Our Climate: Past, Present, Future

Why are climate scientists worried about our future?

The simple answer to this question is that they know the Earth's climate has varied enormously in the past and that this has often been due to changes in the amount of carbon dioxide (and other greenhouse gases) in the atmosphere. They also know that human activity has increased the current level of carbon dioxide (CO_2) in the atmosphere by 40% in the last century or so and that CO_2 levels are now higher than they have been for millions of years.

Over geological times Earth's climate has been far from stable. The left hand section of the graph below shows how the climate has swung, over many millions of years, between a 'hothouse' and a frozen 'snowball'. Over the last one million years (centre section) Earth has gone in and out of the glacial (snowball) state and the current pleasant 'inter-glacial' state. However, the last 10,000 years (right section) has been remarkably stable. This stability has enabled the growth of human civilization. But in just the last half century or so we are heading upward, out of that stable period at an alarming rate. The question, of course, is does that matter?

What's wrong with a hotter Earth?

The problem is not so much the eventual hotter Earth, it's getting there. Conditions in hothouse Earth were very different to today's. Sea levels were up to one hundred metres higher and many of today's arable areas were deserts. In fact, even in the last inter-glacial period (about 120,000 years ago) when conditions were only about one degree warmer than last century's average, enough ice melted to raise sea levels by up to ten metres. We have already reached that level of warming and it is accelerating!

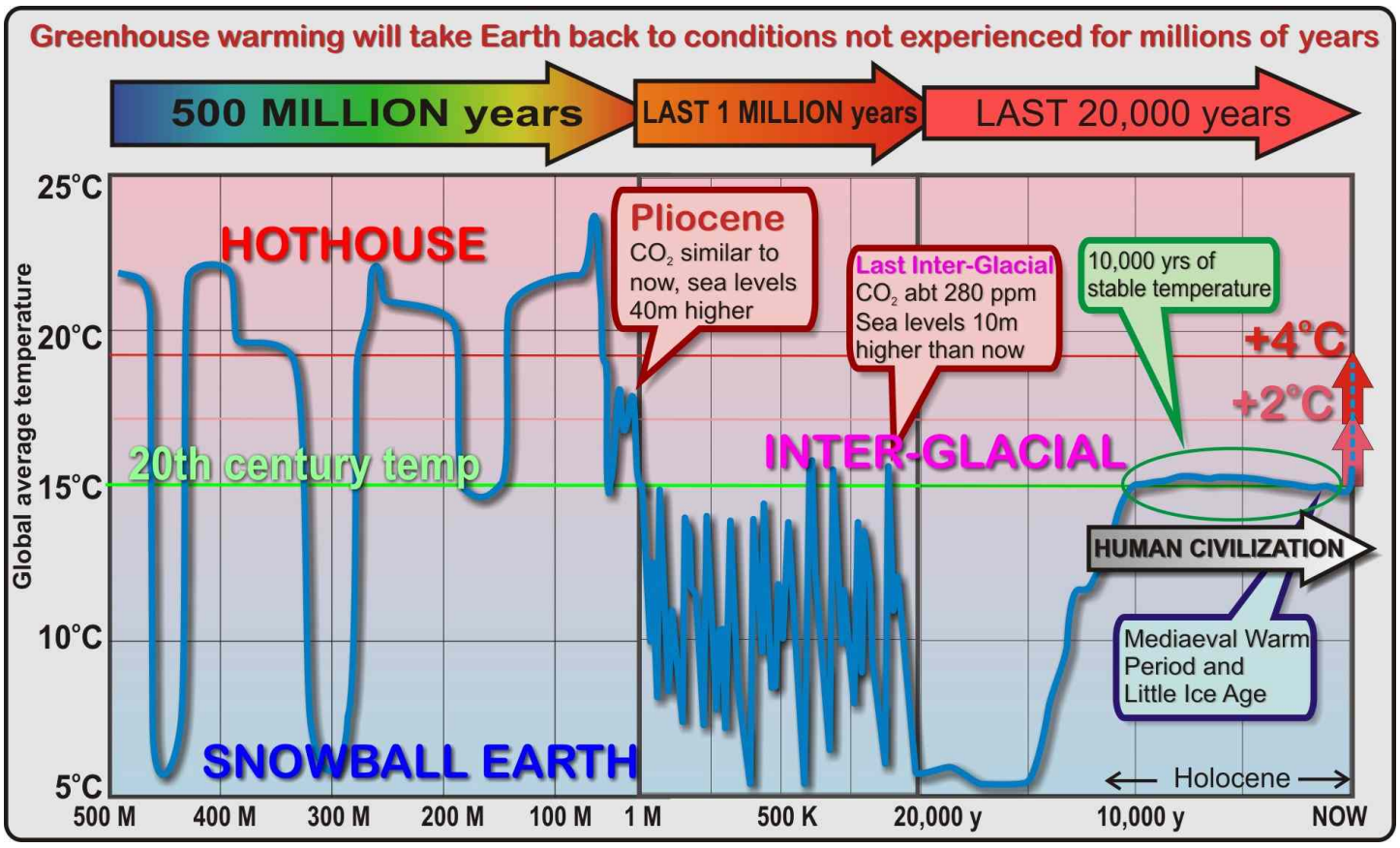
If the warming, and consequent changes in climate and sea levels were to take place over many centuries, perhaps humans could adapt—despite the loss of all major coastal cities and crop lands. The problem is that we are looking at extremely rapid changes—much faster than any past 'natural' changes. Even in the last inter-glacial, when there was much less CO_2 in the atmosphere, sea levels rose at a rate of a metre or so in less than a century. But the problem is not just rising seas, it is changing climate patterns with the consequent loss of arable land as well as increasingly severe weather events.

Is CO_2 really to blame?

Earth's temperature is determined by two key factors; 1) the incoming energy from the Sun and 2) the outgoing infrared (or 'heat energy') radiation.

The first is obvious—we can feel it. The second is more subtle, but crucial to our story. Any warm object, including a person, radiates warmth away as infrared radiation. It's what you feel when you put your hand near the person. The temperature of anything, including the Earth, is the result of the balance between incoming and outgoing energy. Earth's temperature is the result of the balance between the Sun's incoming warmth and that outgoing (but invisible) infrared 'heat' radiation.

For over a hundred years, scientists have known that, in the absence of something in the atmosphere trapping the outgoing infrared, the Earth would be a frozen snowball. Fortunately for us, water vapour and CO_2 in the atmosphere do just that. They trap



enough heat radiation to warm the Earth by 33°C. This is the 'greenhouse effect'. It's rather like wrapping a person in a blanket. Earth and person inevitably warm until the energy balance is restored.

The greenhouse effect, then, means that the Earth is a comfortable average +15°C instead of a frozen –18°C. The problem is that our CO_2 emissions are increasing that 33°C, and hence our average +15°C.

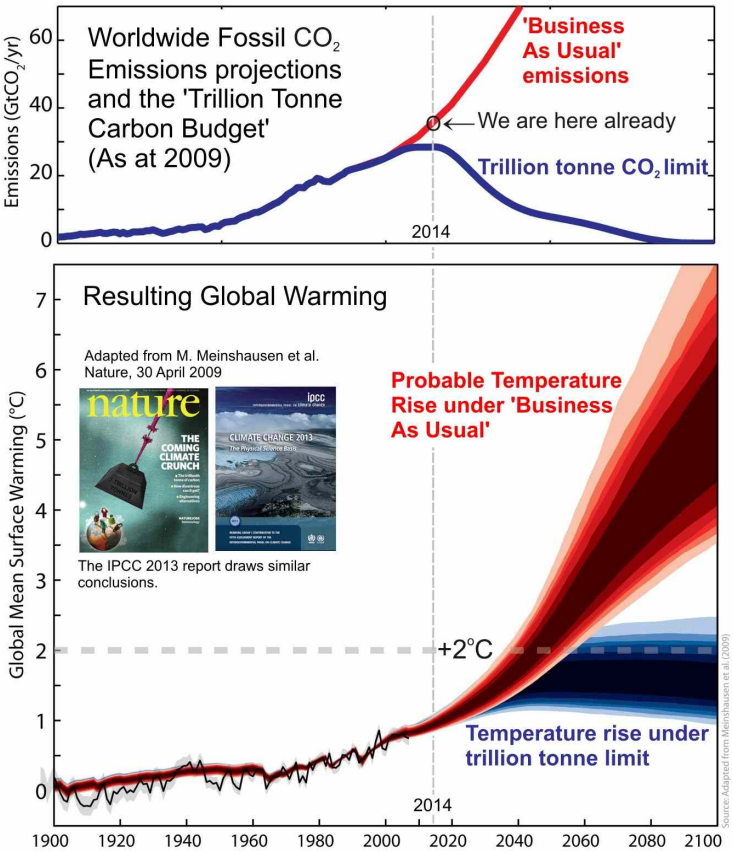
The big question

The big question then is: As we humans have already increased the amount of CO_2 in the atmosphere by 40% (from around 280 parts per million to over 400 ppm, and rising rapidly) by how much will the greenhouse warming also increase?

The answer to this question involves some complex science, but to cut a long story short, scientists can either look at how the Earth's climate has responded in the past to changes in greenhouse gases or use sophisticated computer modelling based on the fundamental physics of the atmosphere. Either way, they come up with similar results: At the rate we are currently emitting greenhouse gases we can expect a temperature rise of something like at least four or five degrees by the end of this century.

It is worth noting that the last time CO_2 levels were as high as now—in the Pliocene era a few million years ago—temperatures were only about 3 degrees higher and yet sea levels were tens of metres higher than now, suggesting that is where we are heading.

A 4 degree rise would clearly be devastating. It would take Earth back to conditions not experienced for millions of years. It may take several centuries to reach that point, but over that time conditions would be continually changing, resulting in enormous instability in our climate and our ability to produce food—not to mention continually changing coastlines. Life on land and in the oceans, would be precarious. Political and social upheaval would result. Resource wars would be all but inevitable.

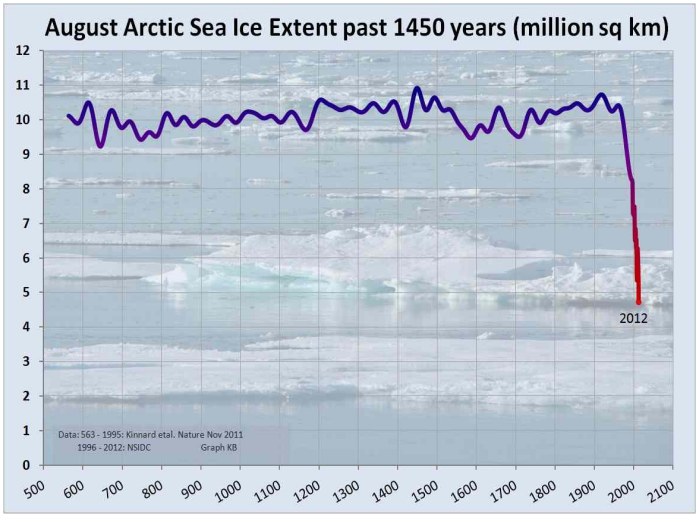


The 'Carbon Budget': If the world is to avoid catastrophic climate change, emissions must be kept below a total of a trillion tonnes CO_2 in the first half of this century. The trouble is we have already used up about half that budget in the first decade of this century. BAU will use up the rest very soon.

Wait and see is not an option

There are those who advocate a 'wait and see' approach. This is not a rational option. Adding CO_2 to the atmosphere changes the balance between incoming sunlight energy and outgoing infrared radiation. But it takes many decades before the balance is restored. This means that CO_2 emitted today will warm the Earth for decades to come. So, even if we stopped all greenhouse gas emissions today, warming would continue for a very long time.

There is also the possibility of runaway warming resulting from various possible 'tipping points' in the climate system. For example the melting sea ice in the Arctic means greater areas of darker ocean, which absorbs more sunlight energy than white ice—resulting in more warming and yet more melted ice!



The amount of summer sea ice in the Arctic has already fallen to about half the long term average - and it is falling more and more rapidly.

Likewise, the warming Arctic is thawing permafrost, which is releasing increasing amounts of methane, another very potent greenhouse gas. In the South, the West Antarctic glaciers are already melting at probably unstoppable rates—which will inevitably lead to around an added 4 metres of sea level rise.

We can not afford to simply wait and see whether the warming is dangerous. Once it goes beyond a certain point there is no sensible way in which we can stop runaway warming. The only ethical—and indeed practical, course of action is to cut emissions as rapidly as possible, NOT by a few percent, but by as much, and as fast, as we possibly can.

Climate scientists have calculated that to have even a fair chance of keeping temperature rises to around 2°C (by no means a 'safe' temperature rise itself) we can not release even another half trillion tonnes of CO_2 (the 'carbon budget') in the coming decades!

The good news is that the world still has a chance of seriously cutting emissions and avoiding a climate catastrophe. But we need to act urgently. How we can do this is the subject of the next in this series.

This leaflet was produced by Keith Burrows for 'Science Teachers for Climate Awareness' scitca@optusnet.com.au.
A pdf colour version can be downloaded from www.vicphysics.org