

Hydromet Gap Report 2024

Alliance for Hydromet Development



Alliance for Hydromet Development



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Acknowledgements

The present report is the product of the collaborative work of the members of the Alliance for Hydromet Development and the Systematic Observations Financing Facility (SOFF) peer advisers. The production of the report was coordinated and led by Assia Alexieva and Anaïs Bellalouna (WMO). The report would not have been possible without the input and support of many partners and colleagues, namely:

Alliance for Hydromet Development: Gerard Alleng (Inter-American Development Bank), Anna-Maria Bogdanova (World Bank/Global Facility for Disaster Reduction and Recovery (GFDRR)), Isabelle Braly-Cartillier (Inter-American Development Bank), Jahan-Zeb Chowdhury (International Fund for Agricultural Development), Bapon Fakhruddin (Green Climate Fund), Alexandra Galperin (Asian Development Bank), Amir Habchi (European Bank for Reconstruction and Development), Niels B. Holm-Nielsen (World Bank/GFDRR), Kevin Horsburgh (Green Climate Fund), Portia Hunt (United Nations Environment Programme), James Kinyangi (African Development Bank), Emmanuel Kouadio (Climate Investment Funds), Benjamin Laroquette (United Nations Development Programme), Xianfu Lu (Climate Investment Funds), Kouassi Malvika Monga (Global Environment Facility), Silvia Mancini (Adaptation Fund), Jesse Mason (World Food Programme), Daouda Ndiaye (Islamic Development Bank), Solomon Ngoze (African Development Bank), Maria Anna C. Orquiza (Asian Development Bank), Moussa Sidibe (World Bank/GFDRR), Vladimir Tsirkunov (World Bank/GFDRR), Jochem Zoetelief (United Nations Environment Programme);

SOFF peer advisers: Bureau of Meteorology (Australia), Danish Meteorological Institute (Denmark), Deutscher Wetterdienst (Germany), Finnish Meteorological Institute (Finland), GeoSphere Austria (Austria), Icelandic Meteorological Office (Iceland), Meteorology, Climatology and Geophysical Agency (BMKG) (Indonesia), Nigerian Meteorological Agency (Nigeria), Norwegian Meteorological Institute (Norway), South African Weather Service (South Africa);

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Permanent Representatives of Members with WMO and staff of the National Meteorological and Hydrological Services:

National Center for Hydrology and Meteorology (Bhutan), National Institute of Meteorology and Geophysics (Cabo Verde), Agence Nationale de la Météorologie (Chad), Ethiopia Meteorology Institute (Ethiopia), Fiji Meteorological Service (Fiji), Guyanese Hydrometeorological Service (Guyana), Kiribati Meteorological Service (Kiribati), Liberia Meteorological Service (Liberia), Direction Générale de la Météorologie (Madagascar), Department of Climate Change and Meteorological Services (Malawi), Maldives Meteorological Service (Maldives), Mozambique National Meteorology Institute (Mozambique), Nauru National Meteorological and Hydrological Service (Nauru), National Weather Service (Papua New Guinea), Meteo Rwanda (Rwanda), Samoa Meteorology, Geoscience and Ozone Services Division (Samoa), Solomon Islands Meteorological Service (Solomon Islands), South Sudan Meteorological Department (South Sudan), Tanzania Meteorological Authority (United Republic of Tanzania), National Directorate of Meteorology and Geophysics of Timor-Leste (Timor-Leste).

Special thanks go to the SOFF Secretariat (Ana Heureux, Markus Repnik, Laura Tuck) and WMO (Victoria Alexeeva, Meerim Ashakeeva, Moyenda Chaponda, Albert Fischer, Veronica Grasso, Cristina Grigoras, Leonid Kadinski, Fatih Kaya, Daniel Kull, Laura Paterson, Yi Wang) for their contributions to this report and to the Country Hydromet Diagnostics. Sincere thanks are also extended to WMO Governance Services, in particular the Linguistic Services and Publishing Section.

The funding to conduct the CHD was provided by SOFF as part of the work of the SOFF Readiness phase. Financial support to produce the report was provided by WMO.

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Foreword

People and our planet are facing a crisis due to the intersection of inequality and climate change. In 2023 we witnessed another record-breaking year in terms of greenhouse gas levels, surface temperature, ocean heat and acidification, sea-level rise and glacier retreat. The climate crisis is further exacerbated by an inequality crisis, which has led to growing food insecurity, population displacement, health risks and environmental degradation.

Adapting to the effects of a changing climate is not a choice but an essential necessity which developing countries and vulnerable communities are struggling to achieve, given the scale of the challenge and resources required. The [United Nations](#) estimates that adaptation costs in developing countries could reach 300 billion US dollars every year by 2030. Yet only 10% of the climate finance provided by wealthier countries to assist developing nations goes towards adaptation and resilience.

Recognizing the urgency to act, the Alliance for Hydromet Development has moved with determination to increase the volume, effectiveness and sustainability of hydrometeorological investments. Since its creation at the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP25) in 2019, the Alliance has established the Systematic Observations Financing Facility (SOFF), an innovative financing mechanism that supports countries with the most severe shortfalls in basic weather and climate observations. Today, 60 developing countries are already benefitting from SOFF support, with the first investments starting to reach their beneficiaries. The Alliance has further designed the Country Hydromet Diagnostics as a tool for informing investments in National Meteorological and Hydrological Services. Thanks to the expert-generated data from country visits and peer exchanges, upon which the diagnostics are based, the Hydromet Gap Report 2024 shows us where assistance is most needed, where political support is paramount and where the Alliance partners should focus their efforts.

Looking forward, the Alliance is well positioned to contribute to the Early Warnings for All Initiative spearheaded by Secretary-General António Guterres. The Initiative's timeline is bold and its ambition daunting: to ensure that every person on Earth is protected by early warning systems. However, there is no hurdle that our collective effort cannot overcome. Science and unity will get us there.

The world is awakening to the increasingly palpable and devastating effects of climate change. Countries across the globe are facing incredible challenges due to the increasing frequency and intensity of record-breaking weather events. The need to build resilience and adaptive capacity is imperative, particularly for small island developing States like mine. It is also critical for developing countries that bear the greatest burden of climate change but lack the resources to prepare and respond.

I am truly encouraged by the work of the Alliance for Hydromet Development in harnessing resources and acting in solidarity with the developing world to build the foundation for effective climate adaptation and resilience. High-quality weather and climate services underpin economic prosperity and sustainable development. They are a prerequisite for protecting lives, property and livelihoods, but are sadly an investment that many developing countries cannot afford.

My country is privileged to benefit from support from several members of the Alliance for Hydromet Development. Additionally, we are proud to be among the first countries benefiting from the Systematic Observations Financing Facility (SOFF). This assistance not only aids in addressing fundamental weather and climate data gaps, but also enhances weather and climate forecasting capabilities – essential tools for reducing the impacts of climate extremes. While expressing gratitude to the Alliance, I urge scaled-up and better-coordinated efforts to assist all developing nations in bridging their hydrometeorological capacity gap by 2030.

The recommendations laid out in the Country Hydromet Diagnostics and in the present report represent a road map to strengthen the capacity of our National Meteorological and Hydrological Services. It is of utmost importance to strengthen these national services, as they provide the foundation for effective development and climate investments – creating significant socioeconomic benefits for our own countries and for the whole globe.



Prof. Celeste Saulo
Secretary-General, WMO
On behalf of the Alliance
for Hydromet Development



H.E. José Ulisses Correia e Silva
Prime Minister of Cabo Verde

Executive summary

In this second edition of the Hydromet Gap Report, the Alliance for Hydromet Development – a consortium of international development, humanitarian and climate finance institutions – takes stock of progress on priorities and outlines its future direction, almost five years after its establishment at the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP25) in Madrid in 2019. The report further presents important analysis based on Country Hydromet Diagnostics (CHD) conducted in 20 least developed countries (LDCs) and small island developing States (SIDS).

The findings shed light on the weakest links in the hydrometeorological value chain, which require urgent attention from governments and development partners. A set of recommendations is also addressed to the National Meteorological and Hydrological Services (NMHSs) with concrete advice on steps that would help them reach a higher level of maturity in terms of infrastructure, operations and services. The CHD results are instrumental to the Alliance members' investment planning, project design and coordination on the ground.

The advances

The Systematic Observations Financing Facility (SOFF) has rapidly become a crucial vehicle for improving the foundational data required for weather forecasting and climate prediction. Sixty countries are currently benefitting from SOFF assistance which has amounted to 74 million US dollars in the first year of funding operations. Significant country demand for support and speedy implementation calls for enhanced support to ensure that SOFF funding keeps up with its ambition and enables it to deliver on its work programme.

The CHD has proven its value as a standardized tool for assessing NMHSs, their operating environment and their contribution to weather, climate, hydrological and environmental services. In less than two years, the number of CHDs was scaled up from 8 countries, in which the diagnostic had been road-tested in 2021, to 56 countries in which it has now been completed or is currently in progress. Critical insights into capacity gaps at country level and beyond have been made available. The peer-to-peer advisory support on which both CHD and SOFF are based has further created a spirit of solidarity among NMHSs.

The Hydromet Gap Report 2024 raises awareness of the value of hydrometeorological services to the implementation of the entire Sustainable Development Agenda. It presents trends across countries along ten elements of the hydrometeorological value chain and points to the areas with the biggest capacity gaps, thus informing investments and policies.

The gaps

The results of the 20 CHDs show that the **overall capacity of the assessed NMHSs varies considerably**: from institutions with very little service delivery ability to developed organizations that have taken on the role of regional centres supporting neighbouring countries.

From the ten elements of the hydrometeorological value chain, **those with the biggest capacity gaps** stand at the core of NMHS operations and production processes:

- **Observational infrastructure (Element 3).** All of the assessed NMHSs face gaps in coverage, with a large portion of inoperable stations, difficulties in maintenance, particularly of automatic weather stations, and frequent data quality issues. Surface land data availability has improved, but there is still a significant gap in data availability. Most of the assessed NMHSs lack the capacity to conduct regular upper-air observations, with particularly large data gaps over Africa and the Pacific islands.
- **Data/product sharing and policies (Element 4).** Data transmission represents a significant challenge for the 20 NMHSs assessed. The majority do not have a centralized, automated data management system, while the rest rely on limited systems, hindering their operational processes. Behind this gap stands a general lack of enabling information and communication technologies (ICT) infrastructure and qualified personnel, as well as limited financial resources.
- **Numerical weather prediction (NWP) model and forecasting tool application (Element 5).** All of the assessed NMHSs use global NWP model outputs which do not have the spatial resolution appropriate to forecast meteorological conditions with the level of detail necessary for providing elaborate early warning services. Most depend on manual forecast production processes and limited systems, which restrict their ability to develop tailored products serving specific users and economic sectors.
- **Warning and advisory services (Element 6).** Though maturity among the 20 assessed NMHSs is higher for this element, none of the NMHSs fully implement impact-based forecasting, with deficiencies in training, technical resources, vulnerability and impact data, and collaboration with other national institutions. Other prevalent shortcomings involve the lack of standard alerting procedures, unavailability of alert services 24/7, non-employment of the Common Alerting Protocol (CAP) and lack of integrated multi-hazard early warning systems (MHEWS).

Overall, the NMHSs across all the countries reviewed are chronically under-resourced. The majority are dependent on internationally funded projects. Those with less-than-basic to basic capacity spend the vast majority of their resources on staffing, and yet most face acute staffing shortages and competency gaps.

The lack of resources significantly impacts the ability of these NMHSs to provide life-saving services, support the national economy and government, and meet international obligations.

Most of the 20 NMHSs lack the full legislative mandate and related governance necessary to fulfil their responsibilities. Furthermore, they **frequently work in operational isolation** from other national institutions and stakeholders.

The takeaways

NMHSs in developing countries work in an environment of growing demand for services, more stringent international requirements, such as for GBON compliance, and raised expectations in terms of climate action and early warnings delivery.

At the same time, **severe resource shortages significantly hinder their operational capacity.** Coordinated support from both government and development partners is required to:

- **Promote the promulgation of appropriate legislation and build governance mechanisms for hydrometeorological and other MHEWS-relevant services:** both National Frameworks for Climate Services and National Climate Outlook Forums have proven to be successful models for building national cooperation and coordination as well as for showcasing the value that NMHSs bring to society;
- **Close the ICT gap to unlock service capacity:** support the ICT capacity development of NMHSs (including systems and personnel), including for data management, data quality control and for the implementation of WIS 2.0, to unlock NMHSs' capacity to produce quality services;
- **Implement sustainable, context-responsive and cost-effective solutions and processes:** carefully consider the technical characteristics, resource intensity (including maintenance requirements) and full potential for added value service of the equipment and systems procured for NMHSs to ensure maximum longevity and best impact on service delivery capacity. Co-design project outcomes which are fitting to NMHS resources and operational capacity and whose benefits are realized across the interlinked value chain of hydrometeorological services;
- **Help NMHSs respond to the needs for hydrometeorological services across sectors:** support the development of cross-sectoral relationships and build in-house expertise

to produce tailored services (for example, for agriculture, water management, energy and so forth), including with the implementation of quality management systems to foster NMHSs' services quality and partners' trust;

- **Prioritize in situ trainings** with consideration of gender and diversity empowerment. Provide trainings on service production processes and institutional management and governance, as well as ensure that the personnel receiving the training have the technical and other relevant resources available to implement their new competencies;
- **Support regional technical cooperation frameworks** to leverage capacity at a higher scale, learning from successful examples (such as Regional Climate Centres).

The way forward

In response to these findings and policy recommendations, the Alliance for Hydromet Development has outlined a set of priority actions in four areas falling within its mandate and related to its long-term commitments, as outlined in its founding declaration. The proposed actions build on the competitive advantages of the Alliance members and are designed to offer viable solutions to closing the capacity gaps identified. In the medium term, the Alliance's objective remains unchanged: to increase the effectiveness and sustainability of hydrometeorological investments by 2030. The priority actions are:

1. Coordination for impact

- Enhance development partner coordination at the regional level for a more focused and targeted approach to supporting hydrometeorological services;
- Address the gap in middle-income countries;

2. Analytics for impact

- Promote CHD as a universally utilized tool for informing investments in hydrometeorological services;
- Continue publishing regular Hydromet Gap Reports capturing data, trends and insights from the gradually increasing sample of countries covered;

3. Financing for impact

- Optimize tracking of early warning system investments to effectively manage disaster risks associated with climate-related hazards;
- Sustain SOFF and expand to other parts of the hydrometeorological value chain in support of the Early Warnings for All Initiative;

4. Empowerment for impact

- Climate Science Information for Climate Action: enable NMHSs in mobilizing climate and development finance;
- Continue to advocate for and champion sustainable national funding.

1. The roll-out

The development and regular publication of the Hydromet Gap Report is one of the 10 commitments outlined in the founding declaration of the Alliance for Hydromet Development (“the Alliance”). The report is designed to monitor progress in closing the global capacity gap on weather, climate, hydrological and related environmental services. It is also intended to generate knowledge, facilitate learning, promote partnerships and foster innovation by capturing lessons learnt from the work of the Alliance.

The first Hydromet Gap Report was published in 2021 and laid out the case for investing in multi-hazard early warning systems (MHEWS). It showcased the benefits of building resilience to extreme weather and of better weather forecasting and climate prediction, while stressing the large gaps in the observations data upon which warning services, forecasts and predictions depend. The 2021 report further presented the Country Hydromet Diagnostics (CHD) methodology as a standardized operational tool of the Alliance for assessing hydrometeorological services and guiding investment decision-making. It summarized the results of a first round of CHD undertaken by peer meteorological services in eight countries. The diagnostics confirmed the feasibility, robustness and utility of the

methodology. They also highlighted the strengths and gaps among the National Meteorological and Hydrological Services (NMHSs) in terms of equipment, skills and user engagement.

This second Hydromet Gap Report deepens the analysis by aggregating and examining the data collected in 20 CHD conducted from March 2023 to February 2024. It presents trends across countries along 10 elements of the hydrometeorological value chain, as observed by the pool of peer advisers who performed the diagnostics. The report further takes stock of progress on the Alliance’s commitments, particularly in terms of the creation and operationalization of the Systematic Observations Financing Facility (SOFF) towards the establishment of the Global Basic Observing Network (GBON). A special section sheds light on the Early Warnings for All (EW4All) Initiative and its link to the CHD methodology. Relevant trends and patterns are further featured in the “EW4All in focus” text boxes across the report. Lastly, this second Hydromet Gap Report outlines a set of priority actions for stakeholders engaged in closing the capacity gap on weather, climate, hydrological and related environmental services and delineates the direction in which the Alliance for Hydromet Development sees its future.

Hydromet Gap Report

- Tracks progress in closing the capacity gap
- Analyses the state of NMHSs in developing countries, along 10 elements of the hydrometeorological value chain
- Presents the results of 20 Country Hydromet Diagnostics
- Outlines actionable recommendations to policymakers, NMHSs, donors
- Showcases the benefits of investing in multi-hazard early warning systems

2. The rationale: bringing value to humanity



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“We stand at the intersection of inequality and climate change, and our strategies must reflect the urgency of the times.”

Prof. Celeste Saulo, Secretary-General of WMO, speaking at the International Gender Champions Climate Impact Group launch. WMO is the United Nations system’s authoritative voice on weather, climate and water, and a leading member of the Alliance for Hydromet Development.

Equipping NMHSs with the infrastructure, resources and knowledge to sustainably perform their societal mission of saving lives and improving livelihoods is the *raison d’être* behind the activities of the Alliance. Prioritizing the needs of the most vulnerable is at the centre of its approach, which aims to demonstrate that investments in the delivery of weather, climate and hydrological services leverage significant socioeconomic benefits to communities.

Despite concerted efforts, the **world is not on track** to achieving its internationally agreed goals, including those set out in the 2030 Agenda for Sustainable Development, the Sendai Framework and the Paris Agreement. The first global stocktake of the Paris Agreement expressed serious concern that 2023 was set to be the warmest year on record, and that impacts from climate change were rapidly accelerating.¹ It has since been confirmed by WMO that 2023 surpassed global temperature records by a large margin, reaching 1.45 °C above pre-industrial levels.² At the 2023 Sustainable Development Goals (SDGs) Summit, countries agreed that, without immediate course correction and acceleration of progress towards achieving the SDGs, the world is destined to face continued poverty, prolonged periods of crisis and growing uncertainty.³ They also expressed their deep concern that the pace of implementation of the Sendai Framework for Disaster Risk Reduction is neither sufficient nor equal.⁴ **People in developing countries and small island developing States (SIDS) are particularly vulnerable to the impact of climate change and extreme weather.**

Hydrometeorological services present an under-recognized and cost-effective opportunity to turn commitments into actions, and accelerate delivery across all the SDGs, the Paris Agreement, Sendai Framework and other internationally agreed targets (see Box 1). When NMHSs have the capacity to utilize freely shared international data, predictions and knowledge, the hydrometeorological services they provide have consistently been shown to deliver significant return on investment, with **benefit-cost ratios up to 36:1**.⁵ These services can also help to inform efforts to mitigate and adapt to human-induced climate change, and to save lives and livelihoods. However, in many developing countries NMHSs do not have the capacity to benefit from these shared resources, to maximize the power of prediction and to provide tailored services that support food, health, energy, civil protection, water systems, national infrastructure and cities. To accelerate tangible delivery across all the global goals, **it will be critical for hydrometeorological development to become a priority at the global, regional, national and local levels.** As the Global Commission on Adaptation estimates, improved weather, climate and hydrological observations and forecasting could lead to **an annual increase in up to 30 billion US dollars (USD) in global productivity**, and an **annual reduction of up to USD 2 billion in asset losses**. The benefit-cost ratios of enhanced climate services for adaptation are estimated at 10:1 or higher.⁶

¹ United Nations Framework Convention on Climate Change (UNFCCC). *Outcome of the First Global Stocktake; 2023*. <https://unfccc.int/documents/636584>.

² World Meteorological Organization (WMO). *WMO Confirms that 2023 Smashes Global Temperature Record*; 12 January 2024.

³ *Political Declaration Adopted at the High-level Political Forum on Sustainable Development (HLPF), Under the Auspices of the General Assembly*: <https://undocs.org/Home/Mobile?FinalSymbol=A%2FRES%2F78%2F1&Language=E&DeviceType=Desktop&LangRequested=False>

⁴ *Political Declaration of the High-level Meeting on the Midterm Review of the Sendai Framework for Disaster Risk Reduction 2015–2030*: <https://www.undrr.org/media/88061/download?startDownload=20240530>

⁵ World Meteorological Organization (WMO). *Valuing Weather and Climate* (WMO-No. 1153). Geneva, 2015.

⁶ World Meteorological Organization (WMO). *Valuing Weather and Climate* (WMO-No. 1153). Geneva, 2015; Global Center on Adaptation (GCA). *Adapt Now: Global Call for Leadership on Climate Resilience*; 2019. <https://gca.org/reports/adapt-now-a-global-call-for-leadership-on-climate-resilience/>.

Box 1**How do hydrometeorological services support the SDGs?**

SUSTAINABLE DEVELOPMENT GOALS

**SDG 1. No poverty**

- Climate projections help us understand adaptation measures that promote socioeconomic well-being in vulnerable populations.ⁱ (SDG Target 1.b)
- EWSs help build the resilience and reduce exposure of the poor and vulnerable to climate-related extreme events. (SDG Target 1.5)

**SDG 2. Zero hunger**

- Forecast services are used for agricultural planning, to determine planting dates and crop selection.ⁱⁱ (SDG Target 2.3)
- Weather analytics are used to improve food supply chains and reduce waste.ⁱⁱⁱ (SDG Target 2.4)

**SDG 3. Good health and well-being**

- EWSs for extreme temperatures enable preventative measures to be taken to minimize heat health risks.^{iv} (SDG Target 3.d)
- Real-time observations of aeroallergens provide information to allergy patients and health practitioners.^v (SDG Target 3.4)

**SDG 4. Quality education**

- Training helps to ensure that staff meet Members' responsibilities for providing hydrometeorological information and services.^{vi} (SDG Target 4.4)
- Public education and outreach material help ensure that the available products and services are better used. (SDG Target 4.7)

**SDG 5. Gender equality**

- Gender sensitive EWSs support empowerment and safety by ensuring that evacuation and disaster preparedness plans address women's needs.^{vii} (SDG Target 5.5)
- Gender sensitive weather services can help to protect those with the lowest adaptive capacity to climate change impacts.^{viii} (SDG Target 5.5)



SDG 6. Clean water and sanitation

- Hydrological services are essential for water resource management.^{ix} (SDG Target 6.5)
- Hydrological monitoring is used to identify pollutants and contamination, and to inform measures to safeguard water resources.^x (SDG Target 6.3)



SDG 7. Affordable and clean energy

- Climate services inform site selection for wind, solar and hydropower investments.^{xi} (SDG Target 7.2)
- Climate services can inform energy load planning in energy systems to reduce costs.^{xii} (SDG Target 7.3)



SDG 8. Decent work and economic growth

- EWSs enable workers, employers and authorities to act to prevent human and economic losses.^{xiii} (SDG Target 8.8)
- It is estimated that improvements in the weather observation system can deliver socioeconomic benefits of over USD 5 billion annually. (SDG Target 8.1)



SDG 9. Industry, innovation and infrastructure

- Weather services are critical for the operation of airports, roads, train networks and seaports.^{xiv} (SDG Target 9.1)
- Climate services inform infrastructure planning in the face of sea-level rise.^{xv} (SDG Target 9.4)



SDG 10. Reduce inequalities

- People-centred early warnings, co-developed with vulnerable groups, support socioeconomic inclusion. (SDG Target 10.2)
- The Alliance for Hydromet Development encourages official development assistance and finance, by bringing together international partners to scale up and unite efforts to close the hydromet capacity gap in developing countries by 2030.^{xvi} (SDG Target 10.b)



SDG 11. Sustainable cities and communities

- Urban climate maps guide urban planning, to make cities more resilient.^{xvii} (SDG Target 11.b)
- Air quality predictions inform mitigation strategies for reducing population exposure to pollutants.^{xviii} (SDG Target 11.6)



SDG 12. Responsible consumption and production

- Climate services are used to design renewable energy systems, supporting sustainable energy production and consumption.^{xxix} (SDG Target 12.a)
- Hydrological services are essential for sustainable natural resource management.^{xxx} (SDG Target 12.2)



SDG 13. Climate action

- Greenhouse gas observations help Parties to understand the impact of mitigation actions taken to achieve the Paris Agreement.^{xxxi} (SDG Target 13.2)
- Climate projections inform policymakers so they can prepare to adapt. (SDG Target 13.3)



SDG 14. Life below water

- Predictions provide coastal flooding information to keep coastal communities safe.^{xxxi} (SDG Target 14.2)
- Ocean observations are vital to understanding ocean acidification and its impacts.^{xxxi} (SDG Target 14.3)



SDG 15. Life on land

- Drought management services help countries to take preventative measures to minimize impacts of drought.^{xxxiv} (SDG Target 15.3)
- High mountain observations enhance our understanding of mountain ecosystems and support their sustainable development.^{xxxv} (SDG Target 15.4)



SDG 16. Peace, justice and strong institutions

- Hydrometeorological services support the achievement of food, water, energy and health security, reducing the risk of conflict.^{xxxvi} (SDG Target 16.1)
- The EW4All national roll-out plans enhance the effectiveness of national institutions in providing early warnings to citizens. (SDG Target 16.6)



SDG 17. Partnerships for the Goals

- The EW4All Initiative builds on and scales up existing efforts in early warnings, promoting synergies among initiatives and partnerships.^{xxxvii} (SDG Target 17.17)
- The international hydrometeorological community works to mobilize resources to support weather, climate and water activities in developing countries. (SDG Target 17.3)

The ability to predict and prepare for changes in weather and climate allows societies to improve resilience and economic prosperity. Improved forecasts of extreme events, accompanied by the effective dissemination of information and appropriate response measures, can save lives and substantially reduce economic losses. Businesses recognize the potential of weather, climate and hydrological services to reduce operational costs and increase revenues in weather- and climate-sensitive sectors. For instance, improved climate services in the agricultural sector can result in increased crop yields, reduced production costs, increased farmer's income, lower usage of fertilizers and better adaptive capacity in the event of unfavourable expected weather conditions. In a study assessing the investment plan of the Economic Community of West African States (ECOWAS) Hydromet Initiative, the **cost-benefit ratios at the country level range from 1:4 to 1:19 for each dollar invested** (Figure 1).



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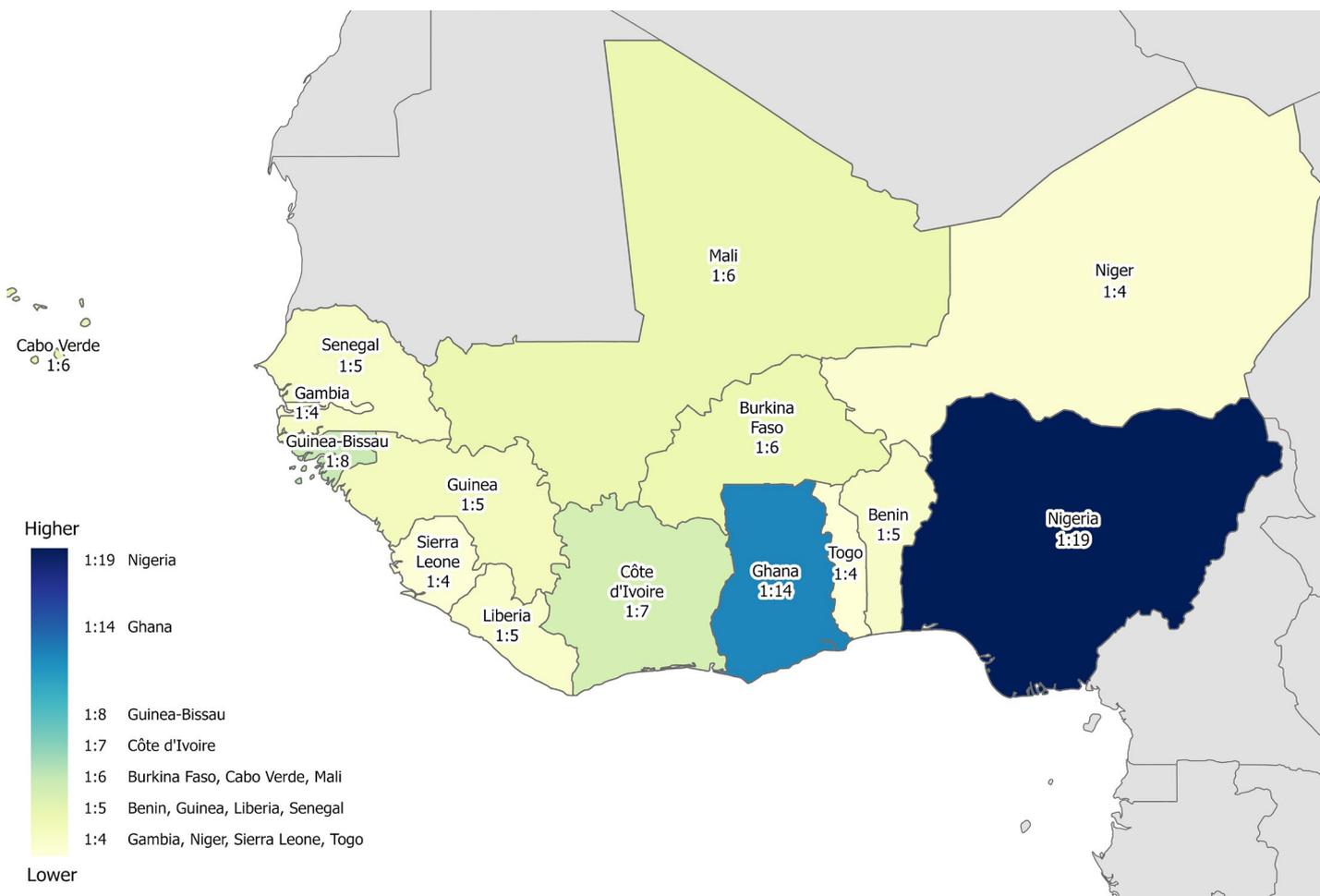


Figure 1. Cost-benefit ratios associated with the investment plan in the ECOWAS Hydromet Initiative

Source: Adapted from Economic Community of West African States (ECOWAS). *ECOWAS Hydromet Initiative: Strengthening Weather, Climate and Water Services in West Africa – An Analytical Report*; ECOWAS: Abuja, 2021. <https://www.ecowas.int/publication/ecowas-hydromet-initiative/>.

3. New developments: transforming threats into opportunities



In 2021, the Alliance for Hydromet Development set as a priority exploring ways of enhancing the effectiveness and range of early warning systems in a more coordinated and systematic manner.⁷ **This need has subsequently been escalated in the global climate change agenda with the launch of the United Nations Early Warnings for All Initiative.**

Instigated by Mr António Guterres, Secretary-General of the United Nations, on World Meteorological Day 2022, the initiative aims to ensure that everyone on Earth is protected from hazardous weather, water or climate events through life-saving early warning systems by the end of 2027.⁸ Recognizing the vast and longstanding efforts of a wide range of hydrometeorological development actors, including pre-existing and planned investments of approximately USD 4 billion,⁹ the initiative aims to achieve its goal by implementing a whole of society approach. This approach brings together the United Nations system, governments, civil society and development partners across the public and private sectors to build on and scale up existing hydrometeorological efforts and capacities, promote synergies and enhance collaboration to address gaps and deliver people-centred, end-to-end multi-hazard early warning systems that leave no one behind. **In 2023 an initial**

set of 30 focus countries was announced for accelerated implementation.¹⁰

Since its inception, Early Warnings for All has received universal political support, providing an area within climate negotiations where countries of different perspectives can find agreement, and build trust and cooperation. Following its launch, **political momentum has continued to grow, and Early Warnings for All has increasingly been referred to in internationally agreed documents, including the outcome decision of the first global stocktake of the Paris Agreement at COP28 in Dubai¹¹ and the text on the operationalization of the new loss and damage fund.**¹²

The initiative calls for an increased investment and coherence of development partners, international financing institutions and bilateral partners for early warning systems.

This includes SOFF, which is recognized as a foundational mechanism for helping to deliver EW4All, as well as the other climate funds, including the Climate Risk and Early Warning Systems Initiative (CREWS). In their COP28 Joint Statement, multilateral development banks committed to supporting EW4All through scaling up adaptation and disaster risk management financing.¹³

According to the United Nations Office for Disaster Risk Reduction (UNDRR) and WMO report *Global Status of Multi-Hazard Early Warning Systems 2023*:

- The global average score of MHEWS has improved from 2015 to 2022. However, regional and country disparities persist.
- Africa has doubled the quality of early warning systems coverage, but is still falling below the global average.
- Less than half of the least developed countries and only 40% of small island developing States have a multi-hazard early warning system.
- Countries with low MHEWS coverage have nearly a six times higher disaster mortality rate and five times more disaster-affected people, when compared with countries with high MHEWS coverage.

⁷ Alliance for Hydromet Development. *Hydromet Gap Report 2021*. Geneva, 2021.

⁸ United Nations. *Early Warnings for All* web page. <https://www.un.org/en/climatechange/early-warnings-for-all>.

⁹ Estimates include direct and indirect investments (total project amounts) by: Climate Risk and Early Warning Systems (CREWS), Green Climate Fund (GCF), Global Environment Facility (GEF), Adaptation Fund (AF), Global Facility for Disaster Reduction and Recovery (GFDRR), World Bank (WB), African Development Bank (AfDB), Inter-American Development Bank (IDB), SOFF, Climate Investment Funds (CIF)

¹⁰ Antigua and Barbuda, Bangladesh, Barbados, Cambodia, Chad, Comoros, Djibouti, Ecuador, Ethiopia, Fiji, Guatemala, Guyana, Haiti, Kiribati, Lao People's Democratic Republic, Liberia, Madagascar, Maldives, Mauritius, Mozambique, Nepal, Niger, Samoa, Solomon Islands, Somalia, South Sudan, Sudan, Tajikistan, Tonga, Uganda

¹¹ United Nations Framework Convention on Climate Change (UNFCCC). *Outcome of the First Global Stocktake; 2023*. <https://unfccc.int/documents/636584>.

¹² United Nations Framework Convention on Climate Change (UNFCCC). *Operationalization of the New Funding Arrangements, including a Fund for Responding to Loss and Damage* Referred to in paragraphs 2–3 of Decisions 2/CP.27 and 2/CMA.4; <https://unfccc.int/documents/636618>.

¹³ COP28 Multilateral Development Banks Joint Statement: <https://www.eib.org/attachments/press/cop28-joint-mdb-statement.pdf>

While political support is critical, **the success of the initiative will be judged on its effectiveness to finance delivery at the national and local level, as well as how this translates into national early warning system capacities and the protection of people's lives and livelihoods.** Building on the Country Hydromet Diagnostics methodology, a rapid assessment of NMHSs' capacity for monitoring and forecasting hydrometeorological hazards has been conducted

for all 30 initial focus countries.¹⁴ Implementation is being rolled out through a series of nationally led, multi-sector, inclusive processes, informing the creation of national Early Warnings for All road maps which are matched with funding to enable coordinated implementation of relevant actors. **A key priority for 2024 will be to scale up the number of countries supported and the availability of coordinated finance to help achieve the Initiative's overarching goal.**

The Alliance for Hydromet Development supports Early Warnings for All delivery through its:

Products and mechanisms

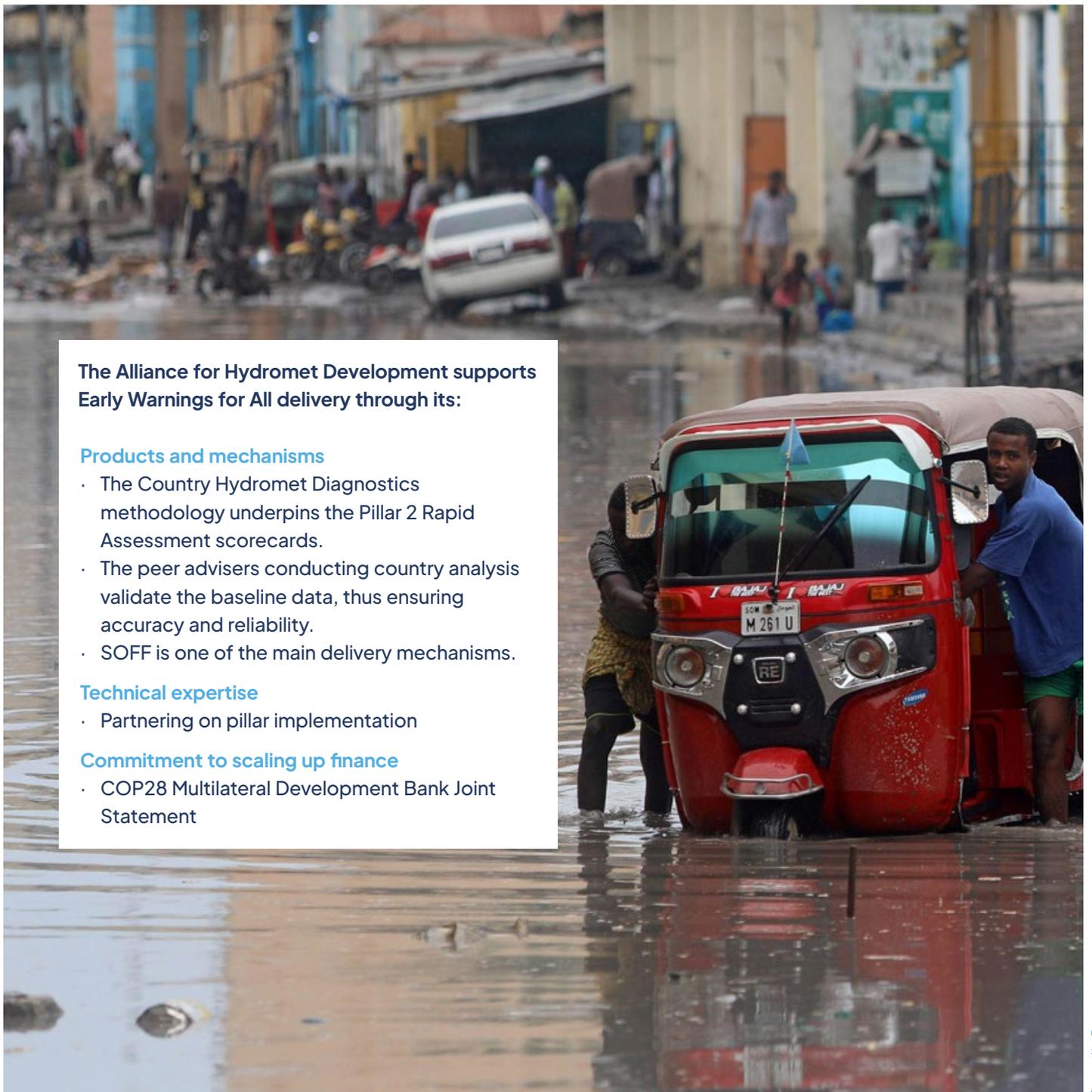
- The Country Hydromet Diagnostics methodology underpins the Pillar 2 Rapid Assessment scorecards.
- The peer advisers conducting country analysis validate the baseline data, thus ensuring accuracy and reliability.
- SOFF is one of the main delivery mechanisms.

Technical expertise

- Partnering on pillar implementation

Commitment to scaling up finance

- COP28 Multilateral Development Bank Joint Statement



4. Progress on the Alliance commitments: 2022–2023 in perspective

Created at the twenty-fifth session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP25) held in Madrid in 2019, the Alliance for Hydromet Development was founded in recognition of the urgent need to unite and scale up efforts and resources in closing the capacity gap on weather, climate, hydrological and related environmental services. Bringing together major international development, humanitarian and climate finance institutions, the Alliance committed **to increase the effectiveness and sustainability of hydrometeorological investments by 2030**. This clear objective, together with its **targeted approach on strengthening the observing capacity of NMHSs**, mobilized the Alliance members along 10 commitments as stated in its founding declaration.¹⁵

For the shorter term, the Alliance outlined the following priorities:¹⁶

- Fine-tune and consistently apply the CHD;
- Establish SOFF;
- Explore ways to enhance the effectiveness and range of early warning systems in a more coordinated and systematic manner;
- Continue to engage with the private sector to explore innovative and financially viable business models to close the gap in developing countries;
- Continue to increase awareness among other public international development, humanitarian and financial institutions, in recognition of the importance of coordination to realize the full benefits of the hydrometeorological value chain.

A brief account of the status of implementation of the short-term priorities as of March 2024 is given in sections 4.1 and 4.2 (see also Figure 2).

Alliance members

- Adaptation Fund
- African Development Bank (AfDB)
- Asian Development Bank
- Climate Investment Funds
- European Bank for Reconstruction and Development
- Global Environment Facility
- Green Climate Fund
- International Fund for Agricultural Development
- Inter-American Development Bank
- Islamic Development Bank (IsDB)
- United Nations Development Programme (UNDP)
- United Nations Environment Programme (UNEP)
- World Bank
- World Food Programme
- World Meteorological Organization

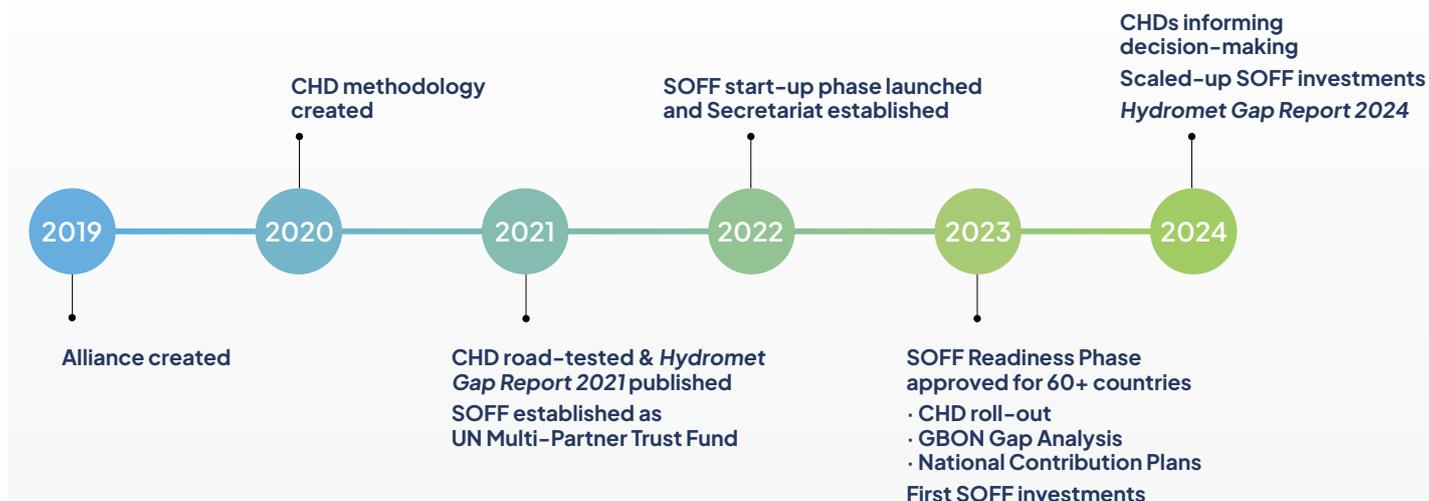


Figure 2. Alliance deliverables 2019 to date

¹⁴ Rapid Assessment Scorecards are available through the EW4All Dashboard:

<https://wmo.int/activities/monitoring-and-evaluation-merp/early-warnings-all-dashboard>.

¹⁵ Alliance for Hydromet Development. Alliance Declaration, Madrid, 10 December 2019. In *Hydromet Gap Report 2021*, Annex 1.

¹⁶ Alliance for Hydromet Development. The Alliance Going Forward: Further Actions to Close the Capacity Gap. In *Hydromet Gap Report 2021*, Chapter 8.

4.1. Country Hydromet Diagnostics

The CHD was developed as a priority of the Alliance for Hydromet Development to provide a common assessment and benchmarking tool. It has been operationalized and financially supported through the SOFF Readiness phase. It is closely interlinked with the WMO Monitoring System and has served as a methodological basis for the Early Warnings for All Pillar 2 Rapid Assessment.

CHD is a tool designed to provide a high-level strategic assessment of NMHSs, their operating environment, and their contribution to weather, climate, hydrological and environmental services. Using a standardized methodology (see Annex 2), peers from advanced NMHSs from both developed and developing countries undertake diagnostics structured along 10 elements of the hydrometeorological value chain. For each element, a maturity score is established based

on a set of common criteria and objective data, stemming from the WMO Monitoring System and country visits. The diagnostics are conducted with the full participation of the host NMHS, and the resulting report is co-signed by the peer entities. The results **are used to inform policy and investment decisions by providing coherent, standardized and authoritative assessments across countries.**

Methodology updated. In line with the Alliance commitments, the CHD methodology was fine-tuned in 2022 to reflect lessons learnt and feedback from the road-testing phase. The updated CHD tool:

- Retained the structure of the initial prototype, including its 10 elements, to provide a maturity score assessment across the operations of an NMHS;
- Included additional indicators and data sources;
- Preserved the initial focus on meteorological services, with hydrology being considered primarily from the downstream user angle and the contribution of NMHSs to hydrological services according to mandate and country requirements.¹⁷

Standardized process guidance developed. As part of the methodological update, the CHD delivery principles were firmed up and detailed process guidelines were produced for deployment as part of the SOFF Readiness phase (see Figure 3).

From road-testing to full implementation. In less than two years, the number of CHDs was scaled up from 8 countries,



Shutterstock

- A strategic level assessment
- Across 10 elements of the value chain
- Using a peer review approach
- A standardized methodology
- Data from the WMO Monitoring System and in situ visits

Figure 3. CHD standardized process guidance

Stage 1		Stage 2				Stage 3		Stage 4	
Peer reviewer identification		Information gathering				Validation and analysis		Closure	
Step 1 Establish a pool of peer reviewers	Step 2 Select peer reviewer for a specific assignment	Step 3 Kick off data gathering	Step 4 Review data	Step 5 Synthesize and investigate	Step 6 Draft CHD	Step 7 Refine draft CHD	Step 8 Finalize CHD	Step 9 Share CHD results	Step 10 Use lessons learnt and continuously improve

¹⁷ The term "NMHS" is used throughout the present report to recognize this approach and the frequent co-location of meteorological and hydrological services.



Freepik

60 CHDs at various stages of implementation
(status as of 30 April 2024)

- 19 reports published
- 7 reports being finalized
- 30 reports in progress
- 4 reports planned

in which the tool had been road-tested in 2021, to 56 countries in which it has now been completed or is currently in progress. SOFF Readiness funding was approved for a total of 60 countries (see list in Annex 4) with the target to support 100 countries by 2027. Offered as an “on-demand” step of the Readiness phase, CHD was requested by all recipients of SOFF support in recognition that the tool allows for better targeted and aligned investments.

A pool of experienced peer advisers deployed. SOFF peer advisers from 20 countries are currently engaged in CHD implementation (Annex 4), offering peer-to-peer advisory support as well as technical and institutional assistance, including South-South peer support. With WMO support, a CHD community of practice was established to enable the peer advisers to share experience, discuss capacity trends and shape policy and technical recommendations. This active group of CHD practitioners played an instrumental role in informing the findings and recommendations presented in Chapter 5 of the present report.

Used as a basis for Early Warnings for All capacity monitoring.

As the leader of Pillar 2 (detection, observations, monitoring, analysis and forecasting of hazards) of the Early Warnings for All Initiative,¹⁸ WMO developed a two-pronged approach to assess the baseline capacity of the 30 initial focus countries: (1) a rapid assessment of their hazard monitoring and forecasting capacity, which was methodologically grounded in the CHD (see Figure 4), and (2) complementary CHDs conducted under the SOFF Readiness phase, which provided the broader country capacity context. The peer advisers’ role in ensuring reliable and comprehensive country data is of great value to the Early Warnings for All Initiative.

A CHD Dashboard developed. To provide easy, at-a-glance access to the CHD results and the data underlying the country maturity score, an interactive dashboard was created, featuring the results of both the CHD and the Early Warnings for All Pillar 2 Rapid Assessment (see Figure 5).

Figure 4. Interlinkages and alignment between CHD and the Pillar 2 Rapid Assessment tools

Country Hydromet Diagnostics	Pillar 2 Rapid Assessment
Big picture on NMHS capacity	Zoom-in on early warnings capacity
10 elements	8 elements based on CHD
Maturity scale of 1–5	Maturity scale of 1–5
Peer-to-peer assessments	WMO-led, with peer advisers’ contribution
Self-reported data verified during country visits	Self-reported data collected in structured interviews
Fully validated	Gradually validated through CHDs
An assessment of NMHS operating environment and contribution to weather, climate, hydrological and environmental services and warnings	An assessment of NMHS hazard monitoring and forecasting capacity, including for selected hazards based on the WMO Catalogue of Hazardous Events

¹⁸ The lead organizations for the Initiative – WMO and the United Nations Office for Disaster Risk Reduction (UNDRR), with support from the International Telecommunication Union (ITU) and the International Federation of Red Cross and Red Crescent Societies (IFRC) – identified four pillars as the foundation for establishing sustainable multi-hazard early warning systems (MHEWS): Pillar 1 – Disaster risk knowledge; Pillar 2 – Detection, observation, monitoring, analysis and forecasting; Pillar 3 – Warning dissemination and communication; and Pillar 4 – Preparedness and response capabilities.

The dashboard:

- Shows aggregate views of the maturity scores by CHD element;
- Allows at-a-glance comparison at the global and regional level;
- Facilitates granular analysis by filtering the diagnostic results by country, region and income group,¹⁹ and by political, socioeconomic and environmental vulnerabilities;²⁰
- Provides access to the full set of validated data, searchable by country and element;
- Offers direct links to the CHD reports;
- Contains an embedded copy of the Early Warnings for All Dashboard, which ensures an automated feed of any updates and functional enhancements.²¹

The CHD Dashboard gives open access to comprehensive country-specific analysis and data on key aspects of NMHSs’ institutional setting, operational capacity and partnerships. In addition to providing a wealth of validated data and authoritative peer analysis, **it brings transparency to the maturity assessments** by making the underlying data freely available.

To access all CHD reports, visit [Country Hydromet Diagnostics](#).

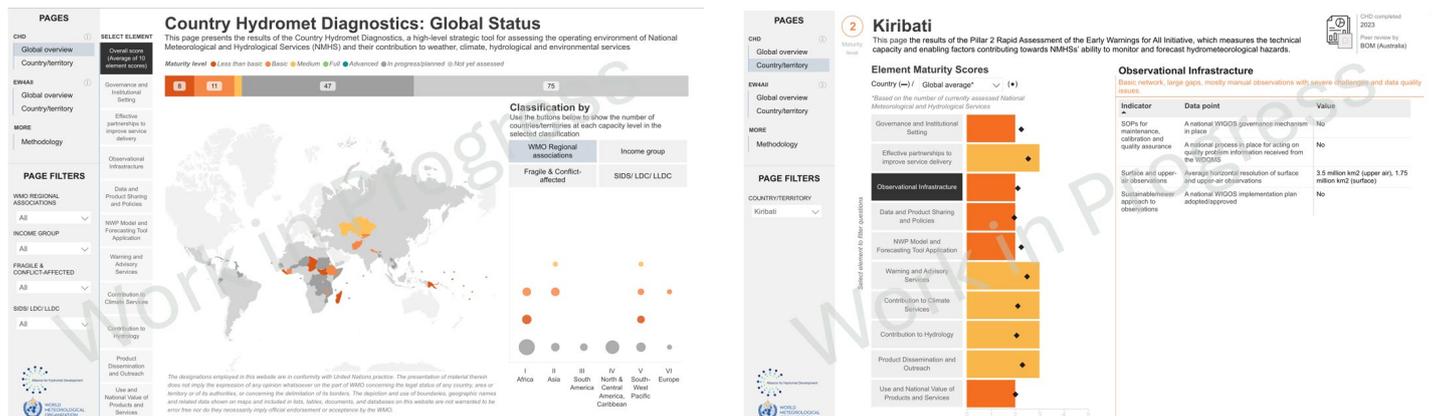


Figure 5. Screenshots of the CHD Dashboard

Emerging needs and challenges

Go beyond meteorological services: Both CHD peer advisers and NMHSs recommend expanding the assessment to cover other areas in greater depth, such as hydrological, marine and climate observations and services. Such an approach would respond to the needs of countries benefitting from the Early Warnings for All Initiative, which have identified flash floods, riverine floods and coastal floods among their top priority hazards.

Scale up: More comprehensive and granular analysis (by region, by vulnerability, by element) would be possible if the CHD reports and dashboard covered an expanded range of countries, including middle-income countries, thus maximizing value for the Alliance members.

Increase use: Whereas the CHD fully informs the Alliance’s decisions with respect to SOFF, it is still underutilized in the design of projects and investments of the Alliance members, which support elements of the hydrometeorological value chain other than observations.

¹⁹ Based on the World Bank’s classification of low, lower middle, upper middle and high income:

<https://datatopics.worldbank.org/world-development-indicators/the-world-by-income-and-region.html>

²⁰ Small island developing States (SIDS), least developed countries (LDCs), landlocked developing countries (LLDC); countries in fragile and conflict-affected situations: <https://www.worldbank.org/en/topic/fragilityconflictviolence/brief/harmonized-list-of-fragile-situations>

²¹ <https://wmo.int/site/early-warnings-all/early-warnings-all-dashboard>

4.2. Systematic Observations Financing Facility

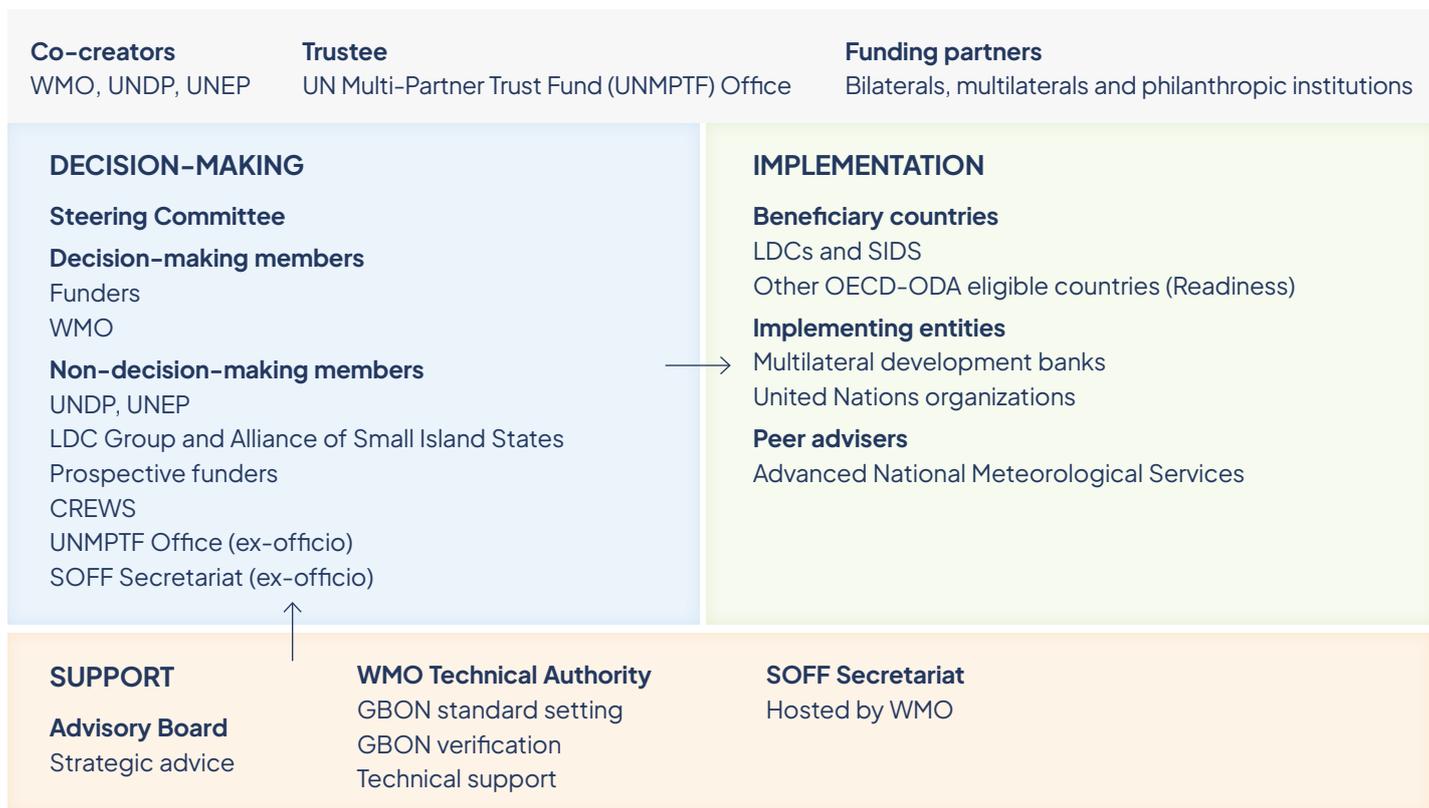
The Alliance for Hydromet Development played a foundational role in developing the SOFF concept and advocating for a new way of addressing the persistent problem of missing foundational observations in a systematic manner. It committed to establish SOFF as an innovative mechanism for financing developing country surface-based observations that recognizes the economic value of observations as a global public good. Since the launch of SOFF in 2022, the Alliance has consistently supported its development and fundraising.

SOFF United Nations Multi-Partner Trust Fund co-created by WMO, UNEP and UNDP. This unique single-purpose financing facility provides long-term finance and technical assistance with the sole objective of furthering sustained GBON data exchange and compliance (see Box 2). SOFF Readiness support to beneficiary countries comprises peer-to-peer support for countries to assess the national GBON gap and to develop their GBON National Contribution Plan for sustainable progress towards GBON compliance. Such support also allows countries to evaluate their national meteorological services' capacities throughout the entire meteorological value chain in the form of Country Hydromet Diagnostics. Based on the Readiness phase outputs, SOFF countries can access grants financing and technical assistance provided by the peer advisers during the Investment phase to establish the infrastructure and human and institutional capacity required to achieve GBON compliance through nine standardized outputs and outcomes. In the Investment phase, SOFF works with multilateral development banks and United

Nations organizations as Implementing Entities, supported by technical assistance from the peer advisers. During the Compliance phase, results-based and long-term grant finance is provided to support operations and maintenance of GBON data-sharing compliant stations.

SOFF governance set-up. The development of SOFF has benefited from the contributions of many partners and stakeholders, including beneficiary countries, funding partners, the Alliance for Hydromet Development and several other international organizations. At present, there are **nine multilateral development banks and United Nations organizations** serving as SOFF Implementing Entities, all of them members of the Alliance for Hydromet Development. Furthermore, **28 advanced national meteorological services** have confirmed their willingness to provide technical assistance to beneficiary countries as peer advisers. Currently, 20 peer advisers are active. The SOFF governance and its partners are shown in Figure 6.

Figure 6. SOFF governance and partners



Box 2

What is the Global Basic Observing Network?

The Global Basic Observing Network (GBON) paves the way for a radical overhaul of the international exchange of observational data which underpin all weather, climate and water services and products. It represents a new approach in which the basic surface-based observing network is designed, defined and monitored at the global level, with an obligation placed on all WMO Members to make and share observations at a minimum horizontal resolution. As such, it is a fundamental element of the WMO Integrated Global Observing System (WIGOS).

The implementation of GBON improves the availability of the most essential surface-based data, which have a direct positive impact on the quality of weather forecasts, thus helping to improve the safety and well-being of citizens throughout the world. GBON was adopted in 2021 by

an extraordinary session of the World Meteorological Congress. GBON came into force on 1 January 2023, after which compliance with its standard density requirements has become mandatory for WMO Members.

Consequently, WMO Members are now encouraged to assign surface land stations and upper-air stations operated from land to GBON, and to share data internationally, to be considered compliant with the correct temporal and horizontal resolution. The variables to be observed by WMO Members are, at a minimum, atmospheric pressure, air temperature, humidity, horizontal wind, precipitation and snow depth, where applicable. The variables to be observed at upper-air stations are, at a minimum, temperature, humidity and horizontal wind.

SOFF Readiness phase launched and first investments

approved. SOFF opened its doors for business in July 2022, and since March 2023 the SOFF Steering Committee has approved funding for the Readiness phase in 60 beneficiary countries. SOFF support is provided in three phases to ensure sustainability of investments, namely the Readiness, Investment and Compliance phases. It takes approximately nine months on average for a country to complete the Readiness phase and move to the Investment phase.

Delivering with ambition and speed. Less than two years since opening its doors for business in July 2022, SOFF's rapid development and take-off are a testament to the clear demand for its outputs, the support from many visionary early funders,²² and the community of operational partners it has created, including SOFF beneficiary countries, peer advisers, implementing entities and the SOFF Secretariat. Significant country demand for support

and speedy implementation calls for enhanced support to ensure the SOFF funding keeps up with the ambition and enables it to deliver on its work programme, including provision of investment support to 50 countries and readiness support to 75 countries by June 2025. Box 3 offers a glimpse into on-the-ground work in Maldives.

Critical need to scale up fundraising. In total, 101 countries have so far requested SOFF support. Currently there is a significant gap in funding available to deliver the work programme by 2025 and to meet the fundraising target of USD 400 million by 2027 as part of the EW4All commitment. Therefore, there is a critical need to scale up fundraising efforts and contributions. To meet this urgent demand, SOFF is exploring additional bilateral and multilateral funders to consider new contributions to the SOFF United Nations Multi-Partner Fund. More detailed information is available in the [SOFF Action Report 2023](#).

SOFF operating at speed and scale (status as of 31 March 2024)

- 60 countries are already benefitting from SOFF support.
- 13 countries have completed the Readiness phase and 11 countries have moved to the Investment phase. SOFF investments in those 11 countries are expected to close 20% of surface land station gaps and 18% of upper-air station gaps in LDCs and SIDS.
- Total SOFF readiness and investment funding approved since March 2023 is USD 74 million.

²² SOFF Funders: Austria, Belgium, Canada, Denmark, Finland, Iceland, Ireland, Kingdom of the Netherlands, Nordic Development Fund, Norway, Spain, United States of America

Emerging needs and challenges

Rapidly growing demand: 101 countries have requested SOFF support as of March 2024

An ambitious goal: 50 countries with SOFF investment support, 75 countries with readiness support by June 2025

A funding gap: urgent need for action to meet USD 400 million target by 2027



Asad Photo - Pexels

Box 3

Advancing efforts to close the hydrometeorological capacity gap in Maldives

Maldives is an Early Warnings for All initial focus country and a frontrunner for SOFF. In 2021, Maldives participated in road-testing the CHD, which highlighted key gaps in the country's hydrometeorological capabilities as well as provided valuable lessons learnt to help refine the diagnostics tool. The SOFF Readiness phase, launched in early 2023 and supported by the Finnish Meteorological Institute (FMI), updated the CHD and identification of the country's requirements for GBON compliance. Maldives is commencing its SOFF Investment phase in 2024, with USD 4.8 million approved to help close its critical weather and climate data gaps.

In July 2023, Maldives became the first country to launch national efforts towards achieving EW4All. A national consultation was convened to support a country-level gap analysis and discuss national ambitions relating to MHEWS. The second day of the national consultation focused on identifying priority actions to be included under a new Green Climate Fund (GCF) proposal "Toward Risk-aware and Climate-resilient Communities (TRACT)

– Strengthening Climate Services and Impact-based Multi-hazard Early Warning in Maldives" (approved at concept note stage), which is being developed with the support of UNEP.

The TRACT project aims to ensure a holistic and integrated approach to delivering reliable climate services and a people-centred, impact-based MHEWS in Maldives. Both the CHD and EW4All country-level gap analysis have informed development of the GCF proposal – demonstrating the value of these assessments in baseline-setting and determining where additional investment is needed, so that the GCF support can be better targeted. The TRACT project will build on complementary investments, such as SOFF, to reinforce capacity development efforts across the entire MHEWS value chain. As a GCF Accredited Entity and SOFF Implementing Entity, UNEP will seek to maximize synergies and support joined-up, scaled-up action to close the hydrometeorological capacity gap in Maldives, effectively linking SOFF investments with GCF funding.

5. Hydromet Gap Analysis: Country Hydromet Diagnostics results

Twenty CHDs were completed between March 2023 and February 2024 as part of the SOFF Readiness phase, with the joint work of peer advisers and NMHSs. The diagnostics assessed the capacity of NMHSs in 12 least developed countries (LDCs), 5 small island developing States (SIDS) and 3 countries that are both LDCs and SIDS, distributed across 4 of the 6 WMO Regions (see Figure 7).

The CHD reports were conducted in partnership between six implementing entities (African Development Bank, Inter-American Development Bank, United Nations Development Programme, United Nations Environment Programme, World Bank and World Food Programme) and ten peer adviser NMHSs from both developed and developing countries:

- Bureau of Meteorology (Australia);
- Danish Meteorological Institute (Denmark);
- Deutscher Wetterdienst (Germany);
- Finnish Meteorological Institute (Finland);
- GeoSphere Austria (Austria);
- Icelandic Meteorological Office (Iceland);
- Meteorology, Climatology and Geophysical Agency (BMKG) (Indonesia);
- Nigerian Meteorological Agency (Nigeria);
- Norwegian Meteorological Institute (Norway);
- South African Weather Service (South Africa).



Danish Meteorological Institute

The process involved an extensive desk review and in-country visits, including on-site infrastructure assessment and workshops with national partners. The results were then reviewed and formally agreed upon by both peer advisers and assessed NMHSs.

Figure 7. The CHD reports from these 20 countries form the basis of the analysis presented hereinafter.





Figure 8. CHD element maturity scores of the 20 assessed NMHSs

Figure 8 depicts the CHD maturity scores of the 20 NMHSs, by CHD element. The individual country results are available in Annex 1, including highlights of the main capacity gaps. The following analysis is based on the aggregate results of these 20 CHD reports, and presents a detailed account of

the capacity gaps identified for each element of the hydrometeorological value chain, including recommended actions for NMHSs, particularly those in developing countries, and for international development partners.

Key results and capacity gaps identified by the Country Hydromet Diagnostics

The bar has been raised: the NMHSs of developing countries around the world are expected to quickly develop their capacity to meet the challenges of climate change adaptation and the increased frequency of some extreme hydrometeorological events. Many do not have adequate capacity to do it alone.

Whether it is to achieve GBON compliance to strengthen the global prediction system upon which all weather forecasts rely, or to provide impact-based warnings to support effective early action against potential disasters, considerable investments are needed to build the human, technical and institutional capacity of developing countries' NMHSs to the level required to reach these goals.

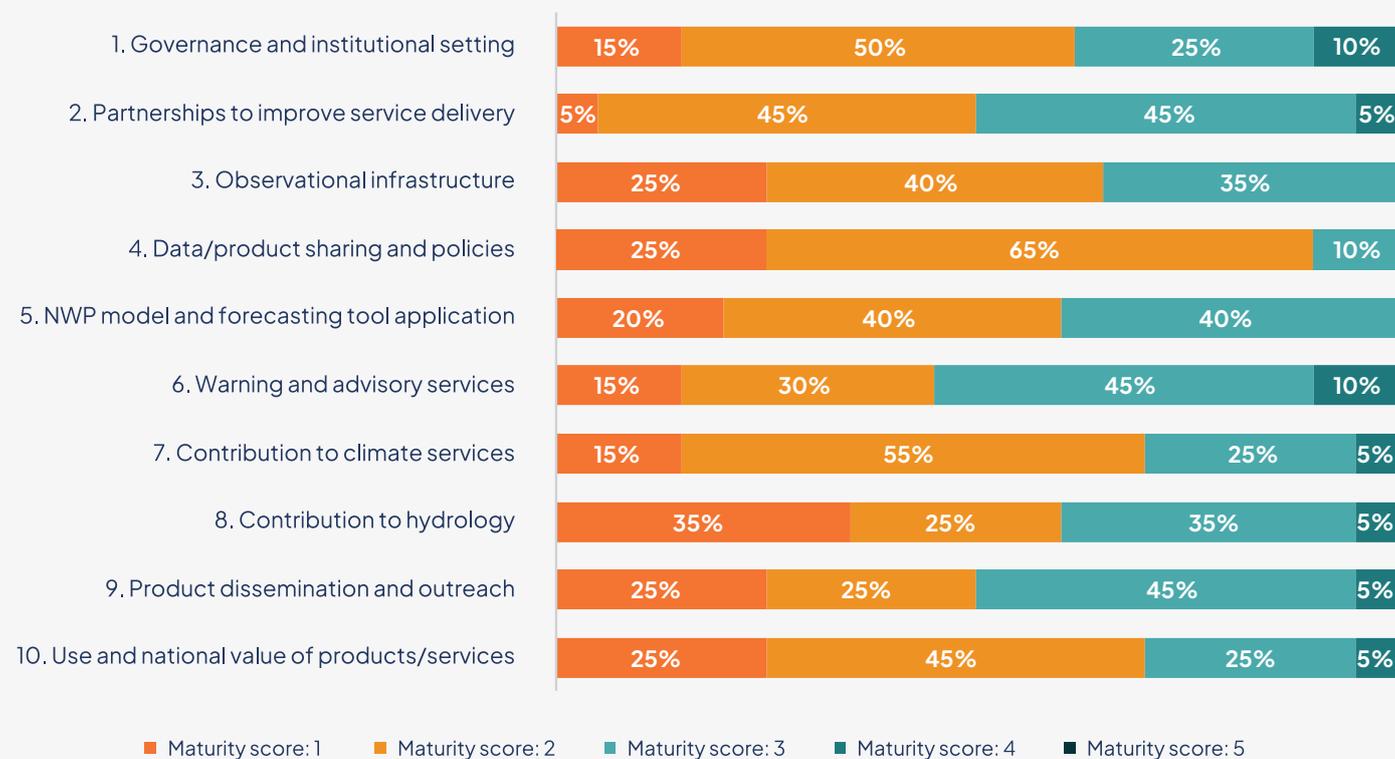
The 20 CHDs conducted show that the overall capacity of the assessed NMHSs varies considerably, from institutions with very little service delivery ability to developed organizations that have taken on the role of regional centres supporting neighbouring NMHSs. Nevertheless, the CHDs reveal that NMHSs across all countries reviewed are chronically under-resourced. The lack of resources

significantly impacts their ability to provide life-saving services, support the national economy and government, and meet international obligations. In addition, most NMHSs lack the full legislative mandate and related governance necessary to fulfil their responsibilities, and frequently work in operational isolation from other national institutions and stakeholders across the value cycle of weather, climate, hydrological and related environmental services.

A comparison of the aggregate maturity scores of the 20 CHDs shows a clear trend: the elements forming the core of NMHSs' operations and production processes have consistently received the lowest maturity scores (that is, Elements 3. Observational infrastructure, 4. Data/product sharing and policies, and 5. Numerical weather prediction (NWP) model and forecasting tool application) (Figure 9).

These challenges are presented in further detail in the 10 sub-sections that follow. For each CHD element, key capacity gaps are identified and recommended actions for NMHSs are included.

Figure 9. Distribution of the maturity scores of the 20 assessed NMHSs for the 10 CHD elements



Element 1: Governance and institutional setting

Key challenges

- More than half of the NMHSs assessed operate under partial, outdated or no legislative framework, limiting their ability to fulfil their mandate and develop operations and services.
- All of the NMHSs assessed operate with insufficient sustainable financial resources, significantly impacting their ability to provide life-saving services, support their national economy and government, and meet international obligations.
- Three quarters of NMHSs depend on internationally funded development projects to support their operations and investments.
- For NMHSs with basic or less-than-basic capacity, staffing costs represent 76% on average – and up to 97% – of expenditure, thus limiting their operations and development.
- Most of the assessed NMHSs also face acute staffing shortages and competency gaps, exacerbated by: (i) non-replacement of retiring experts, (ii) non-competitive remuneration leading to brain drain, and (iii) inability to hire local qualified staff.

Figure 10. Distribution of the maturity scores of the 20 assessed NMHSs for Element 1: Governance and institutional setting



1. Weakly defined mandate; serious funding challenges; essential skills lacking; little formalized governance and future planning.
2. Ongoing efforts to formalize mandate, to introduce improved governance and management processes and to address resource challenges.
3. Moderately well mandated, managed and resourced and clear plans for, and sufficient capacity to address operational gaps.
4. An effective service, but with a few shortcomings related to its mandate, governance, and resourcing, and in the process to address the gaps.
5. Strong and comprehensive mandate, highly effective governance, secure funding and readily available skills base.

The CHDs show that a large proportion of the assessed NMHSs are facing significant challenges relating to their governance and institutional setting. Half were assigned maturity score 2, while 15% face even wider gaps and received maturity score 1 (see Figure 10).

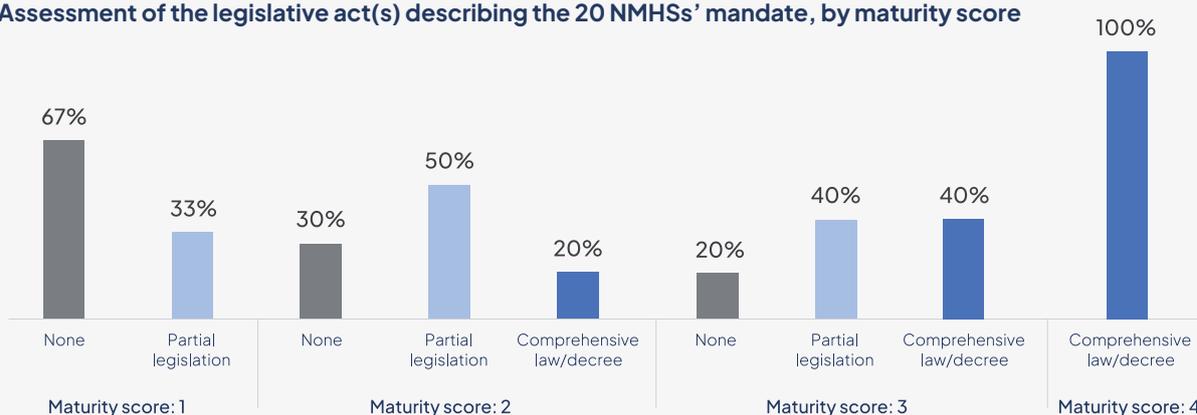
Though all are established as government or state-owned entities, in effect only 40% of the assessed NMHSs benefit from comprehensive legislation (that is, a law and/or decree) describing their mandate and enabling their operations in their country. Almost 60% work under partial or even no legislative framework. “Partial” legislation reflects legislative instruments which have outdated provisions, which do not cover the full mandate of the NMHS across hydrometeorological services or which do not establish with sufficient clarity and details the

roles, responsibilities and mechanisms necessary for the NMHS to fulfil its duties.

Such gaps often bear cascading consequences that penalize NMHSs’ abilities to fulfil their mandate and affect their capacity to secure adequate and sustainable financial resources (both government funding and cost-recovery mechanisms) and to collaborate efficiently with other national institutions.

The disparities of these legislative arrangements are reflected in the maturity scores assigned, with the vast majority of the NMHSs scoring 2 or below, having no comprehensive enabling legislation (Figure 11). Efforts are ongoing to address these gaps, as updates to existing legislation are being developed in five of the countries assessed, although some have been delayed for years.

Figure 11. Assessment of the legislative act(s) describing the 20 NMHSs’ mandate, by maturity score





Duncan Bullock - Australian Bureau of Meteorology

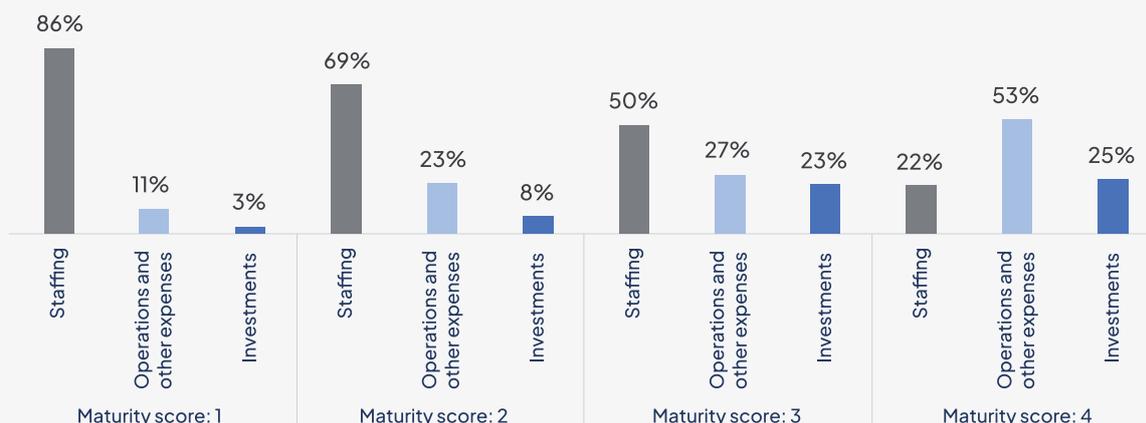
Despite these legal gaps, most NMHSs are striving to strengthen their internal management framework. Sixty per cent of those assessed have a strategic plan in place, though it is rarely complemented with related operational and risk management plans. The strategic plan implementation is often constrained due to funding challenges. Government funding comprises 88% of assessed NMHSs’ budget on average, and it is mainly used for staffing (Figure 12). For NMHSs with a maturity score of 2 or below, the low level of funding significantly limits their capacity to support their regular operations and maintain their observing network. It further inhibits their ability to develop specific services for distinct users and economic sectors.

Consequently, 80% of the assessed NMHSs, across all maturity scores, rely upon resources from development agencies to support their operations and investments. The NMHSs’ lack of sufficient resources leads to frequent challenges in their ability to ensure the continued provision of new services and operation of new equipment established by international cooperation projects after their end.

Despite allocating a high portion of their budget to human resources, the vast majority of the assessed NMHSs also face significant staffing shortages and competency gaps. The chronic understaffing commonly stems from a combination of lack of appropriate succession and replacement of experts close to retirement age, limitations in NMHSs’ ability to recruit qualified staff on the national job market, and difficulties in retaining skilled personnel due to non-competitive remuneration, thus often leading to a brain drain.

Likewise, developing the competencies of current staff members represents a significant challenge for most NMHSs, as many do not have a national institution which can provide the required courses and trainings. As such, 40% of the assessed NMHSs have no arrangement for staff capacity building in place, while 25% rely entirely on regional training centres or faculties, which impose additional financial and practical constraints on their limited resources.

Figure 12. Average percentage of the 20 assessed NMHSs’ budget dedicated to staffing, operations and investments respectively, by maturity score



EW4All in focus: governance of multi-hazard early warning systems

Various types of legislative frameworks give NMHSs and partner agencies general mandates to monitor, forecast and produce warnings for the hazards affecting their countries. However, many fall short of establishing clear roles and responsibilities for the institutions involved in these processes.

Whereas two thirds of the countries under review have a law or other types of legislative instruments covering

early warning systems in place (Figure 13 (a)), only 40% clearly and comprehensively mandate the roles and responsibilities of all institutions involved in generating and issuing warnings for all hydrometeorological hazards (Figure 13 (b)). Such gaps in governance frequently impede coordination and cooperation between the governmental agencies contributing to the value chain of multi-hazard early warning systems and can even lead to inter-institutional competition and duplication.

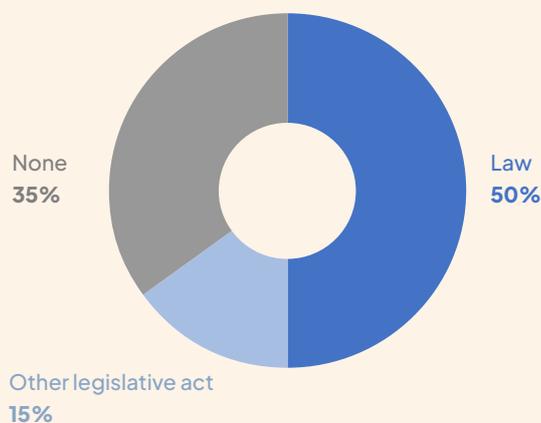


Figure 13 (a). Legislative act established for multi-hazard early warning systems (MHEWS) in the 20 assessed NMHSs' country or territory

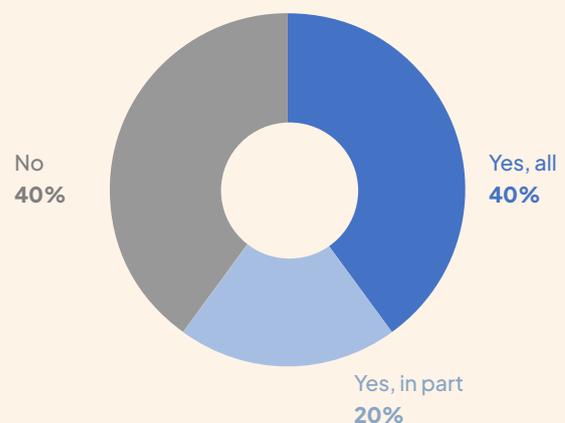


Figure 13 (b). Roles and responsibilities of all institutions involved in national early warning system of the 20 assessed NMHSs clearly defined and mandated for all hydrometeorological hazards

Recommended actions for NMHSs

- Actively engage policymakers to strengthen national governance frameworks for hydrometeorological services, including for early warnings;
- Establish medium- and long-term sustainability plans;
- Seek the support of WMO (e.g. through WMO Regional Offices) and other international organizations and partners, as appropriate, to boost high-level engagement and visibility, both nationally and at regional events;
- Pursue South-South cooperation: where appropriate, seek the support and guidance of regional hydrometeorological partners (e.g. Caribbean Meteorological Organization (CMO)) and neighbouring NMHSs for developing suitable governance and institutional frameworks (e.g. legislation template, organizational structure);
- When possible, foster close collaboration with national and regional education and training institutions to address competency gaps;
- Develop a plan to achieve staff gender parity, also among technical positions.

Element 2: Partnerships to improve service delivery

Key challenges

- Most NMHSs collaborate with other national governmental agencies, but formalization and operationalization of these partnerships remain a challenge.
- NMHSs' engagement with the private sector remains limited, especially for service delivery, as 80% lack an enabling legislative framework for public-private engagement (PPE).
- The vast majority of the NMHSs assessed engage in development cooperation projects with international partners, but have little say in these relationships and face significant barriers in ensuring continued operations past the projects' end.

Figure 14. Distribution of the maturity scores of the 20 assessed NMHSs for Element 2: Partnerships to improve service delivery



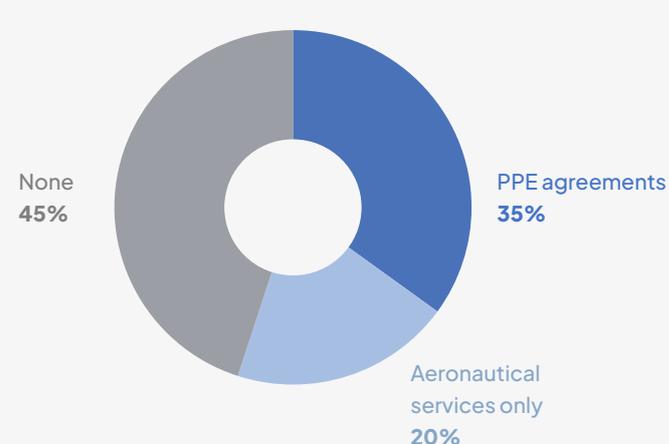
1. Works in isolation and does not value or promote partnerships.
2. Limited partnerships and mostly excluded from relevant finance opportunities.
3. Moderately effective partnerships, but generally regarded as the weaker partner in such relationships, having little say in relevant financing initiatives.
4. Effective partnerships with equal status in most relationships and approaching relevant funding opportunities in a coordinated manner.
5. Regarded as a major national and regional player; extensive and productive partnerships; viewed as an honest broker in bringing parties together; and provides national leadership on relevant finance decisions.

While the vast majority of the assessed NMHSs are engaged with national and international partners in some form, the strength, formalization and operationalization of these relationships vary greatly (see Figure 14). While 80% have partnerships with other government institutions (such as disaster risk reduction (DRR) management agencies, hydrological authorities, department of agriculture and so forth), only about two thirds have formalized some of these relationships. Operationalization, such as for the systematic exchange of data or towards the co-production of services, remains an obstacle.

As much as these gaps are challenges, these relationships also represent tangible opportunities. NMHSs stand to gain significant advantages by fostering robust collaborative relationships with other governmental ministries and public sector entities involved in and benefiting from meteorological, hydrological and environmental services to enhance coordination, service delivery (including co-design) and data exchange. In this regard, the establishment of a National Framework for Climate Services (NFCS) has emerged as a pivotal platform with a successful track record in facilitating partnerships and framing impactful, mutually beneficial relationships.

While most NMHSs strive to develop working relations with other national governmental institutions, engagement with the private sector remains limited. About half of the NMHSs assessed have no relation with private entities, whereas for another 20% this engagement is restricted to the provision of aeronautical meteorological services (Figure 15).

Figure 15. Twenty assessed NMHSs' formalized agreements with the private sector



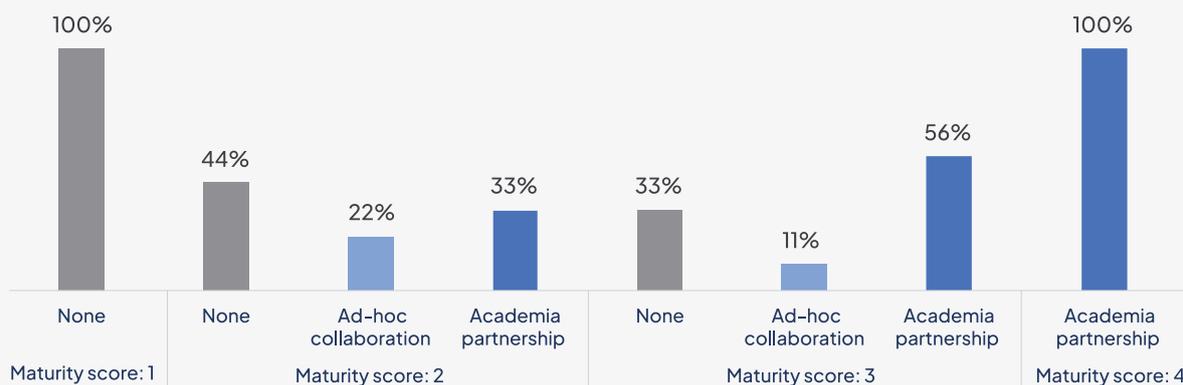
Regarding the agreements established with the private sector by the remaining 35% of NMHSs, most relate to the exchange of observational data, while others involve subcontracts for the operation and maintenance of the observing network. Only a handful concern the provision of tailored hydrometeorological services to private companies.

Contextually, the NMHSs are often constrained from engaging with the private sector due to a lack of enabling regulatory framework and related budgetary arrangements. Eighty per cent of the assessed NMHSs do not have legislative provisions in place on the participation of the private sector in the delivery of hydrometeorological services, and most lack a platform for fostering dialogue and cooperation with private actors.

In addition, NMHSs are scientific institutions whose mandate and services bear enormous relevance to environmental science research. In that respect, collaboration with academia remains rare for the 50% of assessed NMHSs with a maturity score of 2 or below, while most NMHSs that were attributed a score of 3 or above regularly collaborate with research institutions (Figure 16).

Finally, while almost all NMHSs assessed have a long history in engaging in multiple projects with international climate finance and other development cooperation partners, tangible and lasting evidence of the improved services born from these relationships was often difficult to identify, especially a few years after the closure of the projects. Echoing the insights of Element 1, fundamental gaps in capacity and resources hinder NMHSs' ability to sustain activities and infrastructure in the long term.

Figure 16. Twenty assessed NMHSs' collaboration with academia and research institutions, by maturity score



Recommended actions for NMHSs

- Support the establishment of national platforms to closely engage with governmental agencies across sectors, e.g. through a National Framework for Climate Services;
- Strive to develop long-term mutually beneficial partnerships to achieve whole-of-government outcomes (such as meeting Sendai targets, International Civil Aviation Organization (ICAO) requirements or increasing agricultural productivity), including with the private sector, where relevant;
- Seek to deepen and formalize existing and future partnerships with suitable agreements (e.g. memoranda of understanding), including with the assistance of WMO to provide guidance on how to draft such agreements;
- Develop in-house expertise to respond to information needs across sectors (such as agriculture, energy, hydrology);
- Promote the use of CHD as the technical basis for institutional development planning and for framing hydrometeorological international cooperation projects.

Element 3: Observational infrastructure

Key challenges

- All assessed NMHSs face significant gaps in their observing system’s coverage.
- Most do not have the capacity to conduct regular upper-air observations.
- Insufficient technical and financial resources prevent 95% of NMHSs from ensuring the necessary maintenance and calibration of their observation stations.
- On average, 45% of stations in their observational infrastructure are inoperable.
- Even operational stations frequently face significant data transmission and data quality issues.
- Automatic weather stations, while allowing for more frequent measurements, often prove more difficult to maintain operational over time than manual stations.

Figure 17. Distribution of the maturity scores of the 20 assessed NMHSs for Element 3: Observational infrastructure



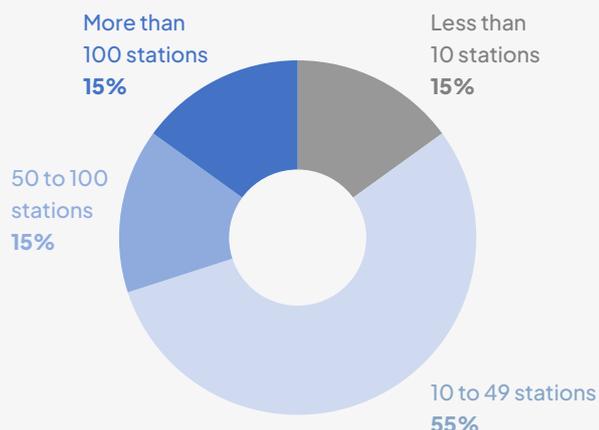
1. No or limited basic surface observations and no upper-air observations.
2. Basic network, large gaps, mostly manual observations with severe challenges and data quality issues.
3. Moderate network with some gaps with respect to WMO regulations and guidance, and with some data quality issues.
4. Comprehensive, mostly automated network providing good traceable quality data, fully compliant with WMO regulations and guidance.
5. Comprehensive and highly automated advanced network including additional measurements and remote sensing platforms providing excellent data, fully compliant with WMO regulations and guidance.

None of the assessed NMHSs were assigned a score of 4 or above (Figure 17), despite the varying sizes of their surface observational infrastructure (Figure 18). All are facing substantial challenges, including observation gaps as well as data quality and data transmission issues.

In addition, 65% of the assessed NMHSs do not have the infrastructure or the technical, human and financial resources necessary to perform regular upper-air sounding of atmospheric conditions, although for a minority (10%) such observations are being conducted by other institutions, commonly civil aviation authorities. Similarly, only 35% of the assessed NMHSs operate a radar for weather observations.

The impact of these technical, human and financial constraints is not limited to upper-air and radar observations, but also severely affects NMHSs’ ability to operate their surface infrastructure network. Critically, the vast majority of assessed NMHSs – even those with a maturity score of 3 – do not have complete capacity to perform the necessary regular maintenance and calibration of their observation stations (Figure 19), which leads to frequent data quality issues from

Figure 18. Surface observation stations in the 20 assessed NMHSs’ meteorological observational infrastructure

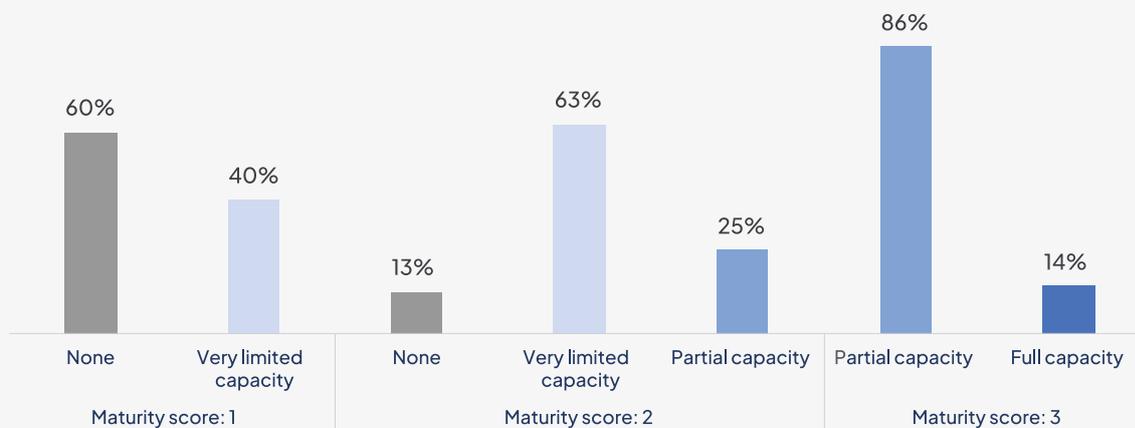


Global Basic Observing Network requirements

The overall purpose of the Global Basic Observing Network (GBON) is to secure an adequate supply of observational data to the global numerical weather prediction centres that serve all countries with model products. GBON requirements were established with a view to achieving this goal. The standard density requirements refer to the station coverage and the distance between them: they are set at 200 km for the horizontal resolution of surface land stations and 500 km for upper-air stations. GBON requirements also mandate the frequency with which observations should be made and shared: hourly for surface land stations, and twice a day for upper-air stations.

To achieve GBON compliance, WMO Members have committed to implementing GBON stations as per the requirements and sharing at least 80% of their observational data internationally at least 80% of the time.

Figure 19. Twenty assessed NMHSs’ capacity to perform regular maintenance and calibration of their infrastructure networks, by maturity score. Note – the maturity score assessment is determined by multiple elements.



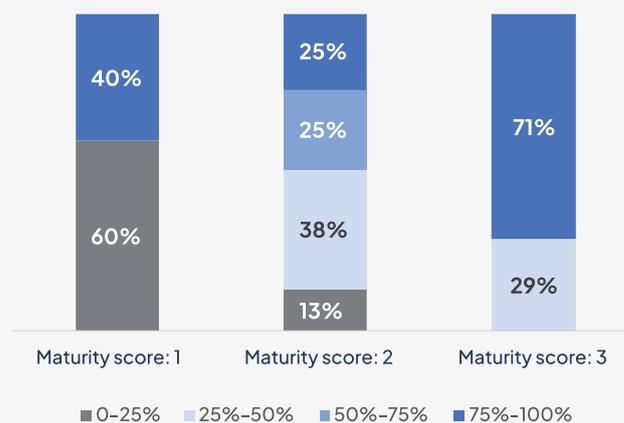
uncalibrated sensors, data transmission disruptions and even complete failure of the equipment.

On average, 50% of the observation stations of the NMHSs with a maturity score of 2 or below are inoperable. The proportion is still relatively high (35% on average) even for NMHSs with a maturity score of 3.

In parallel, significant efforts have been made towards the automation of NMHSs’ observational infrastructure network through the adoption of automatic weather stations (AWSs). AWSs enable NMHSs to conduct more frequent measurements, also at night, which is a key element towards achieving compliance with GBON requirements, and should reduce the labour intensity of observational networks, thus cost-effectively increasing the coverage and efficiency of NMHSs’ observing systems.

Nevertheless, the CHD assessments revealed that these stations often prove more difficult than manual stations to maintain operational over time, especially for NMHSs with less technical resources or those operating in fragile contexts. Forty per cent of the NMHSs with a maturity score of 1 have observational infrastructure that is almost fully automatic (Figure 20).

Figure 20. Percentage of automation of the 20 assessed NMHSs’ observing networks, by maturity score



Recommended actions for NMHSs

- Take advantage of SOFF long-term support to achieve sustained GBON compliance;
- Establish straightforward standard operating procedures for the installation, maintenance and calibration of observation stations in line with WMO regulations and guidelines;
- Where appropriate, consider the installation of hybrid observation stations (manual and automatic) to foster stations’ long-term resilience;
- Implement automatic data transmission systems;
- Establish agreements, practices and systems for automatic data exchange with the other institutions conducting observations nationally;
- In general, emphasize to governmental and international funding partners the importance and role of suitable observing systems to provide and sustain quality hydrometeorological services.

Element 4: Data and product sharing and related policies

Key challenges

- Most NMHSs lack adequate ICT infrastructure and related qualified personnel.
- Many operate with no centralized and automated data management system, severely limiting their ability to store, use, quality control and share their observational data.
- All NMHSs require support to build up their technical capacity to transition from the WMO Global Telecommunication System (GTS) (due to be retired by 2033) to the new WMO Information System (WIS) 2.0, a global data-sharing system.
- NMHSs struggle to operate and sustain disparate and costly project-funded infrastructure, equipment and systems, limiting their ultimate operational benefit.
- 95% of the assessed NMHSs do not have agreements in place for the free and open sharing of observational data at the national level.

Figure 21. Distribution of the maturity scores of the 20 assessed NMHSs for Element 4: Data and product sharing and related policies

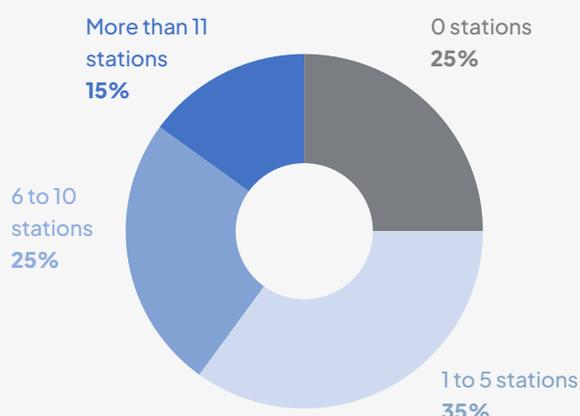


1. No observational data are shared internationally, either because not available to be shared, or because of a lack of data-sharing policies or practices, or because the existing infrastructure does not allow data sharing.
2. A limited amount of GBON-compliant data is shared internationally. The existing data-sharing policies or practices or the existing infrastructure severely hamper two-way data sharing.
3. Partial GBON data-sharing compliance with regard to either surface or upper-air data. A data policy in place that promotes the free and open use of data for research, as well as the in-house use of external data.
4. Fully meeting GBON data-sharing compliance with data policy, practices and infrastructure in place, which support free and open sharing of data nationally and internationally, as well as the use of external data.
5. Exceeding GBON data-sharing compliance, and additional data (marine, radar, etc.) contributing to regional and international initiatives, with policies that promote free and open two-way sharing of data and products.

Of all the elements of the hydrometeorological value chain, Element 4: Data and product sharing and related policies is the one where the assessed NMHSs scored the lowest on average (see Figure 21). This is consistent with the significant gaps in the Global Basic Observing Network (see Box 4).

Due to limited resources, NMHSs are only able to share the data from a fraction of their observation stations internationally, most commonly through the GTS. Moreover, a quarter were not sharing any data at all at the time of the CHD peer assessments (Figure 22).

Figure 22. Number of surface stations whose observational data is shared internationally by the 20 assessed NMHSs



In that respect, data transmission, whether nationally or internationally, represents a significant challenge for the vast majority of the NMHSs assessed. While some NMHSs tend to rely on manual processes for data entry and data transfer, which severely limit transmission scope and frequency, others struggle with outdated or defective data loggers and high telemetry costs. A second barrier to international data sharing lies in the lack of adequate data-management systems, a problem shared among all the NMHSs assessed. Sixty per cent do not have a centralized, automated data-management system which allows for sustainable and effective data storage, quality assurance, sharing and downstream use for output production, while the remainder rely on limited systems, hindering their operational processes. Behind this gap stands a general lack of enabling information and communication technologies (ICT) infrastructure and qualified personnel, as well as limited financial resources to support the continued usage of commercial software with comparatively high licence costs.

Even for NMHSs with higher maturity scores, these issues are often compounded by the additional challenge born from trying to operationally integrate disparate, costly equipment and systems established by different international development projects. The CHD reports reveal that many of the projects from which the NMHSs have benefited did not sufficiently consider the operational integration and sustainability of the equipment and systems they procured. This frequently led to NMHSs being unable to efficiently take full advantage of these investments or discontinuing use of the equipment and systems entirely, following a project's closure. Similarly, the CHDs also bring to light several cases of project-funded observation stations which were installed with no arrangement made to ensure the international transmission of their data.

Finally, it should be noted that all NMHSs will require support to build their technological capacity to adopt the new global data- and product-sharing system: WMO Information System 2.0 (WIS 2.0) and move away from the GTS which is due to be retired by 2033. To this end, WMO is supporting NMHSs with training workshops and free open-source software – WIS2 in a box – to support implementation by LDCs and SIDS. By the end of 2023, 20% of the assessed NMHSs had started implementing WIS 2.0 following WMO workshops.

In parallel to international data sharing, national data transmission is also a challenge for most NMHSs. Ninety-five per cent of those assessed do not have agreements in place for integration and open sharing of observations with other national institutions in line with the WMO Integrated Global Observing System (WIGOS). This leads to inefficiencies and, on a number of occasions, even duplication of efforts.

EW4All in focus: data sharing for multi-hazard early warning systems

Effective monitoring of hydrometeorological hazards can only be achieved through the integration of observations across domains of the Earth system, including meteorological observations, hydrological observations, coastal and marine observations and so forth. As the mandate for monitoring is frequently distributed across multiple agencies at the national level, operational observational data exchange is critical.

Such practices remain a major challenge in most countries. In effect, half of the assessed NMHSs do not receive any observational data from any governmental or private institution conducting hydrometeorological observations in their country, while the other half only receives such data infrequently or partially.



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Recommended actions for NMHSs

- Prioritize the implementation of centralized data-management systems;
- Favour the implementation of open-source software solutions to foster operational sustainability, such as Open CDMS and WIS 2.0 in a box;
- Seek support to implement WIS 2.0;
- Develop policies and practices for open, two-way sharing of observational data with other national institutions as well as with the entire hydrometeorological community.

Box 4

Status of and gaps in the Global Basic Observing Network

Local weather forecasts depend on constant access to global observations, but there are large geographical gaps in availability. In some parts of the world, observations are either not made or not exchanged internationally, and in other parts they are either not made or not exchanged frequently enough.

Figures 23 and 24 show the global GBON target compliance of surface land stations and upper-air stations, respectively, for January 2020 and January 2024.

The GBON regulations in the *Guide to the WMO Integrated Global Observing System* (WMO-No. 1165), Chapter 11, were not yet adopted in January 2020; therefore, the maps on the left in Figures 23 and 24 show Members' potential to comply with the regulations, based on the data exchanged at that time (January 2020), and indicate where efforts needed to be increased by certain Members. The maps on the right of the two figures, for January 2024, present the current status of global GBON compliance and the gaps remaining, with an additional category identifying the

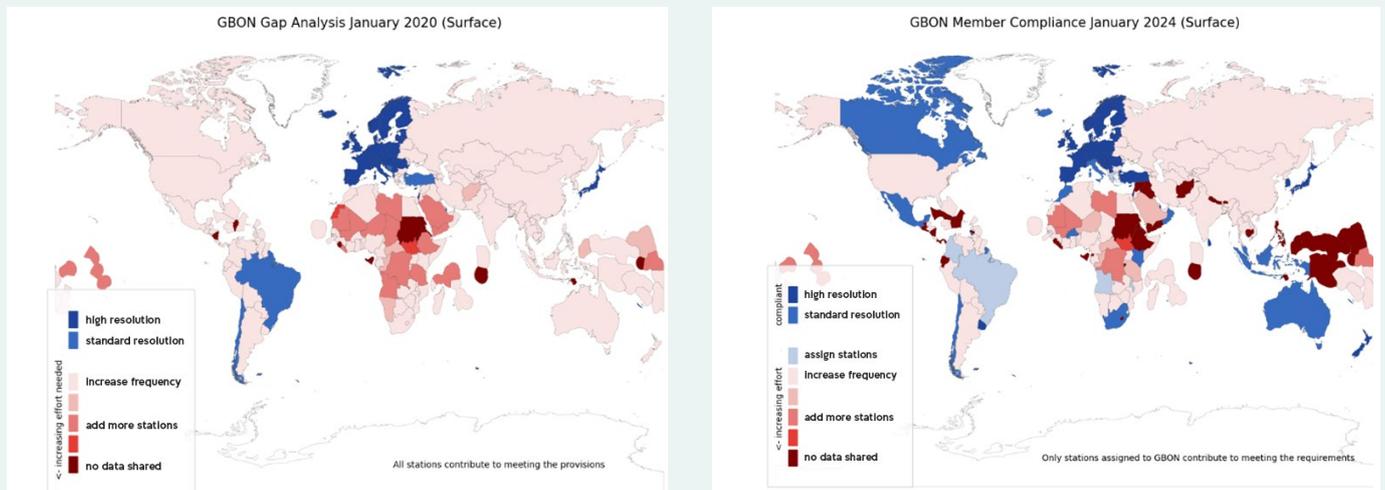


Figure 23. GBON gap analysis for January 2020²³ (left) and GBON compliance for January 2024 (right) for surface land stations

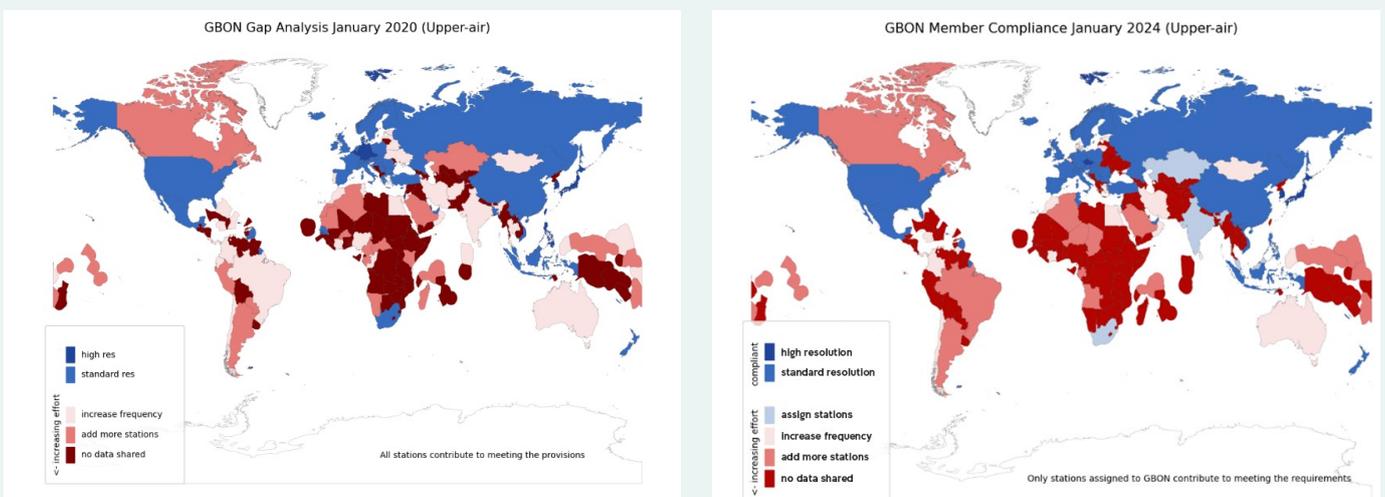


Figure 24. GBON gap analysis for January 2020 (left) and GBON compliance for January 2024 (right) for upper-air stations operated from land

Members that would be considered GBON compliant if they would assign to the GBON network more stations whose data they already share internationally.

Figure 23 shows that surface land station data availability has improved since the adoption of GBON by the World Meteorological Congress in 2021. In reaction to the new data policy, some Members have increased reporting frequency of their stations to meet the hourly reporting requirement, whereas other Members installed new stations. However, there is still a significant gap in data availability: many Members operating manual stations are not compliant with the reporting frequency requirement of GBON. Furthermore, there are several Members that would achieve compliance if they would assign more stations to GBON.

Figure 24 shows a large gap in upper-air radiosonde stations making available two soundings per day, significantly impacting global NWP and the hydrometeorological value chain. While the general trend for GBON compliance from January 2020 to January 2024 is positive, there are still large data gaps, especially over the African continent and the Pacific island States.

WMO is updating the technical guidelines, processes and procedures needed to ensure the expedient and efficient implementation of GBON and to establish effective performance and compliance monitoring. GBON is being implemented relatively quickly by most Members in the developed world. In many developing countries, however, substantial additional investment and capacity development is needed. To this end, WMO is working closely with the international development and climate finance communities to support countries to close the GBON data gap through the SOFF.

²³ In Figures 23 and 24, for the “compliant” categories (in blue), the maps for January 2020 (left) count all stations that shared data internationally to meet the provisions, while the GBON compliance maps for January 2024 (right) only count stations assigned to GBON. For small island developing States whose Exclusive Economic Zone (EEZ) is significantly larger than their land surface area, the maps show a total area composed of both the EEZ and land surface area. This is in accordance with the GBON requirements, as specified in the *Manual on WIGOS* (WMO-No. 1160).



Element 5: Numerical weather prediction model and forecasting tool application

Key challenges

- 60% of NMHSs assessed rely solely on static graphs, charts and texts derived from global NWP model outputs to produce their forecasts.
- Most NMHSs do not take full advantage of the external resources available to develop their services due to a lack of awareness and training and insufficient technical resources. In addition, 55% lack the connectivity to reliably access and efficiently use online resources, especially Pacific SIDS.
- All assessed NMHSs use global NWP model outputs, which do not have the spatial resolution appropriate to forecast meteorological conditions with the level of detail necessary to service their users, and particularly for early warning services.
- 45% of NMHSs invest considerable resources in building capacity to run limited-area NWP models internally, but none of them assimilate the data from their observing system, which severely limits these models' added value.
- Most assessed NMHSs depend on manual forecast production processes and limited systems, which restrict their ability to efficiently develop additional tailored products to serve specific users and economic sectors.

Figure 25. Distribution of the maturity scores of the 20 assessed NMHSs for Element 5: Numerical weather prediction model and forecasting tool application

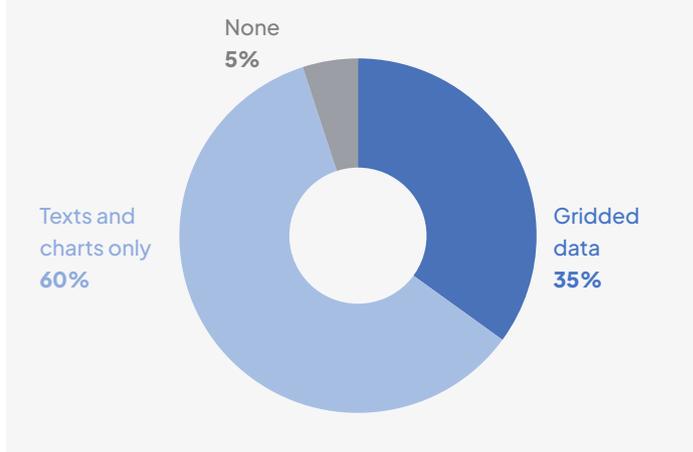


1. Forecasts are based on classical forecasting techniques without model guidance and only cover a limited forecast time range.
2. Basic use of external model output and remote sensed products in the form of maps and figures, covering only a limited forecast time range.
3. Prediction is based on model guidance from external and limited internal sources (without data assimilation) and remote sensed products (maps, figures, data) and covers nowcasting, short and medium time ranges.
4. Digitized model output from internal (with data assimilation) or external (regional) sources, as well as remote sensed products and data are used. Value is added through postprocessing techniques extended into longer time ranges.
5. Optimal combination of global/regional/local models, remote sensed data, postprocessing and automated probabilistic product generation, over weather and climate time scales, with up-to-date verification statistics.

Virtually all NMHSs around the world rely on external data and products to generate their forecasts: these mainly consist of (a) satellite remote sensed data and (b) products and NWP model outputs that are made available by the World Meteorological Centres (WMCs), Regional Specialized Meteorological Centres (RSMCs), space agencies and other stakeholders collaborating under WMO frameworks. This is part of the global effort to enhance the free and unrestricted exchange of data and availability of numerical analysis and prediction products (WMO Integrated Processing and Prediction System).²⁴ Differences materialize when considering what types of products are being used by NMHSs and how efficiently and effectively they are operationally integrated in NMHSs' forecast production processes (see Figure 25).

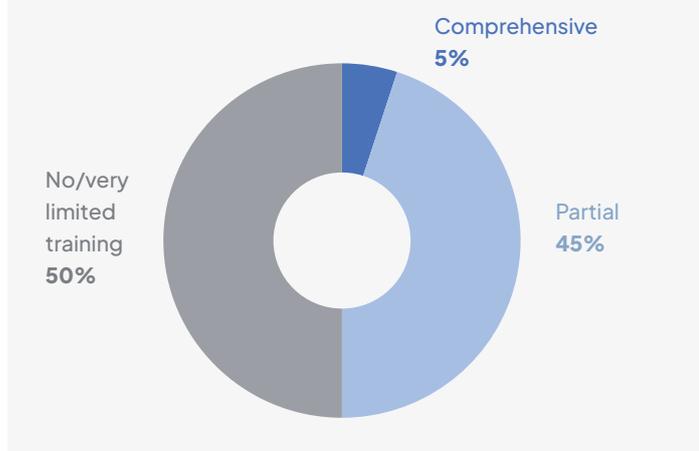
In that respect, most of the assessed NMHSs solely rely on static products (texts, figures and maps, most commonly derived from global NWP model outputs) to support their

Figure 26. Forecast products from external sources used by the 20 assessed NMHSs to generate predictions



²⁴ The WMO Integrated Processing and Prediction System (WIPPS) is the worldwide network of centres operated by WMO Members that make available numerical weather, climate and oceanic prediction products. WIPPS is structured in a three-level system, whereby World Meteorological Centres, Regional Specialized Meteorological Centres and National Meteorological Centres, all referred to as "WIPPS Centres", contribute to and benefit from the system in accordance with their needs and ability (see *Manual on WMO Integrated Processing and Production System* (WMO-No. 485) and *Guide to the WMO Integrated Processing Prediction System* (WMO-No. 305)). The list of designated WIPPS Centres and their products are available on the WIPPS Web Portal.

Figure 27. Twenty assessed NMHSs' staff training on remote sensed data access and interpretation



forecasting activities, while only 35% make use of gridded data products (Figure 26). A small minority is not accessing any external products and does not have the capacity to provide forecasting services.

Sixty per cent of the NMHSs assessed also make use of satellite data and products to develop their services, though for 45% this usage is limited to a few resources and the monitoring and forecasting of a small number of parameters.

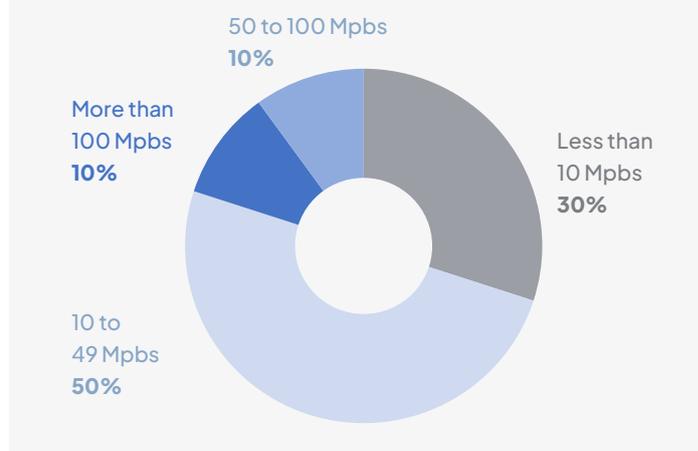
Overall, the CHD reports reveal that most of the assessed NMHSs do not take full advantage of the external resources which are theoretically available to them.

Multiple capacity gaps accumulate behind this apparent disparity. First is a lack of awareness and relevant training of forecasters. Figure 27 highlights that the vast majority of the assessed NMHSs are in need of further training on the access and use of remote sensed data and products. About half have received no or very limited training in this area.

Furthermore, the diagnostics report common occurrences where forecasters do not have the technical resources at their disposal to implement the training they received. In addition to frequent limitations in hardware and software born from insufficient financial resources, 55% of the assessed NMHSs operate with unstable internet connectivity, preventing them from reliably accessing and efficiently using external data and products, especially in remote SIDS in the Pacific. Additionally, 30% of the NMHSs are restricted by very low bandwidth speed (less than 10 Mbps) which stops them from operationally using available online resources in their forecast production processes (Figure 28).

In parallel, the global NWP model outputs used present their own limitations. The first issue relates to their spatial resolution, which for all the assessed NMHSs is too low to respond to their need to: (a) provide accurate predictions accounting for

Figure 28. Bandwidth download speed available at the national forecasting centre of the 20 assessed NMHSs



their country's specific topographic conditions; and (b) meet the requirements of users across sectors. This is particularly important for NMHSs' ability to precisely and accurately forecast hydrometeorological hazards and provide effective early warning services.

Another factor highlighted in the CHD reports relates to the global models' uneven accuracy across regions, which notably stems from a lack of international exchange of local observational data. Not having such data assimilated by WMCs and RSMCs ultimately affects the quality of the NWP outputs for these areas. In this circular system, the NMHSs of developing countries – which face the most challenges in conducting and sharing observations and are the most reliant upon external NWP products – are also the most likely to be impacted by these models' limitations. This is the very issue that spurred the Alliance into supporting the establishment of the SOFF towards the implementation of GBON (see Chapter 3).

Partially in response to these issues, many NMHSs strive to run limited-area NWP models (LAM) internally, a highly resource-intensive activity whose continued operation and development present an ongoing challenge. A number of CHD reports point out the difficulty in quantifying the added value realized by some of these internally run models. None of the assessed NMHSs which operate NWP models in-house do so while performing data assimilation from their local observations. Likewise, only 10% conduct limited verification of their models' forecasts, and postprocessing techniques are also most often not implemented.

Overall, these gaps may restrict the models' ultimate potential to significantly outperform external products and provide NMHSs with good returns on their investment. However, the majority of NMHSs are engaging in efforts to enhance their services. Half of those assessed provide services based on probabilistic prediction techniques, most commonly for longer timescales, including seasonal forecasts and climate services.

In this respect, most NMHSs assessed rely on manual forecast production processes, which restrict their ability to efficiently develop additional tailored products to serve specific users

and economic sectors. Similar to Element 4, high software license costs and inadequate hardware play a major role in these limitations, as do gaps in staff capacity building.

Recommended actions for NMHSs

- Through the WMO Integrated Processing and Prediction System (WIPPS), seek support and agreements with relevant World Meteorological Centres and Regional Specialized Meteorological Centres to access high-resolution NWP model outputs (both in graphical and data formats suitable for low bandwidths), potentially as an alternative to running models locally;
- In general, only consider running NWP models which have higher resolution than global model data and products already available, and in circumstances where models can be maintained and verified to operational quality standards;
- Seek trainings to increase forecasters' awareness, access and use of available WIPPS data and products, to enhance service delivery (e.g. through WMO Regional Training Centres);
- Where possible, seek partnerships with neighbouring NMHSs that already run limited-area models at higher resolution, including to assimilate local observational data. Otherwise, prioritize the implementation of data assimilation in models already run internally;
- Establish capacity to postprocess model data to produce local tailored guidance, whether by developing in-house forecasters' capacity or through partnerships with neighbouring NMHSs;
- Enhance internal forecasting production processes and systems, including towards the implementation of further automation;
- Consider the timescales most relevant to users' needs in order to prioritize the development of forecasting activities, including nowcasting.

Peer adviser testimonial: Bureau of Meteorology (Australia) Plugging meteorological observation gaps in the Pacific

"As part of the SOFF programme, the Bureau of Meteorology was invited to work with six SIDS (Fiji, Kiribati, Nauru, Papua New Guinea, Samoa and Solomon Islands) as a peer adviser to plan for the uplift of their meteorological capacity to contribute data, in order to meet GBON requirements. In all six countries there were challenges which limited their ability to meet the standards with their existing observing networks, for some or all of the following reasons:

- Out-of-service equipment;
- Insufficient budget for spares, repairs and travel to maintain sites;
- Logistical challenges in sourcing and providing spare parts;
- Communication and power reliability issues, limiting transmission of data;
- A tropical environment resulting in rapid vegetation growth and invasive pests;
- Insufficient qualified and trained technical staff to support systems.

A Bureau of Meteorology team visited each country to work directly with the meteorological services staff and to meet

with stakeholders. This enabled the team to tap into local knowledge to assist with decisions such as the optimal locations for sites, the type of equipment best suited to the environment, and the communications, maintenance and training that needs to be addressed to achieve sustainable capacity development in weather services for each country. Working across six countries enabled the team to identify common issues and consider options for regional solutions such as regionally-based procurement, calibration and training to enable skill sharing and support.

More frequent surface and upper-air observations from the Pacific will provide tremendous value locally and globally. For the Pacific, improved accuracy of forecasts and warnings, including for severe weather events, will greatly assist NMHSs, government departments and community-based organizations to better prepare people and businesses at risk for storms, cyclones, inundation and so forth, potentially saving lives and property. The more frequent observations will also enhance global NWP through better availability of high-quality weather forecasts and climate data, improving the safety, security and livelihoods of our Pacific neighbours and global communities".

Element 6: Warning and advisory services

Key challenges

- Half of the assessed NMHSs do not have the resources to operate alerting services 24/7 year-round, leaving them vulnerable to unexpected short-onset hazards.
- 55% do not generate their warnings and advisories in the Common Alerting Protocol (CAP) format.
- Most NMHSs are lacking close operational collaborative relationships with the other national agencies and stakeholders involved in early warnings:
 - There is no national integrated multi-hazard early warning system (MHEWS) established in 75% of the assessed NMHSs' countries.
 - NMHS warning service responsibilities range from meteorological hazards only to hydrometeorological and geological hazards.
 - 70% of the NMHSs assessed do not have any standard alerting procedure (SAP) in place with their national alerting authorities.
- No NMHS assessed is able to generate impact-based warnings. Building such complex, multi-dimensional capacity will require strong and sustained support from their national government and the international community.

Figure 29. Distribution of the maturity scores of the 20 assessed NMHSs for Element 6: Warning and advisory services



- Warning service not operational for public preparedness and response.*
- Basic warning service in place and operational but with limited public reach and lacking integration with other relevant institutions and services.*
- Weather-related warning service with modest public reach and informal engagement with relevant institutions, including disaster management agencies.*
- Weather-related warning service with strong public reach and standard operational procedures driving close partnership with relevant institutions, including disaster management agencies.*
- Comprehensive impact-based warning service, taking hazard exposure and vulnerability information into account, with strong public reach. Close partnerships with relevant national institutions, including disaster management agencies and registered Common Alerting Protocol alerting authorities.*

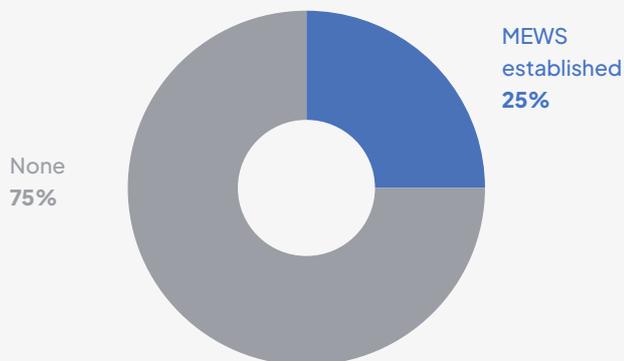
As the distribution of maturity scores for Element 6 reveals (Figure 29), the vast majority of the assessed NMHSs provide warning and advisory services in their country for the hydrometeorological hazards under their mandate (indicated by a maturity score of 2 or above). Further increments in maturity reflect the processes by which these warnings are developed and disseminated, which are notably influenced by the cascading impacts of the capacity gaps identified in the previous elements.

In striving to deliver effective warning and advisory services, half of the assessed NMHSs operate alerting services on a continuous basis all year round, while an additional 15% increase their operations to 24/7 during periods with higher likelihood of extreme events, such as tropical cyclones, and during monsoon season. The remaining 35% only operate during office hours. Moreover, 45% deliver their warnings and advisories in the Common Alerting Protocol (CAP) format to enhance their dissemination.

Given the importance of close collaboration between NMHSs and other national institutions, including disaster management agencies and (in some countries) separate hydrological or geological agencies, for the effectiveness of early warning systems, most countries have established a disaster risk reduction (DRR) coordination mechanism at the national level. Of the NMHSs assessed, 95% are a member of their national DRR committee.

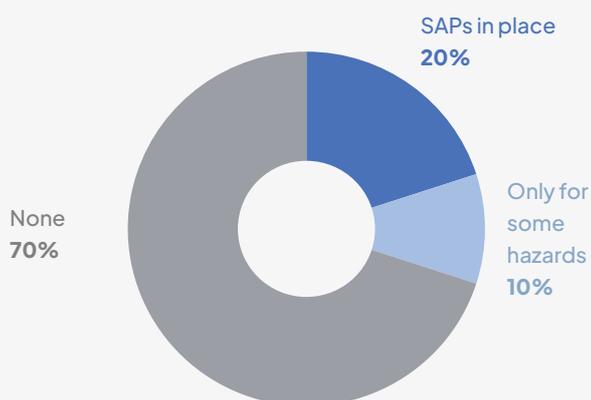
While these platforms allow for high-level cooperation, inter-agency operational coordination and collaboration remain a major gap towards the establishment of effective early warnings systems. The EW4All Initiative has highlighted this gap and advocates for the worldwide implementation and strengthening of integrated multi-hazard early warning systems (MHEWS), in line with the United Nations Sendai Framework for DRR. The CHD assessments confirmed the relevance of this call: only a quarter of the assessed NMHSs are part of an established MHEWS in their country (Figure 30).

Figure 30. Multi-hazard early warning systems (MHEWS) established in the 20 assessed NMHSs' country



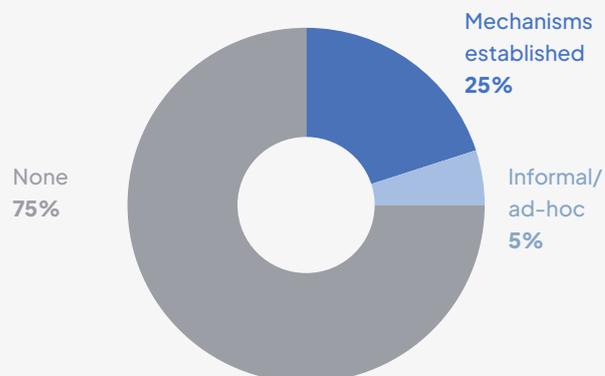
This gap bears cascading consequences on the effectiveness of NMHSs' warning and advisory services. In effect, 70% of the assessed NMHSs lack standard alerting procedures (SAPs) with the alerting authorities in their country, which hinders the warning dissemination processes (Figure 31). Similarly, three quarters have no feedback mechanisms in place with users to verify their warnings, thus preventing institutional learning and the improvement of services (Figure 32).

Figure 31. Established standard alerting procedures in place between the 20 assessed NMHSs and their respective national alerting authorities



Furthermore, the EW4All Initiative has shed light on the importance of the implementation of warnings based on the impact-based forecasting (IBF) technique to guide effective early action, by indicating not just what the forecast hazardous event will entail, but by providing specific indications as to its precise, context-responsive expected impact.

Figure 32. Feedback mechanisms implemented between the 20 assessed NMHSs and their users for verifying warnings



As recognized by the CHD methodology, IBF is an advanced forecasting technique resting on a complex production process integrating a wide scope of technical datasets and information (maturity score of 5). All NMHSs around the world are called to implement this with urgency to support countries' adaptation to the increased frequency of hydrometeorological extreme events that are in some cases amplified by climate change. This represents a very substantial challenge for developing NMHSs, which will all require strong and sustained support to develop such capacity in a short time frame.

Some NMHSs have already started the process of building IBF capacity. Of the assessed NMHSs, 15% are implementing the principles of IBF to produce their warnings and advisories, and 25% have access to some basic vulnerability and exposure data (such as hazard-specific risk maps) to inform their service production. Nevertheless, all still require considerable capacity building to implement IBF effectively and to see its benefits fully realized in their warning services. Notably, all NMHS need, among others:

- Extensive training of their forecasters in the IBF technique and methods;
- Suitable hardware and software solutions to implement IBF;
- Detailed historical data and ancillary information (e.g. historical hydrometeorological data, spatial digital data, hazard vulnerability, exposure and impact data), most often to be provided by other national agencies.

This last point emphasizes once again the crucial role that inter-institutional operational cooperation plays in the delivery of effective early warnings. To succeed in the implementation of an effective integrated MHEWS and to build their capacity to produce impact-based warnings, all NMHSs need to develop closer working relationships with the other relevant national agencies, including for systematic data exchange.

Recommended actions for NMHSs

- Engage MHEWS partner agencies and stakeholders to develop close collaboration and operational linkages, and to identify where joint work is required to improve early warning services and achieve the objectives of the Sendai Framework for Disaster Risk Reduction, especially Global target G (that is, substantially increase the availability of and access to MHEWS and disaster risk information and assessments by 2030);
- Strive to enhance the dissemination process of warnings and advisories, for example by implementing CAP, establishing standard alerting procedures with alerting authorities and building partnerships with telecommunications stakeholders;
- Based on established guidance, develop with the relevant stakeholders a joint plan to build the mechanisms and capacity for multi-hazard impact-based warnings.

EW4All in focus: regional cooperation for multi-hazard early warning systems

Many regional technical cooperation programmes have been established through WMO structures over the years to leverage national, regional and global capacities to help NMHSs develop improved hydrometeorological services, advisories and warnings. These initiatives seek to maximize the technical capacities of each NMHS through a cascading forecasting process: Global Centres make available global prediction products; Regional Centres interpret information received from global centres and process them to prepare guidance products for distribution to NMHSs; the latter use these guidance products to inform their national warnings services. The mutual exchange of data between NMHSs further enhances the whole forecasting process.

All these initiatives are based on the free and voluntary contribution of participatory NMHSs and demonstrate how the worldwide community can bridge the hydrometeorological gap through effective international technical and scientific cooperation.

Tropical Cyclone Programme

Started in 1980, the Tropical Cyclone Programme (TCP) establishes national and regional coordinated systems to ensure that the loss of life and damage caused by tropical cyclones are reduced to a minimum. Six Regional Specialized Meteorological Centres and four Tropical Cyclone Centres provide advisories and bulletins with up-to-date meteorological information to help 89 NMHSs around the tropical belt to monitor and forecast tropical cyclones, hurricanes and typhoons everywhere in the world.

Severe Weather Forecasting Programme

Started in 2006, the Severe Weather Forecasting Programme (SWFP) is strengthening the capacity of developing NMHSs to deliver improved forecasts and early warnings of severe weather to save lives and livelihoods, and protect property and infrastructure, thanks to the contributions from WMO Integrated Processing and

Prediction System (WIPPS) Centres and to support from several development partners and donors.

Through SWFP, 9 regional centres support 85 countries with products and guidance to help them warn of incoming heavy rainfall, strong winds, high waves and storm surges. In support of EW4All, SWFP aims to expand its geographical coverage to more subregions and countries and to facilitate improved tools and guidance products for the NMHSs to improve their early warning services.

Regional Climate Centres

WMO Regional Climate Centres (RCCs) are centres of excellence that create regional climate products, including long-range forecasts in support of regional and national climate activities, and thereby strengthen capacity of NMHSs in a given region to deliver better climate services to national users. RCCs generate regional and subregional tailored products at climate timescales, such as seasonal outlooks. Twelve RCCs support NMHSs across all six WMO Regions to monitor slow-onset climate hazards (such as drought) in support of their efforts to protect lives and livelihoods (for example, by contributing to food security).

Flash Flood Guidance System with global coverage

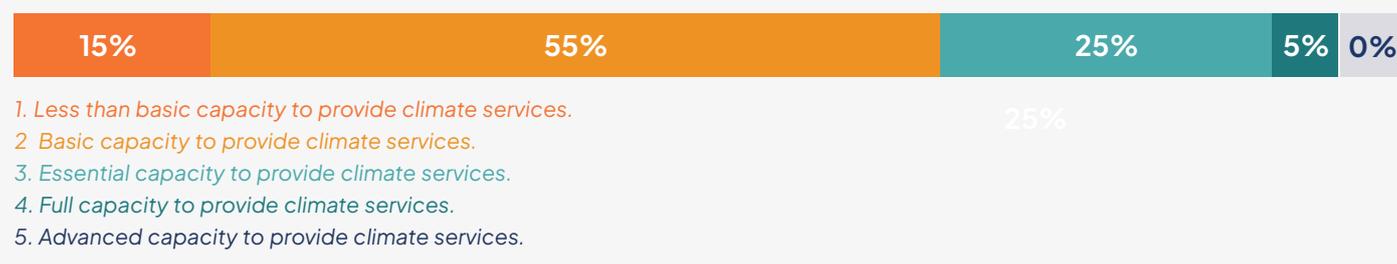
To enhance the worldwide capacity to develop effective flash flood warnings, the Flash Flood Guidance System (FFGS) was developed and implemented through a cooperative initiative between WMO, the United States Agency for International Development/Office of U.S. Foreign Disaster Assistance, the United States National Oceanic and Atmospheric Administration/National Weather Service and the Hydrologic Research Center. Since 2009, the implementation of FFGS has expanded to cover 3 billion people across 71 countries, through 13 regional and 2 national implementation projects. Through these regional cooperative frameworks, 14 regional centres support 69 countries by providing them with operational products and guidance to support NMHSs' provision of effective flash flood warnings and alerts.

Element 7: Contribution to climate services

Key challenges

- The main barriers to the development of NMHSs' capacity to contribute to climate services are the limitations of their climate monitoring and forecasting systems and related staffing capacity.
- Most assessed NMHSs lack sufficient engagement with their users to effectively understand the users' needs and to develop and improve climate services to meet those needs.
- 60% of the assessed NMHSs have not started monitoring the socioeconomic benefits of the climate services they provide, hindering the demonstration of their added value and hindering advocacy for increased support and resources.

Figure 33. Distribution of the maturity scores of the 20 assessed NMHSs for Element 7: Contribution to climate services



While most of the NMHSs assessed endeavour to contribute to the provision of climate services for their country, 55% are limited to basic capacity (Figure 33).

Going into further details, the CHD methodology builds its assessment following the framework of the WMO Checklist for Climate Services Implementation,²⁵ which is structured along six dimensions of capacity that foster NMHSs' overall ability to provide climate services:

- Governance:** national governance mechanisms to ensure coordination for climate services and enable NMHS contributions to national adaptation planning.
- Basic systems:** comprising observing networks, data, data management, monitoring, and forecasting systems that allow the production and delivery of climate information and services.
- User interface:** mechanisms, tools and systems that allow climate services users and providers to interact, to ensure co-production and tailoring of services for decision support and feedback.
- Provision and application of climate services:** decision support products and services.
- Monitoring and evaluation (M&E) of the socioeconomic benefits:** monitoring of the socioeconomic benefits resulting from the provision of climate services to users across sectors.
- Capacity development:** technical advisory services and training to address capacity development needs for climate service provision and use.

The evaluation of the level of capacity of the assessed NMHSs across these six dimensions is presented in Figure 34.

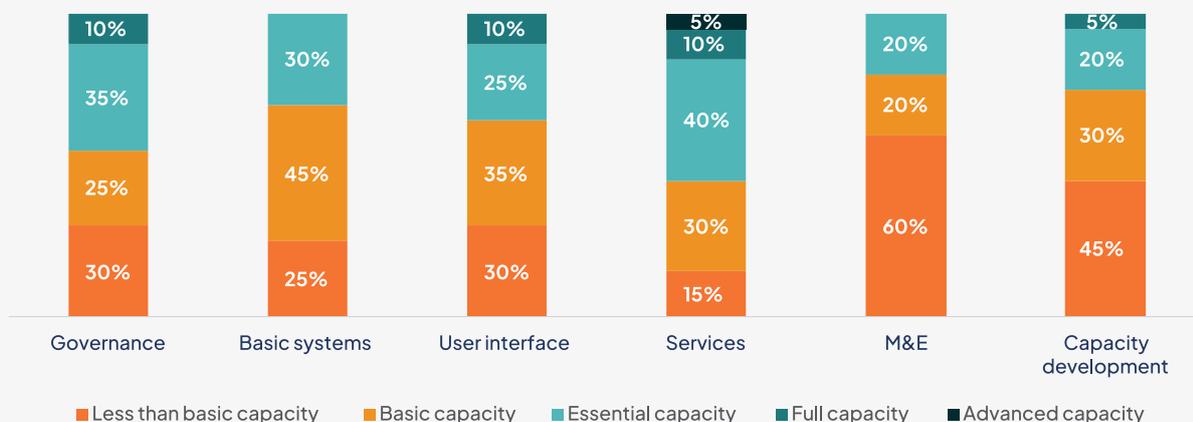
Echoing the challenges identified in Elements 3, 4 and 5, limitations in the basic monitoring, data management and forecasting systems supporting the value chain of climate services stand as examples of the main areas of capacity deficits faced by the NMHSs assessed. In addition to gaps in observing systems, to inefficiencies in data management and to limitations in forecasting capacity, climate services are specifically impacted by NMHSs' inability to operationally integrate their records of historical data held in physical



Freepik

²⁵ The WMO Checklist for Climate Services Implementation is a tool designed for NMHSs to self-assess progress with respect to climate services implementation and identify areas where support is needed. The checklist refers to the country-focused results-based framework for WMO contribution to the Global Framework for Climate Services approved by the WMO Executive Council at its sixty-eighth session (Decision 16 (EC-68)). Data from the Checklist for Climate Services Implementation are presented on the WMO Climate Services dashboard.

Figure 34. Twenty assessed NMHSs' level of capacity for the six dimensions of the WMO Checklist for Climate Services Implementation



format. Most NMHSs have made efforts to digitize parts of these records, often through project partnerships, but much data remains undigitized. A quarter have not performed any data rescue to date. Special urgency should be given to these efforts as, with time, all physical copies face the risk of deterioration and displacement, and the data could ultimately be lost.

Moreover, although 70% of the NMHSs have some form of contact with the users of their services, most would benefit from sustaining closer engagement to support the continuous improvement of their services through co-production practices. Establishing national coordination, governance and collaboration across the climate service value chain, including the users of the services, through National Frameworks for Climate Services, is proving to be successful in a growing number of NMHSs and countries around the world.



Finally, the CHD reports highlight that the most common gap relates to the monitoring of the socioeconomic benefits born from climate services: 60% of the assessed NMHSs have not started such an evaluation, which could equip them with the tools and arguments to demonstrate the value of their services and effectively advocate for increased resources and investments.

Recommended actions for NMHSs

- Establish a National Framework for Climate Services (NFCS) to coordinate and improve the development, delivery and use of climate services at the national level to support decision-making.
- Regularly engage the users, and potential users, of climate services to identify their requirements for climate information for decision-making. Establishing an NFCS enables this engagement, along with activities such as regular organization of National Climate Forums.
- In collaboration with users, evaluate the socioeconomic impact and benefits of the climate services provided, in order to demonstrate their value and advocate for further investments across the climate service value chain, including monitoring and forecasting capacity enhancements.
- Seek partnerships with international partners and academia to build capabilities and capacities where needed.

Peer adviser testimonial: GeoSphere Austria Sustainably building up hydrometeorological capacity in least developed countries and small island developing States

“GeoSphere Austria is acting as a peer adviser, through SOFF, for eight countries across three continents: Africa (Chad, Djibouti and South Sudan), Asia (Lao People’s Democratic Republic) and the Americas (Dominica, Guyana, Saint Lucia and Saint Vincent and the Grenadines). The goal of SOFF is to improve the observational networks of these countries, so that they are able to comply with the GBON requirements and share more data internationally, from both surface and upper-air stations. Out of these eight countries, four are classified as LDCs and four as SIDS.

However, observations and stations are not a stand-alone issue, and their proper maintenance and use depend on more than just the availability of equipment or budgets. Despite these countries’ innate differences, our teams have found that all tend to face similar challenges related, directly or indirectly, to their observational network:

- Lack of a sufficient legal framework;
- Insufficient budget for investments, maintenance and other operations beyond salary payments;
- Insufficient qualified and trained staff, but even more, real difficulties with finding and recruiting new personnel;
- Challenges related to accessibility of stations (due to weather, large distances, poor road infrastructure or security issues);
- Limited coordination between different international implementing actors, resulting in stations and equipment from multiple vendors, without proper synergy between them;
- Considerable gaps between the suggested development goals and the actual capacities of the NMHSs;
- Missing or limited partnership with other entities running their own observation stations;
- Technical issues related to communication, data management and storage, spare parts, SOPs and calibration, among others.

Our teams visited each one of the countries separately, meeting the staff and local and regional stakeholders, in a continuous learning process to understand the challenges of each meteorological service. Through these experiences, we have learnt to look at the wider picture, trying to bring together as many players as possible – seeing stations and data as one part of the total value chain.

The GBON National Contribution Plans that we have supported involve different approaches to strengthening the NMHSs and addressing the capacity gaps we have identified, in a systemic and sustainable approach: from governance to partnerships and capital investments in training current and potential future staff through collaboration with national and regional educational institutions and capacity development at the technical level. All of these approaches look at the current realistic state of the specific NMHS and build upon it in a gradual and sustainable way. Where possible, such as in the Caribbean region, we also aim at developing a regional approach to help foster sustainable results for smaller countries lacking resources.

Additional real-time and high-quality data from these countries will help improve both global weather and climate models, thus improving their abilities to issue better forecasts and warnings. Not least, they will help the NMHSs to broaden their possibilities in terms of providing current and new services and products, improving their ability to serve their countries and societies, and becoming key players in the national and international effort to combat the impacts of weather and climate extreme events in the era of climate change”.



Element 8: Contribution to hydrology

Key challenges

- Most NHMSs lack effective operational integration across meteorology and hydrology, even those in which both meteorological and hydrological services are housed under a single institution.
- Only 55% of the assessed NMHSs provide standard hydrological data/products to the national hydrological service (some are limited to model output data only).
- Only 30% have established standard operating procedures (SOPs) between the meteorological and hydrological services.
- Overall, hydrological services face the same challenges as meteorological services throughout their value chain (lack of observations, systems, personnel, etc.), which further exacerbates the danger posed by the worldwide intensification of floods and droughts.

Figure 35. Distribution of the maturity scores of the 20 assessed NMHSs for Element 8: Contribution to hydrology



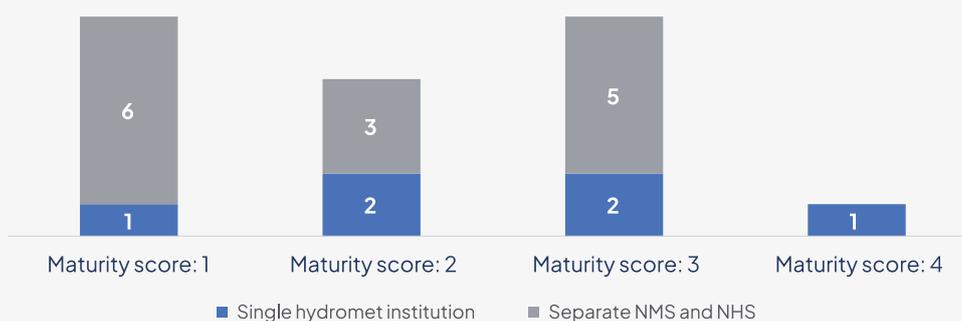
1. No or very little meteorological input in hydrology and water resource management.
2. Meteorological input in hydrology and water resource management happens on an ad hoc basis or during times of disaster.
3. There is a moderately well-functioning relationship between the meteorological, hydrological and water resources communities but considerable room for formalizing the relationship and SOPs.
4. The meteorological, hydrological and water resources sectors have high-level agreements in place and working relationships (including data sharing), but products and services still tend to be developed in isolation.
5. The meteorological, hydrological and water resources sectors have robust SOPs and agreements in place to work closely in developing new and improved products and providing seamless and advanced services.

While the maturity of scores of the other elements have tended to follow a standard distribution curve, those of Element 8 demonstrate a higher degree of polarization between national meteorological services which have started the work to close the hydrometeorological value chain gap between meteorology and hydrology, and those for which engagement remains at an informal level (Figure 35).

Of the NMHSs assessed, 30% house both meteorological and hydrological services in the same institution, while the other 70% are only mandated for the field of meteorology

and related services,²⁶ and collaborate with administratively separate national hydrological authorities. The CHD reports reveal that while the institutional arrangements which bring together meteorology and hydrology under the same roof tend to promote collaboration and operational linkages, they do not guarantee them. From the NMHSs assessed, those that represent a single national hydrometeorological authority have not consistently outperformed their counterparts for Element 8, but are instead distributed evenly among the maturity scores (Figure 36). This highlights the importance of institutional and management capacity building for effective service delivery.

Figure 36. Institutional arrangement of meteorological and hydrological services in the country of the 20 assessed NMHSs, by maturity score



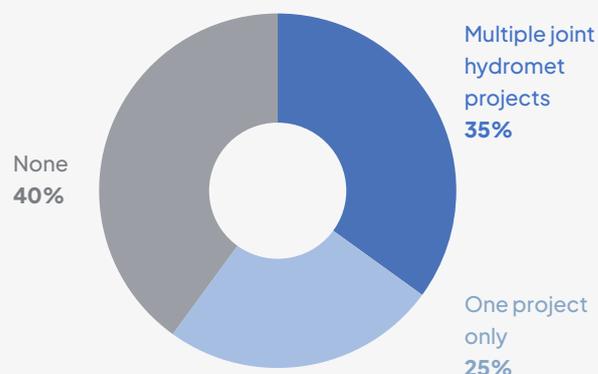
²⁶ These services most commonly include climate services. Some NMHSs are also responsible for other fields, such as seismology/volcanology and oceanography.

Even though meteorological data, such as precipitation observations and quantitative precipitation estimates, are an important component of the value chain for hydrological services (for example, to inform flood forecasting), only 55% of the assessed NMHSs provide standard hydrological data and products to the national hydrological service. Some are limited to numerical model output data only.

This operational gap is the result of a lack of capacity described in the preceding elements (observing systems, data management, personnel) as well as insufficient inter-institutional agreements and processes. Indeed, only 30% of the institutions assessed have established SOPs to formalize the relationship between meteorological and hydrological services. Similarly, only 35% have a formal mechanism in place to coordinate the activities of the two fields on a regular basis.

Joint projects and initiatives provide a platform to build hydrometeorological cooperation. In this respect, 60% of the assessed NMHSs have implemented at least one such project (Figure 37). However, when these projects are externally funded, operations tend to stop after their closure.

Figure 37. Twenty assessed NMHSs' experience in implementing joint projects and initiatives with the hydrological community in their country



Finally, the CHDs report that the hydrological observing systems (including data management) generally face similar gaps as the ones identified in Elements 3 and 4 for meteorological observations, limiting the availability of hydrological data. Hydrological data sharing is a further challenge both at the national and international level. Only 35% of the assessed NMHSs have any sort of agreement on hydrological data sharing in place.



Gabon UNDP

Recommended actions for NMHSs

- Foster closer collaboration with the hydrological agency and the broader hydrological community at the national and regional level, including to establish automatic data exchange and to provide relevant products and tailored services, and in particular towards the development of integrated flood and drought monitoring, forecasting and warnings;
- Seek to formalize this collaboration through agreements and SOPs.

Element 9: Product dissemination and outreach

Key challenges

- Although 75% of the assessed NMHSs use social media to disseminate their products and services to the public, they often lack the technical resources and expertise to do so effectively, reducing their following and reach.
- Only 45% have established some special measures to cross the “last mile” to reach marginalized communities in their country.
- Most NMHSs conduct education and awareness initiatives for the public and specific users (such as farmers), but they are limited in scope and frequency.

Figure 38. Distribution of the maturity scores of the 20 assessed NMHSs for Element 9: Product dissemination and outreach



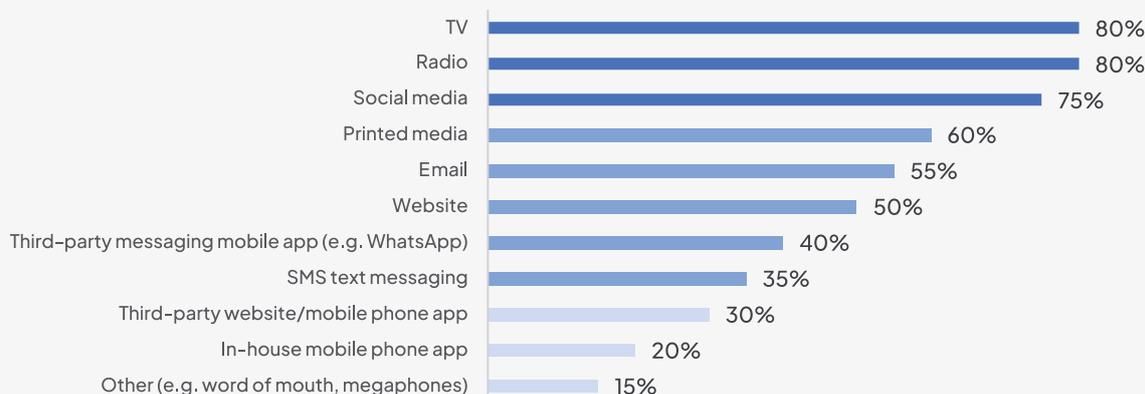
1. Dissemination using only limited traditional channels such as daily newspapers and the national broadcaster, and with little control over messaging and/or format.
2. Traditional communication channels and a basic dedicated website are used to disseminate forecasts and basic information.
3. A moderately effective communication and dissemination strategy and practices are in place, based only on in-house capabilities and supported by a user-friendly website.
4. A large fraction of the population is reached using various communication techniques, in collaboration with partners, and a user-friendly website and apps. Outreach and education activities occur regularly.
5. Advanced education, awareness and communication strategy, practices and platforms in place using various technologies, tailored to reach even marginalized communities and in close cooperation with several partners.

Most NMHSs endeavour to modernize their communication practices to reach new users. Even though TV and radio broadcasts remain the most widely used communication platforms, 75% of the assessed NMHSs have also adopted social media as a means to disseminate their products and services to the public (Figure 39). At the same time, they often lack the technical resources and expertise to tailor their communication style and content to effectively develop their social media presence, resulting in comparatively modest following and reach. Due to similar limitations, only a minority (20%) have produced their own smartphone application.²⁷



Pexels

Figure 39. Communication channels used by the 20 assessed NMHSs to disseminate their products and services



²⁷ N.B. Another 10% were in the process of developing their own mobile application at the time of the CHD review.

At the same time, the ultimate effectiveness of hydrometeorological services rests on the way they are received, understood and acted upon by their intended users. Bridging this last mile in an effective and timely manner is crucial for early warning services. It has been widely established that users access risk information in various ways and may act differently upon it, depending on their specific relationship with and trust in the information source.^{28,29}

This pattern in user behaviour highlights the need for NMHSs to develop multi-channel, multi-provider communication partnerships for comprehensive dissemination of warnings and advisories. The challenge of doing so is compounded by the telecommunications and connectivity gaps suffered by a large portion of the population in developing countries. Another layer of difficulty is added in multilingual countries. Of the NMHSs assessed, only 45% have established some

special measures to reach marginalized communities, such as Indigenous people, the elderly and minority linguistic communities, mainly due to lack of resources. NMHSs that have been empowered to conduct community-based engagement and develop two-way communication mechanisms have found these relationships to be mutually beneficial for fostering trust and informed decision-making as well as for including traditional knowledge in services.

The analysis shows that most NMHSs attempt to proactively engage with the public: three quarters of those assessed perform education and awareness initiatives, although these are commonly conducted on an ad hoc basis, are often limited in scope (for example, school visits) and are contingent upon resource availability.

Recommended actions for NMHSs

- When possible, develop in-house expertise in communication and media presentation to enhance the user-friendliness of the products and services disseminated online (website, social media);
- Seek to establish partnerships with the national disaster risk management agency, local governments, NGOs, community organizations and the telecommunication sector, as relevant, to ensure effective dissemination of products and services to all end users across population groups, especially for warnings and advisories;
- As noted earlier, implement the Common Alerting Protocol (CAP) for warning dissemination;
- Continue to engage with users from weather- and climate-sensitive sectors to build climate awareness and improve tailored services, including the recognition and inclusion of traditional knowledge.



UNDDR

²⁸ Lloyd's Register Foundation. *World Risk Poll 2021: A Resilient World? Understanding Vulnerability in a Changing Climate*; 2022. <https://wrp.lrfoundation.org.uk/2021-report-a-resilient-world-understanding-vulnerability-in-a-changing-climate/>. See also World Risk Data Explorer graph *Who would you trust most to provide information about a disaster?*: https://lookerstudio.google.com/reporting/a83a8818-fe7f-46c6-b15a-3561e2a6d7d8/page/p_au2c7jvx5c?s=jVcgfElq434 (navigation: A Resilient World?>Natural Hazards>Disaster Information)

²⁹ United Nations Department of Economic and Social Affairs. *Enhancing Public Institutions' Risk-informed Communication to Address Multifaceted Crises for Disaster Risk Reduction, Resilience and Climate Action*; Policy Brief No. 156, December 2023. <https://www.un.org/development/desa/dpad/wp-content/uploads/sites/45/PB156.pdf>.

Element 10: Use and national value of products and services

Key challenges

- More than half of the assessed NMHSs lack established mechanisms and processes to engage with their main national stakeholders and users: only 40% regularly organize a consultative platform for collaborative dialogue, and just 35% have co-design mechanisms in place to develop tailored services.
- Implementing quality management systems (QMS) is an effective way to enhance service quality and foster NMHSs partners' trust. Yet only 30% of the assessed NMHSs have fully implemented a QMS for aviation services, and only 10% have done so for early warning services.
- 90% of the assessed NMHSs have not conducted a socioeconomic benefits study demonstrating the national value of their products and services.

Figure 40. Distribution of the maturity scores of the 20 assessed NMHSs for Element 10: Use and national value of products and services



1. Service development lacks any routine stakeholder feedback.
2. Service development draws on informal stakeholder input and feedback.
3. Service development draws on regular dialogue with major stakeholders.
4. Service development draws on survey data and regular dialogue based on formal relationships with major stakeholders to ensure continuous improvement.
5. Strong partnerships and formal and objective survey and review processes exist with all major stakeholders, enabling service co-design and continuous improvement.

The national value of NMHSs' products and services is promoted both by internal processes sustaining their quality and external mechanisms enhancing their relevance to users. The majority of the 20 assessed NMHSs do not formally and systematically implement such mechanisms to develop their services (see maturity scores 1 and 2, Figure 40). Looking inward, only 35% of the assessed NMHSs conduct regular reviews and reports on their services' accuracy and timeliness. The analysis demonstrates that most NMHSs with a maturity score of 3 or higher do so (Figure 41), thus advancing their institutional transparency and ultimately improving their service delivery.

The CHD reports further highlight the important role that QMS implementation plays in enhancing service quality and increasing partners' trust, leading to more opportunities for closer relationships. To this end, most NMHSs start implementation in relation to the provision of aeronautical meteorological services, as QMS is a requirement in this respect.³⁰ Services for the aviation sector also hold the potential for bringing resources from cost-recovery mechanisms. Nevertheless, only a minority of the assessed NMHSs (30%) have been able to fully implement a QMS for

aviation services, with 30% more being in various stages of partial implementation (Figure 42). These numbers drop considerably when considering QMS implementation for other types of services: for example, only 10% of assessed NMHSs have done so for early warning services (Figure 43).

Externally, the analysis of previous elements has already stressed the importance of close collaboration and engagement between NMHSs, their national partners and users at all steps of the hydrometeorological value chain. The CHD results however reveal that most developing NMHSs lack established mechanisms and processes to engage with their main national stakeholders and users: only 40% of the assessed NMHSs regularly organize a consultative platform for collaborative dialogue, and just 35% have co-design mechanisms in place to develop tailored services. These gaps limit NMHSs' ability to identify and respond to their partners' needs and requirements.

In addition to improvement in service delivery, successful provision of user-relevant tailored services to partners also increases the visibility and position of NMHSs in their national landscape. Such recognition is a strong enabler of

³⁰ International Civil Aviation Organization (ICAO). *Annex 3 to the Convention on International Civil Aviation – Meteorological Service for International Air Navigation*, 20th Edition; ICAO: Canada, July 2018, amended in November 2021.

<https://store.icao.int/en/annex-3-meteorological-service-for-international-air-navigation>. Part 2 section 2.2.2 requires quality management to be established for meteorological information supplied to [aviation] users.

Figure 41. Twenty assessed NMHSs regularly reviewing and reporting on their services’ accuracy and timeliness, by maturity score



NMHSs’ capacity to develop mutually beneficial relationships with other institutions and to increase their resources (both through government funding as well as through cost-recovery mechanisms and the provision of services to the private sector).

As identified in Element 7, monitoring of the socioeconomic benefits (SEB) of hydrometeorological services is another mechanism through which NMHSs can demonstrate the national value of their work. In this respect, 90% of the assessed NMHSs have not conducted such a study.

Figure 42. Twenty assessed NMHSs’ implementation of a QMS for aviation services

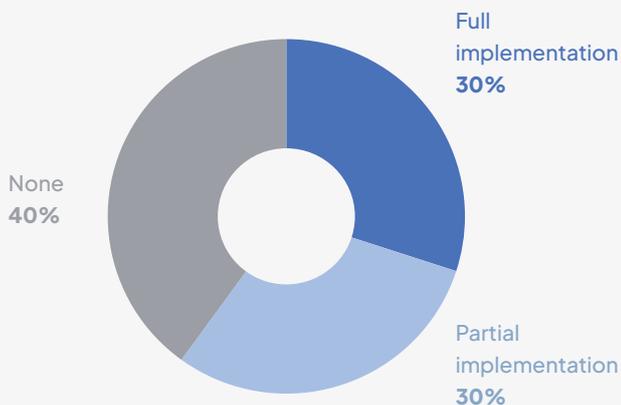
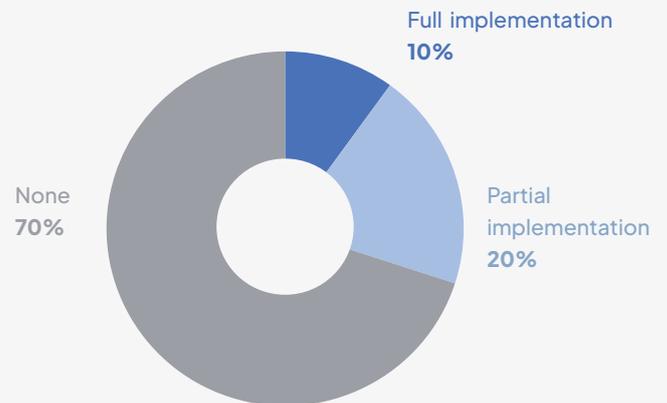


Figure 43. Twenty assessed NMHSs’ implementation of a QMS for early warning services



Recommended actions for NMHSs

- Prioritize the progressive implementation of QMS for all services (e.g. by following established guidance such as the WMO *Guide to the Implementation of Quality Management Systems for National Meteorological and Hydrological Services and Other Relevant Service Providers* (WMO-No. 1100);
- Establish and sustain regular mechanisms for open and constructive dialogue with national partners and users, including feedback on products and services and development of tailored services;
- Engage with relevant partners (e.g. international development partners, academia, government) towards the development of SEB studies assessing the value of hydrometeorological services, including cost-benefit analysis of the investments required to be able to respond to national needs.

6. Alliance way forward

Based on the preceding analysis, the Hydromet Alliance identifies eight priority actions to be taken forward, outlined in the present Chapter.

Analytics for impact: standardized country analysis and data-driven reports

1. Promote the Country Hydromet Diagnostics as a universally utilized tool for informing investments in hydrometeorological services

The Alliance recognizes the utility of CHDs for providing an overview of NMHSs' capacity gaps, validated up-to-date data and recommended modernization actions based on the expert assessment of peer advisers. It sees scope for increasing and broadening the use of the CHDs for project identification and preparation, coordination of development projects and programmes, including in the framework of Early Warnings for All, as well as in national development planning. The Alliance also sees scope for refining and expanding the methodology to cover certain areas more thoroughly, such as hydrological, marine and climate services, as well as developing approaches for more in-depth thematic reviews. To this end, it will capitalize on the technical expertise of WMO and the pool of CHD peer advisers. It will also promote and raise awareness of the CHDs as big-picture, strategic assessments of NMHSs. Finally, the Alliance will also endeavour to improve methodologies for the assessment of the socioeconomic benefits of hydrometeorological services and include them in the CHDs.

2. Continue publishing regular Hydromet Gap Reports capturing data, trends and insights from the gradually increasing sample of countries covered

In addition to the regular Hydromet Gap Reports, the Alliance will further consider the development of thematic global reports that may also include thematic chapters focused, for example, on a particular topic, region or a group of countries (SIDS, LDCs, countries in fragile or conflict-affected situations and so forth). In this way, the Alliance will continue to increase awareness among other public international development, humanitarian and financial institutions on the need to strengthen developing countries' hydrometeorological capacity.

Financing for impact

3. Optimize financial tracking of early warning systems investments to effectively manage disaster risks associated with climate-related hazards

The Alliance recognizes the critical importance of tracking and analysing investments in EWSs to bolster advocacy for and coordination of support across the MHEWS value chain. This involves identifying key trends in investment portfolios to reveal funding priorities and gaps, examining investment portfolios from various sources to assess distribution and effectiveness, and sharing findings from country needs assessments to pinpoint areas requiring further investment and support. The Alliance therefore supports optimizing financial tracking methods to better inform Alliance members' planning and decision-making processes, potentially including the development of a Finance Tracking Observatory to be integrated in the EW4All Dashboard for streamlined data visualization and informed decision-making.

4. Sustain and expand the Systematic Observations Financing Facility

The Alliance aims to maintain and expand the scope of SOFF to support the continuous improvement and sustainability of hydrometeorological observations. As the United Nations climate fund dedicated to systematic observation, SOFF is a vital mechanism for closing today's basic weather and climate data gaps. Furthermore, the Alliance has as its long-term goal to extend SOFF's scope to also include other Earth observation domains, including greenhouse gases and marine and hydrological variables, depending on potential future intergovernmental additions to GBON. The Alliance will advocate for expanding SOFF financial support to middle-income countries, which also face significant observation gaps. By broadening SOFF's focus, the Alliance seeks to create a comprehensive approach to strengthening the Earth systems monitoring critical for MHEWS, climate adaptation and mitigation.

Coordination for impact

5. Enhance development partner coordination at the regional level for a more focused and targeted approach to supporting hydrometeorological services

Programmes and projects play a crucial role in advancing the global climate action agenda by addressing country needs and ensuring reliable hydrometeorological information. With numerous development partners committed to supporting weather, water and climate services, coordination challenges persist, leading to duplication of efforts and inefficient resource allocation. To address this, the Alliance will support the WMO effort to establish regional coordination mechanisms among development partners,³¹ aligned with the EW4All financial tracking described in point 3 of the present section. These provide a platform for the systematic and sustained exchange of project and programme information in order to: enhance collaboration among partners; provide a forum for donors to align their resources and collaborate on ways to improve approaches and harmonize interventions at national and regional levels; and help align development partner objectives with identified WMO Member priorities and needs, to ensure ownership of interventions and maximize impact and sustainability of investments.

6. Address the gap in middle-income countries

Despite facing significant climate-related risks, middle-income countries often struggle to prioritize investment in their hydrometeorological services and have very limited access to concessional financing. This occurs despite the fact that addressing capacity gaps in hydrometeorological services in these countries requires relatively modest investments and straightforward solutions in a stable and fairly robust context. As such, middle-income countries represent low-hanging fruits in terms of their potential for sustainable improvement. Recognizing the importance of this issue, the Alliance commits to scaling up initiatives aimed at strengthening hydrometeorological services in middle-income countries.

Empowering for impact

7. Climate Science Information for Climate Action: Enabling NMHSs in mobilizing climate and development finance

Climate science and information are critical to effective climate change decision-making processes and to the identification and design of climate investments, serving as key enablers for mobilizing climate and development finance. NMHSs' data, knowledge and expertise are essential for informing climate-related national strategies, processes and investments. This must therefore be acknowledged and NMHSs empowered to effectively fulfil this pivotal role. The Green Climate Fund (GCF) and WMO have in the past collaborated to provide the international community with new science-based climate information and tools based on NMHSs' authoritative data and expertise to strengthen climate change decision-making.

The Alliance will scale up technical and capacity development support to empower NMHSs as critical actors in national climate decision-making, ensuring national strategies, activities and investments are grounded in robust climate science. Such support recognizes the crucial importance of empowering NMHSs to engage and inform national policymaking and decision-making for climate change action, including for mobilizing climate finance, seeing as climate science and information should fundamentally shape climate-related decisions and investments. Members will ensure that pipeline proposals are linked through the [Climate Science Information for Climate Action \(CSICA\) initiative](#), and they will work together to support countries and regions and their direct access entities (DAEs) to mobilize climate financing.

8. Continue to advocate for and champion sustainable national funding

Sustained investment in hydrometeorological services is essential for building resilience to climate change, reducing disaster risks and achieving sustainable development goals at the global, regional and national level. The Alliance remains dedicated to advocating for sustainable national funding for hydrometeorological development and operations, and engaging with governments, policymakers and stakeholders. By emphasizing the economic, social and environmental benefits of investing in hydrometeorological infrastructure and capacity building, the Alliance will underscore the cost-effectiveness of early warning systems, disaster preparedness measures and climate adaptation strategies. Through these efforts, the Alliance strives to foster widespread recognition of the importance of sustained investment in hydrometeorological services for national resilience-building efforts, disaster risk reduction and the attainment of sustainable development goals at the country level.

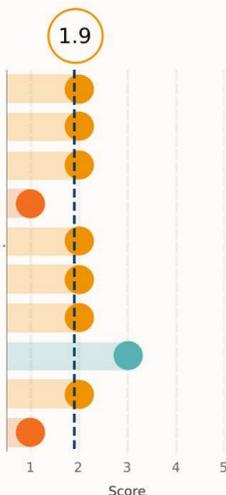
³¹ WMO has led the roll-out of the Africa Partner Coordination Mechanism (APCM) and, most recently, established the Pacific Partner Coordination Mechanism with the Secretariat of the Pacific Regional Environment Programme (SPREP) which aligns with existing strategies and priorities, including the Pacific Islands Meteorological Strategy and the Weather Ready Pacific Program, which call for coordinated support for NMHSs.

Annex 1. Country Hydromet Diagnostics country results

Bhutan

II: Asia
Lower middle income
LDC/LLDC

Score (overall)



National Centre for Hydrology and Meteorology of Bhutan (NCHM)

Highlights of Gaps and Challenges:

- Sustainability risks due to dependence on external donors.
- Inadequate resources to operate and develop observation networks and data management solutions.
- No specific policy for data sharing, no open data policy.
- Inadequate resources to operate and develop numerical weather prediction (NWP) and forecasting tools, particularly for hydrological forecasting and modelling.
- Not all areas or basins are covered with early warning services.
- Missing impact-based forecasting operations and implementation of Common Alerting Protocol (CAP).
- No skills in development of tailored climate products and quality control of data.
- Public trust and confidence are a challenge.

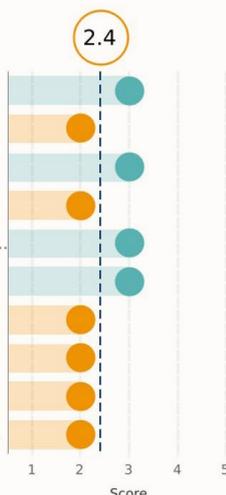
Recommendations:

- Training on software and hardware components of Automatic Weather Stations, on operation and maintenance of stations; basic training in weather forecasting.
- Establishment of operational NWP verification system.
- Piloting of new warnings and developing threshold levels for hazardous phenomena. More lead time for warnings.
- Improved use of satellite and remote sensing information in monitoring.
- Provision of early warning services for floods and impact-based forecasts.
- Establishment of National Framework for Climate Services.
- Awareness activities to enhance communities' knowledge and trust in services.

Cabo Verde

I: Africa
Lower middle income
SIDS

Score (overall)



National Institute of Meteorology and Geophysics (INMG)

Highlights of Gaps and Challenges:

- Issues in national governance structure and accountability related both to legal frameworks and operational mandates of key national players.
- Financial challenges and staff capacity are currently impeding INMG from effectively fulfilling all its roles at the national, regional and international levels.
- Financial dependency from aviation authorities does not easily permit INMG to diversify its services to other economic sectors.
- Limited funds hinder staff capacity development and recruitment, as well as station infrastructure and instrument maintenance across the nine inhabited islands.
- A fully functional multi-hazard early warning system (MHEWS), CAP and operational emergency operations centers are still under development.

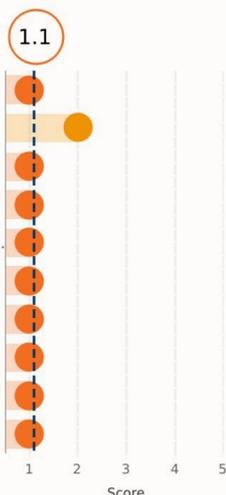
Recommendations:

- Review regulations and decree(s) to better identify role and responsibilities and increase the visibility of INMG.
- Develop services for the private sector, using activity-based service level agreements and pricing.
- Investigate option of installing and deploying marine buoys to increase monitoring capacity of marine meteorological conditions, in cooperation with regional partners.
- Develop and implement a data-sharing policy and mechanism (with urgency).
- Review and better define mandates and responsibilities concerning MHEWS.
- Develop and produce tailored climate products and services to key economic sectors.
- Establish a data-sharing mechanism for hydrometeorological data with the National Hydrological Service (NHS).

Chad

I: Africa
Low income
LDC/LLDC

Score (overall)



Agence Nationale de la Météorologie (ANAM - National Meteorological Agency)

Highlights of Gaps and Challenges:

- Existing legislation is too generic.
- Lack of resources (human, technological and financial). Insufficient governmental allocation without any real opportunities for cost recovery services.
- Severe lack of sufficient professional staff, especially forecasters and climatologists.
- Lack of capacity to maintain the network of 54 Automatic Weather Stations (AWSs) installed through a UNDP project.
- Only partial coverage of the country's territory with stations (all in the south).
- Lack of proper and adequate working facilities, especially for operational staff.
- Forecasters, observers, station operators and ICT technicians are not in a position to perform the daily activities due to lack of staff, competences and training.
- Insufficient exchange with other government entities such as the Agriculture, Civil Protection and Water Resource Division.

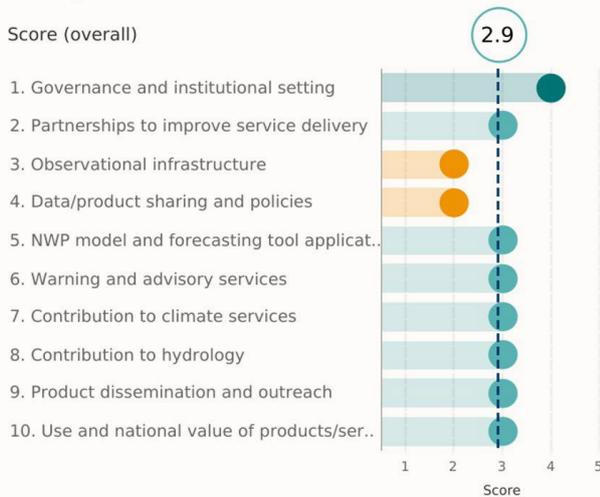
Recommendations:

- Enact additional legislation that clearly defines the role and responsibilities of ANAM.
- Increase the budget of ANAM to enhance its capacity to employ additional professional staff, procure suitable equipment and ensure basic maintenance.
- Strengthen ANAM's cooperation with the francophone regional training centres.
- Establish a well-equipped operational forecasting centre; hire and train forecasters.
- Hire and train additional, trained climatological staff, fully digitize data on paper and reconsider the timing of the issuance of the seasonal forecasts.
- Strengthen cooperation with the hydrological service, including on data sharing.

Ethiopia

I: Africa
Low income
LDC/LLDC

Score (overall)



Ethiopian Meteorology Institute (EMI)

Highlights of Gaps and Challenges:

- Financial constraints are hindering EMI's ability to fulfil its various roles. Progress has been made but insufficient funds affect human capacity building, infrastructure installation and sustainable project implementation.
- EMI requires regular recruitment of dedicated staff, improved training and ICT expertise for sustainability of increased observational infrastructure.
- The observational infrastructure, mostly the ICT infrastructure and services including skilled specialists for the increased data management capabilities, is lacking.

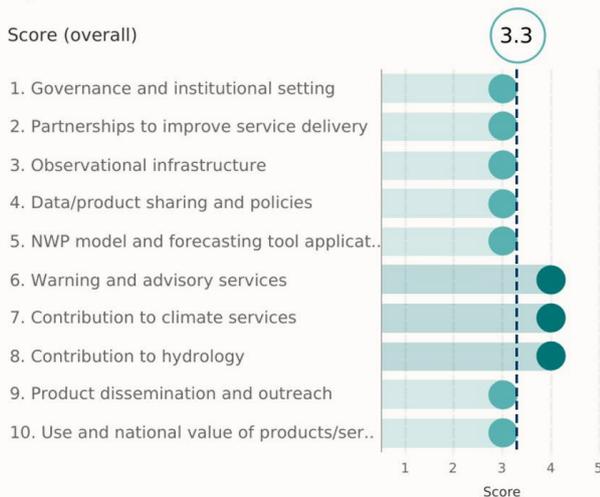
Recommendations:

- To achieve a progressive target toward Global Basic Observing Network (GBON) compliance, urgent development needs are required.
- Improved capabilities and standard operating procedures (SOPs) regarding organizational datasets management throughout the entire value chain.
- A review of EMI's data-sharing policy.
- Improved numerical model and forecasting tool application capabilities, including re-incorporating data assimilation practices.
- The development of existing structures can significantly improve the contribution of EMI to hydrology, enhancing the capabilities of hydrometeorological cooperation.
- Expertise in different fields, such as research and climatology, will be an asset.
- EMI can enhance stakeholder engagement and visibility through grass-roots workshops and partnerships with media platforms and broadcasting companies, thereby promoting early warnings for societal benefit.

Fiji

V: South-West Pacific
Upper middle income
SIDS

Score (overall)



Fiji Meteorological Service (FMS)

Highlights of Gaps and Challenges:

- Parts of the FMS role are not well formalized (both regionally and locally).
- No establishing legislation.
- Staff and budget are mostly sufficient to meet FMS's current roles, although there is strong dependence on donor programmes for service improvements.
- Observations and ICT operate in an unsustainable fashion with too many disparate technologies and projects requiring support from too few staff.
- Difficulties in complying with global observational standards.
- Further difficulties in sustainably supporting with current resourcing the servicing of weather stations and radars, the development of forecasting system environment, and aspirations towards having an internal modelling capacity.

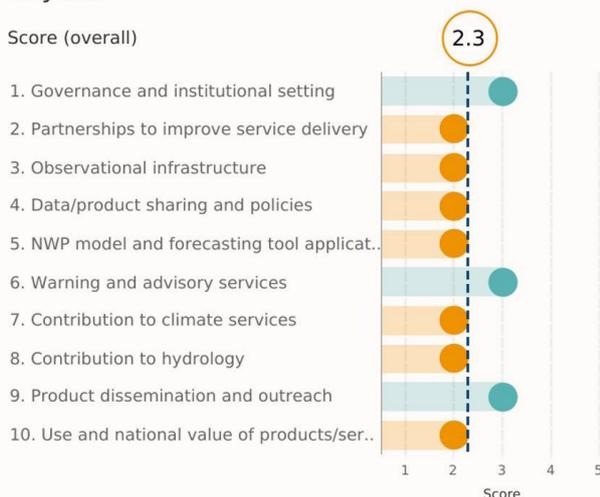
Recommendations:

- The FMS has a recent Strategic Plan (2021-2024) that provides a road map forward.
- Improved user relationships, clarification of legislative mandate, sustainable network and ICT practices, and continued collaboration with agencies and the international community are all vital to ensuring FMS's continued ability to serve the Fijian public and the wider region.
- Important initiatives such as Weather Ready Pacific and Systematic Observations Financing Facility (SOFF) have potential to substantially support FMS in this work.

Guyana

III: South America
High income
SIDS

Score (overall)



Hydrometeorological Service of the Cooperative Republic of Guyana (GHMS)

Highlights of Gaps and Challenges:

- Insufficient and too narrow formal mandate that does not cover many of the most vital fields of modern National Meteorological and Hydrological Services (NMHSs): disaster risk reduction, aviation, marine services, climate services, etc.
- Uncompetitive salaries: causing strong staff rotation and a constant brain, experience and know-how drain.
- Human resources limitations: most GHMS departments are understaffed.
- Limited observational capacity: the current weather monitoring network is too small, providing data in much less than an hourly base, with extended gaps and mostly not on a real-time basis.
- Lack of centralized data management system. Large parts of the historical data are still not digitalized.
- Lack of communication with stakeholders: exchange is limited and mostly ad hoc.
- Limited outreach: especially to faraway communities due to country having only limited, if any, access to Internet, TV or even radio.

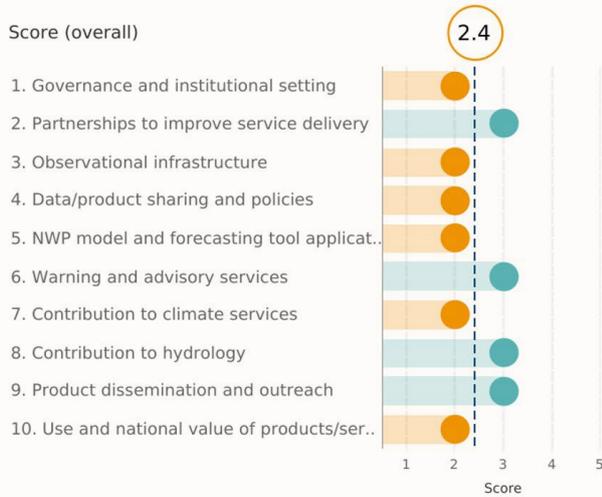
Recommendations:

- Work with the government to substantially increase the salaries offered to GHMS employees to match local and regional market conditions.
- Finalize the law-making process and pass the new legislation for Parliament approval.
- Upgrade the observational network (both meteorological and hydrological) to provide real-time accurate hourly observations, both for forecasts/warnings as well as their post-event verification and validation.

Kiribati

V: South-West Pacific
Lower middle income
LDC/SIDS

Score (overall)



Kiribati Meteorological Service (KMS)

Highlights of Gaps and Challenges:

- Insufficient overall level of resourcing, though rising.
- An insufficient observations network spread over a vast area.
- Staff training resourcing hurdles.
- A relatively low level of product development.
- An inability to currently provide the full range of expected services including aviation and marine.
- Poor communications networks in-country, which limit KMS capacity to reach remote users.
- Strong needs to strengthen relationships with the water resources sector.

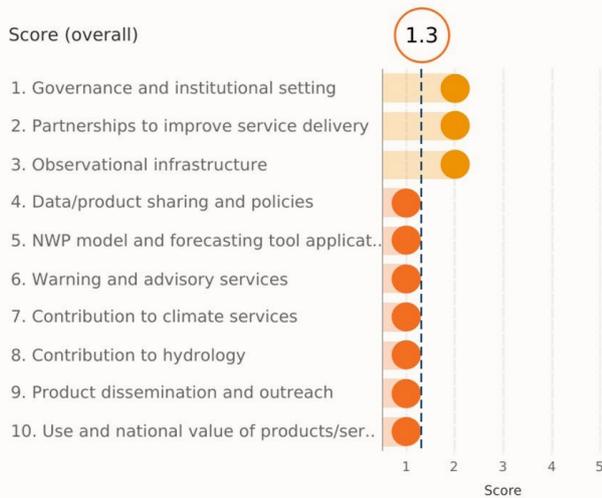
Recommendations:

- The implementation of the KMS Strategic Plan will need long-term, well considered institutional partnership support from the global community.
- SOFF has considerable potential to improve Kiribati's observational situation, but will not cover all requirements (particularly marine observations) and additional investment will be required.
- The development of Kiribati-specific forecasts and warnings, underpinned by appropriate numerical weather modelling and observations, and within a quality managed impact-based MHEWS, will also need partnership support.
- Quality management systems for other key areas, such as aviation and marine services, will also require support.

Liberia

I: Africa
Low income
LDC

Score (overall)



Liberia Meteorological Service (LMS)

Highlights of Gaps and Challenges:

- There is an urgent need to give legal backing to the activities and operations of LMS.
- Poor investment has greatly affected the observation network and infrastructure. LMS has not been able to maintain equipment donated in the past, largely because such projects were executed without its direct involvement and provisions for maintenance were not made.
- The lack of a standard operating procedure and strategic plan has hindered the operations of LMS and its ability to deliver products and services.
- No proper channel for national downscaling and dissemination of products generated through Regional Climate Outlook Forums, Regional Climate Centres, Regional Specialized Meteorological Centres and fellow NMHS.

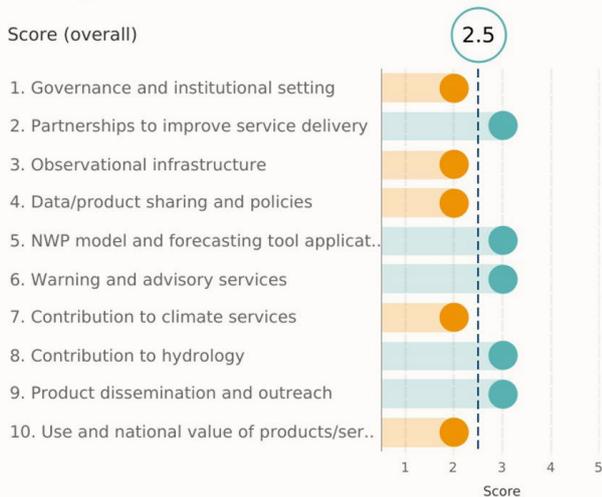
Recommendations:

- Ensure the active participation of LMS throughout the SOFF process and include a period of post-installation maintenance.
- Develop a well-detailed post-installation sustainability plan in conjunction with the Liberian Government.
- Develop a Strategic Plan for LMS as well as standard operating procedures.
- Introduce a WMO-supported co-generation of impact-based products with adequate training and competency framework.
- Downscale regional products for national use.
- Conduct targeted capacity development towards the communication of weather and climate information.

Madagascar

I: Africa
Low income
LDC

Score (overall)



Direction Générale de la Météorologie (DGM)

Highlights of Gaps and Challenges:

- DGM experiences severe institutional constraints that impede its ability to implement planned activities, mostly due to budget limitations. As a result, planning for activities is challenging and there is an inadequate budget allocation to hire the required number of personnel.
- Financial resources are lacking to meet mandate, undertake tasks in accordance with standards, and update and maintain the necessary technical equipment.
- Quality management is poor. There are significant shortcomings in user feedback loops, which are essential to better address user needs and ensure that products and services, as well as important warnings, actually reach users.
- Lack of research on the social and economic benefits (SEB) provided by weather, climate and hydrological services.

Recommendations:

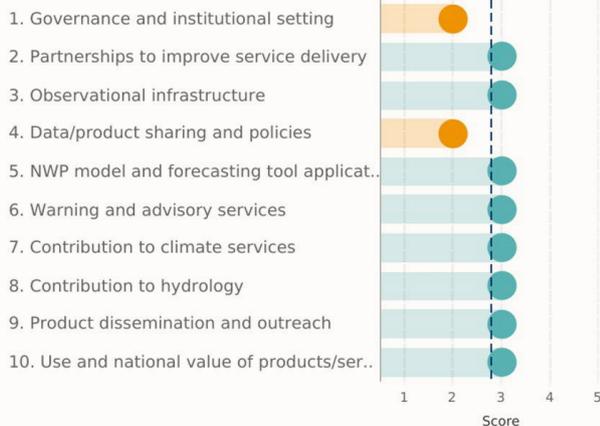
- Capacity building activities could further enhance the NMHS's ability to expand its skills and thus its scope of action. This could further increase the importance of the NMHS, both nationally and internationally, and thus attract more attention in international projects to enable budget reallocation.
- Expansion of the "last mile" is urgently required.
- SEB analysis could provide a significant foundation for budgetary increments by the government and other stakeholders, to further invest in the NMHS as a sustainable investment in the country's economic future.

Malawi

I: Africa
Low income
LDC/LLDC

Score (overall)

2.8



Department of Climate Change and Meteorological Services (DCCMS)

Highlights of Gaps and Challenges:

- Progress has been made in simplifying and coordinating governance structures in meteorology, climate and disaster risk management, but unresolved issues persist, hindering a clear and comprehensive mandate for key players in the system.
- Insufficient funds hinder human capacity building, infrastructure installation and maintenance, and the implementation of crucial sustainable projects and services.
- The observational network and data handling and sharing components currently lack essential elements for successful and sustainable operation.
- Absence of service agreements and comprehensive documentation for standard operating procedures in network maintenance and quality control.

Recommendations:

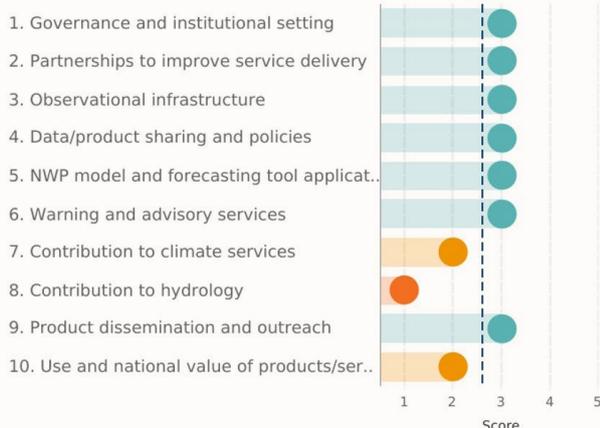
- The incorporation of modern and stable ICT solutions is recommended as it would greatly benefit DCCMS across the entire hydrometeorological value chain, from monitoring to the dissemination of forecasts and warnings.
- DCCMS has established various early warning services, mainly with donor financing. It is essential to build upon them by aligning with contemporary procedures, such as the Common Alerting Protocol and impact-based forecasts.
- A more systematic approach to stakeholder and user engagement could result in co-designed and co-financed user-tailored products, along with sector-specific services.
- Efforts should be maximized to ensure the dissemination of information, warnings and forecasts to the entire society.

Maldives

II: Asia
Upper middle income
SIDS

Score (overall)

2.6



Maldives Meteorological Services (MMS)

Highlights of Gaps and Challenges:

- The main issue is that MMS 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.
- No cost recovery mechanism in place for any services, including aviation services.
- Insufficient staff to provide climate services.
- Service development currently draws on informal stakeholder input and feedback.

Recommendations:

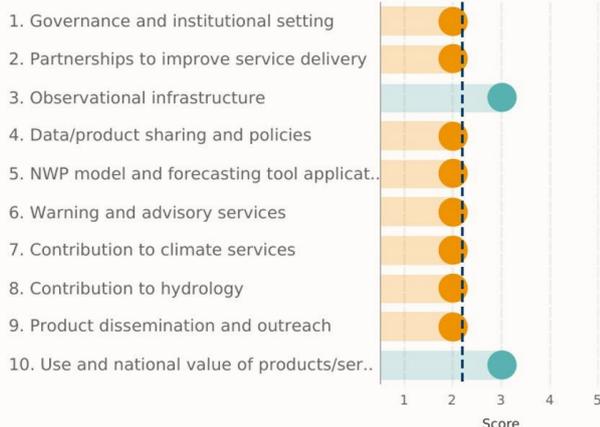
- Develop a strategic plan for MMS.
- Develop a stakeholder engagement strategy to increase MMS engagement with other national and international agencies, development agencies and the private sector.
- The new Meteorological Act, under preparation, would enable cost recovered activities. It is strongly encouraged to ensure that the MMS has financial flexibility to independently support and sustain operations. Inclusion of the cost recovery mechanism in the next strategy of the MMS is also recommended.
- Recruit well-trained staff to enhance the capacities of the climate division.
- Improve customer/client feedback and its involvement in institutional strategies, enhancement and service provision.
- Expand the implementation of quality management systems (QMS) to NMHS operations.

Mozambique

I: Africa
Low income
LDC

Score (overall)

2.2



National Institute of Meteorology (INAM)

Highlights of Gaps and Challenges:

- Budget allocation does not fully cover the needs of the NMHS in terms of national, regional, and global responsibilities. 78% of the budget goes into staff costs.
- Only a limited amount of GBON compliant data is shared internationally due to communication infrastructure limitations.
- The NMHS does not have capabilities such as supercomputing to assimilate data from the national observations infrastructure or to run own models.
- No common alerting procedures in place.

Recommendations:

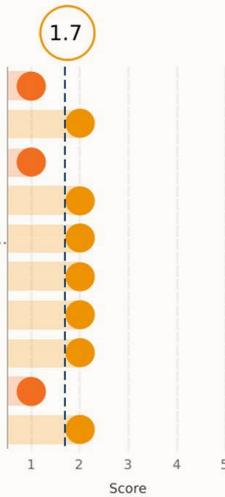
- Update the law to make it more comprehensive and concrete, with a focus on providing and defining a stronger and clearer mandate for ANAM.
- Increase the budget to enhance ANAM's capacity to employ additional professional staff, procure suitable equipment and ensure its basic maintenance.
- Upgrade all surface weather observation stations to automate data transmission.
- Upgrade all sensors and data loggers.
- Develop standard operating procedures for the deployment, maintenance, calibrations and quality assurance of the observational network.
- Develop National WIGOS Implementation Plan.
- Capacitate the INAM forecasting personnel to effectively utilize the existing web-based forecasting tool.

Nauru

V: South-West Pacific
High income
SIDS

Score (overall)

- Governance and institutional setting
- Partnerships to improve service delivery
- Observational infrastructure
- Data/product sharing and policies
- NWP model and forecasting tool applicat..
- Warning and advisory services
- Contribution to climate services
- Contribution to hydrology
- Product dissemination and outreach
- Use and national value of products/ser..



Nauru National Meteorological and Hydrological Service

Highlights of Gaps and Challenges:

- The NMHS needs a fully operational building, observations equipment, office equipment, a website, strategic planning processes and operations processes.
- Core functions are not sufficiently covered at this stage, although the increasing staffing is a positive indicator.
- Acute need for training, particularly forecasting training and Basic Instruction Package Meteorological Technician (BIP-MT) level as per ICAO requirements.
- One partially compliant weather station and no operational upper-air station.
- Insufficient capacity to run models sustainably, in terms of ICT infrastructure, training or scientific expertise.
- Climate services are in their initial stages of development.

Recommendations:

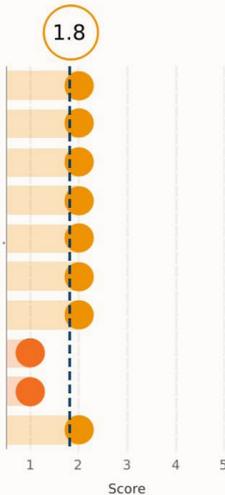
- Development of a strategic plan.
- Finalization of governing legislation, continued growth in community partnerships and product development, an upgrade of observational practices and climate record-keeping, including transmission of surface observations into WIGOS, the establishment of an upper-air station, and continued training of staff, including in observations, forecasting and maintenance practices.
- If Nauru is able to establish the ability to maintain 24/7 meteorological operations, consideration could also be given to issuing aviation forecasts in-country (currently issued from the NWS in Papua New Guinea).

Papua New Guinea

V: South-West Pacific
Lower middle income
SIDS

Score (overall)

- Governance and institutional setting
- Partnerships to improve service delivery
- Observational infrastructure
- Data/product sharing and policies
- NWP model and forecasting tool applicat..
- Warning and advisory services
- Contribution to climate services
- Contribution to hydrology
- Product dissemination and outreach
- Use and national value of products/ser..



National Weather Service (NWS)

Highlights of Gaps and Challenges:

- Declining budget, deteriorating physical facilities, acute need for professional training for less experienced staff.
- Observations network and supporting infrastructure are in a strongly deteriorated condition with few reliable surface observations and no upper-air observations.
- Forecasting services have low visibility and are compromised by the state of the observations network, as are numerical modelling approaches, which lack ground, sea or upper-air validation.
- No effective flood warning arrangements, following the decline and collapse of the extensive river monitoring network in the 1990s.
- The quality of services has directly contributed to a downgrading of quality certification periods granted by the Civil Aviation Safety Authority, with the NWS only certified for meteorological services to aviation for three-month periods.

Recommendations:

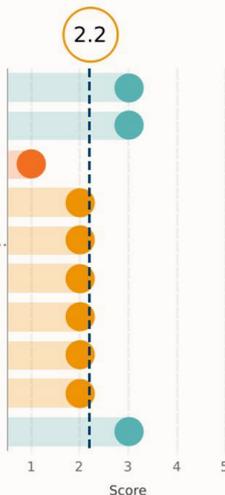
- Reform of legislative and budgetary mechanisms relating to NWS, in particular to establish a stand-alone agency with stronger capacity to manage its own budget, and transparently cost-recover aviation and other commercial services.
- Closer integration of national multi-hazard arrangements which could encourage external capacity-building partnerships.
- Improved daily weather intelligence for improving the decision-making of small boat operators as well as other essential sectors such as the aviation industry.
- Improved quality and availability of weather observations and forecasts to directly assist the quality and safety of aviation services.

Rwanda

I: Africa
Low income
LDC/LLDC

Score (overall)

- Governance and institutional setting
- Partnerships to improve service delivery
- Observational infrastructure
- Data/product sharing and policies
- NWP model and forecasting tool applicat..
- Warning and advisory services
- Contribution to climate services
- Contribution to hydrology
- Product dissemination and outreach
- Use and national value of products/ser..



Meteo Rwanda

Highlights of Gaps and Challenges:

- The current legal framework does not allow cost recovery services.
- No lightning locating system, only one weather radar with limited use of data, no upper-air sounding system, no lidar systems, semi-automatic surface weather observation system with manual data transfer, no integrated data management system.
- Customer engagement process is only partial, with no regular user feedback collection or co-creation process to develop tailored services.
- The weather forecasting and early warning process is mostly manual and lacks modern software and tools. The forecast verification is made manually and includes very limited number of scores.
- No efficient internal training system in place.
- No mobile telephone application to disseminate forecasts and warnings efficiently.

Recommendations:

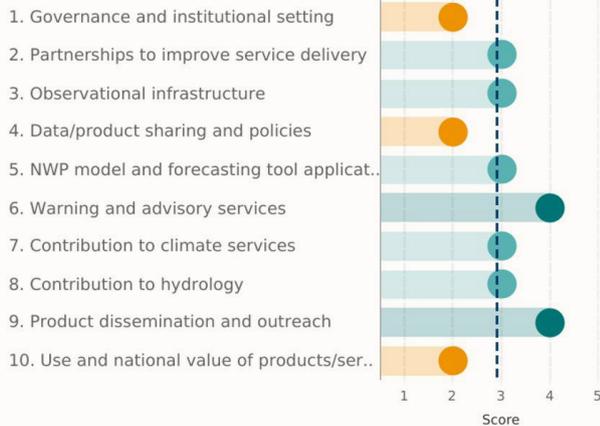
- Amendments of the legal framework to enable cost recovery are in process and are highly recommended.
- There is an urgent need to develop a weather app for the efficient dissemination of public weather services and warnings.
- Impact-based forecasting should be further developed. The NWP system and available global NWP data should also be further developed and made available.
- There is an urgent need to implement new automated forecast verification system with multiple verification scores.
- The customer engagement process should be enhanced when new tailored services are developed.

Samoa

V: South-West Pacific
Lower middle income
SIDS

Score (overall)

2.9



Samoa Meteorology, Geoscience and Ozone Services Division

Highlights of Gaps and Challenges:

- Insufficient budget or staffing numbers and training to support operations, including maintaining ICT infrastructure, observations calibration and maintenance, further development of forecasting services, etc.
- Largely reliant on overseas assistance for elements of its basic operations, resulting in some incompatible and unintegrated systems.
- Vulnerable ICT infrastructure (including core forecasting and monitoring systems, website for service delivery, receipt and transmission of internationally required observations and other important network observations).
- Only a small minority of weather observations are internationally transmitted.
- The forecasting models are of insufficient resolution for resolving the detail of extreme weather (such as heavy rainfall).
- Climate records are compromised by the quality management standards of observations and ICT system fragility.
- No weather radar or upper-air observing station.
- Sub-optimal parts of the physical infrastructure.

Recommendations:

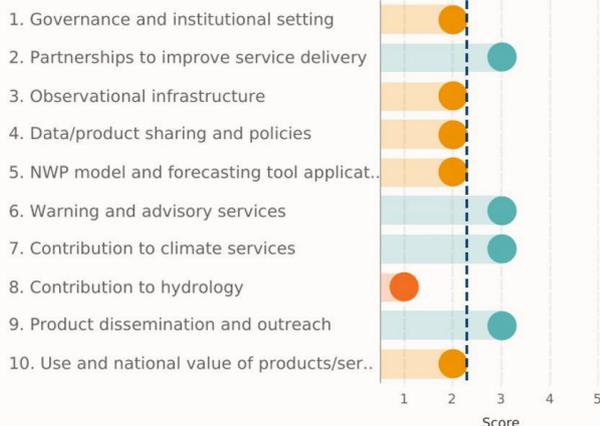
- Long-term partnerships with other peer agencies, as well as capacity development agencies. Where such partnerships exist (for example with the Climate and Oceans Support Program in the Pacific (COSPPac)), they have generally been effective.
- Areas such as ICT, governance and budget, quality management and geohazard relationships will also require long-term attention.

Solomon Islands

V: South-West Pacific
Lower middle income
LDC/SIDS

Score (overall)

2.3



Solomon Islands Meteorological Service (SIMS)

Highlights of Gaps and Challenges:

- Operates in a difficult budgetary environment, with low and unstable core government funding due to competing priorities, and a large reliance on assistance from development agencies for any major projects.
- Upper-air observations have been discontinued for some time due to the high cost of consumables, and maintenance of instrumentation is an ongoing issue.
- Very few calibrated and reliable observations that can be used in global and regional numerical weather, ocean and climate models.
- Virtually no marine observations are available despite small craft marine transport being the dominant transport mode for the country.
- Engagement with the broader population is achieved through social media and traditional media, although inhibited by generally low levels of literacy and communications challenges across the physically and socially complex archipelago.

Recommendations:

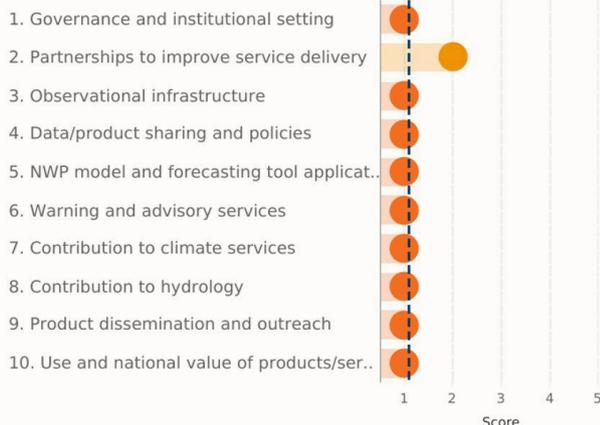
- Refine the SIMS mandate through improved foundational legislation. A national strategy has been published to define four major goals around institutional capacity, infrastructure capacity, stakeholder partnerships and operational effectiveness.
- Specific areas of assistance should include observational support to meet global standards for upper-air and surface observations, including marine observations, improving SIMS staff capacity, addressing SIMS facility needs, expansion of quality management approaches, partnership and stakeholder engagement, integrated forecasting systems and supporting information technologies, targeted efforts to build flood warning capabilities, and continued work to implement a country-wide, impact-based, multi-hazard forecasting and warning system.

South Sudan

I: Africa
Low income
LDC/LLDC

Score (overall)

1.1



South Sudan Meteorological Department (SSMS)

Highlights of Gaps and Challenges:

- SSMS currently operates without a formal mandate. It also requires proper and fit for purpose facilities to support its daily activities. Currently, very limited working space exists with limited to no infrastructure.
- There is a clear shortage of qualified personnel with the right expertise.
- Very limited observations capacity.
- IT infrastructure is needed to perform routine activities that involve data collection, data analysis, access to third party sources etc.
- Very limited capacity for data curation (historical data archival, collection, validation and general management).

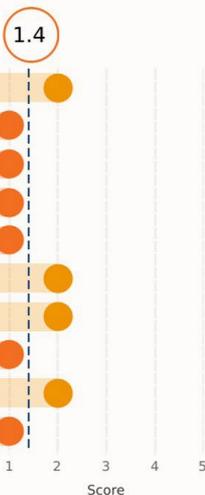
Recommendations:

- Establishment of a legal entity and respective government mandate for the provision of meteorological services, with a clear and wide scope of activities.
- Gradually expand, through different international initiatives such as SOFF, the network at a limited number of strategic locations and commence sustained operations as the backbone of the strategic plan.
- Provide the SSMS with an adequate working space, with appropriate technical infrastructure, systems and all the logistical components that will enable the institution to run the daily operations in a robust and effective manner.
- Address needs for modernization of existing and deployment of new infrastructure.
- Recover raw historical data from the SMA, digitize the entire dataset and ensure sufficient backup for proper data preservation and exploitation.

Timor-Leste

V: South-West Pacific
Lower middle income
LDC/SIDS

Score (overall)



National Directorate of Meteorology and Geophysics of Timor-Leste (DNMG)

Highlights of Gaps and Challenges:

- Forecaster training in critical areas, including aviation and maritime forecasts and alerts production, modelling and satellite interpretation, nowcasting and radar data interpretation, and radio-sounding data interpretation and use.
- Proper software tools and workstations need to be set up in the forecast office to facilitate the data integration and visualization of the information and for forecast production and dissemination.
- DNMG needs to increase the capacity for the operation and maintenance of its observational network; the data transmission from the stations to the database needs to be implemented, as well as the QA and QC of the data.
- Support needed for the maintenance and calibration of stations.

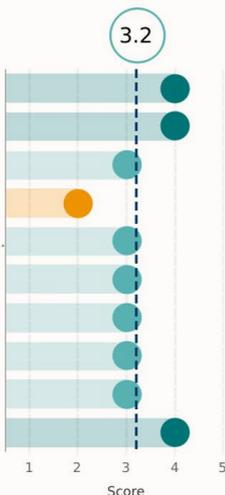
Recommendations:

- Develop a regulatory law for responsibilities of DNMG and the National Directorate for Water and Sanitation (air quality, hydrology, agrometeorology, climatology).
- Adequate budgetary assignment to guarantee the proper operation of the institute and to secure the appropriate network maintenance.
- Include expansion and maintenance of the network in the country's development plan.
- Increase the number of personnel in technical areas, especially to maintain stations and ICT capacities.
- Promote internal cooperation between the different institutes and proper data-sharing policies.

United Republic of Tanzania

I: Africa
Lower middle income
LDC

Score (overall)



Tanzania Meteorological Authority (TMA)

Highlights of Gaps and Challenges:

- At present the United Republic of Tanzania is not compliant with GBON regulations.
- The OSCAR Surface database is not up-to-date and the information on a number of stations, active stations and reporting frequency is currently not accurate.
- A limited amount of GBON compliant data is shared internationally. The existing data sharing policies or practices or the existing infrastructure severely hamper two-way data sharing.
- TMA has limited capacity to provide tailor-made support, but it is working on strengthening its hydrometeorology section.
- There is a moderately well-functioning relationship between the meteorological, hydrological and water resources communities but considerable room for formalizing the relationship and SOPs.

Recommendations:

- Continue to advocate to the government for sufficient budget allocation.
- Conduct impact studies to provide evidence for the socioeconomic value of weather and climate services.
- Articulate data sharing aspects in the TMA data policy.
- Train staff in data assimilation, verification and postprocessing methods of NWP models.
- Enhance availability of vulnerability data to support impact-based forecasting.
- Develop a strategic approach, including continuous cross-sectoral engagement for development of a comprehensive multi-hazard early warning system.
- Strengthen the observation network to provide improved data on the unique topographical/orographic features of the United Republic of Tanzania.

Annex 2. Country Hydromet Diagnostics methodology

The Country Hydromet Diagnostics (CHD) provides a maturity assessment of the National Meteorological and Hydrological Service (NMHS), its operating environment and its contribution to high-quality hydrometeorological services, with 10 elements assessed (see Figure). The elements are grouped into four categories, helping to identify where additional focus and support may be needed. Behind each element sit various indicators, which are informed by data sources (for example, the WMO Monitoring System) and by direct interviews and observation for validation purposes.

The CHD does not provide detailed solutions but indicates the focus areas for deeper consideration for all potential projects in-country. National and international partners supporting hydrometeorological activities in the country are encouraged to collaborate in their thinking and sharing of insights while conducting and using the CHD.

To complete the CHD, peer advisers follow a multi-step process to assess the NMHS along standardized indicators established under each element of the value chain (see Table):

- The process that peer advisers complete in order to perform a CHD assessment starts with a desk review of available data and information sources (including those provided by WMO) along the CHD elements and indicators. This step prevents redundant information requests, and ensures conflicting information is resolved into a definitive report that can be trusted by all parties as a basis for further work.

- Peer reviewers synthesize the existing information and evaluate the potential gaps and conflicts in the information available. They use this preliminary assessment to inform their discussions with the NMHS and to prepare their in-country visits.
- To complete and validate the data underlying the CHD report, peer advisers interview the NMHS’s management, operational and technical staff, as well as selected stakeholders, as relevant.
- Peer advisers prepare the draft CHD report and discuss its findings interactively with the NMHS.
- Once the draft report is completed, it is reviewed by WMO for quality assurance. Peer advisers finalize the report based on the WMO review and in coordination with the NMHS.
- The report is finalized once it has received WMO approval and it has been signed by both the Permanent Representative of the country and the peer adviser.

Throughout this process, the assessment of the CHD elements and related indicators is supported by the systematic collection and examination of a minimum set of data points (CHD tool provided by WMO) as well as additional information collected by peer advisers through on-site visits and interviews with the NMHS and its main stakeholders. The table presents the definition of the maturity scores for all CHD elements as well as the indicators that peer advisers assess in order to attribute a maturity score.

Figure. The 10 elements assessed in the Country Hydromet Diagnostics

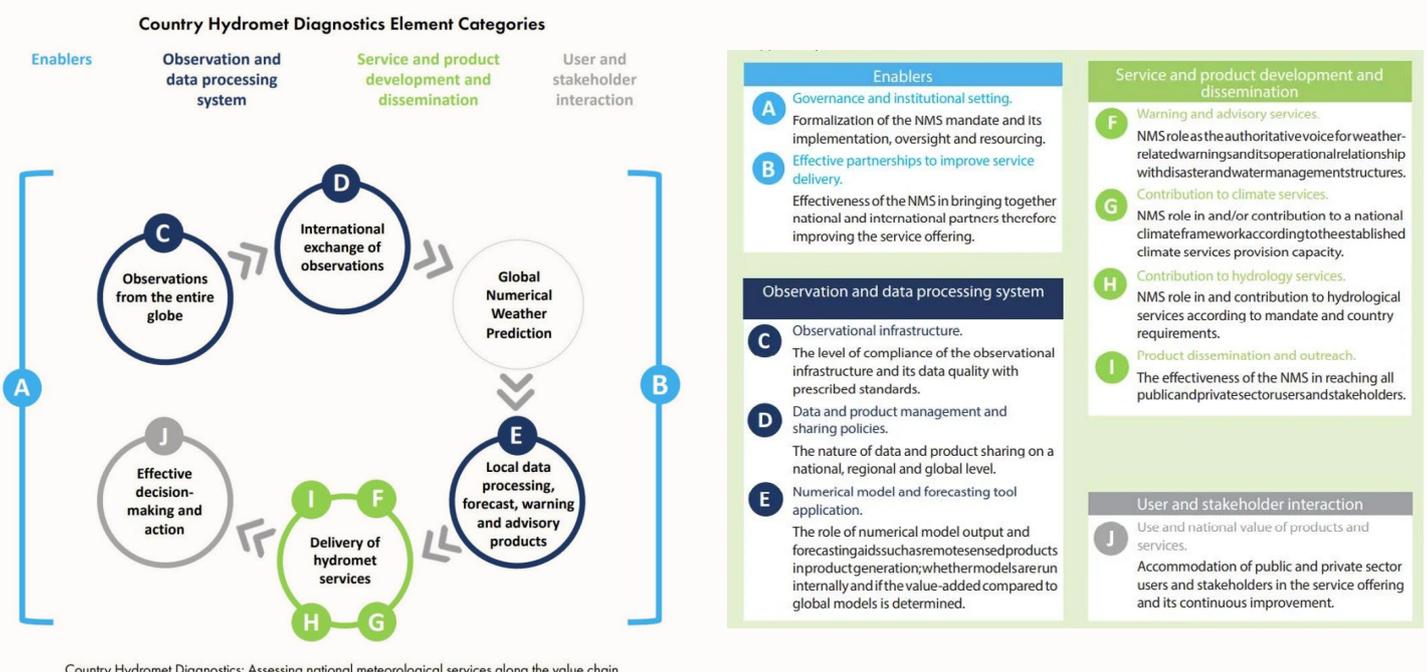


Table. The 10 CHD elements with their related maturity scores and indicators**ELEMENT 1. GOVERNANCE AND INSTITUTIONAL SETTING**

The level of formalization of the NMHS mandate and its implementation, oversight and resourcing

Maturity scores

- Score one: Weakly defined mandate; serious funding challenges; essential skills lacking; little formalized governance and future planning.
- Score two: Ongoing efforts to formalize mandate, to introduce improved governance, management processes and to address resource challenges.
- Score three: Moderately well mandated, managed and resourced and clear plans for, and sufficient capacity to address operational gaps.
- Score four: An effective service, but with a few shortcomings related to its mandate, governance, and resourcing, and in the process to address the gaps.
- Score five: Strong and comprehensive mandate, highly effective governance, secure funding and readily available skills base.

Indicators

- 1.1. Existence of an act or policy describing the NMHS legal mandate and its scope.
- 1.2. Existence of strategic, operational and risk management plans and their reporting as part of oversight and management.
- 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.
- 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.
- 1.5. Experience and track record in implementing internationally funded hydrometeorological projects as well as research and development projects in general.

ELEMENT 2. PARTNERSHIPS TO IMPROVE SERVICE DELIVERY

The level of effectiveness of the NMHS in bringing together national and international partners to improve the service offering

Maturity scores

- Score one: Works in isolation and does not value or promote partnerships.
- Score two: Limited partnerships and mostly excluded from relevant finance opportunities.
- Score three: Moderately effective partnerships, but generally regarded as the weaker partner in such relationships, having little say in relevant financing initiatives.
- Score four: Effective partnerships with equal status in most relationships and approaching relevant funding opportunities in a coordinated manner.
- Score five: Regarded as a major national and regional player; extensive and productive partnerships; viewed as an honest broker in bringing parties together; provides national leadership on relevant finance decisions.

Indicators

- 2.1. Effective partnerships for service delivery in place with other government institutions.
- 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.
- 2.3. Effective partnerships in place with international climate and development finance partners.
- 2.4. New or enhanced products, services or dissemination techniques or new uses or applications of existing products or services that culminated from these relationships.

ELEMENT 3. OBSERVATIONAL INFRASTRUCTURE

The level of compliance of the observational infrastructure and its data quality with prescribed WMO regulations and guidance

Maturity scores

- Score one: No or limited basic surface observations and no upper-air observations.
- Score two: Basic network, large gaps, mostly manual observations with severe challenges and data quality issues.
- Score three: Moderate network with some gaps with respect to WMO regulations and guidance, and with some data quality issues.
- Score four: Comprehensive, mostly automated network providing good traceable quality data, fully compliant with WMO regulations and guidance.
- Score five: Comprehensive and highly automated advanced network including additional measurements and remote sensing platforms providing excellent data, fully compliant with WMO regulations and guidance.

Indicators

- 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.
- 3.2. Additional observations used for nowcasting and specialized purposes.
- 3.3. Standard operating procedures in place for the deployment, maintenance, calibrations and quality assurance of the observational network.
- 3.4. Implementation of sustainable newer approaches to observations.
- 3.5. Percentage of the surface observations that depend on automatic techniques.

ELEMENT 4. DATA AND PRODUCT SHARING AND RELATED POLICIES

The level of data and product sharing on a national, regional and global level

Maturity scores

- Score one: No observational data is shared internationally, either because not available to be shared, or because of a lack of data-sharing policies or practices, or because the existing infrastructure does not allow data sharing.
- Score two: A limited amount of GBON-compliant data is shared internationally. The existing data-sharing policies or practices or the existing infrastructure severely hamper two-way data sharing.
- Score three: Partial GBON data-sharing compliance with regard to either surface or upper-air data. A data policy in place that promotes the free and open use of data for research, as well as the in-house use of external data.
- Score four: Fully meeting GBON data-sharing compliance with data policy, practices and infrastructure in place, which support free and open sharing of data nationally, as well as the use of external data.
- Score five: Exceeding GBON data-sharing compliance, and additional data (marine, radar, etc.) contributing to regional and international initiatives, with policies that promote free and open two-way sharing of data and products.

Indicators

- 4.1. Percentage of GBON compliance – number of prescribed surface and upper-air stations for which observations are exchanged internationally. Usage of regional WIGOS centres.
- 4.2. A formal policy and practice for the free and open sharing of observational data.
- 4.3. Main data and products received from external sources in a national, regional and global context, such as model and satellite data.

ELEMENT 5. NUMERICAL WEATHER PREDICTION MODEL AND FORECASTING TOOL APPLICATION

The role of numerical weather prediction model output and other forecasting tools in product generation. Whether local modelling is sustainably used to add value to model output from WMO Integrated Processing and Prediction System (WIPPS) centres

Maturity scores

- Score one: Forecasts are based on classical forecasting techniques without model guidance and only cover a limited forecast time range.
- Score two: Basic use of external model output and remote sensed products in the form of maps and figures, covering only a limited forecast time range.
- Score three: Prediction is based mostly on model guidance from external and limited internal sources (without data assimilation) and remote sensed products (maps, figures, data) and covers nowcasting, short and medium time ranges.
- Score four: Digitized model output from internal (with data assimilation) or external (regional) sources, as well as remote sensed products and data are used. Value is added through postprocessing techniques extended into longer time ranges.
- Score five: Optimal combination of global/regional/local models, remote sensed data, postprocessing and automated probabilistic product generation, over weather and climate timescales, with up-to-date verification statistics.

Indicators

- 5.1. Model and remote sensed products form the primary source for products across the different forecasting timescales.
- 5.2. (a) Models run internally (and sustainably), (b) data assimilation and verification performed, (c) appropriateness of horizontal and vertical resolution.
- 5.3. Probabilistic forecasts produced and, if so, based on ensemble predictions.

ELEMENT 6. WARNINGS AND ADVISORY SERVICES

NMHS role as the authoritative voice for weather-related warnings, and its operational relationship with disaster and water management structures

Maturity scores

- Score one: Warning service not operational for public preparedness and response.
- Score two: Basic warning service is in place and operational but with limited public reach and lacking integration with other relevant institutions and services.
- Score three: Weather-related warning service with modest public reach and informal engagement with relevant institutions, including disaster management agencies.
- Score four: Weather-related warning service with strong public reach and standard operational procedures driving close partnership with relevant institutions, including disaster management agencies.
- Score five: Comprehensive, impact-based warning service, taking hazard exposure and vulnerability information into account, with strong public reach. Close partnership with relevant national institutions, including disaster management agencies and registered Common Alerting Protocol alerting authorities.

Indicators

- 6.1. Warning and alert service covers 24/7
- 6.2. Hydrometeorological hazards for which forecasting and warning capacity is available, and whether feedback and lessons learnt are included to improve warnings.
- 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.

ELEMENT 7. CONTRIBUTION TO CLIMATE SERVICES

NMHS role in and contribution to a national climate framework according to the established climate services provision capacity

Maturity scores

- Score one: Less than basic capacity to provide climate services.
- Score two: Basic capacity to provide climate services.
- Score three: Essential capacity to provide climate services.
- Score four: Full capacity to provide climate services.
- Score five: Advanced capacity to provide climate services.

Indicators

- 7.1. Where relevant, contribution to climate services according to the established capacity for the provision of climate services (including governance, basic systems, user interface, provision and application of climate services, monitoring and evaluation of the socioeconomic benefits, and capacity development).

ELEMENT 8. CONTRIBUTION TO HYDROLOGY

NMHS role in and contribution to hydrological services according to mandate and country requirements

Maturity scores

- Score one: No or very little meteorological input in hydrology and water resource management.
- Score two: Meteorological input in hydrology and water resource management happens on an ad hoc basis or during times of disaster.
- Score three: There is a moderately well-functioning relationship between the meteorological, hydrological and water resources communities but considerable room for formalizing the relationship and SOPs.
- Score four: The meteorological, hydrological and water resources sectors have high-level formal agreements in place and working relationships (including data sharing), but products and services still tend to be developed in isolation.
- Score five: The meteorological, hydrological and water resources sectors have robust SOPs and agreements in place to work closely in developing new and improved products and providing seamless and advanced services.

Indicators

- 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.
- 8.2. SOPs in place to formalize the relation between Meteorological Service and Hydrology Agency, showing evidence that the whole value chain is addressed.
- 8.3. Data-sharing agreements (between local and national agencies, and across international borders, as required) on hydrological data in place or under development.
- 8.4. Joint projects/initiatives with hydrological community designed to build hydrometeorological cooperation.

ELEMENT 9: PRODUCT DISSEMINATION AND OUTREACH

The level of effectiveness of the NMHS in reaching all public and private sector users and stakeholders

Maturity scores

- Score one: Dissemination using only limited traditional channels such as daily newspapers and the national broadcaster, and with little control over messaging and/or format.
- Score two: Traditional communication channels and a basic dedicated website are used to disseminate forecasts and basic information.
- Score three: A moderately effective communication and dissemination strategy and practices are in place, based only on in-house capabilities and supported by user-friendly website.
- Score four: A large fraction of the population is reached using various communication techniques, in collaboration with partners, and a user-friendly website and apps. Outreach and education activities occur regularly.
- Score five: Advanced education, awareness and communication strategy, practices and platforms in place using various technologies, tailored to reach even marginalized communities and in close cooperation with several partners.

Indicators

- 9.1. Channels used for user-centred communication and ability to support those channels.
- 9.2. Education and awareness initiatives in place.
- 9.3. Special measures in place to reach marginalized communities, Indigenous people, the youth and the elderly.

ELEMENT 10: USE AND NATIONAL VALUE OF PRODUCTS AND SERVICES

Accommodation of public and private sector users and stakeholders in the service offering and its continuous improvement

Maturity scores

- Score one: Service development lacks any routine stakeholder feedback.
- Score two: Service development draws on informal stakeholder input and feedback.
- Score three: Service development draws on regular dialogue with major stakeholders.
- Score four: Service development draws on survey data and regular dialogue based on formal relationships with major stakeholders to ensure continuous improvement.
- Score five: Strong partnerships and formal objective survey and review processes exist with all major stakeholders, enabling service co-design and continuous improvement.

Indicators

- 10.1. Formalized platform to engage with users in order to co-design improved services.
- 10.2. Independent user satisfaction surveys are conducted, and the results used to inform service improvement.
- 10.3. Quality management processes that satisfy key user needs and support continuous improvement.

Annex 3: Status of Country Hydromet Diagnostics progress (as of 1 May 2024)

Country	Status
Bhutan	Completed
Cabo Verde	Completed
Chad	Completed
Ethiopia	Completed
Fiji	Completed
Guyana	Completed
Kiribati	Completed
Liberia	Completed
Madagascar	Completed
Malawi	Completed
Maldives	Completed
Nauru	Completed
Papua New Guinea	Completed
Rwanda	Completed
Samoa	Completed
Solomon Islands	Completed
South Sudan	Completed
Timor-Leste	Completed
United Republic of Tanzania	Completed
Belize	Finalization ongoing
Burkina Faso	Finalization ongoing
Mozambique	Finalization ongoing
Nepal	Finalization ongoing
Uganda	Finalization ongoing
Zambia	Finalization ongoing
Antigua and Barbuda	In progress
Bahamas	In progress
Bangladesh	In progress
Barbados	In progress
Cambodia	In progress
Comoros	In progress
Cuba	In progress
Djibouti	In progress
Dominica	In progress
Dominican Republic	In progress
Grenada	In progress
Guinea-Bissau	In progress
Jamaica	In progress
Lao People's Democratic Republic	In progress
Marshall Islands	In progress
Mauritius	In progress
Micronesia, Federated States of	In progress
Niger	In progress
Palau	In progress
Saint Kitts and Nevis	In progress
Saint Lucia	In progress
Sao Tome and Principe	In progress
Senegal	In progress
Seychelles	In progress
Somalia	In progress
Saint Vincent and Grenadines	In progress
Tonga	In progress
Trinidad and Tobago	In progress
Tuvalu	In progress
Vanuatu	In progress
Democratic Republic of the Congo	Planned
Ecuador	Planned
Haiti	Planned
Suriname	Planned
Tajikistan	Planned

Annex 4. List of Systematic Observations Financing Facility beneficiary countries and peer advisers

SOFF Country	Peer Adviser
Antigua and Barbuda	Met Office, United Kingdom of Great Britain and Northern Ireland
Bahamas	Finnish Meteorological Institute, Finland
Bangladesh	Norwegian Meteorological Institute, Norway
Barbados	Finnish Meteorological Institute, Finland
Belize	Met Office, United Kingdom of Great Britain and Northern Ireland
Bhutan	Finnish Meteorological Institute, Finland
Burkina Faso	Agencia Estatal de Meteorología, Spain
Cabo Verde	Royal Netherlands Meteorological Institute (KNMI), Netherlands
Cambodia	Met Office, United Kingdom of Great Britain and Northern Ireland
Chad	GeoSphere, Austria
Comoros	Météo Maroc, Morocco
Congo (DRC)	MeteoSwiss, Switzerland
Cuba	Agencia Estatal de Meteorología, Spain
Djibouti	GeoSphere, Austria
Dominica	GeoSphere, Austria
Dominican Republic	Agencia Estatal de Meteorología, Spain
Ecuador	MeteoSwiss, Switzerland
Ethiopia	Norwegian Meteorological Institute, Norway
Federated States of Micronesia	Met Office, United Kingdom of Great Britain and Northern Ireland
Fiji	Bureau of Meteorology, Australia
Grenada	Agencia Estatal de Meteorología, Spain
Guinea-Bissau	Portuguese Institute for Sea and Atmosphere, Portugal
Guyana	GeoSphere, Austria
Haiti	MeteoSwiss, Switzerland
Jamaica	Finnish Meteorological Institute, Finland
Kiribati	Bureau of Meteorology, Australia
Lao PDR	GeoSphere, Austria
Liberia	Nigerian Meteorological Agency, Nigeria
Madagascar	Deutsche Wetterdienst, Germany
Malawi	Norwegian Meteorological Institute, Norway
Maldives	Finnish Meteorological Institute, Finland
Marshall Islands	Met Office, United Kingdom of Great Britain and Northern Ireland
Mauritius	South African Weather Service, South Africa
Mozambique	South African Weather Service, South Africa
Nauru	Bureau of Meteorology, Australia
Nepal	Finnish Meteorological Institute, Finland
Niger	Nigerian Meteorological Agency, Nigeria
Palau	Met Office, United Kingdom of Great Britain and Northern Ireland
Papua New Guinea	Bureau of Meteorology, Australia
Rwanda	Finnish Meteorological Institute, Finland
Saint Kitts and Nevis	Finnish Meteorological Institute, Finland
Saint Lucia	GeoSphere, Austria
Samoa	Bureau of Meteorology, Australia
Sao Tome and Principe	Royal Netherlands Meteorological Institute (KNMI), Netherlands
Senegal	Royal Netherlands Meteorological Institute (KNMI), Netherlands
Seychelles	GeoSphere, Austria
Solomon Islands	Bureau of Meteorology, Australia
Somalia	South African Weather Service, South Africa
South Sudan	GeoSphere, Austria
St Vincent and Grenadines	Nigerian Meteorological Agency, Nigeria
Suriname	Royal Netherlands Meteorological Institute (KNMI), Netherlands
Tajikistan	Finnish Meteorological Institute, Finland
Tanzania, United Republic of	Danish Meteorological Institute, Denmark
Timor-Leste	Finnish Meteorological Institute, Finland
Tonga	MetService, New Zealand
Trinidad and Tobago	Finnish Meteorological Institute, Finland
Tuvalu	MetService, New Zealand
Uganda	Royal Netherlands Meteorological Institute (KNMI), Netherlands
Vanuatu	MetService, New Zealand
Zambia	Met Office, United Kingdom of Great Britain and Northern Ireland

List of abbreviations

ADB	Asian Development Bank
AfDB	African Development Bank
AOSIS	Alliance Of Small Island States
CAP	Common Alerting Protocol
CDMS	Climate Data Management System
CHD	Country Hydromet Diagnostics
CMO	Caribbean Meteorological Organization
COP	Conference of the Parties to the United Nations Framework Convention on Climate Change
CREWS	Climate Risk and Early Warning System Initiative
CSICA	Climate Science Information for Climate Action
DAEs	Direct Access Entities
DRR	Disaster Risk Reduction
ECOWAS	Economic Community of West African States
EW4All	Early Warnings for All
EWS	Early Warning Systems
FFGS	Flash Flood Guidance System
FMI	Finnish Meteorological Institute
GBON	Global Basic Observing Network
GCF	Green Climate Fund
GTS	Global Telecommunication System
IBF	Impact-Based Forecasting
ICAO	International Civil Aviation Organization
ICT	Information And Communication Technology
IDB	Inter-American Development Bank
IFAD	International Fund for Agricultural Development
IsDB	Islamic Development Bank
LAM	Limited-Area Numerical Weather Prediction Model
LDCs	Least Developed Countries
M&E	Monitoring And Evaluation
MHEWS	Multi-Hazard Early Warning Systems
MoU	Memorandum of Understanding
NFCS	National Framework for Climate Services
NMHSs	National Meteorological and Hydrological Services
NWP	Numerical Weather Prediction
ODA	Official Development Assistance
OECD	Organisation for Economic Co-Operation and Development
PPE	Public-Private Engagement
QMS	Quality Management Systems
RCCs	Regional Climate Centres
RSMCs	Regional Specialized Meteorological Centres
SAP	Standard Alerting Procedure
SDGs	Sustainable Development Goals
SEB	Socio-Economic Benefits
SIDS	Small Island Developing States
SOFF	Systematic Observations Financing Facility
SOPs	Standard Operating Procedures
TRACT	Toward Risk-Aware and Climate-resilient communities
UN	United Nations
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction
UNEP	UN Environment Programme
UNMPTF	UN Multi-Partner Trust Fund Office
WB	World Bank
WFP	World Food Programme
WIGOS	WMO Integrated Global Observing System
WIPPS	WMO Integrated Processing and Prediction System
WIS 2.0	WMO Information System 2.0
WMCs	World Meteorological Centres
WMO	World Meteorological Organization

Endnotes

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