A study of Long-Term Trend and Variability of Global Ocean Surface Wind Fields through Synthesizing Scatterometers with SSM/I and COADS Observations

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Global climate is changing. Near surface wind over the ocean, being a key component of the Earth's climate system, has also been changing.

NASA OVWST meeting, July 5-7 2006
Salt Lake City, Utah

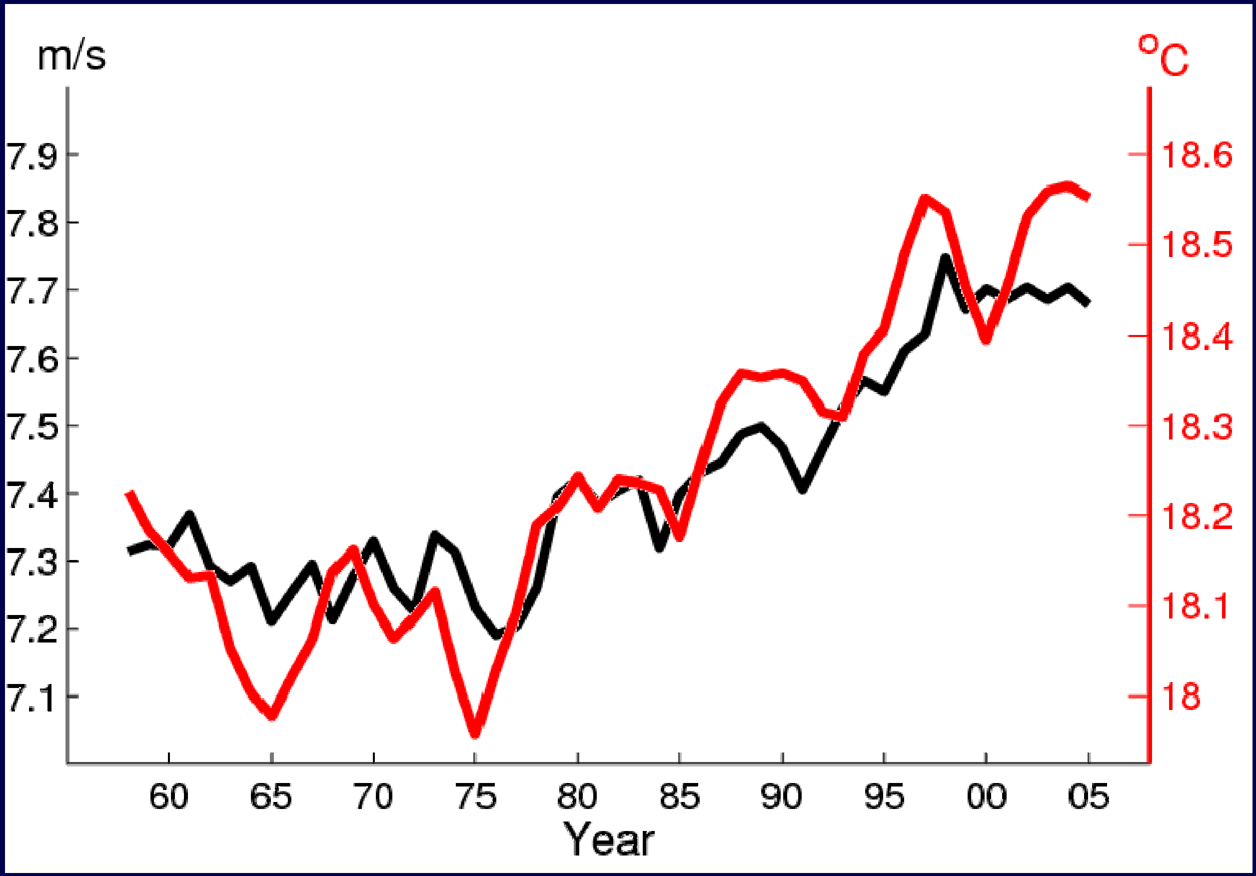
Major topics of the talk

1) How have the global surface winds been changing? What are the climate impacts?

2) Why is there a need for a synthesized global surface wind product that integrates satellite and in situ observations? How do we do it?

3) What are to be delivered by this project?

How have the global surface winds been changing?



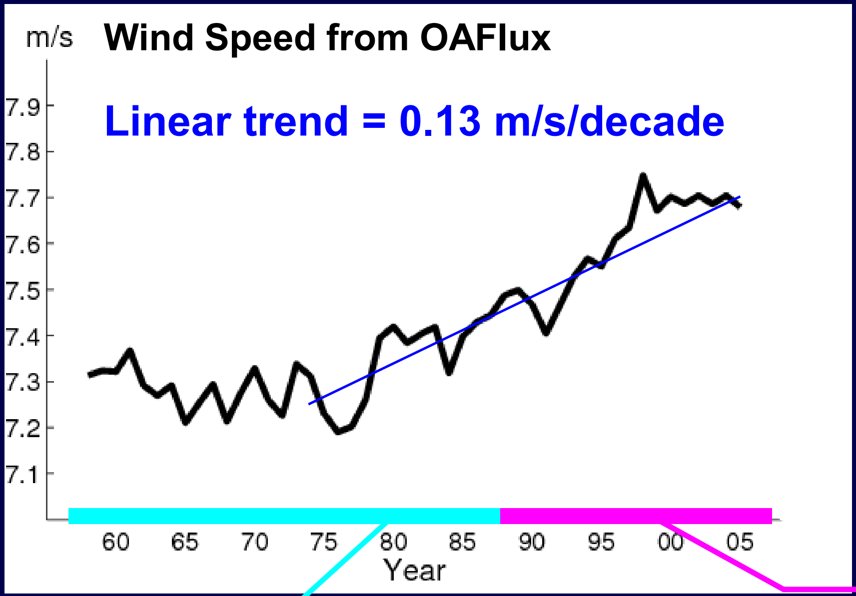
Wind Speed is from the WHOI Objectively Analyzed air-sea Fluxes (OAFlux) project. http://oaflux.whoi.edu/

SST is from the Hadley Centre Global Sea Surface Temperature (HadSST) Analyses. http://badc.nerc.ac.uk/data/hadisst/

How is the wind speed derived?

- It is produced by the WHOI Objectively Analyzed air-sea Fluxes **(OAFlux)** project supported by NOAA/OCO&CCDD (PIs: Yu & Weller, Programming support: X. Jin) **Project website: http://oaflux.whoi.edu/**

- It is obtained by objective synthesis of surface wind fields from
  - Satellite retrievals (SSM/I, NSCAT, QuikSCAT),
  - COADS ship observations
  - Atmospheric reanalysis and operational model outputs (NCEP, ECMWF)

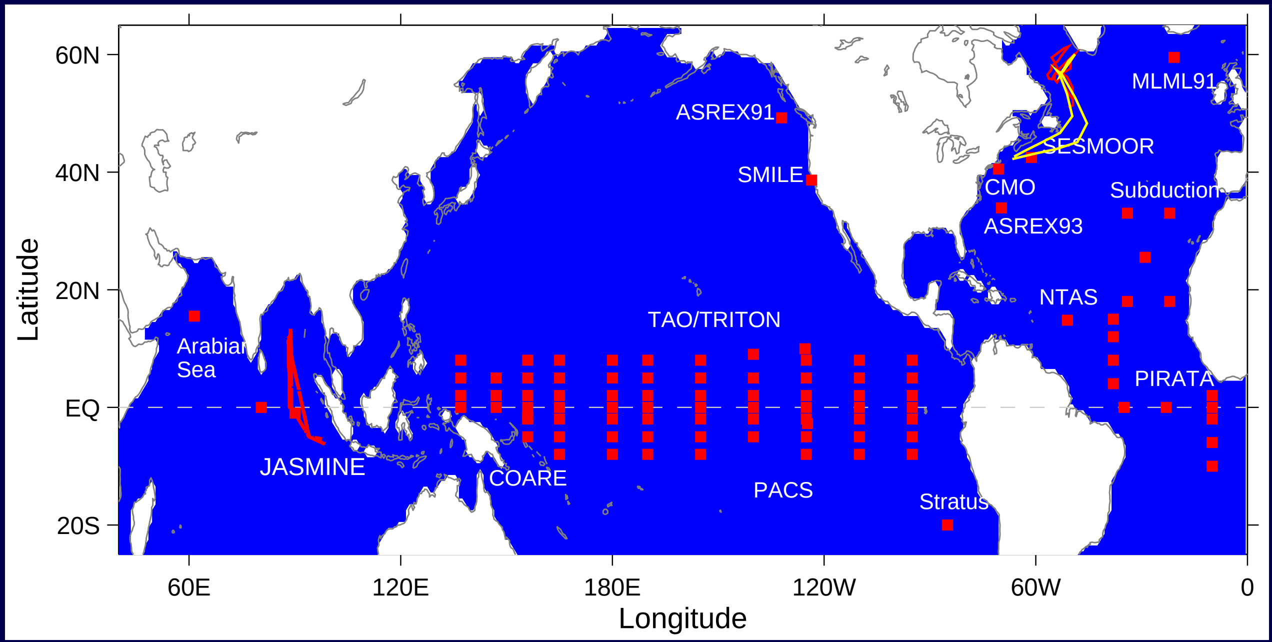


COADS ship observations
NCEP, ECMWF reanalyses

SSM/I, QuikSCAT,
NCEP, ERA40 reanalyses
ECMWF operational

Validation with in situ measurements (1985-2002)

Total in situ time series: 102



U: Mean buoy-model differences relative to buoy mean value

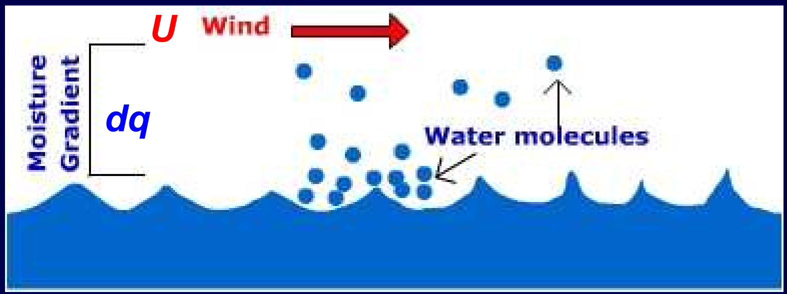
	TAO/TRITON (69)	Others (33)
OAFlux	0.21 m/s (3%)	0.27 m/s (3%)
NCEP1	1.04 m/s (17%)	0.44 m/s (6%)
NCEP2	0.24 m/s (3%)	0.68 m/s (10%)
ERA40	0.42 m/s (6%)	0.51 m/s (8%)

(From X.Jin)

Climate implications of increasing near-surface wind speed

Impact #1: Larger evaporation over the global oceans

Evaporation is the phase change of a liquid to a vapor.

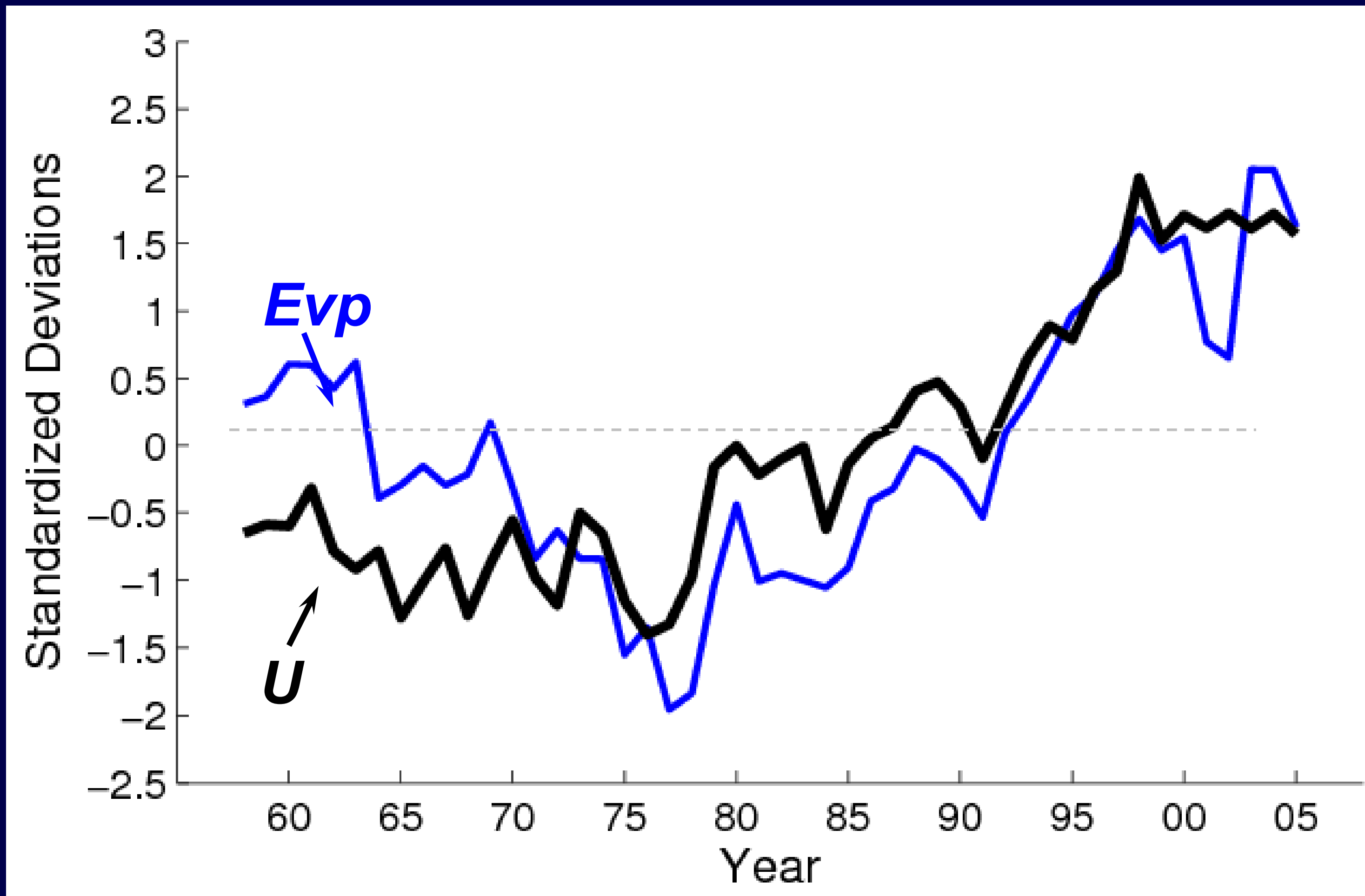


Latent heat is required to break the bonds between the clusters creating individual molecules that escape the surface as a gas. It is "latent" because it is being stored in the water molecules to later be released during the condensation process.

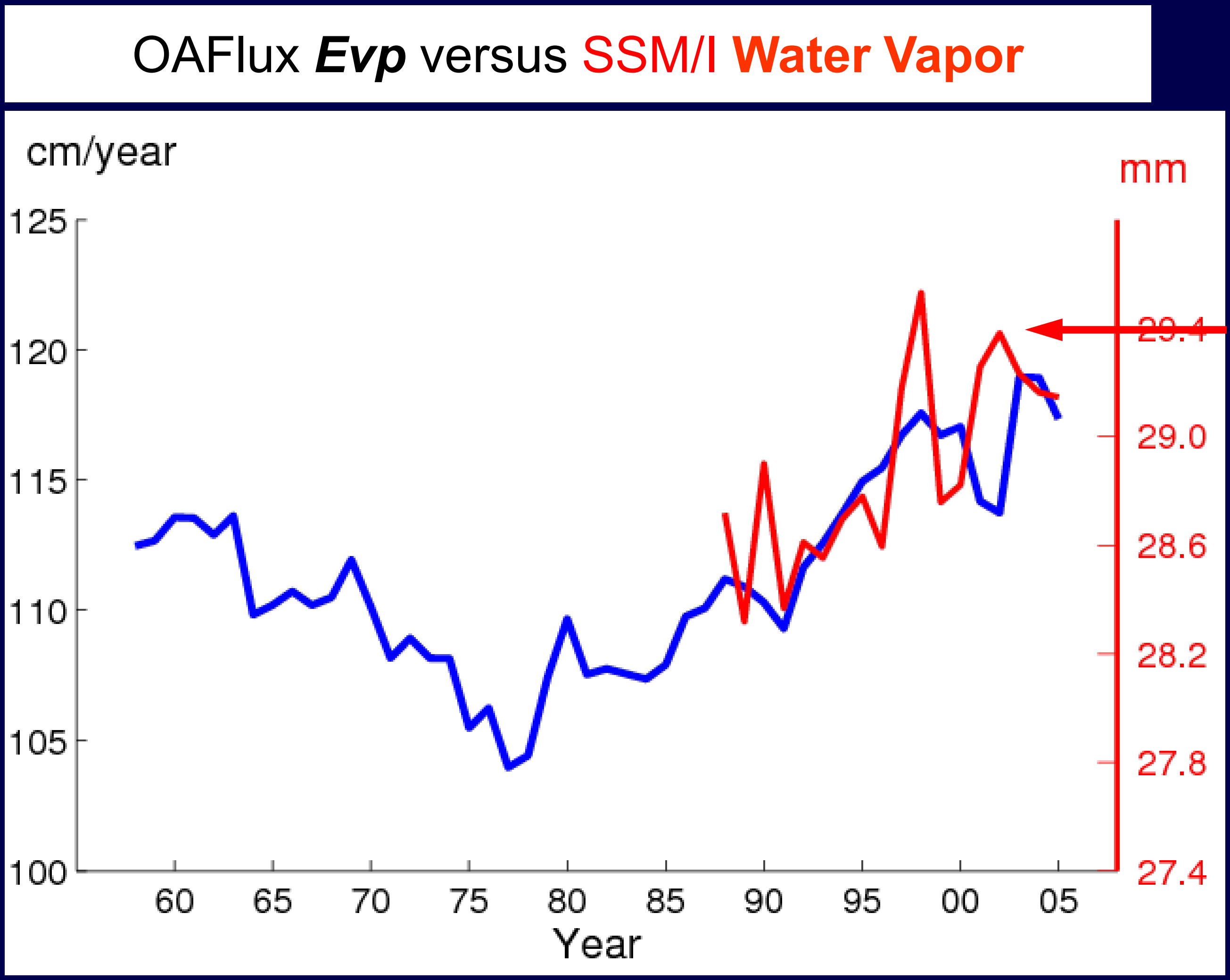
Wind speed — **dq, Sea-air moisture gradient**

$$Evp \sim U\,(q_s - q_a)$$

Wind speed is the leading cause for the *Evp* increase



Does the atmosphere become more moist?

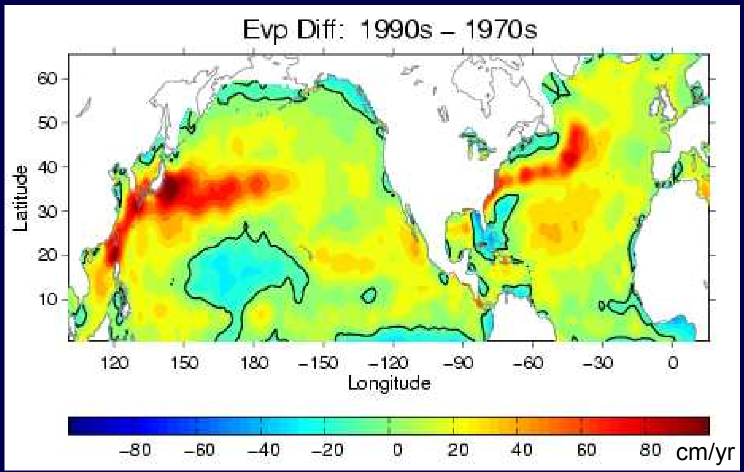


Column integrated water vapor from SSM/I retrievals from Frank Wentz http://www.ssmi.com

How could *U* be a leading factor for the *Evp* increase?

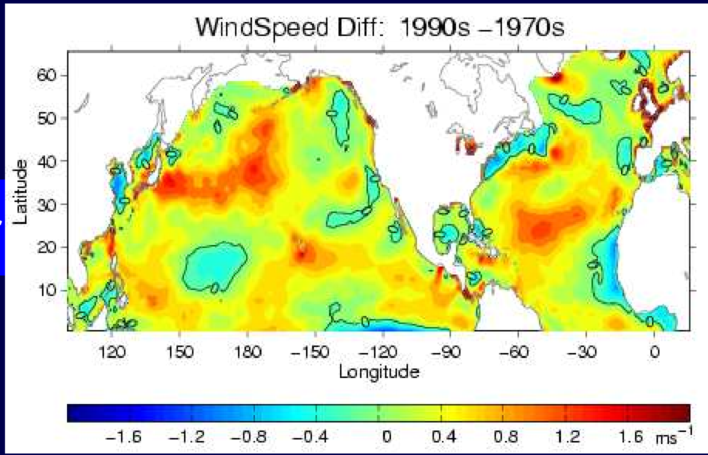
$$Evp \sim U\,(q_s - q_a)$$

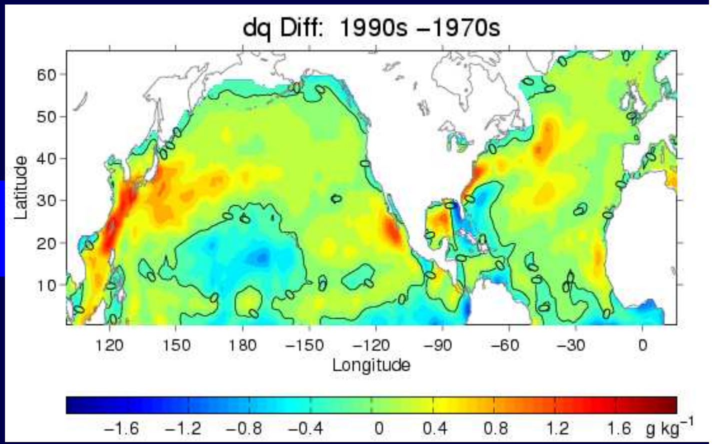
North Pacific and Atlantic Oceans



Ocean interior

Boundaries



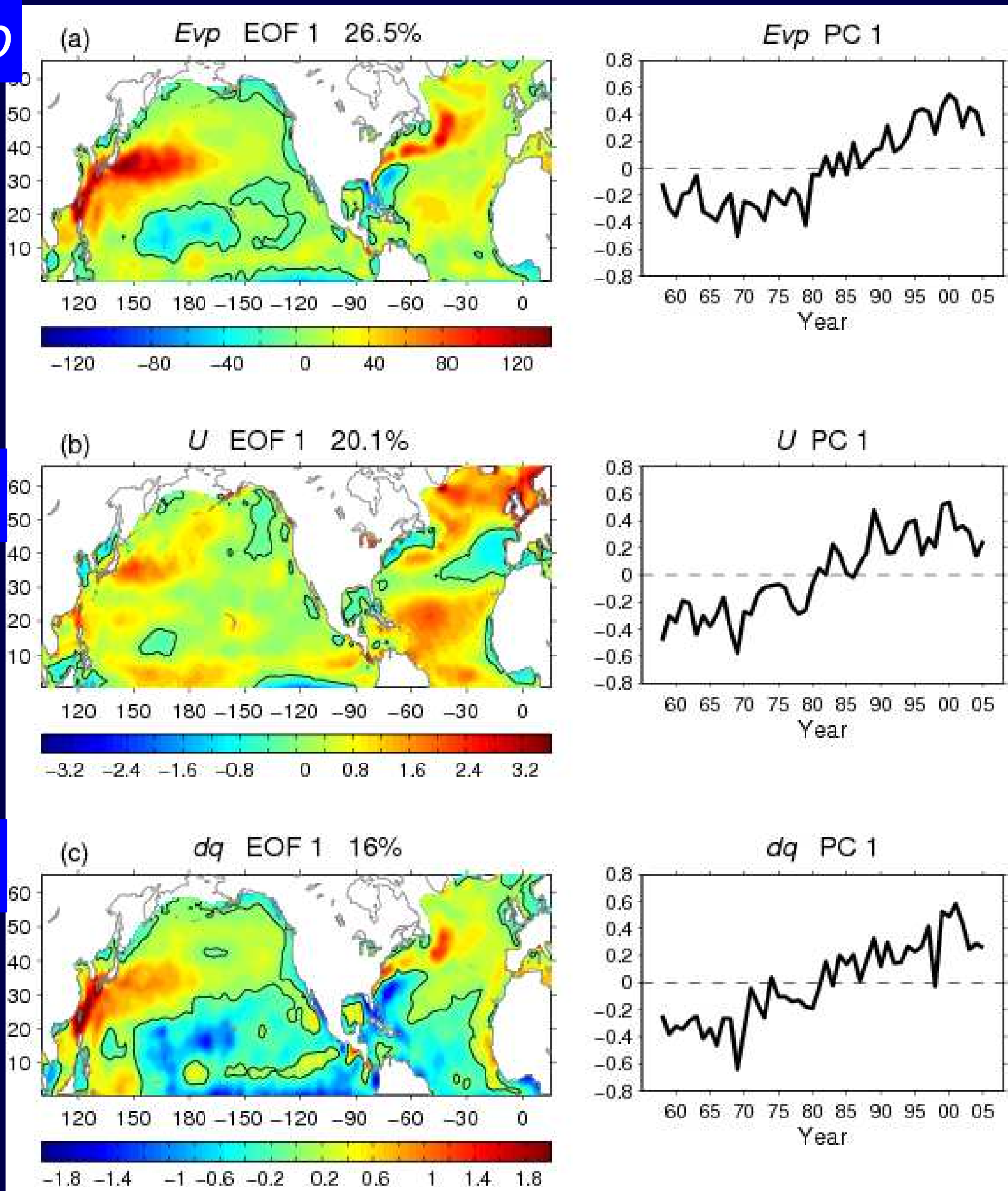


EOF Mode 1 for *Evp, U,* and *dq*

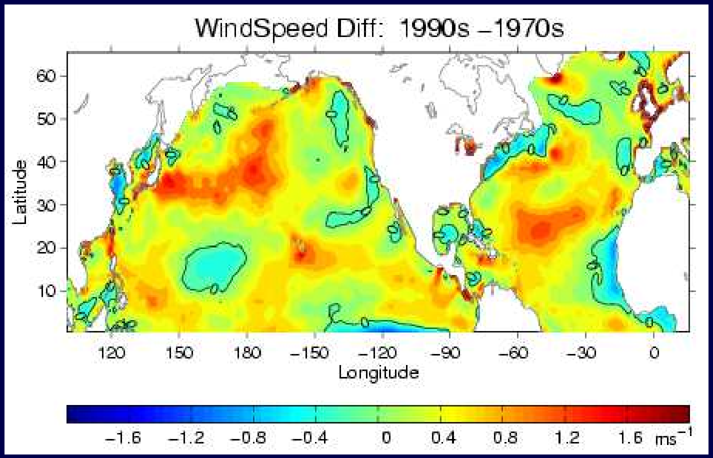
Evp

U

dq



Effects of increasing surface wind on Evp



Direct:

Wind speed (*U*) → *Evp ~ Udq* → *Evp*

Indirect:

Intensifying **gyre circulations** → Warming up Kuroshio and Gulf Stream → Enhancing *dq* over WBCs and their extensions → Increasing *Evp*

Impact #2: Stronger wind-driven subtropical gyres

Decade-to-Century-Scale Climate Variability and Change: A Science Strategy (1998)
http://www.nap.edu/openbook/0309060982/html/R1.html, copyright 1998, 2000 The National Academy Press, all rights reserved

Decade-to-Century-Scale Climate Variability and Change

A Science Strategy

Panel on Climate Variability on Decade-to-Century Time Scales
Board on Atmospheric Sciences and Climate
Commission on Geosciences, Environment, and Resources
National Research Council

Chapter "Ocean Circulation"

Qiu and Joyce (1992) found a gradual increase in the Kuroshio and North Equatorial Current transport of about 5 Sverdrups (1 Sv = 10^6 m3/s) per decade, starting in 1970 and continuing into the 1980s, which implies greater wind forcing.

Bingham (1992) showed that during the period 1978-1982 the subtropical gyre was stronger than during 1938-1942, which again implies greater wind forcing.

Deser et al. (in press) found an intensification of the winds associated with the regime shift of 1976, and showed that the enhancement of the Kuroshio was part of a general North Pacific response to this wind shift.

Decadal Spin-up of the South Pacific Subtropical Gyre

D. Roemmich[1], J. Gilson[1], R. Davis[1], P. Sutton[2], S. Wijffels[3], S. Riser[4]

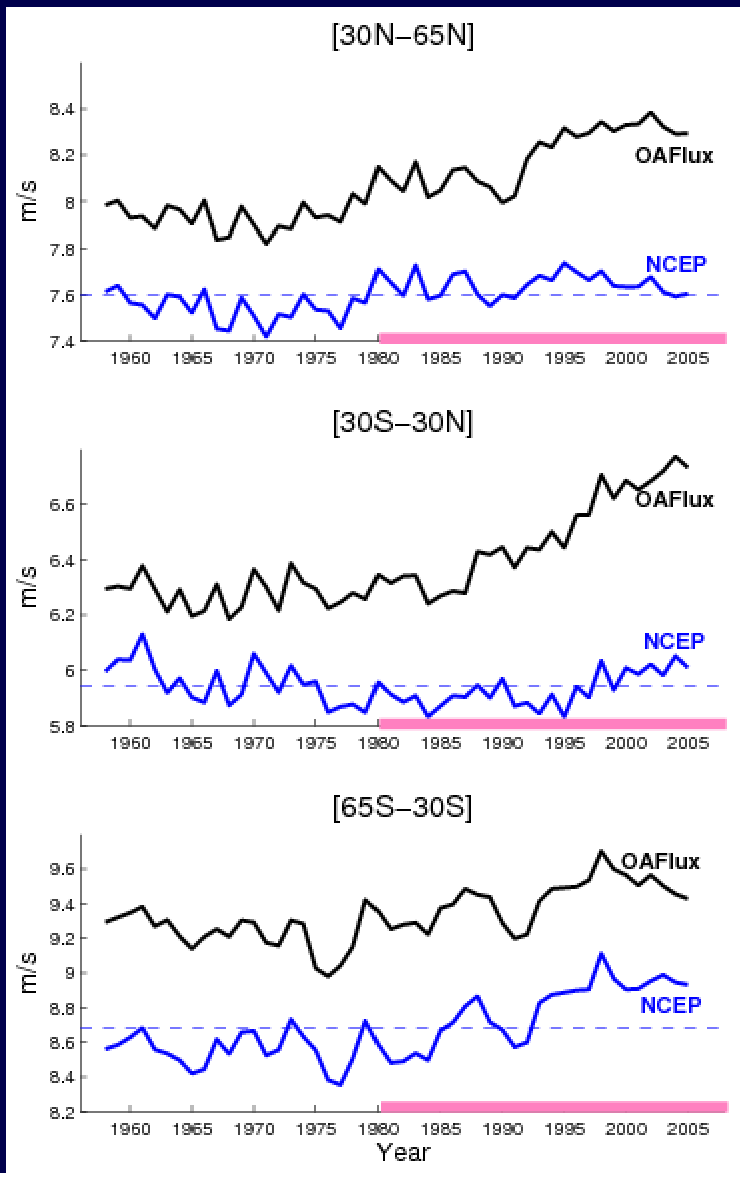
2nd Argo Science Workshop
Venice March 17, 2006

Argo profile and trajectory data, along with altimetric height and WOCE/CLIVAR hydrography, reveal a decadal spin-up of the South Pacific gyre in the 1990s.

The 1990s' increase in wind-driven circulation resulted from decadal intensification of wind-stress curl east of New Zealand, variability associated with an increase in the southern hemisphere annual mode (SAM).

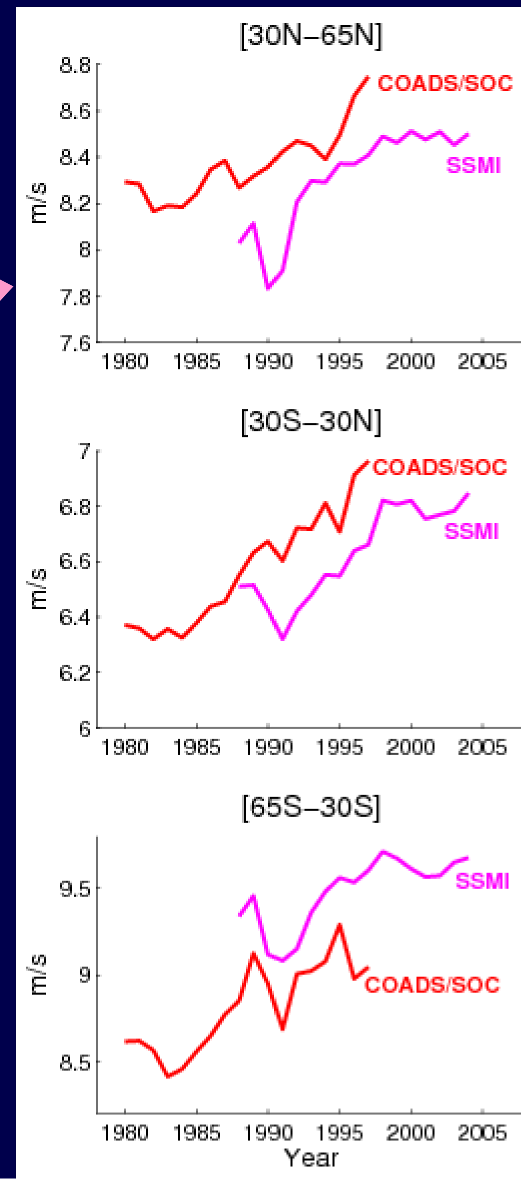
Differences in wind speed products

NCEP versus OAFlux



1980-2005

Satellite and COADS



Synthesizing wind from different sources (1958 onward)

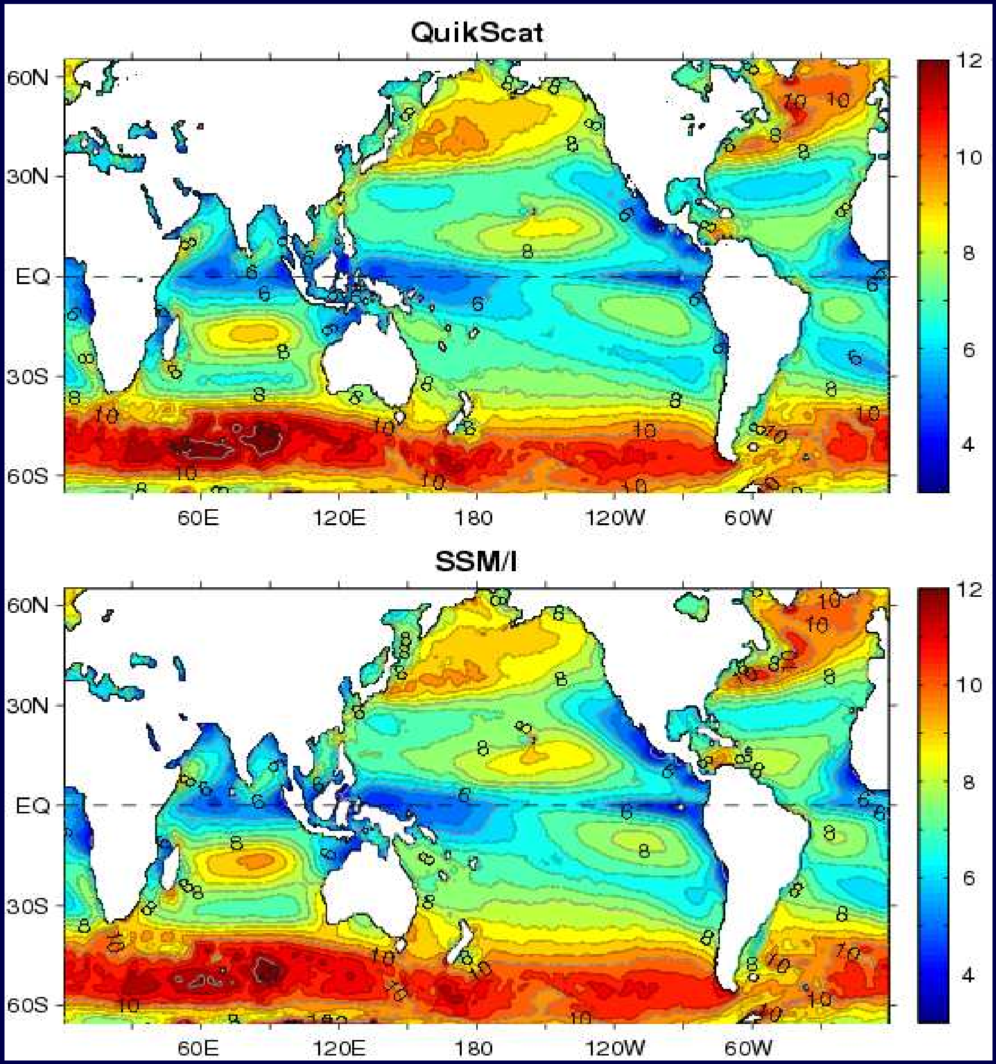
- Multi-sensor retrievals:
  - SSM/I wind speed
  - Scatterometer winds from ERS1&2, QuikSCAT, …
- Numerical weather prediction model outputs:
  - NCEP, ECMWF reanalyses and operational
- COADS ship observations

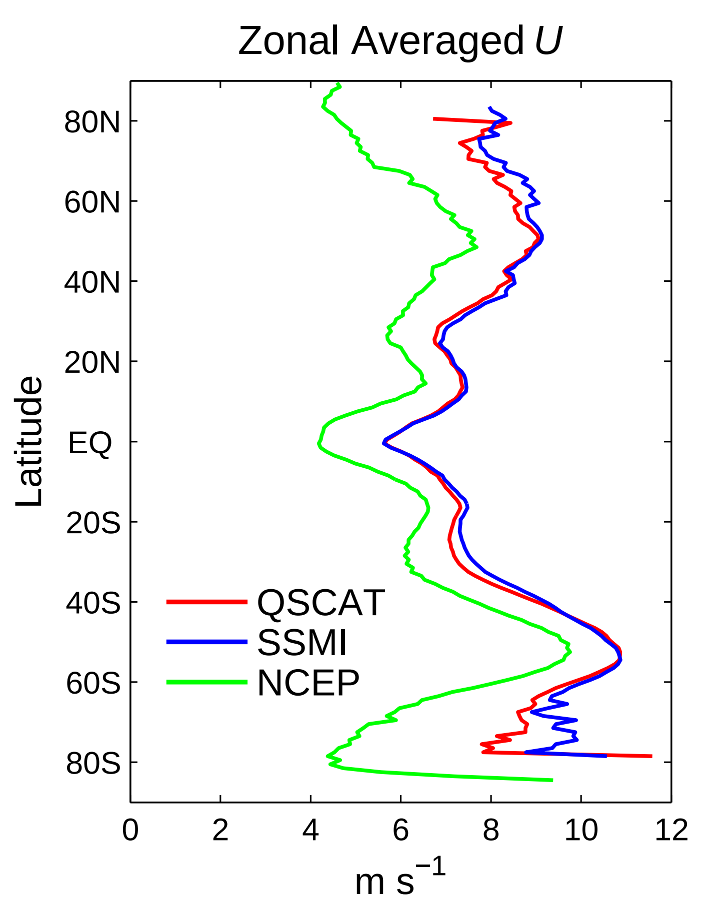
How do we do it?

(1) Bias control through intercomparison and buoy validation
(2) Objective synthesis

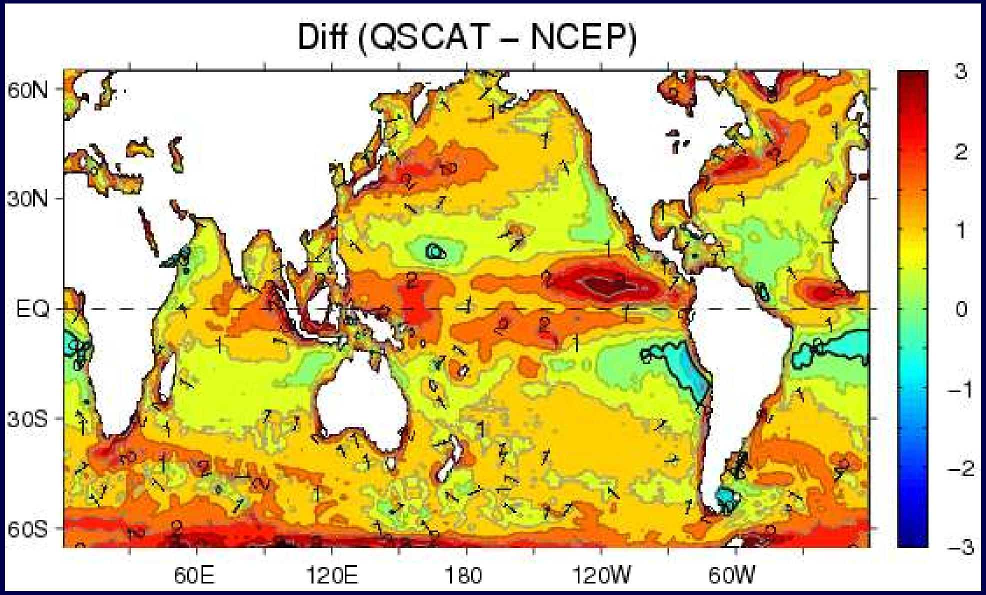
Where are the biases?

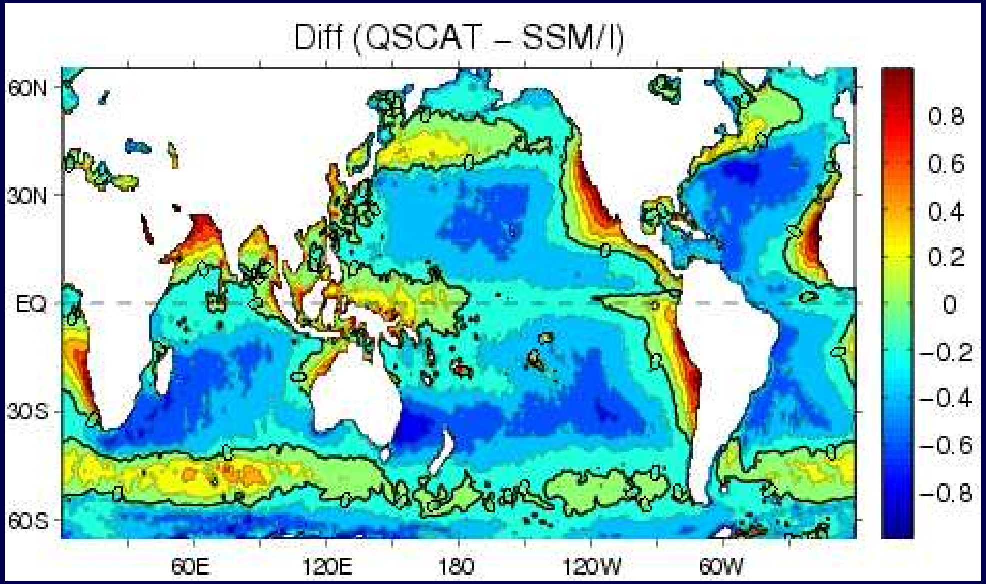
Mean Wind Speed (2000-2005)





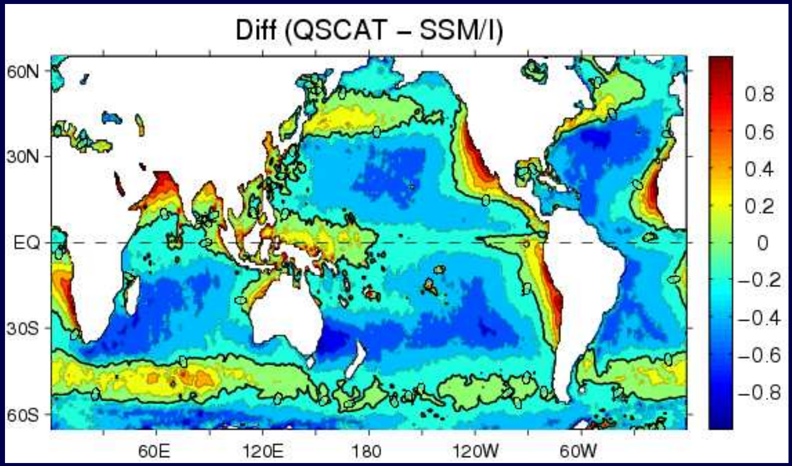
Differences between products



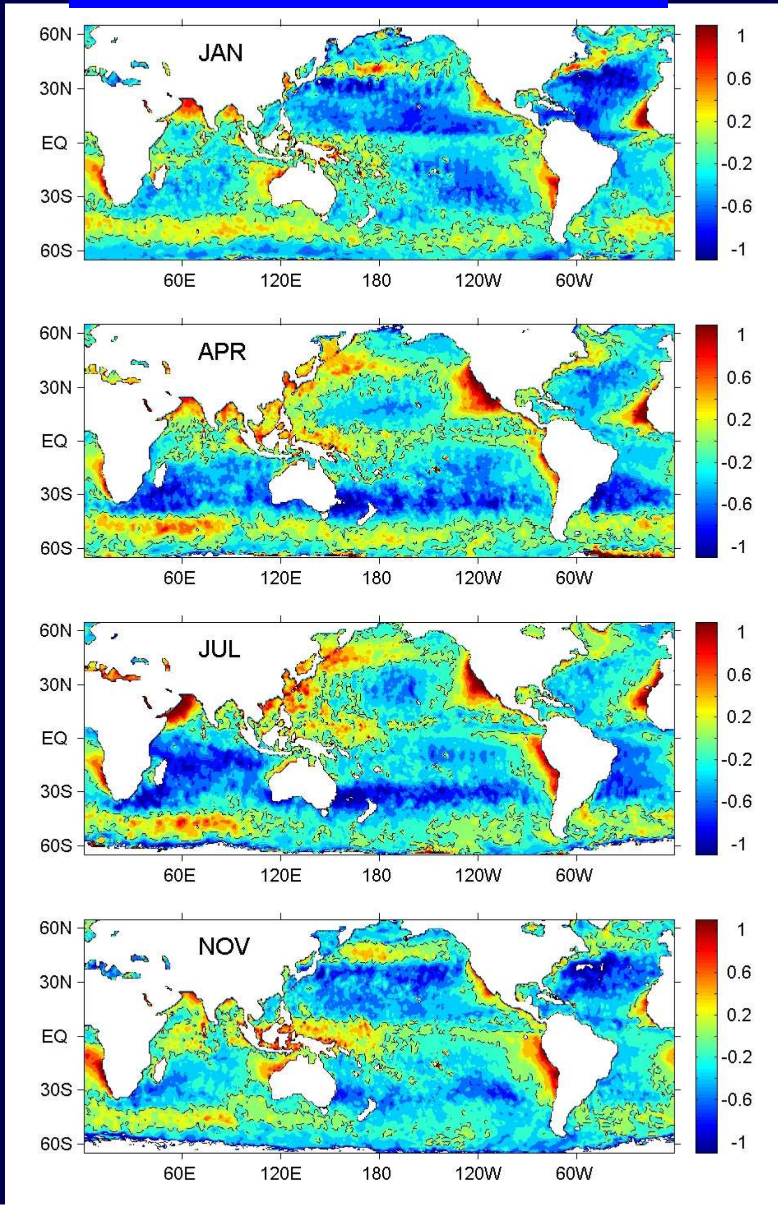


Difference between QuikScat and SSM/I wind speed

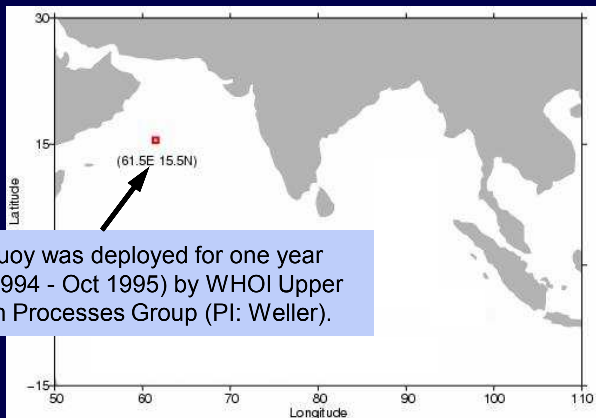
Mean differences



Seasonal dependence



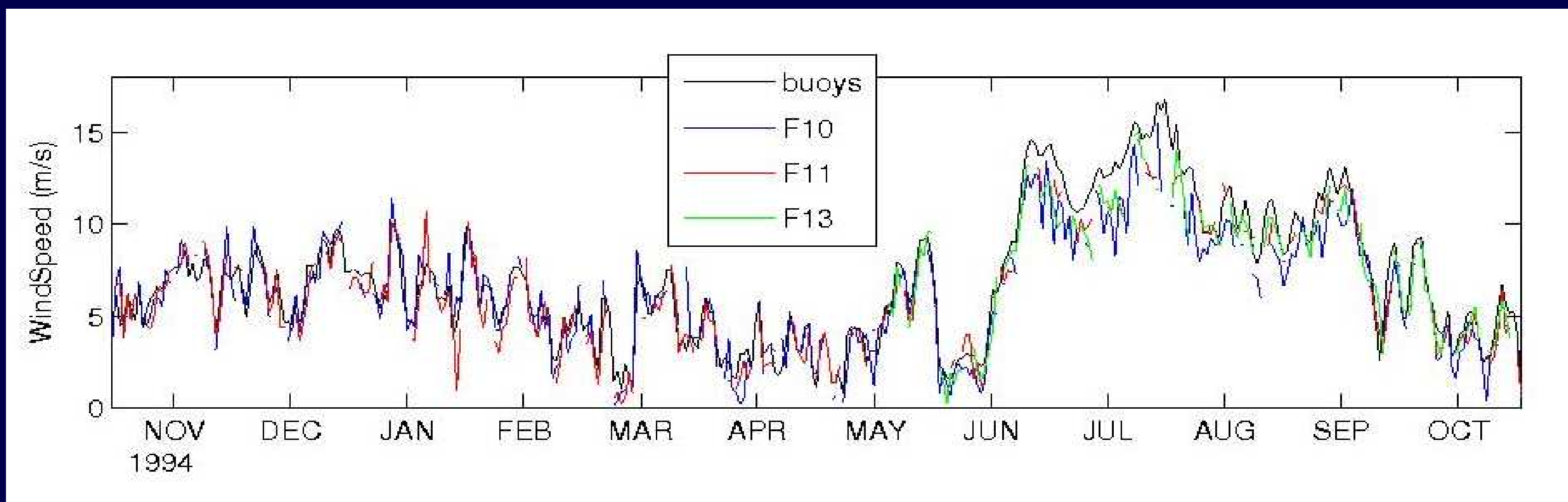
SSM/I comparison with buoy measurements



The buoy was deployed for one year (Oct 1994 - Oct 1995) by WHOI Upper Ocean Processes Group (PI: Weller).

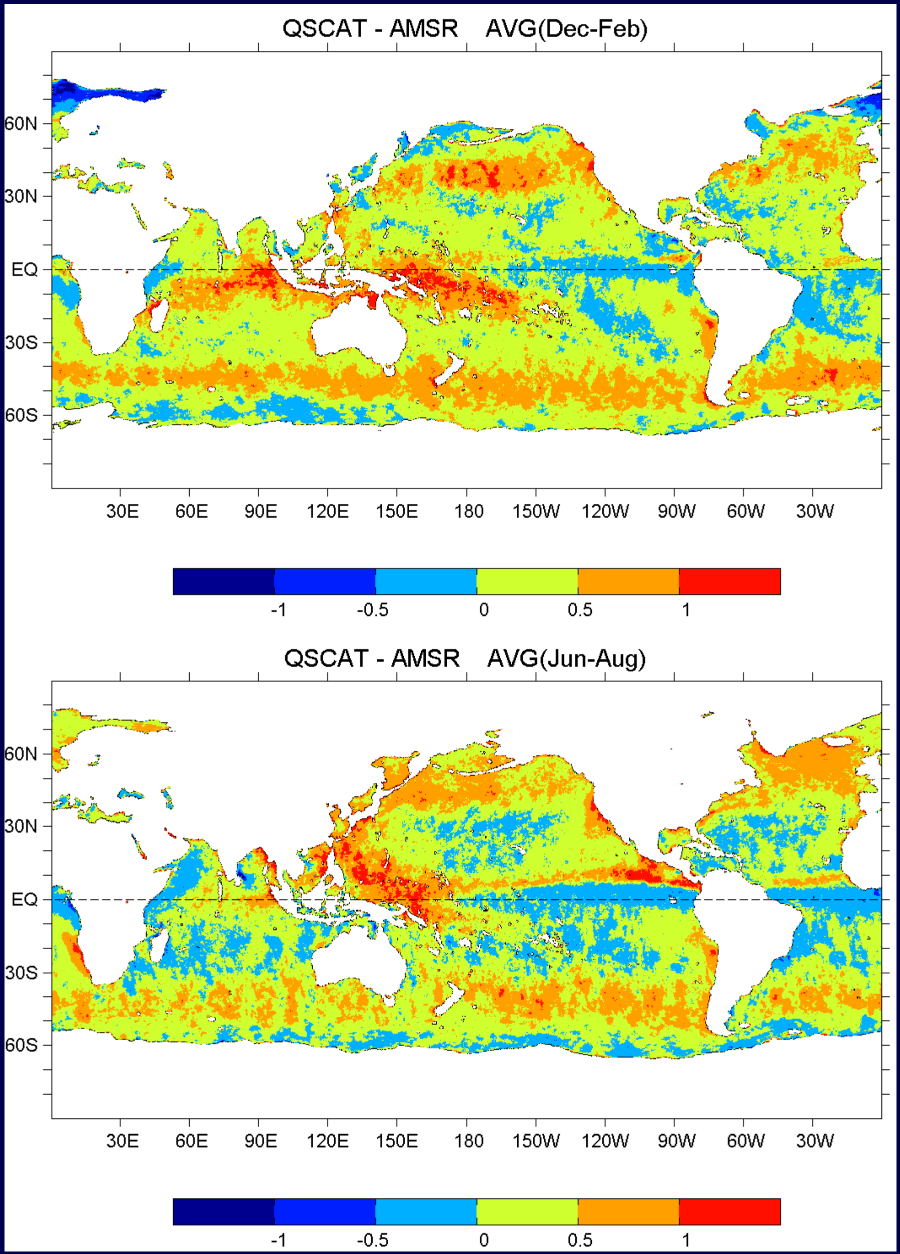
Statistics based on daily values (Jun-Aug)

	Buoy	F10	F11	F13
Mean	**12.73**	**11.76**	**11.61**	**11.58**
Diff	**----**	**–1.97**	**–1.12**	**–1.31**
STD	**----**	**2.26**	**1.55**	**1.74**



Wind speeds from the three SSM/I sensors are all biased low during the southwest monsoon (Jun-Aug) – the time that features **strong wind, humid air, and lower SST.**

AMSR versus QuikSCAT



Summary and Upcoming Activities

1) How have the global surface winds been changing?

- Wind speed has been increasing in tandem with increasing SST.
- Climate impacts:

  # 1: ocean evaporation and global hydrological cycle

  # 2: the wind-stress curl and the wind-driven gyre circulation.

  # 3: wind-wave??

➢ **We are investigating the cause of change in global wind fields, the linkage to global SST change, and the climate implications.**

2) Why is there a need for a synthesized global product?

- NWP products are not reliable to represent long-term variability
- Different sensors have different biases.

➢ **We are developing a multi-decade time series of global vector wind fields through using bias control and objective synthesis.**

3) What are to be delivered?

➢ A time series of global vector wind fields over the past 50 years

➢ A knowledge of error characteristics in different sensors and different sources.

➢ An enhanced understanding of the climate behavior of the past, present, and future global wind stress and stress curl fields.

Integrated research activities

The project website at http://oaflux.whoi.edu/ will provide a comprehensive global analysis of ocean surface forcing fields that includes:

— Wind, wind stress, and stress curl (this project)

— Latent, sensible, short- and longwave radiation heat fluxes (NOAA)

— E–P fluxes (in collaboration with NCEP/CPC CMAP Precipitation)