

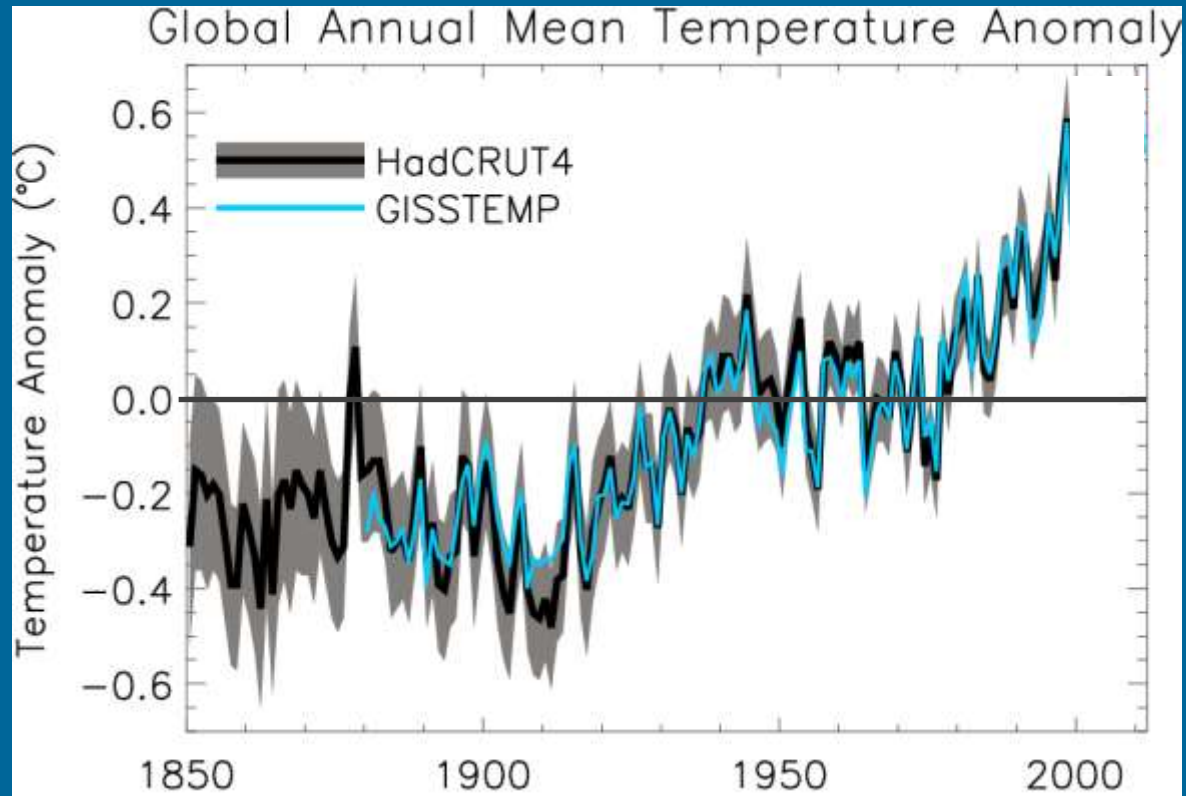
Where has the warming gone?

Richard Allan

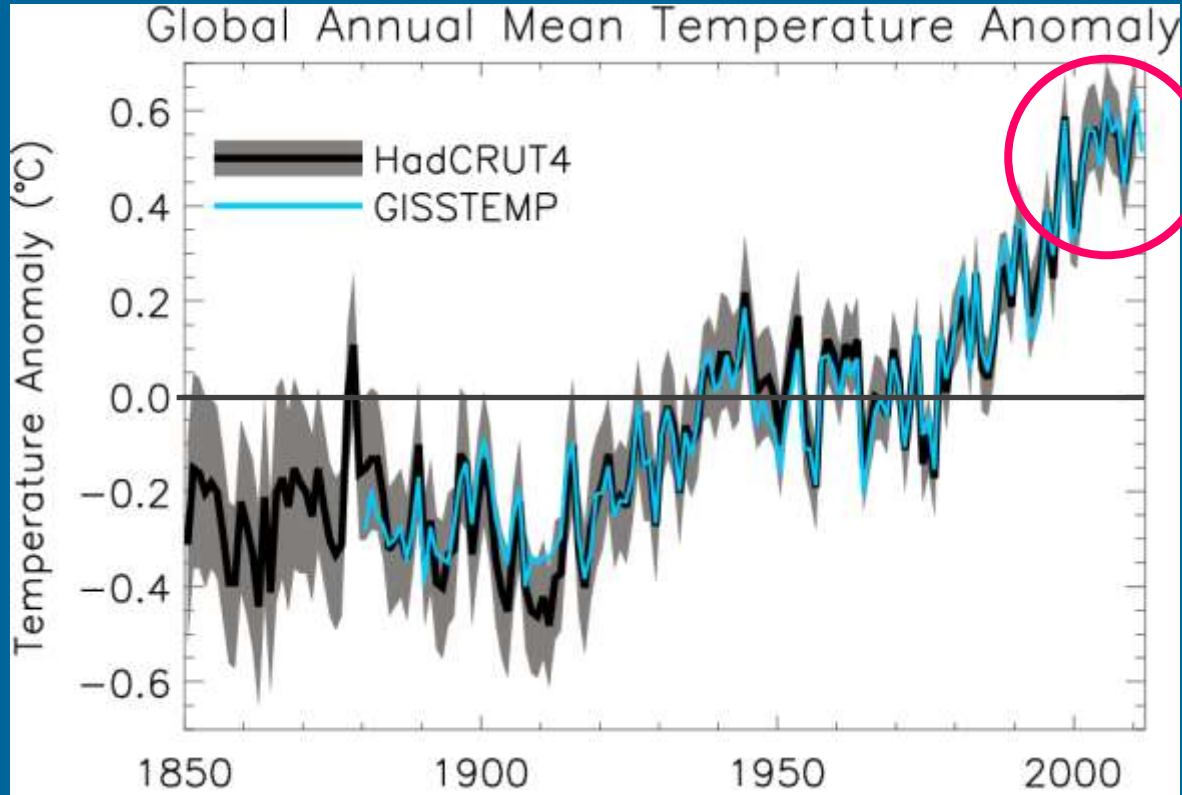
University of Reading/NCAS climate

Collaborators: Norman Loeb (NASA, USA), Greg Johnson (NOAA, USA),
John Lyman (NOAA, USA), Brian Soden (Univ Miami, USA)

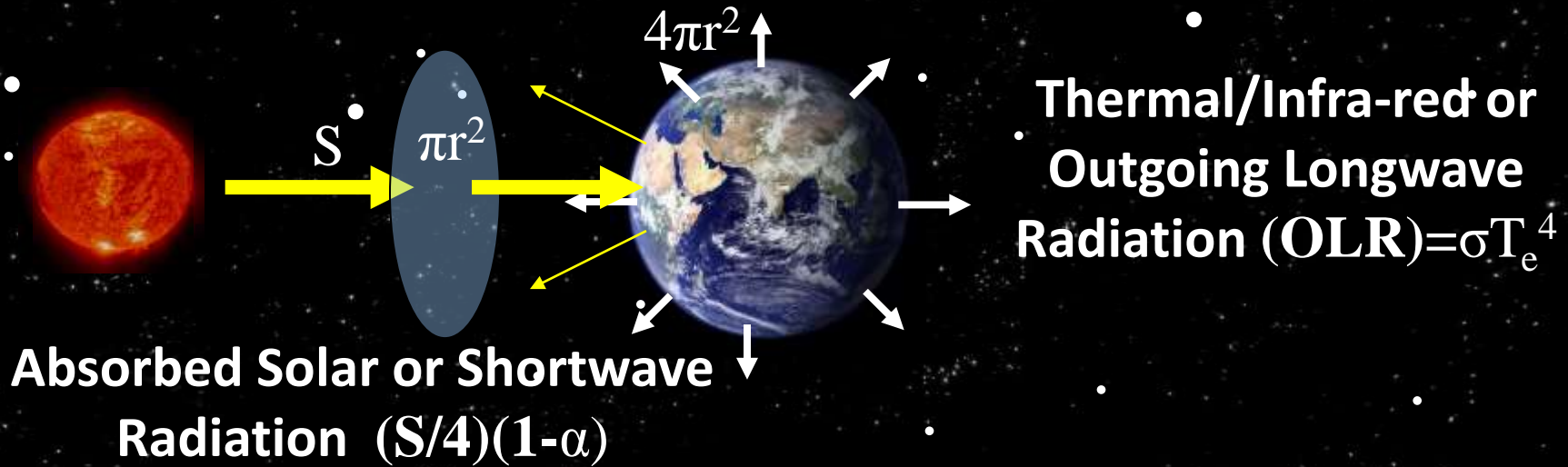
Global Warming...



Global Warming ?



Earth's energy balance in space

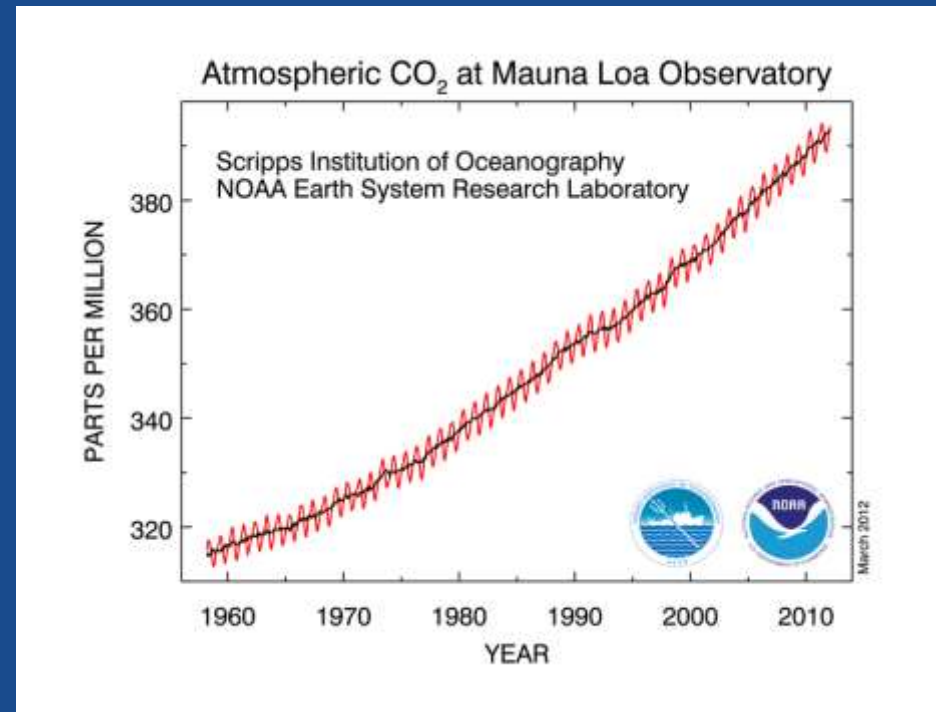


- There is a balance between the absorbed sunlight and the thermal radiative cooling of the planet

“Radiative forcing” of climate

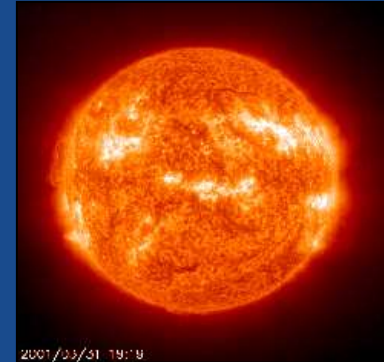


- Increases in greenhouse gases heat the planet by trapping heat
- Small pollutant particles (aerosols) cool the planet by reflecting sunlight
- If more energy is arriving than is leaving the planet, Earth should warm...



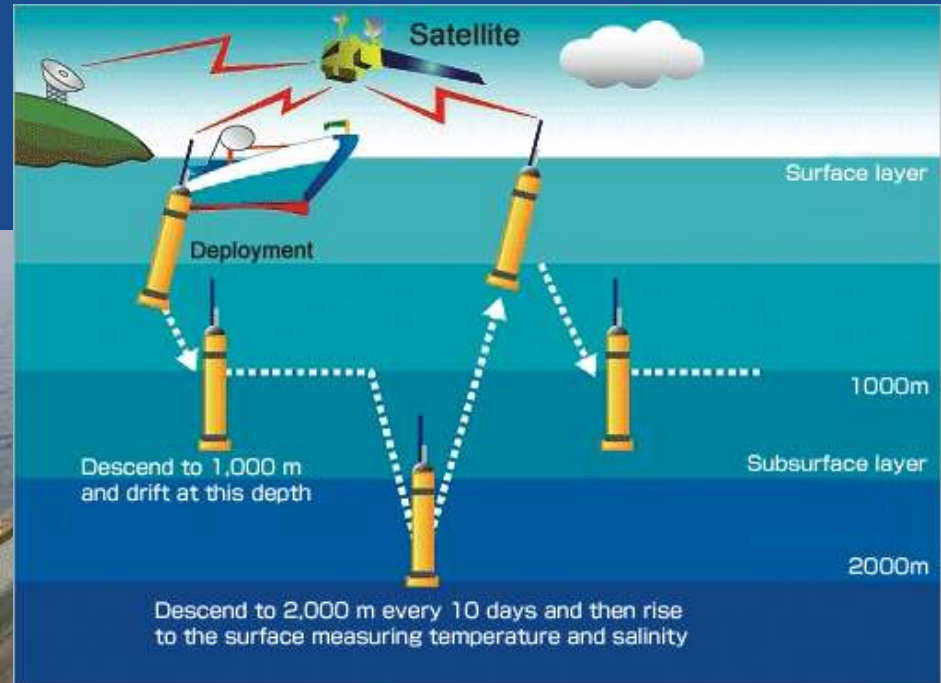
Have other factors offset warming from greenhouse gases?

- The sun has been weaker in the 2000s
- There were a series of small volcanic eruptions causing reflection sunlight
- Particle pollution from Asia, changes in the stratosphere (where the “ozone layer” is) may also be important
- Scientists think that natural fluctuations in the ocean also play an important role



Measuring Earth's energy flows

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

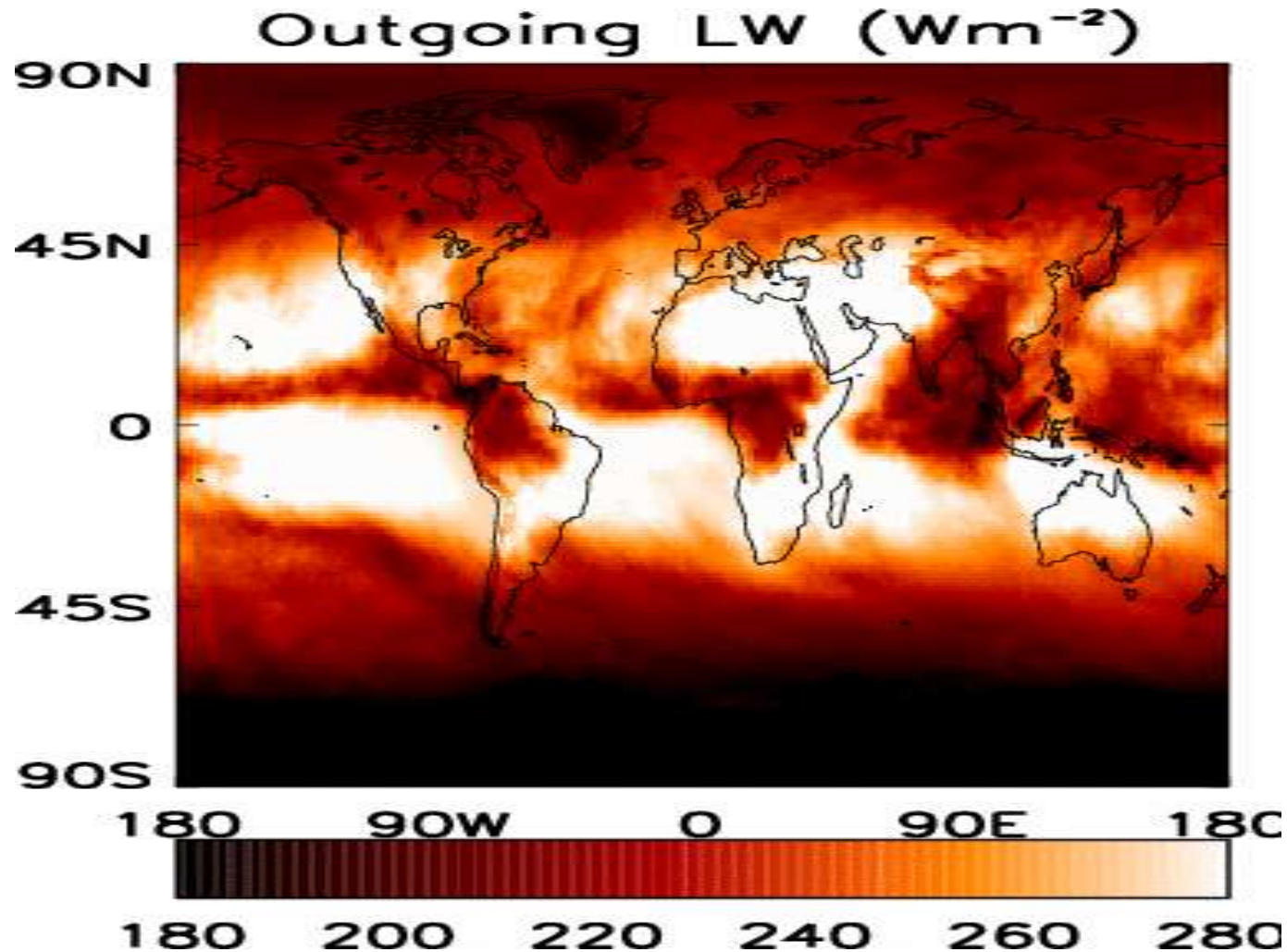


ARGO floats →



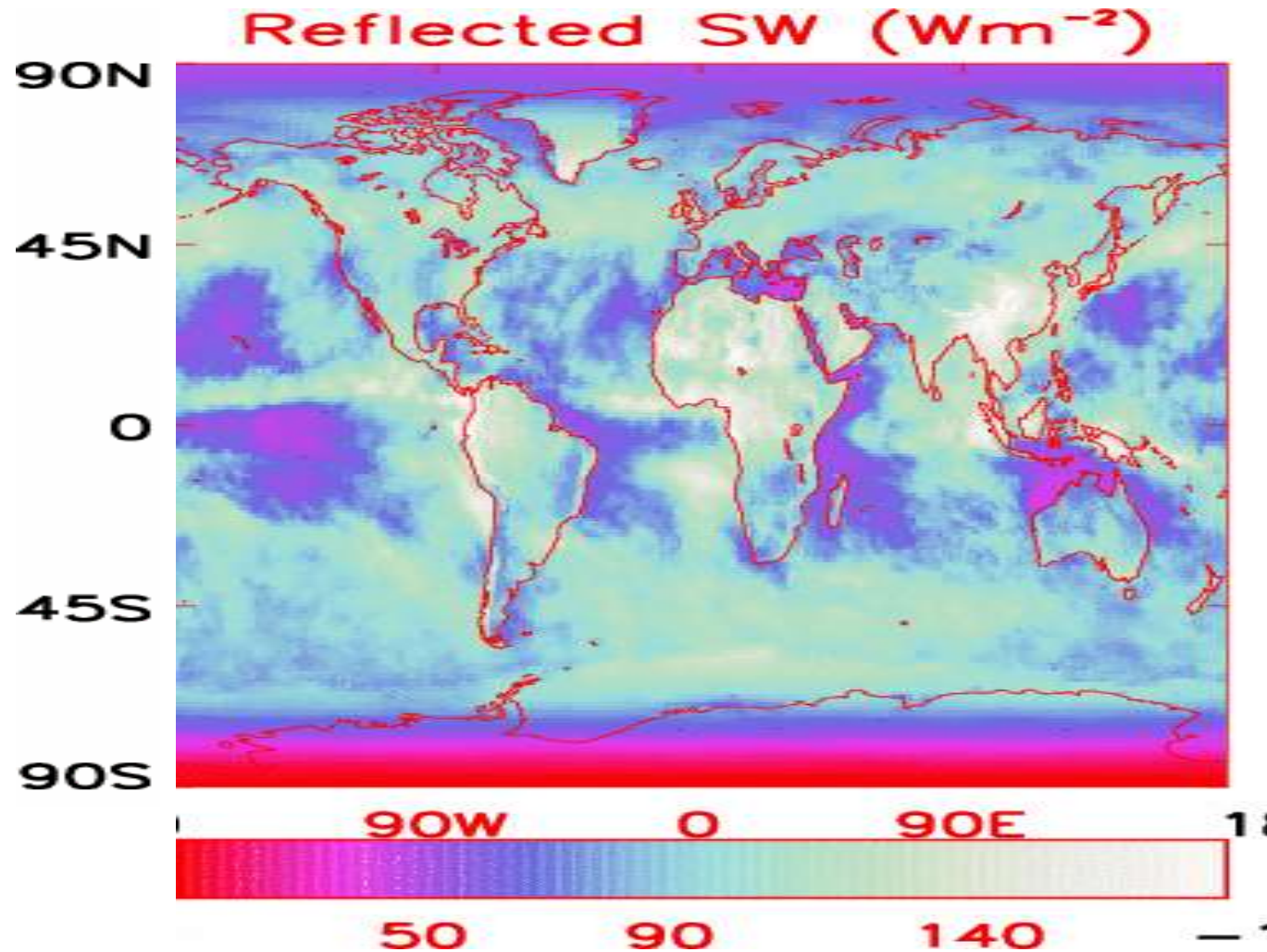
Top of Atmosphere Radiative Energy Fluxes

CERES/TERRA, September 2004



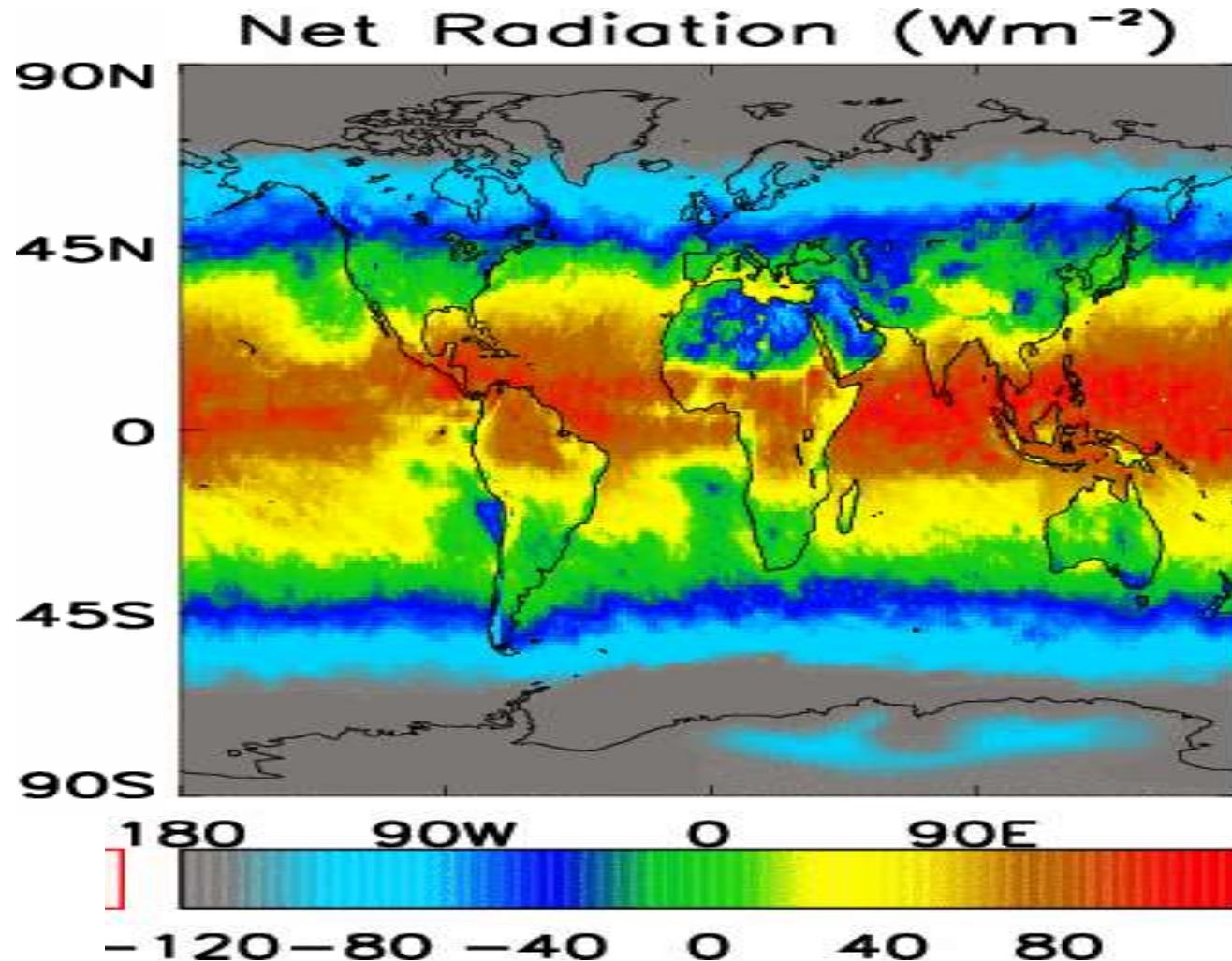
Top of Atmosphere Radiative Energy Fluxes

CERES/TERRA, September 2004

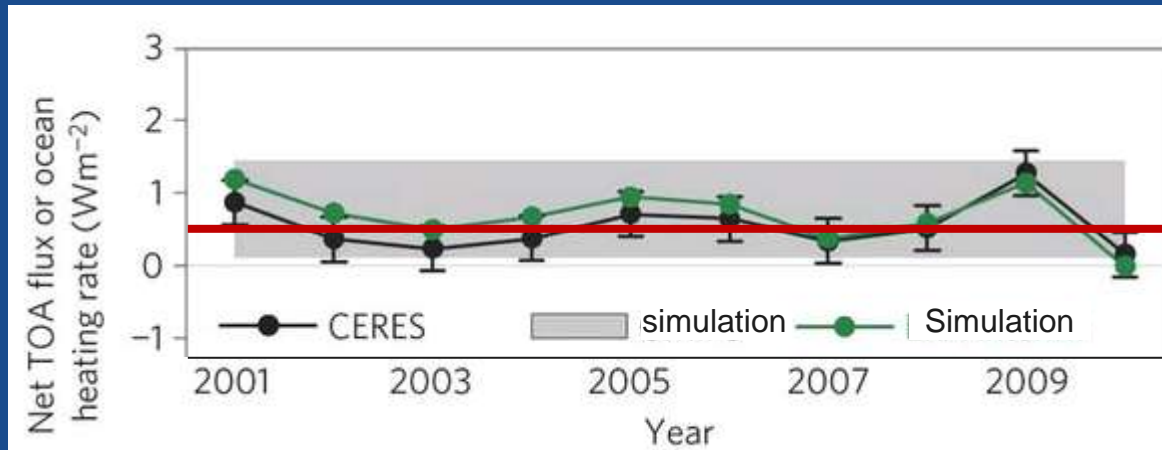


Top of Atmosphere Radiative Energy Fluxes

CERES/TERRA, September 2004



Combining satellite measurements with ocean observations...

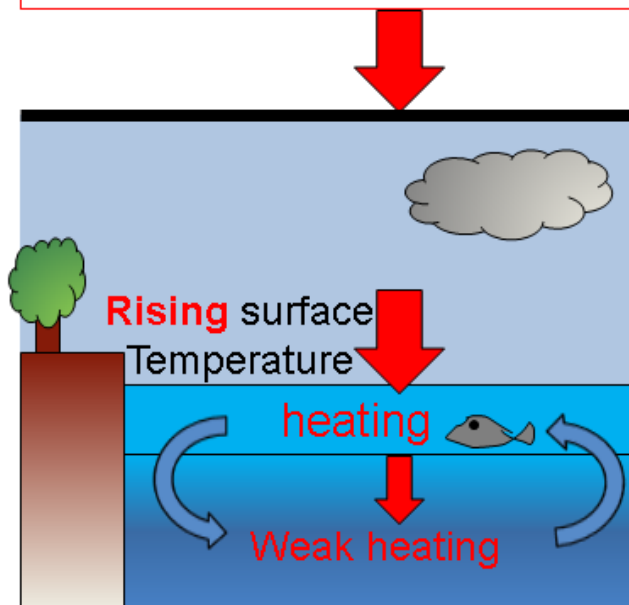


- We found that heat is continuing to accumulate at 0.5 Watts per square metre (this is equivalent to the heat of 250 billion 1 kilo-Watt electric heaters distributed over the planet)

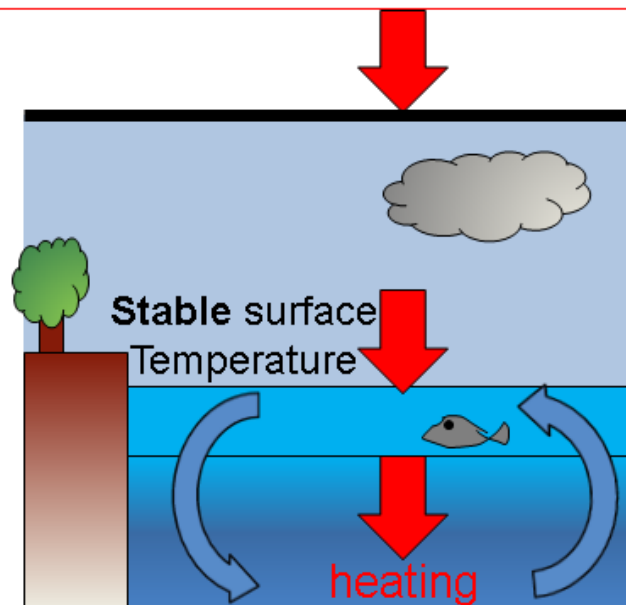


New research shows natural changes in the ocean explain slower warming

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 – rising surface temperature



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