Climate Science – how do we decide?

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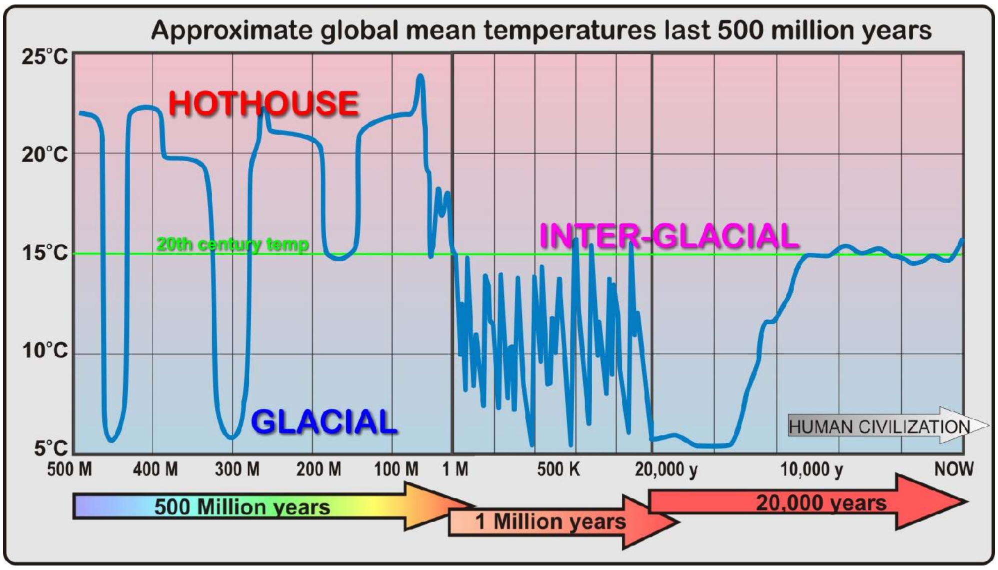
Tackling, or not tackling, climate change is the biggest question modern civilization has had to face. How can we make sensible decisions about it? The question of whether dangerous climate change is upon us is a scientific one, but it has become a political one. Politicians like definite answers. Unfortunately science will never supply them.

This leaflet tries to summarize some of the results of a three year investigation of the science behind the issue. My original aim was to help science teachers come to grips with the controversy over anthropogenic global warming. I have had a long career as a physics teacher and text book author. I must also declare a vested interest – our grandchildren. My research has given me considerable cause for concern, and I hope that by sharing this brief summary of it I can help you come to a more informed opinion on this extremely important issue.



"Climate change is natural"

It certainly is. As the graph shows, over the last 500 million years the Earth has gone in and out of 'hothouse' and 'snowball' states many times. For most of that time it has either been much hotter, or much colder than the present state. In both cases it was a very different Earth – ocean levels a hundred metres higher or lower, deserts, forests and plains in very different places. Our present climate turns out to be a somewhat precarious balance between the two.

Over the last million years or so the climate has oscillated between full 'ice ages' and 'interglacials' such as we are in currently. It turns out that our current interglacial has been longer than normal, lasting around 10,000 years so far. The climate during that period has been particularly steady. There have been 'warm periods' and a 'little ice age', but these have varied by less than a degree – in contrast to changes of more than 5°C between glacials, interglacials and hothouse conditions.

In other words, human civilization has developed in a particularly steady climate – and we have come to depend on it. Left to itself, the climate would most likely cool very gradually (over thousands of years) toward another ice age. But are we leaving the climate to itself?

Why the climate changes

What has caused these large changes in the climate? Scientists have discovered various reasons. Some are cataclysmic events such as meteor strikes or huge volcanic activity. Most, however, appear to have resulted from rather smaller scale changes including small variations in the Earth's orbit (Milankovitch cycles) and changes in greenhouse gases. The latter have occurred in the past as the result of, for example, volcanic activity, differing uptake by plant life and out-gassing from permafrost or ocean clathrates. Clearly our current concern is whether human additions to the atmosphere, over 35% of carbon dioxide (CO_2) an important 'greenhouse gas', could result in significant climate change again.

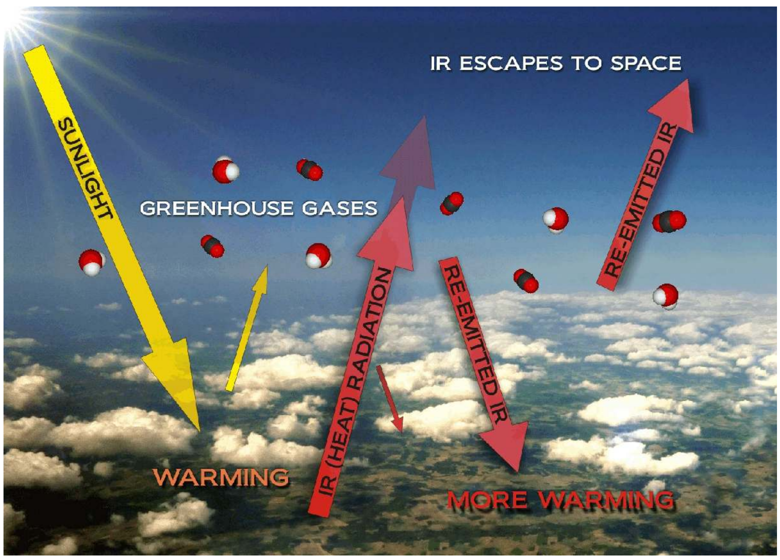
It is important here to note that claims that only around 3% of CO_2 is 'human produced' are very misleading. While huge amounts of CO_2 go in and out of the atmosphere naturally each year we have steadily added it by burning fossil fuels and now the total concentration is 390 ppm (parts per million) as compared to the pre-industrial 280 ppm.

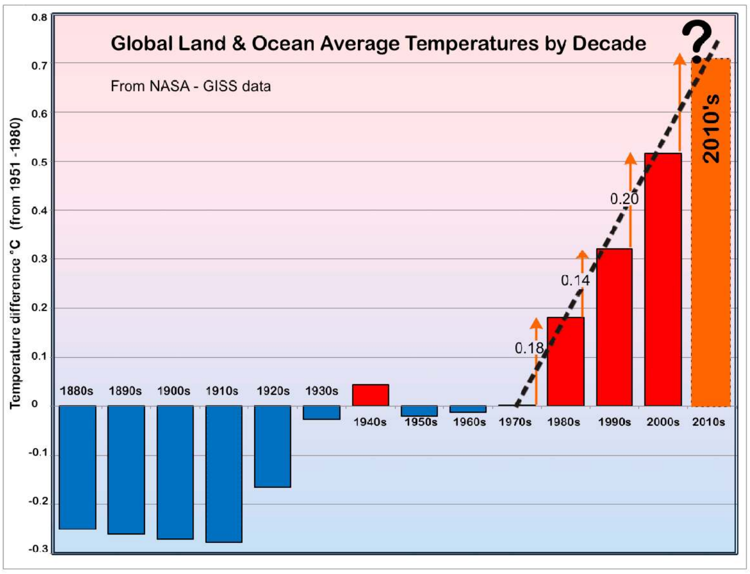
The 'Goldilocks planet'

The planets are all warmed by the Sun. Our neighbours are far too hot (Venus, 450°C) or too cold (Mars, –65°C). Venus has a runaway greenhouse effect and Mars has a very thin atmosphere. The Earth is just right for life. This is because there is a delicate balance between the Sun's incoming heat energy and the Earth's invisible outgoing infrared radiation (IR, the sort of radiation you feel near a warm object) such that the Earth's surface averages around +15°C. However, straightforward laws of physics tell us that in the absence of anything trapping the outgoing IR radiation the Earth would be a frozen snowball at around –18°C. Fortunately for us something does trap a large amount of this IR radiation. It is the so called greenhouse gases that trap this heat. They are mostly water vapour (H_2O) and CO_2. Unlike nitrogen and oxygen molecules (which constitute 99% of air) H_2O and CO_2 molecules absorb IR radiation and trap it in the atmosphere (diagram below). Consequently, in order to maintain a balance between the incoming and outgoing heat energy, the Earth's temperature has to increase by 33°C to an average +15°C. (This is all basic well established physics which has been known for over a century.)

Clearly, the question we face now, is by how much will this +33°C greenhouse effect increase as a result of our increasing the CO_2 levels by 35%? Fortunately not by 35% of 33°C! This is because H_2O molecules are a greater IR trap than CO_2. However, there is a complex interplay between the two. First, they absorb different parts of the IR spectrum. Second, while H_2O goes in and out of the atmosphere with the weather, CO_2 molecules, once in the atmosphere, stay there for something like a century. So it is not possible (as is sometimes rather misleadingly done) to assign a simple percentage of the greenhouse effect to each gas.

Here, things get a little more complex. We have to deal with 'feedback effects'. Putting more CO_2 in the atmosphere warms it a little. A warmer atmosphere absorbs more water vapour and hence the total greenhouse effect increases, which again results in still more H_2O in the atmosphere. This is a 'positive feedback' – a small





initial effect becomes amplified. Fortunately there are negative feedback effects as well! More water vapour means more clouds, more clouds reflect sunlight back into space – less warming. But clouds also have a positive feedback – they trap outgoing IR radiation and increase warming.

Computers do the physics

To take all this physics and chemistry into account, scientists use computers to do all the calculations. They use the basic laws of physics and chemistry and feed in the initial conditions. In much the same way as weather forecasts are produced, so too can long term trends in the climate be predicted. The 'models' are checked by 'back forecasting' – putting in the conditions, say, 100 years ago and then running the model to see whether it reproduces what actually happened. In this way scientists can adjust and refine the model until it accurately reproduces what has actually happened.

This is not to say that models predict all the year-to-year variations. While we can be very sure that January will be warmer than July, it may well be that some days in January will be cooler than some in July. Similarly, while the models predict, for example, that added CO_2 in the atmosphere will cause warming, this warming is only about a tenth of the normal year-to-year variation and so it is not noticeable on anything less than decade-to-decade trends. To look for trends over periods of less than a couple of decades simply makes no sense as there are all sorts of short term influences on the climate. Sure enough, when the average decade temperatures over the last 40 years are graphed (above) there is a clear upward trend of around 0.2°C per decade since the middle of last century – just as the models predict. But only if they include human added CO_2 in the atmosphere. It the models are run without the added CO_2 they actually predict slight cooling. There is no other coherent explanation for the rise in recent decades. Our problem, of course, is that, not surprisingly, the models also predict the possibility of dangerous amounts of warming in the next decades.

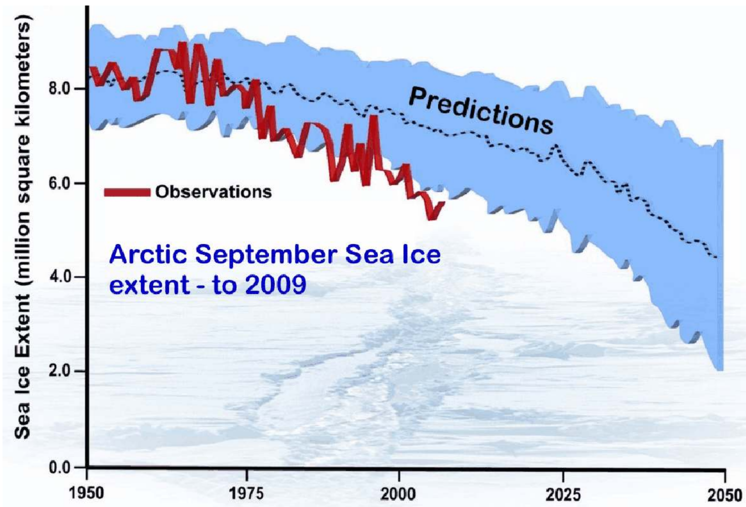
Computer climate models are sometimes compared to economic models – which are notoriously unreliable. It is important to remember, however, that economic models are based on human guesses about how other humans will behave. Climate models are based on the very reliable and well known laws of physics and chemistry. It is also important to remember that the basic mechanisms of the way in which CO_2 molecules absorb and re-emit IR radiation are thoroughly understood. Claims, for example, that the greenhouse effect is 'saturated' are based on early theories that were outdated in the 1940's. This is not to say that computer models are perfect – far from it. But given that we don't have the luxury of a spare Earth to experiment on they are the best we can do.

The biggest science experiment ever?

Scientists like to test their theories by experiments. This is clearly not possible with climate science and hence the need to create an 'artificial climate' in a computer. However, the scientists do have one real climate experiment to study – the one we are currently carrying out by adding huge amounts of CO_2 to the Earth's atmosphere. We don't know what the results of this experiment will be, but we do know that there is a real possibility that they could be very bad for us. Normally, when scientists want to carry out an experiment they have to go through rigorous processes to ensure that they will do no harm. Perhaps, because it was not scientists who initiated this experiment, we seem to have ignored that requirement!

Most theory suggests that the result of this experiment will be that the climate will warm and the Earth will head back towards a 'hothouse'. Just how far it will go in that direction is unclear, but it will certainly depend on how much more CO_2 we add. As the relatively small addition so far has already caused around 0.8°C rise (with more locked in due to the inertia in the climate system) we should expect at least two or three degrees this century. That could well be enough to trigger unstoppable melting of glacial and polar ice – because of the feedback effects of losing ice which reflects sunlight far more effectively than water. If that happens we will have sea level rise of metres.

We know already that Arctic sea ice, as well as Greenland ice is melting more rapidly than even the IPCC predicted. Some people like to point out that the Antarctic is not warming as fast as the Arctic – indeed the sea ice there may even be growing. One reason for this could well be that a warming atmosphere contains more moisture resulting in more precipitation (snow) over the Antarctic. It is true however, as a result of the huge thermal mass of the southern oceans, that the Antarctic is the one place on Earth that is warming at a slower rate. The climate is complex!



The nature of science

So, is the science 'settled'? The answer is simple: Science is never settled. That, however, is not the point! Thousands of scientific papers have been published on various aspects of climate change. Most of them suggest that we are changing the climate dangerously. A much smaller number claim that we are not. In such a situation it would be normal to stop changing the climate until we can be sure it is safe. Some people, however, look at it the other way around – we should continue the experiment until it is proven to be dangerous, ie., wait and see what happens. One wonders if these people would take the same approach to a problem with an aeroplane. If an engineer claimed there was a fault with the wings, would they take off and wait to see what happens?

The 'do nothing dangerous' position on this matter is clear. We must stop experimenting on our only atmosphere unless it can be positively shown that we will not push it back to a hothouse Earth which could well result in the destruction of civilization as we know it. At present the overwhelming balance of scientific opinion is that the risk is far too great.

This leaflet was prepared by Keith Burrows for 'Science Teachers for Climate Awareness' an initiative of the Australian Institute of Physics (Vic) Education Committee. For more, see our website at www.vicphysics.org 'Teachers' 'Climate Change'. Email: scitca@optusnet.com.au