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| WEATHER CLIMATE WATER | **World Meteorological Organization**  **EXECUTIVE COUNCIL**  **Seventy-Sixth Session** 27 February to 3 March 2023, Geneva | **EC-76/Doc. 3.1(10)** |
| Submitted by: President of the Services Commission  21.XII.2022  **DRAFT 1** |

**AGENDA ITEM 3: IMPLEMENTATION OF CONGRESS DECISIONS:   
TECHNICAL MATTERS**

**AGENDA ITEM 3.1: Long-term goal 1: Services for societal needs**

# WMO Guide for National Meteorological and Hydrological Services in Support of National Multi-Hazard Early Warning Systems, Procedures, Coordination Mechanisms, and Services

**Guide No. 1 – Tropical Cyclone**

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| **SUMMARY** |
| **Document presented by:** President of SERCOM following the [Recommendation 5.6(7)/1 (SERCOM-2)](https://meetings.wmo.int/SERCOM-2/_layouts/15/WopiFrame.aspx?sourcedoc=/SERCOM-2/English/2.%20PROVISIONAL%20REPORT%20(Approved%20documents)/SERCOM-2-d05-6(7)-TECHNICAL-GUIDE-ON-TROPICAL-CYCLONES-approved_en.docx&action=default), regarding WMO Guide for National Meteorological and Hydrological Services in Support of National Multi-Hazard Early Warning Systems, Procedures, Coordination Mechanisms, and Services, in response to request by the World Meteorological Congress at its eighteenth session under [Resolution 16 (Cg-18)](https://library.wmo.int/doc_num.php?explnum_id=9827/#page=84).  **Strategic objective 2020–2023:** 1.1 – Better serve the societal need through established multi-agency coordination and synergy in response to meteorological/hydrological hazards – tropical cyclones.  **Financial and administrative implications:** within the parameters of the Strategic and Operational Plans 2020–2023, will be reflected in the Strategic and Operational Plans 2024–2027.  **Key implementers:** SERCOM, in collaboration with INFCOM, RB, CDP and Regional [Mr Obayashi] Tropical Cyclone bodies [Mr Obayashi], and WMO Members prone to tropical cyclones.  **Time frame:** the first Guide on Tropical Cyclones: 2020–2023. Other meteorological/ hydrological hazards will be added beyond 2023.  **Action expected:** review the proposed draft [resolution 3.1(10)/1 (EC-76)](https://meetings.wmo.int/EC-76/English/Forms/AllItems.aspx?RootFolder=%2FEC%2D76%2FEnglish%2F1%2E%20DRAFTS%20FOR%20DISCUSSION&FolderCTID=0x0120002E248E5BDF8F774FB72A5FDD5565F016&View=%7BBF176166%2DEC65%2D44AF%2DAED2%2D269501CD0FA0%7D) |

# GENERAL CONSIDERATIONS

**WMO Guide for National Meteorological and Hydrological Services in Support of National Multi-Hazard Early Warning Procedures, Coordination Mechanisms, Systems and Services**

**Guide No. 1 – Tropical Cyclones**

1. The [*WMO Guide for NMHS in Support of National Multi-Hazard Early Warning Systems, Procedures, Coordination Mechanisms, and Services*](https://wmoomm.sharepoint.com/:w:/s/wmocpdb/EcmFtn_ABoZNmABQ0F1jgd0BlfSWCTUamRggPVtJr2R7rg?e=zZDv89&CID=17237dd9-c962-e3d9-da64-a7383375540f) (hereafter the guide), was developed at the request of the World Meteorological Congress at its eighteenth session under [Resolution 16 (Cg-18)](https://library.wmo.int/doc_num.php?explnum_id=9827/#page=84) guiding on the Support of National Meteorological and Hydrological Services (NMHSs) to their National Multi-hazard Early Warning procedures, Coordination Mechanisms, Systems and Service, which:

(a) Decided to task the Technical Commissions and other bodies with the development of guide(s) on procedures/mechanisms for effective support by NMHSs to their national disaster risk management, focusing on Multi-hazard Early Warning Systems (MHEWS) operations, legislation and policy making and leveraging existing guidance material and good practices related to the four elements of MHEWS;

(b) Requested the Executive Council to oversee the development of guide(s) on NMHSs support of their national MHEWS (possibly including a set of hazard-cluster guidelines);

(c) Requested the Technical Commissions and other bodies to start developing the guide(s) in collaboration with other relevant WMO bodies and Members; focusing on tropical cyclones;

(d) Requested Regional Associations to contribute to the development of the guide(s).

2. The [guide](https://wmoomm.sharepoint.com/:w:/s/wmocpdb/EcmFtn_ABoZNmABQ0F1jgd0BlfSWCTUamRggPVtJr2R7rg?e=zZDv89&CID=17237dd9-c962-e3d9-da64-a7383375540f) has been developed by the Expert Team on MHEWS Technical Guidance (ET-MTG) of SERCOM Standing Committee on Disaster Risk Reduction and Public Services (SC-DRR) and reviewed by experts from members of Tropical Cyclone committees of Regional Associations I, IV and V and ESCAP/WMO Typhoon Committee and WMO/ESCAP Panel on Tropical Cyclones, members of the Advisory Group on Tropical Cyclones and members of the SERCOM Management Group.

3. The purpose of the [guide](https://wmoomm.sharepoint.com/:w:/s/wmocpdb/EcmFtn_ABoZNmABQ0F1jgd0BlfSWCTUamRggPVtJr2R7rg?e=zZDv89&CID=17237dd9-c962-e3d9-da64-a7383375540f) is to bridge the gap between early warnings and early actions and to enable outreach to the last mile to support early actions, and coincidently to support [Resolution 3 (EC-75)](https://library.wmo.int/doc_num.php?explnum_id=11331#page=19) – UN Global Early Warning/Adaptation Initiative.

**Expected action**

Based on the above, the Executive Council is invited to adopt the draft [Resolution 3.1(10)/1 (EC-76).](#_3znysh7)

# DRAFT RESOLUTION

## Draft Resolution 3.1(10)/1 (EC-76)

## WMO Guide for National Meteorological and Hydrological Services in Support of National Multi-Hazard Early Warning Systems, Procedures, Coordination Mechanisms, and Services

**Guide No. 1 – Tropical Cyclones**

THE EXECUTIVE COUNCIL,

**Recalling:**

(1) [Resolution 16 (Cg-18)](https://library.wmo.int/doc_num.php?explnum_id=9827#page=84) – Guide(s) on the Support of National Meteorological and Hydrological Services to their National Multi-Hazard Early Warning Procedures, Coordination Mechanisms, Systems and Services,

(2) [Resolution 3 (EC-75)](https://library.wmo.int/doc_num.php?explnum_id=11331#page=19) – UN Global Early Warning/Adaptation Initiative,

**Having examined** Recommendation 5.6(7)/1 (SERCOM-2),

**Having agreed** Recommendation 5.6(7)/1 (SERCOM-2),

**Adopts** the [*WMO Guide for NMHS in Support of National Multi-Hazard Early Warning Systems, Procedures, Coordination Mechanisms, and Services*](https://wmoomm.sharepoint.com/:w:/s/wmocpdb/EcmFtn_ABoZNmABQ0F1jgd0BlfSWCTUamRggPVtJr2R7rg?e=zZDv89&CID=17237dd9-c962-e3d9-da64-a7383375540f), as provided in the [annex](#_3dy6vkm) to the present Resolution;

**Requests** the Secretary-General to publish and disseminate the [guide](https://wmoomm.sharepoint.com/:w:/s/wmocpdb/EcmFtn_ABoZNmABQ0F1jgd0BlfSWCTUamRggPVtJr2R7rg?e=zZDv89&CID=17237dd9-c962-e3d9-da64-a7383375540f); and support Members prone to Tropical Cyclones to implement the guide; [Mr Teshome]

**Also requests** the Services Commission in coordination with the Infrastructure Commission Regional Associations, Research Board and regional intergovernmental entities on tropical cyclones and other relevant WMO bodies and partners to promote implementing the [guide](https://wmoomm.sharepoint.com/:w:/s/wmocpdb/EcmFtn_ABoZNmABQ0F1jgd0BlfSWCTUamRggPVtJr2R7rg?e=zZDv89&CID=17237dd9-c962-e3d9-da64-a7383375540f) and to support WMO Members prone to tropical cyclones to use the guide for developing or updating their national MHEWS procedures, coordination mechanisms and synergy, systems and services, and to report to the Executive Council progress and status on implementing the guide initially in 2024;

**Urges** Members to take desired actions to implement the recommendations provided in this [guide](https://wmoomm.sharepoint.com/:w:/s/wmocpdb/EcmFtn_ABoZNmABQ0F1jgd0BlfSWCTUamRggPVtJr2R7rg?e=zZDv89&CID=17237dd9-c962-e3d9-da64-a7383375540f) to establish their national MHEWS procedures, mechanisms and systems to enable information on warnings and response actions to reach everyone, and report to SERCOM via secretariat on their successes and challenges.

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[Annex: 1](#_3dy6vkm)

## Annex to draft Resolution 3.1(10)/1 (EC-76)

**WMO Guide for NMHS in Support of National Multi-Hazard Early Warning Systems, Procedures, Coordination Mechanisms, and Services**

**Guide No.1 — Tropical Cyclone**

**By WMO Expert Team on Multi-Hazard Early Warning Systems   
Technical Guidance**

**(Version 2022 — recommended by SERCOM-2)**

### Acknowledgements

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The ET-MTG is one of the expert teams within the Standing Committee for Disaster Risk Reduction and Public Services (SC-DRR) in the Commission for Weather, Climate, Water and Related Environmental Services and Applications (SERCOM) of the World Meteorological Organization (WMO).

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### Executive summary

The implementation of MHEWS will improve our ability to prepare communities for hazardous weather and climate related events and mitigate the impacts.

The eighteenth session of WMO Congress (Cg-18, 2019) approved [Resolution 16 (Cg-18)](https://library.wmo.int/doc_num.php?explnum_id=9827#page=84) tasking Technical Commissions in collaboration with Regional Associations to develop a guide for WMO Members to establish procedures/mechanisms for more effective MHEWS. The guide is aimed at 1) enabling early warnings of responsible warning authority to be transformed into those of corresponding level of government that can initiate early actions for all partners and public under its jurisdiction; 2) thus enabling outreach to the last mile to support early actions.

The guide will serve to encourage WMO Members to establish and develop their national abiding procedures and mechanisms through legislation or administrative protocol specifying transforming NMHS early warnings into government-level warnings; strategies/actions in response to the government warnings; and defining who does what with accountabilities in case of failure to respond. These procedures and mechanisms should be supplemented with hazard monitoring and assessment systems to enable early warnings based on impacts and risks, including hazard observation, monitoring, and modelling.

Published in 2021, the [*WMO Guidelines on Multi-hazard Impact-based Forecast and Warning Services (IBFWS) Part II: Putting Multi-hazard IBFWS into Practice*](https://library.wmo.int/index.php?lvl=notice_display&id=21994) (WMO-No. 1150) (WMJO, 2015) has helped countries in applying the concepts of Impact-Based Forecasting and warning services (IBFWS). However, there are still gaps between these concepts and actual implementation in both the developed and the developing worlds.

WMO Congress [Resolution 16 (Cg-18)](https://library.wmo.int/doc_num.php?explnum_id=9827#page=84) identified the need for a full guide to aid NMHS to support the early alerting of governmental and non-governmental decision-makers, thus permitting preparatory steps to be taken well ahead of the occurrence of hazards through MHEWS.

This document is designed to provide practical guide for MHEWS operations to help NMHSs to provide effective and institutional support to their national disaster risk management mandates. In the present context, MHEWS operations cover procedures, coordination mechanisms, services, legislation, and policy making. This includes leveraging existing guidance material and good practices related to the four elements of MHEWS from within WMO but also from its partners with the following emphases:

1. Risk knowledge — Institutional coordination in the areas of risk information and assessment for IBF and risk-based warning;
2. Hazards awareness and warning — Detection, monitoring, analysis and forecasting of the hazards and assessment of possible consequences;
3. Service delivery — Procedures and dissemination of advisory and warning information including the service delivery to communities and communication with partners;
4. Preparedness — Preparedness and response capabilities at all levels, including support for national response and recovery planning.

[Chapter 1](#_3rdcrjn) introduces hazards, impacts, knowledge, and challenges for MHEWS. Strategies for hazard awareness, warning, coordination, service delivery and emergency response are addressed in [Chapter 2](#_3as4poj). Procedures followed in multi-hazard early warnings are depicted in [Chapter 3](#_19c6y18). Good practices from around the world are reviewed in [Chapter 4](#_4k668n3). [Annex 1](#_1jlao46) includes case studies submitted for this guide. Further references and resources were summarized in the final section.

This is the first guide prepared by the WMO Expert Team on MHEWS Technical Guidance (ET-MTG). It is hoped, given the multi-hazard nature of tropical cyclones (TCs), that this first guide will shed light onto other similar hazard clusters and be generalized to other early warnings.

### CHAPTER 1: An introduction to MHEWSs and the challenges

***1.1 Definitions, Essentials, and Benefits***

To build capacity and strengthen resiliency a few definitions are essential. These are prescribed by the United Nations Office for Disaster Risk Reduction (UNDRR) (<https://www.undrr.org/terminology>) (UNDRR, n.d.):

RESILIENCE: The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.

PREVENTION: Activities and measures to avoid existing and new disaster risks. While certain disaster risks cannot be eliminated, prevention aims at reducing vulnerability and exposure in such contexts where, as a result, the risk of disaster is removed. Examples of prevention activities and measures include dams or embankments to eliminate flood risks, land-use regulations to restrict any settlement in high-risk zones, etc. Prevention measures can also be taken during or after a hazardous event or disaster to prevent secondary hazards or their consequences.

PREPAREDNESS: The knowledge and capacities to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current disasters. Preparedness is based on a sound analysis of disaster risks and good linkages with early warning systems and includes such activities as contingency planning. A preparedness plan establishes arrangements in advance to enable timely, effective and appropriate responses to specific potential hazardous events or emerging disaster situations that might threaten society or the environment.

RESPONSE: Actions taken directly before, during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected. Effective, efficient and timely response relies on disaster risk informed preparedness measures.

RECOVERY: The restoring or improving of livelihoods and health, as well as economic, physical, social, cultural and environmental assets, systems and activities, of a disaster affected community or society, aligning with the principles of sustainable development and ‘build back better’ to avoid or reduce future disaster risk.

Strengthening resilience depends on building capacity through prevention and preparedness leading to an effective response and recovery. Having the following resources through legislation will bolster the response and recovery of any hazardous event. The UNDRR’s *My City is Getting Ready Campaign Kit* provides a ten-point checklist on the essentials for making cities resilient:

1. Put in place organization and coordination to understand and reduce disaster risk, based on participation of citizen groups and civil society. Build local alliances. Ensure that all departments understand their role in disaster risk reduction and preparedness;
2. Assign a budget for disaster risk reduction and provide incentives for homeowners, low-income families, communities, businesses, and the public sector to invest in reducing the risks they face;
3. Maintain up-to-date data on hazards and vulnerabilities, prepare risk assessments and use these as the basis for urban development plans and decisions. Ensure that this information and the plans for your city’s resilience are readily available to the public and fully discussed with them;
4. Invest in and maintain critical infrastructure that reduces risk, such as flood drainage, adjusted where needed to cope with climate change;
5. Assess the safety of all schools and health facilities and upgrade them as necessary;
6. Apply and enforce realistic, risk-compliant building regulations and land-use planning principles. Identify safe land for low-income citizens and develop upgrading of informal settlements, wherever feasible;
7. Ensure that education programmes and training on disaster risk reduction are in place in schools and local communities;
8. Protect ecosystems and natural buffers to mitigate floods, storm surges and other hazards to which your city may be vulnerable. Adapt to climate change by building on good risk reduction practices;
9. Install Early Warning Systems (EWS) and emergency management capacities in your city and hold regular public preparedness drills;
10. After any disaster, ensure that the needs of the survivors are placed at the centre of reconstruction with support for them and their community organizations to design and help implement responses, including rebuilding homes and livelihoods;

The publication continues by providing benefits for cities that proactively seek to reduce disaster risk, as part of their sustainable urbanization efforts, can benefit greatly in the following ways: saved lives and property in case of disaster with dramatic reduction in fatalities and serious injuries

1. Protected development gains and less diversion of city resources to disaster response and recovery;
2. Active citizen participation and local democracy;
3. Increased investment in houses, buildings, and other properties, in anticipation of fewer disaster losses;
4. Increased capital investments in infrastructure, including retrofitting, renovation, and renewal;
5. Business opportunities, economic growth and employment as safer, better-governed cities attract more investment;
6. Balanced ecosystems, which foster provisioning and cultural ecosystem services such as fresh water and recreation;
7. Overall better health and well-being;
8. Improved education in safer schools.

Building capacity leading to strengthened resiliency is a calculated, consistent, deliberate, laborious and an ongoing process bringing great benefits to the local community reaching to those governing the county. Investing into local communities’ resiliency allows the government to put greater emphasis on social equity, inclusion and addresses actions needed in underserved or neglected populations, which are typically living in disaster prone areas. It truly is more cost effective to prepare a community for hazardous events than to pay for the injuries, death and damages following a disaster.

***1.2 Hazards and Impacts***

In accordance with [*WMO Guidelines on Multi-hazard Impact-based Forecast and Warning Services*](https://library.wmo.int/index.php?lvl=notice_display&id=17257)(WMO-No. 1150), a “hazard” is defined as a hydrometeorological-based, geophysical, or human-induced element that poses a level of threat to life, property, or the environment.

For this guide we will focus on the hazards associated with TCs, among which they include high winds, rainstorms, storm surges, and flooding. High winds are when windspeed exceeds a certain threshold, defined for a given location, for a specific period of time. A rainstorm is a marked precipitation event occurring for one hour, with a total precipitation exceeding a certain threshold defined for a given location. Storm surge is an abnormal rise in water caused by atmospheric weather systems above the normal tide levels. Flooding is an overflow of water that covers or submerges land that is normally dry, this can include riverine flooding.

Multiple hazard events or cascading events can lead to a more significant impact on human society and the Earth system than a single hazard. A TC is one of the strongest atmospheric hazards and is one hazard that can create cascading events. TCs produce high winds, heavy rainfall, and storm surges, combining for more significant flooding than a single hazard. They can also produce tornadoes and cause wildfires. Flooding and wind will disrupt transportation networks, energy supplies, and other critical infrastructure, causing loss of life or physical harm, social isolation, interruption to employment and livelihood activities, and psychological distress. To solve the problems of multi-hazards in TC with an effective MHEWS, a thorough understanding of the multi-hazards is crucial. For a comprehensive review including hazards classification, interested readers are referred to [*WMO Comprehensive Risk Assessment for Natural Hazards*](https://library.wmo.int/doc_num.php?explnum_id=9104)(WMO/TD No. 955).

To make an effective assessment and prediction possible, hazards need to be further quantified with magnitude, duration, severity, and extent (see Table 1 for a summary). Impact is quantified in terms of levels of magnitude or severity. Impact is defined as the effect or influence from a hazard or weather event. Such effects or influence can change people’s lives, including changes in knowledge, skill, behaviour, health, or living conditions. The impact can be economic, socio-cultural, and environmental.

**Table 1: Factors that determine the extremity of a hazard**

|  |  |
| --- | --- |
| Factor | Definition |
| Magnitude | It is based on an index or a set of indices of condition(s) exceeding certain threshold(s). Such an index can be as simple as one meteorological element (e.g., maximum sustained windspeed) or as complicated as a combined index by multiple variables such as windspeed, storm surge, etc.  Magnitude of impacts are often categorized into four categories:   * Low-impact – minor inconvenience, small and local economic losses * Moderate impact – minor damage, some social disruption * High-impact – damage, risks to health, broad economic impact * Extreme-impact – Catastrophic losses, deaths, injuries, major social disruption   Indices, criteria and thresholds should be defined by NMHS at national and subnational scale, according to its own climate conditions and applications. |
| Duration | How long does the event/hazard last? The computation of the persistence of a weather event (e.g., duration of strong winds) and should be based on recording the starting time and the ending time of the event. |
| Severity | A measure which integrates two aspects of the event, its magnitude, and its duration. |
| Extent | The geographical area affected and the widespread aspect of the weather event. |

Different magnitudes and duration can have different impacts on the environment. For example, different types of trees will have different responses and may break at different wind speed thresholds. Wind damage extent or severity may also be affected by orography or man-made structures around the trees. As such, direct prediction of impact from known hazard is typically difficult if not impossible. With this limitation in mind, WMO has promulgated the adoption of IBF. If the relationship between a hazard and the associated impact is known, we are able to estimate the resulting impact.

***1.3 Risk Knowledge***

Risk is the probability and magnitude of harm possible to humans, their livelihoods and assets because of exposure and vulnerability to a hazard; sensitivity or susceptibility to harm and lack of capacity to cope and adapt. It is thoroughly discussed in previous WMO documents such as [*WMO Comprehensive Risk Assessment for Natural Hazards*](https://library.wmo.int/doc_num.php?explnum_id=9104)(WMO/TD No. 955)*,* [*WMO Risk Management Framework*](https://library.wmo.int/index.php?lvl=notice_display&id=14740)(WMO-No. 1111), and [*WMO Guidelines on Multi-hazard Impact-based Forecast and Warning Services*](https://library.wmo.int/index.php?lvl=notice_display&id=17257)(WMO-No. 1150).

Exposure is the presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected.

Vulnerability is the susceptibility of exposed human beings, their livelihoods and property, to suffer negative effects when impacted by a hazard.

Risks arise from the combination of hazards, exposure of people and assets to the hazards, and their vulnerabilities and coping capacities in a particular location. Assessments of these risks require systematic collection and analysis of data. It should consider the dynamics and compounding impacts of hazards coupled with vulnerabilities resulting from unplanned urbanization, changes in rural land-use, environmental degradation, and climate change.

Communicating the risk in a given area requires clearly conveying the likelihood of an event occurring coupled with the potential impact the event will cause. See Figure 1 for an example.

Calendar

Description automatically generated with medium confidence

**Figure 1. An example of risk matrix based on likelihood and impact,   
taken from WMO-No. 1111.**

***1.4 Hazard Detection, Monitoring, Analysis and Forecasting***

All MHEWSs are founded on the detection, monitoring, analysis, and forecasting of the hazards. Typical monitoring tools for TCs utilize satellite and radar imageries, surface and upper air observations from weather stations, oil rigs, buoys and ships, satellite wind data, and data from aircraft. When a TC is close to a landmass, Doppler radar, if available, is essential for monitoring both the location and intensity. In some TC basins, aircraft-reconnaissance flights are also used to make measurements in and around the centre of a TC and collect flight-level and surface wind data, central pressure, profiles of wind, temperature and moisture from dropsondes, and radar data. Automatic or manual Dvorak analysis by forecasters is applied to the satellite imageries for TC intensity assessment, supplemented with surface observations, in particular winds and pressure to confirm the formation of a TC.

Good quality observation data and analysis of the actual meteorological situation are not only the key to hazard detection by the NMHSs but also a major input to numerical weather prediction (NWP) models. An accurate prediction of TC evolution by NWP models will determine how well the associated multi-hazard event can be forecast. The latter in turn influences potential impacts to the affected locations and the local communities. No NWP model can be 100% accurate, implying that the predicted potential impacts are subject to varying degrees of uncertainty. To quantitatively calculate the likelihoods of different hazards, major NWP centres operate their own ensemble prediction system (EPS) to simulate the possible hazard scenarios as exhaustively as possible. Together with the known relationships between hazards and risks, the magnitudes of the impacts can all be assessed. Given known exposure and vulnerabilities of people and property, risk assessment plays an essential role in preparedness before an event to protect life and livelihood.

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 and disaster management. Partnership and collaboration with a wide range of partners can include governments, international bodies, scientific institutions, disaster management authorities, the insurance industry, and local communitiesas needed.

***1.5 Effective MHEWS Partnerships***

Effective MHEWS is based on partnerships at various levels. This ensures actionable warnings, including potential impacts and related information, are provided to the public in a timely and effective manner. Clearly defined roles and responsibilities of partners are important. The coordination mechanisms should be documented in national to local legislation, policies, strategies, and plans. Arrangements should be made between partners well ahead of the TC season on the corresponding actions needed when a TC is detected.

Partners and decision-makers usually need to take actions before the warnings are issued and may ask for longer lead times from NMHS before warning decisions can be confirmed. Given the uncertainties involved in TC forecasting, likelihood- or risk-based communication terminology is recommended.

To provide key information to the public in a timely and effective manner, NMHS should start with a more casual layman style “weather note” on the potential weather changes and impacts when the lead time is a few days long. Then the dissemination of TC information can gradually be stepped up through social media as well as short messages on website/app, then formal news and press conference, leading up to the issuance of TC warning.

***1.6 Risk-Based Warning and Decision-Making Authorities***

The NMHSs have their national mandates to establish and develop the full sequence of national systems from observing, data acquisition, data processing, forecasting, and delivery of forecasting and warning services. One step further could be forecast and warning information provided with a multi-hazard approach and based on impacts and risks. The positive effects of the forecasting and warning information can only be realized if the information reaches every person in the warning areas, and if they respond to the warning information. To realize this, NMHSs must collaborate with other government agencies, private sector, and academic institutions to take joint and well synergized actions to support mitigation and reduction of hydrometeorological hazards.

With hazard monitoring, IBF, and risk assessment tools in place, warning decisions can be made by the NMHS, or other decision-making authority based on the calculated risks. To ensure warnings can be delivered to the potentially impacted areas, it is important to establish programme management roles and responsibilities for the development, implementation, delivery, and Standard Operating Procedure (SOP); develop a communication strategy that explains what the expected services are, the respective roles of partners, and outreach activities; develop a plan for [quality management](https://library.wmo.int/doc_num.php?explnum_id=4141) and assurance of products and services; and ensures the technical information is communicated in a way that communities and authorities outside the NMHS can understand.

***1.7 Importance of Legislation***

Legislation is a key tool to help mobilize and coordinate the efforts of the whole society; to prevent and control the risk; and mitigate the damages caused by a major hazard. It helps to safeguard people’s lives and property.

One agency cannot do it all! Therefore, there is a “… need for effective coordination arrangements … to be articulated and set within a legislative and public policy framework. The arrangements must reflect the role of all agencies in the EWS within the context of community safety and sustainability”. Without the backing, through legislation, of the government, the EWS is bound to fail. Agencies need designated authority from their lawmakers to include roles and responsibilities; agencies involved, including Non-Governmental Organizations; operational mechanisms; funding and technical support; resources available; the designated agency to initiate warnings; and the agency leading coordination activities, maintenance of the mechanisms, etc. With a legal framework, agencies’ SOP can be synergized along with Memorandums of Understanding and agency directives to produce the most comprehensive, collaborative, and united EWS leading to the best chance for success.

Some countries have put into force laws and regulations that support and validate the work of NMHSs in providing timely forecasts, watches, and warnings for the protection of the public and the economy of the countries. For example, the Meteorological Law of the People’s Republic of China is used in China. The National Disaster Risk Reduction and Management Law was enacted in the Philippines through Republic Act. Japan and Korea regulate their work through the Meteorological Service Act and Weather Act respectively. More examples are available in [Chapter 4](#_4k668n3) and the [Annex 1](#_1jlao46).

***1.8 Global Doctrine Supporting MHEWS***

The WMO Convention reaffirmed the vital importance of the mission of the NMHSs. This includes observing and understanding weather and climate as well as providing meteorological, hydrological, and related services in support of protecting life and property and to safeguard the environment.

The “[*Geneva Declaration (2019) on Building Community for Weather, Climate and Water Actions*](https://library.wmo.int/doc_num.php?explnum_id=10367)”called on governments to safeguard and strengthen the authoritative voice of NMHSs for the issuance of warnings and information to support critical decisions related to hazards and disaster risks, in collaboration with national disaster management authorities. This calls for governments to take the lead role in their national disaster mitigation and reduction mechanisms.

Furthermore, the [*Sendai Framework for Disaster Risk Reduction 2015–2030*](https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf?_gl=1*lj4uog*_ga*MzI3MzM4NjUuMTY2MDgyNjExMg..*_ga_D8G5WXP6YM*MTY2Mjk5MDYxNS4zLjEuMTY2Mjk5MDYyNy4wLjAuMA..) set up seven global targets to support the reduction of hazard and disaster impacts. Target G requires a substantial increase in the availability of and access to MHEWSs and disaster risk information and assessments to people by 2030.

Lastly, in March 2022, the United Nations Secretary-General Dr António Guterres announced that the United Nations will pursue [*new action to ensure every person on Earth is protected by EWSs within five years*](https://public.wmo.int/en/media/press-release/%E2%80%8Bearly-warning-systems-must-protect-everyone-within-five-years). These mandates combined require more WMO Members to establish their national MHEWS and their operating mechanisms.

***1.9 Addressing the Challenges for Strengthening MHEWSs***

The large and expensive impacts of disasters, including TCs, on society are a significant concern for all countries. Despite technological advancement, there are challenges that continue to be faced when implementing MHEWS. To assess and see the gaps in an effective MHEWS, it is best to identify and address the major challenges. The components of an effective MHEWS that have significant challenges are the warning procedures and coordination mechanisms.

*Major challenges from warning procedures*

If the risks are not known or are not accurate, they create a challenge for MHEWS. Risks arise from both the hazards and the vulnerabilities that are present in a community. We need to understand if the hazards and vulnerabilities are well known. Hazard and risk assessment should be based on historical experience, traditional and indigenous knowledge, as well as human, social, economic, and environmental vulnerabilities. Risk analysis and hazard assessment must be properly implemented.

The major concern here is the availability of data and development of appropriate tools where different geo-referenced hazard maps can be superimposed together with exposure data and vulnerability information. Updating of exposure databases including damage to infrastructures due to meteorological hazards is an issue due to rapid urbanization. Another challenge is educating the people on the interpretation and use of hazard and risk maps and other tools. Understanding of hazard and risk information by the public will guide them in proper preparedness actions and measures prior to the approach of natural hazard. Hazard and risk mapping must be a priority for disaster risk reduction management.

In recent years there has been great technological advancement in monitoring and forecasting TCs. Many systems that can issue warnings for multi-hazard events are in place and forecast accuracy has improved greatly over recent decades. However, further studies must be done on estimation and forecasting of quantitative rainfall and wind structure; sudden change in intensity; and TC tracks, erratic track, and rapid intensification leading to shorter lead times for warning. The interaction between the TCs and the sea is not well understood scientifically.

The big challenge in communicating early warning is that forecasts cannot be 100% accurate. Forecast errors and uncertainties are inevitable in actual operational forecasts. Therefore, the early warning and related response must cope with sufficient tolerance for false alarms. Additionally, there needs to be continued work on how to communicate uncertainty to the public.

To address this co-design and co-development of forecast-warning value cycles at national level should be enhanced for accurate interpretation of forecast guidance and uncertainties. Regional to global capabilities can be used to enhance the application of the Earth system modelling and prediction data products available from the WMO Global Data processing and Forecasting System (GDPFS), and to advance the co-development process through regional/global coordinated activities such as demonstration programmes and pilot projects.

Effective responses are strongly reliant on multi-hazard Impact-Based Forecasting and warning system (MH-IBFWS), which need stating “what the weather will do” instead of the traditional forecasting system telling “what the weather will be”. People demand forecasts to be exact in terms of intensity, location, and time of occurrence. With Impact-Based Forecasting (IBF) numerical values of weather parameters are not needed, and the focus will now be on the severity of impacts with likelihood of occurrence at a projected time. The IBF system requires weather data translated to hazards then impact estimation using risk information. The current challenge is the IBF cannot be done by NMHSs alone or are inconsistent with their existing responsibilities. Cooperation of the Civil Defence and emergency management agencies and other service institutions is necessary to address this challenge, a good partnership and protocol must be in place.

In some countries the availability of qualified technical staff is still a concern. Having an adequate number of competent meteorologists and hydrologists to ensure that there is smooth operation to analyse, compose appropriate messages, and communicate with the National Emergency Operations Centre, media, and public is essential. Staff development programmes on EWS should be enhanced within NMHS taking into consideration the [competency](https://library.wmo.int/doc_num.php?explnum_id=4237)-based capacity building and succession planning.

In addressing the challenges in MH-IBFWS, the recent publication of the [*WMO Guidelines on Multi-Hazard Impact-based Forecast and Warning Services (IBFWS)*](https://library.wmo.int/index.php?lvl=notice_display&id=17257) (WMO-No. 1150) and [*Part II: Putting Multi-hazard IBFWS into Practice*](https://library.wmo.int/index.php?lvl=notice_display&id=21994)(WMO-No. 1150) will be of great help.

*Major challenges from coordination mechanisms*

People should be reminded of the responsibility that comes with the release of forecasts and other information. To address this, policy makers should develop legislation to improve and strengthen the mechanisms around forecasting, warnings, information sharing, and communication of risk to help educate people.

Another challenge is that reference forecast information issued by the global and regional operational centres and NWP models, which were originally used by professional forecasters for internal communication, are being shared to communities through the internet, causing information confusion in the community. As a result, NMHSs struggle to explain the uncertainty of the forecast itself, but also the inconsistency with international NWP model forecasts. Once the international forecast is proven to be more accurate afterwards, it will have a negative impact on the authority and credibility of the national and local forecast services.

The forecasts and warnings issued on the internet by entities which are not the authoritative voice pose a problem, especially when there are discrepancies with the official forecasts and warnings issued by the mandated NMHS. These result in confusion and could lessen the trust and confidence in the NMHS.

A successful warning needs effective delivery of information and execution of proper actions depends also on applications of social and behavioural sciences. For MHEWS to be considered effective, the forecast and warnings must be disseminated, and communicated to the maximum extent possible and well understood. Based on these messages appropriate preparedness actions can be taken by the different types of users such as disaster managers, media practitioners, responders, and the public. To attain this NMHSs need the full cooperation of different partners, other service institutions and the users. Success lies in how the message is written by the sender and perceived by the receiver that commands action. In communicating, one of the challenges of forecasters is to express the forecast and warnings using simpler terms and statements that are clear and easily understood by all people in society. More often warning messages are said to be so highly technical that ordinary citizens cannot understand them. The messages should include information about the uncertainties associated with the TC hazards. Communication experts and social scientists are of great help in this aspect.

Timely delivery of warning messages to the farthest communities in remote areas affected by the TC is also one of the major challenges of NMHSs. Isolated areas not yet covered by advanced communication access and technology have no access to weather forecasts and warning advisories shared on social media platforms. In these cases, traditional and indigenous communication practices such as ringing of church bells, rhythmic beating of drums etc. are utilized. Public awareness campaigns, drills, and simulations must be done regularly. Annual exercises are critical to ensuring that the various agencies and the people know exactly what they must do to reach a high level of effective response.

The mode of transmission of warning messages is another area to be monitored and evaluated. Aside from the conventional newsprint, tele/fax, TV and radio broadcasts, NMHSs maintain their own websites and are now using social media platforms and apps. Website content should be regularly updated to ensure that information is communicated to the public in a timely manner. Messages must be monitored to ensure that official information is captured, especially in dealing with social media platforms.

To increase the value of weather-related warnings, a value cycle approach is necessary with continuous evaluation and updating of communication strategies through post-event analysis, user-engagement, user-testing, and awareness of design principles. False alarms or missed events are remembered by the people but not accurate forecasts. One false alarm against ten accurate forecasts has a substantial impact on the trust of the people.

Management of communication between the NMHS and the disaster management organization, other agencies, and partners including the media is critical to ensure a proper response to any hazard. It is important to note that during the passage of a storm, it is critical to either have a liaison for the NMHS at the National Emergency Operational Centre or direct uninterrupted communication with the Weather Service.

TCs mitigation is a complex systematic endeavour, and its success or failure and benefits depend not only on the timely and accurate forecasts and early warnings of the NMHSs, but also on the effective response actions of the various governmental entities and society. Multi-agency cooperation mechanisms on disaster management must be established at the national, regional, and local levels. The challenge here is for NMHS to maintain a strong partnership and coordination with other government agencies, private organizations, and institutions involved in disaster management activities. The establishment of an integrated TC preparedness and mitigation system with "government-led entities’ cooperation, and extensive social participation” defining the responsibilities of each partner and the coordination mechanisms is crucial. This includes the development of an agreed SOP. Legislation or national administrative measures are another method that can be used to compel relevant parties to do their part to respond to the warnings. In some countries there are legal documents or policies where roles and responsibilities of entities involved are clearly stated.

Not all countries and regions have preparedness plans to support the response mechanism, or the plan itself may be outdated or just not utilized. Abundant and applicable preparedness plans are the guarantee for the effectiveness of the linkage coordination mechanism. Once the NMHS issues a TC warning, all relevant departments and social forces should take corresponding coordinated actions.

### CHAPTER 2: Recommended strategy for MHEWS

*As Pat played on the beach, a village elder approached with word of an approaching storm. Pat, just being a child, hurried home with the news. The family gathered to discuss their options. Evacuation was out of the question because their island was too far away to get to a safer island with their boats. Finding a hardened structure to withstand the onslaught of wind, rain and coastal inundation was useless since the strongest structure was too small for all the villagers to squeeze into, although the most vulnerable among them would request this option from the elders. Their only effective option was to move their canoes to the highest point on the island, which was only three metres above high tide, and prepare for the storm surge to wash over the area. This meant tying their boats to palm trees and protecting themselves from blowing debris and heavy rain. As the family prepared for the approaching cyclone, they sent Pat to the village centre to gather the latest information which came through the only communication device available to the villagers — a shortwave radio. Pat learnt that the cyclone was increasing in strength, with the storm surge expected to rise above three metres. Pat hurried home to let the family know of the dire situation. Preparations continued. The island council gathered to finalize preparations, including working together to protect the most vulnerable folks and those who needed extra help. They also needed to arrange for immediate recovery needs, such as medical attention, food, shelter, transportation, and potable water, which was a struggle since many island communities would require this response after the passage of the storm.*

Having the ability to plan, knowing where to get authoritative information, being ready to act, and identifying how to recover from the experience makes all the difference. Before one begins to plan for a hazardous event there needs to be recognition and acceptance that a disaster can happen. Therefore, having a written plan starts one on the path of success, but the plan needs to be widely distributed, practiced, reviewed, and updated. In this chapter we will explore recommendations for good practices, and successes of, and failures by, “the system” through describing technical guidelines and regulations developed for National Multi-Hazard Early Warning procedures, coordination mechanisms, system protocols, and services.

***2.1 Overarching Principles***

*Keep it Aligned for REsults (KARE)*

The KARE principle – Keep It Aligned for REsults will help tremendously in getting the desired end results, including keeping people and their loved ones safe and decreasing property damage. While developing an EWS, keeping the goals in mind throughout the process is paramount for the outcome to be robust, successfully oriented and interconnected. As partners, a shared and aligned vision can bring, and keep, everyone together to create and sustain an effective set of plans. For example, having an initial gathering with disaster risk reduction managers; meteorological, hydrological, and climatological forecasters; politicians; faith-based community organizers; village elders; Red Cross/Red Crescent representatives; first responders; disaster recovery experts; and other community leaders focussed on meeting, greeting, and getting to know one another while brainstorming a vision leads everyone on the road to success. A modest vision is all that is needed, such as, “everyone in harm’s way receives timely warnings, reacts to save lives and livelihoods, and obtains necessary supplies for recovery”.

*Keep it Simple for Success (KISS)*

The KISS principle – Keep It Simple for Success will help tremendously in getting the desired action to keep people and their loved ones safe and decrease property damage. The more complex a set of plans the better the chance of failure. Also, it will be easier for anyone new working with the procedures to understand and apply them quickly and effectively. Procedures tend to expand as post-storm reviews are applied without considering the set of plans as a whole. Therefore, applying the KISS principle each time the procedures are amended will lead to a successful outcome.

*Lives OVer Economy (LOVE)*

The LOVE principle – Lives OVer Economy will help tremendously in keeping the focus on humane choice to prioritize the safety of people and their loved ones ahead of protecting property from damage. The more developed an economy and society, the greater the potential loss of property caused by a TC with the same intensity. However, over-protection of property can sometimes lead to unnecessary injuries, and even loss of life and wealth. Where there is life, there is hope and wealth. Therefore, applying the LOVE principle in the absence of sufficient response time will lead to a successful outcome for those lives who are in harm’s way.

***2.2 Preparedness***

A perfect warning with plenty of lead time is worthless unless those in harm’s way receive the warning and respond appropriately, which is why preparation is of the utmost importance for protecting lives and property. A simple, people-centric preparedness approach will ensure the actions are coordinated and seamless, disorder during an event is reduced, leading to improved efficiency of TC response and reduction of disaster impacts. This includes establishing SOPs to ensure consistent operations; data and information exchange; clear roles and responsibilities; and provision of information in an understandable and timely manner. It needs to incorporate TC exercises, which include communities and partners. A strong exercise programme will produce an effective TC early warning and response system.

*Standard Operating Procedures*

SOPs are a standard set of steps to be followed to ensure tasks are performed in the same way and to the same standard each time. They often specify at a high level the “who” (responsible agency) and “what” (roles and responsibilities) and many times the “when” and “why” of agencies’ roles and responsibilities in the EWS. SOPs have different levels of procedures. There are two effective levels of procedures. The “high level” procedures which can be developed into Synergized SOPs are the ones that specify the “who”, “what”, “when”, “where”, “why”, and “how” tasks or activities associated with disasters to support the national level policy documents. The “lower level” procedures, sometimes referred to as operational directives or checklists, specify the more detailed “how to” and are internal to a particular workplace or agency. These are not shared or synergized because of their specific, internal nature.

Protocols must be established to activate and mobilize emergency operators (e.g., emergency managers, local police, firefighters, health services) who disseminate warnings to the public and decide public measures, including issuing orders for evacuation or sheltering in place. This way the public and other partners are aware of which authorities issue the warnings resulting in trust of the message. The standard step, to create synergy through a cooperative development, sharing, review, analysis, and documentation process in a multi-hazard and multi-agency way so the whole is greater than the sum of its parts. Through this process, the overall EWS will be improved, and overall efficiency will be increased. SOPs should be updated, as needed, after every event based on the after action review.

SOPs may refer to Memorandums of Understanding (MOUs). MOUs help to ensure different agencies and organizations understand each other’s roles and responsibilities and how they can perform in an integrated manner as partners. MOUs can either be bilateral (between two agencies) or multi-lateral (among multiple agencies). An MOU identifies the parties involved; defines the subject matter and objectives; and establishes agreed upon roles and responsibilities.

*Integration*

Disaster preparedness measures, including response plans, need to be fully developed, disseminated to the community, practiced, and underpinned by legislation where appropriate. Accounting for the needs of people with different degrees of vulnerability (urban and rural, women and men, older people and youth, people with disabilities, special needs individuals, etc.) within the SOPs is essential to protect lives. The vulnerable populations are most likely where the greatest casualties will occur. Incorporating traditional knowledge and redundancy into the SOPs will build a robust and complete set of plans. Another important aspect of early action and response options across time and geographical scales are linked to the provision of funding to support them. In order to keep SOPs fresh and updated, regular exercises need to be undertaken to test and optimize the effectiveness of early [warning dissemination](https://public.wmo.int/en/our-mandate/focus-areas/natural-hazards-and-disaster-risk-reduction/mhews-checklist/warning-dissemination-and-communication)processes, preparedness, and response to warnings.

Integration incorporates concepts of synergy through multi-hazards, multi-agencies, and integration methods. To avoid conflicting information different agencies’ interrelated roles and responsibilities must be incorporated into each other’s SOPs. This can be accomplished through a systematic review of the roles and responsibilities assigned to all agencies within a country involved in the EWS. All levels of government, from national to subnational to local, who are involved in the warning processes must be interwoven in the development, execution, and revision of SOPs.

Preparation includes reaching out to the most vulnerable communities to train, educate, practice, and develop individual plans for when disaster strikes. By using the KARE, KISS, LOVE processes, one can design a successful outreach campaign. Keeping your campaign aligned with the vision of protecting lives and property, arranging a simple process, and focusing on saving lives before protecting property will allow one to achieve the highest possible victory over a hazardous event. Having a variety of formats for disseminating information provides the best chance for reaching most people in a style they will understand. In today’s society, it seems visuals and less text are preferred, leading to easily interpretable information. Therefore, one may consider integrating social science into their programme to consider risk perception and to understand how the public consumes and processes TC information.

A TC preparedness system should be composed of:

1. General provisions, including purpose, basis, scope of application, and review, update and maintenance schedule;
2. General hazard and vulnerability information, including physical geography, socioeconomic, and critical infrastructure;
3. Organizational system, including leading agencies, emergency liaison agencies, and working agencies;
4. Emergency preparedness, including communication and information, search and rescue, professional guarantee, security, and medical, material, and financial, social mobilization;
5. Supervision and management, including public information exchange, training, exercises, rewards and applying lessons;
6. EWS information, including warning information, warning level classification, warning operations, and main defence protocols;
7. Emergency response measures, including general requirements, organization, response grading and action, and transitioning to recovery procedures; and
8. Disaster assistance, supply of emergency response materials, repair of TC-damaged properties, reconstruction, insurance and compensation, investigation and lessons captured.

To begin your preparedness campaign, the knowledge of hazards and where safety exists during each hazard is necessary to design a successful operating plan. Each community has its own history with hazardous events and can provide local knowledge that may not be widely known. For example, a normally trickle of a stream may become a raging river when moderate rain over the basin falls for only a few hours due to the steepness of the terrain, or a harbour is very sensitive to tsunami waves intensifying the surges as compared to the beaches surrounding the harbour. Reaching out to vulnerable communities can bring this local knowledge to the surface and help NMHSs provide impact-based warnings leading to a response with greater success. Other parts of a preparedness campaign include educating, training, and exercise. As one can see, several visits will need to take place as the relationships build trust, inclusion, understanding and awareness.

To develop and improve MHEWS, one must know and anticipate the potential hazards, including downstream and after hazard dangers. The best way to understand the impacts from hazards is to understand the history and talk to those who have been in harm’s way. Gaining local knowledge is imperative to building a robust impact-based MHEWS.

Once the typical hazards are obtained and planned for, looking into a complex situation will be the next step in honing your SOPs. For example, a flood followed closely by a TC may require moving those already evacuated from the flood to a different location because of the predicted fierce winds.

In a national survey conducted by the United States of America’s Citizens Corps, it was reported that 67% of those surveyed agreed that preparing in advance would help them be able to handle a disaster (p.30), however only 35% of those surveyed consider themselves prepared (p.33). This is a big gap, not to mention that just over one in ten of those surveyed said preparing for a disaster was not at all useful (p.30). Therefore, trying to motivate people to prepare will take a concerted and consistent effort. Elsewhere in the survey a question about barriers was presented. “The most commonly mentioned primary reason for not preparing was the belief that emergency responders such as fire, police, or emergency personnel would help them (29%). Other primary reasons included lack of knowledge (24%) and lack of time (26%)” (p.19).

Looking at what motivates people to take training and prepare for potential disaster, the survey found, “most individuals taking preparedness classes or emergency training attributed their motivation to a mandatory function of their job or school (48%). The second most common response was for the concern and safety of family or others (21%). Some respondents (14%) also reported taking preparedness training because family or friends did”.

This is a big obstacle to overcome! Basically, only one-third of those surveyed attended through their own motivation leaving the conundrum between making training mandatory and providing incentives. Mandatory training for the public is not realistic, consequently, providing incentives may be the only tool available to reach those who need to prepare. What do those incentives look like? Simple things such as safety fairs where displays of emergency vehicles and demonstration of emergency procedures draw large crowds. During safety fairs, educational material can be handed out along with conducting short training sessions. A full scale exercise where the community actively participates, especially engaging children or the older generation can be a fun and an educational experience. But it can be very expensive. Another motivator for attendance is sustenance. When a community or organization gathers for an event or meeting, providing an inexpensive treat can bring more people out and, in some communities, culturally appropriate or expected. Remember, when community leaders support preparedness those around them will have that mindset too. In the International Federation of Red Cross and Red Crescent Societies (IFRC)’s guide on [*Community Early Warning Systems: Guiding Principles*](https://www.ifrc.org/sites/default/files/CEWS-Guiding-Principles-EN.pdf), Chapter 13 provides copious information of how to engage at a community level, including good practices and lessons learnt. Getting specific preparedness training and education into the hands of those who need it is vital for a successful MHEWS.

According to the [Sendai Framework for Disaster Risk Reduction](https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf?_gl=1*lj4uog*_ga*MzI3MzM4NjUuMTY2MDgyNjExMg..*_ga_D8G5WXP6YM*MTY2Mjk5MDYxNS4zLjEuMTY2Mjk5MDYyNy4wLjAuMA..), children have a vital role in strengthening community resilience. In recognition of the need to promote DRR education, COPE, which is named “through the lives of four orphan children, Candy, Ollie, Ping and Eddy and under the guidance of Grand Mistress Fu, the COPE squad embark on journeys of discovery into the world of disasters”, has been developed in response to that call to empower children. COPE is a series of illustrated, not-for-profit storybooks created in 2018, aiming to increase the disaster resilience of children. The books cover natural hazards ranging from floods to earthquakes, and wildfires to cyclones, providing coping tools, preparedness and relatable stories in an imaginative way that are easy to understand. COPE uses a creative, narrative, collaborative, and contextually sensitive educational approach to disasters that highlight key DRR messages that are easy to remember such as EVACUATE for floods or DROP COVER HOLD for earthquakes. WMO has served as COPE’s Scientific Adviser since 2020, advising so far on wildfires, storm surges, droughts, and volcanoes books. The COPE messages are being disseminated globally, with a recent partnership being secured with UNICEF Learning Passport for COPE to be uploaded on the Global Digital Library and the East Asia and Pacific Library as supplemental content, which means these DRR key messages will be spread to millions of children, far and wide.

Getting authoritative information into the hands of those who can make a difference is vital for saving lives. Having recurring outreach campaigns will assist in getting the desired reaction. For any warning system the first step is to make sure those in harm’s way recognize they are in danger. This comes through education and training even before the disaster occurs. Knowing the hazards for where one works, lives and plays goes a long way to knowing how to remain safe. The second step is knowing how to get warning information. This usually comes through a multitude of sources, but sometimes it comes through only one source. Mobile phones are found in many communities and can be the fastest way to get warning information into the hands of those who can react appropriately and inspire others to do the same. Other popular means of communication are social media; internet sites; television; radio; satellite connections; and community warning sounds, such as sirens, gongs, bells, horns, loudspeakers, and other signals. Once a person gets a warning, they are likely to attempt to verify it through other electronic sources and even through other family members and neighbours. If conflicting information is received, the likelihood of proper action getting initiated decreases rapidly demonstrating the importance of providing collaborative and enhanced information by partners and stakeholders. Also, having a mature authoritative source such as a National Meteorological Service, National Hydrological Service or National Disaster Management Agency will lend credence to any warning issued.

Once people have preparedness education and training, the next step is to develop a response plan. The IFRC provides a family safety-plan checklist and a template for family safety plans (see [Annex 2](#_2ce457m) for links). When individuals have a plan, they will be confident in their decisions to keep themselves and their loved ones safe and may even be able to help others in need.

***2.3 Exercising the Plan***

The effectiveness of any warning system is based on achieving the expected results. Therefore, exercising the system not only provides the greatest chance of success, but also a means of evaluating and improving the system. When conducting exercises, it is important to be inclusive, encompassing all spheres of those involved in responding and reacting.

From [*Flood Emergency Planning, WMO Technical Document No. 11*](https://library.wmo.int/doc_num.php?explnum_id=7331), “Coordination is required between government agencies, including disaster management committees at different levels, line departments, public works, health, armed forces and police, economic and finance, planning, education, rural development, transport, communication, environmental and natural resources, where disaster management committees can take the lead and coordinate the planning process. Active Non-Governmental Organizations (NGOs) may play an important role in interacting with government agencies and in undertaking emergency measures at the local level within an overall flood emergency plan”. And to take this on step further, those in harm’s way need to know how to react, which means bringing the national level plans into the community where neighbourhoods, families, and even individuals can participate in functional drills. The practice will give all involved confidence in the system and the planning, it will reinforce what is necessary for a successful outcome. Continuing in [*WMO Technical Document No. 11*](https://library.wmo.int/doc_num.php?explnum_id=7331), “In many vulnerable communities, experience shows that flood issues are not always given a high priority compared with daily survival issues, such as livelihood, lack of water and sanitation facilities, law and order, and so forth. This often makes communities behave passively towards flood risks, as they are seen as a remote occurrence without a perceived chance to control events (otherwise described as a fatalistic behaviour). This renders communities more vulnerable and sometimes more exposed to floods. To avoid this situation, motivation for initiating community participation, such as socioeconomic incentives and systematic training, are indispensable”. Although the document is focussed on flood planning, its concepts can be applied to all hazards.

Exercising an emergency response plan comes in many different forms and names. Other names commonly used are practice, drill, and play. For our purposes we will use the term exercise. Common forms of exercise start from basic knowledge and understanding risk to tabletop exercises, where the participants talk through a scenario, to functional exercises, where those involved perform their duties in a simulated operational environment, to full scale exercises, which gets everyone on location simulating as close to the real thing as possible. Even pre-season campaigns, such as press conferences; TC activity forecasts; communication about SOPs and the TC alert system; participation in exercises; and where to get more information, are useful to remind vulnerable populations to get prepared. The USA’s Ready website (<https://www.ready.gov/exercises>) provides basics and resources for developing and conducting exercises.

***2.4 Building Capacity and Resiliency Leading to Effective Response and Recovery***

After preparation, developing plans and exercising the procedures, capacity building continues as the ability to respond grows through investing in people, infrastructure, and emergency management. Since governments have the responsibility to prepare their citizens and visitors for hazardous conditions, these matters need to be resourced through legislation or administrative directive. When the capacity to respond to an impending hazard is robust it, as stated in The World Bank’s publication [*Ready2Respond: A Framework for Emergency Preparedness and Response*](https://www.gfdrr.org/en/publication/ready2respond-framework-emergency-preparedness-and-response) “…reduces felt consequence and enables rapid recovery, reducing cumulative impacts to public safety and the economy. Therefore, ensuring capacity for emergency response protects World Bank Group (WBG) investment across development sectors and the development gains that have resulted from those investments”. Thus, the return on investment in building a robust response capacity is well worth it. The publication provides results of studies reviewing how investing in a response ready community before a hazardous event occurs saves both time and money. Out of the forty-nine investments considered, “… 64% saved both time and money. The investments saved a total of USD 12 million [United States dollars] toward future response costs for a net savings of USD 6.4 million and an average return on investment (ROI) of 2.1. However, certain investments, such as those that focussed on personnel development, produced a much higher ROI of 18.7. Perhaps more importantly, 93% of preparedness investments saved time for emergency response operations and no investment slowed operations down”.

The more resilient a community is, the quicker those within the community can get back to living normal lives and restoring livelihoods once the hazardous conditions have passed. Obtaining funding to invest in capacity building and resilience is generally the key to enriching a MHEWS. The publication provides a short list of financial instruments that were available when the publication was released in 2017

1. Program-for-Results (PforR) Financing;
2. Caribbean Catastrophe Risk Insurance Facility (CCRIF);
3. Climate Risks and EWSs (CREWS) Initiative;
4. Catastrophe Deferred Drawdown Option (CAT-DDO);
5. Global Facility for Disaster Reduction and Recovery (GFDRR);

Another WMO finance mechanisms includes:

1. Systematic Observations Financing Facility ([SOFF](https://library.wmo.int/doc_num.php?explnum_id=10377))

*Becoming weather ready*

Preparing is built on a long history of lessons learnt and adjusted based on evolving circumstances, such as climate change. One can see in the following example of success versus an example of dissolve how important having a plan can be. The full example can be found in [Chapter 4](#_4k668n3). The tail of neighbouring islands, Saint Barthélemy and Saint Martin, display vastly different preparation techniques when provided resources. Saint Barthélemy’s government used resources to bolster their construction and resilience while Saint Martin floundered. Investigation found that there were major differences with each institutional and administrative organization and level of economic development, exhibiting that a one-size-fits-all approach is inadequate. Therefore, each plan must be tailored to the needs of the people. Every government must look at equity of services to serve the most vulnerable among the people.

Citizens and visitors want the best chance to live their lives in a safe environment and generally rely on the government to make that happen. Therefore, making your nation, region, county, prefecture, community, and family weather ready provides a large share in this safety effort. The WMO has developed a programme to do this called Weather Ready Nations. “The programme strengthens capacity at NMHS and NDMAs (National Disaster Management Agencies) towards better and augmented use of weather, water and climate information to save lives, reduce human suffering and lessen the economic impacts of hydrometeorological hazards”, states the WMO. Prepare your communities, by developing IBF, including the use of technology and communication tools; developing, maintaining, practicing, and improving Synergized SOPs; and by all means provide education, training and outreach to those who could be in harm’s way.

***2.5 Response***

Once a disaster occurs, relying on preparedness, training, and SOPs during a response will provide the best chance for success in keeping people safe along with decreasing damage to infrastructure and property. Being ready to respond is key to achieving the collective goal established at meetings leading up to the disaster. Keeping a people-centred, goal-oriented frame of mind as response gets underway will help build cooperation leading to the best results possible. As stated in the publication [*A Framework for Ready2Respond*](https://www.gfdrr.org/en/publication/ready2respond-framework-emergency-preparedness-and-response) from The Emergency Preparedness and Response Thematic Group of the World Bank, “To achieve preparedness …, response systems, and the EWSs that enable response, need to work horizontally across government ministries and departments and vertically through national, regional, and local levels of government. Inclusive in these systems is the role of NGO response partners for the delivery of assistance and aid regardless of the event’s scale and impact intensity. An effective preparedness system enables local level preparedness as a priority while in parallel creating supportive and aligned coordinating capacity and specialized resources at the national and subnational levels for larger scale events”. The framework provides a discussion on, “… five primary components that enable a high-functioning capacity. These are a) Personnel, b) Facilities, c) Equipment, d) Information, and e) Legal and Institutional Framework”.

Personnel: A highly skilled and experienced workforce is the most valuable resource in any disaster preparedness and response system. To achieve this, a culture of preparedness must be established that places the trust of the public and political body in the agencies tasked with ensuring public safety and minimizing economic disruptions. This requires intensive and extensive training of those involved in emergency preparedness and response to acquire knowledge, develop skills, and gain practical experience. This development of personnel must take advantage of the best available plans and information, facilities, and equipment to ensure an interoperable systems approach is broadly understood. It must also enable deep capability in focussed areas of expertise to ensure investment in personnel development transitions from the individual to the team, and from the team to the agency culture.

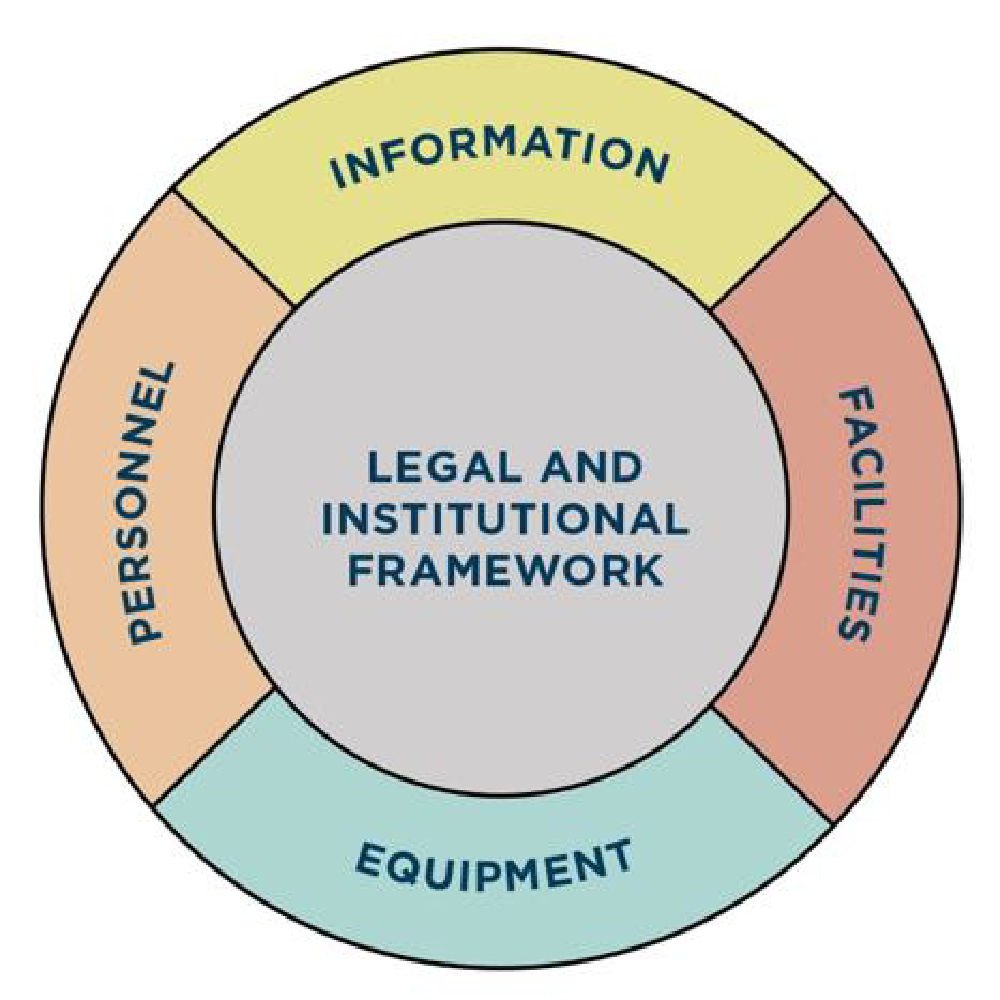
Facilities: Coordination of effort for emergency preparedness and response activities requires a structural presence, be it for command and control, movement of emergency aid or the staging of response teams and their equipment. These facilities act as a core element in establishing a culture of preparedness, ensuring a dependable common operating picture and resilient services when most other critical infrastructure and government service is disrupted. This component ensures that there is a nexus for information, personnel, and equipment as an emergency preparedness and response system matures through focussed investment.

Information: The collection, analysis, and swift dissemination of information enables better decision-making in advance of emergencies, during response operations, and through the transition to early recovery. Impacts from emergencies are felt locally, and so community engagement is vital to a well-developed state of preparedness. The information used for preparedness and response includes the information generated from EWSs to provide residents, and the response teams that support them, with advance notice of emerging hazardous events. The coordination of emergency information from responding agencies and social media ensures horizontal and vertical situational awareness that enables efficient, coordinated, and prioritized response operations. Finally, the development of hazard and vulnerability maps along with other geo-referenced emergency information, captured digitally and shared electronically, provides decision-makers with a key resource for planning across timescales to reduce risk. For quality information to have an impact, it must be utilized by well-trained, committed personnel that have the appropriate equipment to respond safely and effectively.

Equipment: The appropriate acquisition, use, and maintenance of preparedness and response equipment ensures timely information sharing and safe, effective rescue operations. It ensures the ability to effectively communicate despite the harshest possible conditions. These investments assist governments to overcome the capital requirements to ensure access to life-saving technologies and resources. Combined with an established parts and service supply chain, it enables governments to ensure its core preparedness and response agencies have the tools to deliver their service safely and effectively.

Legal and Institutional Framework: Clarity about the role of various public and private agencies is critical during disaster and emergency response. Where ambiguity exists, so does inefficiency and jurisdictional overlap. When lives and economic loss are threatened during an event, this ambiguity can increase both potential and actual losses. To address this challenge, improvements regarding preparedness and response roles can be a potent means to improve resilience at various levels of government. Ideally accountabilities are clearly enshrined in legislation with directive regulations. Wherever possible, de-conflicted policy instruments identify the operational expectations of those agencies that are assigned a preparedness and response mandate. However, even in the absence of complete organizational clarity, investment in preparedness and response can often improve a jurisdiction’s ability to mitigate impacts and limit disaster and emergency related losses.

As one can see in the diagram (Figure 2), the Legal and Institutional Framework is at the core of the components and enables the functions of the others. For success, SOPs must address these components.



**Figure 2: Adopted from ‘*Ready2Respond: A Framework for   
Emergency Preparedness and Response’***

In the end, through a plethora of preparedness practices and through effective writing, executing, training, and exercising SOPs, responding to a pending disaster should be a relatively smooth process. However, there will be things that are not expected leading to new lessons learnt as well as things that went quite well which turn into good practices. The result, by incorporating these new ideas in the SOPs, will be a more robust plan.

***2.6 Recovery***

1. Once again planning is key for an effective recovery after disaster strikes, and codifying recovery efforts into policy are required to procure resources and direction in a timely manner. Ideally this should be done before an event as part of preparedness. After the policy is established a lead agency can be assigned to develop a framework for recovery. According to the [*Guide to Developing Disaster Recovery Frameworks*](https://www.gfdrr.org/en/publication/guide-developing-disaster-recovery-frameworks) (GFDRR, 2015), “it is the role of the lead agency to establish and oversee the coordination mechanisms that guarantee coherent policy application and effective implementation at the regional and local levels”. The publication also states, “putting the recovery framework in place prior to a disaster increases the likelihood that the gains from the recovery process will carry over into sustainable development”. Therefore, policy will not only establish roles and responsibilities, but will increase resiliency after the hazard passes.
2. The *Building Back Better, Achieving resilience through stronger, faster, and more inclusive post-disaster reconstruction* by the GFDRR describes the need to have the “appropriate policies and tools…available to affected households, firms, and local and national authorities *before the disaster hits*. These are usually incorporated into a *disaster recovery framework* that include contingency plans and institutional arrangements with a clear allocation of responsibility in the recovery period, access to practical knowledge and information, and strong and inclusive financial protection provided by a combination of disaster response social safety nets, insurance mechanisms, and access to borrowing to finance the reconstruction”.
3. An inclusive recovery plan with increasing resilience, especially for the poorest and most vulnerable populations, must start with access to reconstructive support, including financial assistance. According to the DFDRR’s [*Building Back Better, Achieving resilience through stronger, faster, and more inclusive post-disaster reconstruction*](https://openknowledge.worldbank.org/handle/10986/29867), implementing the following three strategies, “could generate major benefits, totalling USD 173 billion per year, or 31% of current well-being losses due to natural disasters”.
4. Building back more inclusively ensures that post-disaster support reaches all affected population groups. This emphasizes the importance of providing reconstruction support to low-income households, which are typically more exposed, more vulnerable, and less comprehensively supported. If all countries had the ability to provide the poorest people with the post-disaster support found in developed countries, global well-being losses due to disasters could be reduced by 9%, equivalent to a USD 52 billion increase in annual global consumption. The effect is particularly pronounced in countries with high inequality, and where poor people have little access to social protection and financial instruments. According to available estimates, in those countries [Mr Shumakov] building back more inclusively could reduce disaster losses by 27% or more.
5. Building back stronger reduces well-being losses by ensuring that reconstructed infrastructure can resist more intense events in the future. If all countries were to “build back stronger” in the next 20 years — ensuring that rebuilt assets can resist hazards with a 50-year return-period — then global well-being losses due to disasters would be reduced by 12%, a gain equivalent to USD 65 billion annually. Stronger reconstruction would reduce overall well-being losses due to disasters by more than 40% in ten countries in particular: Antigua and Barbuda, Dominica, Vanuatu, Myanmar, Laos, Tonga, Guatemala, Trinidad and Tobago, Peru, and Fiji.
6. Building back faster reduces disaster impacts by accelerating reconstruction through measures such as contingent reconstruction plans, pre-approved contracts, and financial arrangements. Estimates in this report show that if the average reconstruction speed is reduced by two-thirds (without compromising the quality of reconstruction), global well-being losses could be reduced by 14% — equivalent to increasing global consumption by over USD 75 billion per year. These gains are especially pronounced in countries with frequent events, such as small island countries or Sub-Saharan countries.

Having a plan to build resilience into recovery will provide those in future harm’s way the confidence for a quicker recovery and protection during disasters. Recovery also provides an opportunity to train and educate those in previous underserved communities further building capacity and resilience.

1. Another vital element for recovery is communication, both among agencies as well as to those rebuilding their lives. To communicate effectively there must be multiple methods of getting messages to and from those involved and affected. Having numerous means of two-way communication is essential and requires planning, deliberate effort, and resources. Relying on a single point of failure, even if it is robust, can leave a country without vital means of receiving data or getting crucial information to others in the field. Having a communication plan with various redundancy built in should allow reliable transmission of critical information during hazardous events.

***2.7 Summary***

The story of Pat’s village provides a great example of how a people-centric, simple, and aligned EWS can allow those in harm’s way the ability to take appropriate action to save lives, reduce property damage and be ready to recover from a hazardous situation, including TCs. The village was prepared, knew exactly how to receive the warning, took appropriate action without hesitation, assisted those who needed help, and was preparing for recovery. The last step, which was not part of the story, is to review the process and update the plan as necessary (more on this in [Chapter 3](#_19c6y18)). The story shows how a simple plan can make the difference for quick action. Also, working together made the difference to those who needed assistance as well as a smooth execution of the plan. Ensuring correct action is taken starts with outreach, education, training, and exercise well before a disaster is pending. Make sure you know your partners, partners and local leaders by name through exercise and training. The time to meet them for the first time is not when a disaster is pending. Therefore, plan, communicate, collaborate, educate, reach out to the local level, practice, and always aim to improve which will lead to a well-prepared civilization.

### CHAPTER 3:  Recommended Multi-Hazard Early Warning Procedures

***3.1 The Process***

With the ability to forecast disasters, comes the capability to provide early warning.

Being able to detect an impending disaster is necessary for an EWS to be effective. Creating and improving monitoring systems are essential to detecting an upcoming event. Table 2 provides a glimpse of worst-case scenarios for which EWSs should be developed.

**Table 2: Reproduced from the IFRC’s *Community EWSs: Guiding Principles* showcasing the “worst-case” scenarios for early warning lead times.**

A picture containing table

Description automatically generated

Once monitoring and detection systems are in place, accurately forecasting the hazard is necessary to provide early warning. Tolerance for false alarms and the inability to detect the severity of impacts needs to be taken into consideration. For example, a community living along a riverbank may accept several near misses (false alarms) for flooding because the time it takes to evacuate the village only allows low confidence in forecasts. This example shows the importance of how outreach and education enhance the EWS by working with communities to understand their needs and for the community to understand the government’s limitations.

The following sections assist in developing and enhancing processes to reach those in harm’s way, ultimately saving lives and reducing property damage (for more details see references in the [Annex 2](#_2ce457m)).

*Monitoring*

Detecting threatening situations is vital in providing early warning. Having the knowledge of what is typical, what is possible, and what an extreme event produces are necessary to start the process. A systematic monitoring of the environmental parameters and meteorological elements forms the basis for an accurate prediction. These parameters are used for the preparation of meteorological analysis and to diagnose the current scenario. The same analysis field serves as the first guess to the numerical models for generating the forecast fields. This emphasizes the importance of establishing a standardized (as prescribed by WMO), quality controlled, and optimal network of meteorological observatories.

Since weather does not recognize political boundaries, sharing data is vital for understanding the larger scale of the atmosphere. The WMO encourages and even provides ways to share.

Space-based monitoring and aircraft observations of cloud pattern and other derived parameters like vertical wind shear, low level convergence, upper-level divergence, mid and upper tropospheric humidity and warming, sea surface temperature, among others forms an integral part of the basic diagnostic inputs over the data sparse oceanic regions, where the TCs originate.

Resources provided in the [Annex 2](#_2ce457m) provide a way forward, including a way to finance your observing system.

*Forecasting*

The ability to provide relevant, effective, and actionable forecasting starts with an understanding of how the atmosphere and water movement across the Earth, both over land and on the seas, affects those in harm’s way.

An accurate prediction of the TCs determines how accurately the multi-hazard event can be forecast which in turn influences potential impacts to the affected communities. Some of questions should include:

1. How much uncertainty is there in the forecast of the TC track and likely landfall area?
2. How much uncertainty is there in the forecast of the wind speed,intensity, and wind field structure of the TC?
3. How much uncertainty is there in the forecast of the wind speed, precipitation, and storm surge both in terms of the temporal period (i.e., when are they likely to affect people) and spatial (i.e., the areal extent of these associated hazards)?
4. How well understood are the single and multi-directional interactions between these different TC-relevant variables and are they captured by the models?
5. Which models or combinations of models offer the best skill for different components of the TC multi-hazard event and best capture the situational forecast uncertainty?
6. What role do observations play in improving multi-hazard forecasting, for both simultaneous hazards and cascading hazards?
7. How do uncertainties influence the forecasting of simultaneous and cascading hazards, and how do these uncertainties influence risk and impact scenarios?

The empirical, statistical, numerical, and new emerging techniques like artificial intelligence and machine learning are methods that are in vogue for prediction of track, intensity, landfall, structure and multi-hazards (storm surge, gale winds, and heavy rainfall).

There has been a lot of research focussed on understanding the interactions and relationships between TCs and their associated hazards (i.e., wind, rainfall and storm surge). For example, work by Chen et al. (2010) considered the physical mechanisms of rainfall associated with landfalling TCs and found that rain rates are related not only to TC intensity but are also influenced by moisture transport and latent heat release. There are some links established between sea surface temperature and TC rainfall area and wind size in the tropics (Lin et al.,2015). For TC related storm surge, there are several drivers including maximum wind speed, central pressure, and storm size (Irish et al., 2008), speed of movement (Rego and Li, 2009) and angle of approach towards the coastline and the surrounding geography (e.g., shape of the shoreline, coastal features, offshore morphology), which can influence surge height and extent. In terms of real-time forecasting, Knaff et al. (2016) illustrates the importance of correctly estimating the TC wind radii so it can inform warnings and provide initial conditions for downstream applications including, wind speed probabilities and wave forecasting. It is well recognized that the inputs (i.e., TC track, surface winds, and pressure) used to drive storm surge warning models (e.g., Murty et al., 2017), and other downstream hazard models, will have a direct impact on forecasts and therefore the accuracy of warnings. Understanding which parts of the forecasting chain would influence the predictability to the highest extent of various simultaneous and cascading hazards is essential for improved multi-hazard communication and subsequent decision-making.

Proper education and application are necessary to be successful in developing and enhancing NMHSs. A wealth of reference links are provided in [Annex 2.](#_2ce457m)

*Early Warning Methodologies*

For those in harm’s way to prepare for an event obtaining timely and relevant information about the impending hazards is necessary. One can follow the guidance of the Coastal Inundation Forecasting Initiative (CIFI)). CIFI guidance facilitates development and implementation of warning services for TCs, with the goal to operate and maintain a reliable forecasting system that informs national decision-making by:

1. Identifying national and regional requirements, particularly user needs;
2. Encouraging full engagement of all partners;
3. Implementing coastal inundation end-to-end operational forecasting and warning systems;
4. Developing cooperation among scientific disciplines and user communities;
5. Building communication platforms among researchers, forecasters, and disaster managers involved in coastal inundation management;
6. Transferring technology to participating countries; and
7. Providing specialized training for operators, forecasters, and disaster managers.

As previously mentioned, the WMO’s Typhoon Committee’s[*Synergized Standard Operating Procedures (SSOPs) for Coastal Multi-Hazards Early Warning System (2015)*](https://typhooncommittee.org/SSOP/indexSSOP.html) project guidance describes an effective EWS as requiring the following items:

1. Involvement and commitment of high-level government policymakers;
2. Legal and legislative framework;
3. National plan or policy identifying roles and responsibilities;
4. EWS as an integral part at all levels of government;
5. Coordination across many/all agencies at national to local levels;
6. Operational mechanism defined;
7. Identification of budgetary and technical support;
8. Designation of an agency for coordination activities; and
9. A comprehensive national hazard risk assessment.

In addition, the IFRC provides guiding principles for community EWSs:

1. Integrate within disaster risk reduction, EWSs is not stand-alone;
2. Aim for synergy across levels: community, national and regional/global;
3. Insist on multi-hazard EWS;
4. Systematically include vulnerability;
5. Design EWS components with multiple functions;
6. Accommodate multiple timescales;
7. Embrace multiple knowledge systems;
8. Account for evolving risk and rising uncertainty;
9. EWS without borders: target the full vulnerability and hazard-scape;
10. Demand for appropriate technology;
11. Require redundancy in indicators and communication channels;
12. Target and reach disadvantaged and vulnerable groups;
13. Build partnership and individual engagement.

These frameworks for developing a people-centred, effective, efficient, well understood, and practiced EWS for all partners can make processes seem routine even during hectic and frenzied times pre-event. Synergy, cooperation, and confidence are essential for quick action. When those in harm’s way receive the early warning from authoritative sources, they have confidence in and know how to react as education, training, and outreach occurred prior to the event. Hopefully leading to casualties being significantly reduced or eliminated. Plans for communication, dissemination, response, recovery, and after action reviews are components of the basic needs for any EWS.

In developing or improving an effective EWS the WMO’s MHEWS Checklist, Quick Reference Guide for SSOPs, and the IFRC guidance should be utilized. Also, keep in mind the KARE, KISS and LOVE principles introduced in preparedness ([Chapter 2](#_3as4poj)).

*Standard Early Warning Protocols by NMHSs*

Another important factor for a successful EWS is the role of the NMHSs. Their ability to not only detect and forecast a pending event, but to effectively communicate the impacts is vital to the success of executing the plan. Having SOPs leads to saving lives and reducing property damage. In developing or improving protocols of NMHSs for an effective EWS we turn once again to the WMO’s MHEWS Checklistand theQuick Reference Guide for SSOPs. These guides recommend developing and maintaining good working relationships among NMHSs and disaster management agencies for coordination and effective and consistent communication. Identify risk through monitoring of hydrometeorological hazards; providing high quality archived and real-time data; conducting multi-hazards and vulnerability analysis and mapping; and forecasts with potential impacts. Reduce risk through provision of short-term hazard forecasts and warnings related to specific impacts (e.g., a flood or storm surge) to support emergency preparedness planning and response; and medium- and long-range forecasts (probabilistic information on hazards and their changing patterns) to support sectoral planning. Lead or actively participate in the development and improvement of effective EWSs. It should be noted that NMHSs-operated observation systems and an efficient communications system form the backbone of the NMHSs warning service and play a crucial role towards the effectiveness of the entire EWS.

Building partnerships and involvement of partners leads to greater success. This includes agreement on warning standards, procedures, and systems for consistent warning and education information; ways of getting vulnerable populations to take effective action; sharing experience, knowledge, and lessons learnt from a wide range of people; accomplishment of tasks that cannot be done by a single agency or organization; better use of financial resources and cost sharing through a commitment by all to a common goal.

NMHSs can tailor the warning information and decision support services they provide to the specific needs of partners by understanding different aspects of the national economy, cultures, vulnerabilities, economic statuses, community capabilities, decision-making processes, and impact on partners’ operations. Care should be exercised to ensure the warning is not too long or complicated (KISS). NMHSs are responsible for creating the warning content and distributing the warning message. NMHSs may consider using warning tones, colour codes and/or graphical warnings. A standard format and plain language are essential to spark action. A good Early Warning Message must contain the following elements:

* 1. Timing: When is the hazard expected to begin?
  2. Location: Which areas are potentially going to be affected?
  3. Scale: What is the potential magnitude of the hazard? (e.g., level of water, wind speed, likely area of inundation, etc.)
  4. Impact: What will be the potential impacts of the hazard on the communities and environment?
  5. Probability: What are the chances of this happening?
  6. Response: What should at risk populations do to protect themselves?
  7. Uncertainties: alternative hazard scenarios and the anticipated potential impacts on society.

***3.2 Produce Procedures***

As part of the emergency response management procedures at the national level, the government should set out a contingency plan for disasters. The plan should be multi-hazard, clearly delineating the administrative strategy, organizational framework, and warning and alerting systems for responding to all possible types of events for their geography and climate. The contingency plan should stipulate the functions and responsibilities of, as well as the coordination/collaboration among, all key partners including but not limited to government bureau/departments, public utilities companies, transport operators, and NGO.

When developing procedures to deliver early warning for a multitude of hazards, one must keep in mind the goal: save lives and livelihoods, and when possible, protect property. People-centred, impact-based, easy to understand and simple to use procedures are a must for getting the desired response by those in harm’s way. For procedures to be effective, “coordination, collaboration, support, and assistance are needed not only horizontally with other agencies at the same level of government, but also vertically, to involve all levels of government, citizens, and media. An effective EWS must provide the required information to the people at risk so they in turn can perform the correct actions to save their lives and property regardless of whether they live in a large city or a rural, coastal location”, states the WMO Quick Reference Guide for SSOPs.

From the national level of government to the individual in harm’s way, the possession of written procedures for how to react when disasters are pending is essential for success. Developing, maintaining, practicing and improving these SOPs will lead to the best possible outcome, as presented in [Chapter 2](#_3as4poj). One step further, synergizing as defined in the Quick Reference Guide for SSOPs“To create SOPs through a cooperative development, review, analysis, and documentation process in a multi-hazards and multi-agency way so the whole is greater than the sum of its parts” the SOPs throughout all levels will lead to the smoothest, most collaborative method available. In the Quick Reference Guide, the purpose of having Synergized SOPs is fivefold: “Ensure tasks are performed in the same way and to the same standard each time; maintain high quality and consistent service in hazard situations; discuss, determine, and approve the most efficient and effective method to perform tasks before an emergency occurs; improve cooperation and integration of different tasks among agencies involved in EWS; and to reduce training time”. To this end, all levels can be prepared to have the most robust, people-centric, impacted-based response possible.

To achieve success, it takes thorough and close collaboration and coordination with partners and those vulnerable to pending disasters. The WMO’s MHEWS Checklist provides a structure, “… around the four key elements of EWSs, aims to be a simple list of the main components and actions to which national governments, community organizations and partners within and across all sectors can refer when developing or evaluating EWSs. It is not intended to be a comprehensive design manual, but instead a practical, non-technical reference tool to ensure that the major elements of an effective EWSs are in place”. Also, the Quick Reference Guide for SSOPs is “… designed to provide flexible approaches, operational guidance, and recommendations based upon good practices and available resources to prepare SSOPs for coastal MHEWSs. It includes key concepts, basic principles, and basic standards for SSOPs”. Combining these two resources as a country or region develops or refines their procedures will assist in delivering an effective set of processes based on a holistic and well-rounded approach.

***3.3 Dissemination and Update of Alerting and Warning Messages***

Before a TC comes into the proximity or during the quiet seasons, early alert messages, public education, and outreach activities shall also be practiced as mentioned in [Chapter 2](#_3as4poj) as resources allow.

During cyclone season, depending on the context and available communication means, publishing a “extended weather outlook” article on the potential weather and impacts should be adequate to alert people. To ensure wide coverage and sufficient reach, all available media platforms should be utilized to push or promote the weather article, e.g., website, social media, weather blogs, and mobile app. If cooperative and long-term working relationships can be built with the mass media, weather stories from the weather authority have a good chance to be covered by newspapers and TV channels. Nowadays, video content is predominantly much more popular than text to an average audience. If affordable or already available, educational video materials on TCs and other natural hazards could be extracted or replayed to alert the public of the characteristics of the approaching TC. As longer-range TC forecasts become more available from major NWP centres, briefings on TC outlook up to four weeks ahead may be organized for special users or even the public on a regular basis. They include information about possible TC formation areas and the subsequent movements based on a large number of NWP model runs.

Both the wind speed and direction over a location may change rapidly, likewise, for the associated impacts, e.g., storm surge. It is of paramount importance to keep the warning signal and message updated and reflecting the potential impacts. While the update frequency on TV/radio may not be controlled by the weather authority, bulletins on website and push notifications on mobile phones can be synchronized quickly and frequently. For effective exchange of hazardous information across borders, the Common Alert Protocol is highly recommended for packaging the warning messages.

Closer to but still before the time warranted for TC warning signals, some form of weather advisory or an actionable weather advice could be formulated and sent out through all the dissemination channels available. To raise public awareness to the highest level, media briefings or press conferences will be needed. Within the expected lead time that a TC will exert influence or impact to the location of concern, the appropriate cyclone warning signal, among other weather warnings, shall be disseminated by all available means without delay.

In some places where TV remains the primary channel of warning dissemination, meteorologists from weather authorities are recommended to conduct briefings on TV or even take part in the production process before and during TC signals. This can reinforce the Weather Service authority. During the media briefing on TCs potential impacts from cascading hazards should be communicated to the public together with precautionary actions to be taken.

*Communication, Collaboration, and Coordination Among Partners*

When a TC warning signal is issued by the weather authority, other government departments are expected to make corresponding arrangements, for example the Education Department for an announcement on school closure, the Department of Transportation for road closures, in accordance with prescribed procedures and coordination mechanisms in the contingency plan. By law or by agreed practices, relevant government authorities should publish and maintain guidelines for hazard preparedness so employers-employees and schools-parents can develop arrangements for suspension and resumption of work and school, based on the level of warnings.

Key partners usually need to take actions before the public do once the warning is issued. They will typically ask for longer lead times from the weather authority before the warning decision can be confirmed. Under such scenarios, communication protocols between the two sides will be important to exchange information in a clear, easily understandable, and unambiguous manner. Given the uncertainty involved in TC forecasting, likelihood- or risk-based communication terminology is recommended. For example, “high chance to raise TC signal during X to Y PM” instead of saying “TC signal will be issued at time X”, or “high-risk of shoulder-level storm flooding” instead of “storm surge will reach X metres above MCD”.

To ensure all members of the public, including partners, can understand the TC signals and warning messages to take appropriate actions, short videos, radio programmes, public talks, governmental seminars, as well as site visits to key partners, should happen as a means of public education. It shall be conducted on a regular basis throughout the year, especially during the quiet seasons. Physical and virtual open day of the NMHS can be organized to introduce the work of the weather authority and boost public understanding and awareness on severe weather including TC. Through such interactive engagements, trust may also be built up between the weather authority and the people.

***3.4 After Action Review***

Assessing performance after a disaster is an important step for improving response during the next disaster, updating standard operating procedures, building resilience, increasing capacity, and determining where training and education is needed. During the process good practices can be identified, suggestions on how to incorporate lessons learnt, address accountability, consider how to address vulnerable and underserved communities, and ascertain how well the response was executed can be reviewed.

According to the World Health Organization’s [*Guidance for After Action Review (AAR)*](https://www.who.int/fr/publications-detail/WHO-WHE-CPI-2019.4#:~:text=The%20WHO%20guidance%20for%20after%20action%20review%20%28AAR%29,routine%20management%20tool%20for%20continuous%20learning%20and%20improvements.), “an AAR is a review of all actions taken during the response to an event. The review aims to identify capacities in place before the response, any challenges that came to light during it, the lessons identified, and any good practices observed during the response, including the development of new capacities”. You may refer to the Figure 3 for the AAR roadmap.

Graphical user interface, application, table

Description automatically generated

**Figure 3: AAR roadmap**

The benefits of an AAR are described as:

1. Ensures critical thinking to determine underlying factors that may have led to the success or failure of the event;
2. Builds consensus on issues for follow-up as it involves all those that were engaged in the response;
3. Allows identification and documentation of lessons for immediate adjustment;
4. Allows cross-sectoral learning as it involves more partners than just those in the weather sector. This helps to bring new perspectives and strengthening relationships and coordination across sectors;
5. An AAR can be used as an advocacy tool for domestic financing for all involved;
6. Builds capacity for preparedness and response.

During the AAR calculating a few statistics can help to verify the information disseminated by the authorities. For example, the NMHS may issue flood warnings. To verify whether the event occurred and was warned upon (probability of detection) and the lead time, or if the event did not happen (false alarm), can provide important data for the NMHS to improve their warning capability. They determine the level of tolerance a community has for false alarms. This may already be ingrained into the local culture or even woven into the government’s fabric. If one is to increase lead time, normally one must expect a greater number of false alarms. This is where education, training, and outreach in local communities can assist with understanding the limitations of the EWS and gain support of local communities in contributing to the efforts in the future.

***3.5 Conclusion***

Developing and refining a set of procedures is not an easy task. It takes dedication, hard work, significant relationship building, multi-discipline partner interaction, flexibility, intimate knowledge of disasters, and recognizing how vulnerable communities can react to impending hazards. In addition, motivating people to prepare for possible disasters can be a daunting endeavour. However, the effort applied to preparing people, producing procedures, practicing plans, and performing during the peril will save lives and livelihoods, and decrease property damage.

The ultimate goal – save lives and livelihoods, and when possible, protect property. To accomplish our goal planning, building capacity, fostering resiliency, and communicating appropriately will lead to an effective response and quicker recovery. Also, codifying through legislation and policy the roles and responsibilities; agencies involved; operational mechanisms; funding; and resources available will set those in harm’s way up for success. Preparing those vulnerable to hazards through education and training will begin the process of changing behaviour leading to coordinated and proper response when the warnings are issued. The plans already in place can be executed so lives can be protected and property can be safeguarded. By building a weather ready nation, communities can increase capacity and advance resilience to become confident in response and recovery during hazardous conditions decreasing the chance of a disaster. As a world community we must, and we will, take up this challenge, working together to foster resilience.

### CHAPTER 4: Practices and approaches to MHEWS

***4.1 Introduction***

Governments of all countries give great importance to disaster prevention, mitigation, and relief work related to TCs, and establish their own TC and related MHEWS. Years of TC response practice has proven that the system has ensured the safety of people's lives and property; the sustainable development of the national economy to the maximum extent, and mitigated disaster related losses to TCs.

This chapter presents some of the responses to the [questionnaire](https://wmoomm.sharepoint.com/:f:/s/wmocpdb/Eop07D_XMY1EmBxDP4Lxc3cBwXH08r5YqryemDZWTLzojQ?e=hJ424I) distributed through the WMO TCs Programme. The responses are examples of practices from different member states on their own national TC and related multi-hazard early warning and response procedures, coordination mechanisms, systems and services. It was nearly impossible to show all the work that is being done in all geographical areas where there is the threat of TCs, but those responses could give a sense of what is being done. Some countries are presented here, while other and further responses are presented in the [Annex 1](#_1jlao46) in their entirety.

Some conclusions will follow at the end, to highlight the most interesting aspects and to point out the gaps that yet exist, showing the way in which MHEWS could improve.

***4.2 Legal Basis for Tropical Cyclone EWSs***

Most of the casualties and financial losses from disasters in coastal areas are related to TCs. Risk and disaster related TC management has always been a major issue for the governments in high-risk areas. To mobilize and coordinate the efforts of the whole society to prevent and control the risk and mitigate the damages caused by TC to safeguard people’s lives and property, laws were enacted in most countries located in TCs prone areas.

Laws and regulations have paved the way for a paradigm shift in those countries’ national disaster management systems from one primarily focussed on response and preparedness for response to one focussed on reducing and managing disaster risks. A comprehensive national disaster management system is usually established based on the laws and people-centred philosophy. It has become clear that for DRR and management to succeed, an effective EWSs must be established.

All the countries have laws and regulations in force for warnings on TCs, though they might differ, according to the different cultures.

In the Cayman Islands, provisions have been made in the Disaster Preparedness and Hazard Management Law. There shall be established a National Emergency Notification System for the Islands, and, additionally, the Hurricane Plan provides the framework for preparedness, response recovery.

The people’s Republic of China has formulated and improved its laws and regulations, including the Meteorological Law of the People’s Republic of China, and the Law of the People's Republic of China on Flood Control. A prevention-oriented, holistic, and integrated approach was adopted. It has made efforts to take scientifically sound measures during the entire process from early warning to response, including monitoring, forecasting, prevention, resistance, rescue and assistance, and to leave no regrets.

Cuba has a wide legal basis regulating the functioning of EWSs at all levels. Which goes back to the Law No. 75/94 (21 December 1994) of National Defence which establishes the main missions and measures of the Civil Defence System and the principles for its territorial and institutional organization. It has been updated, by the new Law on the Environment and Natural Resources (May 2022), in replacement of the Act Law No. 81/97 (11 July 1997) on the Environment, updating, and englobing in it, the principles and processes of EWS in Cuba, considering the best experiences. Several legal bodies on the issue will be updated in the coming months.

In Hong Kong, China, the Hong Kong Special Administrative Region (HKSAR) Government has the “[Contingency Plan for Natural Disasters](https://www.sb.gov.hk/eng/emergency/ndisaster/Contingency%20Plan%20for%20Natural%20Disasters_Oct%202019_ENG.pdf)”. It is the Government’s strategy, organizational framework, and alerting system for responding to disasters. The plan also stipulates the functions and responsibilities of Government departments, utilities companies, and NGOs in the event of disasters. TCs warning system is an integral part of contingency plan.

In Japan, the Meteorological Service Act defines the duties of the Japan Meteorological Agency (JMA), such as observation, forecasting, and warning. The Act stipulates that JMA shall give warnings for concerning meteorological phenomena caused by TCs (Article 13, etc.). In addition, restrictions on warnings are imposed on those other than the agency (Article 23), ensuring JMA as a national single authoritative voice for warnings. The Disaster Countermeasures Basic Act stipulates the disaster management system for the entire government, including local governments and municipalities. JMA plays a major role in providing up-to-date weather information including warnings in the system. TCs EWS in Japan is built based on the above Acts and related regulations.

In Sultanate of Oman, the National Multi-Hazard Early Warning Centre is the base of all TC forecast and warning system, which is in the Civil Aviation Authority that was established based on Sultani Decree No. 2012/33. However, this Centre is following the legislations and procedures of Regional Specialize Meteorological Centres (RSMC) and WMO regulations on TCs.

In the United States, the legal basis upon which the United States TC EWS is based, comprise the 1890 National Weather Service (NWS) Organic Act, the 2017 Weather Research and Forecasting Innovation Act, the Robert T. Stafford Disaster Relief and Emergency Assistance Act (public law 93-288), the annual budget appropriations and associated Congressional language. The National Hurricane Centre (NHC) is the source of all TC forecasts and warnings, with the Central Pacific Hurricane Centres (CPHC) responsible for forecasts and warnings in the central Pacific and Hawaiian Islands.

***4.3 Governance and Institutional Arrangements***

A complete and collaborative partnership for EWS is an important foundation for TC disaster response. In all the countries that responded to the questionnaire there is the presence of this partnership, in one way or another.

The China Meteorological Administration (CMA) has a major responsibility for TC early warning — monitoring and forecasting. Regarding the TCs, CMA analyses and predicts floods and disasters, issues forecasts and warnings in a timely manner, and participates in the emergency response. To form a joint prevention and response effort for an integrated TC response at a national level, the State Flood Control Headquarters (SFCH) and a collaborative partnership system were established. Under the leadership of the State Council, the SFCH is responsible for leading and organizing the national TC early warning and response efforts, with vice premier of the State Council as the general commander, the deputy Director General of CMA as one of the two deputy secretaries general, and several members served by the officer from the member agencies. The member agencies of the SFCH, as the partners of CMA, work closely and collaboratively to perform their duties in TC response. The major partnerships of CMA are including but not limited to the Ministry of Emergency Management; the Ministry of Natural Resources; the Ministry of Water Resources; the Ministry of Transport; the National Radio and Television Administration; the Ministry of Civil Affairs and the General Staff Department of the People’s Liberation Army.

In India, shifting from relief and response mode, disaster management has started to address the issues of EWSs including forecasting and monitoring setup for various weather-related hazards. A structure for flow of information, in the form of warnings, alerts, and updates about the ensuing hazard also emerged within this framework. A multi-partner high-powered group was set up by involving representatives from different ministries and departments. Some of these ministries were also designated as the nodal authorities for specific disasters. Following a *High-Powered Committee Report on Disaster Management* for establishment of a separate institutional structure for addressing disasters and enactment of a suitable law for institutionalizing disaster management in the country, multi-level links between these ministries and the disaster management framework have emerged. In the present structure, there is a NDMA at the centre, and State Disaster Management Authority (SDMA) at state and district authorities at district level. In addition to this, there is the National Crisis Management Committee (NCMC).

In Sultanate of Oman, the exchange of information between the Meteorological Department (National Multi-Hazard Early Warning Centre) and the National Emergency Management Committee is regulated in a Memorandum of Understanding that provides for the monitoring of TCs. The Operational Plan (SOP) of the National Multi-Hazard Early Warning Centre includes all technical procedures for guaranteeing the implementation of this agreement, the frequency of the reports, and their content.

The Philippine Atmospheric, Geophysical and Astronomical Agency (PAGASA), as the NMHS is involved in the first three elements of EWS, which particularly focus on the monitoring, forecast, and dissemination warning. For response capabilities it is the responsibility of members of the National Disaster Risk Reduction and Management Council (NDRRMC) and the local government units (LGUs).

TCs operational forecast and warning responsibility in the United States is met through a combination of national centres and local forecast offices. The NHC and the CPHC are responsible for all meteorological and storm surge decisions concerning analysis and forecasting of ongoing and potential TCs within their respective United States areas of responsibility. The two centres also operate as WMO RSMCs for TCs in their respective basins. While the centres issue tropical wind and storm surge warnings along the United States coast, local weather forecast offices (WFOs) issue tropical wind warnings inland that are consistent with their respective centre’s forecast.

***4.4 Use of Risk Information in Tropical Cyclone Warnings***

Risk information has been introduced in most of the Meteorological Centres that forecast TCs. The way to do it may differ somewhat, but the intention is the same, to assess vulnerability and exposure to better guide the people to mitigate risk. A brief information on how it is used, follows in the coming paragraphs.

In Cuba, the local office of the Ministry of Science, Technology, and the Environment in each province coordinates with the rest of the organizations in the territory to obtain the necessary data to determine the risk. The organizations involved are the territorial divisions of Housing, Physical Planning, Statistics, Water Resources, Public Health, Education, and others. The findings are all stored in a database supported by a system of geographical information, which is updated as actions are implemented to reduce the vulnerabilities. The methodology allows for the local governments to periodically determine the risk so that its reduction is monitored. This requires the specialists from each organization to update the information related to each indicator of vulnerability.

TCs warnings in Hong Kong, China, are primarily designed with reference to territory-wide sustained wind strength near sea level. Risk information is conveyed to the public through the warning bulletin and precautionary statements associated with different levels of TC warnings. The TC warning bulletin issued by the Hong Kong Observatory (HKO) will include flood risk for low-lying areas and flood prone areas when storm surge is predicted to exceed warning levels. For TCs high winds coming from changing directions, people will be warned of sudden changes in wind direction within their locations. Even before the local winds pick up and when the weather may still look calm, HKO will alert the public about the risk and impact of swells and waves generated from afar from an approaching TC.

A web-GIS based hazard vulnerability atlas has been prepared by India Meteorological Department (IDM), bifurcating each of the hazards associated with cyclones, such as strong/ gale force winds, heavy rainfall, pluvial and fluvial floods, and storm surges. The possible risk associated with secondary hazards associated with cyclones, like landslides, are being handled and planned for by the local administration. Other non-structural measures include introduction of objective analysis and forecasting platform along with the decision support system; synergized standard operation procedure; policy and guidelines of government; collaboration and partnership with various partners; press and electronic media; and disaster managers and introduction of user specific and sector specific impact-based warning along with suggested actions.

In Japan, among the hazards posed by TCs, warnings for floods, inundation, and landslides caused by heavy rainfall are issued by using indices corresponding to the type of hazard instead of simply observed or predicted rainfall amount. Based on these indices, a 1 km mesh “real-time risk map” is provided with five levels of colours to indicate the current and predicted risk level at each location, depending on how close it is to the predetermined warning threshold in which the past disaster occurrence and the vulnerability of the area are considered. The risk distribution is automatically created, announced, and updated every 10 minutes as supplementary information to weather warnings. For meteorological warnings, their criterion/thresholds are predefined based on the various indices (e.g., soil water index), or disaster statistics, vulnerabilities of the region, and the status of infrastructure facilities such as the height of levees prepared by local meteorological offices and relevant agencies, or the corresponding quantities of meteorological elements such as wind speed and wave height. The criterion/thresholds are updated periodically based on the latest disaster statistics. It is the basic practice of JMA to improve warnings and weather information based on lessons from past disasters.

In the Sultanate of Oman, the risk information is conveyed to the public through the warning bulletins and precautionary statements associated with different levels of TC warning signals. The TC warning bulletin issued will include winds (S/D), thunderstorm, wave height and flood risk for low-lying areas. All of that depends on the regions that are expected to be affected by TC and its nature.

The Philippines learnt lessons from past disasters (i.e., Super Typhoon *Haiyan*), and felt the urgent need to innovate from focusing on the accuracy of hazard-based forecasting to also outlining the potential impacts of a hazard. An evolution from “what the weather will be” to “what the weather will do”. An ongoing project that will catalyse a paradigm shift from the traditional weather forecasts to MHIBF and early warning. The project innovation includes combining the best available science and local knowledge on probabilistic hazard mapping, modelling, forecasting, and risk assessment. Probabilistic risk assessment, mapping, and technologies will be developed to provide risk information that will inform development policies, investment programmes, and resilience plans for pilot areas, Metro Manila, and Cebu (at local levels).

***4.5 Monitoring, Forecasting, and Mandates for Warning***

All meteorological forecast offices or centres have activities on monitoring, forecasting, and mandates for warnings development, although some names could differ.

In the Cayman Islands, the NWS is responsible for monitoring the region for any possible threats. The warning process begins when the Chair of the National Hazard Management Council (NHMC) convenes a meeting, depending on the time (e.g., approaching weekend), and characteristics of the coming storm. The Director GIS (Government Information Service) and/or Chair, Joint Communication Service (JCS) EST (Emergency Support Team), will liaise with the Director General of the National Weather Services, the Director of Hazards Management Cayman Islands (HMCI) and Chair NHMC, to prepare advisory bulletins, and ensure that copies are sent to the Governor, Premier, Ministers, MPs, members of the NEOC, heads of government departments, Radio Cayman and other local media, cellular service providers, and utility companies. Information must be posted on the HMCI website [www.caymanprepared.ky](http://www.caymanprepared.ky), as well as on Twitter, Facebook, gov.ky and weather.gov.ky. All advisories should also be posted on HUB.gov.ky and WebEOC.

The CMA has built up a comprehensive TC monitoring and forecasting system covering the Northwestern Pacific and the South China Sea, with multiple observation resources, objective methods, and NWP models. Five-day operational forecasting of TC intensity, track, and precipitation through the cyclone’s lifespan are issued to public; for those cyclones likely to make landfall over the mainland, potential impact and hazards pre-assessment are provided to authorities.

The India Meteorological Department (IMD) maintains a 24-hour watch over the north Indian Ocean to monitor any development of cyclonic disturbance and its further intensification, movement, and impact. A well-defined SOP is followed to monitor and predict TCs. It starts with organization of pre-cyclone exercise prior to the beginning of each cyclone season and maintenance of daily round-the-clock watch. It is followed by extended range, medium range, short range, and nowcast predictions till landfall, post-landfall forecast and warnings till the system maintains the intensity of depression.

The implementation of operations in JMA is carried out in accordance with the Meteorological Services Act and related regulations, and various internal rules. The monitoring of TCs and the forecasting of their track and intensity are carried out at the JMA Headquarters based on observations by meteorological satellites and other sources, as well as NWP. Forecasters at the headquarters and Local Meteorological Observatories (LMOs) share information closely with each other to prepare warnings and other related information, taking lead time into consideration. Weather warnings for each municipality are issued by LMOs using a dedicated application based on track and intensity forecasts, various guidance products and indices based on observations and NWP, and predetermined criterion/thresholds.

In the United States, the general process follows what is commonly done in a modern forecast service. TCs monitoring is a multifaceted effort in the United States, with multiple government agencies and the private sector participating. Observational data is processed by the United States NWS into systems and displays used by forecasters whenever possible or provided via the web. Observational requirements for TCs are updated internally on a 10-year cycle and resource investment is determined accordingly. Forecasts are issued every six hours and NHC and CPHC will issue updated text products and graphics that include track and intensity forecasts for the next five days. In the Atlantic basin, a potential storm surge flooding map and storm surge watch/warning graphic are included in this “advisory package”. Details on the products and services provided by these centres can be found in NWS Directive 10-607: TCs Forecast Centre Products; the Mandates for Warning Development to carry out these operations and in the Compact of Free Association. These mandates come from the United States Congress.

***4.6 Dissemination Mechanisms***

In the Cayman Islands, the EWS process commences once the TC/hurricane is expected to impact the area within 72 hrs. This is listed as the alert. The meteorologist’ responsibility is to provide the most current storm location, intensity, track, and expected impact timeline to the area to the local media sources. This provision of storm information is initially provided via email but as the system approaches the area the meteorologist may provide warnings to the public through TV and radio broadcasts. Meteorologists play a critical role in the communication for preparedness. Once a tropical storm/hurricane watch is issued 48 hours from impact, the NWS and Hazard Management Cayman Island work with GIS/JCS to tailor specific response messages for broadcast by Radio Cayman and other media houses.

In China, the TC EWS includes the TC’s current position/intensity and future changes, and winds, precipitation, waves and tides, and the TC-induced flush flooding, debris flow, rivers flooding and urban waterlogging etc. CMA introduces colour based TC Warning System. The red, orange, yellow and blue warnings with the red warning as the top category. In case of significant TCs, meteorologists or experts from national, provincial, or municipal meteorological offices could present the warnings to the public through TV and radio broadcasts.

The early warning messages in Cuba begin to be issued by the National Forecast Centre 120 hours in advance of a possible impact, repeating them every 24 hours. When the hurricane enters the area of surveillance of the Caribbean Sea, warnings are issued every 12 hours, and when the hurricane poses a potential threat to Cuban territory within 72 hours or less, warnings begin to be issued every 6 hours. When the hurricane is very near, warnings are issued continually every 3 hours or less. The Institute of Meteorology’s National Forecast Centre permanently monitoring the formation and development of TCs and tropical waves from their formation in the West African coast and during their traveling across the Atlantic towards the Caribbean. Any TC that enters or is formed in the region, known as the “Area of Reinforced Surveillance”, is closely monitored, even if it is just a tropical wave with some likelihood to develop. The National Staff of the Civil Defence evaluates the warning and issues a notice for the governments of the threatened provinces and for the state organizations whose resources might be affected (Ministries of Agriculture, Tourism, Information and Communications, and others.) Television channels and radio stations, both national and local, transmit in a special way 24 hours a day with reports, interviews with specialists and authorities; reports related with the evolution of the hurricane; the protective measures being adopted in each place; and guidance on measures to be completed.

In Hong Kong, China, TC forecasts and warning information are delivered to the public via HKO’s website and mobile app “MyObservatory”, TV/radio broadcasts and social media (Facebook, Instagram, Weibo, Twitter, and WeChat inclusive), with push notifications from MyObservatory becoming the most important means. HKO’s meteorologists comprise an internal media unit responsible for the production and broadcast of both regular TV weather programmes and ad hoc media briefings to both TV and radio when TC warning is in force.

The IMD organizes a pre-cyclone meeting to develop direct interaction with the disaster managers and to create awareness about lessons and initiatives just prior to the start of the cyclone season. An extended range outlook is issued every Thursday giving probability of cyclogenesis (formation of depression) as low (1–33%), moderate (34–67%) and high (68–100%) for next 2 weeks. Daily watch is maintained over the north Indian Ocean and a detailed bulletin discussing the model guidance, prognostic and diagnostic features and probability of cyclogenesis during next 7 days is prepared under Forecast Demonstration Project during 15 October–30 November. A bulletin “Tropical Weather Outlook” is issued every day throughout the year discussing the convective cloud features over the Indian Seas and probability of cyclogenesis during next 5 days as nil (0%), low (1–25%), moderate (26–50%), fair (51–75%) and high (76–100%).

Since the Meteorological Service Act imposes restrictions on warnings to those other than JMA, JMA is basically the national single authoritative voice for weather warnings in Japan. JMA is highly recognized as the issuer of weather warnings. The dissemination of weather warnings is conducted online through multiple channels. Some government agencies and telecommunication companies are obligated by the Act to notify weather warnings or to endeavour to do so. In addition, private Meteorological Service providers and media organizations are actively disseminating weather information through multiple media such as broadcasting, newspapers, websites, and social networking services. The JMA has a press club, and it usually has good communication with reporters from major media organizations. When impacts of severe weather phenomenon is expected, forecasters from the headquarters and LMOs hold press briefings as necessary, and they appear in a variety of media, including broadcasting. Recently, when there is a need to warn of severe river flooding, a joint press conference was held with the government agency in charge of river management to share the sense of crisis with the public. In some regions, even more related organizations, such as public transportation, join such joint press conferences. In preparation for an approaching TC, the LMO holds a "typhoon briefing session" to provide detailed explanations of forecasts and meteorological information to prefectures, municipalities, river administrators, and other front line disaster management organizations. The LMO dispatches the JMA Emergency Task Team (JETT) to municipalities that are expected to be in significant danger and supports their disaster management efforts by providing explanations of weather information. To provide support to these local disaster management officials, the LMO has a team of forecasters called "Forecaster in Your Town" to strengthen cooperation with municipal officials. In addition, as part of the "Forecaster in Your Town" initiative, a short, remote weather briefing is provided daily to local governments, not only in times of emergency but also during normal times. Local governments are free to participate and can ask questions to the forecaster after the briefing. The briefings are recorded so that they can watch later even if they cannot do it in real-time.

In the Philippines, PAGASA recognizes that delivery of timely and reliable warning information is of utmost importance to ensure protection of people’s lives, properties, and livelihoods. As soon as the warning is generated, information is disseminated to the concerned agencies and public using various platforms and channels. During TC occurrence, press conferences are conducted on a regular basis where warning information is directly reported by meteorologists and experts through TV and social media platforms. Likewise, forecasters conduct daily weather updates aired through various PAGASA social media platforms such as Facebook and Twitter. The forecaster presents the warnings on Facebook and YouTube via livestreaming. Before the pandemic, regular media briefing is being done during issuance of Severe Weather Bulletins every 6 hours where radio and TV personnel come to the PAGASA office for live coverage. But now with COVID-19 pandemic, these are broadcasted via livestreaming in Facebook and YouTube. PAGASA had a partnership with Google for the initial development of Common Alerting Protocol that TC warnings are shown in Google Public Alerts.

In the United States, hurricane specialists at hurricane centres work on a 6-hour cadence to deliver a standard set of products and services. When TCs affect land, the cadence can be shortened to provide information more frequently in accordance with [*NWS Directive 10-607: Tropical Cyclone Forecast Center Products*](https://www.nws.noaa.gov/directives/sym/pd01006007curr.pdf). NHC and CPHC issue a standard set of text and graphical products with the same look and feel, making them recognizable to the user. They also disseminate TC products through multiple channels including, but not limited to, www.hurricanes.gov, Advanced Weather Interactive Processing System (AWIPS) Satellite Broadcast Network (SBN), and NOAA (National Oceanic and Atmospheric Administration, USA) Weather Wire Service (NWWS), in addition to social media. In addition, WFOs convey coastal hurricane centre warnings and their inland tropical warnings via Common Alerting Protocol (CAP) on alerts.weather.gov, through the United States Emergency Alert System (EAS), and through Wireless Emergency Alerts (WEA) sent to wireless devices via the United States Federal Emergency Management Agency’s (FEMA) Integrated Public Alert and Warning System (IPAWS). NWS forecasters provide information through media interviews and generic broadcasts made available to television and radio stations. Official warnings are directly disseminated to the public through automated systems which broadcast warning messages over television and radio stations, in addition to mobile broadband networks. The NHC provides a media spokesperson (typically the NHC Director) who performs dozens of national and local media interviews during TC threats. In addition, the NHC and WFOs use social media to provide live and recorded briefings to make the public aware of the TC hazards.

***4.7 Multi-Hazard Approach and the Concepts of IBF in Tropical Cyclone EWS***

A multi-hazard approach and the concepts arising from the IBF is an important basis for the understanding of the warning messages by the public. Several, though not all, weather services are making use of these important tools in the forecast and warning process of TCs.

Cayman Islands NWS is producing relevant infographics with IBF that are shared with the public, as part of ongoing efforts in this sense.

In China, when CMA issues TC EWS, a multi-hazard approach and IBF are included. This includes the cyclone’s current position/intensity and future changes, the strong winds, precipitation, waves, and tides caused by the cyclone, and if possible, the TC-induced flash flooding, debris flow, rivers flooding and urban waterlogging.

In Cuba, a multi-hazard framework is being used by the National Forecast Centre as well as an IBF concept is to be introduced in the information regarding TCs. However, further coordination should be done with the Civil Defence System, who has the mandate for the protection of people and the economy.

In Hong Kong, China, multi-hazard approach includes the potential impacts of high and changing winds, drowning risk due to swells and waves, squalls and flooding due to either storm surge or heavy rain. In autumn, TC hazards along the coastal areas of southern China can become very tricky and highly unpredictable due to the interplay of a TC with the northeast monsoon. TCs Lionrock, October 2021, brought record-breaking rainfall of over 300 mm to Hong Kong. Lionrock was still located about 500 km away and the local winds did not warrant a higher TC signal yet. As far as possible, potential of hazards is communicated to the public by TV weather programme, press conference, push message via HKO’s website and mobile app “MyObservatory”, etc. before a TC arrives so that the public can be better prepared.

The IMD of India follows a multi-hazard approach in providing the early warnings. The warning graphics are assigned with specified colour based on the impact matrix. IBF comprising a list of potential impacts in association with the forecast weather event and suggested actions for reducing the impacts are incorporated in the warning bulletins in a textual format. There is a web-based Dynamic Composite Risk Analysis — Decision Support Tool being implemented for the use of disaster managers enabling them to arrive at better risk informed decision-making during cyclones.

In Japan, the various weather warnings that play a major role in TC EWS and their announcement criteria are based on the concept of IBF. JMA issues not only individual warnings for each hazard, but also TC information (text and graphic information) that comprehensively describes the hazards caused by TC, such as wind, flooding, inundation, landslides, storm surge, and high waves.

In the Philippines, the development of an IBF and Warning Service is currently ongoing. PAGASA has been utilizing a multi-hazard approach in its early warning information. During a cyclone event, associated hazards are incorporated into a series of Severe Weather Bulletins that are disseminated to the public and concerned DRR agencies. PAGASA is utilizing a pseudo-IBF approach where potential impacts are indicated in the warnings; however, no comprehensive risk information is integrated into the analysis. As soon as the IBF development is completed and the system is well-verified, PAGASA will adopt and implement an impact-based approach in its EWS.

In the United States, multi-hazard approach is applied with extensive coordination from experts in each hazard seen in a TC event, including wind, storm surge, coastal and inland flooding, rainfall, and severe weather (i.e., tornadoes and thunderstorms). Impact information is coordinated on the storm scale through the NHC and CPHC and these offices provide impact-based decision support to national partners. WFOs provide hurricane threat and impact graphics and text products (Tropical Cyclone/hurricane local statements and TCs watch/warning) in accordance with[*NWS Directive 10-601: Weather Forecast Office Tropical Cyclone Products*](https://www.nws.noaa.gov/directives/sym/pd01006001curr.pdf) that provide local information on wind, storm surges, flooding rain, and tornado threats specific to their local area of responsibility. WFOs use these products and other routine NWS products to provide impact-based decision support services to locals.

***4.8 Role of NMHS’s in Public Awareness and Education Activities***

One of the most important activities in countries affected by cyclones should be that of public awareness and education, because of the potential they have in decreasing the number of fatalities in the hazards related to TCs.

In the Cayman Islands, at the start of the hurricane season, the NMHS alongside the other government entities commence a public campaign and appropriate training programmes for all aspects of disaster preparedness, disaster mitigation, loss reduction and disaster management.

CMA is devoted to increasing public awareness of the prevention and mitigation of meteorological disasters through various ways. It plans and organizes nationwide science activities on World Meteorological Day, National Disaster Prevention and Reduction Day, and Meteorological Science and Technology Week, etc.; also carries out targeted science popularization for different groups of people like teenagers, farmers, community residents, policymakers, and civil servants. They organize the construction of meteorological popular science resources in various forms such as books, illustrations, videos, web pages, courseware and exhibits, as well as promote the nationwide sharing of these resources. Through cooperation with China's mainstream media, all kinds of popular science information are widely disseminated on TV programmes, websites, social networks, and other mass media.

Citizen preparedness for disaster situations in Cuba extends from the top authorities to the people in their workplaces, schools, and communities. It is aimed at making each capable of organizing or carrying out the actions planned, according to their responsibility, and aware of the risk they may be exposed to and the measures they must take to protect their lives and their property. A separate mention should be made of the yearly, two-day long “METEORO” National Drill Exercise for Disaster Case Actions. Usually conducted during a weekend in May, it helps authorities and communities to prepare for disaster situations. It is used to test the warning, communication, and information systems, check the logistics needed for the different protection measures such as the evacuation of people, goods, and economic resources, the vulnerability mitigation actions, and it receives ample coverage by all communication media (television, radio, newspapers, etc.) regarding aspects that the population ought to know for every territory. The Cuban Meteorological Service plays an important role in the public's awareness and in educational activities. Hundreds of conferences and chats are offered every year in working places, factories, as well as in social organizations of different types.

Outreach activities in India are a part of the early warning services provided by IMD. There are various programmes being conducted routinely to create awareness about weather forecasting, early warning, and weather-related natural hazards, especially due to cyclonic storms over the seas and coastal areas. Twice every year, IMD HQ and all its field forecasting offices observe open day for the public during which the weather experts explain educate about these activities. Prior to each cyclone season, the ACWCs and CWCs conduct a series of lectures, meetings and film shows to impart knowledge on the impending hazards associated with such systems. IMD also takes part in the mock drills, and training of the public and police, organized every year by National Disaster Response Force (NDRF) and State Disaster Response Force (SDRF).

In Japan, weather warnings and related information are referred to by residents in making evacuation decisions and by the mayor of a municipality in issuing evacuation orders to residents in accordance with the law, it is important to conduct activities to deepen the understanding of weather warnings and other information among residents and municipal officials. Based on this understanding, LMOs are strategically working to promote understanding among municipalities and to disseminate knowledge to residents. Specifically, we are strengthening cooperation between municipalities and LMOs, conducting workshops with local disaster prevention leaders, and promoting public awareness activities in cooperation with educational institutions. The JMA Headquarters and LMO offer several days during the summer vacation for children to tour the office so that they can gain a better understanding of the service offered. The headquarters has a permanent “Meteorological Science Museum” where people can learn the knowledge of meteorology, earthquakes, tsunamis, and volcanoes through various exhibitions. JMA’s website also provides e-learning materials and supplementary materials for the public, as well as materials for local governments to use in their workshops.

The United States NWS including the NHC and CPHC and WFOs, executes an extensive hurricane outreach and educational programme. This includes providing training to core partners (such as emergency managers and media) as well as to other NMHSs through the annual WMO RA IV Workshop on Hurricane Forecasting and Warning. In addition, Hurricane Awareness Tours are conducted both in the United States and in the Caribbean to engage local communities and the public to increase awareness of hurricane hazards and encourage hurricane preparedness activities prior to the start of each hurricane season. Some of these activities occur during the United States’ National Hurricane Preparedness Week, a time to emphasize the importance of individual preparedness.

***4.9 Final Thoughts***

All countries have, in one way or the other, put into force laws and regulations that support and validate the work of the NMHS in providing timely forecasts, watches, and warnings for the protection of the public and the economy.

The same could be said relative to the collaborative partnerships for EWS in all the countries, usually in a very close way with the civil protection and disaster management agencies as well as with local governments.

The use of risk and vulnerability information has been introduced in most of the Meteorological Centres that forecast cyclones. There are different ways to do it considering the local scenarios, but the intention is the same, to assess vulnerability and exposure to better guide people to protect themselves.

Timely, authoritative, recognizable, and understandable warnings, as well as standard dissemination mechanisms, are present in all countries. In many countries the meteorologist and experts from the NMHS do not present the warnings to the public, they do it by means of journalists or special bulletins to be read on air by news anchors or any other means.

The use of a multi-hazard approach and the concepts of IBFs in TC EWS have been implemented in only some countries, while others are beginning to look at the use of IBF. There is an urgent need for a multi-hazard approach coupled with IBF to be developed and implemented in all TC basins. This is a gap that must be filled in the near future.

While several NMHSs play an important and leading role in public awareness and education activities There are many of them that have a very limited activity in this field due to lack of personnel or economic resources. There needs to be shared material available to help the countries that are less engaged in public awareness and education.

Previous events which the operational TC EWS led to improvements in emergency preparedness and prevention are the norm for countries located in TC basins. It should be noted that though successful events are important, events that are not an overall success and even those that result in a disaster are also important. This is where lessons, though in a hard way, can be captured and addressed, giving way to future steps for improving TC EWS and to more successful events in the future.

## Annex 1: Country Showcase Examples

Annex 1 showcases examples of good practices from a number of WMO Members who have already established MHEWS systems, procedures, and coordination mechanisms for their national services under TCs circumstances. This Annex is open to all WMO Members who wish to share their good practices and success stories with others in their national services with MHEWS procedures and coordination mechanisms.

### 1.1 Cayman Islands — case study

The Cayman Islands TCs EWSs (CIEWS) includes numerous agencies to support HMCI as the lead agency. The functions of HMCI are to facilitate and coordinate the development and implementation of Comprehensive Disaster Management Programs. The Disaster Preparedness and Hazard Management Law 2019 provides the legal framework for HMCI to function. A collection of senior government managers chaired by the Deputy Governor serves as the NHMC whose responsibility is to manage the response to any non-security threat to the Cayman Islands including warnings for tropical systems. As a UK overseas territory a National Hazard Management Executive is created and led by the Governor to communicate with the UK authorities, Overseas Territories, other jurisdictions, and International Organizations through the Governor’s Office. HMCI and the Cayman Islands NWS (CINWS) operate very closely together as components of the CIEWS. The Met Law 2010 provides the legal framework for the CINWS to function.

The CINWS maintains watch over a monitoring area that extends from South America to 25 N and from Central America to 60 W. As part of its monitoring and warnings responsibilities creates and disseminates updates and warnings in both text and graphical forms to all media contacts, the public and members of the Disaster Management community. The CINWS releases statement and graphical images for the genesis of all systems and will continue these updates depending on the location of the system. For systems outside of the monitoring area no further updates are provided. For systems within the monitoring area the number of these graphical images is increased to include data for all bulletins released by the NHC whenever system especially for those on a path to threaten the Cayman Islands. To improve its services the CINWS has started a process of developing an IBF and Warning system with its partners beginning with the passage of Hurricane Grace in August 2021.

In terms of public education, the NWS works closely with Hazard Management Cayman Islands in holding joint events to educate the public. Although there are numerous events where the two agencies work together, they also provide public education separately as well.

Annual Hurricane Exercises, post-storm reports and assessments are key methods to improving EWSs. A Good example of this was in 2021 reports and post-storm assessment indicated that the CINWS website was not fit for purpose leading to the Government approving funding for the creation of a new website. While improving the EWS is a key result of holding Annual Storm Exercises and post-storm assessments there remains no better test for an EWS than a live event. This hard lesson was taught to the Cayman Islands when Hurricane Ivan passed through the islands in 2004 leading to major changes in the EWS.

### 1.2 China — The typhoon early warning and response system in China

***1.2.1 Introduction***

To mobilize and coordinate the efforts of the whole society to prevent and control floods and droughts and mitigate the damages caused by subsequent disasters in order to safeguard people's lives and property, China has formulated and improved its laws and regulations, including the Meteorological Law of the People's Republic of China, the Law of the People's Republic of China on Flood Control, the Drought Control Regulation of the People's Republic of China, the law on response to emergencies, and the national overall emergency plan for public emergencies, the measures for the release and dissemination of meteorological disaster early warning signals promulgated by the State Council.

A comprehensive typhoon and flood control system was established, which was "led by the government with joint forces from multiple departments, accountability assigned to different levels, and extensive social participation". During practice, the principles of "be people-oriented" were followed to ensure the safety of people's lives and property, which were prioritized to prevent fatality and minimize losses. A "prevention-oriented, holistic, and integrated" approach was adopted. In response to typhoon and flood, all efforts have been made to take scientifically sound measures during the entire process of "monitoring – forecast – prevention – resistance – rescue – assistance" and to leave no regrets. The working system whereby the administration head assumes full responsibility was adopted to maximize the unique political and institutional strengths of China in terms of mobilizing social resources efficiently and to make sure that the responsibilities of flood control were assigned to all levels and to all people at the same level.

Years of typhoon and flood control practice has proved that the system that was "led by the government with joint forces from multiple departments, accountability assigned to different levels, and extensive social participation" has been a successful and effective institutional arrangement.

***1.2.2 Organizational chain of command***

1.2.2.1 Organizational structure

A complete organizational structure for typhoon EWS is an important foundation for typhoon response. According to laws and regulations, and in accordance with the principles of unified leadership, the assignment of responsibilities to different levels of government, and the combination of vertical and horizontal levels of government functions while relying primarily on horizontal government function blocks, the national, provincial, municipal, and county governments have all established typhoon early warning and response headquarters over which the government assumes the overall responsibility, with the participation of leaders from relevant departments. These headquarters are responsible for the organization, command, coordination, supervision, and other daily work of the typhoon early warning and response in their specific region. Each township (subdistrict), as well as the departments and units related to typhoon response tasks, have also established its headquarters or leadership group, and were responsible for the daily work such as the organization and coordination in their own township (subdistrict), departments, and units according to the division of responsibilities. Thus, a system that is "led by the government with joint forces from multiple departments, accountability assigned to different levels, and extensive social participation" was established from an organizational point of view, which formed a joint prevention and response effort for an integrated typhoon early warning and response system at a national level.

Under the leadership of the State Council, the SFCH is responsible for leading and organizing the national typhoon response efforts, with one general commander (vice premier of the State Council), two or three deputy general commanders, a Secretary-General (Vice Minister of Emergency Management), two deputy Secretaries-General (Deputy Director-General of the CMA and the officer from the Central Military Commission), and several members (served by the officer from the member agencies).

1.2.2.2 Division of responsibilities

The SFCH has set up its office in the Ministry of Emergency Management, where it is responsible for organizing, coordinating, guiding, and supervising the national efforts on typhoon early warning and response. The member agencies of the SFCH, in accordance with the Responsibilities of the Member Agencies of the State Flood and Drought Control Headquarters stipulated by the SFCH, work closely and collaboratively under the leadership of the SFCH to perform their duties in typhoon early warning and response. The major member agencies of the SFCH and its duties are:

* The CMA is responsible for typhoon monitoring and forecasting. It analyses and predicts floods and disasters caused by typhoons, issues typhoon forecasts and warnings in a timely manner, and participates in the emergency response to typhoon-induced disasters.
* The Ministry of Emergency Management assumes the daily work of the SFCH and is responsible for organizing, coordinating, supervising, and guiding the daily typhoon response work. The ministry organizes water management during typhoon events on major rivers and water projects and is responsible for organizing and guiding the construction and management of national typhoon response projects and supervising the local governments to complete the repair of water projects damaged by typhoon floods.
* The Ministry of Industry and Information Technology is responsible for the security and emergency repair of public communication facilities to support communication during typhoons.
* The Ministry of Transport is responsible for the safety of highways, railway, aviation, and water transport facilities during typhoons, for the search and rescue at sea, and for the transport of personnel, materials, and equipment during typhoons.
* The National Radio and Television Administration is responsible for radio and television stations at all levels to publicize the typhoon response, and for the timely reporting of flood information issued by the SFCH and important information on typhoon response around the country.
* The Ministry of Civil Affairs is responsible for disaster relief during typhoons. The ministry coordinates the efforts to verify the disaster, releases unified official disaster updates, and provides information on major disasters to the SFCH in a timely manner. The ministry is also responsible for organizing and coordinating disaster relief and livelihood assistance for the affected people in typhoon-hit areas. It also manages, distributes, and supervises the central relief funds for the affected people. In addition, the Ministry of Civil Affairs organizes, guides, and manages disaster relief donations, etc.
* The Ministry of Public Security maintains social order in the affected areas, combats disinformation, looting and theft of materials for typhoon response, and criminal activities that damage typhoon response facilities. The ministry also assists in organizing the evacuation and relocation of people from hazardous areas.

1.2.2.3 Work system

China's typhoon early warning and response set-up has adopted a system whereby the administration chief assumes full responsibility. The administrative chiefs of local governments, departments, and agencies at all levels are the primary principals for the typhoon response, who are responsible for establishing the local headquarters (or leading groups) for the typhoon response under the leadership and guidance of the higher headquarters, and they provide overall leadership and guidance to the local headquarters in carrying out the typhoon response activities in their areas of responsibility. Under the unified leadership, command, and coordination of the SFCH, the headquarters (or leading groups) at each level carry out the nationwide typhoon response that is "led by the government with joint forces from multiple departments, accountability assigned to different levels, and extensive social participation". A work system of typhoon early warning and response under the leadership of the SFCH has been established to strengthen and standardize the typhoon early warning and response of the SFCH. In case of emergencies, the meteorological departments at all levels may send the "Special report on typhoon monitoring and forecasting" directly to the local government, and the responses should be promptly organized and implemented by its flood control and typhoon response headquarters after obtaining approval from the government. A "working guidance team" should be sent to the front line to guide the work for a typhoon response if necessary.

1.2.3 Early warning and preparedness system

To minimize casualties and losses by typhoons, governments at all levels as well as relevant departments and agencies should take their responsibilities for typhoon response work and the practical conditions of defence projects into account and formulate protocols for typhoon response. The Regulation of the People's Republic of China on Flood Control specified the procedures for the preparation of typhoon response protocols and the responsibilities of departments and agencies undertaking typhoon response tasks during the preparation of typhoon response protocols. The regulation further stipulated the legal responsibilities for those who fail to prepare and implement plans as per the requirements.

A complete protocol should include: organizational system (leading, emergency liaison, and working agencies), prevention and warning (signal, classification, and main defence protocols), emergency response (grading and action, measures, information release, and ending responses), post-disaster management (assistance, supply of materials, reconstruction, insurance and compensation, investigation and summary), emergency preparedness (communication and information, emergency and rescue, professional guarantee, security and medical, material and financial, social mobilization preparedness), supervision and management (public information exchange, training, exercises, rewards and punishments, and protocol management). Combining the typhoon early warning and response, some of the core elements of the protocol are summarized below:

1.2.3.1 Early warning signals

The National Meteorological Centre of the CMA identifies the 24- and 48-hour warning zones (typhoons located in this warning zone will make landfall or affect mainland China within 24 or 48 hours) based on the climatic characteristics of the typhoons affecting China. In practice, the CMA closely monitors and provides rolling forecasts for typhoons in the northwest of the Pacific Ocean (including the South China Sea). When a typhoon has entered or is predicted to enter the warning zone and has or is expected to have an imminent impact on (mainland) China (bringing strong wind, heavy rainfall and flooding, storm surge and floodplain, etc.), CMA will use the national information release platform for emergency disasters to issue typhoon warnings and promptly report them to the SFCH.

The warnings are generally divided into four levels according to the potential hazard, urgency, and the activities of the typhoon: Level IV (general), Level III (serious), Level II (severe), and Level I (extremely severe), with colour labelled as "blue warning", "yellow warning", "orange warning", and "red warning", respectively, as indicated in the Figure 1.2-1.

Graphical user interface, application

Description automatically generated

**Figure 1.2-1: The typhoon warning signals by colours   
(Blue, yellow, orange, and red warnings)**

* Blue warning for typhoon – Level IV: The typhoon is likely to or has affected the area within 24 hours, with an average coastal or land wind force of six or above, or wind gusts of force 8 or above, which are likely to persist.
* Yellow warning for typhoon – Level III: The typhoon is likely to or has affected the area within 24 hours, with an average coastal or land wind force of eight or above, or wind gusts of force 10 or above, which are likely to persist.
* Orange warning for typhoon – Level II: The typhoon is likely to or has affected the area within 12 hours, with an average coastal or land wind force of ten or above, or wind gusts of force 12 or above, which are likely to persist.
* Red warning for typhoon – Level I: The typhoon is likely to or has affected the area within 6 hours, with an average coastal or land wind force of 12 or above, or wind gusts of force 14 or above, which are likely to persist.

1.2.3.2 Response actions

The SFCH and its member agencies should analysis the possible impact of typhoons based on the typhoon alert signals and the characteristics and responsibilities of their own sectors, jointly issue special alerts, such the "flash floods and geological hazards", with CMA and activate emergency responses accordingly. The emergency response status is also divided into four levels (Levels IV, III, II, and I in ascending order), which usually corresponds to the four-tier colour-coded warnings, but the response status may be inconsistent with the warning levels. In practice, by observing the principles of "be people-oriented, better to err on the side of overestimation than a missing forecast", the level of response status is usually slightly higher than the level of the warning (such as initiating a Level I response when receiving a Level II alert, etc.). In addition, when the flood stabilizes and the hazard is over or eliminated, the Meteorological Department and the headquarters will lift the typhoon alert and the emergency response status according to the consultation results. Listed below are the response actions for Level I:

* SFCH: The general commander should preside over the national special meeting on the typhoon, which the heads of the headquarters should attend and make emergency arrangements for a typhoon response. The guidance on the response should be enhanced. The principal leader of the State Council should broadcast a televised speech to mobilize the military and civilians to fight the disaster.
* Headquarters at all levels: The head of the headquarters should take command and promptly implement all typhoon response and rescue measures. Possible hazardous conditions should be resolved timely, and every effort should be made to protect people's lives and property.
* Member agencies of the headquarters at all levels: The principal leaders should take command to organize and require the system or the industry to work in full gear in typhoon response and rescue as well as to ensure that the response measures are in place.
* Typhoon response agencies at all levels and the relevant emergency response agencies: All response measures should be implemented as per the centralized deployment by the headquarters. The public should be reminded to check if the self-protective measures are implemented. Classes should be suspended, or other specific protective measures should be taken for primary and secondary schools (including high schools, technical secondary schools, and vocational and technical schools), kindergartens, and related institutions. Production, work, and business should be suspended as appropriate for companies and institutions other than government agencies, enterprises, and public institutions that are directly related to ensuring social functioning.
* All professional rescue teams should declare a state of emergency, clear the drainage and roads, and perform emergency repair as soon as possible. All institutions responsible for emergency materials should provide a guarantee for a typhoon response.
* Troops and armed police should carry out rescue and relief tasks according to the instructions from the headquarters.
* Media agencies and management institutions of large displays in public spaces should be prepared to put up typhoon-related alerts, safety tips, and emergency notices at any time. Telecommunications carriers should assist in the dissemination of the above-mentioned information via SMS.

***1.2.4 Information assurance system***

The information assurance system is composed of information collection, information release, decision support, and command conferencing systems, which can collect and transmit real-time typhoon wind, rain, and flood information and perform functions such as the digital management of seawalls, pump stations, embankment facilities, vulnerable projects and project sections as well as flood and typhoon response materials, video monitoring of major flood and typhoon response locations and time periods, and remote conferencing and command attended by multiple departments. The system ensures real-time updates on the disaster and immediate mass mailing of typhoon response information.

1.2.4.1 Information collection system

The information collection system integrates real-time information on typhoons and the accompanying hazardous factors that may lead to disasters such as wind, rain, and tide. The system also monitors changes in the hazard or disaster of flood control infrastructures (seawalls, embankments, pump gates, etc.) of the SFCH and its member agencies, the stockpiling of typhoon response materials, and the dispatch of typhoon response personnel.

1.2.4.2 Information release system

Typhoon warning signals are issued through the National Emergency Warning Release System (NEWRES), which is organized and coordinated by the government departments and constructed and operated by the meteorological departments. This system serves as an authoritative platform for the collection and distribution of warnings for multiple types of hazards. The NEWRES consists of one national level release centre, thirty-one provincial-level release centres, 343 prefectural and municipal-level release agencies, and 2015 county level release agencies, which are responsible for the release of local typhoon warnings to all levels of government.

Once the typhoon warning signal is released, media agencies and facilities such as broadcasts and large display screens in public spaces should promptly insert (and/or scroll) relevant alerts, safety tips, and emergency notices. Television stations should place the alert signal in a prominent position on screen. The web portals of each level of headquarters and its member agencies should also provide the weather report, typhoon forecast, flood notices, flood bulletins, Watergate monitoring, daily water level reports, disaster briefings, real-time tracking, and other information related to the typhoon and the typhoon response. In recent years, a fax broadcasting platform and a mobile phone SMS mass sending platform have been set up to send warning signals and signals of upcoming actions such as the upgrading/downgrading or cancellation of warning signals (called "pre-notification") via fax or SMS to all levels of headquarters and their member agencies. Telecommunications carriers should assist in the SMS release of the above information.

***1.2.5 Rescue and relief system***

A typhoon rescue and relief system mainly consist of rescue materials as well as rescue and relief teams. Among them, the rescue materials mainly include more than thirty varieties; for example, straw bales, woven bags, timber, steel, blocks, and stones, which are stockpiled by the headquarters at all levels and their member agencies, departments, institutions with typhoon response tasks, and professional organizations (including NGOs). The rescue and relief teams include highly specialized rescue experts such as meteorological, water, electric power, greening, gas, transportation, fire, communications, environmental protection, and biochemical teams. The teams also include mobile rescue experts such as from the construction and industrial field, troops, armed police, and public security as a rescue task force. Meanwhile, the satellite, civil affairs, and insurance departments should also set up professional teams for medical rescue, disease control, civil assistance, and insurance claims in order to protect people's lives and property to the maximum extent possible.

1.2.5.1 Material stockpiling

The necessary typhoon response materials are stockpiled and allocated reasonably according to the principle that responsibilities should be assigned according to levels. A certain amount of emergency supplies should be stocked in the key typhoon response areas in case of emergencies. A detailed description of the storage location, transportation protocol, contact information, and responsible personnel of the above materials must be stated in the typhoon response protocol.

1.2.5.2 Emergency response teams

According to the principle of combining professional teams and civilian teams, the joint response task force of the military (police) and civilians was formed during typhoon responses at all levels. The rescue teams generally consist of professional rescue teams by the member agencies of the headquarters, the resident troops, armed police, fire department, and public security officers. The teams are required to be well organized, flexible upon dispatch, obedient to commands and orders with prompt actions in order to become teams that are readily available, with the ability to fight and succeed.

1.2.5.3 Disaster relief

Upon the occurrence of disasters such as typhoons or major hazards in typhoon response engineering projects, the local typhoon response headquarters should monitor and track the incident promptly according to the nature of the incident and contact the relevant departments immediately; propose emergency disposal measures immediately according to the protocols and report to the headquarters at the next higher level; mobilize the typhoon response resources and personnel task forces under its jurisdiction promptly to conduct an on-site response or rescue.

When dealing with typhoons and other related disasters as well as major engineering hazards, all member agencies shall be subject to the centralized command of the headquarters and perform their individual tasks according to the division of responsibilities and work in solidarity in order to respond quickly and efficiently. The security and order on the site as well as local social stability should be maintained to prevent triggering secondary and subsequent disasters and to minimize losses.

1.2.5.4 Drills and inspections

Based on the principles of "safety first, always ready, prevention first, do the best in emergency rescue" in typhoon response, the inspections are made on the "implementation of ideas, institutional arrangements, and response measures". The purpose of the inspection is to identify and eliminate the hidden dangers of typhoon response activities to ensure safety during the typhoon season. Inspections should highlight uninspected spaces, hidden or weak components, unclear causes of hidden or weak components, improvement measures that are not implemented, unclear responsible persons, and instances where the person responsible for incidents caused by human errors are not held accountable. The inspections should follow the above principles and be carried out in a targeted and uninterrupted manner so as to supervise the implementation of various flood control measures and avoid hidden hazards and accidents before they arise. Typhoon response inspections include self-inspection of the agencies responsible, inspections of the professional agencies, random inspections of the management departments. The inspections also include pre-typhoon inspections, special inspections during the typhoon, and reviews after the rectification of hidden dangers.

The drills are an effective means to test the quality and implementation of typhoon response protocols and to publicize typhoon responses. Typhoon response headquarters at all levels should conduct different types of emergency drills regularly as per the protocol to test, improve, and enhance emergency preparedness and emergency response capabilities and to ensure the relevance and operability of the protocols. Professional emergency response teams must conduct targeted typhoon response drills annually for various types of local hazards related to typhoons that are prone to occur. Professional drills conducted jointly by multiple departments are generally held once every two to three years and are organized and implemented by typhoon response headquarters at all levels.

***1.2.6 Concluding remarks***

With socioeconomic development, on the one hand, the technical means of typhoon response activities have been improved and the response capability has been enhanced. On the other hand, the exposure to typhoons and vulnerability to disasters have increased, especially in the context of climate change, where the intensity of typhoons and the extremity of disaster-causing factors such as storm surges have also increased. Meanwhile, along with the socioeconomic development, the latest and higher requirements for typhoon response work have been proposed. Therefore, typhoon response protocols and work systems should be improved in practice over the years.

At present, there are still uncertainties in the refined typhoon forecast. It is well known that although the forecasting of a typhoon track has improved significantly in recent years. Typhoon intensity forecasts have progressed slowly during the past few decades, and the capability of quantitative forecasts of the wind and rain as well as the distribution remains low. Therefore, there is considerable uncertainty in the timing, intensity, and area of typhoon alerts. Such uncertainty should be considered in the preparation of typhoon response protocols and in the design and construction of the working system, especially when dealing with issues such as the standardization of the protocols and the adaptability of warnings with uncertainties.

In the six components of "monitoring – forecast – prevention – resistance – rescue – assistance" during typhoon response work, "monitoring" and "forecast" serve as the basis for "prevention". If the prevention is successful, there would be no disaster or only a small disaster. If the prevention fails, "resistance – rescue – assistance" must be carried out. Good resistance leads to easier "rescue" and "assistance" with lower costs; otherwise, it would make “rescue” and “assistance” more difficult and costly. Therefore, "resistance" is the key to "rescue" and "assistance". The most effective means of resistance to a typhoon is to enhance typhoon response engineering projects. In the future, it will be necessary to conduct a scientifically sound assessment of the effectiveness (safety) and construction cost of these engineering projects, especially to update the engineering standards and improve the engineering facilities as well as the intelligent work mode (adaptive typhoon warning signals) when faced with changes in the exposure and vulnerability to typhoon hazards in the context of climate change and socioeconomic development.

### 1.3 Cuba — TC early warning system in Cuba

***1.3.1 Introduction***

Cuba’s island condition, and its geographic location in the route of most TCs that develops in the Atlantic basin and the Caribbean Sea, makes these hydrometeorological events the greatest hazard for the nation. Yet, official reports by agencies of the United Nations recognize that Cuba is one of the less vulnerable countries with regards to these weather events.

This is possible, to a large extent, by the EWS that Cuba has had in place for several years now, supported by numerous national institutions as well as by an efficient Meteorological Service, with a wide monitoring network of meteorological and hydrological stations, as well as meteorological radars, that guarantee a permanent monitoring and a timely warning, with effective communication links between the monitoring systems and the branches of the Civil Defence, from the national down to the local level.

The dissemination of forecasts and warnings is assisted by a secure system of communication and the use of all mass media, including radio, television, newspapers, alternative resources, and the people. Plans have been designed for the different situations on the basis of the most likely disaster scenarios.

All resources existing in the territories are made available during these contingencies, guaranteeing that people are effectively protected against the different risks they might face there where they live.

The Cuban Government has been investing in material resources and human capital in the creation and invigoration of this and other systems of alert for more than 40 years. As a consequence, the resolution possibilities of the meteorological and hydrological systems of surveillance have been strengthened with the acquisition of new equipment, the training of specialists and the development of working tools that improve the appreciation of the hazard. The plans and the structures that guarantee their implementation from the national level to the local, as well as the population's preparation have been perfected. A wide network of radio and television stations, as well as newspapers and other facilities have been created, so they guarantee the quick dissemination of alert messages including the transmission of information from person to person. Recently, local spots for early warnings have been created in the communities with more risk, associated to the administration centres for the reduction of the municipal risk that contribute to guarantee the timely transmission of information.

***1.3.2 Legal basis***

The Cuban EWS system on TC has as key components a) the technological possibilities of the Meteorological Service to predict the impact of the destructive effects of these events and the emission of specialized warnings for the Civil Defence as well as the clear explanation on the current and future situation to the people and, b) the existence of plans elaborated from modelling scenarios on the base of the risk to ensure its application from the early preparations, with institutions trained for their implementation and a prepared population with an appropriate perception of the hazard, that allows a quick mobilization.

A set of institutions are entrusted with the monitoring of all events that threatens the country. They guarantee the surveillance against hydrometeorological events, drought, forest fires, floods, earthquakes, epidemics, and animal and plant diseases, and keep systematically informed the relevant state authorities, with reporting frequency going from daily to monthly according to the variables and phenomena involved.

These institutions have branches in all provinces, and some have municipal representations, which supply data on the variables they measure to both the national and the territorial authorities. This surveillance network makes up the base of Cuba’s EWS and is part of its Civil Defence System.

Cuba has a wide legal basis regulating the functioning of EWSs at all levels. Only those which have a guiding character are mentioned bellow:

Law No. 75/94 (21 December 1994) of National Defence establishes the main missions and measures of the Civil Defence System and the principles for its territorial and institutional organization.

Decree-law No. 170/97 (8 May 1997) on the Civil Defence System of measures, as a complementary document to law 75, regulates the role and position of state agencies and organizations, economic entities, and social institutions in the disaster reduction process; the organization and implementation of these measures to protect the people and the economy; the establishment of phases during the response and the funding for disaster reduction plans.

Guideline No. 1/05 (20 June 1995) of the Vice President of the National Defence Council[[1]](#footnote-1) on the planning, organizing, and preparing by the country for disaster situations establishes the regulations for the disaster reduction process and the guidelines to organize response and recovery at all levels. This document provides for the supply of updated information by the surveillance and EWSs and its contribution to the actions implemented during the response, as one of the most important elements within disaster reduction plans. It also stipulates that in case of tropical storms, “Early warning notices will be issued prior to the establishment of the response phases, so that the necessary measures are taken in advance”.

According to this guideline, the National Staff of the Civil Defence is the agency in charge of ensuring the implementation of the Civil Defence measures and the observance of international standards and agreements regarding the civilian population signed by Cuba and coordinating with the Ministry of Foreign Investment and Economic Cooperation concerning international cooperation and aid programs in case of disasters or other types of catastrophes. In addition, its powers and functions include organizing, coordinating, and controlling the work of state agencies and organizations, economic entities, and social institutions with a view to protecting the people and the economy”, as well as acting as a national organizing platform for the system.

Resolution No. 43/06 (8 August 2006) of the Ministry of Science, Technology and the Environment establishes that the Environment Agency is the body that has the mandate to organize, lead and conduct the hazard, vulnerability, and disaster risk studies.

There are other legal texts that complement this guiding document at all levels. These include Law No. 81/97 (11 July 1997) on the Environment, Law No. 41/83 (13 July 1993) on public Healthcare, Law No. 77/95 (5 September 1995) on Foreign Investment and Law No.85/98 (21 July 1998) on Forestry, as well as ministerial and local resolutions which address specific aspects regarding the functioning of the EWS for TCs and other hydrometeorological events

Resolution 106/99 (6 December 1999) of the Ministry of Science, Technology and Environment establishes the General Norms of Direction, Organization and Operation of the Institute of Meteorology (INSMET), under the Ministry of Science, Technology, and the Environment (CITMA).

In this document it is described the general structure of the INSMET of Cuba as the National Meteorological Service with the main mission of “giving authorized weather and climatic information, reliable and opportune, on the state and future behaviour of the atmosphere. This information is directed to look after the security of the human life and to reduce the losses of material goods before natural disasters of meteorological origin, contributing directly to the well-being of the community and the sustainable socioeconomic development”.

In section 11 of the document, it is set down that one of the functions of the Cuban Meteorological Service is to improve the weather and climatic prediction, especially of the phenomena that constitute hazards for human life, as well as the material goods and the national economy.

Among the Attributions and Functions of the INSMET in this Resolution, is to give this institution state responsibilities and to issue through the media, as the only authorized institution, meteorological and climatic information that be required, especially the warnings and forecasts of variables, processes and meteorological phenomena that constitute a hazard for human life, material goods, the economy and for the development of the country.

Something similar is settled down for provincial Meteorological Centres in their attributions and functions, as the ones to be allowed to give out and to issue through the provincial media meteorological and climatic information that be required, as the only institution authorized in the territory, especially the warnings and forecasts, processes and meteorological phenomena that could constitute a hazard for human life, the loss of material goods, the economy and for the development of the county.

On the other hand, the Executive Committee of the Council of Ministers issued the Ordinance Law No. 279/07 (19 March 2007) "On General Principles, Organization, Preparation and Provisions of the Hydrometeorological System of Cuba for Exceptional Situations”. This document sets down that the Hydrometeorological system for Exceptional Situations is the group of hydrological and meteorological entities deployed in the territory of the country that has as main mission to obtain, to analyse, to evaluate, to process, and to issue the necessary hydrological and meteorological information for the execution of the protective measures directed to the mitigation of the effects of disasters.

This process is repeated every year and it serves to make the system better each year, by considering the experiences of the previous year.

Recently, the National Assembly passed a new Law on the Environment and Natural Resources in May 2022, in replacement of the Act Law No. 81/97 (11 July 1997) on the Environment, updating, and englobing in it, the principles and processes of EWS in Cuba, considering the best experiences, and so, several legal bodies on the issue will be also updated in the coming months.

***1.3.3 Structure and division of responsibilities***

The Cuban Meteorological Service is an active part in the preparation and planning procedures of the EWS. Their fundamental function is the raise of awareness among the people, as well as in the institutions of the country, by giving information of what is a hurricane, of its several hazardous phenomena linked to it, of the different risks to face and how to avoid them, and of how the system of warnings is organized, as well as the interpretation of warnings messages. The Meteorological Service also participates in the phase of preparation of the National Exercise "Meteoro", which year is held every year by the Civil Defence before the start of the hurricane season. Meteorologists also participate with frequent talks on hurricanes and the forecasted behaviour of the next hurricane season, with provincial and local governments, Civil Defence bodies and with journalists. These activities are covered by radio and television, and they also serve to prepare the population for the next hurricane season.

Plans, including communications links, are also updated between the Meteorological Service and the Civil Defence, to have a complete readiness in all the system before the start of the hurricane season.

The Cuban Civil Defence is organized throughout the national territory based on the country’s political-administrative division and state structure. Its activity is supported by the use of the human and material resources available at government agencies and organizations, economic entities, and social institutions, i.e., the organized forces of society.

The President of the Republic heads the Civil Defence System through the Minister of the Revolutionary Armed Forces. In this capacity, the minister is supported by the National Staff of the Civil Defence, which is the leading agency in this system.

The presidents of local governments are the heads of the Civil Defence in their territories. To carry out this work, they have the support of the local professional Civil Defence entities, which coordinate, organize, and plan, along with state organization at all levels, the periodic assessment of risks associated with each event, the disaster reduction measures, the people’s preparedness, the spreading of information regarding actions to take and the behaviour to be observed during the different situations. They also control the implementation of protection measures for the different segments of the population, their property, and the economy.

Likewise, the top authorities of the central state administration and those of social institutions and entities are the heads of the Civil Defence in them and are responsible for the implementation in their areas of the measures contained in the disaster reduction plans approved.

Those at the head of ministries, industries, companies, education centres, hospitals, banks, cooperatives, stores, workshops and other production, service or research centres are also the heads of the Civil Defence in their respective institutions. They are in charge of planning, organizing, and implementing Civil Defence measures, which are binding in nature for all institutions.

Political and mass organizations at all levels play an important role in the implementation of Civil Defence measures because of their autonomy and characteristics. These organizations have always had an active participation when it comes to evacuation, rescue operations, and citizen’s orientation and information in case of disasters.

Disaster reduction plans are drafted for every territory and for all economic entities. These plans include an assessment of the risks at every place and are yearly updated using the data provided by the entities regarding the vulnerability parameters established by the methodology.

These plans include vulnerability mitigation measures, and preparedness, response, and recovery actions. They are designed following the instructions provided by the entities’ higher government level and the decisions adopted by the local governments.

Disaster reduction plans that are elaborated in each territorial level as well as in the entities of each organism and ministry, start from an upgrade of the risk difference of each place, which is defined for the magnitude of the hazard associated to each meteorological event and the vulnerabilities identified at that level. Starting from the upgrade and appropriate zoning of the risk, actions of mitigation of vulnerabilities are settled down for that year, according to the available material and financial resources, prioritizing the riskiest areas. In correspondence with the level of risk for each place, measures for the protection of the population and the economic resources are upgraded and the response actions are staggered accordingly to face each event, as well as the planning of measures to guarantee a quick and efficient recovery. The national organisms and ministries upgrade the indications for their entities, which also upgrade their plans on the base of the risk of the territory where they are located, considering the particular indications from their ministry or organism.

The Cuban Meteorological Service is engaged from the very beginning in the process of planning the early warning. It is the Meteorological Service the one that issues the first early warning sign by means of a document named "Early Warning Message", which is sent to the Civil Defence and the Central Government when the first element that considers a meteorological situation as potentially dangerous for the country over the next 120 hours period is glimpsed by the Met Service. This Early Warning Message is issued in a clear, understandable language for non-meteorological personnel, in order to assess the uncertainties of a meteorological process that could happen and affect the country within a relatively long time frame of 120 hours, but which, nevertheless, may happen. This type of information is transmitted to the population through the media, in order to increase the level of concern, without causing any feelings of immediate alarm.

The purpose of these "Early Warning Messages" is precisely to timely inform the Civil Defence and the High Authorities of the Country, as well as the people, that it is necessary to follow the meteorological situation during the next days, so that if a hazardous meteorological system occur, be ready to take the needed prevention measures.

***1.3.4 Work system***

The Cuban EWS takes advantage of the existing socioeconomic structure, the strength of the institutions, and the levels of organization and education of both the authorities and the general population, among other aspects that help its functioning.

In general terms, the main elements of the Cuban EWS are:

* The central surveillance entities in charge of monitoring the hazards and their territorial branches, in charge of this work at regional and local level. The central surveillance entity for meteorological systems is the National Forecast Centre of the INSMET (National Meteorological Service).
* Authorities at the different levels, entrusted with the provision and dissemination of disaster related information and with implementing the relevant protection measures, advised by officials and experts of the Civil Defence. These authorities are the top officials at provincial (Governors or Presidents of the Provincial Government) and Municipal (Majors or Presidents of the Municipal Government) levels.
* The media and mass and social organizations at the local level, which help disseminate information. The local media, newspapers, radio and television station, are those that exist in all the provinces and most of the municipalities of the country. The mass and social organizations that participate in the dissemination of the information in urban and rural areas, respectively, are fundamentally the association of neighbours, known as the CDR, which gathers residents and exists in all neighbourhoods of the country, as well as the national association of small farmers — ANAP.
* The people, who are well organized and prepared. They are fundamentally people of the already mentioned previous mass and social organizations that get ready to disseminate the messages of alert, in communities far from the main cities and towns. There also people in charge of the operational spots for early warning located in key places, with difficult access, that are prepared to measure rainfall and the level and flow of the rivers. They have means of communication to rapidly inform the centre of risk management located at the municipal government site.

***1.3.5 Early warning system (EWS)***

The EWS for TCs is a well-structured, coherent, nationwide system which works closely with the INSMET’s National Forecast Centre and the National Staff of the Civil Defence. These two organizations exchange and analyse information, allowing authorities to take the necessary measures and establish the relevant phases or “call for action”.

The EWS for TCs includes the following elements:

* An effective meteorological and hydrologic surveillance system, with the appropriate human and material resources for guaranteeing permanent monitoring and timely warning, both at the national and local levels.
* Effective communication between meteorological and hydrologic surveillance systems and Civil Defence institutions, both at the national and local levels.
* A network for transmitting information supported by secure communication systems.
* The use of all the mass media for spreading warning notices, including radio, television, newspapers, alternative means and people, both at the national and local levels.
* Plans designed for the different situations on the basis of likely pre-disaster scenarios and assisted by all resources available in each territory, in order to guarantee the effective protection of people under different levels of risk.

In the context of risk management and the handling of disaster hazards, the EWS plays an important role in reducing the loss of human lives and material losses. In Cuba, the EWS is considered a major Civil Defence asset and is systematically used and strengthened.

A Drilling Exercise, called "Meteor", is held once a year during a whole weekend in May, prior to the beginning of the next hurricane season. The first day (Saturday), at all levels of the country (nation, province, municipality, people's council, community and entities) the general preparation, as well as all measures planned for the response and the recovery are reviewed and exercised. On the second day (Sunday) practical activities with the population and the forces that participate in the response, such as evacuation and protective measures, are carried out. The Meteorological Service prepares a set of drilling warnings to be disseminated by all communications links, that also serves to test the system. The Meteorological Service plays also the role of increasing awareness, recalling main aspects of hurricanes, the warning service, and the correct interpretation of warnings, as well as an overview of the coming season. These talks are performed at the opening of the exercise on Saturday, at provincial and municipal levels, and this activity is covered by national, provincial, and municipal media.

***1.3.6 Response actions***

The exchange of information between the National Forecast Centre of the INSMET and the National Staff of the Civil Defence at the national level allows establishing the phase of the response for the threatened territories, which presupposes a certain time for the adoption of measures in those places. As the EWS works with more effectiveness, it would be greater opportunity that provinces and municipalities react and so be able to protect the lives of people and the resources of the economy exposed to different risk levels.

Whenever a province receives an Early Warning Message or the establishment of one of the phases of the response, they begin immediately to complete the measures stated in the plan for disaster reduction for that phase, in correspondence with the characteristics of the threatening event and the level of people's risk and the exposed economic resources. In this decision-making process, a similar exchange, like that of the national level, takes place in the province between the authorities and the Meteorological Service of that province, to determine the magnitude of the impact of winds, rains, and the level of the sea in the territory, starting from the appreciations that are received from the National Meteorological Service. Carried out this assessment, the planned measures for protection for each situation of those that were designed in the preparations for each possible scenario, begin implemented, making this a fast and efficient process.

Starting from the information of the Forecast Centre of the INSMET, the National Staff of the Civil Defence analyses the initial situation, and a note of the Civil Defence can be sent giving an early warning to the governments of the threatened territories. This exchange of information between the Centre of Forecast and the National Staff of the Civil Defence continues while the hazard threat is maintained over the country or some portion of the country. The response action is staggered in Cuba with three phases or stages: Informative, Alert and the Alarms phases. In each phase, and for each event, protection measures are planned, with the EWSs working according to the phase set, because as the hurricane comes closer to the territory, the ways to disseminate the messages also varies. The establishment of each one of the phases is approved by the Central Government, being proposed by the National Staff of the Civil Defence, which considers, among other factors, the recommendations given out by the National Meteorological Service.

Likewise, the meteorological and hydrological services in each province interact with the authorities and are responsible for keeping them and the general population informed through all available communication means in each area.

There are three levels of local government in Cuba, namely, province, municipality, and people's council. These three instances of government have a President and a structure that allows organizing the government's administration. The National Centre of Forecast (Meteorological Service) interacts with the Government at national level, while the Meteorological Provincial Centres interacts with the Government at provincial, municipal and people's council levels, offering information and advice during the different Civil Defence phases.

The INSMET (Meteorological Service of Cuba), through the National Forecast Centre, interfaces directly with the Central Government, the National Civil Defence, national media, the provincial Meteorological Centres, and the National Institute of Hydraulic Resources.

The provincial Meteorological Centres offer information on their territory to the Provincial and Municipal Governments, to the Civil Defence at that level, to the provincial and municipal media, as well as to the Provincial Delegations of the National Institute of Hydraulic Resources.

Provincial Meteorological Centres have the same role as the National Forecast Centre, except that their roles are played with provincial and municipal Government, Civil Defence, and local users, including people’s Council. The provincial Meteorological Centres are indeed the representation of the INSMET before the province level. However, only the National Forecast Centre can make Early Warnings and Warnings in the case of a big scale weather system such as a hurricane, and in this case, they serve as advisors to assess the local impact that the hurricane would have over a certain province. In the case of severe local storms or other local weather features of quick development, the Provincial Meteorological Centre can make its own local warning for local authorities. In that case they would have only to inform to, and receive advise from, the National Forecast Centre.

The role of the National Staff of the Civil Defence in drafting the early warning reports, the operation of the mass media and the activities conducted by local authorities to guarantee that the warning messages reach the entire population and that the necessary measures be taken, are regulated in additional documents, which are issued at each level and are included in the disaster reduction plan.

Local authorities also elaborate indications for the inferior levels, specifying the functions to be completed by the different structures; for example, in the transmission of alert messages down to the level of people's council, on reports that should be done by the Early Warning Points; on the operation of the informative flow. Considering the great number of additional documents that exist, they are not related to in detail.

According to what is establish in the Guideline No. 1 of the Vice President of the National Defence Council, the head of all state organisms and local authorities issue resolutions and instructions to regulate the functions assigned to their dependences and entities within the general frame of the EWS and for the execution of other activities within the disaster reduction process. With this objective, the Chief of the National Staff of the Civil Defence, the Minister of the Institute of Hydraulic Resources and the Minister of Radio and Television, have issued indications regulating this issue.

After the response to every event, an analysis is made of how effective the EWS worked, and measures are taken to strengthen the system through the experience gained in facing each event. This guarantees the consolidation of the procedure. The operation of the EWS is checked during the yearly “METEOR” drill, which lasts for two days and involves all structures from the national to the local levels. In addition, before the beginning of each hurricane season, the mechanism is reviewed to guarantee that everything is in place.

The Drilling Exercise "Meteor" is held once a year during a weekend in May, prior to the beginning of the next hurricane season. The first day (Saturday), at all levels of the country (nation, province, municipality, people's council, community and entities) the general preparation, as well as all measures planned for the response and the recovery are reviewed and exercised. On the second day (Sunday) practical activities with the population and the forces that participate in the response, such as evacuation and protective measures, are carried out. The Meteorological Service prepares a set of drilling warnings to be disseminated by all communications links, that also serves to test the system. The Meteorological Service plays also the role of increasing awareness, recalling main aspects of hurricanes, the warning service and the correct interpretation of warnings, as well as an overview of the coming season. These talks are performed at the opening of the exercise on Saturday, at provincial and municipal levels, and this activity is covered by national, provincial and municipal media.

### 1.4 France/La Réunion Island showcase — from TC *Batsirai* (February 2022)

The French TC EWS has proved its effectiveness for decades in La Réunion. However, improvements are still regularly made in order to increase anticipatory actions, better describe the potential impacts of TCs, improve messaging or deliver an improved representation of uncertainty. TCs *Batsirai* is a good showcase in order to highlight key recommendations and progress.

***Meteorological context***

First advisories were issued by RSMC La Réunion on 26 January when the nascent system was just a mere tropical disturbance. The budding storm was already considered as a potential threat since long-term NWP was letting envisage a future track sending a mature storm in close vicinity of the sister islands of Mauritius and La Réunion. The cyclone warning system was activated the 30 January by the Prefect of La Réunion Island (representative of the prime minister appointed on the territory) following the advice of Météo-France, with the cyclone pre-alert stage being declared. Deteriorating weather conditions were expected to in the next few days (beyond 48 hours).

Figure 1.4-1 is the best track of TC *Batsirai*. From the Figure, it showed that *Batsirai’s* centre eventually passed no closer than 190 km off the north shore of La Réunion Island in the evening of 3 February. This was for sure a lucky scenario for the two islands since *Batsirai* had gone through a third round of intensification leading it to its peak of intensity just after its nearest passage to Mauritius and making it become a very dangerous intense TC, while it had in parallel undergone a large expansion in terms of size.

Chart, scatter chart

Description automatically generated

**Figure 1.4-1: *Batsirai* track and timing of TC alerts for La Réunion island**

TC *Batsirai* had a strong influence on the weather conditions felt in La Réunion. Despite avoiding the dangerous inner core of the cyclone, the island was shocked by strong winds (in line with the initial forecasts and messages delivered four days earlier, with strong winds gusting up more than 150 km/h in mountainous areas), drenched by heavy rain lastingly pouring down on the inland mountains and affected by severe flooding. The volcano area has hit the 2 000 mm threshold in four days due to the large size of the cloudy and rainy envelope of the cyclone and also due to the slowing down of the storm’s motion on 3 February. Despite the combination of exceptional rainfall and very strong winds on the reliefs, no casualties were to be deplored during this episode. The state of disaster has been declared in almost all the municipalities of the island. For the agricultural sector only, the damage was estimated at EUR 47 million.

***Lessons learnt and key progress***

***1.4.1 Increasing anticipation and dealing with uncertainties***

TC Warning System has been activated when *Batsirai’s* centre was still far away, as spotted some 1 150 km to the east-northeast of the island. Pre-alert stage has been declared more than 73 hours before “cyclonic conditions” affected La Réunion Island. Providing early warnings with important lead time contributed to improve emergency preparedness, pre-positioned stock capacity and to increase anticipatory action and to improve

The TCs EWS in the French Overseas Territories is ruled under the leading authority of the main local administrative authority. The regulatory framework governing the French TCEWS is defined in a specific reference official administrative document which is a SOP that describes all the procedures and protocols ruling the warning system and which also provides guidelines and action sheets for all the different departments and partners involved in the crisis and emergency management. Actions taken by emergency management included preparations of emergency shelters, cancelling school attendance, preventive evacuation of people requiring medical care at home, closing roads exposed to landslides and coastal inundation and preparation of lock down during the red alert phase.

The TC Warning System is based on a chronological countdown implying shifting and increasing the warning level whenever the threat is being confirmed and the deadline for a potential impact from the storm approaches. The different stages of the TC Warning System (pre-alert stage, orange alert stage and red alert stage) have been well anticipated, resulting in an efficient preparedness of all partners involved the emergency management. Orange alert stage was declared 24 hours before “cyclonic conditions” are expected to affect the island. The red stage of alert has been declared by the Prefect with a 5-hour prior notice in order to give enough time to everyone to go back home or to go to a safe place. During a red stage of alert all activities stop, and everyone is compelled to stay home or in a shelter — moving out being liable to a fine.

Uncertainty plays a vital role into what actions are to be taken. Uncertainties in track, intensity and wind extension forecasts leads to major uncertainties regarding impacts, especially for small islands. In order to improve communication regarding uncertainties Météo-France now provide to local authorities a specific “timeline” product displayed for “worst-case scenario” and “average scenario”. It integrates prediction of alert level changes and expected impacts for each parameter (wind, rainfall amounts and coastal inundation) at more local scale including local vulnerabilities. This bulletin has become a key product for emergency management coordination briefings. Providing alternative scenarios for decision-making process is crucial to be prepared to different scenarios (including a direct impact of the dangerous inner core of *Batsirai*).

***1.4.2 Maintaining a close cooperation between NMHS, partners and stakeholders***

The Governance is under the leading authority of the Prefect assisted by sub-prefects based in the different subregions (they are three of us in La Réunion Island). In terms of emergency management, the armed wing of the Prefect is the Civil Defence administration. Météo-France is the official institution which is recognized as the unique technical adviser of the Prefect and of the local authorities. At the local level each mayor is in charge of protecting the citizens of his municipality and as such has authority to take all necessary measures the meteorological situation would require.

This event showcases the importance of a close collaboration among partners and stakeholders in providing the most relevant information for an evolving hazardous event, resulting in NMHS, DMO (Disaster Management Organizations), NGOs, broadcast and print media working together, with one voice, through an authoritative source. Pre-season training sessions and exercise are crucial in this context to build trust, understanding and awareness. One of the recommendations of the post-evaluation report carried out by Civil Defence will be to increase the number of participants (up to 250) of the pre-TC season seminar in La Réunion.

Once the warnings went into effect, two TC forecasters from RSMC La Réunion were dispatched to the Emergency Operations Centre to provide direct contact impact-based decision support services. The Head of RSMC La Réunion directly assisted the Prefect during all the red alert phase.

***1.4.3 Efficient and consistent Communication***

The warnings are announced by the prefecture who is in charge of the official communication on the levels of warning and related recommendations to the population in terms of preventive measures and behaviour guidelines. Météo-France is in charge of the “technical” communication about the meteorological situation and forecast, including the expected consequences for the island in terms of winds, rains, swell, etc., linked to the approach of the storm. A perfectly consistent information is needed. Thanks to the coordination of the emergency management community, information flowed through all dissemination sources, including social media: website, mobile app, Facebook, broadcast and print media.

All the main messages — with a strong emphasis on easily understandable key messages — are delivered on the Météo-France website and Facebook account while live radio and TV interviews are regularly given either by the cyclone forecasters specialists (for radios) or by the chief forecasters (on TV). Warnings are also disseminated at national level (mainland France), including French Civil Protection (DGSCGC) and National Disaster Centre (COGIC)

During the red alert phase: 4 press conferences have been held the Prefect, who systematically involved the director of Météo-France. Several journalists from broadcast and print media were accommodated in the premises of the Emergency Operations Centre

***1.4.4 The importance of Impact-based forecasts***

Track and intensity forecast are not very relevant to describe impacts at local level. This is why TC products should focus on associated hazards (violent winds, torrential rainfall, storm surges, coastal inundation, floods and landslides). During the *Batsirai* event, specific attention has been paid to deliver impact forecasts, including rainfall amounts prediction, flash flood prediction and coastal inundation forecasts, including TC products based on new methods merging TC forecasters human expertise and spread information included in NWP ensemble models.

In order to better take in account, the potential impacts of TCs, the TC EWS for La Réunion Island is now based on a two-dimensional approach mixing winds and rains. Formerly the criteria defining “cyclonic conditions” was solely based on the winds (cyclonic winds corresponding to peak gusts exceeding 150 km/h). Since December 2018 the system has changed in La Réunion and is now based on a matrix of decisions combining forecasted max winds and expected return periods of the rains (Figure 1.4-2). Hydrological background is also considered (if heavy rains were observed before the event, the level will be raised to consider the impact of saturation of soils on the water run-off or overflow.

**Chart

Description automatically generated with low confidence**

**Figure 1.4-2: A two-dimensional matrix mixing winds and rains for decision combining forecasted max winds and expected return periods of the rains.**

The importance of teaming up with third parties: The hydrological aspects are not dealt by Météo-France but by another specialized administration (Directorate of the Environment, Development and Housing — DEAL in French) which is in charge of its own specific warning system for the different river catchments on the island (Vigicrues). This impact-based flash flood warning system is however operated in close collaboration between DEAL and Météo-France. High resolution rainfall forecasts are integrated as an input of the flood warning system, which integrates local people experience, direct information from civil protection, altitude of roads, urbanized areas. During TC event hydrological forecasters are located in Météo-France premises in order to guarantee the consistency of meteorological forecast and hydrological predictions.

As regards coastal impacts, the high swell warnings formerly disseminated have now been replaced by warnings of coastal inundation. Probabilistic forecast of cyclone-induced coastal inundation now routinely produced by Météo-France are an input of the warning system.

### 1.5 Hong Kong China — Some tips on MHEWS and DRR in the face of a super typhoon

Super Typhoon *Mangkhut* in 2018 posed the biggest threat to Hong Kong, China in recent years. At the same time, *Mangkhut* offered an excellent example showcasing how zero causalty could still be achieved in a highly developed and densely populated city such as Hong Kong when exposed to extremely high winds, heavy rain and record-breaking storm surge impacts. One week before the hit, the HKO, the official Weather Service in Hong Kong) has proactively blown the whistle and started various communication approaches to raise the awareness of not only the public but also the HKSAR Government, among other key partners such as the mass media. Closer to the warning time, strategic social media posts with short videos on multi-hazards and potential impacts to Hong Kong were pushed to mobile devices in order to escalate public awareness and call for preparedness.

Government-wide joint press conference on Super Typhoon *Mangkhut* was held two days before its closest approach in order to forewarn the public on the one hand and guarantee the government’s readiness on the other. One day later, several government bureau/departments including HKO appeared on radio programmes to urge the public to get prepared for *Mangkhut* (Figure 1.5-1). Together with the emergency response and rescue actions laid down in the contingency plan of the government, the people of Hong Kong knew exactly what to do and what to not even attempt. Through years of education and “rehearsals” on a yearly basis, Hong Kong survived through the devastating impacts of *Mangkhut*. Post-*Mangkhut*, HKO initiated and sustained an ongoing effort of crowd sourcing photos and videos on TC (TC) impacts, including a dedicated webpage “[Interactive Map of Storm Damage by *Mangkhut*](https://www.hko.gov.hk/en/cwsrc/index_mangkhut.html)” (Figure 1.5-2) and new mobile app feature “[My Weather Observation](https://www.hko.gov.hk/en/Whats-New/106130/The-Observatory-launched-My-Weather-Observation-feature-for-trial)”. Subsequently, research studies on *Mangkhut* continued covering not only [scientific](https://www.weather.gov.hk/en/publica/pubreprint_search.shtml?db_type=reprint&html_name=pubreprint.htm&search_field=1&search_for=mangkhut&action=Search&search_page=&search_page=) but also [economic](https://www.sciencedirect.com/science/article/pii/S2225603220300564?via%3Dihub) impacts aspects. According to a joint study by HKO and the Hong Kong Federation of Insurers, the estimated direct economic loss due to *Mangkhut* in Hong Kong is about HKD 4.60 billion (or USD 0.6 billion)!

A group of people posing for a photo

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**Figure 1.5-1: Intergovernmental press conference (left) and HKO’s “Cool Met Stuff” videos (right) to alert the public on multi-hazards and potential threats from *Mangkhut*.**

Graphical user interface, map

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**Figure A1.5-2: Webpage of interactive map of damages by *Mangkhut***

Some key elements can be learnt here. First, a foundation stone by legislative or executive means such as the [contingency plan](https://www.sb.gov.hk/eng/emergency/cp.html) is crucial to all kinds of EWS to achieve the last mile result because it sets out the government’s strategy, organizational framework, alerting system and emergency action plans for responding to disasters. The contingency plan also stipulates the functions and responsibilities of Government bureaux/departments, utilities companies and NGOs in the event of disasters, including those in relation to TC. The TC Warning System operated by HKO is an integral part of contingency plan.

Effective and efficient coordination is the second key element to successful DRR. When a TC warning signal is issued by HKO, other government bureaux/departments will make corresponding arrangements, e.g., announcement on school closure, installation of demountable flood barriers at flood prone areas and evacuation of residents from flood prone areas, etc., in accordance with prescribed procedures in contingency plan. The Labour Department of HKSAR publishes a “[*Code of Practice in Times of Typhoons and Rainstorms*](https://www.labour.gov.hk/eng/public/typhoon.htm)”, in accordance with which employers and employees developed mutually agreed arrangements for suspension and resumption of work, mainly according to the level of TC signals.

The third key element is effective and efficient information dissemination. TC forecast and warning information are not only issued by HKO in one authoritative voice but also delivered directly to each member of the public via HKO’s website and mobile app “MyObservatory”, TV/radio broadcasts and social media (Facebook, Instagram, Weibo, Twitter and WeChat inclusive), with push notifications from MyObservatory becoming the most important means. HKO’s meteorologists comprises an internal media unit responsible for the production and broadcast of both regular TV weather programmes and ad hoc media briefings to both TV and radio when TC warning is in force.

With the system and information at hand, the next key element is an all-round communication strategy. What differentiates a TC from other natural hazards is their potential for multi-hazards. Such an important aspect cannot be overlooked and will be communicated to the public of Hong Kong by all means possible, including TV weather programme, press conference, push message via mobile app “MyObservatory”, etc. before a TC comes so that the public can be better prepared beforehand. Sometimes, a piece of infographic or even cartoon can help project complicated information and clear the minds of people. In a typical course of public communication to raise public awareness and preparedness, HKO will blow the first whistle by publishing a “[Weather Note](https://www.weather.gov.hk/tc/forecaster_blog/index.htm)” blog article in native language on potential weather changes and impacts through mobile app and website based on the latest TC forecasts. Depending on context, readily available video content from the popular educational TV series “[Cool Met Stuff](https://euc-word-edit.officeapps.live.com/we/PLBdhEGSPvUGVuK7fZUxHKzv51Y_2hy_hW)” would be extracted or replayed to alert public of the characteristics of the approaching TC. Closer to the time for TC warning signals, a “Special Weather Tips” message will be disseminated, followed by media briefings by professional meteorologists of HKO. During the quiet seasons, short videos, radio programmes, public talks, governmental seminars, as well as site visits to key partners, would be adopted as the means for public education. Physical and/or virtual open day has been organized every year to introduce the work of HKO to boost public understanding and awareness on severe weather including TC. Starting from TC season of 2021, online briefings on TC outlook up to four weeks ahead have been organized for government and special users on a bi-weekly basis.

The fifth element is the TC warning operated by NMHS/RSMC that often plays a pivotal role throughout the DRR process. While the majority may not know much about weather and meteorology, most people have life experience on risks and a risk-based warning is therefore more effective in general. The TC Warning System in Hong Kong are primarily designed with reference to territory-wide sustained wind strength near sea level. Risk information are conveyed to the public through the warning bulletin and precautionary statements associated with different level of TC warning signals. For example, the TC warning bulletin issued by HKO will include flood risk for low-lying areas and flood prone areas when the total sea level is predicted to exceed warning/alert levels. For TCs coming into the proximity of Hong Kong warranting high winds coming from changing directions, people will be warned of sudden changes in wind direction with their locations potentially exposed to damaging winds from a different direction than before. Even before the local winds pick up and the weather may still look calm to most people, HKO will alert the public about the risk and impact of swells and waves generated from afar by an approaching TC.

As a concluding remark, having known the key elements is not enough. A sustainable capacity building strategy shall also be in place. As technology and science continue to advance, NMHSs need to get in synchronization with various R&D on global/regional/local in-situ and remote-sensing observations, AI-based automatic algorithms, objective guidance from multiple NWP models, EPS and post-processing products, just to quote a few from HKO’s experience. Meanwhile, traditional wisdom and local knowledge still form an important part of HKO operational procedures. To cater for the changing needs of the society, public feedbacks, survey results with special users, as well as liaison group meetings for key sectors, are being adopted to collect inputs for the continuous improvement of HKO’s TC warning service which is operated under an ISO-9001-certified quality management system.

### 1.6 India — Good practices followed in India and by RSMC, New Delhi for the member countries of the WMO/ESCAP panel

***1.6.1 Introduction***

Consequent upon the establishment of the Tropical Cyclone Programme by the WMO in 1971 to assist vulnerable countries in minimizing the loss of life and property caused by TCs, the RSMC New Delhi took over the responsibility of providing Cyclone early warning advisories to the countries bordering the north Indian Ocean, under the purview of the WMO/ESCAP Panel on TCs (one among the five regional bodies designated to look after the regional components of the Tropical Cyclone Programme).Based on the Tropical Cyclone Operational Plan for the region, RSMC New Delhi issues 'Tropical Weather Outlook' daily at 0600 UTC and ‘special tropical weather outlooks’/'Cyclone Advisory Bulletins' at 6/3-hour intervals to the member countries, whenever a cyclonic storm develops in the northern Indian Ocean. RSMC New Delhi is co-located with the Headquarters of the IMD, the national agency entrusted with the responsibility of providing early warnings for all weather and climate related natural hazards affecting India.

Nationally, IMD has a three-tier organizational structure for cyclone warnings with Cyclone Warning Division (CWD) at IMD headquarter, three Area Cyclone Warning Centres (ACWCs) at Chennai, Mumbai and Kolkata and four Cyclone Warning Centres (CWCs) at Bhubaneswar, Visakhapatnam, Thiruvananthapuram and Ahmedabad to cater to the country’s requirements. (Figure 1.6-1).

Map

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**Figure 1.6-1: Cyclone warning — organizational structure**

The CWD is also co-located with RSMC for TCs and TCs Advisory Centre for civil aviation. At regional level, the Director General of Meteorology leads all discussions with WMO and Permanent Representatives of all 13 WMO/ESCAP Panel member countries. At national level, the Director General of Meteorology is responsible for briefing the Prime Minister Office, Crisis Management Committee, Cabinet and Home Secretary and Chief Secretaries of affected states. Head CWD liaisons with central level disaster managers including the National Disaster Management Agency, NDRF, Secretary Railways, Road and Shipping, Chief Secretaries of concerned states, the national television and all India Radio. The ACWCs and CWCs are responsible for liaison with state and district level disaster managers. The ultimate responsibility for operational storm warning work for the respective areas rest with the concerned ACWCs and CWCs.

***1.6.2 A few examples of good practices***

1.6.2.1 Attempt to include the latest data in assessing the exposure conditions and vulnerabilities while communicating the risk information into Cyclone early warnings

The risk management of the cyclones depends on several factors including: (i) hazard and vulnerability analysis, (ii) preparedness and planning, (iii) early warning and (iv) prevention and mitigation. There have been significant improvements in impact-based forecast and risk-based warnings of cyclones landfalling over India in recent years due to the introduction of the impact matrix based on historical damage data, augmented rain gauge and gauge-satellite merged data set for real-time rainfall monitoring, along with Scatsat, Doppler Weather RADAR (DWR) and High wind speed recorders and Automatic Weather Stations (AWS) for wind monitoring, introduction of multi-model and single model EPS and other dynamical statistical tools, cyclone specific models like HWRF for rainfall and wind assessment and storm surge and coastal inundation modelling by Indian National Centre for Ocean Information Services (INCOIS) in collaboration with IMD.

A web-GIS based hazard vulnerability atlas has been prepared by IMD, bifurcating each of the multi-hazard associated with cyclones, such as strong/gale force winds, Heavy rainfall, pluvial and fluvial floods and storm surges. The possible risk associated with secondary hazards (such as landslides triggered by heavy rains) are being dealt and planned by local administration. Other non-structural measures in this direction include introduction of objective analysis and forecasting platform along with the decision support system, synergized standard operation procedure, policy and guidelines of Government, collaboration and partnership with various partners, press and electronic media and disaster managers and introduction of user specific and sector specific impact-based warning along with suggested actions. It is further being fine-tuned with implementation of web-based dynamical cyclone risk assessment system by NDMA in collaboration with IMD, state governments and other partners.

1.6.2.2 A synergized SOP based process of monitoring and forecasting of Tropical Cyclones for the region

IMD maintains a round-the-clock watch over the north Indian Ocean to monitor any development of cyclonic disturbance and it is further intensification, movement and impact. A well-defined standard operation procedure is followed to monitor and predict TCs starting with organization of pre-cyclone exercise prior to the beginning of each cyclone season and maintenance of daily round-the-clock watch. It is followed by extended range, medium range, short range and nowcast predictions till landfall, post-landfall forecast and warnings till the system maintains the intensity of depression.

A systematic check list is prepared for identification and prediction of location, intensity, landfall and adverse weather associated with a TC. In addition to all the observations and model guidance, IMD utilizes a digitized forecasting platform to compare, comprehend and analyse guidance from various sources for making final decision and generating user friendly warning products. The decision support system (DSS) has the facility to plot and analyse different weather parameters, satellite, radar and NWP model products in GIS platform with a facility to generate warning graphics. The final consensus follows post discussion with various forecasters countrywide through daily video conferencing. Thus, the analysis and prediction of a TC involves blending guidance from dynamic and statistical models, meteorological observations, technology with knowledge, experience and expertise of forecaster.

For predicting cyclogenesis (development of depression), guidance from an array of models including IMD’s Genesis Potential Parameter Index, Multi-Model Ensemble Coupled Forecast System Version2 (Multi-Model Ensemble (MME) CFSv2), Global Forecast System (GFS), Weather Research and Forecast (WRF), Global Ensemble Forecast System (GEFS); National Centre for Medium-range Weather Forecasting (NCMRWF) Unified Model (NCUM) and EPS (NEPS), National Centre for Environment Prediction (NCEP)-GFS, European Centre for Medium Range Weather Forecasting (ECMWF), JMA and Meteo France model is utilized following the criteria for genesis. In addition, planetary scale features like Madden Julian Oscillation Index, La Niña, Indian Ocean Dipole conditions which influence TC genesis, intensification and movement are also monitored.

For predicting the track, landfall, intensity and adverse weather, in addition to models discussed above, IMD also utilizes guidance from IMD’s MME system, cyclone-specific hybrid Ocean coupled with the Hurricane Weather and Research Forecast (Hy-Com HWRF) model, Statistical Cyclone Intensity Prediction (SCIP) model and rapid intensification/weakening model.

1.6.2.3 Significance of outreach and the concept of inclusivity, especially of the personnel involved in managing the disaster at regional and local level for better mitigation via early action

Outreach activities are a part and parcel of the early warning services provided by IMD. There are various programmes being conducted routinely to create awareness about weather forecasting, early warning and weather-related natural hazards, especially due to cyclonic storms over the seas and coastal areas by IMD. Twice every year, IMD HQ and all its field forecasting offices observe open day for general public during which the weather experts explain and educate the average person about these aspects.

Prior to each cyclone season, a pre-cyclone exercise meeting incorporating all the agencies directly or indirectly involved in managing cyclone-associated disasters will be conducted at national level by the CWD (Figure 1.6-2) and at local level by the ACWCs and CWCs. Moreover, a series of lectures, meetings and film shows are also organized to impart the knowledge on the impending hazards associated with such systems.

A group of people sitting at long tables in a room

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**Figure 1.6-2: An ongoing session of pre-cyclone exercise meeting with all stakeholders**

IMD also takes part in the mock drills, and training of local population and police organized every year by NDRF and SDRF. IMD has also published (i) damage potential of cyclones, (ii) Frequently asked questions (FAQs), (iii) terms and terminology, (iv) leaflets in local languages, (v) videos, (vi) SOPs and Do’s and Don’ts for cyclones. In addition, NDMA and state disaster management authorities also have developed many informative and easy to understand audio/ video modules in local languages on cyclones.

1.6.2.4 Practice of utilizing all types of Warning dissemination mechanism available so far on redundant mode

Cyclone warnings are disseminated to users through all possible means including telephone, fax, email, SMS, Global Telecom System (GTS), WMO Information System (WIS), All India Radio, FM and community radio, Television and other print and electronic media, press conference and press release, CAP, mobile apps and social media. Web-GIS based dissemination of a cyclone warning, crowd sourcing and common alert protocol are already in place.

These warnings/advisories are also put on the websites ([www.rsmcnewdelhi.imd.gov.in](http://www.rsmcnewdelhi.imd.gov.in), [www.mausam.imd.gov.in](http://www.mausam.imd.gov.in)) of IMD. IMD also sends cyclone alerts through SMS to disaster managers, media, public, fishermen and farmers. Global Maritime Distress and Safety System (GMDSS) message is also put in RSMC, New Delhi website (URL: [www.rsmcnewdelhi.imd.gov.in](http://www.rsmcnewdelhi.imd.gov.in)) as well as transmitted through GTS. The WIS Portal is also utilized for cyclone warnings dissemination (<http://www.wis.imd.gov.in>). IMD also issues NAVTEX bulletins for the coastal region along the east and west coast of India for the operation of lightships and fishermen. IMD has also installed specially designed receivers in the coastal areas for transmission of warnings in regional language to the concerned officials and people using the broadcast capacity of INSAT satellite. IMD is also working in collaboration with Indian Space Research Organization (ISRO) for disseminating the SMS to fishermen in deep seas through GAMES and NAVIC systems. During cyclone time all possible means of communication are utilized to reach last mile users by IMD headquarters, IMD sub-offices and various disaster management agencies individually and collectively.

Apart from the above depicted means, pre-recorded video clips by the Director General as well as the operational forecasters are circulated via all possible communication media including the social media platforms for wide circulation among the public, during Cyclone period. Also, there would be constant media briefing carried out by the duty forecasters and experts of IMD during the cyclone period.

1.6.2.5 The countdown approach being followed in EWS — Super Cyclone *Amphan* of May 2020 as an example for enhanced preparedness and response capabilities

The following is an example of a success story in managing Super Cyclone “*Amphan*” in May 2020. Though the property damage associated with the cyclone has brought the same into the category of one of the costliest cyclones in the recent past, the step-by-step countdown process as depicted below, enabled the disaster managers to restrict the damages to the minimum as far as possible, especially in the Peak of the COVID-19 pandemic situation.

Countdown for Super Cyclonic Storm “*Amphan*” with disaster management:

For the monitoring of cyclone *Amphan,* preparedness commenced at the beginning of April. At the onset of cyclone season (April–June), a pre-cyclone exercise was held during the first week of April at IMD headquarters and various sub-offices of IMD to take stock of the preparedness for the ensuing cyclone season. Daily diagnosis and prognosis commenced since 25 April as per SOP. The first alert about the possible development of a cyclone was sounded on 7 May. The entire countdown process involved in monitoring the approaching super cyclone *Amphan* is described below:

(i) Countdown stage 8 (6 May 2020, 1330 hrs IST)

The countdown process started on 6th May 2020 when IMD got first signal about the possible cyclogenesis over the Bay of Bengal (BoB) with the formation of upper-air cyclonic circulation over the south Andaman Sea which had the potential for intensification. Since then, continuous monitoring started with the issuing of four bulletins per day by the National Weather Forecasting Centre of IMD in association with the cyclonic circulation meandering over the south Andaman Sea.

(ii) Countdown stage 7 (7 May 2020, 1330 hrs IST)

The extended range outlook issued on 7th May (about 6 days prior to formation of Low-pressure area on 13 May, 9 days prior to formation of depression and 13 days prior to landfall on 20 May) indicated cyclogenesis over south BoB with movement towards north BoB. The IMD continued to monitor and issue four bulletins per day during 7–12 May in association with the cyclonic circulation.

(iii) Countdown stage 6 (13 May 2020, 1330 hrs IST)

It began on 13 May, the day of formation of low-pressure area (LPA) over the south Andaman Sea (3 days prior to formation of depression on 16 May and 7 days prior to landfall). A Special Information Message was sent to the concerned central and state level disaster managers of east coast states and Andaman Nicobar Islands at 1330 hrs IST indicating the likely development of a cyclonic storm over BoB. Press Release was also issued for media and public in this regard. IMD issued a press release and a special bulletin indicating the formation of LPA and its possible intensification into a cyclone. It further advised the fishermen not to venture into identified sea region which was expected to experience adverse weather. IMD continued its monitoring prediction in connection with this low through its daily four bulletins until 16 May.

(iv) Countdown stage 5 (16 May 2020, 0845 hrs IST)

Pre-Cyclone Watch: It commenced with the intensification of LPA into a depression over southeast BoB on 16 May morning. IMD started issuing numbered and structured quantitative track and intensity forecast as well as adverse weather warning. In the first bulletin in this series released at 0845 hrs IST of 16May (104 hrs prior to landfall), Pre-cyclone Watch for West Bengal-north Odisha coasts was issued. In the bulletin, it was indicated that the system would intensify into a cyclonic storm and cross the West Bengal coast with maximum sustained wind speed of 155–165 kmph gusting to 180 kmph. It was also indicated that the system would cause heavy to very heavy falls at a few places with extremely heavy falls at isolated places over Gangetic West Bengal (GWB) on 20 May. For coastal Odisha, heavy rainfall at isolated places from 18 May evening, heavy to very heavy falls at a few places on 19 May and isolated heavy rainfall over northeast Odisha on 20 May 2020 was predicted.

The first NCMC meeting was conducted under the chairmanship of the Cabinet secretary on 16 May forenoon for the preparedness measures and similar meetings were conducted at state level in Odisha and West Bengal. All the partners and disaster management agencies at national level and Chief Secretaries of Odisha and West Bengal participated in this meeting. DGM, IMD delivered a presentation on the status of and forecasting of cyclones, expected adverse weather, areas to be affected, damage expected and the suggested actions. Accordingly, the actions were planned as per the instruction of NCMC.

(v) Countdown stage 4 (16 May 2020, 2030 hrs IST)

Cyclone Alert: It began with the intensification of depression into CS (Cyclonic Storm) *Amphan* in the evening of 16May. The warnings were further upgraded, and Cyclone Watch for West Bengal and north Odisha coasts was issued at 2030 hrs IST of 16May (92 hrs prior to landfall). Structured three hourly bulletins commenced from 16 May evening onwards with regular updates on all sites and social platforms. Cyclone watch was upgraded to Cyclone Alert (Yellow Message) for West Bengal and north Odisha coasts and was issued at 0840 hrs IST of 17 May (80 hrs prior to landfall). It was indicated that the squally wind speed of 40 to 50 kmph would commence along and off the Odisha coast from 19 May morning and along and off the West Bengal coast from 19 May evening. It was predicted to gradually increase becoming maximum wind of 100–110 kmph gusting to 120 kmph along and off coastal districts of north Odisha during 20 May early morning to afternoon and 155–165 gusting to 185 kmph along and off West Bengal coast during 20 May afternoon to night (during the time of landfall). In the bulletin issued at 2030 hrs IST of 17 May when the system lay as VSCS over south BoB, extensive damage expected, and action suggested corresponding to the stage of ESCS (Extremely Severe Cyclonic Storm) was predicted for north Odisha and West Bengal coastal districts. It was precisely indicated that the system would cause extensive damage to all types of kutcha houses and some damage to old badly managed concrete structures. The flying objects were potential threats. Extensive uprooting of communication and power poles was expected. The system was expected to cause disruption of rail/road link at several places, extensive damage to standing crops, plantations and orchards, blowing down of palm and coconut trees and uprooting of large bushy trees. Large boats and ships were expected to get torn from their moorings. At this stage, total suspension of fishing operations during 18 to 20 May 2020 and diversion or suspension of rail and road traffic was suggested. People in affected areas were advised to remain indoors. The disaster management authorities were advised to mobilize evacuation from low-lying areas. People were advised to avoid movement in motorboats and small ships.

(vi) Countdown stage 3 (18 May 2020, 0845 hrs IST)

Cyclone Warning: The cyclone alert was upgraded to a cyclone warning. It started with the intensification of *Amphan* into an ESCS on 18 May early morning. Cyclone Warning (Orange Message) for West Bengal and north Odisha coasts was issued at 0845 hrs IST of 18 May (56 hrs prior to landfall). In this bulletin, it was also indicated that storm surge of about 4–5 m above astronomical tide would inundate low-lying areas of south and north twenty-four Parganas and about 3–4 metres over the east Medinipur districts of West Bengal around the time of landfall. Subsequently, it intensified into an SuCS around noon of 18 May. Continuous monitoring and prediction of its location, track intensity and associated adverse weather continued. Regular 3 hourly bulletins along with organization of joint press conferences by IMD and NDRF commenced for creating awareness among the masses about the impending disaster.

The second NCMC meeting was conducted under the chairmanship of Cabinet secretary on 18 May forenoon for reviewing the preparedness measures and similar meetings were conducted at state level in Odisha and West Bengal. The review meeting was also conducted under the chairmanship of Hon’ble Home Minister on 18 May noon. Another review meeting was also conducted under the chairmanship of Honourable Prime Minister on 18 May afternoon with participation of concerned high level disaster management authorities and DGM, IMD presented the current status and forecast of super cyclone *Amphan*, area districts to be affected, expected damages and suggested actions in these review meetings. Accordingly, the follow-up actions on the ongoing preparedness and mitigation measures were sharpened for necessary action. The joint press conferences organized by the Press Information Bureau (PIB) were addressed by DGM IMD and DG NDRF on 18, 19, 20 and 21 May for briefing media and public about the impact of SuCS *Amphan*. DGM IMD also appeared live on Facebook on 18 May and facilitated frequent briefings to media persons from IMD HQ and CWC, Bhubaneswar and Kolkata to create awareness among masses about the expected adverse weather and damages in association with *Amphan* and actions to be taken by disaster managers and public.

(vii) Countdown stage 2 (19 May, 2330 hrs IST)

Post-Landfall Outlook: It commenced in the midnight of 19 May (17 hrs prior to landfall) with the release of the post-landfall outlook (Red Message) for interior districts of GWB, Assam and Meghalaya after landfall in addition to continued cyclone warnings for coastal districts of north Odisha and West Bengal. The third NCMC meeting was conducted under the chairmanship of Cabinet secretary on 19 May forenoon.

(viii) Countdown stage 1 (20 May 2020, 0630 hrs IST)

Hourly Updates: It commenced from 0630 hrs IST of 20th May when the system lay about 155 km south of Paradip and 280 km south-southwest of Digha. IMD started issuing hourly updates on current location, intensity, closest distance from different coastal cities/towns of Odisha, West Bengal and Bangladesh, current observation w.r.t. rainfall and wind and forecast track, intensity, wind, rainfall and storm surge. This continued till the system crossed and thereafter maintained the intensity of the cyclone. A total of 20 special hourly updates were issued in this regard.

(ix) Countdown stage zero (20 May 2020, 1430 hrs IST)

Commencement of landfall process: It started with the commencement of the landfall process at 1430 hrs IST of 20th May, continued for 2–3 hours and the system crossed West Bengal coast between Digha (West Bengal) and Hatiya Islands (Bangladesh) over Sundarbans between 1530 and 1730 hrs IST of 20 May with wind speed of 155–165 gusting to 185 kmph and maximum storm surge of 4.6 metres above the astronomical tide as per prediction. Also, the extremely heavy rainfall occurred over the north coastal Odisha districts and the coastal districts of West Bengal including Kolkata as per prediction.

(x) Count up stage 1 (20 May 2020, 1830 hrs IST)

Post-landfalls follow-up: Thereafter, hourly bulletins continued till the system maintained the CS intensity over the Indian region i.e. till 0230 hrs IST of 21 May. It passed over Kolkata around 2100 hrs IST of 20 May as a VSCS with wind speed of 120–130 kmph gusting to 145 kmph as per the prediction 3 days earlier. Regular 3-hourly bulletins continued till the system maintained the CS intensity (morning of 21 May). Six hourly structured bulletins in the weakening phase continued for various users till midnight of 21 May by IMD. Thereafter, IMD maintained watch over the system till it became insignificant and issued regular six hourly bulletins.

(xi) Count up stage 2 (21 May 2020, 1330 hrs IST)

Preparation of Preliminary Report: The preliminary report on the system was prepared and released in the form of a press release on 21 May 2020. Detailed report on Cyclone *Amphan* was issued on 13 June 2020. The fourth NCMC meeting was conducted under the chairmanship of Cabinet secretary on 21 May forenoon for post-landfall follow-up actions

IMD issued a total of three information messages prior to genesis, 45 national bulletins for national disaster managers, forty-five bulletins for WMO/ESCAP members including Bangladesh and Myanmar, 11 press releases and 19 hourly bulletins apart from other user specific bulletins in association with SuCS *Amphan*. All these bulletins and messages were sent by email and FAX to central and state level disaster managers and through GTS to WMO/ESCAP member countries. The messages were also flashed on all social networking sites including various websites of IMD ([*www.mausam.imd.gov.in*](http://www.mausam.imd.gov.in)*,* [*www.rsmcnewdelhi.imd.gov.in*](http://www.rsmcnewdelhi.imd.gov.in)*,* [*www.internal.imd.gov.in*](http://www.internal.imd.gov.in)*)*, Facebook, Twitter, mobile apps, CAP, SMS, WhatsApp, etc. The joint press conferences organized by PIB were addressed by DGM IMD and DG NDRF on 18, 19, 20 and 21 May for briefing media and public about the impact of SuCS *Amphan*. DGM IMD also appeared live on Facebook on 18 May and facilitated frequent briefings to media persons from IMD HQ and CWC, Bhubaneswar and Kolkata to create awareness among masses about the expected adverse weather and damages in association with *Amphan* and actions to be taken by disaster managers and public.

In case of *Amphan*, the forecasters faced multiple challenges with respect to the prediction of the genesis, landfall point, landfall time and intensification. Even predicting genesis (formation of depression) was a challenge. *Amphan* originated from the remnant of a LPA which persisted over the south Andaman Sea from 1 until 6 May. This remnant cyclonic circulation meandered over southeast BoB for a long time up to 12 May. It again organized as an LPA on 13 May over southeast BoB that in due course intensified into SuCS *Amphan*. Considering the model guidance about genesis, there was false alarm from 25 April onwards about the genesis of the cyclone over the BoB and its landfall over different coasts (like Bangladesh, Myanmar, and Andaman and Nicobar Islands). It was a challenge to predict the place and occurrence of LPA and its possible intensification into a depression, its further intensification into a cyclone and movement towards a particular coast. Also, the translational speed of *Amphan* varied greatly and determination of landfall time correctly was a difficult task. IMD usually examines about 12 global and regional models including six models run by Ministry of Earth Sciences and six international models. There was large spread in model guidance even two days before the landfall. Even during the night before landfall day, i.e., during the night of 19 May 2020, a few models were suggesting landfall over the Odisha-West Bengal border around noon of 20 May 2020. Thus, predicting the landfall point correctly was not easy. *Amphan* underwent rapid intensification from 17 May noon (1130 hrs IST) to 19 May early morning (0230 hrs IST) with an increase in wind speed 2.3 times during this period. But, with the technological intervention and utilization of knowledge, experience and expertise, IMD provided timely and accurate cyclone warnings to disaster managers, media and public to manage Cyclone *Amphan* like many intense cyclones in recent years including *Phailin* in 2013, *Hudhud* in 2014, *Titli* in 2018 and *Fani* in 2019.

Overall, the key lessons learnt as a result of this is the importance of developing close relationships with partners to foster trust when communicating information about significant risk.

### 1.7 Oman — National Multi-Hazard Early Warning Centre (NMHEWC)

The NMHEWC is the base of all TCs Forecast and Warning System of multi-hazard related to weather in the Sultanate of Oman, with established SOP. The centre is located in the Civil Aviation Authority that was established based on Royal Decree No. 2012/33. However, this centre is following national legislations and [WMO GDPFS Manual](https://library.wmo.int/index.php?lvl=notice_display&id=12793) (WMO-No. 485) on TC forecasting, including marine-related hazards.

In Oman, the NMHEWC is representing and leading the sectors of observations and early warnings in the National Emergency Management Committee that is considered as main driver for national emergency managements. The Committee includes several sectors, for example, Civil Aviation Authority (Meteorological Department), Civil Defence, the National Government, the different media, the National Institute of Hydraulic Resources and different ministries. In this Committee, each sector is considered to be the leader in cases of emergencies that are under sector’s responsibility. As a result, NMHEWC is leading and directing activities through providing the information to the rest of the Committee members.

The exchange of information between the Meteorological Department and the National Emergency Management Committee is regulated in a Memorandum of Understanding that provides for the monitoring of TCs and different weather-related hazards. The SOP of the NMHEWC includes all technical procedures for guaranteeing the implementation of this agreement. Once the SOP of NMHEWC is activated, other sectors in the Committee should activate their own SOP accordingly.

The SOP of NMHEWC describes how the risk information is conveyed to the public through the warning bulletins and alarms associated with different levels of TC warning and dealing with other hazards. For example, the TC warning bulletin issued will include winds (S/D), thunderstorm, wave height and flood risk for low-lying areas. All of them depend on the regions that are expected to be affected by TC and its associated hazards.

The NMHEWC maintains a round-the-clock watch over the north Indian Ocean and Arabian Sea to monitor any development of cyclonic disturbance and its further intensification, movement and impacts. A well-defined SOP is followed to monitor and predict TCs in our region.

After observation of a TC, a long process starting with a systematic check list is prepared for identification and prediction of location, intensity, landfall and adverse weather associated with the TC by the centre through the SOPs. In order to forecast different weather parameters of a TC, several tools must be used, such as satellite, radar and NWP model products, etc. In our centre, the process of comparison, comprehension and analyses of guidance is important for making a final decision and generating warning bulletins. Moreover, the final discussion is usually carried out with various forecasters through participating a weather briefing (discussion).

The NMHEWC disseminates weather bulletins based on the SOP through multiple channels including recorded videos distributed through social media. The meteorological staff produce many TV and radio live interviews to deliver the accurate information and updates of the TC. At the same time media sectors has major roles in delivering and clarifying situations to the public. Programmes, video clips and interviews include the impact-based warnings considering the local vulnerability and exposure of the areas to that specific hazard.

Civil Aviation Authority (CAA) in The Sultanate of Oman is the umbrella under which Oman Meteorology is taking the responsibility of observing and delivering warnings on different hazards. It is playing a major role in public awareness as well as conducting activities and workshops for the sake of public education and preparedness. Oman meteorology is conducting many training workshops targeting public, governmental ministries and even companies. CAA (Meteorology Department) is also working with the Ministry of Education to prepare teaching materials regarding different hazards to fit different school grades and inject them in teaching the curriculum. As part of preparedness, CAA conducts training for similar events like earthquakes and tsunami threats as well as storm surges and floods caused by TCs. These events can target schools and sometimes entire small villages.

The last TC that affected the Sultanate of Oman was Tropical Cyclone “*Shaheen*”. *Shaheen* was an exceptional TC in terms of its initiation that was in BoB at which point it had a different name. It then crossed the Indian subcontinent to the Arabian Sea when it strengthened again before hitting an unusual area in northern Oman. The experience that was gained by the NMHEWC from previous TC events allowed the centre to deal with the TC in an efficient way that resulted in minimum destruction and loss of lives and properties.

The NMHEWC works according to the SOP developed from lessons learnt in the past. Also, new lessons learnt from this event will be used to update the current SOP of the Centre.

From the experience in dealing with TCs, here are some thoughts and ideas that will enhance sectors to respond TC related hazards:

* Improving communication methods between the NMHEWC and other sectors with specifying focal point(s) in each sector.
* Continuous meeting among sectors for developing/updating proper SOP to reach satisfaction in terms of who is doing what and when.
* Continuous evaluation of sectors performance after each event.
* Internal training among sectors for the sake of harmonized response during events.
* Joint technical development among sectors and sharing manpower and knowledge.
* Creating a single platform that brings together partners to share reports, warnings and needs.

### 1.8 Philippines — Some good practices in the end-to-end warning system in the Philippines

One of the good practices in the Philippines is the enactment of the National Disaster Risk Reduction and Management (NDRRM) law, Republic Act 10121(RA 10121) creating the NDRRMC with four pillars, namely (1) Disaster Preparedness, (2) Disaster Prevention and Mitigation (DPM), (3) Disaster Response, and (4) Rehabilitation and Recovery (Figure 1.8-1). The Department of Science and Technology (DOST) is the Vice-Chair of the DPM and PAGASA as the mandated warning agency for hydrometeorological hazards particularly TCs is a member of DPM, NDRRMC.

Diagram

Description automatically generated

**Figure 1.8-1. Four DRRM Thematic Areas (Source: NDRRMC).**

Enactment of the NDRRM law (RA 10121) in 2010 paved the way for a paradigm shift in the country’s disaster management system from one primarily focussed on response and preparedness for response to one focussed on reducing and managing disaster risks. Also under RA 10121, regional and local level Disaster Risk Reduction and Management Council (DRRMC)s are also created. Hence, there are Regional DRRMC (RDRRMC), Provincial DRRMC (PDRRMC), City DRRMC (CDRRMC) and Municipal DRRMC (MDRRMC) making DRRM activities not only centralized but delegated to local levels for faster actions.

Other good practices in the Philippines are summarized as follows:

* Conduct of pre-disaster risk reduction assessment (PDRA) meeting with the members of the NDRRMC when a TC or even a Low-pressure system is projected to pose a threat to the country in the next 3–4 days. Possible scenarios and impacts are explained to the Disaster Managers and Decision-Makers to for early preparations. Hazards and risks are identified with area focussed and time bound.
* Development of Community-based Early Flood Warning System (CBFEWS) wherein the local communities are involved in the hazard mapping, observation, monitoring, warning and response. PAGASA provides technical assistance and develops the standard methodology on how the CBFEWS is established. After installation of rain and water level gauges in the area, local communities and government units are trained and capacitated on the operation of the CBFEWS, conducting drills regularly. It is the LGUs responsibility to ensure the sustainability of the CBFEWS through government ordinances and policies. CBFEWS is people-centred; it fosters cooperation, ownership and responsibility on the part of the local community.
* PAGASA is starting to shift from the basic EWS into an Impact-Based Forecasting (IBF) and warning. Through the assistance of U.K. Met Office, it is now working on the development of IBF system for heavy rainfall and severe wind in Metro Manila and Metro Cebu.
* On warning communication, PAGASA registered its first CAP Feed URL containing TCs Alert and TCs Warning initiated by Google Partnership in 2014. Right after, PAGASA ICT developed a web application to generate CAP alerts. In the application, the alert generated includes TCs Alert, TCs Warning, General Flood Advisory and Flood Bulletin.

### 1.9 USA — A close call — Effective messaging when a hurricane is just not quite going to make landfall

*Hurricane Lane’s* sustained wind speed strengthened to 95 knots (177 km/hr) 1 500 miles (2 400 km) west-southwest of Hawaii, USA. *Hurricane Lane* was moving at a moderate speed of 14 knots (26 km/hr) toward the west, placing Hawaii five days away from possible impacts. Although the forecast track had *Hurricane Lane* strengthen and then weaken and stay south of the Hawaiian Islands, the NWS, the USA’s NMHS, in Honolulu, Hawaii, sprang into action sending early coordination information to DMOs, referred to emergency management in the USA, partners and stakeholders. The next morning an official briefing commenced linking emergency management from the village/town/city level to county level to state level and even the national level. The briefing began with the Honolulu, Hawaii Weather Service providing the situation report for *Hurricane Lane’s* (now considered a major hurricane with sustained wind speeds of 115 knots (213 km/hr)) forecast and uncertainty. With this information the emergency management was able to coordinate amongst the varying levels and prepare for a stand ready posture. In the USA, the local government (village/town/city) has the responsibility to provide emergency services with support from the county or state or national emergency management entities. Therefore, resources are provided based on need and availability. Prepositioning resources, such as generators, heavy equipment and personnel is paramount in responding to and recovering quickly from pending hazards. With coordination of the emergency management community, information flowed through all dissemination sources, including social media. Preparations had begun.

Two days before the first possible impacts to Hawaii from still major *Hurricane Lane*, the forecast track had it moving dangerously close to the Hawaiian Islands with the potential of damaging winds, life-threatening flash flooding and damaging surf. Emergency management coordination briefings continued along with broadcast media now camped out in the Honolulu Weather Forecast Office. Elected officials from the county mayors to the Governor and all the way up to the President were briefed on the pending hazards to the Hawaiian Islands. With *Hurricane Lane* so close to the islands the meteorologists’ confidence in *Hurricane Lane’s* movement became an important aspect to the emergency management planners. As always explained with TC forecasting, uncertainty plays a vital role into what actions are to be taken. The focus turned toward the potential for heavy to extreme rain leading to flash flooding and landslides during the close passage of *Hurricane Lane* as the forecast track brought the right front quadrant through all of the Hawaiian Islands. Hurricane watches (a get ready bulletin with a goal of issuance 48 hours in advance of impacts), which were eventually upgraded to Hurricane Warnings (a bulletin indicating hurricane conditions are imminent or occurring with a goal of issuance 36 hours in advance of impacts) were issued for portions of the islands with an emphasis on heavy rainfall and high surf. Once the warnings went into effect, a meteorologist was dispatched to the Hawaii State Emergency Operations Centre to provide direct contact impact-based decision support services. Confidence by the meteorologist that *Hurricane Lane* would track south of the Hawaiian Islands continued to increase allowing the main message to remain focussed on the impacts of heavy rain, flooding and high surf. Actions taken by emergency management included preparations of emergency shelters, cancelling school attendance, closing beaches and major parks, and even having buses display “Evacuation — will be provided to shelters on demand”. Large scale evacuations did not take place due to the emergency management trusting the NWS’s impact-based decision support services focusing the major impacts on the heavy rain and high surf. This trust did not form overnight. Several years of building relationships, participating in exercises, conducting outreach and executing preparedness events together formed the trust that the NWS would provide the needed actionable information for emergency management to take appropriate measures.

*Hurricane Lane* with a closest point of approach to Hawaii of around 115 miles (185 km) produced massive amounts of rainfall with most islands experiencing at least 10 inches of rain, several locations recording over 30 inches and a peak rainfall total of over 52 inches. The heavy rain caused severe flooding, mainly on Hawaii Island (locally known as the Big Island), with more than 100 structures affected and at least USD 22 million in damage to public infrastructure. One death was recorded when a man drowned after jumping into a rain-swollen stream in an attempt to save a dog

This event showcases the importance of trust among partners and stakeholders in providing the most relevant information for an evolving hazardous event. The terms hurricane, severe TC and typhoon bring pictures of destruction from wind to people’s minds. However, when NMHSs, DMO, NGOs, and broadcast and print media work together, with one voice, through an authoritative source, because of the relationships forged well before an event, those in harm’s way can take the appropriate action to keep themselves and their loved ones safe and protect their property as best they can.

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1. National Defence Council is the highest level in the response structure in the Country [↑](#footnote-ref-1)