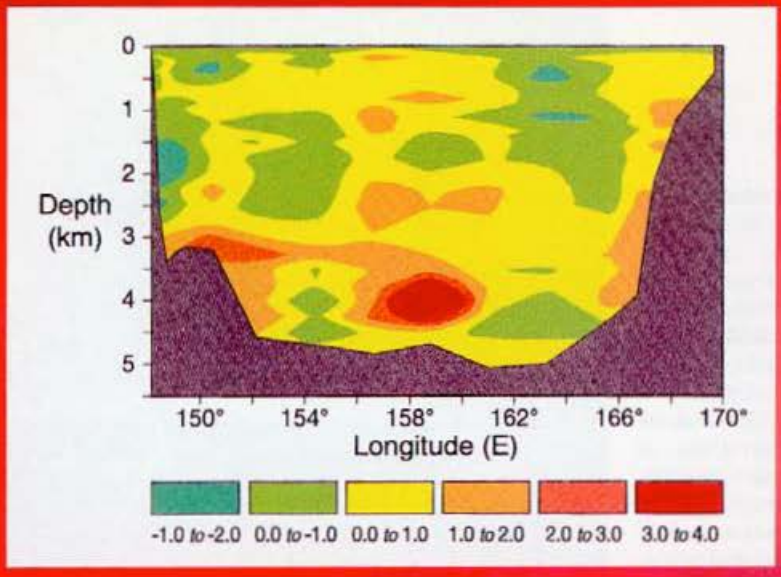


The diagram shows 'normalised temperature differences' (expressed in degrees C divided by an estimate of how much temperature varies over a period of 6 months) between 1967 and 1989 — at 43°S between Australia and New Zealand. The most significant changes occurred in the depth range 500–600 m and at depths exceeding 2·5 km.

Photo: David Johns

Unravelling the climate-change conundrum

With 'greenhouse scenarios' arousing growing controversy and public concern, this *Ecos* feature provides a broad update on the scientific state of play

In 1967, an American research vessel, *Eltanin*, completed an oceanographic survey across the Pacific Ocean between Australia and Chile, collecting water samples from the ocean's interior. The 'Scorpio cruise', as it is known, measured temperature and salinity levels in ocean waters from the near-surface to depths below 4·5 km.

More than 20 years later, the CSIRO research ship, RV *Franklin*, retraced part of the earlier cruise, following the same lines of latitude (28°S and 43°S), collecting water samples at 72 sites across the Tasman Sea. The findings were striking — the first firm evidence of climate change in the Southern Ocean, perhaps due to the enhanced greenhouse effect. The follow-up survey found evidence of warming in the oceanic interior (see the print-out above), a rise in sea level and changes in salinity suggestive of surface warming in the Southern Ocean.

Although the observed temperature rises since the 1960s appear to be slight (for example, 0·04°C on average at 43°S), the differences are highly significant. Long-term rises, however small, in the deep interior of the ocean are less likely than observed changes in

air or surface water temperatures to be the consequence of natural climatic variability.

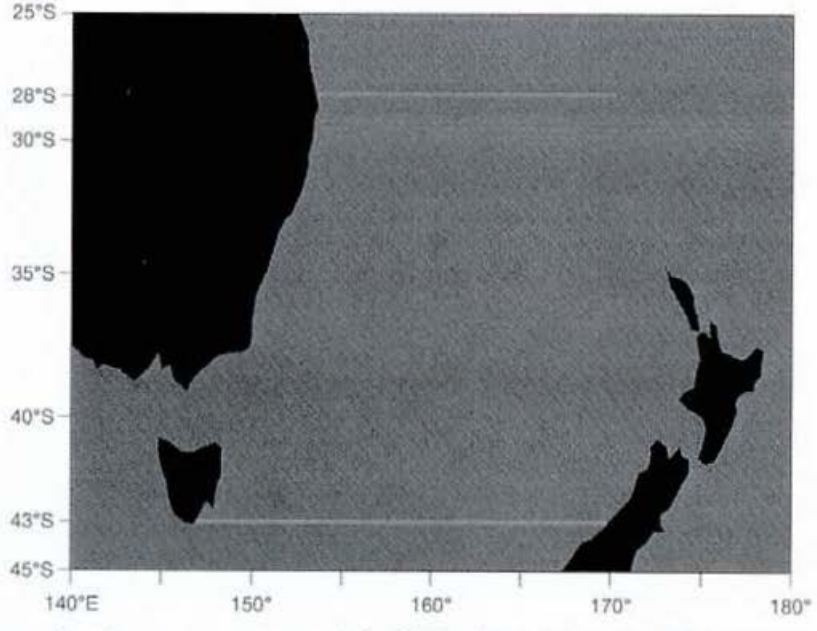
Two researchers analysed the *Franklin* data — Dr Nathaniel Bindoff, now at the Co-operative Research Centre for Antarctic and Southern Ocean Environment, and Dr John Church of the Centre and the CSIRO Division of Oceanography. They have given a cautious interpretation of the results, arguing that conclusive evidence of global change will require a continuing survey of the oceans on a global scale. They say that, while the changes might have resulted from natural variation in the climatic system, that appears unlikely and at this stage greenhouse-induced climate change provides the most plausible explanation.

The enhanced greenhouse effect is the biggest single environmental issue of the 1990s, and the stakes are high. A recent analysis of options for the abatement of global warming in the United States put the estimated direct cost of replacing all existing fossil-fuel power plants with nuclear and renewable energy sources at about $US90 billion. Not surprisingly, governments and big business periodically question the need for such massive expenditures and call on scientists to provide stronger proof that climate change is occurring, and more detail about its likely consequences.

RV *Franklin*

The work by Dr Bindoff and Dr Church — which Dr Bindoff describes as 'another bit of the picture' — is one of numerous highlights to emerge from CSIRO's climate-change research program, now in its fourth year. (This has guaranteed federal government funding for another 3 years). The $12 million program is CSIRO's largest inter-Divisional research effort, involving more than 100 scientists in seven Divisions and centres. Already it has produced an enormous outpouring of new scientific findings on climate variability and possible change. For example, in 1990/91 the scientific staff within the program published or prepared for publication more than 170 research articles, technical reports and conference papers on topics related to climate change.

In little more than 3 years, they have developed a global atmosphere model that has been shown to perform well in simulating climate in the Asia–Pacific region (see page 36). In addition, the program has produced global ocean and sea-ice models, valuable new mathematical schemes for describing the interaction of soil and vegetation with the atmosphere and a haul of new insights from ice-core and trace-gas measurements.



Water samples taken on two cruises made by RV *Franklin* in September 1989 and March 1990, as a follow-up to an American survey in 1967, provided strong evidence that climate change due to the enhanced greenhouse effect is under way.

Work by program researchers has also contributed considerably to the scientific basis for the estimates of global warming made by the Intergovernmental Panel on Climate Change (IPCC).

Despite the current extent and intensity of research here and abroad, climate change due to the enhanced greenhouse effect remains an unproved scientific hypothesis, although the sceptics are mostly non-scientists. In a recent speech to the Australian Academy of Technological Sciences and Engineering, the managing director of Western Mining Corporation, Mr Hugh Morgan, questioned the reasoning behind the IPCC's estimates, implying that the scientific community had yet to deal adequately with 'the corrupting influence of power and money'.

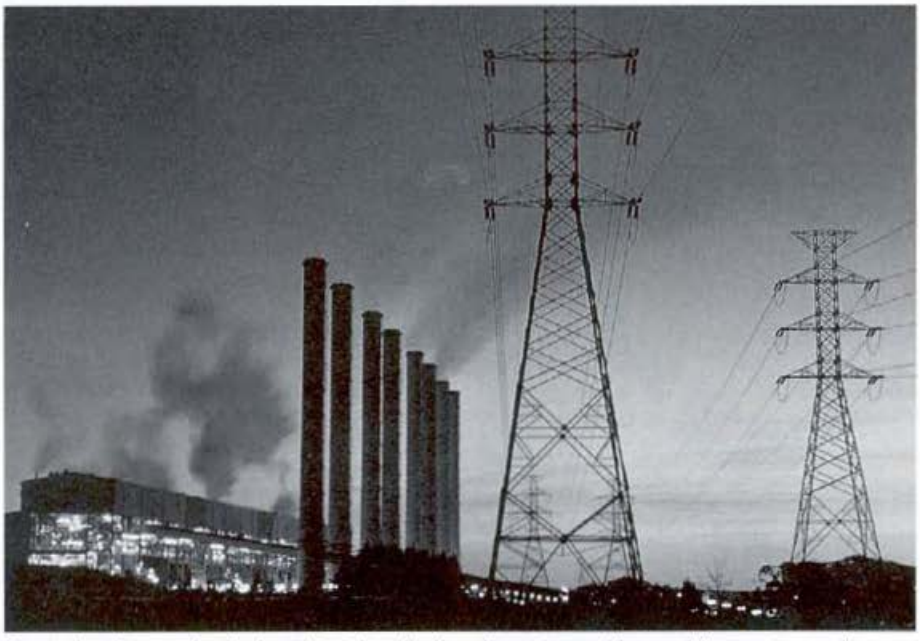
Most climate scientists see global warming as the inevitable thermodynamic and hydrodynamic consequence of a continuing build-up of greenhouse gases in the atmosphere. Those gases absorb heat that would otherwise radiate into space and re-emit the trapped energy back to Earth's surface. While large uncertainties remain about the rate and extent of climatic response by the oceans and atmosphere (and the rate of accumulation of greenhouse gases from human activities), almost all scientists accept that significant global warming will occur in the next 50 to 200 years.

A noteworthy exception is Dr Richard Lindzen, Professor of Climatology at Massachusetts Institute of Technology in the United States, and an authority on atmospheric dynamics.

On a visit to the CSIRO Division of Atmospheric Research in Melbourne last July, Dr Lindzen told a packed conference room that the computer models in use today exaggerate the likely impact of greenhouse gases such as carbon dioxide by wrongly assuming that water vapour will increase throughout the lower atmosphere.

Water vapour is a trace gas that most scientists believe will substantially magnify any initial warming in the atmosphere due to CO_2 or other gases. Its effects are seen as the most important of the feedback processes that influence the energy budget in the atmosphere.

Dr Lindzen argued that the models did not adequately represent the physics of water vapour in cloud formation and convective mixing, and hence overstated the strength of the feedback that would result from a doubling of CO_2 concentrations. In his view, a small rise in global air temperatures may cause more moisture to fall out of the atmosphere as precipitation and thereby flood the upper layers of the troposphere with relatively dry air, weakening the influence of water vapour on the energy budget. In support of his argument, he quoted from a new, unpublished analysis of global humidity trends that he claimed — if it was sound — would settle the global warming debate.



Power for the people: the burning of coal, oil and gas to meet the world's energy needs contributes about 5 million tonnes of carbon (as CO_2) to the atmosphere each year. Scientists are still not sure where all this carbon goes.

Dr Graeme Pearman, co-ordinator of the CSIRO climate-change research program, said Dr Lindzen's view, if correct, would significantly alter the estimates for global warming. But the published observational evidence strongly supported the accepted view that, as greenhouse gases accumulated, water vapour levels would increase at all levels of the troposphere, and therefore magnify the climatic impact of the build-up. 'However, we are doing some tests to see if we can look at aspects of his proposals', he said.

Dr Pearman was highly critical of a growing tendency among scientists to publicly propound scientific views based on evidence unconfirmed by the accepted process of peer review. Mr Morgan, in his Academy speech, called on scientists to accept a 'duty of care' in respect of the wider public and 'no longer confine their publishing activities to the scientific literature'.

The scientific methodology, Dr Pearman said, depended on the peer-review process. 'We (the scientific community) have established a culture that tries to protect us from bias, and tries to protect us from concepts that can't be justified in an entirely objective way.

'Without that we are vulnerable to poorly developed arguments, even arguments developed on the basis of pre-determined outcomes. Therefore any time one uses observational or experimental data that haven't undergone the peer-review process to start with, and uses them very publicly, that's very dangerous, and I don't think Dr Lindzen's doing anyone justice, especially himself, in doing that.'

Brett Wright

More on the topic

'CSIRO Climate Change Research Program Annual Report 1990–91.' G.I. Pearman and C.D. Mitchell (eds). (CSIRO: Melbourne 1991.)

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Realistic mitigation options for global warming. E. S. Rubin, R. N. Cooper, R. A. Frosch, T. H. Lee, G. Marland, A. H. Rosenfeld and D. D. Stine. *Science*, **257**, 1992, 148–66.

Can our society survive without science? H.M. Morgan. Speech given to the Australian Academy of Technological Sciences and Engineering, Victorian Division, Clunies Ross House, Parkville, 4 August 1992.