Changes in global net radiative imbalance 1985-2012

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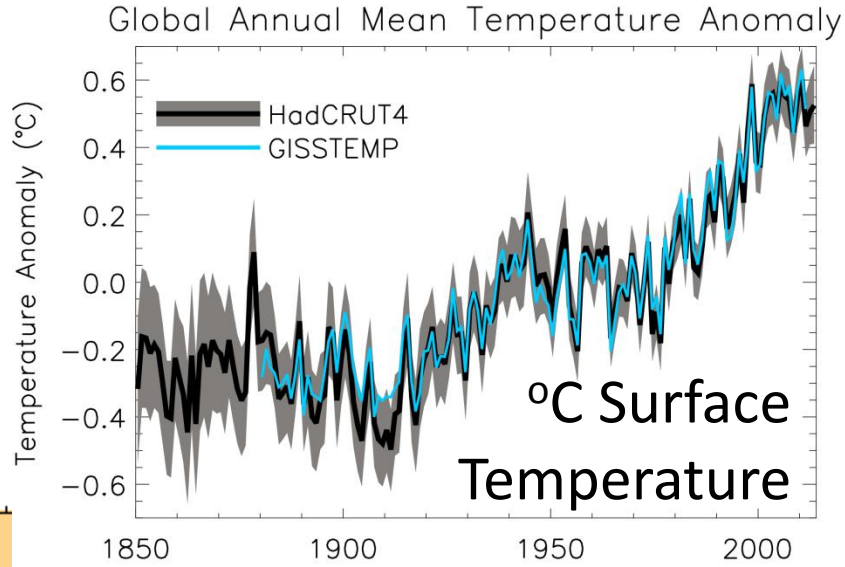
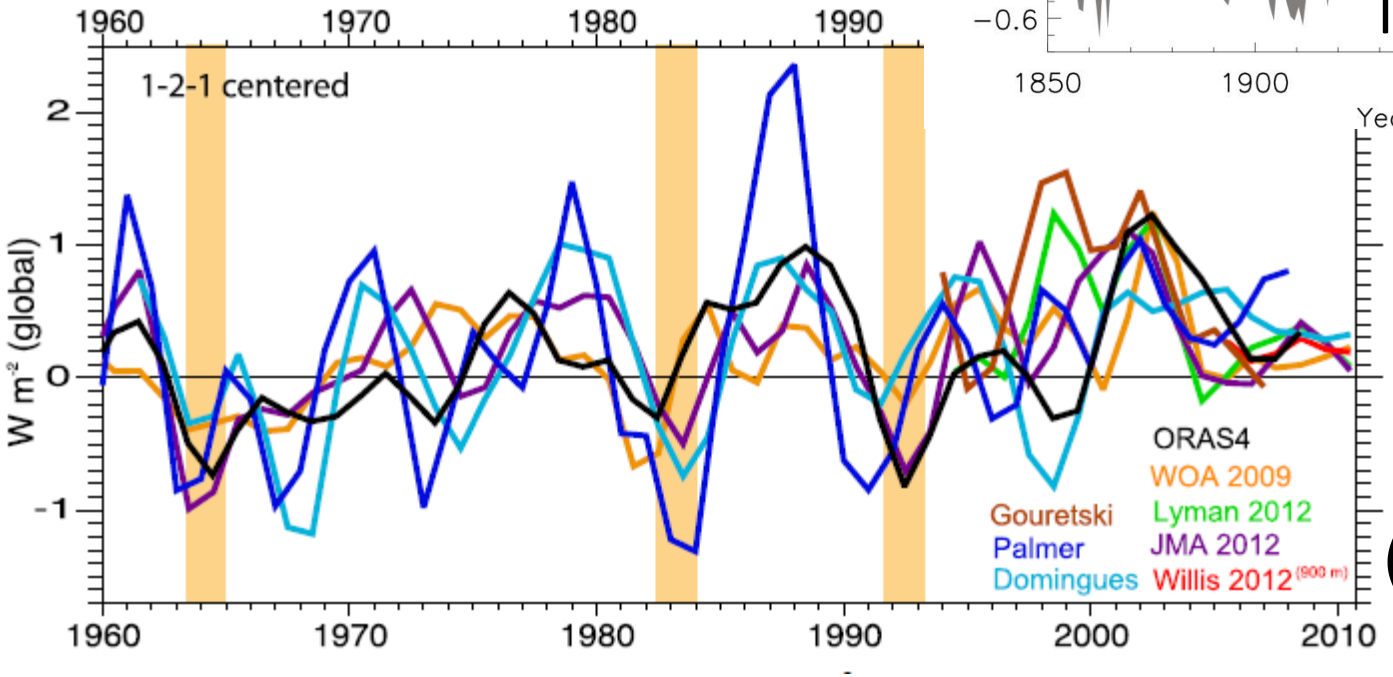
At what rate is Earth heating?



°C Surface Temperature

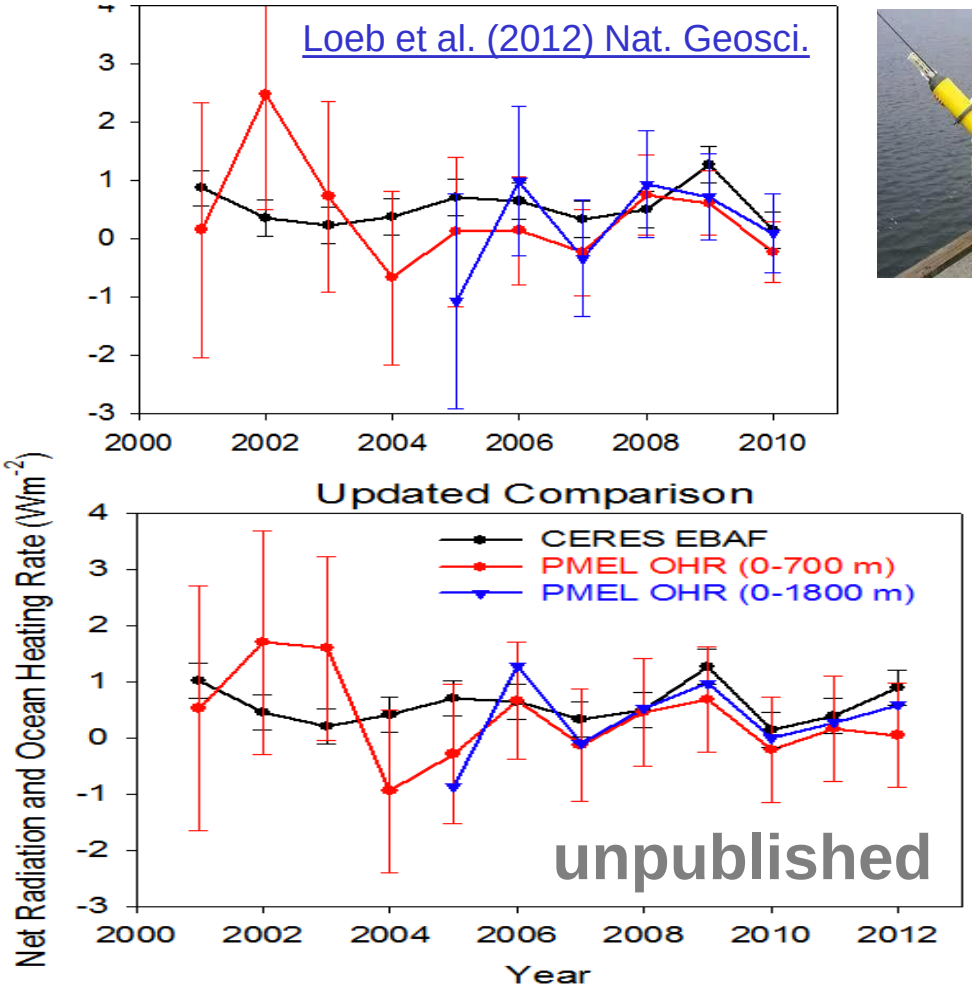


Upper ocean (Wm^{-2})

Trenberth et al. (2014) J Clim

Combining Earth Radiation Budget data and Ocean Heat Content measurements

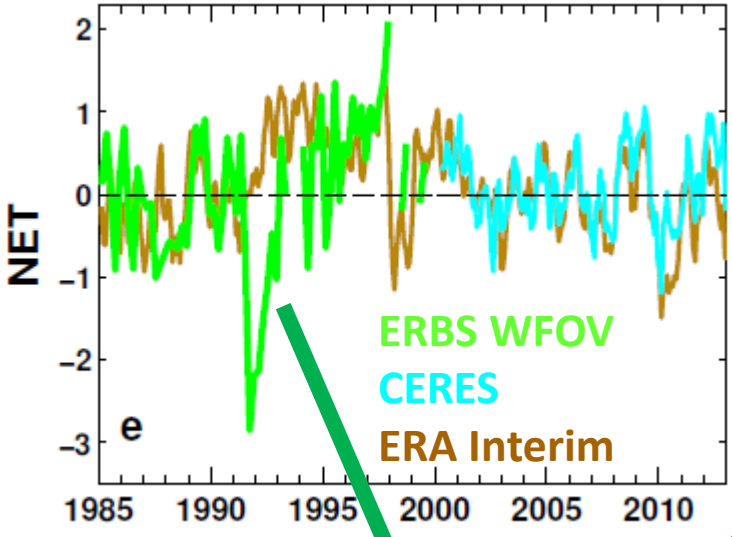
- Tie 10-year CERES record with SORCE TSI and ARGO-estimated heating rate 2005-2010 + minor additional storage terms
- Variability relating to ENSO reproduced by CERES and ERA Interim
- Updated estimate of net energy imbalance 2000/03-2013/03: **0.60±0.43 Wm^{-2}**



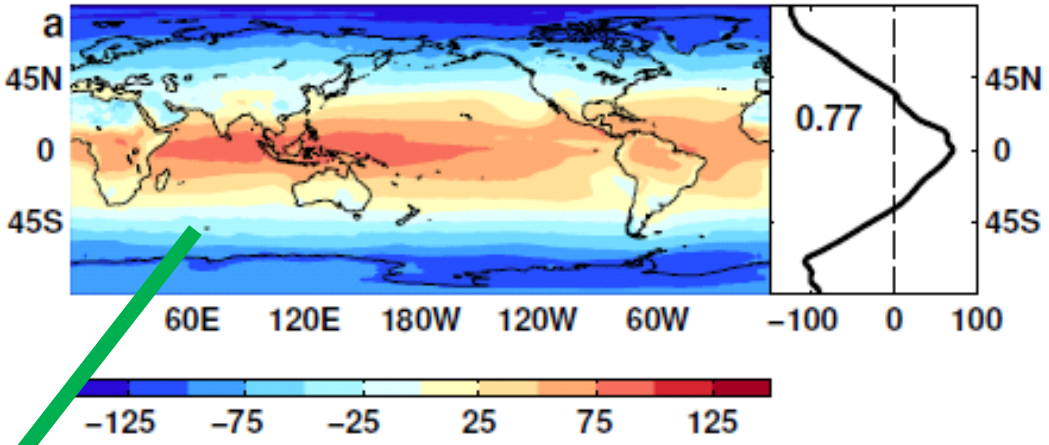
Loeb et al. (2012) Nat. Geosci. See also Hansen et al. (2011) ACP

Reconstructing global radiative fluxes prior to 2000

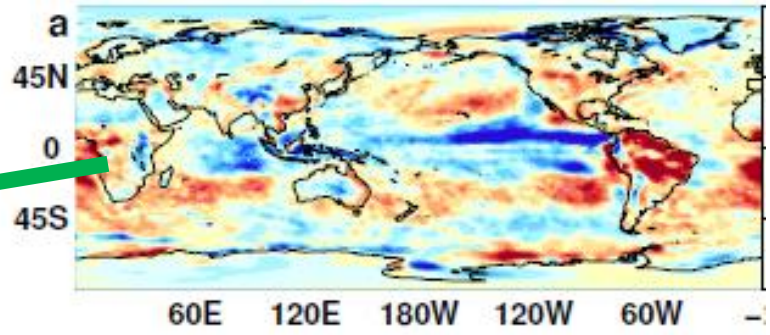
ERBS/CERES variability



CERES monthly climatology



ERA Interim spatial anomalies

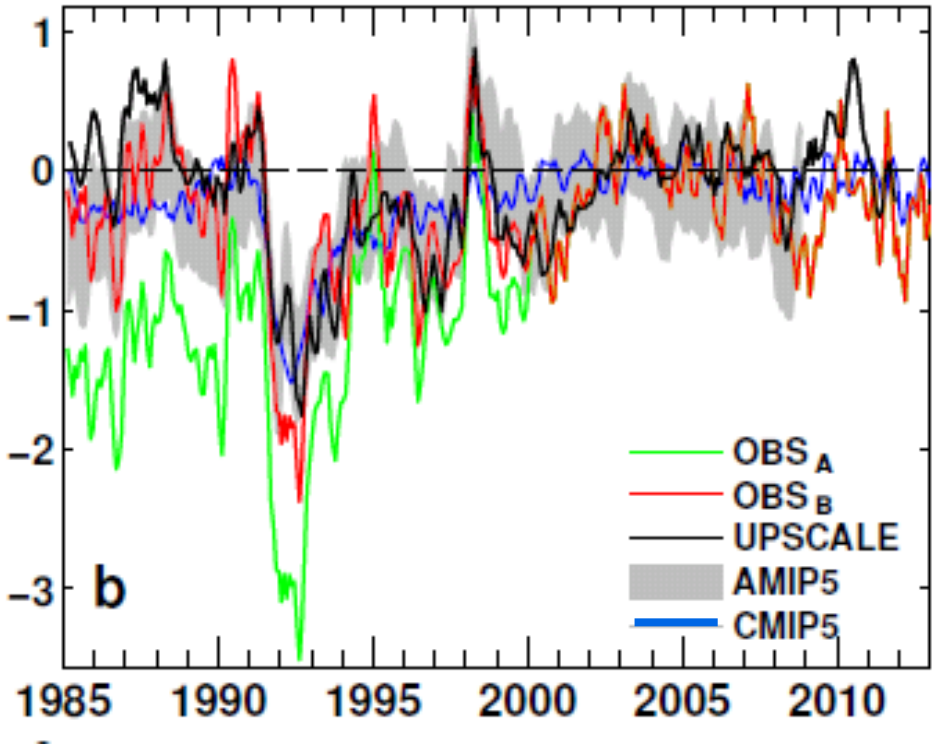


Combine CERES/ARGO accuracy, ERBS WFOV stability and reanalysis circulation patterns to reconstruct radiative fluxes

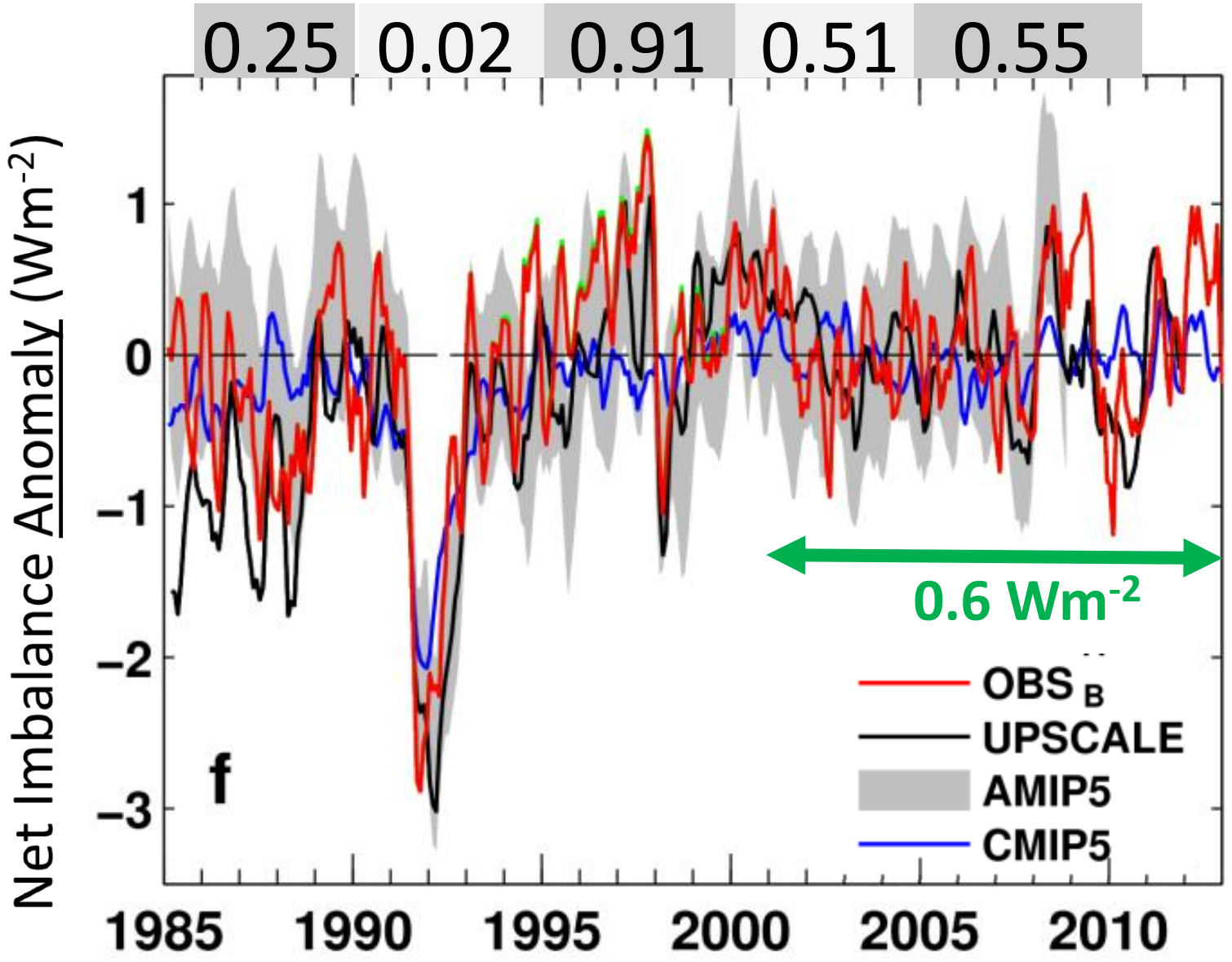
Use reanalyses or models to bridge gaps in record (1993 and 1999/2000)

- ERA Interim trends suspect. Use model…
- **UPSCALE** simulations (obs. SST, sea ice & realistic radiative forcings) "**OBS_B**"
- Net less sensitive to method than OLR/ASR

Outgoing Longwave Radiation Anomalies (Wm^{-2})

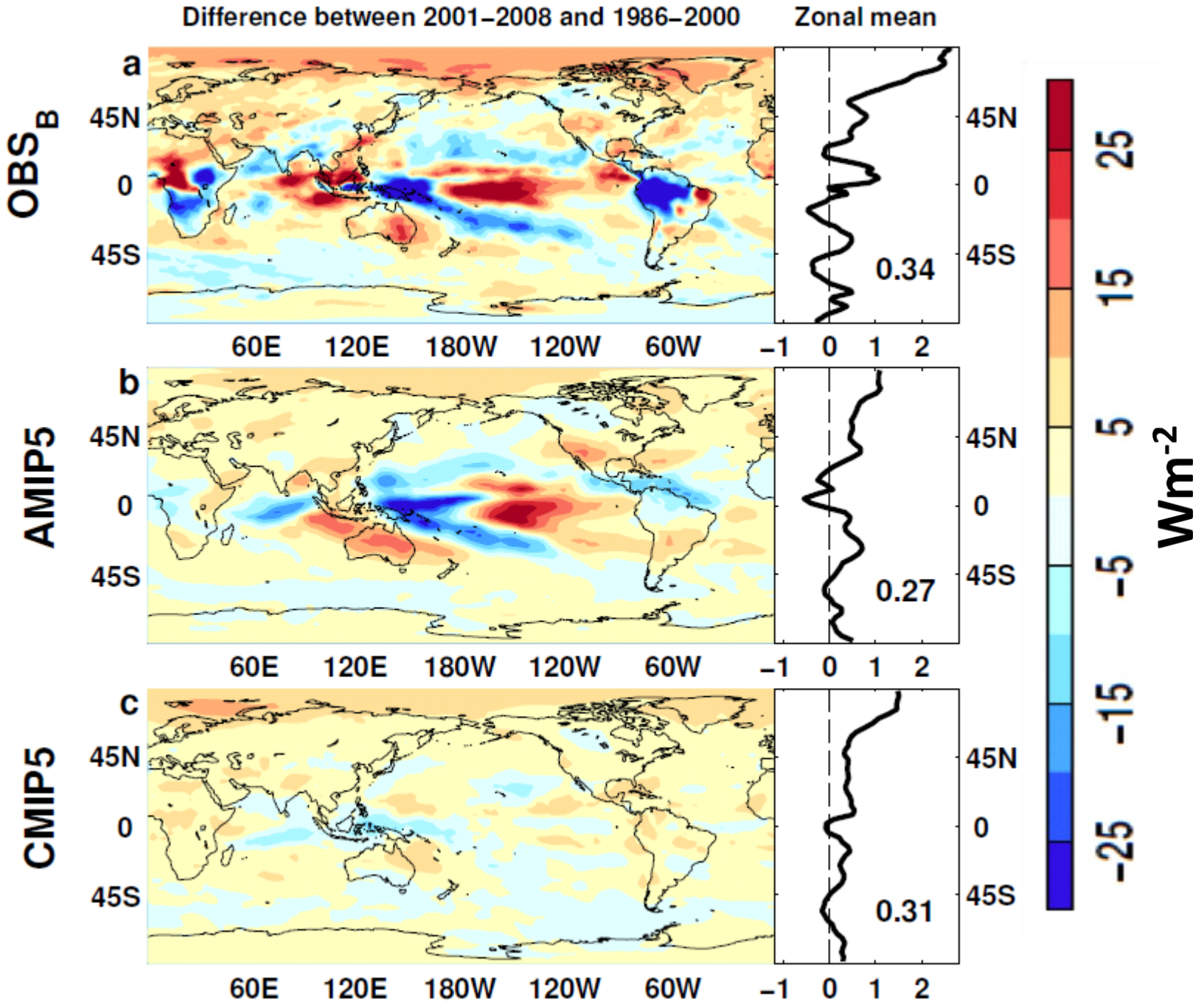


Reconstructed Net Flux (Wm^{-2})

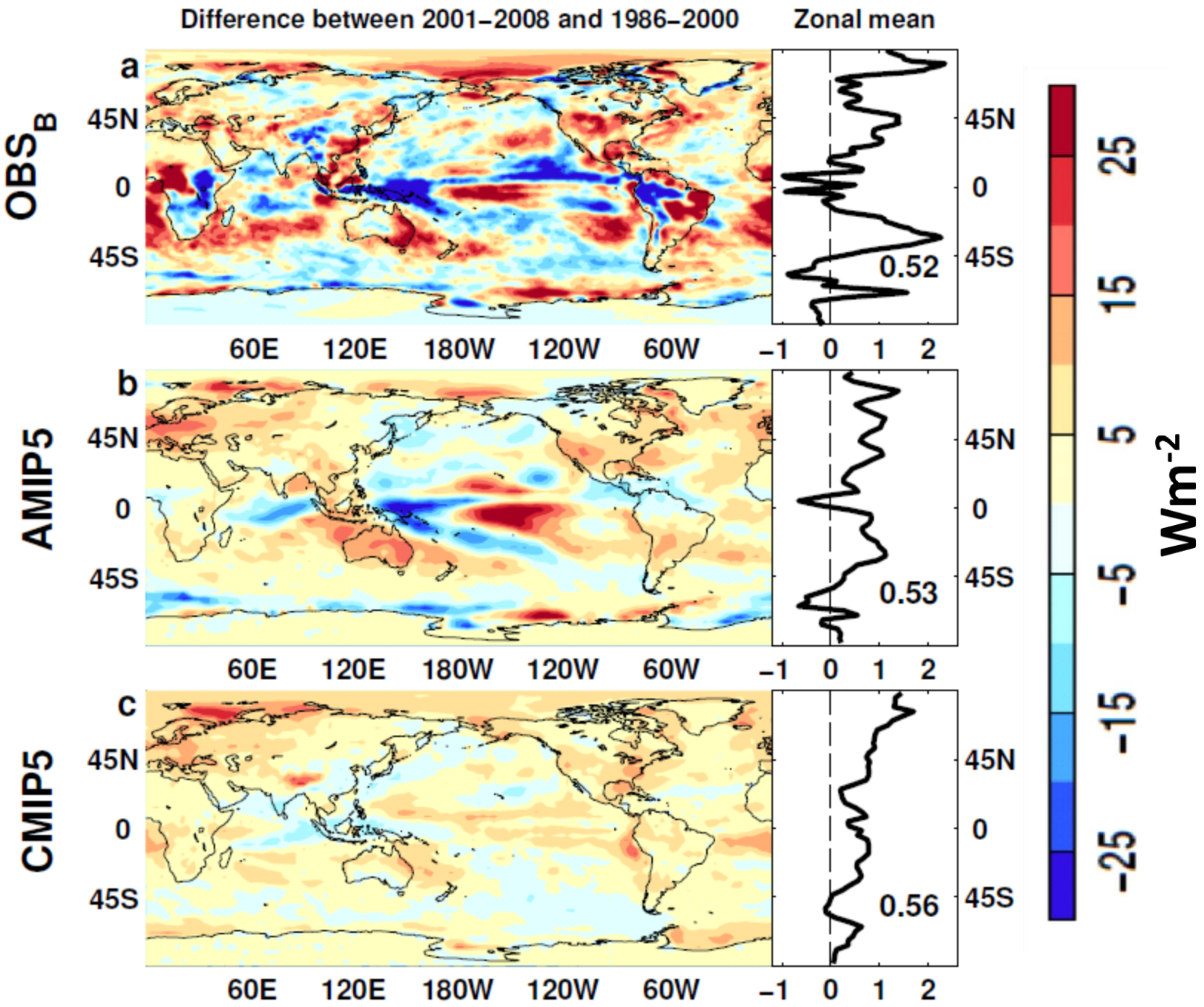


See also: Wong et al. (2006) J Clim; Wielicki et al. (2002) Science

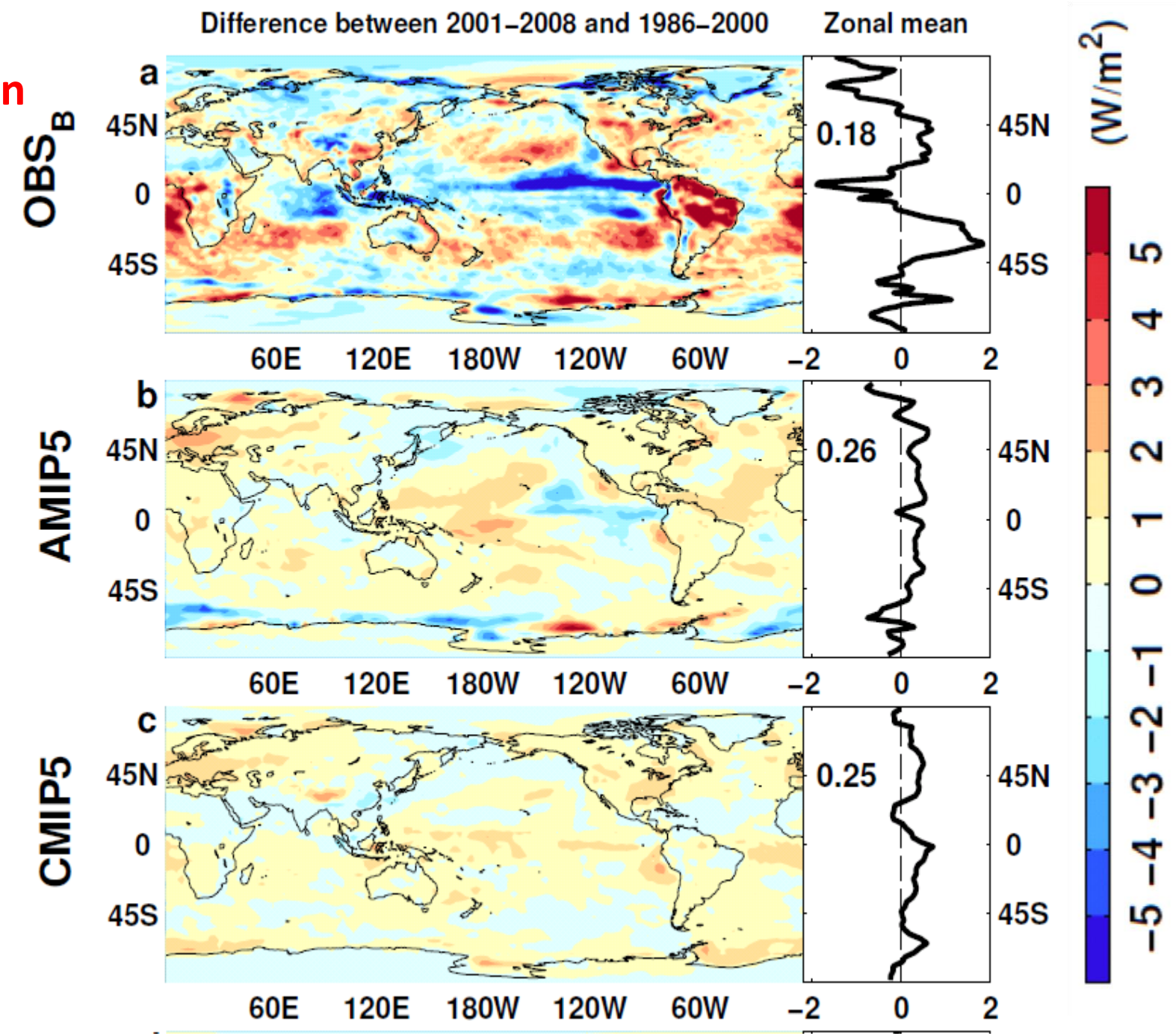
Outgoing Longwave Radiation



Absorbed Shortwave Radiation



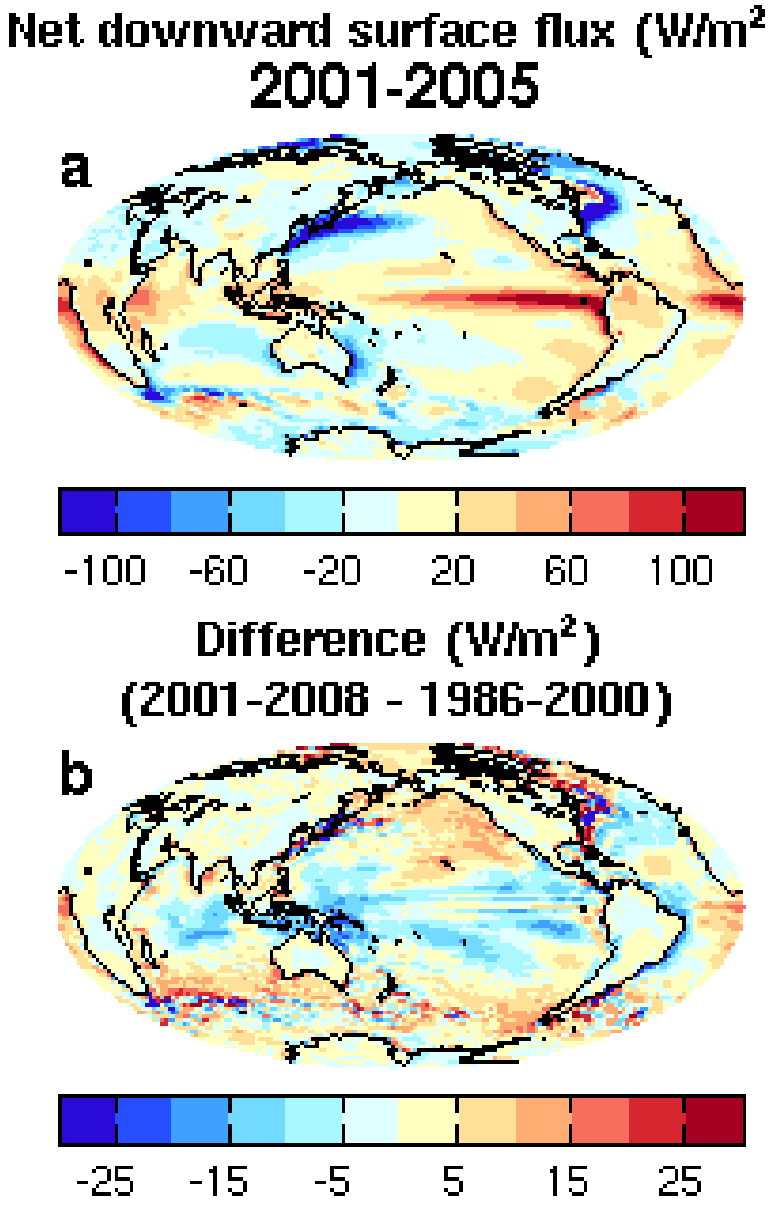
NET Radiation

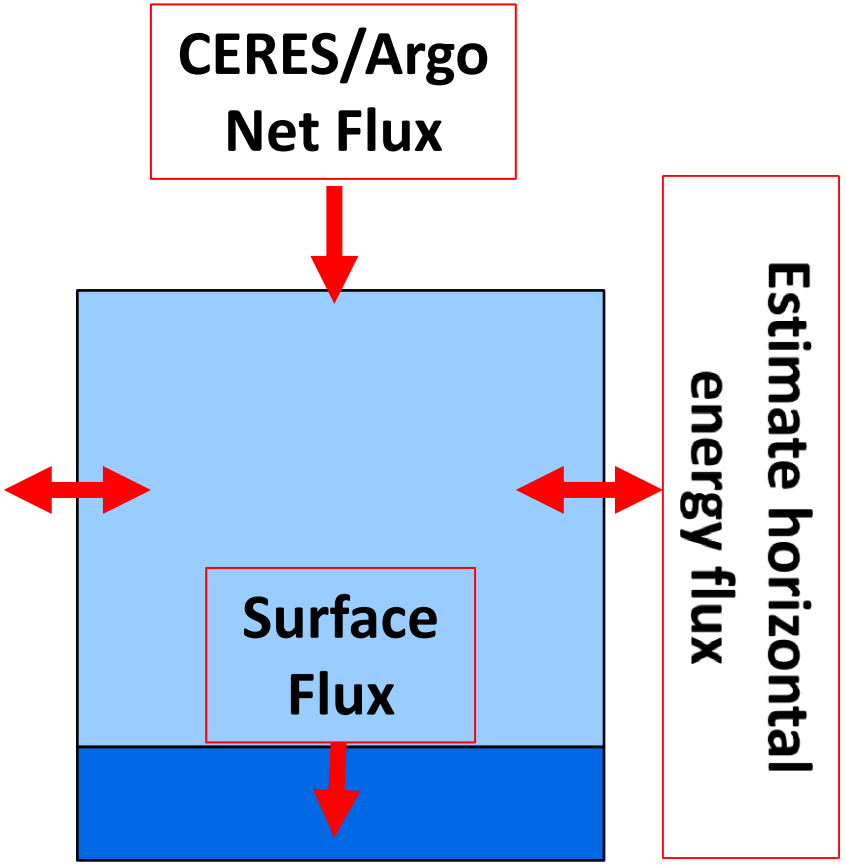


Preliminary results

- Heating of Earth continues at rate of ~0.6 Wm-2
- Current variability in TOA radiation (1985-2013)
- Net radiative flux imbalance fairly stable
  - Requires anchoring to ARGO ocean heating rate + minor terms
  - Influence of Pinatubo and ENSO
  - ~0.3 Wm^{-2} higher in 1995-1999 than 2000-2013 period
- Distinct East Pacific signal in ΔT and ΔN
- Radiative forcing alone can't explain surface warming slowdown: internal variability important
- Next steps: combining with reanalyses energy transports to estimate surface fluxes

Estimates of Surface Flux



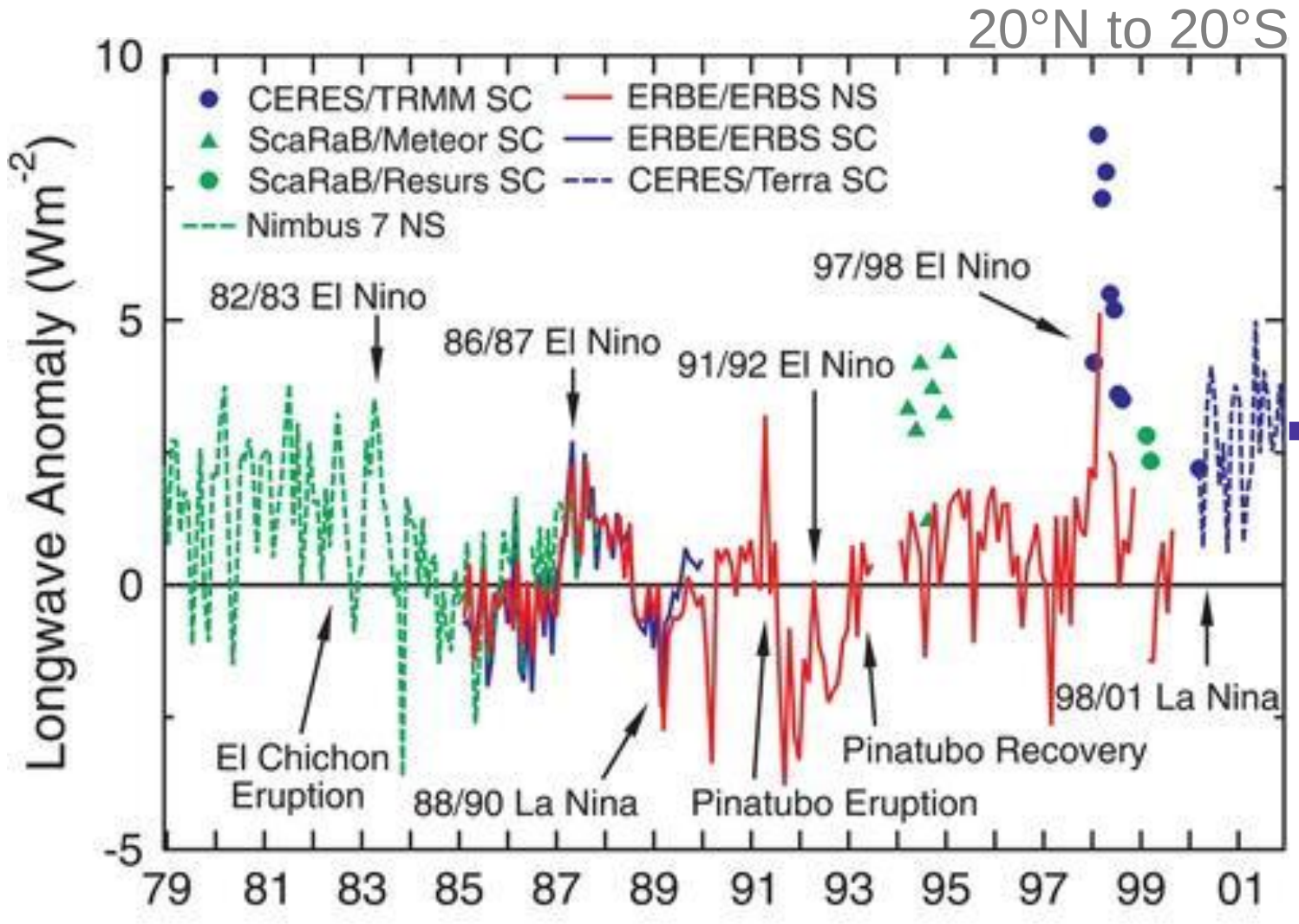


Poster by Chunlei Liu
EGU2014-11067

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

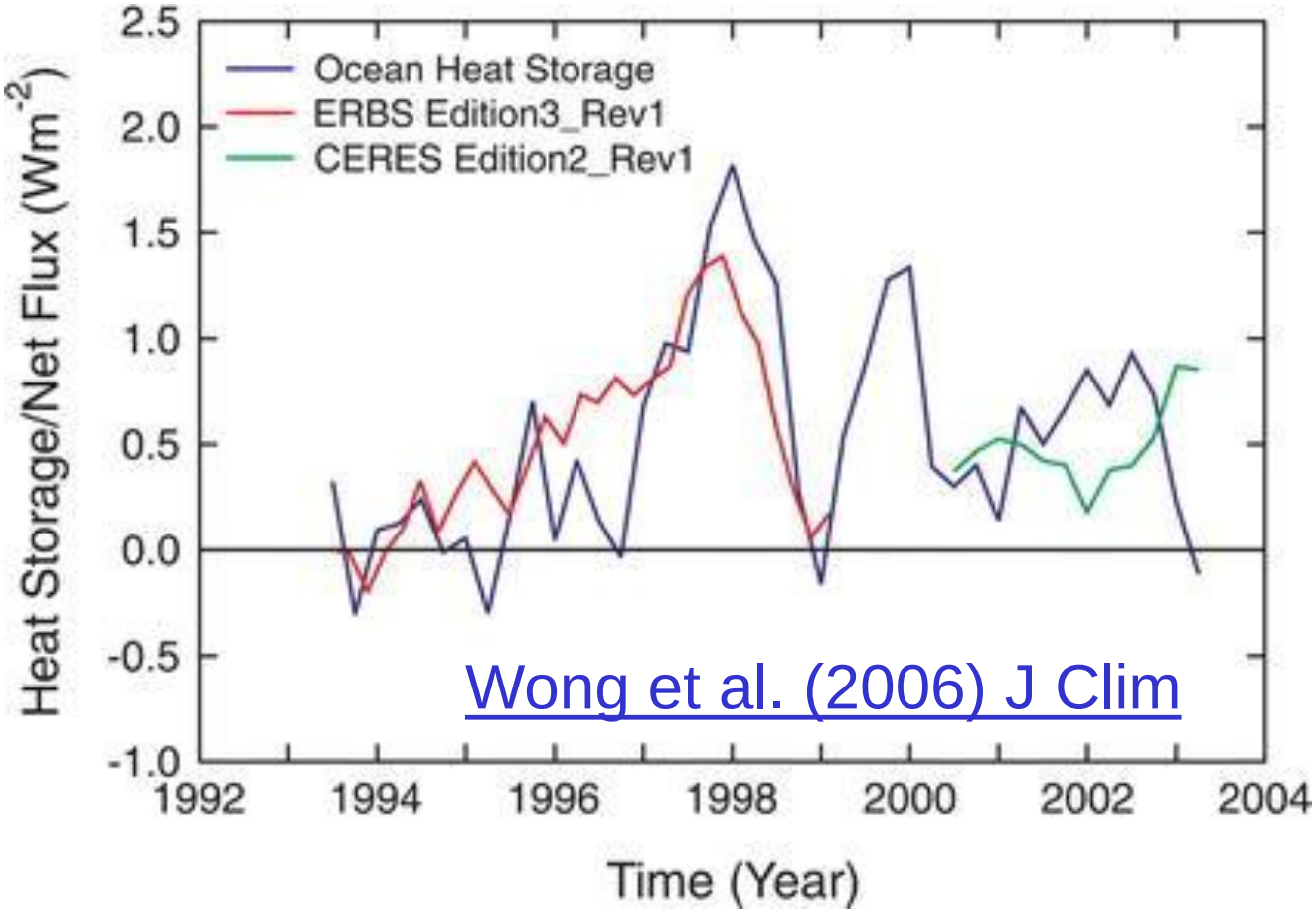
Extra slides

Earth Radiation Budget Satellite Data



Wong et al. (2006) J Clim; Wielicki et al. (2002) Science

Combining Radiation Budget and Ocean Heating Data

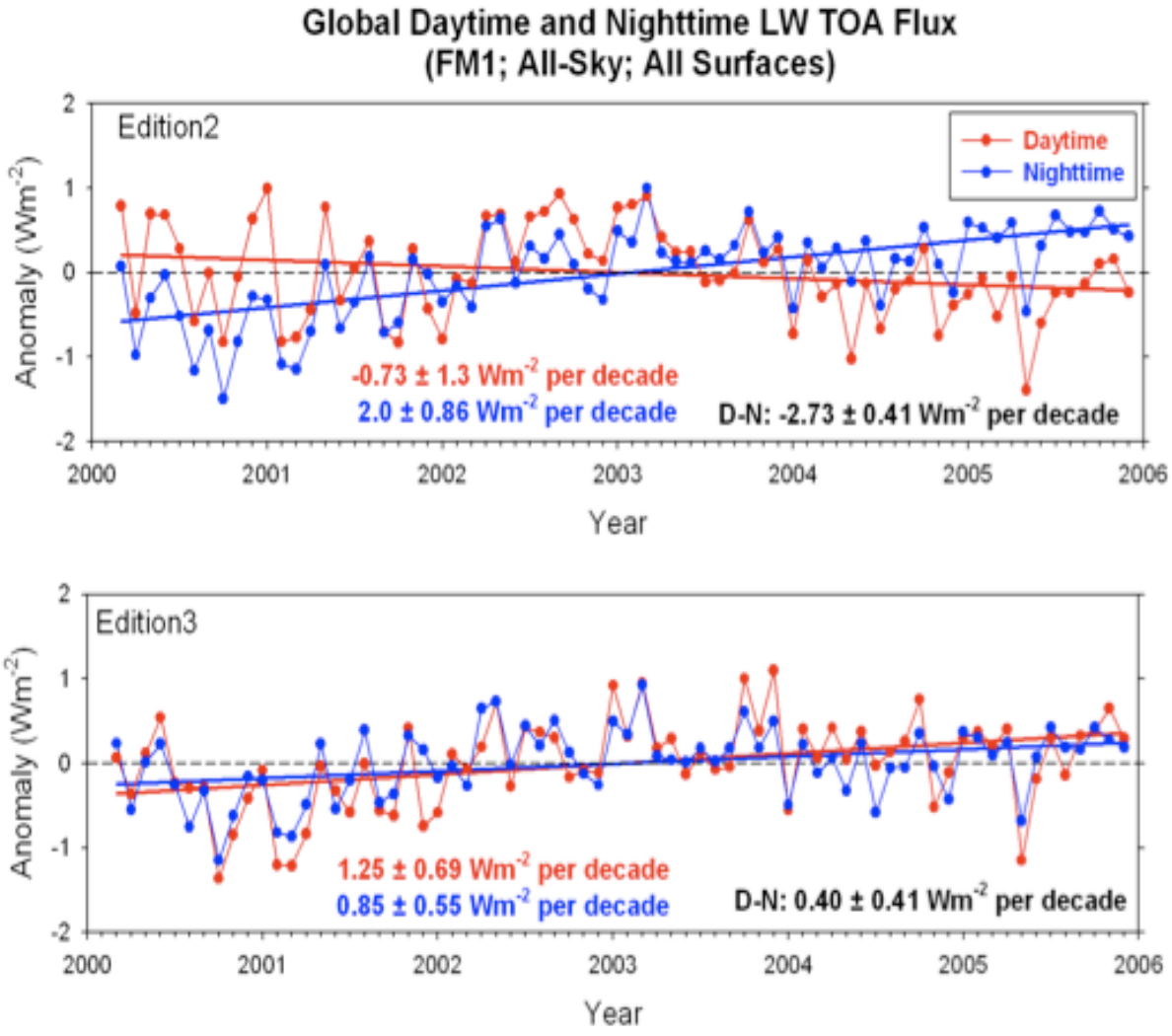


Combined CERES/Argo data

- Incoming Solar: SORCE Level 3 V10
- Reflected Shortwave/Outgoing Longwave from EBAF
  - (v2.6r → v2.8 → V3…)
- Added errors in quadrature to give ± 0.43 Wm^{-2}
  - Argo 0-2000m dOHCA/dt = 0.47 ± 0.38 Wm^{-2} (2005-2010)
  - >2000m ~ 0.07 ± 0.05 Wm^{-2}
  - Heating/melting ice, heating land/atmos ~ 0.04 ± 0.02 Wm^{-2}
  - CERES standard error ± 0.2 Wm^{-2}
- Jan 2001-Dec 2010: 0.50 ± 0.43 Wm^{-2} (EBAF V2.6r)
- March 2000 – February 2013: 0.60 ± 0.43 Wm^{-2} (EBAF V2.8)
- CERES scanner data: cloud mask → clear-sky fluxes; not possible for ERBS wide-field of view

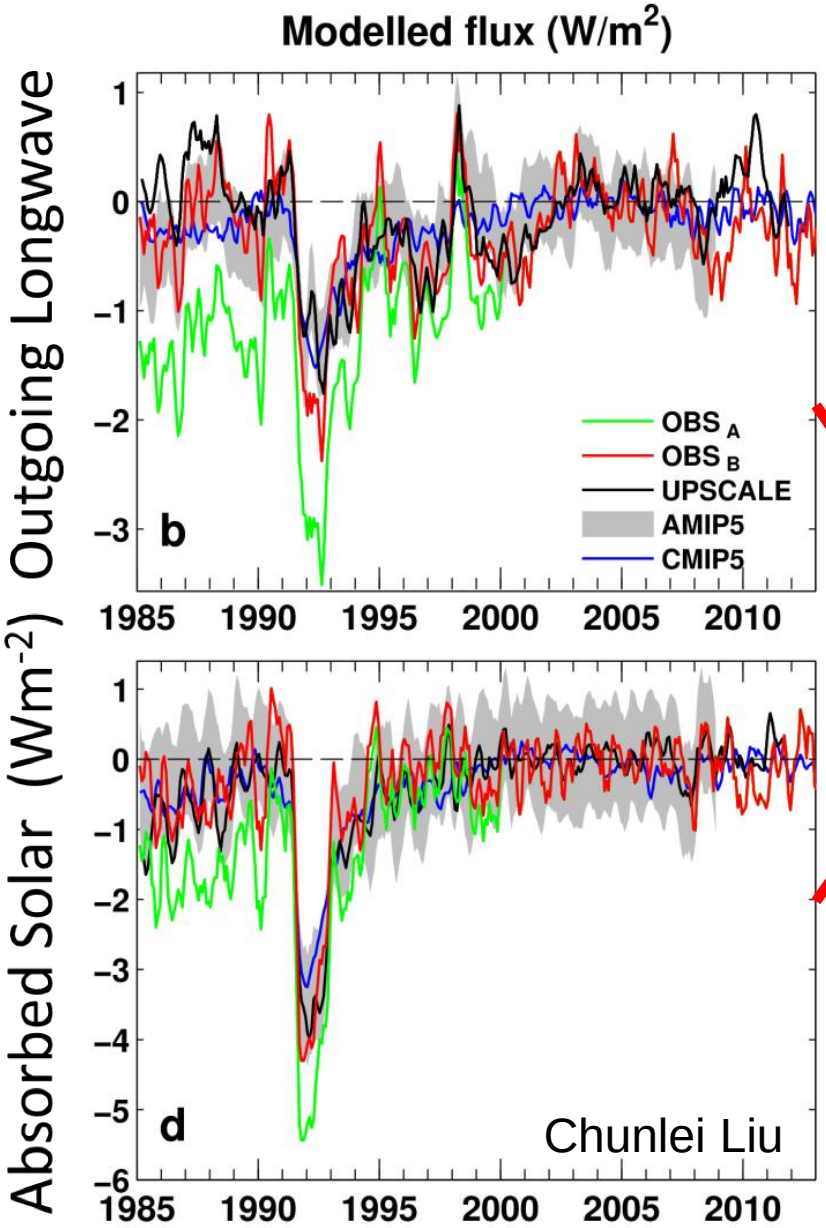
Updated CERES satellite data

- Issues with sampling, radiance to flux conversion, calibration, etc
- Correction for degradation of shortwave filter
- Correction also improves physical consistency of trends in daytime longwave

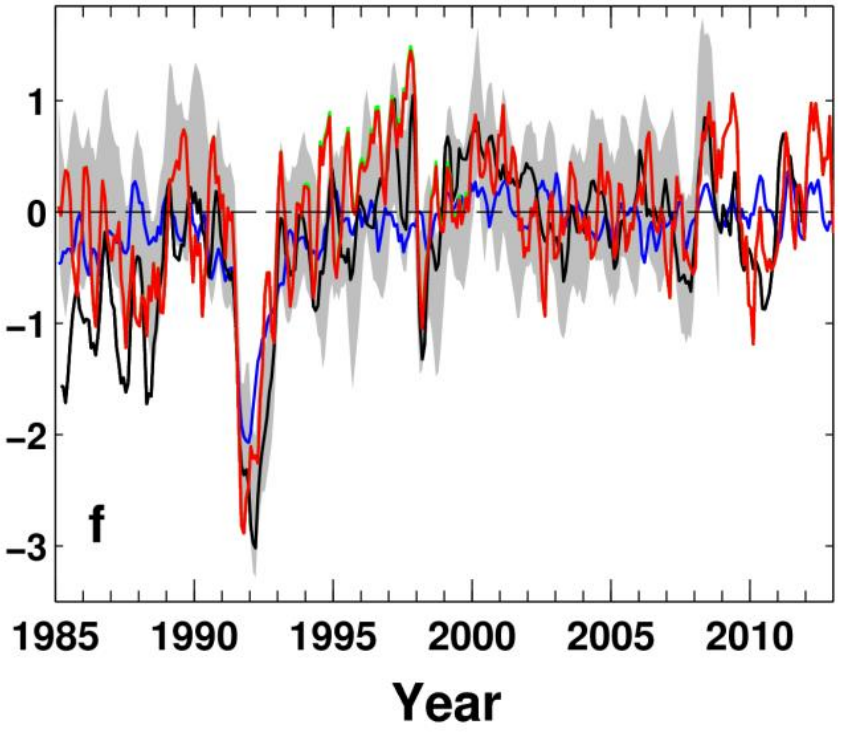


We used version CERES_EBAF-TOA_Ed2.6r; currently v2.8

Changes in top of atmosphere radiative fluxes since 1985

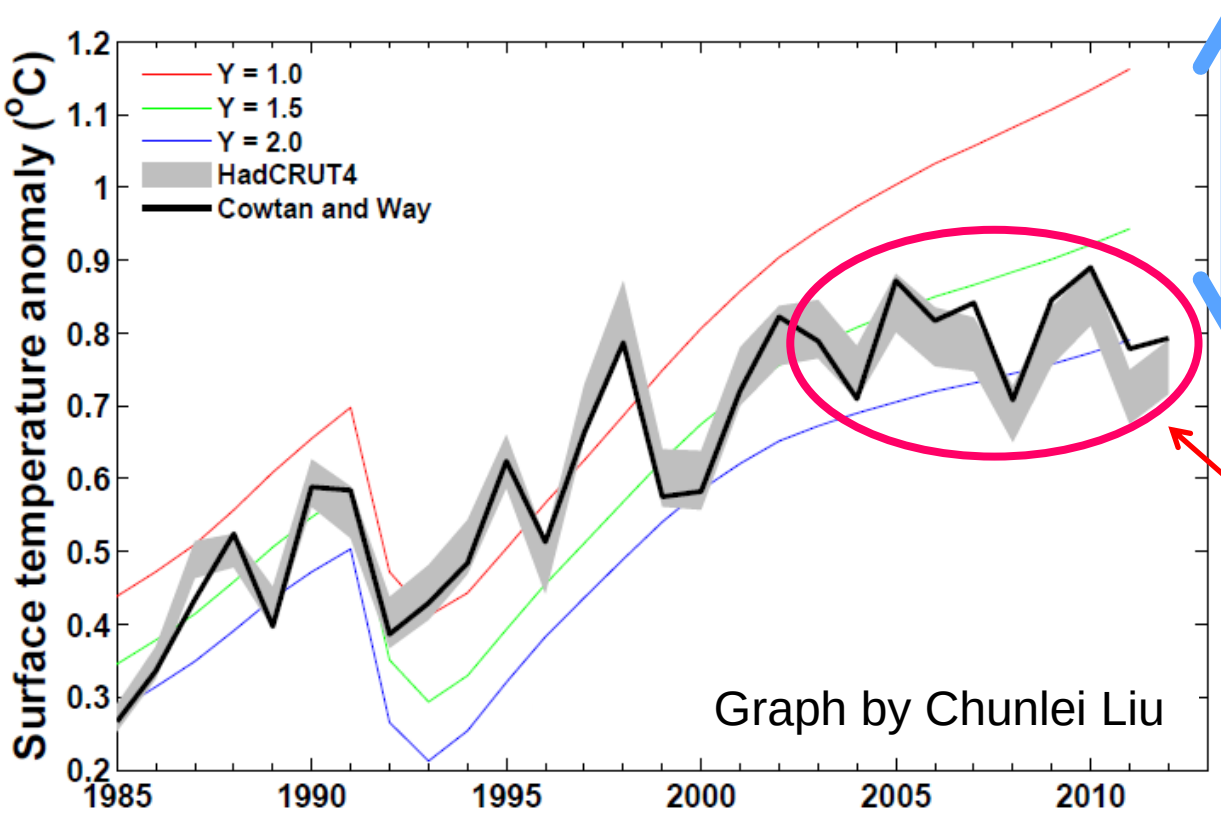


Net Imbalance Anomaly (Wm^{-2})



Research in DEEP-C project at Reading…

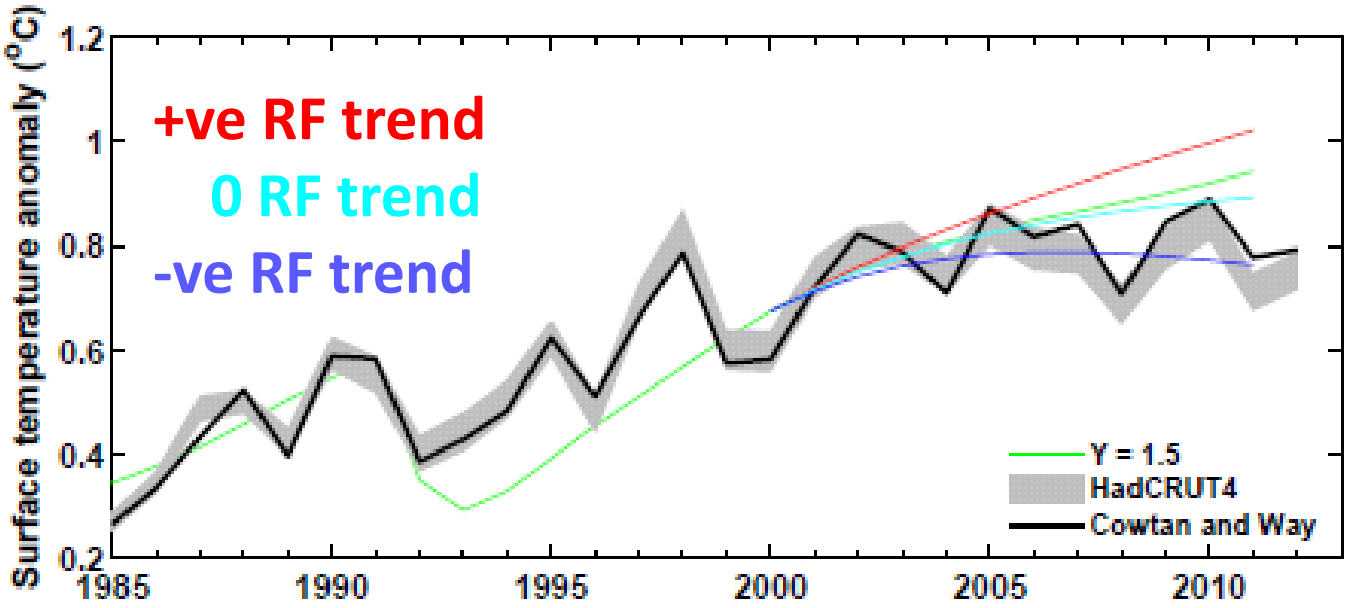
Is the temperature record wrong or are computer models inaccurate?



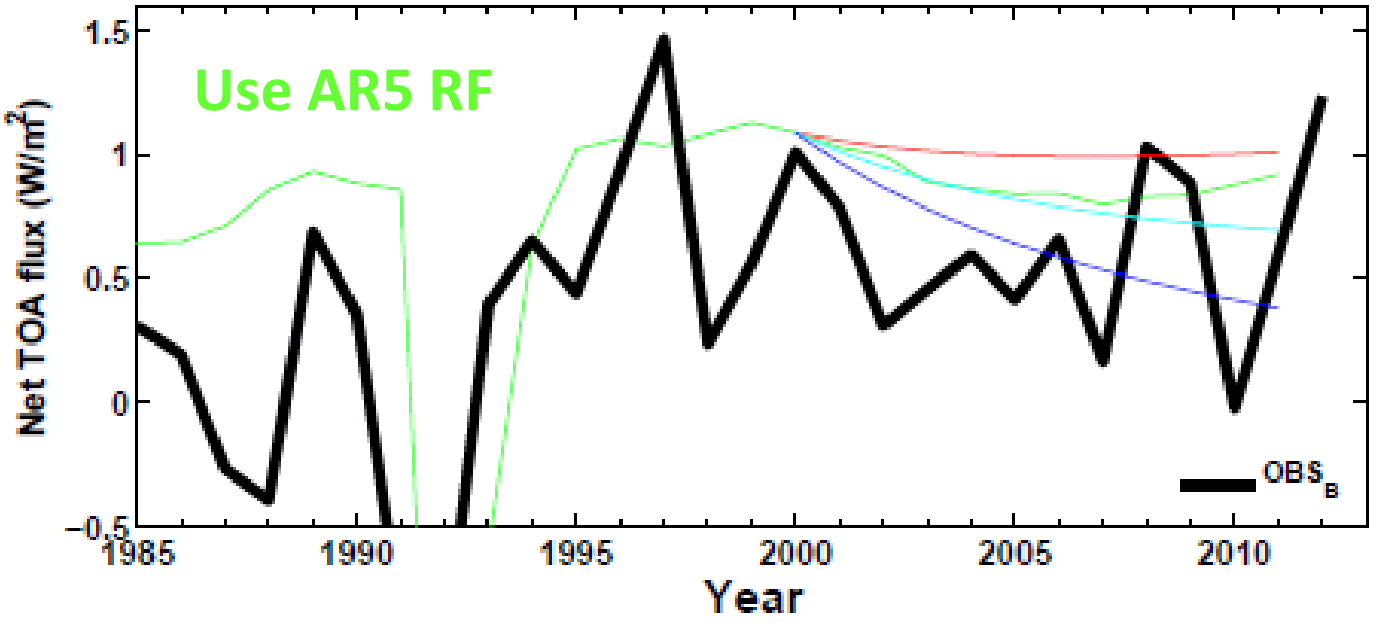
Can comparisons tell us about how sensitive climate is to radiative forcing? e.g. Otto et al. (2013) Nature Geosci

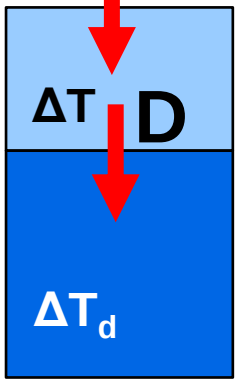
Spatial infilling of data gaps influences trends in surface temperature (Cowtan & Way, 2013 QJRMS) and ocean heat content (Lyman & Johnson 2014 J. Clim.)

ΔT



N



Analysis using simple energy balance model

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