# WMO Guidelines on Multi-hazard Impact-based Forecast and Warning Services

## Part II: Putting Multi-hazard IBFWS into Practice

2021 edition

WEATHER CLIMATE WATER

WORLD
METEOROLOGICAL
ORGANIZATION

WMO-No. 1150

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**EDITORIAL NOTE**

METEOTERM, the WMO terminology database, may be consulted at https://public.wmo.int/en/meteoterm.

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WMO-No. 1150



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ISBN 978-92-63-11150-0

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**ACKNOWLEDGMENT**

The WMO Disaster Risk Reduction and Public Service Branch (DRR-PS) would like to take this opportunity to thank the authors who contributed to this publication: Juan Bazo (National Meteorological and Hydrological Service, Peru), Dan Beardsley (NOAA, United States), Helen Bye (UK Met Office), Rochelle Campbell (Hydrologic Research Center, United States), Carolina Cerrudo (National Meteorological Service, Argentina), Julia Chasco (National Meteorological Service, Argentina), Erin Coughlan de Perez (Red Cross/Red Crescent Climate Centre), Gerald Fleming (Met Eireann, Ireland, retired), Brian Golding (UK Met Office), Clemens Gross (International Federation of Red Cross and Red Crescent Societies), Eli Jacks (NOAA, United States), Catalina Jaime (Red Cross/Red Crescent Climate Centre), Celina Kattan (Environmental Observatory, El Salvador), John Koch (NOAA, United States), Andrew Kruczkiewicz (International Research Institute for Climate and Society, United States), Will Lang (UK Met Office), Jeff Lazo (independent consultant, United States), Jennifer Milton (Environment and Climate Change, Canada), Ming Mei Li (China Meteorological Administration), Evan Morgan (Bureau of Meteorology, Australia), Chris Noble (MetService, New Zealand), Elizabeth Page (COMET, University Cooperation for Atmospheric Research, United States), Adriaan Perrels (VATT Institute for Economic Research, Finland), Nyree Pinder (UK Met Office), David Rogers (World Bank), Siobhán Ryan (Met Eireann, Ireland), Fatima Saba (Department of Meteorology, Morocco), Elizabeth Webster (South African Weather Service, SAWS), Saskia Willemse (Meteo Swiss) and Linus Yeung (Hong Kong Observatory).

# INTRODUCTION

Published in 2015, *WMO Guidelines on Multi-hazard Impact-based Forecast and Warning Services* (WMO-No. 1150) caught the crest of a wave of interest in Impact-based Forecast and Warning Services (IBFWS) and quickly became a standard reference text for those developing forecasting and warning services. The impact-based forecasting paradigm has also become, for many National Meteorological and Hydrological Services (NMHSs) the accepted model for the way hydrometeorological advice is presented and used. IBFWS is also intimately linked to many other fundamental concepts in the modern world of hydrometeorological services which include: service delivery, understanding of socioeconomic benefits, competencies, effective communication through both traditional and new media, and the effective use of standards such as the Common Alerting Protocol.

In December 2019, WMO organized the "Symposium on Impact-based Forecast and Warning Services", held at the Met Office, Exeter, United Kingdom of Great Britain and Northern Ireland, to bring together IBFWS experts to share their experiences and insights as academics, implementers, users and funders. A key element of this symposium was that, unlike many WMO events, the user communities were strongly represented, and this facilitated a rich and productive sharing of views.

During the symposium it was concluded that the themes and content of WMO-No. 1150 remained valid, though it was also noted collectively that the communal knowledge of IBFWS has increased greatly since 2015. Those present agreed collate this wealth of experiences and new ideas into a series of additional materials that would contribute to a new publication building on the foundations established in the original five chapters of WMO-No. 1150.

This new addition to the Guidelines, Part II – Putting Multi-hazard IBFWS into Practice, is intended to be authoritative and useful. It is certainly not dogmatic or exhaustive. IBFWS is a rapidly evolving field and the additional chapters here should be considered as reflecting and complementing the growing body of literature on IBFWS, emanating from WMO such as the HiWeather project The Future of Forecasts: Impact-based Forecasting for Early Action, the 2020 guide published by the International Federation of Red Cross and Red Crescent Societies (IFRC). In addition to these Guidelines, a wealth of additional material, including many more case studies and information and training resources, is available on a companion web page at the WMO website.

Globally, we are still in the very early stages of implementing IBFWS, and there is still much benefit to be offered, especially to the most vulnerable communities in the world, through continuing the work of applying the concepts of IBFWS and strengthening them wherever possible. The team of experts who assembled these Guidelines hope that they can make some contribution to this progress.

**Participants at the WMO Symposium on Impact-based Forecasting, Exeter, United Kingdom, December 2019**

## AN OVERVIEW OF WMO-NO. 1150 PART II: PUTTING MULTI-HAZARD IMPACT-BASED FORECAST AND WARNING SERVICES INTO PRACTICE

*WMO Guidelines on Multi-hazard Impact-based Forecast and Warning Services* (WMO-No. 1150) was published in 2015 as a single volume (hereafter referred to as Part I). In the intervening years, as many NMHSs and their partner agencies developed IBFWS, understanding, experience and knowledge in this area has developed and grown significantly. The material presented in this WMO-No. 1150 Part II seeks to distil and summarize that knowledge and to provide examples of good practices in IBFWS, illustrating and augmenting the insights contained in the original Guidelines.

The themes and focus areas of the new chapters were selected following thorough discussion with a wide range of experts in IBFWS, in particular those who attended the symposium held in Exeter, United Kingdom in late 2019. A brief overview of those themes and why they were chosen is provided here.

### 1. Partnerships

The foundation for an effective IBFWS is built when knowledge and understanding of geophysical hazard threats are combined effectively with knowledge and understanding of vulnerability and exposure relating to all elements of society. NMHSs have developed considerable expertise and capacity in providing hydrometeorological forecast and warning services; however, they will often not be familiar with the concepts of vulnerability and exposure, nor with the workings of emergency disaster management. Partnership and collaboration with a wide range of institutions, from governments, international bodies, scientific institutions and disaster management authorities through to local communities is therefore needed.

The aim of such partnerships is to improve the overall response to hazards and disasters, and to reduce adverse outcomes. Strong and regular communication between partner agencies is essential, formalized through Memorandums of Understanding (MoUs) and similar agreements, and fostered through joint exercises.

An essential element in successful IBFWS is an understanding of mandates, governance structures, and partnerships which should address, foster and enhance these non-geophysical elements of functional IBFWS. Clear distinctions also need to be made between science-based guidance and consequent decision-making, which can also encompass political and economic considerations.

Enhanced, substantial engagement between meteorological service providers and decision makers is required with roles and responsibilities defined as clearly as possible, and resources provided to ensure ongoing and sustainable engagement.

### 2. Communications

Gathering a group of partners is an important and essential first step, but it is not in itself enough. For effective transfer of information, knowledge and experience between partners, excellence in communication is necessary.

Chapter 2 looks at the basics of good communication and how these concepts can be applied, for example to the presentation and formatting of hazard information. Also those who receive information about a hazard, information that they rely on to inform actions, the need for clarity in the information being provided and trust in the identity of the provider. Such clarity and trust can only come about through excellence in communication. The provision of such excellence is a fundamental enabler in promoting better dialogue and understanding of user needs and better delivery of actionable information to disaster management experts and citizens alike.

In many countries the link between NMHSs and partner agencies is provided through advisors – individuals with (typically) a strong background in meteorology who work closely with partners.

Their role is to understand and appreciate their perspective and to bridge the communication gap that so often exists between specialists from different backgrounds and organizations. Chapter 2 considers the role of advisors and the importance of facilitating the essential work of outreach and public education. Taken together, these capabilities empower the public to fully appreciate hazard warnings and take necessary actions to ensure the safety of themselves and their livelihoods.

Chapter 2 also considers the critical role of media in supporting IBFWS. Even in the short period since the publication of WMO-No. 1150 Part I, the developments in media (and in particular in social media and in "apps") have been profound, while the roles of the traditional media of radio and television remain strong. Techniques and tools are suggested that can help to ensure consistency in the meteorological message, notwithstanding that it will typically be delivered across multiple platforms.

## 3. **Risk communication**

Following on from a wider view of communication issues, Chapter 3 considers in more detail the challenges with risk communication. For persons to take appropriate actions in response to a hazard, they must be able to form an accurate perception of the risks – to themselves if they are individuals, or, if they are agencies, to communities, facilities or infrastructure for which they are responsible.

Risk communication is closely bound up with the effective communication of probability. The chapter examines strategies and examples connected with using, sharing and promoting appropriate practices for communicating risk in a reliable, comprehensible manner.

Chapter 3 also provides an overview of the concepts of awareness and reach and describes a structured approach to considering what level of information should be matched with each communication medium. Trust and authority are also considered – how these can be built and maintained through good communication practices.

Special attention is given to the sources of information known variously as community, traditional or indigenous knowledge. Impacts – their nature, severity and consequences – are usually well known and appreciated in communities that can draw on generations of communal memory and wisdom. Such knowledge is an essential complement to scientific understanding in gaining a holistic view of potential hazard impacts.

Ultimately, IBFWS are about driving effective actions, and effective communication of risk is an essential element in achieving this.

## 4. **Impact information and methodologies for analysis**

There are well-established methods and standards for collecting weather information, formats for coding them, systems for sorting and sharing them with others, and symbols for communicating them to the user. No such global system exists in regard to impacts, which can be collected haphazardly and communicated through a wide variety of formats. There are huge challenges in finding and collating information about the impacts of hazards in a systematic manner, and even in assigning the appropriate impacts to the underlying hazard.

Information on exposure and vulnerabilities likewise exists in a variety of formats and will be held in a range of institutions.

Chapter 4 reviews the landscape of the information on exposure, vulnerability and impact, focusing on the type of information that might be needed and where it might be found. These sources can include historical archives, information held by Disaster Reduction and Civil Protection Agencies (DRCPAs) and similar, government ministries, universities, newspapers, the insurance sector, inter alia. The formats in which such information may be found may include text, maps, charts, tables and oral history.

Severe weather events represent a key opportunity to collect impact data through methodologies such as post-event surveys, collation of information from affected agencies or businesses, or from Non-governmental Organizations (NGOs) active in disaster relief; indeed, from anyone involved with mitigating impacts or whose work or home activities have been subject to those impacts.

Chapter 4 provides a range of examples of how impact information has been collected, organized and used. The companion web page to these Guidelines provides links to further sources of methods and formats through which impact information can be collected and organized, together with details of some publicly available databases and other resources where impact information can be found.

## 5. Value of IBFWS

Along with developing the technical capacity to generate and deliver IBFWS there is a need to validate the socioeconomic benefits of these services and to collect and analyse case studies that can demonstrate the value of IBFWS to governmental and other key decision makers.

Chapter 5 addresses these issues and considers the range of benefits that can flow from IBFWS and how these can be identified and assessed. There is no one measure of the value of potential benefits arising from IBFWS, and the chapter describes three broad categories for measuring value: timeliness, relevance and outcomes.

Chapter 5 also covers a range of measures of value that might be considered, and the possible methods for estimating those measures. Measuring value can itself help to improve the overall value of IBFWS through highlighting where value can be "lost" between advice and action.

The chapter is illustrated with rich examples covering a range of approaches to both validating IBFWS and measuring their value.

## 6. Training priorities and initiatives in IBFWS

The development of IBFWS entails many topics that are not typically covered in the academic teaching of meteorology. However, success in the advancement and implementation of IBFWS will rely on development of the necessary competencies within NMHSs and partner organizations. The evolution towards impact forecasting will require a change in culture for many NMHSs as well as stronger relationships with existing and new partners.

For IBFWS to progress, NMHSs and partner organizations must provide the means to develop the required set of skills and competencies, as well as knowledge of how partners mutually use information to deliver on their mandates. Understanding how hydrometeorological concepts are integrated within partners' decision-making is essential. The following need to be considered:

(a) Identifying required competencies and skills: Once roles and responsibilities are established within organizations, a professional competency framework should be determined with respect to both functional and behavioural competencies such as communication;

(b) Cross training on specific requirements and procedures: Staff of NMHSs and partner organizations should develop a common understanding of system features, and potential limits of accuracy and precision, in order to adequately interpret information and data that will be exchanged. Simulation exercises and collaborative workshops are recommended to achieve this;

(c) Educating users on how to use impact forecast information: Media, public and specific users should be educated and trained in how warning information can be best used to mitigate impacts.

Chapter 6 outlines the training requirements for the key competencies that are needed for the successful implementation of IBFWS and provides a range of examples of training strategies to achieve competency development. The chapter considers the importance of community-based training through engagement and touches on theories around adult learning that can help to inform the design of successful training initiatives.

## CHAPTER 1. PARTNERSHIPS – THE IMPORTANCE OF COLLABORATION IN IMPROVING IMPACT-BASED FORECAST AND WARNING SERVICES

| **Five key messages:** | |
|---|---|
| (1) | Partnerships are essential in developing IBFWS. NMHSs and similar technical agencies cannot achieve success on their own. Key partners will include the relevant disaster response and civil protection agencies. |
| (2) | Establishing strong and regular communication with partner agencies is essential. |
| (3) | While the development of formal MoUs and service-level agreements is important, regular exercises are vital. Collaborative exercises help to develop inter-agency familiarity, identify barriers to effective operation, and help to reach true readiness. |
| (4) | Technical guidance and advice need to be seen and understood as clear and distinct from decision-making, which can encompass political and economic considerations, among others. |
| (5) | Research is continually needed, especially engaging with the social sciences, so that new knowledge can be developed and incorporated into operations. |

Forecast and warning services are designed and developed to benefit the many elements that make up society, including individuals, families, communities, local authorities, commercial enterprises, civil contingency agencies, government departments and politicians. Warnings, in particular, support and promote appropriate decision-making to avoid or mitigate potential impacts relating to geophysical hazards. At all levels of society there are networks of cooperating bodies that contribute to decision-making, taking early actions to mitigate threats, produce information on the evolution of threats and taking some responsibility for the outcomes.

The NMHSs need to develop some understanding of how their hazard warning services will be used if they are to meet the needs of society and decision makers. Impact-based warnings are typically issued in partnership with or jointly by other agencies, typically DRCPAs. The procedures enacted during the issuing of an impact-based warning should capture considerations such as what form the warning should take, how the warning should be communicated, the extent to which the warning message should incorporate "calls to action", and the like. These are all aspects of warning services that will benefit from the combined knowledge, experience and insights of all partners in the process.

Warning systems need to be planned and designed in advance, in close coordination between all partners and, where possible, informed by social and behavioural scientists. Forecasters need a clear knowledge and understanding of how and when to issue effective warnings, such that the impact of a natural hazard on society is minimized. Successful impact-based warnings need effective and efficient partnerships and the availability of appropriate or sufficient resources. Achieving these requires full support from the leadership of the relevant agencies as well as excellent working relationships at the operational level. Different frameworks require different considerations and governance models. One size does not necessarily fit all.

There are six primary elements that can be considered in the development of partnerships:

(a) Users

(b) Communication of warnings

(c) Civil contingency and related DRCPA actors in public and private sectors

(d) Information producers

(e) Political and administrative decision makers and aid agencies

(f) Continuous improvement of services through research and development

## 1.1 Users of warnings

Warnings are aimed at individuals, communities and enterprises that are vulnerable and exposed to the impact of a hazard or group of hazards. Gathering information on vulnerability and exposure can involve many different entities including social and behavioural scientists, national offices of statistics, national and local government sectors, disaster managers, NGOs, civil and structural engineers, risk finance and risk transfer specialists, and, of course, those at risk. Information and perspectives from all of these may be needed to develop a targeted and useful warning service. It may even be the case that multiple warning methods may be needed to address the risks and interests of different user groups (see Chapter 3). The relevant data needs to be integrated into decision support systems, and this is a task best realized within partnerships. Collaborative development of decision support mechanisms, which are based on local data and shared across government sectors, can help ensure that knowledge of vulnerabilities of people and livelihoods are well understood and supported in times of crisis.

## 1.2 Communication of warnings

When scientific or technical information is presented to non-technical partner agencies there can be an assumption that such information will be understood and acted upon in a logical, rational manner. This is rarely true. Decision makers must balance a wide range of factors, both internal and external. These might include influences that are psychological, emotional, political or economic in character, as well as the purely rational. Decision makers operate in a complex framework. Appreciating the existence of these other influences and using that insight to communicate effectively is a key enabler of successful partnerships.

Understanding how to effectively deliver warning and forecast information to decision makers can be gained through strong engagement with partner agencies implicated in civil contingencies and disaster risk management, which can provide feedback to meteorological service providers to help them tailor services that are both usable and used.

It is also important to recognize the need for consistency of messaging to all partners and through all communication channels. Experience suggests that messages will often tend to diverge or conflict over time without proactive communication management. The aim should be to deliver timely and appropriate alerts to people who need them. While this will primarily be local communities, the needs of those who will be visiting or travelling through an affected area (and thus not familiar with local conditions) should also be addressed.

## 1.3 Building partnerships with DRCPAs

Central to mitigating the impacts of hazards are disaster managers and first responders. However, the role played by disaster management and their engagement with other entities will vary considerably from country to country. The examples in Boxes 1.1 and 1.2 illustrate well-defined interfaces between DRCPAs and the providers of hazard information in two different countries. In other countries the DRCPAs may simply take warning information and pass it on to the local level, or initiate response and mitigation activities as they see fit.

**Box 1.1. Met Office advisors in the United Kingdom**

The Met Office Civil Contingencies Advisors engage with the appropriate multi-agency resilience groups across the United Kingdom. These groups are made up of representatives from responder organizations such as the emergency services, local authorities, health sector and utilities advisors who also engage with civil contingency coordinating departments, particularly when severe weather is expected to have a major impact on the public. The advisors assist the emergency planning community to:

- Assess the risk in their particular area from predicted or ongoing severe weather, allowing preparations to be put in place to mitigate the impacts;
- Prepare and participate in multi-agency exercises by developing realistic weather scenarios and exercise injects;
- Provide guidance on the use of Met Office services available to emergency responders through presentations, workshops and exercises;
- Help with weather-related risk assessments as used in community risk registers.

**Box 1.2. Partnerships in Guatemala**

The Instituto Nacional de Sismología, Vulcanología, Meteorología e Hidrología works closely with the Coordinadora Nacional para la Reducción de Desastres (CONRED) to exchange information and prepare for severe water, weather and climate hazards. This relationship was strengthened by the new civil protection laws implemented in 2018, which assisted CONRED in preparing for hazards, rather than being limited to reacting. The advisors from both agencies work together to:

- Assess the hazard and risk in their communities;
- Improve monitoring and forecasting of hazards and possible consequences by exchanging feedback on local conditions;
- Ensure warning messages are accessible, understood and disseminated to community members;
- Increase community response capabilities, by encouraging and enabling early action and response.

Additional efforts have been made to engage partners from universities, churches, NGOs and private industry. These partners contribute to the dissemination of impact-based forecast information and promote protective actions.

Investment in collaboration and partnership is needed on both sides, especially to develop an understanding of the roles, responsibilities and expertise of the respective organizations, and to foster familiarity between their key people. Their combined knowledge of the hazard, the vulnerabilities of people to the hazard and how exposure further exacerbates vulnerability, is essential for development of effective IBFWS.

These advisors may be assigned to the role temporarily – to establish the collaboration or partnership; however, a more permanent role represents a better approach, enabling learning and application where adaptation of services is key for effectiveness. This is an area where better cooperation among government agencies, local authorities, NGOs, the media and information producers could improve data and information sharing, and lead to better decisions and outcomes.

Collaboration is also needed with specialist service areas whose operations can be jeopardized by weather and climate, such as water management or flood mitigation organizations, energy supply agencies, public health and other medical services, agricultural and food suppliers, transport companies, and urban management and development and relief agencies.

Partnerships can be codified through formal documents such as MoUs, service level agreements and standard operating procedures between agencies, and these procedural steps are important. Routine exercises, however, are essential in building a common understanding at the operational level and promoting best practice at times of crisis. NMHSs should be proactive in establishing and maintaining a series of exercises with user sectors, engaging with all opportunities to collaborate on regularly scheduled routine exercises.

## 1.4 Information producing agencies

Detection and forecasting of hazards are the primary responsibility of national technical agencies such as NMHSs. It is not obvious, however, that the same agencies are responsible for impact-based warnings, and the authority to issue such warnings may have different claimants, including DRCPAs that hold vulnerability and exposure data (see Box 1.3).

**Box 1.3. IBFWS in Sri Lanka**

A project is underway to develop IBFWS in Sri Lanka. The Department of Meteorology is responsible for weather forecasts and warnings, the Irrigation Department for flood warnings, and the National Building Research Organization for landslide warnings. The Disaster Management Centre holds a great deal of vulnerability and exposure data. All four agencies will have a key role if the development of impact-based warnings for Sri Lankan society is to be successful.

The ultimate aim is the "co-production" of IBFWS, where all the agencies, and potentially non-governmental partners, work together to provide the services. The term "co-production" is intended to mean a partnership and coordination between equals, recognizing that each participating agency brings important skills and capabilities to the process.

Cooperation between NMHSs and the Red Cross and Red Crescent Climate Centre also demonstrates ways and means of shifting from meteorologically oriented warnings to impact-based warning services (see Box 1.4).

**Box 1.4. Ecuadorian partnership to improve IBFWS**

In addition to threats to life, threats to livelihoods are also critical, especially for communities or individuals with an inadequate store of resources to tide them over difficulties. Forecast-Based Financing (FBF) and warnings-based insurance schemes are means to mitigate the impact of natural hazards on livelihoods, reducing the need for post-disaster relief funding and reducing the dependency of communities by allowing them to return more rapidly to normal social and economic activity.

The Ecuadorian Red Cross and the Red Cross and Red Crescent Climate Centre have developed a long-term partnership with the Instituto Nacional de Meteorología e Hidrología (INAMHI) of Ecuador. The partnership has established a set of dedicated tasks for both the Ecuadorian Red Cross and INAMHI, contributing to the development of an Early Action Protocol (EAP). Activation of the EAP facilitates the release of funding to the Red Cross to allow the agency to take anticipatory action to decrease the risk of impact from natural hazards. INAMHI has recognized the Red Cross with an award noting the success of the partnership and the value of the collaboration. Work is ongoing to expand the collaboration for various types of floods, including flash floods, riverine floods and flooding in urban areas.

Internationally, a good example of cooperation between national producers of warnings and regional emergency management is that of the European Multi-service Meteorological Awareness and the European Commission's Emergency Response and Coordination Centre.

There are barriers to the acceptance of IBFWS. A paper by Kaltenberger et al. (2020) reported that while two-thirds of European NMHSs are currently issuing impact-oriented warnings, that is, warnings in a format describing "what the weather will do", up to 30% face legal obstacles or see impact-oriented warnings as the task of another authority.

Major gaps that can prevent NMHSs from developing effective IBFWS include deficiencies in impact data, technical standards, cross-border exchange of impact data, impact databases, verification methods and understanding user needs. The communication of real-time impact data to the NMHS or technical agency, to "see what's happening out there", helps adapt warnings and is an essential feedback to operational meteorologists. Crowdsourcing is one possible way to close the gap of "ground truth" (Krennert et al., 2018).

Furthermore, many NMHSs cannot run impact models because of cost or the unavailability of data on exposure and vulnerability. This might be a key problem for NMHSs, particularly in many developing countries, which could hinder them in moving towards objective impact-based warning systems. However, all NMHSs, including those in developing countries, will have some knowledge and understanding of the context in which weather information is used in their respective societies. They can build on this knowledge through engagement with users to develop impact-based services in a qualitative manner. Impact models and objective impact-based systems can come later.

## 1.5 Political and administrative decision makers

Large-scale hazards often require political intervention and decision-making, which drive the response of everyone. Evacuation and sheltering orders are normally the responsibility of high levels of government and must be well informed. These decisions are not only based on science but are also driven by political and economic considerations, as was evident in the global response to the COVID-19 pandemic in 2020 and 2021. Engagement with the political sphere may affect public trust in basic IBFWS. Transparency in the decision process at this level is seldom easy, but every effort should be made to separate technical guidance from political decisions. Frequent exercises with civil contingency leaders and their political counterparts can foster a better appreciation of the technical input and its place in political decision-making processes.

The many examples of partnerships developed within the anticipatory humanitarian action community in different countries provide an opportunity to learn from their experiences. This community, which includes organizations running operational programmes such as FBF, has demonstrated the value of investing resources in the development of partnerships with defined roles, responsibilities, and accountability structures. The degree to which the IBFWS originators or users of IBFWS can fund collaborative efforts will help determine the level of positive returns on these investments.

## 1.6 Research and development

The development of IBFWS is an ongoing process informed by new knowledge. It is important to encourage multidisciplinary academic research that can help to deepen knowledge and understanding of the interdependencies of hazards and impacts; and of social and behavioural responses to warnings; thus developing better decision support systems and services; improving decision-making; and advancing understanding of probabilistic approaches to the forecasting of high-impact hazards.

More research is also needed on examples of funded collaborations between NMHSs and partner or user organizations – including exploration of examples in which a translator or advisory function was funded or in some other way played a pivotal role in brokering and sustaining the partnership. The ultimate aim is the transformation of multi-hazard warnings to an all-hazards system, applying the skills developed in meteorology to other natural and human-caused hazards and in turn learning from other technical agencies and disciplines. This is particularly important when considering the compound effect of multiple hazards occurring simultaneously, posing new and very demanding challenges.

## CHAPTER 2. EXCELLENCE IN COMMUNICATION AS A KEY ENABLER OF IMPACT-BASED FORECAST AND WARNING SERVICES

| **Five key messages:** | |
|---|---|
| (1) | A "5W" messaging format of "who, what, when, where and why" can best enable users of NMHS hazard information to quickly assess the threat. |
| (2) | It is critical for NMHSs to retain their role as the single authoritative voice for hazard information to maintain public trust and response. |
| (3) | Effective IBFWS rely on close partnerships with disaster manager agencies to ensure mutual understanding and readiness. |
| (4) | Implementing seasonal outreach campaigns utilizing a variety of media and approaches is a highly effective means to ensure timely public preparation. |
| (5) | The skills needed to provide excellent IBFWS are evolving to include an ability to utilize social media and to learn how to message in clear, consistent formats. |

### 2.1 Excellence in message clarity and formatting

Even the best forecast or warning can be of little value to users unless the information is clearly communicated in the way that the users need. To that end, NMHS staff who issue forecasts and warnings must ensure that information is (a) clearly articulated to the target audience; (b) clearly highlighted in terms of impact as it may affect them; (c) specific in terms of the timing and location of the hazard.

#### Clearly formatting hazard information: The "5W" format

Disaster managers must often act quickly in the face of impending hazards. Their work is helped if NMHSs place information in clearly articulated, brief formats that are easily digested. More specifically, forecasters are encouraged to convey this information using a "5W" format as "who, what, when, where and why" (see Box 2.1). The following are more specific recommendations on this messaging approach:

– **Who:** Forecasters should specify to whom the information is targeted. This is to account for the fact that different communities of users have different needs and areas of focus. For example, transport departments may be most interested in precipitation that impacts roadways, while other civil authorities may be more interested in wind speed and direction.

– **What:** This section of the message should contain details about the hazard to be expected. However, these details should not be restricted to quantitative measures of the hazard (for example, centimetres of snow expected or range of wind speed). It also should contain basic information regarding possible impact (for example, slippery roads or likely impacts on power lines) to inform the user. Such information may be customized to specific user needs.

– **When:** Civil authorities and other users need to be able to plan their operations around hazard onset, duration and termination. Consequently, this information should be clearly articulated in this section of the message. In addition, details to the level of desired specificity should be coordinated with users (for example, "rain will begin at 4.00 a.m." versus "rain will begin early in the morning").

– **Where:** Hazard location also has a high importance to users. As with all other sections of the hazard message, the level of desired specificity should be coordinated with different user requirements. The level of location specificity expressed may vary based on a number of factors. These include the nature of the hazard (for example, local versus regional scale), dissemination capabilities (for example, ability to display graphical, fine scale information via Internet or phone) and user need based on their operations.

– **Why/possible impacts:** This section is of key importance as it translates the detailed information provided by the forgoing 4Ws into recommendations that users can follow. The information may include more specific details for planning purposes (for example, “bridges over the river may be closed to high profile vehicles”) or calls to action (for example, “Turn Around Don’t Drown”). Information on the spatial and temporal frequency of impacts within the warning area and period may also be very useful.

**Box 2.1. United States National Weather Service message**

URGENT – WEATHER MESSAGE

National Weather Service Phoenix AZ

206 AM MST Sat Aug 1 2020

AZZ530-531-533-535-536-CAZ569-012115-/O.CON.KPSR.EH.W.0008.000000T0000Z-200802T0300Z/Parker Valley-Kofa-Central La Paz-Southeast Yuma County-Gila River Valley-Palo Verde Valley-Including the cities of Parker, Ehrenberg, Palm Canyon, Brenda, Harcuvar, Quartzsite, Vicksburg, Vicksburg Junction, Salome, Ligurta, Martinez Lake, Blythe, Palo Verde, and Ripley

206 AM MST Sat Aug 1 2020 /206 AM PDT Sat Aug 1 2020/

...EXCESSIVE HEAT WARNING REMAINS IN EFFECT UNTIL 8 PM MST /8 PM PDT/ THIS EVENING...

* WHAT...Dangerously hot conditions. Afternoon temperatures 110 to 118.

* WHERE...In Arizona, Southeast Yuma County, Gila River Valley, Kofa, Parker Valley and Central La Paz County. In California, Palo Verde Valley.

* WHEN...Until 8 PM MST /8 PM PDT/ this evening.

* IMPACTS...High Heat Risk. Overexposure can cause heat cramps

and heat exhaustion to develop and, without intervention, can

lead to heat stroke.

Effective IBFWS will use various types of content, media and formats to maximize reach, understanding and action across the user community. Each should be chosen according to the desired response and will be a function of lead time and confidence about impacts as well as the levels of engagement, trust and understanding of the users.

The content itself should contain a number of core elements common to all warning information. These elements will be structured to provide a “trigger”, followed by additional information on impacts and the suggested response. Such statements will often include some of the following:

| **Trigger statements** | **Action statements** |
|---|---|
| • Event name (if applicable)<br>• Risk level (and trend)<br>• Hazard/impact severity<br>• Who is affected? | • Monitor/prepare/act now<br>• Escape instructions/routes<br>• Action plan reference<br>• Seek help |
| **What-will-happen statements** | **Context statements** |
| • Hazard(s)/threshold<br>• Impacts(s)/severity<br>• Location(s)/area(s)/proximity<br>• Start time & duration<br>• Likelihood<br>• Risk level<br>• Scenarios | • Current situation<br>• Cause<br>• Historical events(s)<br>• Pre-conditioning/compounding factors<br>• Reference to local knowledge/name |

This common, core content can be tailored to particular user groups, however, using different language or different action or context statements to increase understanding.

The medium should be determined considering factors such as coverage, reliability, dependence on human action for activation, timeliness, market penetration and format flexibility. Use of multiple media and use of intermediate channels (such as via partners or influencers) is recommended to reinforce and give confirmation to a message.

Factors influencing choice of format include the ability to attract attention, convey information and promote response. Data volume, readability and the ability to be shared across different systems and users are also important.

Each medium and format has advantages and disadvantages, as indicated in Figure 2.1 (a) and (b).

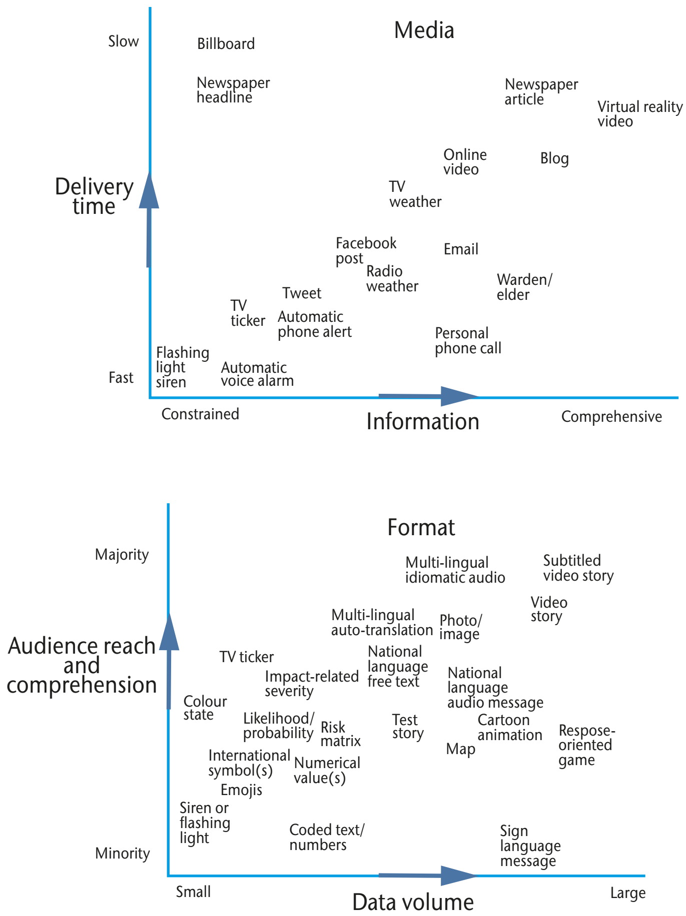



**Figure 2.1 Media (a) and formats (b) for risk communication**

Appropriate and complete alerting is complicated by the wide variety of hazards, and of warning systems and communication channels. In addition to the traditional media of radio and television, and the many Internet-driven communication platforms, there are the specialist devices used by those with disabilities (of sight or hearing, for example) and physical alerting devices such as highway signs, sirens, warning lights and flags. A major advancement in providing the technology to support the rapid and consistent dissemination of warning messages was the introduction of the Common Alerting Protocol[1] (Box 2.2) and the establishment of the Register of WMO Members Alerting Authorities by WMO and the International Telecommunication Union.[2]

[1] WMO, 2013: *Guidelines for Implementation of Common Alerting Protocol (CAP)-enabled Emergency Alerting* (WMO-No. 1109).

[2] https://alertingauthority.wmo.int.

**Box 2.2. Sharing information across partnerships – the Common Alerting Protocol (CAP)**

CAP replaces single-purpose interfaces between alert sources and dissemination media, serving as a "universal adapter" for alert messages and enabling the provider to communicate alerts to targeted users. A key benefit is that the alert message sender can activate multiple warning systems with a single input. Using a single input reduces the cost and complexity of notifying many warning systems. A further benefit of CAP for emergency managers is that standardized alerts from many sources can be compiled for situational awareness and pattern detection. Managers are then able to monitor at any one time the whole picture across all types of local, regional and national alerts.

CAP is compatible with all kinds of public alerting information systems, including broadcast radio and TV as well as data networks. Rather than being particular to a specific communications technology, CAP defines a digital message format applicable to all types of alerts. CAP is therefore compatible with new technologies such as web services as well as existing technologies. CAP is also very useful where alerting systems serve multilingual and special-needs populations. The alerting authority that issues an alert in CAP format enables the dissemination of that alert to the public via multiple delivery means, and the sharing of information with other organizations, such as other government agencies, NGOs and private sector entities. CAP will be most effective when all entities use it and contribute to joint acquisition of CAP interfaces that facilitate the integration of alerts in common products and services.

### Use of clear language to account for population heterogeneity

In any diverse society, NMHSs must ensure their information is communicated in ways that meet the needs of all users and enables rapid and appropriate response. As a first principle, the information must be conveyed according to the single or multiple languages used in each country.

For some NMHSs, this may require a translation capability to ensure that the meaning of certain hazard information is not misunderstood or misperceived. One way to mitigate possible confusion around language is to supplement text with clear graphics that provide a sequence of instructions.

It is important to note that there are other members of the community, such as those with impaired hearing or sight, who require information in specific formats. Care should be taken to ensure an understanding of these needs. NMHSs must also comply with overarching national regulations associated the needs for specialized user communities.

## 2.2 Clarity of source: Promoting the single "authoritative voice"

In the age of Internet and social media it is critical NMHSs retain their position as the single authoritative voice for hazard information. This requires an in-depth socialization of NMHS protocols and processes, not only with disaster managers and other civil authorities but also with the general public.

For example, users can be educated to consider that information is only official if the NMHS itself is seen as issuing hazard information via standard, repeatable, familiar protocols. In addition, the NMHS should monitor for any false information that can be identified and point it out to key users. It is recommended that a list of persons authorized to communicate for all communication channels be formalized.

The concept of the authoritative voice will be discussed further in Chapter 3.

## 2.3 Promoting partner relationships to enhance IBFWS

There are a wide variety of users of information generated by NMHSs. Naturally, information that is intended to protect life and property that is accessible to the public should be made as clear and succinct as possible (see Box 2.3). At the level of professional partners, however, the requirements demanded are more specialized. Consequently, excellence in collaboration among these partners is key to successfully delivering the message.

As highlighted in Chapter 1, successful collaboration depends upon the establishment of trusted relationships between the NMHS and the partners they work with. These relationships are needed for mutual understanding of the following factors:

– **Sharing of protocols and needs:**

  The NMHS and professional advisors need to understand each other's service delivery and receipt practices and protocols to best support the operations of both entities. This includes an understanding of how the information should be delivered, along with when and how it should be delivered.

– **Mutual understanding of local knowledge and vulnerabilities:**

  The establishment of enduring decision-making structures depends on creating a customized approach to service and information exchange. NMHS staff must clearly articulate to partners well-understood, hydrometeorological effects that can influence the local forecast and ensuing impacts within the broader weather regime. In turn, disaster managers and other officials must share local vulnerabilities (either infrastructure or population based) that should direct forecasters in their focus. This is where experience and investments in relationships can pay high dividends in successfully protecting the public.

– **Identify preferred partner engagement modes:**

  Another benefit of NMHSs developing strong relationships with professional partners is the opportunity for partners to share their preferred means of information receipt. Particularly with the advent of social media and easily available video conferencing technology, NMHS forecasters can deliver briefings and graphics to partners on demand or at regularly scheduled intervals. For some partners, direct engagement by embedding NMHS forecasters within the operational environment is the preferred means of engagement, particularly during high-impact events. NMHS staff should use partners' preferred means of collaboration to ensure success.

– **Training and drills:**

  NMHS should work with partners to establish regular and as-needed training sessions for different users and partners. Such training can be held immediately prior to the seasons for particular hazards (for example, severe thunderstorms, tropical storms). These sessions should include a review or education on NMHS probabilistic information to ensure clear understanding by partners.

– **Assessments:**

  To assure a consistent delivery of service excellence, NMHS must develop ad hoc and recurring assessment vehicles to collect partner feedback. Such assessments may take the form of end-of-season reviews (either in person or via surveys). Additionally, NMHSs may elect to conduct targeted assessments following specific, high-impact events to gather feedback on the efficacy of service delivery, usefulness of impact-based forecast and warning information, and reliability of dissemination systems and other protocols.

## 2.4 Developing and maintaining effective public outreach

A well-coordinated and appropriately resourced outreach programme is an effective communication and engagement mechanism for NHMSs. Activities may include the following:

– **Organizing and engaging in events such as seminars, symposia and open houses to explain IBFWS and to collect public user needs:**

NMHSs should be proactive in their dealings with schools, colleges and other scientific institutes through various campaigns, collaborations and initiatives, significantly building a broad understanding of IBFWS. NMHSs should use recognized calendar dates, such as a nationally established "science week", or the globally appreciated World Meteorological Day, to liaise directly with the public. Such key calendar dates present opportunities for events to be organized to discuss and elaborate on IBFWS.

**Box 2.3. An example of seasonal preparedness campaigns in Ireland**

"Be Winter-Ready" and "Be Summer-Ready" campaigns have proved successful in Ireland.

These are annual campaigns launched by Met Éireann in partnership with various governmental departments and agencies tasked with aspects of emergency planning and response. They highlight a whole government approach that is taken to winter and summer preparations.

The media are asked to attend the campaigns along with various stakeholders, institutions and businesses.

For instance, the Be Summer-Ready campaign was launched to provide the general public with information on issues that may affect them during the summer months; included therein is helpful advice on water safety (particularly with regard to coastal and water-based actives), road safety, fire safety, health preparedness, and potential vulnerabilities of older people, people with disabilities, and people in the workplace, on farms and in school.


*Source:* Booklets produced by the Government of Ireland Department of Defence Office of Emergency Planning.

– **Implementing relevant training, outreach and education; ensuring the NMHS is an educational source for weather information:**

Training and education broadly apply to three groups – NMHS staff, stakeholders and the general public. NMHS staff should receive continual professional development and training, particularly with regard to the communication of uncertainty. The concept of IBFWS needs to be clearly explained with particular attention given to notions of hazard, impact, probability and uncertainty, and vulnerability (people, places and regions). Consequently, the general public and stakeholders should be encouraged to grasp the basics of meteorology and climatology to help assist their understanding of IBFWS. A fundamental understanding of numerical weather prediction, probabilistic forecasting and inherent forecast limitations all help to ensure optimum appreciation for the overall product.

In addition, NMHSs should also be a source of educational material for weather- and climate-related matters. Educational material can be developed to support first- and second-level students. Educational packs, infographics, videos, blogs and the like help to convey complex material in an inviting and inclusive manner, helping to engage the younger demographic.

– **Providing videos of the impacts of typical meteorological situations on NMHS websites and social media to sensitize people about IBFWS:**

Videos, infographics and audio clips explaining the premise and benefits of IBFWS can be developed for all aspects of society. These should target all ages and have a wide appeal, including reaching out to all relevant language groups as well as those in the population with disabilities.

The material should be easy to follow and inviting to peruse. Identifiable branding from an NMHS and other government bodies help to endorse the overall product and message.

– **Communicating relevant information, warnings and impacts through TV, radio, websites and social media:**

Information should be easy to grasp, clear and succinct, and make reference to key websites, phone numbers, email and other contact details so that people can seek out additional detail if so required. NMHS branding should be attached to the message to reinforce it. All platforms should be used to attract the attention of multiple arrays of possible users. As similar impacts are frequently connected to the same weather element, it is worth compiling typical impact tables and charts and elaborating upon these for key events.

The NMHS app is a key tool in relaying critical impacts and upcoming severe weather. "Opt-in" for warning notification via NMHS weather apps should be offered and the uptake and use of these tools encouraged among the wider public.

– **Engage with younger demographics and other sections of the wider community who do not currently avail of NMHS services for whatever reason:**

Share publications and virtual training to enable further knowledge gathering of IBFWS approaches and design for services. This will enable knowledge sharing and skill development in the absence of engagement of certain sections of the population within the country.

– Equality, diversity and inclusion – providers of IBFWS working together to ensure that successful methods of engaging with particularly vulnerable groups are shared for wider implementation among them.

## 2.5 Developing internal NMHS capabilities

The advent of IBFWS as a primary goal of the work of NMHSs has changed the nature of the internal capabilities that are required for success. These capabilities are as follows:

– **Staff training and professional development:**

The continuing advance of hydrometeorological sciences and associated technical capabilities requires NMHSs to promote associated education for staff. However, expectations of NMHS forecasters to develop their understanding reaches well beyond the realm of science. Forecasters must also become cognizant of impacts and vulnerabilities of people, places and regions for a variety of hazards. As cited in this chapter, such education depends upon the development of close relationships with NMHS partners and local officials to better understand how forecast and warning information must be targeted. In addition, forecasters must learn to become expert communicators, becoming skilled in clear writing, graphics development and oral presentation.

– **Research to link hydrometeorology and climate to impacts:**

Traditionally, NMHSs have invested in a better scientific understanding of weather, water and climate systems. However, in the new IBFWS paradigm, this research must now extend to developing a better understanding of vulnerabilities and possible impacts as it links to these systems. This is especially important given the changing climate and the associated geoeconomic impacts. NMHSs should take every opportunity to prioritize and fund work in these areas – such as hazard impact modelling – to enhance forecaster understanding of these factors.

– **Integration of social and behavioural science:**

Over the decades, the development of outwardly facing products and similar material for partners and the public has largely been left to professional hydrometeorologists. However, more recently NMHSs have become aware of the significant value that Social and Behavioural Science (SBS) can bring to the physical sciences. SBS brings expertise in how the public and partners perceive and respond to information provided by NMHSs.

In addition, SBS brings sampling and survey expertise that facilitates analyses that reach beyond whether users “like” the information presented. Rather, the focus is on whether the information successfully attains the desired response (for example, awareness, preparation, action). NMHSs should consider infusion of such expertise as new information modes are developed, rather than as an assessment means once such information has already been developed.

– **Marketing communication:**

Alongside SBS, skills from the business world can be very effective when applied within IBFWS, including understanding the needs of different user groups and designing services and communication strategies to address them.

## 2.6 Traditional and Internet-based media in support of IBFWS

### Traditional or conventional media

Traditional or conventional media, such as TV, radio and print (papers, journals, weather magazines, and the like) continue to play a fundamental role in supporting and communicating IBFWS, as there remain many locations where Internet, broadband and mobile device capabilities are not fully developed.

Many users are very comfortable receiving their information via these channels, so their usefulness should not be overlooked simply because Internet-based media has now moved centre stage. In addition, these presentations, with the correct infrastructure, can be repeated and uploaded on social media platforms to amplify the message. Further, the conventional TV set has now become a smart TV, with the result that media channels are increasingly overlapping and interchangeable.

Newspapers are still a means of receiving the latest news and weather for many, although revenue for publishers has dropped substantially in recent years as readers turn to the Internet to obtain information. These traditional communication means remain reliable and are easily shared.

## Utilization of websites and other online media sources

While there is an indisputable requirement for traditional lines of communication, in recent years, Internet-based media has become increasingly part of our daily routine. As such, it is a very important means of communicating and engaging with the public at large, in particular the younger demographic, whom traditional or conventional routes may not reach. It plays an integral role in relaying IBFWS via a host of platforms, including websites, social media, podcasts and mobile applications.

The number of sources used to transmit impact-based hazard information continues to expand, reaching more users than ever before. Examples include news feeds, Facebook, YouTube, Twitter, blogging and online chat, email, Flickr, Instagram, Wikipedia, LinkedIn, Google products, live streaming platforms such as Meerkat and Blab, and educational video, reading and presentation-sharing sites such Howcast, Scribd and SlideShare.

Email, Facebook and Twitter are among the most popular means of communication across a host of NMHSs. In fact, many NMHSs have adopted social media platforms as their primary means to regularly transmit authoritative information. These channels of communication are easily accessible via smartphones and computers, ensuring a fast, interactive and real-time response between the public and an NMHS.

During times of severe weather, warning alerts and updates, observations, impact photos and infographics can all be shared instantaneously, ensuring that the user is kept up to speed with the very latest happenings. Queries and comments can be readily answered by NMHSs and shared for many more to see. It can be a very personal way of communicating and yet has the potential to engage with significant numbers of people.

It is important that NMHSs redesign their web presence and branding as needed, and take ownership of their digital content to emphasize the NMHS role as the single authoritative voice. This includes removing obsolete content on websites, and using a consistent style, tone of voice and guidelines around social media posts.

## Risk and media charts

Many NMHSs are using innovative graphics to provide a snapshot of expected hazards and their impacts. These include risk matrix or charts for use by partners and the public that can be widely distributed (TV, radio, newspapers). The purpose of these graphics is to provide hazard information that is immediately identifiable, recognizable and comprehensible. An example of such graphics is provided below (see Figure 2.6):

| | | | |
|---|---|---|---|
| Sustained (10-min mean) wind speed | > 50 km $h^{-1}$ (27 kt) | > 65 km $h^{-1}$ (35 kt) | > 80 km $h^{-1}$ (43 kt) |
| Gust (3-sec mean) speed | > 90 km $h^{-1}$ (48 kt) | > 110 km $h^{-1}$ (59 kt) | > 130 km $h^{-1}$ (70 kt) |

**Figure 2.6 Example of a wind hazard risk matrix**

## 2.7 Consistency in media and partner engagement

### Communication consistency

One of the key challenges in an environment where provision of hazard information is ubiquitous among the government and private sector is that there exist a variety of means to display such information. This includes not only the style of presentation graphics, but also the varying use of colour to depict certainty, severity, urgency and impact.

This fact underscores the need and opportunity to broaden collaboration with the media (see Box 2.4) and other providers of hazard information to strive for consistency of presentation. This is a major challenge given the desire for maintenance of proprietary information formats by some, but it is still a challenge that merits discussion and collaboration with partners in the interest of public safety.

**Box 2.4. Media collaboration in El Salvador**

In El Salvador, the Ministerio de Medio Ambiente y Recursos Naturales (MARN) has for many years had a strong collaborative relationship with the media. Reporters have reached out to MARN and consulted with the technical staff on a daily basis to find out the weather conditions and broadcast them in the local news. As MARN has moved to an IBFWS approach, training for the media has been developed to strengthen the relationship and explain the new concepts. This has permitted the media to better understand and communicate the forecasts. On 4 June 2020, Moises Urbina, a local news broadcaster for El Noticiero of Channel 6, described the IBFWS forecast and recommended actions for El Salvador as it was suffering the severe impacts of Tropical Storms Amanda and Cristobal.

Extra weather bulletins and additional TV and radio interviews should be readily facilitated; these can be easily uploaded and shared via other channels, such as social media platforms. Blending branded images in such combinations reinforces the authoritative voice of the NMHS.

Wider warning map areas, such as those used on Meteoalarm, can also be showcased, illustrating the universality of use of the IBFWS colour-coded warning scheme. Internet-based media has made the world a much smaller place; those travelling to a new country, or experiencing language barriers, would benefit greatly from universal schemes using wider warning map areas.

### Establishment of an NMHS media section

A centralized, overarching communication staff should be employed within the NMHS to oversee the wide variety of communications tools available for use. A significant benefit of establishing such a section is to promote consistency of communication across the service. Available tools to support media outreach include digital and social media, open website and app content, and open data, as well as outreach programmes and exhibitions, lectures, school visits, and consultancy work with public bodies and industry.

The NMHS website should contain a dedicated media section, with a formalized system for facilitating proactive dealings with the media. This is especially useful during periods of severe weather when an NMHS can be inundated with queries. Issuing press releases and providing audio and video recordings for uploading, together with suitable infographics, can all be efficient and effective means of explaining the impacts of severe weather.

One best practice is to sponsor “host days”, when the media is invited into the NMHS work space. Such host days may be especially valuable during unusually severe weather to ensure key NMHS messages are clearly and consistently delivered.

## CHAPTER 3. RISK COMMUNICATION, USER ENGAGEMENT AND ACTION

| **Five key messages:** | |
|---|---|
| (1) | Effective risk communication is essential to IBFWS and should be carefully considered, calling on expertise from the social sciences and professional marketing where available. |
| (2) | User engagement and understanding of the needs of user groups is fundamental to designing IBFWS. This includes engagement with community (traditional) knowledge. |
| (3) | NMHSs should consider how best to serve these users groups given the available resources for IBFWS, balancing the needs of society as a whole with the needs of at-risk or hard-to-reach communities within it. |
| (4) | It is best practice to use a range of content, communication styles, media and formats to ensure reach, understanding and action across user groups. |
| (5) | NMHSs should build trust through continuous engagement, a strong brand, and "real world" metrics that demonstrate benefits and improvements. |

### 3.1 **Introduction**

In addition to the general IBFWS communication guidelines presented in the previous chapter, it is constructive to focus on how risk is communicated and understood. Risk communication is a complex and rapidly developing field, particularly in the light of the lessons being learned from the COVID-19 pandemic. The following pages do not claim to represent an exhaustive or rigorous study, and it is clear that the subject will demand a broader view in the coming years from practitioners, users and academia, particularly the social sciences.

The effective communication of uncertainty has long proved a challenge and a source of continuing debate within the meteorological community and elsewhere. But we should recognize that uncertainty is just one factor in the risk equation, and that communication of risk brings additional, distinct challenges.

Most importantly, the fundamental role of the user is implicit in the concept of risk communication. Slovic et al. (1979) note that "danger is real, but risk is socially constructed". If impact-based forecasting represents a shift from "what the weather will be", to "what the weather will do", then effective risk communication in IBFWS also considers the user perspective: "what the weather might do to you". It is clear, therefore, that user engagement and behavioural considerations are important facets of the IBFWS paradigm; there must be a dialogue between IBFWS providers and users, and the providers have a responsibility to ensure this is effective.

Additionally, market research techniques from the business world are very useful tools. Some NHMSs now have dedicated marketing communications functions, which have proved very beneficial in aligning IBFWS to user needs. For instance, by using a marketing "reach model" (Figure 3.1), risk communication for forecasts and warnings may be broken down into a number of steps in order to achieve user understanding and action:

– Awareness and reach – making sure users' needs are understood, and that they know about, and have access to, risk advice

– Trust – making sure users trust this advice

– Understanding – making sure users accurately perceive their risks and know how the advice applies to them

– Action – enabling users to take the right actions on the timescales they need

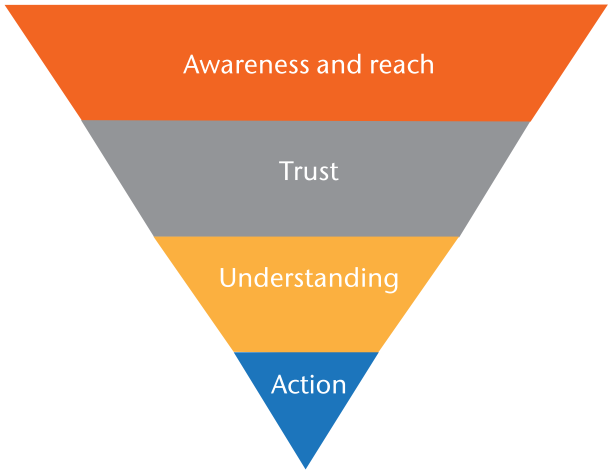



**Figure 3.1. A simple reach model for IBFWS**

The following sections develop these ideas and present practical examples of risk communication for effective early action.

## 3.2 Awareness and reach

### Knowing the users

Providers of IBFWS should establish a clear understanding of the range of users in society who can receive forecasts and warnings and make decisions and take action based on them. Early engagement with users is critical to effective warning systems, so providers designing or improving these systems should undertake a preliminary survey of the user landscape in terms of their needs, interests, values and possible points of conflict.

Questions to be considered in such surveys might include:

- What risks and impacts are users trying to reduce?
- What challenges do users face at the onset of and during a hazardous event?
- What forecast and warning information do users need to enable informed decision-making and action to reduce risk? When? How? At what levels of precision?
- What forecast and warning information, if any, is currently being used? From whom?
- What are the costs of action, and what would be the consequences of false alarms?

An important point is that users fall naturally into groups. Figure 3.2 indicates key categories, which can themselves be included in still broader groups with common interests and needs.

**Public**
- Individual citizens
- Communities (including at risk groups)
- Community leaders ("influencers")

**Government**
- National government departments
- Local government

**Disasters risk reduction and civil protection**
- Emergency responders
- Humanitarian and development agencies

**Businesses**
- Local, national and multinational

**Infrastructure providers**
- Transport
- Telecommunications
- Utilities

**Figure 3.2. Examples of key IBFWS user groups**

Breaking society down into its constituent user groups in this way also allows prioritization and focused engagement, leading in turn to the vital understanding of user needs and co-development necessary for successful IBFWS.

### Can one size fit all? – The tailoring conundrum

Many hydrometeorological warning systems will have evolved from threshold-based systems that adopt a "one-size-fits-all" approach in which the warnings essentially replicate the same textual and graphical content across a small number of distribution channels but aim to reach the maximum number of users. This is a naturally efficient approach in which the inbuilt consistency also enables easier control of the message. It may still be the best solution for an NMHS. But we should also consider that this methodology may not ultimately prove most effective in terms of promoting understanding and optimum action among some users, particularly those in at-risk groups.

Results of a user landscape survey, as described in the previous section, may suggest a different approach. From the point of view of society as a whole, each of the IBFWS users has an optimum action in response to a severe weather warning. It is important to note that an optimum action for an individual user may not necessarily be optimum for their community, user group or society, so a degree of coordination is needed to encourage all actors to play the parts they need to play. In an ideal world each of these actors would understand and act correctly on a single one-size-fits-all warning. It seems more likely, however, that a certain amount of tailoring of the warnings, to improve understanding of their specific risk and options for mitigating actions, will make them more beneficial overall. In marketing terms, this represents a "segmentation" of the users into subgroups with different characteristics and needs.

Tailoring may take many forms, considering both the content of the warning and its delivery mechanism. However, communicating a consistent underlying message in a number of different ways to different users comes at the expense of complexity and resources. There is thus a trade-off between the benefits of tailoring, which may be marginal in some cases, versus costs, which may be substantial in comparison to the one-size-fits-all approach. Another consideration is that many individuals will be part of more than one user group and may therefore receive warning information in different ways. It is important that these products and services remain consistent.

### Engagement with the "at risk" and the "difficult to reach"

Some user groups may be more difficult to reach – geographically, technologically, culturally or linguistically – than others. Some of these may also be more at risk. Consultation with these categories to understand their needs or engage in co-design of services may also be much more difficult than with others. An NMHS should therefore encourage less vocal and more vulnerable groups to have their say.

Some of the reasons why people cannot, or do not, properly receive, interpret or respond effectively to warnings can be physical (age, infirmity, physical or mental challenges, and the like), while others may be social or cultural (such as implicit bias in development of messaging, male versus female roles, the protection of property or livelihood, over-estimation of personal capability, poor judgement of risk). As a public good, weather warnings should aim to be equally accessible and usable by all, but frequently groups that are vulnerable to hazard are also marginalized within society.

Special effort is required to ensure that the benefits of IBFWS are also available to these marginalized groups. They may need specially tailored and targeted messages to ensure their safety, ideally coming from or supported by sources that they trust. Understanding how to reach people with timely warnings that drive appropriate actions and decisions requires that warning providers understand and take into account all of these factors, ensuring that they are engaging appropriately with differently abled community groups to ensure that warnings are accessible and actionable.

The knowledge and insights of social and behavioural scientists can aid the understanding of how differently abled people access, comprehend and use warning and forecast information. By incorporating this information into IBFWS, warnings can be targeted and tailored to individual needs or to the specific needs of groups of users.

The decisions concerning which user categories to focus on when developing an IBFWS system may ultimately involve socioeconomic, environmental, political and ethical issues, to be made following discussion between providers and their stakeholders. In all cases these decisions should be based on a firm understanding of user needs, as described above.

### Service improvement through co-development

Community information services such as weather warnings should be user-focused and co-developed. In order to build a good information service, interaction with those who will use the service is fundamental. General principles of service delivery (as outlined in *The WMO Strategy for Service Delivery and its Implementation Plan*, WMO-No. 1129) suggest that users of early warning systems should not be considered purely as passive recipients and should be included in the process of service creation and improvement. This will have the benefit of building more robust systems that meet the demands of decision makers. But, how much do we know about the decisions made by the users?

A good practice is to develop solutions through an interdisciplinary approach. In Argentina, the National Meteorological Service (Servicio Meteorológico Nacional) has a team of social science professionals focused on working on risk reduction strategies and user approaches. They have the skills and resources to collect and analyse data around users' perceptions of services in a methodical way, applying qualitative and quantitative techniques. Box 3.1 provides an example of this methodology.

**Box 3.1. User engagement in Argentina**

This methodology is applied frequently by the Servicio Meteorológico Nacional in Argentina to explore users' decision-making needs and processes in certain scenarios:

(1) Organize a meeting with a sample of decision-making representatives from a particular sector (such as water management, emergency agencies, the agricultural sector or transport).

(2) Divide them into groups of 3–5 people.

(3) Outline a high-impact weather scenario likely to affect their sector.

(4) Ask each group to consider the information they would use, and the decisions they would make based on their needs and experience at the following times: 3 months, 15 days, 7 days, 24 hours, 1 hour before the event.

(5) Each group then presents its decisions and the reasons for them.

(6) Collate results into an extensive and prioritized list of decisions made, and the diverse information used.

(7) Use this information to inform product development.

## 3.3 Trust and authority

### Building trust in an NMHS

Responsibility for protecting citizens from hydrometeorological hazards lies ultimately with a nation's government. This responsibility will usually then be delegated to its NMHS (or the group of organizations which together provide a similar function), which will then act as the "authoritative voice" for IBFWS. WMO Members are encouraged to clearly identify their designated national warning providers and record them in the Register of WMO Members Alerting Authorities.

This privileged status as an authoritative voice should be earned, rather than just awarded, through demonstration of an effective and credible warning capability designed around user needs and in line with service delivery principles.

However, being effective and accurate is not enough. In many nations, the official warning providers are in competition with other unofficial providers, usually in the private sector. It is important for an NMHS to position itself favourably with respect to this wider landscape of weather information when it comes to advice and warnings around impactful weather. Official warning providers no longer exist in isolation. There will always be other weather providers, and other sources of information – whether valid or not – will continue to multiply. Closely monitoring for false or misleading information may be most important when clarity is needed most, such as during particularly hazardous events. Equally, NMHSs should be vigilant and proactive in promoting the consistency of warning information, including that provided by partners and by the private sector. An NMHS should have the visibility, reach and reputation to be competitive in the wider information and warning landscape; the service should be recognized as the authoritative voice by users on its own merits.

So, the perception of an NMHS's authority among users is as important as government-mandated authority, and having a process for building this authority and trust is important, in addition to improving the accuracy of forecasts. It requires continuous collaboration with users.

### The importance of brand

National Meteorological and Hydrological Services are also encouraged to strengthen their brand image. In addition to association with values such as accuracy and authority, brand can also be built through presentational techniques. These may include branded graphics to clearly identify that the information is definitively that of the NMHS, particularly when shared on social media platforms or via other media outlets. The corporate logo should be fresh, modern and up to date with an identifiable colour palette and typography.

Similarly, a strong brand should also be showcased when the NMHS communicates with public bodies, government departments and industry. The same style of branding should be repeated via all communicative channels in a variety of formats and shapes to suit various applications.

**Trust through evidence**

National services often attempt to demonstrate their performance through abstract metrics allowing intercomparison with other NMHSs but which mean little to users. Where possible, "real world" metrics should be used to display tangible performance and improved service quality to a general audience in a form that can be easily understood. Confidence and trust can be built through such transparent measures of progress.

Building user confidence takes time and constant practice. Trust is not only the element that will allow people to take an action based on certain information, but it may also strongly determine their perception of risk. The aspects to work on will depend on the receiver, but in general, three broad categories can be identified: the general audience (that is, the public), specific users such as institutions and partners, and communities.

**Gaining the trust of the general audience**

The general audience is very difficult to characterize due to its heterogeneous nature. It is made up of people from different generations and beliefs, different relationships with technology, and different risk appetites (the level of risk that one is prepared to accept in pursuit of an objective), vulnerabilities and experiences. It is a mistake to consider the public as a homogeneous actor. However, there are some common communication approaches that may enhance trust in forecasts and warnings across the majority of the public. For example:

– **Use of technology is attractive and can inspire confidence:** Communication campaigns that show use of complex technology (such as supercomputers) is something that increases trust;

– **Most people believe in scientists:** Highlighting in social networks that forecasts and warnings are based on scientific knowledge also tends to increase trust;

– **Including data on reliability of IBFWS information is very important:** For example – "Did you know that 80% of our heat wave alerts are accurate?".

Of course, there will be exceptions to the above, such as user groups sceptical of science and technology. Again, NMHSs should judge whether a more tailored approach is necessary to gain acceptance of IBFWS advice among these groups.

Public trust in a public information agency will often increase if there is a possibility of interaction, for example, via social media. IBFWS providers should consider the following means of interaction to build trust:

– Answering (and asking) questions on social media;

– Displaying and sharing images from users (for example, of weather phenomena);

– Allowing users to submit weather or impact reports;

– Interacting with the weather enthusiast community to build advocacy;

– Positive engagement with "influencers".

### Gaining trust from specific users

It takes time and dedicated resources to maintain and increase the trust of specific users – government departments, emergency responders, businesses, humanitarian aid organizations and other institutions. Proactive relationship management by NMHS is advised. When taking into account these specific users or groups of users, the following should be considered:

- The key public or private actors in this sector, and whether links with the NMHS are established;

- An engagement strategy for these users;

- An open communication and consultation channel using NMHS staff who "speak the same language" as the users and can act as relationship managers and intermediaries;

- A mechanism for co-design and testing of services, along with the sharing of feedback.

These interactions will build trust if they are clear, open and jointly planned. Users will trust services if they feel they have a part in their creation and improvement.

### Gaining trust from communities and using community knowledge

It is important for an NMHS to gain a level of trust among communities as the authoritative voice for weather-related warnings. This can be done through using relationships that are already in place between community leaders and disaster managers. Often DRCPAs work very closely with the most vulnerable communities and therefore already have a relationship in place. An NMHS can use this relationship and work with the disaster managers as conveyors of the warning message.

In South Africa, for example, community engagement workshops have proved a very good means to gain trust with communities, and relationships are then built directly with the community members. At these workshops all role players are invited, including the grandmothers, who are often the primary caregivers in the communities. The workshops can also be used to understand a community's basic need to effectively respond to early warnings. For example, this need could be to receive a warning in the local language, which is something that could easily be addressed.

It is very important that communities are involved in prioritizing their own risks and in determining their solutions. By excluding communities there is a risk of creating distrust and any interventions are likely to fail (see Boxes 3.2 and 3.3).

Community (indigenous, traditional) knowledge can be defined as locally sourced information that has grown over many years and passed down through generations (Dube and Munsaka, 2018). Indigenous communities possess an immense amount of knowledge relating to certain practices that have been successful when dealing with disaster risk reduction (Balay-As et al., 2018) and this information plays a significant role in increasing their resilience to natural hazards (Howell, 2003). In addition, communities that make use of their traditional knowledge are often found to need very little external support when dealing with disasters (Dube and Munsaka, 2018).

A challenging situation often occurs in communities with the older generation being reluctant to accept new technologies or a scientific approach, while the younger generation is not so interested in traditional methods. Research has shown that by combining traditional and scientific approaches, disaster risk reduction activities will be more successful. To develop methods of using both traditional and scientific approaches in early warning systems, local workshops can be held in collaboration with the community leaders and the local disaster managers.

As a further consideration, the traditional concept of community can be broadened to cover the virtual communities within society created through mass communication and social media.

Interestingly, many of the approaches above have an equivalent in these online communities, with influencers playing a role analogous to the community leaders described above. Their views, and their approval, carries weight within the communities and can be a strong influence on group response to severe weather warnings.

**Box 3.2. Using traditional means of communication to disseminate warning messages in South Africa**

In certain communities in South Africa, disaster managers make use of both traditional and modern disaster risk communication methods. In the Joe Gqabi District within the Eastern Cape province, conventional methods are used for issuing severe thunderstorm warnings via WhatsApp, bulk SMSs and social media. However, the disaster managers also recognize the importance of including more traditional methods of communication. It is believed by local inhabitants that when a severe thunderstorm producing hail is approaching an area, it can be scared away if a loud noise is made. The challenge for disaster managers to integrate this traditional knowledge into an effective response to the storm is the very short lead times normally involved, which do not allow sufficient time for community members to take effective precautionary measures, as communities respond only when they see or hear the thunderstorm approaching. However, if disaster managers take into account this traditional practice, when they receive a warning for severe thunderstorms they can alert the relevant community leader ahead of time, who can then send out a community member to run around hitting pots and ringing church bells. This fulfils the traditional need to "chase away" the thunderstorm, while at the same time ensuring all community members are fully aware of the possibility of severe thunderstorms ahead of time in order to take necessary steps to mitigate or avoid its potential impact.

These methods have proven to be successful in these communities and work is being done to expand and adapt such methods to be used in other communities around South Africa.

**Box 3.3. Community knowledge in seasonal outlooks for Pacific Island countries**

In partnership with meteorological services in Niue, Samoa, Solomon Islands and Vanuatu, the Australian Bureau of Meteorology's Climate and Ocean Support Program (http://cosppac.bom.gov.au/traditional-knowledge/) has developed a pilot project to produce an integrated forecast that uses both traditional knowledge and science-based data.

Pacific Island communities have a long history of coping with extreme events and climate variability by reading the signs in their natural environment. By combining this traditional knowledge with conventional forecasts, the aim is to produce a valuable forecast product for improved communication, decision-making, risk management and disaster prevention.

## 3.4 Understanding

The advice above, along with that in the previous chapter, highlights that IBFWS might consist of several different modes of risk communication, using different media, formats and styles tailored to inform the various user groups.

### The risk information hierarchy

Chapter 2 describes the variation in amounts and detail of warning information across different IBFWS formats and media, with a consideration of the choices to be made as to which to use.

In addition, IBFWS providers should judge how to best present the warning content itself to each user group. Assuming the IBFWS use a risk matrix approach as described in WMO-No. 1150 Part I, providers should assess if the users should be exposed to the complexities of the matrix itself, along with its component impact and likelihood assessments. For example, it may be that use of the warning colour alone, along with supporting text, is appropriate for use by the general public. This may be sufficient for most situations. The subtleties of the warning may be lost if user decisions are based purely on colour, but conversely a full appreciation of a warning's matrix position may be lost on the general public, and understanding might be adversely affected.

Again, a full knowledge of the user categories is needed to ensure warnings are understood. An effective general approach is to design warnings with a hierarchical approach – with universal and immediate access to the aspects that all users need to know, including the colour, and the "5W" format described in Chapter 2 – and which then allows more specialized or experienced users to mine down into more detail, such as the matrix itself or other information specific to emergency management.

**Communicating probabilities**

The probabilistic approach is one component of risk communication, and as such the challenge of communicating uncertainty also has the public perception of uncertainty to take into account. One cognitive psychological effect that can interfere with the perception of uncertainty is the preference for categorical information.

There might be different perceptions of the uncertainty expressed as a single value, a range of values, or using verbal statements. This will also depend on the receiver, and the action to be taken with the information. The addition of uncertainty introduced through ambiguous communication can easily outweigh the meteorological uncertainty. The language used, or even the order of the information provided, can result in marked differences in users' understanding and the actions they take. Through engagement with users, it is important for IBFWS providers to understand the consequences of the ways they choose to communicate probability and risk. For example, the two statements "it is likely to be wet" and "it is unlikely to be dry"' may be meteorologically equivalent but may well provoke very different responses in some users. This is another reason for using multiple ways to communicate a single message, and to then verify that the users have understood this message.

**Perception of risk**

Effective communication of risk is dependent on an understanding of people's perception of risk. Risk perception suffers biases that depend on personal memories, history, and mechanisms that people use to reduce difficult mental tasks to simpler ones. The hazards interact with psychological, social, institutional and cultural processes in ways that may distort public responses to the risk.

Amplification of perceived risk may be due to different mechanisms, such as extensive media coverage of an event, or association of the event to the agenda of a particular social group. Psychological processes such as attention, memory and information processing may be directed by a user's emotions or worldview.

## 3.5 Action

Recalling the reach model introduced in section 3.1, the ultimate aim of IBFWS is to inspire appropriate actions from users to protect themselves, their communities, their societies and their prosperity. Following the previous steps to ensure reach, trust and understanding, we now turn our attention towards these actions, which again will be dependent on the users as well as the nature of the hazard.

**Risk communication for early action**

One advantage of the risk-based IBFWS approach is its ability to inform early action planning, for example based on high-impact, low-probability weather events at lead times of several days or more. The warning system should provide the necessary information, including likely impacts, to help users decide where and when early action should be taken.

Early action decision-making can be made at individual, or general public, level based on widely communicated, national or regional level public service warnings. But early action decisions can also be made by the institutions described in previous sections. In the former case, early actions decided by an individual, family or community will depend on the degree of risk appetite, perception and preparation they have as well as the quality of the risk communication. In the latter case, government and non-government institutions play a key role during the co-production process of the IBFWS. This enables the pre-planning process to identify which risks can be reduced based on the forecast probability, expected impact, lead times and other factors. By knowing this information, institutional users and decision makers are able to decide the expected scale of interventions, budget allocations and the development of standard operational procedures to enhance contingency planning.

**Early action by individuals**

Public capacity to act ahead of a disaster depends on several factors, including:

– Trust in the forecast services and source of information;

– Understanding of the warning message;

– Enough lead time to act;

– Knowledge about the type of actions they can undertake to reduce risk and prepare for disaster response;

– Resources to be able to implement early actions.

**Early actions by institutions and forecast-based finance**

Government agencies – as well as non-governmental institutions such as civil society organizations, the private sector, humanitarian and development actors – have additional considerations when deciding to act based on a forecast. Risk appetite might vary according to the type of institution, their goals and missions. For DRCPAs, early warnings are essential to ensure effective readiness for disaster response. In recent years, however, there has been a strategic move towards more proactive use of warning services. In the humanitarian sectors, anticipatory approaches have been developed to ensure that early actions are implemented in the window of time between an impact-based forecast and the onset of the impactful event. Such early action decision processes are dictated by several factors, including:

– A warning message indicating when and where disaster-related impacts may be felt, and who and what are likely to suffer the impacts of a hazard;

– A detailed early action planning process, from scenario development, enhanced contingency planning and specific early action plans that indicate what actions can reduce risk and enable effective readiness to respond to disasters. Consideration of aspects such as cascading and compound hazards is essential in this planning process;

– A clear delivery strategy, deciding how early action will be implemented; this includes considerations such as doing no harm, access, logistics and security, among others. In some contexts, social protection systems are being explored as potential effective delivery channels for early action support;

– A financing mechanism that can release funding based on a forecast. This has been for many years one of the key gaps in effective early warning and early action processes. If the financial means are not enabled to take early action it is challenging to execute any early action plan. Some advances have been made in this area, and different organizations including the United Nations, IFRC and the NGO sector have created FBF mechanisms that can be triggered automatically based on impact-based warnings. The development of such mechanisms is promoting a radical change in the way that IBFWS are developed and applied in practice. For more information see Forecast-based Action by the Disaster Relief Emergency Fund of IFRC.

At governmental level, there are countries that are moving towards the allocation of disaster risk financing instruments to enable early action. In the Philippines for example, the disaster risk reduction fund that is allocated to all governmental administrative units adapts to enable the use of a certain percentage of the fund based on the forecast. In some provinces this has been possible on an ad hoc basis. However, the ambition is to institutionalize this process in a way that local government units can trigger funding based on forecasts that indicate a specific likelihood of impact.

## CHAPTER 4. IMPACT INFORMATION AND METHODOLOGY

| **Five key messages:** | |
|---|---|
| (1) | In advance of risk data collection, define clear long-term goals that are specific and measurable with clearly defined and agreed targets prior to initiating activities. Also, support clear communication between project partners and stakeholders. |
| (2) | Cultivate relationships between partners and stakeholders that can contribute to risk information collection efforts and help facilitate the transparent communication of activities, sharing of knowledge and results. |
| (3) | Risk information is complex and yet the hazards and vulnerabilities that risk data seeks to describe are of concern to everyone. It is critical to explore ways for this information to be accessible and relevant to as wide an audience as possible. |
| (4) | Wherever possible, the collection of risk information should be an inclusive process within which the intended users (stakeholders) of the data contribute to the planning and execution of activities related to producing risk data. |
| (5) | While all the types of risk data are important, it is not necessary to collect them all. Focus on data sets that support decision makers in mitigation, preparedness, response, recovery and reconstruction. |

### 4.1 Introduction

To realize the benefits of IBFWS, as described in the previous chapters, NMHSs need to address the collection of relevant data and the development of data management systems in collaboration with other relevant partner agencies. The following sections describe some elements to be considered.

Countries adopting an IBFWS approach require information gathered from technical provider partners and users to understand how communities are vulnerable, and what their exposure is to natural hazards. This information helps all to understand and mitigate the risks associated with the impacts of the hazards.

**Where to begin when managing and creating risk assessments?**

A risk assessment, like many processes, answers the following questions:

- Why is the assessment needed?
- What are the information gaps?
- What are the end-user requirements for information?
- What data are needed to inform the assessment about the associated risks in the community, country or region, and how do these risks affect lives and livelihoods?

However, recognizing the risk is not enough. Understanding the benefits of a set of decision alternatives, linked to the risk, is also key. Credible knowledge, community (indigenous or traditional) knowledge, expert experience, personal experiences – all informed by hazard, vulnerability and exposure data – are essential elements of IBFWS (see Box 4.1).

**Box 4.1. Tropical Cyclone *Idai* in Mozambique**

In Mozambique many residents in Beira didn't take action on the warnings issued for Tropical Cyclone *Idai* as their previous experience of tropical cyclones was "manageable". They had been able to save their houses, remain safe and protect their livelihoods from the impacts of past cyclones and also from secondary risks, such as looting. Unfortunately, Tropical Cyclone *Idai* was stronger than previous cyclones, so this prior experience hindered rather than helped people to reduce the impacts of the storm. This information and learning are invaluable for ensuring IBFWS are communicated to the people of Mozambique in a contextual and understandable way in order to ensure action in the future.

Effective IBFWS integrate forecast information, social vulnerability and behavioural processes, natural resource and hazard-related maps, and reference maps for vulnerability and risk assessment in the forecast and early warning system:

– This information is essential to ensure access to the best possible science, combined with the best possible evidence base for impacts on populations and infrastructure;

– Sourcing and integrating this information into IBFWS requires a multidisciplinary approach with partners from other government agencies with missions involving the protection of life and property, such as the National Hydrological Services where they are separate agencies from the NMHS; and other entities such as national, regional or local emergency management agencies, first responders, infrastructure managers (responsible for dams, highways, bridges), the media, NGOs, local communities, and even individuals.

This chapter is organized to help providers and users work together to identify where to source the data and knowledge, how to access this information and how to integrate it into mitigation activities.

## 4.2 Identify data and partnerships (data challenges)

One of the first activities to conduct when developing IBFWS is to identify and use existing information (for example, previous studies, statistical data, maps, reports, newspaper and magazine articles, proceedings from hazard-related workshops, historical records) and partnerships as a desk-based research approach to understanding what hazards exist within a country, town or neighbourhood.

For example, hazard, vulnerability and exposure data and documentation can be informed by a range of sources, including: (a) stakeholders (for example, transport companies, local communities) can have information on high-water marks, flood or drought areas of exposure, dam level sensitivities; (b) DRCPAs host information on early action planning protocols and vulnerability maps down to community level; disaster response protocols, disaster outreach materials, hazard-specific risk assessments and requirements for effective disaster response; (c) infrastructure planning departments host information on building damage data, urban environments and sensitivities; (d) environment agencies may know the geographical extent of damages that will have a wider economic impact, for example, reduction in mangroves and the consequent salinization of agricultural land; (e) meteorological and climate agencies will have information on the likely frequency of an extreme event, hazard-specific risk assessments and mitigation strategies.

The method or process for developing IBFWS that identifies hazards and analyses the vulnerabilities and exposure of lives and livelihoods to hazards needs to be conducted with partners who have essential and complementary information on the impacts, vulnerabilities and exposure. For example, after the eruption of the Fuego Volcano in Guatemala, there was political will, immediate experience, and strong opportunity for education that prompted ministries and citizens to obtain new hazard impact and vulnerability data, as well as to develop and implement mitigation techniques in preparation for future incidents.

Obtaining and integrating hazard, exposure and vulnerability information must be collated in partnership, discussed and be adaptable depending on the different impacts experienced from different hazards, and aligned to the possible frequency and magnitude of the hazard. This work requires a commitment to collect, manage and analyse data in dynamic urban and rural environments on a regular basis over the long term. Annex 1 referenced on the companion web page to the present Guidelines offers examples of where to find hazard information.

While all types of maps and studies may be important, it is not always necessary to collect them all. Data sets that support decision makers around risk assessment, mitigation, preparedness, response, recovery and reconstruction should be focused on. The collation of data should be concentrated on:

– Those data necessary for solving the problems of stakeholders;

– Key partnerships that can facilitate sharing data. Partners may include DRCPAs, ministries, universities, the general public and the insurance sector.

For a more complete list see Annex 2 referenced on the companion web page.

## 4.3 Methodologies for impact data collection

Data gathering allows professionals and others to develop an understanding of what hazards and risks exist within a country, town or neighbourhood. Existing approaches to develop impact-based forecasts involve an integration of a variety of data on hazard, exposure and vulnerability, thus requiring expertise from a wide range of disciplines in the physical sciences (for example, meteorologists, hydrologists, geologists or geophysicists), engineering and socioeconomic sciences. Even in the most simplistic approach, scientific knowledge needs to be complemented with local knowledge and expertise (see Chapter 3). Further communication skills are needed to deliver appropriate messages that can help translate scientific knowledge and influence other people's decisions and actions. In the era of big data, some more advanced approaches are being used or developed by NMHSs around the world based on artificial intelligence or machine learning techniques (see Box 4.2). Some examples are listed below for general reference.

Approaches with a lesser requirement of resources:

– Regular damage surveys with stakeholders (government departments, public utilities, and the like) by questionnaires;

– Collaboration with the insurance sector in estimating economic losses after major disasters;

– On-site survey and interview with spotters after major hazard events;

– Post-hazard impact information collection by crowdsourcing via social media campaign and sharing on the public domain.

Approaches more demanding of resources:

– Near-real-time impact information collection by crowdsourcing via mobile app and social media platform;

– Near real-time impact information collection from incident and damage reports by emergency response personnel and the general public;

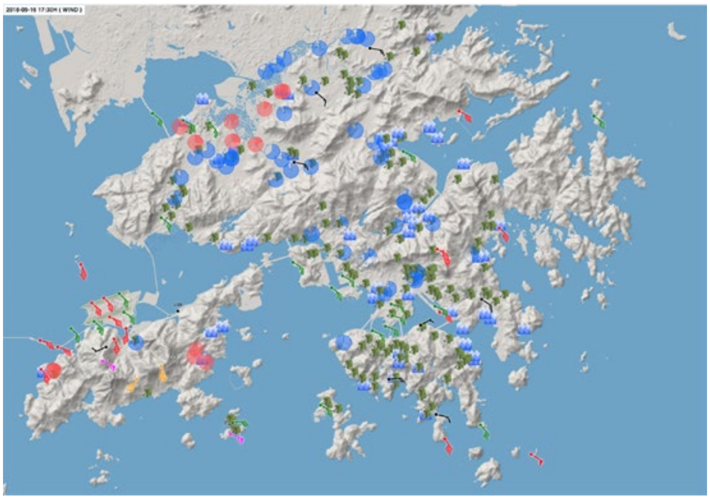
– Near real-time traffic impact analytics from online news and live traffic updates captured by road traffic cameras using machine learning algorithms.

Future possibilities under research or discussion:

– Real-time traffic impact nowcasting based on traffic speed sensor data and rainfall nowcast data using machine learning algorithms.

**Box 4.2. Gathering data during typhoons in Hong Kong, China**

In the big data era, an ever-increasing amount of information has become available from both meteorological and non-meteorological sources as exemplified by the case of Super Typhoon *Mangkhut*. For weather services, the challenge is how to mine the "treasure" hidden under the massive amount of data after collection. In recent years, the Hong Kong Observatory has explored innovative ways to gain access to non-meteorological impact data streams, for example, incident reports and traffic data, from external partners with a view to promoting common situational awareness and decision-making by the weather forecasters. With the application of artificial intelligence techniques to "deep learn" from the impact data, more insights have been gained from the big data treasure. Meanwhile, Geographic Information System (GIS) techniques have also been applied to visualize and integrate the impact data with weather data to give weather forecasters a holistic view of the data, enabling them to identify weather-related risks and to quantify the potential impact of extreme weather events.



Above is an integrated GIS display of meteorological information and impact data in Hong Kong, China during the passage of *Mangkhut* on 16 September 2018. (Note: water level above/below alert thresholds as pie charts in red and blue respectively; fallen tree as icon; and flood reports (not exhaustive) as icon. For meteorological information only wind barbs are shown here for simplicity.)

The companion web page to the present Guidelines lists some important parameters and considerations and serves as a reference to think about the details that may be needed when collecting impact information by whatever methods.

## 4.4 Assessing vulnerabilities to hydrometeorological hazards

Factors that determine vulnerability include resistance (the ability to withstand impacts) and resilience (the ability to maintain basic structures and recover from losses). Many see vulnerability as one of the keys to understanding disasters because it is correlated with the underprivileged, past losses, and susceptibility to future losses (Blaikie et al., 1994; Cutter, 1996, Cutter et al., 2003). Social inequities along the lines of class, race, ethnicity, gender, age and national origin are key elements in people's vulnerability to environmental calamities. Therefore, vulnerability is situation specific, interacting with the hazard to generate risk and may also be time and space dependent.

Various methods exist to carry out vulnerability assessments and it is critical that they are infrastructure, system and service specific. For example, there are at least three different approaches for assessing vulnerability due to tropical cyclones. These include (1) the examination of inundation of the land by ocean water, which is pulled up by low pressure and pushed onshore by tangential wind stress at the ocean surface by the wind field associated with the cyclone; (2) assessment of high winds and the associated huge waves from cyclones which usually cause tremendous damage to the coastal structures and (3) the effects of the heavy precipitation from cyclones or hurricanes, which can cause significant rise in water level of rivers, thereby increasing the severity of flooding when storm surge rides on top of the fresh water at the estuaries or river banks near to them. Potential data sources in this process include historical events, modelling, experience, community memory, scientific studies, experimentation and testing. Additionally, maps, remote sensor images, and reports can be integrated with meteorological, hydrological and modelling information and combined with knowledge of human land use and occupation, and overlaid onto maps that capture critical infrastructure, key producing areas and population densities. See Table 4.1 for an example of different data sources for a risk assessment for storm surge.

**Table 4.1. Examples of data, elements and sources for a vulnerability assessment for storm surge**

| *Index categories* | *Factors* | *Elements* | *Data sources* | *Introduction* |
|---|---|---|---|---|
| Socioeconomic (*A*) | Population | Density | China sixth census in 2010 | Person/km$^2$ |
| | | Age structure | | Ratio of ≥65 and ≤14 year old |
| | | Urbanization level | | Ratio of urban population |
| | | Education level | | Ratio of illiteracy |
| | Traffic | Road density | National Geomatics Center of China | Unit: km/km$^2$ |
| | | Road grade | (http://www.ngcc.cn/) | Ratio of low level road |
| | Economy | Industrial production | National Bureau of Statistics of China | Unit: 10 thousand Yuan |
| | | Agricultural output | | Unit: 10 thousand Yuan |
| | | GDP | | Unit: 10 thousand Yuan |
| | | Area | Land use planning of each county | Unit: km$^2$ |
| Land use (*L*) | Residential land | Area | | Unit: km$^2$ |
| | Arable land | Area | Report of Chinese offshore investigation and assessment, 2010. | |
| | Aquaculture | Area | Report of Chinese offshore investigation and assessment, 2010. | Unit: km$^2$ |
| Ecological environment (*E*) | Coastal wetland | Area | Report of Chinese offshore investigation and assessment, 2010. | Unit: km$^2$ |
| | Water area | Ratio of water area | | Water area ratio |
| Resillience (*k*) | Seawall | Proportion | National Bureau of Statistics of China | Proportion of seawall to coastline |
| | Financial revenue | Gross income | | Unit: 10 thousand Yuan |

*Source:* Taken from Gao et al. (2014).

## 4.5 Identify events and hazards

The case of El Salvador (Box 4.3) demonstrates the benefits for both users and providers. By working together with adequate knowledge of the impact of the hazard, the users and providers can achieve the desired response, saving lives. It also highlights that the efforts to develop IBFWS forecasts and analyses to build scenarios and issue appropriate warnings affect what actions the public, communities and sectors take to avoid disasters.

**Box 4.3. El Salvador**

In El Salvador hydrologists, engineers and social scientists from the NMHS have worked with local communities bordering main rivers to identify thresholds for flooding, assets and livelihoods at risk, and to establish a close collaborative relationship to ensure community-centred early warning systems and increase community resilience. As a result, during Tropical Storms Amanda and Cristobal in 2020, they were able to take actions to minimize damage and prevent casualties.

The process typically involves:

– Use of workshops or technical meetings to identify and agree on key hazards;

– Use of previous examples of hazards experienced by providers and users in the room – this is useful in terms of a learning tool and to ensure all are starting from the same page;

– Use of community or local place-based knowledge (for example, an experience-based connection to one's surroundings and environment (see Nyong et al., 2007)).

Some key questions are:

– Are key hazards and related threats identified?

– Are exposure, vulnerabilities, capacities and risks assessed?

– Are roles and responsibilities of stakeholders identified?

– Is risk information consolidated?

– Is risk information properly incorporated into the early warning system (WMO, 2018)?

To be effective, an IBFWS approach should not focus on the initial event (for example, a cyclone), but should account for the multiple hazards that can cause a series of cascading threats (Table 4.2) or consequential effects – public health, accidents, infrastructure damage, civil unrest, food insecurity, and others. This highlights not only the technical requirements, but also the need for an effective operational partnership among stakeholders.

**Table 4.2. Example of multiple hazards resulting from a cyclone**

| *Event* | *Primary hazards* | *Secondary hazards* | *Tertiary hazards* |
|---|---|---|---|
| Cyclone | • Strong wind | • River flood | • Damage in dam and appurtenant structures, embankment, irrigation and drainage facilities, pumping facilities |
| | • Lightning | • Surface water flooding | • Submerging paddy fields |
| | • Heavy rain | • Flash flood | • Migration |
| | • Tornado | • Landslides | • Food shortage |
| | | • Storm surge | • Loss of infrastructure systems and services (shelter, transportation, schools, hospitals, energy supply, communication) |
| | | • Water level rise in reservoirs | • Waterborne diseases |
| | | • Riverbank erosion | • Environmental degradation |
| | | • Mudslides | • Snake bites |
| | | | • High sediment transport into reservoirs |

## 4.6 Development of global impact databases

Recognizing the importance of capturing the losses and damages associated with the impacts of disasters, many institutions have developed global disaster loss databases. These are useful sources of information and are widely used to keep governments up to date on large-scale disaster losses and to mobilize resources to support improved IBFWS. They inform annual global and country statistics.

Countries that do not have their own database can access the databases created by international development banks, such as the World Bank or International Monetary Fund, by academic researchers, and by major re-insurance companies. However, a nationally owned disaster loss database built on the data collected and validated by national and subnational agencies is preferred as vulnerability is often location, infrastructure and community specific.

A local and regularly updated impact database provides information in a contextual way in order to enable key stakeholders to better analyse disaster trends and impacts at country level through to community level, allowing policy makers and planners to plan better for the future. For more details see Annex 3 referenced on the companion web page to the present Guidelines.

## CHAPTER 5. THE VALUE OF IMPACT-BASED FORECAST AND WARNING SERVICES

| **Five key messages:** | |
|---|---|
| (1) | IBFWS adds value by helping users understand the impact of the hazard, enabling better decisions and preventative actions to be taken. |
| (2) | There is no one measure of value – this can be assessed from a number of different viewpoints or links in the warning chain from the national to the individual. |
| (3) | Value can be measured in three broad categories: timeliness, relevance, outcomes. |
| (4) | Social science plays an important role in evaluating indicators of IBFWS value with public or user-specific surveys providing valuable insights. |
| (5) | Evidence of value is important to further enhance products and services. |

In recent years there has been increased focus on the need to quantify the value of weather and climate services in general. *Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services* (WMO-No. 1153) defines an NMHS's benefit in social, economic and environmental terms. Such measures provide a starting point for asking how the value of IBFWS may be determined. However, in this particular case there are additional considerations based around the IBFWS goal of enabling action and mitigating risk. For example, value might be measured differently depending on one's viewpoint and which part of the chain of users is being considered. Also, the value to intermediary users such as DRCPAs may be different to those of "end users" such as the individual, communities, vulnerable groups, the general population or the nation as a whole.

As noted in Chapter 3, a full understanding of benefits to each of these user groups is required to determine value. How to balance and prioritize their potentially differing needs within the constraints of finite resources then often involves financial, ethical and political decisions. For example, providing value to all may reduce value to the most at risk. Hence there may be difficult choices for NMHSs and their governments.

### 5.1 How can IBFWS add value?

Impact-based forecasts and warnings can be easily integrated into the decision-making process. Such forecasts and warnings then influence the recipient's perception of the hazardous events and understanding of potential impacts, thus enabling more effective preparatory and protective actions to be taken before the hazardous conditions occur. This kind of risk-informed early action and as such, preparations for response requires reliable, accessible and people-centred information. From these users can perform rapid estimations of the benefits of action and the costs of inaction, and estimate resource requirements to plan for early response.

Impact-based forecast and warning services that recommend early actions can help bridge the gap between knowing something, making the knowledge available and accessible, and applying what is known, hence enabling recipients to take the right decisions to protect themselves and their communities.

Cascading hazards followed by a chain of consequences can trigger secondary or indirect socioeconomic impacts compounding risks and disruptions well away from the origin of the hazard, even at national and regional scales. This increases the vulnerability of affected populations and reducing their coping capacity. Again, effective IBFWS will encourage actions that help mitigation and avoidance of this range of impacts (see Box 5.1).

**Box 5.1. Measuring the benefits of IBFWS-informed anticipatory action in Bangladesh**

In 2017, Bangladesh experienced the worst floods in recent decades. Based on an impact-based forecast and pre-defined trigger level, an IFRC project distributed an unconditional cash grant of BDT 5 000 (US$ 60 equivalent) to each of 1 039 poor households in highly vulnerable, flood-prone communities in the Brahmaputra River basin before an early flood peak. A post-disaster household survey was carried out among the affected population to assess the effectiveness of the forecast-based cash distribution in helping beneficiaries to take preparatory early actions and reduce the negative impacts of the flood on their health, well-being, assets and livelihoods. The assessment showed that the IBFWS-driven cash grants contributed to improving households' access to food; a reduction in high-interest debt accrual of vulnerable households; and reduced psychosocial stress during and after the flood period (Gros et al., 2019).

## 5.2 Measuring the value of IBFWS: Suggestions for metrics and methods

### What to measure?

The socioeconomic benefits of IBFWS can be measured in three broad categories:

- **Timeliness:** Enabling early action and response – questions to be answered include:
  - Did IBFWS allow organizations and individuals to take early actions in anticipation of an extreme weather event to mitigate its impacts?
  - Did IBFWS enable public services and disaster response agencies to prepare themselves for the extreme event and inform an earlier, better targeted response?
- **Relevance:** Informing the right actions to avoid or mitigate anticipated impacts – questions to be answered include:
  - Was the information content of IBFWS sufficiently specific, accurate and actionable to enable organizations and individuals to take appropriate disaster preparedness and response actions where the impacts were likely to be greatest?
- **Socioeconomic outcomes:** People and communities experience fewer losses and damages, and safeguard health, well-being and livelihoods – questions to be answered include:
  - Did people and communities experience fewer physical losses and damages (compared to similar extreme weather events previously or elsewhere without IBFWS)?
  - Were people able to avoid or mitigate negative impacts on their health, well-being and livelihoods?
  - Did affected populations adopt fewer negative coping strategies (for example, making destitution sales of valuable assets when livelihoods are destroyed)?

### How to measure it?

- **Qualitative** information obtained via a user engagement programme. This may include standardized and customized feedback mechanisms (such as focus groups, user interviews and surveys, email solicitations or partner webinars).
- Observational or survey-based **quantitative** data are best used to determine whether IBFWS information has contributed to fewer losses and damages, impacts on health, well-being, livelihoods, and coping strategies.
- Example indicators of interest could be:

- ◦ The proportion of houses intact, partially or fully destroyed;
- ◦ The number of days people were unable to go to work due to the extreme weather event;
- ◦ The number and proportion of people suffering from illness, injury or death.

– **Data sources:** When IBFWS are available and used at scale – informing public and private actions across entire geographic or administrative units – they increase the likelihood that the socioeconomic outcomes from IBFWS-informed behaviour can be detected in routine data sources that do not require separate data collection efforts. For example, if the IBFWS alert the entire population in a district of an impending flood event, data from hospital admissions or insurance claims would indicate the extent to which people were able to take anticipatory actions to protect their health and assets.

The following table (adapted from Appendix D of WMO-No. 1153, 2015) presents a range of indicators and associated example measures and methods used to evaluate meteorological warnings issued by NMHSs. As noted in the example methods here, the application of methods adopted from the social sciences through public surveys is important to evaluate many indicators, especially when establishing the value of IBFWS relating to relevance and intent.

| *NMHS performance indicator* | *Example measures* | *Example methods* |
|---|---|---|
| Accuracy<br>(location, timing, severity) | • Traditional numerical verification (e.g., probability of detection, false alarm ratio)<br>• Likert rating scale (e.g., 1–5) or “percentage of time correct/accurate” | • Statistical analysis of warning forecasts relative to observations<br>• Survey to assess public or user-specific opinion |
| Reach<br>(warning accessed by intended audience) | • Counts of warnings issued to public or users over a period of time | • Summation of warnings by region, time period, channel<br>• Descriptive or relative statistics over longer period of time (multi-year trend in annual counts) |
| Understanding<br>(warning meaning, consequences and suggested actions are understood as intended) | • Percentage of correct interpretations (i.e., intended by NMHS) by public or users<br>• Post-event interviews | • Survey to assess public or user-specific opinion |
| Behavioural intent | • Percentage of people intending to take action in response to the warning | • Survey to assess public or user-specific opinion |

**How to attribute socioeconomic benefits to IBFWS?**

Assessing the socioeconomic benefits attributable to IBFWS can best be done by using a counterfactual, that is, analysing what would have happened without IBFWS. The challenge is that the counterfactual cannot be observed directly. It must be approximated with reference to a comparison case that resembles the conditions of the counterfactual (“what if?”) as closely as possible. The two most likely counterfactual data sources for IBFWS are:

– **Historical impact data** from the same or comparable geographic areas that were affected by a comparable extreme weather event in the past when no IBFWS were available;

– **Impact data** from communities or households who are affected by the same extreme weather event and who are comparable in every other aspect except that IBFWS were not available in their area. These could be districts with similar geographic properties and socioeconomic composition of the population but not reached by the IBFWS or for which the extreme event was not forecasted for these areas (see Box 5.2).

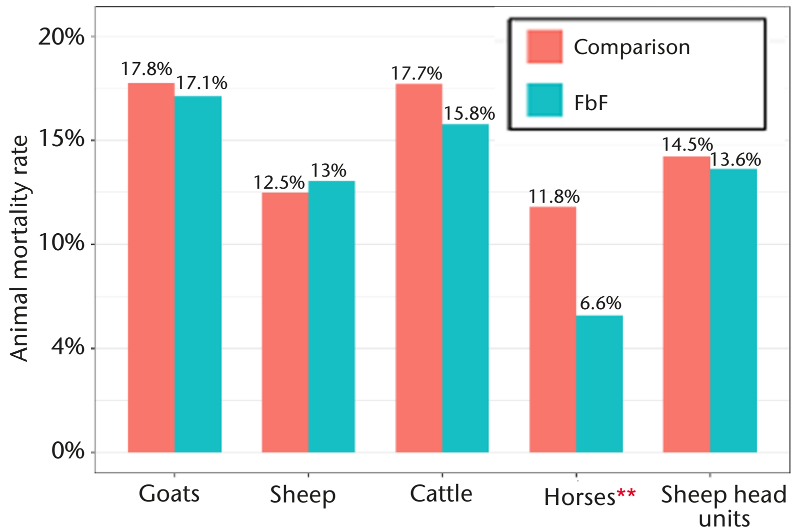
**Box 5.2. Mongolia's IBFWS dzud risk map drives early actions that help vulnerable herders reduce livestock losses and safeguard livelihoods**

In Mongolia, the Red Cross uses impact-based forecasting to anticipate extreme winter conditions, locally known as dzud. Dzud risk maps are developed and released every year in November before the beginning of winter, using multi-criterion analyses based on data including pasture carrying capacity, forecast temperature, snow and drought (Nandintsetseg et al., 2018). When hot and dry summers reduce pasture availability, weakened livestock may not survive a subsequent dzud because of the harsh cold or lack of fodder.

In the winter of 2017/2018, an impact-based forecast signalled a high risk of dzud in multiple areas of Mongolia. Using FBF, the Red Cross provided targeted cash transfers and animal care kits to vulnerable herder households across the entire country in 40 districts that would be most affected by dzud. The intention was to provide these essential resources before winter conditions would reach their most extreme and animals would become weak.

To assess the effects of providing IBFWS-informed cash and animal care kits on the livelihoods and well-being of herder households, a quasi-experimental study design was developed by the Red Cross to collect representative sample survey data from recipients of anticipatory assistance and comparison households. In May 2018, survey data was collected from 446 herder households across 4 provinces and 10 districts, including 223 cash and care kit recipients and 223 randomly selected comparison households.

The assistance appears to have had a strong, statistically significant effect on helping beneficiaries reduce the mortality of horses, among their most valuable animals, by approximately 50% compared to households who did not receive anticipatory assistance (see figure). The survey data also show a significant positive effect of FBF assistance on the survival rates of goat and sheep offspring, thereby helping herders to secure the future of their livelihoods.




**Animal mortality by species, comparison of households having received FBF assistance and a comparison group of similarly vulnerable households without anticipatory assistance; statistically significant differences indicated by asterisk (Gros et al., 2020).**

Notes:

"Sheep head units" represents the total herd size in sheep head equivalents, for example, one horse is worth seven sheep.

** Only horses as a species showed a statistically significant difference at the $p<0.05$ level.

IBFWS dzud risk maps are now routinely incorporated into the FBF approach of the Mongolian Red Cross and form the basis for the development of the dzud early action protocols, which trigger the automatic release of funds before the impacts of dzud are felt. The funds are used to support vulnerable individuals and communities with the supply of animal feed and care supplies.

### 5.3 Using evidence of the value and benefits of IBFWS

Evidence on the value and socioeconomic benefits of IBFWS can be used to serve multiple and important purposes:

- **Accountability and IBFWS quality assurance:** Evidence on whether or not IBFWS contributed to improved socioeconomic outcomes helps to verify whether impact-based forecasts and warnings were accurate and effective in informing the intended audience. Producers of IBFWS can use these data to strengthen their information products and services.

- **Strengthening early warning and early action capacity:** Data that show where and how IBFWS-driven actions added value or failed to protect lives and assets in anticipation of an extreme weather event can inform investments in public and private disaster preparedness and response capacity, for example, by establishing additional information dissemination channels, prepositioning supplies and equipment, training personnel, or reinforcing critical infrastructure.

- **Enabling community preparedness and risk management:** Individuals and communities can learn from evidence on IBFWS benefits and outcomes – provided that it is made accessible and communicated in a manner suitable for diverse audiences – to better prepare for the next extreme event, empowering decentralized risk management.

- **Advocacy for IBFWS:** Publishing evidence on the potential and actual benefits of IBFWS, and actively communicating it to relevant audiences, helps decision makers appreciate the importance of impact-based forecasts and warnings to drive early actions and mitigate impacts.

## CHAPTER 6. TRAINING PRIORITIES AND INITIATIVES IN IMPACT-BASED FORECAST AND WARNING SERVICES

| **Four key messages:** | |
|---|---|
| (1) | Implementation of IBFWS should include training considerations for NMHSs, partners and users as part of the implementation plan. |
| (2) | Learning activities should be adapted to the local situation, context, expected outcomes of the IBFWS and to the levels of awareness of all involved. Sufficient resources and time should be allocated to this activity. |
| (3) | Optimal learning activities should involve both NMHSs, partners and users. For example, these can be through combined workshops that support active collaborations and exchanges. |
| (4) | Training development and delivery should be supported by sound quality management principles that ensure the quality and continuous improvement of the training evolving with the provision of IBFWS. |

This chapter on training and professional development for IBFWS provides a few suggestions to enable training supporting the development of the relevant competencies.

### 6.1 Learning about IBFWS

Developing impact-based services involves stakeholders with various backgrounds, education and competencies and would be expected to include: (a) personnel from NMHSs (meteorologists, hydrologists, staff involved in developing partnership agreements, communicators, and so on); (b) partners in DRCPAs, NGOs involved in supporting humanitarians activities, academia, specific sectors among which health, agriculture, transport; (c) end users of the information, including specific sectors such as the media, communities and the population at large.

There are multiple providers of training. Academia, WMO Regional Training Centres[1] and institutional organizations are increasingly integrating aspects of IBFWS within their curricula and learning activities, or encouraging cross training in associated fields (see Box 6.1)

Although many of the following sections focus on the development of competencies for NMHS personnel, many concepts identified are applicable to all that offer IBFWS.

| **Box 6.1. WMO Workshop Instructor Guide for Regional Training Centres Regional Workshops on Hydrometeorological Information for Disaster Risk Reduction: Interaction between NMHSs and decision makers (follow link to view the Guide)** |
|---|
| IBFWS workshops initiated by WMO with specific NMHSs have led to the ongoing development of a workshop-based guide to support IBFWS. This guide presents various learning activities, led by Regional Training Centres or training institutions, that enable the development of collaboration between NMHSs and national DRCPAs that can be completed through various means, including online or live discussions. Individual and team pre-workshop assignments include members of NMHSs and civil protection agencies. This training workshop includes four modules: (1) getting to know DRR partners; (2) DRR communications and actions; (3) integrated risk management and event analysis; (4) challenges, opportunities, outcomes and lessons learned. |

### 6.2 Developing foundational competencies for forecasters and advisors

As many NMHSs orient their activities towards impact-based services, personnel must be trained and engaged in these activities in order to be fully functional, able to adapt to the change in paradigm, and participate in the development of tools, products and services supporting these activities (see Box 6.2). (See Annex 4 reference on the companion web page).

[1] https://public.wmo.int/en/resources/training/regional-training-centres.

*Technical Regulations* (WMO-No. 49), Volume I – General Meteorological Standards and Recommended Practices, Part V, defines, through the Basic Instructional Package for Meteorologists, the required knowledge and skill development that functional operational meteorologists and forecasters must acquire to:

– Analyse and continually monitor the evolving meteorological and hydrological situation;

– Forecast meteorological and hydrological phenomena and parameters;

– Warn of hazardous meteorological and hydrological phenomena;

– Communicate meteorological and hydrological information and potential impacts to internal and external users;

– Ensure the quality of meteorological and hydrological information and services.

These top-level competencies are the foundation for much of the work done by the forecasting personnel in NMHSs. However, services related to impact-based approaches also require that operational meteorologists, and others, be knowledgeable, and in some cases proficient, in other domains supporting IBFWS. As we have seen in previous chapters, impact-based services expand into areas that may not be directly associated with the scientific concepts of hydrometeorology.

**Box 6.2. Examples of IBFWS competency development**

Competency development for “warning preparedness meteorologists” was initiated by the Meteorological Service of Canada through a 3-day interactive workshop – entitled “Decision support training for operational and weather preparedness meteorologists”, the first pilot for which was run in 2015 – during which learning activities fell into three main categories: (a) establishing collaborative work with emergency management organizations and the media; (b) working with internal partners, including prediction centres; (c) effective communication practices. These learning activities were mapped to the competencies outlined in the Employment Developmental Framework of staff. Public Safety Canada and the local police service were guest speakers, and media experts provided context and situational mock-ups to develop communication competencies. Good practices in collaborative work and defining requirements for impact-based approaches were discussed. Experience sharing among participants also contributed to the success of the workshop and the development of on-the-job practices that followed.

## 6.3 Developing competencies in IBFWS within NMHS and partner organization personnel

*Compendium of WMO Competency Frameworks* (WMO-No. 1209) provides the spectrum of competencies for public weather service forecasters and advisors. Knowledge and enabling skills serve as fundamental requirements for the development of competencies related to specific job functions. Some job functions will not necessitate as much proficiency in certain competencies compared to others.

As services and technology evolve, competencies must be reviewed and adapted. Organizations that adhere to quality management system standards will improve their performance by identifying the required competencies related to specific job functions, recognizing the training needed to support these, and by organizing periodic review of the relevance and performance of these elements to ensure efficient and effective services,[2] including those related to impact-based services.

Some of the competencies supporting functions within IBFWS are a subset of those for public weather services, such as:

[2] See *Guide to the Implementation of Quality Management Systems for National Meteorological and Hydrological Services and Other Relevant Service Providers* (WMO-No. 1100) available at https://library.wmo.int/index.php?lvl=notice_display&id=15574#.X19iNMZ7ke0.

– Public weather service advisors supporting disaster prevention and mitigation, and other user activities;[3]

– Personnel working in the development and delivery of meteorological and hydrological products and services;

– Weather broadcasters and communicators.

The reader should refer to *Compendium of WMO Competency Frameworks* (WMO-No. 1209) for other competencies and skills supporting IBFWS, such as those for climate services.

### ***General concepts in the provision of services***

Fundamental to IBFWS is the concept of services. In 2014, WMO published *The WMO Strategy for Service Delivery and its Implementation Plan* (WMO-No. 1129) from which many of the concepts supporting the development and delivery of services can be applied to IBFWS.


The six elements necessary for moving towards a more service-oriented culture are:

**1** Evaluate user needs and decisions

**2** Link service development and delivery to user needs

**3** Evaluate and monitor service performance and outcomes

**4** Sustain improved service delivery

**5** Develop skills needed to sustain service delivery

**6** Share best practices and knowledge

**Figure 6.1. Process for developing and delivering services**

*Source: The WMO Strategy for Service Delivery and its Implementation Plan* (WMO-No. 1129).

Applying an impact-based approach requires that teamwork, understanding of purpose, and efficient communication with partners is established. It also requires that all parties are aware of each other’s realities, understand the relevant issues, and have a common vision of the objective of the services.

Understanding the principles underlying disaster risk reduction is also essential for all those involved in IBFWS.

[3] Based on Resolution 13 (EC-69) – Amendment to the Technical Regulations (WMO-No. 49), Volume I – General Meteorological Standards and Recommended Practices, Public Weather Services Provisions; and on the outcomes of the Joint Meeting of the Expert Team on Impact (ET/IMPACT) and the Expert Team on Services and Product Innovation and Improvement (ET/SPII) of the Commission for Basic Systems Open Programme Area Group on Public Weather Service Delivery (CBS/OPAG-PWSD), Beijing, 30 October–2 November 2017.

***Concepts in user engagement and developing partnerships***

This topic deals with partnership building and what needs to be in place to support the delivery of services and continuous improvement. Competencies in customer engagement and partnerships include:

- Establishing partnership, collaboration practices, working relationships and formal arrangements (and supporting documentation, such as MoUs) with partners; and communication and listening skills;
- Understanding and identifying roles, responsibilities and requirements of partners, contributors and users in the continuum of the IBFWS value chain;
- Understanding and including the decision-making processes of DRCPAs, including health partners and NMHS within-service development;
- Developing and implementing community-based partnerships.

***Concepts in the development and implementation of IBFW products and services***

This topic identifies how hydrometeorological multi-hazards can have an impact on human health and safety, the environment, other sectors, and societies. It informs which products and services can be put in place to help partners in their operations. Collaboration and user requirements are key components. Learning activities should be developed to support the following competencies – personnel should be able to:

- Analyse historical events and trends of hydrometeorological events and impacts for various situations. These would include primary, secondary and tertiary impacts;
- Predict and apply warnings through early warning systems as appropriate for the situation and priorities, and consider how best to:

    (a) Adapt forecast and warning paradigms, such as:

    - Hazard-only warnings;
    - Warnings that include exposure information;
    - IBFWS that include exposure and vulnerability information;

    (b) With partners, develop and implement products and services that bring together the hydrometeorological expertise with requirements of users, taking into account:

    - Assessments and integration of vulnerability and exposure information in decision-making and IBFWS approaches for various timescales (from short term to seasonal) and spatial environments (see Box 6.3);
    - Developments of risk analyses, risk matrices and impact tables for various hazards and circumstances, resulting from the assessment of the cumulative impacts of successive events;
    - Assessments of uncertainty, probability, likelihood of hazards and limits of prediction.
    - Developments and the implementation of the appropriate infrastructure (for example, data interoperability, platforms and archiving) related to the production, delivery and verification of products and services.

**Box 6.3. IFRC and Red Cross and Red Crescent Climate Centre and partners "learning by doing" – developing partnership and service-related competencies**

Work groups composed up of hydrometeorologists and climate experts working with humanitarian experts conducted national climate risks analyses, enhancing the usefulness of forecasts of extreme events through the use of early warning indicators (forecast-based actions). Integrating up to 120 hours forecast wind information with vulnerability and exposure information enables aid workers from the Philippines Red Cross to better prepare and respond to potentially high-impact situations. Early actions reduce impacts by either adapting buildings, or by supporting preventative actions in communities. Learning about the applicability of data analysis within impact-based approaches is supported through pilot projects to test the approaches with stakeholders. See https://www.510.global/automated-impact-map-sent-120hrs-before-typhoon-kammuri-arrives/.

***Concepts in delivery and communication***

The importance of good and efficient communication practices applicable to IBFWS and to partners and users (and public outreach) of the services has been highlighted in the chapters on excellence in communication (Chapter 2) and risk communication (Chapter 3). Developing competencies in this area will support the successful establishment of partnerships necessary for the development and implementation of IBFWS, and the development or use of communication applications; and assure that messaging will be relevant, adaptable and useful by taking into account social contexts, specificities of the audiences, gender, and perception of risks. Developing competencies in communication will also support the delivery of training, sharing of lessons learned, and outreach.

Multiple training resources exist, in particular through COMET's MetEd website (www.meted.ucar.edu/index.php). However, role playing, simulations and on-the-job activities and specific media-related training are effective methods of putting into action the learning outcomes that support the development of communication related competencies.

***Concepts in evaluation and improvement***

This topic deals with the evaluation of IBFWS as part of an overall quality management system, vitally important to any organization that seeks to have a culture of continuous improvement.

Employees involved in these aspects should be able to:

- Assess the effectiveness and relevance of products, services and systems throughout the processes, including through community engagement and awareness;
- Produce and deliver post-event analyses and structured debriefs;
- Develop, evaluate and interpret verification metrics;
- Determine reasons for shortcomings and be able to identify how to address these through analysis.

## 6.4 Community-based training and training for partners through engagement

Health organizations, DRCPAs and humanitarian agencies work with NMHSs to develop IBFWS. Collaborations and partnerships are based on a common understanding of the objectives to be attained, as well as the means to do so. Cross training is key within collaborative partnerships in IBFWS and can be enabled through workshops involving these various stakeholders.[4]

[4] See examples of various capacity building workshops under "Past Meetings" on the following webpage: https://community.wmo.int/activity-areas/public-weather-services-programme-pws.

The media, the public and specific users must also be informed as to how to interpret the information produced to mitigate impacts. In addition, their feedback is key to improving the services through case studies or after-event analysis that can also serve as learning opportunities. In order to help promote the adoption of IBFWS, communities and local governments should be engaged in the development of the services and of the training supporting them. Considerations regarding social and gender influence, and technology should be included in learning activities.

An approach to improving resilience of communities has been the use of trained local people who act as ambassadors and are active participants in the design, monitoring and management of the community's early warning system. Local community members can be provided with training on each of the four pillars of such an end-to-end multi-hazard early warning system: (a) on risk knowledge by being trained and helping to assess the hazard and risk in their communities; (b) on providing feedback to the NMHS regarding impacts that could improve the monitoring and forecasting of hazards; (c) on understanding impact-based warnings and how to share these with community members; (d) on community response capabilities, by encouraging and enabling early action and response (see Boxes 6.4 and 6.5).

**Box 6.4. User training in El Salvador**

"With the coloured maps (impact-based forecasts) it is easier for us to understand, one only sees the map and already has an idea of what is going to happen. The information they (the Observatory) sent us allowed us to take actions, we were able to anticipate and put our boats in safe places, since we usually leave them anchored in the river. People in the community were able to build riverbanks to reduce the impact of the floods on their crops" commented Álex Cabrera from Caserío Barrancones located near the Goascorán River in El Salvador.

Source: Celina Kattan, International Weather Ready Nations Initiative (of the National Oceanic and Atmospheric Administration).

**Box 6.5. The Bushfire and Natural Hazard Cooperative Research Centre, Australia**

The Centre put in place collaborative training practices developed with local communities (Bininj and Balngara, among others). As members of these remote communities also participated in training activities related to response to fire hazards, feedback helped refine requirements for additional leadership training. Training on response to fire hazards was also adjusted to include knowledge about the behaviour of local fires, given by those members of the community participating in the initial pilots. Key lessons include the importance of building training that corresponds to local requirements; engaging local communities in the development of this training so that it can be tailored to their needs and include traditional knowledge; and ensuring that all that need to be trained, are trained. See https://www.bnhcrc.com.au/resources/poster/4886.

## 6.5 Learning practices

This section presents some common practices used to promote learning in IBFWS that are most applicable to adult learners. For further information regarding competency-based training, the reader should refer to references listed on the WMO Trainer Resources Portal, and in *Guidelines for Trainers in Meteorological, Hydrological and Climate Services* (WMO-No. 1114) and *Guide to Competency* (WMO-No. 1205).

Adult learning theories stress the importance of learning by doing through informal training, purpose-oriented objectives that are of interest to the learner and adapting the learning experience to the context. Figure 6.2 provides options in learning solutions applicable to the context of IBFWS. A combination of many of these options, as a function of topic, context and the learner, can support the various aspects of competency development provided by WMO Regional Training Centres, NMHS affiliated training institutions, numerous United Nations organizations, and others.

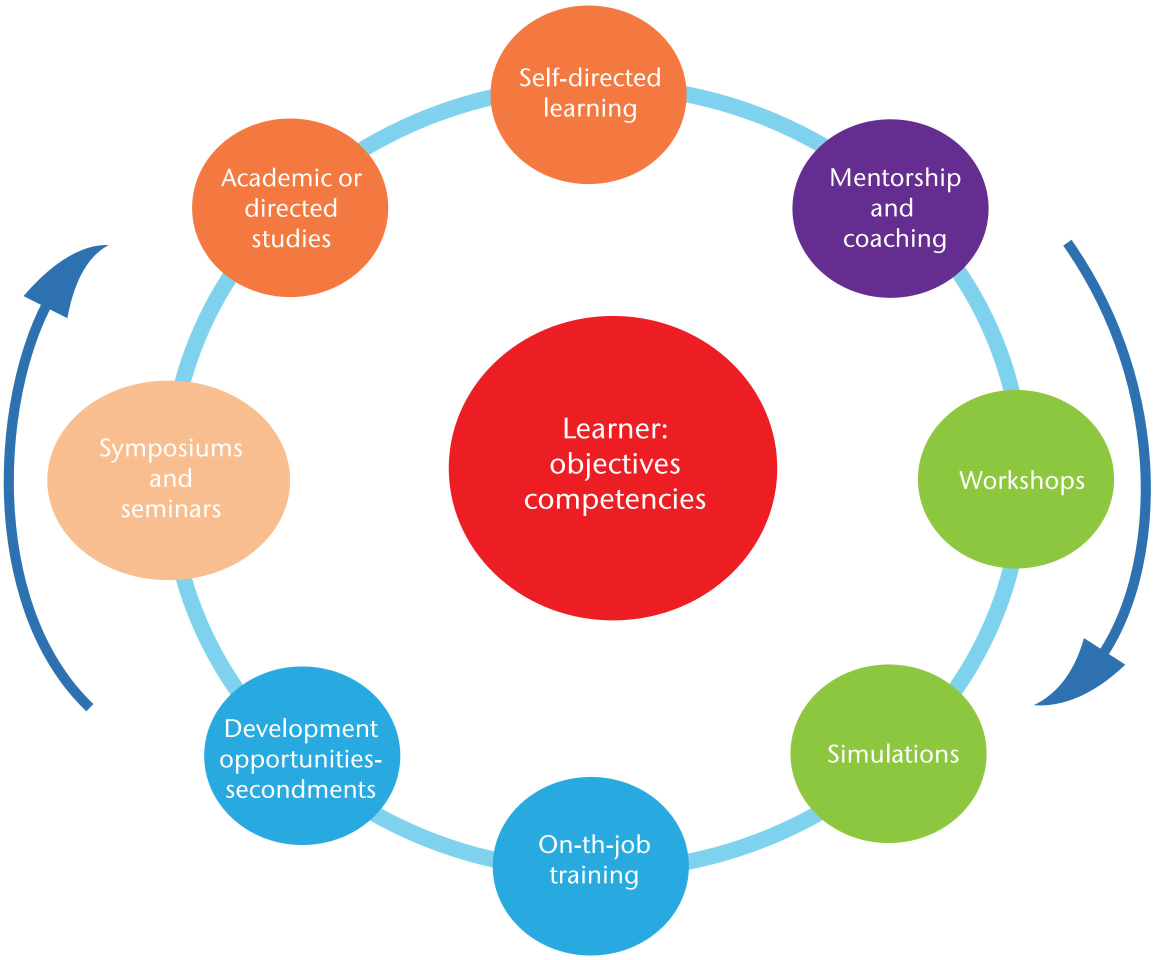



**Figure 6.2. Learning solutions for IBFWS**

*Source:* Adapted from *Guide to Competency* (WMO-No. 1205).

In addition to the examples presented within this chapter, the following options can also be considered:

– Conferences and seminars, self-directed studies or more formal education, although perhaps less job or function related, focus on the underlying theoretical understanding of the topic;

– Exercises or interactions between various stakeholders promote the sharing of experience and expertise;

– Mentorship and coaching enable a one-to-one approach fostering discussion and personalized direction-setting to address objectives;

– Interactive role playing and simulations during collaborative workshops, and case studies assessing the end-to-end performance of responses to specific events enable and enliven discussions and the understanding between the different partners and stakeholders within IBFWS. These opportunities enable cross training between partners involved in the development and delivery of IBFWS;

– Experiential learning through on-the-job training and practices, secondments and participation in projects provides the hands-on benefits of integrating knowledge and past experiences in the development of new competencies.

Annex 5 referenced on the companion web page to the present Guidelines provides a non-exhaustive listing of references and resources that can support the development of training and additional learning activities for IBFWS.

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