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Reducing the impact of high impact weather

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सार — मौसम सेवाओं की प्राथमिकता जान- माल को खतरनाक मौसम से बचाना है। विश्व मौसम अनुसंधान कार्यक्रम के तीव्र प्रभाव मौसम (HIWeather) परियोजना का यह मिशन है कि सबसे प्रभावी ढंग से कैसे कार्य किया जाए, इस पर शोधकिया जा रहा है। HIWeather मौसम की निगरानी से लेकर प्रभावी सुरक्षात्मक प्रतिक्रियाएं बनाने तक की प्रक्रिया के प्रत्येक चरण का अध्ययन करने के लिए विभिन्न प्रकार के विषयों और दुनिया भर के भौतिक और सामाजिक वैज्ञानिकों को एक साथ लाता है। HIWeather चेतावनी उत्पादन और संचार श्रृंखला के सरल मॉडल का उपयोग करता है जो चेतावनी तैयार करने और अंतिम उपयोगकर्ता को संचारित करने में मौसम के पूर्वानुमान, परिणामी खतरे और इसके सामाजिक आर्थिक प्रभावों में शामिल प्रमुख कार्यकर्ताओं और संगठनों की भूमिकाओं पर प्रकाश डालता है। इस पत्र में मैंने उस शोध के परिणामों का उल्लेख किया है जो अब मेरी पुस्तक, "टुवार्ड्स द 'परफेक्ट' वेदर वार्निंग: ब्रिजिंग डिसिप्लिनरी गैप्स थ्रू पार्टनरशिप एंड कम्युनिकेशन" (गोल्डिंग, 2022) में प्रकाशित हुआ है। मॉनसून से जुड़े प्रचंड मौसम के संदर्भ में, मैं यहाँ मौसम संबंधी चेतावनी प्रणालियों के डिजाइन के लिए इस काम को समुदाय आधारित चेतावनी प्रणालियों के डिजाइन से विचारों को जोड़कर,सोशल मीडिया संचार में विकास, प्रभाव आधारित पूर्वानुमान पर शोधऔर संवहन-अनुमति और उच्च विभेदन वाले NWP मॉडल में प्रगति के साथ प्रमुख सिद्धांतों की पहचान करूंगा। इस परिणाम का सार यह है कि ज्ञान का संचार उतना ही महत्वपूर्ण है जितना कि इसकी सामग्रीऔर संगठनों के बीच साझेदारी और पोषण महत्वपूर्ण है।

ABSTRACT. A priority of weather services is to protect lives and property from hazardous weather. Research on how to achieve that most effectively is the mission of the World Weather Research Programme's High Impact Weather (HIWeather) project. HIWeather brings together physical and social scientists from a wide variety of disciplines and from across the world to study each step of the process from monitoring the weather to making effective protective responses. HIWeather uses a simple model of the warning production and communication chain that highlights the roles of key actors and organisations involved in forecasting the weather, the resulting hazard and its socio-economic impacts, in formulating the warning and communicating it to the end-user. In this paper I draw on the results of that research which has now been published in our book, "Towards the 'perfect' weather warning: bridging disciplinary gaps through partnership and communication" (Golding, 2022). In the context of severe weather associated with monsoons, I shall identify key principles for the design of weather-related warning systems, connecting this work with ideas from the design of community-based warning systems, developments in social media communication, research on impact-based forecasting and with progress in convection-permitting and higher resolution NWP models. A key result is that the communication of knowledge is at least as important as its content and that the creation and nurturing of partnerships between organisations is critical to that.

Key words – HIWeather, Sendai, Japan.

1. Introduction

In 2015, the world's leaders convened in Sendai, Japan to agree the Sendai Framework for Disaster Risk Reduction, with the aim of substantially reducing the human and economic cost of disasters, worldwide by 2030. Within the broader context of risk governance and risk management, a key component of the Sendai Framework is to make early warnings of hazards available to everyone so that they can take action to avoid the hazard or reduce its consequences. In this paper I first look at the nature and value of a warning, then give a brief introduction to the HIWeather project. I then identify some key lessons that experts in the HIWeather project have identified for making warnings effective and look at how these relate to some extreme weather events of 2021. I finish with a few concluding remarks.

2. Warnings and their value

Weather-related hazards are occurring more frequently due to climate change and are affecting more people as a result of growing populations. This is especially the case in monsoon climates where the occurrence of flood and drought years is already a characteristic of the climate. Occurrences of these hazards not only kill people. They destroy valuable property, crops and infrastructure. They affect people's health, whether through contaminated water, lack of food, or through the trauma of seeing homes destroyed and family members killed. They force migration, to avoid the hazard and its consequences, such as food shortages. They destroy livelihoods where agricultural land is degraded and where businesses are forced to close. Many of these consequences can be reduced or avoided if early action is taken.

A forecast provides information about a likely future event, but a warning is a call to action. It therefore needs to be designed from the viewpoint of the person who will take the decision to act. Their requirements will change as the event draws nearer and the actions they need to take become more specific. In a time of changing climate, we have a warning that floods and droughts will get worse in many parts of the world. For those in charge of risk management policy, this feeds directly into policies for land zoning for flood protection and water supply and for risk management. Where seasonal forecasts have skill, the seasonal rainfall warning provides emergency managers with the trigger to review and practice plans for flood response including evacuation. Specific severe weather events are often first predicted at a week or so ahead. While the probability may be low at this lead time, the resulting warnings can be used for "no regrets" preparations. For emergency managers, these may include clearing gullies, checking that pumps work, reviewing staff availability, while for the public it may be preparing an emergency evacuation bag, checking the batteries in a torch or making arrangements for animals. As the event approaches, forecasts become more accurate and the confidence of the warning grows, enabling decisions about closing down transport systems, suspending industrial operations and evacuating populations to be taken. Even after this time, a warning can still be valuable if information about specific areas affected can be monitored and shared with those who need to respond. In a major disaster getting this information quickly to senior officials can also support the rapid deployment of external assistance. In general, the provision of warnings enables protective and response actions to be taken earlier than would otherwise be the case. Through the last fifty years, the death toll from weather-related disasters has steadily fallen mainly as a result of the introduction of effective early warnings.

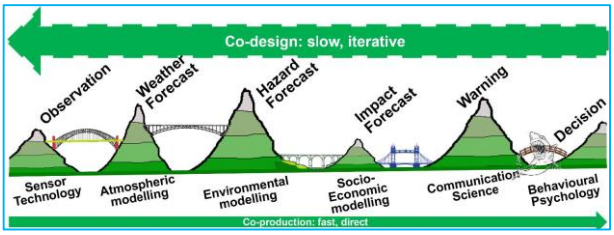

Fig. 1. HIWeather concept of the warning value cycle © Crown Copyright 2020, Met Office

3. Introduction to HIWeather

The WMO World Weather Research Programme High Impact Weather project (HIWeather) is a 10-year project of the World Weather Research Programme. It has core themes in the disciplines of predictability and processes of the weather, multi-scale hazard forecasting, human impacts, vulnerability and risk, communication of warnings and cutting across all areas, evaluation of the warning chain. HIWeather has brought together physical and social scientists to jointly explore what makes an effective warning. A disaster occurs when vulnerable people are exposed to hazards. We find that the weather-related hazard is produced by combinations of environmental processes that act together to create a flash flood or a drought for instance. Vulnerability is similarly produced by combinations of socio-economic processes such as urban expansion, demographic change and poverty. When highly vulnerable people are exposed to severe hazards, the ingredients for disaster are present.

Research in HIWeather has found the following conceptual model to be helpful in understanding the ingredients of an effective warning (Fig. 1).

In this conceptual model, mountains represent the contribution of knowledge from experts in disciplines and organizations involved in producing warnings. The valleys reflect the fact that if that information is passed on without consideration of who will receive it and how it will be used, much of its value will be lost. The shark highlights that this is particularly true when passing the warning to the decision maker or user. By working together in partnership, organizations and experts can build the bridges that minimise this loss of information and value so that a more effective warning that saves lives and livelihoods, reduces damage and protects infrastructure. The bridges must operate in both directions. When designing a warning system, the starting point must be the needs of decision makers for information that will enable them to take protective decisions for themselves and their communities (*i.e.*, at the right hand end of the diagram). The potential sources of that information then need to be identified. If the required information cannot be provided,

e.g., because the atmosphere is not sufficiently predictable at the scale required, the design process must loop back to the user and look for alternative options. Once a match has been obtained between what it is possible to produce and what is needed, a warning system can be designed to deliver it. When producing a warning, the flow of information will be mostly from left to right, with triggers from the weather observations and forecasts leading to production of warnings for decision makers to use. In this situation speed and reliability of the system are essential. However, the information flow is still not all one-way, as the decision maker will often have access to impact and response information that can provide valuable situational awareness for the forecasters and warners.

4. Ingredients of an effective warning

HIWeather has promoted, reviewed and synthesised a vast body of research from multiple disciplines. Out of this research we have distilled the most important ingredients for an effective warning in our book, "Towards the 'perfect' warning: bridging disciplinary gaps through partnership and communication" (Golding, 2022). As the title suggests we have found that communication and partnership are the key enablers at all stages of designing and producing a warning. Specific aspects of an effective warning include:

(*i*) A successful warning system depends on all participants working together in partnership. To do this requires effort for each to learn the language, culture and needs of the other participants, including those who will receive and act on the warnings.

(*ii*) A warning system should be co-designed with those who will receive and act on the warnings. This not only ensures that the warnings will reach and be understood by users, but also increases their trust in their value.

(*iii*) It should be clear who has produced the warning so that the user recognises that the source is trustworthy.

(*iv*) The communication of the warning is as important as its content. Choosing communication media that will reach everyone and formatting the warning so that it will be understood are essential.

(*v*) A warning needs to alert the recipient that action is needed. It should also provide information on what action to take and on why the action is needed, *i.e*., what the hazard is and what its impact will be. In order to provide impact information, the warning must use information on exposure and vulnerability to the predicted hazard. Such information may be drawn from city plans and directories, censuses and health records.

(*vi*) Dangerous impacts of hazards often occur at very small spatial scales. In order to provide warnings on the required scales observations and forecasts of weather and associated hazards need to be sourced at the highest available resolutions.

(*vii*) To ensure that the warning remains appropriate and that the necessary responses are being made, the hazard, its impact and the response should be monitored using any information sources available, including social media. Where it is evident that false information is being shared, action should be taken to correct this.

(*viii*) Early warnings are based on uncertain information about the weather, its impact and the situation of those who will be exposed. These uncertainties should be tracked and should be reflected in the warning message.

(*ix*) The success of a warning must be measured by its impact on the behaviour of those who receive it. This should be monitored. The reasons for any downward trend in response must be identified in discussion with users.

(*x*) A successful warning system may be summed up as one that produces warnings that are useful, usable and used. Useful, in that they contain the required information. Usable, in that the information is understood by the recipient. Used, in that the recipient actually takes appropriate action.

5. Hazards in monsoon climates

Monsoon climates experience many weather-related hazards, especially those associated with tropical cyclones and with intense rainfall (including floods, landslides and lightning). They are also often associated with droughts (and associated wildfires) and heatwaves (often accompanied by poor air quality). Climate change is shifting the location and intensity of some of these hazards, so that previously recorded extremes are being exceeded more frequently. The monsoon climate is characterised by seasonal and diurnal variability. Changes to the timing and magnitude of this variability may be as important as individual hazard events.

The risk associated with these hazards is also changing due to increasing populations and urbanisation, including the growth of informal settlements in hazardous locations. When mapping the risk from hazards, considerations of the different exposure of rural and urban populations, of different occupations, of women and children and the elderly are needed. Urban populations are particularly vulnerable to loss of infrastructure services such as water and power.

	Weather	Hazard	Impact	Warning	Response
Filomena (Spain)	Winter Storm	Snow	Transport, Waste	3-days 1-day	Transport Homeless shelter
Uri (Texas)	Winter Storm	Cold, Snow	Transport, Power, Deaths	3-days	Transport, Farming Warming stations
Seroja (Indonesia)	Tropical Storm	Flash flood & mudslide	Deaths, Infrastructure	12-hours	None known
Hot Dome (Canada)	Blocking Anticyclone	Heatwave, Wildfire	Deaths	3-days	Cooling stations
Floods (Germany)	Rainstorm	Flood	Infrastructure Deaths	3-days 12-hours	Targeted Evacuation
Floods (China)	Rainstorm	Flood	Industry Deaths	1-day	None known
Wildfires (Greece)	Blocking anticyclone	Wildfires	Trees Displacement	3-days Hours	Targeted Evacuation
Ida (Louisiana)	Tropical Storm	Wind, Flood	Deaths Infrastructure	4-days 2-days	Partial Evacuation
Ida (New York)	Tropical Storm	Wind, Flood	Deaths	3-days	Gully clearance

Fig. 2. Summary of forecasts, warnings and responses in nine disasters that occurred during 2021

Warnings need to lead to action, but the availability of actions that protect people will depend on their situation and on the country that they live in. It is a function of government to create and resource a structure for management of risk that defines who will issue warnings and who has the responsibility to protect people.

6. Some 2021 disasters

During 2021, several disasters occurred due to hazards that exceeded anything in the memory of those affected, and in several cases exceeded the historical record, sometimes by a substantial margin. In every case a warning was issued, but there were deficiencies in the response. Sometimes this was due to a short lead time. In others it was due to lack of communication or to a lack of response plans for the magnitude of the event. In many cases, however, the lack of response was because of a failure to recognise the magnitude of the threat. The following table summarises the events studied, based on information available publicly at the beginning of 2022. In many cases, enquiries are continuing that will clarify the information that was available and the actions that were taken. Based on this information, the darkness of the green shading provides an indication of the quality of the information available at each stage of the warning process for these events. A general feature is that the weather forecast information was good - though less good for extreme rainfall than for windstorms and heat waves. Forecasts of impact were less commonly available. Communication of warnings was quite variable, with some countries having very good systems and others restricting the information to emergency managers. Most institutional responses depended on a pre-prepared plan being available for the threat. For several of the cases, the size of the threat exceeded what had been planned for. The public response was particularly deficient when the hazard exceeded people's experience, producing impacts that were of a different nature from those seen in the past (Fig. 2).

7. Concluding remarks

The object of a warning is to mobilise people to take action. This is much more likely to be achieved if the warning is not a surprise - not just in the weather but in its consequences and in the expected responses, especially for those with specific vulnerabilities.

To achieve this, a warning must:

(*i*) Be delivered through trusted channels

(*ii*) Reach the people at risk and be understood

(*iii*) Provide advice to people on what to do and why

For unprecedented hazards warnings need to be based on:

(*i*) Models that produce unbiased predictions of relevant processes and conditions

(*ii*) Initial conditions that capture the ingredients for an extreme event

(*iii*) Ensembles that reliably identify the range of uncertainty

(*iv*) Diagnostic tools for communication of low probability, high impact events

(*v*) Prediction of hazard-related impacts, including for specific vulnerabilities

It is important to monitor and track warning performance, including the proportion of people who received the warning and of those who took some action. The aim should be to assess whether lives were saved, essential services maintained, properties and livelihoods protected, as a result of the warnings issued.

Disclaimer : The contents and views expressed in this study are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

Reference

Golding, B.W. (Ed), 2022, "Towards the 'Perfect' Weather Warning: bridging disciplinary gaps through partnership and communication", Springer Cham, https://doi.org/10.1007/978-3-030-98989-7, ISBN 978-3-030-98988-0.