The 28+ Years of Ocean-Surface Vector Wind Analysis Merged from Scatterometers and Radiometers

- New insights into wind-ocean interaction on meso to planetary scales

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OAFlux (Objectively Analyzed air-sea Fluxes):

The project develops gridded ocean-surface flux products for climate and ocean studies.

Recent completion of three sets of high-resolution (HR) products:

(1) 10-m equivalent neutral vector winds merged from 15 sensors;

(2) 2-m air temperature and humidity retrieved from 11 sensors;

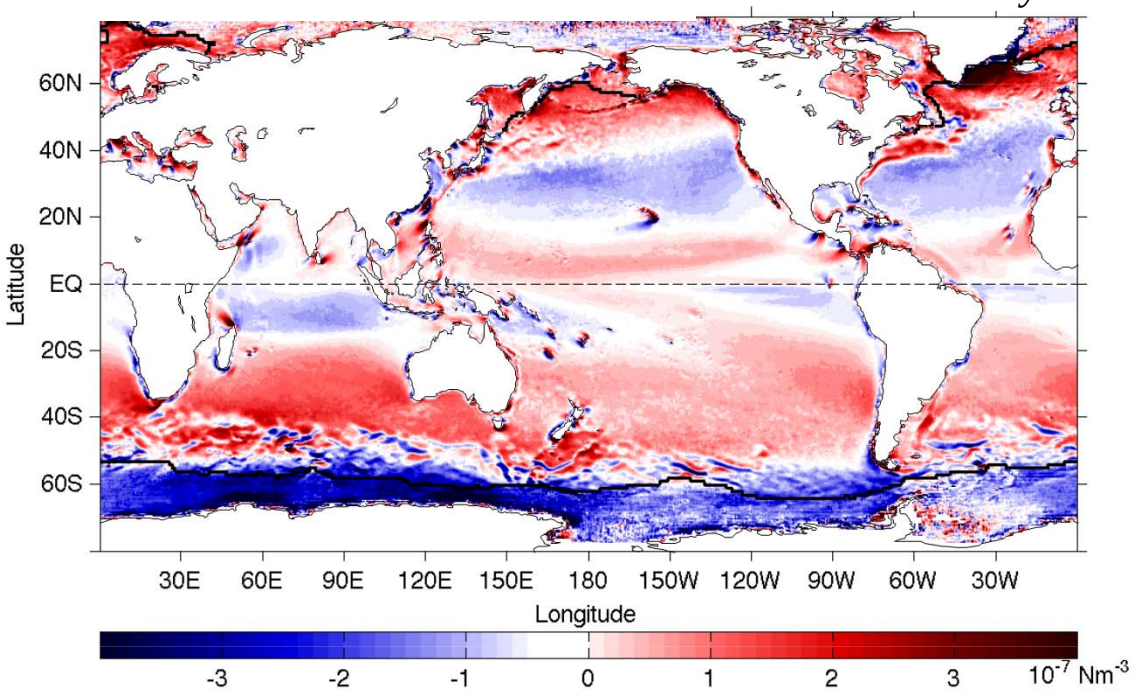
(3) Full suite of turbulent heat, moisture, and momentum fluxes computed from the COARE algorithm.

Resolution: daily and 0.25-degree grids from 1988 onward

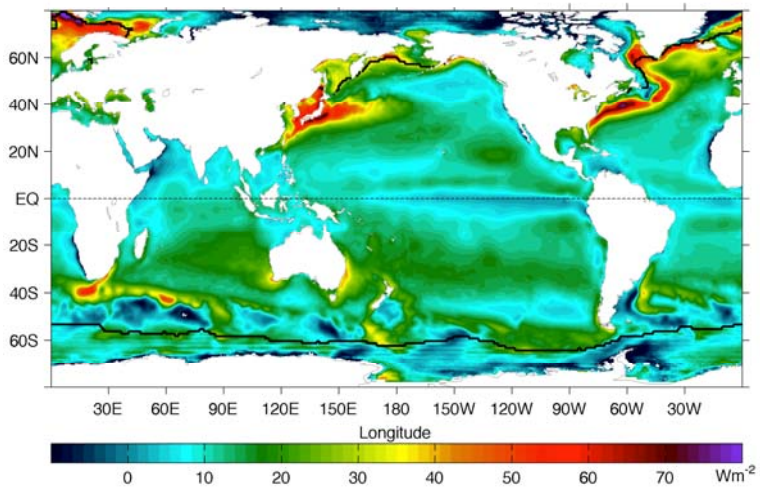
OAFlux–HR (1988-2015): 28-yr mean

Wind Stress Curl

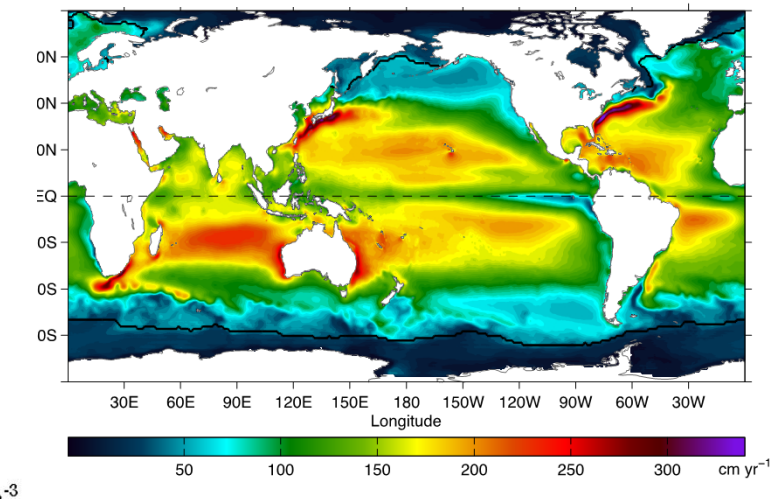
$$\nabla \times \tau = \frac{\partial \tau^y}{\partial x} - \frac{\partial \tau^x}{\partial y}$$



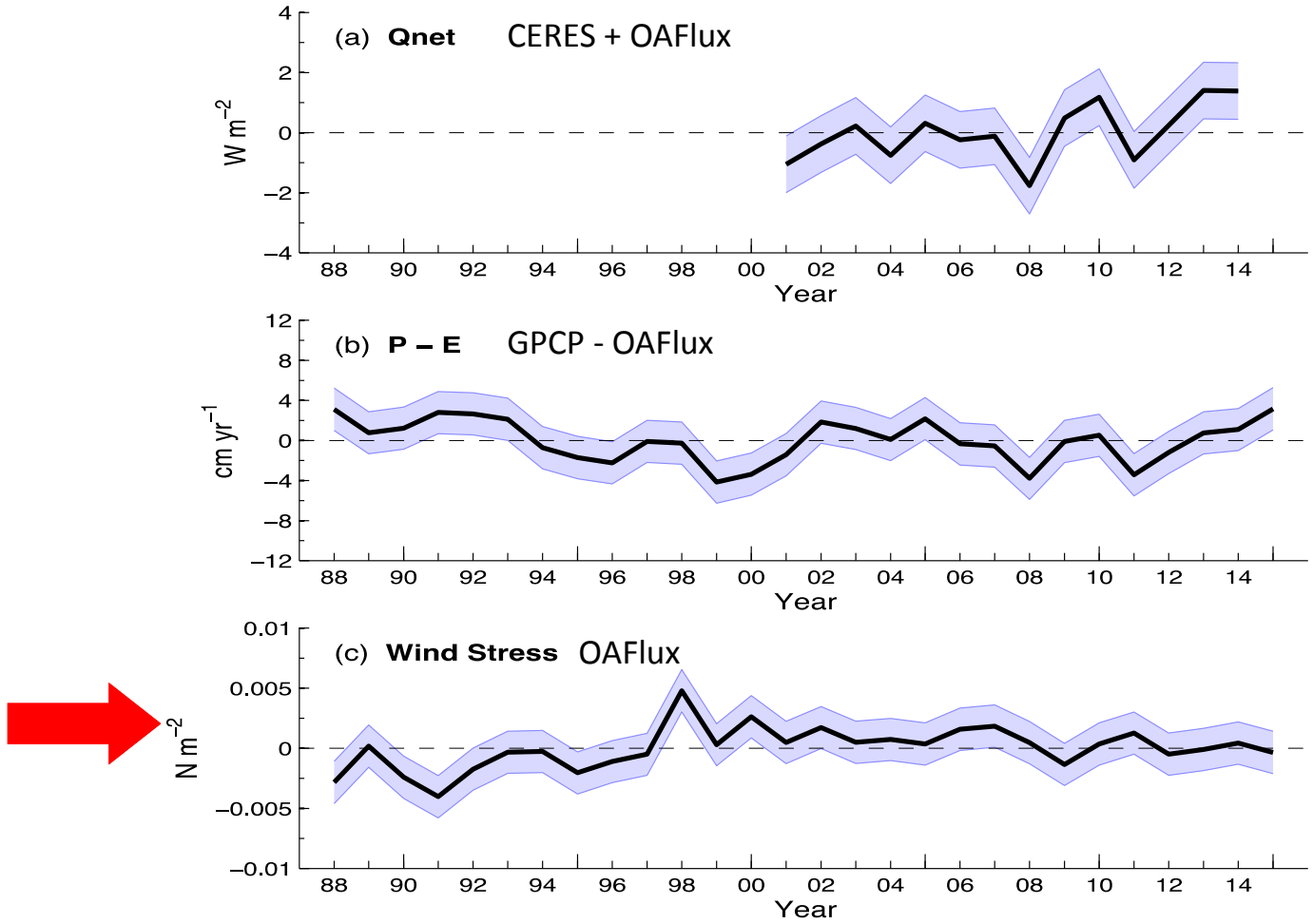
Sensible heat flux



Moisture flux (Evaporation)



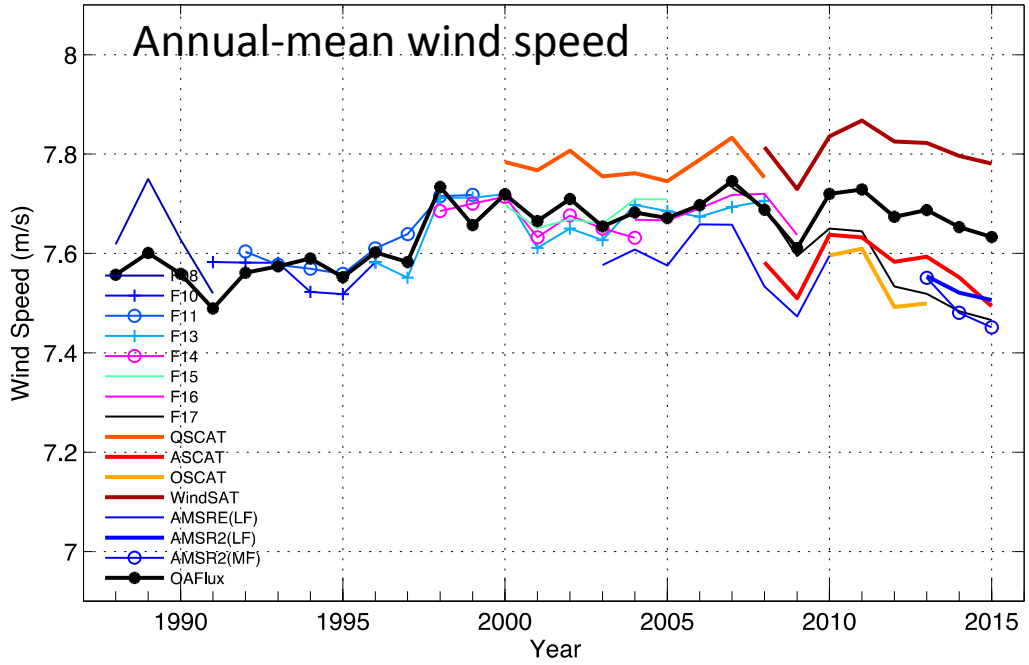
Ocean-surface energy, freshwater, and momentum budgets during the 1990s and 2000s (Yu et al. 2016)



Reference:

Yu, L., R. A. Adler, G. J. Huffman, X. Jin, S. Kato, N. G. Loeb, P. W. Stackhouse, R. A. Weller, and A. C. Wilber 2016: Global Ocean Heat, Freshwater, and Momentum Fluxes. State of Climate in 2015, Bull. Amer. Meteor. Soc., 97. In press.

The new OAFlux vector wind data record: How is it developed?

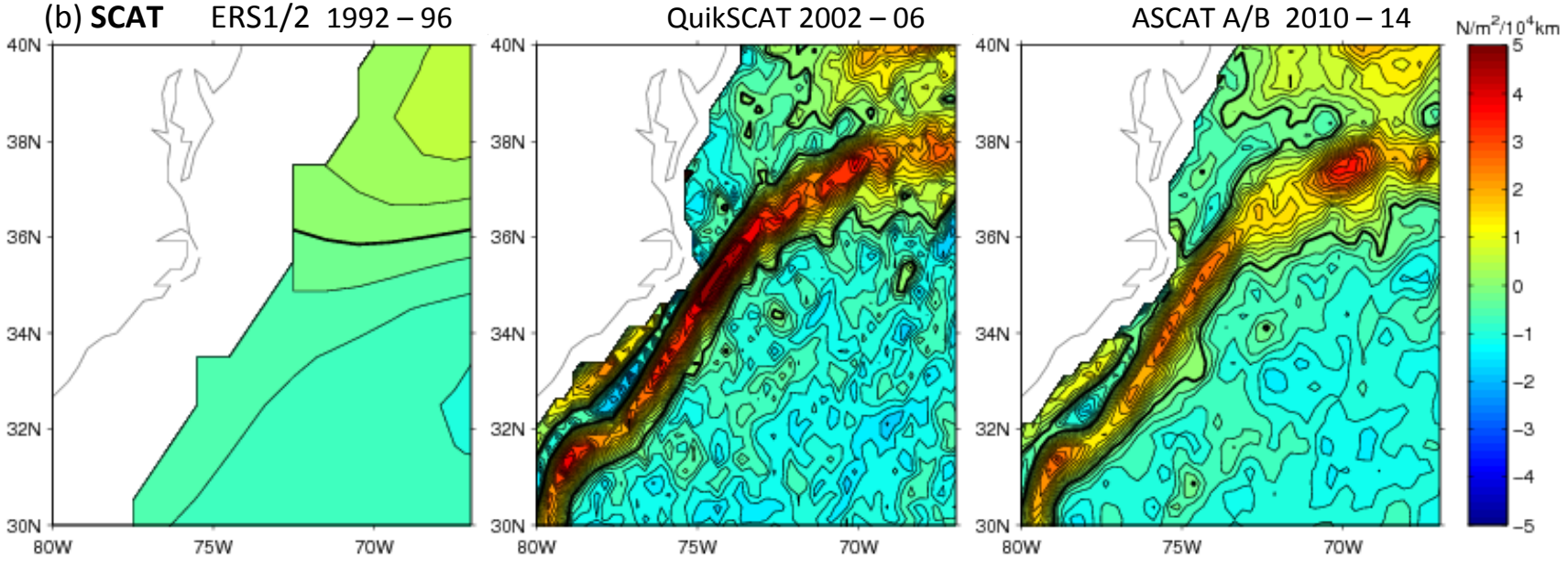


1. **Input sensors**:
   4 scatterometers (QuikSCAT-JPL, OSCAT, ASCAT A+B)
   11 passive microwave radiometers (SSM/I, SSMIS, AMSR-E, AMSR2, WindSat)
2. **Auxiliary datasets**: ERA-interim, NSCAT, Seawinds
3. **Validation database**: 126 buoy time series (not used in the synthesis)
4. **Advanced statistical techniques**: neutral network approach, objective analysis.
5. **Output**: daily-mean wind speed and components on 0.25° resolution

Additional Products: wind stress and components, wind stress curl, convergence, vorticity

The 28+ years encompass three scatterometer periods: ERS (1992-2000), QuikSCAT (1999-2009), ASCAT (2007-)

Wind Stress Curl in the Gulf Stream region: the consistency issue



Sensors differ from each other.

Key to the multi-sensor synthesis: Consistency

Cause of inconsistency:

- Rain, swath gaps, high winds, sub-daily variability, mean drift in radiometers, bias in reanalysis winds when used as background, …

Our strategy and approach:

- **Rain:** establish a rain flag database using microwave radiometer measurements.
- **High winds**: develop statistical model to adjust ASCAT towards QuikSCAT/WindSat
- **Mean drift in radiometers**: calibrate each sensor with buoy observations.
- **Bias in reanalysis**: use buoy-based correction algorithm.
- **Sub-daily variability:** incorporate 6-hourly fields into the daily-mean synthesis
- **Validation:** 126 buoy time series

References on technical development of OAFlux multi-sensor synthesis:

Jin, X., and L. Yu, 2013: Assessing high-resolution analysis of surface heat fluxes in the Gulf Stream region. J. Geophys. Res., 118, 5353–75, DOI: 10.1002/jgrc.20386.

Yu, L., and X. Jin, 2012: Buoy perspective of a high-resolution global ocean vector wind analysis constructed from passive radiometers and active scatterometers (1987–present). J. Geophys. Res., 117, C11013, doi:10.1029/2012JC008069.

Yu, L., and X. Jin, 2014a: Insights on the OAFlux ocean surface vector wind analysis merged from scatterometers and passive microwave radiometers (1987 onward). J. Geophys. Res. Oceans, 119, 5244-5269, doi:10.1002/2013JC009648.

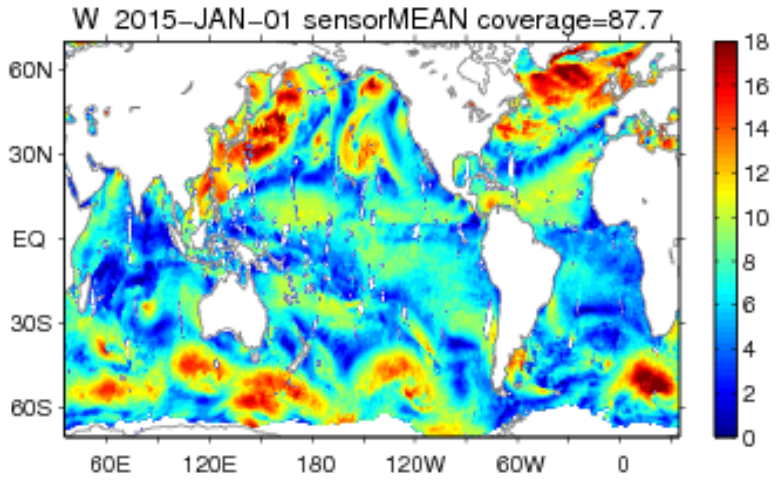
Yu, L., and X. Jin, 2014b: Confidence and sensitivity study of the OAFlux multi-sensor synthesis of the global ocean-surface vector wind from 1987 onward. J. Geophys. Res. Oceans, 119, 6842–6862, doi:10.1002/2014JC010194.

Data gap filling in: need of reanalysis winds

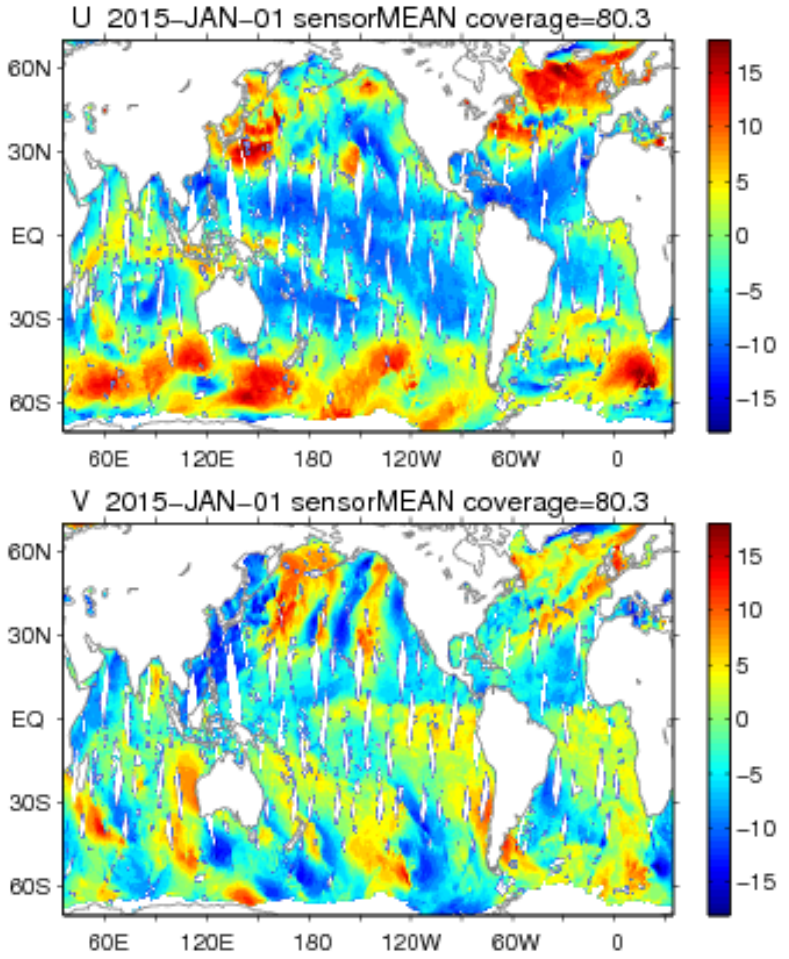
- A data coverage of 100% over the ocean is not provided even on daily-mean basis.

→ NO gap-free gridded product can be established without the use of atmospheric reanalysis winds.

ASCAT A+B, AMSR2, SSMIS F17



ASCAT A+B

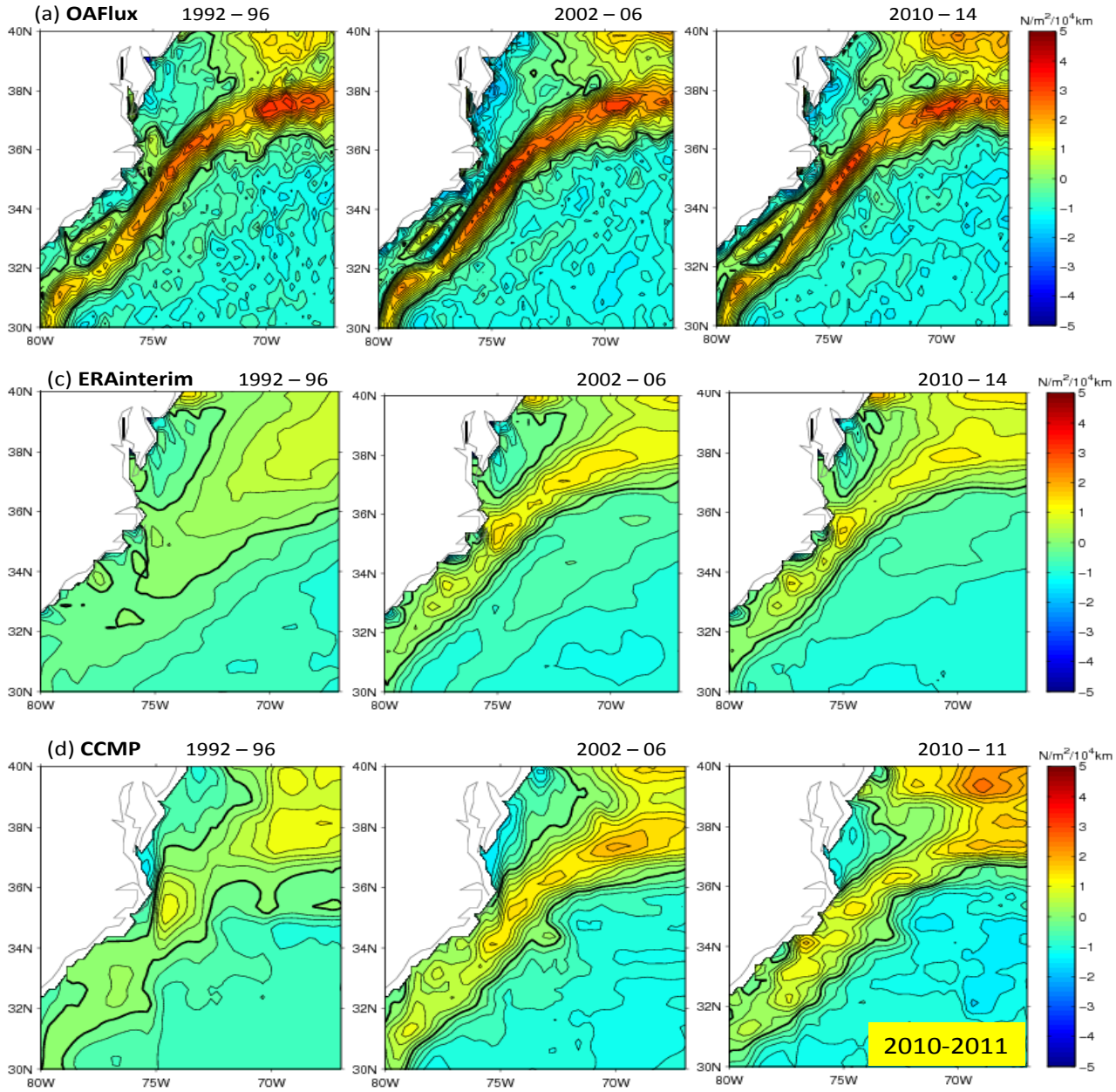


Art of using reanalysis:
use it because it helps, not because it fixes your problem

OAFlux:
Consistency across the three periods can be achieved.

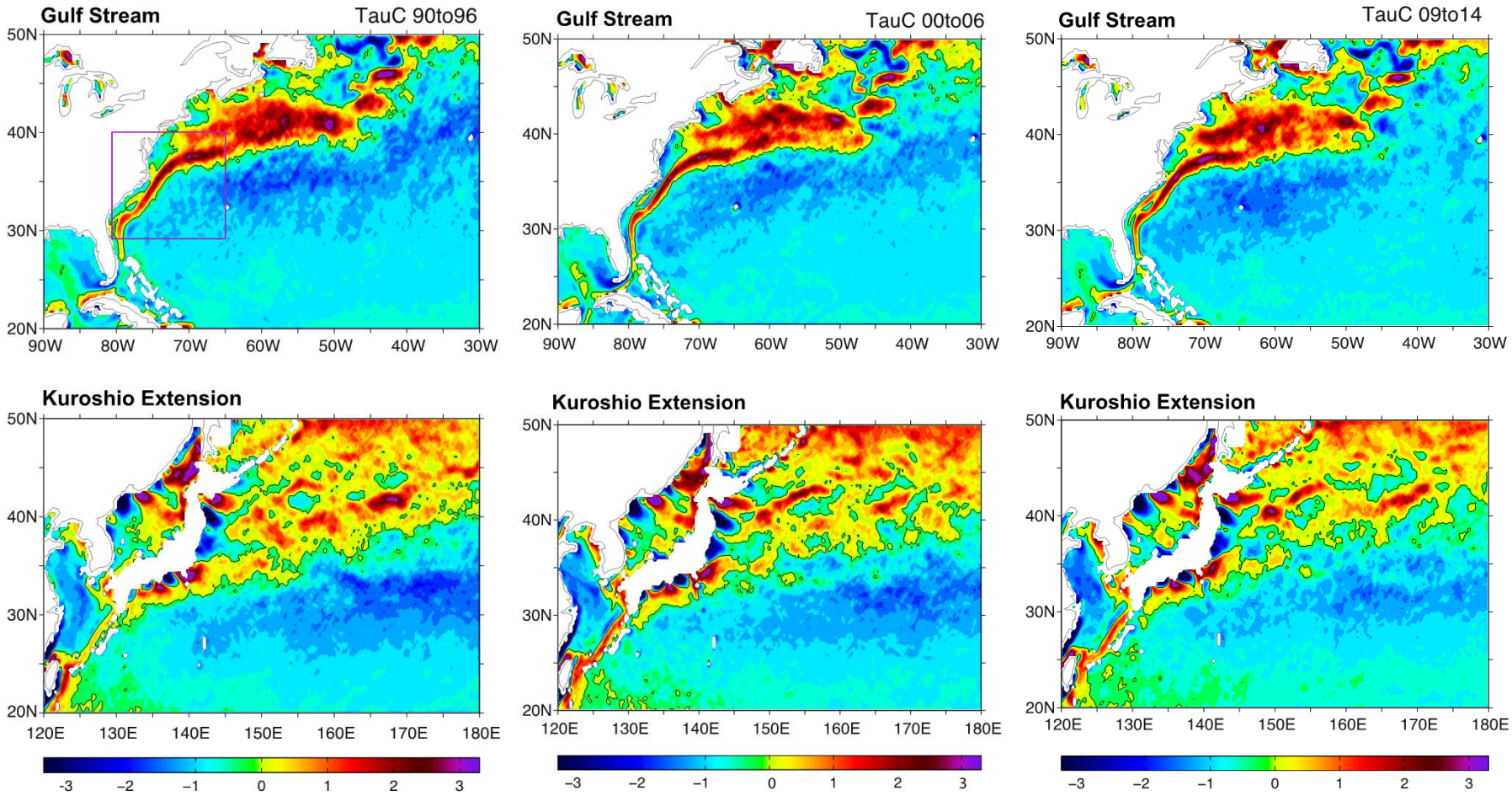
ERA-interim:
has its own internal problem.

CCMPv1:



OAFlux Wind Stress Curl over the GS and KE

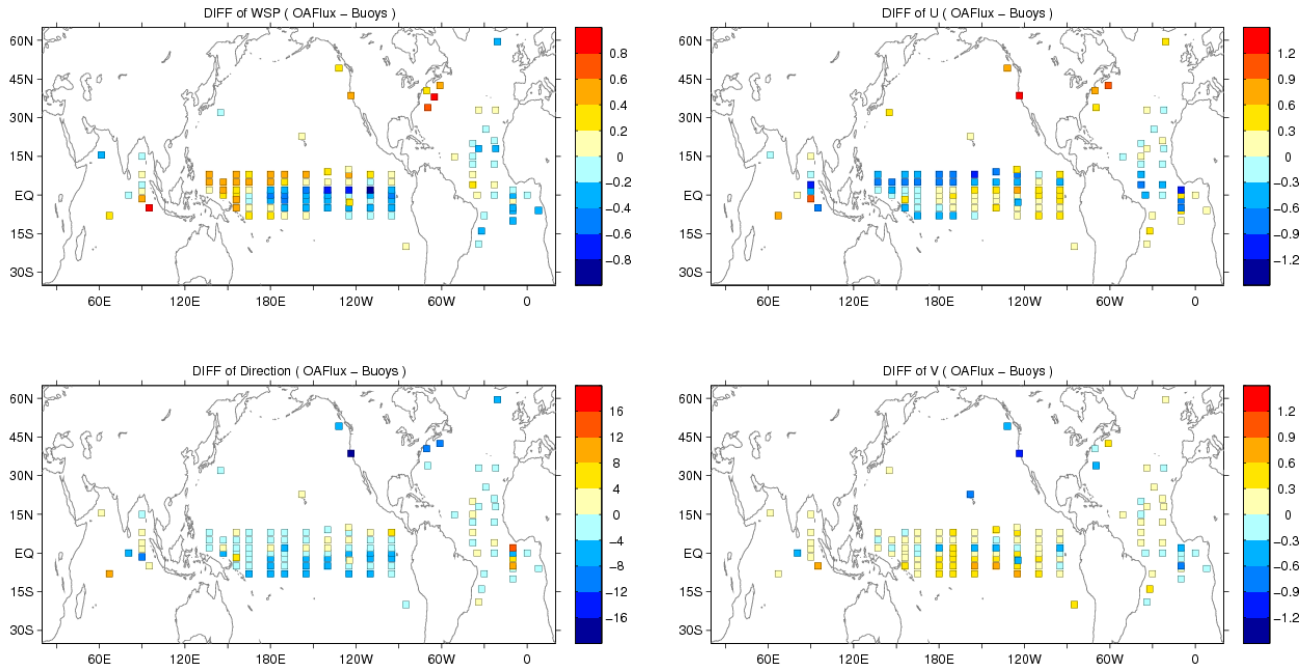
1990-1996 | **2000-2006** | **2009-2014**



Buoy measurements (not used in synthesis): validation analysis

Statistics averaged over buoy Locations Diff = OAFlux - Buoys

	U	V	WSP	Direction
Mean Difference	-0.03	0.10	0.03	-1.79
Mean Correlation	91.8	91.6	93.1	77.3
Mean Daily Mean RMS	1.15	1.07	0.70	18.7



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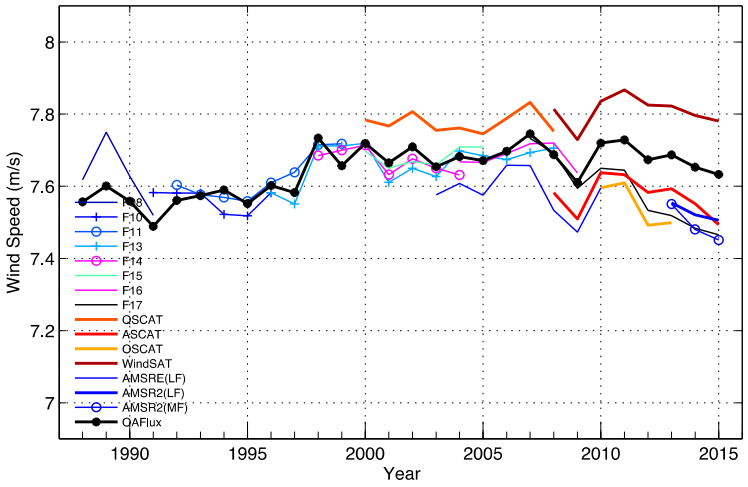
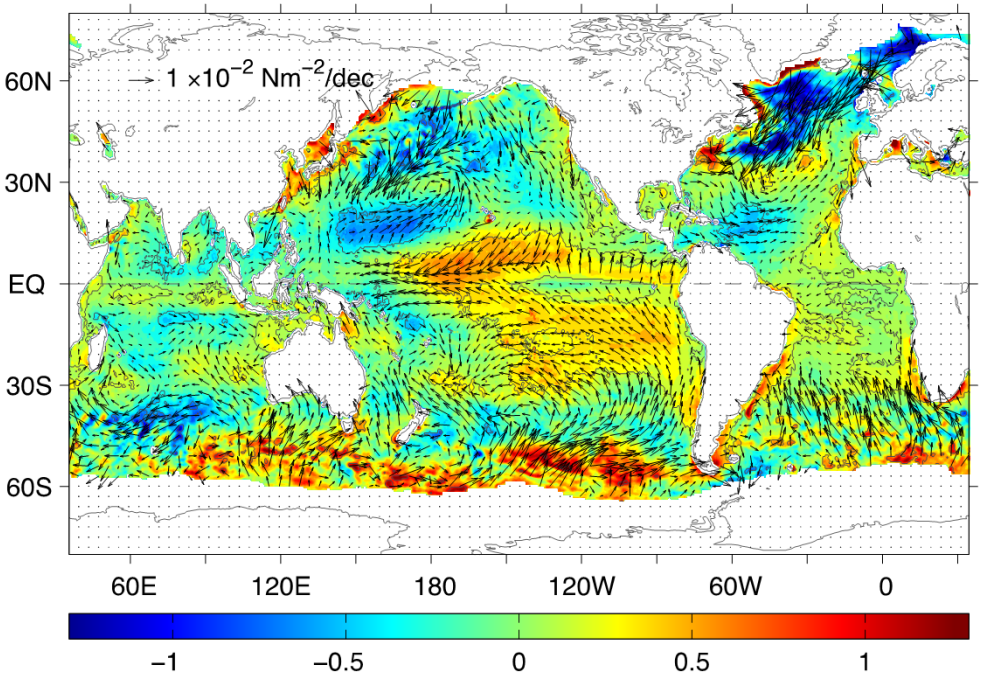
The new OAFlux vector wind data record: what new insights we can gain? (1) Trends

Annual-mean wind speed

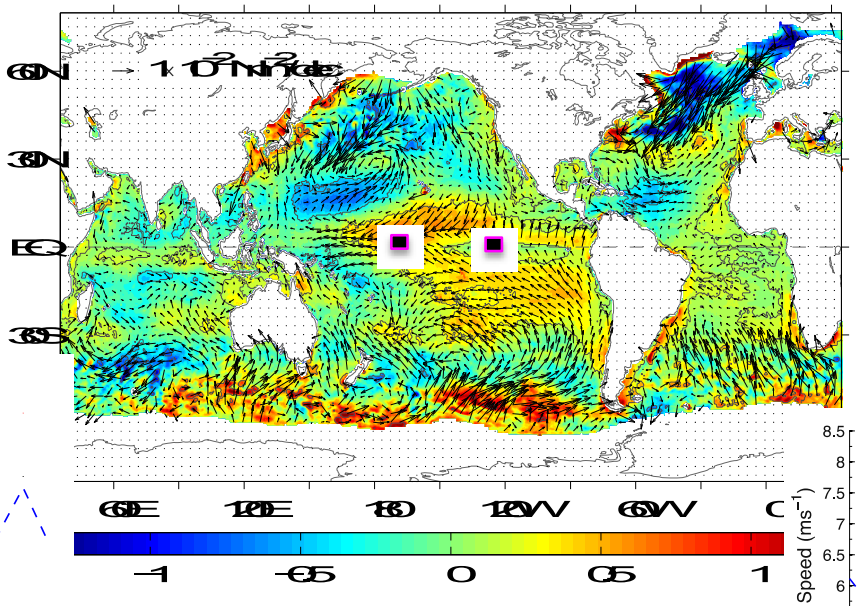


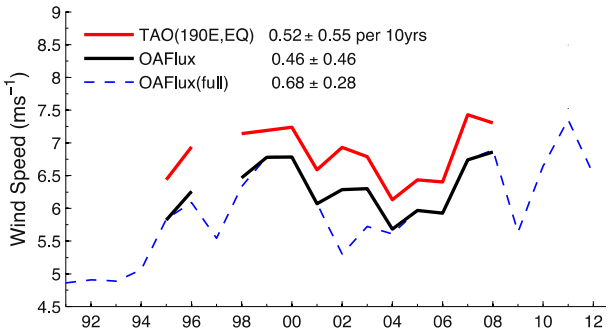
Linear trends

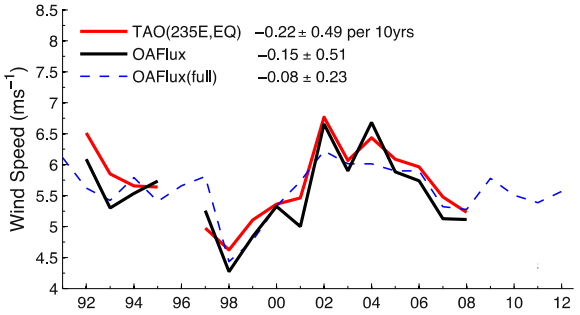


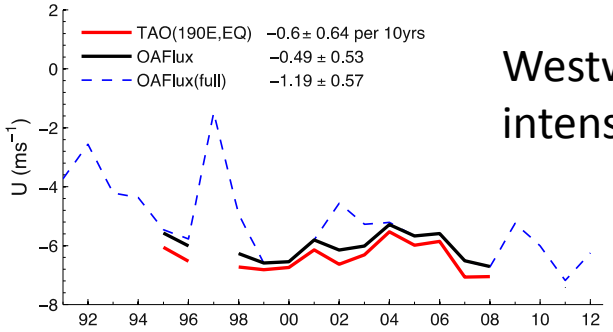
(1) Are the trends real or an end-point effect?

Buoy verification

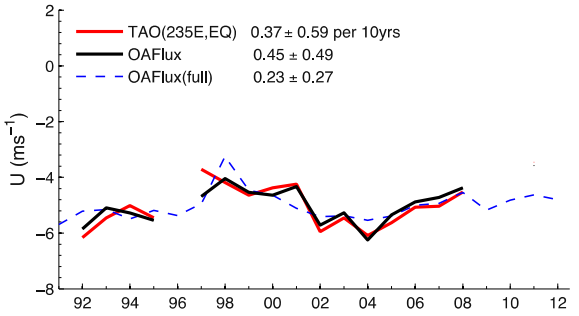


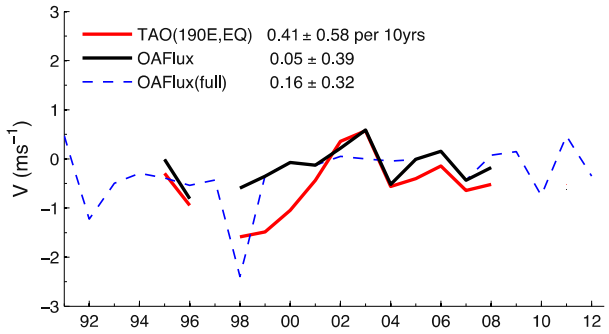




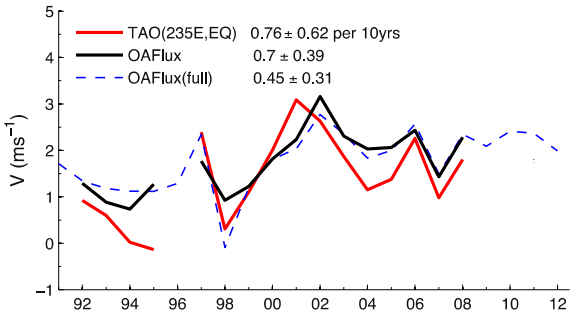


Westward intensification

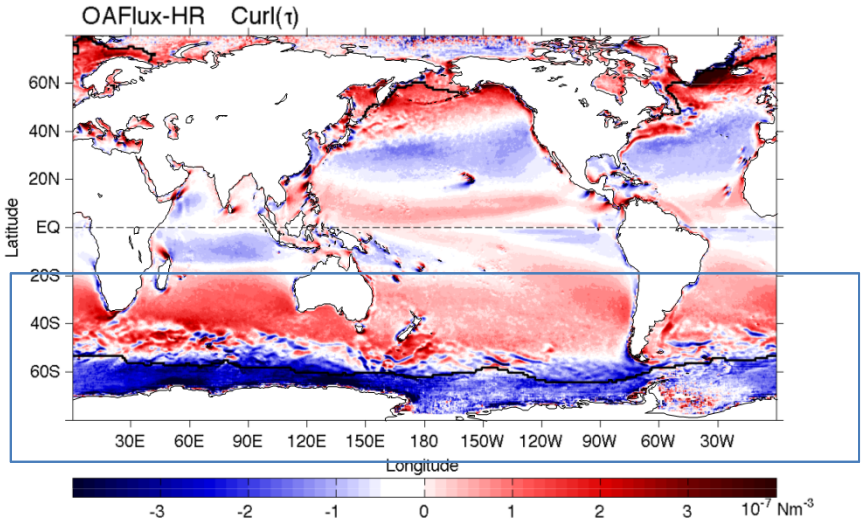




Northward strengthening



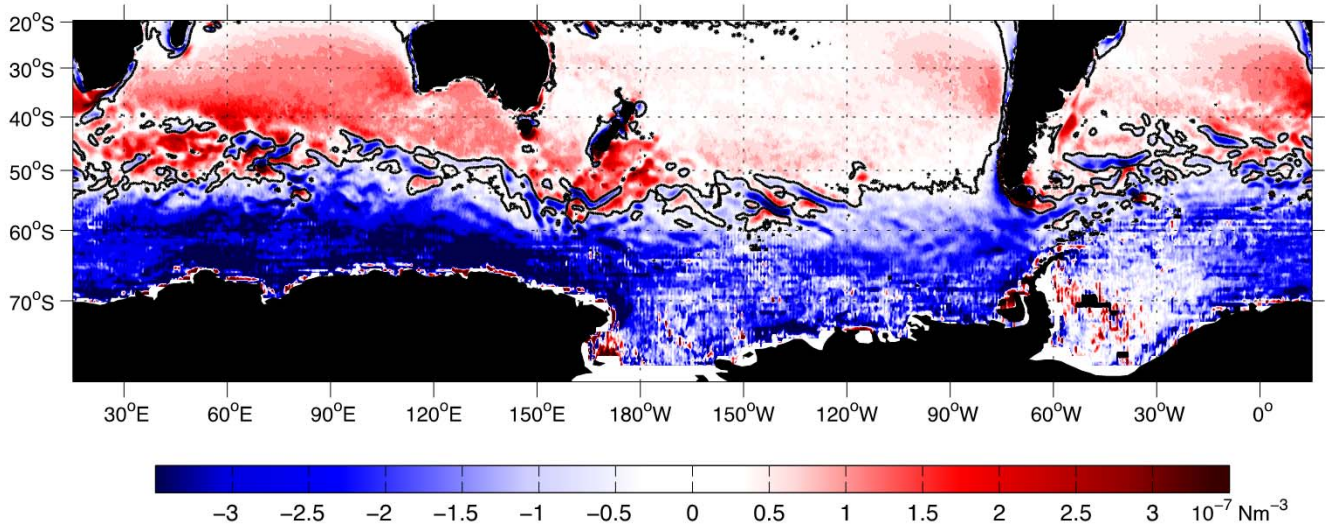
What new insights we can gain?
(2) SST-wind coupling at meso and frontal scales



Wind Stress Curl (1988-2015)

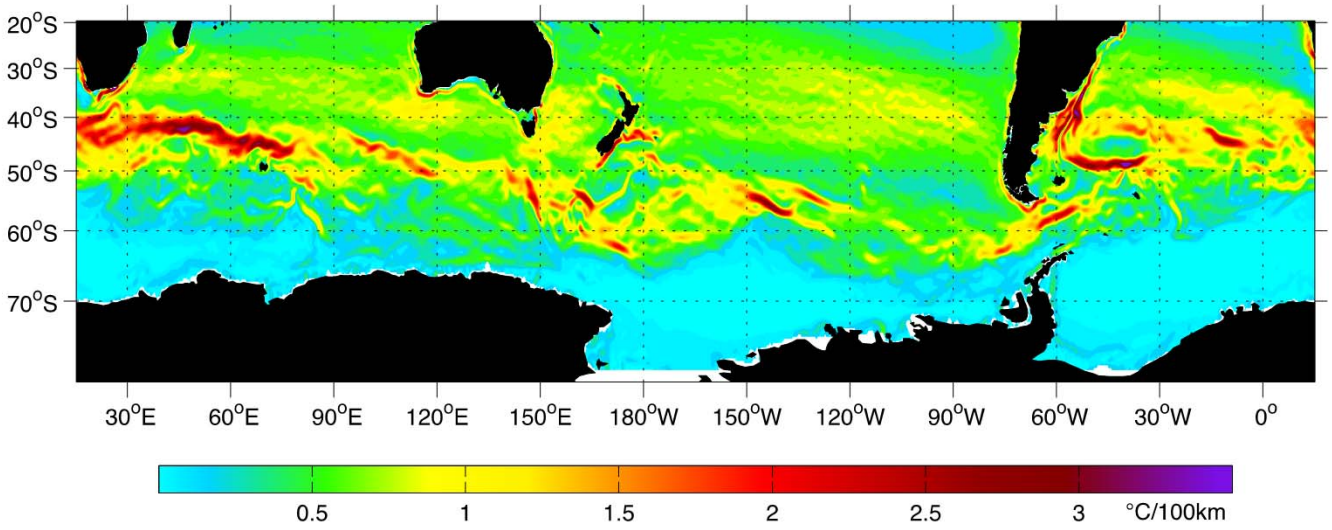
Southern Ocean

zero wind stress curl (black contour)

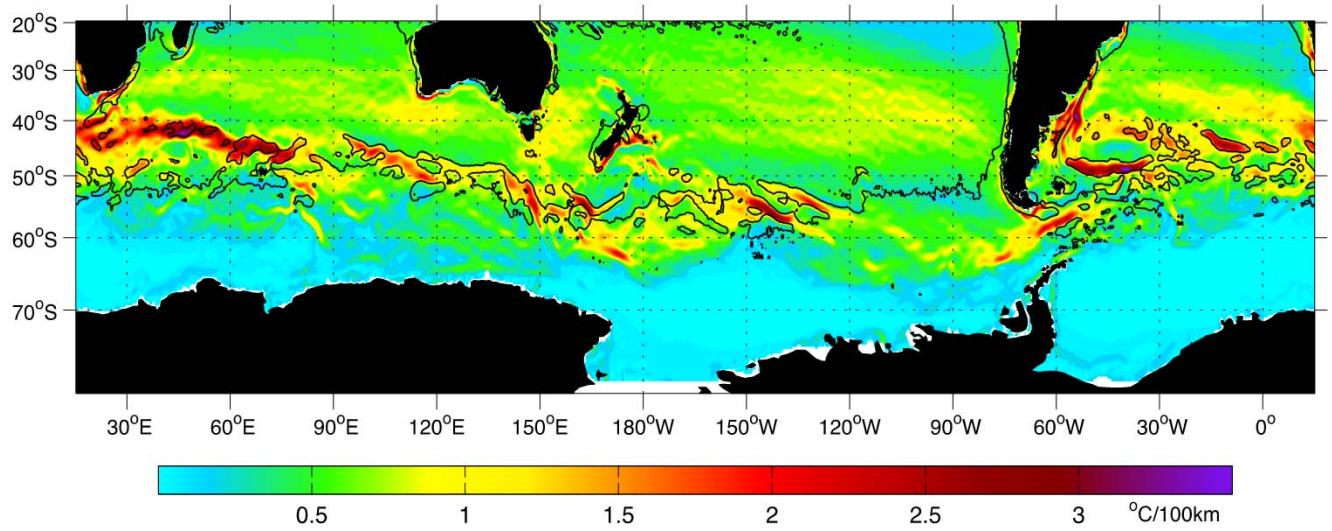


SST – wind coupling

SST gradients (1988-2015)



SST gradients (1988-2015) + zero wind stress curl (black contour)



Zero wind stress curl is locked to ocean bathymetry via the topographically induced SST effect

Summary

- **OAFlux has recently completed three sets of high-resolution (HR) products:**

(1) 10-m equivalent neutral vector winds merged from 15 sensors;
(2) 2-m air temperature and humidity retrieved from 11 sensors;
(3) Full suite of turbulent heat, moisture, and momentum fluxes computed from the COARE algorithm.

Resolution: daily and 0.25-degree grids from 1988 onward

- **Ensuring the accuracy and consistency across different sensors are the primary goals during the development of the OAFlux-HR flux analysis.**

(1) Buoy time series measurements at 120+ locations serve as a validation base. OAFlux does not assimilate buoy measurements.
(2) Every expected cause of inconsistency was examined and specific approach was developed to reduce the potential impact.
(3) Effort were made to develop advanced statistical techniques to better use reanalysis. We use the reanalysis to help, but not to fix the problem.
(4) The approach we have developed seems to work well. A high level of consistency is evidenced in wind and wind derivative fields.
(5) Merging wind retrievals from different sensors is a highly challenging task. We continue to improve our schemes and incorporate new datasets and techniques.

- The new vector wind time series demonstrates good accuracy in depicting the wind variability and its coupling with SST on meso and frontal scales. It shows high consistency with buoy wind records in documenting the change of trade winds in recent decades .

- We are working toward online dissemination of the HR products.