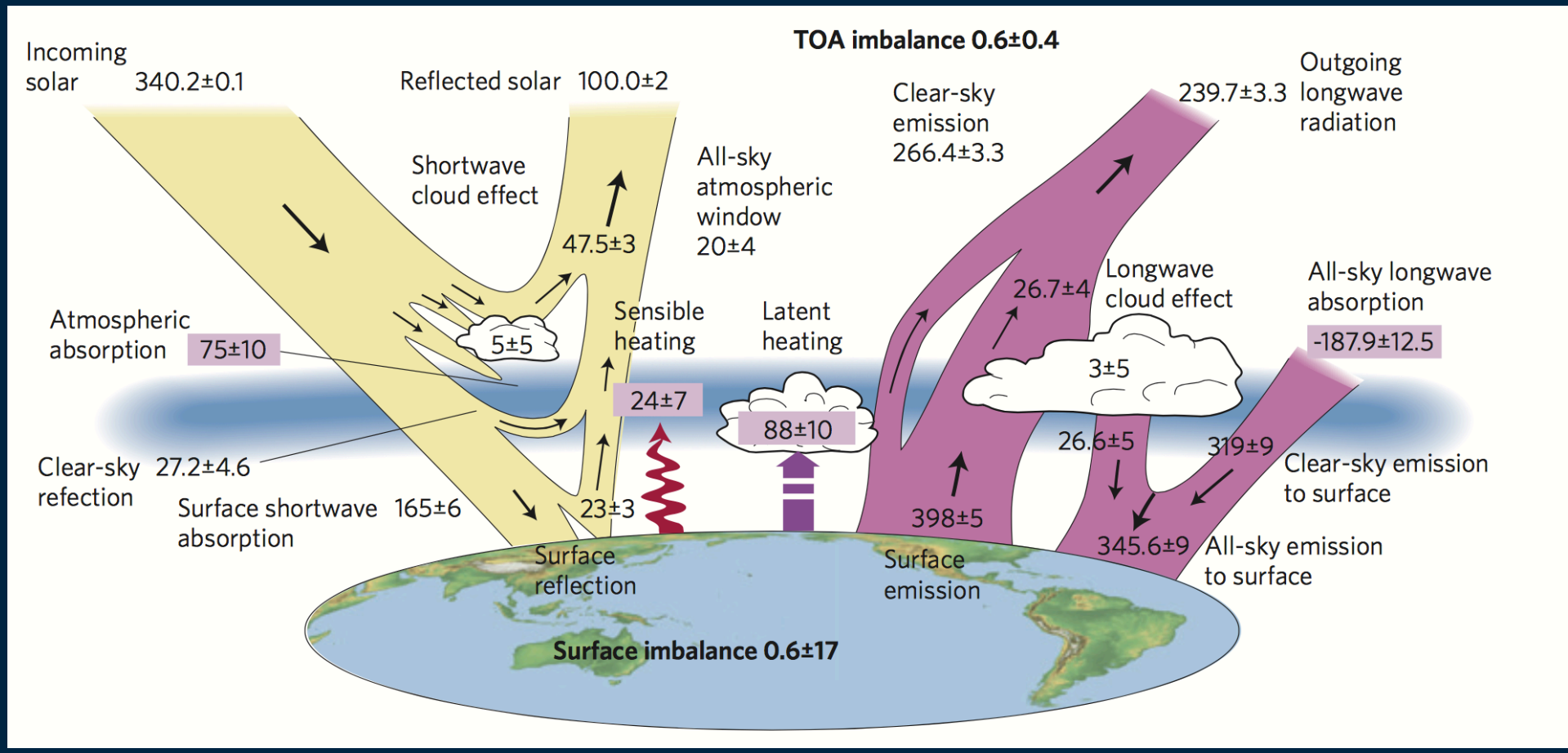
Surface heat fluxes and ocean heat content budget

Carol Anne Clayson

Kyla Drushka

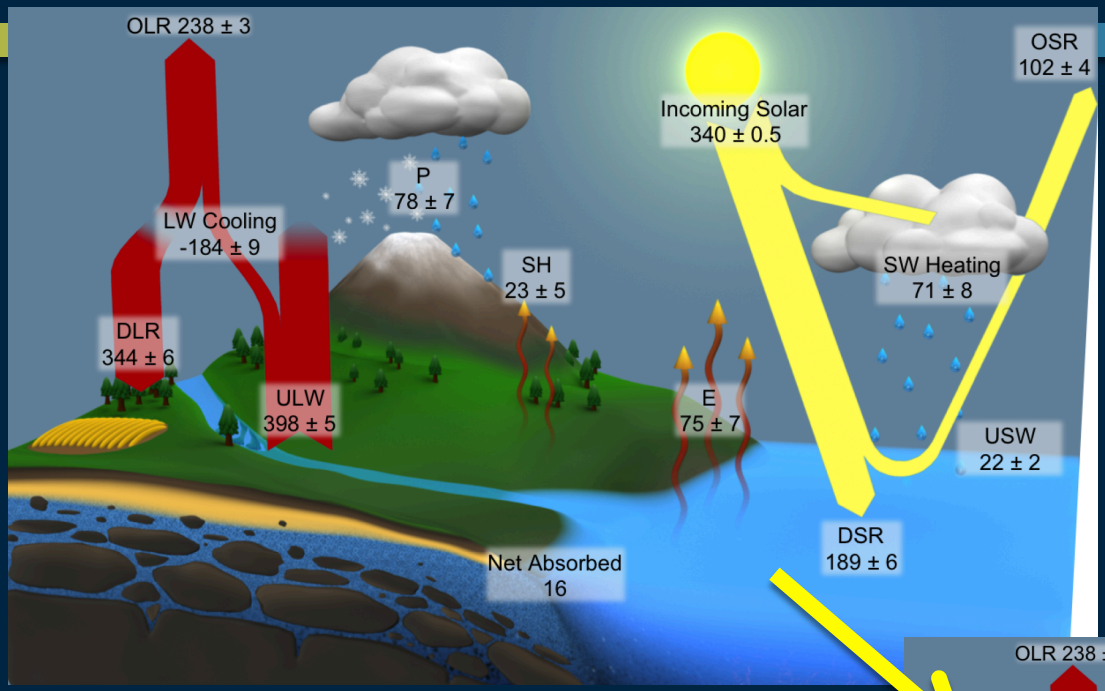
2015 US CLIVAR Summit
Tucson, AZ
5 August 2015

One estimate of the global heat budget

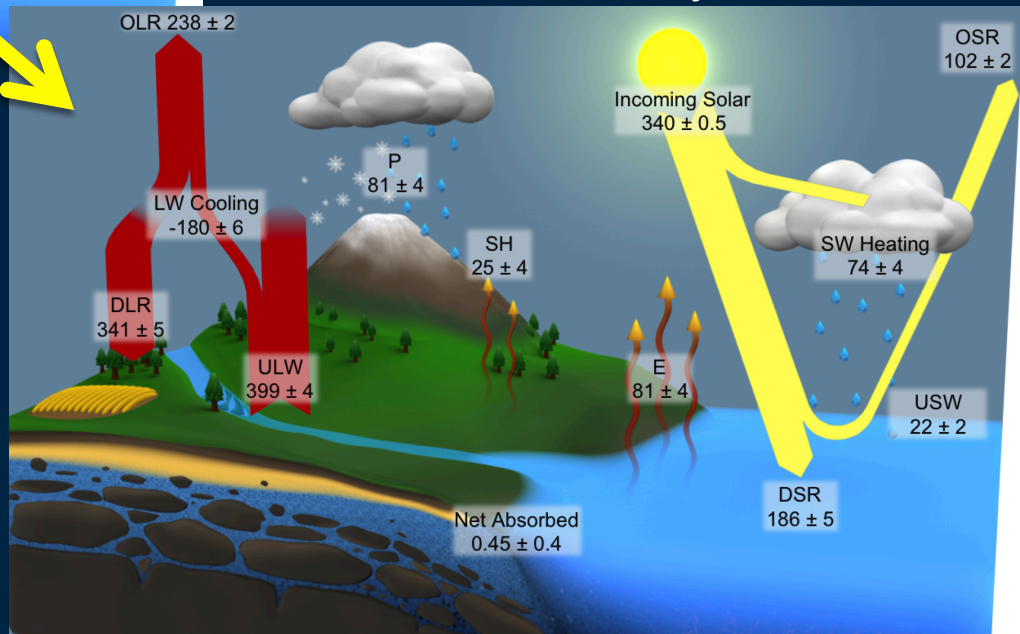


Stephens et al. 2012.

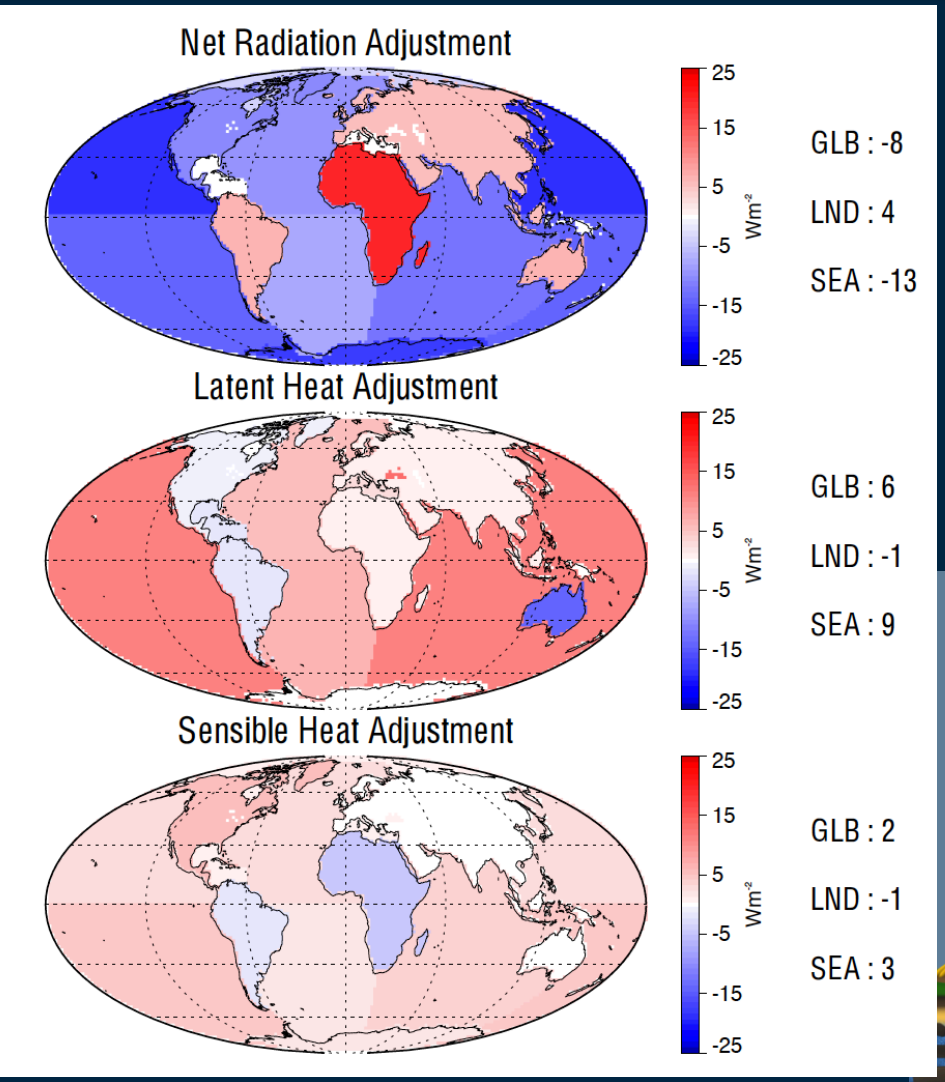
Another estimate



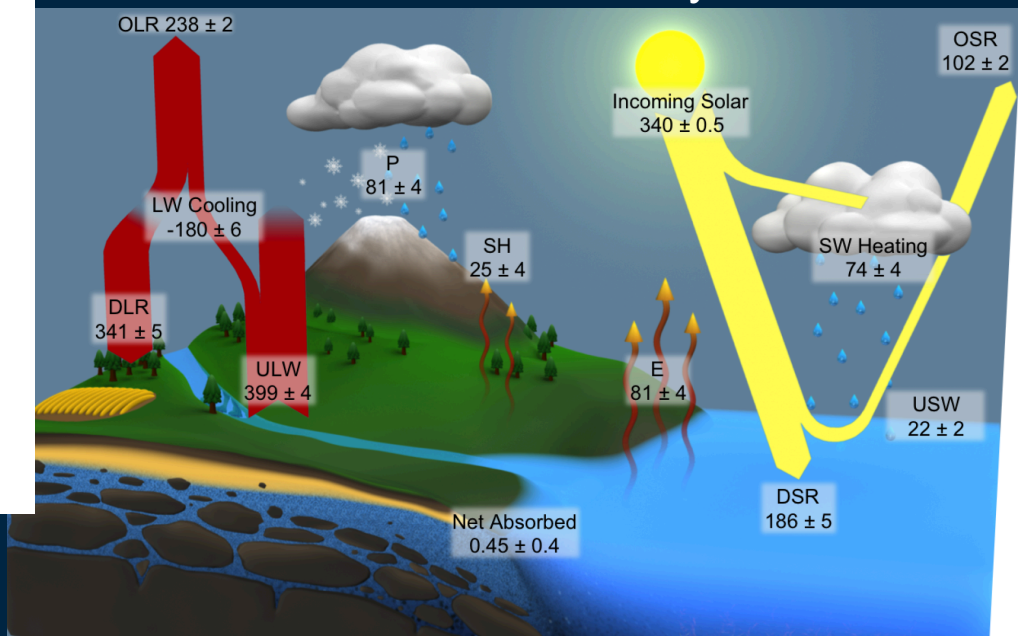
L'Ecuyer et al. 2015.



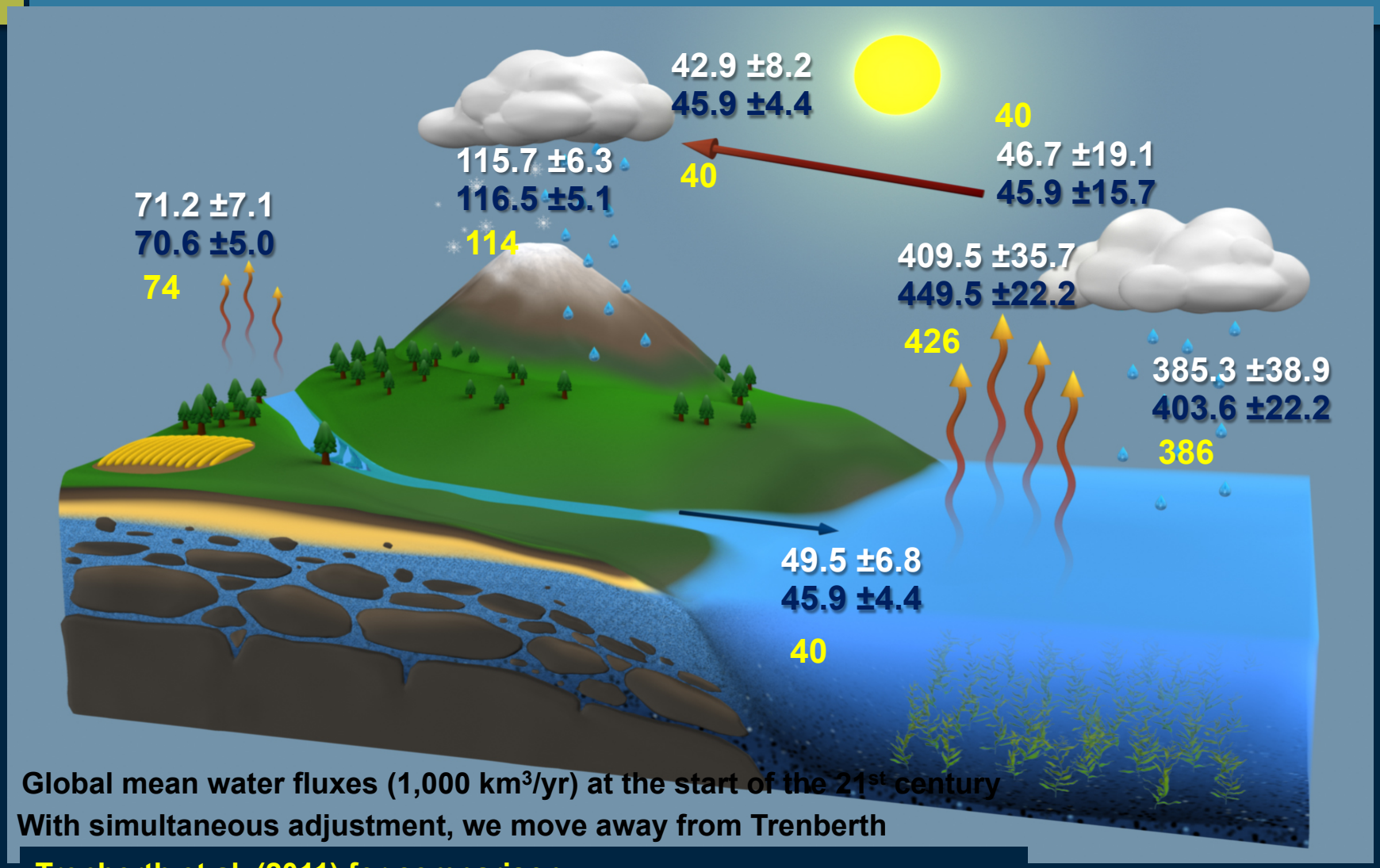
Another estimate



L'Ecuyer et al. 2015.



Global Mean Water Budgets



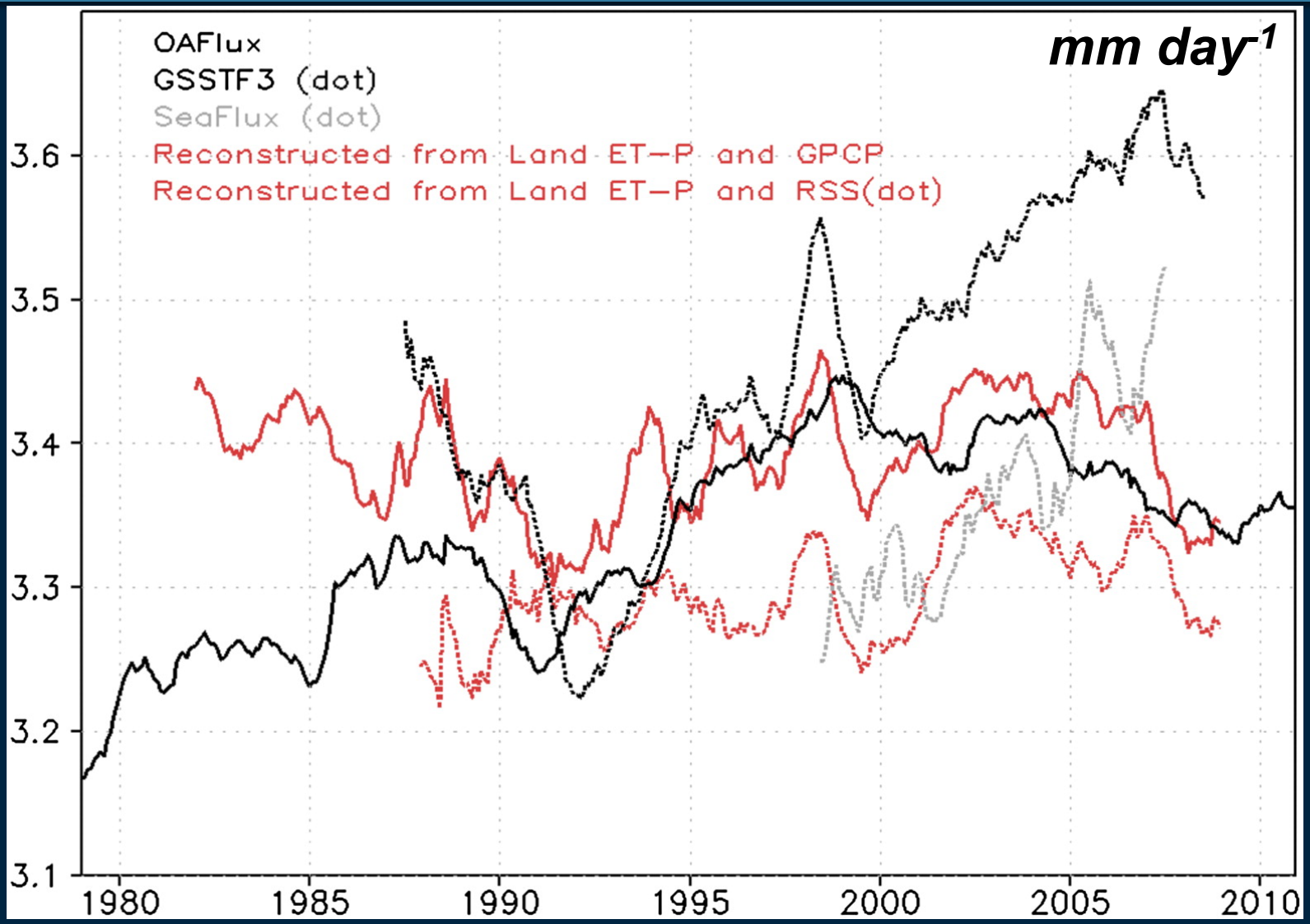
Global mean water fluxes (1,000 km^3/yr) at the start of the 21st century

With simultaneous adjustment, we move away from Trenberth

Trenberth et al. (2011) for comparison

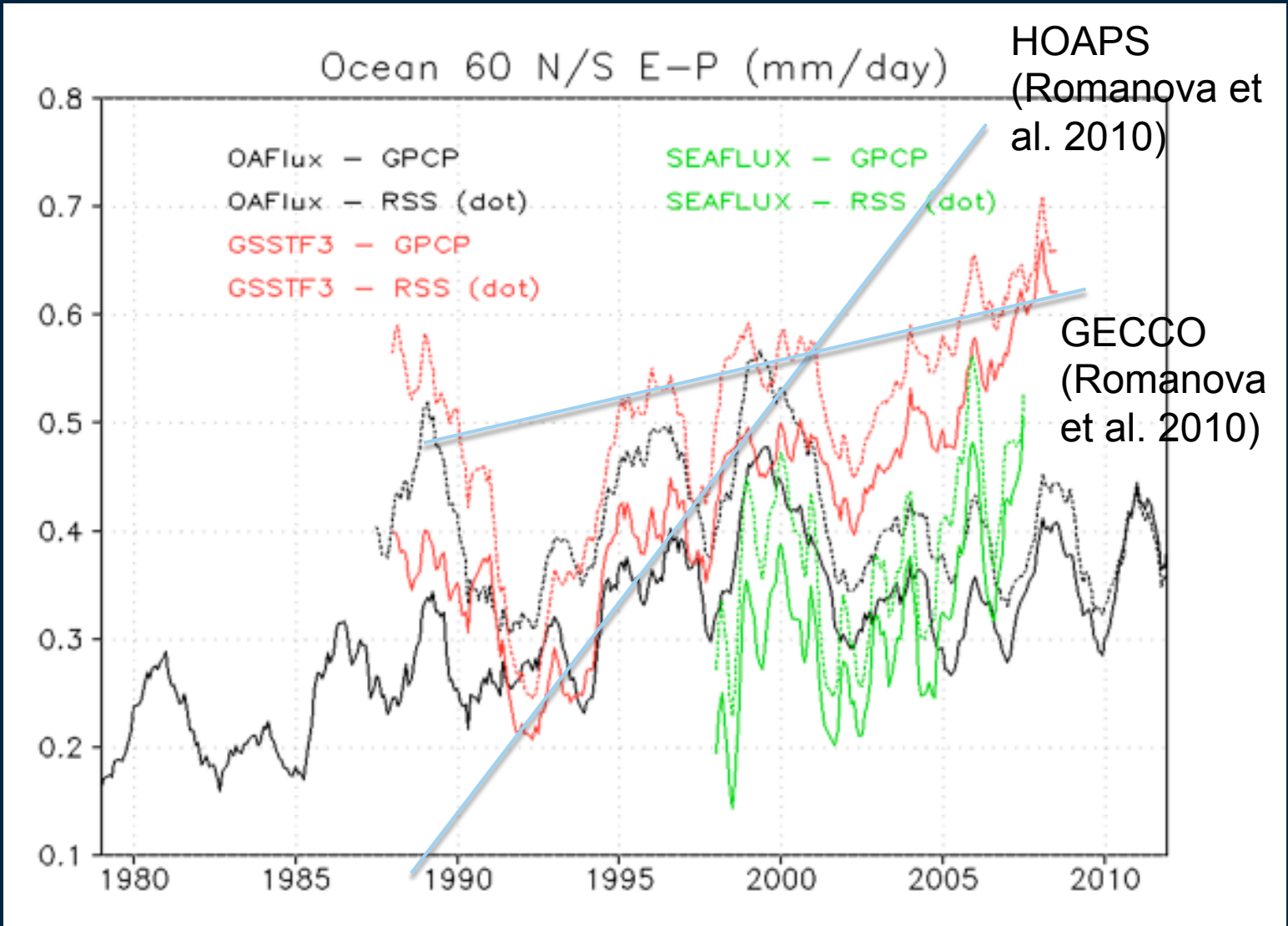
Rodell et al. 2015

Trends in Evaporation



Robertson et al. (2015)

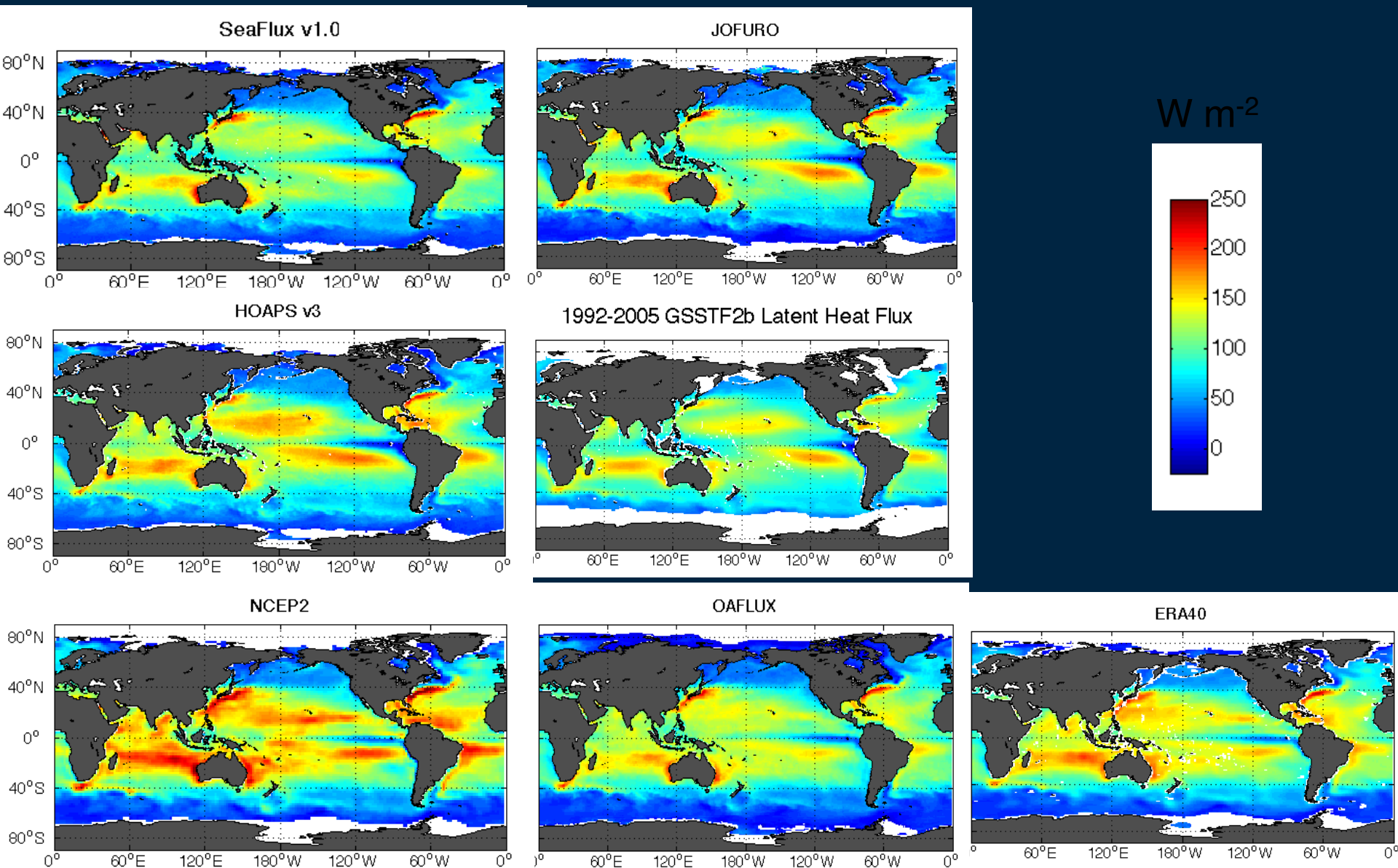
Trends in E-P


Ocean 60 N/S E−P (mm/day)
OAFlux − GPCP
OAFlux − RSS (dot)
GSSTF3 − GPCP
GSSTF3 − RSS (dot)
SEAFLUX − GPCP
SEAFLUX − RSS (dot)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1980
1985
1990
1995
2000
2005
2010
HOAPS (Romanova et al. 2010)
GECCO (Romanova et al. 2010)

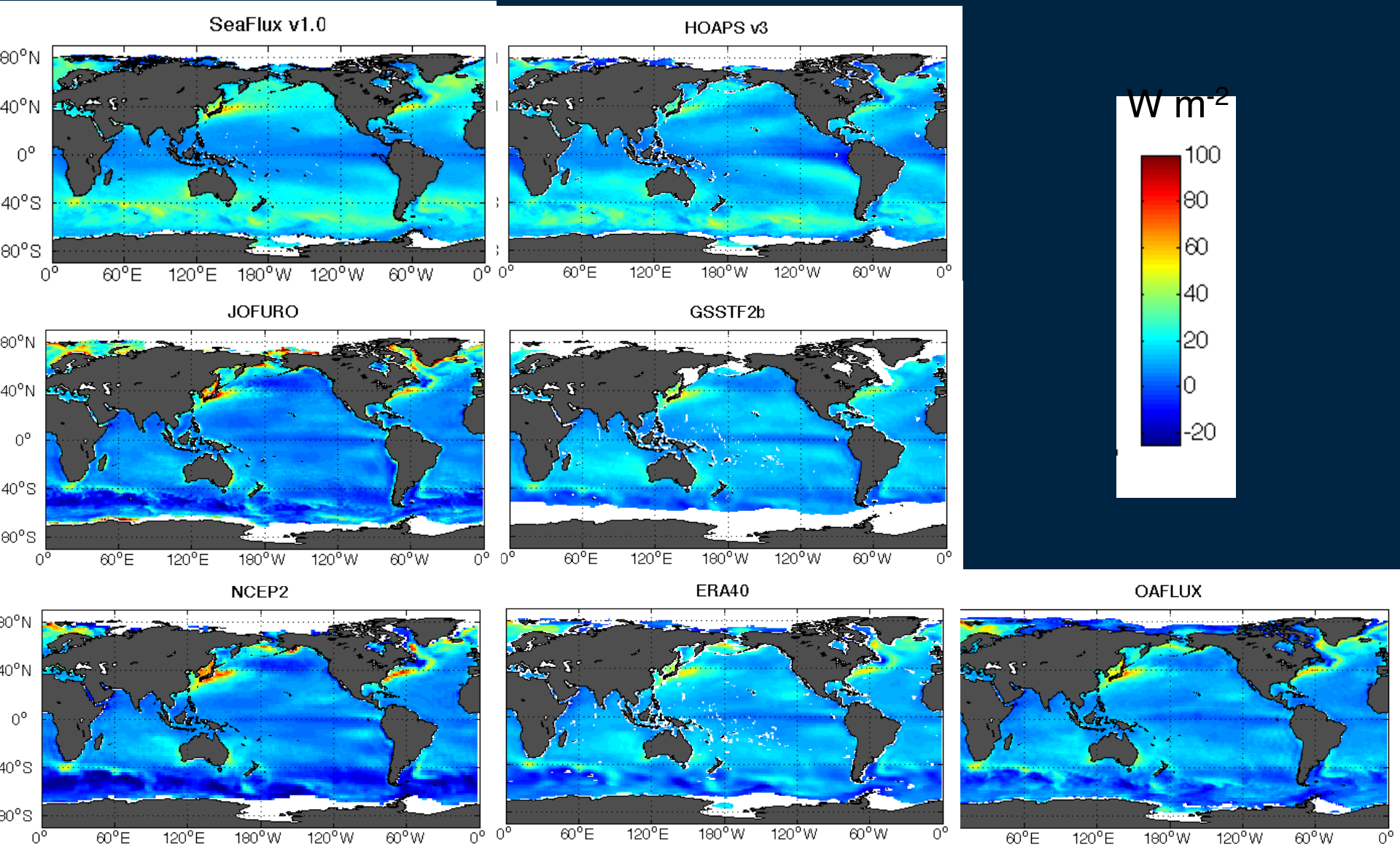
Current Satellite/Blended Datasets

- Goddard product: GSSTF3
  - Daily, 0.25°, input variables and turbulent fluxes;
    - satellite plus Ta from reanalysis
  - 1988- 2008; global oceans
- IFREMER version 3
  - Daily, 0.25°, input variables, turbulent fluxes; satellites plus Ta from reanalysis
  - Currently available: 1992 (1999 with QuikSCAT) – November 2009; global oceans
- Japanese Ocean Flux datasets: J-OFURO2v2
  - Input variables, fluxes, radiation, satellites plus Ta from reanalysis
    - Daily, 1°, 1988 – 2005; global oceans
    - Satellites, JMA model analyses
- HOAPS3.2
  - 6-hourly, 0.5°, global oceans; input variables, precipitation; satellites
  - July 1987 - December 2008
- OAFlux
  - Daily, 1°, global oceans; blended using reanalysis, in situ, satellites
  - July 1985 – current (monthly available back to 1958)

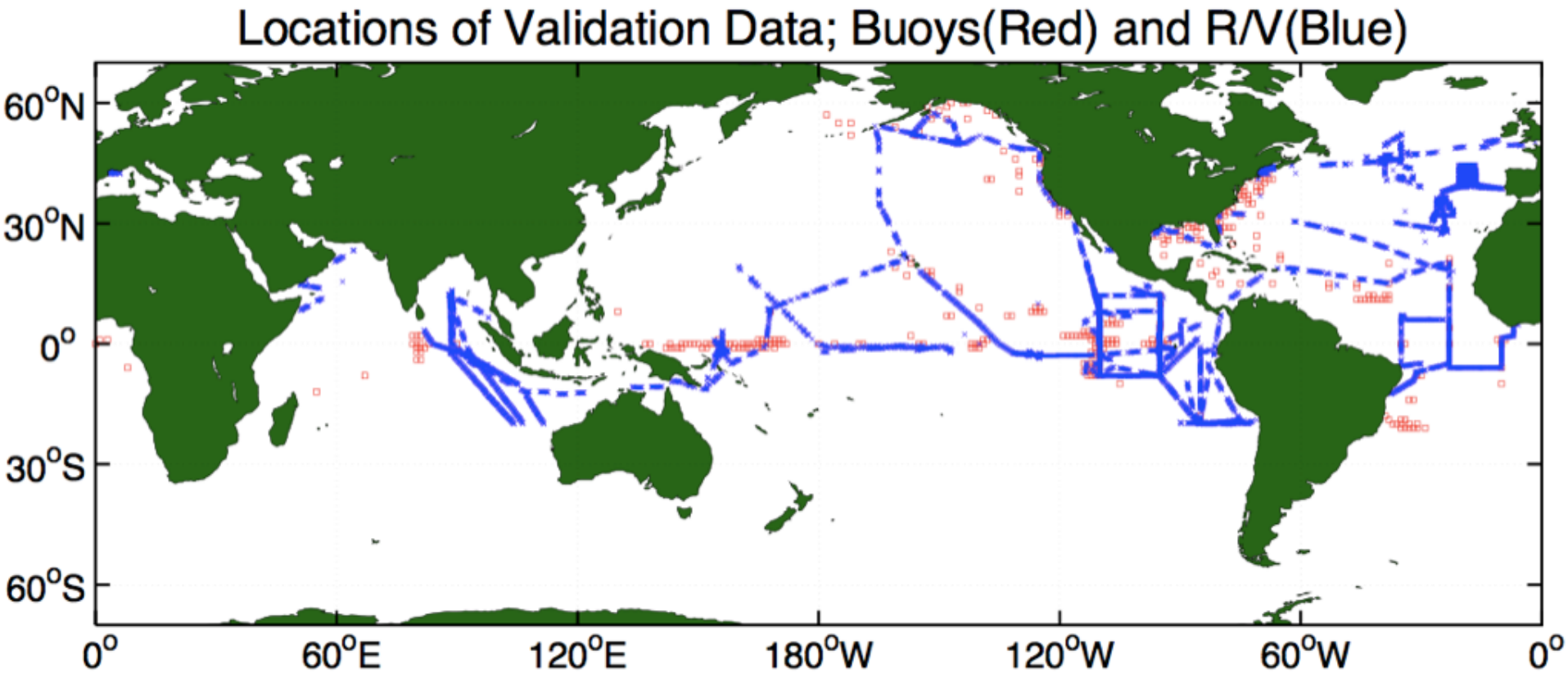
Latent Heat Flux: 1999-2005



Sensible Heat Flux: 1999 - 2005

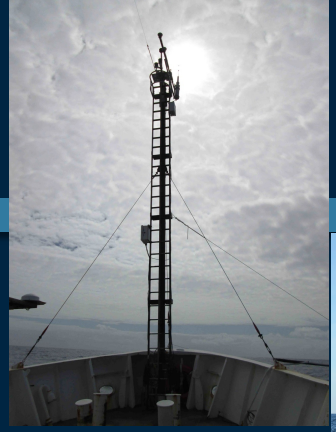


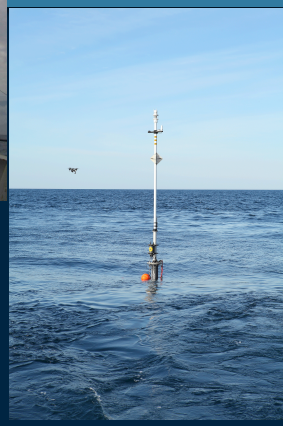
In-situ measured fluxes used in comparisons: true eddy-correlation fluxes in blue



NOTE: ONLY SHOWING MEASUREMENTS DURING TYPICAL SATELLITE COMPARISON TIMES (1990 – 2005)

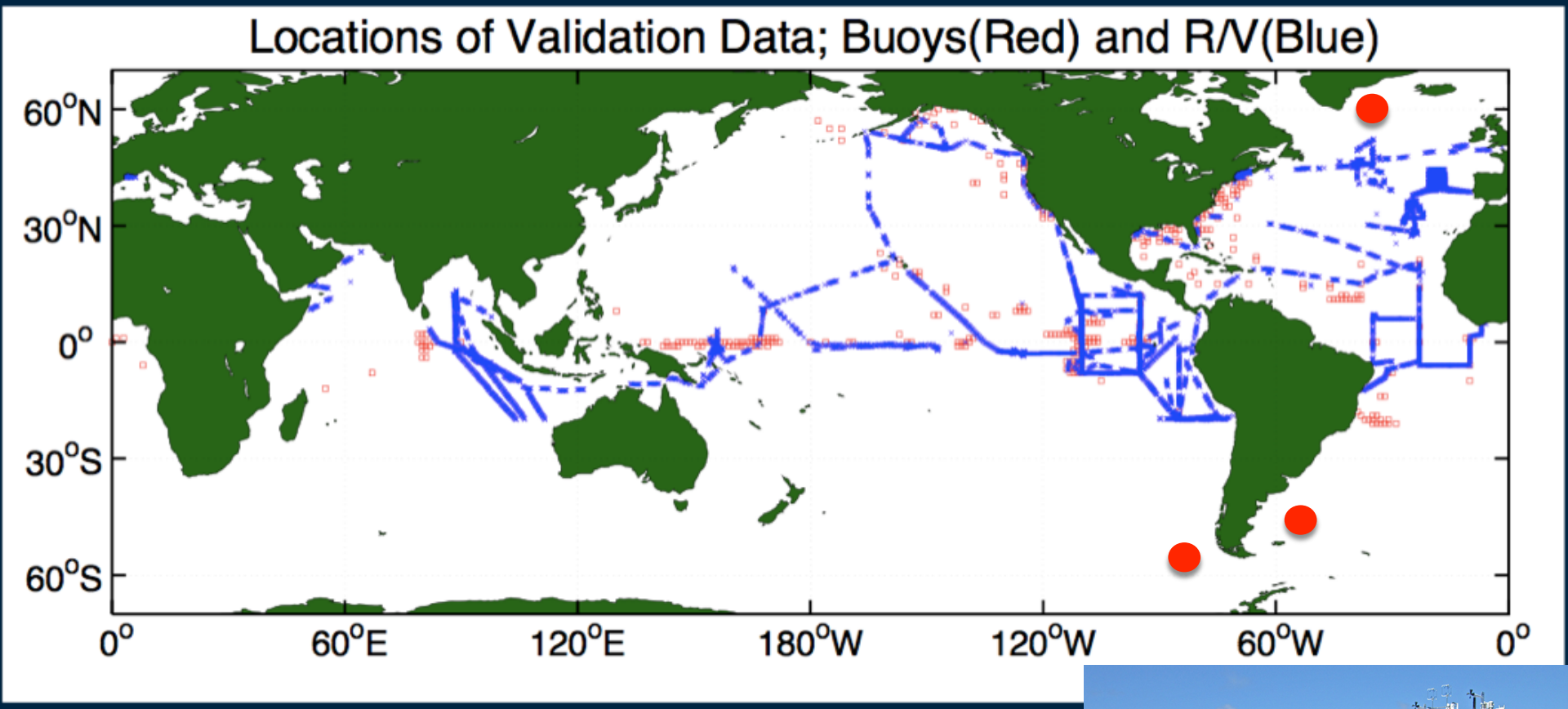
In situ measurements





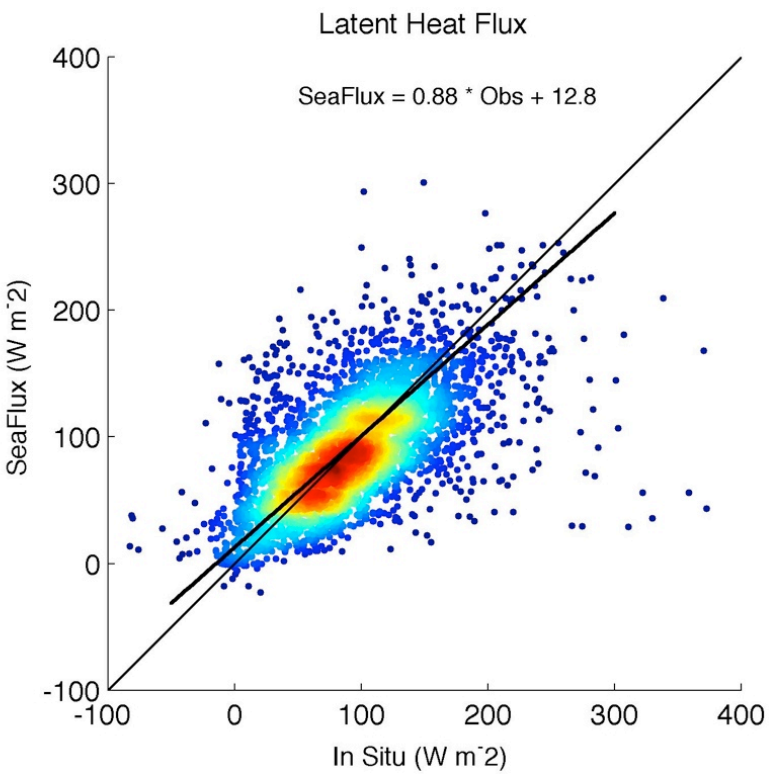
- Directly measured fluxes covariance fluxes): the GOLD STANDARD
  - Buoys
  - Ships
  - Floating (Xspar, etc.?)
- Calculated from measured bulk parameters (SST, Ta, Qa, U)
  - Wave information very important – rarely captured
  - Need to know depth of SST
  - Ocean surface current information important
- Need to know characteristics of platform for distortion

Measurements of fluxes over the oceans

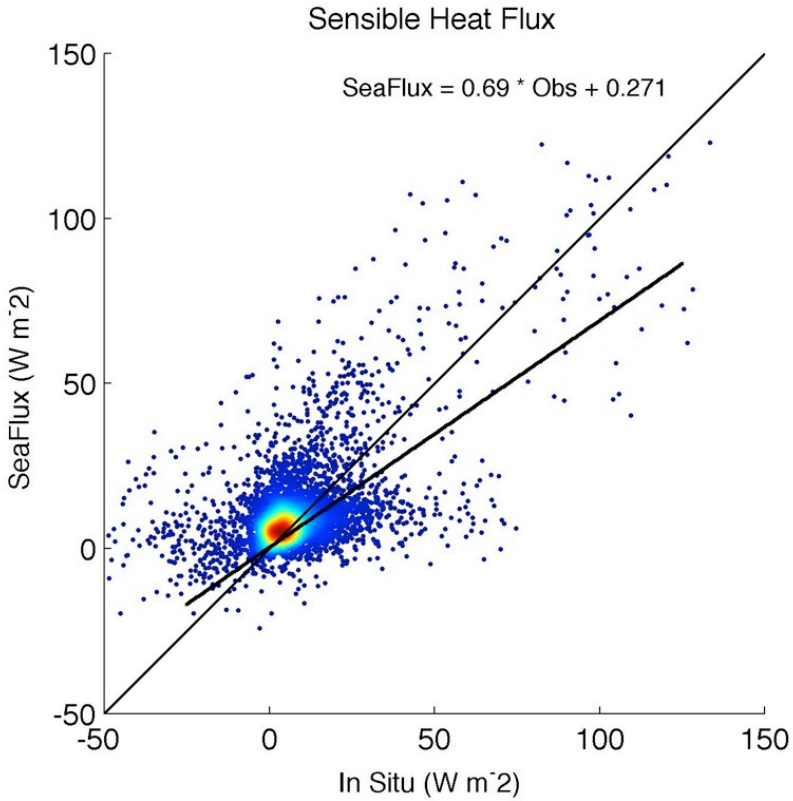


New OOI moorings

Some comparisons



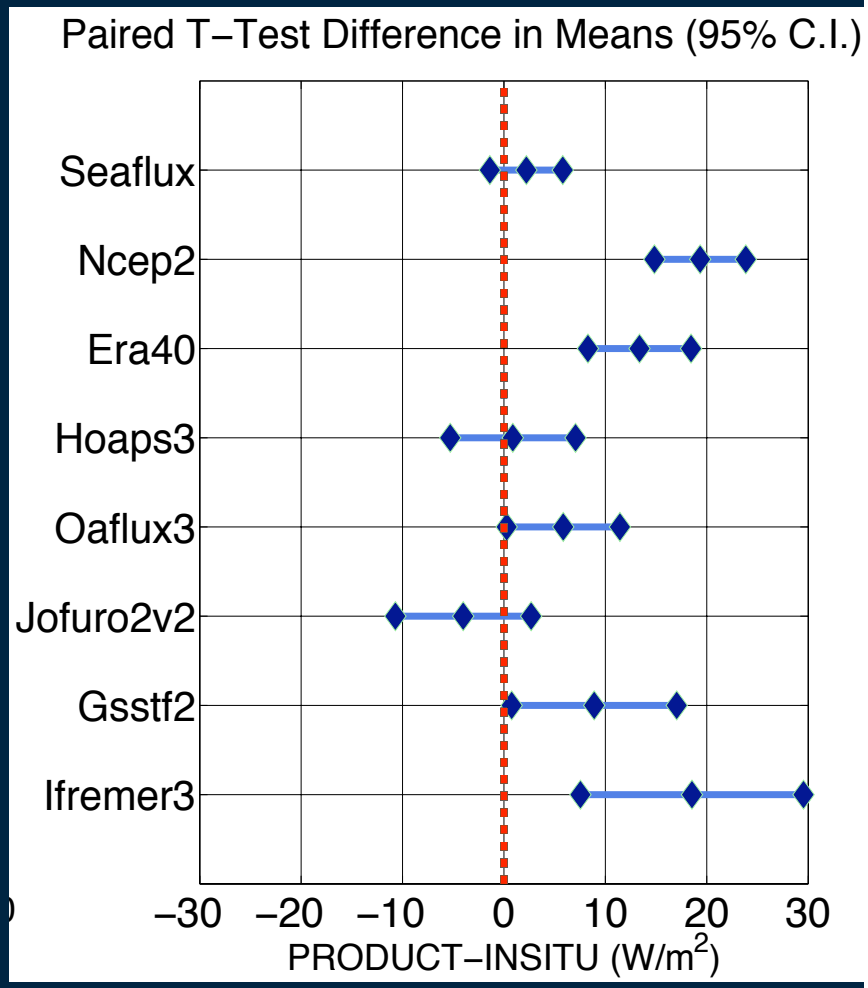
Bias: 2.1 W m^{-2}
Std Error: 38 W m^{-2}

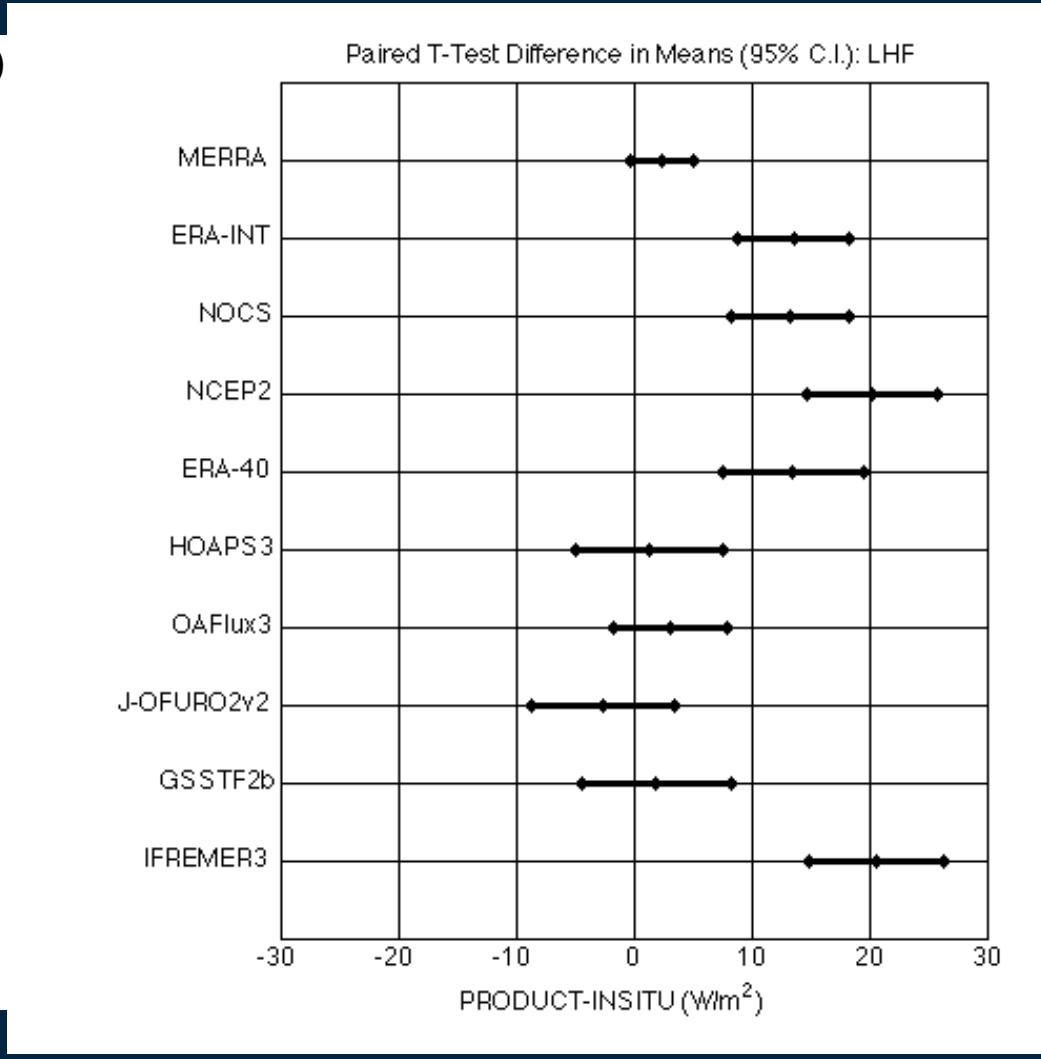


Bias: -3.1 W m^{-2}
Std Error: 13.2 W m^{-2}

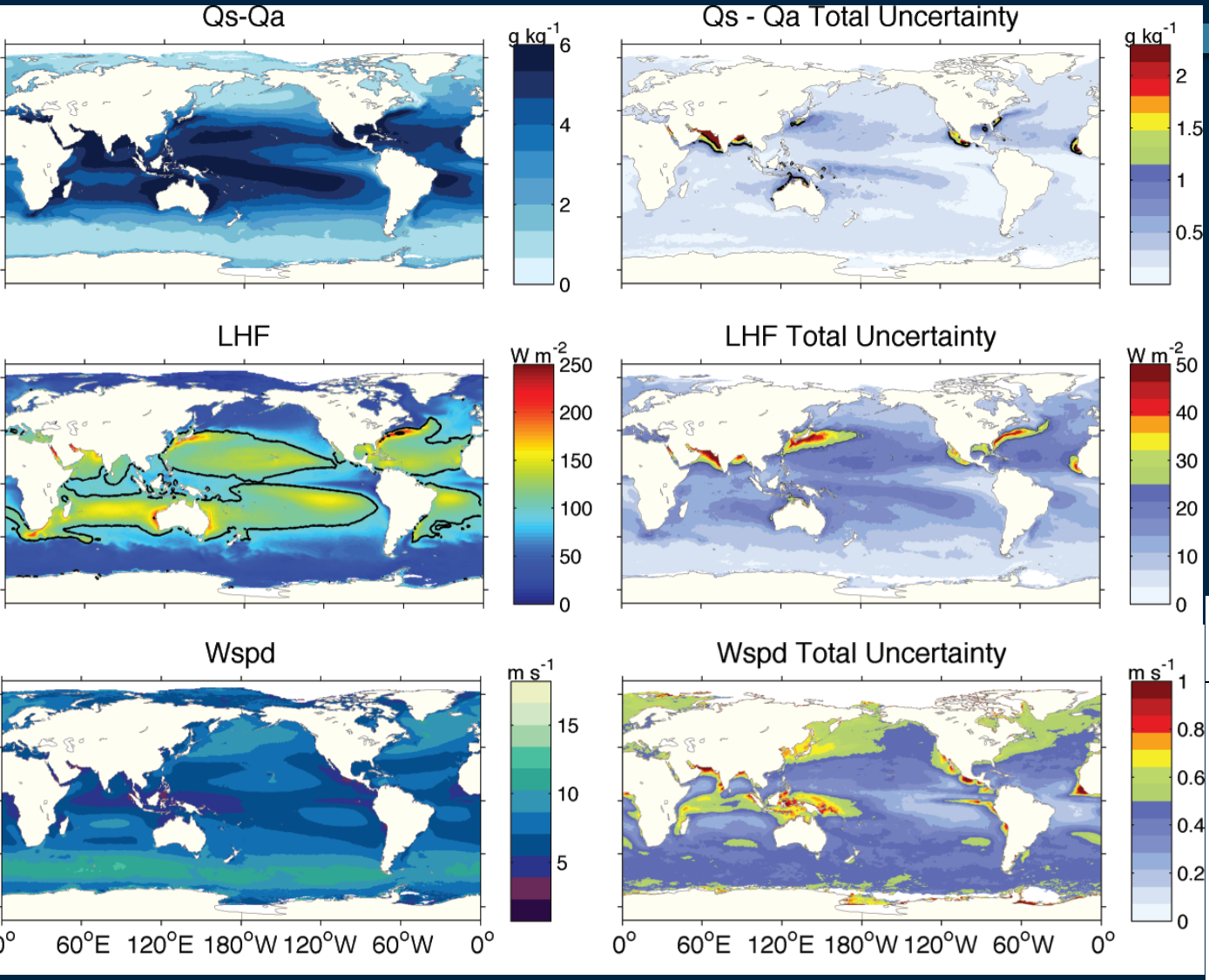
Here we do comparison with eddy covariance fluxes from research vessels -- they are our "ground truth"

Some sample comparisons





Some estimated errors from satellite

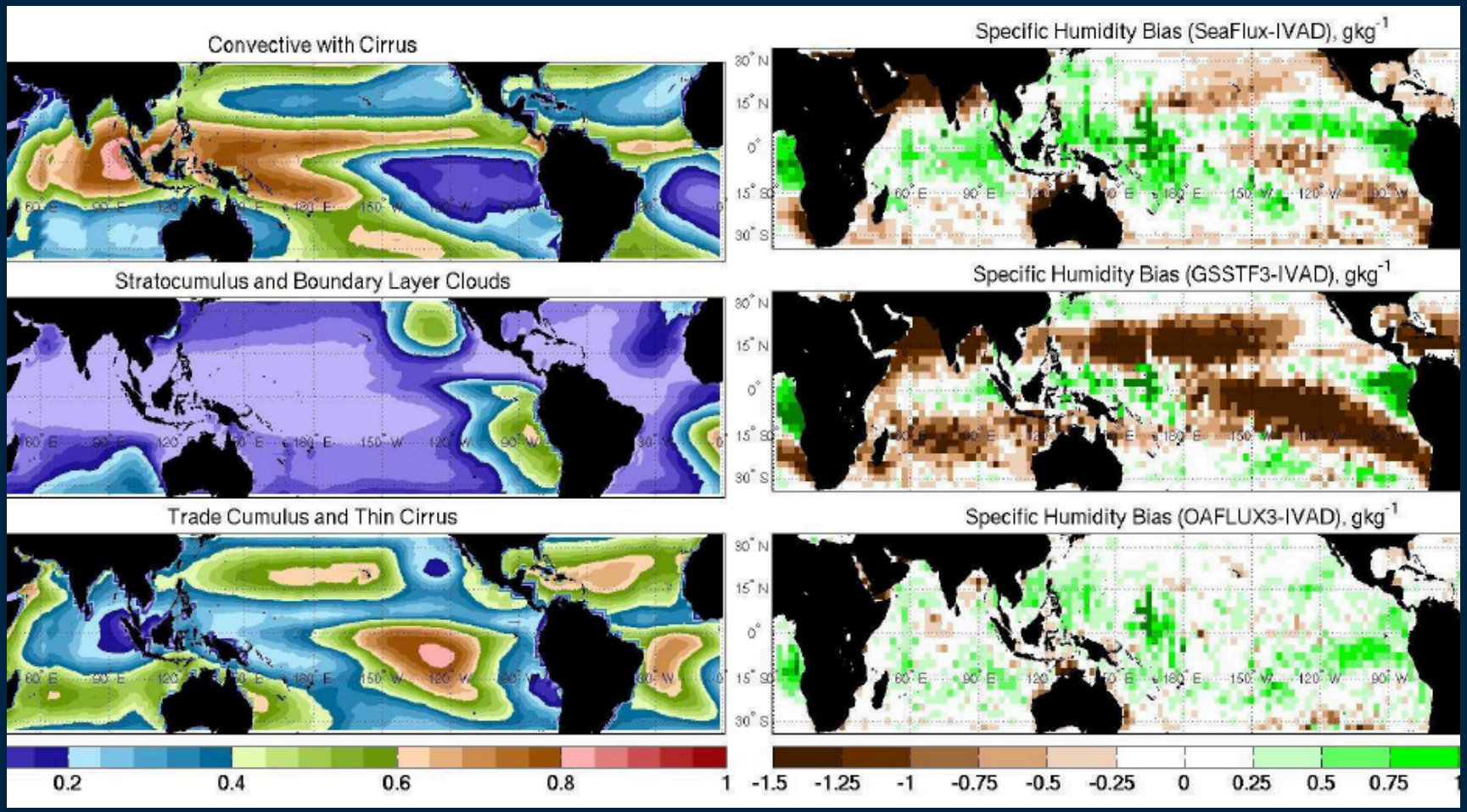


Variable	Global uncertainty
LHF (W m^{-2})	8.2 (9%)
SHF (W m^{-2})	4.2 (24%)
Windspeed (m s^{-1})	0.39 (5.2%)
Qa (g kg^{-1})	0.45 (4.0%)
SST (^{o}C)	0.12 (< 1%)
Ta (^{o}C)	0.35 (2%)
Ts - Ta (^{o}C)	0.44 (33%)
Qs - Qa (g kg^{-1})	0.27 (8.2%)

Errors correlated with weather states (?)

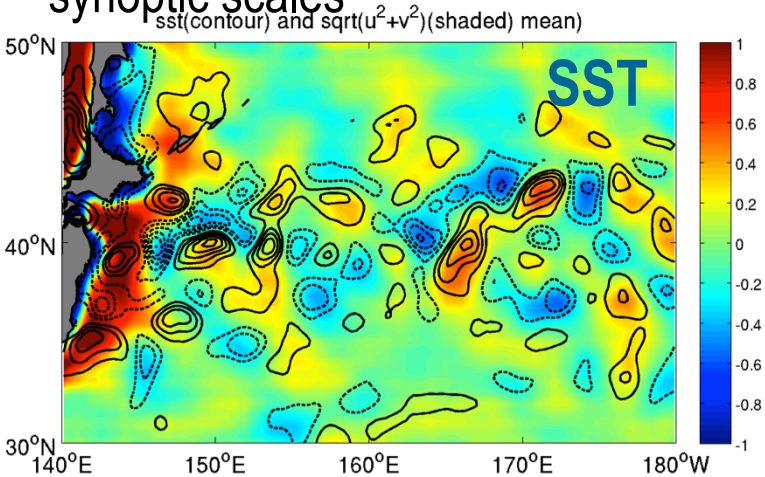
Relative Frequency of Cloud

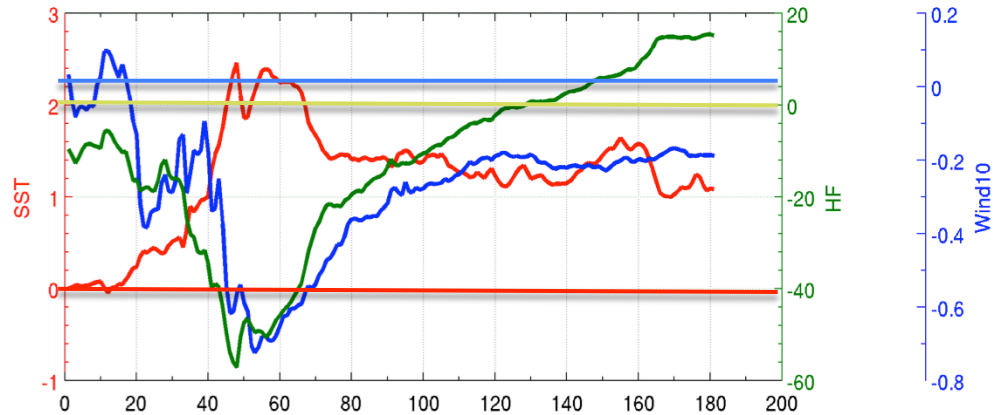
Errors in Surface Humidity

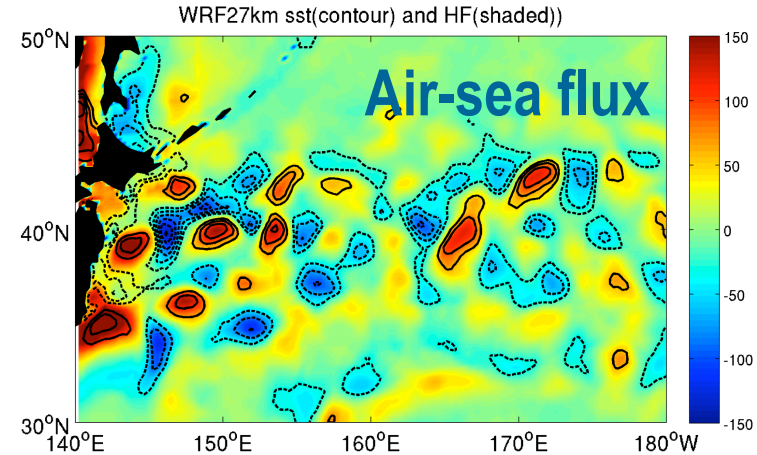


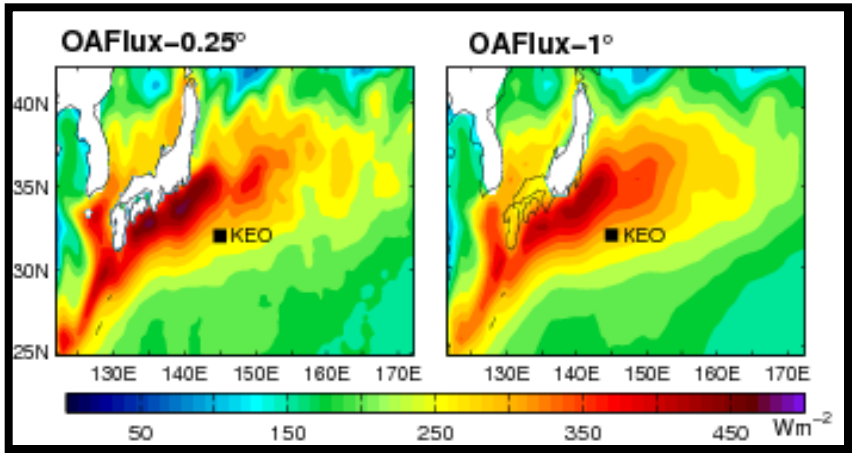
Surface fluxes and predictability – synoptic scales (space-time resolution matters)

Ping Chang: surface flux – SST relationship is scale dependent on mesoscales and synoptic scales









¼ OAFLUX (1987- onwards) – LIsan Yu

Joint challenges of CLIVAR and GEWEX in fluxes

Inventory, classification and discrimination of the existing products by their accuracy and relevance for different purposes

Satellite products, NWP (atmospheric reanalyses and operational analyses), VOS and in-situ, ocean reanalyses, blended products

Accuracy of state variables – from in-situ, satellites (retrievals), NWP

Space-time scaling of fluxes → understanding the applicability of parameterizations → Uncertainties associated with scaling

Ocean precipitation (validating GPCP, TRMM, potentially GPM, NWP and reanalyses; VOS-approach – does it have the future?) → in-situ campaigns

More observed fluxes (OCEANSites, more in mid and high latitudes)

Test beds → forcing functions for OGCMs, synoptic air-sea interactions in mid latitudes (diabatic sources of heat and moisture), decadal and longer variability

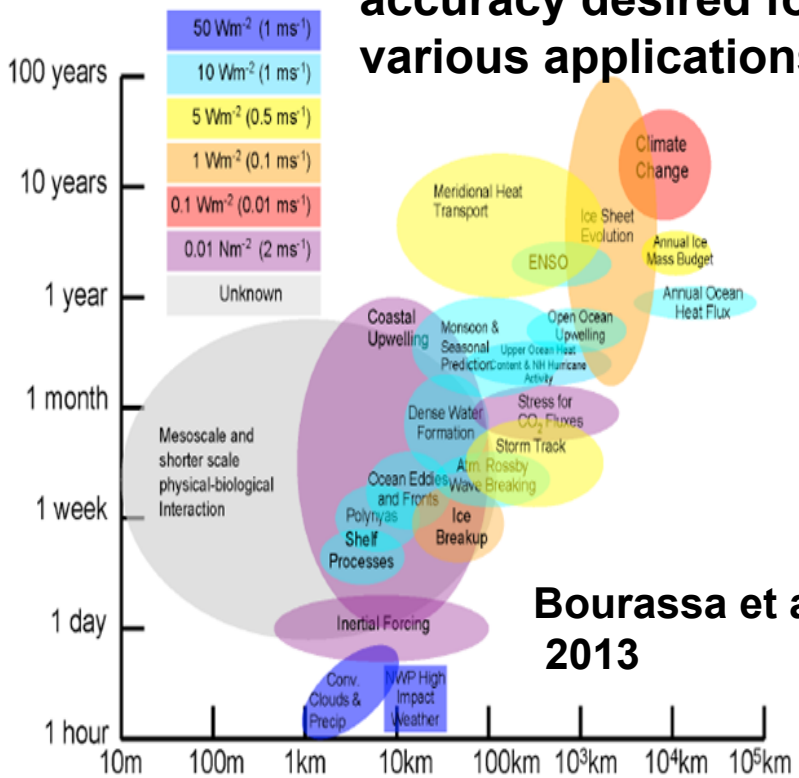
Under WCRP Data Advisory Council (WDAC)

- Discussion of need for coordination and highlighting surface flux issues
  - Land, ocean, ice
  - Biogeochemical, heat, moisture, momentum
  - Turbulent, radiative
  - In situ, remote
- Formation of a Surface Flux Task Team (C. A. Clayson, chair)
  - Cuts across GEWEX, CLIVAR, other WCRP groups

TIE-OHF: Towards Improved Estimates of Ocean Heat Flux (**ESA ITT Project**)

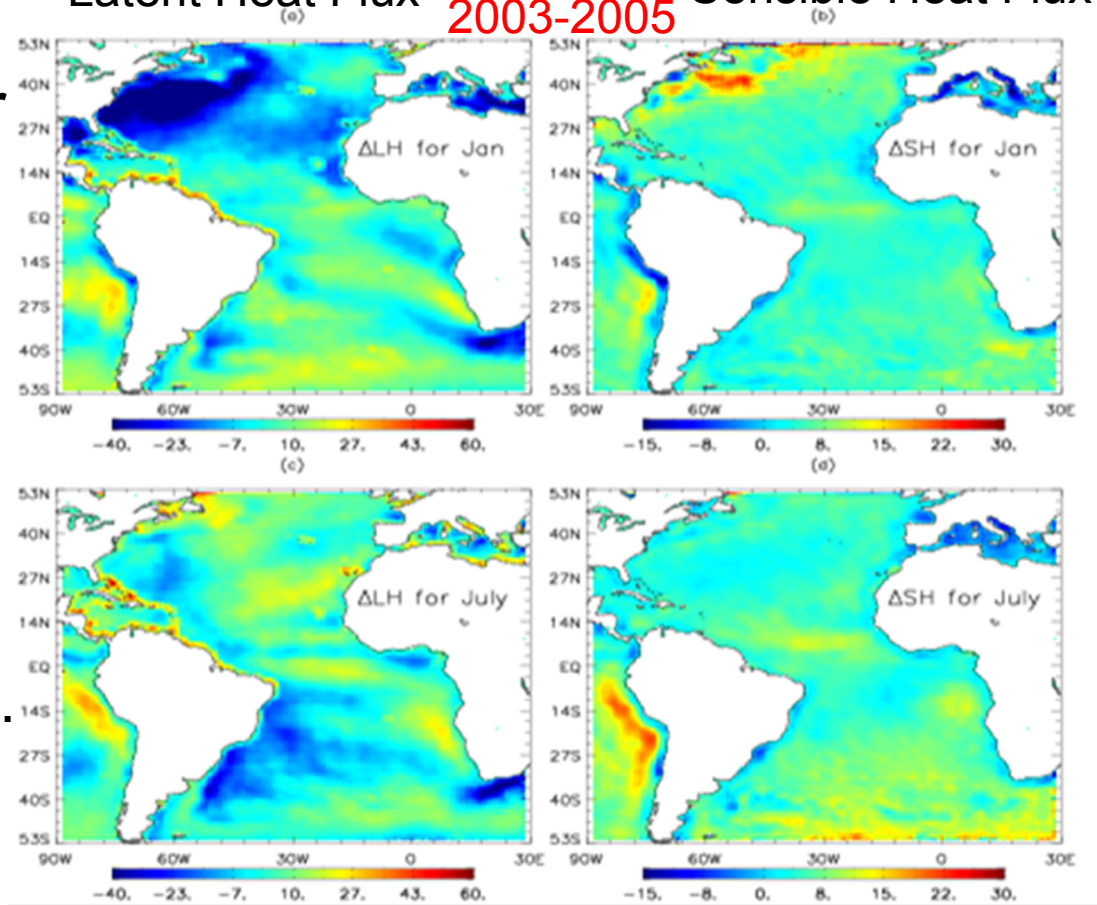
PROBLEM: Significant quantitative differences between the different products at regional scales ➔ inconsistencies in methodology and data input and use of different time constants

First order flux accuracy desired for various applications



Bourassa et al. 2013

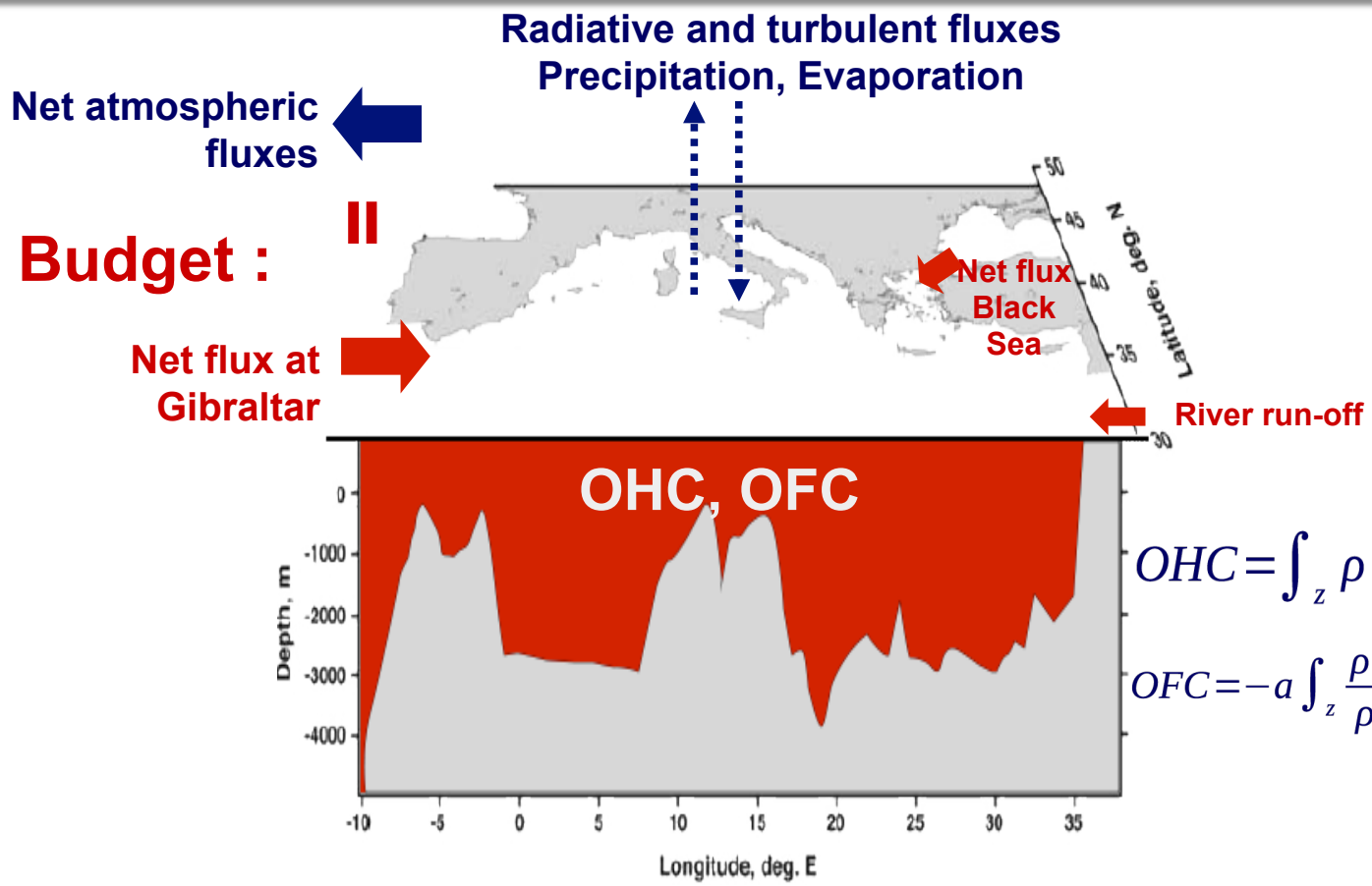
Latent Heat Flux 2003-2005 Sensible Heat Flux



17 August 2015

Differences between IFREMER and WHOI OAFlux adopted from Pinker et al, 2014

First steps done … Natural cage: Mediterranean Sea



$$OHC = \int_z \rho c_p T_0(z)\, dz$$

$$OFC = -a \int_z \frac{\rho(T,S,p)}{\rho(T,0,p)} \frac{S_0}{(S_r + S_0)}\, dz$$

Budget = Lateral net flux – Ocean integrated heat and/or freshwater

Next steps? …

Implementation plan (suggestion):

1.) Develop 2 “test-cages” for method development: Mediterranean Sea, North Atlantic: (note that for high latitudes uncertainties for turbulent fluxes increase, and hence, knowledge of uncertainty scales are needed (➔ DWD (CM SAF) will deliver uncertainty scales in March 2015)

2.) Clarify which datasets aught to be used for the test-cages: organize teleconf in beginning of January?
i) OHC: for MedSea developped (2004-2012); next step: develop OHC for North Atlantic box

3.) Develop team and strategy plan for implementation (teleconf.) and start to draft scientific paper for cage method

Suggestion for cage-team:

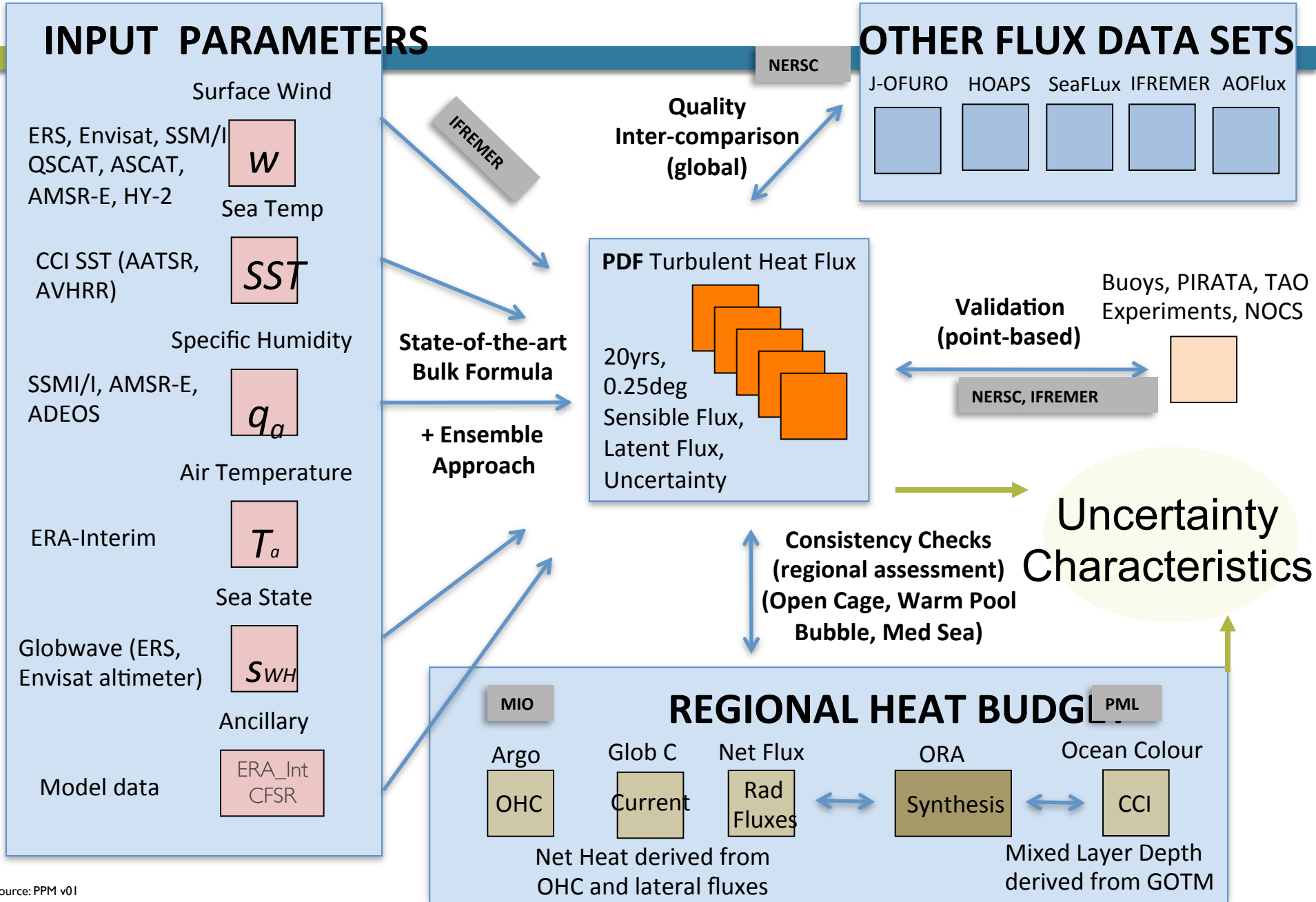
General concept: Sergey Gulev, Simon Josey, Carol-Anne Clayson, Bertrand Chapron, Keith Haines, Semyon A. Grodsky, Rachel T. Pinker

OHC: Karina von Schuckmann, Clement de Boyer Montégut

Net atmospheric flux: Axel Andersson, Chris Merchant, Rainer Hollmann, Abderahim Bentamy, Richard Danielson, Igor Esau

Lateral flux: Keith Haines, Maria Valdivieso, Semyon A. Grodsky

Ocean Heat Flux Thematic Exploitation Platform



Source: PPM v01

Upcoming CLIVAR-sponsored workshops

- Air-Sea Fluxes for the Southern Ocean: Strategies and Requirements for Detecting Physical and Biogeochemical Exchanges. Workshop in Frascati, Italy, September 21 – 23, 2015.
  - Sponsored by US CLIVAR, NOAA, ESA, WCRP, SOOS
- Workshop on energy flow through the climate system, 29 September - 01 October 2015, MetOffice - Exeter – UK.

Strategies for Improving Ocean Turbulent Fluxes

- More routine observations:
  - Extremes: cold air outbreaks, hurricanes
  - High-latitudes
  - Both limited duration focused on physical processes and long time series at given locations
  - Should be noted: we also need the actual turbulent flux measurements as well for continued understanding of bulk flux paramaterizations

- Clearly defined, common measures of accuracy:
  - Tropical array of surface flux moorings (some sub-tropical) – use to benchmark
  - Process studies – why are some biased?
  - More flux intercomparisons with standardized methods

- More process studies: put together evap, precip, latent heating profiles into some case studies

- Better calibration: we need to resolve what are appropriate calibrations for multiple uses

- More global coverage: "missing" events significant problem

- More funding: compare surface turbulent flux with precipitation groups

- Increase accessibility of available datasets

Questions to be discussed

- *How do we work across the three very different communities: atmospheric radiation, air-sea flux communities, ocean heat content communities?*
- *What are the reasons for the disconnects?*
  - *Communities do not understand the uncertainties of the others*
- *What should we be promoting for measurements/ platforms?*
- *Satellies? Microwave, for instance?*