National Tidal Facility

South Pacific Regional
Environment Programme

South Pacific Sea Level and Climate Change Newsletter

Quarterly Newsletter Vol. 1, No. 2, January 1996

Project Update

During the first six months of Phase II of the South Pacific Sea Level and Climate Monitoring Project, six regular Monthly Data Reports (Vol II, No. 1-6) were issued to disseminate information on the development of the project and the status of data. In the new format of the Monthly Data Report for Phase II, only time-series plots of the data for the current month with a few brief notes and comments on data, operational performance and some special events during the month are included. The latest issues of the Monthly Data Report for the second phase of the South Pacific Sea Level and Climate Project have been distributed to the new mailing list addressees, as well as to participants attending the Workshop Round Four held in Adelaide in October 1995 and many others who expressed an interest in receiving it.

Having gone through the busiest month of the project in October, November and December were relatively quiet. However, we were reasonably busy since proceedings of the October International Conference held in Adelaide are in final preparation and are expected to be published before March 1996. At the moment, ten Sea Level and Climate Monitoring stations are in operation (Manus in Papua New Guinea will restart operation from March 1996), providing a wide coverage across the Pacific region. The results from these stations will provide various benefits to the Forum Countries, such as increased knowledge in sea level and climate change, immediate input for local meteorological services, for harbour operations, and for planning of coastal development.

In order to achieve some immediate aims of the project, tidal predictions for Pacific Island Countries (PICs) have been published and distributed in November by the National Tidal Facility (NTF), as a special activity of the Information and Training Component. This is to be regarded as a service to the local Pacific community and it is hoped that people concerned will find it useful. The booklet has been distributed to the project member countries, especially to the personnel of ports and harbours. However, these predictions are not intended to be used for navigational purposes and do not replace official predictions where they exist. If anyone wishes to receive a copy of the tidal predictions booklet, please write to NTF, indicating the specific country or area. Please remember that the prediction is based upon the sea level measurements from our SEAFRAME stations. Accordingly, it covers 11 Pacific Island Countries and, unfortunately, FSM and Niue are not included since they do not yet have a SEAFRAME station.

The *Quarterly Newsletter* for the project is jointly issued with the South Pacific Regional Environment Programme (SPREP). Due to a very heavy schedule during the end of 1995 and unforeseen circumstances arising in SPREP, the first issue of the Quarterly Newsletter was issued much later than expected. This second issue contains an account of the data interpretation in terms of regional sea level and climate change, a general rule of thumb on sea level and other related matters as discussed and highlighted. A special section, called Education, is also included and focuses in this issue on the greenhouse effect and experiments on sea level change.

Ulrike Wiehr,
Chalapan Kaluwin (SPREP) & Than Aung (NTF)
Editors

Contents

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AusAID

A Rule of Thumb

J. L. Luick

In this article, a simple rule of thumb for thermal expansion of the upper ocean is discussed. We have been asked to explain the derivation of a standard rule of thumb used by oceanographers to estimate the seasonal change in sea level as a result of solar heating of the upper layer. I emphasise the "upper layer" and "seasonal" because the rule of thumb is *not valid for long term global sea level rise*, which requires a more complex analysis.

In its simplest form, we say that in the subtropics, a 1°C change over the upper 50 metres will raise sea level by 1 cm. More precisely, we can express the resulting sea level rise h as $h=\alpha \cdot q \cdot \delta T$, where α is the "thermal expansion coefficient", p is the thickness of the layer that experiences an increase in temperature, and δT is the size of the temperature increase. This is still fairly simple, although for precision, one requires a table of thermal expansion coefficients to look up α. Near the ocean surface, at 25°C and S=35, $\alpha \approx 3 \cdot 10^{-4}$ per degree C, while at 15°C and S=35, $\alpha \approx 2 \cdot 10^{-4}$.

Finally, how is the expression $h=\alpha \cdot q \cdot \delta T$ derived? From basic calculus, one can write

(1)
$$dV=\frac{\partial V}{\partial T}d$$

It is necessary to know the basic definition of α (the termal expansion coefficient), which comes from thermodynamics:

(2) $$\alpha=\frac{-1}{\rho}\frac{\partial \rho}{\partial T}$$

Here ρ is density. If we substitute ρ=m/V, where m is mass and V is volume, and differentiate, we find that another way to write α is

(3) $$\alpha=\frac{1}{V}\frac{\partial V}{\partial T}$$

Substituting the new expression for α into (1), we see

(4) $dV= V\alpha dT$

We want to express sea level rise in height h, not volume V which is defined as V=height·area.. If we divide both sides by area, letting h=dV/area, and p=V/area, we arrive at the correct expression, $h=\alpha \cdot q \cdot \delta T$.

If we assume that $\alpha \approx 2 \cdot 10^{-4}$ (see above), we can verify that a 1°C temperature increase over the upper 50 metres will raise sea level by ~1 cm.

The author *Dr J L Luick* is a Research Associate in National Tidal Facility.

Benefits of the Project

W. M. Mitchell

The South Pacific Sea Level and Climate Monitoring Project developed as an Australian response to concerns raised by members of the South Pacific Forum countries about potential impacts of the greenhouse effect on climate and sea levels in the region. The primary aim of the project is monitoring of sea level and climate which may require twenty years or so to achieve a reasonable and reliable estimate of sea level trends in the region.

In addition to serving the South Pacific Forum interests, the South Pacific Sea Level and Climate Monitoring Project is an important link in international endeavours to collate and model data on global atmospheric and oceanographic systems. The project will provide access for Australia and the Pacific Island Countries [PICs] to regional and global research on climate variability and the impact of the enhanced greenhouse effect. In particular, it will enable social and economic planners to forecast and develop strategies in the key areas of agricultural development and coastal management.

The results from this project may provide various benefits to the Forum region, such as increased knowledge and immediate input for local meteorological services since meteorological data from the project are extremely precise. Based upon the project data, NTF has produced tidal predictions for harbour operations, and for planning of coastal development. Other benefits include public safety issues during extreme sea level events such as storm surges and tsunamis as well as information relevant for agriculture, fish farms, coastal erosion and exclusive economic zone problems.

Even though it is not possible to forecast extreme events from our data sets, cyclones around Fiji and other localities in the region have been detected from the records of our stations. Some time ago, we helped to provide some estimates based upon the wind and sea level data of the Project to try to track a missing boat in the vicinity of Nauru. Without the accurate data set from the project, this kind of special assistance would not have been possible. Although we do not intend to use our data to predict El Niño events, we may verify the situation using our oceanographic and meteorological data. In the future, we wish to be able to provide information on sea surface currents in near real time using our data base.

These simple examples demonstrate the values of the project data and how they can be used in many different ways. Naturally, there are also benefits to the international scientific community in terms of timely and accurate data. Both the project title, *South Pacific Sea Level and Climate Monitoring Project*, and the managing organisation, the National Tidal Facility clearly indicate the fundamental nature of work of the project.

The author *Mr W M Mitchell* is the Deputy Director of National Tidal Facility and the Coordinator of the Pacific Project.

Notable Features of Oct, Nov & Dec Sea Level Data

J. L. Luick

Perhaps the most significant climatological feature of the last quarter of 1995 was the realisation that for the first time in three years, the new year would *not* bring with it an El Niño! In fact, in some quarters, the opposite conditions — a so-called "cold episode" or "El Viejo" — seem to be prevailing.

During the final quarter, equatorial trade winds were stronger than usual across most of the Pacific. The 'Outgoing Longwave Radiation' (OLR) index over the central equatorial Pacific was also above normal. (An increase in OLR implies a decrease in cloudiness, and therefore also decreased rainfall.) Sea surface temperatures along the equator from South America to 160° were below normal. All of the factors are in agreement with the conclusion that cold episode conditions will prevail.

Another indicator of climate conditions is the sea level at Honiara, Solomon Islands. As can be seen from figure 1 below, 'Climate Anomalies', when the "Southern Oscillation Index" (SOI) drops — an indicator of El Niño Southern Oscillation, or ENSO — the Honiara sea level drops too, by as much as twenty centimetres. If we turn then to the figure 3, 'Sea Level Anomalies', we see that the Honiara sea level has been rising consistently over the final quarter of 1995.

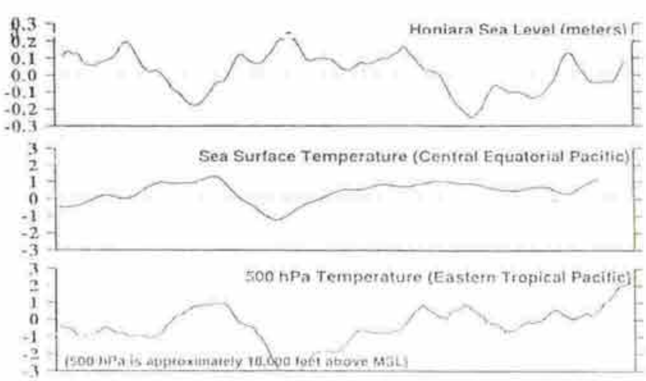


Figure 1. Atmospheric and sea surface indices expressed as *anomalies*. Data from US NOAA Climate Analysis Center and University of Hawaii Sea Level Centre

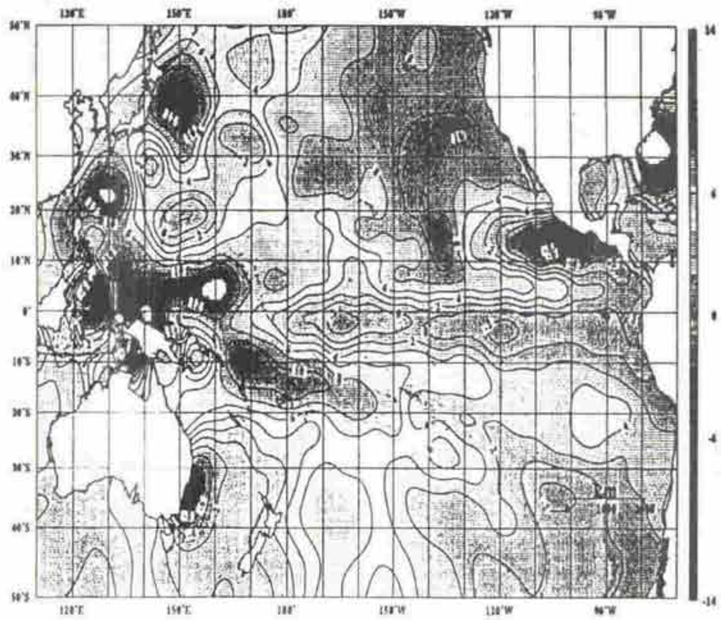


Figure 2. TP Sea Level Anomalies (cm) 08/09/95 - 08/10/95 (January 1996, National Tidal Facility)

Another gauge that responds in a similar manner is the one at Tuvalu. In fact, the satellite altimeter map figure 2 for September/October (the most recent one available at this time) reveals higher-then-normal sea levels, on the average, over a wide area of the western Pacific within 10° of the equator. The only exception is within the Solomon Sea (south of the Solomon Islands), which exhibits a completely different pattern. The sea level along the equator east of the dateline is below normal, reflecting the stronger trade winds and cooler temperatures there. Most of the sea level anomalies in the SEAFRAME data agree with the regional trends; the main exception is at the Cook Islands, where local effects appear to dominate.

Of course, the reason why all these temperature, wind, sea level, and other indices are correlated is that the ENSO occurs due to various inter-related phenomena. Unfortunately, it is unlikely that watching the Honiara sea level alone will ever provide a useful way of predicting the onset of an ENSO episode. Again referring to the Climate Anomalies figure 1, the Honiara sea level reaches a minimum slightly *after* the SOI.

This issue of the Newsletter covers most of the first half of the cyclone season. As of the midway point in the season, the Fiji Meteorological Service reports that there have been no tropical cyclones so far (other than Cyclone Barry in the Gulf of Carpentaria). It is interesting to remember that the past "hurricane season" in the North Atlantic was, in contrast, one of the worst on record. The factors that determine whether conditions will be favourable for the spawning of cyclones are just as complex and inter-related as those governing the onset of ENSO. For example, in one well-known (and remarkably successful) method for predicting the number of hurricanes in the coming season in the North Atlantic, the following factors are considered: water temperature off Africa, trade wind strength in the Atlantic, jet stream velocities, atmospheric wave activity, SOI, and rainfall in the African "Sahel" region.

Turning to the "Sea Level Residuals" figure 3 (i.e., the sea levels after removal of tides), there are several features of note:

- The Marshall Islands sea level rose by some ten centimetres over much of November. This rise can not be explained by local water temperature expansion, wind setup, or barometric pressure, as none of these varied in such a way as to lead to the sea level change at the time. It is likely to be connected to the larger scale ocean processes.
- The effects of an earthquake in Mexico were felt in the Western Samoa and Vanuatu gauges on 10 October. Details can be found in the October Monthly Bulletin.
- A short term rise in sea levels at the Cook Islands in mid-December can be ascribed to a strong low pressure system that passed over the islands at the time.

The author would like to thank Souk Douangphoumy for the plot "Sea Level Residuals" and Greg Musiela for the plot "T/P Sea Level Anomalies". *Dr J L Luick* is a Research Associate in the National Tidal Facility.

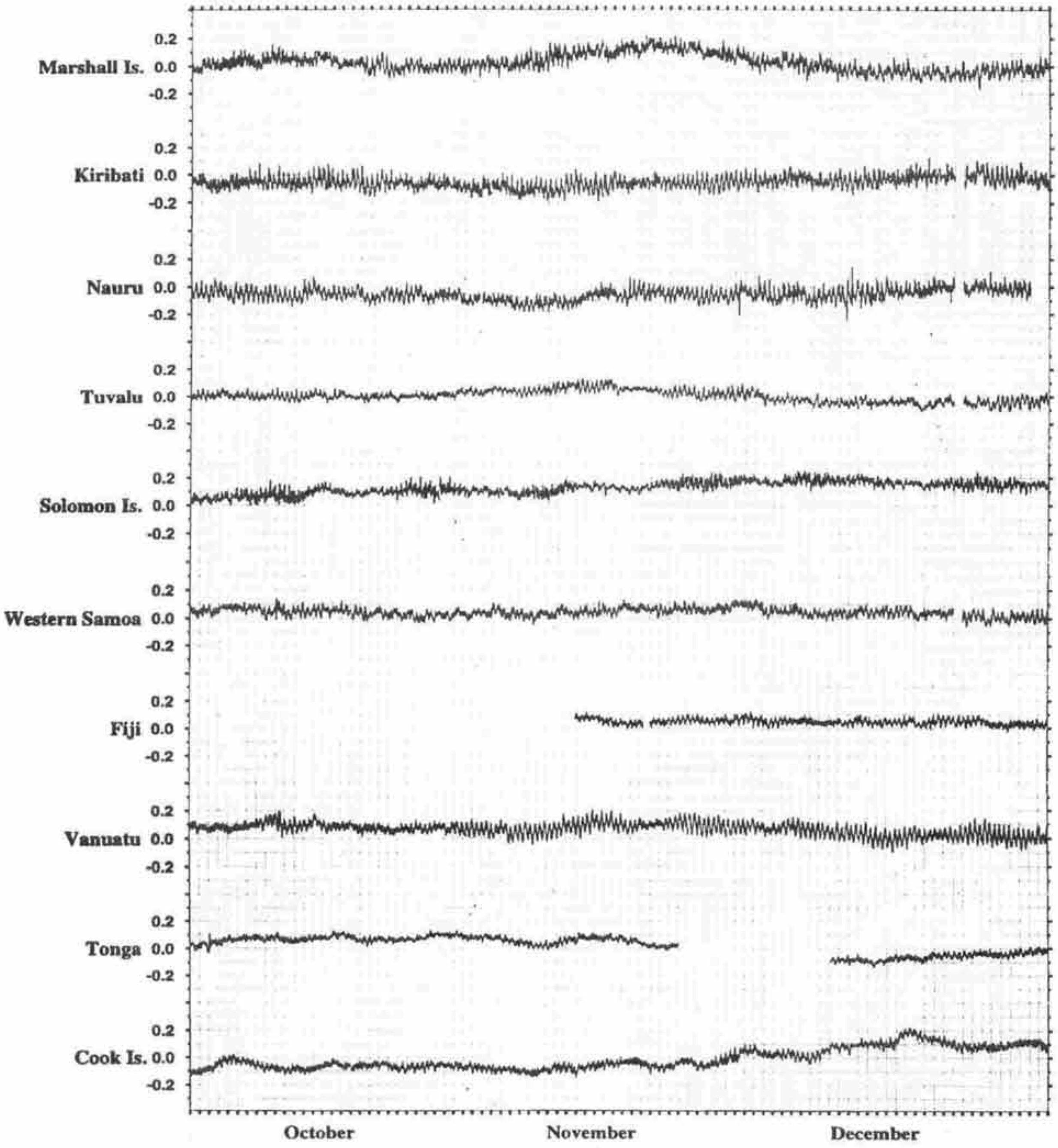
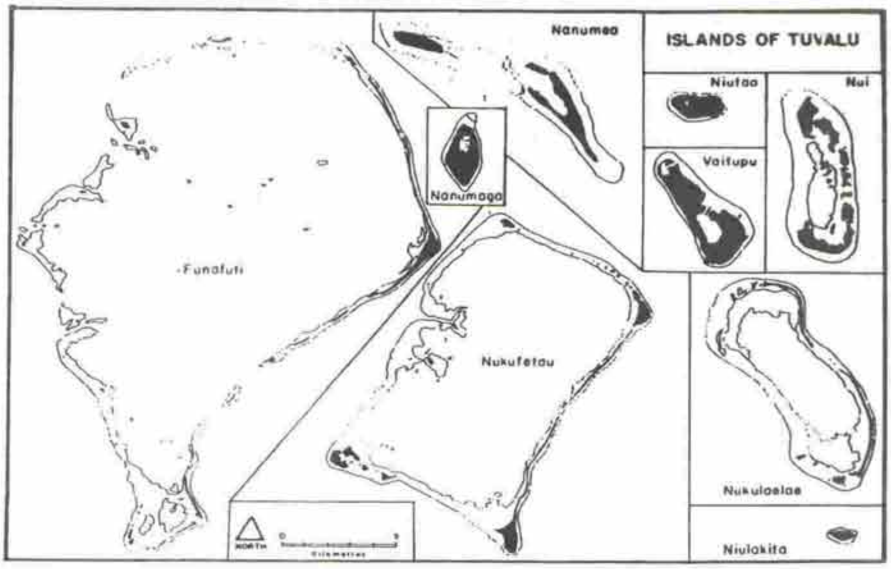


Figure 3. Sea level residuals; (observed - predicted) metres

Vulnerability assessment report for Tuvalu

C. Kaluwin



The report 'Vulnerability assessment for and response strategies to sea level rise and climate change for Tuvalu' has been completed and will be published in fall 1996. This report is one of a series of reports produced for a number of Pacific Island countries identified to be particularly vulnerable to sea level rise enhanced by climate change due to global warming where a wide range of serious impacts on the natural resources and human activities is expected.

The Tuvalu report is the result of a collaborative consultation mission to Tuvalu between November 22 and 28 1995 by two teams of experts from SPREP and the Environmental Agency of Japan (EAJ). The objective of the trip to Tuvalu was to gather natural, physical and socio-economic information from various agencies and authorities of government as well as from the general population so as to contribute to establishing national strategies for adaptation to climate change, climate variability and sea level rise through vulnerability analysis. The two specific objectives were:

(1) to assess the possible impacts of current and past climate variability as well as sea level rise on a wide range of sectors (natural and socio-economic systems) including the coastal zones, and to produce a national vulnerability profile for Tuvalu; and

(2) to study the national adaptive strategy and its major elements based on the vulnerability analysis.

A number of methodologies were employed to assess the vulnerability of Tuvalu which are outlined in the main report. Tuvalu is already sensitive to the vagaries of events associated with, or resulting from, changing climate and rising sea level. It is seriously impacted by variations in the present climate, including extreme events as the Tuvalu islands experience some of the greatest interannual variations in climatic and oceanic conditions. Strategies for adaptation to climate change and sea level rise in Tuvalu are already in place, particularly those which constitute sound environmental management, wise use of resources and appropriate responses to present day climate variability.

In trying to develop a vulnerability profile for Tuvalu through vulnerbility assessment, it was important to portray conditions that *might* be found in Tuvalu around the middle of next century, i.e. in 2050. This date is chosen because the doubling of CO_2 is expected to occur about this time, it is understandable in human terms and is consistent with other scenarios used in studies undertaken elsewhere.

A number of exposure units which will be seriously impacted by sea level risehave been identified in Tuvalu. These include population growth which may place increasing pressure on environmental resources. Currently, the population growth rate is 3.6 per cent which is considered to be fairly high. Population growth is directly linked to other exposure units like subsistence agriculture, copra production, tourism, settlement characteristics, government services, society and culture.

Climate change and sea level rise will also have serious effects on the natural systems which are already under stress from the present conditions of climate and sea level. Some of the serious impacts on the Tuvalu environment are inundation and flooding of land by extreme events; loss of good land (coastal erosion); and threats to terrestrial and coastal ecosystems as well as hydrological systems. It is of particular concern that the life-supporting qualities of thes natural systems will be reduced. Terrestrial and coastal ecosystems (including the marine area) provide resources that contribute to sustained quality of life and, in fact, the basis for livelihood in many Pacific Island countries. Most countries, including Tuvalu, rely very much on these systems and are vulnerable owing to their physiographic and ecological characteristics. However, the rate and the extent of the impacts enhanced by climate change, variability and sea level rise will not be known until further vulnerability assessments are made for Tuvalu.

Tuvalu and indeed many of the Pacific Island countries already have a number of organisations responsible for developing, managing and protecting a wide-range of structures and activities pertaining to the natural, socio-economic and cultural environment. It is this quality which needs to be encouraged and enhanced to cope with greenhouse induced climate change and consequent sea level rise in the longer term. It is hoped that the Tuvalu vulnerability assessment report helps the responsible organisations in adapting and implementing sound response strategies.

The author, *Chalapan Kaluwin*, is Climate Change Officer in SPREP and editor of the Tuvalu report.

Geodetic survey

S. M. Turner

The primary goal of the South Pacific Sea Level and Climate Monitoring Project is the establishment of a monitoring network to obtain direct and accurate measurements of the relative motion of land and sea levels in the Pacific Island Countries. The South Pacific region is a tectonically active area which makes the task of measuring sea level trends difficult. In order to separate the motions due to oceanic processes from those due to crustal processes, the vertical movements of the Earth's crust need to be determined.

An integral part of this project is a therefore geodetic survey crucial for monitoring the stability of the tide gauges and for the accurate measurements of relative land and sea level movements. Without this geodetic survey program the project's aims could not be met. The tide gauge equipment being used in this project has been designed with the special feature of datum stability and is of sufficiently high resolution to monitor sea level with respect to a deep seated tide gauge bench mark [TGBM]. This survey program monitors the vertical stability of each tide gauge in relation to the TGBMs which enables the separation of vertical crustal motions at the TGBMs from any real sea level movements.

The stability of the TGBMs also needs to be monitored. This is done by regularly surveying between an island array of deep bench marks and the TGBMs. These bench marks have been placed to satisfy the following conclusion from the report 'Geodetic Fixing of Tide Gauge Bench Marks' prepared by the Commission on Mean Sea Level and Tides for the International Association for Physical Sciences of the Ocean:

> "*All gauges to be used to monitor sea level must have a local network of several [6 to 10] bench marks that are resurveyed by sprit levelling or Global Positioning System [GPS] at least once per year.*"

Precise geodetic survey techniques including precise levelling, and Global Positioning System (GPS) observations are regularly taken at all sites within the project area. Survey staff from all countries actively participate in this survey and are being progressively trained to take over the field observations using equipment supplied by the project. All precise differential levelling and GPS equipment used in this project satisfies the requirements as set out in the report 'Standards for the Conduct of Differential Levelling and GPS Surveys'. Similarly, all field observation and data reduction procedures conform to the standards as prescribed in the same report.

The South Pacific Sea Level and Climate Monitoring Project aims to help Pacific Island Countries and their governments understand the scale and implications of changing sea levels and climate. In order to meet this objective and to evaluate realistic sea level trends, other necessary factors, such as surveying and geodesy have to be taken into account.

The author, *Mr S M Turner* is a Geodetic Expert in NTF and visited all PICs for geodetic survey.

TOPEX/POSEIDON Altimetry and the Pacific Region

G. J. Musiela

The South Pacific Sea Level and Climate Monitoring Project has been established by setting up high resolution monitoring stations in eleven island countries; carrying out a supplementary survey and geodetic programme; helping identify changes to sea levels with reference to a similar network of stations in Australia and collaborating with on-going international geodetic programmes. In order to achieve a better accuracy and more reliable sea level data set, an attempt has been made to compare the project data with the sea surface elevation data observed from satellites.

The TOPEX/POSEIDON is a French-American satellite mission which uses altimetry to make precise measurements of sea level. The mission is jointly conducted by the United States' National Aeronautics and Space Administration (NASA) and the French Space Agency, Centre National d'Etudes Spatiales (CNES), to study the global ocean circulation from space. The mission was launched on 10 August 1992 and has used the technique of satellite altimetry to make precise and accurate observations of sea level for several years. The sea surface topography data set from TOPEX/POSEIDON mission will undoubtedly help the South Pacific Sea Level and Climate Monitoring Project with the long term observation of sea level.

The purpose of this short article is to share and highlight the experience of NTF with the TOPEX/POSEIDON altimetry data processing. The TOPEX/POSEIDON satellite altimetry is complementing observations from the array of eleven Sea Level Fine Resolution Acoustic Measuring Equipment (SEAFRAME) tide gauges stations in the Pacific to investigate long term sea level variations. An attempt has been made for comparison between the two data sets. Considerable amounts of the TOPEX/POSEIDON satellite altimetry data and the demand for effective data manipulation, analysis and visualisation present interesting challenges to the NTF. In fact, an initial interpretation of the TOPEX/POSEIDON sea surface topography colour plots has been done and presented in the monthly data reports during the first phase of the project. A more systematic approach on this issue will be conducted in the future.

It is also important to realise the availability of AVISO [Archivage Validation Interprétation des données des Satellites Océanographiques] altimetry which is a multi-satellite databank dedicated to space oceanography. AVISO processes, archives and distributes TOPEX/POSEIDON merged products, i.e. the orbit files used by the Pacific Project on CD-ROM. As a sample, sea surface topography of the Pacific region for September/October 1995 is presented in Figure (2). AVISO has been developed by the French Space Agency CNES and it generates merged POPEX/POSEIDON products.

The author, *Mr G. J. Musiela* is a Computing Systems Officer in NTF; concerned with the data from the Pacific Project.

SPREP/WMO Meteorological Satellite Receiving Equipment Project in the Pacific islands

N. Koop

The World Meteorological Organization (WMO) and the South Pacific Regional Environment Programme (SPREP) are providing meteorological satellite receiving equipment in four Pacific island countries to improve their national capacity for monitoring and predicting meteorological events. The countries involved are Cook islands, Kiribati, Tonga and Western Samoa.

Background

Between 1992 and 1995, SPREP conducted 11 national studies in 10 of its member countries to determine their vulnerability to climate and climate change impacts. The inability to monitor meteorological activity in the region on a real-time basis was a consistently recurring theme among Pacific islanders involved in this vulnerability assessment process.

The frequent and severe meteorological and climatological hazards in the region, the small geographical size of the islands, and the intimate links between economic, social and environmental activity and the climate of the region, leads to a very real sense of insecurity, given the inability to monitor day-to-day weather and climate. Recent advances in modern technology means that the equipment required to provide meteorological and climatological monitoring via satellite is now available in relatively cheap, simple and robust systems.

The project

Through the working arrangement between SPREP and WMO, and using WMO Technical Cooperation Programme funds, a pilot project was developed and implemented to provide meteorological satellite systems in the Cook Islands, Kiribati, Tonga and Western Samoa. In all, five satellite monitoring systems were purchased. The first was installed at SPREP for to assess its suitability and modify the system for use in the Pacific. Four other units were then purchased for installation in the participating countries because of the good results of the initial phase .

To ensure installation is conducted efficiently and effectively, SPREP undertook to visit the countries involved with technical and meteorological specialists. It was recognised that, as the Regional Specialised Meteorological Centre (RSMC) for tropical cyclones, the Fiji Meteorological Service should be utilised to reinforce its responsibility as tropical cyclone warning centre. The cooperation of the Fiji Meteorological Service in this project has been important in the success of the project to date, and will continue to be so for the future of the project.

Systems have been successfully installed in all four countries (Western Samoa July 1995, Cook Islands August 1995, Tonga August 1995 and Kiribati December 1995). Significantly the first three of these countries are all new members of WMO.

The installation phase has included training of local staff in the management, operation and maintenance of the system, and satellite image interpretation. The skills of meteorological staff in the Pacific are limited, and vary significantly from country to country In November 1995 the first satellite interpretation training workshop for countries involved in this workshop was convened in Apia. 12 participants from the 4 countries attended the one-week course, which was conducted by Mr Graeme Kingston, lecturer at the Australian Bureau of Meteorology Training College. It is recognised that further ongoing training will be necessary, and a further training workshop is being planned for later in 1996.

The system

A commercial software system developed by the Quorum company in Texas, USA, is used for this project. The Quorum "Explorer" card has been available for less than 12 months. It has a number of significant benefits over the many others considered in the feasibility study. They are:

- The system is widely used by the US Military. and is thus well supported with a high likelihood of continued development.
- As it is used by the military, it is one of only a few systems universally adaptable to all geostationary and polar orbiting satellites.
- It is considerably cheaper than any other system offering compatible services.
- The developers have offered, and demonstrated, considerable interest in supporting the systems in the Pacific. Indeed they have responded to over 50 requests for software changes, usually within 24 hours, and have pledged to support software development peculiar to the region.

The system operates on a 486 or Pentium PC with 10 MB of RAM. A parabolic mesh antenna is provided for geostationary satellite reception, with a quadrifilar antenna for polar orbiters. The system can receive Wefax and APT transmission, with auto capture and archival. Up to 24 pictures can be sequenced in animation, and over 300 images can be kept on hard disk at any time. Colour palettes for picture enhancement come with the system, and there is the capability of customising new palettes for individual use. On APT images it is possible to navigate a cursor to locate latitude and longitude, as well as bearing and distance from a known reference point, of cloud features. A simple menu system with pull-down tables ensures ease of operation.

The system comes with a fax-modem which allows access to international time services to keep the computer clock sufficiently accurate to grid polar orbiter images. The fax-modem also allows for images to be sent by fax if necessary, and has the added feature of allowing remote use from SPREP to assist in maintenance and servicing of software. An uninterruptable power supply provides up to three hours of operation in the event of power failure. An operators' manual has been developed for the region by Quorum in consultation with SPREP and its consultants.

Future activities

Future training workshops will focus on the use of the system for the public and media. It is possible to transfer images via floppy disk to generate images suitable for print and electronic media including television. This is recognised as a very important aspect of the project, and once the systems are well established SPREP will assist users to liaise with the media, schools and community groups to ensure the information is used to educate and inform the wider public.

The early success of the system has come to the attention of other meteorological services in the region, and SPREP has received a number of requests for similar systems from other countries in the region. Now that the pilot phase for this project has successfully concluded we hope to be able to provide similar systems to other countries in the Pacific.

A fifth system for the region is soon to be installed at the Headquarters of the Solomon Island Meteorological Service in Honiara. This system has already been purchased by SPREP under a project between the Australian IDNDR Secretariat and Solomon Island Meteorological Service. SPREP is also cooperating with WMO to prepare Voluntary Cooperation Programme (VCP) requests for the Federated States of Micronesia, Niue, Papua New Guinea and Vanuatu for similar systems. Fiji is purchasing this system also as part of its headquarters upgrade project.

Conclusion

The satellite monitoring systems provided for the Pacific Island countries through this project have been successfully installed in four participating countries to much acclaim from local meteorological staff, government and the public. It is an excellent demonstration of the many benefits that evolve from the working arrangements between SPREP and WMO. As well as providing security and information, the project has left a lasting impression of both SPREP and WMO. In the commissioning demonstrations, the involvement of WMO was emphasised, which is important given that three countries involved are new members of the organisation.

Acknowledgements

As well as the valuable assistance of WMO, in particular the Regional Office for Asia and the South West Pacific and the Technical Cooperation Programme, SPREP is grateful for the generous support of the Fiji Meteorological Service, the Australian Bureau of Meteorology and the New Zealand Meteorological Service for this project.

The author, *Neville Koop*, works as Climatology and Meteorology Officer for SPREP.

COMING EVENT

Curriculum writing workshop on climate and climate change

C. Kaluwin

From 3–14 June 1996, a regional workshop on curriculum writing on climate and climate change will be held Apia, Western Samoa. It is coordinated by the South Pacific Region Environment Programme (SPREP) in collaboration with the National Tidal Facility (NTF), Flinders University, Schools of the Pacific Rainfall Climate Experiment (SPaRCE) and Atmospheric Radiation Mesurement (ARM) Projects from USA.

This workshop is the second part of a three-phase regional curriculum development project on climate change for use by schools and other agencies in the Pacific region. The three phases are as follows:

1. development of a 'Teachers curriculum framework manual on climate and climate change';
2. regional workshop to review the framework, revise the overall plan and to write draft curriculum modules and activities; and
3. in-country modification and refinements of the modules for national use.

The need for a curriculum on climate change

While it is well known that the Pacific region with its vast waters surrounding the Island states is extremely vulnerable to climate and sea level changes, very little information on this subject is available for use in schools. A variety of projects related to climate and environmental studies have been implemented in the region and currently yield sound scientific information. However, this information does usually not reach a broader public even though impacts of climate on the environment and effects of climate change are certainly of great interest and, in fact, of increasing concern not only for scientists. Therefore, a need exists to translate scientific knowledge into understandable and attractive teaching material that facilitates including the topic of climate and climate change into school curricula.

Goals of the workshop

It is intended that the workshop will bring together curriculum experts and authors from thirteen Pacific countries who will:

(a) review the 'Teachers curriculum framework manual on climate and climate change'; and
(b) write draft curriculum modules on the seven areas 'Atmosphere', 'Climate', 'Water,' 'Ocean', 'Economic and environmental policy', 'Biosphere' and 'Coastal processes'.

Participants

Participants are invited by SPREP from the following countries of the Pacific Region: Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Papua New Guinea, Solomon Islands, Tonga, Tuvalu, Vanuatu, and Western Samoa. Participants should all be practising curriculum writers in their countries.

Outputs:

At the end of the workshop, the expected products will be a draft 'Climate change education teachers manual' including seven teaching modules that will be circulated to the governments for testing and trailing before the documents are finalised. This process may take up to 2 years before the final product is agreed.

The author, *Chalapan Kaluwin*, is editor of the Quarterly Newsletter and Climate Change Officer for SPREP.

EDUCATION

Danger in small doses

T. H. Aung

When a frog jumps into a pan of hot water, it will feel the intense heat and will jump right out of the pan. Frogs can only live in cool water, and just as any other animal or human beings, they know that too much heat is dangerous for them. But what happens when a frog sits in a pan of cool water which is heated slowly? The story goes that it will just sit there. The frog will remain there as the water gets warmer and warmer. It does not sense any danger because the water temperature only changes very slowly and in small amounts. Finally, when the water boils, the frog will still be sitting there, having boiled to death.

Like frogs, we human beings do not sense the danger of small temperature changes. In fact, our 'pan of water', planet Earth, is slowly heating up at this very moment. Scientists say that this is not a natural phenomenon, but caused by humans. We can see that our factories and cars blow fumes into the air we breathe, the so-called "atmosphere". Normally, the Earth's atmosphere is like a house with open windows: when the sun shines, it heats up a little bit inside, but most of the heat can escape through the windows to the outside. The same is true for the Earth which is heated up during daytime when the sun shines, but cools down at night time when the heat escapes into space.

However, when the atmosphere is full of fumes, it is like someone closing the windows of the house. The heat becomes trapped inside and temperature rises. We call this the 'greenhouse effect', because in greenhouses the windows are permanently shut. For the same reason, the fumes which cause the Earth to heat up are called 'greenhouse gases'. Climate scientists from all over the world say that the greenhouse effect can already be felt on Earth as temperatures are increasing and are likely to pose a threat to humans, animals and plants.

One of the first consequences of higher temperatures on Earth is that frog communities are in decline. Frogs have been living in moist, cool conditions on Earth for approximately 200 million years. Now that the greenhouse effect brings about a warmer and drier climate, frogs seem to be disappearing from almost every continent, and may even become extinct. Climate scientist say that humans are threatened as well because warmer temperatures on Earth will cause droughts and more difficult conditions for agriculture as well as stronger winds such as the cyclones Val and Ofa that the Pacific region experienced in the past years. Also, the ice of the Arctic and Antarctica will slowly start melting, and if all 23 million cubic kilometres of ice in the world melted, sea level would rise by about 180 ft or 55 m. This is higher than most church towers, and enough to submerge many of the Pacific countries.

But since we know that rising temperatures threaten all plants, animals and humans on Earth, why is it that too little action has been taken to prevent the danger of global warming? The reason is the same as in the story of the frog. We do not sense any urgency because the Earth's temperature is changing very slowly and it may take hundreds or even thousands of years until it is too hot and dangerous for us. If we behave like the frog in the story, we will not realize the danger until it is too late.

However, climate scientists can measure the slow increase in greenhouse gases and the rise in temperature on Earth with their sophisticated equipment. This is the aim of the South Pacific Sea Level and Climate Monitoring Project which will help us make better judgements about the real threat of global warming and the consequences of rising sea levels. Whilst climate scientists remind us that danger comes in small doses, it is up to all of us to reduce the the amount of greenhouse gases which cause global warming.

Further Reading: Emerging Impacts of Climate Change? GREENPEACE, Greenpeace International, Keizersgracht 176, 1016 Amsterdam [June 1993]

Simple experiments on sea level change

T. H. Aung

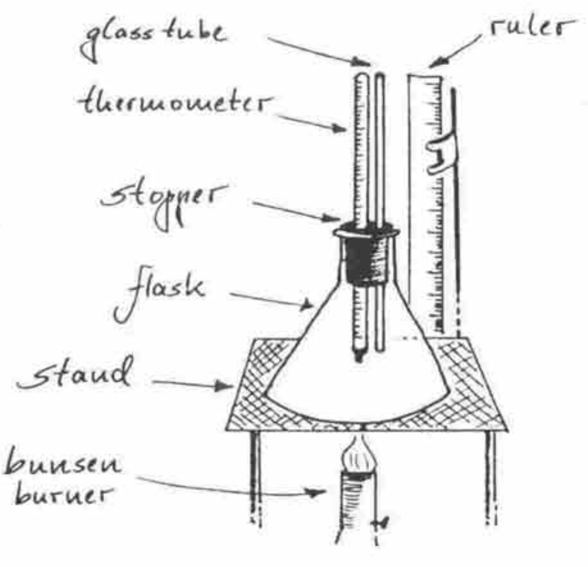
In the above article we explained how greenhouse gases cause warming of the Earth's atmosphere. This heat will be passed on to the water on top of the oceans (the 'upper layers') which will expand and increase their volume. The volume is the space that a certain object takes up; for example, the space inside a one litre bottle of spring water is exactly the volume of one litre of water.

Most gases like air, fluids such as water, and solids like iron expand and increase their volume when heated. Try this: Go into a cool room or wait until a cool period such as night time, and blow air into a balloon until it nearly explodes. At noon, place the balloon in direct sunlight and wait a while. As the sun-rays heat up the air inside the balloon its volume will increase and it will eventually explode. The same phenomenon takes place in the upper layers of the ocean: when global warming causes them to heat up, they expand. It is this thermal expansion of the ocean water which makes the sea level rise.

Activity 1. As the atmosphere traps more heat, the oceans will warm. Water expands when heated.
What you need: 500ml conical flask, two-hole stopper, hollow glass tube, thermometer, ruler, stand with gauze mat, bunsen burner.

What to do: Fill the flask to the top with water. Place the hollow glass tube and thermometer in the stopper and gently press the stopper into the flask. Mount the ruler so that the water level in the glass tube can be measured. Record the temperature and water level. Heat the water slowly and record the water level at 2 C intervals.

Plot your results on graph paper.

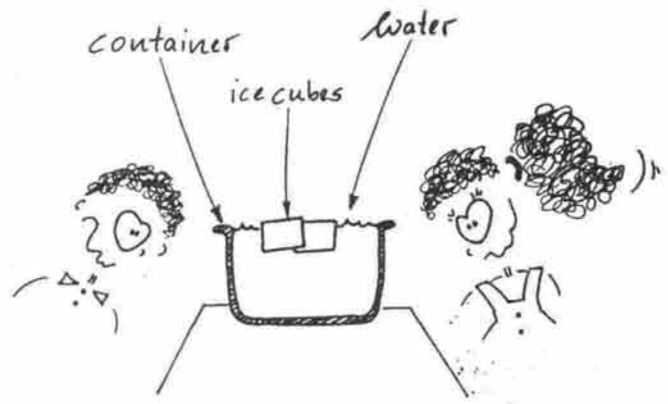


As global warming heats up the upper layers of the ocean, it will also cause the melting of the large amounts of ice that float in the water near Arctic and Antarctica. We may think that, with the melting of these icebergs, even more water will enter the oceans and cause an additional rise in sea level. However, it is true that floating ice in the ocean does not raise the sea level when it melts.

Activity 2. Floating ice does not raise the sea level when it melts.
What you need: Container, ice cubes, water.

What to do: Place the ice cubes in the container. Gently fill the container with water until it is almost overflowing. Watch the water level as the ice melts.

Try to answer the following questions:
(1) Did the water overflow?
(2) Do you think melting icebergs will make the sea level rise?

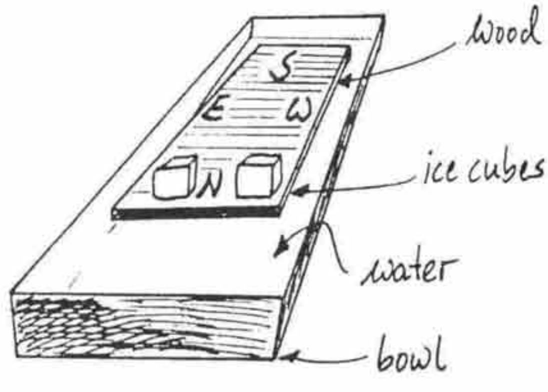


The Arctic and Antartica are covered with large, heavy sheets of ice. Other continents like New Zealand have ice masses in the form of glaciers on them. What happens if this ice on land masses melts and more water flows into the ocean because of global warming? And what happens to the continents which are floating on the Earth's molten core when they are relieved of their heavy burden of ice?

Activity 3. When land-based ice melts, sea level rises. However, the land on which the ice used to be rises, too.

What you need: Bowl, piece of wood (15cm x 15cm), water, ice.

What to do: On the surface of the wood mark the points of the compass N.S.E.W. From N to S across the surface draw lines at 1cm intervals. Fill a bowl with water and place the wood in the water. Put 1 or 2 blocks of ice on the N edge of the wood. Note the level of water in the bowl and on the N and S edges.



Try to answer the following questions:
(1) What happens to the water level in the bowl?
(2) What happens to the N and the S edge of the block of wood as the ice melts?
(3) Do you think melting glaciers and land-based ice masses will make sea level rise? Will it submerge the continents on which the ice used to be?

To observe changes in sea level, scientists regularly measure the sea level at certain places. If they want to predict what will happen to sea level in the future, say at a particular beach, they look at the past trends: Has sea level at this beach been rising or falling over the past years? Has the beach sand been eroded by rising sea level or accumulated because of falling sea level?

Activity 4. Close study over long periods of time is needed to determine if sea levels are moving or erosion is taking place.

What to do: The information in the table below shows a study of estimated volume of sand on a part of the beach at Lefaga, Western Samoa.

Year	1972	1973	1974	1975	1976
Sand (cubic metres)	268	331	192	394	201
Year	1977	1978	1979	1980	1981
Sand (cubic metres)	185	286	252	323	351
Year	1982	1983	1984	1985	1986
Sand (cubic metres)	364	385	343	349	377

Plot the figures on graph paper, time in years on the horizontal axis and the volume of sand on the vertical axis.

With your graph, try to answer the following questions:
(1) Which years showed erosion and which years showed deposition?
(2) Can you predict what will happen to the beach over a long period of time (say 50 years) from these data?

Activity 5. In the past the sea level has not always been the same.
What to do: The information in the table on the right shows the sea level for the last 250 000 years as recorded by Thorium/Uranium dating of coral reefs off Papua New Guinea.

Thousand years before present	Metres below present sea level
0	0
10	23
20	119
30	54
40	44
50	72
60	55
70	71
80	22
90	59
100	20
110	48
120	27
130	5
140	16
150	123
160	111
170	30
180	57
190	87
200	46
210	32
220	7
230	25
240	12
250	32

Plot on graph paper, time on the horizontal axis (starting at 250 000 before present) and depth on the vertical axis (down from the horizontal).
Try to answer the following question:
(1) How does the present-day sea level compare with that of the recent past?

Further reading: Morris, B, T. Sadler and W. Bouma (1990) *The Greenhouse Effect: Exploring the Theory*, CSIRO Publications, Distributed by Science Press, 314 Albert Street, East Melbourne, VIC 3002, Australia.

The author, *Dr T H Aung* is the Training Officer of the South Pacific Sea Level and Climate Monitoring Project working at NTF.

BOOK REVIEW

Climatic change and the Mediterranean

L. Dosung

The book 'Climatic change and the Mediterranean: Environmental and societal impacts of climate change and sea level rise in the Mediterranean region', edited by L. Jeftic, S. Keckes and J. C. Pernetta, has recently been published by the United Nations Environment Programme (UNEP). It is the second volume in a series of books recording the results of studies on the impact of climate change on the ecological systems and socioeconomic structures of the Mediterranean. These comprehensible studies are well presented for a broad audience interested in a global view on climate change.

The book takes a regional perspective on likely impacts of climatic change on marine and coastal ecosystems within the Meditteranean. As part of the UNEP-sponsored Regional Seas Programme, a Mediterranean Task Team was set up comprising several national multidisciplinary teams. These teams conducted regional site-specific case studies in such different natural systems as river deltas, lakes, gulfs, bays, islands and the mainlands' coastline. Among those countries covered were France, Italy, Greece, Croatia, Egypt, Syria and Malta where the national teams worked under the guidance of UNEP and with the appropriate national authorities.

The Mediterranean Task Team is one out of eleven task teams established worldwide, two of which are concerned with the South and the South-West Pacific region. All task teams are to conduct regional studies on the following nine selected topics:

- climate and precipitation;
- sea level;
- hydrological and water resources;
- land degradation;
- socioeconomic activities
- vegetation and land-use;
- oceanographic characteristics;
- archaeological and historical heritage; and
- coastal lowlands.

The scope of the Mediterranean case studies was to:

- identify and assess possible implications of expected climate change on ecosystems, population and economic activities;
- identify areas most vulnerable to climate change; and to
- suggest policies and measures that may reduce negative effects of the expected changes.

Likely effects of climatic change on eleven vulnerable sites along the Mediterranean coastline and available options to avoid, mitigate or adapt to these to these foreseeable impacts are presented in the book as is a comparative analysis of the main findings, conclusions, and recommendations of the completed case studies. Regional and site-specific climate scenarios and the methodoiogy used for the analysis of impacts are described, and general conclusions are drawn about the climatic changes within the Mediterranean region as a whole.

L. Jefti'c, S. Keckes and J. C. Pernetta (eds.)
Climatic change and the Mediterranean: Environmental and societal impacts of climate change and sea level rise in the Mediterranean region, volume 2. - London:
UNEP, 1996. xi + 564p. ISBN: 0340645652

The author, *Lucas Dosung*, works as Library and Information Centre Coordinator for SPREP.

CLIMATE CHANGE CALENDAR

17 – 21 April 1996
Coast to Coast '96 (climate change impacts on coastal areas)
Adelaide, South Australia
Contact: Coast to Coast '96 Secretariat
Sapro Marketing
PO Box 8253
Hindley Street
Adelaide SA 5000
Phone: (08) 212 7555
Fax: (08) 212 7148

29 April – 3 May 1996
The Science and Impacts of Climate Change in the Pacific Islands
Apia, Western Samoa.
Organised by the South Pacific Regional Environment Programme SPREP
Contact: Neville Koop
SPREP
PO Box 240
Phone: (685) 21929
Fax: (685) 20231
email: sprep@pactok.peg.apc.org

17 - 22 June 1996
'PACON 96'—The Seventh Pacific Congress on Marine Science and Technology
Honolulu, Hawaii, USA.
Contact: PACON International
PO Box 11568
Honolulu, HI 96828, USA
Phone: (808) 956 6163
Fax: (808) 956 2580
email: pacon@wiliki.eng.hawaii.edu.

8 - 19 July 1996
UN Framework Convention on Climate Change
Geneva
Conference of the Parties 2, including:
Ad Hoc Group on the Berlin Mandate, fourth session
Subsidiary Body for Scientific and Technological Advice, third session
Subsidiary Body for Implementation, third session
Ad Hoc Group on Article 13, second session

7-17 October 1996
World Meteorological Organisation (WMO) RA-V
Tropical Cyclone Committee, Sixth Session and Fourth SPREP Meeting of Regional Meteorological Service Directors.
Honolulu, Hawaii.
Contact: Neville Koop, SPREP
(address: see above)

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