SEVENTH MEETING OF THE PACIFIC METEOROLOGICAL COUNCIL (PMC-7)

"At the Frontline of Weather, Climate, Water, and Ocean Action in the Pacific"

17-19 September 2024, Warwick Le Lagon-Vanuatu Resort, Port Vila, Vanuatu

Agenda Item 10.4: Pacific Regional Climate Centre Network Update

Purpose:

1. To report on activities and achievements of the WMO RA-V Pacific Regional Climate Centre Network (RCC-N) since PMC-6;
2. Highlight the need to halt the decline in quality and quantity of climatological standard observations and recommend activities to address the decline.

Background:

1. The Pacific RCC-N, currently in demonstration phase, is a virtual Centre of Excellence that assists Pacific Island NMHSs deliver enhanced climate products and services and strengthens NMHSs capacity to meet national climate information and service delivery needs. All Pacific Islands and Territories that are members of the PMC are supported by the Pacific RCC-N (excluding the Australian and NZ Islands and US State of Hawaii). The RCC-N is made up of five nodes covering four mandatory activities (Long-Range Forecasting, Climate Monitoring, Operational Data Services and Training) and a highly recommended function, Climate Change.
2. The Pacific RCC-N management committee is operational and meets at a minimum, four times a year.
3. The management committee is made up of representatives from the node leads/co-leads and representatives from the PMC panels. The current representatives are: Simon McGree (Bureau of Meteorology, chair), Nihmei Salesa (SPREP), Leanne Webb (CSIRO), John Mara (NOAA), Moleni Tu'uholoaki (SPC), Ben Noll (NIWA), Arieta Baleisolomone (vice chair, PICS panel), Leonard Bale (PICI panel), Malaki Iakopo (PHS panel), Paula Acethorp (PIAWS panel), Zulfi Begg (PIMOS panel) and Ray Tanabe (PIETR panel).

Progress/Update:

1. **Amendments to the Pacific RCC-N Terms of Reference** (ToR). Several changes were made to the ToR at an RCC-N management meeting in Nadi, Fiji on 12 April 2024. The revised ToR is presented as Annex 1. Major amendments include:
   - the creation of a vice-chair role, with the aim that the vice-chair replaces the chair at the end of the chair's term. The purpose of the change is to ensure management continuity. Following the meeting, elections were held for the new role. Mr Ben Noll (NIWA) was appointed as the new vice-chair;
   - the Node for Climate Change projections has become the Node for Climate Change. Long-term climate change monitoring is now the responsibility of the Node on Climate Change (previously Node on Climate Monitoring).
   - node membership changes include NOAA becoming a member and co-lead of the Node on Climate Change. SPC is now a Node on Training Function co-lead;
   - membership and leadership requirements have been clarified. Any SPREP Member or Observer that is an NMHS or another institution which is a recognised entity producing climatological and/or ocean services with relevant expertise, technology, and capability is welcome to join the Pacific RCC-N as a new member at any time provided they meet requirements outlined in the revised ToR.

2. **Review of the Pacific RCC-N.** WMO and ClimSA consultant, Dr. Rupa Kumar Kolli, has produced a Report titled "Pacific Regional Climate Centre Network" Current Status and Way Forward", December 2023. Dr. Kumar *notes that on the whole, the Pacific RCC-Network currently serves as a clearinghouse for global as well as regional products and services, which needs to be slightly re-oriented to more actively generate and serve its own consolidated/optimized regional products. The assessment provides several recommendations to improve/strengthen each node of the Pacific RCC-Network and also the overall coordination and oversight. It also proposes an action plan to pursue these recommendations, both in the short term and the long term. While the Pacific RCC-Network appears to satisfy the essential requirements for designation in terms of the mandatory functions, there is a need for some reorganization of the presentation of their products to effectively demonstrate the same. A training cum technical coordination workshop is also considered to be crucial to work on*

the recommendations in a complementary manner. The Executive Summary of the Report is included as Annex 2.

3. **Development of a new website.** The tender for the development of the new website has been awarded to Phoenix Design Aid. The developers have produced a sitemap and wireframe. Over the coming weeks the developers will work with Pacific RCC-N members to determine website content requirements and begin developing the new website. This activity is funded by ClimSA;

4. **Pacific RCC-N designation application.** Partly drafted. Work on the application will continue when web development has been completed as the designation application depends heavily on the website as a product delivery tool;

5. **Pacific RCC-N logo.** A logo has been drafted and released in April 2024. The logo is presented as Annex 3. This activity was funded by ClimSA;

6. **Activity - Pacific Islands Climate Outlook Forum** (PICOF). Two PICOFs continue to be held per year. Changes to PICOF include amending Day-2 stakeholder engagement from single-theme sector engagement with national stakeholders to multi-sector engagement with regional representatives. The sectors are those identified in the Pacific Roadmap for Strengthening Climate Services. These include Agriculture and Food Security, Tourism, Water, Fisheries and Aquaculture, Energy, Disaster Risk Management and Health. Ideally, these representatives would attend PICOF every year with the sectoral 'expert' consequently supporting national climate outlook forums (NCOF) as and when required;

7. **Activity – Review of models/multi-model ensembles used to produce multi-week to seasonal outlooks.** SPREP has recently submitted a tender for this activity. The objectives include comparing and ranking hindcast skill of models that are used for rainfall, air temperature and sea surface temperature multi-week to seasonal prediction, determining which models/MME are used by NMHSs, their model/MME preferences and reasons for selection and determining if Pacific RCC-N member model/MME hindcast and near real-time verification information (including assessment method used) is publicly available for NMHS use. This activity will be funded by ClimSA;

8. **Activity – Second Pacific Islands Climate Change Forum (PICCF-2**). Under the auspices of the Pacific RCC-N Climate Change Node Pacific Island NMHSs, sector representatives and policy/decision makers will be invited/supported to attend the second PICCF in mid-late 2025 (TBC). Objectives include: to update and report out information in the 2021 Pacific Island Climate Change Monitor (PCCM) to NMHS and sector representatives, covering: Climate Observations; Observed Climate Impacts; and Climate projections and projected impacts and provide such information in a form that is accessible and useful to a wide variety of stakeholders in the public and private sectors as well as the education and scientific communities, thereby facilitating communication and informing decisions related to management, research, and education;

9. **Activity - Decline in the quality/quantity of observations from long-lived meteorological stations in the Pacific Islands.** A paper has been drafted as an activity under the Node on Operational Data Services (led by NIWA) which highlights the degraded state of many long-lived Pacific climate stations and illustrates why these stations are so important. The paper outlines the issues which have led to the degradation of the network and provide recommendations for remediation. The draft paper is presented as Annex 4.

   Data from long-lived meteorological stations underpin climate monitoring, research, and modelling at the national, regional, and global scale. They are critical to our understanding of past, present and future climate and to adaptive capability. Pacific Island Leaders have identified climate change as the single greatest threat to Pacific. Sectors such as health, agriculture, and water management are increasingly calling for high-resolution decision-making tools to inform climate resilient adaptation– without long-term, continuous, near complete records to validate and debias climate simulations, such tools are unreliable and useless.

10. **Activity – WMO Centennial Observation Stations.** Long-term meteorological observations are crucial in serving the needs of current and future generations for long-term high quality climate records. They are unique sources of past information about atmospheric, hydrologic and marine parameters, which serve as references for climate variability and change assessments. To highlight this

importance, WMO has a mechanism to recognise centennial observing stations to promote sustainable observational standards and best practices that facilitate the generation of high-quality time series data. The mechanism involves close collaboration between WMO climate, hydrology and marine, network and instrument experts, representing WMO Technical Commissions, the Global Climate Observing System (GCOS), Members and the WMO Secretariat. **There are currently no Pacific centennial stations**. RCC-N members can assist PMC members with the applications for designation. Further information can be obtained from https://wmo.int/centennial-observing-stations

Recommendations:

The Meeting is invited to:

- **Acknowledge** the ongoing work of the WMO Pacific RCC-N, which delivers enhanced regional climate products and services and strengthens NMHS capacity to meet national climate information and service delivery needs;
- **Request** BOM, NIWA, NOAA, University of Hawaii, CSIRO, APCC, SPC, SPREP, Meteo-France, USGS and UPNG as members of the Pacific RCC-N to note past pledges to support the functions of the Pacific RCC-N and ensure they continue to deliver core and where possible highly recommended functions ideally with programmatic/sustained resources;
- **Request** the PMC endorse the revised and improved Pacific RCC-N Management Committee ToR;
- **Request** the PMC promote the allocation of resources via national and regional projects with the aim to identify, refurbish, maintain and enhance meteorological observations from long-lived observation stations which are essential for the delivery of operational climate services and research;
- **Request** PMC members and observers to increase data sharing at national, regional and international levels (e.g. GTS/WIS) and request appropriate regional technical partners and organisations support NMHSs with this task with the aim of better understanding weather and climate in region, reducing vulnerability to weather, climate and ocean extremes and increase economic development;
- **Request** PMC members and observers consider the benefits of long-lived observation stations being classed WMO 'Centennial Observing Stations' and apply for designation as soon as possible;

- **Note** progress with reference to the application for RCC-N designation. The new Pacific RCC-N logo is available and work on the new website has commenced and will be completed as soon as possible. The designation application will be submitted to WMO as soon as possible, with designation ideally obtained before PMC-8;
- **Note** PICOF amendments which aim to include regional level climate-sensitive sector representatives in future PICOFs, to better identify potential impacts in the coming season and identify response strategies to potential impacts. This will be followed by regional sectorial experts supporting national representatives with preparations for the coming season.

Annex 1.

Pacific Regional Climate Centre Network Management Committee

Terms of Reference (as of 12 April 2024)

PREAMBLE

According to the Manual on the Global Data-processing and Forecasting System (WMO No. 485) the WMO RA V Pacific Regional Climate Centre Network (Pacific RCC-N), currently in Demonstration Phase (DP) comprises of four mandatory (Long-Range Forecasting, Climate Monitoring, Operational Data Services and Training) and Climate Change (node) as a highly recommended function, each led by one or two members with one or more consortium members.

MISSION AND OBJECTIVES

The mission of the Pacific RCC-N Management Committee is the coordination of the whole operation process aimed at the integration of actions and goals of each node and its contributing members in order to achieve common goals.

The committee objectives are to coordinate the Pacific RCC-N operation from planning, implementation, to monitoring of progress and follow-up of the activities. This includes the following activities:

- Maintain and update the Pacific RCC-N's Operating Plan where required,
- Oversight of the development of the Pacific RCC-N's products and services, organisation of regular Regional Forums of Users and Management Meetings,
- Monitoring the operation of the Pacific RCC-N, specifically for the support of member NMHSs, aiming for enhanced visibility and a strong role of the member NMHS,
- Foster the participation of Pacific NMHSs in existing partnerships and their contribution to the establishment of potential new private, public and academic intersectoral partnership and collaboration towards the achievement of Sustainable Development Goals, with a particular focus on SDG 13.
- Foster informal collaborations between nodes and/or consortium members
- Existing consortium members are encouraged uplift the capacity of NMHS or other institutions that indicate interest in becoming future consortium members.

COMPOSITION

The management committee is composed of Pacific RCC-N Node leads, PMC Panel chairs (or nominees) and a WMO representative with invited consortium members or other experts, as necessary members (Annex 1), led by the Pacific RCC-N chair and supported, as necessary, by the Pacific Met Desk & Partnership (PMDP). Contact details are given on the Pacific RCC-N home page https://www.pacificmet.net/rcc

The role of the chair and vice-chair, and composition of the management committee is reviewed biennially or as required. The chair can be rotated among the Node lead

institutions. The intention is that the vice-chair succeed the chair at the end of the chair's term.

MODUS OPERANDI

RCC Networks are Regional Specialized Meteorological Centres (RSMC) included in the Manual on Global Data Processing and Forecasting Systems (GDPFS). RCC Node leads and the Management Committee are required to work closely with the WMO bodies in charge of changes of RCC's functions, criteria and designation of RCCs as described in the Manual. The RCC Node leads and Management Committee will engage with the PMC and its panels to ensure the needs the NMHSs are adequately addressed.

Pacific RCC-N Management Meetings

- Such meetings should be held each quarter during the demonstration phase;
- Can be organised as physical, virtual or hybrid meetings;
- Be announced at least two weeks ahead;
- Be attended by the Pacific RCC-N Chair, and a majority of node leads and a majority of the PMC Expert Panel Chairs (Annex 1).

Pacific RCC-N Lead or Consortium members may raise an issue for discussion by the Management Committee in writing to the Pacific RCC-Network Chair, who will request the Management Committee convene as per the regular schedule or as out of session meeting.

The current Pacific RCC-N website and social media platforms will be used for communication, collaboration and information exchange. All Pacific RCC-N products are to include Pacific RCC-N branding.
Informal exchange within or among nodes members can be organised at any time without a formal procedure. Decisions relevant for the Pacific RCC-N are to be made at a Management Committee Meeting or by email or letter exchange with all Pacific RCC-N Management Committee members.

Results from Management Committee Meetings should be recorded in minutes and distributed to all members. The minutes should include all decisions and a list of all follow-up actions agreed upon in the meeting. All decisions and agreements of the Management Committee should be made unanimously on consensus basis.

INCLUSION OF NEW CONSORTIUM MEMBERS AND NODE LEADERSHIP

Any SPREP Member or Observer which is an NMHS or another institution which is a recognised entity producing climatological and/or ocean services with relevant expertise, technology, and capability is welcome to join the Pacific RCC-N as a new member at any time. The high level principles of engagement include:

1. servicing the climatic and oceanic information needs of NMHSs in the region and associated user community;
2. producing products and/or services which are novel and add value to the existing suite of products and services;
3. producing products and/or services that are consistent with WMO guidelines;
4. actively advocating for and supporting the governance of the RCC-N;
5. agreeing to provide their products and services in an open access manner;
6. contributing mandatory and/or highly recommended products to one or more nodes as defined by the WMO and/or PMC;
7. contributing products and/or services for the whole Pacific RCC-N region or sub-region (two or more countries/territories)

The request for admission must be approved by the Permanent Representative (or designated authority where a Permanent Representative does not exist) of the member host country. The decision of inclusion of new consortium members is to be made by the Management Committee unanimously. After approval the manual on the GDPFS (WMO-No. 485) should be amended accordingly.

Application for admission involves sending the chair of the Pacific RCC-N Management Committee an email or letter requesting admission. The letter should include details on the product or service the proposed member wishes to contribute and the node they wish to join. The chair will present the application for admission at the next Management Committee meeting. Following the meeting the chair will notify the applicant of the Management Committee decision in writing.

All new members including existing members are required to self-support their contributions to the Pacific RCC-N ideally via core funding. Delivering ongoing products and services via short-term projects is discouraged.

Nodes of the Pacific RCC-N are required to have lead or co-leads and meet at least once a year. To be a node lead or co-lead, the member(s) are required to produce a substantive majority of the functions associated with the node for a majority of the

RCC-N region. The node lead(s) are to be elected by node consortium members. Node lead(s) and composition of the node is to be reviewed biennially or as required.

The current composition of the Pacific RCC-N is

Node Title	Lead Agency/Co-Lead	Consortium members
Node on Long-Range Forecasting	NIWA & BOM	Meteo-France, NOAA, University of Hawaii, APCC, SPREP & SPC
Node on Climate Monitoring	NOAA & University of Hawaii	BOM, SPC, SPREP & NIWA
Node on Climate Change	CSIRO & NOAA	USGS, BOM and SPREP
Node on Operational Data Services	BOM	NOAA, University of Hawaii, SPC & NIWA
Training Function	SPREP & SPC	NOAA, University of PNG, BOM & NIWA

LEAVING THE CONSORTIUM

Any Pacific RCC-N member can leave the network voluntarily at any time without further obligations. The end of the membership needs to be documented by email or letter from the corresponding Permanent Representative to the chair of the Pacific RCC-N Management Committee. The manual on the GDPFS (WMO No. 485) needs to be amended accordingly.

Annex 2.

Pacific Regional Climate Centre Network: Current Status and Way Forward

Report by Dr Rupa Kumar Kolli, December 2023

EXECUTIVE SUMMARY

This assessment is in support of World Meteorological Organization (WMO) contributions to the ClimSA programme, which has a major thrust in strengthening the Regional Climate Centres (RCCs) in the ACP regions. RCCs constitute key entities in Climate Services Information System (CSIS), one of the foundational pillars of the Global Framework for Climate Services (GFCS), based on the fundamental concept of cascading information from global to regional to national scales. Recognizing that many countries share common regional climate drivers, there is an enhanced focus on a regional approach for CSIS operations, and it is critical that RCC operations are closely aligned with the overarching CSIS functions. The Pacific RCC-Network, which is currently in demonstration phase to seek formal WMO designation, has been the central player in the implementation of CSIS in the Pacific Islands region in support of the National Meteorological and Hydrological Services (NMHSs) of the Pacific Islands. This document is in support of the delivery by WMO, under the ClimSA Programme, guaranteed and secured provision of climate services at regional and national levels through a strengthened CSIS at the regional levels. This document also informs the development of an action plan for WMO to support the enhancement of RCC capacities to deliver climate services to the NMHSs in the Pacific region and other relevant stakeholders.

The establishment of several strategically located regional centres, in particular, will allow the tailoring of global climate products to meet regional needs on a sustainable operational mode, and also in supporting national requirements where needed through mutual arrangements. Making regional implementation a first priority will give countries that need help the most access to initially available products and services in the short term, while the longer-term efforts to build their national climate capacity and capability are described, funded and accomplished. It will also allow for regions that need support to deliver on regional needs in the short to medium term to benefit from interregional cooperation with designated RCCs in the neighbourhood or twinning with a global centre, while long term effort to develop regional capacity gradually materializes. A regional approach to CSIS operations is increasingly being recognized as an effective and sustainable pathway to strengthen climate services. There are already some early successes in the ACP regions, which need to be further strengthened and upscaled to fulfill the ClimSA vision.

At the regional level, RCCs or similarly mandated regional institutions play the key role, including through collaborative mechanisms such as Regional Climate Outlook Forums (RCOFs), which are now proposed to expand their portfolio of products beyond seasonal outlook and evolve into Regional Climate Forums (RCFs). RCCs, including through their mandatory function on operational data services and highly recommended function on non-operational data services can assist in regional data coherence, and develop regional climate data sets for regional climate monitoring and prediction activities. Such data sets will enable the RCCs, with active participation of the NMHSs of the respective domains, to optimize the global-scale products (including reanalyses, sub-seasonal to decadal climate predictions and climate change projections) to the region of interest, by carefully evaluating model skills and MME approaches to maximize skills for the region of interest. RCCs can also support verification of the various forecast products on the regional scale. RCCs also have a highly recommended function on climate change projections.

Based on an implementation plan (IP) developed under the auspices of WMO Regional Association V (RA V, South-west Pacific), the demonstration phase of the Pacific RCC-Network was initiated in September 2018. A Pacific RCC-Network website was also established within the PMC website, with provision for the Node Leads to post their contributions to the Pacific RCC-Network operations.

The Pacific RCC Network in its current structure consists of five nodes. Each node is composed of a consortium with a lead institution or co-leads:

- Node on Long-Range Forecasting:
  - NIWA & BoM (co-leads)
  - Meteo France, APCC, NOAA, UH, SPC and SPREP (consortium members)
- Node on Climate Monitoring:
  - NOAA & UH (co-leads)
  - BoM, SPC, SPREP and NIWA (consortium members)
- Node on Operational Data Services:
  - BoM (lead)
  - NOAA, UH, SPC and NIWA (consortium members)
- Node on Training:
  - SPREP (lead)
  - NOAA, UPNG, BoM, NIWA, SPC, USP and CSIRO (consortium members)
- Node on Climate Change Projections:
  - CSIRO (lead)
  - USGCRP, BoM and SPREP (consortium members)

PMC's PICS Panel provided leadership to progress the implementation of the RCC initiative and other decisions taken by the PMC. The PICOF has been slowly moving towards being led by the Long-Range Forecasting (LRF) Node of Pacific RCC-Network. The sixth meeting of the Pacific Meteorological Council (PMC), in August 2023, has established Pacific RCC-Network Management Committee (MC) with the overarching mission to coordinate the whole operation process aimed at the integration of actions and goals of each node and its contributing members. With the three layers of formal regional oversight under the RA V and PMC, it can be stated with confidence that the Pacific RCC-Network has excellent governance arrangements, probably one of the best in WMO RCC/RCC-Network implementation in the world.

The present assessment is based on a detailed review of the Pacific RCC-Network as evidenced from their official portal, publicly available documents from WMO and other sources, and also through the available responses to a comprehensive survey questionnaire distributed to all the node leads and consortium members.

A major advantage that the Pacific RCC-Network has is the commitment and support from a large number of advanced climate centres leading its nodes and also supporting as consortium members. All the node leads and consortium members have adequate technical capabilities and have longstanding commitments to support Pacific RCC-Network operations. However, their resource dependence on limited-term projects for RCC-Network operations is evidently substantially high, which can have some implications for sustainability. There is a wide range of products available through the Pacific RCC-Network far beyond those required for designation purposes. There is a mix of operational arrangements within the host institutions to support RCC-Network operations and dependence on current leadership, but this is unlikely to pose a significant risk for sustained operations in the near term. That said, it is noted that monitoring and evaluation processes are weak if not inexistent, and need to be strengthened to objectively determine the operational status of the RCC functions and the responsibilities of the multiple stakeholders and to identify gaps that need to be addressed. Pacific RCC-Network also needs to facilitate better coordination and complementarity among the various hosts and also the NMHSs. Pacific RCC-Network is unique in terms of the expectations of NMHSs for a one-stop shop for all the climate information products needed for climate services at the national level, which can be an advantage in standardizing and mainstreaming the use of their products in NMHS operations, and at the same time can be a challenge to be able to adequately meet the expectations. Concerted efforts may be made to fully engage the NCFPs to facilitate

mainstreaming the use of Pacific RCC-Network products and services by the NMHSs, and also obtain the necessary national inputs and feedback to improve RCC operations;

- Pacific RCC-Network website needs to be improved, both in terms of the organization of the products, and also to make the mandatory functions/products better visible
- Given the multiple sources of information, Pacific RCC-Network Node Leads may pursue development of consolidated regional products;
- Some of the suggestions for improvement may need additional work only in the initial stages, and may not impose substantial burden on the hosts for maintaining the operations;
- Outreach efforts are needed to raise awareness of NMHSs about Pacific RCC-Network products and services and encourage them to mainstream their use in national climate service operations.

On the whole, the Pacific RCC-Network currently serves as a clearinghouse for global as well as regional products and services, which needs to be slightly re-oriented to more actively generate and serve its own consolidated/optimized regional products. The assessment provides several recommendations to improve/strengthen each node of the Pacific RCC-Network and also the overall coordination and oversight. It also proposes an action plan to pursue these recommendations, both in the short term and the long term. In the short term, the Pacific RCC-Network should put together a status report to seek formal WMO designation. While the Pacific RCC-Network appears to satisfy the essential requirements for designation in terms of the mandatory functions, there is a need for some reorganization of the presentation of their products to effectively demonstrate the same. A training cum technical coordination workshop is also considered to be crucial to work on the recommendations in a complementary manner.

Annex 3.

Vertical logo

Horizontal logo

ELEMENTS

Sun
Represents life and known to typify energy, power, positivity, and clarity

Tropical Cyclone/Wave
The most obvious hazards in the region

Coconut Tree
Symbol of the Pacific and resilience

PACIFIC REGIONAL
CLIMATE CENTRE NETWORK

Annex 4.

August 2024

Deline in Climate Observations in the Pacific Islands

Urgent action required to restore long-term Climate Stations

Information Paper

ATTN: Members of the Pacific Islands Climate Services (PICS) Panel of the Pacific Meteorological Council (PMC)

Prepared by: Molly Powers-Tora[1], Shane O'Neill[1], Simon McGree[3], Alan Porteous[1], Andrew Harper[1], Ben Noll[1], Andrew Tait[1], William Wright[2], Anuragh Chandra[1], Terry Atalifo[3], Siosinamele Lui[3]

[1] *National Institute of Water and Atmospheric Research, Wellington/Christchurch/Auckland, New Zealand*
[2] *Australian Bureau of Meteorology, Melbourne, Australia*
[3] *Secretariat of the Pacific Regional Environment Program (SPREP), Apia, Samoa*

Purpose

The purpose of this paper is to highlight to the World Meteorological Organization (WMO) via the Pacific Regional Climate Centre Network (RCC-N) and Pacific Meteorological Council (PMC) via the Pacific Island Climate Services Panel concerns within the region regarding the degraded state of meteorological observations in the Pacific and to advocate for the formal establishment of regional and national Climate Reference Station (CRS) Networks and investment in these networks under Weather Ready Pacific, SOFF, COSPPac, ClimSA, and other regional initiatives. A well-maintained, sustainable, and adequate network of climate reference stations underpins many of the goals endorsed by the programs noted above, is critical to regional and global climate models, and allows Pacific National Meteorological and Hydrological Services (NHMSs) to better meet stakeholder requests for climate data and products (e.g. design rainfall for road and building construction, solar radiation for renewable energy projects and evaporation for agriculture research projects).

Background

CRSs serve as a cornerstone for climate monitoring, research, and decision-making processes. Multi-decadal, near-complete data records are essential for accurately assessing trends, variability, and extremes in climate parameters critical for understanding and mitigating the impacts of climate change. High-quality station records also contribute to calibrated climate predictions and downscaling of climate change projections.

CRSs are part of the Global Climate Observing System (GCOS) [1]. GCOS was established in 1992 and its main aims are to:

- Monitor the climate system;
- Detect and attribute climate change;
- Assess impacts of climate variability and change, further supporting adaptation measures;
- Aid economic development,
- Further support research to improve understanding, modelling, and predication of the total climate system.

Prior to this, the World Meteorological Organisation (WMO) in 1986 published guidelines on the selection of reference climatological stations (RCSs) from the existing climatological station network.[2] The purpose of this was to establish a Reference Climate Data Set. The focus of this network was stations that met certain criteria including, but not limited to:

- At least one observation per day of temperature and precipitation;
- Be permanent;
- Be preferably located in an environment unaffected by densely populated or industrialized areas;
- Have trained observers, reliable instruments and be subject to regular inspections and technical servicing;
- Have long records;
- Have few significant relocations, changes of observing times, instruments and exposure, or observing techniques;
- Be subject to careful quality control;
- Measure at a minimum, mean temperature (preferably including maximum and minimum) and precipitation.

GCOS further defines Essential Climate Variables (ECVs) which are a group of linked climate variables that help characterise the Earth's climate. GCOS currently defines 55 ECVs[3] which contribute to:

- Understanding and predicting the evolution of the climate;
- Guiding mitigation and adaptation measures;
- Assessing risks and enabling attribution of climate events;
- Aiding in the delivery of climate services.

The ECVs are spread across three main domain areas, Atmosphere, Land and Ocean. Atmosphere is further subdivided into Surface, Upper-air, and Atmospheric Composition. A typical climate station will measure the six Surface ECVs:

[1] The 2022 GCOS Implementation Plan (GCOS-244) (wmo.int)

[2] Guidelines on the selection of reference climatological stations (RCSs) from the existing climatological station network (WMO/TD-No. 130)

[3] https://gcos.wmo.int/en/essential-climate-variables/table

- Precipitation
- Temperature
- Pressure
- Radiation budget
- Water vapour (relative humidity)
- Wind speed and direction

GCOS works closely with National Meteorological and Hydrological Services (NMHSs) in each partner country to support the maintenance and sustainability of the system. However, without a robust observing system that accurately and consistently maintains the reporting of ECVs, delivering targeted support to states vulnerable to climate variability and change impacts may be severely hindered. Beyond targeted support being negatively impacted by non-reporting of ECVs, the overall effort carried out by the UN Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC) may also be undermined. In the IPCC Sixth Assessment Report, small island states, including the Pacific Islands, were highlighted as highly vulnerable to observed climate change to date [4]. Without continued reporting of climate observations, climate change mitigation efforts become difficult to support due to a lack of science-based findings.

In 1997, a GCOS Surface Network (GSN)[5] was designed with the purposes:

- To establish national commitments for the preservation of a set of valuable climate stations for the foreseeable future;
- To build a collection of validated data from these stations in standardized formats;
- To provide this information to the global climate community with no formal restrictions;
- To create a baseline and benchmark data set for more enhanced regional and subregional climate networks and for newly-developed observing systems, including remote-sensing systems.

In 1999, COP-5 adopted ten basic principles commonly known as the GCOS Climate Monitoring Principles[6].

1. A suitable period of overlap for new and old observing systems is required.
2. The details and history of local conditions, instruments, operating procedures, data processing algorithms and other factors pertinent to interpreting data (i.e., metadata) should be documented and treated with the same care as the data themselves.

[4] Mycoo, M., M. Wairiu, D. Campbell, V. Duvat, Y. Golbuu, S. Maharaj, J. Nalau, P. Nunn, J. Pinnegar, and O. Warrick, 2022: Small Islands. In: *Climate Change 2022: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 2043–2121, doi:10.1017/9781009325844.017.

[5] https://library.wmo.int/records/item/48325-guide-to-the-gcos-surface-network-gsn-and-gcos-upper-air-network-guan

[6] https://gcos.wmo.int/en/essential-climate-variables/about/gcos-monitoring-principles

3. The quality and homogeneity of data should be regularly assessed as a part of routine operations.
4. Consideration of the needs for environmental and climate-monitoring products and assessments, such as IPCC assessments, should be integrated into national, regional and global observing priorities.
5. Operation of historically-uninterrupted stations and observing systems should be maintained.
6. High priority for additional observations should be focused on data-poor regions, poorly observed parameters, regions sensitive to change, and key measurements with inadequate temporal resolution.
7. Long-term requirements, including appropriate sampling frequencies, should be specified to network designers, operators and instrument engineers at the outset of system design and implementation.
8. The conversion of research observing systems to long-term operations in a carefully-planned manner should be promoted.
9. Data management systems that facilitate access, use and interpretation of data and products should be included as essential elements of climate monitoring systems.

WMO recommendations for parallel measurements vary. Ideally a period of 24 months for air temperature and 60 months for rainfall is suggested when transitioning from manual to automated observations (WMO-No. 1202)[7], however the Guide to Climatological Practices[8] is more pragmatic recommending "at least one year, and preferably two or more years".

In the 2022 GCOS Implementation Plan[9], several key actions were highlighted, including the sustainability of in situ observations of ECVs to be achieved via long-term funding. It was noted in the report that continuity of observation reporting was hindered by short-term funding and investment in systems. Short-term funding jeopardises the overarching aim of developing long-term records of ECVs which in turn impacts the success of GCOS' main aims. It was also found in the report that data gaps for ECVs is consistently deficient over certain regions, including the Pacific Island region.

Since the time of inception, technology implemented across the GCOS network has improved. Further to technological advancement, the governance and structure of the GCOS network has also developed. The World Meteorological Organisation (WMO) Integrated Global Observing System (WIGOS [10]) was introduced in the late 2010s, becoming fully operational in 2020 as the new overarching framework for all WMO observing systems. GCOS, along with WIGOS, in the past have focussed on gaps in climate observation systems in Pacific Island states.

[7] https://library.wmo.int/records/item/55812-challenges-in-the-transition-from-conventional-to-automatic-meteorological-observing-networks-for-long-term-climate-records (WMO-No.1202)

[8] https://library.wmo.int/records/item/60113-guide-to-climatological-practices (WMO-No.100)

[9] library.wmo.int/viewer/58104/download?file=GCOS-244_2022_GCOS_Implementation_Plan.pdf&type=pdf&navigator=1

[10] https://community.wmo.int/en/activity-areas/WIGOS

Current Situation

Not all Climate Stations are part of the GCOS network.. Stations in Figure 1 represent the availability and reporting of surface land observations in the past month (data obtained March 2024 from the WIGOS Data Quality Monitoring System [11]). Of the 66 stations present in the PCRSN, only:

- 58% are reporting greater than 80% of observations collected (considered normal operation);
- ~ 30% have report availability issues, with ~ 24% reporting between 30% and 79% of observations while ~ 6% are reporting less than 30% of observations;
- ~ 12% of stations are did not report any observations in the past month.

While these statistics are helpful in demonstrating the reporting status to GCOS, it should be noted that these do not necessarily indicate that a station is faulty or in disrepair. They simply indicate if a CLIMAT message has been sent, and received, as stated in the registered station metadata in OSCAR/surface.

These stations, as described by the main aims of GCOS, are used to monitor ECVs to enable understanding and predicting the evolution of the climate, informing mitigation and adaptation measures, assessing risks while enabling attribution of climate events, and aiding in the delivery of climate services. Without the maintenance of long term reporting of reference climate observations and ensuring acceptable standards of reporting, the main aims of GCOS and many other climate mitigation and adaptation programs in the Pacific will be undermined.

[11] WDQMS (wmo.int)

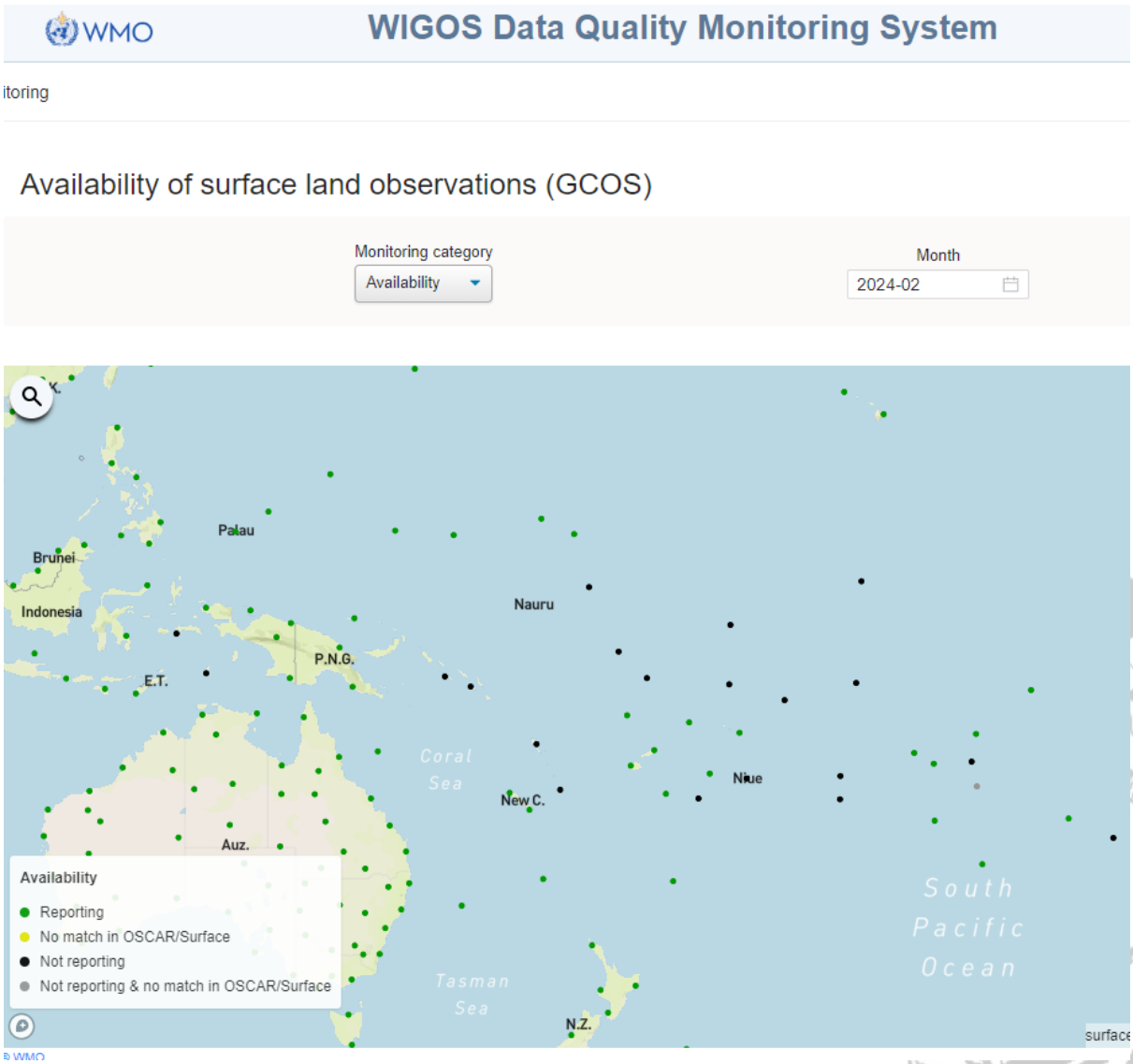

Figure 1: Climate stations across the Pacific Island region which are part of the WIGOS network. The state of reporting of Essential Climate Variables at each station is highlighted and colour coded.

The data collected from climate stations support climate research and understanding trends in key ECVs. For example, Figure 2 shows the annual maximum temperature (non-homogenized) recorded at Nadi Airport, Fiji, since the station installation in 1942 to 2020 (obtained from the Pacific Climate Change Data Portal (PCCDP) [12] hosted by the Australian Bureau of Meteorology). A linear trend in temperature of around 0.04° C per decade is observed. Such data, when collected accurately and completely, can help identify trends in ECVs and aid in climate change attribution studies or in decision-based tool development for adaptation and mitigation activities.

[12] Pacific Climate Change Data Portal (bom.gov.au)

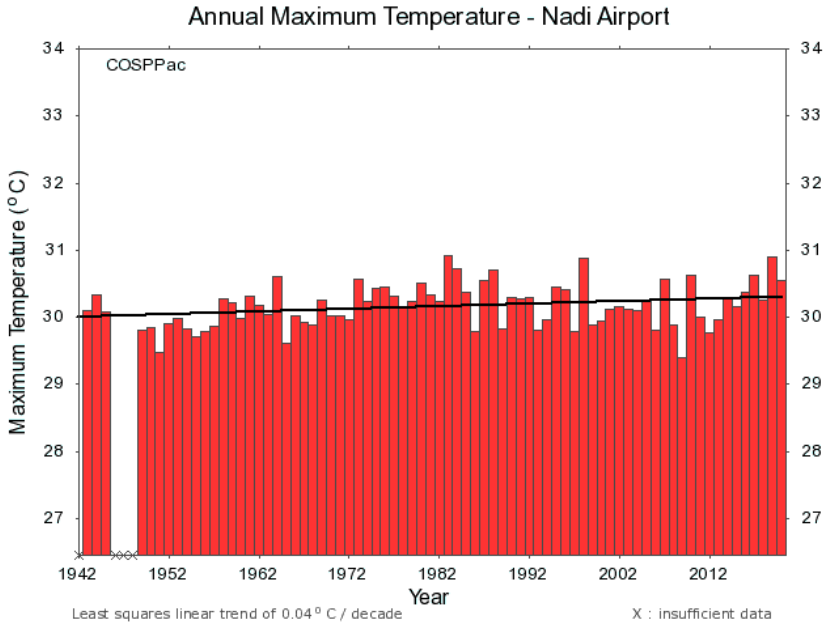

Figure 2: Annual maximum temperature (raw) data collected from the Nadi Airport station in Fiji. Included is a linear trend fit obtained by a least squares method.

While the example of Nadi Airport raw temperature record appears complete up to 2020, other stations in the PCRSN have significant data gaps in the records. An example is shown in Figure 3 at Udu Point, Fiji, where significant gaps in the annual maximum temperature record is present. Note: the PCCDP requires all months of the year to be present and monthly totals/average to have no more than five missing days.

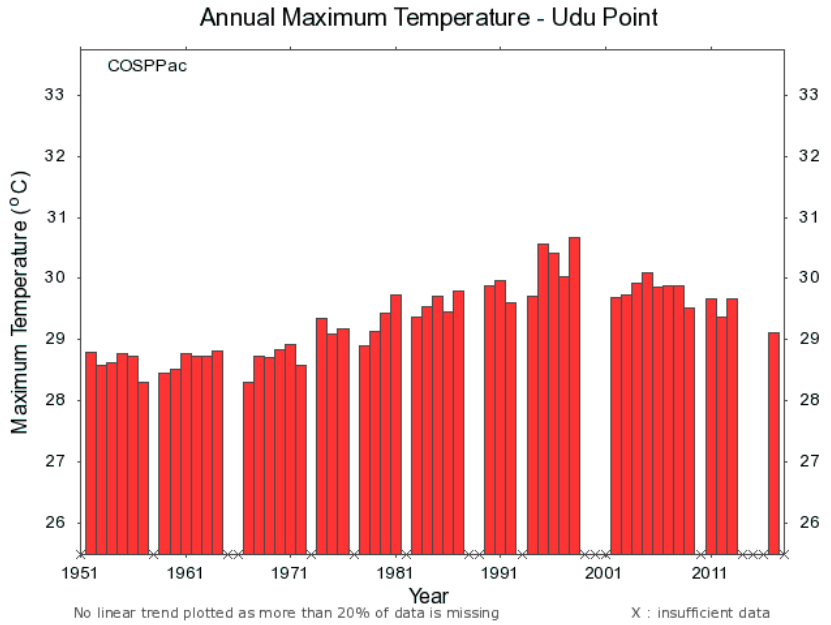

Figure 3: Annual maximum temperature (raw) data collected from the Udu Point station in Fiji. No linear fit by a least squares method is achievable due to a lack of data.

A linear trend of annual maximum temperature is not shown here due to there being greater than 20% of the data (complete years) missing. The importance of reporting and reducing data gaps in ECV observations is clearly highlighted in this example. The lack of a robust and consistent reporting of ECV observations hinders the ability to develop robust, accurate information regarding the impact of climate change. Missing data makes it difficult to obtain a clear picture of the climate evolution from observations, and this results in large uncertainty in applying decision-support tools.

Reasons for suspect/failed reporting/missing observations

Suspect, failure to report, or a rate of reporting below normal operation, of observations collected at climate stations throughout the Pacific region may be due to several factors. These include, but are not limited to:

1. E **quipment change/replacement**
    a. Transition from manual to Automatic Weather Stations (AWSs). During this transition, observations may not be collected due to non-registration of the station, station downtime, lead-in time for the training of NMHSs staff in best practice reporting, technical and calibration issues with AWSs.
    b. New regulations have been adopted by the WMO regarding weather station apparatus. With the banning of maximum thermometers due to their use of mercury and subsequent environmental and human health impacts [13], many challenges have been faced in transitioning to automated observations[14], such as the need to install data loggers and associated telemetry equipment; consistency of practice; maintenance and calibration; spike filtering, time sampling and other algoritms.
    c. Delays in obtaining replacement equipment can also result in suspect observations or gaps in a record. Many Pacific NMHSs hold limited to no spares so when an instrument is faulty , a parameter continue to be observed from a suspect instrument or may not be observed until the replacement is received. The issue is compounded when forced transition to automation (1b) applies.
    d. Local regulations can also affect observations for example limited availability and high cost of high quality hardwoo d has resulted in lower quality wood being used for Stevenson screens (which have a shorter life) and the transition to plastic screens.
2. **Change in observation site or surroundings**
    a. Changes in an observation site or in the environment surrounding a site (e.g. construction new buildings, increased overgrowth, or other obstruction of the

[13] Homepage | Minamata Convention on Mercury

[14] https://library.wmo.int/records/item/55812-challenges-in-the-transition-from-conventional-to-automatic-meteorological-observing-networks-for-long-term-climate-records (WMO-No.1202)

observation site) can negatively impact the quality and continuity of climate measurements.

b. Any site relocation should be minimised if possible, or if unavoidable, parallel observation at old and new sites should be planned for the recommended duration to ensure continuity of climate measurements.

c. Urban warming could already and will increasingly become an issue in the more densely populated Pacific cities.

3. Maintenance issues

a. The high percentage of stations with observation capability issues, or failing to consistently report observations, may in part be due to the lack of maintenance of the equipment. Lack of maintenance, and instrumentation malfunction, along with poorly calibrated instruments, have been observed widely across the network. This is a greater issue with automated instruments which require more frequent maintenance/calibration than traditional instruments.

4. Resource allocation

a. Automated observations do not simply mean fewer staff are required, but instead the requirements have changed. "People change" management is required. That is staff need to be trained in more technical acpects.

b. Failure in the reporting of observations may be a result of insufficient resource allocated to network maintenance at a national level. A failure to provide adequate resource may also result in degraded infrastructure, unreliable data collection, as well as reporting issues due to staff shortages.

c. Most NMHSs have experienced a shift in primary focus from taking and reporting observations to producing weather and climate services. Unfortunately this has also resulted in a reducing staff numbers dedicated to observations, instrument maintenance and data management. In recent years there have been increased delays in entering metadata and data into CliDE.

5. Reporting mechanism

a. Recent in-country visits indicated a high degree of unawareness that the CLIMAT messages were required to be sent or that a CLIMAT message can be generated by CliDE.

b. Reporting of observations require proactive human intervention to close the reporting loop. This may be detrimentally affected by funding, staff shortages, change in personnel at NMHSs and a failure to handover responsibility of reporting.

c. Inconsistencies in reporting standards and methodologies across stations may impede data interoperability and ingestion through the WIGOS station reporting protocols. This may also be a symptom of insufficient fund allocation for staff training, leading to inaccurate reporting that does not meet expected standards.

6. **Weather vs. Climate**

a. New stations installed under a 'climate' banner, but where the intent is that they are used more for operational forecasting. The overall focus of SOFF programs, and a key outcome of Weather Ready Pacific, is to enhance forecasting capabilities across the

Pacific. While forecasting capabilities are vital for early-warning systems, accurate monitoring and reporting of ECVs is also of similar importance in understanding the evolution of the climate. Future climate network remediation and development must meet the requirements and standards of both operational forecasting and monitoring of ECVs.-

7. **Training**
    a. With a high turnover of staff in many NMHSs on-going training in ALL aspects of AWS maintenance and operations is required.
    b. Trainings should be specific and targeted at a level suitable for the recipient e.g., the training for a remote station observer (provision of first line maintenance basic fault identification) is very different to that for an instrument technician.
    c. There is currently limited training conducted by Regional Training Centres in the Region for Instrument Technicians.
    d. The WMO Competency Framework for Instrument Technicians[15] is clear, however the curriculum for Instrument Technicians is still being developed by the WMO Expert Team on Transition to Modern Measurements.

Priority stations

It is essential that stations with near complete records over multiple decades be protected and priortised to ensure data continues to be available for the full spectrum of meteorology. Ideally these station enclosures and surrounds would remain unchanged for years and decades to come and only where unavoidable site changes would take place after a reasonable period of duplicate observations. Where there are instrument shortages in a country, ideally these station would be prioritised. They would also be the among the first to be repaired following a disaster.

Based on a literature survey of Pacific stations used for climate change research the following are proposed as priority stations:

Country	Station Name	Start Date	GSN (from OSCAR/Surface)	Additional information
Northern Mariana Islands	Saipan International Airport	Jan-1954		Previously Saipan Loran
Guam	Guam International Airport	Mar-1957	91212	
Federated State of Micronesia	Pohnpei WSO	Nov-1949	91348	Japanese observations exist from 1926-43

[15] https://community.wmo.int/en/news/compendium-wmo-competency-frameworks-wmo-1209

Country	Station Name	Start Date	GSN (from OSCAR/Surface)	Additional information
	Yap WSO	Nov-1941	91413	German observation exist from 1901-1914
	Chuuk WSO Airport	Dec-1945	91334	
	Kosrae International Airport	Feb-1951		
Marshall Islands	Majuro	Aug-1945	91376	
	Kwajalein	May-1945	91366	Japanese observations exist from 1932-37
Palau	Koror WSO	July-1951	91408	Existed previously as a US Navy station (same location from 1947). German observations in the same location from 1905 to 1912 and Japanese observations from 1924 to 1941. Station downgraded from October 2018.
	WSO Palau	Jan 2004		Took over from Koror WSO in August 2018 as the official Palau station
Papua New Guinea	Port Moresby W.O.	Jan 1939	92035	Also known as Jackson's Airport
	Wewak W.O.	1923	92004	
	Madang W.O.	1916	92014	
	Momote W.O.	1950	92044	
	Kavieng W.O.	1916	92076	
	Misima W.O.	1923	92087	
	Daru W.O.	1957	92003	
	Gurney W.O.	1996	92077	
	Hoskins W.O.	1990	92072	
	Kiunga W.O.	1985	92001	
	Nadzab W.O.	1986	92047	

Country	Station Name	Start Date	GSN (from OSCAR/Surface)	Additional information
Solomon Islands	Honiara	Dec-1949	91520	In OSCAR station is called Honiara/Henderson
	Henderson Airport	Sept-1974		
	Taro	1975		
	Munda	1962	91503	
	Auki	Jan-1962		Data also available from 1918 to 1935
	Kira Kira	1964		
	Lata (Santa Cruz)	1970		
Vanuatu	Sola	Dec-1948	91551	Sola International Airport AWS 2.6km NNW
	Pekoa Airport	Jul-1950	91554	Also AWS
	Lamap	Jul-1960	91555	AWS only
	Port Vila	1947		Also AWS
	Bauerfield Airport	Jan-1972	91557	Also AWS
	White Grass Airport	Jul-1958	91565	Also AWS
	Aneityum	Aug-1948	91568	Also AWS
New Caledonia	Noumea	Jan-1951	91592	
	La Tontouta	Jan-1951		
	La Foa	Jan-1951		
	Poya	Jan-1952		
	Kone	Jan-1951		
	Koumac	Jan-1951	91577	
	Poindimie	Jan-1964		
	Ponerihouen	Jan-1952		
	Houailou P	Jan-1952		
	Ouanaham	Jan-1960		
Fiji	Rotuma	Jan-1905	91650	Also AWS
	Lautoka	Jan-1901		Also ARG
	Nadi Airport	Jan-1942	91680	Also AWS
	Penang Mill	Jan-1926		Also ARG
	Nausori Airport	Jan-1955	91683	
	Laucala Bay (Suva)	Nov-1941		

Country	Station Name	Start Date	GSN (from OSCAR/Surface)	Additional information
	Tokotoko (Navua)	Jan-1992		Also AWS
	Nabouwalu	Jan-1918		
	Udu Point	Jan-1946	91652	Also AWS
	Lakeba	Jan-1924		Also AWS
	Vunisea	Jan-1929		Also AWS
	Ono-i-Lau	Jan-1943	91699	Also AWS
Tonga	Nuku'alofa	Jan-1945	91789	Also AWS
	Fua'amotu Airport	Jan-1979		Also AWS
	Ha'apai	Jan-1947	91784	Also AWS
	Lupepau'u (previously Vava'u)	Jan-1995	91779	Also AWS, Vava'u from Jan-1947
	Niutoputapu (Keppel)	Jan-1947	91776	Also AWS
	Niuafo'ou	Jan-1971	91772	Also AWS
Niue	Hanan Airport	Sept-1996	91824	Also AWS, Alofi from Oct-1905
Wallis & Futuna	Maopoopo (Futuna)	Jan-1979		
	Hihifo (Wallis)	Jan-1971	91753	
Samoa	Apia	Jan-1890	91762	Also AWS
	Faleolo Airport	Jan-1956	91759	Also AWS
American Samoa	Pago Pago International Airport	Jan-1956	91765	
Tokelau	Nukunonu	Jan-1946	91723	Also AWS
Cook Islands	Penrhyn	Jan-1937	91802	Also AWS
	Rarotonga	Jan-1899	91843	Also AWS
	Aitutaki		91831	
French Polynesia	Tahiti-Faaa	Jan-1919	91938	
	Mataura (Tubuai)	Jan-1951	91954	
	Rapa	Jan-1951	91958	
	Bora-Bora	Jan-1961	91929	
	Hiva Oa (Atuona)	Jan-1954	91925	
	Takaroa	Jan-1953	91943	
	Hereheretue	Jan-1962	91945	
	Magareva (Rikitea)	Jan-1980	91948	
	Anaa	2013	91933	

Country	Station Name	Start Date	GSN (from OSCAR/Surface)	Additional information
Pitcairn Islands	Pitcairn	Jan-1940	91964	Now AWS
Nauru	Nauru	Jan-1893		Station closed
Kiribati	Tarawa	Jan-1946	91610	
	Kiritimati	Jan-1951		
	Butaritari	Jan-1945		
	Kanton	Jan-1937	91701	
	Beru	Jan-1932		
	Arorae	Jan-1950		
Tuvalu	Nanumea	Jan-1947	91631	Also AWS
	Nui	Aug-1941		Also AWS
	Funafuti	Jan-1941	91643	Also AWS
	Niulakita	Jan-1947		Also AWS
Australia	Norfolk Island Aero	Jan-1891	94996	Now AWS
	Lord Howe Island Aero	Jan-1886	94995	Now AWS
	Willis Island	Jan-1921	94299	Now AWS
New Zealand	Raoul Island	Jan-1937	93994	Now AWS

Call to Action

Following the findings outlined in this report, it is recommended that the Pacific Meteorological Council prioritise the following actions:

a. **Advocacy:** Recommend that the Pacific Meteorological Council (PMC) advocate for increased investment in climate observation systems and data management infrastructure to address systemic challenges and ensure the long-term sustainability of the Pacific Climate Stations .

b. **Immediate Regional (?) Assessment:** Recommend that as a matter of urgency, a desktop review of instrumentation assessments conducted under existing projects (SOFF, ClimSA) are leveraged and a comprehensive assessment of data quality issues is produced.

c. **Collaboration and Coordination:** Formally establish both **Pacific National** and **Pacific Regional Climate Reference Station Networks** and drive collaboration and coordination among member states, regional organizations, and international partners to strengthen the resilience and reliability of our climate monitoring infrastructure at national, regional, and global levels.

d. **Capacity Building:** Allocate resources and support for capacity building initiatives aimed at enhancing station maintenance, data collection protocols, quality control measures, data archival and reporting.

e. **Safeguard:** Identify and nominate long-term stations to Centennial status under WMO.

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