DEEP-C:
Introduction & WP1 update

Richard Allan, Chunlei Liu - University of Reading

Thanks to: Norman Loeb, Matt Palmer, Doug Smith

DEEP-C Meeting, University of Reading, 9th June 2015

DEEP-C project meeting, 9th June 2015 University of Reading

- **11:00 Coffee**
- 11:30 Introduction and summary of recent literature (Richard Allan)
- 12:00 Independent estimate of surface energy fluxes based upon satellite data and reanalysis atmospheric transports (Chunlei Liu)
- 12:20 Assessing and applying new DEEP-C net heat flux product (Pat Hyder)
- **13:00 Lunch**
- 13:40 Temperature trends form Argo and Hydrography Data (Elaine McDonagh)
- 14:00 Report on Deep Argo workshop, CSIRO, Hobart, May 2015 (Brian King)
- 14:20 Deep Argo float deployment critical in Southern Ocean to resolve (Freya Garry)
- 15:00 (1) Pseudo profiles from climate and ocean models to evaluate ocean heat content mapping methods (2) Intercomparison of ocean heat content in ocean reanalysis“ (Matt Palmer)
- 15:30 Plans for collaborative work (WP4)
- **16:00 Tea and final discussions.**

DEEP-C Work Plan

Start date: March 2013; Project Ends February 2017

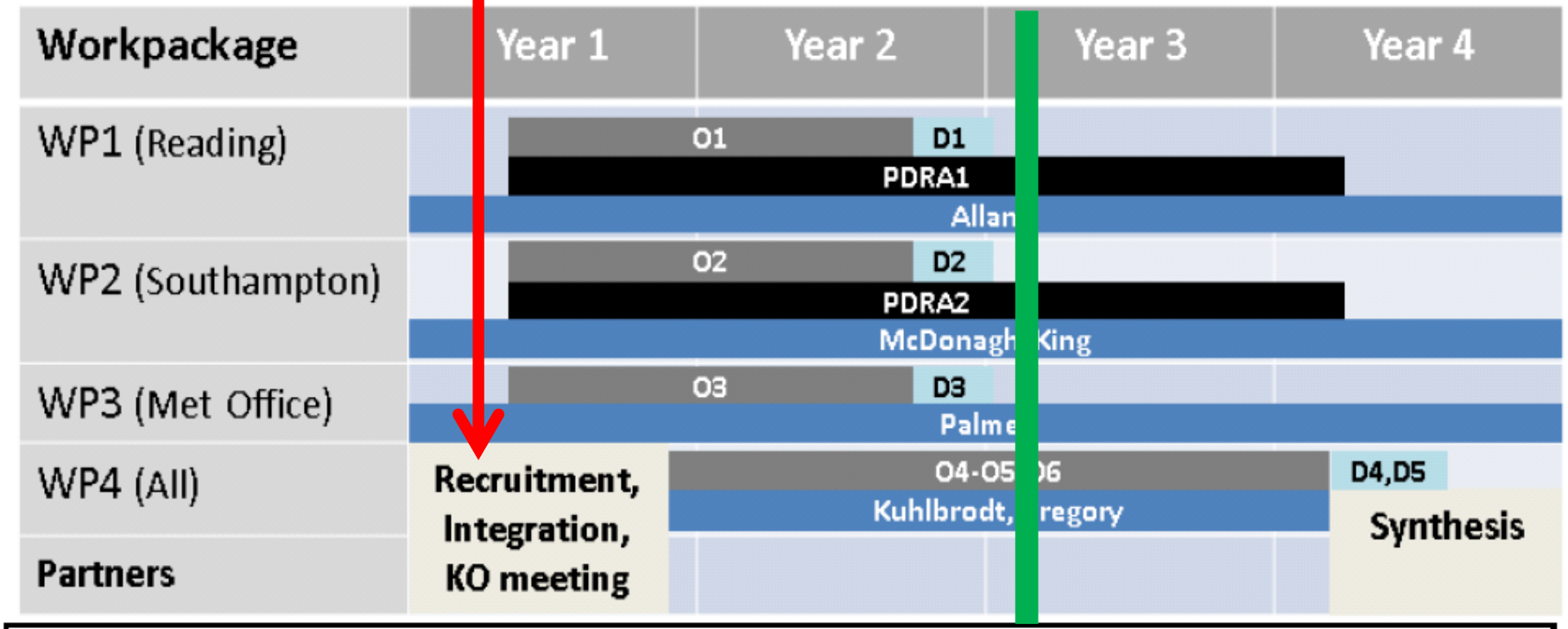


Table 2 - Management timeline for DEEP-C.

Project Objectives

O1. Combine satellite radiation budget measurements with atmospheric reanalyses, providing improved 2D estimates of surface heat fluxes across the ocean surface (WP1)

O2. Calculate global 3D ocean heat content and its changes since 2003 using ARGO and ship-based observations, leading to improved understanding of energy propagation through the climate system (WP2)

O3. Investigate spatial patterns of surface and sub-surface temperature changes in distinct hiatus decades using simulations and observations (e.g. Fig. 4); evaluate the processes fundamental for ocean heat uptake and redistribution (WP3)

O4. Combine ocean and satellite data (from O1-2) to provide new estimate of Earth's net radiative energy balance (2000-2015) and compare with CMIP5 climate simulations (from O3) (WP1-4)

O5. Monitor co-variations in net radiative energy imbalance and ocean heating (from O1,O2,O4); quantify and understand lags between OHC and TOA radiation (WP1-4)

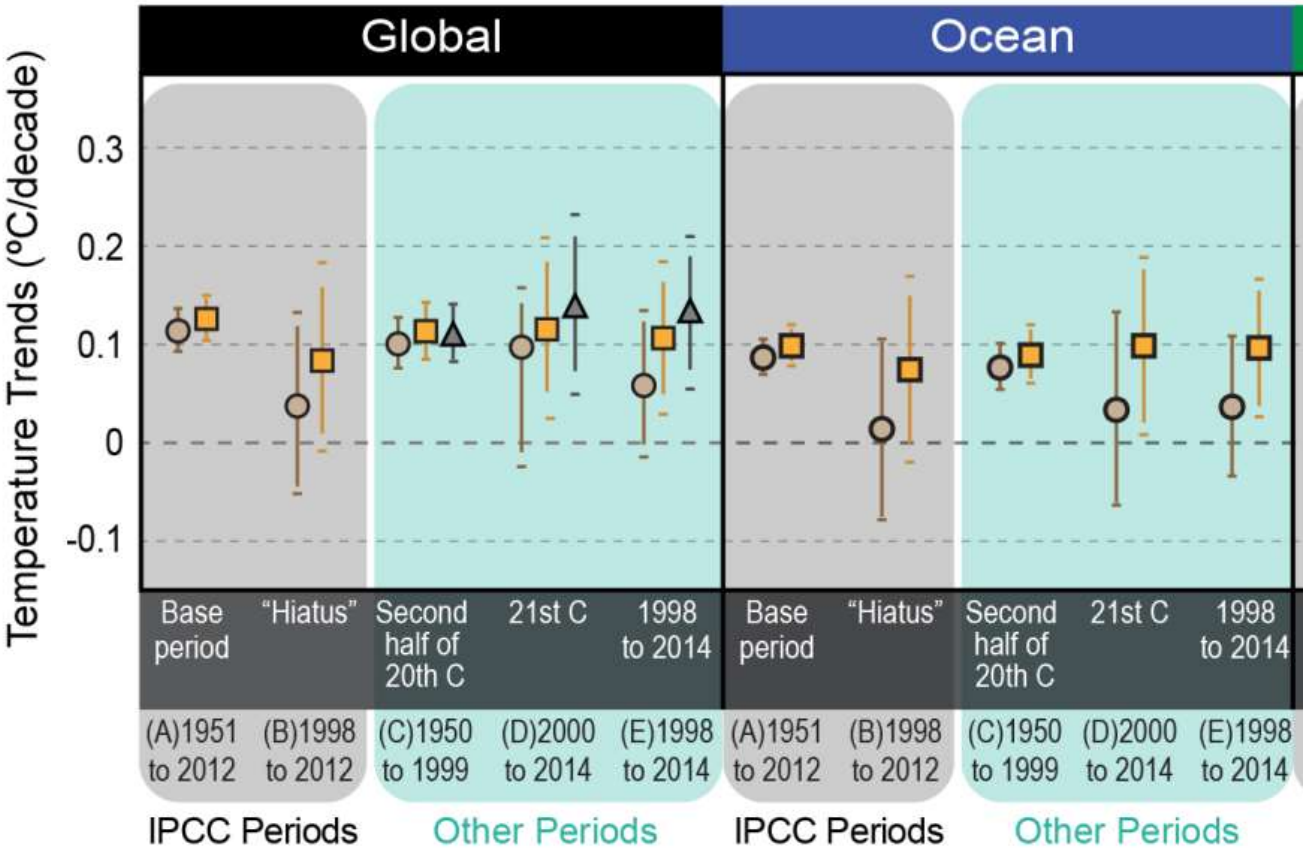
O6. Characterise spatial signatures and mechanisms of ocean and atmospheric heat re-distribution (from O4-5) during the hiatus period 2000-2015 using observations and simulations (WP1-4)

Some recent updates to the literature:

No “hiatus”? Karl et al. (2015) Science

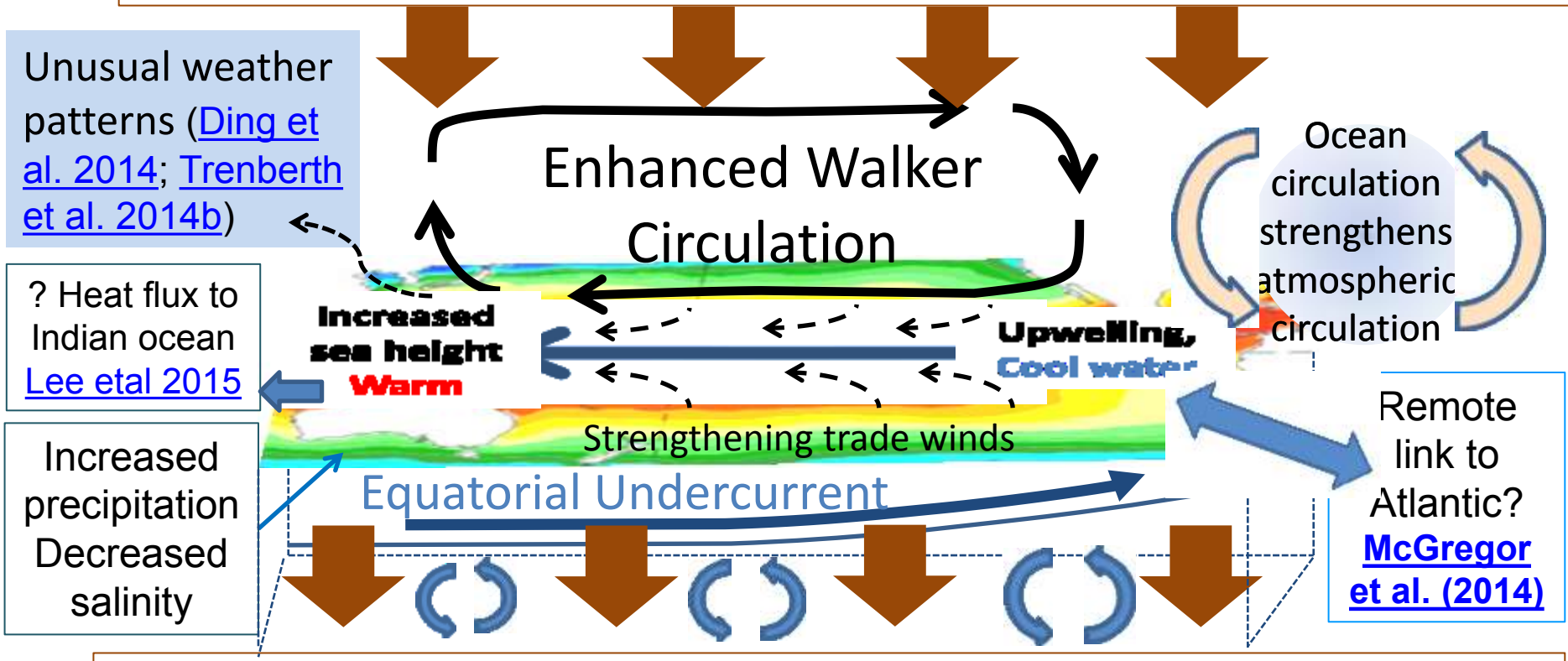
Doesn’t explain slower warming compared to:

- 1980s/90s
- coupled models
- Climatically unusual conditions in 2000s



Role of Pacific Ocean Variability?

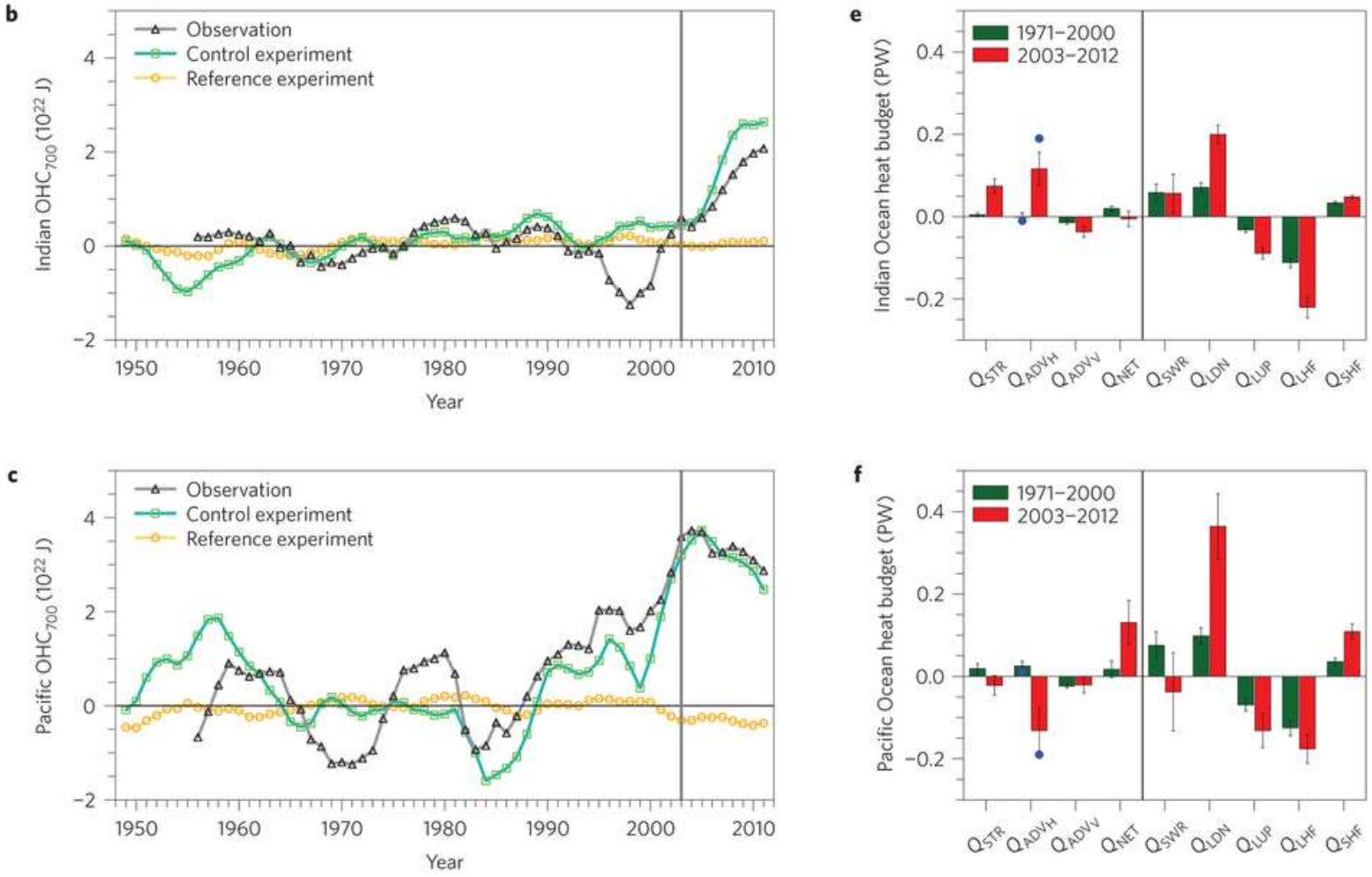
Continued heating from rising greenhouse gas concentrations



Enhanced mixing of heat below 100 metres depth by accelerating shallow overturning cells and equatorial undercurrent

See: Merrifield (2010) J. Clim.; Sohn et al. (2013) Clim. Dyn.; L'Heureux et al. (2013) Nature Clim. Change; Kosaka and Xie (2013) Nature; England et al. (2014) Nature Clim. Change; Watanabe et al. 2014 Nature Clim. Change; Balmaseda et al. (2013) GRL; Trenberth et al. (2014) J. Clim.

Increased heat flow from Pacific to Indian Ocean?



Lee et al. (2015) Nature Geosci

WP1 - Planned work

1. Analyse and update observed variability in TOA radiation balance (Allan et al. 2014: delivered)
2. Combine reanalyses/satellite data to provide independent estimates of surface flux (in revision: C. Liu et al.)

   - Wider use of flux products by Pat Hyder et al. (Met Office)

3. *Other topics:*
   - *Inter-hemispheric heating asymmetry and water cycle*
   - *Investigate lags in climate system (preliminary work)*
   - *Evaluation of ERA CLIM radiation budget?*
4. *Monitoring of changes in energy balance (ongoing)*
5. *Reconcile TOA radiation balance and ocean heating (WP4)*

WP1 Objectives/Deliverables

O1. Combine satellite radiation budget measurements with atmospheric reanalyses, providing improved 2D estimates of surface heat fluxes across the ocean surface (WP1)

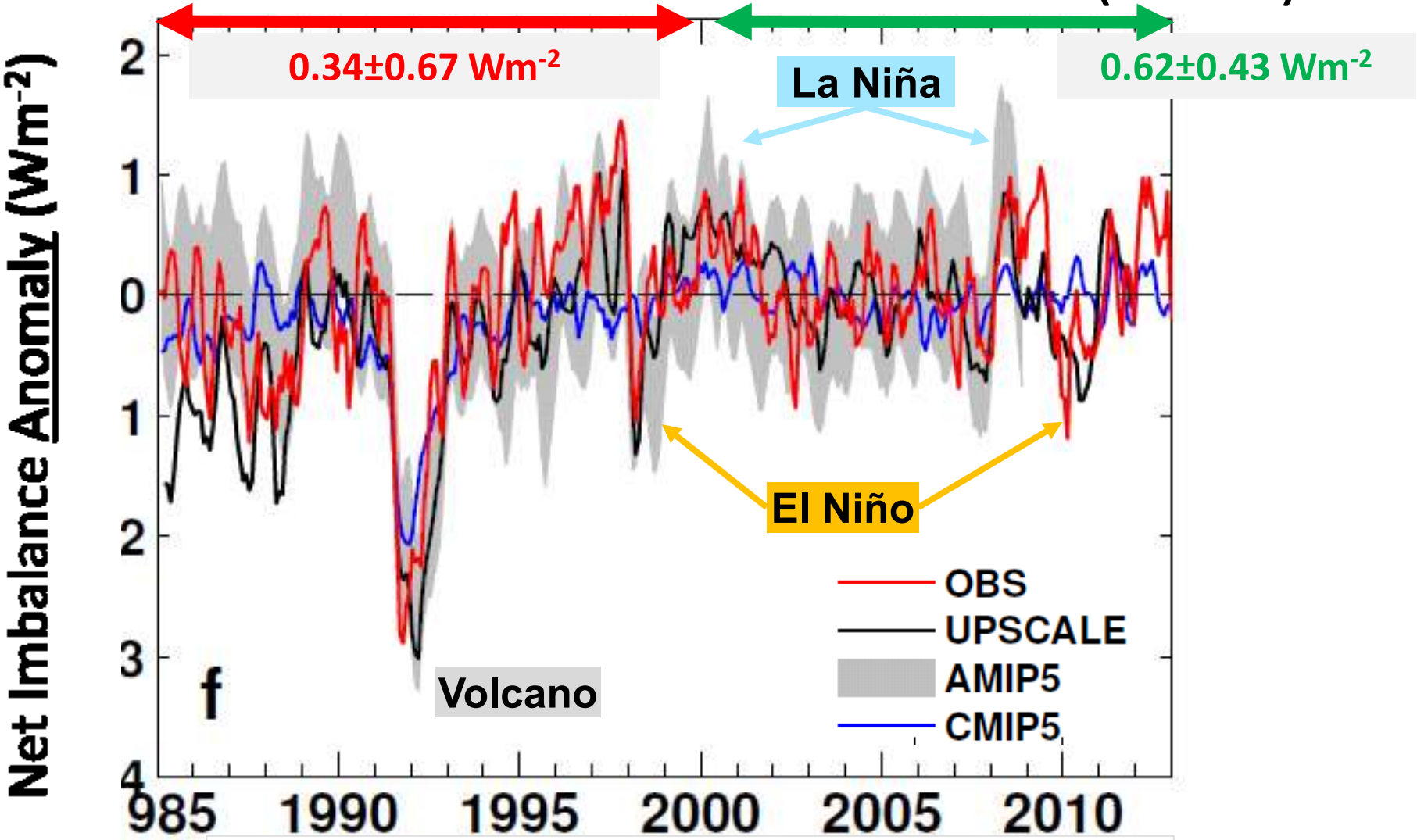
D1. Combined satellite-reanalysis atmosphere/surface energy flows: methodology, uncertainty and exploring lags in the climate system (paper 1,2; WP1, O1,4)

O5. Monitor co-variations in net radiative energy imbalance and ocean heating (from O1,O2,O4); quantify and understand lags between OHC and TOA radiation (WP1-4)

O6. Characterise spatial signatures/mechanisms of ocean and atmospheric heat re-distribution (from O4-5) during the hiatus period 2000-2015 using observations and simulations (WP1-4)

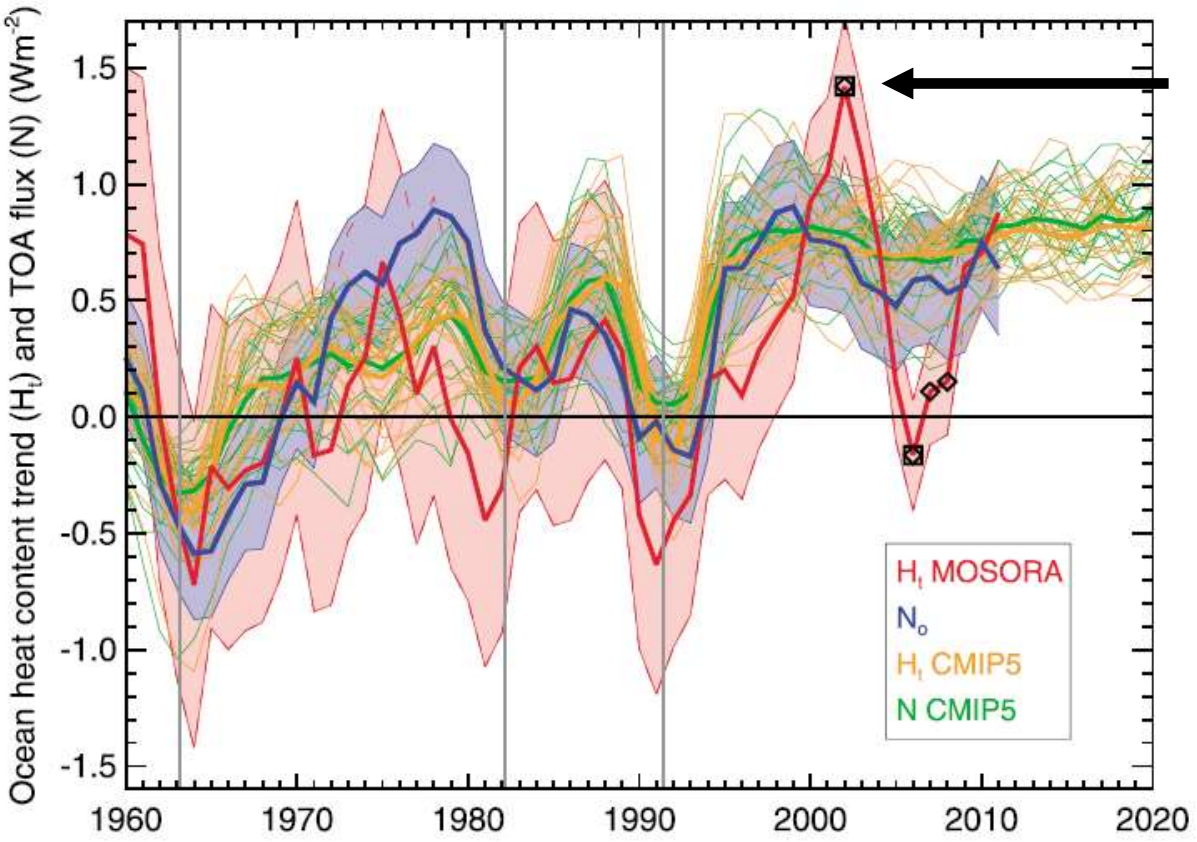
Changes in imbalance in models & observations

Imbalance: 0.23 0.00 0.78 0.63 0.63 (Wm^{-2})



Allan et al. (2014) GRL

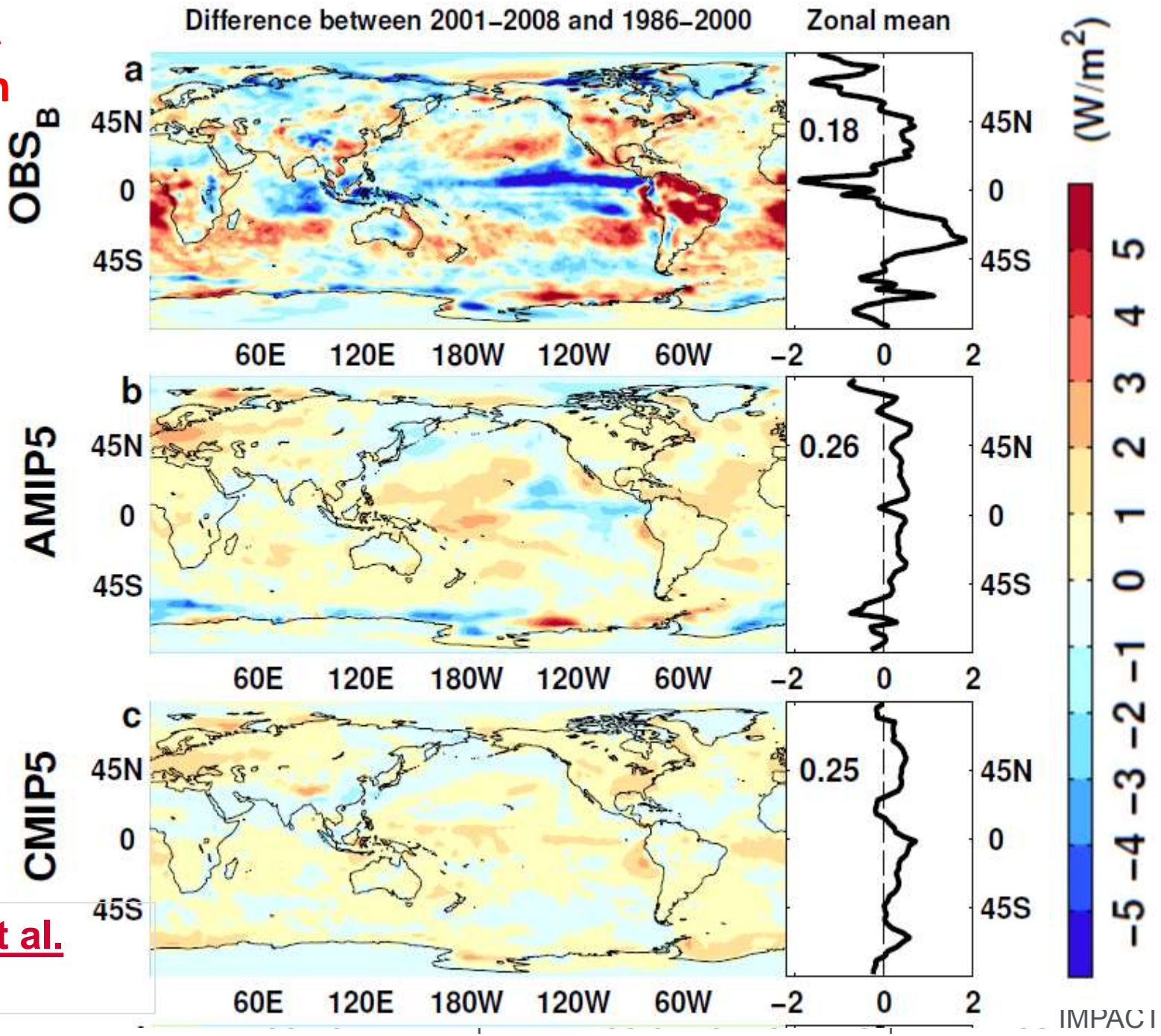
DISCREPANCY BETWEEN RADIATION BUDGET & OCEAN HEATING



- Large ocean heating anomaly in 2002
- Inconsistent with radiation budget observations and simulations
- Changing observing system influence?
- Slight drop in net flux 1999-2005?

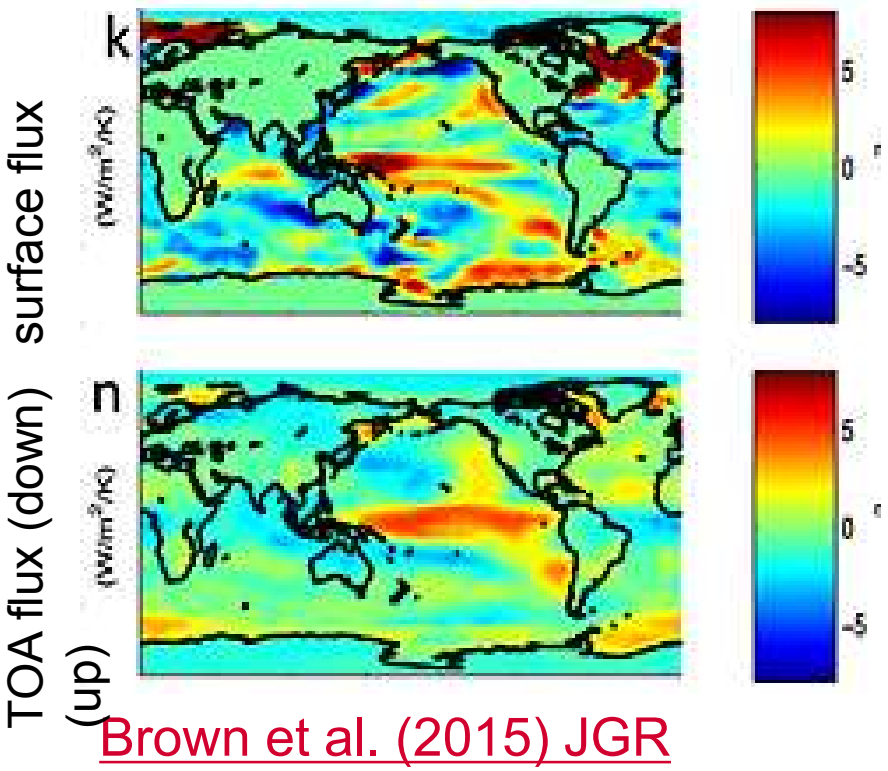
Smith et al. (2015) GRL

NET TOA Radiation



Allan et al. (2014)

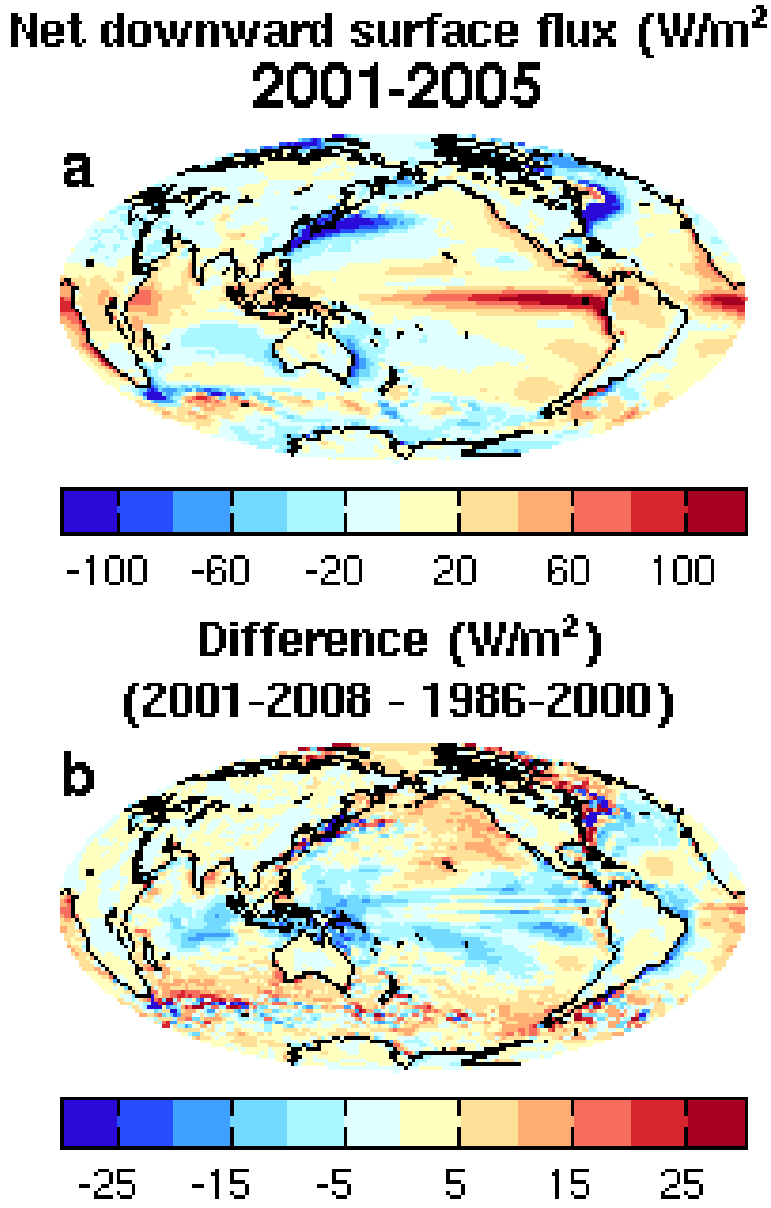
FEEDBACKS ON INTERNAL VARIABILITY?



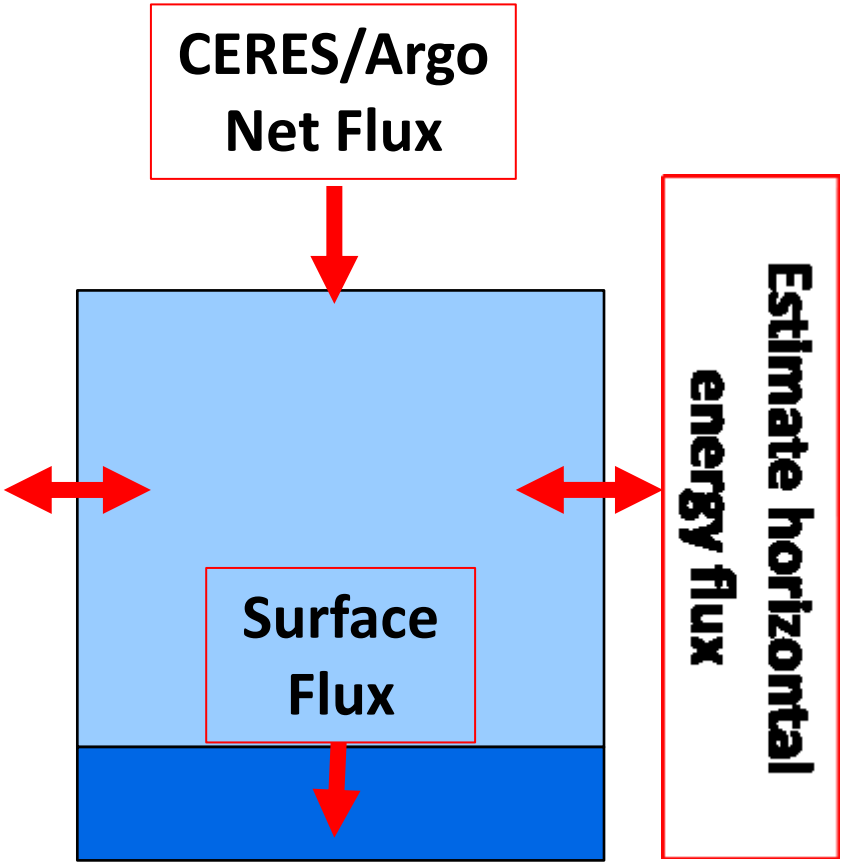
Brown et al. (2015) JGR

← **top:** less heat flux out of east Pacific during warm phases?

- Models may underestimate interdecadal variability
- Are there positive heat flux feedbacks which amplify internal climate variability?

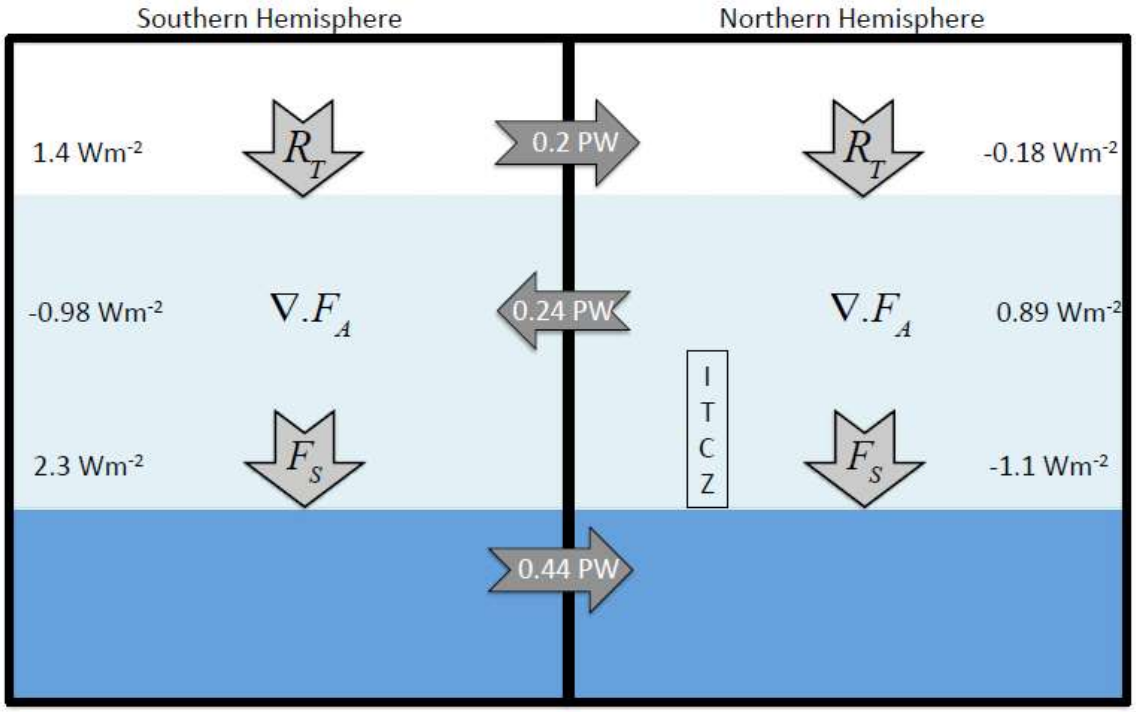


Current work: estimates of Surface Flux (Chunlei Liu)



$$F_{SFC} = F_{TOA} - \frac{\partial TE}{\partial t} - \nabla \cdot \frac{1}{g} \int_0^1 V(Lq + C_p T + \varphi_s + k) \frac{\partial p}{\partial \eta} d\eta$$

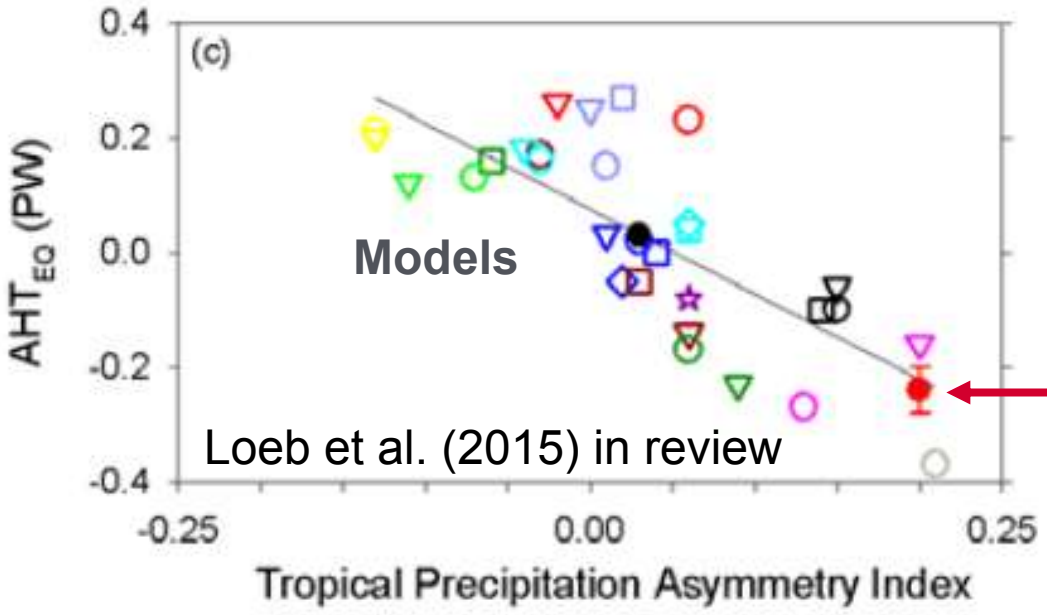
OBSERVED ASYMMETRY IN EARTH'S ENERGY BUDGET



Loeb et al. (2015) submitted

- Observed inter-hemispheric imbalance in Earth's energy budget
- Not explained by albedo: brighter NH surface but more clouds in SH (Stephens et al. 2015)
- Imbalance explains position of ITCZ (Frierson et al. 2013)

EQUATORIAL HEAT TRANSPORT AND MODEL PRECIPITATION BIAS



- Clear link between bias in cross-equatorial heat transport by atmosphere and inter-hemispheric precipitation asymmetry

CERES/ERA Interim

More rain in NH →

Conclusions

- Heating of Earth continues at rate of ~0.6 Wm^{-2}
- Current variability in TOA radiation (1985-2013)
  - Net flux higher in 1995-1999 than 2000-2012 period
  - Radiative forcing alone can't explain surface warming slowdown: internal variability important
  - Pacific signal in $\Delta T/\Delta N$; atmos. transports dominate surface
- Plans:
  - Development of surface flux estimate (finalising)
  - Evaluate with other datasets; basin-scale flux changes
  - Work with WP2 (surface fluxes) and WP3 (simulations & intercomparisons) and comparison with surface fluxes products (Met Office)

WP1 Dissemination Activities

- **Late 2015 - DEEP-C workshop?? TBD**
- **November 2015: Megha Tropique workshop, Paris**
- **September 2015: NCEO meeting Southampton; CliVar workshop Exeter**
- **July 2015:** Talks/posters at IUGG Prague & Common Future Climate conf.
- **June 2015:** Comments on Karl et al. paper (Carbon Brief/SMC/Reuters); Seminars at Imperial College & NCAS
- **April 2015:** Presentation at Decision Analysis for Policy Support workshop
- **February 2015:** Comment on detection of greenhouse gas radiative effect
- **January 2015:** Smith et al. (2015) GRL dissemination work & U3A outreach
- **October 2014**: Conversation article on Durack/Llovel papers; BBC2 Jeremy Vine show; CERES/GERB/ScaRaB Science team meeting talk
- **August 2014**: Allan et al. (2014) NCAS highlight, Nature Climate Change highlight ; Climate Lab Book , Carbon Brief , Met Department & Conversation blogs; Telegraph ; Eddington Astronomical Society talk
- **July 2014**: DEEP-C talks at GEWEX and AMS conferences
- **April 2014** – Royal Society "Hiatus" discussion meeting; EGU talk

Discussion

- Activities to combine work packages?
  - Joint publications
  - Intercomparison of ocean heating/imbalance data
  - Assess uncertainty in surface flux product
  - Lags in system/feedbacks on decadal variability
  - Estimated imbalance + regional/vertical structure
  - Heating by ocean basin and surface fluxes
- Big issue questions to aim for?
- Future funding opportunities?
- Next meeting
  - Dates…
  - Should we arrange a larger 2-day workshop?

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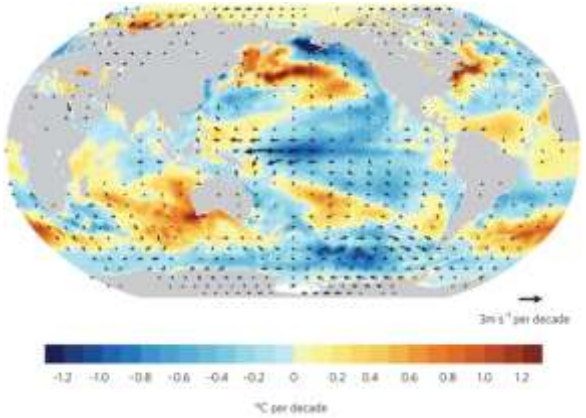
POSSIBLE FUTURE WORK

- Can we reconcile ocean heating and top of atmosphere imbalance?
- Time-scales and lags associated with net imbalance (Harries & Futyan 2006 GRL)
- Observational constraint on radiative feedbacks & climate sensitivity
- What controls decadal variability: “hiatus” and “surge” events?
- Feedbacks associated with unforced variability
  - Cloud and latent heat fluxes in the Pacific e.g. Brown et al. 2014 GRL
- Do patterned radiative forcings force distinct feedback responses?
- To what extent does inter-hemispheric imbalance control rainfall patterns? e.g. Hwang et al. (2012) GRL

Spare slides

Mechanisms of ocean variability

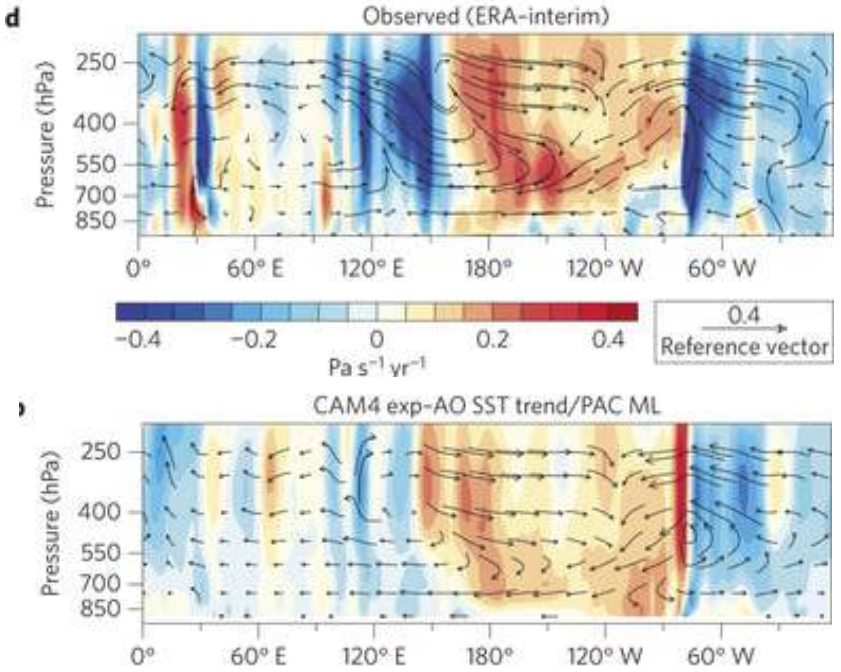


(Kosaka 2014)

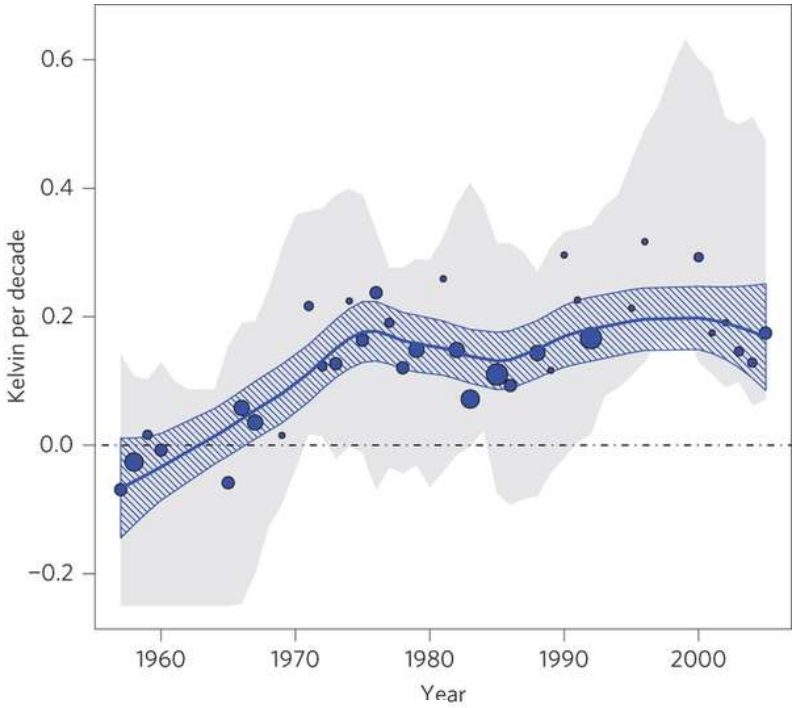
- Pacific Decadal Variability Pattern
- Is Atlantic driving Pacific changes?
- Atlantic circulation salinity feedback? (Chen & Tung 2014)

Model simulates stronger Pacific trades when apply Atlantic SSTs + Pacific SST allowed to respond →

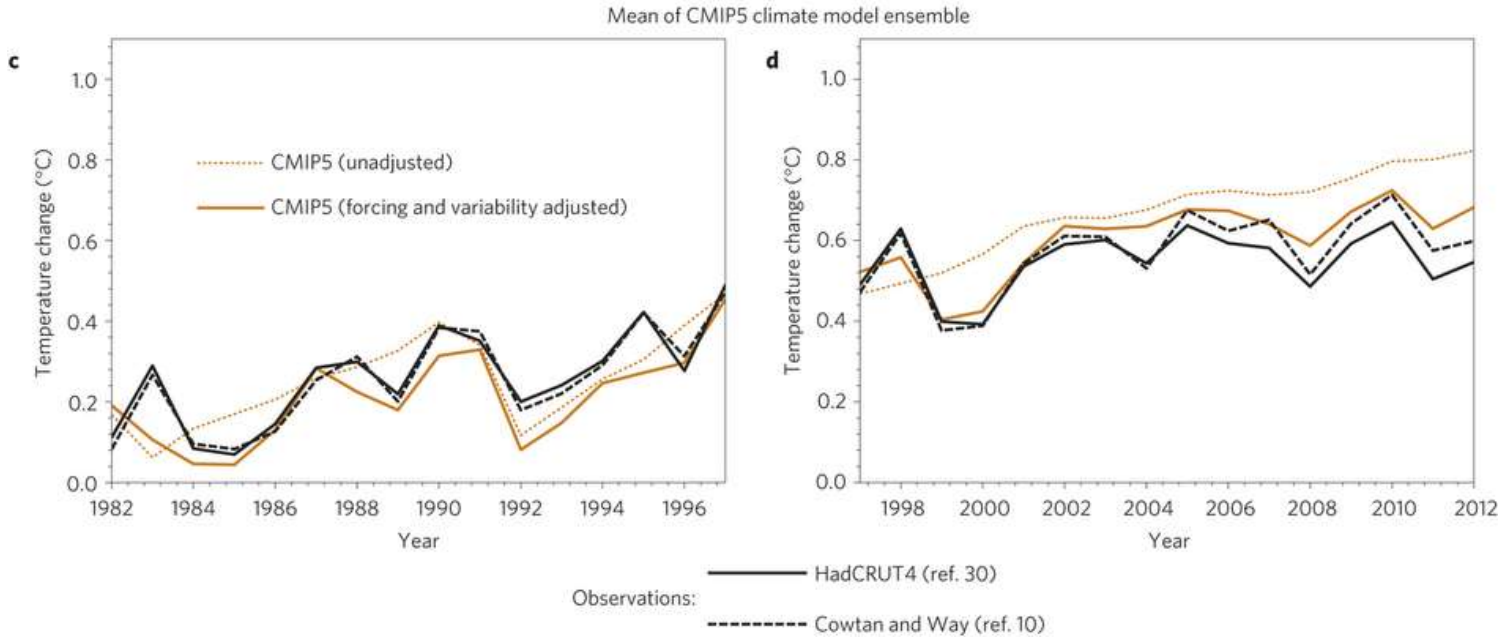
McGregor et al. (2014)



Better agreement accounting for ENSO & natural forcings

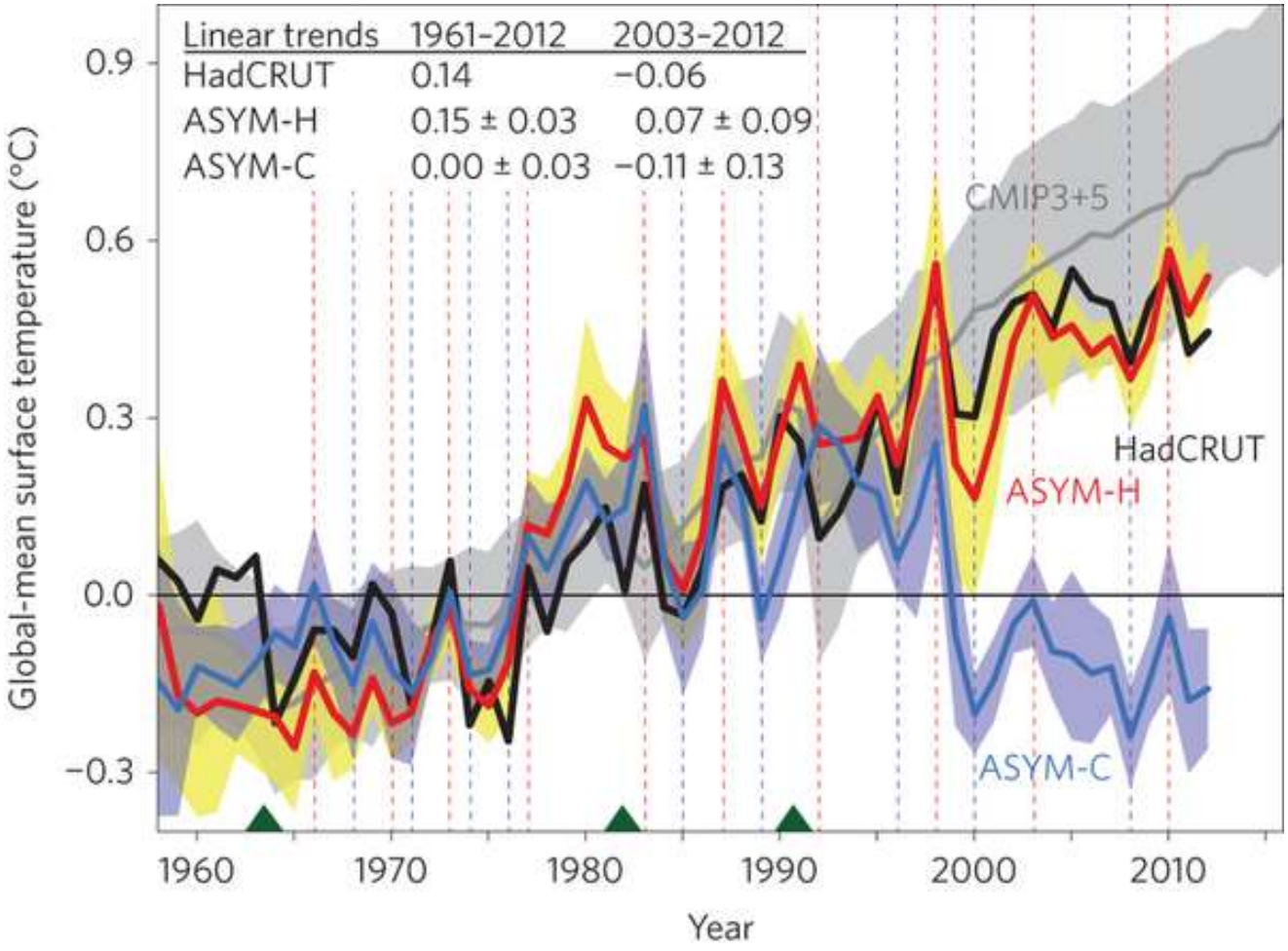


Risbey et al. (2014) Nature Climate Change →



← Huber & Knutti (2014) Nature Geosci

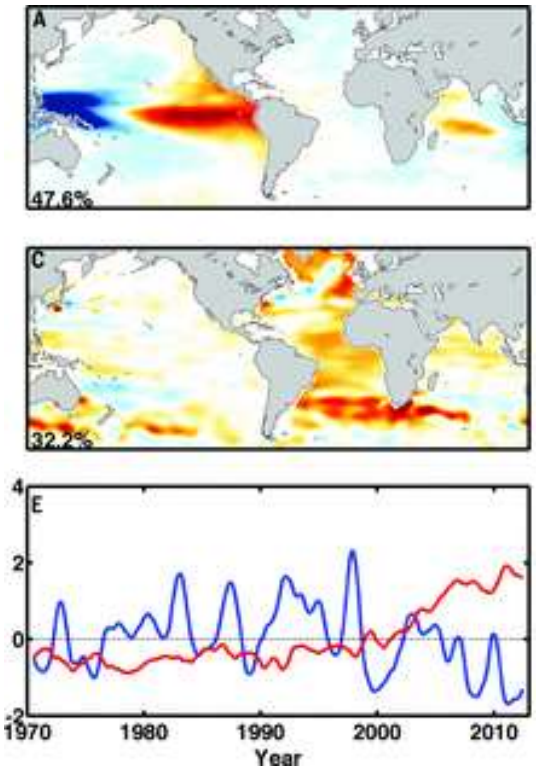
Role of Pacific Trade Winds



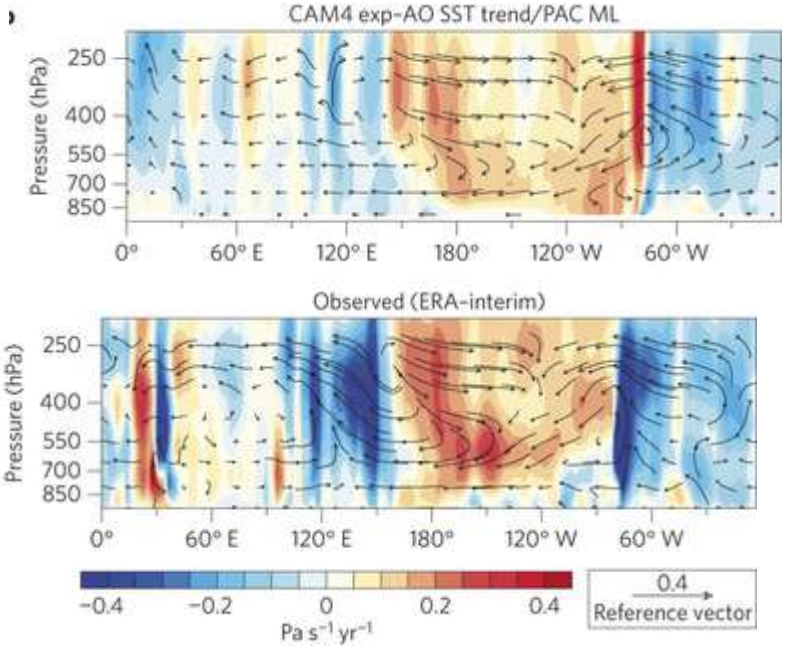
Watanabe et al. (2014) Nature Climate Change:

- Prescribe observed changes in Pacific trade winds
- Estimate Internal variability contributes ~+0.11-0.13°C in 1980s/90s and -0.11°C in 2000s
- Is it all internal or is there a forced component?

Role of the Atlantic ?

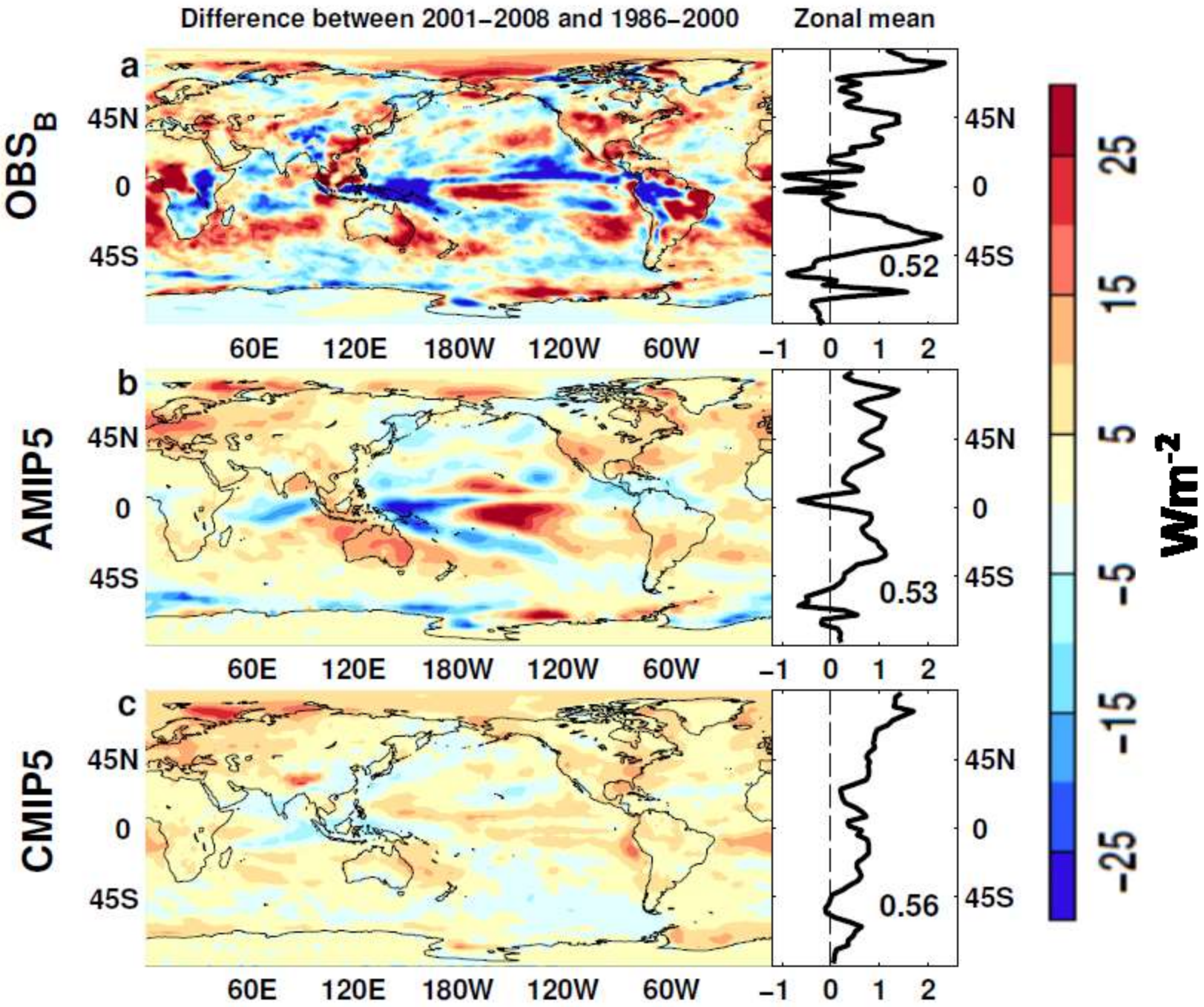


Chen & Tung (2014) Science → propose mechanism involving deeper AMOC circulation and salinty feedbacks

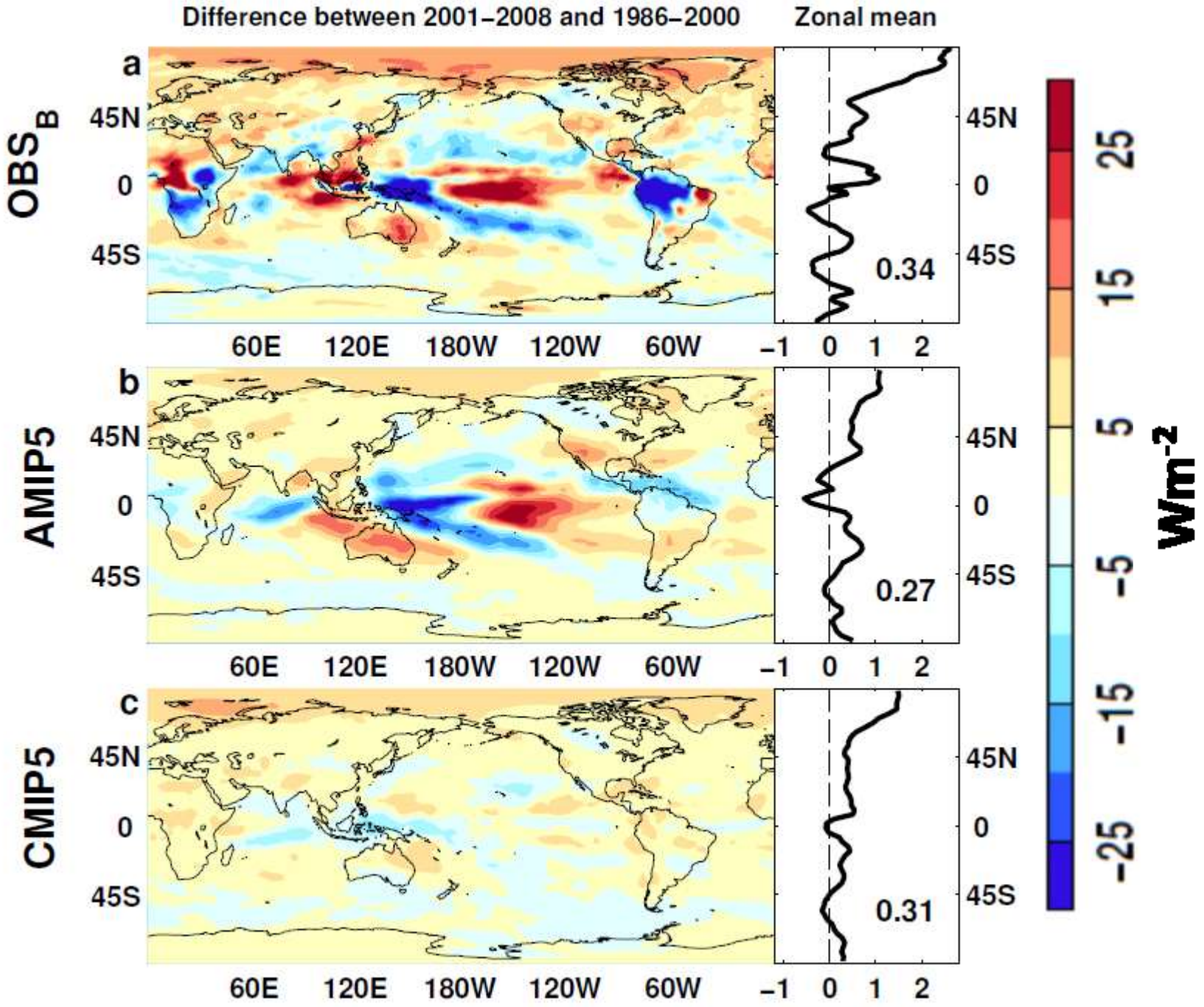


McGregor et al. (2014) Nature Clim. Model simulated strengthened Pacific trades when forced by Atlantic SST and Pacific SST is allowed to respond

Absorbed Shortwave Radiation



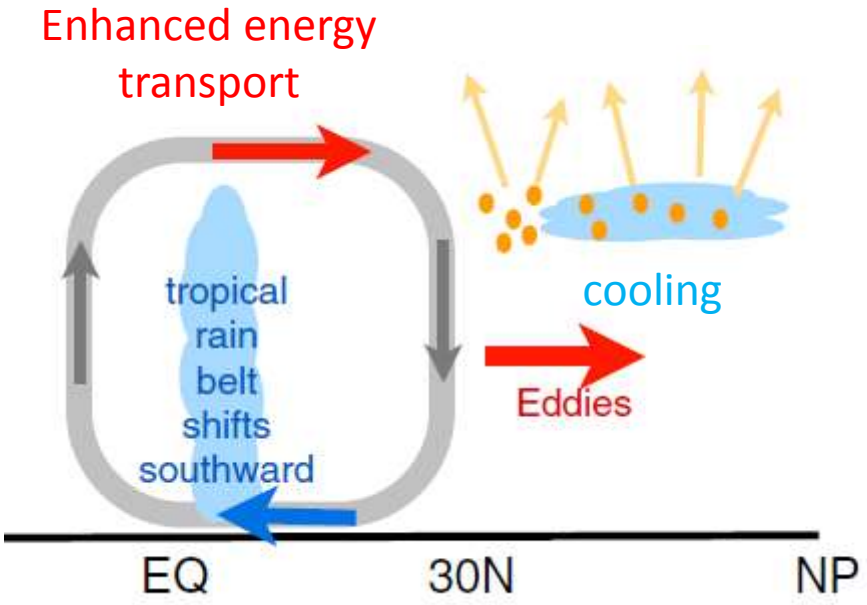
Outgoing Longwave Radiation

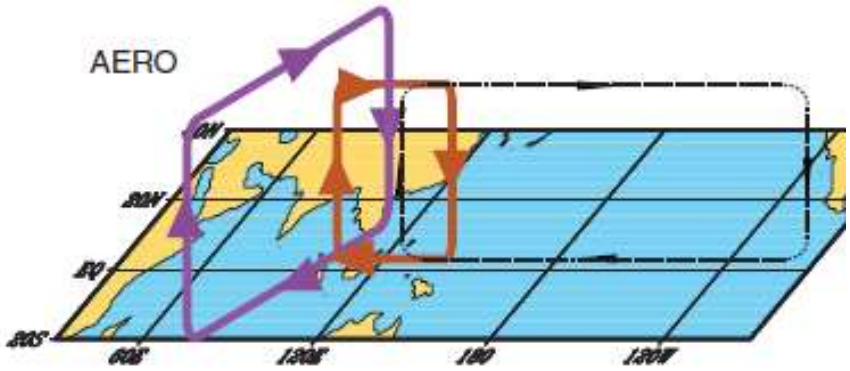


EARTH'S ENERGY BUDGET & REGIONAL CHANGES IN THE WATER CYCLE

- Regional precipitation changes sensitive to asymmetries in Earth's energy budget
- N. Hemisphere cooling: stronger heat transport into hemisphere
- Reduced Sahel rainfall from:

- Anthropogenic aerosol cooling 1950-1980s: Hwang et al. (2013) GRL →
- Asymmetric volcanic forcing e.g. Haywood et al. (2013) Nature Climate

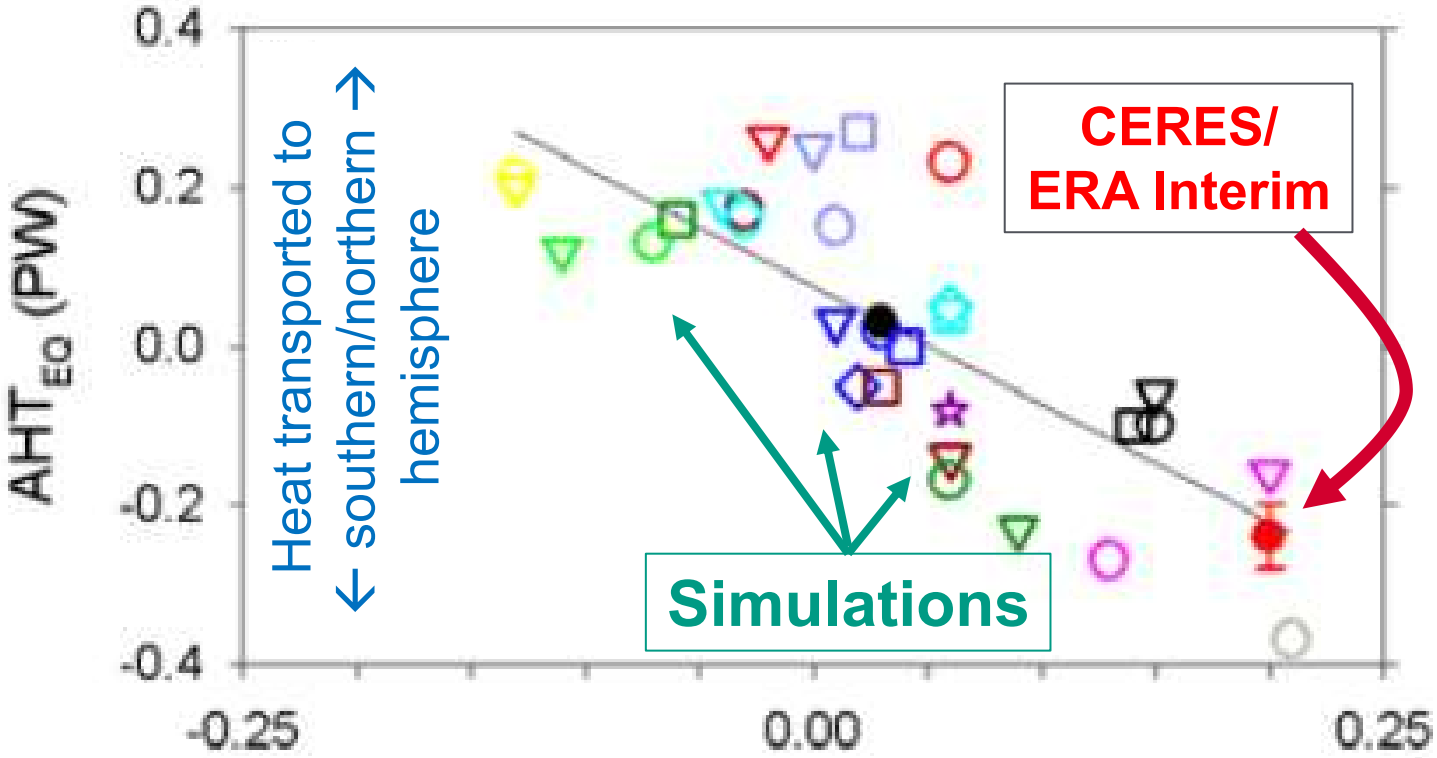




- Sulphate aerosol effects on Asian monsoon e.g. Bollasina et al. 2011 Science (left)
- Links to drought in Horn of Africa? Park et al. (2011) Clim Dyn
- GHGs & Sahel rainfall recovery?

Dong & Sutton (2015) Nature Clim.

Loeb et al. (2015) submitted



TPA index - more rain in:

← Southern tropics/Northern tropics →