Monitoring Climate Change from Space

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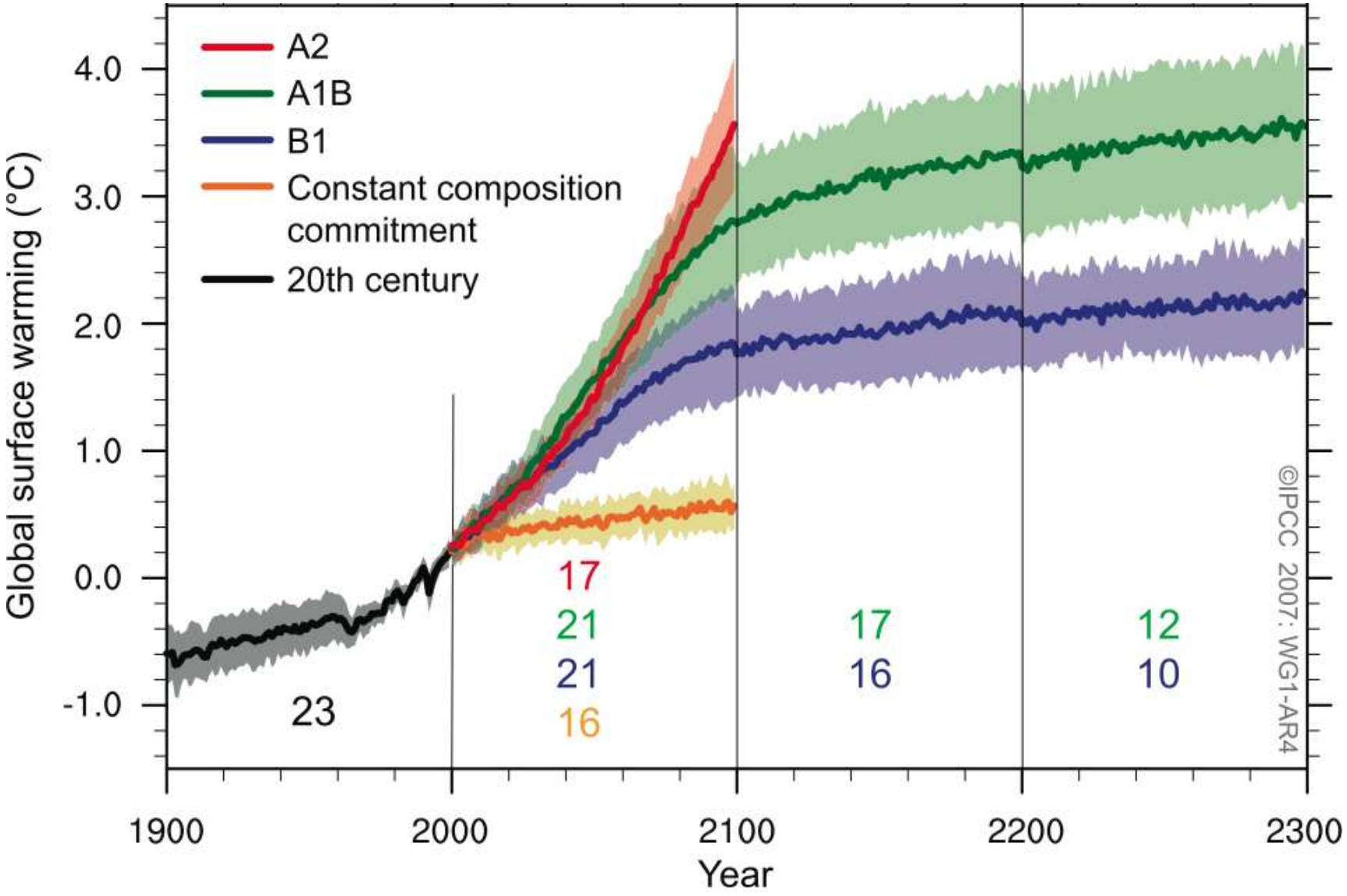
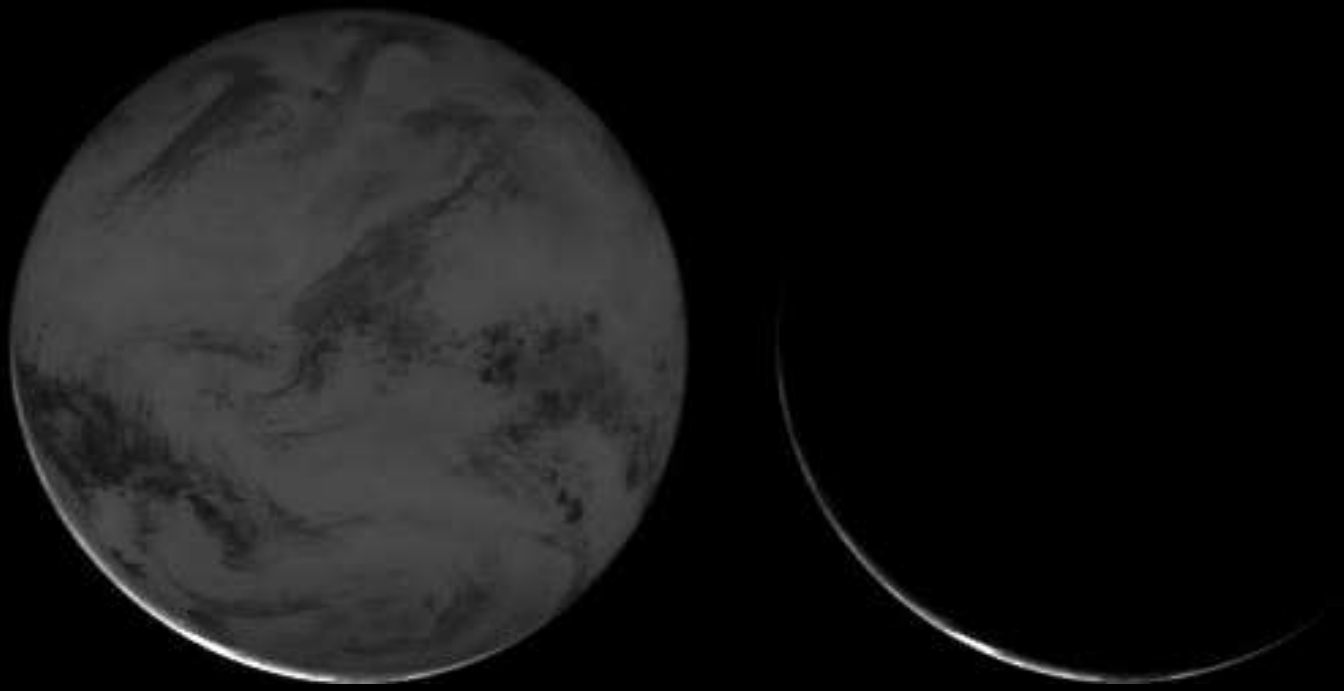
Why Monitor Earth's Climate from Space?

- Global
- Spectrum
- Current
- Detection
- Understanding
- Prediction

The problem…

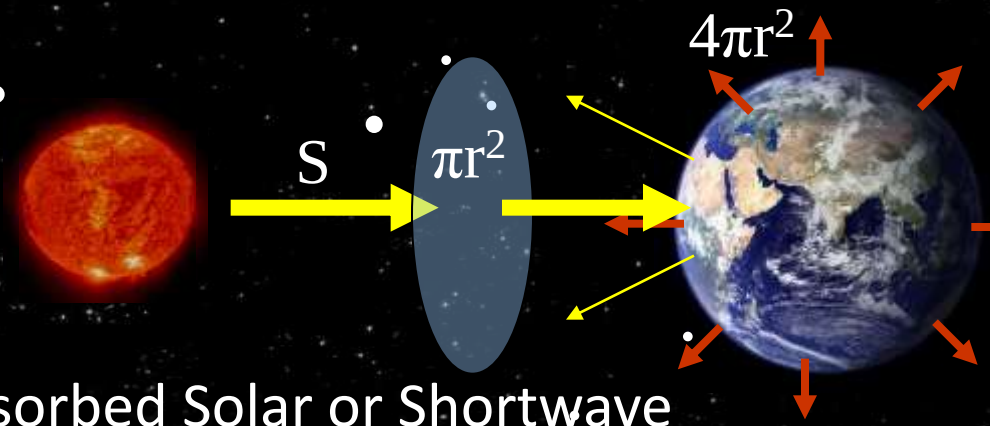


IPCC: www.ipcc.ch/ipccreports/ar4-wg1.htm



Link to animation

Earth's Radiation balance in space



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

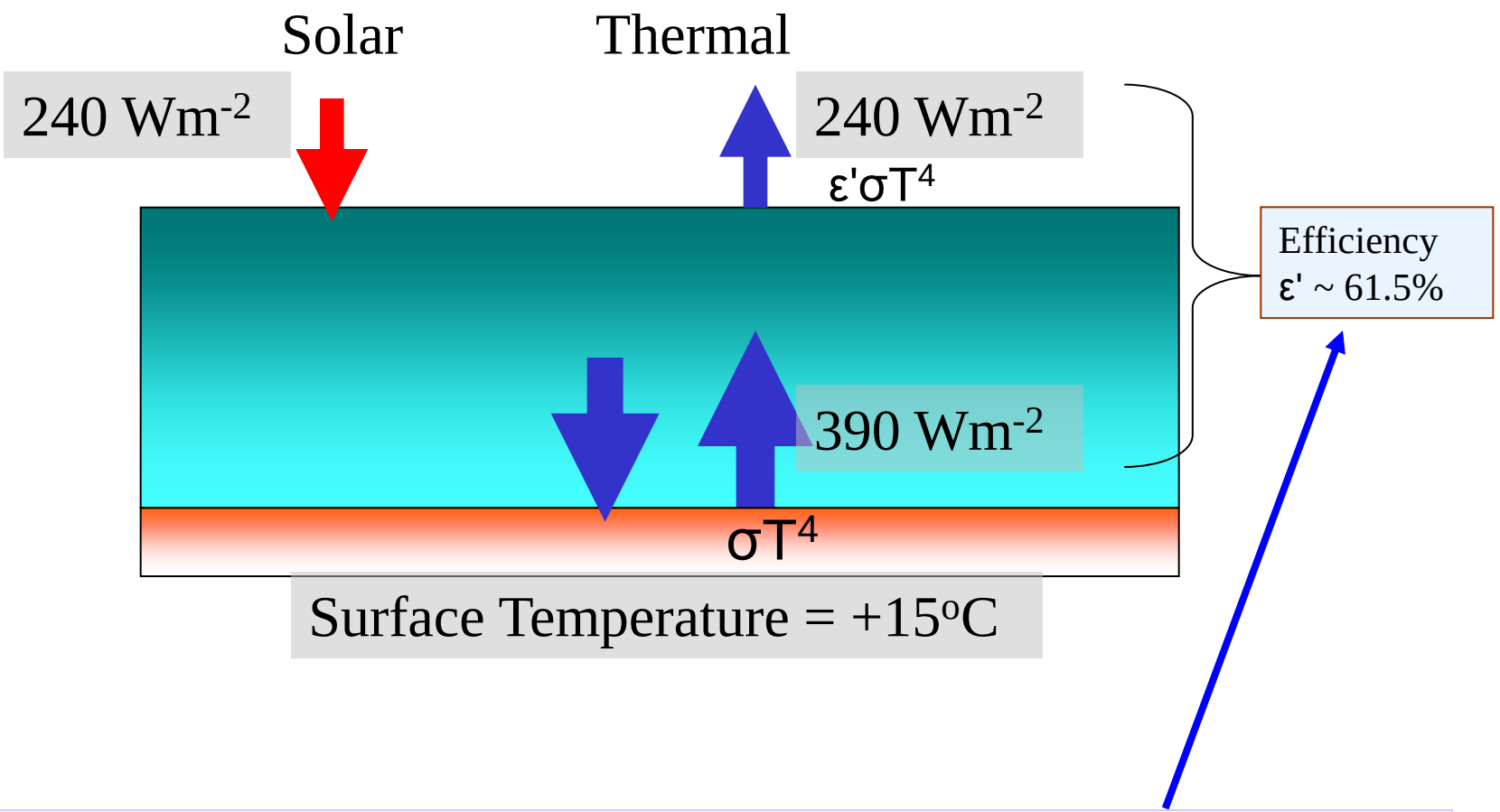
Absorbed Solar or Shortwave Radiation (S/4)(1-α)

- There is a balance between the absorbed sunlight and the thermal/longwave cooling of the planet:

$$(S/4)(1-\alpha) \approx \sigma T_e^4$$

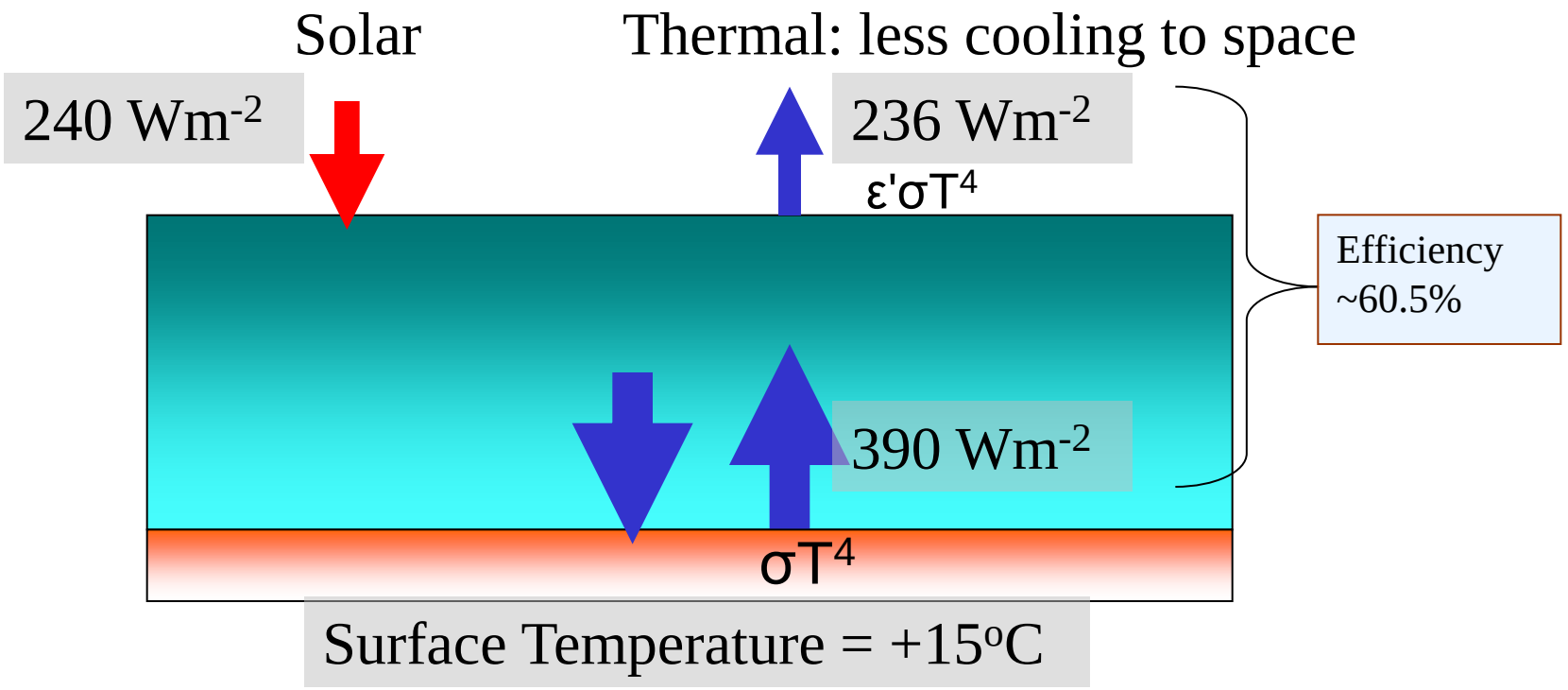
- How does it balance? Why is the Earth's average temperature about 15°C? e.g. Lacis et al. (2010) Science

Earth's global annual average energy balance



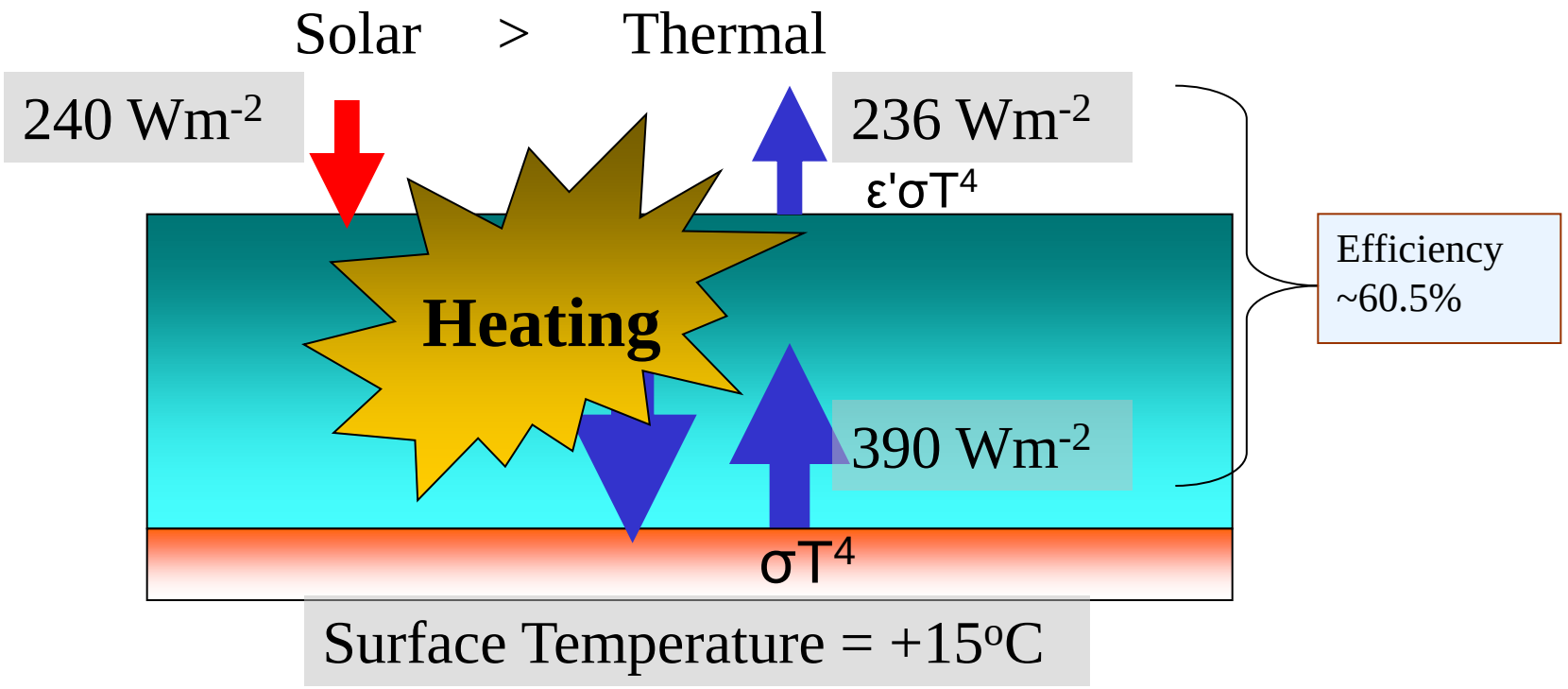
Radiating Efficiency, or the inverse of the Greenhouse Effect, is strongly determined by water vapour absorption across the electromagnetic spectrum

Now double CO_2 - a "radiative forcing"

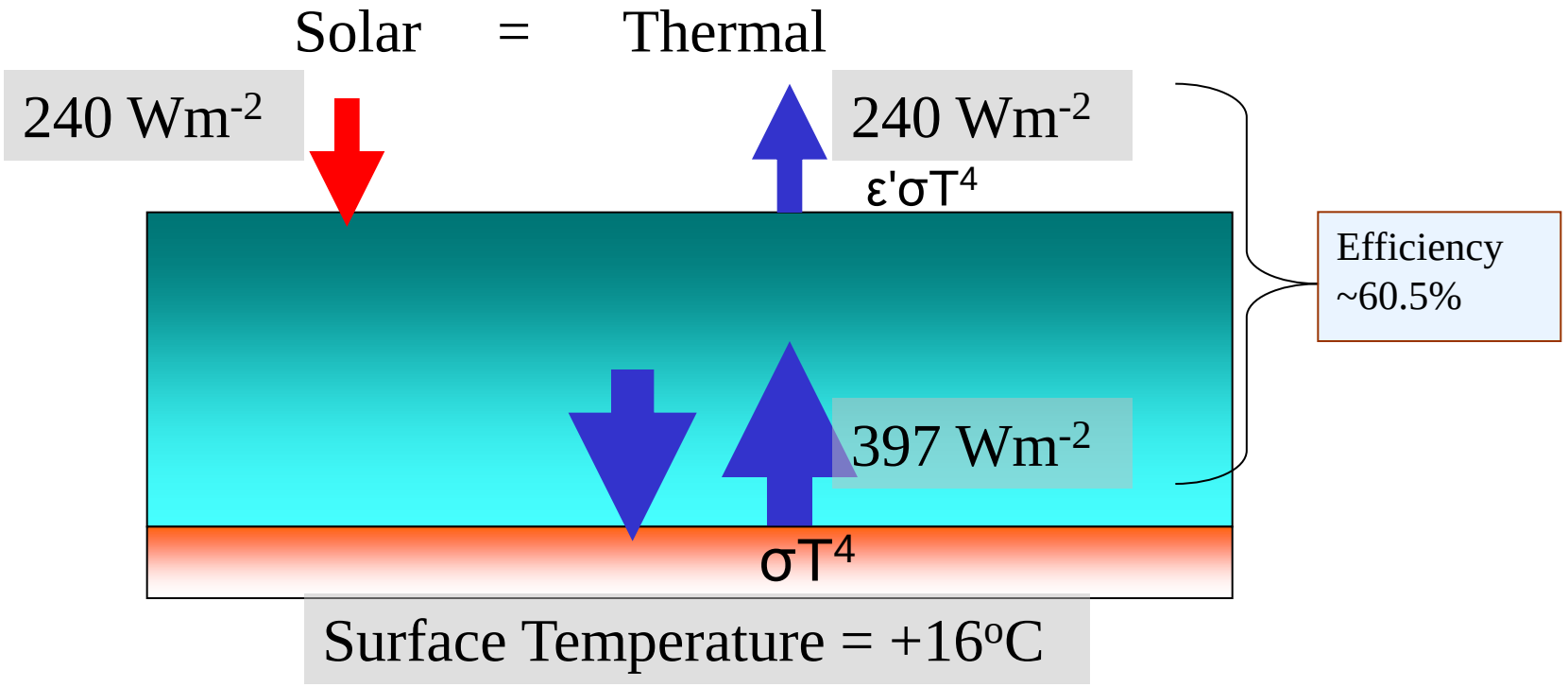


Radiative cooling to space through longwave emission drops by about 4 Wm^{-2} resulting in a radiative imbalance

The climate system responds by warming

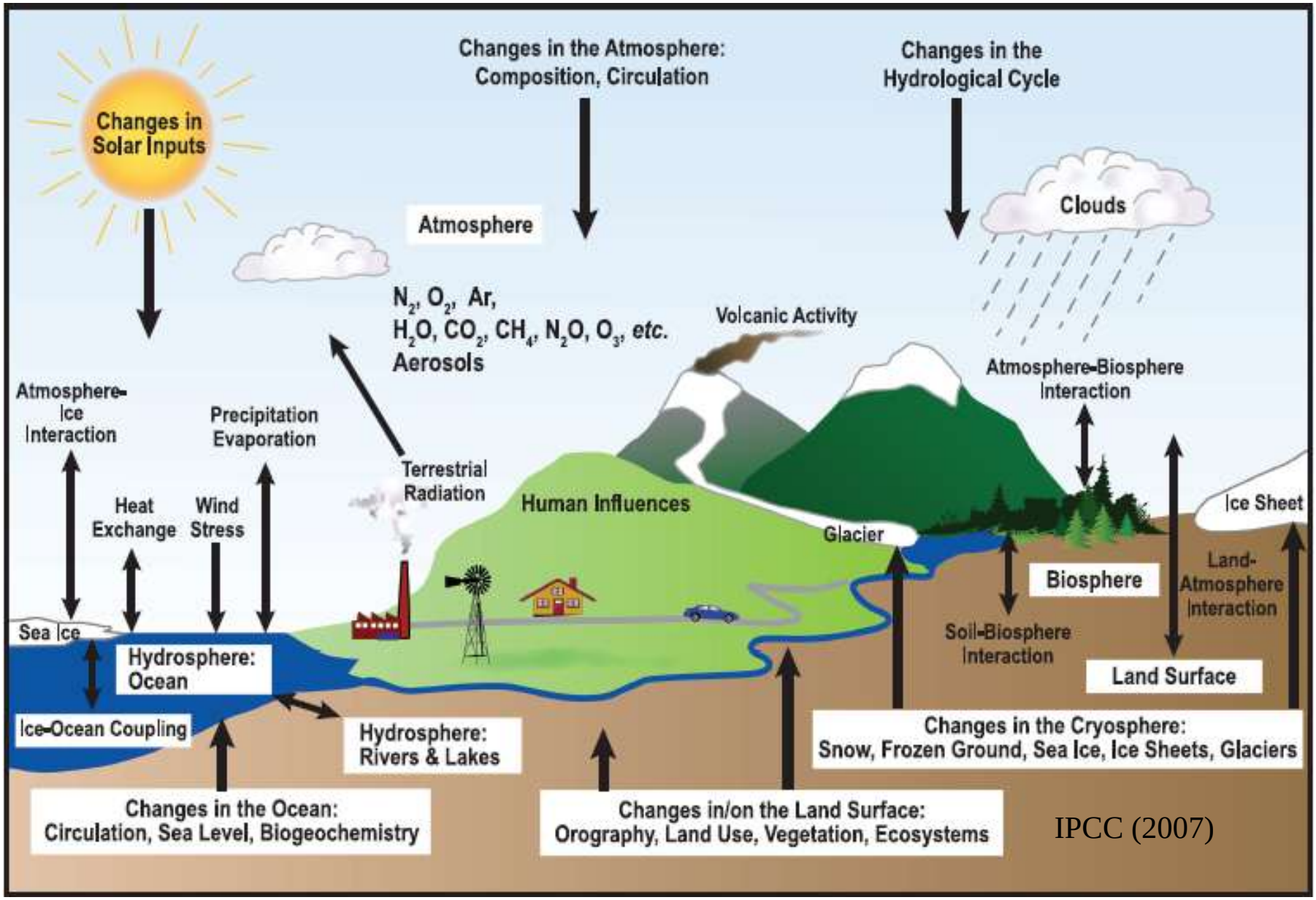


The climate system responds by warming



The 2xCO_2 increased temperature by about 1°C in this simple example. So what's to worry about?

But it's not that simple…



IPCC (2007)

Link to animation

Climate forcing and feedback : a natural experiment


29/3/06 11.05am
© Stuart Webster 2006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29/3/06 12.26pm
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Clouds affect radiation fluxes

Radiation fluxes affect clouds

Feedback loops or “vicious circles” amplify or diminish initial heating or cooling tendencies

e.g. Ice “albedo” Feedback

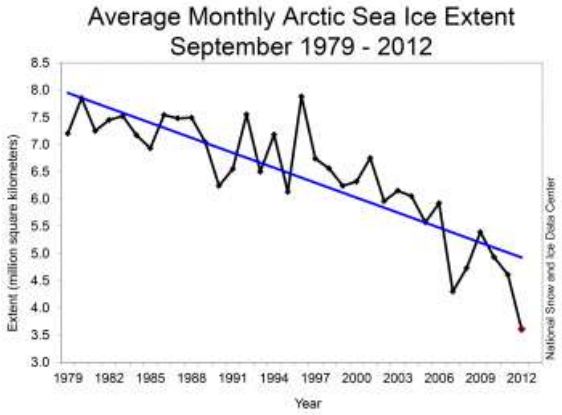
↑ CO_2

Melting ice and snow

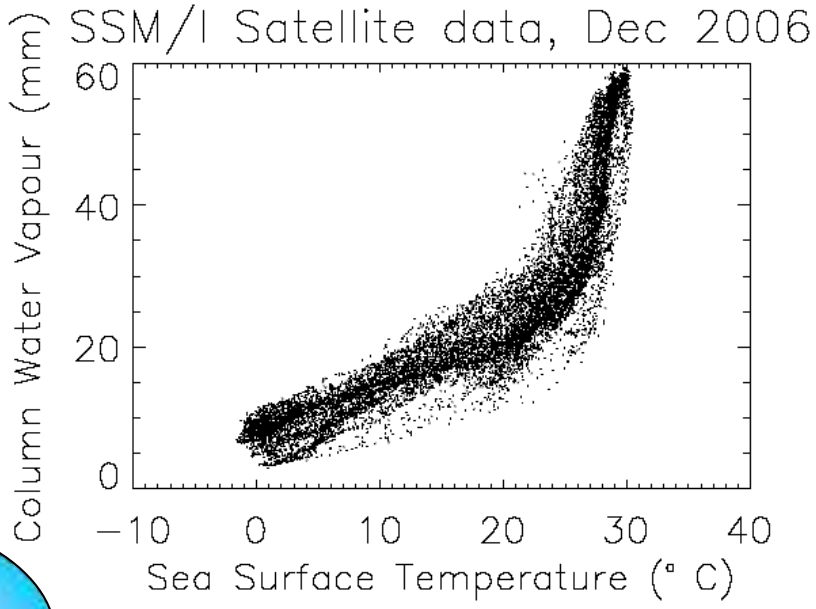
↑Temperature

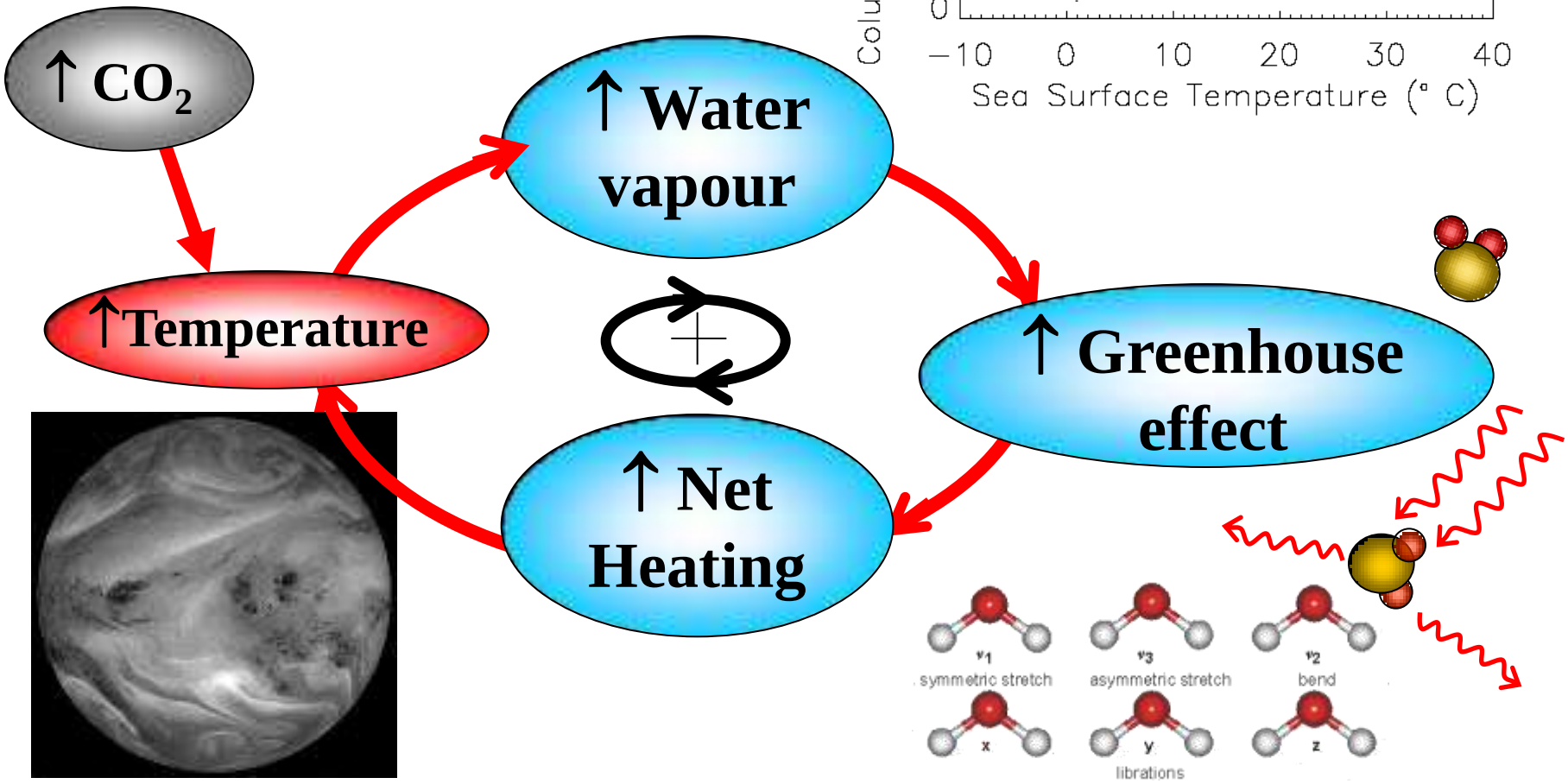
Reduced reflection of suns rays

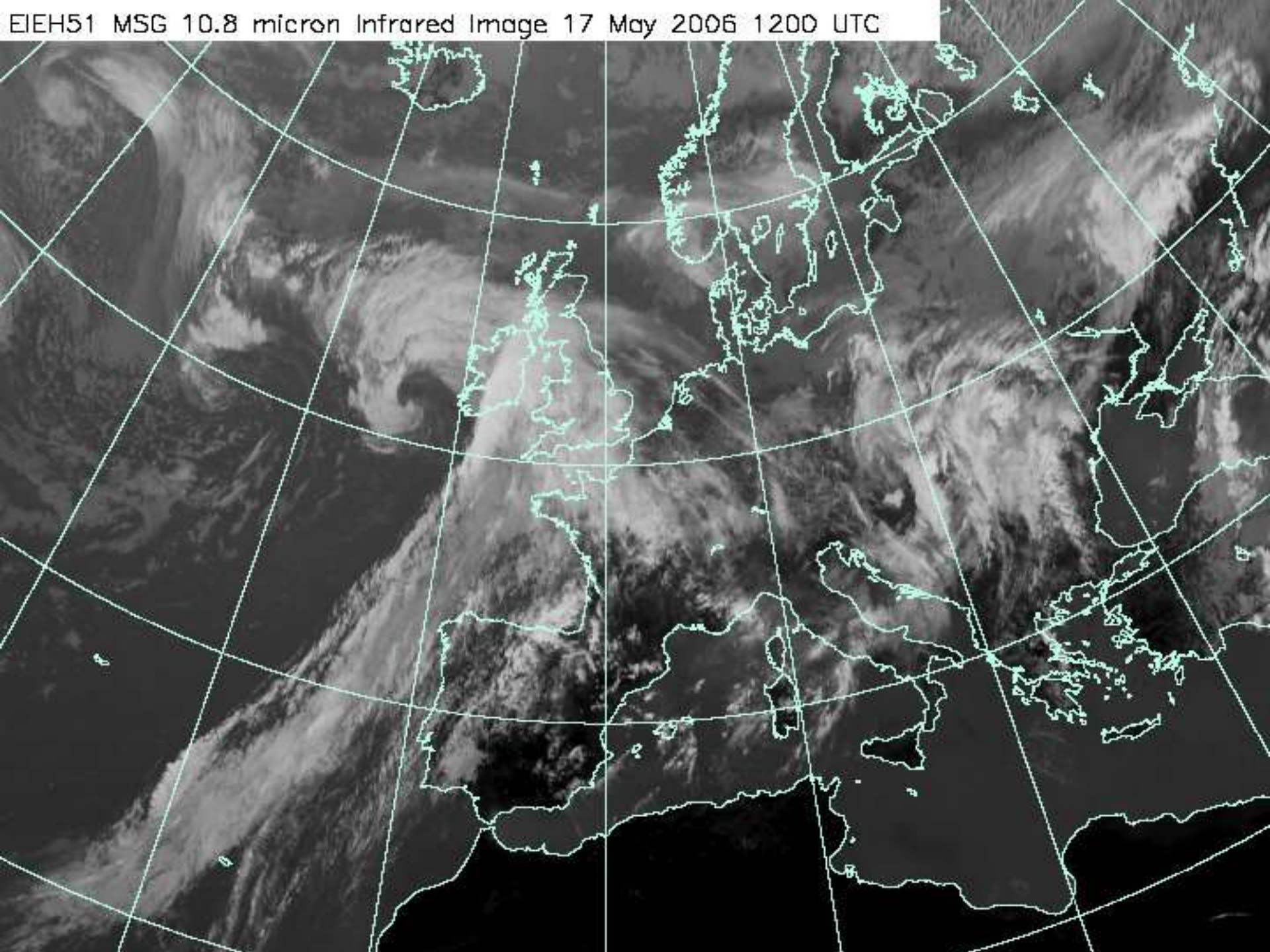
Additional surface heating

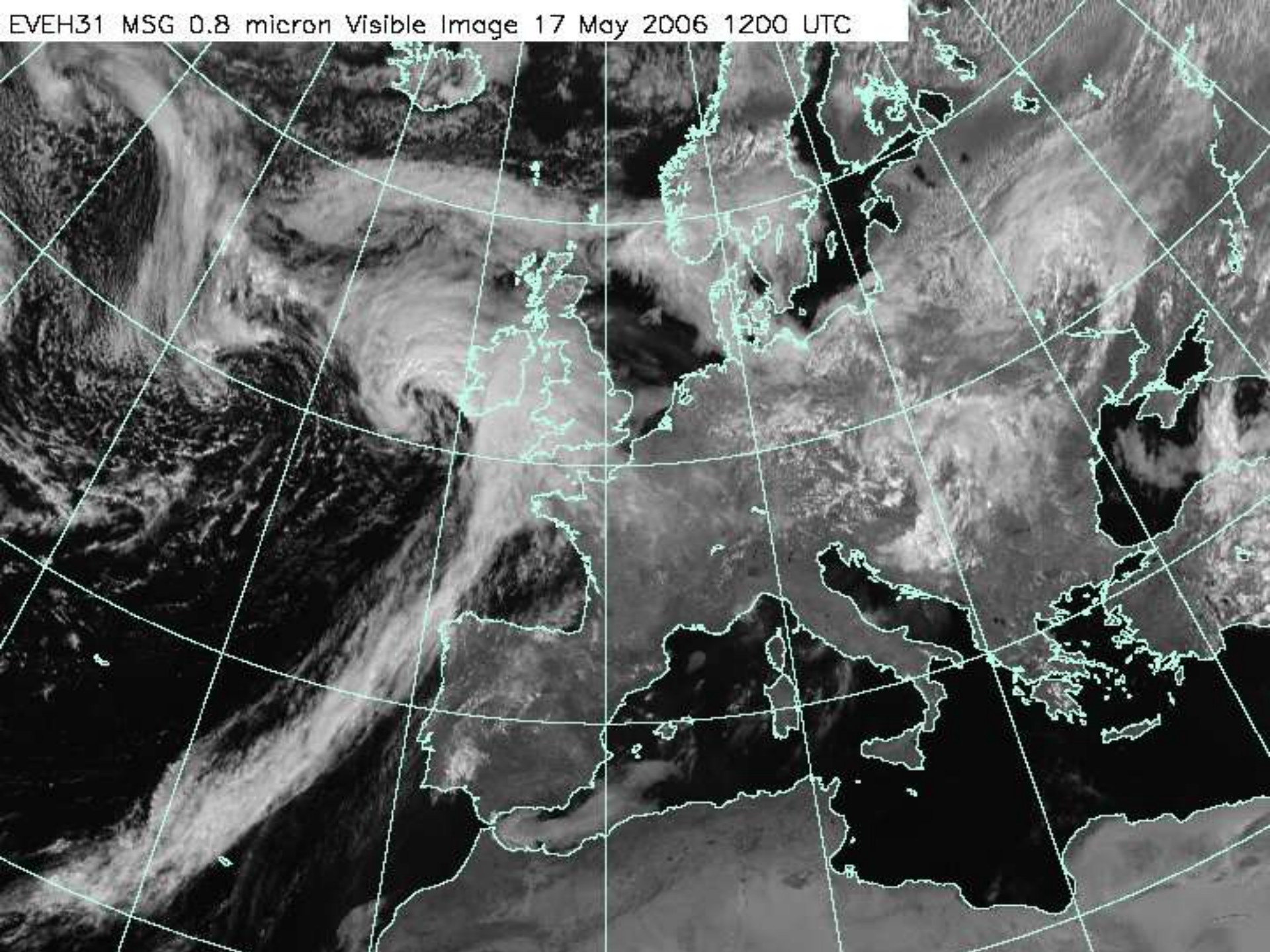


One of the strongest positive amplifying feedbacks involves gaseous water vapour






EIEH51 MSG 10.8 micron Infrared Image 17 May 2006 1200 UTC

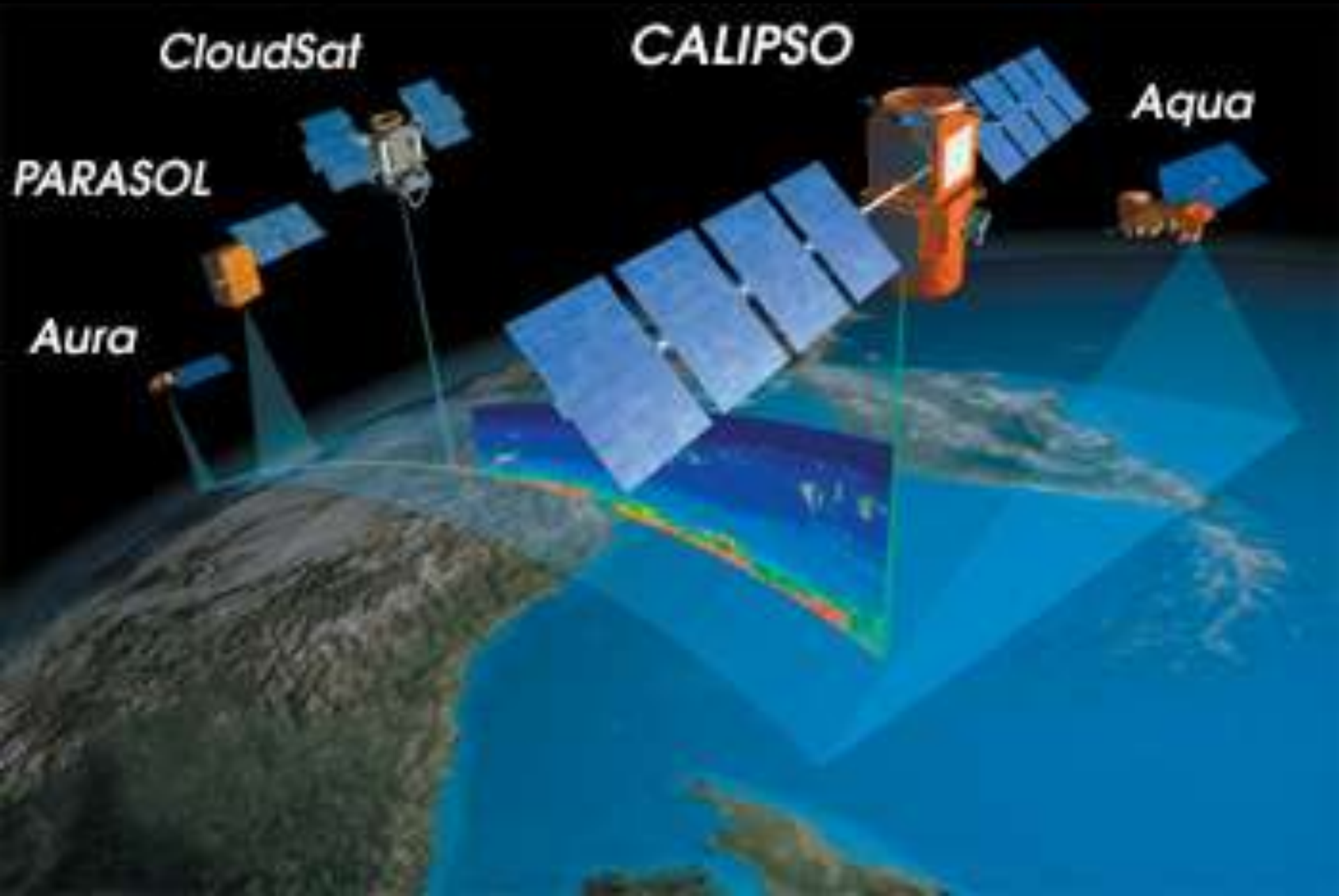

EVEH31 MSG 0.8 micron Visible Image 17 May 2006 1200 UTC

Cloud Feedback: a complex problem

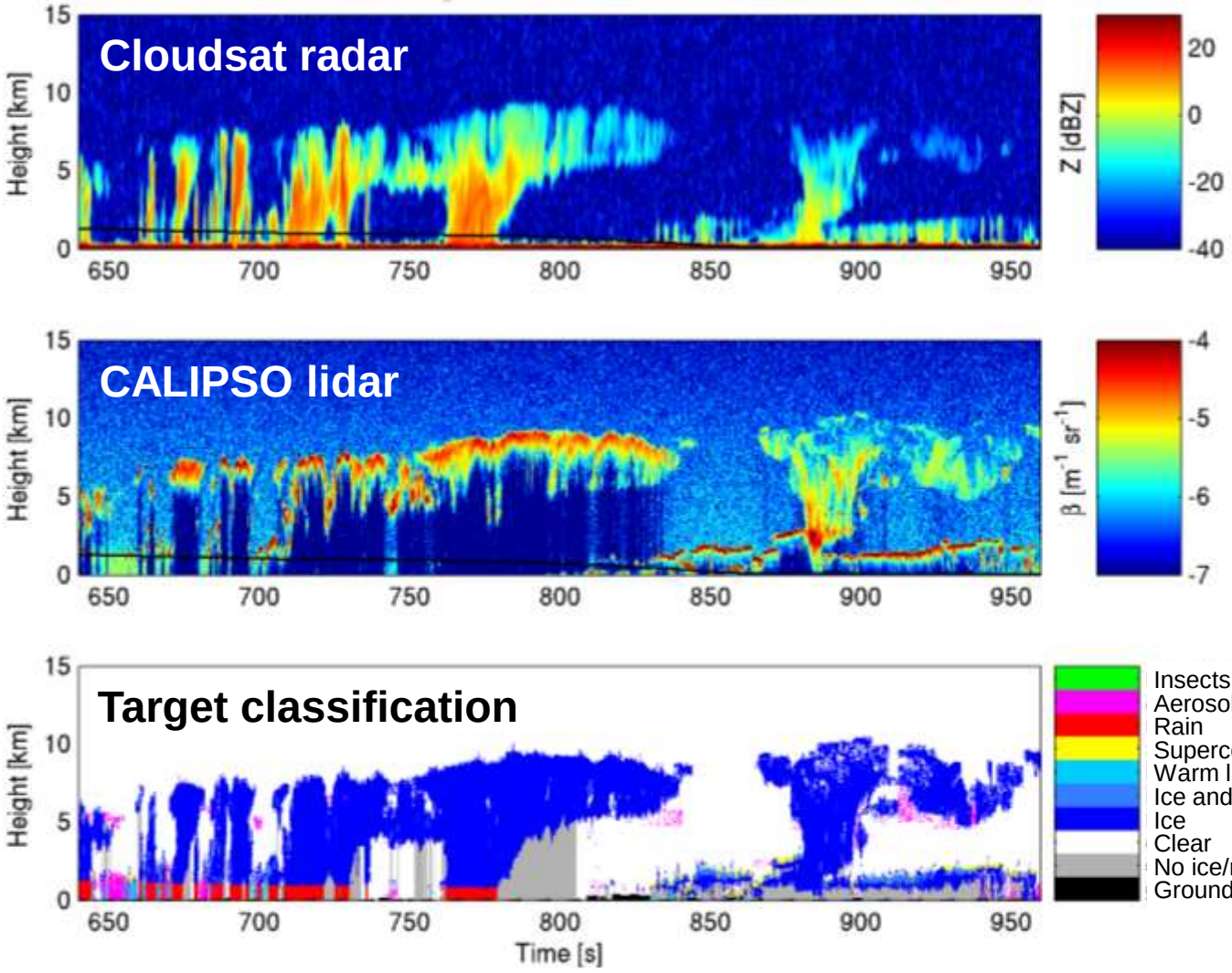
- Clouds cool the present climate

- Will this cooling effect enhance or diminish in the future?
- Will clouds amplify or reduce future warming?

Monitoring Climate From Space

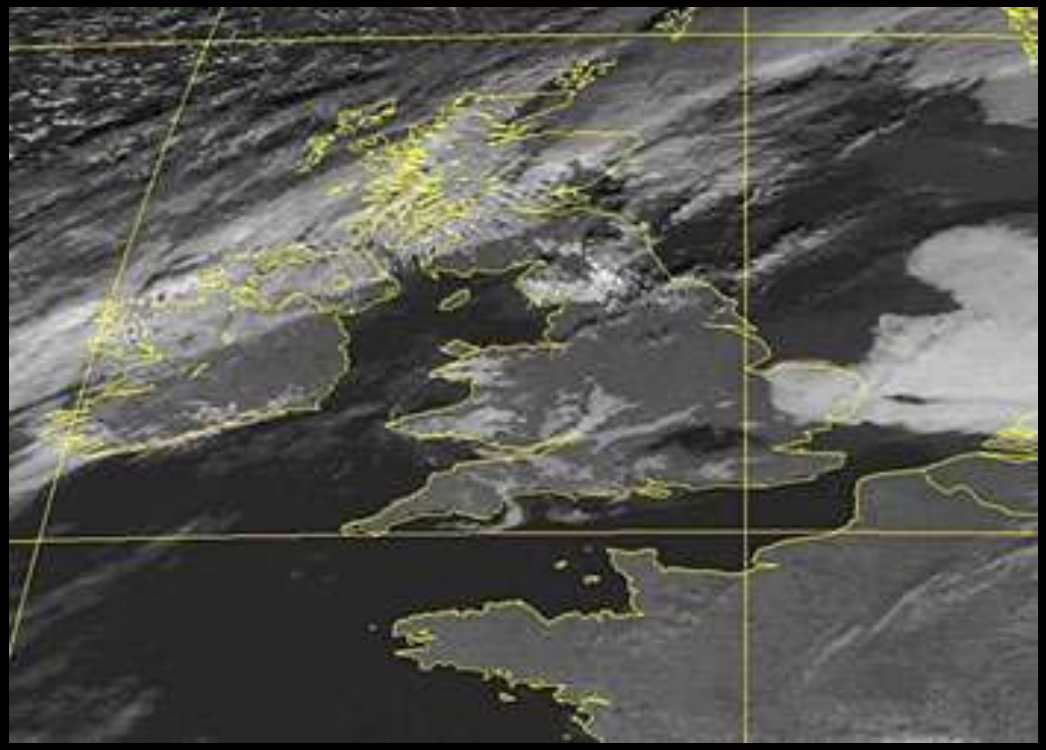


Remote sensing clouds and aerosol from space: Cloudsat and CALIPSO

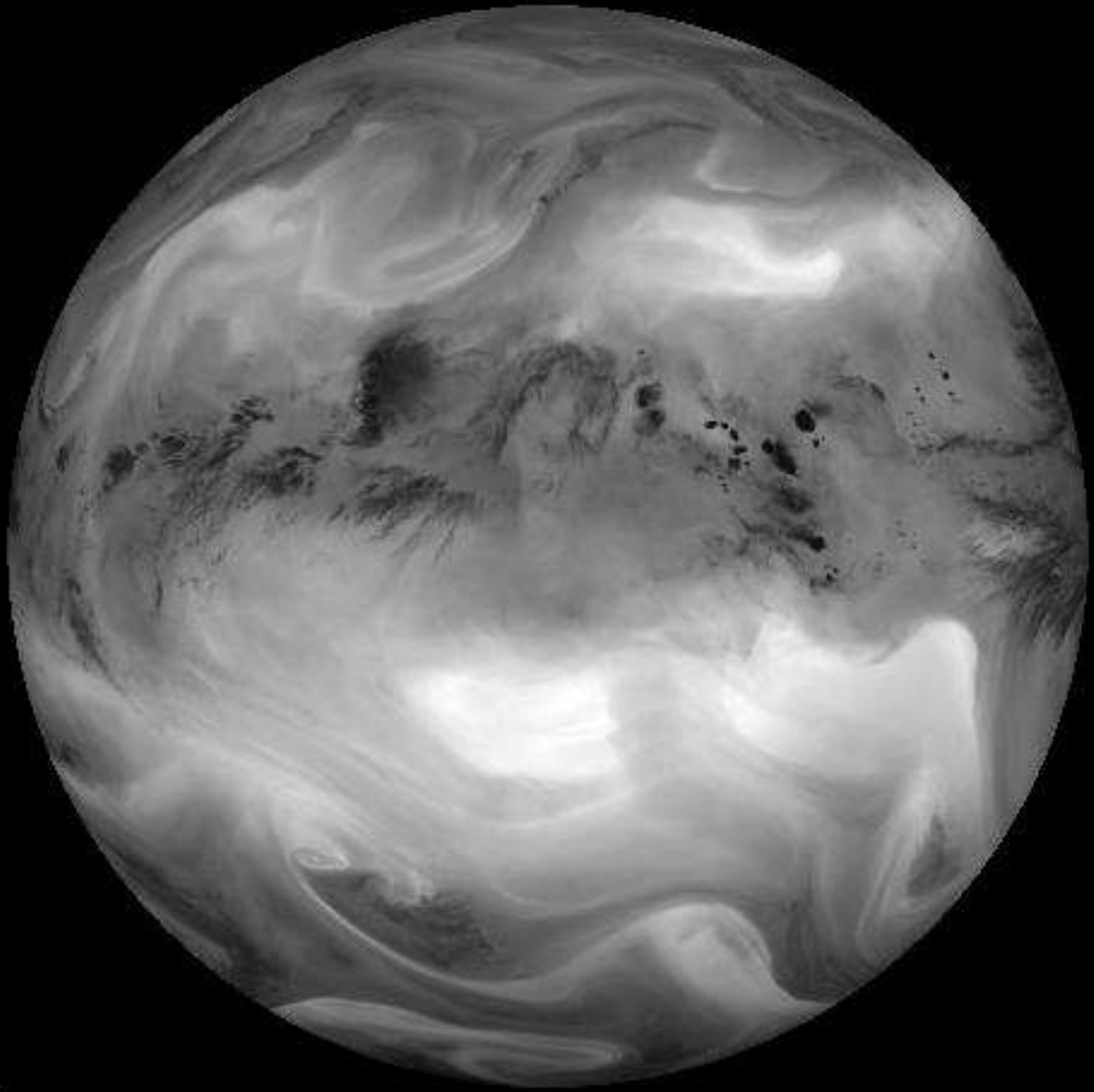


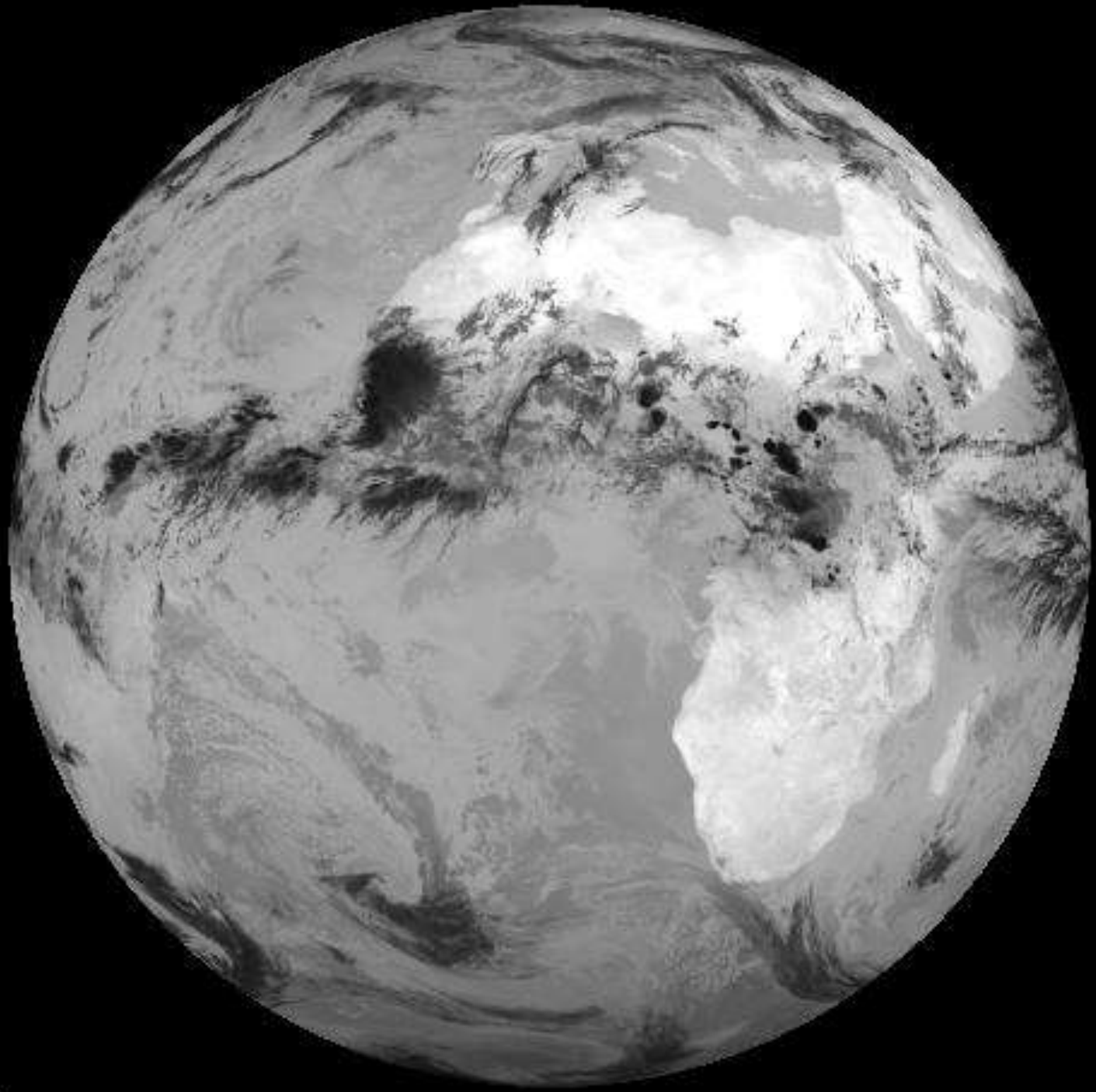
- **Radar:** ~D^6, detects large particles (e.g. ice)
- **Lidar:** ~D^2, more sensitive to thin cirrus, low-level liquid clouds and aerosol pollutants but signal is attenuated

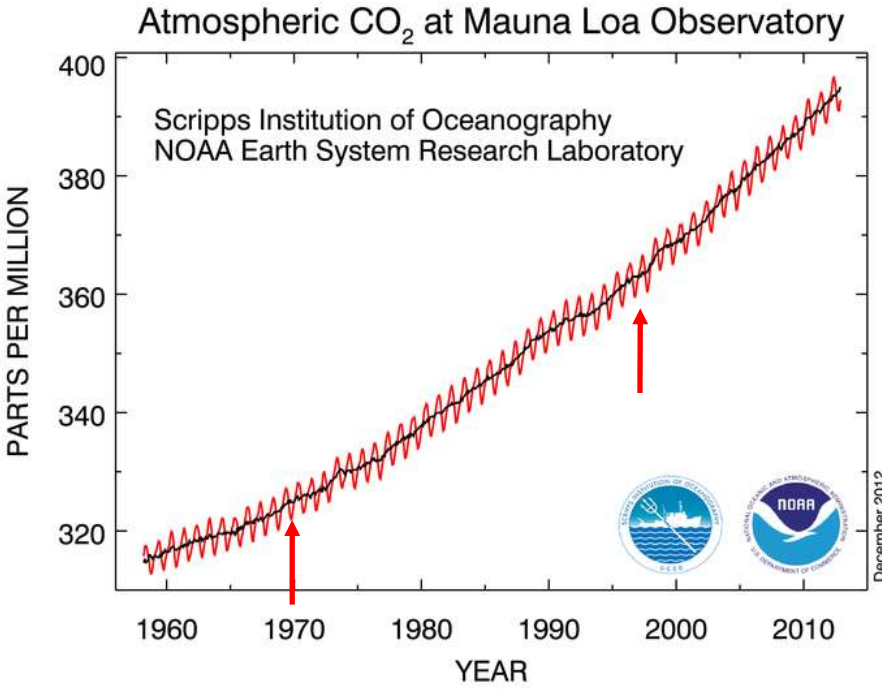
Work by Dr. Julien Delanoë and Prof. Robin Hogan, University of Reading



Link to animation

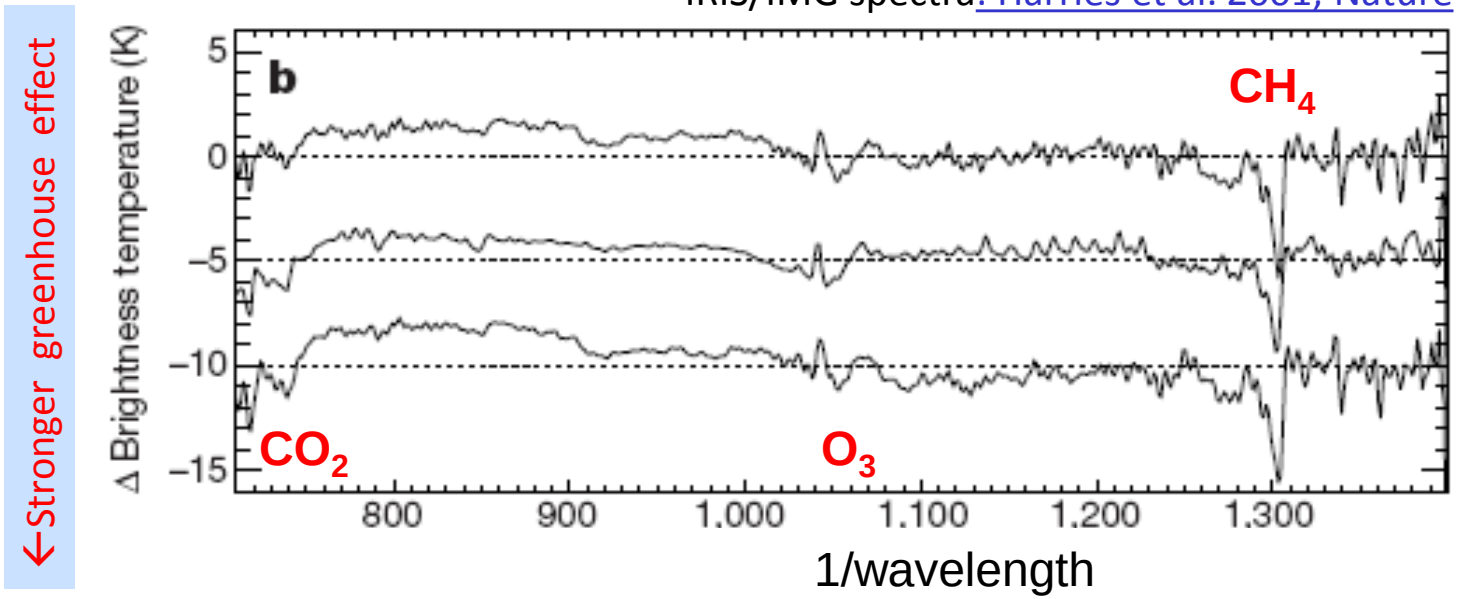




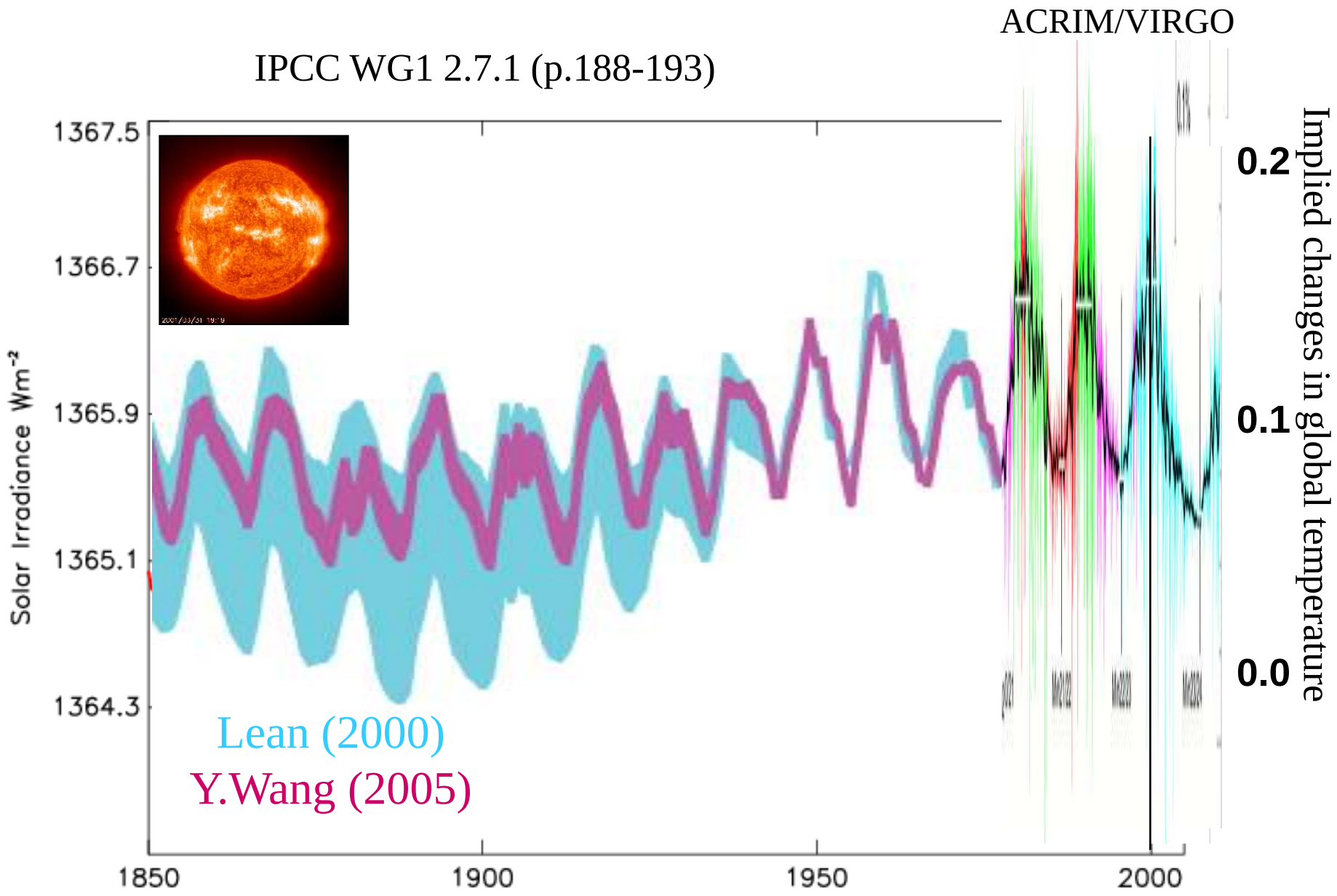


Satellite measurements (1970, 1997) confirm the effect of increasing greenhouse gases

IRIS/IMG spectra: Harries et al. 2001, Nature

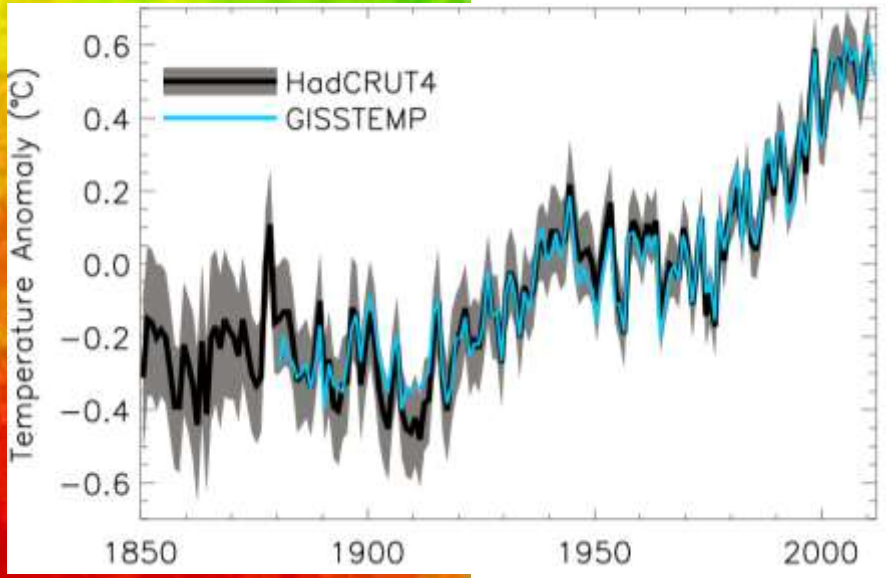


Energy from the Sun; stable over last 50 years

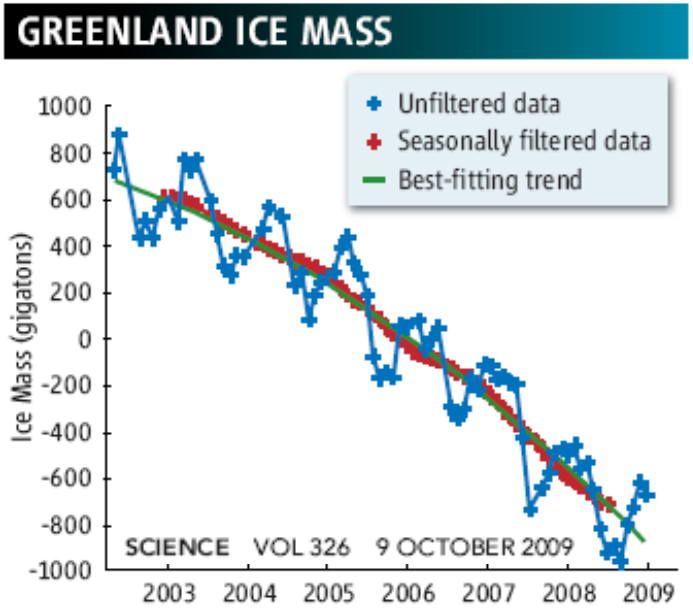


See also: http://www.pmodwrc.ch/pmod.php?topic=tsi/composite/SolarConstant

Monitoring sea surface temperature



Monitoring Land Ice From Space



Above: results from Gravity Recovery And Climate Experiment (GRACE) mission

Right: NASA's ICE-Sat satellite - Ice, Cloud and land Elevation Satellite

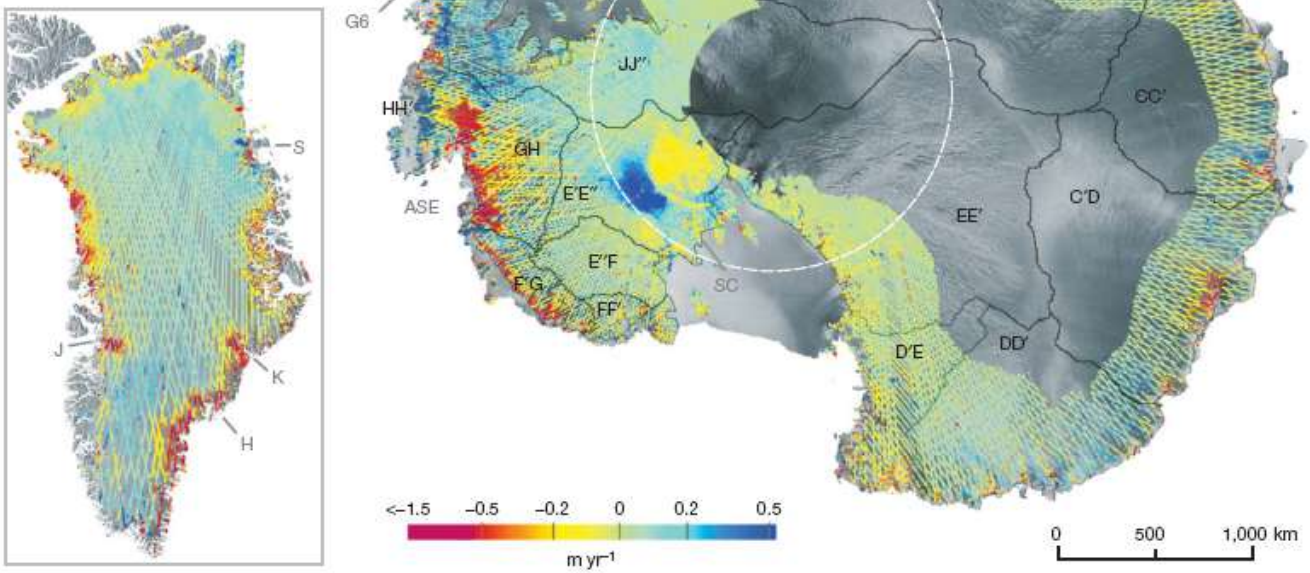
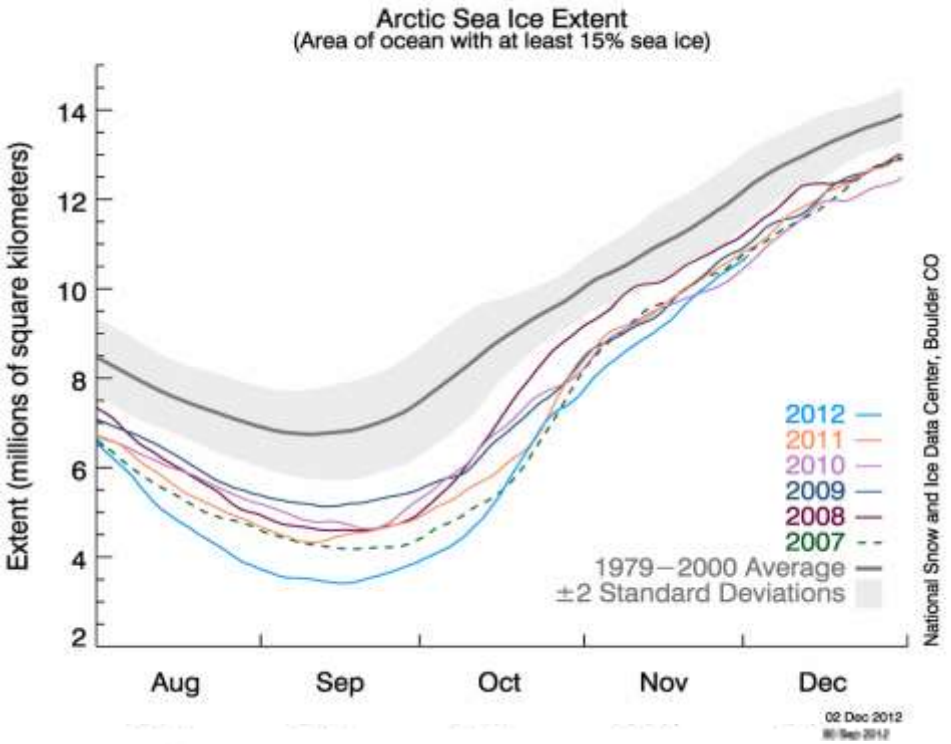


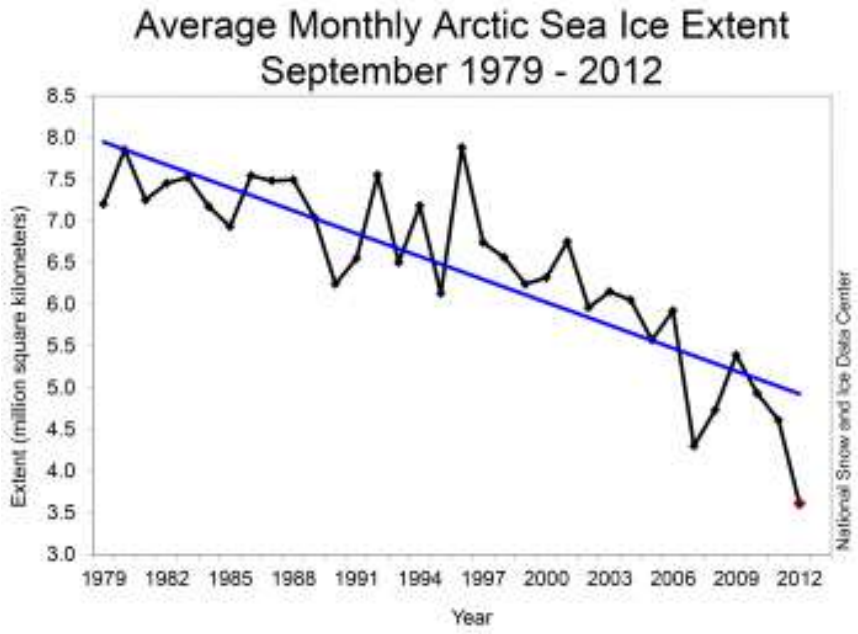
Figure 2 | Rate of change of surface elevation for Antarctica and Greenland. Change measurements are median filtered (10-km radius), spatially averaged (5-km radius) and gridded to 3 km, from intervals (Δt) of at least 365 d, over the period 2003–2007 (mean Δt is 728 d for Antarctica and 746 d for Greenland). East Antarctic data cropped to 2,500-m altitude. White dashed line (at 81.5° S) shows southern limit of radar altimetry measurements. Labels are for sites and drainage sectors (see text).

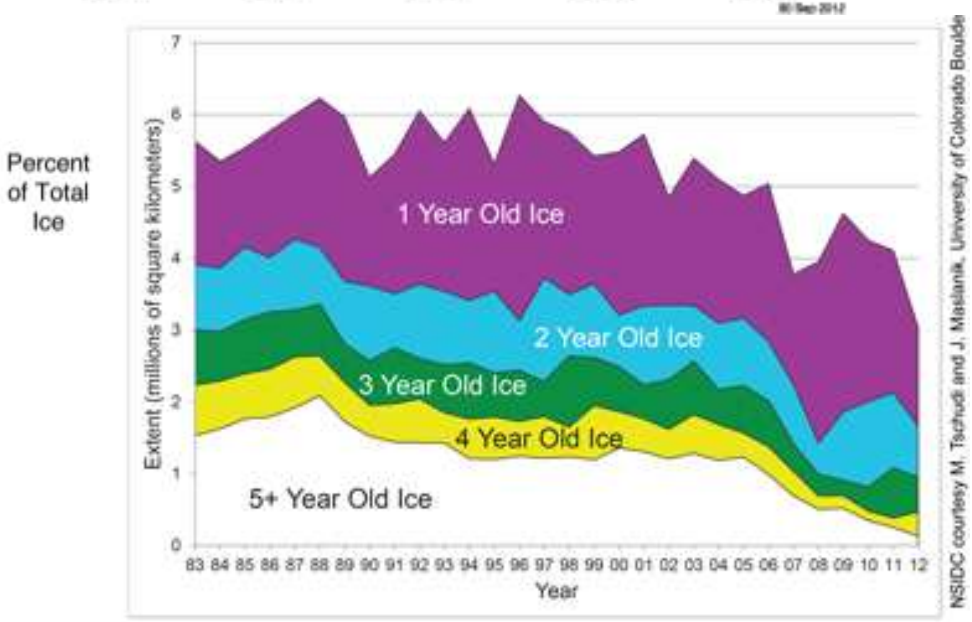
Arctic sea ice: Rapid decline in extent over satellite record since 1979, especially at ice minimum during Sept

+ Declining thickness

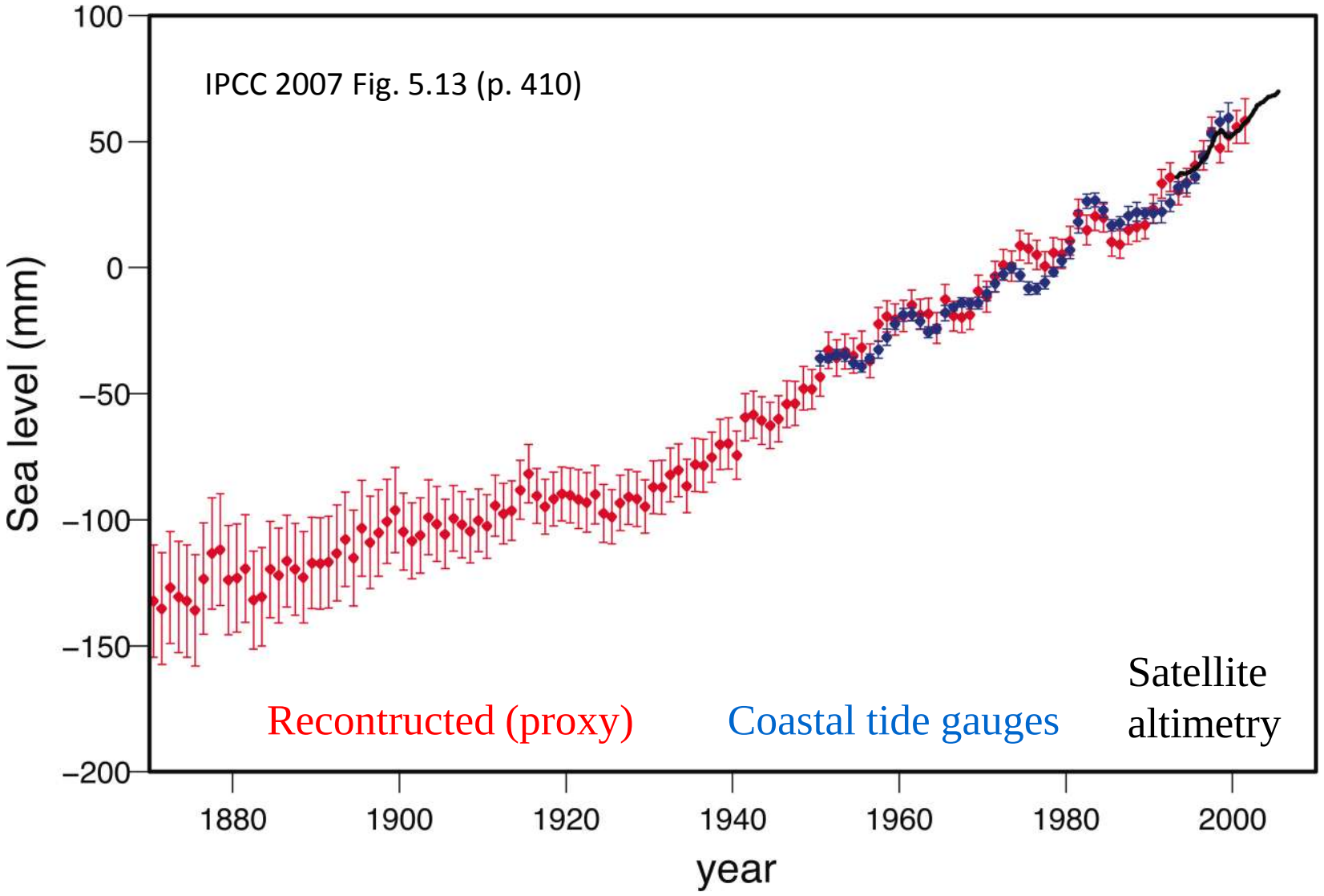


http://nsidc.org/news



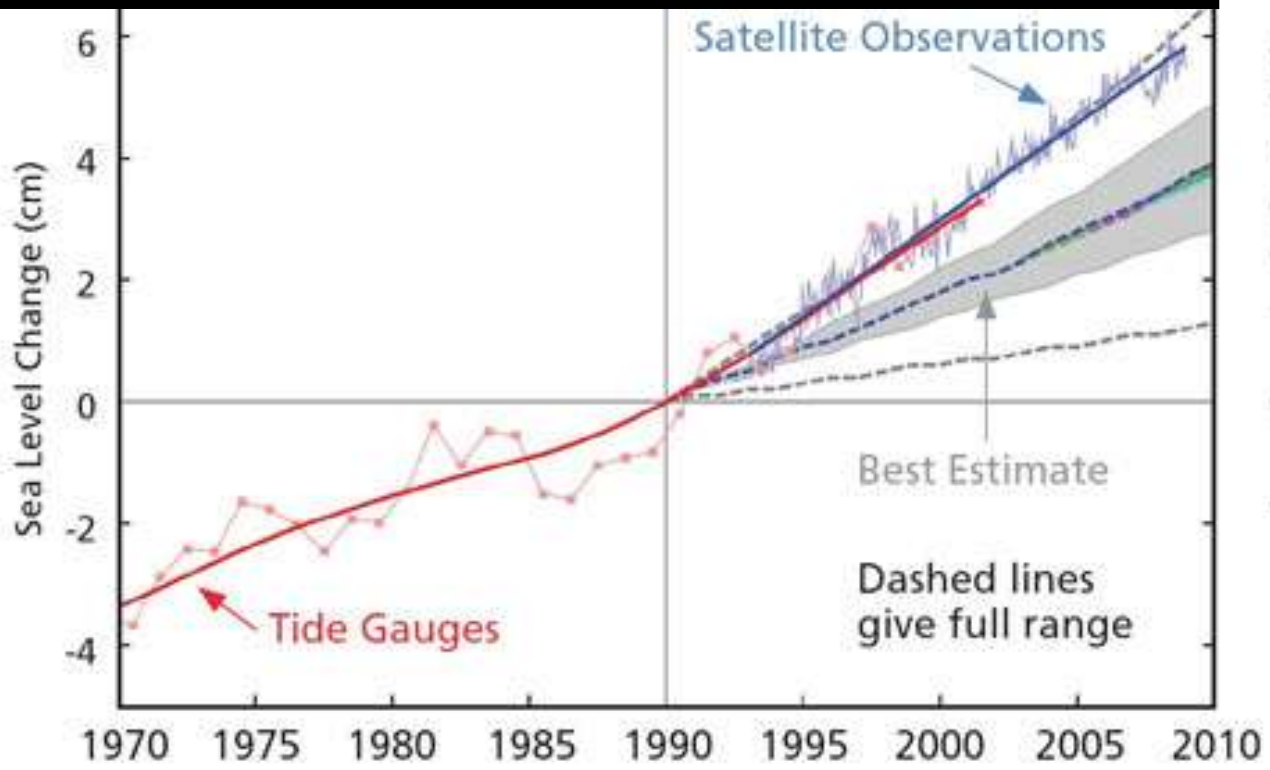


Monitoring Sea level



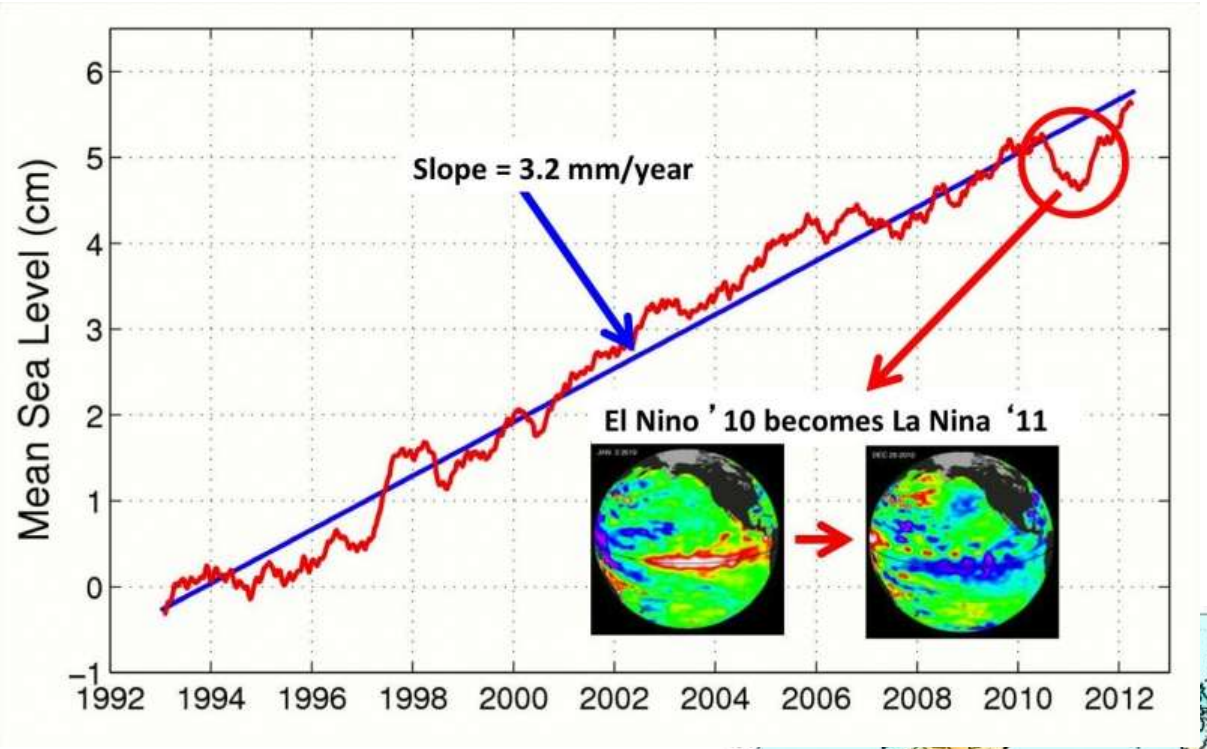
Current rises in global sea level

Is sea level rising faster than projections made by numerical climate simulations?



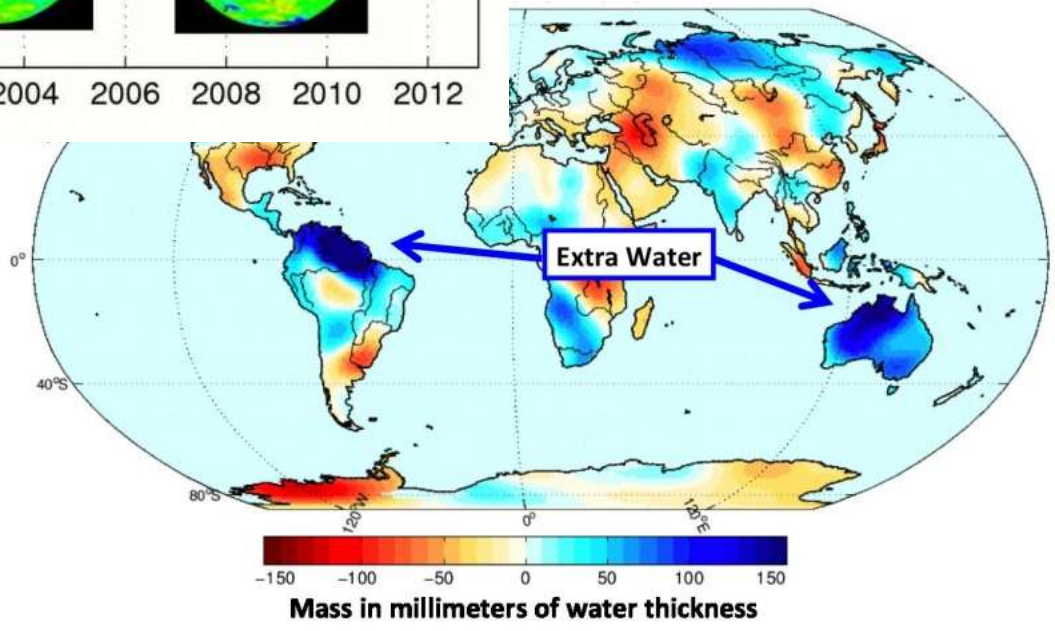
Research by Rahmstorf et al. (2007) Science, 4 May

La Niña so strong the oceans fell



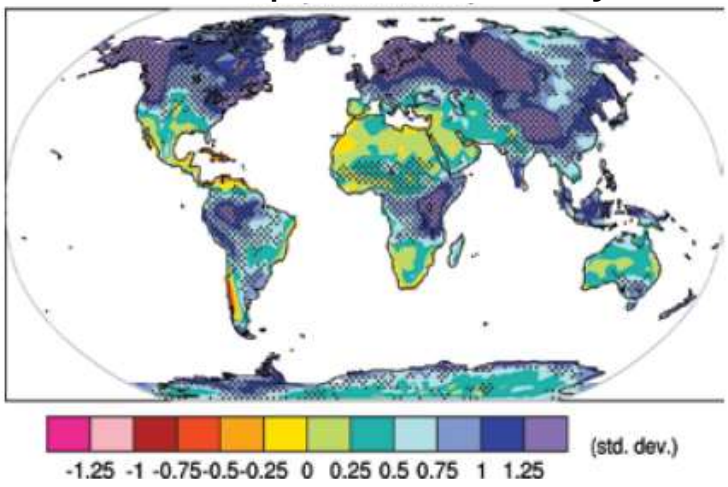
Boening et al. (2012) Geophysical Research Letters

New satellite instruments including GRACE can “weigh” the mass of the oceans and ground water

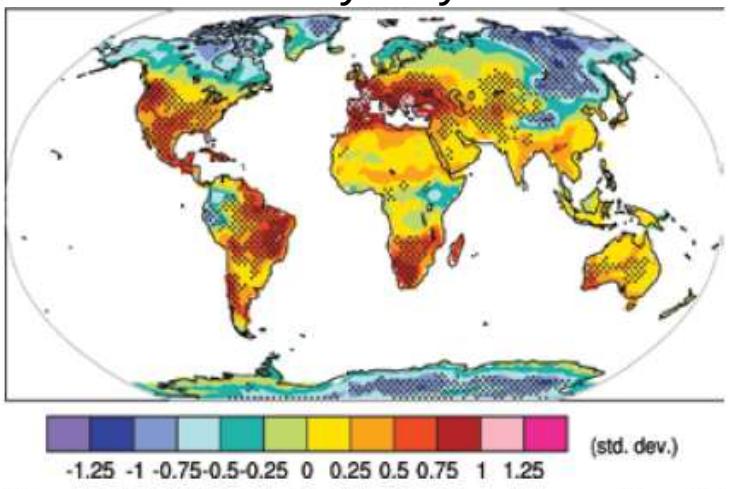


How will the water cycle change?

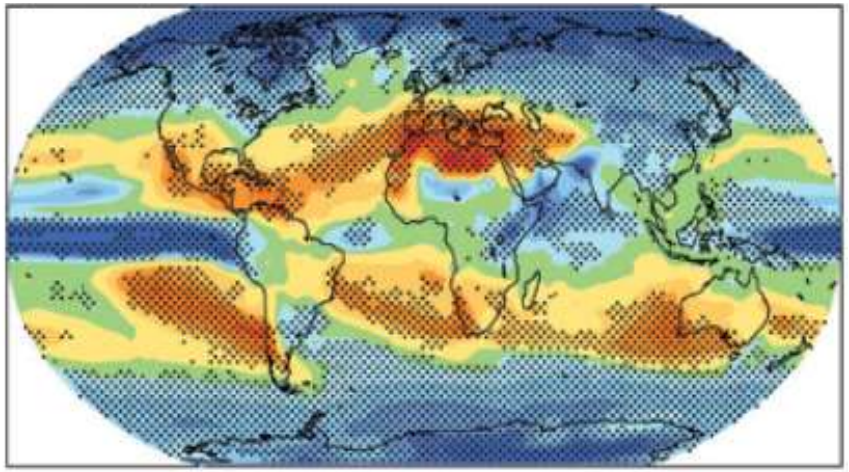
Precipitation Intensity



Dry Days



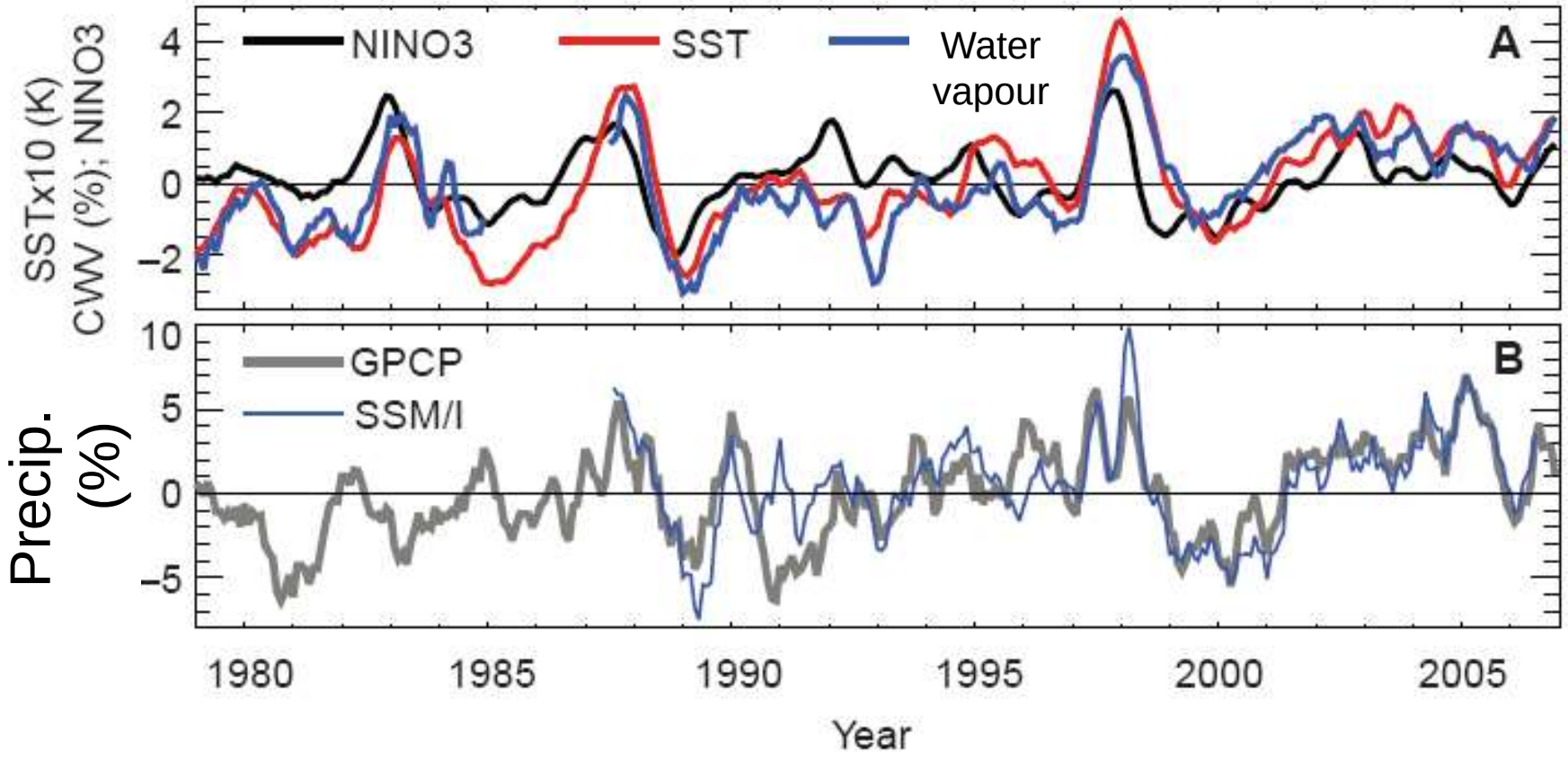
- Increased Precipitation
- More Intense Rainfall
- More droughts
- Wet regions get wetter, dry regions get drier?
- Regional projections??



Precipitation Change (%)

-25 -20 -15 -10 -5 0 5 10 15 20 25 (%)

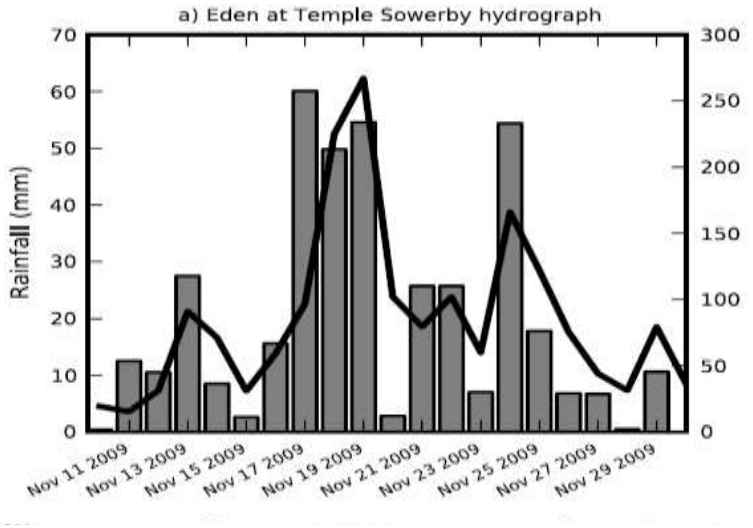
Using microwave measurements from satellite to monitor the water cycle

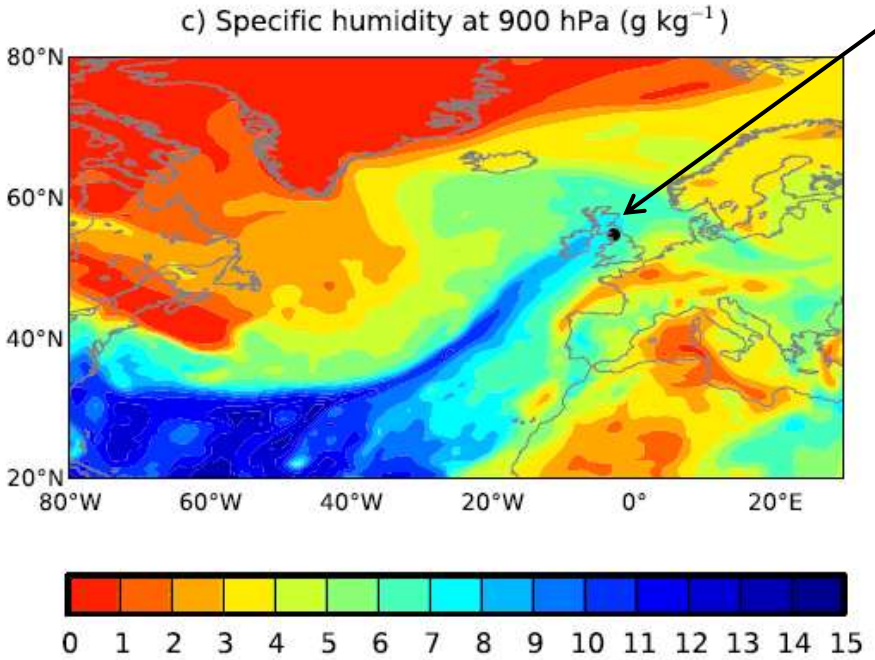


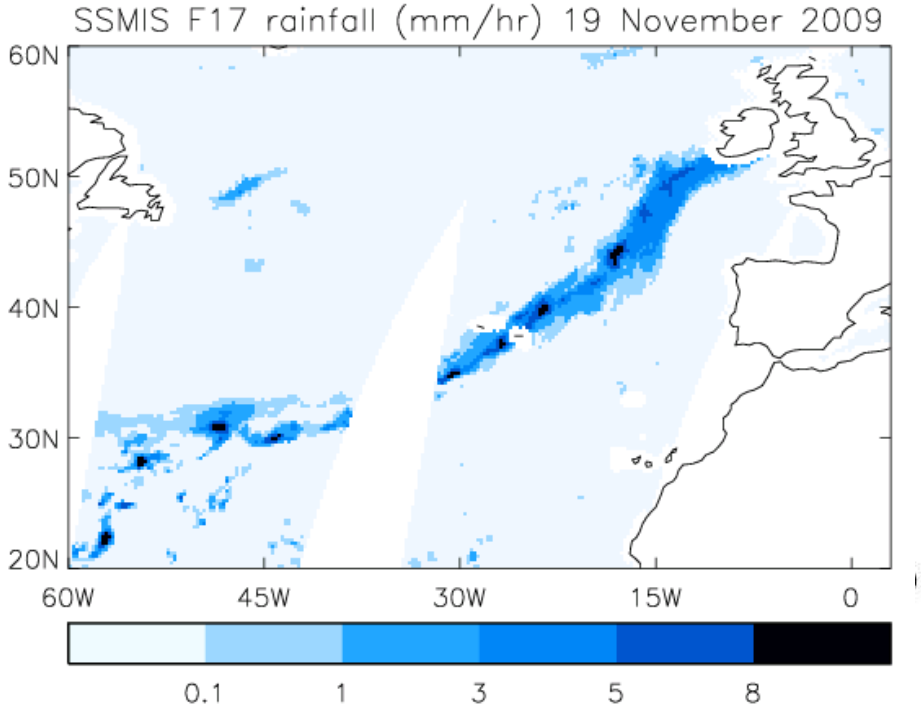
Allan and Soden (2008) Science

Linking atmospheric rivers viewed from space with flooding

HydEF project: Importance of large-scale atmospheric precursors for flooding e.g. 2009 Cumbria floods







[Lavers et al. (2011) Geophys. Res. Lett.]

Conclusions

University of Reading

- Earth's radiative energy balance drives climate change
- It also provides a rich spectrum of information
  - ❑ Monitoring and detecting climate change
  - ❑ Understanding physical processes
  - ❑ Enabling and evaluating prediction
- Challenges...
  - ❑ Clouds & Aerosol
  - ❑ Precipitation
  - ❑ Regional impacts

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