

*Climate Variability and Change and Sea-level Rise  
in the Pacific Islands Region*

*A Resource Book for  
Policy and Decision Makers, Educators  
and other Stakeholders*

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## ***Preface***

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In recent years, global warming has come to the fore as one of the world's most serious environmental problems. Meanwhile, over the past ten years, international negotiations and the accumulation of scientific knowledge in this field have led to remarkable progress — such as the adoption and entry into force of the UN Framework Convention on Climate Change, the adoption of the Kyoto Protocol, and the release of the Third Assessment Report of the Intergovernmental Panel on Climate Change. With regard to the Kyoto Protocol, which sets forth the commitments of developed countries for reductions of greenhouse gas emissions, Japan completed its ratification procedures in June 2002, and is also working with other countries to make the Protocol's entry into force a reality.

Pacific Island Countries are in one of the most vulnerable regions of the world. Here, international assistance is especially needed in order to carry out the appropriate adaptation strategies for global warming. For this reason, the South Pacific Regional Environment Programme (SPREP) and Ministry of the Environment of Japan have implemented a variety of initiatives in cooperation with a number of the countries in this region, from the perspective of promoting implementation of adaptation measures by these countries. Vulnerability assessments of coastal zones and the feasibility of adaptation measures were the subject of studies conducted during 1992 to 1995 in a number of Pacific Island States (Tonga, Fiji, Western Samoa and Tuvalu), in collaboration with SPREP and the University of the South Pacific (USP).

This *Resource Book* was prepared based on the “Assessment of Possible Climate Change and Sea-level Rise Activities to be Undertaken in Pacific Island Countries in Cooperation with Japan” which was conducted in 1999 and 2000, through cooperation between SPREP and the Ministry of the Environment. The *Resource Book* is designed to be used widely as a tool for awareness-raising, being a summary of the latest knowledge about climate change as it relates to the Pacific Islands Region. A compilation of the latest literature, scientific knowledge and data, with frequent use of diagrams and tables, it is designed to be readily understood by readers with a variety of viewpoints and backgrounds, such as policy-makers, educators and research coordinators.

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In preparation of this *Resource Book* we sought the cooperation of many leading experts in many fields. We would like to express heartfelt appreciation to Prof. John Hay from the International Global Change Institute (IGCI) of the University of Waikato, Prof. Nobuo Mimura of Ibaraki University, and others who were so generous in giving their assistance. It would give us great satisfaction if this *Resource Book* contributed further to the implementation of adaptation measures by Pacific Island States.

## ***Summary for Policy and Decision Makers***

This *Resource Book* has been prepared in order to meet the following objectives:

- To provide policy- and decision-makers in Pacific Island Countries with a coherent, authoritative and readily accessible body of knowledge and resource materials that characterise the region's resilience and vulnerability to climate and sea-level variability and change and identify a suite of proven and potential response options that are deserving of further consideration and implementation;
- To provide educators, outreach and related practitioners with an integrated and functional resource portfolio for use in formal education and professional development programmes and in support of efforts to enhance political and public awareness of the implications of global and regional variability and change for the Pacific Islands Region.

The *Book* comprises four main sections, reflecting the four principal dimensions of the climate issue – the changing climate, the observed and potential impacts, and the two broad categories of policy responses and actions, namely mitigation and adaptation

The key messages contained in this *Resource Book* are as follows:

- The Pacific Islands Region is noteworthy for its vibrant and dynamic nature – extreme events, variability and change are ubiquitous;
- Natural systems and human societies in the Pacific Islands Region had attributes that made them remarkably well attuned to the relatively large variations in environmental conditions that occurred in the recent and more distant past, with the associated high resilience fostering an ability to cope with natural environmental changes;
- The large uncertainties in specifying the future conditions that will stress both natural and human systems leads to a preference to use scenarios rather than attempt to make precise predictions;
- While climate change mitigation initiatives undertaken by Pacific Island Countries will have insignificant consequences climatologically, they should nevertheless be pursued because of their valuable contributions to sustainable development;
- Acting now to reduce the current vulnerability of Pacific Island Countries to natural climate extremes and variability, such as the El Niño-Southern Oscillation (ENSO), is one of the most effective ways to prepare for future changes in climate;
- Climate change will increase the likelihood of extreme events, and hence disaster risk; since, even today, extreme events are a major impediment to sustainable development, development planning must reflect both recurrent historical risks and new risks, including those associated with climate change, for effective risk management prevents precious resources from being squandered on disaster recovery and rehabilitation;
- Natural and human systems in the Pacific Islands Region will continue to face pressures that are not climate related, including those related to population growth, social change and economic transformation; responses to the climate and sea-level variability and change should be coordinated with the mainstream policies of

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socioeconomic development and environmental protection, to facilitate sustainable development;

- Any plausible climate change scenario will require Pacific Island Countries to implement adaptation measures due to the unprecedented and potentially devastating nature of the resulting changes; and
- The most desirable adaptive responses are those that augment actions which would be taken even in the absence of climate change, due to their contributions to sustainable development.

### **Climate and Sea-Level Variability and Change: Processes and Projections**

The Pacific Islands Region is noteworthy for its naturally vibrant and dynamic nature – extreme events, variability and change are ubiquitous. Despite the many uncertainties as to the nature and consequences of global warming, the climate of the Pacific Islands Region will continue to be dominated by the inter-annual variability associated with ENSO, by extreme events such as tropical cyclones, floods and drought and by persistent features such as the trade winds and convergence zones.

But in addition, due to the enhanced greenhouse effect the Region will likely warm, by between 0.6 and 3.5°C in this century, a rate of warming which is much larger than the observed changes during the last century and very likely without precedent during at least the last 10,000 years. The projected temperature increase can be compared to the temperature difference, for the region, of around 3 to 4°C between the middle of the last Ice Age and the present day.

During the present century the climate may become more “El Niño-like”, with central and eastern equatorial Pacific sea surface temperatures projected to warm more than the western equatorial Pacific, and with a corresponding mean eastward shift of precipitation. Furthermore, during future El Niño-Southern Oscillation (ENSO) events anomalously wet areas could become even wetter, and unusually dry areas become even drier. While there is no evidence that tropical cyclone numbers will change with global warming, a general increase in tropical cyclone intensity (lower central pressures, stronger winds and higher peak and mean precipitation intensities) appears likely, as does an eastward extension in the area of formation.

Globally, rates of sea-level rise during the 20<sup>th</sup> century have been in the range of 1 to 2 mm/yr. Due to global warming this rate is expected to increase to between 1 and 7 mm/yr, with a central estimate of 4 mm/yr. While local sea levels change in response to many factors, including local uplift or sinking of the Earth’s crust and variations in air pressure and wind velocity, it is expected that even those areas in the Pacific currently experiencing a relative fall in sea level will, by the end of this century, experience a rising relative sea level. However, interannual variations in sea level associated with ENSO, and storm surges associated with tropical cyclones, are likely to be of greater significance than sea-level rise in the coming decades.

## **Consequences of Climate and Sea-level Variability and Change**

Pacific Island Countries may well be among the first to suffer the adverse impacts of climate change, and the first to be forced to adapt. Most countries are already experiencing disruptive changes consistent with many of the anticipated consequences of global climate change, including extensive coastal erosion, droughts, coral bleaching, more widespread and frequent occurrence of mosquito-borne diseases, and higher sea levels making some soils too saline for cultivation of traditional crops.

While much attention is focused on global warming causing gradual, long-term changes in average conditions, the most immediate and more significant impacts are likely to arise from changes in the nature of extreme events (e.g. flooding, tropical cyclones, storm surges) and climatic variability (e.g. drought, prevailing winds accelerating coastal erosion). Present problems resulting from increasing demand for water, from increasing pollution of water and from current patterns of extreme events and climate variability dwarf those which will result from climate change over the next few decades, in all but a few countries in the Pacific Islands Region. Examination of the impacts of climate extremes and variability, including those associated with seasonal and interannual phenomena, offers valuable insight into the likely potential effects of climate change on agriculture. Given that in the Pacific Islands Region most good quality land is already under intense cultivation, increasing population numbers combined with climate change impacts will threaten food security, as will the increasing reliance on imported food and the consequential vulnerability to short term breaks in supply and world food shortages due to climate events.

Even though terrestrial and freshwater ecosystems have been able to evolve and adapt over time to both climate extremes and variability, and to human pressures, there are indications that changes in climatic conditions coupled with unsustainable use will render terrestrial and freshwater ecosystems increasingly vulnerable in the longer term. Many of the likely impacts of climate change on coastal zones and marine ecosystems are already familiar to island populations, and some have experience in coping with them. However, in most countries and for most coastal and marine areas, coping with climate extremes and variability will be of more significance over the next few decades.

The impacts of climate variability and change on human health are most likely to be adverse in nature, and frequently will arise through initial impacts on ecosystems, infrastructure, the economy and social services. For example, economic hardship resulting from the diverse but collective impacts of climate variability and change may well become one of the key factors exacerbating and perpetuating impacts on human health. Poverty is likely to contribute to most if not all health impacts and to the reduced capacity and ability of individuals and communities to cope with them.

The growing “urbanness” and centralization of Pacific Island populations is increasing the likelihood of adverse impacts from climate variability and change, while repairs and rehabilitation for rural populations after an extreme event may well receive decreasing priority. The possibility of more extreme events such as tropical cyclones and storm

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surges, coupled with currently projected rates of sea-level rise and flooding, places critical infrastructure such as health and social services, airports, port facilities, roads, vital utilities such as power and water, coastal protection structures and tourism facilities at increased risk. A high island such as Viti Levu could experience average annual economic losses of \$US23 to 52 million by 2050, equivalent to 2 to 4% of Fiji's GDP. A low group of islands, such as Tarawa atoll, could face average annual damages of \$US8 to 16 million by 2050, as compared to a current gross domestic product (GDP) of \$US47 million. These indicative costs could be considerably higher in individual years when extreme events such as cyclones, droughts or significant storm surges occur.

### **Regional, National and Community-based Responses to Climate and Sea-level Variability and Change - Mitigation**

On average, individual Pacific Islanders are responsible for producing approximately one quarter of the CO<sub>2</sub> emissions attributable to the average person worldwide. In common with most other countries, the energy sector is the largest source of greenhouse gas emissions in Pacific Island Countries.

Most actions that slow the rate of climate change also contribute to sustainable development. National greenhouse gas emissions data can play a crucial role in national sustainable development planning, and in assessing the success of those strategies over time. For Pacific Island Countries mitigation options fall into three broad, interrelated categories – fuel substitution, energy efficiency and forestry. While more emphasis tends to be given to reducing greenhouse gas emissions, for some Pacific Island Countries there is also the opportunity to enhance the removal of carbon from the atmosphere, for example through new forest plantings.

Mitigation activities in Pacific Island Countries are normally best implemented through a collaborative partnerships involving at least some of the following key players: developed countries, government, the private sector, community-based organizations, investors, donors and the public at large. Despite the small quantities of greenhouse gases emitted by Pacific Island Countries, internationally agreed emissions reduction mechanisms such as the Clean Development Mechanism are still relevant, for the mechanisms are also designed to support sustainable development and, in some cases, adaptation.

### **Regional, National and Community-based Responses to Climate and Sea-level Variability and Change – Adaptation**

Even in the near future climate variability and change (including extreme events) are likely to impose untenable social, environmental and economic costs on Pacific Island Countries. Importantly, such costs are inherently distributed inequitably, preferentially affecting the poor and other vulnerable groups. There is value in exploring and undertaking actions to adapt to current climate extremes and variability, both to deal with today's problems and as an essential step to building long term resilience to withstand the impending changes in climate. Communities and countries in the Pacific Islands Region

have already identified and implemented a range of both indigenous and imported practices that enhance resilience and reduce vulnerability to climate variability. This capacity needs to be strengthened further, for it also forms part of a priority approach to preparing for longer term climatic change.

Failure to grasp the real and pervasive costs of climate-related disasters has made it difficult for policy and decision makers to gain support for diverting scarce resources from one part of the national, enterprise or community budget, in order to support disaster reduction programmes. Moreover, uncertainties in climate change impact estimates, and even more so in the likely success of adaptive responses, have often been judged too large for adaptation to be incorporated into national development planning in a meaningful way.

There is now hard evidence that climate extremes, variability and change are significant impediments to successful economic development – i.e. they represent risks to regional, national and local economies. This highlights the need to mainstream both disaster risk management and adaptation to climate variability and change, in a mutually consistent and supportive manner, by ensuring disaster reduction management and adaptation are integral components of the national risk management strategy and, in turn, of the national development planning process.

Many disaster and climate change response strategies are the same as those which contribute in a positive manner to sustainable development, sound environmental management, and wise resource use. They are also appropriate responses to climatic variability and other present-day and emerging stresses on social, cultural, economic and environmental systems. If adaptation is reactive, as opposed to anticipatory, the range of response options is likely to be fewer and adaptation may well prove more expensive, socially disruptive and environmentally unsustainable.

Many development plans and projects that are currently under consideration have a life expectancy that requires future climate conditions and sea levels to be given due consideration. In addition, Pacific Island Countries depend heavily on valuable and important ecosystems that are sensitive and hence vulnerable to climate change – it is easier to enhance the ability of ecosystems to cope with climate change if they are healthy and not already stressed and degraded. Adaptation also requires enhancement of institutional capacity, developing expertise and building knowledge – all these take time.

People will, as a result of their own resourcefulness or out of necessity, adapt to climate variability and change, based on their understanding and assessment of the anticipated or observed effects, and on the perceived options and benefits for response. In many cases such adaptations will be adequate, effective and satisfactory. However, under some circumstances such adaptation may not be satisfactory or successful. An external entity, such as central or local government, may need to facilitate the adaptation process to ensure that obstacles, barriers and inefficiencies are addressed in an appropriate manner.



## **International Responses to Climate and Sea-Level Variability and Change**

The United Nations Framework Convention on Climate Change, and its related Protocol and procedures, provides important and effective means for ensuring a coordinated international response to climate change, through both mitigation and adaptation. The financial mechanism for the Convention, the Global Environment Facility, has been mandated to provide financial resources to developing country Parties, in particular to the Least Developed Countries and Small Island Developing States, for implementing adaptation planning and assessment activities and for establishing pilot or demonstration projects, amongst other responses. The Alliance of Small Island States has been effective in highlighting and promoting the interests of Pacific Island Countries at the international level. The Barbados Programme of Action was the first real opportunity for the international community to give practical effect to the agreements of the Rio Earth Summit, in that it acknowledged that Small Island Developing States have unique problems and special vulnerabilities, and need support to overcome them.

Monitoring networks and climate information systems (including seasonal and longer term forecasts) in the Pacific Islands Region are making an important contribution, not only to helping Pacific Island Countries address climate related issues, but also to international understanding of climate variability and change, including extreme events.

National, regional and international efforts to enhance the use of indigenous renewable energy technologies, and decrease reliance on imported petroleum and other energy products, are critical to the sustainable development of Pacific Island Countries, while also contributing to global efforts to slow the rate of climate change;

## **Retrospect and Prospects**

The Small Island Developing States of the Pacific are sensitive microcosms of the Earth system. As such they can be considered a bell weather to the rest of the world. But more importantly, the people who inhabit these islands can be rightly portrayed as the “innocent victims” of global warming. But such facts are small comfort to those who are already experiencing disruptive changes consistent with many of the anticipated consequences of global climate change. The precursors of global climate change impacts now being experienced by Pacific Island Countries provide some of the more compelling and tangible indications of the seriousness of global warming, certainly more than the often quoted projections of increased global temperature and sea levels. The adverse consequences of climate variability and change are already an unfortunate reality for many small island inhabitants. They highlight the serious and wide-reaching consequences future climate changes will have on small island countries, likely exacerbating the existing adverse impacts of the high natural variability of the climate and related systems.

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The combination of current and anticipated impacts of climate variability and change for Pacific Island Countries is thus of great and urgent concern, given the extensive, available and growing evidence of the vulnerability of these countries to climate variability and change and given the acknowledged limitations these countries have for adapting to climate change.

As noted above, variability and change are ubiquitous in the Pacific Islands Region. As a result, both natural systems and human societies in the Region are in some ways remarkably well attuned to relatively large variations in environmental conditions, and have in the past been able to cope with many of the repercussions of environmental change. However, the cumulative pressures on the closely integrated biophysical and human systems of the Pacific, many of which are resulting from rapid increases in total and urban population and in unsustainable production and consumption patterns, mean that these systems are less well placed to accommodate the unprecedented changes in climate and related environmental conditions that are anticipated to occur during the remainder of the current century.

Any plausible climate scenario will require Pacific Island Countries to implement adaptation measures due to the unparalleled and potentially devastating nature of the resulting changes. The most desirable adaptive responses are those that address the adverse impacts of present day climate variability (including extreme events) and augment actions which would be taken even in the absence of climate change, due to their contributions to sustainable development. Similarly, while climate change mitigation initiatives undertaken by Pacific Island Countries will have insignificant consequences climatologically, they should nevertheless be pursued because of their valuable contributions to sustainable development.

By making even greater efforts to implement these strategies, Pacific Island Countries will further enhance their international leadership in the integration of climate information into near term decision making and longer term planning, to the benefit of international, regional and local communities.

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## ***Statement by Chair of the Editorial Board***

**John E. Hay**  
**International Global Change Institute**  
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The Pacific Islands Region is distinctive with respect to its exposure, resilience and vulnerability to climate and sea-level variability and change. This reflects the unique natural, social and economic conditions that characterise the islands and waters of the region. However, to date the nature of both the locally and regionally significant impacts, and appropriate responses to such global changes, have not been researched, synthesised and documented in a systematic and comprehensive manner. National and regional policy- and decision-makers are thus handicapped by the absence of a coherent and readily accessible body of knowledge and resource materials that can inform and empower them as they fulfil their responsibilities to prepare Pacific Island Countries to address the acknowledged serious consequences of climate and variability and change, including sea-level rise.

Financial resources made available by the Government of Japan have now allowed regional and national experts with diverse technical- and policy-related experience to develop and document a comprehensive understanding of how environmental, economic and social characteristics shape the overall characteristics of the impacts, resilience and vulnerability of Pacific Island Countries with respect to climate and sea-level variability and change, and to identify preferred adaptation policies and strategies. The findings are described in this *Resource Book*, and will also be made available in other formats, including CD-ROM and via the World Wide Web.

The necessary research, and the subsequent synthesis of the findings, was undertaken by the following team that constituted members of the Editorial Board for the *Resource Book*:

- John Campbell, Department of Geography, The University of Waikato;
- Solomon Fifita, Secretariat of the Pacific Community;
- John Hay, International Global Change Institute, The University of Waikato;
- Kanayathu Koshy, Pacific Centre for Environment and Sustainable Development, The University of the South Pacific;
- Roger McLean, School of Geography and Oceanography, University of New South Wales, Australian Defence Force Academy;
- Nobuo Mimura, Center for Water Environment Studies, Ibaraki University, Japan;
- Taito Nakalevu, South Pacific Regional Environment Programme;
- Patrick Nunn, Department of Geography, The University of the South Pacific; and
- Neil de Wet, International Global Change Institute, The University of Waikato.

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One of the Pacific Islands Region's great strengths is the ability of individuals, institutions, organisations and countries to work together cooperatively. This *Resource Book* is a manifestation of such cooperation, not only in terms of the research and writing that culminated in the present volume, but also with respect to the assessments and other studies that provided the rich body of information on which the book is based.

July, 2002

## ***Acknowledgements***

The *Resource Book* reflects the collective but differentiated efforts of numerous individuals, institutions, organisations and agencies.

Financial support for the research, writing, design and publication of the *Book* was provided by the Government of Japan, through Pacific Consultants Ltd.

The South Pacific Regional Environment Programme implemented the *Resource Book* project, and was also responsible for design and publication.

The International Global Change Institute, University of Waikato, provided logistic, administrative and other in-kind support to the research and writing team.

Many regional organisations, notably the South Pacific Regional Environment Programme, the South Pacific Applied Geosciences Commission, the Secretariat of the Pacific Community and The University of the South Pacific, gave willingly of data and other information critical to documenting the significance of climate and sea-level variability and change to the countries of the Pacific Islands Region.

Similarly, individuals, government agencies and non-governmental organisations in individual Pacific Island countries have been forthcoming with relevant information. Of note is the significant body of knowledge compiled by countries that are Parties to the United Nations Framework Convention on Climate Change. In the absence of the technical and policy-relevant studies that these countries have undertaken in recent years, mostly under the auspices of the Pacific Islands Climate Change Assistance Programme (PICCAP), this *Resource Book* would have been very much the poorer in both quality and relevance.

Members of the Editorial Board wish to acknowledge the numerous national, regional and international climate assessment initiatives which provided many important resources that underpinned preparation of the *Resource Book*. These source documents are included in the References provided at the end of the *Resource Book*. Interested readers are encouraged to explore these more detailed reports.

Finally, members of the Editorial Board wish to acknowledge the constructive advice and guidance provided by the reviewers who commented on an early draft of the *Resource Book*.