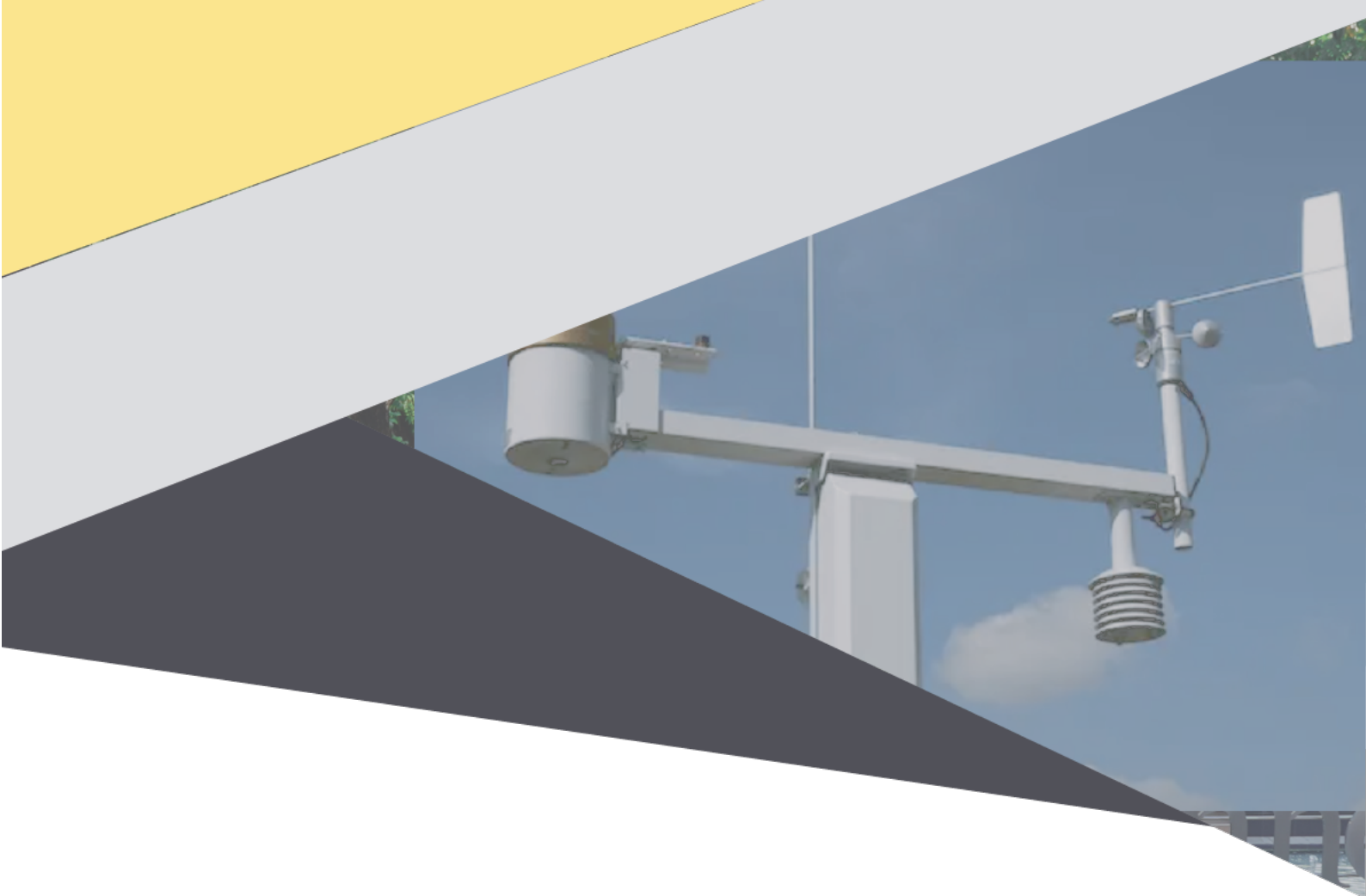
POLICY INCENTIVES AND ECONOMIC RATIONALE FOR

Investing in Multi-Hazard, Multi-Scale, and Multi-Purpose Regional Early Warning Systems to Supplement National Efforts



Key Messages

Impact of Disasters on National Economy and Planning: Climate-related and other natural hazards erode national gross domestic product (GDP) by up to 20%[1] and strain public finances, particularly in Small Island Developing States (SIDS), Least Developed Countries (LDCs), Landlocked Developing Countries (LLDCs), and other developing nations frequently exposed to natural hazards. These impacts could derail development planning trajectories, setting back economic progress in these vulnerable regions.

Increasing Challenges to National Development Planning: Despite the risks posed by multiple hazards, regions prone to disasters, such as coastal low-elevation zones, floodplains, and hilly or mountainous terrains, continue to experience rapid urbanization and population growth. Climate change further exacerbates these hazards by enhancing their variability and intensity, escalating the threat to people, assets, livelihoods and critical infrastructure. This evolving and uncertain risk landscape present a continual challenge to national development planners and the adoption of innovative planning instruments that have the potential to insulate development trajectories against uncertain disruptions.

Early Warning Systems as a Feasible Disaster Mitigation Option: Early warning systems (EWS) offer one of the most feasible disaster mitigation options in developing countries. While relocating people from hazard-prone zones might be an effective prevention measure, it is often neither popular nor practical in these contexts. Instead, reducing risks through preparedness and mitigation are better alternatives. EWSs have proven to be highly effective in this regard, not only in saving lives but also in reducing damage and losses by up to one-third of the total. Moreover, these systems exhibit a favorable cost-benefit ratio – every dollar invested in Weather services and EWS revealed a benefit ratio of 35 - 40[2] and potential to yield savings[3] of 7-30% in avoided damage and losses.

Challenges in National EWS: Despite increased investments to enhance the capacity of national EWS in recent years, significant gaps persist. Limited financial and human resources strain efforts to improve technical capabilities, to sustain critical EWS infrastructure, and to integrate advancements in technology. These challenges hinder the effectiveness and sustainability of EWS, leaving communities and critical sectors outside of EWS coverage and vulnerable to disasters.

Rationale for Regional Collaboration in EWS: Given that climate and weather are transboundary phenomena, regional collaboration offers a cost-effective solution by leveraging economies of scale. By pooling resources and expertise, regional EWS:

- Reduce individual country costs through shared technology, infrastructure, and observation and forecasting data.

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[1] Joint SDG Fund; SIDS Report 2024
[2] by D Rogers · Cited by 141 — Guocai, Z., and H. Wang, 2003. —Evaluating the Benefits of Meteorological Services in China. WMO Bulletin 52(4): 383
[3] AR. Subbiah, Lolita Bildan, Ramraj Narasimphan 2011 Economics of Early warning Systems; Background Paper: World Bank

- Enhance disaster preparedness by enabling coordinated, real-time risk monitoring across borders.
- Attract greater financial and technical support from international organizations and development partners.

This collaborative approach not only strengthens resilience but also maximizes the return on investment for all participating nations.

Contribution of Regional EWS and Its Challenges. Regional EWSs have significantly reduced the loss of lives and livelihoods in many areas. However, these systems are often designed to address single major hazards, such as tropical cyclones, tsunamis, floods, or droughts, limiting their ability to manage complex, multi-hazard risks.

To address these challenges, RIMES Countries established the Regional Integrated Multi-Hazard Early Warning System by leveraging project funding opportunities and integrating project resources from different sources:

1. ESCAP Multi-Donor Trust Fund for Tsunami, Disaster, and Climate Preparedness (2005-2009) – Earthquake Monitoring and Tsunami Early Component
2. DANIDA (2007-2010) – Hydro-Meteorological Hazard Forecast Component
3. American Red Cross (2007 -2011) – Societal Application Component

Subsequently, by leveraging ESCAP's incremental capacity building support projects and valuable contributions from Government of India, WMO, United Kingdom Meteorological Office (UKMO)/Foreign, Commonwealth and Development Office (FCDO), and other humanitarian and development partners, RIMES upscaled its MHEWS, connecting both upstream and downstream components of early warning information/climate services value chain pillars: 1) enhancing data availability and accessibility; 2) modeling and forecasting; 3) translating data into actionable information; 4) societal engagement and feedback; and 5) research and development. These services are being delivered at the country level and also upscaled to subregional levels in South Asia Sub-Region and Southern Africa Sub-Region.

RIMES MHEWS 's salient features have been:

1. **Achieve Economies of Scale**: Supplement and complement national efforts by sharing investments in data sharing, analytics, infrastructure and modeling tools.
2. **Incorporate Advanced Technologies**: Enhance national capacities, enabling National Meteorological and Hydrological Services (NMHSs) to deliver specialized and value-added services such as impact-based forecasting at marginal additional costs.
3. **Connect all components of early warning/climate information value chain:** While scientific and technical investments in upstream components (e.g., observation and modeling) are vital, marginal additional investments enhance the capacities of user sectors, disaster risk management (DRM) institutions, and communities.
4. **Deliver Common but Differentiated Services**: Offer a portfolio of services tailored to the needs and capacities of countries at different stages of development and capacities

5. **Sustained and back-up support:** Provide sustained back-up support to National systems based on needs and demands.
6. **Intergovernmentally mandated and owned**: Maintain an intergovernmental governance structure to ensure that all services provided are needs-based and demand-driven, strategic direction of the regional mechanism is steered by members, and to foster peer to peer learning and exchange.

Through this approach, RIMES regional collaboration in EWS emerged as a cost-effective and scalable solution, enabling countries to anticipate and manage the increasing frequency and intensity of disasters. By leveraging shared resources, advanced technologies, and global/regional institutional partnerships, regional EWS bridge critical gaps in national systems, enhancing resilience across borders.

The RIMES Ministerial Conference and Committee on Disaster Risk Reduction: Platforms for Strengthening Regional EWS. The RIMES Ministerial Conference aims to draw policy lessons from RIMES' experience since its inception and recommend financial and policy instruments to strengthen and sustain regional EWS. Concrete outcomes of the conference will be presented at the relevant subregional SDG forums and further explored through the ESCAP Regional Learning Platform for multi-hazard early warning systems under the ESCAP Committee on Disaster Risk Reduction. These intergovernmental platforms aim to bridge the science-policy divide, bringing together hydrometeorology, disaster risk reduction and planning/financing communities under the purview of the 2030 Agenda for Sustainable Development. ESCAP's comparative advantage can be leveraged to elevate the regional investments in EWS to address broader objectives of sustainability and resilience. These efforts will support national systems, particularly in SIDSs, LDCs, and LLDCs, ensuring they are better equipped to manage hazard risks through regional cooperation.

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List of Acronyms

ASEANCOF	Association of Southeast Asian Nations Climate Outlook Forum
CARE	Climate Adaptation for Resilience
CIEWS	Climate Information and Early Warning Systems
DANIDA	Danish International Development Agency
DataEx	Data Exchange Platform
DRM	Disaster Risk Management
DSS	Decision Support System
ECMWF	European Centre for Medium-Range Weather Forecasts
EPS	Ensemble Prediction Systems
EWS	Early Warning Systems
FCDO	Foreign, Commonwealth and Development Office
GDP	Gross Domestic Product
GTS	Global Telecommunication System
HPC	High-Performance Computing
IBF	Impact Based Forecasting
ISR	Integrated Services for Resilience
JSAP	Joint Strategy Action Plan
LDCs	Least Developed Countries
LLDCs	Landlocked Developing Countries
MHEWS	Multi-hazard Early Warning Systems
NCMRWF	National Center for Medium Range Weather Forecast
NEC	National Earthquake Center
NHMS	National Hydrological and Meteorological Services
NTWC	National Tsunami Warning Center
NWP	Numerical Weather Predictions
RDAC	Resilience Data and Analytics Centre
RDAS	Regional Resilience Data Analytics Service
RIMES	Regional Integrated Multi-Hazard Early Warning System
SAHF	South Asia Hydromet Forum
SASCOF	South Asian Climate Outlook Forum
SDG	Sustainable Development Goals
SIDS	Small Island Developing States
SMEs	Small and Medium-Sized Enterprises
TDR	Triple Dividend of Resilience
UKMO	UK Met Office
UNEP	United Nations Environment Programme
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
USAID	United States Agency for International Development
USD	United States Dollar
WMO	World Meteorological Organization

1. Rationale for Advanced Cross-Country Early Warning Systems

EWSs represent one of the highly cost-effective investments in disaster risk reduction, consistently demonstrating notable returns on investment across various global/national/subnational/local contexts. Multiple studies[4] on investments for EWS have documented benefit-cost ratios ranging from 3:1 to as high as 36:1[5]. These findings highlight the substantial economic gains of investing in EWS, emphasizing their role in mitigating disaster risks and associated losses, and enhancing economic resilience. However, despite benefits, the implementation of EWS faces persistent challenges, particularly in developing countries. Institutional fragmentation, limited financial resources, gaps in technical capacity, lack of national mechanism to connect and de-compartmentalize the segments of the early warning/climate information value chain, and lack of backup mechanism to sustain catalytic investments from donor-funded projects often hinder the sustainability and adoption of advanced systems.

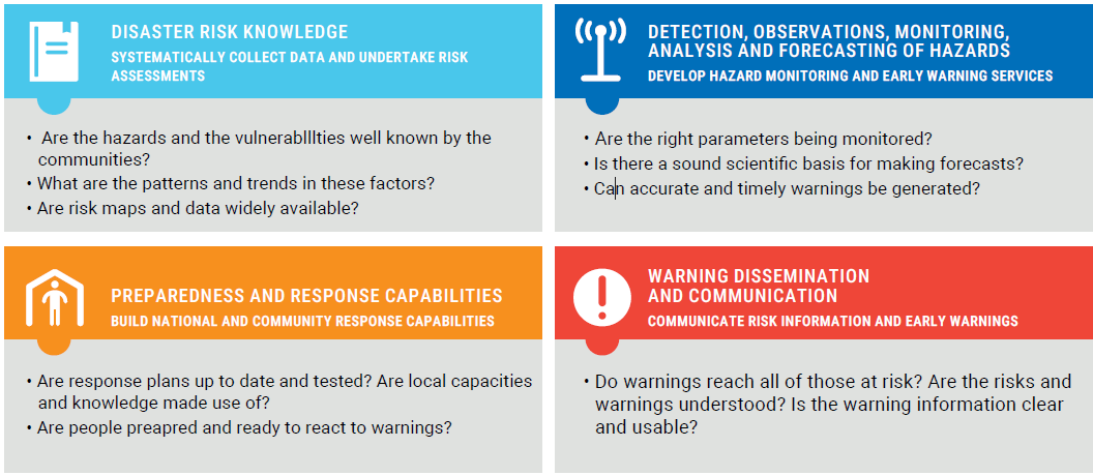
Addressing these challenges requires a multi-faceted, cross-country approach that efficiently utilizes resources, technologies, and advances in science to respond to common hazards but differentiated requirements of countries of varying capacities.

International frameworks and forums have put emphases on cross-country/global EWS to reduce disaster risks and optimize resources management. Among others, the G20 has prioritized global EWS and commits to enhancing investments in research, development, and data sharing to strengthen global early warning infrastructure, ultimately aiming to reduce disaster impacts and protect lives and livelihoods.[6]

The basic framework of an EWS consists of the fundamental components required for a functional warning system, aligning with the four key pillars: risk knowledge, monitoring and warning services, dissemination and communication, and preparedness and response capability (See Figure 1).

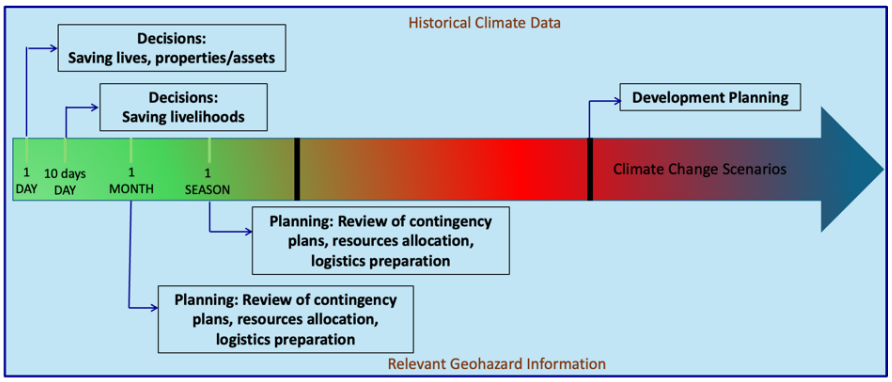
[4] WMO. (2015). Valuing weather and climate: Economic assessment of meteorological and hydrological services.
[5] Hallegatte, S. (2012). A Cost-Effective Solution to Reduce Disaster Losses in Developing Countries: Hydro-Meteorological Services, Early Warning, and Evacuation.
[6] G20 (2025), Priority 2: Global Coverage of Early Warning Systems. https://g20drrwg.preventionweb.net/2025/g20-working-group-areas

Figure 1 Four pillars of early warning system[7]



An advanced system takes forward the value of an EWS beyond disaster risk reduction, to enable countries to seamlessly manage resources and plan development (i.e. application of multi-hazard, multi-timescales information, in Figure 2).

Figure 2. Application of multi-hazard, multi-timescales information



Established in 2009 to address the gaps in earthquake monitoring and tsunami early warning, RIMES focused its efforts in strengthening its multi-hazard and multi-timescales services, to:

- ensure system readiness for low-frequency, high impact events like earthquake, tsunami, and extreme hydro-meteorological events by regularly training the system in high-frequency, low-impact weather events
- capacitate national systems to apply information of all timescales, to take advantage of favorable weather/climate for resources management/development planning, against the backdrop of readiness to undertake decisions for reducing risks.

With the system established by RIMES, marginal additional costs will enable RIMES to expand its services to more Member States.

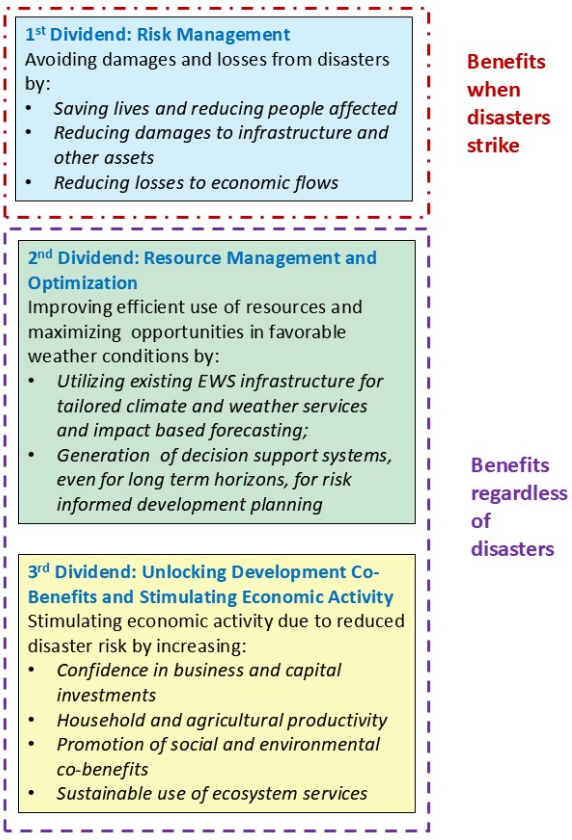
[7] WMO (2023), adapted in ESCAP (2023), 'Seizing the moment: Targeting Disaster Risk Resilience', Asia-Pacific Disaster Report 2023

1.1 Economic Benefits of Advanced MHEWS

Investing in advanced MHEWS through regional cooperation offers nations a pathway to resilience that extends far beyond disaster preparedness. This is better represented by the Triple Dividend of Resilience (TDR) framework which provides a structured methodology to evaluate the socio-economic returns of these investments[8]. This framework identifies three interconnected layers of benefits, namely:

- Risk Management: Minimizing economic losses from extreme weather events by reducing casualties and immediate financial burdens on households, businesses, and the broader economy.
- Resource Management and Optimization: With marginal costs, MHEWS enables the seamless generation and application of customized EWS/climate services-informed decision guidance products for resources management and opportunities optimization during favorable weather/climate conditions, and long-term development planning.
- Economic Stimulation: Reducing disaster risks to unlock broader economic opportunities and co-benefits that enhance resilience and growth.

Figure 3: The Modified Triple Dividend of Resilience framework[5]



[8] Adapted and modified framework based on: Tanner, T., & Rentschler, J. (2015). Unlocking the 'triple dividend' of resilience: Why investing in disaster risk management pays off.

First Dividend: Avoiding losses through Risk Management

The first dividend of resilience centers on avoided damages and losses, with countries having comprehensive EWS experiencing significantly lower disaster-related mortality and fewer affected people compared to those with limited coverage[9]. The Global Commission on Adaptation highlights EWS as the most economically effective adaptation measure, with a remarkable 1:9 cost-benefit ratio – every dollar invested yields nine dollars in benefits. Beyond protecting physical assets, effective EWSs significantly reduce "losses in well-being[10]" which disproportionately affect vulnerable populations, with World Bank research[11] estimating that universal EWS access could prevent $13 billion in annual asset losses and generate $22 billion in well-being gains against an approximate $1 billion implementation cost. These impressive returns demonstrate that EWS investments deliver substantial socioeconomic benefits even before accounting for their primary purpose of saving lives.

Second Dividend: Resource Management and Optimization

The second dividend is realized through the continuous application of EWS infrastructure to generate decision-support systems (DSSs) and tailored climate and weather services that lead to informed decisions and actions to reduce risks. These systems not only address hazardous extreme weather conditions through impact-based forecasting (IBF) but also optimize the longer-lead use of resources associated with favorable weather/climate conditions all throughout the year. By leveraging multi-hazard, multi-timescales information, EWS enables sectors such as agriculture, water management, and energy to operate more efficiently, profitably, and sustainably. For instance, short-term weather forecasts enable farmers to make informed decisions regarding planting, fertilization, irrigation, and harvesting schedules. In India, for example, the application of weather information to crops like paddy, sugarcane, cotton, and wheat has been estimated to yield an economic benefit of approximately $4 billion annually[12]. In agricultural sectors, for example, EWS enables critical decision-making about planting dates and supply chains, enhancing productivity and minimizing disruptions. China's experience demonstrates this economic impact concretely: each 1% improvement in weather forecast accuracy increased crop yields by 0.34% (2.32 million tons of grain) and agricultural sector value by 0.5% (approximately $7.67 billion in 2021)[13].

Various DSSs (including the Regional Resilience Data and Analytics Services [RDAS] and national sectoral DSSs), ingesting critical climate and sectoral data, can also generate risks and opportunities patterns over decades. Integrated with potential future estimation of these risks and opportunities, DSSs can inform development planning that enhances resilience and sustainability.

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[9] WMO. 2023. Global Status of Multi-Hazard Early Warning Systems 2023

[10] "Well-being" here means the ability to meet essential human needs (e.g. to be in good health) and pursue one's goals to achieve satisfaction/fulfillment in life

[11] World Bank (2017). Unbreakable: Building the Resilience of the Poor in the Face of Natural Disasters

[12] NCAER (2015). Economic Benefits of Dynamic Weather and Ocean Information and Advisory Services in India

[13] Shen, D., Shi, W.-F., Tang, W., Wang, Y., & Liao, J. (2022). The Agricultural Economic Value of Weather Forecasting in China.

Third Dividend: Unlocking Development Co-Benefits and Stimulating Economic Activity

In disaster-prone regions, the constant threat of extreme weather creates persistent uncertainty that discourages long-term investments, limits entrepreneurship, and shortens planning horizons. By improving hazard detection, forecasting, generation of actionable early warnings and climate services, and communication to enable proactive actions and decisions, EWS boosts confidence for both local and foreign investments. This third dividend highlights how EWSs reduce "background risk" resulting in positive risk perception and confidence to unlock development benefits.

Beyond economic gains, the third dividend also delivers social and environmental co-benefits, regardless of whether hazards occur. Community engagement, essential for effective EWS implementation, strengthens social cohesion fostering trust and positive relationships. In Vietnam, for example, EWSs have been developed with active community involvement, leading to enhanced disaster preparedness and social cohesion[14]. Furthermore, these benefits can address social inequalities by ensuring that marginalized and underserved communities have equal access to critical information, thereby improving their capacity to respond to and recover from hazards.

Early warnings and climate services also support environmental sustainability by guiding actions to protect and enhance ecosystem services. For example, in East and Southern Africa, early warning systems have been utilized to monitor and manage environmental conditions, supporting sustainable agricultural practices and biodiversity conservation[15]. These benefits make disaster risk mitigation investments more appealing and valuable, as they provide advantages even in hazard/disaster-free periods while also contributing to the first two dividends—preventing losses and optimizing resources and opportunities. These environmental benefits can also contribute to reducing inequalities by improving the livelihoods of communities that depend directly on natural resources, ensuring sustainable use and conservation.

2. Challenges in National EWSs

Despite the benefits and advantages, establishing effective national EWSs with investments through policy reforms and financial commitments remain inadequate. Several key challenges contribute to this predicament:

Risk perception and short-term political cycles.

Policymakers with limited terms in office are likely to deprioritize EWS investments for low-frequency but high-impact events or slow onset disasters, assuming that a 1-in-50-year event is unlikely to occur, especially within their tenure. This reduces political and policy incentives to allocate resources to long-term disaster preparedness.

[14] Pham, et.al. (2024). Community-based early warning systems in a changing climate: an empirical evaluation from coastal central Vietnam.
[15] Braimoh, et.al., 2018. Assessment of Food Security Early Warning Systems for East and Southern Africa, Africa Climate Business Plan Series, World Bank

Political disincentives and lack of continuity.

Changes in leadership, shifts in political priorities, and budget reallocations often result in neglect of previously implemented EWS initiatives. Sustaining improvements and tapping technological advancements within EWSs require sustained political support.

Treating "surprises".

Some extreme events are often labeled as "surprises" due to the lack of recent historical precedence or assumed rarity. Notable examples include the Indian Ocean tsunami of December 2004 which devastated countries with no recent experience of such event; the May 2008 Cyclone Nargis in Myanmar, which made landfall in Ayeyarwady Delta, an area with no recorded cyclone landfall in living memory; the June 2008 Typhoon Frank in the Philippines, which traversed the central part of the country rather than the northern route typically tracked by the storms during that season.

Public institutions argue that these extreme events were unprecedented and, therefore, unpredictable. However, risk knowledge for such events exists, as historical records[16], such as the 1881 Indian Ocean-wide tsunami and the 1945 Makran tsunami, demonstrate that similar events have occurred in the past, establishing a precedent. Risk modelling also present scenarios on the likelihood of future extreme events, however probabilities presented in these scenarios are often misinterpreted.

Essential EWS vs Effective EWS.

Transitioning from an essential EWS (which primarily focuses on saving lives) to an effective EWS (which in addition to saving lives, also minimizes damage, disruptions, and economic losses) remains a significant challenge. One reason for this is the reduced political and emotional incentive to further strengthen warning and response systems due to the weakened sense of urgency once fatalities decrease.

Intangible benefits.

Unlike the immediate and visible impact of saving lives, the broader benefits of an effective EWS are not tangible enough and less apparent to policymakers, making it challenging to justify public funding for improvements. While it is easy to survey and estimate the damage and losses post-disaster, it remains a challenge for responsible agencies to report, quantify and convince decision makers of the value of preventable or avoidable damage that an effective EWS could bring or has already brought. To provide an example, a flood forecast from the NMHS resulting to local government's closure of an exposed bridge to reduce risks to the population is not the sort of preparedness and mitigation action that is recorded formally or reported to policymakers. Thus, the intangible benefits of NMHS services in collaboration with forecast users is often misunderstood and underestimated. To bridge this gap, it is essential to document and showcase EWSs' measurable intangible benefits, engage the media, and raise awareness among policymakers and decision-makers. This approach could help make the long-term advantages of EWS more visible and compelling.

[16] Dominey-Howes, D., Cummins, P., & Burbidge, D. (2007). Historic records of tele tsunami in the Indian Ocean and insights from numerical modelling.

Scientific uncertainty.

There is a lack of incentive in an operational forecasting agency for identifying, experimenting with, and operationalizing new technologies. The system is amenable only towards technology that has been proven and demonstrated, delaying the integration of innovative forecasting tools. In Bangladesh, for instance, early long-lead flood forecasting technology initially received little attention due to its experimental nature[17]. Only after years of demonstrated success did decision-makers begin to recognize its value. This emphasizes the need for stronger incentives and institutional support to encourage adoption of emerging technologies, even when their benefits take time to materialize.

The challenge of a multidisciplinary approach.

Essential early warning services focused on saving lives are relatively straightforward to implement within existing disaster management structures. However, transitioning to the higher level, effective EWS that reduces economic damage and societal disruptions requires longer-lead probabilistic forecasting that serves multiple sectors. This scheme demands greater cross-sectoral coordination, cooperation, and a multi-disciplinary approach, which remains a major challenge for many developing countries.

The challenge of investments and sustainability.

Effective EWS demands high-quality observational networks, efficient data-sharing mechanisms, and high-performance computing capabilities for data analysis and generation of customized information products. These elements are essential to leverage advancements in prediction systems, including the integration of AI/ML, to enhance probabilistic forecasting and nowcasting capabilities, and transform raw data into actionable information. However, this requires significant investment and operational budget which many LDCs, LLDCs, and SIDS could not afford on their own.

3. RIMES Experiences in Supporting National EWSs to Overcome Challenges

RIMES demonstrated the feasibility of supporting National EWSs to overcome these challenges through regional cooperation. RIMES support was established through four distinct but inter-connected phases, below:

3.1 Phase 1: 2005 -2009

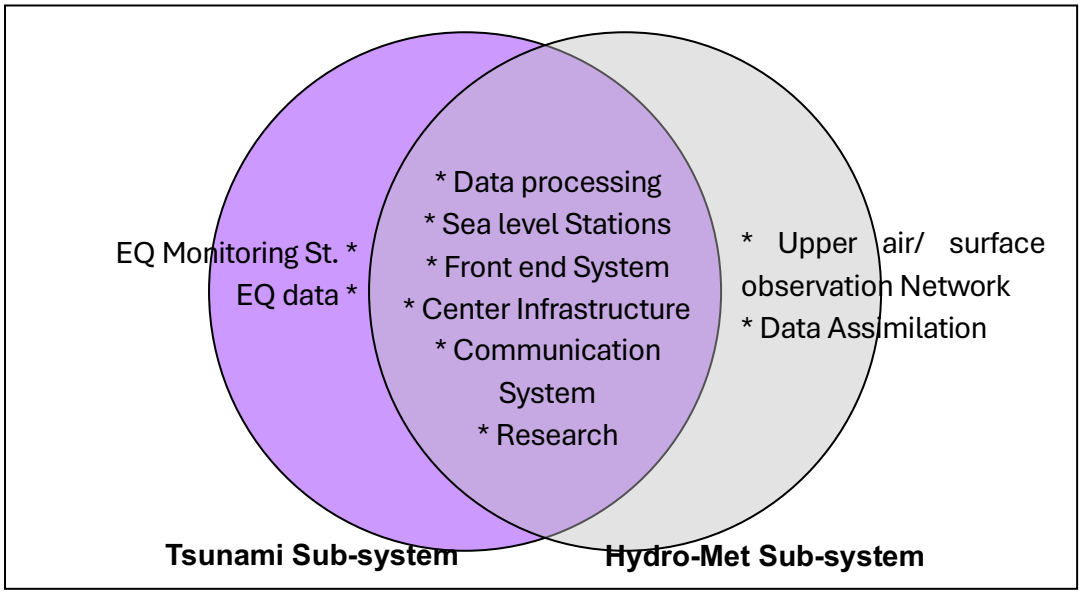
In response to the gaps revealed by the Indian Ocean Tsunami in 2024, UNESCAP established the Regional Tsunami Early Warning Facility through the Thailand-initiated Regional Tsunami Trust Fund. Catalytic support from the Danish International Development Assistance (DANIDA) and American Red Cross (ARC) incorporated hydro-meteorological early waning and societal components into the Regional Multi-Hazard Early Warning Facility, making tsunami early warning a sub-system thereof, considering cost-effectiveness and sustainability of Regional Multi-hazard Early warning system with following features:

[17] World Bank. (2016). Proceedings of the Regional Flood Early Warning System Workshop (23-27 November 2015, Bangkok)

System integration

Integrating tsunami and hydro-meteorological (hydro-met) subsystems under a single regional framework with minimum additional cost

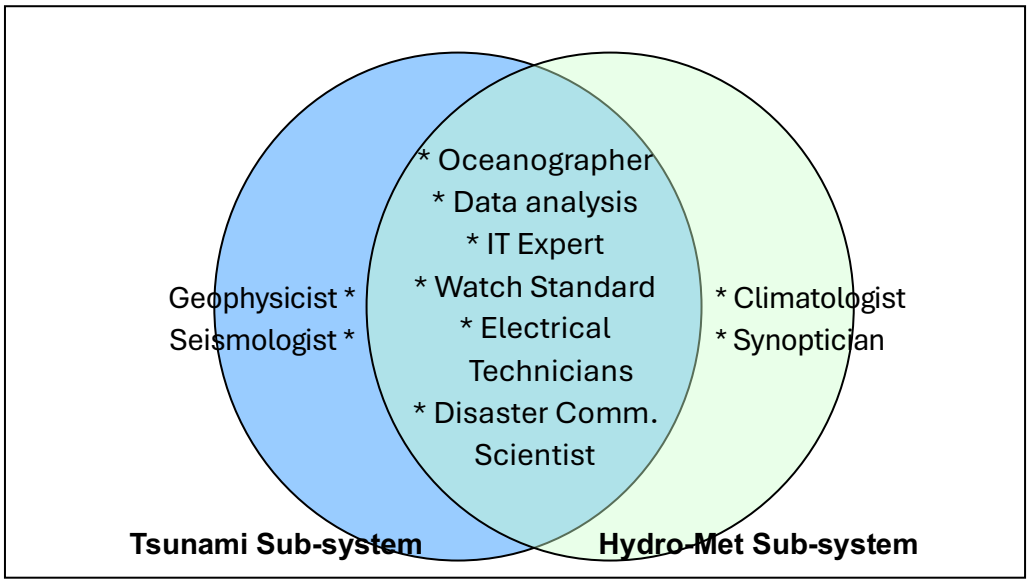
Figure 4. Integration of Tsunami and Hydro-Met Sub-Systems – Human Resource Component



Human Resource Optimization

The technical skills such as data communications, data management, data analysis, modelling and forecasting (particularly Hydrodynamics), forecast data communication, and community reach are important in both Geo- and hydro-climatic hazard monitoring and prediction. RIMES leveraged common skills and reduced costs both toward establishment and operation and maintenance phases. By training personnel to handle multiple hazards, RIMES reduces the need for specialized staff in each country, lowering operational costs while enhancing technical expertise across the region.

Figure 5. Integration of Tsunami and Hydro-Met Sub-Systems in the MHEWS

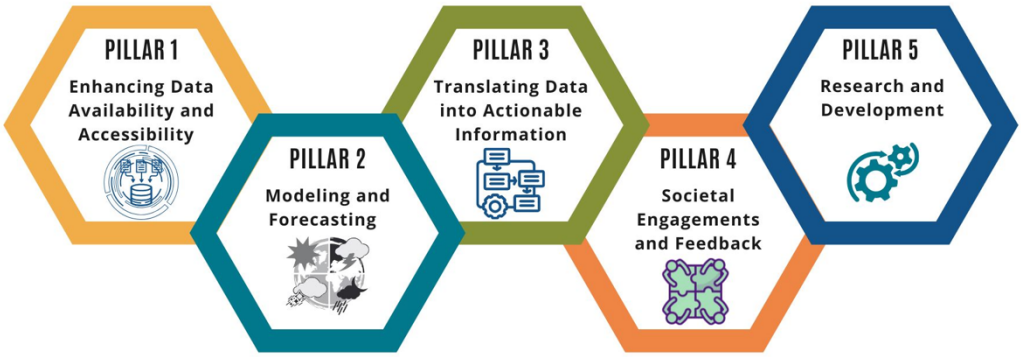


Further integrating value-added and special services into the regional framework also has the benefit of ensuring constant engagement, greater participation of Member Countries, and creating economic advantages through service diversification.

3.2 Phase 2: 2009 -2021

With ESCAP's incremental capacity building support through projects and valuable contributions from the Government of India, WMO, United Kingdom Meteorological Office (UKMO)/Foreign, Commonwealth and Development Office (FCDO), and other humanitarian and development partners, RIMES upscaled its MHEWS to both upstream and downstream components of early warning information/climate services value chain, comprised of the following distinct but inter-connected pillars: 1) enhancing data availability and accessibility; 2) modeling and forecasting; 3) translating data into actionable information; 4) societal engagement and feedback; and 5) research and development, in Figure 6 and elaborated in Appendix 1.

Figure 6. The Five Pillars of Early Warning Information and Climate Services Value Chain



During this phase, RIMES has demonstrated the uniqueness of its **Regional Multi-hazard, Multi-scale, and Multi-purpose Early Warning service delivery**[18], underpinning the following:

i. Economies of Scale

Limited-resource countries particularly Small Island Developing States (SIDS), Least Developed Countries (LDCs), Landlocked Developing Countries (LLDCs), and other developing states achieve economies of scale through shared resources, expertise, tools, and infrastructures. RIMES Regional Early Warning Center allows countries of various capacities to draw from and contribute to the system optimally and cost-efficiently.

ii. Advanced Technologies

One of the challenges that most of SIDS/LDCS/LLDCS and other developing states face is to keep pace with the ever-changing technological advancements and harness their potential benefit. RIMES Early Warning Center addresses this gap to offer advance data and analytics services through its Regional Data Center. Participating countries could draw data, tools, and systems from the Regional Data Center to customize/deliver specialized services and products such as sector-specific, location-specific digital impact forecasting/climate services tools at marginal additional costs.

iii. Connectivity of all the Components of the Climate/Early Warning Information Value Chain

Investments/engagements from development partners are frequently compartmentalized to one or two specific pillars of the climate services/early warning information value chain. RIMES integrates these compartmentalized investments – from the upstream domains of scientific/technical capacity building (e.g. observation data availability/accessibility, modeling and forecasting) to the downstream domains of transforming data into tailor made climate/early warning information and enhancing capacities of user sectors institutions and communities to anticipate and manage risks – with small additional investments.

iv. Delivery of Common but Differentiated Services

RIMES offers a portfolio of services tailored to the differential requirements, demands, and capacities of countries at different stages of development.

v. Sustained Backup Support

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[18] A multi-hazard system ensures that early warnings account for diverse and interconnected risks, from hydro-meteorological events like storms and floods to geohazards such as earthquakes and tsunamis, and are ready to be scaled up to meet potential biohazards threats

A multi-scale system draws from and contribute to global, regional, national, systems through partnerships. Through these partnerships, it provides services across different space and temporal scales to provide demanded services – from immediate short-term alerts to seasonal and long-term projections for national/ sub national / local applications.

A multi-purpose system expands the scope of early warnings beyond disaster response, supporting broader societal and economic resilience. By generating tailored climate services, it empowers diverse sectors to undertake proactive decisions to anticipate and manage extreme weather events (weather scale); harness benefits associated with favorable weather/climate resources (weather/sub-seasonal/seasonal climate scales), while informing development plans (multi-seasonal/decadal scale); and reduces disaster risks and supports economic vitality for resilience.

Sustainability of interventions in climate services/early warning information value chain in capacity/resource-challenged countries require sustained backup support in specialized domains such as data generation and analysis, software/digital tools enhancements, refinement of models, integration of new/advanced technologies, and human resources capacity enhancement through co-development of systems/information products. RIMES provides this sustained backup support to maximize gains from development interventions in climate services/early warning information value chain.

vi. Intergovernmental Mandate and Ownership

The RIMES Council, comprised of Heads of NMHSs and are accountable to RIMES Member Countries and Country Stakeholders, ensures collaborative undertakings that are responsive to the differential requirements of Member States and Collaborating Countries. The operational context of the heads of NMHSs, enriched with feedback from respective national stakeholder/user sector institutions on demanded services/information products, steers the direction of the RIMES Early Warning Center.

3.3 Phase 3: 2021 – 2025

Building on RIMES unique services, World Bank developed and implemented two key projects with RIMES: the Climate Adaptation and Resilience (CARE) for South Asia Component 1 and South Asia Hydromet Forum (SAHF)[19]. These projects upscaled RIMES country-specific service delivery to sub-regional level to ensure:

- a sub-regional institutional mechanism that facilitates collaboration among countries sharing common transboundary climate drivers and disaster risks, such as the South Asian Monsoon and post-monsoon cyclone systems, through the SAHF; and
- leveraging the sub-regional institutional mechanism to enhance technical capacities and support integrated climate and information service delivery through CARE for South Asia Component 1.

The details of CARE Component 1 and SAHF are provided in Appendix 2.

At this period, the World Meteorological Organization (WMO) formalized with RIMES the Joint Strategy Action Plan (JSAP)[20], to enhance the capacities of NMHSs and transform these into socio-economic and other tangible benefits. The WMO-RIMES JSAP is the linchpin in responding to the growing demands of its Member States and Collaborating Countries in deepening CARE for South Asia Component 1 in South Asia, and replicating the best practices to Africa, Southwest Indian Ocean, Middle East, Central/Southeast Asia, and the Pacific.

[19] SAHF, operating with various funding streams and transcending various projects, has been part of CARE Component 1 since May 2023.

[20] The JSAP is a living document, in view of the evolving context of opportunities, risks, science (and ergo, user requirements).

RIMES, partnering with UNEP, implements the Green Climate Fund-supported project in Timor Leste, which leveraged RIMES Multi-Hazard Early Warning Service Delivery and WMO-supported CST Program implemented by RIMES in 16 countries of Southern Africa through SADC Regional Climate Center. This underscores the replicability of RIMES Services from South Africa sub-region to other RIMES sub-regions.

3.4 Phase 4: 2025 -2030

This phase is critical for exploiting the benefits of the Multi-Hazard Early Warning System, particularly for countries exposed to common hazards but having differentiated capacities to respond to these hazards. With more pronounced hazard variabilities, frequencies of extreme events, and increased vulnerabilities from these natural hazards on the one hand; and the established good practices in early warnings/climate services, and unprecedented technological and scientific advancements, on the other, a regional multi-hazard, multi-scales, and multi-purpose system leveraging national early warning capacities has never been more vital.

Financing fit-for-purpose and fit-for-budget early warning business models built on regional cooperation mechanisms as a key avenue for investment was showcased within the G20.[21] More recently, under the Brazil presidency, G20 members "reaffirm[ed] the G20's essential role in enhancing international and regional cooperation in disaster risk reduction and fostering partnerships to promote inclusive and effective governance, mutual learning, and early warning systems for all"[22].

The RIMES Master Plan 2026 – 2030 offers a portfolio services to meet the requirements of RIMES Countries and will be implemented within the framework of the WMO-RIMES JSAP. The RIMES Master Plan 2026 – 2030 is designed to leverage RIMES' Triple M and Triple Dividend Regional Early Warning Center's technical resources for the benefit of RIMES Member Countries.

3.5 Finance Instruments and Policy Advocacy Process

To sustain regional EWS, the following strategies are critical:

1. **Addressing Individual Country Requirements.** Each country has unique processes, policy requirements, and constraints. The regional system must adapt to these contexts, ensuring that all countries can participate effectively and equitably.

2. **Institutional Contributions from Countries.** Countries' contributions could be structured based on the annual value-added services they receive from the regional system. This approach ensures equitable cost-sharing while aligning contributions with the benefits derived by each country.

[21] ESCAP et al. (2023). Input Paper on Early Warnings for All in Asia and the Pacific: Opportunities for action, G20 Working Group on Disaster Risk Reduction, G20 India Presidency
[22] G20 Brasil (2024). G20 Disaster Risk Reduction Ministerial Declaration

3. **Practical Budgetary Considerations.** Each country's budgetary mechanisms must be considered, including planning processes, deadlines for submissions to national planning boards, and the inclusion of new budget line items. These practical aspects are critical for ensuring sustained financial support.

4. **Policy Advocacy Instrument.** A key tool for securing funding is the economics of early warning document[23], which includes country-specific case studies. This document demonstrates the cost-benefit ratio of the regional system to policymakers, decision-makers, and donors, highlighting the tangible returns on investment.

5. **Budgetary and Policy Changes.** Once the benefits of the regional system to each member-state are clearly understood and perceived, policy and budgetary mechanisms would need to be evolved in each member-state to enable it to support the regional system. This could be articulated and commitment made through advocacy at the highest possible level.

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Appendix 1

Five Pillars of the Early Warning Information/Climate Services Value Chain

Pillar 1: Enhancing Data Availability and Accessibility

a) Data Availability

RIMES' focus is two-pronged to maximize data availability for its Member States and Collaborating Countries: i) facilitating establishment/upgrading observation stations[24]; and ii) development and upkeep of global/regional digital platforms for cross-country multi-hazard observation data sharing.

b) Data Accessibility

RIMES makes quality-checked observation data accessible to its Member and Collaborating States. Non-Global Telecommunication System (GTS) data sharing, among participating NMHSs, is pursued via the Data Exchange (DataEx) platform, a digital hub for sharing/accessing, curating, archiving and visualizing observation data. Weather/climate observation data are shared with the European Center for Medium Range Forecasting (ECMWF), and Indian National Center for Medium Range Weather Forecast (NCMRWF) for utilizing observation data in model enhancement.

For geohazards, RIMES leverages real-time earthquake and water level observation data from its established seismic and sea level monitoring stations, with real-time observation data from regional/global centers, to improve the estimation/validation of earthquake and tsunami events.

PILLAR 2: Modeling and Forecasting

RIMES leverages weather/climate forecast data from ECMWF, NCMRWF and various other global/regional centers and generate customized downscaled and value-added forecast data as per country context and shares with each country. Moreover, RIMES enhances capacities of NMHSs to tailor/downscale/enhance forecast data for their country contexts through trainings.

To enhance collaborative engagements among NMHSs to address weather/climate forecast accuracy/customization, RIMES facilitates/provides technical support to the South Asian Climate Outcook Forum (SASCOF)[25], the Association of Southeast Asian Nations Climate Outlook Forum (ASEANCOF)[26], and the South Asia Hydromet Forum

[24] These include telemetered seismic, sea level, deep ocean, weather, water level, and agro-meteorological observation stations/systems.

[25] South Asian nations, supported by the WMO, came together to establish the SASCOF in 2010. Since then, SASCOF sessions are organized every year before the summer monsoon season, while winter sessions are organized from 2015 per stakeholders' demand.

[26] The ASEANCOF, established in 2013, provides a regular platform for collaborative development, among Southeast Asian nations, of seasonal climate outlooks and related information for the region.

(SAHF)[27]. SAHF established the Weekly Forecasters' Forum to facilitate collective expertise/knowledge/insights and experience sharing and forecast refinement among operational meteorologists.

RIMES provides 24/7 earthquake monitoring and tsunami early warning advisories for the reference of NECs/NTWCs, upon receipt of country demands.

PILLAR 3: Translating Data into Actionable Information

a) Institutional Mechanisms

RIMES established the National Seasonal/Monsoon/Climate Outlook Forums as a first-generation platform for co-production of early warning-informed decision guidance products between NMHSs and sectoral institutions (includes agriculture, water resources, disaster risk management, etc.). RIMES have been facilitating the transformation of these Forums into formal national institutional mechanisms through the signing of Memoranda of Agreement/Understanding (MoAs/MoUs) for data sharing and co-production of Decision Support Systems (DSSs)[28]. The IMD-RIMES Unit (IRU) for impact forecasting in India, the Sri Lanka National Center for Climate Application (SNCCA), and the Bangladesh National Center for Climate Application (BANCCA) are in operation. RIMES will engage with the countries to establish such formal institutional mechanisms to facilitate the co-production of Impact Based Forecasting/Climate Services as an integral part of the RIMES Master Plan implementation.

Earthquake and tsunami preparedness are integrated into National Seasonal/ Monsoon/Climate Outlook Forums for sustainable, multi-hazard approach.

b) Tailor-made Decision Support Systems

Bringing together NMHSs/NTWCs/NECs and sectoral institutions, RIMES co-develops and operationalizes user-driven digital DSSs to generate Impact-Based Forecast/Climate services. These DSSs have been made available for disaster risk management, agriculture, and water resources sector. These digital systems translate different timescales of weather/climate data into actionable information for sector-specific decision-making. Information products/outputs from DSSs are further tailored to ensure best fit solutions that address variable information requirements of different user institutions/communities, communicate uncertainties, and disseminate decision guidance information efficiently to drive decisions/actions by end user institutions/ communities.

PILLAR 4: Societal Engagements and Feedback

[27] SAHF – involving the 8 countries in South Asia, and Myanmar, and with support from the World Bank and WMO – was established in 2018 to strengthen regional collaboration to address common and differentiated needs of NHMHSs. In 2019, the SAHF Executive Council (EC), via SAHF II, was established to define the strategic direction of SAHF. The SAHF EC is comprised of the Heads of NMHSs in the region; RIMES is the SAHF Secretariat.

[28] As with any system, the DSSs require life-long work to constantly fine-tune them to evolving advances in science and technologies, risks and opportunities profile, and user requirements.

RIMES has been facilitating mechanisms for empowering local institutions and communities through actionable risk information and two-way interaction for enhanced resilience. RIMES adopts a unified user-centric approach that combines the overall enhancement of national institutional frameworks underpinning DRR/DRM planning, emergency response, and disaster reporting, with robust context-driven last-mile communication and feedback mechanisms.

RIMES have been supporting the national frameworks for climate services and provides feedback to authorities for identifying and addressing gaps in the climate services/early warning information value chain through capacity building on end-to-end early warning system at all levels. RIMES links vulnerable groups to available institutional resources and services for adaptive response with the goal of strengthening resilience and preparedness. RIMES facilitates customization of DSSs and demonstrations at the community level to ensure that information reaches communities in a timely manner and is acted upon to undertake forecast-based actions.

RIMES have been enhancing capacities at all levels: early warning agencies to generate user-tailored forecast products and services, and end-users to receive, understand, and internalize forecasts and warnings through improved dissemination of impact forecasts and risk management advisories of various timescales (in Figure 6).

Institutional and community engagements also serve as robust feedback platform, for experience-based evaluation of decision guidance products by institutional/end users. To assess and address evolving societal demands and needs, RIMES adopts a user-centered bottom-up approach that focuses on the user needs and demands as a driving factor to guide the entire process of climate/weather service co-production

RIMES engages with both the service providers and end-users to create an enabling environment to sustainably deliver and integrate advanced early warning and climate products to meet societal needs.

PILLAR 5: Research and Development

RIMES undertakes research and development, focusing on delivering cutting-edge technologies and building capacity in innovative techniques and tools. Its research agenda prioritizes the development of cost-effective yet efficient solutions for improving accuracy, value addition, last-mile communication of advisories, and ensuring timely and appropriate responses by recipients. RIMES undertakes research in collaboration with national stakeholder institutions, to dynamically update/refine/upgrade the processes and products associated with Pillars 1 to 4. This includes applied research for development of high-resolution climate/weather models and integration of DRM/DRR and CCA into climate services/early warning information delivery, as well as demand-driven services like custom-made applications, toolkits, manuals, and SOPs for effective implementation of risk response.

Appendix 2

The South Asia Hydromet Forum (SAHF)

The South Asia Hydromet Forum (SAHF) - composed of member countries Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka and Myanmar - is a transformative regional initiative designed to strengthen the capacity of NMHSs across South Asia by fostering collaboration, knowledge sharing, and technical innovation. Established to address the unique meteorological and hydrological challenges of the region, SAHF provides targeted capacity-building programs, training, and tools to enable NMHS to generate reliable climate data and translate it into actionable services. By focusing on operational forecasting, ensemble prediction systems (EPS), and impact-based forecasting, SAHF equips NMHS with the skills to deliver timely warnings and advisories that save lives, protect livelihoods, and enhance community resilience. Through its emphasis on regional cooperation, SAHF creates a sustainable framework for NMHS to adopt advanced numerical weather prediction (NWP) technologies, leverage global forecasting products, and address localized risks – ultimately bridging gaps in service delivery and ensuring that climate information reaches vulnerable populations.

SAHF also serves as a coordination hub that pools technical and institutional resources from member countries. Through a regionally coordinated training mechanism, the initiative supports regular capacity-building programs, assessments, and consultations aimed at enhancing operational forecasting and service delivery. Working groups within SAHF conduct regional studies to recommend improvements across the hydromet service value chain, with a particular focus on ensemble prediction, impact-based forecasting, advisory services, and integrating these outputs into business and policy decisions. This collaborative effort not only reduces costs through shared technology and expertise but also promotes a sustainable model for continuous improvement in weather and climate services.

A cornerstone of the SAHF initiative is its Knowledge Hub, a centralized, scalable platform that integrates real-time observation data sharing, forecast visualization, ensemble prediction analysis, and geospatial analytics with capacity-building tools like on-the-job training, online forums, and live conferencing. The hub includes the Data Exchange Platform (DataEx), developed by RIMES under SAHF, which facilitates regional meteorological data sharing and provides access to global forecast products such as those from ECMWF. Additionally, the SAHF Forecasters' Forum convenes weekly with NMHS experts across member countries to discuss extreme weather forecasts, model performance, emerging technologies, and dissemination strategies.

By linking directly to World Bank-supported initiatives like the CARE for South Asia Project, SAHF plays a pivotal role in advancing an efficient, integrated regional early warning system that generates impact-based forecasts incorporating sub-national vulnerability data, ultimately reinforcing regional climate resilience and supporting sustainable development in South Asia.

The Climate Adaptation and Resilience (CARE) for South Asia Project

Under the Climate Adaptation and Resilience (CARE) for South Asia Project, RIMES implements the subregional Resilience Data Analytics Service (RDAS) which complements national DSS by transforming climate data into actionable information for climate-smart decision-making in the

South Asia sub-region. This overarching project component objective is achieved through the following key subcomponents:

1. Establishing Regional Resilience Data and Analytics Services (RDAS) for South Asia: A unified platform to provide high-quality climate data, analytics, and tools for regional and national stakeholders.
2. Strengthening Decision-Support Systems (DSS): Tailored DSS for key sectors in pilot countries – Bangladesh, Nepal, and Pakistan – to support climate-informed planning and decision-making. These sectors include agriculture, livestock, water, road transport, multi-hazard early warning, and planning and development.
3. Building Capacity for Stakeholders: Training programs to equip users with the skills to utilize climate information effectively in their planning and decision-making processes.
4. Supporting the South Asia Hydromet Forum (SAHF): Facilitating knowledge sharing, policy advocacy, and regional coordination to promote the holistic application of climate information.

Regional Resilience Data and Analytics Service (RDAS)

The Regional Resilience Data and Analytics Service (RDAS) is a cloud-based, open-access platform that provides comprehensive climate risk management capabilities for South Asia. It acquires, stores, processes, and visualizes data to screen climate risks, inform decisions, and support investments. RDAS integrates diverse data sources including socioeconomic parameters, generates baseline and projected climate scenarios, and leverages existing national and regional systems to deliver downscaled information specifically tailored for South Asian countries.

RDAS connects with sector-specific DSSs to enhance planning and decision-making across various sectors. The platform also links to the South Asia Hydromet Forum Knowledge Hub, serving as a resource for climate/weather information and facilitating engagement between forecasters, policymakers, and decision-makers throughout the region. As a dynamic system, RDAS adapts to evolving data needs, generating customized climate projections that support research institutions, policy development, and ministerial planning efforts.

Decision-Support Systems (DSSs)

As part of the project, stand-alone DSSs have been developed for key sectors, including water, livestock, road transport, disaster risk management, and planning and development in pilot countries Bangladesh, Nepal, and Pakistan. These systems provide dynamic, forecast-based decision guidance and are linked to the RDAS to ensure seamless data integration and access for national and sub-national decision-makers.

RIMES Data Analytics Center

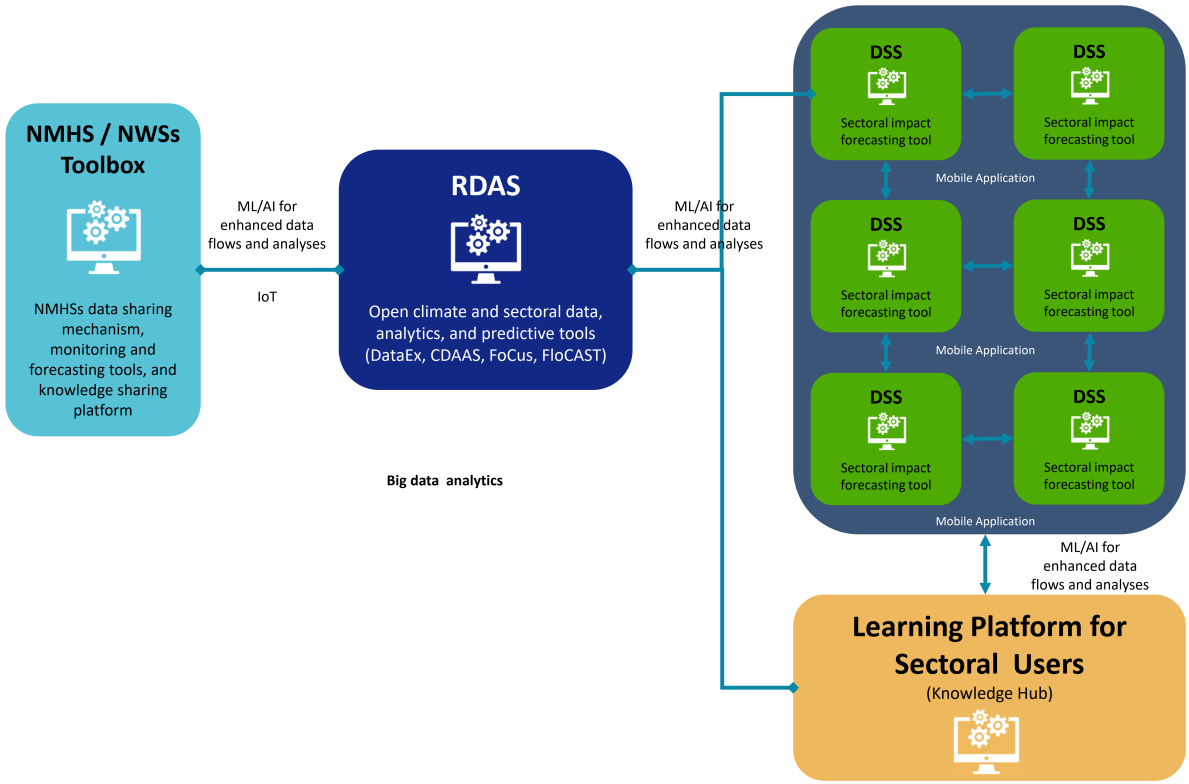
The RIMES Data Analytics Center strengthens the current suite of digital systems for supporting NMHSs and stakeholder sectors. It enhances system management, data security, and sustainability and is divided into three main hubs:

- NMHS Hub: Contains data-sharing tools, observation/monitoring and forecasting tools, and capacity-building/knowledge-sharing platforms for NMHSs.

- RDAS Hub: Manages open-source data leveraged from sub-national, national, and global sources, along with analytics tools and hazard impact prediction models.
- DSSs and Learning Hub: Supports sectoral stakeholders (agriculture, disaster management, health, livestock, planning, transport, water) through tailored DSSs and training resources.

These hubs are interconnected (as seen in Figure 9) for inter-system data flows, analyses, utilization, and curation, employing the latest technologies to enable data sharing and contribution from stakeholders.

Figure 7. Connectivity of systems at the Center for Data, Analytics, and Predictive Tools



Scalability of RIMES' Integrated Services for Resilience:

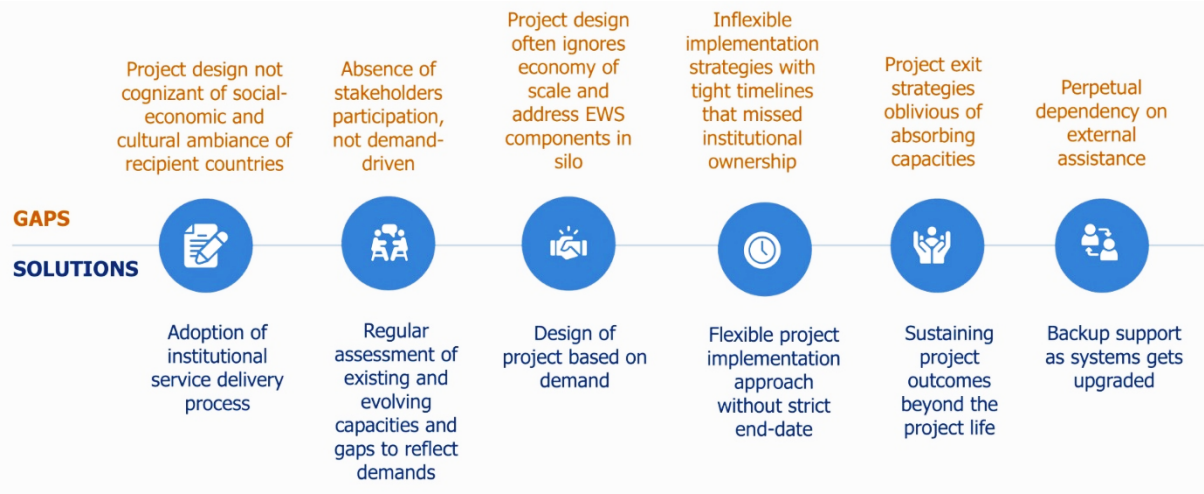
A key advantage of SAHF institutional mechanism and the RIMES Regional Data Analytics Center lies in its scalability and replicability to other sub-regions. The RDAS/DSS framework, systems, and infrastructure are designed to be adaptable, allowing customization based on specific sub-regional and national contexts. Because the core technologies and methodologies are already in place, these systems: a) deepen ongoing programs in the South Asia sub-region; and b) can be customized for other regions, such as Africa, the Southwest Indian Ocean, West Asia, the Middle East, the Caucasus, Central/Southeast Asia, and the Pacific region, which face similar climate challenges. This adaptability ensures that lessons learned, technical innovations, and best practices from one country/sub-region could be leveraged to strengthen regional climate

resilience efforts, fostering a more integrated and cooperative approach to climate adaptation and risk management

The experience of the above-highlighted mechanisms proves that regional collaboration is not just aspirational – it is operational, cost-effective, and ready for expansion. By pooling resources, standardizing tools, and aligning priorities, with institutional frameworks like SAHF's governance and CARE's multisectoral DSSs in place, the region is uniquely positioned to scale these innovations. RIMES' Integrated Services for Resilience (ISR) 2024–2030 framework, built on this foundation, could amplify its benefits to countries through WMO and RIMES Joint Strategy and Action Plan.[29]

RIMES has identified critical capacity gaps at regional, national, and local levels and the corresponding solutions it could provide (see Figure 10). To bridge these gaps, RIMES will continue to engage with countries to offer a more integrated and comprehensive suite of solutions for NMHSs, line ministries, and end-users, including the private sector. These include ICT products (cloud services, software systems, and sectoral tools), data sharing, knowledge management, technology transfer, technical support, capacity building, and expert advisory services. This strategy is guided by the RIMES Integrated Services for Resilience (ISR) 2024–2030 framework.

Figure 8. Gaps in initiatives relating to the enhancement of capacities across the climate information value chain as well as the solutions RIMES shall provide.



[29] WMO and RIMES Joint Strategy and Action Plan (JASP) has been established in 2022 to enhance capacity of NMHS and climate sensitive sectoral ministries institutions to deliver climate early warning services.