

Summer, and other theories



# Summer, and other theories

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First published in England in 2009.  
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ISBN 978-0-9544529-3-3 (paperback)  
ISBN 978-1-906860-01-1 (hardback)

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# *Preface*

## **What's this booklet about?**

A fresh look at Summer, and other controversial scientific theories.

This is a very early draft, not for circulation. It contains incomplete sketches of possible approaches, some of which overlap.

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# 1 *Climate science*

## **Is it all about correlations?**

I think some people have the impression that climate science is all about the historical observations of one quantity – global temperature – and its *correlation* with the concentration of carbon dioxide in the air. In this caricature of climate science, it is observed first that carbon dioxide concentrations have gone up dramatically in the last 100 years (figure 1.1), and second that global temperatures have trended up (figure 1.1). Then the caricature continues, “temperature and CO<sub>2</sub> concentration have been correlated for millenia, so the last century’s rise in temperature must have been caused by the rise in CO<sub>2</sub>.”

If this were the whole argument, it would have much the same status as the claim by Bobby Henderson, founder of the Church of the Flying Spaghetti Monster, that global warming, earthquakes, hurricanes, and other natural disasters are a direct effect of the shrinking numbers of pirates since the 1800s (figure 1.3). But climate science’s theory of global warming has something that the piracy theory lacks: it has a *mechanism*, a physical explanation of how CO<sub>2</sub> influences temperatures. Moreover, climate science isn’t all about one number – the predictions of climate science are rich and detailed, and mankind’s climate experiment has been running for long enough that many of these detailed predictions can be tested.

1975 prediction using computer model. Predictions are not just of a single temperature number, but of temperature at all heights and all latitudes.

Subsequent experimental confirmation – IPCC.

## *Acknowledgments*

I thank Alison Stirling for help with the preparation of this chapter.

## *Key numbers*

Rise of CO<sub>2</sub> concentration from 280 to 375 ppm causes radiative forcing increase of 1.7W/m<sup>2</sup>. If climate sensitivity is 3 °C, this should cause about 0.7–0.9 °C of warming.

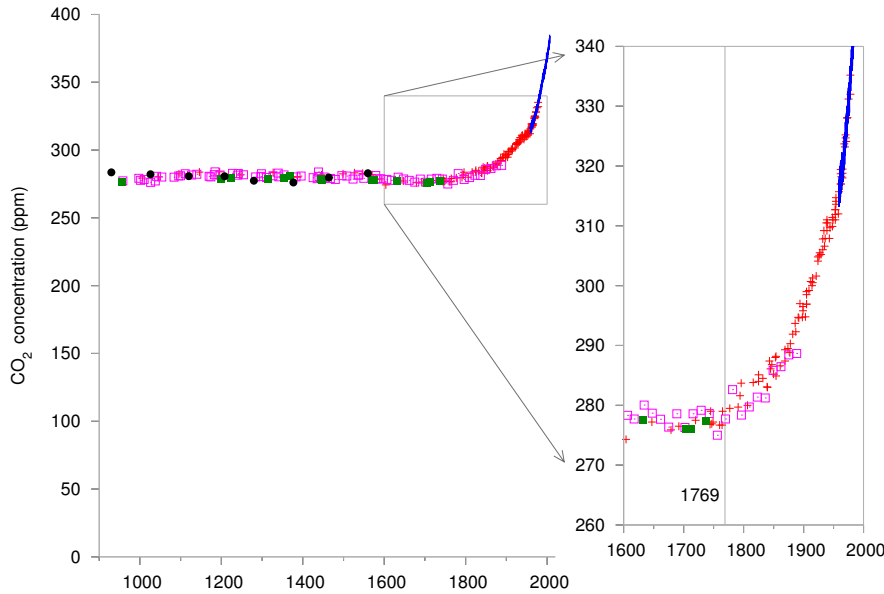


Figure 1.1. Carbon dioxide (CO<sub>2</sub>) concentrations (in parts per million) for the last 1100 years, measured from air trapped in ice cores (up to 1977) and directly in Hawaii (from 1958 onwards).

I think something new may have happened between 1800 AD and 2000 AD. I've marked the year 1769, in which James Watt patented his steam engine. (The first practical steam engine was invented 70 years earlier in 1698, but Watt's was much more efficient.)

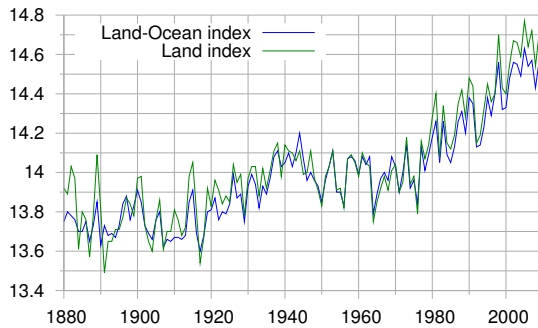


Figure 1.2. Global mean temperature in degrees Celsius, from the land-ocean index and the land index of the Surface Temperature Analysis by the NASA Goddard Institute for Space Studies. <http://data.giss.nasa.gov/gistemp/>

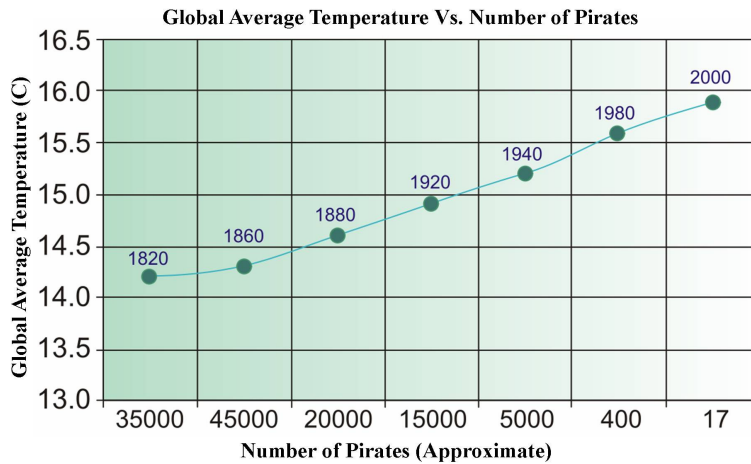


Figure 1.3. Diagram illustrating the influence of pirates decreasing on global warming as per Pastafarian beliefs. From Wikipedia; author, RedAndr; after Bobby Henderson, Open Letter To Kansas State Board of Education, 2005.



## 2 *The Sun wot done it?*

### What about sunspots?

This chapter has graphs.

Text to come...

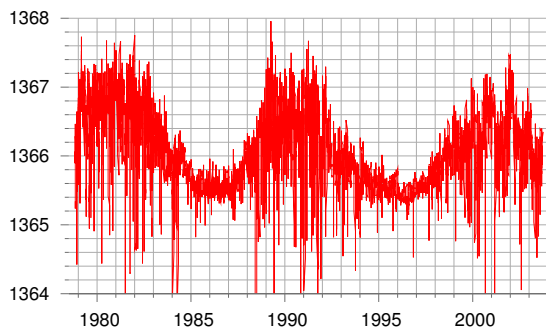


Figure 2.1. The solar irradiance, in  $\text{W/m}^2$ , at a distance of 1 AU (one Astronomical Unit) from the sun, measured by satellites from 1978 to 2003.

<http://www.ngdc.noaa.gov/stp/SOLAR/ftpsolarirradiance.html>

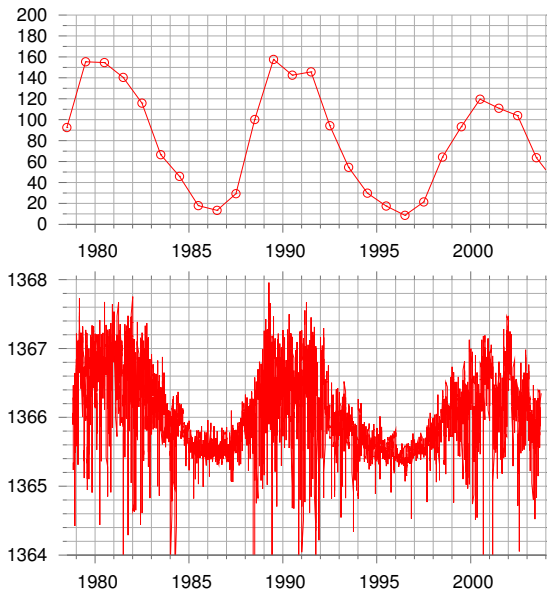


Figure 2.2. Solar irradiance and sunspot numbers.

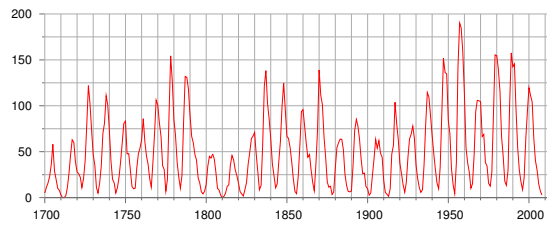


Figure 2.3. Sunspot numbers.

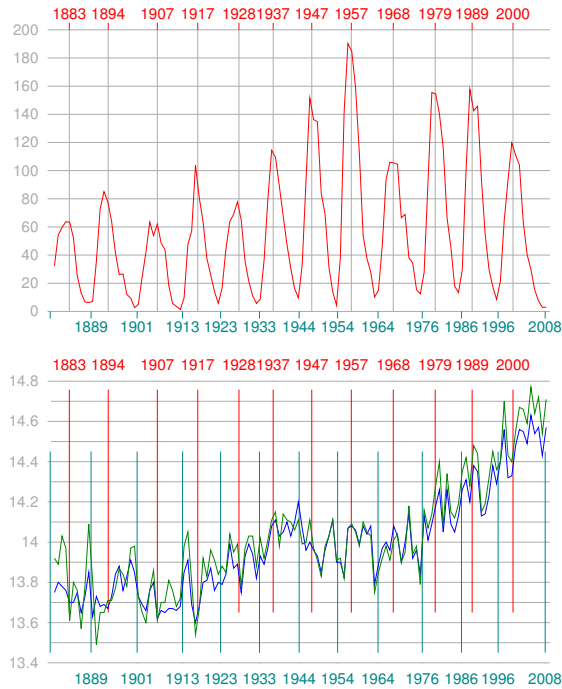


Figure 2.4. Sunspot numbers and temperature. The red and blue vertical lines show the times of sunspot maxima and minima.

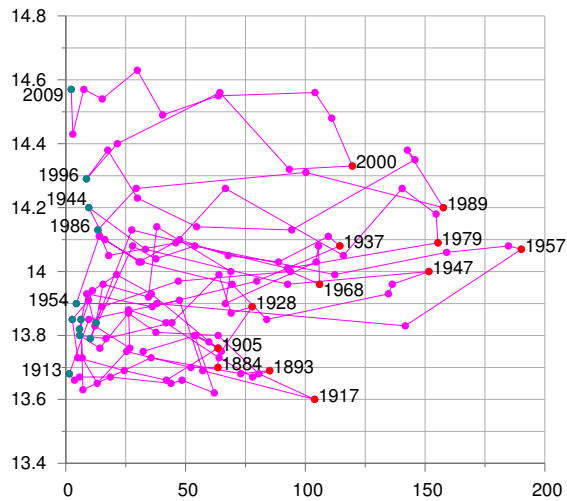


Figure 2.5. Sunspot numbers versus global average land-ocean temperature. The red and blue dots mark the years of sunspot maxima and minima.

### 3 Why believe in Summer?

Some people believe that Summers are warmer than Winters. What grounds might they have for this belief? The justifications for believing in this theory of Summer come in two flavours. First, there's the mechanistic explanation of Summer, which has something to do with the amount of radiation hitting the ground being bigger in Summer than in Winter. According to physics, this increase in radiation causes 'warming'. Second, there's the historical data, which some people find compelling even if they don't trust the laws of physics – the historical data are alleged to show that, in the Northern hemisphere, June the 21st is almost always warmer than December the 21st.

Since both of these ideas are controversial, let's look at the physical mechanism and at the data in some more detail, and introduce some numbers into the discussion.

(While we're at it, we could also discuss another controversial notion: that the North pole tends to be colder than the equator.)

#### A reason for a season

What is the root cause of Summer? Is it because the earth is *closer* to the sun in June than in December? No. The distance from earth to sun does vary a little, which does cause a change in the intensity of the sun's radiation at the earth, but that's not the answer.

The root cause is that the earth is tilted over, with the North pole always pointing at the Pole Star, and as the earth orbits the sun, sometimes the sun can see the North pole, and sometimes it can't. When the sun has a good view of the North pole, the whole northern hemisphere gets more sunshine than when the sun can't see the North pole.

Let's introduce some numbers.

For simplicity, we'll approximate. *[at this point I'll sketch the rest of the chapter]*

Raw intensity of sunshine at ground level at midday, for an area facing the sun:  $1000 \text{ W/m}^2$ . Take into account the latitude, and spin the earth: raw average intensity in Summer, and in Winter: give table showing the answers for different latitudes. There's two effects from the tilt – summer days are longer, and, at latitudes like Britain's, the midday intensity gets bigger because the ground faces straight on to the sun.

How does the difference in average radiation intensity at the ground lead to a difference in temperatures? To explain this, I am going to make a drastic simplification and pretend that the earth is just made of brown earth – no clouds, no sea, no atmosphere, no greenhouse gases. Brown earth absorbs incoming radiation and it also emits radiation – not very noticeably, but it does radiate; the hotter the earth is, the more it radiates. The

Figure 3.1. Because the earth orbits the sun, sometimes the north pole is tilted towards the sun and sometimes it is tilted away.

latitude (degrees)	average intensity (W/m <sup>2</sup> )	midsummer intensity (W/m <sup>2</sup> )	midwinter intensity (W/m <sup>2</sup> )
22	286	349	202
32	264	361	154
42	235	364	103
52	201	361	54
62	166	356	12

Table 3.2. Average powers per unit area.

earth will settle down to a temperature such that on average the outgoing radiation equals the incoming radiation.

Let's pick 42° as a typical northern latitude. Using the Stefan–Boltzmann law, we find that the temperatures corresponding to (235 364 103)W/m<sup>2</sup> are 254 K 283 K and 206 K respectively. Thus this naked-rock earth would have summer and winter temperatures differing by about 74 °C.

Not a great theory, but it has the right flavour.

At latitude of 32 °C, 261 K 282 K and 228 K 54 °C of temperature difference.

At latitude of 22°, 266 K 280 K 244 K. A predicted range of 36 °C. (More of the northern hemisphere is at small latitudes than large.)

Let's check Boulder. Summer–Winter difference is 0.3 to 22.7 C – that is 22.4 °C.

Toronto: −4.9 to 20.8. That is 25.7 °C.

Phoenix: from 10.9 to 32.8 that is 21.9 C.

Let's use the 22° latitude numbers... Empirically, changing the radiation intensity from 202 to 349 W/m<sup>2</sup> produces a temperature change of 36 °C, simple-theoretically; and in practice, 22 °C or so. That latter number corresponds to a sensitivity of 0.15 °C per W/m<sup>2</sup>.

The former, 0.24 °C per W/m<sup>2</sup>.

So, if we increase the intensity of the radiation by 4 W/m<sup>2</sup>, we might expect a temperature rise of 1 °C.

## 4 *What's the effect of clouds on a winter's night?*

A clear winter's night, not a cloud in the sky, and a winter night with cloud cover: which is crispier? Which is colder? Which will really freeze water? We all know from experience: it's clear nights that tend to be more crispy and cold.

## 5 *What happens if we double the carbon dioxide concentration?*

Doubling CO<sub>2</sub> increases greenhouse effect a little – a complicated but well-established calculation – equivalent to a 4 W/m<sup>2</sup> increase in radiation.

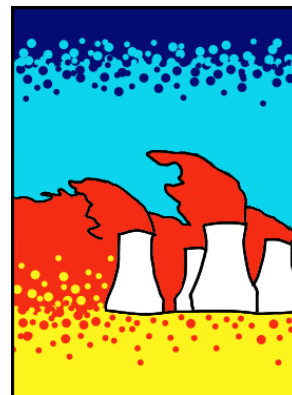
## 6 *Has the experiment already been done?*

Discussion of the geological record from 55 million years ago, when a large natural carbon release occurred, roughly the same size as the carbon release we are half-way through. This carbon release was followed by significant temperature rise and mass extinctions.



*Part I*

# Mechanisms



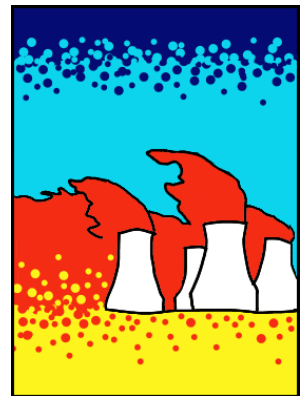
## 7 *Overview*

explain mechanisms using familiar facts, eg summer/winter and cloudy night/starry night. once this theme is complete, the summary chapter would be. "The climate change (mechanistic) argument in 6 simple steps" like realclimate.

- Summer (explanation of black body radiation; first encounter with power flux in watts per square metre).
- Greenhouse gases – clouds versus cloudlessness on a winter's night
- Radiative transfer
- Chris Rapley's simple argument for why the stratosphere cools. Not an essential link in the chain, but nice to have.

*Part II*

Data



Data - lots of data, shown in enough detail to be able to use as a reference. A lot like Houghton but higher resolution.

The nice webpage about "The five most important data sets of climate science" by Stefan Rahmstorf (Vostok ice core; Keeling curve; Observed warming since 1880; Sea level rise; Sea Ice Retreat). Would like to add the "bryan lovell" petm rock from the atlantic too. Science 1999. In all graphs time and height will both go from left to right.

## 8 Overview

- Ice-core data.  $^{18}\text{O}$ , deuterium,  $\text{CO}_2$ , other chemicals, eg lead.

- Keeling.

From Stefan Rahmstorf: “The black curve shows 57% of the cumulative human-caused  $\text{CO}_2$  emissions. This shows that about 57% of what we emit remains in the atmosphere, while the other 43% are taken up by the oceans and by the biosphere. As an aside, this shows that the  $\text{CO}_2$ -rise does not come from natural sources: the natural Earth system is not releasing  $\text{CO}_2$ , but to the contrary it has taken up much of the  $\text{CO}_2$  we have added to the atmosphere. This is confirmed by ocean measurements, which show that  $\text{CO}_2$  in the ocean is also increasing. This  $\text{CO}_2$  dissolves in the water and forms carbonic acid, making the ocean waters more acidic.”

- Sea level. Sea level is the top of a giant thermometer. Would like to include evidence for what Stefan Rahmstorf says: “This sea level rise is modern; we know that there was not even a small fraction of this rise over the preceding millennia. It is also a logical and expected consequence of warming, since warm water expands and takes up more space, and melting glaciers and ice sheets add water to the oceans.”

The last time that global temperatures were above more than  $2^\circ\text{C}$  above preindustrial for a sustained period, sea-level was at least 15 m higher than today. (SR says 20–30 m.)

Stefan Rahmstorf again: “The history of climate thus sends a strong warning: past climate changes by just a few degrees in global temperature have come with very large sea level changes, by tens of meters. In the long run, this is likely to happen again. The sea level rise by the year 2100 (likely below one meter) is only the small beginning of a much larger rise that will unfold over coming centuries and perhaps millennia, caused by our carbon emissions in this century.”

- Arctic sea ice. Would definitely go well on a website so that you can play the movie of sea ice at whatever speed you want.
- ‘Lifetime of  $\text{CO}_2$  increment’ – data from  $^{14}\text{C}$  showing short ‘residence time’ and explanation of how this relates to the long-lasting effect of a  $\text{CO}_2$  increment.
- The PETM rock.

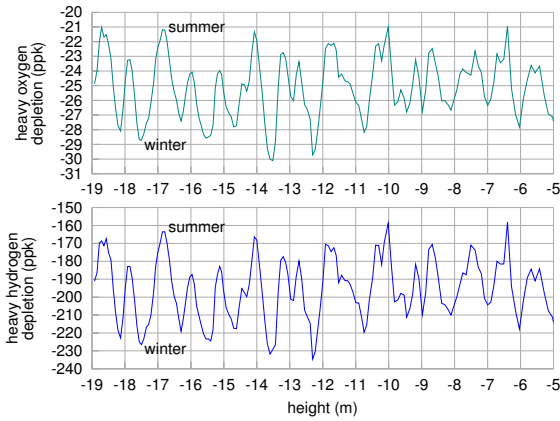


Figure 8.1. BASDyer

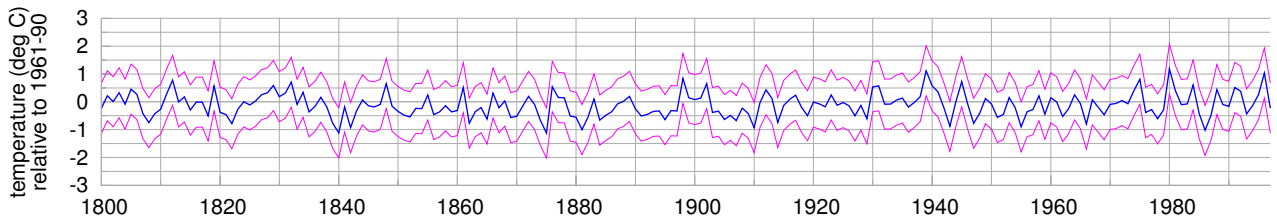


Figure 8.2. antarctica-temp2006

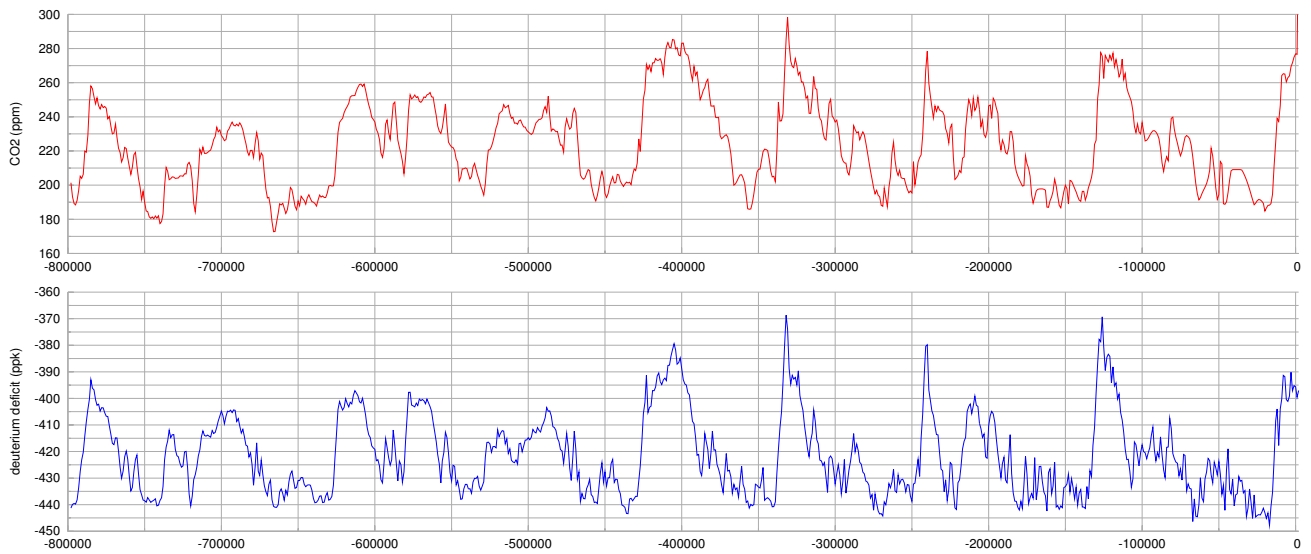


Figure 8.3. BBC2a

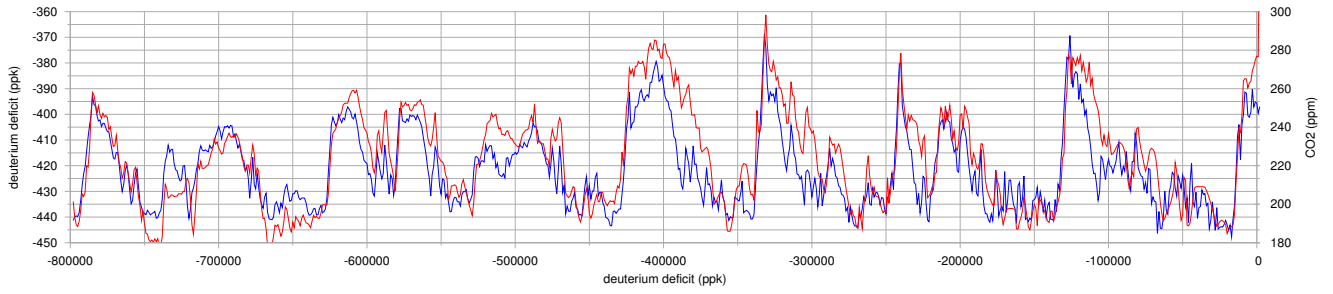


Figure 8.4. BBC2as

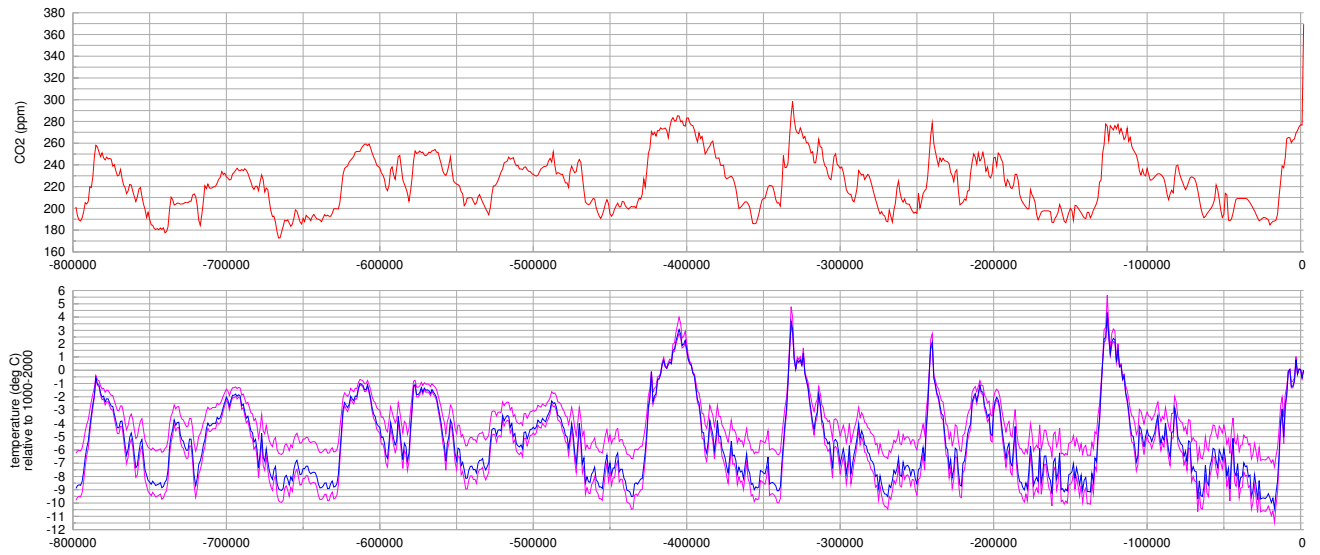
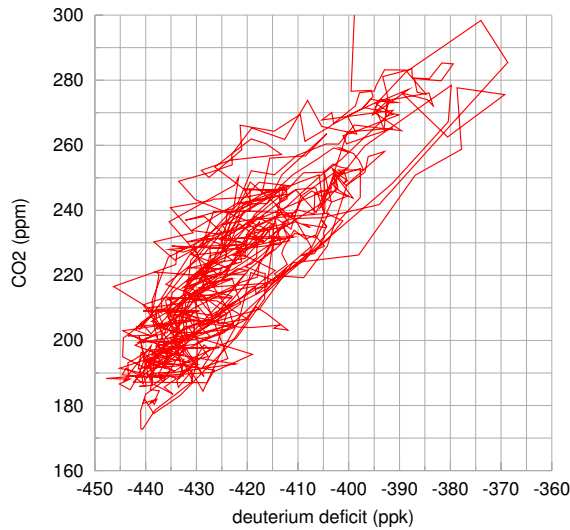


Figure 8.5. BBC2  
Figure 8.6. BBC3



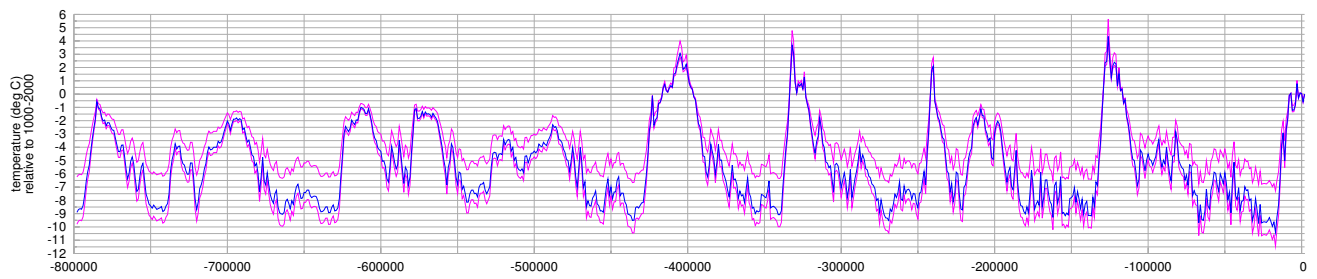


Figure 8.7. BBC – deuterium measurements transformed into inferred temperatures.



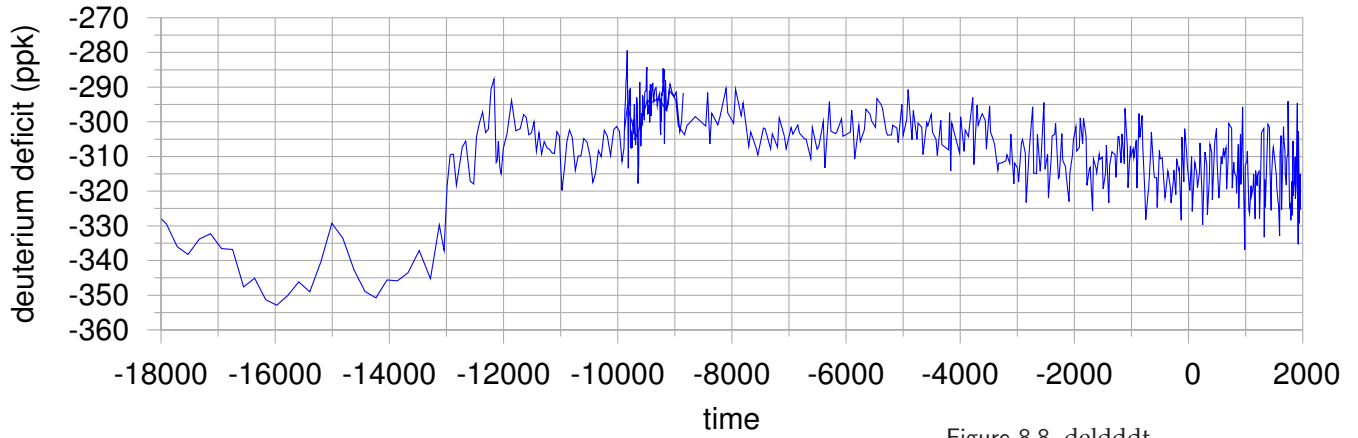


Figure 8.8. deldddt  
Figure 8.9. delddt

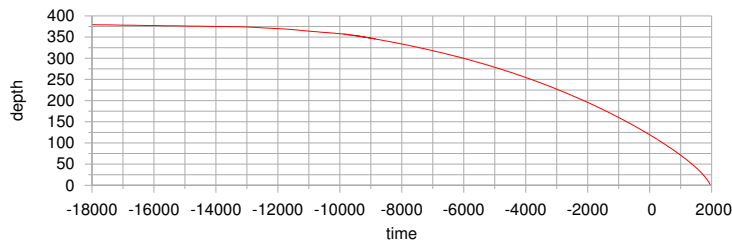


Figure 8.10. deltadd

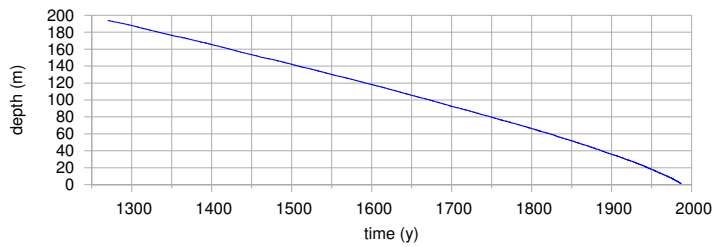


Figure 8.11. deltadetail

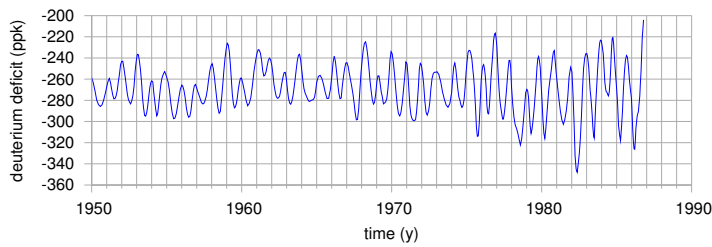
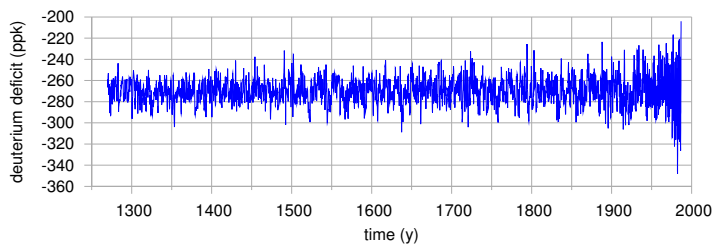


Figure 8.12. deltadt



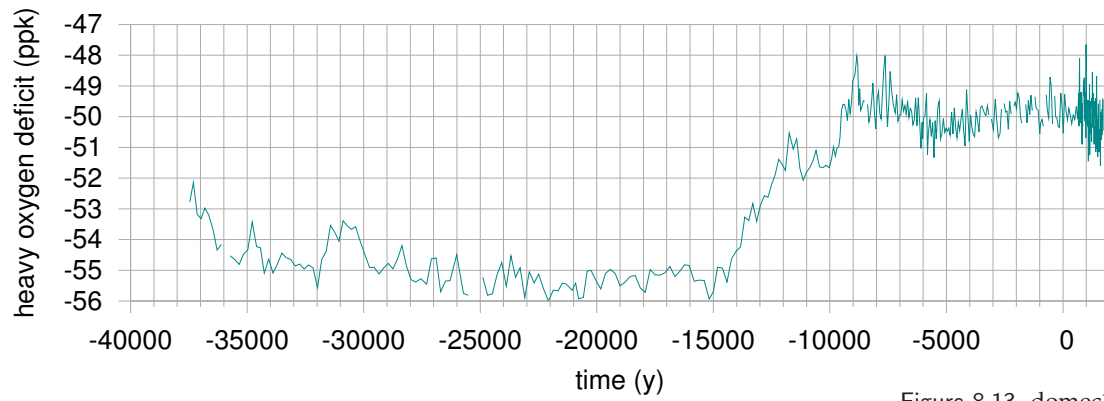


Figure 8.13. domec1.d18O

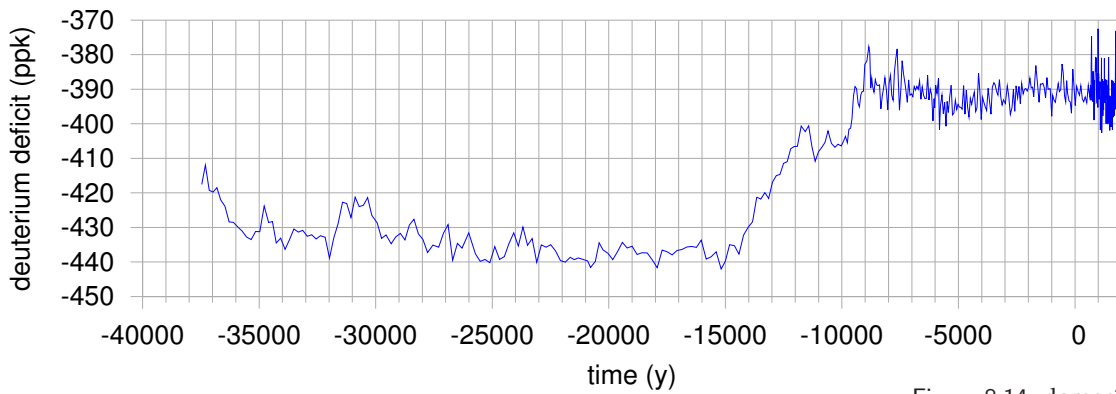


Figure 8.14. domec1.dD

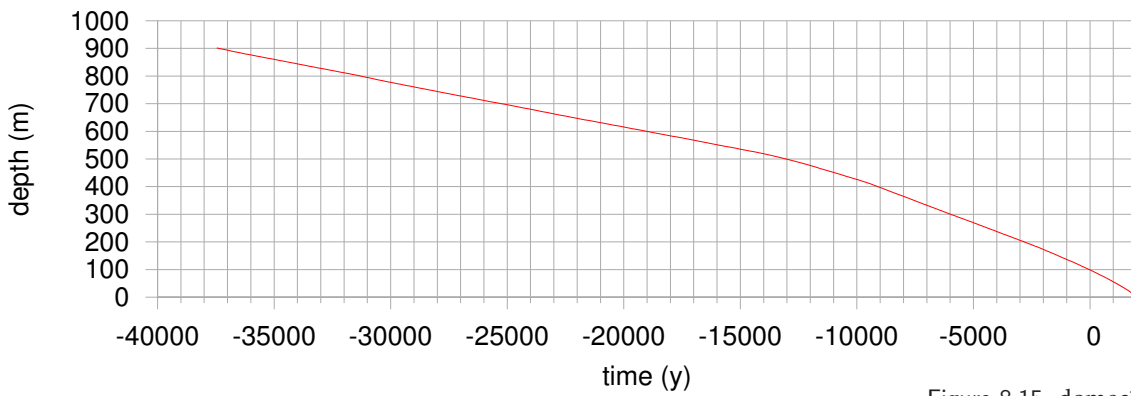


Figure 8.15. domec1.td

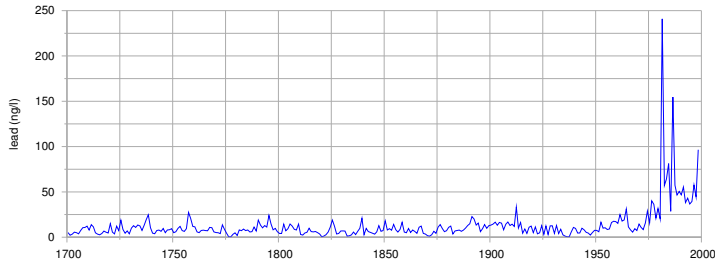


Figure 8.16. mtlogan2008

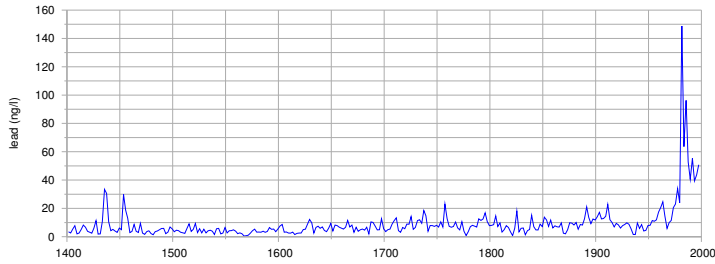


Figure 8.17. mtlogan2008o

Idea: lots of Climate data on a single page.

Year range:

```

-800,000          BBC2
-40,000:          2000 domec
-18,000           :2000 deltadt (very high resolution)
-6000             :2000 lead at mtlogan
1200              :2000 talosdd
+1700             :2009 sunspots
+1800             :1990 antarct-temp
+1880:2009       GISS temp
    
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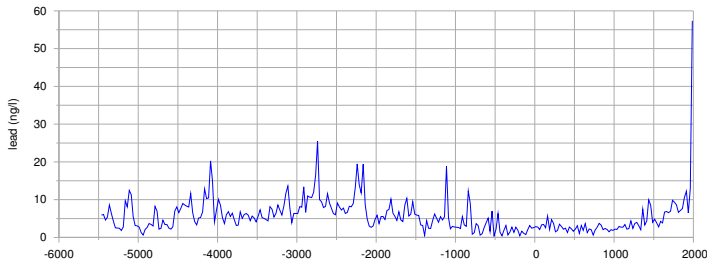


Figure 8.18. mtlogan2008oo

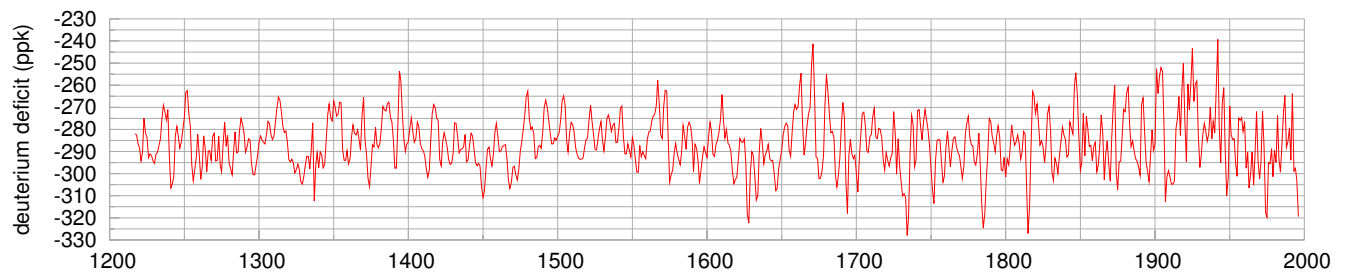
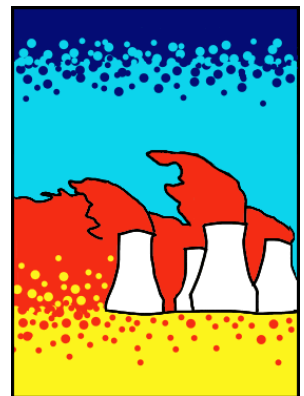


Figure 8.19. talosdd

*Part III*

Questions



## 9 *Overview*

Questions – acknowledge remaining uncertainties – include friendly debunking of skeptical arguments, done in a positive “how science works” way – describe how further research investment may lead to resolution of some uncertainties – point out known defects in current models. – “skepticism, done properly” by scientists. Every major skeptical idea should be addressed. Sunspots. Volcanos. Is the carbon from fossil fuels? What is the lifetime of carbon in the atmosphere? Is there a Milankovich theory that actually predicts?