Was there a pause in global warming?

Results from the DEEP-C project

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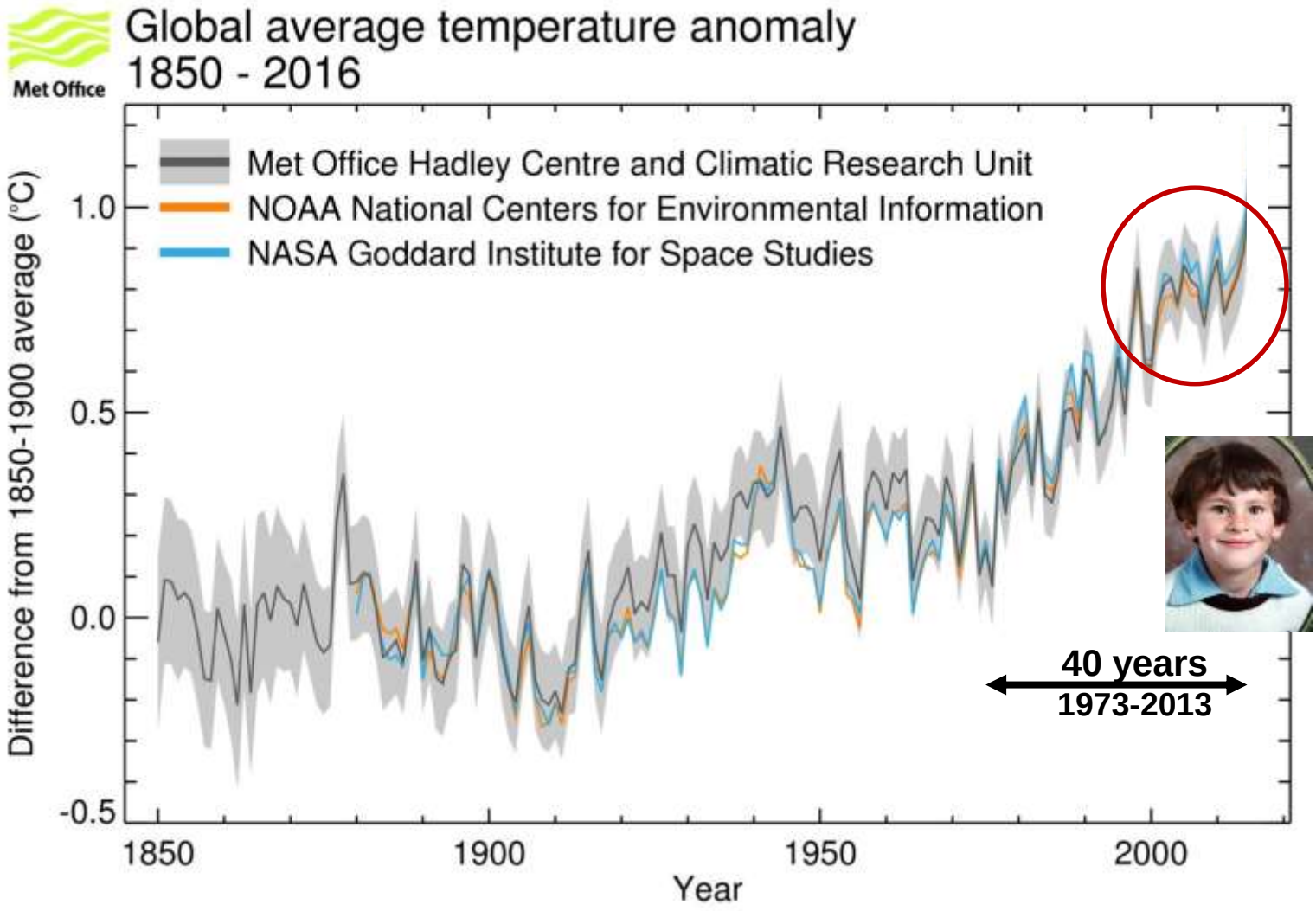
Introduction

- Global warming apparently slowed in the early 2000s
- This motivated scientists to:
  - Test whether global warming had slowed
  - See if warming was less than expected on physical grounds
  - Understand mechanisms that can explain any discrepancy
- The University of Reading teamed up with scientists from the Met Office, National Oceanography Centre-Southampton, the Met Office and NASA to tackle these questions
  - Did global warming pause at the beginning of the century and if so, why?
  - What mechanisms explain reduced global surface warming rate 2000-2013?
  - Where is excess energy from rising greenhouse gas concentrations accumulating?

The planet is warming isn't it?



www.metoffice.gov.uk/research/monitoring/climate/surface-temperature

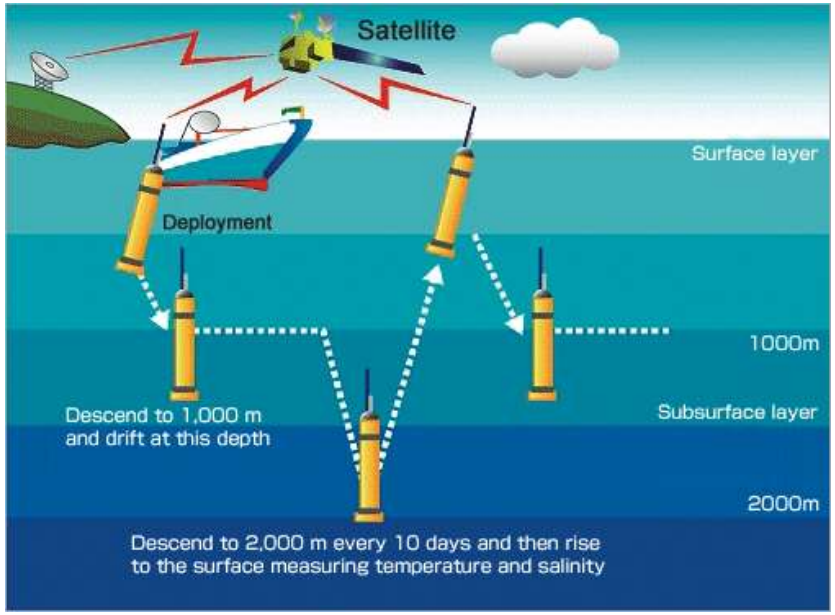
DEEP-C project

Diagnosing Earth's Energy Pathways in the Climate system

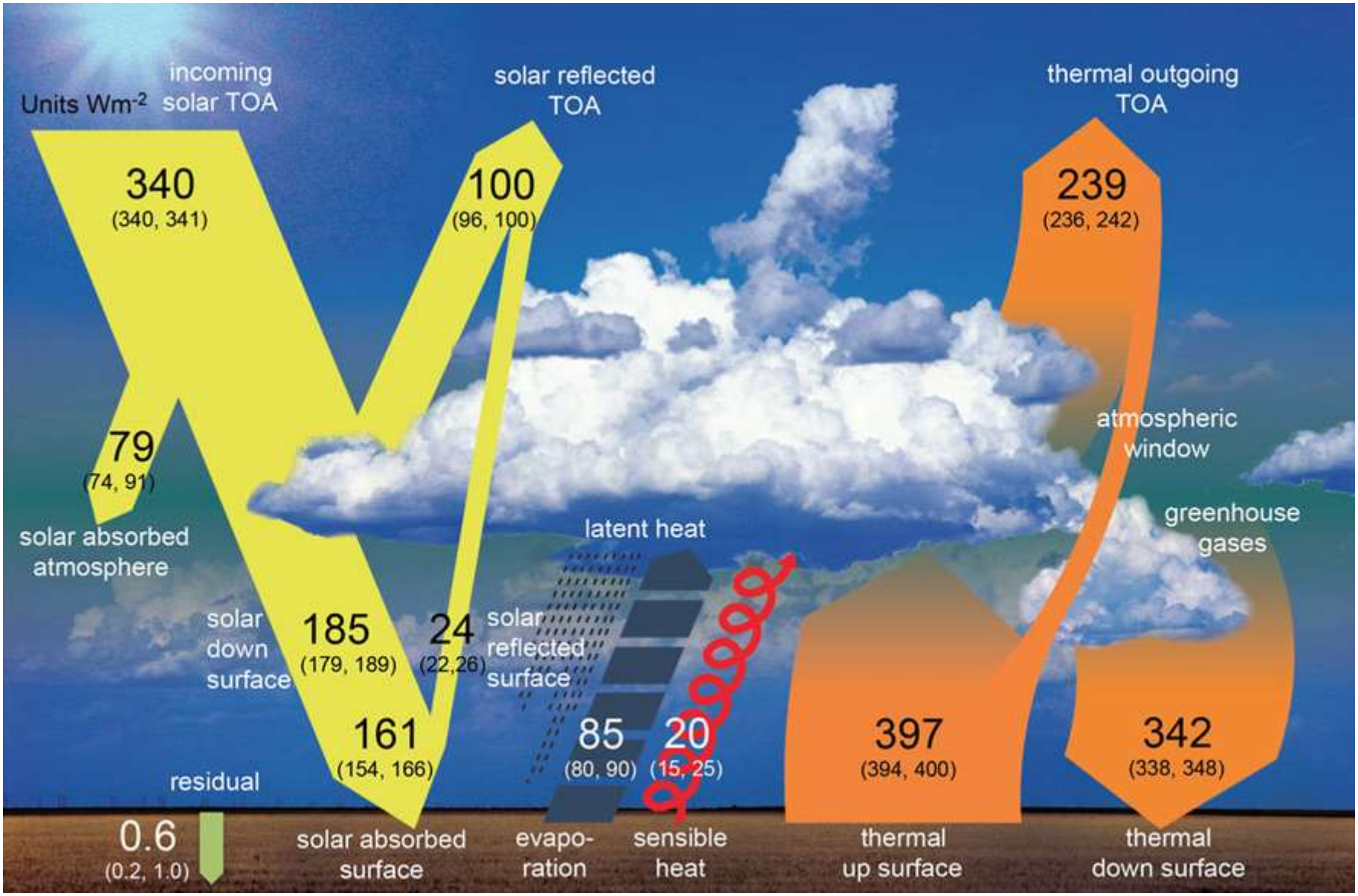
- Combine expertise on Earth's energy budget (Reading, NASA), computer simulations (Met Office) and ocean science (NOC-Southampton)
- Satellite instruments measure energy arriving & leaving planet
  - Sunlight & thermal radiation
- Automated floats measure heating of ocean (ARGO)
- Computer simulations of the atmosphere and ocean provide a laboratory

Hypotheses:

- Heating of Earth did not slow
- Heat went into the "deep" ocean



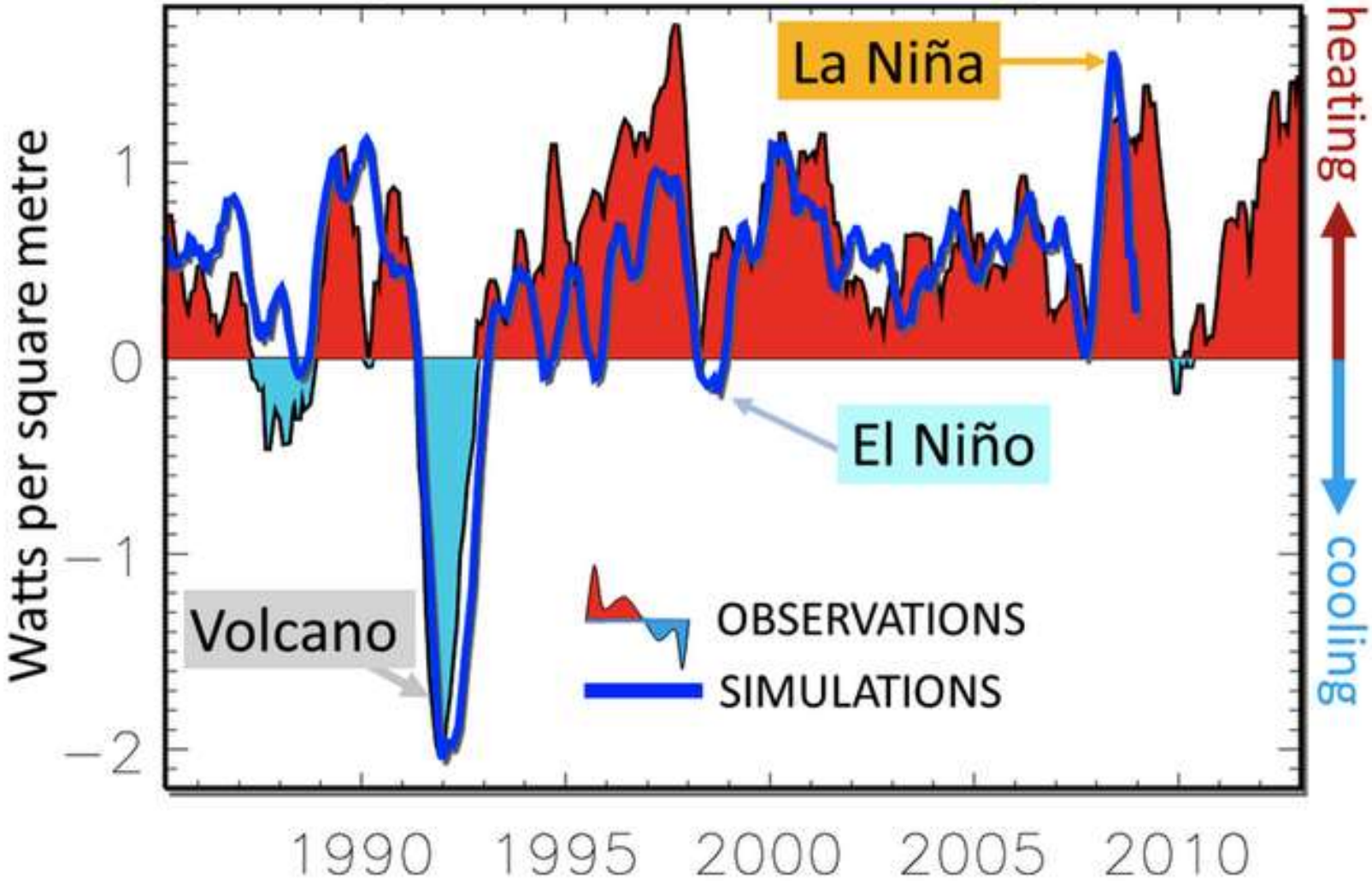
Earth's Global Annual Average Energy Balance



Wild et al. (2012) Clim. Dynamics. See also: Trenberth et al. (2009) BAMS

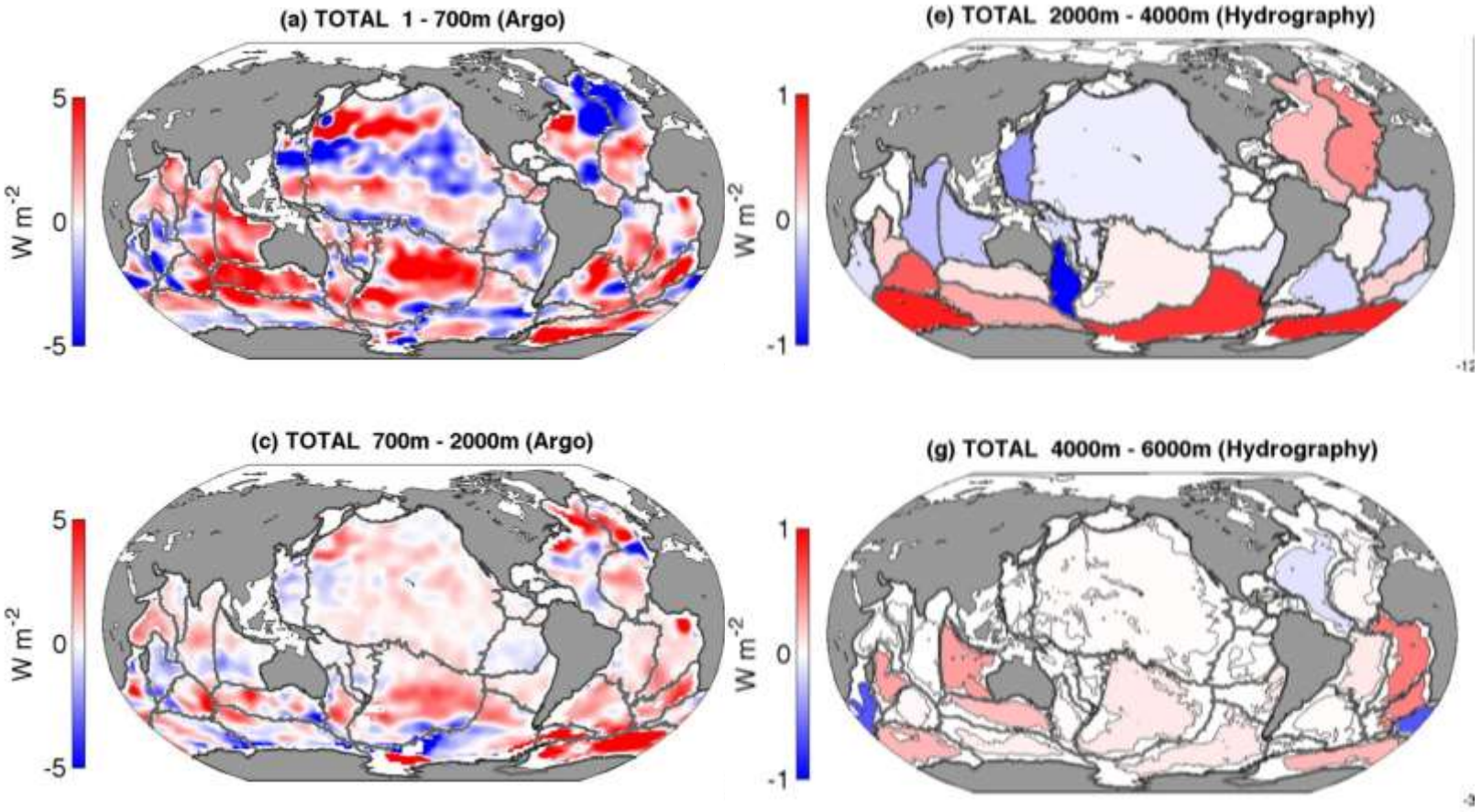
Planet Earth continues to heat up…

The planet is gaining heat at the rate of 300 trillion Watts…



Loeb et al. (2012) Nat. Geosci. ; Allan et al. (2014) GRL

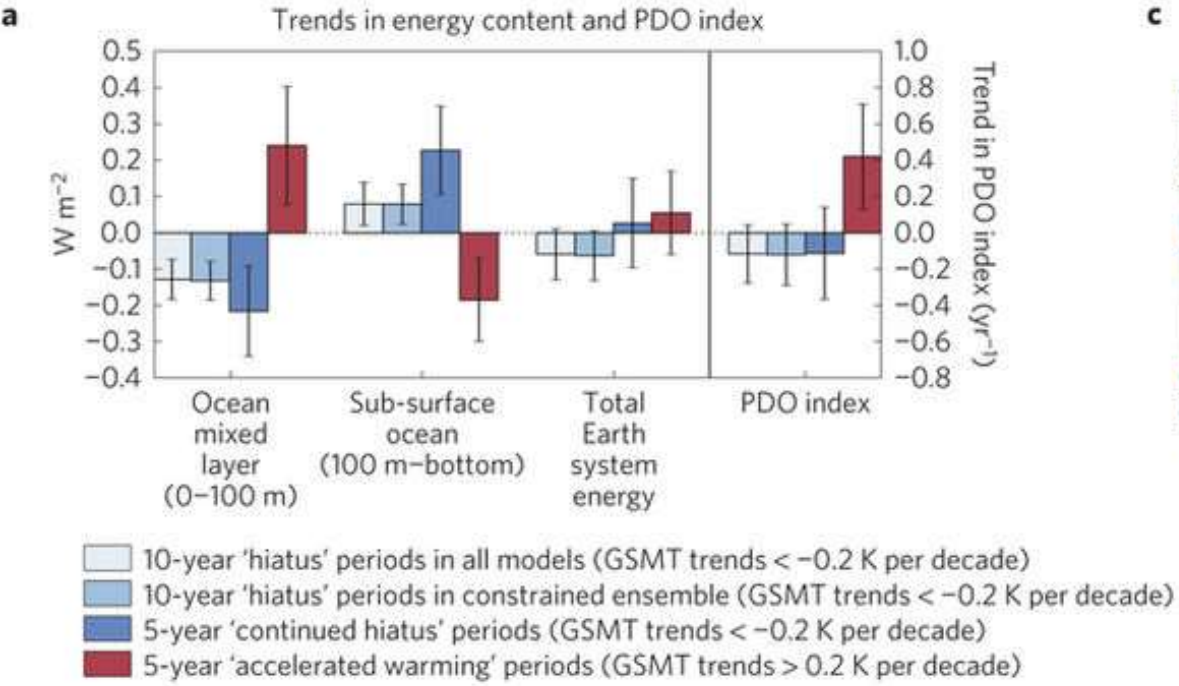
Deep ocean continues to heat up

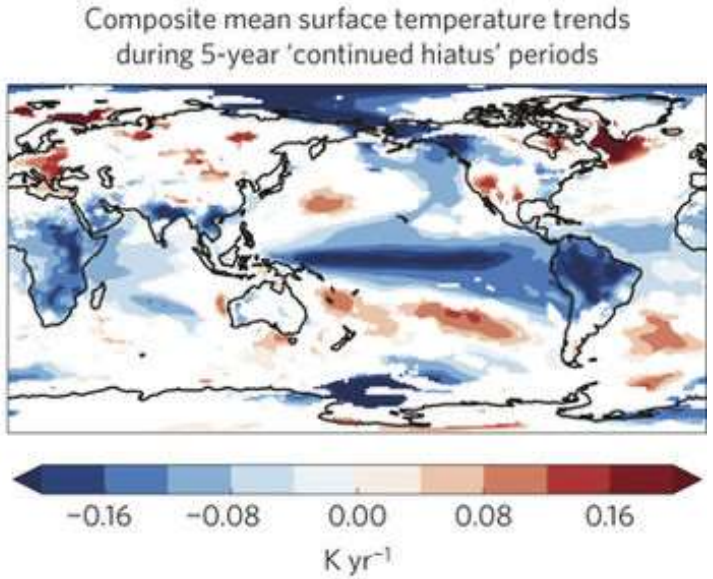


Desbruyères *et al. (2017) J. Climate*

Climate Simulations of hiatus events

- In simulated “hiatus” events less energy accumulates in upper mixed layer of the ocean, more heats deeper layers
- The pattern of east Pacific cooling has a fingerprint of ocean decadal variability, akin to the observed pattern





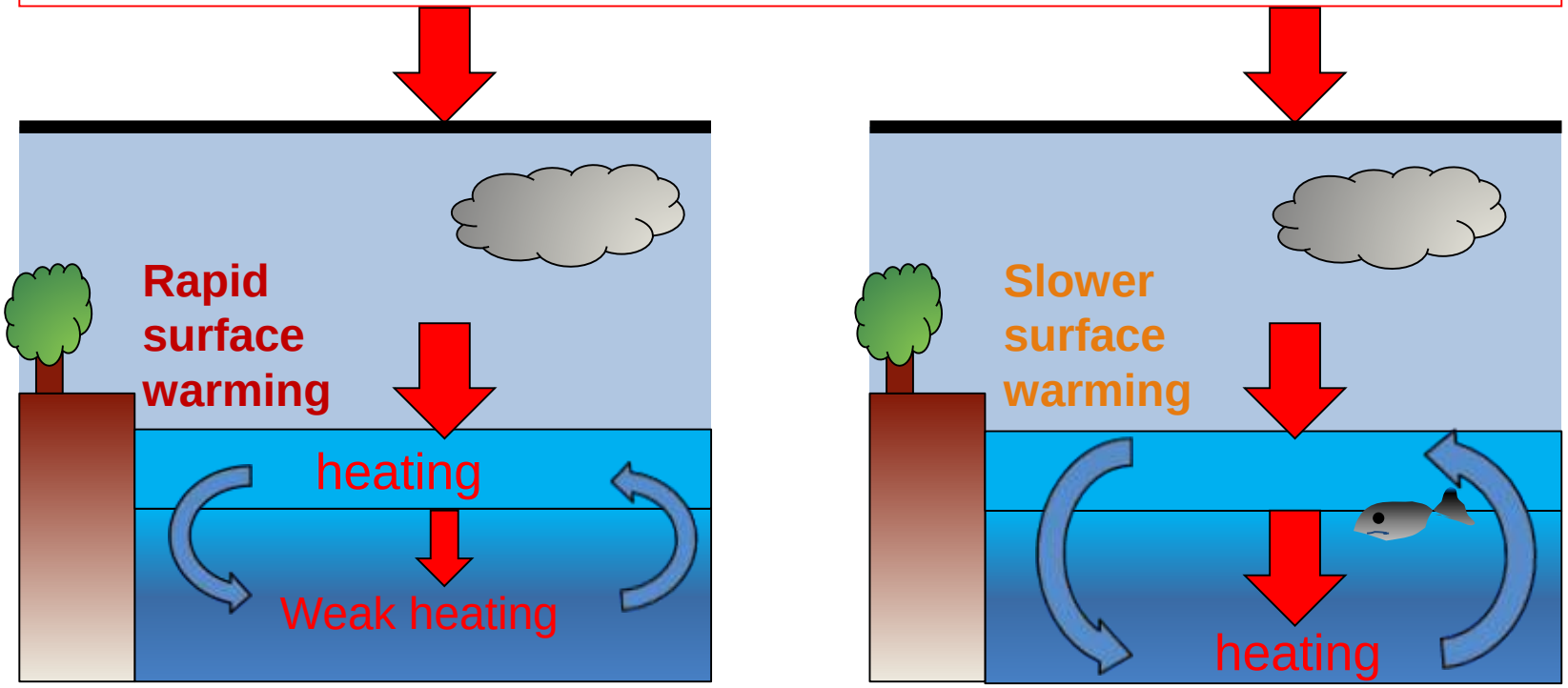
Roberts et al. (2015) Nature Climate Change

Ocean climate fluctuations explain slowdown

e.g. Allan (2017) Nature Climate Change

Heating due to rising greenhouse gas concentrations

also influenced by aerosol pollution and natural factors e.g. volcanoes, the sun



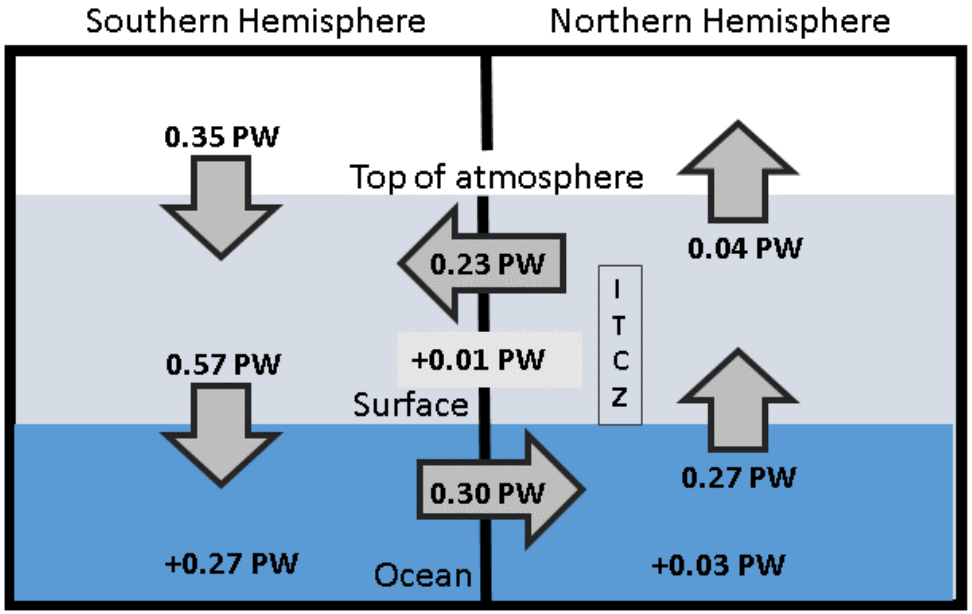
1980s-1990s: heating of upper layers of the ocean – rapidly rising surface temperature

2000s: heating of deeper layers of the ocean – slower rises in surface temperature

Large body of research – listed on DEEP-C project website

Energy flows are important for climate and the tropical rainy belt

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

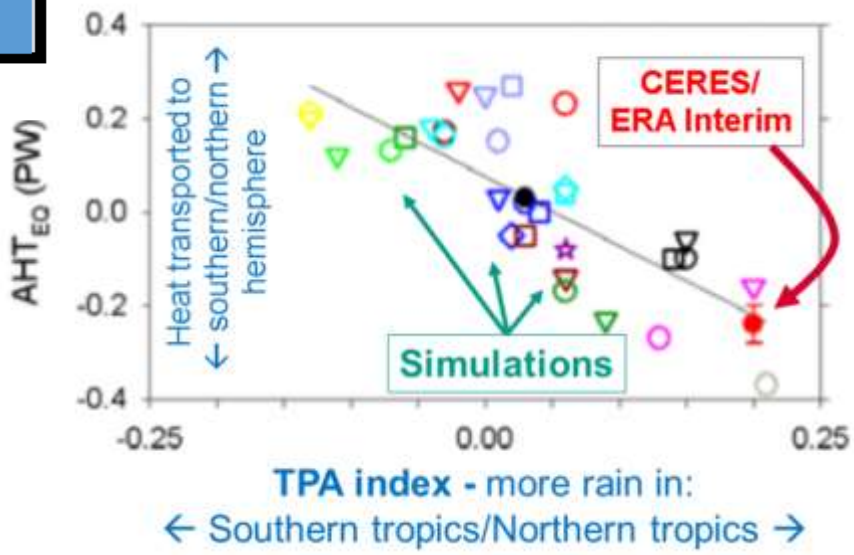


Left: We can now reconstruct how energy is accumulating and moving between each of Earth;'s hemispheres (energy flow in peta watts) Liu et al. (2017) JGR

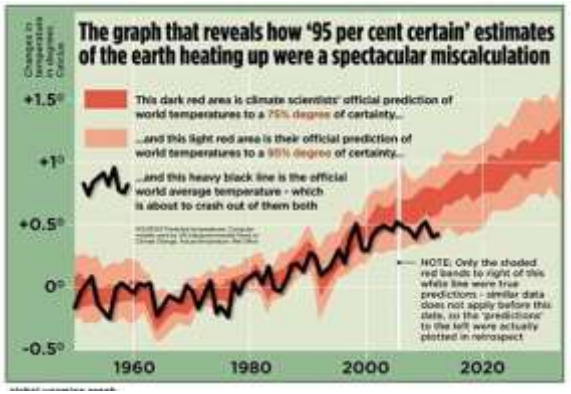
See also Weather & Climate blog post

Right: The flows between hemispheres are important for climate and in the position of the tropical rainy belt which climate simulations struggle to capture

Loeb et al. (2016) Clim. Dyn

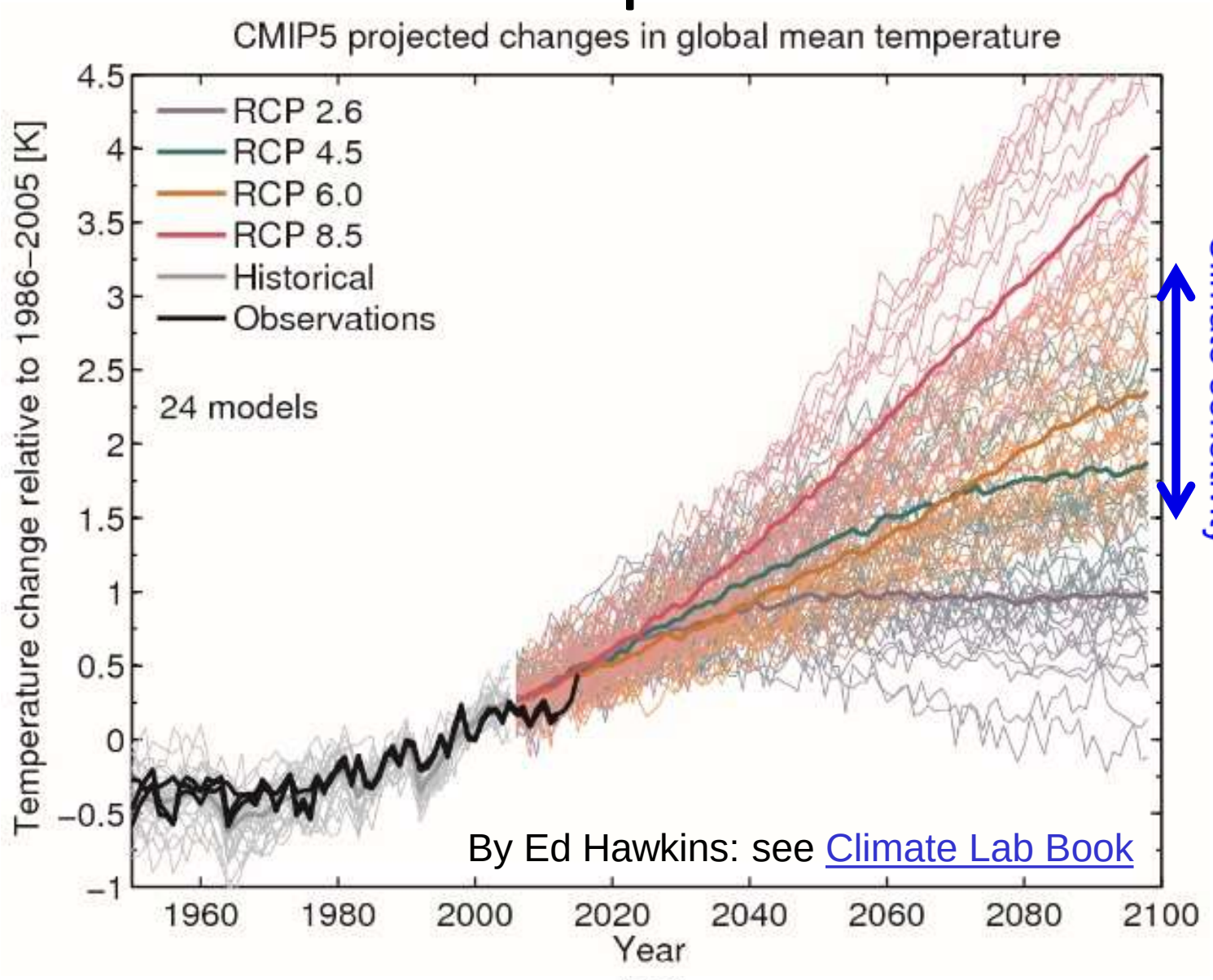


A hiatus in global warming?



- No: the oceans have continued to warm, sea levels have continued to rise…
- But…**natural factors temporarily suppressed the rate of <u>surface</u> warming…** slightly
  - A slight dimming of the sun and small volcanic eruptions offset some of the heating from rising greenhouse gases but…
  - Crucially, ocean fluctuations rearranged where heat has accumulated
  - Climate models can simulate ocean fluctuations but are not designed to capture timings of lumps and bumps in temperature record.
  - Accounting for improved understanding of radiative forcing and ocean "weather" climate simulations are consistent with observations
- DEEP-C contributed to understanding how Earth is continuing to heat, building on a <u>large body of evidence</u>
- How much the planet will warm this century and beyond mostly depends on total greenhouse gas emissions… so us

How much will planet warm?



Climate sensitivity

Climate sensitivity and socioeconomic scenario

COP21 Paris Climate Deal

source: http://www.carbonbrief.org/analysis-the-final-paris-climate-deal

- **Target**: global temperature well below 2°C; efforts to limit to 1.5°C
- **Mitigation**: pursue policies aiming to achieve INDC climate pledges; subsequent pledges progressively more ambitious; global stocktake 2018 & then every 5 years; peak global greenhouse gas emissions “as soon as possible”; “balance” between emissions & sinks 2050-2100
- **Adaptation**: $100bn/yr fund for developing countries: new collective quantified goal by 2025; periodic review of adaptive planning of Loss & damage has its own Article in the agreement — now on par with mitigation & adaptation; liability/compensation excluded.
- **Transparency:** "facilitative, non-intrusive, non-punitive” system of review will track countries’ progress; emissions trading allowed; aviation/shipping not included
- **Treaty:** deal enters force once 55+ parties, covering at least 55% of global emissions have signed up