August 2025

GBON National Contribution Plan of Tonga

Systematic Observations Financing Facility

Weather and climate data for resilience

GBON National Contribution Plan

TONGA

SOFF Beneficiary country focal point and institution	Mr Laitia Fifita Director, Tonga Meteorological and Coast Radio Service Fua'amotu Domestic Airport, Tonga
SOFF Peer advisor focal point and institution	Ms Emma Coombe Senior Advisor – International Development Meteorological Service of New Zealand Ltd PO Box 722 Wellington 6012 NEW ZEALAND

Table of contents

Module 1. National Target toward GBON compliance

1.1 Conduct the national GBON Gap Analysis

Type of station	Baseline (Results of the GBON National Gap Analysis)				GBON National Contribution Target	
	Target (# of stations)[1]	GBON-compliant stations (#)	Gap		To improve	New
			New	To improve		
Surface	3	0	0	4	4	0
Upper-air	1	0	1	0	0	1
Marine	***when applicable**					

Table 1 - GBON National Contribution Target

Note that the advice from the SOFF Secretariat and WMO is that, even though the target is 3 stations, 4 stations re approved for improvement. This reflects the unique geography of Tonga.

1.2 Establishment of the National Target toward GBON compliance

The Tonga Meteorological Service is currently exchanging observations from its manual observing stations, although these do not meet GBON compliance criteria for temporal resolution, and are exchanged in deprecated formats.

For surface stations, compliance would be possible within one year of the commencement of the SOFF *Investment Phase*.

For upper air, the timeframe is longer, as a balloon launching facility will need to be constructed. It should be possible to commence balloon launches within two years of commencement of the investment phase and reach full compliance within four years.

[1] For SIDS, for the WMO GBON Global Gap Analysis in June 2023, the EEZ area has been added to the total surface area which is the basis for the target number of stations. The standard density requirements for SIDS have been calculated with 500 km for surface stations and 1000 km for upper-air stations.

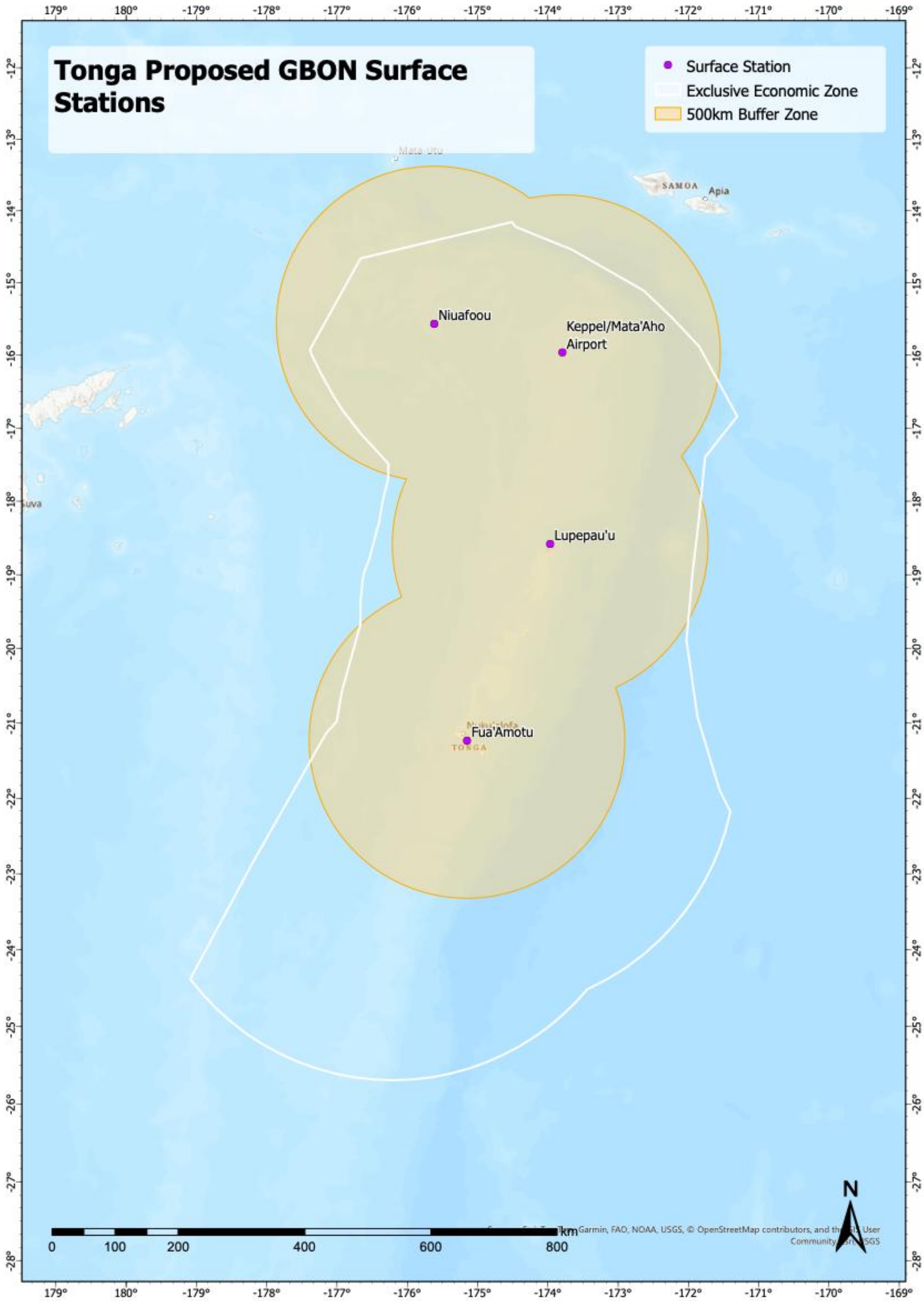

Figure 1 - Proposed GBON Stations showing 500 km circles

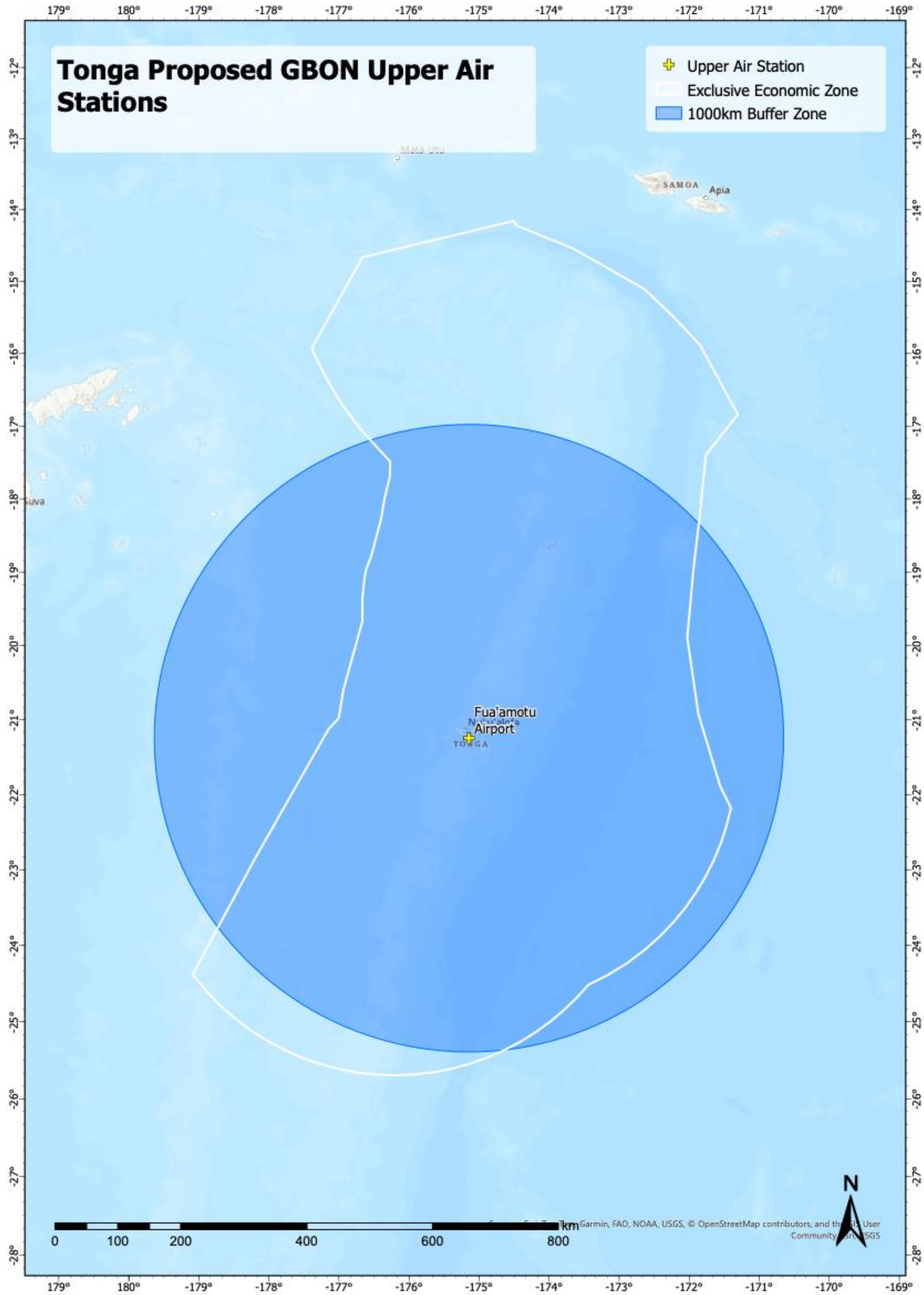

Figure 2 - proposed GBON upper air station showing 1000 km circle

Module 2. GBON Business Model and Institutional Development

2.1. Assessment of national governmental and private organizations of relevance for the operation and maintenance of GBON

Climate and weather-related information in Tonga are the provided by the Tonga Meteorological Service (TMS) as mandated in the Meteorology Act (2017). TMS is solely responsible for providing meteorological services for the country. As such, TMS is the primary organization of relevance to the operation and maintenance of GBON in Tonga.

The Civil Aviation Authority currently have two non-functioning AWOS located at Fua'amotu International Airport (Nuku'alofa) and Lupepau'u International Airport (Vava'u). In the past, these AWOS have not provided data to TMS and TMS have had no responsibility for their operation and maintenance. These stations are not considered further although it is noted that procurement of AWOSs for both these sites in progress under the Partnerships for Aviation project, funded by Australia's DFAT.

For aviation services, TMS provide METARs for Nuku'alofa and Vava'u aerodromes based on manual observations. Fiji Met Service continues to prepare the TAF and SIGMETs based on manual observations.

There are no other operators providing meteorological observations suitable for GBON.

In terms of its ability to support GBON observations in the long term, TMS faces some serious challenges. These are shared with other countries in the region and include a shortage of sufficiently skilled personnel, difficult and expensive logistics, sourcing and procurement of equipment and spares, and unreliable data communications. Together, these factors result in reliability and data quality issues.

In particular, TMS has a shortage of skilled technical staff capable of maintaining AWS. As part of the GBON implementation and compliance phases, **additional funds are sought to support additional staff members and training of current staff on AWS maintenance and radiosonde operations**.

To manage the GBON stations, and the broader network, a comprehensive financial plan for ongoing operational and maintenance will need to be developed, including the total cost of ownership over the life cycle of the infrastructure/system This needs to include spare parts, freight and travel costs to ensure TMS technicians can visit sites for proactive and reactive maintenance, communications costs, logistics costs and all other ongoing costs required to ensure GBON compliance.

To address these challenges, as part of the Investment Phase, TMS will engage with the Ministry of Finance and other potential partners such as SPREP and SPC, to develop a plan for ongoing procurement and funding of essential services to ensure ongoing quality and reliability of the network (**Activity 2.1**).

Customs duties may be imposed for equipment and instrumentation that needs to be sent offshore for calibration and/or maintenance. It is recommended that potential custom duty waivers be investigated by TMS and the World Bank (as the Implementing Entity) (**Activity 2.2**).

2.2. Assessment of potential GBON sub-regional collaboration

The nature of the region, with many smaller countries and a shortage of skilled labour, drives a collaborative approach to common activities. In particular, there is a strong need to work across the region on supporting activities such as technical training and the provision of calibration services.

A Regional SOFF coordination workshop was held in April 2024 and attended by TMS, together with meteorological service directors from across the region.

It is also important to consider the Weather Ready Pacific (WRP) initiative which has the aim of improving capability and capacity for national meteorological services across the region.

To facilitate regional coordination, TMS will continue to be an active participant in relevant regional forums **(Activity 2.3)** including:

- Weather Ready Pacific Steering Committee
- WMO Regional Association and its committees
- Pacific Meteorological Council (PMC) and its committees

The South Pacific Regional Environmental Programme (SPREP) plays an important role in coordinating regional activities and hosts the Weather Ready Pacific Secretariat. The Pacific Community (SPC) also coordinates relevant activities across the region.
The Japan International Cooperation Agency (JICA), the Pacific International Training Desk in Hawaii, and the University of the South Pacific (USP) all contribute significantly to the region, especially in a training capacity.

During the Investment Phase, TMS and World Bank will also look for opportunities for regional synergies for services that can be implemented during the Compliance Phase. Examples include calibration and maintenance services, training, procurement of common equipment types, and development of an Operations and Maintenance Plan.

2.3. Assessment of a business model to operate and maintain the network

TMS's annual core budget for 2023/24 was T$1,400,000 Tongan Pa'anga (approximately USD 574,000). Of this budget, 75 per cent is spent on staff costs. Around 20 per cent of the budget is allocated to operational costs but this is insufficient to completely cover equipment and consumables, communication costs and staff training. The cost of travel to the other island groups in the Kingdom is high and this puts pressure on the operational budgets. As a result, TMS is heavily reliant on donor funding and programmes to support its operations.

To meet the requirements of GBON, additional ongoing funding will be required, noting that the Government also currently supports AWS maintenance in terms of spares and consumables with an additional T$ 150,000 (USD 61,000) annually.

Taking into account governmental processes, the existing skill levels of the NMHS, its legislated mandate, remoteness and the lack of private sector operators, the preferred model is the *Public model – Full state/NMHS owned and operated*. Within this model, there remains opportunity for substantial private sector support to TMS in terms of training, calibration, procurement of equipment and spares, and ICT systems and services.

A critical component of this National Contribution Plan is the development of a comprehensive financial plan for ongoing operational and maintenance, including the total cost of ownership over the life cycle of the infrastructure/system **(Activity 2.4).**

2.4. Assessment of existing national strategies and projects related to observing networks

The *Tonga Meteorological Service Strategic Development Framework and Implementation Plan 2023-2027* (TMS Strategic Plan) was developed under the umbrella of the Tonga Strategic Development Framework II 2015-2025. It sets out five mid- to long-term goals:

- Goal 1: to provide an enabling environment for TMS to enhance performance, strengthen stakeholder confidence and improve its ability to effectively respond to external changes
- Goal 2: to better detect changes in atmosphere, ocean and the environment and provide quality data required to predict future changes
- Goal 3: to reduce vulnerabilities and improve preparedness and response to extreme meteorological, ocean and other environmental events
- Goal 4: to strengthen the capability of the TMS to sustainably met its goals and objectives
- Goal 5: to enhance products and services that meet the users' needs

All of these goals are relevant to the operation of GBON stations, but particularly Goal 2.

Some past, current, and future projects relevant to GBON include:

- The Asian Development Bank Climate Resilience Sector Project (CRSP) funded the supply and installation of 21 AWS.
- The Australian Government-funded Partnerships for Aviation initiative. This is assisting Tonga to upgrade its aviation weather services. This includes, among other activities, replacing the existing, non-operational AWOS at Lupepau'u and Fua'amotu airports.
- Climate and Oceans Support Program in the Pacific (COSPPac). This Australian government programme is, among other activities, assisting Tonga to maintain its CliDE Climate Data Management System. Funded support for the web-based content management system and product generator Climate Data for the Environment Services Client (CliDEsc) is supplemented by support from the New Zealand government.
- New Zealand Ministry of Foreign Affairs and Trade. Includes supporting the procurement and installation of a weather radar at Fua'amotu airport; and short-term training scholarships.
- The World Bank Pacific Resilience Program (PREP). Design of the impact-based multi

hazard early warning system (MHEWS) specific to Tonga.

Weather Ready Pacific is a regional multi-donor initiative which aims to comprehensively strengthen hydro-meteorological capability across the whole value chain in the Pacific. The SOFF investment and proposed regional activities are well-aligned with Weather Ready Pacific. Weather Ready Pacific is currently not funded sufficiently to meet all of its objectives.

It is recommended that at the start of the implementation phase that World Bank and TMS keep up to date with any relevant, planned hydrometeorological development activities to identify other opportunities for leverage and to ensure all planned works are complementary **(Activity 2.5).**

2.5. Review of the national legislation of relevance for GBON

The Meteorology Act 2017 establishes TMS as the sole national authority to provide official meteorological and ocean forecast, prediction, information, warnings and related services including dissemination of long-term and seasonal forecasts. The Act provides the mandate and outlines the functional responsibilities for TMS.

The Act lists, as one of the functions of TMS:

> *exchange of meteorological data with Meteorological Services of other jurisdictions, free and unrestricted, in accordance with the Convention of the World Meteorological Organization for the purpose of meteorology;*

As such, the current Act is adequate in terms of responsibilities and powers given to TMS in complying with its obligations to WMO.

The Act does not cover procurements which is subject to a separate legislation. Custom duties on electronic and specialised equipment range between 3% and 15%. The waiver of custom duties is addressed under Activity 2.2.

Module 3. GBON Infrastructure Development

3.1. Design the surface and upper-air observing network and observational practices

3.1.1. Current State

Tonga's national meteorological service (TMS) observation system currently consists of five staffed offices and twenty-one automatic weather stations (AWS) (Figure 3). There are currently no upper air stations in Tonga.

Figure 3 - Tonga Automatic Weather Stations

Station Name	Assessed reporting status	Station type	Lat	Long	Programs/Network Affiliation
Niuafoou	Partly Operational	Manual	-15.5667	-175.6167	GBON:Operational, RBON:Operational
Keppel/Mata'Aho Airport	Partly Operational	Manual	-15.9607	-173.7927	GBON:Operational, RBON:Operational
Lupepau'u	Operational	Manual	-18.5833	-173.9667	GBON:Operational, RBON:Operational, GSN: Operational
Pilolevu Airport (Haapai)	Operational	Manual	-19.7779	-174.3412	GBON:Operational, RBON:Operational
Fua'Amotu	Operational	Manual, Upper air	-21.2333	-175.1500	GBON:Operational, GOS General:Operational, RBON:Operational

Table 2 - Tonga Staffed Observing Stations

TMS maintains five staffed weather stations: Niuafoou, Keppel/Mata'aho, Lupepau'u, Ha'apai and Fua'amotu (Table 2). The staffed stations have manually-read monitoring equipment, generally including thermometers (mix of liquid-in-glass or digital depending on location) in a Stevenson screen, together with a digital barometer and raingauge. Wind speed and direction are being read from the AWS Display on site (1). If this fails (1), it is being read from the AWS neon website (2). If (2) fails, it is being estimated using the traditional Beaufort scale.

Figure 4 - Lupepau'u Airport (Vava'u) meteorological enclosure

Fua'amotu operates 24 hours per day providing hourly METAR/SPECI observation and targets 3-hourly (eight times per day) SYNOPs. The outer island stations target 3 to 6 hourly (four to seven times per day) SYNOPs depending on staffing. General security and maintenance of the weather stations and surrounds including cutting of vegetation is undertaken by the observing staff on site at the five offices.

Tonga currently does not have direct access to the GTS/WIS. Observations are emailed to both New Zealand MetService and the Australian Bureau of Meteorology for inclusion in onward bulletins. There is no interaction with the Regional WIGOS Centre for metadata management or data quality monitoring.

Station Name	Lat	Long	Station Type
Niuafo'ou Airport AWS	-15.5714	-175.6294	Automatic weather station (AWS, AWOS)
Niuatoputapu Sea Level	-15.9423	-173.7665	Sea level station
Niuatoputapu AWS	-15.9607	-173.7927	Automatic weather station (AWS, AWOS)
Lupepau'u Airport AWOS	-18.5858	-173.9689	Automatic weather station (AWS, AWOS)
Lupepau'u Airport AWS	-18.5858	-173.9689	Automatic weather station (AWS, AWOS)
Fatai AWS	-18.6346	-173.9667	Mini AWS
Longomapu AWS	-18.6421	-174.0617	Mini AWS
Fangatongo AWS	-18.6442	-173.9850	Automatic weather station (AWS, AWOS)
Koloa AWS	-18.6456	-173.9352	Mini AWS
Neiafu Sea Level	-18.6525	-173.9845	Sea level station
Ha'ano AWS	-19.6627	-174.2919	Mini AWS
Tofua AWS	-19.7517	-175.0319	Mini AWS
Pilolevu Airport	-19.7779	-174.3412	Staffed weather station
Ha'apai SL	-19.8022	-174.3523	Sea level station
Lifuka AWS	-19.8036	-174.3481	Automatic weather station (AWS, AWOS)
Ha'Afeva	-19.9500	-174.7000	Mini AWS
Nomuka SL	-20.2502	-174.8155	Sea level station
Nomuka AWS	-20.2562	-174.8005	Automatic weather station (AWS, AWOS)
Kolovai AWS	-21.0986	-175.3434	Automatic weather station (AWS, AWOS)
Mo'unga Olive AWS (Afaa AWS)	-21.1286	-175.0638	Automatic weather station (AWS, AWOS)
Nuku'alofa SL	-21.1370	-175.1810	Sea level station
Nukualofa AWS	-21.1373	-175.1957	Automatic weather station (AWS, AWOS)
Matatoa AWS	-21.1625	-175.2317	Automatic weather station (AWS, AWOS)
Houma AWS	-21.1675	-175.3055	Mini AWS
Lapaha AWS	-21.1840	-175.1095	Mini AWS
Atele College AWS	-21.1848	-175.2305	Automatic weather station (AWS, AWOS)
Toloa AWS	-21.2263	-175.1611	Mini AWS
Fua'amotu Airport AWOS	-21.2377	-175.1583	Automatic weather station (AWS, AWOS)
Eua SL	-21.3384	-174.9553	Sea level station
Hango AWS	-21.3416	-174.9438	Mini AWS
Kaufana AWS	-21.3767	-174.9573	Automatic weather station (AWS, AWOS)

Table 3 - Tonga AWS

In terms of AWS, there currently twenty-one AWS (Table 3) and two AWOS systems installed in Tonga. The two AWOS are not currently operational but are planned to be restored with support from the Australian government under the *Partnerships for Aviation* programme.

Tonga provides an excellent example of a well-planned and well managed tiered network. The AWS were originally installed through an ADP Climate Resilience Sector Project (CRSP) and exist in a range of configurations from wind (6m) and rain only, to fully GBON-compliant AWS. Overall, the AWS enclosures and equipment are well maintained. On each island, Ministry staff regularly visit each station to cut grass and keep equipment clean.

Data from these AWS are not shared internationally, and therefore do not contribute to improving the model products that underpin TMS's forecasts and warnings. AWS data are integrated into the TMS CliDE database and data available to TMS staff via local displays, and/or web portals. This has been highlighted as an issue as, in the event of an internet outage, TMS have no ability to see their AWS data.

Although it has an extensive network, Tonga currently has no GBON compliant surface stations. The staffed offices in the outer islands provide 6-hourly synoptic observations and the station at Fua'amotu provides 3-hourly observations. Of the twenty-one AWS, five are co-located with the staffed offices and, as a result, are the best candidates for designation as GBON stations.

While TMS is in a better situation than many NMHS in the region, they still face challenges in funding and retaining skilled and sufficient personnel, logistics, sourcing and procurement of equipment and spares, maintenance and data communications which all potentially lead to various reliability and quality issues especially in the more remote islands.

TMS technical staff have travelling standards (air and soil temperature, relative humidity, pressure, rainfall and solar radiation) to enable station inspections and verifications at least annually. However, there are no calibration facilities in Tonga for the maintenance and testing of AWS components and systems. As a result, the local verification standards are unable to be calibrated in Tonga and need to be sent offshore. In this regard, TMS make use of neighbouring existing Regional Instrument Centres (RIC) and calibration services in Australia, New Zealand and Fiji. There are plans for appropriate workshop space with the planned building of the new office closer to Nuku'alofa.

Sourcing instruments, parts and materials is a challenge. With no local supplier, all parts and components must be procured from overseas with at times lengthy delivery times and costly freight. Some tools were supplied with the initial project, and recognizing the significant investment, the Government of the Kingdom of Tonga continues to fund the annual purchase of spares for the AWS to maintain, and improve, capacity and reliability of the AWS network.

3.1.2 GBON Surface Stations

As noted in the National Gap Analysis, the four proposed GBON stations are Niuafoou, Keppel/Mata'Aho Airport, Lupepau'u and Fua'amotu. Each of these locations has a staffed office, and a functioning Automatic Weather Station. The AWS are co-located with the manual instruments, except for Fua'amotu where the AWS is located 700 metres to the south-west of the staffed office.

The AWS are recently installed and compliant in terms of variables measured. As such they are the logical choice to be designated as the primary GBON stations for Tonga.

Due to the large expanses of ocean between sites, centralised maintenance and repair is challenging. Taking into account that each of these sites also has a staffed weather office, the proposed approach is for the AWOS/AWS to be designated as the primary GBON data source. On-site support, first-in maintenance and backup will be provided by the staff on site. The surface stations to be designated as GBON as per this plan are listed in Table 4.

Station name	Existing Station Status	Planned GBON Configuration
FUA'AMOTU	AWS and Staffed Station	AWS with on-site staff support
KEPPEL/MATA'AHO AIRPORT	AWS and Staffed Station	AWS with on-site staff support
LUPEPAU'U	AWS and Staffed Station	AWS with on-site staff support
NIUAFOOU	AWS and Staffed Station	AWS with on-site staff support

Table 4 - Planned GBON surface stations

This approach has the following benefits:

- The AWS will provide reliable and regular observations in standard formats.
- Designating the AWS as primary means that there is no need to increase staff to provide 24 hours/day observations.
- Having trained staff and spares on site is a cost-effective way of providing front line maintenance and return to service, ensuring sufficient uptime to meet GBON requirements.
- Having both manual and automated observations provides a degree of redundancy in the case of sensor/equipment failure. In the event of AWS downtime, the frequency of manual observations could be increased as needed.
- The presence of trained staff on site will provide quality control and allow for quick fault identification and restoration of equipment.
- Staff on site will be able to provide security and grounds maintenance to ensure the station continues to comply with WMO siting requirements.

Given that the staffed stations and AWS already exist and are co-located, there are no significant infrastructure investments required. To reach GBON compliance, the main requirement is to establish operational systems and procedures to allow the AWS data to be shared internationally in standard formats.

The activities required are:

- Reviewing equipment at each site and ensuring that items detailed in Table 5 are present. Selection and installation of instruments will be compliant with WMO-No. 8 Guide to Instruments and Methods of Observation and the GBON Tender Specification for AWS (**Activity 3.1**).
- Designating the AWS as the GBON stations and updating the information in OSCAR/Surface (**Activity 3.2**).
- Updating AWS software to provide compliant formats (**Activity 3.3**).
- Developing standard operating procedures for automated measurements including installation, maintenance and verification (**Activity 3.4**).
- Continuing full manual observations at Fua'omotu for two years to characterise the differences between the manual and AWS sites, given the separation (**Activity 3.5**).
- Continuing a subset of manual observations to provide a period of overlap (one year minimum) between manual and automated observations (**Activity 3.6**).

For GBON purposes, one staff member per site is required, and this should be supported by SOFF, freeing up resources in TMS for other high-priority activities (**Activity 3.7**). Staff located on site will require training in basic AWS maintenance (**Activity 3.8**) and this training may need to be repeated at intervals.

There are limited spares (instruments, components, consumables) for both manual and AWS surface stations. A complete set of spares should be procured to ensure manual observations are able to continue in the event of breakages of failures (**Activity 3.9**).

Additional calibration kits are required to ensure that GBON stations provide traceable data. At least one working calibration kit is needed to service the four GBON sites and perform validation and calibration at the required intervals, most likely 6 monthly (**Activity 3.10**).

It is recommended for Tonga to continue to exchange 3 hourly data from all its staffed stations and to expand this to the broader AWS network if possible. This will provide additional data to global NWP systems and improve the quality of forecasts for Tonga and the region.

AWS Sites	**Manual Backup Sites**
Instruments	Instruments
• Barometer (Class A) • Air temperature (Platinum resistance thermometer at 1.25 m above ground level • Relative humidity (Capacitance sensor) at 1.25 m above ground level. • Wind sensors (measured wind speed and direction) at 10 m • Raingauge (≥ 200 mm diameter, tipping bucket • AWS processor to collate and transmit data. (Minimum buffer storage to be 30 days.) • Ceilometer * • Visibility meter * • Present weather sensor *[2]	• Digital readout from all AWS sensors. • Manual (alcohol in glass thermometer) • Wet and dry bulb thermometers (alcohol in glass) • Maximum/minimum thermometer (alcohol in glass) • 5″ (127mm) manual raingauge
Structures	Structures
• Stevenson screen, double louvered (may be same screen as used for manual observations if co-located in same enclosure) • 10 m tilting mast if sensors installed (may be co-located with AWS)	• Stevenson screen, double louvered (may be same screen as used for manual station if co-located in same enclosure)
Facilities	Facilities
• Suitable sized enclosure to meet exposure requirements as specified by WMO. • Mains and/or solar power supply to AWS including batteries to support solar, and/or to act as UPS for message transmission. • An uninterruptable power supply to ensure message transmission.	• Suitable sized enclosure to meet exposure requirements as specified by WMO (shared with automatic instruments). • A power supply for the operation of any digital instruments and displays. • Ability to house and store observing consumables, cleaning materials, station records and stationery, and preferably, a workstation (with PC and monitor/s) for the manual observer. • A local display for any electronic data (T/RH/WS/WD/PP) recorded on site. • Supply of clean water for cleaning and wet bulb readings.
Communications	Communications
• Satellite communications to ensure regular, timely message transmission.	• Cellular, e-mail or HF radio backup.

Table 5 - Equipment requirements at GBON surface stations

[2] *Not a requirement for GBON

3.1.2 GBON Upper Air Station

As noted, there is no upper air station operating in Tonga. The National Gap Analysis proposes one new upper air station at Fua'amotu (Table 6).

Station name	Type	Latitude	Longitude
FUA'AMOTU	Upper air	-21.2465	-175.1436

Table 6 - Tonga Planned Upper Air Station

Considering the availability of staff on site and the difficulty in maintaining complex infrastructure, a manual balloon release system is proposed, consisting of a balloon shed and hydrogen generator. The most convenient location would be in close proximity to the observing office. There appears to be ample land around the airfield. Access to power, water and communications will be critical.

The key activities are as follows:

- **Activity 3.11**: identify an appropriate site and, if necessary, secure a long-term lease.
- **Activity 3.12**: initiate discussions with the airport and aviation authority to seek permission to lunch weather balloons at the airport.
- **Activity 3.13**: develop construction drawings for the balloon shed and any associated infrastructure such as concrete pads, storage of consumables, power, water and communications.
- **Activity 3.14**: obtain the necessary planning permissions for construction.
- **Activity 3.15**: tender for the radiosonde ground system, hydrogen generator and supply of radiosondes as outlined in Table 7. Tender specifications as per WMO recommendations and guided by NZ MetService. Recommended duration is 5 years with the option to extend 2 years.
- **Activity 3.16**: undertake all construction works and installation of the radiosonde system and hydrogen generator.
- **Activity 3.17**: undertake training of staff on site in radiosonde operations and hydrogen safety.
- **Activity 3.18**: configure the upper air system to provide data in WMO-compliant BUFR format.
- **Activity 3.19**: secure funding for provision of consumables to allow a flight schedule of two flights per day.
- **Activity 3.20**: secure sufficient ongoing funding for a roster of staff covering the two balloon launch times (see also Activity 3.7).

Manual balloon release system
Instruments and consumables
• Radiosondes • Balloons • Personal Protective Equipment (PPE) suitable for dealing with explosive environments
Structures
• Balloon shed where manually constructed balloon trains can be safely inflated and released. • Separate (or partitioned) Hydrogen generation shed and storage tanks • Fencing, adequate for the required security of the site. • Exclusion zones (painted lines), beacons/lighting and paths within the site
Facilities
• An area sufficient to ensure exclusion of the public and obstacles that may impact or be impacted by balloon releases. • Ability to store upper air consumables, cleaning materials, various computer and communications systems supporting the upper air observations, and a work area for the manual observer to assemble balloon trains as appropriate. • A local display for the radiosonde profile and access to sensors for ground check data (T/RH/WS/WD/press). • A hydrogen generation system and storage facility to ensure adequate supply for the anticipated upper air program. • Power supply to enable hydrogen generation and monitoring, constant communication with the radiosonde and the transmission of coded messages. • An uninterruptable power supply to ensure the above. • Supply of clean water for hydrogen generation
Communications
• Communications systems integral to the upper air program (to receive sonde data, normally supplied with the Upper Air system). • Robust communications to ensure regular, timely message transmission.

Table 7 - Instruments and observing systems for planned GBON upper air stations

3.1.4 Maintenance

Equipment maintenance and calibration is one of the most significant challenges for TMS to meet its GBON requirements. Maintenance (see also **Module 4**) is therefore a critical focus of the contribution plan. Maintenance is crucial to maintain routine operations, address faults as they arise and ensure the safety of the staff. Examples of typical maintenance tasks are shown in Table 8.

Freight costs within Tonga and the region are very high, especially relative to operational budgets (See also Module 2 and Activities). There is also freight logistics and handling to deal with, adding to the challenges and budget pressures.

Level	Description	Surface tasks	Upper air tasks
1	• Basic tasks requiring few consumables or parts carried out by local personnel, local staff or contractors. • Basic instruction required • Moderately complex tasks carried out by staff following standard operating procedures (SOPs). Tools, parts and consumables will be required. Specific instruction on hydrogen safety also required for staff at Upper Air stations.	• Clean Stevenson screen. • Change wet-bulb wick. • Cut grass/ vegetation.	• Attach sondes and launch balloons. • Change over hydrogen cylinders. • Cleaning of balloon shed and equipment
2	• Technical tasks carried out by staff following SOPs. • Equipment specific. Some instruction required via supplier, and/or TMS technical staff. Tools, parts and consumables will be required. Instrument specific training required.	• Collect station metadata. • First line maintenance e.g., unblocking and checking raingauge. • Under guidance of remote technicians, replace and verify performance of sensors.	• Check operation of HoGen • Check gas lines for leaks • Check operation of water spray
3	• Specialised maintenance actions carried out by trained staff. • Procedures are complex and fault-finding is a required skill. Advanced meteorological (instrument) technician training required.	• Replace infrastructure. • Set up and configure new equipment and sensors. • Advanced fault finding. • Verification and/or calibration of sensor/instruments. • Install data communications system.	• Annual maintenance of UA system. • Advanced fault-finding. • Set up and configure new equipment and sensors. • Install data communications system.
4	• Specialised repair or replacement by vendor or manufacturer	• Return to vendor or manufacturer of component	• Return to vendor or manufacturer of component.

Table 8 - Example maintenance tasks for GBON stations

Therefore, it is important that a detailed Operations and Maintenance plan be developed (**Activity 3.21**) and that this be fully costed and budgeted for (see Activity 2.1) for the GBON observation network and systems, including both preventive and reactive maintenance. This will necessarily include sensor/instrument regular maintenance and calibration, with instrument calibration being carried out in Fiji, New Zealand or Australia.

The cost of calibration equipment and the ongoing operational costs of maintain calibration equipment is high for TMS, and for many NMHS in the region. A key recommendation is to centralise calibration, including calibration of travelling references used by technical staff. This must also be conducted in collaboration with WRP **(Activity 3.22)**

The radiosonde system includes complex components and requires specialised maintenance. For this reason it is recommended that annual maintenance of the balloon facilities, including the hydrogen generation system, be performed by expert staff from New Zealand MetService, the Australian Bureau of Meteorology or the equipment manufacturer (**Activity 3.23**).

Funding for ongoing essential services such as logistics, travel and communications, during both the Investment and Compliance phases will be key to ensuring the reliability of the GBON stations. As outlined in **Module 2,** the World Bank and TMS will develop a plan for ongoing procurement of essential services to support TMS to operate and maintain the stations to a GBON standard through both Investment and Compliance phases.

This funding mechanism will need to support freight and travel costs to ensure TMS technicians can ship equipment for calibration, visit sites for the regular proactive maintenance and for reactive repairs when required. It will also need to support station communication costs (satellite) travel costs (air, boat), logistics costs and all other ongoing costs required to ensure GBON compliance.

As most Pacific Island NMHS have a small staff, an effective and sustainable approach to maintenance would be to establish regionally-based teams that can support multiple Pacific Island Countries. Therefore, it is proposed that a Pacific regional solution also be identified for maintenance and repair, instrument calibration and train-the-trainer services (see also Module 4, Section 4.2**).**

3.2. Design of the ICT infrastructure and services

3.2.1 Data collection and transmission

Internet connectivity in Tonga is via undersea cable. This was disrupted for several weeks by the Hunga Ha'apai eruption and tsunami in 2021 and there have been subsequent disruptions due to damage to the cable.

Remote staffed stations are connected via the cellular network with backup by radio. The observations from these stations are recorded by the observers in logbooks and transcribed into coded messages that are then then relayed to TMS at Fua'amotu, where they are formatted and emailed to the New Zealand MetService and the Australian Bureau of Meteorology for entry onto the GTS. This procedure is labour intensive and has the possibility to introduce errors at multiple points in the process.

The AWS network is connected via satellite BGAN with data then being sent to NIWA in New Zealand. NIWA then make the data available to TMS via a web interface. This design, whilst effective, has some serious limitations. Firstly, the data is not shared internationally where it could improve the quality of model products over Tonga and the region. Secondly, and most importantly, during periods of internet outage (where the international cable has been severed), TMS has had no access to data from its AWS network. Thirdly, Tonga has no control over its own data.

To address these issues, the GBON stations need to be able to transmit data back to TMS Headquarters via satellite, and in agreed formats. There should be a backup communications system available in case of satellite or terminal outages. A WIS 2.0 node will allow two-way data communications from TMS via the internet connection. This will have the additional benefit of facilitating improved access to international observations, model fields and satellite data.

A backup internet connection is strongly recommended to enable uptime targets to be met.

The required activities are:

- Establish primary and backup communications (possibly cellular) between the GBON stations and TMS Headquarters with an uptime target of better than 99% (**Activity 3.24**).
- Establish a WIS2.0 node at TMS Headquarters (**Activity 3.25**).
- Establish a backup **satellite-based** internet connection at TMS Headquarters (**Activity 3.26**).
- Develop standard operating procedures for data quality monitoring and metadata management in cooperation with the Regional WIGOS Centre (**Activity 3.27**).

3.3. Design the data management system

Data from AWS in Tonga are ingested into the Climate Data for the Environment (CliDE). CliDE is a well-established Climate Database Management System (CDMS) used in 14 Pacific Island Countries. Each country maintains a local version of CliDE database along with a product generator, CliDEsc.

CliDE provides many functions including data entry, storage, basic visualization and extraction tools for weather and climate data, comprehensive metadata, instrument/equipment tracking and reporting. AWS data is already ingested into CliDE, which is the preferred system for data visualisation.

There will be some minor work to ensure that data from the four GBON stations is archived and accessible in CliDE (**Activity 3.28**). The establishment of the WIS2.0 node will also ensure that data is available to any future forecaster visualisation systems used by TMS.

3.4. Environmental and sustainability considerations

Preventative maintenance programs are important to extend the life of installed equipment and should be built into the regular work schedules at the stations. Shipment of items in wooden, cardboard or paper packaging rather than plastics is simple to specify and comply with. These materials can be repurposed or recycled.

Education and repeated and progressive training are key to improving the maintenance, repair and reuse of equipment, where practicable, and therefore reducing levels of waste. This can start with relatively simple tasks such as keeping equipment clean to extend its useful life. This can be particularly applicable to masts and housings.

Mercury instruments are in the process of being phased out. Digital systems are used for air temperature (including maximum and minimum) and pressure at the staffed offices. All remaining mercury in glass thermometers and barometers are to be disposed of responsibly (**Activity 3.29**).

Improving coordination between various projects and programmes is crucial. A particular challenge is the proliferation of different systems that are currently being installed. It is important that ongoing operational support (maintenance, fault resolution, data access) are built into any activities. Having multiple types of equipment, such as AWS, increases significantly the training required, the complexity of work and the need to hold multiple types of spare parts.

Module 4. GBON Human Capacity Development Module

4.1. Assessment of human capacity gaps

TMS has a 38 full-time staff (July 2025), including the director. A breakdown is provided in **Error! Reference source not found.**.

Classification	Staff	Staff with degree
Professional	15	14
Technical	23	

Table 9 - Staff numbers and qualifications

There are 31 male and seven female staff. 15 staff are classed as professional, and the remaining 23 as technical staff.

Key gaps, or vulnerabilities, in human capacity necessary for continued GBON compliance are:

- Limited number of technical staff when considering the amount of installed equipment
- Observation staff have no training in basic (first line) maintenance of AWS.
- Technical staff have limited training in end-to-end AWS maintenance and operation.
- Technical staff have limited training in satellite communications and the various tools to support these systems.
- Additional observing staff may be required to support the increased observation programme – specifically two upper air soundings per day.
- Lack of basic electronics training for technical staff

A common requirement of regional meteorological services is for accredited training. Outside of tertiary qualifications, this can be difficult to achieve. The Basic Instruction Package – Meteorological Technicians (BIP-MT) as conducted by the Regional Training Centre in Fiji has Diploma status and future changes to the qualification may increase its relevance to modern automated observing systems.

4.2. Design capacity development activities for technical staff

For the GBON surface stations, whilst the majority of the necessary infrastructure is already in place, there is still significant work in setting up data communications and operational procedures. The upper air station, on the other hand, is a completely new build and will require dedicated project management for the duration of the project.

It is therefore recommended that there be a SOFF-funded programme/project manager to oversee network and programme management during the Investment phase and for the first year of the compliance phase (**Activity 4.1**). The works could be completed within one to two years.

Technical training, especially on AWS maintenance, needs to be ongoing, regular and progressive. AWS training is complex, especially when factoring in the onsite maintenance, calibration, network management and ICT. A multi-level approach is recommended to get the best outcomes as outlined in Module 3, Section 3.1.4.

Each country's contribution to GBON needs to be considered in the context of the neighbouring countries and it is important to view capacity development activities through a regional lens. A regional Pacific approach is the most effective and sustainable way forward. It is recommended that the Pacific Island Education, Training and Research (PIETR) panel, with SOFF funding support, be tasked with preparing advice and recommendations to develop a detailed training plan for the PMC and its members **(Activity 4.2).** This should leverage current WMO and WRP activities.

To address some of the vulnerabilities and gaps identified, the following additional capacity development activities are recommended:

- **Activity 4.3:** Conduct training in basic automated and manual weather station maintenance and field checks for observation staff. This training must be specific to the equipment installed and is essential.
- **Activity 4.4:** Conduct advanced training in automated and manual weather station maintenance and field checks.
- **Activity 4.5**: Conduct training in radiosonde operations and hydrogen safety for all staff involved in balloon operations.
- **Activity 4.6:** Conduct training in WMO WIGOS tools OSCAR/Surface and WDQMS and CliDE/CliDEsc to selected members of the Observations, Climate, and Technical teams for system monitoring and maintenance. This also needs to include compilation and maintenance of discovery and descriptive metadata and use of CliDE and OSCAR/Surface for maintaining metadata.
- **Activity 4.7:** SOFF to support TMS to recruit and fund any additional staff required to meet the expanded observation programme required for GBON compliance. (See also Activities 3.7 and 3.20)

4.3. Design capacity development activities for senior management

Key training for senior management should include aspects important for GBON operations, in particular financial management, asset management, strategic thinking and project/portfolio management.

- **Activity 4.8:** work with Weather Ready Pacific to ensure that the training program delivered to NMHS Directors and senior staff includes the skills necessary to operate and sustain national observing networks.

4.4. Gender and CSOs considerations

TMS currently has 31 male staff and 7 female staff. The TMS Strategic Development Framework 2023-2027 acknowledges this issue as follows:

> *The gender ratio is heavily male dominated and need particular attention to close the staff gender gap.*

TMS is included within Scale-up Inclusive Early Warning and Action in the Pacific (SIEWAP), a four-year, US$ 5.5 million project, funded by the Climate Risk and Early Warning Systems (CREWS) Initiative. This project aims to strengthen multi-hazard early warning systems (MHEWSs) across 14 Pacific nations through delivering gender-responsive services and improved forecasting products to ensure timely and inclusive warnings, especially for the most vulnerable communities.

The SOFF Gender Action Plan includes a target for 50% of the people participating in SOFF-funded capacity development activities to be female.

Recommendations to further address this imbalance:

- **Activity 4.9:** Engagement with civil society organisations (CSO). This could include working with other programmes and/NGOs, community and school group presentations.
- **Activity 4.10:** Active inclusion of gender considerations in SOFF-related recruitment activities with the target of 50% of people participating to be women.
- **Activity 4.11:** Develop a Gender Action Plan during the Investment Phase to guide the mainstreaming of gender and social inclusion initiatives into SOFF investments.

The Gender Action plan could include targets for female participation with SOFF Investment and Compliance phases in Tonga (staff recruitment) and the development of ongoing campaign in schools and communities to promote female participation in roles linked to TMS. It should include metrics and KPIs to be measured over time.

Module 5. Risk Management Framework

5.1 Assess the risks of the observing network and propose mitigation measures

A high-level risk assessment has been undertaken focusing on risks that were identified during the readiness phase, with planned mitigation measures. The mitigation measures will be implemented during the investment phase **(Activity 5.1).**

The risks along with mitigating measures are included in Table 10.

Identified Risk	Mitigation Measures	Responsibility	Monitoring and Evaluation
Failure to meet GBON targets due to inadequate equipment maintenance or delays in return to service **Risk level is high.**	Create a costed operations and maintenance plan. Limit the number of different technologies and systems used. Use common technology and instruments and therefore reduce costs, and risks, of the overhead of operating multiple systems. Establish funding mechanism and protocols for routine procurement of spares and consumables. Establish a funding mechanism for travel to remote stations. Ensure adequate spares are held at all remote stations. Co-location of automated weather stations with manual stations. Train manual observers to provide basic maintenance and redundancy	TMS and WORLD BANK	Regular (annual) review of O&M and budgets. Monthly reporting on logistics needs and activities. Monthly review of GBON compliance via CliDE and WDQMS Annual review of staff training records
Poor data quality or lack of data from unattended AWS due to degradation of site (environmental) conditions, vandalism or theft. **Risk level is high.**	Proactive maintenance by TMS staff funded through establishment of 'logistics fund' Community engagement of importance of reliable data. Fencing protection from wandering animals (dogs, pigs) Review of data that fails automated quality checks	TMS and WORLD BANK	Monthly review of CliDE, WDQMS and GBON compliance. Weekly review of quality flagged data.
Poor data quality due to inadequate workspace and tools for servicing, repair and calibration of equipment and sensors. **Risk level is high.**	Provision of appropriate facilities and tools at HQ for repair and maintenance of equipment and instruments. Make use of regional neighbours and partners for calibration. Establish a funding mechanism for transport of instruments for calibration.	TMS and WORLD BANK	Annual quality audit by TMS quality manager

Poor internet connections or unreliable power leading to communication outages and data transmission delays. **Risk level is high.**	Equip all stations with alternative communication methods e.g., Chatty Bettle, HF Radio. Equip all stations with battery backups.	TMS and WORLD BANK	Monthly review of CliDE, WDQMS and GBON compliance.
Inadequate and/or fragmented storage or workspaces for equipment leading to degradation of equipment. **Risk level is medium.**	Provision of appropriate facilities for storage of equipment to protect from environment and fauna.	TMS and WORLD BANK	Annual quality audit by TMS quality manager
Insufficient human resources or technical skills to install or maintain stations, equipment and ICT system **Risk level is medium.**	Develop training and capacity building plan for technical staff. Regular, and repeated, training of technical and observing staff during Investment and Compliance phase. Recruitment of additional skilled staff during both Investment and Compliance Phase as outlined in Module 4. Workforce planning to address attrition. Use of common technology and instruments to limit the number of different technologies and systems used.	TMS and WORLD BANK	Annual human resources audit by TMS Including review of staff training records.
Radiosonde station installation is delayed significantly **Risk level is high.**	Develop detailed project plan and internal risk analysis Recruit a dedicated project manager Conduct early engagement with key stakeholders	TMS and WORLD BANK	

Table 10 - Risk analysis

Module 6. Transition to SOFF investment phase

The activities outlined in this National Contribution Plan will provide the basis for developing the Investment Proposal for the Tonga National GBON Network. The Investment Proposal will be developed by World Bank and TMS, with input from New Zealand (MetService and NIWA) **(Activity 6.1).**

Summary of GBON National Contribution Plan

Provide summary of GBON National Contribution Plan by filling this table

Components	Recommended activities
Module 2. GBON business model and institutional development	1. Engage with the Ministry of Finance and other potential partners, to develop a robust plan for ongoing funding and procurement of essential services such as travel, communications services and consumables.
	2. Investigate customs duty waivers for equipment and instrumentation that needs to be sent offshore for calibration or maintenance.
	3. TMS to continue to be an active participant in regional fora.
	4. Develop a comprehensive financial plan for ongoing operation and maintenance of the network.
	5. Keep up to date with any relevant, planned hydrometeorological development activities to identify other opportunities for leverage and to ensure all planned works are complementary (Linked to 2.3).
Module 3. GBON infrastructure development	1. Reviewing equipment at each surface site and ensuring that necessary equipment is present.
	2. Designating the AWS as the GBON stations and updating the information in OSCAR/Surface.
	3. Updating AWS software to provide compliant formats.
	4. Developing standard operating procedures for automated measurements including installation, maintenance and verification.
	5. Continuing full manual observations at Fua'omotu for two years to characterise the differences between the manual and AWS sites, given the separation between the two.
	6. Continuing a subset of manual observations to provide a period of overlap (one year minimum) between manual and automated observations.
	7. Support for one staff member for each of the remote sites.
	8. Provide training to on-site staff in basic AWS maintenance.
	9. A complete set of spares should be procured to ensure manual observations are able to continue in the event of breakages of failures
	10. Procure and maintain at least one working calibration kit for each of the four GBON sites and perform validation and calibration at the required intervals, most likely 6 monthly.
	11. Identify an appropriate site and, if necessary, secure a long-term lease for the upper air station.
	12. Initiate discussions with the airport and aviation authority to seek permission to lunch weather balloons at the airport.
	13. Develop construction drawings for the balloon shed and any associated infrastructure such as concrete pads, storage of consumables, power, water and communications.
	14. Obtain the necessary planning permissions for construction.

	15. Tender for the radiosonde ground system, hydrogen generator and supply of radiosondes as outlined in Table 7.
	16. Undertake all construction works and installation of the radiosonde system and hydrogen generator.
	17. Undertake training of staff on site in radiosonde operations and hydrogen safety.
	18. Configure the upper air system to provide data in WMO-compliant BUFR format.
	19. Secure funding for provision of consumables to allow a flight schedule of two flights per day.
	20. Secure sufficient ongoing funding for a roster of staff covering the two balloon launch times (see also Activity 3.7).
	21. Develop a detailed operations and maintenance plan that is fully costed and budgeted.
	22. Regionally centralise calibration, including calibration of travelling references used by technical staff.
	23. Annual maintenance of the balloon facilities, including the hydrogen generation system, be performed by expert staff from New Zealand MetService, the Australian Bureau of Meteorology or the equipment manufacturer
	24. Establish primary and backup communications (possibly cellular) between the GBON stations and TMS Headquarters with an uptime target of better than 99%.
	25. Establish a WIS2.0 node at TMS Headquarters.
	26. Establish a backup satellite-based internet connection at TMS Headquarters
	27. Develop standard operating procedures for data quality monitoring and metadata management in cooperation with the Regional WIGOS Centre
	28. Ensure that data from the four GBON stations is archived and accessible in CliDE
	29. All remaining mercury in glass thermometers and barometers are to be disposed of responsibly
Module 4. GBON human capacity development	1. Recruit a SOFF-funded project manager to oversee network and programme management during the investment phase and the first year of the compliance phase.
	2. The Pacific Island Education, Training and Research (PIETR) panel, with SOFF funding support, to be tasked with preparing advice and recommendations to develop a detailed training plan for the PMC and its members covering all aspects of the data chain.
	3. Conduct training in basic automated and manual weather station maintenance and field checks for observation staff.
	4. Conduct advanced training in automated and manual weather station maintenance and field checks.
	5. Conduct training in radiosonde operations and hydrogen safety for all staff involved in balloon operations.
	6. Conduct training in WMO WIGOS tools OSCAR/Surface and WDQMS and CliDE/CliDEsc to selected members of the

	Observations, Climate, and Technical teams for system monitoring and maintenance.
	7. SOFF to support TMS to recruit and fund any additional staff required to meet the expanded observation programme required for GBON compliance.
	8. TMS to work with Weather Ready Pacific to ensure that the training program delivered to NMHS Directors and senior staff includes the skills necessary to operate and sustain national observing networks.
	9. Engagement with civil society organisations (CSO). This could include working with other programmes and/NGOs, community and school group presentations.
	10. Active inclusion of gender considerations in SOFF-related recruitment activities with the target of 50% of people participating to be women.
	11. Develop a Gender Action Plan during the Investment Phase to guide the mainstreaming of gender and social inclusion initiatives into SOFF investments.
Module 5. Risk Management	1. Implement mitigation measures as outlined in the risk management framework.
Module 6. Transition to SOFF investment phase	1. Develop the investment proposal, incorporating activities from this GBON national contribution plan.

Annexes (if any)

Report completion signatures

Peer Advisor signature

Ms Emma Coombe
Senior Adviser – International Development
New Zealand MetService

Beneficiary Country signature

Mr Laitia Fifita,
Director
Tonga Meteorological & Coast Radio Service, PR of Tonga to WMO

WMO Technical Authority signature