Scatterometer and Evaporation:
Past, Present, and Future Connections

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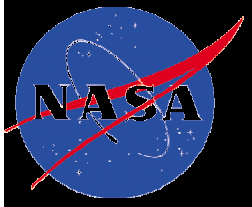
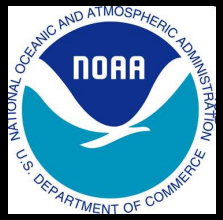
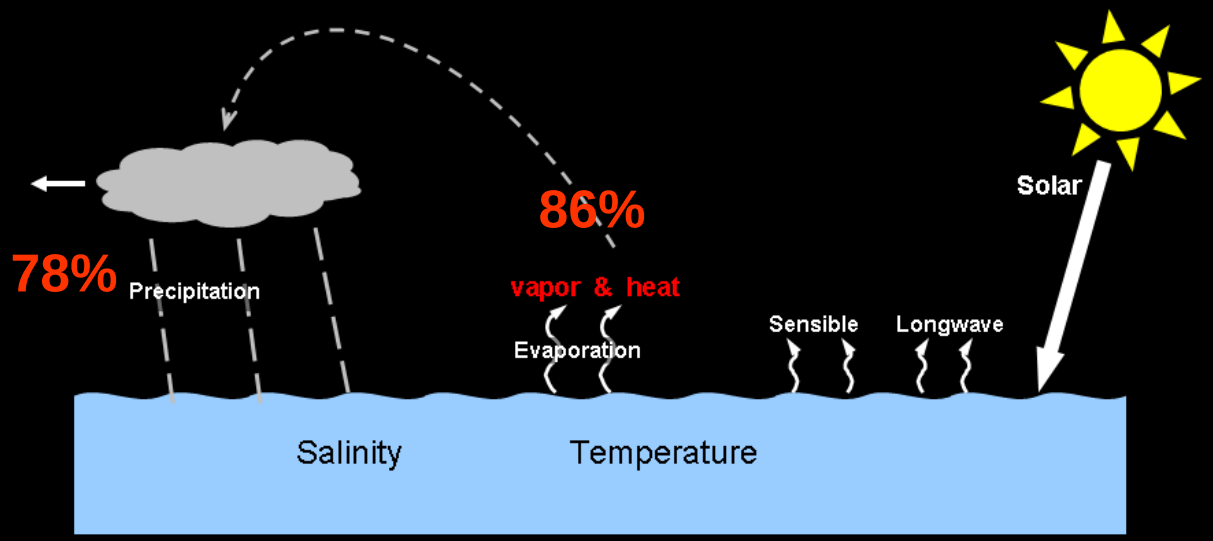




Workshop on "Scatterometry and Climate"
Arlington, Virginia. August 19 - 21, 2009

Evaporation = heat + vapor



Evaporation rate (E) and *latent heat (Q_{LH})* are interchangeable:

$$E = Q_{LH}/(\rho_w L_e)$$

where ρ_w is the density of seawater and L_e is latent heat of vaporization

Net heat budget = Solar – Longwave – Latent heat – Sensible heat

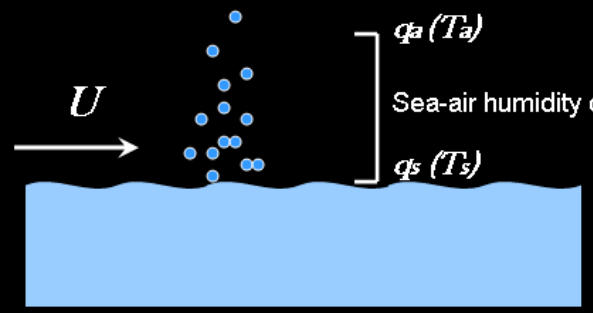
Freshwater budget = Precipitation – Evaporation + runoff

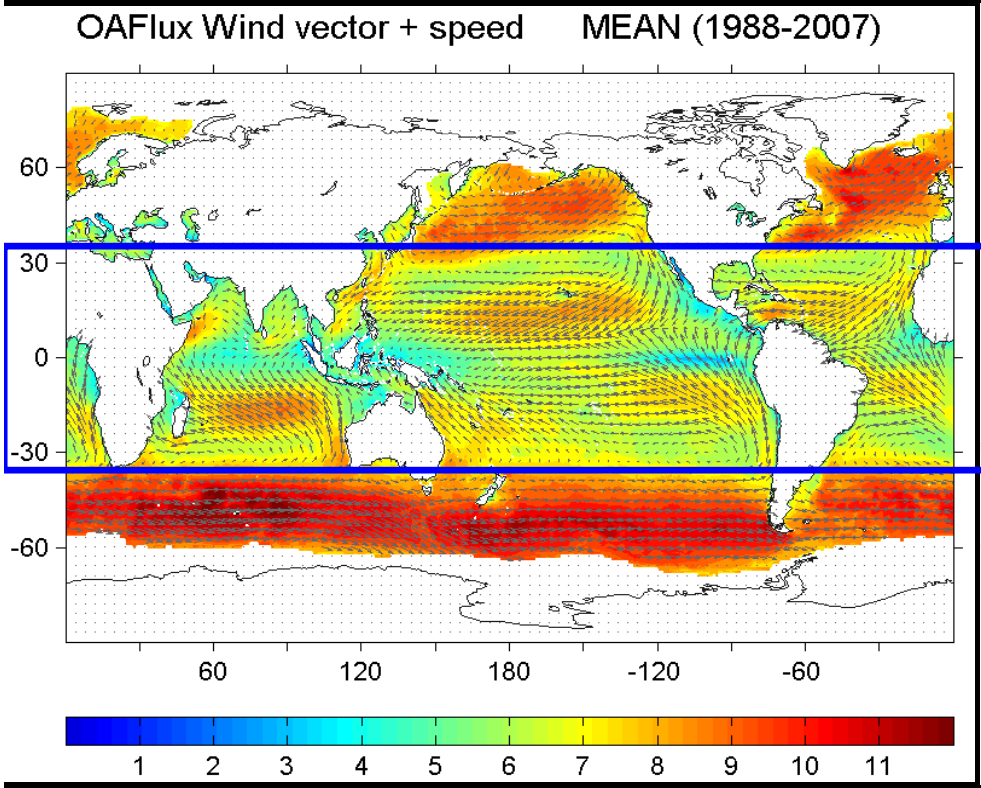
Evaporation connects hydrological \cycle with global heat budget

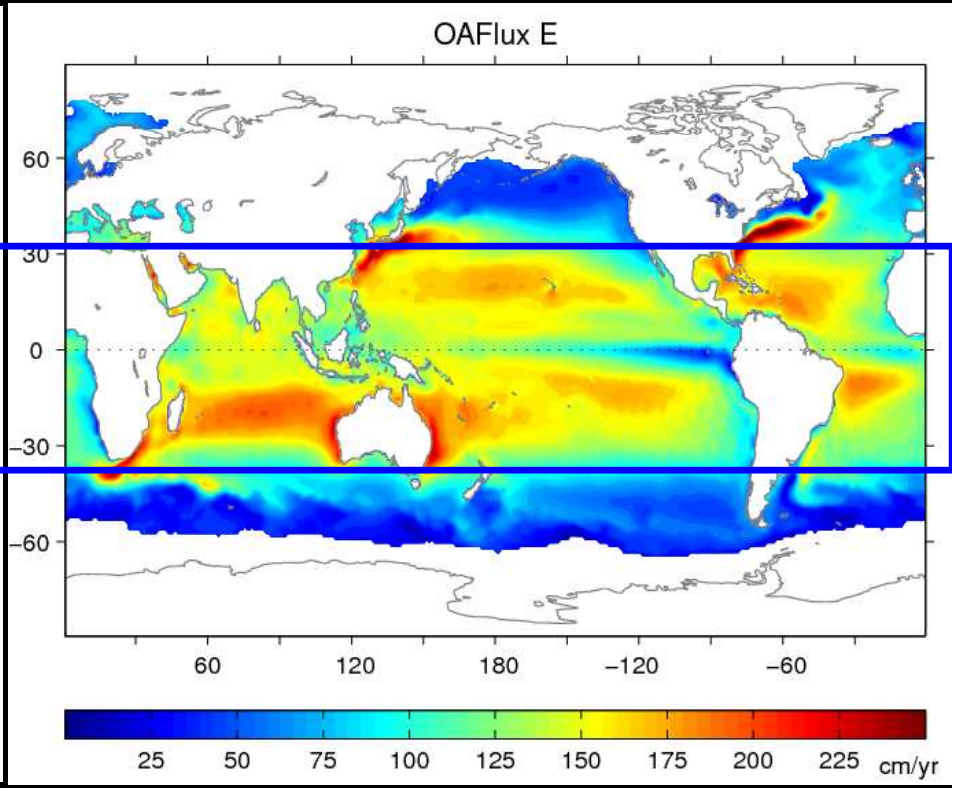
Wind and Evaporation

$$E \sim U \bullet (q_s - q_a)$$

Evaporation — Wind Speed — Sea-air humidity diff.







Topics of this presentation

(1) Past: Important role of ocean wind in climate variability of evaporation

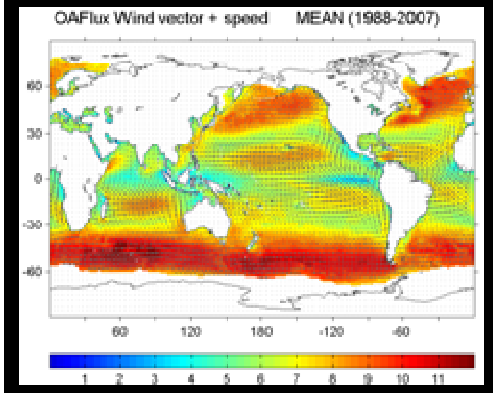
(2) Present: Uncertain issues relating to ocean wind & evaporation estimates

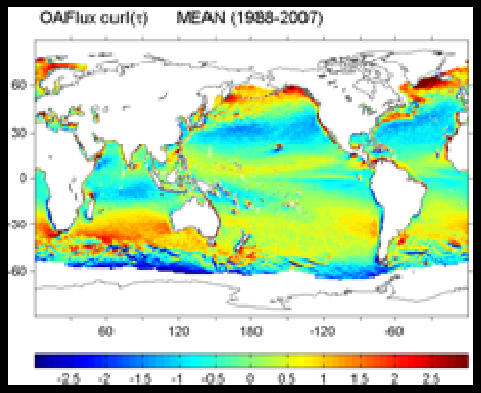
(3) Future: Potential improvement in global water & heat budget estimates from enhanced scatterometer observing capacity

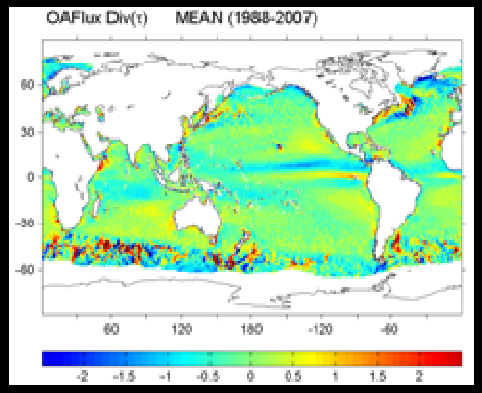
The presentation uses data products developed by WHOI OAFlux Project

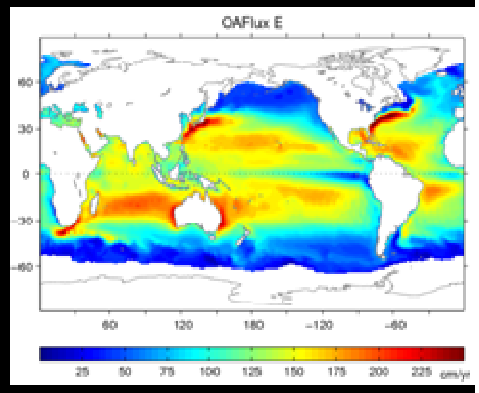
(OAFlux: Objectively Analyzed Air-sea Fluxes http://oaflux.whoi.edu/)

1. Vector Wind products: 1987 – present (20+ years)
2. Ocean evaporation: 1958 – present (50+ years)
3. Latent heat flux and sensible heat flux products: 1958 – present (50+ years)









How is the OAFlux vector wind produced?

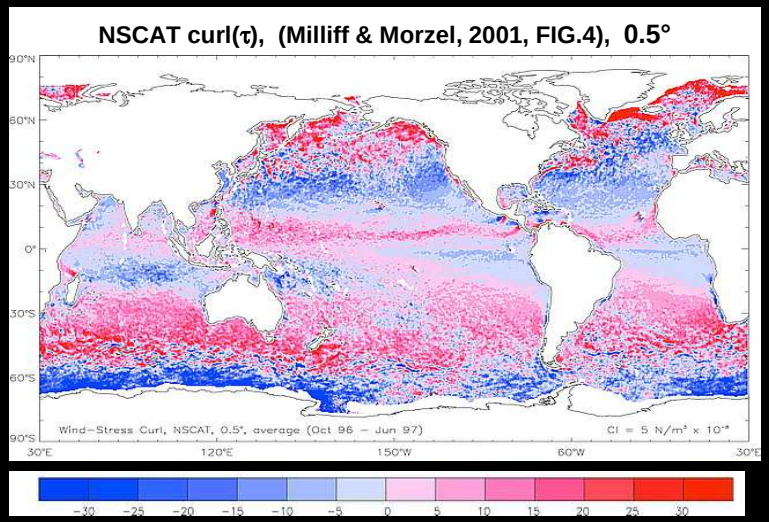
OAFlux Vector Wind products: 1987 – present

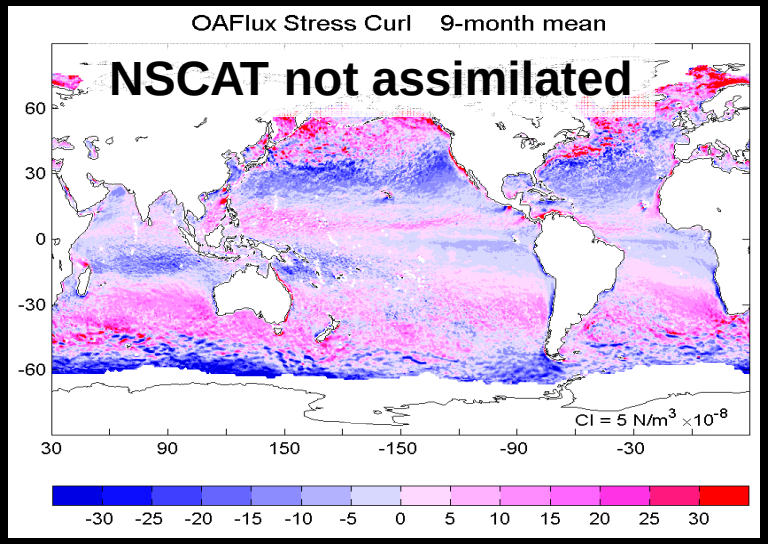
– objective blending of wind retrievals from scatterometers & radiometers with wind directions from NWP reanalyses as initial guess.

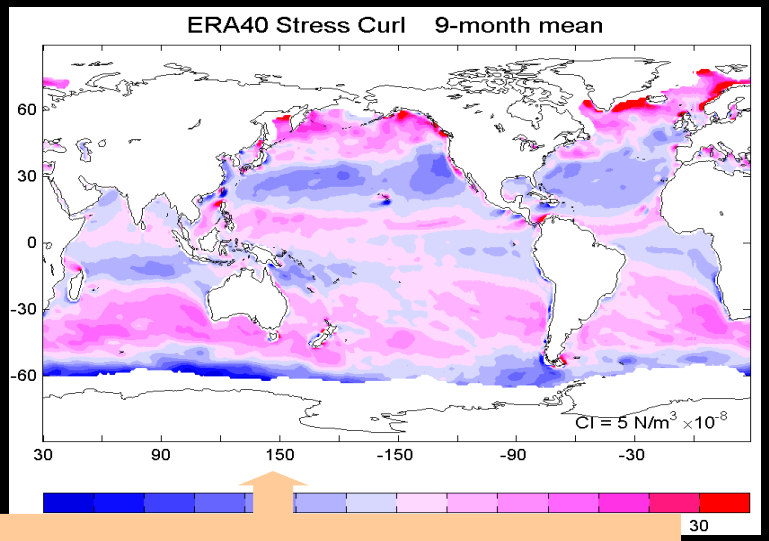
SSMI, AMSR-E, QuikSCAT provided by Frank Wentz & Remote Sensing Systems

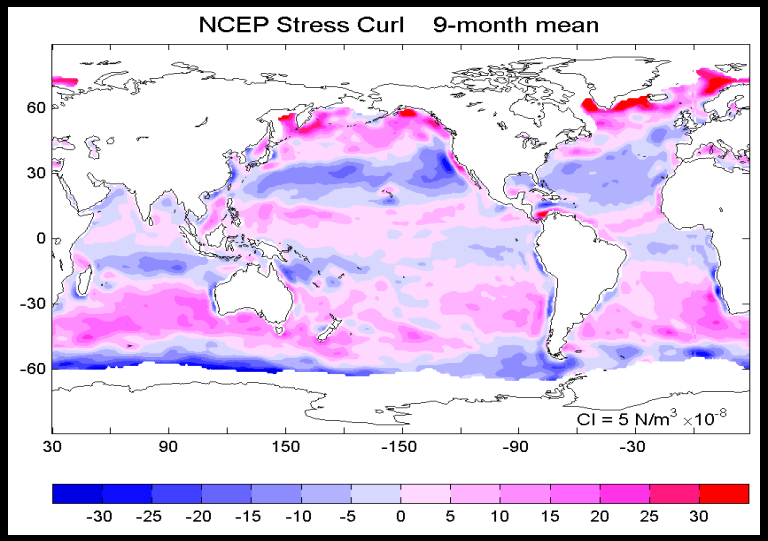
OAFlux vector wind ≠ NWP winds

OAFlux uses NWP wind directions as initial guess, and adjusts the wind directions using the relationship of wind speed and components and a set of kinematic constraints









ERA40 assimilates SSM/I wind speed

OAFlux: Pre-QuikSCAT versus QuikSCAT years

OAFlux

Pre-QuikSCAT

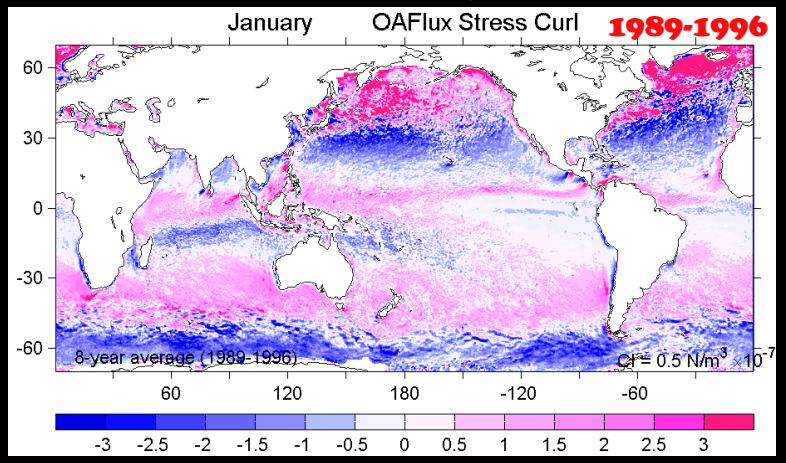
Objective blending of radiometer wind speed and NWP wind directions

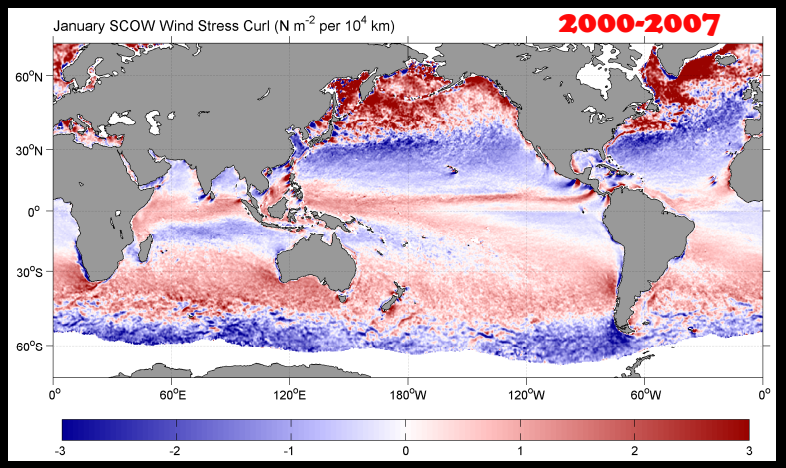
SCOW

QuikSCAT

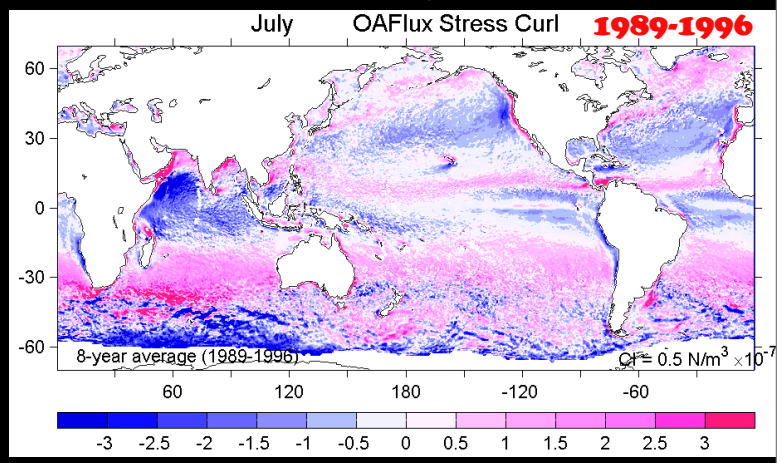
(Risien & Chelton)

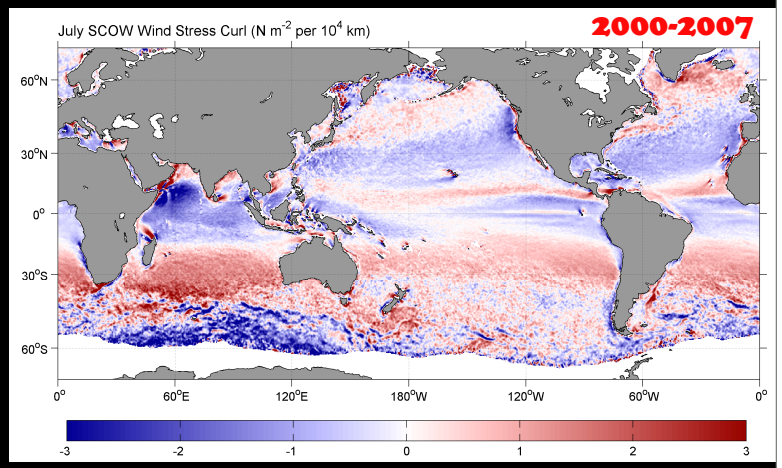
January





July

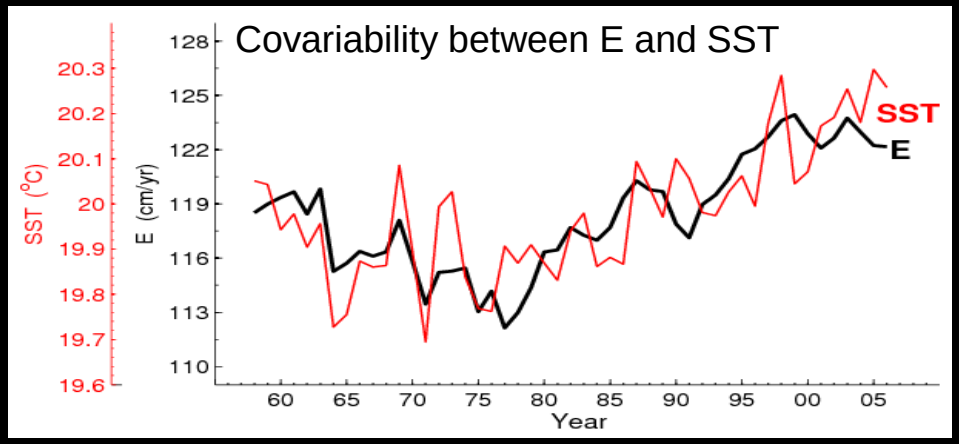




SCOW: Scatterometer Climatology of Ocean Wind (http://numbat.coas.oregonstate.edu/scow/)

Wind and Evaporation:

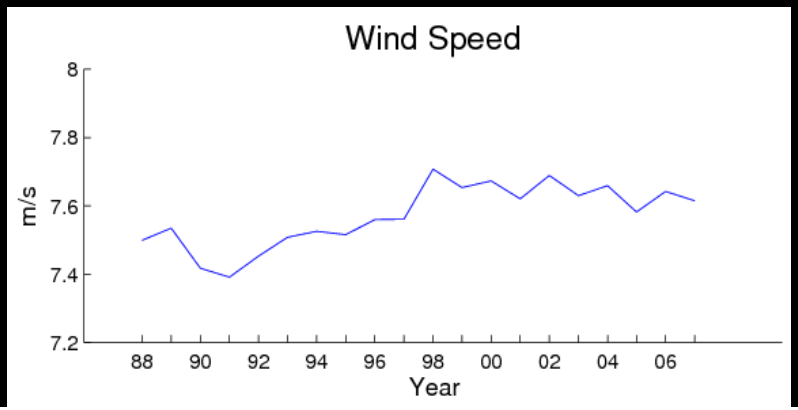
How were the two related during global warming of past decades?



Yu, 2007
Yu and Weller 2007
Yu et al. 2008

Warmer climate, more evaporation (e.g. Held and Soden 2006; Wentz et al. 2007)
Mechanism?

- Warmer atmosphere holds more moisture as indicated by the Clausius-Clapeyron (C-C) equation
- **However,** wind speed has been increasing over past 20+ years of satellite record.



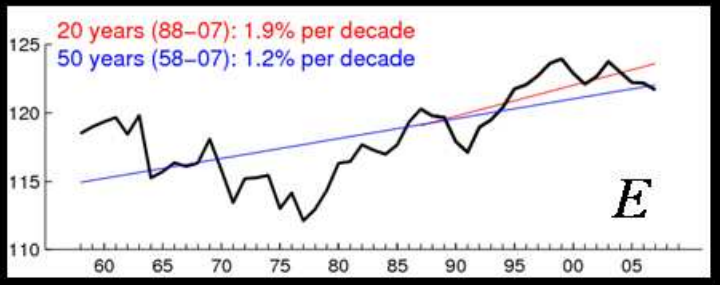
(Yu 2009)

Impact of the changing wind on evaporation – perspective from the OAFlux 50-year time series

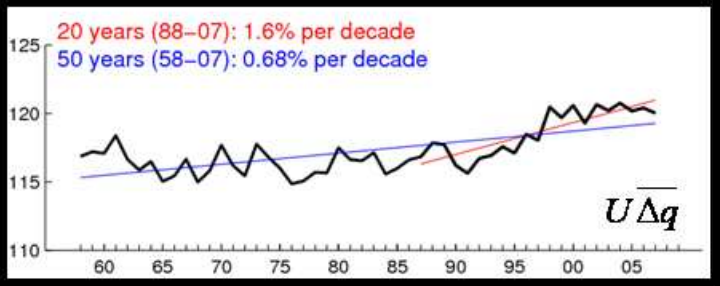
$$E \sim U \bullet (q_s - q_a)$$

Evaporation — Wind Speed — Sea-air humidity diff.

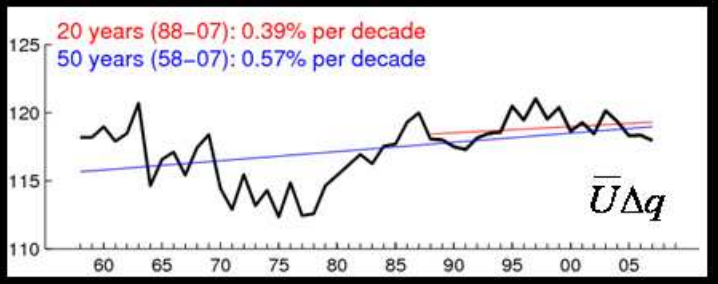
Trend in global *E*



Effect of Wind (U)

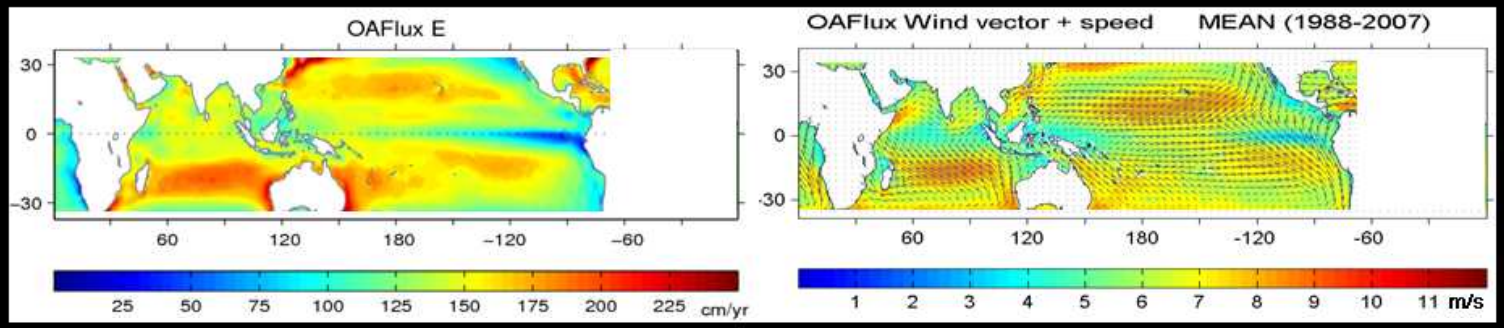


Effect of humidity (Δq)

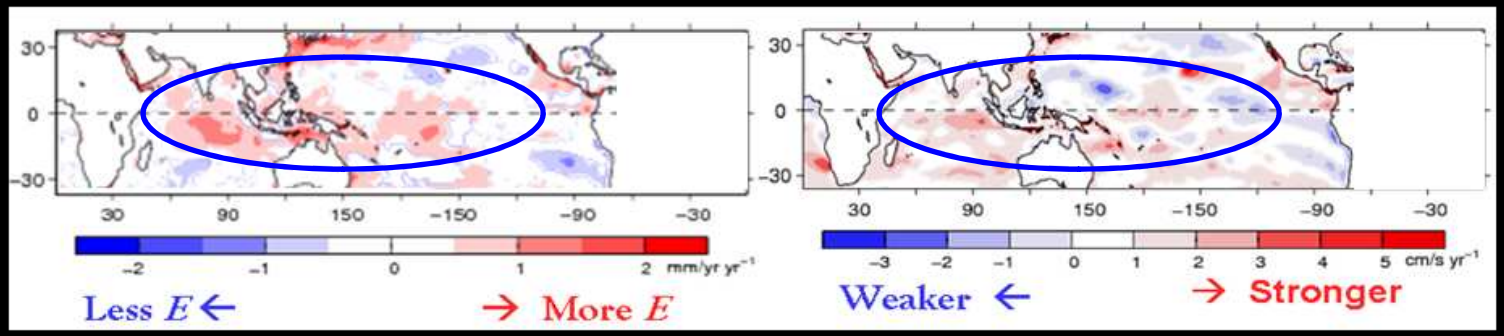


Coherent Changes in E and Wind: tropical oceans

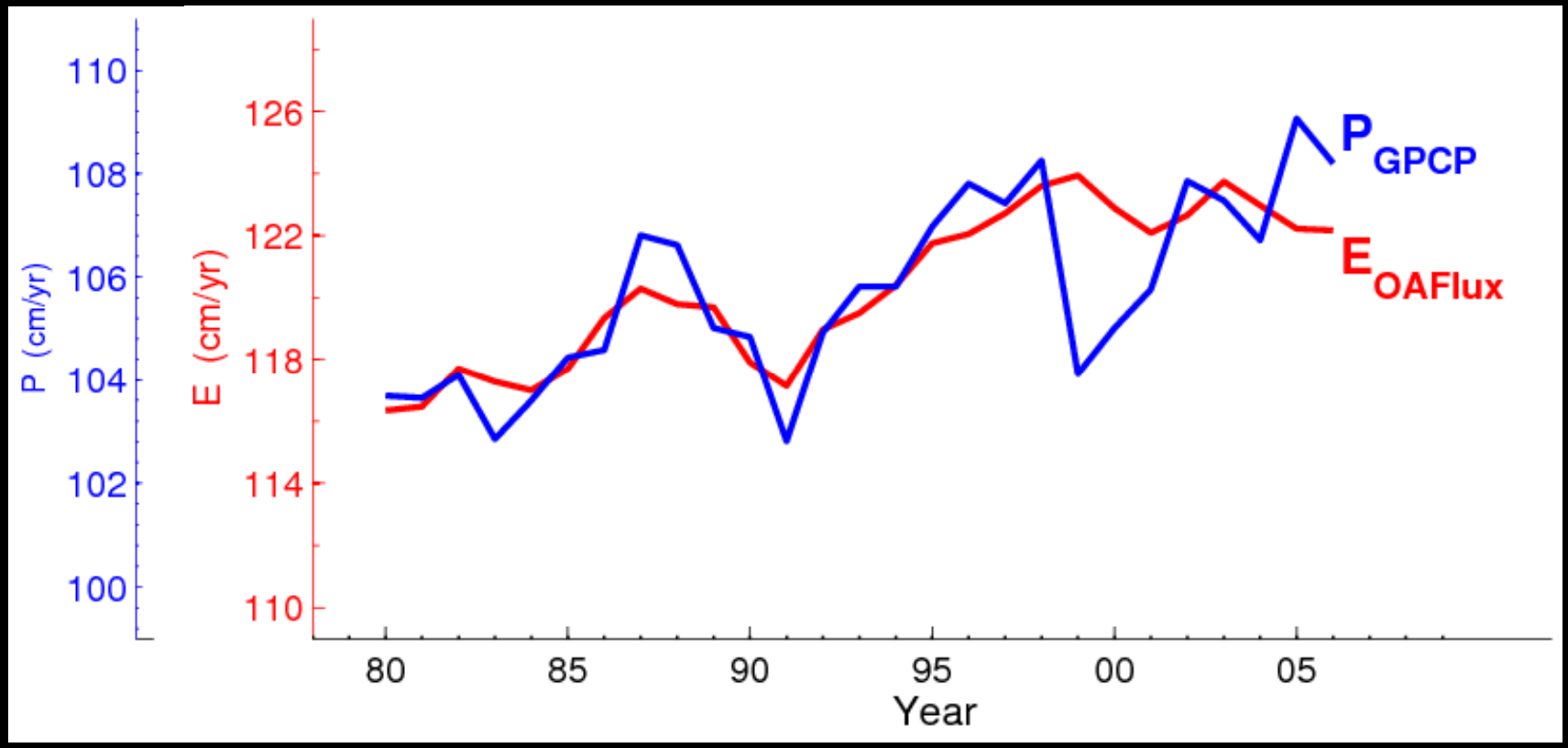
MEAN



LINEAR TRENDS



Is the rate of increase in E too large? Apparently not.



OAFlux and GPCP are independent data sets

How can evaporation (heat & water budget) be improved with the enhancement of scatterometer?

Two major uncertainties regarding the changing climate:

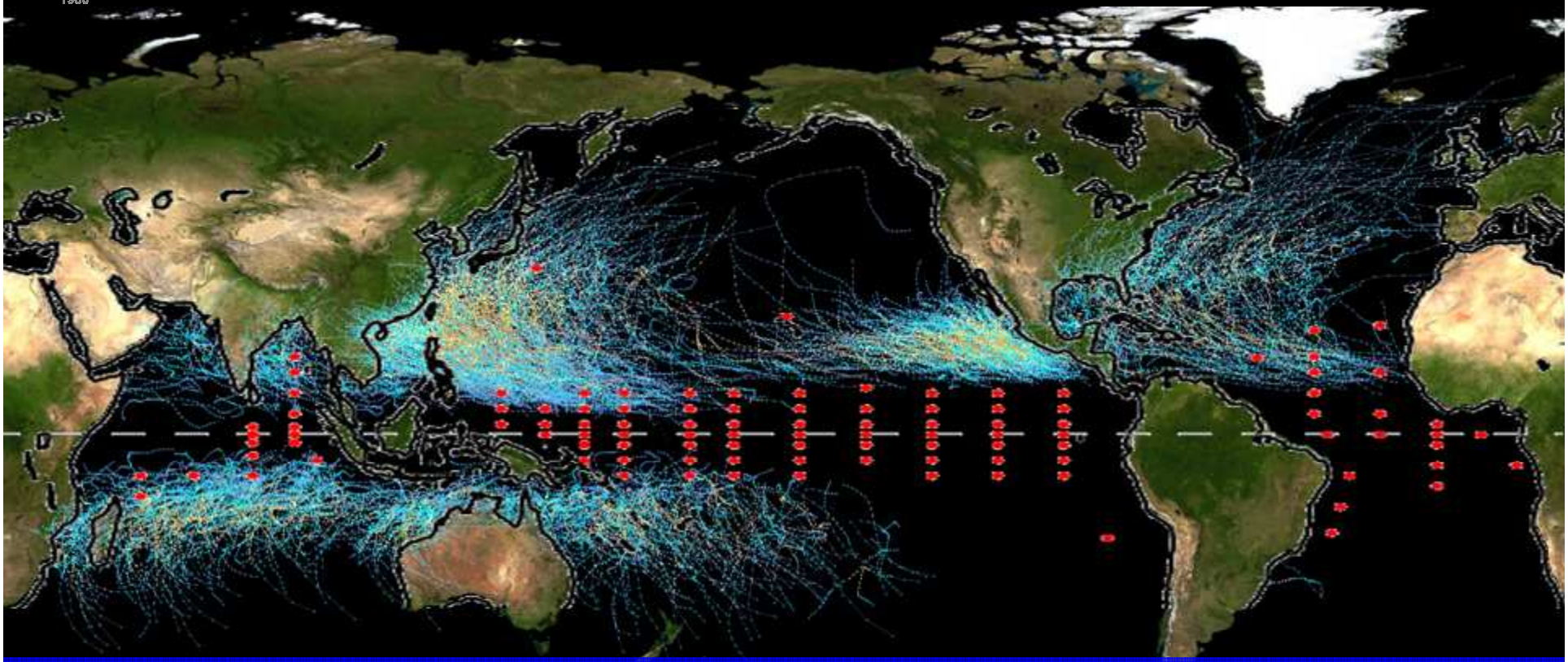
- how does global warming affect synoptic-scale phenomena (e.g. tropical cyclones, winter storms, etc)?
- how do the weather phenomena affect the global budgets of heat and freshwater?

Evaporation connects hydrological cycle with global heat budget

Net heat budget = Solar – Longwave – Latent heat – Sensible heat

Freshwater budget = Precipitation – Evaporation + runoff

Hurricane tracks and location of moored flux buoys



Turbulent heat fluxes due to tropical cyclones are underrepresented.

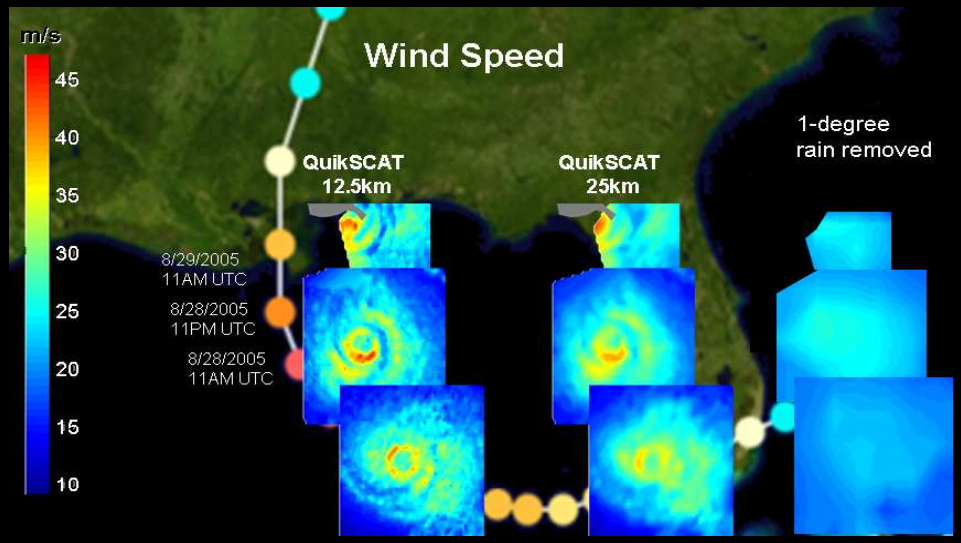
- **Flux buoys that provide valuable observations for tropical air-sea interactions (intraseasonal, seasonal, interannual) have limited coverage of global hurricane regions.**
- **Observations of tropical cyclones and winter storms will continue to rely on satellite sensors.**

Resolving cyclone-scale heat and momentum fluxes requires enhanced scatterometer observations

Hurricane Katrina
8/28 – 8/30/2005

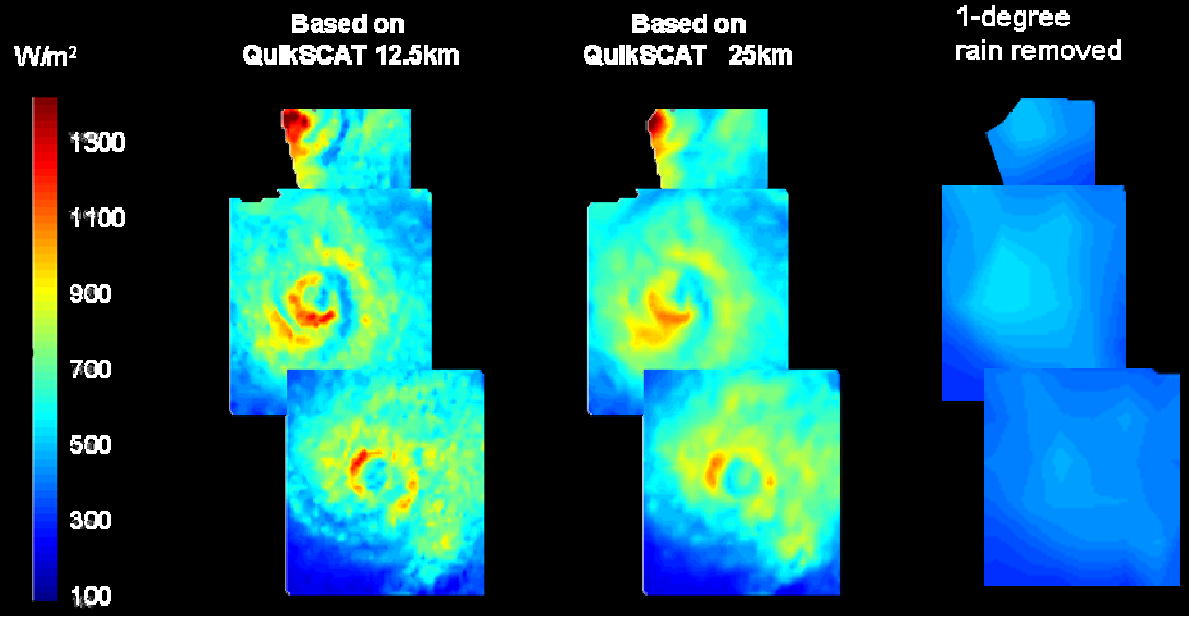
Wind Speed (WS)

Magnitudes of WS differ by 20 m/s



Latent heat flux (LHF)

Magnitudes of LHF differ by 800 W/m^2



How much can tropical cyclones contribute to global heat budget?

- Our estimate based on hurricane climatology indicates that tropical cyclones alone would contribute to ~ 2 – 4 Wm^{-2}

- Contribution from winter storms?

Observations of high winds under rainy conditions are highly desirable.

Summary on wind & evaporation

(1) The OAFlux time series of past 50 years shows that ocean winds have increased by 1.6% during the 1990s and the stronger winds led to larger evaporation.

(2) Turbulent fluxes due to tropical cyclones (and winter storms) are severely underestimated if rain-affected values are removed. The underestimation could be a major source of error for global heat budget.

Most flux buoy moored arrays are designed to monitor basin-scale air-sea interactions. Observations of tropical/extratropical storms will continue to reply on satellite sensors.

(3) Tropical cyclones are associated with high winds and high precipitation. Improving scatterometer retrievals under rainy conditions Is highly needed for improving global budgets of heat and freshwater.