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GBON National Contribution Plan of Trinidad and Tobago

Systematic Observations Financing Facility

Weather and climate data for resilience

GBON National Contribution Plan
Trinidad and Tobago

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Abbreviations

CHUAS	Cooperative Hurricane Upper Air Station
CIMH	Caribbean Institute for Meteorology and Hydrology
CMO	Caribbean Meteorological Organization
DMS	Data management System
FMI	Finnish Meteorological Institute
GBON	Global Basic Observation Network
ICAO	International Civil Aviation Organization
IDB	Inter-American Development Bank
IE	Implementing Entity
NMHS	National Meteorological and Hydrological Service
NWP	Numerical Weather Prediction
NWS	National Weather Service
QC	Quality Control
QMS	Quality Management System
SOP	Standard Operation Procedures
TTMS	Trinidad and Tobago Meteorological Service
UCAR	University Corporation for Atmospheric Research
WMO	World Meteorological Organization
WRA	Water Resource Authority

Module 1. National Target toward GBON compliance

Table1. GBON National Contribution Target

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	1	2	-	1	1	-
Upper-air	1	1	-	1	1	-
Marine	***when applicable**					

The target amount of GBON weather stations for Trinidad and Tobago is one surface station and one upper-air station based on the WMO criteria for SIDS[1].

GBON nominated surface weather station is in need of full replacement for an automatic one, and the upper-air station in need of key component upgrades.

[1] For SIDS, for the WMO GBON Global Gap Analysis in January 2022, 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.

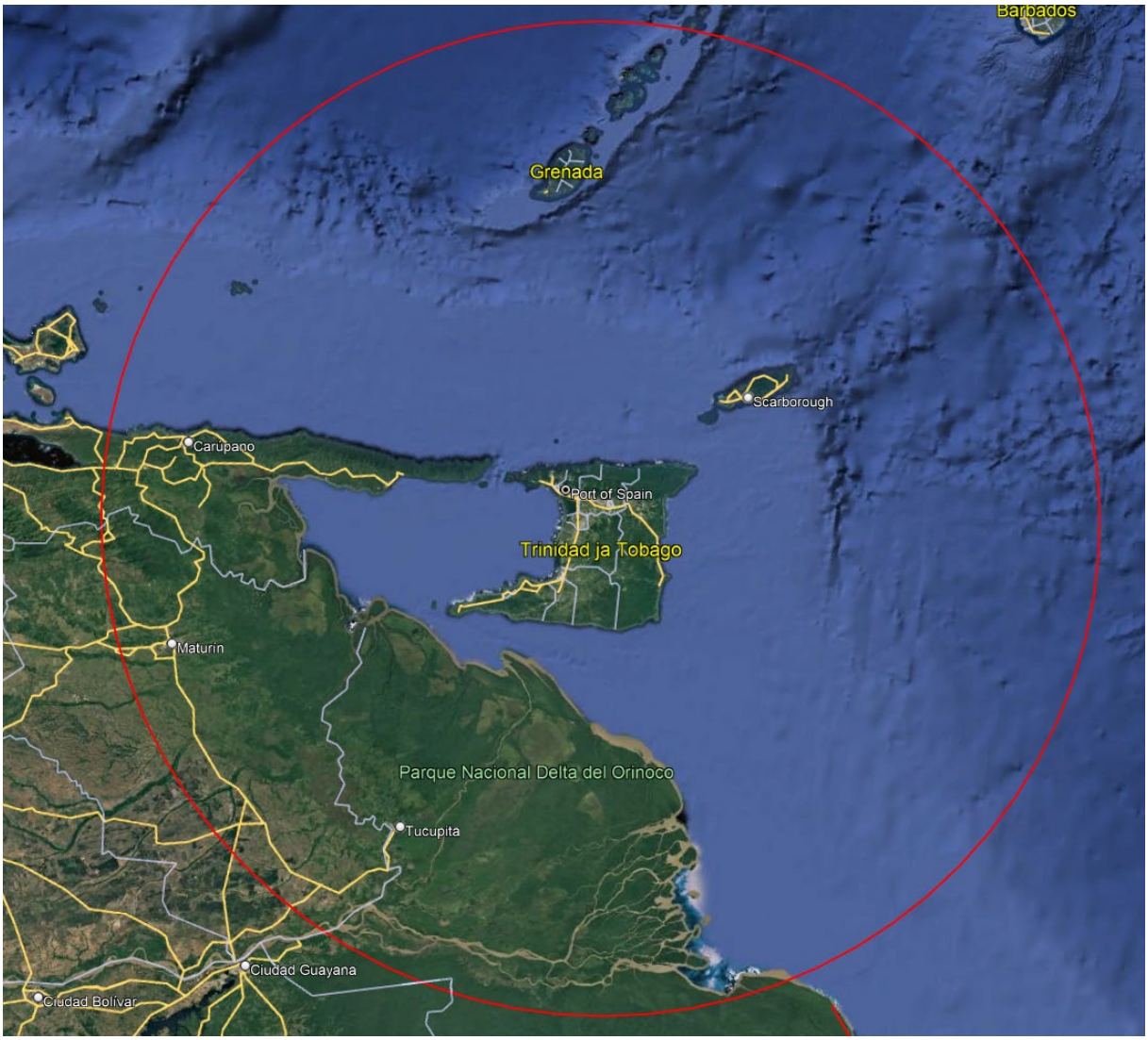

Figure 1. GBON surface weather station on Piarco International Airport. Circle indicated with 250km radius.

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

Trinidad and Tobago Meteorological Service (TTMS) is unofficially recognized meteorological authority for forecasts and warnings and responsible for observation network in the island of Trinidad and Tobago Meteorological office responsibility of the observation network in the island of Tobago. TTMS carries the responsibility of operating the national upper-air sounding systems. TTMS is working closely with the national Water Resource Agency (WRA), who operates the national hydrology observation network and a network of rain gauges, in sharing precipitation related information.

No private organizations are partaking in observing weather in Trinidad and Tobago.

A key stakeholder in supporting the operation and maintenance of GBON in Trinidad and Tobago (and across the Caribbean) is the US National Weather Service (NWS) through the Cooperative Hurricane Upper Air Station (CHUAS) network. Through the CHUAS NWS provides support that includes consumables, spares, and repairs for the systems. This support translates into direct support to the implementation of the GBON network. The collaboration has a long history and is proven to be mutually beneficial. It is recommended to update the **Memorandum of Understanding between TTMS and US NWS as part of the CHUAS initiative to ensure that long-term support is provided sufficiently to maintain the upper-air station as required by GBON standards.**

The national observation network has large gaps in the marine areas. TTMS is interested in expanding and improving its marine services. The marine sector in Trinidad and Tobago is active and in need of more tailored services. **It is recommended to investigate and develop potential partnerships with the marine sector and stakeholders for mutual benefit of marine observations and to support the expansion of observation network with marine stations when SOFF support extends to include marine areas. Support in developing the marine network strategy including assessment of possible technologies is needed.**

2.2. Assessment of potential GBON sub-regional collaboration

The regional collaboration in the Caribbean is very important as many of the countries are small in size and staff and benefit largely from joining efforts. TTMS is an active member in both CMO and CIMH.

The Caribbean Meteorological Organization (CMO) has played a critical role in leading the efforts of increased collaboration and synergy benefits in the region. CMO is a specialized

agency of the Caribbean Community that coordinates the joint scientific and technical activities in weather, climate and water related sciences in sixteen English-speaking Caribbean countries.

CIMH is a training and research organization that assists in improving and developing meteorological and hydrological services and awareness of the benefits of such services for the economic well-being of its member states. CIMH is the main provider of technical operation and maintenance training, hosts the regional calibration laboratory, runs a regional numerical model, and hosts the Caribbean Climate Outlook Forum. These services are critical to the success of the regional GBON sustainability.

CIMH has taken up the role of drafting a network homogenization plan for the surface weather network in the region. In order to provide effective support and services (calibration of the sensors, spare parts, repair and maintenance services and training) for the countries. The plan has not yet been published but has the potential to guide the regional harmonization of the network, although all countries will remain autonomous in selecting the preferred systems.

TTMS provides national observations to the Caribbean Regional Climate Center hosted by CIMH and in exchange receive the regional climate outlooks. For the climate outlook CIMH is centrally collecting observations from a multitude of countries in the region. Most of the observations shared for the climate center are produced by non-GBON stations. Through the collaboration all members can receive observation information and the climate outlooks created from these.

It is recommended that, when appropriate, regional training activities related to the installation, operation, and maintenance of GBON stations and network and the implementation of WIS2.0 protocol and WIS2Box be coordinated with CMO, CIMH and the other countries in the region. Besides directly GBON related activities, regional collaboration in **developing the marine networks, selecting technologies and benchmarking other institutes is recommended**.

When writing the document, the calibration laboratory at CIMH has a very limited capacity to serve the region. Currently the services are limited to pressure sensor calibration. For TTMS to rely on CIMH support the services need to include minimum calibration of pressure, temperature, precipitation, and humidity sensors with high-quality traceable services. TTMS has been looking into other options such as the National Bureau of Standards but has not yet found a solution for this. **The preferred solution to benefit the entire region is to strengthen the regional calibration laboratory to the needed level. Trinidad and unless CIMH capacity are improved, TTMS is recommended to look into other options for reliable annual sensor calibration. TTMS will need to include the service contract and related costs to the annual budget.**

Trinidad and Tobago is working closely with the US through the CHUAS program. NWS is directly supporting many of the region's countries in achieving GBON compliancy with the CHUAS program.

Collaboration that directly can support the GBON initiative are improving the regional calibration laboratory capabilities, facilitating region wide training activities, continuing the regional support for the wis2.0 protocol between the sister institutes, enhancing observation and limited area model data sharing through CIMH, continuing the support on national legislative development and facilitating coordination in the region.

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

TTMS receives its annual budget fully from the Government of Trinidad and Tobago. The annual budget is around 34.5 million TTS$. Most of the budget goes to operation costs such as personnel, membership fees, goods and services. New investments or larger investments, e.g. upgrades or refurbishment can be included in the budget with justification on the necessity. Overall, the budget has little room for new sensor replacements or investments in spares. To ensure sustainable operation of the observation systems it is important to systematically justify budget and project funding allocations for maintenance, spare parts and sensor replacements, calibrations services and other updates. **SOFF is recommended to fully cover the investment costs for the GBON AWS upgrade and needed spares as well as support the costs of operation by covering 75% of the annual calibration and to cover 75% of the personnel costs related to operating of the upper-air sounding system at the twice a day required level**. TTMS will cover the 25% from the annual budget. TTMS estimation for the total cost of a AWS station is $15 500 to $32 700 USD depending on the site and the selected systems supplier. Routine maintenance and calibration for the site is annually estimated to cost between $1 000 and $5 000 USD including minor repairs (higher estimate for remote locations) and the annual total staff cost for operating of the upper-air sounding station twice-a-day with a three technician shift schedule is estimated to range between $40 000 and $60 000 USD.

TTMS is recommended to develop a lifecycle plan for AWS operation and related IT hardware and to link this to the annual budget planning. To address the overall financial sustainability, it is recommended to strengthen TTMS national recognition and funding. A socio-economic benefit analysis is recommended to be conducted to provide proof and justification to the government budget allocation.

Due to the lack of legislative status and the current governmental setup, TTMS cannot directly receive any funds generated from cost-recovery services and all funds go to the consolidated national fund. **As a part of the meteorological legislation development, it is recommended to establish cost-recovery mechanisms that bring revenue directly to TTMS budget to ensure financial flexibility for TTMS to independently support its activities.** TTMS is already providing cost-based services for tailored products for the private sector (mainly oil and gas) and based on the stakeholder interaction the service portfolio could be expanded. However, operational activities will require a sustainable budget and thus cannot be fully dependent on cost-recovery.

The existing collaboration and support in the upper-air observations from the CHUAS network will continue to directly support GBON. It is recommended to renew the existing Memorandum of Understanding with US NWS to ensure that long-term support is provided sufficiently to maintain the station as required by GBON standards.

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

TTMS has been working with the University Corporation for Atmospheric Research (UCAR) to manufacture and deploy 3D-printed Automatic Weather Stations. The leading idea has been to build a network of stations that are low-cost, easy to manufacture and install in order to have good areal coverage. The observation accuracy and site representativeness are not up to WMO GBON standards, but they provide valuable additional information.

TTMS internal strategy is approaching the end of its validity period and will be refreshed soon. The strategy document also outlines key strategic priorities for the national observation network and the different specific observation technologies/uses.

There are no ongoing development projects that are related to GBON. In case project funding is available close coordination with projects and GBON efforts are needed.

2.5. Review of the national legislation of relevance for GBON

No national legislation related to responsibility for measuring and providing weather observations related to GBON is in place in Trinidad and Tobago. The Trinidad and Tobago Meteorological Service (TTMS) is a division of the Ministry of Public Utilities and unofficially recognized meteorological authority for forecasts and warnings and responsible for observation network in the island of Trinidad. In addition, there is the Tobago Meteorological office which is a division in the Central Administrative Services Tobago (CAST), under the Office of the Prime Minister and bears the responsibility of the observation network in the island of Tobago.

TTMS has a mandate by the government, but there is no legal framework in place. TTMS has had the responsibility to coordinate the collaboration between the two meteorological offices. **Clear cooperation and coordination between the two offices throughout SOFF implementation is necessary. It is recommended to include both offices in all training activities and to support the stations on both islands.**

An inter-agency committee, comprising the Ministry of Public Utilities and Central Administrative Services Tobago (CAST), as well as the Caribbean Meteorological Organization, is currently deliberating on, inter alia, an appropriate legal framework to support the operations of the TTMS. The findings of the report will be brought to the Permanent Secretary Cabinet for

considerations. (Source: Cabinet Minutes) The TTMS is recommended to prioritize the development of the legislation and to include the possibility of cost-recovery mechanisms.

Currently the situation is limiting TTMS's capability to implement cost recovery strategies for its services thus limiting the capability to increase budget financing with service costs from the different user groups.

The TTMS has potential to generate revenue from its climate services; the commercialization of such is still in the incubation stage of development. Additionally, the TTMS has ability to implement cost recovery strategies for the delivery of aeronautical meteorological services to the national aviation sector. The TTMS could, in line with the World Meteorological Organization (WMO) and International Civil Aviation Organization (ICAO) guidelines and recommendations, recover cost for services provided to aircraft traversing the Piarco Flight Information Region (FIR). TTMS has calculated the sum of approximately TT$13,000,000.00 which is recoverable from the Trinidad and Tobago Civil Aviation Authority (TTCAA). Funds are also recoverable from Airports Authority of Trinidad and Tobago (AATT), but have not been assessed accordingly. Public Management Consulting Division (PMCD), Ministry of Public Administration, is of the view that the TTMS has the capability to become a revenue generating entity and consideration should be given to developing and implementing the necessary legislation to promote it as the meteorological authority of Trinidad and Tobago. (Source: Cabinet Minutes)

Procurement follows the national tendering process. The TTMS receives full tax exemption for meteorological equipment as it is under the Ministry of Public Utilities (typical VAT in Trinidad and Tobago is 12.5%). Import fees are modest and related to the broker fees.

Module 3. GBON Infrastructure Development

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

The aim of SOFF investment phase project is to maximize the impact of observations on global numerical weather prediction (NWP) skill through:

- Installing or rehabilitating upper-air sounding stations.
- Installing surface weather stations in significantly under-observed regions (far from currently reporting stations).
- A sub-regional optimization of the network design.

According to WMO set GBON criteria one surface weather station and one sounding station is adequate for Trinidad and Tobago. TTMS has registered two surface weather stations to WDQMS database. The stations have less than 100 km between them thus exceeding GBON requirements. One of the stations located in Trinidad Piarco International Airport, is recommended to be supported by the SOFF program.

Based on the Gap Analysis, the following investments are recommended to make Trinidad and Tobago to produce GBON compliant observations:

- Renew AWS with
    - Temperature sensor
    - Humidity sensor
    - Atmospheric pressure sensor
    - rain sensor
    - Wind sensor
    - Data logger including solar panel (including logger cabinet)
    - Two spare sensors for temperature, humidity, atmospheric pressure and wind sensor to be delivered one year after the initial delivery of AWS for a healthy maintenance and calibration cycle.
    - wind mast
- Refurbish upper-air sounding station with key components
    - Line-conditioner
    - water filtration system
- Maintenance toolkit and field calibration kit
- IT hardware for data transfer to WIS2.0. Corresponding open access software and capacity building. Supporting remote access to surface observation data from the AWS in real time.
- Marine surface observation stations as soon as SOFF will include the support for such capabilities.
- Support to purchase hydrogen in bottles during hydrogen generator repair

The TTMS has a long history of operating weather stations and upper-air soundings as well as maintaining the systems. It is recommended to review and update relevant SOPs as part of the implementation phase. The peer adviser will support in reviewing and benchmarking the procedures for the observation systems during the implementation phase.

Previously the TTMS has been successfully operating the upper-air sounding system with the GBON required twice a day interval, or even more frequent during the hurricane season. The TTMS had faced difficulties in operating the upper-air sounding station at required twice a day frequency due to shortage in technical staff to operate the system. In the Gap Analysis it was recommended to hire an additional staff member for the operation of the sounding system. Launches were and will be performed manually with hydrogen filled balloons using radiosondes provided by the NOAA (currently GRAW DFM-17). The support provided through CHUAS includes consumables, spares, calibration of the pressure sensor and repairs for the systems. The hydrogen generator is approaching the end of its lifetime and will need to be replaced. CHUAS provides typically assistance for repairs, spares and replacement. In case of down-time before CHUAS support TTMS has procured hydrogen in bottles. **SOFF is recommended to support the purchasing of hydrogen for twice daily operation during such time.**

The upper-air station is calibrated annually as TTMS receives the calibrated ground sensor from NOAA. Maintenance has been performed based on NOAA schedule and led by the NOAA technical team.

The AWS network maintenance program will be designed together with the TTMS and equipment manufacturer. Initial maintenance plan includes annual preventive maintenance visits to the stations and annual calibration of at least temperature, humidity, pressure and precipitation sensors. TTMS regular maintenance schedule for such sites is:

Activity	Frequency	Description
Visual Inspection	Monthly	Check for any physical damage, corrosion, loose cables and signs of wear
Cleaning	Monthly	Remove dust, debris, and vegetation from sensors, solar panels and equipment housing
Battery and power system check	Quarterly	Inspect and test solar panels, charge controllers and battery capacity. Replace if necessary
Communication system check	Quarterly	Verify data transmission (satellite /cellular /radio) and fix connectivity issues
Firmware/Software updates	Bi-annually	Update AWS software and sensor firmware for optimal performance
Sensor Calibration & performance verification	Annually	Conduct calibration tests and adjust sensors (utilize field calibration kits). Replace sensor with calibrated one.

Structural Integrity inspection	Annually	Ensure stability of masts, enclosure and supports. Repair if needed.
Spare parts inventory check	Annually	Verify availability of spare parts

During annual preventive maintenance visit key tasks are: calibration of sensors, deep cleaning of equipment (including solar panels), testing and verification of power supply and backup batteries, replacement of aging components when required, full system communication check and troubleshooting and final test report and compliancy review.

TTMS has experience of working with field calibration kits and performing comparison of readings on temperature, pressure and wind sensors. Besides the field comparison GBON sensors will need to be calibrated in a reference laboratory. The selection of the preferred calibration laboratory will be sought during the investment phase (the TTMS does not have a calibration laboratory and the regional calibration laboratory operated by the CIMH is currently not capable of serving the TTMS's needs). Sensors are recommended to be replaced annually with a calibrated one whilst the replaced one is send to calibration, additionally one sensor is required as spare part stock.

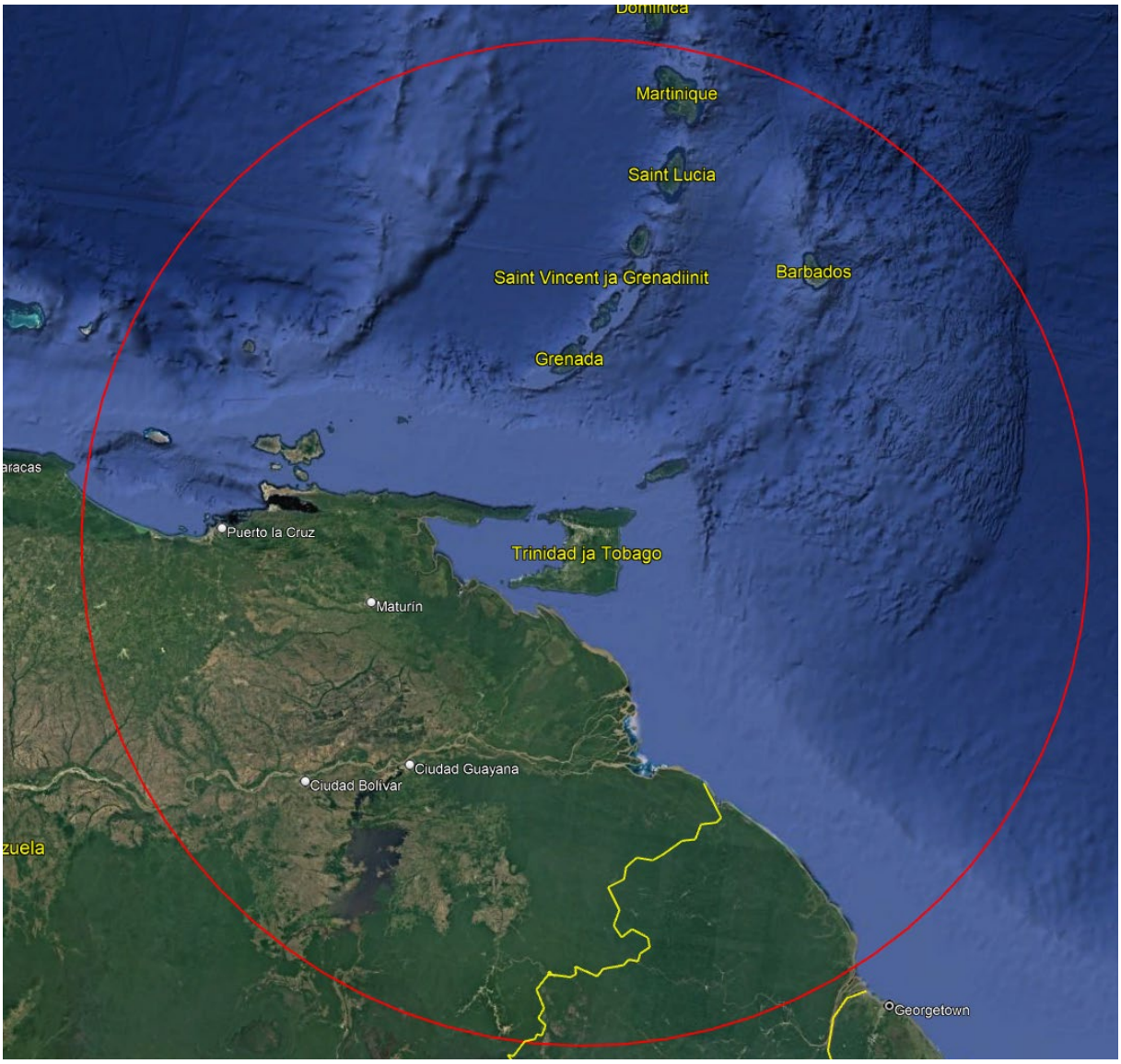

Figure 2. Upper-air station in Piarco International Airport. Circle coverage indicated with 500km radius.

3.2. Design of the ICT infrastructure and services

To support the meteorological observations throughout its value chain a modern functional Data Management System (DMS) is the key. The ICT infrastructure should support automatic data reception, automatic delivery from station to international and stakeholder distribution (supporting WIS2.0 protocol), storage of the data into a database with automatic Quality Control (QC) of observations and data processing. Enough staff with the relevant skillset and IT knowledge relevant to meteorological data are needed to support the infrastructure. The organization is recommended to gain knowledge and skills in meteorological data, data processing principles and tools, data formats (e.g. NetCDFv4 and BUFR), system architecting, software developing, database, API, network management, as well as web developing.

GBON dataflow is recommended to pass through a database to allow centralized real-time monitoring of the system, real-time quality control and centralized source of metadata.

The current central database solution (CLICOM and CLIDATA) that the TTMS operates is ca. 10 years old and in need of hardware upgrades. (The storage capacity is very limited and cannot handle the amount of data the automatic stations generate. Data quality control is currently done manually on the spot when the observation is done and manually prior to archiving to database. Also, metadata is collected manually and stored in a separate destination locally. TTMS is currently using several data reading and transfer processes including manual readout, internet, radio and satellite transmission, varying from site to site. Data transfer from the TTMS headquarters is done via the wis2box solution and the TTMS is hosting a part of the RA IV WIGOS Center and supporting other English speaking Caribbean countries with the WIS2.0 implementation. The current configuration is recommended to be updated to **support automatic data downloading, automatic quality control, improved data management including metadata and tools to import and export data using WIS2.0 protocol and APIs and to strengthen related staff capabilities.**

Main improvements needed for the TTMS ICT environment to support the GBON data quality and sharing are:

- Improving data management system. The TTMS is recommended to use systems based on open-source technologies and open protocols (e.g. OpenCDMS) to ensure sustainable and redundant operation, maintenance, and development through their lifecycles and beyond. OpenCDMS is expected to allow seamless processing of real-time and non-real time data to WIS2.0 and to systems to be fully available starting from 2025.
    - DMS system to support the updating of metadata to GBON station web tool.
- Introducing automatic quality control and quality assurance methods and algorithms.
- Human capacity building on IT and programming skills.

The annual operating budget needs to include the operating costs of the DMS. A valid support contract with the hardware vendor is recommended. The lifespan of such hardware is typically between 5 to 8 years before it needs to be renewed. The SOFF project should include funds for the necessary acquisitions to support full WIS2.0 compliancy. Based on budgetary restrictions it is recommended to prefer license free open software when possible.

Regional coordination and support for the DMS selection is recommended. Supporting the region with e.g. OpenCDMS solution could be facilitated by CMO, CIMH and/or selected countries. Regional approach is expected to improve the sustainability of the solutions and improve the efficient use of resources.

3.3. Design the data management system

Data Management System (DMS) is a key element in the value chain of observation from measurement station to end-user interface. Both technical and budgetary perspectives need

to be considered in the selection and specification of the DMS to ensure a long-term sustainable solution. Additionally, a backup solution is required for the essential data.

DMS is recommended to use open-source technologies and open protocols (e.g. open CDMS) to ensure sustainable and redundant operation, maintenance, and development throughout their lifecycles and beyond. DMS can be built cloud-based or on premises-based depending on national legislation and regulation, staff capacity as well as a decision of the organization. DMS must meet the following criteria/specification:

- Ability to ingest and store multiple different types of weather observation data formats. Including, but not limited to the following:
    - surface weather observations
    - upper-air sounding observations
    - aviation weather observations
    - lightning observations

Since weather radar observation data volumes are considerably larger than the other observation sources, it requires much more storage capacity and is beyond the scope of GBON. Data ingestion to the data warehouse (database) should be made with a modular approach so that new data feeds may be added with minimal effort and modification to the already existing components and database structures.

For smooth data acquisition, database systems must provide relevant APIs for data ingestion. Supported protocols for data transfer must include at least MSQT and SFPT, as defined in GBON specifications. The ability to receive and decode messages from 3rd party data collection systems must be provided. Additionally, a www-based tool for manual observation entry for stations must be provided.

A data quality control (QC) module should be an independent and/or modular part of the system. The QC module must be made so that it is capable of producing quality control regardless of the underlying database system. Additionally, the QC module must be able to perform real-time QC and should enable non-real-time manual QC.

The database system should support queries of time series with adequate performance system must be able to serve as real-time and long-term (climatological) data storage. Modules to calculate added value parameters and use of data from the archive should be made possible. These may include aggregate parameters like daily means, minimums and maximums.

Regional and international observations that are received via GTS or WIS2.0 for the forecasting process should be stored to the same database following same data policy. The priority is to sort out dataflow from the TTMS stations.

The data management system must be made capable of offering data to a standard API for a retrieval of the database contents. The API could include the following, but not limited to:

- WFS
- EDR
- WMS

- Export to SYNOP & BUFR message format and delivery to GTS-network
- WIS2.0 (required for GBON compliance)

The system must be able to store relevant metadata regarding stations, station networks and observations. Automatic updates to the WMO/OSCAR systems are preferred.

The delivery of GBON hourly observations should be reported by following the WMO guidance (no. 306) and GBON practices.

3.4. Environmental and sustainability considerations

The key success factor of sustainable investment, and day-to-day operation of GBON stations relies on highly competent and motivated management and staff in the organization. Generally, environmental and sustainability considerations should be included in any procurement process as part of the specifications. Sustainability of the systems is improved by budgeting and scheduling preventive maintenance and calibration and including these in the SOPs thus lengthening the lifecycle of sensors.

Frequency of the preventive maintenance can be modified based on the scientific experience and statistics gained through calibration. Additionally, holistic network management and planning including the selection of technologies, models and suppliers will support the sustainability as a smaller spare part stock is needed, sensor calibration circulation can be optimized, and all maintenance procedures and tools are well known. Using maintenance service providers from close by the site will not only improve the response time, but also decrease the need for travel to the site.

Surface observations: Proposed new GBON station is recommended to replace existing stations with some of the existing civil infrastructure that is reusable. New AWS need to be powered with renewable energy sources in the form of solar panels. Annual preventive maintenance and calibration needs to be part of all processes.

Scheduled preventive maintenance and calibration routines require, as a rule of thumb, about 1.3 times more sensors than there are stations. As an example, for 10 stations with temperature sensor, the organization is recommended to own 13 temperature sensors, when 3 of them are in storage or under calibration procedure. For the GBON stations each sensor must accompany two spare sensors in initial investment to ensure a sustainable operation of station. Frequency for preventive maintenance may rarefied based on the scientific experience and statistics gained through calibration.

Proposed station is compatible with existing station network, which allows efficient maintenance and instrumentation management. Sensors are rotated between stations, after been checked in calibration laboratory. Therefore, extra spare sensors support the whole station network.

Upper-air observations: Consideration of the use of biodegradable material for upper-air observations should be made where possible. Generating the hydrogen for the balloons locally instead of importing gas increases the environmental sustainability and independence of the station.

Module 4. GBON Human Capacity Development Modul

4.1. Assessment of human capacity gaps

Table 1 Number of staff and established positions in TTMS, excluding staff on Tobago.

Staff position	Established position -quantity	Contract staff -quantity
Director	1	
Assistant Director	1	
Meteorologist IV	1	
System Admin	0	
Chief Climatologist	1	
Climatologist	1	
Meteorologist III	2	
Meteorologist II	3	6*
Meteorologist I	3	
Equipment Repairmen Supervisor	1	
Equipment Repairmen	3	2 **
Senior Meteorological Assistant	2	
Meteorological Assistant	7	10
Communication Manager	1	1
Web Specialist		1
ICT Technician		2
Database Administrator		1
GIS Specialist		1
Radar Compound Watchman		2
Sanitation Officer		1
Office Attendant	1	
Total:	27	27
Grand total:	**54**	

** weather forecaster ** electrical engineer and technician*

The number of staff in the TTMS is 54. Not all of the established positions have been filled.

TTMS has a Competency Assessment framework in place (Manual WI 620-02, 2016/02/10) for the competency standards for Aeronautical Meteorological Personnel.

The overall training level of the staff is good and many of the meteorologists have been studying in the University of West Indies and the Caribbean Institute for Meteorology and Hydrology's joint meteorological programs. As a member of the CIMH, the TTMS can utilize the offered training courses in specific topics e.g. system maintenance training. Additionally, several of the staff have participated in internship programs with the Caribbean Catastrophe Risk Insurance Facility (CCRIF). Technical staff have attended meteorology specific sensor

maintenance and operation training courses for the different acquired technologies and systems, typically offered by the systems manufacturers.

Key shortcomings in the staff capacity are the limited number of staff with adequate data management, processing and programming skills and that QMS system knowledge is concentrated in one person who is in need of a successor.

In the NGA it is recommended to support the recruitment of an additional staff member to operate the upper-air sounding station at the required twice-a-day frequency. SOFF is recommended to cover 75% of staff costs for this new recruited position. TTMS will cover the 25% with the annual budget.

4.2. Design capacity development activities for technical staff

The recommendations on training activities within SOFF framework to support work towards gaining minimum competence relative to WMO guiding no. 1083[2]. The following training needs were identified in the Gap Analysis:

- **Quality management system (QMS):** Effective and continuously developing QMS is the basis for the systematic operation and maintenance of observation networks. An effective development of observation process including lifecycle planning, will require support through benchmarking mature sub-processes for upper air sounding and surface weather stations in other organizations. The TTMS is recommended to develop or enhance the GBON related sub-process in QMS. The TTMS has experience of implementing QMS on the aviation services but doesn't have a sub-component for the surface weather stations excluding specific aviation stations. Knowledge of the system is concentrated in the current QMS manager, who is nearing retirement age and the TTMS will need to train a successor for the position.
- **Observation process:** Effective development of observation process including lifecycle planning and support through benchmarking mature sub-processes in other organizations. Developing and updating of SOPs related to the GBON systems.
- **Data archiving:** Support in programming skills for strong and effective data archiving. Additionally, the TTMS is recommended to benchmark other organizations with mature data archiving system and tools to learn best practices.
- **Data transfer**: Support in programming skills on the automatization of data transfer.
- **Data quality control and assurance:** Training on programming skills and scientific understanding that support the applying of QA/QC methods and algorithms. The relevant staff members need capacity building to manage scientific background behind different QA/QC methods. Recommended to benchmark other organizations QA/QC methods. A roadmap for implementing relevant automatic QA/QC methods must be developed.

[2] https://library.wmo.int/records/item/35676-guide-to-the-implementation-of-education-and-training-standards-in-meteorology-and-hydrology-volume-i-meteorology

- **Instrument and station operation and maintenance at site**: Once sufficient technical training for maintaining different sensor types has been received, the technical staff would benefit from good quality SOPs and competence requirement criteria. Both the SOPs and owning required competence support self-confidence at any work. Training in upper-air system operation and lifecycle maintenance is needed since to support new staff members to assist in the operation of the station. In the GBON National Gap Analysis it is recommended to hire one additional technical staff member to ensure the operation of twice daily upper-air soundings. New technical staff needs to be trained to operate the system, this is recommended to be provided by the US NWS who support the station as part of the CHUAS network.
- **Network monitoring and ICT system operations**: Training for staff members responsible for ICT on their capacity (e.g., in programming skills and technical understanding) to ensure the 24/7 automatic operation of data pipeline from station to international distribution.
- **Calibration and maintenance at workshop:** Training on the concept of quality through calibration and capacity building in scientific understanding and handling calibration results. It is critically important that scientists are capable of analyzing calibration results to support lifecycle and maintenance planning. TTMS is recommended to benchmark other organizations calibration practices.
- **Marine observations:** The TTMS is planning to expand its capabilities in the marine service sector. Support in assessing potential technologies (e.g. unmanned surface vessels) and developing a strategy on the expansion of observation networks on marine areas. Recommended to benchmark other organizations.
- **Meteorological Systems Administrator:** The TTMS has an established position of Meteorological Systems Administrator that is currently vacant. The organization would benefit greatly from filling this position as this would assist in better coordinating all of the varied ICT related facets of its operations some of which are detailed above.
- **Climate Services:** training in climate services can help build a robust framework for climate services within the TTMS, ensuring that the TTMS can effectively address climate issues.

It is recommended to develop a **detailed capacity building plan** with components to monitor and evaluate the training. It is also recommended to utilize **regional collaboration and coordination** for shared GBON specific training programs e.g. in the field of instrument operation, maintenance, and calibration training, and utilizing the standard technical training programs from the regional training center. It is essential to the sustainability of the TTMS capacity building to train all new staff members to the required level.

4.3. Design capacity development activities for senior management

Key trainings for senior management level include:

- **Finance**: to equip the TTMS staff with financial and compliance management best practices, and advanced financial management and planning techniques. Benchmarking processes in other organizations.
- **Strategy**: tools and practices for strategy development and follow-up and aligning project portfolio and financial planning with strategy. Benchmarking processes in other organizations.
- **Project management**: benchmarking of organizations with mature project and portfolio management and coordination culture. Training on efficient planning, executing, and overseeing projects for successful completion, covering international development collaboration projects and new business development.
- **Performance Management:** best practices for evaluating outcomes and utilizing data-driven insights for continuous improvement.

4.4. Gender and CSOs considerations

Climate change and extreme weather events are not gender neutral, but they affect women, girls, men, and boys differently[3]. This is due to socioeconomic circumstances, cultural beliefs or traditions that can all contribute to inequality, resulting in women being put in situations of disadvantage when disasters strike. Therefore, it is important that in the pre-disaster context, those who likely will be the most affected by crisis, are also included in the preparedness process[4]. This includes having equal access on political, social, and economic levels as well as being able to participate in decision making. Not only is it fair, that population is equally engaged in climate change adaptation and resilience building, but there is also substantial evidence that shows that women are often the most resilient members of society and the powerful agents of change in the event of a disaster. They also have historic coping mechanisms that can be of use when designing and tailoring local grass-root level early warning systems or other climate change adaptation services and activities. To include women in designing hydro-meteorological and climate services directly leads to saving lives and livelihoods, as the needs of different groups have been better identified.

The rational for organizations to pursue gender equality in governance, strategy, programs, and decision making, is highlighted in WMO's recently updated Gender Action Plan[5]. It emphasizes that organizations that respect and value gender equality and diversity attract and retain talented staff and improve overall organizational performance, have more satisfied employees, are more innovative and have better governance. Teams that have gender diversity have better decision-making processes and attract more external partnerships, as well as have better access to local communities. Encouraging women to take up leadership positions has also shown to lead to important achievements in the field of climate change adaptation and disaster preparedness.

Trinidad and Tobago has a National Policy on Gender and Development. The policy provides a framework for including gender perspectives in all activities of government and civil society,

[3] https://www.undp.org/publications/gender-adaptation-and-disaster-risk-reduction
[4] Disaster Recovery Guidance Series, 2018, Gender Equality and Women's Empowerment in Disaster Recovery
[5] WMO Gender Action Plan

thereby promoting the full and equal participation. Trinidad and Tobago also has a Equal Opportunity Act to "prohibit certain kinds of discrimination, to promote equality of opportunity between persons of different status, to establish an Equal Opportunity Commission and an Equal Opportunity Tribunal and for matters connected therewith". The TTMS is obliged to follow both the policy and the act.

The current male to female ration in TTMS is 12:16.

The TTMS is recommended to conduct a gender assessment as part of the human capacity assessment. This could be included as part of a Gender Workshop. Based on the findings of the analysis, it is **recommended that the TTMS develops their own institutional Gender Policy**. It is also recommended that the following gender quota as recommended by WMO is implemented at TTMS:

- Women should represent at least 50 % of all participants in SOFF-related and supported
- trainings
- Women should represent at least 50 % of all participants in SOFF consultations,
- planning workshops, etc.
- Women should represent at least 50 % of staff for operating and maintaining GBON
- stations
- Women should represent at least 50 % of decision-making and project management
- positions where applicable

The following actions from the WMO Gender Action Plan, have been selected as recommendations to include in the Gender Policy and to be discussed during the gender workshops:

- Increase the participation of women by: (i) identifying and nominating female experts from NMHSs or other national institutions to participate in the work of WMO governance bodies and their working structures and (ii) seeking equality in the composition of delegations to sessions (1.1.1(c) in WMO Gender Action Plan).
- Strive for gender balance, including in management and working structures (1.1.2(c) in WMO Gender Action Plan).
- Encourage and support female networks of experts (1.1.3(c) in WMO Gender Action Plan).
- Designate NMHS gender equality focal points (1.3.4(c) in WMO Gender Action Plan).
- Develop monitoring mechanisms at the national level by (i) adapting the WMO gender monitoring indicators or (ii) using an existing national framework (2.4.1 in WMO Gender Action Plan).
- Include gender equality (including the WMO Policy, GAP, link to online trainings and gender webpage, information on key activities) in the induction of new PRs and NMHS staff (3.1.4(c) in WMO Gender Action Plan)
- Develop the capacity of NMHS staff on unconscious bias, inclusive leadership, gender mainstreaming, and gender responsive service delivery through trainings and workshops (3.1.5(c) in WMO Gender Action Plan)

- Offer internships to young professionals, especially female, and secondments of staff from meteorological services on a rotational basis. (3.4.2(c) in WMO Gender Action Plan)
- Engage with international organizations field offices, such as UN Women, UNDP, etc. (5.1.4 (c) in WMO Gender Action Plan)
- Conduct research and provide the Secretariat with case studies, stories and examples of gender mainstreaming, including in service provision, for the development of a compendium of good practices (5.3.3(c) in WMO Gender Action Plan).
- Develop and disseminate communication materials (i) highlighting the role of women in meteorology, hydrology and climatology, (ii) promoting female role models, and (iii) advocating for gender responsive weather, hydrological and climate services (5.1.3(c) in WMO Gender Action Plan).
- Customize weather and climate services to the particular needs and roles of women and men and (ii) Provide education and training to target female users in accessing and using weather and climate information and products (7.3.1(c) in WMO Gender Action Plan

The engagement of the civil society is an important factor and including CSO engagement during and after the SOFF implementation phase will bring mutual benefit and grounds for sustainable operation. The following actions are recommended to ensure that CSO's are regularly consulted during the entire length of the program cycle:

- Conduct stakeholder engagement workshops on the implementation of the SOFF project deliverables (observational data exchange to support weather/climate and water services and products), bringing together key stakeholders and CSOs, to involve and collaborate with the TTMS and the SOFF project team from the early onset, as well as ensure the stakeholders are consulted on operations and maintenance.
- Organize high level dialogues on benefits, co-production, and ownership of the new national GBON infrastructure.

During SOFF investment it is strongly recommended to promote 50% of women participating in capacity building activities and in consultations with civil society organizations.

Module 5. Risk Management Framework

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

WMO recommends its members to establish a Quality Management System (QMS) to ensure that customer and end user requirements are met (WMO no. 1100[6]). TTMS is in the process of upgrading the Quality Management System (QMS) to ISO9001:2015 for air navigation services. The process is still ongoing and TTMS has not yet been certified. TTMS is planning to expand the QMS also to cover its other services.

As stated in the SOFF Operations Manual, the risk mitigation procedures of IE will be relied upon the SOFF implementation during the Investment phase. The Operational phase is supported by the risk mitigation procedures of beneficiary.

Potential key risks during SOFF implementation	Mitigation measures and responsibilities	Monitoring and evaluation
US NWS to stop supporting upper-air observations through CHUAS network.	Updating of the MoU between NWS and TTMS. Highlight the value of the CHUAS initiative.	
Lack of budget for CHUAS causing long delays to repair or replace critical parts in upper-air sounding systems. Hydrogen generator approaching the end of its lifetime.	TTMS closely monitoring the situation and communicating with CHUAS. SOFF investments of line-conditioner and water-filtration system to improve the longevity of systems. Existing supply chain for bottled hydrogen. SOFF recommended to support the cost of bottled hydrogen for GBON operation when needed.	TTMS responsible for monitoring the situation and letting IE and SOFF now if the situation critically changes.
Insufficient technical specification of items and other quality criteria in tender process. Price should not be only criteria for choosing a vendor. Compatibility with existing infrastructure needs to be considered.	Seamless collaboration between IE (responsible for tender process), peer adviser (responsible for technical sensor specification), beneficiary (responsible for supporting in setting up quality requirements and technical specifications to best support the needs in the country)	IE (on request with support from beneficiary and peer adviser) will be responsible for monitoring and evaluating the quality of documents before opening the tender process.

[6] https://library.wmo.int/records/item/50552-guide-to-the-implementation-of-quality-management-systems-for-national-meteorological-and-hydrological-services-and-other-relevant-service-providers

Incompatible or suboptimal equipment chosen in bidding process.	Seamless collaboration between IE (responsible for tender process), peer adviser (responsible for technical sensor specification), beneficiary (responsible for supporting in setting up quality requirements and technical specifications to best support the needs in the country). In addition of technical feasibility, also compatibility and synergies with existing infrastructure needs to be considered.	IE (on request with support from beneficiary and peer adviser) will be responsible for monitoring and evaluating the quality of documents before opening the tender process.
Annual calibration not performed in calibration laboratories; regional calibration center not capable of supporting the services.	Annual calibration costs need to be included in the budget. Strengthening the capabilities of the regional calibration laboratory, establishing relations with other calibration facilities or outsourcing calibration to system provider.	IE will be responsible for following up on the regional calibration strengthening. TTMS responsible for monitoring and evaluation of annual calibration practices.
Decrease in funding support for operations.	Sufficient lifecycle planning and subsequent annual budget planning combining different funding sources. (SOFF, budget, project, potential cost-recovery)	IE and the management of TTMS are responsible for monitoring and taking required actions.
Insufficient staff competence and changes in staff members	Internal capacity building plan is developed including the criteria of competence requirements for technical staff. Succession plan and duplication of skilled staff members for critical tasks.	Management of TTMS are responsible for monitoring and evaluation.
The management of observation and data processes is insufficient.	Frequent follow up on how strategic goals and annual targets have been achieved.	Management of TTMS is responsible for reviewing and monitoring that work has been conducted as expected.

Slow procurement process hindering the timely maintenance and upgrading of systems	Redundant and standby systems in place for service continuity	Regular maintenance schedules, inventory management systems to ensure timely ordering of spares and replacements

Both sites are located on secure areas next to the airport. Power and telecommunication are secure at the upper-air station and for the surface weather station the powering will be covered with solar panels and for secure telecommunication satellite telemetry is appreciated. Due to these reasons no significant risk is expected in this regard.

Module 6. Transition to SOFF investment phase

The transition to SOFF investment phase is recommended to be carried out by following the Gap Analysis and National Contribution Plan. It is recommended that, on approval of the Investment Phase Funding Request, a virtual workshop with the peer adviser, IDB and the TTMS is arranged to review the outputs of the readiness phase and discuss the transition to the investment phase.

Summary of GBON National Contribution Plan

Components	Recommended activities
Module 2. GBON business model and institutional development	Follow-up on the development of the meteorological legislation. Facilitate a high-level dialogue to keep the development active and promote including cost-recovery mechanisms in the legislative framework.
	Continue close collaboration with key stakeholders. Seek for new mutually beneficial collaboration opportunities especially in the marine sector.
	Improve regional collaboration with GBON topics such as maintenance and calibration services. Establish ways to receive regional information on the surface weather observations and limited area models directly as input to the local forecasting process.
	Draft and update GBON relevant SOPs, lifecycle plan and risk matrixes. Will support the future QMS expansion.
	Update MoU with NWS on the continuous support for the upper-air observation station.
	Ensure strong coordination with other projects ongoing or planned, to avoid any overlap and to ensure sufficient maintenance budget for sustainable operation.
	Justify budget and project funding allocations for maintenance, replacing of sensors and calibration services.
Module 3. GBON infrastructure development	Two new AWS stations with GBON relevant sensors and adequate amount of sensor replacements for a healthy calibration and maintenance cycle.
	Renewing the hydrogen generator and procuring a line-conditioner for the upper-air sounding station.
	Field maintenance tool and calibration kits.
	Enhance operation processes and benchmarking equivalent operations in other organizations.
	Implement automatic WIS2.0 compliant data sharing including implementation of data management system.
	Improve data sharing to WIGOS/OSCAR platforms.
Module 4. GBON human capacity development	Training on data transfer and data quality control and assurance, ICT systems and data management.
	Training on the maintenance and calibration practices.
	Additional technical staff recruited to operate upper-air soundings twice a day and to assist with maintenance duties.
	Conduct a gender analysis and draft a new organizational Gender Policy, with specific actions that are measurable and regularly monitored, which are based on the WMO Gender Action Plan.
	Project management and product portfolio management training.
Module 5. Risk Management	SOFF Risk Management Framework to be monitored and updated regularly. Any new risks and mitigation measures should be added to the matrix as soon as they are identified.

Module 6. Transition to SOFF investment phase	The transition of SOFF investment phase is recommended to be carried out by following the Gap Analysis and National Contribution Plan documents.

Report completion signatures

Peer Advisor signature

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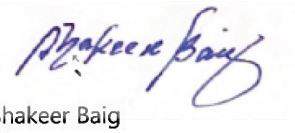
Beneficiary Country signature



Shakeer Baig
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WMO Technical Authority signature