An initiative of the National Agriculture and Climate Change Action Plan

October 2008

Climate change:
the scientific basis for concern

Key facts

- The scientific evidence is clear: our climate is changing and humans are mostly to blame.
- Past climate changes have been driven by natural processes but now the climate is also responding to human influences.
- Global warming is clearly evident in instrumental records of temperature, sea levels, and melting snow and ice.
- The temperature increase over the past few decades is largely driven by greenhouse gas emissions from human activities.
- Climate models are tools for understanding why the globe is warming and whether the warming will continue.
- Climate model projections indicate that the future climate is likely to be different to that of the past.
- Potential threats from climate change have been identified for Australian agriculture.
- Farmers need to prepare for unavoidable climate change, as well as help reduce greenhouse gas emissions.

Natural climate variability

The climate of the Earth is changing; it always has and always will.

At very long time scales, natural drivers of climate change include subtle shifts and wobbles in the Earth's orbit. These shifts account for the ice ages and warm interglacial periods over the last million years. At decadal time scales, natural climate drivers include variations in ocean currents and solar output. At the annual scale, drivers such as volcanic eruptions (which cool the earth by adding reflective aerosols to the atmosphere) and the El Niño - Southern Oscillation play important roles. These natural climate drivers, plus random climate variations, ensure that the Earth's climate is never static—it varies at all timescales.

Natural climate variability is a fact of life for Australian farmers. Not only can it mean great differences in rainfall from one season to the next, but it also means that different generations of farmers can have quite different perceptions of 'normal' rainfall for the same farm.

A cooperative venture between

Managing Climate Variability R&D Program
MLA Meat & Livestock Australia
BCG shared solutions
Australian Government
Department of Agriculture, Fisheries and Forestry
Bureau of Meteorology

The greenhouse effect

The greenhouse effect is nothing new; it has been around since the formation of the planet. Naturally occurring greenhouse gases, such as carbon dioxide and methane, allow incoming short-wave solar radiation to pass through the atmosphere, but trap this energy when it is radiated back to space as long-wave terrestrial radiation (Figure 1). The net result of this natural greenhouse effect is that the Earth's surface is, on average, about 35°C warmer than it otherwise would be if the atmosphere had no greenhouse gases in it. Life on Earth depends on the warmth provided by this natural greenhouse effect.

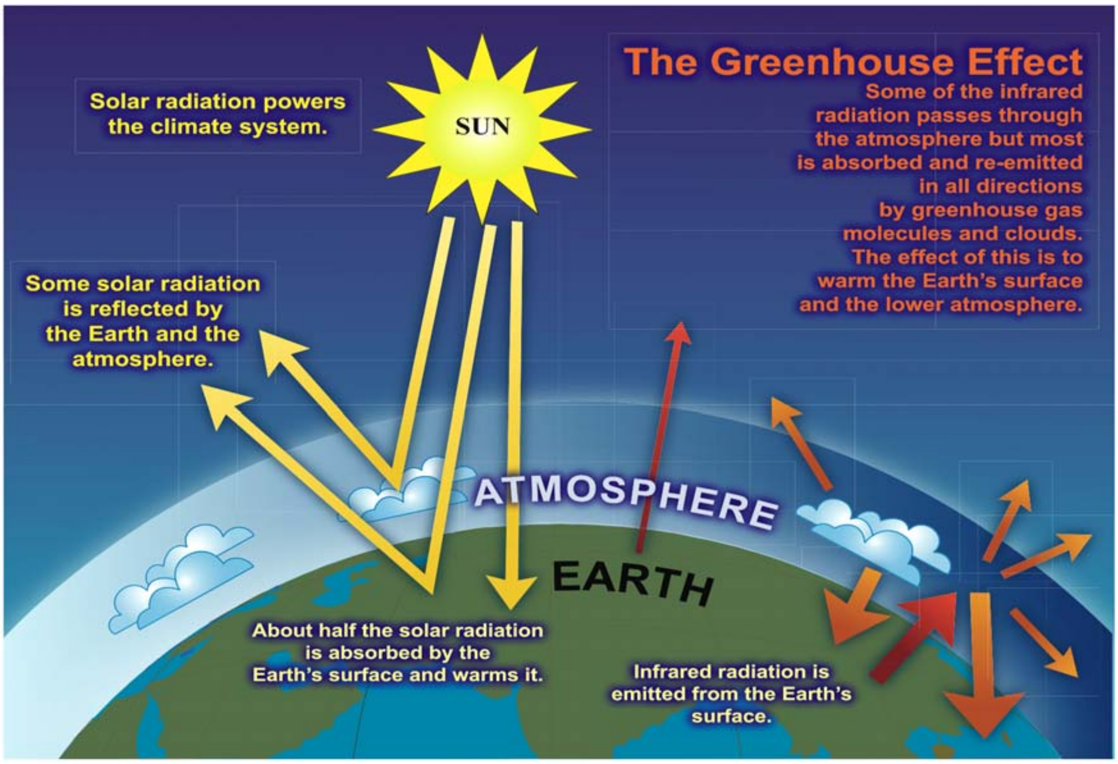

Figure 1: The Earth's natural greenhouse effect

Human-induced climate change

Since industrialisation, deforestation and the burning of fossil fuels have dramatically increased the concentrations of greenhouse gases in the atmosphere (Figure 2). These concentrations are now far greater than concentrations for at least the past 800 000 years. Intuitively, such a massive increase in these greenhouse gases must have an impact on the world's climate. Not surprisingly, scientists have been worried about the potential for human-induced global warming since the 1800s.

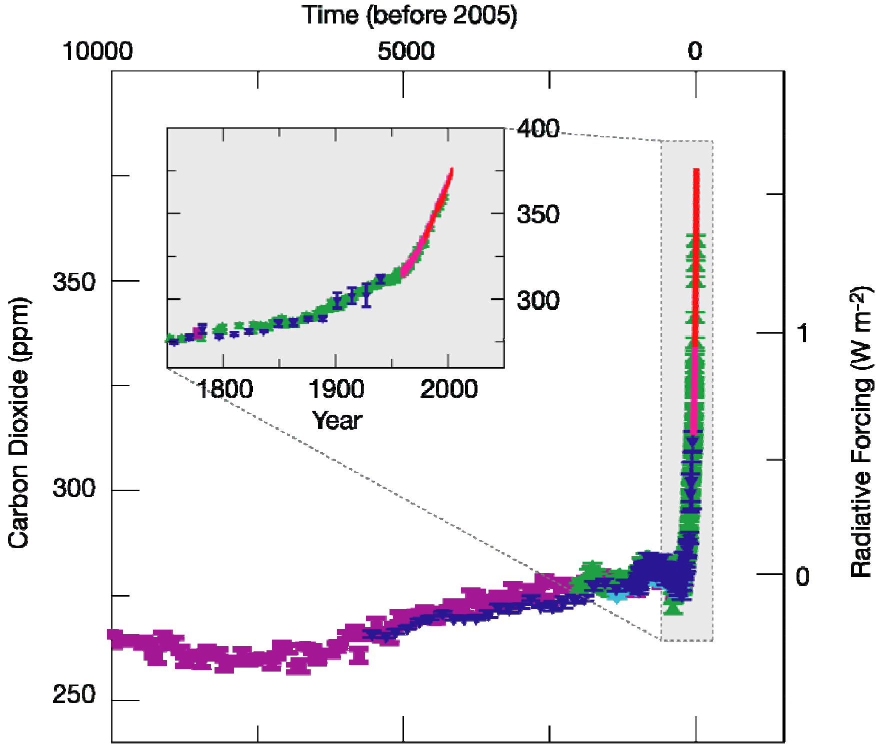

Figure 2: Carbon dioxide concentrations (parts per million or ppm) over the past 10 000 years

Evidence of warming

There are many independent measures that prove that the globe is warming (Figure 3). These include:

- thermometers over land areas
- thermometers in the oceans
- satellite measurements
- melting glaciers and sea ice
- sea-level rise
- earlier flowering and ripening dates
- longer growing seasons
- coral bleaching
- migration of plants and animals towards the poles

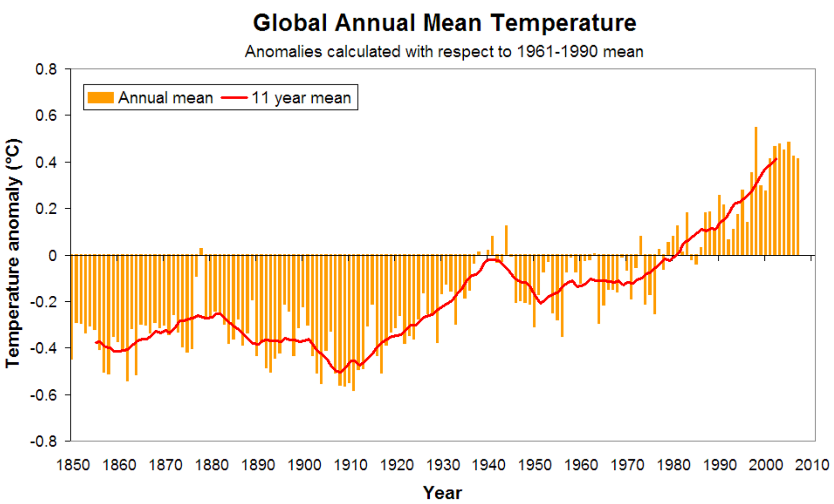

Figure 3: Global annual mean temperature from combined land and ocean observations

Carbon dioxide and temperature – the relationship

Climate records reconstructed from bubbles of ancient air trapped in ice-core samples going back 420,000 years show a strong link between temperature and atmospheric carbon dioxide (Figure 4). Higher temperatures lead to higher levels of carbon dioxide, and higher levels of carbon dioxide lead to higher temperatures.

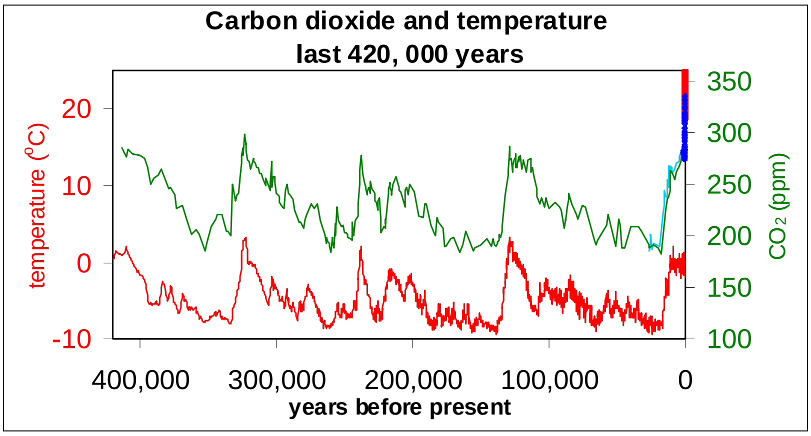

Figure 4: Historical temperature and carbon dioxide concentrations reconstructed from the Vostok ice core, Antarctica (Petit 1999)

How much warming can we expect?

Three scientific facts are enough to expect global warming as a result of industrialisation:

- The Earth has a natural greenhouse effect.
- There is a strong relationship between global temperature and carbon dioxide levels.
- Greenhouse gas concentrations have increased dramatically.

But how much warming can we expect?

If the Earth were simply a huge ball of rock with an atmosphere containing greenhouse gases, it would be relatively simple to calculate how much the surface temperature would increase for a given increase in greenhouse gases. However, the Earth is not just a rocky ball; it has a complex climate system containing oceans and rivers, clouds, ecosystems and ice caps (Figure 5).

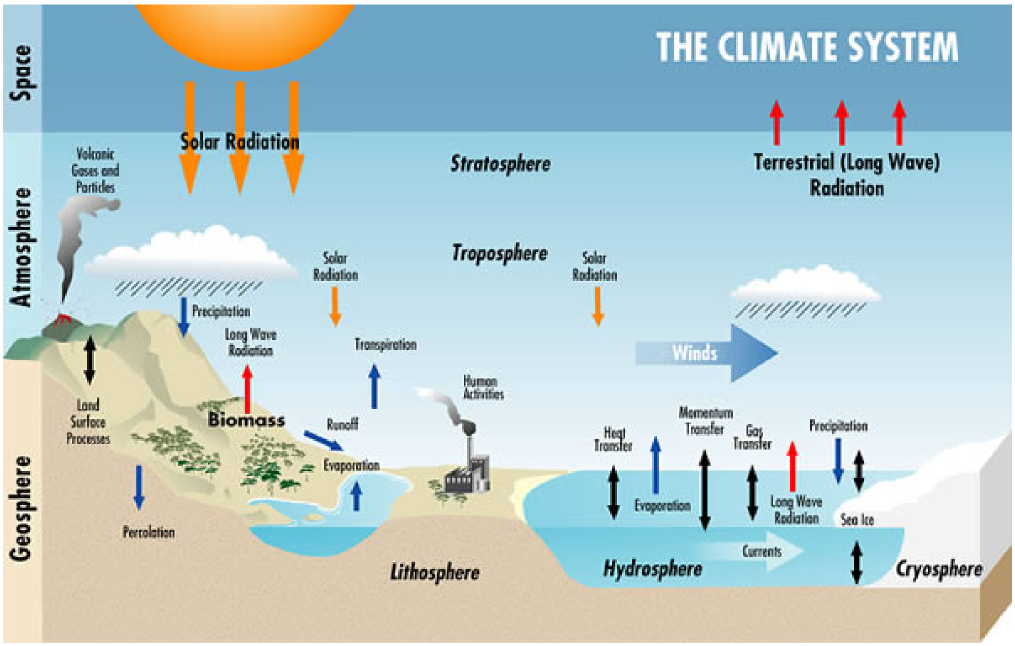

Figure 5: The Earth's climate system

The climate system redistributes energy from the sun and creates '**feedback mechanisms**' that can either amplify or reduce the warming. For example, greater evaporation from higher temperatures leads to more water vapour. Water vapour is a strong greenhouse gas that adds to the warming. But more water vapour also leads to brighter clouds, which reduce the warming by reflecting sunlight.

By burning fossil fuels, we are rapidly releasing carbon back into the climate system—carbon that has taken millennia to become locked away below the Earth's surface.

Scientists have two main ways of understanding what effect this will have by:

- looking to the past
- using climate models

The Earth's climate history tells us that increasing greenhouse gases will lead to a warmer world. To understand this in detail, we need computer simulations of the climate system.

Modelling the climate

Climate models are multi-dimensional mathematical models that simulate the motions of the atmosphere and oceans for decades, or even centuries. They use calculations based on the fundamental laws of physics.

Sophisticated models also include other components of the climate system, such as vegetation and atmospheric chemistry.

Uncertainties in climate models

Climate models are run on the world's most powerful supercomputers. Even so, the great complexity of the climate system means that models must simplify certain aspects of the climate system, particularly those that occur at small scales. This creates uncertainties in climate model output. These uncertainties are well understood and scientists are confident that the models provide reliable insight into how the real climate system works and how it will respond to increased greenhouse gases.

Scientists rigorously assess the ability of models to accurately match the known patterns of present and past climates. Current models are able to reproduce the large-scale patterns and processes of the climate.

Scientists have greater confidence in model output for those aspects of the climate system that models are able to simulate well.

Evidence of human influence

Scientists use a number of techniques to confirm that humans are causing global warming. The most powerful method is to compare what is actually happening with what the climate models predict. These comparisons reveal that the temperature increase observed across the globe over recent decades is far greater than what we would expect from natural climate variations alone.

Spatial patterns of change provide an important clue in determining the cause of this large temperature change. Observed patterns of change that are consistent with patterns of human-induced global warming include:

- greater warming at the poles compared to the equator
- greater warming over land compared to the ocean
- cooling in the upper atmosphere (stratosphere)
- oceans warming from the surface downwards
- greater warming at night
- greater warming in winter
- less rain in the sub-tropics
- changes in atmospheric pressure

By comparing simulated and real-world data, scientists can quantify the relative contributions of different climate drivers such as solar, volcanic, greenhouse gas and sulphate aerosol changes. These studies consistently show that greenhouse gases are responsible for almost all of the warming over the past 50 years.

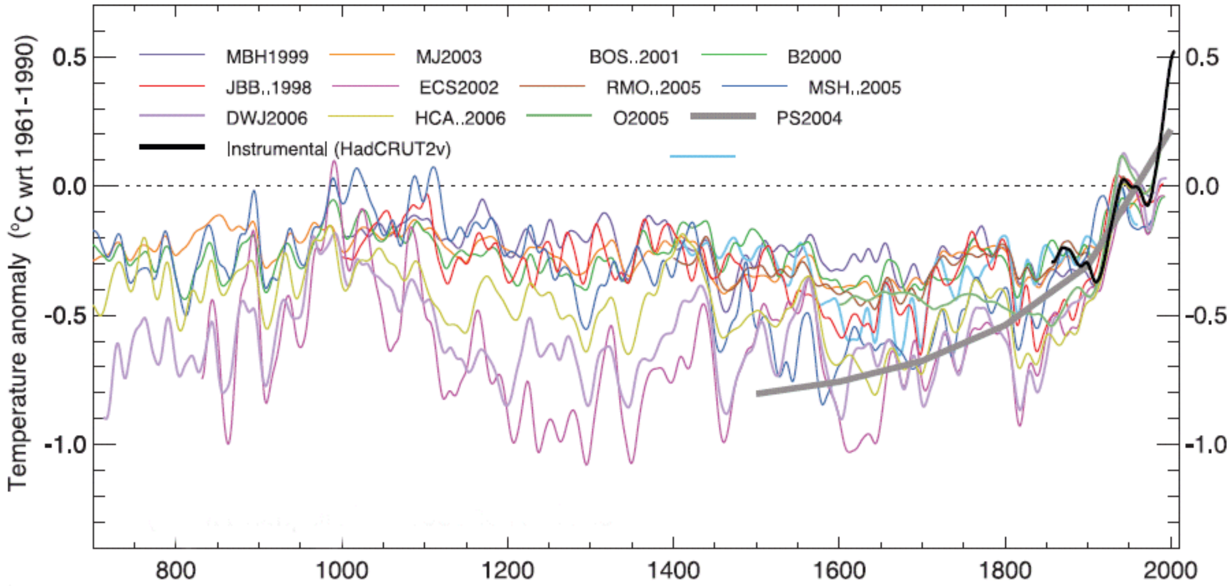

Figure 6: Reconstructions of northern hemisphere temperatures over the past 1300 years

Further evidence for a human influence on the climate comes from records reconstructed from sources such as ice cores, tree rings and corals. When modern instrumental temperature records are put in the context of long reconstructed temperature records (Figure 6), we see that the Earth is currently experiencing a rapid and unusual warming.

Climate change projections

Scientists estimate that the global mean temperature will further increase by 1.1–6.4°C over the 21st century (Figure 7). This estimate is based on climate projections— climate model simulations of the future climate using gradually increasing levels of greenhouse gas concentrations.

Two main **sources of uncertainty** account for the broad range in the estimate of future warming:

- We do not know precisely how greenhouse gas concentrations will vary in the future. Due to demographic, economic and technological factors, a range of greenhouse gas emission pathways are possible for the 21st century.
- Models cannot predict the exact state of the Earth's climate several decades into the future. The climate will warm but the amount of warming projected differs between independent models.

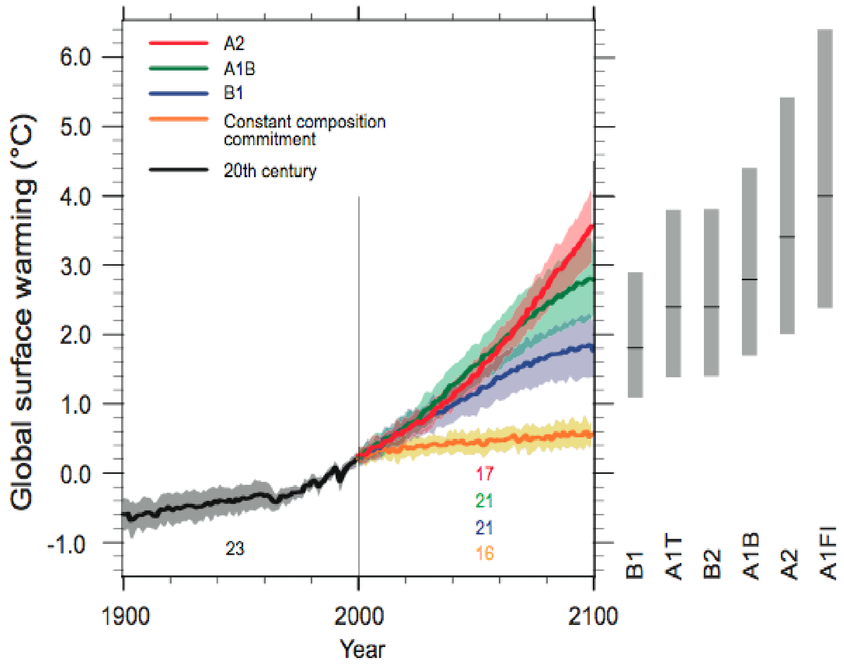

Figure 7: Climate model projections of global mean temperature until year 2100 using different greenhouse gas emission trajectories

Scientists can place greater confidence in climate model projections for regions and variables where independent climate models indicate consistent outcomes. For example, models agree that the future will be warmer, providing scientists with great confidence in this result. By comparison, independent projections of rainfall indicate mixed results for many parts of the world (Figure 8), and are usually regarded with less confidence than those for temperature.

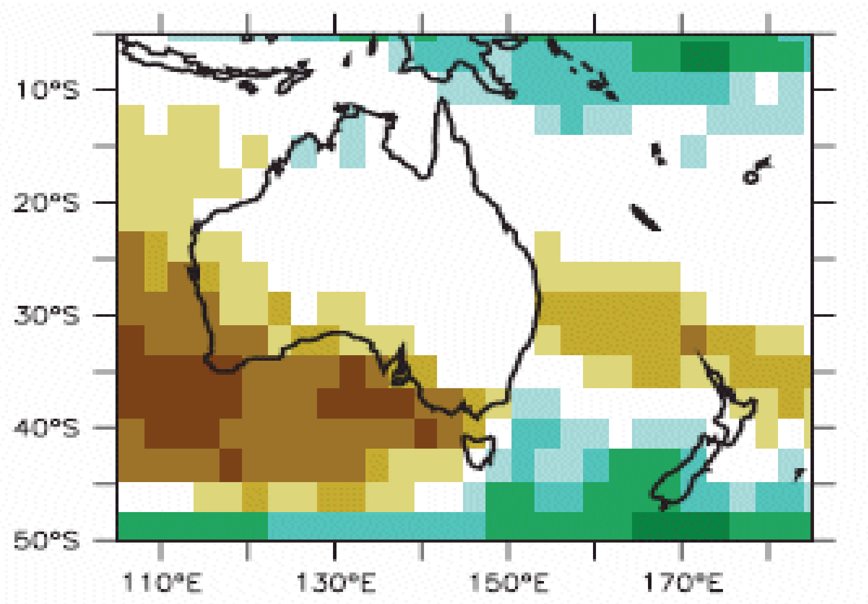

Figure 8: Regional projections of annual rainfall by the end of the 21st Century (brown=consistent decline, green= consistent increase, white=mixed outcomes)

Even when climate model projections are consistent at broad scales, there can still be great variations between different models at specific locations. This makes it difficult for farmers to incorporate model results into strategic decisions about the future. Scientific techniques that downscale model results to the local scale are available.

Threats to Australian agriculture

Climate change will potentially impact specific agricultural industries in Australia. There are large regional differences in vulnerability.

Some of the more broad-ranging threats include:

- decline in productivity due to increased drought and bushfires
- reduced streamflow and quality of water supply across southern Australia
- crop yields benefiting from warmer conditions and higher carbon dioxide levels but vulnerable to reduced rainfall
- greater exposure of stock and crops to heat-related stress and disease
- earlier ripening and reduction in grape quality
- less winter chilling for fruit and nuts
- southern migration of some pests
- potential increase in the distribution and abundance of some exotic weeds

The speed of change

Fossil records indicate that rapid climate shifts caused by natural processes in the past have been accompanied by widespread extinctions of plants and animals. The current rate of global warming is very fast by historical and geological standards. Natural systems have limited capacity to adapt because the rate of change is so rapid, and many plant and animal species are already under other environmental pressures, such as habitat loss.

Greenhouse gas levels are currently increasing at the top end of the worst-case emission scenario. So the time available to address this problem is rapidly diminishing and big changes in climate and hence related systems are becoming increasingly likely.

Further information

The information presented here is sourced from:

- the *Climate Change in Australia* report: http://www.climatechangeinaustralia.gov.au
- the Intergovernmental Panel on Climate Change: http://www.ipcc.ch