Deliverable 1.2

Report on the most relevant methodologies and technologies for enhancing situational awareness and communication during geo and weather emergency events

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Executive summary

This deliverable investigates innovative methodologies and techniques that can **enhance situational awareness and facilitate risk communication** during geo and weather emergencies. The deliverable relies on the experience and expertise of **GOBEYOND** partners.

The structure of the deliverable is divided into 1) data collection, monitoring and analysis tools and 2) communication systems to enhance the situational awareness of authorities, responders, and citizens during emergencies. Each section explores the benefits, limitations, and challenges of implementing these technologies in the context of weather and geo events. Furthermore, this report examines the concepts of operational platforms and systems that integrate individual technologies to create a common operational map during emergencies, along with successful implementations by the **GOBEYOND** partners.

This report aims to guide emergency management professionals, authorities, and stakeholders in identifying the potential technologies and methods to enhance their situational understanding and, thus, build more resilient communities in the face of evolving geo and weather hazards.

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List of acronyms and abbreviations

AI	Artificial intelligence
API	Application programming interface
BRGM	Bureau de Recherches Géologiques et Minières
CB	Cell Broadcast
CEMS	Copernicus Emergency Management Service
COP	Common Operational Picture
CRAHI	Center of Applied Research in Hydrometeorology
DA	Drone analysis
DRM	Disaster risk management
EDO	Europe and Global Drought Observatory
EEWS	Earthquake Early Warning System
EFAS	European and Global Flood Awareness Systems
EFFIS	European Forest Fire Information System
EMSC	European Mediterranean Seismological Centre
EENA	European Emergency Number Association
EWS	Early Warning System
GDO	Global Drought Observatory
GIS	Geographic Information System
GloFAS	Global Flood Awareness System
GMPE	Ground motion prediction equation
GOBEYOND	GeO and weather multi-risk impact Based Early warning and response systems supporting rapid deploYment of first respONders in EU and beyonD
HYDS	Hydrometeorological Innovative Solutions, S.L.
ICT	Information and communication technologies
IoT	Internet of Things
KBS	Knowledge Base Service
LB-SMS	location-based Short Message/Messaging Service
LiDAR	Light Detection and Ranging
MNS	Mass notification systems
MTA	Multilingual Text Analyzer
NLP	Natural Language Processing
NWP	Numerical Weather Prediction
PANGEA	PANhellenic GEophysical observatory of Antikythera
PGV	Peak ground motion
PSAP	Public-safety answering point
PSL	Predict Safety Level
QCRI	Qatar Computing Research Institute
SAR	Satellite-based radar data
SaaS	Software as a service
SMA	Social Media Analysis
SMC	Social Media Clustering
SMS	Short Message/Messaging Service
SS-EWS	Site-specific early warning system
UAV	Unmanned Aerial Vehicle
UPC	Universitat Politècnica de Catalunya

1. Introduction

Situational awareness is crucial for authorities and responders during weather and geological events to effectively manage risks and coordinate response efforts. Understanding the current situation, anticipating developments, and communicating risks to the public are essential for minimising the impact of such events.

As part of **WP1** – *"Comparison and benchmarking of existing technologies to enhance response capacity and proposition of innovations"* – set of deliverables, **D1.2** presents a report on the individual methodologies and technologies for improving situational awareness and communication during geo and weather events, based on the experiences and expertise of the **GOBEYOND** partners and pilot regions. The results of this deliverable serve as a foundation for the dedicated benchmarking work presented in **D1.3,** *"Report on the recommended methodologies and technologies to enhance response capacity during geo and weather events to be integrated into the GOBEYOND platforms."*

Section 2 presents an overview of the methodologies and technologies for enhancing situational awareness, divided into two main subsections. The first subsection presents the individual techniques and tools employed for collecting real-time data, monitoring evolving situations, and extracting relevant information to enhance understanding of emergency events. From Internet of Things (IoT) devices to remote sensing technologies and crowdsourcing for rapid mapping, each methodology is presented in terms of benefits, limitations, and operational challenges. The second subsection focuses on the systems used for disseminating critical information and alerts to relevant stakeholders, people in the field, and citizens at risk. Public warning systems alongside innovative technologies such as social media platforms and smartphone applications are explored, highlighting their roles in facilitating rapid communication and response.

Section 3 introduces the concept of operational platforms that integrate the various methodologies and technologies presented in Section 2 to achieve a common operational picture during emergencies. Through implementation cases based on the expertise of the **GOBEYOND** partners, this section offers insights into the practical application and key elements of these systems in real-world scenarios. Finally, we conclude the deliverable by discussing the challenges and opportunities of integrating the above-presented tools to enhance situational awareness and communication within the emergency response to geo and weather hazards.

2. Enhancing the situational awareness and communication of authorities and responders: Current methodologies, technologies, and innovations.

During weather and geological events, maintaining a high level of understanding of the evolving situations is critical for authorities and responders to make informed decisions to effectively coordinate response efforts. This requires innovative methodologies and technologies to enable continuous monitoring and analysis of various factors such as the events' evolution, impacts, and emerging needs. In parallel, well-established and reliable communication systems are needed to facilitate the interaction between affected people, first responders, and emergency staff, as well as to swiftly inform as many individuals as possible of the latest status and guidance to minimise risk. This section of the report focuses on the individual methodologies, technologies accompanying them and innovations aimed at enhancing situational awareness and facilitating communication during weather and geo emergencies.

Section 2.1 provides an overview of emerging technologies to enhance situational awareness, from innovative approaches such as remote sensing technologies to crowdsourced data collection techniques and social media monitoring tools. Furthermore, Section 2.2 explores traditional and emerging communication and notification systems for delivering timely vital information and enabling effective crisis communication.

2.1. Methods and associated technologies for data collection, monitoring and analysis

Reliable technology and methods for rapid data collection, monitoring, and analysis are vital to enabling authorities and emergency responders to take informed and effective disaster risk reduction actions during weather and geological emergencies. These processes traditionally involve systematically gathering, processing, and interpreting critical local data from diverse sources to provide a broad picture of the potential risks, impacts, and active emergencies in communities and regions. Due to the surge of social media and wireless technology in the last decade, innovative methods and techniques for data collection, such as crowdsourcing, social monitoring tools, and Internet of Things (IoT) devices, have taken an important place in providing combined information to produce a common operational picture (see section 3.2) and enhanced situational awareness during fast-evolving emergencies.

The following section individually explores a selection of traditional and innovative technologies currently used in the context of weather and geological events from **GOBEYOND** partners and their regions.

2.1.1. Internet of Things (IoT) devices

The Internet of Things (IoT) refers to the network of physical devices, vehicles, and other physical objects integrated by sensors, software, and network connectivity, enabling them to collect and exchange real-time data with other devices or central systems (IBM, 2024). These IoT devices have become a key element in emergency management in recent years. They provide timely and diverse real-time data to authorities and responders in the field or at the central offices during ongoing events. They can enable the (i) real-time collection and analysis of key environmental and geological conditions; (ii) the monitoring of vulnerable infrastructure or locations; (iii) assist in the search and rescue operations; and (iv) effective communication and resource coordination. Examples of IoT devices are weather stations, geological and weather sensors (e.g., seismic, flood, air quality, and fire detection), traffic and surveillance cameras, and GPS-enabled devices.

The introduction of IoT for emergency management in urban areas has played a critical role in improving the situational awareness of emergency managers, allowing them to make informed decisions and implement timely emergency actions to mitigate risks and protect lives. The movement towards “Smart cities,” i.e., fully interconnected and automated urban areas through IoT devices, has gained momentum due to the benefits beyond emergency response. Nevertheless, the widespread adoption of IoT can pose several challenges, including operational costs, privacy and security concerns regarding data collection, storage and usage, and constant maintenance and device replacements.

2.1.1.1. Examples of IoT applications for emergency response

Maestro: Managing Forest Fires via IoT in Greece

A recent disaster management initiative in Greece is “Maestro: Managing Forest Fires via IoT” project. The project’s primary outcome is the Maestro telemetry system, designed to predict the risk of forest fires by utilising geolocated weather data gathered through sensor nodes. Sensor nodes provide a low-cost solution to reliably monitor the microclimate of forested areas and correlate the current conditions with possible prolonged drought. In case of fire, nodes fall into emergency mode by transmitting more frequent measurements to support the real-time prediction of how the fire spreads, for effectively managing the available firefighting forces, and for implementing appropriate population evacuation plans. The "Maestro: Managing Forest Fires via IoT" aims to address this challenge by leveraging IoT technology. The plan involves establishing a wireless sensor network in forested areas and optimising real-time monitoring and data collection. This network enhances evacuation plans, especially in urban-wildland interface zones, and improves the maintenance of firefighting equipment. By transforming sensor data into actionable insights, the Maestro system aims to contribute to more effective operational strategies and increased readiness for relevant security groups, including the Fire Department, Forestry Service, Local Government Organizations, and Civil Protection.

Smart Cities: Sentilo a municipal example in Catalonia (Spain)

The Barcelona City Council, through the Municipal Institute of Informatics (IMI), began the Sentilo project to define the strategy and actions necessary to position Barcelona as a global reference for Smart Cities. The main objective of the project is to exploit the information “generated by the city” and the layer of sensors deployed across the ground to collect and broadcast this information. For this purpose, the project developed the “Sentilo open-source sensor and platform” to fit into the Smart City architecture of any city that wants freedom and interoperability. By incorporating the local network of sensors, the Sentilo can provide information from the number of people and bicycles that cross the large avenues or arteries of the city, how many decibels the streets sound at, the temperature in each neighbourhood, and the air quality. The advantage of it being free software (published in a repository) is that any city in the world can adapt it and do the same thing that has been done in Barcelona. Implementations of Sentilo can be found across different municipalities in Catalonia, such as Terrassa and Barcelona, as well as public institutions (see Figure 1).

2.1.2. Remote sensing: Satellite imagery and emergency mapping

In recent years, the escalation in both the frequency and severity of extreme meteorological and geo events has sparked a heightened interest in leveraging remote sensing and processing technologies for emergency management and response. Remote sensing is the process of collecting information about an object, parameters, or phenomenon (e.g., flood events) without making any physical contact with it (Jensen, 2014). This is typically achieved by integrating sensors on satellites, aircraft, drones, or ground-based stations that detect and measure electromagnetic radiation emitted or reflected by the Earth's surface or atmosphere. Due to the existence of different types of remote sensing sensors, platforms, and techniques, their application is based on the requirement of end-users (e.g., the type of hazard to be mapped, the extent of the affected areas, required level of detail and temporal resolution) (Boccardo & Tonolo, 2015).

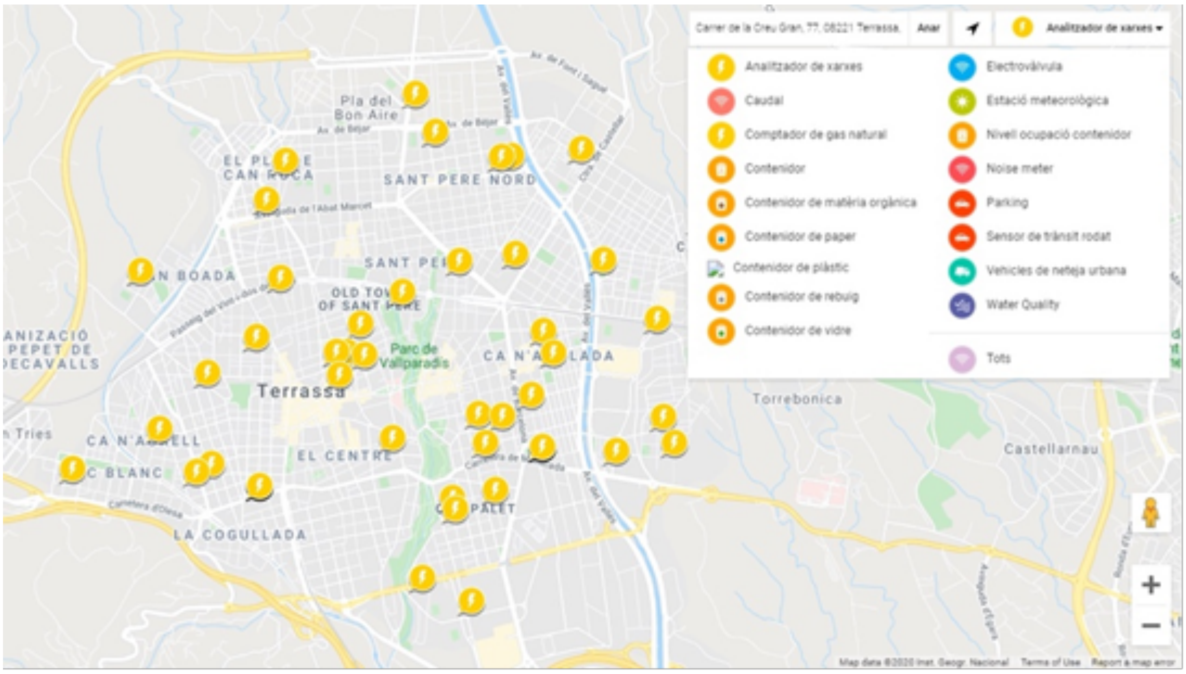


Figure 1 Sentilo IoT platform in Terrassa, Spain

For the emergency response phase, remote sensing technologies have proven essential for monitoring and assessing geological and weather hazards, quickly identifying affected areas, and supporting response efforts by contributing to situational mapping (see more information on situational maps in the context of operational platforms in section 3.2) (Schwarz et al., 2018). In this context, satellite-based radar data (SAR) and optical satellite imagery are two of the most recognised and widely used technologies. Often utilised together, they complement each other's limitations effectively where feasible. For instance, SAR can penetrate adverse weather conditions and dense vegetation, and measure ground deformations, terrain elevation, and subsidence—making them vital for monitoring weather and geological hazards (Cohen et al., 2022). However, they often have lower spatial resolution and require highly specialised algorithms and expertise for data processing (Cohen et al., 2022; Dhongade et al., 2022).

On the other hand, optical satellite imagery can provide high-resolution images with fine spatial detail. Thus, images are visually intuitive and easy to interpret when conducting damage assessments or post-event analyses. However, they rely on optimal weather conditions, making them highly sensitive to sunlight, cloud cover, haze, or atmospheric conditions, and have limitations for observing through dense foliage (Cohen et al., 2022).

Beyond SAR and optical satellite imagery, Unmanned Aerial Vehicles (UAV), such as drones, and LiDARs (i.e., Light Detection and Ranging) are also commonly used for acquiring data over broad areas. For example, UAV can enable authorities and responders to collect data from inaccessible disaster zones (e.g., flood and earthquake zones, landslides), and LiDARs can support the real-time mapping of affected areas during flood events (e.g., measurement of water levels), earthquake assessment (e.g., rapid 3d models) and support the monitoring of geospatial information.

However, like any technology, remote sensing also has its limitations. The data collection, post-processing, analysis, and validation of remote sensing require specialised skills and computational resources, thus increasing the implementation and operational costs. As a result, the situational maps generated by these technologies are mostly limited to on-demand products from international organisations in charge of producing them (see examples in 2.1.2.1). Moreover, based on the technology employed, spatial and temporal resolution, as well as weather and foliage conditions, can influence the quality and availability of up-to-date satellite imagery information. Finally, in the case of satellite imagery, the data may be restricted or subjected to licensing agreements, limiting the accessibility for specific users or regions (Cohen et al., 2022).

2.1.2.1. *Examples of remote sensing applications for emergency response*

Copernicus Emergency Management Service (CEMS)

One of the most recognised applications of remote sensing technologies is the European Copernicus Emergency Management Service (CEMS). CEMS monitors Europe using a combination of satellite, in situ (ground), and model data to provide specific users (e.g., EU Civil Protection Authorities) with rapid information about the scale and timeline of an ongoing disaster for emergency response and disaster risk management (DRM). In this context, CEMS offers two primary services: On-demand mapping and early warning and monitoring. The on-demand mapping provides detailed information for selected worldwide emergencies (artificial or natural) to aid in all the phases of the DRM cycle. This service consists of three modules: (i) Rapid mapping to support the emergency management activities in the immediate aftermath of a disaster; (ii) Risk and recovery mapping for the prevention, preparedness, and reduction phases; and (iii) Validation for quality control improvements. In parallel, the warning and monitoring services component of CEMS focuses on providing, through continuous monitoring and forecasting, anticipatory critical geospatial information for floods, droughts, and forest fires to assist with preparedness and emergency response. The European and Global Flood Awareness Systems (EFAS and GloFAS, respectively), the European Forest Fire Information System (EFFIS), and the Europe and Global Drought Observatory (EDO and GDO, respectively) are all part of the CEMS early warning and monitoring component. For more information, refer to **GOBEYOND Deliverable 1.1**, “*Report on the most relevant methodologies and technologies for enhancing the response capacity to geo and weather events*”.

European Crisis Management Laboratory – ECHO Daily Flash and ECHO Daily Maps

The European Crisis Management Laboratory (ECML) Mapping Team at the Joint Research Centre (JRC) works daily with the Emergency Response Coordination Centre (ERCC) to co-design and draft daily situational awareness products: (i) ECHO daily flash, snapshots or summaries on unfolding disasters and (ii) ECHO daily maps (see Figure 2 DG ECHO Daily Map for the Valencia flood event in 2024 (prepared by the JRC)) that depicts a significant event on a daily basis (short and fixed periods in time). Finally, the ECML also produces on-demand situation Maps/Infographics. As its name suggests, these flag tools are used by the General European Civil Protection and Humanitarian Aid Operations (DG ECHO) for its daily monitoring of disasters worldwide. They contribute to identifying high-risk areas, prioritising interventions, and facilitating communication with stakeholders based on authoritative and official information. The ECML uses a variety of data sources (e.g. satellite imagery, geographical and ancillary data, statistical repositories) to produce maps and situational reports that depict the spatial distribution of hazards, vulnerabilities, and capacities in coping with them.

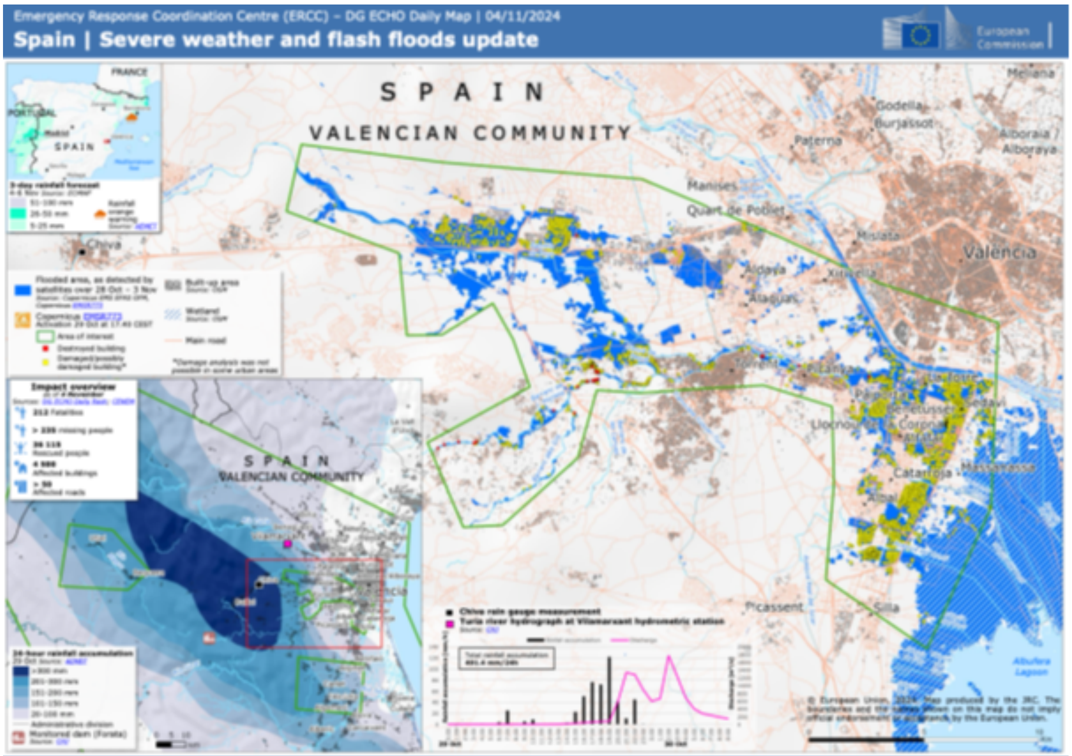


Figure 2 DG ECHO Daily Map for the Valencia flood event in 2024 (prepared by the JRC)

PANhellenic GEophysical observatory of Antikythera (PANGEA)

The PANGEA of the National Observatory of Athens (NOA) in Greece, provides through the implementation of ground-based lidars and sunphotometers, information for monitoring and issuing warnings due to volcanic ash, dust and smoke transport from forest fires. PANGEA - NOA uses the Polly^{XT} LiDAR (see Figure 3), a multi-wavelength Raman-polarization system with 24/7 operational capabilities, to observe the vertical distributions of the particle backscatter coefficient (at 355, 532, and 1064 nm) and the extinction coefficient (at 355 and 532 nm) (Baars et al., 2017; Engelmann et al., 2016). Thus, allowing aerosol classification and microphysical characterisation to derive the particle size distribution and concentration. The information from the Polly^{XT} LiDAR is automatically transferred to the Tropos site, a free-of-charge web portal focused on enhancing situational awareness of volcanic ash hazards by providing continuous and up-to-date worldwide LiDAR observations and categorisation. Additionally, PANGEA-NOA uses the CIMEL sunphotometer, a NASA-AERONET high-precision multiband, automatic sun-and-sky scanning radiometer that provides measurements of the optical properties of the atmosphere by measuring the radiance of the sun and sky. Due to its low power consumption and self-powered system, it meets the requirements of continuous monitoring in terms of reliability, long-term, and low maintenance cost. From CIMEL, the variables used for volcanic ash particles are columnar measurements of the aerosol optical depth, the Angstrom exponent, and the particle size distribution.

Figure 3 The Polly XT ground-based Lidar (left) and the CIMEL sun photometer located at PANGEA station (right).

Autonomous flight devices and analysis: Drone platforms and machine learning capabilities (beAWARE)

Drones, as UAVs, can carry a range of equipment, such as cameras and sensors, facilitating diverse data collection tasks. This enables them to provide distinctive aerial viewpoints and access remote areas difficult for humans to reach. Consequently, combining autonomous flight functionalities with advanced cognitive edge analytics presents opportunities for delivering life-saving solutions. During the **beAWARE** EU-funded project, different remote sensing techniques were implemented. A versatile drone platform was introduced to enable autonomous drone operations for data collection and analysis during emergencies. The drone platform captures media from onboard equipment and sends it to its analysis component, drone analysis (DA), responsible for visual processing. When the DA receives an analysis request, the component performs one of the predefined analysis tasks on machine learning image classification techniques (i.e., Convolutional Neural Networks). These are divided into (i) Object Detection to identify vehicles and people; (ii) Disaster detection for classifying the input images or videos between flood, fire, smoke, or others; and (iii) Evacuation to facilitate the monitoring of evacuation processes during a crisis. In parallel, the DA performs object detection and tracking to identify if a person is left behind and, thus, create the relevant alerts. Although the drone platform was developed under the **beAWARE** project, it was designed to work and be operated as independently as possible. Thus, the platform is simple to set up, initiate, and track operations involving drones. It is an extra component to provide material quickly, safely, and even in locations hard for people and ground vehicles to access.

2.1.3. Early Warning Systems: Algorithms and models for monitoring and forecasting

Early Warning Systems (EWS) are central to disaster risk reduction and emergency management by providing timely and effective information about potential weather and geological hazards (UNISDR, 2006). Through a combination of algorithms, data analysis techniques, and IoT devices, these systems enable monitoring and detecting specific weather and geo parameters linked to critical thresholds for warning activation. As a result, they can support authorities and responders in making informed decisions, mobilising resources, and implementing actions to mitigate the potential negative consequences of upcoming natural events.

Monitoring and forecasting systems can be integrated with various models and algorithms according to the weather and geological hazards in a region. From flood forecasting to producing seismic hazard and shake maps, these systems can be designed and tailored to the specific hazards and risks. Furthermore, in the last decade, there has been a joint effort – supported by international organisations – to move from only forecasting weather and geological parameters to providing information on the potential impacts and risks for urban areas and their specific sectors (International Federation of Red Cross, 2020). For more information on currently available models and algorithms for providing forecasts during weather and geological events, refer to **GOBEYOND Deliverable 1.1**, "*Report on the most relevant methodologies and technologies for enhancing the response capacity to geo and weather events*".

2.1.4. Crowdsourcing for data collection and rapid impact assessment

Accessible internet connections and the widespread use of smartphones have opened the door for citizens to actively contribute alongside emergency responders during weather and geological events. Moreover, previous research has revealed the willingness of citizens to communicate with authorities and provide real-time emergency information (Meléndez-Landaverde & Sempere-Torres, 2023). In this context, crowdsourcing initiatives can rapidly trigger emergency actions, such as mobilising volunteers to contribute to data collection efforts or response actions from authorities. Volunteers can provide valuable real-time information to authorities and responders by submitting reports on incidents or damages in affected areas using mobile apps, social media platforms, chatbots or dedicated crowdsourcing platforms. In return, crowdsourced data can facilitate the rapid impact assessment during an emergency by providing situational updates, identifying areas of concern, and thus, prioritising immediate response actions (Liang et al., 2019).

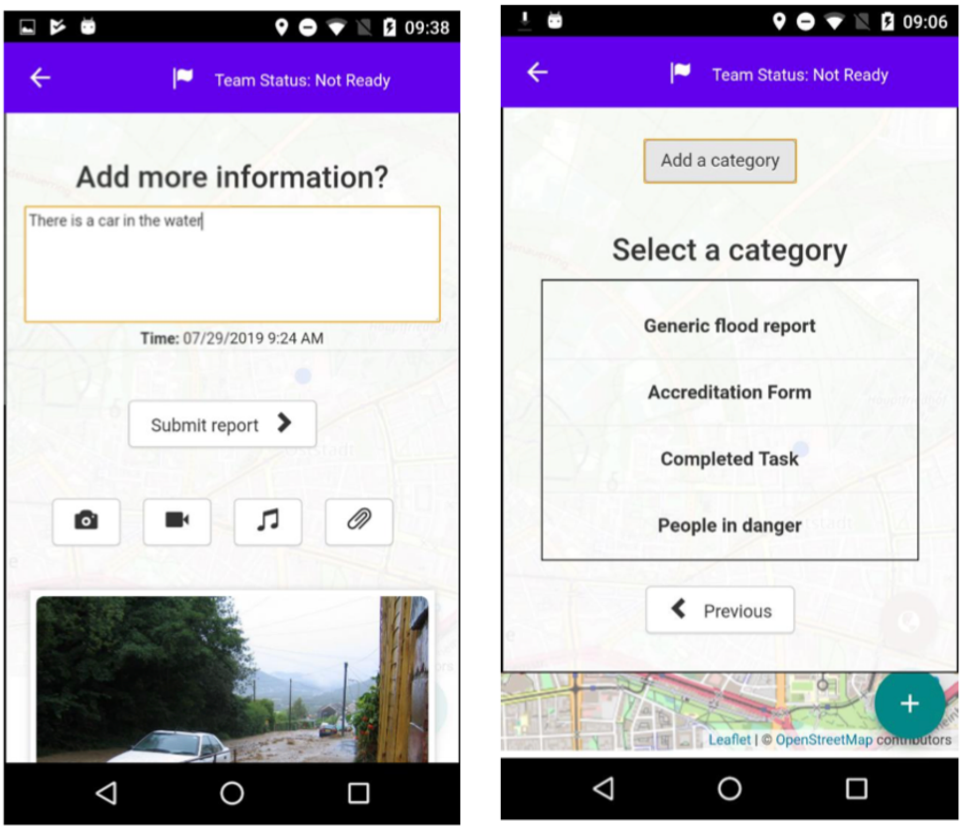
However, similar to new technologies, mobile apps and dedicated platforms have inherent obstacles to first installation, adoption, and continuous usage (Fischer-Preßler et al., 2021). One solution is the parallel integration of Chatbots within popular social and communication platforms such as Telegram, WhatsApp, Facebook Messenger, and X (formerly known as Twitter). Chatbots are automated conversational agents powered by artificial intelligence (AI) algorithms that can interact with users when prompted. Through structured questions, geolocation access, media uploads, and natural processing techniques, chatbots can guide users in facilitating emergency information for further analysis. Responders can aggregate and visualise the collected information to enhance their situational awareness, allocate resources to critical areas, and identify hotspots during emergencies.

Finally, ensuring the quality and reliability of non-biased crowdsourcing data has become a significant area of research in crowdsourcing techniques (Esparza et al., 2023; Gupta et al., 2022). Different methods to group or public validate (through other volunteers) and cross-reference the collected data with official sources can help mitigate concerns about accuracy (Tavra et al., 2021). Due to the surge of self-organised volunteer groups, information reliability can also be improved by categorising the data based on its source, such as informal – volunteers have no official ties or basic training from authorities – and formal digital volunteers trusted and pre-approved by authorities (Horstmann et al., 2018; Reuter & Kaufhold, 2018).

2.1.4.1. Examples of crowdsourcing techniques for emergency response

Chatbots for collecting citizen data

The **beAWARE** EU-funded project introduced crowdsourcing solutions to support emergency responders and authorities during a crisis. These solutions involved mobile applications for civilians, first responders, and control centres. The developed technologies served as channels for users to provide real-time field information to authorities, which is then fed into the **beAWARE** platform for analysis by various modules, integrating the results into the overall situational picture. The mobile application's main screen facilitates sending incident reports to authorities, including essential details like time, position, categorisation, textual information, and multimedia files. Time and position are automatically filled using system time and GPS, though users can specify a different location by tapping on the map. Moreover, reports are categorised for clarity; for example, civilians can choose from default categories (see Figure 4), while first responders have the option of providing more detailed information.



Add more information?

There is a car in the water

Time: 07/29/2019 9:24 AM

Select a category

Figure 4 **beAWARE** crowdsourcing solutions: Main screen of the mobile application for incident report (right) and categories for incident reporting (left)

Before users submit their report, these are presented and summarised. The app allows users to add further information in the text field evaluated by the **beAWARE** platform's text analysis module (see more in Hertweck & Hellmund, 2019). Likewise, multimedia files like images, videos, or audio recordings can be attached, aiding in assessing the significance of the report by identifying vulnerable objects and potential threats. Users can select the most suitable modality or combination to describe an event, given that all elements are optional.

The European company FloodTags B.V., has developed FloodTags, a chatbot that enables users to send geo-located reports (e.g., text or images) for further analysis using artificial intelligence and natural language processing. Similarly, RiskMap, a project from the Massachusetts Institute of Technology, harnesses the power of citizen reporting without installing new applications. Users can provide reports to the Risk Map chatbot by direct messaging it on Twitter, Facebook, or Telegram. In response, the chatbot provides users with a one-time link to input data such as location, flood depth, a picture, and a description. The information collected through the chatbot feeds the live risk map, where citizens and responders visualise (and cross-validate) the information submitted by other users. RiskMap has been implemented in different countries and has had significant success during emergencies in Indonesia and Japan (MIT News Office, 2017).

Finally, the Euro-Mediterranean Seismological Centre (EMSC) launched the initiative LastQuake, where citizens and seismologists can share reports based on an earthquake they have experienced. After an earthquake, citizens can inform seismologists via a report with comments, pictures, videos, and testimonies. In parallel, seismologists support citizens by releasing technical information on location, magnitude, safety tips, and intensity estimates based on citizen reports. As stated by EMSC, bringing citizens into risk management allows the dissemination of local information, improves the situational awareness of citizens at risk or located in surrounding areas, and improves the resilience and response of communities. LastQuake employs a multi-channel approach using a Twitter bot, desktop, website and a mobile app to collect and share reports.

2.1.5. Social media monitoring tools

During an emergency, it is crucial that crisis managers quickly understand the extent of the situation, primarily through the development of “big picture” maps. In the last decade, significant efforts have been made to use social networks to help build this overall picture during emergencies. Monitoring social media can enrich crisis managers' situational awareness of the effects of ongoing events by capturing first-hand information from citizen sensors. However, it's not easy for practitioners to make this data easily usable, which means it must be filtered, enriched, and made reliable on the fly. Despite the great diversity of social media platforms, very few are adapted for operational monitoring in case of an ongoing event. First and foremost, social networks need to be monitored in real-time and have sufficiently large user communities to provide helpful feedback from the field.

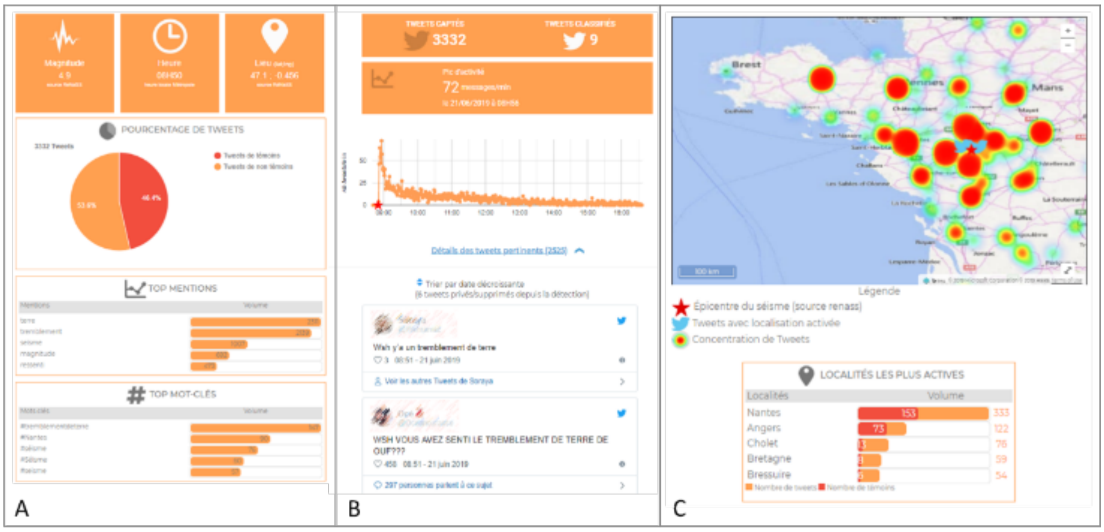
Until February 2023, Twitter proposed helpful features for crisis monitoring: the publication of short messages in real-time, the streaming API that made it possible to automate monitoring tasks, the ability to join images, etc. Although Twitter/X is probably not the most widely used social media, its user community remains significant. Therefore, the occurrence of natural disasters often results in the massive and immediate spread of tweets, leading to the consideration of the Twitter platform as a valuable Distributed Sensor System (Crooks et al., 2013). In practice, the richest information generally comes from the citizens closest to the disaster area. Because natural disasters affect their immediate environment, these “local citizens” (Grace et al., 2017) are indeed more inclined, both in the physical and digital sphere, to help or exchange objective information about the situation on the ground (Starbird et al., 2012). Thus, after the occurrence of natural disasters, many users of social networks concerned by the situation massively exchange information concerning the intensity of the events as they perceive them: either via a description of the phenomena themselves (severity of earthquakes, the extension of flooded areas, wind strength, etc.) or their effects (damage to buildings and infrastructure, shutdown in transport, energy or telecommunications networks, victims, etc.).

Because social media monitoring must be done as automatically as possible (Montarnal et al., 2017), difficulties are mainly related to the need for more tools for effectively monitoring these data. This requires meeting many challenges known as Big Data's “V”: “volume” (i.e., massive amount of data to process), “velocity” (i.e., need for fast computation), “variety” (i.e., heterogeneity of data to merge), “veracity” (i.e., qualification of inferred information) (Castillo, 2016). The difficulty increases with the style of the tweets: short texts that are closer to spoken than literary language, which requires specific Natural Language Processing (NLP). In this context, social monitoring tools must enable successively (i) collect (level of the data) and (ii) interpret (level of information) posts coming from social media platforms so that they can (iii) be exploited (level of knowledge). It is worth noting that methods for analysing messages posted on social media have made great strides in recent years and have become relatively mature for text and image analysis. However, the majority of studies available to date have focused on the English language, and transposition to multilingual models is not easy to deploy in the absence of annotated reference datasets in other languages.

2.1.5.1. *Examples of social media monitoring platforms*

SURICATE Nat platform

To support crisis management practitioners in France and French-speaking countries, the SURICATE-Nat platform has been developed by BRGM (i.e., French geological survey) for the continuous monitoring and analysis of original tweets (i.e., excluding retweets) written in French after the occurrence of natural disasters (earthquakes and floods) (Auclair et al., 2019).



Wsh y'a un tremblement de terre
3 08:51 - 21 juin 2019

WSH VOUS AVEZ SENTI LE TREMBLEMENT DE TERRE DE OUF???
458 08:51 - 21 juin 2019

Figure 5 Suricate-nat website for the earthquake of June 21, 2009.

(A) The synthesis screen has a reminder of the characteristics of the earthquake at the top, a pie chart in the middle representing the proportion of the captured tweets classified automatically as coming from witnesses of the earthquake and a display of top mentions and top hashtags at the bottom.
(B) The screen shows earthquake-related Twitter activity as a timeline and tweet list.
(C) The location screen has a heatmap view of the location of the captured tweets with geotagged (either native geotags or inferred ones) at the top and a list of the most active cities with distinctions in the tweet count between witnesses and non-witnesses at the bottom.

Each tweet captured via the Twitter streaming API is processed to extract thematic information and a preferred geolocation. In addition to feeding a dashboard contributing directly to situational awareness (see Figure 5), this enriched Twitter data can also be merged with instrumental data (i.e., measurements from seismometers) to refine the rapid estimation of seismic intensity (Fayjaloun et al., 2021). Another well-known platform is the AIDR platform from Qatar Computing Research Institute (QCRI), which offers services for processing images contained in tweets, recognising and classifying damage reported after disasters and landslides.

In this context, Pennington et al. (2022) developed a system for monitoring Twitter/X for content related to landslides. This involves collecting photographs to discern and retain important information. To categorise the pictures as either depicting a "landslide" or "non-landslide," the system employs the landslide classification model SoftMax. This demonstrates the platform's effectiveness in rapidly disseminating valuable data related to landslide events, showcasing its potential as a dynamic tool for early detection and response.

beAWARE algorithms

Within the **beAWARE** EU-funded project, two modules for social media monitoring were developed: Social Media Analysis (SMA) for gathering and verifying Twitter posts and Social Media Clustering (SMC) for organising tweets in a spatiotemporal manner (Koulalis et al., 2019). The SMA uses Twitter's Streaming API to collect tweets in English, Italian, Greek, and Spanish containing specific keywords related to flood, fire, and heatwave incidents. Following the data collection phase, SMA employs a three-step validation process to filter out fake or irrelevant tweets. This process involves detecting fake posts, identifying irrelevant emoticons or emojis within the text, and classifying tweets based on their relevance to the examined use cases through visual and textual analysis. Validated tweets are then passed to the Multilingual Text Analyzer (MTA) for concept extraction and the Knowledge Base Service (KBS) to populate relevant incidents. The MTA component extracts concepts and conceptual relations from natural language text sourced from social media or audio message transcriptions in English, Greek, Italian, and Spanish. Similar to other analysis modules, MTA produces an ontology-ready representation, mapping extracted concepts and relations to classes and properties within the project ontology.

Regarding the evaluation of the SMA module's performance, key indicators such as precision, recall, and F-score are utilised to assess its effectiveness. The SMC module, on the other hand, relies on messages from MTA to group tweets based on location data. Upon reaching a sufficient number of tweets or a significant time interval since the last tweet, SMC conducts spatial clustering. The resulting clusters are presented as separate HTML files, known as Twitter Reports, each containing a list of tweets within the cluster. These reports are then sent to the KBS to generate corresponding incidents.

Finally, it is essential to mention that the transformation of Twitter's social network into X has introduced data collection limitations. Platforms, such as SURICATE-Nat or the **beAWARE** algorithms, have lost the free access to dynamically perform data collection in real time. In doing so, X has aligned itself with all the other major platforms that only distribute their data on a pay-per-use basis, with access costs prohibitive for civil security applications. As a result, only certain accounts have been privileged to retain "gold-free access" to the X'APIs, such as the European-Mediterranean Seismological Centre (EMSC).

2.1.6. Comparison of methodologies and technologies accompanying them for data collection, monitoring, and analysis to enhance situational awareness

Table 1 compares the benefits and limitations of the methodologies and their linked technologies for data collection, monitoring, and analysis to enhance situational awareness. It also presents operational challenges to overcome or consider when implementing these methods.

Table 1 Benefits, limitations, and operational challenges of methodologies for data collection, monitoring, and analysis to enhance situational awareness

Method	**Benefits**	**Limitations**	**Operational Challenges**
Internet of Things (IoT) Devices	- Enables real-time monitoring and data collection in an area across devices - Supports fully interconnected urban areas or “smart cities” - Enables early warning and detection	- Implementation costs (i.e., installations of devices and networks) - Operational costs (i.e., replacements) - Privacy and security concerns regarding data collection	- Integration with existing infrastructure - Reliability and connectivity during emergencies or harsh conditions - Data management and analysis of large data volumes
Remote-sensing: Satellite imagery	- Wide-area coverage for data collection - High spatial resolution of a disaster area	- Weather dependence - Costs and accessibility - Foliage sensitive - Revisit times may be limited	- Delays in data acquisition or limited fast availability - Data quality and reliability due to weather and foliage
Remote - sensing: UAV	- High-resolution aerial imagery and video footage of disaster areas - Remote access to hazardous areas - Rapid deployment	- Limited flight endurance - Weather sensitivity - Limited autonomy and control	- Implementation and operational costs - Regulatory compliance - Specialized skills for operation and post-processing
Rapid mapping (situational maps)	- Rapid, visual information for a common situational awareness - Supports decision-making, response and recovery coordination	- Potential information overload - Quickly outdated during fast-evolving crises - Rained users for accurate local analysis	- Implementation and operational costs - Specialized and interdisciplinary skills for processing - Delays in data acquisition or limited fast availability
Early Warning Systems: Algorithms and models	- Timely risk identification - Enables appropriate emergency response and planning	- Warning threshold sensitivity - Data quality and availability -Reliability of forecasts	- Integration of multiple data sources across hazards - Validation and calibration - Incorporation to emergency plans
Crowd-sourcing	- Rapid real-time data collection - Engagement and empowerment of communities and individuals - Cost-effective - Does not required specialized tools in most cases	- Authenticity and verification of data - Data quality - Bias and representation - Digital divide (i.e., inequality in access) - Risk of Misinformation and Rumours	- Community engagement and participation - Quality control and verification - Compliance with privacy and ethical legislations
Social media monitoring	- Early Warning and general impact identification - Detection of hotspots and high-impact locations - Rapid- real time data collection from at-risk individuals	- Information overload - Bias and misinformation - Dependency on third party technologies - Risk of Misinformation and Rumours	- Rapid data volume and management - Operational costs for data processing and storage - Compliance with privacy and ethical legislations - Quality control and verification

The selection of the most suitable approach or combination of approaches to create a common operational picture during emergencies (see section 3.2) will depend on the requirements, resources, and needs of emergency entities, responders, and communities.

Situational awareness is critical for guiding the decision-making processes and actions of authorities and responders during emergencies. However, it relies on the fast availability and interpretation of real-time data. Table 1 can serve as an overview to understand the complexities and benefits of implementing the listed methods for enhancing situational awareness.

2.2. Emergency communication and notification systems

Due to the explosive and rapidly evolving nature of geo and weather emergencies, integrating response and effective risk communication mechanisms to support authorities, responders, and citizens during emergencies is essential and a significant challenge. Aligned with target G of the Sendai Framework for Disaster Risk Reduction, end-to-end EWS must issue understandable, actionable warnings and reach the largest number of exposed individuals in the shortest time possible (UNISDR, 2015). Communities expect hazard and local impact information to be readily available and accessible, especially when the time window for action during emergencies is limited (Dallo & Marti, 2021).

Information and communication technologies (ICT) have become promising tools to support the rapid dissemination of warnings, process and share real-time emergency information, and establish communication channels between authorities, responders, and citizens during evolving flood emergencies (Grinko et al., 2019). While the traditional methods of dissemination (e.g., TV news and radio) remain essential sources of information, the increasing number of people using wireless technologies with accessible internet connection allows the exploration of more flexible and innovative methods for flood risk communication (Stanciugelu et al., 2017).

2.2.1. Public Warning Systems: Cell broadcast and location-based mass notification systems

Effective end-to-end early warning systems must ensure that triggered warnings and critical behavioural advice reach everyone and every sector at risk with enough time to actively take self-protection actions. In this context, mass notification systems (MNS) are an integral component of emergency management systems, facilitating the widespread dissemination of critical information to at-risk populations and responders in the field during weather and geological events. Usually integrated with EWSs, MNS employs different technologies, including mobile networks, to reach a large audience and provide timely emergency guidance.

The technologies or combinations to be used with MNS are based on the needs and requirements of the target audience. From these, Cell Broadcast (CB) and location-based SMS (LB-SMS) technologies have become vital for authorities to communicate emergency information to people at risk or responders in the field. CB makes it possible to send emergency information for them to be displayed on the screen of a mobile device. These messages are sent in real-time with location-specific information to users in an area who have subscribed to the service and have phones supporting CB alerts. Since CB is, as its name suggests, a broadcast, it only takes authorities to send one message to potentially reach all subscribers on the network without identifying the number of mobile devices located in the affected area, thus preserving the privacy of users (European Emergency Number Association, 2019). Although users can opt out of receiving CB messages on their mobile devices, emergency alerts mandated by government authorities (e.g., presidential alerts or national disaster agencies) could still be delivered to all devices within a designated area (EENA, 2019).

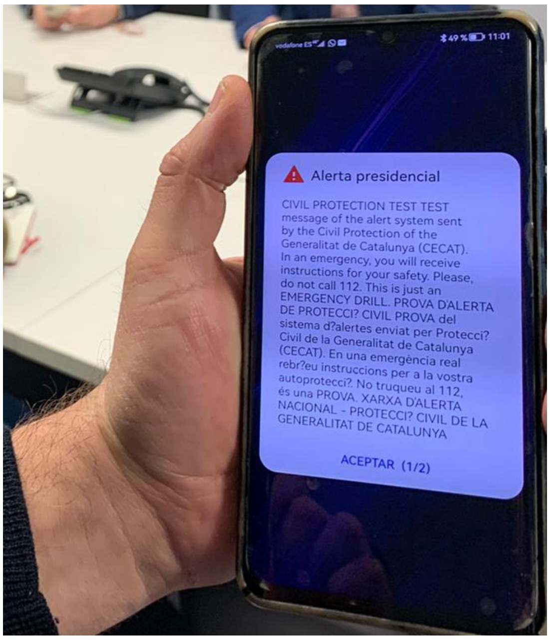
Similarly, LB-SMS sends information to mobile devices but uses a combination of SMS and cell-based location. Hence, LB-SMS identifies the devices (and amounts) within a particular geographic location to send individual SMS with targeted information. In contrast to CB sending a general message in an area, LB-SMS can deliver specific warning information to citizens and emergency responders entering a dangerous area (or leaving it) in a particular language (based on country code device) and retrieve delivery reports (e.g., successful delivery) (EENA, 2019). Additional features or functionalities can be integrated with LB-SMS, such as embedded links to confirm their safety status. Finally, it is important to mention that LB-SMS have limitations and challenges. There are privacy concerns regarding the need for network operators to always keep a database of mobile devices in the target location. Moreover, users cannot opt out of receiving LB-SMS; the only alternative is to turn off their devices.

In 2018, Article 110 of the European Electronic Communications Code made it mandatory for all the Member States of the European Union to deploy a Public Warning system using telephone networks to alert everyone located in a specific area of an ongoing crisis or upcoming disaster by June 2022. While the legal deadline has long passed (more than three years as at the time of this report), implementation across the EU remains uneven. Although most Member States have now deployed mobile-based public warning systems, others are still in various stages of testing, hybrid implementation or partial controlled rollout (EENA, 2025). Procurement coordination, limited technical capacity, and uncertainties regarding governance responsibilities between telecommunications authorities and civil protection agencies have slowed and hindered the successful implementation of this technology (EENA, 2025b; GSMA, 2023).

Although modern technology can reach tens of thousands of people in seconds, it is still insufficient to provide the population with adequate information about impending danger or encourage appropriate behaviour (Medina & Máyer, 2025). As the EENA rightly points out, it is up to each country to ensure that it has a proper doctrine and procedure for using these public alert systems effectively.

2.2.1.1. Examples of mass notification systems

In Europe, a significant number of countries adhere to the EU-Alert standard. The ETSI (European Telecommunications Standard Institute) defines the EU-Alert as the European Public Warning Service based upon CB Technology (ETSI, 2019). Countries adhering to the framework can be recognised by replacing the letter EU with their country identification letters (e.g., NL-Alert). Based on the legislation of each country, the public can receive different types of alerts in the range of extreme threat alerts (e.g., tsunami, flooding) to drill messages. To comply with Article 110 mentioned above, several countries already have fully functioning systems based on the EU-Alert standard or are in the testing stage. Although the majority are focused on adhering to the CB technology, some countries, such as Belgium (BE-Alert) and Sweden (VMA), have integrated the capabilities of LB-SMS into their public warning services to fulfil Article 110. The Ministry of Interior of Spain, through the Directorate-General for Civil Protection and Emergencies, started testing in late 2023 the ES-Alert service across the country (see Figure 6). A sound and vibration accompanied the warnings to notify users they had received a drill test message. The system, also called "reverse 112", allows authorities to broadcast alerts in affected areas due to emergencies or imminent catastrophes. Coincidently, the authorities of the autonomous community of Madrid sent an ES-Alert to its region for the first time due to extreme weather. The messages were received with controversy, with some users considering the method excessive for the actual impacts reported, while others raised privacy concerns (El Debate, 2023). As with other emergency communication methods, a saturation of messages or false alarms can hinder the credibility of the system with the public, diminishing the impact and the actions triggered by communities.



Alerta presidencial

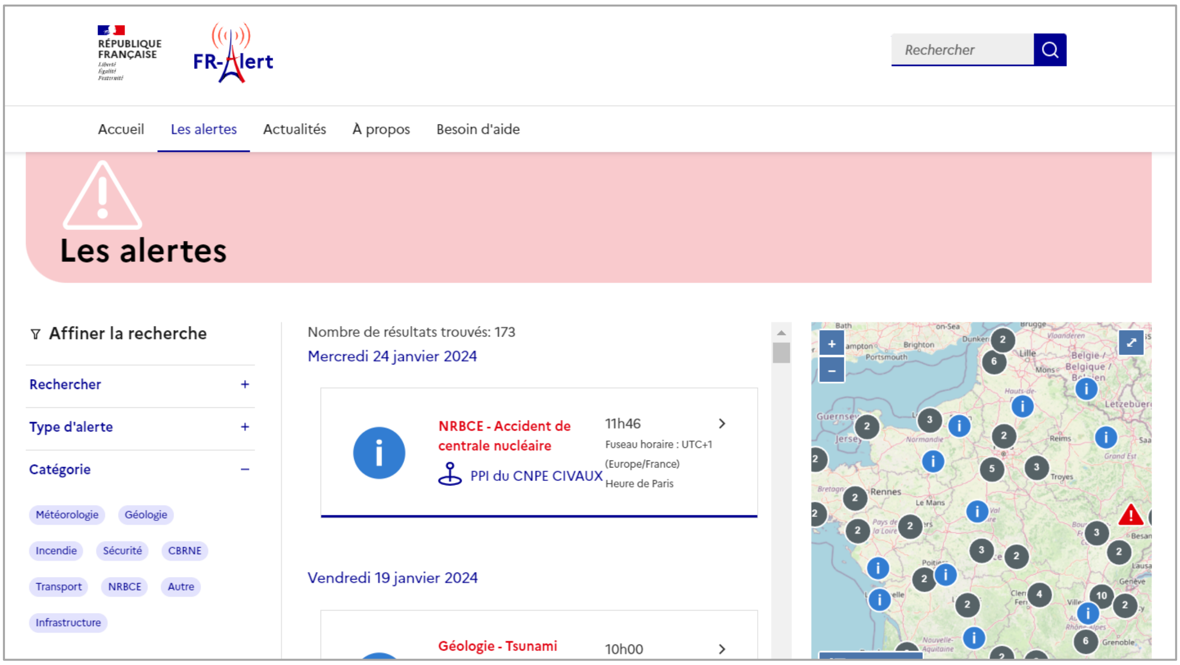
CIVIL PROTECTION TEST TEST message of the alert system sent by the Civil Protection of the Generalitat de Catalunya (CECAT). In an emergency, you will receive instructions for your safety. Please, do not call 112. This is just an EMERGENCY DRILL. PROVA D'ALERTA DE PROTECCI? CIVIL PROVA del sistema d?alertes enviat per Protecci? Civil de la Generalitat de Catalunya (CECAT). En una emergència real rebr?eu instruccions per a la vostra autoprotecci?. No truqueu al 112, és una PROVA. XARXA D'ALERTA NACIONAL - PROTECCI? CIVIL DE LA GENERALITAT DE CATALUNYA

ACEPTAR (1/2)

Figure 6 ES-Alert (provided by Protecció Civil de la Generalitat de Catalunya)

In France, the FR-Alert system has been operational since the summer of 2022 upon activation by government departments. The system opts for a multi-modality approach, using two complementary technologies, LB-SMS and CB. At the European Union level, France's choice of dual-mode LB-SMS and CB is also shared by Croatia, Estonia, and Malta, countries with much smaller populations than France (Douvinet et al., 2021). The national FR-Alert system is complemented by local alert tools operated by private companies on behalf of local authorities (municipalities) or companies to alert their populations and employees in the event of danger. These are mainly solutions based on mobile applications or automated systems for sending mass SMS messages to lists of subscribers. In the general population, 95% of French people are equipped with cell phones (enabling them to receive LB-SMS alerts) and 81% with smartphones (enabling them to receive CB alerts), but this distribution is not uniform.

Hence, individuals lacking access to modern amenities are predominantly observed among the elderly population, as well as those with lower socioeconomic statuses, individuals living in isolation, unskilled workers, farmers, and residents of rural areas (INSEE, 2022). It is also worth noting that the rate of non-equipped people is twice as high in the French overseas departments as in mainland France. This underlines the fact that the FR-Alert system cannot reach the entire population. Another limitation of national systems such as FR-Alert is their time latency in delivering alerts, which can take several minutes. While such delays are acceptable in most hazardous situations, this is not the case for very fast-kinetic phenomena that require alerts to be disseminated to exposed populations in a matter of seconds: this is the case, for example, with early seismic warnings. The new national FR-Alert system has been operational since the summer of 2022 upon activation by government departments. A website allows users to follow all the alerts issued via FR-Alert, whether in real-life conditions or during exercises (see Figure 7).



Les alertes

Nombre de résultats trouvés: 173

Mercredi 24 janvier 2024

NRBCE - Accident de centrale nucléaire
PPI du CNPE CIVAUX
11h46
Fuseau horaire : UTC+1 (Europe/France)
Heure de Paris

Vendredi 19 janvier 2024

Géologie - Tsunami
10h00

Figure 7 Website for monitoring diffuse alerts via FR-Alert

2.2.2. Social media platforms

Timely information during emergencies is key to enabling effective and appropriate protection actions to reduce potential negative impacts. The exponential growth of social media users in the last decade has opened the opportunity to use these platforms as real-time one-way and two-way communication channels alongside existing official sources (Statista, 2023). During disasters, citizens turn to social media to seek updates, share reports, and request assistance and instructions. The user-friendly nature of social media platforms and their integration with day-to-day activities makes them a straightforward tool for emergency managers and authorities to quickly disseminate massive risk information during a crisis. They can connect directly with thousands of citizens and people in at-risk areas by creating and distributing emergency messages, alerts, and updates without needing a specialised platform. Thus, with just a few clicks (or taps on the phone), authorities can publish updates on evacuation orders, shelter locations, road closures, and other critical information to support the affected population and the emergency actions of responders on the field. Likewise, the versatility of social media platforms allows the use of diverse communication formats (e.g., images, videos, and infographics) to enhance the understanding of emergency information.

However, there are clear disadvantages associated with social media. Rumours and fake information can be similarly massively disseminated during emergencies, causing confusion and panic and hindering response efforts due to mistaken guidance (Mirbabaie et al., 2021). Moreover, the volume of information disseminated during emergencies can overload the targeted audience, making it harder to discern accurate and locally relevant information for risk reduction. Authorities have approached these limitations by creating (and verifying) institutional accounts on different social media platforms, especially in the social media platform X. As a result, users and pertinent emergency stakeholders have confidence that the critical information disseminated by these accounts is authentic and officially endorsed. Finally, social media platforms as third-party companies do not have any formal involvement in the official risk communication strategies of authorities. Thus, they are not legally bound to guarantee service or maintain continuity during emergencies.

2.2.2.1. *Present difficulties of institutional social media accounts for emergencies*

The usage of social media platforms by authorities during emergencies is extensive. Nowadays, it is standard for official authorities to have a dedicated social media account for disseminating warning information or the latest updates during emergencies. For example, in Spain, the local civil protection agencies publish the locally relevant official warnings activated by the regional authorities alongside specific emergency actions such as closures and evacuations. These accounts are usually interconnected with other official offices to communicate a unified message during emergencies. Moreover, they enable direct interaction with citizens during emergencies. However, the latest move of Twitter to X, one of the most popular social media platforms for risk communication, has introduced concerns about the content shared within the platform. The changes in content moderation policies have amplified the dissemination of fake content and decreased the trust of users in the credibility of the information shared on the platform (Bloomberg, 2023). This phenomenon demonstrates that although social media accounts are a powerful tool for mass notification and interaction, they cannot be the primary source of emergency communication.

2.2.3. Smartphone applications for natural crisis management

Mobile hazard crisis apps began to be formally adopted in the past decade to help facilitate the distribution of warning messages and direct interaction with different stakeholders during emergencies (Reuter, Kaufhold, & Knipp, 2017). In light of this, various hazard crisis apps (e.g., specialised or multi-hazard) have been designed with features to help the communication and information-sharing process between responders, authorities, and possibly impacted end-users. In the last decade, the technical capabilities and the challenges for real-time application of hazard crisis apps have been the main research focus for emergency-specific technological platforms and apps related to disaster management (Colombelli et al., 2020; Dallo & Marti, 2021). However, acknowledging the importance of employing people-centred design methodologies, the latest work on crisis apps is shifting from the common technological perspective. In this context, the latest research has focused on exploring how apps and their features can effectively support the decision-making process of end-users (Paul et al., 2021). Recent research has looked at several areas, including the end-user's perspective on the usefulness of hazard crisis apps in times of emergency, the functional appropriateness of their features to support their decision-making process, and the technical implications on learnability and social adoption. (Dallo & Marti, 2021; Fischer-Preßler et al., 2021).

Finally, as mentioned in section 2.1.4, hazard crisis apps and dedicated platforms have inherent obstacles to first installation, adoption, and continuous usage (Grinko et al., 2019). As demonstrated by the COVID-19 pandemic, the number of active users has a significant impact on the long-term efficacy of hazard crisis apps during emergencies (Trang et al., 2020). Although the acceptance and public knowledge of hazard crisis apps have increased, the level of integration of these specialised apps in society and maintaining a stable user base are some of the main challenges (Fischer-Preßler et al., 2021). Moreover, vulnerable groups risk being overlooked when considering the design and technical requirements of hazard crisis apps (Paul et al., 2021). However, recent research suggests that groups identified as at risk of being excluded or neglected might have a different perception of hazard crisis apps. For instance, while the elderly have traditionally been characterized as resistant to technology, a recent study by Appleby-Arnold et al. (2019) indicates that these demographics can exhibit a favourable disposition toward utilizing hazard crisis apps to enhance their responses during emergencies.

2.2.3.1. Examples of smartphone applications for natural crisis management

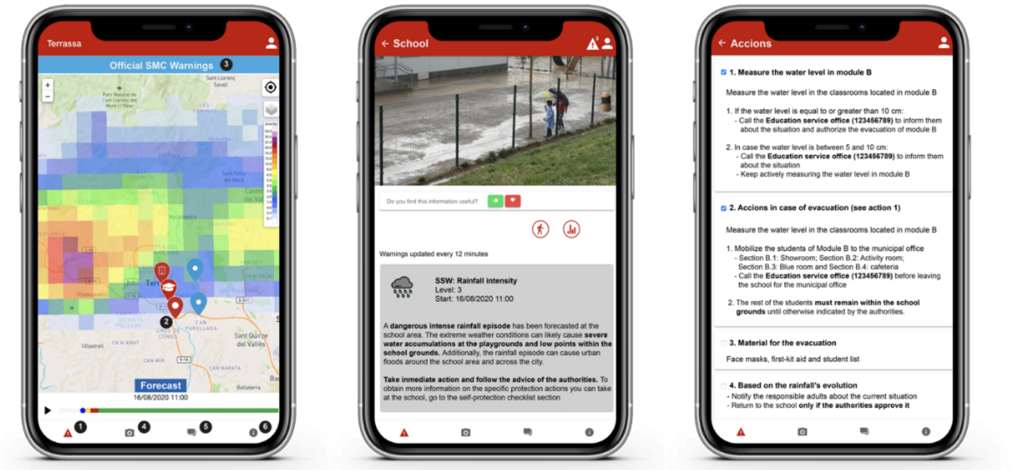
A4alerts mobile app

The A4alerts is a mobile crisis app developed by the Centre of Applied Research in Hydrometeorology of the Universitat Politècnica de Catalunya (CRAHI-UPC) (Meléndez-Landaverde & Sempere-Torres, 2023) during the H2020 EU project **ANYWHERE**. Its purpose is to act as a dissemination platform for alerts generated by the location-specific or site-specific impact-based flood early warning system, also developed at CRAHI-UPC. In this capacity, A4alerts endeavours to facilitate swift flood risk communication and aid in promoting timely actions to mitigate adverse impacts in vulnerable areas or communities.

The operational prototype of the A4alerts is integrated with several functionalities chosen from recent studies on the needs and requirements of the users of crisis apps. In this regard, the A4alerts functionalities have the objective of (i) informing users about the active site-specific and official rainfall warnings; (ii) proposing self-protection actions for mitigating local impacts according to the active warning level and location, and (iii) enabling the participation of the users to support authorities, emergency responders and citizens.

When the operational EWS issues a warning, the A4alerts sends a push notification to users. In the main section of the app (see Figure 8), all locations integrated within the warning system (i.e., receiving specific warnings) are displayed with a distinctive icon and a colour representing the severity of the warning level. By tapping on these icons, users can access detailed information of the (i) active warning level; (ii) pictures of previous flood events in the area; (iii) the appropriate self-protection actions in a checklist format; and (iv) the warning history timeline. For the last two, separate sections (accessible through individual icons) are available to monitor the development of the emergency and review the actions for the current active warning level. When no warnings are active, the action checklist section displays the complete flood self-protection plan per warning level to help increase the awareness and familiarisation of the users with these actions.

Furthermore, if a warning from the authorities is issued, the main section of the app will also display a banner on the top of the screen to access the “official warning” section. Within it, users can review the latest warnings by the authorities, their duration, and any official weather information. Finally, the main screen will show the evolution of the event by displaying the rainfall map from the radar-based nowcasting (for the first 2 hours) and the numerical weather prediction models (up to 24 hours).



Do you find this information useful?

Warnings updated every 12 minutes

SSW: Rainfall intensity
Level: 3
Start: 16/08/2020 11:00

A **dangerous intense rainfall episode** has been forecasted at the school area. The extreme weather conditions can likely cause **severe water accumulations at the playgrounds and low points within the school grounds.** Additionally, the rainfall episode can cause urban floods around the school area and across the city.

Take inmediate action and follow the advice of the authorities. To obtain more information on the specific protection actions you can take at the school, go to the self-protection checklist section

☑ **1. Measure the water level in module B**

Measure the water level in the classrooms located in module B

1. If the water level is equal to or greater than 10 cm:
   - Call the **Education service office (123456789)** to inform them about the situation and authorize the evacuation of module B
2. In case the water level is between 5 and 10 cm:
   - Call the **Education service office (123456789)** to inform them about the situation
   - Keep actively measuring the water level in module B

☑ **2. Accions in case of evacuation (see action 1)**

Measure the water level in the classrooms located in module B

1. Mobilize the students of Module B to the municipal office
   - Section B.1: Showroom; Section B.2: Activity room; Section B.3: Blue room and Section B.4: cafeteria
   - Call the **Education service office (123456789)** before leaving the school for the municipal office
2. The rest of the students **must remain within the school grounds** until otherwise indicated by the authorities.

☐ **3. Material for the evacuation**

Face masks, first-kit aid and student list

☐ **4. Based on the rainfall's evolution**
- Notify the responsible adults about the current situation
- Return to the school **only if the authorities approve it**

Figure 8 The A4alerts mobile app and its different sections.

1. Home screen view; 2. Active SS-EWS; 3. Official warnings; 4. Report an event; 5. Feedback; 6. Information. The sections are identified with a circle and the corresponding number (Left). The SS-EWS section (Centre). The self-protection action checklist functionality (Right)

Further areas for improvement focus on integrating two-way communication capabilities into the A4alerts app. In this aspect, current developments explore enabling users to report local damages or incidents through geo-located photos and text messages while allowing the rest of the users to validate these contributions in real-time. These features have been found to help enhance the situational awareness of authorities and citizens and enrich the local real-time information for emergency actions and future impact validations (Tan et al., 2017; McCallum et al., 2016). For more information on the impact-based and site-specific framework for developing the flood EWS, see Meléndez-Landaverde & Sempere-Torres (2022).

SeismUP app

The SeismUP mobile app for Android devices (smartphones, tablets, and smartwatches) has been developed (Colombelli et al., 2020) to receive the alerts issued by the PRESTo system (for more information on the PRESTo system see **GOBEYOND** Deliverable 1.1) (Satriano et al., 2011), an Earthquake EWS (EEWS) currently operative in southern Italy for detecting small to moderate earthquakes occurring in the Campania–Lucania Apennine region. SeismUP's primary purpose is to inform a wider community of smartphone users about the incoming arrival of ground shaking due to earthquakes occurring in the target region, which represents one of the highest seismic-risk areas in the country. When an earthquake is detected by PRESTo, as soon as the first estimates of location and magnitude are released, the theoretical arrival time of the S-waves is first computed at the user position by assuming a homogeneous velocity model for the wave propagation. Then, using the estimates of location and magnitude and a standard ground motion prediction equation (GMPE), the expected level of ground shaking, in terms of peak ground motion (PGV), is computed at the user position (Bindi et al., 2011). When the predicted intensity exceeds the threshold level, the alert mode is activated. From then on, the alert levels are progressively updated every second based on the estimated outputs of the location and magnitude of the event from the EWS. Depending on the earthquake location and relative distance to the user position, the display shows the countdown with the available lead time (e.g., the time available for safety actions before the arrival of strong shaking waves) and the predicted level of intensity.

SeismUp is intuitive, user-friendly, and highly flexible. In principle, it can interact with various EWS platforms (such as PRESTo, Virtual Seismologist, and ElarmS) if the output parameters are provided in a standardised format (QuakeML). SeismUp can geolocate the user position and use it to decide in real-time how to operate (i.e., whether to issue the warning or not). Depending on the distance from the event and the expected damage potential, SeismUp activates personalised alert messages containing the available lead time, the predicted level of intensity, and instructions on mitigating actions for the users (see Figure 9). SeismUp has a two-way flow of information to and from the user, which allows for the receiving of (as input) the real-time earthquake parameters from the EW core platform and the communicating of (as output, with a dedicated module) the state of health and condition of the user after the alert period (expected shaking duration) has ended. This functionality is of extreme relevance, especially in densely populated areas (such as urban areas and significant industrial settlements), for collecting people's conditions at the end of the event to support efficient planning of rescue operations.

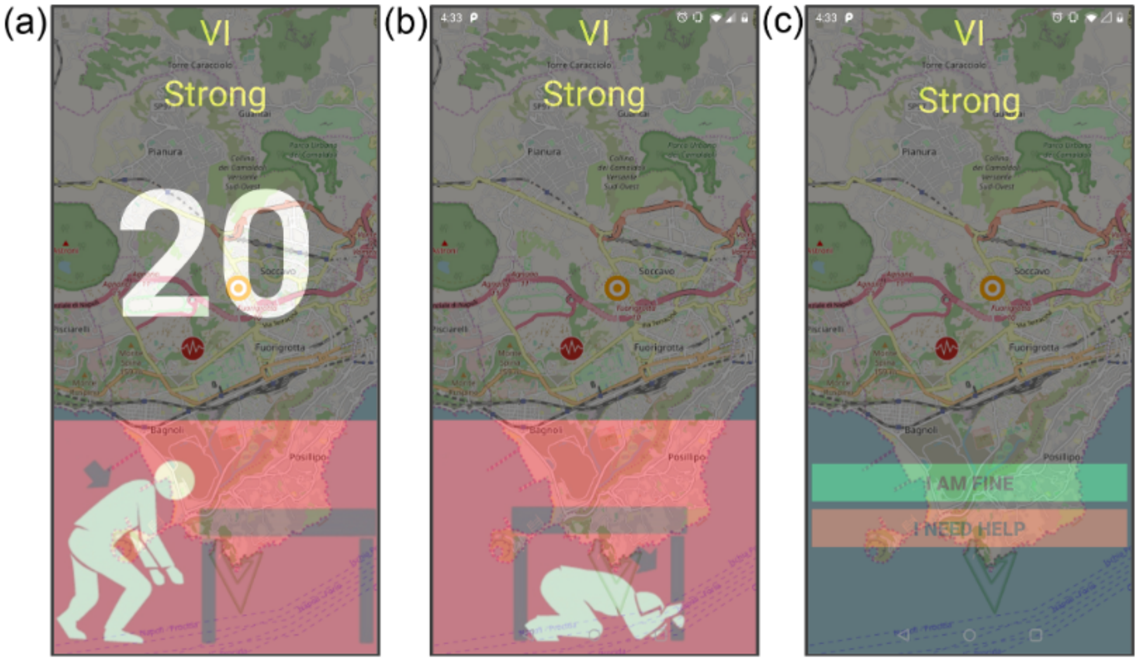


Figure 9 The SeismUp app.

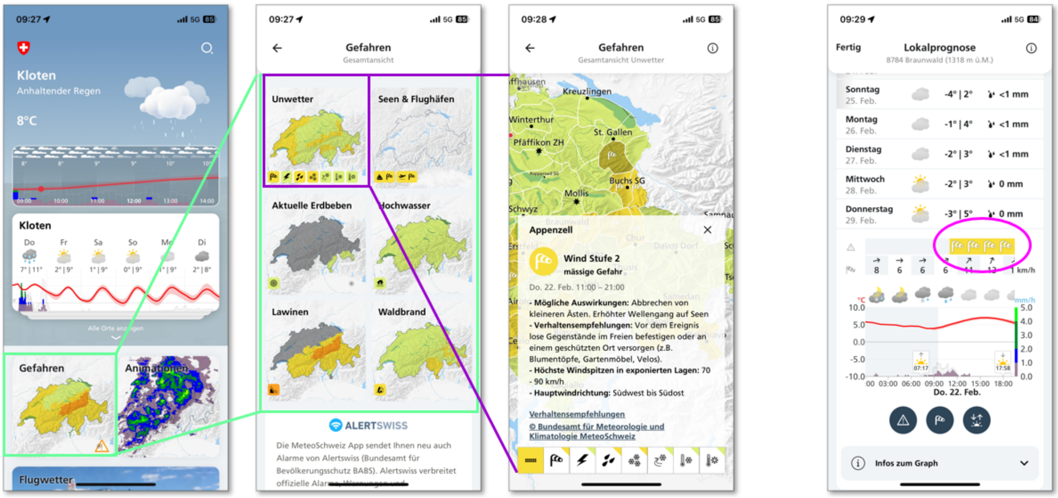
Panels (a) and (b) show the expected shaking (VI, strong), the countdown, and the instructions on how to behave that appear on the screen during the event. Panel (c) shows a screenshot of the screen once the earthquake has finished and the ground shaking has passed. Two buttons (green and red) appear on the screen to quickly communicate the user's condition and position to a list of predefined contacts. The map was created using OpenStreetMaps (© OpenStreetMap contributors 2020. Distributed under a Creative Commons BY-SA License).

Finally, some identified areas for further development in SeismUp have been identified. For example, the app could be interfaced with a decision-and-control expert system, combining the outputs from the regional EEWS with information from local monitoring devices (sensors), for broadcasting personalised safety instructions and customised alert messages, depending, for example, on the location of the personnel inside a given area (or inside a building). Moreover, the current geolocation functionality could be improved by adding the possibility of tracking the position and condition of people before, during, and after the earthquake occurrence. Additionally, the position and condition of the user, as monitored by the smartphone, could be coupled with some other health status parameters, as provided by different devices, such as heartbeat and blood pressure sensors. In both cases, intelligent neural network algorithms, specifically trained, could be used to identify a condition of inactivity and quiescence, which could be synonymous with users in dangerous conditions or potentially trapped under the earthquake ruins.

Another perspective idea for SeismUp is to include a “drill-test mode,” which involves running playback and scenario earthquakes from a dedicated list of events to test, for example, the procedures for the evacuation of people from buildings and/or densely populated areas. For this purpose, an upgraded app version could be specifically developed and released to advanced users only (such as private and public stakeholders and users).

Other mobile apps

In Switzerland, the MeteoSwiss App (see Figure 10) displays measurements, forecasts and all the natural hazard warnings (not only meteorological warnings), as well as collects crowdsourcing observations. When the user chooses the meteogram for a given location, it automatically sets a push message for warnings at this location. It is the most downloaded Swiss weather app (more downloads than inhabitants). Beyond the MeteoSwiss app, authorities have a dedicated official platform, GIN, to access all the available official warnings for natural hazards and real-time measurements, as well as to define specific thresholds of measurements and forecasts to trigger warnings. Interestingly, even though the GIN platform was explicitly set up for the authorities, the MeteoSwiss app is used equally or more than GIN by the authorities due to its easy accessibility and user-friendliness. The MeteoSwiss app doesn’t display real-time runoff information and hydrological forecasts as their target audience is the public. However, this phenomenon demonstrates that a well-designed app can be well integrated into the official emergency management organisation.



Die MeteoSchweiz App sendet Ihnen neu auch Alarme von Alertswiss (Bundesamt für Bevölkerungsschutz BABS). Alertswiss verbreitet offizielle Alar

Appenzell

Wind Stufe 2
mässige Gefahr

Do. 22. Feb. 11:00 – 21:00

- **Mögliche Auswirkungen:** Abbrechen von kleineren Ästen. Erhöhter Wellengang auf Seen
- **Verhaltensempfehlungen:** Vor dem Ereignis lose Gegenstände im Freien befestigen oder an einem geschützten Ort versorgen (z.B. Blumentöpfe, Gartenmöbel, Velos).
- **Höchste Windspitzen in exponierten Lagen:** 70 - 90 km/h
- **Hauptwindrichtung:** Südwest bis Südost

Verhaltensempfehlungen

© Bundesamt für Meteorologie und Klimatologie MeteoSchweiz

Sonntag 25. Feb.	-4° | 2°	<1 mm
Montag 26. Feb.	-1° | 4°	<1 mm
Dienstag 27. Feb.	-2° | 3°	<1 mm
Mittwoch 28. Feb.	-2° | 3°	0 mm
Donnerstag 29. Feb.	-3° | 5°	0 mm

Main entry page

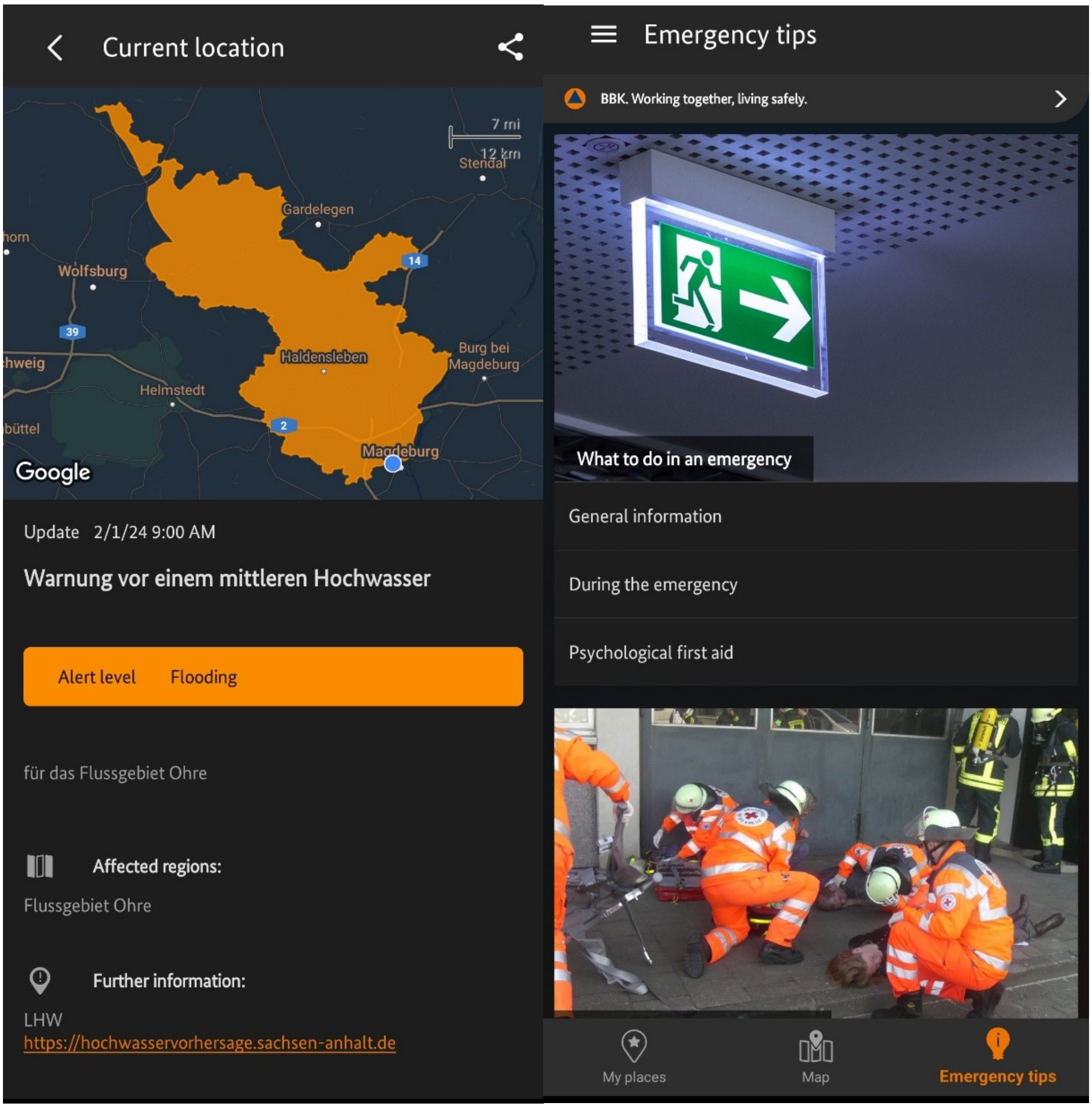
Natural hazards warnings overview

Warning for one warning area

Warning displayed in meteogramm for location

Figure 10 Different levels of displaying natural hazard warnings on the MeteoSwiss app

In Germany, the KatWarn and NINA apps developed by the Fraunhofer Institute (on behalf of the German public insurance companies) and the Federal Office for Civil Protection and Disaster Relief are among the most popular crisis apps officially available (Reuter, Kaufhold, & Knipp, 2017; Reuter et al., 2017). While they share similar functionalities, the mechanism to trigger and disseminate different types of warnings (e.g., weather-induced or for public events) varies and, thus, are encouraged to be jointly used during emergencies. KatWarn sends public alerts and advice directly to individuals in emergencies (e.g., large-scale fires or severe weather.) It operates on location-based notifications, ensuring targeted and effective communication. On the other hand, NINA (see Figure 11) is a satellite-based modular warning system that disseminates warnings to the public and provides further recommendations for preparation and emergency tips. Apps like NINA and KatWarn interact with the community directly, providing warnings and recommendations for preparation and emergency tips, enhancing public readiness and response.



Update 2/1/24 9:00 AM

Warnung vor einem mittleren Hochwasser

Alert level Flooding

für das Flussgebiet Ohre

Affected regions:
Flussgebiet Ohre

Further information:
LHW
https://hochwasservorhersage.sachsen-anhalt.de

Figure 11 NINA app: Screenshot of the Warning (left) and recommendation (right).

2.2.4. Comparison of technologies for emergency communication to enhance situational awareness

Effective emergency warning communication enables authorities, responders, and communities to make informed decisions and take prompt action to mitigate risks and ensure public safety. Each of the above methods has specific strengths and limitations that must be carefully considered in the context of enhancing situational awareness through warning communication. Thus, understanding the operational challenges and their inherent limitations is critical to maximising their impact during emergencies.

Table 2 provides an overview of the benefits, limitations, and operational challenges associated with each method for emergency warning communication. The selection of the most suitable approach or combination of approaches will depend on the requirements, resources, and needs of emergency entities, responders, and communities.

Table 2 Benefits, limitations and operational challenges of methods for emergency communication to enhance situational awareness

Method	Benefits	Limitations	Operational Challenges
Mass notification system: Cell broadcast and location-based	Straightforward and fast dissemination of emergency information Wide – area coverage as well as targeted locations	- Limited message length and content - Potential overuse or alert fatigue - Language and social accessibility - Only supports one-way communication	- Reliability and connectivity to mobile network infrastructure. - Compliance with privacy and ethical legislations -Need of activation and testing protocols
Social media platforms	- Cost-effective Rapid dissemination - Multimedia content - Geotargeting and personalisation - Broad reach and accessibility - Support two-way communication	- Reliability and performance of third-party platforms - Misinformation and Rumours - Potential information overload	- Integration to current communication methods - Continuous interaction and engagement with users
Crisis apps	- Rapid warning dissemination - Multimedia emergency content and self-protection guidance - Can support two-way communication - Can be customised	- Installation and adoption rates from users - Potential information overload - Accessibility and Inclusivity concerns - Device compatibility	- Reliability and connectivity during emergencies - Design, implementation and operational costs - Integration with official warning systems - Continuous advertising and updates - Data management and analysis

3. Bringing it all together: Operational platforms for geo and weather emergency management

Operational platforms have a crucial role in emergency management. They provide capabilities for monitoring observations and dynamic aspects during an emergency (e.g., sensor networks, weather forecasts, traffic conditions, reported impacts), visualising active warnings due to weather and geological events, and communicating them to relevant stakeholders. This section examines their objectives, key elements, their role in enabling situational awareness, as well as their real-world applications.

3.1. Objective and key elements

The primary objective of operational platforms is to integrate various data sources, analytical tools, and communication mechanisms, providing authorities and responders with timely and accurate ground information for informed decision-making and the activation of response protocols. Thus, operational platforms for emergency management are characterised by compiling a wide range of innovative methodologies and technologies (such as those listed in section 2) to facilitate real-time information and enhance situational awareness. Key elements of operational platforms are:

- **Data integration:** Operational platforms aggregate data from multiple sources, for different hazards in one viewer. These can include geo- and meteorological forecasts, IoT devices, satellite imagery, citizen reports, or information coming from social media. By integrating diverse data sources, platforms provide a comprehensive overview of the current conditions and potential geo and weather hazards.
- **Enhanced visualisation:** These platforms provide real-time visualisation of data, warnings, and IoT devices using interactive maps, dashboards, charts, images, and videos. The advanced visual representation can enable operators to quickly identify areas at risk, analyse the potential severity of an event and organise response actions. Recently, the field of user experience and interface (UX/UI) design has gained momentum for understanding how individuals interact with emergency platforms and what visual elements should be incorporated to facilitate their operations (Meléndez-Landaverde & Sempere-Torres, 2023).
- **Widespread risk communication:** Operational platforms usually include technologies for disseminating warnings, advisory information, and situational updates from the operations office to emergency responders, citizens, or key stakeholders. By connecting to alerting and notification systems – including SMS, email, social media, and crisis apps – operational platforms contribute to the wide broadcasting of critical information, enabling authorities and citizens to take the most appropriate actions based on the latest information.
- **Decision support during emergencies:** Operational platforms serve as a key tool for decision support during emergencies by integrating relevant data sources, providing appropriate visualisation, and enabling the capability of communicating risks. The real-time information provided by these platforms empowers users to understand how a particular event is affecting or could affect their community. This enables them to make informed decisions regarding the necessary and effective steps to mitigate any negative consequences.

3.2. Operational platforms for common operational pictures during emergencies

Due to the nature and intended use of operational platforms, they can be considered key elements in enabling the creation of a **Common Operational Picture** (COP) during emergencies (Opach et al., 2020). Originating from the military context, a COP can be generally defined as a continually updated geographical representation of an incident or emergency throughout its active cycle, fed by information from various sources and technologies (see section 2 for more details). By integrating the latest and relevant data into a single cohesive display for emergency responders, authorities, and all actors involved, COPs enable collaborative planning, coordination, and support for informed decision-making (Wolbers & Boersma, 2013).

As identified in previous research (Steen-Tveit & Munkvold, 2021), the concepts of situational awareness and COP are closely linked and crucial factors for effective emergency management across natural and human-made hazards. Due to the inherently interdisciplinary nature and the broad range of actors involved during emergencies, COPs can be crucial for establishing an initial shared understanding of the situation among all involved stakeholders (Hwang & Yoon, 2020). In the literature, the concept of COP has been categorised into three main branches: a method for achieving collective situational awareness, an operational system that integrates data to provide a unified view, or a product that represents the state of an incident or emergency.

For the purpose of this report, COPs are discussed within the context of the second branch, which is closely associated with the development and implementation of operational platforms. Emergency operational platforms share the same objective as COPS: to visualise all relevant information in one place, allowing the constellation of actors involved during emergencies to make rapid and informed decisions.

Although the importance of COPs for situational awareness is clear, their development and use can be challenging. A single COP might not meet the diverse information needs, goals, and expectations of all departments involved in emergency response. In the recent study by Steen-Tveit (2020), community responders were gathered to understand their information needs and requirements for managing extreme weather events. The results indicated that it was not feasible for all actors to operate under a single COP, as supporting effective and efficient operational response requires considering the specific elements and information that organisations need, based on their response protocols, responsibilities, and roles, beyond the shared elements of overall emergency response. However, including all these aspects can quickly lead to information overload, turning the quick decision-making process needed in emergency response into a complex task of identifying relevant information among a sea of data to prepare a fast situational map. Moreover, developing and maintaining such a system would require additional resources that might not be available to all regions or local communities.

The dynamic nature of operational platforms can enable stakeholders to visualise in a single place the specific situational information they need for response operations, as well as geospatial or meteorological data linked to the emergency, and additional elements to build an overall picture of the situation. Although the flexibility offered by operational platforms is beneficial, customisation and identifying necessary information from a catalogue of tools can also be challenging if proper training or support is not provided to stakeholders.

Recognising that each emergency has its own unique features and that stakeholders have different requirements, the specific elements (e.g., functionalities, data sources) of operational platforms should be co-designed and tested with users to support their decision-making process and facilitate the integration of these systems into their current operational protocols. The latest aspect is essential for operational platforms to evolve from simply being an "information warehouse" to enabling decision-support systems that can facilitate the creation of COPs and thus support collaboration between agencies during an emergency.

3.3. Implementation cases

The following section provides examples of operational platforms in different contexts and hazards within the **GOBEYOND** project framework. Designed to support emergency management, the list below offers insights into the real-world functionalities of operational platforms for creating a COP and enhancing situational awareness. For more information regarding their level of maturity, reliability, performance, and other user-oriented technological criteria, see **D1.3:** Report on the recommended methodologies and technologies to enhance the response capacity during geo and weather events to be integrated into the **GOBEYOND** platforms**.**

3.3.1. ARGOS services

ARGOS is a Multi-Hazard Impact Based Early Warning System platform for monitoring and managing weather-induced emergencies. It focuses on generating hyperlocal early action in response to various potential risks (e.g., floods, forest fires, snowfalls, storm surges, air pollution, droughts, and others).

3.3.1.1. Precedents

The platform **ARGOS** was developed by HYDS (Hydrometeorological Innovative Solutions, S.L.) during its participation in the EU H2020 project **ANYWHERE**, which was recognized with the EC Security Innovation Award on Resilience in 2022. With a budget over 14 M€, **ANYWHERE** was implemented between 2016 and 2020 by 34 partners from 12 different countries and was operationally tested in 7 pilot-sites across Europe, involving over 100 stakeholders institutions. Such implementations are the precedents of the **ARGOS** system, which officially started to be in operational service in 2021.

3.3.1.2. Overview

Decision-making during the surveillance and management of meteorological emergencies carries great responsibility and requires that key information is always available. Time is a key factor, and therefore, it is vitally important to optimise all the processes involved in information management. **ARGOS** focuses on this by addressing the following points:

- **Single access:** Real-time data is needed from multiple providers (meteorological services, water sector agencies, municipalities) of different natures (point measurements from sensors, weather forecasts in whole regions). This information typically must be consulted through several web pages simultaneously. **ARGOS** is presented as a single access to different data sources in a simple and homogeneous manner.
- **A dynamic combination of information: ARGOS** makes it possible to dynamically cross-reference real-time hazard data with vulnerability information specific to the

territory. This provides an idea of the impact of the meteorological phenomenon on the population and infrastructure.

- **Access to source data:** The system prioritises access to original data and visual representations such as maps or data aggregations to present the information in a simple way and adapt it to the user's needs. **ARGOS** utilises local sensors and IoT devices to provide real-time information on what is happening in the field.
- **Adaptation and incorporation of existing information: Argos** enables the integration of official studies or emergency plans for decision support during emergencies.

ARGOS is a cloud-based platform accessible from any device with an internet connection. Its modularity gives huge flexibility to include new sources of data, new models to be run in real-time, or adapt the information to the end-user needs. Specific capabilities are listed below (not exhaustively):

- Integration and harmonization of data from different sources:
  - Hydrometeorological information: sensors (rain gauges, river level sensors, radar data, satellite data, etc.), models (Numerical Weather Prediction - NWP data, hydrological and hydraulic models, etc.), official warnings, etc.
  - Real-time contextual data, such as traffic information (cameras, road status, etc.), emergency calls, etc., fosters the cross-integration of data from other organisations.
  - Contextual data: Specific thematic maps (geographical information, flooding areas, infrastructures), critical points, etc.
- Optimised and flexible product generation based on parallelisation or chained processes (e.g., based on combining data and models/algorithms outputs). This is important due to the computational requirements of running several models/algorithms and chained processes to build warnings or impact forecasts based on vulnerability in hundreds of locations.
- Impact-based oriented warnings: Vulnerability information (maps, regions, critical points, road sections, etc.) and its intersection with generated products is a core aspect in **ARGOS**, allowing flexible customisation. Moreover, the activation of critical points can also be linked to auto-protection plans and their follow-up.
- Architecture based on open standards and virtual machine orientation allows for easy deployment, modification, extension, and implementation in custom environments or service-oriented environments (AWS, Azure, Google Cloud, etc.).
- Advanced display web focused on warning information and optimized for the representation of spatiotemporal data, specifically the multi-layer representation of information, which allows combining sensor data, model outputs, dynamic maps (weather radar, satellite, etc.), static Geographic Information System (GIS) information, alerts, etc. Adapted for use with the device used (computer, mobile, tablet).
- Highly customizable, providing capabilities to administrate several types of users, configuration of warning levels, detailed dissemination of warnings for specific users, etc.

3.3.1.3. Implementation of ARGOS

Customisation highly depends on the final user and the specific application of the platform (see Figure 12). Below are different experiences of ARGOS implementations:

ARGOS services for Multi-Hazard Management at national and regional level

ARGOS has been implemented to support several services for Multi-Hazard Management in IRELAND (Met Éireann), Spain (National Center for Monitoring and Coordination of Emergencies), and various internal regions (112 Emergency Centres in Catalunya, Balearic Islands, Valencian Community, and Murcia). These services integrate information and models from the meteorological and hydrological field, local sensor networks (river levels, reservoirs, marine and estuary buoys, meteorological radar, etc.), and forecast models (weather forecast: ECMWF, GFS and Harmonie; hydrological forecast: FEWS models, forecast of tides and "storm surges", forecast of air pollution, etc.). From that data, specific models/algorithms are executed and combined with contextual information (e.g., critical points) to provide high resolutions for forecasted warnings. These systems are used at the organism level with several groups of users and configured to disseminate warnings and information.

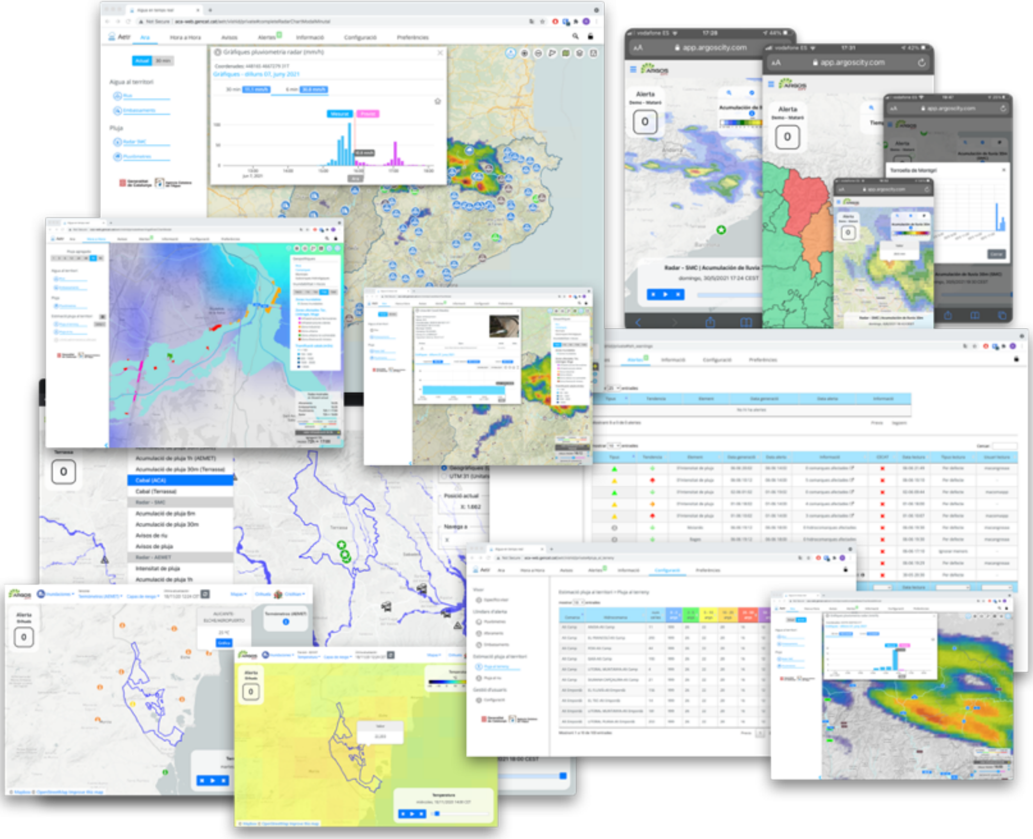


Figure 12 Examples of various displays of Argos implemented services.

ARGOS services for Multi-Hazard Management at the City Level (Argos City)

Argos City services have been implemented in urban areas over various regions (Alicante - Hidraqua, Madrid - Canal de Isabel II and Catalunya). The main characteristic of these solutions is that they allow risk management on specific critical points and the activation and monitoring of response plans from the platform itself. Thus, the platform integrates into a single system all the necessary information (both danger and vulnerability) for real-time management of emergencies at the municipal level, including official notices from public bodies, sensor data, forecast models, etc. It uses all that information to generate hyperlocal alerts by combining and crossing in real-time with the vulnerable elements defined at the municipal level. These alerts are linked to the action plans (self-protection or impact mitigation actions), and the system provides a guide for their deployment and monitoring throughout emergencies.

ARGOS long-term plans are focused on the global extension of the service to virtually any location and any weather-induced hazard. **ARGOS** business model is a cloud SaaS (Software as a Service), which helps to provide a high-quality service and is easily scalable to other regions. **ARGOS** can be easily transposed and expanded to new locations, and can integrate the addition of geo-hazards capabilities.

GOBEYOND developments will profit of the experience of the **ARGOS** platforms through its partner **HYDS**.

3.3.2. Wiki- Predict platform

The **Wiki-Predict platform** is a web – password-protected - platform developed by the French company PREDICT Services. Since its creation in 2009, the platform has enabled real-time monitoring of hydrometeorological risk phenomena and the multi-scale dissemination of information relating to forecast or current risks. Thus, the objective of the platform is to support citizens, companies, local authorities, and crisis management services in France and abroad in their decision-making process before, during, and after a risk phenomenon.

3.3.2.1. Dissemination and extensions

The **Wiki-Predict** platform enables users to disseminate and share information on forecasted or current hydrometeorological events in their area. By classifying their territory as a Predict Safety Level (PSL), platform users quickly know what level of protective action to take in their area of jurisdiction.

As seen in Figure 13, the PSLs are based on the implementation actions of risk managers (i.e., normal state, surveillance, mobilisation, secure/safeguard, maximum safeguard, post-crisis) and allow the anticipation and localisation of risks before they happen.

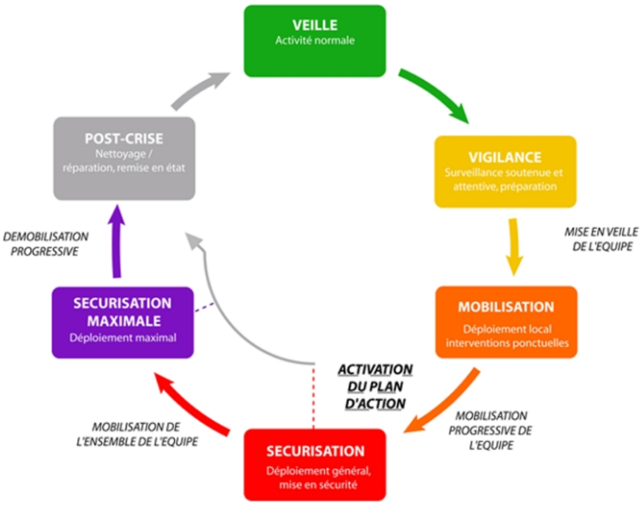


Figure 13 PREDICT's Safety Levels

Today, information is disseminated using several various communication channels, such as SMS, email, and mobile notifications. The risk analysis is carried out on a sub-municipal scale (a few km²), and the associated information is disseminated on several scales, depending on the jurisdiction of the end-users. Thus, the scale of dissemination can vary from several countries to a specific municipality.

3.3.2.2. Platform overview

The **Wiki-Predict** platform is built around a 2D or 3D map (see Figure 14) that centralises a wide range of information concerning (i) hydrometeorological phenomena and real-time risk level; (ii) local vulnerability and exposure information; (iii) IoT devices (e.g., observations stations, cameras) and many more. Moreover, the platform integrates interactive capabilities to enable users to understand the dynamics of the hydrometeorological phenomena and their potential local risks.

3.3.2.3. Operational crisis management: Planning stage

The **Wiki-Predict** platform allows users to design and plan their crisis management procedures for dealing with climatic events in real-time. **Wiki-Predict**'s functionalities enable users to:

- Identify risks in their jurisdiction.
- Identify the issues and crisis management resources present in the area.
- Build a crisis directory to centralise useful contact details in the event of an event.
- Draw up operational action maps for each risk, providing a clear, geo-localized view of the actions to be taken in the area.
- Create and export crisis management planning documents in various formats (operational booklets, support sheets, procedures, action plans, etc.).
- Track actions to be implemented according to the risk level and how they connect to each other.
- Creating feedback reports (in real-time or post-event).

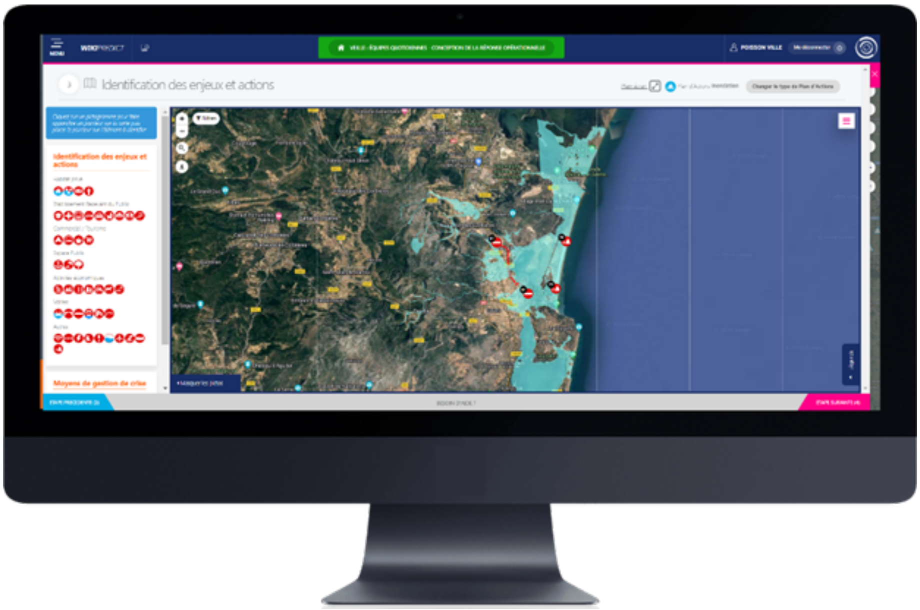


Figure 14 Wiki-Predict platform: Planning stage display

3.3.2.4. Real-time management of high-risk hydrometeorological events

The **Wiki-Predict** platform enables risk managers to manage events in real-time thanks to cartographic and digital handrail functionalities. Using as a basis the work carried out through the construction of action plans, the handrail functionality guides the user in:

- Actions to be implemented (see Figure 15);
- Priority of actions to be taken in relation to each other;
- Tracking and monitoring actions taken;
- The creation of feedback reports by exporting (in real-time or post-event) formatted handrails in PDF format.

Finally, users can add unscheduled actions on the fly directly into the tool, enabling it to adapt to the problems and unforeseen events inherent in managing this type of situation. The Wiki-Predict platform is a full-web platform available 24/7, accessible from all web browsers and protected by a login/password pair specific to each user. It is an adaptive, intuitive, and easily replicated platform for different contexts and users.

Wiki-Predict is constantly evolving to (i) contribute to the global resilience of territories; and (ii) enable crisis management stakeholders to share information at different levels of expertise. One of the most important points at the centre of any development on the **Wiki-Predict** platform is its replicability to other players and other scales of work. In this sense, the platform is easily scalable to suit all types of users and can be made available very quickly as it requires no special installation (Software as a Service - SaaS).

GOBEYOND developments will profit of the experience of the **Wiki-Predict** platform through its partner **Predict services**.

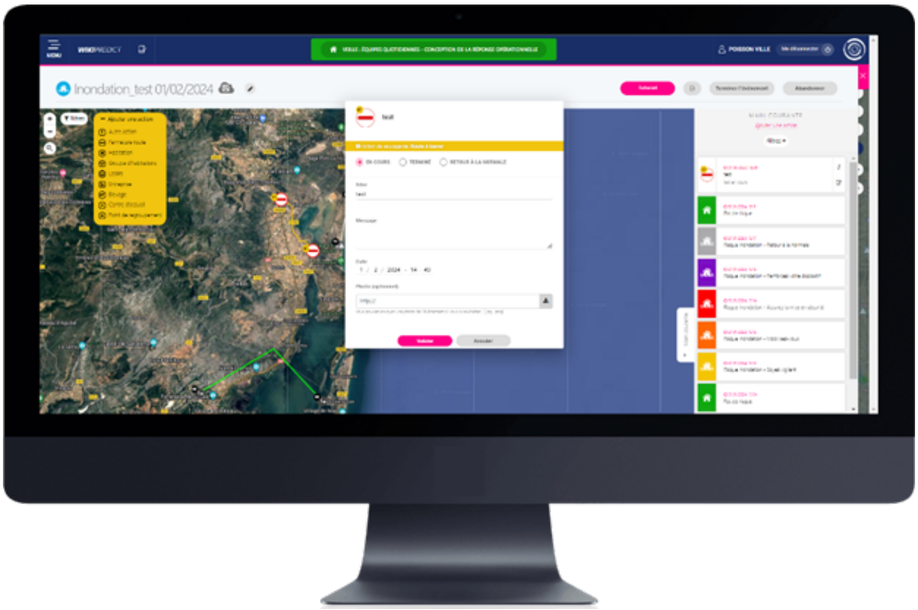


Figure 15 Wiki-Predict platform: Overview of warning levels and actions in an area

3.3.3. beAWARE web-based platform

The platform developed within the EU H2020 **beAWARE** project had the objective of supporting authorities in the management of real-time natural disasters by integrating cutting-edge technologies and machine learning functionalities. These include advanced

(i) automated procedures for extracting data from text messages, social media, and voice calls; (ii) a classification system to analyse weather and diverse data types and issue timely warnings; (iii) computer vision and deep learning methods for identifying crisis events in visual content; (iv) autonomous drone navigation and piloting to gather aerial data; (v) case-based reasoning and decision support algorithms for crisis response; and (vi) automated generation of multilingual reports to convey this information effectively to authorities.

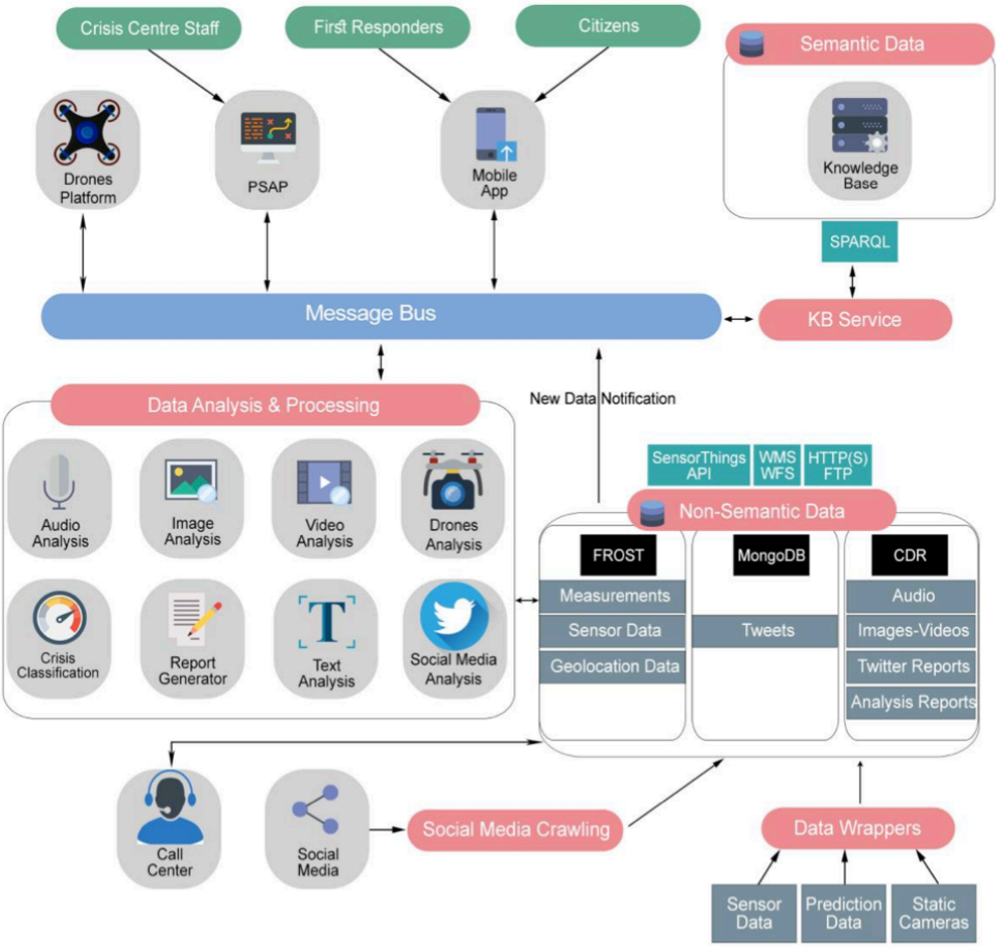


Figure 16 The architecture of the **beAWARE** platform

(Koulalis, 2019)

The **beAWARE** architecture (see Figure 16) contains four major layers:

- **Ingestion layer:** This layer serves as the entry point for data into the platform and includes mechanisms and channels for bringing in various types of information. Inputs can range from IoT devices to dedicated applications, producing data like measurements, images, videos, and audio. Weather-related data is also ingested. Once data is received, it is temporarily stored in a raw storage system, and notifications are sent to interested parties via the service bus. Components in this layer include Social Media Monitoring and the FROST-Server.
- **Internal services layer:** This layer includes all the necessary services for the proper functioning of system components. It includes generic data repositories and communication services, which act as middleware to facilitate data storage and communication. Some of these services also support generic data analytics and

processing. Examples include a central data repository, a message bus, and a knowledge base designed for handling semantic information, including extraction, storage, and inference.

- **Business layer:** It contains the components that perform the actual platform-specific capabilities. It includes elements contributing to crisis classification and decision support, such as Image analysis, Video analysis, Automatic speech recognition - Audio analysis, and Sensor analysis. Additionally, it includes components specialising in analysing weather-related data, such as Climate Emergency Modelling and Prediction Services, Weather Forecast Services, and Flood Prediction Services. Lastly, it manages the processing and analysis of incoming messages in various languages and the preparation of outgoing text messages for delivery via the platform facilitated by the Multilingual Report Generator Multilingual Text Analyzer.
- **External facing layer:** including the mobile application and PSAP (Public-safety answering point), interacting with people and entities outside the platform.

GOBEYOND developments will profit of the experience of the **beAWARE** architecture through its partner **DRAXIS**.

3.4. Strengths and challenges of operational platforms for emergency decision-support

Operational platforms are key innovative elements for situational awareness, communication, and coordinated emergency response. By bringing together different sources of information (e.g., forecasts, remote sensing, IoT feeds, social media) in one place, these systems can help all actors involved gain an understanding of the emergency, even when they are not physically present at the scene.

Despite differences in scale, architecture, and maturity, operational platforms share a common goal: to integrate relevant information into intuitive and reliable environments, that improve situational awareness and coordination during crises. However, due to the complexity of incorporating and visualising heterogeneous data, maintaining these platforms while ensuring their usability for quick access requires careful design that considers users' resources and needs.

Table 3 provides an overview of the benefits, limitations and challenges of operational platforms derived from existing systems, literature on technological applications for emergencies and practical experience of the **GOBEYOND** partners.

Table 3 Benefits, limitations and operational challenges of operational platforms to enhance situational awareness

Dimension	Benefits	Limitations	Operational Challenges
Data Integration and information management	- Combines heterogenous data sources (meteorological, geospatial, IoT, crowdsourced). - Facilitates real-time monitoring and alerts	- Difficulty to ensure data consistency, reliability across multiple sources. - Limited capacity to auto-validate, filter or cross-reference information in real time within the quick pace of emergencies	- Establishing interoperable data-sharing agreements between institutions or sources. - Maintaining continuous, secure and stable data exchange during crisis - Data management and associated costs

Dimension	Benefits	Limitations	Operational Challenges
Decision support and visualisation	- Provides intuitive dashboards and spatial visualisations of complex data. - Supports transparency and shared analysis among all actors.	- Potential overload when multiple data layers are displayed simultaneously. - Heterogenous data coming from different types of hazards during cascading events can be complex to visualise	- Designing user-friendly and flexible interfaces that highlight the relevant information by user role. - Maintaining usability.
Interoperability and scalability	- Supports information sharing among multiple agencies and actors using the platforms. - Can link local, regional, national and transnational scales, based on their scope.	- Diverse nature of information exchanges, dependant of internal protocols, formats and existing systems. - Data ownership and institutional limitations can restrict the information fed to the platforms	- Maintaining reliability and connectivity at different scales and multiple partners at once (high-load operations). - Integration with institutional protocols and legacy systems - Data-share agreements across institutions
User experience and accessibility	- Centralises critical information for decision-making. - Interfaces can be customised to match user role, scale (regional vs local) and priorities.	- Learning curve for non-technical users. - Limited accessibility for users with low technological literacy or in the field.	- Implementing user-centric design methodologies across all stages of development. - Ensuring inclusivity through multilingual and accessibility-compliant interfaces
Communication and collaboration	- Facilitates shared situational awareness and coordination across actors. - Can integrate official information and citizen-generated data (e.g., sensors and crowdsourcing)	- Verification of crowdsourced data in real-time can be limited or slow. - High communication streams can cause overload or loss of critical information. - Uneven communication protocols.	- Incorporating trusted and open-source communication channels. - Integration of verification procedures or algorithms. - Embedding communication protocols of actors involved

4. Conclusions

Situational awareness is essential for authorities, responders and communities to effectively manage risk and coordinate response activities during geo-, meteorological - and weather-related events. This deliverable outlines a range of methodologies and innovative technologies designed to enhance situational awareness and facilitate risk communication during such emergencies, drawing on the experience and expertise of the **GOBEYOND** partners.

Recognising the challenge of mapping all existing technologies, **GOBEYOND** launched an **Open Call for innovative complementary solutions** as part of its **Adoption Accelerator Program** activities (WP6). Through this initiative, institutions were invited to submit proposals, and the selected institution (CIMA Foundation) will receive funding via a FSTP procedure to integrate their innovation into the **GOBEYOND MR-IEWS platforms**.

The technologies presented in this report offer significant opportunities for real-time decision support, response coordination, and community integration. IoT devices, remote sensing technologies, early warning systems, and social media monitoring tools can provide authorities and emergency managers with timely insights into evolving emergencies to identify high-risk areas and optimise resource allocation. Citizen science initiatives, such as crowdsourced data collection, similarly enable individuals and communities to contribute valuable insights and reports to emergency staff during emergencies. In return, these initiatives can foster strong communication and collaboration bonds among the diverse stakeholders involved in emergency management at a local level. Furthermore, communication systems and innovative tools supporting both mass and two-way communication capabilities, such as crisis apps and social media platforms, can facilitate the rapid dissemination of emergency information and effective interaction with individuals at risk, responders, and emergency managers.

However, these methods and technologies can present some challenges for emergency managers, authorities and responders. Data volume, quality and reliability have emerged as critical obstacles in the context of their real-time operation during emergencies. Factors such as misinformation and rumours can compromise the quality of the collected data. Addressing these challenges requires the execution of robust real-time data validation and verification procedures to increase the reliability and integrity of the information used for decision-making during emergencies. Moreover, the mass collection of local data from various sources raises concerns about privacy and surveillance, requiring the implementation of ethical frameworks and transparent data management procedures that comply with legal regulations.

The role of Common Operational Pictures in supporting coordination among agencies with different mandates, information needs, and operational practices was also examined. Realising that a single COP is unlikely to satisfy all user groups without risking information overload. Customisation, user-centric design, and iterative testing, together with attention to interoperability, interface clarity, and scalable architectures, are essential to ensuring that operational platforms evolve from simple data repositories into effective decision-support environments.

Building on these considerations, integrating the innovative techniques reviewed into a single ecosystem to support different phases of the risk management cycle across hazards remains a complex task. Operational platforms play a crucial role in addressing this challenge, serving as a one-stop information hub where various data sources, analytical tools and communication mechanisms are aggregated in an interactive and visual format to support decision-making. Nevertheless, achieving the seamless integration of different techniques while ensuring that the key information is communicated in emergencies requires a comprehensive understanding of users' needs and coordination among relevant stakeholders.

Finally, while implementing the technologies and methodologies presented in this deliverable for enhancing situational awareness presents operational challenges, they also offer considerable opportunities for improving response capabilities, enhancing communication and collaboration, and empowering communities. By understanding the benefits and limitations of each technique presented in this deliverable, their full potential can be exploited by emergency managers and authorities to build more resilient and adaptive emergency management systems for geo- and weather-related hazards.

5. References

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