COUNTRY HYDROMET DIAGNOSTICS

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

October 2023

Maldives Meteorological Service (MMS) Peer Review Report

Reviewing Agency:

Finnish Meteorological Institute (FMI)

and

Agency for Meteorology, Climatology and Geophysics of the Republic of Indonesia (BMKG)

Maldives Meteorological Service
Republic of Maldives

BMKG

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

UN environment
United Nations Environment Programme

SOFF
Systematic Observations Financing Facility
Weather and climate data for resilience

WORLD METEOROLOGICAL ORGANIZATION

Alliance for Hydromet Development

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List of Abbreviations

AWS – Automatic Weather Station

BMKG - Agency for Meteorology, Climatology and Geophysics of the Republic of Indonesia

CAP – Common Alerting Protocol

CREWS – Climate Risk and Early Warning Systems

CSO – Civil Society Organisation

DRR – Disaster Risk Reduction

ECMWF – European Centre for Medium-Range Weather Forecast

EPA - The United States Environmental Protection Agency

EWS – Early Warning Services

FMI – Finnish Meteorological Institute

QMS – Quality Management System

MNDF - Maldives National Defence Force

MoECCT - Ministry of Environment, Climate Change and Technology

MMS – Maldives Meteorological Service

MRC – Maldivian Red Crescent

NDMA - National Disaster Management Authority

NMS – National Meteorological Service

NWP – Numerical Weather Prediction

QA/QC – Quality Assurance/Quality Control

SOP - Standard Operating Procedures

SWFP – Severe Weather Forecasting Programme

UNEP – United Nations Environment Programme

WIGOS - WMO Global Observing System

WMC - World Meteorological Centres

WMO – World Meteorological Organization

WRF - Weather Research and Forecasting

Executive Summary

Climate and weather-related information in the Maldives are provided by the Maldives Meteorological Services (MMS). It is the main government agency mandated by the President's Office, responsible for providing meteorological and seismological services in the Maldives. Daily weather forecasts, aviation forecasts, weather warnings and marine forecasts are issued by the MMS. It is also responsible for the tsunami alerts and Indian Ocean earthquake warnings. Maldives joined World Meteorological Organisation (WMO) on the 1st of June 1980 and as per the WMO practice, MMS station in Hulhule is designated as the national meteorological centre of the Maldives meteorological network[1].

Currently the MMS remains as semi-autonomous body under the Ministry of Environment, Climate Change and Technology (MoECCT). There are no private sector operators providing meteorological observations or data services in the Maldives. A new legislative act designed to strengthen and define the role of the MMS (Maldives Meteorology Act 2016) is currently in process of preparation and awaiting approval. The MMS works closely with the National Disaster Management Authority (NDMA), which is the main coordinating body for disaster management activities and supports the strengthening of emergency communications and early warning systems at the national level. MMS also collaborates with other stakeholders including the aviation sector, regularly providing information for airport and flight operations. The closest CSO partner for the MMS is the Maldivian Red Crescent (MRC). MMS also collaborates and receives funding from international development and humanitarian organisations, including UNEP and USAID.

Weather, climate and early warning services are delivered to the public through multiple channels, including traditional and social media, website, text messaging, fax and emails. Within this strong overarching framework, the MMS faces many operational and strategic challenges. The main issue is that it does not have the budget, adequate staff numbers or training programmes to support its operations, including maintaining ICT infrastructure, observations calibration and maintenance, further development of forecasting services, training, or quality management of services. Whilst efforts to streamline these systems are underway, the underlying issues of support for ongoing operations will remain. It is recommended that the MMS will develop a strategic plan to consider these challenges. It is also recommended it will develop a stakeholder engagement strategy, to increase its engagement with long term partners with other national and international peer agencies, as well as capacity development agencies and the private sector end-users.

Currently the MMS does not have cost recovery mechanism in place for any services, including aviation services. The new Meteorological Act, under preparation, would enable cost recovered activities. This is strongly encouraged to ensure that the MMS has financial flexibility to independently support and sustain operations, including meteorological observations. The flexibility brought by the cost recovered income would also support the planned investments to remain GBON compliant. It is recommended that the cost recovery mechanism would be included in the next strategy of the MMS.

As a result of the CHD process, overall capacity of the MMS could be assessed at level 3. Some exceptions include the Element 8, *Contribution to Hydrology*, which received a rating 1. This is primarily explained by the geography of the Maldives and lack of water resources (rivers, lakes, glaciers), making hydrology mostly irrelevant to the MMS operations. This factor should be considered when evaluating the CHD document. In addition to this, Element 7, *Contribution to Climate Services*, received a maturity level score 2. This is because the MMS doesn't have enough dedicated staff to provide climate services. To address this gap, it is recommended that well-trained staff be recruited to enhance the

[1] MMS official website

capabilities of the climate division. Similarly, Element 10, *Use and national value of products and services*, received a score 2, due to the MMS service development currently drawing on informal stakeholder input and feedback. It is recommended to improve customer/client feedback and its involvement in institutional strategies, enhancement and service provision, as well as expanding the implementing the Quality Management System (QMS) to NMHS operations.

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

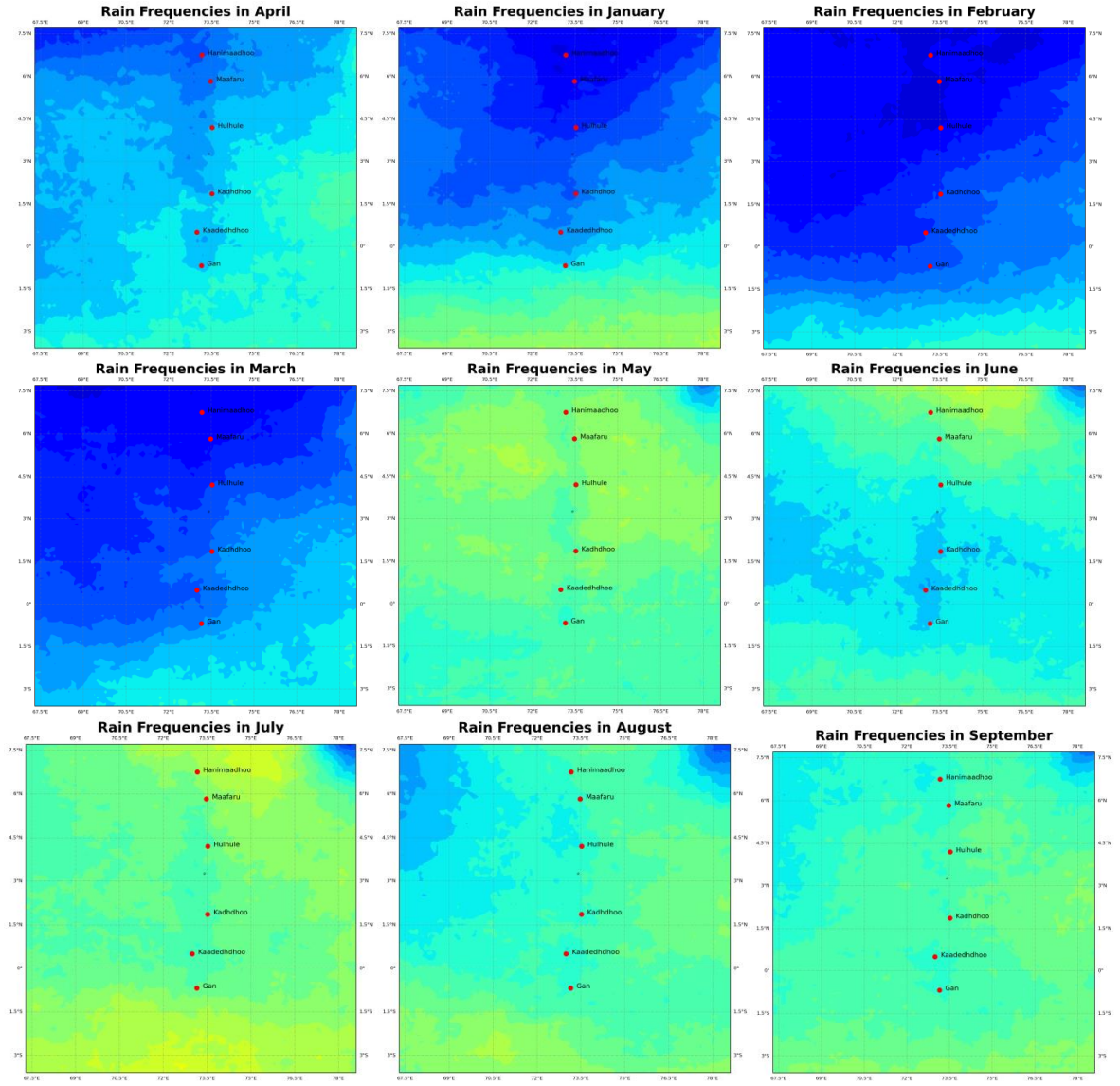
Figure 1 Summary of the Maturity results in MMS.

Chapter 1: General information

Introduction

The Maldives encompasses 1 192 coral islands situated in the Indian Ocean, organized into 26 atolls, spanning a distance of 860 km from latitude 7º6’35”N to latitude 0º42’24”S. With a population exceeding 500.000 residents resides on approximately 200 islands, of which more than 80 islands exclusively dedicated to tourism. The majority of inhabited islands are small, with an area of less than 1sqkm, and predominantly low-lying, with over 80% having ground-level elevations of around 1m above mean sea level.

The country's unique location and geographical characteristics render it highly susceptible to a range of extreme weather hazards, including thunderstorms, cyclones, strong winds, storm surges, high seas, heavy rainfall, coastal floods, and swells.



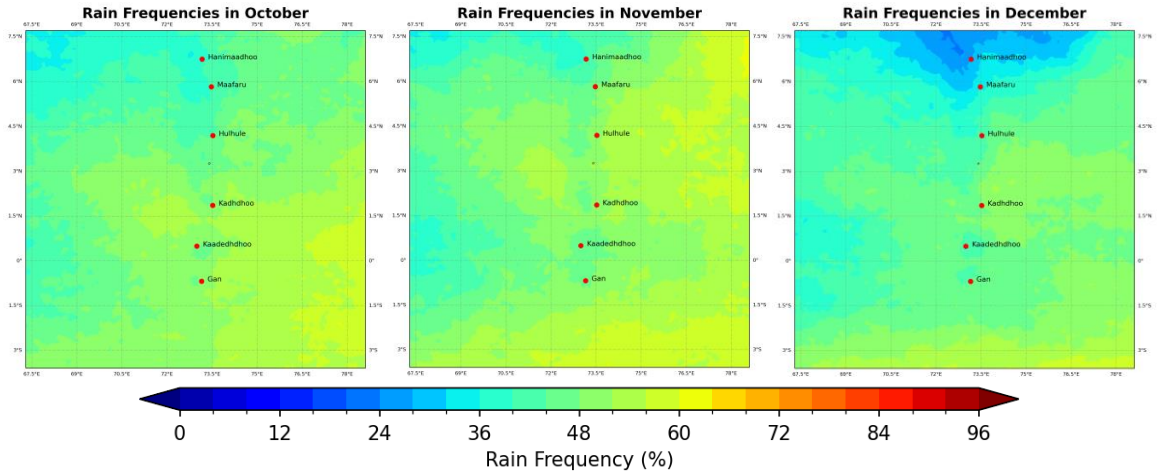


Figure 2 Monthly rain occurrence frequencies (in percentages) based on GSMaP-JAXA data from April 2000 - August 2023

These hazards pose a significant threat to life and property. Approximately half of the country's settlements, along two-thirds of critical infrastructure, and nearly all tourism establishments situated within 100 meters of the shoreline. The challenges of communicating forecasts, disaster risks, and mobilizing emergency response assistance are exacerbated by the geographic spread of the islands, leading to high communication and access costs. Tourism remains the linchpin of the country's economy, while fisheries and agriculture serve as the primary livelihoods in rural areas, albeit constrained by limited arable land and freshwater availability. As an island country, the freshwater needs are met by desalination process and rainwater harvesting. Tuna serves as the primary fish export, with reef fish playing a vital role as live bait in the tuna fishery. Coral reefs support both the fisheries and tourism sectors while mitigating the impact of strong waves on the coastline.

This report follows the CHD 2022 methodology and incorporates a validation process utilizing Country Data and Inventory Sheet provided by WMO. This sheet serves as a robust mechanism for confirming the accuracy of self-reported country data through peer reviewer. Additionally, it incorporates insights from various reports concerning the meteorological and hydromet capabilities of the Maldives, with the primary focus on the MMS. The report presents an assessment of each of the ten critical elements of the hydromet value cycle, assigning a maturity level score to each based on indicator assessments. The report concludes with recommendations from reviewers aimed at enhancing the maturity level ratings for these critical elements.

CHD methodology

The Country Hydromet Diagnostics (CHD) aims to address the necessity for a standardized, integrated, and operational tool and approach for the evaluation of National Meteorological Services. Its core mission is to assess the operational context of these services and their pivotal role in delivering high-quality weather, climate, hydrological, and environmental information services and warnings. This comprehensive diagnostics tool consolidates existing WMO assessment materials, synthesizes various methods and data into an easily comprehensible format, verifies information through peer review, and fills gaps in missing data.

At its core, the CHD strives to furnish invaluable insights that inform policy and investment decisions, with a specific focus on guiding investments from the Alliance for Hydromet Development. This alliance comprises development and climate finance organizations committed to enhancing the capacity of developing country hydromet services. Through

the CHD, developing nations can anticipate more precise and coordinated financial and technical support, thereby enhancing their resilience in facing the meteorological and hydrological challenges.

The CHD centres its evaluation on ten vital elements of the hydromet value cycle, categorized as enablers, observation and data processing systems, service and product production and distribution, and user and stakeholder interaction. Each of these components undergoes evaluation using a set of standardized indicators and explicitly defined data sources. The evaluation of these elements is designed to determine the maturity level of the National Meteorological Service, with Level 5 representing the highest attainable maturity level in the CHD assessment.

While the CHD predominantly relies on primary data, encompassing self-reported and quantitative data from diverse sources, it is also incorporating additional data, particularly from country user/client surveys, to facilitate peer review. The WMO Monitoring System plays a pivotal role as the primary data source for CHD, with the results seamlessly integrated into the platform to offer substantial value and accessibility.

This report presents a CHD assessment tailored to the unique context of the Republic of Maldives.

This CHD is written by using 3 main steps:

1. Review the previous CHD (2021)

The CHD document for Maldives was initially written by the India Meteorological Department (IMD) in 2021. The Finnish Meteorological Institute (FMI) and Agency for Meteorology, Climatology, and Geophysics of Indonesia (BMKG), as peer-reviewers of the SOFF program in Maldives, reviewed the document to ensure that it remains aligned with the latest conditions in the Maldives. This collaborative effort aims to create an updated CHD document that accurately reflects the current status of the meteorological and hydromet capabilities in the Maldives, thus offering valuable insights and recommendations for further enhancement.

2. Interview in separated groups based on MMS and its stakeholders resource person's expertise and CHD elements

The completion of the CHD Data Inventory and Review Sheet was a collaborative effort that involved MMS personnel from various positions and areas of expertise. To facilitate comprehensive discussions, the participants were divided into four groups, each tasked with addressing specific CHD Elements.

In addition to the group discussions, a stakeholder meeting was organised as well as a separate meeting with the NDMA. These sessions were designed to further enrich the assessment process. The input and feedback received from these stakeholders and disaster management authorities proved to be useful in ensuring a comprehensive and well-informed assessment of MMS's capabilities and functions within the CHD framework.

3. Confirmation and preliminary maturity level assessment

After the consultation process, the 10 elements were reviewed and analysed separately, in order to determine an overall maturity level score for each element. The final maturity levels were agreed collectively by FMI, BMKG, and MMS.

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

A meteorological service was established in Maldives in the early 1940s[2]. Working under different offices of the government throughout the years, meteorological office became Maldives Meteorological Service (MMS) in 2009. Today, the MMS is responsible for the seismological and meteorological services in Maldives, operating in five meteorological offices, with the main office being stationed at Hulhule'.

According to its website, the MMS describes that its vision is to "provide accurate, timely and reliable meteorological information to minimize the impact on life and property while supporting sustainable socio-economic development of the Maldives."

The legal mandate and scope of the MMS are outlined in the presidential decree, as stipulated in Act No.3/68 dated 11th November 1968.

MMS holds the designation as a government agency under the Ministry of Environment, Climate Change, and Technology of Maldives. It states as MMS's official mandate the following (un-official translation, as only available in Dhivehi):

- Plan, administer and develop activities related to meteorology in the Maldives.
- Maintaining the data on climate, earthquake, and tsunami, required for economically and socially sustainable development. Develop and maintain such a knowledge base and facilitate access to this information to those who require it.
- Conduct research activities on meteorology and seismology in the Maldives.
- Provide aeronautical meteorological services to international and domestic aviation requirements as per the required standards of International Civil Aviation Organization and World Meteorological Organization.
- Monitor weather, earthquake, and tsunami over the region.
- Issue impact-based forecast and early warning alerts to concerned authorities and public.

A new legislative act related to meteorology (Maldives Meteorology Act 2016) is currently in process of preparation and awaiting approval.

In terms of other regulatory frameworks applicable to National Meteorological Services functions, the Disaster Management Act of 2015 holds significance[3]. Furthermore, the MMS is integrated into the Maldives government's Strategic Action Plan (SAP) for the period of 2019-2023[4], further solidifying its role within the broader governmental regulatory framework. Under the plan, MMS's responsibilities are stated as the following:

- Strengthening aeronautical meteorology and multi-hazard early warning capacity.
- Maritime Safety Information (including navigational and meteorological warnings, forecasts, alerts of missing vessels, and other urgent messages pertaining to the safety of vessels and crews, in line with IMO obligations).
- Strengthening national institutional framework on DRR and climate resilience
- Establishing and strengthening national-level early warning mechanisms to efficiently disseminate early warning information to the public.

Within its mandate, the MMS is responsible for sharing Climate information to all government agencies, specifically including Water Department, Climate Change

[2] MMS website (retrieved 19th October 2023)
[3] National Disaster Management Authority, Maldives, September 2015, Disaster Management Act
[4] Government of Maldives, Strategic Action Plan, 2019 - 2023

Department and Ministry of Fisheries, Marine Resources and Agriculture. Air Quality services are handled by the EPA. In addition, the MMS is entrusted with the responsibility for providing meteorological services for aviation.

The MMS is officially recognized as the national alerting authority for hydrometeorological hazards in the country. As a result, the government empowers the MMS with the mandate to produce services for the Maldives Meteorological and Hydrological Early Warning System. Additionally, the Disaster Management Act grants authority to the MMS to monitor EWS in the Maldives.

Roles and responsibilities of all organizations involved in generating and issuing warnings are officially established and mandated by legislation or other authoritative instruments. This holds true for all hydrometeorological and geological events, with specific attention to five prioritized hazards namely wind, flash floods, high seas, thunderstorms/squall lines, and tropical cyclones.

Cross-border exchanges of warnings with neighbouring countries are effectively realized through bilateral and multilateral agreements. National warnings are shared in CAP format at the WMO Alert Hub, and within the IOC UNESCO framework, regional warnings on tsunamis are coordinated through the Regional Specialized Meteorological Centre (RSMC) in Delhi for tropical cyclones. MMS receives regional warning information from the mentioned sources.

In the execution of its services, the MMS operates in accordance with a Service Charter. This charter serves as a guiding document that outlines the service standards, commitments, and expectations for the MMS's interactions with its stakeholders, clients, and the public. It aims to ensure transparency, accountability, and the delivery of high-quality meteorological and hydromet services in line with established benchmarks and best practices.

In addition to its meteorological services, the Maldives has taken significant steps in addressing climate change by submitting the Maldives's Nationally Determined Contribution (NDC) Implementation Plan in 2018[5]. This plan reflects the country's commitment to mitigating the impacts of climate change and outlines specific strategies and actions to achieve its climate goals. These efforts are closely tied to the work of MMS, particularly in the realm of climate services. By aligning with the NDC, the MMS can contribute significantly to the national climate action agenda. It can provide essential climate information, data, and forecasts that enable informed decision-making and help implement the strategies outlined in the NDC. Furthermore, MMS's role in monitoring and reporting on climate-related indicators is crucial for tracking progress toward NDC goals.

In essence, the NDC serves as a guiding framework that reinforces the importance and relevance of climate services provided by the MMS. It underscores the interconnectedness of climate action and meteorological services, highlighting how MMS contributes to the broader national effort to address climate change and safeguard the Maldives' vulnerable environment and communities.

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

Currently, there is no institutional strategic plan in place for the MMS that covers the next programme period. Instead, the MMS is integrated into the Maldives government's SAP

[5] Ministry of Environment and Energy, 2018, Maldives's Nationally Determined Contribution (NDC) Implementation Plan

for the period 2019-2023. MMS creates an annual workplan after governmental budget allocations. This workplan serves as an operationalization of the strategic plan.

The MMS website has no available link or reference to a strategic plan and there is no public documentation available regarding the most recent report on implementation of national strategic plans. Governmental strategic plan is monitored annually by report on achievements.

While risk management practices are in place, they are not fully documented. Risk management plans exist for some operational systems such as data management and power backups.

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 total annual budget for the MMS in the year 2023 amounts to USD 2,350,000. In the allocation of the budget, it is noted that staff costs account for 70%, operational costs make up 27%, and investments represent 3% of the total budget.

Table 1 – 2022 Annual MMS budget breakdown. Source: MMS.

Type of Activity (2022)	2022 Annual Budget in Maldivian Rufiyaa (MVR) / USD
Staff salary	27,681,439.00 MVR / 1,797,530.94 USD
Operational activities	3,219,343.00 MVR / 209,052.31 USD
Maintenance and replacement of equipment	2,111,948.00 MVR / 137,142.14 USD
Maintenance of the premises	749,870.00 MVR / 48,693.80 USD
Investment in new technology and research	0.00 MVR / 0.00 USD
Training	0.00 MVR / 0.00 USD

The financial status of the MMS consists of governmental funding and funding through international development collaboration projects. The current funding structure reveals that full governmental funding supports operational expenses, while investments primarily rely on donor and project funding, with annual variations. Investments through project or donor funding possesses a risk to the continuation of the operations, as the availability of the funding varies annually. To avoid gaps between the development project funding cycles, the MMS should ensure that there is appropriate maintenance budget available after the development project cycles end, covered either by the main government budget or in the future by cost recovery or commercial activities.

Over the past 3-5 years, there has been an increasing trend in the government component of the budget, apart from 2021, when the budget was cut mostly due to Covid-19. Since then, the budget has increased again, particularly in terms of capital expenses, but continues to be lower than the ambition level of the MMS.

Table 2 - MMS budget trend for the past 5 years. Source: MMS.

	2018	2019	2020	2021	2022
Increasing	3.24%	12.34%	11.73%	-	7.54%
Decreasing	-	-	-	24.73%	-
Steady	-	-	-	-	-

There is no cost recovery mechanism in place for any services including aviation services. Additionally, there are currently no commercial activities contributing to the budget. The new Meteorological Act, under preparation, would enable cost recovered activities.

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 current human resources situation within MMS is as follows:

- Management Staff: There are 7 individuals serving in management roles.
- Meteorologists: A team of 10 meteorologists is responsible for weather-related services and forecasting.
- Meteorological Technicians: The MMS employs 60 meteorological technicians who play a crucial role in supporting meteorological operations.
- Hydrologists: The MMS currently does not have any hydrologists on its staff.
- Hydrological Technicians: A single hydrological technician is part of the workforce.
- Climate Services: There are no staff members dedicated to climate services.
- Researchers: The MMS does not have researchers among its staff.
- Other: An additional 29 staff members are engaged in various roles contributing to the overall functions of the MMS.

In total, the Maldives Meteorological Services employs 107 individuals, comprising 77 males and 30 females. There is no specific Gender Policy, but the MMS has committed to the Ministry of Gender, Family and Social Services Republic of Maldives National Gender Equality Action Plan 2022- 2026[6]. It is recommended that the MMS will conduct a gender assessment and develop a Gender Policy, based on the recommendations by the WMO's Gender Action Plan 2020-2023.[7]

The MMS conducts regular assessments for staff competency frameworks. Specifically, assessments are carried out every two years for forecasters and observers, ensuring that these key personnel maintain and enhance their competencies in line with the evolving requirements of meteorological services.

[6] National Gender Equality Plan, 2022 - 2026
[7] WMO Gender Action Plan

The government has established a comprehensive training policy for civil servants, which encompasses the MMS as well. This policy sets the framework for ongoing training and development activities within the organization.

MMS actively participates in capacity-building initiatives through collaborations with both national and regional institutions. This engagement extends to training programs conducted by the WMO and regional centers, which collectively contribute to the enhancement of the MMS's capabilities and expertise in the field of meteorology.

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

Over the past five years, the Maldives has been involved in several critical hydromet projects, collaborating with various partners. These projects include:

1. **Building Climate Resilient Safer Islands in the Maldives (FP165)**: This initiative is carried out in collaboration with JICA (Japan International Cooperation Agency) and the Green Climate Fund (GCF). The project spans from 2021 to 2027, focusing on building climate resilience in the Maldives, particularly with an emphasis on enhancing safety in the islands.

2. **Strengthening National and Subnational Capacity for Sustainable Disaster Risk Reduction, Climate Change Adaptation, and Mitigation in Maldives**: This project is a collaborative effort involving UNDP (United Nations Development Programme) and UNESCAP (United Nations Economic and Social Commission for Asia and the Pacific), supported by the Joint SDG Fund. The project is active from 2022 to 2024 and is aimed at bolstering the capacity for sustainable disaster risk reduction, climate change adaptation, and mitigation in the Maldives.

3. **Climate Change Adaptation Project:** Supported by USAID (United States Agency for International Development), this project is implemented over the period 2022 to 2027. Its primary focus is climate change adaptation in the Maldives, working toward enhancing the nation's resilience to climate-related challenges.

4. **Italy-Funded Project for Installation of AWSs, Wave Model, and Data Integration**: Italy has funded a project with the objective of installing AWSs, developing a wave model, and integrating data. This initiative represents collaboration between the Maldives and Italy to strengthen the country's meteorological capabilities.

Summary score and recommendations for Element 1

The maturity level for this component is assessed as **Level 3** as "*MMS is moderately well mandated, managed and resourced and has clear plans for, and sufficient capacity to address operational gaps"*.

To further advance its capabilities and operations, several recommendations can be implemented. Firstly, it is imperative to complete the Act and commence cost recovery activities to ensure sustainable funding for its crucial services. Additionally, initiating the strategy process within the MMS, coupled with annual monitoring and clearly defined responsibilities, will provide a structured framework for organizational development. Lastly, developing mid-term and long-term strategic plans for capacity development within the MMS will facilitate the enhancement of its expertise and resilience in effectively addressing meteorological and hydrometeorological challenges. These recommendations hold the potential to elevate the maturity level of MMS, reinforcing its role in safeguarding the nation against climate-related risks and strengthening its capacity to provide critical services.

Element 2: Effective partnerships to improve service delivery

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

Currently, the MMS has established some partnerships with other government institutions for service delivery, particularly with the Maldives Civil Aviation Authority. However, these partnerships require renewal or further strengthening to ensure continued and enhanced collaboration in delivering essential services. To map and evaluate the existing and possible future partnerships will play a pivotal role in optimizing the efficiency and effectiveness of service delivery, particularly in addressing the country's meteorological and hydrometeorological needs.

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.

In the area of public-private sector collaboration within the MMS, the current landscape presents a mix of elements. While formal agreements for service delivery with the private sector are not currently in place, the MMS has established crucial public sector agreements, particularly in the field of civil aviation. This absence of a legal framework leaves room for potential future developments in this regard. While the private sector does not currently provide services within the area of meteorology, the MMS should remain open for potential future developments in this area as the landscape evolves.

To facilitate multi-sector dialogue and cooperative engagement, the MMS orchestrates the Monsoon Forum on an annual basis. This forum brings together a diverse array of participants, including representatives from 9 non-governmental organizations (NGOs) spanning sectors such as fisheries, agriculture, local women's organisations, and more. Additionally, it engages 10 Island Councils from the islands of Laamu Atoll and approximately 13 government officials, with the exact number varying depending on the specific area under discussion. The active participation of these sectors underscores the commitment to fostering multi-sector collaboration in addressing meteorological and hydrometeorological challenges. The MMS serves as the main organizer of this multi-sector dialogue, positioning itself as a central hub for cooperative discussions and information exchange among various stakeholders.

In terms of research activities, the MMS currently undertakes limited research endeavours, often reliant on budget funding, and currently there are no active national or international research projects within the purview of the MMS. Research priorities are primarily established by the MoECCT, which occasionally submits research requests to guide the MMS's focus. However, these findings reflect the current status and do not preclude future opportunities for research expansion and collaboration on both national and international fronts. Furthermore, while direct collaboration with academia and research institutions has not been formalized, the MMS has initiated informal interactions with individuals within these institutions. These efforts lay the foundation for potential future developments in formalizing partnerships and strengthening collaborative ties across various sectors.

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

There are 5 effective partnerships in place with international climate and development finance partners as described in chapter 1.5.

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.

The MMS has embarked on a path of innovation and service expansion, introducing several noteworthy initiatives:

1. A new product has been introduced to support rain harvesting activities, enhancing water resource management.

2. Through collaborative projects with organizations like the Green Climate Fund (GCF), UNDP, and Italy-funded initiatives, the MMS has expanded its infrastructure, installing a total of 33 new AWSs and improving wave modelling data. These advancements enhance data collection and forecasting accuracy while contributing to better early warning systems. Currently 24 AWS are in operational condition out of 43 being installed. All these AWS meet WMO compliance standard as per the sensors and exposures are concerned. Wave model developed under Italy grant aid project is run once a day and it is operationally used in forecasting.

3. The MMS has developed the Common Alerting Protocol tool and a mobile app for efficient warning dissemination, bolstering disaster preparedness.

4. Upgraded TV-Studio facilities, courtesy of Italy-funded projects, enable improved communication and outreach to the public.

5. In 2022, the MMS initiated seasonal forecasting, offering valuable insights into seasonal weather patterns to aid decision-making across various sectors.

Summary score and recommendations for Element 2

The maturity level for this component is assessed as **Level 3** as "*Moderately effective partnerships but generally regarded as the weaker partner in such relationships, having little say in relevant financing initiatives*". To elevate its standing and enhance its effectiveness in strengthening partnerships, several key recommendations can be implemented.

Firstly, adopting a coordinated approach to funding, backed by a comprehensive partnership strategy, can strengthen the MMS's position in resource allocation and financial decision-making. Building upon the Monsoon Forum, to increase coordinated stakeholder consultation mechanisms will facilitate more structured and inclusive dialogue, promoting active engagement from all relevant parties.

Secondly, the development of a strategic plan and a clear development roadmap for the near future will provide a cohesive framework to guide the MMS's growth and strengthen its position within collaborative relationships.

These recommendations collectively have the potential to elevate the MMS to a higher maturity level, enhancing its influence and effectiveness in partnerships and reinforcing its role in safeguarding the Maldives against meteorological and hydrometeorological challenges.

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.

MMS maintains a network of five synoptic weather stations, providing essential surface observations. These stations exhibit an average horizontal resolution ranging from 150 to 300 kilometers. Additionally, one upper-air observation station operates within the country, with a horizontal resolution of 1000 kilometers.

The MMS manages a total of 43 observation stations, including manned and unmanned AWS. Data from the five manual stations is disseminated to the GTS through the New Delhi GTS hub. These stations are proposed for inclusion in the GBON network.

The existing set of AWS are from different suppliers and are just three years in operation. Since there are frequent data gaps and maintenance issues being experienced, these stations are not currently proposed for inclusion in the GBON network. However, some reliable stations could be considered for inclusion into the GBON network. Data transmission into WIS2.0 needs to be automated

Synoptic surface observations are reported at a temporal frequency of every three hours, ensuring frequent updates on weather conditions. However, this is not compliant frequency for the WIS2.0 in the future as it requires hourly observations.

There is one upper-air sounding station in southern Maldives (Gan). The observations are made there once a day. However, currently the upper air sounding system is not functional and should be renewed.

There are also some notable challenges within the observation network. On average, approximately 42% of the stations are not functioning, also impacting the data collection and acquisition of data for the service production, monitoring and forecasting. Geographical, financial, and logistical constraints result in areas of the country where observations are missing. These limitations further hinder comprehensive hazard monitoring.

For various hazards, the MMS monitors key variables, including wind speed and direction, pressure, precipitation, temperature, radar reflectivity, and remote sensing images. However, there are identified gaps in monitoring capacity and the need for additional variables. For instance, for wind-related hazards, improved data quality control is required. In the case of flash floods and thunderstorms, there is a lack of observation stations, insufficient automation, limited access to real-time data, and inadequate data quality control. Similarly, for high seas and rogue waves, challenges include the absence of observation stations, insufficient automation, limited access to real-time data, a lack of remote sensing data, and insufficient data quality control. Additionally, for tropical cyclones, data quality control issues persist, and there is a need to enhance monitoring capacity for additional variables.

3.2. Additional observations used for nowcasting and specialized purposes.

MMS actively engages with a variety of data sources to enhance its observational capabilities for monitoring and forecasting. While the MMS does not receive wind data from other sources, it leverages data from multiple sources for different hazards. For flash floods, the MMS relies on data from the FY-2E and G satellites from the China Meteorological Administration (CMA), as well as data from the INSAT 3D and 3DR satellites, made available by the Indian Meteorological Department (IMD). Similarly, for monitoring high seas and rogue waves, the MMS utilizes open-source altimeter data and products from satellites like ASCAT METOP-B and ASCAT METOP-C, provided by the National Oceanic and Atmospheric Administration (NOAA).

In the context of thunderstorms and squall lines, the MMS again turns to the FY-2E and G satellites from CMA and the INSAT 3D and 3DR satellites from IMD. Additionally, the MMS collaborates with the Regional Specialized Meteorological Centre (RSMC) in New Delhi to receive observations relevant to tropical cyclone monitoring.

The MMS does retain some observations that are not transmitted to the Global Telecommunication System (GTS) or World Meteorological Organization Information System (WIS) but are used for its own specific purposes.

Regarding additional observations used for nowcasting and specialized purposes, specific data sources or details are not provided in the available information.

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

MMS possesses the capability to perform regular calibration, quality control, and maintenance of its observing systems, albeit with limited capacity. While efforts are in place to ensure the reliability and accuracy of observational data, there may be room for further enhancement in this aspect. Currently the instruments are sent to be calibrated to the manufacturer's premises. This is a costly operation and it may also cause issues with the data collection as there is no spare part stock in MMS to replace the instruments under calibration.

The MMS has established manual quality control procedures for data management, as well as Standard Operating Procedures (SOPs) for observation station maintenance procedures. Forecaster duties are outlined based on a defined duty work schedule.

As for a national governance mechanism within the World Meteorological Organization Information System (WIGOS) framework, the Maldives currently does not have such a mechanism established. The absence of this governance structure may impact the coordinated management and utilization of observational data and resources.

In terms of staff training related to the WMO Information System for the WMO Global Observing System (OSCAR/Surface), there is currently no record of staff trained in this specific domain.

Furthermore, there is no established national process in place for acting on quality problem information received from the WMO Information System (WIS) Data Quality Monitoring System (WDQMS). The absence of a structured procedure for addressing data quality issues may require attention to ensure the reliability and accuracy of observations.

3.4. Implementation of sustainable newer approaches to observations.

Sustainability of the observation network operations and maintenance remain as an issue. There is no arrangement with a Regional Instrument Centre (RIC) to assist in the calibration of observation stations. There is a lack of capacity (number of people and knowledge capacity) to configure new stations through WIS2.0. Support through WMO is urgently needed.

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

MMS has made significant strides in automating its observing network, with approximately 82% of the network now operating in an automated capacity. This automation represents a substantial advancement in data collection efficiency and real-time monitoring capabilities.

Over the past five years, the MMS has deployed a total of 23 new automatic weather stations, further enhancing its observational infrastructure. These additions contribute to the reliability and coverage of the MMS's data collection efforts.

Observational data collected within the network are promptly delivered in real-time or near-real-time to the national meteorological center (NMC). This swift data transmission

facilitates timely weather monitoring and forecasting, enabling the MMS to provide accurate information to the public and relevant authorities.

Furthermore, the MMS effectively utilizes radar data to monitor priority hazards within the Maldives. This includes monitoring and tracking weather phenomena such as thunderstorms and squall lines, contributing to early warning systems and hazard preparedness. One S-band Doppler weather radar is installed. This radar is quite old and has frequent maintenance issues. Due to its high down time, the radar is not effectively used all the time. Therefore, there is a project in pipeline (with the support of the Government of Italy) to install four X-band radars to cover Maldives area for increasing the capacity for early detection of severe high impact weather hazards.

Summary score and recommendations for Element 3

The maturity level for this component is assessed as **Level 3** as "*Moderately effective partnerships but generally regarded as the weaker partner in such relationships, having little say in relevant financing initiatives.*"

This level is marked by the presence of certain data quality issues and gaps in coverage. To elevate its observational network to a higher maturity level, several key recommendations can be implemented.

First, reaching the Global Basic Observing Network (GBON) requirements in terms of observation frequency is essential for comprehensive monitoring and data accuracy. Improving station operational rates through enhanced maintenance efforts and calibration capacity is critical to ensure data reliability. To meet these needs effectively, increasing the number of staff, potentially supplemented by local community members trained to support observation maintenance, can significantly strengthen the network.

Secondly, sub-contracted calibration procedure with potential country and the MMS should be considered together with the investment on spare part stock to fill in the gaps of instruments under calibration should be considered.

Finally, initiating the process of implementing a WMO Information System for the WIGOS national governance mechanism and adopting the national plan will enhance coordination and resource management. These recommendations collectively hold the potential to advance the MMS's observational network, addressing data quality issues and improving its adherence to international standards and regulations.

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.

MMS operates a total of 5 stations that contribute to the Global Basic Observing Network (GBON). However, there are challenges with station functionality, as only approximately 29 out of 44 AWS are currently operational. This discrepancy highlights the need for efforts to maintain and potentially expand the network to meet GBON reporting station requirements more comprehensively.

Regarding compliance with GBON standards, the MMS has made progress by operating these reporting stations. Still, there is room for improvement to ensure the full alignment of the network with GBON requirements. The main issues to reach the GBON compliance are: For the surface observation network sharing of data with hourly interval and for the upper air sounding station, renewing the station and reporting the measurements twice a day.

The monitoring of greenhouse gas (GHG) parameters falls under the purview of the Climate Change division within the Ministry of Environment, Climate Change, and Technology. As such, the MMS does not currently observe GHG parameters as part of its meteorological services. This division of responsibilities ensures a specialized focus on climate-related data.

In terms of data transfer protocols, the MMS has yet to migrate to the WMO Information System (WIS) 2.0 protocols for data transmission. Presently, data transfer relies on the Global Telecommunication System (GTS) for this purpose. The transition to WIS 2.0 protocols could offer benefits in terms of data efficiency and accessibility, and it may be an area for future development within the MMS.

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

MMS currently faces certain challenges in data sharing and interagency cooperation. At present, there is no established national agreement within the WIGOS framework for the integration and open sharing of observations from both NMS and non-NMS sources. This absence of a formalized partnership agreement may limit the seamless exchange of vital observational data.

Additionally, the MMS lacks specific data policies and practices for sharing observation data. While data generated by the MMS can be provided to users upon request free of charge, there is no comprehensive data sharing policy or established practices in place. This may impact the accessibility and consistency of data sharing.

Furthermore, the MMS does not currently possess a system for quality control, archiving, and sharing of observation data. The absence of such a system may affect data management and the long-term preservation of critical meteorological information.

Regarding data policy, there is no existing framework that allows for the free and open sharing of observation data. This limitation may restrict broader access to valuable meteorological data.

Nevertheless, the MMS has established agreements and interagency protocols for data exchange related to monitoring systems and baseline data necessary to produce data products for various priority hazards with Civil Aviation Authority and Maldives Airports Company Limited. MMS is mandated to provide these data to NDMA under Disaster Management Act as well. While these agreements are in place, they are described as being only partially effective, suggesting that further enhancements and clarifications may be required for more robust and seamless data exchange, particularly in the context of priority hazards such as wind, flash floods, high seas, thunderstorms, and tropical cyclones.

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

MMS relies on satellite data to monitor various priority hazards within the country or territory. Satellite data plays a crucial role in monitoring the following hazards: flash floods, high seas and rogue waves, thunderstorms and squall lines, and tropical cyclones. While satellite data is instrumental for these hazards, it is not currently utilized for monitoring wind-related hazards.

To effectively utilize satellite data, the MMS has ensured that its staff is trained in remote-sensing data access and interpretation for all priority hazards. This training equips the team with the necessary skills to access and interpret satellite-derived information, enhancing the meteorological services' capabilities in hazard monitoring.

In terms of satellite data reception, the MMS has established various means for accessing this vital information. They maintain a CMACast reception station, facilitating data reception through this system. Additionally, the MMS accesses INSAT 3D and 3DR satellite images through web-based platforms and obtains open-source Altimeter, ASCAT METOP-B, and ASCAT METP-C satellite products (NOAA) via the internet. These multiple channels for satellite data access ensure a diverse and robust data stream for hazard monitoring.

To facilitate data access and communication, the MMS employs a combination of satellite data receiving systems and internet connectivity. These communication systems are pivotal for accessing and disseminating critical meteorological data and products.

Regarding internet stability and bandwidth, the MMS enjoys a very good and stable internet connection at its headquarters, the national meteorological center (NMC). The available bandwidth offers substantial download and upload speeds, with a download speed of 50 Mbps and an upload speed of 30 Mbps. This reliable internet infrastructure enhances the MMS's capacity to access and distribute meteorological data efficiently.

Summary score and recommendations for Element 4

The maturity level for this component is assessed as **Level 3** as "*moderately well mandated, managed and resourced and clear plans for, and sufficient capacity to address operational gaps*."

To enhance the maturity level, the following recommendations are proposed:

1. **Centralized Data Management**: Implement a centralized data collection, management, and dissemination system that encompasses stakeholder data dissemination. This approach will streamline data handling processes and improve accessibility to meteorological information for various stakeholders.

2. **Expand International Data Sharing**: Extend data sharing efforts by incorporating the rest of the observation network data into international sharing mechanisms. This step will contribute to a more comprehensive and globally connected meteorological data network.

3. **Migration to WIS 2.0 Protocols**: Prepare for the migration to the use of WIS 2.0 protocols for data transfer. Collaborate with the WMO to access relevant training and guidance to ensure a smooth transition to this advanced protocol.

4. **Engage with Other Ministries/Institutions**: Establish coordination mechanisms with other ministries, institutions, and local governments that have the potential to conduct hydrometeorological observations. Collaborative efforts will expand the observation network, enhancing data coverage and accuracy.

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.

MMS actively utilizes forecast products from various World Meteorological Centres (WMCs) and Regional Specialized Meteorological Centres (RSMCs) to support its service delivery. These sources include the Korea Meteorological Administration (KMA), China Meteorological Administration (CMA), European Centre for Medium-Range Weather Forecasts (ECMWF), India Meteorological Department (IMD), Regional Integrated Multi-Hazard Early Warning System (RIMES), and the UK Met Office (UKMO).

The types of forecast products obtained encompass a range of formats, including charts, images, texts, and gridded data, with the latter primarily sourced from ECMWF. The

gridded data is employed by the MMS for generating spatial plots, enhancing their ability to visualize and understand meteorological phenomena. While MMS staff do access and use these products, it's important to note that their training in this regard is not official. Nevertheless, they have acquired proficiency in accessing and utilizing the available resources.

In terms of access to products provided by global and regional centres, the MMS generally experiences reliable access, ensuring a continuous flow of critical meteorological information. However, the level of access has not significantly improved in the past two years, indicating a relatively stable status in this aspect of their operations.

Since February 2023, the MMS has collaborated with ECMWF through the WMO scholarship scheme, part of a wider programme designed by WMO to expand its international network of cooperation opportunities between weather forecasters from different countries.[8] This is a good example of international training opportunities aimed at increasing the capacity of the MMS staff in NWP. It is recommended that the MMS continues to pursue such opportunities whenever available.

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

MMS indeed releases forecasts and warnings based on deterministic Numerical Weather Prediction (NWP). These forecasts play a crucial role in their efforts to provide accurate and timely information to support weather and climate-related decision-making.

To achieve this, the MMS utilizes a diverse set of NWP models, each with its own unique capabilities and attributes. These models include the following of which the WRF model is ran in-house in MMS:

- **ECMWF**: This model offers a maximum lead time of 10 days, with a spatial resolution of 9 kilometers and a temporal resolution of 6 hours.
- **WRF**: The Weather Research and Forecasting model provides a maximum lead time of 3 days, with a spatial resolution of 27 kilometers and a temporal resolution of 1 hour. This model is run in-house in the MMS.
- **UM-UKMO**: Utilizing the Unified Model from the UK Met Office, this model offers a maximum lead time of 7 days, with a spatial resolution of 27 kilometers and a temporal resolution of 3 hours.
- **IMD model output (WRF)**: The MMS relies on output from the India Meteorological Department (IMD) model, which has a maximum lead time of 5 days, a spatial resolution of 3 kilometers, and a temporal resolution of 3 hours.
- **CMA model output**: Output from the China Meteorological Administration (CMA) model is used, offering a maximum lead time of 144 hours, a spatial resolution of 0.5 degrees, and a temporal resolution of 6 hours.
- **JMA model output**: Data from the Japan Meteorological Agency (JMA) model is incorporated into their forecasting efforts, providing a maximum lead time of 10 days with a 6-hourly temporal resolution.

[8] ECMWF, 17 February 2023, "Maldives Meteorological Service and ECMWF collaborate through the WMO Fellowship Scheme"

- **Oceanic model**: The MMS also utilizes oceanic models, including those from the Indian National Centre for Ocean Information Services (INCOIS) and the WAVE4M model, which is supported by Italy and, in the near future, by USAID.

By harnessing the capabilities of these NWP models, the MMS is better equipped to generate forecasts and warnings that are vital for safeguarding the Maldives against weather-related hazards and ensuring the well-being of its citizens and visitors. The WRF model is ran in-house in MMS. However, the data assimilation and verification methods should be developed for the model.

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

While MMS does not directly release forecasts and warnings based on probabilistic NWP, it is worth noting that probabilistic NWP is used as one of their valuable references in the forecasting process. This means that while probabilistic forecasts may not be published as standalone products, they play a role in enhancing the overall accuracy and reliability of the MMS's weather predictions.

In this pursuit, the MMS leverages model output from various Global NWP and climate prediction centers. These models provide valuable probabilistic information that contributes to the MMS's decision-making processes, ultimately leading to more informed and precise forecasts and warnings.

However, it's important to note that the MMS currently lacks the capacity to post-process NWP data, including Ensemble Prediction System (EPS) products. The absence of post-processing capabilities means that they do not perform additional statistical or numerical operations on the NWP data to generate ensemble forecasts or other probabilistic products.

In terms of their NWP equipment, the MMS employs a range of hardware and software resources to support their forecasting activities. Hardware includes mini server PCs and desktop PCs, while software tools such as Python, QGIS, and ArcGIS are used to facilitate data analysis, visualization, and other critical tasks related to weather forecasting and monitoring.

While the MMS may not currently release probabilistic forecasts as standalone products, their use of probabilistic NWP data as a reference underscores their commitment to improving forecast accuracy and providing the best possible weather information to protect lives and property in the Maldives.

Summary score and recommendations for Element 5

The maturity level for this component is assessed as **Level 3** as *"prediction based mostly on model guidance from external and limited internal sources (without data assimilation) and remoted sensed products in the form of maps, figures and digital data and cover nowcasting, short and medium forecast time ranges."*

The MMS predominantly relies on external model guidance and remote-sensed products to provide predictions. While this approach serves as a foundation for weather forecasting, there are opportunities for significant improvement. To enhance forecasting capabilities, several key recommendations have been identified.

- The MMS should invest in improved resources, including strengthening technical capacity of the staff, training of IT and modelling experts, and consider the installation of a High-Performance Computing (HPC) system, for which training of staff to manage the HPC would be needed. Adequate training for staff members is essential to harness the full potential of these resources.

- Implementing post processing methods, such as the Model Output Statistic (MOS), is another crucial step towards enhancing forecast accuracy. Post processing can refine the skill of existing models and contribute to more reliable predictions.
- Expanding the forecast range and improving the spatial resolution of the existing WRF model outputs can lead to more precise forecasts for the Maldives. Moreover, data assimilation covering the surface observation stations, soundings and radars would improve the initialization of the model and the forecast quality in general.
- Furthermore, archiving raw model data in a centralized storage system allows the MMS to build model climatology and develop time-lagged ensemble forecasts, which can provide valuable insights for decision-makers.
- Considering the potential benefits of cloud computing for heavy model post-processing tasks is also recommended, as it can streamline operations and improve efficiency.
- The implementation of a centralized data management system capable of integrating both internal and external model data, along with conducting post-processing operations, can significantly enhance the MMS's capacity to produce accurate and reliable forecasts, ultimately contributing to improved weather services for the Maldives. The data management system should include or be integrated into forecaster workstation tool and automated forecast production system to improve the product dissemination.

Element 6: Warning and advisory services

6.1. Warning and alert service cover 24/7.

MMS operates its warning and alert service 24/7 throughout the year, ensuring that it is consistently available to provide timely and critical information to the public. This continuous service is vital for addressing the unique weather and climate challenges faced by the Maldives, given its vulnerability to extreme weather events.

The Maldives has also established a Multi-Hazard Early Warning System (EWS), which operates in the country. This system is structured based on the Common Alerting Protocol (CAP), which provides a standardized approach to disseminating alerts and warnings for various hazards. The presence of a well-defined SOPs further enhances the EWS's effectiveness in responding to multiple hazards.

The country's monitoring and forecasting systems are designed to handle situations where multiple hazards may occur simultaneously or cumulatively over time. This capability allows the MMS to provide comprehensive and integrated early warnings to mitigate potential risks effectively.

Moreover, the MMS takes into account the possibility of cascading impacts caused by various hazards. The MMS disseminates advisory information that alerts the public to the potential hazard and in the future aims at also distributing information about potential impacts, ensuring that people are well-informed about the risks they face.

Currently MMS alerts are at Atoll level. As its core systems are further strengthened, it aims to reach every community in the country with early warning information, vital alerts and warnings. This widespread reach is essential for safeguarding lives and property across the nation.

In terms of lead times for warnings, the MMS provides advisories based on the potential hazard as it develops. This approach allows for proactive communication with the public, ensuring that they are informed and prepared for impending weather-related challenges.

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

MMS provides a comprehensive range of warning services to address various priority hazards, including tsunami, tornado, storm surge/coastal flood, wind, tropical cyclone, thunderstorms/squall lines, high seas/rogue waves, rain/wet spells, lightning, and flash floods. These services cater to a wide spectrum of potential weather and climate-related risks, ensuring that the public is well-informed and prepared.

To ensure the effectiveness and relevance of these warnings, user feedback mechanisms and public surveys to verify the warnings' timeliness and relevance have been conducted at times. Regular feedback is especially collected during annual Monsoon Forum where MMS engages with all their major stakeholders. There is a feedback mechanism established in the MMS mobile app as well, from which the results are reviewed regularly, allowing the MMS to fine-tune its services based on the valuable input received from users and stakeholders. This feedback mechanism should be continuous and repeated for example annually.

The MMS actively evaluates its performance and role within the national Multi-Hazard Early Warning System (EWS) and Disaster Risk Reduction (DRR) platform. This ongoing evaluation ensures that the MMS continually enhances its service delivery and coordination efforts, aligning them with the evolving needs of the nation.

While the MMS conducts internal evaluations, the country does not have a specific mechanism in place to evaluate the overall performance of the EWS. However, the MMS utilizes guidance products provided by Regional Specialized Meteorological Centres (RSMCs) to enhance its local warnings. For instance, in the case of wind warnings, the MMS relies on RSMC advisories as the basis for issuing local warnings, ensuring alignment with international standards.

The use of a Flash Flood Guidance System for issuing flash flood warnings is not currently implemented by the MMS. However, the MMS maintains a warning and forecast archival system for all priority hazards, ensuring that historical data is readily accessible for reference, research, and verification purposes.

The MMS also ensures the accessibility of monitoring data and metadata for verification of forecasts, research, and other applications. This open access to data contributes to transparency and allows for robust scientific evaluation and analysis.

While the national EWS conducts regular system-wide tests and exercises to assess its preparedness and response capabilities, the country has implemented certain fail-safe systems. These include power backup options to ensure continuous operations, helping to maintain essential services even during unforeseen disruptions.

In summary, the Maldives Meteorological Services demonstrates a commitment to delivering a wide range of warning services and actively engages in user feedback, evaluation, and coordination within the EWS and DRR framework. While certain areas, such as flash flood guidance and overall EWS evaluation, present opportunities for improvement, the MMS remains dedicated to enhancing its capabilities and safeguarding the nation from weather and climate-related hazards.

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.

MMS is committed to delivering its warnings in the Common Alerting Protocol (CAP) format, ensuring that alert messages are compatible with international standards and can be effectively disseminated to the public and relevant authorities.

To enhance its warning services, the MMS has established SOPs in coordination with registered authorities and stakeholders. The MMS SOP is synergised with other stakeholders' SOPs. For example, MMS alerts of different category will trigger the SOPs of the stakeholders including NDMA, Airport Emergency Operation, Education Sector Schools, Government Ferry Transport, Coast Guard, Marine Police etc. These SOPs are tailored to different hazard types, including wind, flash floods, high seas/rogue waves, thunderstorms/squall lines, and tropical cyclones. This proactive approach helps streamline communication and response efforts during adverse weather events.

While the MMS provides traditional forecasts and warnings, impact-based forecast and warning services, which consider potential consequences and impacts, are currently not produced or provided by the MMS. There is an opportunity for the MMS to further enhance its services by incorporating impact-based forecasting (IBF) principles.

To bolster IBF capabilities, it is essential that forecasters receive training in the principles, methods, and application of impact-based forecasting. Currently, few staff members at the MMS have received such training, indicating room for expansion in this area.

Access to impact information from various sectors and post-disaster analytics is currently limited for the MMS. The incorporation of such information into impact-based forecasts could significantly improve the quality and relevance of warnings.

The use of hazard-specific impact models is not a current practice at the MMS, and responsibility for impact modelling primarily lies with other agencies or ministries in the country.

Regarding software tools for producing impact-based forecasts and warnings, the MMS currently lacks sufficient resources in this regard. Investment in appropriate software tools could enable the MMS to develop more sophisticated and impactful warning products.

The warning messages issued by the MMS currently do not advise on specific actions that can be taken to reduce risks. Incorporating actionable guidance in warning messages could empower the public and authorities to make informed decisions during hazardous events.

The Registry of Alerting Authorities for the Maldives is complete and up to date, ensuring effective communication and coordination among relevant entities during emergencies.

Summary score and recommendations for Element 6

The maturity level for this component is assessed as **Level 3** as "weather-related warning service with modest public reach and informal engagement with relevant institutions, including disaster management agencies".

To elevate its warning services to a higher level of effectiveness and engagement, the MMS should consider several key recommendations.

- Conducting regular evaluations of the performance and accuracy of warnings and initiating continuous operational verification of these warnings is crucial. This process should include the establishment of user feedback mechanisms to ensure that warnings are not only timely but also relevant and reliable.
- Implementing a Quality Management System (QMS) tailored to warning services is essential for maintaining and improving the quality of warnings. This framework

can help streamline processes, enhance data management, and ensure that warnings meet established standards.

- To enhance the utility of warning messages, the MMS should consider including statements for action in its communications. These actionable steps can empower the public and authorities to take appropriate measures in response to weather-related hazards.
- Exploring the implementation of impact-based forecasting (IBF) is another critical step. IBF takes into account potential consequences and impacts of weather events, providing more comprehensive and informative warnings.
- To better serve specific sectors and local contexts, the MMS should identify and develop sectoral-based and locally contextualized warnings. This approach ensures that warnings are tailored to the unique needs and vulnerabilities of different communities and industries.
- Investing in the development of weather radar-based nowcasting algorithms, such as MAPLE or PySTEPS, can significantly improve the accuracy and timeliness of short-term weather predictions. Additionally, leveraging satellite-based products like GSMAP RIKEN NOWCAST for nowcasting references can enhance the MMS's capabilities.
- Conducting customer surveys of warning services can provide valuable insights into the effectiveness of warnings and areas for improvement. By actively seeking feedback from the public and relevant institutions, the MMS can refine its services and enhance its engagement with stakeholders.

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.

In assessing the climate service capabilities in the Maldives, several key aspects have been examined.

Governance: The Maldives has established national governance mechanisms to ensure coordination for climate services. These mechanisms align with climate change adaptation and mitigation efforts outlined in the National Determined Contribution (NDC). The country has also embraced an open data policy, reinforced by a presidential instruction to respond to data requests within three days. These governance structures provide a foundation for coordinating and integrating climate services into national adaptation planning.

Basic Systems: MMS maintains fundamental climate systems, including observing networks, data management, and forecasting systems. These systems enable the production and delivery of climate information and services. The MMS climate division generates monthly climate reports distributed through the Global Telecommunication System (GTS) and the MMS website. Seasonal and sub-seasonal forecasts are made available on the website and discussed during the South Asian Seasonal Climate Outlook Forum (SASCOF).

User Interface: Mechanisms for user interaction and engagement in climate services are present in the Maldives. An annual national the Monsoon Forum serves as a platform for dialogue and feedback. Additionally, the MMS offers a dedicated email and maintains an informative website to facilitate communication between climate service users and providers.

Provision and Application of Climate Services: The MMS offers various climate services, including time series plots of temperature, rainfall, sunshine, and wind. It also provides seasonal climate outlooks and publishes monthly climate reports. However, it's

important to note that there is no dedicated staff specifically allocated to climate service provision, which may affect the depth and customization of services.

Monitoring and Evaluation of Socio-Economic Benefits: The Maldives currently lacks a structured mechanism for monitoring and evaluating the socio-economic benefits of climate services. While climate data is available, its direct translation into quantifiable socio-economic impacts remains an area for further development.

Capacity Development: The country has yet to establish formal technical advisory services and training programs to address capacity development needs related to climate service provision and use.

Data Rescue: Data rescue efforts have been undertaken across various variables; however, there are still records unavailable and scattered in other institutions that have not been rescued, indicating room for improvement in this area.

Summary score and recommendations for Element 7

The maturity level for this component is assessed as **Level 2** as "*Basic Capacity for Climate Services Provision"*

To enhance and elevate its climate service capabilities, several key recommendations have been identified.

- The establishment of dedicated staff members specifically tasked with climate services provision and capacity building is essential. These experts can facilitate the development of tailored climate information based on user needs, enabling more effective communication and coordination among stakeholders.
- The implementation of a robust climate database management system with end-user production capabilities is imperative. Such a system would enable the efficient collection, management, and dissemination of climate data and information, fostering accessibility and usability.
- Intensifying coordination and communication efforts among relevant institutions and stakeholders is essential. This collaborative approach can lead to the creation of more specific and tailored climate information, as well as enhance observation and data sharing, ultimately improving the quality and relevance of climate services.
- Conducting impact-based analyses or loss and damage assessments for weather and climate services across various sectors is crucial. These assessments can provide valuable insights into the potential impacts of extreme hydro-meteorological events on different sectors in the Maldives. Such analyses are particularly important given the country's vulnerability to climate-related risks and the need to strengthen disaster risk reduction efforts.

Element 8: Contribution to hydrology

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

The relevance of hydrological services at MMS is low due to its geographical characteristics, mainly lack of rivers, lakes and glaciers. As the MMS is mandated by the government to carry out activities related to meteorology, tsunamis and earthquakes, there is no single authority to carry out tasks related to hydrology. Hence, the standard products such as quantitative precipitation estimation and forecasts are not made ready and produced on a routine basis at the MMS. The QPE is produced according to the requirements of the hydrological research community.

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

There is no SOP for the exchange of information between MMS and hydrological agencies, as the state tasks for hydrology in the Maldives is not carried out by a single organization. There is also no clear flood management plan currently established in the Maldives.

Yet Maldives is particularly vulnerable to rising sea levels due to climate change. With global sea level rising 3 to 4 millimetres per year, some studies suggest that the low-lying islands of the Maldives are at serious risk of becoming uninhabitable as wave-driven flooding becomes more frequent.[9] The country is also regularly affected by high frequency low impact seasonal monsoonal flooding, with 90% of the islands having been reported to experience annual flooding. Due to this, the NDMA has several flood response mechanisms in place that have been activated in the past.[10]

Although accessible for flood prediction, QPE/QPF data is yet to be verified to evaluate either the longer-term effects of climate change or the availability of hydrological groundwater.

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

MMS is currently not sharing any hydrological data. However, it has committed to responding to any data request between local and national agencies or across international borders within 3 days. This is a regulation related to open data policy regulating government institutions under the instructions by the President's Office of the Maldives.

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

One of the key hydrological collaboration initiatives that the MMS has taken part in, is the practice of rainwater harvesting. As the Maldives has suffered from severe shortage of freshwater, in 2017 the Government launched a 28-million-dollar project dedicated to improving fresh water supply in several of the islands, jointly funded with the Green Climate Fund and UNDP[11]. The initiative included completion of Rainwater Harvesting Systems and installing new water resource managing systems, designed to combine ground water, rainwater, and desalinated water. As one of the project's goals was to enable improved harvesting of rainwater, it was also closely collaborating with the MMS.

In 2020 Ministry of Environment made enhancing water security as one of its main priorities, indicating that rainwater harvesting continues to remain a high priority for the government in the future.

Summary score and recommendations for Element 8

The maturity level for this component is assessed as **Level 1** as *"no or very little meteorological input in hydrology and water resource management."*

The relevance of hydrological services through the MMS is very low, but the level can be improved by increasing interaction with the hydrological sector, offering climatic information and services considering the long-term impact of climate change into the hydrological ground water availability.

Element 9: Product dissemination and outreach

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

In the Maldives, the MMS employ a comprehensive set of communication channels to ensure the effective dissemination of weather products and services. These channels are instrumental in delivering timely and accurate weather-related information to the public and other end-users.

The MMS operates a weather studio that functions 24/7, providing continuous monitoring and updates on weather conditions and forecasts. This round-the-clock operation is essential for staying informed about evolving weather patterns and disseminating critical information promptly. Radio channels are utilized as a primary means to review and disseminate updated weather information, ensuring that the public remains well-informed.

To reach a broad spectrum of users, the MMS employs various communication channels, including television, radio, web applications developed in-house, social media platforms, mobile phone applications (both in-house and third-party), as well as SMS text messaging and push notifications. This diverse array of channels ensures that weather warnings and forecasts are accessible to a wide audience with varying preferences for information sources.

Furthermore, the MMS extends its reach to regional and local levels within the Maldives. This approach ensures that weather warnings are not only available nationally but are also tailored to the specific needs and challenges faced by communities in different regions of the country. By providing localized information, the MMS enhances community resilience and preparedness in the face of weather-related hazards. Currently the MMS alerts are at Atoll level. The MMS plans to demonstrate IBF at Island level once its computation capacity to run NWP models at higher resolution has been improved.

9.2. Education and awareness initiatives in place.

MMS collaborates with island communities, NGOs (Red Crescent), local government officials, and disaster management organizations to organize outreach activities. Interaction with stakeholders and end-users also takes place during regional user forums or outreach initiatives undertaken by international partners such RIMES. College students

[9] USGS, 2018, "Many Low-Lying Atoll Islands Will Be Uninhabitable by Mid-21st Century"
[10] UNDRR, 2019, Disaster Risk Reduction in Republic of Maldives: Status Report 2019
[11] UNDP, 2022, On tap: How the Maldives is restoring water security on its most vulnerable outer islands

and students frequently visit MMS as part of community awareness program. This is also done at existing observation stations on other islands. In the case there is no local MMS office, the awareness program is carried out virtually upon request. Further, awareness campaigns are carried out regularly in partnership with local CSOs

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

Some initiatives together with CSOs have been undertaken to reach vulnerable and marginalised groups like the youth, the elderly, people with disabilities, and others. These initiatives are mostly run by the MRC, which disseminates information provided by the MMS to underserved groups withing their local networks. In October 2022 the NDMA, UNDP and MRC, with few other partners, established a new platform of cooperation on strengthening DRR planning at island community level, with a specific emphasise on the most vulnerable people (women, elderly, disabled people) most at risk from climate change[12]. MRC also works with migrants, to ensure that no-one is left behind in the event of a crisis.[13] This is particularly important, as Maldives is a home to an estimated 200,000 international migrants.

As it is crucial that all citizens will be able to reach, read and understand weather forecasting and early warning systems, it is recommended for the MMS to conduct a social communication plan, tailored to different languages, as well as a socioeconomic communication strategy customized to the needs of the local population. In addition, MMS is striving to eliminate language barriers and create sector-based warnings in order to implement IBFRBW. There is potential to improve this service in collaboration with MRC.

Summary score and recommendations for Element 9

The maturity level for this component is assessed as **Level 3** as "a moderately effective communication and dissemination strategy and practices are in place, based only on in-house capabilities and supported by user-friendly website."

The maturity level can be further raised by making the website more informative, including by developing more sector-based warnings beyond aviation and tourism, and holding more awareness-raising and capacity-building activities within the end-user community. Moreover, increasing the number of end-user products and implementing more dissemination methods would require implementation of automated forecast production process and forecast production tools in the MMS.

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.

In the Maldives, the MMS actively engages with various stakeholders and organizations to enhance the coordination of DRR activities. At the national and sub-national levels, a Disaster Management Steering Committee has been established to oversee and coordinate DRR efforts. This committee consists of ministries, agencies, and other stakeholders dedicated to disaster management. Notably, the MMS is a valued member of this committee, highlighting its crucial role in contributing to the broader national DRR framework. However, despite Committee having been established, it is not yet operational.

[12] UNDP, 2022, Supporting Sustainable Disaster Risk Reduction, Climate Change Adaptation and Mitigation in Maldives

[13] IFRC, 2018, Disasters and Displacement in a Changing Climate: The Role of Asia Pacific National Societies

While there is no formal multi-sector consultative platform specifically dedicated to meteorological and hydrological services in the country, the MMS collaborates closely with stakeholders from various sectors, including agriculture, fisheries, gender, and local government. These partnerships foster regular cooperative dialogue and enable the co-development of tailored weather and climate products and services that meet the specific needs of these sectors.

The MMS provides a range of services compliant with the International Civil Aviation Organization (ICAO) Annex 3 standards, ensuring the safety and efficiency of aviation operations. These services are essential for maintaining air travel safety in the country.

In recognition of the importance of assessing the social and economic benefits (SEB) of weather, climate, and hydrological services, the MMS has taken part in a stakeholder workshop in collaboration with the World Bank. This workshop, conducted in June 2023, aimed to evaluate the SEB of meteorological and hydrological services. The findings from this assessment are currently under preparation and are expected to provide valuable insights into the societal and economic advantages of these services.

The MMS maintains an active online presence through social media platforms such as Facebook, Twitter, and Viber. Additionally, they operate a website and a mobile application, providing accessible and up-to-date weather and climate information to the public and stakeholders.

The frequency of multi-sector consultative platforms varies, with the already mentioned Monsoon Forum serving as a prominent event for dialogue and cooperation. The MMS has demonstrated willingness and proactiveness to take the central role as the main organizer and convener of dialogues between sectors, facilitating collaboration and ensuring that weather and climate information effectively support various sectors' needs and operations.

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

The MMS monitors user satisfaction and service improvement through occasional independent user satisfaction surveys. These surveys are conducted annually, specifically targeting the aviation sector. Additionally, a general survey was conducted before the onset of the COVID-19 pandemic. These surveys play a pivotal role in gathering feedback from users and stakeholders, providing valuable insights into the quality and effectiveness of the services provided by the MMS.

To ensure comprehensive and inclusive assessments, the MMS has incorporated multi-lingual assessment tools within its Service Delivery Plan. These tools are designed to facilitate assessments conducted by the MMS themselves and external reviewers. The use of multiple languages, including English and Dhivehi, allows for a more diverse range of users to participate in the evaluation process, ensuring that a broader spectrum of perspectives is considered when assessing the services provided.

Furthermore, the MMS places a strong emphasis on continuous evaluation and reporting to monitor the accuracy and timeliness of its services. This commitment is reflected in the daily and weekly reports prepared by the MMS. These reports provide detailed assessments of the forecast accuracy and timeliness of the services, allowing for ongoing improvements to be made based on the collected data and insights. This dedication to evaluation and reporting ensures that the MMS can maintain the highest standards in service delivery to meet the needs of its users and stakeholders effectively.

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

The MMS has already taken significant steps in implementing QMS to enhance the provision of meteorological and climate warning services. Notably, the MMS has successfully implemented a QMS for its aviation services, achieving ISO 9001: 2015 certification. This certification reflects the MMS's commitment to maintaining high-quality standards in delivering services critical to aviation safety.

In terms of climate services, the MMS conducts quality management standards for various areas, including climate data management, climate monitoring, climate prediction, and service delivery. While the MMS has made substantial progress in implementing QMS for aviation and air navigation, similar initiatives for marine services are not currently in place.

Looking ahead, the MMS plans to implement QMS for the entirety of its forecast services. The timeline for this implementation will depend on annual budget allocations, indicating the MMS's commitment to continuously improving and standardizing its services to meet international quality standards and the needs of its users and stakeholders.

Summary score and recommendations for Element 10

The maturity level for this component is assessed as **Level 2** as *"MMS service development draws on informal stakeholder input and feedback"***.**

To elevate this maturity level, several key recommendations have been put forward. It is crucial to establish a continuous user engagement process that encompasses all service fields of the MMS, facilitating customer feedback through various channels such as the website and mobile applications. Additionally, expanding the implementation of QMS to cover all operational fields of the MMS is essential to standardize and enhance the quality of services provided. These initiatives will contribute to a more proactive and effective approach to meteorological input in hydrology and water resource management, ensuring better preparedness and response to weather-related challenges in the Maldives.

Annex 1 Consultations

- The stakeholder consultations with representatives from key organizations including the National Disaster Management Authority (NDMA), Ministry of Environment, Climate Change, and Technology (MoECCT), Maldives Airports Company Limited (MACL), Water and Sanitation (WATSAN), Ministry of Fisheries, Marine Resources and Agriculture (MoFMRA), Health Protection Agency (HPA), and Maldives Red Crescent (MRC).
- Expert consultations with staff members from different organizational levels at the MMS
- The CREWS Secretariat and Project Managers (for South-Asia sub-region)
- WMO SOFF Team for WIS2.0 and SOFF Readiness Phase

Annex 2 Urgent needs reported

- Enhancement of institutional framework and setup of meteorological and hydrological services; for improved strategic planning, engagement with stakeholders, service provision (public private partnership and cost recovery) to address hydrometeorological challenges effectively, including establishing coordination mechanisms with other ministries, institutions, and local governments that have the potential to conduct hydrometeorological observations.
- Addressing observation data quality control issues through enhancing capacities and capabilities.
- Improve maintenance, calibration and staff capacities for enhancing the operations and sustainability of the observation network.
- Enhancing the ICT for centralized and holistic data archiving, processing, dissemination, and sharing effectively.
- Migration to WIS 2.0
- Focusing on sustainable NWP efforts and enhancement through post-processing, cloud computing and enhanced collaboration with regional NWP centres.
- Improvement of the warning advisory services within MHEWS environment and adopting the IBF, in consultation with stakeholders, e.g. tailoring the messages, supporting decision making, providing enhanced support to sectors and localizing the warnings.
- Improve the staff capacities, enhance the usage of ancillary data (inc. data rescue), focus on service provision through tailoring products in coordination with relevant agencies and stakeholders and step up to quality climate service provision.
- Among the most critical issues, lack of provision of the operational hydrological services stands as top priority, given that water resources management, agriculture and disaster management is highly affected with the current level of services. Hence, it is highly recommended to engage with national agencies, stakeholders and public for developing a national roadmap and increase the efforts for MMS to get international support and funds to cover this critical service gap.

- Stepping up the services (provision of information and warnings) and automated processes for improved dissemination with better focus on sectors, public, e.g. end-users, and their needs.
- Expanding the implementing the Quality Management System (QMS) to NMHS operations (e.g. other hydromet services). Improving customer/client feedback and its involvement in institutional strategies, enhancemet and service provision.

Annex 3 Information supplied through WMO

- WMO Global GBON gap Analysis
- WMO Monitoring System Data
- WMO EW4All Rapid Assessment for Pillar-2
- WMO Hydrology Survey
- Data from Checklist for Climate Services Implementation

Annex 4 List of materials used

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

- Online material included as references to this document.
- The MMS official website
- Official governmental and ministry level documents, shared by and translated to English by the MMS (information on the MMS mandate, procurement procedures etc.)
- MMS internal documents relevant to the report, such as the annual budget, gender balance of the staff etc.
- The following reports:
    - UNEP, February 2018, "Toward Risk-Aware and Climate-resilient communities (TRACT) - Strengthening climate services and impact-based multi-hazard early warning in Maldives"
    - India Meteorological Department, 2021. "Country Hydromet Diagnostics Report on Maldives"
    - USAID, July 2023, "Potential for Impact Based Forecasting in the Maldives to mitigate climate risks"