National Tidal Facility

South Pacific Regional Environment Programme

The South Pacific Sea Level and Climate Change Newsletter

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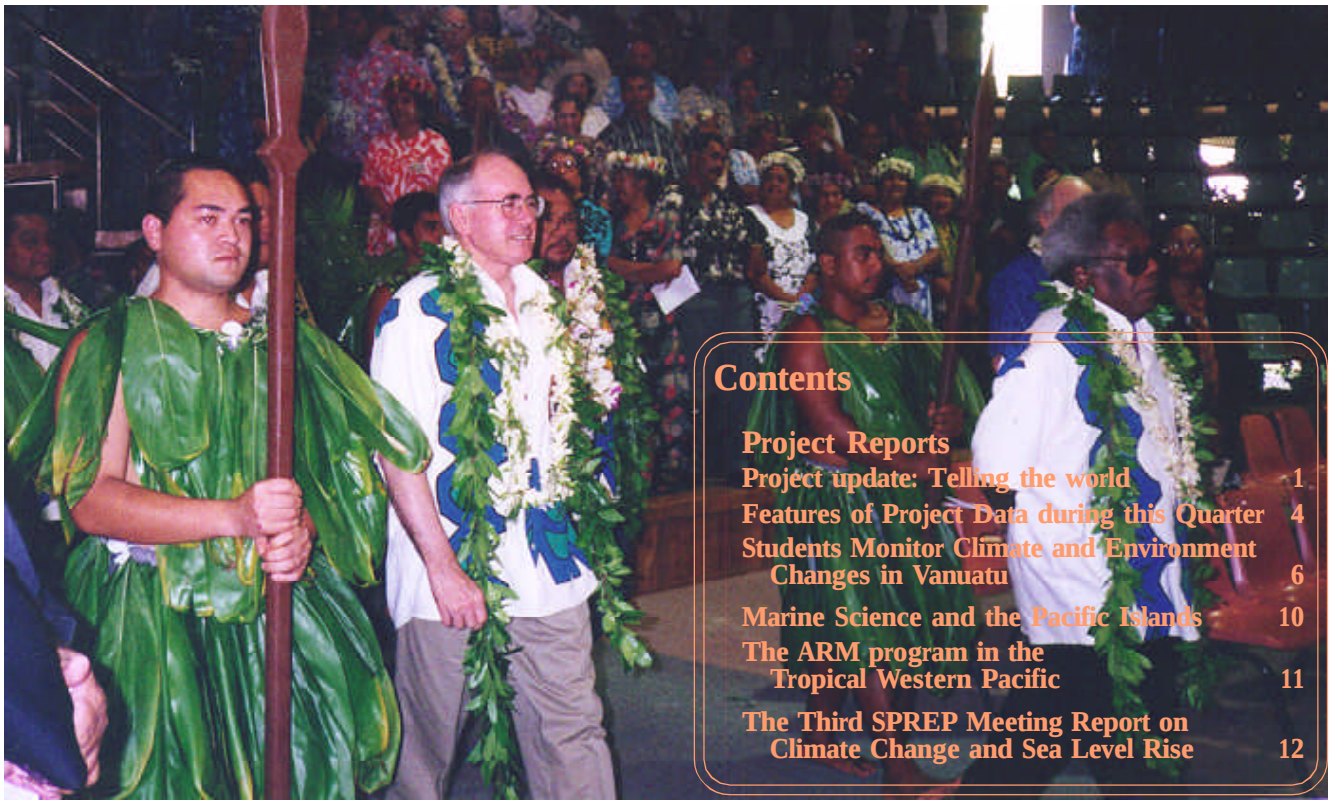
Project update: Telling the world

Since July, the Project staff have been very involved in promoting and making presentations of our results, data and information at international and regional conferences and workshops. Some of the conferences reported here include the VIII Pacific Science Inter-Congress (Islands in the Pacific Century) in Fiji, The Third SPREP Climate Change and Sea Level Rise Conference in New Caledonia and the 28th South Pacific Forum Meeting in Cook Islands. The 28th South Pacific Forum Meeting was held in Rarotonga, Cook Islands, from 8–20 September 1997. Project members including the Acting Director of NTF, Mr Bill Mitchell, the Climate Change Officer, Dr Chalapan Kaluwin and the Training Officer, Dr T Aung took part, together with the Director of SPREP, Tamari'i Tutangata. As the Project was initiated by the Forum leaders to address and improve understanding of climate change and sea level rise issues in the region, these meetings are an important fora where we can continually update the leaders of the region on the science, impacts and response options in this subject area. It is also a long-term strategy of the Project to assist and facilitate our governments' policy developments on this rather complex issue.

During the Forum meeting, general information about the Project and its latest results and products were displayed inside the main meeting venue. In addition, Heads of States and delegates were provided with brochures, booklets



Contents

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(including the Tidal Predictions booklet), fact sheets, Monthly Data Reports, Quarterly Newsletters, our colourful Pacific Surface Currents Charts and Tidal Calendar for 1998. The Prime Ministers of Australia, Tuvalu, Solomon Islands and Presidents of Kiribati and Nauru were among the Heads of States who witnessed and asked questions on the Project's display and activities with great interest.

A PC-based Real Time Graphic Display of the SEAFRAME (tide gauge) data was also demonstrated. Observers were pleased to see the real values of sea level, water temperature, atmospheric pressure, air temperature, wind speed, direction and gust, and how these data changed with time. Most of the questions related to improvements in the understanding of El Niño (climate variability) impacts in the region. All in all, this was quite a successful publicity activity for the Project among high dignitaries from the Pacific region.

Prime Minister of Tuvalu, the Hon. Bikenibeu Paeniu at the Project Display

At the end of the formal meeting, the Cook Islands Government and Forum Secretariat allowed time for a one-hour technical presentation of the Project's activities. An update on the science of climate change and sea level issues was made for the first time to our Forum Officials by Mr Bill Mitchell and Dr Chalapan Kaluwin.

The NTF and SPREP management would like to express their deepest appreciation to the staff of the Cook Islands Meteorological Services, namely Mr Arona Ngari (Director), Ms Marie Mani and Ms Susan Tuare (both officers), who provided round-the-clock assistance to the Project team during the meeting.

Islands in the Pacific Century

The VIII Pacific Science Inter-Congress (Islands in the Pacific Century) was held at the University of the South Pacific, Suva, Fiji on 13–19 July 1997. The main theme of the Congress was chosen to focus attention on islands and their development in the 21st century. This offered an excellent opportunity for the Project to present important activities and early Project results before both international and Pacific delegates during the Climate Change (Environmental Change in the Pacific) session. It was also an opportunity to promote the Project in the region, as people from the Pacific region are genuinely concerned about the climate change and sea level rise. The Climate Change Officer, Dr Chalapan Kaluwin and Training Coordinator, Dr Than Aung both presented papers at this conference, and these will be included in the proceedings which will be published soon.

The Third SPREP Climage Change and Sea Level Rise Conference, held in Noumea, New Caledonia from 18–22 August 1997, attracted a lot of international and regional experts on this subject. The conference was organised by SPREP and ORSTOM (The French Scientific Research Institute for Development through Cooperation) with the support of the Pacific Community, formerly known as South Pacific Commission. The conference was sponsored by several member governments and international organisations. Over 120 people, including approximately 80 people from overseas, participated in this 5-day event. Over 70 papers on climate change and sea level issues were presented. The conference proceedings will be published in a few months time. However, a summary of the meeting report is included in this issue (see page 12).

The Project Coordinating Committee (PCC) members, Prof Roger McLean and Dr Bob Brook, the Acting Director of NTF, Mr Bill Mitchell, Computing Systems Officer, Mr Greg Musiela and the Training Coordinator, Dr Than Aung all presented papers. A display of the Project activities and Topex/Poseidon products was made throughout the conference, and the project promotional publications were also distributed.

His Excellency the Hon. Kinza Clodumar inspects the Project display at the Forum in Rarotonga

ORSTOM and SPREP deserve to be praised for the smooth operation of the conference, extremely warm hospitality and enjoyable social functions. The continual assistance of back-up staff members from ORSTOM and SPREP, led by Mrs Jacqueline Thomas and Dr Chalapan Kaluwin, was highly appreciated. Without them, the success of conference would be very much reduced.

Coming up . . .

Other activities and meetings that are on-going and planned for the near future include:

- Another *Short Term Training Attachment* at NTF will be conducted to assist with the understanding of data and information on sea level and climate change issues and technology transfer to the Pacific. The timing of the next training course has been tentatively fixed for 13–31 October 1997. Expenses, including travel fares, daily allowances and accommodation, will be fully funded by AusAID through the Project. The training will be jointly organised by the National Tidal Facility and SPREP. Thirteen candidates from the 13 Forum member countries of the Pacific have been invited to participate through their respective governmental agencies.

- In 1998, two *Short Term Training Attachments* are being planned for 1–19 June and tentatively for October/November.

- The *Project Coordinating Committee* (PCC) will be holding its annual meeting in Port Vila, Vanuatu on 10–11 February 1998.

- The completion of a draft curriculum manual on Climate Change and Sea Level Rise, containing eight modules targetting secondary schools and their teachers in the Pacific region, should be ready by early 1998.

- The *Pacific Regional Conference for Education* will be held in Suva, Fiji, from 29 June to 5 July 1998. The Project will be involved in this conference by trialling and promoting the curriculum manual on climate change and sea level rise. It is envisaged that one of the important topics/issues to be covered will be climate change.
- The *1998 Tidal Predictions Calendar* for individual Forum Countries has been published. Governments and individuals interested in recieving copies must contact Dr Than Aung at NTF as soon as possible. Tidal predictions are based upon the sea level data observed from the SEAFRAME stations and the predictions are valid for the surrounding areas. The calendars are user-friendly and provide an excellent resource material for

fishing, boating and swimming for the local Pacific community.

- The *Australia/SPREP Vulnerability Initiative for Atoll States* of the Forum Governments ran a training programme for the Government of the Marshall Islands in Majuro on 13–23 October 1997. One of the main objectives was to build confidence and improve the skills and knowledge of Environmental Protection Agency (EPA) staff in the assessment of, and response to, coastal impacts of climate change and sea level rise through the sharing of experience, expertise and ideas. The Project's data and information helped in developing the management and planning of the coastal programmes and activities of the island. Mr Seluka Seluka (Tuvalu), Peter Waterman (Australia) and James Aston (SPREP) were the resource people.

- Did you know that our project *Monthly Data Reports* are now received by more than 200 people? Now how about this one: the *Quarterly Newsletter* has a much wider circulation of more than 700 people!

- Other articles in this issue include a look at data interpretation in terms of regional sea level and climate change, and a report from secondary school students in Malapoa College, Vanuatu which examines how climate and enivironment changes have impacted important economic and social sectors of the community. In the Children's section, we find out about the importance of marine science in the region as well as another global project, called the Atmospheric Radiation Measurement (ARM). This is funded by the USA Government and is studying ocean-atmosphere coupling research in the region. Finally, we have included the summary report of the 3RD SPREP Climate Change and Sea Level Rise Conference in Noumea, New Caledonia.

Features of Project Data during this Quarter

by T H Aung

Prior to this issue of the Quarterly Newsletter, we have analysed the significance of sea level data from the SEAFRAME stations (tide gauges) based upon the changes of atmospheric pressure, winds, strong underwater earthquake and so on. However, sea levels result from the combination of a wide range of factors including vertical land movement. In this article, TH Aung outlines the importance of this influence and how it can be measured.

The height of sea surfaces is affected by a complex combination of factors including: (a) tides; (b) atmospheric pressure; (c) winds; (d) thermal effect (global warming); (e) seismic activity (tsunami); (f) oceanographic effect (El Niño, Rossby waves, Kelvin waves, etc); and (g) vertical land movement.

Although SEAFRAME stations in the Pacific region are continuously and very accurately taking measurements of sea levels, winds, water and air temperatures and atmospheric pressure, the measurement of vertical land movement is needed to complete the study and overall understanding of sea level changes. How can we differentiate the rising sea level and the sinking land? The result may be the same, but a proper identification is necessary.

In the 28th South Pacific Forum Meeting recently held in Rarotonga, Cook Islands during September 1997, leaders of Smaller Island States (Cook Islands, Kiribati, Nauru, Niue and Tuvalu) reaffirmed that global warming and sea level rise are among the most serious threats to the region and the survival of some island states. As we are aware, the Project aims to help the Pacific Island Countries and their governments understand the scale and implications of changing sea level and climate.

An unstable region

In the Pacific, climate is only one part of the problem of changing sea levels. Others include the movement of the Earth's crust due to movement of continental plates, active volcanoes and earthquakes, which all occur in the region. The Pacific region is tectonically unstable. All the SEAFRAME stations have been installed on man-made structures within port and harbour areas. Most of these sites are on unstable or reclaimed land and therefore the stations are prone to movement.

In order to separate the motions due to oceanic processes or signals from those due to crustal processes, the vertical movements of the Earth's crust need to be determined. Consequently, a geodetic survey is an integral part of this Project, which is crucial for monitoring the stability of the tide gauges and for the accurate measurements of relative land and sea level movement. A special Survey and Geodetic Programme was set up at the commencement of the Project to measure the vertical movements of the land.

The Survey and Geodectic Programme

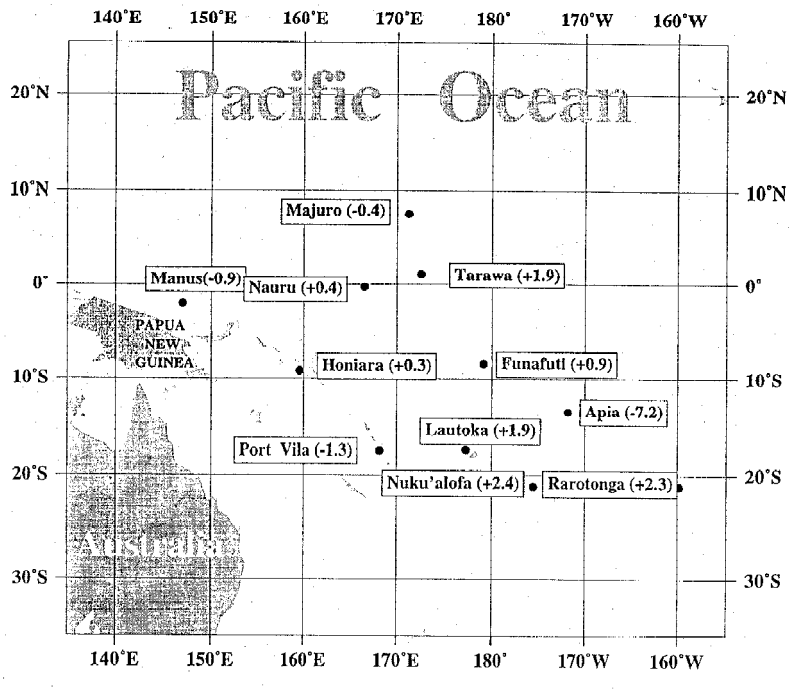
The tide gauge equipment being used in this Project has been designed with the special feature of data (the reference level, below which depths on a nautical chart are measured and from which water levels are measured and tidal predictions are made) stability. It is of sufficiently high resolution to monitor sea level with respect to a deep seated tide gauge bench mark i.e., a bench mark near the tide gauge used to check levelling (TGBM). The survey programme monitors the vertical stability of each tide gauge in relation to the TGBM. This enables the separation of vertical crustal motions at the TGBM from any real sea level movements. Subsequently, the stability of the TGBM also needs to be monitored. This is regularly done by surveying between an island array of deep bench marks and the TGBM.

Relative movement (measured in millimetres) between the SEAFRAME station bench mark and the nearest deep bench mark for the 1992–1996 period is illustrated in the map shown. For example, at Apia, Samoa, the total relative movement over three years is -7.2 mm. This indicates that the SEAFRAME station area in Apia sunk 7.2 mm during 1992–96 relative to TGBM. When we consider the sea level trends in Samoa based upon the 55 months Project data at Apia, the calculated trend is 19.5 mm y^{-1}. But if we consider the vertical land movement, the sea level trend is not that high since the land is sinking 2.4 mm $^{-1}$ (a total of 7.2 mm in 3 years). Accordingly, the sea level trend is 17.1 (19.5 - 2.4) mm y^{-1}.

If we look at another example, the relative vertical land movement in Rarotonga is +2.3 mm. This means that the land rose 2.3 mm (total in three years) relative to the TGBM during 1992–96. According to our Monthly Data Report (Sept 1997), the sea level trend calculated for Rarotonga is 17.4 mm y^{-1} based upon the 55 months Project data. If we include the vertical land movement, the net sea level trend in Cook Islands area is 18.2 (17.4 + 0.8) mm y^{-1}. Although the length of our data set is not long enough to produce more reliable sea level trends in the Pacific areas, it is clearly evident that the results in Samoa and Cook Islands are consistent. It is to be noted that the sea level trends in the Pacific region are much higher than the global trends values of ~2 mm y^{-1}.

As seen in the map that follows, results to date show that not all the sites are stable. Only a geodetic survey can monitor the stability of the SEAFRAME stations. Without this geodetic survey programme the main aim of the Project cannot be met. Accordingly, regular geodetic surveys are essential to assist in the determination of changes in absolute sea level in the region.

Note: *The above article was written by* Dr T H Aung *while the*



Geodetic Specialist, Mr Steve Turner *was away. Many thanks are due to Mr Turner for all the information provided. The author is Training Coordinator of the South Pacific Sea Level and Climate Monitoring Project, based at the National Tidal Facility.*

Students Monitor Climate and Environment Changes in Vanuatu *by C. Pierce*

For the past three years, senior geography students at Malapoa College, Port Vila, Vanuatu, have conducted a research project on a two-kilometre stretch of beach at nearby Mele Village. The aim is to find out how the beach shape and profile are changing over time, both in the short term and long term, and to determine whether such changes are related to global warming.

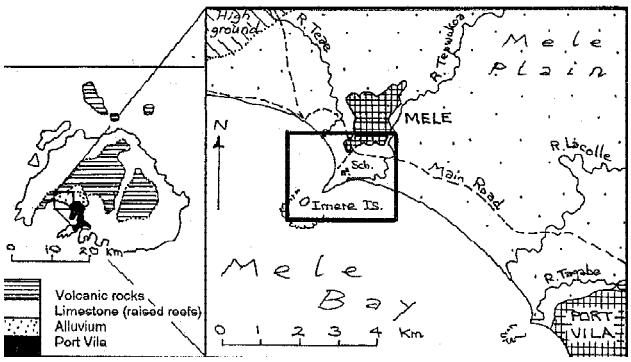


Figure 1: Location of the Mele Beach area, near Port Vila, Efate Island, Vanuatu.

The selected area (Figure 1) is at the seaward edge of an alluvial plain built up in Quaternary times from materials that were removed from the volcanic interior of Efate Island by four rivers. Situated in the south-west of the island, it comprises the "deflected" River Tepwukoa, a well-defined sand spit and the offshore islet of Imere with its surrounding coral reef.

Imere Island may have originated as a small raised reef on which coral fragments collected during cyclones. For several hundred years, it was the home of the Mele people, who artificially raised its height to about 5 metres by bringing coral fragments from other parts of the mainland. The Mele villagers moved off the islet in 1950, and Imere is now an internationally famous resort known as "Hideaway Island".

A case of direction

Due to the alignment and unconsolidated nature of the coastline, the prevailing South-East Trades produce a longshore drift that can move large quantities of sand westwards along the beach, so deflecting the River Tepwukoa and producing the sand spit that extends out towards Imere Island. However, during the hot season (December to March), Vanuatu comes under the influence of the Inter-Tropical Convergence Zone and winds are much more variable.

At this time, it is quite common for the longshore drift to move in the opposite direction, and the mouth of the river migrates back eastwards. It is also at this time that cyclones can dramatically upset the beach equilibrium, moving enormous quantities of sand to new locations, greatly increasing the river's discharge and its ability to bring in more sediment from the interior, eroding the seaward cliffs of Hideaway Island and transporting pieces of broken coral from the Imere Reefs to other places. Figures 2 and 3 attempt to show the seasonal changes of the river mouth and sand spit at Mele Beach—changes that appear to figure in the traditional "custom" stories of Mele people who talk of the river moving backwards and forwards towards the spit.

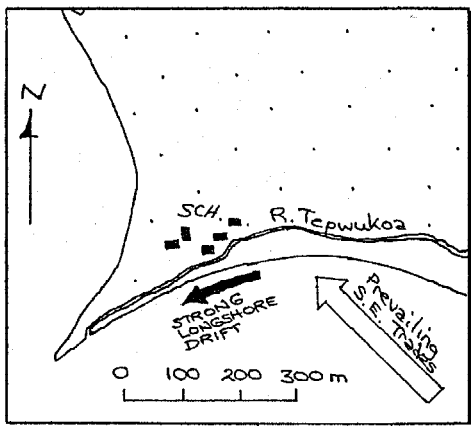


Figure 2: Location of the Mele Beach area, near Port Vila, Efate Island, Vanuatu.

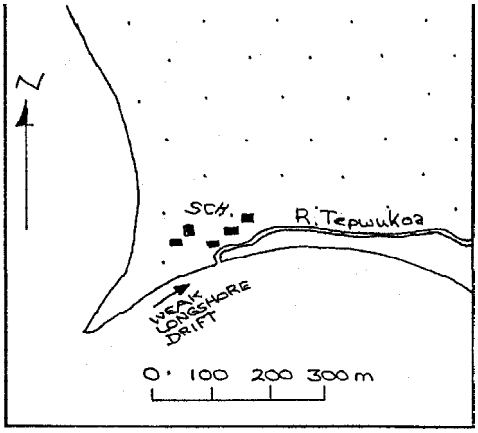


Figure 3: Location of the Mele Beach area, near Port Vila, Efate Island, Vanuatu.

Emerging marine scientists

The Malapoa geography students (see photo above) study this beach area as one of their internally assessed tasks for the New Zealand Bursary examination. They must:

- measure the slope of beach profiles at five different points;
- observe the size, shape and colour of beach particles;
- map the exact location and shape of the sand spit and the mouth of the River Tepwukoa;
- measure the river discharge just before it enters the sea;
- sketch erosionals and depositional features that they observe;
- look for ways in which humans are interfering with beach features and beach processes;
- postulate "sand budgets" for the beach on both mainland and islet; and
- measure wind speed, wind direction, wave frequency and strength of longshore drift at high tide, low tide and on different days.
- In analysing their findings, they must try to assess how the beach is being affected by such processes as marine erosion, transportation and deposition; fluvial erosion, transportation and deposition; wind erosion, transportation and deposition; coral reef growth; tectonic uplift; sea level rise; and the effect of major tropical storms and cyclones.

We are fortunate in that an accurate map of this area was produced by an aerial survey in 1975. Two of the infrastructures existing in 1975 (the basketball court and the old Golf Clubhouse) are still there today, and these are used as fixed points from which the students can produce their up-dated maps, using a simple "bearing and distance" method. By comparing the students' maps of the coastline produced in 1995, 1996 and 1997 with the same coastline some 20 years earlier, it is possible to assess the changes that are taking place and to postulate the reasons.

There is ample evidence that most of Efate is currently being affected by tectonic uplift. The older volcanic rocks of the interior are surrounded by a series of raised reefs, and the Mele Plain is bordered by limestone uplands that show at least three sets of terraces. On the Mele Plain itself, the four rivers all appear to be incised into their flood plains by several metres, and this, too, indicates uplift. Under such conditions, the Mele Plain should be extending seawards, and the coastline should be one of aggradation.

Why so much coastal erosion?

A study of the 1975 and 1997 maps, however, indicates otherwise (Figure 5). Not only has the coastline east of the River Tepwukoa receded by almost 40 metres, but the sand spit has itself shrunk drastically in surface area.
There may be several reasons for this increase in coastal erosion. A major factor has undoubtedly been the occurrence of several

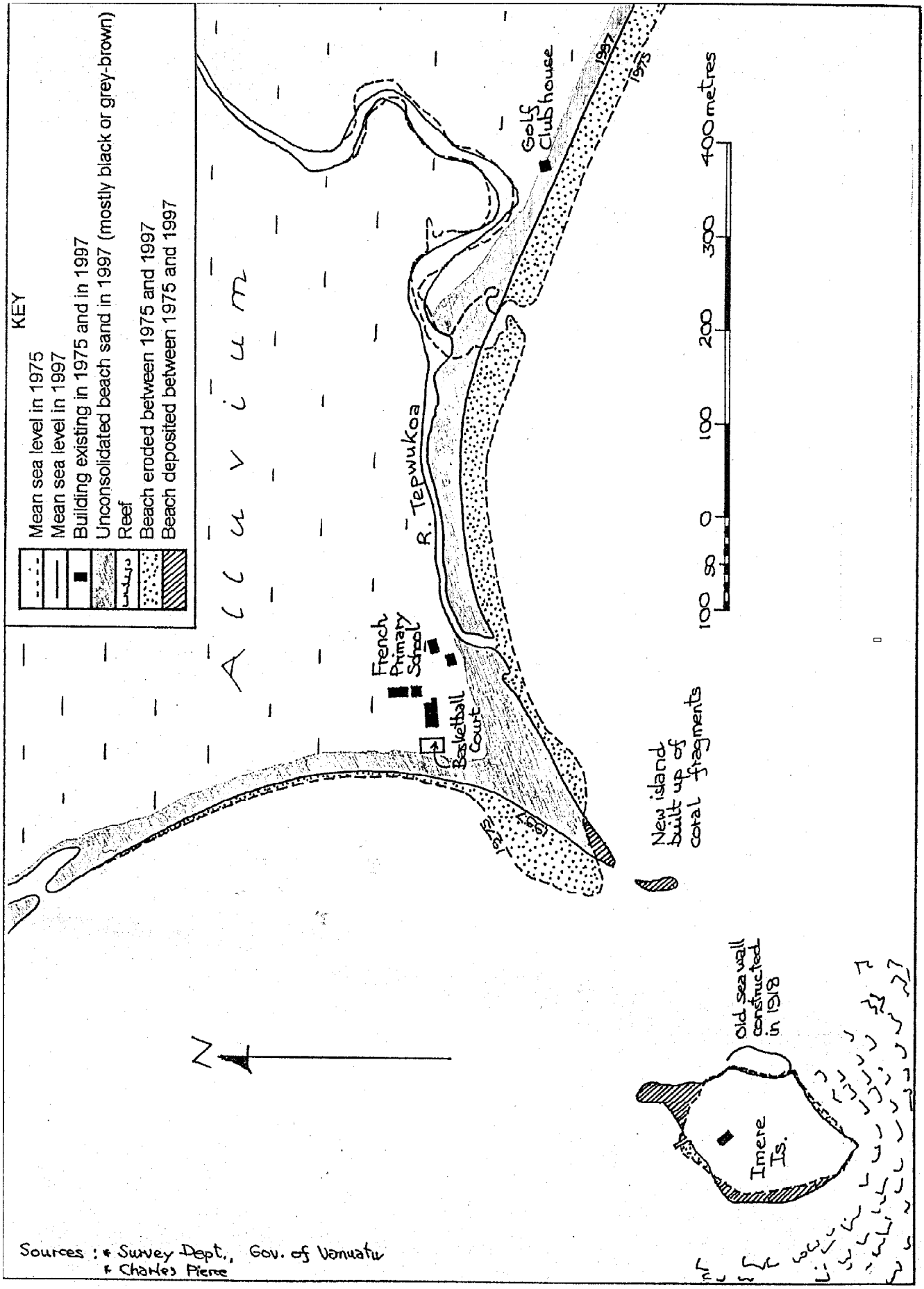


Figure 5: Comparison of the coastline at Mele Beach in 1975 and 1997

very intense cyclones, of which the strongest was Cyclone Uma in 1987—termed by the Vanuatu Meteorological Department as the "worst cyclone in living memory to have hit South Efate". As Uma moved south of Efate, winds came in from the south-west at speeds reaching 220 kilometres per hour, and Mele Beach felt their full force.

A major factor (contributing to the coastal erosion) has undoubtedly been the occurrence of several very intense cyclones, of which the strongest was Cyclone Uma in 1987 . . . the "worst cyclone in living memory to have hit South Efate".

Cyclone Prema in 1993 was another strong cyclone that removed all the sand in front of the Golf Clubhouse and then battered the house itself. Hitherto, the building had served as the social centre for Efate golfers, but no longer!

Human factors must also have contributed to the diminution of the sand spit: a lot of sand had been removed in recent years for building concrete houses in Mele (the largest village in Vanuatu) and in Port Vila, and the whole beach east of the river has been destabilised by the removal of coastal vegetation (for the Golf Club, for example) and by additional quarrying. The long term effect of tourists and local villagers walking on the Imere Reef and increasing the amount of broken coral must also be noted: in severe cyclones, such broken pieces can only increase the erosive power of the waves.

It is tempting, of course, to postulate that sea level has also risen, due to global warming. However, there is no direct evidence of this to date, and the SEAFRAME station in Port Vila Harbour has not been operating for long enough to offer any proof.

Students will continue to monitor this stretch of coastline in the foreseeable future, and it is hoped that a sufficient body of evidence can be gradually built up to prove, one way or another, what is happening to the coastline. The present situation of the mouth of the River Tepwukoa is illustrated in Figure (6).

There are several questions which remain. Is the land at Mele Beach subsiding, while the rest of Efate is rising? Are the increased number of severe cyclones and the erosion of the beach over a 20-year period providing evidence of global warming? Are humans making a significant contribution to the increased erosion of the beach? Has the sand store simply been re-distributed and piled up higher on the beach? Or is this just a short term geomorphic cycle of coastal retreat, soon to be replaced by a cycle of coastal advance? Hopefully further work will shed more light on these areas.

Note: *The author* Mr Charles Pierce *has been the Head of Geography and Development Studies at Malapoa College, Port Vila, Vanuatu for the last 18 years. Mr Pierce actively took part in the* Curriculum Writing Workshop *for the Pacific Project held at Apia, Samoa, in June 1996.*

Figure 6: Topography of the River Tepwukoa

Marine Science and the Pacific Islands

by G. R. South

The Pacific Islands are situated in a region where the oceans occupy more than ninety percent of the Earth's surface. Accordingly, marine science is a vital subject in the curricula of Pacific education systems. In this article, Prof. Robin South looks at the different ways a foundation in marine science can be important for us all.

Living in an area so dominated by ocean, it is easy to think that marine science is only important locally. Yet the scientific principles of marine science are universal. Our vast ocean is interconnected with all other oceans which, together, form the most important feature of our Earth. If one is able to grasp the main theme of marine science, one will have also obtained a foundation in science itself.

Within the solar system the Earth is unique. The feature that makes it different from all the other planets is its oceans, and it is to the oceans that we, and all living creatures, owe our existence. The study of marine science is therefore central to any study of our own past, present and future.

The stability of the oceans and the harmony with which we live with them will determine our future, and that of all life on Earth. An important reason for studying marine science is to investigate the role that the oceans play in the environment and in our own well-being. How is it that the oceans, by interacting with the land and the living organisms on land and in the sea, have stabilised the environment on Earth? Marine science examines this crucial question.

How can we expect our governments to make sound judgements concerning the management of our ocean resources if, for example, they do not have an understanding of at least the basic principles of marine science?

A strong foundation in marine science is also important for those who do not intend to specialise in the sciences, but who realise that a good grasp of scientific principles is an essential adjunct to their social scientific and management-oriented concern with marine issues. How can we expect our governments to make sound judgements concerning the management of our ocean resources if, for example, they do not have an understanding of at least the basic principles of marine science?

It might not come as a surprise to you to know that, even in some of the most important maritime nations of the world such as Canada, there is at any one time an almost complete lack of elected politicians who have any kind of science background, and usually none has any direct knowledge of marine science. Yet these are the people charged with making sweeping decisions about marine resources, decisions that can have a major influence on the future of their nation and people, even on the whole globe. Think about your own government and see whether a similar description would be accurate. However, I am proud to mention that the leaders of South Pacific Island Countries are relatively very aware of these problems and their special concern for climate change and sea level rise is as strong as ever.

Reference: Introduction to Marine Science for the Pacific Islands: UU111—Course Book One, The University of the South Pacific, Unit 1, p 7.

Note: *The author* Prof G Robin South *is the Director of the Marine Studies Programme in the University of the South Pacific, Suva, Fiji.*

The ARM Program in the Tropical

Western Pacific

W. E. Clements, F. J, Barnes, T. P. Ackerman and J. H. Mather

The Department of Energy's Atmospheric Radiation Measurement (ARM) Program was created in 1989. It is part of the US Global Change Research Program to improve the treatment of atmospheric radiative and cloud processes in computer models used to predict climate change. This article looks at the programme more closely.

In the context of ARM, "radiation" refers to solar and terrestrial radiation (i.e. sunlight and radiant heat). The overall goal of the ARM Program is to develop and test parameterisations of important atmospheric processes, particularly cloud and radiative processes, for use in atmospheric models. This goal is being achieved through a combination of field measurements and modelling studies.

Three primary locales were chosen for the implementation of extensive field measurement facilities. These are the Southern Great Plains (SGP) of the United States, the Tropical Western Pacific (TWP), and the North Slope of Alaska and Adjacent Arctic Ocean (NSA/AAO). The SGP covers approximately 55,000 square miles in north-central Oklahoma and south-central Kansas in the central United States. Implementation of the SGP began in 1992 and it is now in full operation. The TWP began phased operations in 1996 and is planned to be fully operational by 2001. The NSA/AAO is scheduled to begin operating in 1998. Each of these sites is planned to operate for at least 10 years. In addition to these three primary sites, ARM may establish several supplementary sites to obtain data at other locales for shorter periods of time. Each locale has an education programme associated with its measurement programme.

The Tropical Western Pacific cart locale (an area where equipment is held) is a large expanse of tropical ocean and maritime continent lying roughly between 10° S and 10° N latitude and from 135° E to 150° W longitude. Climatologically, the locale is characterised by warm sea surface temperatures, deep and frequent atmospheric convection, high rain rates, strong coupling between the atmosphere and ocean, and substantial variability associated with the El Niño–Southern Oscillation (ENSO) phenomenon. The relationship between climatic variability in this region and variability in other areas of the planet is well-known.

ARM is establishing five observation sites in the Tropical Western Pacific locale to provide data to better understand the effects of clouds and water vapour on the Earth's radiation budget and to improve parameterisations in climate models. Each site will be equipped with an Atmospheric Radiation and Cloud Station (ARCS). An ARCS is a self-contained, semi-autonomously operating set of meteorological instruments, data acquisition systems, monitoring and control systems, communications systems and support equipment.

The first site in the TWP began operating in Manus Province, Papua New Guinea, in October 1996. The second site is scheduled to be installed on Nauru in the Spring of 1998. Subsequent sites are planned for a location near the equator in the eastern portion of the locale and at locations north and south of the equator in the central portion. It is hoped to have all five sites operational by 2002. Educational programme activities have begun at established sites and within the Pacific Basin.

Note: *The authors,* Drs Clements, Barnes, Ackerman and Mather *are the leading figures of the ARM Project in the Pacific region for administration and science.*

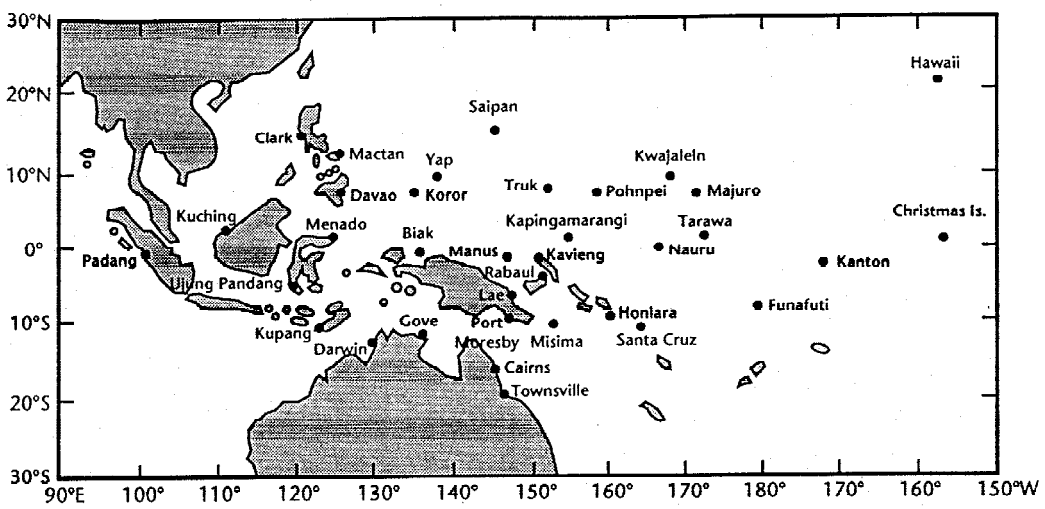


Figure 7: Tropical Western Pacific region

The SPREP Meeting Report on Climate Change and Sea Level Rise in Noumea, New Caledonia, 18–22 August 1997.

Compiled by: Kaluwin, C. (SPREP) and Hay, J. (Auckland University)

Chairpersons Summary of Findings and Future Needs

(The Chairpersons for the meeting were the Government Representatives and Administrators of American Samoa, Cook Islands, Kiribati, Samoa and Vanuatu)

The science of climate change has been summarised periodically for some twenty years. Some findings were well-accepted whereas others were more widely debated. The increasing levels of greenhouse gases (GHGs) (e.g 0.4 percent per year for carbon dioxide, or $C0_2$) and their effect on enhancing the heating of the Earth (2.5 W/m^{-2}) are well-established. A doubling of $C0_2$ concentration would directly increase global temperatures by 1.2^{0}C. When feedback mechanisms are considered, a total heating of 1.5–4.5^{0}C has been agreed to over the last 20 years. It is also agreed that the world has heated 0.3–0.6^{0}C since 1860 but there is debate as to whether this can be attributed to an enhanced GH effect. The Intergovernmental Panel on Climate Change (IPCC) Second Assessment Report, in a major change from its 1990 Report, stated that it is unlikely that the heating is entirely natural. There is now a discernible effect of human activity. But how much the earth will warm and how much sea level will rise in the future depends on many factors. By 2100 the temperature is expected to increase by 1–4^{0}C (1.7^{0}C middle scenario) and global sea level by 13–94cm (49 cm middle scenario). Unfortunately at present, little can be said with any certainty about regional scale changes, especially in the Pacific.

A review of scientific information and understanding in the Pacific regarding Climate Change and Sea Level Rise (CCandSLR) draws on information from a range of sources. They show that temperatures have been increasing by 0.1^{0}C per decade in the region and sea levels by 2mm/yr. There is also evidence that climate phenomena such has El Niño–Southern Oscillation (ENSO) will have major influences on the impact of CC&SLR. It is also recognized that the Pacific region plays an important role in understanding global climate change.

Modelling, scenario development and vulnerability assessments will play key roles in helping the Pacific respond to CC&SLR. Models currently suggest a doubling of $C0_2$ concentration will increase sea-surface temperatures by 1^{0}C and increase rainfall intensity in the central equatorial Pacific. Although the second assessment of IPCC did not reveal a consensus regarding tropical cyclones in a changed climate regime, recent research has indicated a possible intensity increase of 10–20 percent with a doubling of $C0_2$. Vulnerability assessments have shown Pacific Islands Countries (PICs) to be highly vulnerable to CC&SLR with a low capacity to respond.

This response capability needs to be strengthened through regional and international cooperation and education, training and awareness-raising. Countries also need to be encouraged to perform integrated impact assessments in addition to sectoral ones.

The National Tidal Facility, established by Australia at Flinders University in 1989 as a service to Australia and the region, operates eleven sea level monitoring sites in the South Pacific. In its five years of operation the data has provided information on sea level changes during cyclones and tsunamis as well as for modeling tidal information. Especially interesting, most stations are showing accelerated SLR with increases of up to 25 mm/year. This is more than ten times the trend this century. The findings have been validated by satellite data showing 20–30 mm/year rises in a region from Papua New Guinea south-east to Fiji. The cause and duration of this variation is unknown, but is likely related to ENSO.

The New Zealand Meteorological Service has supported a number of PIC meteorological services since around 1940. Analysed data show that since 1920 temperature has risen 0.6–0.7^{0}C in Noumea (New Caledonia) and Rarotonga (Cook Islands), much greater than average worldwide increases, based on data from 34 stations throughout the Pacific from about 160° East and mostly south of the equator. Research shows that surface air temperatures have increased by 0.3^{0}C to 0.8^{0}C this century, with the greatest increase in the zone south-west of the South Pacific Convergence Zone (SPCZ). This is well in excess of global rates of warming. The records also indicate that rainfall had increased in the north-east and decreased in the south-west of the Pacific. Interannual variations in temperature and rainfall were found to be associated with the Southern Oscillation Index (SOI) and the research also found an eastward movement of the SPCZ had taken place. The changes observed in the twentieth century were considered to be consistent with anthropogenic activity.

Research results such as those reported above are highly dependent on the continued support of Pacific meteorological services. Long-term, high quality data with consistent standards are required to study climate change, both in the region and as they affect global processes. To ensure a maintenance of quality data, Pacific Island governments need to ensure that financial support for national meteorological services is maintained, that

there is ongoing training, capacity building and that appropriate technologies are used for that purpose.

A great deal of international effort has enabled the identification of seasonal and interannual trends in oceanic conditions, but scientists are not yet in a position to identify long term trends in temperature and salinity. More oceanographic observational work is needed to achieve understanding of the mechanisms that govern climate in the region.

Carbon dioxide exchanges between the ocean and atmosphere in the equatorial zone east of the international dateline resulted in 1000 million tonnes of carbon being exported to the atmosphere as a result of upwelling. This figure would be considerably higher were it not for biological processes which re-use carbon brought to the surface by upwelling in the eastern Pacific. Results from ORSTOM Research Institute in Noumea, New Caledonia also indicated that during El Niño events atmospheric $C0_2$ concentrations tended to increase less rapidly and during La Niña $C0_2$ measurements indicated a more rapid increase in atmospheric concentration. While $C0_2$ fluxes can be monitored, there are physical dimensions of the process which are not well understood, such as seasonal differences.

Recent data and modelling indicate that we are proceeding into a significant El Niño event with a multivariate ENSO index showing the current event was occurring with greater rapidity than any of the six previous events for which data was available. The Pacific ENSO Applications Centre in Hawaii (USA) provides information to a number of PICs regarding ENSO. Currently experimental climate forecasting is being carried out. It is considered that climate forecasts will be of considerable assistance in planning agricultural production, fisheries, human health and civil defense activities. While some locations and for certain seasons a high degree of skill can be obtained in forecasting ENSO-related climate conditions, in other areas prediction is more difficult.

Communications in the Pacific region are badly in need of significant improvement for a better Tropical Cyclone (TC) warning system. Although meteorological services are doing their best, the error in predicting the locality to be hit by a TC is quite high. For example, if a warning is given 12 hours ahead, the error is 122 km. Due to this high error, its likely that an unprepared area may be hit by a TC. Media reports on TCs are not as accurate as would be desired and such reports have been criticised.

According to the statistics of TCs between 1940 and 1994, there is an average of 7 TCs per year. Although the general TC season is between October and May, most TCs occur between January and March each year. Changes in frequency, area of occurrence, time of occurrence, mean intensity and the maximum intensity of the TC cannot be predicted by present numerical models. Based on the present records, no two TCs are the same. However, TCs usually take place between latitudes 8^0S and 20^0S and longitude 145^0E and 125^0W. Probability of occurrence is maximum near 8^0S and decreases with increasing latitude. During ENSO, there is more than a 40 percent chance of a TC being severe.

Climate change and its impact on human health is a new area of research. One of the problems is that we do not know enough about what might happen in the future. This highlights the importance of integrated assessment models (IAM) for assessing the climate change impacts on human health. At present there are a significant amount of health-related disasters in the developing world. Many areas of the world suffer from tidal waves at present and there is little knowledge of how this phenomenon might be affected in the future by climate change. There is a threat posed by infectious and vector-borne diseases such as malaria and cholera in the developing world. Cholera incidence is on the rise and there have been reports of malaria incidence in areas which previously did not have malaria, such as the highlands of Papua New Guinea. Future work should include:

(i) identification of vulnerable population to health risk;

(ii) developing indicator species of vectors and response strategies; and

(iii) establishing early warning system for phenomenon such as ENSO.

This work is particularly relevant for PICs. Regional, national and international communities should focus on adapting to present natural variability and prepare for extreme events. The National Oceanic and Atmospheric Administration (NOAA) and the South Pacific Commission (SPC) are in the process of collaborating on work related to health indicators and ENSO-related extreme events.

The impacts of climate oscillation on tuna fisheries in the Pacific Ocean have been studied by the SPC. Some 70 percent of tuna catches come from Pacific Ocean and tuna activities have expanded considerably. These catches are mostly skipjack and yellowfin tuna, with the majority coming from the western equatorial Pacific. The tuna resource is very closely linked to position of warm pools. This is an area of low primary production. The result is surprising as tuna need to consume 10% of the body weight each day. The reason for this may be the convergence zone along the eastern boundary of warm pools. This may provide a possible mechanism for replenishing productivity in warm pool. Hence research is being made into the presence of the convergence zone and the presence of tuna. Results from a 1988–95 study show a large interannual variation and high spatial variability. Conclusions based on simulation studies indicate that secondary production (upwelling) enables the concentration of tuna in otherwise "poor" productivity areas as a result of convergence zones. The impact of ENSO is clearly established: zonal movements include east-west movement of primary production and tuna levels.

The IPCC assessment of the social and economic dimensions of climate change has little reference to Pacific Island Countries. The focus is mitigation. The IPCC report uses models which are mainly for developed economies. All islands are treated as if they are the same. For the world as a whole, the IPCC estimates a net loss for a doubling of $C0_2$ of about 1.5–2.0 percent of global Gross National Product (GNP). Developing countries are estimated to have net loss of 2–9 percent GNP.

The social and economic dimension of Global Climate Change has a number of implications to Pacific Countries such as:

(a) PICs make a small or negligible contribution to GHG;
(b) they are among the countries which are most impacted; and
(c) knowledge of relevant parameters is very low.

Thus Pacific Island Countries should take precautionary approaches and should acquire more understanding and knowledge about the causes than effects and more about migration than adaptations. Understanding effects and adaptation is essential in the political arena and thus public awareness is important to the Pacific region.

Most Pacific Island governments are aware of climate change, but they wish to know what they have to do to address the problem. The cultural dimension involves the environmental influence on both people and culture. For example, the larger islands with more resources would influence class structure and the culture of communities living in them. Traditional knowledge has governed activities and survival of people in the region both in the past and present. The socio-economic dimension has indicated a change from subsistence to dual economy. Issues that need to be addressed include population concentration and location infrastructure, food security, culture and activities.

The response options that have been, and will continue to, exist in the region include migration, resettlement and decentralisation. All these need planning as they have policy implications. Thus the future direction will have to be researched so that some response strategies can be planned and recommended for the future adaptations.

Papers presented during the meeting, and subsequent discussions, identified the need for:

A. At the National Level

- Implementation of *locally-based* "coping/sensitivity" studies taking into account social and economic consequences of such phenomena as droughts, foods, tropical cyclones, high abnormal tides and storm surges, coastal erosion, outbreaks of cholera and failure of food supplies.

- Development, validation and application of integrated (i.e. multi-sector), national-level impact assessment models (e.g CLIMPACTS) which meet the requirements and challenges of producing meaningful results for Pacific Island Countries.

- Development and validation of seasonal forecasts of key national indicators, including rainfall anomalies, wind anomalies, tropical cyclone frequency and intensity and sea level variations and change.

- *In-country* assessments of *local* adaptation and mitigation strategies, including assessment of their technical effectiveness, economic effectiveness, cultural and social acceptability and links with traditional methods.

- *Public awareness-raising* including such activities as translation of technical information into local languages, songs, plays and so on, briefing of decision-makers and policy-makers, information exchange, and education, including curriculum development and preparation of resource materials of local relevance such as case studies and practical projects. (Current relevant examples are the South Pacific Sea Level and Climate Monitoring, Project, the US Atmospheric Radiation Measurement (ARM) and the School of the Pacific Rainfall Climate Experiment (SPaRCE) projects.)

- *Non-targeted* (i.e. generic), in-country training to empower decision-makers, planners and community organisations in such skills as consensus building, priority setting and conflict resolution.

- *Targeted*, in-country training to equip key individuals with technical skills to use locally and internationally derived information (e.g. Pacific Islands Climate Change Assistance Programme (PICCAP) in-country training activities).

- *Capacity building*, including strengthening of national meteorological services and port authorities.

B. At the Regional Level

- Regional assessments of probable environmental changes, including production of high resolution scenarios leading ultimately to predictions, and assessing economic consequences, social and cultural consequences and environmental consequences.

- Development and dissemination of guidelines for coastal protection, including technical assessment, economic assessment and cultural assessment (e.g. compatibility with traditional practices) of the various options.

- Development and dissemination of guidelines for coastal management, including such features as set-back "rules."

- Development and dissemination of technical guidelines for such procedures as storm surge calculations.

- Regional assessments of mitigation and adaptation strategies, including assessments of their technical effectiveness, economic effectiveness and cultural and social acceptability, including compatibility with traditional methods.

- Preparation of materials for public awareness-raising, such as translation of technical information into local languages, songs, plays and so on, for briefing of regional decision-makers, information exchange, and education, such as curriculum development and resource materials of regional relevance (e.g. case studies, practical projects).

- Non-targeted (i.e. generic) "training of trainers" for empowering decision-makers, planners and leaders of community organisations (an appropriate example is the Australian/SPREP Atoll Project).

- Targeted "training of trainers" for equipping key individuals with technical skills to use locally and internationally derived information (an example is regional training initiatives under PICCAP and The South Pacific Sea Level and Climate Monitoring Project).

- Capacity building, including regional activities to strengthen national environmental agencies and meteorological services.

C. At the Sub-Regional Level

- This involves similar activities as those undertaken on a region-wide basis, but with a sub-regional focus, bringing together those island countries with common needs, settings and backgrounds. Activities might relate to such themes as adaptation strategies for high islands, coastal protection for low islands, forest management, water catchment management, "natural" catchments (e.g rivers) and "artificial" catchments (e.g. roofs).

D. At the International Level

- Technical support to Alliance of Small Island States (AOSIS) and PIC negotiators, by establishing a Technical Support Network (e.g. AOSIS-TSN).

- Input to IPCC activities, including responsibilities of Pacific Islanders as lead authors and contributors to reports.

- Sector-based, regional studies of consequences of environmental changes such as those related to tuna fisheries and energy supplies.

- Technical support for sustainable development of Small Island States, including reference to human dimensions as well as biophysical aspects.

- Global awareness-raising through such activities as a Pacific Island Countries' Home Page on the Internet. This would help counteract inappropriate lobbying by industries and would help spread the AOSIS/PIC messages.

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