Measurements of Air-Sea Interaction from the HY-2A Scatterometer

Dudley B. Chelton[1], Michael G. Schlax[1], Larry W. O'Neill[1], Qingtao Song[2,3], Bo Mu [3], Marcos Portabella[4], Wenming Lin[4] and Ad Stoffelen[5]

[1] Oregon State University, Corvallis, Oregon, USA

[2] Key Laboratory of Space Ocean Remote Sensing and Applications, State Oceanic Administration, Beijing, China

[3] National Satellite Ocean Application Service, Beijing, China

[4] Institut de Ciènciesdel Mar (ICM-CSIC), Barcelona, Spain

[5] Royal Netherlands Meteorological Institute (KNMI), De Bilt, The Netherlands

The HY-2A L2B wind products used in this study are provided by the Chinese National Satellite Ocean Application Service (NSOAS) through a trilateral collaboration among IOWVST members.

Overview

1. Brief summary of air-sea interaction over SST fronts from past studies.

2. Summary of data processing:

   - HY-2A Versions 1, 2 and 3

   - Filtering applied to investigate air-sea interaction

3. 13-year history of coupling coefficients for wind speed, divergence and vorticity from <u>monthly averages</u> of QuikSCAT and ASCAT-a.

4. Coupling coefficients for January-December 2012 monthly averages:

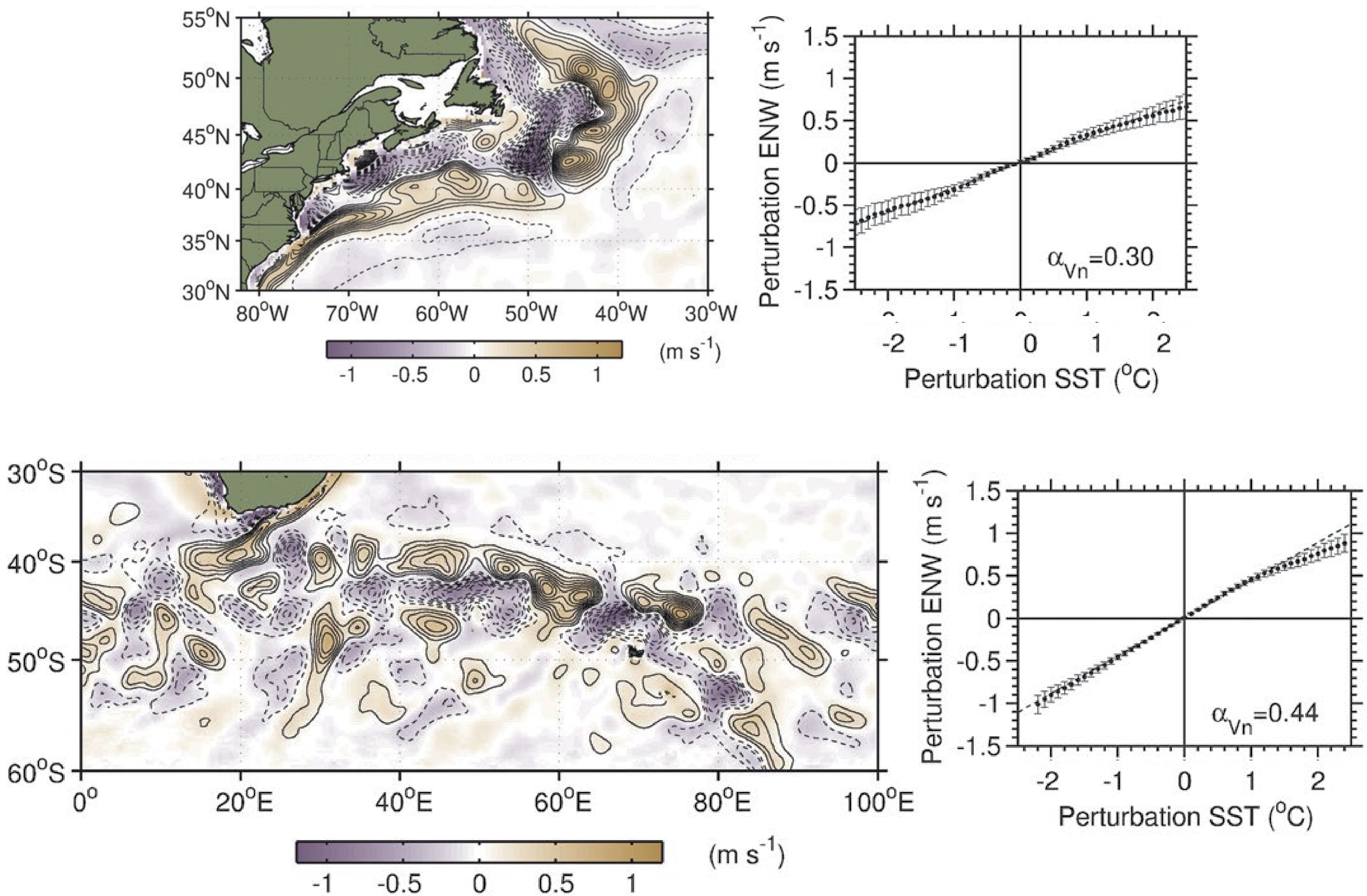
   - from HY-2A Versions 1, 2 and 3

   - from ASCAT-a

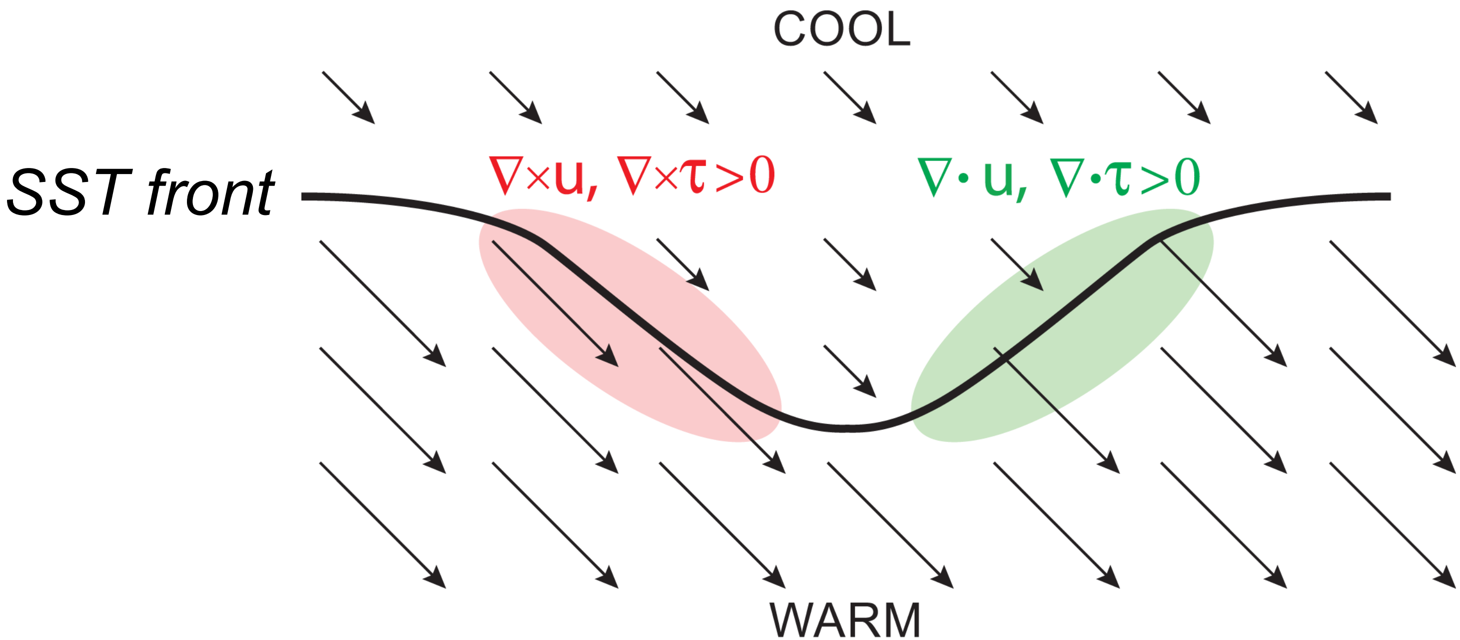
5. Comparison with coupling coefficients for January-December 2008 monthly averages from QuikSCAT and ASCAT-a.

Equivalent Neutral Wind Speed Response to SST Anomalies

June 2002 - May 2009 Averages



SST Effects on the Curl and Divergence of Surface Wind and Stress

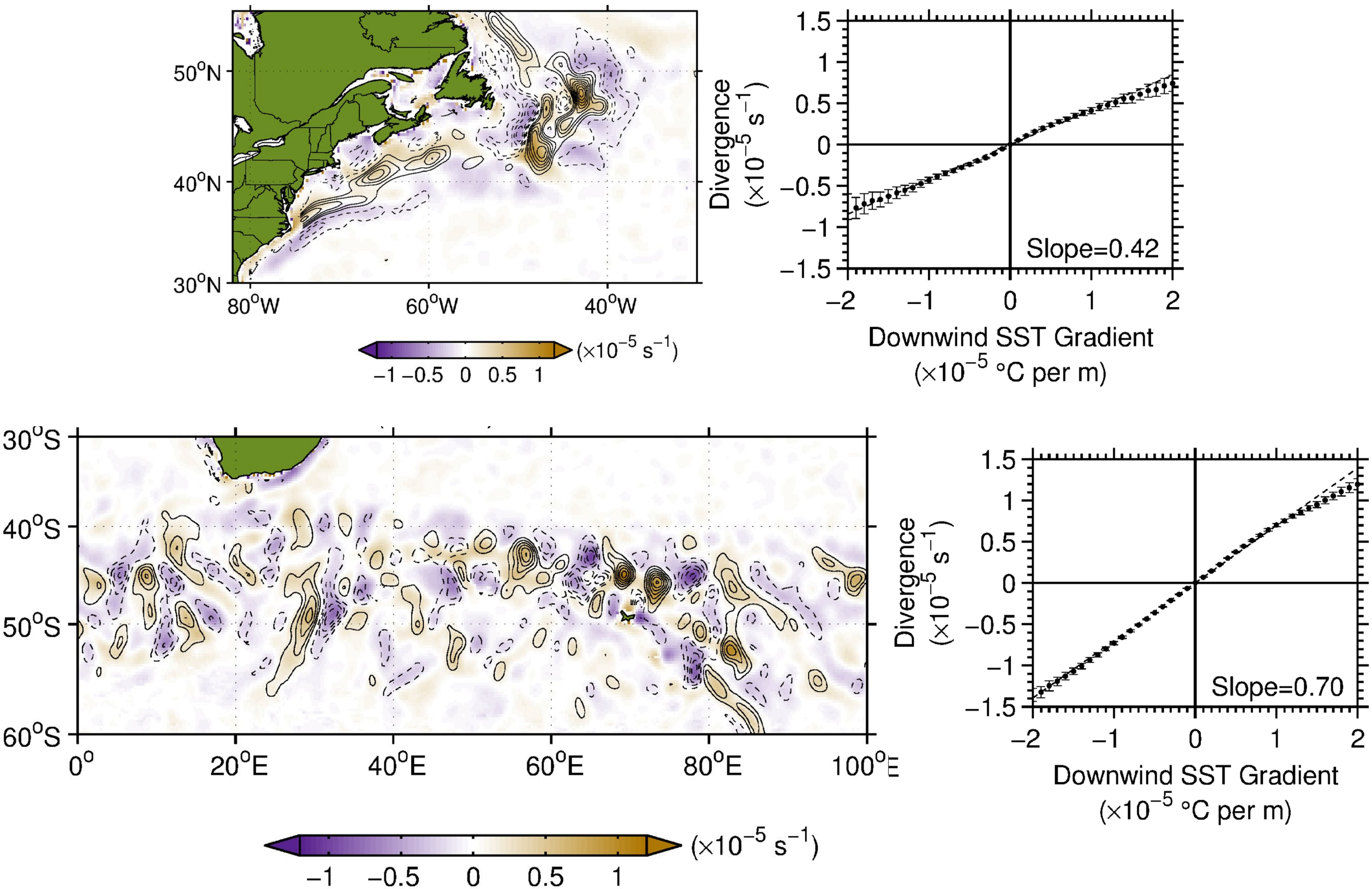


Wind vorticity and curl of the wind stress associated with crosswind SST gradients

Wind divergence and wind stress divergence associated with downwind SST gradients

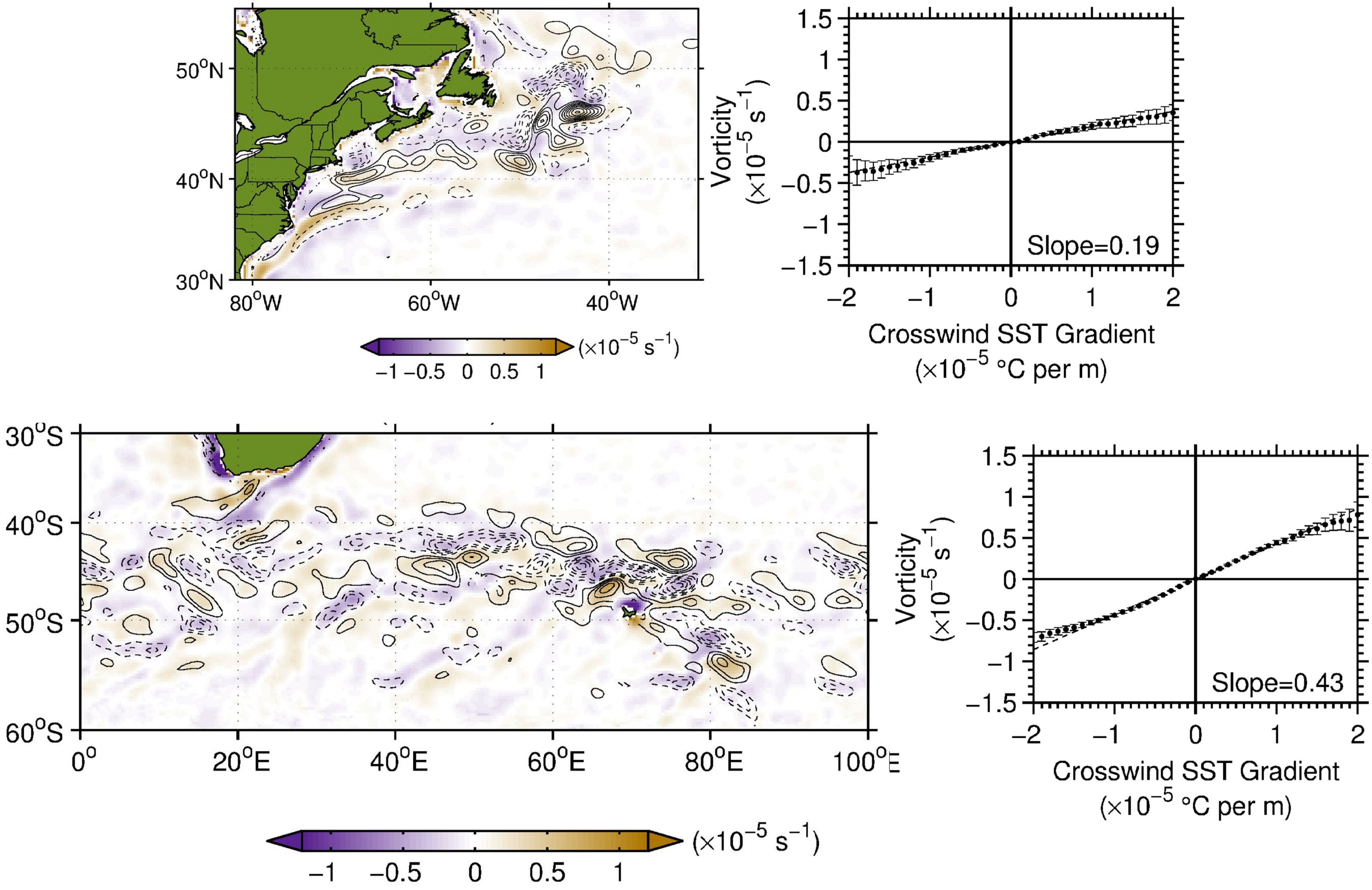
Equivalent Neutral Wind Divergence Response to Downwind SST Gradients

June 2002 - May 2009 Averages

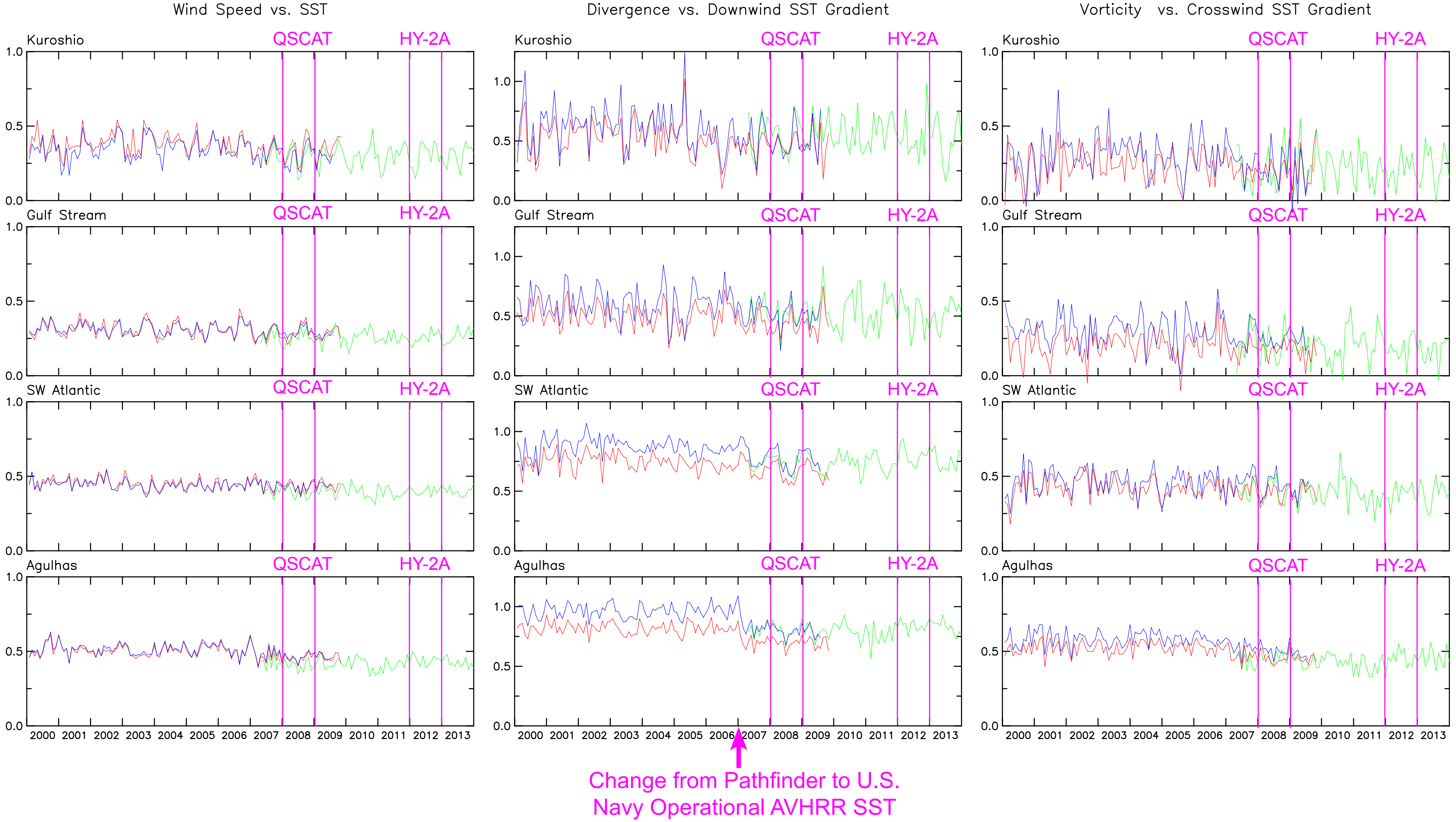


Equivalent Neutral Wind Vorticity Response to Crosswind SST Gradients

June 2002 - May 2009 Averages



Coupling Coefficients for Wind Speed, Divergence and Vorticity
Historical Context from Calendar Years 2000-2013
JPL QuikSCAT, RSS QuikSCAT and ASCAT-a



- *The coupling coefficients for all three variables are quite stable and generally similar for all three datasets.*
- *Exceptions: 1) abrupt drop in divergence in SW Atlantic and ARC in January 2007; 2) RSS QuikSCAT is biased low for divergence and vorticity; 3) some minor trends; 4) some seasonal variability.*

Parameters of HY2-SCAT and QuikSCAT

	HY2-SCAT	QuikSCAT
Transmit power P_t/ W	120	110
Antenna gain/ dB	38	Inner beam：38.5 Outer beam：39
Wavelength, λ/ m	0.022 616	0.022 385
Transmit pulse width T_r/ ms	2.1	1.7
Instrument loss L_f/ dB	7	3.6
Repetition bandwidth/ MHz	1	0.375
Noise bandwidth/ MHz	2	1
Polarization	HH at Inner beam, VV at outer beam	HH at Inner beam, VV at outer beam
Incidence angle	Inner beam : 41º, Outer beam :48º	Inner beam：46º Outer beam：54º
Swath/ km	Inner beam：1 350 Outer beam：1 700	Inner beam：1 400 Outer beam：1 800

HY-2A scatterometer winds

- HY-2A satellite was launched on August 16, 2011.

- On-orbit testing phase was completed on December 31, 2011 for all three payloads (scatterometer, radiometer, and altimeter).

- V1 HY-2A wind product (L2B) was released in January 2012 (operational).

- V2 HY-2A wind product was released in February 2014 (operational).

- V3 HY-2A was released in May 2014.

HY-2A wind retrieval algorithms

V1: NSCAT-2 based wind retrievals

- The design of the HY-2A scatterometer is similar to that of QuikSCAT.

- However, due to the different incidence angles from QuikSCAT, the geophysical model function (GMF) used in the HY-2A wind retrievals is NSCAT-2.

- V1 HY-2A winds are retrieved through finding maxima of objective function and then applying a median number filter algorithm to find the best estimate of wind vector.

V2: NWP initialization of ambiguity removal procedure

- The baseline ambiguity removal algorithm for HY-2A incorporates the NCEP operational wind products.

- In this “nudging” technique, a median filter algorithm is initialized with either the first or the second ranked wind vector solution, whichever is closer to the direction of the NCEP wind.

- The median filter algorithm then proceeds to generate the final wind vector selections.

V3: Using HY-2A radiometer to flag rain wind vector cell

- The design of the HY-2A radiometer is similar to that of AMSR-E

- The collocated HY-2A radiometer measurements of cloud liquid water (CLW) are used to flag rain-contaminated wind vector cells.

- The threshold of CLW for a rain-contaminated wind vector cell is 0.18 kg/m^2.

V2 and V3 HY-2A winds accuracy (NDBC buoys)

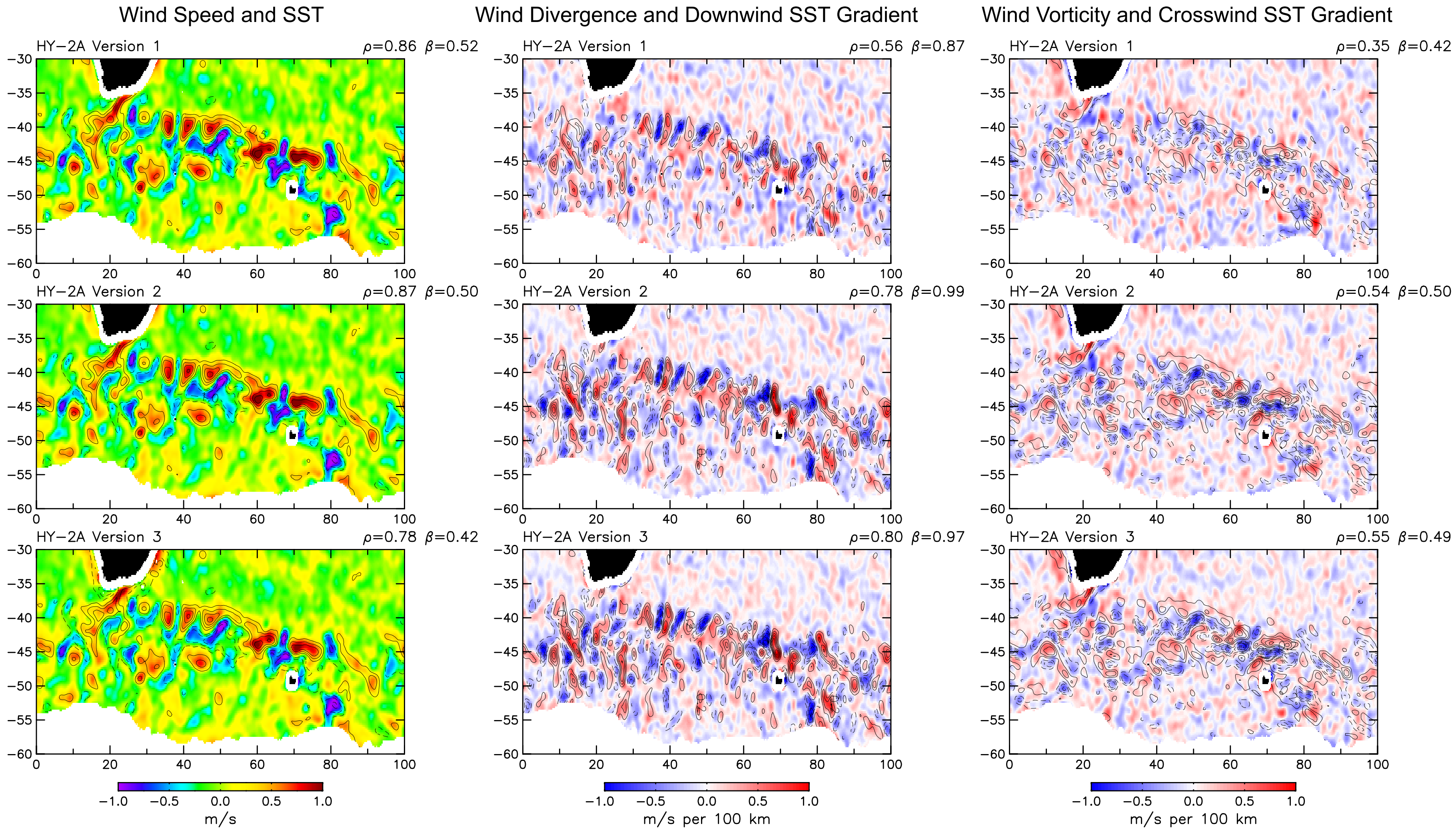
Time	Wind direction				Wind speed			
	V2		V3		V2		V3	
	RMS	Bias	RMS	Bias	RMS	Bias	RMS	Bias
2012, Jan-Jun	35.990	1.229	30.572	1.090	1.351	0.024	1.028	-0.087
2012, Jul-Dec	36.521	0.797	31.691	1.382	1.739	0.065	1.415	-0.056

Summary of the Data Processing for Investigation of Air-Sea Interaction from HY-2A Scatterometer Data

1. In-swath equivalent neutral wind vectors were smoothed onto a 0.25° grid using a 2-d loess smoother with a 75-km half-power filter cutoff.
2. Wind divergence and vorticity were computed from these gridded wind vectors with derivatives computed by centered differences.
3. For each HY-2A dataset (V1, V2 and V3), wind speed, divergence and vorticity were monthly averaged on a 0.25° grid in 4 regions: Kuroshio, Gulf Stream, SW Atlantic and Agulhas Return Current.
4. The Reynolds Daily OI SST fields constructed from AVHRR data only were monthly averaged for the same 4 regions.
5. All of the wind and SST fields were spatially high-pass filtered with half-power cutoffs of 20° x 10°.
6. The resulting wind and SST fields were spatially low-pass filtered with half-power cutoffs of 2° x 2°.

Annual Average Maps of Wind Speed, Divergence and Vorticity with Contours of SST, Downwind SST Gradient and Crosswind SST Gradient

Agulhas Return Current Region, Calendar Year 2012

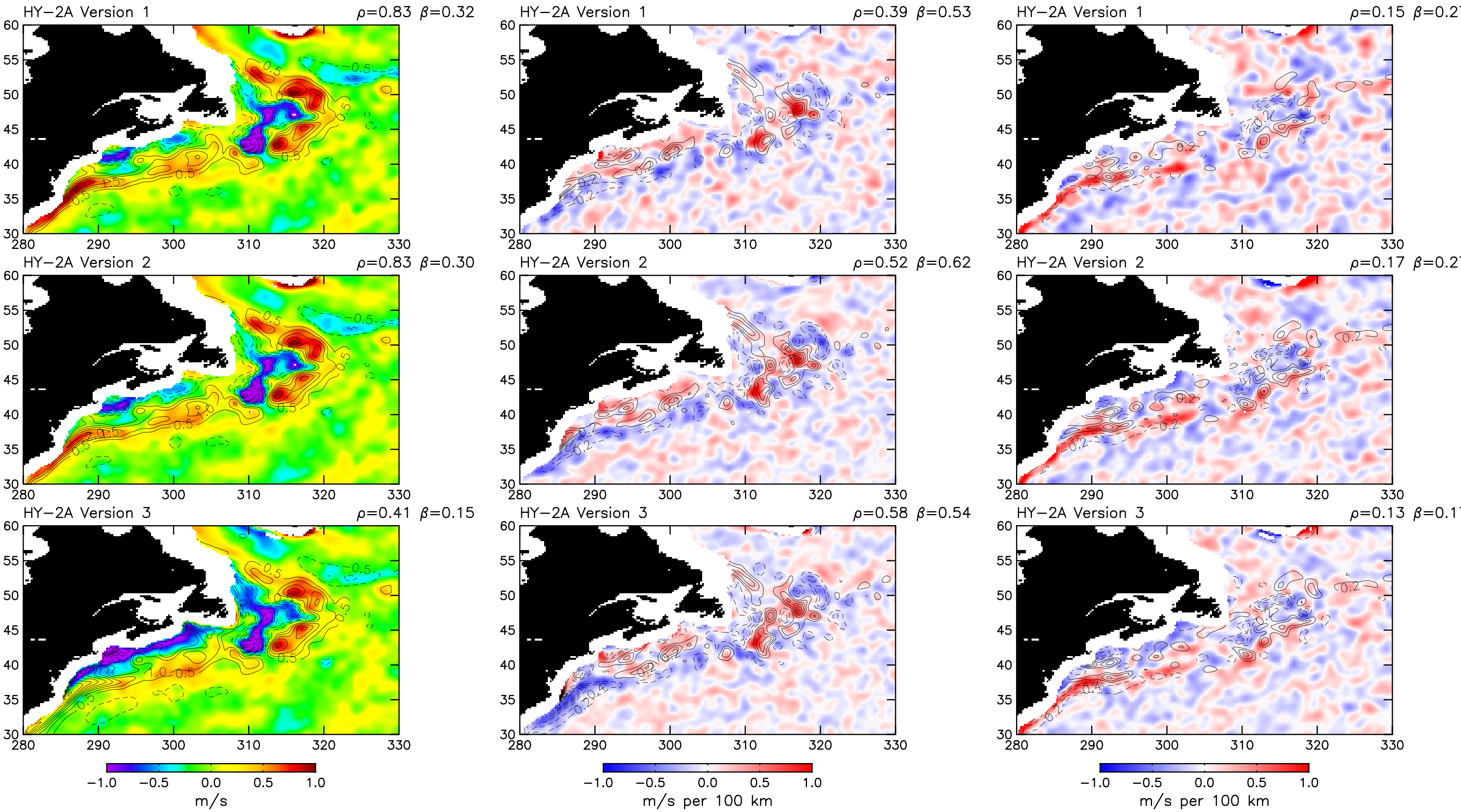


- *The lower correlation for wind speed in V3 <u>may indicate a problem with the rain flagging</u>.*
- *The lower correlations for wind divergence and vorticity in V1 indicates <u>better wind direction accuracy in V2 and V3</u>.*

Annual Average Maps of Wind Speed, Divergence and Vorticity with Contours of SST, Downwind SST Gradient and Crosswind SST Gradient

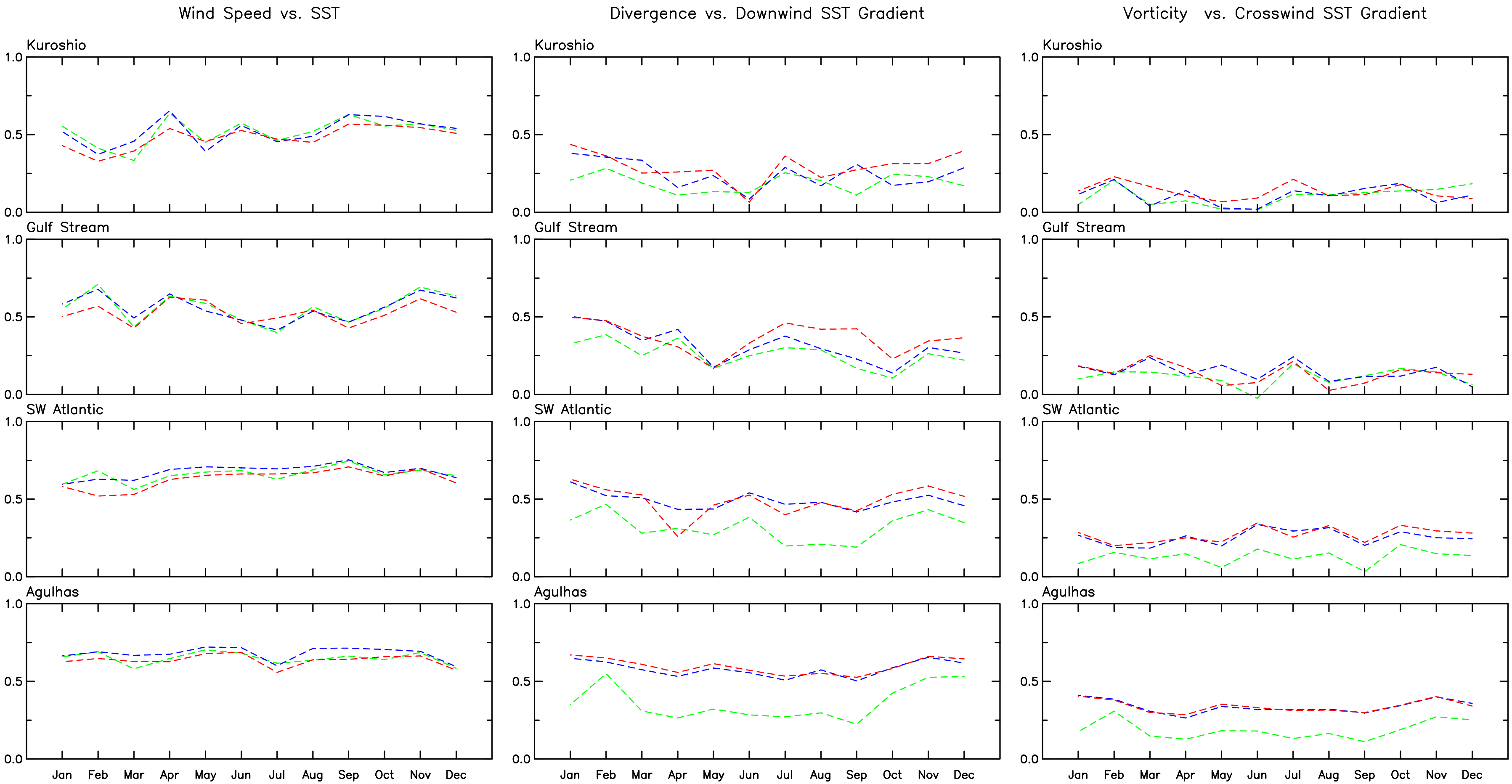
Gulf Stream Region, Calendar Year 2012

Wind Speed and SST | Wind Divergence and Downwind SST Gradient | Wind Vorticity and Crosswind SST Gradient



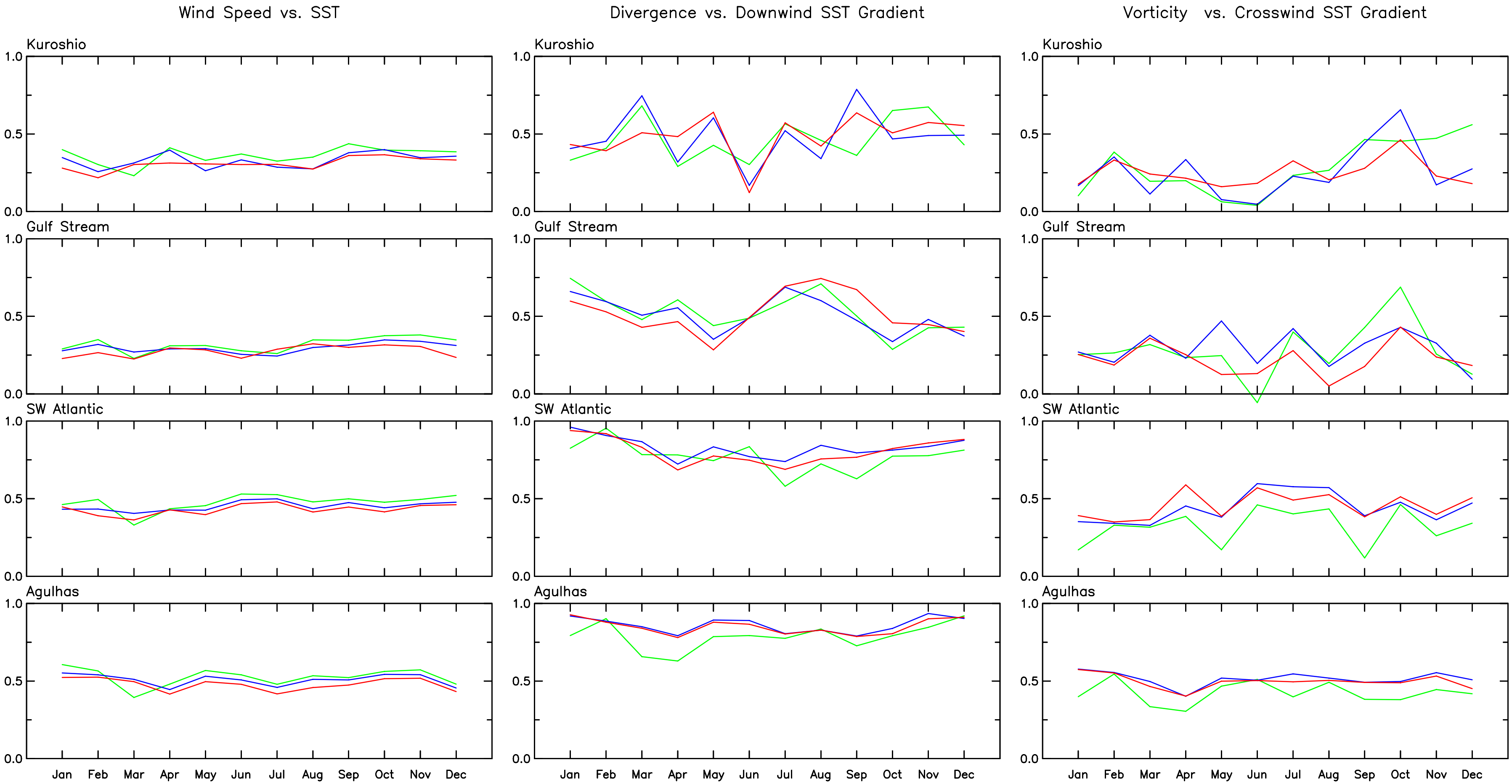
- *The lower correlation for wind speed in V3 <u>may again indicate a problem with the rain flagging</u>.*
- *The lower correlations for wind divergence in V1 indicates <u>better wind direction accuracy in V2 and V3</u>.*
- *Wind vorticity is difficult to judge in the Gulf Stream region because of the effect of the strong currents on the relative wind.*

Cross Correlations for Wind Speed, Divergence and Vorticity
Calendar Year 2012
HY-2A Version 1, Version 2 and Version 3



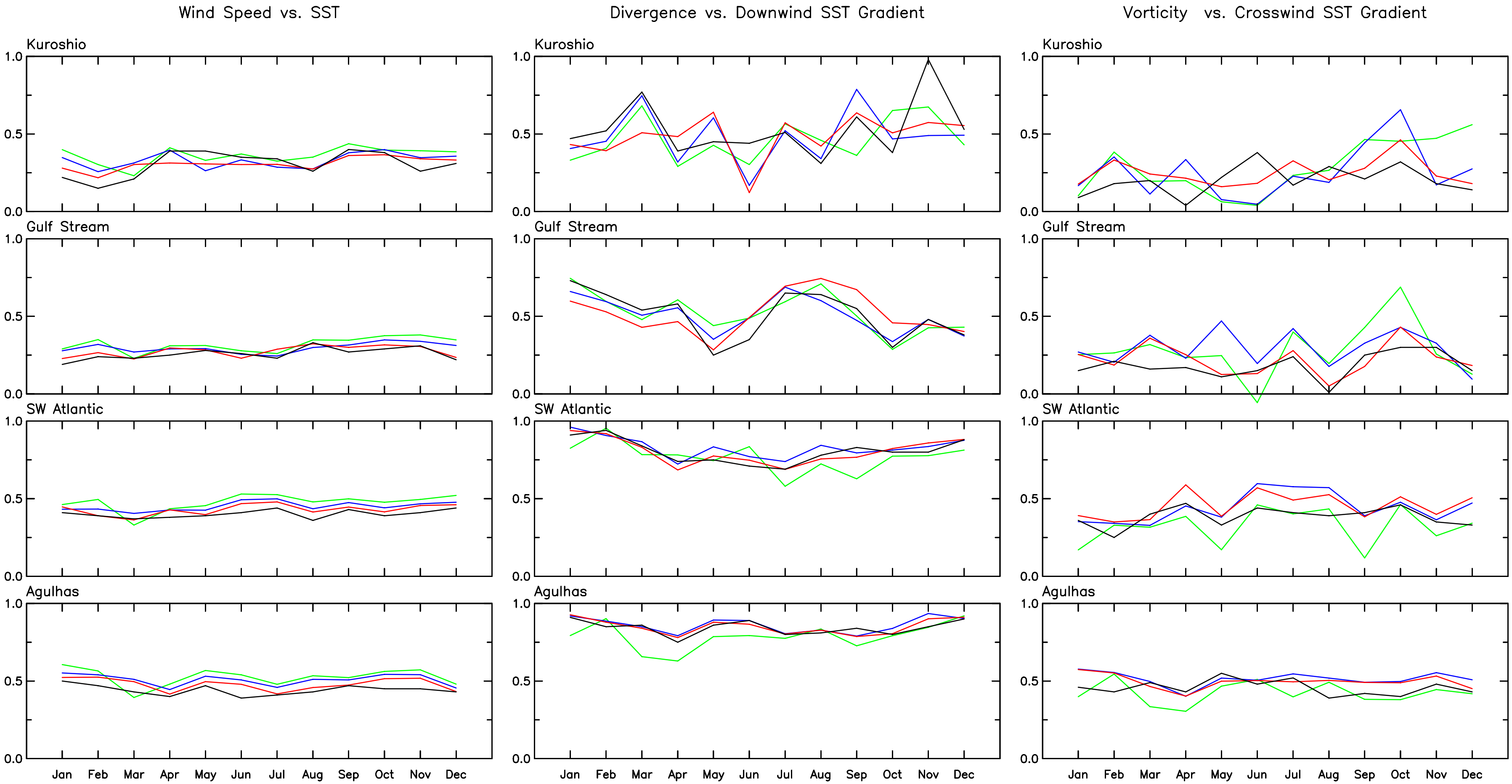
- *The correlations between the wind wind speed and SST are similar for all three versions of HY-2A data.*
- *The correlations between wind divergence and downwind SST gradient, and between vorticity and cross-wind SST gradient are lower for V1 than for V2 and V3, especially for the SW Atlantic and Agulhas Return Current regions => <u>better wind direction accuracy in V2 and V3</u>.*

Coupling Coefficients for Wind Speed, Divergence and Vorticity
Calendar Year 2012
HY-2A Version 1, Version 2 and Version 3



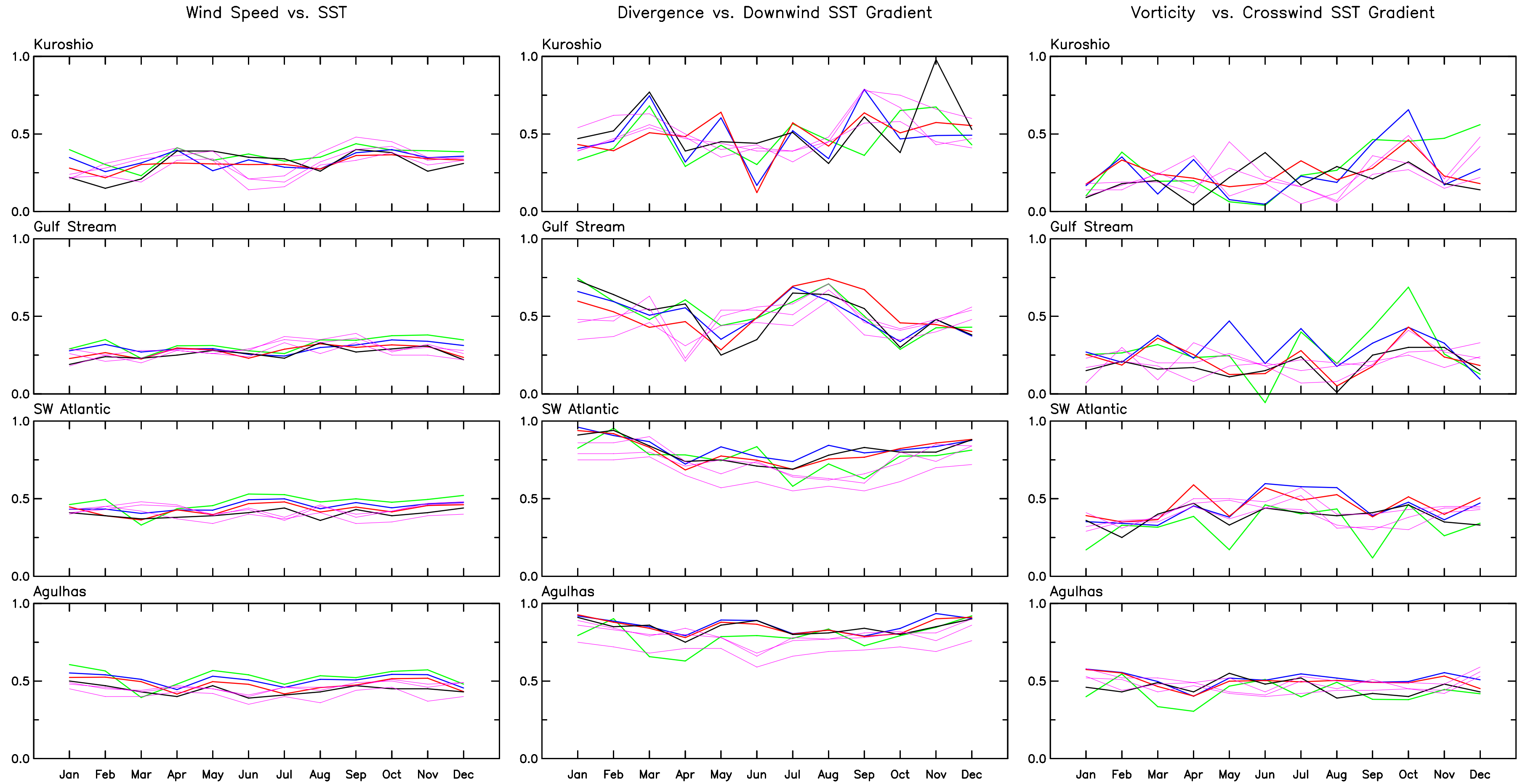
- *V2 and V3 are more similar to each other than either is to V1, again indicating better wind direction accuracy in V3.*
- *The differences between the coupling coefficients are largest in the Kuroshio and Gulf Stream regions.*

Coupling Coefficients for Wind Speed, Divergence and Vorticity
Calendar Year 2012
HY-2A Version 1, Version 2, Version 3 and ASCAT-A



- *The HY-2A coupling coefficients are consistent with the ASCAT-A coupling coefficients.*
- *The differences are again largest in the Kuroshio and Gulf Stream regions.*

Coupling Coefficients for Wind Speed, Divergence and Vorticity
Calendar Year 2012
HY-2A Version 1, Version 2, Version 3 and ASCAT-A
Calendar Year 2008 JPL QuikSCAT, RSS QuikSCAT and ASCAT-a



- *The HY-2A and ASCAT-A coupling coefficients are consistent with historical values for 2008 from Quik-SCAT and ASCAT-A.*
- *The variability is again largest in the Kuroshio and Gulf Stream regions.*

Summary and Conclusions

1. SST influence on the surface wind field is clearly evident in all 3 versions of HY-2A data for the January-December 2012 period analyzed here.
   - *The coupling coefficients are consistent with the values obtained from ASCAT-a for the same time period.*
   - *The results are also consistent with the coupling coefficients obtained from QuikSCAT for January-December 2008.*
2. Comparisons of V1, V2 and V3:
   - *Wind direction errors are significantly reduced in V2 and V3, as evidenced from the wind divergence and vorticity fields.*
   - *Improvements of V3 compared with V2 do not significantly improve the analysis of air-sea interaction from monthly averages presented here.*
3. Close inspection of various aspects of the wind fields suggests that we may not be interpreting the rain flagging correctly in V3.
   - *For example, this may explain the curious lower correlation between wind speed and SST in the annual averages from the V3 data.*
4. An important point to note is that the analysis of monthly averages presented here is somewhat less demanding of wind speed and direction accuracy than are many other applications of scatterometer data.