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SOUTH PACIFIC ENVIRONMENTS: THEIR INTERACTIONS WITH WEATHER AND CLIMATE

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ABSTRACT

A recent international conference examined the interactions between atmospheric, marine and terrestrial systems in the South Pacific in order to identify the role of weather and climate in environmental change within the region. The weather and climate of the South Pacific is characterised by large variability, with significant impacts on both natural and human environmental components as a consequence of the sizable extremes in atmospheric and the related oceanic conditions. In many cases it is a combination of weather or climate extremes which bring about the most rapid and detrimental changes.

The large uncertainties in future weather and climate make it difficult to develop appropriate response strategies. Moreover, in the immediate future, impacts of climate change are likely to come from policy responses rather than from the physical changes themselves. To help ensure that the most fitting action is taken in the face of extreme weather or substantial shifts in climate conditions, more attention needs to be given to increasing the skill in both short- and long-term forecasts, and to equipping decision-makers and the public with the ability to comprehend the information and act appropriately.

Thus increased knowledge is seen as a means by which the impacts of weather and climate can be ameliorated. This can be achieved through information exchange, education, and training, and through improved predictions of weather and climate conditions in the South Pacific.

INTRODUCTION

Weather and climate play a major role in determining the present character of, and changes in terrestrial, aquatic and marine environments in the South Pacific (Fig. 1). But these environments also influence the weather and climate of that region, and beyond. The interactions are numerous, substantial and, often, complex. They typically extend beyond the immediate physical and biological systems to encompass the social fabric and economic activity in the region. The time scales of these interactions vary from hours and days (e.g. tropical cyclones and storm surges and their devastating effects on coastal areas in particular) to decades and beyond. In the longer term the region faces serious consequences from the predicted greenhouse warming and associated sea level rise. But even a repeat of the variations seen in the historic record, such as those associated with El Nino/Southern Oscillation (ENSO) events, place increased stress on biophysical and human systems that are already under pressure as a result of technical, social and economic change.

The spatial scales for these interactions are equally wide ranging. Some influences are felt locally (e.g. flooding or the loss of fertile top soil) while others affect the entire South Pacific region, though seldom in a uniform manner. Many areas experience rainfall extremes during positive (and negative) ENSO phases - in some locations these result in drought while in others there is frequent and prolonged flooding.

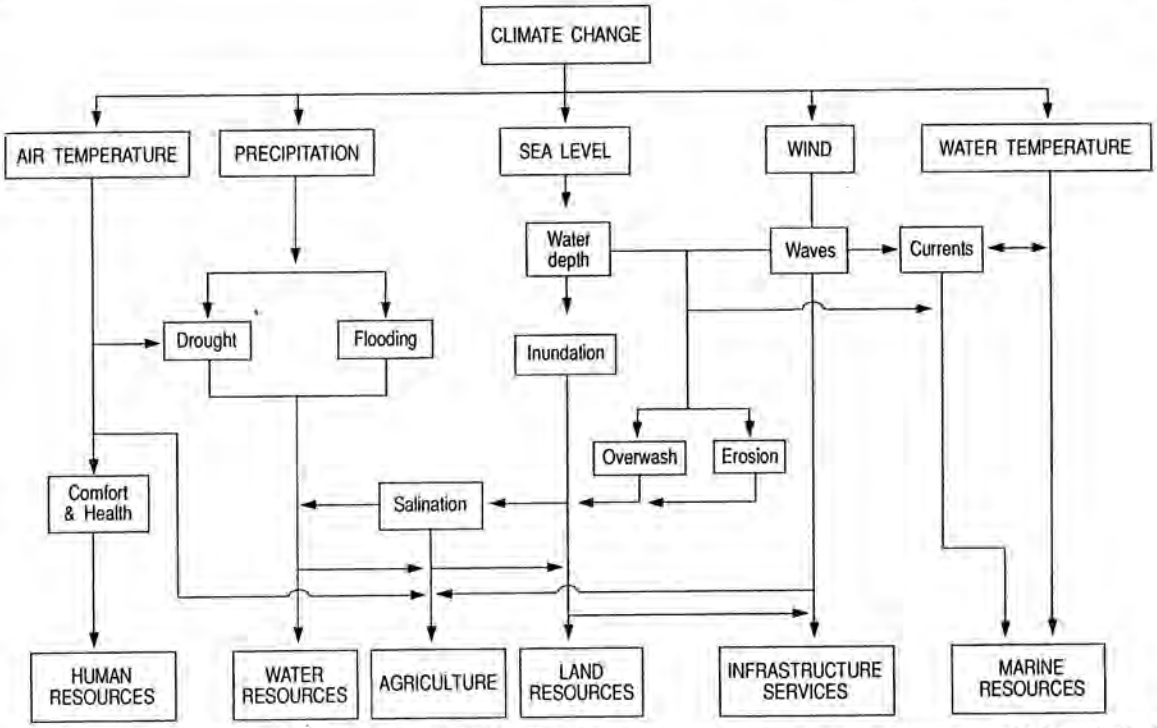

Fig. 1. Generalised effects of selected changes in the climate system on the environment and resources of a hypothetical Pacific atoll (from Aalbersberg and Hay, 1992).

There is growing recognition of the extent of past environmental changes in the South Pacific, induced by both humans and natural events such as tropical cyclones and climatic variations. This awareness, and the increasing concerns as to the effects of future changes, have helped to highlight the vulnerability of small island nations to the extremes of weather and the consequences of climate change. The people and governments of the South Pacific took this message of concern to the recent United Nations Conference on Environment and Development (South Pacific Regional Environment Programme, 1992).

At a recent international conference (Hay, 1991) these same issues were addressed by scientists, policy makers, planners, managers and various other people with an interest in environmental processes and change and in the implications for the quality of life for humans and other species. This paper seeks to summarise some of the main findings of the conference and its associated workshops. Emphasis will be placed on topics of interest to meteorologists and climatologists, including those which provide a context for the five more comprehensive and specific papers that follow this contribution.

LARGE VARIABILITY

As Mullan notes (next issue), the tropical atmosphere is characterised by large variations, in space as well as in time. Not only is it a distinctive property of the current atmosphere, but large variations have prevailed in the past and there is no reason why they should not do so in the future. Ballantine (this issue) emphasises that it is a similar situation for the oceans, although the time and space scales are typically somewhat larger.

Significant shorter-term and local variations are more commonly influenced by interactions within the trade-wind and convergence zones, materialising as convective disturbances, tropical cyclones and their associated oceanic counterparts such as eddies and storm surges. At somewhat larger time- and space-scales the variability is related to changes in the locations of the main

convergence zones and to the intensity of the convection within them. Two distinctive modes of variability have been described - the El Nino/Southern Oscillation on interannual time scales and the 30-60 day oscillation. Extreme phases of the former may persist for a year or more and are associated with dramatic changes in atmospheric pressure, the strength, direction and location of low-level trade winds and upper-level winds, positions of convergence zones, rainfall, drought, sea surface temperatures, sea level, ocean currents and the depth of the oceanic thermocline. The shorter-term oscillation manifests in the tropical Western Pacific as variations in the intensity of convective activity and in associated cloud, wind and rainfall features.

Descriptions of past atmospheric and ocean conditions reveal substantial long-term changes, with important regional variations. While such historic changes in temperature, rainfall and sea level can be reasonably well documented (e.g. Salinger, 1992), the work by Flenley and his collaborators in Tahiti (Flenley et al., 1991) emphasises the considerable effort required to reconstruct prehistoric conditions. Nevertheless, the effort is worthwhile for it provides insights to the way in which the natural environment and human activities have responded to conditions far different to the present but possibly similar to those which may prevail in the future.

What can be said about this future climate? The issue is clouded with uncertainty, particularly for the South Pacific. Despite the concerted efforts of individual scientists and such groups as the Intergovernmental Panel for Climate Change only *global* generalisations regarding changes in temperature and, to a lesser extent, sea level over the coming century have any real credibility. Regional characteristics, and especially those for oceanic areas such as the South Pacific, are poorly represented in state-of-the-art numerical models. Important features, such as the ENSO phenomenon, have yet to be simulated realistically by global climate models. So far this century changes in observed mean sea levels in the South Pacific have failed to track those for the globe as a whole. Such distinctive responses of the South Pacific atmosphere and ocean, and the need for high spatial resolution in predicted changes in order to describe island climates, suggest that reliable area- specific climate forecasts for the South Pacific are some time off. Meanwhile, the desire for something tangible with which to justify and plan response strategies can only be met by the development of regional climate scenarios, such as those described by Pittock (this issue).

SIGNIFICANT INTERACTIONS

There is little doubt that the relatively small area of land in the South Pacific provides few significant opportunities for terrestrial processes to influence the atmosphere, except at sub-regional scales. On the other hand, atmospheric conditions have a substantial influence on the terrestrial environments of the region. Fig. 1 describes several of these linkages and subsequent effects for a typical South Pacific atoll. The substantial repercussions for human and natural systems will be discussed in the following section.

The atmosphere-ocean system in the South Pacific is truly interactive. The ENSO phenomenon is a dramatic manifestation, with the strong positive feedbacks between the ocean and atmosphere allowing the extreme phases to persist for many months. Further more, in an El Nino, which is characterised by weaker easterly trade-winds and positive ocean temperature anomalies in the central and eastern Pacific, tropical cyclones tend to develop much further east than their normally preferred region of the Coral Sea. Many of the interactions also involve biological systems. For example, during the early and ending stages of the 1986-88 ENSO event, highest and lowest values, respectively, of zooplankton biomass were observed in a transect along 165E and between 20S and 6N. These changes were accompanied by significant variations in the depth of the nutricline (Le Borgne, 1991). Both phenomena are related to changes in the intensity of upwelling, with carbon uptake being 2.5 times greater when upwelling occurs than during ENSO events. Such conditions and processes are of immediate importance to both fisheries and the global carbon cycle.

MAJOR REPERCUSSIONS

Weather and climate have a major impact on the environments of the South Pacific but it is unclear whether climate or humans have played the dominant role in past environmental changes. For example, Flenley et al. (1991), using a five-metre-long core from the

bed of a lake in Tahiti, identify a period of accelerated erosion between c1500 and 1700 AD. It is not certain if this indicates greater frequency of cyclones or unprecedented human activity in the interior valleys.

The repercussions of extreme weather events and climate variability are nowhere better demonstrated than in the coastal margins of the South Pacific - the zone that physically and economically dominates most land masses in Oceania. In the last 20,000 years sea level has risen some 100 m bringing about a reduction in the number of islands in the region (the number north of the present Fijian group reduced from about 50 to 4), while many others were reduced in size and changed in type - from emergent limestone islands to atoll motu or reef islands (McLean, 1991). About 4-6,000 years ago the regional sea level first reached its present position, continuing to rise to a level of approximately 1 m above present level 2-4,000 years ago and subsequently falling to its present position. With a relatively stable sea-level close to its present position and reefs at the surface, the accumulation of coastal deposits around high islands and the development of atoll motu and reef islands from reef and lagoon materials were able to occur. In this way the essential features of the modern coastal zone were created. These processes were and still are occasionally enhanced by catastrophic storm-wave deposition to form the high coral-rubble ridges found on the ocean side of many motu and reef islands and the large storm blocks found on reef flats. On volcanic islands land-derived sediments and soils are also swept to the coast during storm episodes.

Similar episodic events are accorded significance in the west Pacific region, but in this case the emphasis is on rainfall variability for periods from months to a year or more. Drought, and fire during drought, have important effects on vegetation and hence on the people of the region. So too do frost, excessive rain and flood. All appear to have a higher frequency during extreme phases of the Southern Oscillation (Brookfield and Allen, 1991). But it is often the combination of these weather and climate extremes that bring about the most devastating consequences. In the high mountains of New Guinea weather conditions conducive to drought also favour fire and frost - the present altitudinal limit of forests in Papua New Guinea may well reflect the combined impact of drought, fire and frost. Dry weather following excessive rain prevents sweet potato tubers from growing. This is a common cause of food shortage in New Guinea and is the most probable cause of the worst single famine event in the Tari basin during 1934-35.

As Buddemeier shows (this issue), island water resources are also very sensitive to climate change and variability. The amount, frequency and intensity of rainfall have a major impact on small island water resources. Temperature, wind and ocean waves and currents may also have an influence, but local human activity can have an over-riding effect on water quantity and quality. The absence of locally reliable predictions of changes in the physical factors which determine the water resource presents a significant challenge to those responsible for its management and protection.

IMPORTANT RESPONSES

Given the high sensitivity of South Pacific environments to extreme weather events, to climate variations and to climate change, every effort must be made to ameliorate the impacts of existing conditions and develop mitigation and limitation strategies related to possible future changes. Increased knowledge is a key factor and has many components including information exchange, education and prediction.

In some cases climate-change problems are being confused due to inferior reporting by the media and selective exchange of information between the public and politicians. Many Pacific Islanders believe that ENSO-related climate variability is actually climate change. For the Pacific Islands more use should be made of radio, with an improved format for tropical-cyclone warnings and the inclusion of present-weather conditions. Increased understanding of present and future tropical weather and climate will come with additional study of historic data archives, but their present inaccessibility inhibits such studies. Likewise, current atmospheric and oceanic information-bases should be extended through the increased use of remote sensing (particularly satellite) systems and the expansion of key monitoring networks such as the upper-air stations. Pacific Island nations should be di-

rectly involved in these monitoring activities and in the planning and implementation of regional projects such as TOGA.

Community-based education and training programmes are an essential aspect of environmental awareness in the South Pacific. Appropriate support should be provided for the development of environmentally appropriate and locally relevant formal education and training programmes. This will, amongst other things, facilitate local involvement in the evaluation and management of critical environmental resources. Community, national and regional groups should be asked to assess the effectiveness of current activities leading to the distribution of materials and information on extreme weather events and climate change. They should be asked to suggest improvements and participate in their implementation. One such need is to translate pertinent environmental literature into local languages. A particular difficulty is the translation of scientific terms and the description of unfamiliar concepts. The conference highlighted the interactive and multidisciplinary significance of atmospheric and oceanic processes - this should be reflected in the development and implementation of school and tertiary level curricula. In addition to weather forecasting, training should include topics in climatology, oceanography, marine biology, agriculture and their combined interactions with the environment.

Such education and training will improve understanding and be reflected in an increased ability to manage the causes and consequences of environmental degradation. Benefits will include reduced potential for local and regional environmental hazards and damage and an increased opportunity for nations of the South Pacific to play a full role in international negotiations on issues of environment and development.

Predictive capability is an important component of environmental policy development and management. The ocean hemisphere presents numerous difficulties to the forecaster, be they attempting to predict severe weather, sea state, ocean currents or climate. The vast area coupled with the need for island specific forecasts, the sparsity of observing stations and other forecasting resources, and the complex interactions between land, ocean and atmosphere all conspire to limit the validity of such forecasts. An informed public is also required if the objective to minimize damage to life and property is to be achieved. Even an accurate tropical-cyclone warning can have little benefit if people are unsure of the contents of the message or uncertain as to appropriate actions. Presentation, layout and language are critical attributes of a public forecast. Before seasonal forecasts are provided to the public of the South Pacific a comprehensive public education programme should be implemented in order to increase the success of such forecasts as a risk-management tool. Preference has been expressed for categorical as opposed to probabilistic forecasts.

Credibility of seasonal forecasts becomes a problem at times when short-term deviations from the forecast conditions occur. These may be due to the 30-60 day cycle. In order to maintain user interest and confidence in seasonal forecasts it is suggested that the service be implemented during an extreme ENSO event — in this way the skill will likely be higher for an extended period. When the prevailing conditions downgrade forecast validity it is appropriate to acknowledge this and, if advisable, refrain from issuing more than a statement to that effect.

In her paper, Henderson-Sellers (1991) notes that the real problem of climatic change today is that policies are likely to be sought to mitigate the forcing of the atmospheric system before we have a real understanding of the likely regional outcomes. This statement is especially true for the South Pacific. She goes on to state that the current, very-poor level of regional-climate predictability is an important factor which must be recognised in the development of policies related to climate change. In the immediate future impacts of climate change are as likely to derive more from policy responses than from the physical changes, especially for small or vulnerable nations. For the moment, at least, the best descriptions of future climates in a greenhouse-warmed Earth derive from the multipronged approach advocated by Pittock (this issue). This combines the information contained in the output of global climate and limited area models, paleo and historical data, and in statistical relationships. As research on this approach progresses we can expect increasingly reliable climate change scenarios.

CONCLUSIONS

The conference on which this paper is based was able to go some way towards establishing the relative contributions, both direct and indirect, of atmospheric factors to the occurrence of environmental change in the South Pacific. But as consideration moves from the present back into the past or forward into the future the degree of understanding and the certainty in the conclusions and the appropriate responses decreases markedly. Increased knowledge is a major key to the development of effective policies and management strategies which will ameliorate rather than exacerbate the diverse biophysical, economic and social changes arising from weather extremes and climate variability and change.

The current, limited understanding of environmental change in the South Pacific must be addressed through education and other cooperative activities. Increased knowledge and the sharing of support systems can occur at all levels. Typically, awareness brings participation and from that comes direct action to limit the processes bringing about environmental degradation. No matter whether these responses take place at an individual, community, national or regional level, or in a formal or informal manner, the consequences are typically sustainable and comparatively rapid — two important considerations.

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