PARLIAMENT OF AUSTRALIA

Legislative Research Service

THE GREENHOUSE EFFECT

Implications for the Southwest Pacific

Bryan Stait

Science, Technology & Environment Group

BACKGROUND PAPER

2 March 1990

ISSN 1034 – 8107

Published by the Department of the Parliamentary Library, March 1990.

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EXECUTIVE SUMMARY

The "greenhouse effect" is a natural phenomenon that has supported life on earth. Current concern relates to the impact of human activity, through the increase in concentration in the atmosphere of some trace gases. (pp. 1-9)

Models to predict the effects of these alterations to the greenhouse effect are imprecise and do not allow accurate prediction of what may happen as a result, in particular, of a doubling of atmospheric CO_2. There is a lag between greenhouse changes and some impacts. (pp. 9-13)

The weight of scientific evidence suggests that greenhouse warming of the atmosphere has not yet been demonstrated, particularly because of the need to take into account other factors influencing climate and weather. A clear indication will be evident in 10 to 20 years. (pp. 13-16)

Nevertheless a number of potential consequences especially for Australia and the South Pacific require examination and concern. (pp. 16-21)

There have been a number of conferences to discuss the greenhouse effect (pp. 21-23); there have been some official research responses in Australia and some consideration of policy options. (pp. 23-26)

Without diminishing the responsibilities of individual countries, a global approach to the issue is clearly required. While greenhouse impacts remain speculative, there are actions that can be taken now, particularly in energy conservation, that would be economically rational and advantageous in reducing use of non-renewable reserves, with the objective of diminishing greenhouse impacts later. There would be clear benefits from energy efficiency and environmental quality even if predicted climate changes do not occur. (pp. 26-28)

ISSUES

There are two main issues for national governments in relation to the greenhouse effect.

- Is the predicted warming due to the greenhouse effect occurring, and to what extent can we anticipate the changes that may occur.

- What policy options can be adopted to mitigate adverse effects and what should be the priorities for action.

INTRODUCTION

What is the greenhouse effect

Although first suggested nearly 129 years ago (Tyndall 1861) the greenhouse effect has only reached the notice of the wider scientific, public and political community late in the 1980s.

In the last two hundred years the growth of industry, agriculture, transport and energy use have increased the levels of certain gases in the atmosphere, known collectively as the "greenhouse gases".

Warming of the atmosphere occurs as short wave length radiative energy that reaches the earths surface is re-radiated at a longer wave length. This re-radiated longer wave length radiative energy is absorbed by the greenhouse gases. Therefore as greenhouse gases increase in level more heat is retained in the atmosphere resulting in a warming, the greenhouse effect.

Without a natural greenhouse effect in the atmosphere the Earth's temperature would be 30^{o} C cooler than at present and

life as we know it would not be possible. Thus it is not the "greenhouse effect" per se that is the problem but instead the rapid and profound magnification of the effect resulting from human activity that is a cause for concern.

Throughout geological time, global temperatures have varied considerably resulting in widespread ice caps as well as periods of higher temperature. Levels of CO_2 have been higher than present in the last 160,000 years but the current rate of increase is unusually high (Barnola et al 1987).

The issue, in any discussion of the greenhouse effect, is the extent to which human activity can precipitate change which results in rapid variations in climate and sea level. The effects of these changes are as yet difficult to quantify but preliminary indications are that for many areas of the globe the results would cause considerable social, environmental and economic dislocation.

The greenhouse effect is not restricted to a particular nation or grouping of nations but is a global problem requiring a global solution. However, this does not mean that nations should not take actions individually or as groups. Such actions will not only contribute to the slowing of greenhouse warming but will act as an example to other nations and may establish the basis for effective international agreements if these are achievable.

Climate v weather

Throughout the following discussion it is vital to understand the difference between climate and weather. Weather "describes the state of the global atmosphere - ocean - ice - land system (i.e. the climate system) at one instant in time". Climate is the "aggregation of the weather, usually expressed in terms of the mean (or average) conditions and variations about this mean, ..." (MacCracken and Luther 1986).

Weather can be predicted only a few days ahead, at best. Thus, while the weather on a particular day in the future cannot be predicted, we may be able to predict that a day in that month will be warmer than a typical day in the same month at present.

Greenhouse gases

The greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs), water vapour (H_2O), ozone (O_3) and a number of other trace gases. The majority of these gases (but not CFCs) occur naturally, were present in the pre-industrial atmosphere and contributed to the regulation of past climate. The current concern about global warming comes about because recent human activities have dramatically increased the amount of these gases being released, disrupting long term relationships between components of the atmosphere. CFCs are a major contributor to the greenhouse effect and did not exist prior to this century, being products of modern science (Figure 1).

RADIATIVE GAS	PERCENTAGE CONTRIBUTION BASED ON TEMPERATURE RISE POTENTIAL	PRINCIPAL SOURCE
CO_2 50%± 5	(15%±5	Deforestation and Land Use
	(	Petroleum
	(14%	Coal
	(10%	Natural Gas
	(5%	Other Fuel and Process
	(5%	
METHANE	15%±5	Agriculture, Cattle Biomass Burning, Natural Gas
C.F.C's	13%± 3	Aerosols Airconditioners Refrigeration Plastics
OZONE	10%± 5	Motor Vehicles
N_2O	9%± 2	Fertilisers, Motor Vehicles Fossil Fuel Burning Biomass Burning

Figure 1. Relative contribution of greenhouse gases resulting from man's activities (from Sullivan 1989).

Carbon dioxide.

Carbon dioxide only makes up about 0.03% of the atmosphere, but it is extremely important in controlling climate. CO_2 has increased by 25% in the last 100 years and is predicted to double by 2040. The average annual increase in CO_2 is 0.4% (Figure 2). It contributes approximately 50% of the greenhouse warming of which 15% is due to deforestation and land use, and 35% due to the burning of fossil fuels.

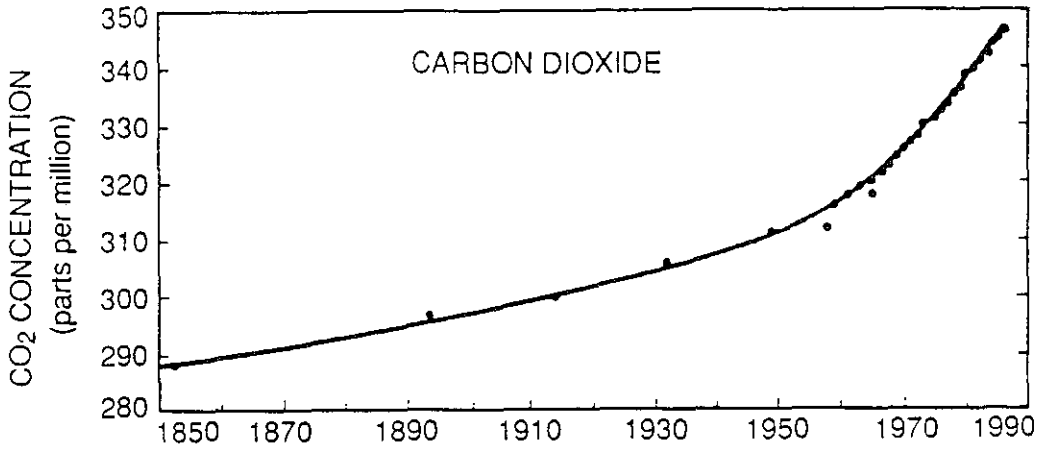

Figure 2. The build –up of atmospheric carbon dioxide over the past 140 years (from Zillman et al. 1989).

Methane.

Methane comprises 15% of the total greenhouse warming effect, and comes predominantly from agricultural activities (e.g. rice growing and cattle), biomass burning and natural gas (Figure 3).

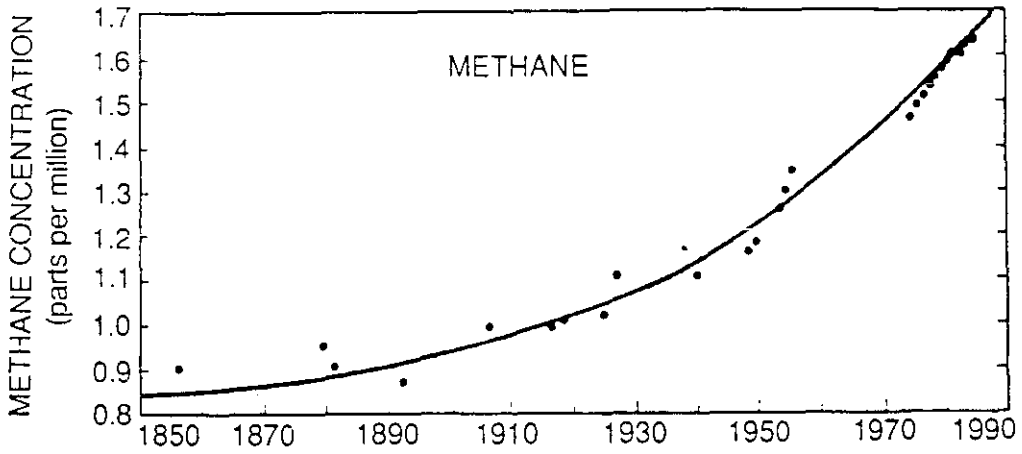

Figure 3. The increase in atmospheric methane concentration over the past 140 years (from Zillman et al. 1989).

CFCs.

CFCs are entirely man-made and have recently received wide publicity because of their links to stratospheric ozone depletion. CFCs in the troposphere (lower 12 kilometres of the atmosphere) are very efficient greenhouse gases and currently contribute about 13% of the greenhouse effect (Figure 4). They are mainly released from aerosols, air conditioners, refrigeration and foam blowing.

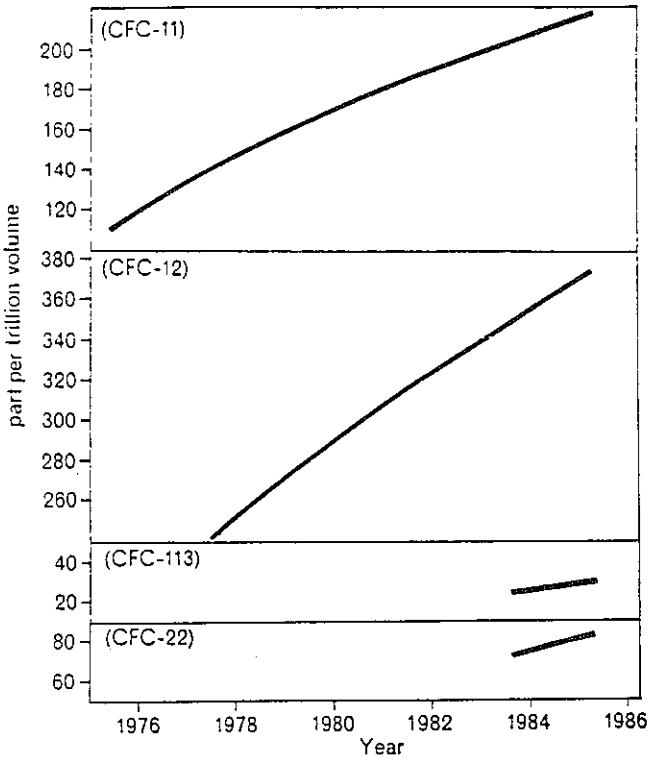

Figure 4. The increase in the concentration of CFCs in the atmosphere (modified from Fraser and Derek 1987).

Ozone.

Although stratospheric ozone is vital to life on earth it is a major source of pollution in the troposphere as well as being an effective greenhouse gas. It is estimated to contribute 10% of greenhouse warming and mainly comes from motor vehicles.

Nitrous oxide.

This produces about 9% of the current greenhouse warming effect and is derived from fertilisers, biomass burning, motor vehicles and other fossil fuel use.

Other gases.

About 3% of the current contribution to the greenhouse

warming effect comes from other gases but these must be seen as relatively unimportant when compared to the contribution of those mentioned above.

THE GREENHOUSE EFFECT - WHAT GLOBAL CHANGES ARE SUGGESTED

Atmospheric warming

Increasing the concentration of greenhouse gases in the atmosphere is predicted to lead to an increase in global mean temperature. The predictions are for between 1.5° to 4.5° C rise for every doubling of the level of greenhouse gases. However, there is considerable variation between models and very large errors in all of them (Figure 5). Recently, (and since the following table was prepared) consideration of cloud effects within the United Kingdom Meteorological Office (UKMO) model has halved the predicted temperature change (Mitchell et al. 1989).

Figure 5. Pridicted temperature changes and rainfall rate for a doubling of CO_2 under six general circulation models.

Model	Grid (Lat x Long)	No. of Layers	Period of Integration	Temperature Change (°C)	Rainfall Change (%)
UKMO	5° x 7.5°	11	45(15)	+5.2	+15.0
GFDL	4.5° x 7.5°	9	49(10)	+4.0	+8.7
NCAR	4.5° x 7.5°	9	12(3)	+3.5	+7.1
GISS	7.83° x 10°	9	35(10)	+4.2	+11.0
OSU	4° x 5°	2	20(10)	+2.8	+?
JMA	–	–	–	+4.3	+7.4

UKMO, UK Meteorological Office; GFDL, Geophysical Fluid Dynamics Laboratory; NCAR, National Center for Atmospheric Research; GISS, Goddarad Institute for Space Studies; OSU, Oregon State University; JMA, Japan Meteorological Agency (from Zillman et al. 1989).

Current rates of increase will result in a doubling in greenhouse warming effect by mid-21st century. Most studies indicate that the global mean temperature has increased by about 0.5° C in the last 100 years (Zillman et al. 1989). This is consistent with greenhouse effect predictions but does not prove that the greenhouse effect is actually occurring.

Sea level rise

One major concern is the predicted rise in sea level as a result of greenhouse warming. This sea level rise would come about through thermal expansion of the oceans. It would require a much longer time span before ice caps in Antarctica melt producing large sea level rises (hundreds of years for 100-300 metres sea level rise) (Figure 6).

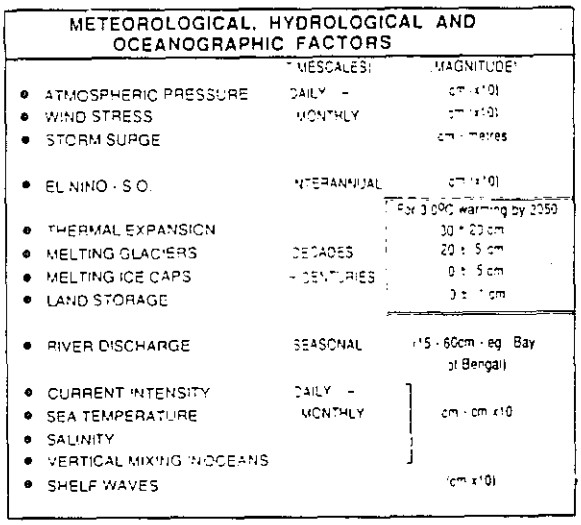

Figure 6. Factors influencing sea level including indicative time scales and magnitudes of the resulting fluctuations in sea level (Zillman et al. 1989).

Thermal sea level rise lags the increase in temperature by some years (Figure 7). The generally predicted rise in sea level following a 1.5° to 4.5° C increase in temperature is 20 to 140 cm. Recent reassessments have resulted in a new prediction for sea level rise of 30 ± 20 cm (Tucker 1989). However, model uncertainty is still great and further alteration of these predictions can be expected in the future. Sea level rise induced by the greenhouse warming will continue as temperatures continue to rise.

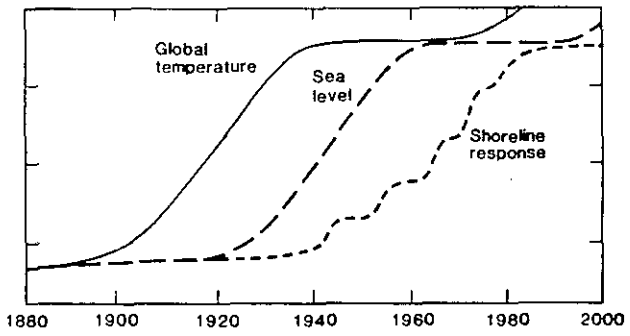

Figure 7. Schematic representation of relationships between global warming (°C), sea –level rise (m) and shoreline response (m) (from Gordon 1988).

Increased storm activity

Increase in atmospheric and ocean temperature will result in an increase in storm activity and intensity. Cyclones form over water at 27° C or above, although once generated they can move into other areas. Thus areas previously not subject to cyclones

would now be affected by storm activity.

Climatic changes

Considerable changes in climate will occur if the greenhouse effect progresses as predicted. These changes result from changes in wind and current patterns and affect temperature and rainfall locally, often in quite different ways, and not necessarily as predicted by generalised computer models.

HAS GREENHOUSE WARMING BEEN DEMONSTRATED ?

The simple answer is no! However, this simple answer needs some amplification as the complexity of the atmosphere and controls on climate are only partially understood. Major phenomena that produce short term aberrations in the global mean temperature are volcanic eruptions, solar variation and climate features such as the El Nino.

Major volcanic eruptions produce a cooling effect due to the injection of large amounts of aerosols (dust and gases) into the atmosphere. The Krakatau eruption in 1883 caused a temperature reduction of 0.5^{o} C for some years, this being equal to the total warming observed during the last 100 years. However, the eruption of El Chichon in 1982 produced no measurable cooling. This may be a result of a simultaneous warming due to El Nino. If the effect of El Nino is removed a cooling of about 0.1^{o} C becomes apparent. Such effects cause perturbations on the long term trend but do not alter it.

El Nino, and its cooling counterpart La Nina, also cause considerable short term changes in global mean temperature (see appendix 1 for discussion). An illustration of the profound effect that El Nino can have on climate in the Australian region is the dramatic difference in the tropical cyclone tracks between El Nino and non-El Nino years (Figure 8).

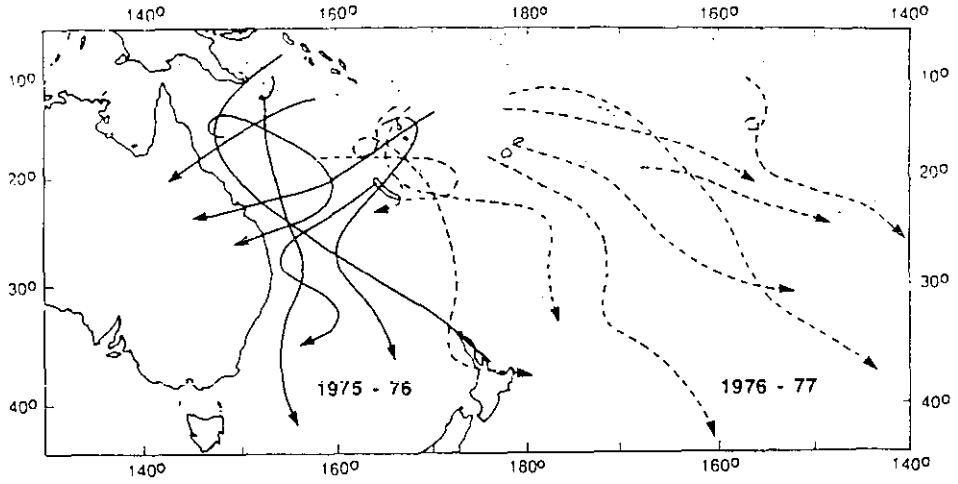

Figure 8. Tropical cyclone tracks for 1975 –76, a non –El Nino year (solid) and 1976 –77, an El Nino year (broken) (Zillman et al. 1989).

If there is a link between solar variation and climate change (Roberts 1989) the sun's changing influence must be removed from the climate signal before it will be possible to isolate warming due to the greenhouse effect. As these changes can be of a similar magnitude to those resulting from greenhouse warming they are commonly quoted by opponents of the greenhouse warming model as an explanation for the temperature pattern of the last century. Thus future research in this area may be fruitful in helping to isolate the various components involved in climate variation.

The above factors, as well as short and medium term climate variations help to mask any greenhouse warming-induced trend in temperature (Figure 9). The past glacial and interglacial periods also serve as a timely illustration of the amount of variation that can naturally occur in the Earth's climate.

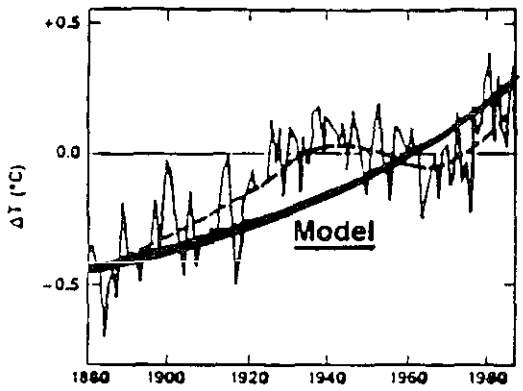

Figure 9. Difference between global mean warming predicted by greenhouse model and the actual data (from Levine 1989).

Exactly how long it will take to determine if the undeniable increase in greenhouse gases in the atmosphere is producing an increase in temperature is open to debate. However, many scientists expect a clear indication within the next 10 to 20 years (Levine 1989).

EFFECTS OF GREENHOUSE WARMING

Any warming of the atmosphere by greenhouse gases will have a considerable effect on the climate in the medium to long term. However, unlike destruction of the stratospheric ozone layer, greenhouse-induced climate changes would not necessarily be detrimental. Like all climate changes they will be to the advantage of some regions while disadvantaging others. For example, whereas increased rainfall predicted for some drier regions of eastern Australia is clearly beneficial, some Pacific and Indian Ocean Islands may be rendered uninhabitable.

A major difficulty in quantifying greenhouse changes is the lack of resolution of the computer models (Figure 10). These

models often represent an entire continent by only a small number of data points (Figure 10). They generally do not take into account ocean/atmosphere interactions or the effects of clouds, although sometimes these are included in a simplistic form.

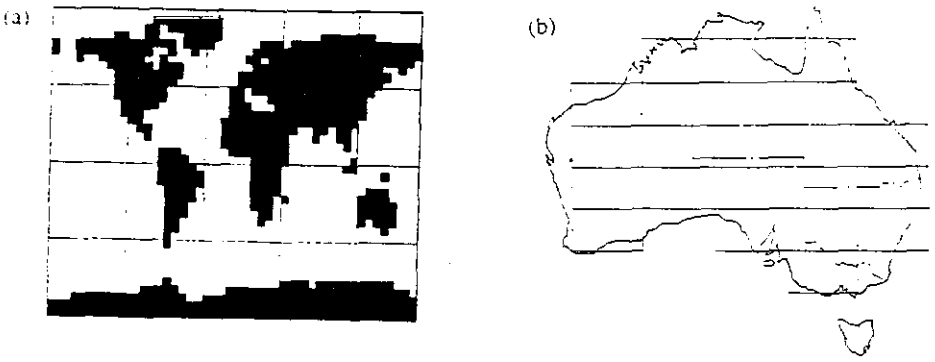

Figure 10. The course spatial resolution of global climate models. (from Henderson –Sellers and Blong 1989).

Detrimental effects of greenhouse warming are well known. With the possible drying of the US mid-west, the flooding of many low lying areas due to a sea level rise and the more widespread and intense storm activity has received considerable publicity. However, climate changes resulting from greenhouse warming may not necessarily be detrimental. Many areas of the globe will obtain higher yields from crops than previously and rainfall may become more reliable. Mikhail Budyko of the USSR has recently claimed that the greenhouse warming should be encouraged, stating that "The great majority of continents will be in a better condition of moisture. Deserts should disappear in the future. In warm epochs there was no desert." (Miller et al. 1989). Certainly the USSR under most scenarios would benefit, with warmer weather and longer growing seasons.

CO_2 enhances plant growth with plants being bigger, faster growing and able to grow in drier conditions. Experiments have been carried out to assess the changes in yield from various plant varieties due to increased levels of CO_2. One study found that a doubling of CO_2 from 340 to 680 ppm would result in a 0 to 10 % increase in growth and yield of C_4 crops (including; maize, sorghum, millets) and 10 to 50 % increase in C_3 crops (including; wheat, rice, potato, barley) (C_3 and C_4 refer to plant groupings based on method of CO_2 fixation; Warrick and Gifford 1986). Yield increases were calculated for an atmosphere with higher CO_2 only and therefore are not necessarily the increases that would actually be achieved. This is because higher levels of CO_2 would produce a number of other changes which may not be beneficial to crop growth.

The difficulty in determining how crops would be affected on a regional basis stems from the limited knowledge of climate patterns. The lack of sophisticated climate models that could be used to quantify the relative effects of various changes is also a problem. Very simplistic models have been developed and give some indication of the changes that would occur, but only in terms of extremely broad regions (Figure 11).

Effects on Australia and the South Pacific

The CSIRO in its book "Greenhouse - planning for climate change" proposed the following scenario for Australia. It is not necessary that all, or any, of the listed would occur but they are included below to give an indication of changes thought possible under the greenhouse model.

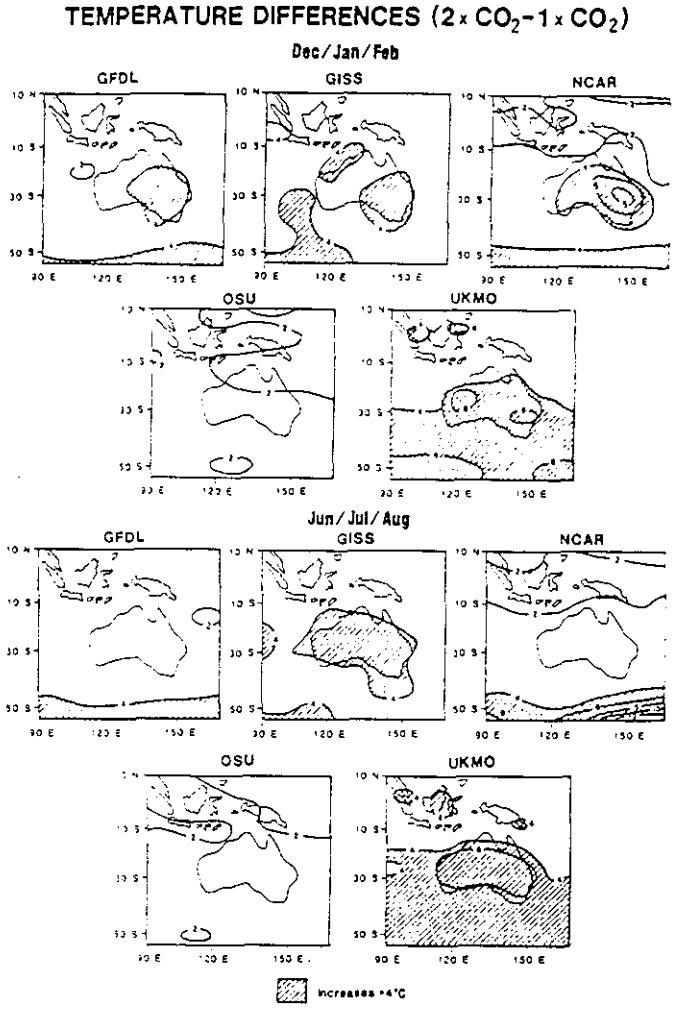

Figure 11. Predicted temperature changes for Australian region given various models. (from Henderson –Sellers and Blong 1989). GFDL; Geophysical Fluid Dynamics Laboratory: GISS; Goddard Institute for Space Studies: NCAR; National Centre for Atmospheric Research: UKMO; United Kingdom Meteorological Office.

Temperature: up 2-4° C

Rainfall: summers 50% wetter (except southern Australian regions)
winters 20%+ drier
More variable rainfall

Large regional changes in:
soil moisture
runoff
water supply

Tropical cyclones:

further south, more frequent

More frequent extremes (such as floods, droughts)

Salinity problems inland.

Higher snowline.

Sea level rise by 20-140 cm resulting in:
coastal flooding
salinity
erosion
storm damage

Plant growth increases due to higher ambient CO_2 levels.

(source: The Greenhouse Effect, implications for Queensland).

South Pacific

In the South Pacific a major concern is the proposed sea level rise predicted to occur during the next 40 years due to greenhouse warming. Other problems resulting from climate change are of less concern in tropical regions, because increases in temperature will be lower in the tropics than at higher latitudes. The general patterns of rainfall, etc, may not change appreciably.

Thermal expansion of the oceans is modelled to produce a rise of 20 to 140 cm with a doubling of CO_2. This would not completely flood many, if any, of the South Pacific islands. However, this rise could cause the reduction of the freshwater lens in many islands and make them uninhabitable, or unable to support the current level of population, with a one metre rise (Roy and Connell 1989). Recent reductions in the modelled sea level rise to 30 ± 20 cm would greatly reduce the urgency expressed by the previous higher rates.

The dilemma facing governments, at local or national level,

in small or large countries, is how and when to prepare for uncertain contingencies which are perhaps 40 to 50 years away, in circumstances where reputable scientists believe accurate forecasting may only be available in the next 10 to 20 years.

Economic ventures and engineering works that can be expected to be written off within 40 to 50 years can proceed without necessarily taking into account these predictions (also see comments below, pp. 23-24, on the relationship between economic rationality, energy efficiency and environmental sensitivity). However, for major new infrastructure and construction work, prudence would suggest that if something can be done about as well for an acceptable cost beyond the reach of a rising sea or a more hostile climate, then that is how it should be done. If the cost of such prudence is prohibitive then it may be worth examining the feasibility of interim works. Similarly, if infrastructure in vulnerable areas is nearing replacement, its maintenance, if possible, rather than replacement, may be advisable while awaiting a clearer outlook.

We can expect considerable advances in the next decade or so in methods, including by appropriate engineering, to deal with the encroachment of the sea. This allows the breathing space necessary to delay some actions while we establish a clearer forecast.

If the predictions of the greenhouse model occur it may be that populations will have to move. However, at this stage it requires constructive and creative thinking rather than contingency planning.

Countries like Australia with considerable scientific expertise may need to accept responsibility for making reliable and objective information available to the decision makers in their part of the world.

A recent article published in the South Pacific, while having the laudable objective of attempting to reduce fear and apprehension over the possible problems for the region due the the greenhouse effect, contained errors which may not help produce a rational and informed debate (Keith-Reid 1989). It is hoped that this paper will act as a base upon which debate can progress and any actions will follow comprehensive appraisal of all options.

CONFERENCES ON THE GREENHOUSE EFFECT

There has been a considerable number of conferences and meetings looking at the greenhouse effect and possible solutions. These are often only local in scope but there have been some very important meetings both in Australia and overseas. The following list is not exhaustive but instead is intended to illustrate the range of conferences held or planned.

Australia

GREENHOUSE 87

A major conference in Melbourne, this resulted in the publication of "GREENHOUSE - Planning for climate change" by the CSIRO. This is a very good book and invaluable reading when trying to understand the problem in an Australian context.

GREENHOUSE 88

Held in many centres in Australia in late 1988 this conference was predominantly designed to raise public awareness. It concluded that the "... greenhouse effect is a reality". This very strong view, while being good public relations, is not supported by the scientific evidence. Even the keynote speaker at this conference, Dr Stephen Schneider, a strong greenhouse proponent, would not take this strong a stand (Schneider 1988).

MINERAL FUELS ALTERNATIVES and the GREENHOUSE EFFECT

Held in Melbourne, Sydney and Brisbane on the 25th, 26th and 27th of July 1989 respectively. Sponsored by the Australian Institute of Mining and Metallurgy.

GREENHOUSE and ENERGY

Sponsored by the CSIRO and held at Macquarie University from 4-8 December 1989.

International

THE CHANGING ATMOSPHERE : IMPLICATIONS FOR GLOBAL SECURITY

Held in Toronto, Canada, June 1988. This is known as the 'Law of the Atmosphere' conference as it made a series of recommendations regarding an international agreement on atmosphere pollution. A copy of the statement from this conference is included (Appendix 2).

THE DECLARATION of the HAGUE

This declaration signed on the 11 March 1989 by 24 nations. A copy of the text is included in appendix 3.

ENERGY TECHNOLOGIES FOR REDUCING EMISSIONS of GREENHOUSE GASES

Held in Paris from 12th to 14th April 1989 and sponsored by the International Energy Agency of the OECD.

WORLD CLIMATE CONFERENCE

This conference will be convened in Geneva from the 12-22 November 1990. It would be jointly run by the UNEP and WMO of the United Nations.

AUSTRALIAN RESPONSES TO THE GREENHOUSE EFFECT

In Australia, recognition of the importance of the problem of global warming due to the greenhouse effect has led to a number of conferences (see above) and other bodies discussing the options. However, as yet there has not been a formal commitment to any particular action by the Australian Government in order to reduce greenhouse gas emissions.

However, the Government has made available $7.8 million for high priority initiatives over two years. Of this $5.54 million is for research, predominantly going to the CSIRO and the Bureau of Meteorology.

The National Greenhouse Advisory Committee, under the chairmanship of Prof. H. Nix, has been established to set objectives and tender advice on priority areas for a dedicated greenhouse research scheme to begin in 1990-91.

The Federal Government has also made available $6.25 million to establish a network of climate monitoring stations in the South Pacific region. This area will be one of great concern if the predicted sea level rises come to fruition (see article appendix 4).

A further $350,000 over two years has been made available by the Federal Government for a public awareness and education campaign.

The issue of greenhouse warming is actively being considered by a number of intergovernment bodies which hopefully will result in an agreed Australian position for action. These bodies include the Australian and New Zealand Environment Council, the Australian Minerals and Energy Council, the Australian

Agricultural Council and the Australian Health Ministers' Conference.

At its October meeting, the Australian and New Zealand Environment Council agreed to look at ways of achieving a 40 % cut in the emission of greenhouse gases by 2005. This is double the rate proposed by the Toronto Conference and may be very difficult to achieve without major economic dislocation.

The National Health and Medical Research Council is attempting to isolate and assess potential health impacts of the greenhouse effect. The Australian Minerals and Energy Council and the National Energy Consultative Council are also examining possible changes to energy policy.

Various States have produced draft position papers on the greenhouse effect. Those available to me are from Victoria, Queensland and South Australia. The executive summaries and any recommendations of these studies are included in appendix 4.

Many of the actions that can be taken to cope with the modelled effects of greenhouse warming are the responsibility of local government in Australia. Some councils in Australia are attempting to get planning regulations in place that will take into account projected effects, for example Warringah Shire in New South Wales and the Salisbury Council in South Australia (O'Neill 1990). These actions generally take the form of planning regulations that require the possibility of sea level rise and increased flood frequency and severity to be taken into account when considering developments.

INTERNATIONAL AGREEMENTS AND ACTIONS

There are as yet no international agreements on the greenhouse effect paralleling the Vienna Convention on Protection of the Ozone Layer. However, Australia is a signatory to the

Declaration of the Hague on Protection of the Atmosphere. Australia has also been strongly supporting the aims and activities of the Intergovernmental Panel on Climate Change.

Australia has not yet announced any planned limits on emissions of greenhouse gases. However, the Federal Government has stated its strong support for the aims of the Toronto conference, namely, a 20% reduction in greenhouse gas emissions by 2005 (a copy of the statement and recommendations of this conference are included in appendix 2).

SUMMARY - CONCERNS AND ACTIONS

It is important that a global approach be taken to the greenhouse effect as these gases and the resultant warming do not recognise national boundaries. Individual action, while important and necessary, will not solve the problem of global warming. There are some practical issues that need to be addressed locally (pp. 18-19). However, all nations must act together in an attempt to reduce emissions into the atmosphere, and not only greenhouse gases. In the context of reaching global agreement, strong positions by regional blocs such as the Pacific nations could be very influential in aiding the establishment of an international agreement. Support for the recommendations of the Toronto Conference could help spur on international progress towards agreement.

> "The identification of economic, environmental and other impacts of the projected changes is thus, at this stage, a matter of pure speculation" (Zillman et al. 1989).

The above statement illustrates the problems facing governments wishing to take action to ameliorate the effects of greenhouse warming. However, actions can be taken that are economically rational. These include best technological

solutions to new electricity generating capacity and transmission as well as substantial savings in energy use by industry and individuals. Such would be beneficial to all as well as reducing possible problems of the greenhouse effect.

The greenhouse effect has raised public awareness of problems of pollution and the environment and may produce desirable results in energy efficiency and environmental quality. Thus benefits accrue even if the predicted climate changes do not come to fruition.

Options being examined are not necessarily disruptive to the economies of countries involved. Actions which result in more efficient energy use, for example, will result not only in a reduction of greenhouse gases but also will preserve valuable non-renewable natural resources.

Levine (1989) listed both near term and long term strategies, reproduced below, that should be considered when developing policies and responses to the greenhouse effect.

Possible strategies in response to global warming

Near term

. Improve Energy Efficiency.

. Protect and Refurbish Major Global Forest Resources.

. Continue Initiatives to Limit CFCs.

. Consider Cost Effective Limits on Other Trace Gases.

Longer term

- Balanced Approach to Developing New Technology for Fossil Fuel Energy Resources as well as Renewable and Nuclear Energy Resources.

- Mitigate Impacts of CO_2 from Fossil Fuels

- Achieve Cost Competitive Renewable Energy

- Resolve Nuclear Safety/Waste Disposal/Cost Problems so that Nuclear is a Viable Option.

(source Levine 1989)

However, other authors have drawn up different lists and all options should be examined. It has not been the intention of this paper to explore and analyse policy options, but instead to provide a basis on which options could be developed and assessed.

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UNDER THE WEATHER

When it's raining cats and dogs in Australia, you can be pretty sure it's dry in Peru. BOB BEALE nails the globe-trotting culprits responsible for our erratic weather.

IF YOU live in rural Australia, the legendary lines from Dorothea Mackellar's poem *My Country,* "I love a sunburnt country, a land of sweeping plains, of rugged mountain ranges, of droughts and flooding rains . . ." ring obviously true. The evidence of this continent's climate of extremes is written all over its face, for those who care to look. But city dwellers lead far more insulated lives. Perhaps that's why extreme weather seems to take them so much by surprise. Sydneysiders have been obsessed by the long strings of wet days they've had over the past few seasons. The subject ▷

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El Niño at work: a gigantic dust cloud looms over Melbourne during the 1982-83 drought.

has even overshadowed real estate as a topic of dinner conversation.

"The big wet" has affected much of eastern and northern Australia. Some trendy environmental ogres have been raised to explain it, notably the greenhouse effect and the thinning of the ozone layer. Outside contenders include an unusually active sunspot cycle, and even nuclear weapon testing.

But there's another theory that not only seems quite capable of explaining it, but may be of much more long-term significance. It goes to the heart of the fire-and-rain cycle that so often bares its teeth out there in the bush.

BACK IN 1981, Dr Neville Nicholls and his wife, Jill, bought a vacant lot in north-eastern Melbourne, on which to build their long-awaited family home. Although the land had been scraped bare by a bulldozer, it was surrounded by houses with green lawns, mature gardens and plenty of trees.

At the time, farmers in many parts of Australia were starting to worry about the prospect of a widespread drought. But the long stretch of fine weather was a boon to builders, and the Nicholls' new house was finished by May 1982.

Their neighbours took pride in their gardens and were surprised that Neville Nicholls made so little effort to beautify his back and front yards, which were still little more than dirt and weeds.

It wasn't that he was a reluctant gardener. He knew something his neighbours didn't.

As the leader of a climate research group with the Bureau of Meteorology, Nicholls had spent many years studying the complex forces that influence Australia's weather patterns. Now, events happening thousands of kilometres away, in the middle of the Pacific Ocean, were making him cautious.

By July 1982, he and his colleagues were certain: no good spring rains would break the spreading drought, and it would almost certainly continue and worsen through the next summer.

Nicholls's more optimistic neighbours were simply battling the strongest El Niño event this century; a devastating climatic hiccup that disrupted the weather worldwide for almost a year.

The term El Niño (Spanish for "the boy child", pronounced nee-nyo) relates to a mysterious series of atmospheric and oceanic events, mainly centred on the Pacific Ocean, which occurs every two to seven years. The oceans, land and air interact in complex ways, but the interplay in and around the Pacific Ocean can have profound effects on climate far beyond it. Sometimes the effects are weak, sometimes strong. When the waxings and wanings were noticed earlier this century, the fluctuating cycle was dubbed the Southern Oscillation.

It was once thought that changes in atmospheric pressure above the Pacific — see-sawing up and down from east to west — were responsible for the cycle, and that El Niño related to temperature variations. These days, the two are seen to be intimately connected so the umbrella term ENSO (El Niño/Southern Oscillation) is used.

El Niños are essentially extreme ENSO events, although most come and go without pushing our weather too far away from the variability expected from year to year. Another El Niño occurred in 1986-87, for example, but it was much milder and attracted little attention.

The climatic events of 1982-83, however, worsened Africa's deadly drought, spawned the first typhoon to hit French Polynesia in 75 years, caused severe winter storms in California, ▷

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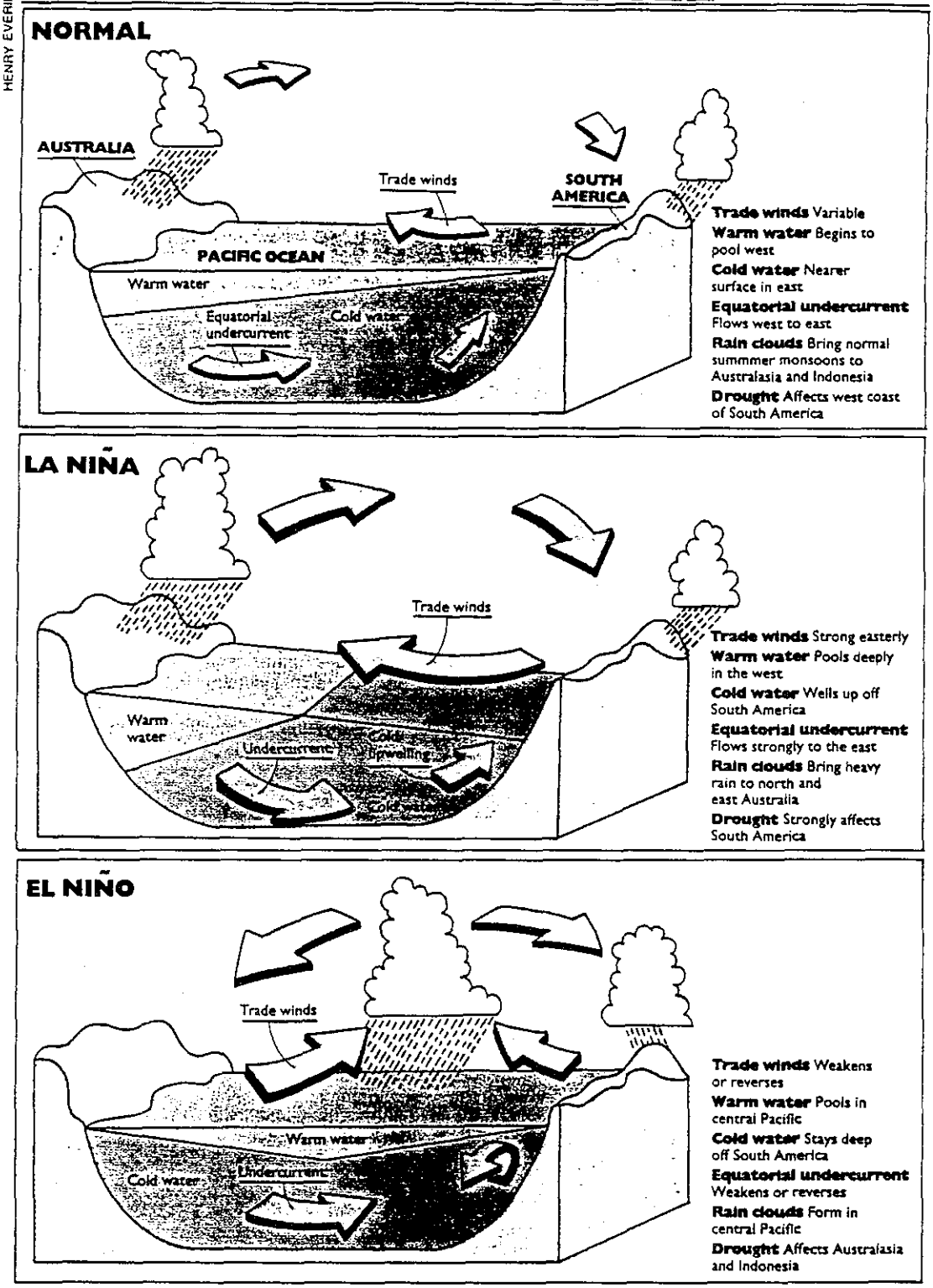
The Ash Wednesday fires were another spin-off from the severe drought: the worst in 200 years.

THE ENSO CYCLE

HENRY EVERINGHAM



The interplay of land, air and sea creates a global climate rhythm. Normally, easterly trade winds blow across the Pacific, driving the sun-warmed surface water into a pool off northern Australia. High cumulus clouds form above it and bring rain in the summer wet season. In a La Niña event, the trade winds blow consistently stronger, raising the sea level off northern Australia and bringing extended rain. Meanwhile, the west coast of South America has a drought. In an El Niño event, the trade winds mysteriously ease. The warm water pool that has banked off northern Australia flows downhill into the central Pacific: the rain falls there and Australia suffers a drought.

reduced fish catches in South America, and produced heavy rainfalls in Peru and Ecuador.

Australia suffered its worst drought in 200 years. Its wheat crop was devastated, and cattle and sheep died like flies. Bushfires in South Australia, Victoria and NSW — including the Ash Wednesday fires — took a terrible toll of life and property. Wind stripped millions of tonnes of parched topsoil off the continent, with one spectacular dust storm boiling out of the south-eastern Mallee country to shroud Melbourne's central business district.

That one El Niño was blamed for causing 1,500 deaths and damage valued at up to $10.2 billion worldwide.

For many Australians, the 1988-89 summer and autumn have been almost the reverse of events in 1982-83. Sydney-siders have been belly-aching long and hard (to the glee of Melburnians) about a seemingly endless drenching by rain. It hasn't been so much the amount of rain that has fallen — Sydney can turn on spectacular downpours in any year — but the number of grey, wet days.

Elsewhere in NSW and Queensland, paddocks are so moist and green they could be mistaken for English fields. Some rivers have burst their banks, flooding towns several times over. The wet season in the north was heavy, and summer cyclones were felt right across the Top End as late as May. Even Lake ▷

Eyre, in the usually arid centre of the continent, is brimming with water.

What we have been experiencing is the other ENSO extreme, the mirror image of an El Niño: La Niña.

This time last year, Neville Nicholls and other Australian climate researchers were almost certain that the east and north were about to fall into La Niña's grip, and that the coming summer was going to be a wet one. They did not anticipate, however, exactly how wet it would be. That prediction of a long, wet summer, publicised last spring, was based on the same sort of information that signalled the 1982-83 El Niño.

Important details of the ENSO cycle are starting to be unravelled. There is growing hope that long-term climate forecasts, covering whole seasons, will soon be more than wishful thinking. It takes little imagination to see how useful warnings of droughts and floods would be. Farmers, builders, developers, resort operators, water and energy-supply authorities, and the tourism industry would all benefit.

Nicholls, whose special interest has been to try to predict some of the more important secondary consequences of ENSO events, has extended historical weather records by going back through letters sent to England by early governors in the Australian colony. "We now have 200 years of records establishing a clear relationship between droughts and El Niño in Australia," he says. "Since white settlement, we've had two moderate or strong ENSO events every decade."

• Outbreaks of the mosquito-borne disease, Ross River virus, also seem linked to La Niña.

In another analysis, he has shown that countries directly affected by ENSO events have more variable weather than those that do not. Australia's weather is among the most variable in the world.

Nicholls has made intriguing headway with his prediction efforts, aided by El Niño's stability. "Once it gets into a particular phase it tends to run for about 12 months, starting around April."

Months before a single seed is planted in October for the annual sorghum crop in northern NSW and southern Queensland, Nicholls can accurately predict what the average yield of grain a hectare will be, since that is closely tied to spring and summer rainfall.

Similarly, health authorities can be warned well in advance of the probability of an outbreak of Murray Valley encephalitis (MVE). Since 1916, when the serious and sometimes fatal disease was first noticed, there have been seven outbreaks. It generally strikes between January and April, and every outbreak has occurred at the end of a La Niña event, with the extra rain favouring the mosquitoes which act as hosts to the MVE virus. Given notice, health authorities can judge whether they need to undertake costly and environmentally undesirable spraying.

Nicholls put the odds of an MVE outbreak earlier this year at about 50:50. It didn't happen, but there were outbreaks of another mosquito-borne disease, Ross River virus, which also seems to be linked to La Niñas.

WHILE the ENSO pattern is now familiar, scientists are still trying to pinpoint the triggers that disturb the rhythm and push it to extremes. For instance,the crunch in the El Niño chain of events comes when the easterly trade winds weaken or even turn around. That often begins in the western or central Pacific, and often late in the year, just before the southern summer.

There have been many suggestions as ▷

WATER LOGGED

• SYDNEY HAD 94 rainy days in the first five months of the year — the highest on record. The previous highest record was 88 days' rain in 1890. Melbourne had 50 rainy days in the same period, 11 above average.

• Umbrellas are going up. The umbrella manufacturer Phillips and House sold more than 250,000 brollies in the six weeks to mid-June in Sydney, Melbourne and Brisbane, a 100 per cent increase on the same period last year.

• Sydney had an average 4.2 hours of sunshine a day this autumn, compared with the usual average of 6.2. It was the lowest since 1960 when the figure was 3.5. There were 5.2 hours of sunshine a day in Melbourne in autumn, just below the average 5.6 hours.

• Rainwear sales were up 80 per cent in Sydney, according to Agmer Drywear Australia general manager Peter Blackburn. In Melbourne, where the wet weather came later than usual, sales were up 15 to 20 per cent.

• Until the end of May, Sydney had 922.4mm of rain, well above the average 597.7mm, and compared with 1133.2mm for the same period last year. Melbourne had 322mm of rain until the end of May, compared with 202.0mm for the same period last year and an average 263.2mm.

• Until mid-June, Sydney had only one rain-free weekend in 1989 — April 15 and 16 — while Melbourne had 14 clear weekends.

• Melbourne had nine thundery days, compared with an average six. Sydney had eight — its average is 5.7.

• Melbourne had only one foggy day, compared with an average six. Sydney had four, three below average.

• The NSW golf industry has lost millions of dollars because of wet weather. Golf professionals' annual turnover was down by between $100,000 and $200,000, and clubs with financial difficulties were charging levies of up to $150. In contrast, a warm, dry autumn meant the Victorian golfing business was booming.

• Suburban coin laundries reported big increases in business over the past four months. Bruce Tozer of Kirribilli Wash House said dryer usage was up by about 25 per cent. In Melbourne, the cold weather saw business pick up 30 per cent, according to Sandy Waterton, who works at The Washing Line in Albert Park.

• In NSW, 31 race meetings were abandoned due to bad weather between March and mid-June. The NSW TAB's turnover is down about $30 million — officials say it's a minimal loss under the circumstances. In Victoria, the TAB lost an estimated $22.7 million gross sales on meetings cancelled because of bad weather, but punters placed more bets, reducing the loss to about $11.3 million.

• Builders have been bogged down by the rain. Master Builders Association of NSW deputy executive director John Elder said builders have lost hundreds of millions of dollars since February because of the weather. On a $10 million job, for example, a proprietor was losing $50,000 a week in holding charges if work was held up. In Melbourne, sites have been affected by wet weather, but not to the same degree as in Sydney.

• Demand for mould removers trebled from March to June at Coles New World supermarkets in NSW. In Melbourne, sales remained stable.

• By June the lawns in Sydney's CBD were so wet that council workers had to mow them with push mowers — heavier mowers would have sunk. At last report, Melbourne City Council's big mowers were still afloat. □

KIM LANGLEY

to the cause. One relates to the amount of snow falling over Eurasia in winter, which may affect the strength of the subsequent Asian summer monsoon. Another proposal is that sea-floor earthquakes in the Pacific may be linked to El Niños. Falling air pressure at Easter Island, 3,200 kilometres west of Chile, tends to be a good indicator of El Niño's arrival, according to Daniel Walker, of the University of Hawaii.

He has found a correlation between air-pressure drops and increases in sea-floor earthquakes in the Easter Island region, where sea-floor fractures vent large amounts of heat into the ocean.

Normally, the force of the trade winds is enough to lift the sea level off northern Australia, creating a huge elevated pool of warm water. Whatever triggers the weakening of the trade winds, once it happens, the elevated pool of warm water off northern Australia is free to run downhill, pulled by gravity. It sends out a long tongue of warm water across the central Pacific. The flow of the equatorial undercurrent may ease up, or even go into reverse.

When the huge pool of warm water floods away from the Australian-Indonesian region, it drags with it the huge cumulus clouds that form above it, due to evaporation. The powerful updraughts inside the clouds can push their tops up to 16 kilometres above sea level, high enough to penetrate the stratosphere. They can dump the world's most intense downpours, and are thought to be the main route globally by which water vapour finds its way into the stratosphere.

As an El Niño develops and intensifies, however, the rain that would normally fall over Australia and Indonesia tends to fall more and more towards the central Pacific. In turn, regions of South America that are normally dry get drenching rains. "When it rains in Peru, they measure it in buckets," says Hunt.

Back in Australia, an initially dryish summer progresses into an autumn, winter and spring of drought. Often, the drying effect of an El Niño can persist through into the next summer as well until the trend decays in the following autumn, around March. The trade winds then pick up and begin to blow consistently towards Australia again, starting the whole cycle over. The trade winds see-saw and the Pacific slops in slow motion between Australasia and South America, likes waves in a tub. An El Niño might recur any time between two and nine years later.

THE LA Niña ("the girl") label was coined in 1985. It is thought to be associated with a pool of colder-than-normal water forming in the tropical Pacific, though there is still debate about it.

Eastern Australia's 1988-89 big wet has been linked with a huge pool of cold water present in the central Pacific for most of last year and well into 1989. Its centre was up to three degrees colder than normal at one stage.

La Niñas seem to be even less predictable than El Niños. It is glaringly obvious, for example, that not every El Niño is punctuated by a La Niña.

If we can't yet explain how an El Niño occurs, nor can we yet accurately predict it. However, after recently studying the life strategies pursued by animals and plants in ENSO-affected countries, Nicholls believes he can say that El Niños and La Niñas have been causing wide variations in their climate for a long time, and that living things have had to adapt to the famine-or-plenty cycle.

"Our farmers have learnt it over 200 years of hard knocks," Nicholls says. "In many cases, they've been faster to realise it than the scientists have." He believes ENSO's message for all Australians is that they must learn to expect and plan how to survive the hard times, and be equally ready to take advantage of the good times when they come again. □

Bob Beale is the The Sydney Morning Herald's science writer. His last story for Good Weekend was on chimpanzees.

Appendix 2

ORIGINAL: ENGLISH AND FRENCH

ANNEX

THE CHANGING ATMOSPHERE:
IMPLICATIONS FOR GLOBAL SECURITY

CONFERENCE STATEMENT

TORONTO, ONTARIO, CANADA

JUNE 27 - 30, 1988

FOREWORD

At the invitation of the Government of Canada, more than 300 world experts – leaders in science, law and the environment; ministers of government; economists; industrialists; policy analysts; and officials from international agencies assembled in Toronto, Ontario, Canada from June 27-30, 1988 to consider the threats posed by the changing global atmosphere and how they might be addressed. They came from 46 countries and quickly arrived at a consensus that the concerns about the effects of atmospheric change – greenhouse gases, ozone-layer depleting substances, toxics, smog and acid rain – are justified and that the time to act on the problems is now. The Conference was the first direct response to the call for action of the UN's World Commission on Environment and Development. It was also the first comprehensive meeting between specialists on the issues at hand and high-level policy-makers. The significance of the event was underscored by the participation of Prime Ministers Mulroney of Canada and Brundtland of Norway, the participation of Ministers McMillan and Masse (Canada), Salim (Indonesia), Nijpels (Netherlands), Cissokho (Senegal), Luttenbarck Batalha (Brazil), Harilla (Morocco), by Senator Wirth (United States) and by ambassadors from Algeria, Canada, The Maldives, and Sweden.

The message from the Toronto Conference was clear. The Earth's atmosphere is being changed at an unprecedented rate, primarily by humanity's ever-expanding energy consumption, and these changes represent a major threat to global health and security. Sound policies must be quickly developed and implemented to provide for the protection of the planet's atmosphere. That message and an agenda for action are embodied in this Statement of the Conference's conclusions and recommendations. The Statement builds on important preceding conferences and workshops, and draws heavily from ideas and discussion of the Conference's 12 Working Groups. Its careful reading is recommended to all decision-makers seeking solutions to the problems of climate change.

I wish to take this opportunity to thank my colleagues on the Conference Statement Committee. These colleagues, who worked long and difficult hours in drafting the Conference Statement and who also served as advisors on Conference planning over the past two years, are J. P. Bruce, G. Goodman, J. Jaeger, G. A. McKay, J. MacNeill, M. Oppenheimer, and P. Usher. Dr. Jaeger also produced the main background paper to the Conference. In addition I must thank the Conference General Chairman, Canada's Ambassador to the United Nations, Stephen Lewis, for his important contributions to the final draft of the Statement.

My thanks also go to the many international experts who wrote the theme papers that provided background to the Conference discussions, to the chairpersons and rapporteurs who so skillfully managed the Working Group sessions, to those who assumed special speaking assignments, and to persons and groups who prepared special reports for Working Group discussions and for general consideration by the Conference. Finally, I extend my deep gratitude to all who participated in the Conference – delegates, observers, media and staff – and thereby contributed to its outstanding success. Their collective efforts constitute a landmark in confronting one of humankind's biggest challenges.

I believe the Conference will prove to have been an important step forward in reconciling environmental, societal and developmental goals. We still have a long way to go. However, I am confident that the Toronto Conference gave us the right agenda and conviction to act. It also provided an opportunity to share our views with world leaders from many disciplines – scientific, social and political.

H. L. Ferguson
Conference Director

CONFERENCE STATEMENT

SUMMARY

Humanity is conducting an unintended, uncontrolled, globally pervasive experiment whose ultimate consequences could be second only to a global nuclear war. The Earth's atmosphere is being changed at an unprecedented rate by pollutants resulting from human activities, inefficient and wasteful fossil fuel use and the effects of rapid population growth in many regions. These changes represent a major threat to international security and are already having harmful consequences over many parts of the globe.

Far-reaching impacts will be caused by global warming and sea-level rise, which are becoming increasingly evident as a result of the continued growth in atmospheric concentrations of carbon dioxide and other greenhouse gases. Other major impacts are occurring from ozone-layer depletion resulting in increased damage from ultra-violet radiation. The best predictions available indicate potentially severe economic and social dislocation for present and future generations, which will worsen international tensions and increase risk of conflicts between and within nations. It is imperative to act now.

These were the major conclusions of the World Conference on The Changing Atmosphere: Implications for Global Security, held in Toronto, Ontario, Canada, June 27-30, 1988. More than 300 scientists and policy makers from 46 countries, United Nations organizations, other international bodies and non-governmental organizations participated in the sessions.

The Conference called upon governments, the United Nations and its specialized agencies, industry, educational institutions, non-governmental organizations and individuals to take specific actions to reduce the impending crisis caused by pollution of the atmosphere. No country can tackle this problem in isolation. International cooperation in the management and monitoring of, and research on, this shared resource is essential.

The Conference called upon governments to work urgently towards an *Action Plan for the Protection of the Atmosphere*. This should include an international framework convention, while encouraging other standard-setting agreements along the way, as well as national legislation to provide for protection of the global atmosphere. The Conference also called upon governments to establish a *World Atmosphere Fund* financed in part by a levy on the fossil fuel consumption of industrialized countries to mobilize a substantial part of the resources needed for these measures.

THE ISSUE

Continuing alteration of the global atmosphere threatens global security, the world economy, and the natural environment through:

- Climate warming, rising sea-level, altered precipitation patterns and changed frequencies of climatic extremes induced by the "heat trap" effects of greenhouse gases;
- Depletion of the ozone layer;
- Long-range transport of toxic chemicals and acidifying substances.

These changes will:

- Imperil human health and well-being;
- Diminish global food security, through increases in soil erosion and greater shifts and uncertainties in agricultural production, particularly for many vulnerable regions;
- Change the distribution and seasonal availability of freshwater resources;
- Increase political instability and the potential for international conflict;
- Jeopardize prospects for sustainable development and the reduction of poverty;
- Accelerate the extinction of animal and plant species upon which human survival depends;
- Alter yield, productivity and biological diversity of natural and managed ecosystems, particularly forests.

If rapid action is not taken now by the countries of the world, these problems will become progressively more serious, more difficult to reverse, and more costly to address.

Scientific Basis for Concern

The Conference calls for urgent work on an *Action Plan for the Protection of the Atmosphere*. This Action Plan, complemented by national action, should address the problems of climate warming, ozone layer depletion, long-range transport of toxic chemicals and acidification.

Climate Warming

1 There has been an observed increase of globally-averaged temperature of 0.7° C in the past century which is consistent with theoretical greenhouse gas predictions. The accelerating increase in concentrations of greenhouse gases in the atmosphere, if continued, will probably result in a rise in the mean surface temperature of the Earth of 1.5 to 4.5° C before the middle of the next century.

2 Marked regional variations in the amount of warming are expected. For example, at high latitudes the warming may be twice the global average. Also, the warming would be accompanied by changes in the amount and distribution of rainfall and in atmospheric and ocean circulation patterns. The natural variability of the atmosphere and climate will continue and be superimposed on the long-term trend, forced by human activities.

3 If current trends continue, the rates and magnitude of climate change in the next century may substantially exceed those experienced over the last 5000 years. Such high rates of change would be sufficiently disruptive that no country would likely benefit *in toto* from climate change.

4 The climate change will continue so long as the greenhouse gases accumulate in the atmosphere.

5 There can be a time lag of the order of decades between the emission of gases into the atmosphere and their full manifestation in atmospheric and biological consequences. Past emissions have already committed planet Earth to a significant warming.

6 Global warming will accelerate the present sea-level rise. This will probably be of the order of 30 cm but could possibly be as much as 1.5 m by the middle of the next century. This could inundate low-lying coastal lands and islands, and reduce coastal water supplies by increased salt water intrusion. Many densely populated deltas and adjacent agricultural lands would be threatened. The frequency of tropical cyclones may increase and storm tracks may change with consequent devastating impacts on coastal areas and islands by floods and storm surges.

7 Deforestation and bad agricultural practices are contributing to desertification and are reducing the biological storage of carbon dioxide, thereby contributing to the increase of this most important greenhouse gas. Deforestation and poor agricultural practices are also contributing additional greenhouse gases such as nitrous oxide and methane.

Ozone Layer Depletion

1 Increased levels of damaging ultra-violet radiation, while the stratospheric ozone shield thins, will cause a significant rise in the occurrence of skin cancer and eye damage, and will be harmful to many biological species. Each 1% decline in ozone is expected to cause a 4 to 6% increase in certain kinds of skin cancer. A particular concern is the possible combined effects on unmanaged ecosystems of both increased ultraviolet radiation and climate changes.

2 Over the last decade, a decline of 3% in the ozone layer has occurred at mid-latitudes in the Southern Hemisphere, possibly accompanying the appearance of the Antarctic ozone hole; although there is more meteorological variability, there are indications that a smaller decline has occurred in the Northern Hemisphere. Changes of the ozone layer will also change the climate and the circulation of the atmosphere.

Acidification

In improving the quality of the air in their cities, many industrialized countries unintentionally sent increasing amounts of pollution across national boundaries in Europe and North America, contributing to the acidification of distant environments. This was manifested by increasing damage to lakes, soils, plants, animals, forests and fisheries. Failure to control automobile pollution in some regions has seriously contributed to the problem. The principal damage agents are oxides of sulphur and nitrogen as well as volatile hydrocarbons. The resulting acids can also corrode buildings and metallic structures causing overall, billions of dollars of damage annually.

The various issues arising from the pollution of Earth's atmosphere by a number of substances are often closely interrelated, both through chemistry and through potential control strategies. For example, chlorofluorocarbons (CFCs) both destroy ozone and are greenhouse gases; conservation of fossil fuels would contribute to addressing both acid rain and climate change problems.

Security: Economic and Social Concerns

As the *UN Report On The Relationship Between Disarmament And Development* states: "The world can either continue to pursue the arms race with characteristic vigour or move consciously and with deliberate speed toward a more stable and balanced social and economic development within a more sustainable international economic and political order. It cannot do both. It must be acknowledged that the arms race and development are in a competitive relationship, particularly in terms of resources, but also in the vital dimension of attitudes and perceptions." The same consideration applies to the vital issue of protecting the global atmospheric commons from the growing peril of climate change and other atmospheric changes. Unanticipated and unplanned change may well become the major non-military threat to international security and the future of the global economy.

There is no concern more fundamental than access to food and water. Currently, levels of global food security are inadequate but even those will be most difficult to maintain into the future, given projected agricultural production levels and population and income growth rates. The climate changes envisaged will aggravate the problem of uncertainty in food security. Climate change is being induced by the prosperous, but its effects are suffered most acutely by the poor. It is imperative for governments and the international community to sustain the agricultural and marine resource base and provide development opportunities for the poor in light of this growing environmental threat to global food security.

The countries of the industrially developed world are the main source of greenhouse gases and therefore bear the main responsibility to the world community for ensuring that measures are implemented to address the issues posed by climate change. At the same time, they must see that the developing nations of the world, whose problems are greatly aggravated by population growth, are assisted in and not inhibited from improving their economies and the living conditions of their citizens. This will necessitate a wide range of measures, including significant additional energy use in those countries and compensating reductions in the industrialized countries. The transition to a sustainable future will require investments in energy efficiency and non-fossil energy sources. In order to ensure that these investments occur, the global community must not only halt the current net transfer of resources from developing countries, but actually reverse it. This reversal should embrace the technologies involved, taking into account the implications for industry.

A coalition of reason is required, in particular, a rapid reduction of both North-South inequalities and East-West tensions, if we are to achieve the understanding and agreements needed to secure a sustainable future for planet Earth and its inhabitants.

It takes a long time to develop an international consensus on complex issues such as these, to negotiate, sign, and ratify international environmental instruments and to begin to implement them. It is therefore imperative that serious negotiations start now.

Legal Aspects

The first steps in developing international law and practices to address pollution of the air have already been taken: in the Trail Smelter arbitration of 1935 and 1938; Principle 21 of the 1972 Declaration of the UN Conference on the Environment; the Economic Commission for Europe (ECE) Convention on Long Range Transboundary Air

Pollution and its Protocol (Helsinki, 1985) for sulphur reductions, Part XII of the Law of the Sea Convention; and the Vienna Convention for Protection of the Ozone Layer and its Montréal Protocol (1987).

These are important first steps and should be actively implemented and respected by all nations. However, there is no overall convention constituting a comprehensive international framework that can address the interrelated problems of the global atmosphere, or that is directed towards the issues of climate change.

A CALL FOR ACTION

The Conference urges immediate action by governments, the United Nations and their specialized agencies, other international bodies, non-governmental organizations, industry, educational institutions and individuals to counter the ongoing degradation of the atmosphere.

An *Action Plan for the Protection of the Atmosphere* needs to be developed, which includes an international framework convention, encourages other standard-setting agreements and national legislation to provide for the protection of the global atmosphere. This must be complemented by implementation of national action plans that address the problems posed by atmospheric change (climate warming, ozone layer depletion, acidification and the long-range transport of toxic chemicals) at their roots.

The following actions are mostly designed to slow and eventually reverse deterioration of the atmosphere. There are also a number of strategies for adapting to changes that must be considered. These are dealt with primarily in the recommendations of the Working Groups.

Actions by Governments and Industry

- *Ratify the Montréal Protocol on Substances that Deplete the Ozone Layer.* The Protocol should be revised in 1990 to ensure nearly complete elimination of the emissions of fully halogenated CFCs by the year 2000. Additional measures to limit other ozone-destroying halocarbons should be considered.

- *Set energy policies to reduce the emissions of CO_2 and other trace gases* in order to reduce the risks of future global warming. Stabilizing the atmospheric concentrations of CO_2 is an imperative goal. It is currently estimated to require reductions of more than 50% from present emission levels. Energy research and development budgets must be massively directed to energy options which would eliminate or greatly reduce CO_2 emissions and to studies undertaken to further refine the target reductions.

- *Reduce CO_2 emissions by approximately 20 percent of 1988 levels by the year 2005 as an initial global goal.* Clearly, the industrialized nations have a responsibility to lead the way, both through their national energy policies and their bilateral and multilateral assistance arrangements. About one-half of this reduction would be sought from energy efficiency and other conservation measures. The other half should be effected by modifications in supplies.

- *Set targets for energy efficiency improvements* that are directly related to reductions in CO_2 and other greenhouse gases. A challenging target would be to achieve the 10 percent energy efficiency improvements by 2005. Improving energy efficiency is not precisely the same as reducing total carbon emissions and the detailed policies will not all be familiar ones. A detailed study of the systems implications of this target should be made. Equally, targets for *energy supply* should also be directly related to reductions in

CO_2 and other greenhouse gases. As with efficiency, a challenging target would again be to achieve the 10 percent energy supply improvements by 2005. A detailed study of the systems implications of this target should also be made. The contributions to achieving this goal will vary from region to region; some countries have already demonstrated a capability for increasing efficiency by more than 2 percent a year for over a decade.

Apart from efficiency measures, the desired reduction will require (i) switching to lower CO_2 emitting fuels, (ii) reviewing strategies for the implementation of renewable energy especially advanced biomass conversion technologies; (iii) revisiting the nuclear power option, which lost credibility because of problems related to nuclear safety, radioactive wastes, and nuclear weapons proliferation. If these problems can be solved, through improved engineering designs and institutional arrangements, nuclear power could have a role to play in lowering CO_2 emissions.

- *Negotiate now on ways to achieve the above-mentioned reductions.*

- *Initiate management systems* in order to encourage, review and approve major new projects for energy efficiency.

- *Vigorously apply existing technologies* in addition to gains made through reduction of fossil fuel combustion, to reduce (i) emissions of acidifying substances to reach the critical load that the environment can bear; (ii) substances which are precursors of tropospheric ozone; and (iii) other non-CO_2 greenhouse gases.

- *Label products* to allow consumers to judge the extent and nature of the atmospheric contamination that arises from the manufacture and use of the product.

Actions by Member Governments of the United Nations, Non-Governmental Organizations and Relevant International Bodies

- *Initiate the development of a comprehensive global convention* as a framework for protocols on the protection of the atmosphere. The convention should emphasize such key elements as the free international exchange of information and the support of research and monitoring, and should provide a framework for specific protocols for addressing particular issues, taking into account existing international law. This should be vigorously pursued at the International Workshop on Law and Policy to be held in Ottawa early in 1989, the high-level political conference on Climate Change in the Netherlands in the Fall, 1989, the World Energy Conference in Canada in 1989 and the Second World Climate Conference in Geneva, June 1990, with a view to having the principles and components of such a convention ready for consideration at the Inter-governmental Conference on Sustainable Development in 1992. These activities should in no way impede simultaneous national, bilateral and regional actions and agreements to deal with specific problems such as acidification and greenhouse gas emissions.

- *Establish a World Atmosphere Fund*, financed in part by a levy on fossil fuel consumption of industrialized countries, to mobilize a substantial part of the resources needed for implementation of the *Action Plan for the Protection of the Atmosphere.*

- *Support the work of the Inter-governmental Panel on Climate Change* to conduct continuing assessments of scientific results and to initiate government-to-government discussion of responses and strategies.

- *Devote increasing resources to research and monitoring efforts* within the World Climate Programme, the International Geosphere Biosphere Programme and Human Response to Global Change Programme. It is particularly important to understand how climate changes on a regional scale are related to an overall global change of climate. Emphasis should also be placed on better determination of the role of oceans in global heat transport and the flux of greenhouse gases.

- *Increase significantly the funding for research, development and transfer of information on renewable energy,* if necessary by the establishment of additional and bridging programmes; extend technology transfer with particular emphasis on the needs of the developing countries; and upgrade efforts to meet obligations for the development and transfer of technology embodied in existing agreements.

- *Expand funding for more extensive technology transfer and technical cooperation projects in coastal zone protection and management.*

- *Reduce deforestation and increase afforestation* making use of proposals such as those in the World Commission on Environment and Development's (WCED) report, "Our Common Future", including the establishment of a trust fund to provide adequate incentives to enable developing nations to manage their tropical forest resources sustainably.

- *Develop and support technical cooperation projects* to allow developing nations to participate in international mitigation efforts, monitoring, research and analysis related to the changing atmosphere.

- *Ensure that this Conference Statement, the Working Group reports and the full Proceedings of the World Conference, "The Changing Atmosphere: Implications for Global Security"* (to be published in the Fall, 1988) *are made available* to all nations, to the conferences mentioned above, and to other future meetings dealing with related issues.

- *Increase funding to non-governmental organizations* to allow the establishment and improvement of environmental education programmes and public awareness campaigns related to the changing atmosphere. Such programmes would aim at sharpening perception of the issues, and changing public values and behaviour with respect to the environment.

- *Allocate financial support for environmental education* in primary and secondary schools and universities. Consideration should be given to establishing special groups in university departments for addressing the crucial issues of global climate change.

SPECIFIC RECOMMENDATIONS OF WORKING GROUPS

The recommended actions in the Conference Statement are mostly general in nature and common to a number of Conference Working Groups. The specific recommendations of the Working Groups are given in the following section.

ENERGY

1 Targets for energy supply should be directly related to reductions in CO_2 and other greenhouse gases. A challenging target would be to reduce the annual global CO_2 emissions by 20% by the year 2005 through improved energy efficiency, altered energy supply, and energy conservation.

2 Research and demonstration projects should be undertaken to accelerate the development of advanced biomass conversion technologies.

3 Deforestation should be reduced and reforestation accelerated to significantly reduce the atmospheric concentrations of CO_2 and to replenish the primary fuel supply for the majority of the world's population.

4 There is a need to revisit the nuclear power option. If the problems of safety, waste and nuclear arms proliferation can be solved, nuclear power could have a role to play in lowering CO_2 emissions.

5 It is necessary to internalize externalized costs. Policies should be fashioned to achieve broad, complementary social objectives and to minimize total social, economic and environmental costs.

FOOD SECURITY

1 National governments are urged to reduce the contributions of agricultural activities to the concentration of greenhouse gases in the atmosphere. These contributions arise from the destruction of forests, the inefficient use of inorganic nitrogen fertilizers, the increased conversion of land to paddy rice cultivation and the increased number of ruminant animals.

2 National governments should take the prospect of climate change into account in long-term agricultural and food security planning, particularly with respect to food availability to the most vulnerable groups.

3 National governments and international agencies should give increasing emphasis to a wide array of policy measures to reduce the sensitivity of the food supply to climatic variability in order to increase resilience and adaptability to climate change.

4 National governments are urged to increase their efforts to build sub-regional and regional cooperation aimed at achieving food security. International agencies should assist in promoting these regional cooperative efforts.

5 FAO, World Bank, WMO, UNEP, UNDP,CGIAR and other international organizations should encourage research leading to ecologically sound agricultural management systems.

URBANIZATION AND SETTLEMENT

1 Environmental impact statements and land-use management plans should consider future climatic conditions including the local effects of rising sea-level on coastal communities.

2 Urban authorities should undertake risk assessments and develop emergency planning procedures that take into account the effects of climate change, for example, the increased incidence of natural hazards.

3 National governments and the international aid community should develop policies and actions to deal with the likely increased movements of environmental refugees resulting from climate change.

4 Environmental education must be stressed, particularly with respect to the sustainable development of urban areas and human settlements, and should be strongly promoted by local and national authorities and by international bodies such as WMO, UNCHS, UNEP, UNIDO and UNDP.

5 Comprehensive world-wide assessments should be made by national and international organizations of the vulnerability of specific geographic regions and urban areas to the increased risk of higher incidence and spread of infectious diseases due to global climate change, including both vector-borne and communicable diseases. In these areas, assessments should be made of health care infrastructures and of their ability to cope with the projected increased risks of the spread of infectious diseases; and steps should be identified to be taken by local and national authorities and international organizations to improve such capabilities.

6 Assessments should be made of the vulnerability of nuclear facilities, municipal and hazardous waste dumps, and of other waste disposal facilities to the increased hazard of sudden flooding or gradual inundation, and of their potential for the consequent spread of infectious pathogens or toxic chemicals to the surrounding land and sea areas, and appropriate steps should be taken to minimize such risks.

WATER RESOURCES

1 The efficiency of water-use and the resilience of existing and planned water resource systems and management processes must be increased to meet the existing climate variability.

2 Existing acid rain conventions must be extended to the global scale and modified to include toxic organic pollutants.

3 Integrated monitoring and research programs are urgently required to improve the methods of assessing the sensitivity of water resource systems, to identify critical regions and river basins where changes in hydrological processes and water demand will cause serious problems, and to understand and model the hydrological, ecological and socio-economic impacts of climate change.

4 To alleviate present and future water problems and to achieve sustainable development, we strongly endorse the global principle of inter-regional and inter-generational equity in all actions. International cooperation, open technology transfer, meaningful public involvement and effective public information programs are essential.

LAND RESOURCES

An international fund should be created specifically for development assistance and research in order to:

1 Maintain the terrestrial reservoirs of carbon through the careful management and protection of tropical and temperate forests and their soils, tundra and wetlands that represent major carbon pools.

2 Encourage the development of varieties of sustainable land-use practices through such activities as agroforestry, reforestation, development of varieties for adaptation to climate change, and development of effective management practices for waste treatment and disposal, and through policies for the use, settlement and tenure of land. This requires major changes in the aid policy, commercial practices and policies of related organizations (ITTO, FAO/TFAP and ICRAF) as well as possible "debt swapping" for forest protection and access to a reforestation fund.

3 Identify the most productive agricultural lands so as to be able to implement a land reserve system that can be used to mitigate losses resulting from a more adverse climate and sea-level rise.

4 Increase awareness among the public of issues posed by climate change in relation to the continued wise use of lands in a sustainable manner.

5 Broaden existing programs that address the impact on land resources of acid and other toxic depositions, by taking account of their global dimension.

COASTAL AND MARINE RESOURCES

1 Research is required to understand which natural and human factors determine the productivity and variability of marine and coastal resources.

2 Institutional and legal arrangements for the wise use of common property resources must be greatly improved.

3 The flexibility of marine-dependent industries and coastal communities must be greatly enhanced to respond to climate-induced changes.

4 Site-specific impact studies of the effects of sea-level rise must be undertaken. These should include consideration of the human, economic and environmental risks and should result in local education programs.

5 The implications of climate change for coastal-zone planning must be considered, particularly the risk of sea-level rise and/or the potential need to locate new developments inland.

FUTURES AND FORECASTING

1 In order to have any hope of coping with future change, we must acquire and make use of the knowledge of the past and develop the ability to anticipate the possible future. No one model can or should be expected to deal with the uncertainties in forecasting, the details needed for making decisions, and the social, technical and economic implications of change. Hence an array of techniques must be used in order to produce useful results.

2 Not only are continued efforts needed to improve forecasting-methodologies and to integrate cause-and-effect modelling, but also improvements are needed in our ability to communicate and convey their implications for the broader culture so that individual and collective decisions can be made appropriately and with foresight. Attitudinal and institutional changes will be necessary because of the projected serious global consequences. Equally important is the need to take action, in an environmentally sustainable way, on the interrelated issues of population growth, resource use and depletion, and technological inequalities.

DECISION-MAKING AND UNCERTAINTY

1 The reduction of uncertainties requires advanced understanding of the chemistry of the atmosphere, of the implications of climate change for health, agriculture, economies, and other social concerns, and of the legal, political and other aspects of the possible responses to climate change (prevention, compensation and adaptation).

2 The industrialized nations should begin to restore the integrity of the environment, making atmospheric change the turning point for an ecological innovation of industrial economy.

3 Emission targets ought to be the subject of an international treaty between the nations that take the first step. Those nations should invite all the others to join them in advancing environmentally sustainable economic development.

4 Open decision-making may well provide for decisions that are not easily accepted by the public. We recommend a democratic discussion about possible responses to the atmospheric threat. Non-governmental organizations should play a decisive role in furthering this discourse.

INDUSTRY, TRADE AND INVESTMENT

Proposed as matters for urgent action are:

1 Creation of a World Atmosphere Fund financed by a levy on the fossil fuel consumption of industrialized countries, sufficient to support development and transfer fuel-efficient technologies.

2 Development of mechanisms for incorporating environmental considerations and responsibilities into the internal decision and reporting processes of business and industry.

3 Formation of an international consultative mechanism at the highest level, reporting to heads of government, to assure:

- accelerated research and development efforts
- reduction of institutional barriers to the adoption of appropriate low-emission technologies by industries and households

- improvement of market information to promote the shift of consumption toward ecologically appropriate products.

GEOPOLITICAL ISSUES

1 The particular regions of the world or sectors of the economy that will be damaged first or most strongly by a rapidly changing atmosphere cannot be foreseen today, but the magnitude and variety of the eventual impacts is such that it is in the self-interest of all people to join in prompt action to slow the change and to negotiate toward an international accord on achieving shared responsibility for care of the climate and the atmosphere.

2 Coordinated international efforts and an all-encompassing international agreement are required along with prompt action by governmental agencies and non-governmental groups to prevent harmful changes to the atmosphere. Such actions can be based on improvements in energy efficiency, the use of alternative energy sources, and the transfer of technology and resources to the Third World.

LEGAL DIMENSIONS

1 More states should observe the international principles and norms that exist and all should be encouraged to enact or strengthen appropriate national legislation for the protection of the atmosphere.

2 The offer of the Prime Minister of Canada to host a meeting of law and policy experts in early 1989 should be accepted. That meeting should address the question of the progressive development and codification of the principles of international law taking into account the general principles of law set out in the Trail smelter, Lac Lanoux, Corfu Channel cases, Principle 21 of the 1972 Declaration of the United Nations Conference on the Human Environment, the Convention on Long-Range Transboundary Air Pollution and related protocols, Part XII of the Law of the Sea Convention and the Vienna Convention for the Protection of the Ozone Layer and its Montréal Protocol. The meeting should be directed toward the elaboration of the principles to be included in an umbrella/framework Convention on the Protection of the Atmosphere – one that would lend itself to the development of specific agreements/protocols laying down international standards for the protection of the atmosphere, in addition to existing instruments.

INTEGRATED PROGRAMS

1 A thorough review is required to establish the institutional needs for cooperation in research, impact assessment and development of public policy options at the international, intergovernmental and non-governmental levels, at regional levels and at national levels. This review should be completed by 1992.

2 Extension and further development is required for a United Nations global monitoring and information system that will incorporate technological advances in measurement, data storage and retrieval, and communications in order to track systematic changes in the physical, chemical, biological and socio-economic parameters that collectively describe the total global human environment. The responsibility for development rests with governments. The monitoring system should be in place by the year 2000.

3 Also required is the development of an educational program to familiarize present and future generations with the importance of addressing issues concerning sustainable development including the actions and integrated, interdisciplinary programs needed.

THE DECLARATION OF THE HAGUE ON PROTECTION OF THE ATMOSPHERE

"This is the biggest problem, the biggest challenge faced by man in this or any other age.....The Declaration is eloquent testament to our determination - as a representative group of Nations of this Earth - to act promptly and effectively to meet this challenge."

- Senator Gareth Evans, Minister for Foreign Affairs and Trade of Australia, on the adoption of The Declaration of The Hague, 11 March 1989.

On 11 March 1989, Australia together with 23 other countries from all the regions of the world, signed a path-breaking Declaration which sets out important new principles to meet the challenge posed by changes to the Earth's atmosphere caused by the activities of mankind.

Senator Gareth Evans, Minister for Foreign Affairs and Trade, represented the Prime Minister of Australia at the gathering of Heads of State and their Representatives at the Hague, the Netherlands, to sign the historic Declaration.

The Declaration of the Hague establishes three important new principles to guide international efforts to counter the threat to the global atmosphere:

- the development of new institutional authority within the framework of the United Nations responsible for combatting further warming of the atmosphere
- appropriate measures to ensure effective implementation and compliance with the decisions of the new authority, decisions which will be subject to control by the International Court of Justice
- fair and equitable compensation for those countries which may suffer an abnormal or special burden as a result of decisions taken to protect the atmosphere.

DECLARATION OF THE HAGUE

The right to live is the right from which all other rights stem. Guaranteeing this right is the paramount duty of those in charge of all States throughout the world.

Today, the very conditions of life on our planet are threatened by the severe attacks to which the Earth's atmosphere is subjected.

Authoritative scientific studies have shown the existence and scope of considerable dangers linked in particular to the warming of the atmosphere and to the deterioration of the ozone layer. The latter has already led to action, under the 1985 Vienna Convention for the Protection of the Ozone Layer and the 1987 Montreal Protocol, while the former is being addressed by the Intergovernmental Panel on Climate Change established by UNEP and WMO, which has just begun its work. In addition the U.N. General Assembly adopted Resolution 43/53 on the Protection of the Global Climate in 1988, recognizing climate change as a common concern of mankind.

According to present scientific knowledge, the consequences of these phenomena may well jeopardise ecological systems as well as the most vital interests of mankind at large.

Because the problem is planet-wide in scope, solutions can only be devised on a global level. Because of the nature of the dangers involved, remedies to be sought involve not only the fundamental duty to preserve the ecosystem, but also the right to live in dignity in a viable global environment, and the consequent duty of the community of nations vis-a-vis present and future generations to do all that can be done to preserve the quality of the atmosphere.

Therefore we consider that, faced with a problem the solution to which has three salient features, namely that it is vital, urgent and global, we are in a situation that calls for implementation of existing principles but also for a new approach, through the development of new principles of international law including new and more effective decision-making and enforcement mechanisms.

What is needed here are regulatory, supportive and adjustment measures that take into account the participation and potential contribution of countries which have reached different levels of development. Most of the emissions that affect the atmosphere at present originate in the industrialised nations. And it is in these same nations that the room for change is greatest, and these nations are also those which have the greatest resources to deal with this problem effectively.

The international community and especially the industrialised nations have special obligations to assist developing countries which will be very negatively affected by changes in the atmosphere although the responsibility of many of them for the process may only be marginal today.

Financial institutions and development agencies, be they international or domestic, must co-ordinate their activities in order to promote sustainable development.

Without prejudice to the international obligations of each state, the signatories acknowledge and will promote the

following principles:

A) The principle of developing, within the framework of the United Nations, new institutional authority, either by strengthening existing institutions or by creating a new institution, which, in the context of the preservation of the Earth's atmosphere, shall be responsible for combatting any further warming of the atmosphere and shall involve such decision-making procedures as may be effective even if, on occasion, unanimous agreement has not been achieved.

B) The principle that this institutional authority undertake or commission necessary studies, be granted appropriate information upon request, ensure the circulation and exchange of scientific and technological information - including facilitation of access to the technology needed - develop instruments and define standards to enhance or guarantee the protection of the atmosphere and monitor compliance herewith.

C) The principle of appropriate measures to promote the effective implementation of and compliance with the decisions of the new institutional authority, decisions which will be subject to control by the International Court of Justice.

D) The principle that countries to which decisions taken to protect the atmosphere shall prove to be an abnormal or special burden, in view, inter alia, of the level of their development and actual responsibility for the deterioration of the atmosphere, shall receive fair and equitable assistance to compensate them for bearing such burden. To this end mechanisms will have to be developed.

E) The negotiation of the necessary legal instruments to provide an effective and coherent foundation, institutionally and financially, for the aforementioned principles.

The Heads of State and Government or their Representatives, who have expressed their endorsement on this Declaration by placing their signatures under it, stress their resolve to promote the principles thus defined by:

- *furthering the development of their initiative within the United Nations and in close co-ordination and collaboration with the existing agencies set up under the auspices of the United Nations;*
- *inviting all states of the world and the international organisations competent in this field to join in developing, taking into account studies of the IPCC, the framework conventions and other legal instruments necessary to establish institutional authority and to implement the other principles stated above to protect the atmosphere and to counter climate change, particularly global warming;*
- *urging all states and the international organisations competent in this field of the world to sign and ratify conventions relating to the protection of nature and the environment;*
- *calling upon all states of the world to endorse the present Declaration.*

The original of this Declaration, drawn up in French and English, will be transmitted to the Government of the Kingdom of the Netherlands, which will retain it in its archives. Each of the participating States will receive from the Government of the Kingdom of the Netherlands a true copy of this Declaration.

The Prime Minister of the Netherlands is requested to transmit the text of this Declaration, which is not eligible for registration under Article 102 of the Charter of the United Nations, to all members of the United Nations.

The Hague, 11 March 1989.

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SIGNATORIES

Helmuth Kohl
Chancellor of the Federal Republic of Germany.

Gareth Evans
Minister for Foreign Affairs and Trade of Australia

Paulo Tarso Flecha de Lima
Secretary General of External Relations of the Federative Republic of Brazil.

Brian Mulroney
Prime Minister of Canada

Felix Houphouet-Boigny
President of the Republic of Cote d'Ivoire

Muhammed Hosni Mubarak
President of the Arab Republic of Eygypt

Felipe Gonzalez
Prime Minister of Spain

Francois Mitterand
President of the French Republic

Miklos Nemeth
Prime Minister of the Hungarian Peoples's Republic

P.V. Narasimha Rao
Minister of External Affairs of India

Emil Salim
Minister of State for Population and Environment of the Republic of Indonesia

Giorgio Ruffolo
Minister of the Environment of Italy

Masahisa Aoki
Minister of State of Japan

Hussein Ibn Talal
King of the Hashemite Kingdom of Jordan

Daniel Toroitich arap Moi
President of the Republic of Kenya

Edward Fenech Adami
Prime Minister of the Republic of Malta

Gro Harlem Brundtland
Prime Minister of the Kingdom of Norway

Geoffrey Palmer
Deputy Prime Minister of New Zealand

Ruud Lubbers
Prime Minister of the Kingdom of the Netherlands

Abdou Diouf
President of the Republic of Senegal

Ingvar Carlsson
Prime Minister of the Kingdom of Sweden

Hedi Baccouche
Prime Minister of the Tunisian Republic

Enrique Colmenares Finol
Minister for Environment of the Republic of Venezuela

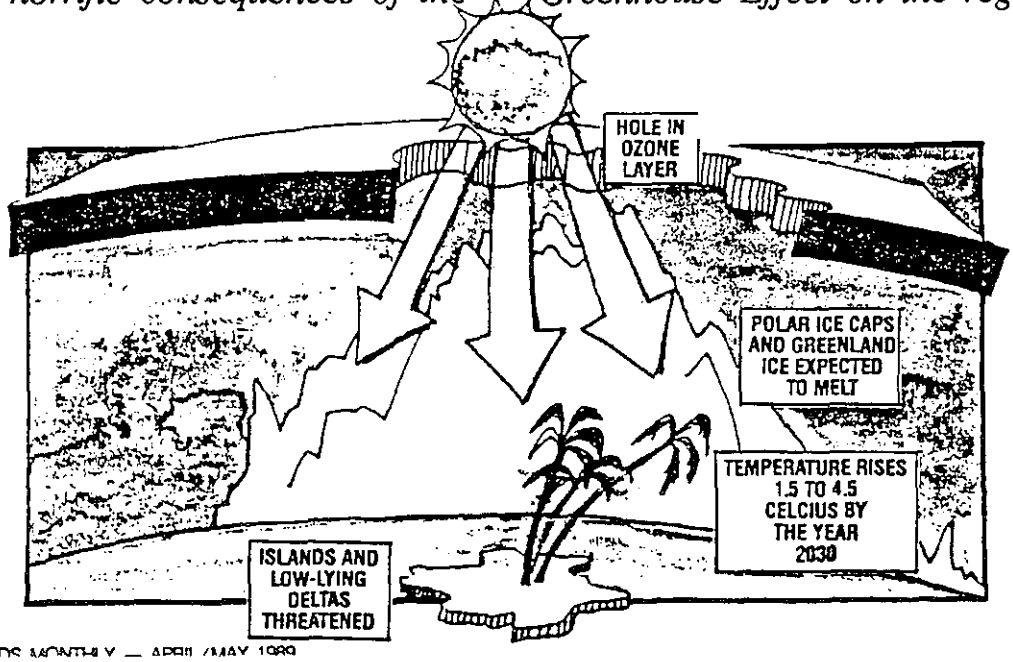
Robert Gabriel Mugabe
President of the Republic of Zimbabwe.

SPECIAL REPORT

THE GREENHOUSE EFFECT

Where have all the islands gone?

The spectre of the Greenhouse Effect has dramatically raised the developed world's interest in the environment, but positive action is slow in coming. In the Pacific, where entire nations may be swallowed, time is already running out. Peter Roy of the New South Wales Department of Mineral Resources and University of Sydney Geography lecturer John Connell examine the horrific consequences of the Greenhouse Effect on the region.



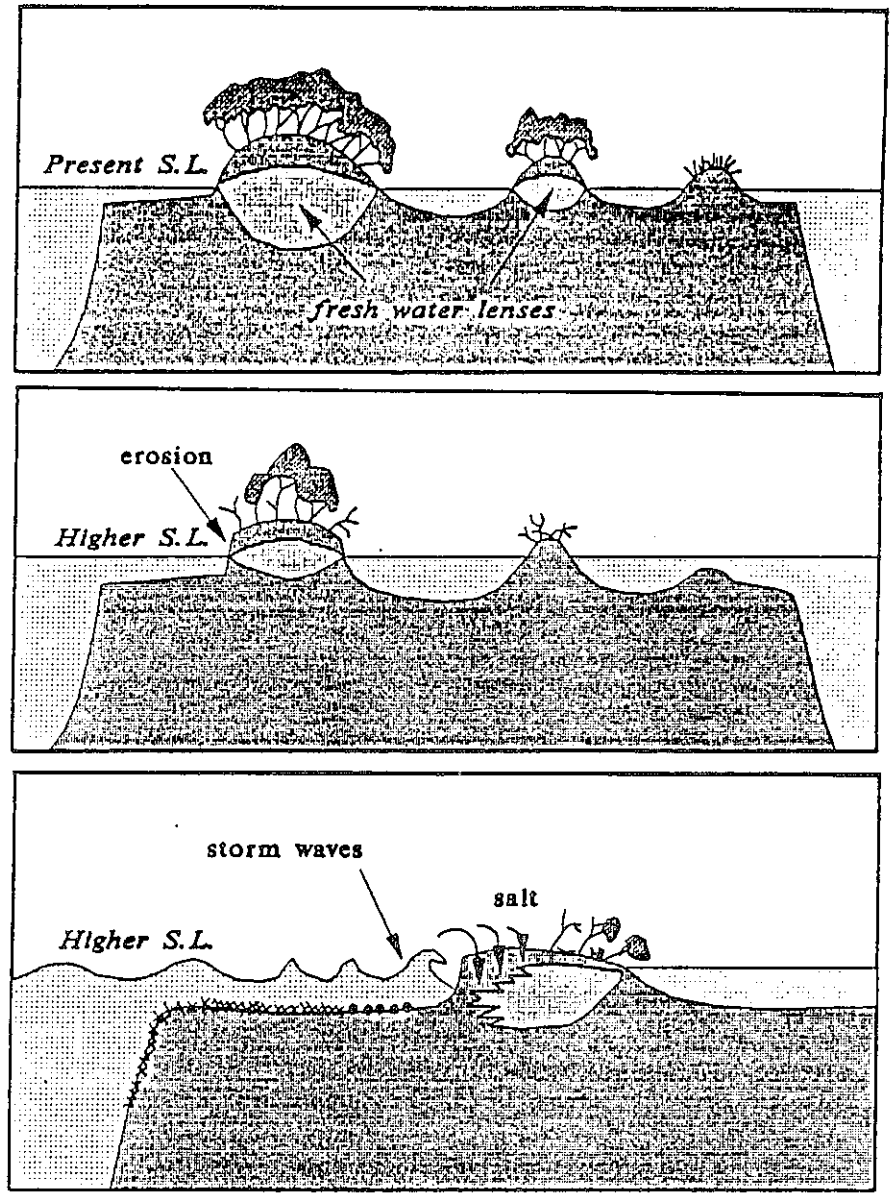
ENVIRONMENTAL issues have attracted unprecedented media and public attention in the past 12 months, and everywhere there is a growing awareness of the problems, if not the solutions. The Greenhouse Effect has become the 'flagship' of the international environmentalist cause, and the springboard to the front pages for many other man-made ecological problems.

No environmental issue has ever stimulated such global interest and spawned such a variety of popular and academic accounts: ironically, however, while it is a 20th century dilemma, the term "Greenhouse Effect" was coined almost a century ago. Yet there is still considerable uncertainty over the actual nature of the Greenhouse Effect and future rates of climatic change. In the absence of concrete information prophets of doom have gained wide exposure with forecasts of cataclysm, but recent scientific studies have increasingly begun to draw consistent conclusions about future trends and point to the regions where the Greenhouse Effect will cause the most severe problems.

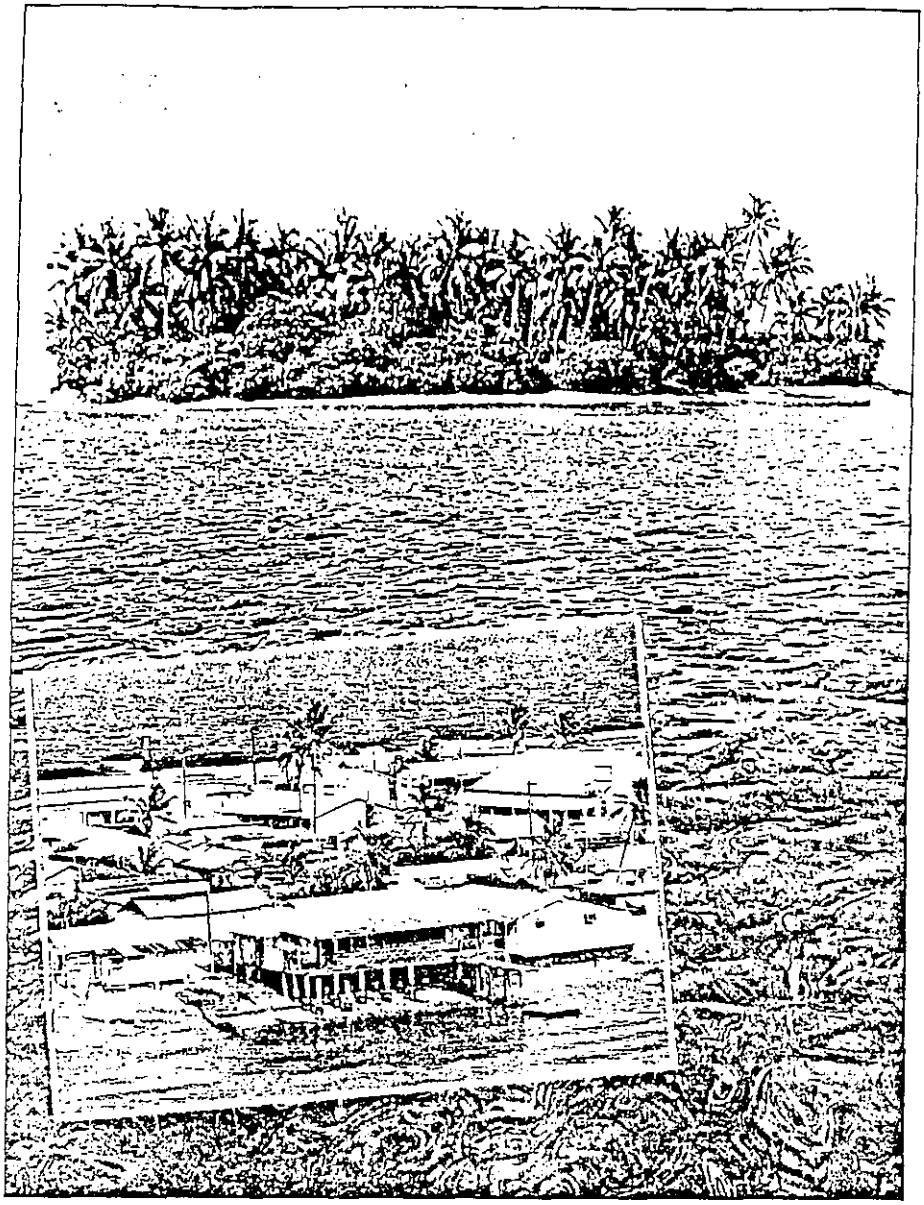
Most nations of reasonable wealth and substantial land mass will adapt to the climatic changes — some may even find considerable economic advantage in new agricultural possibilities. But in the Pacific, the predicted rise in sea level will mean widespread upheaval and potential disaster. "If the Greenhouse Effect raises sea levels by one metre it will virtually do away with Kiribati," says that nation's President, Ieremia Tabai. "In 50 or 60 years my country will not be here."

He is only too aware that the most extreme situations will be faced by small ocean island states occupying low coral islands. Four Pacific nations — Kiribati, the Marshall Islands, Tokelau and Tuvalu — are composed entirely of low relief atolls and recent studies warn that these states will be devastated if projected sea level rises occur. They may simply cease to contain *any* habitable land.

The four atoll states are quite different in language, culture, history and physical environment. Tuvalu and Tokelau are part of Polynesia; the Marshall Islands and Kiribati are in Micronesia. The state of Tuvalu consists of nine coral atolls and reef islands with a total land area of no more than 24 square kilometres, yet spread over 590 kilometres. Kiribati has 20 populated atolls and a land area of 700 square kilometres, but more than half of this (363 square kilometres) is on Kiritimati (Christmas Island), some 3500 kilometres from the national capital, Tarawa. The Marshall Islands has 24 populated atolls, but the majority of the population lives in the capital, Majuro, or on



From top: Lenses of freshwater will shrink or disappear as erosion increases and intruding salt water will pollute them.
Bottom: Broad islands with relatively large fresh wates lenses form where converging waves build ridges and recurved sand spits. Lower, swampy areas are highly productive but vulnerable to salinisation.



The sights that lure tourists — and their dollars — to the South Pacific seem destined to disappear unless all the world's nations work together to limit the damage. In any case, out-migration will be necessary as lowlying atolls are abandoned to the waves.

Ebeye near the American missile range on Kwajalein Atoll.

The buildup of industrial gases in Earth's atmosphere over the past 30 to 40 years is now well documented. The resulting Greenhouse Effect is expected to raise temperatures over much of the planet's surface and lead to a rise in ocean levels. The rise will initially come about through an expansion of surface waters and the melting of mountain glaciers; not until much later will melting of the polar ice sheets significantly augment ocean volumes. Coastal erosion will increase as sea-level rises accelerate beyond the upward growth of corals, and will probably be accentuated by a greater frequency of storms.

Analysis of tide gauge records from around the world reveals a small rise in relative sea level (1.0-1.5 mm per year) over the past few decades. These results have been variously interpreted and it is not clear whether the apparent sea level changes are caused by a global Greenhouse Effect, local climatic variability or increased river discharges into the oceans following the construction of large irrigation schemes and dams.

Rates of expansion of the oceans cannot be determined with any accuracy because of uncertainty concerning the pattern and extent of future heating of the earth's surface, and the rate at which the heat will be absorbed by the oceans.

Extreme scenarios for the next 50 years range from virtually no change in mean sea level to an elevation many metres higher.

The basic effect of a Greenhouse-induced rise in sea level is for lowlying lands to be inundated and for coasts to erode. Erosion, as opposed to inundation, is most severe on shorelines composed of unconsolidated sediment exposed to storm wave attack: a gradual rise of mean sea level will progressively lift the zone of flooding, storm wave and surge effects to new levels, eroding areas previously considered safe. Human responses will vary depending on the values of the coastal land under attack and the resources available to provide protective measures. In Pacific atoll states, where resources are very limited, the provision of expensive engineering works will rarely be an option.

Atolls are accumulations of the remains of reef-forming organisms usually arranged into a rim around a central lagoon and restricted to tropical ocean waters within 20 degrees of the equator. Drilling results from a number of atolls essentially confirm the early speculations of Charles Darwin that the reef deposits accumulated on the peaks of submerging mid-ocean volcanoes. Atoll islands are among the most recent of geological formations — and the youngest in terms of human colonisation.

Islands on atoll rims vary enormously in size and shape, but rarely rise more than three metres above mean sea level. They may be stable but the occurrence of exposed and eroding outcrops of beachrock/coral conglomerate on one hand and newly formed boulder ridges and sand spits on the other indicate that islands are constantly changing shape. The building of atoll superstructures, especially islands, results from a combination of processes of small scale erosion and accretion that can be observed on a day-to-day basis, interspersed by catastrophic changes caused by rare but extremely violent cyclones and hurricanes. Storms have been documented in which waves passed across islands up to eight metres above their land surfaces, hundreds of islanders died and whole island environments were destroyed — either washed away or buried in rubble.

These changes have been viewed in terms of dynamic equilibrium rather than stages in an evolutionary progression, with periods of island accretion alternating with (and largely balancing) erosion. A state of disequilibrium may arise if environmental conditions such as relative sea level or storminess change with time. The theoretical effect of slow changes in relative sea level can be predicted: negative movements would tend to promote the accumulation of sediment masses, while positive movements should increase erosion.

While the spectre of rising sea levels ▶

in the future seems to follow inevitably from a Greenhouse-induced warming of the atmosphere, there is growing evidence that its impact will not be the same everywhere. It has been shown that past sea level changes have been influenced by local climatic and oceanographic factors, and the variability of those factors may increase with the Greenhouse Effect. The nature of existing coastlines — whether composed of cliffs or swamps — will also determine the impact.

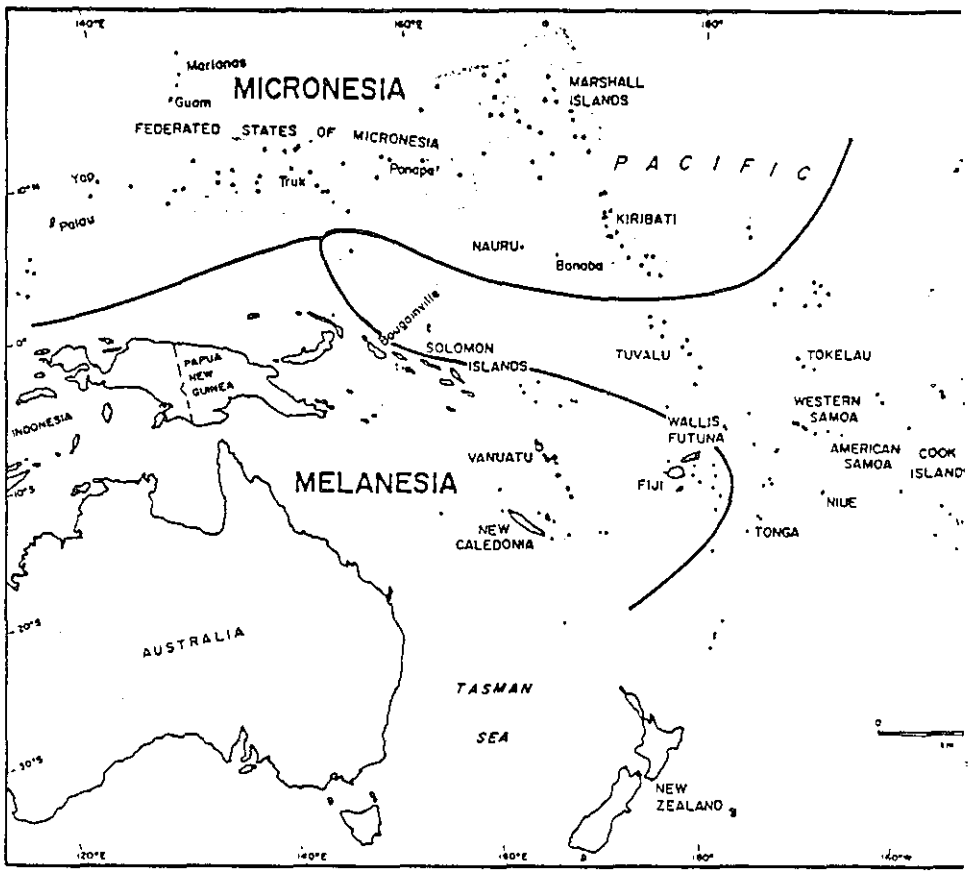
Atoll flora and fauna are generally limited in species diversity, with only a few plant types predominating. The Greenhouse Effect would wreak havoc on island ecology because of the relatively small size and low elevation of atoll islands and the subsequent low salt tolerance of their plants.

Species such as coconut and pandanus can withstand quite high levels of salt and even occasional inundation by storm waves. They are hardy and quickly colonise even small rubble mounds that rise above high tide level, while taro is much more sensitive to salinity changes and grows in low areas, usually in manually excavated pits. Salinity increases after storms have caused substantial decreases in taro productivity.

An atoll's capacity to support human life is closely tied to the existence of a permanent groundwater system. Islands larger than about 1.5 hectares and 200 metres in diameter contain a permanent lens of fresh water surrounded by salt water; the volume of the lens is roughly proportional to the surface area of the atoll. Any decline in island area has a very dramatic influence on the availability of freshwater supplies. Conceivably, in the next 50 years, Greenhouse Effect shoreline erosion of one or two metres a year could reduce the dimensions of some presently inhabited islands to the point where their groundwater supplies would no longer support viable natural environments or permanent human habitation.

EROSION

As erosion reduces island size, groundwater lenses will shrink beneath larger islands and virtually disappear under smaller ones. All except the most hardy vegetation will perish. Sea levels rising at the rates contemplated under future Greenhouse conditions would outstrip the ability of the islands to grow upward, leading to a reduction in 'island freeboard' — height above mean sea level. Storm overwash will therefore become an increasingly frequent occurrence, causing damage to buildings and vegetation and irreversible salinisation of the groundwater lens.

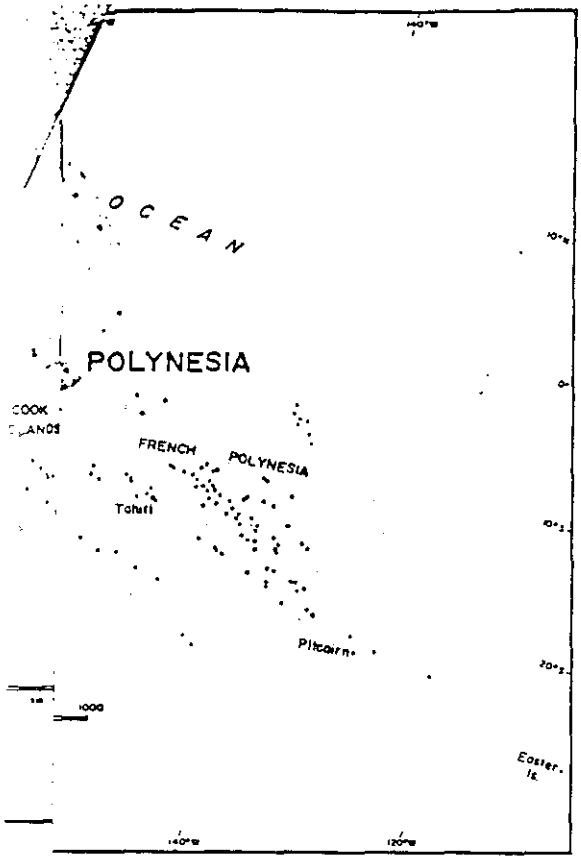


The most severe situations are likely to occur on what are today the widest and most productive islands. These typically occur at bends in the reef crest where waves approach from two or more directions and recurved spits form around a central low area. Many islands of this type support relatively high population densities, and the effect of a marine incursion on this type of island would be destruction of food-producing areas in the interior by salt water and a reduction in the groundwater lens and decreased productivity of coconut and breadfruit crops. Construction of expensive sea walls would be, at best, a stopgap measure; as sea levels continue to rise, so will the ground water table. The central parts of the island would become a shallow and relatively unproductive lake of fresh water that becomes increasingly brackish as storms wash over the island surface.

Coral reefs provide the most limited range of resources for human existence and the most tenuous of human habitats in the Pacific. The soil is infertile and fresh groundwater is very limited; maintaining a livelihood is a considerable task and many atolls have been depopulated and repopulated following abandonment in the wake of storm damage, inspiring migration movements of various kinds. The dying phases of the small community on Merir atoll in Palau were well documented: during the 1960s the women of Merir grew too old to cultivate taro and the men could not keep the coconut groves clear. The island was depopulated and the few survivors were moved to the Palau mainland, an option open to atoll dwellers in some form of political liaison with larger islands and states.

Resource-poor atoll states have faced a host of development problems and have thus moved rapidly into absolute dependence on the outside world, primarily for aid, concessional trade and migration opportunities. Modern health facilities and medicines have allowed more rapid natural increases in population and population control measures have enjoyed little success. The Marshall Islands now has one of the fastest-growing populations in the world, with widespread adoption reducing the perceived need for family planning. Kiribati and Tuvalu are not far behind and, as populations increase, extra strain is placed on local and imported resources.

Migration is certainly not a new concept in the Pacific. Higher postwater rates of population increase, lack of employment prospects, increased desire for consumer goods and the concentration of facilities on central islands have in many cases resulted in out-migration from atolls. But the concentration of population in urban areas leads to overcrowding and its attendant problems — squatter settlements, pollution, poor nutrition,



increased unemployment and higher crime rates. Thus the idea of permanent emigration to seek one's fortune elsewhere is often the only answer to economic problems confronting the atoll microstates.

It is already well established in Tokelau, where for at least 70 years some of every group of siblings must *tahe* (emigrate) simply because the local resources are seen as insufficient. Tokelau islanders are technically citizens of New Zealand and a majority of Tokelauans now live in NZ.

Migration to the USA from the Marshall Islands (and the Federated States of Micronesia) is possible under the terms of the Compact of Free Association. But for the former British colonies, Tuvalu and Kiribati, only temporary labour migration to Nauru is currently possible. This is constrained by a combination of fixed employment opportunities on Nauru and the inevitable closure of its phosphate mine in the near future.

Permanent international migration is increasingly viewed by many as a key solution to a range of development problems. The 1984 Jackson Review concluded that even Australian foreign aid could not resolve all the region's problems, and suggested that "limited opportunities" for immigration from Kiribati and Tuvalu would be a better option.

Rising sea levels can only worsen in a number of ways the problems of achieving development in atoll states, though the extent of the changes will vary over time and from place to place in ways that are not yet possible to predict. The erosion of fringing reefs is likely to seriously disturb island environments, reduce the distinctive ecology of tropical lagoons and diminish the fishing potential of all atolls. The Greenhouse Effect is likely, in time, therefore, to lead to a substantial decline in agricultural and fisheries production, and a loss of vital water, timber and firewood resources. These problems will increase over time and reduce the small degree of self-reliance currently demonstrated by relatively few atoll states.

The majority of atoll states will never achieve a significant degree of self-reliance (unless they discover new sources of mineral wealth), but they *are* capable of moving away from their massive dependence on migration, aid and trade. Self-reliance entails reducing dependence on imported 'necessities' including foods, oil, capital equipment and expertise — a situation that already poses major problems for most atoll states and one that is even less likely under the influence of the Greenhouse Effect.

It is difficult to predict the extent and impact of Greenhouse-induced climatic change in the next 50 to 100 years. Some forecast little change; others feel the Apocalypse is at hand. It is an act of irrational optimism to expect that humanity's past and present degradation of the world's natural environment will not induce some future change in global climate.

Questions as to how much and when the climate will change are largely unanswerable, at least in detail, at this time. There may be geological precedents for different world climates in the past, but there is no precedent for the speed at which present changes are taking place. Even more alarming is the lack of evidence that our present socio-political systems have the capacity or the will to control such global events. The best-case scenario for a technological fix is the development of a non-polluting form of energy production, such as solar energy. But even if this were developed immediately, many decades would pass before it replaced the planet's present energy sources — and pollution — and would likely be defeated by high costs and the vested interests of developed nations that export coal and uranium.

Atoll states are the most helpless of all nations in the face of the Greenhouse Effect. They cannot act individually or collectively to remove or reduce the causes of the effect, and they generally do not have the international legal or economic muscle required to elicit urgent action from the major developed nations.

They will, eventually, be overwhelmed: everything they have is coastal and therefore vulnerable; there is no higher ground to which populations and infrastructure can be moved. The cost of constructing dikes and pumping stations, an option favoured by developed nations threatened by Greenhouse, is beyond atoll states and would probably do little to solve the problem in any event.

Much more research is vital if we are to understand the Greenhouse Effect's physical, environmental and economic impacts at the local level; research that is likely to be undertaken with financial assistance from the metropolitan states, though in the past nations such as Australia have been unenthusiastic about funding research or development programmes that will strengthen environmental conservation because of their limited contribution to economic growth.

Increased emigration must be seen as one response to the Greenhouse Effect; it is a solution that builds on existing trends but that depends almost entirely on the policies of metropolitan states. A 1985 review of a possible concessionary Australian migration scheme raised the spectre of a new wave of 'boat people' — a situation where islanders take migration matters into their own hands.

Resettlement will pose particular problems as islanders move into environments quite different from their own and the social, psychological and economic consequences take their toll on individuals and groups. Resettlement within the region has often proved unsuccessful in the past, and moves to the metropolitan states would be no more easy.

Long before the contemporary implications of the Greenhouse Effect were recognised, the choice of appropriate development strategies for the atoll states had caused concern. Few world states have ever had such limited prospects for development, have gained so little from contemporary technological change but have nevertheless become so dependent on the outside world. Now it is even more crucial for there to be a focus on development issues in the atoll states. Without further substantial external assistance, there is little doubt that people who were once described as real and potential 'economic refugees' will become, in less than 50 years, a new group of environmental or ecological refugees.

It is extremely unlikely that action within the atoll states alone will allay this gloomy forecast. Some of the most recently populated islands in the world may be depopulated . . . and some of its most recently formed islands may disappear forever. □