

Notes to accompany Revd Professor Ian James' powerpoint on the science of climate change

(Prepared for Climate Justice Fund, September 2009)

[DRAFT]

Slide 1: This powerpoint presentation was prepared by Revd Professor Ian James. It begins by looking at the science of climate change, and then offers some evidence for climate change – and a brief overview of the potential impacts.

Slide 2: We'll start with the science.

Slide 3: Most people by now are familiar with terms like “carbon footprint” – and realise that climate change is linked to the concentration of greenhouse gases, such as carbon dioxide, in the atmosphere. The next slide shows the concentration of atmospheric CO₂ over the last 1000 years. Concentrations remained roughly constant at 280 parts per million (ppm) until the early 19th century.

After the industrial revolution they increased more and more rapidly. Currently – as indicated by the red star on the graph – they are around 387ppm. (For latest data see www.esrl.noaa.gov/gmd/ccgg/trends/)

These data are mostly obtained from analysis of air samples trapped in bubbles in ice drilled from the Antarctic and Greenland ice sheet. Since 1958, daily high accuracy measurements have been taken at the Mauna Loa observatory on Hawaii and are in good agreement with the ice core data.

Slide 4: Even 387 ppm doesn't seem a lot.

Why does such a tiny amount of carbon dioxide matter?

The answer is that even small amounts of CO₂ greatly change the transparency of the atmosphere to infrared light.

A homely illustration shows how small concentrations can make a big difference **[you will need to click three times to see the sequence]** – add a few drops of milk to clear water and it becomes completely opaque. A few drops in a litre of water is a similar proportion to the carbon dioxide in our atmosphere.

In the earth's atmosphere, the major constituents are nitrogen and oxygen, which are transparent to both visible and infra-red light . But there are also present in the atmosphere small quantities of “radiatively active gases” (RAGs).

The most important RAGs are water vapour and carbon dioxide. Less important but still significant are ozone and methane.

These gases make the atmosphere opaque to infrared radiation.

Slide 5: The next slide shows two satellite views of the Earth from a meteorological satellite. The first **[click to get left hand picture]** is taken at the wavelengths of visible light. Away from clouds (typically covering about 30% of the Earth), the atmosphere is transparent at these wavelengths.

The satellite can see right down to the ground.

[click again to get the right hand picture] However, in the wavelengths of infra-red light (right) the atmosphere is opaque: it looks milky in this view. In fact, the lowest levels seen by the satellite are some 10km above the ground.

This difference in the transparency of the atmosphere to visible and infra-red light is the key to the “greenhouse effect”.

Slide 6: What is the “greenhouse effect”?

Energy from the Sun reaches the Earth mostly in the form of visible light. This heats the Earth’s surface which in turn, like any warm body, emits longer wavelength infra-red light back to space.

If Earth were an airless planet, these processes would balance as the Earth reached its equilibrium temperature – a frigid -20°C . However, because we do have an atmosphere containing traces of RAGs, infra-red light from the Earth’s surface cannot escape directly to space. Instead, it is absorbed by the atmosphere. Some is re-emitted into the ground. Some eventually diffuses to the top of the atmosphere and escapes to space.

The result is that the Earth is a great deal warmer than it would be without an atmosphere containing RAGs - $+15^{\circ}\text{C}$.

This is the greenhouse effect – a very good thing, without which life would not be possible on Earth.

The problem is, that if the atmospheric loading with RAGs increases, if, in other words, the concentrations of these gases go up even further, the greenhouse effect will get too effective, less infra-red radiation will escape the atmosphere, and the Earth will warm up.

Slide 7: There are numerous examples of the linkage between atmospheric concentrations of CO_2 and temperature in the geological record.

This slide, based on ice core data, shows the variation of CO_2 (black line) and temperature (red line) over the last 450,000 years. The CO_2 concentrations vary between the immediately pre-industrial 280ppm to as low as 200ppm. When the CO_2 concentration is larger, the temperature is higher and vice versa.

These fluctuations have a period of roughly 100,000 years – they represent the recent alternations of ice ages and interglacial periods.

The inset is on the same vertical scale but shows the fluctuations only over the last 2,000 years. The pre-industrial level of 280 ppm was already at the high end of one of these fluctuations. But the post-industrial change of CO_2 is considerably larger than the ice age fluctuations and is moving upwards – above the highs of the cycles of the past 400,000 years. CO_2 levels are now higher than

they have been for millions of years. And this change has happened not over many thousands of years, but in only around 150 years.

Slide 8: The Earth's atmosphere is unique in the solar system. All its major constituents are continually recycled by living things – taken out of the atmosphere for a time and then eventually either returned to the atmosphere or becoming locked up in the Earth's crust.

On average, a CO₂ molecule spends around 15 years in the atmosphere.

CO₂ is naturally removed from the atmosphere by photosynthesis in green plants and algae and built into organic matter. This organic matter passes down the food chain. Eventually when organisms die and decay, or when they burn sugars for energy, the CO₂ is either released back into the atmosphere or some is buried in the Earth, especially in ocean floor sediments, and is incorporated into the Earth crust.

Since the Industrial Revolution, humanity has created a new pathway in the “carbon cycle”. Carbon buried for hundreds of millions of years in the Earth's crust has been burned for energy – coal, oil, natural gas, and so on.

At the same time, by destroying forests and polluting oceans, humanity is damaging the Earth's capacity for removing CO₂ from the atmosphere.

The net effect is that since the Industrial Revolution, about half the CO₂ released by burning fossil fuels has built up in the atmosphere.

Slide 9: We would expect to find the following effects from an increase in carbon.

Slide 10: Are there examples of current phenomena that suggest that these effects are occurring?

Slide 11: In terms of warming, the obvious thing is simply to measure the global mean temperature. Easier said than done! Observing sites are distributed erratically – lots in Europe and North America, and almost none over the Southern Oceans. Satellite data gives good cover but is less accurate. Widespread measurements have only been available in the latter part of the 20th century, and there were very few indeed before WW1. So establishing trends is difficult.

Some of the odder claims you will hear (eg, temperatures now decreasing) are based on data just for North America, not the whole globe.

This graph shows our best estimates of global temperature over the past 1,000 years **[click]** and this one since 1850.

Slide 12: Climate change is not uniform.

The next picture shows the trend in surface temperature since 1975 at different places. Warming has been most marked at high northern latitudes where it has been as much as 0.75 degrees in a

decade. This is a very large change in so short a time compared to past variations of climate. Warming has been least around Antarctica.

Slide 13: As well as direct temperature measurements, there are many indirect ways of inferring that change is taking place.

Tropical storms (“hurricanes” or “typhoons”) form over the tropical ocean when temperatures exceed 26°C. **[click]** They become more violent and destructive for every fraction of a degree that the sea temperature exceeds the 26°C threshold.

[click] This picture shows hurricane Katrina, which did so much damage to New Orleans – and **[click]** this one shows Katrina superimposed on a picture of sea surface temperature. Katrina tracked along the warmest sea temperatures.

Katrina was a category 5 hurricane, the most intense category, for part of its lifetime. Category 5 hurricanes historically used to form once every 4-5 seasons. In recent years, 2003, 2005 and 2007 all saw multiple category 5 hurricanes.

Slide 14: Extreme weather events such as droughts and heat waves are expected to increase in frequency and severity as CO₂ warming develops.

The summer of 2003 was very hot and dry in western Europe. Parts of France were 5°C warmer than average for a three month period. Paris was deserted as many people left for long vacations in the mountains or at the seaside.

The poor and elderly had no such option. It is estimated that this heatwave was responsible for some 20,000 premature deaths in and around Paris. This is far in excess of the number of deaths caused by any recent newsworthy terrorist outrage – yet it too is a result of human action.

Slide 15: The Arctic sea ice is a sensitive detector of climate change. It is a thin skin of ice, just 2-3m thick, floating on the ocean. Each summer it retreats, reaching a minimum extent in September. Each winter it re-forms.

This picture from 1979 shows that at that time even in September, most of the Arctic Ocean remained ice covered, with ice against the shore along much of the Siberian coastline.

In recent years, the ice has thinned and retreated dramatically. There are now several hundred kilometres of open water between the Siberian coast and the ice in September.

If the present rate of retreat continues, there will be no summer ice cap by 2020.

Slide 16: Almost everywhere in the world, whether in the Alps, Himalaya, Andes, Rockies, Scandinavia and so on, mountain glaciers have been retreating since the 19th century. The only major exceptions are some of the glaciers in New Zealand.

The next two photographs of the Pasterze glacier in Austria were taken from the same spot, the

first in 1875 **[click]** and the second in 2004 **[click]**

Slide 17: Another expected consequence of global warming is sea level rise, initially due to the thermal expansion of sea water, and then due to increasing amounts of meltwater from ice sheets running into the ocean.

Presently, sea levels are rising at about 0.5m per century.

[click] Bangladesh, with about 17% of its land and around 7 million people living below the 1 metre contour line shown here, is one of the most vulnerable countries.

[click] Increasingly, as sea levels rise and tropical storms become more intense, storm surges flood huge areas of agricultural land in Bangladesh, home to some of the world's poorest people.

Globally, a some 10% of the human population live in coastal cities or on coastal plains which are vulnerable to a 1 metre rise of sea level.

Slide 18: The impacts expected from continuing global warming are many and various, and will affect everyone. The next slide, based on a figure from the latest IPCC [Intergovernmental Panel on Climate Change] report, summarises the major impacts.

Many of these impacts are projected to hit poor people in developing countries particularly hard: for example, subsistence farmers in the tropics are likely to be especially vulnerable, which would increase the risk of hunger for people in those areas. It is for this reason that projects like the ones the Climate Justice Fund supports, which will help farmers to adapt to climate change, are vital. And it is because of our role in creating the circumstances which will cause such hardship that we have a moral obligation to support adaptation.

Slide 19: This picture, of the blue-green watery living Earth, rising above the arid surface of the moon, was taken by Apollo astronauts as they orbited the moon.

It has become one of the iconic images of the twentieth century.

That thin skin of air and water, is home to everything we value.

It is no longer a violent enemy, to be subjugated, appeased and exploited.

Our world nurtures and protects us all; it is beautiful, vulnerable and infinitely precious.