The WHOI OAFlux Project

Objectively Analyzed Air-Sea Fluxes (OAFlux)
for improved representation of short and long-term changes
in global ocean heat, freshwater, and momentum fluxes

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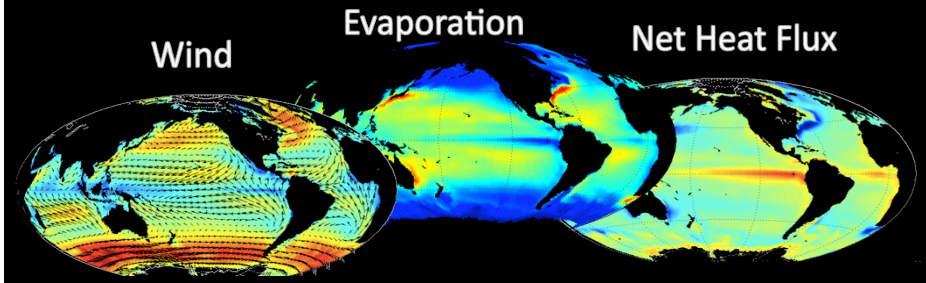


WCRP Open Science Conference
Denver, Colorado
October 24-28, 2011

The OAFlux Project: Methodology and Strategy

Global air-sea fluxes of heat, freshwater, and momentum are computed from bulk flux parameterizations using observed/modeled air-sea variables as inputs.

Existing Problems

Not all flux-related variables can be observed by satellites.

All data have errors, particularly the reanalyzed variable fields.

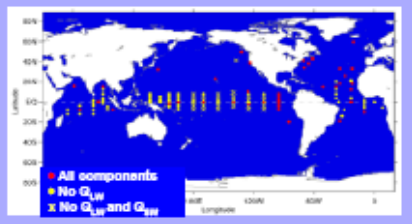
Error in each dataset needs to be quantified for optimization.

Our Remedies

Use atmospheric reanalyses to fill in missing information.

Obtain the best possible estimate through **objective synthesis** of all available sources (least-squares estimation based on the Gauss-Markov theorem)

Global flux buoys as validation database



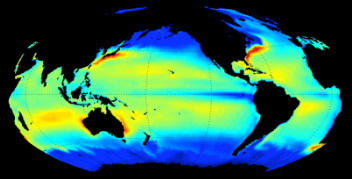
OAFlux = Objectively Analyzed air-sea variables + bulk flux parameterization (COARE3.0)

OAFlux Research Products

Project website: http://oaflux.whoi.edu

Evaporation

Latent and Sensible heat fluxes



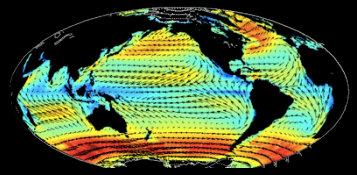
- 1958-present, 1°, daily, monthly
- 1999-present, 0.25°, daily
- Objective synthesis of satellite products (wind speed, SST, qair and Tair) and selected atmospheric reanalysis fields from NCEP, ERA40, and ERA-interim.

Freshwater flux (E-P)

OAFlux evaporation
GPCP precipitation
Smith et al. Reconstructed P

1958 to present (>50 yrs)

Wind and Wind Stress

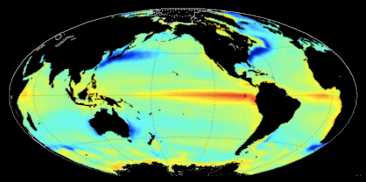


- 1987-present, daily, 0.25°
- 1° analysis is from a spatial average of 0.25°
- Objective synthesis of 11 satellite sensors (SSMI, SSMIS, AMSRE, QuikSCAT, and ASCAT).

Momentum flux

OAFlux wind stress
1987 – present (>23 yrs)

Net Heat flux



Work in progress

- 1983-present, 1°, daily
- Synthesis of satellite products and selected reanalysis fields

Net heat flux

OAFlux latent and sensible
SRB (or ISCCP) surface radiation
1983 – present (>25yrs)

Main questions

- OAFlux is not independent of reanalyses (NCEP, ERA40, ERAinterim).
  - -- How much improvement has OAFlux made?
  - -- How is OAFlux compared to the latest reanalyses (MERRA, CFSR, ERAinterim)?

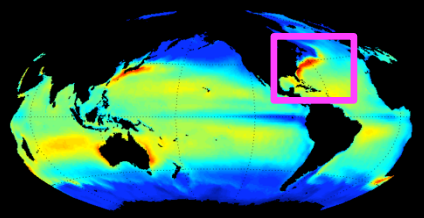
- OAFlux is completely independent of GPCP/Smith and SRB/ISCCP.
  - -- Are they consistent in terms of balancing global water and energy budget?
  - -- What issues need to be explored?

In this talk, the following five aspects are examined:

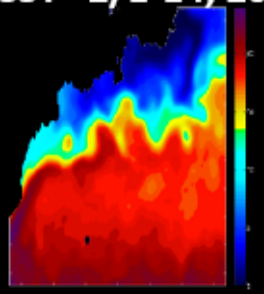
(1) Mesoscale air-sea interactions
(2) Synoptic atmospheric variability
(3) Decadal changes in global near-surface wind fields
(4) Decadal trends in ocean water cycle
(5) Global ocean heat budget

(1) Front-scale air-sea interaction

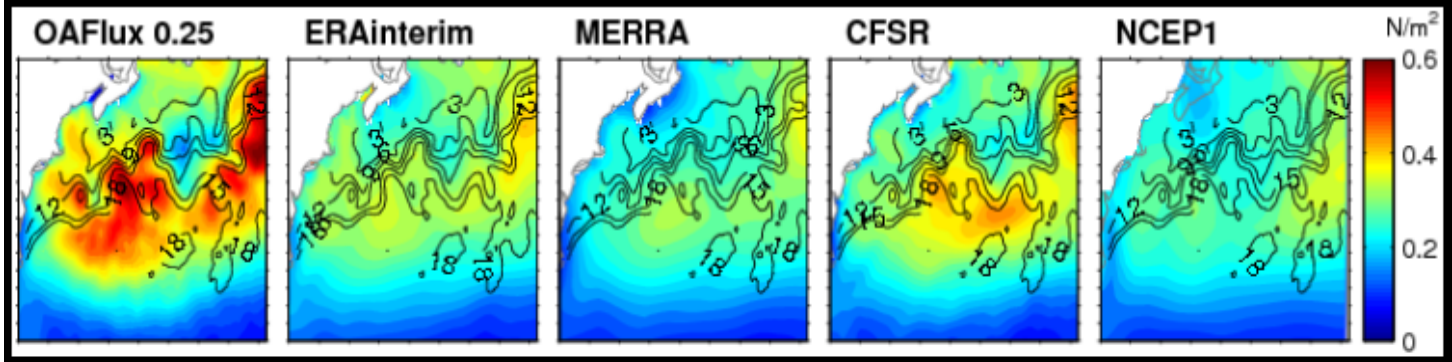
Gulf Stream, A Cold Air Outbreak Event, FEB 1-14, 2007



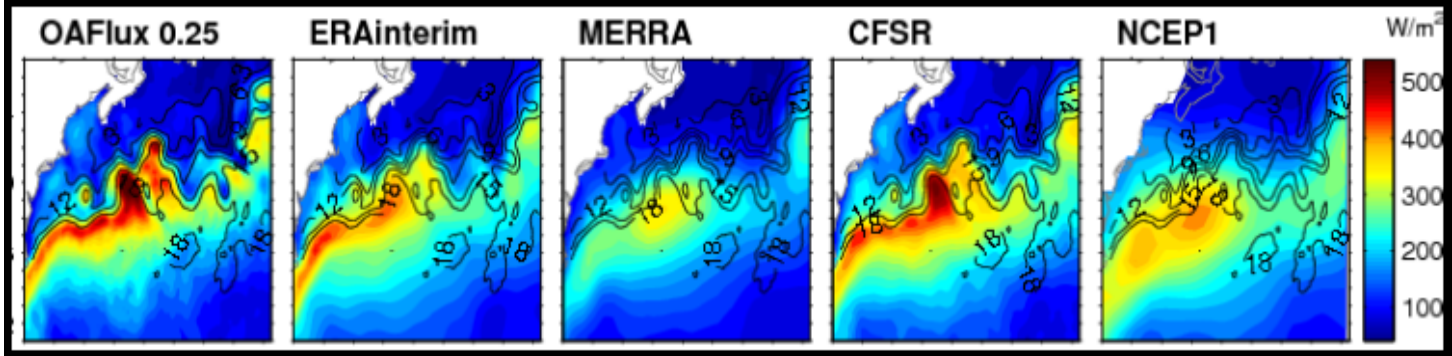
SST 2/1-14, 2007



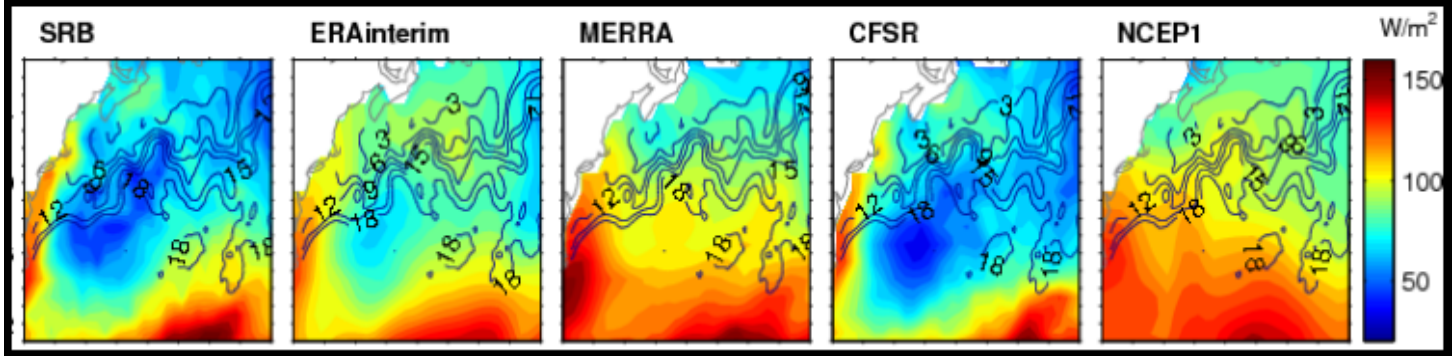
Wind Stress



Latent heat flux



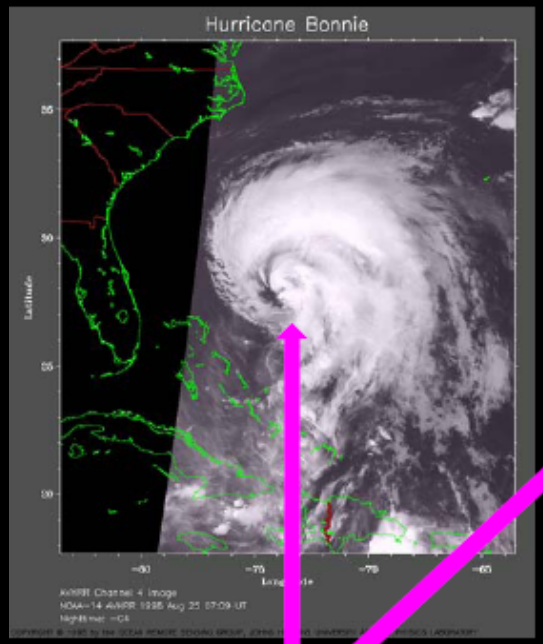
Shortwave Radiation



- Reanalyzed fluxes have a weaker response to the SST fronts than satellite-based analyses.
- CFSR can feel the SST fronts, perhaps due to the benefit of being a coupled system.

(2) Synoptic scale variability

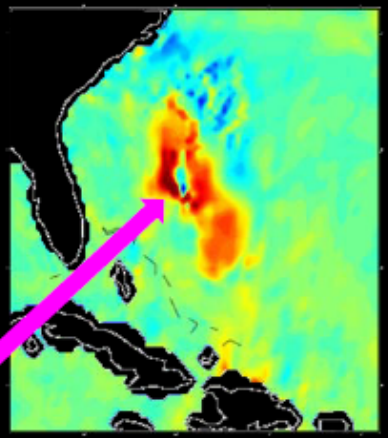
Hurricane Bonnie
25-08-1998



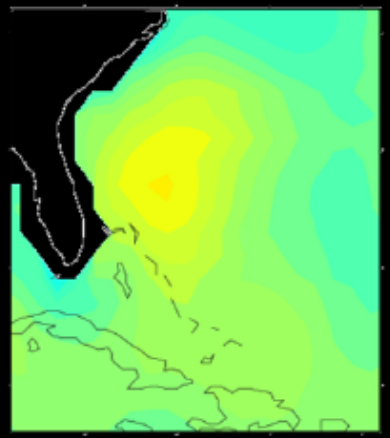
Eye

Near- Surface Wind Convergence

OAFlux 0.25°

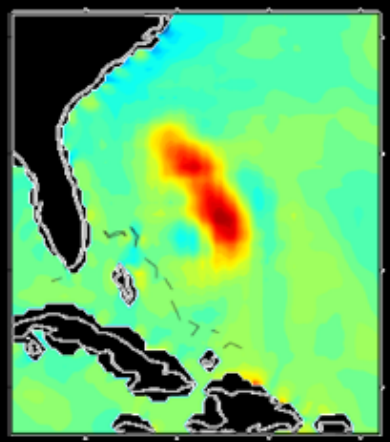


NCEP1

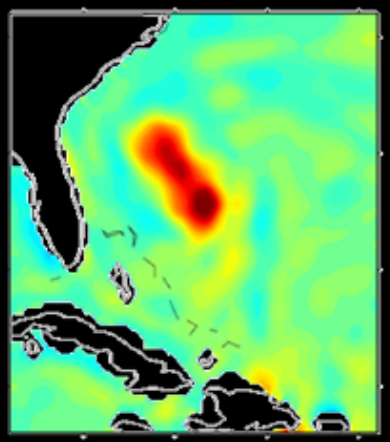


- OAFlux before 1999 is constructed from SSMI wind speed with wind direction from reanalysis as initial guess.
- None reanalysis winds reproduce the eye of the storm.

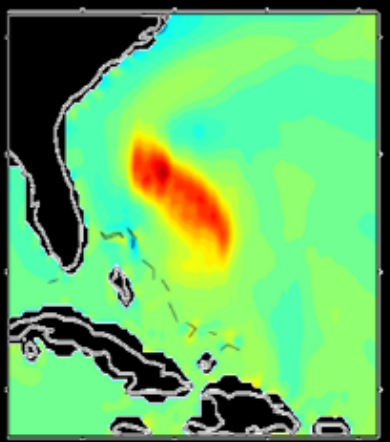
ERAinterim



MERRA



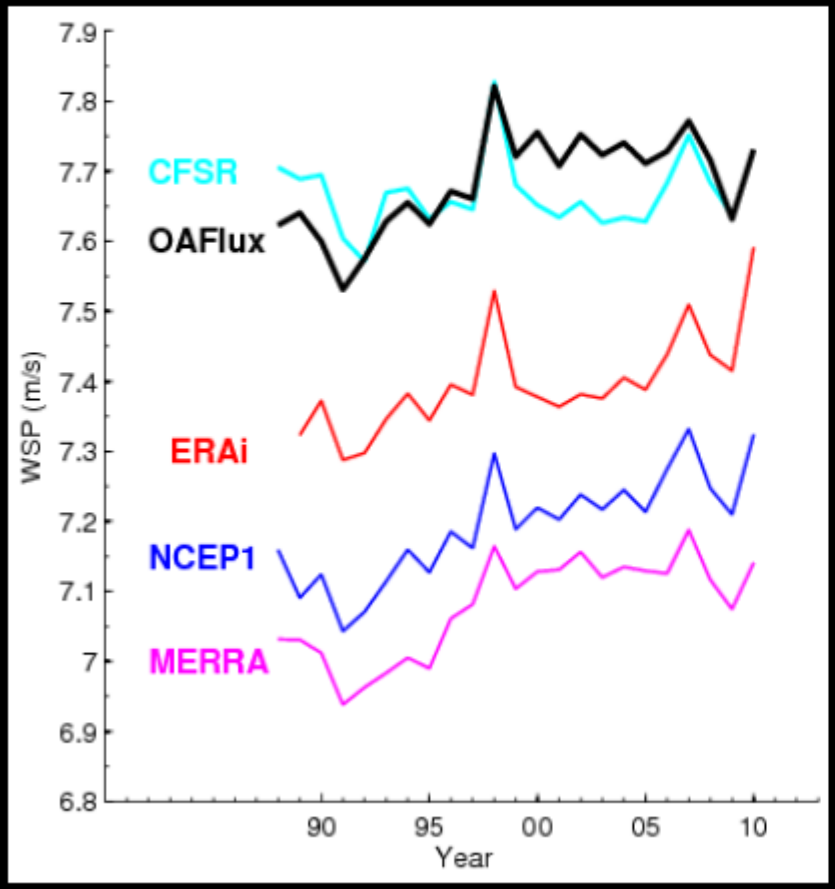
CFSR



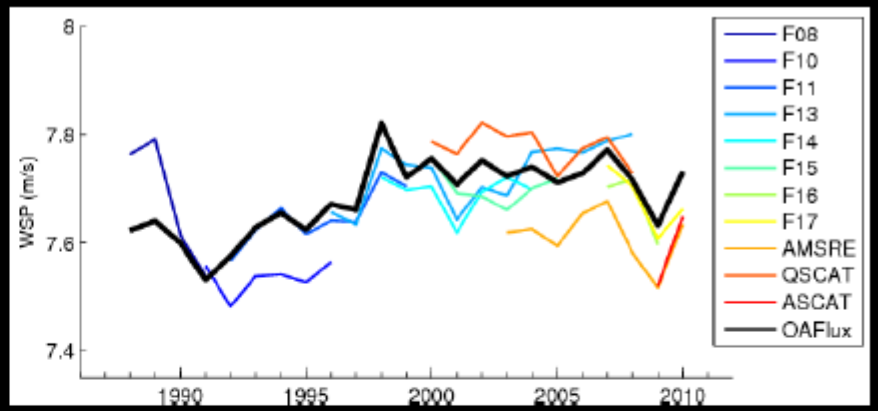
ms^{-1}/100km

(3) Decadal changes in near-surface wind

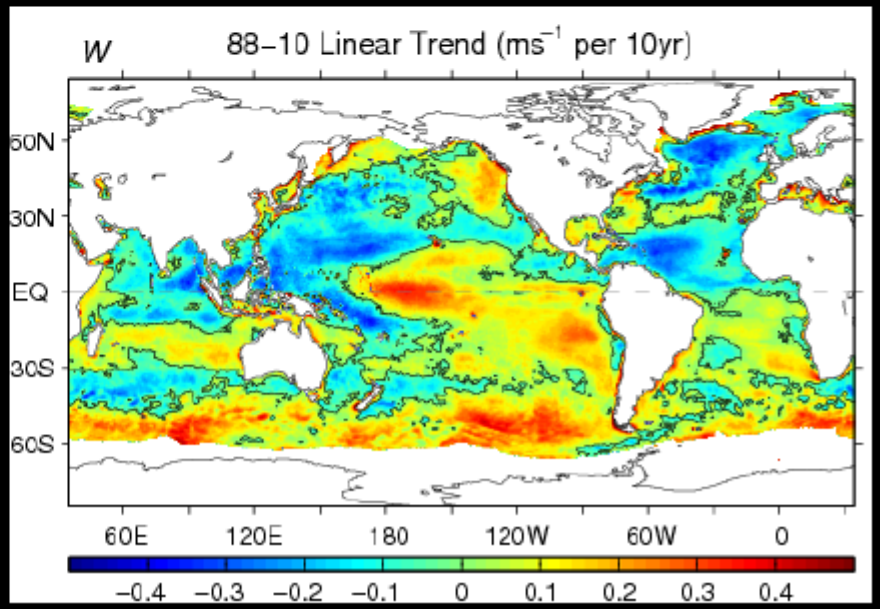
OAFlux versus Reanalyses

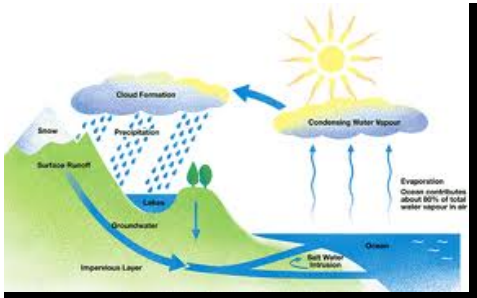


OAFlux 0.25 is a synthesis of 11 sensors



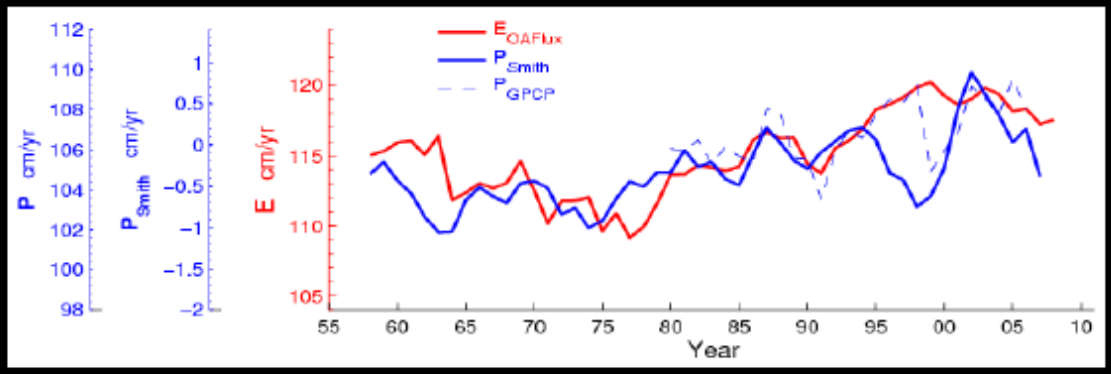
OAFlux Linear trends



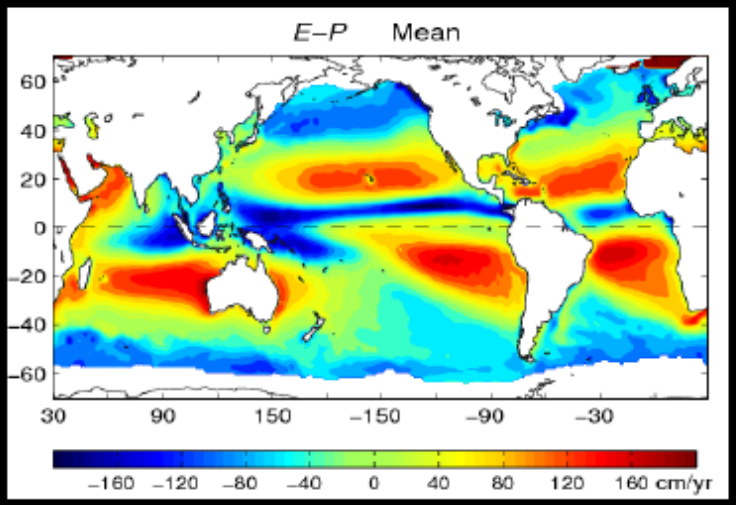


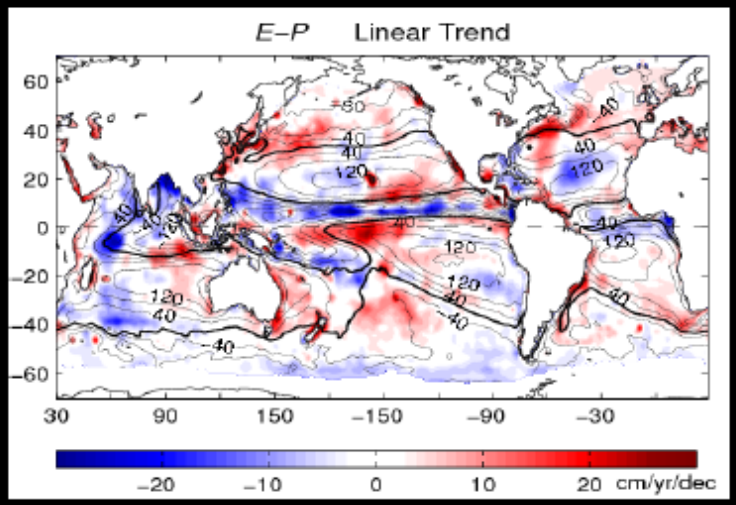
(4) Decadal trends in ocean water cycle

Acceleration of the ocean water cycle in the past 50 yrs may be part of multi-decadal variability.



Ocean Freshwater flux ($E_{OAFlux} - P_{GPCP}$) 1979-2008





Are dry regions getting drier? Not really.

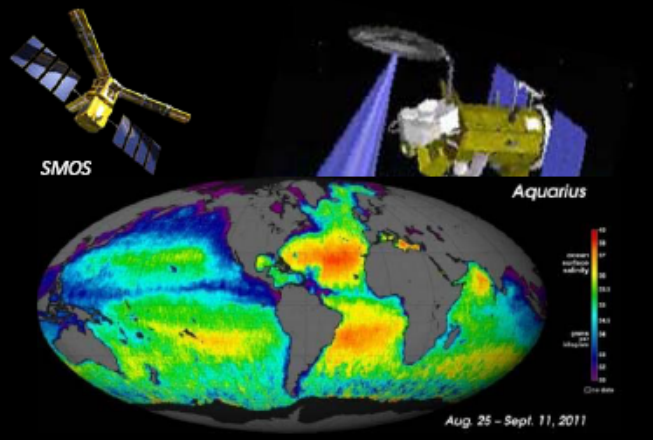
Are wet regions getting wetter? In the tropics.

The Water Cycle & Ocean Salinity:

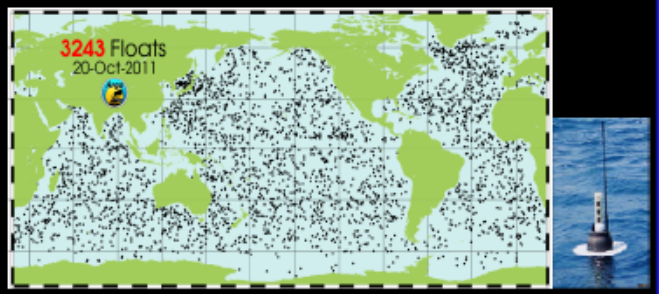
Can the oceans be a rain gauge?

Salinity Observations

From Space ...



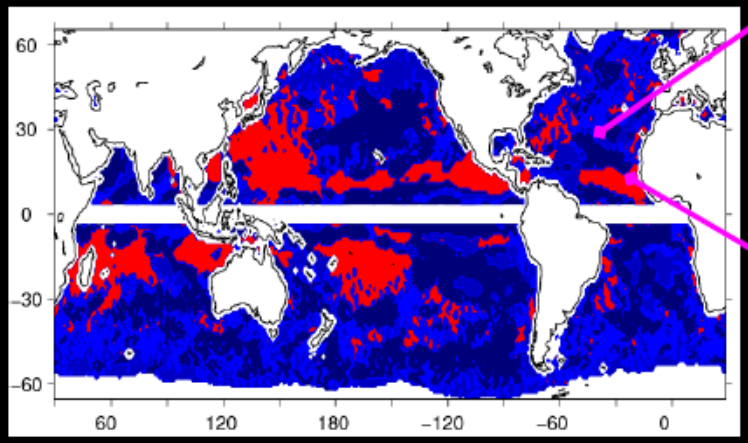
From the Ground ...

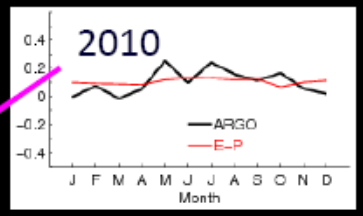


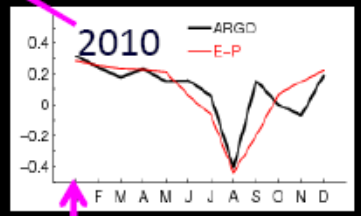
http://www.argo.ucsd.edu

Salinity Change = (E – P) + advection + mixing + etc

"Rain-gauge regime" based on WOA







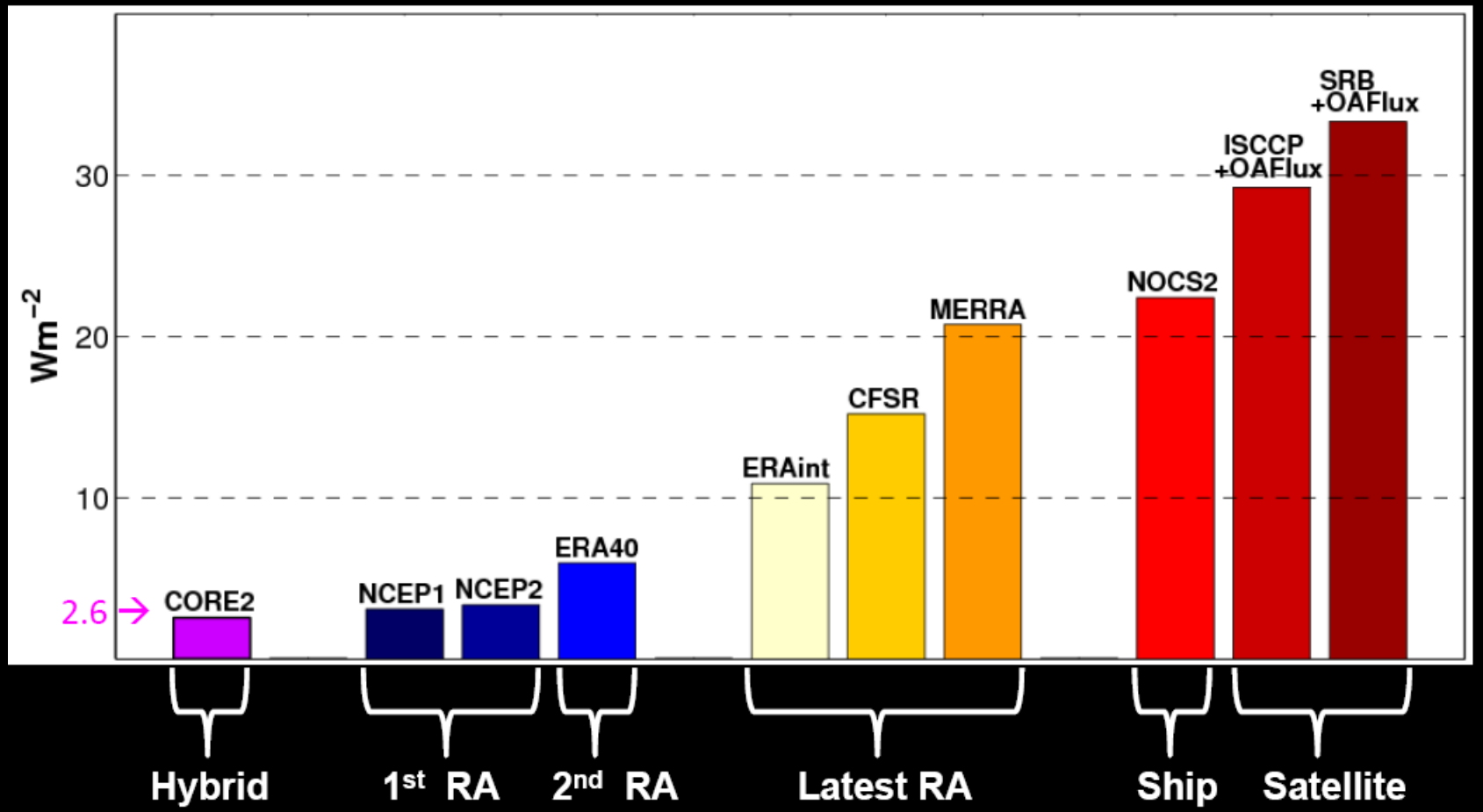
Red areas: salinity change is governed by E-P.

Blue areas: salinity change is governed by ocean dynamics.

There is a broad consistency between E-P and ARGO-based salinity, showing the promise of the tropical oceans as rain gauge.

(5) Global ocean heat budget

How much heat is the global ice-free ocean gaining?



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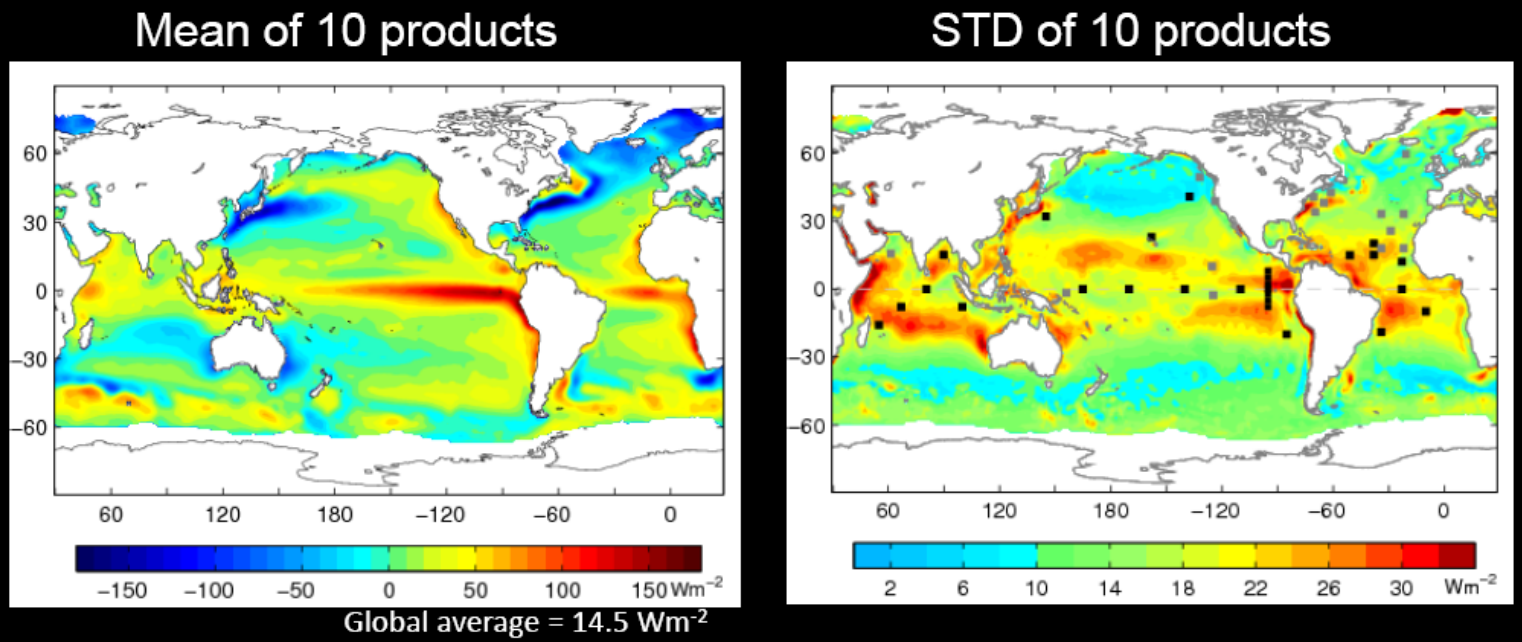
Differences in net heat flux products



- The difference in the 10 mean Qnet products is mostly larger than 10 Wm^{-2} (the desired accuracy)
- Turbulent (Latent+Sensible) and Radiation (Long+Shortwave) have equal contribution to the total STD.
- Buoy observations for Qnet are extremely limited.

The Road Ahead: close collaboration

- with improved and expanded ocean time series sites (e.g. OOI; PI: Weller),
- between atmospheric reanalyses and satellite-based analyses,
- between atmospheric scientists and oceanographers.

Summary

- **OAFlux versus Reanalyzed fluxes:**

-- The OAFlux synthesis of satellite observations together with the selected reanalysis fields has led enhanced representation of meso-scale and synoptic scale variability, and enhanced depiction of decadal and longer-term variations.

-- The latest reanalyses (MERRA, CFSR, ERAinterim) show improvement over the first generation, but details are still significantly lacking when compared to satellite-based flux analyses.

- **OAFlux versus GPCP/Smith Precipitation and SRB/ISCCP radiation**

-- There is a broad consistency between OAFlux and GPCP/Smith, showing that the intensification of the water cycle in the past 50 years might be part of multidecadal variability. Detailed pattern of changes differs from the theoretical projection.

→ Integration with ocean salinity observations

-- There is large heat imbalance in the latest reanalyses and in the combined satellite flux analyses.

→ Close collaboration

- with improved and expanded ocean time series sites,
- between atmospheric reanalyses and satellite-based flux analyses, and
- between atmospheric scientists and oceanographers.

We thank the supporting grants from
NASA ocean vector wind science team
NOAA Ocean Climate Observations program

The presentation is developed from the following publications:

Yu, L., 2011: Strengthening of global near-surface winds as ocean warms. *Deep Sea Research II,* Special Collection of Satellite Oceanography and Climate Change. *Sub Judice*.

Yu, L., 2011: A global relationship between the ocean water cycle and near-surface salinity. *Journal of Geophysical Research – Oceans*. J. Geophys. Res., 116, C10025, doi:10.1029/2010JC006937.

Yu, L., and X. Jin, 2010: Satellite-based global ocean vector wind analysis by the Objectively Analyzed Air-sea Fluxes (OAFlux) Project: Establishing consistent vector wind time series from July 1987 onward through synergizing microwave radiometers and scatterometers. WHOI OAFlux Technical Report.

Schanze, J. J., R. W. Schmitt, and **L. Yu**, 2010: The global oceanic freshwater cycle: A state-of-the-art quantification. *Journal of Marine Research*, **68**, 569-595.

Joyce, T., Y-O. Kwon, and **L. Yu**, 2009: On the relationship between path shifts in the Gulf Stream and the Kuroshio Extension and synoptic wintertime atmospheric variability. *J. Climate.* **22**, 3177-3192.

Yu, L., X. Jin, and R. A. Weller, 2008: Multidecade Global Flux Datasets from the Objectively Analyzed Air-sea Fluxes (OAFlux) Project: Latent and sensible heat fluxes, ocean evaporation, and related surface meteorological variables. Woods Hole Oceanographic Institution, OAFlux Project Technical Report. OA-2008-01, 64pp. Woods Hole. Massachusetts.

Yu, L., 2007: Global variations in oceanic evaporation (1958-2005): The role of the changing wind speed. *Journal of Climate*, **20**, 5376–5390.

Yu, L., and R. A. Weller, 2007: Objectively Analyzed air-sea heat Fluxes for the global ice-free oceans (1981–2005). *Bull. Ameri. Meteor. Soc.*, **88**, 527–539.