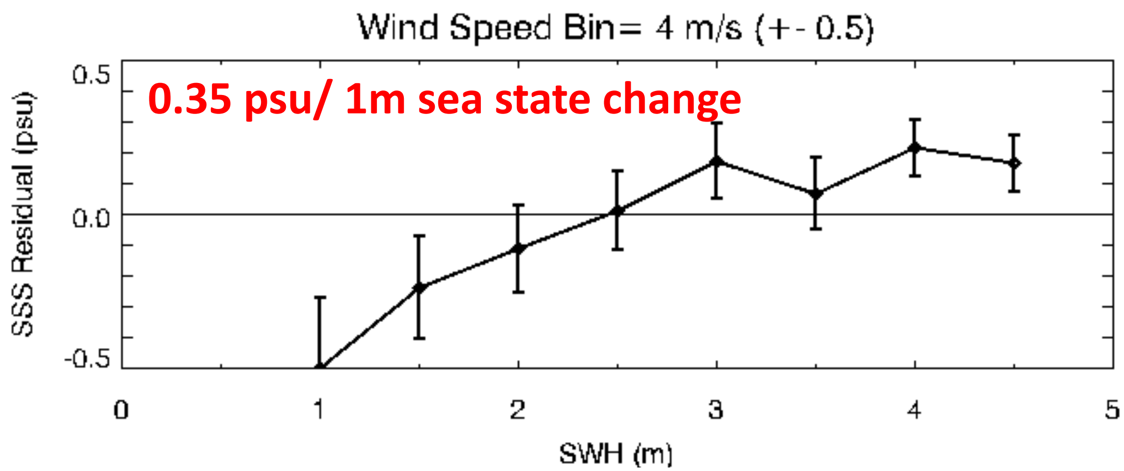
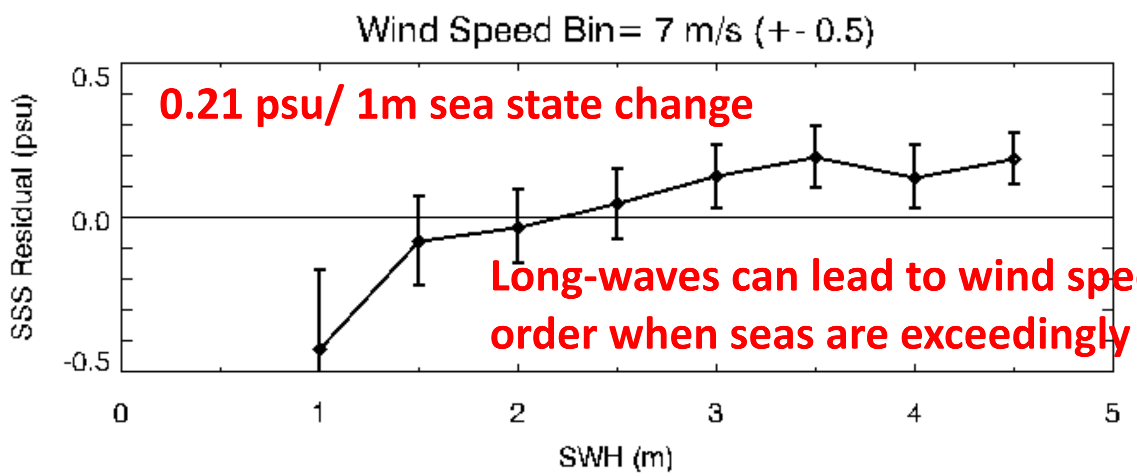
Aquarius Scatterometer Wind vs. significant wave height (17 weeks; Day 240-362) ; X-axis=NCEP wind; V1.2



OUTER BEAM
θ = 46 deg.

DESCENDING V1.2



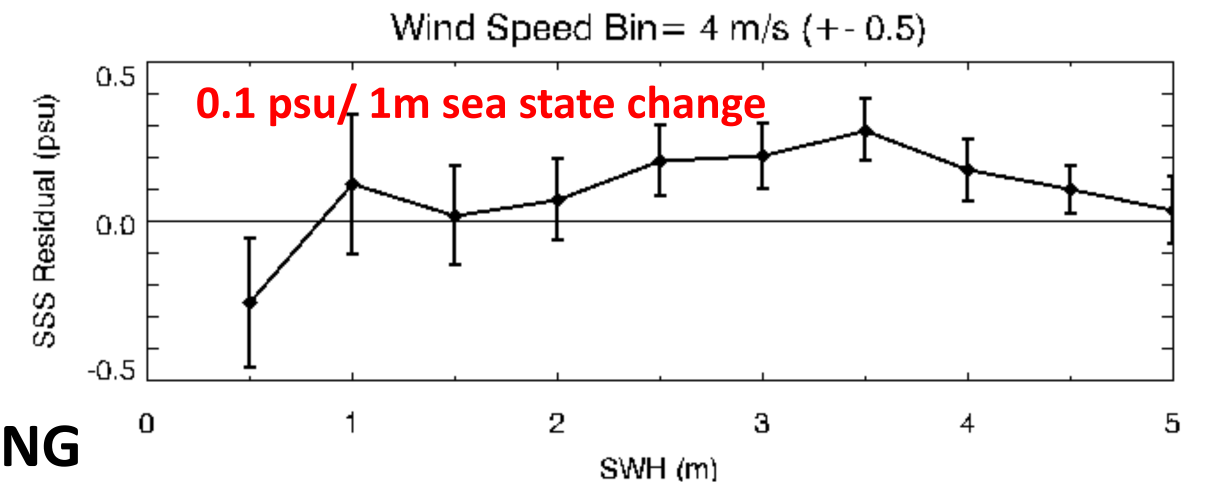
OUTER BEAM
θ = 46 deg.

Long-waves can lead to wind speed error of order when seas are exceedingly high

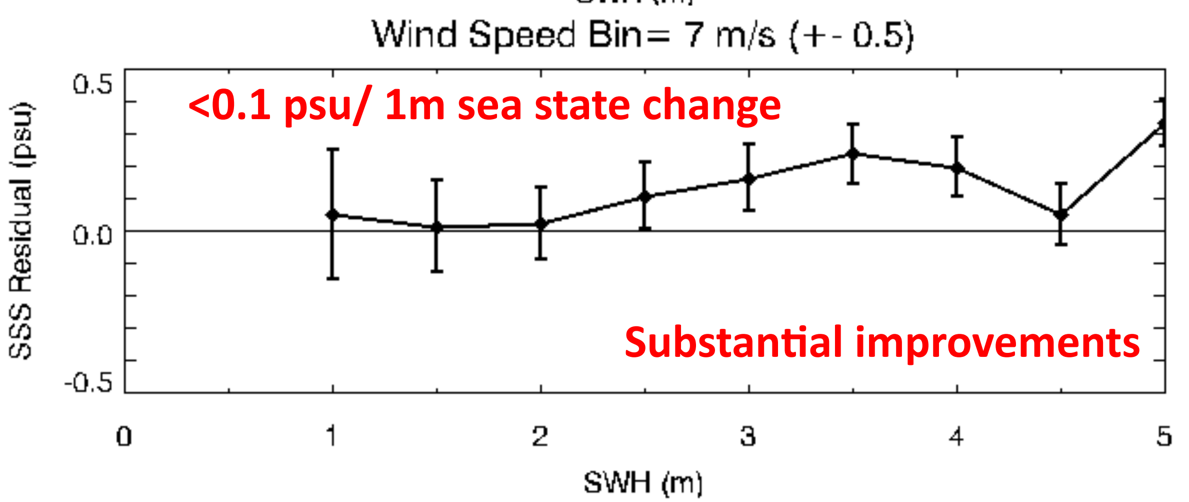
Desc Pass data, Galactic refl < 1 K

Aquarius Scatterometer Wind vs. significant wave height (17 weeks; Jan-Feb2012) ; X-axis=NCEP wind; Ver. 1.3

DESCENDING V1.3



OUTER BEAM
θ = 46 deg.



OUTER BEAM
θ = 46 deg.

Desc Pass data, Galactic refl < 1 K

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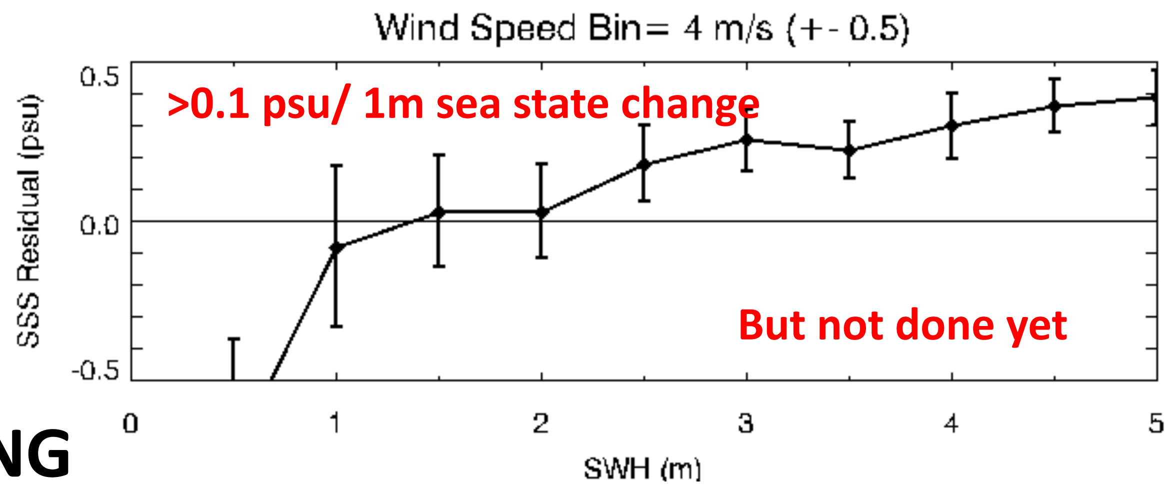
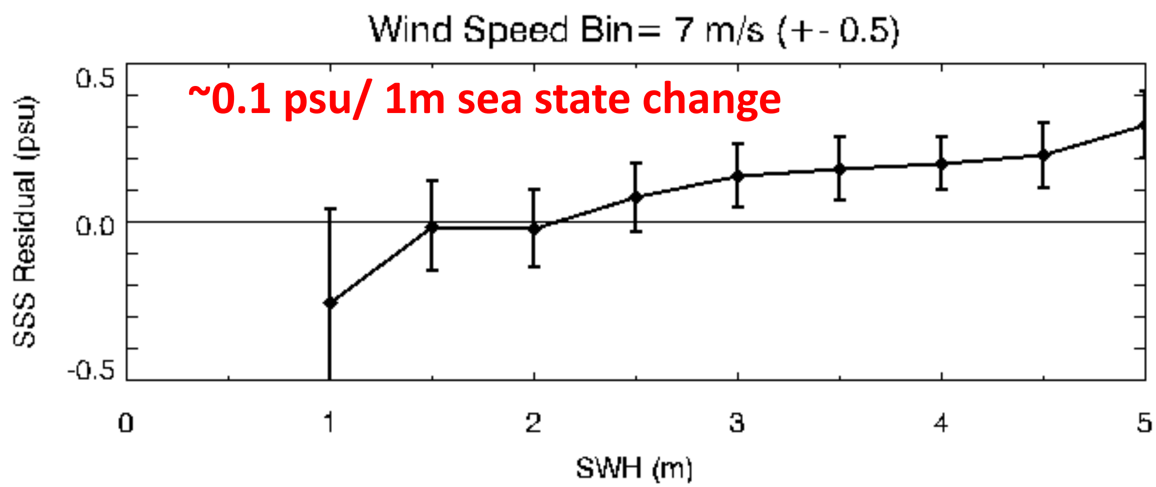
Aquarius Scatterometer Wind vs. significant wave height (17 weeks; Jan-Feb2012) ; X-axis=NCEP wind; Ver. 1.3

ASCENDING V1.3



OUTER BEAM
θ = 46 deg.



OUTER BEAM
θ = 46 deg.

ASC Pass data, Galactic refl < 1 K

Some caveats and future work

Final Aquarius surface Tb_V and Tb_H are still being developed with issues such as reflected Galaxy and Faraday rotation correcting impacting these 2nd order ocean wave impact results (V1.4?)

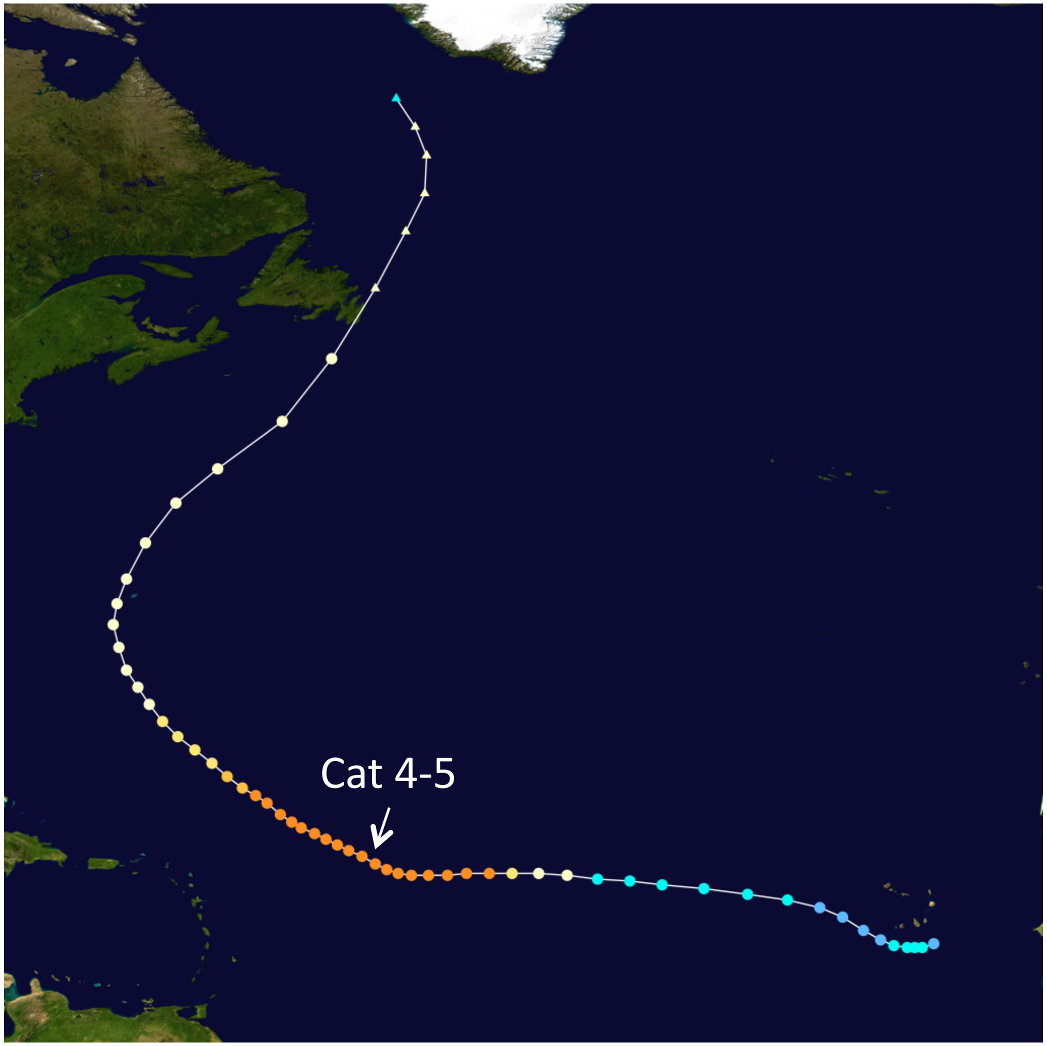
- ascending vs. descending results differ
- time dependence
- highest wind/wave environment are in coldest waters
- SST-wave covariance

Fully exploit and document the certain benefit of using the scatterometer for SSS inversion

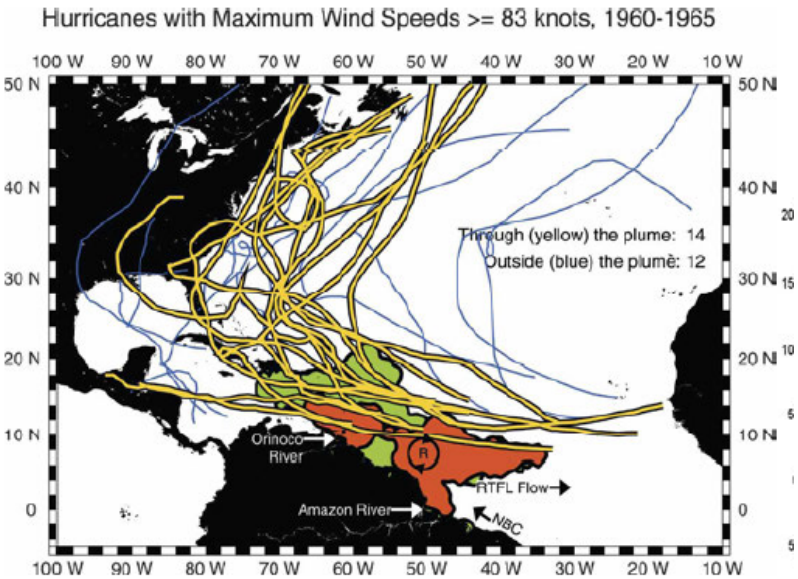
Further formal evaluation of the radiometer and radar data within a scattering/emission model + global wave field data

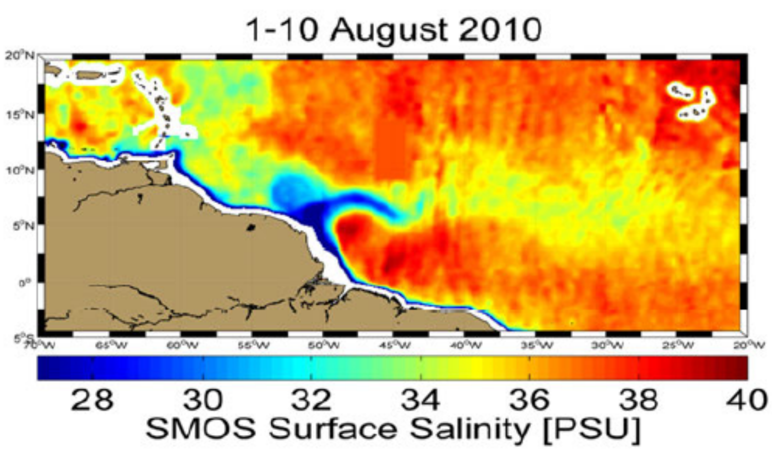
What wind model to use as a reference?   SSM/I != NCEP != ECMWF

Analysis of Satellite SSS signatures over Hurricane IGOR 11-24 Sep 2010 using SMOS



Surface salinity signal variability associated with Hurricane-induced mixing near the Amazon/ Orinoco plume – Igor case study – Sept 2010





Nico Reul with Chapron, Tenerelli, Vandemark, Vialard, ...

✓Freshwater Plume=> warmer SST & shallow stable surface layer (barrier layer)

✓65% of TC crossing the Amazon Plume evolve into cat 5 Hurricanes *Ffield (J. Clim 2007)*

✓Amazon & Orinoco plumes =>Strong positive SST anomalies (~1°C)

✓Impact of plume SST on storm intensity addressed using WRF simulation *Vizy and Cook, (JGR 2010)*

Can we use SMOS retrieved SSS to study ocean-atmosphere interactions in TCs ?

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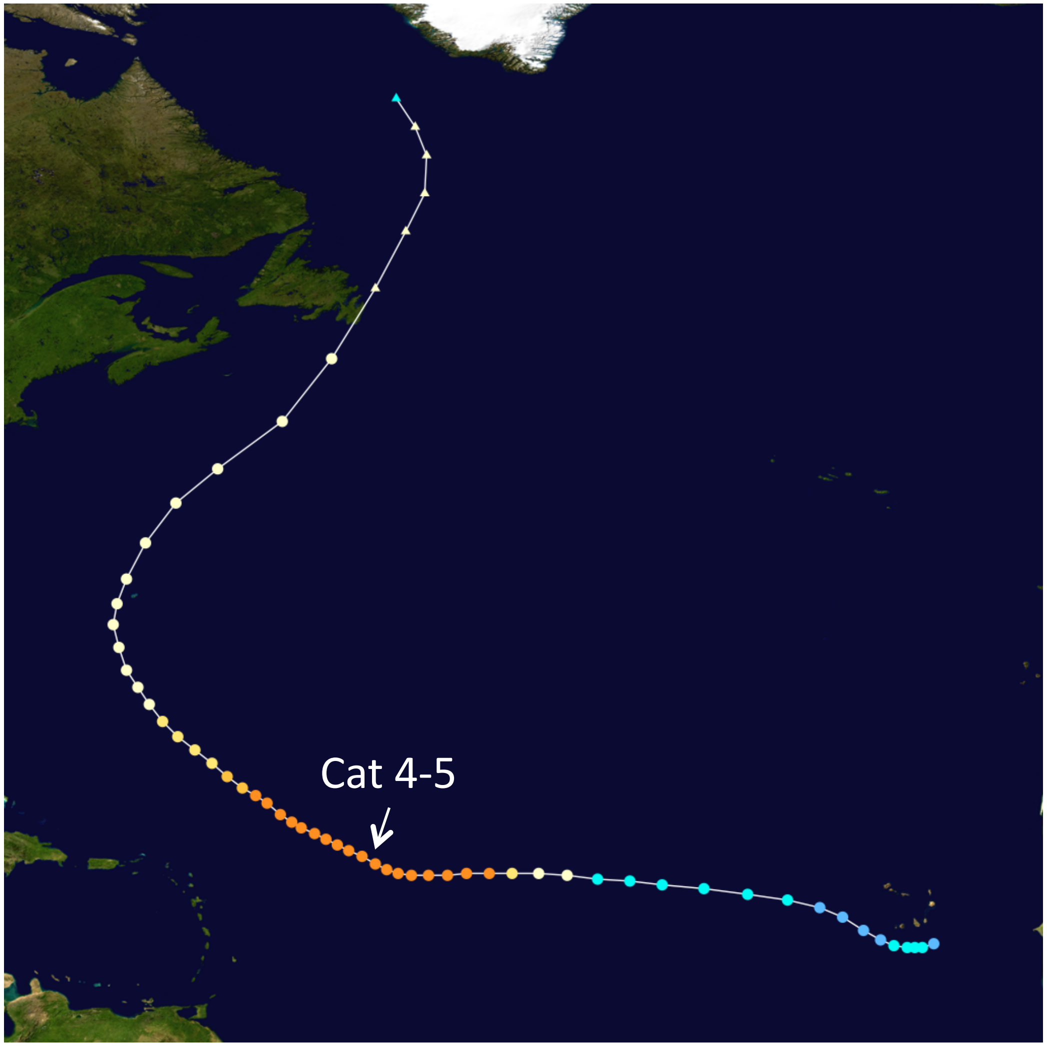
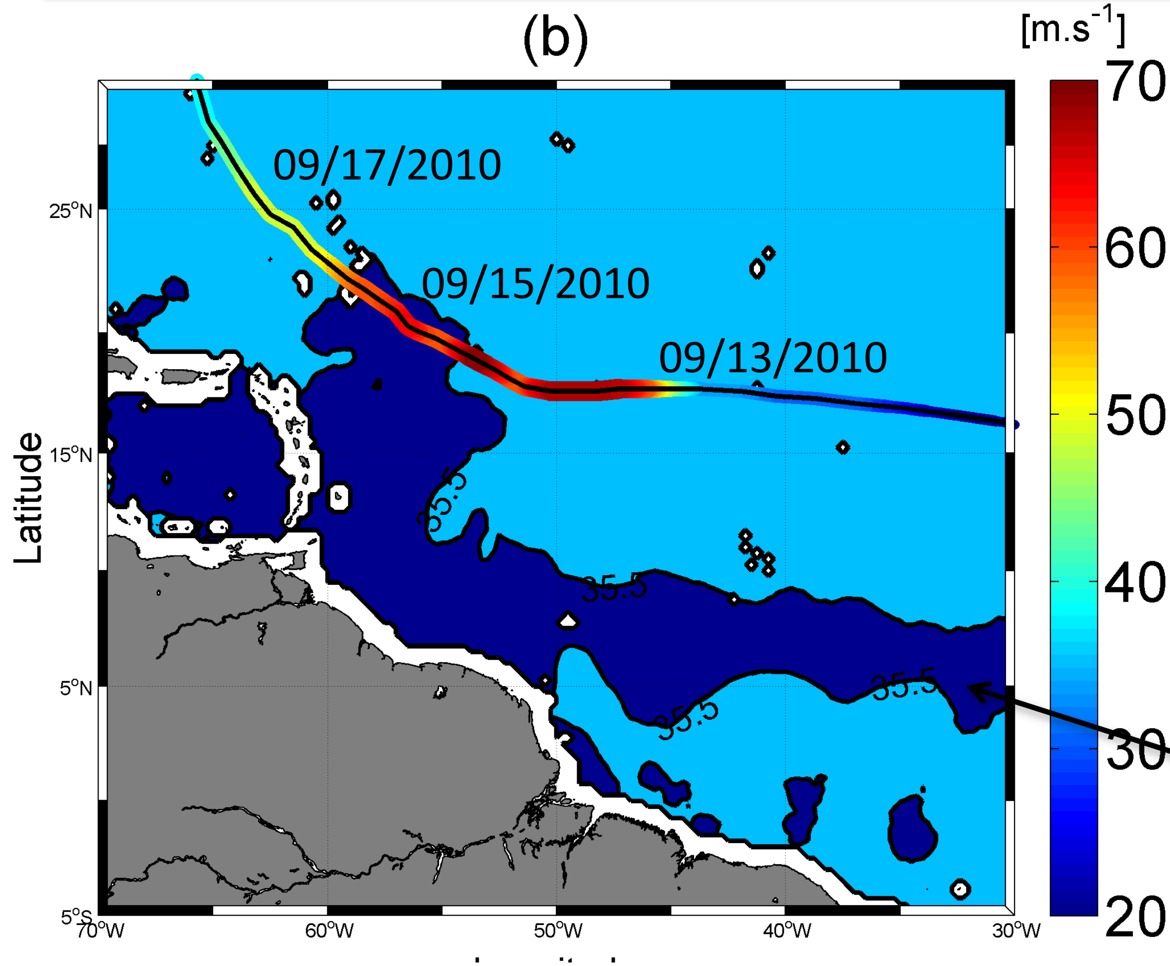
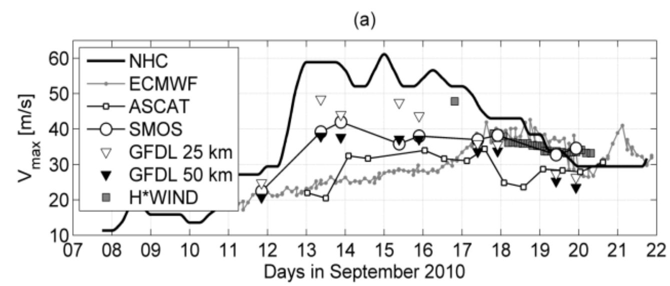
Analysis of SMOS data signature over Hurricane IGOR 11-24 Sep 2010



Coincident or causal Hurricane Igor wind droping at the plume/open ocean transition ?



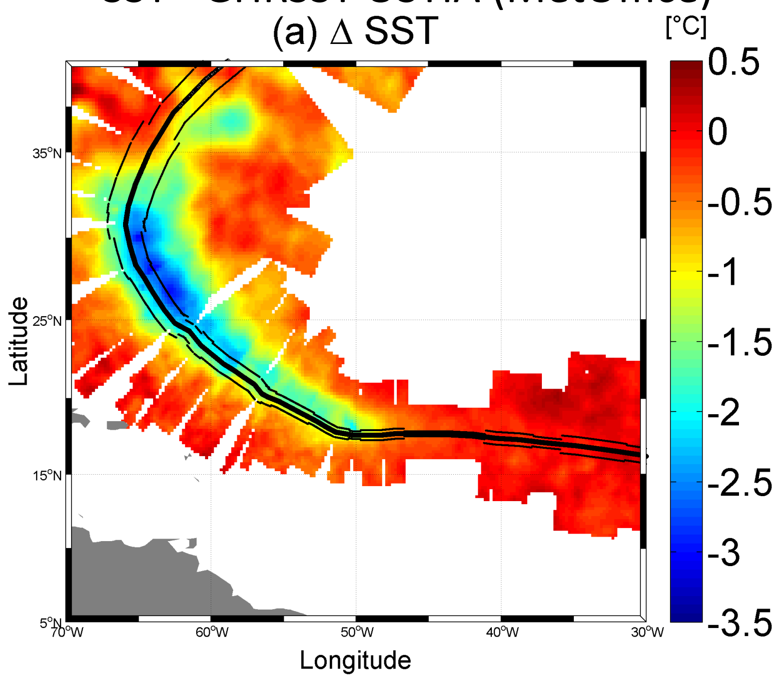


Location of the
Plume (SSS<35.5)
the last
10 days
before
Igor passage (5->13 Sep)

Thermo-haline wakes behind Igor hurricane

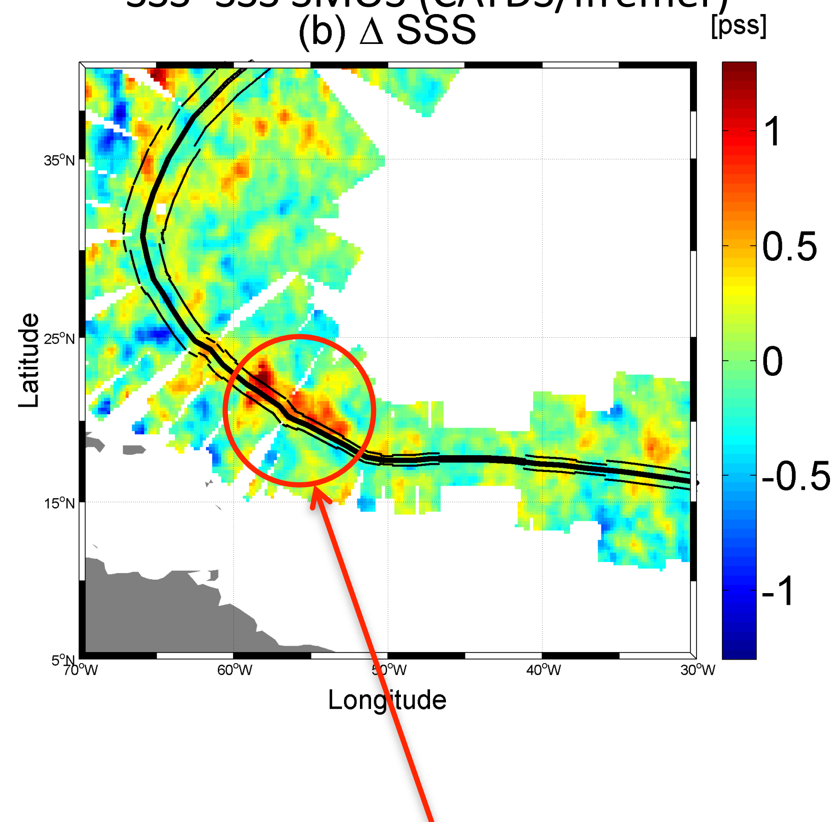
<u>Cool Wake induced by Igor:</u>

SST= GHRSST OSTIA (MetOffice)



<u>Salty Wake induced by Igor:</u>

SSS=SSS SMOS (CATDS/ifremer)



$$\Delta SST(x(t_o),y(t_o)) = \frac{1}{\Delta T}\int_{t_o+1day}^{t_o+5days} SST(t,x,y)dt - \frac{1}{\Delta T}\int_{t_o-5days}^{t_o-1day} SST(t,x,y)dt \quad where\ \Delta T = 5\ days$$

$x(t_o),y(t_o)$ are cross-track locations from the eye at t_o

Strong resalinisation of the SSS after Igor passage, over the path of the storm Right-hand quadrant: ΔSSS~>+1-1.5 pss

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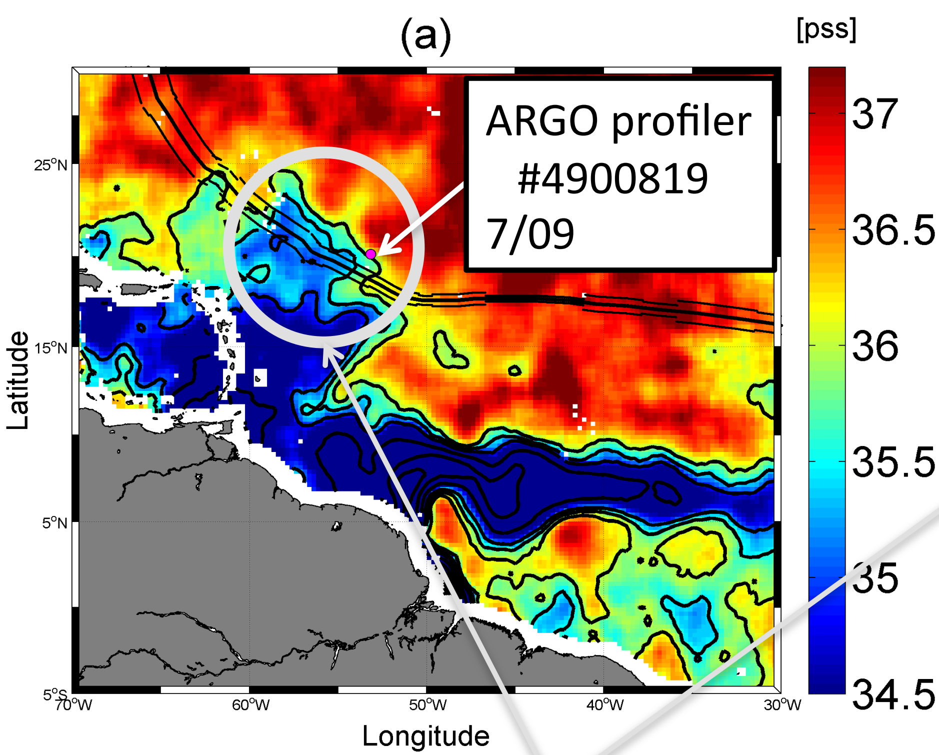
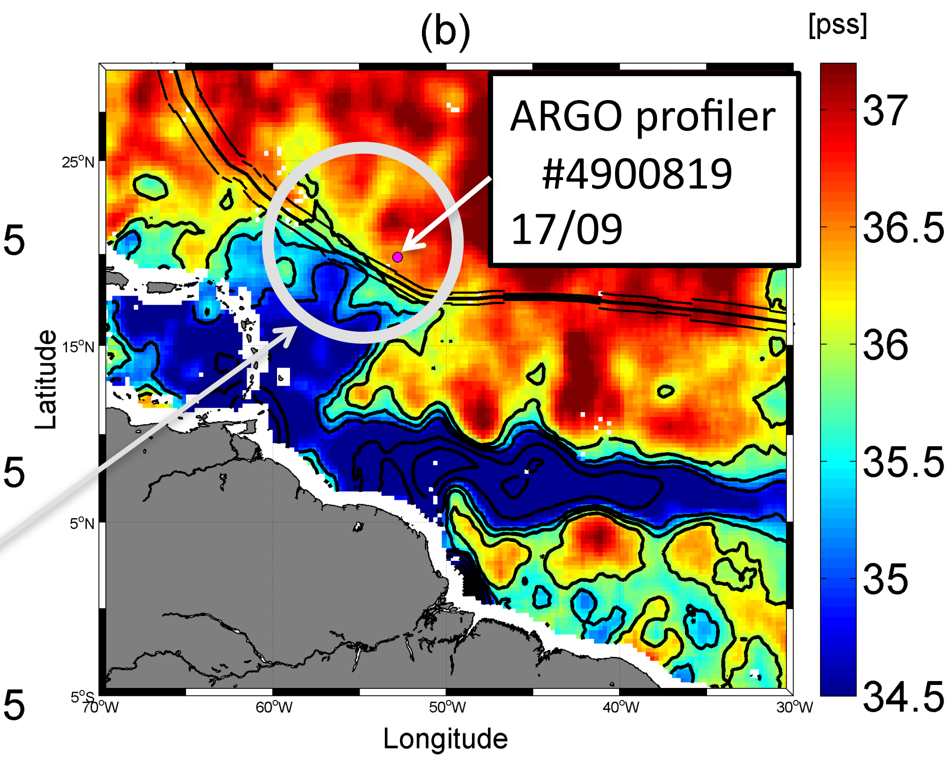
Erosion of the Amazon/Orinico Plume after Igor passage (Right-hand side of the TC)

SSS averaged 5-11/09
(3-5 days **before Igor**)

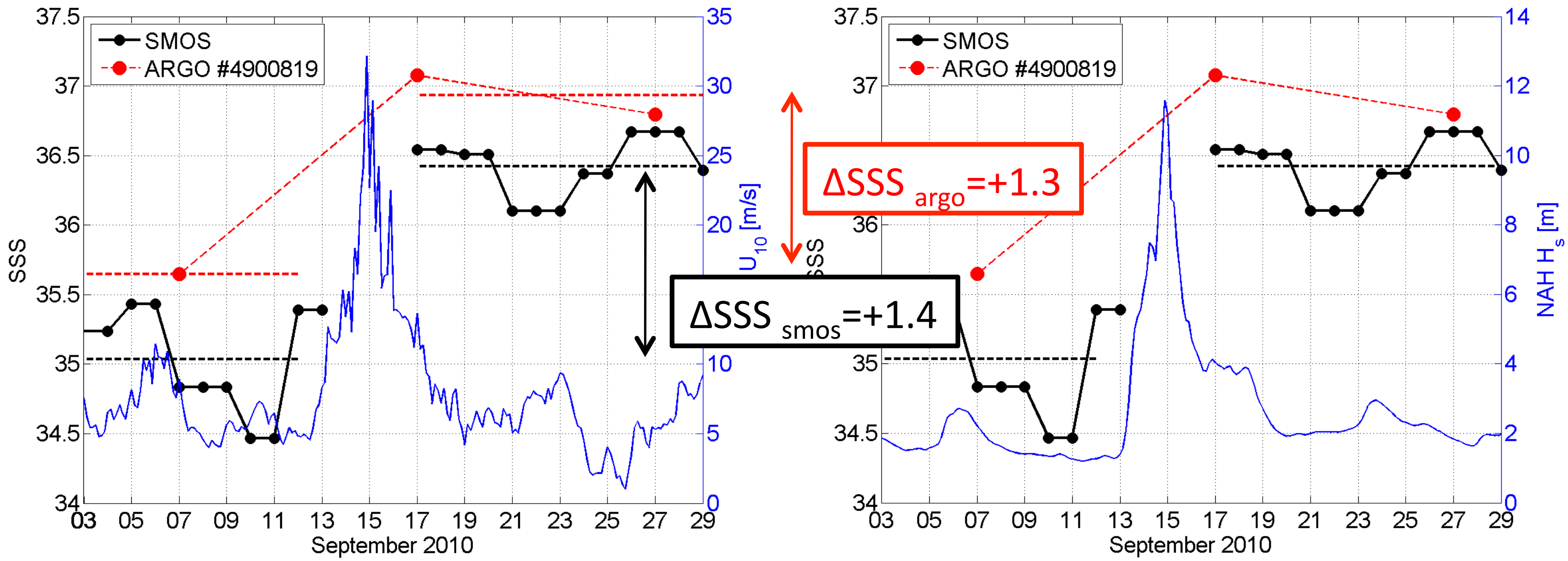
SSS averaged 19-24/09
(3-5 days **after Igor**)





Apparent Erosion of the freshwater surface layer on the right-hand side quadrants of the storm

Sea surface Salinity conditions at the ARGO float location before/after IGOR (right-hand side quadrant)

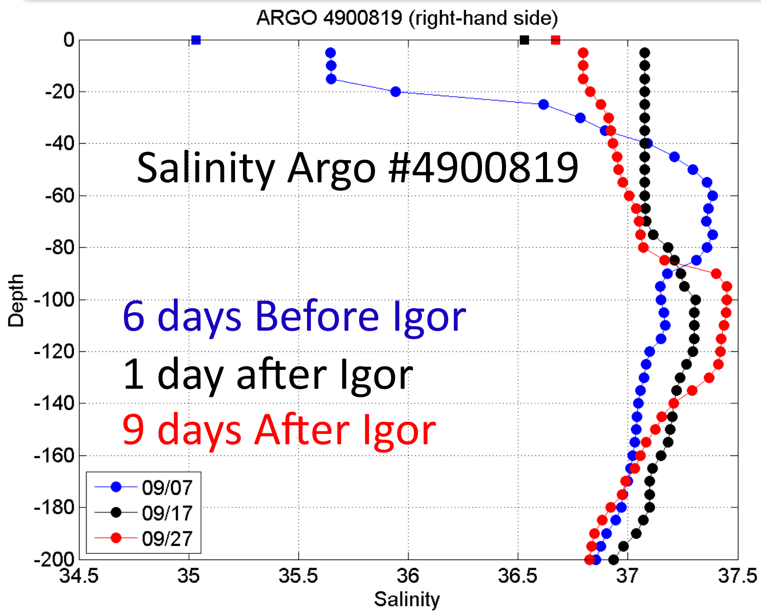


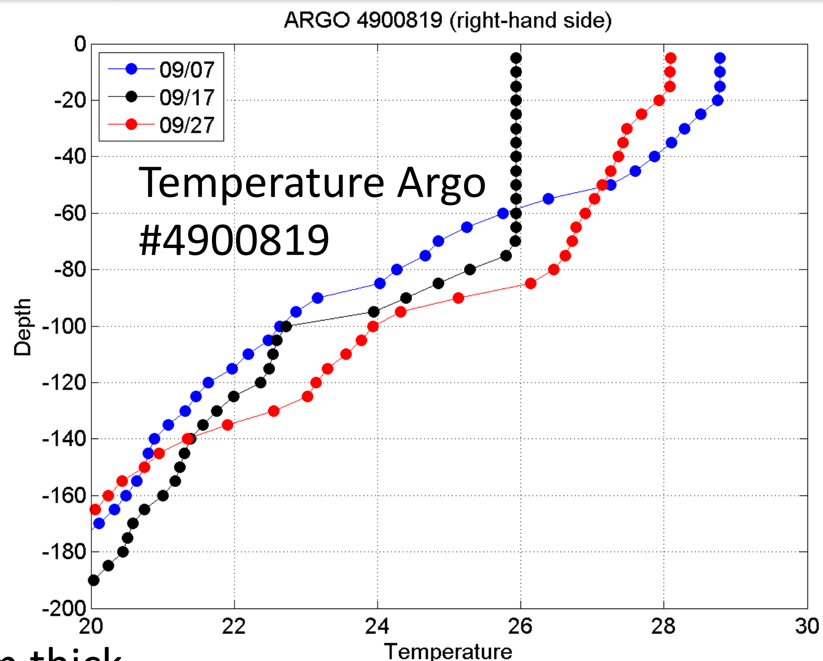
Enhancement of Sea Surface Salinity as seen by ARGO after IGOR passage: ΔSSS_{argo}~+1.3
Excellent consistency with SMOS observation trend: ΔSSS_{smos}~+1.4 .

SMOS SSS is however systematically ~0.5 pss fresher than ARGO observations at 5 m depth

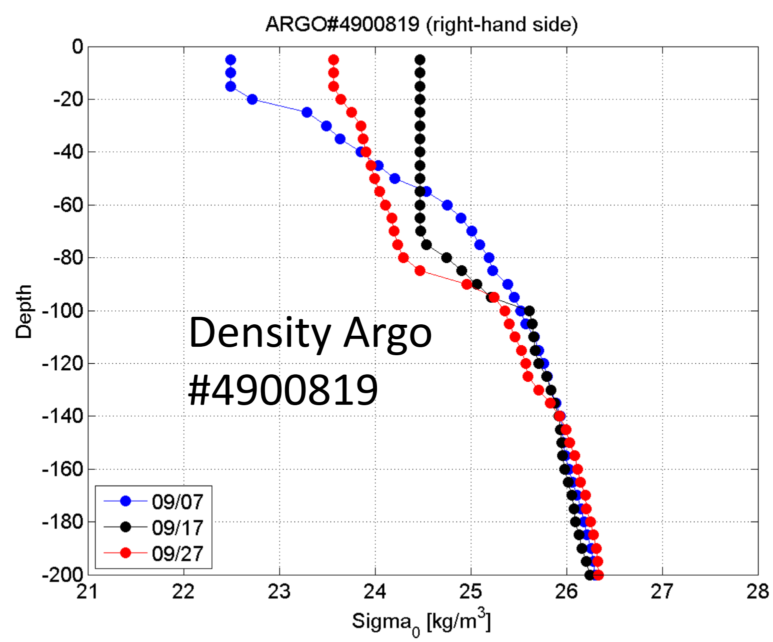
Maximum surface Wind encountered at the argo float location is ~33 m/s (GFDL model)
Maximum significant wave height up to 11 m (Wave Watch III, NAH)

Vertical stratication before/after in the right-hand side quadrant





Original Plume surface freshwater layer ~20 m thick



<u>After the passage of Igor:</u>

=>Drop of sea surface temperature Δ T~2.8°C

=>Enhancement of Sea Surface Salinity by ΔS=1.4

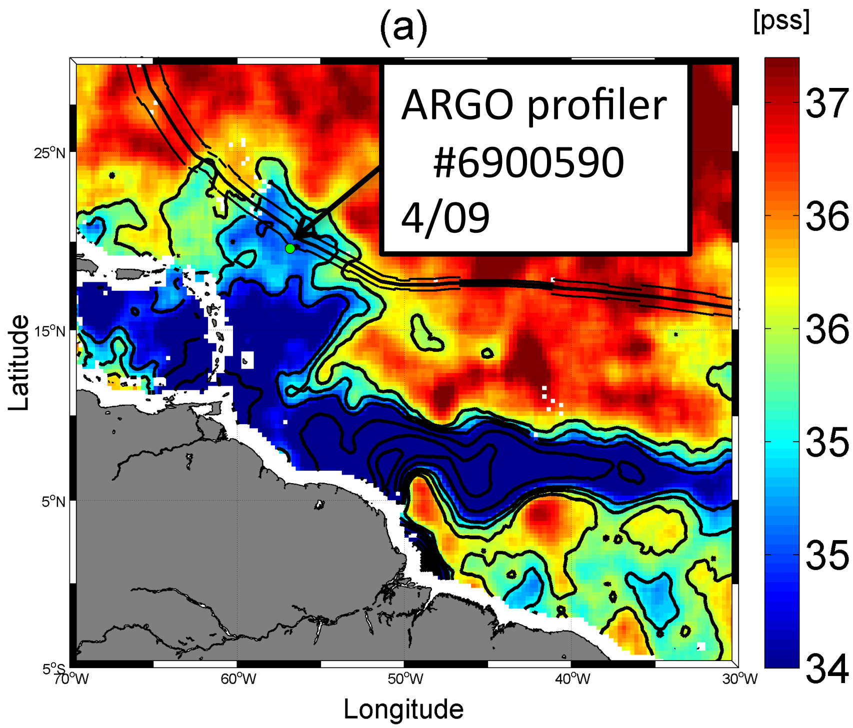
Excellent consistence with SMOS obs~1.5

Increase in sea surface density ~2 kg/m^3

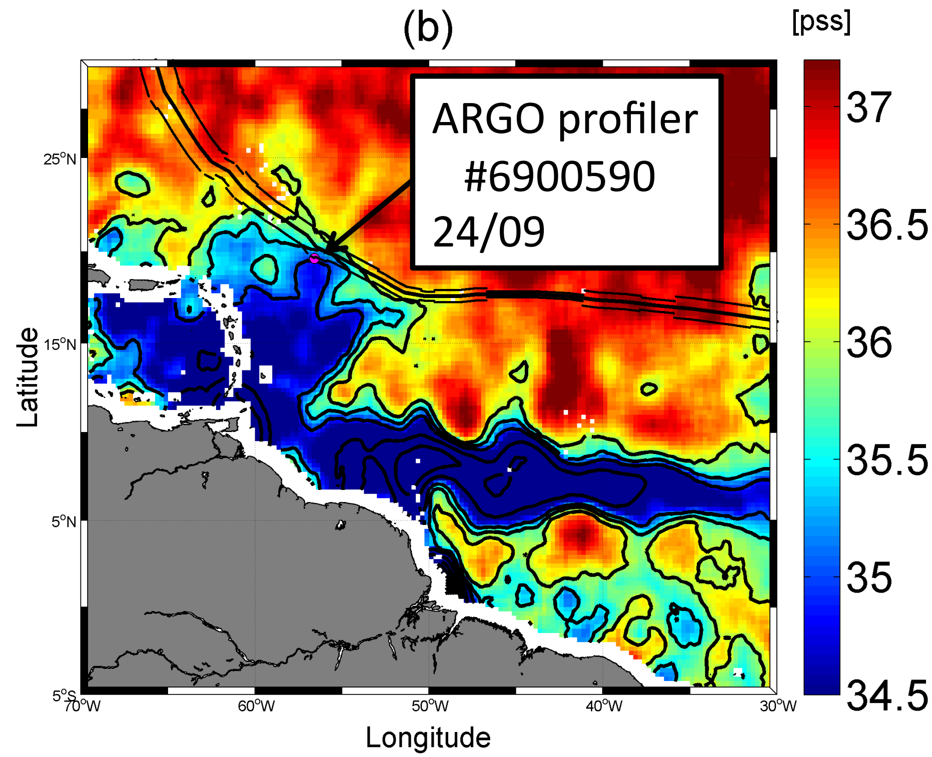
Deepening of the Mixed surface layer
From 20 m down to ~90 m depth

Erosion of the Amazon/Orinico Plume after Igor passage (Left-hand side of the TC)

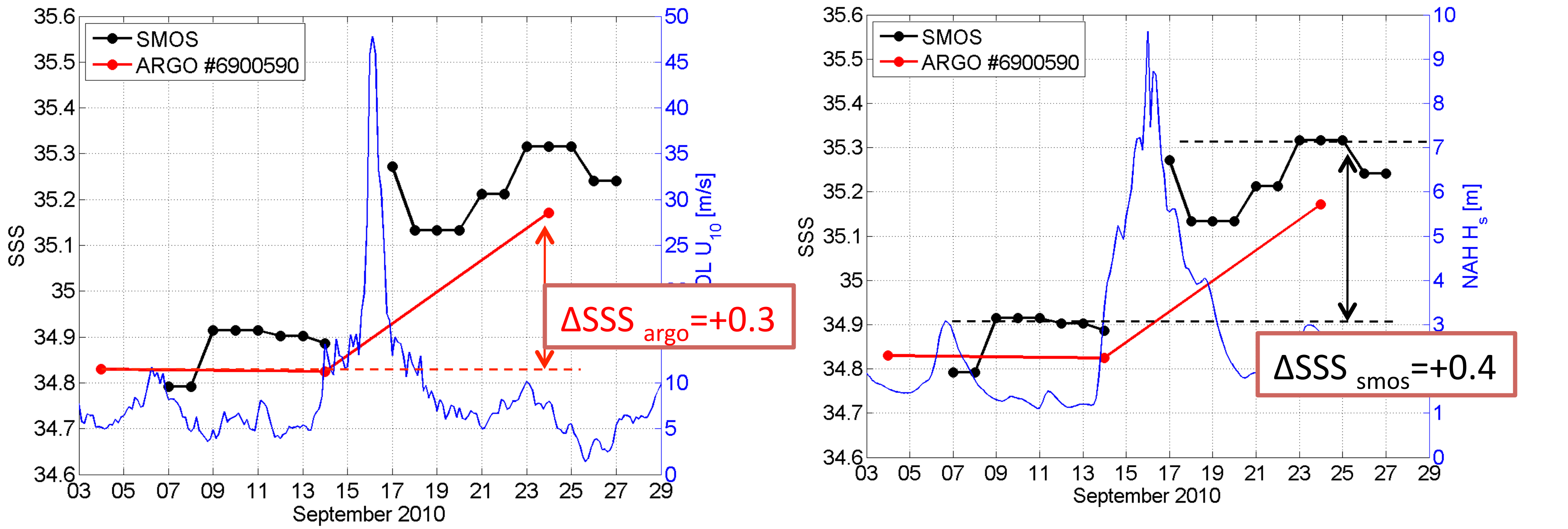
SSS averaged 5-11/09
(3-5 days **before Igor**)



SSS averaged 19-24/09
(3-5 days **after Igor**)



Sea surface Salinity conditions at the ARGO float location before/after IGOR (left-hand side quadrant)



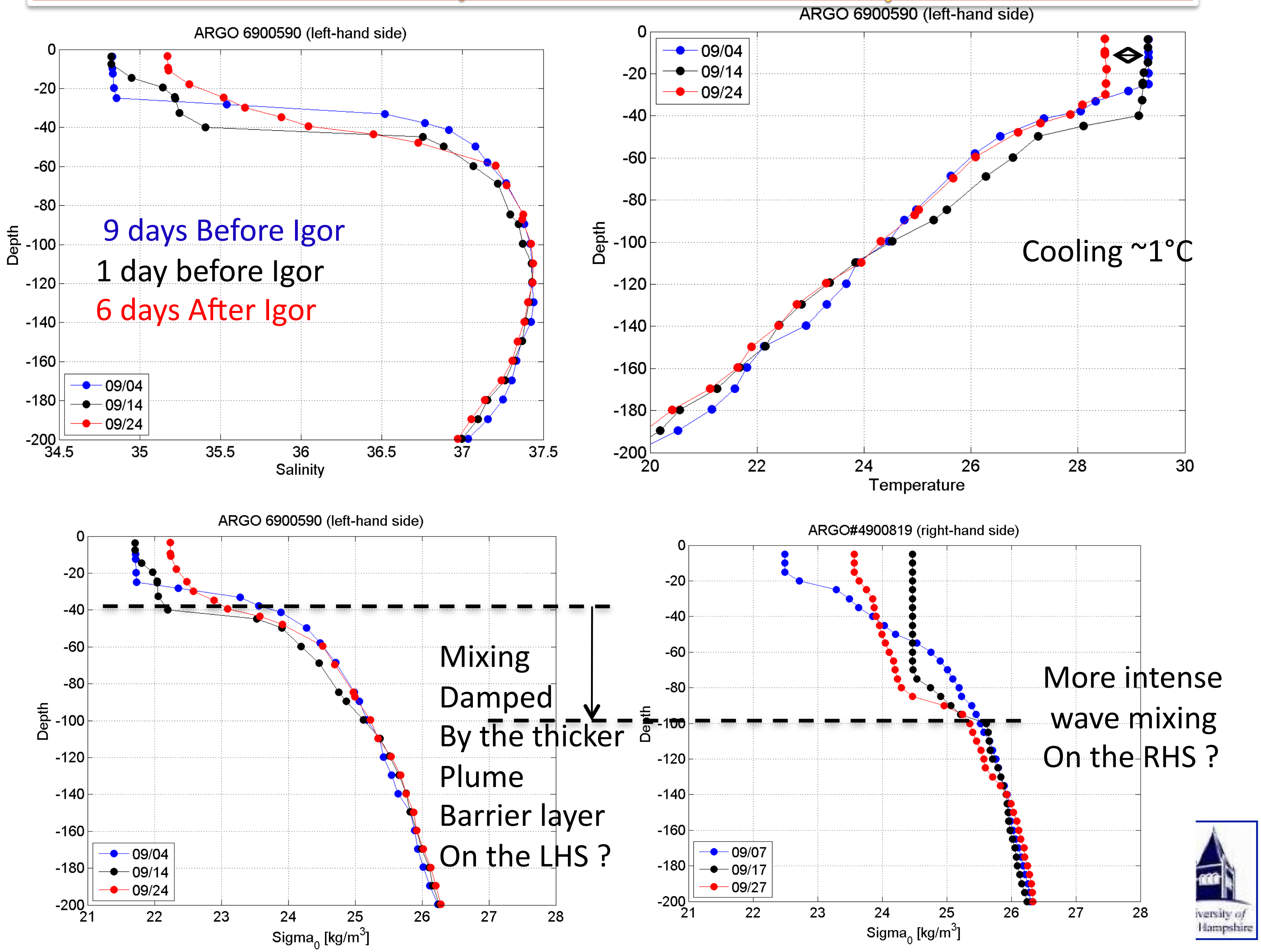
Surface wind speed encountered >15 m/s up to 48 m/s from 09/15->09/17

Significant wave height >3 m up to 9 m from 09/15->09/17

SMOS SSS in general saltier than Argo SSS by ~0.05-0.1 pss

However very consistent SSS temporal trend from before to after Igor between ARGO float & SMOS surface data:
=>both are showing a +0.3-0.4 pss increase following the surface mixing induced by IGOR on its left hand side quadrant.

Vertical stratication before/after in the left-hand side quadrant



EARLY CONCLUSIONS

- SMOS SSS data able to produce before and after snapshots of plume location associated with TC passage

- Satellite SSS data yielding accurate SSS perturbation due to to TC as compared to two ARGO floats – 0.5 to 1.5 SSS INCREASE

- New look at plume-TC interaction with SSS + SST perhaps allowing enhanced diagnosis

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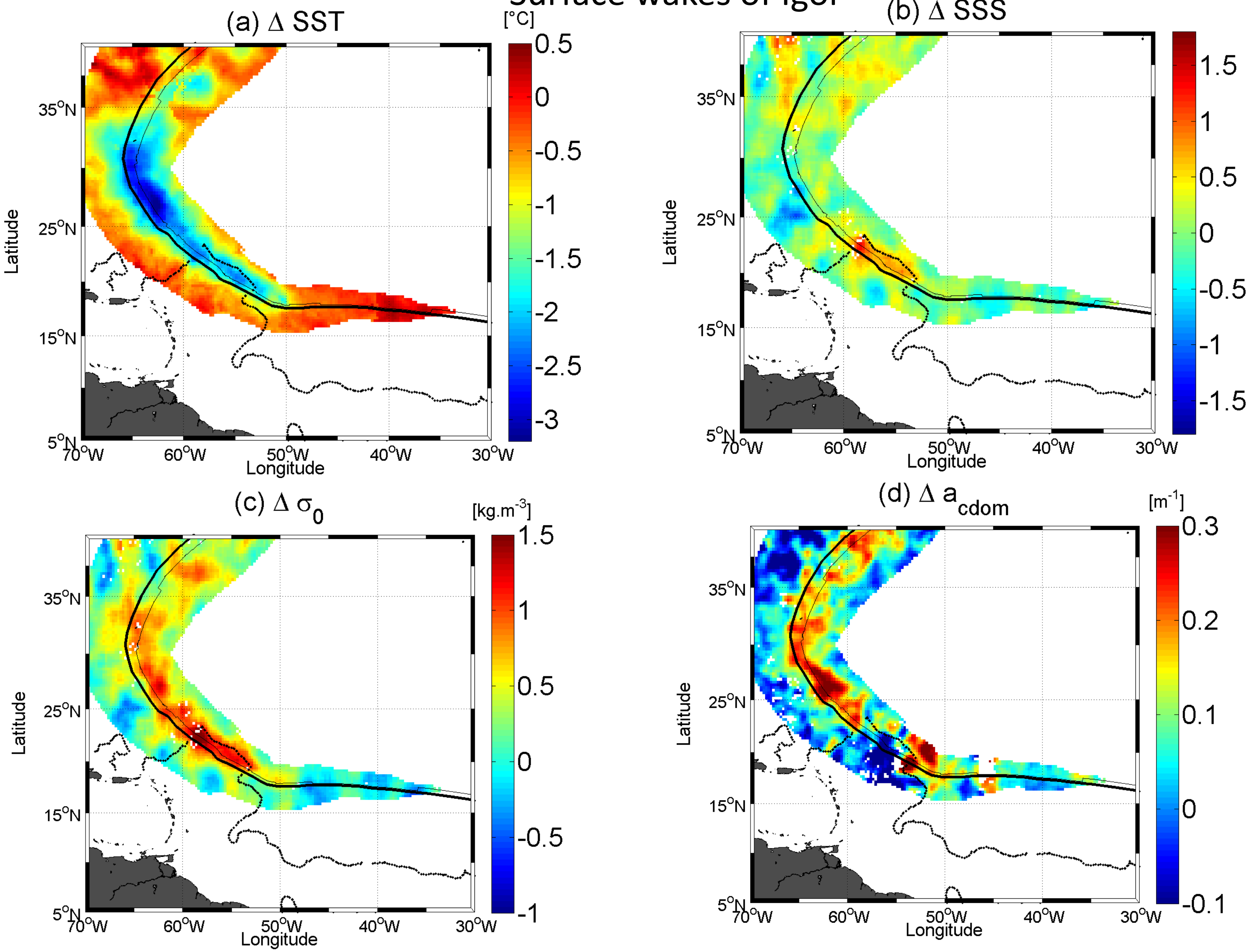
Surface wakes of Igor



Six days of data centered on t_o–(+) 4 days have been averaged to construct the pre (post)-cyclonic quantities.

Here

$a_{cdom} = a_d + ag$

ag: CDOM (dissolved matter)

ad: non living particulate organic material, bacteria, inorganic material and bubbles

Figure 4: Surface wakes of Hurricane Igor. Post minus Pre-hurricane (a) Sea Surface Temperature (ΔSST) (b) Sea surface Salinity (ΔSSS), (c) Sea Surface Density ($\Delta\sigma_o$) and (d) Sea Surface CDOM absorption coefficient .The thick and thin curves are showing the hurricane eye track and the locii of maximum winds, respectively. The dotted lines is showing the pre-hurricane plume extent. ΔSST, ΔSSS, $\Delta\sigma_o$ wakes were only evaluated at spatial locations around the eye track for which the wind exceeded 34 knots during the passing of the hurricane.

Thanks!

This work is supported by NASA's Ocean Surface Salinity Science Team – Grant NNX09AU69G