THIN ICE – the Inside Story of Climate Science

(chapter lengths for 73 minute version with 56 minute version in brackets)

A synopsis of the science presented in the film by Simon Lamb

Note: The 56 minute version leaves out 5 minutes on the measurement and history of atmospheric CO2 between the ice coring section and the physics, and leaves out another 5 minutes from the sea voyage including "the forests of the ocean". Both topics are covered by video shorts on the DVD and website. The extended version also includes 2 more young female scientists and another young male – all great role models, but the 56 minute version is more direct and accessible for a first viewing, and shorter.

1-Thin Ice **3:13 mins [3:01]**

Simon Lamb is a geologist and also a keen cinematographer. He has become concerned at the unprecedented attack on climate scientists by climate skeptics and the media, who have accused the scientists of fraud. Therefore he decided to make a film recording his experiences with climate scientists as they explain why they think humans are changing the planet's climate through our emissions of greenhouse gases, such as carbon dioxide. This conclusion has been challenged by many in our society, including some scientists, because it has profound implications for our future.

2-Antarctica **5:44 mins [3:34]**

Simon's office is just down the hall from the Antarctic Research Centre at Victoria University of Wellington. Through them he finds many scientists working there on a range of climate-related issues building on the work of past expeditions. Only scientists and their support staff are allowed to live and work in Antarctica. One of the main topics of research is climate science.

3-Ice story **10:16 mins [11.52]**

It turns out that snow and ice are extraordinarily good recorders of local climate. For example, the temperature at which the snow formed is recorded in the chemistry of the snow. Each year, a new layer of snow accumulates, burying the previous year's snow. Eventually, the deeper layers are compressed and turned into ice.

By drilling into the ice, it is possible to go back in time, year by year, and see a record of past climatic conditions in Antarctica. In addition, bubbles in the ice contain samples of the ancient atmosphere. One of the most important results that has come out of this work is that the level of carbon dioxide in the atmosphere varies with time in a regular way over the last 800,000 years – 8 glacial-interglacial cycles. These variations correlate closely with the temperature of the atmosphere: when the level of carbon dioxide was high, the temperature was much warmer than when the level of carbon dioxide was lower.

This strong correlation between atmospheric temperature and the level of carbon dioxide is one of the most important results to come out of Antarctic science. It is highly suggestive, but does not prove on its own, that rising levels of carbon dioxide are causing the warming.

4-CO2 today **4:10 mins [0]**

The composition of the atmosphere is routinely measured at a few 'clean air' monitoring sites around the world. The most important one in the southern hemisphere is at Baring Head in New Zealand, and it provides an accurate and continuous record over the past 40 years of the composition of the cleanest air on the planet, blowing from Antarctica and the Southern Ocean.

These measurements clearly show that the concentration of carbon dioxide in the atmosphere is rising year by year. At the time of filming (2008) this was around 385 ppm (parts per million), increasing by about 2 ppm each year, and now, in 2013, it is very close to 400 ppm. The observed rise in CO2 during the industrial era can be clearly linked to human burning of fossil fuels for a number of reasons. Firstly, we know how much fossil fuel we are burning - we can even observe the CO2, using satellite sensors, coming out of power stations. Secondly, we can fingerprint this CO2 and show that it has the molecular signature of fossil fuels. Thirdly, we can observe oxygen levels falling in exactly the right proportion, because combustion involves combining oxygen and carbon to make carbon dioxide. However, the decrease in oxygen is barely noticeable because of the overall much higher concentration of oxygen in the atmosphere

(~20%), compared to that of carbon dioxide (0.03%). In fact, only about half the CO2 created from our burning of fossil fuels is currently ending up in the atmosphere - the rest is being absorbed by the oceans and biosphere (see section below on the oceans).

Given current energy consumption, and we burn all the fossil fuel there is, then it is relatively straight forward to show that CO2 levels in the atmosphere in the early 22nd Century will be about 4 times pre-industrial levels, and at the sort of levels the Earth last experienced nearly 50 million years ago (see section below on evidence from ancient climates), when there were no ice sheets at either pole and crocodiles were swimming off the coast of Greenland, and sea level was about 60 metres higher!

5-The Greenhouse Effect **11:18 mins [11.20]**

If you ask an atmospheric physicist to predict what would happen if you increased the level of so-called 'greenhouse gases', such as carbon dioxide, in the atmosphere, they would tell you that you will get a warming. This conclusion is based on scientific principles in physics that have been known for over a hundred years, because carbon dioxide is a strong absorber of infrared radiation, as the simple experiment in the film shows.

The way that this warming effect actually operates is best understood in terms of the balance between the energy the Earth receives from the Sun, and the energy it radiates back into space. The hotter something is, the more energy it radiates. This energy is in the form of infrared radiation, and it finally escapes from the Earth where the atmosphere becomes thin enough. And so it is the temperature higher up in the atmosphere – at an altitude of about 5 km – that determines the rate at which this energy is radiated out into space. Thus, in the long term, this temperature is set by the requirement that the atmosphere must reach an energy balance such that the amount of energy radiated out into space equals the amount received by the Earth from the Sun.

As we emit more and more carbon dioxide into the atmosphere, the concentration of greenhouse gases in the atmosphere steadily increases, constantly pushing up the radiating level - where the atmosphere loses energy into space - to higher and higher altitudes. However, as any meteorologist regularly observes, the atmosphere gets colder as you go higher, decreasing by about 6°C for every kilometer in altitude. This is primarily a consequence of weather, controlled by the rising and sinking of air masses. So, as the radiating level rises, it also becomes colder. But a colder radiating level emits less energy into space, tipping the atmosphere's energy balance so that now more energy is being received from the Sun than is being lost to space. As a response, the atmosphere must warm up until the new radiating level is hot enough to re-establish an overall energy balance. In fact, a rise in the radiating level of only about 300 metres is enough to cause about 2°C of global warming. This is why global temperatures are so sensitive to our greenhouse gas emissions.

6-Global warming **6:21 mins [3:00]**

Measurements since 1957 show that the level of greenhouse gases such as carbon dioxide is rising year by year. On this account our basic physical understanding of the atmosphere would predict a significant warming. So, is the atmosphere warming?

Daily temperatures are routinely recorded all round the world. Several international science organisations have been compiling this data to look for global trends in temperature over the last 150 years or so. By averaging temperature measurements all round the world, including the surface of the oceans, these organisations have found essentially the same result. This is that average temperature varied little until it began to rise in the 1920s, since when there has been an overall warming of about 0.8°C, with a slight cooling in the 1950s to 1970s, but strong warming in the last 3 decades.

Extending these records further back in time is more difficult, but estimates from tree rings, peat bogs, corals and written records indicate that in the last thousand years, the 20th century has been the warmest, and the 17th century was the coldest.

7-The Changing Arctic **4:24 mins [3:18]**

The temperature records show that the fastest warming place on the planet today is the Arctic. This is confirmed by the testimony of the Sami people of northern Norway, who live very close to the environment. They have noticed that it has become much warmer in winter, with even rain in December now, and also it is much windier. The thickness of the ice on frozen rivers is much reduced, and trees are starting to grow on the tundra, affecting the ability of reindeer to dig in the snow for lichen in winter.

8-Southern Ocean **9:01 mins [6:19]**

Two thirds of the surface of the Earth is ocean. The oceans play a huge role in the link between our emissions of carbon dioxide and global warming. This is for two main reasons.

Firstly, as the scientists explain, for the surface of the planet to warm, the oceans must warm as well. At the moment the oceans are absorbing an enormous amount of heat and this is delaying the final warming caused by the increase level of carbon dioxide and other greenhouse gases. In fact, the observed global warming over the past 30 years or so is between half and two thirds of the expected warming, once the oceans heat up. Thus, warming from past emissions will continue for some decades.

Secondly, the oceans absorb carbon dioxide from the atmosphere, either through direct mixing of ocean water and air, or through the growth of marine algae. At the moment the oceans are absorbing about a third of the carbon dioxide we are emitting, but scientists are unclear whether it will continue to do so in the future as the oceans become warmer and more acidic.

9-Climate Models **2:55 mins [4.56]**

Climate scientists are making predictions about future warming with computer models. These use mathematical equations to represent our physical understanding of the atmosphere and ocean, the role of life, as well as future possible scenarios for human greenhouse gas emissions.

A key parameter is the sensitivity of the climate to our emissions, expressed in terms of expected global warming for a doubling in the level of carbon dioxide in the atmosphere. In fact, sensitivity depends on how long the warming continues for. For example, if the level of CO_2 in the atmosphere suddenly doubled, the initial warming over a period of say 10 years would be only 1 – 2°C, but over many decades the surface layers of the oceans would begin to warm up too, increasing the global warming. But the vast expanse of ice near the poles reflects a significant part of the Sun's energy straight back into space, Over periods of hundreds to thousands of years, as all this ice and snow start to melt, less and less of the solar energy will be reflected away from the Earth, further increasing the warming. With our current scientific understanding, the sensitivity over many decades is somewhere between 1°C and 5°C of global warming for a doubling of carbon dioxide in the atmosphere, with a middle value of about 3°C per doubling .This means that if we continue with our emissions today, by the end of the 21st Century carbon dioxide levels could be between 2 and 4 times the pre-industrial values, and global average temperature could be as much as 6°C higher (11°F).

10-Past climate **6:54 mins [4:04]**

One way to improve our understanding of the sensitivity of the climate to greenhouse gas emissions is to look at past climates when the level of these gases was higher or lower.

It is clear from the geological record that the planet's climate has been far from stable, but has swung between warm and cold periods. These marked changes in climate through Earth History are the strongest evidence we have that there is not some stabilizing mechanism that keeps the climate constant, and so we should expect future climate change from both human and natural causes. The geological record shows there is a strong correlation between past climates and the level of carbon dioxide in the atmosphere.

For example, 50 million years ago, there were crocodiles, tortoises and palm trees near the North Pole. At this time, both minerals in rocks and fossils show that the level of carbon dioxide in the atmosphere was at least twice that today. However, these past levels of CO_2 in the atmosphere have been controlled by natural geological processes. For example, over tens of thousands to millions of years, volcanism adds CO_2 to the atmosphere, whereas the weathering of rocks tends to suck CO_2 out of the atmosphere. If, on these timescales, there are periods of intense volcanism, then CO_2 builds up in the atmosphere. This is the likely explanation for high CO_2 over 50 million years ago. However, if there is a lot of mountain building, then this tends to promote weathering of rocks and CO2 is sucked out of the atmosphere over millions of years. Thus the growth of the Andes and Himalayas over the past 50 million years is the likely reason that the level of CO2 in the atmosphere has declined over this period to the relatively low pre-industrial values.

Both living organisms and the oceans can also affect the level of CO2 in the atmosphere. Thus, cooling oceans tend to absorb CO2 from the atmosphere, promoting further cooling; warming oceans reverse this. As plants and animals grow, they lock up carbon in their bodies. If, when they die, they are buried to become layers of rock, this carbon stays out of the atmosphere over geological periods of time. Humans, of course, as the dig up and burn coal, oil and gas, are now returning much of this carbon back to the atmosphere, causing the level of CO2 to rise.

The rise in atmospheric CO2 over the past 100 years or so is many orders of magnitude faster than geological processes. For example, CO2 from global volcanic activity is less than 1% of our industrial CO2 emissions. In fact, the ice core record shows that the level of CO2 in the atmosphere only changed by about 20 ppm in the ten thousand years preceding the industrial era, but has risen by over 100 ppm in the last 150 years or so. So the current rise in CO2 is at least 300 times faster than the combined effect of natural processes during the last ten thousand years.

Computer models of these past climates strongly suggest that the long term climate sensitivity is at the high end of current estimates, in the range 4 to 5°C per doubling of carbon dioxide in the atmosphere.

11-The future **7:42 mins [5:23]**

Our geological past gives an idea of the sort of climates we are heading for in the future if we continue as we are doing with our greenhouse gas emissions.

Thus, when the level of carbon dioxide was only marginally higher than today, with global temperatures 2-3 °C higher, both the West Antarctic ice sheet, and most likely the Greenland ice sheet did not exist, and sea levels were 10 to 20 m higher. The water currently locked up in these ice sheets is equivalent to about a 10 metre rise in sea level, and so sea level rise is likely to be one of the most dramatic long term consequences of global warming. Scientist predict about a metre of sea level rise by the end of the 21st century if we continue with our current emissions of greenhouse gases.

As the oceans continue to absorb CO2 they will become more acidic, making life impossible for many marine organisms. In addition, there will be changes in rainfall on land, with the wetter regions becoming wetter and the drier regions drier. For example, the monsoon of Asia is projected to be more intense, contributing to flooding and erosion.

However, desert regions, such as the Sahel in Africa or the interior of Australia, are likely to expand. Ultimately, the planet is on course for climates last experienced about 50 million years ago, when crocodiles lived at the North Pole and there were no large bodies of permanent ice anywhere on the planet.

Of all human endeavours, science uniquely allows us to make predictions about the future. Thus, our understanding of the causes of modern global warming, as well as our knowledge was like in the past when atmospheric CO2 levels were much higher, are together helping us look into the future. As our scientific understanding grows, so will our ability to predict the future. Armed with this knowledge, we are in a much better position to both prepare for the future as well as shape the sort of future we want. Scientists will also have a major role in developing technologies to both mitigate CO2 emissions and allow us to adapt to a warmer world.

12-Credits **1:48 mins [0:30]**

RUNNING LENGTH 73 minutes 13 seconds [56 minutes 45 seconds]