National Tidal Facility

South Pacific Regional
Environment Programme

The South Pacific Sea Level and Climate Change Newsletter

Quarterly Newsletter Vol. 1, No. 4, July 1996

Project Update

During the last twelve months of the South Pacific Sea Level and Climate Monitoring Project (Phase II), twelve regular Monthly Data Reports (Vol. II, Nos. 1-12) were issued to disseminate information on the development of the project and the status of acquired data. In the new format of the Monthly Data Report for Phase II, only time-series plots of data for the current month with brief notes and comments on operational performance and special events, together with progress reports on the project's development during the month, are included.

The *Proceedings of the Ocean and Atmosphere Pacific International Conference,* from the conference held in October 1995 in Adelaide for the achievements of the first phase of the project, have been distributed. A copy of the 417-page proceedings has been sent to all conference participants. Those interested in obtaining a copy of the proceedings are requested to contact SPREP or NTF. The proceedings report focuses mostly on science studies with a few papers devoted to the impacts and policy responses.

As stated in previous issues, the project aims to help create awareness and understanding in Pacific Island Countries (PICs) and their governments of the scale and implications of changing sea levels and climate. Efforts are being made to introduce atmospheric and marine science curricula to the primary, secondary and tertiary level for all PICs, and as part of the programme approved by the Panel on Climate Change (PCC) meeting, from the second year of Phase II (starting from July 1996), there will be several short-term attachments at the National Tidal Facility to train PIC personnel. The first course has been tentatively set for 18 November to 13 December 1996. A total of 13 candidates from 13 Forum member countries will be invited to participate. Based on the requirements of the PICs, 14 specialised courses have been carefully structured. The first-round courses will focus on:

1 Instrumentation
2 Surveying and Geodesy
3 NTF Information System
4 Data Management
5 Tides and Tidal Data Analysis
6 Integrated Coastal Zone Management (ICZM)
7 Bio-assessments in the Tropics

To run the courses effectively, entry requirements and pre-requisites will be applied. More information on the short-term attachment programme and the detail of the courses is available from NTF and SPREP. The duration of the courses will vary from two to four weeks depending on the subject chosen and in this respect, Pacific personnel are requested to take a minimum of three courses at this time. NTF, SPREP and USP (University of the South Pacific) academics together with

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Published by the South Pacific Regional Environment Programme (SPREP) and the National Tidal Facility (NTF)
with financial assistance from AusAID

NTF general staff will run the courses. Although a few official nominees have been received, a formal letter of invitation has been sent out from SPREP to Forum island governments. All interested people from PICs are strongly encouraged to contact us through their governments for the short-term attachment programme at NTF.

SPREP coordinated and liaised with NTF, Atmospheric Radiation Measurement (ARM), Western Samoa Teachers College and Schools of the Pacific Rainfall Climate Experiment (SPaRCE) to conduct a two-week workshop, Curriculum Development on Climate and Climate Change, held from 4 to 14 June 1996 in Apia, Western Samoa. There were 14 participants from 11 PICs who took part in the workshop along with the six-member resource team from SPREP, NTF, Western Samoa Teachers College and SPaRCE. The workshop is another special activity of the Information and Training Component of the South Pacific Sea Level and Climate Monitoring Project.

The opening ceremony, which was attended by the Minister of Education from Western Samoa, Acting Director of SPREP, and a high-ranking official from the Australian High Commission, also received extensive media coverage.

The actual workshop programme and framework for the Curriculum Modules were conducted by SPREP's Environmental Education Officer, Mrs Gisa Gaufa-Uesele and the Principal of Western Samoa Teachers College, Mrs Tili Afamasaga. They were supported by the resource team for science which included Dr C. Kaluwin of SPREP, Dr T. Aung of NTF and Drs M. Morrissey and S. Postawko of SPaRCE.

Approximately 80 per cent of the financial support was provided by AusAID, through the South Pacific Sea Level and Climate Monitoring Project, with the remaining 20 per cent provided by the ARM Program.

All participants were from the education sector of the region and suitable candidates to achieve the aims of the workshop. As a result the workshop was a great success.

The outcomes of the workshop are substantial. Drafts of eight Curriculum Modules on Climate and Climate Change for teachers were produced during the two-week period, mainly targeting the upper primary and lower secondary level of schools in the Pacific.

Contained in this issue of the newsletter is data interpretation of regional sea level and climate change, together with other related issues. There is a section on Integrated Coastal Zone Management (ICZM) which will discuss why we need to plan for climate change and sea level rise. Also included is a special section, called *Children's Education*, written especially for children. The *Quarterly Newsletter* has been found to have a wider audience and readership than the Monthly Data Report, and therefore may be utilised as a tool to increase information dissemination in the Pacific region regarding climate change and sea level rise issues.

Project Reports

Notable Features of Sea Level Data during this Quarter

Dr T. H. Aung

*The author **Dr T. H. Aung** is the Training Officer of the South Pacific Sea Level and Climate Monitoring Project based at the National Tidal Facility.*

Conventional tide gauges are suitable for monitoring changes to sea level due to storm surges, tsunamis and other natural hazards. However, more sophisticated instruments are necessary to measure the long-term sea level trends and other climate factors. This is especially true if one needs to look at the very small and gradual changes which some scientists predict are results of enhanced greenhouse effect and global warming. These instruments must be very sensitive, accurate and stable.

Monitoring sea level change in the Pacific region and globally requires an understanding of several related problems. Three of the most important factors affecting sea level are outlined below:

1 vertical land movement due to movements in the earth's crust;

2 warming or cooling of ocean water; and

3 adding or removing water due to changes in land-based glaciers and the Antarctic and Greenland ice caps.

Since its commencement, the South Pacific Sea Level and Climate Monitoring Project has been measuring some oceanographic and meteorological parameters such as sea level, water temperature, atmospheric pressure, wind speed, direction and gust, and water temperature. Sea level is a measurable quantity and is the result of all influences which affect the height of the sea surface (moon and sun for daily tides, atmospheric pressure, winds, seismic activity etc.). Tides are only part of the sea level and are related in frequency, amplitude and phase to astronomical forcing. The common terminology, *residual*, is equal to "*sea level minus tides*". The residual is part of the observed change in the sea level which is not due to tides. It is due to meteorological effects, seismic activity and other influences generated locally or perhaps many thousands of kilometres away, e.g. tsunamis.

The depression of the water surface under high atmospheric pressure and its elevation under low atmospheric pressure are often described as the *inverted barometer* effect. Usually, a change of barometric pressure by 1 hPa may cause ~1 cm variation in sea level. The effect of wind stress (*stress* is like *pressure*, force acting on a unit area) on sea level is highly variable and is largely dependent on the topography of the area. The effect of wind stress at the surface is transmitted downwards as a result of internal friction within the upper layer of water. Generally, wind will raise the sea level in the direction normal to the wind direction depending upon the duration of the wind. If we consider the upper 50 m of the ocean, a change of water temperature by 1°C may cause ~1 cm variation in sea level due to thermal expansion.

Accordingly, whenever we find unusual sea level residual trend or significant spikes in residuals of our monthly data, we need to look at the causes and scientific reasons to justify why it happens. Strong winds, high or low atmospheric pressure and water temperature are the usual causes in this respect. Detailed treatment of these causes is presented in the Monthly Data Report. In this quarter, we highlight another phenomenon which may affect sea level—earthquakes.

There were two significant earthquakes in the Pacific Ocean in June 1996 and their details are given in the following table (the magnitude is measured on the Richter Scale).

Date	Time [UTC]	Lat.	Long.	Strength	Vicinity
10 June	0403	51.7°N	178.7°W	7.7	Alaska
11 June	1823	13°N	125°E	6.9	Samar, Philippines

As an example, when we look at the sea level observations (residuals) at Vanuatu SEAFRAME station in Figure 1, it is found that significant signals were observed at ~1400 hours because of the tsunami generated by the earthquake. The speed of the tsunami can be calculated using the formula, $v = [gh]^{1/2}$, where h is depth and g is acceleration due to gravity. Referring to the Tsunami Travel Time Chart, from the epicentre the tsunami would take approximately 10 hours to reach Vanuatu. Therefore it is reasonable to infer that our calculations of tsunami travel time are correct based on the observed signals at Vanuatu. Another significant sea level signal on 11 June at ~2000 hours may be due to another

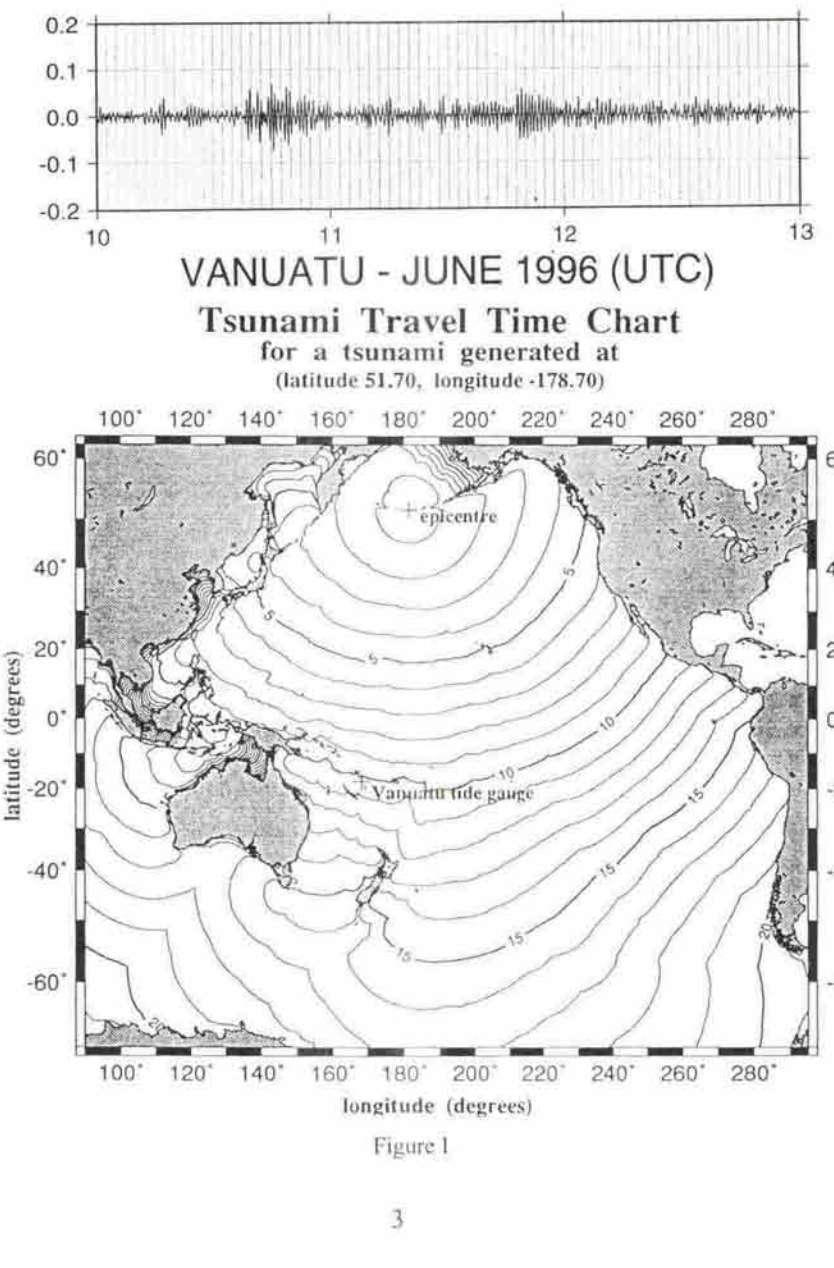

Figure 1

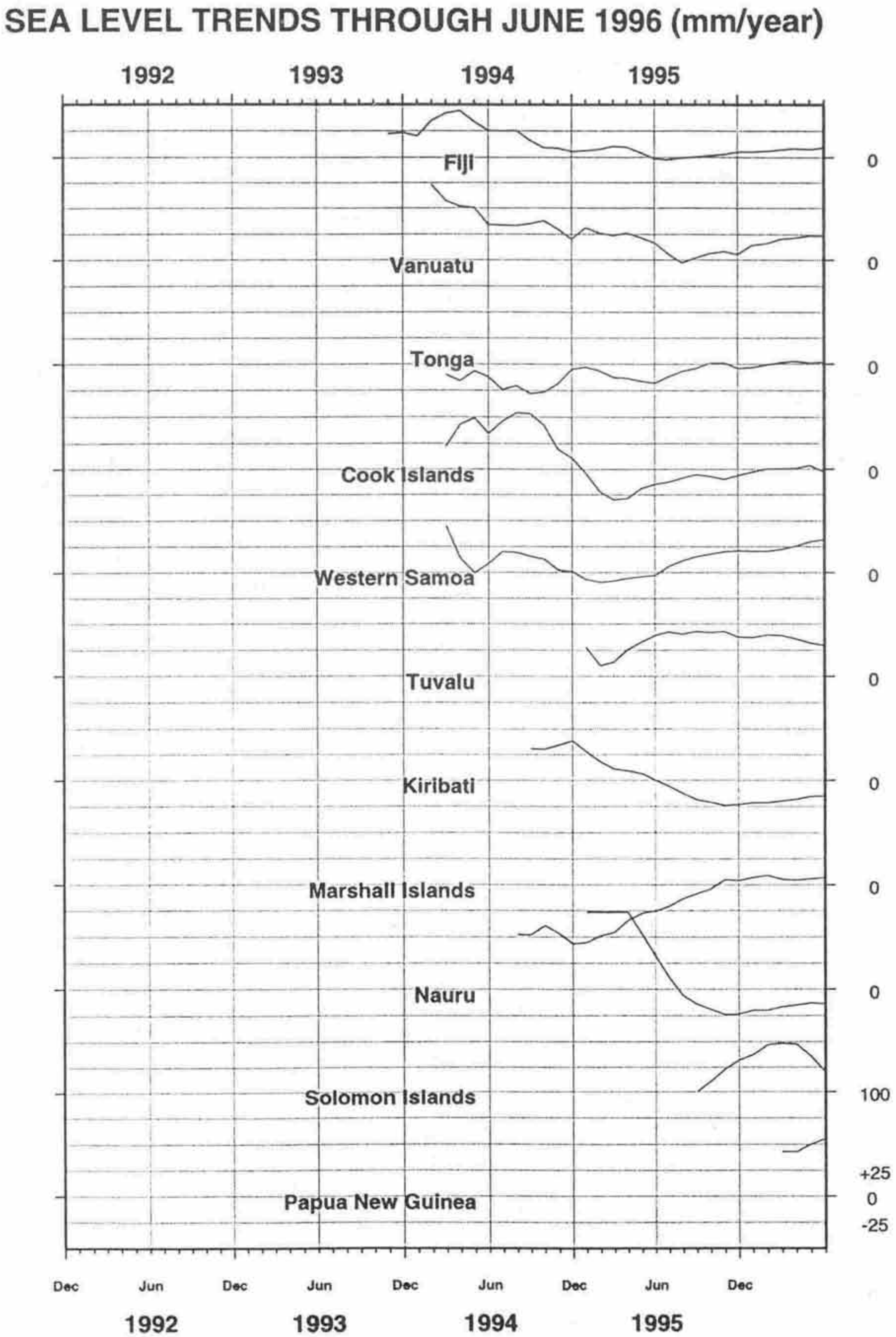
SEA LEVEL TRENDS THROUGH JUNE 1996 (mm/year)
1992
1993
1994
1995
Fiji
0
Vanuatu
0
Tonga
0
Cook Islands
0
Western Samoa
0
Tuvalu
0
Kiribati
0
Marshall Islands
0
Nauru
0
Solomon Islands
100
Papua New Guinea
+25
0
-25
Dec
Jun
Dec
Jun
Dec
Jun
Dec
Jun
Dec
1992
1993
1994
1995

Figure 2

earthquake that occurred at Samar, Philippines, although no significant tsunami was generated from that event.

The monthly variations in mean sea level do not necessarily repeat themselves exactly from month to month or year to year. Variations in mean sea level over short periods may be considerably greater but do not reflect the long-term sea level trends. In addition, oceanographic effects such as El Niño Southern Oscillation (ENSO) can produce large-scale variations in mean sea level of up to ~50 cm.

Relative sea level trends (mm per year) at individual stations from their starting date to the present are depicted in Figure 2 as a new feature following recommendations from the recent PCC meeting. The values are calculated based on the statistical methods utilised by each individual station. It is noted that the observed trends in sea level include natural variability events such as El Niño and effects due to several other atmospheric, oceanographic and geological processes. The station at PNG was recommissioned on 8 March 1996 and the length of the sea level data set is not long enough to calculate the trends. Longer term data sets for all stations are necessary to identify the effects of different signals.

Numerical Modelling: Macquarie Island

Dr R. F. Henry

*The author **Dr R. F. Henry** is the Head of Research at the National Tidal Facility and the Research Scientist for the South Pacific Sea Level and Climate Monitoring Project.*

A finite element model has been adapted to investigate diurnal and semidiurnal tides around Macquarie Island. The island lies on a submarine ridge, with the result that water depths are relatively shallow for substantial distances north and south of the island, but reach abyssal depths a few kilometres east and west of the ridge.

Fairly accurate estimates of the amplitudes and phases for the diurnal tidal constituents K_1, O_1, P_1 and K_1 and semidiurnal constituents M_2, S_2, N_2 and K_2 have been derived recently from Topex/Poseidon satellite observations and are readily available from various sources. Due to the low spatial resolution used in the calculations, these estimates are not reliable near land, but provide sufficiently accurate outer boundary conditions for numerical tidal models such as that developed for Macquarie Island.

Model results show that semidiurnal and diurnal tides behave quite differently in the vicinity of Macquarie Island. Figure 3(a) shows that the amplitude of M_2, the largest semidiurnal tidal constituent, is influenced only slightly by the presence of the ridge, whereas K_1, which is typical of the diurnal constituents, is substantially affected. From Figure 3(b) it can be seen that at locations on the ridge some distance north and south of the island, K_1 experiences greater amplitude amplification than in the shallow water around the island. This contrasts with the usual finding that amplitudes generally decrease with distance from islands.

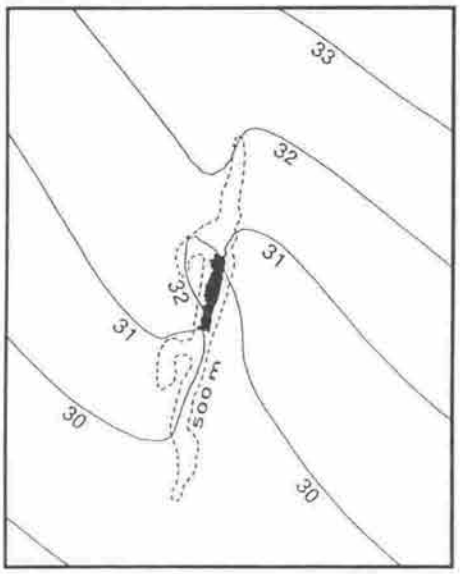

Figure 3(a): Computed amplitude of M_2 at Macquarie Island (cm)

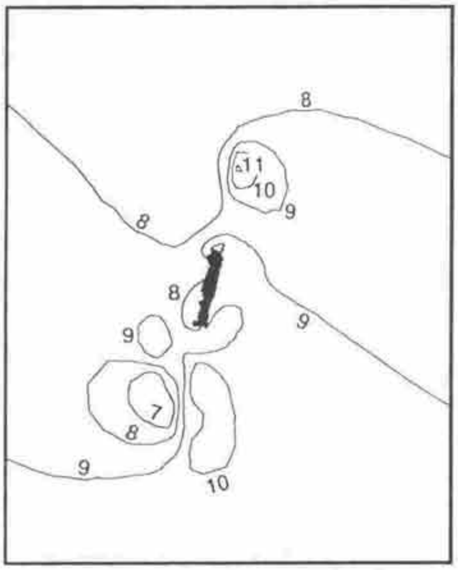

Figure 3(b): Computed amplitude of K_1 at Macquarie Island (cm)

These results will be reported in greater detail in the Proceedings of the Third Workshop on the Southern Ocean Sea Level Network.

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Some Reliable Seismic Precursors

A. V. Bapat

Periodic occurrences of destructive earthquakes force intellectuals into deep states of contemplation and pondering, with the general feeling amongst these people that something should be done to avoid the loss of life and property. Despite the large number of seismological, geological and geophysical measurements being taken round the clock in many parts of the world, no useful forewarning of an impending earthquake could be issued.

Immediately after the occurrence of any destructive earthquake, a sizeable number of seismologists claim that the "earthquake was expected", "... it was due ...", etc., but such claims do not help reduce the human misery of the post-seismic periods.

In fact, outlined below are five reliable premonitory seismic precursors, which are highly predominant about ten to thirty hours before the occurrence of any medium to large earthquake. Moreover, these can be seen and observed by the general public without the aid of any scientific instrument or formal specialised education in seismology.

Water Precursor

About 10 to 30 hours before the occurrence of any medium to large earthquake, some reliable water precursors are observed.

1 The discharge in the river or rivulet suddenly undergoes change—it may increase or decrease.

2 The water levels in the wells also undergo an abrupt change.

3 The well water may turn muddy or a water spring may sprout in the well.

4 New water springs may appear on the ground. Sometimes, the appearance of a new water spring may be accompanied by a cracking sound. It also should be noted that under certain geological conditions, the water precursors could appear two to seven days prior to the occurrence of the earthquake.

Thermal Precursor

One or two days prior to the occurrence of an earthquake, the ground and atmospheric temperatures are much higher than their average values. On the day of the earthquake, a few hours before the quake, say about 5 to 10 hours before the quake, the atmospheric temperature starts rising rapidly and it reaches the maximum value which is about 4 to 8 °C higher than normal.

Seismo-Electromagnetic Precursor

Prior to the occurrence of any medium or large earthquake, some changes in the earth's magnetic field take place. As a result of this, the charged particles in the upper atmosphere undergo some change in their configuration. Therefore, electromagnetic communication is adversely affected. Due to this effect, there will be continuous and repeated disturbances on radio reception. Similarly, wireless communication is also disturbed. There are audio, visual and spectral disturbances on transmitted TV signals. The picture, voice and the colour in TV reception may be disturbed. Sometimes a "Communication Black Out" is observed. This means that a few hours before the occurrence of an earthquake no wireless communication from outside the vulnerable seismic area is received in the seismic area.

Animal Precursor

A mountain of literature is available on this subject. It has been observed in several places and in different countries that the entire zoological species get terribly disturbed about 10 to 30 hours before the occurrence of any medium to large earthquake. Domestic animals such as horses, donkeys, cows, pigs, dogs, cats etc. show signs of being utterly disturbed. They do not want to be tied by chain or rope and every act of these animals indicates their restlessness. It is necessary to set them free to save their lives. Reptiles and rodents such as snakes, rats, mice etc. come out of their underground hide-outs in a disturbed or frightened condition. The birds fly at low heights in small groups making shrilling noises. Similarly ants, millipedes, centipedes and other insects are seen moving in large numbers.

Human Precursor

Human beings are also sensitive to seismic premonitory conditions and these conditions could be seen clearly by the medical profession. It may be true that in the future earthquake prediction will be done by the medical profession, rather than seismologists. About 10 to 30 hours before the occurrence of the quake, there is an abnormal rise, up to three to five times more than the average rate, in cases of:

1 delivery and abortion;

2 blood pressure and other cardiovascular patients;

3 asthma, bronchitis and other pulmonary patients;

4 headache, migraine, restlessness and uneasiness patients; and

5 some people vomit or have acute vomiting sensation.

Incidentally, the intensification of the above ailments is rapid and apparently there is no cause of provocation.

It has been noted from several reports of destructive earthquakes that the seismo-electromagnetic and animal precursors are the most reliable and time proven. The human precursors are also very reliable but these would be observed usually by doctors and hospitals.

If one observes any of the above precursors one should come out of the house and investigate one's neighbours and surroundings. If similar precursory seismic indicators are observed, contact the nearby village, town or city by telephone and enquire about conditions in those places. If similar observations are confirmed from these locations, then it is logical to expect a seismic jolt within the next few hours. At such time people should come out with food, medicines, battery-operated radios etc. and sit in open ground, away from the collapse range of any man-made structure, and wait for the earthquake. It is most likely that while waiting in the open space, with several other people, some of the above-mentioned human precursors would be seen on an intensive scale.

Among all the natural disasters, the earthquake is the gentlest. The earthquake itself does not kill anybody, it is the collapse of man-made structures that kills. Earthquakes cannot be avoided or stopped but the losses due to earthquake could definitely be reduced and the disaster mitigated. This could be done most effectively by the active participation of the general public.

Note: The author Mr Arun Bapat is a seismologist at the Central Water and Power Research Station, Pune, India and visited NTF for two weeks in May 1996.

Introduction to Integrated Coastal Zone Management (ICZM)

Prof. T. S. Murty

*The author **Prof. T. S. Murty** is the Director of the National Tidal Facility and the Director of the South Pacific Sea Level and Climate Monitoring Project.*

Integrated Coastal Zone Management (ICZM) means many things to many people. If you talk to a physicist or a physical oceanographer, the emphasis would be on the physical processes: the tides, coastal erosion, estuarine processes etc. A geologist looks at it from land uplift or subsidence and tectonic processes. A chemist is interested in the chemical inputs into the coastal waters from industry, sewage and the pollution problems associated with these. On the other hand, a biologist will think of nutrients, algal growth, red tides etc., commercial and sports fishermen look at it as a place to catch fish, while a government official will think of legislation and jurisdiction. The public on the other hand looks at the coastal zone as a place for recreation and having fun. What then is Integrated Coastal Zone Management? ICZM is all of these and much more. In light of various diverse and conflicting interests, how should we manage the coastal zone for the benefit of all without causing damage to the coastline so that it can be sustained?

This is much easier said than done. As you will see, no two people agree on what exactly comprises the coastal zone. Do we arbitrarily set a zone of 1 km in width either side of the coastline (1 km onto land and 1 km onto the water)? One may ask why 1 km, why not 2 km, or 5 km, or 10 km, or even 20 km? Do we include the back waters, the lagoons and the estuaries? How far do we go into the ocean, how high do we go up on the land? There is a general consensus that something like a 12 nautical mile limit from the coastline towards the ocean may be acceptable. However, what is not clear is the limit on the landward side—the hinterland. This so-called hinterland is crucial because human activities in this zone ultimately determine the quality of the marine environment. In the end there are no easy answers to these questions which will satisfy everyone. Nevertheless, let us look at some basic concepts and see that an ICZM must at least include some of these processes, parameters and phenomena. The ideas we discuss here are not with reference to any particular country, but are general enough to be applicable to many countries. However, for any individual Pacific island nation, one has to tailor the plan to meet its own special needs.

We will discuss various processes and problems, not in any particular order. The siltation of river deltas is a major problem. One could use remote sensing techniques and numerical (computer) models to predict the movement of sediment from the rivers and the formation of new islands. Aquaculture needs very detailed baseline studies to provide information for setting up fish farms. Therefore we cannot consider a sustainable coastal zone without paying adequate attention to the health of the oceans as a whole.

There are multiple uses for the coastal zone, namely navigation, fisheries, mining, oil and gas exploration, industrial activity, recreational activity, housing, dumping of sewage and industrial wastes etc. Because the same area is used at the same time for several activities, conflict occurs between various interests. Other factors we have to consider in the development of the coastal zone are natural hazards such as earthquakes, cyclones, storm surges, tsunamis etc. Without plans to minimise the damage from these and other mitigating plans against natural hazards, Coastal Zone Management will not be achievable. To make sure that the coastal zone development is ecologically sustainable, we have to monitor the mangroves, coastal forests and beaches.

Even though the coastal zone issues may be local in scale, we cannot plan the management in isolation from global phenomena such as the greenhouse effect and El Niño events. However, one could broadly divide the coastal zone issues into the following four categories: physiographic, hydrological, environmental and socio-economic.

To find solutions acceptable to most people—if not all—one must consider the major users of the coastal zone: fisheries, aquaculture, agriculture, plantations, navigation, industry, forestry, tourism, recreation, housing, sand mining, oil and gas exploration and disposal of domestic and industrial waste. We have to balance these activities against the problems of erosion, flooding, wave action, tidal action, cyclones, storm surges, tsunamis and pollution.

Integrated Coastal Zone Management will be an important tool to assist countries plan to adapt to climate change and sea level rise. In the next volume, we will discuss how this tool may be developed and applied in the Pacific.

Ongoing Coastal Integrated Management and Planning for the region: SPREP on the Move.........

Wetland Issues

Pacific Coral Reef Initiatives

The International Coral Reef Initiative (ICRI) Pacific Regional workshop, held from 27 November to 1 December 1995 in Suva, Fiji, was called to give direction and life to ICRI at the regional and local levels by fulfilling its objectives and to develop an ICRI Pacific Regional Strategy which is realistic and clearly defined. Two of the important results of the Strategy were to nominate SPREP as the ICRI Coordinator for the Pacific region and recommend that 1997 be the "Pacific Year of the Coral Reef".

1997 "Pacific Year of the Coral Reef"

The endorsement of these two actions by SPREP member countries paved the way for the Planning Meeting for the 1997 "Pacific Year of the Coral Reef". In this Planning Meeting (8 to 12 July 1996 in Nadi, Fiji) more than 30 representatives from 17 countries, including 15 non-government organisations, participated in working groups to formulate the logistics for a campaign network. They also drafted the Pacific Year of the Coral Reef Regional Campaign Plan and the Draft National/NGO Campaign Plans which will be finalised in-country.

Regional Wetlands Action Plan

A Regional Wetland Action Plan (RWAP) was prepared, reviewed by the ICRI Pacific Regional Workshop in Fiji in 1995, and was endorsed by SPREP member countries. There will be a range of in-country activities based on issues and needs identified in the RWAP.

1997 PACIFIC YEAR OF THE CORAL REEF
"CORAL REEFS: THEIR HEALTH, OUR FUTURE!"

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Climate and Climate Change Teacher's Curriculum Project Manual

Chalapan Kaluwin (SPREP)

Introduction

Very little information on climate change and its potential impacts is available in the current educational materials in the Pacific region. Current curricula lack information on the rapidly expanding field of climatology, oceanography, sea level rise and climate change, impacts on the environment, and economic results from these circumstances. The South Pacific Regional Environment Programme believes there is a need to address these issues, and as a result SPREP is coordinating the development of a Regional Curriculum on Climate and Climate Change for use by schools and agencies in the Pacific region.

The curriculum provides teachers and trainers in a wide variety of schools and agencies with information on the current status of climate change and its effects and on the progress of various climate change and sea level rise projects in the Pacific. The curriculum also addresses scientific concerns including the importance of economic and environmental impacts of climate change, as well as encouraging teachers and students to enter the fields of climate study to encourage response options for the continued benefit of the countries in the Pacific region. This manual is designed to introduce the programme, up-date progress reports, and inform potential participants and curriculum specialists on the scope of the project.

There are many important projects related to climate and environmental studies that are currently being implemented in the Pacific region. These include the South Pacific Sea Level and Climate Monitoring Project (endorsed by South Pacific Forum Governments), Atmospheric Radiation Measurement, South Pacific Regional Meteorological Services, TOGA-COARE, Schools of the Pacific Rainfall Climate Experiment, and others. Most of these organisations have mandates from their funding sources to engage in education and/or research programmes at differing levels of regional involvement. The need to integrate the information resources and technical results from these climate activities is imperative so that the information already within our reach and originating within our region is available to governments and educators. This will facilitate policy making in arriving at sound decisions for short and long term benefits to the region.

The development of the proposed curriculum was designed in three phases. First, representatives from the National Tidal Facility (Flinders University), Atmospheric Radiation Measurement (USA Department of Energy) and SPREP outlined the overall project and prepared the first draft of this manual in October 1995 in Adelaide, Australia. The second phase began with a regional workshop for curriculum writers from the Pacific nations to review and address the overall plan, and to write draft curriculum modules and activities. During the workshop, which took place in April 1996 in Western Samoa, materials and resources/references were made available to the curriculum writers and teachers. Technical and scientific staff from SPREP, ARM, NTF, SPaRCE and other organisations presented mini-workshops on various topics and were available for discussion and review of materials. Educators and curriculum writers wrote curriculum modules and planned activities, assisted by technical writers and/or editors from SPREP and ARM.

The third phase of the project is envisioned to take place within each country or region and will consist of fine-tuning the curriculum to the needs of respective country or grade level. SPREP and other participating research and educational organisations will assist with Phase III as much as possible, depending on available funds.

Preparation of this regional curriculum is executed by SPREP and funded by the Australian Government through the South Pacific Sea Level and Climate Monitoring Project and the Atmospheric Radiation Measurement Program. By developing this curriculum, SPREP hopes to provide information to teachers, extension officers and other trainers in order to help them make climate and science an integral part of their teaching and training activities.

Rationale

This curriculum has been developed in response to several needs expressed over the last few years by participating organisations and entities in the Pacific region. Primarily, the South Pacific Forum Island Governments identified and reaffirmed that global climate change, natural climate variability and sea level rise were among the most serious environmental and economic threats to the region. These concerns were raised in international fora such as the UNCED Conference, the Barbados Conference and the UN Framework Convention on Climate Change. The lack of scientific research and monitoring programmes in the Pacific region was a concern to all nations, particularly as the low level of financial commitment for these efforts directly reduced the capability to plan for future development and take full consideration of environmental needs.

In order to address these issues, the need to develop regional programmes to promote understanding, and to study the impacts of global climate change, analyse ocean processes and examine natural climate variability at all levels became imperative. The general lack of curriculum materials for use in the region's schools reinforced the need for the development of a flexible curriculum and resource base that can be fine-tuned to regional needs by individual educational systems.

The curriculum provides the basis for an exploration of the global and regional issues of climate change and natural climate variability. It addresses the impacts of climate change on the future environment, including social, economic, cultural and political aspects. It is intended that the curriculum will help promote responsible stewardship of the environment through the development of critical thinking skills and practical experiences.

The curriculum is designed to draw upon and coordinate the many related educational programmes and resources that already exist in the region. It is supported by current information, a database on relevant research, and will utilise feedback and evaluations from participating educators to improve the content of the material. The knowledge base created should provide a basic foundation for future studies on climate and climate change. At the same time, there should be flexibiity in this knowledge to respond to contextual differences among the island countries.

Background

Weather and climate are intuitively understood and are an integral part of everyday life throughout the Pacific region. Although these topics are very complex to understand scientifically and often very difficult to explain in an educational setting, every child in the Pacific region learns from an early age the usual weather patterns of a region, and in addition learns to predict the economic consequences of weather extremes. Using weather and climate as a focus for teaching basic science (physics, chemistry, mathematics, biology) as well as social sciences (economics, geography, civics) and humanities (literature, history, writing) has tremendous relevance to our children. They have an existing body of local knowledge in this area and great respect for the importance of local weather and the environment. We can use this existing interest and sense of importance as a vehicle to increase the relevance of basic educational topics, to promote informed stewardship of the environment and also to inform communities and governments about climate and climate change.

Weather can be thought of as rain, clouds, wind, pressure and temperature—those phenomena affecting our daily lives. Climate, however, is the average observations of weather, including extreme or unusual events in an area or region over a given time. Normally scientists summarise climate information from year to year or longer. In addition, climate is observed at a global level because interdependencies between atmosphere, oceans, snow, ice, land surface and vegetation affect changes in the global climate patterns.

Many more variables affect the climate and daily weather patterns. These include changes in the amount of energy received from the sun, variations in the earth's orbit around the sun, continental drift, movements of the earth's crust and volcanic activities. Other factors that occur over a long period will also affect the climate.

Some climatic terms and their definitions

Climate	The long-term behaviour of the atmosphere for a given region, as determined by its weather over the year or season.
Climate change	Long-term changes in the climate for a given region/global as a whole, and associated with the greenhouse effect.
Climate variability	Natural fluctuations in the climate for a given region, year to year or from decade to decade.
Atmosphere	The gases which surround the planet. The atmosphere actually has a layered structure. The lowest two layers are the troposphere and stratosphere.
Weather	Behaviour of rain, clouds, wind, pressure and temperature as daily observations.
Anthropogenic	Of human origin; man-made.
Greenhouse gases	Those gases (e.g. carbon dioxide, methane, nitrous oxides) which contribute to the greenhouse effect by affecting the radiation transfer through the atmosphere.
Greenhouse effect	The phenomenon whereby water vapour and other gases present in small quantities in the atmosphere affect the earth's radiation balance, resulting in a higher temperature.
Geosphere	The collective name of solid land and rocks, the oceans, rivers, inland waters and the ice masses.

The need to integrate the information resources and technical results from these climate activities is imperative so that the information already within our reach and originating within our region is available to governments and educators.

Regional Curriculum on Climate and Climate Change—Guidelines

Needs Assessment

The curriculum on climate and climate change was developed in response to many needs expressed over several years by organisations and other entities in the Pacific region. In particular, the South Pacific Forum Island Governments identifed and reaffirmed in various fora that global climate change, natural climate variability and sea level rise were among the most serious environmental and economic threats to the region. It was also realised that very little information on climate change and its potential impact on Pacific environments was taught in Pacific schools. In order to address these issues, SPREP responded by formulating the regional climate and climate change curriculum project.

Approach to the Curriculum

There are many important projects related to climate and environmental studies that are currently being implemented in the tropical western Pacific. These projects are generating masses of information on climate change and its impacts on the environment. This information provides the basis of the content knowledge in this curriculum. The regional monitoring and research projects make available up-to-date statistics and other related information which can be utilised in the teaching of this curriculum.

The modules which are written for this curriculum make the assumptions that the field of climate change is expanding as more and more resources are devoted to studies of the causes and effects of climate change and their impact on the physical environment as well as on human society. The nature of the information therefore is quite dynamic and teachers must understand and learn about the available sources of knowledge for this curriculum. It is exciting to know that students can be involved directly in the generation of the information, as in the SPaRCE project.

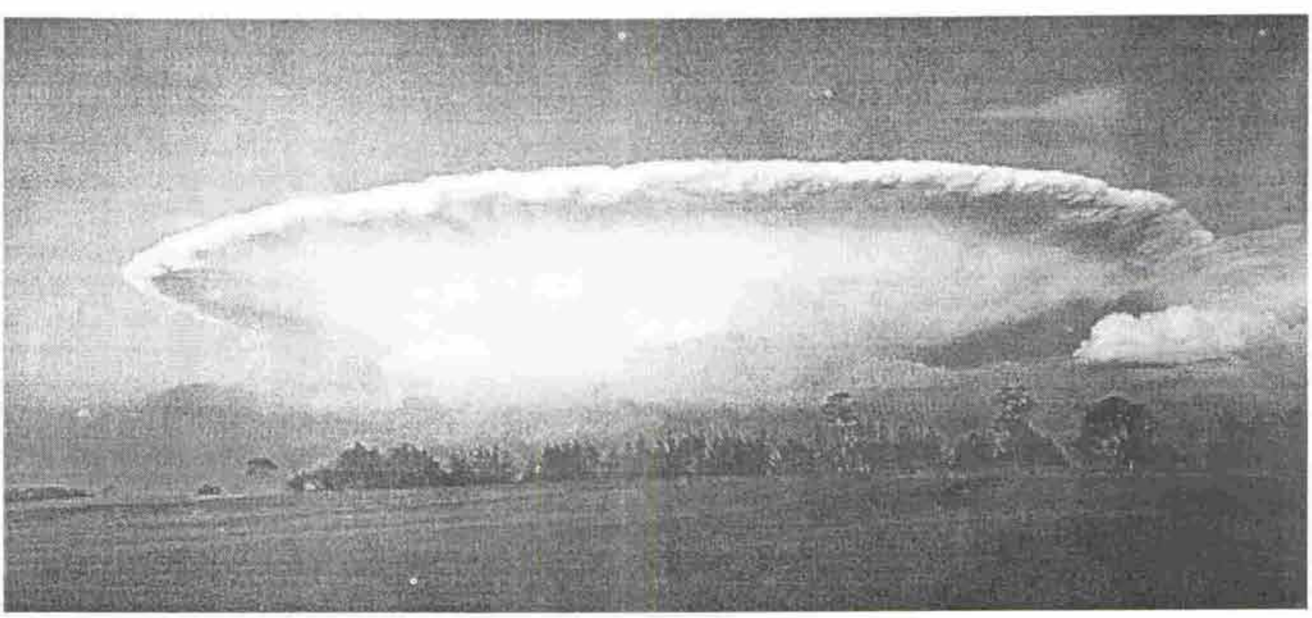
The Scope and Sequence of the Modules

The modules are arranged in a sequential order and include background information on the atmosphere, weather and climate, the oceans and ocean circulation before moving on to look at the evidences of climate change and their causes. An understanding of the nature of climate change is essential before studying the effects and the impact of climate change on the physical environment and on human society. Each module, however, is designed so that it is autonomous and can be taught on its own. This design builds flexibility into the curriculum to enable the most appropriate decisions to be made in each island country with regard to how it ought to be incorporated into their existing school curricula.

Target School Population

This curriculum is intended for the upper two levels of primary as well as the lower two levels of secondary, i.e. Forms 1 to 4 or Years 7 to 10 depending on the school system concerned. The modules are written expressly for the use of the teacher using the following format:

- Overview of content
- Background information (knowledge base)
- Aims of the module
- Objectives of the module
- Sample activities
- Assessment and evaluation



The study of storm clouds is one of the scientific components of the South Pacific Sea Level and Climate Monitoring Project (produced courtesy of the Australian Commonwealth Bureau of Meteorology)

The activities are written in such a way that they can be duplicated and handed to students without further work. The modules are intended to provide the teacher with enough scope to develop lessons for the appropriate class level, and parts of a module can also be used at different class levels.

Implementation Strategy

The decision regarding incorporating climate change issues into school curricula must be made at the national level. Climate change issues have been declared to be critical to the environment and to economic development considerations in most Pacific countries. The extent to which this curriculum is integrated or separated in the total school curricula must be taken upon consideration of the relevance and importance of such knowledge to development in any Pacific island country.

Aim

The goal of this curriculum is to increase the awareness, understanding and knowledge of climate change, ocean processes and natural climate variability as a vehicle to develop:

1 Critical thinking skills.

2 Fundamental basics in scientific methodology.

3 The acquisition of and ability to use a strong knowledge base in environmental science, including fundamental concepts and a historical perspective.

4 An appreciation of environmental system complexity, including integration and feedback between subsystems.

5 An understanding of environmental processes at national, regional and global scales.

6 An introduction to and appreciation of current environmental scientific research and innovative technology.

7 An introduction to and enhancement of planning and management responses to address the impacts of climate change.

8 A consideration of environmental ethics.

9 Encouragement for careers in environmental science and management.

Summary of Objectives

1 Raise the awareness and understanding of the region's oceanographic, atmospheric and terrestrial science, and the state of the environment including the impact of human activity on the region.

2 Promote activities, including research to protect atmospheric, terrestrial, freshwater, coastal and marine ecosystems while ensuring sustainable use of resources.

3 Increase the fundamental understanding of meteorology and oceanography, global warming, greenhouse effect, basic radiation concepts and recent climate history.

4 Develop activities, including research to protect atmosphere, biosphere and oceans, with specific focus on water resources, mangroves, coral reefs, fishery agriculture, control processes, El Niño/ENSO, cyclones and extreme climatic events.

5 Promote integrated planning and management in each country.

6 Increase the visibility and utilisation of resources from international and regional organisations involved in monitoring and research aspects of environmental science.

7 Assist in strengthening national and regional networking capabilities and institutional cooperation in the area of environmental education.

8 Develop activities, including public awareness and community outreach, that integrate basic environmental scientific concepts with planning and management strategies in economics, agriculture, fisheries, forestry and industrial development.

Methodology

The first step in the compilation of this curriculum was completed by representatives from the various scientific and government organisations who met in October 1995 in Adelaide, Australia, and prepared the draft curriculum proposal. Since then, various agencies have compiled materials on climate change, natural variability, sea level rise and environmental topics. This part of the task was done by a small group of people from NTF (Flinders University), ARM Program (University of California) and SPREP.

A scheduled regional workshop for curriculum experts and teachers was held in Western Samoa in June 1996. Invited curriculum experts and teachers from the Forum Island Countries and elsewhere attended the two-week workshop which reviewed and assessed the draft manual. The group modified the content and reconceptualised the modular framework of the curriculum materials, which included materials, references and information from the various regional projects. The work produced in the workshop comprised all the documents of the Draft Regional Climate and Climate Change Curriculum as follows:

1 The Regional Climate and Climate Change Curriculum Project Manual

2 The Regional Climate and Climate Change Curriculum Modules

Curriculum Content

The approach to organising knowledge, skills and attitudes in this curriculum has been determined largely by

Participants of the Climate and Climate Change Teacher's Curriculum Workshop held at IRETA (USP), Alafua Campus, Apia, Western Samoa from 3 to 14 June 1996.

considering class levels towards which this curriculum is oriented. The level targeted is the junior secondary level or in some educational systems, the upper primary and lower secondary levels. The content emphasis is distributed equally on climate change and impacts and responses to climate change. The curriculum modular framework reflects the emphasis as follows:

Background

1 Atmosphere

2 Weather and Climate: Measurement and Elements

3 Oceans and Ocean Circulation

Nature and Causes of Climate Change

4 Definition of climate change; Historical perspectives; Long and short term impacts

5 Evidence of current climate change, e.g. climatic statistics (precipitation, El Niño etc.)

6 Causes of Climate Change such as:
- natural, e.g. volcanoes, changes in solar radiation
- human, e.g. coal burning
- changes in atmospheric composition, e.g. deforestation, CFCs
- changes in land features, e.g. vegetation

Impacts and Responses to Climate Change

7 On the physical environment
- sea level rise (NB local tectonic movement)
- increase in cyclone frequency
- changing patterns in climate
- coastal processes
- ecosystems and biodiversity

8 On human society
- migration and settlement
- agricultural patterns
- health, e.g. malaria
- economic and political effects
- local variations within the Pacific

Therefore there are eight modules which are designed for the teacher's use and guidance.

Evaluations

The process of evaluating the regional climate and climate change curriculum is a continous one. This will involve the trialling of the modules at classroom level in the countries of the region for 4 to 6 months before the modules are finalised, as well as the decisions made by individual countries for incorporation in full or in part to the existing school curricula.

SPREP, NTF, ARM and the curriculum developers from the region ensured that the curriculum modules were of high quality to be used in national as well as regional institutions.

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Climate Change Calendar of Meetings

- First SPARC General Assembly (Stratospheric Processes and Their Role in Climate)
  2-6 December 1996, Melbourne, Australia
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The Sun

T. H. Aung

The sun, at a distance of 150 million kilometres, is the closest star to the Earth. After the sun, the next closest stars are the members of the triple star system known as Alpha Centauri. In fact, the sun is an incandescent ball of gases (just as Pumbaa said in the movie Lion King, "... burning billions of miles away"). Its mass is 330,000 times greater than the Earth. Composition of the sun is briefly given in the following table.

Element	% of mass
Hydrogen	73.46
Helium	24.85
Oxygen	0.77
Carbon	0.29
Iron	0.16
Neon	0.12
Nitrogen	0.09
Silicon	0.07
Magnesium	0.05
Sulfur	0.04
Other	0.10

The temperature of the centre of the sun is about 15,000,000°C. The surface temperature of the sun is approximately 5500°C. There are some cooler regions which appear to be darker (sunspots) than the surrounding surface. These sunspots are at about 4000°C.

The sun is approximately 4.5 billion years old. About 5 billion years from now, the sun will burn all of its hydrogen fuel into helium. When this process occurs, the sun will change from the yellow dwarf as we know it to a red giant. The earth will be burnt to a cinder and will be incapable of supporting life.

Sunlight contains all the colours of the rainbow which blend to form white light, making sunlight appear white. At times, some of the wavelengths of different colour become scattered, especially blue, and the light appears coloured. When the sun is high in the sky, some of the blue rays are scattered in the Earth's atmosphere. At such times, the sky looks blue and the sun appears to be yellow. At sunrise or sunset, when the light follows a longer path through the Earth's atmosphere, the sun looks red (red having the longest wavelengths). Sunlight takes about 8 minutes and 20 seconds to reach the Earth, travelling at 299,792 kilometres per second.

Reference: *The Handy Science Answer Book (1994), Science and Technology Department, The Carnegie Library of Pittsburgh, USA.*

The *Quarterly Newsletter* for the *South Pacific Sea Level and Climate Monitoring Project, Phase II* (Con 4990) is prepared jointly by SPREP and NTF with funding from AusAID. Further communication on the *Quarterly Newsletter* may be made to Directors of both organisations:

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