STRENGTHENING WEATHER AND CLIMATE INFORMATION SERVICES:

HIGHLIGHTS FROM PPCR-SUPPORTED PROJECTS

KNOWLEDGE FOR RESILIENCE SERIES - SEPTEMBER 2020

CIF CLIMATE INVESTMENT FUNDS

CONTENT

INTRODUCTION

A surveyor takes GPS altitude on a water-control canal for the Baixo Limpopo Irrigation and Climate Resilience Project in Mozambique.

Photo: CIF.

Climate change and its widespread impacts threaten lives and livelihoods, impeding global efforts to reduce poverty and promote shared prosperity (GCOS et al, 2006).[1] The most recent World Economic Forum once again highlighted extreme weather, climate action failure, and natural disasters as the top three global risks in terms of likelihood, with climate action failure as the top global risk in terms of impacts (WEF, 2020).[2] The Global Commission on Adaptation underscores the human, environmental, and financial imperatives to take action to build the climate resilience of communities, the environment, and economies (GCA, 2019).[3]

1 Global Climate Observing System (GCOS), United Nations Economic Commission for Africa, African Union Commission (2006). Climate information for development needs: An action plan for Africa. Report and implementation strategy. https://archives.au.int/bitstream/handle/123456789/1026/Assembly%20AU%2011%20VIII%20a_E.pdf?sequence=1&isAllowed=y.

2 World Economic Forum (2020). Global Risks Report 2020. http://www3.weforum.org/docs/WEF_Global_Risk_Report_2020.pdf.

3 Global Commission on Adaptation (2019). Adapt Now: A Global Call for Leadership on Climate Resilience. https://cdn.gca.org/assets/2019-09/GlobalCommission_Report_FINAL.pdf.

To effectively manage the risks associated with an uncertain and warming climate, information and understanding of the nature and magnitude of change in the hydrological and meteorological (hydromet) system is essential. Knowledge of short-term (weather) and long-term (climate) variations and uncertainties is required to enable public and private sector organizations to make climate risk-informed decisions. Fundamental to the provision of such information and knowledge is a well-functioning weather and climate information services (WCIS) system typically provided by a country's national meteorological and hydrological services (NMHS) (see Box 1).

Due to chronic under-investment in vital infrastructure and technical capabilities in developing countries, there is a considerable gap in the provision of WCIS. Many countries' Nationally Determined Contributions (NDCs) under the Paris Climate Agreement identify strengthening climate services as a national priority for moving toward a low-carbon and climate resilient development pathway (see Figure 1).

Box 1

WEATHER AND CLIMATE INFORMATION SERVICES

In this document, weather and climate information services (WCIS) is used as a broad term to encompass the full spectrum of activities related to the generation, processing and analysis, and the flows of weather and climate data and information, involving a wide range of stakeholders and service platforms (WMO, 2011).* By definition, weather information services focus on the shorter-term information (from minutes to seasons) that is important for decision making on operations and logistics. Climate information services require information gathered over longer periods of time (from years to decades) to inform longer-term decisions, such as a water utility company making investment decisions to ensure the viability of the business over the next decade. WCIS system is therefore a broad term to include a series of core components required to produce and deliver WCIS, i.e. the WCIS value chain (see Figure 3).

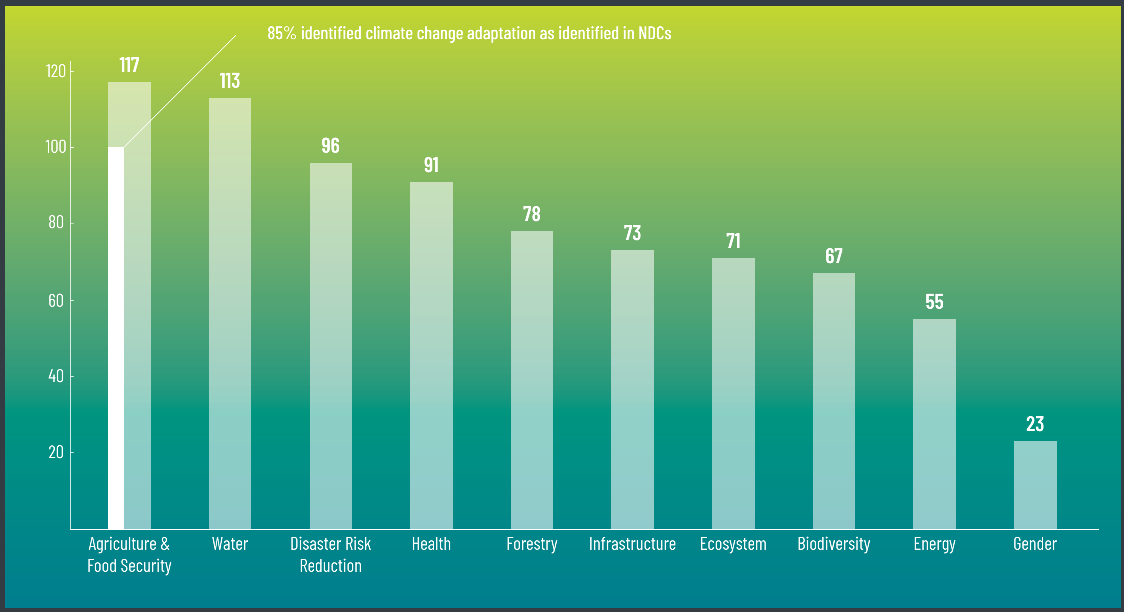
** World Meteorological Organization (2011). Climate Knowledge for Climate Action: A Global Framework for Climate Services—Empowering the Most Vulnerable.* https://library.wmo.int/doc_num.php?explnum_id=5092.

Despite the apparent need for investment in WCIS to effectively address the adverse impacts of climate change, developing countries (which are often at higher risk) are confronted with national budgetary constraints. As a result, as shown in Figure 2, notable disparities exist in the level of spending on WCIS among country groups of different economic development status.

A Stream Flow Monitor installed under the Improving Climate Data and Information Management Project in Jamaica.

Photo: CIF.

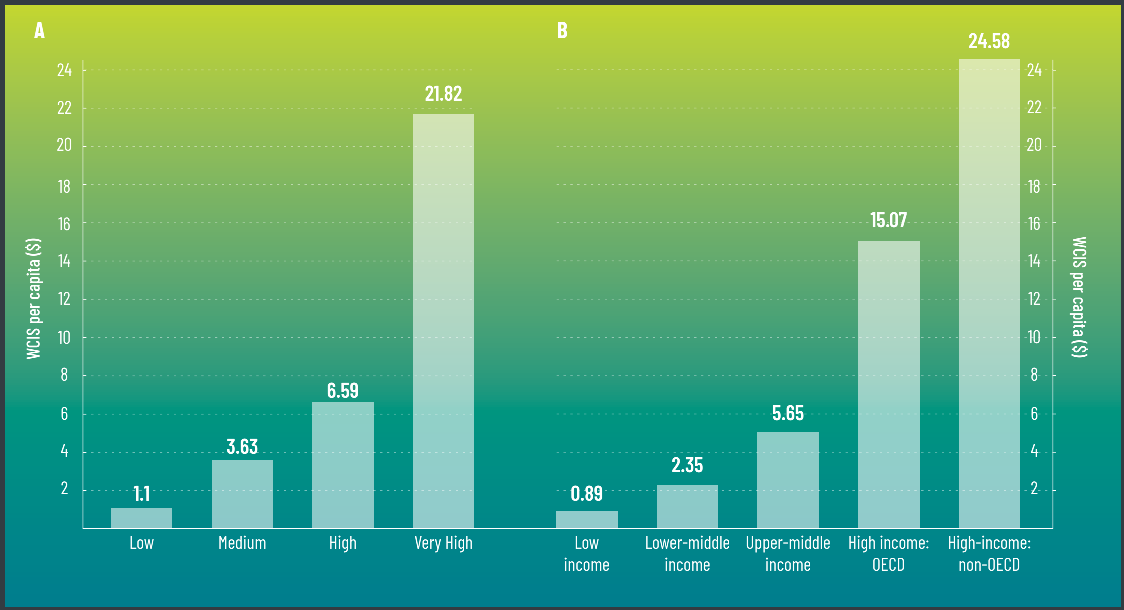
Figure 1.
PRIORITIES FOR CLIMATE CHANGE ADAPTATION AS IDENTIFIED IN NDCS



Source: WMO (2019). 2019 State of the Climate Services: Agriculture and Food Security. WMO-NO.1242.
https://library.wmo.int/doc_num.php?explnum_id=10089.

Figure 2.
RELATIVE SPENDING IN WCIS

Average per capita spending in WCIS (USD) in countries grouped by developmental status
A: UNDP Human Development Index tier (179 countries). B: World Bank income group (185 countries)



Source: L. Georgeson et al. (2017). Global disparity in the supply of commercial weather and climate information services. Sci. Adv. 2017;3: e1602632.

CIF SUPPORT FOR WCIS

To address this disparity, and in response to the requests of partner countries, the Climate Investment Funds (CIF), through its Pilot Program for Climate Resilience (PPCR), supports a portfolio of projects aimed at strengthening WCIS in developing countries. CIF has invested USD 202 million[4] in PPCR financing to support WCIS-focused projects in various countries across Africa, Asia, the Pacific, and the Caribbean. These projects, either largely or exclusively focusing on WCIS, form integral parts of partner countries' Strategic Program for Climate Resilience developed under the PPCR. Activities supported by PPCR cover all five components of a WCIS value chain (see Figure 3):

1 | Observation and monitoring

2 | Data and information management

3 | Research, forecasting, and modeling

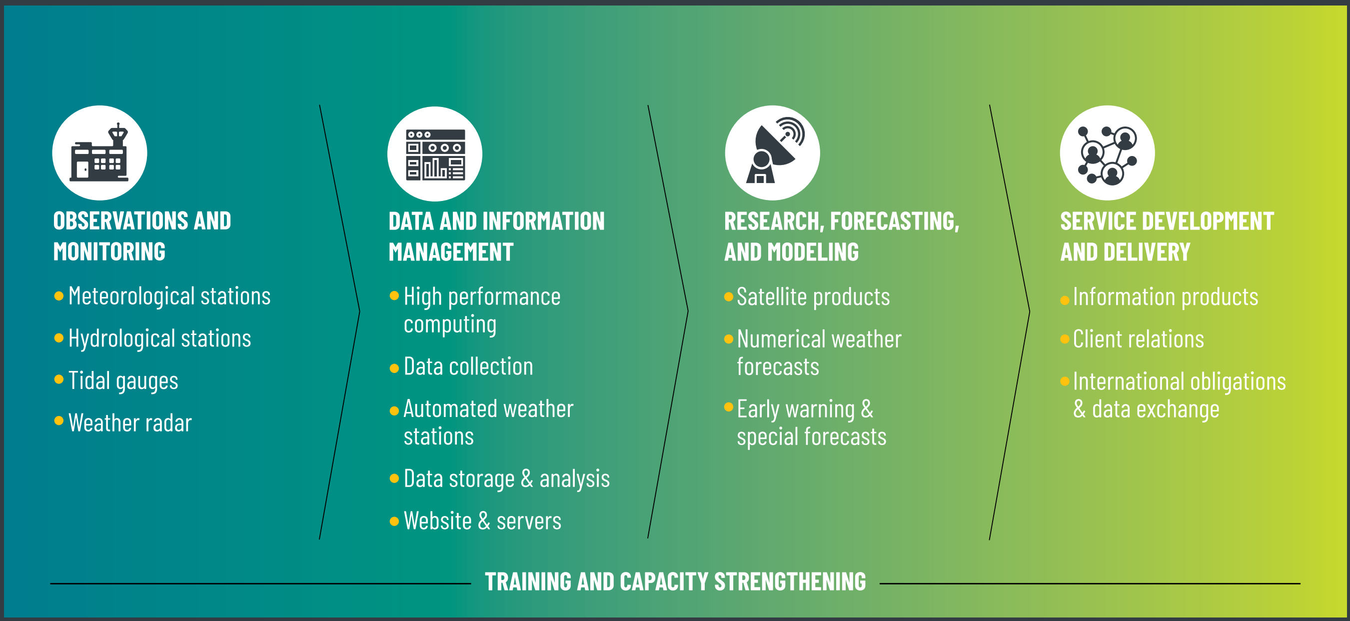
4 | Service development and delivery

5 | Training and capacity building

CIF support is unique in its country-driven and programmatic approach to planning and project development. It adopts an inclusive and participatory approach throughout the whole process. Before

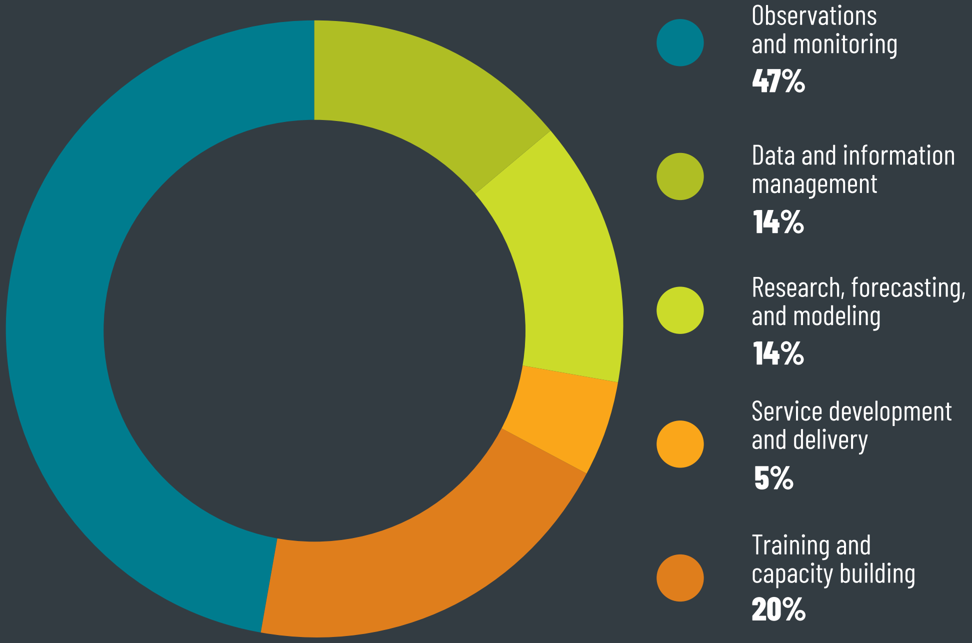
4 Total investments in WCIS-focused projects under the PPCR totals USD 316 million. This includes USD 202 million of PPCR funds and USD 114 million of MDB co-financing. This estimate is based on budgets of projects with a specific focus on improving capabilities of countries in the development and delivery of weather and climate information services, and therefore an under estimate as there are other PPCR projects with components that aim to contribute to this objective.

Figure 3.
COMPONENTS OF THE WCIS VALUE CHAIN



Source: Adapted from World Bank, GFDRR & Zoï Environment Network (2019).

Figure 4.
PPCR FINANCIAL SUPPORT FOR THE DIFFERENT COMPONENTS OF THE WCIS VALUE CHAIN



Source: CIF.

initiating PPCR projects, CIF assists countries in elaborating strategic programs (also known as Strategic Program for Climate Resilience or SPCR) that contextualize investments in adaptation within national and sectoral development plans. The implementation of SPCR projects follows a multi-stakeholder and inclusive approach that engages community-based organizations, vulnerable groups, and the private sector. CIF's way of working has proven beneficial and represents progress toward engendering transformative impacts of investments in climate action.

In addition to its existing portfolio of WCIS projects, CIF has partnered with other financial and development partners to address the gap in WCIS. CIF has made active contributions to the work of the Alliance for Hydromet Development, established in 2019 at the 25th session of the Conference of the Parties to the UN Framework Convention on Climate Change to bridge the hydromet capacity gap in developing countries. Together with the Alliance members and other partners including those from the private sector, CIF has contributed to the establishment of a Systematic Observations Financing Facility (SOFF) and the development of a country hydromet performance diagnostics tool. Given that these collaborative efforts are still at an early stage, this brief focuses on experiences and lessons learned between 2011 and 2020 from PPCR activities in relation to the WCIS value chain.

As indicated in Figure 4, the largest portion of PPCR financial support can be attributed to observations and monitoring due to the relative high cost of monitoring infrastructure. Nonetheless, the diversity of PPCR activities reflects the varying needs of partner countries and provides great opportunity for learning. Implementation of projects has been in full swing since 2011, and while some project activities are still ongoing, a wealth of results has been achieved.

Using the five components of the WCIS value chain as a framework, this brief highlights some of the early results and lessons learned from the PPCR projects in Grenada, Jamaica, Mozambique, Nepal, and Tajikistan (see Box 2).

Box 2

OVERVIEW OF FEATURED PPCR PROJECTS

GRENADA: Disaster Vulnerability Reduction Project
The project is being implemented as part of the Regional Disaster Vulnerability Reduction Project, with the aim of supporting priority risk-reduction investments and activities that contribute to building Grenada's capacity to better manage climate risks. This includes support for optimizing and modernizing the hydromet data collection network and data management system; training on watershed and flood modeling; drought hazard mapping; and adjusting hydraulic parameters for climate-proofing infrastructure design.

JAMAICA: Improving Climate Data and Information Management Project
The project seeks to improve the quality and use of climate-related data and information for effective planning and action at local and national levels. It aims to upgrade hydromet data collection, processing, and forecasting systems; improve climate resilient planning and hydromet information services; and support climate change education and awareness toward behavioral change.

MOZAMBIQUE: Transforming Hydrometeorological Services Project
The project is part of national efforts to strengthen hydromet services. The aim is to deliver reliable and timely climate information in support of economic development and improved decision making, particularly in three areas (Zambezi, Limpopo, and Incomati River basins). Investments focus on hydromet monitoring networks; more effective data management and data exchange; and improved forecasting capabilities, training, and skills development to staff.

NEPAL: Building Resilience to Climate-Related Hazards
The project aims to increase the country's resilience to climate-related hazards by improving the accuracy and timeliness of weather and flood forecasts and warnings for vulnerable communities countrywide. It also aims to develop agricultural information management system services to help farmers mitigate climate-related production risks. The project has provided support to establish multi-hazard information and early warning systems; upgrade the existing hydromet system and agricultural information management system; and strengthen the capacity of the hydromet agency.

TAJIKISTAN: Improvement of Weather, Climate, and Hydrological Delivery Project
The project is being implemented as part of the regional project, Central Asia Hydrometeorology Modernization Project, aimed at strengthening hydromet services in the Republic of Tajikistan. The PPCR-supported project component is helping strengthen Tajikhydromet to ensure that it has the infrastructure and capability to sustainably observe, forecast, and deliver weather, water, and climate services that meet the country's economic and societal development needs.

PROGRESS AND LESSONS LEARNED

INSTALLING, UPGRADING, AND MODERNIZING HYDROMET MONITORING SYSTEMS

Effective climate services require monitoring various variables and ensuring adequate quality and quantity of data collected at the right place and at the right time. Basic observational data on the key elements of the weather and climate system are fundamental to the understanding of ongoing weather patterns and climate trends, to the development of weather forecast and climate modeling, and to the provision of WCIS for different users (e.g., farmers, public health practitioners, disaster risk managers, water and energy utility managers, insurers, and the aviation industry, among others).

As reported by the World Meteorological Organization (WMO), important observational data are missing in several parts of the world, particularly in Africa and small island developing states. Local observations are not only important for local purposes, but through their exchange, they also contribute to the global public good. They enable weather forecast, early warning, and climate analysis across the globe. For instance, despite covering a fifth of the world's total land area, Africa has the least developed land-based observation network of all continents. Moreover, Africa's network is in a deteriorating state, amounting to only 1/8 of the minimum density required by WMO and only 22 percent of stations fully meet the Global Climate Observing System (GCOS) reporting requirements (down from 57 percent in 2011) (WMO, 2019).

RESULTS AND LESSONS LEARNED IN GRENADA, JAMAICA, MOZAMBIQUE, AND TAJIKISTAN

To help address this gap, PPCR supports developing countries to upgrade and modernize their observation and monitoring systems. This includes the procurement and installation of new monitoring and associated data transmission equipment for weather and hydrological monitoring stations.

In **Grenada,** as of February 2020, a total of 33 new stations, which measure a variety of variables required for both weather and climate forecasting, have been installed in Grenada, Carriacou, and Petite Martinique.

In **Jamaica**, a key component of the Improving Climate Data and Information Management Project is upgrading the country's hydromet monitoring network. As of April 2020, an impressive range of essential equipment and infrastructure had been put in place:

- 35 automatic weather stations installed
- 54 intensity rain gauges and stream flow monitors installed or upgraded
- 16 soil moisture probes installed
- 1 water-monitoring situation room established at the Water Resources Authority (WRA)
- 1 sea level tidal gauge installed
- 2 back-up power supplies installed

In **Mozambique**, at the completion of the project in December 2019, 70 percent of river gauge stations were open and reporting (against a baseline of 37 percent in September 2013 and project target of 60 percent), and 80 real-time hydrological monitoring stations were reporting (against a baseline of 8 and project target of 40). In addition, 66 synoptic weather stations were open and reporting (against a baseline of 41 and project target of 60), and 65 real-time meteorological monitoring stations reporting (against a baseline of 17 and project target of 25).

In **Tajikistan**, as of March 2020, 90 percent of meteorology stations are now monitoring main meteorological parameters (against a baseline of 19 percent in August 2011 and project target of 90 percent for March 2023), with 44 percent of stream gauges reporting operational data (against a baseline of 16 percent and project target of 50 percent).

Modernized weather station in Tajikistan.

Photo: World Bank, GFDRR & Zoï Environment Network, 2018.

KEY LESSONS

Use of technologies: The use of satellite, radar, mobiles, cloud computing technologies, and online database is an integral part of improving hydromet data provision, but **for these technologies to function properly, some basic conditions need to be in place.** As observed in Mozambique, tight local government budgets often cannot stretch to make use of radar technology or supply the electricity needed to run the radar or air conditioning required to house the essential equipment.

Procurement of equipment and hardware: Due to a limited number of domestic vendors in many developing countries, procurement of equipment and hardware is often a challenge for project teams. As experienced in Jamaica, **it is critical to thoroughly research all options and ensure the final purchased items are fit for purpose and on-site technical support from the supplier is available,** particularly for initial installation and maintenance work.

An automatic weather station installed at Mona Dam.
Photo: Planning Institute of Jamaica, 2018.

DEVELOPING AND UPGRADING HYDROMET DATA AND INFORMATION MANAGEMENT SYSTEMS

Hydromet data and information systems are critical to facilitating the collection, storage, and processing of observations and to developing weather and climate data products and services. Without a viable data and information management system, benefits of a strengthened monitoring network are undermined and efforts to develop decision-relevant WCIS severely curtailed. Due to a combination of insufficient investment in key IT infrastructure and gaps in technical expertise, the systematic collection, storage, and (post)processing of hydromet data remain major challenges for many developing countries.

In addition, the use of climate data is becoming more sophisticated, meaning that more data are required more frequently and rapidly (e.g., for the calculation of sub-daily Intensity-Frequency-Duration design rainfalls) and often combined with other environmental data to inform decisions (e.g., response to climate-sensitive disease outbreak). Near-real-time high frequency observations are only feasible using automatic electronic instrumentation, which comes at a higher cost both financially and technologically compared to the traditional manual methods.

RESULTS AND LESSONS LEARNED IN GRENADA, MOZAMBIQUE, AND TAJIKISTAN

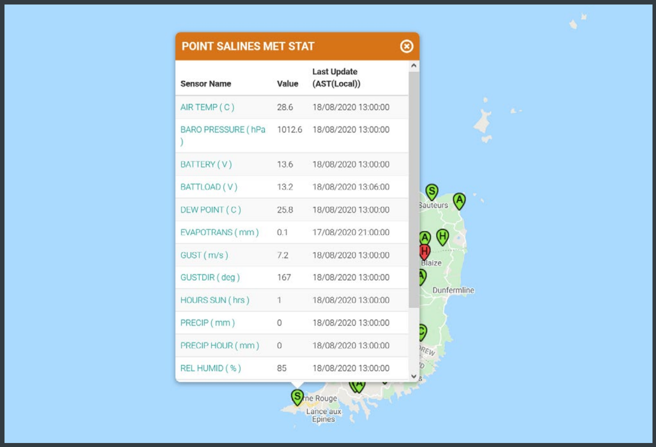
Recognizing the fundamental importance of a functional data management system, PPCR supports countries in developing and upgrading their hydromet information management systems. Working closely with key stakeholders and partners, these efforts aim to develop a national hub of hydromet data, improve data integrity and consistency, and better manage the workflow for data access and processing.

In **Grenada,** an online data platform has been developed to automatically collect data from 33 newly installed hydromet stations. The platform offers access to both real-time and historical records from the stations along with tools to analyze the data and create information products. Government staff is being trained to maintain the hardware and use the platform.

This data platform allows the government of Grenada to view and analyze climate patterns at a watershed scale. It enables improved forecasting of climate variability, which is crucial for the national agricultural industry. Engineering of hydraulic structures will also greatly benefit from the availability of rainfall and streamflow records for most watersheds in Grenada.

Also hosted on the same data platform is a combined topographic and bathymetric model of Grenada, Carriacou, and Petite Martinique created using topographic LiDAR and Multibeam Sonar under the PPCR project. This model allows determination of elevation in Grenada, accurate to a few centimeters, at one-meter intervals offshore and half-meter intervals on land. Along with the model, high resolution aerial imagery was also collected. Data from the models and aerial imagery can be accessed, with varying levels of permission, by both the public and government personnel. The models have been key to formulating Grenada's long-term development strategy and identifying key national infrastructure development projects, including the Renewal of St. George's Project, installation of coastal defenses around the Maurice Bishop International Airport, and rehabilitation of transportation links to communities surrounding St. George's.

In **Mozambique,** the PPCR project supported the Climsoft-based data management system at the National Institute for Meteorology (INAM) to enable more effective integration of multiple data streams for forecasting and reporting. This was made possible through the installation of fiber-optic connections and internet broadband, which improved connectivity between INAM's central office and decentralized centers across the country. Consequently, 28 (against the project target of 20) out of 40 conventional weather stations now report to WMO's Global Observation and Telecommunication System. In addition, the National Integrated Water Resources Management Information System (NIWRMIS) and the time-series hydrological data system were developed, allowing more effective integration, processing, and management of multiple streams of water resources data in a single information-sharing platform. At project completion, the NIWRMIS database hosted information from 717 water stations, 17 reservoirs, 1,389 rain gauges, 7,686 boreholes, 3,598 sites of the National Directorate for Water Supply and Sanitation, 428 water use licenses, and 6,598 recovered and digitalized (historical) records.



Homepage of the online hydromet data platform developed to automatically collect and process data from the 33 hydromet stations installed under the PPCR project in Grenada.

Source: http://hydromet.gov.gd.

View of St. George's Grenada Terrain/Bathymetric Model on Grennode.

Source: https://grennode.gov.gd/geoserver/GrenadaLiDAR/wms?-service=WMS&version=1.1.0&request=GetMap&layers=Grenad-aLiDAR%3ADTM_50_HS_DC&bbox=630000.0%2C1325000.0%2C677000.0%2C1386000.0&width=591&height=768&srs=EPSG%3A32620&format=ap-plication/openlayers.

In **Tajikistan**, with its modernized hydromet data management system, over 98 percent of observed hydromet data are transmitted in real time to global telecommunications systems for wider sharing. In addition, 1.35 million paper pages of historical data have been digitized and archived, significantly extending the coverage of observed data series and enabling vital analysis on past climate in the country and Central Asia region.

A large volume of hydromet observations previously recorded in paper format is being digitized and archived under the PPCR project in Tajikistan.
Photo: World Bank, GFDRR & Zoï Environment Network, 2018.

KEY LESSONS

Although PPCR support, as with the majority of current public funding for WCIS, focuses on "hardware" installation, the project partner in Mozambique pointed out that data collection and management are just as important. To realize the full benefit of the hardware and equipment, the **design and development of an effective data collection and management system** merits due consideration. As the project team in Mozambique witnessed, there is huge potential to tap into **information technologies and innovation** to maximize the WCIS data management system. Despite initial scepticism, the open-source and cloud-based system for data collection, storage, processing, and forecast and warning has proven highly effective and efficient.

DEVELOPING CLIMATE RESEARCH, FORECASTING, AND MODELING CAPABILITIES

To fully tap into the benefits of improved observational data, technical capabilities are essential to develop weather and climate foresights that can inform weather-sensitive decision making. For many developing countries, weather forecasting and climate modeling are nascent. Out of the 28 major modeling groups contributing to the ongoing sixth phase of the international climate modeling inter-comparison project (CMIP6),[5] only three are from developing countries (China, India, and Thailand).

RESULTS AND LESSONS LEARNED IN JAMAICA, MOZAMBIQUE, AND TAJIKISTAN

To help address this notable capacity gap, PPCR supports developing countries' efforts to strengthen climate research, analytics, and modeling capabilities—from the training on and application of analytic tools to the generation of local and decision-relevant weather forecasts and climate projections. This work has directly contributed to national policy discourses on climate change and more operational decisions in various countries.

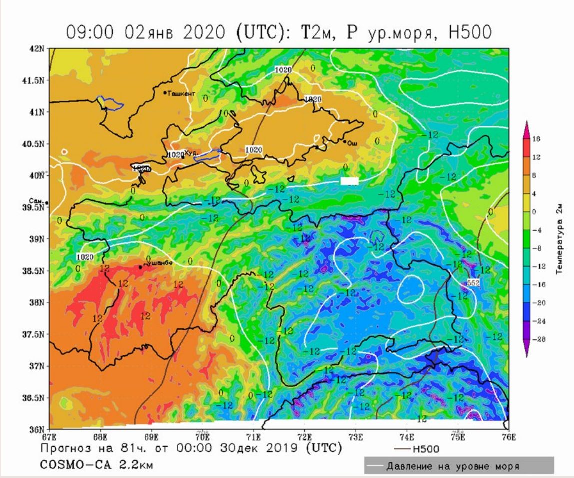
Research conducted under **Jamaica's** PPCR project informed the 2015 State of the Jamaican Climate Report (SOJC) . Considered as the first point of reference with respect to climate information in the country, the 2015 SOJC assesses historical climatic trends and variability and produces near- to long-term climate projections for Jamaica. One of the key features that distinguishes the 2015 SOJC from its predecessor in 2012 is the provision of climate projections at higher spatial resolution (at the sub-

5 The CMIP is an ongoing global climate modeling initiative, coordinated by the World Meteorology Organization's Working Group on Coupled Modeling. Results from the different phases of the CMIP inform the succession of assessment reports of the Intergovernmental Panel on Climate Change (IPCC). Model outputs from CMIP6 will be assessed in the upcoming IPCC sixth assessment report.

national level) and that it is based on the latest Intergovernmental Panel on Climate Change's (IPCC) emissions scenarios.

In **Mozambique,** improvements to weather forecasting were made using the higher-resolution Weather Research and Forecast Model. At project completion, downscaled daily weather forecasts were delivered to 28 districts (exceeding the original target of 6). Further improvements in the near future could come through the open-source integrated forecast product platform. Similarly, hydrological models for Limpopo and Zambezi have been installed, and are running in the National Directorate for Water Resource Management and relevant regional water authority offices. These models are open-source and will not require license extensions going forward. Improved weather forecasts are now systematically accessed and used as inputs to the hydrological models developed for each basin to generate flood forecasts, improving the forecast lead time from one to three days.

In close collaboration with other Central Asian countries, the PPCR project team in **Tajikistan** has made significant progress in enhancing in-country climate modeling capability. Six hourly forecasts of basic weather parameters are now being produced with the COSMO-CA model, at horizontal resolutions of up to 2.2 km.

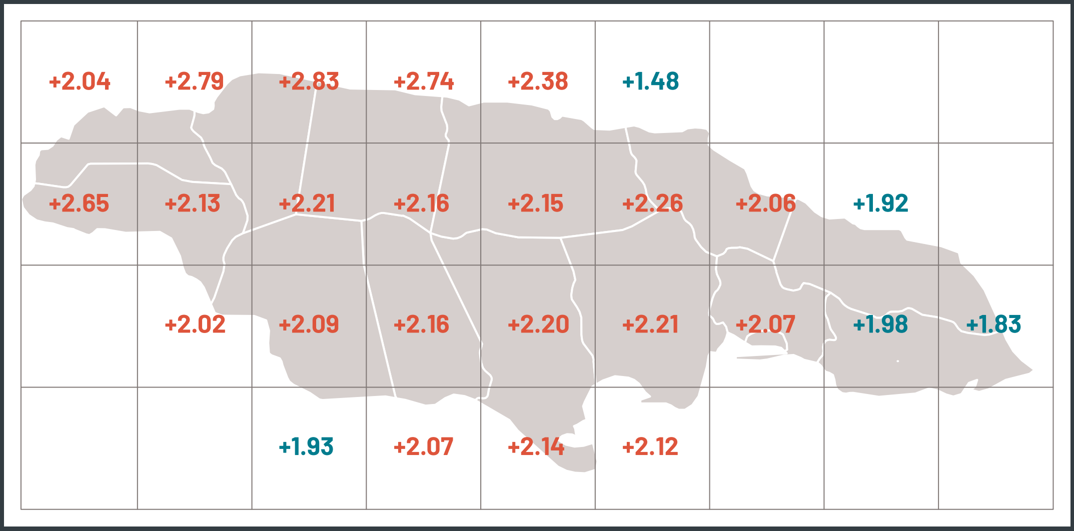


Temperature forecast at 0900 hours on January 2, 2020 using COSMO-CA model at horizontal resolution of 2.2 km for Tajikistan.

Source: http://ca.meteo.uz.

KEY LESSONS

The Mozambique project showed that hydromet research, forecasting, and modeling capacities are most effectively enhanced by **bringing together technical expertise and a data and information management system.** A seamless flow of observational data within the weather forecast and flood warning modeling frameworks is particularly important to provide more accurate and timely model outputs. The open-source nature of the hydrological models used for flood modeling is particularly helpful to ensure that improved weather forecast data can be seamlessly fed into the flood model for generating flood warnings with a minimal time lag.



High-resolution projections of annual temperature change for the 2030s with a 1961–90 baseline from the PPCR project directly contributed to the State of the Jamaican Climate 2015 report.

Source: Climate Studies Group Mona, University of the West Indies (2017). State of the Jamaican Climate Report 2015 (Information for Resilience Building, Produced for the Planning Institute of Jamaica), Kingston, Jamaica.

DEVELOPING AND DELIVERING WEATHER AND CLIMATE INFORMATION PRODUCTS AND SERVICES

The development and delivery of weather and climate products and services represents the weakest link in the WCIS value chain. While there has been a rapid growth in the recognition of the importance and societal value of WCIS—driven by the considerable socio-economic impacts of weather and climate-related events around the globe—progress in the development and delivery of WCIS remains limited. To meet the growing demand for a wide range of WCIS services, a country's NMHS must realign its traditional focus on weather-oriented services.

Depending on the user group (e.g., farming community, public health authority) as well as the particular decision context (e.g., short-term farming operations, long-term infrastructure planning), WCIS can vary widely. For example, Figure 5 illustrates how WCIS can be applied to support the provision of public health services. It ranges from daily to weekly weather forecasts used to issue public health alerts, to climate model projections for multi-decadal time horizons used to inform the planning and design of public health infrastructure.

In addition to the challenges associated with the complexity of designing tailored WCIS to meet the diverse range of user needs, more work is needed to develop and deliver WCIS at the same high standards as other services used widely by the public. As illustrated in Table 1, WCIS, particularly climate services, are still at the early stage of development compared to other public services.

RESULTS AND LESSONS LEARNED IN MOZAMBIQUE, NEPAL, AND TAJIKISTAN

With the growing recognition of WCIS's societal benefits, NMHS in many developing countries have increasingly engaged in the development and delivery of WCIS, expanding operations from hydromet data provision to service delivery. PPCR support has been particularly helpful in increasing services for farming communities and disaster risk management authorities, such as in Mozambique and Nepal.

In **Mozambique**, the PPCR project aimed to improve the accuracy and frequency of hydromet forecasts and impact-based warning in pilot districts. By the end of the project, daily, or twice daily in some districts, hydromet forecasts and early warning notices were reaching over 300,000 beneficiaries in farming and fishing communities in the Malabane, Inharrime and

Figure 5.
WCIS FOR THE PROVISION OF PUBLIC HEALTH SERVICES

	Short-term	*Medium-term*		*Long-term*
TIME SCALE	Hourly, daily and weekly	Monthly, seasonal and annual	Annual and decadal	Multi-decadal
EXAMPLE WCIS	• Daily and weekly weather forecasts • Weather statistics	• Risk indexes of cyclones, floods, wind storms, heatwaves • Seasonal trends • Tercile forecasts	• Status of El Nino • Inter-annual forecast	• Regional and global climate projections
EXAMPLE DECISION CONTEXT(S)	• Operational staff placements • Delivery of supplies • Alert issuance	• Operational investment in preparedness, outbreak prevention, resource allocation • National public health response plans	• Mid-term policy review on disease control research	• Long-term health infrastructure investments, research • Strengthening knowledge on disease patterns, epidemic behaviour at a regional and global scale

Source: Based on WMO (2014). Health Exemplar to the User Interface Platform of the Global Framework for Climate Services. Geneva, Switzerland. *https://gfcs.wmo.int/sites/default/files/Priority-Areas/Health/GFCS-HEALTH-EXEMPLAR-FINAL-14152_en.pdf.*

Massinga districts. Information was delivered by radio, mobile phone apps and placards in designated locations within communities. Most beneficiaries have been using the forecasts to guide day-to-day operational decisions, such as whether or when to go out to sea to fish, depending on the wind and sea level.

The main objective of the PPCR-supported hydromet project in **Nepal** is to improve decision making and planning in the country's key climate-vulnerable and water resource-dependent sectors, namely, agriculture, health, water, and disaster risk management. It has made considerable progress in upgrading the existing hydromet system that feeds into the agricultural management information system and establishing multi-hazard information and early warning systems. The project has now started to deliver regular climate services to key user groups, including a weekly Agro-met Advisory Bulletin (AAB). The AAB provides both summary and detailed weather forecast and advisories on crop, livestock, and aquaculture farming. Each edition follows the same template and is made available at the government website at http://narc.gov.np (see Box 3).

While this service expansion is important, it is not always comfortable as it places additional resource demand on the NMHS and requires new skillsets, partnerships, and infrastructure. In **Tajikistan**, for example, WCIS has a wide range of users. Every level of the government, emergency response authorities, and the general public are users of weather information and notifications of extreme events. The growing list of commercial users of WCIS includes sectors covering hydropower, aviation, transport, construction, tourism, telecommunications, and agriculture.

These commercial users pose both technical challenges and economic opportunities for hydromet agencies. While they must engage these new users to develop specialized WCIS, this same work can make hydromet services financially self-sustaining. The PPCR team has worked to improve WCIS offerings and develop a business plan for the NHMS with a view to establish a "fee for services" for its commercial clients. Collaborating with relevant government agencies and industries, the project team has drafted a Tajikhydromet business plan, which is currently being pilot tested and refined. Once the plan is finalized and fully launched, Tajikhydromet operations are expected to become financially sustainable.

Table 1.
A QUALITATIVE COMPARISON BETWEEN WEATHER AND CLIMATE SERVICES AND OTHER TYPES OF SERVICES

	MATURITY	TANGIBILITY	LEVEL OF RISK	TRUSTWORTHINESS
Financial service	H	M	M	M
Medical Service	H	H	M	H
Car Service	H	H	L	M
Weather Service	H	M	M	M
Climate Service	L	L	H	M

Source: A. Troccoli (ed.). Weather & Climate Services for the Energy Industry. https://doi.org/10.1007/978-3-319-68418-5.

Box 3

A TEMPLATE FOR THE WEEKLY AAB ISSUED BY THE NEPAL PPCR PROJECT TEAM*

Prepared by the Nepal Agriculture Research Council, Agriculture Environment Research Division with support from the Department of Hydrology and Meteorology.

Time period: date/month—date/month/year

1. **Weather summary** (bullet points summarizing the key features of the weather in the upcoming week)
2. **Agriculture summary** (bullet points summarizing the key advisory on relevant agricultural activities in light of the weather in the upcoming week)
3. **Weather forecast for the coming week** (a table presenting the weekly forecast by province, including geographical region, precipitation, maximum temperature, weather change, important weather events, and remarks on particular weather updates)
4. **Agriculture advisory** with the following headings:
    - Staple crops
    - Fruit crops
    - Vegetable crops
    - Coffee
    - Cardamom
    - Fish farming
    - Livestock farming (by animal species)
    - Grass farming
    - Others
5. **The AAB preparation experts group** (list of experts, including name, area of expertise, institutional affiliation, email address and telephone number)

* *A full version of an example of an AAB is available at https://www.climateinvestmentfunds.org/sites/cif_enc/files/knowledge-documents/agro-met_advisory_bulletin_aab.pdf.*

PUBLIC AND PRIVATE SECTOR USERS OF WCIS IN TAJIKISTAN

Source: Adapted from World Bank, GFDRR & Zoï Environment Network, 2019.

KEY LESSONS

As demonstrated through the Mozambique project, it is critically important to **work with WCIS end users** in developing information products. To ensure that the final WCIS products are fit-for-purpose and understood by end users, extensive consultations with the farming and fishing communities took place to determine the type, language, and frequency of the forecasts and warnings. In addition, **impact-based products** have been effective in promoting local ownership and the sustainability of project results. In Mozambique, having benefited first-hand from more accurate and regular weather forecasts and hazardous weather warnings, local communities highly value the services. This led the Government to allocate budgets at local levels to cover the operational and maintenance costs of the WCIS system.

SUPPORTING TECHNICAL AND INSTITUTIONAL CAPACITIES

As shown in Figure 3, the four operational parts of the WCIS value chain (observations and monitoring, data and information management, forecasting and modeling, and WCIS development and delivery) require technical and institutional capacity. Technical expertise is needed to generate robust and decision-relevant weather and climate products and services (i.e., the WCIS supply-side capacity) as well as to define and apply such products and services (i.e., the WCIS demand/user-side capacity). In addition, institutions and policies are crucial to facilitating and enabling a functional WCIS system.

RESULTS AND LESSONS LEARNED IN JAMAICA AND MOZAMBIQUE

Recognizing the integral role of technical and institutional capacities in the WCIS value chain, all PPCR-supported projects devote notable resources to training, capacity building, and general outreach activities. These efforts have resulted in considerable progress.

Complementing the full package of operational activities in **Jamaica,** a comprehensive and energetic program of training, knowledge sharing, and general outreach has been developed and implemented under the PPCR project. Training efforts have reached the following stakeholders:

- 119 Meteorological Service of Jamaica (MSJ) officers and partners trained on automatic weather stations (AWS) and manual rain gauge operations
- 28 government officers (from six agencies) trained on soil moisture probe operations
- 17 MSJ officers introduced to data infilling and recovery techniques
- 7 MSJ officers trained on setup, operations, and maintenance of the AWS network
- 18 Water Resources Authority (WRA) officers trained on installation, operations, and maintenance of the network
- 12 WRA officers trained on the use of Aquarius water management software

To conduct its nationwide information, education, and communications campaign (IECC), the PPCR project team partnered with the Climate Change Division of the Ministry of Economic Growth and Job Creation, the focal point for climate change issues within Jamaica. A national comprehensive communication plan was designed to inform the IECC implementation. This included a review of the Communication for Climate Resilience-National Strategy and Action Plan prepared during Jamaica's initial PPCR programming phase.

The IECC was implemented through three separate but coordinated initiatives: The Voices for Climate Change Education program, a general behavior change communication campaign, and a social media and public relations push. All used the tagline ***"Smart and Steady, Get Climate Ready"*** and the cartoon mascot Barry the Barometer. The tagline suggests that climate change adaptation must be done in a creative and innovative (smart) manner and that the adaptation response must be a consistent (steady) consideration in decision making. Under these initiatives, a large

Participants in the MSJ Voluntary Observers & Automatic Weather Station Partners at the College of Agriculture Science and Education (CASE) Portland.

Photo: Planning Institute of Jamaica, 2018.

Community concert held at Red Bank, St Elizabeth.

Source: Planning Institute of Jamaica, 2019.

number of strategically targeted materials have been prepared and innovative public engagement events have been organized.

Under the Voices for Climate Change Education initiative, six concerts were held between April 2019 and March 2020, involving 21 local artists and eight community leaders to deliver "a message in music" in schools and communities and broadcasted live through a popular national radio station. Over 3,000 participants attended the live concerts and around 190,000 tuned into the live broadcasts. Five other high-profile media events took place, which included radio and TV features. In addition, 42 students (30 girls and 12 boys) engaged in creative writing about climate change and about 250 students across the nation read about climate change on "Reading across Jamaica Day." In collaboration with the PPCR Adaptation Program and Financing Mechanism Project, the project team staged three community expos where government and private sector organizations joined community-based groups to showcase their climate adaptation solutions being implemented around Jamaica.

Between January 2019 and March 2020, the project team developed and delivered a media campaign program for the radio and press. The campaign focused on delivering the messages that Jamaicans must work together to prepare for extreme weather conditions caused by climate change and reduce their impacts by learning, sharing knowledge, and taking action that can preserve lives and livelihoods now and into the future. An estimated 44 million people tuned into the four radio stations and 8.3 million read the three newspapers. The project team also actively participated in a range of associated events and interacted with diverse audiences. These included a three-day Green Expo 2019, Geographic Information Systems Day Expo, Green Climate Fund (GCF) private sector stakeholder event, and MSJ's Weather, Climate and Climate Change Quiz.

In **Mozambique**, the PPCR project provided training to over 370 additional hydromet personnel (250 working at the national and regional hydrological operational centers and over 120 at the national meteorological institute). Further, a new set of hydrological data standards have been developed and approved, and the meteorological Decree on Data Standards, Modeling, and Forecasting been enacted and implemented.

KEY LESSONS

Technical training and capacity building: High levels of hydromet staff turn-over in many developing countries means **sustaining technical expertise can be a challenge.** At the start of Jamaica's PPCR project, the project team was confronted with a significant gap in capacity due to the loss of key personnel in MSJ's data acquisition team. To overcome this challenge, the project team invited back an experienced MSJ retiree to train new staff and supervise the set-up and installation of automatic weather stations, and more critically, to produce a written manual as a point of reference for future use.

Institutional capacity and coordination: Given the fact that hydrological and meteorological services are often mandated to different national agencies, **coordination is vital to ensure effective data exchange and hydromet service delivery**. In Mozambique, supported by the PPCR project, the INAM and the National Directorate for Water Resource Management established a memorandum of understanding that set up a working group and instituted a series of tools to sustain close coordination between the two key agencies. The tools include an interministerial diploma on data sharing and a memorandum of understanding on the formats and frequency of data sharing, manuals of hydromet data, and equipment standards and operating guides.

General education and outreach events: One key lesson emerging from Jamaica's successful public education and outreach campaign is **the importance of going local**. Community leaders were actively engaged in the development of localized messages and calls for action, as were local artists, who were mobilized to promote the central messages through their music. By internalizing the IECC through a bottom-up approach, the grassroot stakeholders (students, local artists, community leaders, and others) have been able to take the general education and knowledge exchange on climate change in Jamaica far beyond the limits of formal events delivered under this PPCR-supported project.

Community-based fish farming under the Zambia Strengthening Climate Resilience Project.
Photo: CIF

MOVING FORWARD

Good practices and early successes emerging from PPCR-supported activities contribute to growing global efforts to strengthen WCIS systems. Nonetheless, much work remains to be done, especially in developing countries confronted with the dual challenge of reducing vulnerability to climate impacts and meeting development aspirations. Among others, two areas of work require further concerted efforts: **facilitating in-country stakeholder engagement to develop and implement country-driven initiatives, and developing a viable business model for WCIS.**

Many externally-funded WCIS initiatives tend to be prescriptive and fall short in engaging the "hearts and minds" of beneficiary communities (G. Vogel et al., 2019).[6] To ensure that the WCIS are fit for purpose, donor-supported programs and projects need to bring in local stakeholders from the outset in order to fully leverage their longstanding local knowledge with a view to identifying the most appropriate interventions. This would usually entail ensuring flexibility in project design so that adjustments can be made as needed to project activities, budget allocation, outputs, and timeline.

Similarly, significant investments are needed to deliver and sustain a functional WCIS system to support vital decision making in developing countries. In its first State of the Climate Services Report, the WMO indicated that, based on the World Bank estimate, up to USD 2 billion in additional investments are needed to create national institutions that are capable, and fully equipped, to deliver timely and reliable climate, weather, and water information and services relevant for policy and investment decisions.[7]

To bridge this finance gap, the private sector must be engaged. Although economy-wide analyses suggest favorable cost benefit ratios for investment in WCIS (see Box 3)[8] and many industries already rely on WCIS for their business operations, the business case for WCIS has not been made in a compelling or industry-

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6 G. Vogel et al (2019). Climate services in Africa: Re-imagining an inclusive, robust and sustainable service. Climate Services 15 (2019) 100107. Available online at https://doi.org/10.1016/j.cliser.2019.100107.

7 WMO (2019). 2019 State of the Climate Services: Agriculture and Food Security. WMO-NO.1242. Available online at https://library.wmo.int/doc_num.php?explnum_id=10089.

8 For example, Kull et al (2016) suggests that the potential socioeconomic benefits of providing global forecasting products to low-income countries outweigh the associated costs by at least a factor of four, with a more probable benefit/cost ratio of more than 80:1. [Kull, D., Graessle, C., and Aryan, B. (2016). Strengthening National Hydrometeorological Services Through Cascading Forecasting: Investing for Sustainability and Impact Across Global, Regional, and National Centres. World Bank Policy Research Working Paper No. 7609, Washington, D.C.].

specific manner to achieve its commercial potential. As estimated by a major European Union-supported study, the WCIS market was worth about EUR 13 billion for the 2016/2017 financial year within the 28 countries of the European Union. Figure 6 presents a summary of WCIS sales for a range of climate-sensitive industries in these countries, illustrating the notable commercial value of WCIS. There is scope to make a stronger business case for private sector investment in WCIS. Not only would this bring the benefits of WCIS to more people, but it would make the WCIS system more sustainable, especially in developing countries with constrained public budgets.

Box 3

BENEFIT-COST RATIOS (BCR) OF INVESTMENT IN WCIS

- NMHS improvements to reduce disaster losses in developing countries: BCRs range from 4 to 1 to 36 to 1
- Current and improved weather forecasts in the US assessed for household: BCR of at least 4 to 1
- Drought early warning system in Ethiopia to reduce livelihood losses and dependence on assistance: BCRs range from 3 to 1 to 6 to 1
- El Niño early warning system in a five-state region of Mexico to improve decision making in agriculture: BCRs range from 2 to 1 to 9 to 1

Source: WMO, World Bank, GFDRR & USAID (2015). Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services. WMO-NO.1153. Available online at https://library.wmo.int/doc_num.php?explnum_id=3314.

On both fronts, international financial institutions and funds, like CIF, can play a pivotal role. Through its pioneering country-led programmatic approach to planning, project design, and implementation, CIF has led the way in facilitating local stakeholder engagement and ensuring a sense of ownership.

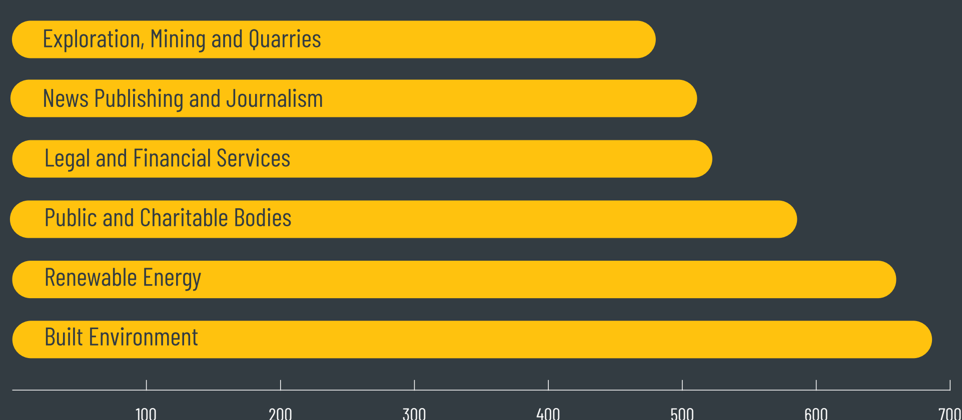
CIF has also been working with fellow members of the Alliance for Hydromet Development to support developing countries in delivering high-quality hydromet services. In particular, CIF has been actively contributing to the Alliance's efforts to finance observations in developing countries as a foundational global public good for climate resilience.

This has been pursued through the establishment of a new SOFF to further strengthen support to developing countries in achieving compliance with the requirements of the Global Basic Observing Network (GBON)[9], deemed critical for climate-resilient development.

The COVID-19 pandemic provides added impetus to strengthen the fundamental societal resilience to physical and socio-economic shocks, including through the provision of and access to robust information and early warning on weather and climate-related hazardous events.

Figure 6.

WCIS SALES IN MAJOR CLIMATE-SENSITIVE INDUSTRIES IN EU28 COUNTRIES IN FINANCIAL YEAR 2016/2017 (EUR MILLION)



Source: Adapted from Figure 5 of S. Howard et al (2020). Quantitative market analysis of the European Climate Services sector – The application of the kMatrix big data market analytical tool to provide robust market intelligence. Climate Services 17 (2020), 100108.

9 https://www.wmo.int/pages/prog/www/wigos/documents/GBON/GBON-exsummary.pdf.

THE CLIMATE INVESTMENT FUNDS

The Climate Investment Funds (CIF) were established in 2008 to mobilize resources and trigger investments for low carbon, climate resilient development in select middle income and developing countries. To date, 14 contributor countries have pledged over US$ 8 billion to the CIF, which is expected to leverage an additional $60 billion in co-financing for mitigation and adaptation interventions at an unprecedented scale in 72 recipient countries. CIF's large-scale, low-cost, long-term financing lowers the risk and cost of climate financing. It tests new business models, builds track records in unproven markets, and boosts investor confidence to unlock additional sources of finance. The CIF is the largest active climate finance mechanism in the world.

CIF CLIMATE INVESTMENT FUNDS

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