COUNTRY HYDROMET DIAGNOSTICS

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

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National Centre for Hydrology and Meteorology (NCHM), Royal Government of Bhutan

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SOFF Systematic Observations Financing Facility — Weather and climate data for resilience

WORLD METEOROLOGICAL ORGANIZATION

Alliance for Hydromet Development

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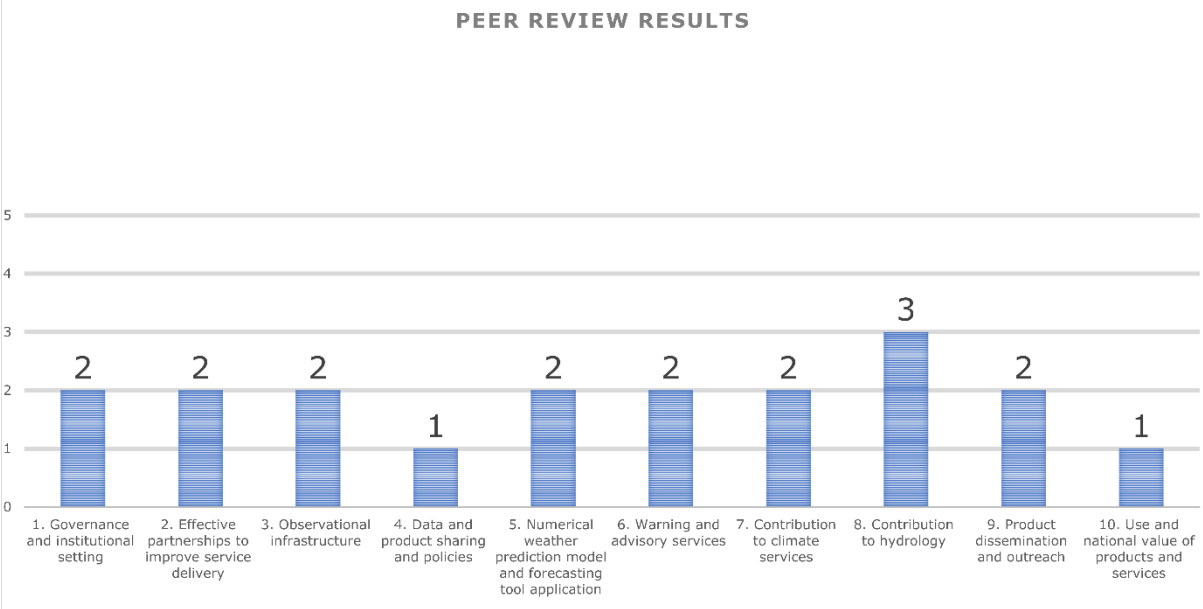
Abbreviations

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

Executive Summary

The National Centre for Hydrology and Meteorology of Bhutan (NCHM) has undergone major development activities in the recent decade and managed them sustainably. Operations have been extended to operate 24/7, production processes have been automated, and NCHM has transitioned into an independent governmental authority. Despite being a small country with limited resources, the NCHM is developing its value chain through well-considered and effective activities.



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

The main capacity gaps identified by this Country Hydromet Diagnostics report are as follows:

- *Governance and institutional setting:* Further inter-institutional cooperation is needed in relation to air quality, water resource assessments, and climate change activities.
- *Effective partnerships to improve service delivery:* Formal MoUs are missing with national partners.
- *Observations:* NCHM has inadequate resources to operate and develop observation networks.
- *Data management:* NCHM has inadequate resources to operate and develop data management solutions.
- *NWP and forecasting tools:* NCHM has inadequate resources to operate and develop NWP and forecasting tools.
- *Warnings:* NCHM has inadequate resources to operate and develop warnings and dissemination channels.
- *Climate services:* The establishment of a National Framework for Climate Services (NFCS), currently missing, is important to enhance NCHM's position. Continuation of current climate services should be prioritized. By enhancing of quality control of observations, the current services could be automatized and tailored services could be developed.
- *Hydrology:* NCHM lacks infrastructure and skills to improve the skills of NWP required for hydrological forecasting and modelling.
- *Product dissemination:* NCHM has inadequate resources to develop warnings and dissemination channels.
- *Use and national value of products and services:* There are gaps in cooperation and collaboration among different sectors. Public trust and confidence on hydromet value chain is another challenge.

Chapter 1: General information

Introduction

Bhutan is a landlocked South Asian country situated in the Eastern Himalayas, between China in the north and India in the south, covering about 38,394 km^2 with highly mountainous topography. The population of Bhutan is 777,486 people (in 2021).

As the World Bank Climate Change Knowledge Portal reports[1]:

"Bhutan's climate is diverse due to dramatic variations in elevation. The Duars Plain tends to be hot and humid; the Lesser Himalaya region is often cooler; while the areas in the Greater Himalayas are closest to that of alpine tundra. The southern belt of the country at the foothills of the Himalayas (150-2,000 meters [m]) above sea level) has a subtropical climate with high humidity, heavy rainfall, and average temperatures of approximately 15°C-30°C year-round. The central belt is characterized by river valleys (2,000-4,000 m above sea level) with cool winters, hot summers between June and September, and moderate rainfall. The Northern belt consists primarily of snow-capped peaks and alpine meadows (4,000 m above sea level) with cold winters and cool summers. Precipitation ranges widely across the country and occurs primarily during the monsoon season between June and September as well as the pre-monsoon and post monsoon season. The country is also characterized into six agro-climatic regions: alpine, cool temperate, warm temperate, dry sub-tropical, humid sub-tropical, and wet-sub tropical.

There is significant seasonal range in temperatures: the summer months of June – August averaging temperatures of 24°C -29°C, compared to the winter months of December – February which are near 0°C, for the most recent climatology, 1991-2020. Average monthly rainfall follows a similar pattern, in which considerably more rainfall occurs during the summer months (approximately 240 millimetres [mm]) than during the winter months (approximately 90 mm)" (World Bank, 2023).

Moreover, as per UNDP[2]:

"*Around 70% of Bhutan is forested (much of it primary forests), and approximately 49.2% of the country's population depends on farming for their livelihoods (National Statistics Bureau, 2021b). Bhutan's hydropower production—much of which it exports to India—is described as the backbone of the country's economy, and there are early concerns that this resource may be adversely impacted by climate change (RGB, 2009)[3]. With high growth rates in population, unchecked rural to urban migration, increased population density in the towns and cities, rapid increases in imports of cars, and rising demand for fuel wood, roads and building construction, the future suggests many negative effects on environmental assets, which can further expose the population to climate change vulnerabilities*" (UNDP, 2023).

Finally, the NCHM[4] indicates that:

"*The National Centre for Hydrology and Meteorology (NCHM) is an autonomous scientific and technical agency of the Royal Government of Bhutan responsible for understanding*

[1] https://climateknowledgeportal.worldbank.org/country/bhutan/climate-data-historical
[2] https://www.adaptation-undp.org/projects/enhancing-global-environmental-management-bhutans-local-governance-system#:~:text=With%20high%20growth%20rates%20in,environmental%20assets%2C%20which%20can%20further
[3] Royal Government of Bhutan (2009). Strategizing Climate Change for Bhutan. National Environment Commission and United Nations Environment Programme. Retrieved from http://www.rrcap.unep.org/nsds/uploadedfiles/file/bhutan.pdf
[4] https://www.nchm.gov.bt/home/pageMenu/10

the behaviours of atmosphere, its interaction with cryosphere and water bodies, the weather and climate and distribution of country's water resources. It is the nodal agency responsible for generation of information and delivery of products and services on weather, climate, cryosphere and water resources in Bhutan.

The Centre is the designated national focal point of Bhutan with World Meteorological Organization (WMO) and Intergovernmental Panel for Climate Change (IPCC) and other regional organizations dealing with weather and climate" (NCHM, 2023).

CHD methodology

The Country Hydromet Diagnostics (CHD) work was done as an additional output for the Systematic Observations Financing Facility (SOFF) project in Bhutan and it was preceded by preparation of the SOFF outputs National GBON Gap Analysis and Contribution Plan. Work towards these documents served as a good platform to become familiar with topics included in CHD and to identify a practical way to conduct CHD work.

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

- A remote workshop to review gaps in terms of GBON compliance followed by preparing the Gap Analysis document.
- One week-long workshop with NCHM experts including a field trip to survey surface weather stations in Bhutan. The National Contribution Plan document was prepared based on this mission.
- A day-long workshop in Paro to collect information for Country Hydromet Diagnostics (CHD). Invitees included representatives from the following agencies and institutes:
    - Department of Local Governance & Disaster Management, Ministry of Home Affairs (MoHA)
    - Department of Air Transport , Ministry of Infrastructure and Transport (MoIT)
    - Department of Surface Transport, MoIT
    - Bhutan Civil Aviation Authority, MoIT
    - Department of Energy, Ministry of Energy and Natural Resources (MoENR)
    - Department of Environment and Climate Change, MoENR
    - Department of Agriculture, Ministry of Agriculture and Livestock (MoAL)
    - Department of Health, Ministry of Health (MoH)
    - Druk Green Power Corporation
    - Bhutan Power Corporation Limited
    - Sherubtse College, Roya University of Bhutan
    - College of Science and Technology , Royal University of Bhutan

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 National Centre for Hydrology and Meteorology (NCHM) was established in 2016 as an autonomous scientific and technical agency of the Royal Government of Bhutan based on the recommendations of Organisational Development (OD) (RCSC, 2015) approved by the Cabinet letter C3/92/169 dated 25 December 2015, by bringing the sciences of Meteorology, Hydrology and Cryosphere under one umbrella. It is the nodal agency responsible for generation of information and delivery of products and services on weather, climate, cryosphere and water resources in Bhutan.[5] The Center is designated by:

- National Disaster Management Authority (NDMA), as the national hydromet hazard Early Warning Service Provider in the country vide Executive Order (C-2/2019/369) dated December 5, 2019 in accordance with Section 108 of the Disaster Management Act of Bhutan 2013.
- Bhutan Civil Aviation Authority (BCAA) as the aeronautical meteorological services provider within Bhutan vide letter BCAA/ANS-MET/010/196 dated August 29, 2017 in pursuant to the Section 13 (1) (e) & 57 of the Civil Aviation Act of Bhutan 2016.
- Ministry of Foreign Affairs as the national focal point for the World Meteorological Organization (WMO) and the Intergovernmental Panel for Climate Change (IPCC). The Head of the Center is designated as the Permanent Representative (PR) of Bhutan with the WMO.

The legal mandates of NCHM are derived from the following legal Acts and Policies:

a. The Constitution of the Kingdom of Bhutan
b. Water Act Bhutan (2011)
c. Disaster Management Act of Bhutan (2013)
d. Civil Aviation Act of Bhutan (2016)
e. Climate Change policy of Kingdom of Bhutan (2020)
f. Hydromet Policy of Kingdom of Bhutan (2023)

Governance and Reporting

NCHM as the National Centre has functional autonomy and the Head/Director oversees administration and management of the Centre. The Head/Director of the Centre reports to the Secretary of the Ministry of Energy and Natural Resources. The oversight on strategic policy and governance of the Centre is guided by the Secretary of the Ministry of Energy and Natural Resources (MoENR).

Scientific and Technical Advisory Council (STAC)

Being a scientific and technical agency, NCHM has a Scientific and Technical Advisory Council (STAC) approved by the Cabinet to advise and provide oversight to the Centre in implementation of its technical mandates in weather, climate, water, cryosphere and related sciences, as well as their related applications and services.

The Head/Director or Specialist from the following climate sensitive sectors is appointed by the Cabinet as an ex-officio member of the STAC

[5] https://www.nchm.gov.bt/home/pageMenu/10

a. The Department of Local Governance and Disaster Management, Ministry of Home Affairs

b. The Department of Energy, Ministry of Energy and Natural Resources

c. The Department of Public Health, Ministry of Health

d. Department of Human Settlement, Ministry of Infrastructure and Transport

e. President, College of Science and Technology, (CST), Royal University of Bhutan

f. The Head/Director, NCHM as a Member Secretary

Mandate

NCHM is mandated to provide scientific and technical services in hydrology, water resources, meteorology, climatology, and cryosphere to ensure the safety and socio-economic well-being of society, and to support national and international needs.

The mandates are listed as:

1. Planning and operation of national hydrological (surface and sub-surface) and meteorological (surface and upper air) observation network and its communications systems required for monitoring and data collection.
2. Study and monitor cryosphere (snow, glaciers, glacier lakes, permafrost) and its associated risks to implement appropriate mitigation and adaptation measures.
3. Study and provide public weather services, severe weather warnings, meteorological data management, aviation meteorological services, agro-meteorology and climate change information and services.
4. Study and carryout water resources assessment, hydrological forecasting, hydrological data management, dissemination of hydrological data and information and provide early warning services related to floods and glacial lake outburst floods (GLOF)
5. Assessment and mapping of hydro-meteorological and GLOF hazards at the sub-basin and basin level.
6. Capacity and human resources development through training and education.
7. Application of science and technology in operational meteorology, hydrology and cryosphere for development of services and products.
8. Promote collaboration and institutional linkage with national, regional, and international organizations related to weather, climate, hydrology, cryosphere, and water resources for exchange of data, research, and technology transfer.

Functions

1. Establish and operate National Observation network and telemetry system for weather, climate, cryosphere, hydrology and water resources;
2. Maintain national database (repository) of hydrology, meteorology, cryosphere and related environmental data and information
3. Provide Public Weather Services (PWS), climate services, agro-meteorology, climate projections and aviation meteorological services.
4. Provide hydrological forecasting (flow and flood), and water resource assessment. Assessment and mapping of hydro-meteorological and GLOF hazards and provide Early Warning Services.

5. Study and monitoring of snow, glaciers and glacial lakes and assess associated risks for mitigation and adaptation.
6. Promote and conduct research on cryosphere, meteorology (weather and climate), hydrology and water resources;
7. Enhance human resources development and professional capacity in the field of hydrometeorology and cryosphere services;
8. Promote and facilitate standardization of hydro-met instruments, methods of observation and recording
9. Establish collaboration and linkage with national, regional and international institutions

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

"Institutional Strengthening and Modernisation of hydro-meteorological and Multi-hazard Early Warning Services in Bhutan- A road map" is under development. It will include both short- and medium-term plans for the development of the NCHM.

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

The overall budget of the NCHM in 2019-2020 was 165,440,000 BTN (approx. 2 M USD). In NCHM all salaries and overhead costs come from the government budget. However, donors cover about 70% of investments. NCHM also receives funding from the Government of India (GoI) through the Central Water Commision (CWC) under the bilateral flood Warning Program. It covers cost incurred for the monitoring, collection and exchange of flood information and water level data for a few selected sites. In 2022, the funding from government of India was Nu. 36.839million.

The governmental budget allocation for NCHM has been steadily increasing in the past 5 years. A cost recovery mechanism is not yet in place, but NCHM plans to study and implement costs recovery from selected sectors as per the provision of recently approved Hydro-met Policy of the Kingdom of Bhutan (2023).

Recent cost-benefit analysis of weather and climate services in Bhutan indicated that the overall net present value cost-benefit ratio is 3.1.[6]

Regarding needs of the NCHM to cover their responsibilities, there is lack of human aquade human resources. These include especially the lack of ICT expert staff capacity in general and resources for maintaining and develop the weather model (WRF). Moreover, the forecast verification procedures are also absent.

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.

The number of permanent staff in NCHM is 170 in total. The following picture shows the organization of NCHM.

[6] https://www.nchm.gov.bt/attachment/ckfinder/userfiles/files/DHMS_SocioEconomicStudy_Bhutan%20(1).pdf

The current gender balance includes about 33% female and 67% male staff members. Out of the total employees, 82% of the employees are technicians with either certificate or diploma, 15% are professionals with either graduate or post graduate degree while others occupy management positions. Key challenges include lack of professionals in hydrometeorology in the market and limited number of graduates with relevant qualifications available for recruitment. Moreover, NCHM lacks resources and infrastructure to build skills and provide refresher training for both technicians and professionals. Areas for capacity development include Numerical Weather Prediction (NWP), forecasting and ICT. Retaining trained and experienced staff has also been a challenge for NCHM.

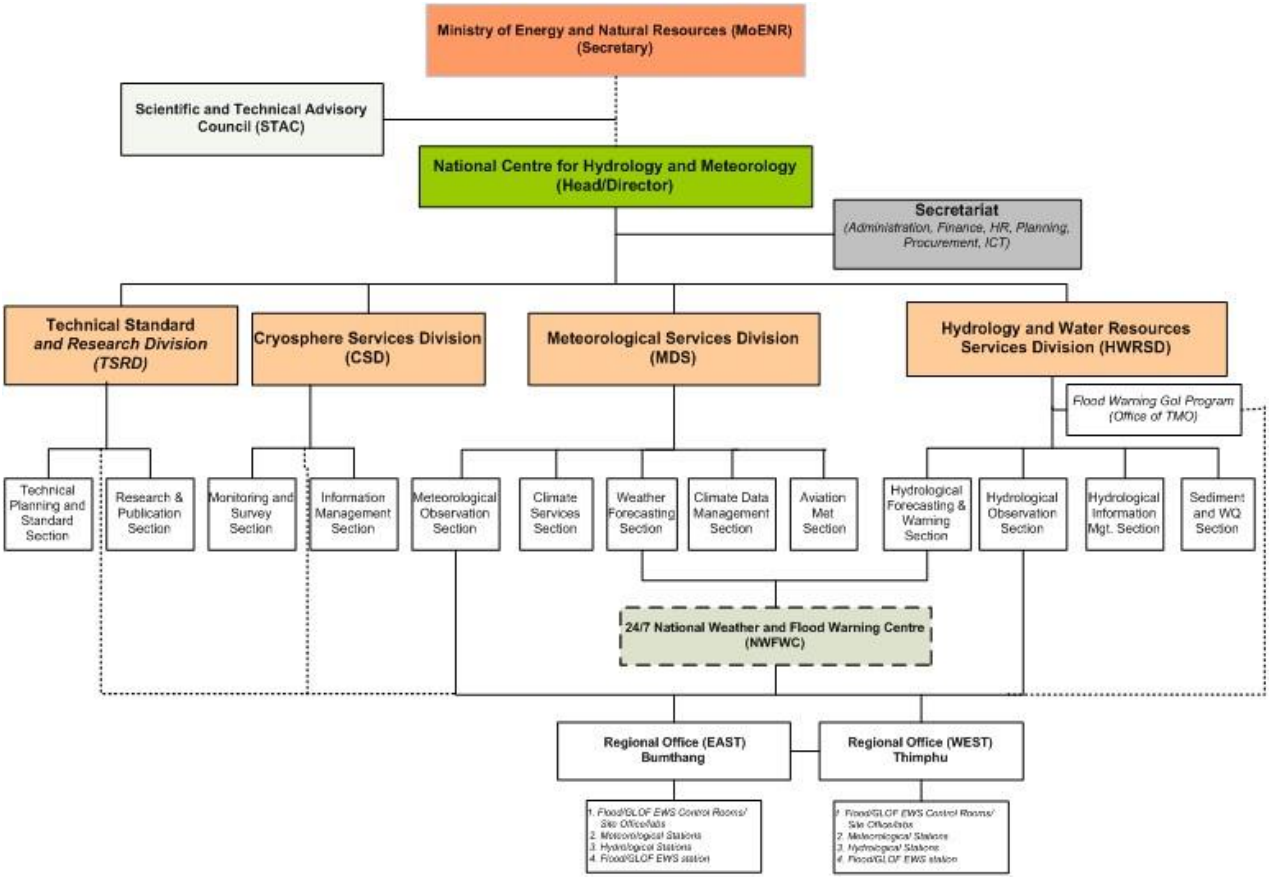


Figure 1 Organogram of NCHM (RCSC/HRMD/7/2021/0411, dated August 5, 2021)

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

NCHM has a vast and strong track record in implementing internationally funded hydrometeorological projects. Additionally, the organization maintains strong partnerships with national and international organizations to ensure sustainable and impactful results from projects. The following list presents the recently completed and on-going projects in which NCHM is involved:

- Government of Finland - Strengthening Hydro-Meteorological Services for Bhutan (SHSB, 2013-2016)

- JICA Technical Cooperation Project on Capacity Development of GLOF and Rainstorm Flood Forecasting and Early Warning in the Kingdom of Bhutan (2013-2016)
- LDCF GEF/UNDP NAPA Project "Addressing the Risk of Climate-Induced Disaster through Enhanced National and Local Capacity for Effective Actions" (2014-2018)
- NORAD through ICIMOD "Cryosphere Monitoring Programme to Bhutan (CMP-B, 2014-2018)
- World Bank supported Hydromet Services and Disaster Resilience Regional Project (HSDRRP, 2016-2021)
- WMO – Developing Capacities for effective climate services in Bhutan (2020-2022)
- JICA Phase II Project for Capacity Enhancement of Meteorological Observation, Forecasting and Flood Warning, for Disaster Preparedness and Response in Thimphu and Paro River Basins (2020-2025)
- Green Climate Fund/UNDP Bhutan for Life- Supporting Climate Resilience and Transformational Change in Agriculture Sector in Bhutan (2020-2025)
- World Bank supported project "Strengthening Risk Information for Disaster Resilience in Bhutan (RIR, 2021-2025).
- Bhutan for Life Project (2013-2032)

Summary score and recommendations for Element 1

The summary score of NCHM for this element is 2 on the CHD scale, reflecting "Effort ongoing to formalize mandate, introduce improved governance, management processes and address resource challenges.".

Strengths

Meteorological and hydrological activities in Bhutan have been mandated to NCHM, which means that there are no overlapping observation networks or hydro-meteorological service providers. All three sciences of meteorology, hydrology and cryosphere are under the same administration, providing opportunities for synergies.

Gaps and recommendations

Currently some 70 % of the investments are covered by the funding from the external donors and it possesses risks to the sustainability of the operations. By developing its services and income the NCHM could downsize this proportion and increase the proportion of self-funded investments. Moreover, number and availability of qualified staff in different fields is currently an issue and it should be addressed.

Element 2: Effective partnerships to improve service delivery

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

NCHM is collaborating and providing support to all the line agencies, universities, and other users, however very few official MoUs or formal agreements on service provision and collaboration are in place. In addition, though partnerships exist between NCHM and local governments related to delivery of information and services, however there are no formal agreements or memorandums for this.

Although meteorological and hydrological observations stations are located within the administrative boundary of Local Governments (LG's), observations are conducted by permanent staff and temporary staff recruited by NCHM with no direct support from LG's themselves. There are neither agreements nor memorandums with LG's on operations and data sharing and NCHM only share data upon request.

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.

At the national level, NCHM work in partnership with all the climate sensitive sectors, such as agriculture, livestock, forest and park services, water, and energy (namely hydropower), disaster management, health etc. NCHM has a MoU signed with colleges under the Royal University and Department of Forest and Park Services for collaboration in research, exchange of experts and data and use of scientific facilities and observations. NCHM participates in several multi-sectoral national forums and climate change and disaster management projects with regular meetings with disaster management authorities, climate sensitives sectors and NGO's.

At the regional level, NCHM work with regional organisations such as ICIMOD, RIMES, BIMSTEC Centre for Weather and Climate (BCWC). BCWC was established in India under the BIMSTEC to promote scientific capacity building in weather and climate research. The Centre also works with other NMHSs in South Asia and Southeast Asia in the WMO Regional Association II (RA-II) such as Indian Meteorological Department (IMD), Japan Meteorological Administration (JMA), Korean Meteorological Agency (KMA) among others. Moreover, the South Asian Hydromet Forum (SAHF) was established under an initiative led by the World Bank and WMO to promote regional collaboration and exchange of data and services. The SAHF Executive Council is chaired by Director General, Indian Meteorological Department (IMD), India and co-chaired by Director, NCHM, Bhutan. Through SAHF, NCHM works in partnership with all the NMHS's in South Asia under the umbrella of WMO.

At the international level, NCHM is the designated national focal point with WMO and IPCC and the Head of NCHM is designated the PR of Bhutan with WMO. Thus, NCHM actively works with WMO, IPCC and with ICAO as the Aviation Meteorological Services Provider (AMSP) in Bhutan.

Currently, there is limited engagement in the Public-Private partnership in the areas of supply of instruments and development of systems.

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

No long-term partnerships are in place, however NCHM is involved in many project-based partnerships with main international climate funders such as the World Bank, the Asian Development Fund, UN Development Programme, UN Environment Programme, FAO, USAID, as well as with the Government of India, Finland, Norway (NORAD), Japan (JICA), South Korea (KMA), GEF, GCF, RIMES and ICIMOD. The future opportunities include for example CREWS and SOFF.

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.

In recent years, all projects have included a component on developing service provision, most notably the following:

- Flood (including GLOF) Early-Warning System was developed in two major river basins in central Bhutan through JICA project and the project includes components from data collection to information dissemination
- The Finnish-funded ICI -project SHSB improved weather forecasting capacity through installation of WRF and several different services were introduced including new product formats
- There is an on-going World Bank Disaster Risk -project that has activities related to improvement of medium range forecasting and a hydro met policy of Bhutan has been formulated to enhance service delivery.

Summary score, recommendations, and comments for Element 2

The CHD Element 2 score is 2, reflecting "Limited partnerships and mostly excluded from relevant finance opportunities".

Strengths

Partnerships with WMO, IMD, BCWC, RIMES, and others provide the mechanism for proving critical services required in early warning, weather and climate, hydrology and cryosphere services.

Gaps and recommendations

No long-term collaboration and MoU's exists for sustaining hydro-meteorological services, and they should be developed. Bhutan is not a member of the Early Warning for All initiative of the WMO and it should be included as a member urgently. Dedicated collaboration and projects and funding as well as commitments are lacking for activities such as early warning, flood forecasting, glacier monitoring, climate change impact assessments.

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.

NCHM maintains a geographically dense network containing both manual and automatic surface weather observation stations. Although spatial GBON requirements are fulfilled with one AWS, location at Himalaya and mountainous topography of Bhutan requires much denser network. In addition, WMO has expressed interest to have more observations from high altitude stations.

There are no upper air observations currently, but one sounding station is proposed to be funded by SOFF. This station fulfils GBON spatial requirement for upper air soundings, but additional upper air observation may be required for aviation meteorological services.

Current station network consists of 84 AWS and 92 manual stations. However, data from only one station (Tsampa 44517) is currently shared to GTS. However, improved and modernized data delivery to WIS2.0 and GTS networks is proposed by SOFF. If approved, the proposed solution allows technically to share observations from all existing stations to the international distribution.

The existing AWS network is relatively homogeneous as the majority of the stations has been provided by a single (NAPA-)project. In addition, a smaller number of automatic stations were provided by JICA-project, and these are different brand compared to the stations provided in the NAPA-project. The JICA stations are operating, but they are in need for spare parts. Moreover, additional maintenance resources are required to ensure reliable and sustainable observations also in future.

Most of the AWS reports every 15 minutes, which fulfils well the GBON requirement of hourly observations. Manual stations report observations twice a day, at 9 am and 3 pm. The main challenges within the observation network are maintenance resources, including calibration facilities and spare parts. The topography of Bhutan makes maintenance visits also more difficult and costly, as not all the stations are accessible by road.

3.2. Additional observations used for nowcasting and specialized purposes.

Bhutan receives satellite information from Himawari –satellites. Moreover, numerical Weather Prediction data is also available from Japan (GSM model from GTS WIS Tokyo). Bhutan runs their own limited area model WRF in premises with a 72 hours lead time. NCHM currently does not have capacity or equipment to support nowcasting.

NCHM also receives direct model outputs from National Centre for Medium Range Forecasting (NCMRWF), India with a for 10 -day lead time. Currently, NHCM pilots 10-days forecasting with these products.

There are no weather radars or lightning detection network currently in Bhutan.

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

NCHM has very basic capabilities for instrument calibration for only a limited number of parameters. At the time of writing this report only temperature sensors can be reliably

calibrated. The investment proposal for SOFF includes a full calibration laboratory to be set up when new headquarters building is ready to house it (estimated in 2025).

The main gaps with the maintenance are the lack of funds for procuring spare parts, lack of technical skills in maintenance of automatic stations and lack of resources for providing training. Another key challenge in maintenance is the lack of calibration facilities and related resources.

NCHM has not established a Quality Management System (QMS), but it has set Standard Operation Procedures (SOP) to cover the main duties and activities related to the observation network. Reviewing the calibration and maintenance SOPs is recommended, once new calibration facilities are available.

3.4 Implementation of sustainable newer approaches to observations.

There is a lack of capacity (number of people and knowledge capacity) in NCHM to develop and implement newer observation methods and approaches. For example, data delivery to WIS will require support through WMO and by other actors.

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

The current surface observation network contains both automatic and manual stations, however the trend is to move towards automatic observations in the future. It is recommended that the priority will be given to ensure the reliability and operation of the existing AWS network before installing additional stations.

A manual station network does not necessarily mean that observations are managed only manually. With modern technology and data transfer methods, observation data management from stations to database can be unified and automated. In practice, when observation has been conducted and entered the data entry program, it is automatically collected, stored into database, quality controlled and delivered to the users. Therefore, manual observation stations are still valuable, assuming there are enough staff at the station, and they can utilize modern tools.

At the moment, dataflow needs still improvement to fulfil all requirements and appropriate technical solutions are already available.

Summary score, recommendations, and comments for Element 3

The CHD Element 3 score is 2, reflecting "Basic network, large gaps, mostly manual observations with severe challenges and data quality issues".

Strengths

Bhutan has a dense observation network, and it is clearly mandated to NCHM. There are no overlapping networks.

Gaps and recommendations

Observation network and related ICT-infrastructure requires resources and funding for operation and maintenance. Observation data is not shared internationally except from 1 station and more stations should be added to the international data sharing procedure.

Recommendations to improve surface observations, NWP and forecasting tool applications:

- Training on software and hardware component of the Automatic Weather Station, for operation and maintenance of the stations

- Training/workshop for site observers for the operation and maintenance in their designated regions
- Requirement of spare parts and extension toolkits with operational health and safety gears.

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.

Currently only one surface station (Tsampa) data is shared via GTS network from Bhutan. Implementation of WIS 2.0 interface would allow technically sharing data from all existing stations. The spatial GBON compliance is fulfilled with only one surface station in Bhutan. However, taking into account the extremely complex terrain of Bhutan the additional station data in international distribution would bring significant benefits to the data users.

NCHM does not currently operate any upper air sounding stations, however one new station is proposed to be acquired in SOFF. Through the JICA TCP project II, NCHM is currently in the process of establishing a few SYNOP stations for global data sharing. Currently the planned sharing method relies on the GTS, however WIS2.0 interface implemented in SOFF, could be utilized with reasonable effort.

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

There is no specific legislation regarding the collection and exchange of hydrological (and meteorological) data and information with line agencies/public/individual or with other regional and international entities. However, NCHM has a policy which provides an oversight and mandates NCHM to collect and share data to user. NHCM also has a data sharing guideline in place for sharing the data on request[7]. NCHM shares hydromet data freely on request to Government, private sector, students, researchers and other stakeholders. Additionally, NCHM shares flood data to India through the Flood warning section office. One station data is shared through the GTS and data sharing from more stations are underway.

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

The following data and products are in use in NCHM:

Satellite:

- Himawari9

Numerical weather prediction models:

- WRF (operated by NCHM)
- GFS,
- GEM,
- ECMWF (open dataset, through ECCharts)
- ICON
- GSM
- Indian Meteorological Department, NCMRWF 10 day forecast

[7] https://www.nchm.gov.bt/attachment/ckfinder/userfiles/files/Guidelines%20on%20Data%20Sharing%20%20(1).pdf

- Free synoptic charts from Thai Meteorological Department. (https://www.tmd.go.th/en/supportData/synopticChartsEn)

Summary score, recommendations, and comments for Element 4

The CHD Element 4 score is 1, reflecting "poor or lack of policies for data sharing. the score should be re-evaluated when the effects for the new Hydromet policy (approved late in 2023) are seen in practice.

Strengths

Bhutan has a new hydromet policy in place mandating NHCM to provide data and service to the users. NHCM has a data sharing guideline in place to share data on request.

Gaps and recommendations

There is no specific policy for data sharing or open data policy. The mode of sharing data needs improvements. For instance, having a data portal for users to send request and download observational data would be beneficial. The data sharing guideline needs to be updated highlighting details of data format, turnaround time and other relevant information. Lack of ICT skills for operation of models and development of forecast products is an issue and it should be addressed.

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.

NCHM actively utilizes forecast products from various World Meteorological Centers (WMCs) and Regional Specialized Meteorological Centres (RSMCs) to support its service delivery.

The sources for numerical weather prediction (NWP) data in use for forecasting purposes includes both local limited area data (LAM) and some global models (GFS, GEM and GSM). The NCHM runs operationally the WRF model in their own hardware. Moreover, the main global models in use are the NOAA's GFS and Japanese Meteorological Agency (JMA) GSM model. NCHM has the FMI-built meteorological forecaster workstation and forecast production system SmartMet where the data is integrated. The ECMWF data is viewed through the ECMWF website and the DataEX platform of RIMES, however, the NCHM does not have direct ECMWF data access as they do not have the license for it.

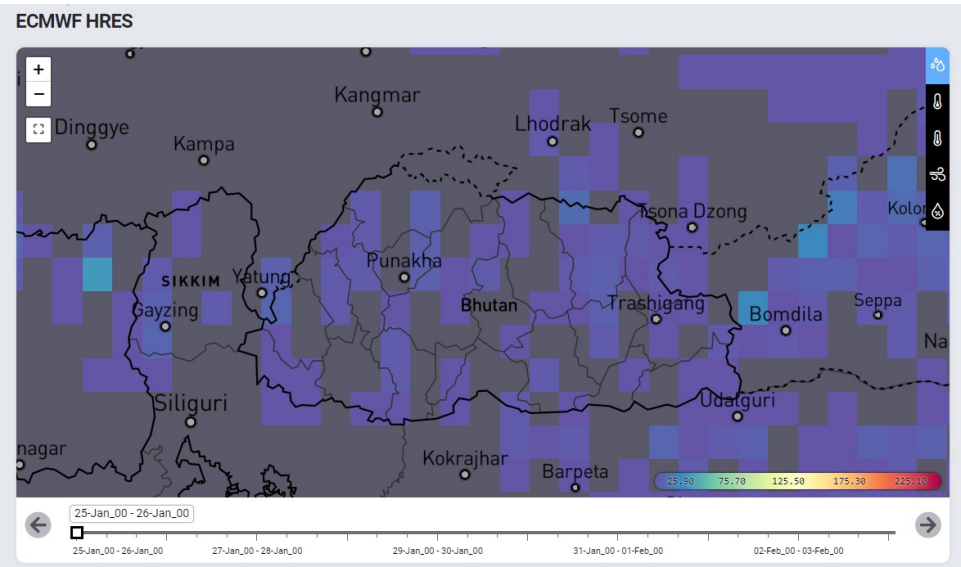


Figure 2 Example of ECMWF data in RIMES's DataEX platform

The available data is used in production of 3-day weather forecast and advisories and the GFS data is also used for boundary conditions of the WRF. NCHM forecasters would need further support to utilize available WMC products further.

The types of forecast products obtained encompass a range of formats, including charts, images, texts, and gridded data. Main challenges with model data are usage fees and large amount of the data. Resolution of the global models is not sufficient for the Bhutan topography due to the complex terrain.

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

NCHM is running the WRF model in 2 domains: 3km & 15 km, with a lead time of 72 hours. WRF is ran every 6 hours based on the latest GFS model data for boundary parameters. By harnessing the capabilities of the NWP model, the NCHM is better equipped to generate forecasts and warnings that are vital for safeguarding Bhutan against weather-related hazards and ensuring the well-being of its citizens and visitors.

However, further development of the model is still needed especially to establish data assimilation and postprocessing measures.

Currently the data assimilation of observation data is absent. Due to extremely challenging terrain a higher resolution model and advanced post-processing techniques are required to improve the forecast data quality. Accordingly with the lack of IT expert staff capacity in general, there is also a lack of human resources to maintain and develop the model. Moreover, the forecast verification procedures are also absent. This is a vital element for monitoring and for the development of forecast data and service quality in NCHM. The data assimilation and verification with WRF model are under study at NCHM and some tests have been performed. However, more work and studies are needed in this field.

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

Not currently in use.

Summary score, recommendations, and comments for Element 5

- The CHD Element 5 score is 2, reflecting "Basic use of external model output and remote sensed products in the form of maps and figures, covering only a limited forecast time range". **Strengths**

NHCM has started running WRF and Common operating platform (COP) for producing forecast products.

Gaps and recommendations

NHCM lack resources to run models more frequently and lack skills to improve the skill of WRF. NCHM do not provide quantitative forecast for most parameters and do not provide probabilistic forecast. There is no verification made for NWP forecast and no data assimilation. NHCM only provide 3-day forecast and needs to work on providing long range forecast products.

Recommendations to improve NWP and forecasting tool applications:

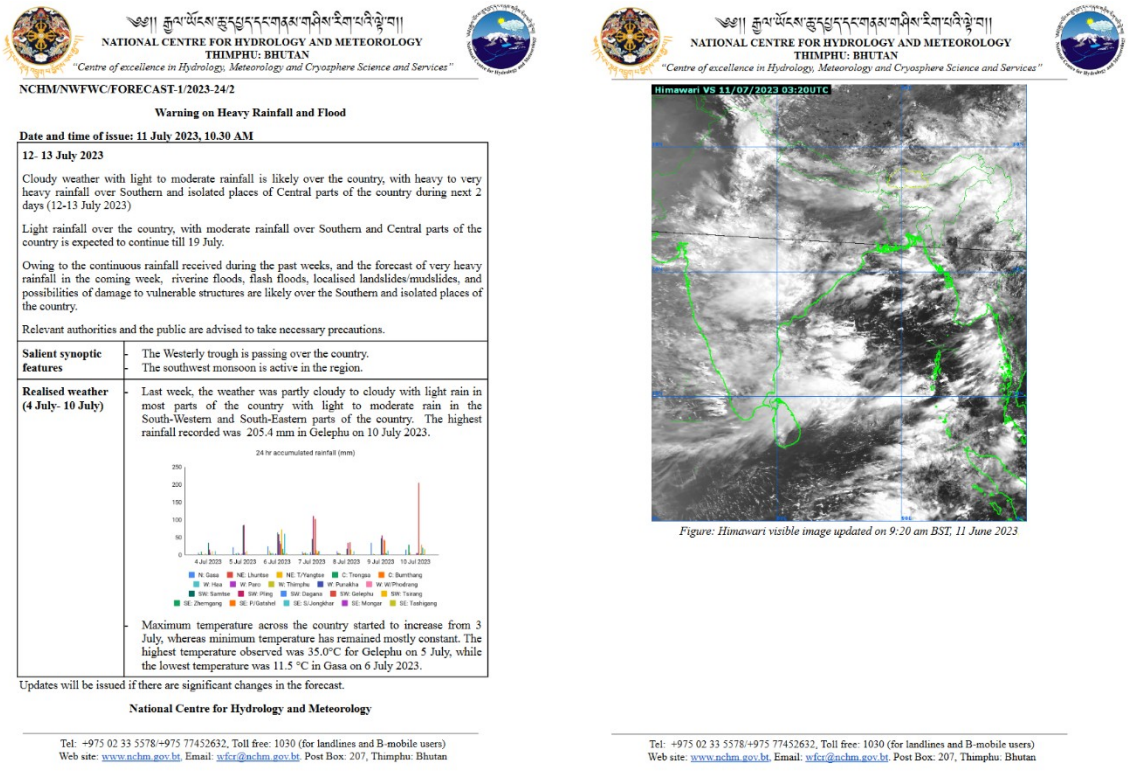
- Basic training on weather forecasting in different time frames and using of ensemble forecasts. Supporting real-time observations for nowcasting purposes and expanding length by global model data.
- Establishment of operational NWP verification system is important for model development and forecasting purposes.
- Strengthening utilization of SmartMet forecaster workstation and forecast production system in forecasting purposes (e.g. model comparison, expert modification, service automatization).
- Establish research co-operation on NWP development including data assimilation.

Element 6: Warning and advisory services

6.1. Warning and alert service cover 24/7.

The warnings issued by NCHM in Bhutan are communicated to the key partners and stakeholders - including for example all governmental agencies and communities - through social media, national broadcasting service and internet. There are also specific Social Media groups in WhatsApp for service delivery for disaster management and transport. However, there are still further needs for developing the early-warnings to be more efficient and user-friendly. For example, the Common Alerting Protocol (CAP) for warning dissemination is currently not being used. CAP would enable improved visual products such as "colour coded" warnings with dedicated thresholds over national warning map. This is described in more detail in chapter 6.3.

Currently Impact Based Forecasting (IBF) is not implemented due to lack of capacity and the development of the IBF methods should be started. Moreover, the lead time of the warning information is still relatively modest, however, NCHM has already started planning and developing a system and process to issue the warnings 24-72 hours before the event with regular updates.



NATIONAL CENTRE FOR HYDROLOGY AND METEOROLOGY
THIMPHU: BHUTAN
"Centre of excellence in Hydrology, Meteorology and Cryosphere Science and Services"

NCHM/NWFWC/FORECAST-1/2023-24/2

Warning on Heavy Rainfall and Flood

Date and time of issue: 11 July 2023, 10.30 AM

12- 13 July 2023

Cloudy weather with light to moderate rainfall is likely over the country, with heavy to very heavy rainfall over Southern and isolated places of Central parts of the country during next 2 days (12-13 July 2023)

Light rainfall over the country, with moderate rainfall over Southern and Central parts of the country is expected to continue till 19 July.

Owing to the continuous rainfall received during the past weeks, and the forecast of very heavy rainfall in the coming week, riverine floods, flash floods, localised landslides/mudslides, and possibilities of damage to vulnerable structures are likely over the Southern and isolated places of the country.

Relevant authorities and the public are advised to take necessary precautions.

Salient synoptic features	- The Westerly trough is passing over the country. - The southwest monsoon is active in the region.
Realised weather (4 July- 10 July)	- Last week, the weather was partly cloudy to cloudy with light rain in most parts of the country with light to moderate rain in the South-Western and South-Eastern parts of the country. The highest rainfall recorded was 205.4 mm in Gelephu on 10 July 2023. 24 hr accumulated rainfall (mm) - Maximum temperature across the country started to increase from 3 July, whereas minimum temperature has remained mostly constant. The highest temperature observed was 35.0°C for Gelephu on 5 July, while the lowest temperature was 11.5 °C in Gasa on 6 July 2023.

Updates will be issued if there are significant changes in the forecast.

National Centre for Hydrology and Meteorology

Tel: +975 02 33 5578/+975 77452632, Toll free: 1030 (for landlines and B-mobile users)
Web site: www.nchm.gov.bt, Email: wfcr@nchm.gov.bt, Post Box: 207, Thimphu: Bhutan

NATIONAL CENTRE FOR HYDROLOGY AND METEOROLOGY
THIMPHU: BHUTAN
"Centre of excellence in Hydrology, Meteorology and Cryosphere Science and Services"

Figure: Himawari visible image updated on 9:20 am BST, 11 June 2023

Tel: +975 02 33 5578/+975 77452632, Toll free: 1030 (for landlines and B-mobile users)
Web site: www.nchm.gov.bt, Email: wfcr@nchm.gov.bt, Post Box: 207, Thimphu: Bhutan

Figure 3. Warning issued at the NCHM web site and shared in the NCHM's Facebook account.

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

The hazards for which NCHM is currently issuing warnings are as follows:

- Heavy rain,
- Gusty wind

- Tropical cyclone
- Snowfall
- Glacial Lake Outburst Flood
- Flash floods and riverine floods

There is no implementation of Impact Based Forecasting (IBF). It is recommended that IBF will be implemented in pilot sites with collaboration with other relevant agencies. The list of the warned hazards seems to be relevant for the hazards occurring in Bhutan; however, it could be expanded in the future to also cover for example forest fires, drought (including long term dry days), heat waves, icing, pest, and disease. Moreover, the lead time of the warning information should be increased. Bhutan is a country with an extremely difficult terrain and the actions based on the warning information may take longer time than in most of the other countries. This should be taken into account when developing the warning services of the NCHM.

The NCHM is evaluating warnings after every event but there is no external evaluation in place. Moreover in 2022 NCHM made a general survey on their services, however no specific surveys are conducted solely for early warning services. Feedback on early warning services are included as a part of surveys conducted for general services.

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.

Currently Bhutan does not use CAP format in issuing warnings, and it is recommended to be implemented alongside with a suitable system and software, capable of CAP formatted early-warning production. In addition, the impact-based forecasting procedures and services are yet to be developed. However, there are standard operating procedures developed related to Flood and glacier lake outburst floods, which creates a decent background of developing the services further.

Moreover, the Disaster Contingency Plan is in operation, and it includes a general Terms of Reference for actions; hydropower projects have disaster risk plan including SOP, but NCHM is not included [8]. Therefore, these Disaster Contingency Plans have to be improved and further implemented.

Summary score, recommendations, and comments for Element 6

- The CHD Element 6 score is 2, reflecting "Basic warning service is in place and operational but with limited public reach and lacking integration with other relevant institutions and services". **Strengths**

NCHM has experience in operating early warning systems and providing services, especially with GLOF. There is a good collaboration with stakeholders for dissemination of information and services.

Gaps and recommendations

Not all areas or basins are covered in providing Early Warning Services. Lack of resources in operation of EWS infrastructure and dissemination channels. NHCM needs to venture into providing forecast based early warning services for flood and impact-based forecast.

[8] https://www.nchm.gov.bt/attachment/ckfinder/userfiles/files/sop%20for%20amochhu.pdf

Lack of capacity and human resources for operating and developing modern early-warning system, is currently also a challenge at the Centre.

Recommendations to strengthen warning services and to achieve objectives of the Early Warning for All Initiative by 2030:

- Availability and utilization of existing technical facilities should be strengthened strongly to establish more reliable and timely warning service. Technical assistance and capacity building are essential to achieve these.
- NCHM should promote MHEWS e.g. by harmonizing dissemination of weather and flood warnings. The CAP format for issuing and disseminate weather warnings should be operationalized.
- Encourage piloting of new warnings and developing threshold levels for different hazardous phenomena in collaboration with stakeholders and in research co-operation
- More lead-time for the warnings is needed: The households are very scattered and therefore reaching of the population with the warning information might be difficult.
- Impact Based Forecasting methods should be developed.
- Strengthened and regular co-operation with authorities connected to DRR. Establishment of an annual user survey.
- Improvement of last mile information dissemination utilizing digital channels.
- Improving using of satellite and remote sensing information in monitoring the weather and hydrological situation (especially important for flood and glacier monitoring).

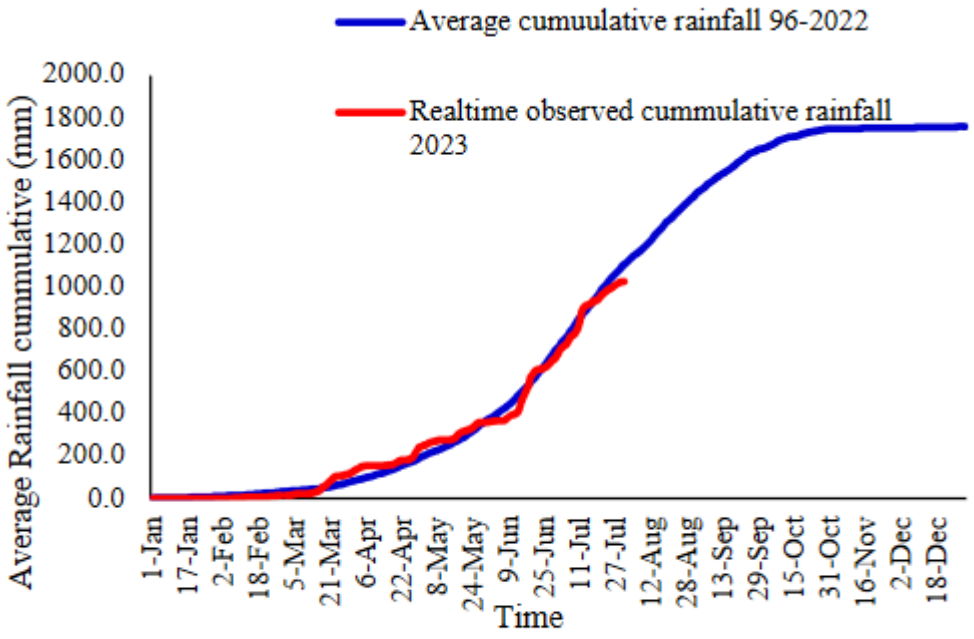
Element 7: Contribution to Climate Services

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

NCHM is organizing an annually the National Climate Outlook Forum (NCOF) meeting and stakeholder workshop related to climate service provision, but a National Framework for Climate Services (NFCS) is not yet drafted or established.

Normally NCHM is publishing annual monsoon outlook and monthly climate summaries on their website. Monthly climate summaries include rainfall, maximum and minimum temperature maps produced through the altitude corrected kriging interpolation method. In addition to climate service production the NCHM prepared the first climate change projection to Bhutan in 2021. According to the socio-economic study[9] implemented in 2014 long-term climatological data would be especially important for design of hydropower, agriculture, tourism, DRM and water management.

RIMES has developed climate service toolkit for agriculture, however it is in limited use in Bhutan. Tailored services for agriculture are planned to be developed develop under ongoing project activities, however the detailed activities and products are not specified yet. Existing Climate Data Management System (CDMS) and Smartmet server are in use to support basic climate service provision, e.g. providing single database for all weather (and climate) observations, but for example adequate quality control or climate monitoring tools are missing.



Observed rainfall (July, 2023) against the long-term average (1996-2022)

Figure 4. Monsoon monitoring 2023.

[9] Pilli-Sihvola, K., Namgyal, P. and Dorji, C., 2014. Socio-Economic Study on Improved Hydro-Meteorological Services in the Kingdom of Bhutan. Finnish Meteorological Institute, Department of Hydro.Met Service, Bhutan.

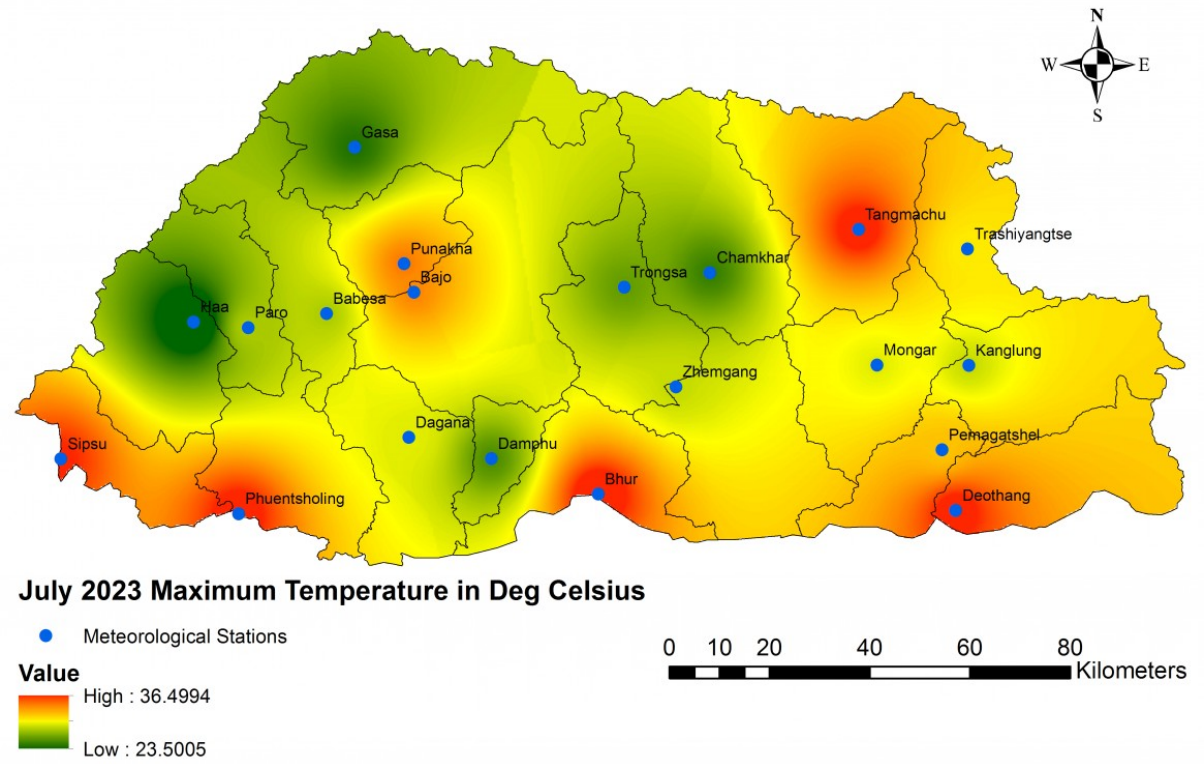


Figure 5. Monthly maximum temperature in July 2023.

Summary score, recommendations, and comments for Element 7

- Summary score for the element is 2 on the CHD scale, reflecting "Basic Capacity for Climate Services Provision".

Strengths

NHCM has a data management system to house all data in one place. Development of climate services would be feasible with such infrastructure in place.

Gaps and recommendations

NHCM has no skills in development of tailored climate products and quality control of data. Manual observational data has lack of quality and AWS data has a lack of continuity. There is a lack of resources and a need to train observers and data managers. There is a lack of ICT skills for data processing and management.

Recommendations to service development are:

- Establishment of NFCS is important to enhance NCHM's position.
- Continuation of current climate service should be prioritized despite of human resources. By enhancing of quality control of observations current services could be automatized. Automatization might need external support.
- Tailored climate products should be developed for the most weather dependent sectors, e.g. agriculture. Development of new products would need strong partnership with stakeholders and research co-operation is recommended.
- NHCM needs to build capacity on climate data management and quality control.
- NHCM can adopt guidelines for improving data quality and observation.

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.

NCHM runs WRF locally and (precipitation) data from WRF is used as input for the hydrological model in NCHM and there are currently a few river basins are selected as pilot basins for hydrological modelling. The key challenges in operating hydrological models include improvement of precipitation forecast skills and lack of skills in integration of the meteorological data to the hydrological models.

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

NCHM is responsible for meteorological, hydrological and cryosphere observations, forecasts, and warnings. Hydrology and Water Resources Services Division (HWRSD) and Meteorological Services Division (MSD) forecasting systems operate under the National Weather and Flood Warning Centre (NWFWC), which is a national supervisory hydro-meteorological monitoring and command centre that provides 24/7 weather and flood forecasting and warning services. All ICT systems related to hydrological and meteorological forecasting are located in the same NWFWC room in Thimphu and the data from WRF-model are directly used as input to hydrological model.

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

NCHM is established as the national agency for collection and dissemination of meteorological, hydrological and cryosphere data and information, thus data is shared based on the "Guidelines on the Exchange and Dissemination of Hydro-meteorological Data and Information (2018)". There is no data sharing agreement between NCHM and other national and local agencies.

All rivers from Bhutan flows to Indian States of Assam and West Bengal. Bhutan as the upper riparian States shares hydrological and meteorological data to designated counterpart office in the above-mentioned two Indian States for flood forecasting and warning based on mutual understanding. The Government of India (GoI) also supports the operation and maintenance of flood warning stations in Bhutan through Flood Warning Program fund and the GOI Flood Warning Program in Bhutan operates under the NCHM. There is no formal data sharing agreement between Bhutan and India, and the data is shared based on mutual understanding.

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

In Bhutan all the three sciences of meteorology, cryosphere and hydrology operates under the NCHM. All projects and plans are implemented in close collaboration and integrated manner with meteorology, hydrology and cryosphere and its applications.

Summary score, recommendations, and comments for Element 8

The CHD Element 8 score is 3, reflecting "There is a moderately well-functioning relationship between the meteorological, hydrological and water resources communities but considerable room for formalizing the relationship and SOPs.".

Strengths

In Bhutan meteorology and hydrology are under the same agency, NHCM, which simplifies the collaboration between these two areas of operations and services. Hydrological Data sharing protocols and mechanisms do exist with neighbouring India. NHCM has well established SOPs and guidelines for hydrological observation, forecasting and Early Warning Services, especially for Glacier Lake Outburst Floods (GLOF).

Gaps and recommendations

NCHM lacks infrastructure and skills to improve the skills of NWP required for hydrological forecasting and modelling. Key challenges also include the capacity to produce quantitative forecast and better skill for providing better flood and hydrological forecasts, warnings and services. These issues could be addressed in phases, by first developing the NWP capacities both technically and by improving the staff resources and then implement these improvements in hydrological services.

Element 9: Product dissemination and outreach

9.1. Channels used for user-centred communication and ability to support those channels

NCHM disseminates daily weather, climate and hydrological information and advisories via different medias for the public. All services are available on the NCHM's website[10] and official Facebook pages. (see Figure 6). The average number of daily users and visitors on the website is around 100, and this number doubles during severe weather events.

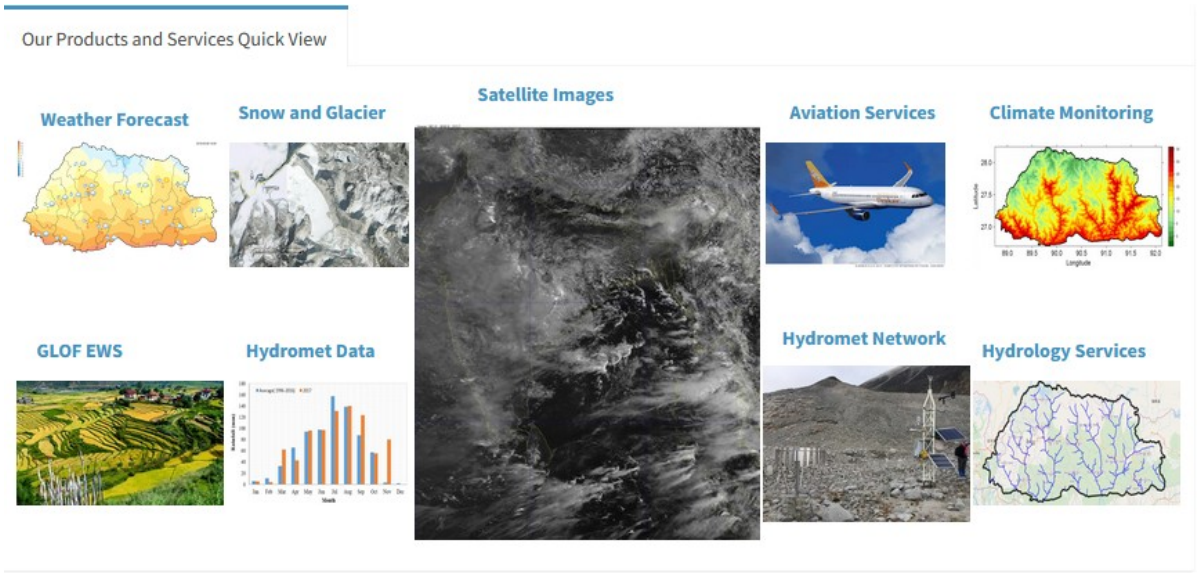


Figure 6. Overview of NCHM service catalogue available at the NCHM's website.

NCHM has two Facebook accounts, "National Centre for Hydrology and Meteorology" and "NCHM Weather and Flood Forecast". Daily weather forecasts and advisories are shared on the NCHM Weather and Flood Forecast -page, where the number of followers is 10 000. The National Centre for Hydrology and Meteorology page includes general posts on NCHM's activities and ongoing projects and has over 19 000 followers. Weather and flood advisories and warnings are also posted on the NCHM website.

[10] https://www.nchm.gov.bt/

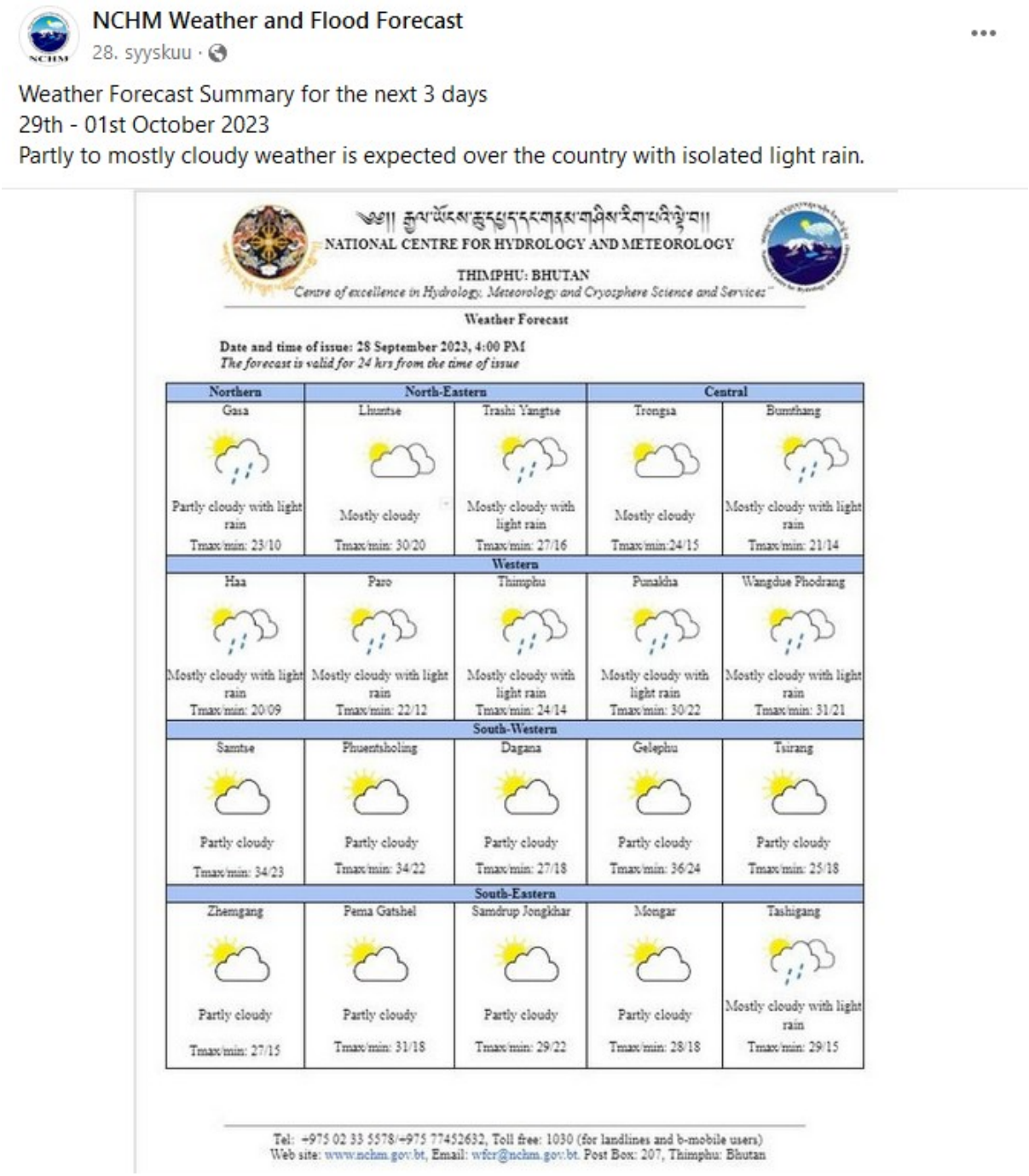


Figure 7. Daily weather summary in Facebook.

A mobile application (Bhutan Weather) is currently being developed and tested under the GCF agriculture project. The mobile application includes currently 3-day weather forecasts and advisories. Moreover, the mobile app already has features to incorporate a 10-day weather forecast when the product and capacity in NCHM to produce one is ready. In severe weather cases the NCHM is disseminating weather information for authorities (such as transport, agriculture, local governments) via WeChat and WhatsApp groups and media briefing as well as TV and print media.

In addition to NCHM's own dissemination channels the media is disseminating daily weather information for public. Bhutan Broadcast Service (BBS) is presenting weather forecast in daily evening news and on their website. A TV studio has been installed in the

NCHM in 2023 and NCHM is planning to begin weather broadcasts during extreme events for BBS and some other media in the near future. Previously NCHM's weather forecasts were only published daily in the main print media (Kuensel) only.

9.2. Education and awareness initiatives in place.

NCHM does not produce regular awareness activities on weather, flood and climatological services and the awareness activities are based on ad-hoc measures. However, in 2023 NCHM organized training for media on weather forecasting. Moreover, schools and university students are visiting at the flood and weather forecasting room occasionally. For authorities and hydro-power sector, the NCHM is preparing training material on EWS annually.

DRM has radio broadcasts where one topic is related to severe weather and floods. DRM has implemented also project based awareness campaigns for public e.g. on GLOF.

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

There are no specific measures in place to reach marginalized communities or indigenous people.

Summary score, recommendations, and comments for Element 9

- Summary score for the element is 2 on the CHD scale, reflecting "A moderately effective communication and dissemination strategy and practices are in place, based only on in- house capabilities and supported by user-friendly website.".

Strengths

Information dissemination has improved in recent years with the use of Facebook and other social media platforms. NCHM uses dedicated groups in social media platforms like WhatsApp for different types of warning or information. Trust and reliance on hydromet products and services has also increased. Public use this information for planning and decision support. If there is a warning in place the information can be disseminated fairly easily.

Gaps and recommendations

Gaps are mainly along awareness of products and services, where information is available. There are gaps along interpreting the hydromet information and how public should prepare or react to the advisories issued. Need for awareness workshops especially at the farmers and grassroots and media personnel. Gaps are mainly along awareness of products and services, where information is available. There are gaps along interpreting the hydromet information and how public should prepare or react to the advisories issued. Need for awareness workshops especially at the farmers and grassroots and media personnel.

Recommendations to service development are:

- The study how public is reaching warnings and emergency communication (especially during breakdown of telecommunication) and how they understood the information should be implemented e.g. by DRM, some NGO or research institute.
- Awareness activities are important to enhance communities' knowledge and trust on available services. Awareness activities could be more effective by co-operation with NGO's and unofficial community groups, media and students.

Awareness activities especially for rural communities are important to ensure the utilization of information.

Element 10: Use and national value of products and services

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

NCHM is organizing a National Climate Outlook Forum annually and co-operating with Department of local Governance and Disaster Management in developing in SOP's related to DRM. Other stakeholder meetings are usually project-based and organized occasionally.

The latest Socio-economic Study[11] was conducted under the SHSB-project in 2014 before implementation of NAPA -project (which included major improvements to the NCHM's infrastructure). The study included an analysis on the most weather-dependent sectors such as energy, agriculture, tourism, aviation, DRM, water management and public health. The initial cost-benefit ration in 2014 was expected to be 3:1, considering the high initial costs of modernization of the NCHM. This ratio was expected to increase in 2025 up to 8–9 after successful implementation of the NAPA II project.

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

The first user satisfaction survey was done in 2022 and NCHM is planning to repeat the survey in the future. It is initiated by the NCHM itself with no external funding and based on a google forms survey. In the future improvements into the survey, based on best international practices, are recommended with a physical event and communication between NCHM and stakeholders for improved information collection and sharing. Timeliness and accuracy of the weather forecasts are verified annually.

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

NCHM is planning to develop QMS for aviation weather service in the coming three years with support of JICA. The project is currently in its planning phase.

Summary score, recommendations, and comments for Element 10

- Summary score for the element is 1 on the CHD scale, reflecting "Service development lacks any routine stakeholder feedback practice".

Strengths

NCHM has been given autonomy by the Government based on the nature of work and the services that has to be provided to all agencies and sectors. NCHM has the mandate and is well placed to support the socioeconomic development of the country. It can provide the critical information and services in hydro-meteorology, early warning and climate change to save lives and property and support the works of other agencies like agriculture.

Gaps and recommendations

Gaps exists along co-operation and collaboration among different sectors. For instance, agencies in the field could support NCHM in data observation. There is duplication of efforts for example in doing climate change studies by several different agencies. No clear roles for water resource assessment among similar mandates of offices. Building public trust and confidence on hydromet value chain are other challenges.

[11] Pilli-Sihvola, K., Namgyal, P. and Dorji, C., 2014. Socio-Economic Study on Improved Hydro-Meteorological Services in the Kingdom of Bhutan. Finnish Meteorological Institute, Department of Hydro.Met Service, Bhutan.

Recommendations to service development are:

- NCHM should promote national multi-sectoral co-operation between weather-dependent sectors, especially co-operation with DRM authorities and NGO's, agriculture, aviation, water management and electricity-sector.
- Enhance service level by developing customer management process including regular stakeholder meetings, user satisfaction surveys for main sectors and development of new services based on feedback.
- Improve aviation weather service by developing service processes according to ICAO requirements (products, QMS, cost-recovery)
- Implement QMS for aviation and enlarge QMS to cover full value chain of NCHM service in future
- Update socio-economic benefits study to cover NCHM's current service level.

Annex 1 Consultations

Figure 8. Post in Facebook on CHD workshop

Annex 2 Urgent needs reported

The main gaps identified by the Country Hydromet Diagnostics are as follows. The detailed assessment of the gaps and recommendations if found in the respective chapters in this report:

- *NWP and forecasting tools:* Inaquadate resources to operate and develop NWP and forecasting tools
- *Observations:* Hardware configuration for the Observation network in the country with software (DMS) training for station metadata management and communication and network status monitoring and management
- *Warnings:* Inaquadate resources to operate and develop warnings and dissimination channels. Missing impact-based forecasting operations and implementation of the Common Alerting Protocol data for warnings.
- *Data management:* Inaquadate resources to operate and develop data management solutions. Hardware and ICT-infrastructure are aging which cause threat to reliability of the services.
- *Hydrology:* NCHM lacks infrastructure and skills to improve the quality of the NWP required for hydrological forecasting and modelling
- *Product dissemination:* Inaquadate resources to disseminate and develop modern weather forecast and early-warning products and to utilize modern dissemination channels
- *Use and national value of products and services: Gaps in co-operation and collaboration among different sectors. Public trust and confidence on hydromet value chain is a challenge.*

Annex 3 Information supplied through WMO

(This summarises information collected from WMO databases in response to questionnaires and other information gatherings. Furthermore, the feedback of the Peer-reviewers will be crucial for validating WMO self-reported data and collecting data from no-data countries)

- CHD WMO Data Inventory and Review Sheet
- WMO Global GBON gap Analysis
- WMO Monitoring System Data
- WMO Hydrology Survey

Annex 4 List of materials used

(this may include WMO Guidance Materials, Data and Information, Review Reports, Database etc.)

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

- Online material and studies included as reference to this document
- NCHM website
- Social media accounts by NCHM