Evaluation of GEF Support to Climate Information and Early Warning Systems

Supporting document:
Climate Information and Early Warning Systems – a review of current practice
(*unedited version*)

January 2024

This review is a supportive document of the Evaluation of GEF Support to Climate Information and Early Warning Systems made by the GEF IEO. This evaluation aims to understand how projects funded by the GEF Trust Fund, LDCF, and SCCF have incorporated CIEWS into their programming strategies. Additionally, it seeks to provide evidence on the performance of these interventions through an assessment of their relevance, results, and sustainability. The overarching objective is to inform future GEF programming on CIEWS by offering valuable insights into successful areas and identifying aspects that require additional focus for achieving sustainable outcomes.

Contents

List of Tables

List of Figures

Abbreviations

AWS	Automated Weather Stations
CIEWS	Climate Information and Early Warning Systems
COP	Conference of Parties
CREWS	Climate Risk and Early Warning Systems
EWS	Early Warning Systems
FFGS	Flash Flood Guidance System
GBON	Global Basic Observing Network
GCA	Global Commission on Adaptation
GDP	Gross Domestic Product
GDIS	Global Drought Information System
GDPFS	Global Data Processing and Forecasting System
GEF	Global Environment Facility
GFCS	Global Framework for Climate Services
GNSS	Global Navigation Satellite System
GTS	Global Telecommunication Systems
IBFWS	Impact-based forecast warning systems
ICAO	International Civil Aviation Organisation
IFRC	International Federation of the Red Cross
LLDCs	Landlocked Developing Countries
LDC	Least developed country
LDCF	Least Developed Countries Fund
MHEWS	Multi-hazard Early Warning Systems
MTF	multi-trust fund
NMHS	National Meteorological and Hydrological Services
NWP	Global Numerical Weather Prediction
RBON	Regional Basic Observing Networks
SCCF	Special Climate Change Fund
SIDS	Small Island Developing States
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNDRR	United Nations Office for Disaster Risk Reduction
UNFCCC	United Nations Framework Convention on Climate Change
WIGOS	WMO's Integrated Global Observing System
WMO	World Meteorological Organization

1 Introduction

Climate change exacerbates disaster risks and the frequency of disaster events (Wen et al., 2023), with climate change adaptation and disaster risk reduction core themes for international sustainable development and development goals. Strengthening Climate information and early warning systems (CIEWS) has been a commonly deployed intervention for the Least Developed Countries Fund (LDCF) and has also been addressed by a number of GEF Trust Fund, Special Climate Change Fund (SCCF), and multitrust fund projects. CIEWS are a vital part of reducing vulnerability to the impacts of climate change and building climate change resilience.

Climate and weather information dissemination has become synonymous with Early Warning Systems (EWS) for responding to the hazards and impacts caused by climate change and are both referred to in this report under the umbrella of CIEWS. This summary report highlights the current good practices in CIEWS for use in climate change adaptation, providing key examples and evidence of what has worked and not worked as well as why. The summary report supports the review of the portfolio of GEF-supported CIEWS, and assessing CIEWS interventions supported by GEF, LDCF, and SCCF.

In order for CIEWS to be incorporated within country-priorities as an integral part of climate change resilience, strengthening CIEWS has become a commonly deployed intervention for the Least Developed Countries Fund (LDCF) and has also been addressed by a number of GEF Trust Fund (GEF), Special Climate Change Fund (SCCF), and Multitrust Fund (MTF) projects. CIEWS are noted in all the adaptation strategies of the GEF programming directions and were one of the eminent four priority themes in the strategy for 2022–2026. While less prevalent, CIEWS have also been included in some past GEF Programming Strategies on climate. However, Both the GEF-7 and GEF-8 replenishment programming directions note that investments to support flood and drought CIEWS will be made under the International Waters (IW) focal area to support the focal area's third objective: *Enhance water security in freshwater ecosystems*, although CIEWS are not mentioned in programming directions from previous periods. To date, project interventions have included investments in automated weather stations and their operations and maintenance; agro-hydrometeorological forecasting; institutional capacity building; and last-mile technologies (streamlining and efficiency technologies). These have addressed both rapid and slow-onset climate threats, including floods, droughts, tsunamis, cyclones, and desertification.

1.1 Methodology

The summary report on good practices in climate information and early warning systems (CIEWS) for use in climate change adaptation is aimed at supporting the review of the portfolio of GEF-3 and later projects referring to climate information and early warning systems. The report provides insights into lessons learnt and accepted good practices for CIEWS in the context of preparing and responding to climate change impacts that programming can draw upon. This report is primarily focused on identifying the factors helping and hindering the development of effective CIEWS. Climate information and early warning systems have been considered together, including to review the GEF portfolio of projects relating to early warning and climate information services for climate change adaptation. Similarly, these are considered as CIEWS (combined) by funds focused on climate change rather than disaster-specific focuses, such as the Green Climate Fund (GCF). The summary of good practice CIEWS includes the elements most effective in CIEWS for climate change adaptation, highlighting critical areas for inclusion in climate information and early warning communication and engagement.

Literature is included from the last three years (e.g. 2019 onwards), with the exception of where pivotal conceptual or fundamental literature with core citations is included. Publications and recent reports from leading institutions were also reviewed as grey literature. This summary is limited in scope to a review of systems beneficial for climate change adaptation. This means that early warning systems for hazards such as earthquakes and tsunamis are not included. However, given that literature and general consensus global on early warning is for multi-hazard early warning systems (MHEWS), where multi-hazard approaches are taken as the gold standard for early warning, then scope extends to include non-climate generated hazards such as earthquake and tsunami in these instances.

1.2 Background

Climate change adaptation and disaster risk reduction measures aim to lessen the impacts of climate change impacts and disaster events by building resilience. The Intergovernmental Panel on Climate Change (IPCC) defines adaptation to climate change [for human systems] as "the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities". Adaptation can be long-term strategies for planning based on and responding to predicted changes and risks, through to short-term responses to extreme events and impacts. Framed as a continuum of resilience, adaptation is generally taken as a spectrum and social process, which reduces vulnerability. On one end of the spectrum is incremental adaptation, and on the other end of the spectrum is transformative adaptation. *Incremental adaptations* are primarily concerned with coping and responding to impacts taken as modifications that accommodate change but do not fundamentally change the system, nor necessarily reduce vulnerabilities or transform resilience.

Adaptation options set out the array of strategies and measures that are available and appropriate for addressing adaptation. They include a wide range of actions that can be categorized as structural, institutional, ecological or behavioral (IPCC, 2022a). Adaptive capacity and resilience are often used as the antithesis to cope with shocks, change and uncertainty with assistance or resources of various types. In the context of climate change, the most widely taken definition of adaptive capacity is "the ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities or to respond to consequences" (IPCC, 2022a). Climate change resilience on the other hand describes the capacity of social, economic, and ecosystems to cope with hazardous events or disturbances. Responding or reorganizing in ways that maintain their essential function, identity, and structure (as well as biodiversity in the case of ecosystems) while also maintaining the capacity for adaptation, learning, and transformation (IPCC, 2022b).

Interlinked with adaptation and resilience, disaster risk reduction is aimed at preventing new and reducing existing disaster risks as well as managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development. Both fields are focused on building resilience and reducing risk and are hence combined given the crossover. This is emphasized particularly in early warning systems (EWS), which offer the best-proven and cost-effective method for reducing disaster deaths and losses (UNDRR, 2022b) for both climate-related and seismological hazards and events. Historically, dealing with disasters focused on emergency response, but towards the end of the 20th century, it became increasingly recognized that disasters are not natural (even if the associated hazard is) and that it is only by reducing and managing conditions of hazard, exposure, and vulnerability that we can prevent losses and alleviate the impacts of disasters.

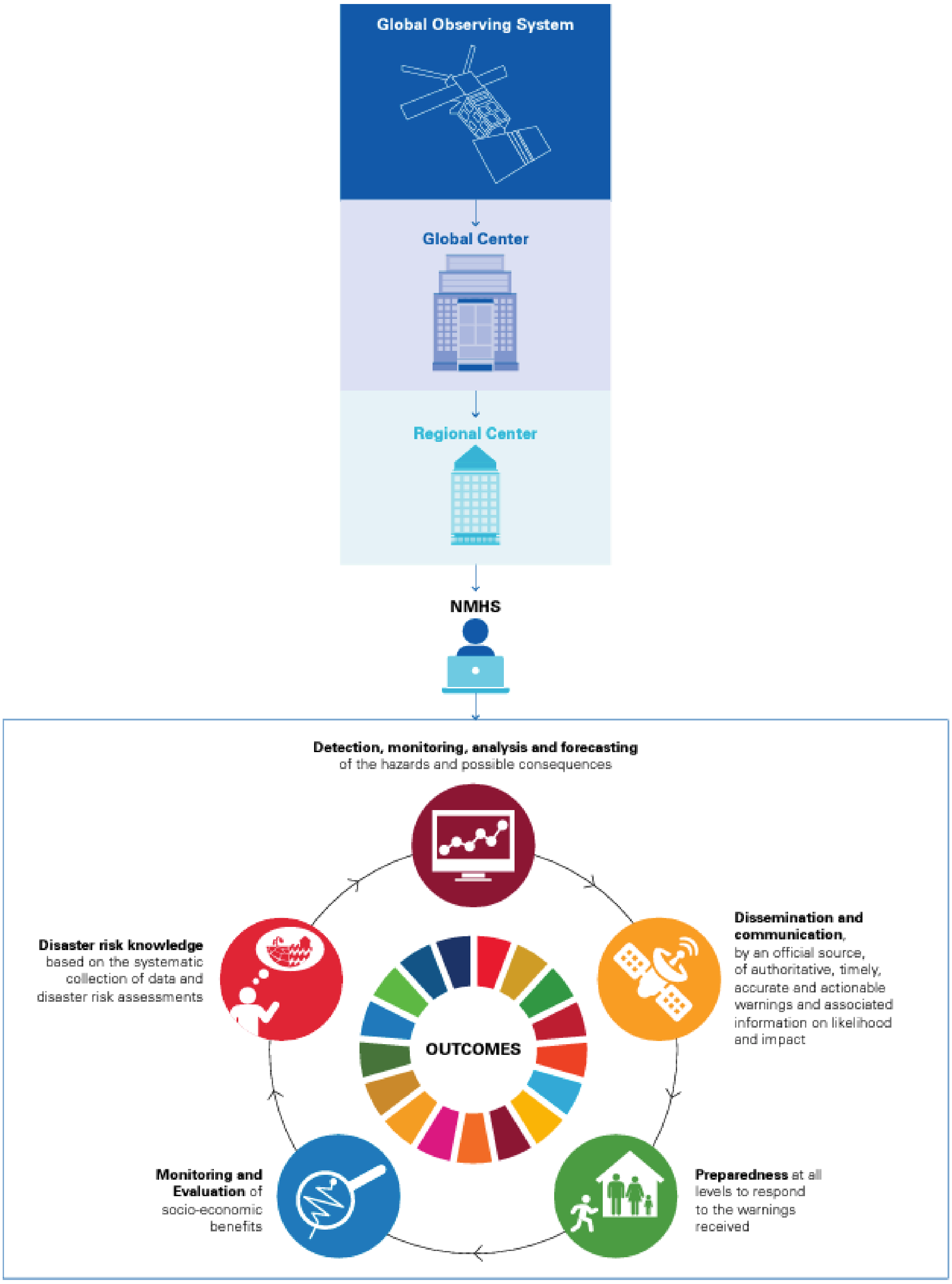
Nowadays, disaster risk reduction strategies and policies define goals and objectives across different timescales and with concrete targets, indicators and time frames. In line with the Sendai Framework for Disaster Risk Reduction 2015-2030, these should be aimed at preventing the creation of disaster risk, as well as the reduction of existing risks and strengthening economic, social, health and environmental resilience. Hazard and risk information inform a broad range of activities to reduce risk, from improving and designing risk reduction measures to carrying out macro-level assessments of different types of risks. Prevention focuses on preventing hazards, primarily from potential disasters. Preventive measures are designed to provide more permanent protection from disasters. While preparedness is a continuous cycle of planning, organizing, training, equipping, exercising, evaluating, and taking corrective action.

This study does not specifically delineate between climate information systems and early warning systems, given the overlap and nature of the two, and the critical consideration of climate-driven disaster. Rather, it is taken that climate information and early warning in good practices for climate change adaptation are integrated, and combine the following:

Climate Information Services (CIS) refer to the collection and interpretation of observations of actual (past and present) weather and climate as well as simulations of both past and future periods (forecasting) to provide a credible, relevant, and usable interpretation of weather and climate information (CARE, 2023). These can include information that assists decision-making based on anticipating and managing the risks of changing and variable climate, to provide access to interpreted targeted climate information that is relevant, reliable, accurate, and communicated appropriately.

Early Warning Systems are the provision of timely and effective information that allows those exposed to hazards to take action and avoid or reduce their risk and be able to prepare an effective response (UNDRR 2004). Each of these agendas recognizes the centrality of resilience and supports for building resilience by facilitating decision-making based on obtaining reliable information on how risks can be reduced for human and natural systems (Flood et al., 2021).

Figure 1 Global data processing and forecasting system of WMO member network at global, regional and national levels in the value chain for climate information services and early warning.



Source: WMO 2020

2 Climate Information and Early Warning Systems (CIEWS)

The importance of CIEWS is being increasingly emphasized globally with the role that CIEWS plays as an integral component of climate change adaptation. The policy frameworks set by the 2015 Sendai Framework for Disaster Risk Reduction 2015-2030, and the 2015 Paris Agreement on Climate Change including adaptation synergize the need to respond to increasing disaster events and climate impacts, by building resilience (UNDRR, 2015; UNFCCC, 2015). The UN Secretary-General for Disaster Risk Reduction, Mami Mizutori, recently highlighted this importance, stating: "Early warning systems are one of the most effective risk reduction and climate adaptation methods for reducing disaster deaths and economic losses" (2023).

2.1.1 Climate impacts and disasters

Disasters involving weather, water and climate hazards constitute 79 percent of disasters, 56 percent of deaths and 75 percent of the economic losses involved in all disasters related to natural hazard events reported over the last 50 years (WMO, 2020). The 2015 Paris Agreement set out the global goal of adaptation to enhance adaptive capacity, strengthen resilience, and reduce vulnerability to climate change in the context of the temperature goals of the Agreement (UNFCCC, 2015). This saw pledges on mitigation to pursue efforts to limit the increasing temperature globally to 1.5°C, the figure needed to avoid severe climate change impacts across ecological systems and human societies (IPCC, 2022b) and commitment to ensuring the global temperature increase would stay below 2°C (UNFCCC, 2015). However, the world has surpassed meeting the 1.5°C limit which would require an additional 50 percent reduction in the current emissions rate by 2030 and is tracking towards a 2.8°C temperature rise by the end of the century (UNEP, 2022). This level of temperature rise is likely to have very serious implications in raising the frequency and severity of climate change impacts, risks and threats. Key risks from climate change are related to low-lying coastal systems; terrestrial and ocean ecosystems; critical physical infrastructure, networks, and services; living standards; human health (e.g. allergens, increased incidents of health impacts from heat, WATSAN issues, vector-borne diseases); food (in)security; water (in)security; and peace and mobility (IPCC, 2022b), affecting all spheres of life. With nine out of every ten disasters being water-related, either as a result of too much or too little water, hydrometeorological impacts and disaster events are a critical consideration for CIEWS (UNDRR, 2023b). Hydrometeorological risks are set to increase under climate change. Floods globally have affected at least 1.4 billion people between 2000 to 2019 and drought has affected at least 1.6 billion people during 2000 to 2019 (UNDRR, 2023b).

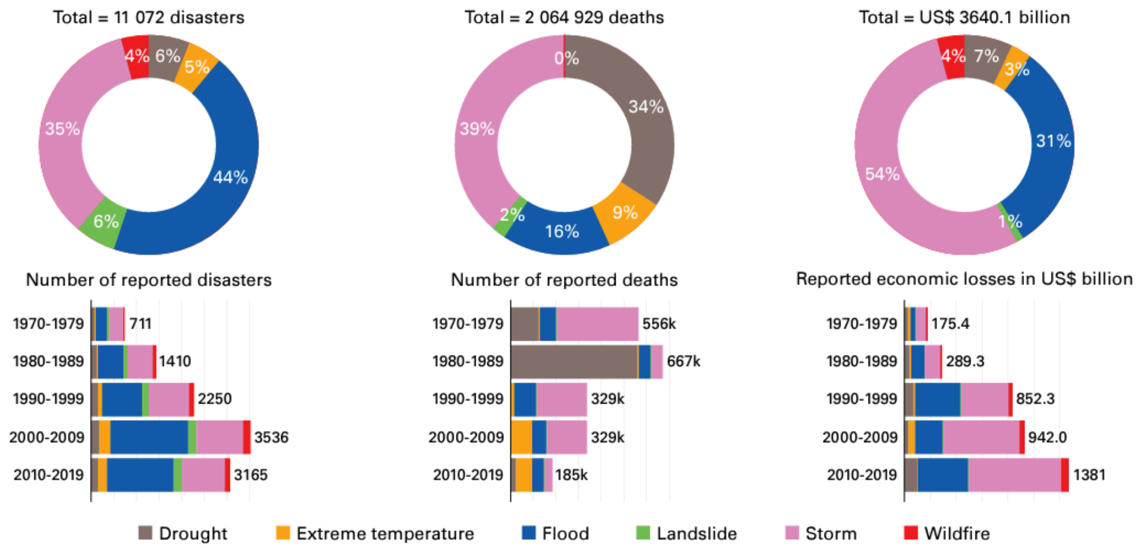
Climate information is critical in early warning and decision-making to avert slow onset and rapid disaster events. Over the last 10 years (2010-2019), the percentage of disasters associated with weather, climate, and water-related events increased by 9 percent compared to the previous decade, and by almost 14 percent for the decade 1991-2000 (WMO, 2020). According to the World Meteorological Organization (WMO), global temperatures will likely surge to record levels for the 2023-2027 period, fueled by heat-trapping greenhouse gases and a naturally occurring El Niño event (WMO, 2023b). There is a 66 percent likelihood that the annual average near-surface global temperature between 2023 and 2027 will be more than 1.5°C above pre-industrial levels for at least one year. There is a 98 percent likelihood that at least one of the next five years, and the five-year period as a whole, will be the warmest on record (WMO, 2023b). Climate impacts related to increased heat levels and disproportionate dry conditions are expected in some areas. However, predicted precipitation patterns for the May to September 2023-2027 average, compared to the 1991-2020 average, suggest increased rainfall in certain areas, and reduced rainfall for others (WMO, 2023b).

Figure 2 Map of the deadliest and most costly climate-related hazards for each country as mapped by WMO analysis for 1970-2019

Source: WMO 2020 (based on 1979-2019 data from the Emergency Events Database of the Centre for Research on the Epidemiology of Disasters CRED)

WMO's Global Annual Decadal Climate Update ensembles data from 145 countries along with historical and projected information from the Coupled Model Intercomparison Project phase 6 (CMIP6). In 2020, the WMO and GCFS produced the 2020 State of Climate Services report on risk information and early warning systems. The report found that between 1970 and 2019, 79 percent of disasters worldwide involved weather, water, and climate-related hazards accounting for 56 percent of deaths and 75 percent of economic losses from disasters associated with natural hazards events reported during that period (WMO, 2020). This increase raises the imperative not only for the mitigation of climate change but also for adapting to climate change impacts and reducing risks and disasters.

Figure 3 Distribution of number of disasters, number of deaths and economic losses globally across hazard types and decade



Source: WMO (2020)

In 2021 alone, 38 million new internally displaced people were recorded, 60 percent of whom were displaced due to climate-related disasters (Ijjasz et al., 2022). Annual reported losses averaged US$ 330 billion (equivalent to 1 to 2.2 percent of GDP) (Ijjasz et al., 2022). In the 2015-2021[1], it was estimated that 1.05 billion people were affected by disasters, and 300,000 people went missing or lost. Between 1970 and 2019, 11 072 weather-related disasters involved more than 2.06 million deaths and caused US$ 3 640 billion in economic losses (WMO, 2020).

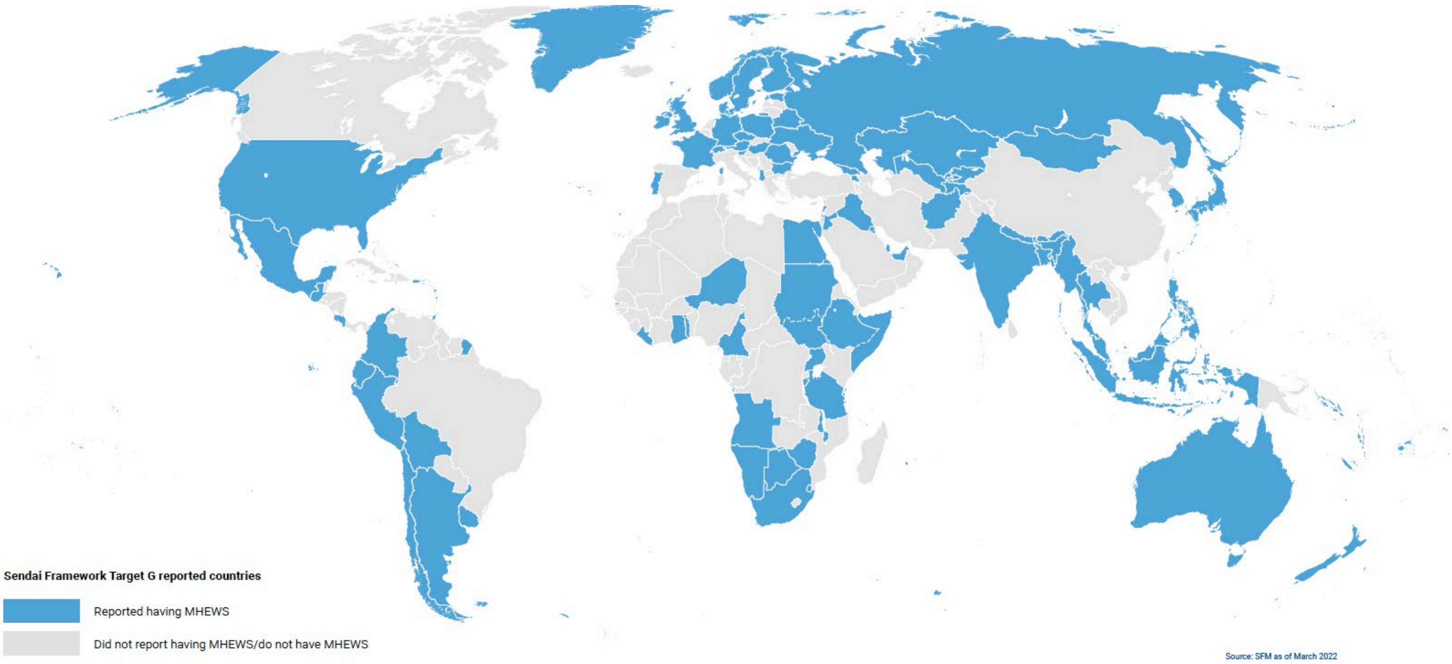
Least-developed countries (LDCs) and small landlocked and island states bore the disproportional burden of disaster-related economic losses relative to their national gross domestic product (Ijjasz et al., 2022). LDCs, landlocked developing countries (LLDCs), and Small-Island Developing States (SIDS) are bearing a disproportional burden of disaster economic losses relative to their national GDP. Combined, these countries accounted for 11.3 per cent of reported economic loss during 2012 to 2021, although only accounted for 2.2 per cent of total GDP of countries reporting (UNDRR-WMO, 2022b). Since 1970, SIDS have lost US$ 153 billion due to weather, climate- and water-related hazards – a significant amount given that the average gross domestic product (GDP) for SIDS is US$ 13.7 billion.4 Meanwhile, 1.4 million people (70 percent of the total deaths) in LDCs lost their lives due to weather, climate and water related hazards (WMO, 2020).

The 2019 Global Commission on Adaptation flagship report Adapt Now found that early warning provides a tenfold return in avoiding damage and loss, on investment costs. Early warning given 24 hours in advance of a disaster event or hazard can reduce damage by 30 per cent, and investing US$800 million in early warning systems in developing countries would reduce losses of between $3 billion to $16 billion annually (UNDRR, 2022b). Early warning systems, climate services, and disaster risk reduction activities are crucial adaptation options that can complement other measures (WMO, 2023a).

[1] The first seven years of the Sendai Framework (2015- 2021)

As of 2022, only half of countries globally were protected by multi-hazard early warning systems (UNDRR-WMO, 2022a), with numbers even lower for developing countries at less than half of the Least Developed Countries and only one-third of Small Island Developing States having a multi-hazard early warning system (UNDRR, 2022b). These figures are also echoed by the WMO, who found in their State of Climate Services 2020 report that data provided by 138 WMO Members (including 74 percent of LDCs and 41 percent of SIDS globally) show that just 40 percent of them have multiple-hazard early warning systems (MHEWS). One-third of every 100,000 people in the 73 countries that provided information is not covered by early warnings (WMO, 2020). At the same time, countries with limited early warning coverage have disaster mortality that is eight times higher than countries with comprehensive early warning systems. Figure 1 below shows the global coverage of reported early warning system coverage by country in March 2022 for the Sendai Framework's target G (UNDRR, 2023a).

Figure 4 Global coverage of reported early warning systems (by country) reported in March 2022



Sendai Framework Target G – Sendai Framework Monitor (SFM) Reported Countries as of March 2022. Source: UNDRR, 2022

The provision of early warning systems accessible to all populations globally would greatly reduce the mortality of disasters and the number of affected people and losses. The UNDRR emphasizes the special assistance needed to the LDCs and SIDS and Africa to ensure the value cycle of early warning and reaching the last mile (UNDRR, 2023b). Regions face disparities in their progress in establishing CIEWS, and special assistance is needed for least-developed countries (LDCs), small island developing States (SIDS), and Africa (UNDRR-WMO, 2022b). In particular, more investments are needed throughout the early warning cycle, with an emphasis on reaching the 'last mile' (UNDRR-WMO, 2022b); the dissemination and use of climate information and early warning to inform action.

2.1.2 International agreements on climate information and early warning

Until now, international agreements on both climate change and disaster have enshrined the importance of early warning and climate information. Key agreements and critical reports on climate information and services and early warning during the last two decades are set out in Table 1 below.

Table 1 Key international policy, agreements, frameworks and conferences on disaster and climate relating to early warning and climate information in the last 20 years

Year	International policy, agreement, framework or conference
2023	UN Early Warnings for All
2022	27th Conference of Parties (COP27) to the United Nations Framework Convention on Climate Change (UNFCCC) Early Warnings for All Action Plan
2022	IPCC Sixth Assessment Report and WGII Report on Climate Change 2022: Impacts, Adaptation and Vulnerability
2015	21st Conference of Parties (COP27) to the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement (CoP21)
2015	Sendai Framework for Disaster Risk Reduction 2015-2030 (endorsed at the World Conference for Disaster Risk Reduction
2015	The Sustainable Development Goals (SDGs)
2014	IPCC Fifth Assessment Report
2012	IPCC Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation
2010	Cancun Adaptation Framework
2007	Bali Action Plan
2007	IPCC Fourth Assessment Report
2005	The Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters (Endorsed at the Second World Conference on Disaster Reduction)

Early warning and climate information play a significant role in the Sendai Framework for Disaster Risk Reduction (Target G) and are crucial for cooperation in the Paris Agreement regarding adaptation (Article 7) and minimizing loss and damage (Article 8) (WMO, 2023a). The United Nations Framework Convention on Climate Change (UNFCCC)'s Paris Agreement (2015) on climate change, encouraged parties to "strengthen scientific knowledge on climate, including research, systematic observation of the climate system and early warning systems, in a manner that informs climate services and supports decision-making" (UNFCCC, 2015).

The target that everyone on Earth should be protected by early warning systems against climate change and resulting extreme weather by the year 2027 (UNCC, 2022) was also recently announced on World Meteorological Day, March 23, 2022, by the UN Secretary General. Early Warnings for All calls for investments of US3.1 billion for early warning during the 2023-2027 period. During the 27th Conference of Parties (COP27) to the UNFCCC in 2022, steps for achieving this were set out in the announcement of the *Early Warnings for All Action Plan,* to achieve early warning systems for all by 2027 (WMO, 2022a). The 2023-2027 five-year action plan sets out four pillars to be enacted under the lead of UN and international agencies. These four pillars are: Pillar 1 – Disaster risk knowledge and management (US$374 million) to collect data and undertake risk assessments to increase knowledge on hazards and vulnerabilities and trends (UNDRR, WMO); Pillar 2 – Observations and forecasting (US$1.18 billion) to develop hazard monitoring and early warning services (WMO, UNDP, UNESCO, UNEP); Pillar 3 – Warning dissemination and communication (US$ 550 million) to communicate risk information so that it can reach all those who need it, and is understandable and usable (ITU, IFRC, UNDP, WMO), and Pillar 4 – Preparedness and response capabilities ($1 billion) to build national and community response capabilities (UNDRR) (UNDRR, 2023c). The Early Warnings for All: Executive Action Plan 2023-2027 leverages existing pooled funding mechanisms through the Systematic Observations Financing Facility (SOFF)[2], the Climate Risk and Early Warning Systems (CREWS) initiative[3], as well as the global multilateral funds (e.g. the Green Climate Fund) and the development banks.

Figure 5 Investments needed under each pillar of the Early Warnings for All Initiative

The Sendai Framework for Disaster Risk Reduction 2015-2030 (UNDRR, 2015) was adopted to set out the goals for reducing disaster risk globally. The Sendai Framework sets out several key global targets that correspond to early warning, including a) substantially reducing the global disaster mortality by 2030 compared with the period during 2005-2015, and; b) substantially reducing the number of affected people globally by 2030 to lower the average global figure compared with 2005-2015; c) reducing direct disaster economic losses to GDP by 2030; (d) substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030; (e) substantially increase the number of countries with national and

[2] The SOFF is an alliance of the WMO, UNEP, UNDP, and a fund established to ensure access to basic weather and climate observations for LDCs and SIDS. SOFF provides long-term, grant-based financial and peer-to-peer technical assistance to support the generation and international sharing of basic weather and climate observations, according to the internationally agreed Global Basic Observing Network (GBON) regulations.

[3] CREWS works directly with countries to increase the access to and availability of early warning systems and provides a financial mechanism that funds projects in the LDCs and SIDS to establish risk-informed early warning services. CREWS initiative claims that an estimated 111 million people are better protected against climate-related hazards thanks to early warning systems put into place in 2022 by the Climate Risk Early Warning Systems (CREWS) Initiative (CREWS Iniative, 2023).

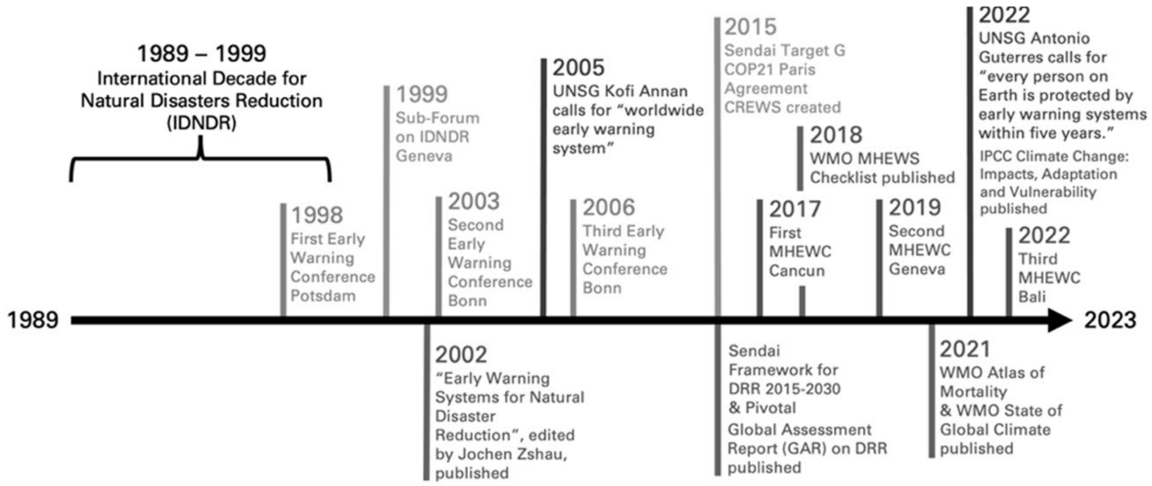
local disaster risk reduction strategies by 2020; and (f) substantially enhance international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of the present Framework by 2030. Yet, the most critical target set out by the framework for early warning is Target G.

Target G aims to substantially increase the availability of and access to Multi-hazard Early Warning Systems (MHEWS) and disaster risk information and assessments to the people by 2030. This also includes an increase in the number of countries that have MHEWS, by increasing the number of countries with multi-hazard monitoring and forecasting systems (e.g. climate information systems). At the same time, Target G includes aims to increase the number of people covered by early warning information through local and national dissemination mechanisms, as well as increase the number of local government plans including early warning and percentage of population protected through pre-emptive evacuation following early warning (UNDRR, 2015). The UNDRR has been mandated to monitor the implementation of the Sendai Framework (as presented in Figure 1), which it does through the online Sendai Framework Monitor (SFM), also contributing to the monitoring of selected targets of SDGs 1, 11 and 13.

The Sendai Framework's Priority 4 to enhance disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation, and reconstruction, also highlights the role of investing in early warning. Specifically, calling for investments in developing, maintaining, and strengthening people-centered multi-hazard, multisectoral forecasting and early warning systems, disaster risk and emergency communications mechanisms, social technologies, and hazard-monitoring telecommunications systems. Investments called for under the Sendai Framework's Priority 4 promote simple and low-cost early warning equipment that facilitates and broadens the release channels of early warning information. This includes ensuring that early warning mechanisms are compatible with systems through regions, and where possible, the Global Framework for Climate Services (GFCS). Specifically, Priority 4 of the Framework calls for investments in developing, maintaining, and strengthening people-centered multi-hazard, multisectoral forecasting and early warning systems. Correspondingly, investments in disaster risk and emergency communication mechanisms, social technologies, and hazard-monitoring telecommunications systems are needed to accompany the multihazard, multisectoral forecasting and early warning systems (UNDRR, 2015).

Within the Sendai Framework for Disaster Risk Reduction 2015-2030, there are several guiding principles encapsulated that oblige global responsibility for preventing and reducing disaster risk, including the enhancement of capabilities through the provision of sustainable international cooperation (UNDRR, 2015). Given that globally, almost 80 percent of disaster events between 1970 and 2019 were hydrometeorological or climate-induced, with least developed countries (LDCs) and small island developing states (SIDS) the most acutely affected (GCF, 2022) deploying climate information and early warning systems is critical. The Sendai Framework highlights those developing countries and particularly least developed countries and small island developing states (SIDS), land-locked countries and African countries, as well as middle-income countries, need adequate sustainable and timely support from developed countries. This support is needed to assist in facing specific disaster risk challenges and critically needed coordination and coordination mechanisms within and across sectors, relevant stakeholders, and all levels. Critically, this support should also be tailored to the needs and priorities identified by the developing countries being supported, through finance, technology transfer, and capacity building.

Figure 6 History of announcements and publication milestones for developing early warning systems from 1989 onward



Source: (WMO, 2023a)

2.2 Climate Information Services

National meteorological and hydrological services provide climate information products and services to their constituents at regional and local levels. Climate services rely on data generated from national and international databases providing information on temperature, rainfall, wind, soil moisture, and ocean conditions as well as projections and scenarios, and risk and vulnerability analyses. Data is combined with socioeconomic variables and other non-meteorological data such as data on agricultural productivity, road and infrastructure plans and mapping, health trends, and human settlements in high-risk zones. The combined information can be customized into climate information services such as projections, trends, forecasts, early warning, and services tailored to assist in adaptation to climate variability and climate change, particularly for climate-sensitive sectors (WMO, 2022b).

Figure 7 Ways Climate Services are provided

Source: Global Framework for Climate Services (GFCS), WMO

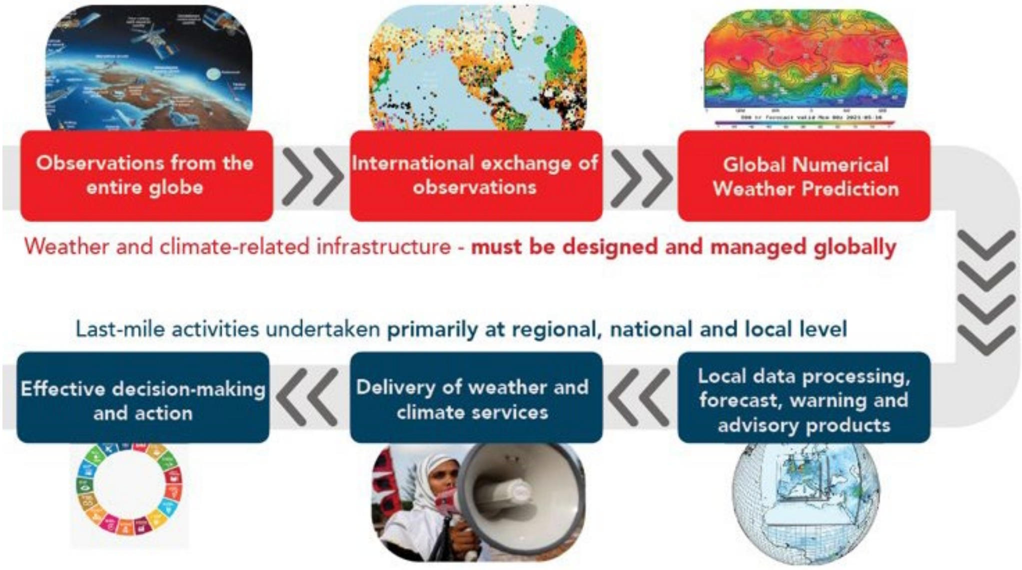
The Global Framework for Climate Services (GFCS) sets out the development and application of climate services. Developed through a multi-government and multi-stakeholder partnership of UN agencies, international organizations, climate service-related programs, donors, governments, NGOs, the private sector, and national meteorological and hydrological services, the GFCS was adopted by an Extraordinary Session of the World Meteorological Congress in 2012. The framework is intended to enable better management of the risks of climate variability, climate change and adaptation through the development and incorporation of science-based climate information for practice and policy at global, regional and national scales. The GFCS is based on components 1) observations and monitoring, 2) climate services information system, 3) research, modeling and prediction, 4) User Interface Platform, and 5) Capacity Development. The GFCS is intended to accelerate and coordinate technically and scientifically sound climate information and measures to improve climate-related decision-making addressing climate-related risks (WMO, 2022b). Climate services are focused on five priority areas under the GCFS. These are: 1) agriculture and food security, 2) disaster risk reduction, 3) energy, 4) health, and 5) water, as they are considered to be the five areas presenting the most immediate opportunities and benefits for human safety and well-being (WMO, 2022b).

Organizations such as the WMO facilitate the collection and exchange of globally consistent observations, however, limited surface-based observational data availability restricts whether high-quality weather and climate products and services can be made available to all. The WMO collects data on risk information and early warning implementation based on a framework co-developed by the WMO and the UNDRR for monitoring implementation of end-to-end, people-centred early warning in the context of the Sendai Framework – Target G. WMO's reporting covers only hydrometeorological-climate early warning and information, whereas the mandate of the UNDRRR and the Sendai Framework is broader, covering geological, hydrological, meteorological, climatological, extra-terrestrial, biological and technological hazards and environmental degradation (WMO, 2020).
The WMO supports national meteorological and hydrological services, especially those of developing and least developing countries, in a number of ways. As part of this, the WMO

also provides technical regulations, standard and recommended practices and procedures, and provides a standard operating procedure as per the Manual on the WMO Integrated Global Observing System (WMO-No. 1160) and the Manual on the Global Data-processing and Forecasting System (WMO-No. 485). The WMO undertakes global collaborative efforts to support national services via the Global Data Processing and Forecasting System (GDPFS). This system is composed of global Regional Specialized Meteorological Centres, including nine Regional Climate Centers (and three network RCCs) as well as National Meteorological and Hydrological Services (NMHSs). These also are supported by the inputs of six specialized regional centers on tropical cyclones forecasting, 24 marine meteorological services, two sand and dust storm forecast, and nine International Civil Aviation Organization (ICAO) volcanic ash advisory centers (WMO, 2020).

The WMO also produces a report “State of Climate Services” annually, issued since 2019 in response to a UN request for more information on adaptation needs of countries, which provides inputs from across 26 different organizations. According to the WMO’s State of Climate Services: Risk Information and Early Warning Systems Report in 2020, 113 Members participated in the World Weather Information Service of the WMO, a platform for sharing authoritative forecasts from Members. Out of those 113, 72 members participated in regional warning platforms in Asia and Europe (WMO, 2020), and 61 members implemented quality management systems for the provision of meteorological, hydrological, and climate warning services (mainly in Europe). Overall, 84 percent of members provide forecasting and warning services for floods and drought, and 64 members are covered by the WMO Flash Flood Guidance System (FFGS). Currently, the system benefits about 3 billion people around the world by providing operational forecasters and disaster management agencies with real-time informational guidance products pertaining to the threat of small-scale flash flooding (WMO, 2020).

Figure 8 Weather and climate services meteorological value chain



Source: WMO 2021[4]

[4] WMO Unified Policy for the International Exchange of Earth System Data, Global Basis Observing Network (GBON) Systematic Observations Financing Facility (SOFF), Extraordinary Session of the World Meteorological Congress 11-22 October 2021

2.2.1 Monitoring and warnings services

Monitoring is the act of collecting information along with a set of proxy variables related to risk (UNDP, 2018a). Technology allows for data to be compiled from multiple monitoring sources and at high speed. Observations can be made through several technologies, each providing different levels of accuracy and spatial coverage: remote sensing, satellite observations, and on-ground measurements (weather and hydrological stations, both manually operated and automated).

Figure 9 Common technological monitoring solutions

Source: (UNDP, 2018a)

Observation undertaken for generating climate information tends to be based on the types of information needed by users. This most commonly involves measurements of precipitation, soil moisture, surface air temperature phenomena (e.g. types of cloud and thunderstorms), and other observations for forecasting and other applications. This observational data determines the basis for defining and validating numerical models used for weather and storm forecasting, as well as for longer-term scenario-based projections of climate change (WMO, 2022b).

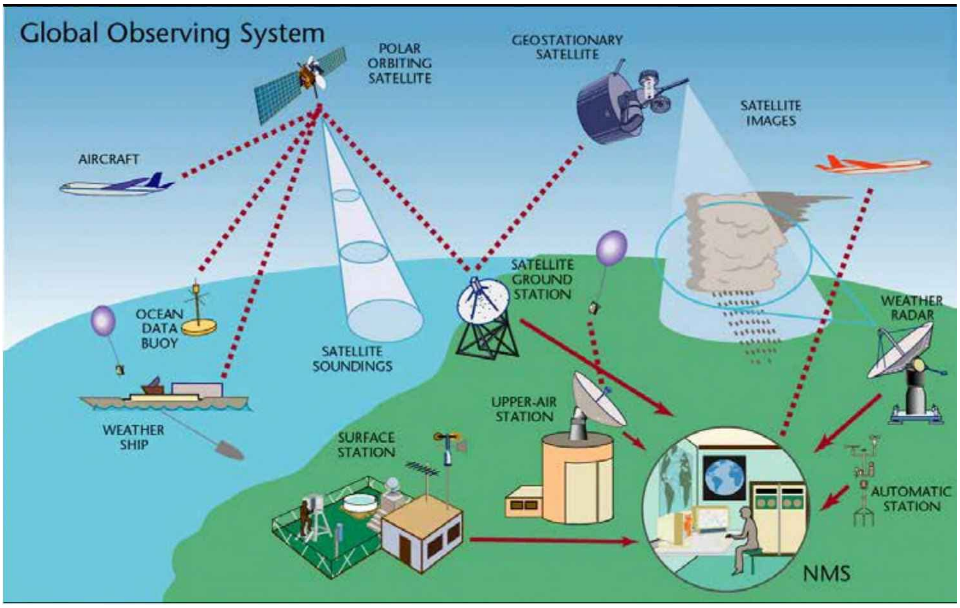
Automated weather stations (AWS) can use either manually logged elements taken hourly, or automatically logged data at minute intervals by sensors. This data from the Automatic Weather Station is then transferred to a central collection system to quality check and store and share the information collected (FAO, 2019). AWS components include data loggers (designed to measure sensors, analyze data, and store the data securely) and various sensors to measure various weather parameters, wind speed, relative humidity (RH) and temperature, monitor solar radiation, measure soil moisture and temperature and rain gauges to measure precipitation. Global Telecommunication Systems (GTS) operate in real-time to collect meteorological data which they collect globally in order to process and distribute data to users and to input into decision support systems and modeling systems such as the Global Circulation Models (GCM) (FAO, 2019). There are three types of space-based technologies including satellite telecommunications, Earth observation and Global Navigation Satellite System (GNSS). Satellite telecommunications and Earth observation are most frequently used in several types of early warning systems. Satellite telecommunications are used in two ways: to transmit data from sensors deployed in remote areas to observatories, where the data is then analyzed and used to elaborate forecasts regarding potentially catastrophic events; to transmit warnings from one geographic region to another region (UN-SPIDER, 2023). Earth observation is used in various types of early warning systems such as to track the path of cyclones at sea before they make landfall, assess the severity of droughts in comparison to historic droughts, to monitor the progress of floods in very large basins, and to track active mass movements including landslides (UN-SPIDER, 2023).

Satellite remote sensing technology fall into four types: 1) persistence forecasting, 2) Synoptic forecasting, 3) statistical or climatological forecasting, and 4) computer modeling forecasting (FAO, 2019). *Persistence forecasting* draws on current weather conditions to forecast future conditions, by judging whether current conditions are likely to persist or change using data from barometers, thermometers and observation and providing forecasting ahead for a number of days in areas where the weather tends to be more predictable such as arctic or tropical regions. *Synoptic* or analog forecasting predicts weather based on accepted principles and theories of meteorology by combining atmospheric pressure, air flow and temperatures with maps, radar and satellite imaging to deliver a forecast. This approach is still used for short-term predictions. *Statistical* or climatological forecasting allows meteorologists to make predictions based on historical trends using averages, highs and lows and drawing on temperature, storm and precipitation records to predict likely future weather for particular periods based on their historical and current patterns (FAO, 2019).

Guidance for undertaking observation and processing data developed by the WMO are included at Annex 1 Manuals and Guidance provided by the WMO.

The Global Observing System (GOS) of the WMO World Weather Watch provides surface and spaced-based subsystems used in conjunction with observational facilities on land, sea, air and space (FAO, 2019). Observations are collected across a plethora of surface and space-based observation systems from a multitude of national and international agencies, through the Global Observing System and Global Telecommunication System. These observations are obtained and exchanged in real time between WMO Members and other partners" (WMO, 2020). These cover daily weather forecasts, monthly climate outlooks, seasonal climate outlooks, observed climate change signals, climate change vulnerability assessment maps, advisories/alerts for drought, flood and other climate events, agroecological mapping, agromet bulletins, seasonal distribution maps – for onset and cessation of rainfall, growing periods, dry and wet spell mapping, and mapping of rainfall variability throughout the seasons (FAO, 2019).

Figure 10 Global Observing System



Source: The World Meteorological Organisation (WMO) (*Global Observing System*, 2015)

The Global Basic Observing Network (GBON) under the WMO's Integrated Global Observing System (WIGOS) proposes the design and definition of a basic surface-based observing network at the global level, called the Global Basic Observing Network (GBON). GBON provides the technical regulations for implementation and compliance monitoring that are essential for surface-based data for weather forecasts. GBON operates in conjunction with the space-based subsystem and other surface-based observing systems to meet the requirements of Global Numerical Weather Prediction (NWP), including climate monitoring. The Regional Basic Observing Networks (RBON) are built on the same foundations as the GBON to provide a broader range of WMO application areas, and all of the GBON stations and observing programs are included in the respective RBON of the region in which they operate.

2.2.2 Modelling and prediction

Accurate and rapid warning can be provided or where longer lead time is possible (weeks to months) for events such as storms, flooding, and droughts, continuous monitoring of significant proxy variables can trigger risk mitigating actions (UNDP, 2018a). Hydrometeorological warnings also have to account for changing climatic conditions due to climate change. the build-up of historical databases of observations allows for the development of statistical methods to calibrate forecasts at all timescales (weather, seasonal, and climate change) (UNDP, 2018a). Overall, weather and climate forecasting types are classified into different groups ranging from instant to extended range forecasting, the shorter the time range, the higher the predictability and accuracy (FAO, 2019).

Table 2 Definitions of weather forecasting and climate outlook ranges

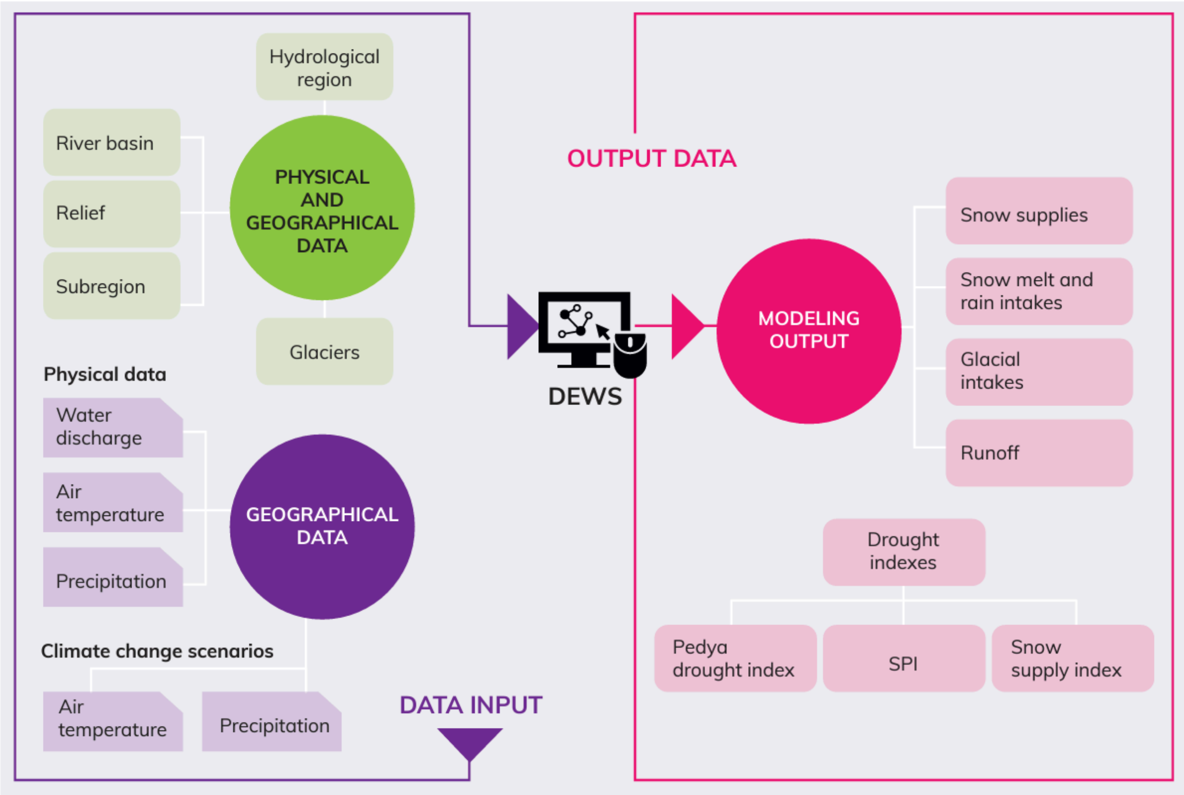
Type	Range	Parameters	Temporal resolution	Spatial resolution	Type of products
Now-casting (NC)	0-2 hours	Description of current weather parameters and description of forecast weather parameters for 0-2 hours. A relatively complete set of parameters can be produced (i.e., air temperature and relative humidity, wind speed and direction, solar radiation, precipitation amount and type, cloud amount and type, and the like).	Minutes	1-2km	Text, graphics.
Very Short Range Weather Forecasting (VSRWF)	Up to 12 hours	A relatively complete set of weather parameters can be produced (i.e. air temperature and relative humidity, wind speed and direction, solar radiation, precipitation amount and type, cloud amount and type and the like).	Eight times a day at three-hour interval	15-25km	Text, graphics, Time series, maps.
Short-Range Weather Forecasting (SRWF)	12-72 hours	A relatively complete set of weather parameters can be produced (i.e. air temperature and relative humidity, wind speed and direction, solar radiation, precipitation amount and type, cloud amount and type and the like).	Eight time a day at three-hour interval	25-80km	Text, graphics, time-series, maps.
Medium-Range Weather Forecasting (MRWF)	72-240 hours (3-10 days)	A relatively complete set of weather parameters can be produced (i.e. air temperature and relative humidity, wind speed and direction, solar radiation, precipitation amount and type, cloud amount and type and the like).	Twice a day	25-80km	Text, graphics, time-series, maps.
Extended-Range Weather Forecasting (ERWF)	10-30 days	A description of main weather parameters usually averaged and expressed as a departure from climate values for that period.	Once a day	80-150km	Text, graphics, time-series, maps.
Long-Range Weather Forecasting' (LRWF)	30 days up to 2 years	Usually restricted to some fundamental weather parameters (i.e. temperature and precipitation).	Once a mont	80-150km	Text, graphics, time-series, maps.
Monthly Climate Outlook	Current month (not necessarily the following month)	A description of averaged main weather parameters (i.e. temperature and precipitation) expressed as a departure in percentage (i.e. deviation, variation, anomaly) from climate values.	Once a mont	150-400km	Text, maps.
Three-month Climate Outlook	90-day period (not necessarily the following 90-day period)	A description of averaged main weather parameters (i.e. temperature and precipitation) expressed as a departure in percentage (i.e. deviation, variation, anomaly) from climate values.	Once every 3 months	150-400km	Text, maps.
Seasonal Outlook	Three-month period	A description of averaged in weather parameters (i.e. temperature and precipitation) expressed as a departure in	Once every 3 months (during the season)	150-400km	Text, maps

		percentage (i.e. deviation, variation, anomaly) from climate values for that season.			
Weather Information & Severe Weather Alert	Occasionally	Weather information, when sudden and important changes of the weather conditions are detected, or severe weather is anticipated. Severe weather alerts include advisories and warnings. Preliminary warnings are issued before severe weather alerts and give information about the type, place and time of the expected severe weather. Preliminary warnings are usually issued several hours earlier than the severe weather alert, giving a crucial time advantage to the mitigation of weather disasters.			Text.

Adapted from the FAO's Handbook on climate information for farmers (2019)

There are a number of examples of these different types of climate information and weather-related forecasting systems that feed into use for early warning systems in use throughout the world and in different regions and scales of use. Below are some of the variations in scales of different systems in use.

Figure 11 Example of structure for drought early warning data from Uzbekistan



Source: (UNDP, 2018a)

Space agencies, for example, have set up applications to combine satellite imagery to generate relevant products that can be used in early warning systems around the world such as the Copernicus programme of the European Commission (which operates the Global Drought Observatory, European Flood Awareness System and Global Wildfire Information System as well as providing free-of-charge access to satellite imagery collected). Similarly, the

National Oceanographic and Atmospheric Administration (NOAA) provide access to satellite imagery from satellites and operate the Global Drought Information System (GDIS) and the National Hurricane Centre (NHC) in the Caribbean and Central America (UN-SPIDER, 2023).

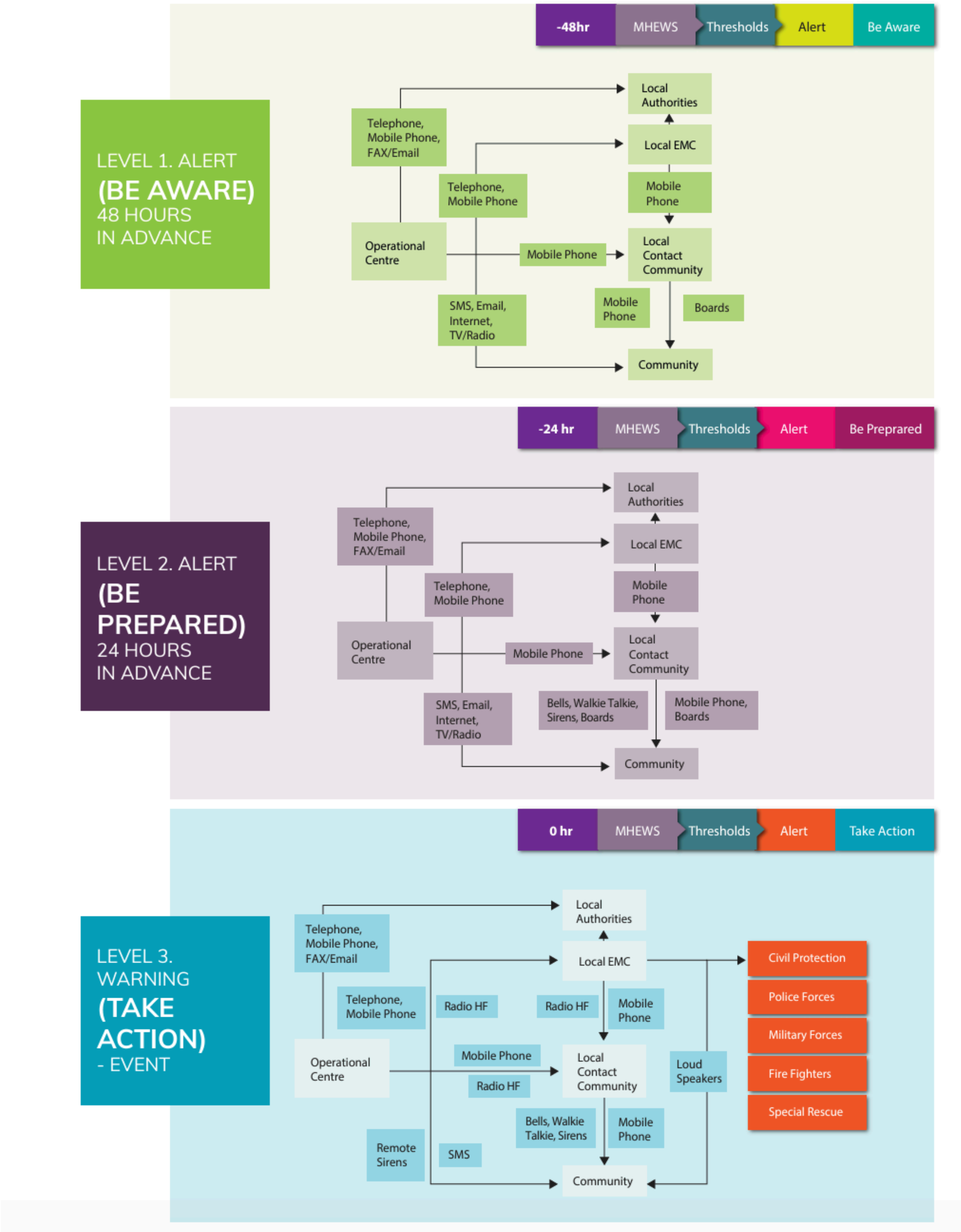
Another example is METEOALARM under the Network of European Meteorological Services EUMETNET, which integrates all important severe weather information originating from the official National Public Weather Services across a large number of European countries. The information is provided for the possible occurrence of severe weather, such as heavy rain with the risk of flooding, severe thunderstorms, gale-force winds, heat waves, forest fires, fog, snow or extreme cold with blizzards, avalanches or severe coastal tides. Other systems such as the Copernicus Emergency Management Service (CEMS) amalgamate several systems including flood forecasting through the European Flood Awareness Systems (EFAS) and Global Flood Awareness Systems (GloFAS) to provide early warning and monitoring; the Europe (European Drought Observatory, and the; European Forest Fire Information System (EFFIS) which manages forest fire activity in real-time. Air quality monitoring including Daily Forecasts for health impacts is also included along with ozone layer and UV radiation monitoring including Daily UV-index forecasts. Rapid Mapping and Risk and Recovery Mapping, which supplies geospatial information in support of Disaster Management activities including prevention, preparedness, risk reduction and recovery phases. The European flood awareness system, part of the CEMS, provides information (e.g. probabilistic, medium range flood forecasts, flash flood indicators or impact forecasts) to the relevant national and regional authorities. Furthermore, EFAS keeps the Emergency Response Coordination Centre (ERCC) informed about ongoing and possibly upcoming flood events across Europe. The Global Framework for Climate Services (GFCS) enables better management of the risks of climate variability and change through the development and incorporation of science-based climate information and prediction into planning, policy and practice on the global, regional and national scale. While the INNOVA project aims to consider climate services innovations for transformational adaptation in addition to incremental adaptation.

2.3 Early warning systems

Early warning systems aim to mitigate the risk produced by disaster, by "providing advanced notice of potential hazards, early warning systems enable individuals, communities, and organizations to take appropriate measures to minimize the potential impact of disasters." (IFRC, 2022). There are various ways of classifying early warning systems such as by the type of hazard (e.g. hydrometeorological hazards including severe weather on land and at sea, floods, droughts, cyclones, cold and heat waves, or forest fires, biological hazards including insect plagues like locust outbreaks and harmful algae blooms, health hazards including vector-borne diseases, viruses and other types of diseases, and for pests and diseases on crops and livestock). Alternatively, they can be classified by the level in which they are operated (community or people-centered early warning systems, national early warning systems operated by a national-level government agency, or regional systems operated such as the Famine Early Warning System Network (FEWSNET) and the European Meteoalarm, or global systems operated at the international level by international organizations such as FAO) (UN-SPIDER, 2023).

Alongside the different characteristics in frequencies and range for climate hazards, there are also great variations in scale of climate impact and disaster events, as well as in the scales that CIEWS are applied. Variations in spatial scale occur at the community, village, local, district, regional, national and global scale and vary greatly also in the targeting of stakeholders within these scales.

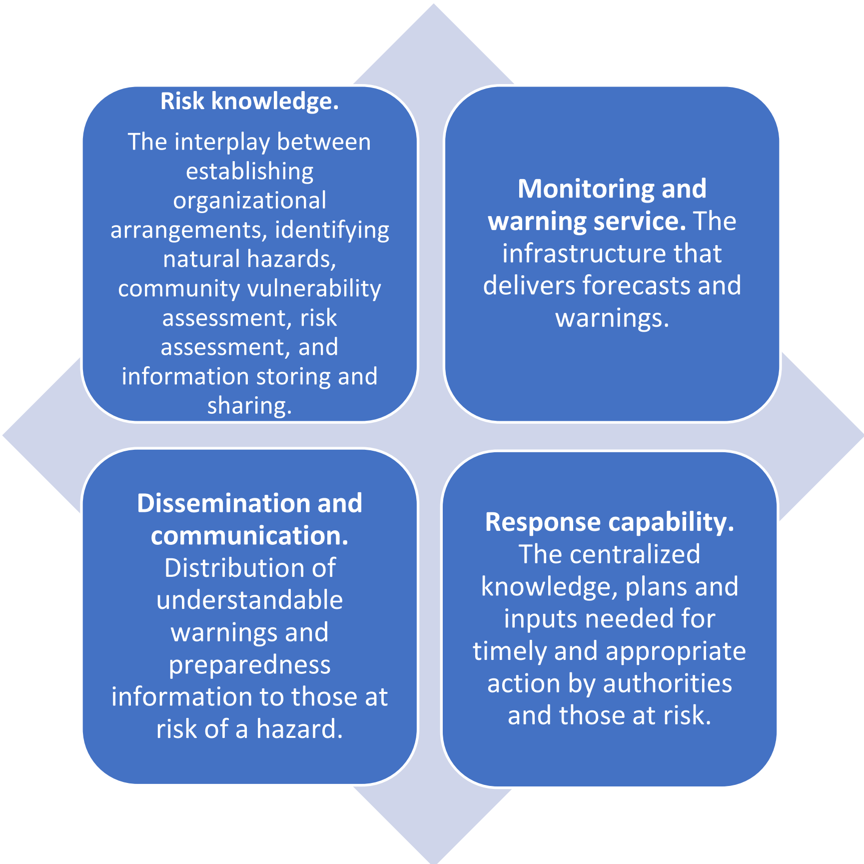
Figure 12 Example of early warning communication flow



Source: (UNDP, 2018a)

Multi-hazard Early Warning Systems (MHEWS) are widely promoted and considered to be an effective disaster risk reduction and climate change adaptation measure for saving lives and reducing losses and disruptions (UNDRR-WMO, 2022a). The movement to ensure that MHEWS are people centric, rather than author driven are being emphasized in the role that MHEWS can play to limit the impacts of both climate and disaster event losses. The push for early warning systems to be multi-hazard inclusive is intended to address all the hazards that might occur alone, simultaneously, cascading or cumulatively over time (UNDRR-WMO, 2022b). The push for MHEWS stretches beyond CIEWS, in that in addition to the hazards related to meteorological and hydrological events that CIEWS target, MHEWS also target hazards that are geological, environmental, biological, chemical, and technological (UNDRR-WMO, 2022b). However, despite this difference, the principles for CIEWS and MHEWS remain ultimately the same, in they should be resource-efficient, enable integrated disaster risk reduction, and should be easily understood by the communities. An End-to-end early warning systems for example "set of components that connects those who need to hear messages to others who compile and track the hazard information of which messages are composed" to create a single, cohesive and robust system (UNDRR-WMO, 2022b). These are made up of the interrelated elements a) Disaster risk knowledge, b) Observations, monitoring, and forecasting systems, c) warning dissemination mechanisms, and d) preparedness and response capability as shown in Figure 8.

Figure 13 Four elements of effective early warning systems



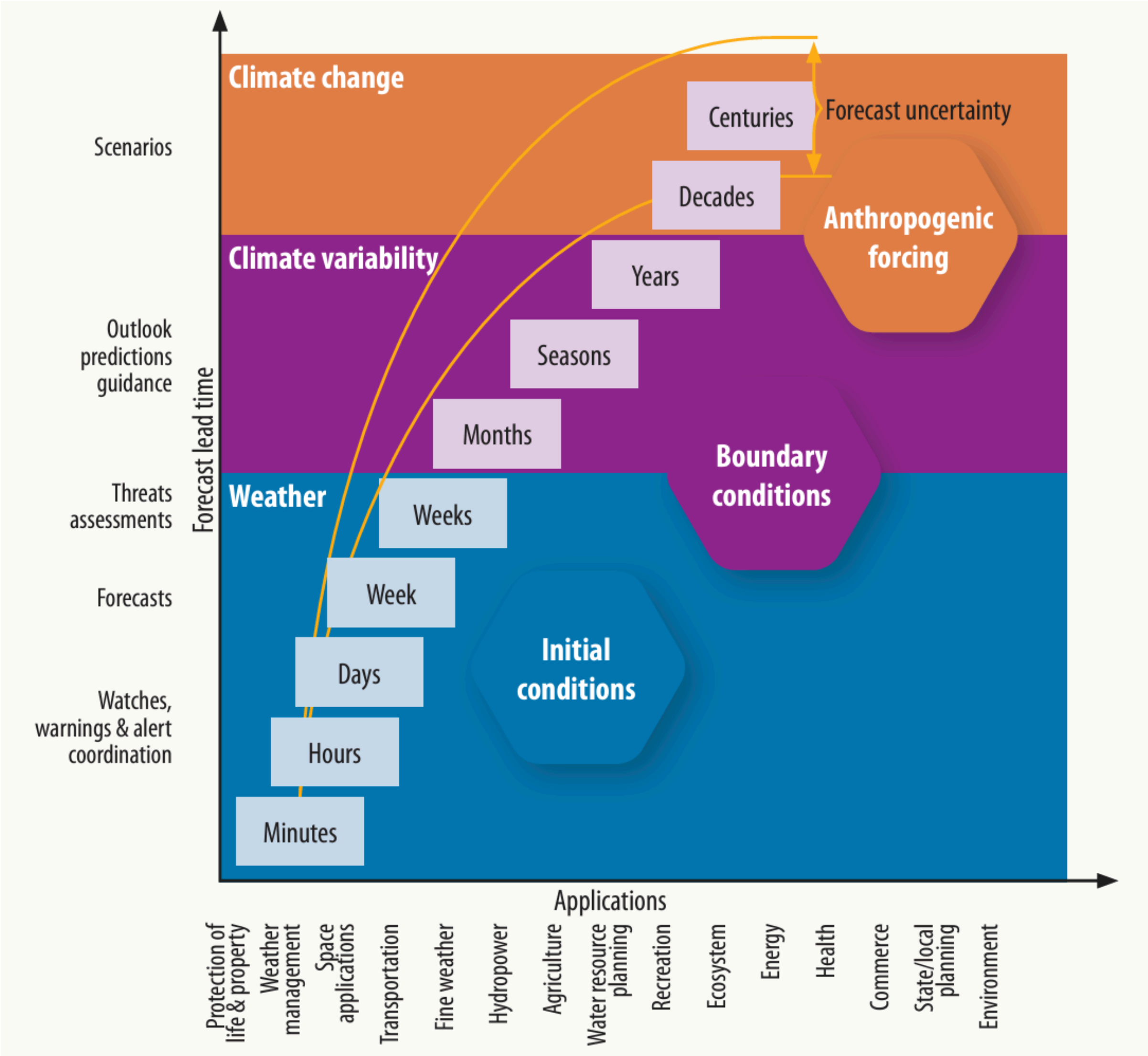
Source: (UNISDR 2006)

Expanding on the UNDRR elements, the WMO lists five components of good practice guidance for climate information and early warning to also include monitoring and evaluation of the results (WMO, 2020): 1) disaster risk knowledge, including hazard, exposure and vulnerability; 2) detection, monitoring and forecasting the hazards; 3) warning dissemination and communication; 4) preparedness to respond; and 5) monitoring/evaluation of the results.

Disaster risk knowledge, including hazard, exposure, and vulnerability
In order to reduce risks and prepare for hazards in a specific spatial area it is imperative to know the nature of risk. Knowing the hazards, exposure and vulnerability to disaster risks via disaster risk assessments directly supports local and national authorities in identifying vulnerable groups, infrastructure, and assets, as well as to develop evacuation plans including evacuation routes and safe locations, and improving warning messages to include potential impacts (UNDRR-WMO, 2022b). Risk assessments can identify the areas prone to risks, as well as the location and nature of vulnerable groups and critical infrastructure and assets in exposed locations (Šakić Trogrlić et al., 2022).

Detection, monitoring and forecasting the hazards
Scientific understanding of the processes that generate hazards, combined with past and current monitoring of conditions, enables the likelihood of their occurrence to be forecasted in advance (WMO, 2010). Times and accuracy for forecasting substantially differ according to the type of risk or hazard and the forecasting capabilities for different hazards. For example, severe weather hazards can often be forecasted a few hours ahead whereas the development of the weather system containing the storm may have been predictable several days in advance (Šakić Trogrlić et al., 2022).

Figure 14 Integration of climate information and applications



Source: World Meteorological Organization Strategic Plan 2012–2015

Warning dissemination and communication

Warning dissemination and communication is one of the crucial elements ensuring that decision-makers at regional, national, and local levels, along with individuals and communities, receive warnings in advance of a disaster events in order to reduce the impact of disasters, and facilitate coordination. Mass media, including mobile phone applications, radio, television, website, e-mail, SMS, social media, sirens, public boards and notices, are some of the dissemination and communication methods. Multiple communication channels can be used to strengthen the communication and extent of warnings, as well as to enhance the outreach and prevent failure of any one channel. Analysis from UNDRR-WMO suggests that the types of communication channels used are usually according to the communications channels that are widely accessed by citizens (UNDRR-WMO, 2022b). The IFRC has notably established the Common Alerting Protocol (CAP) as an international standard format developed by the International Telecommunication Union (ITU) to issue multi-hazard early warning alerts that communicate key information such as: *What is it? Where is it? How soon is it? How bad is it? What should people do?* (IFRC, n.d.).

Preparedness to respond

Coordination within and across different sectors and at multiple levels is crucial for the effective functioning of early warning. The responsibility for warning dissemination and response should be well-integrated with government and local community decision-makers. A well-established and operational national warning center, for example, can ensure the function of a warning system by formulating and disseminating warnings and connecting communities at risk with the capacity to act and respond (UNDRR-WMO, 2022b). Top-down approaches, where scientific information is passed down to the community, have been repeatedly insufficient in providing the local level with appropriate information that allows them to respond and minimize risks and impacts (UNDRR-WMO, 2022b). Having plans for preparedness, evacuation, response and other relevant plans at the local government level is important for responding to warnings issued by the regional or national hydro-meteorological services. This can minimize the impacts of disasters, evacuate people to safe locations, and ensure better coordination among organizations responsible for preparedness and response. Preparedness to respond is critical, and it has been widely acknowledged that the success of an early warning system is dependent on the community's ability to correctly understand and respond to imminent risks (UNDRR-WMO, 2022b).

Monitoring and evaluation of the results

Critical considerations when establishing climate information and early warning should pay attention to: innovation, efficiency and efficacy, sustainability, replicability or transferability, involvement of community, and inclusiveness. Monitoring and evaluation, as a feedback mechanism is important for continuous improvements of these elements. The failure of any of the elements will lead to the overall failure of the entire early warning system, and may, in turn, have dire consequences (UNDRR-WMO, 2022b). There are calls for the synchronization of indicators for early warning monitoring (e.g. the Sendai Framework Monitor or SFM) and for governments and organizations to make use of the accessible tool to systematically document and analyze the impact of disasters, and track progress, which in turn will assist in providing better understanding to plan and target better with (UNDRR-WMO, 2022b).

2.1.1 Inclusivity and identifying and engaging critical and vulnerable populations

To be effective climate information and early warning needs to be appropriate to those who need to make decisions based upon the information. For early warning to be effective, most critically, it requires the direct participation of at-risk communities, facilitates public education and awareness of risks, efficient message and warning dissemination, and maintains a constant preparedness for early action. This includes all members of a community and includes all needs, and perspectives priorities. This also means that there needs to be meaningful participation of all intersections of society - age, sex, disability, gender roles, sexual orientation, literacy, language, cultural practices, race, geographic location, socio-economic position and be accessible to all (UNDRR, 2022a)Practice involves the participation and consideration of vulnerable groups such as the elderly, people with disabilities, LGTBI individuals, women, children, and the environment, and emphasis is on inclusivity in the design of any early warning.

2.1.1.1 Local and indigenous knowledge

The Sendai Framework sets out that indigenous peoples, through their experience and traditional knowledge, provide an important contribution to the development and implementation of plans, mechanisms, including for early warning.” (UNDRR, 2015). At the same time as being disproportionately impacted by climate change, indigenous and local knowledge and resource management practices, are integral to the effectiveness of climate adaptation measures. Power dynamics are important to consider in adaptation decision-making because hierarchical power differentials within and between scientific institutions have implications on decision-making processes that can either, restrict or facilitate the movement of knowledge relevant to informing adaptation planning and policymaking. CIEWS should therefore seek to integrate consideration of:

- Indigenous knowledge systems, and their interrelated practices for governing social, cultural, and ecological aspects of human-environment interactions provide approaches and solutions for reducing climate change risks.
- Place-based communities with strong connections to the local landscape and ecology have often tended to create local institutions that manage resources sustainably and are able to respond to changing social and environmental conditions.
- Customary rules or participation in agency-driven local activities and indigenous, local, and traditional knowledge systems and practices, including indigenous peoples’ holistic view of community and environment, constitute a significant resource for adapting to climate change.
- Where there is widespread knowledge and practice of traditional knowledge and skills, adaptive capacity has been greater.
- A focus on place-based understandings of climate change, local impacts and vulnerabilities and adaptive capacity, is also needed to undertake effective adaptation.

2.1.1.2 Inclusivity for vulnerable groups

The Sendai Framework also sets out that “older persons have years of knowledge, skills, and wisdom, which are invaluable assets to reduce disaster risk, and they should be included in the design of policies, plans, and mechanisms, including for early warning” (UNDRR, 2015). Disasters and their aftermath have a huge impact on persons with disabilities, elderly and their families. They are among the most vulnerable in an emergency, sustaining disproportionately higher rates of morbidity and mortality, and at the same time being among those least able to access emergency support. In addition, there is a large tendency for persons with disabilities to be invisible and overlooked in emergency relief operations and the planning for climate adaptation and disaster risk reduction. When disasters hit, persons with disabilities, the elderly and their families, may have difficulty reaching safe areas, become separated from family and friends which is a key to survival and coping, have trouble accessing vital emergency information, or lose assistive devices such as wheelchairs, crutches, prostheses, canes or hearing aids. In addition, persons with disabilities, the elderly and their families who also belong to other minority groups based on gender, race, religion or ethnicity may face added disadvantages in having their needs met. Inclusive practice in all planning and policy for climate change adaptation and disaster risk reduction and relief operations are needed to ensure that service delivery is not fragmented but mindful of all sources of vulnerability.

As climate change places increased pressure on national budgets and resilient livelihood opportunities diminish, fewer resources are available for affordable and accessible services and infrastructure to the poorest people. This is particularly so for those with a disability who may be more reliant on these. In the aftermath of a disaster, the damage to infrastructure caused by extreme weather events can reduce or completely remove access and safe mobility. Accessible basic health and other services may disappear. As an example, the loss of immunization services will increase the risk of the poorest families, including those of persons with disabilities, contracting preventable disabling diseases. In islands and other coastal communities, sea level rise is expected to exacerbate inundation, storm surge, erosion and other coastal hazards. This will threaten vital infrastructure, settlements and facilities that support livelihoods, as well as transport options and access. All these factors impact heavily on persons with disabilities and their families.

In many communities, persons with disabilities, the elderly and their families already face food shortages daily due to poverty. Climate change is projected to exacerbate food shortages and malnutrition. For example:

- Increases in the frequency of droughts and floods (including from rising sea levels) are projected to cause decreases in local crop production.
- Regional changes are expected to have adverse effects on food production from aquaculture and fisheries. Many of the population and particularly the most vulnerable groups depend on ocean and inland fish as a significant part of their diet. At the same time, malnutrition is estimated to cause approximately 20 percent of impairments worldwide. With increasing malnutrition, we must expect that more children (including those of parents with disabilities) will acquire disabling impairments.

Many persons with disabilities already face daily hardship in accessing adequate safe water for drinking, hygiene, and sanitation. Climate change will affect the physical, chemical, and biological properties of freshwater lakes and rivers, causing reduced quality. In coastal areas, sea level rises will exacerbate water resource constraints due to increased salinization of groundwater supplies. In regions with declining water quality and quantity, it is expected there will be an increasing prevalence of water-borne diseases including those causing diarrhea, with associated dehydration and malnutrition. An estimated 6·8 percent of DALYs (Disability Adjusted Life Years) worldwide are attributable to unsafe and inadequate water for drinking and sanitation. With decreased clean water, an increase in resulting disability is expected, including in families where disability already exists. As the impacts of climate change increase, we must expect that persons with disabilities and their families will face increasing risks.

Table 3 Key ways to ensure inclusivity of vulnerable people

Key ways to ensure inclusivity of vulnerable people:
1. Ensure the meaningful, informed, and effective participation of persons with disabilities, elderly and their families in climate policy-making and decision-making processes;
2. Ensure that the rights of persons with disabilities, elderly and their families are respected, protected, and fulfilled in the design, development, implementation, monitoring, and evaluation of all climate adaptation and disaster risk reduction policies and planning;
3. Adopt and implement disability-inclusive climate change adaptation and disaster risk reduction policies and planning that enhance the resilience of persons with disabilities to different climate impacts;
4. Adopt an intersectional perspective towards disability-inclusive climate action that recognizes and addresses the multiple barriers faced by women with disabilities, children, Indigenous peoples, racialized individuals, and older adults; persons with disabilities living in poverty; and underrepresented groups of persons with disabilities, such as persons with intellectual disabilities, persons with psychosocial disabilities or persons with deaf-blindness;
5. Support measures to ensure the meaningful inclusion of persons with disabilities and their human rights, including in the context of climate-related education, capacity-building, training, and public participation and through a comprehensive set of measures to ensure that disability-inclusive solutions are included.

At the same time, disability is not a gender-neutral experience and has a different impact on women, men, girls, boys, and other gender identities. While all women and girls face inequality, women and girls with disabilities often face additional, severe disadvantages due to discriminatory social norms and perceptions of their value and capacity (CBM, 2019).

2.1.1.3 Gender inclusivity

Women most widely receive the impact of disasters, not because they are inherently more vulnerable, but due to gender norms, roles and relationships.[5] Women are often directly responsible for the care of children or older family members and because of this, may be unable to, or are less likely to be willing to evacuate alone (IFRC, 2012) for example or they may delay evacuation due to rescuing family members or valuables (UN Women & UNICEF, 2019). Women are also more likely to be engaged in work types (e.g. informal work, or engaged as carers), which are economically insecure and also make recovery from disaster events more difficult (UNDRR, 2022a). Lack of timely and relevant early warning information also tends to disparately affect women, who do not have equal access to technology, and communication and services, particularly in the case of women in marginalized groups in rural or isolated areas, due to a lack of communications services or social barriers (UNDRR, 2022a). Women are also more likely (51 percent) to receive information through informal sources –

[5] *CEDAW Recommendation 37, Article 3, 5.*

such as social or community sources, or word of mouth from family members (Brown et al., 2019).

Several recommendations for ensuring that women are better included in early warning systems compiled by the UNDRR (2022a) are relevant also in CIEWS:

Table 4 recommendations for ensuring that women are better included in early warning systems

(i)	Build on existing connections and networks within communities: Listening, learning and engaging with existing networks, particularly women's networks, helps to build strong community connections, and EWS can benefit from locally-led information gathering and greater resource efficiency. Ensuring positive, safe and inclusive participation, and engagement that acknowledges and respects women's experiences and reflects the diversity within each community, helps broaden ownership and community buy-in for early warning. A key component of this is ensuring universal design through use of effective communication in different languages and improving accessibility.
(ii)	Build and unlock community knowledge: Improving community awareness, and in particular women's understanding of climate change and disaster risks, using both traditional and modern scientific knowledge, helps to inform community-level disaster risk management and empower women to participate. Developing advocacy and communication skills to effectively engage with and influence different stakeholders can ensure no one is left behind.
(iii)	Facilitate community-based data collection and hazard monitoring: Supporting communities through appropriate resourcing and capacity building to engage in systematic data collection about hazards, socio-economic vulnerabilities and disaster impacts in their local area and strengthen information and data sharing between the community and national level.
(iv)	Deliver effective early-warning messages: Ensuring early-warning messages are received and acted upon, by involving communities in the development of messaging and using different communication channels to transmit messages. Establishing a two-way communication feedback mechanism that allows communities to share real-time information helps to support continued improvement.
(v)	Integrate and invest in community- and women-led initiatives as an essential part of the early warning ecosystem: Officially recognizing, supporting and investing in community- and women-led MHEWS initiatives, and connect them as part of the broader national and regional EWS, can help to increase access to information, and strengthening links between women-led EWS and scientific entities ensures accurate risk knowledge is communicated widely. This may require adaptations to laws and policies, annual budget allocations and the composition of decision-making bodies to be more inclusive of women, persons with disabilities, and community-led initiatives.
(vi)	Recognize the broader benefits of gender-transformative change: There are widespread positive ripple effects from well-supported community- and women-led EWS, including greater gender equality and status of women, and broader community-level engagement and empowerment.

2.4 Engagement

Ensuring information can reach everyone who may be impacted, and in a way that can be easily understood by all, regardless of disability, or literacy, so that they are able to act on potential impacts and recommended action requires that information is easily understood and relates to people's reality – e.g. impact-based forecasting, explaining what the weather could do to them (UNDRR, 2022a). Effective climate information and early warning are made up of a) coordination and communication - government bodies, community, and partners; b) plans – the guidelines, protocols and agreements being followed and in place; c) community engagement – processes for engagement, the extent of engagement and relationships and capacity building efforts; d) adequate resourcing - including HR, knowledge, ability and availability, and; e) access to knowledge and utilization of information - e.g. particularly technical knowledge. Approaches encompassing multiple types of warning and employing a people-centered approach are critical in CIEWS, given that climate impacts and disasters may occur alone, simultaneously, cascadingly, or cumulatively, and the approach must incorporate these factors.

Studies suggest that in practice the "last mile" [6] approach may not be sufficient to reach the aims of EWS (Marchezini et al., 2018). Multiple studies, for example, have identified challenges such as the "last mile" issue, whereby connecting CIEWS to end users posed the biggest challenge to successful CIEWS. The linear end to end approach is criticised as the last mile is the delivery to people. People therefore are as users also become the last involved in the system and the approach is not considered people centric but rather to be technology centric. In connecting people as the final point in the system, technological and scientific factors are emphasised while at the same time it is assumed that all the relevant data, information, and knowledge are housed outside of local communities (Marchezini et al., 2018). Participation in early warning repositions involvement of end users in the process. Meaningful participation has been highlighted in the Sendai Framework requiring "all-of-society engagement and partnership, empowerment and inclusive, accessible and non-discriminatory participation, paying special attention to people disproportionately affected by disasters, especially the poorest" (UNDRR, 2015). In order to make the last mile effective variations of community-based early warning systems have emerged. For example, people-centred early warning systems, community-centric, community-based, citizen-centred and participatory early warning systems (see Community-based Early Warning Systems). Participatory or people-centred early warning systems also have great potential to improve the decision-making by communities affected and emergency institutions given that stakeholders reflexivity can be greatly enhanced EWS (Marchezini et al., 2018).

CIEWS for many contexts should also take into consideration tailoring information for the audiences that most need the information, including for vulnerable sectors and land and water users. Tailoring information to the agriculture sector, for example: climate information is used for agricultural planning – such as managing overall crop timing and cycles, as well as for strategic decisions on verities, planting dates, water and irrigation demand, soil water content for plant dates, the anticipation of harvest times, irrigation management, amongst other critical decisions (FAO, 2019). Ideally for farmer use, climate information systems,

[6] E.g., coordination, connectivity, efficiency, and integration.

bridge traditional knowledge on long-term climate cycles and seasons with weather forecasting, seasonal climate forecasting, future frequency likelihood of extreme weather and climate events, agrometeorological crop monitoring, and agrometeorological advisories (FAO, 2019).

2.4.1 People-centered approach to CIEWS

A people-centered approach to CIEWS empowers individuals and communities threatened by hazards to act promptly and appropriately to reduce the possibility of personal injury and illness, loss of life and damage to property, assets and the environment (WMO, 2020). Multiple studies, for example, have identified challenges such as the "last mile" issue,[7] whereby connecting CIEWS to end users posed the biggest challenge to successful CIEWS. Despite the worldwide emphasis on the importance of the last mile the last mile remains as issue. The IFRC (2022)[8], for example, highlights that climate information and early warning systems themselves are ineffective if they only provide weather, climate and hydrological information, services, and infrastructure as they also need to ensure that people take appropriate action using the information. Climate and early warning information is only beneficial so as to successfully reduce the impacts of extreme events and help people to prepare for unavoidable impacts before they happen. This therefore also means that preparation and response plans at local levels are crucial (WMO, 2023a). Community engagement is not only essential but communities and traditional knowledge must also be engaged in the "first mile" of the system design (Singh & Zommers, 2014).

A critical approach to addressing this challenge has been the adoption of community-based early warning systems (CBEWS) approaches. These involve "community-driven collection and analysis of information that enable warning messages to help a community to react to a hazard and reduce the resulting loss or harm" (Macherera & Chimbari, 2016).

---

[7] E.g., coordination, connectivity, efficiency, and integration.

[8] IFRC. 2022, Engaging in Climate Risk and Early Warning Systems (CREWS) Projects: To ensure they reach the "lats/first mile, International Federation of Red Cross and Red Crescent Societies (IFRC) Geneva, Switzerland

References

Batchelor, C., Cha, J. Y., & Osterwalder, K. (2021). *Towards disability transformative early warning systems: Barriers, challenges and opportunities*. Practical Action. https://www.preventionweb.net/publication/towards-disability-transformative-early-warning-systems-barriers-challenges-and

Brown, S., Budimir, M., Sneddon, A., Lau, D., Shakya, P., & Upadhyay Crawford, S. (2019). *Gender transformative early warning systems*. Practical Action. https://www.preventionweb.net/publication/gender-transformative-early-warning-systems

CARE. (2023). Climate Information Services. *CARE Climate Change*. https://careclimatechange.org/climate-information-services/

CBM. (2019). *Disability and Gender Anlaysis Toolkit*. www.cbm.org.au/wp-content/uploads/2020/11/CBM_disability_and_gender_analysis_toolkit_accessible.pdf

CREWS Iniative. (2023, June 13). *CREWS 2022 Annual Report launch | UNDRR*. http://www.undrr.org/news/climate-risk-and-early-warning-systems-initiative-helps-protect-111-million-people-2022

FAO. (2019). *Handbook on climate information for farming communities – What farmers need and what is available*. Food & Agriculture Organisation of the United Nations.

Flood, S., Columbié, Y. J., Tissier, M. L., & O'Dwyer, B. (2021). *Creating Resilient Futures: Integrating Disaster Risk Reduction, Sustainable Development Goals and Climate Change Adaptation Agendas*. Springer Nature.

GCF. (2022). *Climate Information and Early Warning Services Sectoral Guide.* (Sectoral Guide Series) [Text]. Green Climate Fund. https://www.greenclimate.fund/document/sectoral-guide-climate-information-early-warning-systems

Global Observing System. (2015, September 17). World Meterological Organisation (WMO). https://public.wmo.int/en/programmes/global-observing-system

IFRC. (n.d.). The IFRC Alert Hub Initiative. *PrepareCenter*. Retrieved January 31, 2024, from https://preparecenter.org/initiative/the-ifrc-alert-hub/

IFRC. (2012). *Community Early Warning Systems: Guiding Principles*. International Federation of the Red Cross. https://www.ifrc.org/document/community-early-warning-systems-guiding-principles

IFRC. (2022). Early Warning Systems. *PrepareCenter*. https://preparecenter.org/topic/early-warning-systems/

Ijjasz, E., Risk, V., & Gianfranchi, R. (2022, December 13). *Bringing the Pieces of the Early Warning Puzzle Together for Climate-Smart Economies*. Global Center on Adaptation. https://gca.org/bringing-the-pieces-of-the-early-warning-puzzle-together-for-climate-smart-economies/

IPCC. (2022a). Annex II: Glossary [Möller, V., R. van Diemen, J.B.R. Matthews, C. Méndez, S. Semenov, J.S. Fuglestvedt, A. Reisinger (eds.)]. In *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]* (pp. 2897–2930). Cambridge University Press.

IPCC. (2022b). *Climate Change 2022: Impacts, Adaptation and Vulnerability* (Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change []). Intergovernmental Panel on Climate Change (IPCC).

Macherera, M., & Chimbari, M. J. (2016). A review of studies on community based early warning systems. *Jàmbá : Journal of Disaster Risk Studies*, *8*(1), 206. https://doi.org/10.4102/jamba.v8i1.206

Marchezini, V., Horita, F. E. A., Matsuo, P. M., Trajber, R., Trejo-Rangel, M. A., & Olivato, D. (2018). A Review of Studies on Participatory Early Warning Systems (P-EWS): Pathways to Support Citizen Science Initiatives. *Frontiers in Earth Science*, *6*. https://www.frontiersin.org/articles/10.3389/feart.2018.00184

Mercy Corps & Practical Action. (2010). *Practitioners handbook for establishing community based early warning systems*. https://answers.practicalaction.org/our-resources/item/practitioners-handbook-for-establishing-community-based-early-warning-systems/

Mizutori, M. (2023, March 23). *Placing Water at the Heart of Climate Action through Locally-led Adaptation*. Water Conference Side Event, United Nations HQ New York.

Pudmenzky, C., Lisk, I., Vitols, L., Ribero, C., & Millar, B. (2022). Gender equality in the context of multi-hazard early warning systems and disaster risk reduction. *World Meterological Organisation Bulletin*, *71*(1). https://public.wmo.int/en/resources/bulletin/gender-equality-context-of-multi-hazard-early-warning-systems-and-disaster-risk

Šakić Trogrlić, R., van den Homberg, M., Budimir, M., McQuistan, C., Sneddon, A., & Golding, B. (2022). Early Warning Systems and Their Role in Disaster Risk Reduction. In B. Golding (Ed.), *Towards the "Perfect" Weather Warning: Bridging Disciplinary Gaps through Partnership and Communication* (pp. 11–46). Springer International Publishing. https://doi.org/10.1007/978-3-030-98989-7_2

Singh, A., & Zommers, Z. (Eds.). (2014). *Reducing Disaster: Early Warning Systems For Climate Change*. Springer Netherlands. https://doi.org/10.1007/978-94-017-8598-3

UN Women. (2012). *Gender-Responsive Early Warning: Overview and How-to guide*. UN WOMEN. https://www.unwomen.org/sites/default/files/Headquarters/Attachments/Sections/Library/Publications/2012/10/WPSsourcebook-04E-GenderResponsiveEarlyWarning-en.pdf

UN Women & UNICEF. (2019). *Gender and Age Inequality of Disaster Risk* [Research Paper].

UNCC. (2022). *UN: Early Warning Systems Must Protect Everyone Within Five Years | UNFCCC* [Press Release]. United Nations Climate Change. https://unfccc.int/news/un-early-warning-systems-must-protect-everyone-within-five-years

UNDP. (2018a). *Five approaches to build functional early warning systems*. United Nations Development Programme. https://www.adaptation-undp.org/sites/default/files/resources/undp_brochure_early_warning_systems.pdf

UNDP. (2018b). *Five approaches to build functional early warning systems*. United Nations Development Programme. https://www.undp.org/eurasia/publications/climate-change-adaptation-europe-and-central-asia

UNDRR. (2015). *Sendai Framework for Disaster Risk Reduction 2015-2030*. United Nations Office for Disaster Risk Reduction. https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030

UNDRR. (2022a). *Inclusive and accessible multi-hazard early-warning systems: Learning from women-led early-warning systems in the Pacific*. United Nations Office for Disaster Risk Reduction - Regional Office for Asia and Pacific Women's International Network for Disaster Risk Reduction. https://www.undrr.org/publication/inclusive-and-accessible-multi-hazard-early-warning-systems-learning-women-led-early

UNDRR. (2022b, December 1). *Early warnings for all* [United Nations Office for Disaster RIsk Reduction]. Early Warnings for All. https://www.undrr.org/early-warnings-for-all

UNDRR. (2023a). *Sendai Framework Monitor Home page*. https://sendaimonitor.undrr.org/analytics/global-target/18/8?indicator=34

UNDRR. (2023b). *Water risks and resilience*. United Nations Office for Disaster RIsk Reduction. https://www.undrr.org/water-risks-and-resilience

UNDRR. (2023c, March 21). *Early Warnings For All Initiative scaled up into action on the ground | UNDRR*. http://www.undrr.org/news/early-warnings-all-initiative-scaled-action-ground

UNDRR-WMO. (2022a). *Global status of multi-hazard early warning systems: Target G* (Sendai Framework for Disaster Risk Reduction 2015-2030). United Nations Office for Disaster Risk Reduction (UNDRR). https://www.undrr.org/publication/global-status-multi-hazard-early-warning-systems-target-g

UNDRR-WMO. (2022b). *Global status of multi-hazard early warning systems: Target G | UNDRR*. http://www.undrr.org/publication/global-status-multi-hazard-early-warning-systems-target-g

UNEP. (2022). *The Closing Window: Emissions Gap Report 2022*. United Nations Environment Programme (UNEP). http://www.unep.org/resources/emissions-gap-report-2022

UNFCCC. (2015, December 30). Paris Agreement, FCCC/CP/2015/L.9/Rev.1 UNFCCC Secretariat. *Adoption of the Paris Agreement*. Conference of the Parties Twenty-first session, Paris.

UN-SPIDER. (2023). *Early Warning Systems | UN-SPIDER Knowledge Portal*. United Nations Office for Outer Space Affairs UN-SPIDER Knowledge Portal. https://www.un-spider.org/risks-and-disasters/early-warning-systems#no-back

Uzair, Y., Balog-Way, S. A. B., Gupta, M. L., Phillips, E. K. A., & Krylova, Y. (2022). *Disability Inclusion in Disaster Risk Management Operations: An Exploration of Good Practices and Resources - Guidance Note* [Text/HTML]. World Bank Group. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099025008152214591/P176516025211304f09f9201fb04c176943

Wen, J., Wan, C., Ye, Q., Yan, J., & Li, W. (2023). Disaster Risk Reduction, Climate Change Adaptation and Their Linkages with Sustainable Development over the Past 30 Years: A Review. *International Journal of Disaster Risk Science*, *14*(1), 1–13. https://doi.org/10.1007/s13753-023-00472-3

WMO. (2020). *2020 State of CLimate Services: Risk information and early warning systems* (WMO-No. 1252). World Meteorological Organization.

WMO. (2022a). *Early warnings for all: Executive action plan 2023-2027* (World Meterological Organization (WMO)). The UN Global Early Warning Initiative for the Implementation of Climate Adaptation. https://www.preventionweb.net/publication/early-warnings-all-executive-action-plan-2023-2027

WMO. (2023a). *Early Warnings for All: The UN Global Early Warning Initiative for the Implementation of Climate Adaptation—Executive Action Plan 2023-2027*.

WMO. (2023b). *WMO Global Annual to Decadal Climate Update (Target years: 2023-2027)*. World Meteorolocial Organisation (WMO). https://reliefweb.int/report/world/wmo-global-annual-decadal-climate-update-target-years-2023-2027

WMO. (2010). *Guidelines on early warning systems and application of nowcasting and warning operations*. https://library.wmo.int

WMO. (2022b). *What are climate services? | GFCS* [World Metorological Organisation (WMO)]. Global Framework for Climate Services (GFCS). https://gfcs.wmo.int/what-are-climate-services

Annex 1 Manuals and Guidance provided by the WMO

Manuals

WMO-No. 9 Weather Reporting:

Volume A – Observing Stations

Volume C1 – Catalogue of Meteorological Bulletins

Volume C2 – Transmission Programmes

Volume D – Information for Shipping

WMO-No. 306 Manual on Codes, Volume I.1, I.2 and I.3

WMO-No. 386 Manual on the Global Telecommunication System

WMO-No. 485 Manual on the Global Data-processing and Forecasting System

WMO-No. 1160 Manual on the WMO Integrated Global Observing System

Guides

WMO-No. 8 Guide to Instruments and Methods of Observation

WMO-No. 100 Guide to Climatological Practices

WMO-No. 134 Guide to Agricultural Meteorological Practices

WMO-No. 168 Guide to Hydrological Practices, *Volume I* and *Volume II*

WMO-No. 305 Guide on the Global Data-processing System

WMO-No. 471 Guide to Marine Meteorological Services

WMO-No. 488 Guide to the Global Observing System

WMO-No. 636 Guide on the Automation of Data-processing Centres (2nd ed.)

WMO-No. 702 Guide to Wave Analysis and Forecasting

WMO-No. 731 Guide to Meteorological Observing and Information Distribution Systems for Aviation Weather Services

WMO-No. 732 Guide to Practices for Meteorological Offices Serving Aviation

WMO-No. 750 Guide to Moored Buoys and Other Ocean Data Acquisition Systems

WMO-No. 788 Guide on World Weather Watch Data Management

WMO-No. 834 Guide to Public Weather Services Practices

WMO-No. 1061 Guide to the WMO Information System

WMO-No. 1115 Guide to Information Technology Security

WMO-No. 1116 Guide to Virtual Private Networks (VPN) via the Internet between GTS Centres

WMO-No. 1165 Guide to the WMO Integrated Global Observing System