Climate Change:
Where has the warming gone?

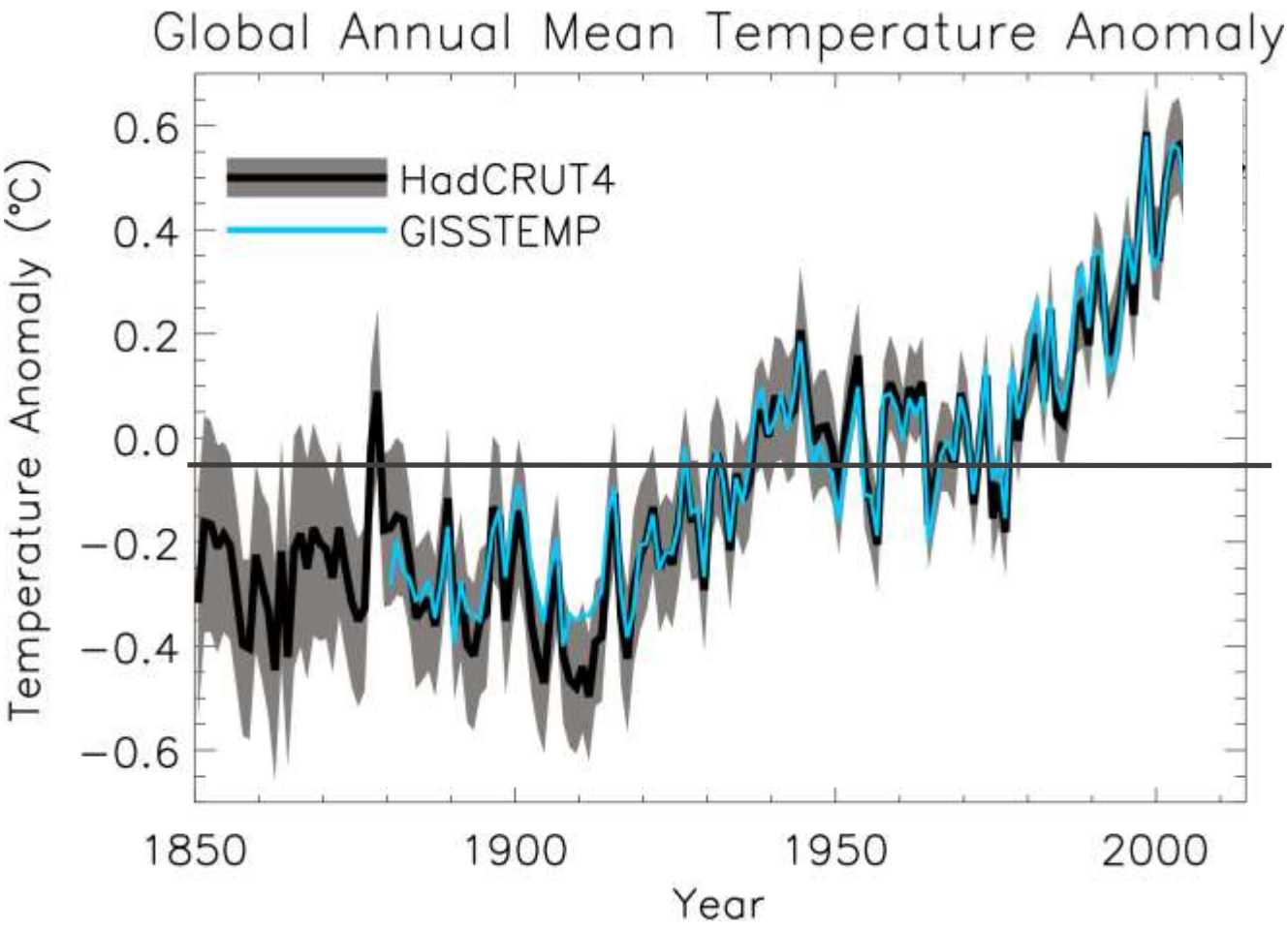
University of Reading

Richard Allan - University of Reading/NCAS climate

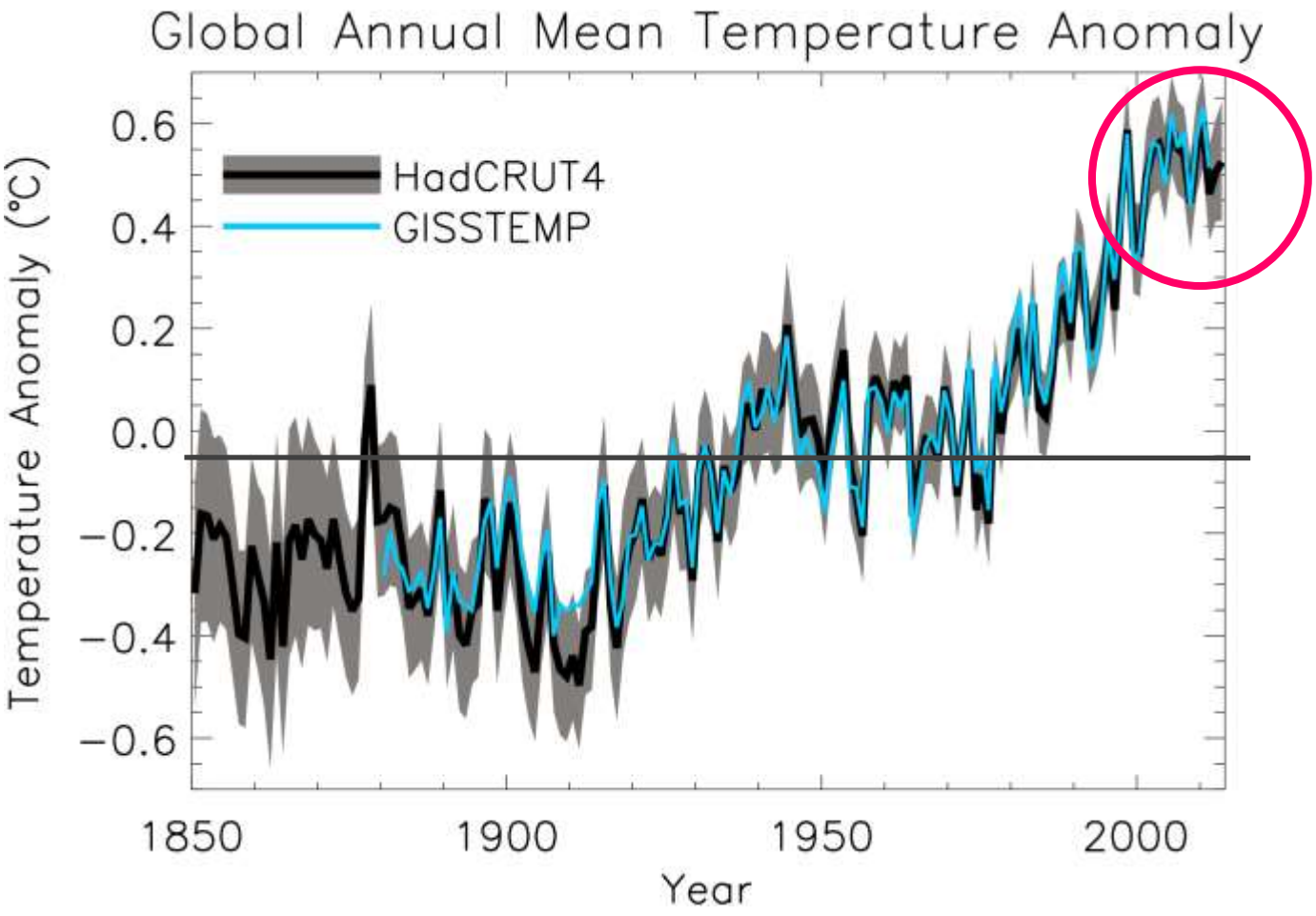
Thanks to: Norman Loeb, Matt Palmer, Chunlei Liu, Ed Hawkins, Piers Forster, Science Media Centre…

RMetS South East Centre Meeting, Wednesday 5th March 2014

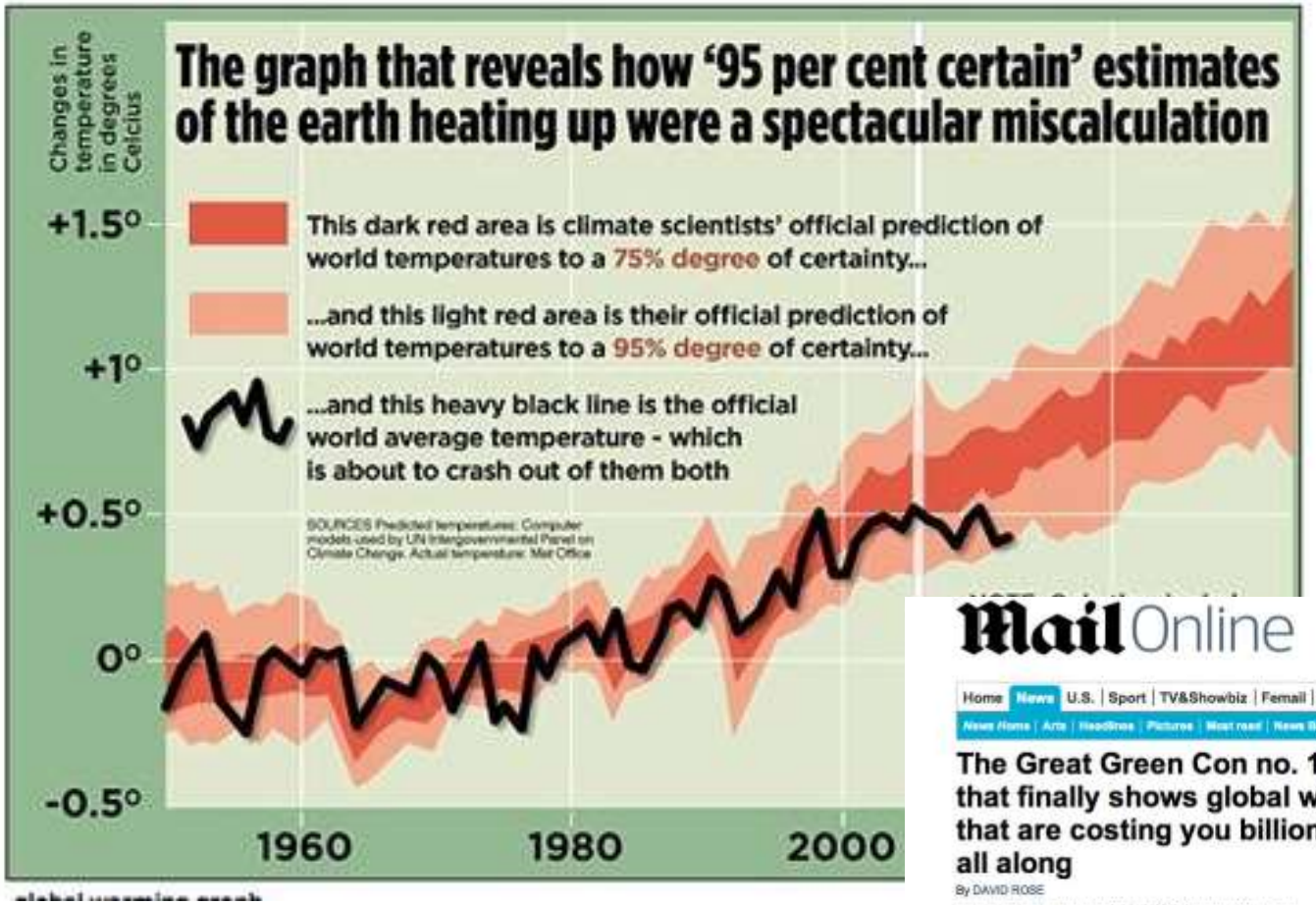
Global Warming…



Global Warming has stalled?



Has global warming stopped?

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The Great Green Con no. 1: The hard proof that finally shows global warming forecasts that are costing you billions were WRONG all along

By DAVID ROSE

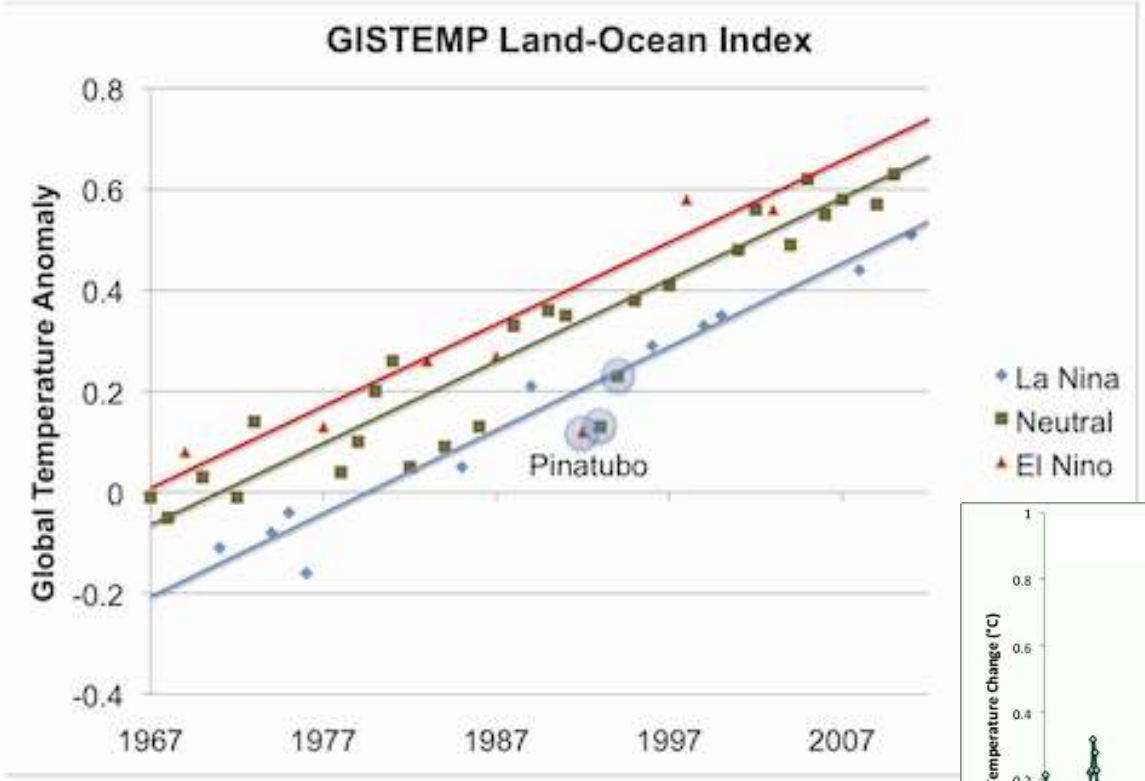
PUBLISHED: 23:37, 16 March 2013 | UPDATED: 13:41, 18 March 2013

Comments (737) | Share

No, the world ISN'T getting warmer (as you may have noticed). Now we reveal the official data that's making scientists suddenly change their minds about climate doom. So will eco-funded MPs stop waging a green crusade with your money? Well... what do YOU think?

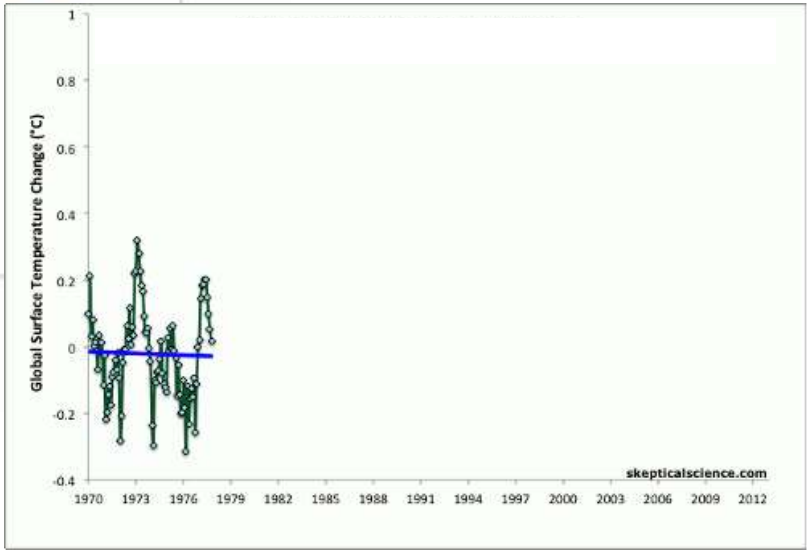
[Mail on Sunday 16th March 2013]

Influence of El Niño and Volcanoes on Surface Temperature Trends

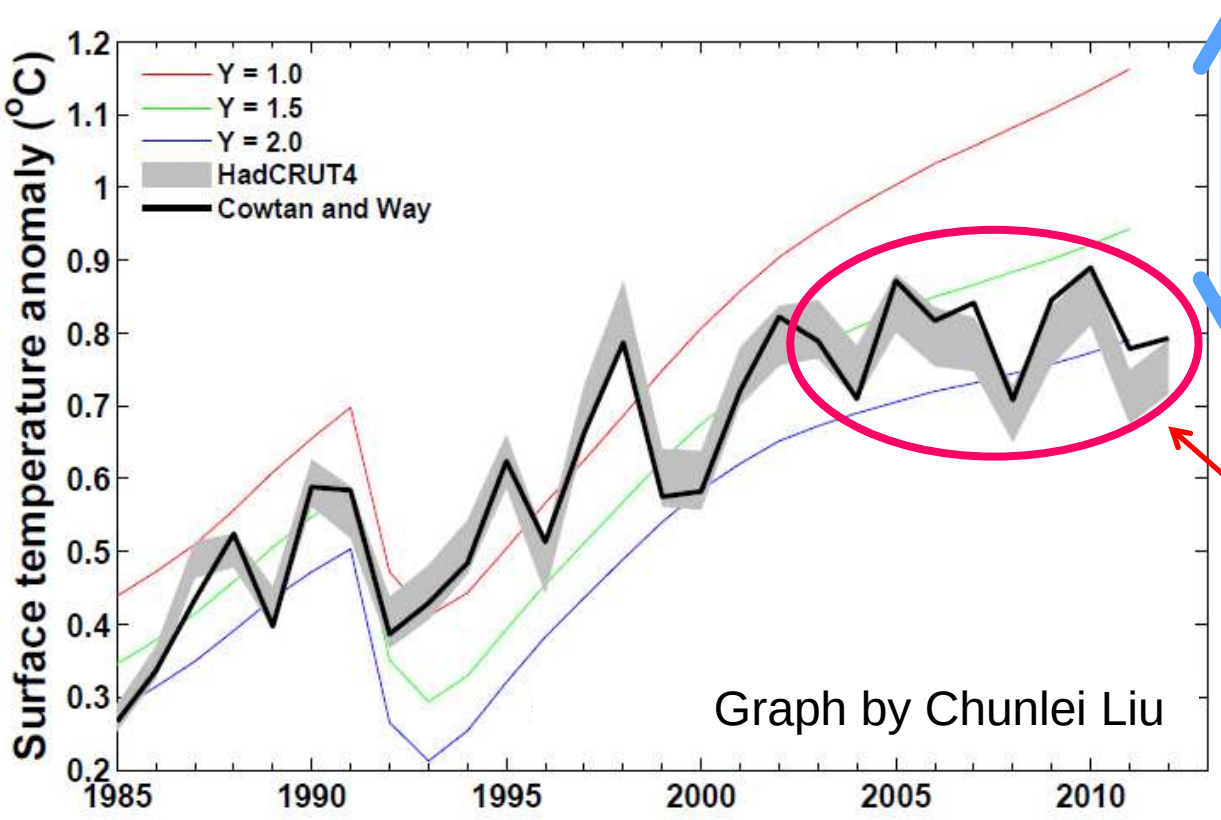


But why have there been more La Niñas recently and hasn't the slowdown in surface warming lasted a long time?

John Nielsen-Gammon, Texas A&M University
see [Foster & Rahmstorf (2012) Environ. Res. Lett.](#).



Is the temperature record wrong or are computer models inaccurate?

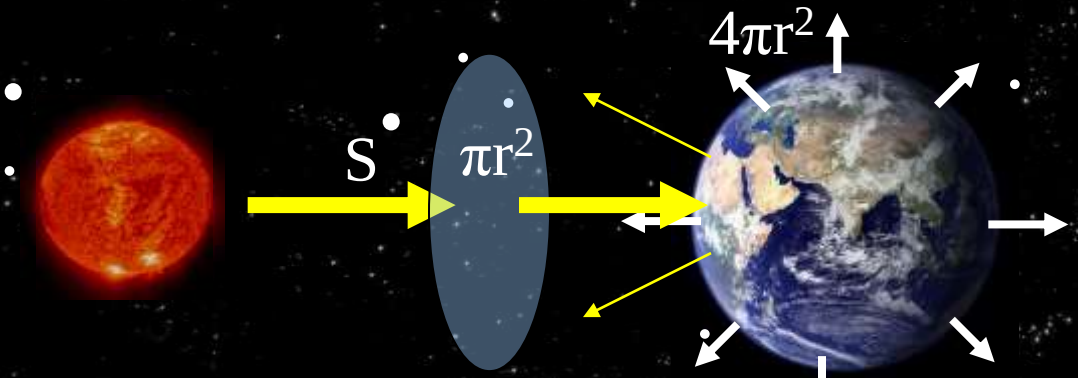


Research in DEEP-C project
(Reading, NOC-Southampton & Met Office)

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.)

Earth's energy balance in space



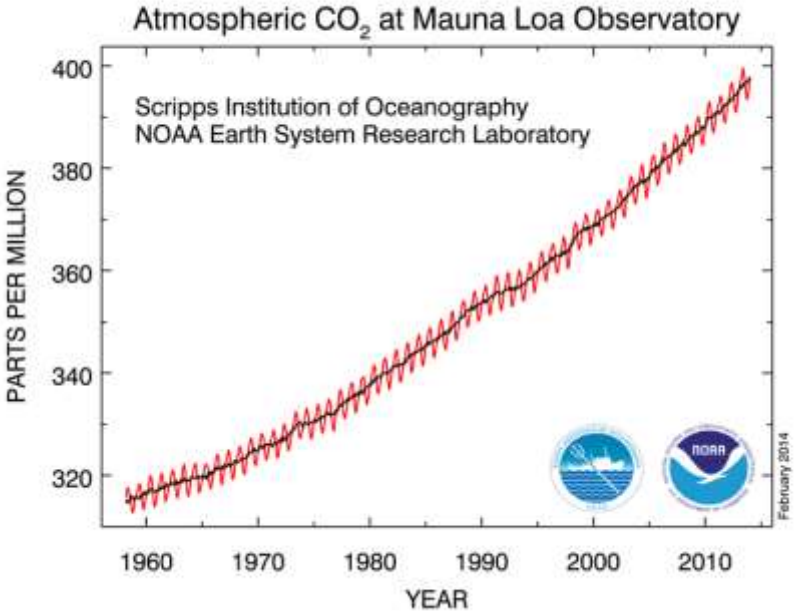
Thermal/Infra-red or Outgoing Longwave Radiation (OLR)=σT_e^4

Absorbed Solar or Shortwave Radiation (S/4)(1-α)

- There is a balance between the absorbed sunlight and the thermal radiative cooling of the planet

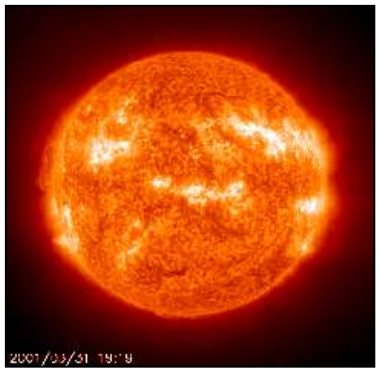
"Radiative forcing" of climate

- Increased concentrations of greenhouse gases heat planet by reducing the efficiency at which Earth can cool to space
- More small pollutant particles (aerosols) can cool the planet by reflecting sunlight
- If more energy is arriving than is leaving the planet should heat up…

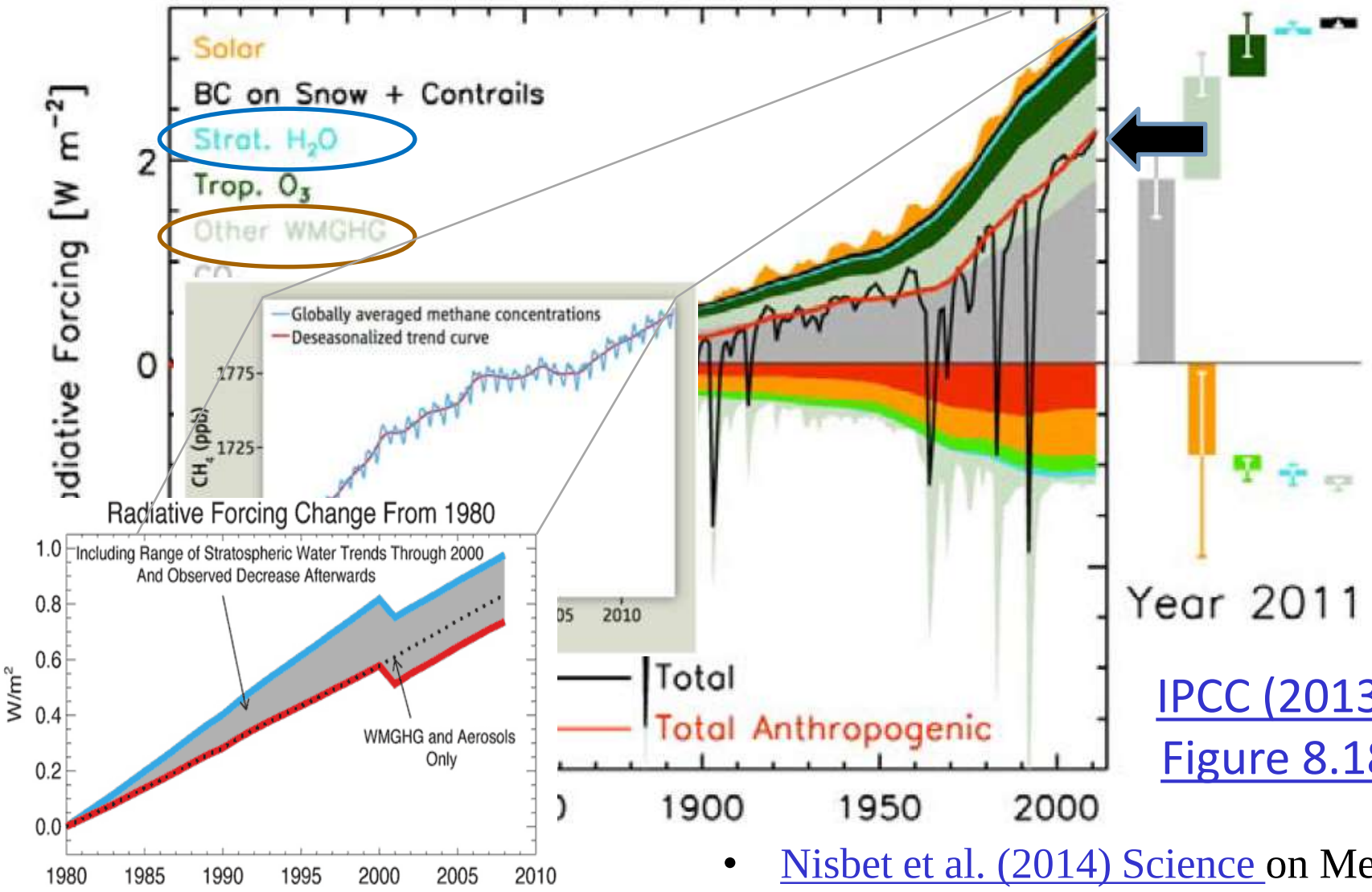


Have other factors offset warming from greenhouse gases?

- The sun has weakened in the 2000s
- There were a series of small volcanic eruptions causing reflection of sunlight
- Particle pollution from Asia, changes in stratosphere water vapour, changes in Methane and sampling of temperature observations may also be important
- Natural chaotic fluctuations in the ocean appear to play an important role



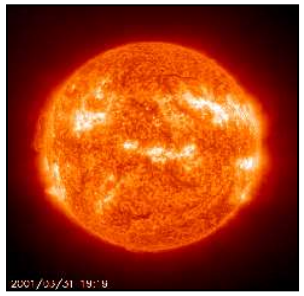
Changes in radiative forcing since 1750



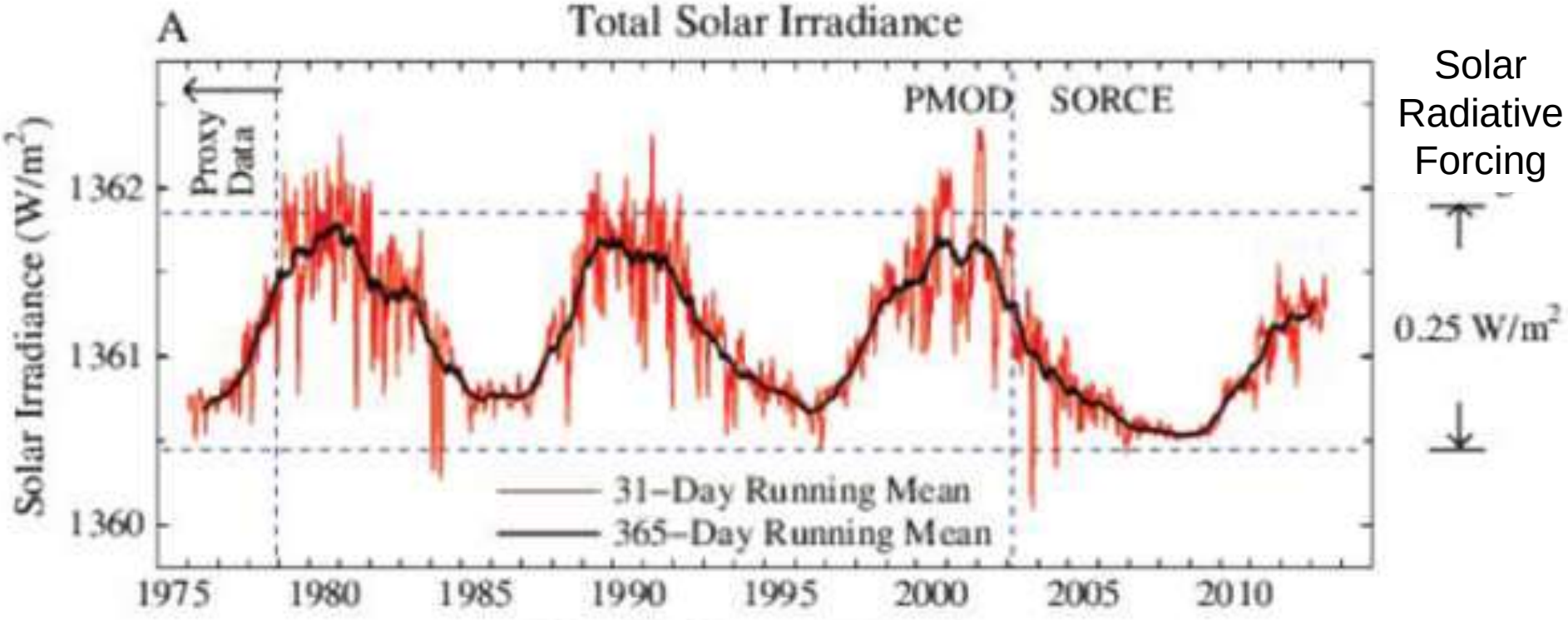
IPCC (2013)
Figure 8.18

- Nisbet et al. (2014) Science on Methane
- Solomon et al. (2010) Science on Stratospheric Water Vapour

Weaker Solar Output?

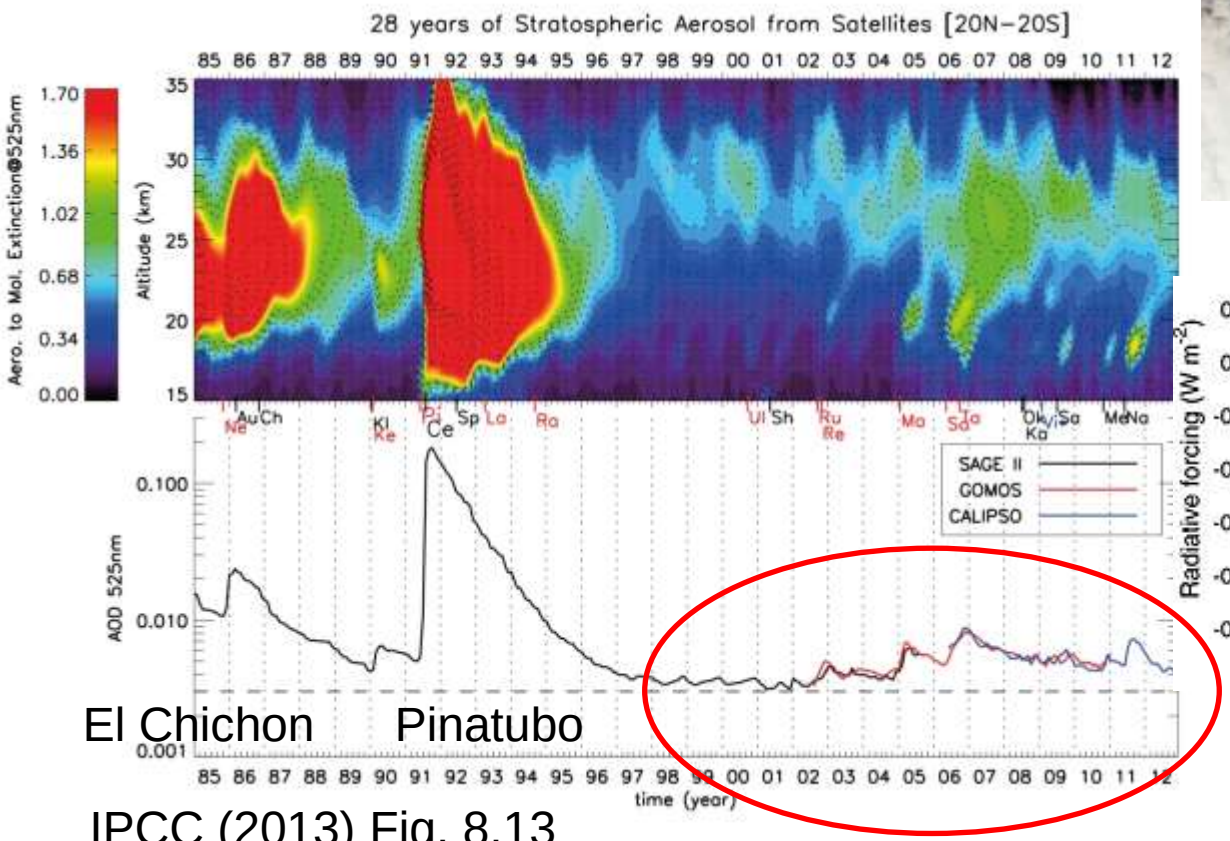


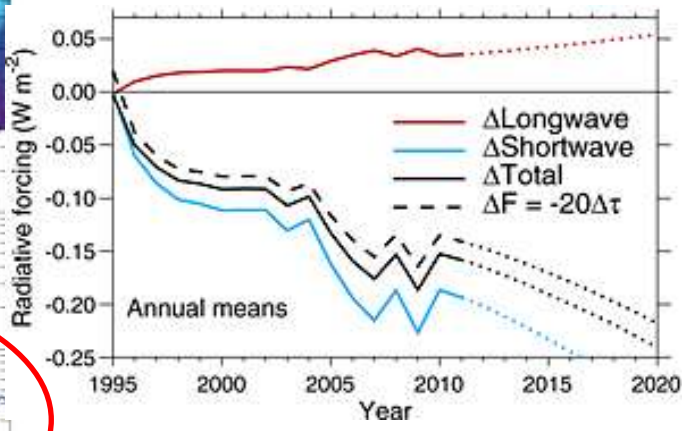
IPCC: Solar Radiative Forcing change of –0.04 Wm^{-2} from 1986 to 2008



Hansen et al. (2013) PLOSONE; see also Kaufmann et al. (2011) PNAS

Cooling from small volcanos?



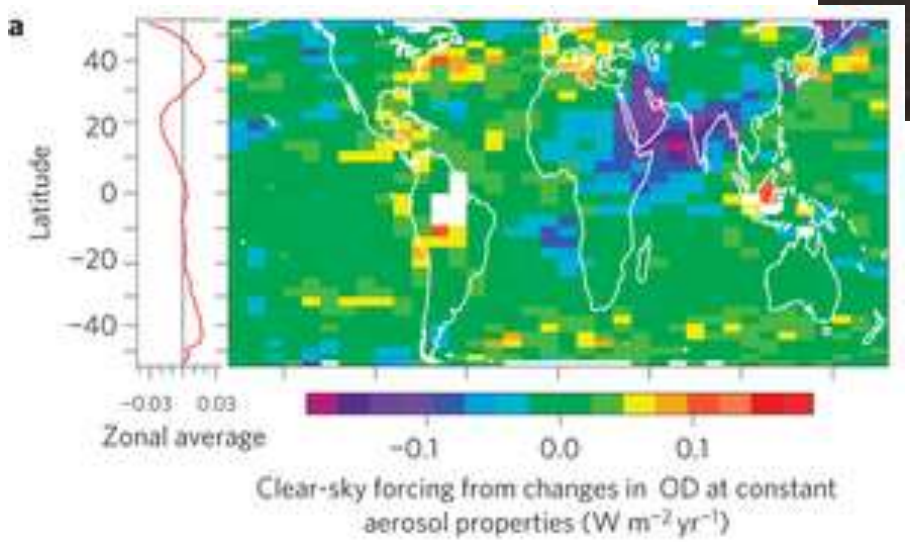


IPCC (2013) Fig. 8.13

Work by Solomon et al. (2011) Science; Vernier et al. (2011) GRL; Fyfe et al. (2013) GRL; Schmidt et al. (2014) Nature Geosci; Santer et al. (2014) Nature Geosci.

Has increased aerosol pollution refelected more sunlight back to space ?

Increased Asian aerosol offset by decreases elsewhere – little change in 2000s: Murphy (2013) Nature Geosci (below)



Causes of Climate Change 1998-2012

Cause	Estimated Change in Radiative Forcing (W per sq.m)[1]
Greenhouse gases	+ 0.48
Solar	– 0.16
Volcanoes	– 0.06
Other (e.g. aerosols)	± ?
TOTAL	**+ 0.26 ± ?**

1. Since 1998 natural factors have **masked** some of the greenhouse gas warming influence

2. In the 1990s natural factors (especially recovery from Mt. Pinatubo) **added** to the greenhouse warming influence

3. Little overall influence of natural factors since the 1950s

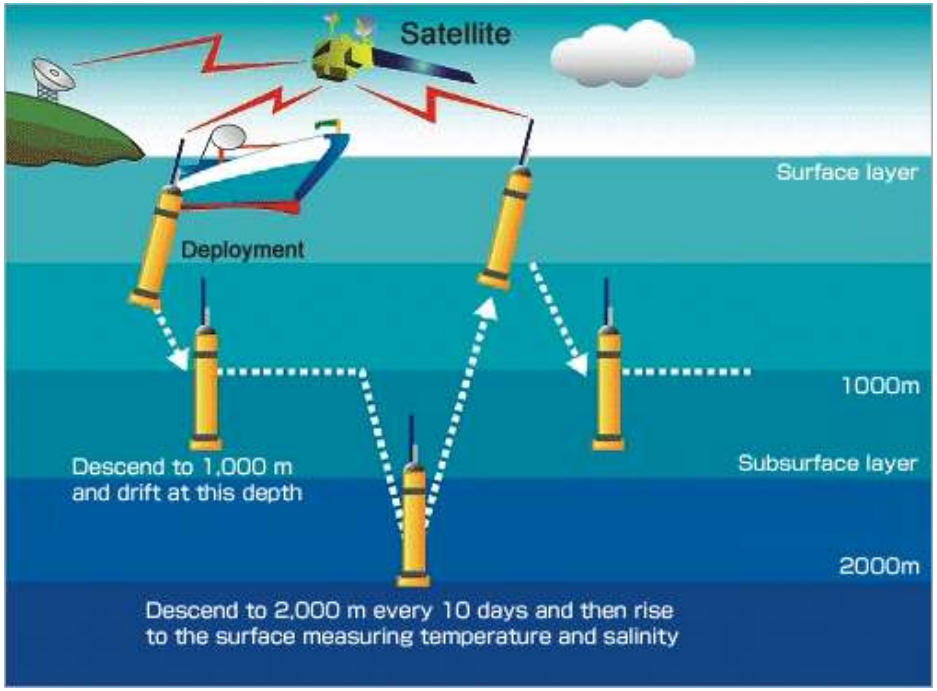
[1] Quantifying other forcings and uncertainties is ongoing research

Piers Forster, University of Leeds

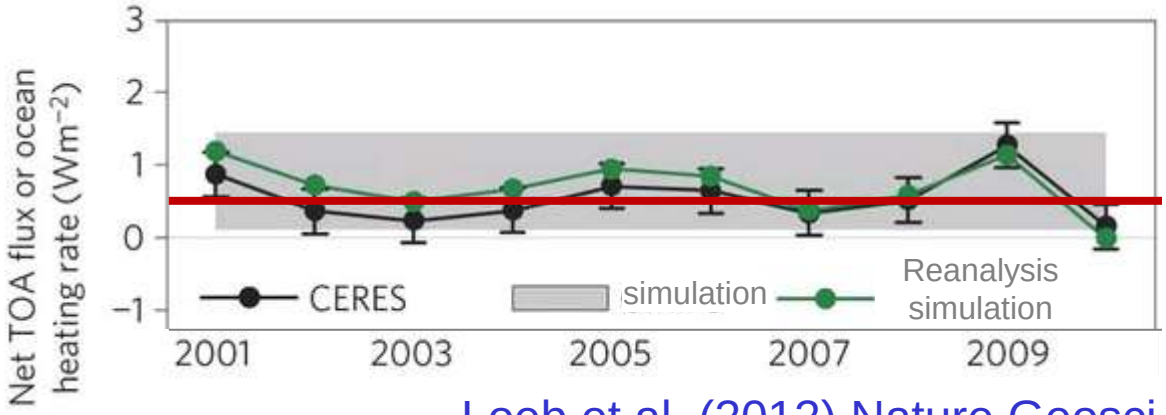
Measuring Earth's energy flows

- Satellite instruments measure energy arriving and leaving our planet
  - Sunlight & thermal radiation
- Automated floats measure heating of the ocean

ARGO floats →



Combining satellite measurements with ocean observations…

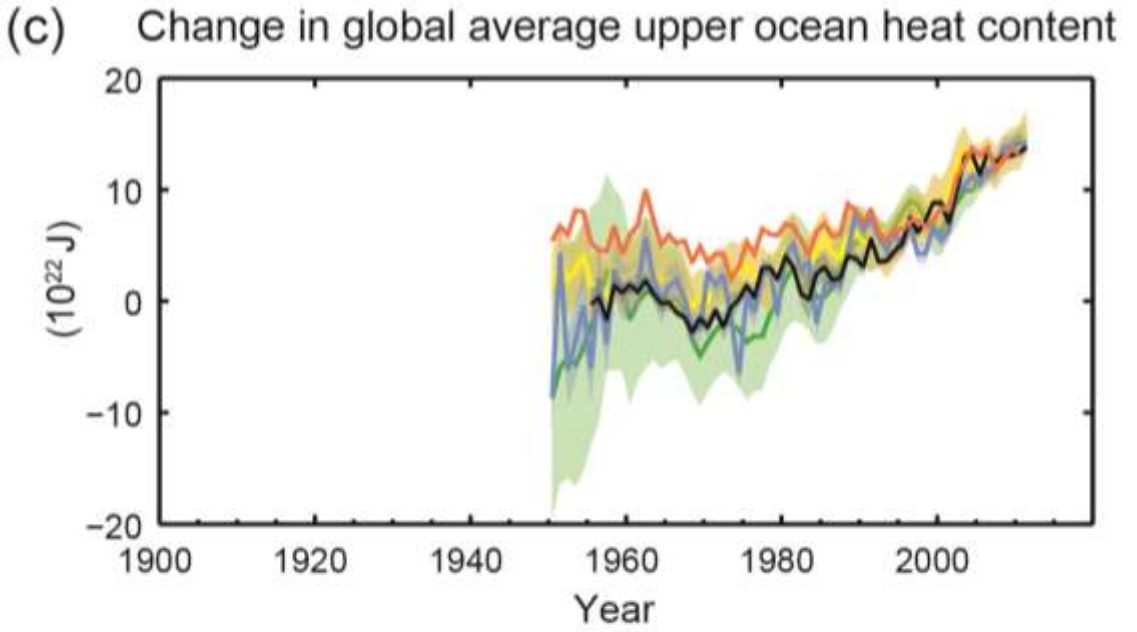


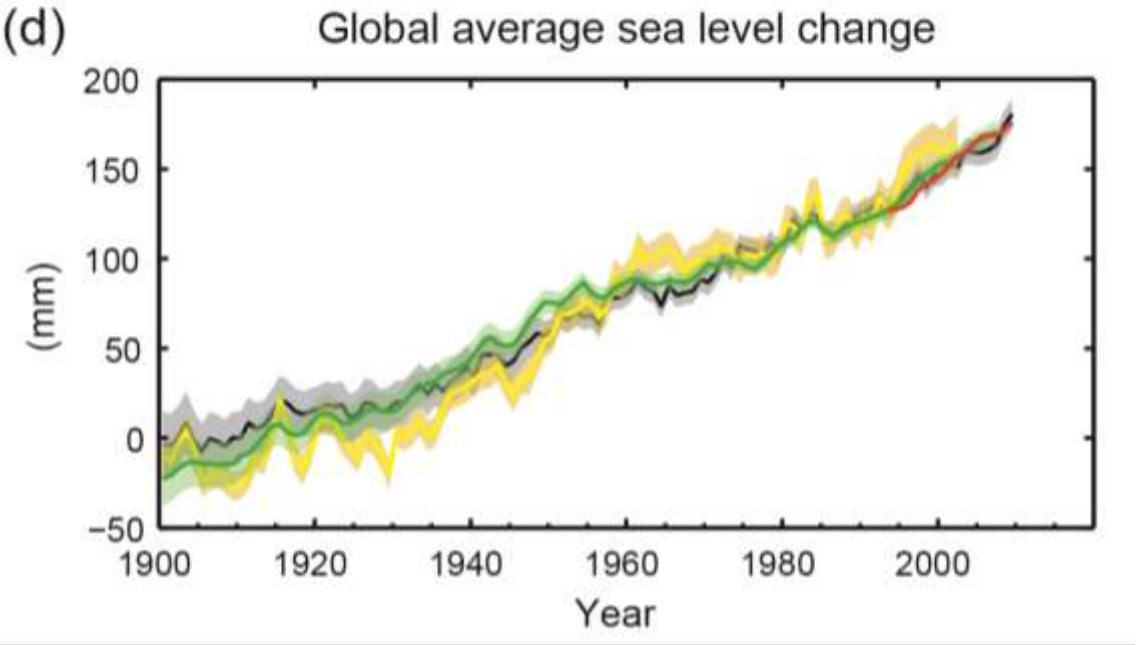
Loeb et al. (2012) Nature Geosci

- We found that heat is continuing to accumulate at 0.5 Watts per square metre

(this is equivalent to the heat of 250 billion 1 kilo-Watt electric heaters distributed over the planet)

…updated estimate 2000-2012: 0.6 Wm^{-2}



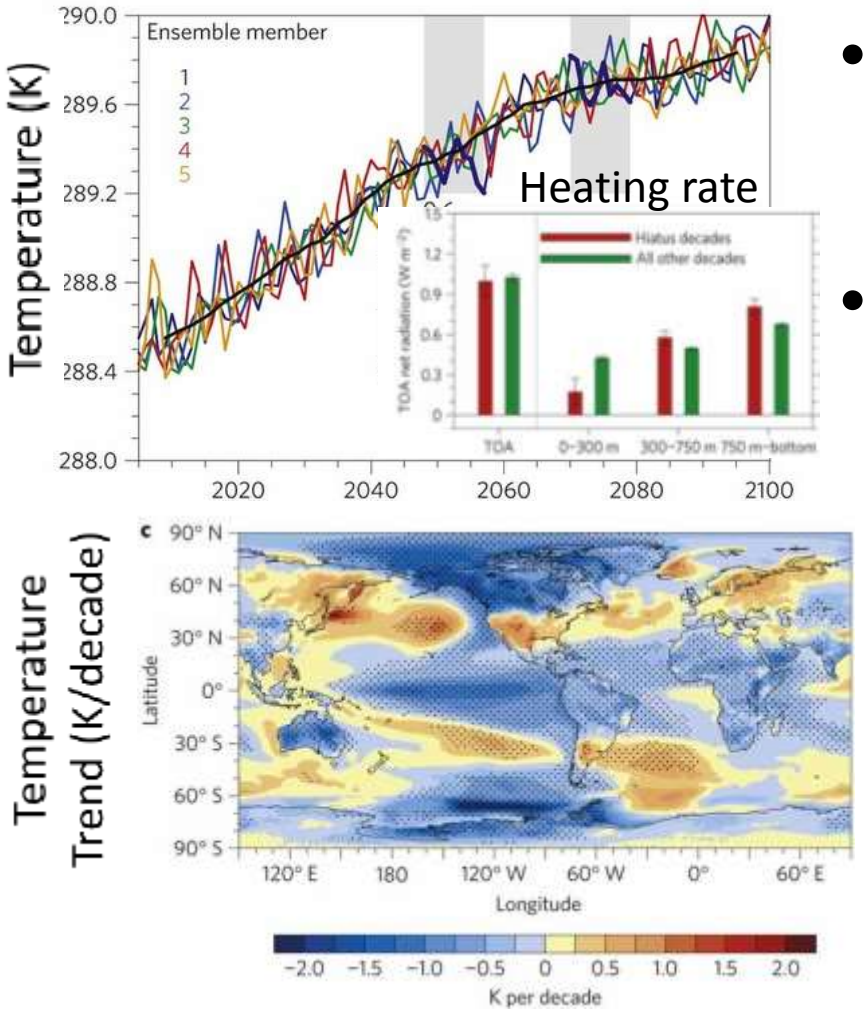


Continued heating of the oceans and sea-level rise

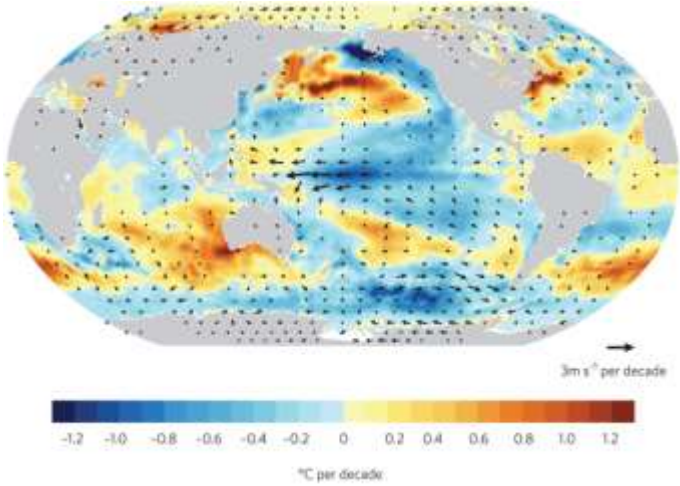
How can the oceans be heating up without warming surface temperatures?

IPCC (2013) Figure SPM.3

Climate models simulate decades with little surface warming despite CO_2 increases



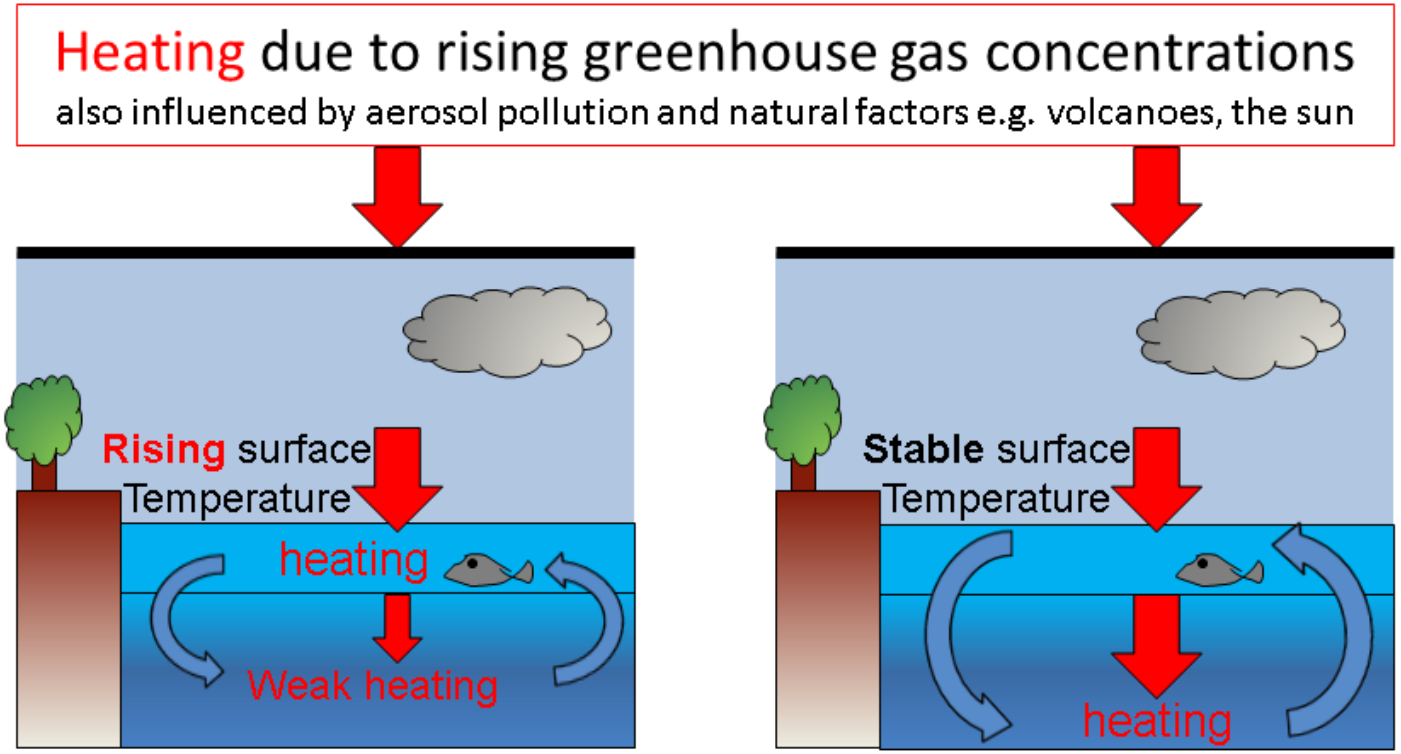
- Ocean variability causes heat to mix to deeper levels in some decades
- Associated pattern of sea surface temperature trends match current observations



Model (Meehl et al. 2011, 2013)

Observations 2001-2013 (Kosaka 2014)

The role of ocean circulation…

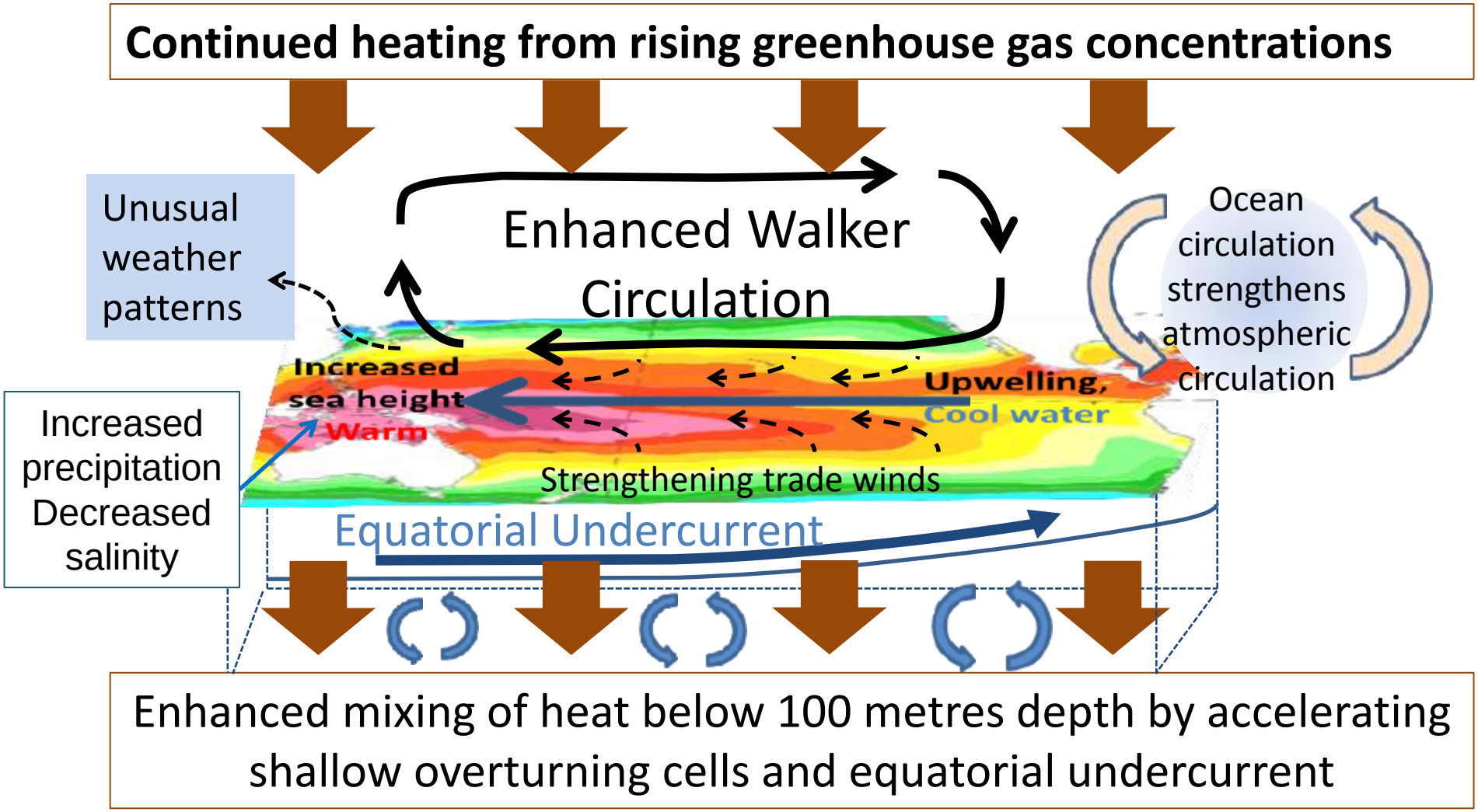


1980s-1990s: heating of upper layers of the ocean – rising surface temperature

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

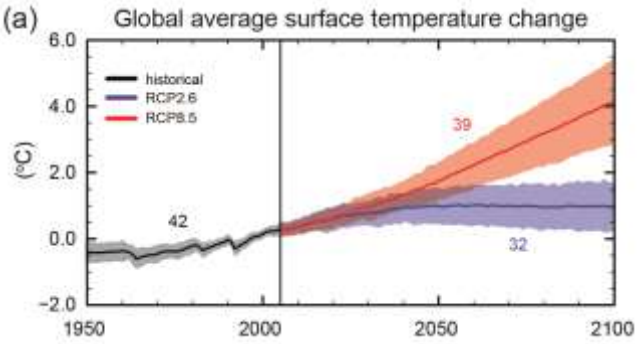
Increased heat flux to deeper layers of the ocean: Watanabe et al. (2013) GRL; Balmaseda et al. (2013) GRL; Trenberth et al. (2014) J. Climate

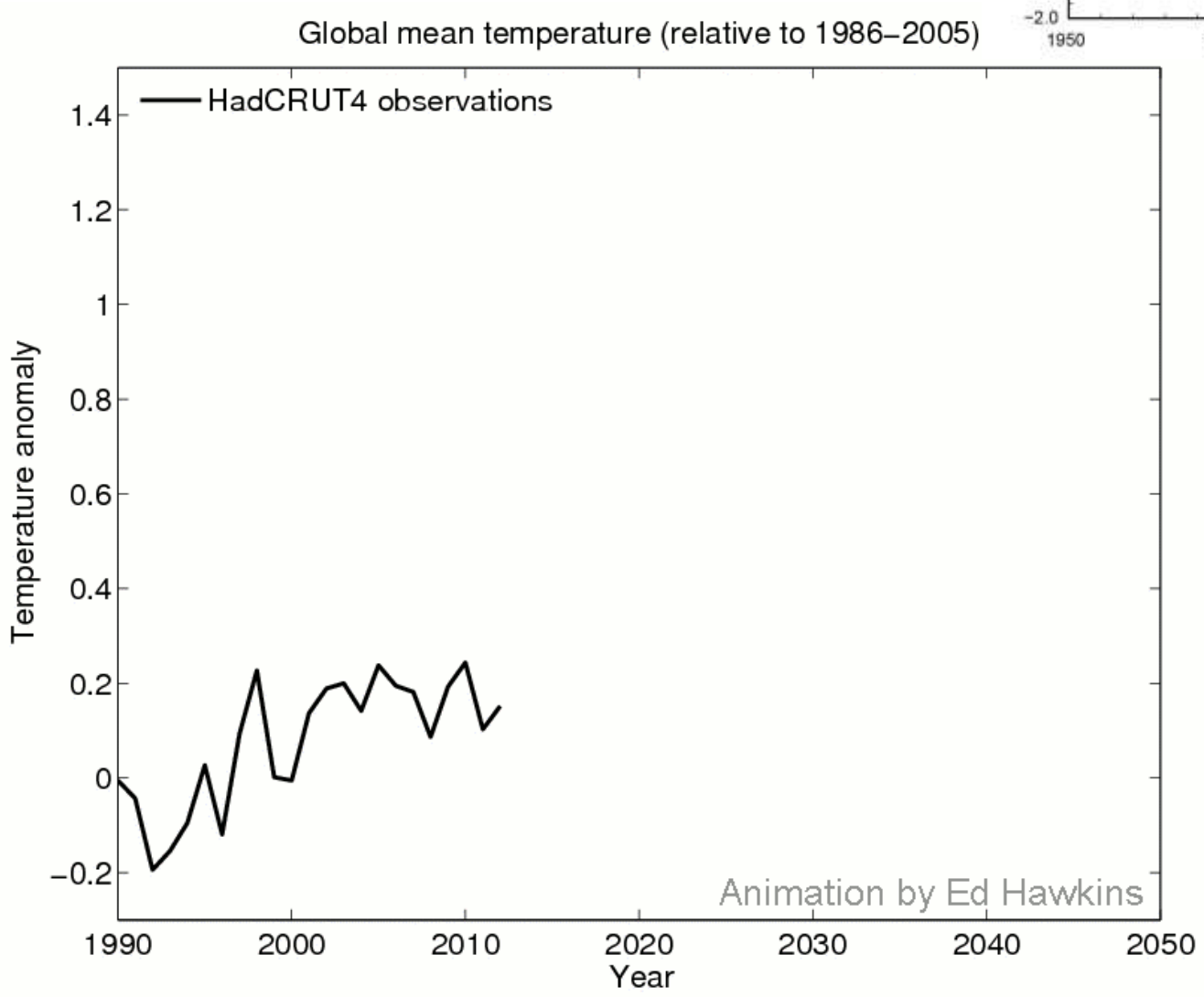
Role of Pacific ocean variability



Work by Merrifield (2010) J. Climate; Sohn et al. (2013) Clim. Dyn.; L'Heureux et al. (2013) Nature Climate Change; Kosaka and Xie (2013) Nature; England et al. (2014) Nature Climate Change

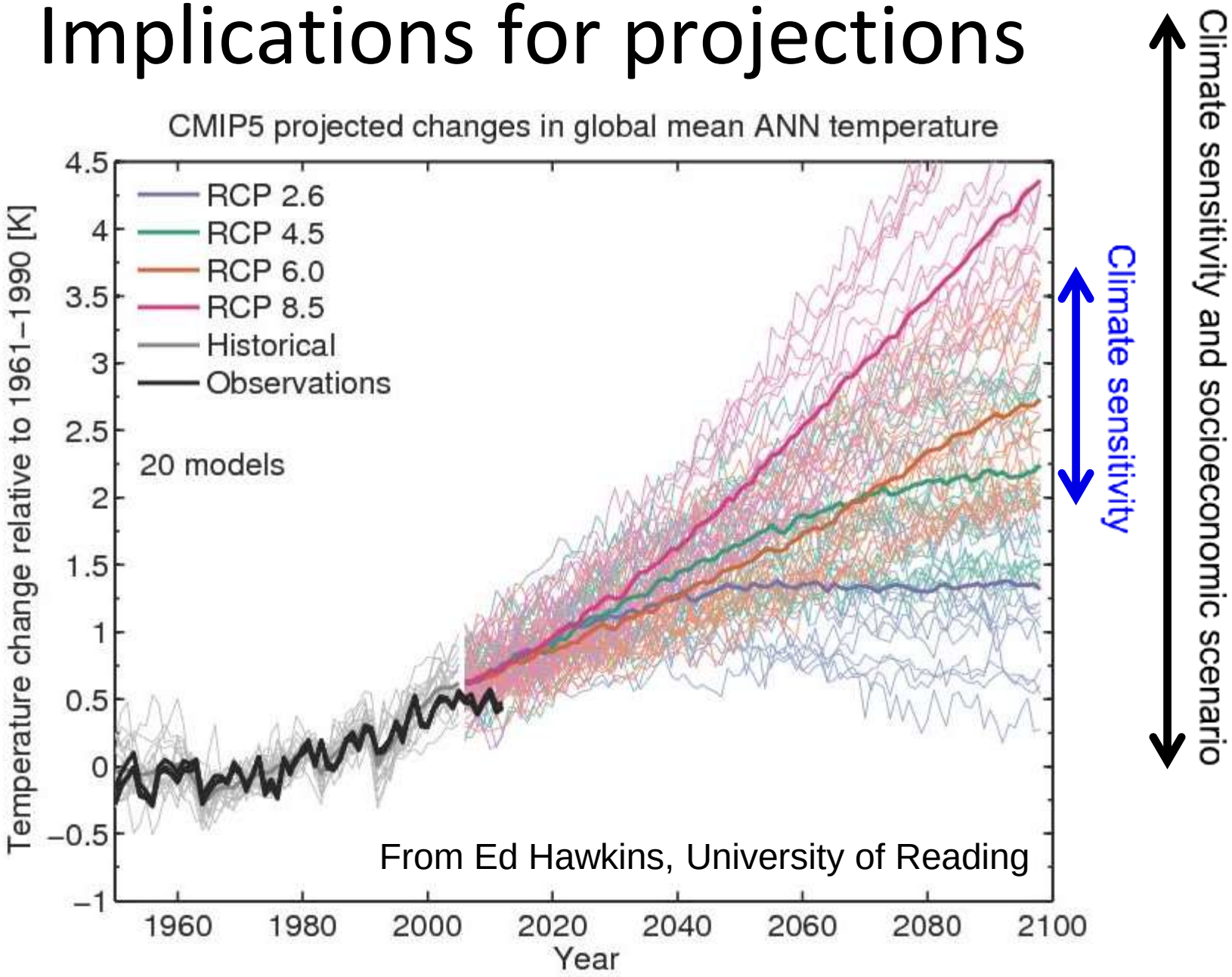
Implications for future





From Climate Lab Book blog (Ed Hawkins)

Implications for projections



Conclusions from recent Science Media Centre briefing

(1) recent changes need to be put in longer term context & other climate indicators such as sea level, Arctic sea ice, snow cover, glacier melt, etc are also important;

(2) explanation for recent slowdown is partly additional ocean heat uptake & partly negative trends in natural radiative forcing (due to solar changes and small volcanic eruptions) which slightly counteract the positive GHHG forcing trend;

(3) the quantification of the relative magnitude of these causes is still work in progress;

(4) climate models simulate similar pauses (due to fluctuations in ocean circulation) but are not designed to predict timing

As summarized on Ed Hawkins' blog:
www.climate-lab-book.ac.uk/2013/recent-slowdown/

Conclusions

- Heating of Earth continues mainly from rising greenhouse gas concentrations
- A mixture of factors (mostly natural) have offset some of this heating since 2000 (weaker sun, small volcanoes, …)
- Pacific ocean circulation currently mixing more heat below surface layers explaining lack of surface warming

Fascinating science: the climate system is complex and will continue to surprise us but the implications of burning fossil fuels are clear

More links on DEEP-C website