



# HYDROMET GAP REPORT 2021

Alliance for Hydromet Development

# ACKNOWLEDGEMENTS

**This report was produced by an editorial team comprised of representatives from all members of the Alliance for Hydromet Development** under the leadership of Laura Tuck, with support from Ede Ijjasz-Vasquez, Rob Varley and Lorena Santamaria and under the guidance of Markus Repnik.

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Special thanks to Lars Peter Riishojgaard, Serena Odianose, Paul Egerton, Laura Paterson and the team from Willis Towers Watson (Lydia Messling, Georgina Wade and Will Bugler).

Financial support to produce the report was provided by the Asian Development Bank, the World Bank, and the World Meteorological Organization.

**Development and 'road-testing' of the Country Hydromet Diagnostics benefited from contributions from many stakeholders.** Development of the prototype was guided by a multi-stakeholder working group, co-chaired by Michael Staudinger and Markus Repnik, with the following members: Abdoulaye Harou, Andrea Rossa, Anthony Rea, Assia Alexieva, Filipe Lucio, Helen Bye, Johannes Cullman, Madeleine Renom, Mary Power, Maxx Dilley, Paolo Ruti, Vladimir Tsirkunov, Wenjian Zhang, and Xianghua Xu.

Deon Terblanche and Rob Varley led the development of the prototype in collaboration with the working group and all members of the Alliance for Hydromet Development.

The financial contributions from the World Bank and the World Meteorological Organization for the development of the Country Hydromet Diagnostics are gratefully acknowledged. Financial support for the road-testing was provided by the African Development Bank, Asian Development Bank, Green Climate Fund, United Nations Development Programme, United Nations Environment Programme, World Bank, and the World Meteorological Organization.

The Country Hydromet Diagnostics road-testing would not have been possible without the leadership of the WMO Permanent Representatives and their teams of the following countries: Afghanistan, Austria, Chad, China, Cote d'Ivoire, India, Kyrgyz Republic, Liberia, Maldives, Morocco, Myanmar, Nigeria, North Macedonia, Sierra Leone, Switzerland, and Turkey.

Special thanks to Michael Staudinger, Daouda Konate, Vladimir Tsirkunov, Deon Terblanche, Rob Varley, Tamara Comment, Leontine Kanziemo, Abdoulaye Harou, Mingmei Li, Yi Wang, Assia Alexieva, Andrew Tupper, Xiaofeng Wang, and Bing Liu for their valuable contributions to the development of the Country Hydromet Diagnostics and the results and analysis presented in this report.

**Development of the Systematic Observations Financing Facility section benefited from inputs from numerous stakeholders.** The SOFF core team comprised of Anthony Rea, Markus Repnik, Lars Peter Riishojgaard, Johannes Linn, Laura Tuck, Lorena Santamaria, Serena Odianose and Mario Peiro Espi is particularly grateful for the contributions received from five Working Groups comprised of colleagues from 30+ organizations, feedback from beneficiary countries including the Least Developed Countries Group (LDC Group), the African Group of Negotiators, the Alliance of Small Island States (AOSIS), and support from many stakeholders.





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# FOREWORD

**Our climate is rapidly changing.** The past decade was the hottest on record. The global mean temperature is approximately 1.2 °C warmer than pre-industrial times. The world is far off track from reducing global greenhouse gas emissions to avert the worst impacts of climate change and limit temperature rise to within 1.5 °C in line with the Paris Agreement.

While reducing greenhouse gas emissions remains essential, United Nations Secretary-General António Guterres has called for a breakthrough on adaptation and resilience in 2021, with significant increases in the volume and predictability of adaptation finance. Such a breakthrough is vital to ensure all people, especially the most vulnerable, can adapt and be more resilient to the consequences of inevitable future weather and climate events.

Science-based, data-driven weather and climate services, such as early warnings, are the foundation for effective adaptation measures. These services are proven to provide a significant return on investments, yielding benefits across all Sustainable Development Goals. Yet large capacity gaps remain to effectively provide these services, particularly in countries most vulnerable to weather and climate events.

The Alliance for Hydromet Development was launched at COP25 in Madrid, bringing together major multilateral development and climate finance institutions for united and scaled-up action in support of better weather forecasts, early warning systems and climate information.

As an Alliance, we made important commitments to increase the effectiveness and sustainability of our work. We prioritized three topics for collective action: developing a common tool to assess countries' hydromet development status, seeking innovative ways to finance developing country surface-based observations, and issuing the first Hydromet Gap Report.

On behalf of all Alliance members I am herewith presenting this report to you. It puts a spotlight on our collective work over the past 18 months. It is an account of progress made and of the major work ahead of all of us to provide a stronger foundation for adaptation and resilient development.



**Prof Petteri Taalas,  
Secretary-General, WMO**

*On behalf of the Alliance for  
Hydromet Development*





Getty Images

**We are in a climate crisis.** While the contribution of developing countries to greenhouse gas emissions is limited, the impacts of disasters from climate related weather events are three times higher than in high income countries. Therefore, investments in adaptation must be substantially increased and prioritized.

Accurate weather forecasts and robust climate prediction is critical to make the right adaptation policy and investment decisions. Yet many developing countries, including my own, do not have the resources to sustain the human, institutional and infrastructure capacity required for the provision of high-quality weather forecasts, early warnings and climate information. In this regard, I warmly welcome the commitment of the Alliance for Hydromet Development to unite and scale up support to countries in need.

We highly appreciate the development of the Country Hydromet Diagnostics as a common tool of the Alliance to inform and guide investments. I am particularly pleased that my country has been among the pioneers that contributed to its development and participated in its early application.

Finally, I am encouraged by the innovative way the Alliance aims at tackling the perennial problem of missing basic weather and climate observations, in particular from Africa. Echoing other African leaders, I firmly support the creation of the Systematic Observations Financing Facility.

Weather and climate do not know boundaries. We all need to work together, across our political and institutional boundaries. The Alliance for Hydromet Development is an example of such collaboration – for the benefits of the most vulnerable.



H.E. Alassane Ouattara,  
President of Côte d'Ivoire

# ALLIANCE MEMBERS' STATEMENTS

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"Providing Hydromet assistance to developing countries is key for scaling up and uniting efforts to achieve the common goal of closing the capacity gap on weather, climate, hydrological, disaster risk management, and related environmental services by 2030, and is critical to enable funders such as the Adaptation Fund to help the most vulnerable communities adapt and build resilience to climate change."

Mikko Ollikainen, Adaptation Fund, Head

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"The Alliance partnership is important to the Bank and to Africa. It offers a platform to strengthen resilient development and climate adaptation through improved ground-based observing systems, leading to better weather forecasts of extreme events and climate prediction services. "

Akinwumi A. Adesina, African Development Bank, President

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"In our region, we have significant gaps in weather observations, especially in our Least Developed Countries and Small Island Developing States, and that's hampering the ability to respond and adapt to extreme weather events."

Bruno Carrasco, Asian Development Bank, Director General

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"The lack of sound climate information services impact people from developing countries the most. Only by taking the pulse of our entire planet can we start to meaningfully assess and manage the risks and future impacts climate change may bring."

Mafalda Duarte, Climate Investment Funds, Chief Executive Officer

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"The region where the EBRD operates is vulnerable to climate change impacts, and includes some of the world's most water-stressed countries. While climate change is exacerbating these vulnerabilities, the aging weather observation systems in many of these countries are not being adequately maintained and are even falling into disrepair. As EBRD recognises the need to help such countries build weather observation and climate forecasting capabilities, the Bank has joined the Alliance for Hydromet Development and fully supports its objectives."

Harry Boyd-Carpenterr, European Bank for Reconstruction and Development, Managing Director

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"We need to scale up and support long-term global cooperation and partnership to strengthen climate resilience of the most vulnerable. The Alliance for Hydromet Development plays a foundational role in this regard."

Carlos Manuel Rodriguez, Global Environment Facility, Chief Executive Officer and Chairperson



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“Better weather forecasts and early warning systems would save millions of lives. Better climate analytics can also dramatically reduce climate physical and transition risks for businesses and preserve livelihoods.”

Yannick Glemarec, Green Climate Fund, Executive Director

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“Having access to the highest quality climate information for forecasts, weather and climate phenomena, including extreme weather events, is crucial.”

Bandar M.H. Hajjar, Islamic Development Bank, President

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“Extreme weather and climate events are now increasing in frequency, intensity and severity as a result of climate change. Vulnerable communities are among the hardest hit. The Alliance for Hydromet Development is supporting countries to generate and leverage climate and weather information.”

Achim Steiner, United Nations Development Programme, Administrator

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“It’s critical that we strengthen local and global resilience and capacity to prepare and adapt. A big part of that success will depend on our ability to predict and protect. Therefore, better weather forecasts, early warnings and climate information are essential.”

Inger Andersen, United Nations Environment Programme, Executive Director

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“Weather and climate observations are essential to realize the full benefits of investments in weather forecasts, early warnings and climate information. There are triple benefits of avoided losses through reliable and accurate early warning systems; optimized production processes through the application of robust weather forecasts in highly weather-sensitive sectors; and social and environmental benefits related to increased capital investments and fiscal stability.”

Mari Pangestu, World Bank, Managing Director

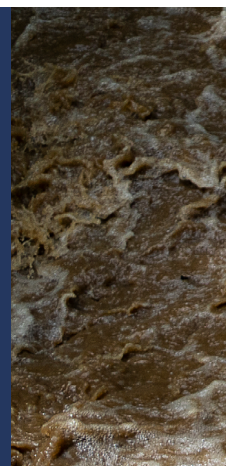
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“Countries need greater ability to forecast and predict this climate crisis, so they can protect lives. One of the many different factors driving global hunger today, climate extremes, are one of the most predictable. So let’s work together to help vulnerable communities be better prepared for them.”

David Beasley, World Food Programme, Executive Director

# EXECUTIVE SUMMARY

With the past decade being the hottest on record,<sup>1</sup> and the increase in average global temperature already surpassing 1.2°C since pre-industrial times, it is clear that climate change is posing an existential threat. Current pledges, made in light of the Paris Agreement, are estimated to result in an average temperature increase of 3.2°C or more by the end of the century.<sup>2</sup> Developing countries, and in particular Small Island Developing States (SIDS) and Least Developed Countries (LDCs), are already experiencing the most devastating impacts from increasing weather, water and climate-related extreme events. This not only calls for ambitious mitigation measures but also for stepped-up adaptation and resilience efforts.



**High-quality weather, climate, hydrological, and related environmental services ('hydromet' services) provide the foundation for effective climate adaptation and resilience action.** Investments in improved weather forecasts, early warnings and climate information make massive economic sense. They create a triple dividend that includes: first, avoided losses – reliable and accurate early warning systems save lives and assets worth at least ten times their cost; second, optimized production – the estimated annual benefits of improved economic production through the application of weather forecasting in highly weather-sensitive sectors amount to about USD 96 billion;<sup>3</sup> and third, improved long-term strategic response to climate change. The Global Commission on Adaptation estimates that strategically investing USD 1.8 trillion between 2020 and 2030 globally could generate USD 7 trillion in total net benefits.<sup>4</sup> High-quality hydromet services are an essential requisite to realize these benefits.

**While hydromet services provide a foundational role for economic prosperity and resilient development, many countries face substantial challenges in delivering them.** To more effectively support countries to address these challenges sustainably, the World Meteorological Organization (WMO) and major development and climate finance partners created the Alliance for Hydromet Development.<sup>i</sup> The Alliance was launched at United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP) 25 in 2019, and aims at uniting and scaling up efforts to close the capacity gap in the provision of high-quality weather forecasts, early warning systems, and climate information.

**The Alliance has prioritized three activities for early collective action:** First, deploying a common tool to benchmark and assess countries' hydromet capacity gaps

– the Country Hydromet Diagnostics; second, creating an innovative mechanism to finance developing country surface-based weather and climate observations – the Systematic Observations Financing Facility; and third, producing a regular Hydromet Gap Report to track progress on closing the hydromet capacity gap – this is the first such report.

**The Country Hydromet Diagnostics (CHD) are a standardized and integrated, operational tool and approach** for assessing National Meteorological Services, their operating environment, and their contribution to high-quality hydromet services. They provide coherent and authoritative peer-to-peer assessments across countries.

**The Diagnostics allow for a more systematic approach to strengthening countries' hydromet capacity,** whereby the coordination, sequencing, and programming of investments are led by the country considering global requirements. The Diagnostics aim to inform hydromet policy and investment decision-making, guiding coordination and sequencing of investments from Alliance members and other funders. Through the Diagnostics, developing countries are expected to benefit from better targeted and aligned support as the assessment of maturity levels indicates where additional focus and investments are needed.

**In partnership with 16 countries,** a first round of the CHD was undertaken.<sup>ii</sup> Among the assessed countries, there was a wide range of maturity across the different elements – with several countries at level 3 for the majority of elements (5 being the most mature), but many others at levels 1 or 2. The countries with the largest gaps lacked the most basic capacity in terms of equipment, skills and user engagement, despite the clear and growing risks. None of the assessed National Meteorological Services had advanced levels of a maturity for

i. Adaptation Fund, African Development Bank, Asian Development Bank, Climate Investment Funds, European Bank for Reconstruction and Development, Global Environment Facility, Green Climate Fund, Islamic Development Bank, United Nations Development Programme, United Nations Environment Programme, World Bank, World Food Programme, and the World Meteorological Organization.

ii. Afghanistan, Austria, Chad, China, Côte d'Ivoire, India, Kyrgyz Republic, Liberia, Maldives, Morocco, Myanmar, Nigeria, North Macedonia, Sierra Leone, Switzerland, and Turkey.





any element. However, there were also encouraging findings as several countries, despite their limited capacity, were making significant contributions to climate services. Based on the results of the Diagnostics, these countries are now able to develop programmatic hydromet interventions in collaboration with the Alliance partners.

**Weather and climate observations ranked among the elements with the lowest average maturity levels reconfirming the fact that generating and internationally exchanging basic surface-based weather and climate observations remains a perennial challenge.** This is particularly true for all LDCs and SIDS, as demonstrated by a global gap analysis undertaken by WMO.<sup>5</sup> These countries are currently far from meeting the requirements of the internationally agreed Global Basic Observing Network (GBON)(see Box 7.2), and the implications are severe. It is nearly impossible to provide high-quality forecasts in these countries. In addition, the lack of observations from these countries impacts the quality of forecasts across the entire globe. Satellite observations are important, but they cannot substitute for surface-based observations, and they themselves need validation from surface data. Without a substantial increase of internationally exchanged surface-based observations, the quality of hydromet services cannot be significantly improved. These services can only be as good as the data they are built upon.

**Therefore, the Alliance is committed to establishing the Systematic Observations Financing Facility (SOFF).**

The goal of SOFF is to strengthen climate adaptation and resilient development through the sustained collection and international exchange of high-quality surface-based weather and climate observations in compliance with the GBON. SOFF will address the persistent problem of missing foundational

observations in a systematic manner. First, it will deploy a global approach with the actual international data exchange of observations as the single measure of success. Second, it will provide innovative finance – long term, results-based grant finance also in support of operations and maintenance. Third, it will enhance technical competence and effective coordination among the many stakeholders required for international data exchange. Through the combination of these features, and by leveraging its resources in close cooperation with other partners, SOFF will channel international support to substantially strengthen SIDS's and LDC's basic observing capacity and data exchange in new, more effective and sustainable ways. It is envisioned to announce SOFF at COP26 and make it operational in 2022.

**Since its launch at COP25 the Alliance has advanced its work on its initial priorities. Going forward, the Alliance commits to:** first, make SOFF operational; second, fine-tune the Country Hydromet Diagnostics and make them a fundamental basis for SOFF support; third, continue to engage with the private sector to explore innovative and financially viable business models to close the hydromet capacity gap; fourth, explore ways to enhance the effectiveness and range of early warning systems in a more coordinated and systematic manner; and fifth to continue increasing awareness to strengthen developing countries' hydromet capacity. The Alliance will capture lessons learned from its scaled-up work to close the hydromet capacity gap in the second Hydromet Gap Report, envisioned for 2023.

# LIST OF ABBREVIATIONS

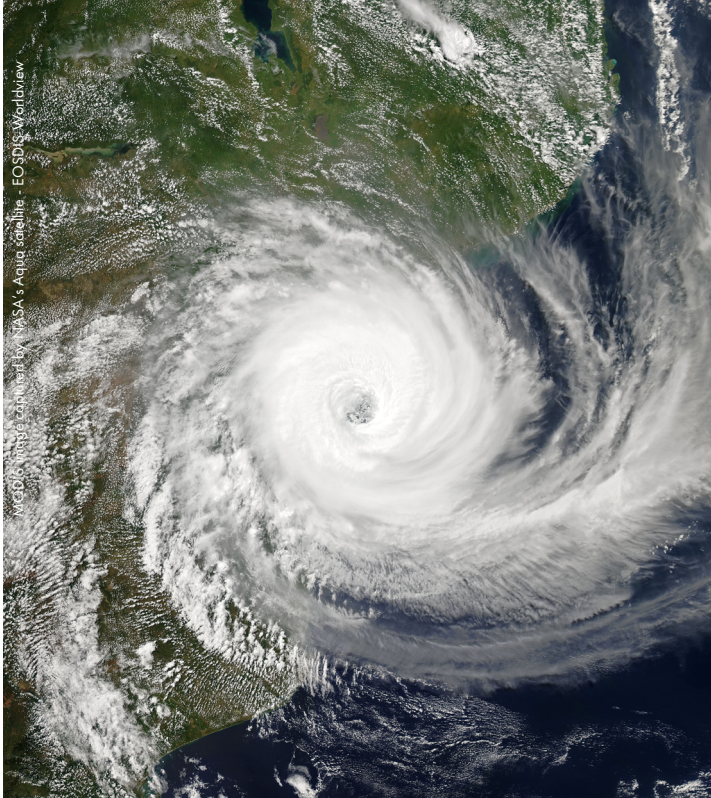
ADB	Asian Development Bank
AfDB	African Development Bank
CAP	Common Alerting Protocol
CHD	Country Hydromet Diagnostics
CIF	Climate Investment Funds
COP25	25th Conference of the Parties of the UNFCCC
CREWS	Climate Risk and Early Warning Systems Initiative
DPS	Data and Product Sharing
EBRD	European Bank for Reconstruction and Develop
EWS	Early Warning System
FAO	Food and Agriculture Organization
GBON	Global Basic Observing Network
GCF	Green Climate Fund
GDP	Gross Domestic Product
GEF	Global Environment Facility
ICT	Information Communication Technology
IsDB	Islamic Development Bank
LDC	Least Developed Countries
NDCs	Nationally Determined Contributions
NGO	Non-Governmental Organization
NMS	National Meteorological Service
NMHS	National Meteorological and Hydrological Service
NWP	Numerical Weather Prediction
OECD	Organisation for Economic Co-operation and Development
QPE	Quantitative Precipitation Estimation
QPF	Quantitative Precipitation Forecast
SIDS	Small Island Developing States
SOFF	Systematic Observations Financing Facility
SOP	Standard Operating Procedures
TCFD	Task Force on Climate-related Financial Disclosures
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollars
WFP	World Food Programme
WMO	World Meteorological Organization





Credit: Luka Vovk





# 1. INTRODUCTION

**All effective action for climate adaptation and resilience requires high-quality weather, climate, hydrological, and related environmental services (defined by the Alliance collectively as hydromet services).** But many countries are facing substantial challenges in delivering these services. In order to more effectively support countries in addressing these challenges, WMO and major development and climate finance partners created the Alliance for Hydromet Development. The Alliance unites and scales up efforts to close the capacity gap on high-quality weather forecasts, early warning systems, and climate information.

**The members of the Alliance are committed to deliver on ten specific tasks (see Annex 1). For its initial work, the Alliance has been focusing on three priorities:**

- Deploying a standardized tool to benchmark and assess countries' hydromet capacity gaps - the Country Hydromet Diagnostics (CHD)
- Creating an innovative mechanism to finance developing country surface-based weather and climate observations - the Systematic Observations Financing Facility (SOFF)
- Producing a regular Hydromet Gap Report to track progress on closing the capacity gap by 2030 - this is the first such report.

## Box 1.1 The Alliance for Hydromet Development – the international community's quest for a new way to support hydromet development

The Alliance recognizes with urgency the mounting impacts of climate change especially on the world's poorest and most vulnerable countries. It shares the concern that many developing countries are facing major capacity constraints to provide hydromet services as the foundation for resilient and sustainable development. The Alliance aims to increase effectiveness and sustainability of hydromet investments through collective action. The members of the Alliance act within their respective resources and mandates and forge a collaborative partnership which recognizes and leverages respective competencies and expertise.

The Alliance was launched at UNFCCC COP25 and is comprised of the following 13 members: Adaptation Fund; African Development Bank; Asian Development Bank; Climate Investment Funds; European Bank for Reconstruction and Development; Global Environment Facility; Green Climate Fund; Islamic Development Bank; United Nations Development Programme; United Nations Environment Programme; World Bank; World Food Programme; World Meteorological Organization.





This report outlines the global context and the importance of hydromet (**Chapter 2**) before explaining the different components of the meteorological value chain and how they interact and influence each other (**Chapter 3**). **Chapter 4** evidences the benefits that can be secured by hydromet services, with **Chapter 5** describing the challenges to strengthening hydromet capacity in a systematic manner. **Chapters 6 and 7** introduce the priority solutions the Alliance has started to implement.

**The Country Hydromet Diagnostics (CHD) have been developed by the Alliance** as a standardized, integrated, and operational maturity assessment of National Meteorological Services (NMS) at all stages of the meteorological value chain, from observational data gathering to 'last mile' value creation. **Chapter 6** outlines the CHD methodology and the key findings from 'road-testing' the CHD in partnership with several countries.

**The CHD will inform the actions of the Systematic Observations Financing Facility (SOFF):** a proposed new financing mechanism aimed at supporting countries with the largest capacity gaps in generating and internationally exchanging basic surface-based weather and climate observations. In **Chapter 7**, the goals, structure and approach of the SOFF are described, explaining how investments in the first part of the meteorological value chain will substantially

contribute to improving countries' capacity in providing high-quality hydromet services.

Finally, **Chapter 8** outlines the Alliance's plans for the next phase of its collective work in continuing to roll out the CHD across regions and in completing the design and resource mobilization for the SOFF for its envisioned announcement at COP26 and operationalization in 2022. The Alliance will also deepen collaboration at the country level and undertake coordinated and/or joint programmatic approaches beyond individual projects. The hydromet gaps identified by the CHD present opportunities for defining structured long-term coordinated programmatic support with clear priorities to address the weakest links in the meteorological value chain.





## 2. THE CLIMATE CRISIS AND THE IMPACT OF HYDROMET DISASTERS

**The past decade was the hottest on record.** The average global temperature has already risen 1.2°C since pre-industrial times<sup>6</sup> and there is more than a 40 percent chance that the annual average global temperature will temporarily reach 1.5°C above pre-industrial levels in at least one of the next five years.<sup>7</sup> Based on current national policies for cutting greenhouse gas emissions, the world can expect to see warming reach at least 3.2°C by the end of the century.<sup>8</sup> Even the pledges and optimistic targets being made in response to the Paris Agreement fall short of limiting warming to 2°C by the end of the century.<sup>9</sup> Therefore, successfully achieving the Paris Agreement objectives to adapt to the adverse impacts of climate change and foster climate resilience will require urgent and significant steps, as evidenced by the impacts caused by climate-related extreme events today.

According to WMO, more than 11,000 disasters in the last 50 years have been linked to hydromet hazards.<sup>iii</sup> LDCs experienced 70 percent of the deaths caused by these disasters.<sup>10</sup> Such events have killed more than 410,000 people in the last decade alone, and in 2020 more than 50 million

people were affected by floods, droughts, and storms.<sup>11</sup> The COVID-19 pandemic has amplified the impact of these events, especially on the poor,<sup>12</sup> and the situation continues to worsen.

**Over the last decade, the percentage of disasters associated with weather and climate-related events has increased by nine percent compared to the previous decade, and by almost 14 percent compared to the decade from 1991-2000.**<sup>13</sup> This increase is likely to continue, impacting lives and livelihoods, and impeding global efforts to reduce poverty. Whilst, relatively speaking, low-income economies rank lowest in economic damages (USD 38 billion over 2000-2019, versus USD 1.99 trillion for high-income countries), they have the highest level of losses compared to their GDP (0.61 percent, or three times higher than high-income countries at 0.18 percent).<sup>14</sup> The situation is particularly acute for SIDS; when ranked by losses as a share of GDP, eight of the top ten countries/territories are island nations.

**Without decisive action on climate adaptation and resilience,** the rapid changes in climate have the potential to reduce agriculture yields by up to 30 percent by 2050.<sup>15</sup> This would be devastating for the 525 million people living in extreme poverty who rely on agriculture, driving even greater

iii. Hydromet hazards include hurricanes, cyclones, tornadoes, winter storms, high winds, floods, storm surges, droughts, and heat waves, among others.





food insecurity.<sup>iv</sup> Water insecurity would increase too. Today, 3.6 billion people face inadequate access to water at least one month per year. By 2050, the total is expected to be more than five billion.<sup>16</sup>

**By 2030, the impacts of climate change are predicted to push up to 132 million more people into poverty.**<sup>17</sup> This would add further burdens on poverty elimination efforts and severely hamper growth in prosperity. It is estimated that the compounded economic impact of climate change could rise from the current levels of USD 7-15 billion per year to as much as USD 50 billion per year by 2040. In Sub-Saharan Africa, climate change could further lower GDP by up to three percent by 2050.<sup>18</sup> This presents a serious challenge for climate adaptation and resilience actions as not only are physical conditions worsening, the number of people they are affecting is increasing.

Whilst global investment in adaptation increased from USD 22 billion a year in 2015-2016 to about USD 30 billion in 2017-2018, this growing trend will not be sufficient to offset expected impacts.<sup>19</sup> The United Nations Environment Programme (UNEP) Adaptation Gap Report calculates annual adaptation funding needs in developing countries alone to be in the range of USD

70 billion, increasing to USD 140-300 billion by 2030, and USD 280-500 billion by 2050.<sup>20</sup> **This means that funding would need to increase ten-fold by the end of the decade to meet expected needs.** The total climate finance share for LDCs and SIDS equates to only 14 and two percent of flows respectively, even though they are disproportionately affected by climate impacts.<sup>21</sup> Therefore, shifts in allocation of grants and concessional funds provided by the international community would also be needed if funds are to flow where the needs are greatest.

**Effective action on climate adaptation and resilience depends on high-quality hydromet services, as well as the observational data that underpin those services, and the capacity to make informed decisions and take action in light of that information.** However, many countries face increasing challenges. For example, out of the 73 countries that have provided information to WMO, only 40 percent currently have effective multi-hazard early warning systems.<sup>22</sup>

iv. Weather extremes were the primary driver of acute food insecurity in 15 countries with around 16 million people in Crisis or worse in 2020 - GRFC 2021 050521 med.pdf (reliefweb.int).

### 3. HYDROMET SERVICES AND THE METEOROLOGICAL VALUE CHAIN

Weather and climate services are generated by the meteorological value chain shown in Figure 1. Good outcomes - users taking action in response to weather and climate prediction, resulting in lives saved, protection of property, and increased economic activity - happen when all links work and are working effectively together.

This value chain can be schematically described as follows:

- **Weather and climate observations** are routinely made over all areas of the globe.
- **Observations are exchanged internationally**, in particular with global Numerical Weather Prediction (NWP) systems (Box 3.1).
- **NWP output monitoring and prediction data** for weather and climate are generated and shared with all WMO Members (193 States and Territories) (Box 3.2)

- **Global NWP output is used** by National Hydrological and Meteorological Services (NMHSs) and other entities, including in the private sector, to generate weather and climate information: i.e., local forecast products, watches and warnings, seasonal outlooks, climate monitoring and prediction products, etc.
- **Weather and climate information services are delivered to users**, including national and local authorities, businesses, media, academia and the general public.
- **Effective decisions** in response to weather and climate information are made by authorities, agents in all economic sectors, and individuals.

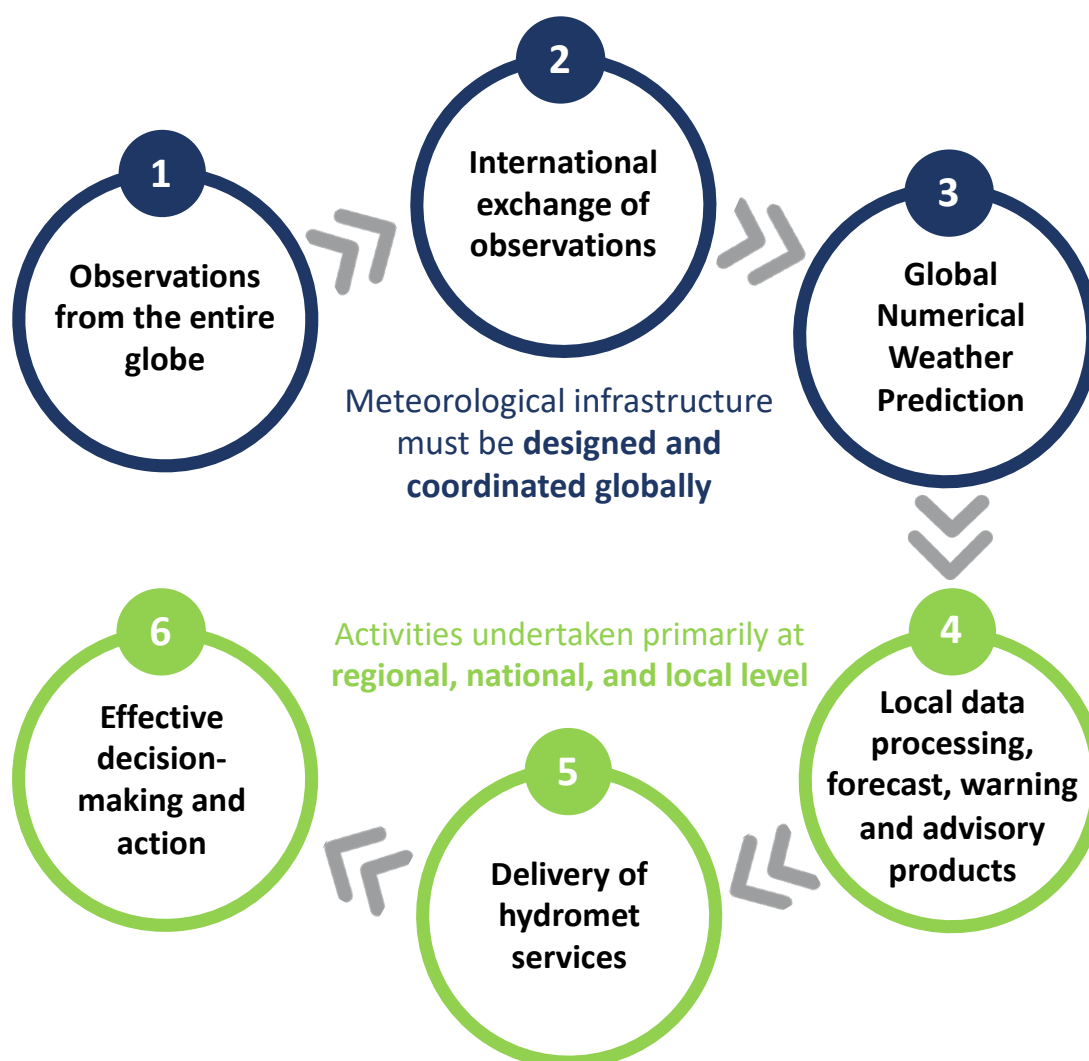
The first three links in the value chain (shown in blue in Figure 1) constitute the global meteorological infrastructure and rely on a global collaboration approach (Box 3.1). In contrast, the last three links (in green) are typically implemented nationally. The importance of the implications relating to the first three links being global in nature cannot be overstated. Beyond a prediction horizon of 24 to 36 hours, global observational data and global models are needed to underpin predictions in any location, even if the target area for a given prediction is very small and local (for example, climate prediction and projections for a city). Conversely, without local efforts everywhere to make and exchange observations, global

#### Box 3.1 A primer on monitoring and predicting the Earth's atmosphere

**Weather or climate prediction is global by necessity, not by choice.** Weather systems develop and move across the planet regardless of political boundaries. The atmosphere has no horizontal boundaries and only in its entirety can it be simulated mathematically.

**Global NWP forms the foundation of all weather and climate monitoring and predictions, and is conducted by the Global Producing Centres operated by WMO Member states and territories.** A NWP prediction starts by assimilating vast amounts of meteorological observations from the entire globe into an Earth system model to build a worldwide model estimate of the instantaneous weather. The model then uses the laws of physics to evolve this 'initial weather' forward in time. The quality of NWP output can be objectively quantified, and progress in NWP relies on extensive use of broadly agreed measures of lead time, or range (the extent forward in time that can be predicted), and skill (the quality of the prediction at a given time).

**The ability to accurately predict the weather is limited by what is known as the 'butterfly effect'.** The impact of the butterfly effect is profound: any small, local gaps or errors in our knowledge of weather anywhere will propagate and amplify in the models, eventually degrading forecast skill everywhere. The only practical way to limit the errors – in other words, to improve the skill and range of the prediction – is to ensure that the 'initial weather' of the model is as accurate as possible everywhere. This can only be achieved with frequent observations made everywhere.



**FIGURE 1:** The meteorological value chain. All links in the chain must operate effectively to yield success.

### Box 3.2: Global cooperation and the World Meteorological Organisation

WMO is a specialised agency of the United Nations with 193 Member States and Territories. Global cooperation is essential for the development and operation of hydromet services. WMO provides the framework for such international cooperation through:

- An integrated global observing system to provide hydromet data.
- Data management and telecommunication systems for rapid data exchange.
- Observation standards to ensure the homogeneity of data.
- The provision of hydromet services.
- Hydromet research and training.

[Source: WMO 2021, Our Mandate]



models cannot effectively generate the data needed for forecasting at the national and local levels. All countries, therefore, share an interest in the first three links in the chain, while they handle the last three mostly individually.

critically on the infrastructure and capabilities of NMHSs, so increasing attention is now being given to their capacity development but more support is needed.

**Critically, the huge potential benefits of hydromet services can only be realized with a successful crossing of the 'last mile'** – that the forecasts, warnings, and other information generated are received, understood, and acted upon by those affected. Despite scientific and technological advances, it remains challenging to present hydromet information in a user-friendly way whilst maintaining sufficient technical detail to inform appropriate responses. This calls for a greater focus on social and behavioral science, as well as building trust and understanding amongst communities at risk.

**At the heart of hydromet service provision are the NMHSs of every nation**, working around the clock to monitor the Earth system and provide vital information and advice. Global investments in adaptation and resilience rely

### Box 3.3 The distinctive but linked roles of hydrology and meteorology for hydromet services

**Meteorology and hydrology are inextricably linked as scientific disciplines, in their impacts on human life and activities, and as service delivery areas.** They are bound together by the water cycle. This close link between meteorology and hydrology through the water cycle is evidenced by the fact that many of the most important manifestations of weather and climate – including some of the worst catastrophes in terms of both economic impact and loss of life - are in fact related to hydrology. For instance, extreme weather events or long periods with varied precipitation, and the resulting floods or droughts, are related to hydrology.

**Despite their interrelation, the two disciplines are of different natures**, resulting in different operational practices and approaches to implementing observing systems and information services. Meteorology is inherently global (see Box 3.1) and, as a discipline, has a history of global cooperation stretching back almost two centuries. Hydrology tends to be defined around geographical areas, such as catchment areas and river basins. Therefore, management of hydrological areas tends to be conducted on a more regional basis. This more local approach is also partly driven by practical considerations, as the need to collaborate among communities and governments sharing a river basin is very clear, with policy issues and national interests in controlling and securing access to water. Water residing in the atmosphere or in the ocean is, due to its nature, largely unmanageable. In contrast, water on or in the ground can be diverted, dammed, stored, and consumed. This is used to support the view that the local part of the hydrosphere can be seen as a national resource akin to underground mineral wealth, which is reflected in policies and practices around data exchange for hydrology.

**The meteorological value chain is, by necessity, fully globally coordinated in the initial stages in observation gathering, sharing, and processing for global NWP**, before evolving into distinct regional and national responsibilities in the later stages of service delivery. For the reasons listed above, there is no corresponding global hydrological value chain, but rather a number of regional (and in some case national or even more localized) hydrological value chains. These hydrological value chains depend on input from the meteorological value chain. They work in similar ways to the meteorological value chain, but the modeling and exchange of observations is conducted at the regional or local level, rather than global level.



Charles Wirawan

## 4. THE BENEFITS OF HYDROMET SERVICES

### 4.1 AVOIDING LOSS AND REDUCING DAMAGE

The World Bank estimates that 23,000 lives per year could be saved by upgrading hydromet and early warning systems in low- and middle-income countries to meet the standards of European systems.<sup>23</sup> Upgraded hydromet systems in low- and middle-income countries could also avoid annual losses to assets of between USD 300 million and USD 2 billion.<sup>24</sup> A global calculation of avoided asset losses for all countries, using factors based on expert opinion, shows that the potential benefits from avoided losses could be as much as USD 66 billion.<sup>25</sup> Reliable and accurate early warning systems create benefits worth at least ten times their cost of implementing, saving lives and assets. Just a 24-hour warning of a coming storm or heatwave can reduce damages by 30 percent.<sup>26</sup>

**In addition to reducing loss of life and assets, losses in well-being can also be mitigated.** A follow-up World Bank study found that losses in well-being<sup>v</sup> can be as much as 60 percent higher than asset losses.<sup>27</sup> Whilst poor people's experience of asset losses is around half of the global average amount, they suffer disproportionately as these losses have larger implications at lower income levels.

**Table 4.1:** The minimum annual socio-economic benefits of weather prediction from both avoided losses (in green) and increasing productivity (in blue).

Sector	Minimum annual benefit (USD)
Disaster Management	\$66 billion
Agriculture	\$33 billion
Energy	\$29 billion
Transportation	\$28 billion
Water Supply	\$5 billion
Construction	\$1 billion
TOTAL	\$162 billion

Source: Kull, et al., (2021)

**Minimizing loss of assets, lives and impact on well-being, and successfully planning anticipatory action requires additional investment in hydromet development:** in observing systems, forecast and early warnings capabilities, communication tools, as well as the ability of decision-makers to understand the information, make informed decisions, and adopt anticipatory action frameworks and post-disaster actions. The most expensive components of the system are already in place (for example, earth observation satellites and global NWP capability). Hence, additional investments in strengthening the hydromet value chain will leverage the benefits of those components already secured.

#### Box 4.1 Early warning systems in Bhutan, a critical measure to avoid loss and reduce damage

**Climate change is causing glaciers to rapidly retreat in the Himalayas,** creating downstream glacial lakes that can burst their moraine dams, flooding downstream communities. A USD 4 million grant from the Global Environment Facility (GEF) focused on Thorthormi Lake in Bhutan - one of the most dangerous lakes in the country. With co-financing from Bhutan, United Nations Development Programme, the Austrian Development Agency, and WWF, and implementation by UNDP, the project lowered the lake's water level and installed an automated early warning system (EWS) with automated water level and weather monitoring stations, and sirens reaching more than 90 percent of the households in the valley. The project also supported identification of evacuation sites and rehearsal of response drills. The automatic EWS provides real-time online data, which is shared with the Indian states of Assam and West Bengal through Bhutan's flood warning system. Whilst being a highly successful and cutting-edge project, the sobering fact remains that climate change and rapid glacial melt continue in the Himalayas – and the scale of effort needed continues to grow.

[Source: [https://www.adaptation-undp.org/sites/default/files/downloads/glof\\_project\\_document\\_2008.pdf](https://www.adaptation-undp.org/sites/default/files/downloads/glof_project_document_2008.pdf)]

v. In this study, well-being loss is expressed as the equivalent loss in national consumption. Disaster losses are concentrated and imperfectly shared across the population, affecting poor people with reduced coping capacity more. People in the bottom 20 percent of income levels experience only 11 percent of total asset losses but 47 percent of well-being losses.



## 4.2 INCREASING PRODUCTIVITY

**Avoiding loss and reducing the duration of interruptions in production is good for productivity. However, hydromet services generate further benefits by helping to increase the efficiency and productivity of many different sectors** (see Table 4.1). Improving economic production through the application of hydromet services in highly sensitive sectors including agriculture, water, energy, transportation and construction are estimated to provide benefits of around USD 96 billion per year.<sup>28</sup> Furthermore, green economies will require strong hydromet services as they expand weather-dependent sectors, such as renewable energy, and climate-smart agriculture among others.

**As a lack of reliable information results in sub-optimal choices, this translates into missed opportunities for improving efficiency and productivity.** The Food and Agriculture Organization (FAO) estimates that, depending on the level of development, around 20 to 80 percent of the inter-annual variability of crop yields is caused by the changes in weather, and five to ten percent of national agricultural production is lost annually due to weather variability.<sup>29</sup> However, they found that better hydromet information can help farmers to take suitable and timely action to reduce these losses and improve production by, for example, using forecasts to optimize their water supply system operations, and can help with the performance of energy generation systems that depend on weather and water. Similarly, the transport sector can benefit from improved routing based on weather



and wave forecasting, creating substantial fuel savings and improving safety in air transport and shipping. Applying hydromet services to transport and construction projects can reduce and remove road transport delays and other operational inefficiencies that may occur due to extreme heat or other disrupting conditions.

The private sector has seen the enormous value the hydromet services have for the economy, with new and established companies entering the hydromet market.

### Box 4.2 Hydromet services and the private sector: regulations on financial disclosure

**The growing significance of climate risk disclosure** by businesses and financial institutions underscores the importance of access to comprehensive and reliable global observational hydromet data.

The recommendations of the Task Force on Climate-Related Financial Disclosures (TCFD), the foremost corporate climate disclosure framework to emerge over recent years, encourage non-financial and financial firms to base their assessments on both historical climate trends and forward-looking projections.

**Consistent, longitudinal hydromet data records are at the heart of the climate modelling necessary for these assessments.** For areas of the globe where such data are missing or incomplete, modelling is often coarse and low in resolution. This is often the case for developing countries.

The challenge of sustaining collection of observational data over the years needs to be addressed in order to strengthen the coverage and accuracy of the climate models that investors require for assessing and managing climate-related financial risks and identifying business opportunities for investing in climate resilience. For example, the European Bank for Reconstruction and Development (EBRD) discloses its climate-related risks through its corporate report. Finding good-quality physical climate analytics are central to the Bank's efforts to integrate TCFD recommendations, including physical climate risk assessment, into its overall risk management practices.





Radiosonde station in Port Moresby, Papua New Guinea

**From telecommunication to artificial intelligence and machine learning**, the rapid advances in technology and innovation have simultaneously contributed to and been expanded by the range of products and services in the hydromet value chain. For example, next-generation smart hybrid public warning systems combine cell broadcast and location-based SMS with situational awareness. These systems allow governments to give specific messages to target populations located in the area before, during and after a disaster.

### 4.3 SUPPORTING A LONG-TERM STRATEGIC RESPONSE TO CLIMATE CHANGE

**Hydromet services support societies and economies in undertaking transformational changes to prepare for a changing climate.** The Global Commission on Adaptation estimates that strategically investing USD 1.8 trillion in five areas between 2020 and 2030 across the globe could generate USD 7 trillion in total net benefits.<sup>30</sup> These five investment areas include: introduction of early-warning systems, construction of climate-resilient infrastructure, improvements in dryland agriculture crop production, mangrove protection, and development of more resilient water resources. Each of these adaptation investment areas relies upon having the very best hydromet information available to identify sustainable solutions and opportunities (see Box 4.2).

**Enhanced hydromet services also support countries in mobilizing climate finance.** A better understanding of the historical and future changes in climate is an important aspect in securing funding for climate finance interventions. Strong, well capacitated NMHS – that can provide and share local observational data and information with stakeholders – are key constituents in mobilizing climate finance to a country.

**In addition, hydromet information is critically important for the insurance and finance sectors.** These sectors are using weather and climate risk information to develop innovative financial risk management approaches. These approaches are needed to complement physical investments and operational and behavioral changes in order to strengthen resilience. Development of innovative products is also opening new opportunities in markets which have traditionally not had a strong insurance culture due to the new forms of insurance that can be offered.<sup>31</sup> This presents an opportunity to enhance the resilience of the world's most vulnerable populations by making insurance accessible to them and enabling agencies and authorities to mobilize aid and payouts in a timely, anticipatory way.<sup>32</sup>





Asian Development Bank





## 5. THE CHALLENGES OF STRENGTHENING HYDROMET CAPACITY IN A SYSTEMATIC MANNER

In its founding declaration (see Annex 1), the Alliance for Hydromet Development committed to increase effectiveness and sustainability of its members' investments. Estimates indicate that members of the Alliance are currently managing an active hydromet project portfolio of at least USD 2.5 billion, not counting national or international co-financing, of which about USD 500 million are aimed at improving observing systems in developing countries.<sup>33</sup> **Yet, investments in hydromet development - in particular those related to strengthening the first part of the meteorological value chain - are confronted with specific challenges that the Alliance is committed to address.**

### 5.1 LACK OF AWARENESS OF THE SOCIO-ECONOMIC VALUE OF HYDROMET

The full value of hydromet services is often difficult to appreciate for country stakeholders: communities, businesses, ministries of finance and planning, and sector agencies. In part, this lack of appreciation is related to the unclear mandate of NMHSs in some countries, and the fact that there are frequently other entities with overlapping responsibilities and services. **This combination of factors makes it difficult to communicate and understand hydromet services and their value, and leads to a low-resource trap.** This is where NMHS do not receive the financial support needed from their governments to provide high-quality services and achieve the full potential of benefits to society and this, in turn, results in a low quality of services.

### 5.2 LACK OF A GLOBAL APPROACH TO STRENGTHEN THE FIRST PART OF THE VALUE CHAIN

Development projects are typically single-country focused, and the way in which they address observing system issues





most commonly entails an attempt to establish national observational infrastructure. However, the action that is needed to establish functioning data exchange is generally not purely national. It will involve collaboration with – and in many cases investment in – system components and entities outside the country such as Regional Telecommunication Hubs, Global Information System Centres, Regional Centres, all the way to the intended recipients of the observations, the Global Producing Centres running the NWP models.

**‘Last-mile’ projects rely heavily on the use of global model data**, and while the importance of these data is well understood by those designing the projects, the role of local observations is less so. The critical link between the exchange of local observations and the local quality of model data – including through their contribution to the quality of high-resolution down-scaled products – is generally not fully recognized, nor is the critical role played by observations as the only objective means of forecast verification. Furthermore, in small or medium-sized countries it is often the case that the observations that would be most important for their weather forecasts would need to come from outside their borders. Traditional single-country, last-mile focused projects with no control over, or even coordination with, projects in

neighboring countries, therefore, often do not see a reasonable value proposition in investing in local observing systems. Ongoing failure to address this problem has been particularly detrimental to the availability of radiosonde observations, especially over Africa where availability of radiosonde data dropped by 50 percent between 2015 and 2020.<sup>34</sup>

### **5.3 A TECHNICALLY AND INSTITUTIONALLY COMPLEX UNDERTAKING THAT REQUIRES COORDINATED GLOBAL AND LOCAL ACTION**

**International development assistance is not always fit for purpose** as the global-local linkages required for effective hydromet services need assistance programs with much higher coordination levels than in other sectors. A different approach to support hydromet services is needed:

- within each country, ensuring systems work well together, with similar standards, and with balance in development along the meteorological value chain; and
- ensuring consistency with a common global approach.

**Without this approach, hydromet development support can result in the disproportionate and incompatible development of some parts of the value chain,** instead of enhancing and unifying the entire system. For example, in terms of observing systems, the technical standards of the equipment, the need for systems to work in conjunction with each other, and the operations and data sharing requirements, mean that for any project to be a success it must have a 'common global approach' - no matter where the project is located or the source of funding.

## **5.4 LACK OF A SUSTAINABLE FINANCING MODEL FOR BASIC OBSERVATIONS**

**In developing countries, SIDS and LDCs in particular, the lack of observations can be directly tied to the lack of local resources** to cover the costs for their generation and international exchange. The combination of very low income with large geographic responsibilities in LDCs and SIDS makes it particularly challenging to achieve a reasonable density of sustained observations in many parts of the world. Externally funded hydromet development projects typically include sustainability of the project's investment as a de-facto

pre-condition. After the project ends the country is expected to cover the long-term operations and maintenance costs of the infrastructure financed by the project. This does not reflect the global public goods nature of basic observational data. The Board of the Green Climate Fund (GCF) acknowledged that the GCF alone cannot ensure the sustainability of recently approved investments in basic observations (see box 5.1).

## **5.5 LACK OF EVIDENCE-BASED DIAGNOSTICS AND PRIORITIES**

**In order to decide where funds and resources can be most efficiently allocated, there needs to be a way of taking stock, assessing gaps and comparing the impact of different resource allocations.** However, the nature of the hydromet sector makes this particularly difficult. Whilst there are numerous assessment materials available, there is not a single easily understandable and coherent approach that would facilitate the monitoring and tracking of countries' hydromet capacity improvements.<sup>35</sup> There is an urgent need for a standardized, integrated, and operational tool to determine the specific capacity needs of developing countries in the areas of technical, institutional, human, and financial resources, for them to deliver hydromet services effectively.

### **Box 5.1 Enhancing climate information and knowledge services for resilience in five Pacific island countries**

In November 2020, the GCF approved a UNEP program for five Pacific SIDS; Cook Islands, Niue, Palau, Republic of Marshall Islands, and Tuvalu, with a total value of USD 49.9 million. The program supports the development of integrated climate and ocean information services, and people-centered hydromet services and early warning systems. The five countries were selected as initial case studies for the GBON country gap analyses.

The objectives will be achieved through four inter-related components: (i) a sustainable business delivery model for climate, hydromet, and early warning services; (ii) strengthened observations meeting GBON requirements; and impact-based forecasting; (iii) improved community preparedness, response capabilities and resilience to climate risks, including forecast-based financing; and (iv) enhanced regional cooperation for climate services.

The program aims to benefit at least 80 percent of the populations of the five countries through the adoption of diversified, climate resilient livelihood practices, with a 15–30 percent reduction in economic damages due to climate-related hazards, and enhanced productivity of climate risk-informed sectors.

The GCF Board and the Independent Technical Advisory Panel assessment of the project considered that compliance with GBON (see Box 7.2) was an innovative approach that strengthened the projects' value proposition and noted the critical role that GBON and SOFF will need to play in order to achieve long-term sustainability of investments in early warning and climate services. After the program implementation period, support from SOFF is expected to be available to continue maintaining GBON requirements in the five countries.

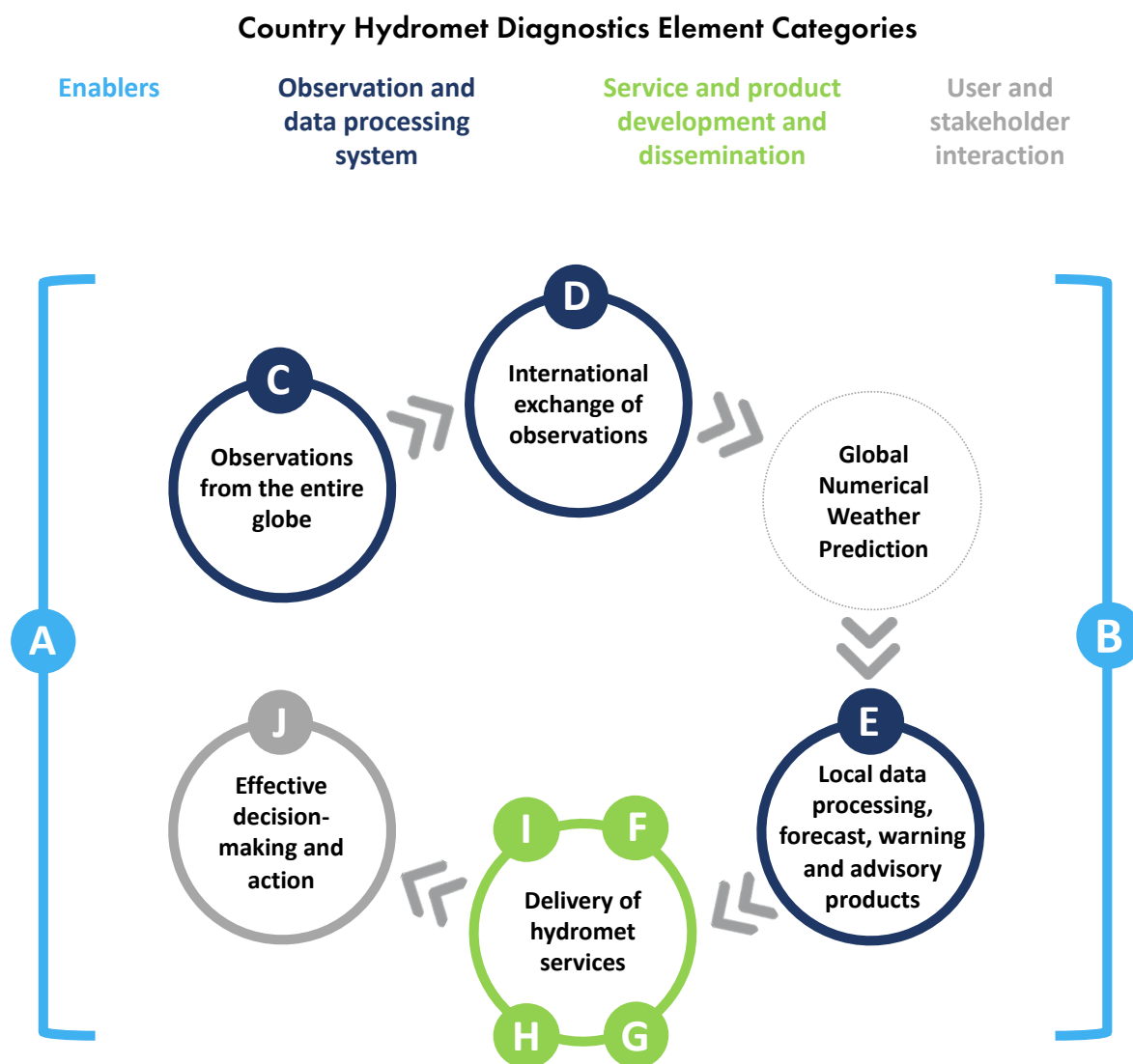




United Nations

## 6. ASSESSING THE HYDROMET GAP IN DEVELOPING COUNTRIES

The Country Hydromet Diagnostics (CHD) are a standardized, integrated, operational tool and approach for assessing National Meteorological Services (NMS), their operating environment, and their contribution to high-quality hydromet services.<sup>vi</sup> The CHD have been developed by the Alliance for Hydromet Development, spearheaded and technically guided by WMO.



**FIGURE 2:** Country Hydromet Diagnostics: Assessing national meteorological services along the value chain

vi. Some countries have combined meteorological and hydrological service bodies (NMHSs), whereas others have separate institutions for these services. The CHD specifically looks at how National Meteorological Services (NMS) – which for some countries will be their NMHS, and others just their NMS - contribute to the meteorological value chain.



**The CHD aim to inform hydromet policy and investment decision-making**, in particular to guide coordinated investments, and their sequencing, from members of the Alliance for Hydromet Development and other funders. Through the diagnostics, developing countries are expected to benefit from better targeted and aligned support as the assessment of maturity levels indicates where additional focus and support are needed.

The CHD allow for a more systematic approach to strengthening countries' hydromet capacity, whereby the coordination, sequencing, and programming of investments are led by the country considering global requirements. Providing countries with the opportunity to have a more coherent, integrated and planned approach to the sector can also help them to seek more effective funding to strengthen their hydromet capacity.

### Box 6.1 The ten elements in the Country Hydromet Diagnostics

The CHD provides a maturity assessment of the NMSs, their operating environment, and their contribution to high-quality hydromet services. The ten elements are grouped into four categories, helping to identify where additional focus and support may be needed:

#### Enablers

- A Governance and institutional setting.**  
Formalization of the NMS mandate and its implementation, oversight and resourcing.
- B Effective partnerships to improve service delivery.**  
Effectiveness of the NMS in bringing together national and international partners therefore improving the service offering.

#### Observation and data processing system

- C Observational infrastructure.**  
The level of compliance of the observational infrastructure and its data quality with prescribed standards.
- D Data and product management and sharing policies.**  
The nature of data and product sharing on a national, regional and global level.
- E Numerical model and forecasting tool application.**  
The role of numerical model output and forecasting aids such as remote sensed products in product generation; whether models are run internally and if the value-added compared to global models is determined.

#### Service and product development and dissemination

- F Warning and advisory services.**  
NMS role as the authoritative voice for weather-related warnings and its operational relationship with disaster and water management structures.
- G Contribution to climate services.**  
NMS role in and/or contribution to a national climate framework according to the established climate services provision capacity.
- H Contribution to hydrology services.**  
NMS role in and contribution to hydrological services according to mandate and country requirements.
- I Product dissemination and outreach.**  
The effectiveness of the NMS in reaching all public and private sector users and stakeholders.

#### User and stakeholder interaction

- J 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.



## 6.1 COUNTRY HYDROMET DIAGNOSTICS METHODOLOGY AND APPROACH

The CHD assesses ten elements (outlined in Box 6.1) along the meteorological value chain, including important contextual elements like the hydromet governance and institutional setting in the country. Descriptions for how to assess and evidence levels of maturity have been developed for each of these ten elements. This maturity model approach is used across a range of disciplines to assess organizational effectiveness and the ability for continuous improvement.<sup>36</sup> Five maturity levels are defined for each element of the CHD, as outlined in Annex 2.

The CHD uses a peer-review approach, following the example of the Organisation for Economic Co-operation and Development's (OECD) process for the peer review of member's development assistance.<sup>37</sup> As peers, advanced NMHSs from developed and developing countries undertake the diagnostics, following the tool's methodology. This enables coherent, standardized and authoritative assessments across countries.

The CHD are being developed through a phased and learning approach:

- **In the first phase, a multi-stakeholder working group supported the development of the CHD methodology and approach.** Alliance members then partnered with 16 countries to road-test the tool as either peer reviewers or reviewed countries: Afghanistan, Austria, Chad, China, Côte d'Ivoire, India, Kyrgyz Republic, Liberia, Maldives, Morocco, Myanmar, Nigeria, North Macedonia, Sierra Leone, Switzerland, and Turkey. The COVID-19 pandemic restricted travel, meaning that all peer-review assessments were conducted remotely. To conduct the assessment, peer-reviewers made use of the WMO's Community Platform datasets which contain information suitable for assessing many of the element maturity levels for each NMHS. Reviewers worked in collaboration with the country's WMO Permanent Representative and their teams, respective country stakeholders, and Alliance members to obtain additional information necessary to complete the full assessment of each of the ten elements. CHD reports were then drafted by reviewers in consultation with the WMO Secretariat support team, which also moderated the process, ensuring consistent application of the assessment tool across all countries. Following completion of the assessments, feedback was collated from all participants to inform

refinement and scaling-up of the tool in the next phase. The road-testing was completed in June 2021, and the results are summarized in section 6.2.

- **The second phase** will see the tool being refined based on the lessons learned from phase one, again supported by a multi-partner working group. The updated CHD tool will be offered to Alliance members that request the diagnostics for the initial stage of project development in a country.
- **In the third phase**, the delivery of the CHD will be upscaled. The tool will become a mandatory first step of the SOFF 'readiness phase' (see section 7.2 for descriptions of the SOFF phases). Assessments will be periodically updated for all SOFF supported countries to track progress in closing the capacity gap and inform future investment priorities.

## 6.2 RESULTS FROM INITIAL COUNTRY HYDROMET DIAGNOSTICS APPLICATION

**The road-testing highlighted important gaps in the assessed countries, providing opportunities for future targeted interventions.** The assessments also substantially improved the availability of information from the assessed countries. The maturity levels from all the participant countries are summarized in Table 6.1, and cross-country analysis of the results are provided in the next section. A selection of CHD summaries covering a range of NMS maturities is provided in Boxes 6.2, 6.3, 6.4 and 6.5. All assessments are publicly available.<sup>38</sup>

**Table 6.1:** Maturity levels, on a scale from 1 to 5, from Country Hydromet Diagnostics road-test undertaken with eight NMSs during spring 2021. Maturity Level 5 indicates the greatest maturity.

Country	Peer reviewer	Supported by	Country Hydromet Diagnostic Elements									
			1.Enablers		2.Observation and DPS			3.Services and Products			4.Users	
			A. Governance	B. Partnerships	C. Observations	D. Data and product sharing and policies	E. NWP model and tools	F. Warning and advisory	G. Climate services	H. Hydrology	I. Dissemination and outreach	J. Value of products and services
Afghanistan	Turkey	WMO	2	3	2	2	2	3	1	2	2	1
Chad	Morocco	WMO	2	1	1	1	2	1	2	2	1	1
Côte D'Ivoire	Morocco	UNDP	2	3	2	2	2	2	3	1	1	2
Kyrgyz Republic	Switzerland	World Bank	3	3	2	2	3	3	1	3	3	2
Liberia	Nigeria	AfDB	2	2	1	1	1	1	1	1	1	1
Maldives	India	UNEP	2	3	3	3	3	3	1	1	3	2
North Macedonia	Austria	GCF	3	3	2	3	2	2	3	2	2	3
Sierra Leone	Nigeria	AfDB	2	2	2	2	2	2	1	1	2	1

Maturity level key - 5 being the most mature:

1	2	3	4	5
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## Box 6.2 CHD Liberia

Critical value chain elements									
1. Enablers		2. Observation and DPS			3. Service and Product				4. Users
A. Governance	B. Partnerships	C. Observations	D. Data and product sharing and policies	E. NWP model and tools	F. Warning and advisory	G. Climate services	H. Hydrology	I. Dissemination and outreach	J. Value of products and services
2	2	1	1	1	1	1	1	1	1

**Reviewed by:** Nigerian Meteorological Agency.

**Supported by:** African Development Bank.

Decades of low investment coupled with fourteen years of civil war have completely disrupted Liberia's Met Service which can be characterized by:

- Only a minimal observations network
- Unreliable broadband internet connectivity
- No access to NWP, low-orbit satellite or weather radar data
- No capacity to issue forecasts or warnings
- No climate or hydrological services
- No channels to reach weather-vulnerable communities

These capacity deficits have particularly negative impacts on rural Liberian communities where there are numerous small-scale farmers who are highly dependent on natural resource-based livelihoods. In urban areas, climate-related and water-borne diseases, and other negative impacts threaten lives, livelihoods, and property.

In response to these challenges, the African Development Bank recently launched a GCF supported project to build Liberia's hydromet capacity, and the Economic Community of West African States declared its commitment to support the development of hydromet services in West Africa, stressing the importance of last-mile connectivity.

## Box 6.3 CHD North Macedonia

Critical value chain elements									
1. Enablers		2. Observation and DPS			3. Service and Product				4. Users
A. Governance	B. Partnerships	C. Observations	D. Data and product sharing and policies	E. NWP model and tools	F. Warning and advisory	G. Climate services	H. Hydrology	I. Dissemination and outreach	J. Value of products and services
3	3	2	3	2	2	3	2	2	3

**Reviewed by:** ZAMG, Austrian Meteorological Service.

**Supported by:** Green Climate Fund.

The Republic of North Macedonia is a small, landlocked country with a highly diverse topography and eight climatic regions ranging from sub-mediterranean to alpine mountainous, all of which are vulnerable to a variety of hydromet-related hazards.

In assessing the NMS, the CHD identified:

- Ageing and under-maintained observations network
- A backlog of historical data in need of digitizing
- A lack of IT capacity for archiving and service development
- Only basic warning services, not Common Alerting Protocol (CAP) enabled
- No process for feedback, evaluation and learning, or development of new products

However, on a positive note:

- Forecasting is aided by access to global and regional models
- There is significant potential for additional services

The underlying issue which raised the most concern was an aging workforce, with a weak pipeline for recruiting and developing the next generation of professionals. This risks further downgrading of the maturity levels as staff retire. Many countries face similar human resource challenges which need to be recognised and addressed.

## Box 6.4 CHD Kyrgyz Republic

### Critical value chain elements

1. Enablers		2. Observation and DPS			3. Service and Product				4. Users
A. Governance	B. Partnerships	C. Observations	D. Data and product sharing and policies	E. NWP model and tools	F. Warning and advisory	G. Climate services	H. Hydrology	I. Dissemination and outreach	J. Value of products and services
3	3	2	2	3	3	1	3	3	2

**Reviewed by:** Federal Office of Meteorology and Climatology MeteoSwiss in collaboration with the Federal Office for the Environment.

**Supported by:** World Bank, Central Asia Water and Energy Program, EU, Switzerland, UK.

The Kyrgyz Republic is a landlocked country in Central Asia, with predominantly mountainous terrain. The country's climate is continental with significant local variations, and has a rural population and agricultural economy that is extremely vulnerable to the impacts of climate change.

In recent years the NMS has received significant investments for modernization, and continues to benefit from the support of international partners including the World Bank.

In assessing the NMS, the CHD identified:

- Recently upgraded observations network but insufficient maintenance staff, especially for remote locations
- A strong NWP team but reliant on one expert
- A legal obligation to charge for data, restricting access
- Forecasting aided by access to global and regional models
- National warning services but lacking user engagement
- Insufficient specialists to contribute to national climate services
- Insufficient expertise in marketing and product development

Like North Macedonia, the greatest challenge is sustaining a workforce of qualified professionals in relevant scientific, technical and ICT disciplines and customer facing roles.

## Box 6.5 CHD Côte d'Ivoire

### Critical value chain elements

1. Enablers		2. Observation and DPS			3. Service and Product				4. Users
A. Governance	B. Partnerships	C. Observations	D. Data and product sharing and policies	E. NWP model and tools	F. Warning and advisory	G. Climate services	H. Hydrology	I. Dissemination and outreach	J. Value of products and services
2	3	2	2	2	2	3	1	1	2

**Reviewed by:** DGM, Moroccan Meteorological Service.

**Supported by:** United Nations Development Program.

The Republic of Côte d'Ivoire in West Africa is in the transition area between the equatorial and tropical weather patterns. As climate change impact these climatic zones, hotter average temperatures, far more inconsistent rainfall, and rising sea levels are already being observed, with increasing impacts on vulnerable populations and agriculture, with cocoa production of particular concern.

In assessing the NMS, the CHD identified:

- NMS well established within government, but lacks clarity in its mandate as the authoritative voice for meteorology
- Inadequate budgets for innovation and service development
- Need for additional, trained staff to strengthen service delivery
- Land-based observations meet minimum GBON requirement
- Lack of resources for maintenance of observation network
- Limited ability to access NWP products from regional and global centers
- National warning services available but lacking user engagement with key sectors
- National climate services established with support from UNDP
- Opportunities for greater user engagement and outreach

The Government of Côte d'Ivoire and l'Agence Française de Développement have earmarked a 28 million Euros investment for the modernization of the NMS under a three-year project to improve the meteorological system of vigilance, weather warnings, and climate services. The NMS has clearly benefited from recent investment and partnership programs.



## 6.3 ANALYSIS OF RESULTS

**Among the eight assessments that were concluded, there was a wide range of maturity across the different elements** – from several countries at level 3 for the majority of elements, to some countries showing the lowest levels of maturity, level 1 or 2, for most or all elements. None of the NMSs were assessed as having maturity higher than level 3 for any element, while the weakest lacked even the most basic capacity in terms of equipment, skills or even basic user engagement, despite the clear and growing risks to vulnerable communities.

**The elements receiving the lowest average maturity level were observations, contribution to climate services, contribution to hydrological services, and use and national value of products and services.** The deficiencies in observing systems are particularly concerning given that the lack of capacity to deliver high-quality observations highly undermines the effectiveness of the rest of elements of the value chain. These findings illustrate and confirm the challenges set out in **Chapter 5**, highlighting specific areas of weakness and underlining the importance of the Alliance’s commitment to close the hydromet gaps, especially in LDCs and SIDS.

**Despite the many gaps identified, there were several encouraging findings** from different NMSs, such as Côte d’Ivoire and Chad which, despite their limited capacity, are recognized as making significant contributions to climate services, enabled by regional partnerships and access to data and products from global centers.

The next section elaborates on some of the key findings of the CHD road-testing in relation to each of the ten diagnostic elements.

### A. GOVERNANCE AND INSTITUTIONAL SETTING

As a government institution, the success of the NMS depends critically on how it relates to other government bodies, its legislative status and how it is funded. Among the factors considered are strategic, operational and risk management plans and their reporting, access to professional skills, and the NMS’s experience in managing internationally funded hydromet projects. The CHD assessments found that:

- Whilst many NMSs have a clearly defined status within their government, there is wide variation in the strength of the legal mandates under which they operate, and many do not have clearly defined strategic plans or objectives.



- Government budgets for NMSs are often substantially below their staffing and operating costs, often leading to the neglect of essential maintenance of equipment and technology, and a reliance on external funding.
- Some NMSs raise additional revenue from direct data sales or service provision, but this only has marginal impact on budgets and restricts the potential for a vibrant partnership with the private sector that will use these data for maximum impact. In the context of the evolving WMO data policy (see Box 7.2) the focus on marketing strategies for hydromet services, rather than data, could be substantially developed. Most NMSs have neither the capacity nor the skills to achieve this alone, but there may be opportunities for public-private partnerships.
- NMSs' experiences with internationally funded hydromet projects varies. Some reported very good engagement and successful outcomes, while others cited difficulties due to disconnects with lead Ministries and lack of engagement with project planning and implementation, resulting in sub-optimal outcomes.
- One of the greatest challenges for many NMSs is in the recruitment, development and retention of staff skilled in scientific, technical, and ICT disciplines. This is exacerbated by inadequate financial resources and lack of access to educational and training opportunities for leadership, scientific and engineering skills. The ageing workforce of experienced staff in the NMSs assessed will present a major challenge as staff retire over the coming decade.

## B. EFFECTIVE PARTNERSHIPS TO IMPROVE SERVICE DELIVERY

Partners included in the diagnosis are other government institutions, the private sector, academia, international NGOs, and climate and development finance partners. Such partnerships help foster joint research and innovation, develop new or enhanced product and services, and improve service reach.

- Most NMSs state that they work effectively with other government agencies. However, the extent to which these partnerships are formalized varies widely, and in the weakest NMSs such partnerships deliver little benefit.

- There are also some excellent examples of international partnerships, at a sub-regional, regional and global level. These make a substantial contribution to the overall effectiveness of those NMSs that engage in them. In particular, the Regional Climate Outlook Forums were cited as a key enabler of seasonal advice and early warnings.<sup>vii</sup>
- By contrast, there were few examples of effective partnerships with academia and none with the private sector. This represents a significant gap, and therefore an important opportunity in capacity building.
- Projects with international development and finance partners were widely cited. However, these are not always well coordinated with and among the different development partners, which creates a major challenge for governments to ensure coherence and effectiveness.

## C. OBSERVATIONAL INFRASTRUCTURE

Observations underpin hydromet services. The CHD reviews the weather observing equipment, networks, and management procedures by which data are gathered and quality assured, and the extent to which they are able to meet the expected standards set out by the GBON (see Box 7.2 in Chapter 7).

- The countries' observational infrastructure ranged from LDCs with very insufficient basic infrastructure to the Maldives, Kyrgyz Republic and North Macedonia where the density of surface observing networks is already very close to being compliant with the GBON requirements. However, radiosonde data from the upper atmosphere are deficient in all but two of the countries.
- Whilst some NMSs have enhanced their observation networks through internationally funded projects, there remain significant challenges in the support and maintenance of these networks, including in the calibration, quality assurance, and the necessary IT provision for data management, sharing, and archiving.
- In some countries, there remains a large quantity of historical data that are archived in paper form and is not easily accessible. Therefore, data rescue and digitization is an important priority.

vii. Regional Climate Outlook Forums produce consensus-based, user-relevant climate outlook products in real time in order to reduce climate-related risks and support sustainable development for the coming season in sectors of critical socioeconomic significance for the region in question. For further information see <https://public.wmo.int/en/our-mandate/climate/regional-climate-outlook-products>

#### D. DATA AND PRODUCT SHARING POLICIES

Assessed at the national, regional and global level, the factors considered for this element include compliance with the expected GBON international data sharing requirements (see Box 7.2 in **Chapter 7** on the global assessment), as well as access to NWP and satellite data and products from external sources.

- NMSs are often constrained by the inability to access data digitally due to the lack of effective data management and archiving systems.
- There is a wide variety in data policies and sharing arrangements. In some countries, data policies strictly limit the amount of free data that can be shared in order to create revenue. However, when looking at the receipts, this monetization only covers, at best, a very small proportion of NMS budgets.
- The availability of NWP data and forecast products through international partnerships is highly beneficial to many smaller NMSs. However, access remains a challenge for some, and in one country without internet access, forecasters are not even aware of global NWP products.

#### E. NUMERICAL MODEL FORECASTING TOOL APPLICATION

Whilst not every NMS has the capacity – or the requirement – to operate its own NWP systems, applying model output and other numerical forecasting tools is a key enabler of effective service delivery. The CHD review NWP systems run internally at the NMS, as well as the NMS's access to these systems and other data sources, and how these tools are used to create value.

- NMSs rely primarily on WMO Global Producing Centres for NWP and satellite data and products.<sup>viii</sup> However, the lowest scoring NMSs do not have the reliable broadband connectivity needed to access these.
- In some cases, limited area models are in use.<sup>ix</sup> These are technically challenging and costly to maintain and in addition, without local data assimilation, they add little, if any, value in the forecast process.
- One of the assessed countries has been able to develop modelling capability through the exceptional skill of a



single employee. Whilst this is impressive, and enhances the NMS's capacity, there is clearly a sustainability risk in that competency being limited to that one person.

- Probabilistic data are increasingly being used to develop risk-based guidance, especially in longer range forecasts and climate services. This is an essential component of impact-based forecasting and warning.
- The weakest NMS in an LDC shows large and fundamental capacity gaps and does not have the information or skilled expertise to produce forecast services.

#### F. WARNING AND ADVISORY SERVICES

Having an NMS recognized as the authoritative voice and having standard operational procedures in place with relevant national institutions helps to maximize the effectiveness of the value chain. The CHD review the scope and extent of warning services, the NMS's relationships with civil resilience bodies, and whether warnings include an assessment of the likely impact on communities.

- Most NMSs have at least a basic national warning capability. However, warnings are often generic in nature and distributed through undifferentiated channels. The lowest scoring NMSs do not have the capacity to produce any operational warning services.

viii. WMO Global Producing Centers are nominated NWP centers that provide WMO Members with a range of forecast products based on their global prediction models.

ix. Detailed local information about weather and climate is provided by downscaling of global model output, typically obtained by using a fine-scale Limited Area Model (LAM).





Mohd Nor Azmil Abdul Rahman



Ministry of Defense, Peru

- Most NMSs do not systematically verify warning accuracy or effectiveness, with little or no user engagement or feedback.
- In all cases warnings are threshold based, meaning they are only triggered when a threshold is passed. Impact-based warning services are yet to be developed.
- The Common Alerting Protocol (CAP)<sup>39</sup> is not yet adopted for hydromet warnings across any of the assessed countries, although some countries are working towards this.

## G. CONTRIBUTION TO CLIMATE SERVICES

Whilst the NMS is not the primary agency for national climate service provision in many countries, it still has a key role to play in monitoring, data provision, and accessing resources from the international hydromet community. This element reviews the NMS's role in and contribution to climate services within its national and regional context.

- Even where NMS capacity is very limited, there is potential for climate services to deliver substantial value, drawing on data from WMO Global Producing Centers and support from regional partnerships. However, some NMSs are not using these resources.
- In some cases, the NMS does not play as full a role as

it has potential for in national climate services due to structural barriers such as inter-departmental relationship challenges or restrictive data policies.

- Capacity gaps limit NMS contributions to national climate services, including inadequately skilled staff, and a lack of the data management and archiving systems required to curate and serve historical hydromet data.

## H. CONTRIBUTION TO HYDROLOGY SERVICES

There is a spectrum of operating structures for hydrology services across different countries, from independent meteorological (NMS) and hydrological institutions (NHS) to fully integrated NMHSs. The CHD are currently defined to focus on the meteorological functions that support hydrological service delivery, so this element considers how weather data and forecasts contribute to hydrology services, irrespective of institutional boundaries.

- The level of interaction between meteorologists and hydrologists varies across the NMSs assessed, with some excellent examples of cooperation but also some serious disconnects even across departments.

- In some instances, the lack of standard operating procedures leads to an ad-hoc approach to communication at times of heightened risk.
- Management of hydrological observation networks presents particular challenges, especially in remote areas. However, data from such areas can be critical in providing early indication of adverse conditions.

## I. PRODUCT DISSEMINATION AND OUTREACH

The 'last mile' effectiveness of the hydromet services relates to how they are received, understood, and acted upon. The CHD look at the NMS's use of broadcast and social media in communicating with the wider public, its role in education and awareness raising, and the effectiveness in reaching marginalized communities. Some Alliance partners have seen significant successes working with community-based organizations to help disseminate weather and climate services. NMSs can benefit from closer collaboration with other national agencies to leverage existing networks of community-based stakeholders (e.g., farm extension services) to help address the 'last mile' challenge.

- Web-based technologies provide powerful means to reach large audiences with hydromet forecasts and warnings. Most NMSs lack the skills or resources to develop effective websites, apps and social media presence.
- Most NMSs have a good relationship with national TV and radio broadcasters, and in some instances have their own studios.
- Few NMSs have an outreach program beyond television and radio, although some countries do conduct some

outreach with farmers and schools and participate in outreach events of other regional disaster management authorities.

## J. USER ENGAGEMENT WITH PRODUCTS AND SERVICES.

Whilst outreach and dissemination can help users and stakeholders engage with products and services, using and identifying value in products requires a different type of ongoing engagement. This engagement can also be used to inform service development and improvement. Formal processes and platforms for dialogue and feedback can help support development of services by co-design improvements with the end user. Independent user satisfaction surveys can also provide valuable feedback to help quantify impact and inform service development. The CHD assesses this type of audience use, engagement, and valuation by looking at the explicit feedback and engagement processes NMSs formally have in place to understand end user interactions with and value given to products and services.

- None of the assessed NMSs have a formal process or platform for user feedback or service co-design. Market research is only undertaken as part of international capacity development projects.
- User engagement is given low priority across all NMSs. Therefore, NMSs are unable to fully understand how their products and services are used and valued. This indicates that they do not possess the mechanisms to know how to develop services for the end user to receive maximum benefit.

### Box 6.7 Demonstrating the value of hydromet services

Partnerships with other agencies or the private sector can be important in overcoming skills gaps. For example, the Climate Investment Funds, through its Pilot Program for Climate Resilience, worked with mobile telecoms companies to develop and deploy mobile apps for dissemination of flood and severe weather warnings to farmers. Technological improvements along with focused involvement of local communities and promotion of services through community leaders can be effective tools to explain the system benefits. This can contribute to significantly shifting the perceived value of hydromet services and therefore Governments are more likely to allocate budgets to cover the ongoing costs.

[Source: CIF (2020) Strengthening Weather and Climate Information Services.]





Oxfam East Africa





WMO



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Launch of radiosonde (weather balloon) in Nadi, Fiji.

## 7. CLOSING THE BASIC OBSERVATIONS GAP – THE SYSTEMATIC OBSERVATIONS FINANCING FACILITY

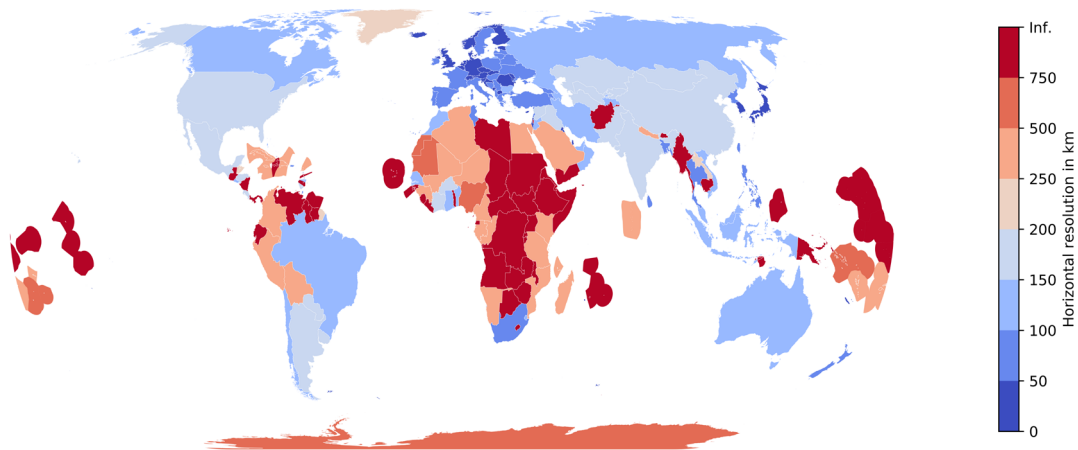
As seen in the previous chapters, developing countries, in particular SIDS and LDCs, face several challenges to deliver effective hydromet services. One particularly critical challenge is the missing basic surface-based observations that need to be generated and shared in order to realize the full benefits of the whole value chain. Therefore, WMO and the other members of the Alliance for Hydromet Development are committed to establishing the Systematic Observations Financing Facility (SOFF).

### 7.1 LACK OF SURFACE-BASED OBSERVATIONS - A PERSISTENT GLOBAL PROBLEM

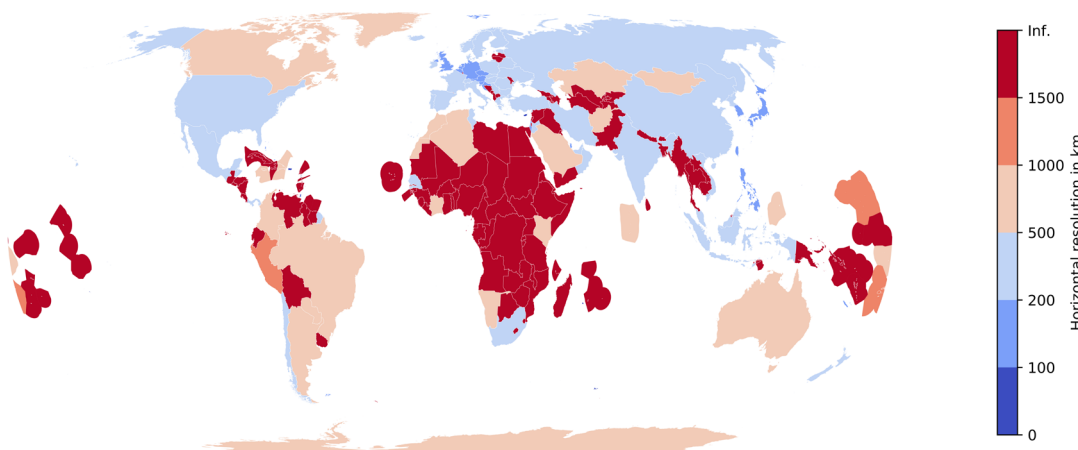
Despite several decades of significant investments made in strengthening the meteorological sector in developing countries, many areas of the globe remain far from achieving the goal of continuous, robust, real-time international exchange of surface-based observations.

Figures 3 and 4 opposite show the capabilities of national observing networks measured against the requirements for the GBON (see Box 7.2) for the two categories of surface-based observations (land-based and upper-air observations). Blue shades indicate areas that are either close to or currently meeting GBON requirements. Red shades indicate areas that are farther from meeting the GBON requirements. **The maps show that SIDS and LDCs are currently far from meeting the GBON requirements**, and this can largely be attributed to a lack of infrastructure and capacity. In these areas, not only will it be nearly impossible to provide high-quality forecast products – in most cases, it will be impossible to even assess how good or how bad those forecast products are, since there are no observations against which they can be verified. Satellite observations can help ensure a realistic





**FIGURE 3:** This map shows the horizontal resolution<sup>x</sup> of surface observations based on stations actively reporting in January 2020. Source: WMO Secretariat.



**FIGURE 4:** This map shows the horizontal resolution of upper air observations based on stations actively reporting in January 2020. Source: WMO Secretariat.

#### Box 7.1 What is SOFF?

- A global initiative to address a persistent problem in a global and systematic manner – missing surface-based weather and climate observations from developing countries.
- An initiative with an exclusive focus on the initial part of the meteorological value chain that creates the foundation for effective policy and investment decisions.
- A dedicated and innovative financing mechanism that provides grants and technical assistance, with a focus on LDCs and SIDS, to enable sustained compliance with the GBON requirements.
- A mechanism that is built on peer-to-peer collaboration and support among national meteorological services, harnessing their operational experience as providers of peer technical advice and assessments.
- A commitment and priority of the Alliance for Hydromet Development, supported by beneficiary countries and international partners.

x. Horizontal resolution is a measure of the geographic density (average horizontal spacing of individual stations) of the observing network. The lower the distance measured in Km between stations, the higher is the resolution of the GBON network.

model representation of large-scale atmospheric dynamics in the upper layers of the atmosphere but cannot be used to verify forecasts of surface weather. Without the exchange of surface-based observations, the rest of the value chain has an inadequate base on which to build.

## 7.2 CREATING SOFF – A COMMITMENT OF THE ALLIANCE

**The goal of SOFF is to contribute to strengthening climate adaptation and resilient development through improved weather forecasts, early warning systems, and climate information services.** SOFF will contribute to this goal through the sustained collection and international exchange of high-quality surface-based weather and climate observations in compliance with GBON. As a result, all countries will benefit from improved weather and climate prediction products from the Global Producing Centers. These global prediction products, and their adaptation for local conditions, will

underpin adaptation and resilient development policy and investment decisions and increase their effectiveness.

**SOFF aims to achieve sustained GBON compliance in all 67 LDCs and SIDS.** This would translate as an up-to 28-fold increase of surface data and 16-fold increase of upper-air data internationally exchanged from these countries. According to a recent World Bank report, the potential benefits directly enabled by the full implementation of GBON (via its implementation in countries with the largest current data gaps) are estimated to exceed USD five billion per year, due to improvements in weather prediction alone. For every dollar at least 25 US dollars in socio-economic return could be realized.

**SOFF will provide its support in three phases:** readiness, investment, and compliance.

- **Readiness** - SOFF will support countries to assess their national hydromet status and gaps through the Country

### Box 7.2 The Global Basic Observing Network (GBON) – addressing the problem of missing data

**In order to address the observational data gaps and help ensure a reliable supply of observational data of the most important variables to the NWP systems, 193 WMO Members (states and territories) decided in 2019 to implement the GBON<sup>xi</sup> and to initiate the development of regulatory material for this network, with the aim of having the regulations take effect in January 2023.**

**The GBON design is based on up-to-date observational requirements for Global NWP assembled by technical experts working under the WMO Commission for Observation, Infrastructure and Information Systems.**

Drawing on 20 years of NWP observational data impact studies coordinated by WMO, the GBON regulations specify in clear, quantitative terms the commitments of the WMO Members to acquire and exchange certain observations: which parameters to measure, how often, at what horizontal and vertical resolution, when and how to exchange them, and which measurement techniques are appropriate to use.

**The implementation of GBON will represent a major strengthening of the global observing capabilities, and the immediate result would be the availability of better model guidance for weather and climate monitoring and prediction at all spatial scales.** This would enable the provision of vastly improved and enhanced weather and climate services at global, regional, national and local levels to all WMO Members. The improvement in service delivery capabilities would be especially large in the areas where the current coverage of observations is poor.

**The successful implementation of GBON goes hand in hand with the implementation of SOFF and of the WMO data policy.** WMO is currently updating its data policy (WMO Unified Policy on International Exchange of Earth System Data) and a major element of the new policy is that it establishes free and unrestricted access to improved model and analysis data for all WMO Members in return for their exchange of observational data. This will allow them to significantly improve and expand their service delivery capabilities. SOFF support to LDCs and SIDS is essential to be able to realize the benefits of the revised WMO Data Policy and GBON.

The World Meteorological Congress in October 2021 is expected to further advance decisions on these three initiatives.

xi. WMO Unified Data Policy Resolution, available at: <https://public.wmo.int/en/unified-wmo-data-policy-resolution-cg-ext-21>



Hydromet Diagnostics (see Chapter 6), define the national GBON gap and develop a plan to close the GBON gap. Readiness support will be offered to all OECD Official Development Assistance eligible countries, in addition to LDCs and SIDS.

- **Investment** - LDCs and SIDS will receive support for capital investments in GBON infrastructure and for developing human and institutional capacity to operate and maintain the observing network. For its investment phase, SOFF will work through multilateral development banks and UN organizations who are part of the Alliance as implementing entities. They will blend their resources and embed SOFF into their larger country hydromet investment operations, either within a country or at sub-regional level to create economies of scale.
- **Compliance** - LDCs and SIDS will receive support to sustain compliance with GBON in the long-term. This will include the provision of results-based finance for GBON compliant beneficiary countries to contribute to operational and maintenance costs and provide incentives for continuous data sharing.

## 7.3 SOFF FEATURES

**SOFF will address several of the challenges outlined in Chapter 5 in a systematic manner by:** (i) deploying a global approach with sustained international data exchange as a measure of success; (ii) providing finance for both investment and recurrent costs; and (iii) enhancing technical competence and effective collaboration. Through the combination of these features, SOFF will channel international support to strengthen countries' basic observation capacity in new, more effective and sustainable ways.

**First, SOFF actions will be guided by an optimal and internationally agreed global design and corresponding metrics – GBON requirements.** For each country, the specific data exchange requirements will be defined by its commitments to GBON. SOFF will then provide the resources for beneficiary countries to close the GBON gap. In other words, GBON metrics will guide the 'right' level of investments. Most importantly, the GBON will allow for an objective assessment of countries' compliance with its obligation for the international exchange of basic surface-based observations. Success - of countries and SOFF – will be measured by the amount and quality of internationally exchanged data.

**Second, SOFF finance will be grants-only, be predictable and long-term, contribute to operations and maintenance costs in addition to investment costs, and use a results-based approach for payments.**

- **Grant finance.** In view of scarce resources, governments need to make trade-off decisions between investments in observations, investments in other parts of the hydromet value chain or investments in other sectors of the economy. This inevitably disadvantages investments in observations where the benefits reach beyond the country making the investment. SOFF will provide additional international resources beyond existing country envelopes set by development and climate finance partners. Grant-only support for SIDS and LDCs is justified by: (i) the global public goods dimension of their contribution to GBON; (ii) their limited fiscal and institutional capacity; (iii) their debt sustainability challenges and rapidly escalating post-COVID debt impacts; (iv) their high vulnerability to extreme weather events and the impacts of climate change; and (v) the global call on all developed countries and climate finance providers to increase the level of grant finance to support the most vulnerable, in particular for adaptation.
- **Predictable long-term finance.** SOFF will provide long-term support, beyond time-bound projects. The long-term nature of support and the predictability of resources will allow countries to make corresponding policy and investment decisions. For example, countries could consider establishing public-private partnerships in support of the generation and exchange of observations that to be successful require long-term engagements.
- **Finance for operations and maintenance.** Achieving sustained GBON compliance in SIDS and LDCs requires not only capital expenditures (e.g. resources to purchase or improve fixed assets like observations equipment), it also requires the provision of finance for operations and maintenance. SOFF will substantially contribute to operations and maintenance costs –over the long term (see above) and through results-based finance (see below).
- **Results-based finance.** In the compliance phase, SOFF will ensure that countries have the means and incentive for the sustained generation and international exchange of observational data through the provision of results-based finance to GBON compliant countries.



**Third, operating and maintaining observing networks and internationally exchanging the data is a complex undertaking**, in particular for countries with limited human and institutional capacity and challenging country circumstances. SOFF will enhance beneficiary countries' capacity by systematically harnessing the operational experience of advanced NMHSs through the provision of hands-on peer-to-peer technical assistance and assessments, including South-South peer support. SOFF will also systematically capture lessons learned and share them with all stakeholders.

**SOFF will ensure coordinated action to strengthen countries' basic observations capacity at the global and country level.** SOFF will provide a mechanism for effective collaboration and coordination among the several scientific, financial, and operational partners involved in strengthening the weather and climate observing system in developing countries. SOFF will effectively bring together all major partners with a clear focus on the primary links of the meteorological value chain that can only be implemented with a globally coordinated approach and with coherent action at the country level to succeed. In order to address the problem of multiple development and climate finance partners supporting different parts of a country's basic observing network in a fragmented manner, relying on different vendors with interoperability challenges and requiring different spare parts, SOFF will close the GBON investment gap through standardized integrated interventions for each beneficiary country or sub-region.



Automatic Weather Station at Goroka Airport, Papua New Guinea.





WMO

## 8. THE ALLIANCE GOING FORWARD: FURTHER ACTIONS TO CLOSE THE HYDROMET GAP

Since its launch at COP25 the Alliance has substantially advanced its work on its three initial priorities: developing the CHD as the common assessment and benchmarking tool; developing SOFF concept and design and advocating for a new way of financing basic observations; and producing the first Alliance Hydromet Gap Report.

Going forward, the Alliance commits to:

- **Establishing SOFF.** Alliance members will continue to jointly pursue the creation of the SOFF, aiming to announce it at COP26 and making it operational in 2022. Alliance members will continue supporting final SOFF design and fundraising.
- **Fine-tuning the CHD and systematically applying them.** The CHD will be refined based on the road-testing results, applied whenever new projects are developed, and fully integrated into SOFF as a centrepiece of its readiness phase. This will allow for effective scaling up of targeted and coordinated hydromet finance. Whilst many Alliance members foresee an increase in hydromet funding,<sup>xii</sup> this will need to be coordinated and strategically placed to maximize benefits from the hydromet value chain. The hydromet gaps identified by the CHD

present the opportunity to define structured long-term programmatic approaches for transformational change of the entire hydromet value chain in these countries. The opportunities to deepen cooperation at the country level, informed by global requirements, and undertake coordinated or joint programmatic approaches beyond individual projects will be continuously explored.

- **Continue engaging with the private sector to explore innovative and financially viable business models to close the hydromet gap in developing countries.** Along with partner countries, Alliance members will explore financially viable business models that can provide sustainable solutions for modernizing hydromet infrastructure and enhancing hydromet services. SOFF creates an important opportunity for deploying public-private business models for establishing, operating and maintaining basic observing systems.
- **Explore ways to enhance the effectiveness and range of early warning systems in a more coordinated and systematic manner,** taking advantage of the increasing body of knowledge about what constitutes effective multi-hazard early warning systems. Collaboration with partners such as United Nations Office for Disaster Risk Reduction (UNDRR), the Climate Risk and Early Warning Systems Initiative (CREWS)<sup>40</sup> and other 'last mile' support initiatives and financing mechanisms will be strengthened.
- **Continue to increase awareness** among other public international development, humanitarian, and financial institutions to strengthen developing countries' hydromet capacity, in recognition of the importance of coordination to realize the full benefits of the hydromet value chain.

The Alliance will capture lessons learned and progress from its scaled-up work to close the hydromet capacity gap in the second Hydromet Gap Report, envisioned for 2023.

xii. For instance, the GCF expects to reach a USD 2.2 billion hydromet portfolio by 2030, equivalent to a rise of 150%. And the UNDP expects a 50% increase of investments in hydromet services by 2030.

# ANNEXES

## **Annex 1 - Alliance Declaration - Madrid, 10 December 2019**

### **ALLIANCE FOR HYDROMET DEVELOPMENT**

*Uniting our efforts to close the capacity gap on high-quality weather forecasts, early warning systems, and climate information as the foundation for resilient and sustainable development*

We,

International development, humanitarian and financial institutions providing assistance to developing countries, jointly with the World Meteorological Organization and the World Bank, are herewith creating the Alliance for Hydromet Development.

As members of the Alliance, we are resolved to scale up and unite our efforts to achieve the common goal of closing the hydromet capacity gap on weather, climate, hydrological, and related environmental services by 2030. The Alliance aims to increase effectiveness and sustainability of hydromet investments through collective action.

We recognize with urgency the mounting impacts of climate change especially on the world's poorest and most vulnerable countries, and we note with concern that many developing countries are facing major capacity constraints to provide hydromet services as the foundation for resilient and sustainable development.

As members of the Alliance, we act within our respective resources and mandates and forge a collaborative partnership which recognizes and leverages our respective competencies and expertise.

We commit to the following actions to close the hydromet capacity gap by 2030:

#### **Article 1: Improving systematic observations for better data**

**We acknowledge** that the principles of the Paris Agreement, adopted by countries with which we work, include a call for cooperation and enhanced action on systematic observation of the climate system, and that any weather forecast, early

warnings and climate analysis depend on continued access to a robust and reliable supply of observational data from the entire globe.

**We note** with urgency that today important data are missing from many developing countries, and that this lack of observational data significantly limits the ability to produce timely and accurate forecasts, early warnings, and climate prediction.

**We commit** to strengthening the capacity of National Meteorological and Hydrological Services for sustained operation of observational systems and data exchange that meet WMO standards for minimum monitoring coverage and reporting frequency.

**We commit** to seeking innovative ways to finance developing country surface-based observations, aiming at the creation of a Systematic Observations Financing Facility that recognizes the economic value of observations as a global public good.

#### **Article 2: Enhancing support for better adaptation, mitigation and resilience**

**We acknowledge** that around the world, individuals, communities and countries are facing the impacts of a changing climate and that the Paris Agreement, adopted by countries with which we work, calls to strengthen scientific knowledge on climate in a manner that informs climate services and supports decision making.

**We note** the extensive body of knowledge developed by the Intergovernmental Panel on Climate Change and other bodies, including the Global Framework for Climate Services, and the need to downscale this knowledge for science-based decision making at national and sub-national scales.

**We commit** to strengthening national capacity for science-based and effective mitigation action, including by promoting global greenhouse gas information systems which are based on atmospheric observations and analysis.

**We commit** to strengthening the capacity of National Meteorological and Hydrological Services and other relevant national institutions to provide meteorological, climatological and hydrological information for science-based national



and sub-national adaptation planning and impact-based forecasting.

**We commit** to working towards common standards for climate-proofing investments in key sectors, built on best available science and identified sectoral needs.

### **Article 3: Strengthening early warning systems for improved disaster risk management**

**We recognize** the goal of the Sendai Framework for Disaster Risk Reduction that many of the countries with which we work have adopted, to increase preparedness for response and recovery and the target to substantially increase availability of and access to multi-hazard early warning systems.

**We commit** to promoting coherent and science-based multi-hazard national early warning systems, comprising better risk information, forecasting capabilities, warning dissemination, and anticipatory response mechanisms, taking advantage of the Climate Risk and Early Warning Systems Initiative.

### **Article 4: Boosting investments for better effectiveness and sustainability**

**We embrace** the principles of effective development cooperation, such as country ownership, focus on results, inclusive partnerships, and mutual accountability, reflected in the Addis Ababa Action Agenda on Financing for Development.

**We commit** to fostering programmatic approaches that go beyond individual projects, including systematically strengthening the Integrated Global Observing System as the backbone for better forecasts, early warning systems and climate information.

**We commit** to leveraging financial resources and expertise from the private sector by exploiting financially viable business models that provide sustainable solutions for modernizing hydromet infrastructure and enhancing services in developing countries.

**We commit** to underpinning development and climate finance with the best technical expertise, including by taking advantage of the Country Support Initiative and its expertise and knowledge from the WMO institutional network.

**We commit** to tracking progress on closing the capacity gap by 2030 through a joint regular Hydromet Gap flagship report, issued by the Alliance. The reports will include benchmarking of National Meteorological and Hydrological Services and facilitate knowledge generation, learning, and innovation.

### **Article 5: Accountability**

As members of the Alliance, we hold ourselves accountable to act on our commitments.

### **Article 6: Membership**

The Alliance for Hydromet Development represents the individual commitments of each of our institutions.

The actions of the Alliance to close the hydromet capacity gap are guided by the principles set out in various United Nations agreements, including the Sustainable Development Goals under the 2030 Agenda for Sustainable Development, the Paris Agreement under the United Nations Framework Convention on Climate Change and the Sendai Framework for Disaster Risk Reduction 2015-2030.

The Alliance is open for membership to all public international development, humanitarian and financial institutions providing assistance to strengthening developing countries' hydromet capacity.

The Alliance does not require additional funding from its members for its functioning.

### **Article 7: Secretariat**

The World Meteorological Organization provides the Secretariat function for the Alliance that facilitates communication, knowledge sharing, and manages the registry of Alliance members.

## Annex 2: Country Hydromet Diagnostics

The Country Hydromet Diagnostics (CHD) are a standardized, integrated, operational tool and approach for assessing National Meteorological Services, their operating environment, and their contribution to high-quality hydromet services. For each of the ten critical elements of the hydromet value chain, the CHD defines maturity levels, standardized indicators and data sources to be used, as set out below.

[Source: World Meteorological Organisation, [2020]. Country Hydromet Diagnostics]

ENABLERS		
A. Governance and Institutional Setting - Formalization of the NMS mandate and its implementation, oversight and resourcing		
Maturity level		Indicators
1	Weakly defined mandate; serious funding challenges; essential skills lacking; little formalized governance and future planning.	<ul style="list-style-type: none"><li>• Act or Policy describing the NMS legal mandate and its scope.</li><li>• Existence of Strategic, Operational and Risk Management plans and their reporting as part of oversight and management.</li><li>• Government budget allocation consistently covers the needs of the NMS in terms of its national, regional, and global responsibilities and based among others, on cost-benefit analysis of Service.</li><li>• Proportion of staff (availability of in-house, seconded, contracted-out) with adequate training in relevant scientific, technical, and ICT disciplines.</li><li>• Experience and track-record in the implementation of internationally funded hydromet projects and research and development projects in general.</li></ul>
2	Effort ongoing to formalize mandate, introduce improved governance and management processes and address resources 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.	
B. Effective partnerships to improve service deliver - Effectiveness of the NMS in bringing together national and international partners therefore improving the service offering.		
Maturity level		Indicators
1	Works in isolation and does not value or promote partnerships.	<ul style="list-style-type: none"><li>• Effective partnerships in place with other government institutions.</li><li>• Effective partnerships in place at national and international level with private sector, research centres and academia, including joint research and innovation projects.</li><li>• Effective partnerships in place with international climate and development finance partners.</li><li>• New or enhanced products, services or dissemination techniques or new uses or applications of existing products or services that culminated from these relationships.</li></ul>
2	Limited partnerships and mostly excluded from climate finance opportunities.	
3	Moderate effective partnerships but generally regarded as the weaker partner in such relationships, having little say in climate financing initiatives.	
4	Effective partnership with equal status in most relationships and approaching climate funding opportunities in a coordinated manner.	
5	NMS is regarded as a major national and regional role player, has extensive and productive partnerships and viewed as an honest broker in bringing parties together and provide national leadership on climate finance decisions.	



## OBSERVATION AND DATA PROCESSING SYSTEM

**C. Observational Infrastructure** - The level of compliance of the observational infrastructure and its data quality with prescribed standards.

Maturity level		Indicators
1	No or limited, basic surface observations and no upper-air observations.	<ul style="list-style-type: none"> <li>Average horizontal resolution in km of both synoptic surface and upper-air observations.</li> <li>Additional observations used for nowcasting and specialize purposes.</li> <li>Standard Operating Procedures (SOPs) in place for the deployment, maintenance, calibrations and quality assurance of the observational network.</li> <li>Percentage of the surface observations that depend on automatic techniques.</li> </ul>
2	Basic network, large gaps, mostly manual observations with serious challenges and/or data quality issues.	
3	Moderate network with some gaps w.r.t. 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.	

**D. Data and product sharing and policies** - The nature of data and product sharing on a national, regional and global level.

Maturity level		Indicators
1	No observational data is shared internationally, and otherwise data are either not available to be shared or any existing data sharing policies or practices or infrastructure effectively does not allow data sharing.	<ul style="list-style-type: none"> <li>Percentage GBON compliance - for how many prescribed surface and upper-air stations are observations exchanged internationally.</li> <li>A formal policy and practice for the freely and open sharing of observational data.</li> <li>Main data and products received from external sources in a national, regional and global context, such as model and satellite data.</li> </ul>
2	A minority of the required GBON compliant data is shared internationally and any existing data sharing policies or practices or infrastructure severely hampers the manner in which two-way data sharing is happening	
3	GBON compliance with regards to either surface or upper-air data and a data policy and practices and infrastructure in place that promote the freely and open use of data for research and academic purposes as well as the in-house use of external data.	
4	Exceeding GBON compliance with a data policy and practices and infrastructure that support free and open sharing of data within a national context and some products regionally or internationally as well as the in-house use of external data.	
5	Exceeding GBON compliance and contributes additional data (marine, radar, etc.) to regional and international initiatives with policies that support promoting and practicing freely and open two-way sharing of data and products on a national, regional and international basis.	

**E. Numerical model and forecasting tool application** - The role of numerical model output and forecasting aids such as remote sensed products in product generation; whether models are run internally and if the value-added compared to global models is determined.

Maturity level		Indicators
1	Forecasts are based on classical forecasting techniques without model guidance and only cover a limited forecast time range.	<ul style="list-style-type: none"> <li>Model and remote sensed products form the primary source for products across the different forecasting timescales.</li> <li>Models run internally, and if so, is data assimilation and verification done and what horizontal resolution applied.</li> <li>Probabilistic forecasts produced and if these based on ensemble predictions.</li> </ul>
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 based mostly on model guidance from external and limited internal sources (without data assimilation) and remote sensed products in the form of maps, figures and digital data and cover nowcasting, short and medium forecast time ranges.	
4	Digitized model output from internal (with data assimilation) and/or external (regional) sources and remote sensed products and data used and value added through post processing techniques extended into the extended range.	
5	Optimal combination of global, regional and local models, remote sensed data, post-processing techniques and automated probabilistic product generation over weather and climate time scales with minimal human intervention supported by up to date verification statistics.	

## SERVICE AND PRODUCT PRODUCTION AND DISSEMINATION

**F. Warning and advisory services** - NMS role as the authoritative voice for weather-related warnings and its operational relationship with disaster and water management structures.

Maturity level		Indicators
1	Warning service not operational for public and civil resilience.	<ul style="list-style-type: none"> <li>Warning and alert service cover 24/7.</li> <li>Hydrometeorological hazards, for which forecasting and warning capacity is available and whether feedback and lessons learned are included to improve warnings.</li> <li>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.</li> </ul>
2	Basic warning service is in place and operational but with limited public reach and lacking integration with other relevant institutions.	
3	Weather-related warnings service with modest public reach and informal engagement with relevant institutions, including disaster management structures.	
4	Weather-related warnings service with strong public reach has standard operational procedures driving close partnership with relevant institutions, including disaster management structures.	
5	Comprehensive, impact-based warning service taking hazard, exposure and vulnerability information into account with strong public reach operates in close partnership with relevant national institutions, including disaster management structures and registered CAP alerting authorities.	



**G. Contribution to climate services** - NMS role in and /or contribution to a national climate framework according to the established climate services provision capacity.

Maturity level		Indicators
N/A	Climate Services provided by another party.	<ul style="list-style-type: none"> <li>Where relevant, contribution to climate services according to the established climate services provision capacity.</li> </ul>
1	Less than basic Climate Service Capacity.	
2	Basic Climate Service Provision Capacity.	
3	Essential Climate Service Provision Capacity.	
4	Full Climate Service Provision Capacity.	
5	Advanced Climate Service Provision Capacity.	

**H. Contribution to hydrology** - NMS role in and contribution to hydrological services according to mandate and country requirements.

Maturity level		Indicators
1	No or very little meteorological input in hydrology and water resource management.	<ul style="list-style-type: none"> <li>Where relevant, standard products such as Quantitative Precipitation Estimation (QPE) and Quantitative Precipitation Forecast (QPF) produced on a routine basis according to the requirements of the hydrological community.</li> <li>SOPs in place to formalize the relation between Met Service and Hydrology Agency.</li> <li>Joint projects/initiatives with hydrological community.</li> </ul>
2	Meteorological input in hydrology and water resource management happen on an ad hoc basis and 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 sector have strong SOPs and agreements in place work closely together in developing new and improved products and providing seamless and advanced services.	
5	The meteorological, hydrological and water resources sector have strong SOPs and agreements in place and work closely together in developing new and improved products and providing seamless and advanced services.	

**I. Product dissemination and outreach** - The effectiveness of the NMS in reaching all public and private sector users and stakeholders.

Maturity level		Indicators
1	Dissemination using only limited traditional channels such as daily newspapers and the national broadcaster and with little control over messaging and/or format.	<ul style="list-style-type: none"> <li>Channels use for communication and does the NMS operate its own television studio.</li> <li>Education and awareness initiatives in place.</li> <li>Special measures in place to reach marginalized communities, the youth and the elderly.</li> </ul>
2	Traditional communication channels and a basic dedicated website is used to disseminate forecasts and basic information.	
3	A moderately effective communication and dissemination strategy and practices in place based only on in-house capabilities and supported by user friendly website.	
4	A large fraction of population is reached using a range of communication techniques and platforms, some with partners, and a user-friendly and informative website and apps. Outreach and education activities occur on a regular basis.	
5	A high advanced education, awareness and communication strategy, practices and platforms in place using a wide range of technologies tailored to reach even marginalized communities and with close cooperation with a number of partners.	

**USER AND STAKEHOLDER INTERACTION**

**J. 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 level		Indicators
1	Service development lacks any routine stakeholder feedback practice.	<ul style="list-style-type: none"> <li>Formalized platform to engage with users in order to co-design improved services.</li> <li>Independent user satisfaction surveys conducted and the results.</li> </ul>
2	Service development draws on informal stakeholder input and feedback.	
3	Services 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.	

# GLOSSARY

<b>Adaptation</b>	In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects .
<b>Alliance for Hydromet Development</b>	The Alliance is a coalition of 13 climate and development finance institutions. Its goal is to scale up and unite efforts to achieve the common goal of closing the hydromet capacity gap on weather, climate, hydrological, and related environmental services by 2030. The Alliance aims to increase effectiveness and sustainability of hydromet investments through collective and coordinated action.
<b>Anticipatory Action (AA)</b>	Refers to methods of providing critical support to at-risk communities before disasters occur or at least before the full extent of a disaster's effects occur. This is done by using forecasts or early warnings of imminent shock or stress with the aim to reduce or mitigate the impact of disasters and enhance post disaster responses.
<b>Common Alerting Protocol (CAP)</b>	The WMO standard for all-hazards, all-media public alerting. It was adopted as International Telecommunication Union (ITU) Recommendation X.1303
<b>Country Hydromet Diagnostics (CHD)</b>	A standardized, integrated and operational tool and approach for diagnosing National Meteorological Services, their operating environment, and their contribution to high-quality weather, climate, hydrological and environmental information services and warnings. The CHD is an umbrella tool that draws on and adds value to existing WMO assessment material by synthesizing existing approaches and data into an easily interpretable form, validating the information provided by WMO Members through a peer review process, and obtaining missing information.
<b>Early Warning Systems (EWS)</b>	Early warning systems (or services) is an adaptive measure for climate change, using integrated communication systems (comprising sensors, event detection and decision subsystems) to help communities prepare for hazardous climate-related events. Effective EWS involve communities at risk to ensure their awareness and preparedness.
<b>Global Basic Observing Network (GBON)</b>	In order to help ensure a reliable supply of observational data to the NWP systems, WMO Members (193 states and territories) decided in 2019 to implement the Global Basic Observing Network (GBON). The GBON regulations will specify in clear, quantitative terms the obligations of WMO Members to acquire and internationally exchange certain observations: which parameters to measure, how often, at what horizontal and vertical resolution, when and how to exchange them, and which measurement techniques are appropriate to use.
<b>Hydromet services</b>	Weather, climate, hydrological, and related environmental services.
<b>National Meteorological and Hydrological Services (NMHS)</b>	The NMHSs, as recognized in the Convention of the World Meteorological Organization, are a fundamental part of national infrastructure and play an important role in supporting vital functions of governments. NMHS own and operate most of the infrastructure that is needed for providing the weather, climate, hydrological and related environmental services for the protection of life and property, economic planning and development, and for the sustainable exploitation and management of natural resources. While they are institutionally set up in several countries as an integrated service, in some countries the National Meteorological Service (NMS) and National Hydrological Service (NHS) are institutionally separated.



<b>Numerical Weather Prediction (NWP)</b>	The foundation of all weather and climate monitoring and prediction is global NWP done by the Global Producing Centres operated by WMO Member states and territories. An NWP prediction starts by assimilating vast amounts of meteorological observations from the entire globe into an Earth system model to build a worldwide model estimate of the instantaneous weather. The model then uses the laws of physics to evolve this 'initial weather' forward in time. The quality of NWP output can be objectively quantified, and progress in NWP relies on extensive use of broadly agreed measures of lead time, or range - the extent forward in time that can be predicted -, and skill - the quality of the prediction at a given time.
<b>Resilience</b>	The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure while also maintaining the capacity for adaptation, learning and transformation.
<b>Systematic Observations Financing Facility (SOFF)</b>	A proposed new global financing mechanism aimed at providing long-term support to countries with the largest GBON gaps to support generation and international exchange of basic surface-based weather and climate observations in a sustained manner.
<b>WMO Global Producing Centres</b>	Nominated NWP centers that provide WMO Members with a range of forecast products based on their global prediction models.

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## ALLIANCE FOR HYDROMET DEVELOPMENT MEMBERS

ADAPTATION FUND  
AFRICAN DEVELOPMENT BANK  
ASIAN DEVELOPMENT BANK  
CLIMATE INVESTMENT FUNDS  
EUROPEAN BANK FOR RECONSTRUCTION  
AND DEVELOPMENT  
GLOBAL ENVIRONMENT FACILITY  
GREEN CLIMATE FUND  
ISLAMIC DEVELOPMENT BANK  
UNITED NATIONS DEVELOPMENT PROGRAMME  
UNITED NATIONS ENVIRONMENT  
PROGRAMME  
WORLD BANK  
WORLD FOOD PROGRAMME  
WORLD METEOROLOGICAL ORGANIZATION

### ABOUT THE ALLIANCE FOR HYDROMET DEVELOPMENT

The Alliance for Hydromet Development brings together major international development, humanitarian and climate finance institutions, collectively committed to scale up and unite efforts to close the hydromet capacity gap by 2030. It aims to increase the effectiveness and sustainability of hydromet investments by forging a coordinated and collaborative partnership which recognizes and leverages the respective competencies and expertise of its members.

The World Meteorological Organization provides the Secretariat function for the Alliance that facilitates communication and knowledge sharing.

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