The 2012 CLIVAR/GSOP/WHOI workshop

Recommendations for Next Steps,

Follow-on Activities,

Specific recommendations for reducing air-sea flux estimation errors.

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Collaborators:

Arun Kumar, Mark Bourassa, Meghan Cronin, Simon Josey, Tony Lee.

Contributors:

Yan Xue, Karina von Schuckmann, and Abderrahim Bentamy

What was the 2012 CLIVAR/GSOP/WHOI workshop about?

GSOP: Global Synthesis and Observations Panel

Motivation:

- Surface fluxes are a cross-cutting theme (e.g., linking CLIVAR and GEWEX).
- WCRP Observation and Assimilation Panel (WOAP) report recommended evaluation of model-based surface fluxes and observation-based estimates.
- CLIVAR/GSOP: bring together observational flux and assimilation/synthesis communities, for joint product/methods evaluation: (60 participants)

Objectives:

- Review current state of surface fluxes (heat, freshwater, & momentum) obtained from synthesis & observation-based products;
- Discuss gaps and limitations in products with particular reference to balancing global budgets;
- Develop requirements/recommendations for future global/regional synthesis activities

(1) Current state of flux estimation

There are MANY heat flux products, but they can all be classified into three groups:

(i) Atmospheric reanalyses

Early: NCEP/NCAR, NCEP/DOE, ERA40,

Latest: CFSR, MERRA, ERA40, …

(ii) Analyses using satellites, ship reports, or combination of several data sources

Ship-based: NOC

Satellite based: GSSTF, J-OFUROS, HOAPS, ISCCP, SRB, CERES, …

Blended: CORE

OAFlux (Objectively Analyzed air-sea Flux: evaporation, latent+sensible, wind)

(iii) Ocean syntheses

ECCO, GODAS,…

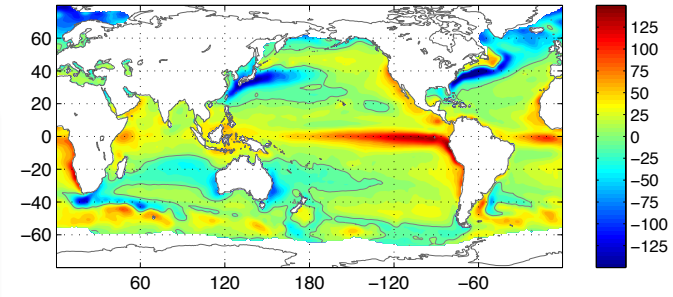
Reference:

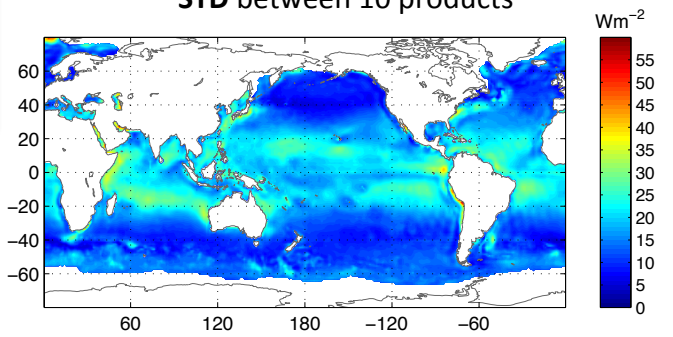
Josey, S.A., Gulev, S. and Yu, L. (2013) Exchanges through the ocean surface. In: Siedler, G., Griffies, S., Gould, J. and Church, J. (eds.) *Ocean Circulation and Climate: A 21st Century Perspective. 2nd Ed.* Oxford, GB, Academic Press, 115-140. (International Geophysics, 103).

Differences in products are large both within each group and between the groups.

Reanalyses/Flux analyses

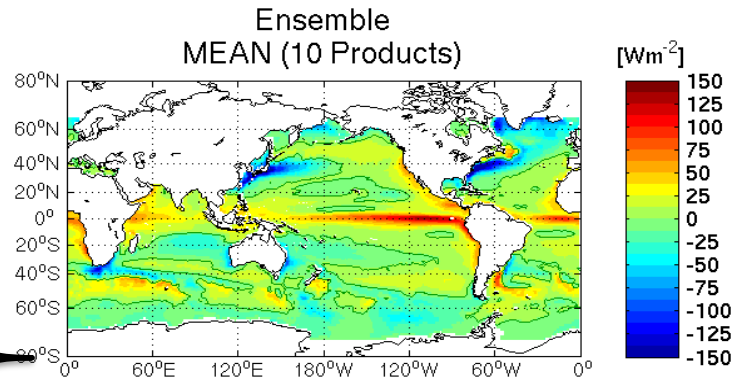
CFSR
ERAinterim
MERRA
NCEP1
NCEP2
ERA40
CORE2.0
NOC
ISCCP/OAFlux
SRB/OAFlux

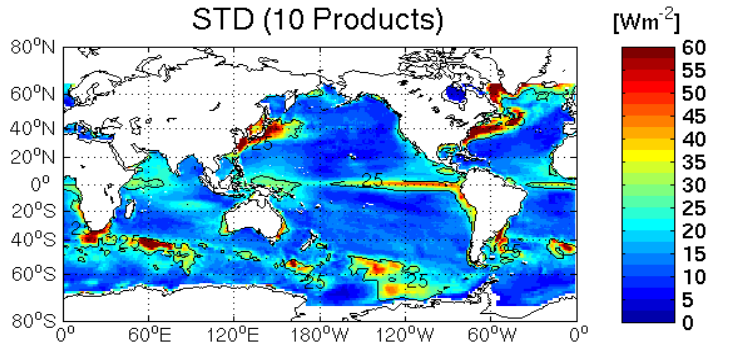




Ocean syntheses

ORAS4
MOVEG2
GECCO2
GODAS
UR025.4
GloSea5
GLORYS
MJM95
CFSR
ECDA



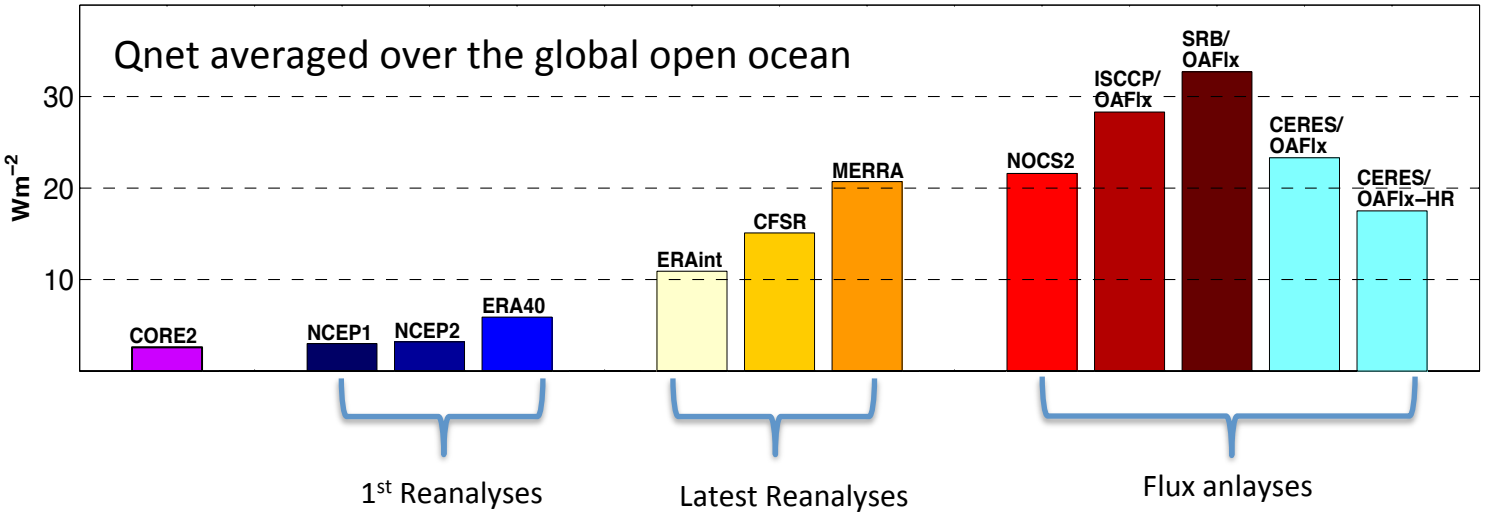


(from Maria Valdivieso)

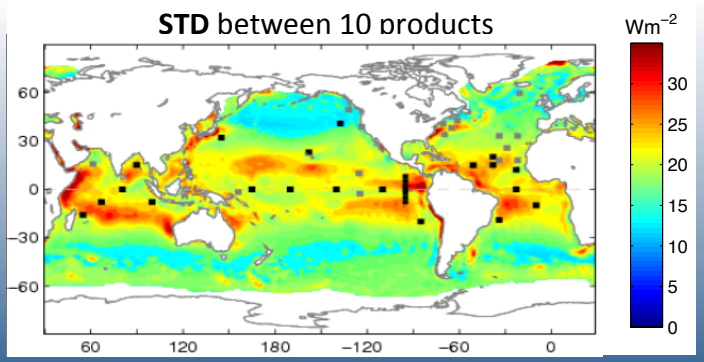
(2) Impacts of the flux biases on climate and weather studies

➢ We cannot balance the **global energy budget.**

The energy budget:
Qnet = Solar – Longwave – Latent heat flux – Sensible heat flux



- The differences in the 10 mean Qnet products are largest in the tropical oceans
- The differences are mostly larger than 10 Wm^{-2} (the desired accuracy).
- Buoy measurements for Qnet are extremely limited.



(black squares: active; grey squares: archived)

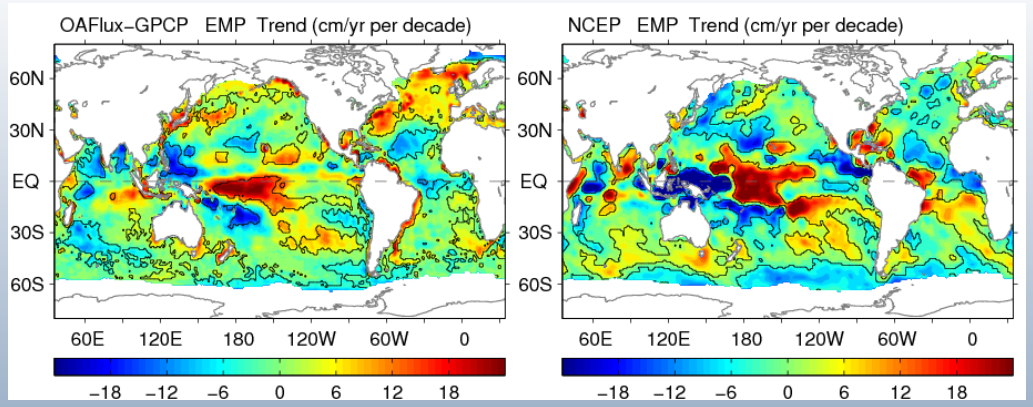
The energy cycle is connected to the water cycle via evaporation

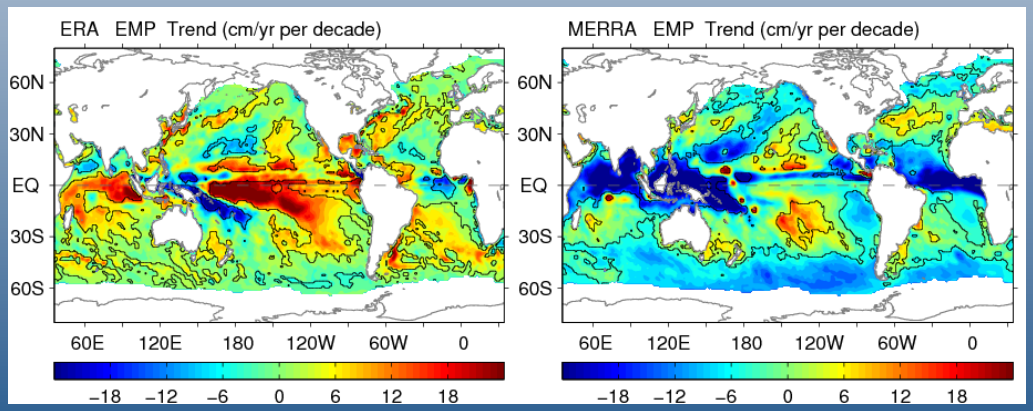
The energy budget:
Qnet = Solar – Longwave – **Latent heat flux** – Sensible heat flux

The ocean freshwater budget:
FW = **Evaporation** – Precipitation + Runoff

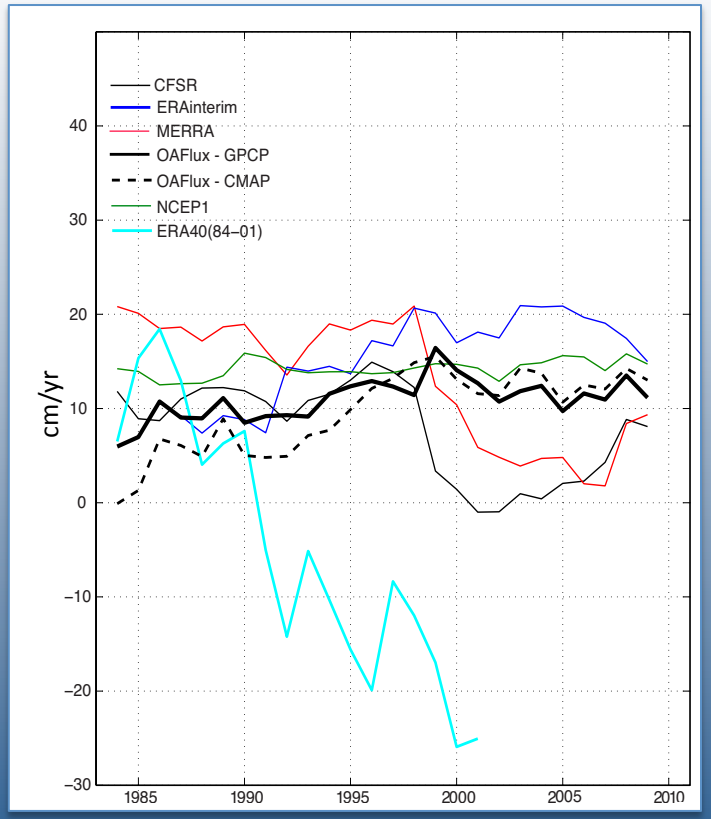
➢ We do not know how the **ocean freshwater budget** (E-P) has been changing.

Linear trends 1979-2012





E-P averaged over the global open ocean



Satellite-only products are NOT bias free

Example: Excessive trends in Satellite-only Evaporation products

Evaporation ~ W (qs – qa)

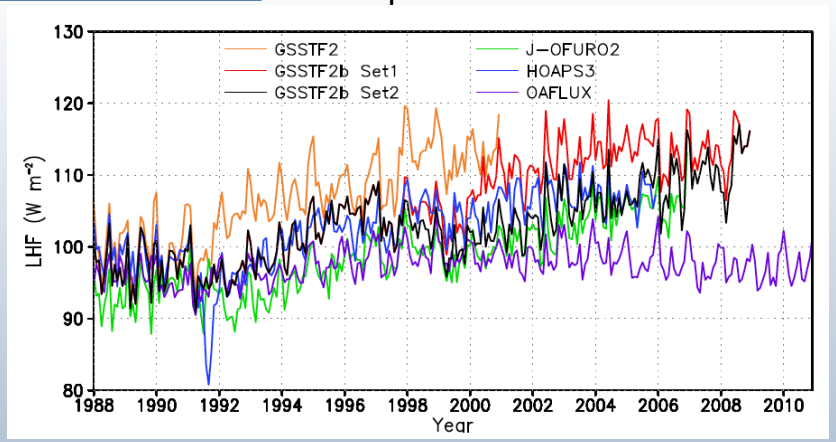
- It is unclear that biases (errors) can be reduced by using only satellite retrievals and derivables.

Because…

- Near-surface Temperature and humidity cannot be retrieved directly.
- The algorithms are empirically based and can be biased if ground reference data are lacking.

Robertson et al. (2014) provided additional evidence that the trends in satellite-only evaporation products are outliners.

Evp Time series



Evp Linear trends

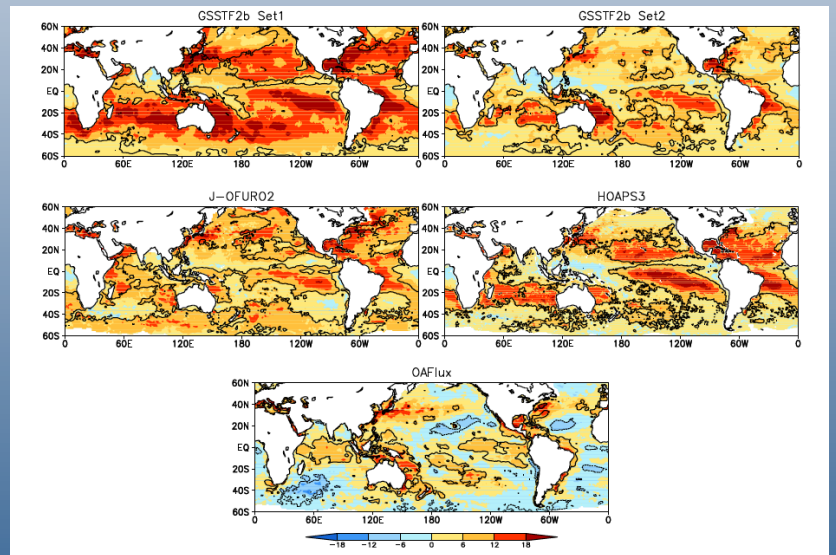
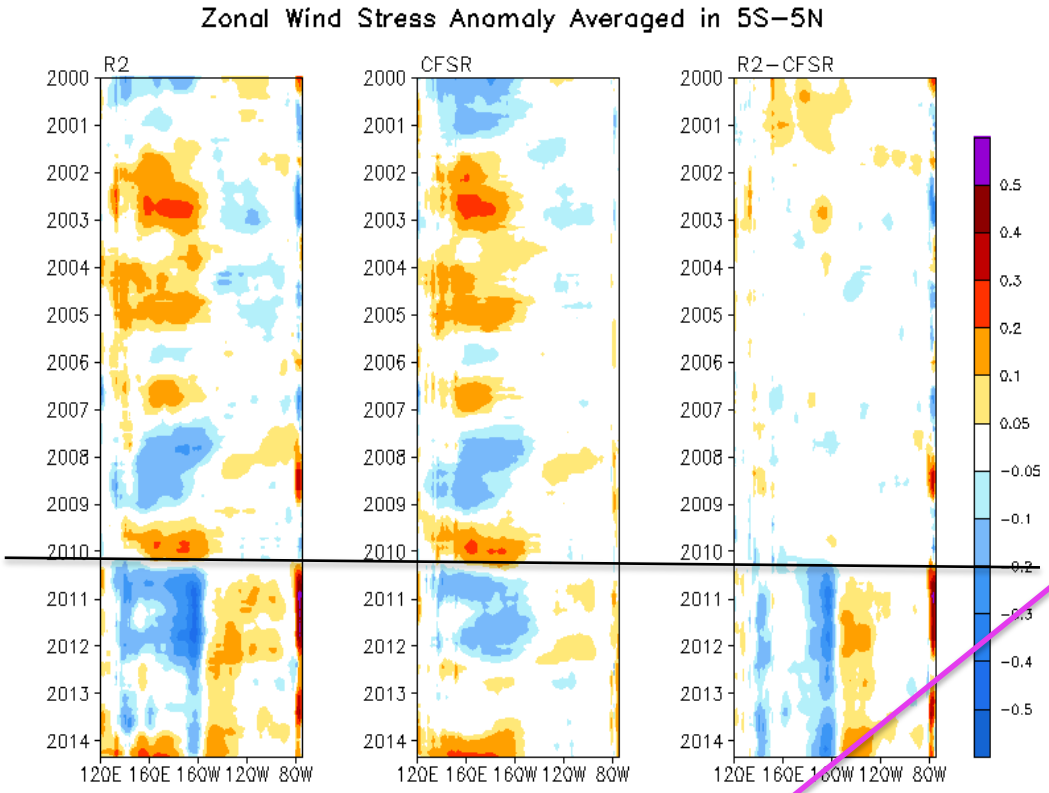
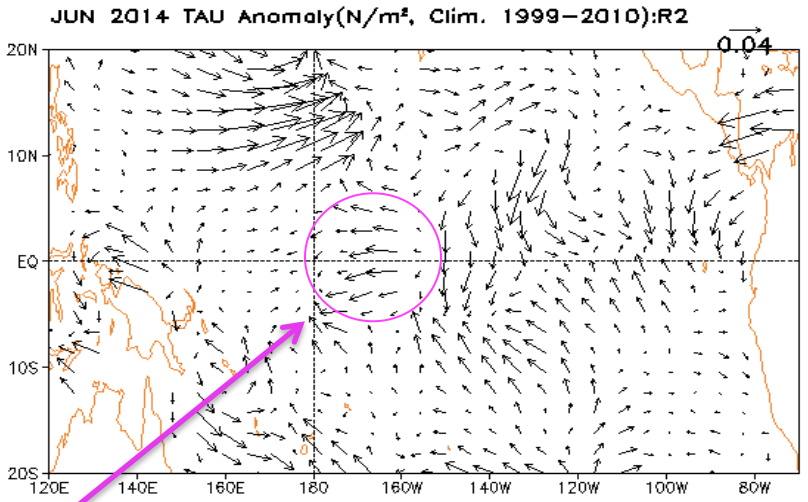


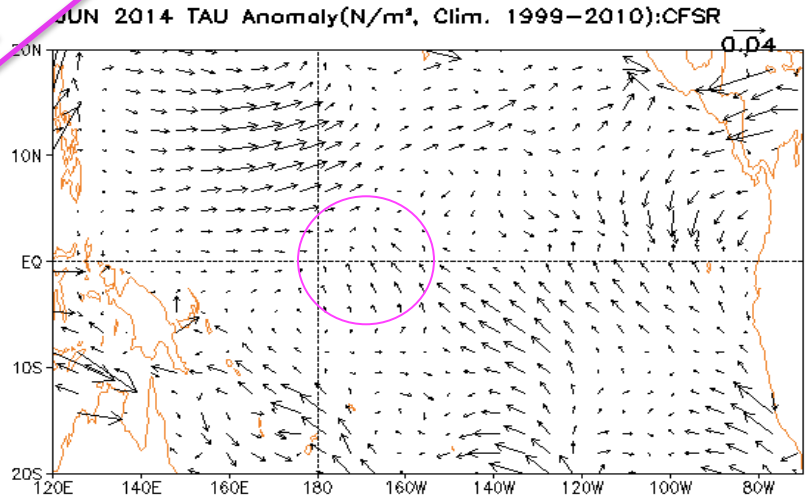
Fig. 3. Linear trends of LHF (W m^{-2} decade^{-1}) over the period 1988–2005. Contours give the trends above 95% confidence level.

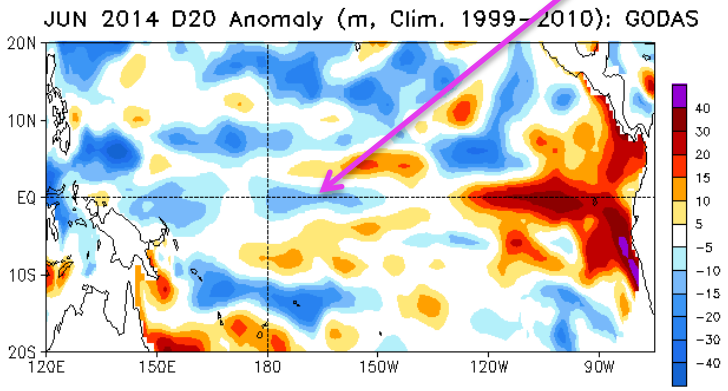
Figures from Chiu, Gao, and Shie, 2012)

Biases in winds could affect Seasonal-to-Interannual prediction skills



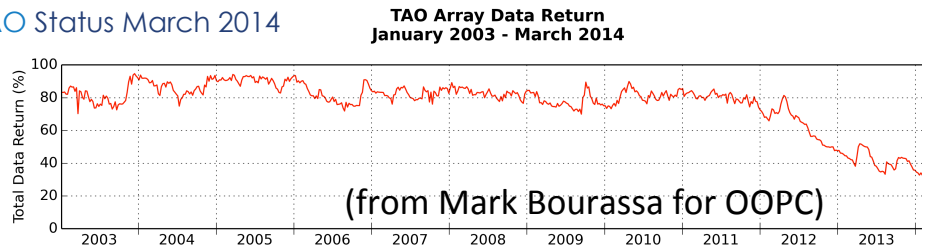






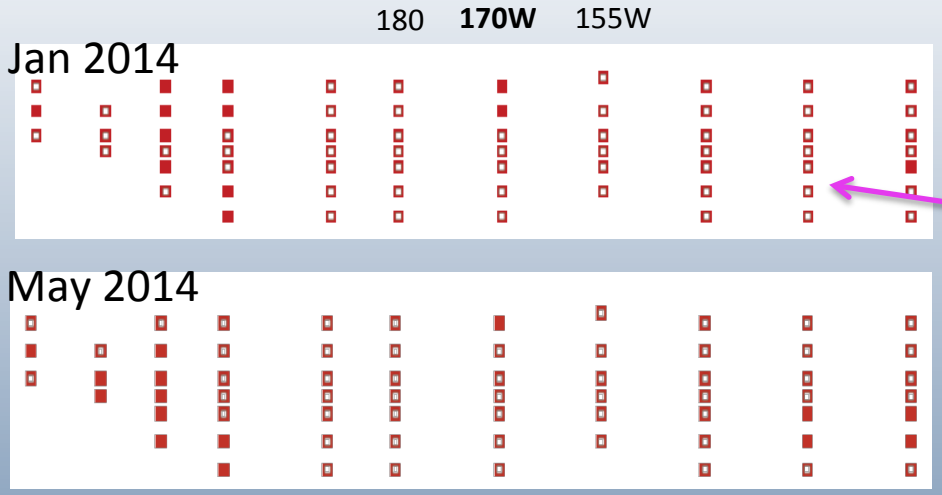
N2 has anomalous easterlies on the equator, whose impacts on ENSO prediction could be significant.

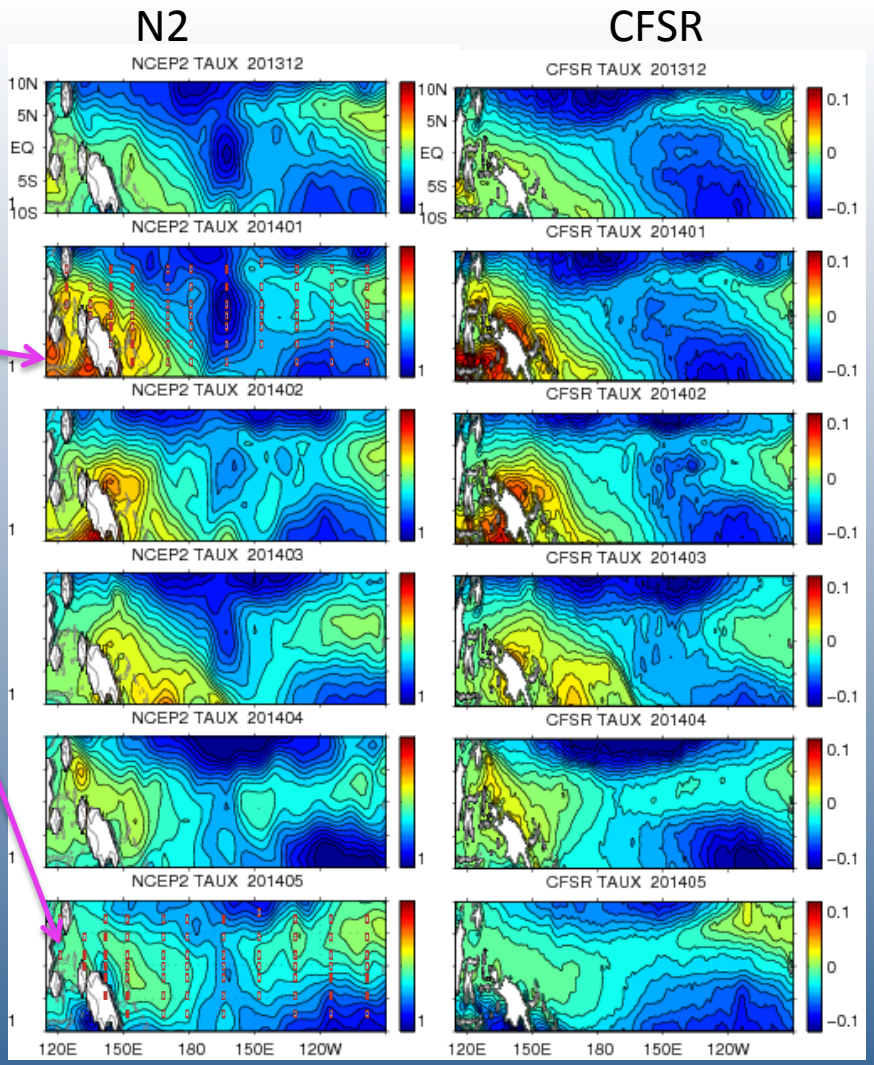
(Figures all from Yan Xue)



Is the degradation of TAO reporting to blame?

TAO buoy monthly reporting



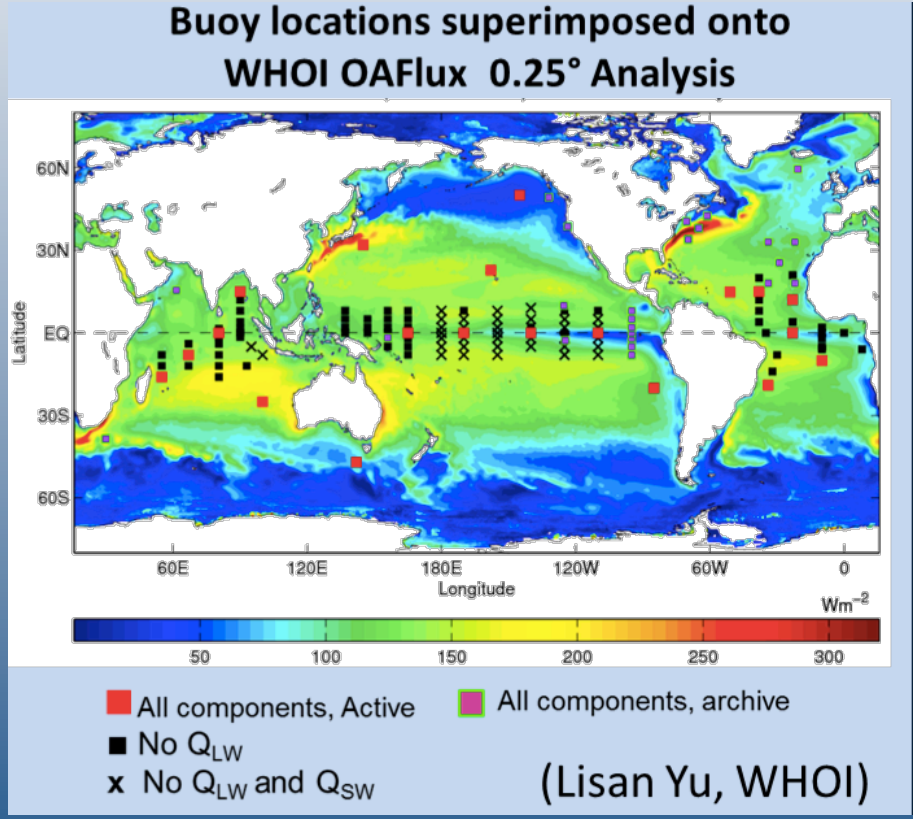


- We suspect that the N2 easterly abnormalty centered at 170W is related to the loss of TAO buoys, making N2 work excessively hard to adjust the remaining 1-2 buoys in the central Pacific.
- N2 does not assimilate satellite winds, while CSFR assimilates WindSat.
- TAO returns are so poor. Scatterometers (ASCATs) may be a good alternative for constraining the mean structure of the trade winds.

Major challenges for air-sea flux estimation

- **There is a lack of clearly defined measures of accuracy to validate existing flux products.**
- **Buoy air-sea measurements set the accuracy standard for gridded flux products but they are limited.**

Air-sea measurements from the global tropical moored buoy array plus buoy stations at selected locations (OceanSITES) provide valuable high-quality reference data.



Towards achieving global closure of ocean heat and freshwater budgets:

Recommendations for advancing research in air-sea fluxes through collaborative activities

CLIVAR/GSOP/WHOI Workshop on Ocean Syntheses and Surface Flux Evaluation

Woods Hole, Massachusetts, 27-30 November 2012

Co-chairs and Lead authors: Lisan Yu and Keith Haines

Co-authors: Mark Bourassa, Meghan Cronin, Sergey Gulev, Simon Josey, Seiji Kato, Arun Kumar, Tony Lee, Dean Roemmich

Sponsor Agencies:
NASA Physical Oceanography (Eric Lindstrom)
NOAA Ocean Climate Observations (David Legler)
US CLIVAR (Mike Patterson)
WCRP/CLIVAR GSOP

WCRP Informal/Series Report No. 13/2013
ICPO Informal Report 189/13

Presented by Arun Kumar
July 2013

CLIVAR/GSOP/WHOI Workshop Summary Recommendations on "Areas of Collaborative Research"

Synopsis:

Given the gaps in present-day knowledge and understanding, a consensus was reached during the workshop that achieving globally balanced energy and freshwater budgets is a long- term challenge, and should be broken down into incremental steps with achievable targets at each stage.

Guided by the NASA and NOAA perspectives and objectives, the workshop discussions were directed toward seeking areas of collaborative research by

(1)maximizing the use of existing observations made at the ocean surface and subsurface, *and*

(2)integrating regional budget analysis with direct pointwise comparison with in situ buoy/ship measurements.

CLIVAR/GSOP/WHOI Workshop
Recommendations on "areas of collaborative research"

Collaborative Activity I:

Regional heat/salt budget analysis by taking advantage of upper ocean heat/salt content observations from Argo.

Rationale: Argo observations , if estimates of uncertainty included, should be capable of providing regional references for calibration of temporally integrated air–sea flux estimates in the same way that flux buoy and ship measurements have previously provided pointwise calibration information.

Collaborative Activity II:

Direct pointwise comparison with selected OceanSITES.

Rationale: In situ air–sea measurements set the accuracy standard for gridded flux products.

The OceanSITES (full-flux) buoys at the following key climate locations are recommended.

- The Tropical Oceans (20°S-20°N, 9 buoys)

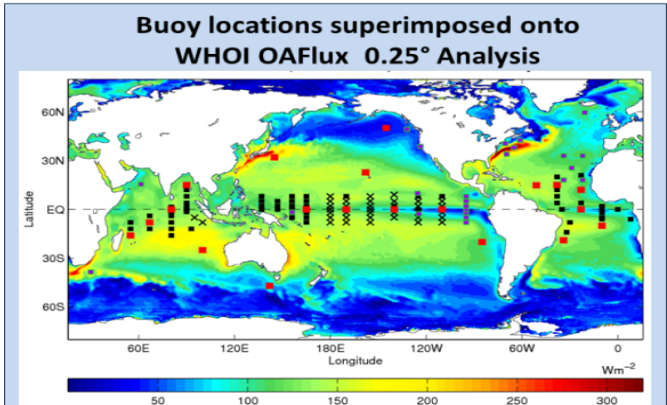
- 2 TAO buoys: (EQ, 110°W), (EQ, 165°E)
- 2 RAMA buoys: (EQ, 80°E), (15°N, 90°E)
- 3 PIRATA buoys: (EQ, 23°W), (10°S, 10°W), (15°N, 38°W)
- STRATUS (20°S, 85°W)
- Northwest Tropical Atlantic Station (NTAS) (15°N, 51°W)

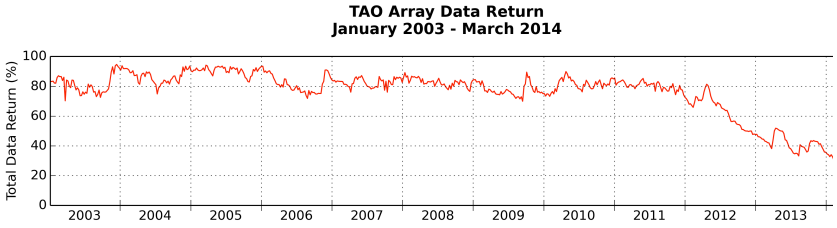
- The subtropical region (20–40° north and south, 6 buoys)

- RAMA in the Indian Ocean southeast trade wind regime: (20°S, 100°E)
- WHOI Hawaii Ocean Time-series Station (WHOTS) in the north Pacific: (22.5°N, 158°W)
- Salinity Processes in the Upper Ocean Regional Study (SPURS) buoy: (24.5°N, 38°W)
- Kuroshio Extension Observatory (KEO) buoy: (32.4°N, 144.6°E)
- JAMSTEC Kuroshio Extension Observatory (JKEO): (38°N, 146.5°E)
- CLIVAR Mode Water Dynamic Experiment (CLIMODE) buoy: 38.5ºN, 65ºW

- Higher latitudes (poleward of 40° north and south, 2 buoys)

- Ocean Station PAPA: (50°N, 145°W)
- Southern Ocean Flux Station (SOFS): (47°S, 140°E)





Reporting below 40%, down from more typical 80%

(From Mark Bourassa)

Achieved Plan: OOPC-sponsored International 'Vision' workshop on the Future of the Tropical Ocean Observing System

- Scientific requirements have evolved
  - Variables/Scales approach to planning
- Components of observing system designed during TOGA
  - TAO TRITON moorings, ships of opportunity.
- New Technology, has evolved
  - existing (Argo, Satellite),
  - potential (profiling moorings, ocean gliders)
- Challenges and new opportunities to support/service existing arrays
- Ran a workshop based on an invited whitepaper process
- Billy Kessler and Neville Smith will guide development of TPOS
- Follow-up sponsors/stakeholders meeting.
- Dissolve TPOS organizing group in 10 years

Meghan Cronin led the effort on:

White Paper #11 – Wind stress and air sea fluxes observations: status, implementation and gaps

Cronin, M.F.[1], Bourassa, M.[2], Clayson, C.A.[3], Edson, J.[4], Fairall, C.[5], Feely, D.[1], Harrison, D.E.[1], Josey, S.[6], Kubota, M.[7], Kumar, B.P.[8], Kutsuwada, K.[7], Large, B.[9], Mathis, J.[1], McPhaden, M.[1], O'Neill, L.[10], Pinker, R.[11], Takahashi, K.[12], Tomita, H.[13], Mathis, J.[8], Weller, R.A.[3], Yu, L.[3], and Zhang, C.[2]

GCOS • GOOS • WCRP OOPC

9 Specific Recommendations and Highlights of follow-on activities

1) Working group to develop strategy for regional heat/salt budget analysis and regional flux assessment using flux buoys and upper ocean heat content from Argo or ocean syntheses.

Relevant Projects developed after the CLIVAR/GSOP/WHOI workshop:

- **New CLIVAR research focus on "Consistency between planetary heat balance and ocean heat storage", led by K. von Schuckmann (France)**
  This new research activity is to provide coherent assessment of changes of energy fluxes from the top of the atmosphere to the ocean to estimate variability/change in the energy of the climate system on interannual/longer timescales.

- **ISSI (International Space Science Institute) working group on "Consistency of integrated Observing Systems monitoring the energy flows in the Earth System", led by K. von Schuckmann (France)**
  This activity will bring a new integrated perspective on uncertainties, in, and consistencies across, both the energy–sea-level budgets.

- **Project on Towards improved estimates of ocean heat flux (TIE-OHF), led by A. Bentamy (France).** The objective is on Evaluation, determination, and analysis of the heat flux components over the global ocean.

Recommendations and Highlights of follow-on activities - 2

2) Continue evaluation of surface fluxes and ocean transports from ocean syntheses and identify regions suitable for regional heat/salt budget studies

3) Further pointwise comparisons of ocean synthesis and atmospheric reanalysis products with flux buoy and OceanSITES measurements, including scaling analysis to estimate uncertainties from spatial/temporal variability.

4) Ocean synthesis and reanalyses should archive components of the air-sea heat flux i.e. Short and Longwave radiation, and sensible and latent heat fluxes, to enable evaluation.

5) Need easier online DB access to daily averaged and higher resolution net heat fluxes, components, and meteorological state variables from mooring sites.

Meghan Cronin and Dongxiao Zhang are funded to (a) create a new flux website for KEO & Papa and (b) do some pointwise comparison and analyses with these data as recommended by report.

6) Reference station data (WMO type "84") should be withheld from reanalyses to allow independent assessment. All data assimilated in NWP should list WMO numbers.

7) Update Seaflux website (http://seaflux.org) with recent data and metadata

Recommendations and Highlights of follow-on activities - 3

8) Revive Fluxnews Letter online, to review of surface flux research and datasets.

Sergey Gulev has restarted the the Flux News newsletter:
http://www.sail.msk.ru/newsletter.php

One newsletter was out last November.

9) Enhance interaction with relevant program activities funded by different agencies (e.g., NASA, NOAA, ESA, …).

US CLIVAR Context

Questions put forth by Arun Kumar
July 2013

- **Develop a US CLIVAR activity focusing on evaluation of surface fluxes (follow up on the 'High latitude surface fluxes' WG)?**

- **Coordinate funded surface flux activities across different agencies?**

- **Plug into upcoming US climate reanalysis activities?**

  NOAA's MAPP program has established 3-year Climate Reanalysis Task Force (TF) activities to address outstanding issues in atmospheric, ocean, and land reanalysis and develop a greater degree of integration among Earth system reanalysis components

  Evaluating the CFSR air-sea fluxes in the context of global energy and freshwater budgets (L. Yu, Y. Xue, A. Kumar)