25th October 2023

GBON National Contribution Plan of Belize

Systematic Observations Financing Facility

Weather and climate data for resilience

GBON National Contribution Plan

Belize

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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	2	0	0	2	2	0
Upper-air	1	1	0	0	0	0
Marine	***when applicable**					

Picture 1. Map of existing and proposed surface and upper-air stations

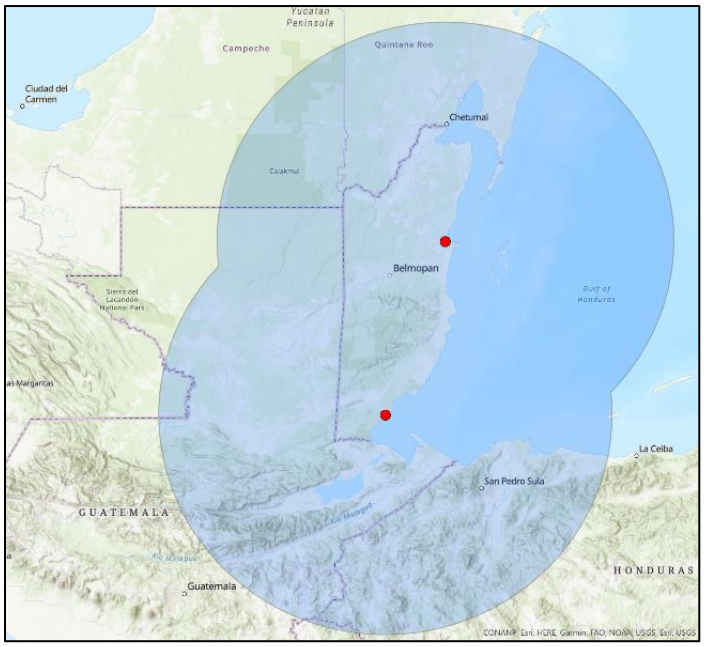


Figure 1a - Proposed surface GBON stations with 200km circles.

[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.

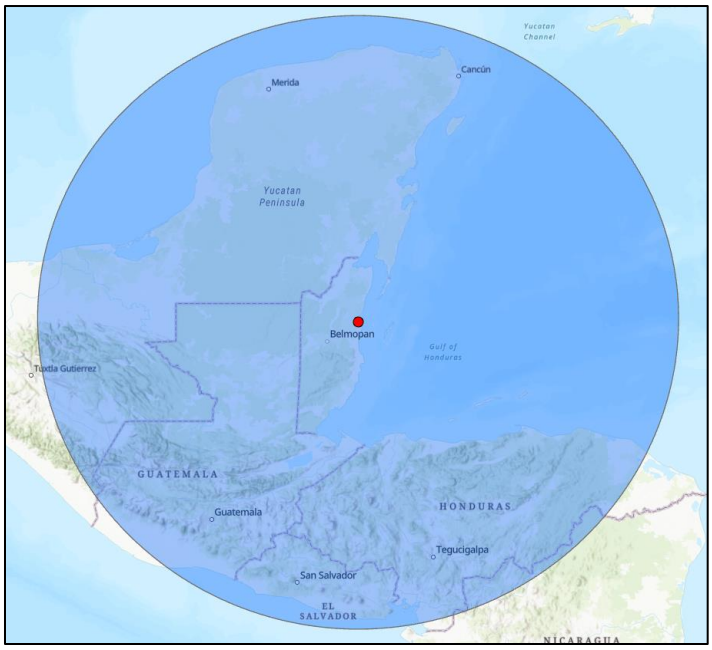


Figure 1b - Proposed Upper Air GBON station with 500km circle

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

NMS Belize collaborate and share data and services with a wide range of organisations including national government departments, industrial and agricultural organisations within Belize and international meteorological organisations.

Within Belize government NMS Belize maintain important relationships with the Agriculture ministry, the Department of Environment, the National Emergency Management Organisation, the Department of Hydrology and the Department of Civil Aviation. These stakeholders have direct access to NMS Belize observations data through the SurfaceCDMS portal via API or by submitting a written request to NMS Belize.

With respect to the surface observation network, NMS Belize have a formal MOU with the Agriculture Ministry relating to maintenance of rainfall instruments and provision of vehicles for access to observation sites of importance to agriculture. While these arrangements assist in the maintenance of the observation network in Belize as a whole and contributes to the vehicle fleet for access and maintenance, there is no significant support of direct relevance to the GBON observation network in Belize due to the geographical distribution of the two GBON sites proposed for Belize.

NMS Belize also collaborate with the private sector, in particular undertaking a project in collaboration with FORTIS Belize for meteorological monitoring in the Macal River catchment area / watershed. FORTIS Belize operates three hydroelectric facilities on the Macal River in western Belize – the Mollejon, Chalillo, and Vaca dams. However, given the geographic location of the FORTIS operations in Belize there is little opportunity for direct collaboration with respect to the operation or maintenance of the GBON network.

The Upper Air observations in Belize are currently supported by the US National Weather Surface as part of a regional arrangement between the US NWS and several countries in the Caribbean region referred to as the Caribbean Hurricane Upper Air System (CHUAS). The support provided through CHUAS includes consumables, spares and repairs for radiosondes, balloons and the hydrogen generation and storage equipment on site. As part of the proposed GBON network in Belize, this support for the upper air observations represents direct support to the implementation of the GBON network. It is recommended that the existing MOU between NMS Belize and the US NWS as part of the CHUAS initiative is updated to reflect advances in technology and to ensure that the support provided is sufficient to maintain the upper air station to GBON standard in the long term.

There is potential to generate new partnerships of relevance to the implementation of GBON with respect to marine observations, in which the Ministry for Blue Economy have previously communicated and expressed interest to NMS Belize. There is an understanding between the two organisations of the mutual benefit of marine observations off the coast of Belize to support the forecasting of algal blooms which can affect fishing and tourism and the shared requirement for early warning systems. There is currently no specific plan for the implementation of marine observations and it is, as such, recommended that when SOFF support extends to include marine observations there is close collaboration between NMS Belize and the Ministry of Blue Economy to explore the potential

for contribution towards the implementation of the observation network and partnership in relation to deployment and maintenance of the observing equipment.

2.2. Assessment of potential GBON sub-regional collaboration

Belize shares national borders with Mexico to the north and Guatemala to the south and west. There is currently good communication between NMS Belize and Servicio Meteorologico Nacional in Mexico and the potential for collaboration and the sharing of data between the two national met services. There is very minimal interaction between NMS Belize and Instituto Nacional de Sismología, Vulcanología, Meteorologiá e Hidrología in Guatemala. While there is some data exchange through the Central American Climate Database (BDCAC), this system has mostly been defunct over the past several years with only a few countries actively updating data.

NMS Belize are involved in three international projects related to the observation network in Belize: the World Bank funded Energy Resilience for Climate Adaptation (ERCAP) project due to complete in November 2024, the International Fund for Agricultural Development (IFAD) Rural Resilience Belize project and the World Bank Climate Resilient and Sustainable Agriculture (CRESAP) project. Through these projects the installation of 35 additional observing stations including soil temperature and moisture sensors have been installed in the western region of Belize to support agricultural development and hydroelectric power generation with FORTIS Belize. As such there is little direct support available of relevance to the GBON surface observation network though improvements to IT infrastructure at NMS Belize undertaken as part of these projects will complement the development required to support data storage and transmission for GBON. Similarly, IT infrastructure required for the implementation of GBON and funded through SOFF including an upgraded data ingestion server and on onsite NAS storage will complement the agriculture and energy development projects in which NMS Belize are already involved.

The regional organisations of relevance to GBON include the Caribbean Meteorological Organisation (CMO) and the Caribbean Institute for Meteorology and Hydrology (CIMH). The Caribbean Meteorological Organization 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 (16) English-speaking Caribbean countries. The Caribbean Institute for Meteorology and Hydrology seeks to improve the meteorological and hydrological services and to assist in promoting the awareness of the benefits of these services for the economic well-being of the CMO countries. This is achieved through training, research and investigations, and the provision of specialised services and advice.

It is recommended that, where appropriate, regional training activities for the installation, operation and maintenance of the GBON network and project management and financial planning be coordinated with CMO and CIMH and other countries in the region, in particular other SOFF beneficiary countries, can jointly benefit from the training opportunities.

Similarly, the continued development of the SurfaceCDMS software, which will be available for use by other national met services, and implementation of WIS2.0 has the potential to benefit other countries in the region. A WIS2Box pilot scheme has been undertaken in the Caribbean with participation and collaboration from several countries coordinated by WMO. It is recommended that NMS Belize continue to engage and collaborate with regional met services and that the benefit of the development of CDMS software and implementation of WIS2.0 are realized as widely as possible.

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

NMS Belize is currently funded through budget allocation from central government via the Ministry of Sustainable Development, Climate Change and Disaster Risk Management, the owning ministry of the department. The running cost for the observing network is not discretely identified in the budget. The overall budget allocated to NMS Belize falls below (around 50%) what's required. Currently, the funding available for the observation network is approximately $75K though it was identified in a recent review of the operating costs of the observing network that the funding required for the operation and maintenance of the network including sensor replacement costs is $150K.

Funding for observing equipment has been provided through the private sector in certain instances, though this funding does not often consider the total cost of operation and maintenance of the network. Such funding includes NMS Belize collaboration with the energy sector through FORTIS Belize which supported the procurement and installation of rainfall observing equipment in the Macal river catchment area which is ongoing.

Given the limited extent of the GBON observation network required in Belize it is recommended that NMS Belize operate the network independently as there is little scope or requirement for the involvement of private sector organisations in the operation of the network. It is recommended that SOFF financial support is sought in the compliance phase for maintenance costs, the provision of spare and replacement equipment and the operating costs of the surface network including IT infrastructure and data storage and transmission systems.

The follow support through SOFF is required to reach GBON compliance in Belize:

- Human capacity. Establish all necessary function to run the GBON in Belize, including NMHS institutional capacity and human capacity - $465,000.
- Observation equipment. Physical infrastructure, enclosure, sensors, and communications equipment for two proposed GBON stations (Belize city and Punta Gorda) plus spare equipment for repairs and resilience - $63,000.
- IT infrastructure. Upgraded data ingestion server, uninterruptable power supply, and additional data storage drives - $43,000
- Software. Development of Surface CDMS, the Climate Data Management System currently under development by NMSB (cost for 1 year of development) - $65,000.
- Running costs for 2 GBON surface stations. This includes, spares and repairs, consumables, vehicle and fuel costs, and NMS staff time - $30,000.
- Running costs for 1 GBON upper air station. This includes NMS staff time. All other costs are covered by the US NWS - $15,000.

It’s noted that the US NWS will provide the infrastructure, consumables, spares, and repairs for the upper air station.

For the upper air observations, the existing model of operations centered around collaboration with US NWS through the Caribbean Hurricane Upper Air System (CHUAS) will continue to support the upper air stations in its contribution to GBON. It is recommended that the existing agreement with US NWS is reviewed to ensure that it reflects the contribution of this vital observation to the GBON network.

As stated earlier, funding the NMS Belize comes from a government grant with no specific allocation for observations. In addition, the overall funding amount falls below what’s required to deliver what’s

expected of a National Met Service. Even so, NMS Belize overachieve, through strong leadership and a competent and committed team. It is recognized that the current situation isn't sustainable, and change is needed. The recommendation is to strengthen the existing links with government and provide the evidence for an increase in recognition and sustainable funding. This can be achieved through providing additional resource to the NMS, and broaden the skillset within the organisation, particularly with stakeholder management skills. In addition, as Peer Advisor, we support the request from NMS Belize to conduct a Socio-economic Benefit analysis of the service, highlighting the importance of GBON compliance in the value chain. This would aim to provide the evidence to the government for investment opportunities with the NMS. This is also in line with WMO's Strategic Plan 2024-2027, overarching priority number 3 – enhancing socioeconomic value of weather, climate, hydrological and related environmental services. It is recommended that through these activities, a sustainable financial and operating model can be achieved for GBON compliance in Belize.

A Socio-economic Benefit (SEB) analysis of the NMS Belize provides numerous benefits, including funding justification, showcasing the value of services to government authorities, private organisations and the general public, and starts the process of quantifying the broader social economic impacts. These benefits include enhanced disaster preparedness, improved agriculture, public health, infrastructure efficiency, environmental conservation, tourism capabilities & challenges, and capacity building. A SEB analysis of this scale would also contribute to the knowledge in meteorology, providing valuable data, research opportunities, and best practices for enhancing meteorological services globally, and would provide as a base for creating a model that can be used in the development of other nations.

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

NMS Belize has produced a draft strategic plan which was updated during the planning process for implementation of GBON in Belize. This strategic plan is a wide-ranging strategy for the development of NMS Belize and includes consideration of restructuring within the met service, the expansion of staffing, the elimination of redundant posts and introduction of additional posts in response to the changing needs of the met service. The plan reflects the changes of the past 10 years to the observation network, which underwent an expansion from less than 10 AWS to more than 50 today and the technological skills and staffing levels required to maintain such a network. In addition, the strategy outlines changes to the capabilities of the met service in other areas including the introduction of new products and services such as Sargassum Forecasts, Seasonal drought, precipitation and temperature forecasts and daily weather forecasts for specific municipalities, amongst others. The owning ministry of the department, the Ministry of Sustainable Development, Climate Change and Disaster Risk Management, have their own strategy which includes support to the NMS Belize strategic development plan.

It is recommended that as NMS Belize move into the investment phase of the SOFF framework regular reviews of existing and upcoming national investments are undertaken to ensure the continued complementarity of the projects. Similarly, it is recommended that as SOFF support extends to include marine observations and forthcoming investments in the marine space are assessed for their potential to contribute to marine observations for GBON.

2.5. Review of the national legislation of relevance for GBON

No national legislation relating to responsibility for measuring and providing weather observations in Belize exists. There is a draft legislation produced with assistance from the WMO and CMO through the CREWS project. A draft cabinet paper was also submitted to the owning Ministry of the NMS Belize. It is recommended that the draft legislation and cabinet paper be enhanced so as to provide the legislative mandate for NMS Belize. It is also recommended that NMS Belize strengthen their relationship management with government, to ensure policy and legislation is appropriate for GBON and other essential services.

The mechanism for procurement in Belize includes a tender process and requires approval through central government. However, as a result of the experience of NMS Belize and their knowledge of the requirements for meteorological instruments deployed in the country, in particular in relation to the resilience of anemometers to the frequent high wind speeds in the region, a precedent for single-source procurement has been established between NMS Belize, the owning ministry and central government. As a result a technical note ‘NMS justification for single sourcing Automatic Weather Station equipment and sensors’ outlining the justification for single-source procurement of all weather station equipment and sensors was produced by NMS Belize and approved by the owning ministry. This enables NMS Belize to procure instruments directly from known suppliers ensuring that the specification and quality of the instruments and supplier support are sufficient for the purposes of meteorological observations in Belize.

Module 3. GBON Infrastructure Development

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

Surface Observations

Belize NMS currently operate a network of network of 54 Automatic weather stations (AWSs) and 22 Manual or Conventional Weather Stations across the country. The network is comprised of a mixture of stations types and sources as well as varying quality of instruments, siting and maintenance practices. Table 1 summarises by station type and district the weather stations in operation and the station locations are shown in Figure 1.

Table 1 – Summary of station type and location by district of Belize NMS observation network

District	Types of Station								
		manual	AWSMET	AWS agro-met	AWS hydro-met	AWS aviation	AWS climat	AWS agro	AWS hydro
	TOT.	22	24	3	0	0	24	22	11
CZ	9	1	2	1			2	3	0
OW	13	2	2	1			1	7	0
BZ	13	3	5	0			6	0	0
CAYO	35	7	4	0			8	5	11
STAN	12	4	3	0			1	4	0
TOL	14	5	1	1			6	3	0
CAYES	7	0	7	0			0	0	0

- MET – Station with 10m Tower measures Essential Climate Variables(ECVs)
- Rainfall, Temperature, RH, Wind Speed, Wind Direction, Barometric Pressure, Solar Radiation
- AGRO-MET – Station with 10m Tower measuring Rainfall, Temperature, RH, Wind Speed, Wind Direction, Barometric Pressure, Solar Radiation, Soil Temperature, Soil Moisture, Wind Speed at 3m
- HYDRO-MET - Station with 10m Tower measuring rainfall, temperature, RH, wind speed, wind direction, barometric pressure, solar radiation, water level
- AVIATION - Station with 10m Tower measuring Rainfall, Temperature, RH, Wind Speed, Wind Direction, Barometric Pressure, Solar Radiation and aviation parameters such as Visibility, Present weather, Cloud height
- CLIMATE - Station with 3m mast measuring rainfall and temperature
- AGRO - Station with 3m mast measuring Rainfall, Temperature, RH, Wind Speed, Wind Direction, Barometric Pressure, Solar Radiation, Soil Temperature, Soil Moisture
- MANUAL – Stevenson Screen, Raingauge, Cup counter, Evaporation pan, Soil Thermometers
- HYDRO - Station that measures water level primarily and have the capabilities to measure rainfall and temperature.

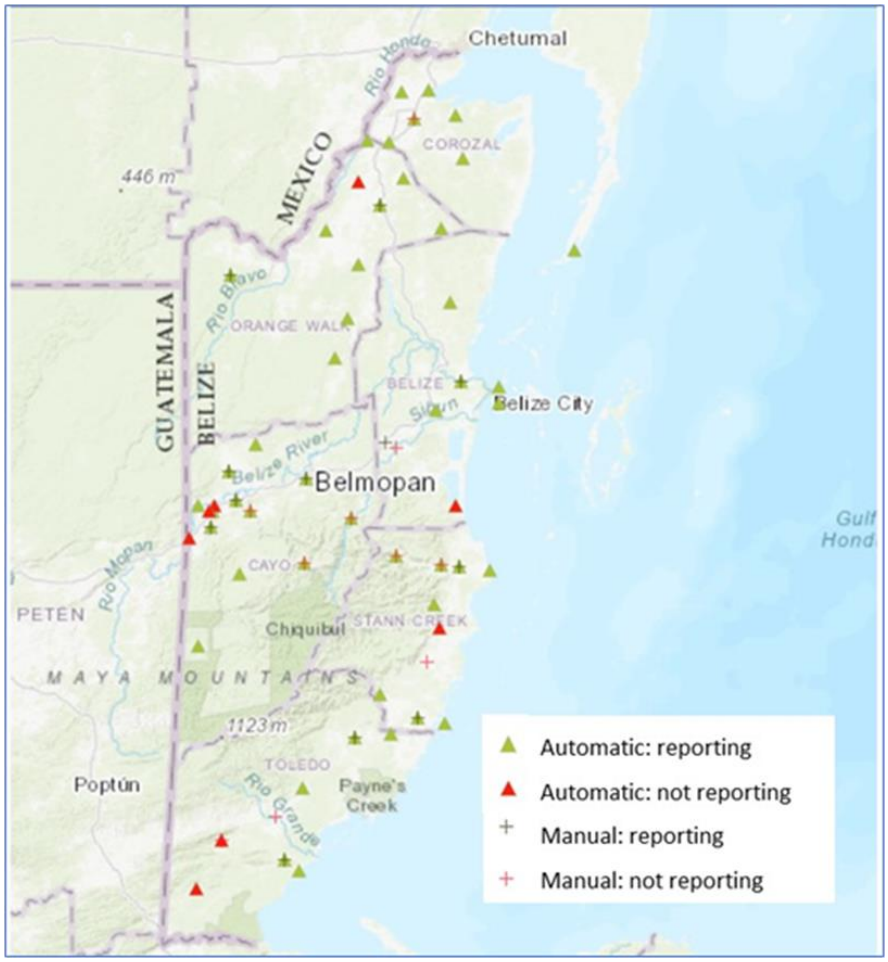


Figure 1 – Map of Belize surface observation network

Observations from the automatic network are recorded sub-hourly, though no data are currently shared internationally. The varying quality of the instruments in the network, as well as the lack of capacity for calibration and maintenance of the entire network, mean that there is relatively low confidence in the quality of the observations recorded at many of these sites. As such, it is recommended that the focus of the NMS in contributing to GBON is on producing reliable, high-quality observations from 2 sites in Belize in line with the GBON National Gap Analysis and in order to meet the 200km requirement for spatial resolution. It is recognized that once these two sites are established and consistently sharing high-quality data internationally with the support of SOFF, there is scope in the future to potentially increase the number of sites in Belize contributing to GBON towards the higher resolution of 100km.

Annex 3.1a – Map of the observing network and list of new or rehabilitated GBON stations

Surface observations

As stated in the GBON National Gap Analysis, it is recommended that Belize NMS improve the existing GBON surface observation site and nominate one additional site in the south-western area of the country at Punta Gorda airstrip. The locations of the 2 stations are shown in Figure 2 and details of the site locations are shown in Table 2. The selected sites are existing observation stations, which are sited in secure, accessible locations away from obstructions in accordance with WMO No.8, Vol 1.

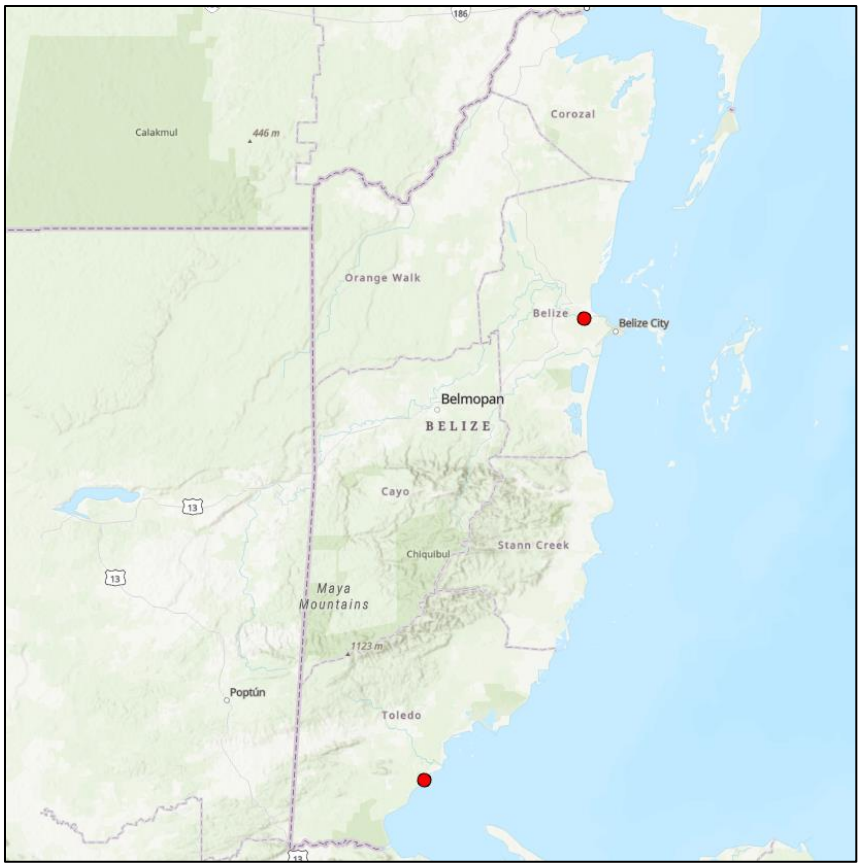


Figure 2 - Map of future GBON surface observation network in Belize

Table 2 - Details of GBON surface observation site locations

Station name	Station type (S/UA)	Lat	Lon	GBON variable measured					
				SLP	T	H	W	P	SD
Philip Goldson Int'l Airport	S	16.1027	-88.8080	Y	Y	Y	Y	Y	N (N/A)
Punta Gorda Airstrip	S	17.5348	-88.3127	Y	Y	Y	Y	Y	N (N/A)

Upper air observations

There is currently one upper air observation station in Belize located at Philip Goldson Int'l airport. From this site Belize NMS undertake two radiosonde launches per day, reporting in high-resolution BUFR format and routinely attaining the target height of 30hPa, thereby meeting the GBON requirements. Launches are performed manually using hydrogen filled balloons carrying the GRAW GP20 radiosonde and there is hydrogen generation and storage capacity on site. The frequency of

launches may increase through specific request from the U.S. National Weather Service / National Hurricane Center during a hurricane threat to the region.

The upper air observations in Belize are currently supported by the US National Weather Service due to their importance in relation to forecasting of tropical storms and hurricanes in the region. This is as part of regional arrangement between the US NWS and several countries in the Caribbean region referred to as the Caribbean Hurricane Upper Air System (CHUAS). The support provided through CHUAS includes consumables, spares and repairs for radiosondes, balloons and the hydrogen generation and storage equipment on site.

Figure 3 – Map of GBON upper air observation network in Belize

Table 3 – Details of GBON upper air observation location

Station name	Station type (S/UA)	Lat	Lon
Philip Goldson Int'l Airport	UA	16.1027	-88.8080

Annex 3.1b / 3.1c Investments and activities needed for the installation of new stations and the improvement of existing stations / list of observation instruments and systems per site

Surface observations

The activities required for the improvement of the two existing stations in Belize in order to enable the collection and international sharing of high-quality data for GBON include the procurement and installation of upgraded instruments at each site. The installation process will be undertaken by Belize NMS technicians with support and advice from the instrument manufacturer regional centre and the peer advisor, wherever necessary. Existing infrastructure, for examples fences and enclosures and

wind sensors platforms can be utilized alongside the upgraded equipment to be procured through SOFF. This will require thorough investigation and review of the infrastructure in place for signs of wear and deterioration ahead of the installation of new equipment and replacements should be procured and installed, if necessary.

In order to ensure the quality and consistency of data collected and reported through GBON, as well as to enable reliable and uniform maintenance and calibration practices, it is recommended that the two nominated sites deploy identical observing equipment. In consultation with NMS Belize it was determined that Campbell Scientific represent the most viable provider of the required observing equipment, this is as a result of the local presence in the area ensuring that maintenance, spares / repairs, instrument calibration and potentially training and assistance in the deployment and maintenance of the instruments can be carried out reliably and swiftly. In addition, there are existing processes in place at NMS Belize for procurement of equipment from this known supplier, subject to approval through the established mechanism referred to in Section 2.5. The list of instruments for each site are shown in Table 4 and a full set of spare instruments for each site should be procured to enable swift replacement in the event of instrument failure.

Table 4 – list of observation instruments and system per site

Item	Suggested model
Instrument enclosure	Stainless steel enclosure ENC24/30SUL-ES-NM
Tower and platform for wind instruments	UT30 UTBASE B18, UTGuy, UTGND
Solar panel	SP50-PT
Battery	BP-24
Power regulator	CH-200
Data logger	CR1000x
4g Modem	CELL205
Enclosure monitor	CS210

Rain gauge	TB-4 + platform
Temperature + RH sensor	HMP155 A-PT + shield
Wind speed and direction	05108 – PT + mounting hardware
Atmospheric pressure	BaroVUE10 + enclosure + replacement card BVC10

Upper air observations

The upper air station in Belize is currently supported by the US National Weather Service and the observation infrastructure in place is sufficient to meet GBON requirements sustainably. Belize NMS undertake two radiosonde launches per day using the GRAW GP20 radiosonde which measures air temperature, air pressure, relative humidity and GPS derived wind speed and direction. The altitude attained by the balloon reliably reaches 30hPa and data are recorded in high resolution BUFR format. The balloons are filled with hydrogen which is generated and stored on site using a generator and storage tank provided by the US National Weather Service which also provides consumables, spares and repairs for the site.

The ongoing agreement between Belize NMS and the US NWS is deemed sufficient to provide the necessary equipment including consumables, spares and repairs on an ongoing basis and, as such, no additional instrumentation is require for the upper air station. It is recommended that the MOA for the Caribbean Hurricane Upper Air System (CHUAS) is reviewed annually in order to ensure the continued provision of the necessary equipment.

Annex 3.1d / 3.1e Observational practices defined per network / preliminary maintenance plan for existing and improved / new stations including calibration practices

Belize NMS currently undertake scheduled preventative maintenance at all observation sites in their network to carry out site inspections, instruments checks and routine maintenance on the observation equipment. The preventative maintenance includes checking the condition of anemometers and thermometer shelters for signs of physical deterioration, corrosion and dirt as well as ensuring that electrical systems are working correctly. The surroundings of the site are also assessed and any changes which may affect exposure recorded.

The preventative maintenance program is carried out on the following basis:

- Site visits conducted 3 days per week, from Tuesday to Thursday
- 30 – 40 day maintenance schedule equates to a 10 – 16 week / 4 month cycle
- Each station will be visited a minimum of 3 times per year

As set out in WMO-No. 8 Vol V, an optimum frequency of site inspection visits cannot be generally specified. The maintenance schedule outlined above ensures that each site is visited at least 3 times per year i.e. more often than the suggested frequency of six months for AWS sites. Continuous remote monitoring of the function and performance of the sites is included in the recommendations in ANNEX A3.2/3.3 and the maintenance schedule outlined above should be reviewed annually to ensure that it is consistent with the provision of continuous, high-quality data.

It is recommended that calibration of sensing equipment is carried out a regular intervals through the manufacturer regional centre at an accredited calibration facility. The period of validity of the calibration will be determined by the sensor type ranging from one year for relative humidity sensors to up to 8 years for platinum resistance thermometer. A full calibration regime and provision of calibration services will be produced in consultation with the instrument provider as part of the procurement process and in accordance with the requirements set out in WMO tender specification for AWS:

"Each instrument should be supplied with a calibration valid for at least 90% of the calibration period as recommended by the manufacturer. The initial calibration should be done by an accredited calibration laboratory or at least be fully traceable to such an ISO17025 accredited laboratory.

Each instruments should be supplied with a paper and electronic (pdf) calibration certificate that at least specifies:
- Manufacturer
- Model
- Instrument type/Principle of Operation
- Serial number
- Hardware/Software version [if applicable]
- Calibration Date
- Validity period of calibration/Recommended next date of calibration
- Calibration range
- Traceability of calibration (including applicable standard)
- Calibration method
- Calibration factor and uncertainty
- Name and signature of calibration technician that performed the calibration. [**]"

Annex 3.1f – Technical specifications for new instruments and observing systems

The specifications for upgraded and replacement instruments at the two GBON surface observations sites are recommended to align with TT-GBON approved material | World Meteorological Organization (wmo.int) for each observation instrument and observing system. The recommended instruments listed in Table 4 meet or exceed these specifications in all cases and should alternative instruments or systems be identified as part of the procurement process, these must meet the specifications referred to above.

3.2. Design of the ICT infrastructure and services

Belize NMS currently have a functional ICT infrastructure system for the reception, storage, processing and transmission of meteorological data, though improvements are required in order to ensure the

resilience of the network and expand the capabilities of the data management and transmission systems, the details of which are set out below.

Belize NMS currently receives data from the following sources:

- Weather stations using data modems
- Weather stations using satellite transmitters
- Lightning detection network
- Radar
- Observation data from Satellites
- Numerical Weather Prediction Models (NWPs) such as GFS and WRF

To properly ingest, store and process these large amounts of data sets the following computers are being used to run a number of applications locally:

1. Server Machine for data storage and backup
    a. Weather station data acquisition and back
    b. Radar files data storage
    c. lightning data storage
    d. CDMS data backups
    e. FTP server to host and server data
2. Physical and virtual Servers for the following applications
    f. CDMS - S.U.R.F.A.C.E. CDMS is a python web application used to manage climate data
    g. PLUVO-AI - Data integrator - Ingests, radar, lightning, satellite and NWP data and displays information as a web application for decision making
    h. W.I.M.P. - Website Information Management Platform, used to update NMS website
    i. WRF NWP
    j. Delt-FEWS - Flood Early Warning System
    k. A number of virtual machines used to operate:
        i.VPN servers - OpenVPN
        ii.nginx - reverse proxy

Data collected by dataloggers at AWS sites are transmitted via modem connection to a data ingestion server at Belize NMS headquarters. These are then transferred for real-time access and long-term storage to the SURFACE CDMS (see below for details) server and transmitted internationally. Currently the data are backed up to a cloud-based One Drive server, though this has limited space and will be insufficient in the long term. Given the recurring costs associated with cloud storage, Belize NMS consider that local server based storage for data backups is the more sustainable and resilient option. Belize NMS are in the process of including a NAS server for data backup though will require funding for the storage drives to complete this process. In addition, the data ingestion server is outdated and requires replacement to ensure the system is resilient and fit-for-purpose.

3.3. Design the data management system

For the past 6-8 years Belize NMS has been using the WMO NO.1131 specifications as a guide in developing a Climate Data Management System (CDMS) based on Open Source technologies. The first version of this CDMS called “HydrometDB” was developed in 2016. Three years later through the Japan Caribbean Climate Change Partnership Project(JCCCP) a technological stack upgrade was done bringing the application in line with modern Big Data web applications. Currently the system is known as

S.U.R.F.A.C.E. CDMS which is an ACRONYM for System for Unified Real-time Forecasting of Atmospheric and Climatic Events.

S.U.R.F.A.C.E. CDMS uses Python as its main backend language and is built on the Python framework called Django. It uses a REST/RESTful API to allow secured backend connections to specific datasets and uses PostgreSQL/PostGIS and TimesecaleDB as the database for storing data; specifically high resolution time-series data. The frontend is currently using Vue.JS as the frontend Javascript framework but there maybe a change to Angular in the future based on the direction of the WMO OpenCDMS project. Finally the application is deployed as a Docker stack using six containers. "Docker" is an open source, industry standard, containerization platform which enables developers to package applications into containers.

S.U.R.F.A.C.E. CDMS provides short-term data storage and access, data delivery to the national CDMS, descriptive metadata management and real-time monitoring of data, processing and services. Over the past 3 years the NMSB has been working with the WMO on the OpenCDMS project and are also part of the WMO Task Team on Climate Data Model (TT-CDM) which was formed in 2022.

"The OpenCDMS Project is a community of collaborators who are working together to address Earth system data management needs of developing and developed countries by setting and implementing global data management standards and good practices, thereby improving data management practices and triggering existing and upcoming data management solutions to adhere to these standards." - https://www.opencdms.org/

As a result of these collaborations S.U.R.F.A.C.E. CDMS has been formally adopted as one of the systems involved in creation of OpenCDMS. SURFACE CDMS / OpenCDMS will incorporate full interoperability with WIS2.0 to enable global sharing of data for GBON. While SURFACE CDMS has been in operational use at Belize NMS for the past 3 years, the advantages of combined development with OpenCDMS and wider adoption of the system would result in better financial and technical support for the software in the long term and enable the inclusion of WIS2.0 as part of the system. Funding is required to complete the development of SURFACE CDMS and / or merge the existing software into OpenCDMS, each of which would be of benefit to other meteorological services seeking to use the software.

3.4. Environmental and sustainability considerations

Environmental and sustainability considerations should be incorporated into the procurement process as part of the specifications including the use of reusable instruments where possible and sustainable methods of observation. Surface instruments should be reusable where appropriate and consideration of the environmental and sustainability impacts of maintenance (including associated travel) should be made as part of the SOP for maintenance and calibration. Similarly, consideration of the use of biodegradable materials for upper air observations should be made where possible as well as the environmental impact of shipping methods and materials.

The project will be governed by IDB's Environmental and Social Policy framework which is a consolidated framework covering environment, involuntary resettlement, and indigenous peoples. The project will undergo environmental and social due diligence at appraisal to help the IDB decide if the project should be financed and, if so, the way in which environmental and social risks and impacts should be addressed in its planning, implementation and operation. The appraisal process also

identifies opportunities for additional environmental or social benefits. Of particular importance to the SOFF project, Section 3 'Resource Efficiency and Pollution Prevention' sets out objectives to:

- Avoid or minimize adverse impacts on human health and the environment by avoiding or minimizing pollution from project activities
- Promote more sustainable use of resources including energy and water
- Avoid or minimize project-related emissions of GHG
- To avoid or minimize generation of waste

The objectives and policies set out in the framework should be adhered to throughout the project life-cycle and should be used to guide environmental considerations in the procurement process, strategic development plan for NMS Belize and SOPs generated in relation to observations, maintenance, calibration and working practices.

Module 4. GBON Human Capacity Development Modul

4.1. Assessment of human capacity gaps

The NMS Belize has both national and international responsibilities, covering a diverse range of activities. These include making observations to GBON and ICAO standards, forecasting the impacts of tropical cyclones and other severe weather, and representing Belize at WMO and IPCC. The NMS Belize is comprised of an Administrative Section and three technical sections, Weather Analysis and Forecasting, Climate Services Section and the Electronics and Information Technology. To deliver to the needs, the NMS requires a team of highly qualified and motivated staff, with a broad range of skills and experience, led with strong and clear leadership. To be able to successfully deliver to these responsibilities, it is essential that NMS Belize receive the correct recognition and support from their government.

The NMS is a small, capable, and well-led NMS, and due to lack of support, lacks the opportunity to plan and develop in certain areas. The most significant skills gaps are in areas such as project management and delivery, stakeholder management, financial management, human resource management. There is also a need to ensure the technical skills base, including the observation's technicians, have a plan, opportunity, and funding to maintain the essential skillset in maintenance and calibration of observing equipment. Similarly, the IT and data management skillset needs to be fully supported to strengthen the capability of the NMS to administer and maintain the network.

NMS Belize is a vital institution for the economy of Belize and requires a team of skilled and motivated staff to carry out its daily responsibilities. There has been no significant restructuring of the NMS since its inception more than 40 years ago. Moreover, the demand for new products and services from the NMS has increased significantly over the past decade or so. With only minimal investment in human resource capacity, it is consistently challenging to satisfy the ever-increasing demands and expectations. Despite this, and testament to the NMS leadership and staff, they still endeavor to meet these demands with the development of new products and services. These new products include Sargassum Forecasts, Seasonal drought, precipitation and temperature forecasts and daily weather forecasts for specific municipalities, amongst others. Additionally, the number of automatic weather stations installed across the country has increased from less than ten a decade ago to more than fifty today. These installations require a team of skilled and motivated staff to maintain these new systems to the required standards. It is recognized that job descriptions and the rewards for such technical staff members have not been revised. At the same time, the addition of such technology means that some positions within the department are rapidly becoming unnecessary while new posts are required for persons with more advanced academic and technical qualifications.

In recognition of this situation and the threat to Belize and the economy if not addressed, the NMS Belize have recently developed a 'Proposed Restructuring of the National Meteorological Service of Belize' plan. The proposal aims to stop redundant work, refocus staff to essential work, and ensure technical staff receive suitable reward and recognition in-line with government guidelines. A phased approach to the restructuring of the department has been proposed, with the creation of additional posts to be introduced over the next 5 years. The Peer Advisor fully supports this essential initiative.

An outline of the human capacity development plan for NMS Belize is highlight in Figure 4 to Figure 11, showing organograms of the four sections of the organisation identified by NMS Belize: the Administrative Section, the Weather Analysis and Forecasting Section, the Climate Services Section and the Electronics and Information Technology Section.

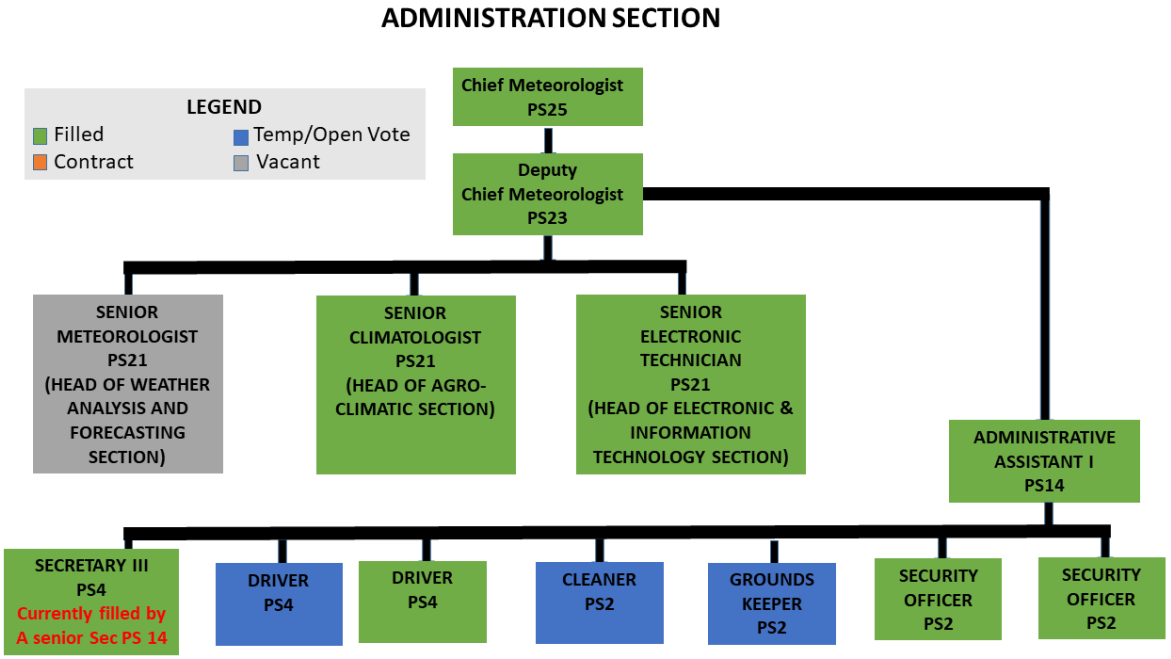


Figure 4 - Current Organogram of the Administrative Section

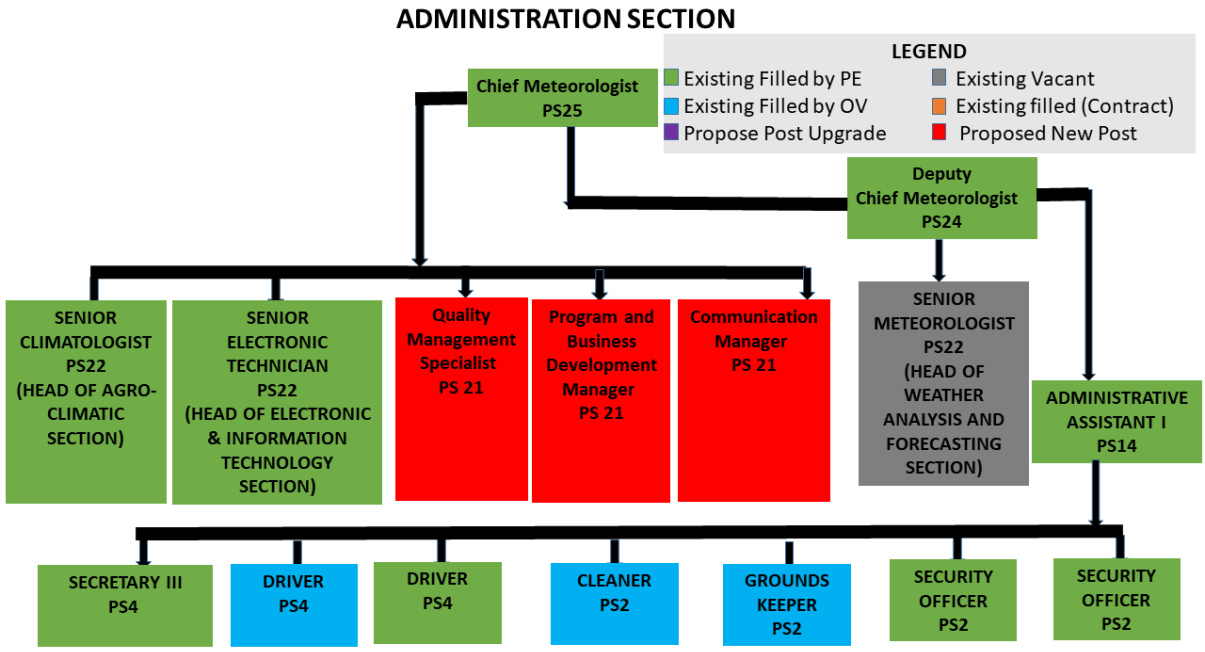


Figure 5 - Proposed new Organogram of the Administrative Section

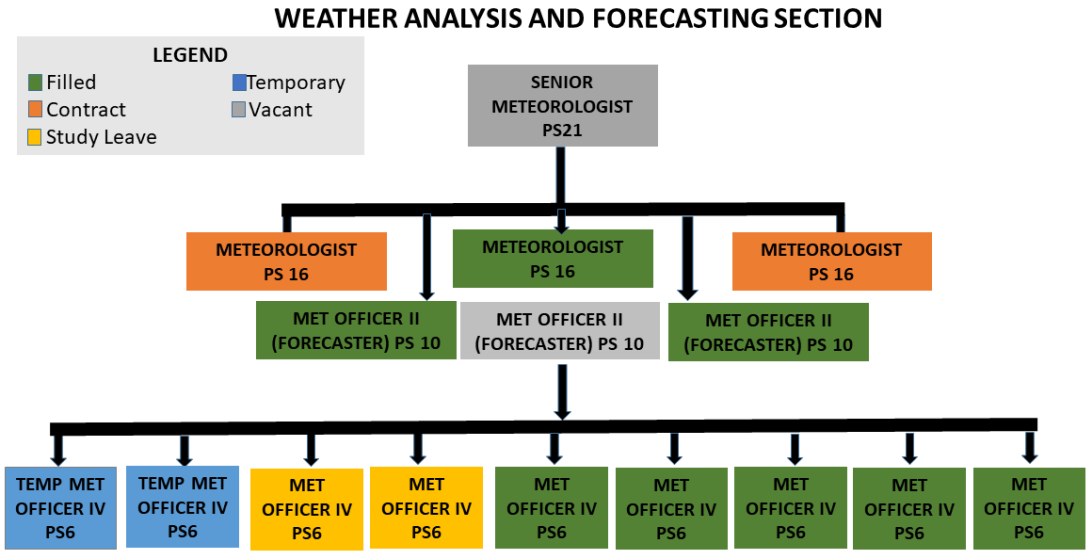


Figure 6 - Current Organogram of the Weather Analysis and Forecasting Section

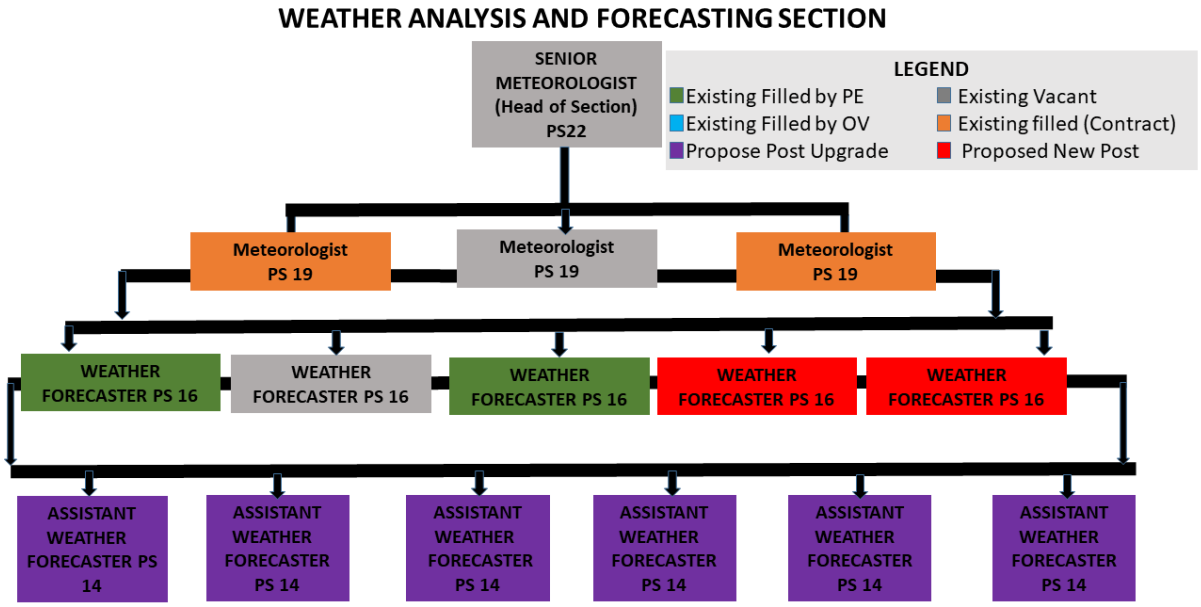


Figure 7 - Proposed new organogram of the Weather Analysis and Forecasting Section

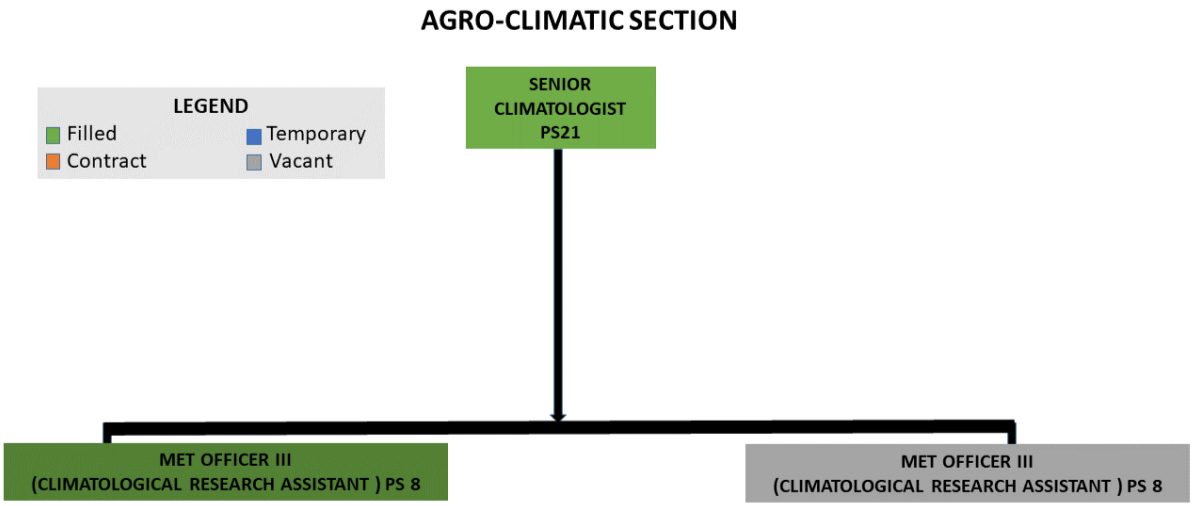


Figure 8 - Current Organogram of the Applied Meteorology and Climatology Section

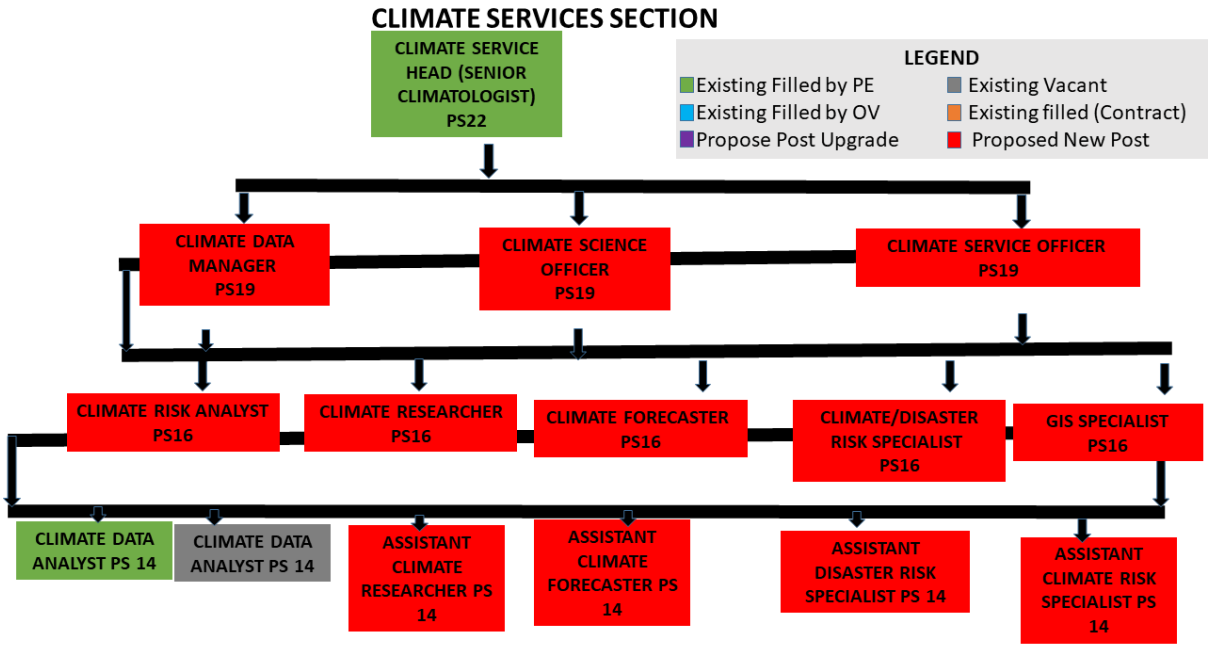


Figure 9 - Proposed new organogram of the Climate Services Section

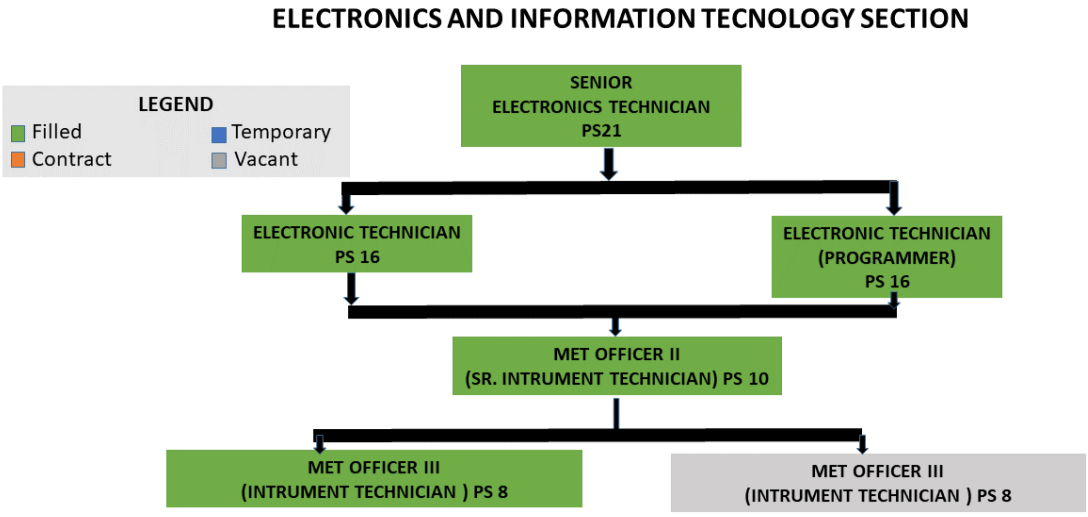


Figure 10 - Current organogram of the Electronics and Information Technology section

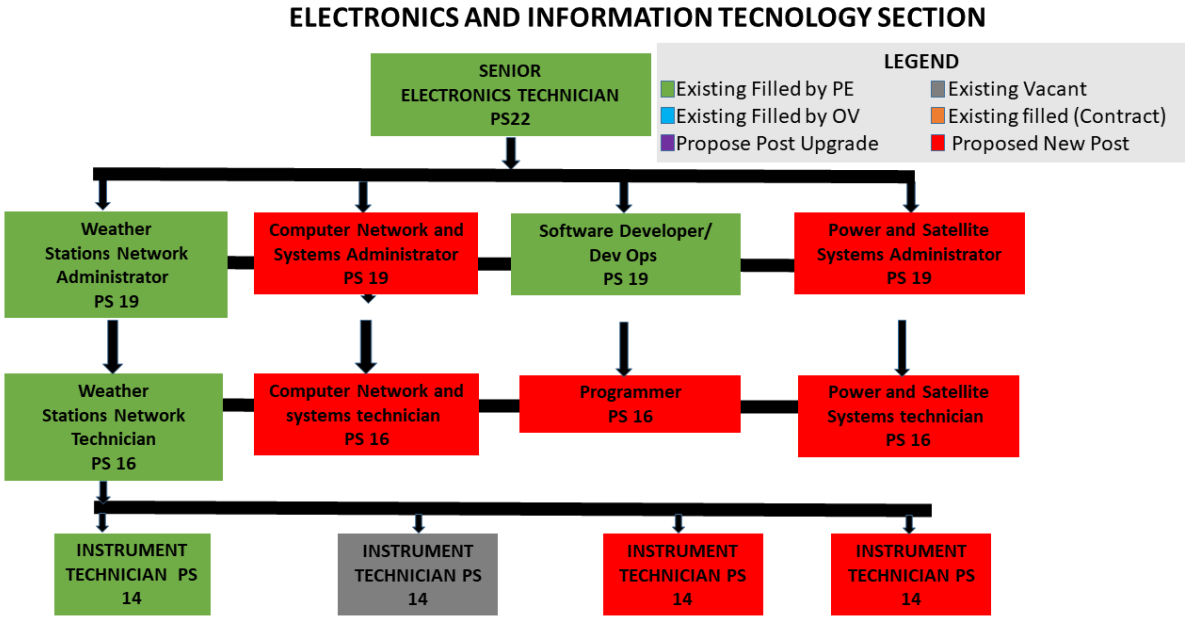


Figure 11 - Proposed new organogram for the Electronics and Information Technology section

4.2. Design capacity development activities for technical staff

In order to ensure that the maintenance and operations of observing and network equipment is high quality and consistent it is recommended that an ongoing programme of formal and informal training is undertaken across the technical staff at NMS Belize. In addition, as the department grows in line with the NMS Belize strategic plan it is essential that all new staff are similarly trained.

It is recommended that the initial procurement and deployment of observations equipment is undertaken by the existing staff from the Electronics and Information Technology section. We also recommend that this activity is managed by the project management unit that is to be established under this project. The head and two of the existing technicians from the Electronics and Information Technology section will assume specific responsibility for operations and maintenance of the GBON sites. As the Electronics and Information Technology section develops, following the NMS Belize modernisation plans, new staff will be identified to be trained and be able to assume responsibility for the GBON, as required.

Technical staff in the Electronics and Information Technology section require formal training in the operation and maintenance of the instruments which could be sourced from the manufacturer or supplier of the instruments and coordinated through CIMH / CMO. Specific training on the maintenance and observation practices associated with the surface observations should be provisioned for existing technical staff in the Electronics and Information Technology Section and extended to new staff as necessary. It is recommended that a repository of reusable training materials be developed and made available to ensure consistent training can be efficiently provided in the case of staff turnover. Similarly, training on the calibration of instruments should be provisioned for the technical staff at the workshop and updated in the event of staff turnover. This is to be coordinated through CIMH / CMO as a regional training workshop activity including other SOFF beneficiary countries in the region.

Training on the operation and maintenance of the upper air observations is provided through the US NWS, who support the upper air station in Belize. It is recommended that this training is provisioned for all new staff with responsibility for upper air observations as required.

It is recommended that technical staff utilise existing online resources including WMO training materials in the WMO Education and Training Programme, in particular courses under the Instruments and Methods of Observation section and the available training and workshops on the implementation of WIS2.

The current head of the Electronics and Information Technology section is responsible for the maintenance of the network and IT infrastructure and bespoke training in network administration has been identified within NMS Belize and it is recommended that this training programme be undertaken as soon as practicable within the SOFF programme to ensure that the network and software implementation of Surface CDMS and WIS2 are robust and maintainable. Further training in network administration and monitoring should be provisioned for the 4 roles identified in the NMS Belize Strategic Plan with responsibility for network administration and monitoring as staff transition into these new roles.

4.3. Design capacity development activities for senior management

The NMS Belize have a broad and diverse range of responsibilities, and as awareness of the climate crisis increases, demand for more services from the NMS is also increasing. At the same time, the NMS hasn’t benefitted from modernisation or commensurate investment since its inception over 40 years

ago. This situation puts an increasing burden on the NMS, especially the Chief Meteorologist and the leadership team, and puts their ability to sustain the GBON at risk.

To manage this situation requires a range of interventions that will rapidly satisfy the needs in an effective and sustainable manner. The first recommendation is to refresh the NMS Strategic and Operational plans. These activities will clearly identify the high priority needs and provide the evidence to government and investors. Thereafter, it is recommended to provide development in two forms. Firstly, through off-the-shelf training packages, such as Management and Leadership training, Managing Successful Projects training, Financial Management and Human Resource Management training. Secondly, through practical implementation of the NMS Observation Strategy and Operational plans with a peer to deliver GBON compliance. This will include the development of standard operating procedures for quality assurance, maintenance, and sustainability, and their adoption into a Quality Management System (QMS).

In recognition of the existing and excessive tasking on the NMS, it is recommended that a project officer/unit is established and recruited. This post(s) will be responsible for the effective introduction of all SOFF funded outputs to the NMS. As the project approaches it end, this post will be evolved to have more stakeholder engagement responsibilities and ensure sustainability of the GBON is maintained.

4.4. Gender and CSOs considerations

It is recognized at NMS Belize the importance of Gender, Equality and Social Inclusion (GESI) and the crucial role of the NMS to address the issues of GESI and support people and communities disproportionately impacted by extreme weather, seasonal events and climate change. Proactively supporting women, girls and marginalised people who are more likely to be negatively affected by the impacts of a climate and weather-related extreme event. It is recommended that NMS Belize undertake Gender, Equality and Social Inclusion (GESI) training as part of a broader activity to ensure GESI is mainstreamed in the NMS working practices. In addition, the following guidelines WISER GESI Minimum Standards should be followed and adhered to on all SOFF activities:

1. Is there a GESI context analysis to inform programming which identifies:
    i. Barriers and enablers to people of different gender, ages and ability, social economic constraints, or marginalised groups accessing project services.
    ii. The risks of project activities which might negatively impact GESI and how to mitigate such risks?
2. Can people of different gender, ages and ability, social economic constraints, or marginalised groups with differing abilities meaningfully participate in the design, implementation and MEL of the project, so they can build individual agency, change gender and group relations, transform systems and structures
3. How does the project contribute to the gender equity, protection, and longer term empowerment of different genders, ages and ability, social economic constraints, or marginalised people?
4. Is there a plan for building the capacity of local partners on GESI using these Minimum Standards and GESI upskilling?
5. Does the MEL system enable analysis of GESI issues and does the project Logframe or results framework integrate qualitative and quantitative:
    i. Gender and social inclusion targets, that capture evidence of leadership, empowerment and meaningful participation in decision-making?

ii. Sex, age, and differing ability disaggregated data and account for intracommunity diversity and complexity?

There was no formal gender assessment of the NMS undertaken during the readiness phase, so it is recommended that the NMS conduct a self-gender assessment of their institution and include insights to their modernisation plans. During the implementation of the National Contribution Plan, and any further modernisation, recruitment and training should follow these guidelines:

- Women should represent at least 50 % of all participants in SOFF-related and supported training
- 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

It is also recognized that engagement with civil society is an important factor, to raise awareness of the NMS and the observation sites and how they play an important role in the value-chain that provides high-impact weather information, especially to women and girls. One CSO (Friend for Conservation and Development – FCD) has worked with department in the past as it relates to site inspection for weather station in the remote areas of western Belize. As it relates to the two GBON station, the one at the airport requires little to no CSO involvement. The proposed station in Punta Gorda will require cooperation with CSOs in that area and an event will be held to engage with this sector to mitigate against the risk of theft and vandalism. Therefore, it is recommended that a consultation event be held with CSOs, including those focused on women's empowerment in the Punta Gorda location.

Module 5. Risk Management Framework

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

The primary risks to the observation network are set out in the risk register below. This risk register should be owned and maintained by the Chief Meteorologist and updated on a quarterly basis.

Operational risks to the observations network						
Risk description	**Impact description**	**Impact level**	**Probability level**	**Priority level**	**Mitigation**	**Owner**
Hurricane direct hit on HQ	Damage to building and ingress of water to damage electrical equipment.	High	Low	High	Project proposal being developed to build a stronger more hurricane resistant building; also proposal to repair and fortify current structure.	Ronald Gordon
Hurricane direct hit on observation site	Physical damage to the equipment or communications infrastructure	High	Low	High	Pre-deploy staff and spares to the vicinity in a safe location.	Dwayne Scott
Insufficient trained resource	Inability to maintain the observations network	High	Medium	Very high	Communicate the risk to the CEO at the ministry. Collaborate with other stakeholders to provide support and maintenance to the network where necessary	Ronald Gordon
Hardware failure	Inability to provide the full GBON compliant observations to GTS/WIS2	Medium	Very High	High	Adequate funding, skills and planning to manage the network. Resilience and redundancy measures to be included in network design and operational plans / SOPs.	Dwayne Scott

Module 6. Transition to SOFF investment phase

It is recommended that, on approval of the Investment Phase Funding Request, a virtual workshop including the NMS Belize, IDB and Met Office is arranged to review the outputs of the readiness phase and discuss the transition to the investment phase. The regular project meetings undertaken in the readiness phase should continue under the coordination of the IDB and should include the peer advisor wherever necessary.

Summary of GBON National Contribution Plan

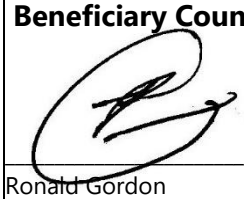
Provide summary of GBON National Contribution Plan by filling this table

Components	Recommended activities	Related outputs and technical details
Module 2. GBON business model and institutional development	1. Update MOU on Upper Air observations with US NWS	Annex 2.1
	2. Identify opportunities for future private sector collaboration with respect to marine observations	Annex 2.1
	3. Coordinate relevant training activities through CMO / CIMH to include regional NMS and other SOFF beneficiary countries	Annex 2.2
	4. Continue development of SurfaceCDMS in Belize and share the benefits and lessons with other regional NMS through CMO / CIMH	Annex 2.2
	5. Commission Socio-economic benefit analysis of the NMS Belize	Annex 2.3
	6. Conduct review of existing and upcoming national and regional investments and development projects	Annex 2.4
	7. Review and revise draft cabinet paper for legislative mandate for NMS Belize	Annex 2.5
	8. Proactively engage with owning ministry to highlight the risks and benefits of investment decisions related to NMS Belize	Annex 2.5
Module 3. GBON infrastructure development	1. Procure and install upgraded observing equipment for 2 surface GBON sites and spares	Annex 3.1
	2. Inspect site infrastructure (fences / enclosures etc) and repair / replace where necessary	Annex 3.1
	3. Update and develop preventative maintenance and calibration regime and SOP	Annex 3.1
	4. Review and update SOPs for surface and upper air observations	
	5. Procure and deploy upgraded data ingestion server and NAS storage	Annex 3.2

	6. Complete development of SurfaceCDMS and implementation of WIS2	Annex 3.3
	7. Review environmental and sustainability guidance and incorporate into procurement specifications	Annex 3.4
Module 4. GBON human capacity development	1. Complete training for technical staff in maintenance, calibration and observing practices	Annex 4.2
	2. Complete training for IT staff in network administration and management	Annex 4.2
	3. Technical staff to attend regional workshop on observations, calibration and maintenance through CIMH / CMO	Annex 4.2
	4. Update NMS strategic plan and obtain approval from owning ministry	Annex 4.3
	5. Develop and adopt within QMS observation strategy for GBON compliance including development of SOPs for quality assurance, maintenance and sustainability	Annex 4.3
	6. Establish a project / stakeholder unit to ensure effective execution of SOFF funding and sustainability	Annex 4.3
	7. Management staff to complete Management and Leadership training, Managing Successful Projects training, Financial Management and Human Resource Management training	Annex 4.3
	8. Management staff to undertake GESI training	Annex 4.4
	9. Mainstream GESI into operational plan	
Module 5. Risk Management	1. Undertake review of risks to the observations network and incorporate into strategic plan and manage through the operational plan	Annex 5
	2. Update and review risk register	Annex 5

Module 6. Transition to SOFF investment phase	1. Undertake workshop with peer advisor and implementing entity on transition to investment phase	Annex 6

Report completion signatures

Peer Advisor signature 
Beneficiary Country signature    Ronald Gordon   Chief Meteorologist   National Meteorological Service of Belize and Belize's WMO Focal Point
WMO Technical Authority signature