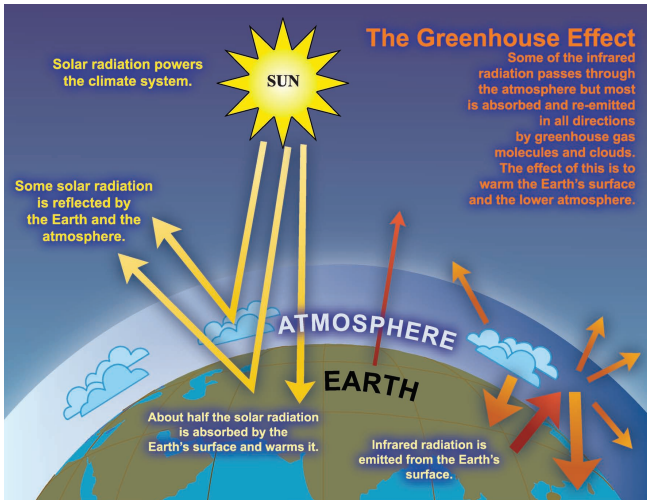
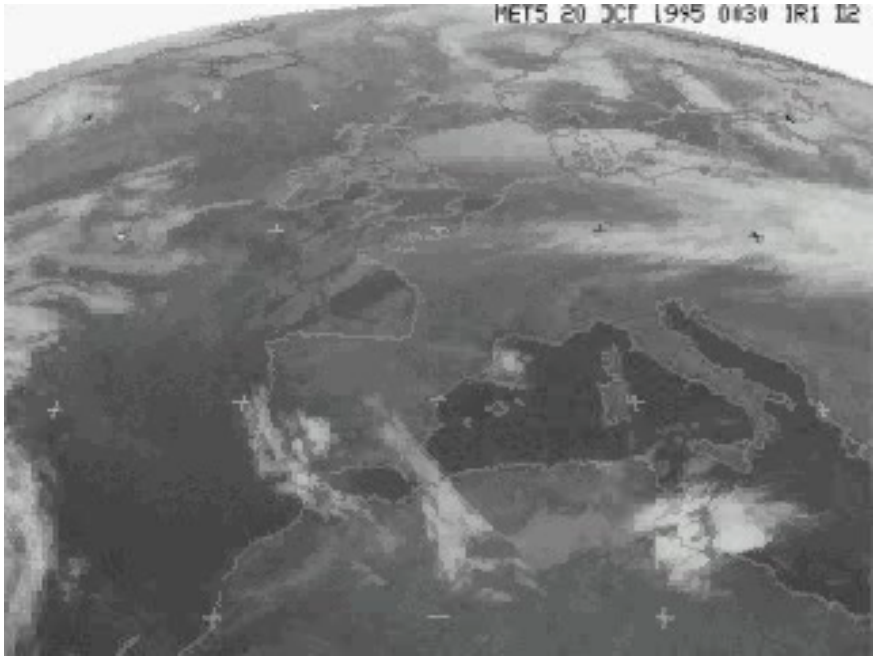
The carbon and climate problem

- What is the evidence?
- What are the caveats?
- What are the long-term implications?





Prof. Ric Williams

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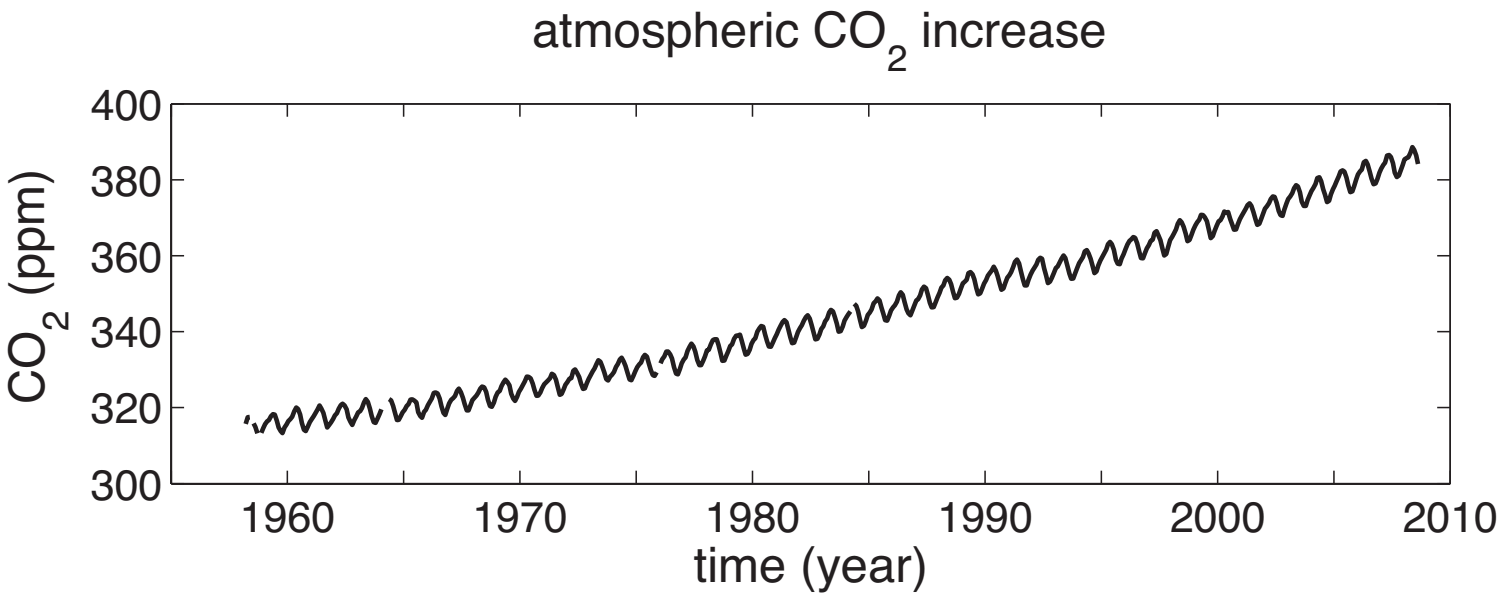
www.liv.ac.uk/climate

1. What is the evidence?

data/simple theory



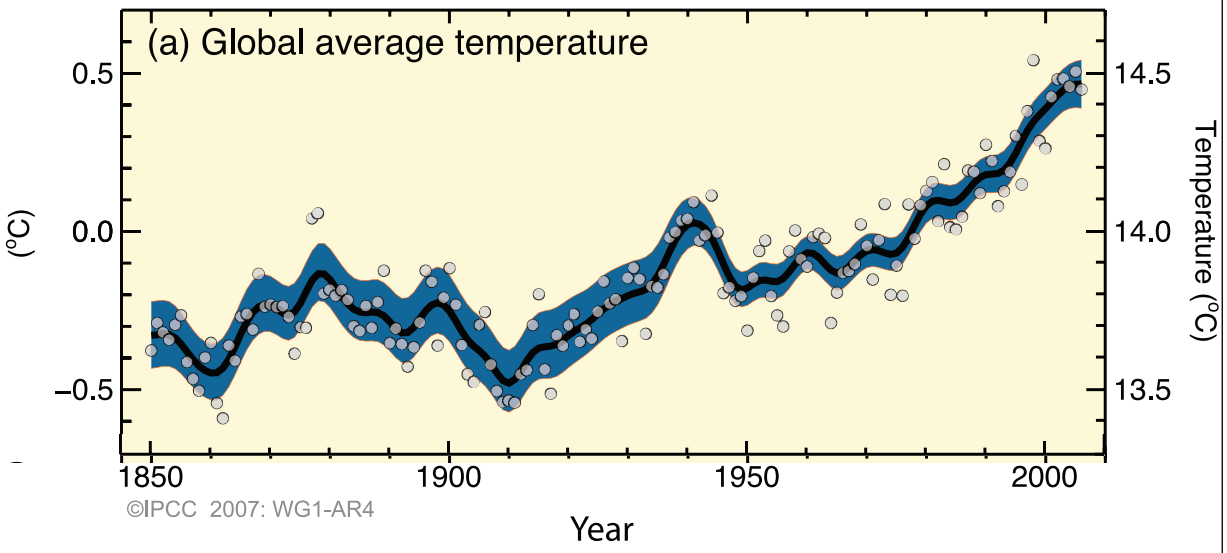
Simple theory suggests rise in atmospheric CO_2 gives

- global rise in surface heat flux ~ 1 W m^{-2}
- ocean temperature rise ~ 0.4°C

Signals of global warming (from IPCC, 2007)

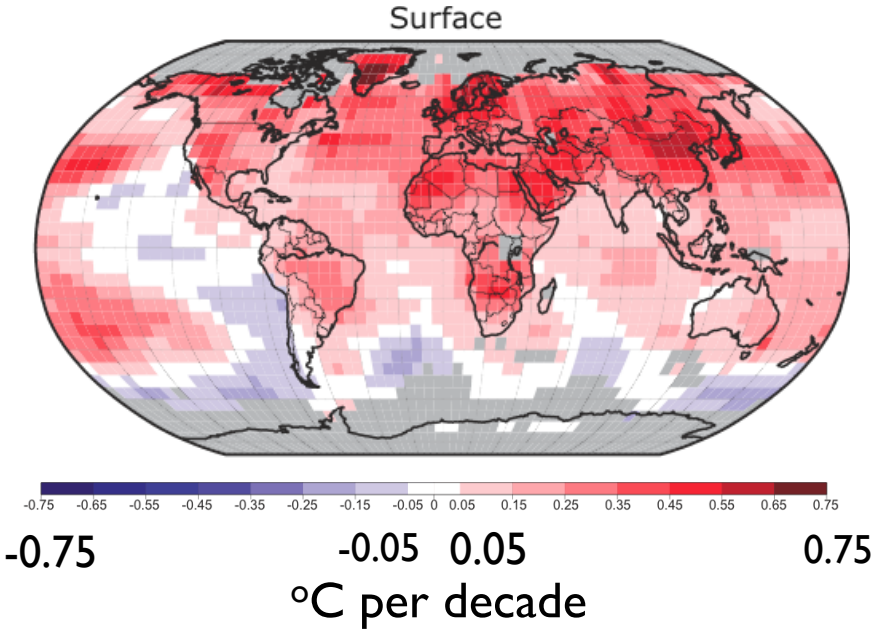
global data

global warming of 0.6°C since 1950



surface warming since 1979:

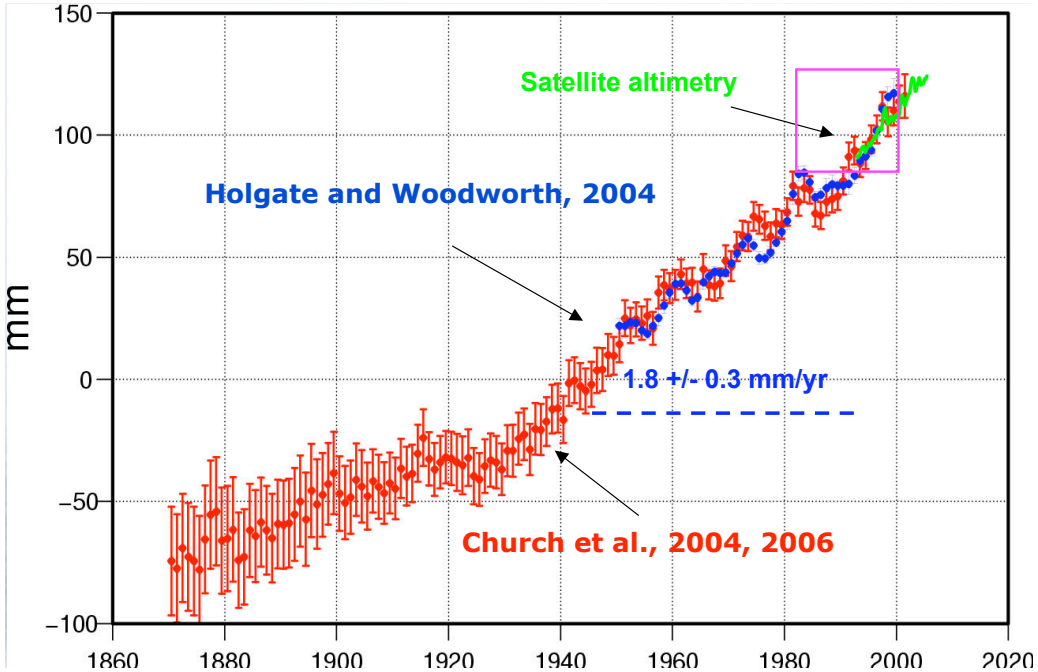
- warming over most of globe
- land warming faster than ocean



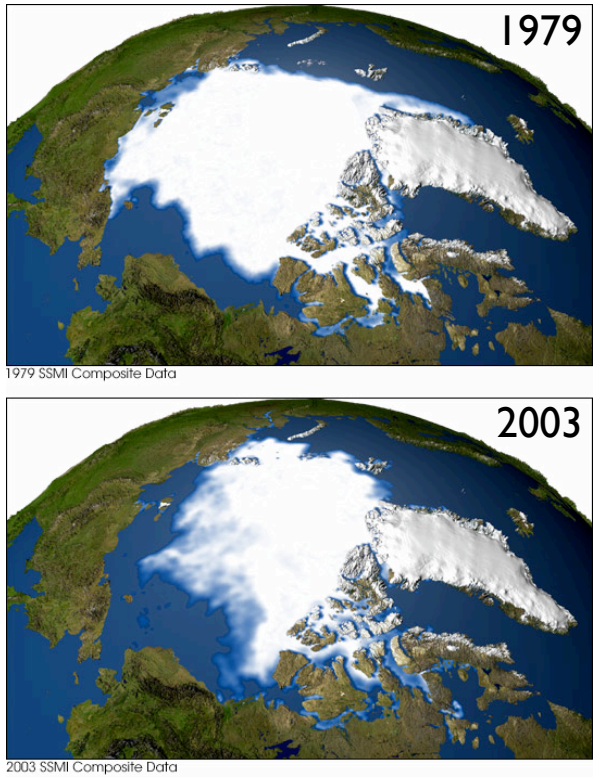
Other signals

global /regional data

- rise in sea level

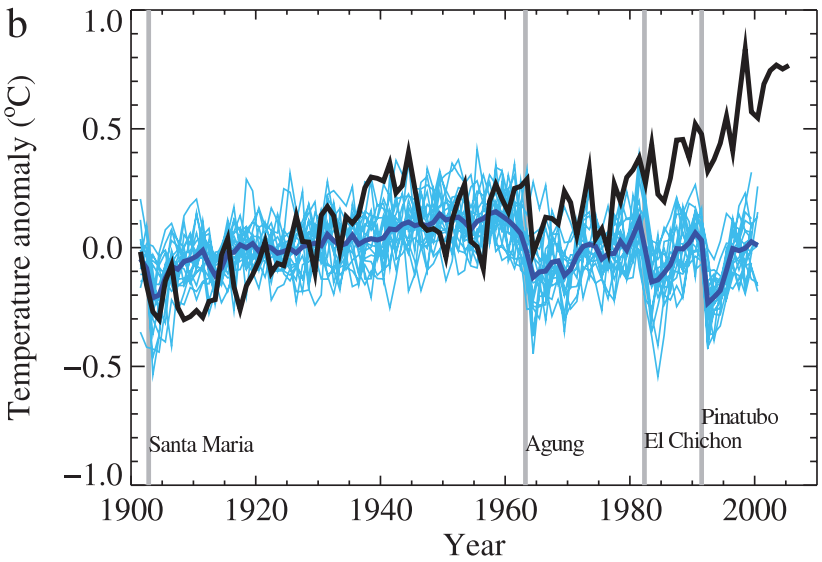


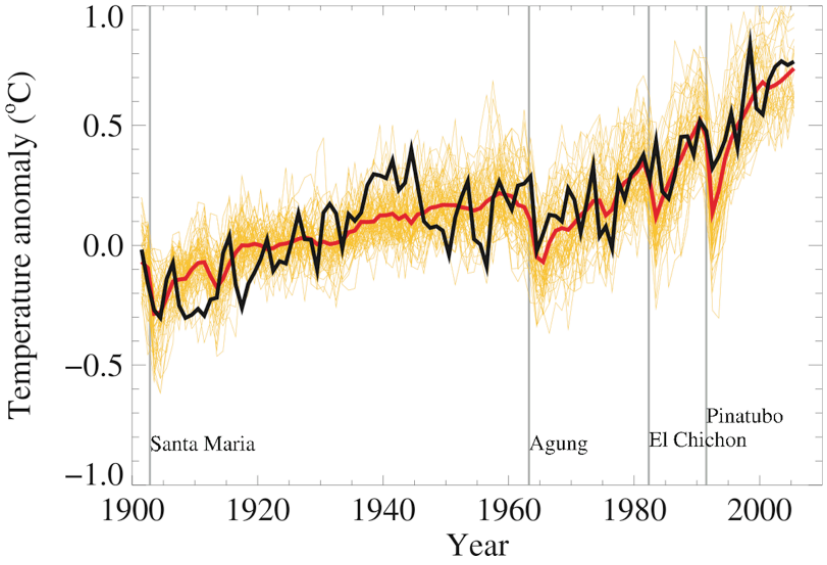
- retreat in summer Arctic sea ice



climate models

Is the recent warming due to carbon dioxide?





data: black line

climate model with only natural forcing: blue line (19 simulations, 5 models)

climate model with anthropogenic forcing: red line (58 simulations, 14 models)

2. What are the caveats?

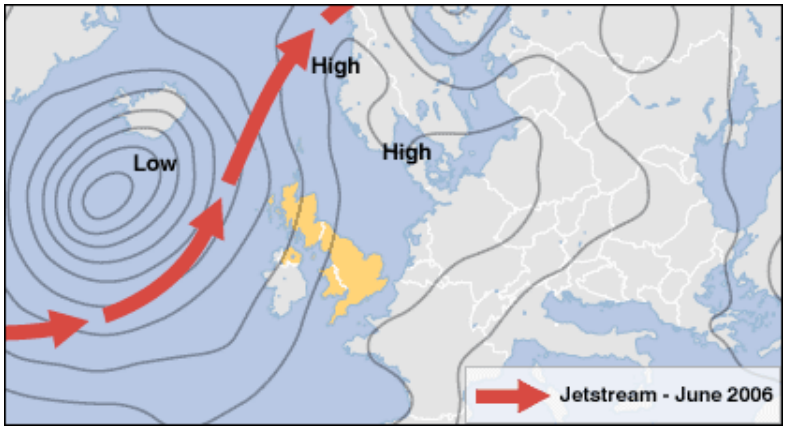
models/regional data

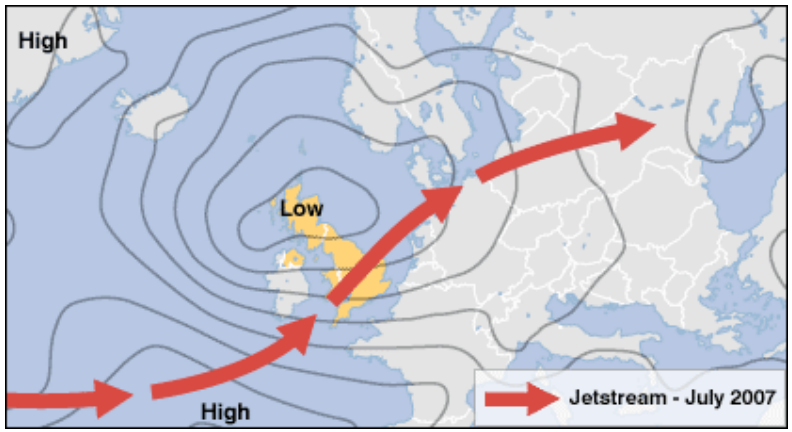
While globe is warming, regional signals are complex.

- How wet is each summer?

In summer 2007, the jetstream is flowing further south allowing low pressure systems to sweep straight over the centre of the country.

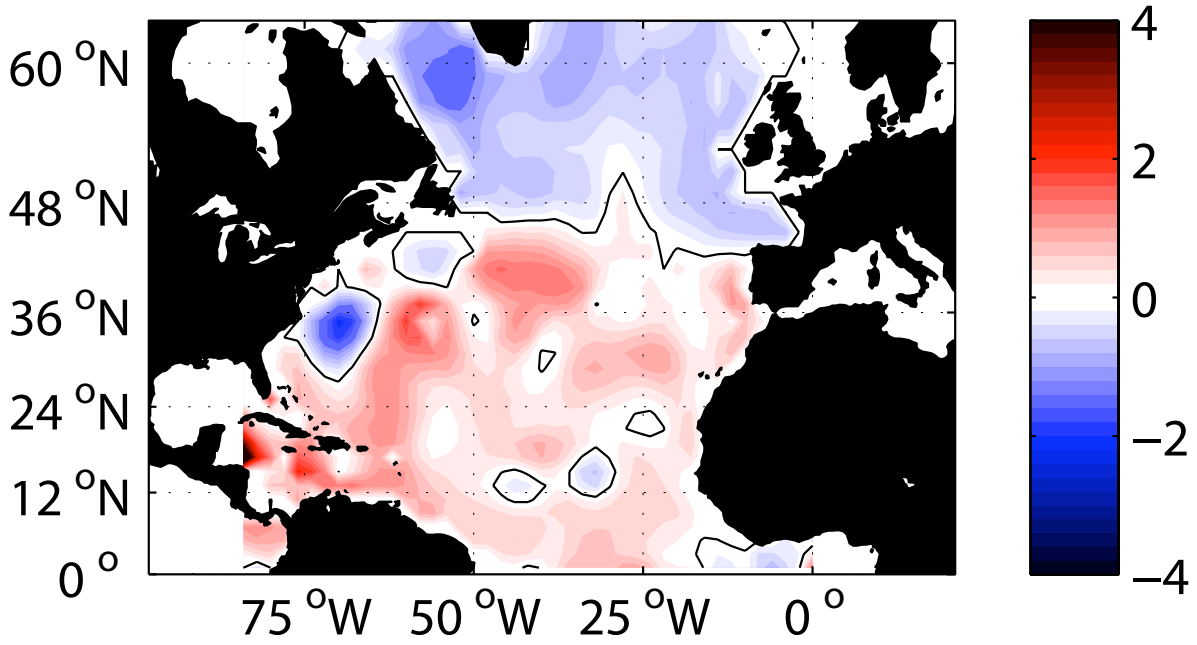
Pressure chart: 4/07/07.
Source: Met Office





data

- How has ocean warmed over last 50 years?



Change in ocean heat content (10^{20}J)
between 1980-2000 and 1950-1970

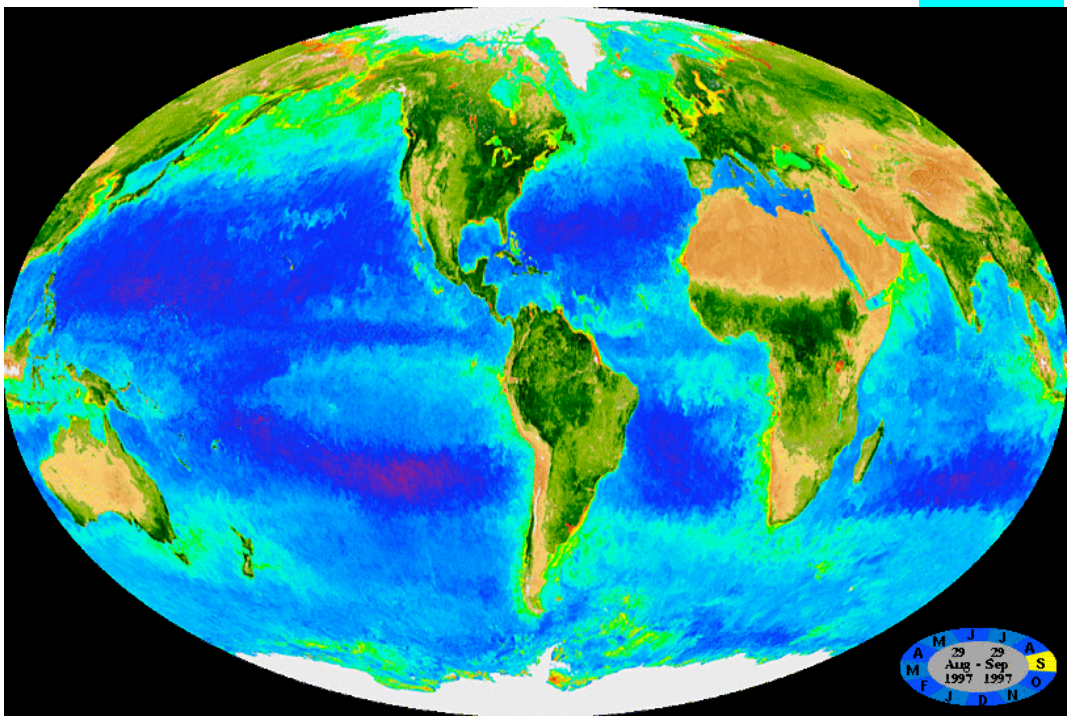
- Decadal, natural variability might mask any **local** signal of greenhouse forcing

Lozier, Leadbetter, Williams et al. (2008) Science

3. What are the long-term effects?

data

- Ocean holds ~ 50 as much carbon as in the atmosphere
- 1/3 of the recent industrial emissions of carbon has gone into ocean



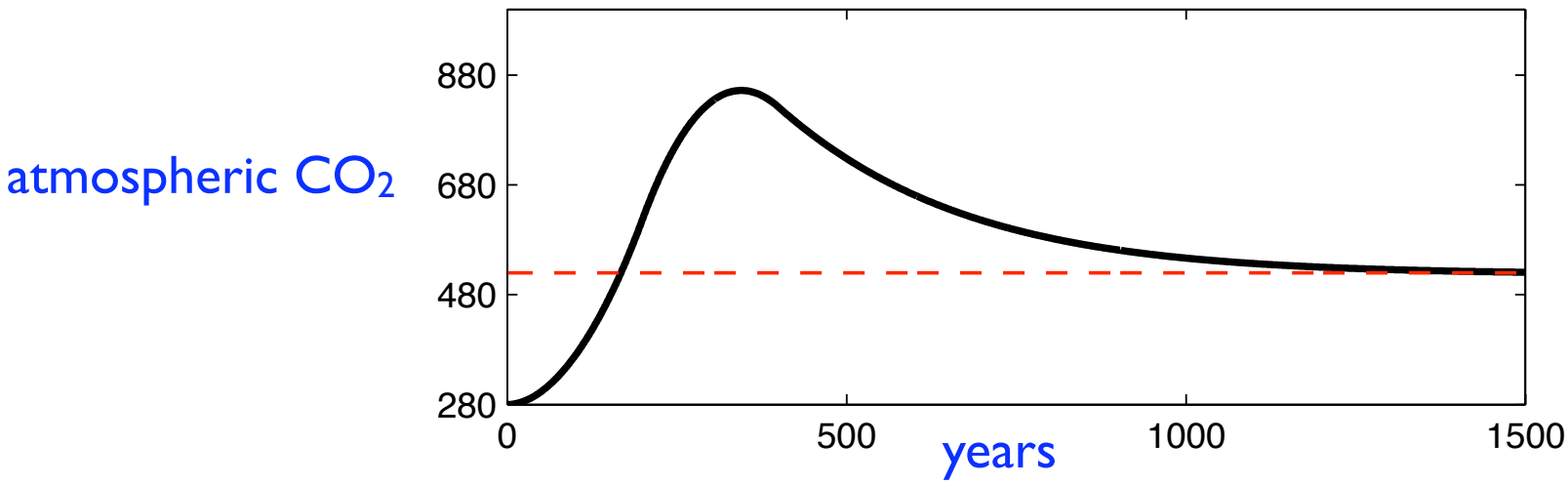
Remotely-sensed picture c surface chlorophyll (NASA

What is the problem?

- Ocean takes up less carbon dioxide as it becomes more acidic

simple theory

So what happens if we burn all our fossil fuels?



- Initial fast rise in atmospheric CO_2
- Eventually approach a steady state

Final radiative heating varies *linearly* with size of carbon emissions

(emit 1000 GtC implies extra heating of 1.5 Wm^{-2} lasting for millennia)

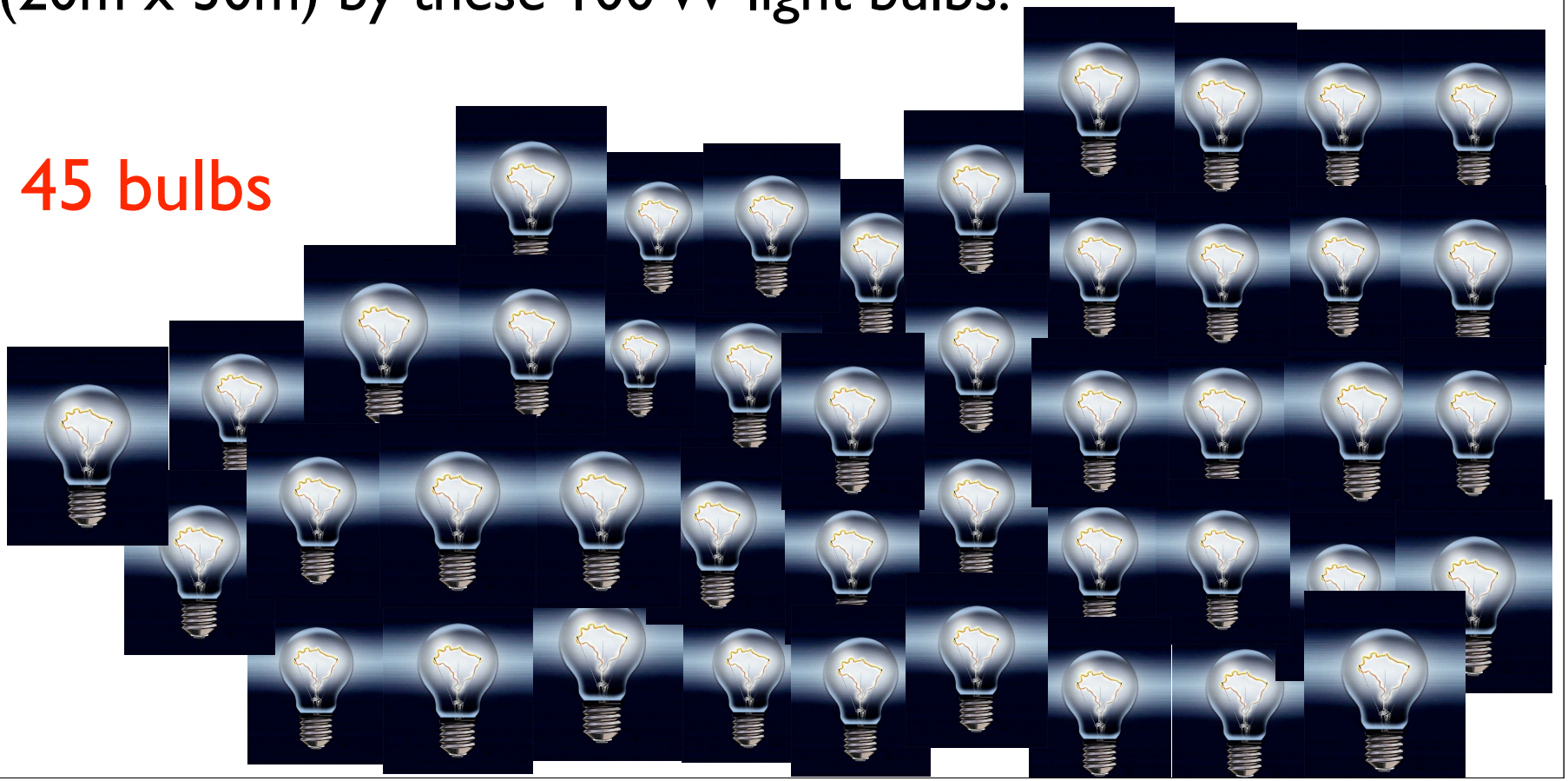
Goodwin, Williams et al. (2009) Nature Geoscience

simple theory

If burn all of conventional fossil fuels, 5000 GtC without carbon capture, then extra heating of $7.5\,Wm^{-2}$

equivalent to heating given in a room (20m x 30m) by these 100 W light bulbs:

45 bulbs



Legacy for future generations

speculations

if release all the carbon in conventional fossil fuels,
~ 5 x present anthropogenic heating lasting for millennia

tipping points:
melting Greenland ice

release methane stored
in frozen tundra

UAF researcher Katey Walter lights a pocket of methane on a frozen lake in Siberia in March of 2007. (Credit: Photo by Sergey Zimov)

Implications

Personal : Institutional : National : International

- Energy policy
- Transport
- Use of resources
- Sustain ecosystems

Liverpool University is setting up an Energy Institute

http://hep.ph.liv.ac.uk/~green/energy/home.html

Tim Greenshaw (Physics)

- Real challenge to produce enough clean electricity

- Need to investigate feasible technologies (solar, wind, wave, tide, fission, fusion, clean coal)

- Solar power (Peter Weightman, Chris Lucas, Physics)

  small fraction of Earth's deserts could provide global needs
  (but cannot make enough photoelectric cells)

- Tidal power (Richard Burrows, Engineering; Judith Wolf, POL)

  minimize environmental impact by extracting energy on part of tidal cycle

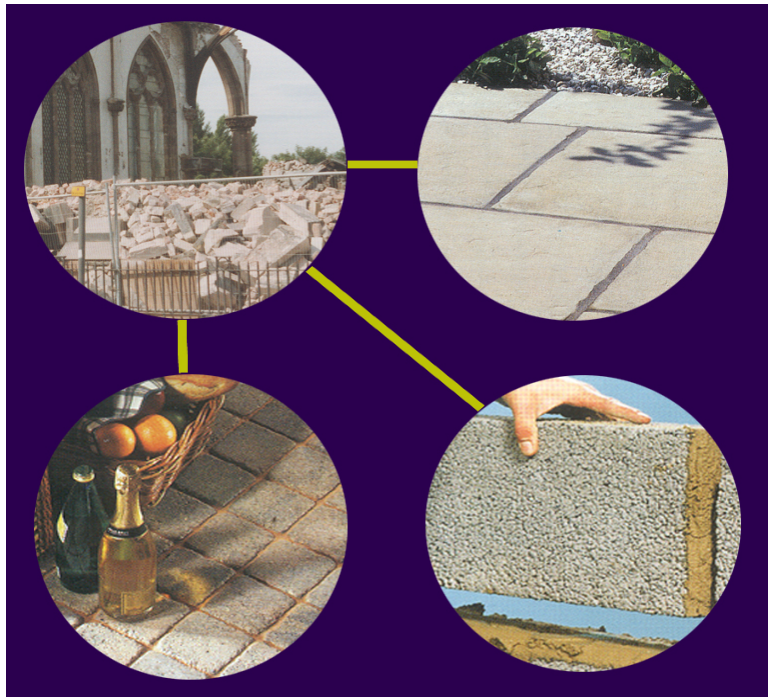
  continuous power supply if several schemes along UK coast

La rance tidal power plant

www.liv.ac.uk/engdept/tidalpower

- Recycle concrete (Marios Soutsos, Engineering)

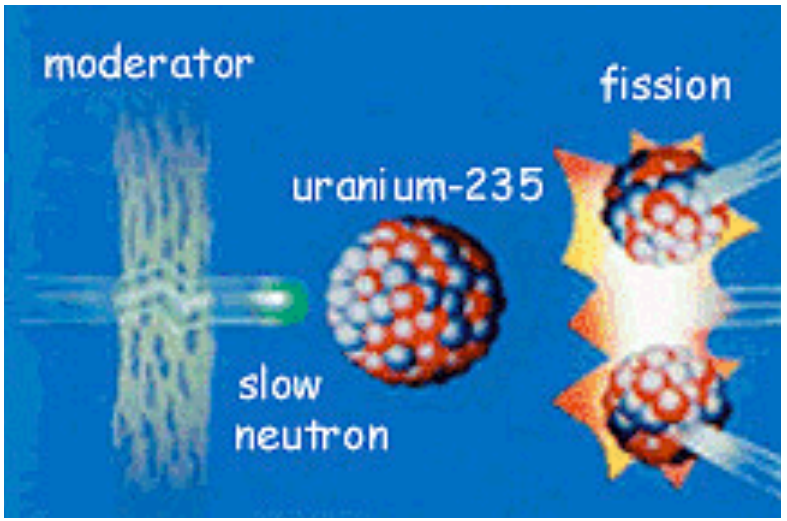
develop concrete products from demolition waste



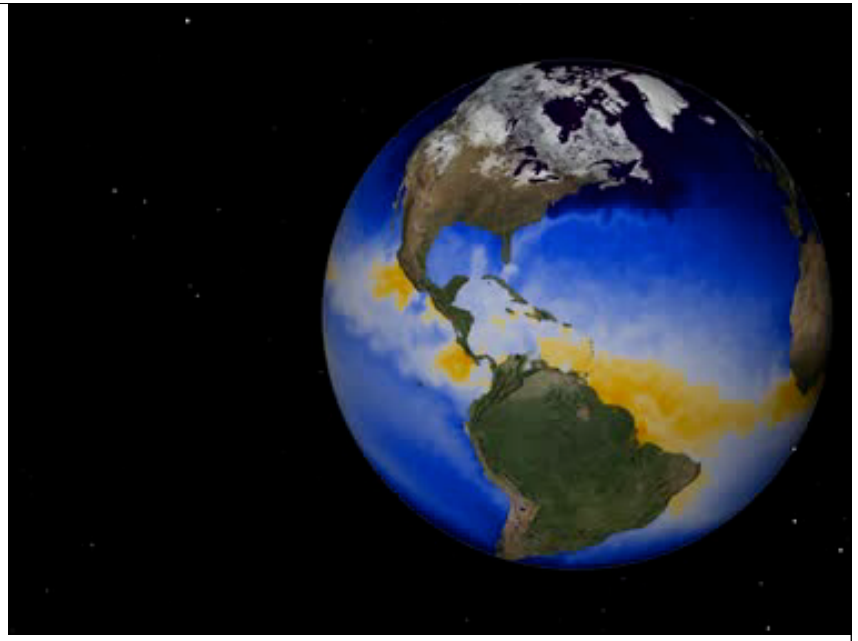
- Nuclear fission (Tim Greenshaw, Physics)

investigate safer alternatives to standard approach

possibly use thorium via sub-critical reactions



Conclusions



1. Science

   Global warming is happening.

   Large regional and
   inter-annual variability.

2. Implications

   Need to take long term and ethical perspective

   Requires co-ordinated planning

   Opportunity to develop new technologies and good practice