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The ANYWHERE Paradigm Shift in Responding to Weather and Climate Emergencies

Impact Forecasting, Dynamic Vulnerability and the Need for Citizen's Involvement

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1.1 Disaster Risk Management in Times of Climate Change: The Need of a Proactive Approach

The world has just seen the hottest decade on record during which the title for the hottest year was beaten eight times (WMO 2023). This tendency will continue for decades, even if global and European efforts to cut greenhouse gas emissions prove effective. We also know today that **'There is no definitive way to limit global temperature rise to 1.5°C above pre-industrial levels'** *(IPCC SR 1.5)*. Even a drastic temporary decrease in emissions (the 2008 financial crisis or during COVID-19 pandemic) has proved to have little effect on the overall trajectory of global warming. Therefore, and especially after the extreme events observed worldwide during 2021 and 2022, it is widely recognized that the effects of climate change (CC) are already happening today.

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Moreover, the analysis of the impacts of natural hazards in the last 50 years (see WMO 2021) shows that the **frequency and severity of these extreme climate and weather events are increasing and exacerbating climate-related economic and social losses.** And the urgency to react to their consequences is a social priority with significant political and economic implications, as proven by the climate emergency declaration of the *EU parliament (November* 2019),[1] and several other *national and regional parliaments*[2] and *leading cities*[3].

As stated by the EU Strategy on Adaptation to Climate Change (EC 2021a, b),[4] the EU and the global community are underprepared for the increasing intensity, frequency and pervasiveness of climate change impacts, especially as emissions continue to rise. We must rapidly build our resilience to CC by moving from raising public awareness and concern to mass action on adaptation. Accordingly, the **'Adaptation to CC, including Societal Transformation**', has become one of the five Horizon Europe Missions to push this significant societal challenge[5].

In this regard, Early Warning Systems (**EWSs**) have become a crucial instrument for disaster risk management **(DRM)**. Now promoted by the United Nations (UN) through the 'Early Warnings for All initiative'[6], EWS can be especially critical during weather/climate emergencies. However, to be effective, they must be able to trigger the intended actions for damage reduction to be undertaken by authorities, first and second responders and citizens (i.e. the earliest responders in place, also seen as the zero-order responders, Briones et al. 2019).

Nonetheless, triggering the full chain of emergency management starting with the hazard forecasts up to the emergency management actions is not a simple objective, as the *catastrophic floods of July 2021 in Germany and Belgium*[7] exemplified (over 180 deaths in just a 200 mm daily rainfall event, see Table 1.2). Currently, the available scientific and technical advancements enabling us to anticipate extreme events are not well integrated into the real-life protocols of authorities and first responders. Hence it is critical to develop and implement EWSs adapted to the local needs of authorities, first responders and the population. And be able to connect them to local/community risk management plans able to ensure that the warnings can trigger the required local actions that can effectively reduce damages and loss.

This chapter, and some of the following ones, summarizes the **paradigm shift in responding to weather and climate emergencies based in the project results and lessons learnt during the ANYWHERE innovation action.**

1.2 Adapting Risk Management to the 'New Normality': The Case of Flood Risk Management

Before describing the details of the **ANYWHERE** proposed tools and results, it is important to illustrate the challenge of what it means to consider the effects induced by the CC through a particular well-known hazard, such as floods.

Floods are the most significant natural hazards in Europe in terms of the number of events, people affected and economic losses. But it is also, together with storms, the most relevant natural hazard worldwide (CRED 2020). Hydrological hazards (floods, and heavy-rain-induced disasters) are also the natural hazard that has most increased in frequency in the last 30 years (Kron et al. 2019).

Table 1.1 Differences between riverine and coastal floods compared with pluvial and flash floods under climate change effects.

	Riverine and coastal floods	Pluvial and flash floods
Time response	Long: days	Short: several 1/4 hours
Location	We know where: • Mapping of risk can be done • Defence and structural measures are possible • **PLANNING** is CRUCIAL	Can be ANYWHERE: • The probability increases with climate change (an increase in heavy rains) • The probability increases with an increase in wildfires • Structural measures are out of the question • **REAL-TIME MANAGEMENT** of the response is crucial
What to do	**We know** what to do • River restoration • Floodplain recuperation • EVACUATION is possible	**At present we DO NOT know** what to do: • Need of a NEW PARADIGM • **CITIZENS'** involvement is crucial • **SELF-PROTECTION** Flood Risk Management Plans • Subsidiarity principle

In this context and as seen in Table 1.1, it is important to recognize the differences between what are considered 'classical or typical floods' (e.g. riverine and coastal floods) and the 'new intensified floods', episodes that are not only increasing in their frequencies but also in their intensities and amount (and level) of seen socio-economic impacts due to CC (e.g. pluvial and flash floods).

On one hand, riverine and coastal flood events have long response times (that can go from several hours to several days) and thus the time between the event starts and the main consequences is of the order of several hours or days. However, pluvial and flash floods are directly related to heavy-rains and the associated torrential phenomena have extremely short response times (usually a few quarters of an hour). Consequently, these types of events trigger emergencies that develop too quick for a reactive response based on direct observations. Thus, the only appropriate emergency response must be based on the timely anticipation of the event (at least a few hours in advance, Alfieri et al. 2016). This implies that decision-making needs to rely into trusted, but uncertain, high-resolution forecasts instead of waiting to receive direct observations (only available when the impacts are already occurring), what it is by itself a significant operational challenge.

On the other hand, for the first category we can anticipate where these kinds of events will happen (around the river flood-prone areas, or in particular areas of the coastal line). Therefore, risk cartographies can be pre-established, making possible to plan defences and structural measures, as well as evacuation plans. Thus, planning is crucial to cope with these types of floods.

Contrarily, heavy-rainfall-induced floods can happen anywhere. Moreover, given the effects of CC on the increase of the frequency and severity of heavy rains, as well as on other factors amplifying the torrential character of flash floods (such as the increase of the number and severity of forest fires, which worsens the magnitude of flash floods due to the loss of vegetation; see Lavabre et al. 1993; Versini et al. 2013; Wine and Cadol, 2016; Wagenbrenner et al. 2021), pluvial and flash floods have multiplied by 3 in the last 30 years[8] and they are at present the climate-induced hazard that has increased the most. In this context, emergency management cannot only be based on planning, and the **real-time management of the response becomes crucial.**

Furthermore, whereas in riverine and coastal floods we have enough experience with effective measures to reduce and manage the associated risks (through river restoration works, floodplain recuperation actions and evacuation plans etc . . .), in the case of pluvial and flash floods, we need to recognize that essentially the current established knowledge in flood risk planning and management turns out to be useless (as in the case of July 2021 in Germany and Belgium).

In these floods, as in any other hazards where climate change is making knowledge based on past experience irrelevant, we need to acknowledge that a change of paradigm is required. Change of paradigm that implies accepting to **move from planning-based strategies towards real-time management strategies, essentially based on EWSs adapted to the local needs**, providing actionable information able to trigger the response, not just of the local authorities, but also of the citizens. This requires a disruptive societal transformation in emergency management through the implementation of flood risk management plans, which should include as a major component the concept of **self-preparedness and self-protection actions**, previously identified and adapted to the most vulnerable points and communities, a transformation that should be supported by advanced and adapted technological tools (Gräßler et al. 2020).

To understand the urgency of such a societal transformation, Table 1.2 shows the main characteristics of recent heavy-rainfall events recorded in Europe in 2020 and 2021. Whereas during the catastrophic floods in Germany in July 2021, the quantities recorded represented the equivalent of 2 months of accumulated rainfall registered in 24 hours, we can see that this event is not extraordinary in our 'new' CC times. Thus, we urgently need to start being prepared to face events delivering these 2-month accumulated rainfall in less than 24 hours or more, such as the event on the 4 October 2021 in Rossiglione, Liguria (IT), where the European rainfall-accumulated record in 12 hours has been beaten: 740 mm in 12 hours, representing **one year mean rainfall accumulated in 12 hours**.

These and the other events in Table 1.2 can help us to understand the magnitude of the new scenarios we need to be prepared to, and the urgency with which we need to start initiating the adaptation to the consequences of climate change.

1.3 Changing the Paradigm: Impact-Based Multi-Hazard Early Warning Systems to Move from Reactive to Pro-Active Emergency Response Strategies

In this context, adapted **DRM** will require an update of the tools and methodologies to evolve our present risk assessment capacities, crisis management and preparedness strategies for the natural hazards under CC. Thus, an enhanced DRM cycle will require tools using different types of information and forecasts that can enable the anticipation of disasters, providing **Early Warnings supporting the situational awareness and rapid deployment of responders in vulnerable areas**.

Table 1.2 Some examples of recent heavy rainfall events giving us what can characterize the 'new normality' under climate change times.

	Total accumulated rainfall	Maximal intensity	In terms of average monthly rainfall
14 July 2021 Germany	200 mm in 24 h	>40 mm in 1 h	2-month rainfall in 24 h
1 September 2021 @ Alcanar (ES)	220 mm in **3 h** 260 in 24 h	**77 mm in 30 minutes**	6-month rainfall in 24 h
8 September 2021 @ Agen (FR)	130 mm in **3 h**	80 mm in 1 h	2-month rainfall in 3 h
18 December 2020 @ Cerdanyola (ES)	**300 mm** in 24 h	>100 mm in 1 h	6-month rainfall in 24 h
4 October 2021 @ Rossiglione, Liguria (IT)	**900 mm** in 24 h **740 mm in 12 h**	**>180 mm in 1 h**	**12-month rainfall in 12 h**

To that end, impact-based EWS (**IEWS**) (WMO 2021) and particularly multi-hazard impact-based EWS (**MH-IEWS**) for weather emergencies have been *promoted by the WMO and the Sendai Framework (Target G),*[9] (Murray 2021) see Figure 1.1[10,11], as the next step to translate forecasts into information **supporting actionable decisions during emergencies** and triggering **site-specific actions based on early risk forecasts.**

Although many current initiatives are trying to develop the concept of IEWS for weather and climate-induced disasters, there are very few successful experiences in implementing and demonstrating MH-IEWS in an operational environment (Merz et al. 2020). The successful H2020 Innovation Action **ANYWHERE** (www.anywhere-h2020.eu), winner of the EC Security Innovation Resilience Award in 2022,[12] is one of them.

1.3.1 From Reactive to Proactive Emergency Response Strategies

This innovative pathway can be clarified by taking the example of the case of the floods in Germany in July 2021. For this event, a clear warning for the *river Ahr*[13] (one of the most affected areas) was available through the European Flood Awareness System (*EFAS,*[14] part of the Copernicus Emergency Management Services, *CEMS*[15]), was available **more than 24 hours in advance of the floods**, see Figure 1.2. Moreover, the *ANYWHERE A4EU system*[16] provided a high-resolution warning based on the *OPERA network radar data*[17] for the portion of the river most affected **5 hours in advance** (with enough time to take self-protection actions and reduce the number of fatalities). Consequently, the technology to activate actionable solutions through a risk management self-protection protocol was fully available and working correctly. However, the EU society has not yet the capacity to react effectively to these new climate-induced emergencies, even if we have already the technology to anticipate their occurrence and impacts,[18] as the declarations in front of the Commission of Inquiry about these floods in the Walloon Parliament have shown.[19] Thus, the main

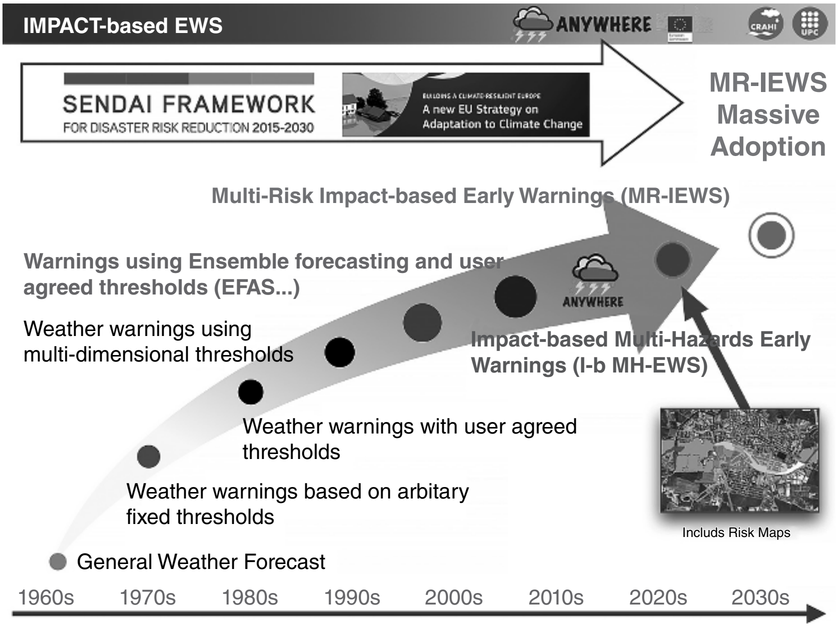

Figure 1.1 Evolution of the warning systems to support decision-making during weather and climate emergency. The initial general weather forecast has been transformed in different families of weather warnings issued by the National Meteorological Services. The advancements of the last years include the integration of probabilistic approaches using ensemble forecasting, as in the European Flood Awareness System (EFAS), or the impact-based multi-hazard early warning systems (MH-IEWS), among which *ANYWHERE* is one of the first real-time systems tested in operational environment in several Emergency Management Centres in Europe. In the next years, it is foreseen that these MH-IEWS could evolve towards new Multi-Risk Early Warning Services able to be massively adopted to support international initiatives such as the Sendai Framework for Disaster Risk Reduction, to promote the EWS4ALL initiative of the WMO as well as the international initiatives supporting climate change adaptation (CCA).

challenge is how to use this technology to empower Emergency Management Centres to transform advanced meteorological forecasts into high-resolution hazard and impact forecasting products providing information about the magnitude of the event and the expected consequences, allowing them to trigger the required actions to minimize damages and losses.

In this strategy, an important step is to understand that nowadays, the usual practices in most emergency management centres (EMCs) are still mainly reactive (first the emergency is detected, usually through 112 calls, then the reaction follows pre-established protocols, see Figure 1.3-above). There are very few exceptions of EMCs **able to act in proactive mode**, i.e. integrating forecasting capabilities or initiating the response based on the early detection of weak signals (before the emergency becomes evident). In the last years, several H2020 projects (**EMERGENT**, **ANYWHERE**, **I-REACT**, **BEAWARE**) have shown that technological developments can be of precious help for an anticipated response of first responders.

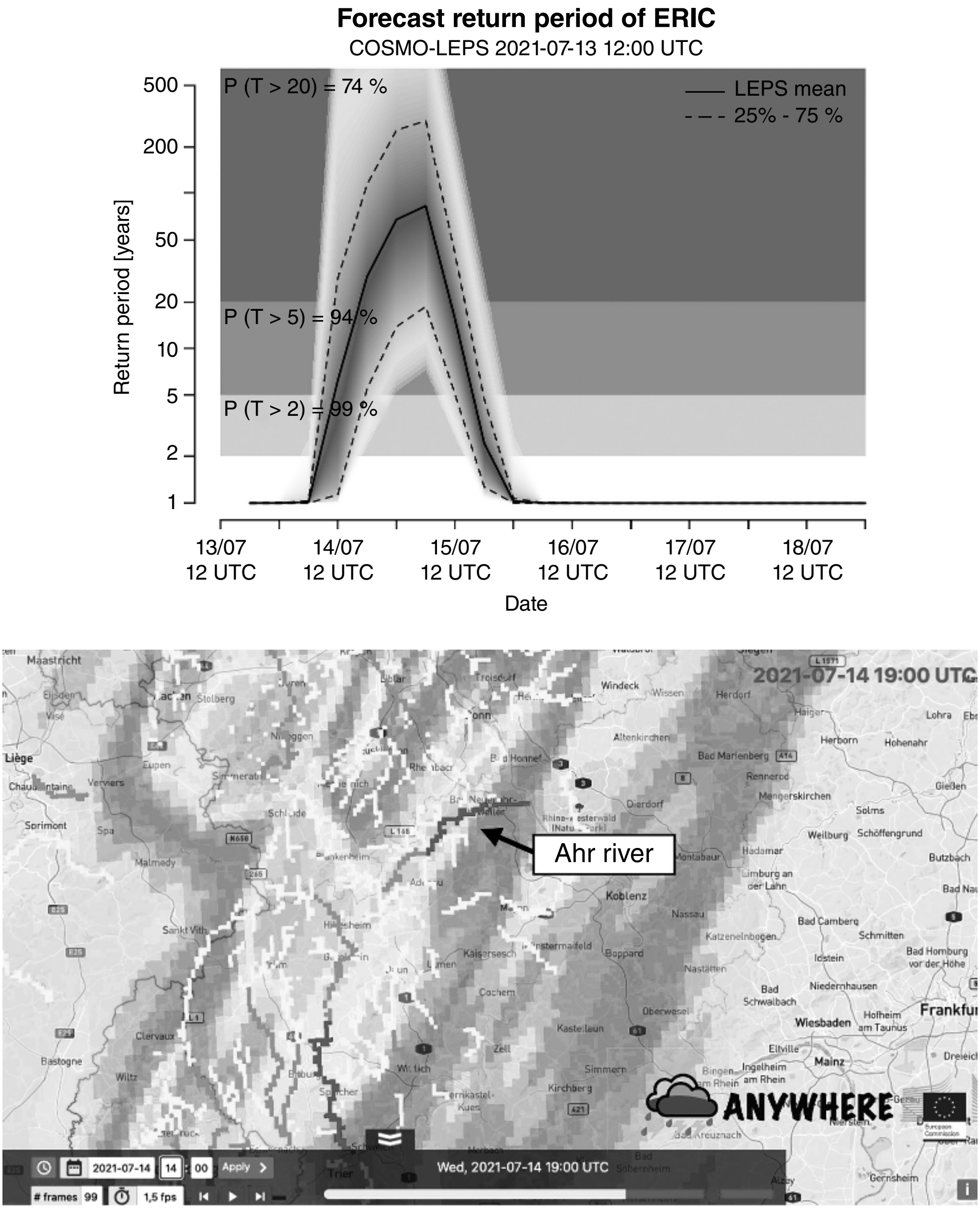

Figure 1.2 (Above) *ERIC flash flood indicator* announcing 74% probability of exceeding the highest warning level for the Ahr river (Germany) using the meteorological model forecast run on the 13 July at 12 : 00 UTC (>24 hours before the flood peak). *Source*: *EFAS*. (Below) Forecasted *ERICHA flash flood indicator* showing the maximum warning level on the Ahr river issued the 14 July at 14 hours UTC (5 hours in advance) using the rainfall nowcasts from the OPERA radars composites. *Source*: *ANYWHERE*.

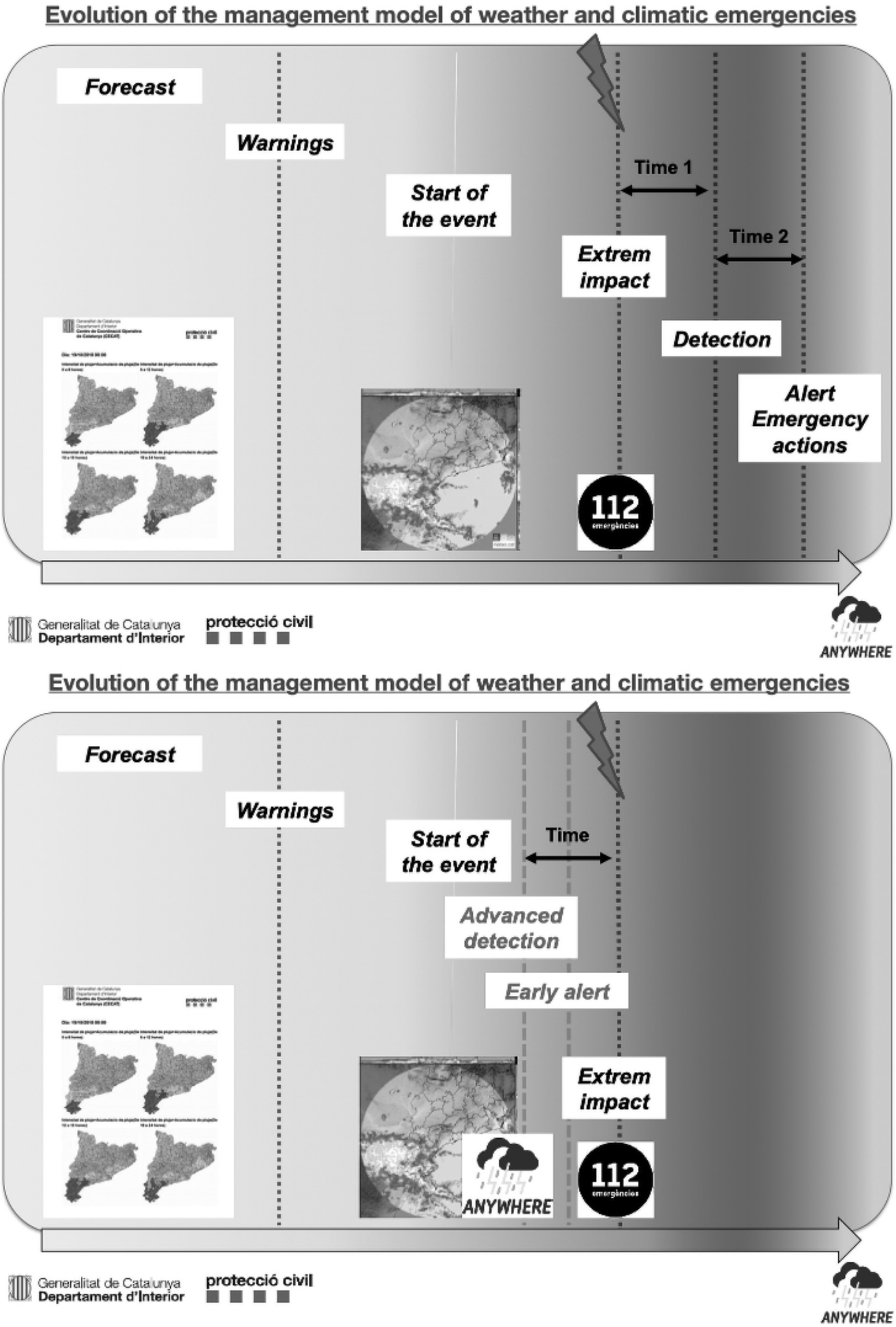

Figure 1.3 Change on the management model of weather-induced emergencies thanks to the *ANYWHERE* project developments: (above) Instead of detecting the impacts with delay time 1, and start the emergency actions with delay 2; (below) the ANYWHERE platform allow to anticipate the detection of the event and advance the response before the occurrence of the impact. *Source*: Courtesy of Sergio Delgado, Department of Civil Protection of the Generalitat de Catalunya.

In particular the *ANYWHERE* project has developed an operational **multi-hazard EWS** for extreme weather and climate events, able to translate the most advanced meteorological forecasts into *impact forecasting products* to support emergency management (Abily et al. 2020, see Section 1.3.2). The system was verified, tested and operationally demonstrated in **7 Emergency Management Centres covering the entire climatic range in the EU for 18 months,**[20] demonstrating in real time that the generalization of the proactive way of working in EMCs is now possible (see Figure 1.3-below).

These **ANYWHERE** innovations translate meteorological forecasts into anticipated impacts and **automatically connect them to critical points to trigger a set of pre-defined actions** (for instance, those of the self-protection plans), allowing civil protections and EMCs to start the response phase before the occurrence of the impacts, **reducing the damages through the concept of dynamic vulnerability** (Sempere-Torres 2019), see Section 1.4.

This capacity was tested operationally during the 50-year return period **Storm Gloria (19–23 January 2020)**, which severely affected the east coast of Spain, and in particular Catalonia in a severe way. During this event the Civil Protection of Catalonia triggered several response actions (including the management of the river Ter dams, and the confinement of tens of thousands of affected inhabitants of different cities) **based on impact forecasting early warnings for the first time in Europe**, before observations were available (saving over six hours for the operations).

1.3.2 The ANYWHERE MH-IEWS

The **impact forecasting concept** implemented by the ANYWHERE project consists of running state-of-the-art hazard-forecasting algorithms and models (driven by advanced meteorological forecasts) and combining them with the available exposure and vulnerability information to translate them into impact forecasts (see Figure 1.4).

In ANYWHERE, these algorithms and models are connected or encapsulated in a joint real-time MH-IEWS running in parallel to generate hazard forecasts for floods, flash floods, landslides and debris flows, storm surges, forest wildfires, droughts, heatwaves and weather-induced health impact, convective storms, severe winds and snowfall. The outputs of these algorithms were compiled in a catalogue of products describing the hydro-meteorological situation and forecasting the hazard level and expected impacts[21] that were served in real time by the ANYWHERE MH-IEWS to support emergency management and self-protection actions in the pilot sites of the project.

Given the differences in the characteristic scales of the different weather and climate hazards considered, the driving meteorological inputs are adapted to each hazard. These included the use of observations and radar-based precipitation nowcasts for the most local and fast-evolving hazards, such as convective storms or local flash floods and landslides (Palau 2021; Palau et al. 2020, 2023); limited-area Numerical Weather Prediction (NWP) models (driving the forecasting systems for floods, flash floods) and medium-range and seasonal forecasts (for the drought impact forecasting algorithms).

The ANYWHERE MH-IEWS is connected to the Continental-scale hazard and impact forecasts generated by the Copernicus Emergency Services (CEMS)[22]: mainly, the hydrological forecasts of the European Flood Awareness System (EFAS); the fire

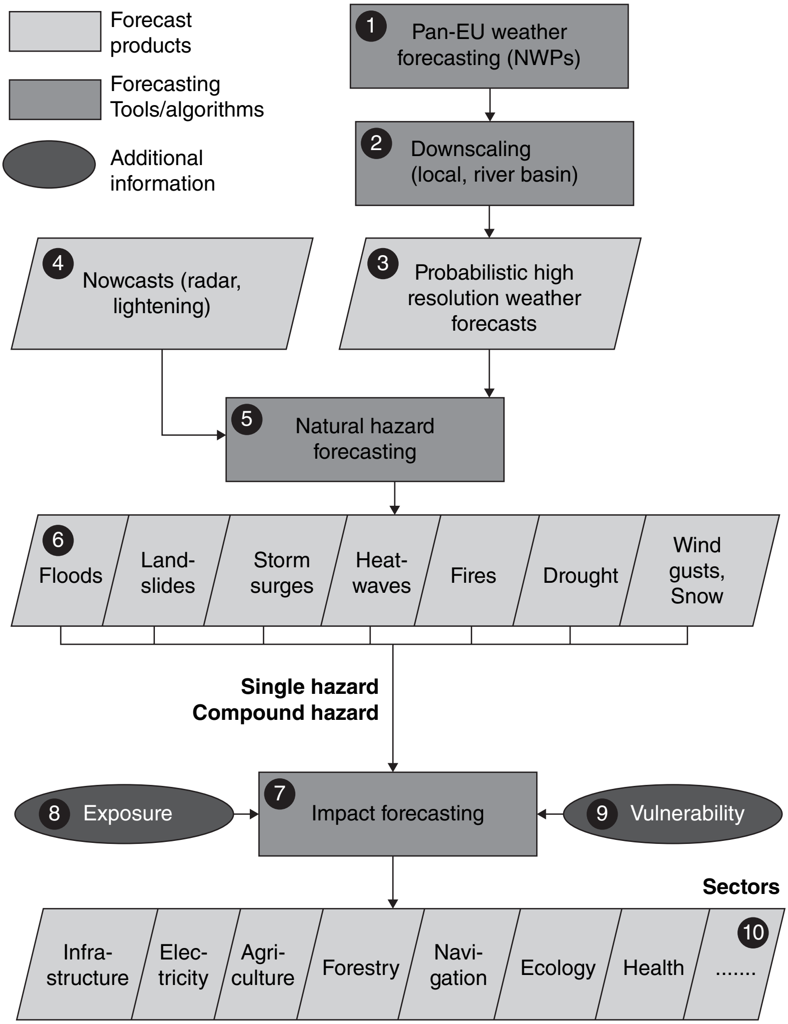

Figure 1.4 ANYWHERE multi-hazard IEWS forecasting platform: products and tools/algorithms to forecast weather-induced natural hazards and associated impacts.

of the European Forest Fire Information System (EFFIS) and the European Drought Observatory (EDO).

The EFAS flood products were complemented with flash flood hazard and impact nowcasts at Continental scale (Park et al. 2019; Ritter et al. 2021) and regional scale (Corral et al. 2019; Poletti et al. 2019; Ritter et al. 2020, 2022; Láng-Ritter et al. 2022), combining the hazard forecasts with the flood hazard and risk maps developed in the framework of the EU Floods Directive (2007); the vulnerability layers at the relevant scale to assess the expected losses and the expected impacts on population and critical points.

The storm surge forecasting models relied on a nested approach covering the European coasts at coarse resolution (EFAS-COAST, Fernández-Montblanc et al. 2019) to regional scale to forecast surge levels and waves parameters, feeding a high-resolution flood/erosion model at local scale providing flow velocity, maximum inundation depth and expected shoreline retreat (Armaroli et al. 2019; Duo et al. 2020).

The ANYWHERE MH-IEWS also integrates weather-induced health impact forecasts at the European scale by including two different types hazards: (i) those related to Air quality from the Copernicus Atmosphere Monitoring Service using a regional multi-model approach (Marécal et al. 2015), and (ii) those due to heat waves based on forecasts of the Universal Thermal Climate Index (UTCI, Di Napoli et al. 2018, 2021a, b) assessing the heat strain on the human body by combining the weather forecasts with a physiological model and an adaptive model for clothing insulation.

Complementing the products from EFFIS (based on computing fire danger indices based on medium-range weather forecasts, Di Giuseppe et al. 2016, 2017, 2018; Vitolo et al. 2018, 2019), the RISICO model (Fiorucci et al. 2008; Perello et al. 2022) is used to forecast the forest fire hazard both at European and regional scales, in the latter using higher-resolution and more accurate exposure datasets. After ignition, PROPAGATOR (Trucchia et al. 2020) is used to estimate the trajectory and extent of the forest fire given the weather conditions and identify the vulnerable areas potentially at risk.

Forecasts of drought impacts are based on transforming hazard forecasts (typically characterized with drought indices computed from medium-range and seasonal weather and hydrological forecasts; Diaz et al. 2020a, b; Sutanto et al. 2020a, b; Sutanto and Van Lanen 2021) into impact forecasts using machine-learning to train the algorithm from a database of historical reported impacts (Sutanto et al. 2019, 2020c, d).

And finally, the impacts caused by precipitation included the analysis of the impacts caused by convective cells (based on radar cell tracking; Rossi et al. 2014) and on forecasting the type of precipitation (Fehlman et al. 2018a, b, 2020; Gascón et al. 2018), particularly focusing on the impacts of snowfall on road conditions and road traffic (Cerreta et al. 2019).

Running the algorithms in parallel in the MH-IEWS allows to explore the compound and cascading effects of weather and climate events (Schauewecker et al. 2019; Sutanto et al. 2019; Láng-Ritter et al. 2022).

These real-time hazard and impact forecasting products are integrated with additional high-resolution local information about vulnerability and exposure with **artificial intelligence** and served by the **MH-IEWS** together with **regional layers of exposure and vulnerability in the emergency command centres** (see Figure 1.5).

All this information, *usually available but not interconnected*, is now processed in the single platform ANYWHERE for EU (**A4EU**)[23] to **automatically identify the affected most vulnerable points**, including their characteristics and location, and other advanced services, with the capacity to **convert the warnings into actionable decisions supporting the response** in emergency management centres (see Figure 1.6).

This is an **innovation disruption in the field of Civil Protection and Emergency Management** because the system allows the emergency response specialist to **focus on**

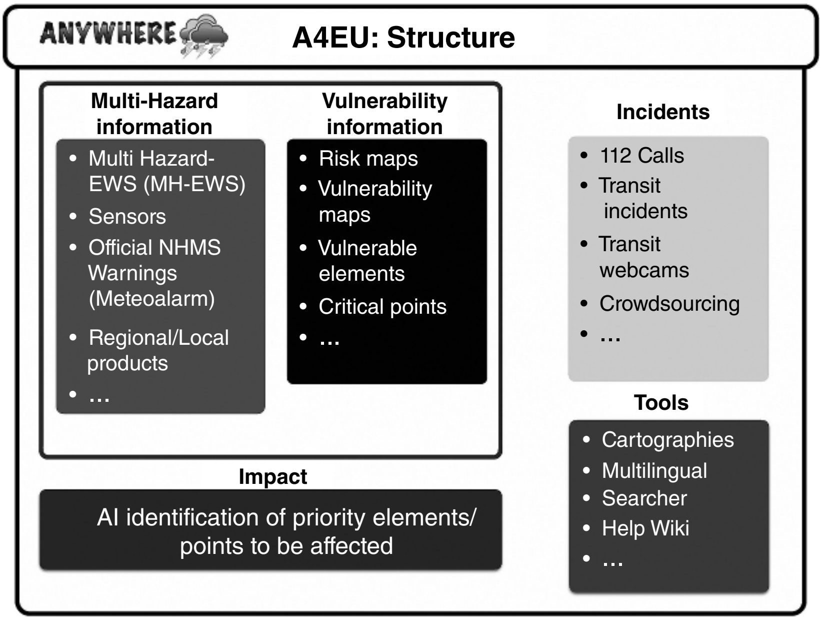

Figure 1.5 A4EU platform impact forecasting scheme: artificial intelligence is used to integrate the hazard impact forecasting products served by the MH-EWS with high-resolution local impact models and local layers of exposure and vulnerability in the emergency command centres.

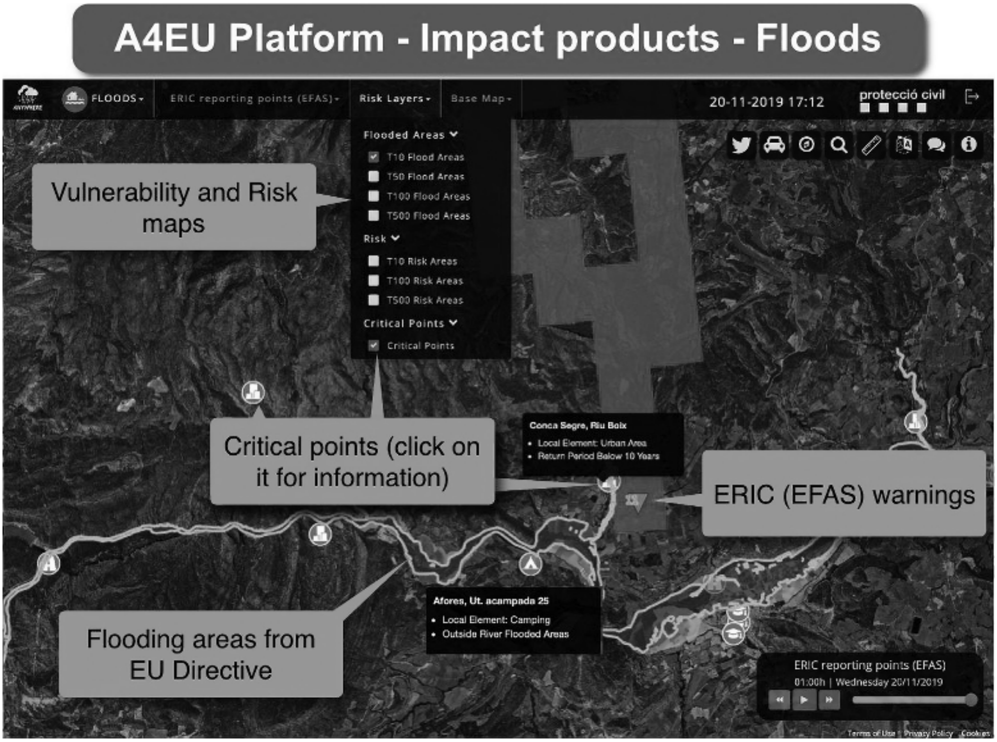

Figure 1.6 Impact forecasting implemented on the A4EU platform, showing critical points that are at risk, by automatic integration of the MHEWS forecasts with high-resolution impact models and the local vulnerability and exposure cartographies. The figure shows how the flash-flood early warning product ERIC (from EFAS) can be used to trigger an automatic warn to the predefined critical points potentially affected using the risk flood maps prepared under the Flood Directive.

local impacts, without the necessity to look in detail on the meteorological forecasts and triggers, **and on a narrow set of vulnerable locations** (i.e. Schools, Train Stations, Hospitals, Seveso facilities, among others) instead of vast regions, supporting them to magnify their response capabilities (see Figure 1.7).

1.4 The New Paradigm: Dynamic Vulnerability

The resilience of societies heavily depends on **how their citizens behave individually or collectively**. Therefore resilience, and emergency management in general, is **primarily based on the capacity to coordinate many human actions**; to share situation assessment; to make, implement and control coordinated actions; and to adapt the response to changing situations. In addition, the **human factor is essentially critical when looking at communications between first-responder authorities and citizens**, obtaining trust and confidence, avoiding false rumours and managing the psycho-social elements during the crisis and the recovery period afterwards.

In this framework, the traditional concepts of the emergency management cycle are facing a **critical paradigm shift due to the rapid change of society** by the disruption of mobile devices, IoT and technologies **transforming the world into an interconnected society**. However, the usual emergency management often disregards that both first responders and, around eighty per cent of European citizens are connected through mobile networks, carrying in our pockets what 15 years ago would have been an unimaginably sophisticated and miniaturized equipment, **wasting what should be seen as an outstanding opportunity**.

On the other hand, the increase of frequency and magnitude of extreme climate events induced by CC requires a **paradigm change in risk governance and policies** at European and global scales. The 'new normality' situation in which we are reaching new records more frequently requires acknowledging that the capacities of public response services might be exceeded and **the key role of the citizens and communities** and their **engagement throughout the phases of climate DRM** and CCA (Hügel and Davies 2020), as well as providing a methodological approach to **empower citizens as 'assets' in terms of self-protection response** (Sempere-Torres 2019).

Moreover, during an emergency situation, citizens and communities will in the first instance depend on themselves. The capacity of professional emergency services is limited and therefore prioritizes the weak and endangered persons who need them most. Thus, it is important that citizens and communities protect themselves during emergencies and this can be more efficiently achieved if **self-preparedness and protection plans** are pre-defined and incorporated into the routine of the communities. The key to the success of these self-protection plans and protocols is a multiple effort, including information (first knowing the risk in your environment, Terti et al. 2019, 2020; Weyrich et al. 2021), preparedness (taking the necessary precautionary measures to cope with emergency situations) and solidarity (reaching out to those in need before, during and after an emergency).

However, involving the citizens in DRM is a challenging societal transformation, especially in such a complex field which involves many stakeholders and organizations;

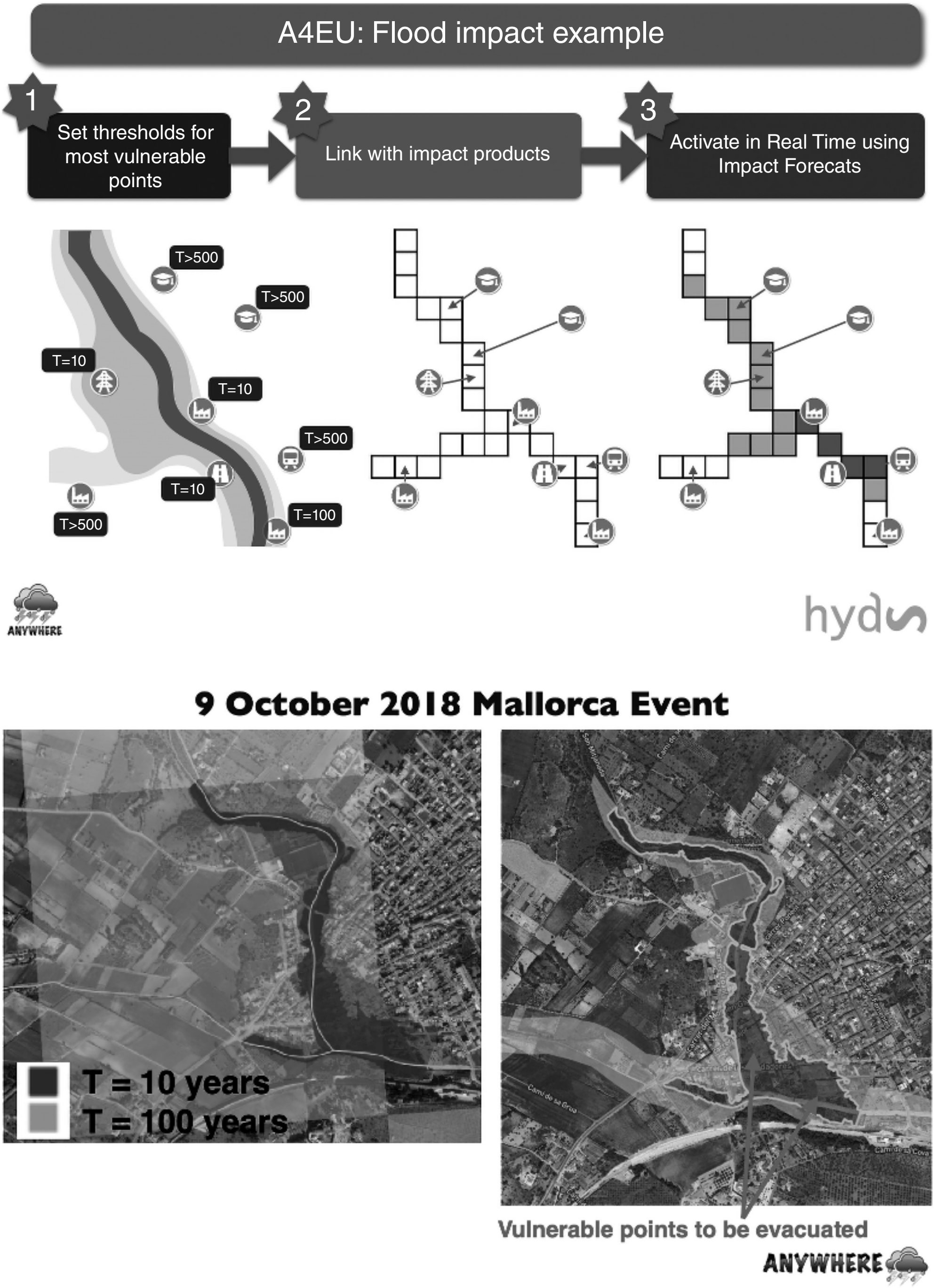

Figure 1.7 (Above) Scheme of the automatic activation of prioritary actions on the most vulnerable points for the A4EU flash flood impact forecasting. The pre-identified vulnerable points are labelled (Courtesy of HYDS). (Below) Application to the event of 9 October 2018 in Mallorca Island (ES). The orange pixel (1 × 1 km) is the trigger for a flash flood warning over 10-year return period The Flood Directive risk map allows the system to identify the associated area to be flooded and the vulnerable buildings in which the self-protection protocols should be activated.

with different objectives, procedures, reporting structures and definitions. And that involves citizens in various roles: as disaster victims, as potential sensors providing relevant information, as well as participating in generating and distributing rumours and fake news (Simon et al. 2015; Venier 2020). **Therefore, citizens can be both an important ‘asset’ to help first responders but may also create a lack of trust or confidence** (Díaz et al. 2016) in the emergency management since they ‘use personal information and communication technology to respond to disasters in creative ways to cope with uncertainty’ (Palen and Anderson 2016; Venier and Capone 2019).

At present, citizens involved in an emergency are **mainly seen by first responders as victims or as a potential nuisance or liability,** but not as a potential source of help ignoring their capacities **as an asset in crisis management**. However, in the next future, given the rising disaster risk due to population growth and CC, citizens as ‘informal’ volunteers (Whittaker et al. 2015) can effectively assist first/second responders by providing the much-needed additional support to react during emergencies. Changing this perception is **not just a technological challenge but a societal challenge** that requires understanding the present barriers and enablers and making a **considerable effort to show the benefits of embracing such a change.**

In this context, *ANYWHERE* has proposed the innovative concept of **dynamic vulnerability** (see Figure 1.8). First **high-resolution local information**, from predefined priority or most vulnerable points, is added to the impact-based early warnings**,** to convert them into **site-specific warnings** (SSWs, Melendez-Landaverde et al. 2020; Melendez-Landaverde and Sempere-Torres 2022). Thus, the information contained in the warnings is not only translated into the expected impacts on citizens, but can **add enriched information beyond text or voice messages**, including images simulating the impacts using augmented reality (e.g. how a specific road passing under a railway track will be

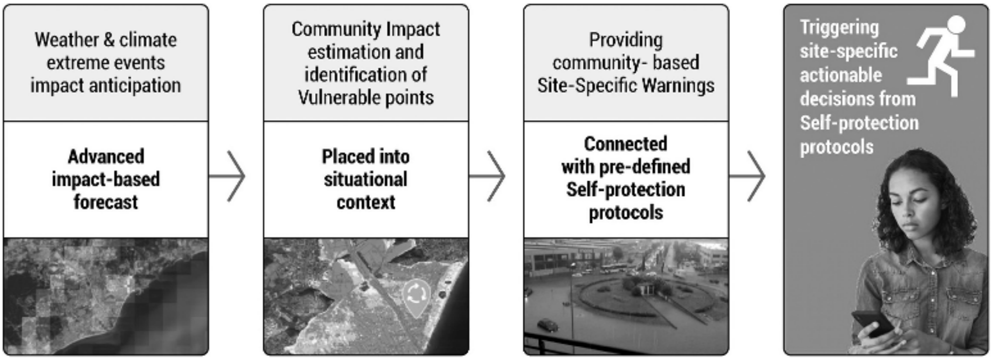

Figure 1.8 Dynamic vulnerability approach: impact forecasting IEWS are used to anticipate expected impacts in the next hours. These forecasts, reinterpreted in their social situational context, identify the most vulnerable points. The system provides SSWs for these points with pre-defined messages for the affected communities. It also enables all actors (authorities, first/second responders, engaged citizens and associations) to trigger pre-defined site-specific actions from the community self-protection protocol to reduce their vulnerability dynamically in a given location and time window.

affected); providing the best way to evacuate the place you are located; or **connecting with pre-defined actions of the self-protection plan of a given location, building or community**, even if the concerned people are just passing by.

These innovative SSWs are **the key instrument to connect the anticipated impacts with adequate actions to reduce vulnerability** as soon as the impacts are forecasted. These actions will emerge from a holistic, participatory approach (van Aalst et al. 2008) involving the civil, private sectors and the citizens **to co-design their community risk management plans and their self-protection protocols** to increase the resilience of their communities. Through these *self-protection plans*,[24] the **SSWs will be able to trigger pre-defined actions to reduce the vulnerability in a given location for a given time window** based on the local risk and response capabilities. This paradigm change in IEWS to support community adaptation is a societal transformation requiring a framework to gain **TRUST among the citizens** and **massively implement multi-risk plans of actions adapted to every city or community**. Chapter 6 of this book illustrates an example of application in the framework of the *ANYWHERE* project.

1.5 Future Work: From Multi-Hazards to Multi-Risk IEWS

The next step is moving from MH-IEWS, as the one proposed in ANYWHERE, into a **real-time multi-risk IEWS platform**, what requires supplying impact products able to identify the magnitude of the consequences (fatalities, damage and loss) triggered by weather and climate hazards. The objective is to provide **impact forecasts and/or estimates of the impacts** triggered by these hazards to generate the earliest impact information (mapping) to support the activation of community self-protection protocols, the rapid deployment of first responders in vulnerable areas, and the efficient management of the emergency.

For each hazard, this is achieved by setting the methodological approach shown in Figure 1.5: Real-time forecasts and estimates of the triggering phenomena are to be used as inputs in the hazard-assessment algorithms; the resulting hazard products are then combined with different layers characterizing exposure and vulnerability to describe the severity of the event in terms of the expected socio-economic impacts.

This new step ahead will need to capitalize on existing algorithms for hazard and impact assessment and extend them for improved impact forecasting/assessment in real-time integrating hazard forecasts with available exposure and vulnerability datasets considering factors such as scale application (from continental to regional and local) and data availability.

The **multi-risk approach** proposed (Figure 1.9) is defined as the integration of this scheme into a **unified real-time IEWS platform running algorithms for impact forecasting/estimation for the different types of weather/climate hazards**. Incorporating this impact-assessment capability for the different hazard types in the central processing core of the MR-IEWS platform supposes a significant step forward with respect to the results achieved up to now and gives direction to future works.

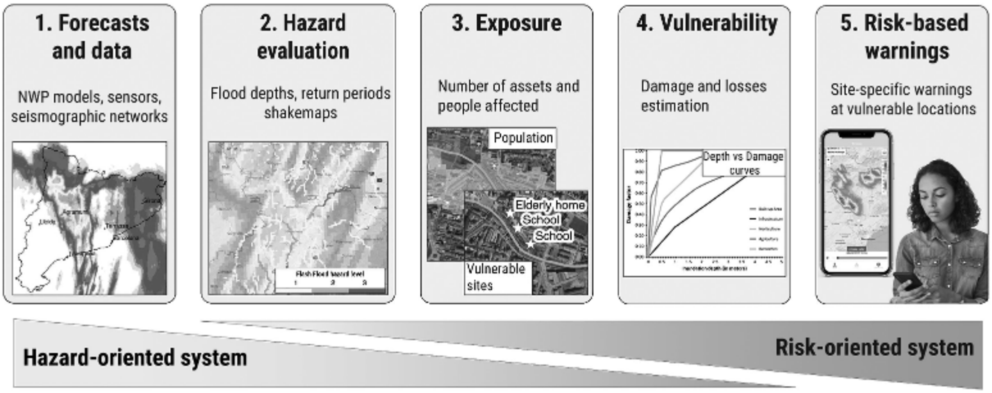

Figure 1.9 Scheme of the methodological approach to transform MH-IEWS into **multi-risk impact-based EWS** (MR-IEWS). *Source*: (5) Krakenimages.com / Adobe Stock.

Notes

1. https://www.europarl.europa.eu/news/en/press-room/20191121IPR67110/the-european-parliament-declares-climate-emergency.
2. https://www.cedamia.org/global/.
3. https://www.cedamia.org/global-ced-maps/.
4. https://ec.europa.eu/commission/presscorner/detail/en/ip_21_663.
5. https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe_en.
6. https://public.wmo.int/en/events/events-of-interest/un-global-early-warning-initiative-implementation-of-climate-adaptation.
7. https://www.thetimes.co.uk/article/germany-knew-the-floods-were-coming-but-the-warnings-didnt-work-cn99wjxzs.
8. https://www.munichre.com/en/solutions/for-industry-clients/natcatservice.html.
9. https://library.wmo.int/index.php?lvl=notice_display&id=17257#.Y_9UAi8zmZx.
10. https://www.efas.eu/en.
11. http://anywhere-h2020.eu.
12. https://home-affairs.ec.europa.eu/news/security-innovation-award-2022-2022-09-30_en.
13. https://www.dw.com/en/flooding-in-germany-before-and-after-images-from-the-ahr-and-eifel-regions/a-58299008.
14. https://www.efas.eu/en.
15. https://emergency.copernicus.eu.
16. http://anywhere-h2020.eu/services/multi-hazard-early-warning-platforms/a4eu/.
17. https://www.eumetnet.eu/activities/observations-programme/current-activities/opera/.
18. https://www.politico.eu/article/germany-floods-dozens-dead-despite-early-warnings/.
19. https://www.rtbf.be/article/comment-les-autorites-pouvaient-elles-anticiper-les-inondations-de-juillet-ce-que-disaient-les-previsions-europeennes-d-inondations-de-l-efas-10842799?id=10842799.
20. see http://anywhere-h2020.eu/services/multi-hazard-early-warning-platforms/a4eu/pilot-sites.
21. The full catalogue of products can be accessed at www.anywhere-h2020.eu/catalogue.
22. https://emergency.copernicus.eu.

23. The system is at present commercialised by ANYWHERE partners HYDS (www.hyds.es) and PREDICT SERVICES (www.predictservices.com) and is the base for a family of operational systems running in Ireland (Met Éireann), Spain (National Civil Protection), Catalonia (Civil Protection of Catalonia) and over 40 cities in Spain.
24. http://www.ingetecnia.com/en/consultori/pau.

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