ICIMOD

PROCEEDINGS OF THE

Regional knowledge forum on early warning for floods and high-impact weather events

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About SERVIR

SERVIR connects space to village by helping developing countries use satellite data to address challenges in food security, water resources, weather and climate, land use, and natural disasters. A partnership of National Aeronautics and Space Administration (NASA), United States Agency for International Development (USAID), and leading technical organizations, SERVIR develops innovative solutions to improve livelihoods and foster self-reliance in Asia, Africa, and the Americas.

SERVIR Hindu Kush Himalaya

The International Centre for Integrated Mountain Development (ICIMOD) implements the SERVIR Hindu Kush Himalaya (SERVIR-HKH) Initiative – one of five regional hubs of the SERVIR network – in its regional member countries, prioritizing activities in Afghanistan, Bangladesh, Myanmar, Nepal and Pakistan.

About GEOGloWS

GEOGLoWS, a Group on Earth Observations (GEO) initiative, has been established to pioneer scientific and global collaboration to provide relevant, actionable water information and to promote the use of Earth observations in the decision-making process, while promoting the strengthening of observational networks.

About Himalayan GEOSS

ICIMOD implements the Himalayan GEOSS Initiative, a Task Group of Asia Ocenia Group on Earth Observation (AOGEO), focusing on the Hindu Kush Himalayan countries to promote Earth observation for societal benefits. Himalayan GEOSS contributes to the development of a spatial data infrastructure in the region through promotion of policy, standards and practices for open access to data, information and services.

Contents

Abbreviations and acronyms

ADPC	Asian Disaster Preparedness Center
AMD	Afghanistan Metrological Department
BUET	Bangladesh University of Engineering and Technology
BYU	Brigham Young University
CBFEWS	Community Based Flood Early Warning Systems
DMH	Department of Meteorology and Hydrology
DRR	Disaster Risk Reduction
ECMWF	European Centre for Medium-Range Weather Forecasts
EWS	Early warning system
FFGS	Flash Flood Guidance System
FFWC	Flood Forecasting and Warning Centre
GEO	Group on Earth Observations
GEOGLOWS	GEO Global Water Sustainability
GPM	Global Precipitation Measurement
GloFAS	Global Flood Awareness System
HIWAT	High Impact Weather Assessment Toolkit
HKH	Hindu Kush Himalaya
HMS	High Mountain Summit
ICIMOD	International Centre for Integrated Mountain Development
LMR	Lower Mekong Region
MAIL	Ministry of Agriculture, Irrigation and Livestock
MLR	Multiple Linear Regression
MRC	Mekong River Commission
MoHA	Ministry of Home Affairs
NASA	National Aeronautics and Space Administration
NCHM	National Center for Hydrology and Meteorology
NDMA	Afghanistan National Disaster Management Authority
NESAC	North Eastern Space Applications Centre
NMME	North American multi model Ensemble
OFDA	Office of U.S. Foreign Disaster Assistance
PCR	Principal Component Regression
RAPID	Routing Application for Parallel Computation of Discharge
S2S	Sub-seasonal to seasonal
SCO	Science Coordination Office
SERVIR-HKH	SERVIR Hindu Kush Himalaya
USAID	United States Agency for International Development
WMO	World Meteorological Organization

Executive summary

National hydrological and meteorological authorities help resilience and recovery in communities by providing early warning information in the face of disaster events. Concurrently, national and local decision makers also require actionable information to make best possible decisions while committing resources before, during, and after disaster events. A lack of skilled human resources and standardized tools and technologies, and weak institutional and governance mechanisms impede efforts to generate and disseminate effective early warning information. As disaster events – particularly floods, which account for a third of all disaster events in the HKH – often transcend country boundaries, national efforts alone are not sufficient. Regional cooperation among neighbouring countries is essential.

In light of these challenges, ICIMOD convened a regional knowledge forum on early warning for floods and high-impact weather events in Kathmandu, Nepal from 22–23 October 2019. The two-day event was organized under ICIMOD's SERVIR Hindu Kush Himalaya (SERVIR-HKH) and Himalayan GEOSS initiatives, jointly with GEO Global Water Sustainability (GEOGLOWS). The event brought together professionals and researchers representing regional, national, and local institutions engaged in providing extreme weather forecasts and flood forecasts, and establishing related Early Warning Systems (EWS).

The forum deliberated on key areas related to regional and national hydrological and meteorological services for EWS in South and Southeast Asia. These included ongoing efforts to generate and disseminate early warning effectively and efficiently across different levels, and computing infrastructure and hydroinformatics tools required to enable widespread use of Earth observation information,

At the forum representatives from national hydrological and meteorological authorities and non-governmental/research organizations in Afghanistan, Bangladesh, Bhutan, India, Myanmar, Nepal, and Pakistan shared current practices and challenges in generating and disseminating early warning on natural disasters. Representatives from global and regional initiatives also shared progress, challenges and best practices in implementing early warning systems in South and Southeast Asia.

The event also shed light on ICIMOD's collaboration with the SERVIR Applied Science Teams to enhance current flood forecasts by integrating global satellite and modelled data with regional and local forecasts. The collaboration has produced ongoing medium-range forecasts for every river stretch and accompanying retrospective hindcasts. Of particular note is the High Impact Weather Assessment Toolkit (HIWAT), a weather forecasting tool that provides additional lead time for forecasting authorities to reduce the impact of high-impact weather events. HIWAT's forecasted precipitation is also routed to predict flooding extents. These regional services can strengthen and support national and local efforts and expertise in developing hydro-meteorological information that allows for investments to enhance decision-making practices.

During a dedicated session on the social components of EWS, communicating risks, and community-based forecasting, participants from ICIMOD, Mercy Corps, Practical Action, Red Cross Red Crescent Climate Centre, and the World Food Programme shared their experiences engaging communities in flood EWS and disaster preparedness activities.

The forum provided a platform to discuss the challenges associated with the development, implementation, dissemination, and sustained use of information services for water and weather-induced disasters. Possible recommendations to address these issues were also discussed. Participants recommended leveraging expertise across national boundaries, holding regular quorums at the regional level, training forecasters to generate user-friendly forecasts, and training media persons and communities on technical concepts in forecasts. They also recommended engaging community networks and the private sector to relay early warning information to end users.

The two-day event was followed by a consultation workshop with partners to discuss achievements and a way forward for early warning systems for flood and extreme weather events developed under SERVIR-HKH.

SECTION 1

Background

Water- and weather-related disasters result in the loss of life and billions of dollars annually. The problem demands an all-hands-on-deck approach from the broad hydrological and meteorological scientific community, in partnership with water and disaster management communities. Collaboration across disciplines is essential in order to develop impactful solutions that support national and local authorities in providing adequate early warning to communities and helping their resilience and recovery in the face of disaster events. In all cases, national and local decision makers have the responsibility of committing resources before, during, and after, and must rely on actionable information to make the best possible decisions.

SERVIR seeks to disseminate such information through its different hubs. SERVIR connects space to village by helping developing countries use satellite data to address challenges in food security, water resources, weather and climate, land use, and natural disasters. A partnership of National Aeronautics and Space Administration (NASA), United States Agency for International Development (USAID), and leading technical organizations, SERVIR develops innovative solutions to improve livelihoods and foster self-reliance in Asia, Africa, and the Americas. The International Centre for Integrated Mountain Development (ICIMOD) implements the SERVIR Hindu Kush Himalaya (SERVIR-HKH) Initiative – one of five regional hubs of the SERVIR network – in its regional member countries, prioritizing activities in Afghanistan, Bangladesh, Myanmar, Nepal, and Pakistan.

Work carried out by SERVIR with the Applied Science Teams has demonstrated that current flood forecasts can be enhanced by integrating global satellite and modelled data with regional and local forecasts. This supports the work of hydromet agencies and their goal of providing access to timely and relevant information for decision makers. It has produced ongoing medium-range forecasts for every river stretch and accompanying retrospective hindcasts – historical simulations that put the forecasts in context and provide surrogate observational datasets to support and strengthen existing national systems.

Moreover, since global models generally do not capture local meteorological phenomena, regional modelling systems are critical for providing valuable information for early warning on floods and high-impact weather events. In an effort to support national systems, SERVIR has developed a High Impact Weather Assessment Toolkit (HIWAT). This weather forecasting tool is intended to provide additional lead time for forecasting authorities so that local decision makers can prepare for and reduce the impact of high-impact weather events – lightning, damaging winds, hail, and flash floods. HIWAT relies on a mesoscale numerical weather prediction model that is partially informed by NASA satellite observations to provide a probabilistic forecast for extreme weather hazards. Also, HIWAT's forecasted precipitation is routed to predict flooding extents. These regional services are intended to strengthen and support national and local efforts and expertise in developing hydro-meteorological information that allows for investments to enhance decision-making practices.

Goals and objectives

Deliberate on key areas related to regional and national hydrological and meteorological services for EWSs in South and Southeast Asia

Understand ongoing efforts on forecast and EWSs and discuss issues related to generation, dissemination, and use of EWSs

Demonstrate and discuss the ICT infrastructure and hydroinformatics tools that are enabling widespread usage of Earth observation data in flood early warning and high-impact weather forecasting

Understand how best to disseminate information effectively at different levels – national governments to communities

Participants

The knowledge forum brought together users and producers of information services in South and Southeast Asia. They included professionals and researchers from regional, national, and local institutions that provide extreme weather forecasts and flood forecasts and establish related EWSs.

Expected outputs

Review and assessment of existing regional and national hydrological and meteorological services for EWSs in South and Southeast Asia

Review of current advances in early warning services, Earth observation technologies, and modelling and its relevance to countries in the HKH region

Identification of gaps and needs for sustained information services at the regional and national levels

SECTION 2

Sessions

Session 1: Opening session

Ghulam Rasul, ICIMOD, welcomed all participants to the regional knowledge forum on early warning for floods and high-impact weather events at ICIMOD. He introduced the SERVIR Hindu Kush Himalaya (SERVIR-HKH) Initiative, and shared the background and objectives of the two-day forum.

Basanta Raj Shrestha, ICIMOD, welcomed partners, representatives from national meteorological and hydrological services from seven ICIMOD regional member countries, UN representatives, USAID and NASA and UN agencies. The recently published Hindu Kush Himalaya Assessment report states that disaster risk is increasing in the HKH region. The rapid pace of climate change, and other changes have resulted in increased frequency and magnitude of disasters – floods, drought, landslides, glacial lake outburst floods (GLOF)s – in the region, exacerbating the vulnerabilities of mountain people, downstream environments, and infrastructure. Floods constitute one-third of these disasters, and many of these events have cross-border ramifications. More than 1 billion people in the region are estimated to be at risk. This forum underscores the importance of developing early warning systems for floods and high-impact weather events and showcases tools, technologies and innovations in this area. The event also underscores the importance of vulnerable people – men, women and children, and the need to develop technology and tools to save lives and property. Reducing disaster risk and enhancing community resilience in the HKH has been the hallmark of many ICIMOD programmes and initiatives for many years. ICIMOD has prioritized strengthening resilience to climatic risks and hazards, focusing on high-intensity rainfall and extreme events. ICIMOD also carried out pioneering work on developing an inventory of potentially dangerous glacial lakes, regional flood information systems and community-based early warning systems. Many of ICIMOD's initiatives and programmes focus on research, applied research, knowledge generation and dissemination, and policy imperatives from a disaster management point of view.

Adriana Hayes, USAID, shared her experiences from the 2007 cyclone Sidr in Bangladesh, which caused a lot of deaths and damage, and resulted in large-scale evacuations. An early warning system helped reduce the number of casualties as people took refuge in schools and cyclone shelters. She offered encouragement and support to participants representing different organizations and different interests at the forum. A lot of people would benefit from the discussions and information shared on high-impact weather events during the two-day forum. The impact of weather in Nepal is visible every year. About 1.5 percent of the total GDP in Nepal is lost due to weather events. A hurricane struck Bara and Parsa districts for the first time in Nepal last year, tragically killing 20 people and displacing hundreds more. This incident shows that we need accurate and timely weather forecasting. We need to be able to share these forecasts so that people can take action. Weather events are now more severe and ever more omnipresent.

SERVIR, a partnership between the US Agency for International Development (USAID) and the National Aeronautics and Space Administration (NASA), ideates that we can take lessons from space to benefit people at the village level. It takes geospatial data and Earth observation information to address challenging development issues including food security, water resource management, and disaster risk reduction, among others. Through this partnership, USAID and SERVIR achieve a common goal of promoting evidence for policy decisions. We are working towards encouraging open data. A lot of expert data is out there – some of it is compartmentalized; some is not shared and not everyone can use it. We want to take some of this data to help government officials and individuals on the ground to make smart decisions. Tootle and Foodmandu are some examples of the private sector making innovative use of open data made available through Open Street Maps. In the same way, open data on natural hazards – floods and disasters, can also be used to improve the lives and safety of millions of people in this region.

Abdoulaye Harou, World Meteorological Organization (WMO), conveyed sincere appreciation on behalf of the secretary general for the invitation to the event. He recognized the regional forum as an important event for sharing expertise and developments on floods and weather-related disasters. He added that the event was timely as the event outcomes would inform the outcomes of the High Mountain Summit (HMS) being organized by the WMO in Geneva, Switzerland at the end of the month. The WMO Congress's approval for the HMS shows how important high-mountain floods and high-impact weather events are for WMO members. The Summit would lead towards the development of a roadmap for high mountains with focused activities and regionally tailored actions. The WMO is also facilitating the sharing of high-value hydro-meteorological information to assist members in delivering early warnings to save lives and properties, primarily through three initiatives – the Severe Weather Forecasting Demonstration Project, the Flash Flood Guidance System, and the Coastal Inundation Forecasting Demonstration Project.

Walter Lee Ellenburg, NASA SERVIR Science Coordination Office (SCO), shared that SERVIR, a NASA and USAID partnership, brings forth science and relevant information in the development context to achieve important development goals. A major mandate of NASA is to understand our Earth better. As NASA continues to send satellites into space, these satellites provide us with a unique vantage point for looking back into Earth and understanding change. Water and weather do not respect physical boundaries. This forum brings together representatives from national meteorological and hydrological institutions, and organizations like Mercy Corps and Red Cross. It aims to address how best to mitigate and adapt to water and weather related disasters.

Birendra Bajracharya, ICIMOD, delivered the vote of thanks, thanking everyone for their time and called for active participation during the two-day forum. He acknowledged support from USAID and NASA and the Applied Science Team in realising this important knowledge sharing event.

Session 2: Regional-scale flood forecasting systems

Arun Bhakta Shrestha, ICIMOD, moderated the session. The session included presentations on regional-scale flood forecasting systems.

Jim Nelson, Brigham Young University (BYU), gave the keynote presentation titled "GEOGLOWS: Revolutionizing the delivery of water information". He introduced the Group on Earth Observations (GEO), and GEO Global Water Sustainability's (GEOGLOWS) goal – to provide relevant, actionable information about water using Earth observation and strengthen observation networks in local observation frameworks. GEOGLOWS aims for a global stream flow forecast that is freely available, providing actionable information as a service, to places where little or none exist, and filling gaps that can complement and strengthen national, regional, and local efforts. If countries adopt GEOGLOWS's global stream flow services, they no longer need to develop their own internal infrastructure for modelling; they can access stream flow forecasts through web services and use them according to their own prioritized needs. This freely provided stream flow information, which leverages the hydro-meteorological computational expertise of the GEOGLOWS partnership, saves millions of dollars and allows national and local agencies to focus precious resources on developing solutions and applications specific to their local water resources management needs.

Mandira Shrestha, ICIMOD, highlighted the ever-increasing frequency of flooding events in the Hindu Kush Himalayan (HKH) region and the economic and human impact of flood disasters. Development in technology has enabled sharing of real-time data and information and development of flood information system at a basin scale to support flood forecasting in the region. The region needs strengthening of monitoring station networks and data sharing along with capacity building and training to enhance cooperation and partnerships in the region. Efforts need to be made for risk communication, awareness raising and better preparedness. The Hindu Kush Himalaya-HYCOS project at ICIMOD was established to strengthen technical and institutional capacities of national hydro-meteorological services, establish a network of key national stations in the HKH region, and promote and facilitate dissemination and use of flood-related information.

Mir Matin, ICIMOD, highlighted key development challenges in the HKH region – flood hazards, drought and food security, damaging extreme weather conditions and forest degradations and vulnerabilities. Current flood early warning systems in the HKH are inadequate – they do not provide enough lead time, provide limited information content, lack skilled manpower for operation, incur high maintenance costs, and lack standardization. The SERVIR medium range flood forecasting service uses downscaled ECMWF Global Flood Awareness System (GloFAS) model outputs for water balance, Routing Application for Parallel Computation of Discharge (RAPID) model for stream flow prediction at river reaches and the Tethys platform for visualization of model forecasts, and development of custom applications to cater to users' needs. The High Impact Weather Assessment Toolkit (HIWAT) flood forecasting tool captures localized extreme event,s and the information is disseminated using the same customizable Tethys platform. The open access Hydrostat tool, part of the Tethys platform, can be used for validation of stream flow prediction outputs against observed data. Martin shared instances of the SERVIR flood prediction tools being used for Bangladesh, Bhutan and Nepal.

Michael Ernst, Office of U.S. Foreign Disaster Assistance (OFDA), talked about USAID/OFDA's support for flood early warning systems. The USAID/OFDA mandate is to save lives, alleviate suffering and reduce the social and economic impact of disasters. Floods are often transboundary, and the region lacks local capacity and regional cooperation to tackle this problem. For an end-to-end early warning system (EWS), improvements in preparedness and early response are necessary. It requires hazard data, forecasts, risk information, communications and dissemination mechanisms for effective preparedness and quick response. USAID/OFDA supported the regional implementation of the Global Flash-flood Guidance System – South Asia Regional Flash Flood Guidance System – in support of national hydromet agencies. OFDA has also been supporting the development of weather-ready nations, by supporting national end-to-end EWSs, impact-based forecasting that rely on local impact knowledge connected to national forecasting capacity, and organization networks to spread and strengthen community-based disaster risk management. Established/operational global and regional centres need to work together beyond borders to promote exchange of data, forecast, information, knowledge and experiences as hydro-meteorological hazards do not recognize national boundaries. USAID/OFDA promotes mentoring among peers to increase lead times for early warnings. Building the capacity of host nations is critical for ensuring uninterrupted service delivery in order to sustain early warning systems. USAID/OFDA has trained about 350 scientists from over 100 developing countries in climate prediction and applications.

Senaka Basnayake, Asian Disaster Preparedness Center (ADPC), presented on how ADPC has strengthened flood forecasting and warning in the Lower Mekong Region (LMR). Floods are common in the LMR, and ADPC has been working to strengthen flood forecasting systems, communication and dissemination approaches, and build the capacity of communities. ADPC has also been identifying and addressing data and information needs to establish long-term geospatial information and tools to support decision makers. Under its SERVIR-Mekong Initiative, ADPC has developed the Virtual Rain and Stream Gauge Information Service to provide near-real time virtual rainfall gauge and virtual stream gauge data sets for the LMR region, for use in disaster risk reduction of hydro-meteorological and related hazards – floods, landslides, etc. Working closely with the Regional Flood and Drought Management Centre of the Mekong River Commission (MRC), ADPC plans to integrate near real-time Global Precipitation Measurement (GPM) into the MRC flood forecasting system to improve early warning on floods in the LMR. ADPC has developed bias correction and data assimilation tools to improve rainfall accuracy, and incorporated satellite-based rainfall products into the MRC flood forecasting system, as well as provided technical trainings to implement bias correction algorithm into the operational flood forecasting system. They conducted hydrological sensitivity analysis to see how three GPM bias-corrected products respond to stream flow within the studied area of the LMR, and conducted trainings on GPM-Bias corrected (BICO) for the MRC, and are planning to implement the GPM-BICO in their system and test in November 2019.

AKM Saiful Islam, Bangladesh University of Engineering and Technology (BUET), shared information on the use of open source tools and techniques for flash flood forecasting in Bangladesh. He shared information on the impacts of flash flood events in Northeast Haor areas of Bangladesh in the upper Meghna Basin, and the challenges of flash flood forecasting. He described the use of open source based flash flood forecasting and early warning in four steps: 1. weather forecast 2. runoff forecast 3. stage forecast, and 4. early warnings.

DISCUSSION

The panellists answered queries about uncertainties in runoff at larger scales, the performance of the flash flood prediction tool in Nepal, and the difference between floods and flash floods:

- A lot of validation work has been carried out at the basin scale, and is accurate enough for use. The model depends on the accuracy of underlying dataset from the European Centre for Medium-Range Weather Forecasts (ECMWF). Over time data from ECMWF will improve, which will further improve the accuracy of the model.
- The flash flood tool for Nepal is able to capture the peaks but due to the lack of data at smaller streams, there is a challenge for validation.
- Floods in general are in riverine areas and

low-altitude areas. Flash floods usually occur in upper mountains, resulting from cloud outbursts and GLOFs, among others. Flash floods usually occur in smaller watersheds. Data standards are different. More models would help provide more information. Global models need to be working in tandem with local models.

PANEL DISCUSSION

Questions:

What are the needs of the regional flood forecasting system in the HKH? What future developments do you see?

What are the issues related to data sharing and what kind of regional collaboration is needed to address those issues?

What are the major gaps in regional scale flood forecasting systems? How can those be overcome?

How can transboundary issues in regional flood forecasting be overcome?

Jim Nelson said that data sharing among agencies is critical and that it is important to integrate simulation data with local station data. Smaller watersheds and flash flood prediction require multiple models and a combination of global and local models and station data.

Mandira Shrestha discussed the importance of continuous data sharing and standardization of data formats and models across countries. Partnerships between host countries, and between partners and local actors, are needed to improve systems. A communication channel from space to country to local users is important.

Mir Matin discussed issues related to data sharing and regional collaboration. Data collection networks are not adequate. Very limited stream discharge data is available. Most of the stations are manual stations and international standards are not followed across countries. There is also a need for a platform for data sharing and data policy. NMHS lack trained human resources.

Michael Ernst highlighted gaps in regional forecasting systems. There are huge opportunities for regional collaboration, and the region could set an example. Using a bottom-up approach rather than a top-down approach and understanding community needs is important. Regional agencies can help national agencies in providing a platform to bring different forecasting tools and communities, and a broader range of players and agencies to learn from each other. Different communities have different problems. To find a good model that fits the community, attention should be paid to the needs of communities, local agencies, women, and vulnerable people.

AKM Saiful Islam spoke about issues in regional flood forecasting systems. He said not only observed data but forecast information is also important. Due to lack of forecast sharing between countries, countries often blame each other during disasters. Downstream communities can benefit from forecast information. Capacity building is important. There is a huge opportunity to learn from each other. Local knowledge is important; the best forecasts for their area can be developed by NMHSs themselves, so sharing forecasts across boundaries is necessary.

The panel also talked about capacity building of media, communities and people.

Session 3: Status of flood forecasting in HKH countries

Jim Nelson, BYU, moderated the session. The session included five presentations on the status of flood forecasting and early warning systems in Afghanistan, Bangladesh, Bhutan, Myanmar, and Pakistan.

Zabiullah Siawash, Afghanistan National Disaster Management Authority (NDMA), presented on “Forecasting Systems in Afghanistan”. He provided an overview of the different forecasting systems in Afghanistan. The Afghanistan Metrological Department (AMD) operates the Afghanistan National Forecasting System. It makes use of the AMD’s network of meteorological stations, EUMETcast satellite images, METCAP+ and the Flash Flood Guidance System (FFGS). Models used in METCAP platform are GFS, EGR1, etc. The Ministry of Energy and Water (MEW) operates 125 hydrological stations (of which 3 are EWSs), 26 weather stations, 30 snow survey stations, 43 cableway stations, and 2 EWS stations. The ministry disseminates warning through social media and has established local warning systems. The Ministry of Agriculture, Irrigation and Livestock (MAIL) also has data stations – 103 rain gauges, 4 classic temperature and humidity data collection stations, and 9 automatic temperature and humidity data collection stations in nine different zones. The State Ministry for Disaster Management & Humanitarian Affairs/ Afghanistan NDMA has the mandate to coordinate and manage all aspects of disasters mitigation, preparedness and response through its national and provincial offices along with partner organizations. The organization gathers early warning information from various sources and disseminates it through state television, radio, mobile phones, and codon telecom. Despite several organizations working on forecasting, there is still a lack of automatic, real-time and coordinated hydro and agro-metrological forecasting and information management.

Arifuzzaman Bhuyan, Flood Forecasting and Warning Centre (FFWC) presented on flood forecasting and warning services in Bangladesh. The Bangladesh Water Development Board is responsible for water and flood management in the country. It implements two strategies for flood management – structural measures (embankments, polders) and non-structural measures (flood forecasting). FFWC provides flood forecast in the form of river water level, and issues flood warning when water level exceeds danger levels in a particular station. It also carries out preparedness activities ahead of flood and emergency management during floods. FFWC has 94 water level stations and 59 rainfall stations. It uses manual methods for data collection: gauge readers transmit data via SMS on mobile phones. Flood forecast during monsoon is based on outputs from 54 stations; 25 stations are used for flash flood forecasting. FFWC uses three flood models for flood forecasts – Basin Scale Hydrological Model, MIKE 11 Hydrodynamic Model and MIKE GIS – and provides five-day deterministic forecasts, and 10-day probabilistic forecast in monsoon. Flash flood forecast is based on 48–72 hour water level forecast. The centre disseminates flood warning through email, fax, phone, websites, SMS, printed materials and IVR using mobile phones. Providing location specific flood forecast and seasonal flood forecasting is still difficult for the current flood forecasting system. Streamflow prediction for the entire country has also been done in collaboration with ICIMOD.

Lha Myint, Department of Meteorology and Hydrology (DMH), presented on flood early warning systems in Myanmar. In Myanmar, the DMH is mainly responsible for observing meteorological, hydrological and seismological phenomena to provide necessary information for disaster prevention/mitigation and the development of socioeconomic activities. The organization cooperates with local and international organizations to upgrade and promote EWSs for natural disaster reduction in Myanmar. A total of 44 stations are used for hydrological monitoring and forecasting. The DMH employs different operational flood forecasting techniques for daily water level forecasts and seasonal water level forecasts. It disseminates flood warning through bulletins, TV, radio/FM, newspaper, website, social media (Facebook), and a call centre operated by the Ministry of Information and DMH. The DMH has already developed a flash flood guidance system for the entire country. The country possesses numerous transboundary basins and has realized the need for coordination and collaboration to further improve the flood forecasting system. The country still lacks hydro-met stations in most upstream rivers in the northern part. There is also need to improve the hydrological monitoring system and hydrological network in the country.

Tandin Wangchuk, National Center for Hydrology and Meteorology (NCHM), presented on the status of flood forecasting and early warning system in Bhutan. The presentation focused on the need to establish or enhance flood forecasting and warning systems. Several models that have been developed run on a daily basis for flood forecasting. Currently, two models are used for two river basins in Bhutan – the HBV hydrology model for the Yebesa basin and the HEC-HMS model for the Wangchu basin. The HBV model provides three-day forecasts, which is a direct output of the WRF model used at the NCHM. This supplements the existing early warning system in the basin. The HEC-HMS model is integrated in the decision support system (DSS), which will be used for forecasting and warning purposes soon. A similar model has been developed for the Amochhu basin, and will be integrated into the DSS. The early warning systems in the country are primarily meant for warnings about glacial lake outburst floods (GLOF). Currently, the NCHM operates the early warning system for two major basins – Puna-wangdi and Chankhar-Mangde. The NCHM also has a Flash Flood Guidance System (FFGS) in place, which aids forecasters in identifying places where flash floods are imminent. The NCHM currently operates over 200 stations across the country at different elevations and river basins. There are 155 meteorological/climate stations, which include both automatic and manual stations. Similarly, the institution operates 59 hydrological stations, both automated and manual, 20 cryosphere monitoring stations and 16 sediment sampling stations.

Nadia Rehman, Global Change Impact Studies Centre, Pakistan, presented on early warning system and flood forecasting in Pakistan. The statistical downscaling technique is used to predict the rainfall, using Multiple Linear Regression (MLR) and Principal Component Regression (PCR) methods. Monthly station data is obtained from the Pakistan Meteorological Department (PMD). An early warning system (EWS) has four key components: risk knowledge, monitoring and warning, dissemination and communication, and response capability. Several institutions are involved in forecasting. In 2018, the World Bank expressed its intent to finance strengthening and upgrading of the PMD's early warning system. The PMD maintains satellite ground stations (HRPT, DVB, SADIS) in Islamabad, Quetta and Karachi. Tools for flood forecasting include a weather surveillance radar with a nationwide network, satellite ground station, computer models, meteorological analysis centre, and remote sensing. Forecast for stakeholders is done for three types of flood – floods due to the intensity of the south-west and south-east monsoon currents; floods due to the indirect effect of monsoon depression; and floods due to the direct effect of monsoon depression. Flood forecasting and warning dissemination is done through national agencies, provincial authorities and fax to media.

DISCUSSION

- The AMD in Afghanistan collects, compiles, organizes, analyzes, and recommends solutions for usage based on information derived from multiple models employed.
- The NCHM in Bhutan implemented the flash flood guidance system a year ago; the FFGS is still being tested to check if it is fit-for-purpose for Bhutan. It captures heavy rainfall really well, but does not capture localized cloudbursts. By ingesting more data on rainfall and land use, the system could possibly give us better data. All models that we developed are integrated with real-time observation stations located in particular basins where we are modelling. Bhutan does carry out hazard assessments, but not for the FFGS. More data is needed and multiple aspects need to be considered specifically for hazard assessment.
- The DMH in Myanmar is working with ADPC and other agencies to prepare flood hazard maps and flood risk maps.
- The FFGS in Pakistan did face some problems in accuracy while providing locations of flash flood. Topographic factors also affect accuracy, which is an important consideration. Such shortcomings can be overcome.
- A major challenge in the Brahmaputra river basin is lack of an accurate digital elevation model (DEM). Bangladesh shares this problem. A more accurate DEM developed from Lidar and Synthetic-aperture radar (SAR) at the regional level would be especially useful for developing more realistic scenarios for the alluvial flood plains.
- For an inundation system, models do not predict accurately because of the presence of embankments, and physical structures. Remote sensing based models can only predict for dry seasons, and will not be as accurate for flood seasons, unless embankments are accounted for by models.
- It would be interesting to know the impact of flood forecasting systems being implemented – how many people have been saved or how many disasters have been prevented? As lots of money is fed into these systems, we would like to know about the impacts of such systems.
- The request for DEMs has been on for quite some time now. We have considered where we invest our money and make the best use of available resources. The Brahmaputra moves a metre a year and has a complex dynamics. Given the unpredictable nature of the river, investing in a DEM may involve some risk. Investing in a DEM in such a situation could be a hard investment to sell. We need to take stock of the situation and start working with what we have now, and reduce risks. Then it will be easier to ask donors for better technology.
- In 2007, ICIMOD installed a flash flood early warning system in a stream in Pakistan. There was no flood-related casualty thereafter. This is a success story. We need to convince governments to invest in early warning systems to save lives and infrastructure.
- We should strive to form other commissions like the Mekong River Commission. This would involve many challenges. We have worked to develop a regional information system. A lot of work needs to done to establish a commission.
- Scientists develop models to meet the expectations of users and stakeholders using available data and information but there are uncertainties. Humans make decisions every day based on uncertainties and risks. Decision making based on models is also based on uncertainties. Scientists need to convey this better so that users can use the information efficiently.

Session 4: Seasonal outlooks

Cedric David, NASA Jet Propulsion Laboratory, moderated the session. The session showcased work carried out under SERVIR-HKH and SERVIR-Mekong on generating sub-seasonal to seasonal (S2S) forecasts to improve agricultural resilience in the Hindu Kush Himalayan and Lower Mekong regions.

Mir Matin, ICIMOD, presented on the drought monitoring and forecast with the NASA HKH S2S. He explained the methods for optimizing monitoring, different meteorological forecasts and the merging of SALDAS with forecasts. Drought monitoring and forecast was meant for seasonal outlook for drought but the system also produces hydrological outlook, which is not ready now but the work is in progress. He showed seasonal forecast results with different forecast models and said that the modelling system is embedded with North American multi model Ensemble (NMME), which is downscaled using the generalized analog regression downscaling method. Downscaled historical information from SALDAS provides inputs to the forecast system and validation of the system is done with CHIRP observed and SALDAS forecast date. He stressed that the system is currently capable of generating outlooks for six months, but they are working to produce three-month outlooks. He showed a user interface for regional drought monitoring and outlook, and the national agricultural drought watch for Nepal.

Senaka Basnayake, ADPC, presented on how agricultural resilience to drought has been improving in the lower Mekong region with seasonal outlooks. He shared a few stories about drought in different countries. Severe droughts in Vietnam have resulted in loss of rice production. Earth observation inputs and Met data inputs are being fed into the model to generate outputs in the form of different maps that are being shared via a web-based user interface, which can be accessed by the public and used for research and decision making at the local and provincial level. Initial testing is being conducted at two pilot sites at the district level to provide information to farmers. Stakeholder engagement at the national level and capacity building for seasonal forecasting in the Mekong region using the Regional Hydro-Extreme Assessment System (RHEAS) modelling have also been undertaken. The VAWR information portal provides information to stakeholders and the MRC drought portal provides information on drought to support national Mekong committees in countries that share the Mekong river basin. ADPC has other technical assistance collaborations with FAO, WFP and PDC for developing drought management strategies for Vietnam and Mekong River Commission (MRC).

PANEL DISCUSSION

- The primary focus of the Regional Drought Monitoring and Outlook System is agricultural drought. The information generated on hydrological drought is supplementary. In June 2018, we developed an agricultural drought monitoring and early warning system which assimilates drought parameters and agricultural practices that can be used to inform better crop management.
- ICIMOD is working with partners to improve the forecast model and provide forecasts at weekly or ten-day intervals.
- Satellite data, CHIRP/CHIRPS have been assimilated in the RDMOS. ICIMOD is working with partners to incorporate in-situ data as well. We are also working to use ground water data in the system. The system is capable of assimilating additional data.
- ADPC is working with partner organizations in drought-affected areas in different provinces in Vietnam and Myanmar to incorporate socioeconomic variables of agricultural drought. ADPC/SERVIR Mekong is planning to work on a pilot site with Vietnam to get more information and to study the increased pressure caused by migration and other socioeconomic variables in surrounding areas.

Eklabya Sharma, Deputy Director General, ICIMOD, talked about the HKH assessment carried out by ICIMOD and partners. The recently published "Hindu Kush Himalaya Assessment" is one of the most comprehensive reports produced by ICIMOD. All three pillars of sustainable development – environment, social, and economic – have been addressed in the report. We agreed to limit global temperature to 1.5°C increase. Four years have passed already. At the current increase rate, temperatures are going to rise by 2.1°C in some places in the Hindu Kush Himalaya, while some places will be 5.5 degrees warmer. In this context, we need to bring more information, more accurate analysis, and decision support to the government actors who are going to be key planners and implement programmes in this region. The assessment found that there are many uncertainties specific to the HKH region that need to be addressed. People living in the mountains and river basins are more vulnerable. People's livelihoods are directly connected with this issue. ICIMOD is working towards a 15–20 year action plan for the eight regional member countries. The call to action will be endorsed at a high-level summit of high-level government representatives from these countries.

Eklabya Sharma concluded the session and invited all participants to attend a reception dinner hosted by ICIMOD.

Session 5: Regional-scale extreme weather forecasting

Ghulam Rasul, ICIMOD, moderated the session. The session focused on regional-scale extreme weather forecasting and incorporated voices from the World Meteorological Office (WMO), NASA Marshall Space Flight Center (MSFC), Indian Meteorological Department (IMD), Bangladesh Meteorological Department, and the North Eastern Space Applications Centre (NESAC). This session showcased the ongoing work across the region and prompted a robust dialogue elucidating the significant overlap of meteorological and hydrological approaches. Through a series of presentations and panel conversations, various challenges such as super computing infrastructure, capacity building and trainings, advancements for impact-based forecasting (IBF), workflows for warning dissemination, and overall communication between agencies and parties were discussed.

PANEL DISCUSSION

- Long-range forecast gets regional scale information from global centres. High-resolution models can provide a guidance system for orographic precipitation in high mountain regions. The model needs to be fine-tuned for better results. More information is needed from high mountain regions to achieve this. A requirement assessment needs to be carried out and the WMO is working on this. National agencies need to implement national climate service plans. In-situ radar station data need to be integrated with regional models.
- The WMO is working on a strategic plan to strengthen cooperation between countries. Technical commissions, regional centres and regional associations should take responsibility and hold discussions to identify the needs.
- The Brahmaputra basin is a good model to follow. Information and data is shared among different nodal agencies in the countries.
- Multiple models are now available. Different assumptions exist regarding model outputs; one model may be more accurate than the other. Ensemble forecasts capture a range of scenarios and one may be more accurate than others. Thus combinations capture events more accurately.
- Ensemble forecast is a new way of moving forward. Ensemble is a key requirement. Although deterministic forecasts are also available, ensemble forecast is now the dominant trend in prediction.
- Multiple rainfall systems occur in India. IMD uses multiple rainfall model systems based on season, resolution and altitude. The forecaster selects the best model for forecasts based on multiple model runs.
- Bangladesh does not have enough satellite observations or sufficient radar stations. More observatories and macro scale models are needed. Observation radar stations currently operate at three-hour intervals; they need to operate at 10-minute intervals to deliver better forecasts.
- In India, NESAC uses data from IMD and vice versa. IMD also contributes to the system. Similarly, ISRO complements IMD's work in disaster management. ISRO provides inundation data and IMD provides forecasts. ISRO provides inundation maps in real time.

Session 6: Social components of EWSs, communicating risks, and community-based forecasting

Amanda Markert, NASA SERVIR SCO, moderated the session. The session included presentations from the World Food Programme (WFP), Red Cross Red Crescent Climate Centre, ICIMOD, Practical Action, and Mercy Corps.

Priyanka Singh, WFP, presented on WFP's approach on forecast-based financing (FBF). Extreme weather events are increasing globally and so is the need for humanitarian response. FBF and emergency preparedness is an innovative mechanism where early actions are taken at the community and government level. It is based on FBF interventions and is vital for minimizing loss of life and property, and increasing resilience of the community. FBF supports governments and communities in Nepal to better understand and manage disasters before they happen. The national policy and strategic action plan for DRR has set a goal to significantly reduce the loss of life and property. Nepal's national DRR policy 2075 B.S. has also endorsed forecast-based emergency preparedness. WFP is implementing FBF plans in Banke, Bardiya, Jhapa and Saptari districts. The Ministry of Home Affairs (MoHA) and the Department of Hydrology and Meteorology have been supporting WFP in implementing FBF since 2015. Partnerships with eight local governments, Nepal Red Cross Society and Koshi Victims Society have been initiated to implement the FBF approach through capacity strengthening and early preparedness.

Pre-disaster action ensures that forecast information is accessible to end users, and resources are pre-allocated based on forecasts, thereby increasing response time and reducing loss of life and property. Key benefits of investing in forecast-based financing are as follows:

With investment based on FBF, we can save up to USD 22 million in response costs

Over a 20-year period we can save USD 34 for each dollar invested after deducting investment cost

0.5 days can be saved and a more systemized response can be expected/achieved

42 kg of CO_2 emissions can be saved per dollar invested over 20 years

In the absence of a proper network of meteorological stations, satellite rainfall estimation can help measure spatial and temporal variations in precipitation after bias correction. Assessing spatial and temporal extent of impending floods based on weather forecast is entirely novel to Nepal. Such flood maps can support DRR stakeholders in emergency preparedness at the community scale. WFP has been supporting provincial and central government in generating knowledge and data on DRR, and producing household level data endorsed by MoHA. WFP has deduced that response in the local context is very important for DRR, and is working towards reducing response times.

Ahmadul Hassan, Red Cross Red Crescent Climate Centre, Bangladesh, presented on impact-based forecasting for early action in Bangladesh, especially for floods and cyclones. Forecast-based financing aims to reduce the risk and damage caused by disasters like floods and cyclones by anticipating such disasters beforehand. This approach provides decision makers with robust forecast information and serves as a basis for decisions on when and where to act, and with what resources. Forecast-based action is a funding mechanism of the International Federation of Red Cross and Red Crescent Societies (IFRC), integrated into the Disaster Relief Emergency Fund (DREF), specifically designed to fund Early Action Protocols (EAP) developed by national societies. Early Action Plan (EAP) describes early actions that can be carried out in particular circumstances, in a given amount of time and with a given amount of resources, to help reduce prioritized risks. When a predetermined threshold is exceeded, forecasts instantly trigger a danger level warning and releases funds for regions under threat before the disaster happens. In Bangladesh each household is provided USD 52 and evaluation support is also provided accordingly.

Neera Shrestha Pradhan, ICIMOD, presented on ICIMOD's experiences with Community Based Flood Early Warning Systems (CBFEWS) in India, Nepal and Pakistan. A CBFEWS is a combination/package of tools and information that upstream communities generate themselves and send to downstream communities so that the latter have enough lead time to prepare for flood. CBFEWS are implemented in river tributaries, as people living along tributaries are as vulnerable as people living along the main rivers. A CBFEWS is a good example of a low-cost ICT tool. Simple and low-cost technology combined with human intervention is highly effective in providing early warnings. Clear and timely communication, proper networks, and preparedness reduce human casualties even with short lead times for flood warning. Even without modelling exercises, a lot can be achieved on the ground. If all basins are equipped with these kinds of systems, it would significantly help reduce the loss of life and property during floods. A CBFEWS installed in Sherqilla village, a flood-prone village in Pakistan, saved lives and livestock of 350 households during a flash flood event in 2017. The CBFEWS was successfully handed over to the Gilgit Baltistan Disaster Management Authority in July 2019, who committed to scale up the system to 40 disaster prone areas. In a CBFEWS, the time between the flood and the reaction of caretaker and other stakeholders is almost equal to real time. The caretaker validates the information and sends messages based on the level of the disaster. The community selects the CBFEWS caretaker. The caretaker lives in a spot from where he or she can see the river and easily access the early warning system. Selected caretakers receive five-day hands-on training from ICIMOD. Trainees include technical people from government and local communities.

Madhab Uprety, Practical Action, gave a presentation titled "Reaching the last mile: Challenges in implementing flood early warning system." Since 2002, Practical Action has been working with communities, relevant government agencies, media and the private sector on EWS, and has been able to reach nine river basins in Nepal. Practical Action works to link data from the DHM's network of hydro-met stations with EWS, and provides technical support to replicate EWS across Nepal. Practical Action collaborated with telecommunication companies – NTC and NCell – to send flood alerts via SMS, which has become a major component of EWS in Nepal. Involvement and participation of local communities is crucial for wide coverage and increase in quantity and quality of EWS in Nepal. Another key element is a long-term institutional mechanism. The DHM has been working to scale up these systems in many of the river basins in Nepal. Practical Action has put in efforts to systematically incorporate the four inter-dependent and binding components of community-centred EWS – risk knowledge; monitoring and warning; communication and dissemination; and response capacity. Additionally, there should be a continued and iterative process to evaluate and validate the EWS's efficiency and impact. Implementers need to ensure that the end user is receiving information, understands the information, and has the capacity to act. They also need to identify barriers to these three critical last-mile components of an EWS, and ensure marginalized populations – women, children, the elderly and disabled – are not left behind. Inclusive and intersectional perspectives are critical.

Dambar Bohara and Dinee Tamang, Mercy Corps, presented on Mercy Corps's integrated model of Disaster Risk Reduction (DRR) on EWS. Since 2005, Mercy Corps has been working in about 30 districts in Nepal, implementing DRR, agriculture development, and gender equity and social inclusion projects. Mercy Corps has realized that communities lack long-term capacity for DRR. Particularly, infrastructures are not well maintained and task forces set up to maintain such infrastructures often migrate for better opportunities. Mercy Corps applied the nexus approach – integration of traditional DRR with market system development. The nexus approach promotes disaster and climate resilience, land management and agriculture technology, incentivizes DRR functions through a market-based approach, and prepares for and mitigates the impact of disasters. Mercy Corps works with communities living in river tributaries which are often neglected and more vulnerable. They have been conducting participatory disaster risk assessment and risk identification at the household and community level in disaster-prone areas. Though many of Mercy Corps's EWS were upgraded to telemetry-based systems, such systems are GSM based, which do not work during the monsoon. They have piloted radio wave systems to address this issue, but have not been able to scale them up. For communication and dissemination of early warning, they have formed a community disaster management committee, which has sub group task forces – early warning task force, first aid task force, and search and rescue task force. An excellent example of incentivizing DRR is sugarcane plantation on river banks. Sugarcanes are cash crops and also help in strengthening river banks against river erosion and scouring. The sustainability of interventions is also very important. Working in silos does not ensure programmatic impact post programme life cycle. Further challenges and opportunities include:

Applying EWS in the federal context and integrating cross boundary EWS

Translating lead time advancements at the community level

Understanding the dynamics of river systems and updating the systems accordingly, especially in cases of meandering river systems

Introduction of weather radar and new telemetric stations

Pushing for investment in flood resilience; allowing translation of larger global scale forecasts to river system level

Chandra Gurung Goodrich, ICIMOD, presented on gender and social inclusion in early warning. Communities are heterogeneous and a lot of social stratification exists within communities. Consequently responses, capacity and vulnerabilities also vary within communities. Women and marginalized groups face unique barriers in disasters, and EWS that do not explicitly consider gender and social inclusion are likely to increase marginalization and inequality. Response times vary depending on gender and accessibility of resources. Apart from gender, a crosscutting category, fluid categories like marital status, number of children, eldest son, etc. also contribute to the stratification. The heterogeneity of these gender groups within communities shape vulnerabilities and capacities, and is termed as intersectionality. Within social structures, the gender structure determines access to resources as well, and is dependent on political, geographical and economical aspects. The interplay of these factors shapes our vulnerabilities and capacities. As women and marginalized groups are often excluded from consultations while developing EWS, DRR policies and strategies, and post-disaster decision making on EWS, their needs, priorities and capabilities are rarely identified or prioritized. Gender inequalities in education, economic and social capital and in access to technology result in differential access to early warning as well. Collaboration between the institutions and the community groups is essential to address this issue, and open discussions on standard operating procedures for EWS and DRR need to be carried out. For a gender transformative EWS, the following actions should be considered:

Consideration and proper understanding of intersectionality

Acknowledge gender and socially differential impacts explicitly

Undertake gender and social analysis

Examine assumptions, stereotypes and implicit biases that are based on sociocultural norms and practices

Make proactive efforts to meaningfully involve women and other marginalized groups and hear what they have to say

Session 7: Challenges and way forward

Walter Lee Ellenburg, NASA SERVIR SCO, and Mir Matin, ICIMOD moderated the breakout session on challenges and a way forward. Divided into three groups, participants discussed challenges, gaps and a way forward related to production, dissemination and use of early warning systems for floods and extreme weather.

Group 1: Production of early warning systems

SYSTEM DEVELOPMENT	COMPUTING RESOURCES	DATA COLLECTION, INTEGRATION, AND VALIDATION	CAPACITY BUILDING	INTEGRATION WITH REGIONAL/GLOBAL SYSTEMS
Who are the users (Group #3)? How will the system get disseminated? (Group #2) Involving end-users from the design phase itself and continuous interactions Defining extreme events: magnitude, impact Incorporating 'multiple hazards' in the EWS Optimize computing resources based on accurate and homogenously distributed observation networks Access remote/cloud computing to bypass hardware issues Account for redundancy	Optimize computing resources based on accurate and homogenously distributed observation networks Adopt cloud computing to bypass hardware issues Account for redundancy	Availability Density Accessibility Accuracy/Quality control Data sharing and standardization Standardization of file formats Calibration/Validation (ground vs satellite) Latency Integration of local/oral knowledge Account for critical data – DEM, precipitation, temperature, siltation, population	Standardized training Continuous training Redundancy Training the trainers Continuity/knowledge retention	Climate variability: mesoscale circulation Low frequency variability (e.g., ENSO) Boundary conditions Outputs from EWS from upstream countries

Group 2: Dissemination of early warning systems

CHALLENGES	GAPS	A WAY FORWARD
Clarity on roles and responsibilities Who disseminates early warning information and can be considered a trusted source? Some institutions have mandates to disseminate early warning information. These mandates often overlap between institutions. Lack of clarity about the roles of different stakeholders involved in disseminating early warning. Disseminating information that contains sensitive data can be tricky as institutions often do not share sensitive data – river stage, upstream-downstream. **The science is not mature enough** Identifying different types of drought is a challenge (is not weather related, but is an important issue). **Communicating disaster information and uncertainties in disaster information** Communicating timelines, explaining probability as events progress. Translating information into comprehensible language for the end users. Finding a balance between lead time and accurate forecasts is tricky. Weather forecast information contains inherent uncertainties. Communicating impact to different audiences; IBF and dissemination are interrelated. Identifying audiences for the different types of information produced (tailoring information to different kinds of audiences) **Delivery mechanism/appropriate channels and platforms** An end-to-end system needs to connect forecasting, remote sensing and early warning systems. The system needs to make business sense as well.	**Addressing differential needs and ensuring last mile connectivity** How do we disseminate warning to the disenfranchised – areas outside of mobile or electricity coverage? Single women headed households are often hardest hit by disasters. While disseminating services, differential needs of the most vulnerable people should be taken into account. It is important to consider their preparedness level to ensure they interpret and respond to warning information effectively. Their literacy level also needs to be considered to ensure they understand the warning information. Forecast information is still not accessible to communities. In-situ early warning information systems are limited to providing only a few hours' lead times. The value addition of national forecast has not yet reached communities affected by flash floods. Examples of gaps in understanding forecast information is often seen in the media. **Clarity on roles and responsibilities** Only government agencies have the mandate to generate and disseminate warning information on disasters – floods. Private companies can create forecast products but cannot disseminate warning. **Sustaining and incentivising services** Limited resources and sustainability – ensuring dissemination channels are sustainable and operational. Early warning systems need to incentivise the work of caretakers or task force members/gauge readers. **Communicating disaster information and uncertainties in disaster information** Communicating uncertainty is difficult; the general public doesn't easily understand forecasters' language. **Delivery mechanism/appropriate channels and platforms** Setting up a platform to bring together producers and users of early warning information What communication medium is the most effective – SMS, human chains, flyers, alternative media like street theatre, radio and television stations, and/or social media? In Nepal, the news media is paying attention to DHM forecasts and relaying them (which is a good sign). In Bangladesh, an IVR has worked well. Community radio plays a pivotal role in relaying warning information in remote areas. Mainstream media often does not reach such remote areas. Linking science with communities An exercise on effective methods of dissemination	**Capacity building** Build on existing capacity and learn from regional organizations. Train forecasters in using media friendly language and train media persons to understand forecasters. Prepare vulnerable communities for extreme weather events **Engaging private sector and communities** Explore the role of the private sector – telecom, media and other actors. For instance, Hydel projects often have early warning systems of their own and can help disseminate such information. Engage volunteers and rely on existing social structures – scouts and youth clubs to help relay warning information and help communities in disaster preparedness. Early warning information should also take the needs of disabled persons into account. **Accounting for redundancies** Ensure redundancies in flood early warning systems – web-based messaging services, SMSs, sirens and others.

CHALLENGES	GAPS	A WAY FORWARD
	Capacity building Training communities to better prepare and respond to disasters is equally important; providing early warning information alone is not enough. Training is important – communicating the extent and magnitude of disasters is difficult as not many people have experienced typhoons in their lifetime. Bangladesh has different alert levels in place for different levels of cyclones. People respond accordingly. Capacity in interpretation and translation Building trust in forecasts **Improving the science/technology** Visualization, uncertainty, translation Right balance between lead time and uncertainty	

Group 3: Ensuring use of early warning

CHALLENGES
Communicating disaster information and uncertainties in disaster information
Current language used in flood warning is complex and difficult to understand – technical vs everyday language
DEOC – Coordinate with local organizations, FM stations, communities and local bodies
Social media presents itself as an opportunity and is an example of disruption in digital technology.
Understanding of message (language is complex and too technical)
Potential damage needs to be categorized into crop damage, property damage, life and infrastructure. Making accurate assessments is a challenge.
Engaging private sector and communities
DHM - Telecom NTC NCELL – SMS (limited reach, language difficulty/lack of literacy)
Trust (excessive commercial message)
Geographically targeted (remoteness)
Gender neutrality
Level of engagement/coordination between the stakeholders
Delivery mechanism/appropriate channels and platforms
Engagement of grassroots actors to exploit existing structures – farmers' organizations, local government, child clubs, women groups, forest groups, and political groups. Building capacity of community leaders is a reliable way to reach out to masses.
Engaging disaster managers (NDMA) in conducting vulnerability assessments, building capacities of local institutions, coordinating with security forces, and working with communities.
Communication mechanism/channel
Trust and cost of means of communication (SMS)
Improving the science/technology
Lag time between risk observed and triggered action poses a major challenge.
Technology related problems/difficulties (GSM/mobile network/electricity and other infrastructure)
Access to information systems
Geographic constraints
Actionable information
Capacity building
Awareness of end users, especially farmers

SECTION 3

Wrap up and closing

Birendra Bajracharya, ICIMOD, formally closed the two-day meeting. He thanked all the participants for their time and contribution to the event. The forum deliberated on key challenges associated with the development, implementation, dissemination, and sustained use of information services for water and weather-induced disasters, and provided recommendations to address these issues. The event also highlighted ICMIOD's collaboration with the SERVIR Applied Science Team to enhance current flood forecasts by integrating global satellite and modelled data with regional and local forecasts. Some of the recommendations from participants at this forum are leveraging expertise across national boundaries, holding regular quorums at the regional level, training forecasters to generate user-friendly forecasts, and training media persons and communities in understanding technical concepts in forecasts. Participants have also recommended engaging community networks and the private sector to relay early warning information to end users.

He shared that a stakeholder's consultation workshop would follow the two-day regional forum and requested all partners to attend and contribute to the sessions.

Additional event information and materials are available at:
https://www.icimod.org/event/regional-knowledge-forum-on-early-warning-for-floods-and-high-impact-weather-events/

File links:
Agenda
List of participants

PDF copies of the PowerPoints from the sessions are available online at https://servir.icimod.org/regional-knowledge-forum-on-early-warning-for-floods-and-high-impact-weather-events

Photos from the event are available online at https://www.flickr.com/photos/icimodgallery/albums/72157711450109223

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