

# Climate change, does it add up?

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UNIVERSITY OF  
**BATH**

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**EXETER**



**Met Office**

Do **you** believe in man made climate change?



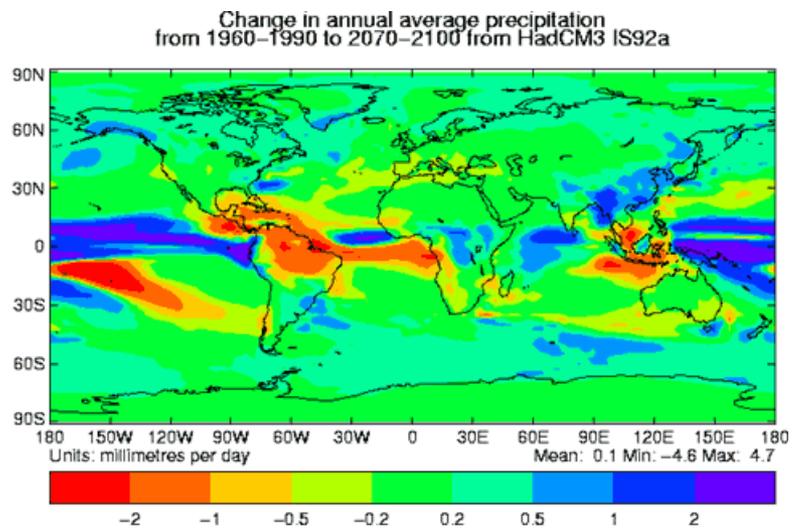
**“Humans are a 'plague on Earth': Sir David Attenborough warns that negative effects of population growth will come home to roost”**



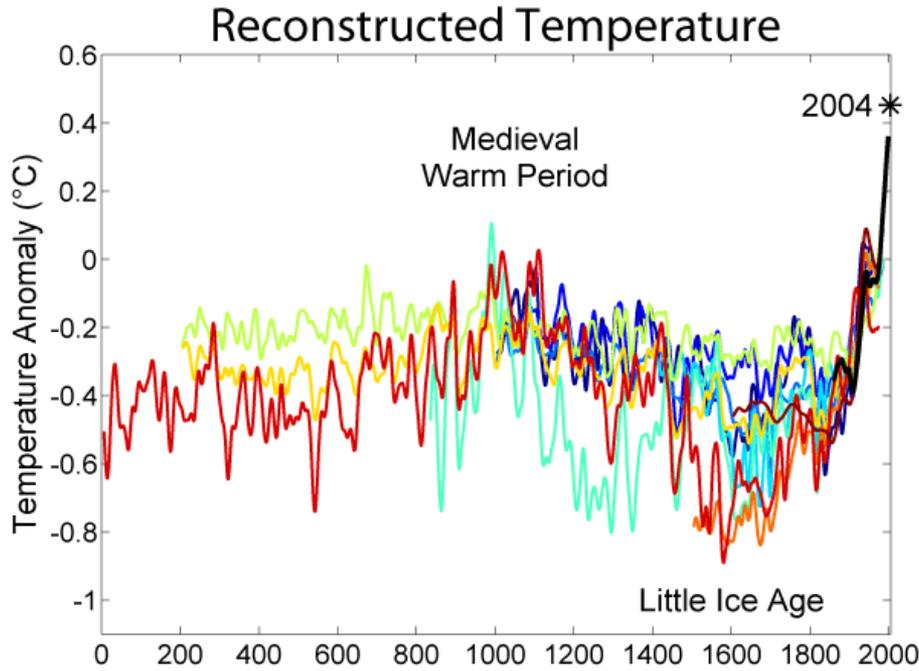
**YES?**

**No?**

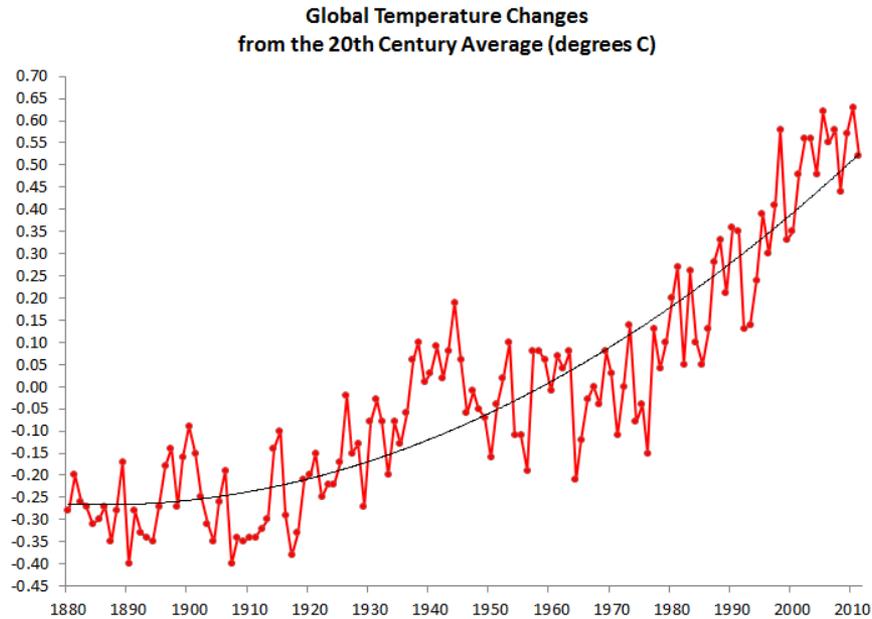
# Five indicators of climate change



# 1. Increasing temperatures

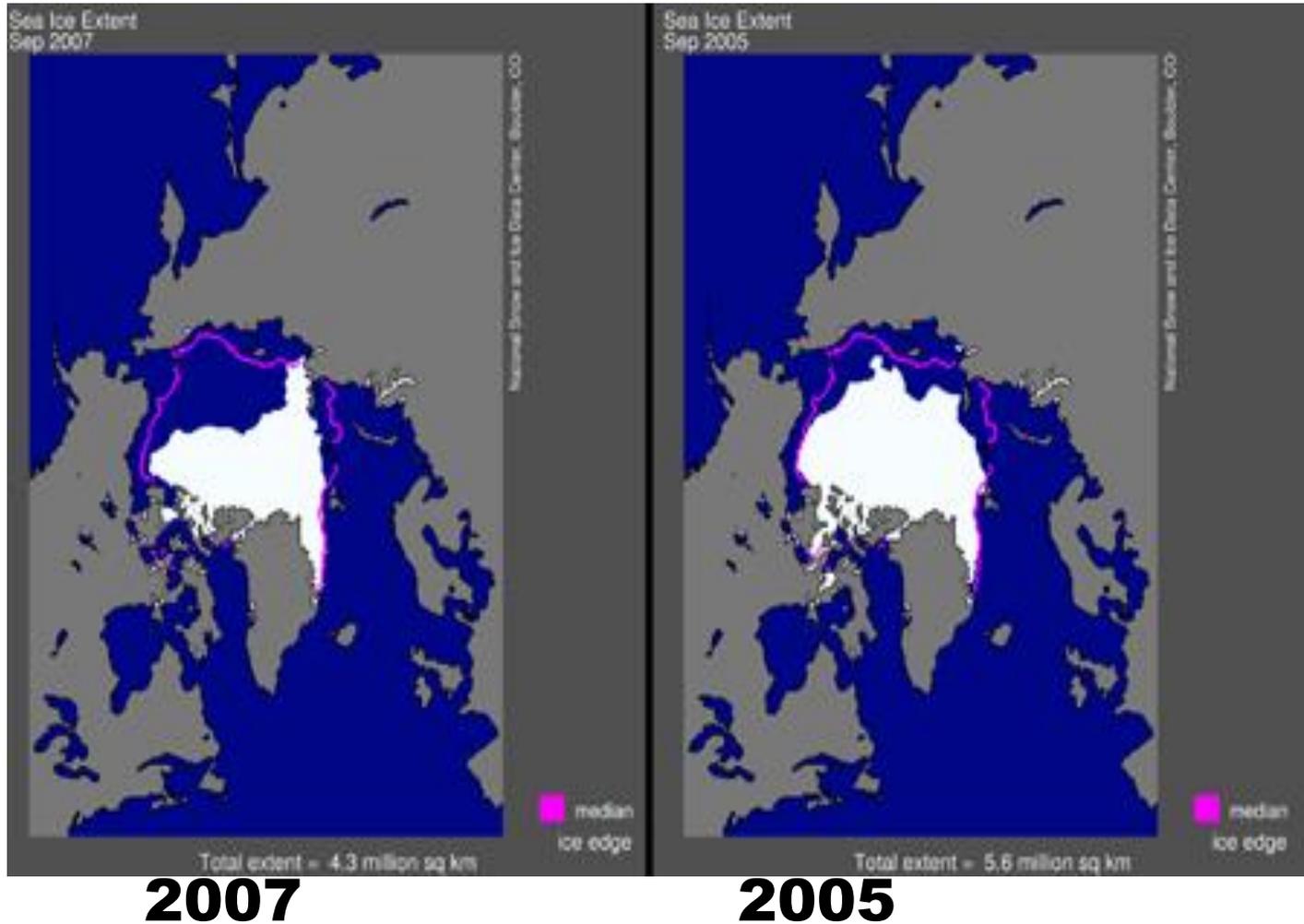


2005 was the hottest year ever recorded!



But note the last ten years

## 2. The Melting Arctic

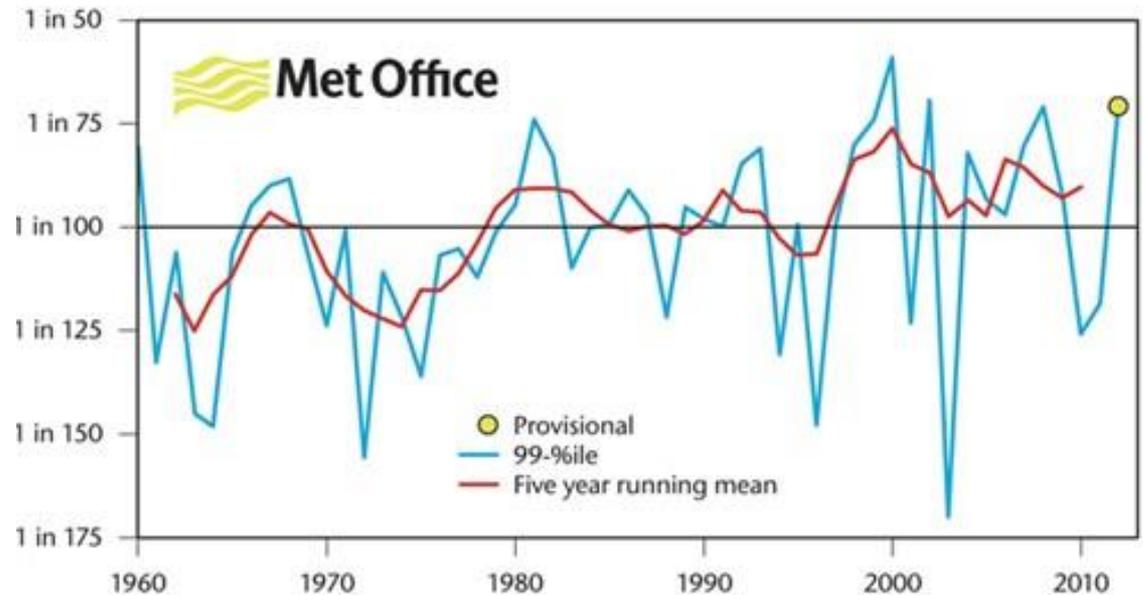


Every year we lose Arctic ice the size of Scotland!

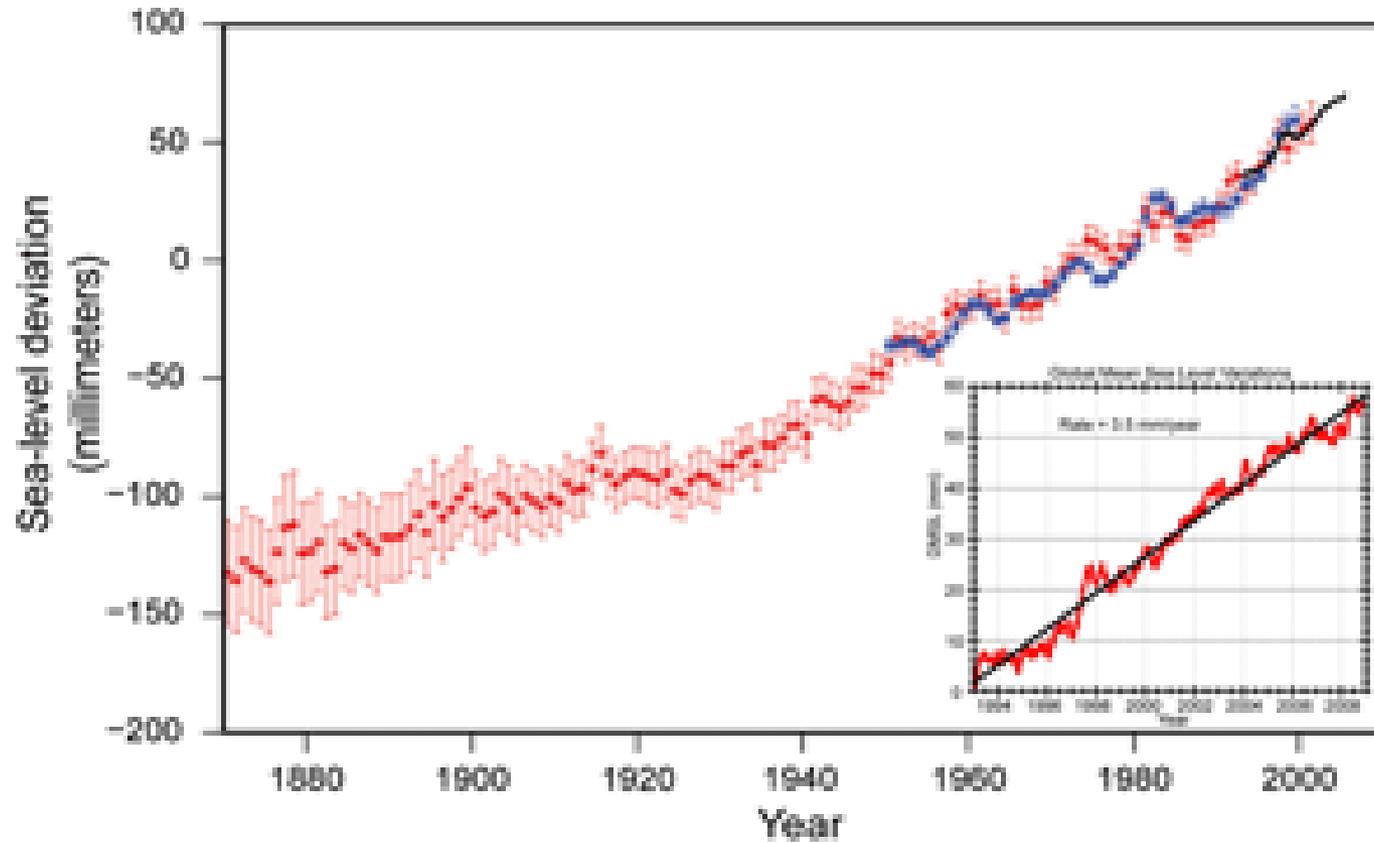
### 3. Changes in rainfall patterns (UK)

2000: Wettest year ever, 2012 second wettest

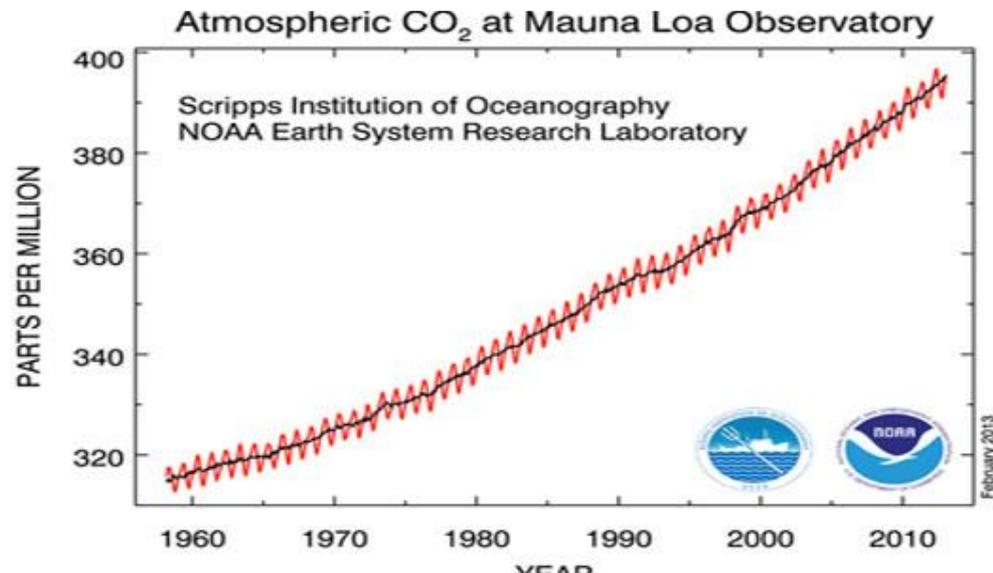
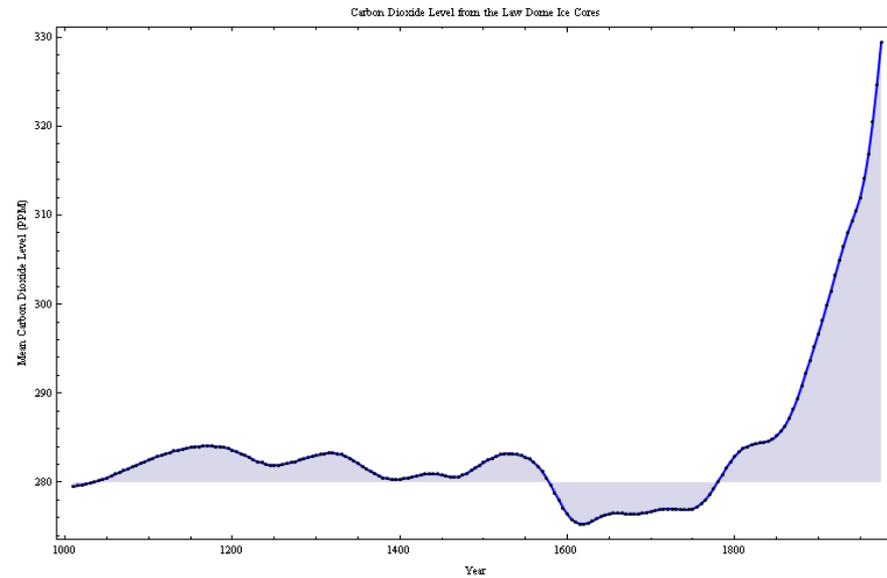
Top five wettest years in the UK		
1	2000	1337.3 mm
2	2012	1330.7 mm
3	1954	1309.1 mm
4	2008	1295.0 mm
5	2002	1283.7 mm



## 4. Sea Level Rise

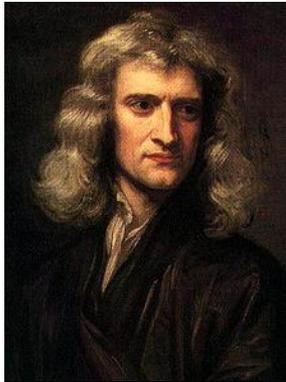


## 5. Increase in Atmospheric Carbon Dioxide

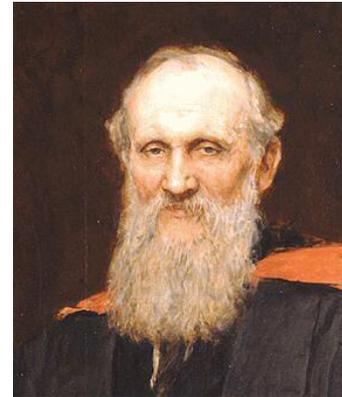


To make future predictions and to make sense of current data we need good climate models

Take laws of physics



**Motion**



**Heat**

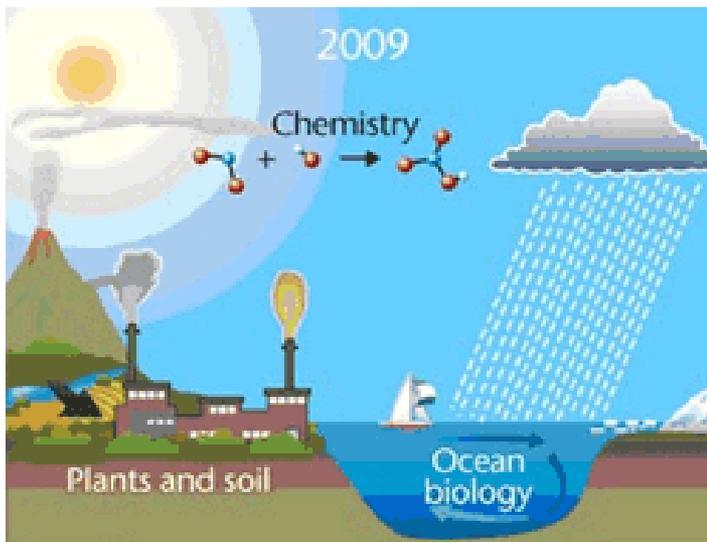
Turn them into mathematical equations

Inform them with data

Solve these on a supercomputer to try to predict the climate

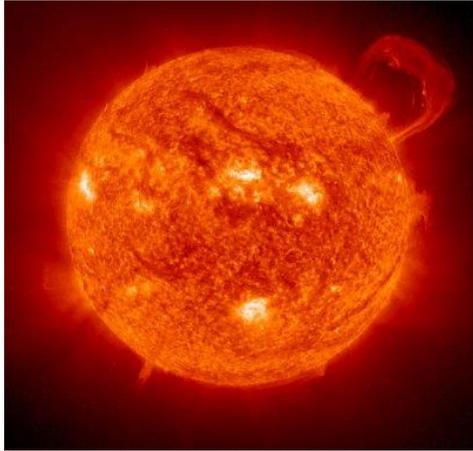


# Climate models are constantly improving to cope with complexity

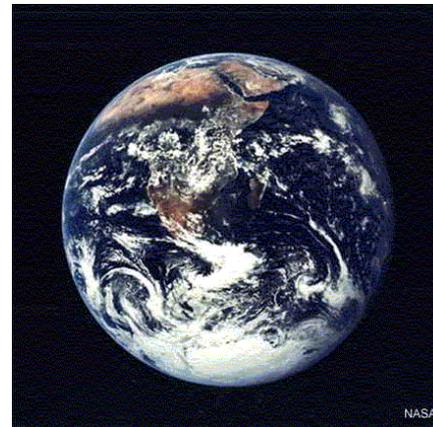
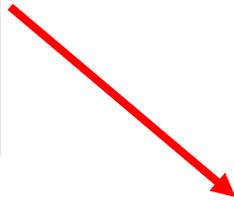


Tested by being used to predict past climate change

Let's see if we can forecast the climate with a simple model

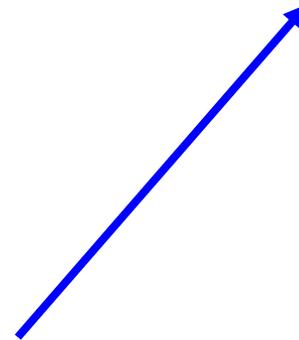


Heat from Sun:  $S$

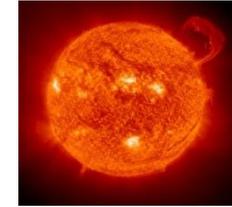


Earth's mean temperature:  $T$

Heat into space

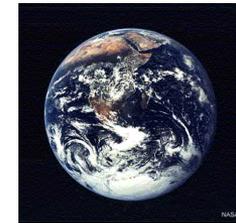


Heat absorbed  $\longrightarrow$   $dS$



d Darkness: How well the earth absorbs the Sun's rays

Heat radiated away  $\longrightarrow$   $e\sigma T^4$



e **emissivity**: How much energy is radiated into space

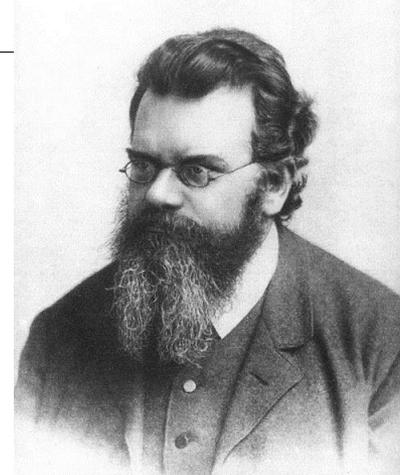
**Balance these to give a simple climate model**

$$e\sigma T^4 = dS$$

# If we know $e$ , $\sigma$ , $d$ , $S$ we can work out $T$ !!!!

## Currently

Emmissivity	$e = 0.55,$
Boltzmann	$\sigma = 5.67 \times 10^{-8}$
Darkness	$d = 0.68,$
Solar heating	$S = 300\text{W}/\text{metre}^2$

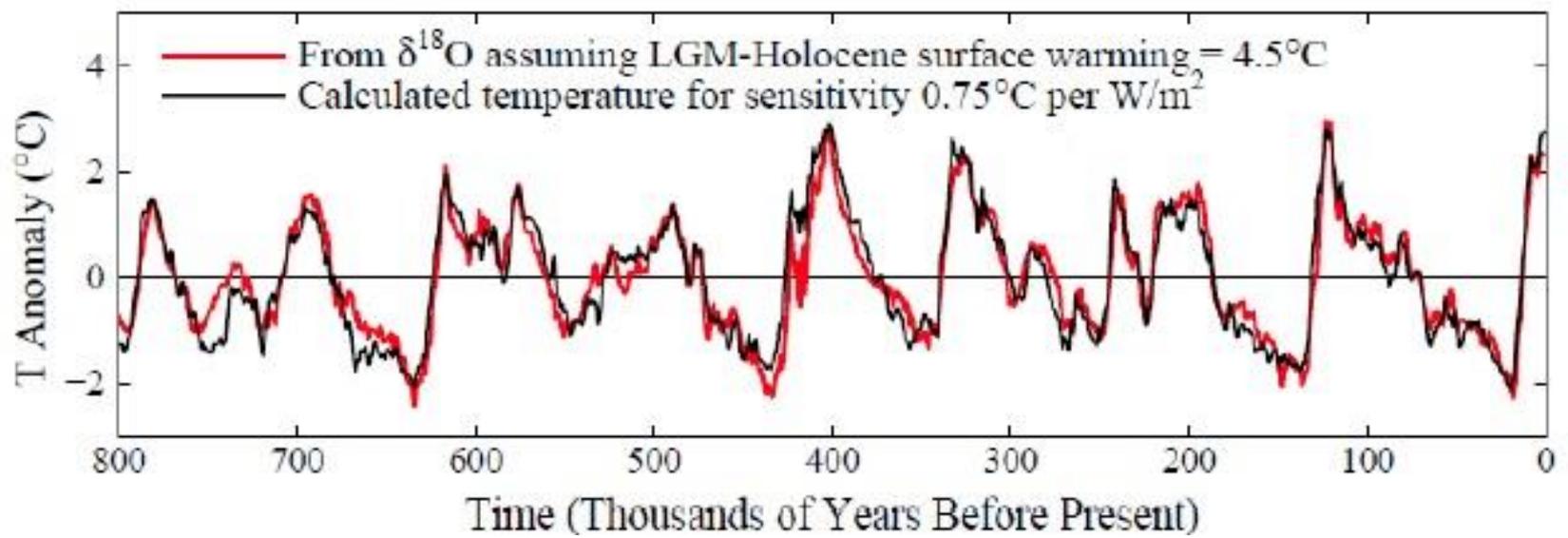
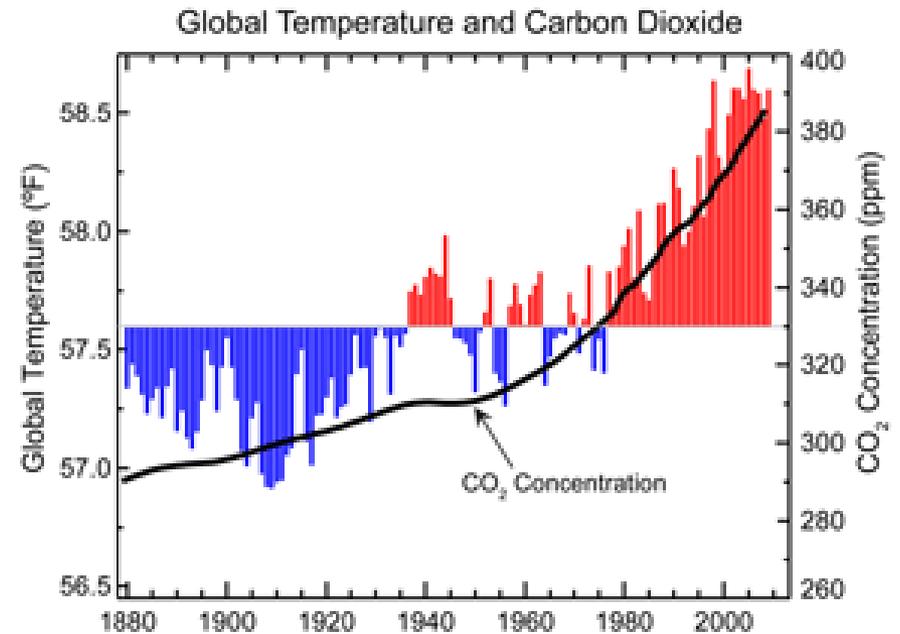
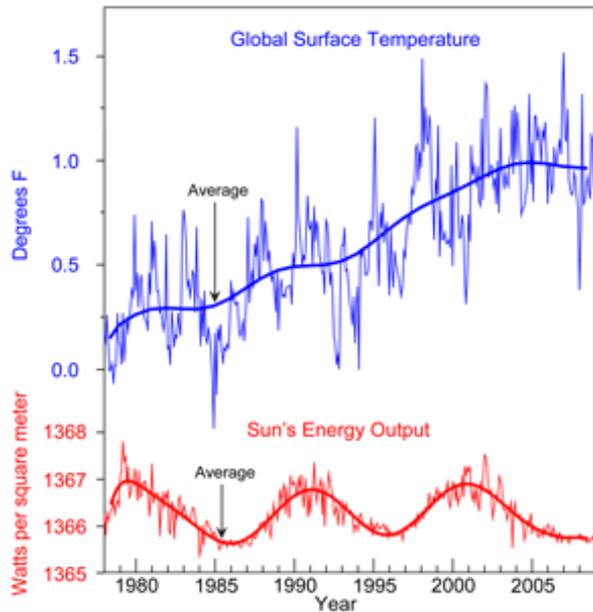


Work out  $T$  from the **heat balance equation**

$$e\sigma T^4 = dS \rightarrow T = \sqrt{\sqrt{dS/e\sigma}}$$

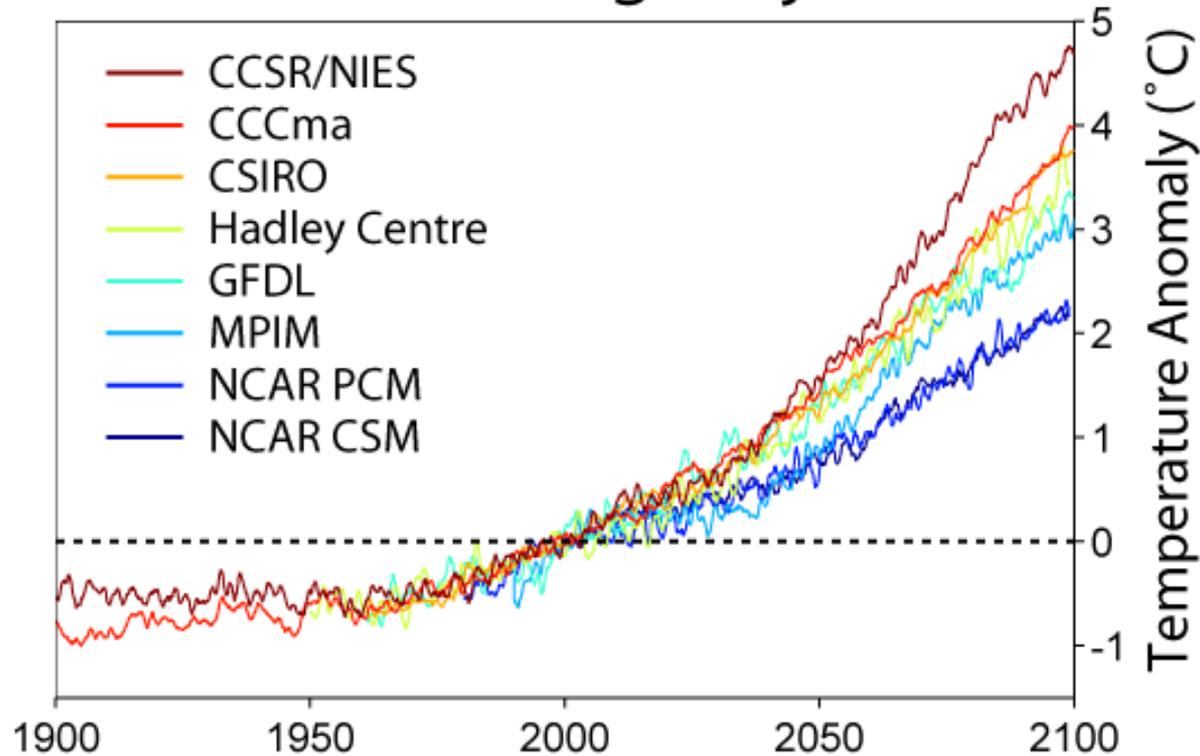
$$\mathbf{T = 284.4 K}$$

T depends upon both  $e$  and  $S$ : Past evidence supports this



Allowing us to make future predictions

## Global Warming Projections



Between a 2 and 5 degree increase by 2100

# Why is climate science so hard?



It is difficult to predict anything, especially about the future!  
*Niels Bohr/Yogi Berra*

Some reasons for the uncertainty

Statistical variation in dodgy data

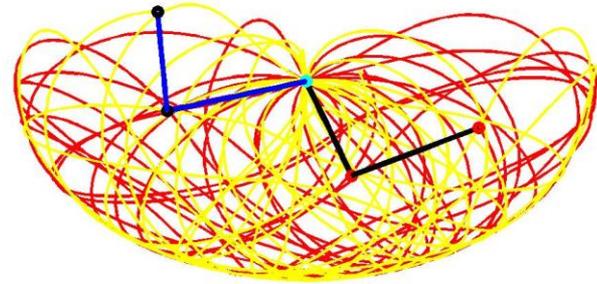
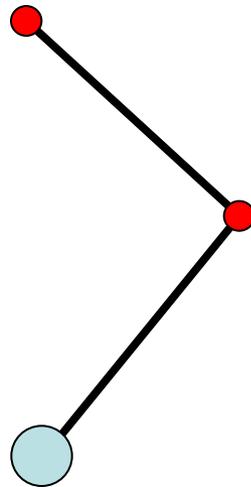
Chaos

Complexity of the system: need much better models



Chaos theory tells us that there is ...

A limit to our scientific understanding of the future



Motion can be **Chaotic** and unpredictable

Even if we understand something we can't always predict it with certainty!!!!!!