The HuT

Standard protocol for evaluating warning systems

Deliverable D1.6

DEVELOPED WITHIN
WP1 Demonstrators' arena, T1.5 End-to-end evaluation of existing warning systems

AUTHORS
Michele Calvello (UNISA); Brian Golding (MET); Guido Rianna (CMCC)

Version 1.0
(4 January 2024)

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement N° 101073957

1. Technical references

Project Acronym	The HuT
Project Title	The Human-Tech Nexus - Building a Safe Haven to cope with Climate Extremes
Project Coordinator	Michele Calvello UNIVERSITA DEGLI STUDI DI SALERNO mcalvello@unisa.it
Project Duration	October 2022 – September 2026 (48 months)

Deliverable No.	D1.6
Dissemination level*	PU
Work Package	WP1 - Demonstrators' arena
Task	T1.5 – End-to-end evaluation of existing warning systems
Lead beneficiary	UNISA
Contributing beneficiary/ies	CMCC, MET, UCL

* PU = Public

PP = Restricted to other programme participants (including the Commission Services)

RE = Restricted to a group specified by the consortium (including the Commission Services)

CO = Confidential, only for members of the consortium (including the Commission Services)

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement N° 101073957

1.1. Document history

Version	Date	Lead contributor	Description
0.1	13.12.2023	Michele Calvello (UNISA)	First draft
0.2	02.01.2024	Ingibjörg Lilja Ómarsdóttir (NIP)	Critical review and proofreading
1.0	04.01.2024	Michele Calvello (UNISA)	Proofreading, final version

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement N° 101073957

2. Table of contents

2.1. List of Tables

2.2. List of Figures

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement N° 101073957

3. Purpose

The key objective of defining a standard protocol to evaluate warning systems is to learn how warnings of all types can be made more effective in saving lives, livelihoods, and properties in order to increase community resilience. In the protocol, the performance of the systems will be measured, at each step in the warning production process, considering the "warning value chain" schematization developed in the HIWeather project of the World Meteorological Organization. The protocol will be calibrated and validated using case studies of existing warning systems, including the ones that are operational in some of the demonstrators.

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement N° 101073957

4. The warning value chain

The High Impact Weather project HIWeather (http://hiweather.net/) is a ten-year activity of the World Meteorological Organization aimed at promoting "cooperative international research to achieve a dramatic increase in resilience to high impact weather, worldwide, through improving forecasts for timescales of minutes to two weeks and enhancing their communication and utility in social, economic and environmental applications." Among the many activities carried out within HIWeather, particularly relevant for the development of a protocol for evaluating warning systems have been the experience and the knowledge produced during two flagship activities, the "Warning Value Chain Project" (http://hiweather.net/Lists/130.html) and the publication of the book "Towards the Perfect Warning" (https://link.springer.com/book/10.1007/978-3-030-98989-7).

The end-to-end evaluation of operational warning systems is based on a framework proposed to address the different components of a warning chain, defined with the aim of building greater resilience to weather-induced hazards in the design and implementation of warning systems (Figure 1). The weather information value chain provides a framework for characterising the production, communication, and use of information by all stakeholders in an end-to-end warning system covering weather and hazard monitoring, modelling and forecasting, risk assessment, communication and preparedness activities (Hoffman et al 2023). Extracts from Golding (2022) are reported in the following to help the reader understand the key concepts of the framework.

- The production of warnings is characterized as a value chain whose aim is to provide the information that enables the best decisions to be taken, both by individuals and by those with responsibility to protect others.
- In a perfect warning chain, the warning received by the end user would contain precise and accurate information that perfectly met their need, contributed by each of the many players in the chain. In real warning chains, information, and hence value, are always lost as well as gained at each link in the chain.
- The term "valley of death" is used to represent the failure of the expert information generated in warning organisations to lead to the desired responses due to inadequate communication along the warning chain. The height of each mountain may be interpreted as the maturity of the expertise available for use in weather warnings. Successful communication of information from one contributor of expertise to the next is represented by spanning the valleys with bridges, whose height can represent the success of the communication between those contributors in avoiding the loss of information.

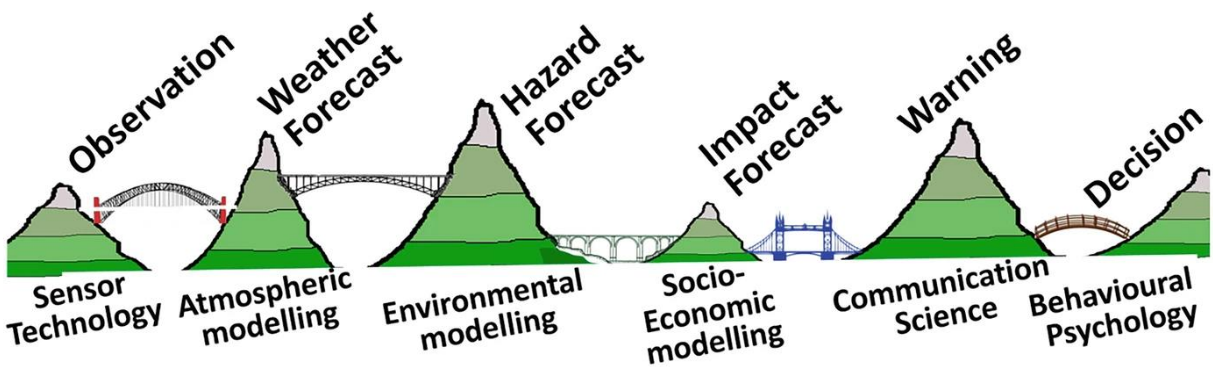
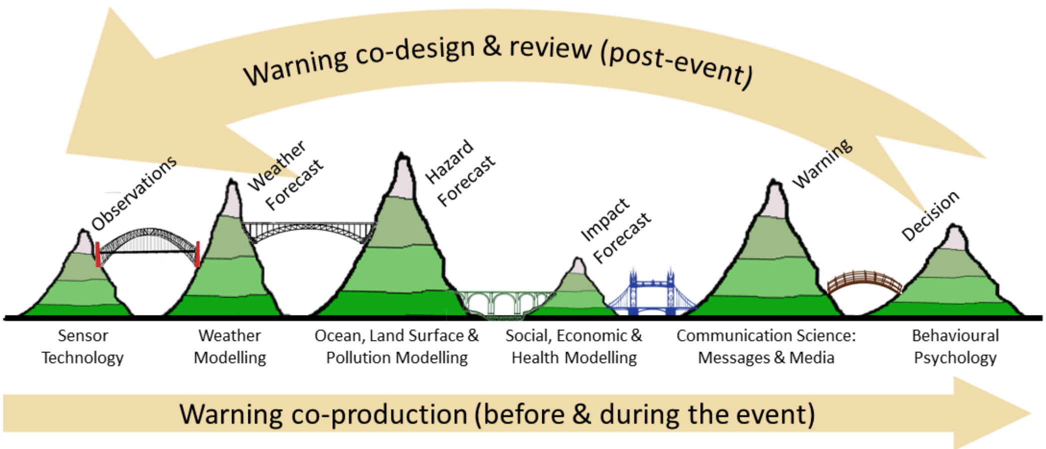


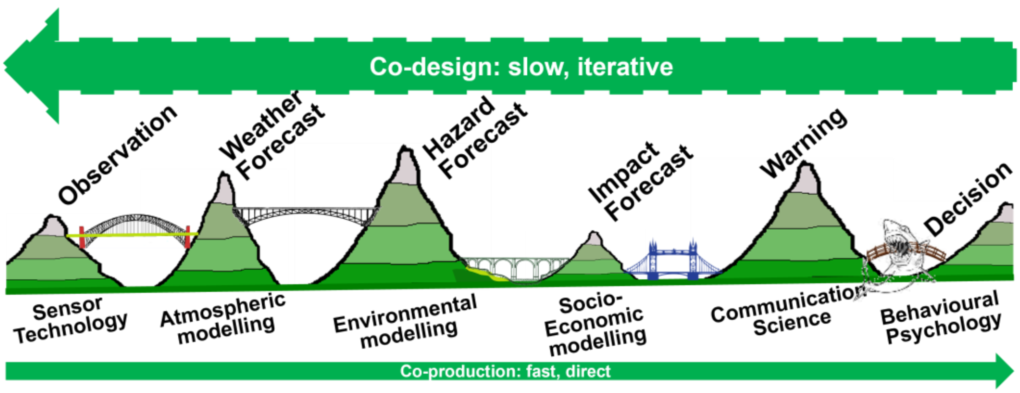
Figure 1: The valleys of death concept of a warnings value chain ((© Crown Copyright 2020 - Met Office, source: Golding, 2022)

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement N° 101073957

The conceptual model devised for the warnings value chain can be read in either direction. That explains why in the original schematic (Figure 1) there are no arrows. More recently, however, to highlight that it is important to consider the chain in both directions, two arrow-augmented schematics have been also produced (Figure 2). For post event assessments, implementation of improvements and creation of new services the chain becomes more like a feedback cycle, while before and during an actual severe event the flow of information is predominantly downstream (Hoffman et al 2023). For instance, the design of a warning system is an iterative process, starting from the decision-maker, progressing up the value chain, then continually returning to the decision-maker in a process of mutual adjustment. The decisions that need to be taken to protect life, property, infrastructure and livelihoods should be the basis for deciding what information is required and how it should be delivered – sometimes referred to as the “first mile paradigm”, because the user is at the start of the process. When the warning system is in operation, the flow of information is predominantly down the value chain from producer to user – and this needs to happen quickly, accurately and reliably to maintain the value of the information (Golding, 2022). The figures also highlight that warning services, typically developed and provided through a multitude of complex and malleable value chains, are often established through co-design, co-creation and co-provision (Hoffman et al 2023).



(a)



(b)

Figure 2: Schematic warning value chain for high impact weather warnings: (a) Tan et al. (2022); (b) Golding et al. (2023).

This project has received funding from the European Union’s Horizon Europe research and innovation programme under grant agreement N° 101073957

5. Developing the protocol

Besides the experiences carried out and the knowledge produced in the WMO's HIWeather project, the following elements have also been instrumental to develop the performance evaluation protocol herein proposed:

- proper acknowledgment of the scale of operation of early warning systems;
- feedback from The HuT Demonstrators;
- pilot studies.

5.1. Warning at regional and national scales

Early warning systems are a risk mitigation measure primarily addressing risk to life. Table 1 reports some widely recognized definitions that have been provided over the years, both in the scientific literature and within terminological lists compiled by relevant international institutions. Many key terms and expressions are adopted in these definitions, such as: meaningful information, sufficient time, empowerment of individuals and communities, appropriate actions.

Table 1: Selected definitions of early warning systems, listed in chronological order.

Definitions	References
The objective of early warning is to empower individuals and communities, threatened by natural or similar hazards, to act in sufficient time and in an appropriate manner so as to reduce the possibility of personal injury, loss of life and damage to property, or to nearby and fragile environments.	IDNDR (1997)
Information system designed to facilitate decision-making in the context of national disaster management agencies, in a way that empowers vulnerable sectors and social groups to mitigate the potential losses and damages from impending hazard events.	Maskrey (1997)
The expression 'early warning' is used in many fields to mean the provision of information on an emerging dangerous circumstance where that information can enable action in advance to reduce the risks involved.	Basher (2006)
The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss.	UNISDR (2009)
Early warning constitutes a process whereby information generated from tailored observations of natural phenomena is provided to communities at risk or to institutions which are involved in emergency response operations so that certain tasks may be executed before a catastrophic event impacts such communities. The goal is to minimize the impacts manifested through fatalities, injuries, damages and losses of various kinds.	Villagran de Leon et al (2013)

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement N° 101073957

An integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities systems and processes that enables individuals, communities, governments, businesses and others to take timely action to reduce disaster risks in advance of hazardous events.	UNGA (2016), UNDRR online
A condition, system, or series of procedures indicating a potential development or impending problem (source: Oxford English Dictionary). Any series of steps established to spot potential problems (source: Dictionary.com).	Guzzetti et al. (2020)

The latest reported definition by UNDRR (UNGA, 2016) also includes annotations highlighting that effective "end-to-end" and "people-centered" early warning systems include four interrelated key elements: (1) disaster risk knowledge based on the systematic collection of data and disaster risk assessments; (2) detection, monitoring, analysis and forecasting of the hazards and possible consequences; (3) dissemination and communication, by an official source, of authoritative, timely, accurate and actionable warnings and associated information on likelihood and impact; and (4) preparedness at all levels to respond to the warnings received. These four interrelated components need to be coordinated within and across sectors at multiple levels for the system to work effectively and to include a feedback mechanism for continuous improvement. Failure in one component, or a lack of coordination across them, could lead to the failure of the whole system. It is important to distinguish a forecast, which produces information about the future state of the weather or some other aspect of the environment without consideration of its use, from a warning, which provides information about a threat so as to enable a response, which will be different according to the lead time, the confidence level, the severity of the threat, the vulnerability of those threatened and other factors (Golding, 2022). The UNDRR 4-box model includes elements that occur on slow timescales (mainly knowledge and preparedness) as well as the elements of the warning production process (monitoring, forecasting and warning communication) which occurs on a very fast timescale. These slow elements create the environment for a successful response to the warning. The evaluation protocol essentially addresses the performance of the fast elements, which will, of course, be influenced by the state of development of the slow ones. Therefore, the conclusions and recommendations of the evaluation are likely to relate to all four of the UNDRR boxes, although the analysis focuses on the performance of the warning process itself.

Warning systems can be designed and employed at different scales, i.e., they may cover significantly different extensions of territory, ranging from specific elements at risk (directly menaced by well-identified local hazards) to municipalities, counties, regions, or entire nations (facing one or more risks). For instance, when dealing with landslides: the purpose of local site-specific systems is the temporary evacuation of people from areas where, at definite times, the risk level to which they are exposed is intolerably high; the purpose of territorial (also called geographical or regional) systems is to provide generalized warnings to authorities, civil protection personnel and the population, when the probability of occurrence of multiple landslides over purposefully defined wide areas increases (Calvello, 2017).

Herein, only systems that operate over wide areas, such as large metropolitan areas, regions or nations, are addressed.

5.2. Feedback from partners in The HuT

The feedback was collected by means of discussions and meetings with the leaders of demonstrators in which warnings are issued, as well as referring to activities carried out in WP2 Human behaviours, more specifically within task 2.2 - Operational warning systems.

The starting point have been the responses to an internal survey conducted in December 2022. The survey questions answered by the leaders of Demonstrators involved with warnings, are reported in the following.

The system

- Organisation(s) monitoring the weather and/or hazard in your warning system
  - What is monitored?
  - How is the information communicated?
- Organisation(s) forecasting the weather and/or hazard in your warning system
  - What is forecast?
  - How is the information communicated?
- Organisation(s) assessing the impact of the weather and/or hazard in your warning system
  - What impacts are assessed?
  - How is the information communicated?
- Organisation(s) issuing the warnings
  - What is warned?
  - How are the warnings communicated with users?

Existing knowledge

- Legal / Policy
  - Do you have a legal requirement to provide warning?
  - If so, what legislation / policy is in place?
  - Which agencies provide warnings and how are they held accountable?
  - How are policy decisions around warnings made - national or local government?
  - Where does accountability lie?
  - Does your warnings legislation tie with DRR policy?
  - How is preparedness / anticipatory action for warnings implemented?
- Warning system design
  - What is the design of your warning (alert level) system, e.g. colours, numbers, criteria, icons etc. How many stages / levels does it use?
  - Is your warning system multi-hazard?
  - Who is responsible for designing your warning systems?
  - What is the purpose of the warnings? Commenting the state of the hazard, warning, actions people should take, potential for event, or impact of event?

  - Does the warning provide hazard or hazard and risk information?
  - Is your warning systems standardised regionally, nationally, other?
- Warning system implementation
  - Does your institution have responsibly for changing the warning?
  - If so, what is your institutions responsibility?
  - What positive aspects does your warning systems have?
  - What negative aspects does your warning systems have?
  - What other challenges have you encountered in using your warning systems?
  - How effective is the warning system, and how do you measure this?
  - How confident are you in the warning systems?
  - How is a decision to change a warning / act on a warning made?
  - Are particular actions assigned to a warning level?
  - How do you communicate warning information to various stakeholders / vulnerable folks?
  - Do you use any electronic warning systems (Common Alerting Protocol CAP)?
  - Do you collaborate with other nations warnings?
  - How do you manage multi-hazard warnings from with concurrent or cascading events?
- Historical warning data
  - Provide links to any key warnings documents / systems (weblink or references)
  - Have there been any historical changes in the warning systems (e.g., standardisation / redesign / new laws)?
  - Are there any useful case studies / events that have shaped the design and operation of warnings in your nation / organisation?

5.3. Pilot studies

5.3.1. Emilia-Romagna region (Italy): assessment of criticalities during high impact weather events

The latest version of the Warning Value Chain Questionnaire developed by HIWeather has been used to document and evaluate an important regional extreme weather event that occurred in May 2023 in Emilia-Romagna (Italy), associated with extensive flooding and landsliding, which produced casualties and huge economic damage in a very wide area of the region. The main results of this evaluation are synthesized in the following “Analysis of the warning value chain” (section f of part 2 of the questionnaire) and “Performance of the warning value chain” (section b of part 3 of the questionnaire).

This project has received funding from the European Union’s Horizon Europe research and innovation programme under grant agreement N° 101073957

Analysis of the warning value chain

Issues with information flow through the warning value chain

Warning value chain component	Was the necessary input information available? (yes/partially/no)	If not or partially available, what input information was missing?	Who should have provided the missing information?
Weather, etc. forecast	Yes		
Hazard forecast	Yes		
Impacts forecast	Yes		
Warning communication	Yes		
Response	Partially	Unprecedented event	

Tools and operational workflows for sharing information between partners

During the period from May 1st to May 31st, 2023, there were:

- 30 Alerts issued.
- 17 Monitoring documents produced.
- 372 instances of exceeding hydrological thresholds.

Additionally, a total of 141,753 SMS messages were sent to alert various authorities and operational structures. These messages were distributed as follows:

- Alerts: 59,817 SMS.
- Exceeding hydrological/pluviometric thresholds: 50,979 SMS.
- Monitoring documents: 30,957 SMS.

The Regional Operations Room was operational 7 days a week from May 1st, with a 24-hour presence from May 1st to May 5th and from May 10th to May 28th, 2023. Territorial operations rooms were activated in the cities of Reggio Emilia, Modena, Bologna, Ferrara, Forlì-Cesena, Ravenna, and Rimini. Furthermore, 7 Rescue Coordination Centers and 160 Municipal Operational Centers were activated to manage and coordinate emergency response efforts during this period.

How useful were social media/crowdsourcing/citizen science in the warning value chain?

The severe weather emergency in Emilia-Romagna is demonstrating the crucial role of social media, which in recent days has become the primary tool for rapid information exchange, requests for help, and fundraising.

From the beginning of May to Thursday, May 18, over 24,000 conversations have been recorded, generating approximately 35 million interactions, highlighting the significant interest generated by the emergency. This information comes from an analysis conducted by SocialCom, which, with the assistance of SocialData, analyzed social media conversations about the weather emergency that has been affecting Emilia-Romagna since the beginning of the month.

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement N° 101073957

In general, the most widely discussed topics on social media are related to rescue efforts (24.5% of total mentions), victims (14.8%), and the ongoing emergency (14%). The content that has attracted the most public interest includes images and videos (28.8%) shared by users, news about rescue efforts (16.3%), updates on victims (11.2%), and appeals and requests for help (10.6%) coming from affected areas. Calls for solidarity have been less prominent (0.8%).

Overall, social networks, especially X (35%), Facebook (18%), and TikTok (7%), are the platforms where users are focusing most of their conversations, along with news websites (21%).

Evidence that warning was effective in reducing fatalities, injuries, damage, and/or disruption

Carlo Cacciamani, a climatologist, and the director of ItaliaMeteo, the national agency for meteorology and climatology, was interviewed by "Il Giornale." He stated, "We were expecting the worst. So much so that, precisely in the affected areas, a red alert had been issued in advance, indicating very intense weather events. The management of the Civil Protection has been optimal. Everything possible, and even the impossible, has been done. Our alert system is excellent. We are no longer at ground zero. Without the preventive evacuations, we would be mourning many more victims of this flood."

What were the strongest links (information flow) in the warning value chain?

Weather forecast and hazard models

What were the weakest links (information flow) in the warning value chain?

From hazard to the impact; scenario analysis did not take into account this actually exceptional event exacerbated by previous events and inducing significant cascading consequences.

What procedures were used to identify lessons learned from the event?

Cascading/compounds events should be better accounted for. More severe scenarios should be included in the analysis

Comment on lessons learnt from previous events and their contributions to greater warning success for this event

None

Additional analysis

None

Performance of the warning value chain

Each part of the warning value chain was rated, on a scale of 1 (poor) to 5 (excellent), as follows.

- How well do you think the event was observed? 5
- How well do you think the source of the hazard (e.g., weather) was forecast? 4
- How well do you think the hazards were forecast? 4
- How well do you think the impacts were predicted? 4
- How well do you think the warnings were communicated? 5
- How well do you think the warnings were used? 4
- How well do you think the entire warning chain performed overall? 4

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement N° 101073957

5.3.2. Amalfi municipality (Italy): routine assessment of daily operations of territorial warning systems

The routine assessment of daily operations of territorial warning systems cannot be conducted by using the current version of the Warning Value Chain Questionnaire developed by HIWeather, as this tool is specifically designed to record information about high impact weather events. However, the framework on which the questionnaire is based, i.e., the valleys of death concept of a warnings value chain, remains perfectly suited to periodically assess operational warning systems. To this aim, a pilot study has been conducted in the municipality of Amalfi in Campania (Italy) explicitly adopting the schematic subdivision of the value chain that shows capabilities and outputs as mountains, and information exchanges as bridges linking the different mountains. The study addresses, at municipal level, the warning system for weather-induced risks operational in the Campania region.

The pilot study has been conducted in three main steps:

1) collection of background information, both on the national laws for regional warning for weather-induced risks in Italy and on the different elements of the system operational in Campania Region;
2) details of the operational capabilities and outputs of the regional system in relation to observations, weather forecast, hazard forecast, impact forecast, warning, and decision;
3) collection and preliminary analysis of relevant data for the municipality of Amalfi from 1 October 2017 to 31 May 2023.

The warning system operational in the Campania region warns, by means of daily bulletins (Figure 3), for the following weather-related phenomena and hazards:

- intense rainfall
- thunderstorms
- strong wind
- sea surges
- high and low temperature anomalies
- hydro-geo hazards, i.e., floods and landslides
- wildfire susceptibility (from May to September)

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement N° 101073957

Figure 3: Example of daily warning bulletins issued by the regional "Multi-risk Functional Center of Civil Protection" in the 8 warning zones of the Campania region.

The main operational capabilities and outputs of the Campania regional system are reported in the following, together with a possible strategy to assess their accuracy in operational conditions.

- The primary weather variable is rainfall amount. Forecast information comes from the Weather & Climate Center of the Campania region, based on guidance from the Italian Air Force. It is communicated in a daily weather forecast. The accuracy of these rainfall amounts can be assessed relative to raingauge observations, although appropriate scaling is needed to compare areal forecasts with local measurements.
- The primary hazards are hydro-geological, and in particular rainfall-induced landslides (mainly shallow landslides and debris flows), and pluvial and fluvial floods (including flash floods). Forecast hazard information is based on 2-, 5-, and 10-year return periods of rainfall accumulation and comes from the Multi-risk Functional Center of Civil Protection for Campania Region. It is communicated in a daily warning bulletin to the public and to relevant institutional stakeholders. In addition, if local real-time rainfall accumulations, set up for different durations, exceed predefined rainfall thresholds, they are notified to the involved Municipal Civil Protection centers. The accuracy of the hazard forecasts can be assessed by comparing the areas identified by the rainfall thresholds with the areas affected by flooding and/or landslides occurred.
- The primary impacts are fatalities and injuries, property damage, infrastructure failure resulting from the hazards. A predefined set of possible impacts associated with the different warning levels is communicated in a daily bulletin to the public and to relevant institutional stakeholders. The accuracy of the impact forecasts can be assessed by comparing the areas defined by the rainfall thresholds with the locations of fatalities and/or injuries, damaged properties, and failure of infrastructure, such as blockage of roads.
- Input to warnings is primarily from rainfall forecasts received from the Weather and Climate Center of Campania. Warnings are colour coded in three levels (yellow, orange and red)

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement N° 101073957

according to return period and are issued by the Multi-risk Functional Center of Civil Protection for Campania Region through the Unified Regional Operations Room. A possible measure of the effectiveness of the warnings can be the % of Municipal Civil Protection centers who take consistent actions in response to the different warning levels.

- Warnings are received from the Unified Regional Operations Room by Municipal Civil Protection centers and by the Public. The effectiveness of the actions taken to reduce the impact of the hazards can be estimated by the fatalities and injuries, damage and disruption that occurred, relative to those expected.

The Municipality of Amalfi is part of the regional warning zone 3. A sample of the preliminary analysis that have been initiated in this pilot case study is shown in Figure 4. The figure reports two years of data (2021 and 2022), including both warning issued and recorded events, with a daily resolution.

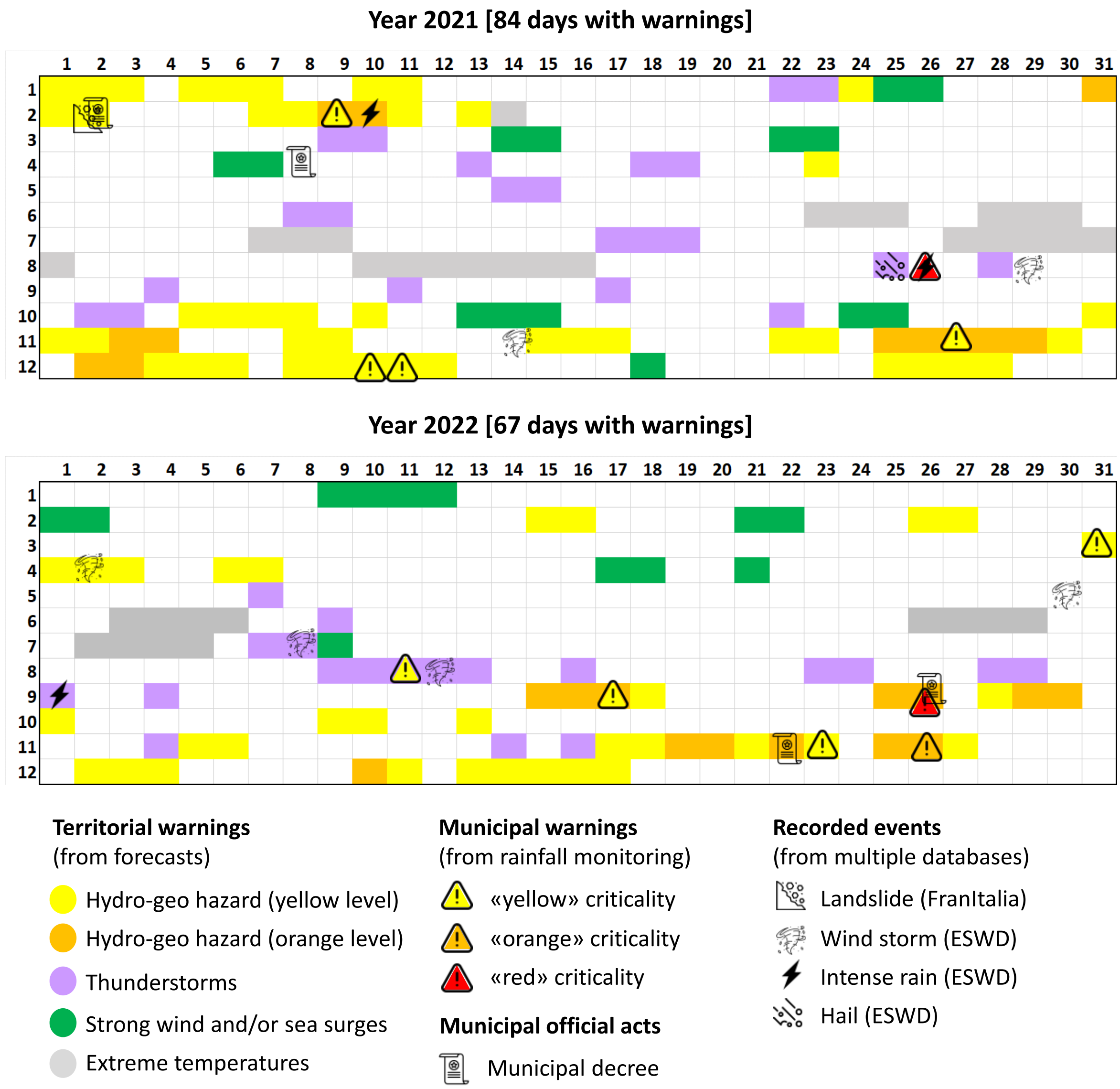


Figure 4: Example of data analysis in the municipality of Amalfi: warnings issued and events recorded in the years 2021 and 2022.

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement N° 101073957

6. The evaluation process

The activities described in the previous sections, which included the adoption of best practices on warning systems coming from ongoing projects (e.g., WMO HIWeather) and research centers (e.g., UCL WRC), feedback from The HuT Demonstrators, and pilot studies, have led to the development of this first version of a protocol for evaluating warning systems for weather-related events and hazards. The protocol is structured as a three-part evaluation process, as follows:

1. description of the system;
2. assessment of criticalities during high impact events;
3. routine assessment of daily operations.

The protocol will be put to test during the remaining time of the project, by applying it to case studies both within and outside the Demonstrators' Arena. Through this action, detailed information from many different warning systems will be collected and then used for a comparative study between warning systems operating, in different areas of the world, for different weather and climate related risks. Another important expected outcome of this action will be the production of templates of concise information sheets, tentatively one for each part of the protocol, to be used to synthetically lay out the main strengths and limitations of the different aspects of operational warning systems for weather and climate induced risks.

6.1. Describing the system

The description of the warning system must be based on the schematic subdivision of the warning value chain (see Figure 1), i.e., the six main capabilities and outputs, represented as mountains in the schematic, and the five information exchanges elements, drawn as bridges linking the different mountains.

All the "decision makers", i.e., institutions and stakeholders formally involved in activities pertaining to the warning value chain, must be identified and all the main activities performed by them must be listed. The relationships between the main activities performed by the decision makers and the mountains and bridges of the warning value chain must be highlighted. Note that: i) the actors in the chain may be in the same or different organisations and may, in some settings, be combined in one person; ii) for some hazards and impacts, the inputs may need to come from more than one source, in which case, the entries for that element of the chain should reflect those multiple sources.

For each activity performed by the "decision makers", the following information must be provided:

- Short description of activity (i.e., what)
- Temporal information (i.e., when)
- Spatial information (i.e., where)
- Activity performed by (i.e., from)
- Results communicated to (i.e., to)

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement N° 101073957

6.2. Highlighting criticalities and strengths associated to high impact events

A special focus on the evaluation of an operational warning system must be devoted to high impact events. For such cases, the evaluation must include the following parts:

1. essential information on the event;
2. information on how each element of the warning value chain has been working during the event;
3. synthetic assessment on the performance of the warning system.

The evaluation is meant to identify the main criticalities and strengths of warning systems that experienced high impact events, as well as to highlight general patterns that can be considered "lessons learned" to be used to improve other warning value chains operating in similar contexts.

Here below are reported examples of questions that can be used to provide information on the performance of the warning system, for the different elements of the warning value chain.

Weather system

- Were the available observations adequate for forecasting the high impact weather?
- Were there different forecasts? If so, how well did the forecasts agree?
- How reliable and accurate were weather forecasts at different lead times?
- How did the observed weather relate to climatology and/or previous extreme events?

Hazards

- Were the available observations adequate for predicting the hazard?
- How reliable and accurate were the hazard predictions?
- What process or trigger(s) identified the event as hazardous and started the warning process?
- How did the observed hazard(s) relate to climatology and/or previous extreme events?
- How was the observed hazard(s) made worse by pre-existing conditions?

Impacts

- What impact prediction models/tools were used (if any)?
- Were informal approaches used to predict impacts?
- What were the main observed impacts (health and social, property and business, infrastructure service disruptions, environmental)?
- How do observed impacts compare to predicted/expected ones?

Warning communication

- What information was provided to emergency responders, government and other stakeholders about the hazard and its possible impact(s), and by whom?
- How was warning information communicated by other organizations including media?
- Was uncertainty conveyed in the warning? If so, how?

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement N° 101073957

- To what extent were communication systems in place and operating effectively?
- How were warning messages received by the public?
- How well were warning messages understood by the public?
- Were the needs of specific communities and populations addressed? If so, how?

Response

- What were the main response actions by the public to the warnings?
- How did the overall response to this event compare to similar previous events?
- How did the key decision makers and institutions interact before, during and after the event?
- What capacity did the community have to respond to warnings?

6.3. Assessing daily operations

The routine assessment of daily operations of territorial warning systems must explicitly adopt the schematic subdivision of the warning value chain. To this aim, the evaluation must include the following parts:

1. identification of the system's operational capabilities, outputs and information exchanges that need to be (and can be) analysed;
2. identification of the areas covered by the system in which to conduct the assessment (e.g., entire warning zones, municipalities, communities);
3. identification of the period for which to conduct the assessment and the sources of data to be used (maximising the amount of relevant information available);
4. identification of appropriate and computable (considering the available data) performance indicators for the different elements of the warning value chain considered in the assessment;
5. analysis of relevant data for the chosen time period in the identified areas;
6. evaluation of the performance of the different elements of the waring value chain considered;
7. final judgment on the overall performance of the system.

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement N° 101073957

7. References

Basher R (2006) Global early warning systems for natural hazards: systematic and people-centred. Phil. Trans. R. Soc. A 364, 2167–2182. http://dx.doi.org/10.1098/rsta.2006.1819

Calvello M (2017) Early warning strategies to cope with landslide risk. Riv It Geotecnica 2:63–91. https://doi.org/10.19199/2017.2.0557-1405.063

Golding B Ed. (2022). Towards the “Perfect” Weather Warning. Springer Cham, pp. 270. ISBN: 978-3-030-98989-7. https://doi.org/10.1007/978-3-030-98989-7

Golding B, Ebert EE, Hoffmann D, Potter S (2023). Preparing for the unprecedented. Adv. Sci. Res., 20, 85–90. https://doi.org/10.5194/asr-20-85-2023

Guzzetti F, Gariano SL, Peruccacci S, Brunetti MT, Marchesini I, Rossi M, Melillo M (2020) Geographical landslide early warning systems. Earth Sci Rev 200:102973. https://doi.org/10.1016/j.earscirev.2019.102973

Hoffmann D, Ebert EE, Mooney C, Golding B, Potter S (2023). Using Value Chain Approaches to Evaluate the End-to-End Warning Chain. Adv. Sci. Res., 20, 73–79. https://doi.org/10.5194/asr-20-73-2023

IDNDR (1997). Guiding Principles for Effective Early Warning. Document by The Convenors of the International Expert Groups on Early Warning of the Secretariat of the International Decade for Natural Disaster Reduction. Available at: https://www.unisdr.org/2006/ppew/whats-ew/pdf/guiding-principles-for-effective-ew.pdf. Accessed 26 November 2023.

Maskrey A (1997) Report on National and Local Capabilities for Early Warning, IDNDR Early Warning Programme. IDNDR Secretariat, Geneva, 33 pp. Available at: http://www.unisdr.org/2006/ppew/whats-ew/pdf/national-and-local-capabilities-ew-maskrey.pdf. Accessed 26 November 2023.

UNGA (2016). Report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction. Note by the Secretary-General. United Nations General Assembly (UNGA). Document No. A/71/644. Available at: https://undocs.org/A/71/644. Accessed 26 November 2023.

UNISDR (2009) ISDR: Terminology. Available at: https://www.undrr.org/publication/2009-unisdr-terminology-disaster-risk-reduction. Accessed 26 November 2023.

Villagrán de León JC, Pruessner I, Breedlove H (2013) Alert and Warning Frameworks in the Context of Early Warning Systems, a Comparative Review, Intersections No. 12. United Nations University Institute for Environment and Human Security, Bonn.

This project has received funding from the European Union’s Horizon Europe research and innovation programme under grant agreement N° 101073957