COUNTRY HYDROMET DIAGNOSTICS

Informing policy and investment decisions for high-quality weather forecasts, early warning systems, and climate information in developing countries.

November 2024

Barbados Peer Review Report

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WORLD METEOROLOGICAL ORGANIZATION

IDB Inter-American Development Bank

Alliance for Hydromet Development

BARBADOS METEOROLOGICAL SERVICES

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SOFF Systematic Observations Financing Facility

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Authorisation for release of this report has been received from the Peer Reviewing Agency and the Country NMHS as of November.

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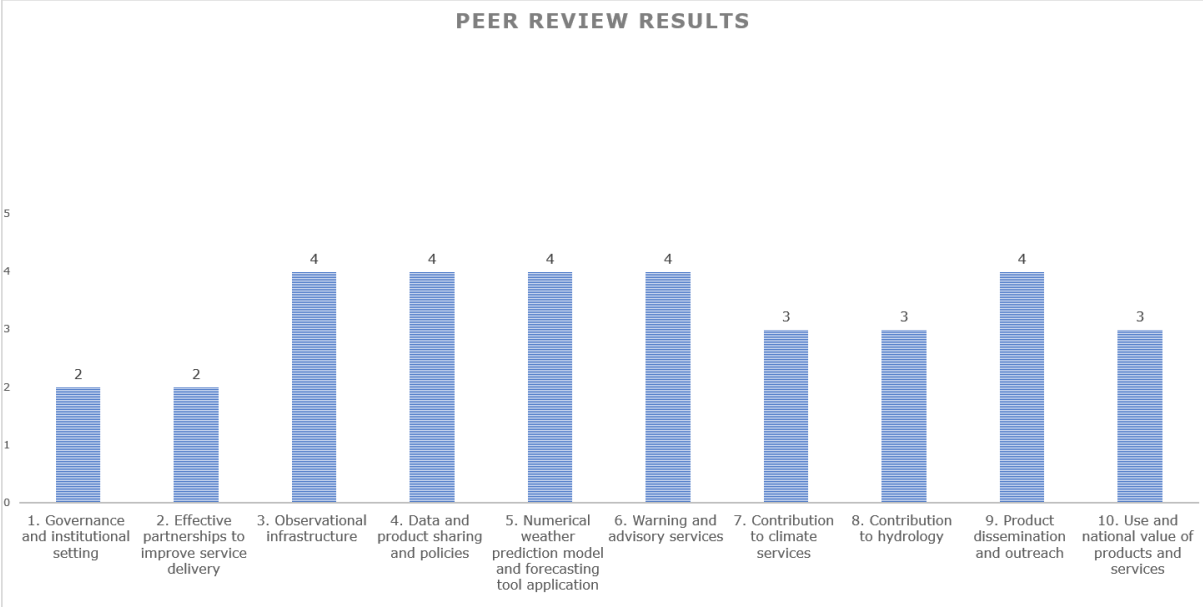
Table of Contents

Abbreviations

BMS	Barbados Meteorological Service
CAP	Common Alerting Protocol
CIMH	Caribbean Institute for Meteorology and Hydrology
CMO	Caribbean Meteorological Organization
CREWS	Climate Risk Early Warning Systems
DEM	Department of Emergency Management
EPD	Environmental Protection Department
FMI	Finnish Meteorological Institute
GBON	Global Basic Observations Network
IDB	Inter-American Development Bank
MHEWS	Multi Hazard Early Warning Services
NEM	National Emergency Management
NEOC	National Emergency Operations Centre
SOP	Standard Operating Procedure
WMO	World Meteorological Organization
5C	Caribbean Community Climate Change Centre

Executive Summary

The BMS has actively and independently been developing its services, ways of working and tools to serve the needs of the general population and national stakeholders. Efforts have been made to utilize modern automatized tools to improve resource efficiency, especially regarding the worktime of staff. Additionally, the BMS has been embracing new and innovative approaches to expanding their weather and climate observation networks with 3D-printed surface stations and unmanned sea surface observation vessels. Beside its national impact, the BMS is participating in the regional hydrometeorological community by hosting the Caribbean regional weather radar mosaic and by providing forecasts and warnings to the countries of Dominica and Saint Vincent and Grenadines.



Element	Maturity level score
1. Governance and institutional setting	2
2. Effective partnerships to improve service delivery	2
3. Observational infrastructure	4
4. Data and product sharing and policies	4
5. Numerical weather prediction model and forecasting tool application	4
6. Warning and advisory services	4
7. Contribution to climate services	3
8. Contribution to hydrology	3
9. Product dissemination and outreach	4
10. Use and national value of products and services	3

The main gaps identified in the Country Hydromet Diagnostics are:

- *Governance and institutional setting:* Currently there is no legislation to stipulate the mandate and responsibilities of the BMS. A draft bill has been developed and submitted for Ministry review.
- *Effective partnerships to improve service delivery*: The BMS is recommended to update critical MoUs with existing partners (CAA) and to assess the need for new MoUs with some of the key stakeholders (EPD, Water Department). The BMS is recommended to coordinate the division of air quality monitoring and forecasting duties with EPD. The BMS has initiated a more systematic approach to stakeholder engagement, including more frequent engagement, and is recommended to continue proceeding with its plans and to include impact-based forecasting more closely in these discussions.
- *Observational infrastructure*: The BMS is recommended to continue with the automatization of its network, including the sounding station, and with the expansion of the network to the marine areas. Funding from e.g. SOFF or regional project initiatives are recommended to be channelled to support these initiatives. To improve the gaps in the calibration services, it is recommended to support the strengthening of the WMO regional calibration centre or to establish new service agreements with other calibration laboratories for the BMS.
- *Data and Product sharing policies:* The BMS is recommended to develop a data policy after the meteorological bill has been passed. The BMS is recommended to provide access to their data archive with quality-controlled data for key stakeholders and to support the access with e.g. API feeds.
- *Numerical model and forecasting tool application:* The BMS is very advanced in its modelling capabilities, and it is recommended to share these experiences with the region. Additionally, the BMS is recommended to develop a process and tools for model verification.
- *Warning and advisory services:* It is recommended to pass the legislation to grant the formal warning mandate to the BMS. Parallel to this, the roles and responsibilities of each national entity involved in alerting and warning should be clarified, including for the dissemination of information on impacts.
- *Contribution to climate services:* The BMS is recommended to consider developing a user interface for accessing quality-controlled climate data for stakeholders.
- *Contribution to hydrology:* it is recommended to formalize the relationship between the BMS and the Water Department and to establish SOPs and mechanisms for effective product co-development.
- *Use and national value of products and services*: the BMS is recommended to establish feedback mechanisms on e.g. their website for collection of user input.

Additional recommendations are described in the respective chapters of this report.

Chapter 1: General information

Introduction

Barbados is a small island developing state in the eastern-most part of the Caribbean Archipelago. As an island state, Barbados is highly vulnerable to hurricanes and other natural hazards and is particularly susceptible to the potential impacts of climate change, including coastal inundations and sea level rise, an increase in tidal and storm surge levels, coastal erosion, rising temperatures, changes in rainfall patterns, drought and more frequent and intense tropical cyclones.[1] As the eastern-most country in the Caribbean Barbados is the first one to observe the development and approach of hurricanes, thus bearing a heightened value for all related observations, including sea surface observations.

The government of Barbados has identified climate change impacts as the largest environmental risk with attendant economic and social challenges and considers climate change to be significant threat to its growth and prosperity.[2] Climate change will impact all key sectors of the economy: agriculture, water resources, human health and settlements, coastal resources, fisheries and insurance. Sectors immediately affected are tourism, fisheries and human settlements that rely on low-lying coastal resources as well as the national food production that is vulnerable to drought, changes in rainfall patterns and storm damages.

The Barbados Meteorological Service (BMS) is working to provide necessary information and services to guide knowledge-based decision making needed to adapt to climate change and to mitigate its negative impacts. The BMS is well connected and valued nationally and provides a wide service portfolio to support national stakeholders and the regional Caribbean meteorological community.

The BMS has been very active in improving its services and developing modern ways of working and tools to improve its capabilities to serve the general public and the different stakeholders. Efforts have been focused on the utilization of modern automatized tools to improve resource efficiency, especially regarding the worktime of staff. This progress has established the BMS as one of the pioneering NHMSs in the region. The BMS has exceptional skills in modelling, and it has been testing out new innovative approaches to expand the weather and climate observation network with low-cost 3D printed surface stations and new unmanned sea surface observation vessels. Besides national impact, the BMS is participating in the regional hydrometeorological community by hosting the Caribbean regional weather radar mosaic and by providing forecasts and warnings also to countries of Dominica and Saint Vincent and Grenadines.

CHD methodology

The Country Hydromet Diagnostics (CHD) work was done as an output for the Systematic Observations Financing Facility (SOFF) project in Barbados and was preceded by the preparation of the SOFF National GBON Gap Analysis and Contribution Plan.

During the SOFF project's readiness phase, the following activities were organized:

- Remote workshop for the kick-off
- A mission to Barbados focusing on discussion on the status of the observation network, its gaps and development plans, including site surveys on the GBON

[1] World Bank Climate Change Knowledge Portal
[2] Barbados 2021 National Determined Contribution

surface weather stations and upper-air sounding station. Mission focused on the information required for the Gap Analysis report and the National Contribution Plan.

- A mission focusing on the Country Hydromet Diagnostics. Workshop with the BMS to assess and evaluate all line-items on the CHD template and a half day key stakeholder workshop to collect input form the users. Stakeholders attended from:
    - National Conservation Commission
    - Barbados Hotel and Tourism Association
    - Environmental Protection Department
    - Barbados Civil Aviation Authority
    - Barbados Fisheries Division
    - Ministry of Health and Wellness
    - Ministry of Agriculture
    - Government Information Service
    - Department of Emergency Management
- Consultation with the US National Oceanic and Atmospheric Administration National Weather Service Office of Observations regarding the Cooperative Hurricane Upper-air station.
- Two visits to the Caribbean Meteorological and Hydrological Institute (CIMH) to discuss regional network support, plans, and the capacity of the regional calibration centre.
- Remote meetings to prepare and comment on the findings and documents.

Chapter 2: Country Hydromet Diagnostics

Element 1: Governance and institutional setting

1.1 Existence of Act or Policy describing the NMHS legal mandate and its scope

The Barbados Meteorological Services (BMS) operates as a department under the auspices of the Ministry of Home Affairs, Information and Public Affairs.

The BMS is nationally recognized as the national warning authority and the responsible actor in the field of hydro-meteorology. Currently there is no act or policy describing the NMHS legal mandate and its scope. A draft bill "Draft model meteorological, hydro-meteorological and climate services bill for Barbados" has been prepared with the support of CMO and presented in 2023 to the line-Ministry of Home Affairs and Information for review. BMS has identified the development of the legal framework as a strategic objective in their strategy plan and is committed to work to co-develop the bill and policy.

Although not legally stipulated, the mandate for the BMS covers public weather and warning services as well as sector specific services such as aviation, shipping and tourism services. The BMS is the Meteorological Authority (as per ICAO Annex 3) and service provider for aviation meteorological services. All services provided are non-commercial as no cost-recovery mechanisms are allowed. The mandate for air quality observations (no mandate for warnings) is with the Environmental Protection Department (EPD)[3] and for hydrology with the Barbados Water Authority[4].

Barbados is a Member State in the WMO with responsibilities set by WMO Convention. The BMS director is appointed as the Permanent Representative of Barbados to WMO.

In addition to having the weather forecast and warning responsibilities over the islands and coastal waters of Barbados, the BMS is responsible for delivering such services for neighbouring countries Dominica, as well as St. Vincent and the Grenadines as agreed in the CMO Resolution 1[5].

The Barbados Department of Emergency Management is governed by the Emergency Management Act 2007, CAP 160A.

1.2 Existence of Strategic, Operational and Risk Management plans and their reporting as part of oversight and management.

The BMS's strategic plan is updated for a three-year period. The latest strategy has been issued in September 2022 and is still relevant. Five strategic objectives with selected actions and KPIs have been identified in the plan. These are:

- Provision of products and services that ensure the safety of life and property against all Meteorological and Hydrometeorological Hazards
- Reduction of the social and economic impacts related to natural disasters across all timescales.
- Supporting essential services in providing better community health, recreation and quality of life.

[3] EPD website
[4] Barbados water authority website
[5] CMO Resolution 1

- Provision for the need of future generations as it relates to the operational structure of the department to support ongoing weather-related activities and climate change planning and mitigation for the public good.
- Development of a legal framework to support the operations of the National Meteorological and Hydrological Services.

Implementation of the plan is reported annually and the success of the plan in relation to the KPIs is assessed by the BMS at the end of the three-year period before drafting of a new plan. The BMS has the right to develop and approve the strategy independently.

Risk Management plans only exist for selected topics that have been assessed to have high operational risk. Such plans exist for the operation of the weather radar and are developed when introducing new technologies such as the use of drones.

1.3 Government budget allocation consistently covers the needs of the NMHS in terms of its national, regional, and global responsibilities and based, among others, on cost-benefit analysis of the service. Evidence of sufficient staffing to cover core functions

Currently the BMS's entire budget is funded by the Barbados Government. The total annual budget for 2023 was 5 000 000 USD. The budget division was 20% for staff costs, 21% for operational costs, 33% for investments and 26% other costs.

The budget has been reviewed accordingly when the BMS has expanded their service portfolio, and the overall budget trend has been slowly growing in the recent years. The BMS core services are not restricted by budgeting issues. Additional funding is required to achieve the BMS's plans to increase marine observations and to develop new impact-based forecasting services.

No cost-benefit analysis has been made of the services. Such analysis would be very welcomed and could be used to demonstrate the national and regional value of the services and to guide the prioritizing of new potential services.

1.4 Proportion of staff (availability of in-house, seconded, contracted- out) with adequate training in relevant disciplines, including scientific, technical, and information and communication technologies (ICT). Institutional and policy arrangements in-country to support training needs of NMHS.

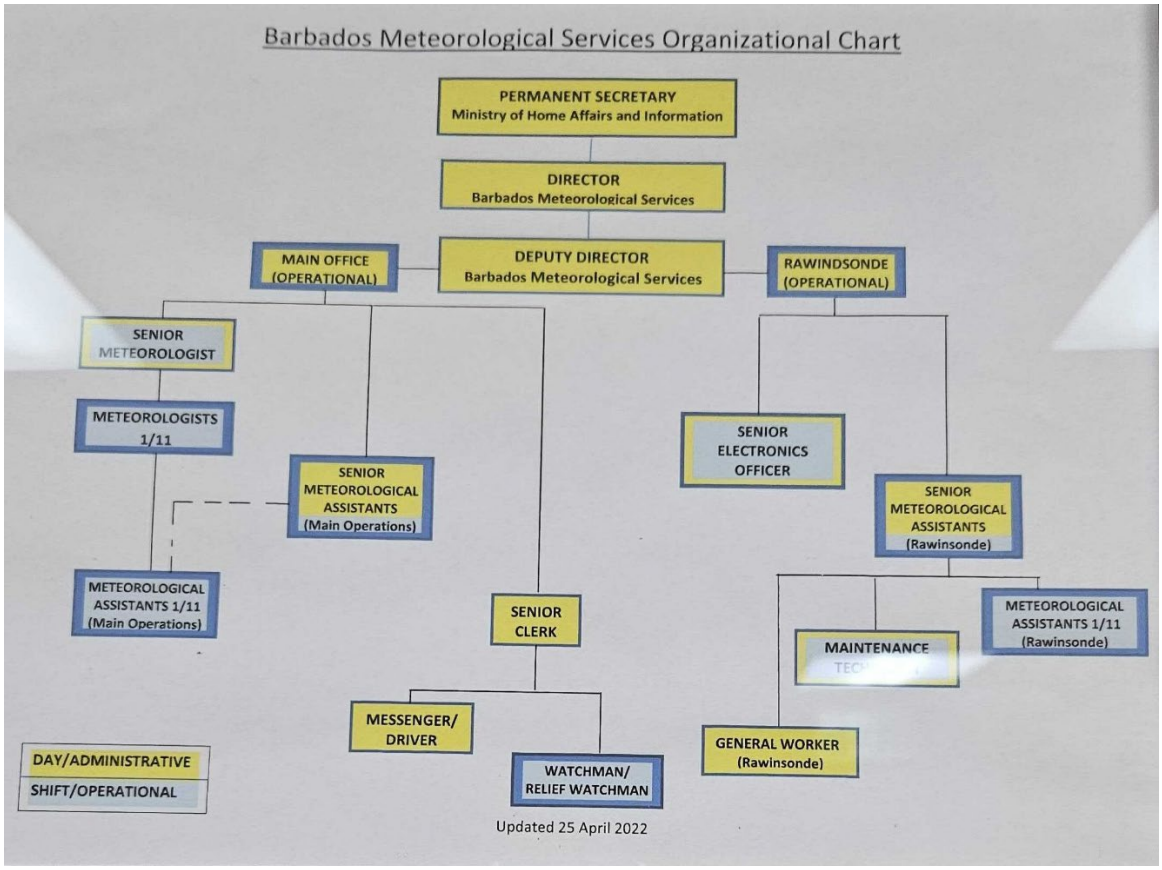


Figure 1 The organizational chart for the BMS.

The total number of staff is currently 43, consisting of 39 permanent members of staff and 4 contract workers. The male to female ratio is currently 28:15, and females are well represented throughout the organization tiers.

Table 1 Number of staff and established positions in the BMS

Position	Number of staff
Management	3
Meteorologist	11
Meteorological Technicians	18
Assisting staff	7

The meteorological staff that forms the bulk of the entire staffing with 11 meteorologists and 18 meteorological technicians have been trained in the WMO classified CIMH training programs. The CIMH is the most frequent partner to collaborate with in the training programs e.g. specific training for system maintenance, but the BMS also works with other training institutes on an ad-hoc basis and attends operation and maintenance training courses by system manufacturers when procuring new technologies or systems.

Staff competency is unofficially assessed every year, but no set framework is followed. A strategic training plan exists that has been updated 2022. Improving staff competency is a cross-cutting topic in the BMS's strategic plan with targeted actions identified for the different strategic objectives.

The main human capacity improvements identified in the strategy are needed for training in Numerical Weather Prediction modelling, ICT services, and improving the staff working capabilities. KPIs for the objectives include: successful enrolment and completion of

training courses on a yearly basis and assessment from the staff as to the state of the working environment in terms of health and safety supplies and environmental conditions of all facilities and equipment.

The BMS has an agreement with the CIMH and the University of West Indies to host the meteorological forecaster apprenticeship at BMS.

1.5 Experience and track record in implementing internationally funded hydromet projects as well as research and development projects in general.

Most of the BMS's internationally funded projects are through the regional collaboration with CMO, CIMH or the Caribbean Community Climate Change Centre (5C) with the funding stemming from instruments and funders such as Climate Risk Early Warning Systems (CREWS) or USAID. Recent programs have been:

- Impact Based Forecasting project chaired by CIMH and funded by USAID. Project kick-off in 2020.
- Enhancing Climate Resilience in Cariforum Countries project by the 5C's in 2023. BMS received three automatic weather stations.
- Multi-precipitation grid with CMO, part of CREWS.

As part of the 3D-Printed Automatic Weather Station (PAWS)[6] initiative the BMS is implementing a supplementary grade network of 3D printed automatic weather stations. The initiative was launched by the University Corporation for Atmospheric Research (UCAR) and the US National Weather Service International Activities Office (NWS IAO) and the BMS has been a part of the initiative from the early stages.

Summary score and recommendations for Element 1

The summary score for the element is 2 "Effort ongoing to formalize mandate, introduce improved governance, management processes and address resource challenges".

The grade is not higher due to the clear lack of formalized mandate. Efforts to fill this gap are ongoing as the draft bill has been submitted for Ministry review.

Budget and human resources are seen as adequate for the current provided services.

There has never been a national socio-economic benefit assessment conducted in Barbados for the meteorological and hydrological services. The assessment is necessary for the monitoring and evaluating of the services' impact and to guide the prioritization for new service development and a strong justification for the mandate of the service. **It is recommended to conduct a national socio-economic benefit assessment of the hydrometeorological services in Barbados**.

Element 2: Effective partnerships to improve service delivery

2.1. Effective partnerships for service delivery in place with other government institutions.

There are little formalized partnerships in place, but BMS has well established practices for service delivery and collaboration with all major government stakeholders.

The BMS is collaborating actively with the National Water Authority, Department of National Emergency Management (NEM), Government Information Services and Coast

[6] UCAR 3D-PAWS initiative

Guard. A Memorandum of Understanding from 2021 is in place between the BMS and the Civil Aviation Authority, although this is in the process to be updated to meet the new regulation.

The main platform for collaboration with relevant national stakeholders in cases of hazardous weather, mainly tropical cyclones, is the National Emergency Operational Centre (NEOC) and its subcommittees. NEOC is the central hub to mobilize and coordinate responses and resources in events of major incidents. The Department of National Emergency Management has the role of coordinating of the stakeholders and activities and is one of the key direct contacts to the BMS. Collaboration is activated before, during and after the events to effectively respond and mitigate the impacts. The committees include: public information, damage assessment and statistics, health and first aid services, food and general supplies, public utilities, emergency transport, road clearance and tree trimming, welfare services, shelter management, telecommunications, emergency housing and rehabilitation, national mitigation, tourism emergency management and technical standing committee on coastal hazards. NEOC and its subcommittees include members from every important national stakeholder: emergency management, police, utilities company, telecommunication providers, as well as private stakeholders from the tourism and energy sectors, among others.

Based on the feedback from stakeholder engagements, the BMS role and services were highly appreciated. Identified shortcomings in the relationships were lack of direct connections or bureaucracy related to requests. To increase the collaboration and to improve the service rate it was suggested to formalize key partnerships especially with organizations located under a different ministry to decrease the need for formal letters of requests. Identified organizations to benefit from such arrangements are the Environmental Protection Pepartment (EPD), Ministry of Agriculture and Food Security. EPD and Ministry of Agriculture both expressed a need to have access to the quality-controlled observation data and to receive training from the BMS to interpret and use the data and services. Key service users such as the National Conservation Commission, Fisheries and Hotel and Tourism Association would benefit from increased collaboration with the BMS and co-creation of tailored services for the specific sectors.

The different marine users and the Ministry of Health and Wellness indicated a need to increase the density of marine observations and creation of impact-based forecasts for the sector. A presented example was the need for sea surface temperature observations to estimate microalgae formation that is related to food chain issues and outbreaks of listeria.

2.2. Effective partnerships in place at the national and international level with the private sector, research centres and academia, including joint research and innovation projects.

The BMS participates actively in collaboration with neighbouring countries and in the wider Caribbean collaborations. Relevant regional organizations to GBON implementation are the Caribbean Meteorological Organization (CMO) and the Caribbean Institute for Meteorology and Hydrology (CIMH). 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. CMO has assisted its members in, for example, drafting of meteorological legislation and most recently in the regional implementation of WIS2.0 support. 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 provides training courses, hosts the regional calibration laboratory, runs a regional numerical model, and hosts the Caribbean Climate Outlook forum.

The BMS has a very good relationship with CIMH and the University of West Indies. The BMS provides facilities and guidance for practical work training for forecasters as a part of the CIMH meteorologist training course.

Another research institute the BMS have experience of working with is the University Corporation for Atmospheric Research (UCAR) with whose assistance the BMS has developed and implemented a network of small 3D printed automatic weather stations 3D-PAWS (below GBON standard quality). To secure suitable sites for the stations the BMS is working with renewable energy companies that allow the stations to be installed on their property in exchange for the information. Near real time observation data from the stations is available on the BMS website for stakeholders to view. A practical use case for the 3D-PAWS network has been the use of accumulated rainfall information for drainage planning.

The BMS is a part of the Cooperative Hurricane Upper Air Station (CHUAS) network program supported by the US National Oceanic and Atmospheric Administration (NOAA). The program aim is to provide upper-air sounding data for hurricane forecasts from the most important regions from the hurricane tracks and formation area. The cooperation provides the BMS with the necessary equipment and consumables. The collaboration is governed by a MoU between the parties and has been mutually beneficial and long-standing.

The BMS is not partaking actively in research projects. Current limitations in human resources do not allow such activities and all development efforts are targeted towards improving the operational systems and services. Inhouse research efforts have been focusing on improving numerical modelling and the deployment of new unmanned surface vessels to monitor sea surface parameters.

2.3. Effective partnerships in place with international climate and development finance partners.

The BMS has very little direct contact with international climate and development finance partners. Most cooperation is through some of the regional institutions such as the CMO, CIMH or 5Cs. In recent years the BMS has received assistance through CREWS, SOFF and the Green Climate Fund (through the 5Cs) to improve its observational and technical capacity.

2.4. New or enhanced products, services or dissemination techniques or new uses or applications of existing products and services that culminated from these relationships.

From the collaboration with UCAR, the BMS has built the capabilities to independently manufacture and deploy 3D-PAWS stations. The BMS is a pioneer in the region to implement this new technology and is expanding the builds to cover coastal weather stations with the 3D printing solutions. A new use case that stemmed from the improved resolution of the surface weather station network was utilizing accumulated rainfall information for drainage planning.

Summary score, recommendations, and comments for Element 2

Summary score for the element is 2 "Limited partnerships and mostly excluded from relevant finance opportunities."

The BMS is **recommended to continue improving the stakeholder engagement by updating the MoU** with the Civil Aviation Authority, **assessing the need for a MoU** with the Department of Emergency Management to clarify the roles for the different actors and to **consider the formalizing of relationships with the key stakeholders that have indicated a need for improving the relations through formalized channels**. **The**

BMS is recommended to consider the division of air quality monitoring and forecasting tasks with the Department of Environmental Protection.

The stakeholders have indicated a wish for more active interaction e.g. annual sector specific meetings to discuss current service level and to co-create new services. The BMS is **recommended to consider increasing the frequency of stakeholder engagement and to participate actively in events directed to the specific sectors the BMS is serving.** Improved collaboration is appreciated by the **marine sector users on marine observations, collaboration with Hotel and Tourism Association and to initiate a closer collaboration with the Ministry of Health and Wellness in the field of impact-based forecasting.**

Element 3: Observational infrastructure

3.1. Average horizontal resolution in km of both synoptic surface and upper-air observations, including compliance with the Global Basic Observing Network (GBON) regulations.

Barbados is fully compliant with the WMO GBON regulations for both surface weather stations and upper-air soundings. According to WMO regulations Barbados is required to have one surface weather station and one upper-air sounding station.

The upper-air sounding station is part of the Cooperative Hurricane Upper Air Stations (CHUAS) network, which is supported by the US National Weather Services based on a MoU between the BMS and NWS. NWS has provided the sounding equipment and consumables for twice a day sounding whereas the BMS provides the premises and housing for the station and the human resources for the operation.

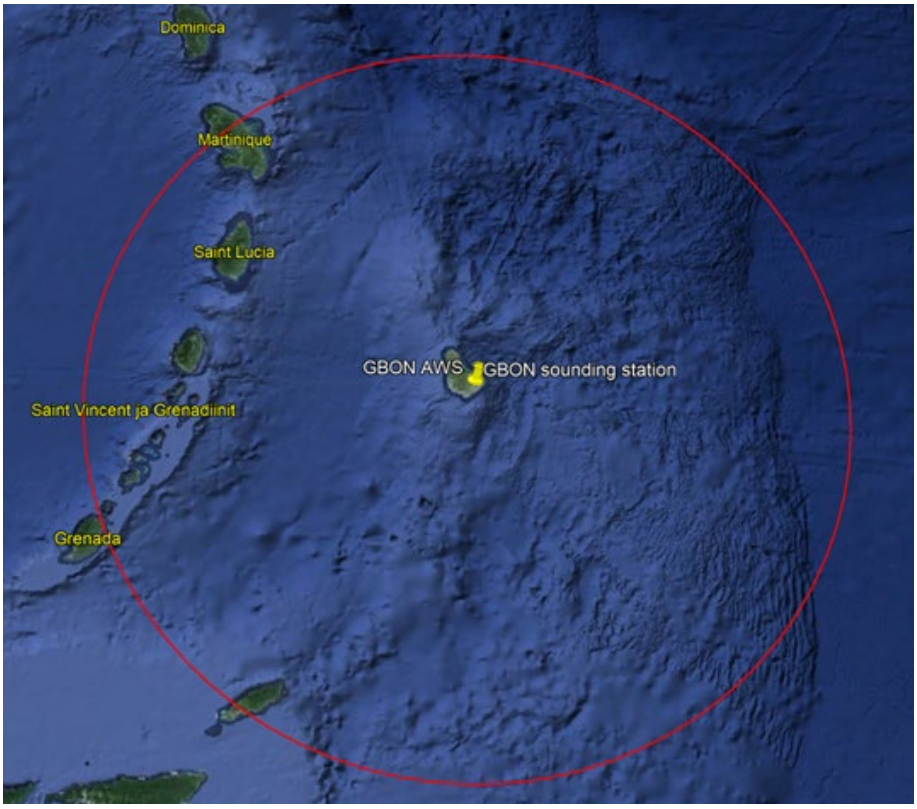


Figure 2 GBON surface weather station and sounding station. Circle indicated with 250km radius.

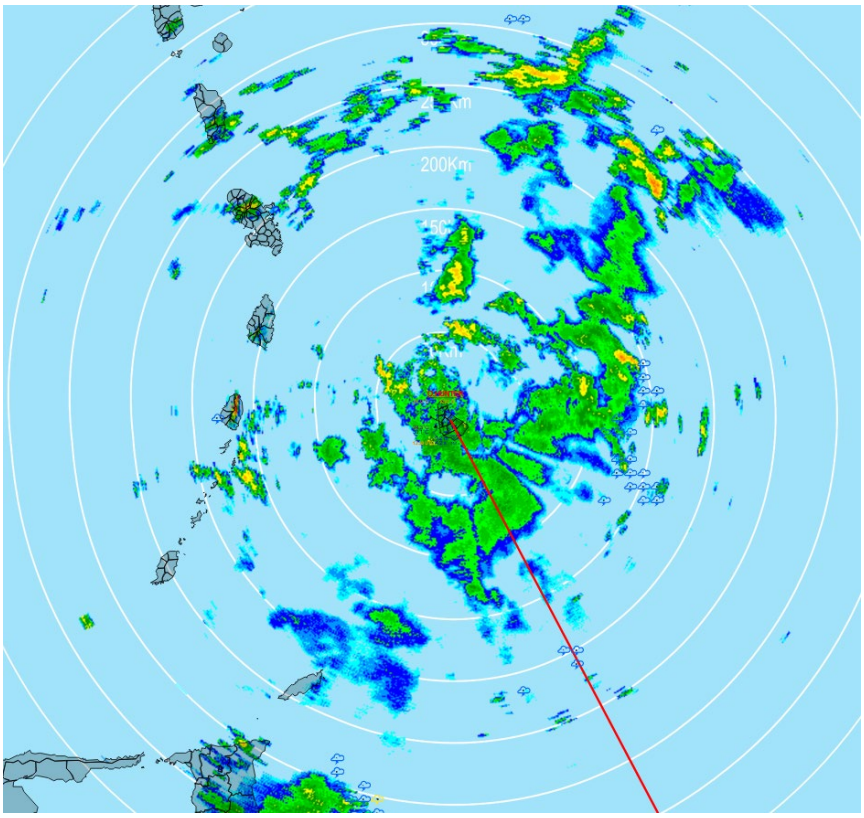
Besides the one GBON-compliant synoptic surface weather station, there are five other synoptic stations in Barbados, including three new automatic weather stations from the project "Enhancing Climate Resilience in Cariforum Countries[7]". Data is transmitted in real time. Additionally, the BMS has deployed a fleet of almost one hundred small automatic weather stations 3D-PAWS (not up to GBON quality requirements).

3.2. Additional observations used for nowcasting and specialized purposes.

The BMS has installed a large network of 3D-PAWS stations (89 stations currently, the goal is to reach 100 stations) and is currently expanding to a coastal station network. The BMS has one lightning detection sensor, operates one weather radar and hosts the regional weather radar composite for the Caribbean. To complement the regional radar coverage, a regional lightning detection network is recommended to provide a full view on the approach and development of storm and hurricane events in the region.

The BMS has recently invested in four unmanned surface vessels (AutoNaut) to observe especially the eastern parts of the ocean so as to monitor the approach and formation of tropical cyclones. The surrounding ocean areas are large and have a profound impact on the weather and climate in Barbados. The four vessels are not enough to cover the observation gaps in the area and the BMS will need to invest in more observation vessels and marine surface weather observation stations in the future. It is recommended to support the expansion of the marine observation stations as they provide key insight on hurricane formation and development, and information much needed by the active marine sector.

While the BMS operates one lightning sensor, the network would require at least one additional sensor in the northern part of the island for improved coverage.



[7] Caribbean Community Climate Change Centre

Figure 3 Barbados weather radar image (from radar animation) available on the BMS website.

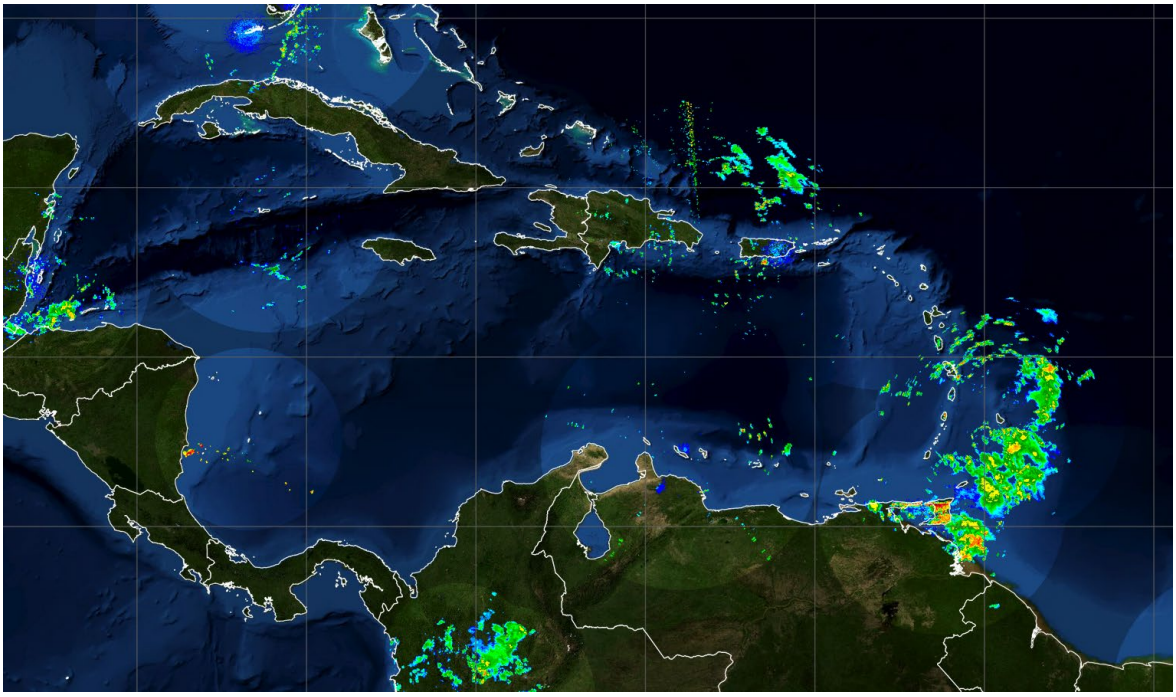


Figure 4 Weather radar composite image (from radar animation) available on the BMS website. The image shows full Atlantic coverage. Images available over smaller regions: North West Caribbean, Central America, Eastern Caribbean and South America.

3.3. Standard Operating Practices in place for the deployment, maintenance, calibrations and quality assurance of the observational network.

The maintenance unit of BMS is working efficiently to maintain and continuously develop the BMS observation network. The maintenance unit is well equipped and run a spare part stock that covers the needs for annual maintenance. For the 3D-PAWS stations, the unit can manufacture a range of spares independently (sensors need to be procured). The BMS has been developing a network management software to be able to remotely monitor the status of the systems and to plan maintenance visits.

The BMS has SOPs and maintenance plans in place for its systems.

The BMS has been developing its quality control and assurance processes during last few years to support the high level of observation automatization. Currently all data is stored in raw format in a database and quality control is done only when the data is pulled.

For the weather radar, the BMS has a service agreement with the radar provider that includes preventive maintenance twice a year.

Calibration has been an issue in the past years as the service capability in WMO Regional Calibration Centre in CIMH has deteriorated (the arrangement between BMS and the regional calibration centre is through CMO). When assessing the capabilities for the document the CIMH's main limitations were the capability to calibrating only pressure sensors, lack of reliability in service times and capabilities to only calibrate sensors from selected suppliers. Due to these circumstances the BMS has started to investigate other possibilities, e.g. utilizing calibration services from system providers or other calibration service providers. The BMS does not have a calibration laboratory or capability to calibrate the sensors independently.

3.4 Implementation of sustainable newer approaches to observations.

BMS, CIMH and UCAR (University Corporation for atmospheric research) have collaborated in a project to produce and deploy locally 3D printed small automatic surface weather stations called 3D-PAWS. The aim of the project is to give meteorological services the potential to fabricate and maintain weather stations independently and at low cost. BMS have successfully implemented the methods and currently has a network of 89 3D-PAWS stations and the goal to reach a total of 100. With the 3D-PAWS design BMS can very rapidly and inexpensively replace parts from the stations when needed. A new service that has been developed based on the network is a new rainfall accumulation product for drainage planning.

Figure 5 Dashboard view of the 3D Paws observations available for all users to view on the BMS website.

3.5. Percentage of the surface observations that depend on automatic techniques.

BMS surface observation network is fully automatic. Upper-air soundings are done manually. For the future BMS is looking to transition from manual sounding operations into fully automatic sounding operations. This is motivated by the cost of human resources needed for the manual operation, the difficulty of hiring technical staff, and the potential to assign them more value added tasks, as well as to support operations in cases when the site is not accessible due to flooding on the access road. This is further aligned with the recommendations of the World Bank report: Charting a Course for Sustainable Hydrological and Meteorological Observation Networks in Developing Countries[8].

BMS will need to look for funding an automatic sounding station for Barbados. This could also be an opportunity to help support other global initiatives, like the implementation plan for the Global Greenhouse Gas Watch (G3W), which calls for more global observations in the upper atmosphere on Greenhouse Gases. It is against that background the BMS envisions contributing to this initiative and others by adding additional or new sensors to the upper air soundings.

In this respect, it is important to understand that SIDS do not generally benefit from the level of financial and human resources available to most developed countries- Therefor, improved technologies give NMHSs like the BMS an opportunity to keep up with the many

[8] WB Charting a Course for Sustainable Hydrological and Meteorological Networks

new global initiatives. Opting for automatic solutions helps build capacity in SIDS by freeing up human resources to focus more on the growing demands of national, regional and international obligations.

Summary score, recommendations, and comments for Element 3

Summary score for the element is 4 "Comprehensive mostly automated network providing good traceable quality data fully compliant with WMO regulations and guidance". The score is close to 5 "Comprehensive and highly automated advance network including additional measurements and remote sensing platforms providing excellent data fully compliant with WMO regulations and guidance" as the BMS is operating a wide network of additional measurements and main remote sensing platforms, but the setback from reaching this is the lack of calibration services.

The BMS is doing excellent work in operating and maintaining the national observation networks and pioneering with new technologies. The level of automation is high: it is **recommended to continue this approach and to support BMS in automating its upper-air sounding operations**. This will free staff time for more value-added work and support the potential expansion of the sounding frequency. Additionally, **it is recommended to support the network extension on the marine areas with both buoy-based observation stations and surface vessels**. This will provide crucial information on the formation and evolution of hurricanes and approaching severe weather.

The support for the upper-air observation station is regulated by the MoU between the BMS and the NWS. It is recommended to renew the MoU with the NWS and to discuss the possibility of offering support when moving towards an automatic solution.

Since the BMS is a pioneer in testing new technologies and solutions in the region, it is **recommended for the BMS to share their insights and experiences in the regional forums.**

The WMO regional calibration centre is recommended to be improved. The main improvements needed are updating the calibration laboratory with capabilities to provide calibration for pressure, temperature and humidity sensors, increase the human capacity to serve the region in a reliable and timely manner and to increase the pool of supported sensor suppliers. In case the regional calibration laboratory cannot be improved **the BMS is recommended to establish connections with other calibration service providers and to increase the annual operating budget to cover the costs of annual calibrations**.

Element 4: Data and product sharing and policies

4.1. Percentage of GBON compliance – for how many prescribed surface and upper-air stations are observations exchanged internationally. Usage of regional WIGOS centres.

All GBON required stations (one surface weather and one upper-air) in Barbados are fully compliant. Both stations are exchanging observations internationally at the required frequency. The data is transferred following the WIS2.0 protocol, utilizing the WIS2box solution.

The data management system, including its database, is designed by the BMS to support automatic data collection from all different data sources. The current design does not include any quality control features for the data as it is stored. This has been selected to

ensure that no data is lost during its filtering and quality checking. Quality control and filtering can be done when pulling the data from the database.

During the stakeholder engagement several participants raised the need for an easier access to quality-controlled weather data. The BMS will filter the requested data for the stakeholders, but in case the need is for entire datasets or direct access to the data, the stakeholders need to filter it independently.

4.2. A formal policy and practice for the free and open sharing of observational data.

No formal data sharing policy exists. The BMS operates under common practice of sharing data related to hazardous situations with all necessary stakeholders. Additionally, the practice is to share all data and products for free (cost-recovery or commercial business is not possible without renewed legislation). Freely available data, forecasts and products are shared via the BMS's website. Additional services can be requested from the BMS. These are also delivered free of charge if the BMS has the time and resources to provide the requested services.

The BMS is operating under the CMO policy of data sharing inside the region through e.g. the CariCOF initiative and regional weather radar composite, which the BMS is running for the region.

4.3. Main data and products received from external sources in a national, regional and global context, such as model and satellite data.

The BMS utilizes all available model data from the region including the global models and two regional WRF models run by the service themselves. In addition to model data the BMS utilizes available satellite data. The data can be utilized via internet and via the GOES direct readout station from where the data is processed inhouse for the preferred input and images. Additionally, the BMS would like to expand the satellite receiving capabilities with a direct readout station for the polar orbiting satellites.

Summary score, recommendations, and comments for Element 4

The summary score for the element is 4 "Fully meeting GBON data sharing compliance with a data policy and practices and infrastructure in place. These support free and open sharing of data nationally and, for some products, regionally or internationally as well as the in-house use of external data", although there is still a clear lack of formal data sharing policies.

It is recommended for BMS to develop a formal data policy after the bill for meteorology has been passed. This has not been a priority for the BMS as the common practices of open and free data sharing has been seen as sufficient.

The BMS is recommended to consider providing access to quality-controlled data for stakeholders e.g. via API feeds for integration into stakeholder's systems. Such a solution would benefit key stakeholders such as the Department of Environmental Protection and Ministry of Agriculture.

Element 5: Numerical model and forecasting tool application

5.1. Model and remote sensed products form the primary source for products across the different forecasting timescales.

The BMS is utilizing a variety of model and remote sensed products in all of its forecasting and service production work. The main models the BMS is utilizing are GFS, ECMWF and

GEM and WRF models run by the BMS. The BMS is utilizing all available model runs in the highest resolution. Local weather model has a resolution of 4 km and is run 4 times a day with one model specialized for tropical modelling and the other for a high-resolution model over Barbados, both receiving the boundary condition input from GFS. Additionally, the BMS runs a local climate model every month with 2 km resolution and a SWAN based marine model 4 times a day with 100m resolution for the coast of Barbados and 1km for the Eastern Caribbean.

Additionally, the BMS is using numerical products from the regional centres, especially from the national hurricane centre and products from the regional tsunami centre. Model data is received as ready-made products; charts and texts and as gridded data and ingested to the inhouse systems and WRF models. Gridded data is utilized in the forecasting and service provision software that the BMS has built for themselves.

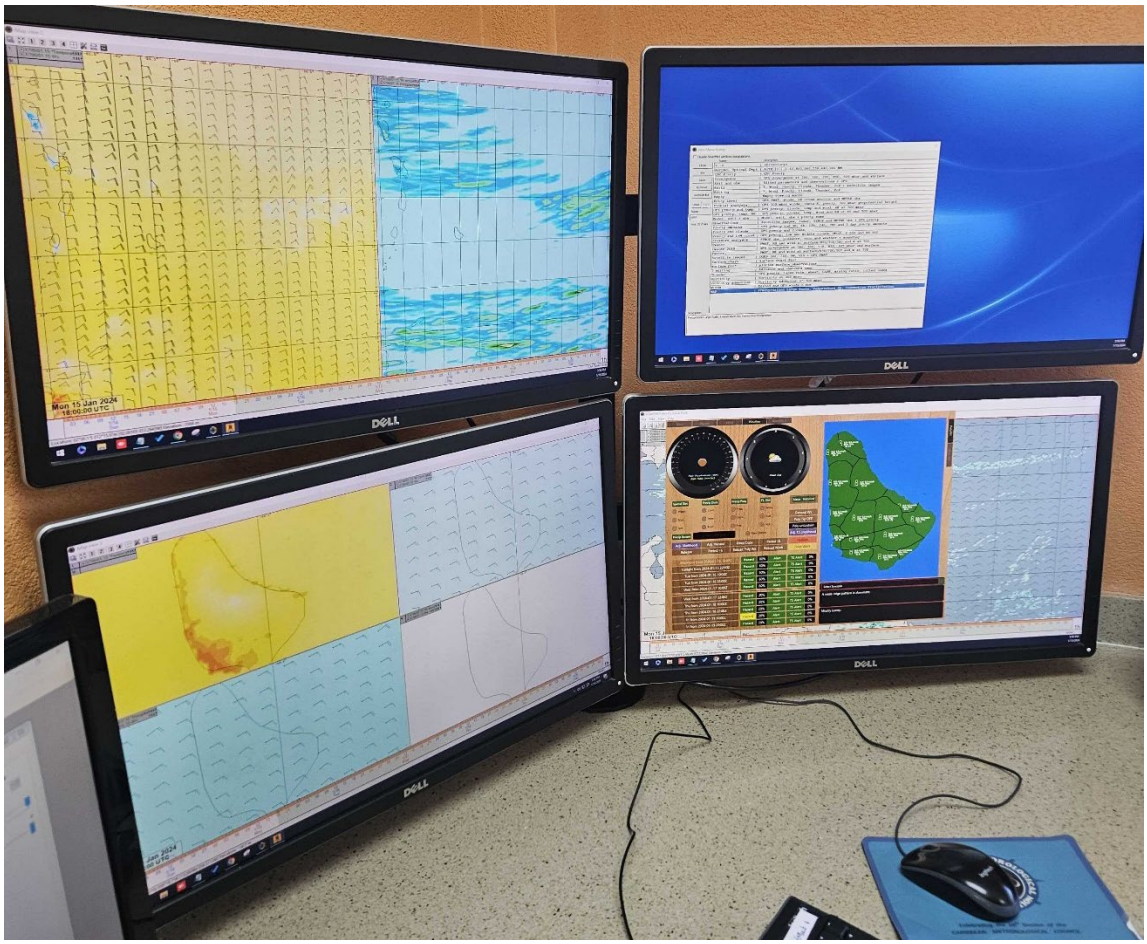


Figure 6 View on forecaster workstation setup with visualized model data. Main tool for forecasting and service creation is the Apparatus that the BMS has developed.

5.2. a) Models run internally (and sustainably), b) Data assimilation and verification performed, c) appropriateness of horizontal and vertical resolution.

The BMS is running two WRF models, one specialized for tropical modelling and the other for high-resolution modelling over Barbados, that both receive the boundary data from

GFS. Additionally, the BMS runs a Near Shore Wave Model SWAN[9]. The BMS has good operation capabilities to run the models and has been successfully doing so for a time.

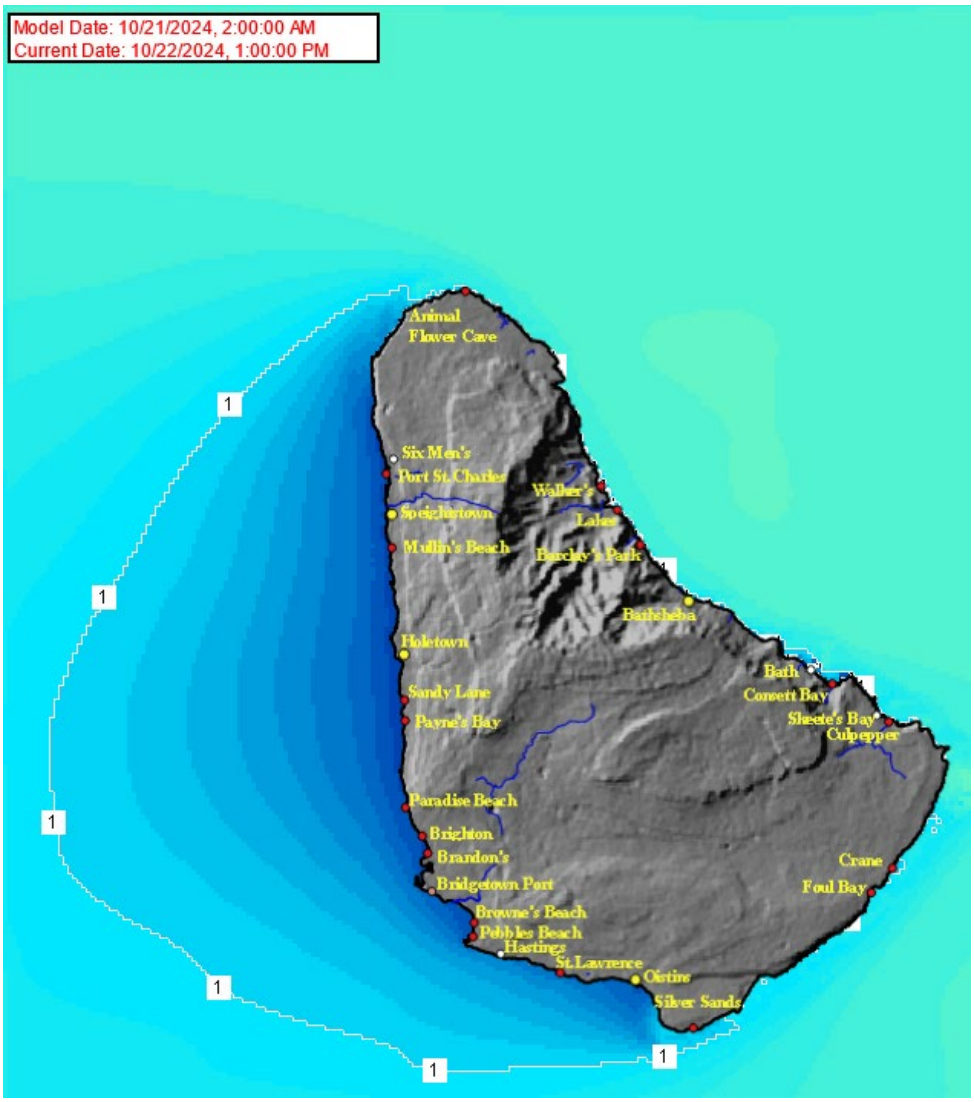


Figure 7 SWAN model run available on the BMS website.

[9] SWAN products available on the BMS website

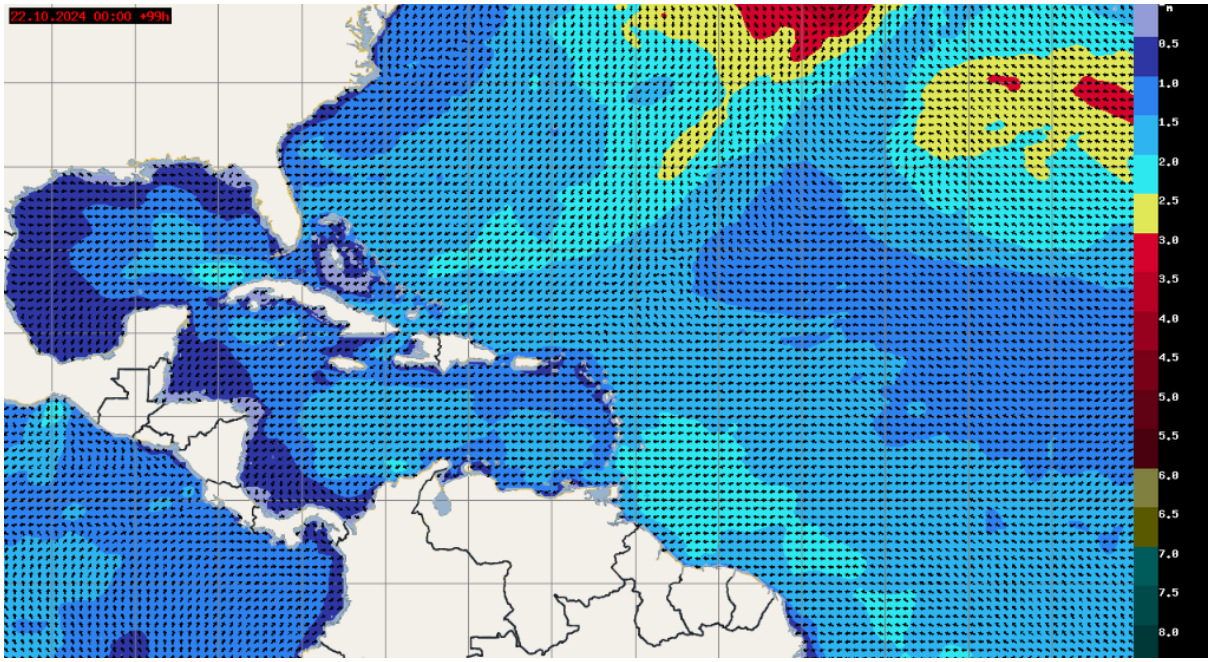


Figure 8 WW3 Swells model data (full Atlantic view) available on the BMS website.

Model data is available for forecasters on the forecaster workstation, used to automatically produce products for e.g. the BMS's webpages and is available for the public on the BMS website. The website provides GFS, WW3 and SWAN model products visualized as map-based animations. Current forecaster workstation setup includes tools for simple parameter based post-processing.

Currently there is no verification process or tools in place for model verification. The BMS is recommended to develop a system to support operational model verification and verification processes for model development.

5.3. Probabilistic forecasts produced and, if so, based on ensemble predictions.

Probabilistic forecasts are not produced. Duty forecasters may view available global probabilistic and ensemble forecasts products, but these are not ingested as such in the process. The BMS has identified some risks in utilizing ensemble forecasts in hurricane events.

Summary score, recommendations, and comments for Element 5

The summary score for the element is 4 "Digitalized model output from internal (with data assimilation) and/or external (regional) sources and remote sensed products and data used and value-added through post-processing techniques extended into longer ranges."

The BMS is recommended to develop a process and tools for model verification for the operational benefit and for model development and to start following the verification statistics.

The BMS has great capabilities in weather modelling and downscaling of larger models. **The BMS is recommended to share their experiences of developing the skills and operating the systems to their peers in the region**. Enhanced regional cooperation in the modelling field and joining forces for the operation of forecasting software systems would benefit many of the NHMSs in the region. **It is also recommended that the BMS seeks opportunities in the future to start producing ensemble and probabilistic forecast data operationally.**

Element 6: Warning and advisory services

6.1. Warning and alert service cover 24/7.

The BMS is producing and disseminating hydrometeorological warning and alert services 24/7 all year-long. Besides covering the area of Barbados and its coastal waters, the BMS provides forecasts and warnings to the islands and coastal waters of Dominica and St. Vincent and the Grenadines, as agreed in CMO Resolution 1[10].

The alerts created by the duty forecaster in the BMS needs to be approved by a member of the management team. This two-step verification process applies to all alert types. In case of national level warnings, the BMS additionally notifies the Ministry before public dissemination. An exception on these are the tsunami warnings that can be issued directly by the Tsunami Bot without human intervention once the events are within a certain range due to the severity and rapid onset time of these events.

Barbados is currently developing its national Multi-Hazard Early Warning System (MHEWS) policy. The Department of Emergency Management (DEM) is responsible for the National MHEWS actions. As of now, the working mode has been to consider most hazards separately without consideration to simultaneous and cumulative events or cascading impact. For the hydrometeorological hazards and impacts directly in the jurisdiction of the BMS the MEHWS approach has been implemented and e.g. monitoring and forecasting multiple simultaneous and cumulative hazards has been implemented. According to the DEM, the work procedures and emergency responses are working very well in hurricane events, but more local hazards e.g. flash floods and thunderstorms are not as structured and could be improved. The DEM is currently working on the development of a three-tiered national warning protocol, where level 1 alerts would be published and updated with a two hour interval, level 2 alerts with 30 min interval and level 3 alerts with a 5 min update interval. The protocol will be used in national dissemination for warnings via radio and emergency mobile application.

The BMS is well equipped to operate in tough circumstances as they have a back-up power generator, UPSs and computational back-up systems (back-up for operational server), back-up service for internet and communication (satellite phones for communication with Disaster Risk Reduction Authorities and radio), redundancy in observation stations and high-availability in the data storage system.

Warnings and alerts are disseminated to the public using the BMS mobile application, WhatsApp, social media channels (Instagram, X, Facebook and YouTube), radio and TV. Radio broadcasts can be interrupted for the warning messages. The Government Information Service provides a way to interrupt radio broadcasts for warning messaging and operates a public alert WhatsApp. Most of the population has very good access to mobile phones and internet and the coverage of the BMS's services is estimated to be excellent. Besides the BMS mobile phone application, warnings are disseminated via a CAP application and the public alert emergency application operated by the Department of Emergency Management.

[10] CMO resolution 1

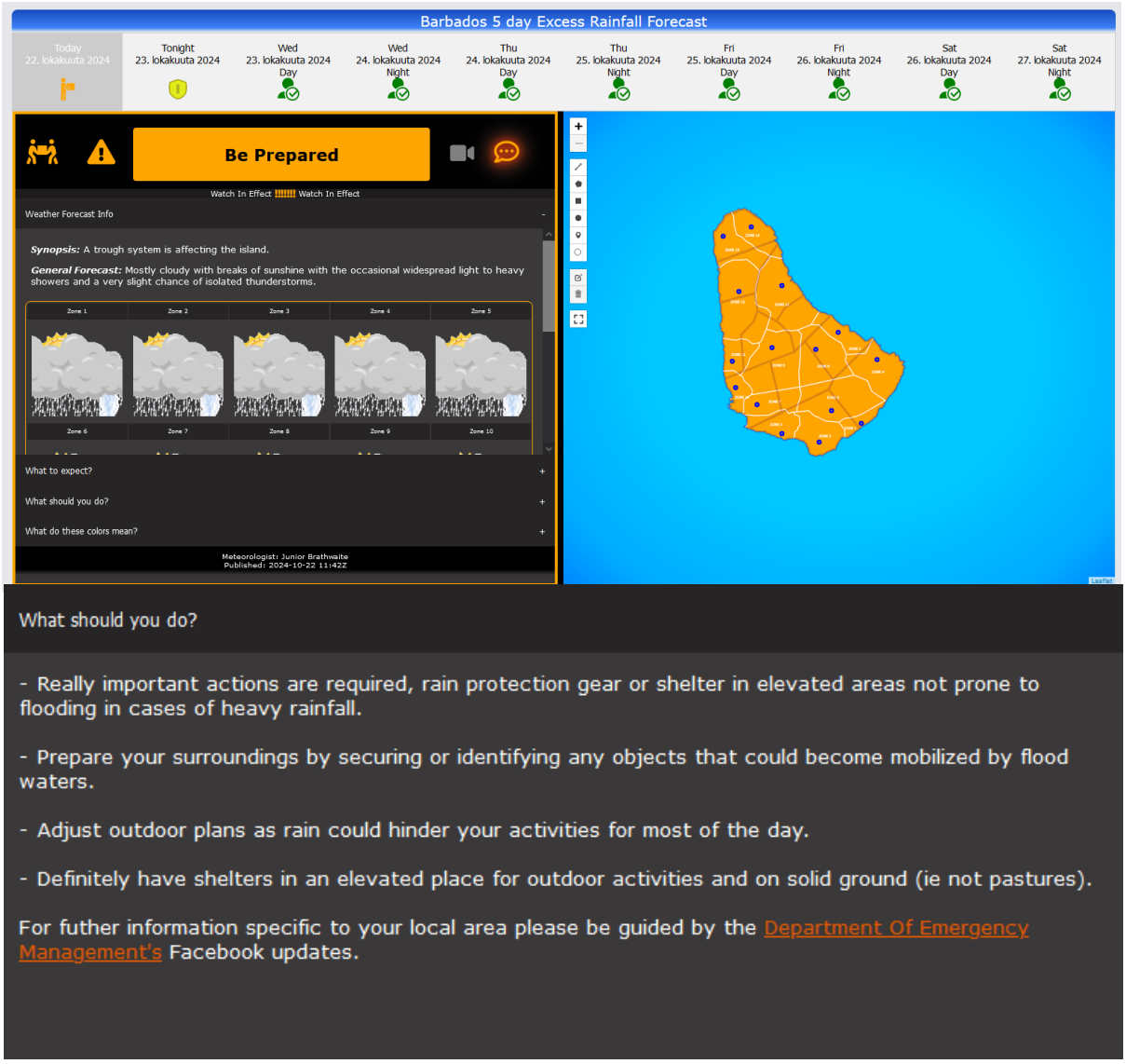


Figure 9 Example of alert messages for Excess Rainfall in Barbados including the information on how to prepare for the event for citizens. Images from the BMS website.

Barbados Meteorological Services
Civil Aviation Department Building
Charnocks, Christ Church
Telephone #: (246) 535-0021, 535-0022|Fax #: (246) 535-0029
Website: www.barbadosweather.org

A FLASH-FLOOD WATCH IS IN EFFECT FOR BARBADOS
Issued: Tue, 22 Oct 2024 07:42 AM

A flash-flood watch is now in effect for Barbados

**** Hazard Info ****

Possible Impacts
Key Message: Possible moderate to significant:- Soil erosion on bared or scarred land surfaces. Water settlements on roads and fields which may lead to commuting delays and possible isolated diversions in and out of city. Increases in water levels of existing water bodies (e.g ponds etc.). Marginally invasive excess water on roads, fields, storm drains/water canals and on property. Residents and visitors should also be aware that this alert level could elevate to red.

What you should do
-The public should follow recommendations from the department of emergency management.

The public is encouraged to monitor the BMS, DEM and GIS websites and their respective social media pages along with the local media networks for further updates.

Discussion

A trough system is currently generating pockets of moderate to heavy showers, periods of rain, thunderstorms and gusty winds. Given that 1 to 2 inches of rainfall, with isolated higher amounts is likely today, the BMS has issued a flash-flood watch.

General Information
A flash-flood watch is issued when heavy or excessive rainfall in a short period of time (generally less than 6 hours) could result in flash flooding within the watch area. It does not mean that flooding will occur, but it is possible. This Flash Flood Watch was issued at 7:35 am Tuesday 22nd October, 2024 and will be updated/terminated at 12:00 pm Tuesday 22nd October, 2024 or sooner if conditions warrant.

For more information specific to your area, please visit
https://www.barbadosweather.org/marineBarResp.php, our social media pages or call our hotline at 976-2376 or the office at 535-0022.

Prepared by Junior Brathwaite
Meteorologist (I) (Ag)
Approved by Sabu Best

Facebook
@BarbadosMeteorologicalServices

Instagram
@BarbadosMetServices

Twitter
@BarbadosMet

Figure 10 Example of a flash flood Watch bulletin. Disseminated via the BMS website.

6.2. Hydrometeorological hazards for which forecasting and warning capacity is available and whether feedback and lessons learned are included to improve warnings.

The BMS issues warnings and alerts on all major hydrometeorological hazards in the country. Such are: tsunami warnings, coastal floods, heat waves, drought events and dry spells, wind warnings, tropical cyclones with storm surges, thunderstorms and squall lines, high seas and rogue waves, intensive rain and wet spells, lightning, flash floods and haze, volcanic ash and smoke events.

The different events have defined national warning thresholds that vary depending on the phenomenon. All of the hazards have defined operating procedures that the forecasters follow. Typical warning time would be 48 hours in advance. The forecasting and warning software (inhouse design) has incorporated the thresholds in the tools for creating and issuing warnings (these can be overwritten by the forecaster if deemed necessary).

The BMS have conducted some user surveys on the benefit of produced forecasts and warnings. Latest results indicated that 70% the users found the warning information informative and useful. The Department of Emergency Management is responsible for monitoring the performance of the MHEWS, but the feedback the BMS receives is mostly ad-hoc or the BMS has to specifically ask for it.

6.3. Common alerting procedures in place based on impact-based services and scenarios taking hazard, exposure and vulnerability information into account and with registered alerting authorities.

SOPs exists for the main warning types with clearly defined actions and dissemination plan describing the actions of the BMS. SOPs cover the collaboration with the Department of Emergency Management (DEM) as well as SOPs for impact-based services. These define the roles of both actors in relation to each other and the level and type of advisories that can be disseminated to the public. The impact-based responses the BMS are issuing have been predefined and are issued together with the warning message. Further information on impacts and recommended actions will be issued by DEM.

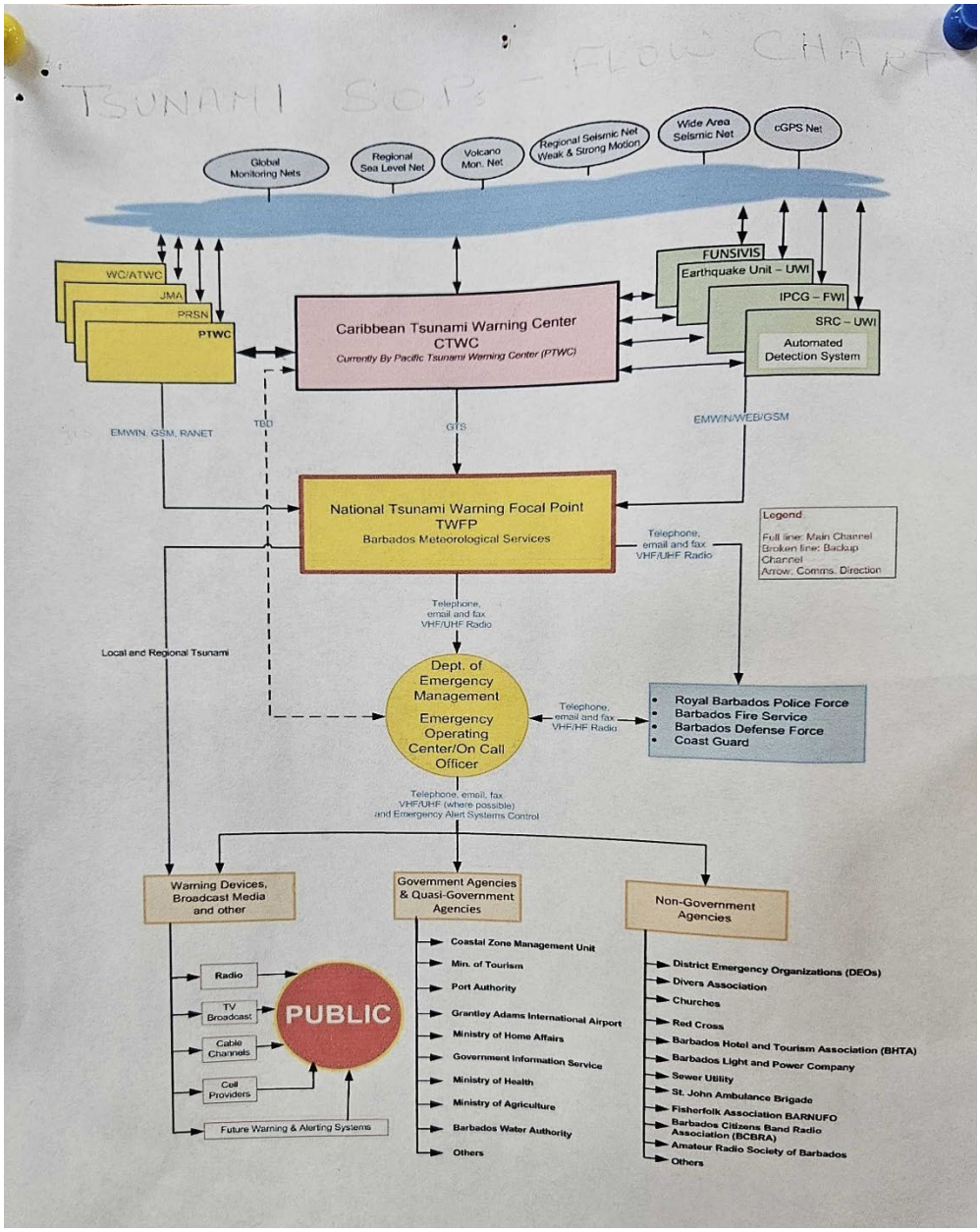


Figure 11 The SOP for tsunami warning used in the forecasting office.

Impact-based services are limited to the advisory messages attached to the warnings. The development of the division of roles and responsibilities in issuing impact forecasts is still ongoing between the BMS and DEM to find the most effective and clear way to come across to the public.

The BMS is not running any models on impact-forecasting and has not planned to expand to the area. The Ministry of Health and Wellness and the Department on Emergency Management has indicated an interest in collaborating with the BMS in developing new impact-based forecasting services.

The BMS receives data on impact information and post-disaster analytics on an ad-hoc basis and the data are not available from any centralized platform. The BMS's focus is on the core hydrometeorological data and services, and they are not currently planning to start utilizing impact information in advanced impact-based forecasting. Exposure and vulnerability maps form the Coastal Zone Management Unit were used when developing

the BMS visual products. Maps for storm surge and flooding are viewed during the forecasting process.

The BMS is delivering warnings and alerts in the CAP format, but these do not include call for action. Impact messages are distributed on the website and social media services.

Summary score, recommendations, and comments for Element 6

The summary score for the element is 4 "Weather-related warning services with strong public reach and standard operational procedures driving close partnership with relevant institutions, including disaster management agencies."

It is **recommended to promote the passing of the meteorological bill to establish a formal warning mandate for the BMS**. Parallel to this the **roles of alerting and warning including informing on the impacts should be clarified** between the different national entities. Possible solution could be signing a MoU between the BMS and DEM or to include the considerations in the Disaster Management Act. Supporting this, it is **recommended to keep developing impact-based forecasting processes and models and to define which entity will take the responsibility of such tasks**.

The BMS is supporting Dominica, Saint Vincent and the Grenadines by creating forecasts and warnings for the islands and coastal waters. The support is recommended to be continued until the countries are prepared to take over the responsibilities.

Element 7: Contribution to climate services

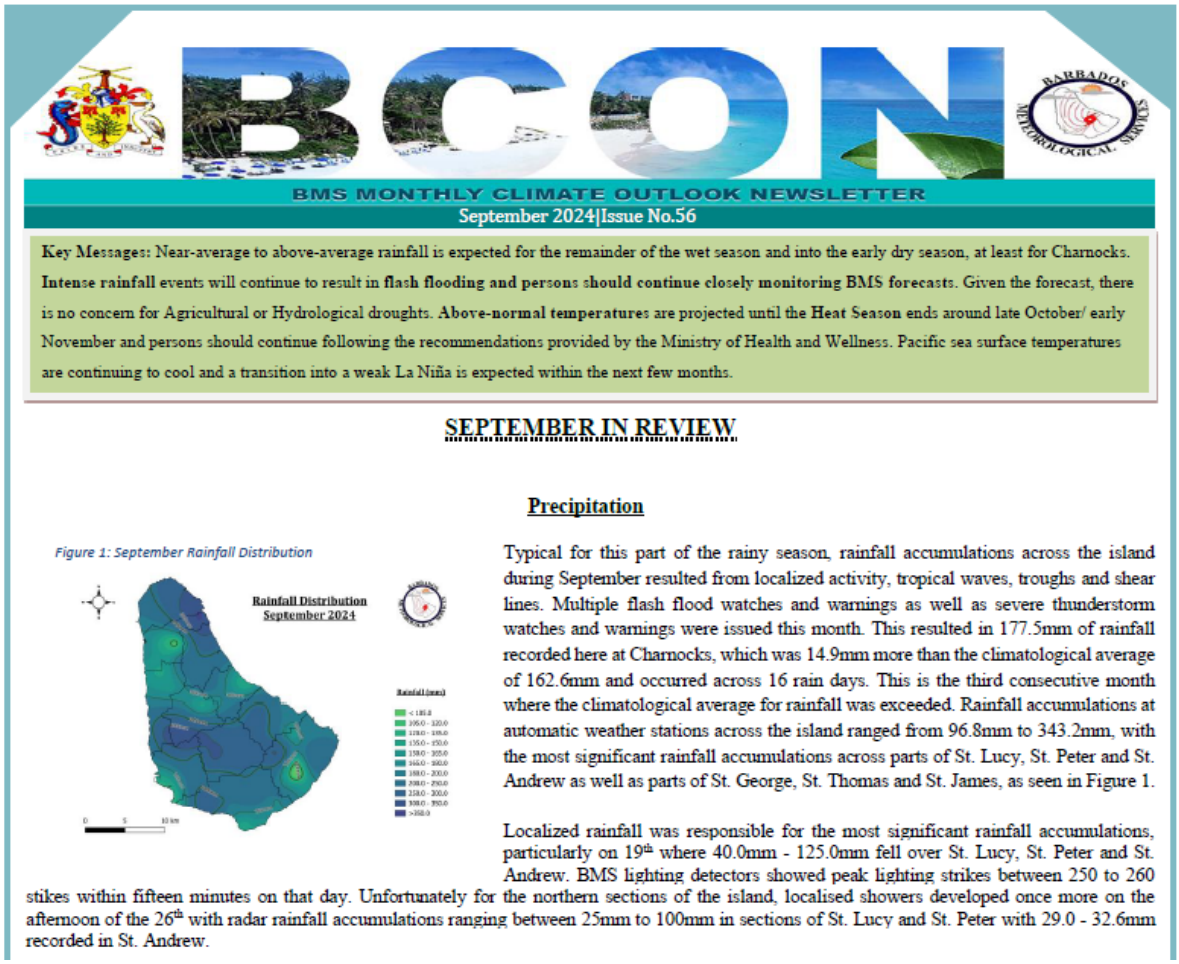
7.1. Where relevant, contribution to climate services according to the established capacity for the provision of climate services.

The BMS does not operate a separate climate database but is utilizing the observation database. The forecast and services production system Apparatus (inhouse designed and built for the BMS use) extracts the climate data when needed. As all of the data is available only in the inhouse system, no user interface for stakeholders has been developed. The BMS database stores all observation data as raw non-filtered data. Quality control and filtering is done only when the data is pulled from the database. This presents an obstacle in creating a direct user interface to the database for other stakeholders.

The BMS is downscaling the GFS climate model for its use. The regional climate model operated by CariCOF is not openly available and the BMS does not have access to the model outputs and can utilize it only as an additional tool when producing seasonal climate forecasts. Additionally, CariCOF produces climate bulletins and outlook products.

The BMS provides the following climate baseline information from the period of 1991-2020: mean wind speed, mean humidity, mean temperature, mean maximum and minimum temperature, mean and maximum rainfall, mean rain days, average maximum wind speed and mean wind direction and mean sunshine hours. Additionally, the maximum and minimum temperatures from 1968-2023 are reported. Information is available on the BMS website in a climate bulletin form.

Besides the climate baseline information, the BMS provides a monthly climate outlook that is available from their website. The outlook includes key messages, review of the monthly temperature and precipitation and a five to six-month outlook for temperature and precipitation, a five-month drought outlook with specific consideration to agricultural and hydrological drought, likely impacts of the climate for the 5-month period, considerations on situation related to ENSO, sea surface temperature and hurricane season.



BMS MONTHLY CLIMATE OUTLOOK NEWSLETTER

September 2024|Issue No.56

Key Messages: Near-average to above-average rainfall is expected for the remainder of the wet season and into the early dry season, at least for Charnocks. **Intense rainfall** events will continue to result in **flash flooding and persons should continue closely monitoring BMS forecasts.** Given the forecast, there is no concern for Agricultural or Hydrological droughts. **Above-normal temperatures** are projected until the **Heat Season** ends around late October/ early November and persons should continue following the recommendations provided by the Ministry of Health and Wellness. Pacific sea surface temperatures are continuing to cool and a transition into a weak La Niña is expected within the next few months.

SEPTEMBER IN REVIEW

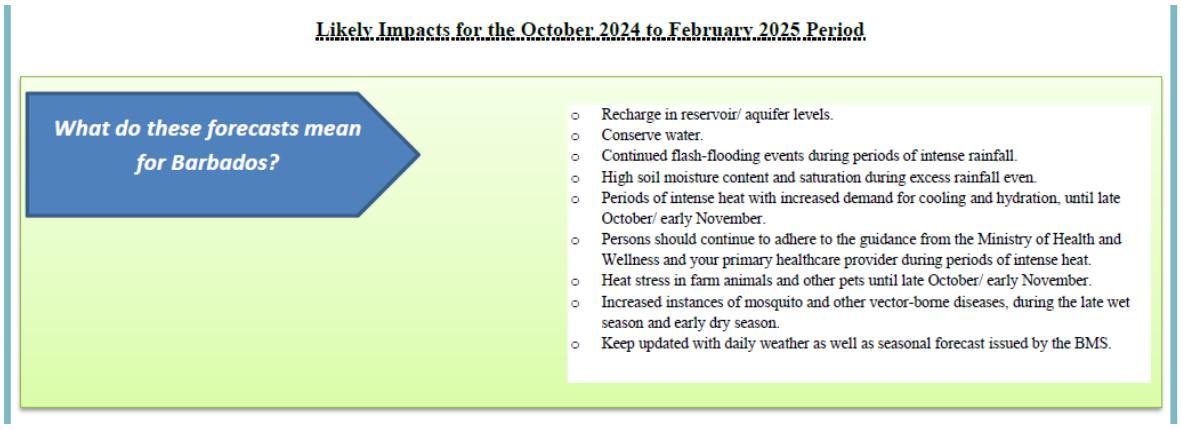
Precipitation

Figure 1: September Rainfall Distribution

Typical for this part of the rainy season, rainfall accumulations across the island during September resulted from localized activity, tropical waves, troughs and shear lines. Multiple flash flood watches and warnings as well as severe thunderstorm watches and warnings were issued this month. This resulted in 177.5mm of rainfall recorded here at Charnocks, which was 14.9mm more than the climatological average of 162.6mm and occurred across 16 rain days. This is the third consecutive month where the climatological average for rainfall was exceeded. Rainfall accumulations at automatic weather stations across the island ranged from 96.8mm to 343.2mm, with the most significant rainfall accumulations across parts of St. Lucy, St. Peter and St. Andrew as well as parts of St. George, St. Thomas and St. James, as seen in Figure 1.

Localized rainfall was responsible for the most significant rainfall accumulations, particularly on 19th where 40.0mm - 125.0mm fell over St. Lucy, St. Peter and St. Andrew. BMS lighting detectors showed peak lighting strikes between 250 to 260 stikes within fifteen minutes on that day. Unfortunately for the northern sections of the island, localised showers developed once more on the afternoon of the 26th with radar rainfall accumulations ranging between 25mm to 100mm in sections of St. Lucy and St. Peter with 29.0 - 32.6mm recorded in St. Andrew.

Figure 12 BMS monthly climate outlook available the BMS website.



Likely Impacts for the October 2024 to February 2025 Period

What do these forecasts mean for Barbados?

- Recharge in reservoir/ aquifer levels.
- Conserve water.
- Continued flash-flooding events during periods of intense rainfall.
- High soil moisture content and saturation during excess rainfall even.
- Periods of intense heat with increased demand for cooling and hydration, until late October/ early November.
- Persons should continue to adhere to the guidance from the Ministry of Health and Wellness and your primary healthcare provider during periods of intense heat.
- Heat stress in farm animals and other pets until late October/ early November.
- Increased instances of mosquito and other vector-borne diseases, during the late wet season and early dry season.
- Keep updated with daily weather as well as seasonal forecast issued by the BMS.

Figure 13 Impacts of the climate for the next 5-month period available from the BMS website.

The BMS produces climate services for the water and agriculture sector in Barbados. Both the Ministry of Agriculture and the Department of Environmental Protection expressed an interest in receiving easier access to the quality-controlled data, both weather and climate in the BMS database during the stakeholder engagement.

The BMS have experience of co-production and tailoring of climate services with the Water Authorities on the topic of aquafers.

Summary score, recommendations, and comments for Element 7

The summary score for the element is 3 "Essential capacity for climate service provision".

The BMS is recommended to consider developing a user interface for accessing the climate data. Accessible data needs to be quality controlled.

The CariCOF is recommended to provide the regional climate model data for the members.

Element 8: Contribution to hydrology

8.1. Where relevant, standard products such as quantitative precipitation estimation and forecasts are produced on a routine basis according to the requirements of the hydrological community.

The BMS routinely share precipitation data (data from precipitation sensors and weather radar) to the Water Authority. The Water Authority in Barbados focuses primarily on provision of potable water, wastewater treatment and the protection of water resources, mainly focusing on wells and aquafers. The Water Authority's mandate is governed by a formal act. Currently there is no hydrological modelling done in Barbados. The BMS is assisting the Water Authority to create hydrological watches and alerts. This is based on climatological modelling and precipitation events from the BMS, with the qualitative assessment input from water levels from aquafers and wells provided by the Water Authority. The BMS issues the products on behalf of the Water Authority.

All main hydrological products the BMS is producing are detailed in the sections of this report discussing climate services (see Element 7) and the warning services (see Element 6).

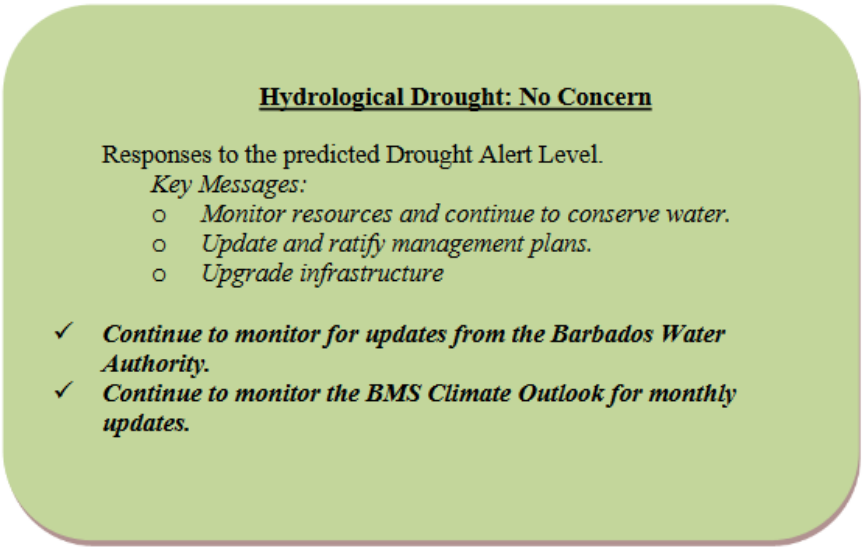


Figure 14 Information on the hydrological drought provided by the BMS available form their website.

8.2. SOPs in place to formalize the relation between Met Service and Hydrology Agency, showing evidence that the whole value chain is addressed.

No SOPs are in place between the organizations. Currently the relationship and communication including data sharing is working well, but both organizations would benefit from SOPs that address the whole value chain.

8.3. Data sharing agreements (between local and national agencies, and across international borders as required) on hydrological data in place or under development.

No agreements the BMS would know of.

8.4 Joint projects/initiatives with hydrological community designed to build hydrometeorological cooperation.

None.

Summary score, recommendations, and comments for Element 8

The summary score for the element is 3 "There is a moderately well-functioning relationship between the meteorological, hydrological and water resources communities but considerable room for formalizing the relationship and SOPs".

The informal relationship between the entities is working very well. **It is recommended to formalize the relationship between BMS and Water Department and to establish SOPs and mechanisms for effective product co-development**.

Element 9: Product dissemination and outreach

9.1. Channels used for user-centred communication and ability to support those channels (for example, does the NMHS operate its own television, video or audio production facilities? Does it effectively use cutting-edge techniques?).

The BMS operates a user-friendly website[11] and weather app (BMS Insight) that are the main dissemination channels to the public and include the widest portfolio of products. The main products on the website are: warnings (including short impact messages), 5 day forecasts (rainfall, wind, marine, dust and thunderstorm forecasts separately), observations (weather radar, satellite) and model (rainfall, winds, temperature) information on map view over Barbados and the Caribbean region, bulletins, aviation products and media products. Also, warning products for Dominica and St. Vincent and the Grenadines are available from the website.

The majority of the population have access to smartphones, internet, radio or TV and receive warning information through multiple channels. Warning dissemination is discussed in more detail in Element 6.

[11] BMS website

Figure 15 View of BMS Insight weather app.

The BMS is active on all major social media platforms: Facebook (28 thousand followers), X (5900 followers), Instagram (31.7 thousand followers) and YouTube (2,63 thousand subscribers) to disseminate warning and forecasting information and other information to improve public awareness and engagement in weather and climate related topics. The information is presented in picture and video format to increase its attractiveness in social media feeds. To create the content the BMS is using a greenscreen and inhouse video editing.

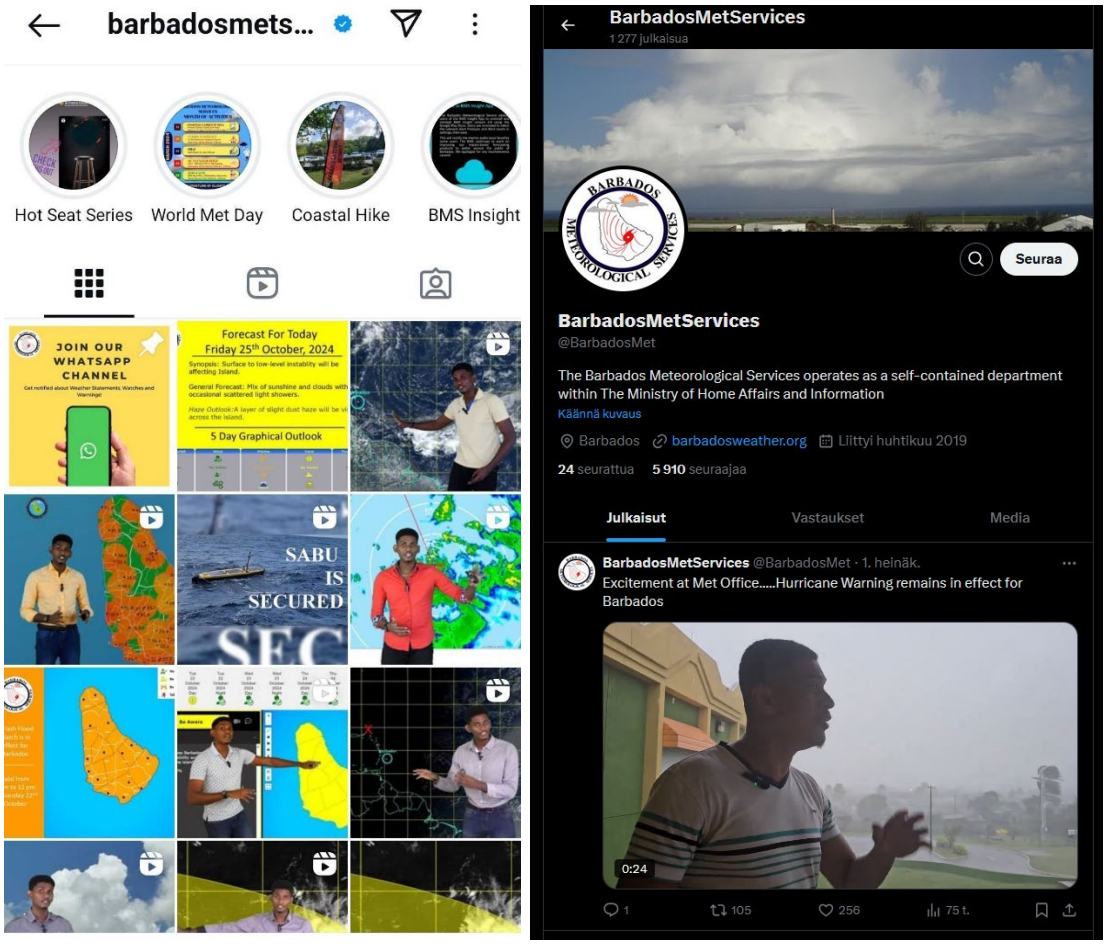


Figure 16 The Instagram profile (left) and X profile (right) of the BMS.

Limited email chains are used to alert and inform emergency management stakeholders of upcoming potential events. The BMS is not utilizing SMS blasts to push messages to the public as this has been estimated as too expensive compared to the effectiveness.

The BMS products appear widely on radio and printed media. TV is mainly used for warning purposes of significant events.

Dissemination of warning are done at national and regional scale and discussions to extend the dissemination to include Saint Vincent and Grenadines is ongoing.

The BMS participates in media stakeholder events when relevant. Such are e.g. media stakeholder workshops focusing on alert messaging organized by the Government Information Service.

9.2. Education and awareness initiatives in place.

The BMS is actively producing educational videos on its social media channels to increase public awareness and knowledge. Especially younger audience is targeted with these actions.

The BMS website includes information leaflets to improve user awareness on impact-based forecasting, water level sensors, meteorologist leaflet, met assistant leaflet, 3D Paws initiative and the Atlantic hurricane names.

The BMS also hosts school visits and visiting days to the forecasting office.

9.3. Special measures in place to reach marginalized communities and indigenous people.

The Department of Emergency Management has in their protocol to reach out and assist people with disabilities at community level in the case of an emergency.

The BMS has considered the inclusivity of its products for hearing and visually impaired by utilizing visual aids for eased understanding of its messages, and by enabling the possibility for messages to be read out loud from the mobile app.

Summary score, recommendations, and comments for Element 9

The summary score for the element is 4 "A large fraction of the population is reached using various communication techniques and platforms, in collaboration with partners, and a user-friendly and informative website and apps. Outreach of education activities occur regularly".

To achieve the level 5 **the BMS is recommended to develop an awareness and communication strategy**.

Element 10: Use and national value of products and services

10.1. Formalized platform to engage with users to co-design improved services.

No formalized platform or engagement with users have been developed or used. Key stakeholder engagement was piloted in 2023 and establishing regular (annual) interactions in this field are planned as a development step. Initial actions have included harvesting user experiences and comments on existing products, as well as ideas and requests for future services.

The BMS is actively working with many stakeholders such as the Civil Aviation Authority, Department of Emergency Management, Barbados Water Authority, Government Information Service, Department of Environmental Protection, National Conservation Commission, Ministry of Health and Wellness, Barbados Fisheries Division, Barbados Hotel and Tourism Association, Ministry of Agriculture, Coastal Zone Management Unit and Barbados Defence Force. Most stakeholder engagement has been informal and ad-hoc, but in recent years the BMS has initiated a more structured approach, with the aim to host more frequent engagement to harvest input and to co-design services.

During the stakeholder engagement workshop for the CHD work, stakeholders expressed interest for more frequent engagement as well as sector specific engagement. The BMS is interested to facilitate this as long as staff restrictions and resources are met. All participated stakeholders expressed the benefit of the services the BMS provides currently to them and the society.

For multi hazard early warning services and disaster risk reduction activities, the BMS is participating in the National Operational Emergency Centre and its subcommittees.

The BMS is not collecting feedback from the public users of its services.

10.2. Independent user satisfaction surveys are conducted, and the results used to inform service improvement.

The BMS has conducted a satisfactory survey on the new Impact Based messages provided on the website and utilized the input to develop the messages.

During 2023, the BMS conducted a survey specifically focused for the marine sector service users to harvest input and improve the communication.

10.3. Quality management processes that satisfy key user needs and support continuous improvement.

BMS is implementing ISO9001:2015 quality management system for aviation services but has not yet been certified. The BMS is currently working to achieve the certification.

Summary score, recommendations, and comments for Element 10

The summary score for the element is 3 "Services development draws on regular dialogue with major stakeholders.".

The BMS has started engaging in a more active stakeholder management with sector specific events and plan for annual engagement. The stakeholders appreciate the engagement and **the BMS is recommended to continue on this path and to allocate staff time for the joint development of products with key users.**

The BMS is recommended to harvest input from also the public by establishing feedback mechanisms, e.g. via their website.

Annex 1 Consultations (including experts and stakeholder consultations)

The CHD was developed as part of the SOFF Readiness Phase. During this time FMI made two missions to Barbados. The following stakeholders were consulted during the work:

- Staff and Director of BMS
- The following stakeholders participated in CHD workshop: National Conservation Commission, Barbados Hotel and Tourism Association, Environmental Protection Department, Barbados Civil Aviation Authority, Barbados Fisheries Division, Barbados Ministry of Health and Wellness, The Ministry of Agriculture, Governmental Information Service and the Department of Emergency Management.
- Consultation of CIMH on the regional training and calibration capabilities.
- National Oceanic and Atmospheric Administration – Upper Air Program Manager.

Annex 2 Urgent needs reported

Main gaps identified in the Country Hydromet Diagnostics are:

- *Governance and institutional setting:* Currently there is no legislation to stipulate the mandate and responsibilities of the BMS. A draft bill has been developed and submitted for Ministry review.
- *Effective partnerships to improve service delivery*: The BMS is recommended to update critical MoUs with existing partners (CAA) and to assess the need for new MoUs with some of the key stakeholders (EPD, Water Department. The BMS is recommended to coordinate the division of air quality monitoring and forecasting duties with EPD. The BMS has initiated a more systematic approach to stakeholder engagement including more frequent engagement and is recommended to proceed with the plans and to include also impact-based forecasting more closely to the discussions.
- *Observational infrastructure*: The BMS is recommended to continue with the automatization of the network, including the sounding station and with the expansion of the network to the marine areas. Funding from e.g. SOFF or regional project initiatives are recommended to be channelled to support the initiatives. To improve the gaps in the calibration services it is recommended to support the strengthening of the WMO regional calibration centre or to establish new service agreements with other calibration laboratories for the BMS.
- *Data and Product sharing policies:* The BMS is recommended to develop a data policy after the meteorological bill has been passed. The BMS is recommended to provide access to their data archive with quality-controlled data for key stakeholders and to support the access with e.g. API feeds.
- *Numerical model and forecasting tool application:* The BMS is very advanced in its modelling capabilities, and it is recommended to share these experiences with the region. Additionally, the BMS is recommended to develop a process and tools for model verification.
- *Warning and advisory services:* It is recommended to pass the legislation to grand the formal warning mandate to the BMS. Parallel to this the role of alerting and warning including dissemination of information on the impact should be clarified between different national entities.
- *Contribution to climate services:* The BMS is recommended to consider developing a user interface for accessing quality-controlled climate data for stakeholders.
- *Contribution to hydrology:* it is recommended to formalize the relationship between the BMS and the Water Department and to establish SOPs and mechanisms for effective product co-development.
- *Use and national value of products and services*: the BMS is recommended to establish feedback mechanisms on e.g. their website for collection of user input.

Additional recommendations are described in respective chapters of this report.

Annex 3 Information supplied through WMO

Peer adviser acknowledges the material and templates provided by SOFF throughout the Readiness phase.

Annex 4 List of materials used

In addition to WMO guides, the following material was utilized:

- The BMS's webpage
- Webpage of Department of Emergency Management
- Material shared by the BMS about their organization and plans to the peer advisor.