Glimpses of a warmer world

Climatologists have identified a lag effect in the global climate system, in the form of the Southern Ocean. **Graeme O'Neill** reports.

In 1998, the average global temperature was 0.66°C above the long-term average, breaking the previous year's record high of 0.43°C. It was the twentieth successive year in which the annual average exceeded the long-term mean.

Although definitive evidence remains elusive, the Intergovernmental Panel on Climate Change (IPCC) believes the warming is probably due to the enhanced greenhouse effect: to greenhouse gases emitted during the past 200 years as a result of human activity.

The portents of this human-induced warming are writ large in the atmosphere.

Atmospheric methane concentrations stand at 680 parts per billion, some 2.5 times their pre-industrial figure (see story on page 4). Much of the increase has occurred this century, during which time the global population has quadrupled.

Atmospheric carbon dioxide concentrations have risen during the past 200 years from 280 parts per million (ppm) to about 360 ppm. By about the middle of next century, the combined rises in carbon dioxide, methane, nitrogen oxides and chlorofluorocarbons will result in increases in atmospheric forcing equivalent to a doubling of the pre-industrial carbon dioxide level.

Dr Peter Whetton and Dr Ian Smith from CSIRO Atmospheric Research, and Dr Z Long from China have identified two ways in which this heating might occur. The first is an 'average' pattern, in which temperatures warm fairly uniformly across the globe. The second is a 'lag effect' which occurs because the Southern Ocean is relatively slow to respond to atmospheric warming (in contrast to the relatively small water masses of the Northern Hemisphere).

The lag effect is characterised by a temperature gradient between the tropics and the higher southern latitudes which becomes more pronounced up to 2100, then decreases as the Southern Ocean catches up when greenhouse gas concentrations stabilise.

Leader of the division's Climate Change Impacts Group, Dr Barrie Pittock, says rainfall patterns are strongly influenced by the tropic-to-pole temperature differential. Because of this, patterns of climate change in the southern hemisphere will continue to vary, and may even change direction, after greenhouse gas concentrations stabilise.

'It's relatively straightforward in the northern hemisphere, but because the climate of southern Australia is greatly affected by what happens in the Southern Ocean, we must be careful that our model accurately simulates the lag effect,' Pittock says. 'That's why the Australian contribution to global climate modelling is so important for all countries in the Southern Hemisphere.'

Peter Whetton has used CSIRO's Global Climate Model (GCM) to study the effect on global temperatures of a tripling of atmospheric carbon dioxide.

In an experiment in which greenhouse gases stabilised at about three times pre-industrial concentrations at 2100, the model predicted a steep warming trend until 2100, followed by more gradual warming well beyond that date.

'The model predicts slow warming, even after 300 to 400 years, because the deep oceans will still be catching up with the atmosphere,' leader of the group, Dr Barrie Pittock, says.

'When nations involved in the Climate Change Convention talk about stabilising greenhouse-gases in the atmosphere next century, they should realise that it won't stabilise the Earth's climate, because of the huge lag built into the system.'

Emre Turak/Australian Institute of Marine Science

Bleached coral caused by warm seawater temperatures occurring in the Indian and Pacific oceans in 1998.

Another challenge for the Climate Impact Group lies in predicting the behaviour of the El Niño-Southern Oscillation (ENSO) – the driver El Niño and La Niña events – under an enhanced greenhouse regime.

El Niño and La Niña events are driven by temperature changes in the surface layers of the tropical Pacific, which in turn influence evaporation. During an El Niño, eastern Australia experiences drought and bushfires, while on the eastern side of the Pacific, coastal Chile and Peru experience storms, flooding and mudslides. La Niña events reverse the El Niño pattern, bringing heavy rain and flooding to eastern Australia.

'We may move into a pattern in which El Niño and La Niña events become more frequent or change their characteristics,' Pittock says.

To find out, the researchers are developing a detailed, regional model of the tropical Pacific surface layer which will be 'nested' in a small area of CSIRO's GCM.

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Rising threats to coral reefs

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MORE frequent or severe cyclones could seriously affect reef ecosystems adapted to the current frequency of cyclone damage and self-repair.

Coral bleaching from higher water temperatures and other stresses is occurring over large areas of the Great Barrier Reef. A more subtle threat comes from rising carbon dioxide concentrations, which will reduce the alkalinity of the ocean's surface waters, slowing reef growth by reducing the rate at which coral polyps deposit calcium carbonate.

'Under a doubled carbon dioxide regime, calcification rates could fall from 10-30%, depending on the species,' CSIRO's Dr Barrie Pittock says.

Another interesting exercise is to attempt to quantify how corals will cope with rising sea levels. Paleooceanographic data indicates that coral reefs can keep pace with long-term sea level rises of the order of 8 mm a year. Estimates for rates of sea level rise next century suggest corals will survive at all but the uppermost rate, about 1 m per century, or 10 mm a year.

'But reduced calcification rates could prevent some corals growing even at 8 mm a year,' Pittock says. 'Slower-growing corals could drop out of the species mix. We also have to consider the effects of rising sea levels on deep-growing corals, which are already pushing the limits of light availability.'

Predicting the impacts of global warming on the Great Barrier Reef is further complicated by the potential effects of increased runoff from the land if rainfall increases.

At the Australian Institute of Marine Science in Townsville, Dr Terry Done is modelling the freshwater plume from the Burdekin River, which feeds sediment, along with chemical residues and nutrient runoff from the farms on the Burdekin Delta, into the reef lagoon.

'Until now the project has been looking at the effects of land management on runoff, but now we want to factor in climate change,' Pittock says.

'Reefs are adversely affected by large influxes of fresh water, by sediment loading, which reduces light penetration, as well as by fertilisers that fuel algal growth, and herbicides that kill algae. We want to know how climate change and sea level rise will influence these factors.'

Climate – particularly through its effect on water temperature – strongly influences the distribution and composition of the world's coral reefs. Pittock says the Red Sea is several degrees warmer than the Great Barrier Reef, and its coral communities are different, and less diverse. In a warming world, the unique biodiversity of the world's richest coral reef ecosystem could be at risk.

This task, being tackled by Dr Steve Wilson, is complicated by the vastness and variation of the surface layer. In the western Pacific, around northern Australia, the warm surface layer is about 300 m deep; off the South American Coast it is often only a few tens of metres deep.

Pittock says German climatologists at the Max Planck Institute for Meteorology in Hamburg have a higher resolution GCM (its grid size is 1°, compared with 3-4° in the present CSIRO model) that generates more realistic ENSO events, of larger amplitude than the CSIRO GCM.

'Both the German model and ours, and most other GCMs, indicate that the eastern tropical Pacific will probably warm faster than the west, creating a temperature differential along the equator resembling an El Niño event,' he says.

'A simplistic conclusion is that this means more droughts in Australia and Indonesia, but that won't necessarily happen. 'Indonesia doesn't become much drier, presumably because global warming puts more moisture in the atmosphere, enhancing the hydrological cycle. So it actually becomes much wetter in the eastern Pacific during El Niño events.

'In the western Pacific, the enhanced hydrological cycle and the stronger El Niño tend to cancel each other out.'

ENSO is one of three climatic phenomena that govern Australia's climate.

Models must also summon forth the so-called Indian Ocean Dipole, which has a similar pattern to ENSO events, but its own phase. In some years, a persistent warm spot in the north-eastern Indian Ocean south of Java spawns cloud bands that move diagonally across the continent, bringing rain to the south-east. In 'off' years, cool sea-surface temperatures in the same region cut off this source of moisture.

The third player is a newly identified phenomenon known as the Antarctic Circumpolar Wave, in which long, low oceanic waves slowly circle the southern continent in a clockwise direction. (See Australia's Climate Cerberus: the puzzle of three oceans, *Ecos* 97.)

The waves, which are enormously long but only a few centimetres high, are associated with a massive expanse of water that is slightly warmer than water in the intervening troughs. As they wash along Australia's southern coastline, the waves create a subtle cycle of alternating warm and cool temperatures that influence evaporation and rainfall.

Human influences could also intervene. For example, large-scale logging and burning of Indonesia's rainforests continues apace. Pittock and colleague Dr Roger Jones say rainforest transpiration remains relatively stable at higher temperatures, but evaporation increases rapidly when the canopy is opened or the forest is cleared.

Opening the canopy dries the forest, leaving it vulnerable to fire – as the recent El Niño drought demonstrated. And when land is cleared for rice paddies, peat bogs in the forest dry out, and can catch fire; peat fires are difficult to extinguish.

These synergies between global warming and human influences must be integrated into climate-change models, Pittock says. The IPCC's next report, due in 2001, will take a more interdisciplinary approach, looking at issues such as sustainable development and equity, and the potential impacts of climate change on important marine and terrestrial ecosystems.