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First G20 Disaster Risk Reduction Working Group (DRRWG) Meeting

Compendium of Good Practices on Multi-Hazard Early Warning Cooperation

30 March - 1 April 2023, Gujarat

Compendium of multi-hazard early warning cooperation

Launched at the G20 Disaster Risk Reduction Working Group Side Event: Early Warning Early Action, 30 March 2023

Overview

The UN Secretary-General António Guterres unveiled an 'Executive Action Plan for the Early Warnings for All' initiative during the World Leaders Summit at COP 27. This call for a universal early warning system coverage within the next five years is recognizant of key challenges, including that disaster mortality is eight times higher in countries with limited early warning coverage. The Secretary-General noted that "one out of three persons globally, primarily in Small Island Developing States and Least Developed Countries… lack access to effective early warning systems".

Investments in early warning systems reduce fatalities and economic losses that are incurred due to disaster events. Since climate hazards do not follow national boundaries, therefore transformative adaptation measures are those that mirror the transboundary nature of disaster risks. Advancing early warning systems, to meet the needs of today and of future generations exposed to intensifying climate hazards, will rely on cooperation.

This compendium of multi-hazard early warning cooperation will capitalize on recent publications[1] to identify county-specific challenges and note good practices cooperation arrangements to strengthen forecasting capabilities, early warning coverage, and systems to act on them. This compendium was launched at the G20 Disaster Risk Reduction Working Group Side Event: Early Warning Early Action, 30 March 2023.

Section 1.0 provides a clear outline of what constitutes an effective multi-hazard early warning system (MHEWS) and the current challenges being faced for its implementation. This section is largely taken from the forthcoming publication, *Words into Action: Multi-Hazard Early Warning Systems*.

Section 2.0 presents good practices that demonstrate the cooperation of G20 countries to strengthen early warning systems through: political commitments; innovative financing; service provision and institution building; data and technology exchange; transboundary advocacy and action; and tripartite arrangements.

Section 3.0 proposes a cooperation framework at the global, regional and transboundary, national and neighbouring levels for deeper engagements among the G20 countries to achieve multi-hazard early warnings system for all. Cooperation should realize a seamless global to local information value chain for early warnings; mobilize proactive, risk-informed, and pioneering investments; scale up appropriate and innovative technological solutions; and incentivize collaboration across all stakeholder groups.

1. United Nations Office for Disaster Risk Reduction (UNDRR) and World Meteorological Organization (WMO), "Global status of multi-hazard early warning systems: Target G", 2022. Available at www.undrr.org/publication/global-status-multi-hazard-early-warning-systems-target-g; World Meteorological Organization (WMO), "State of Climate in Asia 2021", 2022. Available at https://library.wmo.int/index.php?lvl=notice_display&id=22158#.ZBqBQC2l00o; World Meteorological Organization (WMO), "State of Climate in Southwest Pacific 2021", 17 November 2022. Available at https://reliefweb.int/report/world/state-climate-south-west-pacific-2021; *Asia-Pacific Riskscape @1.5ºC: Subregional Pathways to Adaptation and Resilience* (United Nations publication, 2022).

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Acknowledgments

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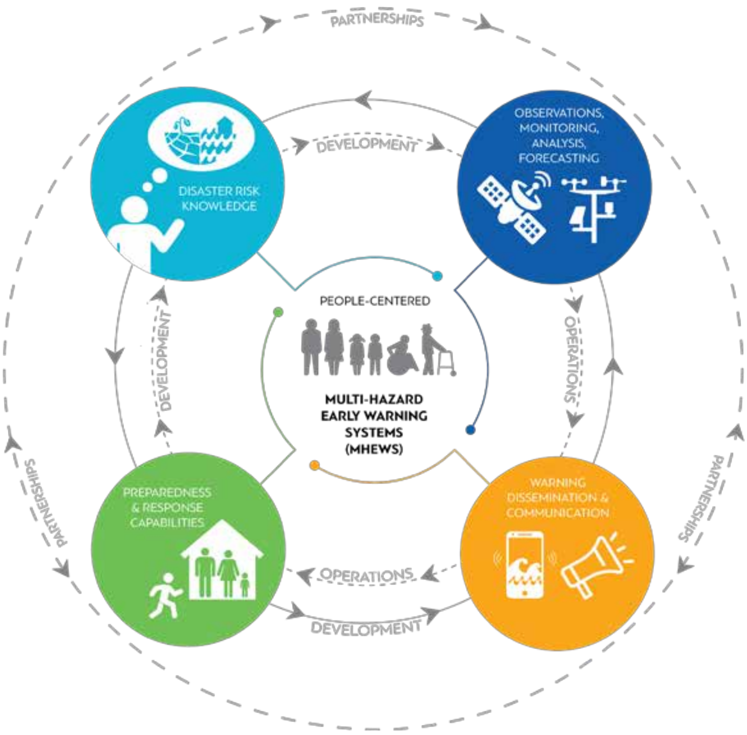
1.0 Multi-Hazard Early Warning Systems (MHEWS)[2]

1.1 Introduction to MHEWS

An early warning system (EWS) is an integrated system and process of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities systems and processes that enables individuals, communities, governments, businesses and others to take timely action to reduce disaster risks in advance of hazardous events.[3]

Figure 1-1: Effective, people-centred EWS includes four key and interrelated components.



1. Disaster risk knowledge based on a systematic collection of data and disaster risk assessments;

2. Observations, monitoring, analysis, and forecasting of the hazards and possible consequences;

3. Warning, dissemination and communication, by an official source, of authoritative, timely, accurate, and actionable warnings and associated information on likelihood and impact; and

4. Preparedness and response capabilities at all levels to respond to the warnings received.

Source: World Meteorological Organization (WMO), "Early Warnings for All: Executive Action Plan 2023-2027 (The UN Global Early Warning Initiative for the Implementation of Climate Adaptation)", 2022. Available at https://library.wmo.int/index.php?lvl=notice_display&id=22154#.Y_qoaHbP3IW

2. This section reflects the guidelines mentioned in the forthcoming publication, *Words into Action: Multi-Hazard Early Warning Systems*.
3. United Nations Office for Disaster Risk Reduction (UNDRR), "Sendai Framework Terminology on Disaster Risk Reduction: Early warning system", 2022. Available at https://www.undrr.org/terminology/early-warning-system

These four interrelated components should be coordinated across all hazards, and within and among sectors, actors, and multiple levels for the system to work effectively.

In addition to those four components, ***governance*** and ***partnerships*** have been recognized as important enablers to shape EWS and facilitate early action.

A multi-hazard early warning system (MHEWS) addresses several hazards of similar or different nature in contexts where events may occur alone, simultaneously, in cascades or cumulatively over time. These cascading impacts threaten communities, assets, public infrastructure, critical services and, in some cases, the whole country. Therefore, they may have interrelated effects which can be considered under a multi-hazard approach.

Harmonized approaches for risk communication, warning dissemination, and preparedness minimize inefficiencies, maintenance costs, and duplication, and maximize investments in awareness, education, and preparedness. Warning messages may also be more widely received, more easily recognized, and better understood if they are presented in the same format and come from the same source. Familiarity with the format and meaning will be reinforced by the greater frequency of warnings received for multiple hazards. A common framework will make it easier to ensure that warning messages for related hazards are consistent and complementary. This will prevent confusion among users. It will also enable actions that address compounding impacts and minimize cascading hazardous events.

A warning system, coordinated under a multi-hazard framework and engaging multiple disciplines, partners, and stakeholders, increases the effectiveness of warning dissemination systems, as well as the efficiency, consistency, and coherence of such preventive, risk or impact mitigating actions. A Checklist for MHEWS,[4] developed by the International Network for MHEWS (INMHEWS), can be followed to ensure that all steps are planned and integrated into the system. The implementation of the four components, plus the overarching governance component, can ensure an integrated approach for an end-to-end MHEWS.

Protecting lives from the impacts of extreme weather and climate events and reducing economic losses are the major benefits of an effective EWS. However, when considering how early warnings can benefit 'all,' it is helpful to consider the plethora of benefits, tangible and intangible, that can be unlocked.[5] Despite the extensive list of benefits, many barriers remain for low-capacity, high-risk countries to access the gains from MHEWS.

1.2 'For All' – what does it mean to ensure access to MHEWS?

Early warning systems are estimated to provide more than a tenfold return on investment – the greatest of any adaptation measures.[6] A 24-hour prior warning for an incoming storm or a heatwave can reduce the ensuing damage by 30 per cent. Spending US$ 800 million on such systems in developing countries would avoid losses of between $3 billion to $16 billion per year.[7] Additionally, the World Bank estimates that providing universal access to improved weather forecasting and early warning could result in US$ 22 billion in additional benefits, globally,

4. World Meteorological Organization (WMO), "Multi-hazard Early Warning Systems: A Checklist", Geneva, 2018. Available at https://library.wmo.int/index.php?lvl=notice_display&id=20228#.YoIq5C8Rp0t
5. Gregory Amacher and others, "Framework for Conducting Benefit-Cost Analyses of Investments in Hydro-Meteorological Systems", Environment and Water Resources occasional paper series (Washington, D.C., World Bank, 2014). Available at https://documents1.worldbank.org/curated/en/633501468047653235/pdf/929580WP0P14940sional0paper0series0.pdf; and World Meteorological Organization (WMO), "Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services', Geneva, 2015. Available at https://library.wmo.int/doc_num.php?explnum_id=3314
6. Global Commission on Adaptation, "Adapt Now: A global. Call for leadership on climate resilience", 13 September 2019. Available at https://gca.org/reports/adapt-now-a-global-call-for-leadership-on-climate-resilience/
7. Ibid.

on average per year.[8] And yet, despite these known benefits (and those outlined in Box 2), one in three persons, globally, is still not covered by early warning services. Moreover, vulnerable people, including those living in geographically remote areas, are disproportionately affected.

To address the glaring disparity in the coverage of EWS, the Secretary-General of the United Nations set out, in March 2022, an ambitious new target; by 2027, everyone on Earth should be protected by early warning systems against increasingly extreme weather and climate change. The World Meteorological Organization (WMO) and the UN Office for Disaster Risk Reduction (UNDRR) are leading the United Nations initiative of 'Early warnings for all'. To achieve this goal, the WMO presented the 'Early warnings for all: Executive action plan 2023-2027' at the UN Climate Change Conference in Sharm El-Sheikh (COP 27). The estimated new targeted investments of US$ 3.1 billion over the five years would be used to advance the four key pillars of multi-hazard early warning system:[9]

- *Disaster risk knowledge* ($374 million) – collect data systematically and undertake risk assessments on hazards and vulnerabilities;
- *Observations, monitoring, analysis and forecasting* ($1.18 billion) - develop hazard monitoring and early warning services;
- *Warning, dissemination and communication* ($550 million) - communicate risk information so it reaches all those who need it, and is understandable and usable;
- *Preparedness and response capabilities* ($1 billion) - build national and community response capabilities.

Successful implementation of the system to ensure that MHEWS covers 'all' requires interrelated work between its four key components, and in close connection with those who need to receive the warnings. An end-to-end warning system connects the people who collect and track information on hazards with those who need to receive the relevant messages to ensure timely action.

When analysing early warning systems at the national or community level, trust is one of the best predictors to the success of an early warning system.[10] Moreover, the International Risk Governance Council has recommended that stakeholder involvement is a dominant characteristic of a disaster risk reduction (DRR) strategy. To reach the most exposed and often hard-to-reach population, commonly called the last mile, an integrated approach built on multi-level cooperation for early warning must be based on and include the needs, priorities, capacities, and cultures of those people at risk. Thus, a people-centred approach is imperative.

8. Daniel Kull and others, "The Value of Surface-based Meteorological Observation Data" (Washington, D.C., World Bank, 2021). Available at https://openknowledge.worldbank.org/entities/publication/2015efb3-066b-5b7a-8b4f-2126bc5d82de.
9. World Meteorological Organization (WMO), "Early Warnings for All: Executive Action Plan 2023-2027 2027 (The UN Global Early Warning Initiative for the Implementation of Climate Adaptation)", 2022. Available at https://library.wmo.int/index.php?lvl=notice_display&id=22154#.Y_qoaHbP3IW
10. International Federation of Red Cross and Red Crescent Societies (IFRC), "World Disasters Report 2022", Geneva, 2023. Available at https://www.ifrc.org/document/world-disasters-report-2022

Effective and people-centred MHEWS must be:

Inclusive by taking into account the needs, perspectives, priorities, and meaningful participation of the various people in society, which depends on their age, sex, disability, gender roles, sexual orientation, literacy, language, cultural practices, race, geographic location, socioeconomic position, among many others.

Accessible to all to ensure that information can reach everyone who may be impacted, and in a way that can be easily understood, regardless of their individual circumstances including disability, literacy, and language.

Actionable in terms of providing information that includes potential impacts and recommended action that people should have the capacity to take, which enables people to reduce their disaster risk, and potential damages and loss.

Source: United Nations Office for Disaster Risk Reduction, Regional Office for Asia and Pacific, "Inclusive and Accessible Multi-hazard Early Warning Systems", 2022, p. 12. Available at https://www.undrr.org/publication/inclusive-and-accessible-multi-hazard-early-warning-systems-learning-women-led-early

People-centred elements should span across each of the four components of early warning systems to ensure inclusivity, accessibility and actionability of any warning.[11]

1.3 Strengthening MHEWS

Despite evidence indicating the economic benefits of early warning systems there are several challenges that proved to be barriers in implementing effective early warning services.

Target G, one of the seven targets of the Sendai Framework for Disaster Risk Reduction, 2015-2023, aims to "substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030". Monitoring the availability and access to multi-hazard early warning systems offers information on where and who requires EWS coverage. This information, in addition to assessments of areas of greatest exposure to disaster risk, is critical for the design, implementation and reinforcement of EWS.

As of March 2022, 120 countries had provided information on the status of their Target G. Of those 120 countries, 95 reported the existence of MHEWS. While this represents a two-fold increase from the achievement reported in 2015, this also indicates that less than half of the countries in the world have MHEWS.[12] Moreover, UNDRR

11. The forthcoming publication, *Words into Action: : Multi-Hazard Early Warning Systems* will include more detail on how people-centred approaches should be considered in each element of early warning systems.
12. United Nations Office for Disaster Risk Reduction (UNDRR) and World Meteorological Organization (WMO), "Global status of multi-hazard early warning systems: Target G", 2022. Available at www.undrr.org/publication/global-status-multi-hazard-early-warning-systems-target-g.

estimates that countries with limited to moderate MHEWS coverage have nearly eight times the mortality rate as compared to those countries with substantial to comprehensive coverage. Coverage is particularly low in the Small Island Developing States (SIDS) and Least Developed Countries (LDCs) – less than half of the LDCs, and only one-third of SIDS, have reported the existence of MHEWS. Advancing the coverage of effective MHEWS especially in areas of risk hotspots, is critical to reducing the number of fatalities due to disaster risks.[13]

Supplementing the Target G global indicators, a set of optional MHEWS custom indicators[14] have been developed that will allow key elements of MHEWS to be monitored, and can be used to identify aspects of MHEWS which may require targeted support. The custom indicators, reflecting the four components of an EWS, will not only facilitate the measurement of the effectiveness of hydrometeorological EWS, but also for those related to geohazards and biological hazards.

Specific challenges that exist across the four components of EWS need to be addressed

Challenges exist at the policy level leading to financing gaps. While it is easy to survey and estimate the damage and losses post-disaster, it is often more difficult to demonstrate the "preventable or avoidable damages" that an effective early warning system could bring. Public finances should be allocated to transition from essential EWS (saving lives) to the next level of an effective EWS (saving lives and reducing damages, impacts and disruptions), especially given the evolving uncertainties of the climate and resulting cascading hazards.

At the technical level, innovation and new science needs to be championed. Tangible benefits come to fruition when multi-sectoral cooperation is fostered, which is sometimes difficult when forecasting uncertainties are misunderstood. Linking scientific advancements and limitations with disaster management offices provides a more amenable partnership to deliver effective EWS. Technological innovations and scientific advancements are necessary and should be encouraged in order to recognize the inherent uncertainties in science around many hazard hotspots.

EWS should be designed to understand long-term risks; the 2004 Indian Ocean tsunami could have been regard as *unsurprising* if practitioners took into consideration the history of Indian Ocean basin tsunamis and the expected return-period (1881 Indian Ocean wide tsunami, 1941 Andaman tsunami, 1945 Pakistan tsunami). Similarly, EWS should be designed for the hazards that can be expected to evolve as climate changes.

Collective learning is needed to ensure that responses to early warnings are informed more by EWS and less by recent experiences as some disasters are beyond living memory, while other more recent disasters can raise panic. Trust and community engagement is imperative to ensure that life-saving early action will be triggered through people-centred early warnings.

Network coverage presents significant opportunities and challenges with regards to EWS. Today, more than 60 per cent (or 4.9 billion people) of the world's population is using the Internet and 95 per cent are within range of a mobile broadband network.[15] This has given rise to many new emergency-alerting services, including through mobile apps, or app-based alerting systems. However, the growth in coverage is uneven; those without Internet connections represent those living in remote areas, often belonging to disadvantaged groups, and in some cases are unfamiliar with what the Internet can offer.[16]

13. Ibid.
14. United Nations Office for Disaster Risk Reduction (UNDRR), World Meteorological Organization (WMO), and The Climate Risk and Early Warning Systems Initiative (CREWS), "Multi-hazard early warning system custom indicators & methodologies for computation", 2022. Available at https://www.undrr.org/publication/multi-hazard-early-warning-system-custom-indicators-methodologies-computation
15. International Telecommunications Union (ITU), "Facts and Figures 2021: Internet Use", 2021. Available at https://www.itu.int/itu-d/reports/statistics/2021/11/15/internet-use/
16. Ibid.

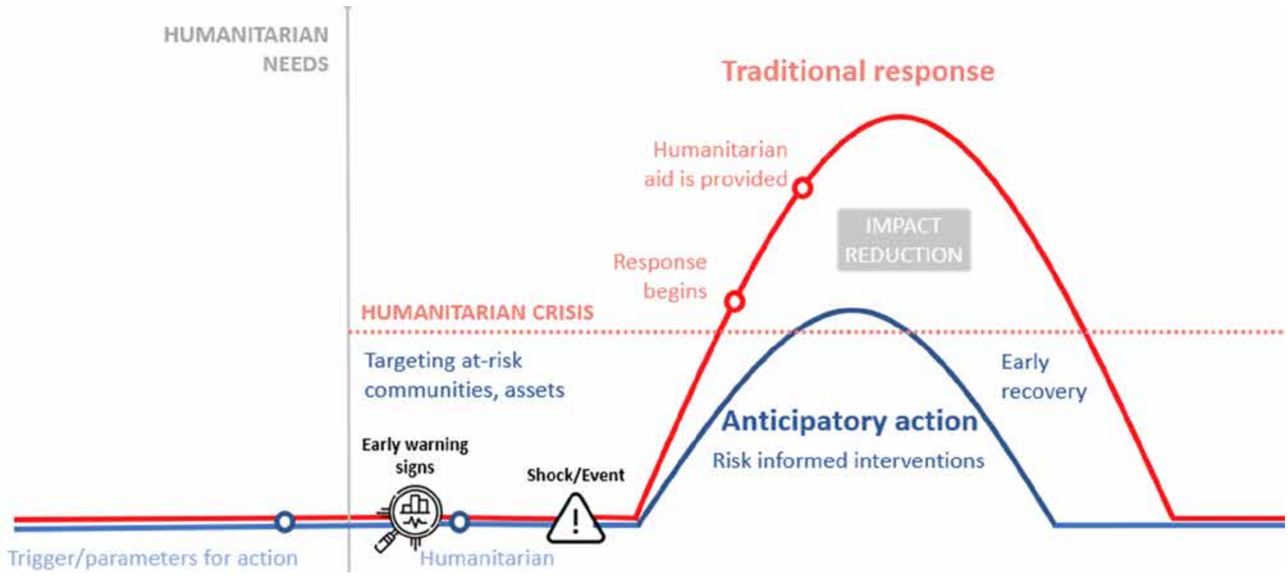
Notable improvements in MHEWS, at present, consist of the widely endorsed commitment to understand 'what the weather will do' through impact-based forecasting, and to ensure early warnings lead to early action, also known as anticipatory action (AA). These two concepts, described below, will facilitate understanding of the good practices discussed in Section 2.

Impact-based forecasting is a second-generation early warning product that enables realization of the shift in paradigm from *what the weather will be to what the weather will do*. ESCAP has developed a methodology to operationalize impact-based forecasting both for extreme events as well as slow onset disasters.[17] It sets an example of operationalizing the WMO global framework of climate services.

Advances in frontier technologies are enabling Asia-Pacific countries to move towards impact-based forecasts. Australia, for instance, provides a hazard risk outlook for four days, giving a daily breakdown, as well as a hazard map, risk matrix, and detailed impacts. The Republic of Korea issues impact-based forecasts for heatwaves and cold waves indicating the level of risk with respective response measures. The Philippines estimates the damages that a tropical cyclone could cause to buildings and the number of people that maybe affected.[18] The Viet Nam Meteorology and Hydrology Administration (VNMHA) has been moving towards impact-based forecasting and risk-informed early warning and is implementing a project on impact-based forecasting and warning services (IBFWS) and communication to strengthen its capacity to provide such services to various stakeholders.[19]

Impact-based forecasting represents the foundation on which anticipatory action can be triggered. This forecasting method allows warnings to be communicated in a way that facilitates early actions to safeguard against the impacts of extreme weather or climate events, while also communicating the uncertainties of the forecasts.

Figure 1-2: Tackling the extent of humanitarian crisis by anticipatory action.



Source: Adapted from United Nations Office for Disaster Risk Reduction (UNDRR), "Understanding disaster risk: Anticipatory Action". Available at https://www.preventionweb.net/understanding-disaster-risk/key-concepts/anticipatory-action

17. United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) and World Meteorological Organization (WMO), "Manual for Operationalizing Impact-based Forecasting and Warning Services (IBFWS)", Manuals and Training Materials, 4 August 2021. Available at https://www.unescap.org/kp/2021/manual-operationalizing-impact-based-forecasting-and-warning-services-ibfws.
18. Green Climate Fund, "SAP010 Multi-Hazard Impact-Based Forecasting and Early Warning System for the Philippines". Available at https://www.greenclimate.fund/project/sap010
19. Member report of Viet Nam for the 15th Integrated Workshop of the ESCAP/WMO Typhoon Committee, 1-2 December 2020.

Anticipatory action (AA) is at the core of early warning and early action. Anticipatory actions not only protect lives and livelihoods, but also help protect development gains in the long run (Figure 1-2).[20] AA programming offers an innovative approach that enables the implementation and financing of actions before an extreme weather event has occurred. These anticipatory actions aim to prevent and mitigate, to the extent possible, the effects of extreme weather on the food security and nutrition of highly vulnerable people.

Anticipatory action is "a set of actions taken to prevent or mitigate potential disaster impacts before a shock or before acute impacts are felt. The actions are carried out in anticipation of a hazard impact and based on a prediction of how the event will unfold. Anticipatory actions should complement longer-term investment in risk reduction and should aim to strengthen people's capacity to manage risks".[21] Though anticipatory actions come in many forms and sizes, they always come before the shock has impacted people, are highly time-sensitive and connected to forecasts.

Many governments have recognized the role of anticipatory action. For instance, the release of the G7 Famine Prevention and Humanitarian Crisis Compact on May 2022 is an important milestone in scaling up anticipatory action.[22] The G7 Members have agreed to avert the deterioration of acute hunger worldwide and curb the growth of humanitarian needs and support by scaling up anticipatory action as a solution. With the growing frequency and number of climate-related shocks and other crises, there is an exponential increase of humanitarian needs while response funding remains limited. Hence, it is important to act even before these needs materialize to reduce suffering and make efficient use of existing resources.

The progress made over recent decades in scientific forecasts and risk assessments makes it possible to have precise predictions about when and where extreme weather, especially large-scale events (cyclones, droughts, river floods), are likely to occur, and what their likely impacts on people will be to avert and minimize the impacts of hazards. This can be different for more localized extreme weather events that affect those localities that lack monitoring and forecasting capacities. Impact-based forecasting and anticipatory action will be explored in reference to the good practices on MHEWS discussed in the next section.

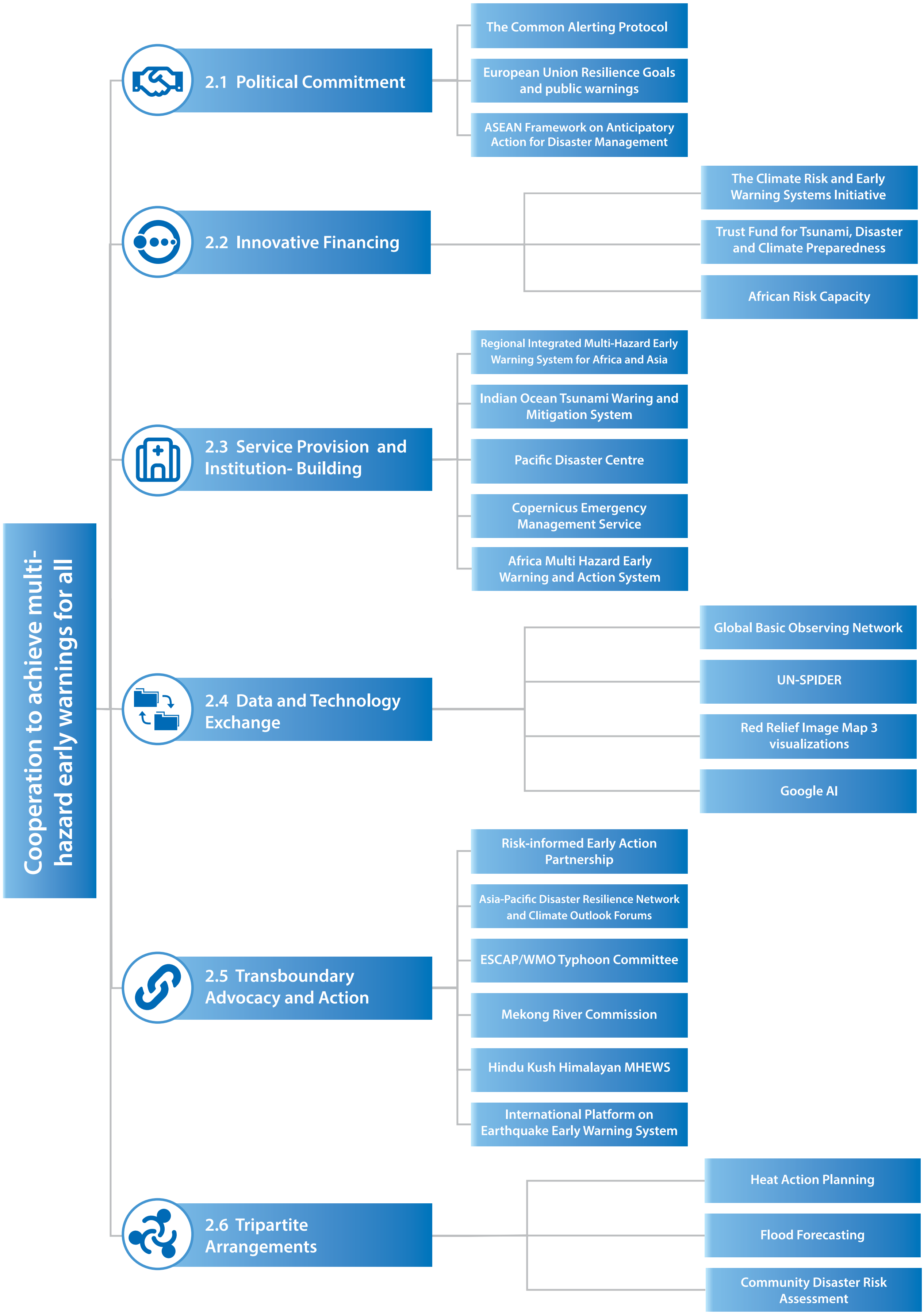
20. United Nations Office for Disaster Risk Reduction (UNDRR), "Understanding disaster risk: Anticipatory Action". Available at https://www.preventionweb.net/understanding-disaster-risk/key-concepts/anticipatory-action
21. International Federation of Red Cross and Red Crescent Societies (IFRC), "World Disasters Report 2020", Geneva, 7 May 2021. Available at https://www.ifrc.org/document/world-disasters-report-2020.
22. Federal Foreign Office (Germany), "G7 Foreign Ministers' Statement on Strengthening Anticipatory Action in Humanitarian Assistance", press release, 13 May 2022. Available at https://www.auswaertiges-amt.de/en/newsroom/news/g7-anticipatory-action/2531236

2.0 Good Practices in Providing MHEWS for All

International and regional cooperation can support the development and sustainability of effective early warning systems (See Annex for an overview of early warning cooperation mechanisms). Hazards, more often than not, cross national boundaries. Thus, disaster risks must also be managed in a transboundary manner. Therefore, the effectiveness of an institutionalized early warning system can only be achieved by strong cooperation between agencies running the system, the vulnerable people exposed to hazards and other relevant stakeholders. The level and scale of international and regional cooperation is related to the complexity of the risk to be governed.

The *International Network for Multi-Hazard Early Warning Systems* (IN-MHEWS) was announced at the Third United Nations World Conference for Disaster Risk Reduction in Sendai, Japan, in March 2015 to facilitate the sharing of expertise and good practices for MHEWS as a national strategy for DRR, climate change adaptation, and building resilience. The IN-MHEWS partners work together to promote a holistic and integrated approach to early warning, building on their respective programmes, activities, and institutional mechanisms for cooperation in EWS. The network supports the strengthening of user-interface platforms as a contribution to the DRR Priority of the Global Framework for Climate Services and has systematically supported country progress with regards to Target G of the Sendai Framework.

The following section showcases best practices to advance multi-hazard early warning systems with cooperation being the major, common enabling factor.


Cooperation to achieve multi-hazard early warnings for all
2.1 Political Commitment
The Common Alerting Protocol
European Union Resilience Goals and public warnings
ASEAN Framework on Anticipatory Action for Disaster Management
2.2 Innovative Financing
The Climate Risk and Early Warning Systems Initiative
Trust Fund for Tsunami, Disaster and Climate Preparedness
African Risk Capacity
2.3 Service Provision and Institution- Building
Regional Integrated Multi-Hazard Early Warning System for Africa and Asia
Indian Ocean Tsunami Waring and Mitigation System
Pacific Disaster Centre
Copernicus Emergency Management Service
Africa Multi Hazard Early Warning and Action System
2.4 Data and Technology Exchange
Global Basic Observing Network
UN-SPIDER
Red Relief Image Map 3 visualizations
Google AI
2.5 Transboundary Advocacy and Action
Risk-informed Early Action Partnership
Asia-Pacific Disaster Resilience Network and Climate Outlook Forums
ESCAP/WMO Typhoon Committee
Mekong River Commission
Hindu Kush Himalayan MHEWS
International Platform on Earthquake Early Warning System
2.6 Tripartite Arrangements
Heat Action Planning
Flood Forecasting
Community Disaster Risk Assessment

#1 2.1 Political Commitment
The Common Alerting Protocol

GLOBAL

Global standardized alerting protocol

Alerting authorities use numerous standards and protocols to transmit warnings. The Common Alerting Protocol (CAP) is an international standard format for emergency alerting and public warning, developed by the International Telecommunication Union (ITU-T Recommendation X.1303) and promoted by several agencies. It is designed for “all-hazards”, that is, hazards related to weather events, earthquakes, tsunamis, volcanoes, public health, power outages, and many other emergencies.

Information and communication technology networks, services, and users are growing, and they offer more opportunities to deliver alerting messages to populations at risk. People may be reached through landline phones, TV and radio, mobile networks, and the Internet via social media and mobile apps, but also through the more traditional use of sirens. Sending the same alerting message over multiple platforms increases coverage and impact, and enhances trust in the alert. Using a standardized alerting format, such as the Common Alerting Protocol (CAP), which is a simple but general format for exchanging all-hazard emergency alerts and public warnings over all kinds of information and communication technologies (ICT) networks, helps to avoid confusion.

CAP is widely used in EWS. Today, 90 per cent of the world’s population lives in a country that has implemented or is implementing CAP.[23] Yet, CAP uptake remains relatively weak in LDCs where ICT capacities are often limited.

Figure 2-1 demonstrates CAP as a key component in the flow of communications that leads from hazard detection to timely and appropriate actions. In the context of CAP, the timeframe of action is from seconds to days, and is distinct from situations that have longer timeframes, such as those that might be addressed in seasonal or annual forecasts, reports, or advisories. Emergency warnings can be prepared using defined thresholds and/or by using an impact-based approach. Risk information for affected community segments, such as vulnerability and exposure, can also be used to refine the warning.

Figure 2-1: The Common Alerting Protocol.

Source: International Telecommunications Union, “Common Alerting Protocol and Call to Action”, 2023. Available at https://www.itu.int/en/ITU-D/Emergency-Telecommunications/Pages/Common-Alerting-Protocol-and-Call-to-Action.aspx

CAP is supported by the free and open-source CAP Editor tool, which has been initialized for over 360 alerting authorities across 200 countries and in 28 languages, and more can be added easily. As a cloud-based service, this is a very simple option for an alerting authority.[24]

23. Eliot Christian, “Common Alerting Protocol (CAP) Implementation Workshop and Training”,19 -21 September 2022, Amsterdam, Netherlands, 2022.
24. This Good Practice was adapted from the forthcoming publication *Words into Action: Multi-Hazard Early Warning Systems*.

STAKEHOLDERS

Community | NGO/CSO | Academia/ Research | Private/ Business | National | International

EARLY WARNING COMPONENTS

Disaster Risk Knowledge | Observations, Monitoring, Analysis, Forecasting | Warning Dissemination and Communication | Preparedness and Response Capabilities

#2

2.1 Political Commitment
European Union Resilience Goals

REGIONAL

Strengthening public warnings through mobile networks

Ninety-five per cent of the world's population now has access to a mobile broadband network and, with a decreasing price, an increasing number of people own mobile phones. With growing mobile services, Mobile Network Operators (MNOs) become essential for efficiently broadcasting an alert.

In this context, as of June 2022, Article 110 of the European Electronic Communications Code (EECC) requires countries in the European Union (EU) to operate a public warning system that can send geographically targeted emergency calls to all mobile phone users in the affected area during a natural or man-made disaster. The European Commission Recommendation of 8 February 2023 on European Union Disaster Resilience Goals further outlined the importance of and regional commitment to enhancing early warning systems in the region. With this initiative, the EU strengthens the warning dissemination and communication part of its EWS.

While the warning dissemination relies on MNOs, the governance mechanisms are in the hands of several institutions around the continent: national disaster management agencies and National Civil Protection Authorities to structure its implementation; the national telecommunication regulatory authority to facilitate coordination with the MNOs and discussions with the national disaster management agency; or international organizations, such as ITU (International Telecommunication Union) or EENA (European Emergency Number Association), to promote the knowledge around the technologies or the regulation of mobile network-based early warning systems.

The practice is not limited to any hazard and can be applied to any emergency and threat. One key advantage is that alerting messages are geolocated since they take advantage of the information that MNOs have on their clients. In this way, warnings can reach all users at any time. In combination with the use of different technological solutions and standards, including CAP, cell-broadcast, and geolocated services, a public warning based on mobile networks and services can deliver clear and live warning messages only to those people located in at-risk areas.

In Europe, several countries equipped with MHEWS have successfully used the mobile network public warning system over the last few years. An example could be the case of the major floods in Belgium, France, and Germany, in July 2021. Belgium sent around 2 million location-based SMS in 48 hours for informing and evacuating their citizens, more than 13,000 voice calls, via their multi-channel MHEWS called Be-Alert. At the same time, 58 warning campaigns were sent by 37 different municipalities with access to MHEWS BE-Alert. Following the impact of floods, more countries vowed to use mobile cellular networks and services to warn citizens at risk.[25]

25. This Good Practice was adapted from the forthcoming publication *Words into Action: Multi-Hazard Early Warning Systems.*

STAKEHOLDERS

Community · NGO/CSO · Academia/Research · **Private/Business** · **National** · **International**

EARLY WARNING COMPONENTS

Disaster Risk Knowledge · Observations, Monitoring, Analysis, Forecasting · **Warning Dissemination and Communication** · Preparedness and Response Capabilities

#3

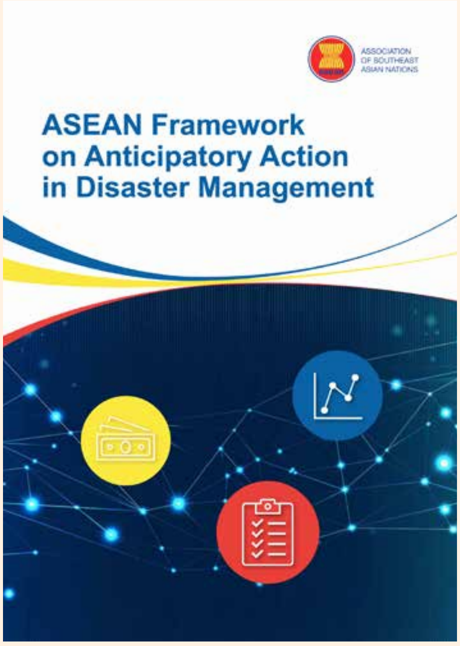
2.1 Political Commitment
ASEAN Framework on Anticipatory Action in Disaster Management

REGIONAL

Subregional specifities for risk-informed early actions

Anticipatory action is a core part of disaster risk management (DRM) and represents how early warnings can lead to predetermined early actions, but is not often implemented systematically.

The South-East Asian countries, or the Association of Southeast Asian Nations (ASEAN) region, is one of the most at-risk regions in the world. Countries are exposed to a variety of climate-related hazards, including floods, storms, typhoons, droughts and extreme temperatures. The ASEAN Framework on Anticipatory Action in Disaster Management aims to ensure that early warnings are reliably translated into effective anticipatory action to reduce the negative impacts of disasters across the South-East Asia subregion. The Framework was developed with relevant ASEAN sectoral bodies between November 2021 and May 2022, and was supported by the Food and Agriculture Organization of the United Nations (FAO), the Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG ECHO) and Asia-Pacific Regional Technical Working Group on Anticipatory Action.



The ASEAN Framework on Anticipatory Action in Disaster Management provides guidance for defining and contextualizing anticipatory action at the subregional level with some considerations for its implementation by ASEAN members.[26] The Plan of Action for 2021–2025, that accompanies this Framework, outlines 12 regional target actions and associated indicators to monitor progress for implementing the three building blocks of anticipatory action. The Plan of Action provides suggestions for coordination with regional and national-level actors and external partners to strengthen anticipatory action in ASEAN. The Plan of Action further builds on the principles of collaboration and alignment of anticipatory action with existing DRM policies and programmes in the region.

Looking ahead to 2025, this Framework highlights prioritized actions in a regional action plan to move forward with the anticipatory action agenda. The Framework thus provides a guide on how countries can collaborate with each other and work with partners based on a collective understanding and point of reference for scaling up and accelerating progress in making anticipatory actions an integral part of DRM in the ASEAN region. It represents a landmark commitment from ASEAN to move the anticipatory action agenda forward in the subregion in support of a climate-resilient future.

26. The Association of Southeast Asian Nations (ASEAN) Secretariat, "ASEAN Framework on Anticipatory Action in Disaster Management", Jakarta, June 2022. Available at https://asean.org/wp-content/uploads/2022/06/ASEAN-Framework-on-Anticipatory-Action-in-Disaster-Management.pdf

STAKEHOLDERS

Community | NGO/CSO | Academia/Research | Private/Business | National | International

EARLY WARNING COMPONENTS

Disaster Risk Knowledge | Observations, Monitoring, Analysis, Forecasting | Warning Dissemination and Communication | Preparedness and Response Capabilities

2.2 Innovative Financing
The Climate Risk and Early Warning Systems (CREWS) initiative

GLOBAL

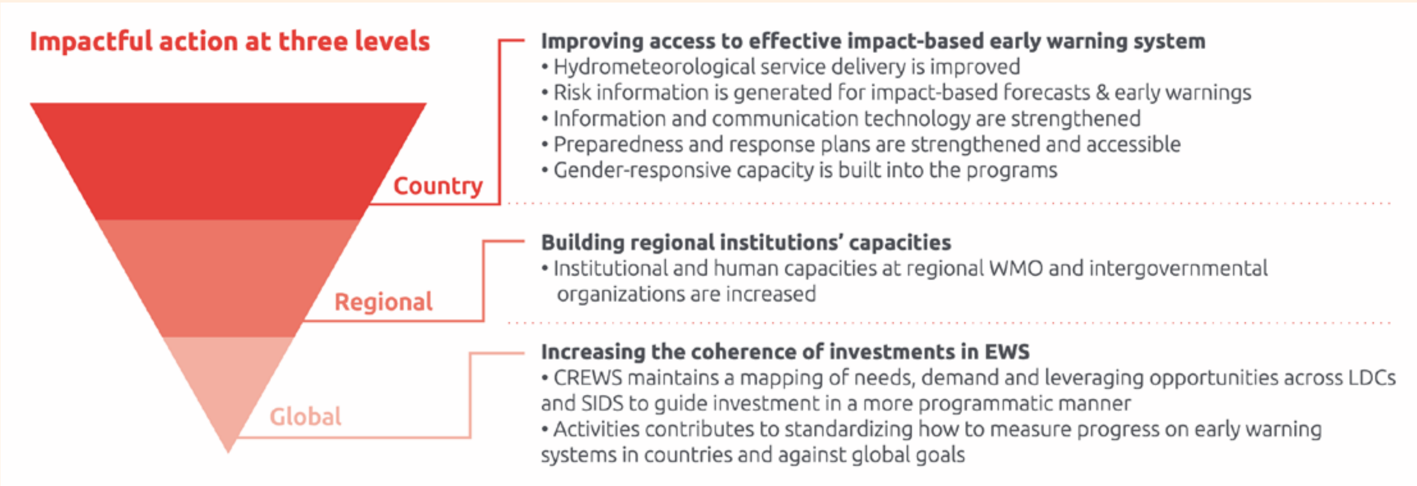
Global to local financing

In the LDCs and SIDS an increasing number of people are at risk of losing their lives as a result of weather and climate-related hazardous events. This trend is in part attributed to low or basic capacity to use risk information and to provide early warning. Although investment to strengthen climate services has increased, funding needs remain unmet. Closing the funding gap requires building on existing investments, leveraging additional funds and improving effectiveness.

In 2015, a financing mechanism, solely focused on early warning systems, was announced by France at the World Conference on Disaster Risk Reduction, that was held in Sendai, Japan, and was launched later that year by five countries (joined by four more countries and the European Commission) at the United Nations Framework Convention on Climate Change (UNFCCC) COP 21 in Paris, France.

The Climate Risk and Early Warning Systems (CREWS) initiative is a Financial Intermediary Fund, managed by the World Bank, which finances early warning systems in LDCs and SIDS, through three partners, United Nations Office for Disaster Risk Reduction (UNDRR), World Meteorological Organization (WMO) and the World Bank. As of 2021, the CREWS initiative had mobilized over US$ 77 million for advancing early warning systems at the global, regional and country level for LDCs and SIDS (Figure 2-2).

Figure 2-2: CREWS: Global, Regional and Country Impacts.



Source: International Telecommunications Union, 2023, Common Alerting Protocol and Call to Action. https://www.itu.int

CREWS works directly with countries to increase the availability of, and access to, early warning systems. Country and regional projects are implemented by the countries with the support from implementing partners who provide technical assistance and capacity development.

STAKEHOLDERS

Community · NGO/CSO · Academia/Research · Private/Business · National · International

EARLY WARNING COMPONENTS

Disaster Risk Knowledge · Observations, Monitoring, Analysis, Forecasting · Warning Dissemination and Communication · Preparedness and Response Capabilities

#5

2.2 Innovative Financing
The ESCAP Trust Fund for Tsunami, Disaster and Climate Preparedness

REGIONAL

Regional financing mechanism to address unmet needs

The 2004 Indian Ocean tsunami resulted in widespread loss of human life and livelihoods, severe damage to infrastructure and ecosystems and large economic costs. Following this disaster, leaders across Asia and the Pacific recognized the criticality of coordinated and long-term preparedness and prevention efforts to mitigate the impacts of natural disasters. A key to this commitment has been the establishment and further strengthening of early warning systems.

Since its inception in 2005, the ESCAP Multi-Donor Trust Fund for Tsunami, Disaster and Climate Preparedness has helped 19 countries to benefit directly from support in building regional and national end-to-end warning systems for coastal hazards, through the financial contribution of US$ 10 million from Thailand, followed by US$ 2.5 million from Sweden and contributions from 10 other donor governments. By pooling resources, the Trust Fund facilitates South-South cooperation to strengthen disaster resilience in high-risk, low-capacity countries and to ultimately reduce disaster loss and damage.

At the regional level, the Trust Fund has provided sustained global-to-regional-to-local financial support for the establishment of key initiatives that deliver cost-effective warning products and services across the region, particularly for tsunamis and extreme weather systems. The Trust Fund has also proven to be an effective vehicle for countries to access and share data, tools, and expertise to support disaster resilience.

For instance, catalytic investment of $7 million by the ESCAP Trust Fund for Tsunami, Disaster and Climate Preparedness has successfully promoted such a model by establishing RIMES (See Good Practice #7) which is owned and supported collectively by member States of Asia and Africa to serve them to build capacity for end-to-end multi-hazard early warning. Further, it is the only dedicated regional trust fund that delivers a coordinated financial and technical support to address the unmet needs and gaps in early warning systems.

At the national level, some of the most valuable and sustainable results of the Trust Fund's projects involve strengthening monitoring and warning services and building capacities for climate preparedness in highly vulnerable countries. Operating in a regionally coordinated and programmatic way, the Trust Fund has helped reduce the total cost of establishing and maintaining early warning systems substantially, as compared to the sum of costs that would have incurred if every country maintained its own system.

Asia and the Pacific's Trust Fund for Tsunami, Disaster and Climate Preparedness is a collective acknowledgement that investments in early warning and climate adaptation are investments in the present and future economic, social and environmental sustainability of Asia and the Pacific.

STAKEHOLDERS

Community | NGO/CSO | Academia/Research | Private/Business | National | International

EARLY WARNING COMPONENTS

Disaster Risk Knowledge | Observations, Monitoring, Analysis, Forecasting | Warning Dissemination and Communication | Preparedness and Response Capabilities

#6

2.2 Innovative Financing
African Risk Capacity (ARC) mechanism

REGIONAL

Risk-informed early action financing

The Sahel region of West Africa and Southern Africa suffer from severe droughts, while coastal countries in West Africa and along the South-Western Indian Ocean are affected by floods due to tropical storms. Given the prevailing poverty, these countries are severely impacted.

In response, the African Risk Capacity (ARC) has developed the Africa RiskView (ARV), an innovative disaster risk financing mechanism that estimates the number of people affected by drought, and the budget needed to respond to emergencies and recover from damages. ARV uses satellite-based rainfall information and household vulnerability data to estimate potentially affected populations and response costs, which are shared with decision-makers to inform early or anticipatory action.

Also, ARC risk models can be used for parametric risk insurance. The organization has developed a system that ensures that payments from the risk insurance are used to implement response interventions following a pre-agreed contingency plan. ARC works with in-country technical experts in emergency response and social protection to explore existing contingency funding mechanisms and response activities that could be complemented and used by ARC pay outs, and to consider supporting the scaling-up of existing social protection programmes.

As the territory covered by ARV is so extensive, one of the most remarkable aspects of this practice is how ARC provides training to in-country technical working groups (TWG) to customize the different natural hazard risk models, ensuring accurate monitoring and response adapted to each territory. Also, the participation of ARC member States in the activities and training ensure the sustainability of the project.

ARC's MHEWS on drought has been used to model the impact of several drought events on the African continent since 2014. Similarly, the drought models have been used to underpin sovereign drought risk insurance in several countries, resulting in insurance pay outs used to implement early response activities.

In 2019, the ARC drought model detected severe drought in Senegal and estimated that more than 900,000 people were affected by severe drought conditions. The Government of Senegal received US$ 23.1 million from African Risk Capacity Insurance Limited to assist in providing early action to support more than the 975,000 people who were affected by drought during the 2019 agricultural season. The pay outs went towards food, cash transfers and nutritional supplements for children under 5 years of age. This is just one example of the several countries that have benefited from ARC's drought monitor.[27]

27. This Good Practice was adapted from the forthcoming publication *Words into Action: Multi-Hazard Early Warning Systems.*

STAKEHOLDERS

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EARLY WARNING COMPONENTS

Disaster Risk Knowledge · **Observations, Monitoring, Analysis, Forecasting** · Warning Dissemination and Communication · **Preparedness and Response Capabilities**

#7

2.3 Service Provision and Institution-Building
Regional Integrated Multi-Hazard Early Warning System

REGIONAL

A fit-for-purpose MHEWS business model

The Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES), established with the support of ESCAP's Multi-donor Trust Fund for Tsunami, Disaster and Climate Preparedness, is an international and intergovernmental institution, owned and managed by its member States. It is a regional early warning system within a multi-hazard framework for the generation and communication of early warning information, and capacity-building for preparedness and response to transboundary hazards.

While RIMES has built its own institutional capacities, it capitalizes on surplus high-end computing facilities of India (Ministry of Earth Sciences) and the European Centre for Medium Range Weather Forecasting. Yet, another important role that RIMES has been playing is to connect the missing links of global observational to national/local networks and vice-versa especially in low capacity developing countries, LDCs and SIDS, which are often missed out in the WMO Global Telecommunications System (GTS).

To illustrate an early benefit of this mechanism as cited by the World Bank,[28] a 1 to 10-day flood forecasting system for Bangladesh was created in 2007 by the European Centre for Medium-Range Weather Forecasts and other parties. In an effort to boost regional capacity, the flood forecast modules were handed over to the Bangladesh Flood Forecasting and Warning Centre (BFFWC) in 2009. However, the large volume of data generated by these modules proved to be too difficult for the BFFWC to handle. As a result, responsibility for using the models to prepare flood forecasts was handed over to an international non-government entity, the Regional Integrated and Multi-Hazard Early Warning System to improve the range of the operational flood forecasting technology to 10-15 days for three major river basins: Ganges, Brahmaputra and Jamuna.

Special efforts were made to reach communities: voice message broadcasting tools were used; barriers of literacy were overcome to accompany the weather and flood forecasts and warning messages; and agrometeorological and livestock advisories were issued. More than 50,000 Bangladeshi recipients can access advisories through this platform.

During the monsoon flood of 2020, RIMES' 15-day flood forecast system proved its efficacy. The flood was successfully detected 14 days ahead, and a post-monsoon assessment carried out in the flood affected areas revealed that more than 97 per cent of the beneficiaries of its practice received forecast-based advisories, flood forecasts, and warnings through its system. With a lead time of more than 5 days to protect themselves and their resources, most of the population was able to take early action. For example, people were able to move their cattle to a safer area or stop planting certain kinds of seeds before the flooding.

RIMES' core services support National Meteorological and Hydrological Services across 48 member countries and collaborating states in Asia and the Pacific and in Africa, and across the full early warning system value chain; from modelling and forecasting support to decision support tools that facilitate climate service delivery for sectoral agencies and end-users. Most of the beneficiaries are LDCs, SIDS and high-risk developing countries.[29]

28. Gregory Amacher and others, "Framework for Conducting Benefit-Cost Analyses of Investments in Hydro-Meteorological Systems", Environment and Water Resources occasional paper series (Washington, D.C., World Bank, 2014). Available at https://documents1.worldbank.org/curated/en/633501468047653235/pdf/929580WP0P14940sional0paper0series0.pdf
29. This Good Practice was adapted from the forthcoming publication *Words into Action: Multi-Hazard Early Warning Systems.*

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EARLY WARNING COMPONENTS

Disaster Risk Knowledge | Observations, Monitoring, Analysis, Forecasting | Warning Dissemination and Communication | Preparedness and Response Capabilities

#8 2.3 Service Provision and Institution-Building Indian Ocean Tsunami Warning and Mitigation System

TRANSBOUNDARY

Unified transboundary science and coordination for collective warnings

The 2004 Indian Ocean Tsunami, which resulted in over 220,000 fatalities and an estimated $10 billion in economic losses across 14 countries, presented the tragic need for regional early warning systems. In response, the Intergovernmental Oceanographic Commission of UNESCO (UNESCO/IOC) led efforts to establish the Indian Ocean Tsunami Warning and Mitigation System (IOTWMS) through multi-level international cooperation.

Over the last two decades of operation, the IOTWMS has made considerable progress in all components of Tsunami EWS. Tsunami monitoring and warning services are provided by Australia, India and Indonesia through the IOTWMS mechanism to support 36 Indian Ocean basin countries. These countries also share a unified Probabilistic Tsunami Hazard Assessment for the Indian Ocean, most recently updated to include the Makran Subduction Zone in the North-West Indian Ocean.

In addition to service provision and scientific advancements, national and sub-national warning and response capabilities are also strengthened through this intergovernmental mechanism. The Tsunami Ready Programme, through a bottom-up approach, supports communities to adopt mitigation measures to cope with their tsunami risk.

Notably, the Odisha region of India stretches over a 480-kilometre coastline and has been categorized as a high-risk area affected by cyclones, floods, droughts, heatwaves, and occasional tsunamis, to which the region's residents are especially vulnerable given to their fragile socioeconomic situation. Building from the Tsunami Ready Programme, the Odisha State Disaster Management Authority, in collaboration with NGOs, the Odisha Disaster Rapid Action Force, and the India Meteorological Department, made Odisha the first Indian state to have an early warning system in place for people living along the length of its 480 kilometre coastline. Their Early Warning Dissemination System (EWDS) has also been praised for facilitating the critical role of women in strengthening community resilience.

Another impressive example of how the IOTWMS has impacted local community resilience is in Tanjung Benoa, Bali, Indonesia. At-risk communities in the low-lying island peninsula partnered with local resorts and hotels to use their facilities as vertical evacuation sites should tsunami risks ever be realized. Local schools, the Meteorology, Climatology, and Geophysical Agency (BMKG), and the National Agency for Disaster Countermeasure (BPPB) joined together for evacuation planning in partnership with private sector resulting in an expansion of the resources available to communities to save lives and livelihoods.

Through cooperation arrangements facilitated by the UNESCO/IOC-led Intergovernmental Coordination Group mechanisms, there are now 11 Tsunami Service Providers (TSPs) that have been established globally. In addition to the Indian Ocean, similar intergovernmental arrangements also cover the Caribbean, North-Eastern Atlantic, the Mediterranean, and the Pacific.[30]

30. This Good Practice was adapted from the forthcoming publication *Words into Action: Multi-Hazard Early Warning Systems.*

STAKEHOLDERS

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EARLY WARNING COMPONENTS

Disaster Risk Knowledge · Observations, Monitoring, Analysis, Forecasting · Warning Dissemination and Communication · Preparedness and Response Capabilities

#9

2.3 Service Provision and Institution-Building
Pacific Disaster Center System

GLOBAL

Public-private partnership for integrated early warnings

The Pacific Disaster Centre (PDC) was established by the U.S. Congress following Hurricane Iniki's devastation of the Hawaiian Island of Kauai in 1992, and became operational in 1996.[31] PDC (global), a public-private partnership entity, is an applied research centre managed by the University of Hawaii that supports the most demanding governmental and nongovernmental organizations (NGOs) worldwide in helping partners enhance disaster management capacity, save lives, and reduce disaster losses through the application of advanced tools and technologies, evidence-based research, and analytical information.

The Centre's DisasterAWARE platform is used by tens of thousands of disaster management professionals, from the senior-level decision maker to the operational practitioner. It provides global multi-hazard early warning, hazard monitoring, and risk intelligence to support rapid and effective disaster response, preparedness, recovery, and mitigation. DisasterAWARE includes the highest resolution impact models for all hazards, advanced analytical reports, and augmented information through artificial intelligence. The system features the largest, scientifically-vetted big data catalogue for disaster management decision-making in the world, that is derived in part from PDC's unique National Disaster Preparedness Baseline Assessment as well as its Global Risk and Vulnerability data. DisasterAWARE provides near real-time analytics about impacts to population, capital, and key infrastructure for multiple hazards, calculating likely humanitarian needs down to a scale of 30 x 30 meters. DisasterAWARE is free to disaster management practitioners and the humanitarian assistance community.

For more information see https://disasteraware.pdc.org.

31. Pacific Disaster Centre (PDC), "About PDC", 2023. Available at https://www.pdc.org/about

STAKEHOLDERS

Community | NGO/CSO | Academia/Research | Private/Business | National | International

EARLY WARNING COMPONENTS

Disaster Risk Knowledge | Observations, Monitoring, Analysis, Forecasting | Warning Dissemination and Communication | Preparedness and Response Capabilities

#10

2.3 Service Provision and Institution-Building
Copernicus Emergency Management Service

GLOBAL

Extensive service provision

The Copernicus Emergency Management Service (CEMS), managed by the Joint Research Centre of the European Commission, supports all actors involved in the management of natural or manmade disasters by providing geospatial data and images for informed decision-making. CEMS constantly monitors Europe and the globe for signals of an impending disaster or evidence of one happening in real time. The service immediately notifies national authorities of the findings or can be activated on-demand and offers to provide them with maps, time-series or other relevant information to better manage disaster risk. CEMS products are created using satellite, in-situ (non-space) and model data.

CEMS provides access (among others) to a number of critical European early warning systems that have been expanded to global coverage:

- *The Global Flood Awareness System (GLOFAS)* is an early warning service provided by the Copernicus programme of the EU and provides forecasts of the levels of floods in various segments of channels of rivers classified into four categories according to the level of the potential flood.
- *The Global Drought Observatory*, also under the umbrella of the Copernicus programme of the EU, provides information on the status of droughts worldwide. The use of the same algorithms worldwide allows this service to homogenize the information on the status of droughts worldwide.
- *The Global Wildfire Information System (GWIS)* launched by the Copernicus programme, NASA and GEO, provides information on the status of wildfires worldwide, and includes a database of historic forest fires that can be consulted for analysis of historical trends at the country and lower levels.

Production of maps and data in line with the above EWS is primarily produced through service contracts with European industry and academia.

Overall benefits of this multi-hazard early warning service delivery include:

- Continuous operational service 24 hours a day over the year;
- Disaster risk reduction, prevention, preparedness, recovery, and reconstruction through information delivery and analysis;
- Fast information about difficult-to access locations;
- Imagery acquisition independent from the time of the day and weather conditions;
- Quick assessment of large areas for damages to transport and infrastructure;
- A unique overview of ongoing and forecasted events.

As an EU service, the CEMS's first priority is responding to the needs and interests of the EU, whether from within the EU or abroad. The Emergency Management Service is provided free of charge to authorized users, including access to high-resolution satellite imagery collected by the fleet of European Sentinel satellites.[32]

For more information and links to relevant services, please see Annex.

32. This Good Practice was adapted from the forthcoming publication *Words into Action: Multi-Hazard Early Warning Systems*.

STAKEHOLDERS

Community | NGO/CSO | Academia/Research | Private/Business | National | International

EARLY WARNING COMPONENTS

Disaster Risk Knowledge | Observations, Monitoring, Analysis, Forecasting | Warning Dissemination and Communication | Preparedness and Response Capabilities

#11

2.3 Service Provision and Institution-Building
Africa Multi Hazard Early Warning and Action System

REGIONAL

Continental-wide MHEWS

Under the vision of the African Union Commission (AUC) to unify multi-hazard early warning systems across the continent, the first ever MHEWS Conference was held in 2021. The Africa Multi-Hazard Early Warning and Action System (AMHEWAS) focuses on hydrological and meteorological hazards across the entire geographic extent of the African continent.

This relatively young mechanism aims to strengthen transboundary coordination mechanisms for efficient mobilization and use of resources in disaster situations to significantly reduce disaster loss and/or damages, and standardize a continental approach for early warnings and response that will be able to be replicated at the national level.[33]

The 24/7 AMHEWS situation room is housed at the AUC premises and provides the opportunity for national representatives to be supported to further enhance technical capacity sharing on hazard detection, monitoring and forecasting.

The AMHEWS can support national EWS with hazard detection, monitoring and forecasting from satellite and geospatial data using the myDewetra platform, which is an open-source web-based system for real-time detection, monitoring, analysis and forecasting of natural hazards.

For warning dissemination and communication products, the AMHEWS currently uses emails and the Telegram App. The Continental Watch and Situation reports distributed include impact-based early warnings to decision-makers (African Union departments, ambassadors and DRR focal persons) to know the status of the disaster in order to be able to take action. There are plans to extend these communication/ mediums and mailing lists to extend the reach of the communication products. There are also plans to issue the communication products in all official languages of the African Union.

Working together with Regional Economic Communities (RECs), Centro Internazionale in Monitoraggio Ambientale – Fondazione (CIMA), UNDRR and humanitarian partners, the AMHEWAS has already seen success in reducing the impacts of adverse weather events.

For example, before making landfall in Madagascar, Tropical Cyclone Batsirai's extreme weather system was tracked and warnings were produced based on numerical weather predictions and the hazard forecasting model implemented in the AMHEWAS. These warnings were displayed twice per week in the Continental Watch bulletin, issued by AUC. This MHEWS also produced an initial situation report including key figures on the event impacts and location, verified by key national partners and shared with the department of humanitarian affairs. Subsequently, an emergency coordination meeting for humanitarian partners was convened based on the impact outlined in the situation report. This emergency coordination meeting revealed the early action that partners took to avoid duplication of actions and enhance the efficient use of resources in response to the disaster.

33. This Good Practice was adapted from the forthcoming publication *Words into Action: Multi-Hazard Early Warning Systems.*

STAKEHOLDERS

Community | NGO/CSO | Academia/Research | Private/Business | National | International

EARLY WARNING COMPONENTS

Disaster Risk Knowledge | Observations, Monitoring, Analysis, Forecasting | Warning Dissemination and Communication | Preparedness and Response Capabilities

#12

2.4 Data and Technology Exchange
Global Basic Observing Network

GLOBAL

Universal disaster monitoring

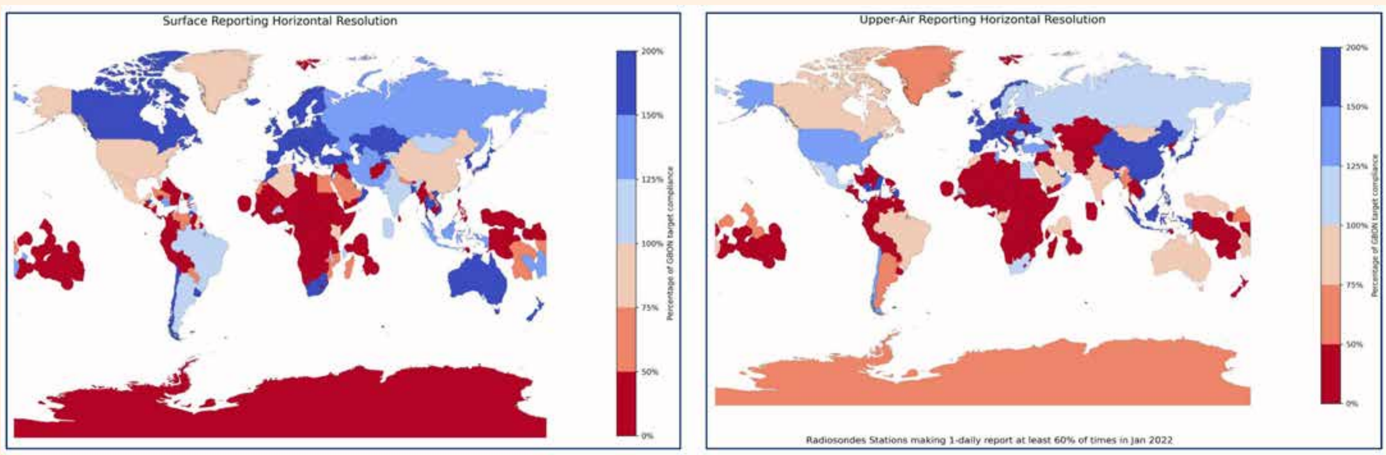
Local weather forecasts depend on access to 24/7 global observations. But there are large geographical gaps in availability. In some parts of the world, observations are either not made or not exchanged internationally, and in other parts they are not made or exchanged frequently enough.

The Global Basic Observing Network (GBON) paves the way for a radical overhaul of the international exchange of observational data, which underpin all weather, climate and water services and products. The 2021 World Meteorological Congress approval represents a historic, binding commitment of all 193 WMO member states and territories to the international exchange of observations specified in technical regulations.

Through this approach, basic surface-based observing network is designed, defined and monitored at the global level. Once implemented, GBON will improve the availability of the most essential surface-based data, which will have a direct positive impact on the quality of weather forecasts, thus helping improve the safety and well-being of citizens throughout the world.

Countries with few resources relative to the size of the area they have to observe (low GDP per unit surface area, dark colours) are expected to have difficulties implementing GBON. According to the WMO Global Basic Observing Network Global Gap Analysis 2022, the Pacific, the Caribbean and Sub-Saharan Africa are areas with significant data gaps (Figure 2-3).

Figure 2-3: Global Basic Observing Network Global Gaps in Surface Reporting (Left) and Upper Air Reporting (Right).



Source: WMO Secretariat, "The gaps in the Global Basic Observation Network (GBON)", Systematic Observations Financing Facility, October 2020. Available at https://library.wmo.int/doc_num.php?explnum_id=10377

The Systematic Observation Financing Facility (SOFF) was launched in July 2022 to finance the gaps in GBON, and will support countries to generate and exchange basic surface-based observational data critical for improved weather forecasts and climate services.

STAKEHOLDERS

Community | NGO/CSO | Academia/Research | Private/Business | National | International

EARLY WARNING COMPONENTS

Disaster Risk Knowledge | Observations, Monitoring, Analysis, Forecasting | Warning Dissemination and Communication | Preparedness and Response Capabilities

#13

2.4 Data and Technology Exchange
UN-SPIDER Exposure Data

GLOBAL

Satellite observations for early warnings and early action

When using space technologies in disaster risk management and emergency response activities, access to space-based data and software is not all that is necessary. Workflows for obtaining and processing satellite imagery to analyse a wide range of natural hazards is also needed.

In its resolution 61/110 of 14 December 2006 the United Nations General Assembly agreed to establish the "United Nations Platform for Space-based Information for Disaster Management and Emergency Response - UN-SPIDER" as a new United Nations programme, with the following mission statement: "Ensure that all countries and international and regional organizations have access to and develop the capacity to use all types of space-based information to support the full disaster management cycle".

UN-SPIDER implemented a global methodology to include exposure information gathered from satellite observations aiming to increase the efficacy of early warning systems. This methodology can be replicated in any country with any type of hazard, and a step-by-step guide has been developed and stored in the UN SPIDER Knowledge Portal to facilitate its implementation. This practice serves as a testament to the effectiveness of strengthening the key element of disaster risk knowledge.

The space community offers access to optical satellite imagery and to products that present information on exposure, such as data on population provided by WorldPop,[34] and information on land cover, such as Globeland. These sources of data can be used to design early warning strategies based on the location of vulnerable groups, and evacuation routes in case of warnings, as well as for impact-based warnings when combined with other types of in-situ data.

The proposed methodology can be applied globally combining a simple approach based on open-source software and free of charge data together with a previously-created map covering the extent of a hazard or disaster to identify potential impacts and the number of inhabitants affected by a hazardous event. This information can then be used to design impact-based warnings to devise early warning/ early action strategies or arrange evacuation routes to safe areas for different types of vehicles or for those people who must be mobilized on foot.

The use of information on exposure gathered from satellite observations allow national disaster management agencies to have an improved knowledge of the risks related to hazards and to elaborate impact-based forecasts using a combination of various sources of information.

The Knowledge Portal offers entry points to explore how space-based information can be used in disaster management, through examples and relevant material.[35]

34. The WorldPop data set provides population data for Africa, Asia as well as Central and South America with a spatial resolution of 100 metres.
35. This Good Practice was adapted from the forthcoming publication *Words into Action: Multi-Hazard Early Warning Systems.*

STAKEHOLDERS

Community | NGO/CSO | Academia/ Research | Private/ Business | National | International

EARLY WARNING COMPONENTS

Disaster Risk Knowledge | Observations, Monitoring, Analysis, Forecasting | Warning Dissemination and Communication | Preparedness and Response Capabilities

#14

2.4 Data and Technology Exchange
Red Relief Image Map

MULTI-COUNTRY

Advances in 3D visualization technology to map unseen hazards

Ground surface visualization is an important aspect of geospatial information analysis. Traditional methods, such as contour maps, aerial photographs, and shaded relief maps, have limitations in terms of expressing topographic features. These limitations can lead to difficulties in understanding ground surface features, especially in cases of natural disasters, such as landslides and volcanic eruptions. To overcome these limitations, an innovative 3D visualization method called Red Relief Image Map (RRIM) has been developed using three elements of landform, topographic slope, positive openness and negative openness.[36]

Using patented technology from Asia Air Survey, Co., Ltd., registered in Japan, as well as the United States and China, the RRIM is a completely new 3D visualization method for topography that overcomes the shortfalls of traditional visualization methods, such as scaling weakness, light direction dependence, necessary stereoscope, and filtering. RRIM uses the chroma of red colour to slope and brightness of red colour to the ridge-valley value calculated from the digital elevation model (DEM) to express the details of topography in a single image map. The RRIM is independent of the direction of the incident light, can visualize landscape from any viewing angles with no shade in it, and can represent a wide range of 3D topographic structures with a single image without any specialized hardware. The RRIM has been found to be suitable for a variety of land features and a wide range of scales with a single image, making it an efficient method for 3D visualization of the ground surface.

The RRIM has significant advantages compared to traditional visualization methods for ground surfaces. The RRIM can be used to interpret natural disasters, such as landslides, debris flow, hazard mapping, and as the background map to show topographical features to help view any map of a large-scale area. Regarding natural disaster reduction, the RRIM can be used to understand the situation of the ground surface after a natural disaster occurred, to contribute to recover the disaster and avoid secondary disasters. Furthermore, the RRIM can be used to interpret micro features of slope deformation and then evaluate the hazard risk of landslides of a targeted area.[37]

Figure 2-4: The Aso landslide was triggered by the Kumamoto Earthquake, April 16, 2016. Left: Arial photograph was taken after a few hours later the earthquake occurred; Right: RRIM of the Aso landslide using Airborne Lidar date taken on April 16.

Source: Trilateral Cooperation Secretariat (TCS) and United Nations Office for Disaster Risk Reduction (UNDRR), "Trilateral Best Practices: Application of Technology for Reducing Disaster Risks in China, Japan and Korea", 2021. Available at https://www.undrr.org/publication/trilateral-best-practices-application-technology-reducing-disaster-risks-china-japan

36. Tatsuro Chiba, Shin-Ichi Kaneta, and Yusuke Suzuki, "Red Relief Image Map: New visualization method for three-dimensional data", *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, vol. XXXVII, Part B2 (2008), pp.1071-1076.
37. Trilateral Cooperation Secretariat (TCS) and United Nations Office for Disaster Risk Reduction (UNDRR), "Trilateral Best Practices: Application of Technology for Reducing Disaster Risks in China, Japan and Korea", 2021. Available at https://www.tcs-asia.org/data/etcData/PUB_1632720421.pdf

STAKEHOLDERS

Community | NGO/CSO | Academia/Research | Private/Business | National | International

EARLY WARNING COMPONENTS

Disaster Risk Knowledge | Observations, Monitoring, Analysis, Forecasting | Warning Dissemination and Communication | Preparedness and Response Capabilities

2.4 Data and Technology Exchange

#15

Google AI

MULTI-COUNTRY

Open-source next generation flood forecasting

Artificial intelligence (AI) enabled a new approach for inundation modelling, called a morphological inundation model, which combines physics-based modelling with machine learning (ML) to create more accurate and scalable inundation models in real-world settings. Additionally, new alert-targeting model allows identifying areas at risk of flooding at unprecedented scale using end-to-end machine learning models and data that is publicly available globally.

Building on the work on flood forecasting in previous years, Google extended its AI-based next generation flood forecasting work in India and Bangladesh. Using Google AI technology to optimize the targeting of every alert the two governments send out, it is estimated that over 200 million people across an area spanning more than 250,000 square kilometres will have benefitted from the early warning system. The new forecasting model allows to double the lead time of many of the alerts in the past providing more notice to governments and giving tens of millions of people an extra day or so to prepare.[38] It also provides people with information about flood depth; when and how much flood waters are likely to rise. The information is provided through mobile phone in different formats, so that people can both read their alerts and see them presented visually and in their local languages (Figure 2-5).

This next generation of flood forecasting systems combine a novel family of hydrologic models, called Hydronets, that leverage river network structures. Specially built for hydrologic modelling across multiple basins, Hydronets are deep neural network models designed to exploit both basin specific rainfall-runoff signals, and upstream network dynamics, which can lead to improved predictions at longer horizons. Prior knowledge of the river structure reduces sample complexity and allows for scalable and more accurate hydrologic modelling even with only a few years of data.[39]

This is an important technological breakthrough to enhance predictive capacity and overall outreach of flood forecasting.

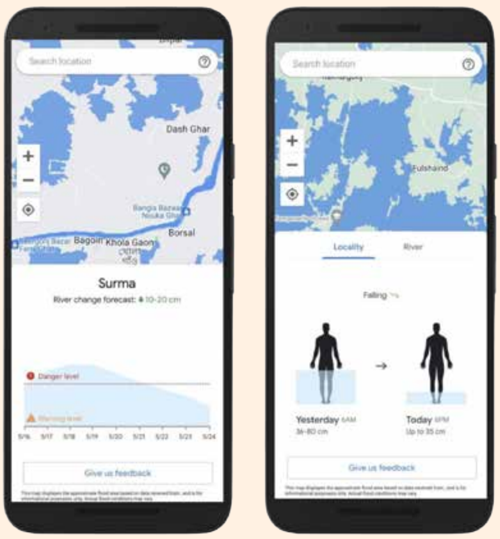


Figure 2-5: Improved flood alerts.

Source: Bharat Sharma, “Google’s AI-Based Flood Forecasting System is Saving Lives in India: Here’s How”, *India Times*, 11 November 2021. Available at https://www.indiatimes.com/technology/news/google-ai-based-flood-forecasting-india-553906.html

38. Sella Nevo, “The Technology Behind our Recent Improvements in Flood Forecasting”, Google Research, 3 September 2020. Available at https://ai.googleblog.com/2020/09/the-technology-behind-our-recent.html
39. Zach Moshe, and others, “Hydronets: Leveraging River Structure for Hydrologic Modelling”, 2020. Available at https://www.researchgate.net/publication/342622572_HydroNets_Leveraging_River_Structure_for_Hydrologic_Modeling

STAKEHOLDERS

Community | NGO/CSO | Academia/ Research | Private/ Business | National | International

EARLY WARNING COMPONENTS

Disaster Risk Knowledge | Observations, Monitoring, Analysis, Forecasting | Warning Dissemination and Communication | Preparedness and Response Capabilities

#16

2.5 Transboundary Advocacy and Action
Risk-informed Early Action Partnership

GLOBAL

Multi-stakeholder network to collectively advance action

In 2019, the Risk-informed Early Action Partnership (REAP) was established by 50 countries and organizations with the goal of making 1 billion more people safer from disasters, including by reaching 1 billion people with financing and delivery mechanisms connected to effective early action plans, ensuring they can act ahead of predictable disasters. Following the success of a wide-range of forecast-based financing pilots, spearheaded by Germany, the World Food Programme (WFP), the International Federation of Red Cross and Red Federation Societies (IFRC), United Nations Office for the Coordination of Humanitarian Affairs (OCHA) and the Food and Agricultural Organization of the United Nations (FAO) in 2014, REAP aims to create a space to continue to learn together to advance preparedness approaches.

Through REAP, partners and aligned organizations use their targets to drive a systemic shift towards acting earlier to reduce the impacts of disasters, mobilize commitments and inspire action. Based on advocacy mechanisms, REAP seeks to enable coherence, alignment, and complementarity of existing initiatives, while learning together what new initiatives are needed to make 1 billion people safer.

Open to all countries, organizations and initiatives, REAP members represent donor and climate-vulnerable countries, UN and other major international organizations, civil society, and the private sector. The partnership acknowledges that by working together across sectoral silos and involving those at risk, global ability to act ahead of climate extremes and disasters can be strengthened.

By joining REAP, partners gain access to a global network of expertise to support their work across the full value chain of Early Warning Early Action interventions. Partners benefit from a platform - the Marketplace - to showcase their achievements and profile their commitments. The Marketplace also facilitates the exchange of knowledge and solutions and fosters greater collaboration and new partnerships, by bringing together the capacities and unique capabilities of the climate, development, hydrometeorological and humanitarian communities.[40]

According to the REAP State of Play 2022,[41] the recommendations for advancing the work for partners are to:

1. Strengthen regional approaches for scaling up early action;
2. Operationalize, incentivize and institutionalize collaboration;
3. Deepen the understanding of and expand accessibility across the full value chain of early warning early action activities;
4. Diversify funding sources and mechanisms while ensuring they complement one another;
5. Ensure better connection along the entire EWEA value chain starting with effective two-way risk communication;
6. Strengthen the coherence of monitoring activities and improve information-sharing on evidence-based progress.

40. This Good Practice was adapted from the forthcoming publication *Words into Action: Multi-Hazard Early Warning Systems.*
41. Marie Wagner, "Early Action: The State of Play 2022", Risk-Informed Early Action Partnership (REAP), Geneva, 20 February 2023. Available at https://www.early-action-reap.org/sites/default/files/2023-02/20230214_REAP_StateofPlay_FINAL.pdf

STAKEHOLDERS

Community | NGO/CSO | Academia/Research | Private/Business | National | International

EARLY WARNING COMPONENTS

Disaster Risk Knowledge | Observations, Monitoring, Analysis, Forecasting | Warning Dissemination and Communication | Preparedness and Response Capabilities

#17

2.5 Transboundary Advocacy and Action
Asia-Pacific Disaster Resilience Network

TRANSBOUNDARY

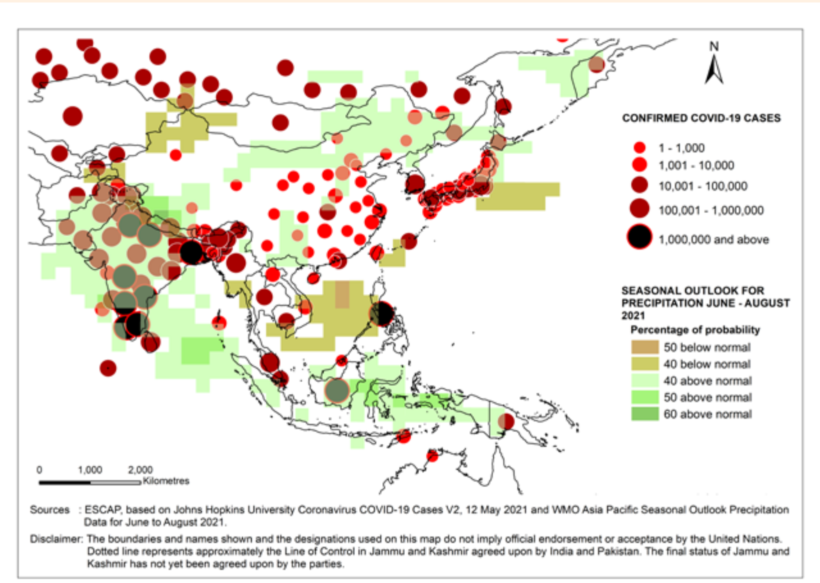
Fostering a culture of multi-sectoral seasonal preparedness

National climate outlook forums, or monsoon forums, are often held around the onset of the monsoon season, and have helped augment seasonal forecast information to understand potential impacts. These multi-stakeholder seasonal forums review the forecasts with National HydroMet Services to prepare for the incoming weather systems across the water management, energy, agriculture, disaster management and urban planning sectors. As a result, risks to end-users in the agriculture, water and energy sectors have been substantially reduced. With a reduction in risks, these end-users now also benefit from a reduction in direct and indirect disaster losses.

These sub-national, national and subregional level forums are reinforced through the ESCAP's Asia-Pacific Disaster Resilience Network (APDRN) that enables partners to work together on regional products and services that seamlessly combine risk information for different timescales. Forecasting of cascading risk scenarios at different time scales at the regional level each season, strengthens and validates the subregional and national climate outlook forums, also providing technical resources and capacity-building to national hydrometeorological services and forecast user sectors in low-capacity, high-risk countries.

To illustrate this multi-layered seasonal forecasting network, the APDRN was particularly active in managing the intersection of the COVID-19 pandemic with extreme climate events. Predictive analytics were presented, capturing the cascading risk scenarios at the regional level. Due to the intensification of extreme weather events expected with the incoming monsoon season, a subregional analysis zoomed in on South Asia to explore the expected intersection with COVID-19 (Figure 2-6). Above normal precipitation was anticipated for five countries and the potential convergence of water-related hazards with the pandemic were identified. This risk knowledge supported national services to better prepare for the impacts of the converging hazards.

Figure 2-6: Convergence of precipitation anomaly with COVID-19 in Asia for June-August 2021.



Source: ESCAP, based on WMO seasonal outlook for June, July and August 2021, issued in April 2021.

Climate-related disasters have different risk pathways than the COVID-19 pandemic but can intersect and converge with the pandemic in complex and destructive ways, just as extreme weather events can adversely affect irrigation systems, hydropower plants, or agriculture in complex ways. Many communities are exposed to risks from many angles, with extensive long-term consequences; in particular, damage to people's health and livelihoods and their prospects of escaping poverty.

A culture of risk-informed seasonal preparedness is a clear pathway to holistically tackle multi-hazards across all sectors.

STAKEHOLDERS

Community | NGO/CSO | Academia/ Research | Private/ Business | National | International

EARLY WARNING COMPONENTS

Disaster Risk Knowledge | Observations, Monitoring, Analysis, Forecasting | Warning Dissemination and Communication | Preparedness and Response Capabilities

#18

2.5 Transboundary Advocacy and Action
ESCAP/WMO Typhoon Committee

TRANSBOUNDARY

55 years of tripartite typhoon preparedness

Established in 1968, the ESCAP/WMO Typhoon Committee is an intergovernmental body that promotes and coordinates the planning and implementation of measures required to minimize the loss of life and material damage caused by typhoons emerging from the Western Pacific ocean. The Typhoon Committee is currently composed of 14 members: Cambodia; China; the Democratic People's Republic of Korea; Hong Kong, China; Japan; the Lao People's Democratic Republic; Macao, China; Malaysia; the Philippines; the Republic of Korea; Singapore; Thailand; Viet Nam and the United States of America.

Supported by the regional specialized meteorological centre in Tokyo, the Typhoon Committee aims to improve the quality of life of the populations of its member countries through integrated cooperation to mitigate the impacts and risks of typhoon-related disasters. This intergovernmental group is evidence of the mutual understanding that resilience to transboundary hazards should be a collective undertaking, where early warning solutions can be shared and strengthened between all at-risk countries.

Working through Annual Operating Plans, each working group under the leadership of specialized agencies of member countries deliver tripartite projects that work to advance the collective resilience against this shared and evolving hazard. Good Practices 23 in this Compendium is just one example of a longstanding tripartite project that has been through the Typhoon Committee Working Group on DRR.

Similar transboundary cooperation mechanisms exist for addressing tropical cyclones such as the ESCAP/WMO Panel on Tropical Cyclones (PTC) which covers the Bay of Bengal and the Arabian Sea and the Tropical Cyclone Committee for the South Pacific and South-East Indian Ocean.

Figure 2-7: 50th Session of the ESCAP/WMO Typhoon Committee, 2018.

Source: ESCAP/WMO Typhoon Committee, "50th TC Session and TECO". Available at https://www.typhooncommittee.org/tc-50-years/

STAKEHOLDERS

Community | NGO/CSO | Academia/Research | Private/Business | National | International

EARLY WARNING COMPONENTS

Disaster Risk Knowledge | Observations, Monitoring, Analysis, Forecasting | Warning Dissemination and Communication | Preparedness and Response Capabilities

#19 2.5 Transboundary Advocacy and Action
Mekong River Commission

TRANSBOUNDARY

Intergovernmental mandate for transboundary hazard monitoring

Around 40 per cent of the world's poor live on or close to the major river basins in South Asia.[42] Successful resilience-building efforts in these transboundary and multi-hazard hotspots requires cooperation.

The Mekong River Commission (MRC) is an intergovernmental organization for regional dialogue and cooperation in the Lower Mekong River Basin. It was established in 1995 based on the Mekong Agreement between Cambodia, the Lao People's Democratic Republic, Thailand and Viet Nam. This active regional platform for water diplomacy and a knowledge hub of water resources management, strengthens regional cooperation and advances the basin-wide monitoring, forecasting and communication capacity of the member countries.[43] Under these overarching objectives, the MRC hosts a number of transboundary early warning initiatives to protect the sustainable development of the region.

Droughts have been increasingly affecting South-East Asia, particularly the Lower Mekong countries, resulting in severe dry conditions and food insecurity. Over the past 30 years, droughts have affected over 66 million people in South-East Asia, with agriculture bearing the brunt of the impact. With rising temperatures and declining rainfall trends, drought stress is a major concern that could lead to wildfires, smoke exposure, and water crises.

In response, the MRC commissioned the Mekong Drought and Crop Watch (MDCW) supported by Asian Disaster Preparedness Center (ADPC) to address the Lower Mekong countries' needs in appropriately monitoring and forecasting drought. This user-friendly interactive web-based interface supports member countries with effective decision-making in the context of climate variability and its impact on agriculture and food security.[44] MDCW provides near-real-time drought information for the entire Lower Mekong region by using multiple satellite data through its RHEAS model and deriving drought information both at nowcast and forecast (See Figure 2-8). The system can also inform assessments of the economic, social, and environmental impacts of drought on vulnerable people and water-related resource systems, and thus inform targeted decisions in the context of drought warnings, crop subsidies, and insurance programmes.

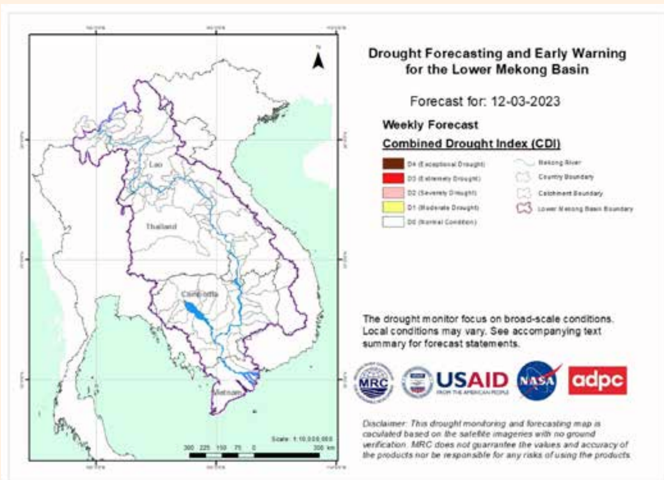


Figure 2-8: Lower Mekong Drought Forecast for September 2022.

Source: Mekong River Commission, "Drought Forecasting and Early Warning for the Lower Mekong Basin", 2019. Available at http://droughtforecast.mrcmekong.org/maps

42. United Nations Economic and Social Commission for Asia and the Pacific, "Asia-Pacific Disaster Report 2019: The Disaster Riskscape across South and South-West Asia: Key Takeaways for Stakeholders", 2020, ST/ESCAP/2879.
43. The Mekong River Commission, "Vision and Mission", 2023. Available at https://www.mrcmekong.org/about/mrc/vision-and-mission/
44. Rishiraj Dutta, "Mekong Drought and Crop Watch in the Context of Changing Climate", Asian Disaster Preparedness Center, Tech Monitor July – September 2021. Available at https://apctt.org/sites/default/files/attachment/2021-12/21Jul-Sep_sf3.pdf.

STAKEHOLDERS

Community | NGO/CSO | Academia/Research | Private/Business | National | International

EARLY WARNING COMPONENTS

Disaster Risk Knowledge | Observations, Monitoring, Analysis, Forecasting | Warning Dissemination and Communication | Preparedness and Response Capabilities

#20

2.5 Transboundary Advocacy and Action
Hindu Kush Himalayan Region MHEWS

TRANSBOUNDARY

Integrated EWS enabling transboundary preparedness

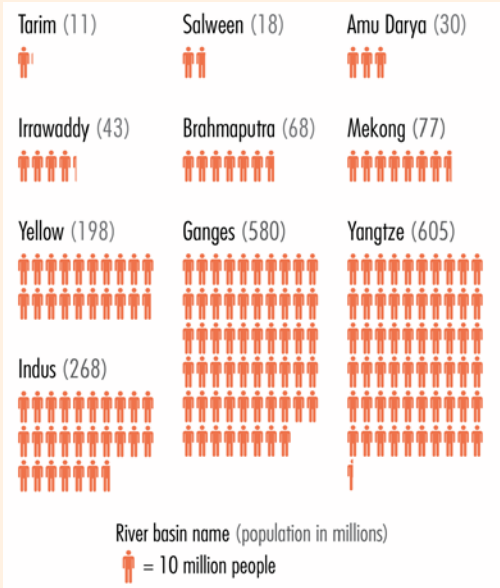
The Hindu Kush Himalayan (HKH) region is home to 1.9 billion people, with approximately 240 million people living in the mountains and hills, making them vulnerable to erosion, earthquakes, landslides, and other natural hazards. More than 1 billion people are at risk of exposure to increasing frequency and intensity of natural hazards caused by climate change and environmental degradation. Natural hazard preparedness in this subregion necessitates transboundary and/or regional coordination, because natural hazards cause fatalities, displacement, and other detrimental effects in areas that are not contained in conventional, geopolitical boundaries. Countries in the HKH region also share certain distinct geographical and topographical features that create shared risks and vulnerabilities for unevenly distributed clusters of residents.

The International Centre for Integrated Mountain Development (ICIMOD) developed a community-based flood early warning system (CBFEWS) in 2010 to address flash floods. CBFEWS is an integrated EWS that leverages a “system of tools and plans managed by and for communities to provide virtually real-time early warnings on floods to reduce risks”. It combines low-cost water level monitoring instruments with a “caretaker” assigned to validate risk levels and transmit early warnings to upstream and downstream communities through locally tailored communication focal points.

CBFEWS has been deployed in four of the eight member countries, including Afghanistan, India, Nepal, and Pakistan, replacing labour-intensive and dangerous watch-and-warn systems with a formalized, end-to-end system.[45]

Improving domestic and regional information-sharing and coordination within the HKH region is identified as a key barrier to effective coordination on EWS. Differences in capacity between national governments and sub-national agencies, as well as standard processes for sharing raw data, especially regarding water availability, hinder information-sharing for all four system elements between relevant actors and stakeholders. ICIMOD has made progress in improving information-sharing and coordination through its work with the Hindu Kush Himalayan region and Hydrological Cycle Observation System (HKH-HYCOS), and the Regional Flood Information System. Based on the foundation of success, this approach is being further expanded to implement MHEWS holistically across HKH, advance data-sharing agreements, and engage with private sector companies.

Figure 2-9: Rivers from the Hindu Kush Himalaya provide water for nearly 2 billion people across Asia.



Source: International Centre for Integrated Mountain Development (ICIMOD), “Summary of the Hindu Kush Himalaya Assessment Report”, Kathmandu, Nepal, 2019. Available at https://lib.icimod.org/record/34450

45. D. Bicknell, C. Narlock, and R. Rambert, “Increasing Access to Multi-Hazard Early Warning Systems: Promoting Climate Change Adaptation in the Hindu Kush Himalayan Region”, Cambridge, Belfer Center for Science and International Affairs, Harvard Kennedy School, August 2020. Available at https://www.belfercenter.org/sites/default/files/files/publication/Increasing%20Access%20to%20Multi-Hazard%20Early%20Warning%20Systems%20-%20Bicknell%2C%20Narlock%2C%20Rambert.pdf

STAKEHOLDERS

Community | NGO/CSO | Academia/Research | Private/Business | National | International

EARLY WARNING COMPONENTS

Disaster Risk Knowledge | Observations, Monitoring, Analysis, Forecasting | Warning Dissemination and Communication | Preparedness and Response Capabilities

#21

2.5 Transboundary Advocacy and Action
International Platform on Earthquake Early Warning Systems

GLOBAL

Global EEWS platform based on multi-industry-and-level collaboration

Earthquake early warning not only represents the forefront of scientific research in geohazards and disaster risk reduction, but also plays a key part in reducing casualties and economic losses, objectives that are closely in line with the Sendai Framework on DRR. Making ‘actionable’ earthquake predictions, beyond 5-10 second alerts following an event, that specify a time, a place and a magnitude are yet to emerge operationally. Thus, any work to advance the scientific understanding of seismic risks, enhance the accuracy of warnings and ensure their effective dissemination will dramatically reduce impacts felt by seismic events.

In December 2015, UNESCO launched the International Platform on Earthquake Early Warning Systems (IP-EEWS), currently represented by leading scientific experts from top institutions in 10 countries, namely China, Germany, Italy, Japan, Mexico, Romania, Spain, Switzerland, Turkey, and the United States of America.[46] The objectives of IP-EEWS include providing an international platform for knowledge-sharing, strengthening cooperation between active groups, assessing current capacities and gaps, building scientific and technical capacities, assisting in developing new EEWS, promoting public awareness activities, and coordinating observation systems and sharing seismic data among neighbouring countries in earthquake-prone areas.

Fully operational EEWS are being implemented in Japan, Mexico, Romania, and Turkey and are able to provide alerts in real time though only few provide alerts to the public and private-end users.

For instance, during the 2011 Tohoku earthquake, Japan’s EEWS was able to provide an effective warning throughout the many telecommunication services; distinctive alerts and instructions were transmitted through phones and TV, high-speed trains engaged in automatic shut downs, and manufacturing industries received an alert to stop hazardous operations.

China, as one of the most earthquake-prone regions in the world, has been working to densify its seismic observation network to strengthen the existing national EEWS. Nationally, more than 50 per cent of the cities and 70 per cent of the large and medium-sized cities with a population of more than 1,000,000 are located in areas with high earthquake magnitude of 7 or above on the Richter scale. Performance improvements consist of optimizing and upgrading the software system embedded in each sensor; improving the real-time data transfer process from datum and basic stations through fibre lines to provincial data processing centres; and developing new criteria for generating early-warning information that focus on seismic network composition.

To further promote the development and implementation of Earthquake Early Warning Systems (EEWS) worldwide, it is crucial to enhance international collaboration, advance earthquake science and technology, promote education and awareness on seismic risk, endorse risk-informed policy and regulation, and expand stakeholder involvement.[47]

46. United Nations Educational, Scientific and Cultural Organization (UNESCO), “International Platform on Earthquake Early Warning Systems (IP_EEWS)”, 2021. Available at https://en.unesco.org/disaster-risk-reduction/early-warning-systems/IP-EEWS
47. This Good Practice was adapted from the forthcoming publication *Words into Action: Multi-Hazard Early Warning Systems.*

STAKEHOLDERS

Community · NGO/CSO · Academia/ Research · Private/ Business · National · International

EARLY WARNING COMPONENTS

Disaster Risk Knowledge · Observations, Monitoring, Analysis, Forecasting · Warning Dissemination and Communication · Preparedness and Response Capabilities

#22

2.6 Tripartite Arrangements
Heat Action Planning

MULTI-COUNTRY

Subregional forecasting to reinforce national planning

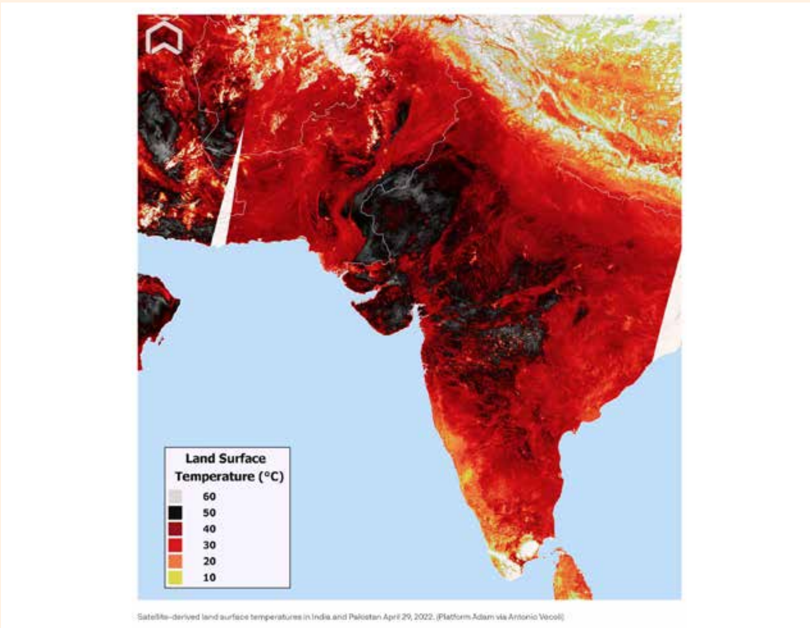
To minimize the impact of heatwaves, countries in Asia and the Pacific have put in place heat action plans to better understand and more effectively predict, prepare, and respond to extreme heat risks.

Following in the successes of cities like Paris, Toronto, Madrid, and New York to name a few, the city of Ahmedabad in India was the first South Asian city to develop and implement a city-wide heat health adaptation in 2013 after experiencing a devastating heatwave in 2010.[48] Since then, this successful approach has been implemented in 23 heatwave-prone states in India, protecting more than 130 cities and districts. Heat Action Plans in India have resulted in reducing heatwave-related fatalities from 24,223, between 1992-2015, to 4 in 2020, and 25 in 2022.

Similarly, in the summer of 2015, a heatwave engulfed much of central and north-west India and eastern Pakistan resulting in thousands of fatalities. This led to the development of Pakistan's Heat Action Plan with a focus on the city of Karachi. China, Sri Lanka, Nepal, and Singapore are other Asian countries that have recently embarked on the journey to becoming heatwave-ready cities.[49]

The successes of a national or city-wide Heat Action Plan relies on precise warnings. Considering the transboundary nature of heatwaves, subregional seasonal forecasting has proved to be an effective tool. In this context, the Global Heat Health Information Network (GHHIN), a joint venture of the WHO and WMO, is an important initiative. The South Asia Heat Health Information Network (SAHHIN) works to share lessons and raise capacity across South Asia. The South Asia Climate Outlook Forum (SASCOF) helps to prepare consensus-based seasonal climate information on regional scale that provides a consistent basis for preparing national level outlooks. Monsoonal forecasts coupled with socioeconomic data, can provide countries with valued information about the population hotspots expected to be vulnerable to upcoming seasonal heatwave risks, in the form of low precipitation and high temperatures. This is an important contribution to initiate anticipatory action for managing heatwaves.

Figure 2-10: Satellite-derived land surface temperatures in India and Pakistan 29 April 2022.



Source: Andrew Freedman, "India heat wave: Climate change-fueled even topples monthly recovers", Axios, 2 May 2022. Available at: https://www.axios.com/2022/05/02/india-pakistan-heat-wave-climate-change-records

48. Rohit Magotra, and others, "Review of Heat Action Plans", Integrated Research and Action for Development (IRADe), 12 January 2021. Available at https://climateandcities.org/wp-content/uploads/2022/01/Review-of-Heat-Action-Plans.pdf
49. Global Heat Health Information Network, "Case Studies, Action Plans and Projects", 2023. Available at https://ghhin.org.

STAKEHOLDERS

Community | NGO/CSO | Academia/Research | Private/Business | National | International

EARLY WARNING COMPONENTS

Disaster Risk Knowledge | Observations, Monitoring, Analysis, Forecasting | Warning Dissemination and Communication | Preparedness and Response Capabilities

#23

2.6 Tripartite Arrangements
Flood Forecasting and Warning System reduces disaster risks

MULTI-COUNTRY

Effective replication of EWS based on regional collaboration

Flash floods caused by heavy rains and downpours are a common occurrence around the world, resulting in substantial damage to infrastructure and loss of life. In 2011, Seoul experienced severe floods and landslides, resulting in the death of over 70 people. Following this event, the Republic of Korea developed its Flood Forecasting and Warning System, which analyses real-time data observations of vulnerable areas to predict potential flooding.[50]

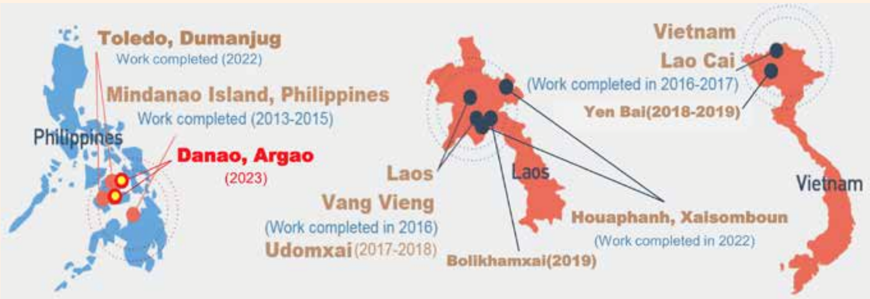
Using a radar system, the Flood Forecasting and Warning System informs the public about areas threatened by a high risk of flooding based on precipitation forecast data. The facility acts as a warning system that observes, analyses precipitation data, and disseminates real-time warning comprising precipitation observatories and warning stations. The system functions by establishing automatic rainfall observation stations (water levelling) at the upper and middle areas of the mountain valley, as well as an automatic warning system at the lower area. The automatic remote observation station at the local Disaster Prevention and Countermeasures Headquarters then receives real-time data and sends out alerts to local administrative offices and the general public.

Between 1996 and 2005, 148 sites had been established and operated in valleys, downstream of rivers, and national parks in the Republic of Korea. In addition, between 2005 and 2009, 113 more sites had been added to the monitoring and warning system. The nation currently has a comprehensive system and covers most of its regions.

Since 2013, the National Disaster Management Research Institute of Republic of Korea (NDMI) has been supporting the Philippines, the Lao People's Democratic Republic, and Viet Nam to reduce the risk using this same flood forecasting technology (Figure 2-11). As a result of these efforts, the three neighbouring countries have established comprehensive flood monitoring and warning systems. NDMI continues to provide support to expand each of these national flood warning systems which will continue to minimize the number of fatalities and economic losses across the region.

Regional collaboration helped share technologies and experiences with neighbouring countries, supporting them with disaster risk management activities. Such cooperation is essential in the replication and scaling up of good national practices to facilitate low-capacity countries to acquire similar technologies and systems.

Figure 2-11: Countries using the Republic of Korea's Flood Forecasting and Warning System.



Source: ESCAP/WMO Typhoon Committee, Working Group on Disaster Risk Reduction (WGDRR), "WGDRR Report: Recommendations", 55th session of the Typhoon Committee, presentation via video conference, Macau, China, 7-9 March 2023.

50. Trilateral Cooperation Secretariat (TCS) and United Nations Office for Disaster Risk Reduction (UNDRR), "Trilateral Best Practices: Application of Technology for Reducing Disaster Risks in China, Japan and Korea", 2021. Available at https://www.undrr.org/publication/trilateral-best-practices-application-technology-reducing-disaster-risks-china-japan

STAKEHOLDERS

Community | NGO/CSO | Academia/ Research | Private/ Business | **National** | International

EARLY WARNING COMPONENTS

Disaster Risk Knowledge | **Observations, Monitoring, Analysis, Forecasting** | **Warning Dissemination and Communication** | Preparedness and Response Capabilities

2.6 Tripartite Arrangements
The resident-engaged community disaster risk assessment and mapping

MULTI-COUNTRY

Household level multi-hazard assessments

Assessing and mapping community disaster risks have become critical for disaster prevention and mitigation globally. However, many countries rely on professional mapping institutions for community disaster risk mapping, which is often costly, complex, and challenging for residents to undertake. To address this challenge, a new method was established in China to introduce single-disaster and multi-hazard risk identification, as well as assessment technology, and increase the risk assessment of community-by-house to improve the accuracy of community disaster risk assessment.[51]

In 2017, seven communities in Nepal, Bangladesh, and China were selected to conduct pilot community disaster risk mapping projects using the resident-engaged community disaster risk assessment and mapping methodology. The base map was created using high-resolution remote sensing imagery, and community administrators and residents were trained to make a set of risk maps through six steps. These steps included the division of community assessment units, community cartographer organization and arrangement, collecting and plotting community disaster risk information, building and plotting disaster risk assessments, and producing community disaster risk maps.

Later, community disaster risk maps for three communities in China, two communities in Nepal, and two communities in Bangladesh were produced using the new method, including single-hazard risk maps for earthquakes, floods, typhoons, fires, etc., and comprehensive risk maps for multiple disasters. These risk maps have been provided to community managers to support their disaster prevention and mitigation efforts, which showed great results as compared to original methods.

The resident-engaged community disaster risk assessment and mapping methodology offers a promising approach to involve residents in mapping their community's disaster risks. By training residents to master related mapping methods, risk maps, based on rich local knowledge and understanding of the situation in the community, can be accurately drawn. This approach increases community engagement and ownership of disaster risk reduction efforts, resulting in more effective and sustainable disaster prevention and mitigation strategies.

Figure 2-12: Integrated disaster risk map of Qiaonan Community, Yinhai District, Beihai, China.

Source: Trilateral Cooperation Secretariat (TCS) and United Nations Office for Disaster Risk Reduction (UNDRR), "Trilateral Best Practices: Application of Technology for Reducing Disaster Risks in China, Japan and Korea", 2021. Available at https://www.undrr.org/publication/trilateral-best-practices-application-technology-reducing-disaster-risks-china-japan

51. Trilateral Cooperation Secretariat (TCS) and United Nations Office for Disaster Risk Reduction (UNDRR), "Trilateral Best Practices: Application of Technology for Reducing Disaster Risks in China, Japan and Korea", 2021. Available at https://www.undrr.org/publication/trilateral-best-practices-application-technology-reducing-disaster-risks-china-japan

STAKEHOLDERS

Community | NGO/CSO | Academia/Research | Private/Business | National | International

EARLY WARNING COMPONENTS

Disaster Risk Knowledge | Observations, Monitoring, Analysis, Forecasting | Warning Dissemination and Communication | Preparedness and Response Capabilities

3.0 A Cooperation Framework to Ensure MHEWS for All

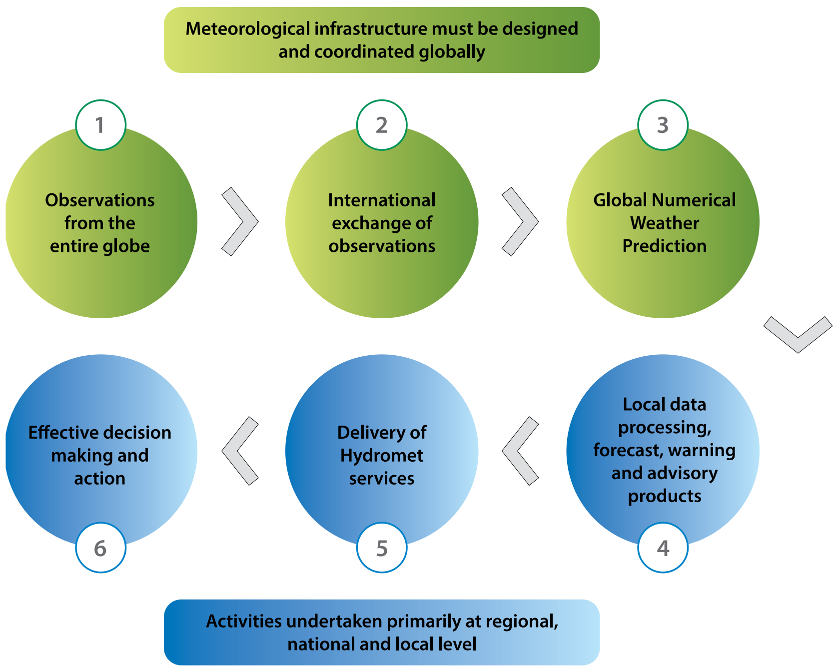
3.1 Opportunities for Realizing Early Warnings for All

Each of the Good Practices presented in Section 2.0 represent cooperation arrangements that should be further adopted and scaled in order to achieve early warnings for all, now and for future generations. These illustrations also highlight several multiplying factors that should be further adopted, as outlined below.

Seamless meteorological value chain linking the global to the local

Weather and climate services are generated by the meteorological value chain and effectiveness of early warning systems depends on when all links work seamlessly.[52] The upper three links in the value chain (shown in Figure 3-1 in green) constitute the global meteorological infrastructure and rely on a global collaboration approach. In contrast, the lower three links (shown in Figure 3-1 in blue) are typically implemented nationally. The importance of the implications relating to the first three links being global in nature cannot be overstated. Beyond a prediction horizon of 24 to 36 hours, global observational data and global models are needed to underpin predictions in any location. Conversely, without local efforts everywhere to make and exchange observations, global models cannot effectively generate the data needed for forecasting at the national and local levels. All countries, therefore, share an interest in the first three links in the chain, while they handle the last three mostly individually. For this reason, support to developing the forecasting maturity of all high risk, low-capacity countries, LLDCs, LDCs and SIDS should be prioritized.

Figure 3-1: The meteorological value chain. All links in the chain must operate effectively to yield success.



Source: Alliance for Hydromet Development, "Hydromet Gap Report 2021", 2021. Available at https://alliancehydromet.org/gap-report/

52. Alliance for Hydromet Development, "Hydromet Gap Report 2021", 2021. Available at https://alliancehydromet.org/gap-report/

Early warning advancements should capitalize on innovative and appropriate technology solutions

Innovative technology solutions offer transformative potential for the success of early warning for all. Big data innovations, using the large data sets from mobile phone tracking to satellite platforms, reveal patterns, trends, and associations of the complex disaster risks. The use of risk analytics: descriptive, predictive, prescriptive and discursive, helps to understand, monitor and predict the risk of both extreme as well as slow onset events. The substantial reductions in mortalities and economic losses due to typhoons in North and East Asia can be attributed to dual engines of advanced nemerical weather prediction and big data applications that enabled impact-based forecasting and risk-informed early warning products. Remote sensing (e.g. from satellites, drones), instrumental networks (e.g. from meteorological, hydrometeorological, and seismic stations) and crowdsourcing, and Earth observational data has grown immensely. As a result, there are increasing applications of AI and ML to improve early warning and alert systems and to help generate hazard and susceptibility maps through ML-driven detection and forecasting of various natural hazards.[53]

Investments in early warning systems should be people-centred and risk-informed

The design and measures of early warning systems need to reflect the current, intensifying and emerging riskscape of each country, and thus meet the needs of exposed populations and sectors. Investments in early warning systems should meet the needs of our societies today, and meet the needs as can be predetermined based on our present understanding of climate projections and population growth.

Disaster risk knowledge should explore existing and evolving transboundary hazards under long-term climate scenarios, as well as with an understanding of populations and climate-sensitive sectors exposed to those hazards. This deepened risk knowledge will then highlight the observation, monitoring and forecasting capacity gaps to be addressed.

Trust should be built with those populations and sectors that are exposed and are receiving warnings, and investments must be made to ensure those warnings will lead to early actions. Investments should also be made to ensure all stakeholders involved in early warnings and early actions are provided appropriate two-way communication channels to further inform the early warning cycle at each stage and level.[54]

Incentivizing collaboration would strengthen early warning systems at every level

To overcome the silos in financing, collaboration should be incentivized. Rather than sector-specific methods, 'whole of society' and 'whole of value chain' approaches mitigate the risk of failure in one component leading to the collapse of the entire system.[55] Likewise, it is necessary to move away from traditional incentive structures that favour traditional reactive responses with regards to disaster management financing. Furthermore, major advancements in early warning systems can come from the untapped potential and empowerment of private sector and civil society. Recognizant of the economies of scale with regards to global and regional early warning systems, proactive and diversified vertical and horizontal collaboration at all levels, all stages and across all four early warning components should be incentivized.

53. Monique Kuglitsch and others, "Artificial Intelligence for disaster risk reduction: Opportunities, challenges, and prospects", World Meteorological Organization, Bulletin No. 71, 2022. Available at https://public.wmo.int/en/resources/bulletin/artificial-intelligence-disaster-risk-reduction-opportunities-challenges-and
54. Marie Wagner, "Early Action: The State of Play 2022", Risk-Informed Early Action Partnership (REAP), Geneva, 20 February 2023. Available at https://www.early-action-reap.org/early-action-state-play-2022
55. Ibid.

A coordinated cooperation framework for deeper engagements among the G20 countries is needed to advance early warning systems across all four components. At the global, regional and transboundary, national and neighbouring levels, cooperation mechanisms succeed in expanding early action financing, early warning-related technology, transboundary advocacy for resilience-building and essential early warning system service provision. These cooperation mechanisms are critical especially for high risk, low capacity developing countries, LDCs and SIDS of Asia and the Pacific.

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Annex: Early Warning Cooperation Mechanisms

Scope	Financing, Service Provision and Data Exchange Cooperation Mechanisms (non-exhaustive)[56]
Global	Adaptation Fund - https://www.adaptation-fund.org/ - UNFCCC financing instrument for adaptation, offers three financing windows and an innovation facility.
Global	Anticipation Hub - https://www.anticipation-hub.org - platform to facilitate knowledge exchange, learning, guidance, and advocacy around anticipatory action.
Global	Central Pacific Hurricane Center https://www.nhc.noaa.gov/?cpac - provides forecasts, warnings, and advisories for tropical cyclones, hurricanes, and typhoons that impact the central Pacific region.
Global	Climate Investment Funds - https:// www.climateinvestmentfunds.org/ - accelerates climate action by empowering transformations in clean technology, energy access, climate resilience, and sustainable forests in developing and middle-income countries.
Global	Climate Risk and Early Warning Systems (CREWS) - https://www.crews-initiative.org/ - funds risk-informed early warning services in LDCs and SIDS implemented by World Bank/GFDRR, WMO, and UNDRR.
Global	Copernicus Emergency Management Service / Joint Research Center / GEO / NASA Global Wildfire Information System https://gwis.jrc.ec.europa.eu/ - provides a comprehensive view and evaluation of fire regimes and fire effects at the global level and provides tools to support operational wildfire management from national to global scales.
Global	Copernicus Emergency Management Service for floods: European https://www.efas.eu/en and Global https://www.globalfloods.eu/ - a service that provides timely and accurate information on flood events and their impacts across Europe and the world.
Global	Copernicus Emergency Management Service, the European Forest Fire Information System - https://www.efas.eu/en - consists of a modular web geographic information system that provides near real-time and historical information on forest fires and forest fires regimes in the European, Middle Eastern and North African regions.
Global	Famine Early Warning System www.fews.net/ - a leading provider of early warning and analysis on acute food insecurity around the world.
Global	Flood and Drought Monitors - UNESCO Intergovernmental Hydrological Programme (IHP) and Princeton Climate Institute (PCI) http://hydrology.soton.ac.uk/apps/ - provides operational near real-time monitoring and forecasting of flood and drought conditions in support of hazard early warning.
Global	Geofon - German Research Center for Geosciences https://geofon.gfz-potsdam.de - A seismological service that provides earthquake information and data from a global network of seismic stations.
Global	Global Data-Processing and Forecasting System https://wmo.maps.arcgis.com/apps/dashboards/7c3d45e5003a417988bad63e91ad8748 - Web portal for the Global Data-processing and Forecasting System.
Global	Global Disaster Alert and Coordination System (GDACS) - https://www.gdacs.org/ - cooperation framework between UN, European Commission, and disaster managers to improve alerts, information exchange and coordination following sudden-onset disasters.
Global	Global Drought Observatory - https://edo.jrc.ec.europa.eu/ - provides information on drought status worldwide.

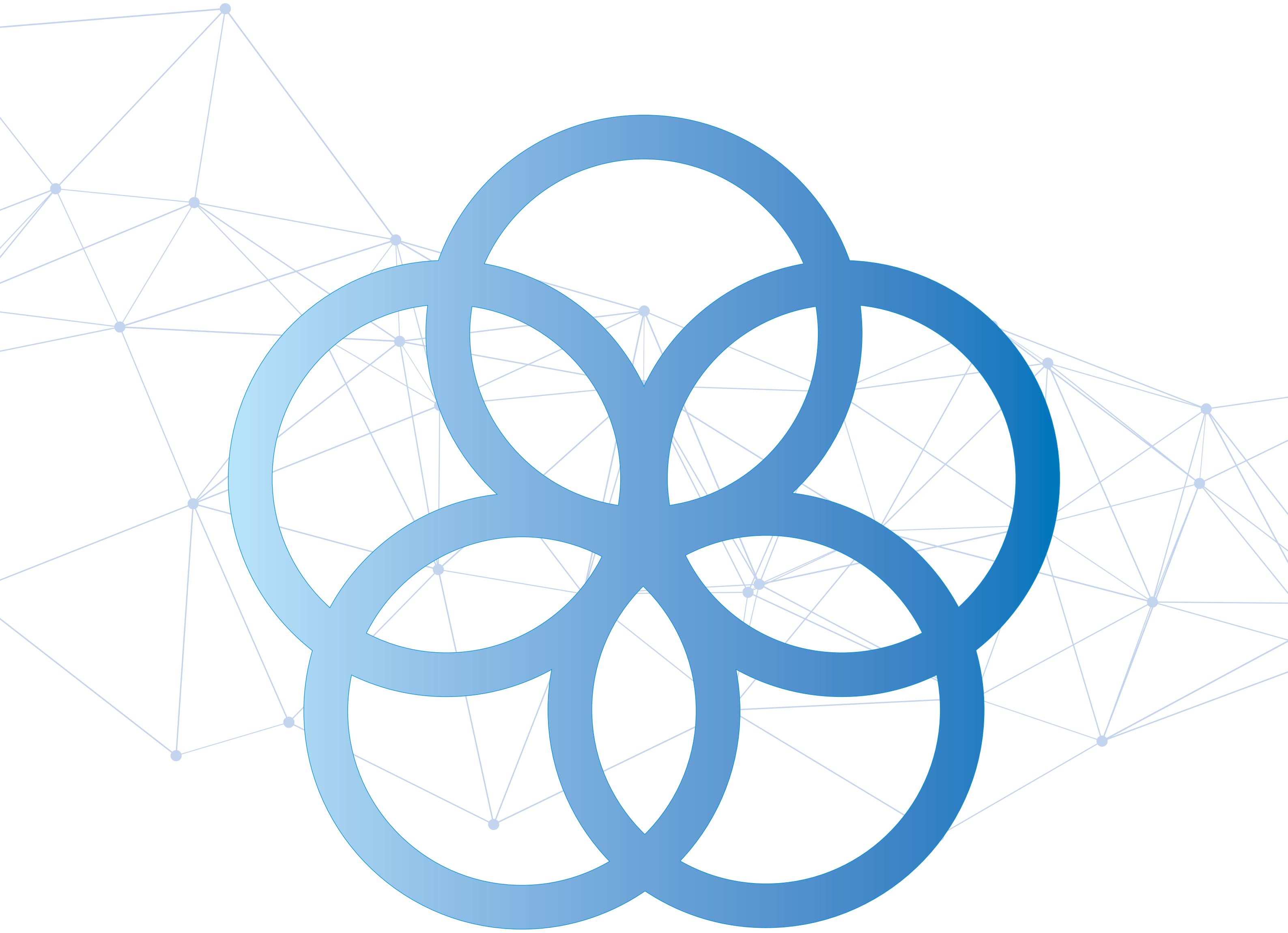
56. Table adapted from the forthcoming publication *Words into Action: Multi-Hazard Early Warning Systems.*

Scope	Financing, Service Provision and Data Exchange Cooperation Mechanisms (non-exhaustive)[56]
Global	Global Earth Observation System of Systems (GEOSS) - https://www.geoportal.org/ - online map-based user interface to discover and access Earth observation data and resources from different providers.
Global	Global Environment Facility - https://www.thegef.org/ - a financial mechanism that helps developing countries to address global environmental challenges, such as climate change, biodiversity loss, land degradation and chemical pollution.
Global	Global Fire Monitoring Center www.fire.uni-freiburg.de - provides a global portal for wildland fire documentation, information and monitoring.
Global	Global Flood Awareness System (GLOFAS) - https://www.globalfloods.eu/ - early warning service provided by the Copernicus programme of the EU to provide forecasts of flood levels in various segments of rivers.
Global	Global Information and Early Warning System www.fao.org/giews/english/index.htm - monitors the food security situation in every country of the world and alerts the world to emerging food shortages.
Global	Global Tsunami Early Warning and Mitigation Programme https://ioc.unesco.org/our-work/global-tsunami-early-warning-and-mitigation-programme - supports Member States in assessing tsunami risk, implementing Tsunami Early Warning Systems (EWS) and in educating communities at risk about preparedness measures.
Global	Global Wildfire Information System (GWIS) - https://gwis.jrc.ec.europa.eu/ - provides information on the status of wildfires worldwide.
Global	Green Climate Fund (GCF) - https://www.greenclimate.fund/ - A demand-led fund that finances investment activities for the generation and use of climate information in Africa.
Global	Humanitarian Early Warning Service www.hewsweb.org/drought/ - A global multi-hazard watch service to support Humanitarian Preparedness developed and maintained by the World Food Programme.
Global	International Consortium of Landslides https://icl.iplhq.org - an international non-governmental and non-profit scientific organization for global promotion of understanding and reducing landslide disaster risk.
Global	International Flood Network http://www.internationalfloodnetwork.org - an international network to promote activities for flood damage mitigation.
Global	International Network for Multi-Hazard Early Warning Systems (IN-MHEWS) - https://riskfinder.climatecentral.org/caribbean - facilitates sharing of expertise and good practices for MHEWS as national strategy for DRR, climate change adaptation and building resilience.
Global	International Platform on Earthquake Early Warning Systems (IP-EEWS) - https://edo.jrc.ec.europa.eu/gdo/php/index.php?id=2001 - promotes collaboration and knowledge sharing within the scientific community and among decision-makers to develop EWS for earthquake-prone regions and countries.
Global	International Tsunami Information Center - ITIC http://itic.ioc-unesco.org/index.php - To mitigate the hazards associated with tsunamis by improving tsunami preparedness for all Pacific Ocean nations.
Global	Rainfall Forecast in Context - IFRC / International Research Institute for Climate and Society http://iridl.ldeo.columbia.edu/maproom/IFRC/index.html - provides information that can be used for humanitarian decision-making around the world, developed by the IRI and the IFRC.

Scope	Financing, Service Provision and Data Exchange Cooperation Mechanisms (non-exhaustive)[56]
Global	Ready2Respond - https://ready2respond.org - Global collaboration of partners from the public, private and non-profit sectors committed to augmenting low- and middle-income countries' readiness to respond against influenza and emerging respiratory viral pandemics.
Global	Risk Informed Early Action Partnership (REAP) - https://www.early-action-reap.org - creates a space for partners to drive a systemic shift towards acting earlier to reduce the impacts of disasters.
Global	Seasonal Climate Forecast https://iri.columbia.edu/our-expertise/climate/forecasts/seasonal-climate-forecasts/ - a platform based on a re-calibration of model output from the U.S. National Oceanographic and Atmospheric Administration (NOAA)'s North American Multi-Model Ensemble Project (NMME) to form reliable probability forecasts.
Global	Severe Weather – WMO https://severeweather.wmo.int/v2/ - provides a single and centralized source for the media and the general public to access official warning and information efficiently and effectively.
Global	Systematic Observations Financing Facility (SOFF) - https://alliancehydromet.org/soff/ - supports SIDS and LDCs in generating and exchanging surface-based observational data critical for improved weather forecasts and climate services.
Global	The Fall Army Worm Monitoring and Early Warning System (FAMEWS) https://play.google.com/store/apps/details?id=org.fao.famews&hl=en_US - a free mobile application for the real-time global monitoring of the Fall Armyworm (FAW).
Global	The FAO Desert Locust Information Service (FAO DLIS) https://www.fao.org/ag/locusts/en/info/info/index.html - monitors the world-wide locust situation and keeps affected countries and donors informed of expected developments.
Global	The FAO Emergency Prevention System for Trans-boundary Animal and Plant Pests and Diseases (EMPRES) https://empres-i.apps.fao.org/ - a web-based application that has been designed to support veterinary services by facilitating the organization and access to regional and global disease information.
Global	The Global Sea Level Observing System (GLOSS) - https://gloss-sealevel.org - a global endeavour requiring coordinated participation of an international group of agencies.
Global	UNESCO/IOC Sea Level Station Monitoring Facility http://www.ioc-sealevelmonitoring.org/map.php - a global station monitoring service for real-time sea-level measuring stations that are part of IOC programmes.
Global	US Geological Survey and Global Volcanism Program https://volcano.si.edu/reports_weekly.cfm - prepares weekly report on volcanic activity around the world based on observations from ground, air, and space sources.
Global	US Tsunami Warning Center – Pacific Tsunami Warning Center (PTWC) http://www.tsunami.gov - serves as the operational centre for TWS of the Pacific issuing bulletins and warnings to participating members and other nations in the Pacific Ocean area of responsibility.

Scope	Financing, Service Provision and Data Exchange Cooperation Mechanisms (non-exhaustive)[56]
Africa	African Center of Meteorological applications for Development (ACMAD) - https://www.acmad.net/ - a continental weather and climate center that improves understanding and applications of meteorology for development in Africa.
	African Risk Capacity (ARC) Group - https://www.africanriskcapacity.org/ - a specialized agency of the African Union that helps African Governments plan, prepare and respond to extreme weather events and natural disasters through innovative financing and collaboration.
	Climate Prediction and Applications Centre (ICPAC) - https://www.icpac.net/ - a regional centre that provides climate services to 11 East African Countries, creating resilience in a region deeply affected by climate change and extreme weather.
	ClimDev-Africa - https://www.climdev-africa.org/ - a joint initiative of the AUC, ECA and AfDB that aims to close climate information gaps and support climate-resilient development in Africa.
Asia and the Pacific	ASEAN Disaster Monitoring and Response System (DMRS) - https://aseandrr.org/ - Integrates data and information from numerous sources into a single platform for issuing alerts and updates on disaster parameters.
	DisasterAWARE - https://www.pdc.org/disasteraware/ - Provides multi-hazard monitoring, warning, decision support, and risk intelligence tools for disaster management agencies and I/NGOs around the globe.
	Regional Integrated Multi-Hazard Early Warning System (RIMES) - https://www.rimes.int/ - Provides regional early warning services and builds capacity in end-to-end early warning of tsunami and hydro-meteorological hazards.
	Trust Fund for Tsunami, Disaster and Climate Preparedness - https://www.unescap.org/disaster-preparedness-fund - a regional multi-donor funding mechanisms to support the unmet needs of multi-hazard early warning systems in Asia and the Pacific

Scope	Financing, Service Provision and Data Exchange Cooperation Mechanisms (non-exhaustive)[56]
Europe	Copernicus Emergency Management Service (CEMS) - https://emergency.copernicus.eu/ - A service that supports disaster management by providing timely and accurate geospatial information derived from satellite remote sensing and other sources.
	EUMETNET - https://www.eumetnet.eu/ - A collaboration of national meteorological services in Europe that coordinates programmes in various fields of meteorology.
	European and Global Drought Observatories - https://edo.jrc.ec.europa.eu/ - a system that monitors and assesses drought conditions, impacts and risks at regional and global scales.
	European and Global Forest Fire Information Systems – https://effis.jrc.ec.europa.eu/ - a system that forecasts dangerous weather conditions and provides near-real-time information on active fires and burnt areas.
	European Centre for Medium-Range Weather Forecasts (ECMWF) - https://www.ecmwf.int/ - an intergovernmental organization that produces global numerical weather predictions and other data for member and co-operating States and the broader community.
	European Natural Hazard Scientific Partnership (ENHSP) - http://aristotle.ingv.it/tiki-index.php - A network of scientific institutions that provides expert advice and rapid response to natural hazards in Europe and beyond.
	Meteoalarm - https://www.meteoalarm.eu/en_UK/0/0/EU-Europe.html - a platform that provides relevant information to prepare for extreme weather expected to occur somewhere over Europe.
Latin America and the Caribbean	Caribbean Disaster Emergency Management Agency (CDEMA) - https://www.cdema.org/ - a regional inter-governmental agency for disaster management in the Caribbean Community (CARICOM).
	CERESIS: Regional Seismology Center for South America - http://www.ceresis.org/ - promotes seismological studies and activities in the South American region and assists in their realization.
	Coordination Center for Natural Disaster Prevention in Central America (CEPREDENAC) - https://www.sica.int/buscar - an entity that coordinates actions for disaster prevention, mitigation, response and recovery in Central America.
	iGOPP - https://riskmonitor.iadb.org/en - an online platform that evaluates the existence of essential DRM processes in LAC countries, including the development of EWS.
	Risk finder for rising Caribbean Sea levels - https://riskfinder.org/caribbean - provides projections of sea levels and flooding for the Caribbean Islands.



The global call for early warning systems for all within the next five years is recognizant of key challenges, including that disaster mortality is eight times higher in countries with limited early warning coverage. Investments in early warning systems reduce fatalities and economic losses that are incurred due to disaster events.

Climate hazards do not follow national boundaries; optimal transformative adaptation measures are those that mirror the transboundary nature of disaster risks.

This compendium of multi-hazard early warning cooperation presents good practices that demonstrate the cooperation of G20 countries to strengthen early warning systems through: political commitments; innovative financing; service provision and institution building; data and technology exchange; transboundary advocacy and action; and tripartite arrangements.

Advancing early warning systems, to meet the needs of today and of future generations exposed to intensifying and transboundary climate hazards, will rely on cooperation.