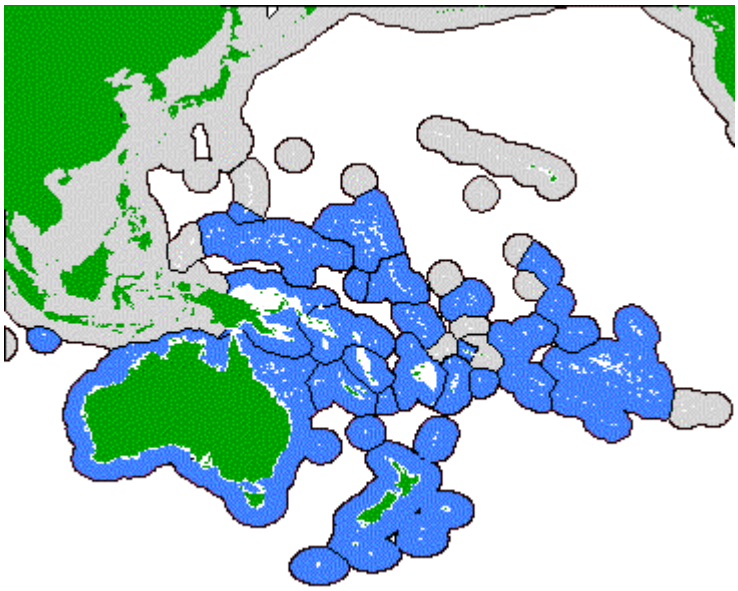
CLIMATE TRENDS AND VARIABILITY IN OCEANIA

3rd APN Workshop on Climate Variability and Trends in Oceania
8-11 December 2003, Auckland, New Zealand

WORKSHOP REPORT



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Climate Trends and Variability in Oceania: 3rd APN Workshop on Climate Variability and Trends in Oceania 8-11 December 2003, Auckland, New Zealand

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Executive Summary

Oceania occupies a large portion of the Pacific Basin, and climate and ocean/atmosphere interactions of global significance occur here on annual to decadal time-scales. These include the El Niño-Southern Oscillation (ENSO), and the Interdecadal Pacific Oscillation (IPO), an ENSO-like variation which modulates climate on time scales of two to three decades. These cause significant climate variability and attendant societal consequences in Oceania and beyond.

The Asia Pacific Network for Global Change Research (APN) workshops on climate variability and trends in Oceania are contributing to increased understanding by searching for and extending historical climate data back over long periods, and refining these for changes in site, exposure and instrumentation. The description of climate variability and trends provides information that Intergovernmental Panel on climate Change (IPCC) assessments will address, and extends previous knowledge on regional climate variability. The compilation of high-quality series of climate data allows the monitoring, detection and attribution of climate change in Oceania. The 1st APN workshop from 13 – 15 September 2000 had wide involvement of Pacific Island Countries and national meteorological services in the region. Fiji, Tuvalu and Tonga were key collaborators with New Zealand and Australia. The workshop also had involvement from nine other Pacific Island Countries, and in collaboration with the South Pacific Regional Environment Programme (SPREP) and the WMO Sub-Regional Office in Apia. The 2nd workshop, from 5 – 9 November 2001 had participants from eleven Pacific Island countries, Australia, New Zealand, and the WMO Sub-Regional Office.

The aims of the 3rd workshop were to widen involvement to thirteen Pacific Island Countries, and introduce new techniques and software for metadata compilation, documentation and interpretation. Following thje workshop, capacity building will continue through training in the use of software specifically designed for storing metadata information. Climate trends were updated and workshop participants discussed how comprehensive climate data sets contribute to a regional climate information service for Oceania. The workshop continued the collaboration and capacity building on climate change analysis.

The workshop made a significant contribution towards providing methods and techniques for capacity building, and to develop a simple database to document and store metadata within Oceania countries. Training and software were provided to the participants. Use of climate information to contribute to a regional climate information service was explored, and capacity building continued through the on-going technical support before, during and after the workshop. This enhances both the regional and national capacity for Oceania countries to determine and understand their own climate variability and trends, and for regional participation in studies to monitor and detect trends and variability in climate.

The first session of the 3rd workshop provided background and guidance material on metadata collection and homogeneity assessment from the global and regional perspectives. As well, the principles and practice of the Global Climate Observing System (GCOS) were introduced, and information on the regional GCOS data portal – the Global Observing System Information System (GOSIC) that is available for Oceania countries to use. The WMO Sub-Regional office presented the programme thrusts of its climate work, including moves to improve regional observations to meet GCOS initiatives. The Fourth Assessment Report of the IPCC was introduced with information on regional participation. At the end of this session participants were surveyed on media communication.

Workshop participants in the second session were then introduced into more detail on metadata assessment and practices. They presented reports on metadata resources and facilities in their countries. This was followed by informational presentations on selected Pacific climate activities including: an overview of the Pacific ENSO Applications Center (PEAC), a case study of integrating traditional techniques of weather and climate observing with modern methods in a Pacific setting, and a summary of the Schools of the Pacific Rainfall Experiment (SPaRCE) project. Details on the Australian and New Zealand climate databases were explained.

The second day started with a session on climate data analysis for metadata and trends. Background on annual to decadal regional climate variability in the region as a result of ENSO and IPO was given. The metadata compiler and software, to assist assessment of country metadata resources and facilities was introduced. After this was demonstrated, attendees analysed country metadata.

On the third day participants discussed the links between climate information and society. An update of the latest research on climate trends, variability and impacts was presented. Participants updated country data and trends. The next session examined the applications of climate information to society and the concept of a Pacific Island climate information system was explored, together with the communication of climate information to the media. This led to a dynamic discussion on the challenges of communicating climate and information to both media and decisions makers. The identification and exploration of some general principles that can assist guide future dialogue and interaction was also discussed.

On the final day the results of the 4th APN Workshop on Climate Extremes, held in Melbourne in December 2002, were presented. Workshop participants then reviewed the results of the analysis of metadata resources and facilities for compilation. In the final session a CD-ROM of all presentations, data and other resource material was distributed. Participants addressed issues, and reported their conclusions to the final plenary session where recommendations were made.

The Workshop recognized the importance of historical climate data and associated metadata for documenting, understanding, anticipating and responding to climate variability and change. The Workshop participants similarly recognized the value that climate information provides to decision makers in all sectors of society and the importance of effective mechanisms for information

dissemination and communication with various user groups. In light of this and in the context of the discussions at the 3rd APN Workshop on Climate Trends and Variability in Oceania (8-11 December 2003; Auckland, NZ), the Workshop:

1. Encourages creation of a simple, easily-maintained, user-friendly local climate database system that meets the needs of any small country. The Workshop acknowledges that initial development of such a system using readily commercially available platforms (e. g MS Access) has already begun in Samoa, and recommends that donor agencies consider support for the further development, demonstration and maintenance of such a system in the Pacific, including a strategy for database backup, and utilization of the GOSIC resource.

2. Recognizes that a complete archive of Global Synoptic Network (GSN) data for the Pacific would have significant national, regional and international benefits and encourages Pacific Island nations to complete their contributions to the GCOS surface reference network archive at World Data Centre-A.

3. Encourages pursuit of planned and proposed initiatives in the context of PI-GCOS for historic data rescue initiatives (prior to the modern period of digitization) to produce climate data that can be used by Pacific Island nations and the international research community. In addition to pursuing a number of funding opportunities highlighted at the Workshop, Pacific Island participants agreed to raise this important issue through their National Meteorological and Hydrological Services (NMHS's) at their earliest opportunity.

4. Recommends the digitization of paper records of climate data to prevent further deterioration or loss of these data resources by aging in situ, or destruction by natural disasters damaging the data archive. This would also make available these valuable data resources to the research community to address key issues on climate variability and extremes.

5. Recognizes the important opportunity that the IPCC Fourth Assessment Report (AR4) provides to assess climate change impacts and opportunities to enhance resilience in the region. The workshop encourages countries to actively participate in the IPCC AR4 process, including nomination of authors and reviewers and ensuring that Pacific Island data and issues are addressed in studies that contribute to the AR4.

6. Recommends enhancement of existing climate related education and training to improve the capabilities of Pacific NMHS's, government agencies, universities, research institutions and other users of climate information. This can be achieved through the development of university based curricula, focussed training programmes and development of educational materials relevant to Pacific Island nations by appropriate institutions in the region.

7. Recognizes that the media provide the public and policymakers with most of their information about climate, and encourages agencies to enhance collaboration with the media to improve the communication and understanding of climate information.

8. Recognizes the benefits of a more effective partnership between decision makers and the providers of climate information, and encourages the development of relevant and useable information. The workshop encourages the establishment of a sustained process of interaction and dialogue between climate scientists and decision makers in Pacific Island Governments, communities and businesses.

9. Recommends an evaluation of the APN sponsored workshops on variability and extremes and develop plans for future workshops including the identification of appropriate themes and the feasibility of venues in Pacific Island countries.

The *3rd Workshop* on *Climate Variability and Trends in Oceania* was organised by the National Institute of Water and Atmospheric Research (NIWA) with generous sponsorship from the Asia-Pacific Network for Global Change Research (APN) and the National Oceanographic and Atmospheric Administration (NOAA) GCOS Programme.

Background to Workshop

Oceania occupies a large 21 million square kilometre portion of the Pacific Basin, and here climate and ocean/atmosphere interactions here of global significance occur on annual to decadal time-scales. The El Niño-Southern Oscillation (ENSO), is the major cause of global climate variability, after global warming, and is primarily driven out of Pacific basin ocean/atmosphere interactions. The behaviour of ENSO has been unusual since the mid-1970s, and recent analysis has uncovered that ENSO variations are modulated on timescales of two or three decades by the Interdecadal Pacific Oscillation (IPO). The IPO is also centred on the Pacific basin, and causes significant shifts in climate on interdecadal time scales.

Both the Intergovernmental Panel on Climate Change (IPCC) and the Global Climate Observing System (GCOS) have noted the paucity of data over the Southern Hemisphere, making it crucial to improve databases for monitoring climate trends and variability, and to develop a network of long-term climate monitoring sites in the region. These Asia Pacific Network for Global Change research (APN) workshops are contributing by searching and extending historical climate data back over long periods, and refining these for changes in site, exposure and instrumentation. The IPCC Assessment is based upon having good climate data and metadata available: without good metadata to describe the nature of the thousands of observations in data centre archives around the world, the data themselves are essentially useless. The output of the APN workshops are another crucial piece to the climate assessment puzzle for the very large Oceania region. The compilation of high-quality series of climate data will assist the detection and attribution of climate change in Oceania.

The first workshop from 13 – 15 September 2000 had wide involvement of Pacific Island Countries and national meteorological services in the Region. Fiji, Tuvalu and Tonga are key collaborators with New Zealand and Australia, with involvement from nine other Pacific Island Countries, in collaboration with the South Pacific Regional Environment Programme (SPREP) and the WMO Sub-Regional Office in Apia. Workshop participants presented overviews of historical and observed climate data resources available in their own countries to study climate trends and variability, along with indications of analyses that had already been undertaken. There was a large

variation in the range of data resources available, with some countries having a high quality reference climate station network and data stored on relational databases with metadata and others having only a very sparse climate network and information stored on personal computers. Many countries have a significant paper archive of data requiring digitisation. Methods of analysis of data for climate trends and variability were discussed in particular, selection of climate indices for analysis, time series analysis and establishment of significance of any trends. The first workshop also established contacts within Oceania to progress research on climate change and variability.

The second workshop, from 5-9 November 2001, had similar wide involvement from Pacific Island countries and beyond. Participants were introduced to the Monthly Data Analyser software for the removal of data biases through homogeneity analyses, to check their data for quality and homogeneity for assessment of trends and variability, as well as methods of time series analysis for calculating trends for their country data.

The latest information on global and regional climate trends from the IPCC Third Assessment Report was presented, along with 21st century temperature and rainfall projections from climate models based on various scenarios. This was followed by consideration of regional climate variability in the region, driven by ENSO and IPO. Palaeoclimatic evidence demonstrates that these features have been a dominant cause of variability in the region for several centuries. After methods for quantifying variability were shown, attendees then analysed country data to ascertain climate teleconnections with ENSO and the IPO. Workshop participants were then able to review the results of analyses of trends and variability.

A significant recommendation from the 2nd workshop was that another shorter workshop be held to validate and update climate trends and variability in Oceania, and to develop techniques and software to compile metadata, documentation and storage of climatic data in Oceania Region. Oceania is a vast region with sparse data points where some stations have been running for decades but there has been very little or no documentation of climate station histories. This would also be a significant and direct contribution to Climate Variability (CLIVAR) and the Global Change System for

Analysis, Research of the International Geosphere-Biosphere Programme (IGBP-START) s, and the World Meteorological Organisation (WMO) Programmes – World Climate Data and Monitoring Programme (WCDMP), Climate Information & Prediction Service (CLIPS), Global Climate Observing System (GCOS), World Climate Research Programme (WCRP) and Intergovernmental Panel on Climate Change (IPCC). This workshop would continue collaboration on climate change and variability work across Oceania, and improve capacity building for analysis of observed climate data**.** Together with the other partner institutions (in Tonga, Tuvalu and Australia) the East-West Center at the University of Hawaii and the NOAA GCOS Office became major collaborators with NIWA in the design of this 3rd workshop.

The *3rd Workshop Climate Variability and Trends in Oceania* was organised by the National Institute of Water and Atmospheric Research (NIWA) with generous sponsorship from the Asia-Pacific Network for Global Change Research and the National Oceanographic and Aeronautic Administration (NOAA) GCOS Programme.

Introduction

The meeting began with opening remarks from Dr Rick Pridmore (Chief Executive, NIWA). Dr Linda Stevenson (Programme Manager, APN) welcomed participants and gave an overview of APN programmes. In particular, the Scientific Capacity Building/Enhancement for Sustainable Development in Developing Countries **(CAPaBLE)** Programme is a concrete initiative to realize parts *107 to 114* of the Plan of Implementation for the World Summit for Sustainable Development (WSSD) and has been registered as a WSSD Type II Partnership/Initiative. This five-year programme is expected to develop and enhance scientific capacity in developing countries to improve their decision-making in the target areas related to climate change and water and food security that are directly linked to their sustainable development. Phase I of CAPaBLE, which will run from September 2003 to March 2006, will focus on climate change.

Dr Jim Salinger (New Zealand) outlined the goals of the workshop, which are to provide a focus on the mix of science and policy, with emphasis on inter-country participation and collaboration. The purpose of the workshop is to provide uniform methodologies, techniques and software for managing station metadata in support of

global change and variability research which can be widely used in Oceania. The major objectives of this workshop are:

- To introduce new techniques and software for metadata compilation, documentation and interpretation, and capacity building through training in software specifically designed for metadata information;
- Validation and updating of climate trends and variability that were analysed in the last two Oceania workshops;
- Exploration of how comprehensive climate data sets contribute to a regional climate information service;
- Preparation of a publication on metadata and climate trends as direct input into various national and international climate programmes, namely country environment reports, IPCC, WCDMP, WRCP, GCOS, CLIVAR and CLIPS;
- Improvement of capacity for methods of collating metadata information at the national level in Oceania;
- Continuation of collaboration on climate and variability throughout Oceania;
- Provide input into human dimensions programmes on climate change and variability (CLIVAR).

Dr Jim Salinger also presented an overview of previous work on climate change and variability in the South Pacific. This shows that surface temperatures have warmed by 0.5 - 0.8°C during the 20th century. The IPO causes climate shifts in the south west Pacific every 20-30 years which results in changes in the mean values of temperature and rainfall. The IPO alters teleconnections with ENSO between phases and the South Pacific Convergence Zone (SPCZ) moves its location on average. Understanding of observed climate change and variability in the region is essential for understanding global climate and provides critical information so as to improve modelling of climate on all time scales.

Regional and Global Overview

The World Meteorological Organization's Commission for Climatology statement of guidance on metadata and homogeneity was explained by Dr Tom Peterson (National Climate Data Center,NOAA,USA). A homogeneous climate time series is defined as one where variations are caused only by variations in climate. Good metadata are needed to ensure that the final data user has no doubt about the conditions in which data have been recorded, gathered and transmitted, in order to extract accurate conclusions from their analysis. For example, the knowledge of the exact date and time when a thermometer was replaced and the technical characteristics of the new and old instruments assists the removal of the non-climatic fingerprint of this change in that particular temperature record. High quality and homogeneous long-term datasets are needed to assess climate related issues. Meteorological data are influenced by a wide variety of observational practices. Data depend on the instrument, its exposure, recording procedures and many other factors. There is a need to keep a record of all these metadata to make the best possible use of the data. This guide will identify the minimum information that should be known for all types of stations, like, for example, location and measurement units. Additional information will be of great advantage for the data users, as well as for the providers.

Climate data can provide a great deal of information about the atmospheric environment that impacts almost all aspects of human endeavour. However, for these and other long-term climate analyses, particularly climate change analyses, to be accurate, the climate data used must be as homogeneous as possible. Unfortunately, most long-term climatological time series have been affected by a number of non-climatic factors that make these data unrepresentative of the actual climate variation occurring over time. These factors include changes in: instruments, observing practices, station locations, formulae used to calculate means, and station environment. Some changes cause sharp discontinuities while other changes, particularly change in the environment around the station, can cause gradual biases to develop in the data. All of these inhomogeneities can bias a time series and lead to

misinterpretations of the studied climate. It is important, therefore, to remove the inhomogeneities or at least estimate the possible error they may cause.

Many researchers have put a great deal of effort into developing ways to identify non-climatic inhomogeneities and then adjust the data to compensate for the biases these inhomogeneities produce. Several techniques have been developed to address a variety of factors that impact climate data homogenisation such as the type of element (e.g temperature, precipitation), spatial and temporal variability depending on the part of the world where the stations are located, length and completeness of the data, availability of metadata, and station density. Each team has developed a different philosophy regarding data adjustments since their requirements and missions have been quite different.

Metadata are important for putting observations into proper perspective, for understanding the biases that might be inherent in the observations. Therefore, metadata should be as complete as possible, as up to date as possible, and as readily available as possible (which generally means storing in digital form rather than relying solely on paper archives).

For placing current observations into an accurate historical perspective for climate change studies, the homogeneity of the data needs to be assessed. More specifically, inhomogeneities need to identified and dealt with. There are many approaches to dealing with inhomogeneities in the climate record. The best method depends on many factors such as the level of detail in the metadata, the human and computational resources available, and the parameters being assessed.

Henry Taiki (WMO) described WMO Region V (Southwest Pacific) efforts in the climate variability and change area. WMO has an emphasis on capacity building to meet Global Climate Observing System (GCOS), UN Framework Climate Change Convention (UNFCCC) and other requirements. It has four climate programs in the region (data management and monitoring, applications and services, impacts and response strategies, research). Each regional association meets formally once every four years with working groups operating in between. RA V (South West Pacific) met last in May 2002.

The process for the IPCC's Fourth Assessment Report (AR4) including capturing of regional information was outlined by Bureau member for the Southwest Pacific, Dr David Wratt (New Zealand). The three AR4 constituent working group reports are due for completion in mid-2007. The structure for the three constituent working group reports (chapter headings and subheadings) has been agreed upon, and a call has gone out to country focal points for nominations of experts to act as authors. For the three work group reports there are the following cross-cutting themes:

- Uncertainty and risk
- Integration of Mitigation and Adaptation (Part-1, Part-2)
- Article 2* of the UNFCCC and key vulnerabilities
- Sustainable Development
- Regional Integration
- Water
- Technology

- Article 2: stabilization of greenhouse gases in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system …

There are now opportunities to nominate IPCC Convening Lead Authors (CLAs), Lead Authors (LAs), Contributing Authors (CAs), Review Editors (RVs) and Expert Reviewers (ERs) from the Southwest Pacific, and nominations, especially for Pacific Island researcher participation were strongly encouraged.

The principles and actual practice of the Global Climate Observing system (GCOS) were explained by Dean Collins (Australia). The purposes of GCOS are for national commitments to secure sites for foreseeable future, build validated datasets based on international standard procedures, provide data to research community with no formal restrictions and create a base for denser national and regional networks. A number of best practises have been defined for the GCOS Surface Network:

- Ensure long-term continuity of site
- Undertake parallel observations for changes in observation regime

- Provide accurate and timely CLIMAT reports
- Undertake rigorous quality control
- Standard WMO site layout
- Regular inspections
- Maintain daily data and metadata archives
- Provide historical data and metadata to GSN archive

Within Oceania, network performance, in terms of the percentage of expected CLIMAT reports that are received, is close to the global average. Within the Pacific Islands, the Pacific Islands GCOS (PI-GCOS) Steering Committee will assist the improvement of GCOS performance as a PI-GCOS co-ordinator has been appointed. The Pacific Islands GCOS Implementation Team is being reconstituted with new terms of reference. The reconstituted PI-GCOS Steering Committee met in February 2004.

Mr Howard Diamond (NOAA, USA) in introducing the regional PI-GCOS data portal, re-emphasised the ten GCOS climate monitoring principles and gave an overview of the four GCOS monitoring networks for the surface, upper atmosphere, oceans and terrestrial observations. The Global Observing System Information System (GOSIC) provides access to data and information, and overviews of the structure and programs for the GCOS, the Global Ocean Observing System (GOOS), and the Global Terrestrial Observing System (GTOS). It is intended that the Pacific Island GCOS data portal from this will provide a Pacific Island information framework in support of many activities such as regional climate forecasting activities, historical data and metadata rescue, training and capacity building. It will be a framework for Pacific Climate data infrastructure.

Metadata Requirements for Climate Research

The general principles of metadata were outlined by Dr Blair Trewin (Australia). Metadata document how, where and under what conditions an observation is made. They assist the interpretation of climate records by helping to determine whether a record is homogeneous, and, if not, indicate the adjustments required. These inhomogeneities are caused by site and instrumentation changes, changes in

observation practice and in the environment surrounding observing sites. Sources of metadata include station files, metadata databases, manuals, diaries, newspapers and other archives, as well as personal knowledge. There has been limited digitisation of metadata with much available only on paper files making it hard to quantify. Undocumented personal knowledge is eventually lost over time.

Mr Ian Muirhead (Australia) and Mr Stuart Burgess (New Zealand) outlined metadata practices in Australia and New Zealand. Metadata covers the end to end process with equipment specification, site descriptions, observational practices, maintenance, climate quality control procedures and data holdings. There are also historical metadata held on voluminous paper files, circulars and published papers and on 35 mm film. Major modernisation commenced in the 1990s and metadata databases are being developed to meet a variety of requirements.

Ms Ashmita Gosai (New Zealand) introduced participants to the metadata compiler. One of the recommendations of the 2nd APN Workshop on Climate Trends and Variability in Oceania was the development of software to assist Pacific Island countries to compile their metadata resources. The compiler is a tool, that, as well as compiling and storing metadata, also allows assessment of the amount of data in paper and digitised form. The program was written using Visual Basic macros which run in MS-Excel. It is an efficient programme which can be run on a standard PC. The compiler facilitates storage of information digitally to minimize paper records and provide easy back up. The compiler has been specifically designed for small Pacific Island requirements.

Country metadata resources and facilities

Australia

Australian metadata are held in the SitesDB database, and are linked with the Australian Data Archive for Meteorology (ADAM), whose primary role is to store the data that comprises the Australian climate record. SitesDB amd ADAM are multi-table Oracle database, which has links to the metadata database. There are data for approximately 19,250 bureau stations and about 4000 others. The latter stations generally have poor metadata. It is planned that both the data and selected metadata will be available on the internet. This will provide an emphasis on metadata including station photos, site diagrams, station summaries, data availability (all elements), site moves and changes in station identification.

Cook Islands

Metadata exists for at least six climate stations. However, with automation there has been difficulties in recording climate data at most of the sites, except Rarotonga, owing to equipment outages.

Fiji

Fiji currently uses a CLICOM database to archive climate records. Of these, 191 stations have monthly records, and 150 stations have daily records. For monthly data, 60 stations have above 40 years of rainfall records, and 26 stations above 40 years of temperature data. The longest station records date back to 1886. For daily data, 51 stations have 40 years or more of rainfall data, and seven stations temperature data. More than half of Fiji's data remains to be digitised. Most of the data that have been digitised are monthly and daily data. The most common elements that are in digital format are rainfall and air temperature. The hard copies are in storage in Nadi. Other records exist with the Fiji Sugar Corporation and at agricultural research stations, with other data possibly archived in New Zealand (NIWA) and in the United Kingdom (UK Met Office), and Australian Colonial Sugar Refinery. Significant amounts of metadata exist in paper form.

French Polynesia

In French Polynesia there is a network of 8 manual climate stations, and five automatic weather stations; all of these except Atuona have the daily data digitised from the commencement of record except. There are 19 climate stations which are closed. There is a voluntary network of 81 climate stations, the majority of these recording rainfall throughout the islands. Of these, data have been digitised for 79 stations. Few data are not in the digital archive. However, metadata is scarce and this may be archived with Meteo-France in Toulouse.

New Caledonia

New Caledonia has 61 climate stations and 42 rainfall stations. Forty rainfall stations with at least 40 years of data and less than 4% of the data missing. The oldest record for Noumea dates back to 1860, although there is a lot of missing data from 1864 to 1900. For climate trends, Noumea, Koumac and Ouanaham are the most reliable, with no missing data or site changes from the 1950s or 1960. Much of the metadata has been lost because these were not archived. Measures have been started to reconstruct

all the metadata. These be reconstructed from other sources and paper archives. There is good information on site location and how the data were recorded, especially for the three reference stations (Nouméa, Koumac and Ouanaham), which have no site changes, good instrumentation and well trained staff. For other stations recording mainly rainfall, the main source of discontinuity is site changes which are in some cases known.

New Zealand

New Zealand holds paper metadata files for all open and closed New Zealand, Raoul Island, Chatham Island, Enderby Island, Campbell Island, and Antarctic stations. The files are held by NIWA climate and MetService meteorological station network staff, depending on station ownership. The paper files are comprehensive for each rainfall and climatological station and include station location map showing layout of instrumentation, trees, buildings, distances from, and panoramic photographs and notes on general station and instrumental exposure. These also include correspondence and notes on minor adjustment to instruments, such as gauge leveling and screen painting, and reports of malfunctioning or damaged equipment.

Significant historical New Zealand climate station metadata has been integrated into the Oracle climate database (>5000 stations) and details about station sites are constantly being added as the original paper files are retrieved for other purposes. These include information on station identification, site location and elevation, instrumentation installation, withdrawal, type, checks, faults, calibration and condition, observational history and practices, changes in location and exposure and a catalogue of data, by element, with start and end dates and data volume and percentage complete. Other resources include the South Pacific Historical Climate Network of Climate Station Histories, which include details of the 25 New Zealand WMO reference stations, having at least 50 years data, and representing good regional coverage.

Niue

Niue has two climate and three rainfall stations for monitoring trends. The longest, Alofi has records dating from 1905. Data is archived using CLICOM, which has been operational since 1995, and monthly climate forms have been stored in MS-Excel from 2003. There are some metadata records available from NIWA for Alofi.

Papua-New Guinea

There are 23 climate stations, of which 20 are operational; and 53 rainfall stations of which 48 are open. There are varying metadata records. Eight climate sites have records extending back at least 50 years, although many sites are comparatively recent.

Samoa

Samoa has 8 climate and 27 rainfall stations. The site with the longest record, Apia, has observations from 1890. Exposure is generally very good and maintained well. Instruments are just sufficient for present work but are not sufficient for future needs are not sufficient. Inspections have been regular for all climate and rainfall stations in the earlier days. The metadata and data for Apia are good until cyclones Ofa and Val occurred, when records were lost, and digitised data was lost due to CLICOM and PC failures. Recently some stations have been closed due to lack of operational funding (instruments/observers) and no replacements have been available for instruments. There are some observations which are questionable for some rainfall stations and observers need some training. With data sufficient quality control is required with PCs committed to data entry and analysis.

Tonga

The Tonga Meteorological Service has 7 synoptic stations which are also climate stations, and one rainfall station. Recently two synoptic stations have ceased reporting mainly due to staff shortages, leaving only five synoptic stations operational. Some old paper records and maps of metadata on some of the closed and open stations, but of very poor quality. Additions are being made to the digital record. The longest site, at Nuku'alofa, has more than 50 years of data with few gaps. The one rainfall stations is operated by a volunteer, and yielding good records.

Vanuatu

Vanuatu has two climate stations and another five which record rainfall. For both these climate sites the records have been digitised from the commencement of records in 1953 and 1961 respectively. Some metadata exists.

Climate Variability and Trends

Dr Jim Renwick (New Zealand) presented the latest research findings on El Niño - Southern Oscillation (ENSO) and the Interdecadal Pacific Oscillation (IPO), which are both very important in influencing tropical Southwest Pacific climate on annual to decadal time scales. These are both coupled ocean/atmosphere modes of variability, and they both affect the location of the South Pacific Convergence Zone (SPCZ). The time scales of variation relate to oceanic propagation. The SPCZ is located further north east with El Niño and the positive phase of the IPO, and more southwest in La Niña and the negative phase of the IPO. These features have related temperature and rainfall effects, and also modulate tropical cyclone occurrence. Increased rainfall in the north east of the region in the last 50 years, with decreases in the southwest has occurred. These trends have been a result of ENSO, IPO and long-term warming.

An update on climate trends in Oceania, past, present and future was presented by Dr Jim Salinger (New Zealand). An analysis of temperature variability and trends in the South Pacific, mainly in the twentieth century, using data from 40 island stations and optimally interpolated sea surface and night marine air temperature data was presented. The latter data set is new and contains improved corrections for changes in the height of thermometer screens as ships have become larger. The analysis shows that the SPCZ plays a pivotal role in both variability and trends in all three data sets. Variations in trends in the island and marine data show reasonable consistency, with distinctly different patterns of decade to decade change in the four regions. However, a notable inconsistency is the recent lack of warming in night marine air temperature in one of the tropical regions relative to sea surface temperature. Another tropical region near the South Pacific Convergence Zone shows recent strong warming in the island data but not in the marine data. Long records, of more than 50 years from tide gauges in the region confirm a trend of about 1.5 mm/year with annual and decadal variability strongly influenced by ENSO and the IPO. Recent research shows that heavy rainfall has increased in some parts of the Pacific, but has decreased in other parts.

Warm ENSO episodes have been more frequent, persistent and intense since the mid-1970s, compared with the previous 100 years ENSO consistently affects regional variations of precipitation and temperature over much of the tropics, sub-tropics and some mid-latitude areas). Current projections show little change or a small increase in amplitude for El Niño events over the next 100 years. Even so, global warming is considered likely to lead to greater extremes with an increase in the risk of droughts and floods than occur with ENSO events. Future climate projections show regional warming in the Pacific at a slightly lower rate of increase than the global average, with the tropical South Pacific near the equator becoming wetter, and areas more poleward

becoming drier. Impacts studies show that most Pacific Island countries have large coastal areas subjected to human pressure exacerbated by storm and wave action leading to erosion and land loss, inundation and wave overtopping and loss of infrastructure with coastal erosion is already a problem on many islands. The IPCC impacts report shows that many coral reefs are facing threats from both climate (bleaching) and non climate factors, and that rainwater and groundwater are susceptible to climate change and sea level rise. IPCC has concluded that sea level rise, and climate and environmental change risk destroying very important cultural and spiritual sites of some Pacific Islands. Finally the tuna fishery is very close linked to the position of the warm pool in the tropical Pacific.

Ms Georgina Griffiths (New Zealand) introduced participants to the Change Point methodology and software for trend analysis. This is a very useful technique to examine time series via a number of exploratory data tools. The Pettitt test has been developed into a simple Excel spreadsheet with tests for change points. Change points can indicate flaws in data or where data are not homogeneous. The test is "objective" and requires further analysis by reference to metadata and other information on how a series may have statistically altered over time. The interpretation of change points is subjective.

Climate Information and Society

The importance of traditional methods for observing weather in climate from Polynesian sources in Samoa was stressed by Pene Lefale (New Zealand). Long before the advent of complex numerical climate models, indigenous communities have used changes in their environment to predict changes in weather and climate. While these changes have been documented for many years using Western scientific techniques, little attention has been given to documenting traditional indigenous knowledge of weather and climate. Therefore, valuable insights are often missed. Research does show that Samoans have their own techniques of observing, monitoring and predicting weather and climate. Birds, hermit crabs, cockroaches, the Palolo "virides" (the worms, which swarms out from certain parts of the Samoan barrier reefs for three days in a course of a year), and other indigenous animals and plants are reliable 'bio-indicators' used by the Samoans as keystone tools to predict weather and climate conditions. Samoans also have their own seasonal calendar. Unlike the European calendar, which is based on astronomical events, the Samoan calendar is based on the observations of seasonal to annual environmental changes which are largely influenced by weather and climate. The ability and knowledge of indigenous people, as demonstrated by the Samoans, to predict the onset of weather and climate

conditions, particularly extremes, relying solely on local knowledge, expertise, and environmental changes, provides an invaluable tool to complement and improve scientific approaches to forecasting weather and modelling climate of the oceanic Pacific region.

The Schools of the Pacific Rainfall Climate Experiment (SPaRCE) rainfall monitoring project was described by Dr Mark Morrissey (USA). This is a cooperative field project involving local meteorological services, elementary, middle school, high school, college, and trade school students from various Pacific islands, atolls, and the U.S. The SPaRCE program (headquartered at the University of Oklahoma in Norman, Oklahoma) began in January 1993 with only a handful of Pacific schools. Since its implementation, the project has quickly grown. There are currently over 160 schools from approximately 22 different countries enrolled. Initially, participants are sent two direct-read, plastic rain gauges along with an instructional video tape and manual for placing, reading, and maintaining the rain gauges. A single-use camera is also sent out to make photographically document the rain gauge locations. Most of the SPaRCE sites are on small islands and atolls which have very little funding for computers or special projects. SPaRCE provides environmental education and enhancement of Pacific island science programs. In addition to the first workbook and video, five additional workbooks and videos addressing topics such as global climate, general weather, and Pacific regional climate are sent to participants. As participants progress in the program, they receive additional instrumentation, such as sling psychrometers and max-min thermometers, and other educational materials, such as science posters and science experiment kits.

Applications to Society

Dr Mike Hamnett (USA) described the activities of the Pacific ENSO Applications Center (PEAC), which was established in August 1994 as a multi-institutional partnership, to conduct research and produce information products on climate variability related to the El Niño - Southern Oscillation (ENSO) climate cycle in the U.S.-affiliated Pacific Islands (USAPI). Activities include work on the ENSO climate cycle, its historical impacts, and latest long-term forecasts of ENSO conditions, in support of planning and management activities in such climate-sensitive sectors as water resource management, fisheries, agriculture, civil defence, public utilities, coastal zone management, and other economic and environmental sectors of importance to the communities of the USAPI. This it does by workshops and briefings on ENSO and forecasting, country and territorial workshops, briefings for Government Offices, presentations at conferences with a focus on relationships with

extreme weather events. PEAC produces the Pacific ENSO Update, a bulletin established to promote research and produce information for the benefit of those involved in such climate-sensitive sectors as civil defence, resource management, and developmental planning in the various jurisdictions of the USAPI. The PEAC experience shows that climate analysis is useful to understand patterns, return periods, and analysis of impacts. Careful post-disaster impact assessment can improve response and mitigation planning, risk and vulnerability assessment.

Dr Eileen Shea (USA) highlighted the implications of climate variability and change for Pacific Island communities and discussed the challenges associated with effective communication and use of climate information to support decision making. In this context, Dr Shea introduced the concept of a Pacific Islands climate information system and some of the principles that are helping to guide the evolution of this collaborative, multi-institutional regional effort, including: Recognizing that climate and society are a single system with interactions and implications on a variety of timescales. Understanding and responding to changes in the climate-society system requires a partnership between scientists and users of climate information in government, communities and business. In turn, this partnership requires the establishment of a sustained process of interaction and dialogue that actively engages both decision makers and scientists in the identification of information needs, the assessment of climate risks and the development of solutions. Successfully enhancing the resilience of Pacific Island communities in the face of climate variability and change requires the creation of a new climate information system in which scientists and decision makers are partners in the development and application of climate information.

Ms Jan Sinclair (New Zealand), in discussing media communication, outlined that there have been many scientific reports on how better to communicate with the public. There are virtually none from the media on improving communication of science. Therefore if communication of science is to improve, the scientific community will need to advance this process. The media generally have little understanding of how the scientific process works. News media aim for balance, and this often leads to an inappropriately "equal" balance given to mainstream science and fringe or suspect views. There is a clear need for education of the media about the scientific process. Most decision-makers and most journalists have little scientific background. Many did not excel in science. Therefore media are often uneasy about approaching scientific information. The same is true of many policy advisers. Science sees its role as advising policymakers. It is important to note that policymakers and politicians pay close attention to the daily news media reports. The media play an important role in informing both policymakers and the general public on scientific issues.

Communication inevitably changes any information. What the producer of information understands is often dissimilar to that the receiver of the information comes to understand. There are many groups within "the public" and the media aim to attract the interest of as many groups as possible. Therefore media aim for open meanings that will appeal to as many groups as possible. This is quite different from science, which aims for precision of meanings. An active discussion session followed, which is summarised in Appendix 3. A questionnaire was distributed to participants at the beginning of the workshop. Analysis of this survey revealed a much higher level of media familiarity than that seen in larger surveys of scientists carried out in the United Kingdom and the USA. The apparently greater confidence and satisfaction from climate scientists may result from the fact that weather and climate are an everyday public concern. Therefore climate scientists are more likely to communicate regularly with the public, generally via the media. Climate science is not unfamiliar with involvement in public debate with global warming and climate change issues. Full analysis of the results are given in Appendix 4.

Synthesis

Dr Blair Trewin (Australia) outlined the last APN extremes workshop held in Melbourne. This updated the climate indices to 2001. Collation of information on data availability and data rescue and collated metadata was done in a consistent form. A paper has been submitted to the Bulletin of the American Meteorological Society. The work shows a general increase in hot days, and decrease in cold nights, with an increase in extreme rainfall in some parts of the Asia-Pacific region. The DARE project was also outlined. This focuses on management, preservation and use of climate data. DARE projects to preserve data and improve its accessibility are in progress in several parts of the world. Underlying principles include that data should be stored as image files onto media that can be regularly renewed to prevent the deterioration of the medium (cartridges, CDs, DVDs, etc); be stored already in computer compatible media so that data can be constantly migrated to storage facilities that conform to changing technologies; and should be key-entered in a form that can be used for analyses. The first step in data rescue is to collate information on what data are available, and their location. Some countries have fully digitised data from a certain date, others have many records that remain on paper. There are special digitisation projects in progress or completed in some countries. For metadata, a common form has been developed with metadata collected in this form for 87 stations, covering the bulk of the climate indices network. This could provide a template for international metadata exchange.

Challenges

There are a number of challenges and opportunities for compiling metadata, and analysing trends and variability. Challenges that were identified included:

Inadequate staff and funding resources. Particularly important in this category are education and training, staff recruitment and retention, funding of staff dedicated to climate activities and facilities. There are also concerns with Pacific Island trained staff leaving for employment in developed countries.

Historic data. Work is still required in most countries on digitising and archiving of climate data, and making it accessible. In some cases there is a lack of knowledge on the variety of data and where they are located. A better understanding and communicating benefits of sharing data, including the important connections between climate forecasts and data updates (with historic holdings) is required. Documentation, understanding, attribution and completing the records for climate change (GSN) reference stations is most important. Policies of cost-recovery, or corporatization of some national meteorological services present challenges in some places although historic data could be a special case for dispensation. It is important to examine opportunities for the expansion of data rescue and digitisation effort to include historic data holdings beyond the current NIWA archives to individual country holdings additional sites and additional parameters.

Observations and instruments. In the Pacific Island situation automated stations have been found to be unreliable for climate, and present, in the Pacific Island situation, maintenance and supply problems at remote sites with remote access, when outages occur. Sustaining voluntary observers is important, as well as computers, software, communications and internet access. Collection, quality control and maintenance of metadata are all issues, together with maintenance of a continual data supply.

Database. There is the requirement for a simple, easily maintained, user-friendly software and database system for small Pacific Islands, with appropriate training.

Assistance for Pacific Island Meteorological Services. Because of the importance of the Pacific climate system to global climate, there is a special role for the World Meteorological Organization to document benefits and represent Pacific Island countries, to convey the importance of supporting, in particular, GCOS within these countries.

Data integrity. Sharing of climate data currently presents a challenge for quality control at least.

Shared ownership of Pacific Island weather and climate services. This is a country, regional and international issue.

Opportunities

There are also a number of opportunities in the Pacific. Those identified include:

Data rescue initiatives. NIWA, NOAA and the Bureau of Meteorology have a number of initiatives for consideration under the various bilateral country climate partnerships.

Integration of traditional knowledge and practices. This provides the bridge between historical and contemporary information.

Partnerships. These can be enhanced with trusted information brokers such as media, NGOs, universities and other institutions.

Metadata. Attention to metadata provides opportunities for engaging local communities and non-government partners. It also allows establishment of effective dialogue and education and outreach on climate variability and change. By these means information requirements can be identified and understood, with opportunities to engage local historians, historical societies, national archives, and newspapers in the metadata and data recovery.

IPCC. Involvement in metadata and data analysis provides an opportunity for Pacific Island experts to become involved in the next IPCC assessment of climate change.

Regional climate service programmes. Data and metadata are part of the process of emerging of National and Regional Climate Centres.

Education and Training. Various initiatives are occurring including the APN funded Pacific Islands Training Institute on Climate and Extreme Events in Fiji, June 2004; developing PI-GCOS opportunities and the WMO-VCP programme. Secondments, internships, fellowships by way of two-way exchanges can provide capacity building as well as the engagement of decision-makers and users in training programmes.

Recommendations

The Workshop recognized the importance of historical climate data and associated metadata for documenting, understanding, anticipating and responding to climate variability and change. The Workshop participants similarly recognized the value that climate information provides to decision makers in all sectors of society and the importance of effective mechanisms for information dissemination and communication with various user groups. In light of this and in the context of the discussions at the 3rd APN Workshop on Climate Trends and Variability in Oceania (8-11 December 2003; Auckland, NZ), the Workshop:

1. Encourages creation of a simple, easily-maintained, user-friendly local climate database system that meets the needs of any small country. The Workshop acknowledges that initial development of such a system using readily commercially available platforms (e. g MS Access) has already begun in Samoa, and recommends that donor agencies consider support for the further development, demonstration and maintenance of such a system in the Pacific, including a strategy for database backup, and utilization of the GOSIC resource.

2. Recognizes that a complete archive of Global Synoptic Network (GSN) data for the Pacific would have significant national, regional and international benefits and encourages Pacific Island nations to complete their contributions to the GCOS surface reference network archive at World Data Centre-A.

3. Encourages pursuit of planned and proposed initiatives in the context of PI-GCOS for historic data rescue initiatives (prior to the modern period of digitization) to produce climate data that can be used by Pacific Island nations and the international research community. In addition to pursuing a number of funding opportunities highlighted at the Workshop, Pacific Island participants agreed to raise this important issue through their National Meteorological and Hydrological Services (NMHS's) at their earliest opportunity.

4. Recommends the digitization of paper records of climate data to prevent further deterioration or loss of these data resources by aging in situ, or destruction by natural disasters damaging the data archive. This would also make available these valuable data resources to the research community to address key issues on climate variability and extremes.

5. Recognizes the important opportunity that the IPCC Fourth Assessment Report (AR4) provides to assess climate change impacts and opportunities to enhance resilience in the region. The workshop encourages countries to actively participate in the IPCC AR4 process, including nomination of authors and reviewers and ensuring that Pacific Island data and issues are addressed in studies that contribute to the AR4.

6. Recommends enhancement of existing climate related education and training to improve the capabilities of Pacific NMHS's, government agencies, universities, research institutions and other users of climate information. This can be achieved through the development of university based curricula, focussed training programmes and development of educational materials relevant to Pacific Island nations by appropriate institutions in the region.

7. Recognizes that the media provide the public and policymakers with most of their information about climate, and encourages agencies to enhance collaboration with the media to improve the communication and understanding of climate information.

8. Recognizes the benefits of a more effective partnership between decision makers and the providers of climate information, and encourages the development of relevant and useable information. The workshop encourages the establishment of a sustained process of interaction and dialogue between climate scientists and decision makers in Pacific Island Governments, communities and businesses.

9. Recommends an evaluation of the APN sponsored workshops on variability and extremes and develop plans for future workshops including the identification of appropriate themes and the feasibility of venues in Pacific Island countries.

The *3rd Workshop* on *Climate Variability and Trends in Oceania* was organised by the National Institute of Water and Atmospheric Research (NIWA) with generous sponsorship from the Asia-Pacific Network for Global Change Research (APN) and the National Oceanographic and Atmospheric Administration (NOAA) GCOS Programme.

Appendix 1. Agenda

Monday 8 December

Introductory Session

0830-0900	Welcome – Dr. Rick Pridmore, Chief Executive Officer
0900-0920	Welcome and Overview of APN – Dr Linda Stevenson, Programme Manager, APN
0920-0930	Introduction and Confirmation of the Programme – Dr Jim Salinger, NIWA.
0930-1000	Overview of previous work on Climate Change and Variability in Oceania – Dr. Jim Salinger, NIWA.
1000-1020	Coffee Break

Session One: Regional and Global Overview

1020-1040	Discussion on WMO CCI statement of Guidance on Metadata and Homogeneity – Dr. Tom Peterson, NOAA National Climate Data Center, Asheville, USA.
1040-1100	The regional view – Mr Henry Taiki, WMO Sub-regional office for Southwest Pacific
1100-1120	Regional Information and Input for the Fourth IPCC Assessment Report – Dr David Wratt, NIWA
1120-1140	Global Climate Observing System (GCOS) principles and practice – Mr Dean Collins, Bureau of Meteorology, Australia
1140-1200	The regional GCOS data portal – Mr Howard Diamond, NOAA, Silver Spring, Maryland, USA
1200-1240	Lunch Break

Session Two: Metadata requirements for climate research

1240-1300	Metadata Assessment – Data about data – Dr Blair Trewin, BOM, Australia
1300-1320	Metadata practices in Australia – Mr Ian Muirhead, Bureau of Meteorology, Australia
1320-1500	Country reports on metadata resources and facilities
1500-1520	Afternoon Tea
1520-1630	Country reports on metadata resources and facilities

Tuesday 9 December

0840-0900	Overview on PEAC – Dr Mike Hamnett, PEAC
0900-0900	Traditional Methods of Observing Weather and Climate in Samoa and integrating traditional and western observation sources – Mr Penehuro Lefale, NIWA. (Presented by Dr Jim Salinger, NIWA)

0900-0920	The SPaRCE Rainfall Project – Dr Mark Morrisey, University of Oklahoma, Norman, USA
0920-1000	Climate Databases – Mr Stuart Burgess, NIWA and Mr Ian Muirhead, BOM
1000-1015	*Morning Tea break*

Session Three: Climate data analysis for metadata and trends

1015-1035 El Niño/Southern Oscillation (ENSO) and the Interdecadal Pacific Oscillation – Dr Jim Renwick, NIWA

1035-1055	A simple exploration of Change Points - Ms Georgina Griffiths
1055-1200	Participants explore Change Points with their climate data (Ms Georgina Griffiths, NIWA)
1200-1240	*Lunch Break*
1240-1300	Introduction to Metadata Compiler – Ms Ashmita Gosai, NIWA
1300-1430	Country Metadata Entry
1430-1500	Participants draft paragraphs on metadata
1500-1515	*Afternoon Tea break*
1515-1530	Recap on Trend Analysis – Ms Ashmita Gosai, NIWA
1515-1700	Participants update country data for trends

Wednesday 10 December

Session Four: Climate Information and Society

0830-0850	Climate Variability and Trends in the South Pacific – An Update – Dr. Jim Salinger, NIWA.
0850-1030	Participants continue updating country data for trends
1030-1050	*Morning Tea break*
1050-1120	Drafting of country text on metadata and trends for report
1120-1200	Draft report discussion and recommendations
1200-1300	*Lunch break*
1300-1330	Preparation of report

Session Five: Applications to Society

1330-1400	Pacific Climate Information System – Ms Eileen Shea, East-West Center, Hawaii, USA
1400-1420	Climate and the Media – Ms Jan Sinclair, The University of Auckland
1420-1500	Climate and Information dissemination – workshop discussion on the media – Discussion
1500-1520	*Afternoon Tea*

1520-1630	Development of a regional climate information plan for production of useful climate information for decision making – Discussion
1630-1700	Preparation of report

Thursday 11 December

Session Six: Synthesis of Metadata, Trends and Information Dissemination

0830 – 0910	4th APN Workshop on Climate Extremes – A Review – Dr Blair Trewin
0910-1000	Report discussion
1000 - 1030	*Morning Tea break*
1030-1130	Final workshop draft distributed to participants along with software and a copy of regional metadata (if agreed) on a CD
1130-1200	Future Steps and Closure of Workshop
1200-1300	*Lunch break*

Appendix 2. LIST OF PARTICIPANTS

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Appendix 3. DISCUSSION FROM APPLICATIONS TO SOCIETY SESSION

1. The media are unlikely to be proactive in improving communication of science, so it's up to science. The media probably will not organise a workshop on improving their coverage of scientific issues. But if scientists organise a workshop to explain how the scientific process works and discuss how to improve communication of science, the media will participate. The media generally hold science in some awe. Suggested techniques include flattering them by inviting them and asking for their advice, as well as explaining science's different processes and methods of communication. Enquire about their problems in communicating science and work with them to come up with solutions.

2. Television or radio news. At most 30 seconds will be used of what is said. It is advisable to prepare 15 second sound bites and not to cover the entire subject. Selection of two or three main points is important to be made briefly in simple, colourful language – sound bites. Rehearsal with a friend who is ignorant of the subject will allow development of the correct tone of information. Further aspects of the subject can be injected into the news on later dates – the drip-feed approach to information dissemination.

3. In any media interview, the scientist has control because they have the information that the media want. If only the sound bite is repeated, then that will be all that is on the tape. However, this should be used rarely and in situations of real difficulty. It is important to be cooperative and helpful in news media interviews.

4. Relationships with media. Journalists and scientists actually come from the same base: that of wanting to establish the best possible knowledge and information. Cultivation of relationships is important including informing them when there are items of interest, and providing updates with scientific developments.

5. It is useful to develop good relationships with particular journalists. However, there can often be a high staff turnover in media organizations. In those cases, it is useful to cultivate a relationship with the news editors or chief reporters. These people tend to stay in their jobs longer, and are the ones who give younger or more junior reporters guidance in their approaches to stories.

6. With enquiries from the tabloid media, where a particular incorrect viewpoint is commenced the question should be rephrased. 'To answer that question, you really need to consider THIS question' followed by an answer to the rephrased question. This will often be accepted because journalists are generalists. Most are acutely aware of their general lack of knowledge of the subject and are grateful for guidance from experts.

7. For questions outside an area of expertise pass the journalist on to the appropriate scientist. As journalists are operating under time constraints, they want all the answers from one person. But it is important to give guidance to the appropriate source to preserve credibility.

8. Closed and open statements: As science wants closed, precise statements and the media want open statements that will appeal to as broad as possible an audience, there is a paradox. Most news media want closure. A definitive statement of fact is sought, even though much of science is uncertain and involves consensus building. This presents an opportunity to explain the scientific process which involves collective agreement. Give the context: 'This is what most of us agree is the situation.'

9. There is a growing body of research showing that the public can in fact reach decisions about scientific issues that are remarkably similar to expert opinion. In the public domain, there is a process of collective wisdom, in which individuals discuss information with their networks of friends, consider the opinions of individuals or groups whom they trust, and come up with an understanding that is much deeper than the original individual understanding of any piece of information. This process is similar to the scientific process, and to the collective discussion processes of Pacific Island cultures.

10. Successfully enhancing the resilience of Pacific Island communities in the face of climate variability and change requires the creation of a new climate information system in which scientists and decision makers are partners in the development and application of climate information.

11. Establishment of a new climate information partnership, involving outreach, involving decision-makers requires consideration of what information decision-makers need, why they need it, and how best to deliver it. An understanding of who is going to use the information, and why they are going to use it is required.

12. Establishing such a climate-society partnership is an ongoing process involving sustained dialogue between scientists and decision makers so they can understand each others' problems and capabilities.

13. Delivery of information involves translating scientific information into useful and useable forms. Decision-makers require provision of climate information in a way that can assist local decisions and planning. This, in turn, requires access to comprehensible, relevant information in a form and format that can be easily integrated into existing decision making frameworks.

Appendix 4. RESEARCH ON SCIENCE AND THE MEDIA: QUESTIONNAIRE ANALYSIS

This research is based on a thesis has focused largely on the recent difficulties which one particular branch of science has faced in communicating with the public. It is apparent from the close analysis of reports on the UK "GM media storm" that biotechnology and the biological sciences were largely unprepared for what was actually a predictably opposed public reaction to GE products. However, unrelated and preliminary research carried out at the end of the thesis suggests that other branches of science may be more familiar with dealing with the media, and could perhaps contribute useful strategies and approaches to the enterprise of improving public understanding of science.

At a workshop of climate scientists held in December 2003 and organised by New Zealand's National Institute of Water and Atmospheric Research (NIWA) and the Asia-Pacific Network for Global Change Research (APN), with sponsorship from NOAA, a questionnaire and discussion involving 20 participants revealed a much higher level of media familiarity than that seen in larger surveys of scientists carried out in the UK and the US. The MORI survey of 1652 scientists in the UK found that 16 per cent had spoken to the media in the past year. Similarly, in the US, a National Science Foundation survey, carried out by the First Amendment Center, showed that nearly a quarter of the participants had never been interviewed or written about in a science news story, while 45 per cent had spoken to the media 'every few years'. In the much smaller survey of NIWA/APN workshop participants, 95 per cent had spoken to the media in the past year. The APN workshop climate scientists also appear to be more comfortable with talking to the media, and more satisfied with the resulting coverage. Ninety per cent were moderately or quite satisfied with news media coverage of information provided by them or their organisation. In their open-ended comments at the end of the questionnaire and in the following discussion, these participants also revealed a more informed approach to the media.

These climate scientists also appear to be more comfortable about talking to the media, and more satisfied with the resulting coverage, than the scientists surveyed by MORI and the First Amendment Center. It is difficult to compare responses from differently phrased questions, and this APN workshop sample is also too small to provide significant comparisons. However, the indications are interesting. While 36 per cent of the MORI respondents did not feel equipped to communicate social and ethical implications of their work to the public, none of the APN workshop participants replied 'not at all' when asked how comfortable they felt when talking to the media. Further, 90 per cent were moderately or quite satisfied with news media coverage of information provided by them or their organisation. In their open-ended comments at the end of the questionnaire and in the following discussion, these participants also revealed a more informed approach to the media. For example, several addressed the difficulties of translation.

As one participant commented, 'We try to provide information in simple terms, however, for them (media) to relay this to local languages is a problem.' They also showed a greater preparedness to recognise the differences between media and scientific processes, and the need for mutual understanding and trust. For example, in an open-ended response to the question about the reasons for scientific dissatisfaction with news media reports of their work, one participant added: 'Scientists' unfamiliarity with the systems and constraints within which the media work; scientists' lack of (or limited) experience working with media (and, thereby, establishing mutual trust)'.

These differences are very interesting. In part, the greater confidence and satisfaction from climate scientists displayed in this sample may stem from the fact that while many scientific fields have little direct contact with the public, weather and climate are an everyday public concern. Therefore climate scientists are more likely to communicate regularly with the public, generally via the media. As a general tenet, because weather and climate are an everyday public concern, climate science has always operated under public and media scrutiny, unlike the biotechnology and biological sciences which excluded the public from information about their research, and kept ethical considerations within their own field. Climate science is not unfamiliar with involvement in public debate. For more than ten years it has had to deal with the close and intense scrutiny of political interpretation and questioning of the science, as research into global warming and climate change has gathered pace. It is clearly outside the bounds of this analysis to investigate further similarities and differences between climate science and other fields of science. However, an area of possibly fruitful further research could be a comparison of experience and attitudes among different scientific fields. Another research possibility is to uncover strategies and approaches used by climate scientists, which could inform colleagues in other scientific fields.