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Current changes in Earth's energy imbalance

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1. Earth's energy imbalance & climate

- **Rising concentrations of greenhouse gases are heating the planet by causing an energy imbalance (there is more absorbed sunlight than infrared radiation emitted to space)**
- **Yet the rate of global average surface warming was slower in the 2000s compared with the 1980s-1990s (see Figure 1)**

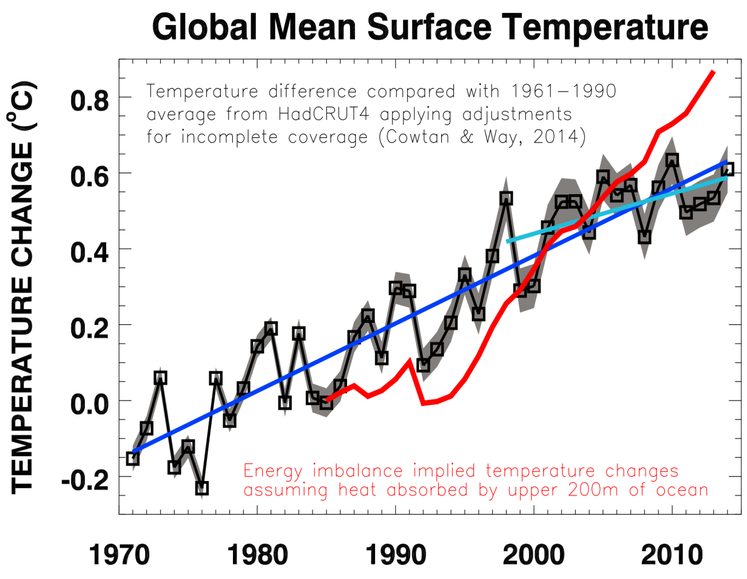


Figure 1: Temperature difference (°C) to the 1961-1990 average using HadCRUT4 data adjusted to account for gaps in the data by Cowtan & Way (2014) and also inferred from energy imbalance data (red) relative to 1985 assuming all energy accumulates in the upper 200m of ocean.

- **We combined satellite and ocean measurements with reanalyses of the atmosphere and climate simulations to:**
  - a) **Monitor changes in Earth's energy imbalance (heating rate)**
  - b) **Understand where energy is accumulating in the climate system and the mechanisms involved**

2. Changes in Earth's energy imbalance

- Earth is gaining heat at the rate of 0.6 Watts per square metre over the period 2000-2012 (equivalent to every human being alive today using 20 kettles each to boil the ocean!)
- If anything, Earth's heating rate has increased since the late 1980s (Allan et al. 2014 GRL; Smith et al. 2015 GRL)

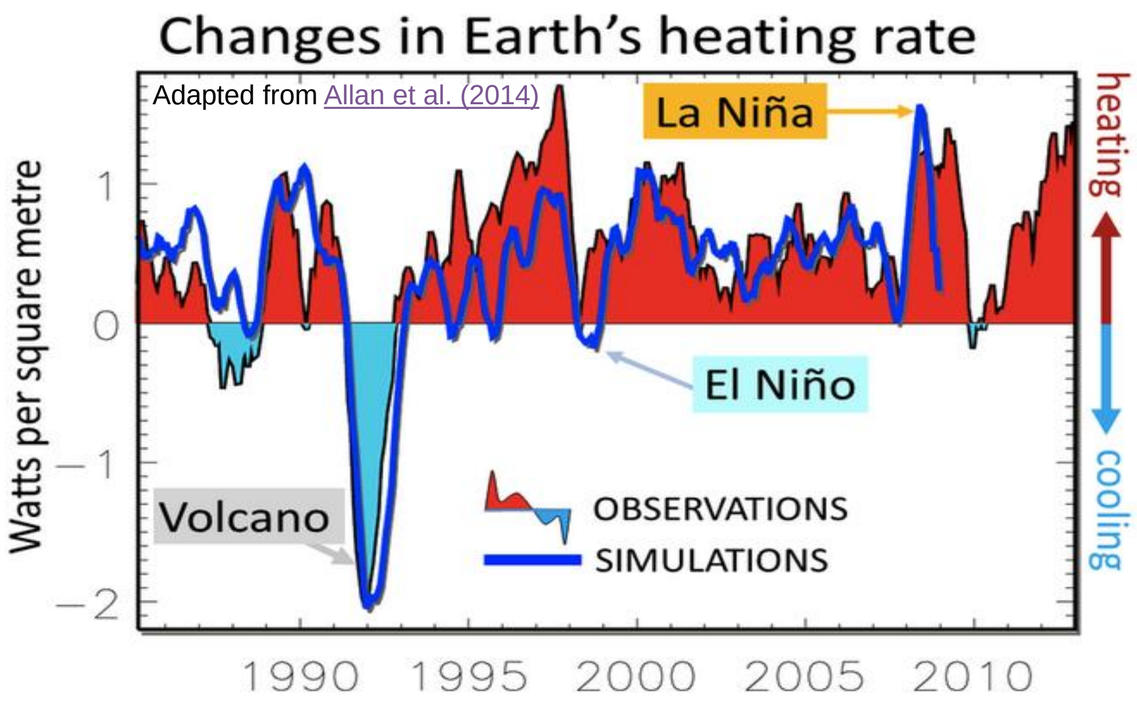


Figure 2: Estimates of changes in Earth's top of atmosphere energy imbalance (or heating rate) from our reconstruction and simulations applying observed sea surface temperature and radiative forcings

- Where is the excess energy accumulating?
- New estimates of surface energy fluxes are derived by combining reconstructions of Earth's energy imbalance with reanalysis energy transports (Liu et al. 2015 submitted; see Figure 3).

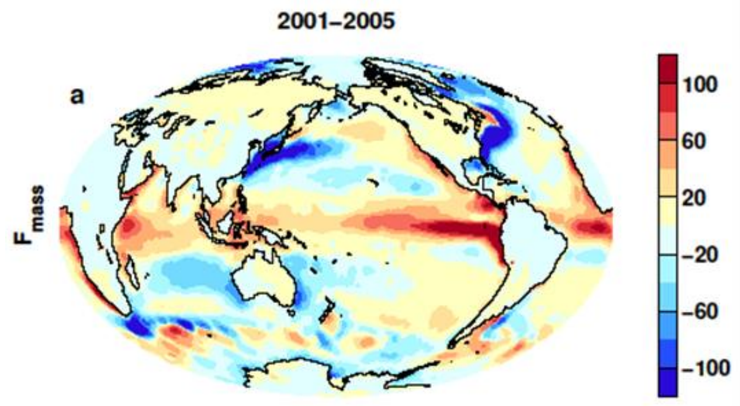


Figure 3: Surface energy flux in Watts per square metre (2001-2005) derived from satellite reconstruction and reanalysis energy transports (Liu et al. 2015, submitted)

3. Implications for cross equatorial energy transport, rainfall and climate

- Energy is accumulating in the southern hemisphere (Figure 4)
- The implied movement of heat by the oceans and atmosphere between hemispheres affects rainfall patterns and climate (Figure 5; see also Stephens et al. 2015 ; Frierson et al. 2013)

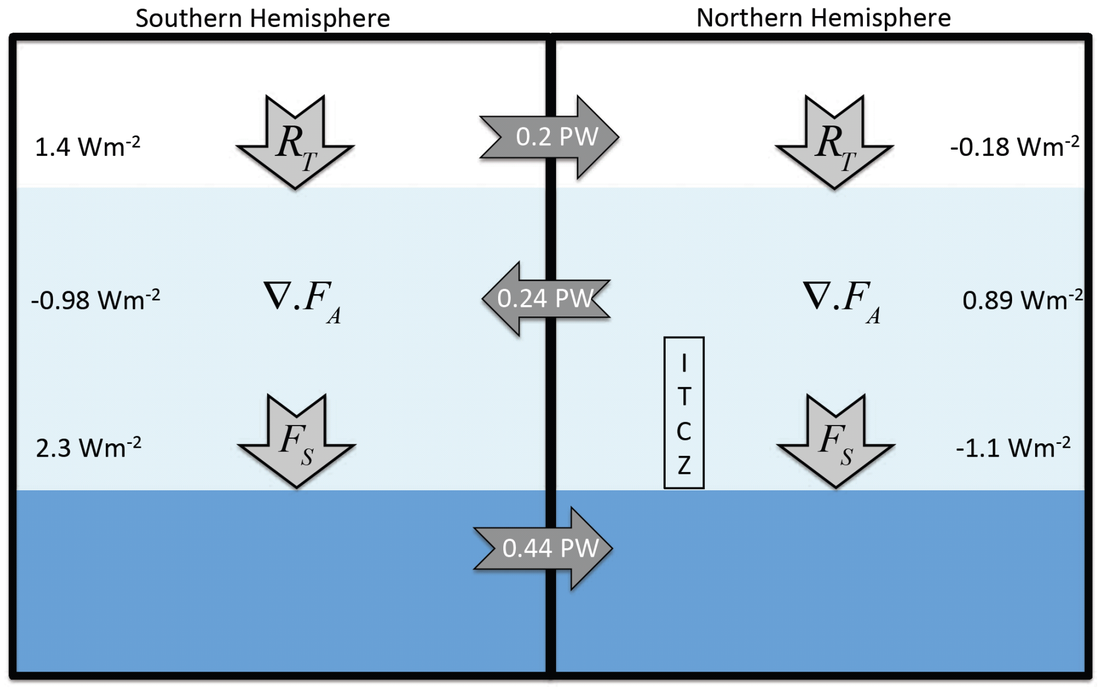
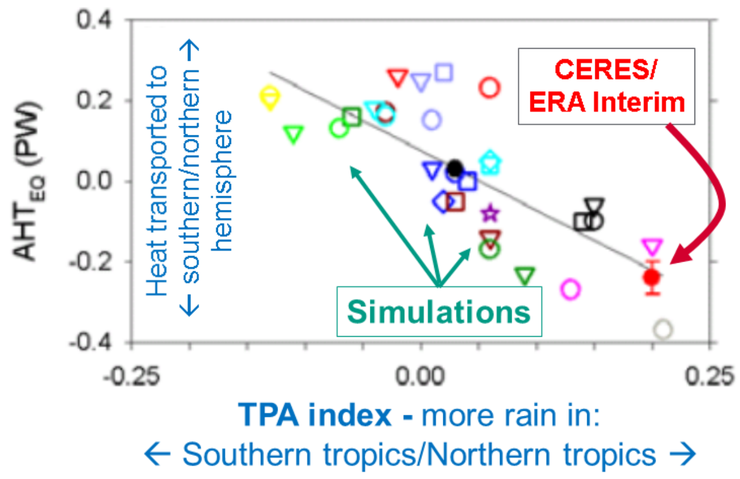


Figure 4: Estimates of top of atmosphere, surface and cross equatorial energy fluxes for 2001-2012 (Loeb et al. 2015 submitted)

Figure 5: Estimated cross equatorial atmospheric heat transport (Peta Watts, $\mathbf{AHT_{EQ}}$) against tropical precipitation asymmetry (TPA) index (from Loeb et al. 2015, submitted)



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