

# CURRENT CHANGES IN EARTH'S ENERGY IMBALANCE 1985-2014



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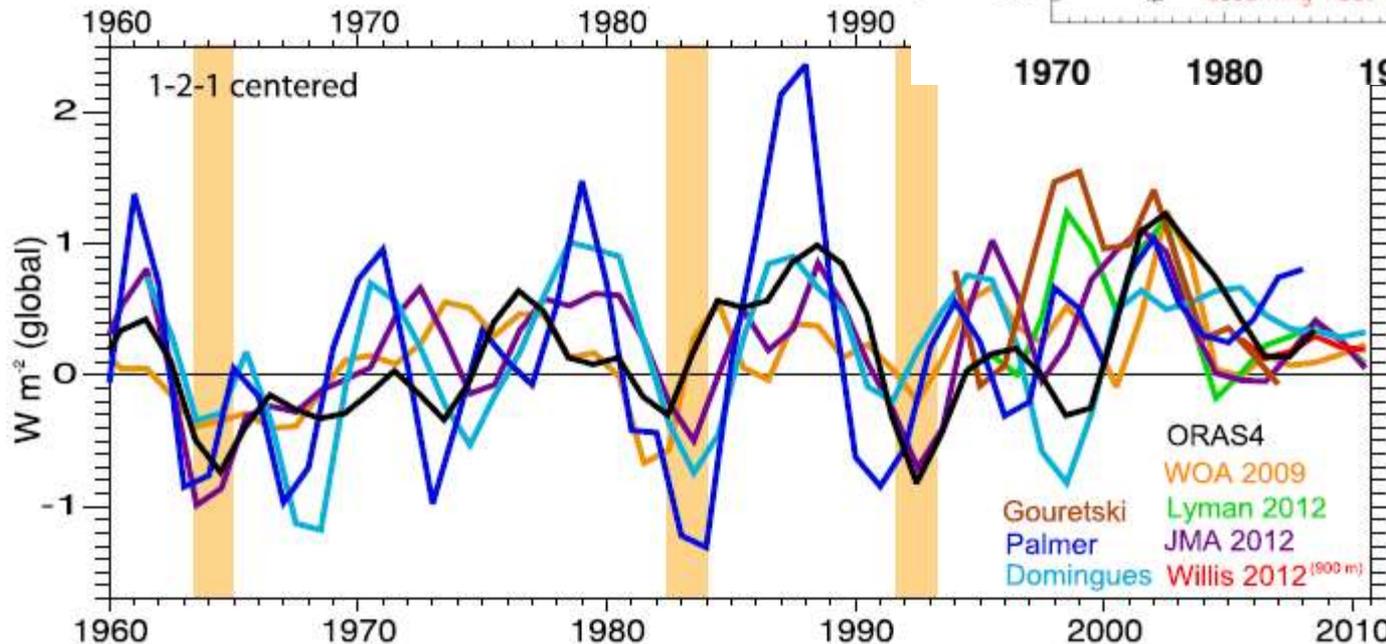
[@rpallanuk](https://twitter.com/rpallanuk)

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



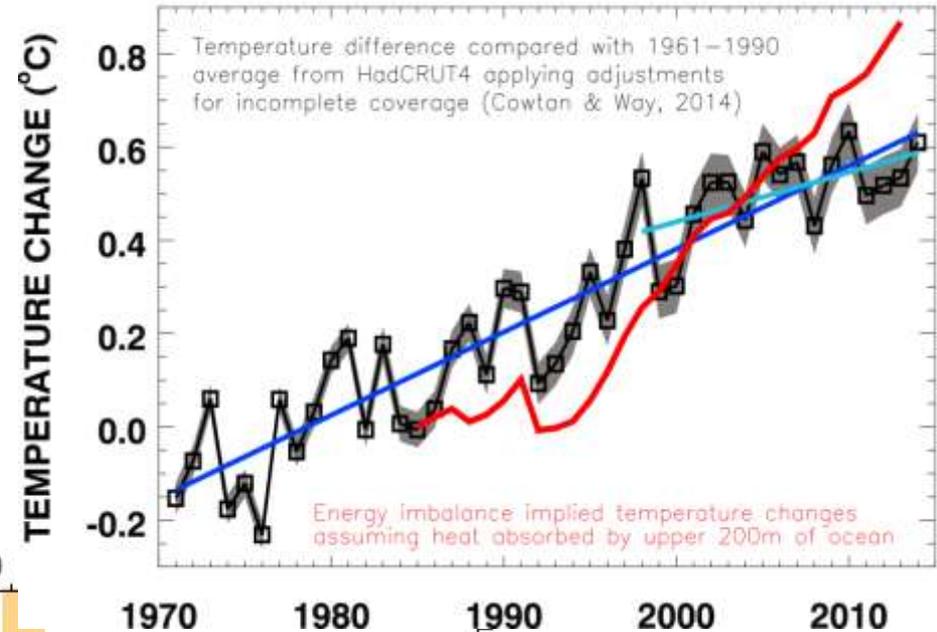
# AT WHAT RATE IS EARTH HEATING?

What are implications for climate sensitivity and the global water cycle?



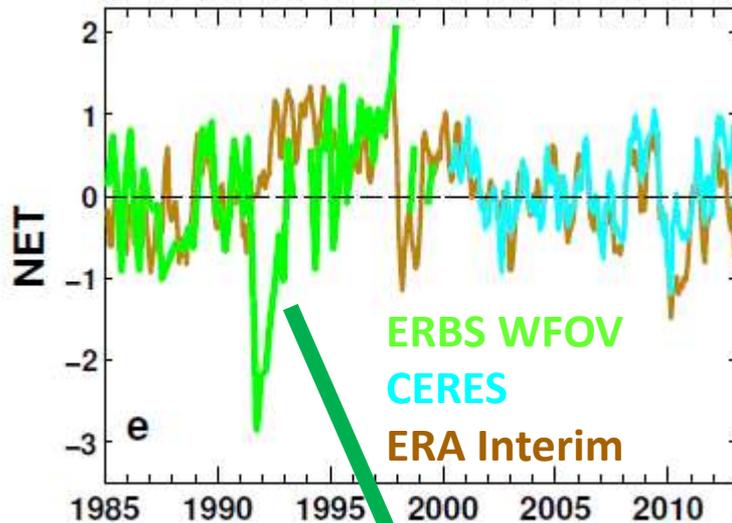
Upper ocean heating rate ( $Wm^{-2}$ )

## Global Mean Surface Temperature

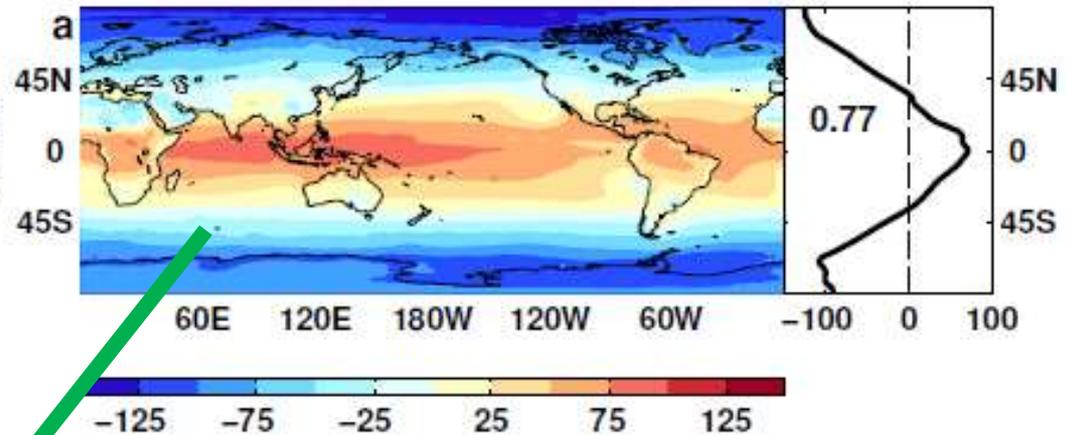


# RECONSTRUCTING GLOBAL RADIATIVE FLUXES SINCE 1985

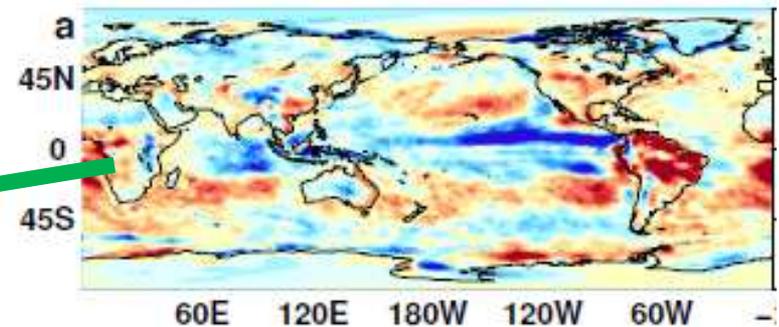
ERBS/CERES variability



CERES monthly climatology

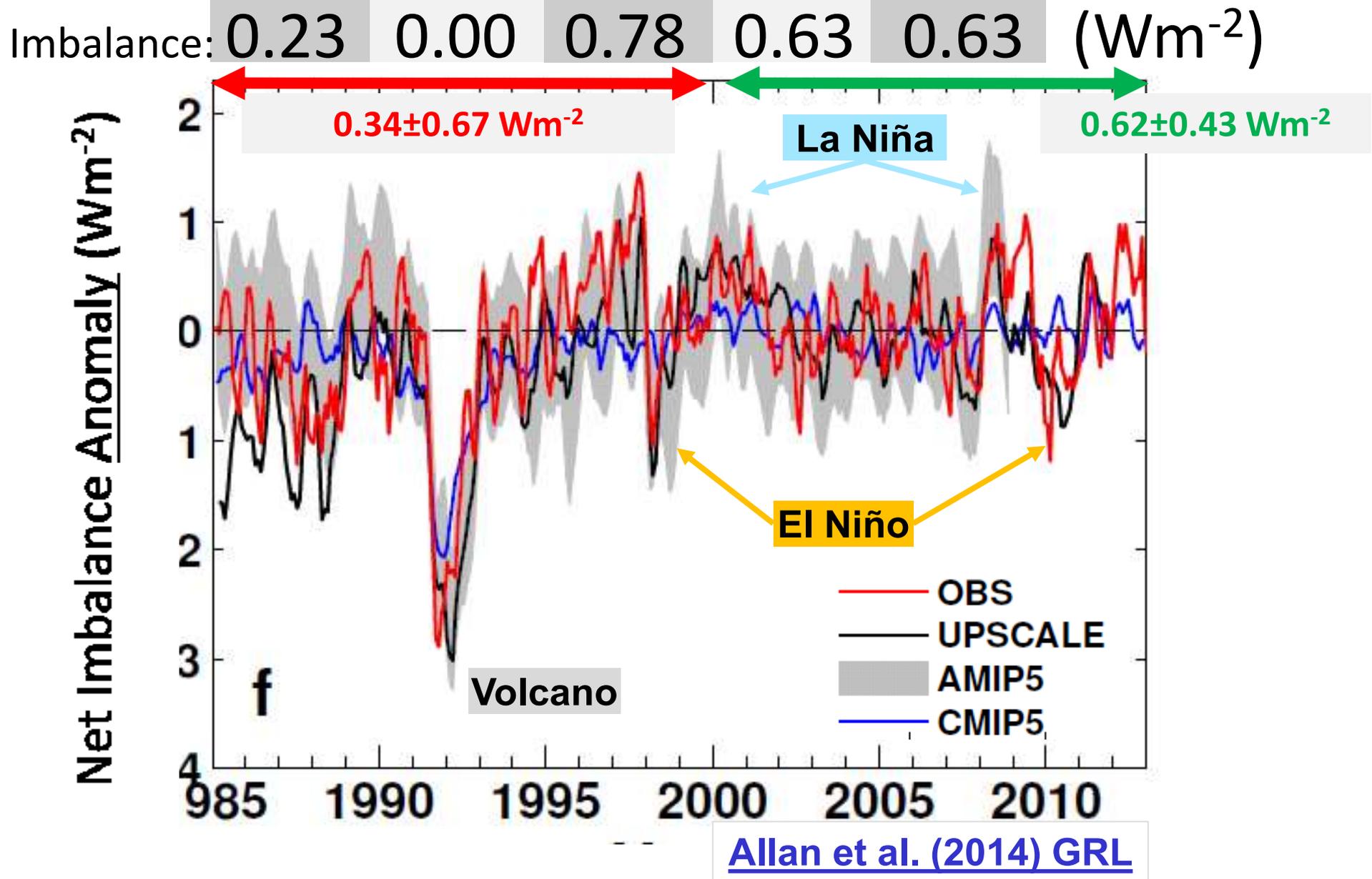


ERA Interim spatial anomalies

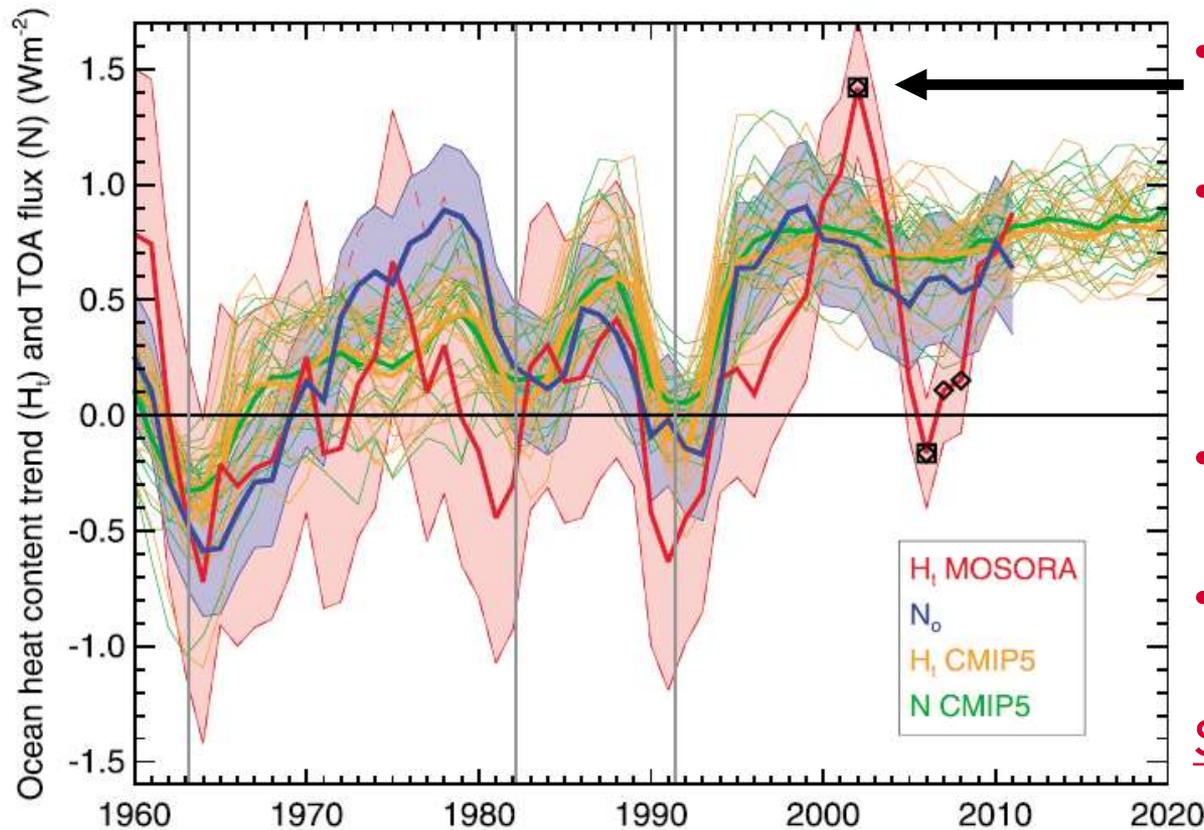


Combine CERES/ARGO accuracy,  
ERBS WFOV stability and  
reanalysis circulation patterns to  
reconstruct radiative fluxes

# EARTH CONTINUES TO HEAT UP



# DISCREPANCY BETWEEN RADIATION BUDGET & OCEAN HEATING



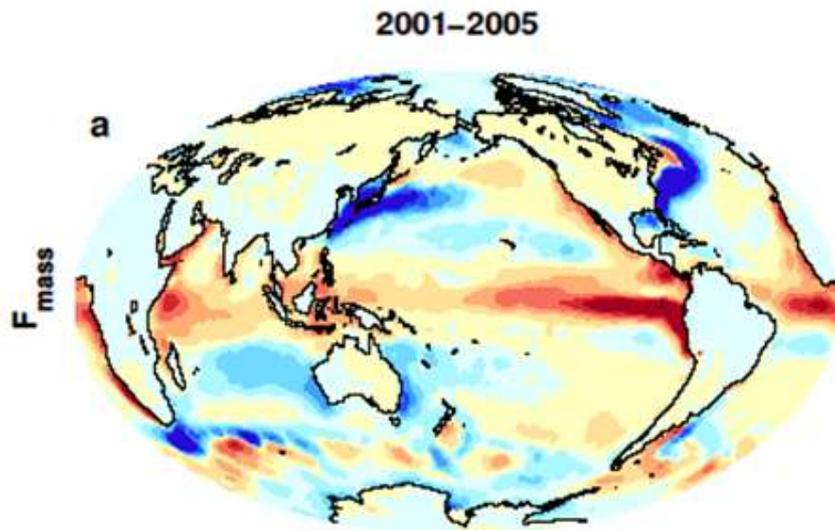
- Large ocean heating anomaly in 2002
- Inconsistent with radiation budget observations and simulations
- Changing observing system influence?
- Slight drop in net flux 1999-2005?

Smith et al. (2015) GRL

# WHERE IS THE HEAT GOING?

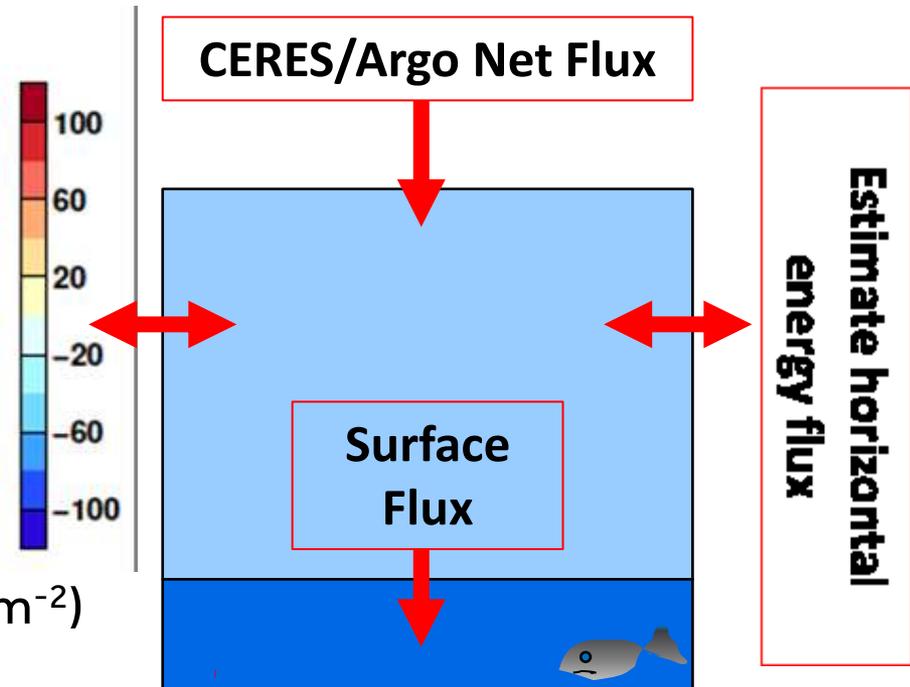
## NEW ESTIMATES OF SURFACE ENERGY FLUX

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



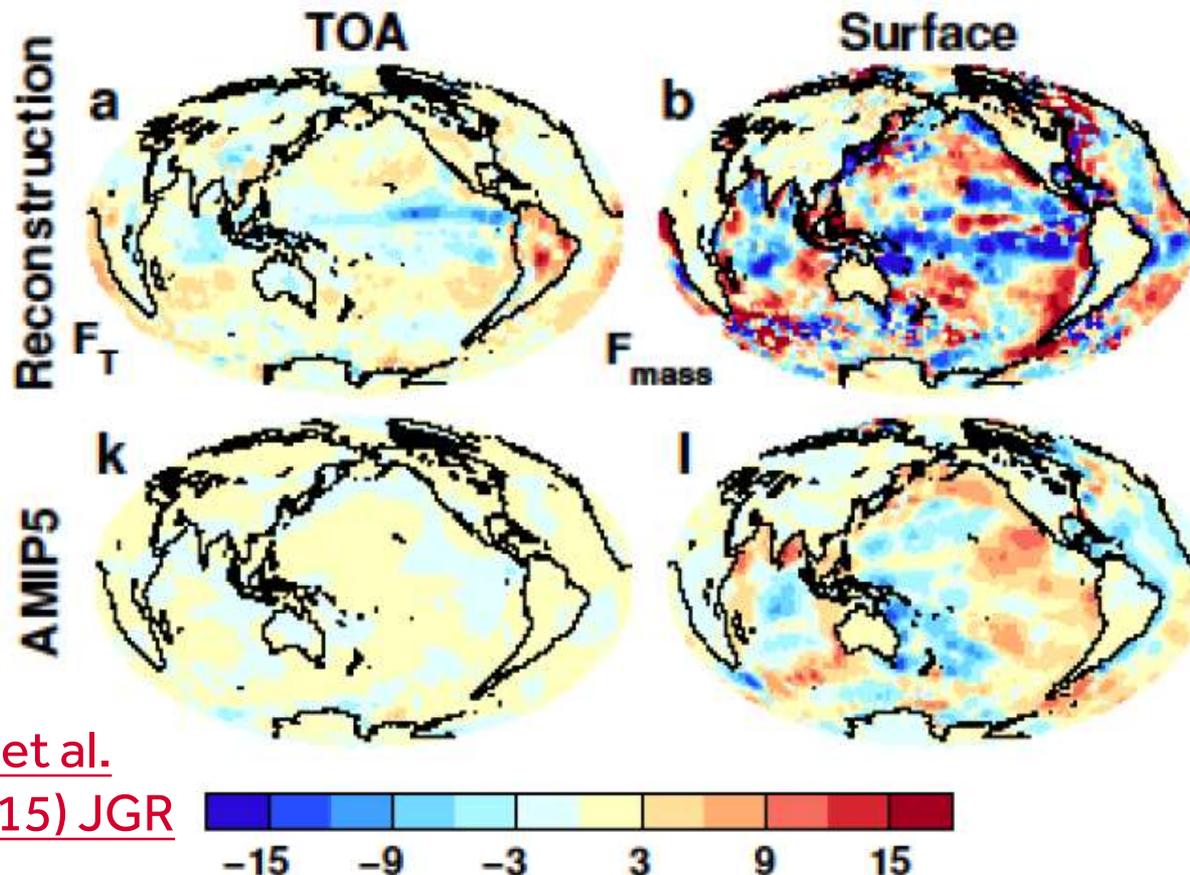
Net surface downward energy flux ( $Wm^{-2}$ )

[Liu et al. \(2015\) JGR](#)



# WHERE IS THE HEAT GOING?

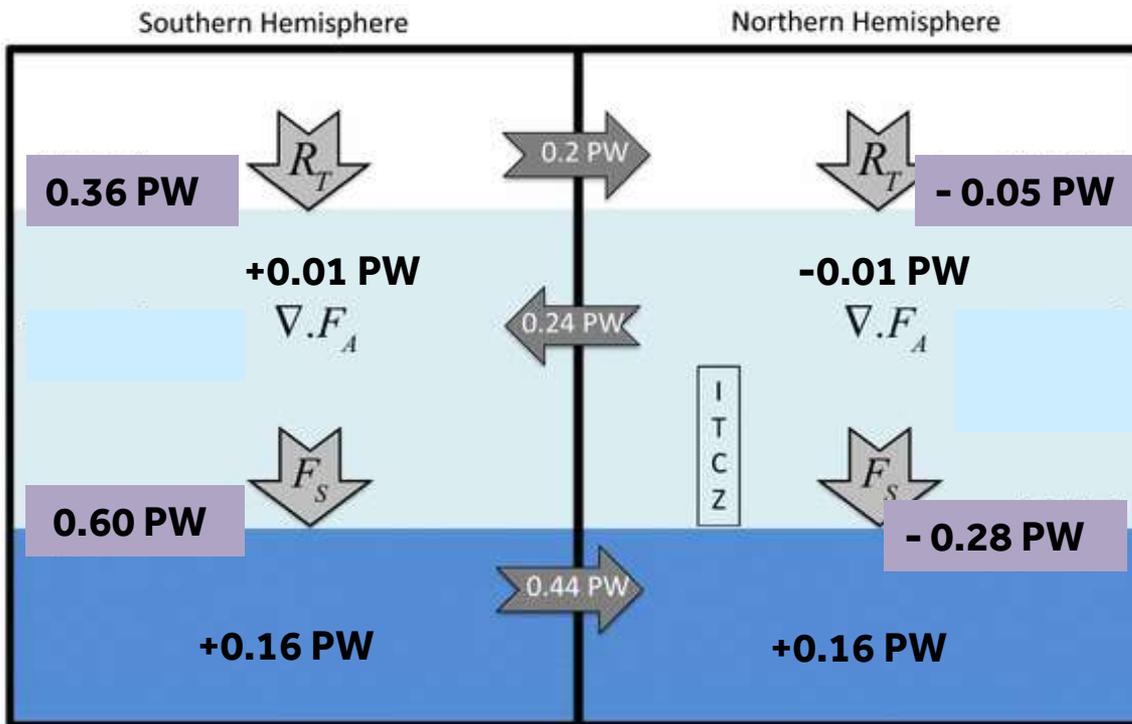
## CHANGES IN SURFACE ENERGY FLUX



- Changes in energy fluxes 1986-2000 to 2001-2008
- Surface energy flux dominated by atmospheric transports
- Contrasting model pattern of change
- Are reanalysis transports reliable?

Liu et al.  
(2015) JGR

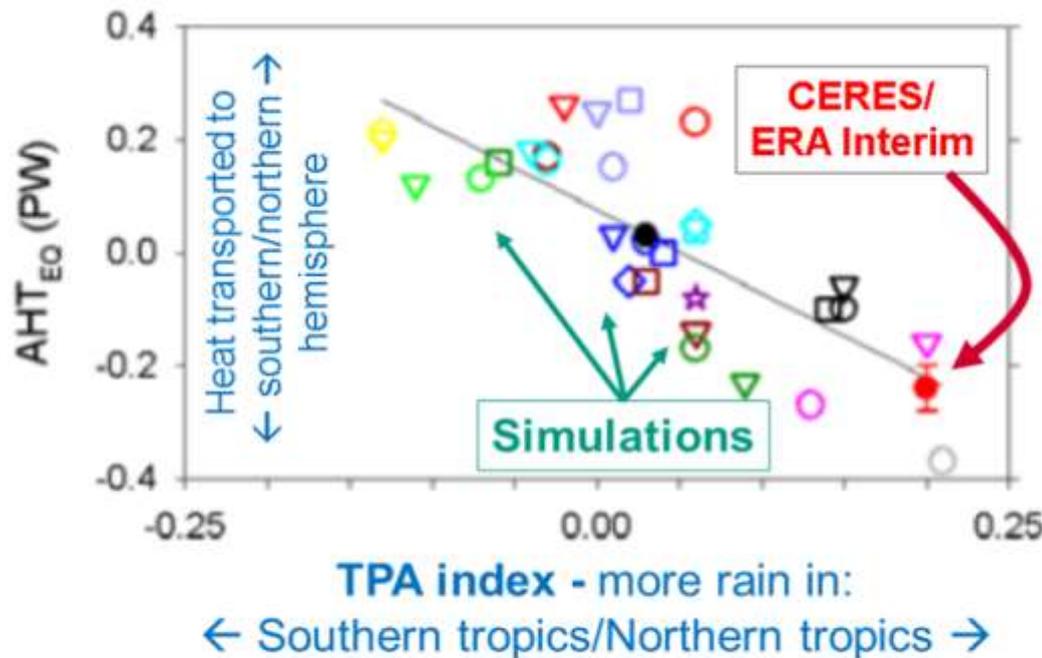
# OBSERVED ASYMMETRY IN EARTH'S ENERGY BUDGET



Loeb et al. (2015) Clim. Dyn.

- 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  
[Loeb et al. \(2015\) Clim. Dyn.](#)

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

# CONCLUSIONS



- Heating of Earth continues at rate of  $\sim 0.6 \text{ Wm}^{-2}$ 
  - Manifest as positive imbalance in Southern Hemisphere
  - Energy transport by ocean to Northern Hemisphere offset by atmospheric energy transport to Southern Hemisphere
  - Variability from radiative forcings & ocean internal changes
- Where is the excess energy going in the oceans?
- Toward reconciled ocean heating & radiation budget changes
- Do feedbacks amplify/extend hiatus/surge events?
- Inter-hemispheric heating links to model precipitation biases

See posters on:

Changing water cycle and interhemispheric energy transports (Allan & Liu)

Recent changes in precipitation over Africa (Maidment et al. )

Clouds, radiation and precipitation in west Africa (DACCIWA; Hill et al.)

