Decadal time series of ocean surface vector wind fields

Accuracy, Consistency, and New Insights of the OAFlux Ocean Vector Wind Analysis (1987 – present)

Lisan Yu

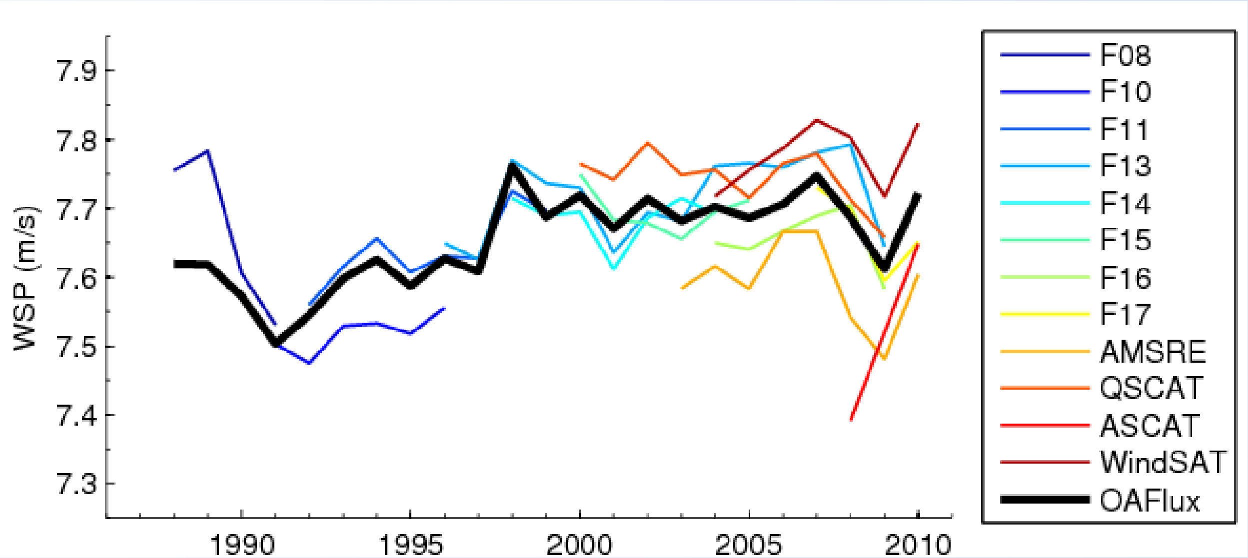
Woods Hole Oceanographic Institution

with programming support from Dr. Xiangze Jin

International Ocean Vector Winds Science Team meeting
Utrecht, Netherlands, June 12-14, 2012

OAFlux (Objectively Analyzed air-sea Fluxes)

Daily, 0.25° Ocean Vector Wind Analysis (1987-present)



We thank Remote Sensing Systems for providing

- AMSRE version 7
- SSMI version 6
- SSMIS version 7
- WindSat version 7
- QuikSCAT version 4

We thank JPL PO.DAAC for providing

- ASCAT version 3

Main issues:

1. How is the OAFlux vector wind analysis constructed?
2. Is the time series consistent across the various periods?
3. What accuracy can be achieved by the OAFlux synthesis?
4. What new insights does the OAFlux time series provide?
5. How have global surface wind fields been changing?

Construction of the OAFlux Ocean Vector Wind Analysis

Methodology and Strategy

- Formulate a linear-squares estimator based on the Guass-Markov theorem

$$F = \sum_k \alpha_k (u_{ana} - u_{o,k})^2 + \sum_k \alpha_k (v_{ana} - v_{o,k})^2 + \sum_m \beta_m (\sqrt{u_{ana}^2 + v_{ana}^2} - w_{o,m})^2 + Dyn(vort, div)$$

- Search the optimal solution through a variational minimization approach.

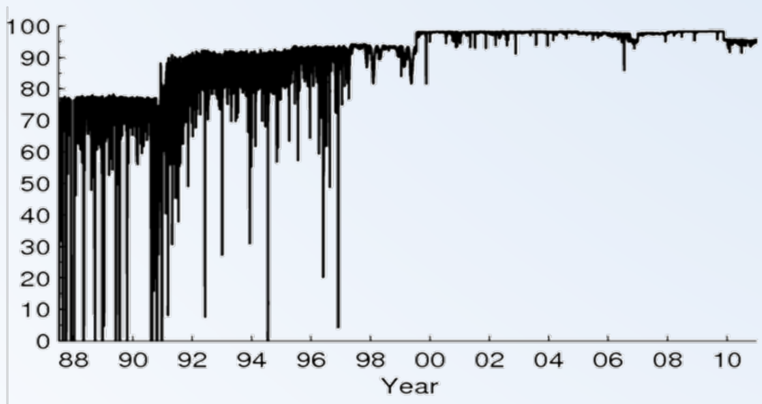
Role of ERAinterim:

- serve as initial guess for wind direction before QuikSCAT was available
- fill in gaps due to the lack of observations or to the removal of rain flagged data.

Daily resolution is chosen to ensure

- maximum satellite coverage on daily basis
- stability of the time series for climate analysis.

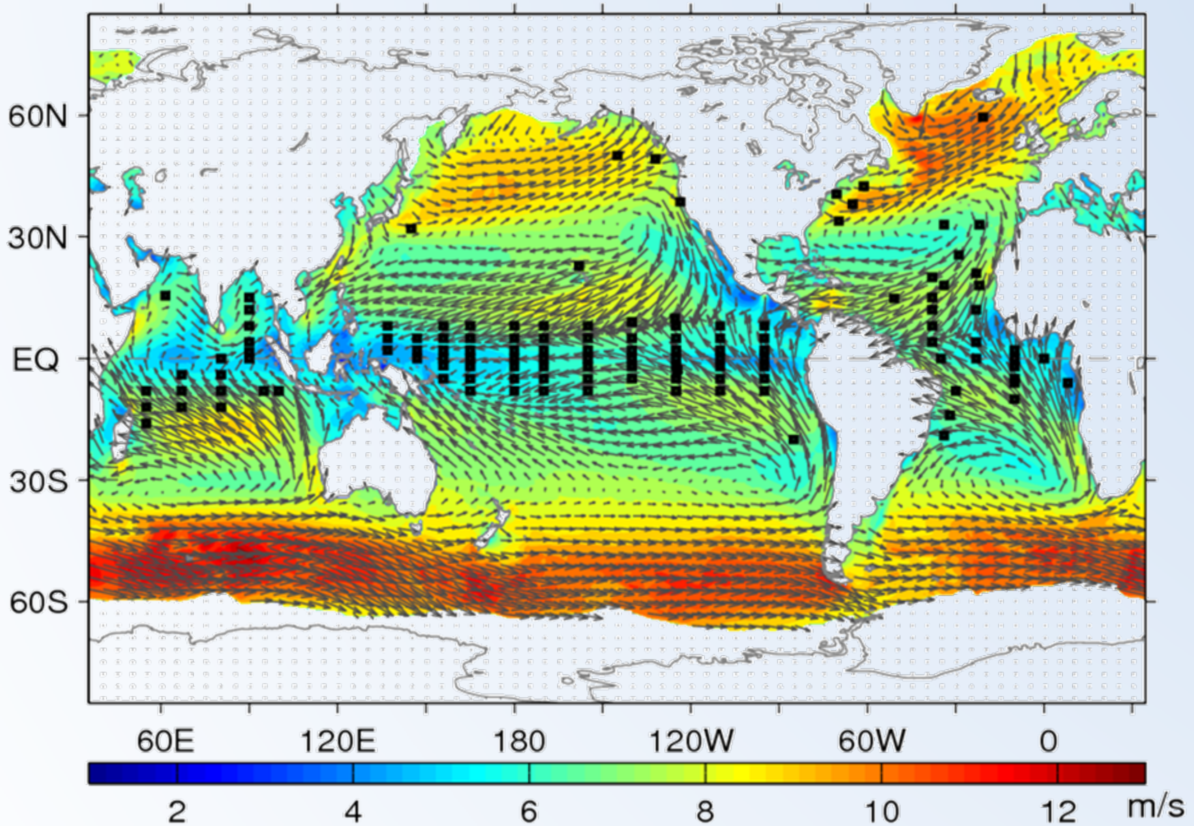
Percentage of daily coverage



Accuracy and consistency of the OAFlux winds:
A buoy perspective

Yu and Jin (2012)

126 buoy locations

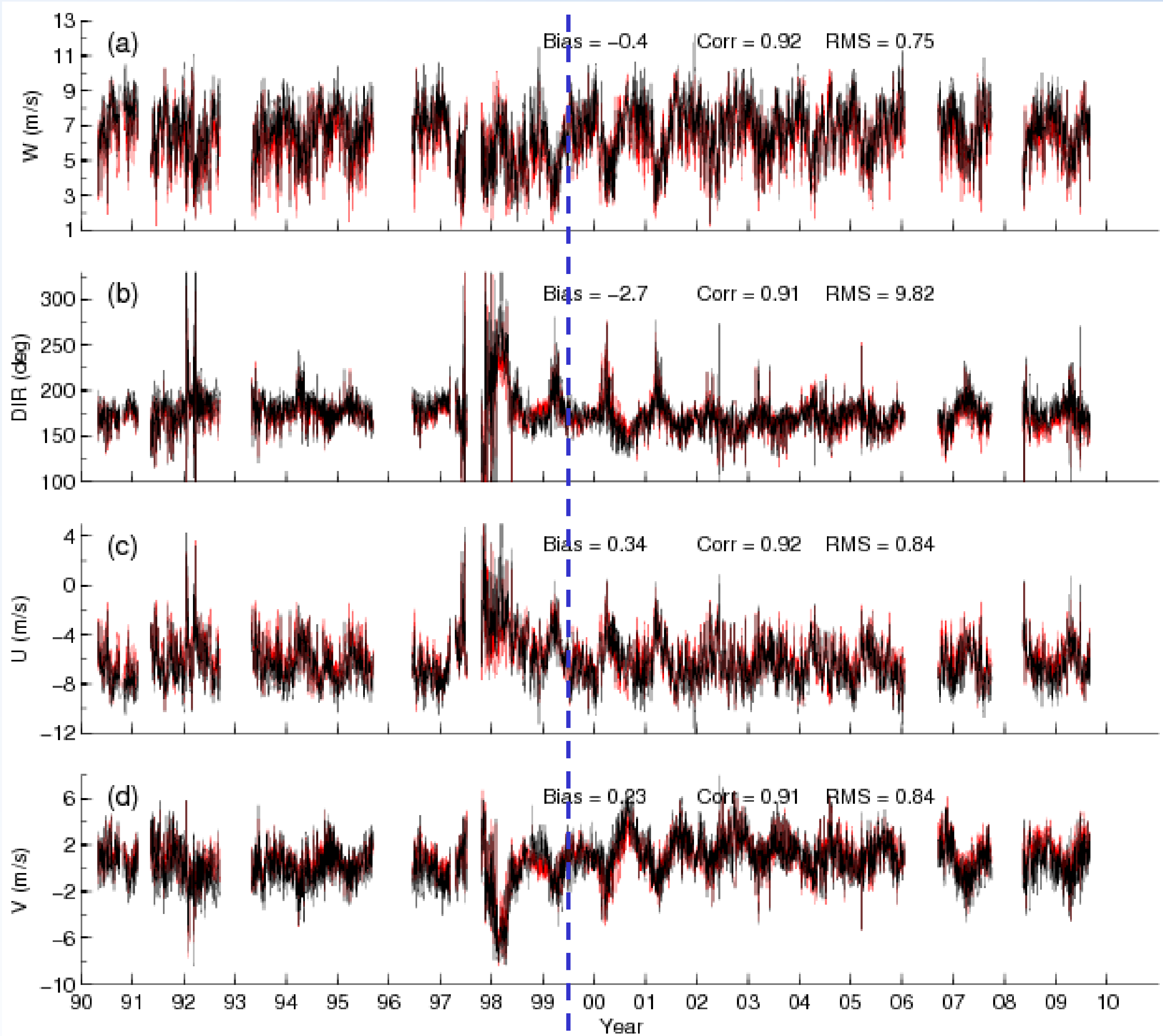


- A total of 168,836 daily values between 1988 and 2010
- The buoy winds are converted to equivalent neutral wind speed at a height of 10 m using the method by Liu and Tang (1996)

Buoy winds are NOT used in the OAFlux synthesis

Consistency

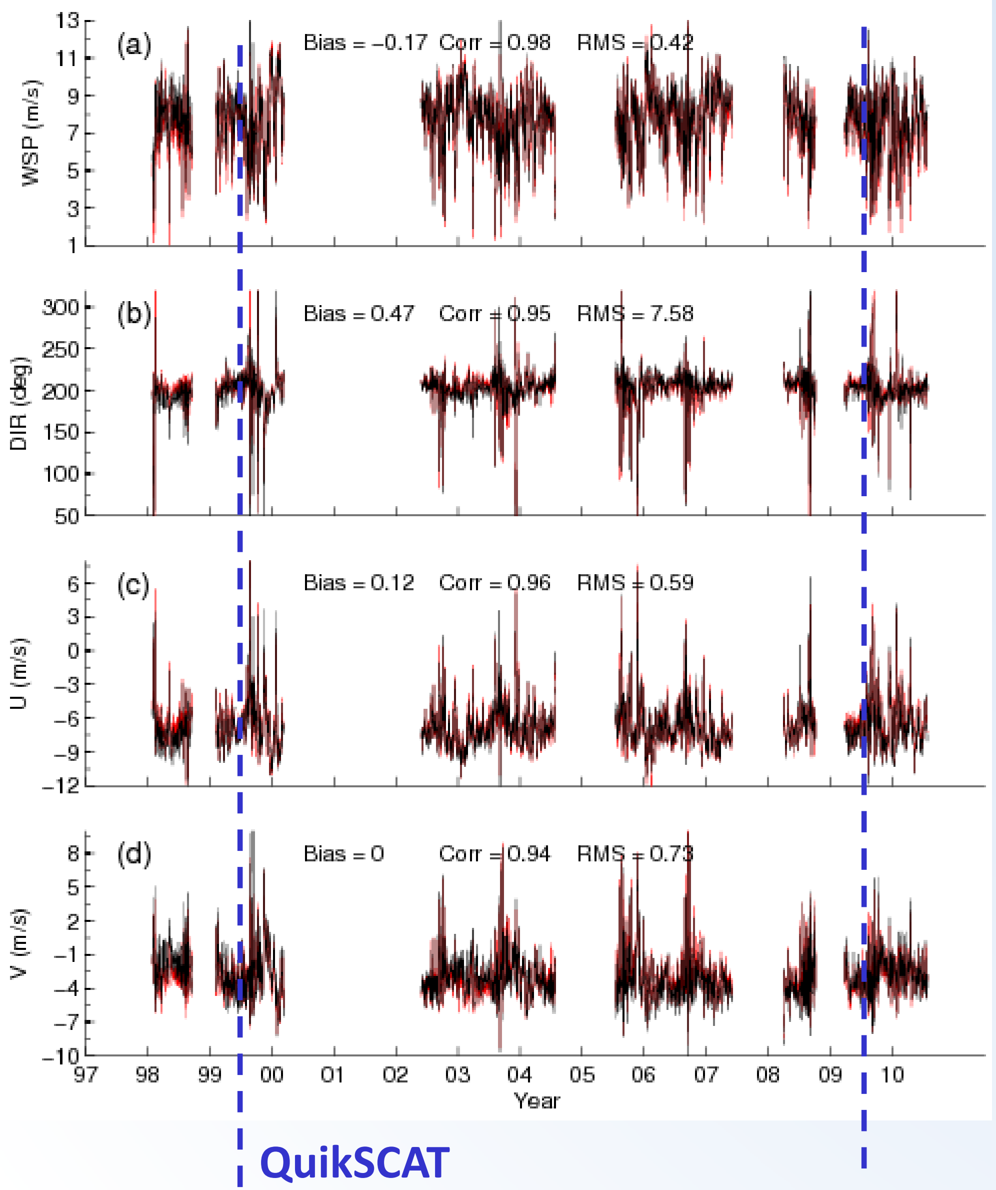
TAO Pacific (140W, EQ)



QuikSCAT

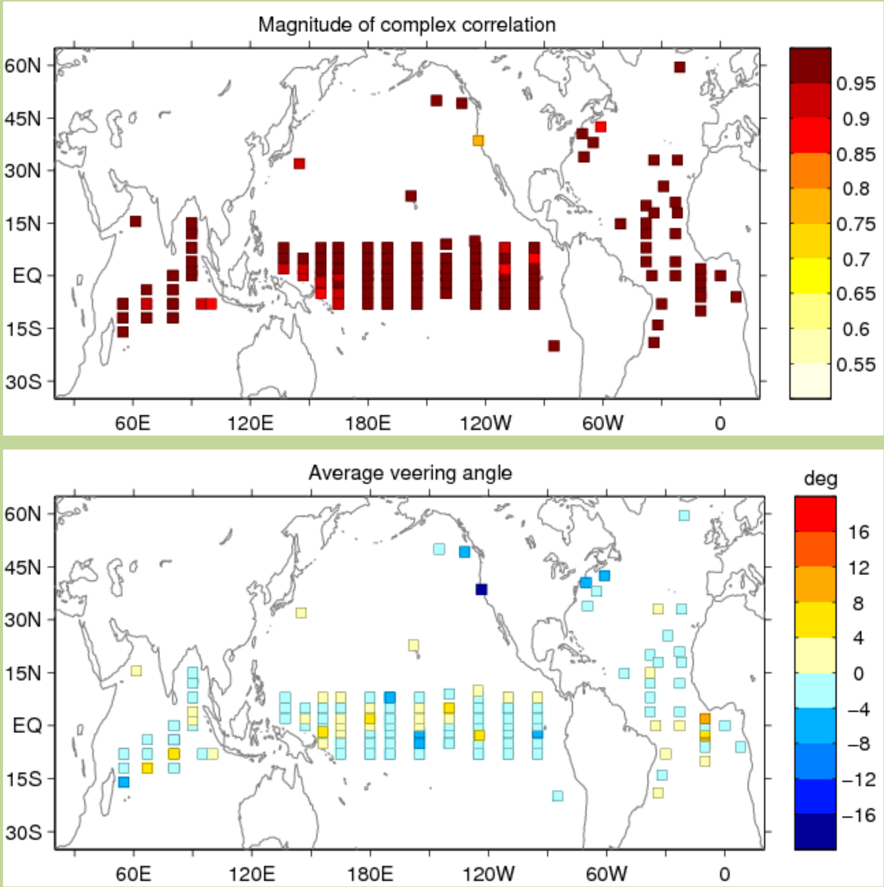
Consistency

Atlantic PIRATA (38W, 15N)



Vector Correlation

Buoy vs OAFlux winds at all locations 1988-2010



A complex correlation coefficient ρ is computed as

$$\rho(w_{OA}, w_b) = \frac{\langle w_{OA} * w_b \rangle}{\langle w_{OA} * w_{OA} \rangle^{1/2} \langle w_b * w_b \rangle^{1/2}}$$

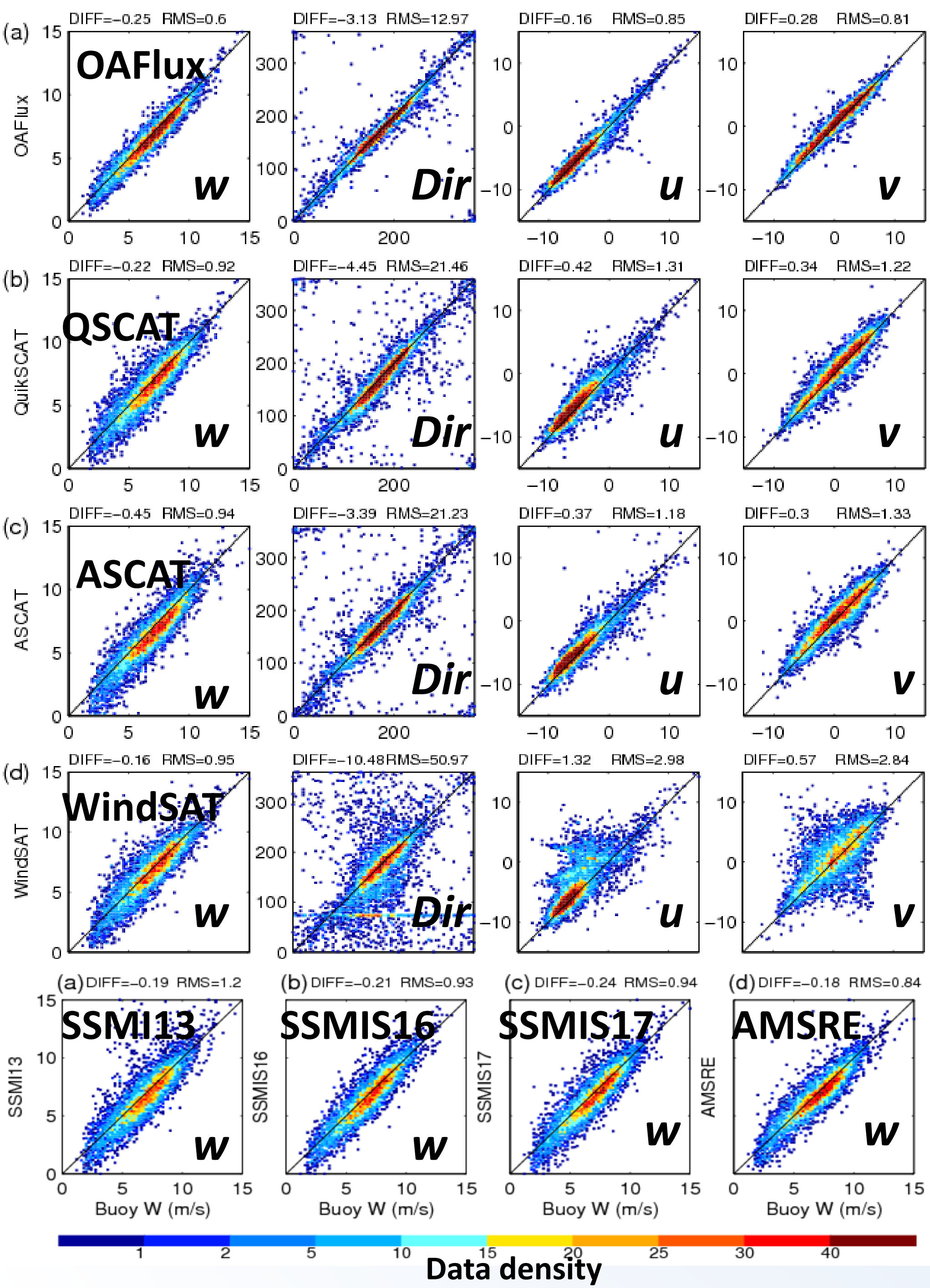
where $w_{OA} = u_{OA} + iv_{OA}$, $w_b = u_b + i\, v_b$.

The phase angle arg(ρ) is the veering angle, positive when OAFlux wind veers counterclockwise from buoy wind.

Accuracy estimate based on OAFlux/buoy comparison

Buoy instrument accuracy:
W: ± 0.3 (ms^{-1}); Dir: ± 5 - 7.8 (degree)

Variable	1988-1998: N= 10,880 2000-2010: N=152,239 1988-2010: N=168,866		
	Mean DIFF	RMS Error	Corr Coef (0-1)
W (ms^{-1})	-0.19 -0.13 -0.13	0.93 0.66 0.71	0.93 0.95 0.94
DIR (degree)	1.48 -0.90 -0.55	21.52 16.98 17.34	0.96 0.95 0.95
U (ms^{-1})	0.07 -0.01 0.00	1.40 1.03 1.09	0.96 0.96 0.96
V (ms^{-1})	-0.15 0.05 0.02	1.30 0.98 1.01	0.96 0.96 0.96



How much can a synthesis improve the accuracy of input satellite retrievals?

Theoretically, the error reduction is ~ 1/sqrt(N) when using N input sensors.

In reality, the covariances between N sensors are not zeros, because sensors are biased and errors are correlated.

For instance, the errors between QuikSCAT and SSMI 16 is 0.35.

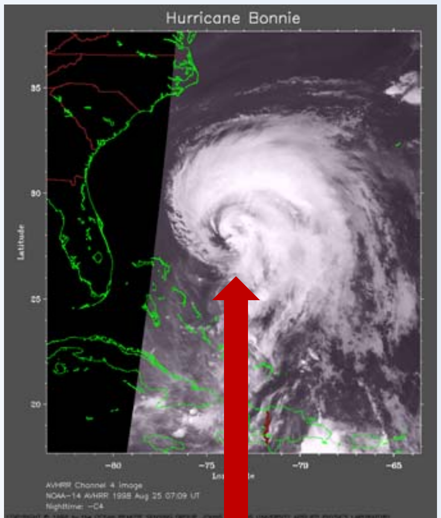
7660 collocations (2008-2009)

	w		
	DIFF (ms^{-1})	RMS (ms^{-1})	cc (0-1)
OAFlux	-0.25	**0.60**	**0.96**
QuikSCAT	-0.22	0.92	0.90
ASCAT	-0.45	0.94	0.92
WindSat	**-0.16**	0.95	0.89
SSMI F13	-0.19	1.20	0.85
SSMIS F16	-0.21	0.93	0.91
SSMIS F17	-0.24	0.94	0.91
Instrument Accuracy	± 0.3 ms^{-1}		

The theoretical number is ~0.36

Depiction of Synoptic Variability: OAFlux vs other products

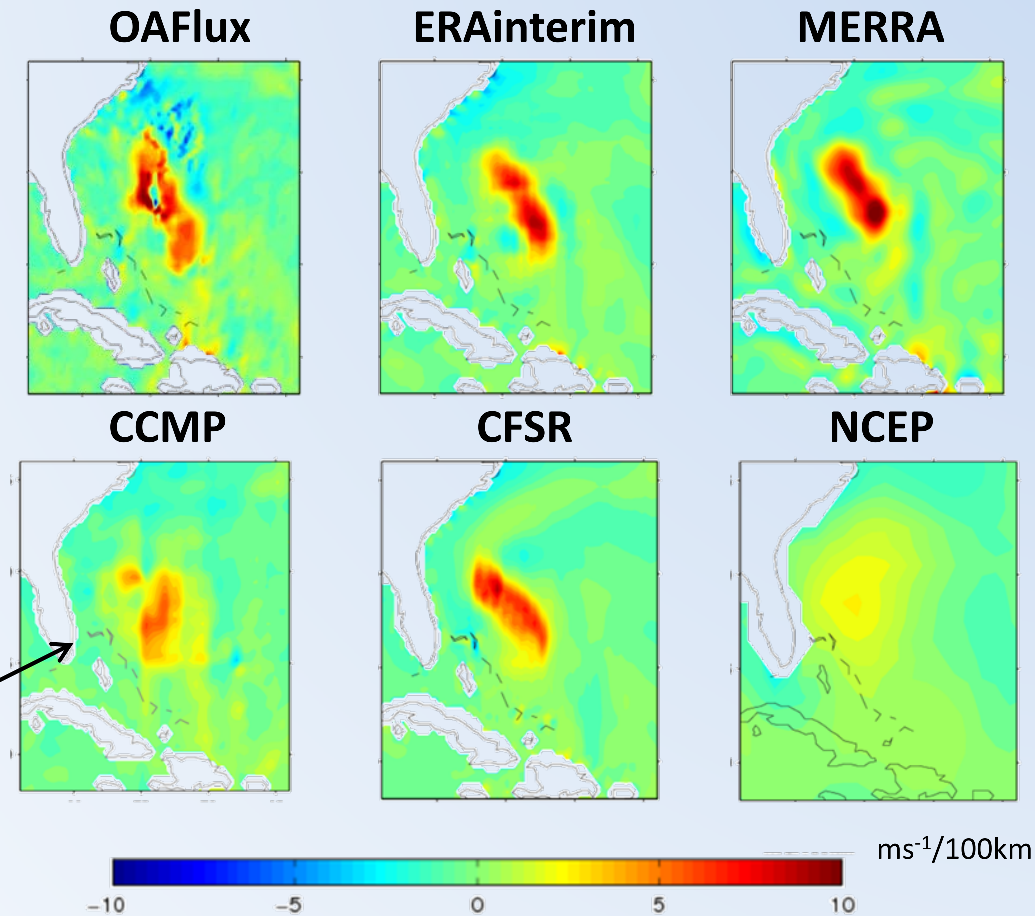
Hurricane Bonnie
25-August-1998
No scatterometer



The Storm's Eye

Atlas et al. (2011)

Surface Convergence: $\partial u/\partial x + \partial v/\partial y$



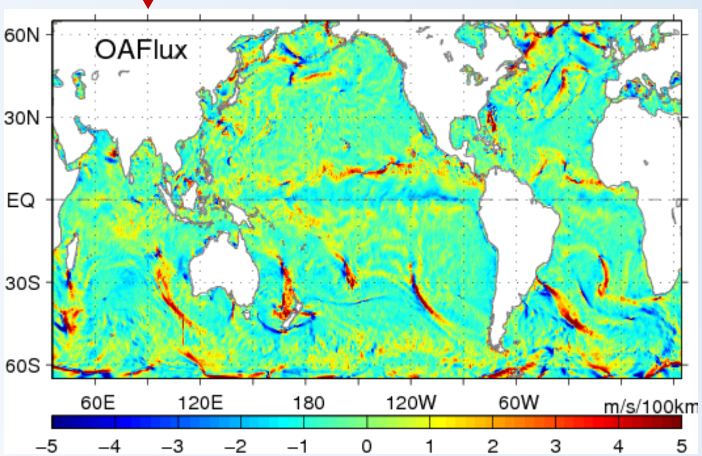
- OAFlux before 1999 is constructed from SSMI wind speed with wind direction from ERAinterim as initial guess.
- CCMP and OAFlux have similar cost function and similar minimization approach , but temporal resolution differs (6h vs daily) and the input sensors differ (CCMP has NSCAT, TMI, SeaWind2 but no ASCAT and SSMS16/17).

Daily wind convergence field: a global view

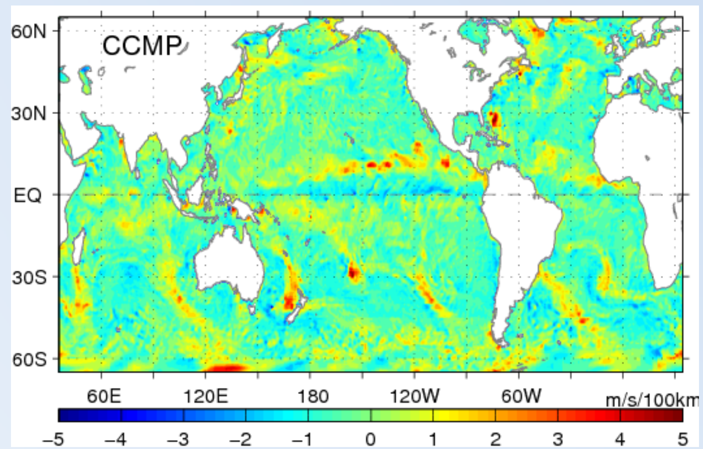
25-August-1998
(no scatterometer)

Couplets of convergence/divergence

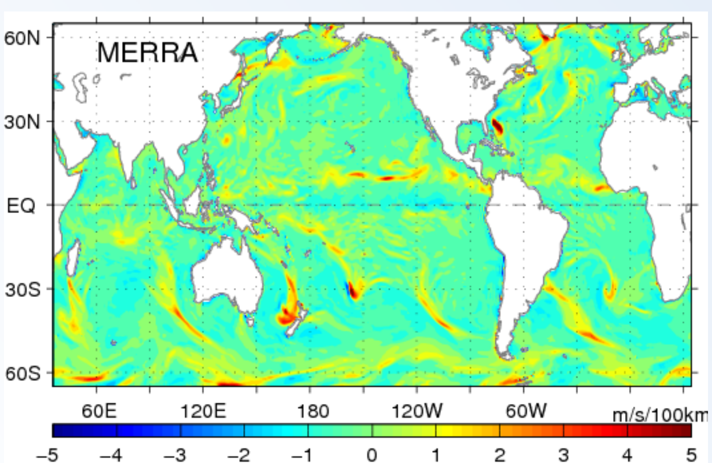
OAFlux



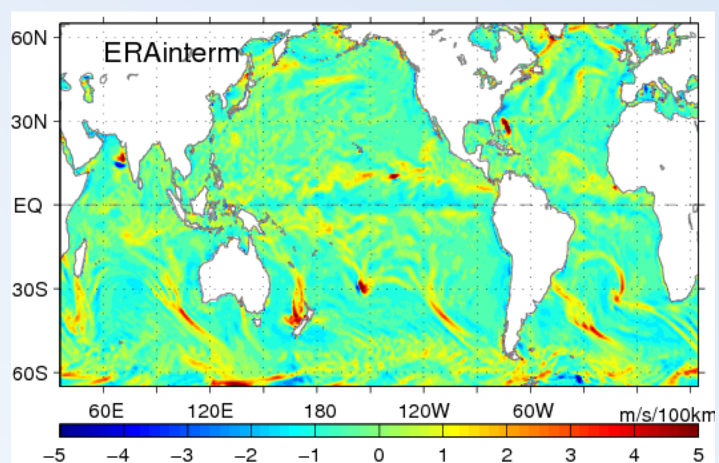
CCMP



MERRA



ERAinterim



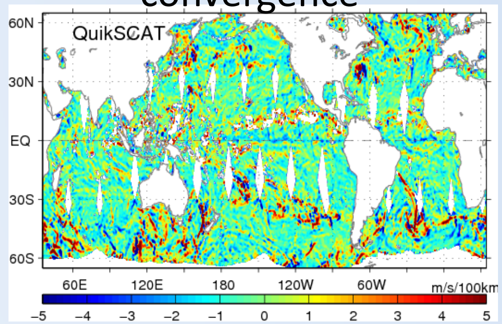
22 August 2009
(QSCAT and ASCAT are included)

Wind derivatives

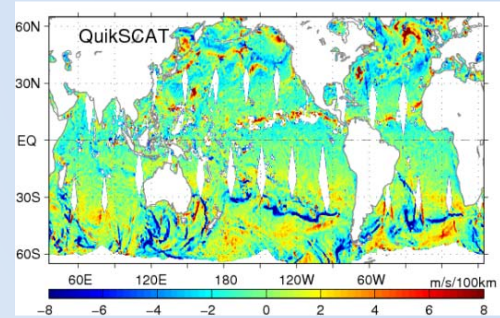
QSCAT and ASCAT are noisy.
Applied 1-2-1 smoothing three times.

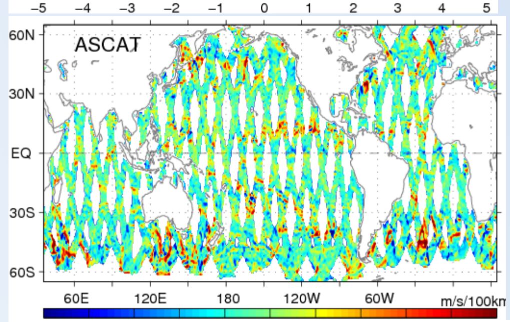
Convergence/divergence couplets become visible.

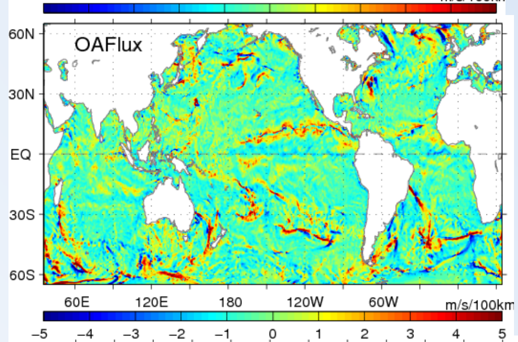
convergence



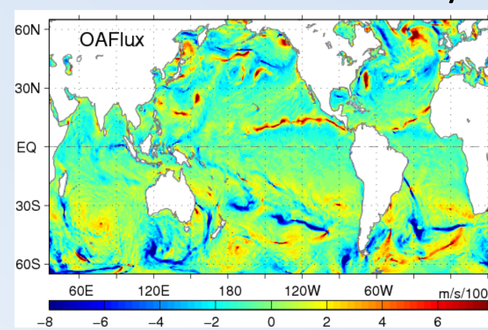
vorticity

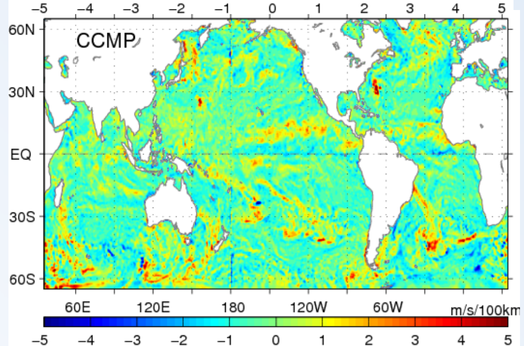






vorticity



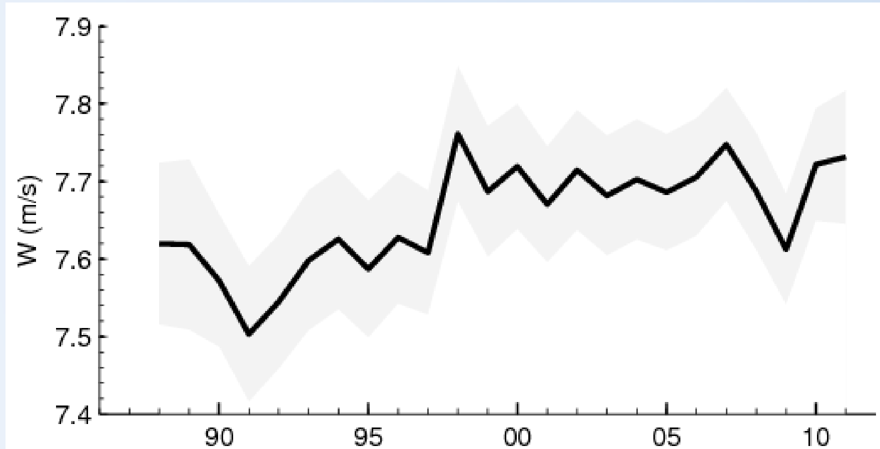


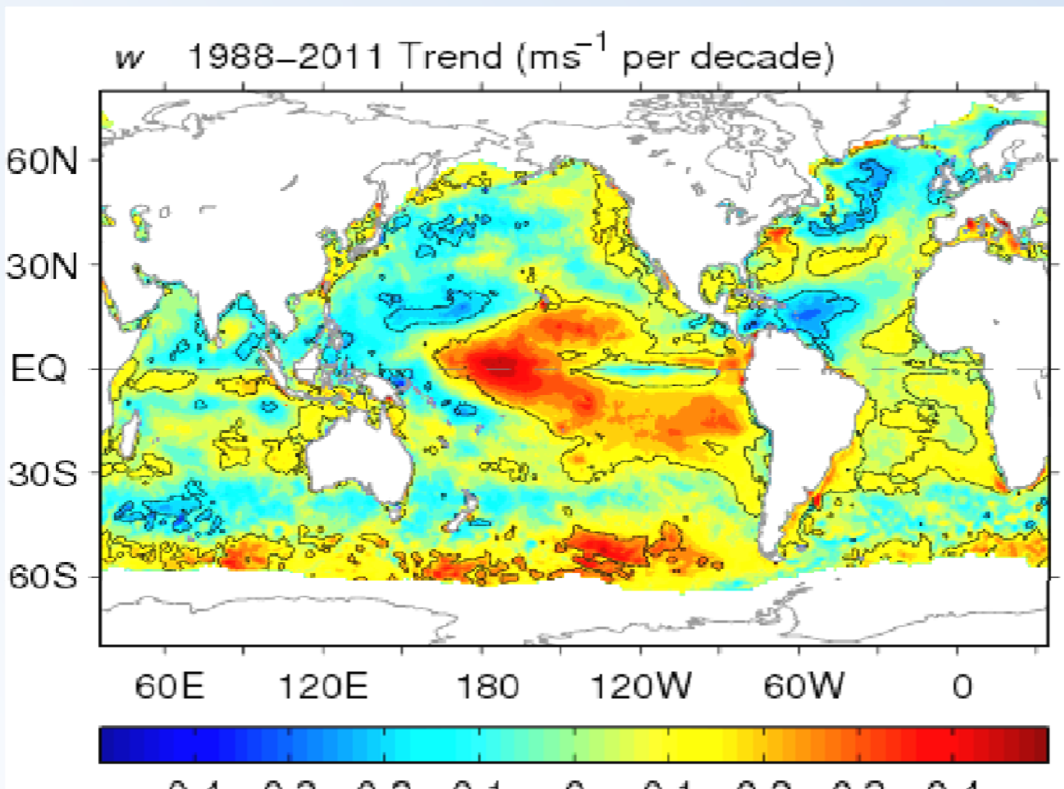
Comments:

OAFlux is able to extract the filamentary structures from multiple satellites, indicating that the signals are buried in noise.

➔The number of samples could be important for obtaining the desired fine-scale processes, even if the sensor is capable of measuring.

Decadal change in global ocean winds





Significant at 90% CI are highlighted

Summary and conclusions

In this presentation:

- A daily, 0.25° analysis of global ocean vector wind fields starting from 1987 is developed by OAFlux from synthesizing 12 passive and active sensors.
- The buoy evaluation obtains that OAFlux wind speed has an rms (mean) difference of 0.71 (-0.13) m/s and the wind direction has an rms (mean) difference of 17 (-0.55) degrees.
- OAFlux shows an improved depiction of the spatial structures associated with synoptic variability, offering a striking view of the convergence-divergence couplets over the open oceans.
- OAFlux winds have distinct decadal changes. Wind speed increased in the 1990s but remained flat in the 2000s.

In planning:

- Dissemination of OAFlux vector wind analysis is planned.
- Data sets being prepared include:
  (i) wind, (ii) wind stress, (iii) stress curl, (iv) wind convergence, and (v) vorticity

Future:

- The OAFlux synthesis framework is versatile and can include latest sensors such as OSCAT.