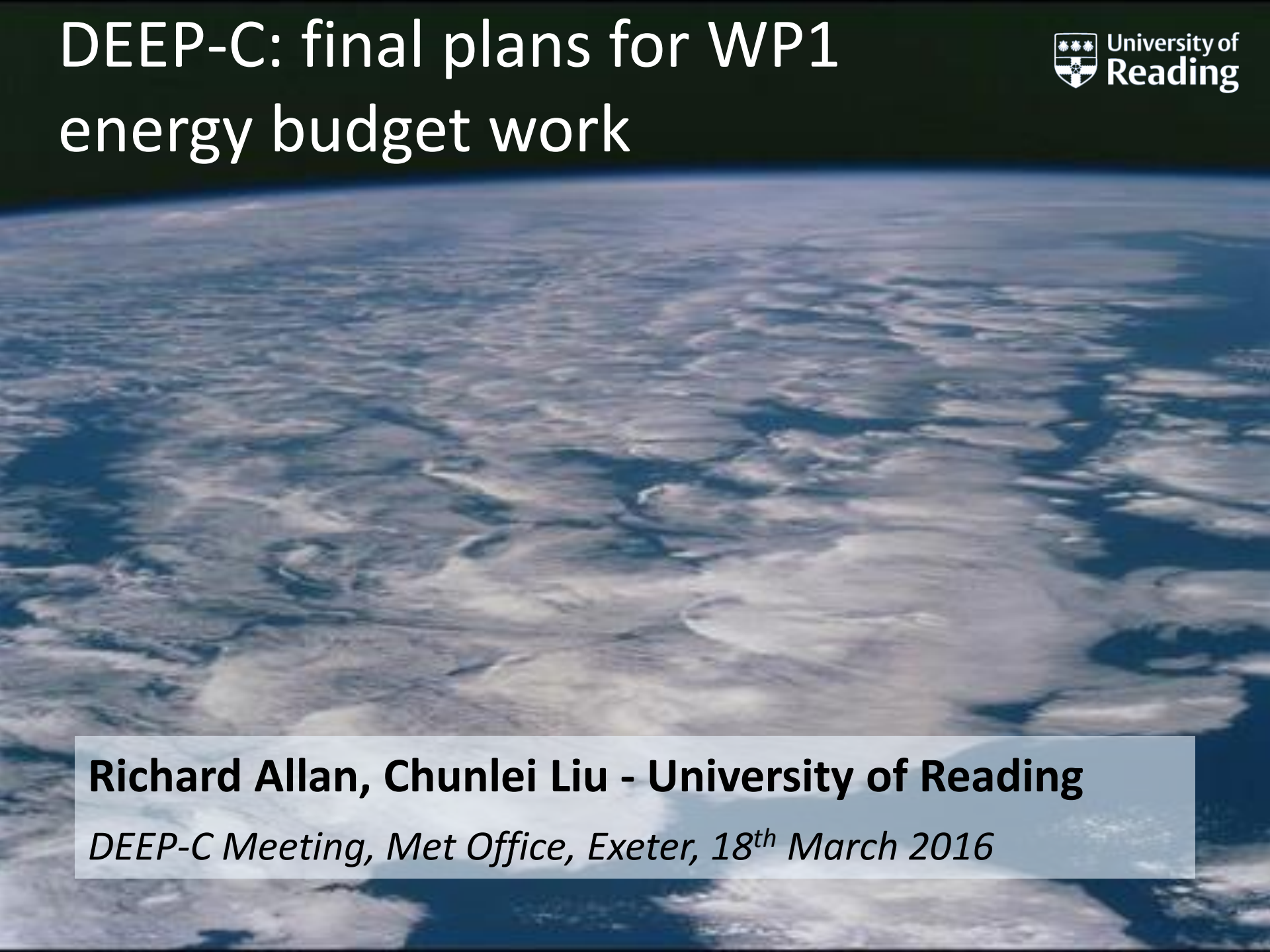
DEEP-C: final plans for WP1 energy budget work



Richard Allan, Chunlei Liu - University of Reading

DEEP-C Meeting, Met Office, Exeter, 18th March 2016

Outline

- Introduction/project objectives/dissemination
- Brief discussion of new literature
- Ongoing WP1 project outputs:
  - Regional mechanisms and feedbacks
  - Surface energy flux product issues and solutions
  - Interhemispheric heating imbalance
- Final plans and conclusions

DEEP-C Work Plan

Start date: March 2013; Project Ends February 2017

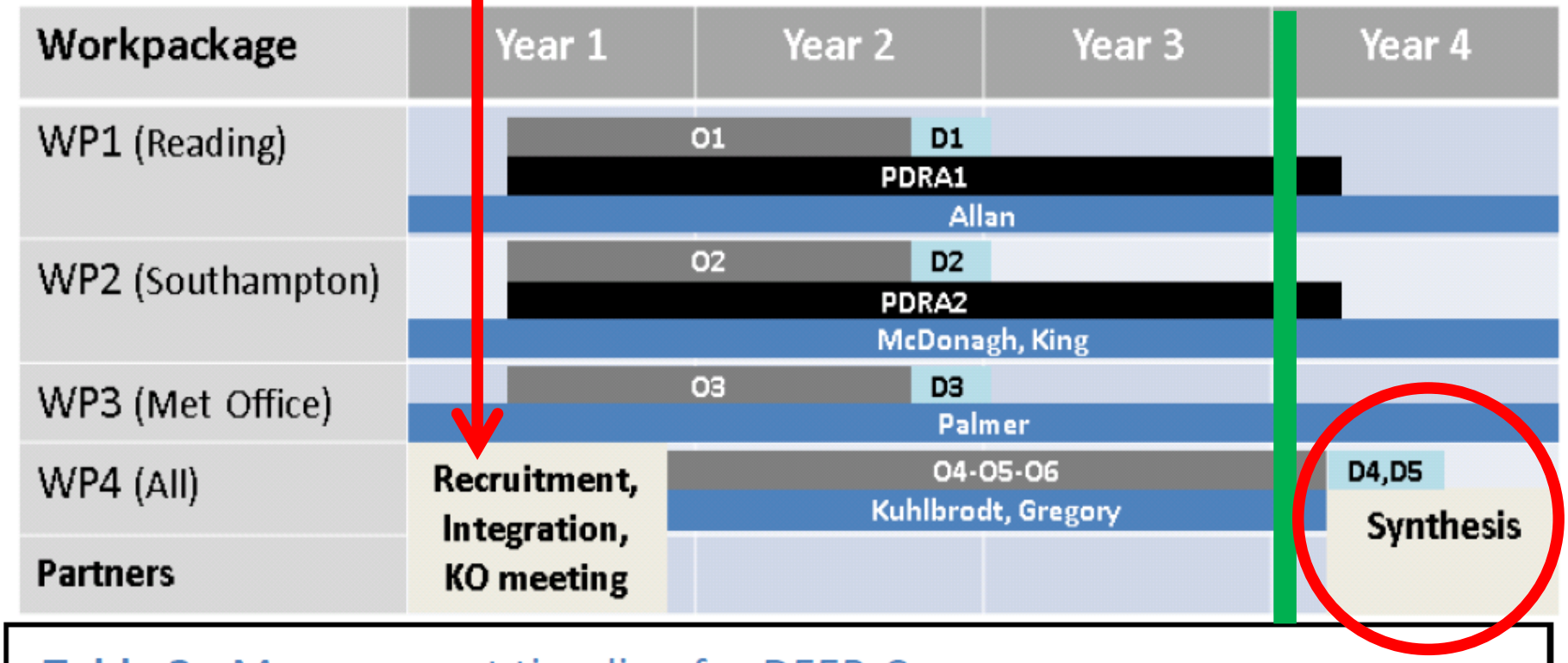


Table 2 - Management timeline for DEEP-C.

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)

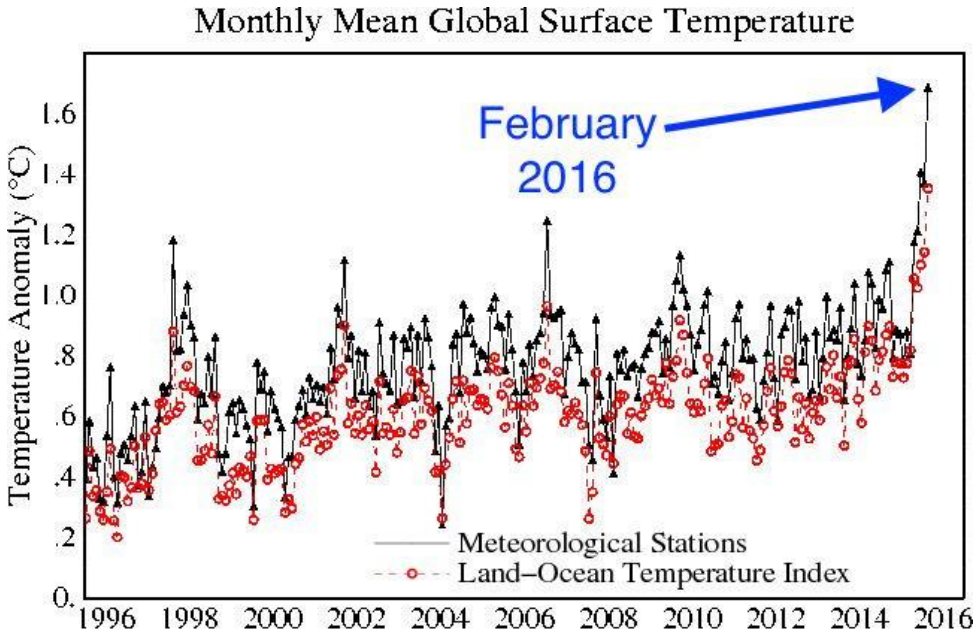
O6. Characterise spatial signatures and mechanisms of ocean and atmospheric heat re-distribution (from O4-5) during the hiatus period 2000-2015 using observations and simulations (WP1-4)

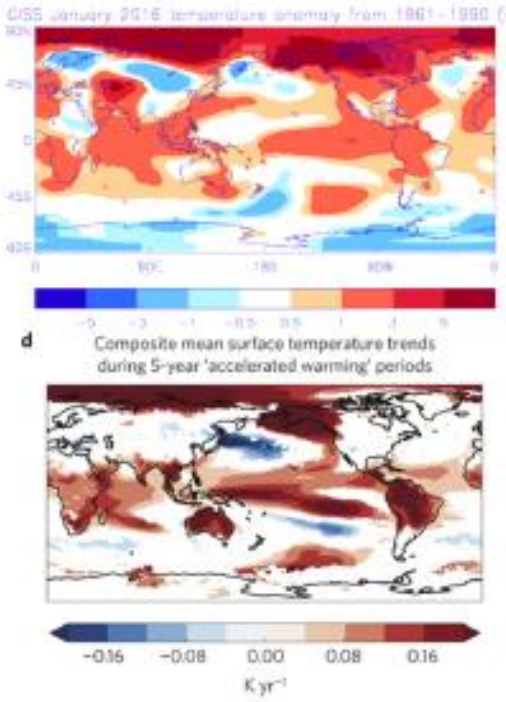
WP1 Dissemination Activities

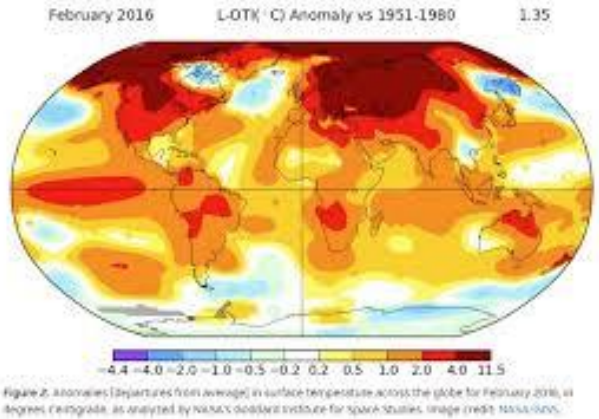
- **Jan 2016:** Energy and water cycle seminar, Reading; El Nino comments (WSJ)
- **Nov 2015:** Paris COP BBC Breakfast, etc; U3A talk; NASA sensing our planet
- **Sep/Oct 2015:** NCEO meeting Southampton; CliVar workshop; outreach talks
- **July 2015:** Commented on Nieves *et al* on BBC Radio 4 Today program; 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
- **Feb 2015:** Comment on detection of greenhouse gas radiative effect
- **Jan 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 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
- **Feb 2014** - **"Where has the warming gone?"** RMetS local group ; **Comment on England et al.** (see also **Guardian** article).
- **Aug/Sep2013** - **Comment on recent Nature paper by Kosaka and Xie** (see also **BBC** and **Independent** articles); Voice of Russia; IPCC Sky/BBC/etc
- **July 2013** - Science Media Centre briefing on "slowdown"
- **May 2013**: **Carbon Brief** article on DEEP-C temperature obs.
- **April 2013** - Meeting with DECC partners in London

Also: twitter, Walker Institute, media interaction http://www.met.reading.ac.uk/~sgs02rpa/research/DEEP-C.html

Welcome to the new surge!

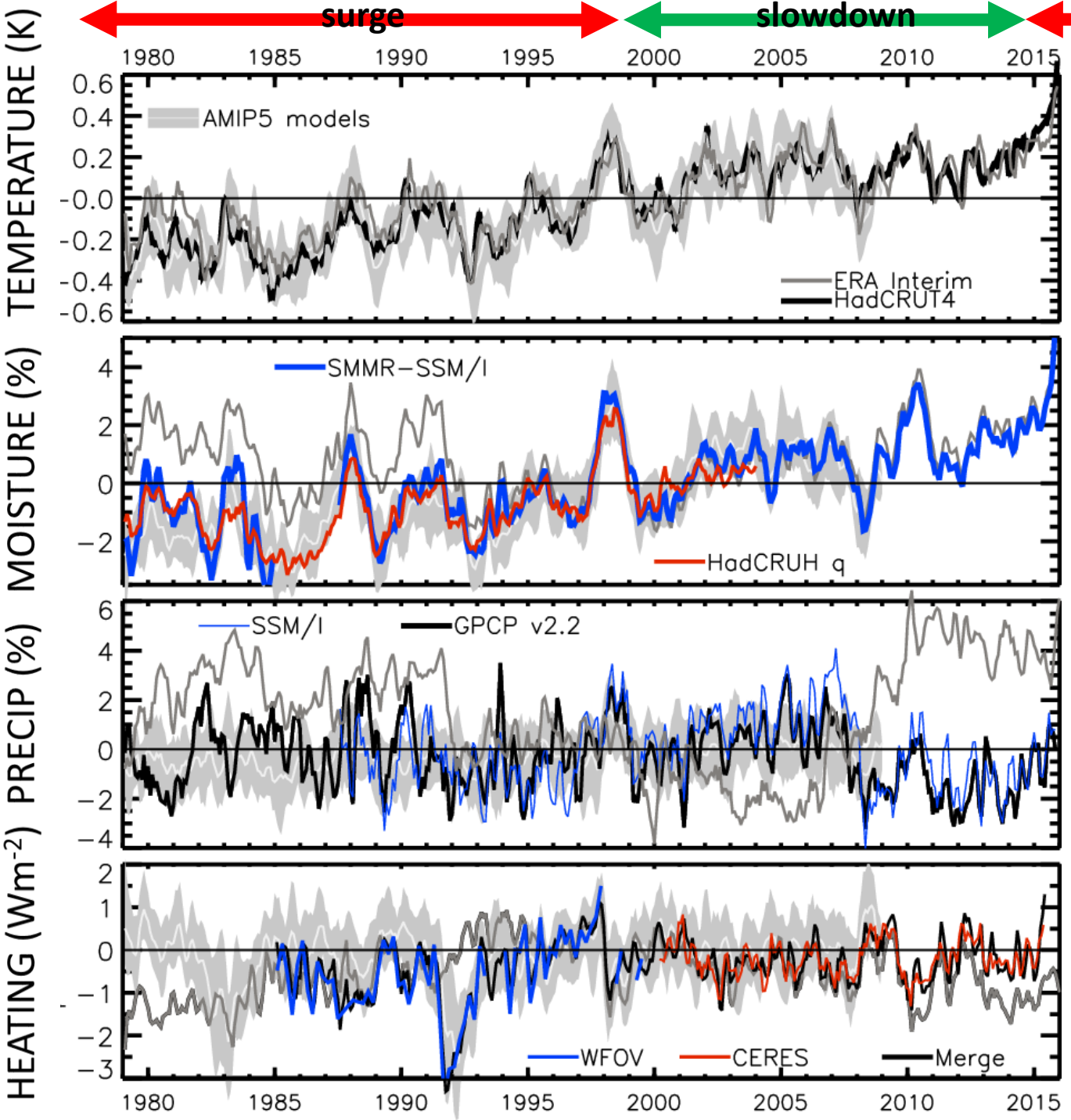






Richard Allan @rpallanuk · Feb 22
Current #Arctic warmth characteristic of #globalwarming surge:
nature.com/nclimate/journ…

5



Changes in Temperature, moisture, precipitation & net radiation through a surge and slowdown

Update from Allan et al. (2014) Surv. Geophys & Allan et al. (2014) GRL

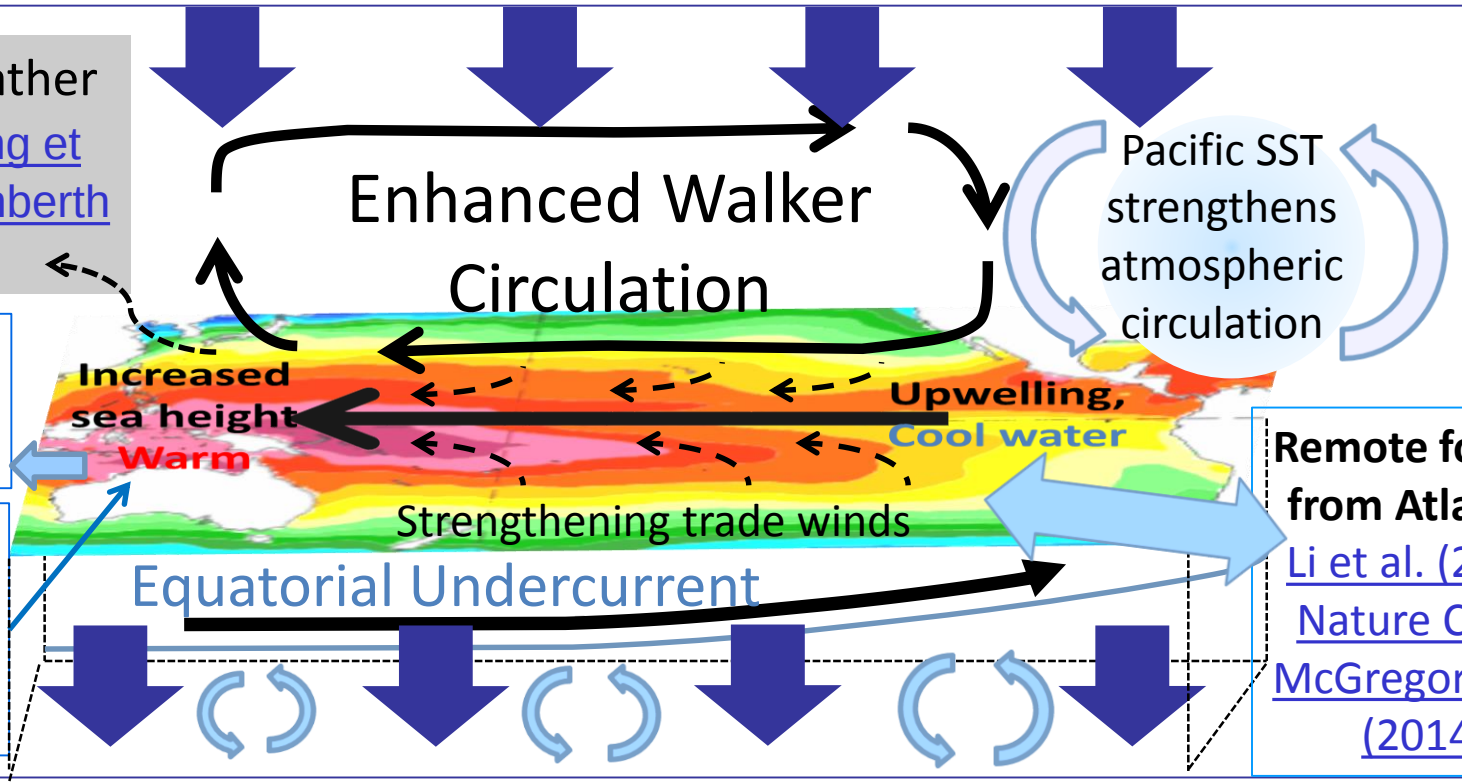
Recent Literature

- **Fyfe et al. (2016) Nature Climate Change**: there was a significant slowing in surface warming from the 1990s to the 2000s
- **Xie et al. (2015) Nature Geoscience**: top-of-the-atmosphere radiation and global mean surface temperature less tightly coupled for natural decadal variability than for greenhouse-gas-induced response.
- **Li et al. (2015) Nature Climate Change**: Atlantic control on Pacific ocean responses through wind-evaporation-SST feedbacks (role of radiative forcing or Atlantic internally generated variability in driving this seems unclear)
- **Brown et al. (2016) J. Clim.:** Role of remote responses to local SST changes in explaining global responses of energy budget
- **Radel et al. (2016) Nature Geosci.** Cloud longwave effect amplifies El Niño through influence on atmospheric circulation
- **Wijffels et al. (2016) Nature Climate Change**: steady accumulation of heat by the oceans up to the large El Niño of 2015/16; an intensifying hemispheric asymmetry, with 75-99% of the heat accumulating south of the Equator, merits consideration.
- **Glecker et al. (2016) Nature Climate Change**: nearly half industrial-era increases in global ocean heat content occurred since ~1997, over a third below 700m depth.

http://www.met.reading.ac.uk/~sgs02rpa/research/DEEP-C.html#PAPERS NOW BACK!

Role of Atlantic/Pacific Variability?

Continued heating from rising greenhouse gas concentrations



Unusual weather patterns (Ding et al. 2014; Trenberth et al. 2014b)

? Heat flux to Indian ocean Lee etal 2015

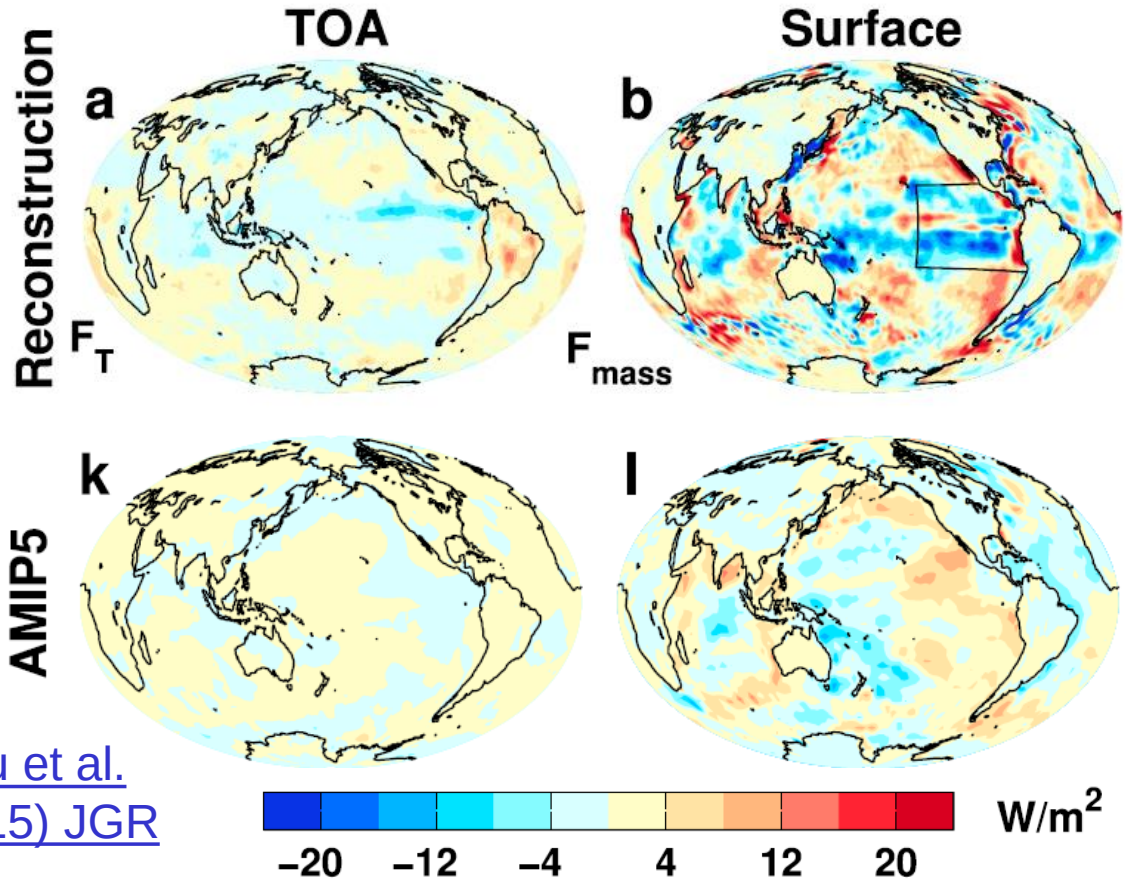
Increased precipitation Decreased salinity

Remote forcing from Atlantic: Li et al. (2016) Nature Clim ; McGregor et al. (2014)

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.; Llovel et al. (2014) Nature Clim;Durack et al. (2014) Nature Clim; Nieves et al. (2015) Science;

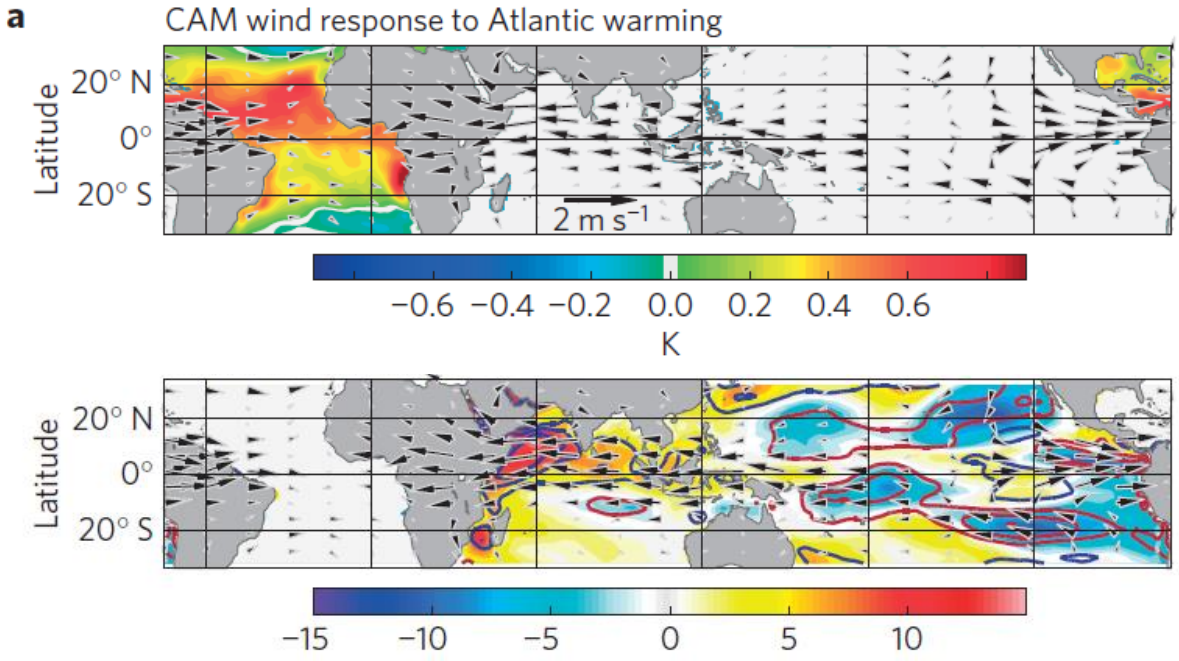
Mechanisms for regional changes in top of atmosphere/surface energy flux



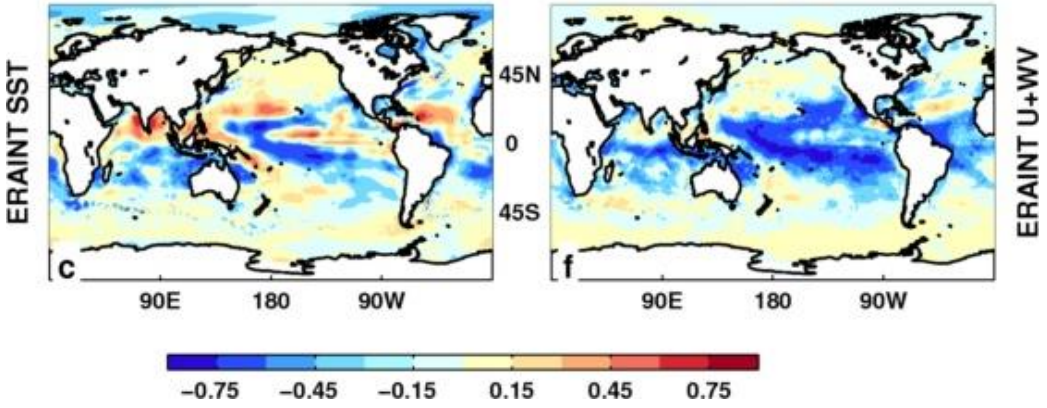
Liu et al. (2015) JGR

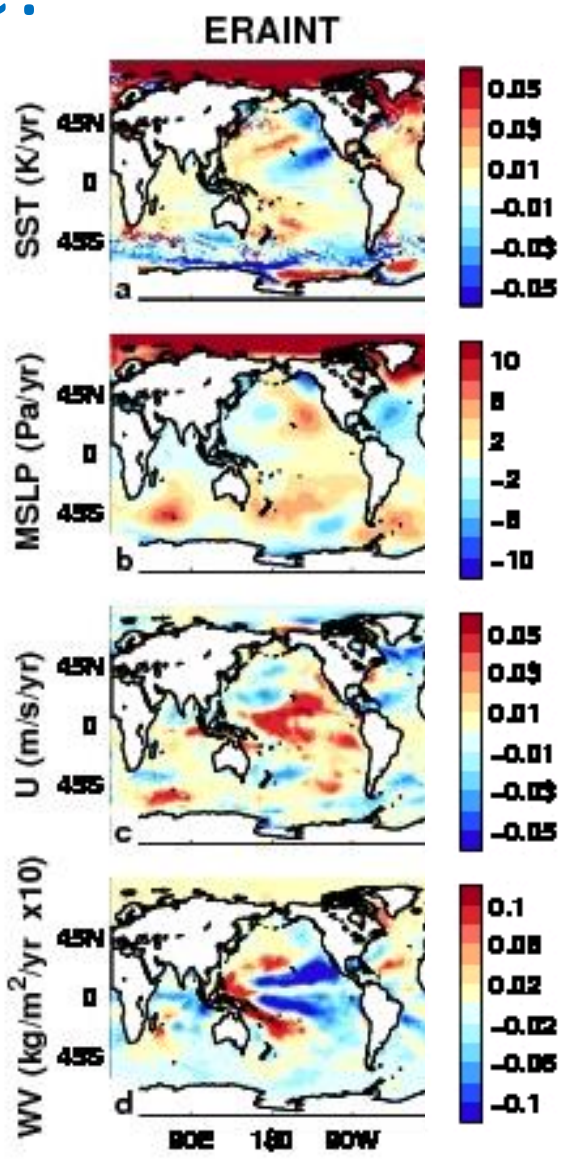
- Changes in ↓energy fluxes 1986-2000 to 2001-2008
- Surface energy flux dominated by atmos. Transports
- Is this realistic? If so, what are the physical mechanisms?

Role of Atlantic & evaporative fluxes in forcing pacific?



Li et al. (2016) Nature Climate



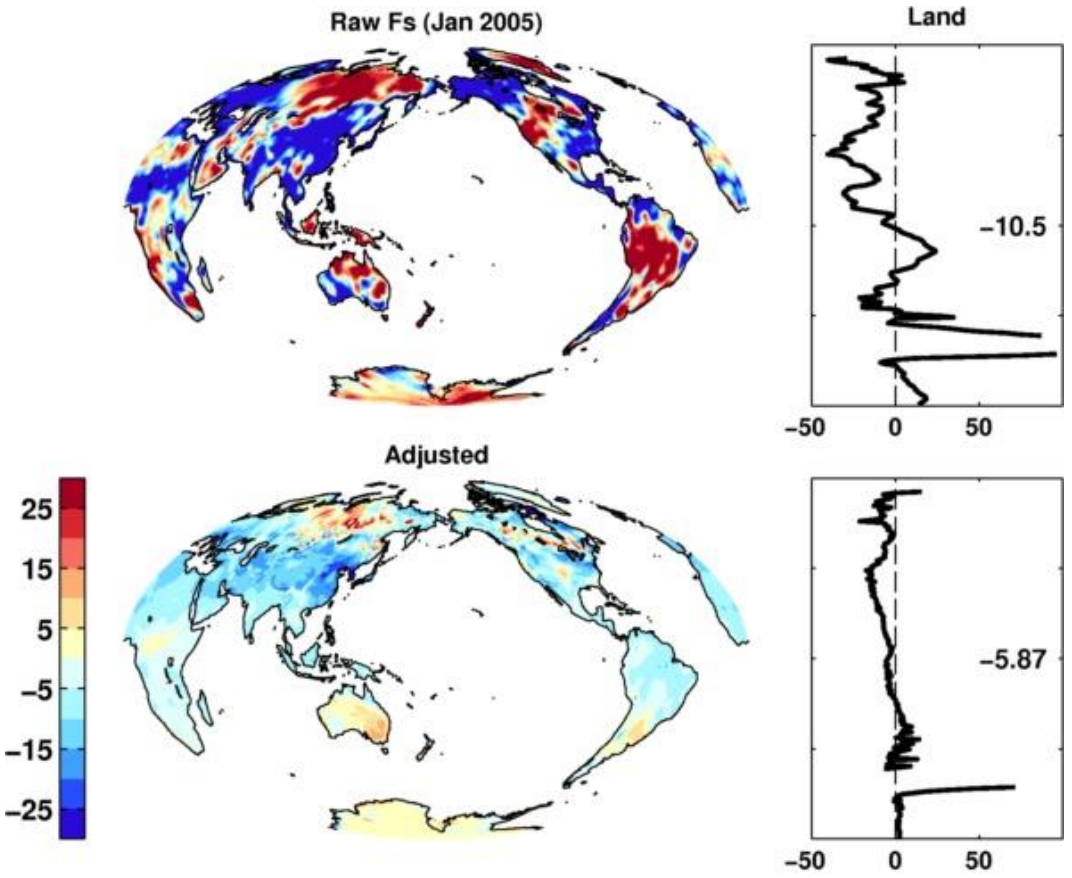


Heat flux product artefacts and solutions

Work by Chunlei Liu

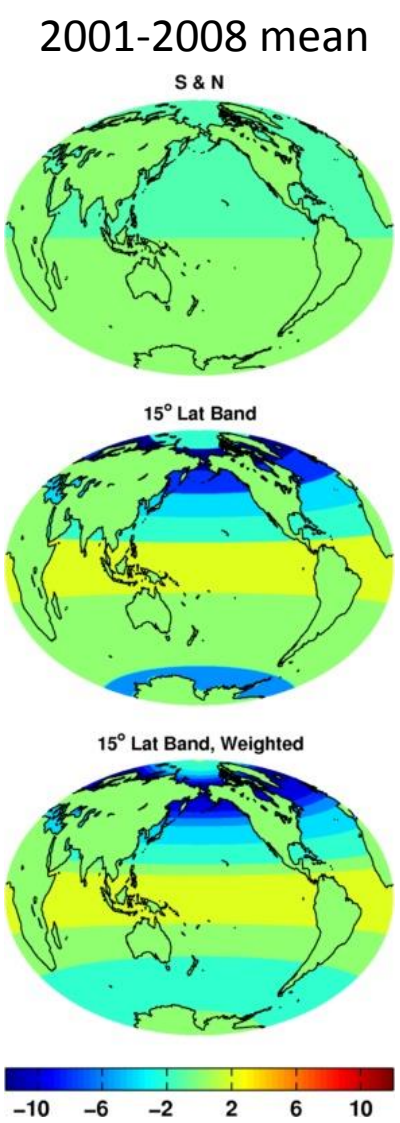
- Unrealistic regional heat fluxes over land
- Constrain based on simple energy balance model
- Redistribute flux "error" over the ocean

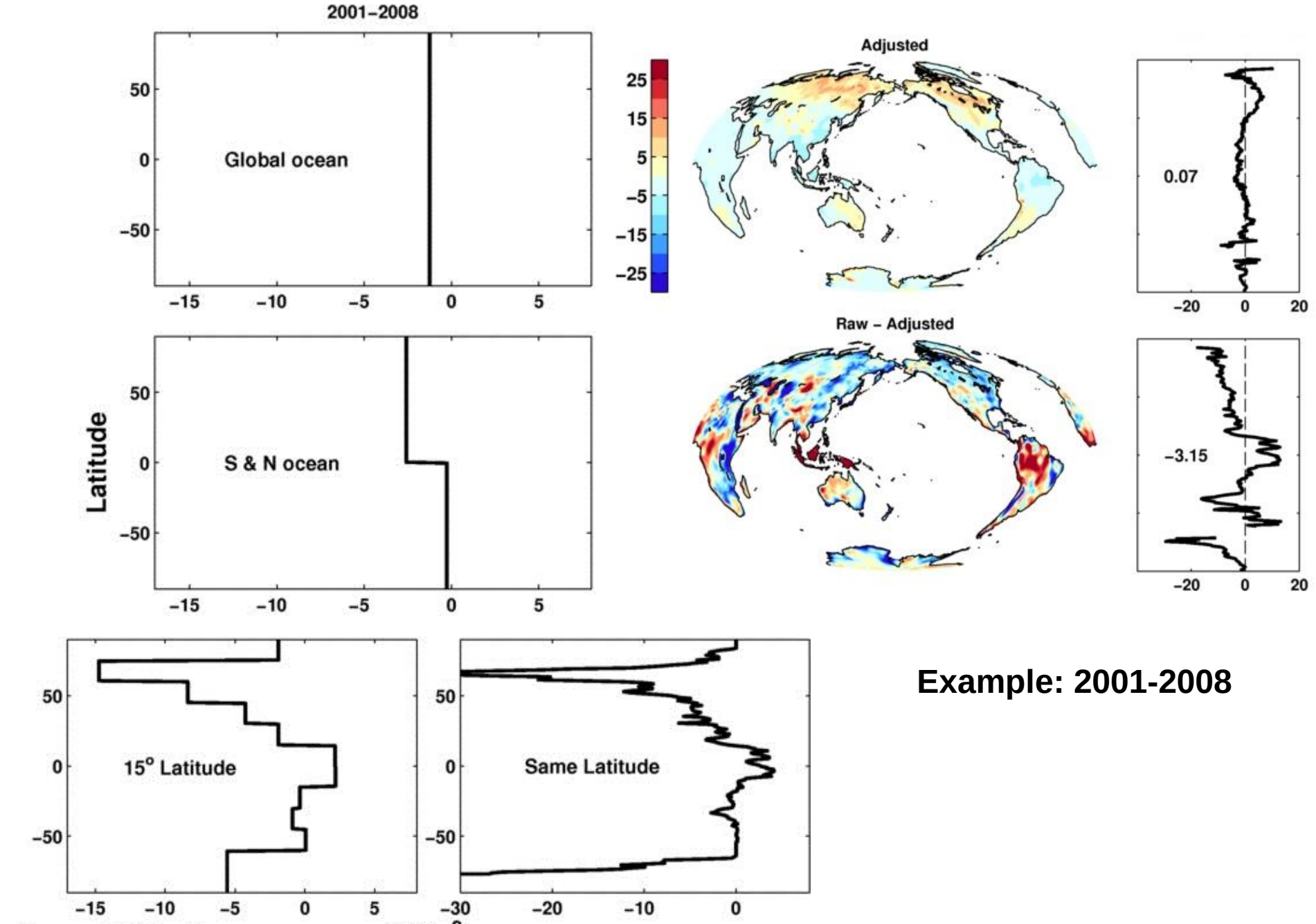
- Does this tell us about regional uncertainty?



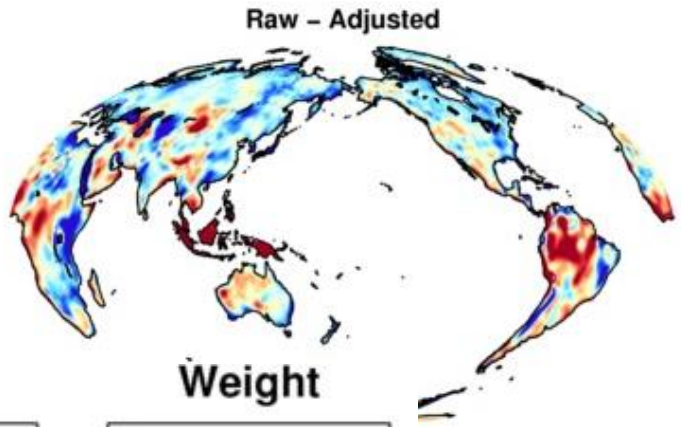
Unphysical land energy flux: solutions?

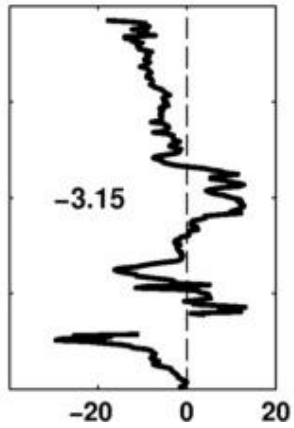
1. No correction to land surface fluxes
   - Unrealistic global land/ocean energy budget
2. Adjust land fluxes and distribute energy
   a. Evenly over global oceans
      - Unrealistic interhemispheric energy imbalance?
   b. As (a) but separately for each hemisphere
      - Jump at the equator
   c. Apply for discrete bands (e.g. 15^{o} latitude)
      - Jumps at band edges
   d. Apply at each latitude
      - unphysical? Jumps too large.
   e. Apply at each latitude, weighting function
      - Too complicated, not *much* more physical than a-d?

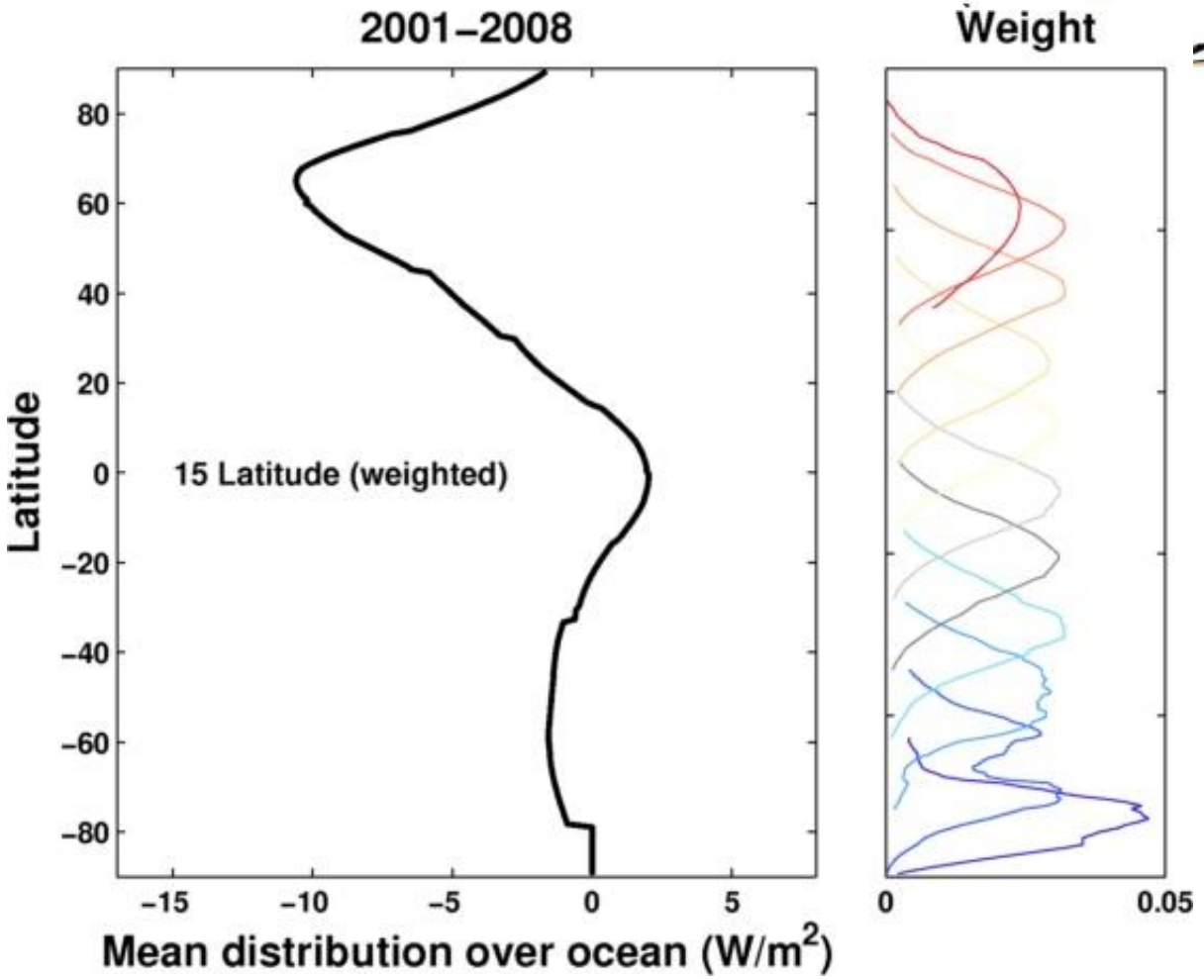



2001–2008
Global ocean
S & N ocean
Latitude
Adjusted
Raw – Adjusted
0.07
−3.15
15° Latitude
Same Latitude
Mean distribution over ocean (W/m²)
Example: 2001-2008

Weighting method?







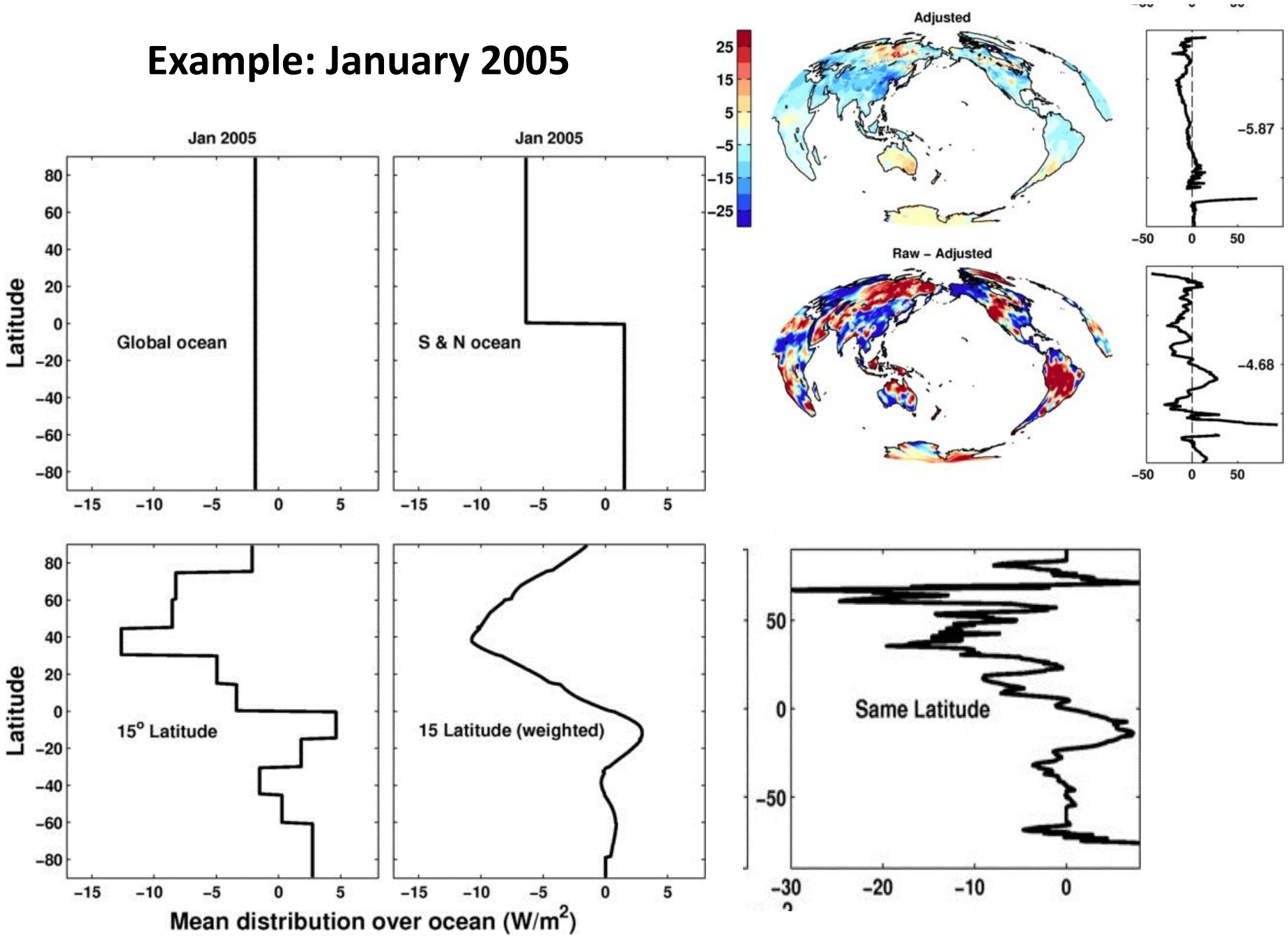
Solutions?

Global method: small correction, inaccurate cross equatorial transport

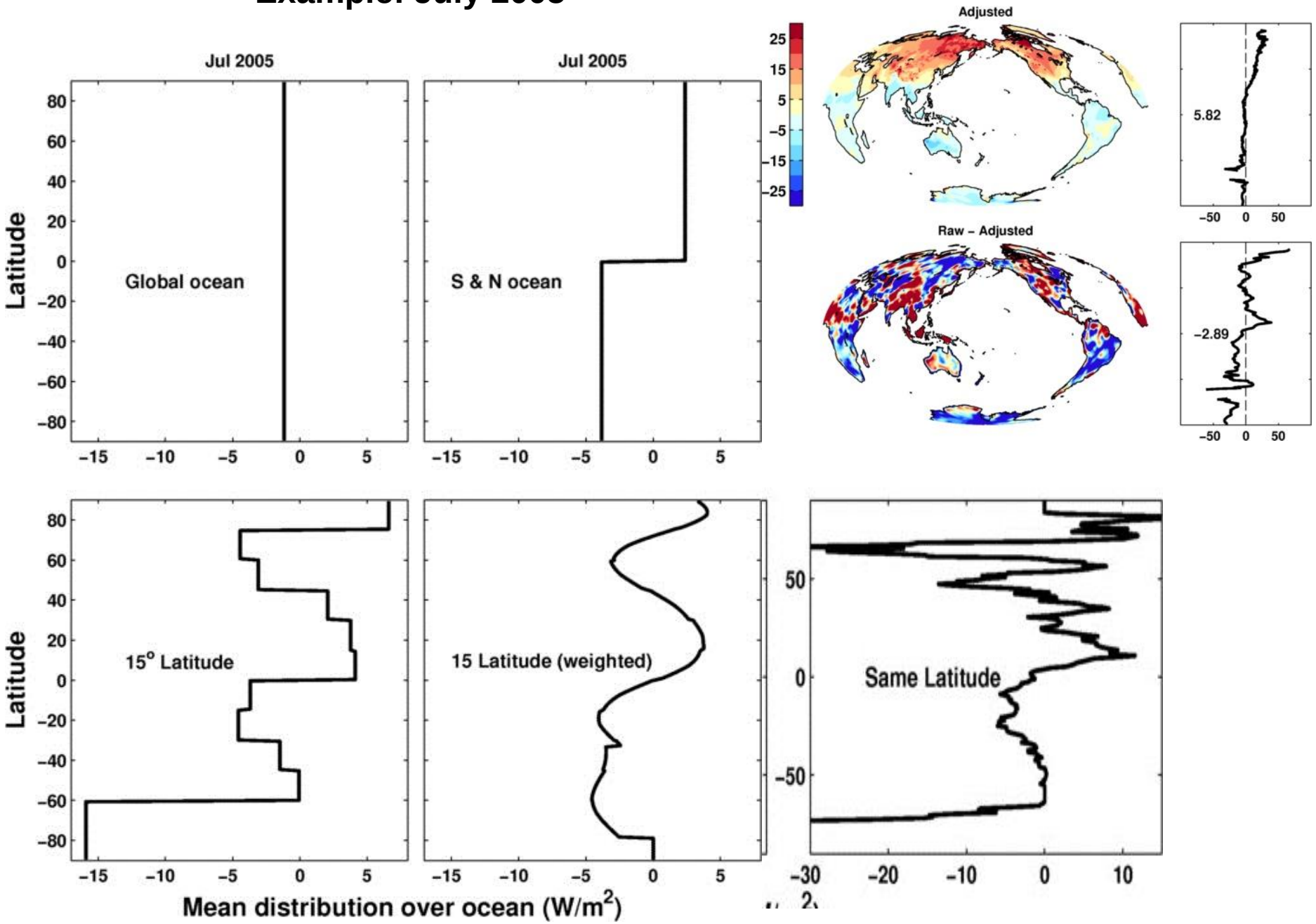
Weighted method: more physical, smaller jumps but big correction in NH

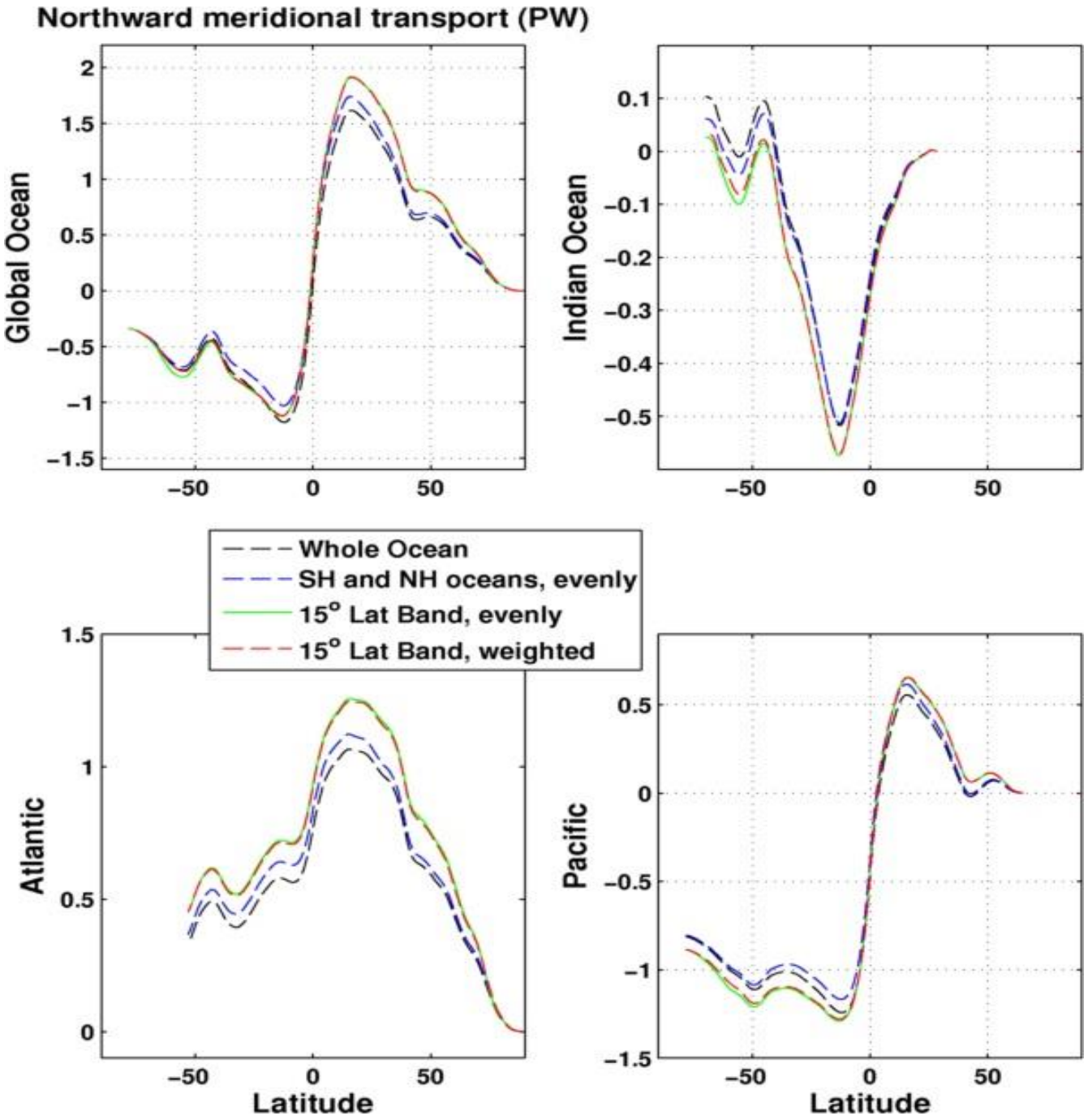
Hemispheric method: jump at equator – smooth?

Example: January 2005



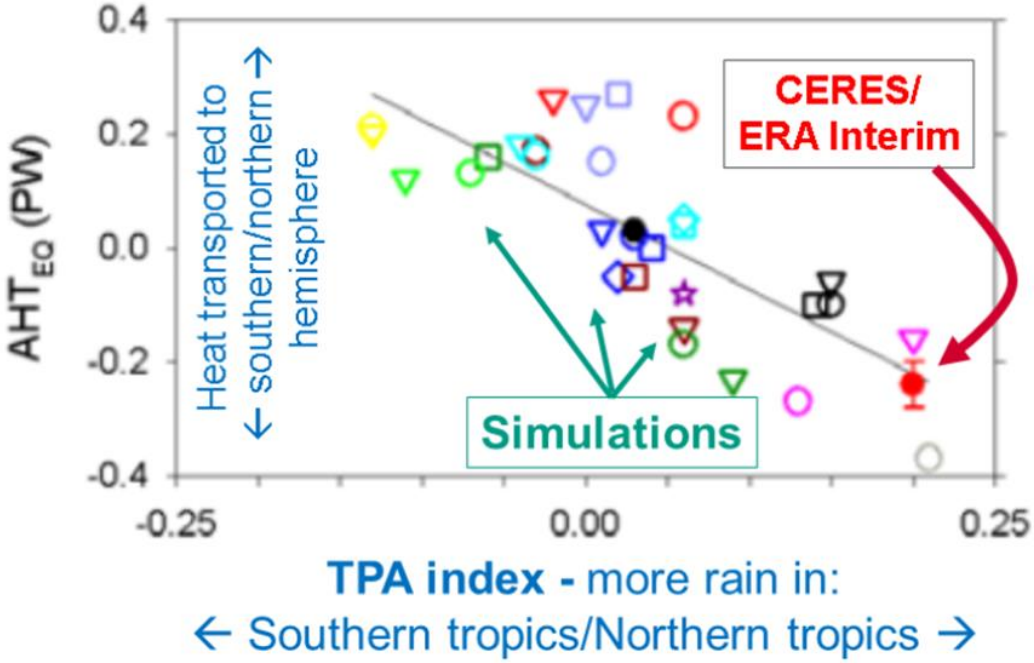
Example: July 2005





Influence on implied meridional transports

Cross-Equatorial heat transport and CMIP5 model precipitation asymmetry bias

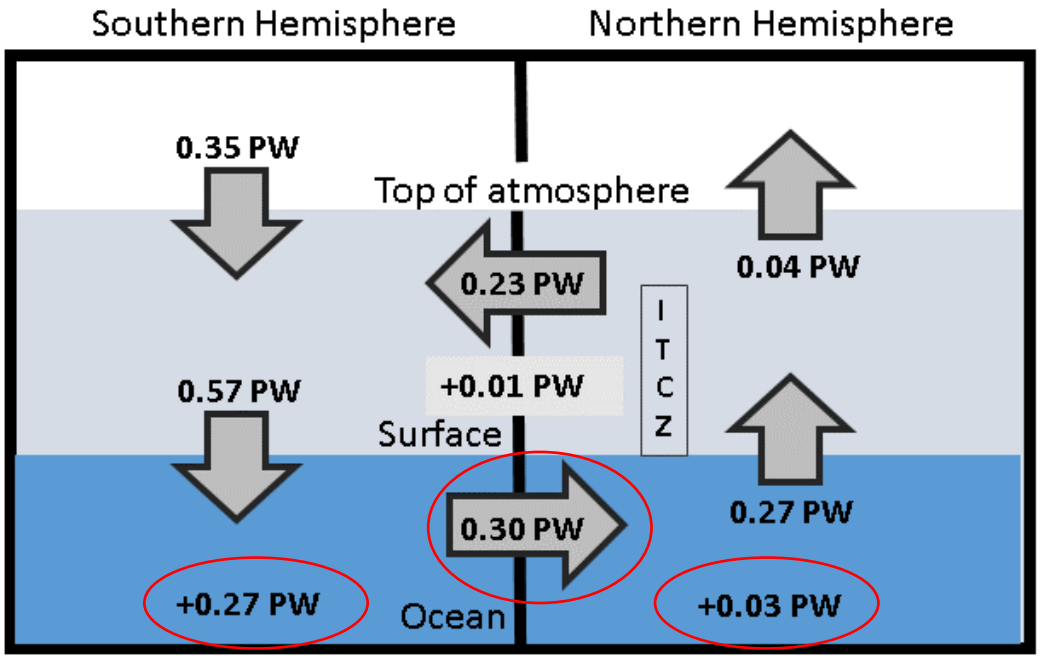


Estimated cross equatorial atmospheric heat transport in peta Watts (AHT_{EQ}) against an index of tropical precipitation asymmetry (TPA) between hemispheres in simulations and observations

Clear link between bias in cross-equatorial heat transport by atmosphere and inter-hemispheric precipitation asymmetry Loeb et al. (2015) Clim. Dyn

Anthropogenic controls and emergent constraints on precipitation asymmetry: Haywood et al. (2016) GRL ; Hwang et al. (2013) GRL ; Dong & Sutton (2015) Nature Clim.

Updated observed energy budget asymmetry



Updated from Loeb et al. (2015) Clim. Dyn. For 2000-2015 based on Liu et al. (2015) JGR

- Observed inter-hemispheric imbalance in Earth's energy budget
- Use asymmetric ocean heating observed by Roemmich et al. (2015) Nature Climate and Purkey & Johnson (2010)
- Derive implied ocean heat transport: smaller that Loeb et al. (2015) and Frierson et al. 2013 (0.44 PW) – unrealistically so?

Final WP1 outputs/conclusions

- Finalised energy flux dataset version
- Understanding Pacific discrepancy in heat flux changes
- Cross equatorial heat transport (NERC highlight topic?)
- Heat flux product uncertainty estimates (Pat et al.)
- Basin scale changes in heat flux, energy content, energy export (Damien et al., Chris et al.)
- SMURPHS work
  - spatial signatures/morphology,
  - links to water cycle,
  - quantify/understand lags between OHC and TOA radiation
  - mechanisms for feedbacks on internal variability)