Lowy Institute Paper 12

heating up the planet

CLIMATE CHANGE AND SECURITY

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LOWY INSTITUTE
FOR INTERNATIONAL POLICY

First published for
Lowy Institute for International Policy 2006

LONGUEVILLE
MEDIA

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Tel. (+ 61 2) 9362 8441

Cover and text design by Shane Grantham
Printed and bound in Australia
Typeset in Esprit Book 10

National Library of Australia
Cataloguing-in-Publication data

Dupont, Alan, 1950- .
Heating up the planet : climate change and security.

1st ed.
Bibliography.
ISBN 1 921004 22 3.

1. Climatic changes - Government policy - Australia. 2. Environmental policy - Australia. 3. National security - Australia. 4. Environmental degradation - Political aspects. I. Lowy Institute for International Policy. II. Title.
(Series : Lowy Institute papers ; 12).

363.707

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Executive summary

In this Lowy Paper we argue that there is no longer much doubt that the world is facing a prolonged period of planetary warming, largely fuelled by modern lifestyles, which is unprecedented in human history in terms of its magnitude and probable environmental consequences. With a few notable exceptions, even sceptics now seem prepared to accept the validity of the basic science underpinning climate change forecasts.

Crucially, however, there is no consensus about appropriate strategies for dealing with the consequences of climate change, primarily because there is no agreement about its seriousness for international security. The reality is that climate change of the order and time frames predicted by climate scientists poses fundamental questions of human security, survival and the stability of nation states which necessitate judgments about political and strategic risk as well as economic cost.

The central problem is the rate at which temperatures are increasing rather than the absolute size of differential warming. Spread over several centuries, or a millennium, temperature rises of several degrees could probably be managed without political instability or major threats to commerce, agriculture and infrastructure. Compressed within the space of a single century, global warming will present far more daunting challenges of human and biological adaptation, especially for natural ecosystems which typically evolve over hundreds of thousands and millions of years.

Our principal conclusion is that the wider security implications of climate change have been largely ignored and seriously underestimated in public policy, academia and the media. Climate change will complicate and threaten Australia's security environment in several ways. First, weather extremes and greater fluctuations in rainfall and temperatures have the capacity to refashion the region's productive landscape and exacerbate food, water and energy scarcities in a relatively short time span. Sea-level rise is of particular concern because of the density of coastal populations and the potential for the large-scale displacement of people in Asia.

Secondly, climate change will contribute to destabilising, unregulated population movements in Asia and the Pacific. Most of these flows are likely to be internal, but the ripple effects will be felt beyond the borders of the states most affected, requiring cooperative regional solutions. Thirdly, more extreme weather patterns will result in greater death and destruction from natural disasters, adding to the burden on poorer countries and stretching the resources and coping ability of even the most developed nations. Fourthly, extreme weather events and climate-related disasters will not only trigger short-term disease spikes but also have more enduring health security consequences, since some infectious diseases will become more widespread as the planet heats up.

Fifthly, even if not catastrophic in themselves, the cumulative impact of rising temperatures, sea levels and more mega droughts on agriculture, fresh water and energy could threaten the security of states in Australia's neighbourhood by reducing their carrying capacity below a minimum threshold, thereby undermining the legitimacy and response capabilities of their governments and jeopardising the security of their citizens. Where climate change coincides with other transnational challenges to security, such as terrorism or pandemic diseases, or adds to pre-existing ethnic and social tensions, then the impact will be magnified. However, state collapse and destabilising internal conflicts is a more likely outcome than interstate war. For a handful of small, low-lying Pacific nations, climate change is the ultimate security threat, since rising sea-levels will eventually make their countries uninhabitable.

Far from exaggerating the impact of climate change it is possible that scientists may have underestimated the threat. If this were to be

the case, the most likely catalysts are a collapse of the Thermohaline Circulation, which could have a detrimental effect on the growth of carbon dioxide in the atmosphere and life in the ocean, and the rapid recession of land-based glaciers and polar ice, which could dramatically increase sea-levels. Abrupt climate change could push the planet's fragile and already stretched ecosystem past an environmental tipping point from which there will be no winners.

In the concluding chapter we make six recommendations for identifying and ameliorating the security consequences of climate change.

Recommendation 1

The Federal Government should encourage a more strategic approach to climate change and establish an interdepartmental task force to examine the policy connections between climate change and national security, with particular reference to the nation's food, water, energy, health and environmental vulnerabilities, disaster planning and unregulated population movements.

Protecting and stabilising our climate is a legitimate objective of national security policy, since human survival is dependent on the health of the biosphere and the coupled ocean-atmosphere system. The public and policy discourse on climate change in Australia has been dominated by arguments about the reliability of the scientific data and the seriousness of climate change. But there has been a notable absence of any real attempt to situate the climate change debate within a broader policy framework or to assess strategic risk, in which the probability of an adverse climate event is measured against the magnitude of its impact. It is essential that we do so and that government takes the lead in encouraging a more holistic approach to climate change, which includes a comprehensive assessment of its implications for national and international security.

The Federal Government should establish an interdepartmental task force to examine, in detail, the policy connections between climate change and national security, with particular reference to the nation's food, water, energy, health and environmental vulnerabilities, disaster planning and unregulated population movements. These studies could be extended geographically, to include the wider region, and functionally to include inputs from relevant non-government expert groups in the fields of climate science, agriculture, energy, health, immigration, defence, foreign policy and emergency management.

Recommendation 2

It is time for the Australian Intelligence Community to focus on climate-change risk and to mainstream the study of this emerging challenge to security.

The Government ought to pay greater attention to the national security implications of climate change. This will require attitudinal change and a willingness to incorporate the strategic, foreign policy and resource implications of climate-induced extreme weather events, sea-level rise and environmental refugees into national security planning.

It is time for the Australian Intelligence Community to focus on climate-change risk and to mainstream the study of this emerging challenge to security. The Office of National Assessments could initiate this process by coordinating an agency-wide, all-source assessment of the climate-change risk to Australia drawing upon the full intellectual resources of the nation. In the longer term, the intelligence community needs to strengthen its analytical capabilities in this field by recruiting more people with backgrounds in science, agronomy, environmental studies and infectious diseases, along with strategists capable of applying multi-disciplinary approaches to the study of climate change.

Recommendation 3

Good policy assumes the ability to conceptualise the problem of climate change in its entirety rather than in a compartmentalised way. Governments — federal state and local — need to think about better ways of growing the intellectual resources to develop this capacity.

One problem is that our education system is not producing sufficient numbers of students and graduates with the requisite skills to effectively analyse the causes and consequences of climate change. The problem is both conceptual and structural. Conceptually, strategic and international security studies in Australia is still overwhelmingly concerned with military conflict and this bias is reflected in our universities and teaching institutions.

Structurally, the study of climate change is very stove-piped. Climate scientists see the issue primarily through the lens of physical science, economists focus on cost-benefit calculations, environmentalists and business sceptics argue about desirable levels of greenhouse-gas emissions and appropriate remedies, while strategists have largely ignored the subject altogether. But good policy assumes the ability to see the problem in its entirety rather than in a compartmentalised way. Governments in this country — federal, state and local — need to think about better ways of growing the intellectual resources to develop this capacity.

They could start by providing incentives for universities and research institutes to ramp up the study of climate change in all its manifestations and to contribute solutions to an issue that will have increased policy salience in the decades ahead. Internationally, there are emerging institutional structures designed to promote ‘sustainability science’, where the study of economics, engineering and the social and physical sciences is integrated to achieve a better understanding of real world problems. The Australian Academy of Science has outlined a ‘blueprint’ for how such science might be undertaken and this interdisciplinary approach would be ideally suited to the study of climate change.

Recommendation 4

Australia should take the lead in working with like minded Asia–Pacific governments to examine the implications of climate change for regional security and stability.

In assessing the threat to national security from climate change it is abundantly clear that Australia cannot quarantine itself from the international impact because climate change, by definition, is a global problem. Glacial melt in the polar ice cap will raise the seas around Australia as much as Europe and North America, and fossil fuel emissions in China and India will affect our climate as well as theirs.

It follows, therefore, that climate change responses require a high degree of international cooperation if they are to have any prospect of being effective. Both the Kyoto Protocol and Asia–Pacific Partnership on Clean Development and Climate explicitly recognise this reality. What is lacking, however, is agreement on how to identify, ameliorate and manage the security consequences. Australia should take a leadership role here, working with like minded Asia–Pacific governments to examine the implications of climate change for regional security and stability. This could be done bilaterally, as well as multilaterally, and follow the same basic pattern as our cooperation with the region on counter-terrorism and HIV/AIDS.

Examples of what might be discussed are: refining natural disaster and response mechanisms; identifying which areas are most likely to be affected by sea-level rise and developing programs to relocate people from threatened areas; improving climate forecasting; fostering more efficient water and energy use; assessing the impact on fish stocks and agriculture; studying the implications of rising temperatures on the spread of infectious diseases and of sea-level rise on maritime disputes.

Recommendation 5

Policy makers must factor climate wild cards into their security calculations and alternative futures planning and 'think the unthinkable'.

Particular attention should be given to the climate wild cards discussed in this Lowy Paper. Even if the probability of their occurrence is low, their potential impact could be very high indeed, and for this reason policy makers ought to factor them into their security calculations and alternative futures planning.

Priority should be given to the consequences of a collapse, or slowing, of the Thermohaline Circulation and worst case scenarios of glacial and ice-cap melt. There has been insufficient study of the effect of changes to the Circulation on the southern hemisphere or of rising temperatures on the Antarctic continent. These are critical issues for Australia and they warrant the establishment of a task force to explore the science as well as the potential security fallout. Like Peter Schwartz and Doug Randall, the government needs to encourage our intelligence agencies, universities and research institutes to 'think the unthinkable' as part of a broad strategy to prepare the country for a very different climate future.

Recommendation 6

The most effective way of ameliorating the security risk of prospective climate change is to reduce the level of greenhouse gases that are responsible for heating up the planet.

Although this Lowy Paper has deliberately not canvassed the wider economic, social and environmental aspects of climate change, it is clear that the most effective way of ameliorating the security risk is to reduce the level of greenhouse gases that are responsible for heating up the planet.

However, it is difficult to see how greenhouse-gas emissions can be substantially reduced this century, the precursor to regaining climate equilibrium in the next, without a fundamental transformation of our approach to energy use. This will require technological improvements encompassing cleaner coal and fuel efficient hybrid cars, as well as the increased use of gas, nuclear power and renewable sources of energy. A continuation of our present reliance on fossil fuels will inevitably warm the atmosphere of the planet to levels that will place unprecedented stress on the earth's ecological fabric and challenge the adaptive capacities of future generations.

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Acknowledgments

This collaboration has been long in the making and has benefited greatly from interviews with prominent scholars in the field of climate science as well as constructive and insightful comments from a number of colleagues. We are particularly grateful to Professors Michael Oppenheimer from Princeton University and Stephen Schneider from the University of California (Los Angeles) for making themselves available to discuss the issues covered in this Lowy Paper during the course of a field trip in November 2005. Professor Peter Curson, from Macquarie University, Dr. Barry Pittock, formerly of the CSIRO and Dr. Kevin Walsh from Melbourne University, cast a collective critical eye over an earlier iteration and made many helpful suggestions for improvements. Joanne Bottcher, at the Lowy Institute, provided a seemingly inexhaustible list of reference material and sage advice on formatting and style. Finally, our thanks go to Jonathan Lusthaus, our tireless but much over-worked research assistant. Without him this Lowy Paper may not have seen the light of day. Any errors of fact or interpretation are, of course, the responsibility of the authors.

List of acronyms

ATHC	Atlantic Thermohaline Circulation
CSIRO	Commonwealth Scientific and Industrial Research Organisation
ERS	Economic Research Service (US Department of Agriculture)
IPCC	Intergovernmental Panel on Climate Change
ppmv	parts per million by volume
UNHCR	United Nations High Commission for Refugees

Introduction

There are many historical examples of climate shifts or extremes of weather triggering conflict and even contributing to the rise and fall of civilisations and nations. Growing aridity and frigid temperatures from a prolonged cold snap caused Huns and German tribes to surge across the Volga and Rhine into milder Gaul during the fourth century, eventually leading to the sack of Rome by Visigoths, while Muslim expansion into the Mediterranean and southern Europe in the eighth century was to some extent driven by drought in the Middle East. The Viking community in Greenland died out in the fifteenth century partly because of a sudden cooling of temperatures across northern Europe known as the 'Little Ice Age'.[1]

However, for the most part these climatic changes were relatively short-lived and far less significant than those in prospect. In a world already populated by 6.5 billion people and destined to reach 9 billion by 2050, deviations from global or regional weather norms, particularly if they occur within the span of a single human generation, could have profound consequences for international security if food production is disrupted, fresh water becomes scarce, diseases spread and natural disasters increase. Climate shifts, manifested in rising sea-levels and more intense droughts and storms, could stimulate large scale movements of people within, and across, international borders.[2] Individually or collectively, such developments could destabilise nations internally, aggravate tensions between states and endanger human security.[3] International society could also be affected because of the often subtle and poorly understood dependence of natural ecosystems on the weather and climate.

Sceptics dismiss any direct connection between climate change and security, maintaining that climatic factors will only marginally influence tomorrow's security environment, if at all. They point to significant natural fluctuations in climate patterns and short-term cyclical phenomena like El Niño and the recently identified Pacific Decadal Oscillation, the causes of which are not fully understood.[4] Even if global warming does take place, they argue, many of its effects may be localised, benign or favourable. While reductions in rainfall may lead to desertification or water shortages in some regions, others will benefit from increased rainfall and higher crop yields.[5] China, for example, could initially benefit as a result of greater productivity in its cooler north and arid interior through a combination of warmer temperatures and higher rainfall. Russia might also gain, as previously dry areas become moister and therefore more productive.[6] Even where the fabric of the state is torn by environmentally induced conflicts, in all likelihood they will be localised and have negligible effects on world order — 'visions of starving millions from the "South" invading the "North" in search of food are far fetched…'.[7]

On the other hand, mainstream climate scientists and some international security specialists contend that the magnitude of expected climate change will be substantial and certainly beyond our societal and eco-system experience, posing genuine and multiple risks to global security. Governments are now beginning to heed their warnings. Australia's Environment Minister, Ian Campbell, sees climate change as a 'very serious threat' and British Prime Minister, Tony Blair, has declared that 'there will be no genuine security if the planet is ravaged by climate change'.[8] Blair's chief climatologist, Sir John Houghton, has gone even further, asserting that climate change is 'a weapon of mass destruction' and at least as dangerous as international terrorism.[9]

Are Campbell, Blair and Houghton right? And, if so, what is the evidence for considering climate change a first order security issue? In seeking answers to these questions it is important to understand how

thinking about security has been transformed by the dramatic reduction in interstate conflicts that have occurred since the end of the Cold War. Historically, national security was considered to be synonymous with defence of the realm against military dangers from other states or polities. Consequently, military strategists and national security specialists were disinclined to consider the implications of non-military threats to security, such as climate change.

But attitudes are changing as evidence grows that many security threats are not immutably linked to the exercise of state power or military force. As has been argued elsewhere, a new class of non-military threats has emerged over the past few decades which have direct implications for international security.[10] They include the activities of non-state actors, such as terrorists and organised criminal groups, as well as unregulated population movements, infectious diseases and the rapid depletion of the Earth's natural resources. Environmental dangers, such as climate change, form part of this new security paradigm. They stem not from competition between states or shifts in the balance of power, but from human-induced disturbances to the fragile balance of nature, the consequences of which may be just as injurious to the integrity and functioning of the state and its people as those resulting from military conflict. They may also be more difficult to reverse or repair, as global warming and the destruction of the ozone layer illustrate. Seen in this light, our climate is a critical part of the Earth's natural support system which sustains all life. Protecting and stabilising our climate is, therefore, a legitimate long-term objective of security policy since human survival is dependent on the health of the biosphere and the coupled ocean–atmosphere.

Until recently, most of the controversy surrounding the climate change debate has centred on the reliability of the scientific forecasts and the adequacy of the international response, especially in reducing greenhouse-gas emissions. In this Lowy Paper we argue that there is no longer much doubt international society is facing a prolonged period of planetary warming, largely fuelled by modern lifestyles, which is unprecedented in human history in terms of its magnitude and probable environmental consequences. With a few notable exceptions, even sceptics now seem prepared to accept the validity of the basic science underpinning climate change forecasts.

Crucially, however, there is no consensus about appropriate strategies for dealing with the consequences of climate change, primarily because there is no agreement about its seriousness for international security. Some economists argue that it makes no sense to make expensive adjustments to industrial or agricultural practices and to attempt substantial reductions in greenhouse gas emissions unless it can be demonstrated that they would be efficacious or that the cost is justified by the consequences of not taking remedial action. In strict economic terms they are right, but the problem is that climate change is not amenable to a simple cost-benefit analysis because it transcends economic calculations.

The reality is that climate change of the order and time frames predicted by climate scientists poses more fundamental questions of human security, survival and the stability of nation states which necessitate judgments about political and strategic risk as well as economic cost. The central problem is the rate at which temperatures are increasing rather than the absolute size of differential warming. Spread over several centuries, or a millennium, temperature rises of several degrees could probably be managed without political instability or major threats to commerce, agriculture and infrastructure. Compressed within the space of a single century, global warming will present far more daunting challenges of human and biological adaptation, especially for natural ecosystems, which typically evolve over hundreds of thousands and millions of years.

The purpose of this Lowy Paper is four-fold. First, we aim to broaden and deepen understanding of the political, economic and strategic impact of climate change by viewing the issue through the lens of security. Most of the literature and public discourse on climate change is dominated by arguments about the utility of setting targets for greenhouse-gas emissions and the costs to industry and the economy. While this debate is important, we argue that the wider security implications have been neglected to the detriment of a more

integrated and informed appreciation of the enormous challenge posed by a rapidly warming planet.

Secondly, although climate change is clearly a global phenomenon, the geographical focus of this paper is Asia and the Pacific. Australia is better equipped than most nations to meet the challenge of climate change because of our wealth, knowledge edge, low population densities and abundant natural resources. But this should not be a cause for complacency. Most of our neighbours are not as well endowed. With few exceptions, they are still developing states, with far less capacity to mitigate or adapt to climate change. As the pace of Australia's integration with the region accelerates, the deleterious effects of climate change in Asia and the micro-states of the Southwest Pacific will be of direct consequence for our own security interests.

Thirdly, climate change cannot be assessed without an understanding of the links between a warming planet, eco-system transformation and human survival. We seek to illuminate this complex and poorly understood interrelationship through this cross-disciplinary collaboration, drawing on the authors' expertise in climate science and international security.

Fourthly, judgments are required about the seriousness of climate change for Australia and the region relative to the other dangers we confront. Policy makers, in particular, must be able to prioritise climate change within their taxonomy of threats to national and international security. Is significant climate change more likely than a terrorist attack by a non-state actor, a military strike by a state adversary or a disease pandemic? Or is climate change better understood as a low probability but high impact event?

Finally, this paper makes no claim to be a comprehensive treatment of the subject which is beyond the scope of a single monograph or the competence of the authors. A more extensive analysis would require input from agricultural science, economics, political science, geography and medicine to name just a few of the relevant disciplines. Nor will the reader find much here about the Kyoto Protocol, greenhouse-gas emission targets, climate policy or technological solutions. Not because they are unimportant, but because these issues have been canvassed extensively elsewhere. We hope, nonetheless, that those interested in the subject will find some enlightenment in these pages.

The structure of this monograph is as follows. Chapter one explains how the natural and human drivers of the earth's climate interact and why the vast majority of the world's scientists believe that significant and potentially destabilising climate change this century is inevitable, notwithstanding the contrary views of sceptics. As the Earth heats up and sea levels rise, there will be demonstrable and largely negative consequences for food production, fresh water availability and the spread of infectious diseases. Chapter two surveys the implications of climate change for food, water and disease transmission, especially in Asia and the Pacific, while Chapter three explores the links between climate change, natural disasters, energy security and environmental refugees, including how each is likely to play out regionally, as well as internationally. Chapter four looks at the possibility that the magnitude of future climate change and the speed with which it could occur has been underestimated, rather than exaggerated, and asks whether we have adequately factored in a number of 'wild cards' in the climate change pack.

Chapter 1

Is climate change real?

Human induced climate change is one of the major challenges confronting the world this century.

Prime Minister John Howard, the National Press Club, 15 June 2004.

Despite nearly two decades of public debate there is still residual scepticism about the seriousness of climate change and the degree to which humans are responsible. In this Chapter we explain how the natural and human drivers of the Earth's climate interact and why the vast majority of the world's scientists believe that significant and potentially destabilising climate change this century is inevitable, notwithstanding the contrary views of sceptics. How do scientists measure changes in the composition of the atmosphere, temperature and ocean currents, the key components of our climate, and how reliable and accurate are the data sets which inform the super-computers that help scientists to predict our climate?

What shapes our climate?

In assessing the significance of climate change for international security it is important to recognise that our climate is in a constant state of flux and today bears little resemblance to the climate of our prehistoric ancestors. An extra-terrestrial observer in 20,000 B.C. would have looked down on a very different planet, where sea levels were 80 metres lower than present, average mean temperatures five degrees colder, 50 % of the Earth's surface was covered in ice, and ecosystems and animal species were markedly different in distribution and composition.[11] Even as recently as 10,000–15,000 years ago, much of the planet lay in the grip of a severe ice age, with the northern ice cap extending almost as far south as present day Portugal, while a large part of Tasmania was covered in ice.

None of these temperature and climatic fluctuations have anything to do with human activity but are primarily the consequence of the Earth's celestial heart beat — the variations in its orbit around the sun and the obliquity and 'wobble' of its axis.[12] The effects are typically measured in hundreds of thousands or millions of years, although some fluctuations occur over much shorter time scales because of decadal variations in solar radiation, periods of greater or lesser volcanic activity and the internal features of the coupled ocean–atmosphere–biosphere system producing, for example, the El Niño and La Niña effects.[13] Changes to the biology of the planet can also influence climate by causing feedback loops, enhancing the magnitude of climatic fluctuations during colder phases.[14] The earth is currently in a warmer interglacial phase, which climatologists expect to last for at least another 10,000 years, human influences excluded, before the redevelopment of another Ice Age resulting in re-glaciation, especially in the northern hemisphere, and a return to a harsher, colder climate.[15]

Our underlying climate is determined by the balance between solar energy that arrives at the outer limits of the atmosphere and the proportion that is reflected or re-radiated back to space by clouds, aerosol particles and the Earth's surface, with the amount of snow and ice being particularly important because of their reflective qualities. So

called 'greenhouse gases' — mainly carbon dioxide, methane, nitrous oxide and chlorofluorocarbons (once used as propellants in aerosols and refrigerants) also play a role by preventing the unimpeded escape of heat from the earth to space. Without these gases the Earth's surface would be 30–33°C colder. This is the radiative budget of the earth.

The energy that is absorbed is not evenly distributed across our planet's surface because of the spherical shape of the Earth and its daily rotation and seasonal progression around the sun, resulting in differential heating of both the atmosphere and the oceans that drives the circulations we call winds and currents. This is the dynamic component of the climate system. Energy absorbed at the earth's surface is responsible for the evaporation of water, which is then carried upwards into the atmosphere, where it forms clouds and rain, the core of the hydrological cycle. These subcomponents of the climate systems are complex and highly interactive which is why detailed predictions of climate change are difficult and contentious. It is simply not possible to conduct empirical studies on a global scale to determine what will happen when the mix of greenhouse gases is varied or the overall level increases.

Nevertheless, scientists have made great progress in measuring the physical characteristics of the climate and its variations, allowing the building of sophisticated computer models that integrate this knowledge into a single description of the climate system. These models have advanced significantly in the past decade due to an improved understanding of our climate and better use of observations of the real system to validate the performance of the models. New developments in computer technology allow models to represent more frequently and accurately the complexity of the atmosphere and oceans across the globe. As a result, climatologists now have far greater confidence in their ability to predict the magnitude and nature of future climate change for a given change in atmospheric greenhouse gases.

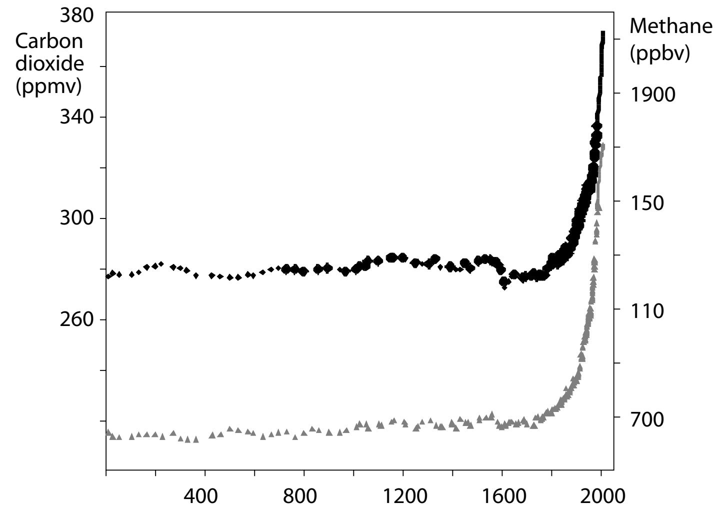
Fortunately, our climate is modified and tempered by the protective layer of the Earth's atmosphere, although it is occasionally disrupted by asteroids and meteors, a number of which have struck the Earth with massive force and catastrophic consequences for all life forms.[16] Sixtyfive million years ago an asteroid, estimated to be about ten kilometres in diameter, slammed into North America at high velocity, leaving a five kilometre deep crater and dispersing vast amounts of dust and particles into the atmosphere. The impact was so severe that the world was plunged into darkness, bringing about a precipitous end to the age of the dinosaurs.[17] Such is the reality of naturally occurring climate change — long periods of relative stability, as measured in human years, punctuated by occasional catastrophic events, significant decadal fluctuations and more severe, longer term cyclical shifts that pose major challenges of adaptation and survival for all species on the planet.

Human influences

Of far more immediate concern, however, is the now irrefutable evidence that human activities are heating up the planet at a rapid rate. This anthropogenic warming could have profound implications for our security and way of life. The reason is that air pollution from industrial emissions, automobile exhausts, the burning of carbon-based fuels, changes in land use, agriculture and the large-scale destruction of forest cover has resulted in a build-up of greenhouse gases in the Earth's atmosphere.

These gases have grown significantly in concentration since the Industrial Revolution (Figure 1.1), primarily due to human activities. The devastating Indonesian fires of 1997–98 caused by land clearing for palm oil plantations, for example, are estimated to have released at least a billion tonnes of carbon as carbon dioxide into the atmosphere, more than the total annual emissions from Western Europe's cars and power stations.[18] But these high impact events are actually less detrimental to our atmosphere than the steady, incremental increase in greenhouse-gas emissions caused by our dependence on fossil fuels. Analysis of direct atmospheric measurements and air trapped in ice-core samples from Antarctica clearly shows that the three key greenhouse gases of carbon dioxide, methane and nitrous oxide are at higher levels than at any time in the last 650,000 years.[19] By 2030, concentrations of carbon dioxide are likely to be 60 % higher than the pre-industrial levels of 200 years ago.

Figure 1.1: Changes in atmospheric carbon dioxide and methane over the past two millennia



Source: Etheridge et al. (1996) and Etheridge and MacFarling (personal communication).

Note: This graph shows the rapid rise of carbon dioxide and methane during the period of industrialisation from data collected by direct measurement at the Cape Grim Observatory, Tasmania. The data points are measurements of air trapped in Antarctic ice. Such information is now available for much of the last million years.

Increased levels of greenhouse gases reduce the heat lost to space, trapping it within the lower atmosphere and causing mean global temperatures to rise over time. Climatologists expect that over the next hundred years the concentration of carbon dioxide accumulating in the atmosphere will eventually more than double, sufficient to increase global temperatures by several degrees and fundamentally alter global weather patterns.

The Intergovernmental Panel on Climate Change (IPCC)

A handful of scientists were aware of the connection between the accumulation of carbon dioxide and other greenhouse gases in the atmosphere and the stability of the earth's climate as early as the middle of the nineteenth century. However, the wider community of climatologists did not evince a great deal of interest or awareness of the connection until the 1970s, when solid evidence began to emerge of a build up of carbon dioxide. In response, the World Meteorological Organisation convened the first World Climate Conference in 1979, which concluded that continued expansion of man's activities on earth may cause significant extended regional and even global changes of climate.[20]

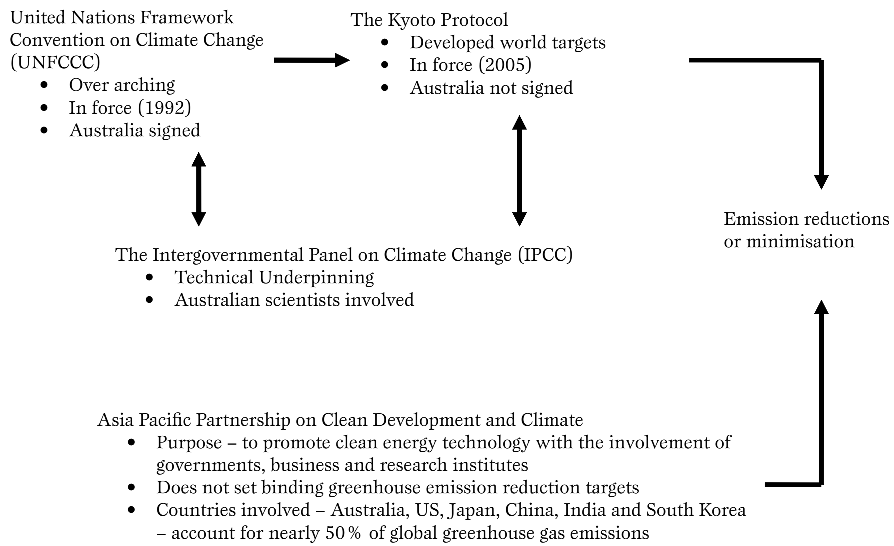
A subsequent 1986 meeting of leading scientists in Villach, Austria went further, forecasting that by the end of the century the general warming of the planet would exceed the natural fluctuations of the planetary mean temperature.[21] However, this prediction was based on theoretical expectations of planetary warming. There was still no convincing 'hard' evidence to support the contention that warming was greater than would be expected from natural variation. But the indicators were sufficiently worrying for the World Meteorological Organisation to establish an Intergovernmental Panel on Climate Change (IPCC) with the United Nations Environment Programme as a partner, tasked to:

- Identify knowledge gaps and uncertainties about climate change and its impacts as well as information needs for policy development;
- Review national and international policy on climate change;
- Conduct scientific assessments (based on peer reviewed and published literature) of all aspects of the climate-change issue and disseminate the results widely.[22]

The IPCC is now a key part of the international regime for assessing the impact of climate change and developing effective responses, based

on the United Nations Framework Convention on Climate Change and associated Kyoto Protocol. The latter is essentially an agreement on the measures needed to reduce greenhouse gases (Figure 1.2).[23] A third element is the Asia Pacific Partnership on Clean Development and Climate. This was established in 2005 and aims to achieve emission reductions voluntarily through the development of clean energy technology and involves governments in partnership with business and research institutes. Its six members — Australia, US, Japan, China, India and South Korea — account for nearly 50 % of greenhouse-gas emissions globally.[24]

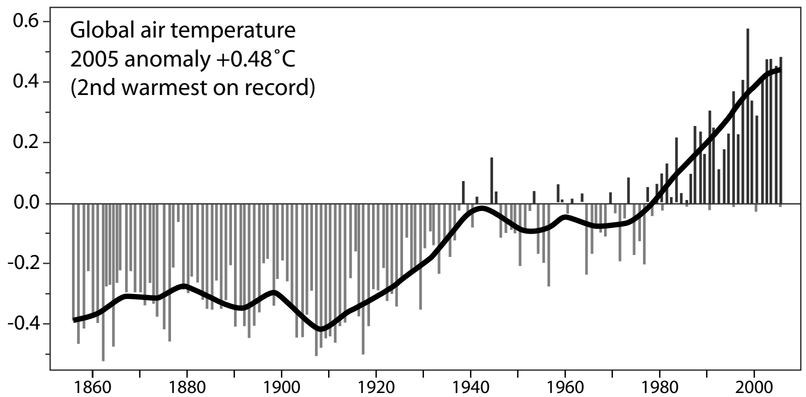
Figure 1.2: The international system for climate change action



The IPCC is today universally regarded as the most authoritative source of information on climate change. So far it has produced three major assessments — in 1990, 1995 and 2001 — and a fourth is due in 2007. The 1995 Second Assessment was politically influential as it received widespread international media coverage and shaped the tenor and parameters of today's climate change debate. Its key conclusions were that:

- Mean global temperatures rose between 0.3°C and 0.6°C in the 20th century, most of it occurring over the last 40 years (Figure 1.3);
- The early 1990s were the warmest years recorded since 1860, the first year that accurate temperature records were kept;
- Temperatures were predicted to increase by 1°C to 3.5°C by the end of this century (the variation is accounted for by different emission scenarios and model uncertainties);
- The average rate of warming was greater than any seen in the last 10,000 years;
- Temperatures will continue to rise beyond 2100, even if concentrations of greenhouse-gases are stabilised;
- Sea levels have risen between 10 and 25 centimetres in the twentieth century and will rise between 15 and 95 centimetres by 2100.[25]

Figure 1.3: Average temperature at the Earth's surface



Source: http://www.cru.uea.ac.uk/cru/info/warming

The IPCC made two other important findings. It identified a number of potentially serious climatic changes, including the probably heightened incidence and severity of extreme weather patterns (such as droughts, high temperatures and floods) that are expected to have a negative impact on agriculture and primary production. While acknowledging the difficulty of making accurate forecasts of local variations in weather cycles, the report concluded that the 'emerging pattern' clearly shows the weather is responding to higher concentrations of greenhouse gases.[26]

In 2001, the IPCC published a Third Assessment Report which reinforces and strengthens the findings of its predecessor and provides further evidence that significant warming and sea-level rise are likely. Precise levels of future greenhouse-gas concentrations are difficult to predict due to uncertainty about key variables such as technological and economic advances, developments in fuel efficiency and the degree of government intervention. Thus, rather than making one definitive assessment, the IPCC developed a number of plausible emission scenarios and extrapolated from them to sketch out likely climatic changes.[27] It is important to note that these scenarios are not predictions, but rather a scoping of what might plausibly occur under a range of different assumptions about the global use of energy.

The Third Assessment Report estimates that temperatures will increase by between 1.4°C–5.8°C this century (compared with the 1°C–3.5°C predicted in 1995) with lower emissions of sulphur dioxide leading to fewer sulphate particles in the atmosphere and thus less offsetting of the warming effect of greenhouse gases. Crucially, even if atmospheric concentrations of these gases are stabilised, temperatures will continue their upward trend over the next several decades. As the heating slowly penetrates to the depths of the world's oceans sea levels will also rise, probably for several centuries. Other key judgments are that:

- Model simulations of the climate system give increased confidence in climate projections;
- Observed warming over the last 50 years is likely to have been due mainly to the increase in greenhouse–gas concentrations;

- Human influence will be responsible for further changes in atmospheric composition (in particular carbon dioxide) throughout the 21st century;
- Sea-level rises of 9–88 cm by 2100 are almost certain.[28]

The climate projections for Australia and the region

We still don't know enough about the regional and national consequences of climate change because accurate predictions become more difficult at the sub-system level since there are many more factors to consider. Nevertheless, the IPCC has identified five likely climate outcomes for Asia and the Pacific:

- more intense summer monsoons, increasing the degree and frequency of destructive floods and soil erosion;
- sea-level rises which will submerge low-lying coastal plains and river deltas, placing at risk already endangered coastal ecosystems;
- changes in precipitation, which could alter river flows and affect hydro-electric power;
- decreasing fresh water availability resulting from higher rates of evaporation and salinisation;
- greater uncertainty associated with water management and supply.[29]

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) has used a number of different models to project the likely consequences for Australia, drawing on the organisation's own research and that of the IPCC. By 2030, relative to 1990 conditions, the CSIRO anticipates:

- a warming of 0.4–2.0°C, the temperature effects being least near the coast and greatest inland;
- a 10–50 % increase in days over 35°C;
- a 10–80 % decrease in days below 0°C;

- up to 15 % less rainfall year-round in the south-east and in spring in Queensland;
- up to 20 % less rainfall year-round in the south-west;
- up to 15 % more summer rainfall on the east coast;
- up to 15 % more autumn rainfall inland;
- heavier rainfall where average rainfall increases, or decreases slightly;
- stronger tropical cyclones, but uncertain changes in frequency and location.[30]

Assessing what is an acceptable risk

Until now, the IPCC has not provided definitive statements on what level of global mean temperature change might be regarded as an acceptable risk, or, in the words of the Framework Convention on Climate Change, what might be regarded as 'dangerous anthropogenic interference with the climate system.'[31] Determining what is 'dangerous' climate change, or change that represents an acceptable risk, is problematic for two reasons. First, our understanding of how climate change will impact at the local or regional level is still uncertain. Secondly, perceptions of what constitutes an acceptable risk depend on location, coping capacity and who is making the assessment. Residents of Pacific island nations, or of Bangladesh, may see things quite differently from people living in inland Australia or the continental United States because of the far greater impact of sea-level rise on coastal and island communities, as well as the limited capacity of less developed countries to respond.[32]

Nonetheless, there is an emerging consensus that if global mean temperature rises can be contained to around 2.0°C an increase of this order can be managed without undue risk to international security.[33] But confidence in this judgment dips sharply once the rise exceeds 2.0°C. Unfortunately, it seems very likely that this de facto temperature ceiling will be breached. In April, 2006, Sir David King, the UK Chief Scientist, warned that temperatures will probably rise by at least 3.0°C, which will cause severe droughts, put 400 million people at risk from hunger and jeopardise water supplies for up to 3 billion people.[34] The figure of 2.0°C is significant politically because it underpins the large number of national emission targets being set around the world by individual states. If the international community accepts that 3.0°C is probable then more stringent emission reductions than those mandated by the Kyoto Protocol will be necessary to stabilise our climate.

Box 1.1: Calculating greenhouse gas emissions

The amount of carbon dioxide in the atmosphere has climbed more than 30 % since the Industrial Revolution and is increasing by an average 0.4 % per year, or 2 parts per million by volume (ppmv). It is now (2006) 379 ppmv. We know this is the result of human activity because the changing isotopic composition of the atmospheric carbon dioxide betrays its fossil origin. Once the concentration of atmospheric carbon dioxide exceeds about 400 ppmv, as seems likely within the next decade, it will be difficult to keep temperature rises below 2.0°C above pre-industrial levels, after which climate change becomes progressively more destructive environmentally, and the likelihood of disastrous impacts on agriculture, water, forests and sea-levels rise exponentially.[35] On current estimates, the 2.0°C threshold could be breached as early as 2026.[36] Agricultural practices and manufacturing have also forced up methane and nitrous oxide, while tropospheric ozone, another greenhouse gas, has risen by 40 % since the beginning of the industrial revolution.

Future concentrations of greenhouse gases, particularly carbon dioxide, will be partly determined by how much the global carbon budget is affected by climate change itself; that is, what proportion of the gases emitted are retained in the atmosphere, and what absolute amount of the gases is emitted. The latter depends on a wide range of interconnected technological and socio-political factors. If all anticipated growth in energy demand over this century were to be met using today's fossil fuel technology, emissions would increase by almost 100 % from present levels. It is reasonable to assume, however, that technological advances will allow greater fuel efficiency and reduced emissions. It may even prove possible to capture the carbon dioxide from power plants and store it under the ground so that it will not be released into the atmosphere. How quickly these technologies come into play depends on how urgent the task of emission reductions is seen by governments, social adaptation, economic costs and the use of alternative fuels like nuclear, wind, solar, geothermal and biomass power, which contribute smaller amounts of greenhouse gases to the atmosphere when power plants are being built.

The Intergovernmental Panel on Climate Change (IPCC) has calculated future emissions by developing several possible global energy scenarios which factor in different levels of demand, technological uptake and emission control. These scenarios were developed to establish what might happen without any policy of intervention. Because of the degree of inertia in the current energy system, the IPCC has a high level of confidence in its assessment that the concentration of carbon dioxide in the atmosphere by 2030 will be 60 % higher than pre-industrial times. Beyond 2030, accurate forecasts become more difficult, reflecting uncertainty about human responses.[37]

The sceptics — do they have a case?

So how much credence should be given to these findings and what are the arguments of the sceptics? A few dissident climatologists and meteorologists contest the IPCC assessments on two main grounds.[38] Some question the reliability and consistency of the temperature and atmospheric data gathered for use in understanding the climate system and validating climate change models, particularly satellite observations. While accepting that concentrations of greenhouse gases have increased and the surface of the planet is warming, they argue that these rises are not demonstrably penetrating the upper atmosphere. If substantial climate change is occurring, warming should be evident throughout the 12 kilometre-deep troposphere. Sceptics also claim that the amplifying effect on global warming predicted by the IPCC may be minimal because water vapour feedback may not reach the upper atmosphere and greenhouse gas-enhancing water vapour in the atmosphere could actually decrease because of the physics of cloud formation.[39]

It is true that early satellite data on temperature was not consistent with the observations of surface warming, raising legitimate questions about its reliability and hence the models they informed. However, a subsequent review by the IPCC showed that 'temperature trends from weather balloons since 1958 for the lowest 8 km of the atmosphere and at the surface are in good agreement with a warming of about 0.1°C per decade.'[40] Indeed, after errors in the processing of the satellite data were corrected, both satellite and balloon observations have since provided clear supporting evidence of surface observations showing an increase in surface temperature extending right through to the troposphere.[41]

A second argument advanced by sceptics is that observations showing temperature change are based on meteorological records taken by weather services around the world and that the sites for these thermometers have been influenced by the so-called 'heat island' effect where the growth of urban development, particularly large, high rise buildings tends to artificially raise temperatures and block natural atmospheric mixing. But climate scientists are well aware of this anomaly and have developed methods for filtering out the distorting effects of urban sites. Most observations are carefully screened for siting inconsistencies, or the actual site is changed over the lifetime

of a particular recording station, to even out temperature anomalies. Studies designed to measure temperature increases typically compare measurements taken in urban areas with those in rural locations, or include remote sites over the ocean or in pristine mountains where the heat island effect is zero.[42]

Moreover, observations from meteorological stations and satellites have been supplemented and compared with those obtained from deep-ocean measurements and analysis of the isotopic composition of ice, tree ring growth and borehole temperatures. The integration of all these measurements is providing a much clearer and richer picture of the history of our climate, enabling scientists to predict future temperature and sea-level rises with greater confidence than ever before.

Unfortunately, the technical and somewhat arcane nature of the scientific arguments makes it difficult for non-specialists to come to grips with the complexities of the climate change debate, which has become highly politicised as the economic, environmental and political stakes have risen. It is important to recognise, however, that expert opinion overwhelmingly supports the view that global warming of the order projected by the IPCC is likely (Table 1.1). The IPCC Assessment Reports represent the collective judgment of 2500 of the most prominent scientists working on climate change and its conclusions are subject to extensive peer review in what is probably the most rigorous scientific collaboration in history.[43]

Other independent reports by leading climatologists have endorsed the basic findings of the IPCC and the evidence for global warming has become more compelling since the 1995 and 2001 Assessment Reports. 1998 is the warmest year ever recorded but the next five hottest years in descending order were 2005, 2002, 2003, 2004 and 2001.[44] An independent panel of experts convened by the US National Academy of Science reported that temperatures have already risen by 0.3°C between 1979 and 2000.[45] This is the highest rate of warming since the beginning of instrumental temperature measurement.[46]

There is broad scientific consensus that glaciers around the world and the polar ice caps are melting at accelerating rates and seas are continuing to warm and expand.[47] The US National Snow and Ice Data Centre has concluded that human induced warming is at least partially responsible for the shrinking of the Arctic ice cap which will disappear entirely by 2060 at present rates of melt.[48] One potentially serious consequence of the loss of the permafrost of the northern hemisphere tundra region is the possible release of otherwise trapped carbon back into the atmosphere as methane or carbon dioxide, adding to the stock of greenhouse gases. While the melting of sea ice does not contribute to sea level change, the melting of glaciers can. We now know from a variety of independent studies that sea levels have risen by around 10 cm globally over the past 55 years, essentially because of the thermal expansion of water and the melting of terrestrial snow and ice.[49] We also know that this rate of sea-level rise is accelerating.[50]

Although the IPCC Fourth Assessment Report will not be released until 2007, its findings are expected to confirm these trends, provide greater clarity in previous areas of uncertainty and endorse the central conclusions of the Third Assessment Report. Among its probable findings:

- Greenhouse gases will continue to rise as a consequence of human activity based on new knowledge of the global cycling of these gases between the atmosphere, ocean and plants, knowledge that has been enhanced through evidence extending back one million years, in the case of ice core samples and palaeontological evidence. Data from satellite and direct observations will be more comprehensive, accurate and reliable and in closer agreement with other indications of climate change, leading to improved forecasting;
- Clearer evidence of change to the global cryosphere (the Earth's ice and snow cover) including evidence of human impact on glacial instability, sea-ice retreat and permafrost melt;
- Greater agreement between different climate models which are now more capable of representing the impact of greenhouse-gas changes on climate;

- Markedly more extensive and reliable evidence of climate-system changes and of the impact on human and natural ecosystems;
- Progress in defining what are acceptable risks in terms of future global average temperature increase, or what is 'dangerous' anthropogenic change to the climate.

Table 1.1: Climate change certainty levels

Level of certainty	**Characteristic of the climate system**	
	Characteristic	**Fact**
Virtually certain 'facts'	Greenhouse gases	Warm the planet's surface
		Cool the stratosphere leading to greater instability of the atmosphere
		Are increasing due to human activities
		Other substances can partially offset this warming effect
	Temperature change	Over the past century, the Earth's surface has warmed at an unprecedented rate in historical terms
	Sea-level rise	Thermal expansion has caused a global rise in sea level
	De-glaciation	Glaciers and the north-polar ice cap are melting

cont ...

Level of certainty	Characteristic of the climate system	
	Characteristic	**Fact**
Very probable (9 out of 10 chance)	Greenhouse gases	There will be a doubling of carbon dioxide concentrations over pre-industrial levels this century
		Global warming will continue and exceed 2°C this century
	Temperature change	By 2100 global mean surface temperature changes are expected to be 1.4–5.8°C higher than today
	Sea-level rise	By 2100 seas will rise by between 25 and 75 cm, mainly because of thermal expansion
	Precipitation	The rate of evaporation increases with warming leading to an increase in global mean precipitation of about 1.5–2.5 % per 1°C
		Higher latitudes of the northern hemisphere are expected to experience temperature and precipitation increases well in excess of the global average
Probable (greater than 2 out of 3 chance)	Soil moisture	Eventual marked decrease over mid-latitude continents
	Sea-ice cover	Little change in the circum-polar Antarctic ocean
	Ocean salinity	Reduced at higher latitudes due to higher precipitation and glacial melt inhibiting tendency of the water to sink thereby slowing ocean currents
	Storm intensity	Increased tropical storm intensity
	Research needs	Response of clouds, water vapour, ice, ocean currents and specific regions to warming remain formidable research challenges

Source: Adapted from Mahlman, J.D., *Uncertainties in projections of human-caused climate warming*. Science 278, 5342, 1997, 1416–1417.

Climate change is real

As with all scientific enquiry, sceptics have played an important role in questioning both the underlying assumptions and the veracity of the data of what is still a relatively new and inexact science. The ongoing dialectic has resulted in better science and therefore greater certainty about the scope, magnitude and implications of climate change. But in our judgment, charges that the extent of climate change is being exaggerated by the IPCC, or that the data is insufficiently precise to support the IPCC's principal conclusions, are not sustained. Of course, the IPCC Assessment Reports are not omniscient but then their authors do not make this claim. Along with other authoritative scientific assessments, they should be seen as periodic snapshots of the state of our current knowledge which facilitate risk assessment and improve our capacity to manage climate perturbations.

Nonetheless, evidence that human activities are significantly warming up the planet is now irrefutable, even if there are still uncertainties about the precise rate of global warming and sea-level rise. A telling survey of the scientific literature on climate change, for example, found that of 928 peer reviewed articles published between 1993 and 2003, not one disagreed with the scientific consensus that human induced global warming is real.[52] Moreover, it should be remembered that climate scientists have drawn on the knowledge and expertise of a wide range of related disciplines in making their forecasts, especially geology, palaeontology and archaeology. It has been the integration of knowledge from all these fields that has provided the foundation of modern climate science and the crucial, observable evidence used for the testing of climate modelling capabilities.

Ironically, while a great deal of the data is no longer in dispute, most people do not have a realistic sense of the magnitude of likely future climate change because scientists have largely failed to communicate the significance of their findings in a way that policy makers, the media and the general public can easily understand. Focusing on mean temperature increases and sea-level rise does not give a true sense of their import. A change of one degree this century would be highly significant, although it doesn't seem much because we routinely experience much greater temperature variations (night-to-day, day-to-day and month-to-month) in our lives. It has to be remembered, however, that average global temperatures normally vary by no more than a few tenths of a degree from year-to-year and decade-to-decade. More than 2°C could push the world into uncharted waters, given that the Earth was only 5°C cooler than today during the last Ice Age.

Figures for average sea-level rise also understate the problem. A rise of 10 or 20 cm seems relatively inconsequential when measured against the large waves commonly seen on any popular surf beach. However, in conjunction with major storm surges associated with mega-hurricanes like Katrina which devastated the US coastal city of New Orleans in 2005, such rises will almost certainly result in episodes of more extreme flooding of coastal and low lying areas, rendering much of this terrain uninhabitable without massive engineering solutions that are simply unaffordable for most countries.[53]

Chapter 2

Food, water and disease

Climate change will, in many parts of the world, adversely affect socio-economic sectors, including water resources, agriculture, forestry, fisheries and human settlements, ecological systems (particularly forests and coral reefs), and human health (particularly diseases spread by insects), with developing countries being the most vulnerable.

Robert T. Watson, Chair, IPCC.[54]

As the earth heats up and sea levels rise, there will be demonstrable and largely negative consequences for food production, fresh water availability and the spread of infectious diseases. While these impacts will not be uniformly felt around the globe, they are likely to be widespread.[55] Food is highly sensitive to the weather, water is already in short supply and meteorological influences affect the transmission dynamics of many diseases.[56] Successfully meeting these challenges will depend on the resilience, adaptability and resources of the populations most affected. While the developed world may be able to navigate these newly exposed shoals with tolerable stress, nations less well endowed will struggle, and in some cases founder. In an interconnected world, the problems of neighbours can quickly become our own, as Australia's recent history attests. In this Chapter we examine the implications of climate change for food, water and disease transmission, focusing on Asia and the Pacific.

Food security

Climate change, food production and security are clearly linked, especially at a time of rising populations in the developing world and concerns that the green revolution of the 20th century may have largely run its course. Crop yield increases have begun to level off since the late 1990s with per capita grain production declining 7 % between 1984 and 1998.[57] Of course Cassandras have long warned of an approaching food deficit and been proved wrong. Most food economists believe that global supply will be able to keep ahead of rising demand. But their assumptions have not adequately factored in the impact of climate change, especially the shift in rainfall distribution, rising temperatures and the increased incidence of extreme weather events. Nor have they accounted for the fact that increased agricultural yields are heavily dependent on high fertiliser use which links food production to climate change through the energy cycle. The need to achieve greenhouse-gas reductions will increase energy costs making it more difficult to maintain the per capita food yield increases of the previous century.

Climatologists originally believed that human induced climate change would impact most seriously on temperate zones, but that view is now being revised in the face of growing evidence that the tropics will also be significantly affected.[58] Tropical and sub-tropical regions are home to the bulk of the world's people and produce much of its food, typically by subsistence farmers for local consumption.[59] Many of these people are poor and, as a consequence, they will be less able to cope with the impact of significant climatic change on their physical environment. Since the tropical countries of Southeast Asia (Box 2.1) and the Southwest Pacific form the core of Australia's near neighbourhood any climate induced political, social or environmental disturbances in this region would be of considerable concern to Canberra.

Box 2.1: Asian food vulnerabilities

The Consultative Group on International Agricultural Research has predicted that food productivity in Asia will decrease by as much as 20 % due to climate change as the geographical boundaries of agro-ecosystems, as well as species composition and performance will change. Marine ecosystems, supplying protein for millions of the poor, will continue to experience major migratory changes in fish stocks and mortality events in response to rising temperatures. In addition to these longer-term, more permanent shifts in seasonal climatic patterns there will be near-term increases in the frequency and intensity of weather extremes. These are already disrupting agriculture, fisheries and the natural resource base.

Poorer countries with predominantly rural economies and low levels of agricultural diversification will be at most risk. They have little flexibility to buffer potentially large shifts in their production bases. Higher worldwide food prices are likely to result—compounding bio-physical constraints on production and negatively affecting both rural and urban poor. Resilient production systems and policy options must be developed that ensure high levels of food production in the face of an increasing incidence and magnitude of extreme weather events.[60]

Although more rain is expected to fall over the Earth's surface in a warmer world, it will not be evenly distributed. The mid latitude desert regions of the world are expected to move pole-wards, benefiting some previously dry areas and hence possibly increasing crop yields. However, in the tropics, changes to major weather systems such as the monsoons and the frequency and strength of El Niño events could reduce crop yields for a number of reasons.[61]

Rainfall across tropical regions will not fall evenly or consistently. And higher temperatures may lead to greater evaporative losses of water, reducing soil moisture and leaving less water for irrigation. Destructive storms will have a far greater human impact in the tropics as their frequency and intensity increases. Unlike rainfall, sea-level rises will be felt more generally across the globe, albeit with some regional variations. In Asia and the Pacific, many millions of people are exposed to relatively high levels of risk from flooding because of the density of urban populations and high value agriculture in coastal regions.

Climate change is likely to have a detrimental effect on regional food production for four main reasons. First, increased temperatures may accelerate grain sterility in cereal, legume root and tuber crops as well as pasture and tree species. Assuming temperature rises of 1.4 to 5.8°C this century, as forecast by the IPCC, tropical grain crops could decrease 5–11 % by the year 2020 because some crops are already near their maximum temperature tolerance.[62] The Consultative Group on International Agricultural Research predicts that agricultural productivity could decrease by as much as 20 % in Asia more broadly if temperature rises are within the forecast band.[63] Other models such as the U.S. Department of Agriculture's Economic Research Service show that as temperatures rise, agricultural production in Southeast Asia would initially increase before declining.[64]

Secondly, shifts in rainfall patterns could render previously productive land infertile, accelerating erosion, desertification, and reducing crop and livestock yields.[65] A reduction in water available for irrigation will have a serious effect on crop yields internationally, especially in Asia, which is more dependent on irrigation than any other region of the world for growing rice and cereals. Although less important than it once was, rice is still a vital food staple, providing 60 % of the carbohydrate and second class protein consumed by Asians.[66] Irrigation now accounts for 40 % of world food production, but it is responsible for 70 % of China's grain harvest.[67] If rice paddies and croplands dry out, the carrying capacity of large parts of Asia will diminish and some countries may be unable to sustain their populations without importing large quantities of food,

which may be simply unaffordable for poorer nations. Where dryland, non-irrigated agriculture dominates, as in many parts of Australia as well as the tropics, yields can be slashed by even small changes in temperature and rainfall.[68]

Thirdly, rising sea levels will inundate and make unusable fertile coastal land, and potential changes in the strength and seasonality of ocean currents may cause fish species to migrate and disrupt breeding grounds. Non-commercial fisheries are likely to decline as coral bleaching takes hold and the movement of deep water fish may become more unpredictable, compounding the problem of overfishing and diminishing global supplies of wild fish.[69] Oceans have already absorbed about half the 800 billion tonnes of carbon dioxide humans have pumped into the atmosphere since industrialisation which, over time, has increased ocean acidity and further degraded the marine bio-system.[70] As carbonate ions in the seas diminish because of increased acidity, tiny marine snails and krill at the bottom of the food chain that are the primary source of food for whales and fish could be decimated, possibly within decades.[71] This is of particular concern to our region as more than 1 billion Asians are dependent on fish for their primary source of protein, and the Pacific and Southern Oceans have been aptly described as the region's 'rice bowl' for the twenty-first century.[72]

Fourthly, there will be an increase in the frequency of extreme weather events, such as cyclones, riverine flooding, hail and drought, which will disrupt agriculture and put pressure on prices. If the gap between global supply and demand for a range of primary foods narrows, price volatility on world markets is likely to increase and will be exacerbated by the reduction in food stockpiles mandated by the implementation of the Uruguay Round agreement. Without the moderating influence of substantial grain stocks, a confluence of unfavourable political and economic influences, aggravated by climate change, could create local scarcities, sparking food riots and domestic unrest. If sustained, reduced crop yields could seriously undermine political stability and regional security.

> ***Box 2.2: Climate change and agricultural productivity***
>
> The U.S. Department of Agriculture's Economic Research Service (ERS) has developed a model that estimates the effects on world agriculture of climate-induced changes in growing seasons. The model links agricultural production to land classes defined by length of growing season. A geographical information system converts changes in temperature and precipitation generated by general circulation models of the atmosphere into changes in land classes. Model results indicate that global warming shortens growing seasons in the tropics and lengthens growing seasons at high latitudes while mid-latitude impacts are mixed. The magnitude of these effects increases as mean global temperature increases. Other studies have found similar results.
>
> Compared with 1990 economic conditions, the model shows that these land resource changes reduce agricultural output in equatorial regions where many developing countries are located. As mean global temperature rises, agricultural production in Southeast Asia initially increases slightly, reaches a peak, and then declines. This does not mean that agricultural production in Southeast Asia will actually fall below 1990 levels. Economic growth and technological advances should enable agricultural production to continue to increase. The equatorial region's average rate of production increase, however, will slow with global warming, and some countries could actually suffer a decline.[73]

Water scarcity

Changes in the variability and distribution of rainfall could also exacerbate fresh water scarcity in water deficient states. In a world where

over two billion people already live in countries suffering moderate to high water stress, and half the world's population is without adequate sanitation or drinking water, relatively small shifts in rainfall patterns could push countries and whole regions into deficit, leading to a series of water crises with global implications.

Australia, and parts of Asia and the Pacific, face a prolonged period of reduced rainfall because of climate change and a possible increase of El Niño events.[74] In Asia as a whole, per capita water availability has declined by between 40 % and 65 % since 1950. Although the total amount of renewable water is several times annual withdrawals, rainfall and population are spread unevenly, and per capita availability therefore varies considerably in Asia and the Pacific — from 200,000 cubic metres on the island of New Guinea to below 3,000 cubic metres in China, South Korea and Thailand. According to the World Bank, by 2025 most states in the region will be facing serious water shortages unless strong action is taken.[75] This steep decline is the direct result of the region's high population growth, the degradation of existing reserves of fresh water and the destruction of water tables through deforestation, urbanisation and environmentally insensitive agricultural practices.

Although it is not possible to forecast accurately detailed precipitation changes at the sub-national and local level, it is clear that countries which are already water deficient will suffer the worst shortfalls, as rainfall patterns shift and become more variable. One study concludes that about 20 % of the global increase in water scarcity is directly attributable to climate change with the remaining 80 % caused by growing demand.[76] By 2025 some five billion people are expected to suffer from serious water shortages, half a billion of them due to climate change (Table 2.1).[77] Regionally, climate change will worsen the growing fresh water imbalance in many states, and pose new supply problems because of changing rainfall patterns and the melting of glaciers which feed Asia's great river systems.

Table 2.1: Climate change and water scarcity

Year	Total Population (millions)	Population in Water-stressed Countries (millions)	Number of People (millions) in Water-Stressed Countries with Increase in Water Scarcity							
			Had-CM2	Had-CM3	ECH-AM4	CG-CM1	CSI-RO	CC-SR	GF-DL	NC-AR
2025	8055	5022	338–623	545	488	494	746	784	403	428
2050	9505	5915	2209–3195	1454	662	814	1291	1439	—	—

Source: Arnell, N.W., *Impact of climate change on global water resources: Volume 2, unmitigated emissions*. Report to Department of the Environment, Transport and the Regions, University of Southampton, Southampton, 2000.

Note: This table shows the calculated increase in water scarcity caused by climate change, assuming a business as usual scenario for greenhouse-gas emissions using 8 different climate models. The acronyms refer to models of different national research institutions. For example, HadCM2 refers to a specific model of the UK Meteorological Office, Hadley Centre.

Tropical and sub-tropical areas in Asia and the Pacific will receive lower and more erratic precipitation made worse by the fact that the great Himalayan glaciers which flow into the Ganges, Indus, Brahmaputra, Salween, Mekong, Yangtse and Yellow rivers are receding at an average rate of 10 to 15 metres a year as their alpine climates heat up.[78] Hundreds of millions of people are dependent on the flow of these rivers for most of their food and water needs, as well as transportation and energy from hydro-electricity. Initially flows will increase, as

glacial runoff accelerates, causing widespread flooding. Within a few decades, however, water levels are expected to decline, jeopardising food production, causing widespread water and power shortages, with potentially adverse consequences for India, Bangladesh, China, Myanmar, Thailand, Laos, Cambodia, and Vietnam.

In Australia declining precipitation in water catchment areas is exacerbating conflict between stakeholders over the appropriate use and sharing of the remaining water. Internecine disputes over scarce water resources are likely to be far more serious and contentious in Asia, however, especially where rivers flow through international borders, because they will be compounded by high population growth and the region's rapidly escalating demand for hydro-power, transport, fishing, irrigation and water storage.

In summary, water shortages, intensified by human induced climate change, will affect the Asia–Pacific security environment in four ways. First, they will aggravate social and political tensions, adding to the internal security challenges faced by the region's developing states. Secondly, diminishing supplies of fresh water will adversely affect key sectors of the region's economy, especially agriculture. Today's water scarcity may become tomorrow's food shortages because of the critical role played by irrigation in Asia's food economy. Thirdly, changes to the magnitude and/or patterns of rainfall have the potential to change the costs associated with flood and drought remediation in countries where low economic development already limits their capacity to respond to natural variations in climate.

Fourthly, water's salience as a driver of interstate conflict will increase in inverse proportion to its scarcity, although this does not mean that water wars are imminent or inevitable, since interstate competition for water is virtually always played out against a complex mosaic of related political, social and economic factors. The underlying strength of the political relationship between the states that share water resources is crucial in determining whether or not water disputes will escalate into serious political or military conflict. Countries with shared values and generally cooperative relations are less likely to go to war over water than those with a history of enmity and confrontation. Nevertheless, with water already in short supply, and becoming scarcer, the region can ill afford a major drop in rainfall or a shift in distribution away from where it is most needed — the wheat fields of Australia and rice paddies of Southeast Asia and China.

Infectious diseases

Climate change will have a number of serious health-related impacts including illness and death directly attributable to temperature increases, extreme weather, air pollution, water diseases, vector and rodent borne diseases, and food and water shortages.[79] 1.7 million people die prematurely every year because they do not have access to safe drinking water and the situation will worsen if water borne pathogens multiply as a result of rising temperatures.[80] A warmer marine environment will also increase the risk of human bio-toxin poisoning from fish and shell fish as tropical bio-toxins such as ciguatera extend their range to higher latitudes.

But the greatest security risk is from infectious disease. In one of the first ever assessments by the US Intelligence Community of the threat to international security posed by infectious diseases, a 2000 National Intelligence Estimate (NIE) predicted that the threat would worsen in this decade before moderating as the world's health and socio-economic environment gradually improved.[81] However, the NIE did not adequately take into account the increase in disease prevalence that could occur should temperatures rise as forecast.

Temperature is the key factor in the spread of some infectious diseases, especially where mosquitos are a vector, as with Ross River fever, malaria and dengue fever. As the planet heats up, mosquitos will move into previously inhospitable areas and higher altitudes, while disease transmission seasons may last longer. A study by the World Health Organisation has estimated that 154,000 deaths annually are attributable to the ancillary effects of global warming, due mainly to malaria and malnutrition. This number could nearly double by 2020.[82] Currently, some 40 % of the world's population lives in areas affected

by endemic malaria and many Asia–Pacific states are seriously affected by the disease.[83]

Extreme weather events and climate related disasters could lead to short-term disease spikes because of the damage to food production, population displacement and reductions in the availability of fresh water. Once again, poorer nations with limited public health services will be especially vulnerable.[84] Health problems can quickly metamorphose into a national security crisis if sufficient numbers of people are affected and there are serious economic and social consequences, as occurred during the devastating flu pandemic of 1918–1919 which killed between 40–100 million people.[85] However, it is difficult to make the case that in all cases climate change will provide a more favourable environment for the spread of infectious diseases, since transmission rates and lethality are a function of many interrelated social, environmental, demographic or political factors. They include the level of public health, population density, housing conditions, access to clean water, and the state of sewage and waste management systems, as well as human behaviour.

All of these factors (Table 2.2) affect the transmission dynamics of a disease and determine whether or not it becomes an epidemic. But where climate is a consideration, temperature, relative humidity and precipitation will affect the intensity of transmission. Temperature can influence the maturation, reproductive rate and survivability of the disease agent within a vector, or carrier.[86] So climate change will alter the distribution of the animals and insects which are host to dangerous pathogens, increasing or decreasing the range of their habitats and breeding places. For example, an explosion in the mouse population of the US during the 1991–92 El Niño event triggered an outbreak of hantavirus pulmonary syndrome.[87] And one of the most severe summer time outbreaks of yellow fever ever to hit the US occurred in 1878 during one of the strongest El Niños on record, causing 20,000 deaths and enormous economic damage. [88] A warmer climate will provide a more hospitable environment for disease-carrying mosquitos in Australia and the region.

Table 2.2: Effect of climate factors on vector- and rodent-borne disease transmission

Climate Factor	Vector	Pathogen	Vertebrate Host and Rodents
Increased temperature	• Decreased survival, e.g., Culex. Tarsalis (Reeves et al., 1994) • Change in susceptibility to some pathogens (Grimstad and Haramis, 1984; Reisen, 1995); seasonal effects (Hardy et al., 1990) • Increased population growth (Reisen, 1995) • Increased feeding rate to combat dehydration, therefore increased vector-human contact • Expanded distribution seasonally and spatially	• Increased rate of extrinsic incubation in vector (Kramer et al., 1983; Watts et al., 1987) • Extended transmission season (Reisen et al., 1993, 1995) • Expanded distribution (Hess et al., 1963)	• Warmer winters favour rodent survival
Decreases in precipitation	• Increase in container-breeding mosquitoes because of increased water storage • Increased abundance for vectors that breed in dried-up river beds (Wijesunder, 1988) • Prolonged droughts could reduce or eliminate snail populations	• No effect	• Decreased food availability can reduce populations • Rodents may be more likely to move into housing areas, increasing human contact
Increases in precipitation	• Increased rain increases quality and quantity of larval habitat and vector population size • Excess rain can eliminate habitat by flooding • Increased humidity increases vector survival • Persistent flooding may increase potential snail habitats downstream	• Little evidence of direct effects • Some data on humidity effect on malarial parasite development in Anopheline mosquito host	• Increased food availability and population size (Mills et al., 1999)
Increases in precipitation extremes	• Heavy rainfall events can synchronise vector host-seeking and virus transmission (Day and Curtis, 1989) • Heavy rainfall can wash away breeding sites	• No effect	• Risk of contamination of flood waters/runoff with pathogens from rodents or their excrement (e.g., Leptospira from rat urine)
Sea-level rise	• Coastal flooding affects vector abundance for mosquitoes that breed in brackish water (e.g., An. subpictus and An. sundaicus malaria vectors in Asia)	• No effect	• No effect
Source: http://www.grida.no/climate/ipcc_tar/wg2/358.htm.			

Chapter 3

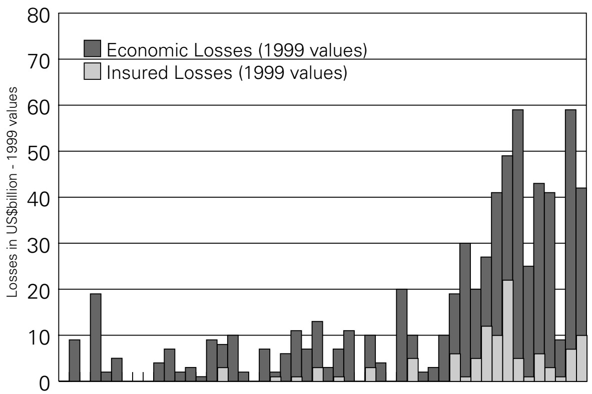
Natural disasters, energy security and environmental refugees

Important though they are, the security implications of climate change are not confined to food, water and health but extend to other critical areas of the environment and human activity. In this chapter we examine the links between climate change, natural disasters, sea-level rise, energy security and environmental refugees, and explore how each of these issues is likely to play out regionally as well as internationally.

Natural Disasters

Though sparse, the available evidence suggests that natural disasters are climbing in line with our warming planet. Of course, the impact of natural disasters may vary for reasons other than climate change. Population growth, higher levels of capital investment and migration to more disaster-prone areas are illustrative. But the insurance industry is adamant that the rise in the number of extreme and damaging climatic events is a significant driver of the upward trend. In its Sustainability Report for 2005, the Insurance Australia Group had this to say: 'We are acutely aware of the impact of climate change on risks faced by the insurance industry. The past 19 out of 20 major insurance events in Australia have been weather related.'[89]

Figure 3.1: Great weather related disasters 1950–1999



Decade comparison							
	Decade 1950-59	Decade 1960-69	Decade 1970-79	Decade 1980-89	Decade 1990-99	Factor 80s:60s	Factor 90s:60s
Number	14	16	29	44	70	**2.8**	**4.4**
Economic Losses	38.7	50.8	74.5	118.5	399.9	**2.3**	**7.9**
Insured Losses		6.7	10.8	21.5	86.0	**3.2**	**12.7**

Source: Vellinga, P. and W.J. van Verseveld, *Climate change and extreme weather events*, Institute for Environmental Studies, September 2000, p 19.

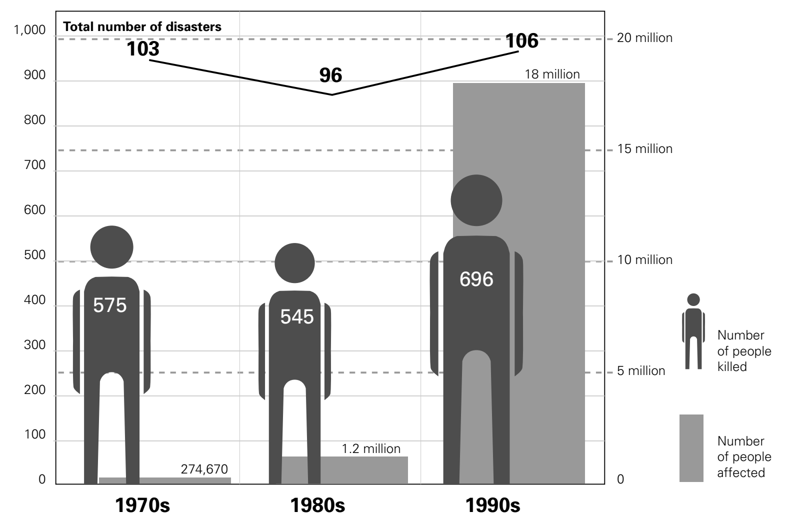
The European Environmental Agency came to a similar conclusion. According to the Agency,

> Economic losses from climate and weather related events have increased significantly during the past 20 years from an annual average of less than USD 5 billion to about USD 11 billion. This is due to wealth increase and more

> frequent events. The average number of annual disastrous weather and climate related events in Europe doubled over the 1990s compared with the previous decade, while non-climatic events such as earthquakes remained stable.[90]

The number of people killed in the Oceania region by weather related disasters rose 21 % in the last three decades of the 20th century including those affected by events such as cyclones, floods, landslides, droughts and extremes of temperature (Figure 3.2).[91] Worldwide, around 188 million people were adversely affected by natural disasters in the 1990s, six times more than the 31 million directly or indirectly affected by war.[92]

Figure 3.2: Natural disasters in Oceania 1970–1999



Source: Walter, Jonathan, ed., *World disasters report 2002: focus on reducing risk*, Kumarian Press for the International Federation of Red Cross and Red Crescent Societies, 2002.

Although such statistics must be treated with caution, since they are not yet sufficiently discerning to enable definitive judgments about cause and effect, they do broadly confirm the upward trend in extreme weather events predicted by climate change models. Hurricane Katrina is instructive. This so-called once in a century hurricane devastated the south-eastern coastal states of the US in August 2005, causing more than a thousand deaths and costing by some estimates around US$125 billion in economic damage, making it the worst natural disaster in US history.[93] More Katrinas can be expected because the Atlantic Basin and Gulf Coast regions, as well as other regions affected by tropical storms, are experiencing a much more intense period of hurricane and tornado activity with major storms (category four and five) having increased in frequency by 100 % since the 1970s. Rather than being a once in a hundred years phenomenon, storms of commensurate strength may become more regular occurrences not only in the northern hemisphere but also in the Pacific's cyclone belt, which affects northern Australia and most Pacific island states.

Scientists are divided about whether this change is due to natural fluctuations or global warming, although the differences are partly explicable by the rigorous scientific tradition which requires a far higher level of certainty than is customary within the intelligence and national security community when assessing strategic risk. Such certainty is not yet possible. However, there is a strong correlation between the steady rise in ocean temperatures attributable to anthropogenic greenhouse-gas emissions and the demonstrable increase in storm frequency and intensity.[94] Hurricanes feed off warm water as trade winds blow over the ocean surface, pulling heat from the water as energy. Typically, large storms require ocean temperatures of 27°C, conditions which are now occurring much more regularly as tropical waters heat up. The strength of category four and five storms is a direct consequence of these warmer ocean temperatures.[95]

Storms of Katrina-like magnitude have a clear security dimension because of the death and destruction they bring in their wake, and the political, economic and social stresses they place on even the most developed states. As temperatures increase, the scale and frequency of

natural disasters is expected to rise in concert with extreme weather events, generating more humanitarian disasters requiring national and international relief. As a result of Katrina, over one million people were displaced, 0.2 % was shaved from US economic growth for the quarter, and oil and gas production in the Gulf of Mexico was seriously disrupted, forcing President Bush to authorise the release of oil from the US strategic petroleum reserve. The devastation was described by Mississippi Governor, Haley Barbour, as akin to the detonation of a nuclear weapon and President Bush compared its impact with the terrorist attacks on the US in September 2001.[96] Eventually, a full Army division, the famed 82nd Airborne, was called in to restore order and assist in emergency relief.

Defence forces often bear the brunt of major emergency and humanitarian operations as they are usually the only organisations with the resources and skilled personnel to respond quickly and effectively to natural disasters. The Australian Defence Force and its Japanese and New Zealand counterparts were crucial to the success of early efforts to provide humanitarian relief and the restoration of essential services in Indonesia's province of Aceh, the area worst hit by the December 2005 tsunami. And in its largest ever peace time deployment, tens of thousands of soldiers from the Peoples Liberation Army performed a similar task during the disastrous floods of 1998 which inundated large areas of northern China.[97] The involvement of defence forces in emergency relief operations will grow inexorably as the scale and frequency of climate induced disasters increases, transforming them into multi-skilled institutions in which disaster relief will become a core task if, indeed, it has not already become so.

Natural disasters linked to climate change may prove an even greater security challenge for developing states, displacing affected populations, calling into question the legitimacy or competence of the national government and feeding into existing ethnic or inter-communal conflicts. In extreme cases, the survival of the nation itself may be in question. For example, the 1998 monsoon season brought with it the worst flood in living memory to Bangladesh, inundating some 65 % of the country, devastating its infrastructure and agricultural base and raising fears about Bangladesh's long-term future in a world of higher ocean levels and more intense cyclones. In the absence of effective mitigation strategies, a one metre rise in sea-level would flood about 17.5 % of Bangladesh and much of the Ganges river delta, which is the country's food basket.[98]

Sea-level rise

Bangladesh is not the only nation with a problematic future because of climate change. Sea-level rise may have dire consequences for low-lying atoll countries in the Pacific such as Kiribati (population 78,000), the Marshall Islands (population 58,000), Tokelau (population 2000), and Tuvalu (population 9000).[99] These small islands are highly vulnerable to climate change because of their topography, high ratio of coast to land area, relatively dense populations and subsistence economies.[100] For example, periodic storm surges could well inundate up to 80 % of the land area of North Tarawa and 54 % of South Tarawa (Kiribati) by 2050 with the economic costs expected to range between 10 % and 30 % of GDP in any given year.[101] By 2080 the flood risk for people living on small islands will be on average 200 times larger than if there had been no global warming and the risk could be even higher if the melting of polar ice continues at present rates.[102] Ultimately, human habitation may not be possible on them even with moderate climate change. If temperature and sea-level rises are at the high end of those forecast, then the sea will either eventually submerge the coral atolls or ground water will become so contaminated by salt water intrusion that agricultural activities will cease.[103]

Larger, more mountainous and populous islands such as Fiji and New Caledonia will also be seriously affected. Michael Edwards contends that in a worst case scenario of sea-level rise, much of Fiji's productive land and urban areas would be flooded. This would exacerbate 'tensions between indigenous Fijians and their Indo–Fijian co-citizens who would find it extremely difficult to access new land.'[104] Intercommunal strife between indigenous Kanaks and French settlers could similarly be inflamed if productive land becomes scarcer and

the Kanaks cannot sustain their agriculture and life styles on their ancestral land.[105] Unsurprisingly, climate change has risen to the top of the political agenda in the Pacific. The President of the Federated States of Micronesia, Leo Falcam, has warned that 'sea-level rise and other related consequences of climate change are grave security threats to our very existence as homelands and nation-states' while the leaders of all 16 Pacific nations expressed their deep concern about the adverse impact of climate variability and sea-level rise at the 2002 Pacific Island Forum.[106]

Box 3.1: Adapting to climate change

Not all change brings disaster, as natural and human systems have an inbuilt capacity to adapt and reduce their vulnerabilities. As a consequence of climate change much of this adaptation will be underway already as animal and plant species modify their behaviour, alter their distribution and frequencies of occurrence, select different genetic-code sets, or even become extinct. There is some observational evidence of these changes, but the subtleties and our lack of data mean that by and large they are occurring without our knowledge. Humans, of course, also have a capacity to adapt and as thinking beings to consciously weigh risk and develop responses.

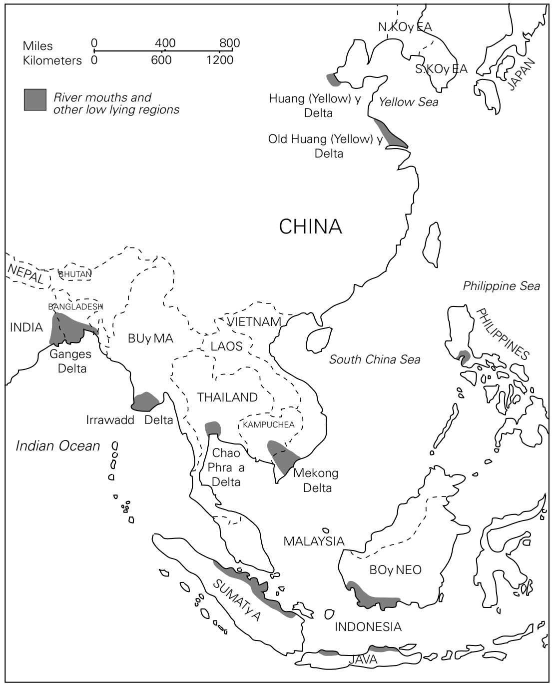
Although adaptation, be it consequential or planned, can substantially lower the cost of climate change the benefits of adaptation are very sensitive to income. Consider, for example, the effect of extreme climatic events such as hurricanes, cyclones, storms, floods and droughts. Both the frequency and the severity of 'natural disasters' affect low-income countries disproportionately. In the last decade of the 20th century, 94 % of all natural disasters and 97 % of deaths due to natural disasters occurred in low-income countries. Around two-thirds of all disaster-related deaths occurred in South Asia alone. Moreover, the cost of natural disasters as a proportion of GDP was 20 % higher in low-income than in high-income economies.

The disproportionate impact of extreme events on low-income economies is due less to environmental factors than to the extreme vulnerability of the poorest sections of those communities. The poorest in society are often the most exposed to disaster risk. The capacity both to avoid and to recover from disasters is quite limited, and the probability that people affected by disaster will lose their lives or livelihoods is often high. People affected by natural disasters in low-income countries are reckoned by the International Red Cross/Red Crescent to be four times more likely to die than people affected by natural disasters in high-income countries.[107]

But rising sea levels pose far wider challenges to regional security than the survival of small island states in the Western Pacific. Most of Asia's densest aggregations of people and productive lands are on, or near, the coast, including the cities of Shanghai, Tianjin, Guanzhou, Hong Kong, Tokyo, Jakarta, Manila, Bangkok, Singapore, Mumbai and Dhaka. The areas under greatest threat are the Yellow and Yangtse River deltas in China, Manila Bay in the Philippines, the low lying coastal fringes of Sumatra, Kalimantan and Java in Indonesia, and the Mekong, Chao Phraya and Irrawaddy deltas in Vietnam, Thailand and Myanmar respectively.[108] Many of these locations have not previously been susceptible to climate induced risks and their vulnerability has increased due to extensive urbanisation and human settlement in coastal and riverine environments, exacerbated by extensive land use clearance. Heightening the risk is the fact that several large Asian cities are susceptible to cyclones driven by warm expanses of water that form in the west equatorial Pacific Ocean during summer. These cyclones produce strong tidal surges, especially in La Niña years, which can greatly

increase the severity of coastal flooding and the consequent threat to lives, infrastructure, agriculture and fresh water.[109]

Map 3.1: Areas at risk from sea-level rise in Asia



Source: Bardach, John E., *Coastal Zone Actvities and Sea level Rise*. East-West Center. Environment and Policy Institute. Working paper no. 11, 1988, p 8.

One aspect of sea-level rise that has received scant attention is the impact the submergence of small atolls, rocks and low lying islands could have on the Exclusive Economic Zones of maritime states and disputed sea bed resources and fishing grounds. This is a critically important issue since small rocks and islets are commonly used to delineate maritime boundaries and to claim vast tracts of ocean which would otherwise fall outside the Exclusive Economic Zones of contiguous states or be designated high seas and therefore open to foreign exploration and exploitation by other nations. It is not clear whether the United Nations Law of the Sea Convention will protect the rights of small Pacific island states whose territory may be partially or wholly submerged by changes in sea level attributable to human activities.[110] Nor is there certainty about who would have ownership rights to marine resources adjacent to recently submerged islands or rocks.

Table 3.1: Potential land loss and population exposure to sea-level rise in selected Asian countries.

	Sea-Level Rise	**Potential Land Loss**		**Population Exposed**	
Country	(cm)	(km^2)	(%)	(millions)	(%)
Bangladesh	45	15,668	10.9	5.5	5.0
Bangladesh	100	29,846	20.7	14.8	13.5
India	100	5,763	0.4	7.1	0.8
Indonesia	60	34,000	1.9	2.0	1.1
Japan	50	1,412	0.4	2.9	2.3
Malaysia	100	7,000	2.1	> 0.05	> 0.3
Vietnam	100	40,000	12.1	17.1	23.1

Source: http://www.grida.no/climate/ipcc_tar/wg2/446.ht.

Note: There are two estimates for Bangladesh.

Rising oceans could complicate the resolution of disputed sovereignty claims in the Spratly Islands, a group of low lying atolls in the South China Sea which sit astride potentially rich deposits of oil and have already been the scene of military tensions between China, Vietnam and the Philippines. Some of these islands are already partially submerged and the highest (Southwest Cay) is only four metres above sea-level.[111] Beijing has also challenged the island status of Okinotorishima, a small offshore islet claimed by Japan at the southernmost part of the

archipelago that is uninhabited and slowly sinking, but which could be significant in any future conflict over maritime resources.[112] Under Article 121 of the United Nations Law of the Sea Convention, islands classified as 'rocks' are not entitled to a 200-nautical mile Exclusive Economic Zone.

Energy security

Climate change, energy security and foreign policy are inextricably linked in other ways. Fossil fuels such as coal, oil and gas extracted from the sediments of long dead animals and plants are the life-blood of modern society, accounting for three quarters of all energy used. But these same fossil fuels are also responsible for producing nearly 80 % of anthropogenic greenhouse gases which are the major cause of planetary warming.[113]

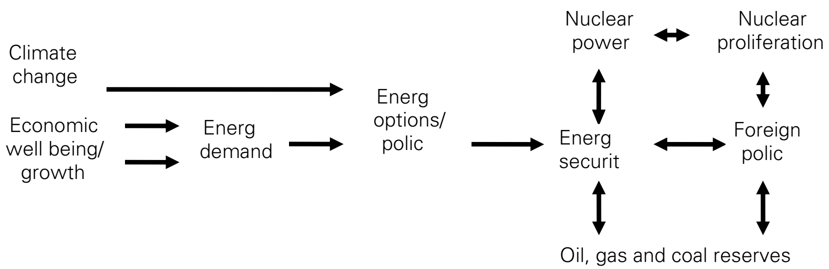
There are, of course, many alternatives to fossil fuels including thermal and photovoltaic solar power, as well as wind, tidal, wave, biomass and nuclear power. And it is possible to lower primary energy demand through improved conversion and end-use efficiency. The problem is that in most cases these alternative technologies are either more expensive than conventional fuels, or politically unpalatable as in the case of nuclear power in the West, or require lengthy periods of time to install, as well as enormous capital investment, if they are to replace current capabilities. And there are questions about the technical feasibility of some alternative fuels. Since there is no single energy panacea a portfolio approach is needed.[114] However, even supposing governments have the political will to implement a well developed alternative energy strategy, renewable energy sources, such as solar, wind and tidal power are unlikely to replace fossil fuels in the near future.

We established in Chapter one, that even if emissions from fossil fuels are stabilised at 1990 levels in all countries, the concentration of greenhouse gases in the atmosphere will continue its inexorable rise, heating up the atmosphere and the earth's surface as a consequence. The short-term increase in these gases can be extrapolated from current fossil-fuel usage (and rates of deforestation), which we can predict with reasonable accuracy. Almost all nations anticipate growth in energy usage in the coming decades.

Australia, for example, is expected to grow at around 2.1 % per year through this and the next decade, powered by conventional fossil fuels.[115]

Globally, the International Energy Agency expects a 50 % increase in fossil fuel usage over the next 15 years which will dramatically push up greenhouse-gas emissions without mitigating measures.[116] In 1990, global emissions of carbon dioxide, the main greenhouse gas, totalled 5.8 billion tons of carbon equivalent, which in a 'business as usual' scenario will rise 34 % to 7.8 billion tons by 2010. If every signatory to the Kyoto Protocol reaches its pledged target, an unlikely eventuality, since only two countries are within their agreed targets (the UK and Sweden), the increase would still be the equivalent of 7.3 billion tons. This small reduction would be more than offset by the rise in emissions from developing countries, which have been reluctant to sign Kyoto for fear that signing up to mandatory targets would set back their economic growth.[117]

Figure 3.3: Schematic representation of the relationship between climate change, energy security and foreign policy



Arguments about climate change are feeding into a parallel debate about energy security, complicating energy choices and touching on issues as diverse as nuclear proliferation and foreign policy (Figure 3.3). Nowhere is this more evident than in changing attitudes towards nuclear power, once seen as the energy choice of last resort because of its undeserved reputation as a dangerous and dirty fuel.

The need to reduce greenhouse gas emissions and growing public anxiety about global warming is reviving interest in nuclear power because many see it as the only significant source of virtual carbon-free energy.[118] In Asia, the influential Japanese business federation, the Keidanren, has urged the government to 'position atomic energy as the central source among the various sources of basic energy', while China is rapidly expanding its nuclear power industry.[119] Asia aside, high profile defections from the anti-nuclear lobby confirm that opposition in the West to nuclear power is waning because global warming is considered to be a greater environmental evil. Among the more prominent apostates are the Chief Scientific Advisor to the British Government, Sir David King, and the conceiver of the Gaia theory, James Lovelock (Box 3.2).

Critics maintain that switching to nuclear power in order to reduce greenhouse-gas emissions is misguided and merely replaces one problem with an even more serious one — the proliferation of plutonium and enriched uranium which can be used for manufacturing nuclear weapons. They argue that safely storing and protecting this material from terrorists and criminal groups intent on acquiring weapons grade material for use or profit is problematic, and the political and security risks too high.

However, the security consequences of unmitigated global warming may well outweigh the risk of terrorists or rogue states acquiring nuclear material from expanded global stockpiles. The reality is that the world is already awash in nuclear material, much of it stored in unsafe temporary storage sites located near nuclear reactors. In Northeast Asia, for example, approximately 50,000 tonnes of spent fuel are likely to be generated between 1990 and 2020, containing 450 tonnes of plutonium.[120] Even if all the nuclear power plants in the world were to be shut down tomorrow and every nuclear weapon dismantled, the accumulated waste of half a century would still have to be isolated, safeguarded and eventually disposed of — either in an underground repository or, less desirably, by reprocessing.[121] So arguing against nuclear power on the grounds of safety does little to address existing problems of waste disposal or proliferation, and even less the issue of global warming.

Box 3.2: James Lovelock: environmental apostate

I am a Green and I have been one for most of my life. I don't hug trees but I have planted 20,000 of them in a mistaken, but well intended, attempt to make the land where I live go back to Gaia faster. I care deeply about the countryside, and even more about the few remaining places as yet untouched. But I am also a scientist, and my main contribution has been Gaia theory, which sees the earth actively sustaining its climate and chemistry so as to keep itself habitable. As a scientist, and from this theory, I consider the earth to have reached a state profoundly dangerous to all of us and to our civilisation. I am deeply concerned that public opinion and, consequently, the government listen less to scientists than they do to the Green lobbies. I know that these lobbies are well intentioned, but they understand people better than they do the earth; consequently, they recommend inappropriate remedies and action.

The outcome is almost as bad as if the medieval plague had returned in deadly form and we were earnestly advised to stop it with alternative, not scientific, medicine. Alternative medicine has its place, and when we are healthy it is good to avoid strong drugs for minor ailments, and many find relief in acupuncture or homeopathy. But when we are seriously ill we need something stronger. Now that we have made the earth sick, it will not be cured by alternative green remedies, like wind turbines and bio fuels alone. This is why I recommend instead the appropriate medicine of nuclear energy as part of a sensible portfolio of energy sources.[122]

Environmental and climate change refugees

In one of the more evocative scenes of the Hollywood blockbuster *The Day After Tomorrow*, and an ironic twist on current reality, thousands of starving, dislocated North Americans stream south across the border to sanctuary in Mexico, fleeing from the frigid winter descending on the continent as the Thermohaline Circulation collapses. Although the film is predictably dramatic in its depiction of this high impact but extremely low probability scenario, the possibility that climate change might cause mass migrations of environmental refugees and displaced persons, with serious consequences for international security, is certainly plausible and should not be dismissed as a figment of Hollywood's imagination.

We already know that refugee flows and unregulated population movements can destabilise states internally, aggravate trans-border conflicts, create political tensions between sending and receiving states, and jeopardise human security.[123] In fact, one of the defining features of the post-Cold War security environment has been the dramatic increase in unregulated population movements around the globe. In 1975, there were around 2.4 million refugees globally but the number of refugees and people of concern to the United Nations High Commission for Refugees (UNHCR) grew ten-fold in the following two decades, peaking in 1995 at 27.4 million.[124] Since 1995, the number of refugees has declined significantly, mainly due to the successful implementation of several ambitious repatriation programs, but the number of people of concern to the UNHCR at the beginning of 2005 was still 19.2 million.[125]

The causes of these people movements are complex and interconnected. Unlike past movements, which were episodic and driven by seminal events such as major war between states, those of the post-Cold War period have been sustained over longer periods of time and are being stimulated by economic opportunism, government fiat and rising levels of intra-state violence. But there is growing evidence to suggest that environmental decline is a contributing cause. In the future, climate change may play a significant ancillary role. Moreover, most of the world's refugees and internally displaced persons are located in developing states and not the affluent West, precisely the countries likely to be most affected by climate change.

Ecological stress in the form of naturally occurring droughts, floods and pestilence has been a significant factor in forcing people to migrate since the beginning of recorded history.[126] So has war-related environmental destruction. But demographic pressures, modern development practices, and the rapid pace of social and economic change have given rise to concerns that a new class of displaced people, sometimes referred to as environmental or climate change refugees, is being created in poorer states.[127] Human induced environmental degradation is stimulating unregulated population movements either by reducing incomes, especially in rural regions, or by rendering the environment so unhealthy and unpleasant that people feel compelled to move.[128] New migrants, regardless of whether or not they cross borders, can impinge on the living space of others, widen existing ethnic and religious divides and add to environmental stress in a self-sustaining cycle of migration and instability.

Some contend that environmental refugees now constitute the fastest growing proportion of refugees globally. Oxford academic Norman Myers, for example, predicts that by 2050 up to 150 million people may be displaced by the impact of global warming. Much of the anticipated impact will be in Asia because of the large number of cities and population aggregations on the coast. Asia already hosts more refugees and internally displaced people than any other region of the world. But climate change could add many more. Myers estimates that up to 26 million people in Bangladesh are at risk from sea-level rise, 73 million in China and 20 million in India.[129] Jacobson believes that by 2050, refugees from environmental causes could exceed all others by a factor of six.[130]

These figures must be treated with caution, as the links between environmental degradation and unregulated population movements are not well established, conceptually or empirically. Since most of the people forced to move because of environmental factors remain within the boundaries of their home state, strictly speaking they are not

refugees. Many definitions do not distinguish between people displaced by naturally occurring climatic events and those resulting from human activities.[131] As Richard Black has pointed out, these conceptual difficulties have practical consequences. Generating corroborating data is critically dependent on what definition is used. Elastic interpretations of environmental refugees can produce large figures that are alarming but misleading. So far there is little hard evidence to support the argument that environmental change is solely or even primarily responsible for unregulated population movements.[132] It is more likely to be one of many causal variables.[133]

Sea-level rise, more frequent storm surges and other climatic factors with the potential to stimulate migration will increase over the course of many decades, allowing affected countries time to make adjustments and to ameliorate the effects. Government capacity will therefore be a critical determinant of the ability of societies to adapt and avoid climate induced political disturbances and population movements. Most population displacements will not result in conflict or threaten human or state survival, and migration attributable to climate change will probably be internal, rather than transnational, in keeping with contemporary trends. Still, climate change is set to stretch the limits of adaptability and resilience in some developing states, overwhelming the carrying capacity of the land, disrupting traditional land-management systems and making migration an attractive option to preserve quality of life.[134]

Climate induced migration is set to play out in three distinct ways. First, people will move in response to a deteriorating environment, creating new or repetitive patterns of migration, especially in developing states. Secondly, there will be increasing short-term population dislocations due to particular climate stimuli such as severe cyclones or major flooding. Thirdly, larger scale population movements are possible that build more slowly but gain momentum as adverse shifts in climate interact with other migration drivers such as political disturbances, military conflict, ecological stress and socio-economic change.[135] Even the benign effects of climate change could lead to conflict. For example, China's Xingiang province is likely to benefit from increased rainfall, attracting an influx of Han migrants into the Muslim Uighur ancestral lands, where tensions between the two communities are already on the rise and a low level insurgency is festering.

Australia will not be immune from consequences of climate induced environmental migration. Although abrupt climate change triggering a surge of environmental refugees is still at the lower end of the probability scale, population displacements caused by sea-level rise, desertification, flooding and extreme weather are a distinct possibility. If affected states have sufficient time and resources to anticipate and plan for such exigencies then the security consequences will probably be minimal. However, poorer states could well be overwhelmed by the task confronting them, in which case Australia may experience the ripple effects of climate induced political disturbances and even violent conflict in the region. Should atoll countries like Tuvalu, Kiribati and Tokelau become uninhabitable Australia will come under pressure to help resettle their people.

Unfortunately, there has been no comprehensive analysis of the numbers of people likely to be displaced as a result of climatic factors, particularly sea-level rises of the order predicted by the IPCC. Australia and regional states need to give this issue more serious attention since three of the areas most vulnerable to sea-level rise globally are in Asia and the Pacific (South Asia, Southeast Asia and low lying coral atolls in the Indian Ocean and the Pacific) and six of Asia's ten mega cities are located on the coast (Jakarta, Shanghai, Tokyo, Manila, Bangkok and Mumbai). It is entirely possible, for example, that large areas of coastal Thailand, Malaysia and Indonesia will be permanently flooded by rising sea levels, notably Bangkok and much of the equally densely populated coastline of northern Java, forcing the relocation of many millions of people because governments will not have the resources to fund protective levy banks or other storm control measures.[136]

However, it is difficult to see a surge of environmental boat people seeking to enter Australia illegally. In Asia most of those internally displaced from environmental causes will find new homes within the boundaries of their native countries and those who do not will probably seek refuge in states where they have strong cultural or ethnic ties. Thus

Bangladeshis would seek refuge in neighbouring India or Pakistan, Indonesians from Sumatra would look to Malaysia, while South Korea and China would be the preferred destinations for North Koreans. The number of Pacific Islanders at risk is relatively small and New Zealand is a much more likely destination for them. Tokelauans already have access to New Zealand, the inhabitants of Tuvalu have negotiated migration rights for nearly all of its citizens, while the Marshallese can settle in the United States under the Compact of Free Association. Of the Pacific Island states most threatened by sea-level rise only the inhabitants of Kiribati have no real migration options.[137] Even an abrupt, catastrophic climatic event is unlikely to send a surge of people across borders, as the Tsunami which devastated the Indonesian province of Aceh in early 2005 reminds us. The survivors will not have the physical resources or mental resolve to move very far from their homes.

Chapter 4

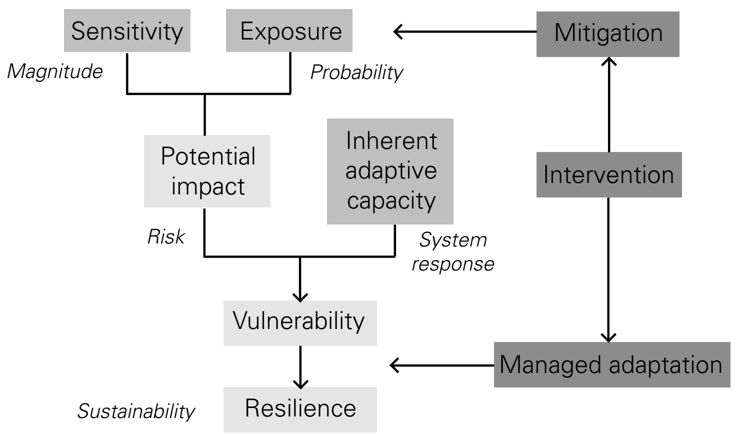
Wild cards and abrupt climate change

Abrupt climate change generally refers to a large shift in climate that persists for years or longer — such as marked changes in average temperature, or altered patterns of storms, floods, or drought — over a widespread area such as an entire country or continent, that takes place so rapidly and unexpectedly that human or natural systems have difficulty adapting to it. In the context of past abrupt climate change, 'rapidly' typically means in the order of a decade.

US National Research Council Report.[138]

In assessing the risk of various climate change scenarios for international security, judgments are required about the probability of their occurrence, the sensitivity of humans and natural ecosystems to the change and their capacity to adapt (Figure 4.1).[139] Risk can be minimised through adaptation and effective mitigation strategies, but both will be influenced by the rate and degree of climate change. As previous chapters make clear, the central problem we face is that the anticipated temperature and sea-level rises will occur over a relatively short period, certainly less than a century, reducing the time available for adaptation and mitigation and therefore increasing human and ecosystem vulnerability. We also need to recognise that the limits to adaptation and mitigation are political and economic, as well as physical.

Figure 4.1: Managing climate-change risk



Source: Adapted from D. Schroter and the ATEAM consortium, 2004, *Global change vulnerability — assessing the European human-environment system*, Potsdam Institute for Climate Impact Research and Allen Consulting (2005).

But what would happen if significant climate change were to take place far more rapidly than our scientists have forecast, over decades rather than centuries? And what might be some of the strategic consequences? Climate researchers have identified several episodes of large scale, abrupt climate change over the past 100,000 years both prior to, and after, the last Ice Age during which rapid warming has taken place (as great as 16°C) in specific regions over spans as short as a decade, although there is still substantial debate over how global these changes were.[140]

In this Chapter we assess, in ascending order of potential seriousness, four low probability but high impact ‘wild cards’ in the climate change pack. Is it possible that:

- aerosols may have masked the real level of global warming?
- forests and other elements of the terrestrial ecosystem might in aggregate actually become a carbon source rather than a carbon ‘sink’?
- the rapid recession of land-based glaciers and depletion of the Earth’s inventory of snow and ice might accelerate the rate of sea-level rise and have major local or regional impacts?
- the collapse of the deep-ocean or Thermohaline Circulation could trigger a rapid cooling of Europe’s climate or temporarily slow the rate of warming and have a detrimental effect on the growth of carbon dioxide in the atmosphere and life in the ocean?[141]

And could these wild cards, individually or collectively, abruptly alter our climate or significantly speed up the changes already underway?

Table 4.1: Climate change wild cards

Phenomenon	Risk
Collapse of the global Thermohaline Circulation	Slowing or shutting down of this circulation could result in: • Significant regional climate change • De-oxygenation of the deep ocean • Reduced capacity of the oceans to absorb part of the released carbon dioxide.
Glacial and permafrost melt	Rapid recession of land-based glaciers and permafrost melt may: • Cause local and regional flooding and affect the distribution and availability of water • Increase the rate of sea-level rise • Release trapped greenhouse gases.
Terrestrial uptake of carbon	Capacity of forests to act as a carbon sink diminishes or reverses leading to more rapid increase of atmospheric carbon dioxide.
Aerosol masking of climate change	Climate may be more responsive to greenhouse gases than we thought.

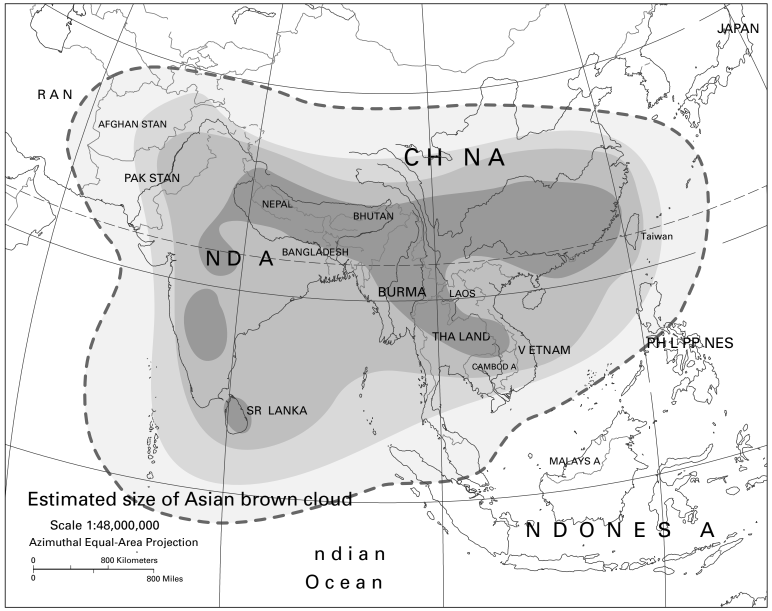
Aerosol masking

As greenhouse-gas emissions increased during the latter half of the 20th century, there was, at least for a time, an accompanying growth in airborne aerosols — primarily sulphate particles resulting from combustion processes — that mitigated the warming which might otherwise have occurred. The reason is that these particulates scatter solar radiation, thereby releasing more energy to space, reducing the heating of the earth's surface and producing a cooling effect. Much of this effect was

concentrated in Europe and North America in the post-World War Two decades, as manufacturing surged and airborne pollution worsened. But towards the end of the century, the concentration of particulates also increased in Asia as first Japan, followed by the Asian tiger economies and then China and India emulated Europe and North America.

The so-called 'Asian brown haze', which has become a semi-permanent feature of the region stretching from the northern Indian Ocean to China and much of Southeast Asia during summer, is graphic evidence of the rise in airborne aerosols in the developing world. A combination of ash from fires lit by humans, vehicle emissions, and soot from millions of inefficient cookers using wood and cow dung, the haze has reduced the amount of sunlight by 10–15%, leading to a 20–40% fall in monsoon rainfall and atmospheric warming. The haze has global implications because it can travel half way around the world depending on the strength and direction of the prevailing winds. And it's getting worse.[142]

Map 4.1: Asian brown cloud



Establishing an unambiguous link between higher aerosol densities and global temperature is complicated by the secondary effects on the formation of clouds and rainfall. All water droplets in clouds are formed around nucleating aerosol particles. Higher concentrations of particulates means more water droplets and clouds reflecting greater amounts of solar radiation back into space, thus reinforcing the cooling effect. Clouds with smaller but more numerous droplets tend to live longer before depositing rain or evaporating, so their cooling effect is extended. However, neither of these secondary effects is well represented in current climate models and there are major uncertainties about their impact on our climate. It is conceivable, however, that the real rate of global warming has been masked by the presence of aerosols produced by human activities. If this masking effect is substantial, as some scientists believe, then our success in reducing emissions from combustion sources through improved power plant filtration, removing sulphur from fuels or moving towards alternative fuels and cleaner energy may paradoxically increase global warming towards the upper end of the IPCC forecasts.

Carbon sink or carbon source?

Forests, along with the oceans, act as carbon ‘sinks’ in the sense that they can absorb more carbon dioxide than they release. There are well-grounded fears that large-scale deforestation will lead to the release of large quantities of carbon dioxide into the atmosphere (the carbon in the standing biomass of the Earth is about equal to that in the atmosphere) and diminish the terrestrial ecosystem’s capacity to act as a carbon dioxide sink. So far there has been no hard evidence to support these concerns. In fact research shows the opposite — that in the last two decades the biosphere has acted as a sink for carbon dioxide which has helped slow the rate of increase in the atmosphere.[143]

Given the large-scale deforestation of recent decades this is somewhat surprising. The most likely explanation is that higher levels of carbon dioxide and sulphur/nitrogen emissions over recent decades have acted as fertilisers, stimulating plant growth and compensating for the loss of

forests. And, as the Earth warms the growing season has been extended in higher latitudes, adding to forest and plant growth, especially in the Northern Hemisphere.[144] However, this ameliorating effect is probably unsustainable for at least three reasons. First, unless reversed, the loss of forest cover will eventually reach the point where the terrestrial ecosystems cease to act as a repository of carbon dioxide. Secondly, while this trapped carbon is retained in the stems and roots of plants for years or even decades, it will eventually be returned to the atmosphere. Thirdly, further warming may mobilise otherwise relatively stable non-living carbon in the soil, returning it to the atmosphere and further warming the planet.

Biologists generally agree that as warming continues, the global biosphere will cease being a net sink and instead become a source of carbon, warming the planet by a third more than the IPCC has predicted. However, because of the complexity of the process, and insufficient data, biologists are divided on when such a carbon tipping point might be reached although it could be within the next few decades, complicating mitigation strategies.[145]

Glacial and permafrost stability

Global warming is already causing glaciers to melt and permafrost thaw, increasing the rate of sea-level rise and the release of trapped greenhouse gases. The accelerating melt of glaciers could lead to catastrophic flooding in alpine countries, followed by shortages of fresh water as the flow of glacier-fed rivers diminishes, or dries up altogether. Bhutan and parts of the Andes have already experienced flash flooding where lakes formed from melting glaciers have collapsed their banks.[146] In Kenya, the snows of Mount Kilamanjaro are destined to fade into memory as the remaining snow and ice disappear, disrupting water dependent highland agriculture.

While the Earth’s ice inventory is unlikely to melt away entirely, at least in this century, a substantial reduction in ice and snow is highly probable. Alaskan glaciers have already retreated so rapidly that they make up about half the glacial melt globally. Sea-ice has declined by 8 % and its thickness by roughly half, in the past 30 years. A four year study released by 250 scientists from eight circumpolar countries in November 2004 found that global warming is heating up the Arctic more quickly than any other region of the earth. Among its key findings is that the average Arctic temperature has increased twice as much as that of the rest of the world over the past few decades and that a substantial melting of the Greenland ice cap is a real possibility.[147] These changes will have global effects because the polar regions act as 'the earth's air conditioner.'[148] As highly reflective ice and snow melt, the Earth will absorb more heat particularly at higher latitudes, and glacial melt-water will disrupt ocean currents and reduce the cooling capacity of the arctic air conditioner.

Of even greater concern, however, is the distinct possibility that a rapid melting of the polar ice caps could dramatically raise sea levels, inundating coastal and low lying areas around the world. If all the water trapped in the Antarctic ice cap as a whole, in the more vulnerable Western Antarctic ice sheet, in Greenland and in other glaciers were to melt it is estimated that sea levels would rise by about 73, 7, 4–6 and 0.5 metres respectively.[149]

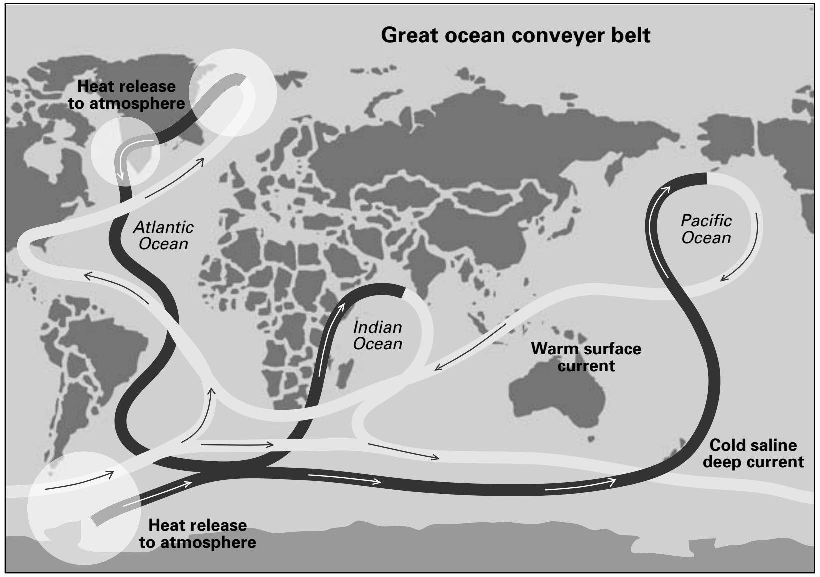
Antarctica is expected to remain relatively stable for some hundreds of years despite the Earth's warming because most of the ice sheet is at a sufficiently high altitude that it will remain below melting point. While there has been a large loss of ice from the Antarctic Peninsula and a smaller observable melt in West Antarctica, the Antarctic ice sheet as a whole may actually grow in thickness because of increased precipitation from heavier snow falls as the atmosphere warms.[150] But there is no doubt that small, lower altitude glaciers are retreating. And satellite data shows that Antarctica is losing 152 cubic kilometres of ice every year — enough to supply Los Angeles with fresh water for 36 years — which is a much higher rate than scientists had expected, raising the prospect that global sea levels could rise more rapidly than predicted.[151] Concern is focusing on those regions where the ice sheets extend to the coast, since melting water seeping through to the base of the glacier will speed up flow rates to the sea, while high water temperatures in the oceans will melt the ice that has flowed to the coast and was previously grounded on the ocean bed. Where these glaciers are still grounded, rising sea levels and warmer conditions could cause the grounded ice to melt faster speeding up the flow of glaciers to the sea.[152]

Another risk factor is the stability of high latitude permafrost. There is clear evidence that ground which was once frozen all year round is melting at higher and higher latitudes. This has observable effects on hydrology, wildlife and indigenous peoples in the Arctic, on the stability of the ground and thus buildings, roads and bridges.[153] But the real danger is that greenhouse gases, such as carbon dioxide and methane, previously trapped under this layer of frozen soil, will be free to escape into the atmosphere as the soil becomes more permeable. Although there are no definitive estimates of the volume of gases trapped under the permafrost they are thought to be considerable — perhaps as much as 500 billion tonnes, the equivalent of 70 % of all carbon currently present in the atmosphere.[154] This release could be quite rapid and widespread, as warming progresses, and would include a significant amount of methane gas, which is one of the most damaging of the main greenhouse gases. Should this occur, then the IPCC predictions of future global warming would have to be revised upward by a substantial margin, since their calculations only take account of emissions from fossil fuel combustion.

Collapse of the Thermohaline Circulation

The major circulation of the deep global oceans is caused by the formation of dense water at high latitudes that sinks and ventilates the deep and middle ocean depths, before moving towards the equator and then upwelling in the tropical regions some hundreds of years later. The formation and sinking of this denser water occurs primarily in the North Atlantic and around the Antarctic coast. This process is an important part of the climate system and is called the Thermohaline Circulation (from the Greek words for heat 'thermos' and salt 'halos'). The sinking of water is a result both of colder temperatures and more saline conditions. It enhances wind-driven surface currents, the best known of these being the Gulf Stream, where low-latitude water flows towards the pole replacing the sinking water (Figure 3.2).

Figure 4.2: Diagrammatic representation of the Thermohaline Circulation



Source: http://www.ipcc.ch/present/graphics/2001syr/small/04.18.jpg.

Note: Black represents the colder, deeper currents and white the warmer, shallower currents.

A slowing of the Thermohaline Circulation may have been responsible for earlier periods of relatively cold temperatures that afflicted the northern hemisphere after the last Ice Age. During the Younger Dryas, frigid winters were the norm with icebergs appearing as far south as the Portuguese coast.[155] Although not as severe as the Younger Dryas, during a period commonly referred to as the 'Little Ice Age' between 1300 and 1850, winters were significantly colder than today and there were more frequent incidences of violent storms and extended periods of drought, leading to serious famines.

There is evidence that the Thermohaline Circulation has freshened and slowed considerably over the past 40 years because of glacial melt and increasing rainfall.[156] If the Greenland ice sheet shrinks dramatically, the resultant massive release of fresh water could further slow the Circulation as the North Atlantic becomes cooler and less dense. A major report by the well credentialed International Climate Change Taskforce, released in January 2005, found that above the 2°C level, the risks of abrupt, accelerated, or runaway climate change increase. 'The possibilities include reaching climatic tipping points leading, for example, to the loss of the West Antarctic and Greenland ice sheets [and] ... the shutdown of the thermohaline ocean circulation …'[157]

One problem in assessing the possibility that the Thermohaline Circulation could slow dramatically or even collapse is that historical climate records are sparse, particularly for the southern hemisphere, and the data that does exist encompasses too brief a period to confidently extrapolate into the future and predict the behaviour of such complex circulations. Since no detailed records are available of our climate earlier than the mid 19th Century we have little direct understanding of the physical/dynamic drivers of major systems like the Thermohaline Circulation. The models, while improving, are still unable to predict precisely the impact of global warming on the deep ocean circulation although they suggest a slower rate of warming of the European region for a period, rather than a cooling, and a significant reduction in the Circulation by the middle of this century.[158]

Most climatologists believe that while the Circulation might slow over the course of this century it is unlikely to fail altogether but that nevertheless the risk must be taken seriously.[159] Others are less sanguine. A 2005 scientific symposium looking at the impact of greenhouse gases concluded that 'there is a greater than 50 % likelihood of an ATHC *(Atlantic Thermohaline circulation)* collapse, absent any climate policy. This likelihood can be reduced by the policy interventions *(carbon tax on fossil fuels)*, but still exceeds 25 % even with maximal policy interventions. It would therefore seem that the risk of an ATHC collapse is unacceptability large and that measures over and above interventions of a carbon tax should be given serious consideration.'[160]

Thinking the unthinkable

It is clear from this analysis that although a sudden collapse of the Thermohaline Circulation may not be likely it ought to warrant serious consideration by policy makers because of the potentially high impact on our physical and security environments. This was the conclusion of Andy Marshall, often referred to as the US Defense Department's 'Yoda', the octogenarian long time head of the Office of Net Assessment, who has been arguably the most influential strategic thinker in the Pentagon over the past three decades. In 2002, he commissioned two consultants, Peter Schwartz and Doug Randall, to explore the strategic implications of an abrupt climate change event for US and international security. In their report for the Pentagon, Schwartz and Randall challenge the view that international society will have sufficient time to adapt to global warming and that climate change is unlikely to be so severe as to adversely affect global food supplies or create security threats.[161] They argue that such views do not take account of potential discontinuities and threshold events that might bring about rapid climate change and overwhelm the coping capacities of governments.

The threshold event they identify as most likely to endanger international security is a sudden or abrupt collapse of the Thermohaline Circulation, or at least that part of it which flows from the Gulf of Mexico to the North Atlantic. Schwartz and Randall postulate that the warm Gulf Stream could cool or shut down altogether, perhaps irreversibly, creating winters of great severity in the northern hemisphere and triggering catastrophic weather. Thus, rather than causing a gradual heating of the atmosphere over the span of a century, the global warming which has already taken place may suddenly push the climate to a decisive tipping point in which the system that controls the planet's ocean-atmosphere system suddenly flips to an alternative state. In the climatic chaos that follows, food and water shortages develop quickly. Crops fail as established patterns of precipitation break down, storms intensify, average annual temperatures drop by up to five degrees Fahrenheit (about 2.8°C) over Northeast Asia and North America and up to six degrees Fahrenheit (about 3.3°C) in Europe.

Box 4.1. Significance of the Thermohaline Circulation

The Thermohaline Circulation is a crucial element of the Earth's climate system because it influences the amount of heat transported from the equatorial to the polar regions and contributes to the relatively mild winters experienced by the United Kingdom and Western Europe. It is also the mechanism where dissolved gases from the atmosphere are transported into the deep ocean, two of which are particularly relevant to climate change and the health of the bio-system, namely:

- Carbon dioxide. Annually, two billion tonnes of carbon each year from the atmosphere are carried into the deep ocean and effectively out of circulation (at least for hundreds of years) thus slowing the rate at which carbon dioxide is increasing in the atmosphere.
- Oxygen. Oxygen from the atmosphere is transported into the deep ocean, where it is available for the maintenance of life.

As the earth warms, the Thermohaline Circulation is expected to weaken since increased precipitation and the melting of ice will make the water less dense and salty at high latitudes, which is likely to temporarily cool temperatures in parts of Europe but exacerbate the overall warming trend globally because of the accelerated release of carbon into the atmosphere. The extent and speed of this shift is still open to question and requires further research.

In this scenario, North America turns sharply colder and the European hinterland might have a climate more like Siberia. Colder winters lengthen the time that sea ice is present over the North Atlantic; frigid, dry air blowing across the Eurasian landmass would lead to widespread soil loss and harsh conditions for agriculture. In southern China and northern Europe, mega droughts extend their grip over the land for at least a decade while storm surges make much of Bangladesh unliveable. China is particularly hard hit because of a combination of unseasonable monsoon deluges, longer, colder winters and hotter summers caused by decreased evaporative cooling.[162]

Initially, countries attempt to deal diplomatically and collegially with the food, water and energy shortages that develop and an upsurge of environmental refugees. But as the decade progresses international order breaks down because the scale and speed of climate change overwhelms the coping capacities of even the most wealthy and technologically advanced states. An age old pattern of conflict over food, water, and energy reemerges but on a global scale. Drawing on the findings of Harvard archaelogist, Steven LeBlanc, Schwartz and Randall observe that 'humans fight when they outstrip the carrying capacity of their natural environment. Every time there is a choice between starving and raiding, humans raid.'[163]

With these pessimistic assumptions informing their security scenarios, Schwartz and Randall imagine refugees from the Caribbean flooding into the US and Mexico, and struggles over diminishing supplies of oil as demand skyrockets, bringing the US and Chinese navies into confrontation in the Persian Gulf. With fossil fuels unable to meet demand, nuclear power becomes the alternative energy of choice, and further nuclear proliferation becomes inevitable as energy deficient countries develop enrichment and reprocessing capabilities. Japan, South Korea, and Germany develop nuclear weapons as do Iran, Egypt and North Korea.

In Asia, energy hungry Japan, already suffering from coastal flooding and contamination of its water supply, contemplates seizing Russian oil and gas reserves on nearby Sakhalin Island to power desalination plants and energy-intensive agriculture. Pakistan, India, and China skirmish at their borders over refugees, access to shared rivers, and arable land. North and South Korea align to create one technically savvy, nuclear-armed entity. Resource rich, wealthy states like the US and Australia build defensive fortresses in an attempt to quarantine themselves from climatically induced political and social disturbances while

strengthening their security alliances against increasingly desperate neighbours whose needs exceed their carrying capacity — the natural resources, social organisations, and economic networks that support the population.[164] Meanwhile, reflecting an age old security dilemma, states suffering from famine, pestilence, water and energy shortfalls strike out with 'offensive aggression in order to reclaim balance', thereby jeopardising their neighbour's security in pursuit of their own. Countries like Indonesia, whose diversity already creates conflicts, will have trouble maintaining order.[165]

Is this plausible?

How plausible is this scenario, scientifically and strategically? While there is some empirical basis to Schwartz's and Randall's imaginings the speed of the climate shift they envisage is highly speculative and unsupported by existing science.[166] Strategically, it should be noted that Schwartz and Randall are not the first to postulate that climate change will have adverse consequences for international security. In the late 1980s, David Wirth argued that climate change would be responsible for tectonic shifts in the global balance of power 'exacerbating the risk of war'. Wirth believed that intensifying competition for land and natural resources from people dispossessed by sea-level rise could initiate new regional conflicts and aggravate old ones.[167] Shifts in rainfall patterns and temperature extremes could thus become the trigger for civilisational shock, instigating fundamental changes in the distribution of wealth and power, a theme taken up by Jared Diamond, who concludes that many cultures have disappeared or disintegrated because of self-induced environmental crises exacerbated by climate change.[168]

But Schwartz and Randall are the first to focus on the potential political and strategic consequences of abrupt climate change. Unfortunately, the exaggerated press reporting which accompanied the leaking of their findings has not been conducive to an informed discussion of their judgments or working assumptions and the Bush Administration's residual scepticism about the seriousness of global warming has not helped.[169] As a result, the authors' important qualifications and caveats about their scenario building have been generally ignored. Schwartz and Randall state, at the outset, that the purpose of the report is to 'think the unthinkable'. They acknowledge that the climate change scenario chosen describes a low probability event, but one which they believe is nevertheless plausible and 'for which there is reasonable evidence'. Furthermore, they openly admit that the scientific experts they consulted cautioned that the impact would be regional rather than global and the magnitude would be lower than suggested.[170]

At one level it is difficult to assess the soundness of their strategic judgments since Schwartz and Randall ask us to accept an underpinning set of scientific assumptions which do not conform to our current state of knowledge or the balance of climate probabilities. If the probability of the Thermohaline Circulation failing altogether is 10 %, for example, then the strategic outcomes imagined by Schwartz and Randall would be significantly less, since it is reasonable to assume that individual countries and the broader international community would take some steps to alleviate their impact. Once governments are alerted and sufficiently motivated to deal with the threat of potentially catastrophic climate change, adaptive strategies can be implemented rapidly and emergency responses developed for natural disasters will be activated. Furthermore, it is doubtful that abrupt climate change of the kind envisaged by Schwartz and Randall will affect the whole world simultaneously or to the same degree, which means that the security fall-out is likely to be confined, in the first instance, to a limited number of countries or sub-regions.

A second questionable assumption is the notion that famine, fresh water shortages and energy crises would inevitably follow in the wake of an abrupt climate event and play out in the manner predicted. The interrelationship between environmental change and security is far more complex, multi-faceted and indirect.[171] Modern day Cassandras are apt to exaggerate the likelihood of food and water shortages or mass migrations. People affected by natural disasters sometimes emigrate but they are just as likely to stay, endure and rebuild as occurred in Indonesia's Aceh province after the 2004 Tsunami. The same may apply to the survivors of abrupt climate events. So we need to know much

more about the specific climatic circumstances that might cause people to move rather than stay, and to contextualise the impact of climate events on the pre-existing political, social and economic landscape of affected communities and states.

Neither Schwartz nor Randall is a security expert and many of their hypotheses are too sweeping or simply misleading, betraying their lack of specialised knowledge of the field. A case in point is their mischaracterisation of Steven LeBlanc's position 'that every time there is a choice between starving and raiding humans raid.' In fact, LeBlanc made a much more sophisticated and in some places contrary argument — that when people live in states they will often starve rather than fight 'because the government won't allow them to fight.'[172] Similarly, the proposition that South Korea and Japan would develop nuclear weapons as they diversify away from fossil fuels to nuclear power is highly questionable because it ignores the very real domestic and international constraints on either country going nuclear.[173] South Korea and Japan have eschewed nuclear weapons despite the fact that they have long produced much of their electricity from nuclear power plants. It is drawing a long bow, indeed, to suggest that abrupt climate change alone would lead either country to reconsider their long standing aversion to nuclear weapons. Nor is it clear how climate change would stimulate South and North Korea to form a technically savvy united country. It is far more likely that adverse climate change could worsen North Korea's precarious agricultural position and trigger an exodus of environmental refugees into China's Jilin province as occurred after the famines of 1997 and 1998.[174]

Nevertheless, Schwartz and Randall should be given credit for 'thinking the unthinkable' and identifying how an abrupt climate change scenario might impact on international security. Even if the probability is low, it is far from zero, and as the potential impact could be very high indeed policy makers ought to factor them into their security calculations and alternative futures planning. They could usefully start by commissioning further studies of the Thermohaline Circulation and other possible high impact events that could destabilise the world's climate, since abrupt climate change of the kind depicted by

Schwartz and Randall is not the only credible scenario which ought to give governments cause to reflect.

The possibility that positive feedbacks could amplify global warming, speeding up the rate of climate change and the likelihood that various ecological thresholds will be crossed cannot be discounted. If increasing concentrations of greenhouse gases reduce the absorption capacities of the land and sea at an accelerating rate then there will be less time than is commonly assumed to adjust to the environmental consequences, and they would not be confined to the northern hemisphere.[175] Of course, any drop in temperatures in the North Atlantic would partially offset greenhouse-gas rise, but this would be temporary as once the Thermohaline Circulation recovered the deferred warming could be delivered within a decade.

The central lesson to be drawn from this Chapter is that there are several wild cards with the potential to exacerbate the consequences of climate change by speeding up the warming process and its impact even beyond the upper limits of the IPCC forecasts. In our view, none of these probabilities have been given sufficient attention by policy makers and they must be included in any serious study of the future impact of climate change on the health of the planet, state survival and human security. Of the four wild cards analysed in this chapter the two likely to have the most deleterious ramifications are glacial and permafrost melt and the collapse of the Thermohaline Circulation.

Conclusion and policy recommendations

There is now sufficient scientific data to conclude, with a high degree of certainty, that the likely speed and magnitude of climate change in the 21st century will be unprecedented in human experience, posing daunting challenges of adaptation and mitigation for all life forms on the planet. Climate scientists overwhelmingly accept that the world's glaciers and northern ice cap are melting at accelerating rates and that sea-level rise will threaten many coastal and low lying areas. And they regard as virtually certain that there will be a doubling of carbon dioxide concentrations over pre-industrial levels this century regardless of what we do to contain or reduce greenhouse-gas emissions. As a result, the Earth's surface will warm by more than 2.0°C, there will be more severe weather events, and higher latitudes of the northern hemisphere will experience temperature and precipitation increases well in excess of the global average.

We also know that these changes are directly attributable to the impact of human lifestyles on the ecological fabric of the Earth and its naturally occurring climate patterns. Our planet's temperature has oscillated four times between frigid (glacial) and relatively warm (interglacial) conditions over the past half a million years but it has to be remembered that these transitions took place over thousands of years, allowing for some degree of natural adaptation. Even so, many species became extinct and the earth's ecosystem underwent a dramatic transformation in response to changes in temperature, soil fertility, sea levels and the distribution and availability of fresh water. Although there may be some localised benefits from climate change in the form of more rainfall and increased cropping in higher latitudes and previously arid areas, the net security consequences are unlikely to be benign, especially for developing states which, as Peter Gleick notes, 'are least responsible for the production of greenhouse gases, least able to adapt or mitigate the changes, and [have] little international or political clout.'[176]

But how significant is the risk of climate change to international security? Our principal conclusion is that the wider security implications of climate change have been largely ignored and seriously underestimated in public policy, academia and the media. Climate change will complicate and threaten Australia's security environment in several ways. First, weather extremes and greater fluctuations in rainfall and temperatures have the capacity to refashion the region's productive landscape and exacerbate food, water and energy scarcities in a relatively short time span. If repetitive floods, or prolonged droughts, were to create even short-term food and water shortages during times of rising social and political tensions, regional governments might find themselves hard pressed to deal with these exigencies. Sea-level rise is of particular concern because of the density of coastal populations and the potential for the large-scale displacement of people in Asia. It will be extremely difficult to carry out forced evacuations or relocations without conflict and political disturbances.

Secondly, climate change will contribute to destabilising, unregulated population movements in Asia and the Pacific. Most of these flows are likely to be internal, but the ripple effects will be felt beyond the borders of the states most affected, requiring cooperative regional solutions. Energy dilemmas will be compounded by the need to reduce greenhouse-gas emissions, requiring a more rapid transition away from our dependence on fossil fuels, or significant changes to the way they are used, than might otherwise have been the case. This could place added pressure on an already tight energy market and heighten

anxieties about energy security. The submergence of reefs, rocks and small islands that are crucial in the adjudication of maritime energy and sovereignty claims could intensify resource disputes in the East and South China seas.

Thirdly, the economic and social costs of managing the deleterious effects of climate change are likely to be substantial, which could reduce growth, depress incomes and circumscribe the ability of developing states to meet the rising aspirations of their people. More extreme weather patterns will result in greater death and destruction from natural disasters, adding to the burden on poorer countries and stretching the resources and coping ability of even the most developed nations, as Hurricane Katrina attests. So-called once in a hundred year storms could well become common weather events along with desiccating droughts, while climate induced water scarcity clearly has adverse implications for food production. As has already been argued, the region can ill afford a major drop in rainfall or a shift in distribution away from where it is most needed — the wheat fields of Australia and rice paddies of Southeast Asia and China.

Fourthly, extreme weather events and climate-related disasters will not only trigger short-term disease spikes but also have more enduring consequences. Infectious diseases such as malaria and Ross River fever will become more widespread as the planet warms up, since temperature is a key factor in their prevalence. For developed countries like Australia, these disease concerns will usually remain within the public health arena, but this may not be the case for more vulnerable societies struggling to cope with other environmental and socio-political pressures.

Fifthly, even if not catastrophic in themselves, the cumulative impact of rising temperatures, sea levels and more mega droughts on agriculture, fresh water and energy could threaten the security of states by reducing their carrying capacity below a minimum threshold, thereby undermining the legitimacy and response capabilities of their governments and jeopardising the security of their citizens. Where climate change coincides with other transnational challenges to security, such as terrorism or pandemic diseases, or adds to pre-existing ethnic and social tensions, then the impact will be magnified. However, state collapse and destabilising internal conflicts is a more likely outcome than interstate war. For a handful of small, low-lying Pacific nations, climate change is the ultimate security threat since rising sea levels will eventually make their countries uninhabitable.

Based on the evidence to date it is difficult to see climate change alone producing major reconfigurations of the regional or global balance of power. Shifts of this order presuppose substantial redistributions of the relative productive capacities of nation states, but current climate models are still not accurate enough to describe in detail how individual states will be affected. The destabilising scenarios outlined for the Pentagon by Schwartz and Randall, in which environmentally stressed states wage war on their neighbours and wealthy nations like Australia build defensive fortresses to quarantine themselves from climatically induced regional political and social disturbances, are improbable, although not entirely out of the question.

Perhaps the key insight of Schwartz and Randall is that abrupt climate change could push the planet's fragile and already stretched ecosystem past an environmental tipping point from which there will be no winners. Far from exaggerating the impact of climate change it is possible that scientists may have underestimated the threat. If this were to be the case the most likely catalysts are a collapse of the Thermohaline Circulation, which would have a detrimental effect on the growth of carbon dioxide in the atmosphere and life in the ocean, and the rapid recession of land-based glaciers and polar ice, which could dramatically increase sea-levels. Other climate wild cards are aerosol masking, which may have disguised the real level of global warming, and deforestation. If the present rate of deforestation continues, along with the destruction of other elements of the terrestrial ecosystem, our forests may soon become a carbon source rather than a carbon sink, adding to the amount of carbon in the atmosphere and further heating up the planet.

Finally, in assessing the long-term consequences of climate change for international security we should be mindful of Jared Diamond's warning. In his study of the reasons for the collapse and survival of societies, Diamond observed that in many historical cases a society that

was depleting its environmental stocks could absorb losses as long as the climate was benign, but when the climate became hotter, colder, wetter, drier or more variable it was pushed over the edge and even collapsed. Conversely, it was able to survive its self-inflicted resource depletion until climate change produced further resource depletion. It was neither factor taken alone, but the combination of environmental impact and climate change that proved fatal.[177]

Whether or not Diamond's observations are germane to our milieu remains to be seen, but can we afford to ignore the risk? In the security domain, strategic doctrines and defence budgets are frequently justified on the basis of far less observable evidence than we have about the climate future which awaits us. Yet very little has been done to research, address or even conceptualise the potential security implications of climate change internationally, or in Australia. Prudence and sensible risk management suggest that policy makers need to take this issue far more seriously. And our strategic planners ought to include worse case climate change scenarios in their contingency planning as they do for terrorism, infectious diseases and conventional military challenges to national security.

Policy recommendations

Recommendation 1

The Federal Government should encourage a more strategic approach to climate change and establish an interdepartmental task force to examine the policy connections between climate change and national security with particular reference to the nation's food, water, energy, health and environmental vulnerabilities, disaster planning and unregulated population movements.

Protecting and stabilising our climate is a legitimate objective of national security policy since human survival is dependent on the health of the biosphere and the coupled ocean-atmosphere system. The public and policy discourse on climate change in Australia has been dominated by arguments about the reliability of the scientific data and the seriousness of climate change. But there has been a notable absence of any real attempt to situate the climate change debate within a broader policy framework or to assess strategic risk, in which the probability of an adverse climate event is measured against the magnitude of its impact. It is essential that we do so and that government takes the lead in encouraging a more holistic approach to climate change which includes a comprehensive assessment of its implications for national and international security.

The Federal Government should establish an interdepartmental task force to examine, in detail, the policy connections between climate change and national security with particular reference to the nation's food, water, energy, health and environmental vulnerabilities, disaster planning and unregulated population movements. These studies could be extended geographically, to include the wider region, and functionally to include inputs from relevant non-government expert groups in the fields of climate science, agriculture, energy, health, immigration, defence, foreign policy and emergency management.

Recommendation 2

It is time for the Australian Intelligence Community to focus on climate-change risk and to mainstream the study of this emerging challenge to security.

The Government ought to pay greater attention to the national security implications of climate change. This will require attitudinal change and a willingness to incorporate the strategic, foreign policy and resource implications of climate-induced extreme weather events, sea-level rise and environmental refugees into national security planning.

It is time for the Australian Intelligence Community to focus on climate-change risk and to mainstream the study of this emerging challenge to security. The Office of National Assessment could initiate this process by coordinating an agency-wide, all-source assessment of the climate-change risk to Australia drawing upon the full intellectual resources of the nation. In the longer term, the intelligence community needs to strengthen its analytical capabilities in this field by recruiting more people with backgrounds in science, agronomy, environmental studies and infectious diseases along with strategists capable of applying multi-disciplinary approaches to the study of climate change.

Recommendation 3

Good policy assumes the ability to conceptualise the problem of climate change in its entirety rather than in a compartmentalised way. Governments — federal state and local — need to think about better ways of growing the intellectual resources to develop this capacity.

One problem is that our education system is not producing sufficient numbers of students and graduates with the requisite skills to effectively analyse the causes and consequences of climate change. The problem is both conceptual and structural. Conceptually, strategic and international security studies in Australia is still overwhelmingly concerned with military conflict and this bias is reflected in our universities and teaching institutions.

Structurally, the study of climate change is very stove-piped. Climate scientists see the issue primarily through the lens of physical science, economists focus on cost benefit calculations, environmentalists and business sceptics argue about desirable levels of greenhouse-gas emissions and appropriate remedies, while strategists have largely ignored the subject altogether. But good policy assumes the ability to see the problem in its entirety rather than in a compartmentalised way. Governments in this country — federal, state and local — need to think about better ways of growing the intellectual resources to develop this capacity.

They could start by providing incentives for universities and research institutes to ramp up the study of climate change in all its manifestations and to contribute solutions to an issue that will have increased policy salience in the decades ahead. Internationally, there are emerging institutional structures designed to promote 'sustainability science', where the study of economics, engineering and the social and physical sciences is integrated to achieve a better understanding of real world problems. The Australian Academy of Science has outlined a 'blueprint' for how such science might be undertaken and this interdisciplinary approach would be ideally suited to the study of climate change.[178]

Recommendation 4

Australia should take the lead in working with like minded Asia–Pacific governments to examine the implications of climate change for regional security and stability.

In assessing the threat to national security from climate change it is abundantly clear that Australia cannot quarantine itself from the international impact because climate change, by definition, is a global problem. Glacial melt in the polar ice cap will raise the seas around Australia as much as Europe and North America, and fossil fuel emissions in China and India will affect our climate as well as theirs.

It follows, therefore, that climate change responses require a high degree of international cooperation if they are to have any prospect of being effective. Both the Kyoto Protocol and Asia–Pacific Partnership on Clean Development and Climate explicitly recognise this reality. What is lacking, however, is agreement on how to identify, ameliorate and manage the security consequences. Australia should take a leadership role here, working with like minded Asia–Pacific governments to examine the implications of climate change for regional security and stability. This could be done bilaterally, as well as multilaterally, and follow the same basic pattern as our cooperation with the region on counter-terrorism and HIV/AIDS.

Examples of what might be discussed are: refining natural disaster and response mechanisms; identifying which areas are most likely to be affected by sea-level rise and developing programs to relocate people from threatened areas; improving climate forecasting; fostering more efficient water and energy use; assessing the impact on fish stocks and agriculture; studying the implications of rising temperatures on the spread of infectious diseases and of sea-level rise on maritime disputes.

Recommendation 5

Policy makers must factor climate wild cards into their security calculations and alternative futures planning and 'think the unthinkable'.

Particular attention should be given to the climate wild cards discussed in this Lowy Paper. Even if the probability of their occurrence is low, their potential impact could be very high indeed and for this reason policy makers ought to factor them into their security calculations and alternative futures planning.

Priority should be given to the consequences of a collapse, or slowing, of the Thermohaline Circulation and worst case scenarios of glacial and ice-cap melt. There has been insufficient study of the effect of changes to the Circulation on the southern hemisphere or of rising temperatures on the Antarctic continent. These are critical issues for Australia and they warrant the establishment of a task force to explore the science as well as the potential security fall out. Like Schwartz and Randall, the government needs to encourage our intelligence agencies, universities and research institutes to 'think the unthinkable' as part of a broad strategy to prepare the country for a very different climate future.

Recommendation 6

The most effective way of ameliorating the security risk of prospective climate change is to reduce the level of greenhouse gases that are responsible for heating up the planet.

Although this Lowy Paper has deliberately not canvassed the wider economic, social and environmental aspects of climate change it is clear that the most effective way of ameliorating the security risk is to reduce the level of greenhouse gases that are responsible for heating up the planet.

However, it is difficult to see how greenhouse-gas emissions can be substantially reduced this century, the precursor to regaining climate equilibrium in the next, without a fundamental transformation of our approach to energy use. This will require technological improvements encompassing cleaner coal and fuel efficient hybrid cars as well as the increased use of gas, nuclear power and renewable sources of energy. A continuation of our present reliance on fossil fuels will inevitably warm the atmosphere of the planet to levels that will place unprecedented stress on the earth's ecological fabric and challenge the adaptive capacities of future generations.

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Notes

[1] The Norse settlers in Greenland contributed to their own demise by depleting the resources on which they were dependent and failing to adapt, like the native Inuit, to the exigencies of Greenland's fragile environment. An illuminating account of Norse Greenland's end can be found in Jared Diamond, *Collapse: how societies choose to fail or survive.* London, Allen Lane, 2005, pp 266–267. For a compelling narrative of the influence of climate historically see Elizabeth Kolbert, The climate of Man-II: the curse of Akkad. *The New Yorker*, May 2 2005. Available at: http://www.newyorker.com/printables/fact/050502fa_fact3.

[2] The current world population of 6.5 billion is expected to rise to 9.1 billion by 2050. See United Nations Population Division of the Department of Economic and Social Affairs. *World population to increase by 2.6 billion over next 45 years, with all growth occurring in less developed regions.* (POP/918) United Nations Population Division of the Department of Economic and Social Affairs, February 24 2005: http://www.un.org/News/Press/docs/2005/pop918.doc.htm.

[3] There is increasing recognition of the need to distinguish between national security and individual, or human, security where the two clearly conflict. Advocates of human security argue that the *who* or *what* of security should be the individual, as a rights-bearing person, or humanity in general, rather than the state. This alternative view of security is not entirely new, since liberals have always considered

the individual to be a central referent of security. There are, however, significant points of departure from classical liberalism as well as realism. Crucially, preserving the political sovereignty of the state is subordinated to protecting human rights and guaranteeing the safety and well being of the individual. In effect, human security decouples security from national identity and the survival of the state.

4 Scientists speculate that the Pacific Ocean switches every 20–40 years between warm and cold phases because of the Pacific Decadal Oscillation (PDO) which significantly affects temperatures and rainfall around the Pacific Rim. The PDO is thought to be moving to a cooler phase which could have its greatest influence at middle latitudes in the Northern hemisphere, especially in the United States and Northeast Asia: World climate: poised for a big shift? *International Herald Tribune*, January 21 2000, p 1. For a technical account of this phenomenon and access to other publications see B.K. Linsley, G.M. Wellington and D.P. Schrag, Decadal Sea Surface Temperature Variability in the Subtropical South Pacific from 1726 to 1997 A.D. *Science* 290 (5494) 2000.

5 W. Harriet Critchley and Terry Terriff, Environment and security, in *Security studies for the 1990s*. ed. Richard Schultz, Roy Godson, and Ted Greenwood. Washington, Brassey's, 1993, p 337; Simon Dalby, Security, intelligence, the national interest and the global environment, in *Intelligence Analysis and Assessment*. ed. David A. Charters, Stuart Farson, and Glenn P. Hastedt. London, Frank Cass, 1996, p 178.

6 These conclusions must be treated with some caution as the models on which they are based have several limitations when used to project regional change. They suggest, however, that if temperatures continue to rise the adverse consequences increase for countries that are already warm, which would include most Southeast Asian nations. Other impacts include higher energy demand for cooling and increasing water deficits. See the results of modelling analysed in Robert Mendelsohn, The impact of climate change on Asian Pacific countries, in *Global warming and the Asian Pacific*. ed. Ching-Cheng Chang, Robert Mendelsohn, and Daigee Shaw. Cheltenham, Edward Elgar, 2003, p 222–226.

7 Dalby, Security, intelligence, the national interest and the global environment, p 184.

8 Quoted in Matt Price, Minister warms to greenhouse theory. *The Australian*, October 27 2005, p 1. and Tony Blair. *Prime Minister: 'Concerted international effort' necessary to fight climate change.* 10 Downing Street, February 24 2003: http://www.number-10.gov.uk/output/Page3073.asp.

9 As evidence, Houghton cited pre-Monsoon temperatures in India which soared to 49°C (five above average) and killed 1,500 people in 2003 — half those killed in the terrorist attacks on the World Trade Centre in 2001. John Houghton, Global warming is now a weapon of mass destruction. *The Guardian*, July 28 2003, p 14. Available at: http://www.guardian.co.uk/comment/story/0,3604,1007042,00.html.

10 For an elaboration of these arguments, see Alan Dupont, *East Asia imperilled: transnational challenges to security.* Cambridge, Cambridge University Press, 2001, especially pp 2–12.

11 For access to literature on the global distribution of plants and animals in glacial times see J.T. Overpeck, D.C. Whitlock and B. Huntley, Terrestrial biosphere dynamics in the climate system: past and future, in *Paleoclimate, global change and the future*. ed. K.D. Alverson, R.S. Bradley, and T.F. Pedersen, *The IGBP Series.* Berlin, Springer-Verlag, 2003, pp 81–103 and Tim Flannery, *The eternal frontier: an ecological history of North America and its peoples.* Melbourne, Text Publishing, 2001, p 404.

12 For a review of the role of paleoclimatology in understanding modern-day climate change and the natural process of climate variability, see J.T. Overpeck, Paleoclimatology and climate system dynamics. Reviews of Geophysics 33 (Supplement) 1995. J.D. Hays, J. Imbrie and N.J. Shackleton, Variations in the Earth's orbit: pacemaker of the Ice Ages. Science 194 (4270) 1976 provides evidence showing how ice ages develop. A summary of the reasons for natural climate variability is provided in J.T. Houghton, Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell and C.A. Johnson, eds. Climate change 2001: the scientific basis

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the past million years can be qualitatively simulated taking into account orbital changes, the so-called Milankovitch variations. These models, along with supporting ice-core evidence, clearly show that the Milankovitch variations influence global temperature, causing the periodic cooling we know as the Ice Ages, reducing biological activity and the level of greenhouse gases in the atmosphere and reinforcing the cooling trend. When these interactions are taken into account in the models, a closer quantitative representation of the fluctuations can be obtained. See for example, S.-I. Shin, Z. Liu, B. Otto-Bliesner, E.C. Brady, J.E. Kutzbach and S.P. Harrison, A simulation of the last glacial maximum climate using the NCAR–CCSM. *Climate Dynamics* 20 (2–3) 2003. While the orbital and greenhouse effects explain the underlying workings of the Earth's temperature variation over the last million years, it is more difficult to be precise about their regional effect. R. A. Pielke Sr., Land use and climate change. *Science* 310 (5754) 2005.

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consequence of the 1997–2001 El Niño event. G.R. Var der Werf, J.T. Randerson, G.J. Collatz, L. Giglio, P.S. Kasibhatla, A.F. Arellano, S.C. Olsen and E.S. Kasischke, Continental-scale partitioning of fire emissions during the 1997 to 2001 El Niño/La Niña period. *Science* 303 (5654) 2004. See also Bog fires to release year's worth of greenhouse gas. *Sydney Morning Herald*, October 17 1997, p 11 and S.E. Page, F. Siegert, J. O. Rieley, H-D. V. Boehm, A. Jaya and S. Limin, The amount of carbon released from peat and forest fires in Indonesia during 1997. *Nature* 420 (6911) 2002.

19 Historically by about 31 %, 151 % and 17 % for carbon dioxide, methane and nitrous oxide respectively, between 1750 and 1995 with various changes to specific chlorofluorocarbon gases (R.G. Prinn, R.F. Weiss, P.J. Fraser, P.G. Simmonds, D.M. Cunnold, F.N. Alyea, S. O'Doherty, P. Salameh, B.R. Miller, J. Huang, R.H.J. Wang, D.E. Hartley, C. Harth, L.P. Steele, G. Sturrock, P.M. Midgley and A. McCulloch, A history of chemically and radiatively important gases in air deduced from ALE/GAGE/AGAGE. *Journal of Geophysical Research* 105 (D14) 2000). The ice-core record for carbon dioxide, methane and nitrous oxide now goes back 650,000 years. Two studies published in 2005 show that pre-industrial concentrations of carbon dioxide lie in the range 180–290 ppmv, with the lower concentrations occurring in the Ice Ages. For methane, pre-industrial concentrations have never exceeded about 700 ppbv during the past 650,000 years, with nitrous oxide showing maximum concentrations pre-industrially of 278 ppbv, slightly higher than early Holocene values. See U. Siegenthaler, T.F. Stocker, E. Monnin, D. Lüthi, J. Schwander, B. Stauffer, D. Raynaud, J-M. Barnola, H. Fischer, V. Masson-Delmotte and J. Jouzel, Stable carbon cycle-climate relationship during the Late Pleistocene. *Science* 310 (5752) 2005 and R. Spahni, J. Chappellaz, T.F. Stocker, L. Loulergue, G. Hausammann, K. Kawamura, J. Flückiger, J. Schwander, D. Raynaud, V. Masson-Delmotte and J. Jouzel, Atmospheric methane and nitrous oxide of the Late Pleistocene from Antarctic ice cores. *Science* 310 (5752) 2005. See also D.M. Etheridge, L.P. Steele, R.L. Langenfelds, R.J. Francey, J.-M. Barnola and V.I. Morgan, Natural and anthropogenic changes in atmospheric CO_2 over the last 1000 years from air in Antarctic ice and firn. *Journal of Geophysical Research* 101 (D2) 1996; EPICA community members, Eight glacial cycles from an Antarctic ice core. *Nature* 429 (6992) 2004; J.T. Houghton, L.G. Meira Filho, J.P. Bruce, Hoesung Lee, B.A. Callander, E.F. Haites, N. Harris and K. Maskell, eds., *Climate change 1994: radiative forcing of climate change and an evaluation of the IPCC IS92 emissions scenarios.* Cambridge, Cambridge University Press for the Intergovernmental Panel on Climate Change, 1995; Intergovernmental Panel on Climate Change Working Group I. *Summary for policymakers: the science of climate change.* Intergovernmental Panel on Climate Change December 1995: http://www.ipcc.ch/pub/sarsum1.htm, p 12; Prinn, Weiss, Fraser, Simmonds, Cunnold, Alyea, O'Doherty, Salameh, Miller, Huang, Wang, Hartley, Harth, Steele, Sturrock, Midgley and McCulloch, A history of chemically and radiatively important gases in air deduced from ALE/GAGE/AGAGE.

20 World Meteorological Organization, *Proceedings of the World Climate Conference: a conference of experts on climate and mankind*. Geneva, World Meteorological Organization, 1979.

21 World Meteorological Organization, *The role of carbon dioxide and other 'greenhouse' gases in climatic variation and associated impacts. Conference statement for the Second Joint UNEP/WMO/ICSU International Conference on the Assessment of the Role of Carbon Dioxide and other Greenhouse Gases in Climate Variations and Associated Impacts*. WMO Bulletin 35. Villach, World Meteorological Organization, 1986.

22 The IPCC does not undertake original research.

23 For details of the Framework Convention see http://unfccc.int/2860.php and for the Kyoto Protocol, http://unfccc.int/essential_background/kyoto_protocol/items/1678.php. The technical summary of what might be achieved through the partnership activities indicates reductions of emission at around 25 % of what they would otherwise have been. See http://www.abare.gov.au/publications/2006/RR06_1_ClimateAsiaPacific.pdf.

24 Details of the Asia Pacific Partnership can be obtained at http://

en.wikipedia.org/wiki/Asia_Pacific_Partnership_on_Clean_Development_and_Climate.

[25] Sea-level rise is caused by thermal expansion of the sea due to increases in temperature from higher levels of greenhouse gases, and melting of mountain glaciers and the major ice sheets in Antarctica and Greenland. G.A. Meehl, W.M. Washington, W.D. Collins, J.M. Arblaster, A. Hu, L.E. Buja, W.G. Strand and H. Teng, How much more global warming and sea level rise? *Science* 307 (5716) 2005; T.M.L. Wigley, The climate change commitment. *Science* 307 (5716) 2005. The low end of these estimates corresponds to the known rate of sea-level rise over the past century while the high end represents an acceleration of sea-level rise based on plausible forecasts of global warming in this century. D. Schneider, The rising seas. *Scientific American*, March 1997.

[26] This summary draws on the findings of the report J.T. Houghton, G.J. Jenkins and J.J. Ephraums, eds., *Climate change: the IPCC scientific assessment.* Cambridge, Cambridge University Press for the Intergovernmental Panel on Climate Change, 1990; Intergovernmental Panel on Climate Change Working Group I. *Summary for policymakers: the science of climate change.* Climatologists have gradually become more confident about the accuracy of their forecasts. Compare, for example, the discussions and assessments made at a major conference on climate change in 1991 at Los Alamos, New Mexico, with the 1995 and 2001 IPCC Reviews. On the former, see L. Rosen and R. Glasser, eds. *Climate Change and Energy Policy: proceedings of the International Conference on Global Climate Change, Its Mitigation Through Improved Production and Use of Energy, Los Alamos National Laboratory, October 21–24, 1991, Los Alamos, New Mexico, USA.* New York, American Institute of Physics, 1992, especially pp 17–31. Recent satellite studies have revealed that the frequency of the more extreme category four and five tropical storms has increased by 100 % in the last 30 years. See P. J. Webster, G. J. Holland, J.A. Curry and H.-R. Chang, Changes in tropical cyclone number, duration, and intensity in a warming environment. *Science* 309 (5742) 2005, although this observation may be partly influenced by El Niño variations.

[27] N. Nakicenovic, J. Alcamo, G. Davis, B. de Vries, J. Fenhann, S. Gaffin, K. Gregory, A. Grübler, T.Y. Jung, T. Kram, E.L. La Rovere, L. Michaelis, S. Mori, T. Morita, W. Pepper, H. Pitcher, L. Price, K. Riahi, A. Roehrl, H-H. Rogner, A. Sankovski, M. Schlesinger, P. Shukla, S. Smith, R. Swart, S. van Rooijen, N. Victor and Z. Dadi, Special report on emissions scenarios — a special report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge, Cambridge University Press for the Intergovernmental Panel on Climate Change, 2000. Available at: http://www.grida.no/climate/ipcc/emission/index.htm.

[28] Main overall points made in Houghton, Ding, Griggs, Noguer, van der Linden, Dai, Maskell and Johnson, eds. Climate change 2001: the scientific basis — contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. More evidence in support of these findings can be found in G. I. Pearman and K. J. Hennessy, Climate science: what do we know? (paper presented at the Living with climate change: a national conference on climate change impacts and adaptation. National Academies Forum, Canberra, 2002). Available at: http://www.cmar.csiro.au/e-print/open/pearman_2003a.pdf.

[29] Intergovernmental Panel on Climate Change Working Group I. *Summary for policymakers: the science of climate change.* ; G.I. Pearman, K.J. Hennessy, R.N. Jones and S. Maheepala, *Climate change and its projected effects* (paper presented at the Water — the Australian dilemma symposium, Parkville, 2003), available at: http://www.atse.org.au/index.php?sectionid = 124.

[30] Pearman, Hennessy, Jones and Maheepala, *Climate change and its projected effects* CSIRO. *Climate change projections for Australia.* CSIRO Climate Impact Group 2001: http://www.cmar.csiro.au/e-print/open/projections2001.pdf and Pittock, *Climate change: turning up the heat*.

[31] *United Nations Framework Convention on Climate Change.* United Nations May 9 1992: http://unfccc.int/resource/docs/convkp/conveng.pdf. Article 2. This issue has attracted significant scientific attention and has been widely discussed in the academic literature.

See, for example, Suraje Dessai, W. Neil Adger, Mike Hulme, John Turnpenny, Jonathan Köhler and Rachel Warren, Defining and experiencing dangerous climate change. *Climatic Change* 64 2004 and James E. Hansen, A slippery slope: how much global warming constitutes dangerous anthropogenic interference? An editorial essay. *Climatic Change* 68 (3) 2005.

32 S.H. Schneider, What is 'dangerous' climate change? *Nature* 411 (6833) 2001.

33 European Council, *Document 7631/04 (ANNEX)*, March 25–26 2004, p 29 (available at: http://ue.eu.int/ueDocs/cms_Data/docs/pressData/en/misc/79589.pdf) says: 'the Council [...] ACKNOWLEDGES that to meet the ultimate objective of the UNFCCC to prevent dangerous anthropogenic interference with the climate system, overall global temperature increase should not exceed 2°C above pre-industrial levels; [...]'. A similar position is taken by the International Climate Change Taskforce (which includes British Prime Minister Tony Blair, former NSW Premier Bob Carr, Senator Olympia Snowe and the Honourable Timothy Worth), in *International Climate Change Taskforce, Meeting the climate challenge: recommendations of the International Climate Change Taskforce, The Institute for Public Policy Research, The Center for American Progress and The Australia Institute, January 2005*, available at: http://www.whrc.org/resources/published_literature/pdf/ByersetalInstPubPolRes.1.05.pdf. Recommendation 1 states '… prevent global average temperatures rising more than 2°C above pre-industrial levels …'

34 Stark warning over climate change. *BBC News*, April 14 2006: http://news.bbc.co.uk/1/hi/sci/tech/4888946.stm and Gerri Peev. Three billion lives hang on three degrees, warns scientist. *The Scotsman*, April 16 2006: http://news.scotsman.com/uk.cfm?id = 573622006.

35 Intergovernmental Panel on Climate Change Working Group I, *Summary for policymakers: a report of Working Group I of the Intergovernmental Panel on Climate Change*. Geneva, Intergovernmental Panel on Climate Change, 2001, p 12. Available at http://www.ipcc.ch/pub/spm22-01.pdf.

36 Retreating glaciers 'threaten water crisis'. *The South China Morning Post*, 15 March 2005, p A13.

37 These scenarios can be found in Nakicenovic, Alcamo, Davis, de Vries, Fenhann, Gaffin, Gregory, Grübler, Jung, Kram, La Rovere, Michaelis, Mori, Morita, Pepper, Pitcher, Price, Riahi, Roehrl, Rogner, Sankovski, Schlesinger, Shukla, Smith, Swart, van Rooijen, Victor and Dadi, *Special report on emissions scenarios — a special report of Working Group III of the Intergovernmental Panel on Climate Change*.

38 We have not canvassed here the views of non-expert critics whose rejection of the IPCC findings is generally ill-informed and frequently polemical. For a general response to specific issues raised by the 'sceptics' see The Royal Society. *A guide to facts and fiction about climate change.* http://www.royalsoc.ac.uk/downloaddoc.asp?id = 1630; CSIRO. *Greenhouse: questions and answers.* http://www.cmar.csiro.au/e-print/open/gh_faq.htm#gh1 and a critique of the rationale of the 'sceptics' by P.H. Gleick. *On truth, fact, values, climate change, and doughnuts — a guest commentary.* Environmental News Network December 29 2005: http://www.enn.com/today.html?id = 9556.

Nor do we take a position on the related economic debates as they are outside the scope of this study other than to note that some economists have been sceptical about the IPCC projections of future warming because they do not accept that developing economies have the capacity to grow emissions at the rate suggested. See for example: I. Castles and D. Henderson, The IPCC emission scenarios: an economic-statistical critique. *Energy and Environment* 14 (2–3) 2003; I. Castles, Evidence submitted to the Select Committee on Economic Affairs, House of Lords, London, for the Inquiry into 'Aspects of the Economics of Climate Change'. *Energy and Environment* 16 (3–4) 2005.

Many other economists, however, take a contrary view. See for example: N. Nakicenovic, A. Grübler, S. Gaffin, T.T. Jung, T. Kram, T. Morita, H. Pitcher, K. Riahi, M. Schlesinger, P.R. Shukla, D. van Vuuren, G. Davis, L. Michaelis, R. Swart and N. Victor, IPCC SRES revisited: a response. *Energy and Environment* 14 (2–3) 2003; A.S. Manne and R.G. Richels, *Market exchange rates or purchasing power parity: does the choice make a difference to the climate debate?* Working Paper 03–11. Washington, D.C., AEI–Brookings Joint Center for

Regulatory Studies, September 2003; A. Grübler, N. Nakicenovic, J. Alcamo, G. Davis, J. Fenhann, B. Hare, S. Mori, B. Pepper, H. Pitcher, K. Riahi, H-H. Rogner, E.L. La Rovere, A. Sankovski, M. Schlesinger, R.P. Shukla, R. Swart, N. Victor and T.Y. Jung, Emissions scenarios: a final response. *Energy and Environment* 15 (1) 2004.

39 F. Pearce, Greenhouse wars. *New Scientist*, July 19 1997.

40 Houghton, Ding, Griggs, Noguer, van der Linden, Dai, Maskell and Johnson, eds. *Climate change 2001: the scientific basis — contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*.

41 See for example, C.A. Mears, M.C. Schabel and F.J. Wentz, A reanalysis of the MSU Channel 2 tropospheric temperature record. Journal of Climate 16 (22) 2003; K.Y. Vinnikov and N.C. Grody, Global warming trend of mean tropospheric temperature observed by satellites. Science 302 (5643) 2003; and Q. Fu, C.M. Johanson, S.G. Warren and D.J. Seidel, Contribution of stratospheric cooling to satellite-inferred tropospheric temperature trends. Nature 429 (6987) 2004.

42 See for example D.E. Parker, Large-scale warming is not urban. *Nature* 432 (7015) 2004.

43 By contrast, dissidents were able to muster only about a hundred climate scientists who were prepared to sign the opposing Leipzig Declaration which maintains that the IPCC conclusions are 'flawed': Andrew Heasley, Heat rises as debate rages over alleged global warming. *Canberra Times*, January 9 1999, p C.4.

44 Statements from other recognised international science organisations that by and large support the findings of the IPCC include: Environment Canada, H. Hengeveld, R. Whitewood and A. Fergusson. *An Introduction to climate change: a Canadian perspective.* Environment Canada 2005: http://www.msc.ec.gc.ca/education/scienceofclimatechange/understanding/icc/icc_e.pdf; the international American Geophysical Union (see http://www.agu.org/sci_soc/policy/positions/climate_change.shtml); the Joint Science Academies' Statement from the Science Academies of Brazil, Canada, China, France Germany, India, Italy, Japan, Russia, UK and USA to be found at http://nationalacademies.org/onpi/06072005.pdf; US Academy of Sciences, National Academy of Sciences. *Climate change science: an analysis of some key questions.* The National Academies Press 2001: http://books.nap.edu/books/0309075742/html/1.html. See also Hot year sweats on Siberia. *The Weekend Australian*, October 15–16 2005, pp 1,19.

45 *Warming to reality.* International Herald Tribune January 10 2000: www.iht.com; Definitely warmer. *International Herald Tribune*, January 18 2000, p 6. See also J. Woodford, World climate: experts predict a grim future. *Sydney Morning Herald*, September 30 1996, p 1. A more pessimistic report looking at the effect of climate change on the United States predicts significantly higher temperature increases than the IPCC and drastic changes in the climate of the United States. It anticipates more severe droughts, increased risk of flooding, mass migrations of species, substantial shifts in agriculture and widespread erosion of coastal zones: C. Suplee, Ominous outlook for the climate. *International Herald Tribune*, June 13 2000, p 3.

46 Regular meteorological measurements of the temperature of the air near the earth's surface, and of the surface of the ocean demonstrate clearly that the earth warmed throughout the twentieth century by about 0.6°C, with much of the warming occurring in the last three decades of the century. This evidence is based on carefully assessed temperature records that avoid the influence of changing site exposure of the temperature sensors over time, something that made earlier interpretation difficult. Comprehensive global temperature data are available from the UK Meteorological Office (http://www.met-office.gov.uk/research/hadleycentre/obsdata/globaltemperature.html), and the US National Climate Data Center (http://www.ncdc.noaa.gov/img/climate/research/1998/ann/j-dlo_pg.gif).

47 C. Flavin, Global temperature goes off the chart, in *Vital signs 1999: the environmental trends that are shaping our future*. ed. L. Starke. New York and London, W.W. Norton & Co., 1999, Arctic Sea Ice has shrunk by 6 per cent in the two decades after 1978; Weather and security: climate change and South Asia. *IISS Strategic Comments* 6 (1) 2000. Significantly, the US National Oceanic and Atmospheric

Administration announced that global ocean temperatures are also rising, which may be a more reliable indicator of global warming. G. Easterbrook, The facts of global warming don't need to be fudged. *International Herald Tribune*, June 15 2000, p 9.

48 A major 2004 study found that the 'Arctic is now experiencing some of the most rapid and severe climate change on earth.' Arctic Climate Impact Assessment, Impacts of a warming Arctic. Cambridge, Cambridge University Press, 2004. See also F. Pearce, Climate warning as Siberia melts. *New Scientist* 2005, p 12 and Hot year sweats on Siberia.

49 See, for example: C. Cabanes, A. Cazenave and C. Le Provost, Sea level rise during past 40 years determined from satellite and in situ observations. *Science* 294 (5543) 2001; J.A. Church, How fast are sea levels rising? *Science* 294 (5543) 2001; S.J. Holgate and P.L. Woodworth, Evidence for enhanced coastal sea level rise during the 1990s. *Geophysical Research Letters* 31 (7) 2004 and N.J. White, J.A. Church and J.M. Gregory, Coastal and global averaged sea level rise for 1950 to 2000. *Geophysical Research Letters* 32 (1) 2005. These issues are discussed in more detail in chapter four.

50 J.A. Church and N.J. White, A 20th century acceleration in global sea-level rise. *Geophysical Research Letters* 33 (1) 2006

51 Most projections show a significant range of temperatures, precipitation and sea-level rise in order to reflect uncertainties in computer simulations of the climate system and future emission levels. The latter reflects uncertainty about the economic, social and technological changes over this period and the on-going review of what order of temperature change constitutes an acceptable risk.

52 See N. Oreskes, The scientific consensus on climate change: beyond the ivory tower. *Science* 306 (5702) 2004. Although there has been some criticism of Oreskes' findings (see, for example, B. Peiser. *The letter Science Magazine refused to publish.* 2005: http://www.staff.livjm.ac.uk/spsbpeis/Scienceletter.htm), it should be noted that her analysis has been accepted by the highly regarded journal *Science* as well as the Royal Society.

53 For evidence of the changing frequency of extreme tropical storms see Webster, Holland, Curry and Chang, Changes in tropical cyclone number, duration, and intensity in a warming environment. For attribution of this change to global warming see Thom Akeman. *Global warming behind record 2005 storms - experts.* [Factiva]. Reuters News April 24 2006.

54 Robert T. Watson, *Presentation of the chair of the Intergovernmental Panel on Climate Change* (paper presented at the Sixth Conference of Parties to the UN Framework Convention on Climate Change, November 13 2000). Available at: www.ipcc.ch/press/sp-cop6.htm.

55 There are real difficulties in providing accurate, detailed assessments of the full social, environmental and economic impact of climate change on international society because of the complexity of the interactions and the large number of unknowns. However, initial estimates suggest that hundreds of millions of people are at risk from water shortages, malarial infection, hunger and coastal flooding based on warming scenarios consistent with those modelled by the IPCC and other expert groups. See M. Parry, N. Arnell, T. McMichael, R. Nicholls, P. Martens, S. Kovats, M. Livermore, C. Rosenzweig, A. Iglesias and G. Fischer, Millions at risk: defining critical climate change threats and targets. *Global Environmental Change* 11 2001.

56 For an assessment of current food and water shortages around the world see: *The Millennium Development Goals report 2005.* United Nations 2005: http://unstats.un.org/unsd/mi/pdf/MDG%20Book.pdf.

57 Lester. R. Brown, Feeding nine billion, in *State of the world 1999: a Worldwatch Institute Report on progress towards a sustainable society.* New York, W.W. Norton & Company, 1999, p 118.

58 Working Group II of the Intergovernmental Panel on Climate Change. *Summary for policymakers — climate change 2001: impacts, adaptation, and vulnerability.* Intergovernmental Panel on Climate Change 2001: http://www.grida.no/climate/ipcc_tar/wg2/pdf/wg2TARspm.pdf; Paul Rogers. *Climate change and global security.* Open Democracy 2003: http://www.opendemocracy.net/themes/article.jsp?articleId=864&id=2.

59 Rogers. *Climate change and global security.*

[60] Consultative Group on International Agricultural Research. Inter-Center Working Group on Climate Change. *The challenge of climate change: research to overcome its impact on food security, poverty, and natural resource degradation in the developing world.* Consultative Group on International Agricultural Research. Inter-Center Working Group on Climate Change 2002: http://www.cgiar.org/pdf/climatechange.pdf, pp 1–2. This authoritative group comprises 15 international centres, the Global Environmental Change and Food Systems (GECAFS), a joint project of the International Geosphere–Biosphere Programme (IGBP), the International Human Dimension Programme (IHDP) and the World Climate Research Programme (WCRP) working in collaboration with the United Nations Environment Programme and the World Bank.

[61] Many of these anticipated climate changes for Australia are discussed in Chapter one. There is some disagreement within the scientific community over whether or not the frequency of El Niño events will change in a warmer Earth.

[62] Ibid. p 3.

[63] Ibid. p 1.

[64] Roy Darwin, *Climate change and food security*. Agriculture Information Bulletin 765–8, United States Department of Agriculture, Economic Research Service, June 2001. Available at: http://www.ers.usda.gov/publications/aib765/aib765-8.pdf.

[65] On this point see International Climate Change Taskforce, *Meeting the climate challenge: recommendations of the International Climate Change Taskforce*, p 3; Working Group II of the Intergovernmental Panel on Climate Change. *Summary for policymakers — climate change 2001: impacts, adaptation, and vulnerability.*

[66] To produce one kilogram of rice requires 5000 kilograms of water. By 2020, East Asia will need to produce 50 % more rice than it did in 1998, but the region's rice yields have levelled off or declined from their peaks in the 1980s. Dupont, *East Asia imperilled: transnational challenges to security*, p 93.

[67] Brown, *Feeding nine billion*, p 123.

[68] Santiago Olmos, *Vulnerability and adaptation to climate change: concepts, issues, assessment methods*. Foundation Paper, Climate Change Knowledge Network, July 2001, p 3. Available at: http://www.cckn.net/pdf/va_foundation_final.pdf.

[69] Jon Barnett and W. Neil Adger, Climate dangers and atoll countries. *Climatic Change* 61 (3) 2003, p 326.

[70] Ocean acidification due to increasing atmospheric carbon dioxide. (Policy document 12/05) The Royal Society June 30 2005: http://www.royalsoc.ac.uk/document.asp?tip = 0&id = 3249; R.A. Feely, C.L. Sabine, K. Lee, W. Berelson, J. Kleypas, V.J. Fabry and F.J. Millero, Impact of anthropogenic CO_2 on the $CaCO_3$ system in the oceans. *Science* 305 (5682) 2004; Melissa Fyfe. Wake up — this is serious. *The Age*, February 12 2005: http://theage.com.au/articles/2005/02/11/1108061868849.html.

[71] Deborah Smith, Shell-shocked snails carry health warning from bottom of food chain. *The Sydney Morning Herald*, September 29 2005, p 3.

[72] Alan Dupont, Indonesian Defence Strategy and Security: Time for a Rethink? *Contemporary Southeast Asia* 18 (3) 1996, p 280.

[73] Darwin, *Climate change and food security*, available at: http://www.ers.usda.gov/publications/aib765/aib765-8.pdf.

[74] As already indicated, there is still no scientific consensus on whether El Niño events will increase as a result of climate change.

[75] Dupont, *East Asia imperilled: transnational challenges to security*, p 117.

[76] Charles J. Vörösmarty, Pamela Green, Joseph Salisbury and Richard B. Lammers, Global water resources: vulnerability from climate change and population growth. *Science* 289 (5477) 2000 cited in United Nations World Water Assessment Programme, *Water for people: water for life — the United Nations World Water Development Report*. Barcelona, United Nations Educational, Scientific and Cultural Organization and Berghahn Books, 2003, p 17. Available at: http://www.unesco.org/water/wwap/wwdr/table_contents.shtml.

[77] This is the average of the projections made in the various climate models shown in Table 2.1 showing the number of people in water stressed countries directly affected by a warming climate.

[78] Retreating glaciers 'threaten water crisis'.

[79] A specific study on the Australian health impacts of climate change concluded that 'policy action to control greenhouse-gas emissions, if taken decisively and soon will reduce the extent and severity of the climate change impacts on the health of Australians'. Rosalie Woodruff, Simon Hales, Colin Butler and Anthony McMichael, *Climate change health impacts in Australia: effects of dramatic CO_2 emission reductions*, Australian Conservation Foundation and the Australian Medical Association, 2005. The report concludes that strong action to control emissions could reduce the number of heat-related deaths in Australia by 135–190 %. With no actions, heat-related deaths could be between 2,600 and 3,200 per year.

[80] World Health Organization, *The world health report 2002: reducing risks, promoting healthy life*. Geneva, World Health Organization, 2002, p 68.

[81] Thomas H. Karas, *Global climate change and international security*. Albuquerque, Sandia National Laboratories, November 2003, p 18.

[82] 'Climate change was estimated to be responsible in 2000 for approximately 2.4 % of worldwide diarrhoea, 6 % of malaria in some middle income countries and 7 % of dengue fever in some industrialized countries. In total, the attributable mortality was 154 000 (0.3 %) deaths and the attributable burden was 5.5 million (0.4 %) DALYs. About 46 % this burden occurred in SEAR-D, 23 % in AFR-E and a further 14 % in EMR-D'. World Health Organization, *The world health report 2002: reducing risks, promoting healthy life*, p 72. See also Nigel Purvis and Joshua Busby, *The security implications of climate change for the UN system*. Environmental Change and Security Project, The Brookings Institution, May 2004, p 2. For a good analysis of the impact of climate change on human health see J.A. Patz, D. Campbell-Lendrum, T. Holloway and J.A. Foley, Impact of regional climate change on human health. *Nature* 438 (7066) 2005.

[83] A.K. Githeko and A. Woodward, International consensus on the science of climate and health: the IPCC Third Assessment Report, in *Climate change and human health: risks and responses*. ed. A.J. McMichael, et al. Geneva, World Health Organization, 2003, p 49.

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[85] Michael T. Osterholm, Preparing for the next pandemic. *Foreign Affairs* 84 (4) 2005. Available at: http://www.foreignaffairs.org/20050701faessay84402/michael-t-osterholm/preparing-for-the-next-pandemic.html.

[86] James J. McCarthy, Osvaldo F. Canziani, Neil A. Leary, David J. Dokken and Kasey S. White, eds., Climate change 2001: impacts, adaptation, and vulnerability — contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge and New York, Cambridge University Press for the Intergovernmental Panel on Climate Change, 2001. Section 9.7. Available at http://www.grida.no/climate/ipcc_tar/wg2/index.htm.

[87] An explosion in the mouse population of the US during the 1991–92 El Niño event triggered an outbreak of hantavirus pulmonary syndrome.

[88] J.A. Patz, A.K. Githeko, J.P. McCarty, S. Hussein, U. Confalonieri and N. de Wet, Climate change and infectious diseases, in *Climate change and human health: risks and responses*. ed. A.J. McMichael, et al., Geneva, World Health Organization, 2003, p 103.

[89] Insurance Australia Group, Sustainability Report 2005, at http://www.iag.com.au/pub/iag/sustainability/publications/report/2005/ExecutiveSummary.shtml

[90] Impacts of Europe's changing climate: An indicator-based assessment. European Environment Agency, http://reports.eea.eu.int/climate_report_2_2004/en.

[91] Jonathan Walter, ed., *World disasters report 2002: focus on reducing risk* Kumarian Press for the International Federation of Red Cross and Red Crescent Societies, 2002, p 87. See also Molly Conisbee and Andrew Simms, *Environmental refugees: the case for recognition*. Nef Pocketbook 10. London, New Economics Foundation, 2003, pp 16–17.

[92] Purvis and Busby, *The security implications of climate change for the UN system*, p 2.

93 Jackie Calmes, Ann Carrns and Jeff D. Opdyke, New architecture: as Gulf prepares to rebuild, tensions mount over control. *Wall Street Journal*, September 15 2005, p A.1.

94 Kerry Emanuel, Increasing destructiveness of tropical cyclones over the past 30 years. *Nature* 436 (7051) 2005; C.D. Hoyos, P.A. Agudelo, P.J. Webster and J.A. Curry, Deconvolution of the factors contributing to the increase in global hurricane intensity. *Science* 312 (5770) 2006; and Webster, Holland, Curry and Chang, Changes in tropical cyclone number, duration, and intensity in a warming environment.

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96 Katrina may wreak havoc on world economy. *The Australian*, September 1 2005, pp 1, 9.

97 During the floods the Yangtse River burst its banks and inundated hundreds of kilometres of adjacent land, causing the deaths of more than 4,000 people and economic losses of US$15–22 billion. Dupont, *East Asia imperilled: transnational challenges to security*, p 50.

98 Olmos, Vulnerability and adaptation to climate change: concepts, issues, assessment methods, p 8–9.

99 Rising sea-levels pose multiple threats — through the erosion of beaches, often the zones where most people live; the destruction of natural coastal habitat upon which both food resources and tourism depend; the inundation of agricultural or habitable land; and the salination of freshwater reserves.

100 Atolls are rings of coral reefs that enclose a lagoon. Around the rim of the reef there are islets called motu with a mean height above sea-level of approximately two meters. Barnett and Adger, Climate dangers and atoll countries. p 322. The other atoll country is the Indian Ocean nation of Maldives (population 269,000), which is located about 500 kilometers from India.

101 Papua New Guinea and Pacific Islands Country Unit, *Cities, seas, and storms: managing change in Pacific island economies*. Summary Report Volume I. Washington, D.C., The World Bank, November 13 2000. Available at: http://web.worldbank.org/

WBSITE/EXTERNAL/COUNTRIES/EASTASIAPACIFICEXT/PACIFICISLANDSEXTN/0, contentMDK:20218394 ~ menuPK:441914 ~ pagePK:1497618 ~ piPK:217854 ~ theSitePK:441883,00.html.

102 R. Nicholls, F. Hoozemans and M. Marchand, Increasing flood risk and wetland losses due to global sea-level rise: Regional and global analyses. *Global Environmental Change* 9 (suppl) 1999.

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109 Kelly and Adger, 2000 cited in McCarthy, Canziani, Leary, Dokken and White, eds. Climate change 2001: impacts, adaptation, and vulnerability — contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, section 11.2.4.5, at http://www.grida.no/climate/ipcc_tar/wg2/445.htm.

110 Edwards, Security implications of a worst-case scenario of climate change in the South-west Pacific. pp 314–315.

[111] Central Intelligence Agency. *Spratly Islands.* The World Factbook March 29 2006: http://www.cia.gov/cia/publications/factbook/geos/pg.html. See also http://www.gesource.ac.uk/worldguide/html/1027_map.html.

[112] The islets, which are only 0.1 to 0.2 m above high tide, are in the western part of a lagoon that is surrounded by an atoll-like submerged coral reef, over which the waves break, that extends 4.6 km East–West and 1.7 km North–South, with an area of roughly 5 km^2 within the rim of the reef. A fourth, even smaller islet is located at the eastern end of the lagoon. http://en.wikipedia.org/wiki/Okinotorishima.

[113] William Blyth and Nicolas Lefevre, *Energy security and climate change policy interactions: an assessment framework*. IEA Information Paper, International Energy Agency, December 2004, p 14.

[114] Robert Socolow, Roberta Hotinski, Jeffery B. Greenblatt and Stephen Pacala, Solving the climate problem: technologies available to curb CO_2 emissions. Environment 46 (10) 2004.

[115] Estimates made by the Australian Bureau of Agricultural and Resource Economics, as part of the Commonwealth Government's Securing Australia's Energy Future policy, are available at http://www.dpmc.gov.au/publications/energy_future/

[116] Energy Task Force, *Securing Australia's energy future*. Canberra, Australian Government: Department of the Prime Minister and Cabinet, 2006. Available at: http://www.dpmc.gov.au/publications/energy_future/

[117] Robert J. Samuelson, The Kyoto delusion. *Washington Post*, June 21 2001, p A25.

[118] Nuclear power emits about 25 grams of carbon dioxide equivalent per kilowat hour compared with around 450–1250 grams for fossil fuels. Nuclear Energy Agency. Organisation for Economic Cooperation and Development, *Nuclear power and climate change.* Paris, OECD Publications, 1998.

[119] Charles J. Hanley, World debates nuclear power. *Associated Press*, November 24 1997, On China's future nuclear power plans see International Atomic Energy Agency. *Nuclear power's changing future: fastest growth in Asia.* (Press Release 2004/05) International Atomic Energy Agency June 26 2004: http://www.iaea.org/NewsCenter/PressReleases/2004/prn200405.html.

[120] David Von Hippel and Peter Hayes, Two scenarios of nuclear power and nuclear waste production in northeast Asia. *Pacific and Asian Journal of Energy* 8 (1) 1998.

[121] There are essentially two methods of dealing with high-level nuclear waste: disposal in long-term, geologically stable repositories or reprocessing for use as a reactor fuel. Highly enriched uranium or plutonium produced from the nuclear power cycle, although technically classified as 'waste', can also be reconstituted for later use either as fuel or for nuclear weapons. Disposal is designed to remove spent fuel and other nuclear waste from the nuclear fuel cycle and to permanently isolate it from the environment. However, low-level waste, while less radioactive, is more voluminous and therefore presents its own storage and disposal problems.

[122] James Lovelock, *Medicine for an ailing planet* (paper presented at the Canadian Nuclear Association Annual Seminar, March 10 2005). Available at: http://www.nei.org/index.asp?catnum = 4&catid = 766.

[123] Sometimes referred to as illegal or undocumented migration and less accurately as the problem of refugees, unregulated population movements may be defined as the forced or unsanctioned (by governments) movement of people across borders and within states for economic reasons, or as a consequence of war, persecution or environmental factors.

[124] United Nations High Commissioner for Refugees, *The state of the world's refugees 1995: in search of solutions.* Oxford, Oxford University Press, 1995, pp 19–20.

[125] The Office of the United Nations High Commissioner for Refugees, *The state of the world's refugees 2006: human displacement in the new millennium.* New York, Oxford University Press, 2006. Available at: http://www.unhcr.org/cgi-bin/texis/vtx/template?page = publ&src = static/sowr2006/toceng.htm. People of concern includes refugees, civilians who have returned home but still need help, persons displaced internally within their own countries, asylum seekers and stateless people.

[126] See for example, Y.N. Gribchenko and E.I. Kurenkova, The main stages and natural environmental setting of Late Palaeolithic human settlement in Eastern Europe. *Quaternary International* 41–42 1997.

[127] See, for example, Jonas Widgren, International migration and regional stability. *International Affairs* 66 (4) 1990, p 759 and Jodi Jacobson, *Environmental Refugees: A Yardstick of Habitability*. Worldwatch Paper 86. Washington, D.C., Worldwatch Institute, 1988.

[128] Department of Economic and Social Affairs. Population Division, *World population monitoring 1997: issues of international migration and development*. New York, United Nations, 1998. See, also the study conducted by thirty scholars under the Environmental Change and Acute Conflict Project, the results of which were published in Thomas F. Homer-Dixon, Jeffrey H. Boutwell and George W. Rathjens, Environmental Scarcity and Violent Conflict. *Scientific American* 268 (2) 1993.

[129] The risk is from starvation, disease, poverty and the effects of forced displacement. Norman Myers, *Global Population Growth* (paper presented at the Seminar on Global Security Beyond 2000, University of Pittsburgh, 2 November 1995), pp 17–18 and Norman Myers, Environmental refugees: a growing phenomenon of the 21st century. *Philosophical Transactions of the Royal Society B* 357 (1420) 2002. According to Myers there were 25 million environmental refugees around the world in 1995 compared with 23 million 'traditional refugees'.

[130] Jacobson, *Environmental Refugees: A Yardstick of Habitability*, pp 6, 38.

[131] El-Hinawi, for example, defines environmental refugees as 'those people who have been forced to leave their traditional habitat, temporarily or permanently, because of a marked environmental disruption that jeopardized their existence and/or seriously affected the quality of their life.' Essam El-Hinnawi, quoted in Steve Lonergan, *Environmental Change and Regional Security in Southeast Asia*. Directorate of Strategic Analysis Project Report PR 659, Department of National Defence Ottawa, Canada, March 1994, p 82.

[132] See for example Idean Salehyan, *Refugees, climate change, and instability* (paper presented at the Human Security and Climate Change conference, Holmen Fjord Hotel, 21–23 June 2005), pp 1–2 and Jon Barnett, Security and climate change. *Global Environmental Change* 13 (1) 2003, pp 11–12.

[133] On this point see Richard Black, *Environmental refugees: myth or reality?* Working Paper 34, University of Sussex, March 2001, pp 4–8.

[134] Edwards, Security implications of a worst-case scenario of climate change in the South-west Pacific. p 317.

[135] This assessment draws substantially on the findings of Robert McLeman and Barry Smit, *Climate change, migration and security*, Canadian Security Intelligence Service, 2 March 2004.

[136] According to the UN Environment Programme, 5,000 square kilometres of land would be inundated in Thailand and Malaysia, and double that in Indonesia. See Handley, Before the flood. p 65.

[137] A. Payne, The politics of small state security in the Pacific. *The Journal of Commonwealth and Comparative Politics* 31 1993, p 125 and R.G. Crocombe, Trends and issues in Pacific land tenures, in *Land issues in the Pacific*. ed. R.G. Crocombe and M. Meleisea. Christchurch and Suva, Macmillan Brown Centre for Pacific Studies and Institute of Pacific Studies, 1994, pp 4–5, cited in Edwards, Security implications of a worst-case scenario of climate change in the South–west Pacific. p 318.

[138] US National Research Council, Abrupt climate change: inevitable surprises (summary). *Population and Development Review* 30 (3) 2004, p 564.

[139] Simply stated, risk = probability x impact.

[140] US National Research Council, Abrupt climate change: inevitable surprises (summary). p 564.

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[143] On the use of oxygen measurements, see Michael L. Bender, Mark Battle and Ralph F. Keeling, The O_2 balance of the atmosphere: a tool for studying the fate of fossil-fuel CO_2. *Annual Review of Energy and the Environment* 23 1998, and for changes in the uptake of the oceans and biosphere, C. Le Quéré, O. Aumont, L. Bopp, P. Bousquet, P. Ciais, R. Francey, M. Heimann, C. D. Keeling, R. F. Keeling, H. Kheshgi, P. Peylin, S. C. Piper, I. C. Prentice and P. J. Rayner, Two decades of ocean CO_2 sink and variability. *Tellus B* 55 (2) 2003. For a general understanding of the carbon cycle, see Christopher B. Field and Michael R. Raupach, eds., *The global carbon cycle: integrating humans, climate, and the natural world*, Scope. Washington, Covelo and London, Island Press, 2004; R.J. Norby, E.H. DeLucia, B. Gielen, C. Calfapietra, C.P. Giardina, J.S. King, J. Ledford, H.R. McCarthy, D.J.P. Moore, R. Ceulemans, P. De Angelis, A.C. Finzi, D.F. Karnosky, M.E. Kubiske, M. Lukac, K.S. Pregitzer, G.E. Scarascia-Mugnozza, Schlesinger W.H. and R. Oren, Forest response to elevated CO_2 is conserved across a broad range of productivity. *Proceedings of the National Academy of Sciences of the United States of America* 102 (50) 2005.

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[146] S. D. Richardson and J. M. Reynolds, An overview of glacial hazards in the Himalayas. *Quaternary International* 65–66 2000; M. Carey, Living and dying with glaciers: people's historical vulnerability to avalanches and outburst floods in Peru. *Global and Planetary Change* 47 (2–4) 2005.

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157 International Climate Change Taskforce, *Meeting the climate challenge: recommendations of the International Climate Change Taskforce*, p 3. The report's authors include prominent politicians, academics and business leaders from North America, Europe, Asia and Australia. See also Cox, Betts, Jones, Spall and Totterdell, Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model.

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Modelling has produced two diametrically opposed conclusions about the impact on the southern hemisphere — colder, drier temperatures as the thermodynamic systems move towards a balance versus warmer and wetter conditions because the southern currents would no longer transfer heat to the northern hemisphere. Allan W. Shearer, Whether the weather: comments on 'An abrupt climate change scenario and its implications for United States national security'. *Futures* 37 2005, pp 448–450.

159 Interviews with Professor Stephen Snyder, Co-director, CESP; SIIS Senior Fellow and Melvin and Joan Lane Professor for Interdisciplinary Environmental Studies, Professor of Biological Sciences at the University of California (Los Angeles); and Professor Michael Oppenheimer, the Albert G. Milbank Professor of Geosciences and International Affairs in the Woodrow Wilson School and the Department of Geosciences at Princeton University.

160 M.E. Schlesinger, J. Yin, G. Yohe, N.G. Andronova, S. Malyshev and B. Li, Assessing the risk of a collapse of the Atlantic thermohaline circulation, in *Avoiding dangerous climate change*. ed. Department of Environment, Food and Rural Affairs. Exeter, UK Meteorological Office, 2006, Chapter 5. Available at: http://www.metoffice.com/corporate/pressoffice/adcc/BookCh2Jan2006.pdf.

161 Peter Schwartz and Doug Randall. *An abrupt climate change scenario and its implications for United States national security.* October 2003: http://www.ems.org/climate/pentagon_climatechange.pdf. Schwartz was previously part of the highly regarded strategic planning group at Royal Dutch/Shell. He has worked as a consultant for the US Central Intelligence Agency and developed futuristic scenarios for Stephen Spielberg's film Minority Report. Randall works on scenario planning at the Monitor Group, a California think tank. Both were commissioned to develop future scenarios by the legendary Andrew Marshall, Director of the Office of Net Assessment, the Pentagon's internal think tank. For an alternative examination of the potential for rapid changes through the collapse of the thermohaline circulation see, Gagosian, *Abrupt climate change: should we be worried?*.

162 Schwartz and Randall. *An abrupt climate change scenario and its implications for United States national security.* pp 12–13.

163 Schwartz and Randall cite Steven A. LeBlanc's book Carrying Capacity, but in fact no book of this name exists. The reference is an inaccurate summation of arguments made by LeBlanc in a book that he co-authored with Katherine Register. Steven A. LeBlanc and Katherine E. Register, *Constant battles: the myth of the peaceful, noble savage.* New York, St. Martin's Press, 2003. On this point see Shearer, Whether the weather: comments on 'An abrupt climate change scenario and its implications for United States national security'.

164 David Stipp, The Pentagon's weather nightmare: the climate could change radically, and fast. That would be the mother of all national security issues. *Fortune* 149 (3) 2004, p 3. Carrying capacity has also been defined as 'the number of people that the planet can support without irreversibly reducing its capacity to support people in the future'. Paul Ehrlich quoted in David Suzuki, *Inside story* Australian Broadcasting Commission, 1997.

165 This is our summation of the scenarios outlined in Schwartz and Randall. *An abrupt climate change scenario and its implications for United States national security.*

166 For a more rigorous scientific examination of abrupt climate change scenarios see the US National Research Council, *Abrupt climate change: inevitable surprises*. Washington, D.C., National Academy Press, 2002. The NRC is the operating arm of the US National Academy of Sciences. See also, Gagosian, *Abrupt climate change: should we be worried?* Gagosian is the director of the Woods Hole Oceanographic Institution in Massachusetts. See also Stephen H. Schneider and Janica Lane, An overview of 'dangerous' climate change, in *Avoiding dangerous climate change*. ed. Department of Environment Food and Rural Affairs. Exeter, UK Meteorological Office, 2006, Chapter two. Available at: http://www.metoffice.com/corporate/pressoffice/adcc/BookCh2Jan2006.pdf.

167 David Wirth, Climate chaos. *Foreign Policy* 74 (Spring) 1989, p 10.

168 Diamond, *Collapse: how societies choose to fail or survive*, p 13. On civilisational change see Alvin Toffler, *The third wave.* New York, William Morrow and Company, 1980.

[169] See, for example, an article in The Observer which described 'a secret report suppressed by US defense chiefs.' Mark Townsend and Paul Harris. *Now the Pentagon tells Bush: climate change will destroy us.* The Observer February 22 2004: http://observer.guardian.co.uk/international/story/0,6903,1153513,00.html. The Administration's scepticism forced the Pentagon to shelve the report, although President Bush now accepts that climate change is real even if he disagrees with the mandated targets for limiting greenhouse-gas emissions as provided under the Kyoto Accords.

[170] Schwartz and Randall. *An abrupt climate change scenario and its implications for United States national security.*

[171] On this point see Dupont, *East Asia imperilled: transnational challenges to security*, p 232.

[172] LeBlanc and Register, *Constant battles: the myth of the peaceful, noble savage*, p 197.

[173] For a more detailed exposition of the reasons why Japan is unlikely to develop nuclear weapons see Alan Dupont, *Unsheathing the Samurai sword: Japan's changing security policy*. Lowy Insitute Paper 03. Sydney, Lowy Institute for International Policy, 2004, pp 34–36.

[174] Dupont, *East Asia imperilled: transnational challenges to security*, p 166.

[175] In this scenario, the earth's absorptive capacities would be further diminished by rapidly melting ice and snow and deforestation, while more heat would be trapped in the resultant higher concentrations of water vapour.

[176] Peter H. Gleick, How will climatic changes and strategies for the control of greenhouse-gas emissions influence international peace and global security? in *Limiting greenhouse effects: controlling carbon dioxide emission: report of the Dahlem Workshop on Limiting the Greenhouse Effect: options for controlling atmospheric carbon dioxide accumulation*. ed. G.I. Pearman. West Essex, John Wiley and Sons Chichester, 1992, p 565.

[177] Diamond, *Collapse: how societies choose to fail or survive*, p 13.

[178] Graeme Pearman, Peter Scaife and Brian Walker, *A blueprint: the science needed to underpin Australia's transition to sustainability* (paper presented at the Science at the Shine Dome 2002: annual symposium — transition to sustainability, May 3 2002). Available at: http://www.science.org.au/sats2002/blueprint.htm.

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