

# **National Science Strategy Committee for Climate Change**

Annual Report  
2000

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## Terms of Reference

1. To develop a comprehensive strategy for climate change research which specifically includes the following:
  - 1.1 identification of priority research and important gaps in the overall climate change research agenda;
  - 1.2 co-ordination of research efforts between Crown Research Institutes, universities, government departments and the private sector;
  - 1.3 identification of the overall level of funding appropriate for research topics by consultation with science funders, science providers and the end users; and,
  - 1.4 report, through the Ministry for the Environment, to the Minister for the Environment by end October each year.
2. To provide input to the portfolio balance process of the Foundation for Research, Science and Technology by serving as a cross-portfolio reference group for climate change research.
3. To develop, in consultation with all interested parties, a portfolio of research which meets the objectives of the National Science Strategy.
4. To establish and maintain strong linkages with researchers and end users in the National Science Strategy topic area to actively promote knowledge of and access to information of common interest.
5. To provide advice to funding agencies on the priority and integration of research proposals in the National Science Strategy topic area.
6. To provide advice to the Ministry for the Environment and the Foundation for Research, Science and Technology on the research necessary to underpin the Government's climate change strategy, including its international obligations, and to provide advice to the Ministry for the Environment and the Ministry of Research, Science and Technology on priorities and funding levels for research closely related to development of government policy.
7. To provide advice on the establishment and maintenance of linkages with the Intergovernmental Panel on Climate Change process, and within the international climate change programme, with particular emphasis on joint/complementary activity with overseas funding agencies within the World Climate Research Programme and the International Geosphere-Biosphere Programme, and on international meetings and conferences of importance to New Zealand.
8. To monitor the progress of implementation of the climate change research strategy and its priorities and provide advice to the Ministry for the Environment and the Foundation for Research, Science and Technology on progress; and to modify the strategy, if necessary, in the light of significant new information.
9. To provide advice to the Ministry of Research, Science and Technology and the Foundation for Research, Science and Technology on strategies and mechanisms that could be used to strengthen the effectiveness and accountability of climate change research.

## Executive Summary

The National Science Strategy Committee for Climate Change (NSSCCC) has completed its ninth year of activity (2000). Because of the convenor's absence from New Zealand for six months, some reporting procedures were delayed and this annual report also covers the period to April 2001.

The report comments on the current state of climate change research, identifies gaps in our knowledge and makes recommendations on future funding, research priorities and policy development.

### *Chapter 1 Context for New Zealand Climate Change Research*

Chapter 1 provides background information on the NSSCCC which was formed in 1991 to develop a comprehensive strategy for climate change research. This chapter goes on to discuss the continuing need for action nationally and internationally. It notes the research strategy and time frame implications of the New Zealand Government's intent to ratify the Kyoto Protocol, assuming its entry into force despite the United States administration's recent rejection of the Protocol.

This chapter also describes the main sources of New Zealand's greenhouse gas emissions and asserts that research-based information and debate are essential for informed decision making.

### *Chapter 2 Climate Change Research Strategy*

Chapter 2 states that the NSCCC strategy is designed to achieve a vision of protecting New Zealand's wellbeing, economy and society. The research required to fulfil this vision falls into three interrelated categories: Processes, Effects, and Responses and Opportunities.

*Processes:* Research into climate processes provides a scientifically-based understanding of the variability and likely future changes in New Zealand's atmosphere and climate system.

*Effects:* Research on climate change effects aims to reduce uncertainty in projections of biophysical and socio-economic effects in the new Zealand region.

*Responses and Opportunities:* Responses and Opportunities research aims to establish effective, sustainable adaptations to climate change, mitigate greenhouse gas emissions and identify potential business opportunities in mitigation technology.

### *Chapter 3 The Challenge for the 21<sup>st</sup> Century*

Chapter 3 summarises what is known about climate change, discusses the knowledge gaps, looks at the barriers to research uptake and poses the question: What needs to be done?

It is now accepted that the climate of the globe is changing and that without global climate policies, atmospheric gas concentrations will continue to increase substantially. This chapter highlights the implications climate change will have for New Zealand. It also draws attention to our knowledge gaps, including those associated with agricultural emissions and regional climate change scenarios.

While the report acknowledges there have been improvements in some areas to research uptake, it notes with concern that scientists have minimal direct input to the policy making process. It also comments that communication between interested parties needs to be improved and draws attention to the lack of young scientists entering the field.

This chapter ends with a number of recommendations for action, including a need for a comprehensive and long-term strategy for reducing greenhouse gas emissions, further research and monitoring, and a mechanism for applying research to policy questions.

#### *Chapter 4 Research Highlights for 2000*

Chapter 4 provides a snapshot of some of the climate change research highlights in 2000. Examples have been chosen to illustrate their contribution within the NSSCCC strategy framework for research on Processes, Effects and Responses.

The Processes research covers studies of the physical climate system and includes studies on atmospheric chemistry, monitoring of regional climate, atmospheric composition and ocean behaviour, regional and global climate modelling and general studies on the coupling of ocean and atmosphere in the climate system.

As the New Zealand economy is closely aligned to agriculture, the Effects of climate variability and change on managed and natural environments are important. This section of the report reviews the research in the areas of health, managed production systems and natural ecosystems.

Under Responses, this chapter notes that we can mitigate the primary drivers of change or adapt to the changes and so capture opportunities and minimise risks. It discusses lowering ruminant methane, improving energy efficiency, transport and the development of response tools.

#### *Chapter 5 Identifying Gaps in Research Efforts, Research Priorities and Opportunities*

Chapter 5 compares the ongoing portfolio of climate change research with the NSSCCC strategy. The Committee has identified specific gaps in the research programme relating to the ratification of the Kyoto Protocol and also for the national interest. This chapter identifies several priorities, including improved understanding and predictions of changes in extreme climate events including floods and droughts, ozone concentrations and UV levels and the arrival of disease vector insects and other pests. As well as national research,

this chapter states that New Zealand also has obligations to contribute to global research and climate monitoring and to participate in research and monitoring in the South Pacific region.

This chapter analyses research spending and concludes that there is a continuing shortage of funds for climate change research, particularly in the Effects area. The report asserts that there is an urgent need to clarify the responsibilities of different funders and ensure that real complementarity exists between parties. Shortage of human capacity is also identified as a future problem as current lead researchers near retirement.

#### *Chapter 6 Global Programmes and Collaboration*

Chapter 6 profiles some of the major global research programmes on climate change. Through collaboration in international research programmes, New Zealand obtains information on climate change and its impacts which it would be impossible to develop on our own. In return, New Zealand makes some significant contributions to the international pool of knowledge.

This chapter includes information on global research and monitoring programmes, international conventions and science assessment programmes, regional programmes and collaboration, and support for international links.

#### *Appendices*

Appendix 1 outlines the Committee's activities for 2000/2001.

Appendix 2 provides details of New Zealand climate change research.

Appendix 3 is a bibliography which lists recent peer-reviewed scientific publications on climate change processes, effects and responses.

Appendix 4 is a glossary of acronyms, abbreviations and scientific terms.

## Recommendations

The National Science Strategy Committee for Climate Change (NSSCCC) has a number of recommendations (see below) to ensure that the Government:

- is well informed for international negotiations leading up to the ratification of the Kyoto Protocol, and for subsequent negotiations on further reductions of greenhouse gas emissions
- has appropriate information for identifying best courses of domestic action on climate change, including commitments to meet its Kyoto Protocol emission reduction targets for greenhouse gases, and likely post-Kyoto emission reduction targets
- is able to develop appropriate adaptation strategies to adjust to inevitable climate changes.

The recommendations are grouped around the new reporting framework proposed by the Minister for Research, Science & Technology in a publicly-released Cabinet paper (POL (00) 201).

### **NSSCCC recommends that:**

#### **Greenhouse Gas Management and Responses**

- 1) Government initiates a comprehensive review of New Zealand's technical and economic potential for reducing greenhouse gas emissions and increasing removals, and develops policy options for their implementation, including the consideration of:
  - all relevant gases
  - all economic sectors
  - likely international long-term policy scenarios after 2013
  - the different time frames applying to different options.
- 2) The Foundation for Research Science and Technology (FRST) and government departments ensure greenhouse gas research is planned to align with appropriate policy development milestones as developed under recommendation 1.

#### **Environmental and Societal Impacts and Responses**

- 3) Government sets up a clear and formal mechanism to enable the best use of New Zealand scientific expertise to be applied to climate change policy questions. This would include the input of appropriate scientists to policy and Cabinet papers as they are being developed.
- 4) FRST maintains support for research on climate variability and its impacts, which will also assist with adaptation to climate change.

#### **Enhanced Environmental Understanding and Research Capability**

- 5) FRST and government departments:
  - maintain funding to existing programmes which address knowledge needs and gaps identified in Chapters 2, 3 and 5 of this paper
  - invest to fill gaps identified in Chapters 2, 3 and 5 of this paper.
- 6) The Ministry for the Environment (MfE) and the Ministry of Research, Science and Technology (MoRST) work together to develop and maintain a skill base in climate research and advice to overcome the potential knowledge gap when current scientists retire. This could be achieved by working with:
  - the education sector to encourage interest in climate change science
  - industry and philanthropic groups which might fund students and research on climate change.
- 7) FRST, Land Information New Zealand (LINZ) and MfE finalise resolution of the issue of support for long-term sea-level monitoring.

#### **International Collaboration**

- 8) FRST and MoRST continue to facilitate New Zealand involvement in appropriate international climate change research projects and assessment activities.

### **Economic Opportunities from Research, Science and Technology**

- 9) Policy departments, science providers and the Royal Society of New Zealand facilitate communication of appropriate research results to central and regional government policymakers and other stakeholders including industry, farmers, technical groups and the public.

### **To assist in achieving those recommendations, the NSSCCC will:**

- 1) encourage increased funding, particularly from industry, government departments, universities and regional councils, with particular emphasis on increasing resources in the Effects and Responses area
- 2) develop, in collaboration with MfE and MoRST, an improved rationale for the funding of climate change research with an emphasis on a clarification of the different roles of resource providers, and complementarity and partnerships between them
- 3) develop a common framework for advice on climate change research funding which links directly with FRST portfolios
- 4) organise an “Opportunities” workshop in 2001 to raise investor awareness of potential technologies arising from climate change research

- 5) encourage the development of an accountability model for government departments to ensure that the best use is made of scientific expertise in policy development
- 6) build its new role as science adviser on climate change policy to the Minister for the Environment and the Convenor of the Ministerial Group on Climate Change
- 7) strengthen its strategic advisory role on climate change research opportunities and priorities.

### **To implement these recommendations, all stakeholders will need to:**

- engage with all potential funders of climate change research
- promote investment opportunities
- maintain and foster key climate change science competencies.

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## Chapter 1

# The Context for New Zealand Climate Change Research

## BACKGROUND

The NSSCCC was established in 1991 with the prime objective of developing a comprehensive strategy for climate change research.

The strategy includes:

- identification of priority research and important gaps in the research agenda
- coordination of research efforts between Crown Research Institutes (CRIs), universities, government departments and the private sector
- identification of the overall level of funding appropriate for research topics by consultation with research funders, science providers and the end user
- provision of advice on the establishment and maintenance of linkages with the international climate change programme, with particular emphasis on the Intergovernmental Panel on Climate Change (IPCC) process
- annual reporting through MoRST to the Minister of Research, Science and Technology.

Since the early 1990s the strategy of NSSCCC has been regularly updated to ensure that New Zealand's effort in climate change research:

- takes into account new knowledge
- remains consistent with changing government policy and changes in levels of funding
- remains focused on the priority issues and problems associated with climate change for the short and long term.

The current Committee was reappointed for a further three-year term in 1999 when the Government reviewed the role of the National Science Strategy Committees after changes to the science infrastructure. The Terms of Reference of the Committee were amended in March 2000 to reflect its new relationship with FRST as a reference group in the Public Good Science Fund (PGSF) round. Also the Committee now reports through MfE to the Minister for the Environment rather than to the Minister of Research, Science and Technology. This was to bring the Committee closer to the users, particularly MfE, the lead government agency under the whole-of-government approach to developing climate change policy.

Because of the Convenor's absence from New Zealand for six months, while on secondment to the OECD in Europe, some of the Committee's reporting procedures were delayed, and this annual report now covers an extended

time period from January 2000 to April 2001. The yearly schedule will be resumed with the annual report 2001 which will be published in January 2001.

## THE NEED FOR ACTION

The New Zealand Government plans to ratify the 1997 Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) by mid-2002. The Protocol obliges New Zealand to reduce its greenhouse gas emissions to 1990 levels, on average, over the period 2008 to 2012, or otherwise take responsibility for emissions in excess of its target. Because Kyoto Protocol constraints are insufficient to stabilise greenhouse gas concentrations in the atmosphere at a level unlikely to cause significant climate impacts, there is an expectation that ongoing international negotiations will consider further reductions in emissions.

The United States administration has signalled that it does not intend to ratify the Kyoto Protocol because of fears that doing so would harm its economy and would be too restrictive. The sixth Conference of the Parties (COP6) to the UNFCCC, which met in November 2000 in The Hague was unable to reach an agreement on details to implement the Kyoto Protocol. It is scheduled to resume its session in July 2001 in Bonn, Germany. It is still unclear at this stage whether the new negotiations will lead to a modification of the Kyoto Protocol enabling the United States government to reverse its statement and ratify, whether the Protocol will enter into force without the participation of the United States, or whether a new Protocol will need to be negotiated.

A large number of countries, including developing and developed countries, have expressed their considerable concern about the United States' position and have made it clear that reductions of greenhouse gas emissions are a key priority regardless of the specific international agreement under which such reductions would be made. The New Zealand government has stated that it still plans to ratify the Kyoto Protocol by mid 2002, assuming that a compromise solution will be acceptable and a sufficient number of countries support it to allow its entry into force.

The New Zealand Government is developing practical domestic policies to meet Kyoto commitments. This is a challenging goal since New Zealand's greenhouse gas emissions are currently increasing in some key sectors. Dealing with this challenge in an economically efficient and broadly acceptable manner requires a strong science input and consideration of long-term strategies for technical, economic and social development. This is

clearly recognised in other Annex I countries, many of which have invested more effort in the development of such strategies than New Zealand.

The main sources of New Zealand's anthropogenic greenhouse gas emissions are energy generation, transport and agricultural activities. The largest increases of greenhouse gas emissions since 1990 occurred in electricity generation and transport, while agricultural emissions have fallen slightly but could rise again in future. The relative importance of different gases and different sectors within our emissions inventory is unique amongst Annex I countries in that agricultural emissions account for more than 50 percent of the total emissions. This potentially provides us with a wider range of mitigation options but requires a substantial amount of local research and analysis, rather than reliance on importing strategies relevant for other countries. Research-based information and debate is essential so policy developers, planners, industries and investors make informed decisions regarding:

- the most efficient and effective options for meeting emission-reductions targets in a way which maximises benefits to New Zealand
- whether selected emission-reduction methods and sink options are economically and scientifically feasible and internationally credible
- opportunities for investment funding and the commercial benefits from developing and using smart technologies
- options for sustainable energy production and for more efficient energy use.

Scientific analyses show that, even if Kyoto Protocol commitments are met and further reductions in greenhouse gas emissions are made throughout this century, significant climate change impacts are still likely.

It is therefore prudent for New Zealand organisations (including central, regional and local government, industries and agriculturalists) to develop strategies for adapting to inevitable climate changes. This requires information on regional physical, environmental and economic changes likely to occur as a result of global greenhouse gas emissions. Such information should be based on a robust scientific understanding of the climate system and the sensitivities and vulnerabilities of natural, human and managed systems.

A side benefit of research to provide such information is that it will help organisations and individuals deal with the natural variability in the climate (such as El Niño-related droughts) by providing a basis for improved seasonal climate outlooks and impact assessments for use in operational decision-making.

## Chapter 2

# Climate Change Research Strategy

### **THE IMPORTANCE OF A CLIMATE CHANGE STRATEGY**

#### **Why is a Strategy for Climate Change Research Important and What Does it Hope to Accomplish?**

Long-term monitoring of ocean and land surface temperatures has suggested that over recent decades surface temperatures appear to be higher than at any time over the last 1000 years. Although it is not yet conclusively proved that human activities leading to a rise in the concentrations of greenhouse gases in the atmosphere are the principal cause of the observed climate changes, the results of recent climate modelling strongly suggest that there is a perceptible human influence on the process.

New Zealand's strong reliance on primary production, the natural environment and tourism for much of its wealth creation could make it economically vulnerable to temperature changes, increases in UV levels and shifts in rainfall patterns. Although primary producers have traditionally adapted to, and generally survived, extreme climatic events, it is expected that predicted future changes in climate will alter the scope, economics and methods by which food, fibre and biologically-based export products are developed in New Zealand. It may also alter our relative international competitiveness. A more significant additional short-term factor for the agricultural industries will be the need to reduce New Zealand's greenhouse gas emissions as part of New Zealand's Kyoto Protocol commitments (55% of our greenhouse gas emissions are from the agricultural sector).

More serious long-term economic, environmental and social effects may result from changes in the intensity and frequency of extreme climatic events, such as:

- droughts and floods
- new and potentially devastating pests, weeds and diseases
- changes in plant species and animal and fish populations
- rises in sea levels
- new human health problems.

The likely influences of predicted climate changes on these issues need to be known to enable adaptation and mitigation response options to be developed and risks managed.

The social and economic impacts of climate change are extremely complex and are generally difficult to predict. The research required to unravel these complexities and

provide robust forecasts is often interdisciplinary, usually long term and covers a wide range of topic areas. The New Zealand region's unique set of environmental conditions and greenhouse gas emissions make it important that much of this research is carried out in New Zealand. Consequently, New Zealand has developed a targeted programme of climate change research which contributes significantly to the knowledge base required to anticipate and respond to global climate change.

NSSCCC uses the strategy to provide advice, coordinate the development of a sound and balanced portfolio of climate change research, and monitor programmes. It also needs to ensure that climate change issues, problems and opportunities for the New Zealand region are prioritised and addressed. The strategy places high importance on ensuring that the results of the research are disseminated to policy makers, industry and other end-users in a timely and cost-effective manner.

#### **Nature of the Research Required by the NSSCCC Strategy**

The NSSCCC strategy is designed to achieve the Committee's vision for the year 2010 which is:

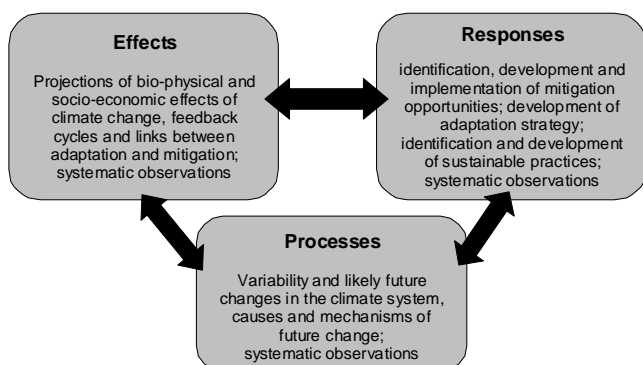
In order to protect New Zealand's well-being, economy and society, by 2010 New Zealanders:

- are well informed on human modification of climate
- have a greater understanding of the uncertainties associated with predicting the effects of climate variability and future climate change
- have identified environmental technologies which underpin successful businesses' contributions to the achievement of the Kyoto commitments
- can participate effectively in managing and adapting to the human modifications to climate at national and international levels.

The strategy recognises that the research required to achieve this vision falls into three broad research categories:

- Processes in the climate system
- Effects of climate changes
- Responses required to mitigate climate change, manage climate change effects and identify environmental technologies.

The basic information flow is intended to be from knowledge of **Processes** to accurate assessments of the **Effects** of change and to the determination of effective **Responses and Opportunities**.



In order to make the strategy work effectively all three areas must develop in parallel and be linked by systematic observations of climate parameters and long-term changes of other variables such as sea level, biosphere and cryosphere responses, human health, population and technology statistics, and inventory data. Within each of the three broad categories, the strategy recognises research which contributes to fundamental understanding, monitoring, validation and predictions, scenarios and options.

## PROCESSES, EFFECTS, AND RESPONSES AND OPPORTUNITIES

### Processes

The intended outcome from the strategy is a scientifically-based understanding of the variability and likely future changes in New Zealand's atmosphere and climate system.

Research into climate processes encompasses studies of the physical climate system including:

- atmospheric chemistry
- greenhouse gases
- stratospheric ozone concentrations and UV levels
- radiative properties of the atmosphere
- climate observations in the New Zealand region
- regional palaeoclimates and geological time
- regional and global climate modelling
- interactions of regional meteorology and the global climate and the oceans' role in climate generally.

There are strong collaborative links with international science programmes and bi-laterally with research groups in other countries.

### Effects

The intended outcome from the strategy is to reduce uncertainty in projections of biophysical and socio-economic effects in the New Zealand region arising from variability and change in the climate system.

Much research is aimed at gaining a better understanding of the actual and potential effects of climate change on land use, land forms and agricultural, forestry and fisheries ecosystems. Specifically predictive modelling on the potential impacts of climate change on the spread of organisms, particularly pests, weeds and diseases, in managed and natural ecosystems will give a better understanding of possible longer-term effects on New Zealand's environmental and economic biology. Research also addresses the effects of atmospheric changes such as elevated carbon dioxide (CO<sub>2</sub>) and UV-B on the biosphere.

Research is widespread, but still limited in nature, on the impacts on other areas, including:

- the health of the population, such as:
  - the effects of increased UV levels on skin cancers
  - conditions favouring the establishment and spread of vectors for human diseases
  - the influence of climate on food and water-borne infectious diseases
- the built environment
- carbon dynamics in forests and scrublands.

Linkages with international programmes and research networks are a feature of this area of research in New Zealand.

### Responses and Opportunities

The intended outcome from the strategy is:

- the establishment of effective adaptations to climate change
- identification of appropriate sustainable practices and technologies for New Zealand to manage human impacts on the climate system
- responses which mitigate greenhouse gas emissions
- identification of potential opportunities for business development in mitigation technology on national and international levels.

Responses to climate change can involve mitigating the primary drivers of climate change (net greenhouse gas emissions and ozone-depleting chemicals), and adapting to the changes by identifying and capturing opportunities and minimising risks.

Mitigation responses include compiling inventories of greenhouse gases and research into processes which mitigate these gases. This is particularly important in New Zealand because estimates of our total greenhouse gas

emissions are more uncertain than in other developed countries due to the high proportion of non-CO<sub>2</sub> gases from agriculture.

Mitigation research focuses on:

- the production and mitigation of methane and nitrous oxide in agriculture
- renewable energy technology development
- energy efficiency
- alternative fuels and building materials
- energy conservation and management
- forestry sinks.

Adaptation research is increasingly focused on identifying options for modifying behaviours and technologies in agriculture, such as improving seasonal climate predictions, human health, and transport use. Surveys to measure trends in personal sun exposure, mosquito control programmes and choice of transport are ongoing, while research into the development of improved sunscreens has started.

### **Integration**

The integration of these research categories - climate change processes, effects, and responses and opportunities - is a crucial part of NSSCCC's strategy to enable policy makers to make informed decisions about the management of New Zealand's resources and environment. This is

being achieved by combined assessments of the current knowledge about climate change vulnerability and adaptation within the region and an integrated modelling programme.

### **Systematic observations**

Systematic observations are necessary in the New Zealand region to detect variations and changes in the climate system and the systems it affects (atmosphere hydrosphere, ocean, human-biological and social, land and ecosystem). These observations are necessary to detect actual trends and variations, attribute them to particular causes, identify their economic, social and environmental impacts and validate theories and predictions.

Such observations are also part of New Zealand's obligations under UNFCCC (Article 4.1(g), Article 5) and the Kyoto Protocol (Article 10 (d)). Their importance was further emphasised by Decision 14 of COP4, which urged parties to undertake and support national and international programmes of systematic observations, based on the information developed by the Global Climate Observing System (GCOS) and its partner programmes. The extent of systematic observations is *inter alia* reported in National Communications which Annex I Parties to the UNFCCC are obliged to prepare at regular intervals decided by the Parties. The next, 3<sup>rd</sup> National Communication is due in November 2001, updating the 2<sup>nd</sup> National Communication submitted in 1997.

## Chapter 3

# Climate Science – The Challenge for the 21<sup>st</sup> Century

### PRESENT UNDERSTANDING OF CLIMATE CHANGE SCIENCE

#### What is Known?

The IPCC has this year (2001) finalised its Third Assessment Report (TAR) on the science of climate change. Three Working Groups cover the scientific basis, impacts, adaptation and vulnerability to climate change, and mitigation. Summaries for Policymakers of the three Working Group reports were adopted by government representatives between January and March 2001 and are now publicly available (<http://www.ipcc.ch>). The full underlying reports are due to be published by the end of June 2001.

The IPCC TAR provides a comprehensive summary of the current state of knowledge on climate change science. A considerable number of New Zealand scientists contributed to the reports as convening lead authors, and lead and contributing authors and reviewers. Detailed work on New Zealand specific climate issues, particularly in the area of impacts and mitigation options, has also been published (see Research Highlights for 2000). The collective body of scientific studies provides an increasingly comprehensive picture of the climate system, its future changes and impacts, and the options to reduce greenhouse gas emissions.

#### *The climate of the globe is changing*

Global average surface temperature has increased by about 0.6°C over the past 100 years. The 1990s were probably the warmest decade in the past 1000 years in the Northern Hemisphere (see Figure 1). In addition to these temperature changes:

- annual precipitation (rain plus snow) has increased over mid and high-latitude land areas of the Northern Hemisphere, with an increase in heavy precipitation events
- some tropical and sub-tropical land areas have become drier
- global sea level rose by about 15cm during the 20<sup>th</sup> century.

The pattern of warming that has been observed is unlikely to be solely natural in origin. Greenhouse gases generated by human activities appear to have been a substantial causal factor, especially over the last 30 years. Evidence for this conclusion has strengthened during the past five years, since the 1995 scientific assessment by IPCC. There is new and stronger evidence that most of the warming

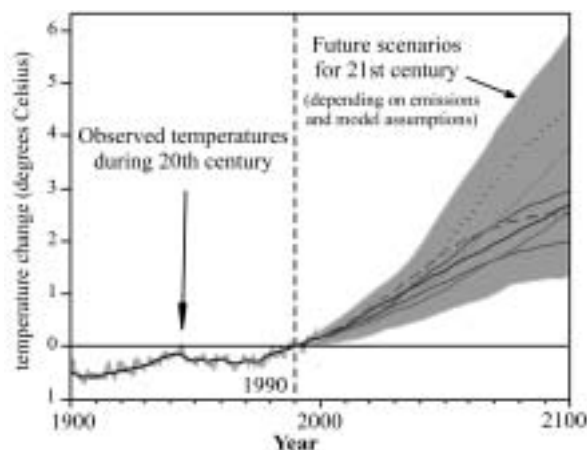
observed over the past 50 years is due to human emissions of greenhouse gases.

#### *Atmospheric greenhouse gas concentrations will increase*

In the absence of global climate policies, atmospheric greenhouse gas concentrations will continue to increase substantially. This is expected to cause the following changes by 2100 (see Figure 1):

- an increase in global mean surface temperature of between 1.4 and 5.8°C
- further changes in precipitation
- an increase in sea level of between 10 and 90 cm
- an increase in the frequency of extreme events, such as floods, droughts and heat waves, while the number of extremely cold days is expected to decrease.

Even if there is strong international policy action to constrain greenhouse gas emissions, concentrations will still rise and significant changes in climate and sea level will occur over the coming century. Adaptation to the impacts of these changes will be necessary.



**Figure 1.** Observed and predicted global average temperatures during the 20<sup>th</sup> and 21<sup>st</sup> centuries. Future temperature rises depend on greenhouse gas emissions. By 2100, the spread in projections due to different emission scenarios is similar to the uncertainty of models for a single mid-range scenario. (Source: Adapted from IPCC TAR)

#### *Global impacts will differ*

Global impacts of climate change are likely to differ between countries. The worst problems will probably be occurring in:

- tropical and sub-tropical countries subject to increasing aridity
- low-lying regions, such as the Ganges and Nile deltas
- low-lying island states including some in the Pacific north of New Zealand.

Increasing greenhouse gas concentrations may also lead to atmospheric conditions which slow the recovery from CFC-induced ozone depletion, including the recovery of the Antarctic ozone hole. This could result in further damage to some people, animals and plants from greater than normal levels of damaging UV radiation.

### *New climate change scenarios*

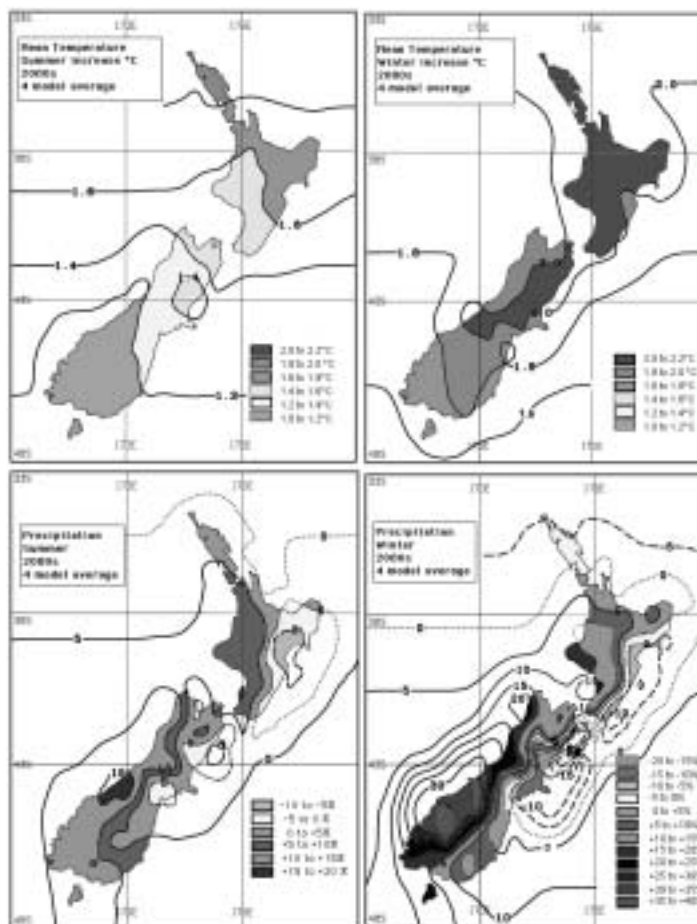
New climate change scenarios have recently been developed for New Zealand by the National Institute of Water and Atmospheric Research Limited (NIWA). These are based on predictions from global climate change models which assume no major climate change policy interventions. Confidence in predictions of regional climate changes is lower than confidence in global predictions, so these scenarios should be used cautiously as

a guide to conceivable impacts, rather than as firm predictions.

The NIWA scenarios, shown in Figure 2 for seasonal changes in temperature and rainfall, are based on an assumed 1% per annum increase in equivalent CO<sub>2</sub> concentration, together with specified emissions of aerosols (small particles which offset some of the warming effect of greenhouse gases).

The scenarios suggest temperatures could rise by 1.6 - 2.0°C in winter and 1.2 - 1.8°C in summer over the next century. Annual rainfall could increase by up to about 12% in the west of the South Island and over the Southern Alps, increase a little less over the west of the North Island, and decrease slightly in the east of both islands.

High intensity rainfall may become more frequent, so that a flood experienced now on average once every 50 years might be experienced once every 25 years. The combination of warmer temperatures and similar or decreasing rainfall in the east may lead to more droughts in eastern areas, and a possible (but not certain) change to more El Niño-like average conditions over the Pacific.



**Figure 2.** Scenarios of future changes in temperature and rainfall for the 2070 to 2099 period, compared to the 1970 to 1999 period. Displayed are the average changes projected by four different global climate models under a 1% per year compound increase of greenhouse gas concentrations. (Source: NIWA; see also <http://katipo.niwa.cri.nz/ClimateFuture/Scenarios.htm>)

### *Impacts on agriculture*

The net direct effect on agriculture in New Zealand as a whole will probably be small (either positive or negative). However, regional changes could lead to activities which are currently being undertaken in one part of the country shifting to others. This assumes there will be adequate water available for irrigation where needed.

One problem may be a shift south of subtropical grasses, requiring more frequent re-sowing to maintain pasture quality. Some scenarios suggest climates will become even more amenable to agriculture in some temperate northern-hemisphere regions of the globe which could affect prices for New Zealand's agricultural commodities.

### *Water resources and floods*

A potentially serious negative effect relates to water resources and floods. In some eastern areas of New Zealand, a combination of possibly drier conditions and more irrigation demands due to shifts in agricultural activities could lead to more competition for available water resources. An increased national frequency of heavy rain and flooding could put more people and property at risk, raise costs for flood protection, and cause more erosion.

### *Negative effects*

Other negative effects are expected. Risks of coastal erosion and inundation will increase due to sea level rise. The climate is likely to become more favourable for the establishment and spread of insects which carry sub-tropical diseases, such as Ross River fever and dengue.

Some natural ecosystems and species may be damaged or lost, if they are isolated by terrain or surrounding farmland which limit their ability to move. Changes in oceanic currents and temperatures could affect the populations of some fish species. Not enough is yet known to predict whether the overall effect on fisheries would be positive or negative.

### *Some benefits*

Some parts of New Zealand could benefit from climate change. Increasing CO<sub>2</sub> levels may improve the growth of some agricultural crops and trees. It may also reduce water demand, partially offsetting effects of reduced soil moisture in drier areas. Some areas may become more suitable for high-value horticultural crops.

A higher snowline may reduce the seasonality of South Island river flows, providing more hydroelectricity generation during winter when demand is highest. Warmer temperatures may reduce incidence of some cold-related diseases.

### *Emission-reduction options*

A wide range of emission-reduction options is available. Analyses of technical and economic potentials for greenhouse gas emission reduction indicate opportunities ranging from the removal of structural inefficiencies to the development of new technology. The IPCC TAR found that the development in technological emission-reduction options has been faster than expected. Technological options for emission reduction include improved efficiency of end-use devices and energy conversion technologies, a shift to low-carbon and renewable biomass fuels, zero-emissions technologies, improved energy management, reduction of industrial by-product and process gas emissions, and carbon removal and storage.

Annex I Parties with developed strategies for meeting commitments under the Kyoto Protocol have planned to use a range of options tailored to local circumstances. Economic modelling studies indicate that the cost of meeting Kyoto targets for Annex I countries varies between 0.2 and 2% GDP without emissions trading, and between 0.1 and 1.1% GDP with full emissions trading. Other Kyoto mechanisms (such as CDM and JI) would reduce these costs further.

Depending on the business-as-usual emissions scenario, reductions in global greenhouse gas emissions to below 2000 levels by 2010 to 2020 could be achieved. Half of the required reductions could be realised with direct benefits exceeding direct costs (e.g. through energy efficiency measures), and the other half at net direct costs of up to US\$100 per tonne carbon equivalent. Table 1 gives a summary of the estimated global emission reduction potential in key sectors by 2010 and 2020 and compares it with historical emission data.

Sufficient technological options already exist to stabilise CO<sub>2</sub> concentrations in the atmosphere at 450 ppm within the next 100 years, but the cost of achieving this is estimated to be substantially higher than at 550 ppm because of the required premature retirement of capital stock to achieve the 450 ppm target. Achieving either stabilisation target would require major changes in policy measures aimed at implementing emission reductions and changing patterns of energy use.

New Zealand has more options to consider than other Annex I countries in areas such as the reduction of agricultural emissions, the expansion of forest estates and the potential for biofuels. Particularly since the contribution of ruminant methane emissions to the total New Zealand emissions budget is very large, the development of sustainable and acceptable options to reduce ruminant methane would offer the opportunity for substantially reducing overall greenhouse gas emission levels in the long term.

**Table 1. Estimates of potential global greenhouse gas emission reductions in 2010 and 2020. Source: IPCC TAR, Working Group 3, SPM.**

Sector	Historic emissions in 1990 [MtC <sub>eq</sub> /yr]	Historic C <sub>eq</sub> Annual growth rate in 1990-1995 [%]	Potential emission reductions in 2010 [MtC <sub>eq</sub> /yr]	Potential emission reductions in 2020 [MtC <sub>eq</sub> /yr]	Net direct costs per tonne of carbon avoided
Buildings <sup>a</sup> CO <sub>2</sub> only	1,650	1.0	700-750	1,000-1,100	Most reductions are available at negative net direct costs.
Transport CO <sub>2</sub> only	1,080	2.4	100-300	300-700	Most studies indicate net direct costs less than \$25/tC but two suggest net direct costs will exceed \$50/tC.
Industry CO <sub>2</sub> only - energy efficiency - material efficiency	2,300	0.4	300-500 ~200	700-900 ~600	More than half available at net negative direct costs. Costs are uncertain.
Industry Non-CO <sub>2</sub> gases	170		~100	~100	N <sub>2</sub> O emissions reduction costs are \$0-\$10/tC <sub>eq</sub> .
Agriculture <sup>b</sup> CO <sub>2</sub> only Non-CO <sub>2</sub> gases	210 1,250-2,800	n.a.	150-300	350-750	Most reductions will cost between \$0-100/tC <sub>eq</sub> . With limited opportunities for negative net direct costs options.
Waste <sup>b</sup> CH <sub>4</sub> only	240	1.0	~200	~200	About 75% of the savings as methane recovery from landfills at net negative direct cost; 25% at a cost of \$20/tC <sub>eq</sub> .
Montreal Protocol replacement applications Non-CO <sub>2</sub> gases	0	n.a.	~100	n.a.	About half of reductions due to difference in study baseline and SRES baseline values. Remaining half of the reductions available at net direct costs below \$200/tC <sub>eq</sub> .
Energy supply and conversion <sup>c</sup> CO <sub>2</sub> only	(1,620)	1.5	50-150	350-700	Limited net negative direct cost options exist; many options are available for less than \$100/tC <sub>eq</sub> .
<b>Total</b>	<b>6,900-8,400<sup>d</sup></b>		<b>1,900-2,600<sup>e</sup></b>	<b>3,600-5,050<sup>e</sup></b>	

<sup>a</sup> Buildings include appliances, buildings, and the building shell.

<sup>b</sup> The range for agriculture is mainly caused by large uncertainties about CH<sub>4</sub>, N<sub>2</sub>O and soil related emissions of CO<sub>2</sub>. Waste is dominated by methane landfill and the other sectors could be estimated with more precision as they are dominated by fossil CO<sub>2</sub>.

<sup>c</sup> Included in sector values above. Reductions include electricity generation options only (fuel switching to gas/nuclear, CO<sub>2</sub> capture and storage, improved power station efficiencies, and renewables).

<sup>d</sup> Total includes all sectors reviewed in Chapter 3 for all six gases. It excludes non-energy related sources of CO<sub>2</sub> (cement production, 160MtC; gas flaring, 60MtC; and land use change, 600-1400MtC) and energy used for conversion of fuels in the end-use sector totals (630MtC). If petroleum refining and coke oven gas were added, global 1990 CO<sub>2</sub> emissions of 7100MtC would increase by 12%. Note that forestry emissions and their carbon sink mitigation options are not included.

<sup>e</sup> The baseline SRES scenarios (for six gases included in the Kyoto Protocol) project a range of emissions of 11,500-14,000MtC<sub>eq</sub> for 2010 and of 12,000-16,000MtC<sub>eq</sub> for 2020. The emissions reduction estimates are most compatible with baseline emissions trends in the SRES-B2 scenario. The potential reductions take into account regular turn-over of capital stock. They are not limited to cost-effective options, but exclude options with costs above US\$100/tC<sub>eq</sub> (except for Montreal Protocol gases) or options that will not be adopted through the use of generally accepted policies.

## What are the Knowledge Gaps?

### *Emissions*

Although there has been much progress over the past decade, more knowledge is still needed on New Zealand ruminant methane emissions and agricultural nitrous oxide emissions to enable practical low-cost mitigation. More detailed scientific, technical and socio-economic analyses are also needed to guide policy on transport use and associated CO<sub>2</sub> emissions.

A requirement for more accurate and more comprehensive measurement of all national greenhouse gas emissions and removals is likely to emerge from Protocol negotiations and become an increasingly valuable aspect of our environmental management. In particular, a substantially improved basis for full carbon accounting should be available by the beginning of the second commitment period (2013) and this will require a significant extension of current resources and skills.

### *Scenarios and effects*

Regional climate change scenarios are still quite uncertain, especially as regards likely changes in:

- extremes (e.g. floods, droughts, windstorms and hail) which can have substantial impacts on land
- regional ocean temperatures, circulation and upwelling which influence fisheries and marine ecosystems.

These scenarios require better regional understanding of atmospheric and oceanic processes, and further improvements to global and regional climate models. More knowledge is also needed about influences of greenhouse-related cooling in the stratosphere on ozone depletion and regional UV levels.

The sensitivities of many plant and animal species and natural ecosystems in this region to climate changes, and the potential threats to biodiversity, are still unknown. Knowledge is required both for assessing potential effects and for developing conservation strategies. This is important for marine and coastal environments as well as for terrestrial ecosystems.

More knowledge is required to improve estimates of the regional and national effects of climate change on agriculture and horticulture. (The Climate Variations and Environmental Effects (CLIMFACTS) programme has made a good start on aspects of this and is expected to publish its research results soon.)

Knowledge is still required for assessing the effects of climate change on drought frequency and irrigation water availability as well as direct information about impacts on some particular agricultural species and practices.

There is insufficient information to enable confident predictions of changes in fisheries productivity due to climate

change. This requires better knowledge of physical and biological processes in the ocean, and improved information on climate sensitivities of fish species.

Important health issues include the effect of climate changes on the potential for the introduction of significant disease vectors, and the health of vulnerable population groups.

### *Responses - Mitigation*

In addition to the mitigation-related research covered under “emissions”, better knowledge is required about public attitudes to mitigation options. Methodology for comprehensive New Zealand economic analyses of impacts and policy options, taking account of human behaviour and using up-to-date scenarios, is still inadequate.

A sustainable long-term mitigation strategy will require more efficient use of energy and renewables. More information is needed on appropriate renewable energy and biofuel options and technology for New Zealand, and on improving energy efficiency (including housing design).

### *Responses – Adaptation*

Better knowledge is needed on:

- the vulnerability of particular population groups (including indigenous people)
- how people and organisations have adapted to past climate variability and changes
- public attitudes to adaptation
- how to communicate changes in risk associated with climate change
- how to reach decisions in the face of uncertainty.

Studies are desirable (in close collaboration with stakeholders) of adaptation options and their acceptability, costs, co-benefits, side effects and limits.

### *Monitoring*

COP is likely to require more comprehensive reporting on:

- national monitoring of the climate system and atmospheric constituents (including greenhouse gases)
- long-term monitoring of vulnerable animals, plants, soils and ecosystems.

Such monitoring is also highly desirable for the continuing development of national strategies and adaptation options. Monitoring of the physical climate system and atmospheric constituents is in reasonable shape nationally, but the long-term New Zealand responsibility and support for sea-level monitoring is still being debated and needs to be resolved. More work is desirable on monitoring vulnerable biological systems.

## Barriers to Research Uptake

Improved mechanisms are now in place for ensuring Public Good Science and Technology (PGS&T) supports the strategic climate change research needed to underpin policy development and to guide adaptation strategies. This is done through FRST's development of Strategic Portfolio Outlines (SPOs), and through its portfolio negotiation process which includes stakeholder reference groups as well as research providers.

The NSSCCC has played an important role in advising FRST on strategic priorities. In addition, government departments are showing increasing interest in contracting scientific work needed for short-term (one to two years) policy development. However, there are still some barriers which reduce efficient uptake of the extensive knowledge and experience of the climate change research community.

### *Making best use of New Zealand's scientific expertise*

The Science "reforms" of the early 1990s removed government-funded scientists from integral participation in the policy development process. Policymakers in government departments make judgements about when to seek specific scientific advice, but there are no standard procedures that would ensure that appropriate scientific experts contribute to the development of policy which has a strong connection to climate change research. MfE has recently appointed science liaison staff. Nevertheless, the formal chain of communication between climate scientists and government policy development has become longer in New Zealand at a time when most Annex I countries have deliberately improved such communication.

New Zealand has a very limited pool of expertise on climate change issues and gets no advantage from keeping the expertise at a distance. Our lead climate scientists have been studying the issues for 20 years or longer and have regular contacts with overseas scientists who play key advisory roles in their countries. Consequently, they are well informed on the policy questions and possible responses. More advantage should be taken of this government-owned expertise by developing mechanisms for better integration of such advice at all stages in the policy process. Close examination of the approach taken in Australia could provide some insights into ways of improving this integration.

### *Communication of policy-relevant results*

Prompt exchange of information between the science community and climate change stakeholders is vital. FRST has been addressing this problem recently by ensuring science providers specify appropriate communication of their results to stakeholders as part of their research contracts.

Nevertheless, there is still room for improvements on the part of science providers, policy development ministries and third parties (such as the Royal Society of New Zealand) to facilitate the communication of policy-relevant scientific results to stakeholders and stakeholder information to scientists.

## Education

Much of the scientific and technical advice is provided by people with 20 or so years' experience. This raises the question of continuity of this advice over the pre and (particularly) post-Kyoto period, when more stringent reduction of emissions will be needed and when these scientists will have retired.

Few young New Zealanders see science as a 'cool' career option, and even fewer are doing science graduate degrees. Internationally, New Zealand salaries and career prospects are not very competitive at a time when there is a strong demand for climate change scientists.

Steps need to be taken with some urgency to:

- encourage young people to seriously consider science as a career option
- educate young people (and others) about the climate change issue so they can become involved in informed debate about adaptation and mitigation options
- ensure that expert scientific advice continues to be available in New Zealand over the next 10-20 years (and beyond) to ensure that soundly-based comprehensive policy measures are developed and implemented to protect and enhance New Zealand's international position.

## What Needs to be Done?

### *Comprehensive long-term strategy*

We need to develop a comprehensive and long-term strategy for reducing greenhouse gas emissions. This is now urgent. Although New Zealand has many options for reducing greenhouse gas emissions, the technical, economic, political, and social challenges should not be underestimated. Analyses so far have been piecemeal and have tended to focus on a small number of specific options, such as expansion of forest sinks. This has acted to create narrowly-focussed debate and has not assisted the development of a cross-sectoral view of greenhouse gas management.

A New Zealand greenhouse strategy is needed that will be robust in the face of changing international policy frameworks (e.g. discounting of carbon sinks) and make best use of all available options. Such a strategy needs to be underpinned by scientific, technical and socio-economic analysis which takes into account the different time scales for implementation and effectiveness of different options. Development of such a long-term strategy will require public and private sector participation, but should be actively promoted at Ministerial level.

### *Maintain existing programmes*

We need to maintain existing programmes addressing knowledge needs and invest to fill gaps. Work has commenced, or expressions of interest have been sought, to

address some of the knowledge gaps identified in Chapters 2, 3 and 5. This is through FRST-funded strategic research programmes and government department research contracts.

Funding should be maintained in those programmes already effectively addressing knowledge gaps identified in Chapters 2, 3 and 5. Research in some of the under-subscribed areas, such as effects, human dimensions, economic modelling, adaptation options and energy efficiency/renewable energy should be encouraged by FRST and government departments.

### *Align research and policy*

We need to ensure the timing of greenhouse gas research is planned to coincide with the development of appropriate policy milestones. FRST and government departments such as MfE and the Ministry of Agriculture and Forestry (MAF) need to ensure greenhouse gas emission and mitigation research is being done with the appropriate time deadlines to feed into Kyoto negotiations and domestic policy development to meet Kyoto targets and post-Kyoto requirements.

### *Long-term sea-level monitoring*

We need to resolve support for long-term sea-level monitoring. LINZ, MfE and FRST need to work together to ensure the sea-level monitoring issue is appropriately resolved and that adequate programmes are in place for long-term monitoring of biological systems.

### *Research on adaptation and climate variability*

We need to enhance support for research on adapting to climate change and maintain support for research on climate variability and its impacts. Social science research can make an important contribution here by addressing:

- the communication of risk
- decision-making in the face of some uncertainty
- public attitudes to adaptation
- the effectiveness of various coping strategies.

Improved seasonal climate outlooks and climate risk analyses, and use of these by stakeholders to improve their resilience to natural climate variability will also contribute to local and national adaptation to climate change.

### *Formal policy mechanism*

We need to set up a clear and formal mechanism to ensure the best New Zealand scientific expertise is applied to climate change policy questions. This includes appropriate scientists having input into policy and Cabinet papers as they are being developed. This could build on the relationship that NSSCCC currently has with the Climate Change Steering Group (CCSG).

### *Communication*

Science providers, the Royal Society's New Zealand Climate and International Geosphere Biosphere (IGBP) Committees and NSSCCC need to facilitate communication of appropriate research results to central and regional government policymakers and other stakeholders including industry, farmers and the public.

### *Education*

We need to work with:

- the education sector to encourage interest in climate change science and science in general
- industry and philanthropic groups which might fund students and research on climate change.

This could be taken jointly by MfE and MoRST and might include some targeted PhD fellowships. This is important if the age structure of scientists in the climate change area is to change and there is to be any sort of continuity in science advice. Currently there exist a number of general postgraduate scholarships available to students across all disciplines.

### *International links*

International collaboration on science projects and assessment activities brings substantial research capabilities (people and equipment) to our region. This applies to research on the climate system, projections for future climate change, studies of impacts and options for reducing greenhouse gases.

Collaboration in assessment and inventories programmes places well-informed New Zealand scientists in the international policy loop. MoRST and FRST can facilitate such collaboration through the International Science and Technology Linkages (ISAT) fund and by supporting scientists to represent New Zealand at appropriate meetings of organisations, such as:

- Intergovernmental Panel on Climate Change (IPCC)
- International Geosphere Biosphere Programme (IGBP)
- World Climate Research Programme (WCRP), including the Climate Variability and Predictability Project (CLIVAR)
- Global Climate Observing System (GCOS)
- Global Ocean Observing System (GOOS)
- Asia Pacific Network (APN).

Participation in activities like the IPCC National Greenhouse Inventories activity is important, as well as involvement in more basic climate and impacts studies. During 2000, such activities were funded by government to the extent of \$86,000, but we believe that more needs to be done to ensure a continued representation of New Zealand scientists in the growing field of international collaboration in climate change research.

## Chapter 4

### Research Highlights for 2000

#### INTRODUCTION

In recent years there have been significant, internationally-recognised advances in New Zealand climate science. This is leading to benefits in terms of a better understanding of potential climate change in our region, as well as substantial improvement in our ability to characterise year-to-year climate variability.

The NSSCCC strategy includes maximising the value to New Zealand of overseas research on global climate change. Most climate research is carried out in the Northern Hemisphere where different conditions often apply. Our research effort must include testing the assumptions and models made in international research against New Zealand conditions and interpreting results with New Zealand scenarios in mind. A strong observational component in New Zealand climate change research is required because our geographic isolation means we are the only country observing a large area of the world. Detailed interpretive and modelling work must be carried out to study the nature of changes in our region in a global context and to understand specific regional factors which may affect us more than other countries.

This chapter provides a snapshot of some of the climate change research highlights for 2000, arising out of research conducted over the last few years. It is not a comprehensive account of all climate change research highlights for 2000, and does not give a full picture of the breadth of climate change research that is occurring. Examples have been chosen to illustrate their contribution within the NSSCCC strategy framework for research on Processes, Effects, and Responses.

Research on climate change is supported by PGSF, the Marsden Fund, Health Research Council, universities, government departments and the private sector.

#### PROCESSES

Research into climate processes covers studies of the physical climate system, including:

- atmospheric chemistry
- radiative properties of the atmosphere
- climate observations in the New Zealand region
- regional and global climate modelling
- interactions of regional meteorology and the global climate
- the oceans' role in climate generally.

#### Changes in Atmospheric Composition

New Zealand continues to play a key role in determining the rates of increase of major greenhouse gases in the atmosphere and the causes of these increases.

New world-leading techniques used to determine the relative roles of the oceans and the biosphere in removing CO<sub>2</sub> from the atmosphere have been developed (see following section). Collaboration with leading overseas groups has achieved ground breaking measurements of past changes in methane (CH<sub>4</sub>) in the Southern Hemisphere, and synthesis of our own and overseas data has led to improved estimates of the different sources of methane and carbon monoxide.

A growing emphasis has been placed on the development of tools to assess the atmospheric and climatic implications of different policy options for meeting commitments under the Kyoto Protocol. Another growth area is the development of better determinations of New Zealand's own greenhouse gas emissions.

A new basis for determining the role of human activities on atmospheric CH<sub>4</sub> has been achieved through the first measurements of radiocarbon in CH<sub>4</sub> recovered from air in Antarctic firn (packed snow). This now allows the current fraction of methane related to fossil fuel activities to be compared with that produced 50 years ago.

Modelling the atmospheric transport of both CH<sub>4</sub> and carbon monoxide (CO) has improved estimates for tropical emissions of CH<sub>4</sub> and Northern Hemisphere emissions of CO — indicating that they are likely to be larger than previously estimated. Careful analysis of the different seasonal cycles of CH<sub>4</sub> and its carbon isotope ratio has provided evidence that reactions with chlorine (Cl) may play a more significant role in CH<sub>4</sub> removal than previously recognised.

#### Improved Measurement Techniques for Trace Gas Emissions

New and more sensitive techniques are being developed to study the exchange of greenhouse gases between the atmosphere, ocean and biosphere. These techniques help to improve understanding of the key sources and sinks of greenhouse gases, and reduce uncertainties about the contributions from various natural and anthropogenic sources.

Progress towards improved estimates of New Zealand greenhouse gas emissions has been made through:

- More extensive characterisations of CH<sub>4</sub> variations in typical agricultural landscapes, and the development of new model techniques to relate such variations to the surface fluxes that cause them.
- Assessment of a new gas flux measurement method in field conditions.
- Construction of tools to assess different scenarios for greenhouse gas reduction consistent with the Kyoto Protocol — results have provided new insights into the validity and limitations of the accounting framework embodied in the Protocol.
- Development of two new experimental approaches that enable the removal of CO<sub>2</sub> from the atmosphere to be separated into oceanic and biospheric components.

### **The Oceans' Role in Climate: Ocean-Atmosphere Gas Exchange**

New Zealand scientists continue to make a strong contribution to international understanding of the oceans' role in climate change.

A 1999 international expedition (SOIREE) led by New Zealand scientists on the NIWA research vessel *Tangaroa* examined the role of algae growing in the Southern Oceans in the removal of CO<sub>2</sub> from the atmosphere. Results were published in 2000 in the prestigious scientific journal *Nature* and generated considerable international interest. The research showed that releasing small amounts of dissolved iron into the "iron-limited" Southern Ocean leads to a rapid growth ("bloom") of algae, taking up CO<sub>2</sub> from the surface layers of the ocean. Satellite ocean-colour images six weeks after fertilisation showed this bloom lasted much longer than was expected.

However during the 13 days they were on site the scientists were unable to measure any appreciable removal of carbon from the surface to deeper waters, as would be required if iron fertilisation were to be effective at reducing the accumulation of CO<sub>2</sub> in the atmosphere. The participants concluded that large-scale iron fertilisation would cause substantial changes to the naturally occurring ecosystems of this pristine environment.

SOIREE also showed that iron fertilisation enhances dimethyl sulphide emissions from marine ecosystems in the Southern Ocean. Dimethyl sulphide leads to small aerosol particles which form cloud condensation nuclei and may thereby affect clouds and the radiation balance over the Southern Oceans.

This fundamental research by New Zealand scientists is improving understanding of the influences of Southern Ocean processes on global greenhouse gas concentrations, clouds and climate.

### **Land and its Interaction with the Atmosphere**

Understanding the capacity of terrestrial ecosystems to remove CO<sub>2</sub> from the atmosphere and mediate the exchanges of the trace gases CH<sub>4</sub> and nitrous oxide (N<sub>2</sub>O) between the land and atmosphere will allow New Zealand to develop effective monitoring and mitigation strategies for meeting its commitments to the Kyoto Protocol.

Results from measuring and modelling exchanges of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O between the land and the atmosphere at a range of spatial and temporal scales are assisting with national inventory reporting, and the development of tools for monitoring carbon changes with land use change, and mitigation strategies.

#### *Carbon dioxide*

- National-scale estimates of New Zealand's net carbon balance indicate that our land systems are a net source of CO<sub>2</sub>. Although planted forests and scrublands are accumulating carbon, some losses from mineral soils may occur when pasture is converted to forest. Harvest practice and rotation length may result in further losses. Also, carbon losses to the coast from soil erosion are potentially larger than current CO<sub>2</sub> emissions from fossil fuel use. The proportion of this soil carbon that is (a) anthropogenic and (b) reaches the atmosphere, has yet to be determined.
- It has been shown that direct measurements of net CO<sub>2</sub> exchange at the landscape scale can be used to verify carbon sequestration by land-based ecosystems. Independent verification is vital for future international audits of New Zealand's CO<sub>2</sub>-emissions-reduction strategies.
- Carbon dioxide research underpins the development of national Carbon Monitoring Systems for soil, and forest and scrub. These will soon to be ready for implementation, and used for international reporting.
- Accumulation of soil carbon in response to long-term exposure of ecosystems to elevated atmospheric CO<sub>2</sub> could at least partly offset losses from global warming, but only recently has research at a natural soda spring in Northland confirmed this assumption for the first time.

#### *Methane*

- Results from paddock-scale CH<sub>4</sub> flux measurements suggest that scaling up of measurements taken from individual sheep may be relatively insensitive to variations in environmental factors and soil fertility. This novel approach when further developed will provide a tool to:
  - verify farm-scale emissions based on individual animal estimates

- reduce uncertainties in our national CH<sub>4</sub> budget through more robust model development
- assess the efficacy of mitigation strategies.
- Additional measurements of CH<sub>4</sub> emissions from individual animals were carried out, adding to the database of the dependence of CH<sub>4</sub> emissions on animal diet, seasonality, and individual conditions. These data form vital input for the revision of CH<sub>4</sub> emission models used in inventory calculations.
- Based on a simple empirical model, a first estimate was made of the contribution of our indigenous forest soils to the national CH<sub>4</sub> budget. The model showed that some forest soils are a relevant sink for atmospheric CH<sub>4</sub>, equivalent to about 4.5% of CH<sub>4</sub> emissions from sheep.

#### Nitrous oxide

- Research on N<sub>2</sub>O is helping to reduce the large uncertainty in national N<sub>2</sub>O emissions. These uncertainties are mainly due to the paucity of information for soil emissions resulting from dung and urine deposition in (mainly) dairy pastures. This uncertainty is being reduced through a collaborative network of New Zealand researchers (N<sub>2</sub>Onet). Their common goal is to understand, quantify and mitigate agricultural N<sub>2</sub>O emissions.
- The high spatial and temporal variability of N<sub>2</sub>O emissions from soil is a major source of uncertainty. Some progress has recently been made to address this problem by estimating paddock-averaged flux density of N<sub>2</sub>O from the simultaneous monitoring of CO<sub>2</sub> and N<sub>2</sub>O using open-path Fourier-transform infrared spectroscopy.
- Current national estimates (based solely on agricultural soils) may underestimate our emissions, as they exclude contributions from other land uses that may be significant.

#### Ozone and Ultraviolet Radiation

UV radiation levels in New Zealand are high compared to corresponding latitudes in the Northern Hemisphere. Understanding the year-to-year and seasonal variability of increasing UV radiation will allow New Zealand to better guard itself against its effects.

The Antarctic ozone “hole” (a rapid loss of more than half the ozone over Antarctica each Spring) remains a striking example of how the atmosphere can be influenced by human activity. In the spring of 2000 the most striking ozone hole yet recorded was observed. Recent model calculations suggest that changes in climate may cause the Antarctic ozone hole to worsen over the next 10-20 years, even though the man-made ozone-depleting pollutants that cause it are decreasing. This is because increasing concentrations of greenhouse gases in the upper

atmosphere cause cooling, which facilitates reactions leading to ozone depletion. (This is an important contrast with the lower atmosphere, where increasing greenhouse gas concentrations cause warming).

The research has also involved the development and use of mathematical models, components of which were obtained from other leading international researchers, to systematically assess the role of the Antarctic in ozone depletion over southern mid-latitudes (where New Zealand lies).

The findings thus far suggest that Antarctic ozone loss has a key role in the long-term decline of summertime ozone over New Zealand. Analysis of seasonal ozone trends over New Zealand shows that the relatively constant annually-averaged ozone levels over recent years are due to ozone decreases in summer being offset by increases in other seasons.

Measurements have confirmed a 10-15% decrease in summertime ozone between the 1970s and the summer of 1998/99, and that peak summer UV levels, when exposure is the greatest, were approximately 12% higher in 1998/99 than in 1990 and perhaps 15-20% more than in the late 1970s.

A paper showing that long-term decreases in summertime ozone over Southern New Zealand have led to a 12% increase in the peak sunburning UV radiation through the 1990s, and a larger increase in DNA and plant-damaging UV radiation, was published in the prestigious international journal *Science*. UV irradiances were not quite as high in the summer of 1999/2000, perhaps because the ozone hole that year was less severe.

An understanding of the various factors affecting ozone depletion has allowed development of statistical models that can predict future ozone levels based on predictions of the underlying geophysical forcings. By using radiative transfer models, these ozone predictions are used to produce UV predictions which are made available to the public.

Evidence has been found that significant mid-atmospheric pollution over New Zealand (such as carbon monoxide and ethane) is due to tropical biomass burning. These elevated levels are detectable only because of the extremely low levels of pollution normally experienced over New Zealand.

Measurements also show that stratospheric aerosol is at its lowest level in 20 years. This is expected to accelerate ozone depletion at high altitudes, but to reduce depletion at lower altitudes in the stratosphere. Measurements of reactive oxides of nitrogen and of chlorine in the stratosphere above Lauder are consistent with these expectations. These measurements have also found unexpected increases in water vapour in the upper stratosphere, which are expected to lead to increases in the hydroxyl radical (OH) which catalytically destroys ozone in a manner similar to chlorine and nitrogen oxides.

## Climate Variability

New Zealand scientists continue to play a key role in monitoring climate and identifying climate variability in New Zealand, the South-West Pacific and Antarctica, determining the reasons for these fluctuations and analysing the implications for the future.

The warmest year recorded globally since instrumental records began about 150 years ago was 1998. It was also the warmest year in New Zealand since instrumental records began, with 1999 the second warmest. Northern Hemisphere palaeoclimate studies suggest the 1990s were the warmest decade in the millennium.

Climate monitoring defined the extent and severity of the 1997/98 El Niño drought in many eastern parts of New Zealand and the 1998/99 La Niña drought in Otago, Southland. One economic analysis has suggested these droughts may have had a similar effect on New Zealand's economy as the Asian economic crisis.

Substantial progress has been made in increasing knowledge of regional climate variations, predicting seasonal climate, assessing regional climate change and providing climate data to users.

NIWA's National Climate Centre, which was formed in 1999, makes seasonal climate information and routine updates of current climate conditions available freely through the Web. Farmers and others involved in climate-sensitive activities can use this information to assist their decision-making. In addition, NIWA provides specialist outlook and update products to individual clients, and regular climate briefings to MAF, which uses them to prepare outlooks of agricultural production for Treasury.

Major contributions during 1998/2000 include:

- Demonstration that the influence of El Niño on New Zealand climate has been modified by longer-term climate shifts caused by large-scale changes over the Pacific Basin (the Interdecadal Pacific Oscillation or IPO). These changes are of significance to agriculture and other climate-sensitive activities in New Zealand.

These shifts led to stronger and more frequent El Niños in the 20 years following 1977 than in the previous 20-30 years, bringing increased annual rainfall (on average) in the west and south of the South Island, and drier conditions in the north and east of the North Island with more droughts. Scientists researching this topic suggest we may have now moved back into the opposite phase of the Pacific Decadal Oscillation (PDO).

- The identification of cyclic variations and trends in the climate of the southwest Pacific from past instrumental and palaeoclimatic data.

- The development of new climate change scenarios for New Zealand based on the latest "transient" Global Circulation Model (GCM) runs. These runs, which make use of improved ocean as well as atmospheric modelling, simulate continually increasing greenhouse gas concentrations. (The earlier "equilibrium model" based scenarios were for a steady CO<sub>2</sub> concentration of double the current value.)

The new scenarios suggest there will be more warming in the north than the south of New Zealand. They also predict stronger or more frequent westerly winds across the country, resulting in increased rainfall in the west and less in the east.

An important infrastructure advance was the commissioning of NIWA's Cray supercomputer in 1999, providing facilities for running global and regional climate models in New Zealand.

## Palaeoclimates

Understanding past climates provides insight into what a warmer world might be like, and also allows calibration and verification of models that predict the nature of future climate change by testing them on past climates.

Studies on sedimentary cores and other sea-floor samples collected in the Tasman Sea and Southern Ocean show climate variations over time for the eastern Tasman Sea — not only the major climate fluctuations, such as ice ages, but also smaller but significant climate variations. This is in accordance with results from other parts of the globe, which suggests that the natural climate fluctuations in the past have been far more frequent than initially thought. Results also seem to support the suggestion that climate variations in the past were globally synchronous.

Studies on kauri tree-rings, and speleotherms (stalagmites etc) have shown:

- A strong relationship between kauri growth and the Southern Oscillation (ENSO). This opens up the exciting prospect of investigating decadal-to-century scale evolution in the occurrence of El Niño and La Niña events.
- Variation of speleotherm oxygen isotopes clearly identifies and delimits the period of postglacial climatic optimum (7500-10,000 years BP), and preliminary results suggest the average temperature in the Waitomo region to have been up to 2.3 C warmer than today. By contrast, 2000 to 3000 years ago average annual temperatures appear to have been up to 1.5 C cooler.
- The timing of a cold interval in New Zealand corresponds to an abrupt cooling that occurred in NW Europe during the Younger Dryas period. Though results are preliminary, this suggests synchronicity of

climate change in the two hemispheres and therefore the operation of a rapid forcing mechanism.

Studies on sediment cores taken from bogs containing evidence of past ecosystems have produced:

- New Zealand's first high resolution, well-dated, on-land record covering the whole of the last glaciation. This has allowed identification of a key 'new' period of past climate change at c. 50,000 years ago which will impact on climate model predictions for New Zealand.
- A new high-resolution technique for reconstructing past moisture balance and demonstration of the technique for a site in Southland. This technique, along with the new pollen database and two other high-resolution palaeoclimate techniques in development will dramatically improve New Zealand's contributions to global palaeoclimate modelling efforts.

Palaeoclimate information, such as that described above, together with the development of New Zealand capability in palaeoclimate modelling, will ultimately allow us to test output of global GCMs and select appropriate climate models for use in New Zealand conditions. This will improve our prediction and management of future climate change.

## EFFECTS

The New Zealand economy is strongly aligned to agriculturally-based production systems and the natural environment. Therefore, the effects of climate variability and change on managed and natural environments are extremely important.

### Health

Climate change poses a risk to human health through changes in the distribution of infectious diseases, the effect on food production systems and the effects of rising sea levels.

UV radiation and its link to skin cancer rates is also of considerable concern for New Zealand. Results from this research have been incorporated in the Australia and New Zealand chapter of the latest assessment of climate change impacts, vulnerability and adaptation by IPCC. The Summary for Policymakers of this report was released in mid February 2001, with the underlying report due in June 2001.

Effects of climate change on human health may be direct consequences of altered temperature or rainfall, or indirect consequences, mediated by climate-sensitive disease vectors. An example of the first kind of effect is heat-stress. A recent study of daily mortality in Christchurch found that above 20.5°C, mortality increased by about 1% per 1°C increase in temperature. Deaths were also increased on days of low temperature, although by a

smaller amount. It is uncertain what the net effect of a shift to a warmer climate would be. Research overseas suggests that the key factor will be the capacity of societies to adapt to more frequent extremes.

Work has also been undertaken in New Zealand on the second category of potential health effects. An example is research into the effects of climate change on the potential distribution of *Aedes aegypti*, a mosquito capable of transmitting dengue fever, the most important insect-borne viral disease worldwide. Preliminary work indicates that suitable climatic conditions already exist in Northland for this mosquito, but under mid-range climate scenarios (SRES B2 greenhouse gas emission scenario, best guess climate sensitivity) by 2050 the range would extend to include Auckland. Under high-range scenarios (SRES A2 greenhouse gas emission scenario, high climate sensitivity), most major urban centres in the North Island would have suitable conditions for this mosquito by 2100.

### Managed Production Systems

Climate is a critical determinant of food and fibre production. Both positive and negative effects on New Zealand agriculture are anticipated from current climate change scenarios.

#### *Pastoral agriculture*

Pastures cover about 40% of the land area of New Zealand and are a primary contributor to the economy. Climate is highly significant in the success of the pastoral sector. Long-term, field-based experiments are being conducted in New Zealand to test the sensitivity of pasture communities to future changes in UV radiation, atmospheric CO<sub>2</sub> and climate variability and extremes. Results to date are confirming both positive and negative impacts of these global climate changes to future New Zealand pastoral ecosystems.

Simulated changes in the climate and atmosphere that we expect to occur within 30 years are having a marked effect on the spread and abundance of species and have implications for grazing management, weed control and biosecurity. Simulation experiments using portable glasshouses have shown that even small changes in the frequency of frosting, hot days and heavy rainfall events have the potential to increase the abundance of subtropical grasses, thus reducing pasture quality and causing management problems.

Studies on the effect of UV-B radiation simulating 15% and 30% depletions in stratospheric ozone show that high levels of exposure to UV-B radiation appear to reduce sensitivity to drought and increase post-drought survival of white clover. Periodic depressions in yield due to high UV-B exposure are also evident. The commonly used cultivar Huia appears quite susceptible to the damaging effect of UV-B compared with other white clover populations.

Experiments based on a CO<sub>2</sub>-enrichment level that is expected in 30 years time have shown a greater abundance of

nitrogen-fixing legumes, greater seed production by some species, and an increased pool of potentially available nitrogen and readily decomposable carbon at some seasons. Research at soda spring sites with naturally elevated CO<sub>2</sub> has shown greater storage of carbon in soils and a greater availability of nitrogen.

These findings have implications for the spread and abundance of pasture species, the long-term fertility of pastures, and the role of pastures as a source or sink of greenhouse gases. Increased carbon storage by soils under pasture has the potential to remove some of the additional CO<sub>2</sub> currently being released into the atmosphere.

### *Plantation forests*

Research to investigate the impacts of elevated CO<sub>2</sub> concentration on plantation forest ecosystems has been concluded after six years, and has improved the prediction of the effects of elevated CO<sub>2</sub> concentration on productivity and wood quality in plantation forest ecosystems.

Results are indicating that while there is enhanced uptake of carbon by trees growing at double present-day atmospheric CO<sub>2</sub> concentration, the extra carbon can be largely lost from the system by increased root turnover, microbial activity and leaching. The findings confirm that increases in long-term carbon storage in biomass and soil for a future elevated CO<sub>2</sub> climate are likely to be small at sites where the nitrogen supply is limiting.

Measurements on stemwood samples from the second year annual ring have shown that there were no significant differences in wood density, spiral grain or microfibril angle between the treatments. Based on these samples, it is unlikely that there will be changes in wood properties resulting from trees growing in an elevated CO<sub>2</sub> environment.

### **Natural Ecosystems**

New Zealand's natural ecosystems have immense intrinsic and cultural value and their vulnerability to climate change needs to be determined. Compared to managed ecosystems, however, they are still poorly understood at both the ecosystem and biogeochemical levels.

#### *Terrestrial temperate ecosystems*

Results from measuring and modelling the relationships between climate, carbon uptake and species composition in indigenous ecosystems have contributed to the development of a policy for carbon storage, regulation of the emissions of greenhouse gases, and restoration of indigenous ecosystems, in relation to climate change.

Research highlights include:

- Under elevated atmospheric CO<sub>2</sub> concentration, the increases in growth of red beech and soil carbon storage are likely to be small when nitrogen supply is limiting.

- Simplified productivity models can be used to monitor biomass accumulation in New Zealand forest and scrublands at regional and national scales. Although some discrepancies still exist between predicted and field values, further improvement in these models should allow carbon sequestration by scrubland to be assessed and verified, thereby adding a useful sink to that already reported for planted forests.
- Development of process-based models using climate variables, and validation using palaeorecords, have led to the ability to predict the distribution of indigenous vegetation at regional and national scales. The results are being used successfully to manage restoration of indigenous ecosystems and for predicting vegetation distribution in relation to climate change.
- The use of an ecosystem process model predicted major changes in long-term (1000 year) forest composition and biomass with increasing temperature, predicted from scenarios of future greenhouse gas emissions. The resilience of the forests to climate change was sensitive to the frequency of large-scale disturbance, e.g. fire.
- Measurements of the effects of present-day levels of UV-B radiation on mountain beech and kanuka have shown that emerging leaves in mid summer, when the seasonal dose of UV-B radiation is highest, contain very high levels of UV-B absorbing compounds. The effects of enhanced UV-B radiation are anticipated to be small because the leaves have developed such resistant properties.

### *Antarctica*

At its maximum extent, Antarctic sea ice covers 20 million km<sup>2</sup> of some of the most productive waters in the world. Sea ice hosts a large community of algae, which are released into the food chain when most of this ice melts. The algae grow rapidly during the Antarctic spring when the ozone hole is largest over the Antarctic continent; a time, coincidentally, when sea ice is most transparent to UV-B.

Studies on the growth rates of these algae were successfully undertaken in pack ice in the spring of 1998 and 1999, and showed that the standard in vitro incubation methods may over-estimate productivity, and a novel new method using oxygen microelectrodes is more reliable. This has important implications for future assessments of Southern Ocean productivity.

Experiments on algae grown under a range of enhanced and reduced UV irradiances in fast ice has shown that total cell numbers and the proportion of UV-B-tolerant species increased under enhanced UV-B.

These results suggest that a UV-B induced change to a more UV-B tolerant, but perhaps less palatable, algal community may be more important ecologically than

modifications of productivity or total carbon and nitrogen contents.

## RESPONSES

Responses to climate change can be made by mitigating the primary drivers of change in climate (i.e. net emissions of greenhouse gases or ozone depleting chemicals), or by adapting to the changes by capturing opportunities and minimising risks.

Mitigation responses include conducting inventories of greenhouse gases and research into processes that might mitigate these gases. Adaptation responses include the development of new strategies to adapt to change. These range from the development of new plant breeds to cope better with climate and higher UV levels, to new building techniques and materials that manage extreme conditions.

There is high potential in developed countries, such as New Zealand, to adapt our agricultural and economic systems to minimise threats of climate change and take advantage of any potential benefits of altered climate. Such a strategy in industries will require good research to identify potential options for making appropriate adaptation management.

### Lowering Ruminant Methane

Methane is New Zealand's major (44%) greenhouse gas. Almost all (89%) of this is produced by microbes in the forestomach (rumen) of grazing sheep and cattle.

Previously, research had shown that 10% of grazing sheep in a flock emit high levels of methane and 10% emit low levels of methane. Recent results suggest that high methane emitters may have a larger rumen volume and that feed residues are retained longer in the rumen than with low emitters.

Measurement of methane emissions from sheep and cattle grazing a wide range of pasture types continues to provide data for developing an accurate methane inventory essential for underpinning mitigation policy and strategies. Research indicates that methane emissions vary with pasture type and this raises the possibility of devising pasture management strategies to reduce methane emission from grazing livestock.

Findings showed that:

- Methane emissions from dairy cows grazing less-digestible subtropical grasses (e.g. kikuyu in Northland) were higher than from cows grazing temperate perennial ryegrass/white clover pastures.
- Methane emission was significantly reduced in sheep grazing *Lotus corniculatus* compared with sheep grazing kikuyu and perennial ryegrass/white clover pastures.

## Energy

Research has been carried out on improving energy efficiency, technological design and implementation of renewable energy options in New Zealand, and on the possible design of emission trading schemes and their impact on implementation costs.

Several exciting research projects being undertaken in New Zealand industry, university and CRI laboratories and testing facilities may well be ready for commercialisation within the next few years. These include the development of ceramic fuel cells (in collaboration with Australia); solid-oxide fuel cells; super-conductors; high temperature solar applications; hydro power load controllers; small wood gasifiers; low head hydro turbines; low cost photovoltaic cells using porphyrin dye on titania; and novel designs of anaerobic digesters.

Specific examples of research projects include:

- Energy efficiency of buildings and appliances. Thermal design programmes have been developed to assist passive energy efficiency design of houses. Appliances were found to consume up to 40% of their total energy consumption in stand-by mode.
- Resource assessments for New Zealand wind farms. Model and feasibility studies of New Zealand's hilly terrain which experiences high wind speeds, but has difficult access and logistics. Improved models reduce the risk in renewable energy investment decisions.
- Artificial photosynthesis. Development of porphyrin arrays, materials similar to chlorophyll used in plants for photosynthesis. These materials have potential for use in new photovoltaic cells.
- Efficient street lighting. Street lighting requires considerable amounts of energy in local government budgets. Research is underway to develop and economically implement new lamp types which will reduce the energy use of lighting systems.
- Tradable Obligation Studies. A project that investigates options for the allocation of carbon emission permits, and the effect of different time horizons and changing incentives on the total implementation cost of innovative energy production and use.

## Transport

Research was aimed at developing an understanding of the constraints affecting consumer preferences and decision-making processes when choosing to travel by car.

The effect of various mechanisms, such as implementing a toll, improved frequency of passenger transport services or increased parking constraints on an individual's decision to

travel by car was estimated and “profiles” of different mode users were developed.

These identified the characteristics of those car drivers most likely to:

- switch to using passenger transport
- be car passengers
- car pool
- switch to other modes of transport (e.g. walking or cycling).

Research identified perception barriers to using passenger transport in particular and “concrete” barriers to mode switching generally. Twenty three percent of car drivers were receptive to the concepts of compressed work-weeks and working from home one or more days per week. A core group of drivers would continue to drive regardless of how expensive it became or how good the public transport seemed.

During the course of research it was also revealed that those driving their children to school showed a strong interest in the “walking school bus” concept, an initiative to reduce the risk for children when walking to bus stops by picking them up along the way. Researchers are now working with Christchurch City Council to trial walking school bus “networks” for four Christchurch schools.

### **Developing Response Tools**

The CLIMPACTS computer model has been developed as an operational tool to conduct integrated assessments of the impacts of climate change for specific sites, for regions and for the entire nation in New Zealand. CLIMPACTS now makes use of the new climate scenarios developed under the climate variability research described earlier in this chapter, which are based on “transient” GCM runs.

New crop-ecosystem models have been incorporated into the CLIMPACTS system over the past seven years. Those crop-ecosystem models previously available at the national scale have now been tailored for application at the regional scale within the CLIMPACTS system. The Rothamsted soil-carbon turnover model was adapted for New Zealand conditions, and incorporated into CLIMPACTS, linking it to the site-specific pasture model.

A wheat model in particular, which has well validated responses to CO<sub>2</sub>, temperature and water supply changes, was used in the national assessment of climate change impacts on agricultural production, because it is typical of several C3 grain crops. It was shown that increased CO<sub>2</sub> levels would raise the potential yields of wheat in Canterbury where 97% of New Zealand crops are grown. But this potential would not be achieved without an additional input of water, which is already in short supply in the region.

For 'Hayward' kiwifruit, warmer winter temperatures mean lower flower numbers, and results suggest that this may cause serious difficulties for production in Northland by around 2050. During the same period, production in the Bay of Plenty will become more reliant on dormancy-breaking technologies to maintain adequate flower numbers. It is not known at this stage whether kiwifruit will grow better in the South Island. Current differences in regional apple production suitability appear unlikely to change.

The pasture model indicated generally positive responses in pasture yield to a warmer climate. The increase in the rate and magnitude of the change in the arable land area suited for grain maize production has been investigated for the Canterbury region from land use classes (LUC) information. It showed a significant increase in the area suitable for grain maize production, but as this crop has a greater water requirement and a longer growing season than wheat, the water shortages would seriously limit the potential for this crop. The low carbon levels in many Canterbury soils would be a further limitation.

## Chapter 5

# Identifying Gaps in Research Effort, Research Priorities and Opportunities

### BACKGROUND

The annual review of climate change research against NSSCCC strategies has identified priority areas for climate change research and had a major influence in the design of the overall current New Zealand effort in the area. By comparing the ongoing portfolio of climate change research against the strategy, NSSCCC has been able to identify gaps, note emerging priorities and consider new research opportunities. This analysis is carried out within the context of the drivers for the strategy's outcomes which are:

- reducing uncertainties
- protecting New Zealand's interests
- identifying opportunities for New Zealand
- maintaining international science contact.

NSSCCC's strategy emphasises the need to ensure that the timing of the research outcomes matches the requirements of international agreements and other initiatives, such as the:

- IPCC Special Report on Land-Use, Land-Use Change and Forestry (2000)
- IPCC TAR (2001)
- Montreal Protocol and subsequent amendments
- COPs to the UNFCCC (annually)
- anticipated ratification of the Kyoto Protocol (2002).

International agreements or initiatives to which New Zealand is a signatory or a participant act as major drivers for a significant part of the total research effort.

NSSCCC has identified not only specific gaps in the research programme which relate to the ratification of the Kyoto Protocol, but also research which is needed to underpin longer-term strategic opportunities and options in the national interest.

The main priorities are:

- research relating to improving understanding and predictions of changes in storm intensities and the resulting floods and erosion
- drought
- ozone concentrations and UV levels
- ocean/atmosphere interactions
- arrival of new pests and weeds

- arrival of disease vector pests for both humans and animals
- effects on the marine ecosystem and fisheries
- health-related issues associated with increased UV levels and exposure, such as skin cancer
- forest and scrubland stores and sinks for carbon
- changes in the composition of the New Zealand motor vehicle fleet
- modification of driver behaviour
- behavioural issues affecting energy supply and use
- the development of building codes that improve the long-term energy performance of buildings
- use of non-fossil fuels, such as liquid bio-fuels, gaseous fuels and renewable electricity in transport
- gas abatement from the agriculture and waste sectors
- reducing industrial emissions.

The latter four priorities are of particular relevance to the development of the Government's policy for the first commitment period under the Kyoto Protocol (2008–2012).

There is also a pressing need for improvements to the national inventory of methane and nitrous oxide and the identification of ruminant methane policy options.

Additionally, new underpinning research and monitoring, including the refinement of New Zealand's sink inventory methodology framework (to take into account sinks under the Kyoto Protocol) will assist in meeting the reporting and verification requirements for any emissions trading under the Kyoto Protocol. This involves setting up a workable allocation policy, rules governing compliance, sanctions, responsibilities and property rights, and a legal framework on the use of sinks and sink credits. It is essential that good technical information and accompanying socio-economic analysis is closely linked to the development of relevant and practical policies and actions.

International commitments, especially under the UNFCCC, require continual monitoring, and an inventory and reporting effort supported by in-depth reviews to produce an annual report of New Zealand's greenhouse gas inventory. Further, the "National Communication" commitment every three years or so requires not only a greenhouse gas inventory, but also detailed information on policy responses, such as mitigation policies, greenhouse gas emission projections, systematic observations of the climate system, and climate change impacts and adaptation plans.

This information is also needed if New Zealand is to develop sensible management of risks and potential liabilities. Filling knowledge gaps, such as soil carbon storage

levels under different land uses in, for example, grasslands, indigenous forests and scrublands, and reducing uncertainties in non-CO<sub>2</sub> greenhouse gas emission estimates, is dependent on a carefully designed research and monitoring programme.

New Zealand also has a responsibility to participate in research on climate change impacts and adaptation in its region, particularly with South Pacific island states, where land and populations are often more vulnerable than New Zealand itself. This includes the International Global Change Institute (IGCI) work on vulnerability and adaptation to climate change and studies on climate variability and arboviral diseases.

## FUNDING OF RESEARCH CATEGORIES

In the NSSCCC strategy published in 1999, the Committee recommended raising funding levels for the Processes, Effects and Responses categories of the research portfolio in order to meet the targets set by the Committee for 2000/2001. It also recommended improving the balance of funding among the categories because expenditure on Effects research, in particular, was well below the others at only 40% of the Committee's target.

The NSSCCC target funding levels are based on the recommended distribution of research efforts across processes, effects and responses, set by the NSSCCC in 1995. Subsequent signing of the Kyoto Protocol, and the associated increase in policy relevance of research into responses (mitigation), imply that the target funding levels have become less relevant than the gaps and opportunities analysis presented in Chapters 2, 3 and 5 of this report. The summary comparison between actual and target funding levels set out in Table 2 should therefore be read with this caveat in mind. A more detailed look at required research outcomes is needed to assess priorities in climate change research (see the list of priorities on previous pages).

New funding patterns have emerged in the 1999/2001 period in relation to the achievement of some targets and changes in the relative contributions of some funders. Consequently some aspects of the 1999 funding recommendations need further examination.

The Committee's assessment of the total overall funding of climate change research in New Zealand covering 1999/2000 and 2000/2001 is just over \$23.5 million/year. This is \$4 million short of the Committee's target for 2000/2001 of \$27.5 million. Ninety percent of the funding comes from government sources with 82% from the PGS&T fund administered by FRST.

There are some marked trends between years with the total PGS&T spend exceeding the Committee's target for 2000/2001, but still significantly short in the Processes and Effects areas. Spending by departments fell by 36% to

\$800K/year<sup>1</sup> and universities by 66% to \$500K/year. Combined, these two groups were over \$5 million short of the Committee's target. Annual expenditure by the private sector has increased three-to-four fold to over \$2 million (10% of the total) in the past two-to-three years, but is still nearly 20% below target. The contribution from the regional councils was below 1%.

An analysis of the total funding of each research category by all resource providers showed that Processes research at 43% of the total had remained virtually static at around \$10 million and is still short of the Committee's target of \$12 million. The Responses category has increased by 80% to over \$9 million (39% of the total) as a result of large increases in contributions from the private sector and a reclassification of some climate change research. The Effects category increased by a third to just over \$4 million (18% of the total) but is still only half way to the Committee's target of \$8 million.

The funding analysis also shows that 93% of Processes research and 96% of Effects research is provided by PGS&T. Although it is not too surprising that the Foundation should fund a high proportion of basic processes work, it is clear that the drop in university funding has also contributed to the failure of this category to reach the Committee's target.

In the case of Effects research, PGS&T is nearly \$1 million below target, but a large part of the failure to reach the Committee's milestone is due to the absence of appropriate funders such as operational departments, regional councils and industry.

The Responses category shows a more balanced portfolio with PGS&T funding of 63% and significant contributions from the private sector (25%) and government departments (9%).

## SOLUTIONS TO THE FUNDING SHORTFALL

This funding analysis and the continuing shortage of resources for climate change research, particularly in the Effects area, illustrates the urgent need to clarify the responsibilities of the different funders and to ensure that real complementarity exists between the parties.

If this does not occur many of NSSCCC's key priorities, such as social and behavioural research, energy use, transport policy and national inventories will not be achieved, and New Zealand will not be able to develop credible policies on climate change.

As a very large majority of the funding for climate change research (82%) is through PGS&T, it is important to have

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<sup>1</sup> A large proportion of this drop was the result of delays in spending on the New Zealand carbon monitoring system (CMS). The money was carried forward to the following financial year 2000/2001.

confidence in the allocation of this investment. The funding analysis shows that within the government science policy framework, climate change and variability research constitutes part of 12 SPOs.

The SPO of most relevance to climate change research is that on “Global Environmental Processes and Change”, and 80% of the climate change relevant PGS&T funding contributes to research goals in this SPO. Research within 11 other SPOs is also relevant with the link being made through research on climate change issues with direct implications to a specific sector. For example, the programme on “Reducing CO<sub>2</sub> emissions from coal-fired electricity generation” is in the Energy SPO and “Mitigation of ruminant methane emissions” is in the Animal Industries SPO. The remaining 20% of PGS&T support for climate change research is invested in this way.

Since climate change issues will increasingly impact on a wider range of sectors, an expansion of this investment approach should be encouraged as it will have the advantage of adding value to the relationship with other potential investors from the relevant industries and appropriate departments. Greater participation should also be encouraged by the private sector in the various Foundation schemes to support research partnerships with industry.

This large, mainly taxpayer funded, expenditure on climate change related research has the potential to benefit the whole New Zealand community beyond the immediate issues related to climate change. Large industries, small businesses and homeowners can all reduce costs through more efficient use of energy including better-designed buildings and the use of non-carbon energy sources. If methane production by ruminants can be reduced, the farmer will have animals which convert feed more efficiently. Many strategies for reducing vehicle emissions can reduce costs for the individual motorist and transport operator.

It is certain that new, marketable technologies will result from climate change research, but to date New Zealand has been slow to recognise the potential commercial benefit from this investment. NSSCCC, in conjunction with technologists, investors and funders, will organise an “Opportunities” workshop in 2001 to raise interest in these exciting options.

In line with the strategy of broadening the taxpayer funding base and in recognition of the increasing role of industry and the private sector, it is important to widen membership of the Committee beyond the current dominance by government-owned science providers, universities and government departments, and provide an increase in specialist support for the Committee. This also raises the issue of whether Committee members should be expected to continue to give their time freely during a period of very intense activity in climate change research and policy development.

**Table 2. Climate Change Research Funding**

Summary of actual climate change research funding (in \$000) by category for previous and current years

	1998/99	2000/01*	Target 2000/01**
<b>Processes</b>			
PGS&T/NSOF	10019	9277	10000
Marsden	0	327	0
Universities	383	367	2000
Government Operational	0	0	0
Private Sector	0	0	0
Regional Councils	4	0	0
<b>Total for category</b>	<b>10406</b>	<b>9971</b>	<b>12000</b>
<b>Effects</b>			
PGS&T/NSOF	2506	4094	5000
Marsden	100	145	0
Universities	500	45	500
Government Operational	0	0	1000
Private Sector	0	0	1500
Regional Councils	147	0	0
<b>Total for category</b>	<b>3253</b>	<b>4284</b>	<b>8000</b>
<b>Responses</b>			
PGS&T/NSOF	3018	5890	3000
Marsden	40	0	0
Universities	562	82	250
Government Operational	1270	809	3000
Private Sector	158	2294	1250
Regional Councils	4	197	0
<b>Total for category</b>	<b>5052</b>	<b>9272</b>	<b>7500</b>
<b>Totals by funding source</b>			
PGS&T/NSOF	15543	19261	18000
Marsden	140	472	0
Universities	1445	494	2750
Government Operational	1270	809	4000
Private Sector	158	2294	2750
Regional Councils	155	197	0
<b>Overall Total</b>	<b>18711</b>	<b>23527</b>	<b>27500</b>

\* Funding by PGS&T/NSOF is for 2000/01. Funding by all other agencies is for 1999/2000.

\*\* The target funding levels are based on the recommended distribution of research efforts, set by the NSSCCC in 1995. Subsequent signing of the Kyoto Protocol, and the associated increase in policy relevance of research into responses (mitigation), imply that the target funding levels are of less relevance than the gaps and opportunities analysis presented in Chapters 2, 3 and 5 of this report.

## Chapter 6

# Global Programmes and Collaboration

### OVERVIEW

There is now a huge international investment in all aspects of climate change research - processes, prediction, impacts, adaptation and mitigation. New Zealand benefits from collaborating in this international activity. We obtain information on climate change and its impacts which it would be impossible for us to develop alone.

In return, New Zealand research and measurements provide an essential contribution to the international pool of knowledge. Our observations fill important gaps in an otherwise isolated portion of the globe. These observations also address our monitoring obligations under UNFCCC and the Montreal Protocol for reducing emissions of ozone-depleting substances.

The contribution of New Zealand research to international knowledge is demonstrated in the Science Highlights section of this report. By participating in planning committees and meetings for international programmes, New Zealand scientists encourage investment of international science resources and capabilities on projects which address issues important for our region.

New Zealand scientists are also playing an important role in international activities to assess the state of knowledge about climate change as a background for national and international policy development. One member of the Bureau for IPCC is a New Zealander, as are three convening lead authors and four lead authors for IPCC's TAR. Summaries of the individual working group reports were adopted and released between January and March 2001, and the full reports are expected in June 2001. New Zealand scientists also made substantial contributions to the 1999 United Nations Environment Programme (UNEP) evaluation of effects of ozone depletion.

### GLOBAL RESEARCH AND MONITORING PROGRAMMES

Global climate change research forms part of a broader international global change research portfolio coordinated through three complementary programmes:

- WCRP
- IGBP
- International Human Dimensions Programme (IHDP).

Results from these three programmes will be brought together in a Global Change Open Science Conference in Amsterdam in July 2001, bringing closer co-ordination between the three programmes. Projects will be set up

jointly on key cross-cutting issues of major societal importance, beginning with the global carbon cycle, food systems and water resources.

Observations, which underpin the research undertaken in the WCRP, IGBP and IHDP programmes and monitor the changing state of the globe are primarily coordinated through the GCOS, GOOS, and the Global Terrestrial Observing System (GTOS).

#### The World Climate Research Programme

WCRP coordinates international collaborative research on the physical climate system needed to improve predictions of:

- Climate changes caused by human activities, such as greenhouse gas emissions
- Natural climate variations, such as the El Niño and La Niña.

WCRP comprises the following programmes:

- CLIVAR
- Global Energy and Water Cycle Experiment (GEWEX)
- Arctic Climate System (ACSYS) which is now being expanded into the Climate and Cryosphere Initiative (CLIC)
- Stratospheric Processes and their Role in Climate (SPARC)
- World Ocean Circulation Experiment (WOCE), which is expected to merge into CLIVAR.

#### CLIC

The new CLIC programme was approved internationally in March 2000, and will be of interest to New Zealand since it will integrate studies of the impact and response of the cryosphere in the global climate system and the use of cryospheric change indicators for climate change detection.

#### CLIVAR

Two new CLIVAR panels of particular interest to New Zealand are in the process of formation:

- A workshop in Perth in November 2000 endorsed the formation of a Southern Ocean Panel to co-ordinate research and data gathering. The main areas of interest relate to decadal-scale climate variability and climate change, and include:

- Improving the description and understanding of the Antarctic Circumpolar current
- Ocean overturning
- Water mass transformation in the Southern Oceans.

Efforts in these areas will be coordinated with the CLIC programme, as well as other global observing programmes. Dr Michele Morris, an oceanographer from NIWA, represented New Zealand in the discussions in Perth.

- A panel with similar aims covering work in the Pacific Basin was endorsed during a meeting in Honolulu in February 2001. Particular emphasis in the Pacific Basin panel will be placed on an ocean observing system, to which a network of sub-surface drifters (Argo) will make a major contribution. New Zealand participated in this programme and was represented by Dr Phil Sutton, NIWA.

Dr John Kidson, a member of the New Zealand Climate Committee, has continued in his role as principal New Zealand contact for the CLIVAR programme. He submitted a national annual report outlining progress to the executive meeting in May 2000.

### **The International Geosphere-Biosphere Programme**

The IGBP focuses on interactive physical, chemical and biological processes which regulate the total earth system, the unique environment that it provides for life, the changes which are occurring in this system and the manner in which they are influenced by human activity.

IGBP research currently focuses on six key questions that are addressed by eight Core Projects:

- How is the chemistry of the global atmosphere regulated and what is the role of biological processes in producing and consuming trace gases? *International Global Atmospheric Chemistry Project (IGAC)*.
- How will global changes affect terrestrial ecosystems? *Global Change and Terrestrial Ecosystems (GCTE) and Land-Use and Land-Cover Change (LUCC)*, which is sponsored jointly by IGBP and IHDP.
- How does vegetation interact with physical processes of the hydrological cycle? *Biospheric Aspects of the Hydrological Cycle (BAHC)*.
- How will changes in land-use, sea level and climate alter coastal ecosystems, and what are the wider consequences? *Land-Ocean Interactions in the Coastal Zone (LOICZ)*.
- How do ocean biogeochemical processes influence and respond to climate change? *Joint Global Ocean Flux Study (JGOFS)* (sponsored jointly by the IGBP and ICSU Scientific Committee on Oceanic Research

(SCOR). *Global Ocean Ecosystem Dynamics (GLOBEC)* project.

- What significant climate and environmental changes have occurred in the past and what were their causes? *Past Global Changes (PAGES)*.

The integration of IGBP Core Projects is assisted by three cross-cutting Framework Activities:

- IGBP Data and Information System (IGBP-DIS)
- Global Analysis, Interpretation and Modelling (GAIM)
- Global Change System for Analysis, Research and Training (START), which addresses regional research initiatives and needs, jointly with the IHDP and WCRP.

New Zealand's links with IGBP are maintained through the Royal Society of New Zealand's National Standing Committee for the IGBP Programme. Individual members of this committee liaise with and disseminate information from the Core Projects listed above.

In addition, Dr Martin Manning, NIWA, is a member of the international IGAC Scientific Steering Committee. Dr Bruce Campbell, AgResearch, is leader of the GCTE Pasture and Rangelands Network, and several New Zealand projects are core research components of GCTE.

### **The International Human Dimensions Programme**

The IHDP promotes and coordinates research aimed at describing, analysing and understanding the human dimensions of global environmental change.

It addresses the questions:

- How do human actions contribute to global environmental change?
- Why are these actions taken?
- How does global environmental change feed back into people's lives?
- What actions can be taken, by whom, to respond to, reduce and mitigate the effects of environmental change?

The IHDP comprises the following programmes:

- Land-Use and Land-Cover Change (LUCC, co-sponsored by IGBP)
- Global Environmental Change and Human Security (GECHS)
- Institutional Dimensions of Global Environmental Change (IDCEC)
- Industrial Transformation (IT).

New Zealand's links with IHDP are maintained through the Royal Society of New Zealand's Standing Committee for the IGBP Programme. Dr R. Bedford is the IHDP contact person.

## **The Global Climate Observing System**

The GCOS was established in 1992 to promote improved observations of the climate system and to ensure that the observations and information needed to address climate-related issues are obtained and made available to all potential users.

The GCOS is co-sponsored by the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC) of UNESCO, UNEP, and the ICSU.

The GCOS coordinates the acquisition of the critical observations needed for the:

- prediction of seasonal and inter-annual climate variability
- detection of climate change
- reduction of uncertainties in climate prediction.

The GCOS has been tasked by COP4 and COP5 to coordinate the national reporting of the systematic observations of climate by Parties to the UNFCCC. This coordination role spans the systematic observations of climate parameters in the atmosphere and ocean as well as the terrestrial system. A GCOS focal group has been formed in New Zealand to liaise with the GCOS Secretariat and the local community. Dr Andrew Matthews, NIWA, is the National Coordinator.

Several New Zealand scientists, including Dr Matthews, attended a GCOS workshop in Apia in August 2000. This workshop identified needs and priorities for climate observations in the Pacific region.

Dr Matthews also attended an informal meeting of GCOS National Coordinators in Melbourne earlier in August to develop a paper on supplementary guidance to Parties to the UNFCCC on the preparation of detailed National Reports on global climate observing systems. This paper was tabled at the COP6 meeting in The Hague in November 2000.

## **The Global Ocean Observing System**

The GOOS, which focuses on oceans, was established by IOC, WMO, UNEP and the International Council for Science (ICSU) as a sister programme to GCOS.

The GOOS is developing and implementing an international strategy for identifying users of marine observational data and their needs, co-ordinating the acquisition and exchange of this data, and encouraging its use. The mandate of GOOS includes data for climate change studies and co-ordination of global sea-level monitoring (including needs for climate change research).

Dr Julie Hall, NIWA, is Vice Chair of the international GOOS Steering Committee and a member of the Coastal Ocean Observing Panel. Several New Zealand scientists attended the Pacific GOOS meeting in Apia in August

2000, which was held in conjunction with the Pacific GCOS meeting.

International pressure is growing for enhanced New Zealand involvement in regional ocean observations. Improved ocean observations are vital for better understanding and prediction of seasonal-to-decadal climate variations.

## **The Global Terrestrial Observing System**

The GTOS was established in January 1996. Together with GCOS and GOOS, GTOS was created in response to international calls for a deeper understanding of global change in the earth system.

The central mission of GTOS is to provide data for detecting, quantifying, locating and giving early warning of changes in the capacity of terrestrial ecosystems to sustain development and improvements in human welfare. One of the key questions being addressed by GTOS is: What are the impacts of climate change on terrestrial ecosystems?

## **The Network for the Detection of Stratospheric Change**

The international network for the Detection of Stratospheric Change (NDSC) is a coordinated international programme to characterise changes in the physical and chemical state of the stratosphere, particularly related to ozone depletion and its relation to climate change.

The NIWA site at Lauder is one of the five primary stations in this network and the observations there involve intensive international collaboration and use state-of-the-art equipment, some of which has been installed by collaborators from several other countries. New Zealand measurements at Scott Base and Arrival Heights also contribute to the distributed Antarctic primary NDSC station.

## **International Energy Agency Greenhouse Gas Research and Development**

The International Energy Agency (IEA) Greenhouse Gas research and development programme is a major international collaboration investigating technology for reducing emissions of greenhouse gases. It is open to governments and industries worldwide, and New Zealand is one of 17 current member countries.

The programme's three main activities are:

- evaluating technologies
- publicising the results
- facilitating practical research, development and demonstration.

## **INTERNATIONAL CONVENTIONS AND SCIENCE ASSESSMENT PROGRAMMES**

### **The United Nations Framework Convention on Climate Change**

The year 2000 saw a large increase in work on all aspects of the UNFCCC and Kyoto Protocol agenda, with the aim of taking sufficient decisions at COP6 to enable developed countries to ratify the Protocol.

This work included development of:

- rules for international emissions trading and the other Kyoto mechanisms (joint implementation and the Clean Development Mechanism)
- compliance procedures
- definitions and other issues related to implementation of Articles 3.3 and 3.4 (“sinks”)
- guidelines for reporting and review under Articles 5, 7 and 8.

COP6 met in November 2000 in The Hague, but was suspended without reaching agreement. It will resume in Bonn in mid July 2001.

New Zealand, through MfE, submitted its latest national greenhouse gas inventory and national inventory report in April 2001, using the UNFCCC Common Reporting Format for the greenhouse gas inventory data. The Common Reporting Format has been introduced to improve the consistency and transparency of developed country inventory reporting, and will be reviewed after two years.

New Zealand volunteered to be one of the first countries to have its greenhouse gas emissions inventory subjected to a thorough review by international experts. This review took place in May 2001, and a final report of the expert team's findings is expected to be delivered in August or September.

The importance of well-documented greenhouse gas inventories is increasing because of the more stringent requirements of the Kyoto Protocol. This is reflected in the guidelines being developed for reporting and review under Articles 5, 7 and 8.

### **The Vienna Convention and Montreal Protocol for Protection of the Ozone Layer**

Ozone depletion and consequent increases in damaging UV radiation are important issues for New Zealand. Our scientists play important roles in processes associated with the Montreal Protocol (and its amendments and adjustments).

Dr Richard McKenzie of Lauder was lead author of the UV chapter in the last Scientific Assessment Document, which was published in 1999, and other New Zealand scientists were involved as co-authors, contributors and reviewers. Planning is already under way for the next Sci-

entific Assessment due for publication in 2004 and several New Zealanders have again been nominated to participate.

Dr McKenzie is the only Southern Hemisphere representative on the UNEP Environmental Effects Panel, which reports to the signatory parties of the Montreal Protocol in a similar process to the Science Assessment Panel. Under the terms of the Montreal Protocol, the panel is required to meet once a year. Dr McKenzie attended the most recent panel meeting in Abisko, Sweden in August 2000, with funding from the FRST-administered International Technical Input Programme (ITIP) programme. In the next fiscal year, two meetings will be held; one in India and the other in New Zealand (probably Wellington).

Both the Science Assessment Panel and the Environmental Effects Panel are paying increased attention to the linkages between ozone depletion and global warming.

Another emerging issue of importance to New Zealand is the responsible use of methyl bromide for quarantine and pre-shipment purposes. This usage is currently increasing and Parties to the Montreal Protocol have been asked to review their regulations and encourage alternatives where possible. The MfE staff member who deals with ozone layer protection advises that this area hasn't received much attention from New Zealand scientists to date, and it deserves a higher profile.

### **The Intergovernmental Panel on Climate Change**

IPCC, established by UNEP and WMO, has continued with its work of preparing policy-relevant assessments of the scientific and technical information relating to climate change. These reports provide underpinning scientific information for the development of UNFCCC and its protocols, as well as an impartial source of thoroughly reviewed scientific information for national policy formulation.

A Special Report completed and published this year, of particular interest to New Zealand, was the report on Land-Use, Land-Use Change and Forestry. It was undertaken by IPCC, on request from UNFCCC, to assist the negotiation process regarding definitions and other issues associated with Articles 3.3 and 3.4 of the Kyoto Protocol.

Article 3.3 deals with greenhouse gas sources and sinks associated with direct human-induced land-use change and forestry activities, and modalities. Article 3.4 states that rules and guidelines must be negotiated covering how national greenhouse gas sources and sinks from agricultural soils, land-use change and forestry activities will be accounted for within the national greenhouse gas emissions allowed under Annex 1 of the Protocol.

The Special Report also included information on project-based activities (relevant to Articles 6 and 12 of the Kyoto Protocol which cover joint implementation and the Clean Development Mechanism).

A Special Report on Good Practice and Uncertainty Management in National Greenhouse Gas Inventories was also completed and accepted. This is a companion volume to the IPCC 1996 Revised Guidelines for National Greenhouse Gas Inventories. It is assuming a high level of importance within the UNFCCC and Kyoto Protocol reporting systems as “good practice”, and is being incorporated into the reporting guidelines currently under development.

Other special reports completed and accepted by IPCC in 2000 were:

- Special Report on Methodological and Technological Issues in Technology Transfer
- Special Report on Emission Scenarios.

Summaries for policymakers and technical summaries of all these special reports are available on the IPCC website (<http://www.ipcc.ch>).

The major ongoing work of IPCC has been the TAR, which covers all aspects of climate change. The three Working Group Reports which comprise the TAR have been through expert and government review and were approved in plenary sessions between January and March 2001. The Summaries for Policymakers were made public immediately after conclusion of the plenaries and are available from the IPCC website, and publication of the full underlying reports is expected in June this year.

The Synthesis Report, which draws together information from the three Working Group Reports related to policy-relevant questions is due for completion and consideration for approval in September 2001.

New Zealand has been assisting with the preparation of TAR in several ways:

- Many New Zealand scientists are convening lead authors or lead authors of chapters, or reviewers
- MfE has formal governmental responsibility for liaison with IPCC
- Dr Martin Manning, NIWA, is a member of the IPCC Bureau
- New Zealand (through NIWA) hosted the lead authors' meeting for Working Group I in Auckland in February 2000
- Five people, including two scientists and three policy analysts (from MfE and MAF) represented New Zealand at the IPCC 16<sup>th</sup> plenary meeting in Montreal in May 2000.
- New Zealand scientists and officials participated in plenary sessions in which the Summaries for Policymakers of each of the three Working Groups were approved line-by-line by government delegates.

## REGIONAL PROGRAMMES AND COLLABORATION

### The Global Change System for Analysis, Research and Training

START, a joint initiative of IGBP, WCRP and IHDP, was established to build capacity for global change research and response in developing countries. Its structure is based on regional committees established around the globe, including a START-OCEANIA committee which has a secretariat at the University of the South Pacific in Fiji.

New Zealand links to START are through the Royal Society's National Standing Committee for the IGBP Programme. Committee member Dr John Campbell, Waikato University, has responsibility for START liaison.

### Asia-Pacific Network for Global Change Research

The APN is an inter-governmental network for the promotion of global environmental change research and links between science and policy-making in the Asia-Pacific Region.

In particular, APN promotes the following objectives:

- Support for regional cooperation in global change research on issues that are particularly relevant to the region
- Standardisation, collection, and exchange of scientific data relating to global change research
- Improvement of scientific and technical capabilities and research infrastructure of nations in the region
- Cooperation with research networks in other regions
- Provision of scientific knowledge to the public, and input to policy decision-making
- Development of appropriate mechanisms for transfer of know-how and technology.

Over the last two years, the New Zealand science community has received funding support for activities from APN of approximately US\$200,000 (marginal funding), particularly for capacity building in Pacific Island States. Capacity building in developing countries is also an activity to which New Zealand is obliged under UNFCCC, and international scientific collaboration programmes form an important part of this responsibility.

Projects have included:

- The use and extension of the PACCLIM integrated computer model for climate change vulnerability and adaptation in Pacific Island countries (New Zealand)
- APN Workshop on Climate variability and trends in Oceania (New Zealand)
- Workshop for inter-calibration of isotope ratio measurement for atmospheric CO<sub>2</sub> (Japan)

- Recent sea-level change and coastal management implications in Oceania (Australia)
- International Human Dimensions Workshop - 2000: Human dimensions issues in the coastal zone (Australia)
- Training Institute on Climate and Society in the Asia Pacific region (Hawaii).

The New Zealand representative on the APN scientific committee is Dr Andrew Matthews, NIWA.

### **Valdivia**

The Ministry of Foreign Affairs and Trade (MFAT) leads New Zealand's interest in the Valdivia Group. This group of temperate-latitude Southern Hemisphere countries attempts to identify common interests in international environmental negotiations and aims to collaborate on scientific and technical matters. Climate change is one of the identified issues and Dr David Wratt is the New Zealand representative on the Valdivia Climate Change Working Group.

This working group has developed concepts for a project entitled: *Valdivia Group Climate Change Adaptation Project - Climate Change Capacity Building in the Southern Hemisphere*. A meeting to develop a detailed funding proposal to the Global Environment Facility (GEF) to support this project has not yet eventuated. The 2000 Valdivia Group Meeting, which was to be held in South Africa, was postponed.

### **South Pacific Regional Environment Programme**

The South Pacific Regional Environment Programme (SPREP) is the intergovernmental organisation charged with promoting cooperation and supporting protection and improvement of the Pacific environment and ensuring its sustainable development. Its members are the governments and administrations of 22 Pacific Island countries and four developed countries with direct interests in the Pacific Islands region.

MFAT coordinates New Zealand's involvement with SPREP, with the Department of Conservation (DOC) and MFE being technical focal points. SPREP staff, most of whom are located in Apia, have played an important role in South Pacific-related science activities covered in this chapter, including the GCOS Pacific Workshop, the preparation of the Small Island chapter for the IPCC TAR, and the APN workshops with a Pacific dimension.

### **Pacific Islands Climate Assistance Programme**

The Pacific Island Climate Change Assistance Programme (PICCAP) was established to enable Pacific Island countries to provide National Communications under UNFCCC. It has also served as a major capacity building programme in which country teams have been established to conduct greenhouse gas inventories and vulnerability and adaptation assessments.

The first phase of PICCAP has been successfully completed. A major component of the training was conducted by IGCI at the University of Waikato.

### **Other Regional Collaboration and Support**

This chapter has not attempted to summarise the many institution-to-institution collaborations which have facilitated much of the New Zealand climate change research outlined in the Research Highlights section of this report. However, three other regional items which should be noted are:

#### *The Island Climate Update*

The *Island Climate Update*, which started in October 2000, is a monthly publication coordinated by NIWA and disseminated throughout the Pacific. It summarises current climate conditions across the Pacific and provides seasonal climate outlooks. Data, and contributions are provided by many countries (developed and developing) from around the Pacific. Preparation and publication costs are supported by Italian aid funding.

#### *World Bank Report on Managing Change in Pacific Island Economies: Volume IV, Adapting to Climate Change*

IGCI, Waikato University made an important contribution to the World Bank Report on Managing Change in Pacific Island Economies: Volume IV, Adapting to Climate Change. It was produced through a partnership between the World Bank and several institutes and organisations from the Pacific or Pacific Rim.

#### *Climate Information and Prediction Services Training Course*

The Climate Information and Prediction Services (CLIPS) forms part of WMO's World Climate Programme, and is designed to help countries make productive use of climate information, including climate outlooks.

NIWA hosted a CLIPS' training course in Auckland in December 2000, for Regional Association Five (which covers the Pacific Islands and SE Asia as well as Australia and New Zealand) of the WMO.

## **SUPPORT FOR INTERNATIONAL LINKS**

### **International Science Linkages Fund**

New Zealand scientists can not always obtain support to attend appropriate meetings of some of the organisations listed in this chapter out of FRST research contract funds or their organisational overheads, since they are often representing the interests of New Zealand rather than those of their employers. The Government provides assistance through the International Science and Technology Linkages Fund (ISAT) in some of these cases.

### The International Technical Input Programme

The ITIP is a subprogramme of ISAT, which provides support for participation by scientists and technologists in international programmes of foreign relations, trade or policy significance to New Zealand. In July 2000 administration of the ITIP passed from MoRST to FRST. Table 3 lists ITIP support (\$86,000) to New Zealand scientists during the 1999/2000 financial year.

### The Technical Participation Programme

The Technical Participation Programme (TPP) is another subprogramme of ISAT. It is allocated on a contestable basis by MoRST to support science experts' input into areas of significant policy relevant for government policy advice. No TPP contracts were awarded for climate change topics in the 1999/2000 financial year since no applications met TPP funding criteria.

**Table 3: Support from ITIP 1999/00 Financial Year**

Meeting	Scientist
Executive Assembly, World Energy Council	Dr Rob Whitney, CRL Energy Ltd
IPCC TAR Lead Authors Meetings	Dr Peter Read, Read Consultancy Ltd
Montreal Process Meeting	Dr Paul McFarlane, FRI
UNEP Panel Meeting on Effects of Ozone on the Environment	Dr Richard McKenzie
IPCC TAR WG II Lead Authors' Meeting	Dr David Wratt, NIWA
IPCC Work as member of Bureau	Dr Martin Manning, NIWA
IPCC Two meetings, TAR Working group III	Assoc Prof Ralph Sims, Massey University
IPCC TAR WG II Lead Authors' Meeting	Dr Blair Fitzharris, University of Otago
IPCC TAR WG II Lead Authors' Meeting	Dr Alistair Woodward, University of Otago
IPCC TAR WG II Lead Authors' Meeting	Dr Richard Warrick, University of Waikato
IPCC TAR WG I Meeting	Dr Jim Salinger, NIWA
11th COP to the Montreal Protocol and 5th COP Vienna Convention	Mr Iain McGlinchy, private consultant

## Appendix 1

### Committee Activities for 2000/2001

#### *Committee meetings:*

- 29 March Review of past five years recommendations
- 29 June Planning of Annual Report and other business
- 2 October Input to policy process, "Kyoto and Beyond" special report.

#### *January 2000*

Convenor met with FRST Reference Group on Climate Change to discuss funding bids.

#### *February 2000*

Distribution of 1999 Annual Report and letters of introduction to incoming Ministers and party spokespeople on environment and research, science and technology matters.

#### *March 2000*

Transfer of Committee to MfE and according revision of Terms of Reference.

#### *April 2000*

Review of PGSF programmes and meeting with FRST to provide more detailed feedback.

Submission to Ministerial Inquiry into Electricity Industry.

#### *May 2000*

Distribution of information on climate change and ultraviolet radiation, supplementing research summaries contained in the 1999 Annual Report.

Meeting with Minister for Research, Science & Technology to discuss research gaps, industry involvement, and input by the Committee to policy development.

#### *June 2000*

Meeting between the Convenor and the Minister for Research, Science & Technology to discuss options for expanding the Committee's membership, ensuring clear communication of climate change issues to give direction and incentives to industry, and directing FRST to address research gaps and cross-portfolio climate change research.

Meeting between the Convenor and the Convenor of the Officials' Climate Change Steering Group to discuss opportunities to work across the science-policy interface.

#### *July 2000*

Organised and attended meeting between key stakeholders to discuss long-term sea-level monitoring issues, including responsibilities for database administration by LINZ.

Development and launch of web page for the Committee.

#### *August 2000*

Commencement of Annual Report 2000 and strategy document "Kyoto and Beyond".

Correspondence with Minister for Research, Science & Technology on funding priorities in climate change research, and suggestions to direct FRST to consider climate change as a priority investment across all relevant portfolios.

Invitation to New Zealand Energy Federation to discuss matters of common interest and identify opportunities for promotion and development of mitigation options.

#### *September 2000*

Revisions to financial information contained in draft annual report 2000.

Discussions with FRST on draft "Strategic Report on the Foundation's Climate Change Investment Portfolio" and recommendation of changes.

#### *October 2000*

Acting Convenor met with Climate Change Steering Committee of officials to present NSSCCC vision and key contacts.

Acting Convenor attended strategic planning workshops, organised by MAF, on research into nitrous oxide and methane inventory and mitigation options.

Acting Convenor met with FRST to correct financial information contained in draft FRST report "Strategic Report on the Foundation's Climate Change Investment Portfolio".

*November 2000*

Supply of financial information and analysis contained in draft "Kyoto and Beyond" report to MoRST.

Acting Convenor briefed Convenor of the Ministerial Group on Climate Change during UNFCCC conference in The Hague on recommendations contained in "Kyoto and Beyond".

On-going discussion with FRST on content of "Strategic Report on the Foundation's Climate Change Investment Portfolio".

*December 2000*

Correspondence with Minister for Research, Science & Technology on FRST report "Strategic Report on the Foundation's Climate Change Investment Portfolio" and arising communication and relationship issues.

Proposal sent to key stakeholders regarding development of a comprehensive and long-term sea-level monitoring programme.

*January 2001*

Publication of strategy report "Kyoto and Beyond", outlining key science issues and research priorities.

*February 2001*

Secretariat transferred from Wellington School of Medicine to MfE.

Meeting between Acting Convenor and FRST to discuss relationship between NSSCCC and FRST, and issues arising out of FRST report "Strategic Report on the Foundation's Climate Change Investment Portfolio".

*March 2001*

Contributions to and review of MfE summary report on climate change impacts on New Zealand by individual committee members.

*April 2001*

Organisation and presentations in collaboration with New Zealand Climate Committee and the Royal Society at seminar on key messages in IPCC TAR on Climate Change and relevance for New Zealand.

## Appendix 2

### Details of New Zealand Climate Change Research

Agency	PGS & T main SPO (abbreviated)	Programme Title	\$,000
<b>(I) Public Good Science &amp; Technology (PGS &amp; T) Research Funding 2000/01</b>			
<b>1. Climate change processes</b>			
a. Fundamental Understanding			
NIWA	Global	Atmospheric ozone, ultraviolet radiation and stratospheric change	1339
NIWA	Global	Ocean-atmosphere interactions	951
NIWA	Global	Greenhouse gases and climate change	828
NIWA	Global	Ocean variability of currents and water masses	748
NIWA	Global	(Global) climate variability, predictability and change	322
NIWA	Marine	Ocean ecosystems: their contribution to New Zealand marine productivity	314
NIWA	Global	Processes and interactions in the Antarctic atmosphere	311
UOA	Land	Contact, colonisation, environmental and economic change in pre-treaty Northern Aotearoa/New Zealand	86
IRL	Global	Sea-Ice and Southern Ocean processes	60
GNS	Global	Geological time and environmental change	48
MNZ	Peoples	Bridge and barrier: 800 years of Maori culture in Cook Strait	10
NIWA	Hazards	Floods and droughts: forecasting their occurrence and predicting their effects	9
<b>Total</b>			<b>5026</b>
b. Monitoring and Validation			
NIWA	Global	Nationally significant database: water resources and climate	850
GNS	Global	Geological time and environmental change	676
NIWA	Marine	Ocean ecosystems: their contribution to New Zealand marine productivity	314
VIC	Global	Regional palaeoclimates and climate modelling	298
NIWA	Global	Processes and interactions in the Antarctic atmosphere	289
LCR	Global	Greenhouse gas emissions from the terrestrial biosphere	243
UOA	Global	Palaeoclimate records from tree rings and speleotherms	160
PVT	Global	Climate change – the marine record from the South Pacific	100
PVT	Global	Ecology and palaeocology of New Zealand foraminifera	48
NIWA	Hazards	Natural and physical hazards affecting coastal margins and the Continental shelf	23
<b>Total</b>			<b>3001</b>
c. Predictions, Scenarios and Options Analysis			
NIWA	Global	Greenhouse gases and climate change	512
NIWA	Marine	Ocean ecosystems: their contribution to New Zealand marine productivity	314
NIWA	Global	Ocean-atmosphere interactions	82
NIWA	Global	Ocean variability of currents and water masses	75
NIWA	Hazards	Natural physical hazards affecting coastal margins and the Continental shelf	52
<b>Total</b>			<b>1035</b>
<b>2. Effects of climate change</b>			
a. Fundamental Understanding			
AGR	Global	Ecosystem change processes and their management	583
GNS	Global	Geological time and environmental change	252
LCR	Global	Carbon and biodiversity dynamics in forests and shrublands	100

UOO/UOA/HRC	Health	Population health impacts of global environmental change	75
CRF	Sustainable	Knowledge management systems for sustainable crop production	50
NIWA	Land	Antarctic aquatic ecosystems	50
NIWA	Marine	Sustainability of sea bird populations in the Southern Ocean	37
IRL	Global	UV-B effects on bottom ice algae	25
UOA	Built	Life-cycle resource efficiency in the building industry	25
NIWA	Land	Environmental hydrology and habitat dynamics	25
NIWA	Global	Active seabed processes	21
BRA	Built	Building innovation	14
PVT	Energy	The extraction of energy from waste water	10
NIWA	Hazards	Floods and droughts: forecasting their occurrence and predicting their effects	9
<b>TOTAL</b>			<b>1276</b>

b. Monitoring and Validation

AGR	Global	Ecosystem change processes and their management	583
GNS	Global	Geological time and environmental change	224
UOA	Global	Palaeoclimate records from tree-rings and speleotherms	160
HRT	Sustainable	Knowledge-based tools for environmental action	132
BRA	Built	Better built environment	100
LCR	Global	Carbon and biodiversity dynamics in forests and shrublands	100
PVT	Land	Fossil avifaunas – tracking the development of current ecosystems	80
NIWA	Land	Antarctic aquatic ecosystems	50
LCR	Global	Landscape evolution: controls on sediment and nutrient fluxes	40
NIWA	Land	Environmental hydrology and habitat dynamics	25
UOA	Built	Life cycle resource efficiency in the building industry	25
PVT	Global	Time-course of Holocene vertebrate extinctions	25
IRL	Global	UV-B effects on bottom ice algae	25
NIWA	Land	River ecosystems and land use interactions	20
OPS	Cities	Sustainable transportation	17
PVT	Energy	The extraction of energy from waste water	10
MNZ	Peoples	Bridge and barrier: 800 years of Maori culture in Cook Strait	10
<b>TOTAL</b>			<b>1626</b>

c. Predictions, Scenarios and Options Analysis

NIWA	Global	Climate impacts on land use	364
UOW	Global	The CLIMPACTS programme	240
BRA	Built	Better built environment	100
NIWA	Global	Atmospheric ozone, ultraviolet radiation and stratospheric change	94
UOA	Built	Life cycle resource efficiency in the building industry	25
NIWA	Hazards	Natural physical hazards affecting coastal margins and the Continental shelf	25
NIWA	Land	Environmental hydrology and habitat dynamics	25
BRA	Built	Building innovation	14
<b>TOTAL</b>			<b>887</b>

### 3. Responses to climate change

a. Fundamental Understanding

AGR	Animal	Advanced nutritional and phytochemical solutions for premium products	514
FR	Global	Mitigation of climate change	473
NIWA	Global	Ocean variability of currents and water masses	357
LCR	Global	Carbon and biodiversity dynamics in forest and shrublands	325
LCR	Global	Greenhouse gas emissions from the terrestrial biosphere	111
CRA	Energy	Environmentally sustainable and efficient mining and energy from coal and other fuels	89
NIWA	Global	Processes and interactions in the Antarctic atmosphere	64
DRC	Animal	Sustainable dairy systems to meet consumer demand	56
NIWA	Land	Environmental hydrology and habitat dynamics	25
LCR	Global	Landscape evolution: controls on sediment and nutrient fluxes	20

PVT	Cities	Identifying factors to change peoples' transport use	13
NIWA	Hazards	Floods and droughts: forecasting their occurrence and predicting their effects	9
<b>TOTAL</b>			<b>2056</b>

b. Monitoring and Validation

LCR	Global	Greenhouse gas emissions from the terrestrial biosphere	911
LCR	Global	Carbon and biodiversity dynamics in forests and shrublands	325
FR	Global	Mitigation of climate change	237
DRC	Animal	Sustainable dairy systems to meet consumer demand	112
NIWA	Global	Climate variability, predictability and change	78
PVT	New Wealth	Improved sunscreens	75
NIWA	Energy	Resource assessment for New Zealand wind farms	60
HRT	Fruit	National Climate Laboratory: a means to new ends	50
LCR	Global	Landscape evolution: controls on sediment and nutrient fluxes	20
PVT	Cities	Identifying factors to change peoples' transport use	13
<b>TOTAL</b>			<b>1881</b>

c. Predictions, Scenarios and Options Analysis

HRT	Sustainable	Knowledge-based tools for environmental action	268
LCR	Global	Greenhouse gas emissions from the terrestrial biosphere	216
NIWA	Global	Climate variability, predictability and change	200
NIWA	Global	Greenhouse gases and climate change	172
MAU	Energy	Promoting Biofuel and other sustainable technology	172
DRC	Animal	Sustainable dairy systems to meet consumer demand	112
CRA	Energy	Environmentally sustainable and efficient mining and energy from coal and other fuels	89
NIWA	Global	Processes and interactions in the Antarctic atmosphere	70
NIWA	Global	Atmospheric ozone, ultraviolet radiation and stratospheric change	56
CRF	Sustainable	Knowledge management systems for sustainable crop production	50
IRL	Energy	Advanced solar technologies	40
UOO	Energy	Process integration and energy efficiency	25
LCR	Global	Landscape evolution: controls on sediment and nutrient fluxes	20
PVT	Cities	Identifying factors to change people's transport use	13
<b>TOTAL</b>			<b>1503</b>

## (II) PGS & T Non-Specific Output Funding 2000/01

### 1. Climate change processes

a. Fundamental Understanding

NIWA	Modes of temperature variability in the Southwest Pacific	9
<b>TOTAL</b>		<b>9</b>

b. Monitoring and Validation

GNS	Silicon-32 dating of glacial ice	70
GNS	GNS on-line	60
GNS	Late Pleistocene climate reconstruction and probabilistic volcanic assessment	60
<b>TOTAL</b>		<b>190</b>

c. Predictions, Scenarios and Options Analysis

NIWA	Phytoplankton and climate	16
<b>TOTAL</b>		<b>16</b>

### 2. Effects of climate change

b. Monitoring and Validation

GNS	Tracking landscape change	50
<b>TOTAL</b>		<b>50</b>

c.	Predictions, Scenarios and Options Analysis		
LCR	Carbon sequestration by shrublands		150
CRF	Simulation models for the assessment of climate change impacts on crop production and pest and disease risk		105
		<b>TOTAL</b>	<b>255</b>

### 3. Responses to climate change

#### a. Fundamental Understanding

AGR	Microbial inhibitors of ruminant methane		130
LCR	Soil erosion effects on the national carbon budget		20
		<b>TOTAL</b>	<b>150</b>

#### b. Monitoring and Validation

NIWA	National Climate Centre		185
NIWA	Development of effective greenhouse gas management strategies		60
FR	New remote sensing tools for precision forest inventory		10
		<b>TOTAL</b>	<b>255</b>

#### c. Predictions, Scenarios and Options

LCR	Spatial extrapolation of New Zealand's net greenhouse gas emissions		25
LCR	Erosion-related soil carbon losses		20
		<b>TOTAL</b>	<b>45</b>

## (III) Marsden Fund 1999/00

### 1. Climate change processes

#### a. Fundamental Understanding

UOA	Palaeoclimate determined from isotopic compositions of hydrated water in volcanic shards in New Zealand		85
UOO	Water clusters in the atmosphere		81
UOW	New Zealand palaeoclimate record applied to ice age theory		54
UOC	Gravity wave processes in the atmosphere		50
PVT	Palaeoclimate from the Ocean Drilling Project in the Bounty Trough		38
GNS	A long terrestrial quaternary record of environmental change from Auckland: climate reconstruction and volcanic hazards assessment		19
		<b>TOTAL</b>	<b>327</b>

### 2. Effects of climate change

#### a. Fundamental Understanding

LIN	Slices through time: past climate from ancient Kauri ( <i>Agathis Australis</i> ) tree-rings		145
		<b>TOTAL</b>	<b>145</b>

## (IV) Universities 1999/00

### 1. Climate change processes

#### a. Fundamental Understanding

UOW	Quaternary environmental change using palaeopedology and tephrochronology in the Waikato/Bay of Plenty		40
UOW	Palynological evidence for glacial – interglacial climatic instability on the West Coast		20
UOA	Holocene evolution of the Ross Sea Coast		20

UOO	Younger Dryas environmental change in the South Island	13
MAU	Environmental history of the Hawke's Bay	12
UOA	Palaeo-reconstruction of the El Niño-Southern Oscillation (ENSO) from sub-fossil kauri	11
UOA	Deciphering the glacial history of Northern Victoria Land, Antarctica	8
VIC	Temporal and spatial distribution of dust particles in the atmosphere between Australia and New Zealand	5
	<b>TOTAL</b>	<b>129</b>

b. Monitoring and Validation

VIC	Cape Roberts Project	140
UOW	Long-term climate change – Ocean cores	40
UOW	Climate evolution of New Zealand during the last glacial – interglacial transition	40
UOA	Ecological history of the Islands of the Hauraki Gulf/prehistory of the Hauraki Gulf	10
UOC	The scaling of physiological responses to global environmental change from the leaf to the canopy	5
	<b>TOTAL</b>	<b>235</b>

c. Predictions, Scenarios and Options Analysis

UOA	Climate change and water resources in the Auckland region	3
	<b>TOTAL</b>	<b>3</b>

## 2. Effects of climate change

b. Monitoring and Validation

UOO	Responses of seasonal snow to climate change	25
UOO	Response of glaciers to climate change	20
	<b>TOTAL</b>	<b>45</b>

## 3. Responses to climate change

a. Fundamental Understanding

LIN	Nitrous oxide emission and methane production/consumption by arable agriculture. Ph.D student	22
LIN	Influence of soil water potential, temperature and gas composition on nitrous oxide emissions. Ph.D student	22
	<b>TOTAL</b>	<b>44</b>

b. Monitoring and Validation

LIN	Light and water stress on lucerne productivity and quality. Ph.D student	5
LIN	Influence of climate and disturbance on Beech treelines. Ph.D student	11
	<b>TOTAL</b>	<b>16</b>

c. Predictions, Scenarios and Options Analysis

LIN	Climate reconstruction using pink pine. Ph.D student	22
	<b>TOTAL</b>	<b>22</b>

## (V) Government Department Operational Research 1999/00

### 3. Responses to climate change

a. Fundamental Understanding

MAF	Ruminant Methane (AGR)	84
MfE	Pilot study to measure nitrous oxide emissions from livestock urine on pasture (AGR)	58
MfE	Nitrous oxide emissions from animal urine applied to two Canterbury soils (LIN)	50
MfE	New Zealand Carbon project (LCR/FR)	20
EECA	Household energy end-use project (BRANZ/IRL/TRP)	7
EECA	Energy efficiency resource assessment	5
	<b>TOTAL</b>	<b>224</b>

b. Monitoring and Validation

MfE	International Review of the New Zealand Carbon Project	135
MfE	New Zealand Carbon Project (LCR/FR)	130
MfE	Completion of Landcover database	70
MOT	Greenhouse gas emissions from road transport	69
MAF	Sustainable irrigation – reductions in energy use and energy efficiency gains (LIN VEN)	28
MOT	Vehicle Fleet Emissions Control Strategy (VFECS)	25
MfE	Nitrous oxide scoping project and facilitation of N2O net (AGR)	15
EECA	Update on the viability and economic benefits of minimum energy performance standards (MEPS) and mandatory labelling	10
EECA	Study tour on voluntary agreements	7
MAF	Nitrous oxide emissions review (LIN)	6
MfE	Industrial process and solvent use emission update	6
EECA	IEA indicators programme	5
EECA	Rideshare (carpooling) development and monitoring	2
EECA	Office equipment programme	2
	<b>TOTAL</b>	<b>510</b>

c. Predictions, Scenarios and Options Analysis

MfE	Economic modelling, interpretation and analysis	70
EECA	Assessment of status and options for implementation of mandatory MEPS and labelling regimes	3
EECA	Assessment of future options for the Energy Saver Fund	2
	<b>TOTAL</b>	<b>75</b>

**(VI) Regional Councils Research 1999/00**

**3. Responses to climate change**

b. Monitoring and Validation

All Councils	Hydrometric and climate measurements for PGSF programme. Nationally significant database: Water resources and Climate	100
Environment Waikato	Natural Emissions for the Waikato region	30
Christchurch City Council	Target Zero – a waste minimisation initiative	20
Taranaki	Emissions inventory for the Taranaki region	2
	<b>TOTAL</b>	<b>152</b>

c. Predictions, Scenarios and Options Analysis

Marlborough District Council	Climate risks to expansion in Viticulture - quantitative risk assessment of climatic impacts	35
Environment Canterbury	Contribution to CLIMPACTS programme	5
Environment Waikato	Contribution to the CLIMPACTS programme	5
	<b>TOTAL</b>	<b>45</b>

## VII Private Researchers 1999/00

### 3. Responses to climate change

#### a. Fundamental Understanding

NZFMRA	A qualitative study of nitrogen mineralisation (LIN)	30
NZFMRA	Investigation into nitrogen cycling and efficiency of nitrogen utilisation in dryland hill pasture (MAU)	30
NZFMRA	Evaluation of several novel procedures for estimating nitrogen supplying capacity of arable soils (CRF)	20
BOP Fertiliser Ltd	Ammonia losses (LIN)	20
NZFMRA	Nitrogen transformations in soil and plant at cold temperatures (LIN)	14

**TOTAL 114**

#### b. Monitoring and Validation

New Zealand Forestry Sector	Alternative energy sources, building materials and industrial processes for improved energy efficiency, reduced emissions and greater sustainability	300
NZDRI/NZDB	Carbon Dioxide/Methane emissions for the New Zealand Dairy Industry	231
New Zealand Cement Industry	Alternative materials and fuels for greater energy efficiency and reduced emissions	200
Hydro-Electricity Industry	Hydrometric measurements for PGSF programme. Nationally significant database: Water resources and Climate	100
CRL Ltd	Voluntary agreements and Energy Federation project	50
CRL Ltd	IEA Greenhouse Gas R & D Programme	50
NZDRI/NZDB	New technology (Energy Efficiency)	49
CRL Ltd	Advanced combustion and gasification technologies	10
New Zealand Lottery Board and Bruce Trust	Influence of climate on beech tree lines	7

**TOTAL 997**

#### c. Predictions, Scenarios and Options Analysis

New Zealand Electricity Industry	Energy efficiency and alternative energy sources	700
New Zealand Forestry Sector	Alternative energy sources, building materials and industrial processes for improved energy efficiency, reduced emissions and greater sustainability	200
Central Power Trust	Renewable energy projects in rural communities	103
New Zealand Cement Industry	Alternative materials and fuels for greater energy efficiency and reduced emissions	100
CRL Ltd	Information dissemination on greenhouse issues	30
New Zealand Consumer Association	Solar Water Heater Tests	12
Powerflow Technologies Ltd	GRIF project (MAU) Rural community power supply schemes using renewable energy	12
Meridian Energy Ltd	GRIF project (MAU) Clean Development Mechanism business opportunities	12
C. Alma Baker Trust	Community Power Supplies – renewable energy – monitoring project at Limestone Downs (MAU)	8
Worley Consultants	Post graduate scholarships to look at renewable energy for community power supplies (MAU)	6

**TOTAL 1183**

## Appendix 3

### Bibliography of New Zealand Climate Change Research

The following bibliography covers most of the scientific papers and major reports published in 1999 and 2000 related to climate change published in New Zealand or involving New Zealand authors. The material was collated at the end of 2000. Some 1999 publications were included in the 1999 Annual Report of the National Science Strategy Committee for Climate Change.

The principal database searched was the Sci-Tech Index (SIRIS), a collective CRI database of scientific papers about New Zealand or by New Zealand authors. Additional information was obtained from MfE, overseas databases, committee members and other sources.

Because of the extensive nature of the research relevant to climate change issues and the decentralisation of bibliographic databases in New Zealand, it has not been practicable to ensure that all New Zealand research has been captured.

The assistance of Ms Kerrie Goold, NIWA, in producing this bibliography is gratefully acknowledged.

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## Appendix 4

### Glossary of Acronyms, Abbreviations and Scientific Terms

$^{13}\text{C}$ ,  $^{14}\text{C}$  – Isotopes of carbon

**Aerosols** – Small airborne particles which can be either natural in origin or produced by human activities (such as fossil fuel combustion)

**APN** – Asia Pacific Network

**Argo** – A global array of drifting instruments for measuring the temperature and salinity of the upper 2000m of the ocean.

**BRANZ** – Building Research Association of New Zealand

**C3 plants** – Plants that produce a three-carbon compound during photosynthesis, including most trees and agricultural crops such as rice, wheat, soybeans, potatoes, and vegetables.

**C4 plants** – Plants that produce a four-carbon compound during photosynthesis; mainly of tropical origin, including grasses and the agriculturally important crops maize, sugar cane, millet, and sorghum.

**Carbon dioxide fertilization** - Enhancement of the growth of plants as a result of increased atmospheric carbon dioxide ( $\text{CO}_2$ ) concentration. Depending on their mechanism of photosynthesis, certain types of plants are more sensitive to changes in atmospheric  $\text{CO}_2$  concentration. In particular, C3 plants generally show a larger response to  $\text{CO}_2$  than C4 plants.

**CEARS** – Centre for Environmental and Resource Studies

**CFC** – See chlorofluorocarbons

**$\text{CH}_4$**  – Methane, a greenhouse gas

**Chlorofluorocarbons** – (CFCs) The synthetic chemical compound identified as the major cause of stratospheric ozone depletion. CFCs are also greenhouse gases.

**CLIMPACTS** – Climate Variations and Environmental Effects

**CLIPS** – Climate Information and Prediction Services

**CLIVAR** – Climate Variability and Predictability

**$\text{CO}_2$**  – Carbon dioxide, a greenhouse gas

**COP** – Conference of the Parties to the Framework Convention on Climate Change (FCCC)

**CRF** – NZ Institute for Crop and Food Research Limited

**CRI** – Crown Research Institute

**CRL** – Coal Research Ltd

**Cryosphere** – Perennially frozen parts of the earth including land-ice, sea-ice, permanent snow cover and permafrost

**EECA** – Energy Efficiency and Conservation Authority

**El Niño** – A recurrent set of climate conditions in the Pacific region marked by warming of surface ocean water off the western coast of South America which also extends westward for several thousand kilometres across the equatorial Pacific. It is usually accompanied by heavy rainfall in coastal Peru and Chile, drought in Australia, a more complex pattern of wetter and drier than average conditions over New Zealand and South Pacific islands, and cooler than normal conditions in New Zealand.

**ENSO** – El Niño / Southern oscillation. The recurring sequence of El Niño and La Niña

**FCCC** – Framework Convention on Climate Change

**FRST** – see The Foundation

**GCM** – Global Circulation Model, a complex global climate model

**GEF** – Global Environmental Facility

**GEWEX** – Global Energy and Water Cycle Experiment

**GHG** – Greenhouse Gas

**GLOBEC** – Global Ocean Ecosystem Dynamics

**GLOS** – Global Sea Level Observing System

**GNS** – Institute of Geological and Nuclear Sciences Limited

**GOOS** – Global Ocean Observing System

**Green Package** – The Budget “Green Package” was announced by the government in 1996. Through this Green Package, additional funding was made available to assist the government achieve its environmental and conservation objectives, including addressing the risks of climate change.

**GSN** – GCOS Surface Network

**GTOS** – Global Terrestrial Observing System

**GUAN** – GCOS baseline upper air approach

**GWP** – Global Warming Potential, a measure of the relative globally averaged warming effect arising from emissions of a particular greenhouse gas, compared with the effect of an emission of the same weight of  $\text{CO}_2$ . GWP depends on the time horizon (e.g., 20, 50, or 100 years) over which the warming is being considered.

**$\text{H}_2$**  – Hydrogen gas

**HCFC** – Hydrochlorofluorocarbons, a group of greenhouse gases

**HFC** – Hydrofluorocarbons, a group of greenhouse gases

**HRC** – Health Research Council

**HRT** – The Horticulture and Food Research Institute of New Zealand Limited

**ICSU** – International Council for Science

**IDCEC** – Institutional Dimensions of Global Environmental Change

**IEA** – International Energy Agency

**IGAC** – International Global Atmospheric Chemistry

**IGBP** – International Geosphere-Biosphere Programme

**IGCI** – International Global Change Institute

**IGU** – International Geographical Union

**IHDP** – International Human Dimensions Programme

**IOC** – Intergovernmental Oceanographic Commission

**IPCC** – Intergovernmental Panel on Climate Change

**IRI** – International Research Institute for Climate Prediction

**IRL** – Industrial Research Limited

**ISAT** – International Science and Technology Fund

**ITIP** – International Technical Input Programme

**JGOFS** – Joint Global Ocean Flux Studies

**Kyoto Protocol** – International agreement to limit emissions of greenhouse gases under the FCCC

**La Niña** – A recurrent set of climate conditions in the Pacific region marked by cooler than normal surface ocean temperatures in the eastern equatorial Pacific. These tropical ocean temperature anomalies are approximately opposite to those during an El Niño. Warm moist easterly or north easterly conditions are more frequent than usual over New Zealand during a La Niña, and usually result in wetter than normal conditions in the north and east of the North Island.

**LCR** – Landcare Research New Zealand Limited

**LIN** – Lincoln University

**LINZ** – Land Information New Zealand

**LOICZ** – Land-Ocean Interactions in the Coastal Zone

**LUC** – Land Use Classes

**LUCC** – Land-Use and Land-Cover Change

**MAF** – Ministry of Agriculture and Forestry

**MAU** – Massey University

**MfE** – Ministry for the Environment

**MED** – Ministry for Economic Development, formerly Ministry of Commerce

**Montreal Protocol** – International agreement to reduce emissions of ozone-depleting substances

**MoRST** – Ministry of Research, Science and Technology

**MoT** – Ministry of Transport

**N<sub>2</sub>O** – Nitrous oxide, a greenhouse gas

**NASA** – National Aeronautical and Space Agency

**NDSC** – Network for the Detection of Stratospheric Change

**NERF** – New Economy Research Fund

**NIWA** – National Institute of Water & Atmospheric Research Limited

**NSOF** – Non-Specific Output Funding

**NSSCCC** – National Science Strategy Committee for Climate Change

**NZAS/Comalco** – New Zealand Aluminium Smelter

**NZDRI** – New Zealand Dairy Research Institute

**O<sub>3</sub>** – Ozone

**OPEC** – Oil Producing and Exporting Countries

**PAGES** – Past Global Changes

**Palaeo** – a prefix which means “past”

**PDO** – Pacific Decadal Oscillation

**PFC** – Perfluorocarbons, a group of greenhouse gases

**PGS&T** – Public Good Science and Technology

**PIC** – Pacific Island Countries

**PICCAP** – Pacific Island Climate Change Assistance Programme

**PVT** – Private

**Reservoir** – Component(s) of the climate system where a greenhouse gas or a precursor is stored.

**SAR** – Second Assessment Report of the IPCC

**SARCS** – Southeast Asian Research Committee for START

**SBSTA** – Subsidiary Body for Scientific and Technological Advice

**Sink** – Any process, activity or mechanism which removes a greenhouse gas, aerosol or a precursor of a greenhouse gas from the atmosphere.

**SOE** – State Owned Enterprise

**SPARC** – Stratospheric Processes and their Role in Climate

**SPC** – South Pacific Commission now known as the Secretariat of the Pacific Community

**SPM** – Summary for policymakers

**SPO** – Strategic Portfolio Outline

**SPREP** – South Pacific Regional Environment Programme

**START-Oceania** – An international organisation designed to foster research and training in global issues in the region

**Stratosphere** – The layer of the Earth’s atmosphere directly above the troposphere, within which is a high concentration of ozone, called the ozone layer.

**TAR** – Third Assessment Report of the IPCC

**The Committee** – the National Science Strategy Committee for Climate Change

**The Foundation** – Foundation for Research, Science and Technology

**TPP** - Technical Participation Programme

**Troposphere** – The lowest layer of the Earth’s atmosphere (from the surface to 8–16 km altitude) within which the weather occurs

**UNDP** – United Nations Development Programme

**UNEP** – United Nations Environmental Programme

**UNFCCC** – United Nations Framework Convention on Climate Change – also known as FCCC

**UOA** – University of Auckland

**UOC** – University of Canterbury

**UOO** – University of Otago

**UOW** – University of Waikato

**UV** – Ultraviolet

**UV-B** – Solar radiation at wave lengths of 290–320 nm, which are capable of damaging biological systems. Ozone depletion in the stratosphere can lead to increased ground level UV-B.

**Valdivia Group countries** – Argentina, Australia, Chile, New Zealand, South Africa, Uruguay

**VIC** – Victoria University of Wellington

**WCRP** – World Climate Research Programme

**WMO** – World Meteorological Organization

**WOCE** – World Ocean Circulation Experiment