Department of Meteorology

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CURRENT CHANGES IN EARTH'S ENERGY IMBALANCE 1985-2014

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Thanks to Chunlei Liu, Norman Loeb and all co-authors

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NERC SCIENCE OF THE ENVIRONMENT

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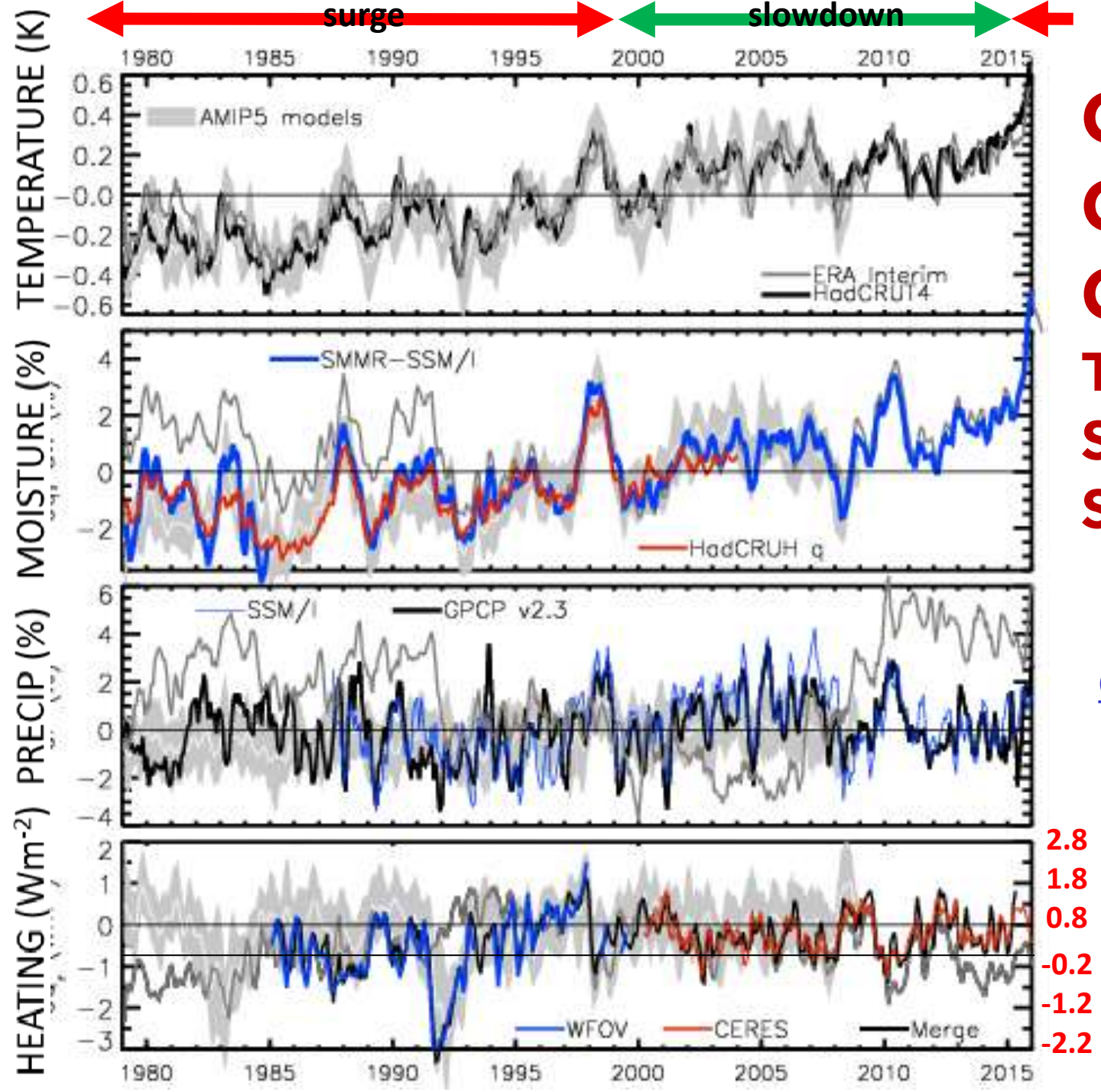

CURRENT CLIMATE CHANGE THROUGH SURGE AND SLOWDOWN

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

Earth's energy imbalance (Wm^{-2})

INTERPRETING CHANGES IN NET IMBALANCE

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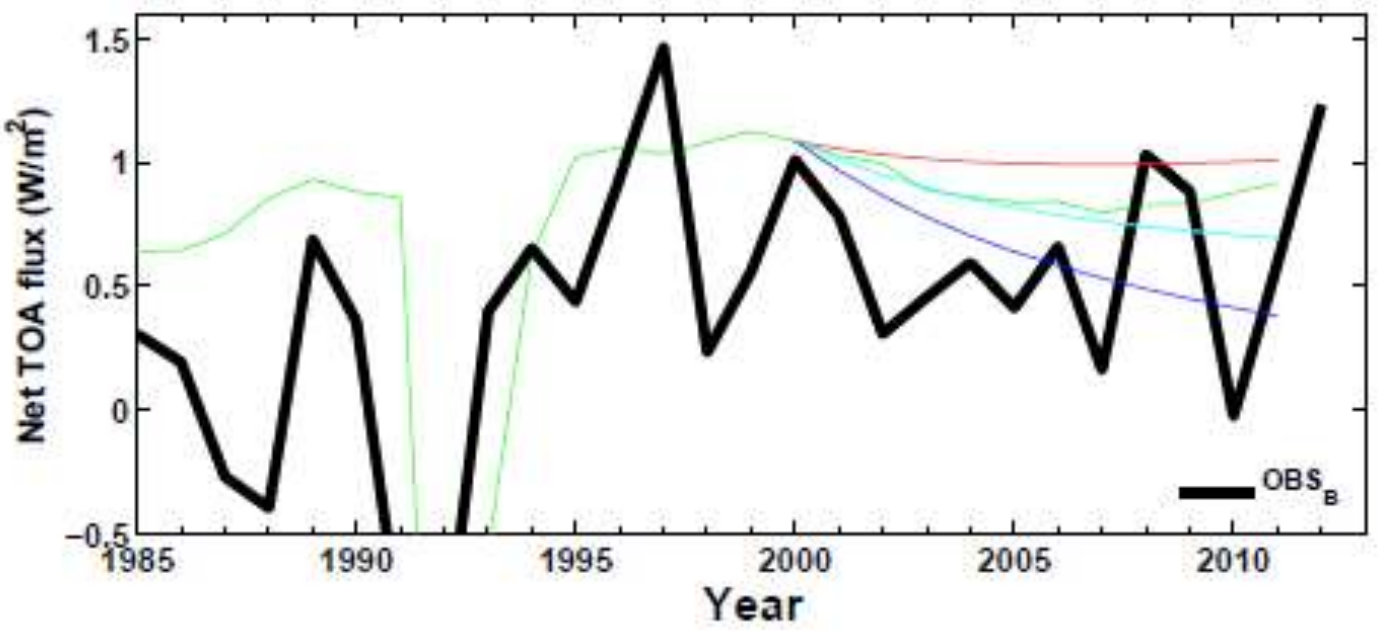
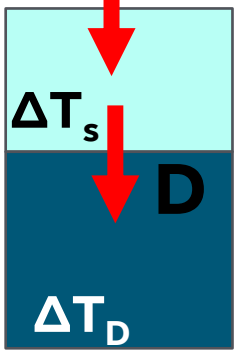
N



+ve RF trend
AR5 RF
zero RF trend
-ve RF trend

$N = \Delta F - Y\Delta T_s$



Analysis using simple energy balance model
Allan et al. (2014) GRL supplementary

$$\frac{d\Delta T_s}{dt} = \frac{N - D}{C_m} = \frac{\Delta F - Y\Delta T_s - D}{C_m}$$

$$\frac{d\Delta T_D}{dt} = \frac{D}{C_D}$$

$$D = k(\Delta T_s - \Delta T_D)$$

See also **Checa-Garcia et al. (2016) ERL**

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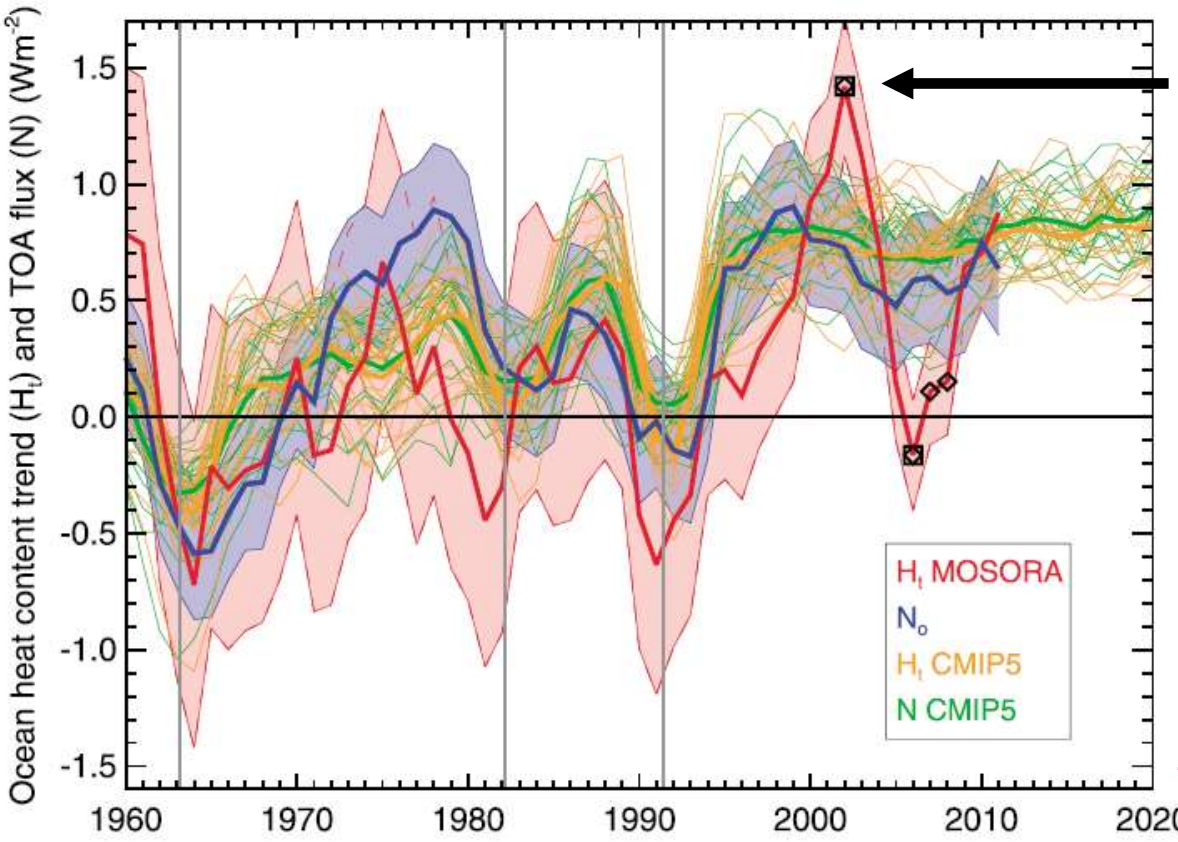
DISCREPANCY BETWEEN RADIATION BUDGET & OCEAN HEATING



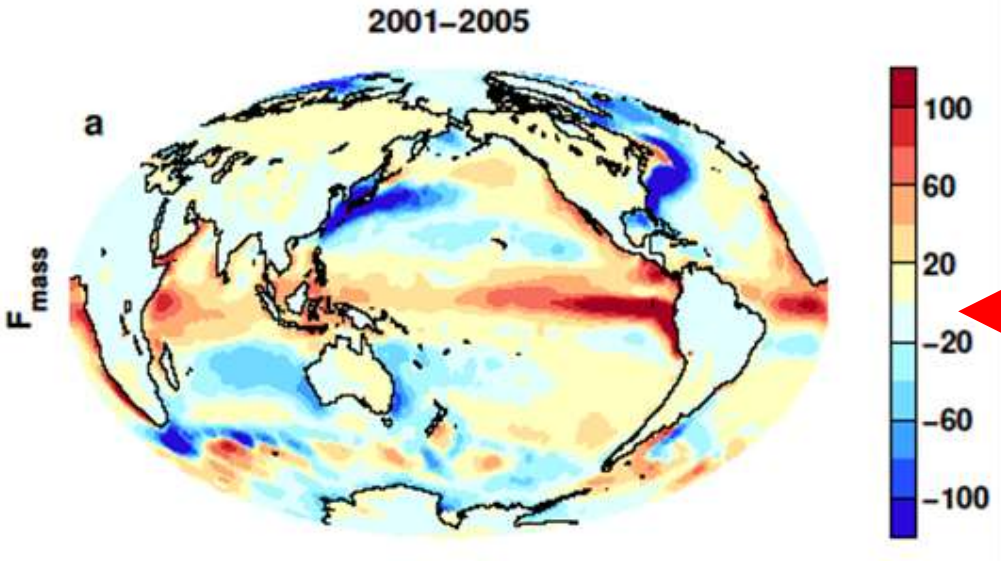
- Large ocean heating anomaly in 2002
- Inconsistent with radiation budget observations and simulations
- Changing observing system influence?
- Slight drop in net flux 1999-2005?

Smith et al. (2015) GRL

WHERE IS THE HEAT GOING?

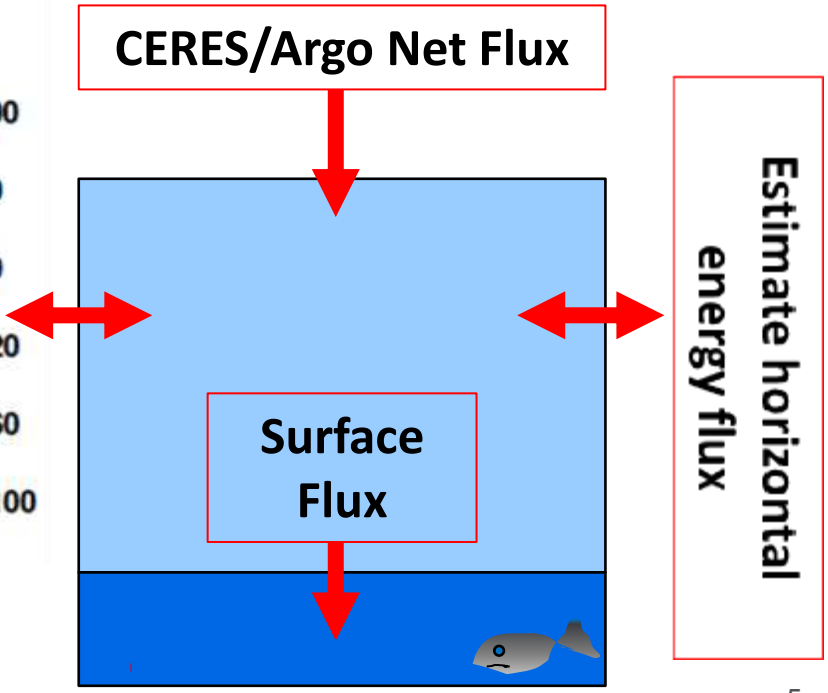
NEW ESTIMATES OF SURFACE ENERGY FLUX

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



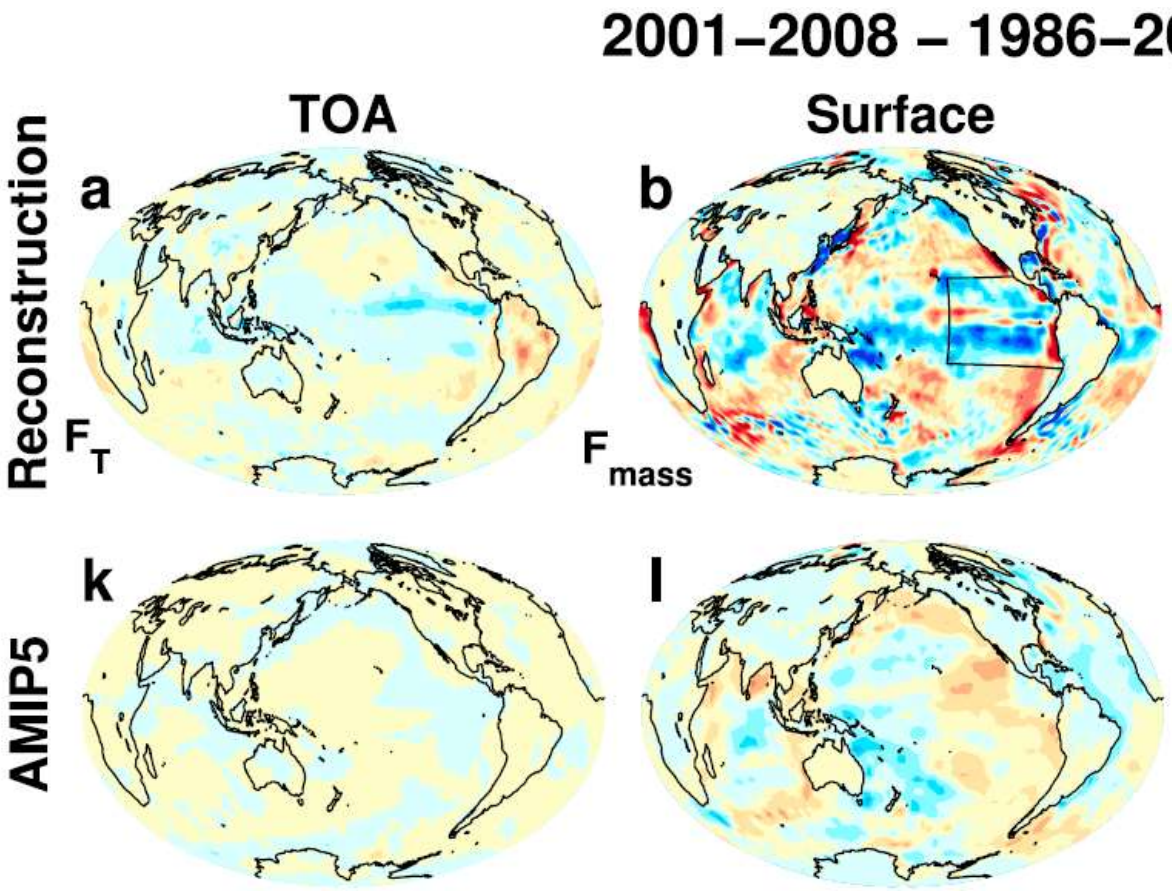
Net surface downward energy flux (Wm^{-2})

Liu et al. (2015) JGR



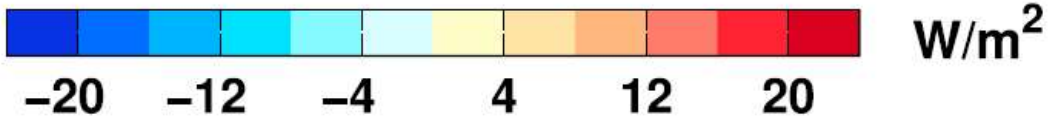
WHERE IS THE HEAT GOING?

CHANGES IN SURFACE ENERGY FLUX



- Changes in energy fluxes 1986-2000 to 2001-2008
- Surface energy flux dominated by atmospheric transports
- Contrasting model pattern of change, realistic? e.g. **He & Soden (2016) J. Clim**
- Are reanalysis transports reliable?

Liu et al. (2015) JGR



UPDATED OBSERVED ENERGY BUDGET ASYMMETRY

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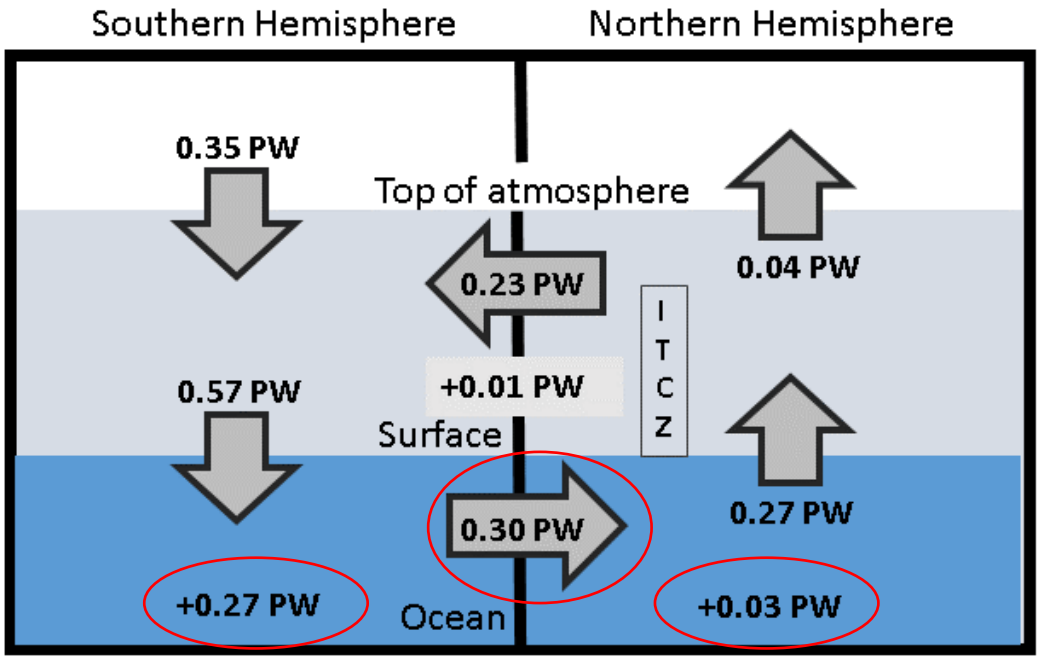

Updated from Loeb et al. (2016) Clim. Dyn. For 2000-2015 based on Liu et al. (2015) JGR

see also Stephens et al. (2016)

- 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?

CONCLUSIONS

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- Heating of Earth continues at rate of ~0.6-0.8 Wm^{-2}
  - Manifest as positive imbalance in Southern Hemisphere
  - Variability from radiative forcings & ocean internal changes
- What are pathways/mechanisms for ocean heat uptake?
- Toward reconciled ocean heating & radiation budget changes
  - are realanysis energy transports reliable?
  - do climate models capture internal variability & coupling?
- Do feedbacks amplify/extend hiatus/surge events?
  - e.g. **Brown et al. (2016) J. Clim** ; **Kosaka and Xie (2013) Nature**, etc

See also posters on:

Chunlei Liu: The DEEP-C surface and TOA energy budget reconstruction

Peter Hill: Clouds, radiation and precipitation in west Africa (DACCIWA project)

See DEEP-C website for data and links to journal paper:

http://www.met.reading.ac.uk/~sgs02rpa/research/DEEP-C.html