Report of the

Joint GCOS-WIGOS Workshop for the Pacific Small Island Developing States (SIDS)

9-12 October 2017, Nadi, Fiji

Fiji Meteorological Service

Key messages from the Joint GCOS-WIGOS Workshop for Pacific SIDS,

- Systematic observation of the Earth's climate is a global common good that supports the implementation of the Paris Agreement, in the context of sustainable development and efforts to eradicate poverty.
- Many meteorological observations, made at high spatial and temporal density, support local forecasting and warning applications. These observations are a national responsibility contributing to national and regional needs with some additional global value.
- However, systematic upper air observations, made routinely by radiosondes under the WMO World Weather Watch (WWW) Programme, including the GCOS Upper Air Network (GUAN), support numerical weather prediction (NWP) leading to global benefits. These observations are used primarily for forecasting and climate applications at the international level, including climate reanalyses which form the basis of much of our understanding of climate and climate change; and
- Systematic upper air observations in the Pacific region, tend to have the highest measured impact, of all ground-based measurements, on the quality and accuracy of weather and climate analysis and prediction not only locally, but globally. The resulting products underpin weather and climate aspects of early warning systems as well as other climate-related services.
- Both the spatial density and observing frequency of the upper air network over the South Pacific region currently fall short of GCOS and WMO requirements. Due to the unique geography of the region – vast swathes of ocean surface with relative little land mass distributed over some 20 small island states with modest-size populations and correspondingly modest GDPs – systematic observation is particularly challenging in this region.
- The upper air network over the South Pacific therefore needs sustained international support.
- The workshop developed an outline for a *Pacific region observing network plan in support of the GCOS Implementation Plan and the Implementation Plan for the Evolution of Global Observing Systems (EGOS IP) t*o:
    - Strengthen regional and national meteorological networks to support adaptation actions and avert loss and damage;
    - Identify capacity building needs to ensure the sustainability of the networks;
    - Be used to support requests for finance from the operating entities of the financial mechanism under the Convention, the GCOS Cooperation Mechanism and other relevant funding sources.
- Support of the observing network in the region should be based on transparent processes and a commitment to free and open data sharing in accordance with WMO Resolutions 40 and 60 and the GCOS Monitoring Principles. The network should be designed to be, efficient, sustainable, it should meet agreed international standards as well as national requirements. Ensuring sustainability is of paramount importance, and the network plan must therefore also include the necessary elements of capacity development.
- The draft plan will be developed by GCOS and WMO in collaboration with Secretariat of the Pacific Regional Environmental Programme (SPREP), the Pacific Islands Communication and Infrastructure Panel (PICI), and Pacific Meteorological Council, and submitted to COP 24.

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Joint Global Climate Observing System (GCOS) and WMO Integrated Observing System (WIGOS) Workshop for the Pacific Small Island Developing States

1. Introduction

This workshop was organised jointly by the Global Climate Observing System (GCOS), and the WMO Integrated Global Observing System (WIGOS) focusing on gaps in climate observation systems in Pacific island states. The meeting was hosted by the Fiji Meteorological Office whose support was essential to the success of the meeting. The Secretariat of the Pacific Region Environment Programme (SPREP) provided logistical and technical support.

2. Session I: Scope and Purpose of Workshop including Background Information on UNFCCC, GCOS and WIGOS

In 2016, the UNFCCC, in decision 19/CP.22, emphasized "*the need to maintain, strengthen and build capacities for climate observations*…" and SBSTA 45 "*noted the need for regional workshops, as identified by the GCOS 2016 implementation plan, […] and invited the GCOS to organize such workshops, taking into consideration the benefit of organizing these workshops in collaboration with relevant partners*". SBSTA also highlighted the need for support in the LDCs and small island developing States.

For the first of these regional workshops a meeting was organised jointly by the Global Climate Observing System (GCOS), and the WMO Integrated Global Observing System (WIGOS) focusing on gaps in in the observing systems for weather and climate in Pacific island states. The workshop focussed initially on two areas: precipitation and upper air (radiosonde) measurements. Water is a primary resource and high quality and useful information on water needs to be made available on a free and easily accessible basis. Water (e.g. floods, extreme rainfall and droughts) has been identified as a major issue of concern for adaptation by parties in their submissions to the UNFCCC. Upper air measurements have been identified as the in-situ observations whose improvement would give most benefit to the models that underpin both numerical weather prediction and climate prediction and analysis - which will have local, regional and global benefits.

The workshop had the following goals:

- Develop an understanding by all parties of how improved local observations can contribute to climate analysis, weather forecasting and early warning systems
- Based on national priorities expressed by the participants, identify the most important cost-effective observational improvements and develop plans to implement these improvements to observations
- Advocate for improved data stewardship including open access to data products
- Identify funding opportunities

- Improve GCOS communication with international, regional and national stakeholders, especially in developing countries.
- The experience gained should be the basis for future regional workshops.

The agenda is attached in annex B.

The UNFCCC has an important interest in systematic observations of the climate system as expressed in article 5 of the convention, together with national reporting requirements in article 4. Adaptation and early warning systems together with the Global Stocktake are all important parts of the UNFCCC's Paris Agreement and systematic observations play an important role in addressing all of these.

GCOS, established in 1992 and supported by WM0, aims to ensure that systematic observations are undertaken and that the results are made available to all users. It reviews the status of the climate system (GCOS 2015) and prepare Implementation plans (GCOS 2016) that are presented to the UNFCCC. These plans identify what needs to be monitored the Essential Climate Variables (ECV), and specific actions that should be undertaken to ensure the continuation and improvement of the global climate observing system.

WIGOS is an all-encompassing approach to the improvement and evolution of WMO and WMO co-sponsored observing systems in support of all WMO application areas, including their contributions to GCOS. It will foster the orderly evolution of the present WMO global observing systems, in particular the Global Observing System (GOS), the hydrological observing systems and the observing components of the Global Atmosphere Watch (GAW) and the Global Cryosphere Watch (GCW) , into an integrated, comprehensive and coordinated system. It will satisfy, in a cost-effective and sustainable manner, the evolving observing requirements of WMO Members, while enhancing coordination of the WMO observing system with systems operated by international partners. Together with the WMO Information System (WIS), WIGOS will be the basis for the provision of accurate, reliable and timely weather, climate, water and related environmental observations and products by all Members and WMO Programmes, which will lead to improved service delivery.

3. Session II: Observational Data Requirements for the Pacific

Observational requirements clearly depend on the applications areas they are addressing. Therefore, requirements for global observations may not meet all the local needs. GCOS provides requirements for 54 Essential Climate Variables (ECV). However, not all these need to be observed by each state. Some are provided by satellite observations, while ocean observations are often performed by international consortia.

Observations must be exchanged internationally in order for them to be used in climate and weather modelling at global and regional scales.

Precipitation observations are made locally and reported internationally. Figure 1 shows data for July 2017 received and processed by the Global Precipitation Climatology Centre (GPCC) by DWD under the auspices of the World Meteorological Organization (WMO). These show that, given the amount of ocean and land in the region, the density of

observations appears to be consistent with other countries. However, a particular problem with observations of precipitation is the spatial inhomogeneity of the measured quantity, especially in mountainous terrain. As participants pointed out, a single site on a volcanic island may not be representative of the whole island.

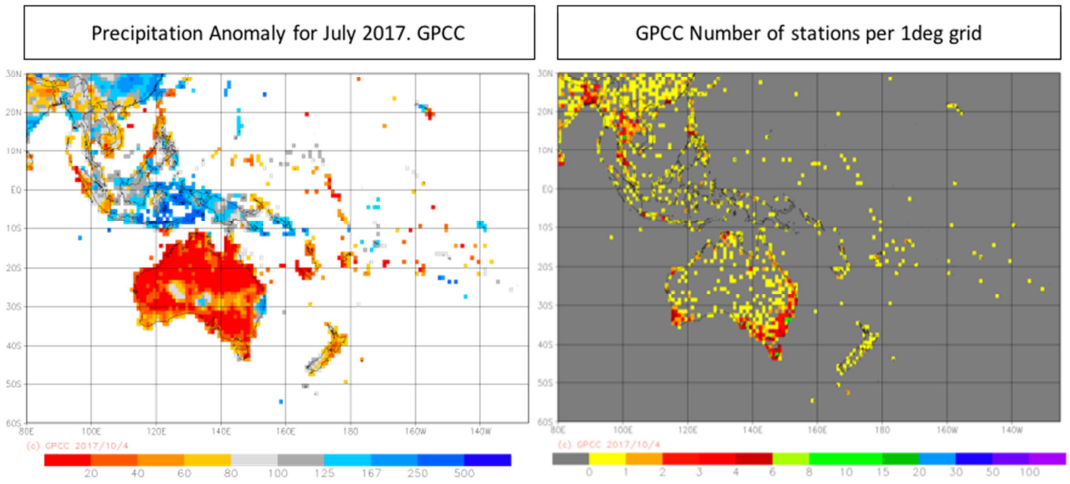

Figure 1 Data form the Global Precipitation Climatology Centre (GPCC) for July 2017

Upper air (radiosonde) observations are very important for global numerical weather predictions, both regionally and globally. The impact of these observations can reach planetary scale. ECMWF has thus stated that better upper air observations in the south Pacific are critical for extended range forecasts over Europe. Isolated radiosonde observations in the Pacific are routinely shown to have the highest impact of all observations on skill of global NWP models.

4. Session III: National Observing Capabilities and Needs

All the countries in the region have relatively small populations and land areas but have large areas of ocean in their exclusive economic zones (EEZ), (Table 2). It should be noted that even taking into account the EEZs will not cover all areas of the ocean, while the requirement for observations for global NWP and climate analysis remains in essence the same irrespective of national borders and EEZs.

Table 1 summarises the observations in the region. All the Pacific Island States noted a number of common issues:

- The large distances between islands and the remoteness of monitoring sites poses special challenges. Access to some islands by ship may be infrequent and time consuming.
- Communications between monitoring sites and central offices can be difficult without internet, land lines or reliable electrical power.
- Costs of consumables can be prohibitive for small low-GDP countries, and are often at a premium price owing to the low quantities being ordered and cost of shipping.

- Training and capacity building are important widespread needs. This covers all aspects of meteorological service provision from observations, maintenance and repair, to reporting and using data. Assistance is needed to ensure that procurements deliver high-quality, cost-effective equipment.

Table 1 Summary of Observing capabilities reported by countries, recorded in OSCAR and data exchanged

	Presentation	OSCAR	SYNOPS (OGIMET) (8th – 9th October)	CLIMAT	Radiosonde
Fiji	32 AWS 10 TB3 Rainfall stations 41 Rainfall stations (manual) 34 Manual synoptic/climate 4 Lightning stations 1 Wind Profiler, 1 Tidal, 3 Weather Radar Hydrological Network 12 Stations for International Exchange	50 Stations → 22 GOS Stations → 22 WHOS Stations → 4 GCOS/GSN Stations → 1 GCOS/GUAN Station (91680)	16 stations (metadata) 8 stations (3 Hourly or better) 5 stations (zero obs) No hourly reports	5 Stations providing monthly reports	2 per day (62 August) Timeliness good (<60mins) Max Height 93% > 30hPa (Jan – Aug 2017) TEMP and BUFR
Cook Islands	7 AWS (Project to replace above with 10 new systems) 1 Upper-Air (No consumables)	13 Stations → 13 GOS Stations → 4 GCOS/GSN Stations → 1 GCOS/GUAN Station (91843)	8 stations (metadata) 91831 (Hourly) 91843 (3 Hourly) 91844 (2 Hourly) 5 stations (zero obs)	GSN stations not reporting CLIMAT	Silent since Jan 2017 (No Consumables)
Federated States of Micronesia	3 Weather Service Offices 2 SAWRS 21 COOP Stations 3 Upper-Air Stations	27 Stations → 27 GOS Stations → 3 GCOS/GSN Stations → 1 GCOS/GUAN Station (91334)	14 stations (metadata) 4 (6 Hourly) 9 (1 to 3 obs) 1 stations – zero obs No hourly/3hr'ly reports	3 Stations providing monthly reports	2 per day (62 August) Timeliness good (<70mins) Max Height 89% > 30hPa (Jan – Aug 2017) TEMP and BUFR
Kiribati	9 Stations	16 Stations → 14 GOS Stations → 3 GCOS/GSN Stations → 1 GCOS/GUAN Station (91610)	8 stations (metadata) 2 stations (3 Hourly) 4 stations (1 – 3 obs) 2 stations (zero obs) No hourly reports	GSN stations not reporting CLIMAT	1 per day (30 August) Timeliness good (<70mins) Max Height 84% > 30hPa (Jan – Aug 2017) TEMP **No BUFR**

	Presentation	OSCAR	SYNOPS (OGIMET) (8^{th} – 9^{th} October)	CLIMAT	Radiosonde
Marshall Islands	7 Stations 22 drought monitoring stations 2 Radiosonde stations	19 Stations → 19 GOS Stations → 2 GCOS/GSN Stations → 1 GCOS/GUAN Station (91376)	8 stations (metadata) 1 (6 Hourly) 4 (1 – 3 obs) 3 stations (zero obs) No hourly reports	2 Stations providing monthly reports	2 per day (62 August) Timeliness good (<60mins) Max Height 95% > 30hPa (Jan – Aug 2017) TEMP and BUFR
Nauru	Zero active stations	4 Stations → 4 GOS Stations → 0 GCOS Stations			
Niue	1 Station	3 Stations → 3 GOS Stations → 1 GCOS/GSN Stations	1 stations (metadata) 91824 (3 obs) No hourly reports	1 Stations providing monthly reports but not every month	
Palau	1 NWS Station 6 Coop Stations	3 Stations → 3 GOS Stations → 1 GCOS/GSN Stations → 1 GCOS/GUAN Station (91408)	1 station (metadata) 1 (6 hr'ly or better) No hourly reports	1 Stations providing monthly reports	2 per day (62 August) Timeliness good (<80mins) Max Height 90% > 30hPa (Jan – Aug 2017) TEMP and BUFR
Papua New Guinea	14 Manual Stations (3 closed) 22 Climate Stations 200 Rainfall Stations 6 AWS 2 Tide Gauges	43 Stations → 43 GOS Stations → 3 GCOS/GSN Stations → 1 GCOS/GUAN Station (92035)	9 stations (metadata) 1 station (3 Hourly) 7 stations (1 – 3 obs) 1 stations (zero obs) No hourly reports	6-8 Stations providing monthly reports	Silent since Feb 2013 (No Consumables) (Hydrogen generator issues)
Samoa	2 Manual Stations 13 Sites (AWS) Wind Profiler and RASS Tide Gauge	17 Stations → 17 GOS Stations → No GCOS Stations	10 stations (metadata) 8 stations (Hourly) 2 stations (3 Hourly) No hourly reports	No CLIMAT but none are GSN. Apia is a RBCN	

	Presentation	OSCAR	SYNOPS (OGIMET) (8th – 9th October)	CLIMAT	Radiosonde
Solomon Islands	6 Synoptic Stations 1 Upper-Air Station (stopped) 8 AWS 12 Auto-Rainguage 4 Lightning stations 5 Hydrometric Stations 3 Agro Met Stations	9 Stations → 9 GOS Stations → 2 GCOS/GSN Stations → 1 GCOS/GUAN Station (91517)	7 stations (metadata) 4 stations (3 Hourly) 3 stations (4-5 obs) No hourly reports	No CLIMAT reports	Silent since Oct 2011 (No Consumables) All equipment is now questionable
Tonga	8 Stations (7 Manual, 1 AWS) Seismic Network	9 Stations → 9 GOS Stations → 2 GCOS/GSN Stations	5 stations (metadata) 3 stations (3 Hourly) 2 stations (6 Hourly) No hourly reports	No CLIMAT reports	
Tuvalu	4 Manual 5 Rainfall (non operational) 1 Upper Air 1 Tide Guage 1 Lightning Detector 1 GPS positioning system 1 Seismic Station	5 Stations → 5 GOS Stations → 2 GCOS/GSN Stations → 1 GCOS/GUAN Station (91643)	4 stations (metadata) 1 station (3 hr'ly) 3 stations (6 hr'ly) No hourly reports	No CLIMAT reports	1 per day (30 August) Timeliness good (<80mins) Max Height 90% > 30hPa (Jan – Aug 2017) TEMP **No BUFR**
Vanuatu	8 Synoptic Stations 1 Upper-Air Station (Not working) 75 Rainfall Stations 4 Tidal Guages	13 Stations → 7 GOS Stations → 6 AWS with no affiliation → 2 GCOS/GSN Stations → 1 GCOS/GUAN Station (91557)	7 stations (metadata) 2 stations (3 hr'ly) 5 stations (2-4 obs) No hourly reports	No CLIMAT reports	Silent since Apr 2016 (No Consumables) Issues with Hydrogen Generator

Table 2 Basic statistics for the Pacific Island States. with USA, and Japan added for comparison. Data form UN and World Bank.

	Land Area	Area of EEZ	Population	GDP	GDP per km^2	Population Density including EEZ
	km^2	*million km^2 including land area*	*thousands, UN Estimate for 2017*	*World Bank. 2016, US$*	*US$ per km^2*	*km^2 per person*
Cook Islands	240	1.80	17	311 [a]	0.00017	0.01
Federated States of Micronesia	702	3.00	106	322	0.00011	0.04
Fiji	18,274	1.30	906	4632	0.00360	0.70
Kiribati	811	3.44	116	166	0.00005	0.03
Marshall Islands	181	1.99	53	183	0.00009	0.03
Nauru	2	0.31	11	102	0.00033	0.04
Niue	26	0.39	2	10 [b]	0.00003	0.00
Palau	535	0.60	22	293	0.00048	0.04
Papua New Guinea	45,258	2.87	8,251	16929	0.00590	2.88
Samoa	283	0.13	196	786	0.00600	1.50
Solomon Islands	2,799	1.62	611	1202	0.00074	0.38
Tonga	72	0.66	108	395	0.00060	0.16
Tuvalu	3	0.75	11	34	0.00005	0.01
Vanuatu	12,300	0.68	276	774	0.00110	0.41
Total above	**81,486**	**20**	**10,687**	**26,139**	**0.00130**	**0.55**
USA	**9,525,067**	**11.35**	**325,958**	**18,569,100**	**1.60**	**28.72**
Japan	**377,930**	**4.48**	**126,670**	**4,939,384**	**1.10**	**28.28**

Notes: [a] data for 2014, [b] data for 2003

4.1. Fiji

The Fiji Meteorological Service (FMS) is now under the Ministry of Disaster Management and Meteorological Service. It operates all the year around providing daily weather forecasting and warnings to Fiji, Cook Islands, Kiribati, Nauru, Niue, Tokelau, Tonga and Tuvalu. It is recognised as a WMO Regional Specialized Meteorological Centre. In Fiji there are networks of meteorological, rainfall and hydrological stations and weather radar. The site at Nadi Airport launches radiosondes twice daily. 12 stations report data internationally to the WMO WIS/GTS.

While Fiji has its own training needs, it also serves as a focal point for capacity building for the surrounding island states.

Transport to and from the smaller outlying islands adds to the difficulties of maintaining the observation system while deploying a reliable communications system is a priority.

4.2. Cook Islands

The Cook Islands have an upper air station that launches radiosondes once a day. This was supported by the UK until the end of 2016. The precipitation measurements are not representative, as rainfall on different sides of the island is markedly different. They have experience with a voluntary observing system using cheap rainfall gauges situated at schools.

4.3. Federated States of Micronesia

The Federated States of Micronesia Weather Services Offices (WSO) are built, operated and funded by the US while the Federated States of Micronesia hires and employs the WSO staff.

There are three Weather Service Offices (METAR/SPECI) on Pohnpei, Chuuk and Yap, and two SAWRS Stations (METAR/SPECI that operate for 2hrs pre/post US Airlines flights) at Pohnpei and Kosrae Airports. There are also 27 COOP Stations. There are upper air soundings from all three WSOs, twice daily at 00Z and 12Z.

Installation and maintenance can be a problem due to remoteness of islands with both communication problems and travel issues.

4.4. Kiribati

Of the nine meteorological stations 3 are silent and only 2 provide continuous hourly observations. Issues include the lack of resources for the maintenance and operation of equipment. Communications is also an issue and the use of existing internet links is being investigated.

Kiribati is looking for assistance with international tendering and donors to support the Kiribati joint implementation plan for climate change and disaster risk reduction which includes both the reactivation of existing meteorological stations and the establishment on new stations.

The upper-air station is supported by funds from the UK, managed through SPREP.

4.5. Marshall Islands

Majuro National Weather Services first started in 1950. It operates under the US National Oceanic and Atmospheric Administration (NOAA) and it's contracted by the Marshall Islands government to provide weather products and services to the RMI citizens. Its staff are employed by NOAA. NOAA has assigned the WFO Guam and Honolulu to provide services and warnings for the North Pacific island states including the Marshall Islands.

The observations include surface stations, weather radar and an upper air station that operates twice daily.

There is a need for more observation sites in the outer islands to improve drought forecasting and monitoring. There also needs to be a sustainable and robust communication system for observation transmittal and for Early Warnings. Installation of Chatty Beetles[1] in 5 to 8 other atolls is underway.

4.6. Nauru

Currently there are no meteorological stations in Nauru. There are some limited observations made at the airport. Plans are being implemented to establish a meteorological office and to provide some equipment. Two officers are being trained in Nadi, Fiji.

4.7. Niue

Hanan Airport is Niue's only meteorological station. It is operated only in the event of active tropical cyclone in the area. Daily weather forecasts are provided by RMSC Nadi but Niue produces its own three-day weather forecast. There are also rainfall and seismic observations.

4.8. Palau

Due to cooperation between the NOAA National Weather Service and The Government of the Republic of Palau, the Palau Weather Service is 100% funded by the US Government and on the basis of a reimbursable funding. It employs a total of 13 staff.

There is a weather station at Koroor (which will move closer to the airport) and two COOP Stations measuring temperature and precipitation as well as three stations observing surf conditions.

Additional rain gauges are needed, and access to NOAA data should be improved.

4.9. Papua New Guinea

Currently Papua New Guinea Weather Service has:

- 14 manual observation stations (3 recently closed)
- 22 climate stations & less than 200 rainfall stations
- 6 AWS & 20 rainfall data loggers
- 2 tide gauges (1 not operational)
- Hydrology network is under Ministry of Environment

[1] a portable Iridium satellite terminal that permits text-based alerts and messaging in remote locations, where communication options are limited.

However, it is unclear how well these operate and there is a lack of stations in the Highlands region. The two upper air stations ceased operation in early 2015 due to lack of funds for consumables.

Currently the National Weather Service needs to be restructured and to receive an adequate budget to restore the silent stations and train staff. There needs to be an effective communication strategy to allow the transmission of information from the data loggers and AWS and to link to airport observations. Data records from manual stations need to be rescued and digitized. The capacity of the staff needs to be enhanced.

4.10. Samoa

Samoa has 7 automatic weather stations in addition to those at the airport. It has a weather forecasting capability using satellite data and effective communications for data transmission. It operates a multi-hazzard early warning system with a smart phone app to distribute warnings.

It does not undertake upper air soundings but relies on those made in American Samoa which is nearby.

4.11. Solomon Islands

Currently the Solomon Islands has

- Six (6) Surface Synoptic Observation Stations,
- One (1) Upper Air Stations (not operational)
- Eight (8) Automatic Weather Stations -1 mSTAR, 1 iSTAR, 4 SWoCK, 2 NDMO,
- Twelve (12) Automatic Rain Gauges – 4 yet to be installed,
- Three (3) Agro-Meteorology Stations – Funded/Installed by CWB (Taiwan) but the data form these is not currently available
- Himawari High Resolution Satellite R/Stations. – Installed by JMA funded by JICA

Issues include lack of expertise and resources. This has led to a lack of upper air observations due to the lack of consumables and maintenance, lack of maintenance and calibration to ensure data quality. Poor international procurement of meteorological instruments contributes to these issues.

There are also problems with timely data transmission. Finally, the use of Mercury substance with Meteorological instruments needs to be phased out.

4.12. Tonga

Since 2005 Tonga has been producing its own weather forecasts, previously these were done by Fiji. Tonga has 8 meteorological stations. It does not perform any upper air observations. Limits on resources mean that equipment is not inspected regularly and few spares are held.

4.13. Tuvalu

The Tuvalu Metrological Office has:

- 4 manned synoptic stations including the capital – on operational
- 5 rainfall stations – non-operational

- 1 upper air program (Release time 2300UTC)
- 1 tide gauge with tsunami warning system
- Lightning detector

The upper air station is supported by funds from the UK, managed through SPREP.
The increasing population results in an increase in both the vulnerability and exposure of people to natural hazards such as sea-level rise, increased variability of weather, climate, storm surges and coastal inundation.

There are severe problems with communications to the outlying islands where there is limited internet access, no mobile coverage, no television and no HF radios. There are power and cabling issues for land phones lines and there is one radio station service (AM radio) with a limited transmission. The electricity supply is insufficient. Solutions could include Chatty Beetles and HF radios.

4.14. Vanuatu

In Vanuatu there are:

- 8 Synoptic sites
- 3 are GCOS Stations (91551,91555,91568)
- 75 Rainfall sites
- 4 tidal Gauge
- 6 volcano monitoring station
- 3 broadband station

In addition, one upper air station, which has not been operational since September 2016 due to lack of funds.

There is limited expertise in maintenance and calibration of instruments (both manual and AWS) and upper air stations. Capacity development to help improve the quality of the stations is needed.

Communications is an issue with a need for improved back-up communications tools (such as HF radios)

5. Session IV: Regional Observing System Capabilities

In order to serve specifically the needs of global climate applications, two networks of observing stations have been established as GCOS Baseline Networks, mainly on the basis of existing GOS networks. These are:

- the GCOS Surface Network (GSN) (1023 stations as of April 2017)
- the GCOS Upper-Air Network (GUAN) (177 stations as of April 2017)

These networks form a minimum configuration required for global applications. Regional climatic needs can be much more extensive, and it is anticipated that such needs will be served by more dense networks on a regional basis, possibly with more extensive requirements for observing programmes and specifications.

Concerning the availability of surface observations for weather predictions and warning, the situation could be improved by simply ensuring the international exchange of hourly data. In many case this is a very low- or no- cost option with substantial benefits. However, most of the upper air observations in the region are funded externally with regional meteorological services unable to find and justify the funds needed for consumables and maintenance.

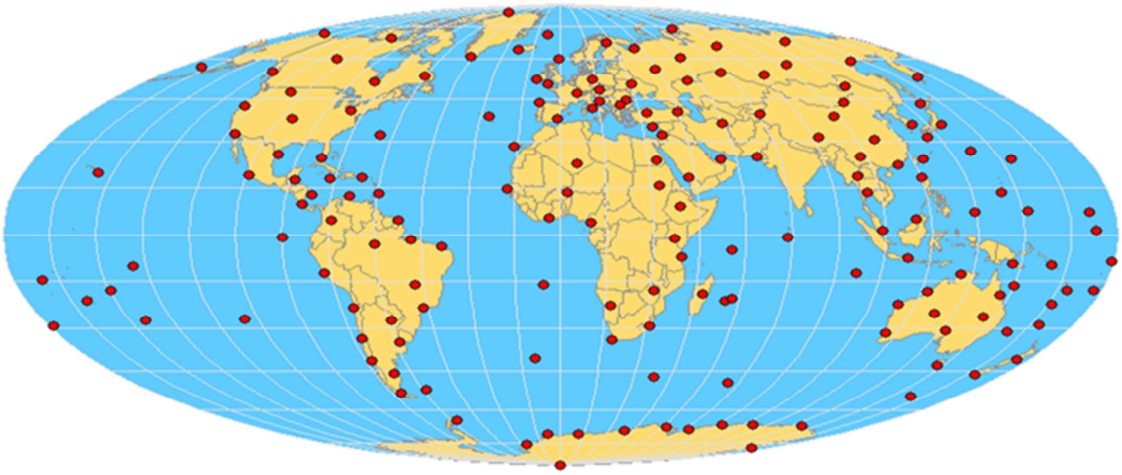

Figure 2 The GCOS Upper Air Network (GUAN)

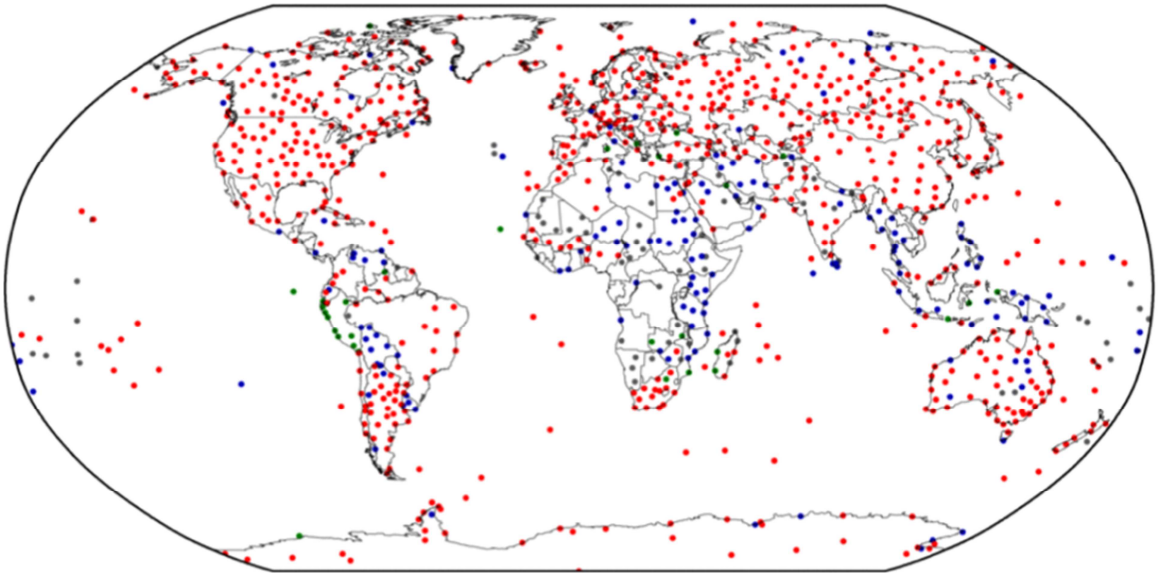

Figure 3 The GCOS Surface Network (GSN). Number of months reporting July 2016-Jun 2017. (Red=12, Blue =5to 10, Green = 1, Grey =0)

6. Session V: Gap Analysis and Mitigation Steps

Radiosondes are critical for climate reanalysis produced by Global NWP systems. Langland et al. (2011) show that local uncertainties in analysis are substantially larger in areas with no

conventional (non-satellite) upper air observations. Isolated radiosonde stations have a large impact and twice daily soundings more so than a single daily sounding
This has implications for trend analysis, process understanding, adaptation and the Global Stocktake under the 2015 Paris Agreement.

For global NWP we should focus on improving surface pressure and upper air wind observations. These parameters are amongst the fundamental variables for NWP (the others are temperature and humidity) and both provide driving requirements for surface-based observing systems, since – as opposed to temperature or humidity - neither is currently measured from space.

Surface pressure is derived in experimental mode from total CO2 column measurements and satellite imagers provide horizontal wind components by feature tracking, but only for a single layer with no vertical resolution and limited height information. Wind observations are particularly important in the tropics.

The threshold requirement (given in WMO's OSCAR database) is 500 km, which means that in principle every grid cell of 500 km x 500 km = 250,000 km2 should have a radiosonde station as a minimum. This may make sense for the continental landmasses: in Europe and over North America the design separation is 200 to 250 km. However, a 500 km resolution is unachievable in the Pacific.

A practical alternative would be to consider adopting a lower regional (Pacific) threshold resolution of 750 or 1000 km. Even 1000 km would be quite ambitious, given that the total surface area of the Pacific is about 165,000,000 km2, which would require on 165 radiosonde stations.

The ECMWF Deputy Director of Forecasts noted in September 2017 regarding the potential value of rehabilitating the upper air network over Papua New Guinea:

> *"Radiosondes in PNG can help capture the amplitude and phase of the MJO, and the Kelvin waves, and help predict when Rossby wave trains may be triggered from that area, and then propagate across the Pacific to N. America, and where they influence the mid-latitude storms tracks and ultimately the weather in Europe"*
>
> *"Isolated radiosondes are individually much more valuable and bring much more benefit to forecast quality than observations in a dense network (benefit per station that is!)"*

Therefore, it is proposed to design a network around a regional WMO Requirement for Global NWP. This would be a foundational activity with a significant impact on almost all weather and climate products. This would consider surface pressure and upper air winds provide for non-satellite observations. A slightly lower threshold resolution requirement that recommended by WMO could be considered due to unique geography of the South Pacific. Such a redesigned network would be ambitious but not impossible.

However, the meeting also noted that the current financing model (asking the WMO Members to fund this out of their NMHS budgets) will not be adequate for a redesigned Regional Basic Observing Network for the South Pacific: As noted in the previous section all upper air observations in the region, apart for Fiji, are funded by countries outside the region (e.g. USA and UK).

7. Session VI: Workshop Deliverables and Next Steps

The meeting discussed issues surrounding improving the observational systems in the Pacific. The meeting concluded that:

- Systematic observation of the Earth's climate is a global common good that supports the implementation of the Paris Agreement, in the context of sustainable development and efforts to eradicate poverty.
- Many meteorological observations, made at high spatial and temporal density, support local forecasting and warning applications. These observations are a national responsibility contributing to national and regional needs with some additional global value.
- However, systematic upper air observations, made routinely by radiosondes under the WMO World Weather Watch (WWW) Programme, including the GCOS Upper Air Network (GUAN), support numerical weather prediction (NWP) leading to global benefits. These observations are used primarily for forecasting and climate applications at the international level, including climate reanalyses which form the basis of much of our understanding of climate and climate change; and
- Systematic upper air observations in the Pacific region, tend to have the highest measured impact, of all ground-based measurements, on the quality and accuracy of weather and climate analysis and prediction not only locally, but globally. The resulting products underpin weather and climate aspects of early warning systems as well as other climate-related services.
- Both the spatial density and observing frequency of the upper air network over the South Pacific region currently fall short of GCOS and WMO requirements. Due to the unique geography of the region – vast swathes of ocean surface with relative little land mass distributed over some 20 small island states with modest-size populations and correspondingly modest GDPs – systematic observation is particularly challenging in this region.
- The upper air network over the South Pacific therefore needs sustained international support.
- The workshop developed an outline for a *Pacific region observing network plan in support of the GCOS Implementation Plan and the Implementation Plan for the Evolution of Global Observing Systems (EGOS IP) t*o:
    - Strengthen regional and national meteorological networks to support adaptation actions and avert loss and damage;
    - Identify capacity building needs to ensure the sustainability of the networks;
    - Be used to support requests for finance from the operating entities of the financial mechanism under the Convention, the GCOS Cooperation Mechanism and other relevant funding sources.
- Support of the observing network in the region should be based on transparent processes and a commitment to free and open data sharing in accordance with WMO Resolutions 40 and 60 and the GCOS Monitoring Principles. The network should be designed to be, efficient, sustainable, it

should meet agreed international standards as well as national requirements. Ensuring sustainability is of paramount importance, and the network plan must therefore also include the necessary elements of capacity development.

- The draft plan will be developed by GCOS and WMO in collaboration with Secretariat of the Pacific Regional Environmental Programme (SPREP), the Pacific Islands Communication and Infrastructure Panel (PICI), and Pacific Meteorological Council, and submitted to COP 24.

Annex A contains the outline of the plan that will be further developed. Some issues in the region that need to be addressed were highlighted by the participants. These included:

- Communications. Many of the islands are remote and communications are not straightforward. Cheeky Beetles provide a suitable option and their use should be encouraged.
- Transport. The distances involved and the need to use infrequent ships mean that remains and maintained are often delayed and equipment takes longer to be repaired. Additional expense is involved in addressing this.
- Precipitation is an important parameter both in mountainous islands where issues include flooding and drought, and atolls where drought and sea water intrusion are large concerns.
- Typical metrological stations do not reflect the variable nature of precipitation on many islands and simpler, cheaper voluntary observing systems should be considered to address some of these needs.
- Assistance in procurement to ensure cost-effective solutions are purchased that meet requirements specified by WMO is needed. A joint purchase of equipment and consumables for several countries is may be part of the solution.
- Training is needed and suitable facilities to do this are available in Samoa (SPREPO) and Fiji (the Metrological Office).

Annex A – Outline Plan

Pacific Region Observing Network Plan:

in Support of the GCOS and EGOS Implementation Plans (Simon)

1. **Articulate requirement: how does it contribute to (JP, SE, TO, LPR)**
    a. Firstly, Global Climate needs – a global good
    b. Secondly, Early Warning Systems
2. **Link to quantitative requirements WMO RRR and GCOS ECV (SE, TO, LPR)**
    a. These are achievable and these are what the scientific community says are needed
3. **Alignment with PICI Panel strategy (PICI Panel, Pacific Met Desk)**
    a. How regional approach meets local plans, and other plans such as Region V plan, Pacific Met Plan
    b. Regional Partnerships
4. **Make a strong case for Basic Observing Needs observations as a global good (LPR)**
    a. Simple economic arguments, local funding makes no sense, present numbers, e.g. Look at GDP/km^2 and UK Met Office studies
    b. Build case for long-term international support to ensure sustainability of radiosondes
5. **Explain gap between what is needed and what exists (TO, LPR – global aspects, Pacific Met Desk)**
    a. Country by country status,
    b. Also, national aspects
6. **Define an achievable and realistic end state (TO, LPR, SE, Pacific Met Desk)**
    a. Look at region and define a reasonable proposal for sites that are fundable.
    b. Buy in from national met offices
    c. Regional support of smaller Met offices, regional cooperation on maintenance, spares, training
    d. Define common standards and equipment, to have common spares and consumables (reduce costs etc.)
7. **Outline the necessary steps (Wilson, PACIFIC MET DESK, TO, All countries!)**
    a. Rehabilitation of existing stations
    b. Upgrade of telecommunications
    c. Installation of new stations as needed
    d. Integration with measurements from aircraft, ships and buoys (show that we are integrating other measurements as much as possible)
    e. Optimise integration of use of satellite data (particularly as there is so little land for monitoring)
    f. Build the necessary HR capacity: Staffing, Training Education. Consider regionally based training and expertise. Practical skills needed
    g. Equipment should match local personnel skills
    h. Consumables
    i. Regional quality management (Regional WIGOS Centre)
8. **Estimate Required Financial Resources (Wilson, PACIFIC MET DESK, TO, All countries!)**
9. **Sustainability (Arona)**
    a. How is this achieved – global responsibility
    b. National commitment
    c. Technical aspects (of network, maintenance, HR capacity etc.)
    d. Equipment should match local personnel skills
    e. Transparent procurement – a regional approach? – ISO?
10. **Possible management and procurement structures (PICI Panel)**

Annex B – Agenda

Monday, 9 October

Workshop Opening Ceremony Master of Ceremony (MC): Mr. Henry Taiki, WMO Secretariat		
08:30 – 09:00	Registration	
09:00 – 09:10	Welcome Quests and Opening Prayer	
09:10 – 09:20	Statement on Behalf of the WMO Secretary-General	Mr. Lars Peter Riishojgaard, WMO Secretariat
09:20 – 09:30	Statement on Behalf of the GCOS Secretariat	Mr. Simon Eggleston, GCOS Secretariat
09:30 – 09:40	Statement on Behalf of the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat	Ms. Joanna Post, UNFCCC Secretariat
09:40 – 09:50	Statement on Behalf of the Secretariat of the Pacific Regional Environment Programme (SPREP)	Ms. Siosinamele Lui, SPREP
09:50 – 10:00	Opening Address on Behalf of Fiji Government	Mr Ravind Kumar, Director of Fiji Meteorological Service and PR of Fiji with WMO
10:00 – 10:30	*Group Photo & Coffee / Tea Break*	
Session I: Scope and Purpose of Workshop including Background Information on UNFCCC, GCOS and WIGOS (Chairperson: Mr. Ravind Kumar, Fiji)		
10:30 – 10:50	Setting the Scene of the Workshop: Workshop Goals	Mr. Simon Eggleston, GCOS Secretariat; and Dr Lars Peter Riishojgaard, WMO Secretariat
10:50 – 11:10	UNFCCC Need for Systematic Observations	Ms. Joanna Post, UNFCCC Secretariat
11:10 – 11:35	GCOS Implementation Plan	Mr. Simon Eggleston, GCOS Secretariat
11:35 – 12:00	Introduction to WIGOS	Mr. Lars Peter Riishojgaard, WMO Secretariat

12:00 – 12:30	Activities of Pacific Meteorological Council (PMC) and the Pacific Islands Communication and Infrastructure (PICI) Panel	Ms. Siosinamele Lui, SPREP; and Mr. Wilson Leguvaka, Chair of the PICI Panel
12:30 – 14:00	*Lunch Break*	

Session II: Observational Data Requirements for the Pacific (Chairperson: Mr. Arona Ngari, Cook Islands)		
14:00 – 14:30	GCOS Essential Climate Variables and Implications for the Pacific SIDS	Dr. Simon Eggleston, GCOS Secretariat
14:30 – 15:00	The WMO Rolling Review of Requirements and the Observing System Capability Analysis and Review Tool (OSCAR)/Requirements Database	Dr. Lars Peter Riishojgaard, WMO Secretariat
15:00 – 15:30	WMO Regional Activities	Mr. Henry Taiki, WMO Secretariat
15:30 – 16:00	*Coffee / Tea Break*	
16:00 – 16:30	WMO Region V (South-West Pacific) Working Group on Infrastructure (RA-V WG-INFR)	Mr. Karl Monnik, Chair of RA-V WG-INFR
Session III: National Observing Capabilities and Needs (Chairperson: Mr Henry Taiki, WMO Secretariat)		
16:30 - 16:50	Fiji	
16:50 – 17:10	Cook Islands	
18:00 – 20:00	*Welcome Cocktail Reception @ Tanoa Nadi Hotel*	

Tuesday, 10 October

09:00 – 09:20	Statement on behalf of UNFCCC Subsidiary Body for Scientific and Technological Advice (SBSTA)	Mr. Carlos Fuller, Chair of UNFCCC SBSTA.
Session III: National Observing Capabilities and Needs Continued (Chairperson: Mr Henry Taiki, WMO Secretariat)		
09:20 – 09:40	Federated States of Micronesia	Mr. Wilfred Nanpei
09:40 – 10:00	Kiribati	Mr. Kiaronga Iabeti
10:00 – 10:20	Marshall Islands	Mr. Nover Juria
10:20 – 10:40	Nauru	Mr. Barassi Botelanga
10:40 – 11:00	***Coffee/Tea Break***	
11:00 – 11:20	Niue	Mr. Robert Togiamana
11:20 – 11:40	Palau	Ms. Joyleen Tmatk
11:40 – 12:00	Papua New Guinea	Ms. Kisolel Posanau
12:00 – 12:20	Samoa	Mr. Eseese Ah Ken
12:20 – 14:00	***Lunch Break***	
14:00 – 14:20	Solomon Islands	Mr. Barnabas Tahunipue
14:20 – 14:40	Tonga	Mr. Selusalema Vite
14:40 – 15:00	Tuvalu	Mr. Tauala Katea
15:00 – 15:20	Vanuatu	Mr. Joe Stanley Mala
15:20 – 16:00	***Coffee/Tea Break***	

Session IV: Regional Observing System Capabilities (Chairperson: Dr. Simon Eggleston, GCOS Secretariat)		
16:00 – 16:20	Overview of GCOS Network	Mr. Tim Oakley, WMO Secretariat

Wednesday, 11 October

Session V: Gap Analysis and Mitigation Steps (Chairperson: Ms. Joanna Post, UNFCCC Secretariat)		
09:00 – 09:10	WMO Country Profile Database	Mr. Lars Peter Riishojgaard, WMO Secretariat
09:10 – 09:30	UNFCCC National Adaptation Plans	Ms. Joanna Post, UNFCCC Secretariat
09:30 – 09:50	WIGOS-Related Gaps in the Pacific Region	Mr. Lars Peter Riishojgaard, WMO Secretariat
09:50 - 10:30	Overview of GCOS Network / GCOS Essential Climate Variable - Related Gaps in the Pacific Region / Network performance - Precipitation data in support of climate monitoring / Network performance - Upper air data in support of climate monitoring	Mr. Tim Oakley, WMO Secretariat; and Dr. Simon Eggleston, GCOS Secretariat
10:30 – 11:00	*Coffee/Tea Break*	
11:00 – 12:30	Regional WIGOS/GCOS Plan	Plenary discussion
12:30 – 14:00	*Lunch Break*	
14:00 – 15:30	Possible Gap Mitigation Steps: Technical Elements	Breakout groups discussions
15:30 – 16:00	*Coffee/Tea Break*	
16:00 – 16:30	Groups' presentations	Plenary discussion
16:30 - 17:00	Start discussion on workshop's communication	Plenary discussion

Thursday 12 October

Session VI: Workshop Deliverables and Next Steps (Chairperson: Dr. Lars Peter Riishojgaard, WMO Secretariat)		
08:30 – 08:50	Network performance - Upper air data in support of climate monitoring	Mr. Tim Oakley, GCOS Secretariat
08:50 – 09:10	Network performance - Precipitation data in support of climate monitoring	Mr. Simon Eggleston, GCOS Secretariat
09:10 – 09:45	Workshop Outcomes/Deliverables: Input to COP-23, WMO EC-70, RA-V-17, GCOS Collaboration Mechanism, …	Plenary
09:45 – 10:00	Introduction to breakout groups' discussions	Plenary
10:00 -12:30	*Group Visit to Fiji Met Service*	
12:30 – 14:00	*Lunch Break*	
14:00 – 15:00	Breakout groups' discussions	Breakout groups
15:00 – 15:30	*Coffee/Tea Break*	
15:30 – 16:00	Breakout groups' presentations	Plenary
16:00 - 16:30	Reflection on breakout groups presentations & discussion on way forward	Plenary
16:30 – 17:00	Closing remarks	

Annex C – Participants

List of Participants

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