Response to Senator Fielding's questions about the climate change science

Question 1

Is it the case that CO_2 increased by 5% since 1998 whilst global temperature cooled over the same period?

If so, why did the temperature not increase; how can human emissions be to blame for dangerous levels of warming?

When climate change scientists talk about global warming they mean warming of the climate system as a whole, which includes the atmosphere, the oceans, and the cryosphere (ice, snow and frozen ground).

The observational evidence clearly indicates that the climate system has continued to warm since 1998. During this period ocean heat content has risen, ice and snow have continued to melt, and there has been no material trend in global air temperatures.

Air temperatures

When changes in surface air temperature are considered, it is important to note that at time scales of around a decade, natural variability can mask the atmospheric warming trend caused by the increasing concentration of greenhouse gases. For example, global average surface temperatures clearly increased between 1975 and 2008 but some shorter periods, such as 1981-1989, showed no warming. Such behaviour is consistent with the outputs of climate models such as those assessed by the IPCC (see below for more details).

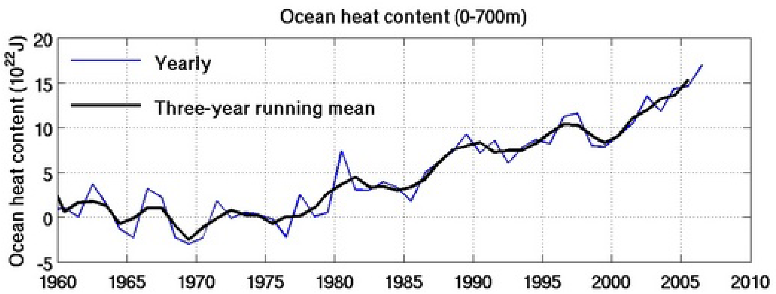
Regarding the 1998-2008 period, the year 1998 was unusually warm due to a strong El Nino event. We note that Question 1 uses 1998 as the beginning year for its trend analysis. So, in addition to the period of analysis being too short to detect underlying trends, the use of a highly unusual year to begin the trend analysis will also give misleading results. This is a simple feature of statistics. Furthermore, globally 13 of the 14 warmest years on record have occurred since 1995.

In terms of the climate system as a whole, only about five percent of the warming since 1960 has taken place in the air.

Ocean heat content

Most of warming since 1960 (about 85 percent) has happened in the oceans. Thus, in terms of a single indicator of global warming, change in ocean heat content is the most appropriate.

The change in ocean heat content since 1960 is shown in the figure below. Note the significant warming trend since 1998.



An analysis of a 42-year record of change in ocean heat content (from 1962 to 2003) shows that over half of the total increase during that period occurred in the last 10 years of the period (1993-2003). That is, the rate of change of ocean heat content has risen sharply over the past 15 years. So, not only is the heat content of the oceans increasing, it is increasing faster.

Ice, snow and frozen ground

Since 1998 there has been continued decline in Arctic sea ice, reduction in the area of snow and frozen ground, melting of glaciers and melting of the Greenland and West Antarctic ice sheets. There has also been a small increase in the area of Antarctic sea ice, although it is not known whether the amount of Antarctic sea ice has changed because there are no data on ice thickness.

Overall the amount of ice, snow and frozen ground has declined. A small amount of ice or snow melt corresponds to a large amount of heat, since additional (latent) heat must be added to cause the melt itself, even without a temperature rise.

About five percent of the warming since 1960 has been in the form of melting ice, snow and frozen ground. The remaining five percent of the warming since 1960 has gone into the land.

The basis of the IPCC assessment

The argument presented in Q1 above is not new and has been thoroughly refuted by a very wide range of observations, reported in the peer-reviewed scientific literature and summarised in the IPCC Fourth Assessment Report, which concludes (SPM page 5) that

> Warming of the *climate system* is unequivocal, as is now evident from observations of increases in average air and *ocean temperatures*, widespread *melting of snow and ice*, and rising global average sea level. (emphasis added)

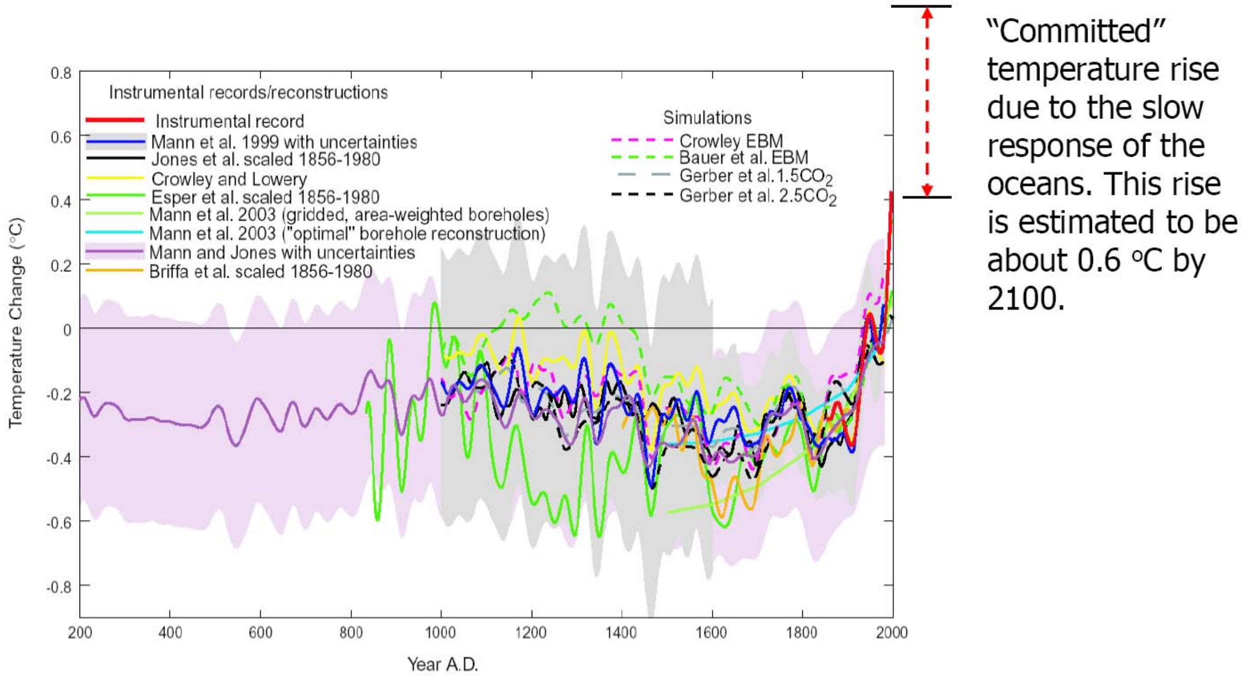
Question 2

Is it the case that the rate and magnitude of warming between 1979 and 1998 (the late 20th century phase of global warming) was not unusual in either rate or magnitude as compared with warmings that have occurred earlier in the Earth's history?

While the Earth's temperature has been warmer in the geological past than it is today, the magnitude and rate of change is unusual in a geological context. Evidence from ice cores shows that between ice ages and warm inter-glacial periods temperatures increased by 4 to 7°C. However this was a gradual process taking approximately 5,000 years. More rapid changes in temperature, such as those associated with the well-known Dansgaard-Oeschger events during the last ice age, are not global but rather highly regional in character. Globally, the Earth has already experienced warming of 0.76°C since 1850, a very rapid change in geological terms.

In terms of timescales of importance for humans, the last 2,000 years are most relevant, because this is the period over which our civilisations have developed. The figure below shows an 1800-year northern hemisphere air temperature record including a variety of estimates of past temperature trends. The light grey shading indictes the uncertainties surrounding these estimates and thus represents the envelope of natural variability over the past 1800 years. The red line at the right is the instrumental record since 1850. The broken red line is the "committed" additional temperature rise due to the thermal inertia of the ocean. Even without this additional rise, the current observed temperature is now outside the envelope of natural variability over the past 1800 years and thus would certainly be considered "unusual".

Trends in Northern Hemisphere air temperature for the past 1800 years. Note that this is the top panel of Fig T.S 20 of the AR4 WG1.



If the warming was not unusual, why is it perceived to have been caused by humans carbon dioxide emissions; and in any event, why is warming a problem if the Earth has experienced similar warmings in the past?

As noted above, the current warming is unusual as past changes have been triggered by natural forcings whereas there are no known natural climate forcings, such as changes in solar irradiance, that can explain the current observed warming of the climate system. It can only be explained by the increase in greenhouse gases due to human activities.

The greenhouse effect is a well-understood physical phenomenon, like gravity. Greenhouse gases have a known ability to absorb heat emitted from the Earth's surface and re-emit it in the lower atmosphere. The net effect – measured as "radiative forcing" – is to increase the heat content at the Earth's surface. Radiative forcing is the common currency for the effect of all factors that influence the heat content at the Earth's surface – solar irradiance, surface reflectivity, greenhouse gas concentrations, and so on. Analysis of the climatic shift between the last ice age and the present warm period gives the quantitative relationship between the change in radiative forcing and the resulting change in global air temperature; this relationship includes all feedbacks within the climate system in an empirical way that is derived without using models. Applying this relationship to the post-1850 warming shows that the magnitude of the warming at equilibrium (that is when the system settles into a stable state) is in proportion to the change in radiative forcing, which in turn is large due to the increasing concentration of greenhouse gases (that is, solar irradiance and surface reflectivity have not changed significantly over this period).

The evidence is thus very strong that the post-1850 warming trend is primarily caused by the increasing concentration of greenhouse gases in the atmosphere due to human activities.

The reason that the post-1850 warming trend is important is because it is moving the Earth outside of the climatic envelope – the patterns of natural variability – within which contemporary civilisation has developed and thrived and within which the ecosystems on which we depend have evolved. For example, many plants and animals will be unable to adapt quickly enough to the warming trend, placing them at risk of extinction. The increased temperature will also alter natural systems such as the hydrological cycle, changing the rainfall patterns on which humans have become dependent.

Research shows that Australia is highly vulnerable to the impacts of climate change and that these impacts will become increasingly severe over time. River flow in the Murray-Darling Basin may decline by 10 to 25 percent by 2050 and by 2100 irrigated agriculture may decline by 92 percent. The Garnaut Review also found that the climate change impacts on infrastructure will have a significant effect on Australia's output and consumption of goods and services, and that the costs of adaptation could be high. In summary, if the current warming trend is allowed to continue unabated through the rest of this century and beyond, the risk of impacts to which contemporary society cannot adapt rises sharply.

Q3

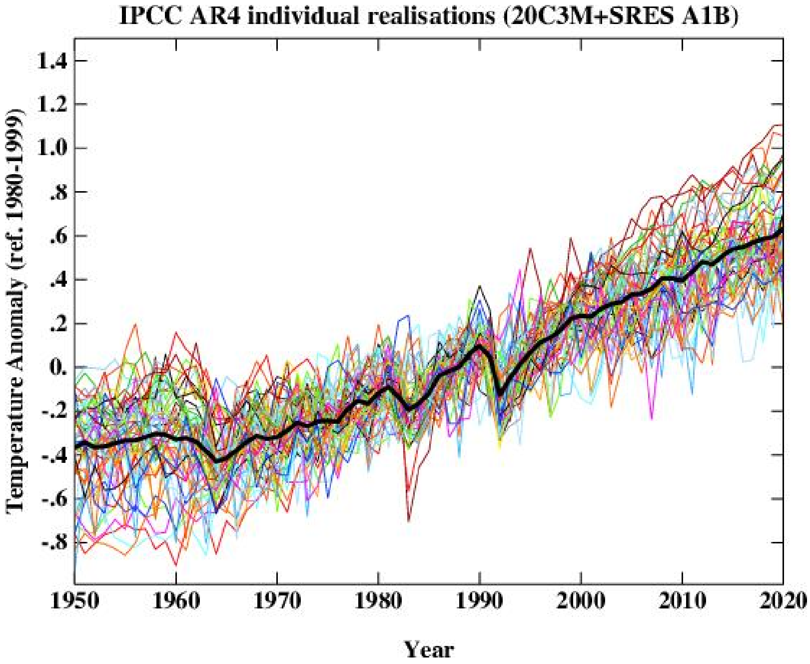
Is it the case that all GCM computer models projected a steady increase in temperature for the period 1990-2008, whereas in fact there were only 8 years of warming were(sic) followed by 10 years of stasis and cooling.

If so, why is it assumed that long-term climate projections by the same models are suitable as a basis for public policy making?

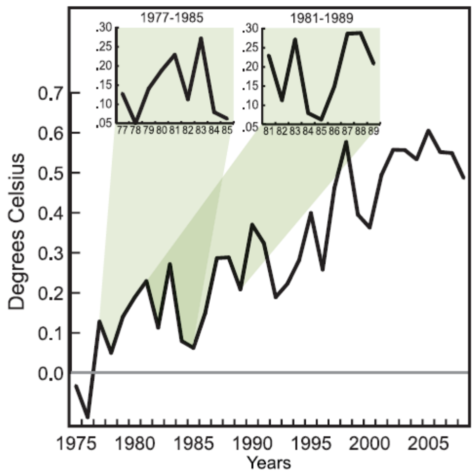
It is not the case that all GCM computer models projected a steady increase in temperature for the period 1990-2008.

As noted above, air temperatures are affected by natural variability. Global Climate Models show this variability but are not able to predict when such variations will happen.

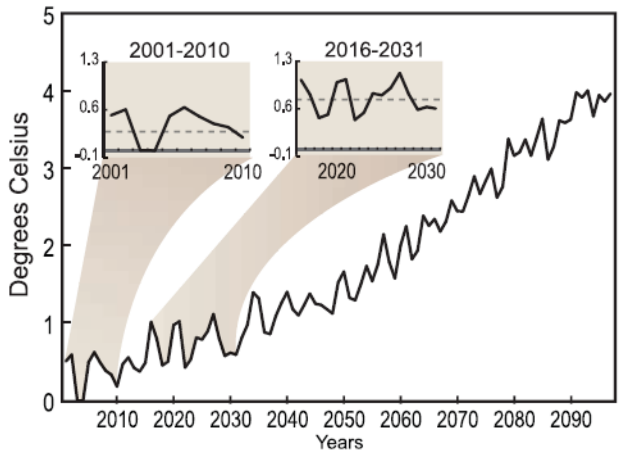
The Global Climate Model data presented in the IPCC Fourth Assessment are averages of many individual simulations. By averaging across simulations natural variability is 'smoothed over' and the result shows only the underlying trend due to large-scale forcings such as greenhouse gases. This is illustrated below. The coloured lines are individual 'realisations' or simulations of global average temperature over the period 1950 to 2020 using a particular model (called 20C3M). The dark line is the average of the individual realisations.



The figure below shows that GCM simulations do capture the decadal patterns of variability evident in the temperature record. They do not predict a steady, uninterrupted increase in air temperatures. The left panel shows two periods – 1977-1985 and 1981-1989 – in the global average air temperature record where no substantial warming was observed, although they are embedded in the longer term trend that does show substantial warming. GCMs reflect this type of pattern. The right panel shows a GCM-based projection of 21st century global average air temperature using a single realisation. Note that the 2001-2010 period and the 2016-2031 period show no significant trend although the century-scale trend is one of strong warming – between 3 and 4°C.



Globally averaged surface air temperature for land and ocean based on the data set by Smith et al [2005]



One realisation of the globally averaged surface air temperature from the ECHAM5 coupled climate model forced with the SRES A2 greenhouse gas increase scenario for the 21st century

Therefore, GCMs can and do simulate decade-long periods of no warming, or even slight cooling, embedded in longer-term warming trends.