6 February 2024

GBON National Contribution Plan of Bhutan

Systematic Observations Financing Facility

Weather and climate data for resilience

GBON National Contribution Plan

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Abbreviations

ADB	Asian Development Bank
AMSP	Aviation Meteorological Services Provider
AWS	Automatic Weather Station
BCWC	BIMSTEC Centre for Weather and Climate
BIMSTEC	Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation
CAP	Common Alerting Protocol
CREWS	Climate Risk and Early Warning Systems
CWC	Central Water Commission
DRR	Disaster Risk Reduction
ECMWF	European Centre for Medium-Range Weather Forecast
EWS4ALL	Early Warnings For All -initiative
EWS	Early Warning Services
FAO	Food and Agriculture Organization of the United Nations
FMI	Finnish Meteorological Institute
GBON	Global Basic Observation Network
GCF	Green Climate Fund
GLOF	Glacial lake outburst floods
GOI	Government of India
IBF	Impact Based Forecasting
ICAO	International Civil Aviation Organization
ICIMOD	International Centre for Integrated Mountain Development
IMD	Indian Meteorological Department
IMD	Indian Meteorological Department
IPCC	Intergovernmental Panel on Climate Change
JICA	Japan International Cooperation Agency
JMA	Japan Meteorological Agency
KMA	Korea Meteorological Administration
LAM	Limited Area Model

LG	Local Government (Dzonka/district in Bhutan)
NAPA	National Adaptation Programme of Action
NCHM	National Center for Hydrology and Meteorology of Bhutan
NCOF	National Climate Outlook Forum
NFCS	National Framework for Climate Services
NGO	Non-Governmental Organization
NHMS	National Hydrological and Meteorological Service
NMS	National Meteorological Service
NORAD	Norwegian Agency for Development Cooperation
NWP	Numerical Weather Prediction
QA/QC	Quality Assurance/Quality Control
QMS	Quality Management System
RA-II	WMO Regional Association II
RIMES	Regional Integrated Multi-Hazard Early-Warning System
SAHF	South Asian Hydromet Forum
SOFF	Systematic Observation Financing Facility
SOP	Standard Operation Procedure
SWFP	Severe Weather Forecasting Programme
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
USAID	United States Agency for International Development
WB	World Bank
WMO	World Meteorological Organization
WRF	Weather Research Forecast model

Module 1. National Target toward GBON compliance

Table1. GBON National Contribution Target

Type of station	Baseline (Results of the GBON National Gap Analysis)				GBON National Contribution Target	
	Target (# of stations)[1]	GBON-compliant stations (#)	Gap		To improve	New
			New	To improve		
Surface	1	0		1	1	
Upper-air	1	0	1			1
Marine	**Not applicable**					

Table 1 presents GBON National Contribution Target with standard density. However, according to the GBON Global Gap Analysis[2], a GBON high density of surface stations would suggest 4 stations to Bhutan.

In the National GBON Gap Analysis, feasibility of 1 existing AWS (Tsampa, WIGOS ID: 0-20000-0-44517) reporting to GTS (Global Telecommunication System) was studied. Tsampa was provided by JICA-project, and it **differs technically and operationally from rest of the NCHM AWS network**. The most importantly, the **location of Tsampa is very challenging**. The station is located 3800 m above mean sea level in a remote area with two days long journey on foot. Station may not be accessible during wintertime at all. This can lead to significant temporal gaps in observations for international distribution, Additionally, data from Tsampa is delivered only as SYNOP-messages to GTS-network, and therefore, it fails to fulfil GBON requirement for hourly distribution. Currently, reporting is made only to GTS, not WIS2.0. Given these facts and challenges in the continuous, reliable operation of the station and hourly data distribution, Tsampa is not, with existing technical setup, suitable as the first Bhutanese GBON-station.

NCHM is receiving support from JICA to share data from 5 existing stations providing SYNOP-messages to the GTS network. However, JICA-project does not include WIS 2.0 component and there is no financial support for the operation nor maintenance of stations. Geographically these stations are not located in central Bhutan, which however, does not lessen the value of available observational information. Technically these stations are like most of the network.

[1] For SIDS, for the WMO GBON Global Gap Analysis in January 2022, the EEZ area has been added to the total surface area which is the basis for the target number of stations. The standard density requirements for SIDS have been calculated with 500 km for surface stations and 1000 km for upper-air stations.

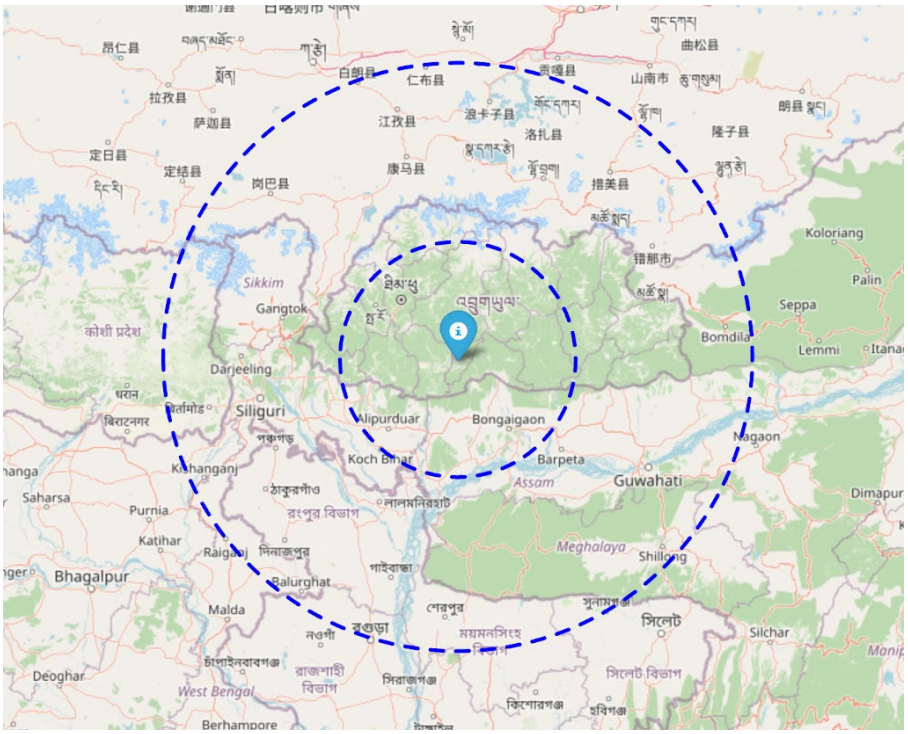
[2] https://www.un-soff.org/wp-content/uploads/2023/11/INF-6.2-WMO-GBON-Baseline-2023-1.pdf

As the GTS-network is still used extensively, these stations will be useful in sharing observations from Bhutan. Later, data from these stations can be shared via WIS 2.0 interface implemented in SOFF-project. Therefore, **there is no practical overlap with SOFF and supporting the maintenance and operations of these stations can be considered as easy fix in terms of data sharing.**

As a **c**onclusion, based on discussions and feedback as well as above-mentioned information **1 GBON compliant automatic surface observation station is proposed to Bhutan (manual station upgraded to AWS)**. In addition of improving GBON network, station would support the operations of sounding station. By setting up WIS 2.0 interface, there is potential to share many more existing stations globally (including above mentioned "SYNOP"-stations). With proposed technical approach, also data from manual stations could be shared, even though they do not fulfil the temporal resolution requirement of GBON. **Main concern of NCHM regarding the sharing the observations of the existing stations is their operation and maintenance.** Therefore, financial support in station maintenance, setting up data flow and extra sets of spare parts are proposed as an easy fix.

Proposed SOFF investment in automatic surface observation station would go to Tsirang Damphu in central Bhutan, at the same place as proposed upper-air station. Collocating upper air and surface observation infrastructures would bring the necessary synergies in terms of operation and maintenance, as well making a sounding requires surface observations as a base line information. Currently there is only manual surface observation station at the proposed site which does not meet the temporal requirement of GBON.

Picture 1 Map of proposed surface and upper-air station to Tsirang Damphu. Inner circle shows AWS with 200 km diameter (100 km radius) and the outer circle upper air station with 500 km diameter (250 radius).



Module 2. GBON Business Model and Institutional Development

The operation of NCHM relies on public sector partnerships in terms of collaboration, mutual support, and service provision throughout the value chain of making observation at the station and proving quality assured information at the end user interface (Section 2.1). In terms of financing, however, the operation and maintenance of observation infrastructure rely on public-private model (Section 2.3).

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

The National Centre for Hydrology and Meteorology of Bhutan (NCHM) is an autonomous government agency with **the mandate for making observations and providing information and services** of Meteorology, Hydrology, and Cryosphere including hydrometeorological early warning services.

Meteorological observations operated earlier by other governmental agencies (e.g., Department of Agriculture, Department of Civil Aviation) have been transferred to the NCHM to avoid duplication of the work and effective utilization of resources, to harmonize observation networks, and to improve the quality of the measurements. **Thus, NCHM is the sole operator of the GBON relevant weather observation networks.**

There are no hydrometeorological observation networks relevant to GBON outside of NCHM in Bhutan. Some weather stations are operated by line agencies, universities, and research institutes for research purposes. These are stand-alone systems, often temporary installations for special purpose and usually without real-time data transfer. The location or equipment of the stations may not follow standards nor the requirements of GBON. However, NCHM supports the installation and operation of these stations, and data is shared with NCHM from relevant stations.

NCHM is cooperating continuously with weather dependent governmental agencies in daily operations and in separate projects. For example, NCHM is currently improving weather forecasts for the agricultural sector under the Green Climate Fund project of the Ministry of Agriculture & Livestock. In addition, NCHM cooperates with private or state-owned corporations, such as Bhutan Broadcasting Service (project with JICA) for the weather forecast dissemination.

Related to ICT-activities, one of the key partners is a government agency for overseeing and supporting ICT related developments (GovTech, IT-centre).

NCHM has signed Memorandum of Understanding (MoU) with the College of Science and Technology (CST, Phuentsholing), the College of Natural Resources (CNR, Lobesa), and the Sherubtse College (Kanglung) under the Royal University of Bhutan to foster partnership and collaboration in the areas of long-term climate monitoring and research.

NCHM is recommended to seek further collaboration partnerships from both public and private sectors in areas where its own capacity requires further building or there is a lack of resources. Such areas include at least a maintenance of IT infrastructure, as well as technical and scientific capacity in calibration activities.

2.2. Assessment of potential GBON sub-regional collaboration

Bhutan/NCHM is a member of several regional organizations cooperating in the field of hydrometeorology, such as:

- International Centre for Integrated Mountain Development (ICIMOD)
- Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES)
- Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC).

  Bhutan is a member country of the BIMSTEC and NCHM is a member of the BIMSTEC Centre for Weather and Climate (BCWC). NCHM closely works with RIMES, ICIMOD and other NMHS in South Asia. Many of these organizations are focused for the research, general co-operation, and data exchange. SOFF/GBON would enhance data exchange capacity in the future.

  Increased number of good quality observations supports both regional and global scale weather modelling which is particularly important for the downstream riparian states. Since all originating rivers from Bhutan flow to India, Bhutan also exchanges hydro-meteorological and flood data with the Indian States of Assam and West Bengal for forecasting and warning. Also sharing of data amongst the regional partners supports in providing early warning services.

Regarding the GBON requirements, there are only a few surface observation stations in the Himalayan region and none fully working close to Bhutanese borders. Given the size of the GBON network in Bhutan, most of the optimization will take place in neighbouring countries if they enhance their surface observation networks compliant with GBON. Proposed enhancements in GBON compliant surface observation network in Nepal through SOFF project have been closely monitored while planning the Bhutanese GBON network to ensure the best possible areal coverage in the region.

NCHM has MoU with the RIMES and currently, they do technical cooperation with the South Asian Hydromet Forum (SAHF) promoted by the World Bank. RIMES focuses on regional collaboration and technical support for the development of a flood Decision Support System (FDSS), verification of numerical weather models, and capacity building.

Most of the co-operation is carried out on a need basis and apart from MoU with RIMES. In general, there are quite a few MoUs defining officially the co-operation between parties.

Four main topics for collaboration with Himalayan region countries were identified: 1) subregional distribution of GBON compliant observation stations, 2) radio sounding, 3) calibration laboratory, and 4) international observational data distribution. The amount of GBON compliant stations existing and required in the Himalayan region is small. It is expected that the new GBON station would fill the global data gap and contribute for understanding current weather and support regional and global modelling and forecasting.

Data sharing and research

NHMC in Bhutan has traditions in exchanging hydrometeorological observation data in international context. SOFF project is foreseen to strengthen collaboration through enhancing the capacity of organization and its staff, as well as the quality of observations and data exchange platform and methods (e.g. WIS 2.0). Due to its topography, Bhutan has quite dense surface weather observation network, including both manual and automatic stations, providing observations from Himalayan mountainous area at several different heights. Although majority of data is produced by non-GBON stations, it remains as valuable information within regional co-operation in the fields of operational service provision and research. (RIMES, BIMSTEC, BIMSTEC Centre for Weather and Climate (BCWC) (research centre) etc).

Station networks

GBON requirements in Bhutan are fulfilled with one AWS and one upper air station. Their location has been chosen to provide optimal coverage for Bhutan, while taking daily operations into account as well.

In general, the spatial coverage of GBON (Global Basic Observing Network) stations has been optimised between Bhutan and Nepal in SOFF readiness phase project. The GBON compliant networks in India and China has been considered in National Gap Analysis. There are WIGOS stations near Bhutan borders, however, their data availability does not meet GBON requirements and will not be considered further here.

One issue to be considered, is the size and topography of Bhutan, which sets some limitations for optimization of the GBON surface observation network. If better regional coverage in GBON perspective is needed, focus should be in neighbouring countries. The surface observation station network of Bhutan provides valuable information from high altitudes and inhomogeneous topography, even the density of network exceeds GBON requirement for horizontal resolution. This is addressed through proposing maintenance support in the form of spare parts/sensors to 5 stations sharing SYNOP-messages internationally through technical and capacity support from JICA-project.

SOFF will be about to facilitate an investment of the very first radio sounding system in Bhutan. This means that sharing experience and expertise (including benchmarking operation and maintenance practices) with the sister organisations in the region will be critically important

and recommended when implementing this Plan. The closest country for the benchmarking would be Nepal.

Technical co-operation

On the technical side, both Bhutan and Nepal are using Microstep stations. Purchases of equipment must be implemented nationally but there are potential for synergies in network operation, training, and maintenance. The same applies to soundings if both countries happen to purchase sounding stations from the same supplier.

Calibration laboratory must be operational and providing high-quality, tracible services. NCHM is recommended to regularly evaluate cooperation possibilities in calibration services. When writing this report, calibration laboratory in Nepal is not in operational condition. NCHM has a small calibration laboratory with support of Japanese government. Calibration laboratory has very limited facilities and it allows calibrating temperature probes. Pressure chamber exists, but it is not working currently. Therefore, upgrade of current calibration laboratory with new facilities in NCHM headquarters (to be relocated 2025-2027) is recommended. When **operational, NCHM can offer calibration services to other actors in Bhutan and neighbouring countries.**

Indian IMD was one potential provider for calibration services. **There has been formerly co-operation with IMD regarding calibration** of the manual equipment and some aviation equipment. **However, challenges encountered in transportation of equipment and customs procedures shows that this is not sustainable nor cost-efficient solution, especially considering the number of automatic stations in NCHM** (more than 200 automatic stations including hydrological stations).

Regional instrument centres for RA-II are located at Beijing (China) and Tsukuba (Japan). Co-operation with these centers is important especially for maintaining the traceability for the NCHM calibration laboratory. Support for annual or semi-annual calibration of references is required.

Collaboration in general with several countries exists through SAARC/ BIMSTEC/ BCWC and other mechanisms like RIMES/ ICIMOD etc. Co-operation possibilities are continuously discussed but are often difficult to institutionalize.

Recommendation NCHM to set up improved national calibration laboratory for GBON parameters with SOFF support.

Recommendation Continue to evaluate and seek synergies between organizations in the Himalayan and South-East regions where feasible

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

SOFF Operational Manual defines 4 possible basic business models for operating and maintaining observation infrastructure:

1. **Fully public:** Fully State/NMHS owned and operated GBON infrastructure
2. **Public-Private:** State/NMHS owned and Private Partner operated
3. **Public-Private:** State/NMHS and Private Partner owned
4. **Fully Private:** Owned and operated by a private partner contracted by the State/NMHS

There are **very few, if any, feasible private sector partners in the fields of operating and maintaining hydrometeorological observation infrastructure in Bhutan**. Currently, the only feasible operation model is the **fully public**. In addition to governmental budget funding, NCHM has received possibility for cost-recovery mechanism and commercial operations. Cost-recovery and commercial operations were enabled by acceptance of Hydromet policy late in 2023. In this transition period, possibilities following the allowance of cost-recovery mechanism remain to be evaluated and impact in the budget of operating and maintaining observation infrastructure to be measured. The most potential end user sector is civil aviation which involves private aviation company(ies).

The financial status of the NCHM to carry out GBON compliant operations consists of Governmental budget funding, international development collaboration projects, and financial support from UNEP (IE) for the station maintenance (including financial support for maintenance missions). **Thus, in terms of financing, the operation and maintenance of observation infrastructure rely on public-private model.** To systematically justify budget and project funding allocations for maintenance, and replacing sensors at stations, NCMH **needs to develop a lifecycle plan for AWS and radiosounding station and ICT infrastructure**. The lifecycle plan will support sufficient financing for timely maintenance.

Majority of the stations outside of GBON are maintained through annual budget from the Government funding. Stations under the Flood Warning Section of the Government of India (GoI) are maintained through GoI program. However, gaps exist, and budget does not adequately cover the maintenance of the entire network nor investment in spare sensors. Other issues include a lack of capacity, large network, communication, in- accessibility of stations, among others. The SOFF investment phase funding request aims at addressing some of these challenges relative to GBON compliant station and 5 JICA stations. In longer term, it remains as a task of NCHM to seek benefiting partners (such as aviation operators) to support financially operating and maintaining GBON observation infrastructure (i.e. AWS and radio sounding system) and explore the possibilities of cost-recovery mechanism.

Given the limited Government resources to maintain and sustain a large network, the primary objective of the SOFF proposal is to set up a model with sustained funding to always keep it operational and contribute to global data. And to fill the significant observational data gaps particularly in the Himalayan and high-altitude areas. Contributions from the Government budget to enhance the infrastructure of non-GBON network are also possible.

Sl. No.	Funding	2016-2017	2017-2018	2019-2020	2020-2021
1	RGoB	55.0	76.87	110.063	115.893
2	Donor (GoI, World Bank, GCF, PHPA, etc.)	250.6	117.93	64.290	48.533
	Total	**305.6**	**194.80**	**170.353**	**164.426**

Table 2: Summary of NCHM budget, numbers in million of NU. Source: World Bank[3]

Recommendation: evaluate regularly possible public and private partnerships in infrastructure maintenance and operations throughout the value chain of observation from station to end user interface. Equally important will be to explore the possibilities of cost-recovery mechanism,

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

The hydrometeorological policy will define the NCHM mandate more clearly and support chances for revenue or cost recovery operations.

The hydrometeorological policy provides NCHM with following mandates

1. Recognize NCHM as the nodal agency for hydrology, meteorology, aviation meteorology, climatology, climate and cryosphere sciences and its application.
2. Shall establish, maintain, operate, and modernise hydro-met infrastructure and related Information and Communication (ICT) facilities to ensure effective delivery of services.
3. Establish, operate, and maintain hydromet stations, modernise hydro-met observations, early warning systems and scientific facilities through innovative financing including adoption of cost recovery mechanism for data and specialised services, to ensure sustainability of hydro-met network and its operation.
4. Maintain and provide reliable, accurate, and quality weather, climate, hydrological and cryosphere information, and services through use of state-of-art technology.
5. Ensure access to reliable and quality hydromet data and services for all times.
6. adopt hydro-met data exchange and dissemination mechanisms for regulating data exchange.
7. Ensure adoption of standards for observation, instruments, data collection and forecasting in compliance with the known international and national standards to ensure quality services.

[3] World Bank, 2023. Strengthening Hydromet and Multi-hazard Early Warning Services in Bhutan. A Road Map, V2-Rev. April 2023.

8. Promote research and development to enhance knowledge and understanding of science in hydrology, meteorology and Cryosphere and its applications.
9. Ensure adequate and competent human resources to abreast with emerging science and technology.

Strategies follow national 5-year plans of the government.

The current AWS network was established during the years 2016–2017. The civil infrastructure is robust, and equipment is still working. However, there is a need for the replacement and maintenance of all sensors and data loggers of the network. This is one of the primary focus areas in the NCHM. **To systematically operate and maintain all observation stations a lifecycle plan together with tight connection to annual and long-term budgeting needs to be developed where the SOFF programme is foreseen as the right platform** (easy fix). The lifecycle plan also supports better coordination between budget funding allocation, projects and working towards strategic goals.

The current projects include:

- JICA TCP Phase II
- Green Climate Fund Bhutan for Life

Hydrometeorological projects have been proposed with donors like JICA and GCF which to improve the observing network. Ongoing project with JICA on EWS for Thimphu and Paro will also improve the existing network.

JICA-project also supports proposal to share data through the GTS from 5 synoptic surface observation stations, providing better coverage and density for the region. This project does not include WIS 2.0 interface, so stations are not GBON-compliant. However, with proposed approach, data from these stations can be shared via WIS 2.0 interface provided during SOFF investment phase.

2.5. Review of the national legislation of relevance for GBON

There are no known constraints regarding GBON implementation nor subsequent international data distribution in Bhutan.

World Bank roadmap states that there is no specific legal statute regarding the collection and exchange of hydrological and meteorological data and information with line agencies/public/individual as well as with other regional and international entities. However, acknowledging the importance of exchange of hydrometeorological data and information for sustainable development, protection of lives and properties, research and decision support, and mitigation of hydro-meteorological induced hazards, in 2019, NCHM developed

"Guidelines on the Exchange and Dissemination of Hydrometeorological Data and Information".[24]

The Guidelines provide the technical and conceptual principles/framework required to promote data exchange and interoperability within the line agencies/public and individuals. Furthermore, the Guidelines intend to provide a framework for exchange and dissemination of data and information within national as well as bilateral, regional, and international organizations to whom the RGoB is signatory. **Data sharing and exchange is included in "Hydro-met Policy of the Kingdom of Bhutan, 2023"** under Objective 3: Strengthen Database Management and Data Exchange, which states that The Royal Government of Bhutan shall strive to ensure adequate resources to develop appropriate database management systems and archival to enhance data quality, data security and promote data exchange.

The Royal Government of Bhutan has adopted the Hydrometeorological Policy of Kingdom of Bhutan (2023) on 13 September 2023. The objective of this policy is to ensure reliable and quality hydro-met services for socio-economic development, disaster risk reduction, protection of lives and properties. This policy will guide for the development, enhancement, and provision of services on meteorology, hydrology, and cryosphere in the Kingdom of Bhutan. NCHM is developing a "Institutional Strengthening and Modernization of Hydromet and Multi-hazard Early Warning Services in Bhutan: A Road Map and 13th Five Year Plan (2024-2029) that will guide systematic development of hydromet sector in Bhutan.

There are no known constraints by national legislation regarding GBON implementation. NCHM has a full mandate in the field of hydrometeorological observations and data distribution, and thus, can make required decisions.

Legislation related to procurement, importation, and customs processes

Most of the Automatic Weather Stations (AWS) network in Bhutan was installed under the NAPA II project in 2016. The AWS as well as the aviation Automated Weather Observing System (AWOS) are MicroStep-made which was supplied by M/s MicroStep MIS, an Original Equipment Manufacturer (OEM), based in the Slovak Republic. NCHM has been procuring the AWS instruments and spares through the Direct Contracting Method according to the to *Procurement Rules and Regulation, 2023, Chapter-IV, sub-clause 4.2.4, Royal Government of Bhutan*. This method will be used in purchase of the proposed AWS as well.

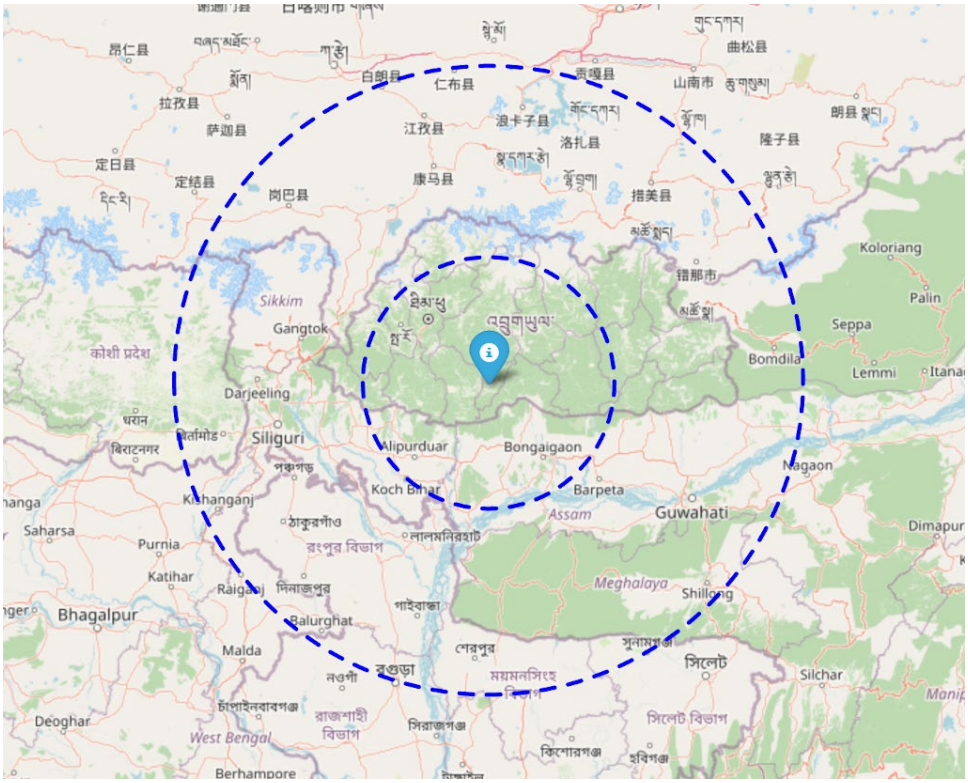
By following the law of procurement in Bhutan and the rules of IE, bigger purchases, such as upper air sounding station or calibration laboratory must go through international bidding process. In some cases, local supplier is required.

It should be noted that purchases must include 10% import tax. Based on information from Bhutan, tax exemption will not be possible.

Module 3. GBON Infrastructure Development

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

Picture 1 Map of proposed surface and upper-air station to Tsirang Damphu. Inner circle shows AWS with 200 km diameter (100 km radius) and the outer circle upper air station with 500 km diameter (250 radius). Existing manual and automatic stations are included in following pictures.



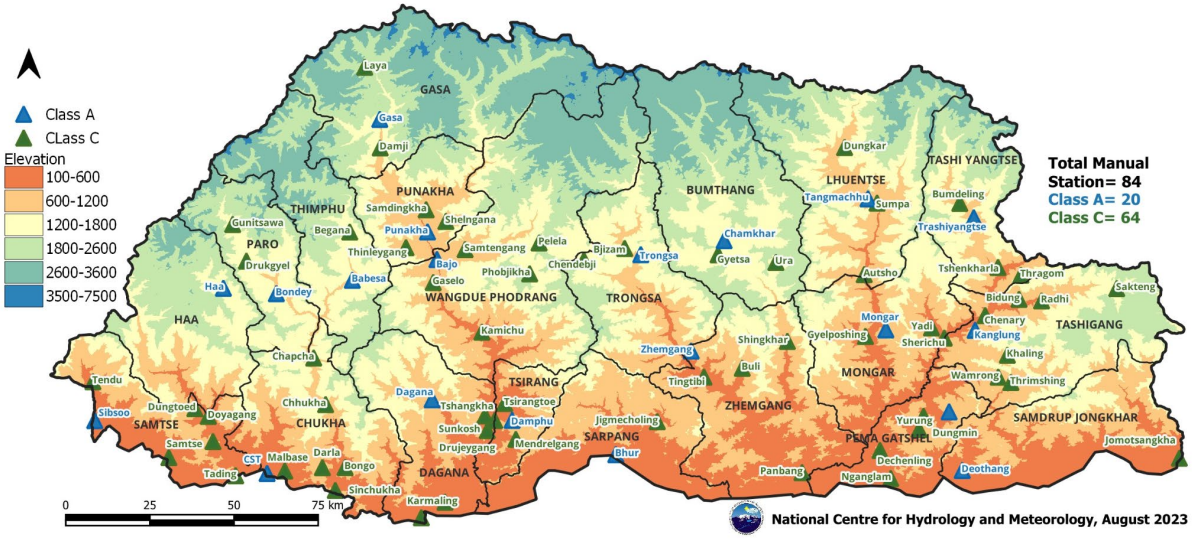
The aim of SOFF investment phase project is to maximize the impact of observations on global numeral weather prediction (NWP) skill through:

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

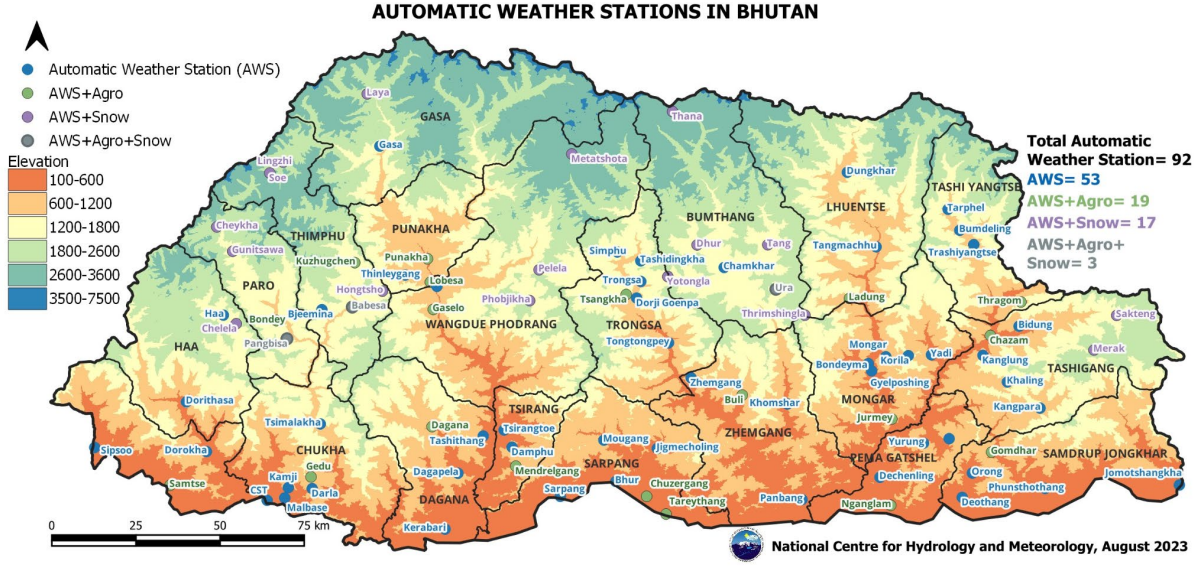
In Bhutan, these impacts (GBON) impacts are addressed with **one upper-air and one surface station.** However, technical solutions used with surface station, enables data sharing from existing stations to GTS/WIS2.0 (actual sharing requires separate decision by NCHM)

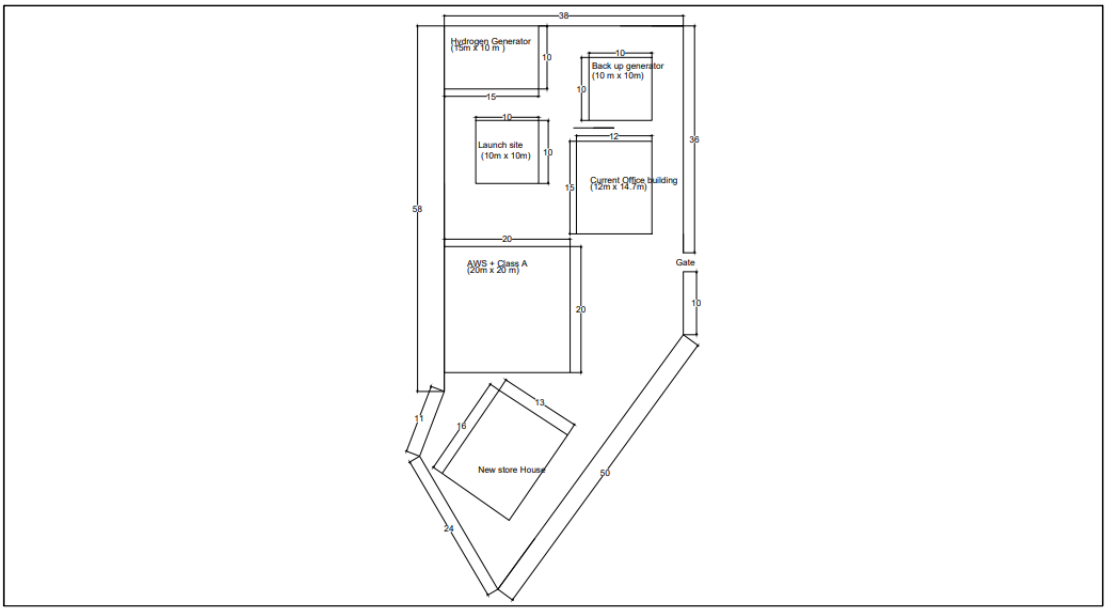
Bhutan has quite dense surface manual and automatic weather networks.

MANUAL WEATHER STATIONS IN BHUTAN



AUTOMATIC WEATHER STATIONS IN BHUTAN





METEOROLOGICAL SERVICES DIVISION NATIONAL CENTER FOR HYDROLOGY & METEOROLOGY	DRAWING TITLE: Site Plan PROJECT TITLE: Upgradation of Class A Station at Tsirang	DRAWN BY: Monju Subba, Engineer, MSD CHECKED BY: Dr. Singay Dorji, Chief, MSD APPROVED BY: Dr. Singay Dorji, Chief, MSD	DATE:2 November, 2023 SHEET NUMBER: / REVISION NUMBER: / REVISION NOTE: NOTES: All dimensions are in mm unless otherwise stated. Dimensions shall be read and drawings shall not be scaled.	SCALE: NTS

i. AWS instruments

SI	Sensors	GBON variables
1	wind sensors	X
2	solar Panel	
3	Air temperature	X
4	Humidity sensors	X
5	Rain gauge (tipping bucket)	X
6	Pressure sensor	X
7	Rain gauge weighted	X
8	Ground temperature sensors	
9	Water temperature	
10	Water level sensor	
11	Soil temperature sensor	

- **One manual upper-air radiosounding station including**
  - Hydrogen generator and required shelter (ATEX requirements apply)
  - Consumable parts (balloons, sondes etc.) for the first year of operation
  - Required maintenance/renovation to infrastructure
  - Include annual maintenance during warranty period

Exact specifications for manual sounding station, in addition of those defined by GBON, are defined in the bidding phase.

Estimates for Civil work

Sl	Activities	Cost Estimate (Nu.)
1	Civil work including work for installation and fencing of AWS area	20,00,000
2	Construction of Hydrogen generator shed	4,000,000
3	Construction of store for spare parts	8,000,000
4	FAT and training for installation and maintenance	3,000,000
5	Capacity building for system integration, WIS, CDMS and ICT	5,000,000
	Total	**18,000,000**

Sl	Activities	Cost Estimate (Nu.) per annum
1	Bill for Electrical supply and water (accounted only for AWS) annually	1,000,000
2	Maintenance of the stations, at least 4 times in a year for one station including travel expenses and vehicle fuel	11,000,000
3	Bill for internet	100,000
4	Salary for 4 staff with RGOB norms	2,000,000
	Total	**14,100,000**

Observational practices defined per network

Most of the automatic weather stations in Bhutan do report every 15 minutes to the CDMS so GBON requirement of hourly observations would be fulfilled.

However, due to missing interfaces to WIS 2.0 or GTS, data from these stations is not shared. **NCHM is interested to share more data, but to ensure reliability and quality of the data, support for station maintenance and operation is needed.**

Upper air sounding stations will be new instrument and it will follow GBON recommendation of 2 daily observations.

Preliminary maintenance plan for existing and improved/new stations, including calibration practices

The AWS -network maintenance program will be designed together with the NCHM, and equipment manufacturer based also on the conditions and recommendations set by the manufacturer. However, initially the maintenance plan includes maintenance visits to the station twice a year and annual calibration of at least temperature, humidity, pressure, and precipitation sensors.

There are no foreseeable issues with security of stations. Automatic data distribution and maintenance may pose a challenge which needs to be addressed through careful planning and capacity building during investment phase.

Main challenges with automatic data distribution are communication challenges from stations. These are mitigated as much as possible with technical solutions (mobile internet, satellite), but given the topography of Bhutan, these will be challenges also in the future. Coverage and robustness of mobile networks will also increase over time which will improve the situation.

Preventive and corrective maintenance will be addressed in investment phase with planning spare parts to be stored at convenient locations for maintenance, improving SOPs and practices for maintenance as well as ensuring availability of cars or other transportation means.

- Calibration of sensors will be conducted in NCHM calibration laboratory. Calibrated sensors will be installed to the station during maintenance visit and old sensors retrieved for the calibration. **This practice requires adequate pool of spare parts to be truly affective and support environmental sustainability goals of SOFF programme.**

Technical specification for new instruments and observing systems for the procurement process

Automatic surface weather station
NCHM has been harmonizing their station network and has acquired most stations, data collection and data management system (CDMS) from a company called Microstep. To fully utilize and support existing network, including spare part pool, it is highly recommended that the new station is integrated into the existing system. This station is located at same place as upper air sounding station and would provide necessary surface weather information to the upper air station.

Specifications for the AWS are detailed including model numbers from certain supplier based on existing station network. Sensors providing non-GBON variables are also included, as they provide important data for NCHM operations.

Sl No.	Item	Model No	Price per quantity (Euro)	Quantity	Price per quantity (Euro)
1	Supply and delivery of light weight 10 Mtrs Aluminium tube Antenna Mast with appropriate base an anchoring acessories for AWS	MM10	4,500	1	22500
2	Supply and delivery of Air Temperature & Relative Humidity sensor including radiation shield with complete accessories i.e. connectors, cables and mounting fixtures.	RHT175 / Metcover3b	1,350	1/5	6750
3	Supply and delivery of barometric pressure sensor with complete accessories i.e. connectors, cables and mounting fixtures.	MSB181	850	5	4250
4	Supply and delivery of wind sensor (Speed and direction) with complete accessories i.e. connectors, cables and mounting fixtures.	1390-75-B-311	4,650	5	23250
5	Supply and delivery of rain gauge (tipping bucket) with complete accessories i.e. connectors, cables and mounting fixtures	MR3-02v	1,245	2/5	6225
6	Supply and delivery of Rain gauge (Weighing type) with complete accessories i.e. connectors, cables and mounting fixtures.	TRWS 425	3,650	5	18250

7	Supply and delivery of Solar radiation sensor.with complete accessories i.e. connectors, cablesand mounting fixtures	CMP6	2,150	5	10750
8	Global Solar Radiation Pyranometer	CMP6	1,790	5	8950
9	Reflected Solar Radiation Pyranometer	CMP6	1,790	5	8950
10	Mounting Fixture for 1 or 2 unventilated radiometers and Glare screen kit for downward facing unventilated radiometers	CMF1	650	5	3250
11	Albedometer Kit • 2 x CMP6 • CMF1 • Glare Screen Kit • 2 x 10 meter cable	CMP6	3,968	5	19840
12	Snow depth Sensor including cables, connectors and all mounting accessories	SHM31	3,590	5	17950
13	Supply and delivery of data logger capable to interface with GSM-GPRS modem for transmission of data in real or near real time to meteorology server via GPRS and to NWFFWC server via FTP at HQ,	AMS 111 IV	4,375	2/5	21875
14	Supply and delivery of GSM-GPRS Modem with accessories including antenna		520	3/5	2600
15	Supply and Delivery of Power supply: Solar Panels, controller, Charger, Maintenance free rechargeable batteries(12V/100AH)		2,550	5	12750
16	Supply and Delivery of NEMA-4X or IP 66		960	1/5	4800

	electronic enclosure with built in locking system and 3 nos. of spares keys.				
17	Supply and delivery of grounding, lighting, and surge protection equipment.		485	1/5	2425
18	Supply and delivery of soil temperature at different depths viz., 5cm, 10 cm, 20cm , 50 cm and 100 cm with complete accessories i.e. connectors, cables and mounting fictures.	PT100.1/5.10	1,150	5	5750
19	Supply and delivery of soil moisture snesor at ground level and five other depths viz.,7.5cm, 15 cm, 30cm, 45 cm and 60 cm with complete accessories i.e. connectors, cables and mounting	SM150T	2,150	5	10750
20	Supply and delivery of evaporimeter: evaporation gauge analog output, evaporation pan class A, Evaporation guage automatic refill system and stainless-steel pipe and fitting with complete accessories	EvapTSP	5,000	5	25000
21	Maintenance Toolkit		1000	5	5000
	Spare parts:				
1	PTTN Connection terminal		350	10	3500
2	PTEP connection terminal		385	10	3850
3	Charge Controller		390	10	3900
4	Data Logger	AMS 111	3750	10	37500
5	Filter for Air Temperature & Relative		250	10	2500

	Humidity sensor (10 pieces)				
				Total (Euro)	**293115**

Manual upper air sounding station is recommended. As there isn't existing upper air sounding station, general description is included

One manual upper-air radio sounding station including

- Hydrogen generator and required shelter (ATEX requirements apply)
- Consumable parts (balloons, sondes etc.) for the first year of operation
- Required maintenance/renovation to infrastructure
- Include annual maintenance during warranty period

	Manufacturer 1	**Manufacturer 2**
System	€ 18,150.00	€ 45,247.00
System with sea container	€ 41,650.00	-
Training + tests + site acceptance etc.	€ 14,000.00	€ 28,100.00
Consumables (750)	€ 90,000.00	€ 129,750.00
Hydrogen generator	€ 174,000.00	250k€-300k€
FAT+training hydrogen generator	€ 10,000.00	?
Sea container + integration of hydrogen gen.	€ 103,900.00	?
Annual service	-	€ 1,507.00
1y service set	-	-
5y service set	€ 5,500.00	-
Total (first investment)	€ 433,550.00	€ 503,097.00

Table: Preliminary cost estimates for the manual sounding stations

Upper air soundings are new technology for Bhutan, so study tour to nearby country (Nepal or India) to follow how soundings are made is proposed.

3.2. Design of the ICT infrastructure and services

A development of ICT infrastructure for a value chain of automatic observation network is recommended to begin by building required human capacity and resources. Adequate staff to ensure resilience should be hired, tasked and trained in skills and knowledge relevant to IT in meteorological observation. The organization is recommended to gain knowledge and skills in meteorological data, data processing principles and tools, data formats (e.g., NetCDFv4 and BUFR), system architecting, software developing, database, API, network management, as well as web developing.

NCHM has decent ITC environment, and it should be strengthened while planning the SOFF/GBON related improvements. Many of the required components do exists, although they may not be fully utilized yet.

NCHM has been harmonising their station network and in addition of stations, they have acquired data collection and data management systems (CDMS) from a company called Microstep. Data collection system allows real time data flow from AWS, including the Tsirang Damphu station to database. Although the CDMS is still in deployment phase and it will take time before it is fully in use, it can be considered as operational system from GBON surface observation point of view.

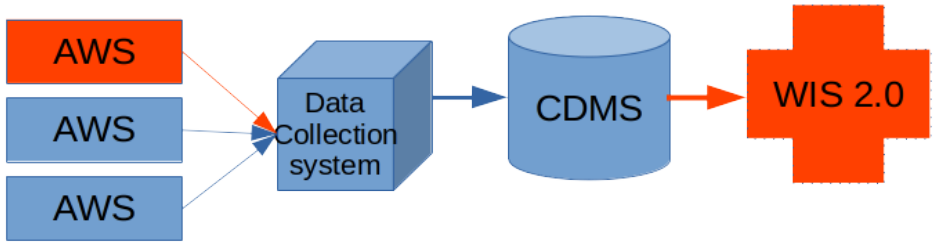
CDMS can serve a real time database and it is recommended to be used also as data source for the WIS2.0 interface. With this approach, there is **no need for separate short-term storage**, although data collection system could serve in that role to some extent.

Dataflow via database allows centralized real-time monitoring of the system, real time quality control and centralized source for metadata. Manual quality control will be performed with delay and therefore it is excluded from these plans.

While considering data management in general at NCHM, dataflow via database simplifies overall data management remarkably. Station or data collection providers need only to plan how to get data to CDMS, without knowing about who and how data will be used or accessed. Users, including delivery to WIS, do not need to worry about how the data is collected or which station has produced it, as they can acquire all observations from CDMS. On the perspective of metadata-management, CDMS would be used as main storage. If dataflow bypasses CDMS, it would require metadata to be maintained in several locations separately.

As mentioned earlier, automatic real time quality control (QC) can be performed in CDMS preventing delivery of the clearly erroneous values. Developing and adjusting the QC-routines to Bhutan environment is outside of this project. Initial QC would be using broad quality checks.

This approach is used by peer advisor (although with different technical solutions which cannot be copied feasibly). Dataflow through the database and real time quality control does not cause problems for the real-time needs (at peer advisor system, delay is < 1 minute in general).



Picture 5: Simplified dataflow for NCHM setup. Blue components are existing, and red components are proposed to be implemented with SOFF support.

Proposed AWS (red) would be located at same place with upper air sounding and in addition to WIS, it provides necessary data also to sounding system.

Dataflow from AWS to CDMS exists, but WIS 2.0 interface is missing. With **implementation of WIS-module, it enables technically sharing the data from existing stations as well. (easy fix).**

Other, sometime proposed approach is to deliver data directly from stations to international delivery (GTS/WIS 2.0). This approach is not feasible in modern times, especially if the CDMS exists. As mentioned earlier, centralized data collection and storage allows real-time quality control, centralized source for metadata and centralized real-time monitoring system. It also simplifies dataflow in NCHM in general.

CDMS is and will be crucial component in the NCHM infrastructure, so its operations need to be ensured. Adjusting and improving the dataflow to optimal situation is expected to be performed gradually and take some time. However, peer advisor sees this approach most feasible to Bhutan as well.

Technical specifications

Technical specifications for database (which existing CDMS fills at least to some extent): In addition to automatic and/or manual meteorological observations, a modern, functional Data Management System (DMS) is a key element in the value chain of observation from measurement station to end user interface. The following specifies general key elements to consider in technical and budgetary perspectives.

Ability to ingest and store multiple types of weather observation data formats. Including, but not limited to, the following:

- Surface weather observations
- Upper-air radio sounding observations

- Aviation weather observations
- Lightning observations

Bhutan does not have any weather radars. In addition, their data have such a big volume and requires much more from storage capacity than a single point/profile data and is thus beyond the considerations of this document. Data ingestion to the data warehouse (database) should be made with a modular approach so that new data feeds may be added with minimal effort and modification to the already existing components and database structures.

A data quality control (QC) module should be an independent and/or modular part of the system. Additionally, the quality control module must be able to perform real-time quality control and should enable non-real-time manual quality control.

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

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

- WFS
- EDR
- WMS
- Export to SYNOP & BUFR message format and delivery to GTS-network
- WIS 2.0 (GBON compliance)

Some of these API's or modules can be provided by external programs.

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

Management of Metadata in general is on basic level at time of the writing this document. In general, all metadata should be stored and maintained in specific location, which would be CDMS. Extent of the available metadata and updates to and from WMO/OSCAR needs to be clarified on implementation phase of the WIS 2.0 interface.

Hosting of the infrastructure

NCHM has own computer rooms which hosts their infrastructure. There are plans to establish governmental ICT-center in next few years, which would provide also hosting services. These plans should be followed carefully, and utilization of server hosting facilities of ICT-center be considered. Server hosting by ICT-center, can provide main or backup computer rooms. It is assumed that services will include also cloud services.

While maintaining their own computer room, addition of IT-staff or support contract with private company is highly recommended.

Data delivery & main gaps

The delivery of GBON hourly observations will be reported by following WMO guidance (no. 306[1]) and GBON practices where applicable. However, although GBON defines certain protocols which should be used in the data collection from weather stations, given the existing infrastructure and software, GBON protocols should be considered as recommendations, not mandatory requirements.

The delivery of GBON hourly observations should be reported by following WMO guidance (no. 306) and GBON practices. Main GAP of proposed existing system is the lack of the WIS 2.0 capable interface, and which needs the most of the SOFF support in ICT-field. **WIS 2.0 interface** needs to be provided either by existing CDMS or more likely by external software, such as WIS2Box. The delivery of GBON hourly observations should be reported by following WMO guidance (no. 306) and GBON practices.

First step is to get dataflow from proposed GBON station to international dissemination to work efficiently via WIS 2.0. On the next phase, existing stations can be added to international delivery utilizing these solutions.

Observations coming from abroad via GTS or WIS 2.0 will be utilized in the forecasting process. Storing of international observations to the same database and data policy needs to be developed in the next step. First step is to get dataflow from Bhutanese stations to work efficiently.

NCHM will be the sole hosting authority of WIS 2.0 in Bhutan.

Recommendation

It is highly recommended that the new station and dataflow to WIS2.0 are integrated into the existing system via CDMS, and efforts are used to improve robustness and efficiency of the current system.

Resilience and continuity of the full data processing chain requires reliable equipment, adequate human resources, and full-time monitoring. On the technical side, it also means doubled environments with backup and recovery plans, starting from AWS to data communications and servers.

Recommendation

Follow closely plans to form governmental ICT-center and evaluate their services when plans realize.

Budget considerations; Resilience and the continuity of the full data processing chain:

Budget must consider the infrastructure needed to run a CDMS and store the data. Also, a solution for a backup of essential data needs to be accounted for when making investments. A valid support contract with a hardware vendor is advisable during the lifetime of the hardware. The lifespan of such hardware may be estimated to be between 5-8 years before the need of renewal of the systems.

Resilience will be supported by two main resource factors: skilled staff and IT hardware including sufficient lifecycle plan and budget. NCHM will be solely responsible for taking care of the complete data pipeline. Thus, development of ICT infrastructure for a value chain of automatic observation network is recommended to begin with building required human capacity and resources. Adequate staff to ensure resilience should be addressed and trained in skills and knowledge relevant to IT in meteorological observation. The organization is recommended to gain knowledge and skills in meteorological data, data processing principles and tools, data formats (e.g., NetCDFv4 and BUFR), system architecting, software developing, database, API, network management, WIS2.0 as well as web developing. Please find further considerations on human capacity resilience in section 4.

3.3. Environmental and sustainability considerations

Bhutan is the first and so far, only carbon negative country in the world: over 70% of the country is covered by forest and power production is based on renewable sources. Main source of electricity is hydropower, in addition to wind and solar power. Bhutan also exports renewable energy to India.

Zero Waste Bhutan in 2030 programme with target of waste reduction and management are supporting development toward environmental-friendly GBON operation. Currently NCHM is participating and encourages citizens to join to national Zero Waste Hour with disposal practices monthly. These practices will be implemented in daily GBON operation whenever possible.

In general, all activities in Bhutan are following Gross National Happiness (GNH) approach which is promoting environmental conservation in addition to other key priorities and thus, providing solid based for environmental and sustainable development of GBON stations.

These aspects will be naturally utilized in the SOFF implementation. The sounding station and AWS are operated by the AC power from renewable sources and back-up batteries are supported by solar power.

Regarding the transportation of goods and personnel, the progress of electrifying the transport sector is ongoing, making national logistics more carbon neutral in the future. International import of goods is in practice possible only via India or as flight cargo.

The key success factor of sustainable investment, and day-to-day operation of GBON stations relay on highly competent and motivated management and staff in the organization. Further system specific considerations include at least:

Upper air sounding station: The GBON compliant sounding system (despite of being fully or semi-automatic) is recommended to be located at a site where permanent staff works daily. This will decrease unnecessary travelling and burdening financial implications when the sounding station requires an attention of staff. Such regular attention will include e.g., filling the system with sondes. The tender process should emphasize quality criteria related to environmentally friendly and plastic free, where applicable.

The investment in sounding system is made for 20-30 years, and thus, care must be taken to ensure that annual maintenance is ensured throughout its lifecycle. This has high financial cost implication for the operation, especially in the case of fully automatic sounding systems.

Generation of hydrogen, needed by balloons, locally at the station will make the operation more environmentally sustainable, energy effcient and independent from importing gas by the 3rd party.

AWS: The renewed, GBON compliant weather station, also compatible to existing infrastructure, is recommended to replace/upgrade with civil infrastructure (e.g., electricity, wind mast etc.) that is reusable. With scheduled preventive maintenance and calibration, the lifecycle of sensors will be lengthened as long as appropriate.

The location of station has been selected to be near of one NCHM local office, which reduces transport needs.

Scheduled preventive maintenance and calibration routines require, as a rule of thumb, about 1.3 times more sensors than there are stations. As an example, for 100 stations with temperature sensor, the organization is recommended to own 130 temperature sensors, when 30 of them are in storage or under calibration procedure. In the case of GBON compliance in Bhutan, only one surface weather station will be invested in, and thus, each sensor must accompany a spare sensor in initial investment to ensure a sustainable operation of station. Frequency for preventive maintenance may rarefied based on the scientific experience and statistics gained through calibration.

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

Use of solar panels support environmental sustainability through an availability of renewable energy.

3.4. Upgradation of calibration and instrumentation laboratory

Accurate measurement and calibration of meteorological variables are essential for the efficient operation of the National Meteorological and Hydrological Services (NMHS) throughout the world. Among the many factors that significantly influence Meteorology, Hydrology and Cryosphere are temperature and pressure. Recognizing the significance of accurate temperature and pressure readings, the National Centre of Hydrology and Meteorology (NCHM) has started with the calibration of meteorological instruments through the support from Japan International Cooperation Agency (JICA) experts.

The NCHM is responsible for overseeing the instrumentation and calibration of hydromet instruments and accessories. However, up until now, the centre has not conducted calibration of the hydro-met instruments. Acknowledging the significance of accurate measurements, NCHM proposes to upgrade the existing calibration Laboratory. Under SOFF, NCHM proposes to procure the additional calibration equipment for GBON variables (temperature, pressure, humidity, wind (*)). There is also need for calibration of solar radiation sensors which produces useful information from mountainous area. **Calibration facilities for solar radiation parameters is proposed as easy fix.** Further, the centre proposes to procure the spare parts for the existing temperature & pressure sensors.

Headquarters of NCHM and current calibration facilities are located in campus area of ministry. However, in coming years, NCHM will be relocated to outside Thimpu. New headquarters are being planned and will provide more room for calibration facilities as well.

Due to relocation and lack of decent facilities at current location, construction of the new laboratory facilities is proposed to take place with new headquarters (calibration lab estimated 2025-2026, HQ fully in use little bit later).

(*) Calibration possibilities of wind sensors depend on chosen technology

Sl. No	Item	Qty.	Price	Total amount (Euro)
1	Temperature	3		
2	Pressure	3		
3	Rain Gauge	5		
4	Humidity	5		
5	Solar Radiation	5		
6	Training + tests + site acceptance etc.	1	€ 15,000.00	
7	FAT + Capacity Building + SOP	1	€ 15,000.00	
8	Construction of Calibration Laboratory to new HQ	1	€ 85000.00	
	Total cost Estimate			

Tentative price estimate for calibration equipment for GBON parameters is 150 000 – 250 000 Euro, depending on supplier.

Module 4. GBON Human capacity Development Module

4.1. Assessment of human capacity gaps

Summary of Human Resources Capacity of NCHM

SI	Position	Qualification	Number of Employees	Existing Capacity	Capacity Gaps and Challenges
1	Support and Supervisory Category (Technicians)	Class XII/Certificate/ Diploma	144	Technicians are mostly involved in data collection, key entry and operation of stations in the field. While employees in most of the stations are professionally trained, some are not certified.	Challenges include lack of resources to provide regular trainings, certification and refresher courses to keep abreast of the emerging science and technologies in the field of

					hydrology and meteorology
2	Professional and Management Category (Officers)	Undegraduate and Masters	26	Professionals are involved with operation of stations, forecasting, and modelling and research activities. It includes professionals for ICT, Management and Database systems and HRD	Support is required for training professionals on ICT, forecasting and modelling. Key challenges include lack of ICT skills for system integration, data quality, data management and system security
3	Management Category	Masters/PhD	5 including heads of Divisions and Director	Most of head are trained in basic management, performance monitoring and evaluations through workshops and seminars	

General

One of the main challenges in NCHM, and Bhutan in general, is high change rate of staff. Many Bhutanese are moving abroad, either for study or work, and this also affects NCHM. Also lack of personnel causes challenges for the operations and development of the processes. Persistency of the staff is key issue to be solved to ensure sustainable operations of NCHM.

Due to changes of staff, basic trainings need to be repeated more often. Especial care must be given to ensure that in-house capacity and process for competence building are strong and ensure effective knowledge transfer to new staff members. It is also important to provide advanced level training (IT, programming, server administration, forecasting etc) to the staff members who master the basic level.

Building capacity through training activities and cooperation with other WMO members is indispensable for a modern NMHS such as NCHM. These activities should be conducted regularly and continued and include access to new skills for new and existing staff. A major challenge for NCHM as for many other NMHSs is to create a professional and technical workforce with access to training opportunities that will enable them to take advantage of rapid advances in many areas of meteorology, particularly advances in information technology, modelling, and forecasting.
NCHM has defined Competency Based Framework (CBF) for Hydrology Officer and Meteorology Officer (2021), which however, does not implement all the WMO Guidelines for Education and Training of Personnel in Meteorology and Operational Hydrology (WMO-No. 258) requirements for PWS personnel and thus does not meet the appropriate education and competency requirements.

A successful and sustainable human capacity building of an organization depends on three main components:

1) the individual him/herself
2) the organization
3) the availability of training opportunities

Learning is a self-driven process. This means that every staff member is responsible for his/her own learning results when participating in training events or doing self-studying through online courses and other material. Motivation, attitude, in-advance preparedness, understanding the benefit of learning new skills, as well as undistracted and concentrated participation in training events are in key role to gain sufficient and sustainable learning results. Acting as a trainer by him/herself further strengthens the capacity of the staff member.

The organizational culture and support from the management ensure the competence of staff members and their possibilities for sustainable learning results, and further, facilitate the operation and development of organization through enhanced human capacity. The organization must determine the necessary competence of staff in each task, as well as it must ensure that the staff is competent through appropriate education, training, and exercise. The

organization should also have and develop an internal competence development process to support the main service provision processes of quality management system. Special emphasis is recommended to give for guiding new staff members into their duties with the appropriate evaluation methods of required skills. Additionally, the management must ensure that staff members can participate in training events without requirement to carry out daily duties or any other distraction.

The availability of training opportunities depends on internal competence development process, annual development planning of individuals, and access to training outside the organization (e.g., through national and international partnership and development collaboration). The organization must ensure equal access to training events despite gender, age, or position.

In the following, capacity development needs and proposed activities will target technical staff who operate and maintain the observing network and senior management who implements the Plan.

Recommendation: NCHM is recommended to further enhance its Competency Based Framework (CBF) to ensure that the competence of new and existing staff members is built consistently and effectively. In addition to ensuring high quality operations, good quality competence building motivates staff and is foreseen to support job satisfaction, and subsequently, decrease job rotation rate.

4.2. Design capacity development activities for technical staff

Although NCHM does not have capacity building process defined in the Quality Management System, they have extensive list of SOP's and training new persons. This approach could be enhanced within the framework of SOFF (*easy fix*). **The NCHM is recommended to develop and enhance competence building process by following WMO guidance** (no. 1205). Additionally, external trainings supporting competence building depends much on external funding, projects, and trainers.

Recommendations on training activities within SOFF framework to support work towards gaining minimum competence relative to WMO guiding no. 1083[15]. The training needs were identified during Gap Analysis.

- **Quality management system (QMS):** Effective and continuously developing QMS is the basis for the systematic operation and maintenance of observation network(s). The organization has strong understanding and knowledge about QMS, as well as trained staff for internal auditing. An effective development of observation process including lifecycle planning, however, require support through benchmarking mature sub-processes for upper air sounding and surface weather stations in other organizations.

NCHM is recommended to enhance the existing surface station sub-process, where needed, and develop upper air sounding sub-process (*easy fix*).

- **Data archiving:** Programming skills of staff members must be strengthened to support strong and effective data archiving. Additionally, NCHM is recommended to benchmark other organizations with mature data archiving system and tools to learn best practices.
- **Data transfer:** Programmers need training on the automatization of data transfer from stations to data base, and subsequently, to WMO WIS2.0 interface, which will replace GTS system. Complementary training to manage and update information in OSCAR surface service is much needed by staff members (*easy fix*).
- **Data quality control and assurance:** Basic programming skills and scientific understanding must be upgraded to sufficient level to apply QA/QC methods and algorithms. The relevant staff members need capacity building to manage scientific background behind different QA/QC methods. Benchmarking QA/QC methods in other organizations would provide substantial benefits for the NCHM. A roadmap for implementing relevant automatic QA/QC methods must be developed.
- **Instrument and station operation and maintenance at site:** Once sufficient technical training for maintaining different sensor types has been received, the technical staff would benefit from good quality SOPs and competence requirement criteria. Both the SOPs and owning required competence support self-confidence at any work. Training on upper-air system operation and lifecycle maintenance is needed since it will be a new measurement technique in the organization.
- **Calibration and maintenance at workshop:** NCMH is responsible for calibrating meteorological observation sensors in Bhutan**.** For this, calibration laboratory is necessary but training and support in building calibration processes are needed. Also, full understanding of a concept of quality through calibration and how calibration information must be inserted in the value chain of observation (*easy fix*). It is critically important that scientists are capable of analysing calibration results to support lifecycle and maintenance planning. Here benchmarking sister organizations would support in developing this area in the beneficiary organization.
- **Network monitoring and ICT system operations:** The staff members responsible for ICT need upgrade in their capacity (e.g., programming skills and technical understanding) to ensure the 24/7 automatic operation of data pipeline from station to international distribution.

4.3. Design capacity development activities for senior management

Based on discussions, the whole project organization (from the management to project contact points/project managers) would benefit from capacity building in portfolio and project management and coordination, as well as ensuring that project portfolio is aligned with the strategy of organization. The organization is recommended to consider training through at least the following:

- international development collaboration

- Benchmarking human resource management with peer advisor and other relevant agencies
- benchmarking organizations with mature project and portfolio management and coordination culture
- by certifying key staff members for portfolio and project management with an internationally recognized certificate.

4.4. Gender and CSOs considerations

Climate change and extreme weather events are not gender neutral, but they affect women, girls, men, and boys differently. This is due to socioeconomic circumstances, cultural beliefs or traditions that can all contribute to inequality, resulting in women being put in situations of disadvantage when disasters strike. Therefore, it is important that in the pre-disaster context, those who likely will be the most affected by crisis, are also included in the preparedness process[15]. This includes having equal access on political, social, and economic levels as well as being able to participate in decision making. Not only is it fair, that population is equally engaged in climate change adaptation and resilience building, but there is also substantial evidence that shows that women are often the most resilient members of society and the powerful agents of change in the event of a disaster. They also have historic coping mechanisms that can be of use when designing and tailoring local grass-root level early warning systems or other climate change adaptation services and activities. To include women in designing hydrometeorological and climate services directly leads to saving lives and livelihoods, as the needs of different groups have been better identified.

The rational for organisations to pursue gender equality in governance, strategy, programmes, and decision making, is highlighted in WMO's recently updated Gender Action Plan[16]. It emphasizes that organizations that respect and value gender equality and diversity attract and retain talented staff and improve overall organizational performance, have more satisfied employees, are more innovative and have better governance. Teams that have gender diversity have better decision-making processes and attract more external partnerships, as well as have better access to local communities. Encouraging women to take up leadership positions has also shown to lead to important achievements in the field of climate change adaptation and disaster preparedness.

In Bhutan, the government encourages the institutions to have a gender balance, and significant policy papers to combat gender inequality have been introduced recently

According to the Bhutan at a Glance 2023 by the National Statistics Bureau, in year 2023 there are 369,184 female and 401,092 males in the country. Bhutan does not have gender policy nor measures for gender discrimination. Human resource recruitment is based on their competence, not based on gender. In Bhutan, as in many countries, it is men who tend to study topics like IT, engineering, electronics, physics, and meteorology more often compared to female. This can cause natural gender unbalance in different tasks.

Recommendations:

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

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

The following actions from the WMO Gender Action Plan[17], have been selected as recommendations to include in the Gender Policy and to be discussed during the gender workshops:

- Increase the participation of women by: (i) identifying and nominating female experts from NMHSs or other national institutions to participate in the work of WMO governance bodies and their working structures and (ii) seeking equality in the composition of delegations to sessions (1.1.1(c) in WMO Gender Action Plan).
- Strive for gender balance, including in management and working structures (1.1.2(c) in WMO Gender Action Plan).
- Encourage and support female networks of experts (1.1.3(c) in WMO Gender Action Plan).
- Designate NMHS gender equality focal points (1.3.4(c) in WMO Gender Action Plan).
- Develop monitoring mechanisms at the national level by (i) adapting the WMO gender monitoring indicators or (ii) using an existing national framework (2.4.1 in WMO Gender Action Plan).
- Include gender equality (including the WMO Policy, GAP, link to online trainings and gender webpage, information on key activities) in the induction of new PRs and NMHS staff (3.1.4(c) in WMO Gender Action Plan)
- Develop the capacity of NMHS staff on unconscious bias, inclusive leadership, gender mainstreaming, and gender responsive service delivery through trainings and workshops (3.1.5(c) in WMO Gender Action Plan)
- Offer internships to young professionals, especially female, and secondments of staff from meteorological services on a rotational basis. (3.4.2(c) in WMO Gender Action Plan)
- Engage with international organizations field offices, such as UN Women, UNDP, etc. (5.1.4 (c) in WMO Gender Action Plan)
- Conduct research and provide the Secretariat with case studies, stories and examples of gender mainstreaming, including in service provision, for

the development of a compendium of good practices (5.3.3(c) in WMO Gender Action Plan).

- Develop and disseminate communication materials (i) highlighting the role of women in meteorology, hydrology and climatology, (ii) promoting female role models, and (iii) advocating for gender responsive weather, hydrological and climate services (5.1.3(c) in WMO Gender Action Plan).

- (i) Customize weather and climate services to the particular needs and roles of women and men and (ii) Provide education and training to target female users in accessing and using weather and climate information and products (7.3.1(c) in WMO Gender Action Plan).

Recommendations on activities, consultations, and areas of collaboration for the implementation of the Plan to ensure active CSOs participation and promotion of gender balance and gender opportunities.

CSO Participation

To include CSO engagement during and after the SOFF implementation phase will bring mutual benefit and grounds for sustainable operation. The following actions are recommended to ensure that CSO's are regularly consulted during the entire length of the programme cycle:

- Conduct stakeholder engagement workshops on the implementation of the SOFF project deliverables (observational data exchange to support weather/climate and water services and products), bringing together key stakeholders and CSOs, to involve and collaborate with the NCHM and the SOFF project team from the early onset, as well as ensure the stakeholders are consulted on operations and maintenance.
- Organise awareness-raising activities for the community by engaging the Red Cross, i.a. to prevent vandalism.
- Organise high level dialogues on benefits, co-production, and ownership of the new national GBON infrastructure.
- Organize stakeholder engagement workshops/consultations including, where possible, local civil society organizations (CSOs) focused on women's empowerment (e.g. with RENEW)
- Ensure that 50% of the NCMH staff and stakeholders participating in consultations with civil society organizations are women.

Module 5. Risk Management Framework

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

WMO recommends its members to establish a Quality Management System (QMS) to ensure that customer and end user requirements are met (WMO no. 1100[1]). So far NCMH hasn't implemented QMS, although SOPs (Standing Operating Procedures) exist for all main functions of the NCHM. SOPs need to be updated to include upper air radio sounding, as it is new technology in NCHM and country.

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

The following summarises overarching key risks for investment and operation phase to be carefully considered and handled by IE, beneficiary, and peer adviser.

Potential key risks for investment and operation during SOFF implementation	**Mitigation measures and responsibilities**	**Monitoring and evaluation**
Investment phase		
Insufficient technical specification of items and other quality criteria in tender process. Price cannot be the only criteria for choosing a vendor and compatibility with existing infrastructure is crucial.	Seamless collaboration between IE (responsible for tender process), peer adviser (responsible for technical sensor specification), beneficiary (responsible for supporting in setting up quality requirements and technical specifications to best support the needs in the country)	IE (on request with support from beneficiary and peer adviser) will be responsible for monitoring and evaluating the quality of documents before opening the tender process.
Incompatible or suboptimal equipment chosen in bidding process	Seamless collaboration between IE (responsible for tender process), peer adviser (responsible for technical sensor specification), beneficiary (responsible for supporting in setting up quality requirements and technical specifications to	IE (on request with support from beneficiary and peer adviser) will be responsible for monitoring and evaluating the quality of documents before opening the tender process.

	best support the needs in the country). **In addition of technical feasibility, also compatibility and synergies with existing infrastructure needs to be considered.**	
Failure in tax exemption when importing the goods	Before shipment IE will be responsible to ensure that shipper and freight agent are aware of the tax exemption process in Bhutan border. Beneficiary is responsible for providing all required documentation, information, and support for the tax exemption declaration process.	IE will be responsible for following up the shipment process until it has been tax exempted in the Bhutanese customs.
Operation phase		
Decrease in funding support for operations	Sufficient lifecycle planning, and subsequent, annual budget planning combining different funding source (SOFF, budget, UNEP support, cost-recovery)	IE and NCHM are responsible for monitoring and taking required corrective actions.
Insufficient staff competence, changes in staff members	The beneficiary develops an internal training programme including the criteria of competence requirements for technical staff. A duplication of skilled staff members for critical tasks.	The management of beneficiary organizations is responsible for monitoring and evaluation.
The management of observation and data processes is insufficient.	Frequent follow up how strategic goals and annual targets have been achieved.	The management of beneficiary is responsible for reviewing and monitoring that work has been conducted as expected

Station security is not sufficient	Bhutan is safe country, and main reason for fencing is to keep wild life away of stations. NCHM staff will be available most of the time at station, especially around sounding times. Natural hazards, apart from lightning, are not expected to cause damage to equipment. Equiment is checked regurarly according to maintenance plan.	Security of station is monitored by NCHM and proper actions taken as necessary.
Natural hazards: Earthquake	Himalayan area is prone to earthquakes, but major quakes are rare in Bhutan area. Possibility of earthquake is addressed in civil works as best practices.	
Natural hazards: Land slides and GLOF	Landslides and GLOs are possible, but location of station is selected so that they are not expected to cause damage.	

Module 6. Transition to SOFF investment phase

This module involves supporting the beneficiary country and the IE in preparing the Investment phase funding request based on the recommendations provided in the Plan.

Please provide any additional recommendation relevant for the translation of the National Contribution Plan into an Investment Phase Funding Request.

Summary of GBON National Contribution Plan

Components	Recommended activities
Module 2. GBON business model and institutional development	1. The business model of NCHM relies on fully public model. The financial status of the NCHM to carry out GBON compliant operations consists of Governmental budget funding, international development collaboration projects and financial support from UNEP (IE) for station maintenance (including financial support for maintenance missions). To systematically justify budget and project funding allocations for maintenance, replacing sensors at stations, NCHM must develop lifecycle plan for AWS and radiosounding station. Lifecycle plan will support sufficient financing for timely maintenance.
	2. Evaluate co-operation opportunities with nearby countries with similar equipment to find out if some maintenance could be done more regionally
	3.
	4.
	5.
Module 3. GBON infrastructure development	1. The GBON compliant observation infrastructure and subsequent data pipeline is recommended to build and develop by following WMO guidance, utilizing the existing infrastrucutre and good practices, enhancing operation processes and SOPs in the beneficiary organization, as well as by benchmarking equivalent operations in other organizations.
	2. Install GBON-eligible automatic weather station to Tsirang Damphu
	3. Install a new upper air station (in Tsirang)
	4. Implement WIS2.0 compliant data sharing integrated to existing data management system.

	5. Establish a spare part stock, design calibration procedures and training of the staff
	6.
	7.
	8.
Module 4. GBON human capacity development	1. The gaps in capacity of NCHM staff have few main reasons; lack of workforce, continuous changes in staff and resources for the trainings. There is no meteorological training in Bhutan, so forecasters need to study abroad. In specific job/task related areas challenges are the installation, maintenance, and calibration of observation networks. In a similar way, a capacity gap exists in automatic data transfer, handling, and quality control. The staff turnover is also an issue in NCHM which causes continuous need for an internal training of capacity. The main gap in human capacity development includes resources for external trainings. The enhancement of the competence building process is recommended as an urgent and very first task which is supported with specialized trainings
	2. Increase number of staff to meet challenges mentioned in #1.
	3. Increase training activities on impact-based forecasting, NWP, calibration, aviation, radar, and satellite operation, product generation and relevant IT-topics. Map opportunities to collaborate with neighbouring countries or institutions related to training on maintenance and calibration of instruments.
	4. Include training on data transfer and data quality control and assurance, ICT system operations and data management.
	5. Increase capacity building and allocate budget for media and communications training, to better be able to answer

	the growing needs and requests from the media and other news outlets.
	6. Conduct QMS training to ensure QMS is fully implemented in the NCHM
	7. Ensure that CSO's are regularly consulted during the entire length of the programme cycle
	8. Conduct a gender analysis and draft a new organizational Gender Policy, with specific actions that are measurable and regularly monitored, that are based on the WMO Gender Action Plan. Work closely with local CSOs to implement the new Gender Policy and action plan. Clarify the responsibilities of the NCMH' existing Gender Committee and designate an active Gender Equality Focal Point
	9. Ensure a quota is enforced of 50% of women participating in the capacity building activities and 50% of women participating in consultations with civil society organizations
Module 5. Risk Management	1. The SOFF Risk Management Framework should be monitored and updated regularly to ensure that it is up to date, and any new risks and mitigation measures should be added to the matrix as soon as they surface.
	2.
	3.
	4.
	5.
Module 6. Transition to SOFF investment phase	**The transition to SOFF investment phase is recommended to carry out by following the Gap Analysis and National Contribution plan** (this document). The peer adviser, IE and beneficiary have together filled in funding request for SOFF implementation phase. This supports the best coordination in the transition phase.

Annexes (if any)

Report completion signatures

Peer Advisor signature

HARRI PIETARILA, Director, Expert Services

Beneficiary Country signature

Director
PR of Bhutan with WMO
National Center for Hydrology & Meteorology
Royal Government of Bhutan
Thimphu : Bhutan

WMO Technical Authority signature