ANYWHERE

Project Number 700099
Call: H2020-DRS-01-2015

Project Title:

ANYWHERE

EnhANcing emergencY management and response to extreme WeatHER and climate Events

Subject:

Deliverable 6.5:
Final report compiling the results of the A4EU in each pilot site

Dissemination Level:
PU Public

Delivery date: **30th November 2019**
Month: **Month 41**
Organisation name of lead contractor for this deliverable:
CIMA Research Foundation

European Commission

This project has received funding from the European Union's H2020 Programme under the topic of potential of current and new measures and technologies to respond to extreme weather and climate events under grant agreement no. 700099.

Document Information

Title	**Final report compiling the results of the A4EU in each pilot site**
Lead Author	Nicola Rebora (CIMA)
Contributors	Cristina Vicente (INTC) Roberto De Ferrari (CDG) Arnau Cangros (ACA) Samuel Sutanto (WUR) Henny A.J. van Lanen (WUR) Mikko Karvonen (FMoI) Annakaisa Von Lerber (FMI) Tuomo Bergman (FMI) Adrian Peter (VOLBE) Jan Sigurd Moy (HSUH) Patric Botey (SIS2B) Rosa Maria Torres (DGPCE) Antonio Santiago (AMAYA)
Distribution	PUBLIC
Document Reference	

Document History:

Date	Revision	Prepared by	Organisation	Approved by
08.10.2019	Rev_1	Nicola Rebora	CIMA	
20.12.2019	Rev_2	Nicola Rebora	CIMA	Alexandre Sánchez (UPC_CRAHI)

Related Documents:

This report and others are available from the ANYWHERE Project Website at: http://www.anywhere-h2020.eu/

Summary

This Deliverable reports the results of the demonstration activities in each pilot site. It provides a summary of the process that leaded to the demonstration activities, reporting, for each pilot site, both feedbacks and recommendations from the end-users and from developing partners.

An overall evaluation of the demonstration activities will be presented by comparing, for each pilot site, the operational situation before and after ANYWHERE. In this way, it is possible to evaluate not only the level of maturity of A4EU in each pilot site, but also the advancement brought by an active collaboration between operators, developers and research partners.

The demonstration activities have been carried on by the local operators and responders' personnel of the pilot sites by using the systems 24/7. During the demonstration period seven ANYWHERE pilot sites were operational from May 2018 (M24):

1. Liguria, Italy – A4EU prototype: A4Lig. Operational Partner CDG - Developer Partner: CIMA.
2. Catalonia, Spain – A4EU prototype: A4Cat. Operational Partner: INTC - Responsible Partner: HYDS.
3. South Savo, Finland – A4EU prototype: A4Finn. Operational Partner: FMoI - Developer Partner: AIRBUS.
4. Canton of Bern, Switzerland – A4EU prototype: A4Alps. Operational Partner: VOLBE - Developer Partner: AIRBUS.
5. Rogaland region (Norway) – A4EU prototype: A4Nor. Operational Partner: HSUH - Developer Partner: AIRBUS.
6. Corsica (France) – A4EU prototype: A4Cor. Operational Partner: SIS2B - Developer Partner: PREDICT.
7. Spain – A4EU prototype: A4CENEM. Operational Partner: DGCPE – Developer Partner: HYDS

In this document are reported the results of a change of approach in designing the A4EU system and its implementation in each pilot site, by involving from the beginning operators, developers and scientists together.

The aim was to provide the pilot site users with systems that can improve their daily activities in anticipating high-impact weather-related events and move towards a more proactive approach in emergency management. This document reports practical experiences in dealing with weather -related emergencies in the different pilot sites during the demonstration period.

Table of Contents

List of Figures

List of Tables

1 Introduction

The final objective of ANYWHERE is to provide to the:

- institutions responsible for early warning of high-impact weather events (floods, landslides, fires, droughts, etc.),
- institutions in charge of managing emergencies caused by such events and
- citizens,

tools aimed at improving the ability to advance and proactively respond in the emergency situations induced by high-impact weather events. This has been done by using innovative technologies and components as an element to strengthen the protection of citizens and safeguard human lives.

ANYWHERE has developed A4EU, a platform of products and services capable of improving emergency management and strengthening the response capacity of Local and Regional Authorities in the event of emergencies caused by high-impact weather events. The A4EU system has been adapted from different developers (CIMA, HYDS, AIRBUS and PREDICT) in the ANYWHERE pilot sites.

During the initial phases of ANYWHERE 6 pilot sites have been identified and, in each site, has been defined an operational partner that had the capability of using it 24/7 for proactively respond to the emergency related to several hazards that were happening in its area. The operational partner has been supported by a developer partner defined case by case with the aim of customizing and fine tuning the A4EU prototype and guarantee a seamless connection with the legacy systems. The 6 pilot sites are:

1. Liguria, Italy – A4EU prototype: A4Lig. Operational Partner CDG - Developer Partner: CIMA.
2. Catalonia, Spain – A4EU prototype: A4Cat. Operational Partner: INTC - Responsible Partner: HYDS.
3. South Savo and Karelia, Finland – A4EU prototype: A4Finn. Operational Partner: FMoI - Developer Partner: AIRBUS.
4. Canton of Bern, Switzerland – A4EU prototype: A4Alps. Operational Partner: VOLBE - Developer Partner: AIRBUS.
5. Rogaland region, Norway – A4EU prototype: A4Nor. Operational Partner: HSUH - Developer Partner: AIRBUS.
6. Corsica, France – A4EU prototype: A4Cor. Operational Partner: SIS2B - Developer Partner: PREDICT.

In addition, just before the demonstration phase, it was decided to set a new Pilot Site having a national scope for Spain and the Civil Protection of Spain (DGCPE) upon request of a specific implementation of the A4EU prototype developed by HYDS. Therefore, a seventh pilot site has then been added:

7. Spain – A4EU prototype: A4CENEM. Operational Partner: DGCPE – Developer Partner: HYDS

Figure 1. Image showing the seven pilot sites where the A4EU system was implemented and run operationally 24/7 for one year (1st October 2018 – 30th September 2019).

The seven pilot sites are reported in Figure 1.

Starting from the national, regional and local systems already in place, the ANYWHERE aim was of not creating new tools superimposed (in whole or in part) on the current ones, but rather building on the existing tools and procedures to fill any technological/procedural gap present in the legacy systems and reported by local operators.

The innovations proposed in the project were oriented to:

- allow faster impact analysis and improve (where possible) the tools to provide a reliable assessment before the event occurs,
- allow better coordination of the bodies involved in the early warning and in the emergency
- encourage the self-preparedness and self-protection of the population, based on a better identification of the events, their expected impacts and their position in time and space.

The aim of this "Final report compiling the results of the A4EU in each pilot site" (WP6) is to provide an overall description of the WP6 demonstration activities in each pilot site trough some relevant operational example in which the different A4EU systems have been used during the operational period (1st October 2018-30th September 2019).

The pilot site users selected the most significant cases where the different A4EU systems played a major role in increasing the awareness of the local stakeholders and improved the efficient management of high-impact weather events.

This deliverable also provides a demonstration of the improved capabilities of emergency response centres that participated in the demonstration activities. In Figure 2 are reported the seven pilot sites classified in terms of operational area and population density.

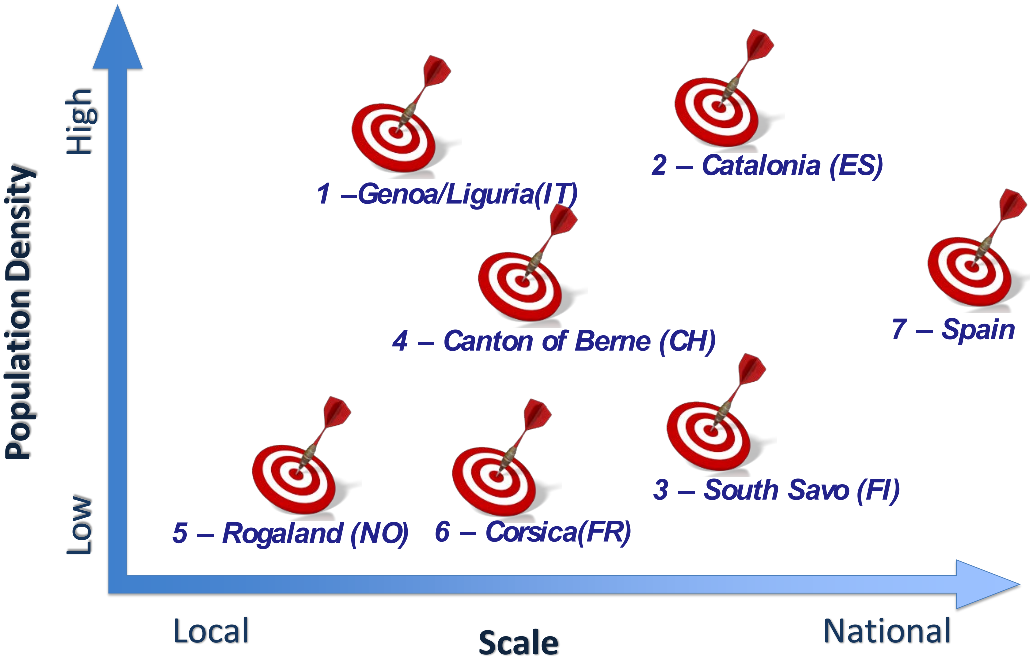


Figure 2. Image showing the different pilot sites in terms of spatial dimension and population density. The different pilot sites cover well all the different situations that are possible across Europe.

In order to have a complete picture of the demonstration activities carried on in the ANYWHERE project this deliverable should be read together with D4.5 “*A4EU prototypes (A4Lig, A4Cat, A4CENEM, A4Nor, A4Finn, A4Alps, and A4Cor): final versions and performance assessment with focus on the comparison between the different A4EU systems’ capabilities and functionalities*“ *that is focused on the different A4EU developed and specialized in each pilot site*”, with D1.4 “*Results of the co-evaluation of the ANYWHERE tools, products and services on the pilot sites*“ and D6.4 “*Report compiling the conclusions and the recommendations of the users in the use of the A4EU systems implemented in each pilot site*“ that provide an evaluation of the ANYWHERE activities and results of the demonstration period from an end-user perspective.

2 Results of the A4EU (A4Lig) demonstration - Liguria pilot site, Italy

2.1 Institutions leading Liguria Pilot Site operations

The operation of A4Lig have been done by The Municipality of Genoa (CDG) with the data support of ARPAL the Meteo-Hydrological Centre for Civil Protection – Liguria Region (ARPAL). CIMA supported the operational partners during all demonstration activities and used a continuous feedback approach to iteratively improve the system.

In particular the demonstration activities have been coordinated by the Civil Protection of the city of Genoa (CDG) in strong collaboration with the regional level (ARPAL) and with the National Level trough the support of CIMA who is a Competence Center of the Italian Civil Protection Department for Flood and Fire risk and who is the developer of the A4Lig system based on MyDewetra an IT MH EWS and decision support tool operationally used by the Italian Civil Protection Department.

2.2 Pilot site description and A4Lig main features

The area of the pilot site covers the entire Liguria Region located in the north-western part of Italy which has a total area of 5.422 km^2 is composed by 3.500 km^2 of mountainous areas (64% of the total) and by 850 km^2 of hills (34% of the total) with only less than 100 km^2 of plain areas mainly composed by flood plains in the latest part of the main rivers of the region, that only in one case (Magra River in the La Spezia province) overpass 1000 km^2 as drained area.

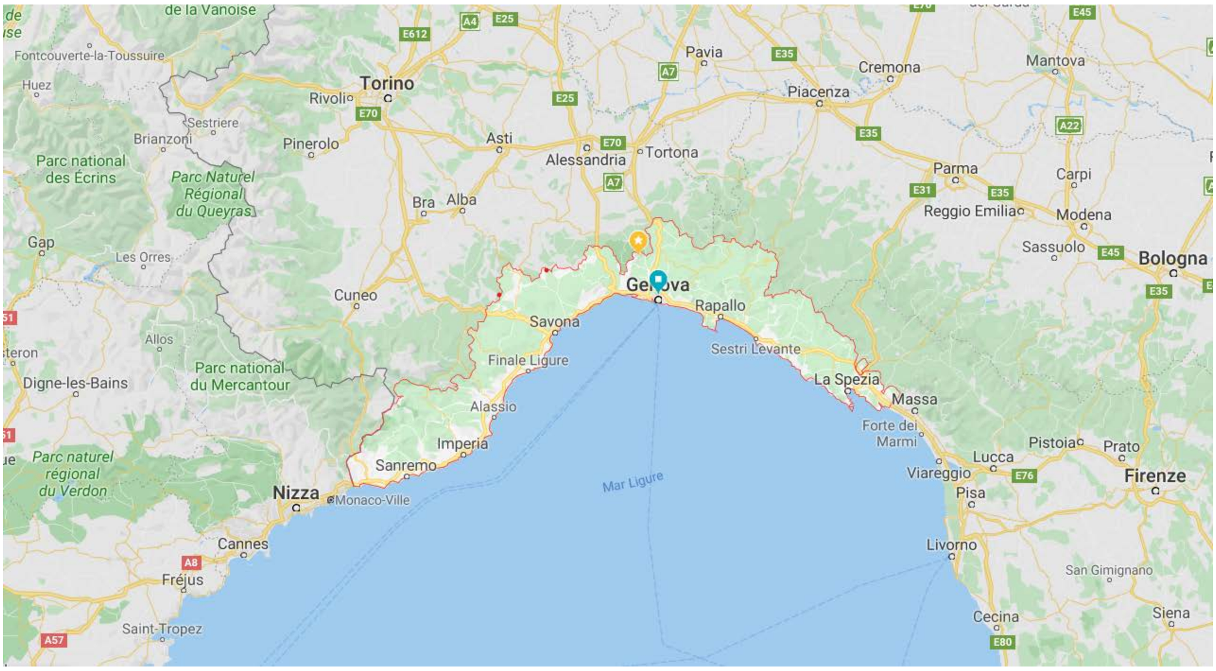


Figure 3. Liguria Region (red borders), representing the full area covered by the demonstration period activities.

Liguria Region has a total of 1.550.000 inhabitants and is composed by a total of 942 catchment basins:

- 737 smaller than 1km^2
- 139 within 1km2 and 10 km^2
- 66 bigger than 10km^2

Liguria Region is interested by 100 Forest Fires each year and by more than 13.000 landslides.

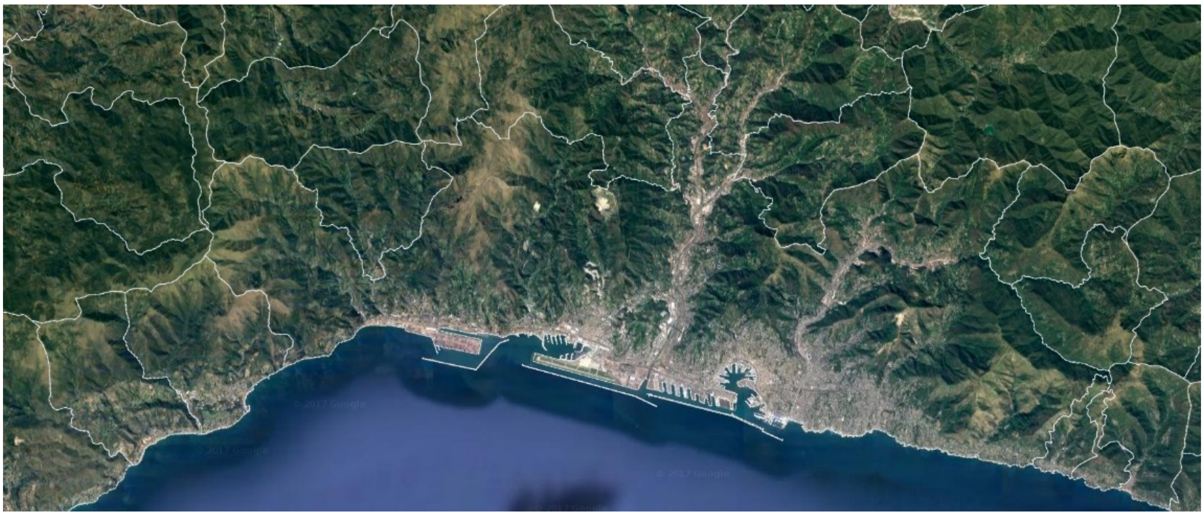


Figure 4: Image of the A4Lig pilot site core area of the demonstration period (Municipality of Genoa).

More than 33% of Liguria inhabitants lives in the municipality of Genoa, the capital city of the Liguria Region that covers an area of 243 km^2 between the Ligurian Sea and the Apennine Mountains. The city stretches along the coast for 44 km and 10 km from the coast to the north through Polcevera and Bisagno valleys. The elevation is between sea level and 1183 m. There are approximately 600.000 people living in Genoa with a density of 2400 inhabitants/km^2.

At regional and local level, the Civil Protection's objective within ANYWHERE was to organise actions aimed at coping with collective threats caused by natural or human induced disasters. The Mayor, head of Civil Protection at the Genoa Municipality level, assumes the direction and co-ordination of the rescue services and assistance to the population hit by disasters. In addition, he oversees all operations to be carried out in an emergency. It works with the local police, volunteers and, if necessary, the Prefecture and Regional administration departments for managing the disasters.

The main hazards that affect Liguria are:

1. Flood/Flash Floods
2. Forest Fires – (with main focus on Wildland-Urban Interface Fires)
3. Landslides due to heavy rainfall

4. Storm surges
5. Heatwaves
6. Droughts

A4Lig is a web-based system aimed at displaying information about different hazards together with local vulnerability layers and impact on critical points. A4Lig produced scenarios about the evolution and the impacts of a specific weather event. This is done through the integration of hazard-related information, provided by the MH-EWS at European and National level and by ARPAL at regional level, and the exposure and vulnerability information, provided by CDG at local level.

The main features of A4Lig systems used during the operational period are:

- Web Viewer of georeferenced information web-based system to display information about different hazards together with local vulnerability layers and impact on critical point. The A4 Lig system has functionalities and interfaces that allow for easily manage data inputs and outputs, connection to MH-EWS, database user management system and authentication.
- System fully interoperable with the OMIRL systems used by ARPAL and with the system used at National level with the Italian Civil Protection Department. This was one of the main requests of the Pilot site representative and ensures a seamless exchange of information, data and forecast model between the different governance levels.
- Visualization of the local vulnerability layers (e.g. flood-prone areas, burned areas due to forest fires, critical points and infrastructures available both from EU level maps – e.g. flood directive – and from regional local databases of exposed elements)
- Possibility of combining (crossing) in real time as many layers as are needed by the operational requirement for better decision making. In particular, the operator can choose one or more hazard layers (related or not to the same hazard) and combine them both in a qualitative and quantitative way with the exposed elements available at local, regional and (if available) national scale.

During the demonstration period the A4Lig system has proved to be reliable in terms of operational capabilities and has guaranteed a full 24/7 capabilities. Operators (both IT and Hazard experts at CIMA) were checking and supporting the system operation in agreement with CDG operators.

Another important aspect of the A4Lig systems is its capability of data storage. The system is able to store continuously in time all the MH-EWS data made available directly to its servers.

2.3 Main hazards faced during the operational period

The operational period started the 1st of October 2018. The A4Lig system has been used for supporting the Civil Protection of the Municipality of Genoa in the emergency management of the main event that happened in the area as well as in supporting the emergency management at regional level. During this period different emergencies have had to be faced. The most significant events that interested Italy and Liguria Region during the demonstration period were:

- High-impact weather event that interested the whole Italy the 28 and 29 October 2018 and in particular Liguria Region with heavy rain episodes as well as with storm surges that caused a harbor dam failure with millions of euros in terms of damages in the city of Rapallo (close to Portofino).
- Two wildland-urban interface forest fire events, in March 2019, in the central-western part of Liguria Region.
- One flash-flood/heavy rain event, that happened just after the end of the operational period, but that was considered by CDG since the A4Lig is still operationally used.

2.4 High-impact weather event (Heavy rain, storm surges), 28 October 2018

2.4.1 Description of the event

Between 27 and 30 October Liguria, like most of the Italian peninsula, has been affected by a long period of bad weather characterized by intense, locally persistent rains, strong winds and a storm that has devastated a large portion of the coast. The most relevant precipitations were recorded in the central and eastern areas of the region, with cumulative average ranges in the 24 hours of about 200 mm and point maximums of over 600 mm over the duration of the whole event, reaching very strong and very high quantitative intensities. The recorded water levels showed strong increases consistent with the observed rainfall. Substantial flow rates occurred in the central and eastern basins of the region that did not generated particular criticalities, however the smaller rivers near the larger watercourses caused local problems during the more intense phases of the event. The greatest damages were consequent to wind and intense storms.

The forecasting tools on the A4Lig platform showed a critical situation on medium-large basins throughout northern Italy. The Ligurian basins seemed to be less affected by rainfall events, while the scenarios related to wind and storm surges were more worrying.

2.4.2 ANYWHERE tools and products used

During the event the forecasting tools on the A4Lig platform and the monitoring tools were used and in particular the radar tool that considers the data of the rain gauges. (from Figure 5 to Figure 9).

Figure 5. ECMWF NWP model at European Level as seen through the A4Lig system operational at CDG premises

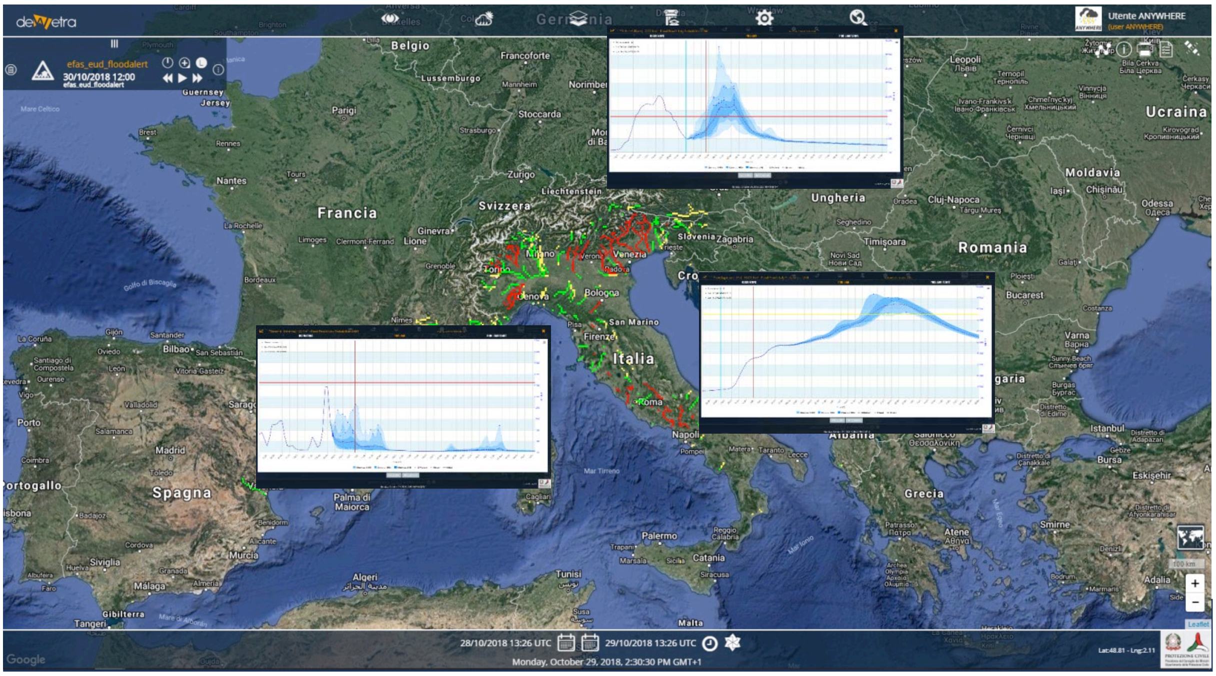


Figure 6. EFAS EU Flood Alert product and the output of discharge predictions, from the Italian Civil Protection river discharge model, for three different catchments among those indicated in red by EFAS. This picture shows how this

event interested the whole Italian area and how products available at EU level can complement the national products (and vice-versa)

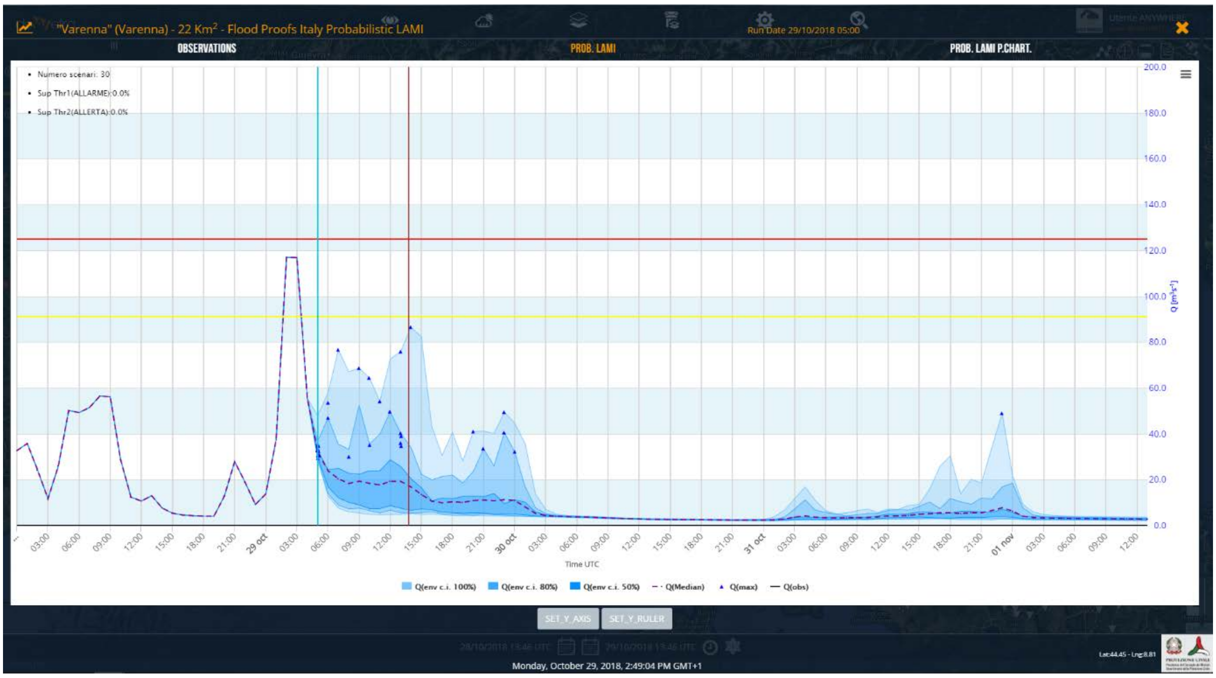


Figure 7. Discharge predicted, in ensemble probabilistic mode, by the Italian Civil Protection river discharge model for the Varenna catchment in the central part of Liguria.

Figure 8. Observed precipitation field obtained by merging Opera radar mosaic at EU level available through the MH-EWS with rain gauges available at Italian level (the output of this product is only available over Italy).

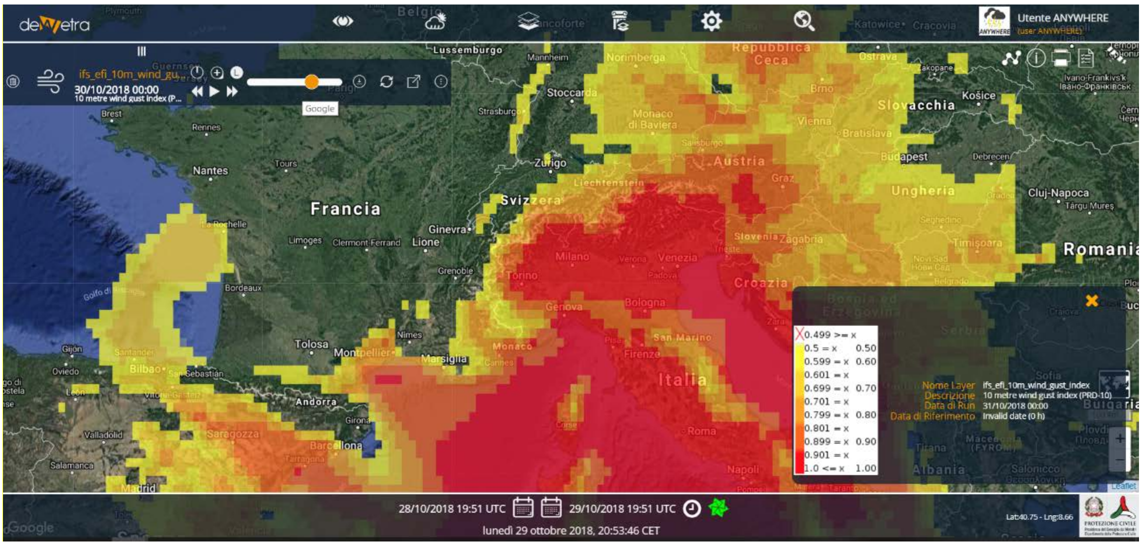


Figure 9. Strong wind predictions trough the ECMWF model available within the MH-EWS. The strong wind was well forecasted and generated relevant storm surges and damages along the whole Ligurian coastline. In Rapallo (close to Portofino) the storm surges destroyed the harbour dam causing damages for more than 100 MEuros both to infrastructures and boats and yachts.

2.4.3 Main impacts of the event

Although rainfall has reached cumulative points even higher than 600 mm during the event, the damages associated with the rains have been represented at most by local flooding. The most significant damage was related to the wind and the sea. The event was marked by a victim hit by a piece of roof that flew by the wind to Albisola Superiore.

Figure 10. Rapallo harbour (close to Portofino): the storm surge destroyed the harbour dam causing damages for more than 100 MEuros both to infrastructures and boats and yachts.

The winds have caused numerous falls of trees and in general quite large. In addition to the victim, there were two injured, one on the A10 motorway, the other in Genoa for a tree collapsed on the house. Strong difficulties for the wind also in the ports of Spezia, Genoa and Savona with frequent breaks of moorings. The sea has caused severe damage to the entire coast, in particular by destroying the Rapallo breakwater and damaging the structures near the coast (Figure 10). The road to Portofino collapsed, extensive damages to bathing facilities and to the railway network were registered, with trains blocked throughout Liguria.

2.5 Forest Fire (WUI Fire), 19 March 2019, Voltri - Liguria

2.5.1 Description of the event

In the month of March, after a long period of no rainfall, the conditions predisposing to the possible ignition of fires were very high. Liguria Region issued the state of danger for fires and just in the days of 18 and 19 March due to some malicious triggers, a fire developed in the Municipality of Genoa.

The work of the fire brigade and volunteer teams limited the movement of the fire towards inhabited areas. Within two days the fire was completely managed.

2.5.2 ANYWHERE tools and products used

Following the issuing of the state of danger for fires by the Liguria Region, the Risico tool was used with which the areas of the city of Genoa in which the risk was greater were identified (Figure 11 and Figure 12)

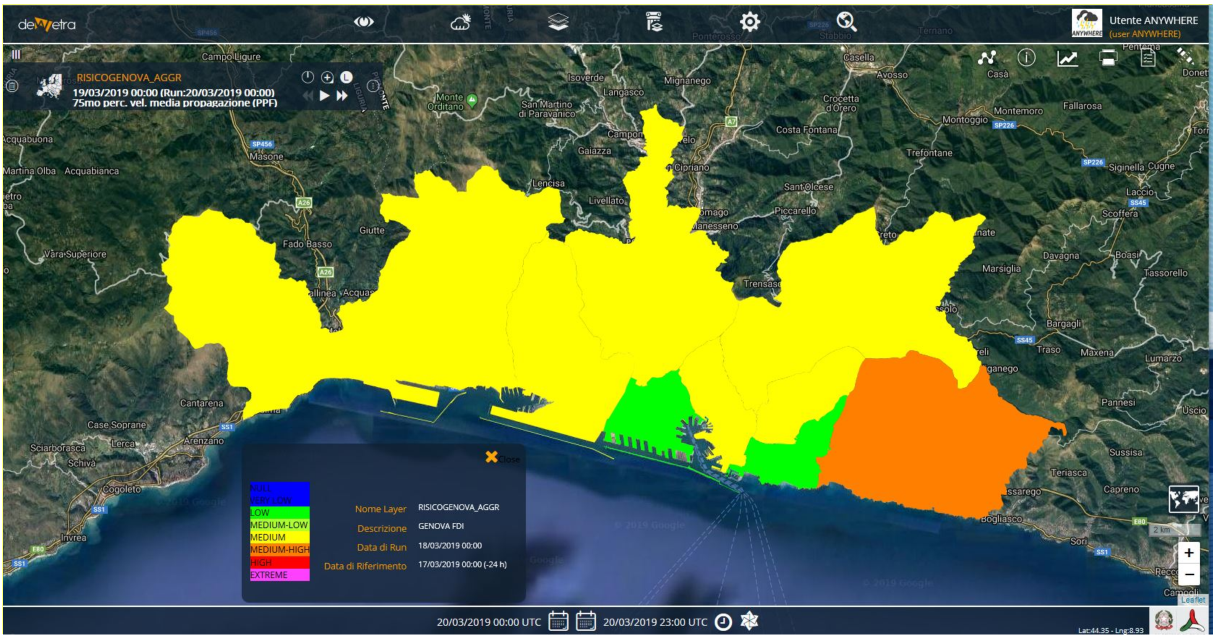


Figure 11. Fire risk map obtained from the RISICO model on the A4lig platform the day before the fire of March 19th was triggered

Once the fire started, the Propagator tool was used to understand if areas with a resident population could be involved in the event (Figure 13).

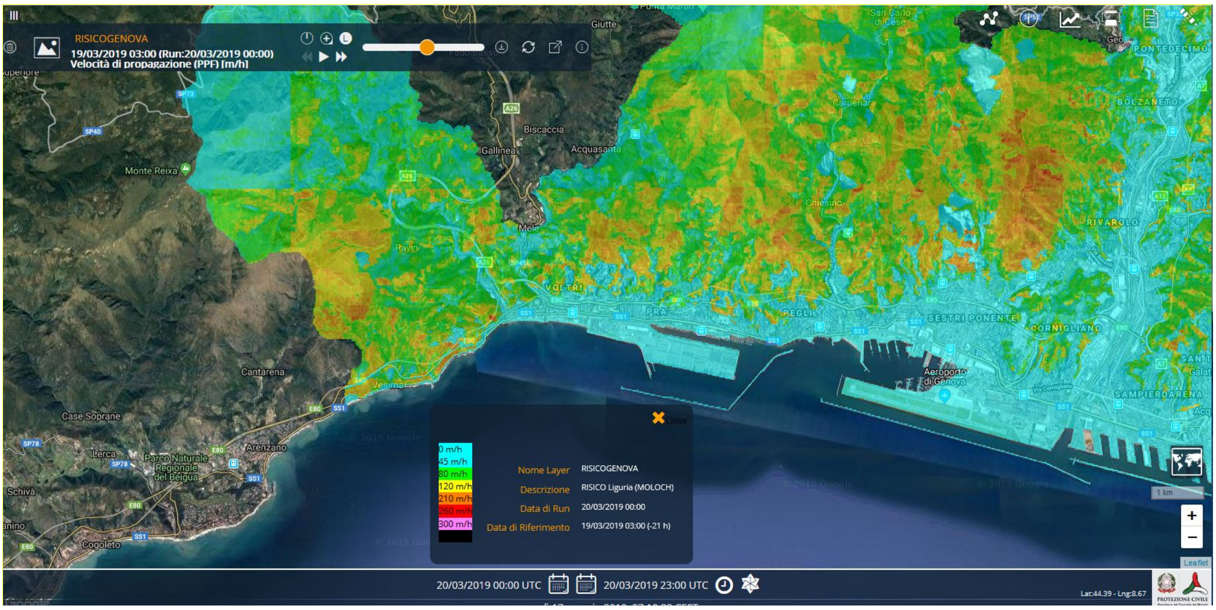


Figure 12. Fire risk map obtained from the Risico tool, on the a4lig platform, the day before the fire of March 19th was triggered

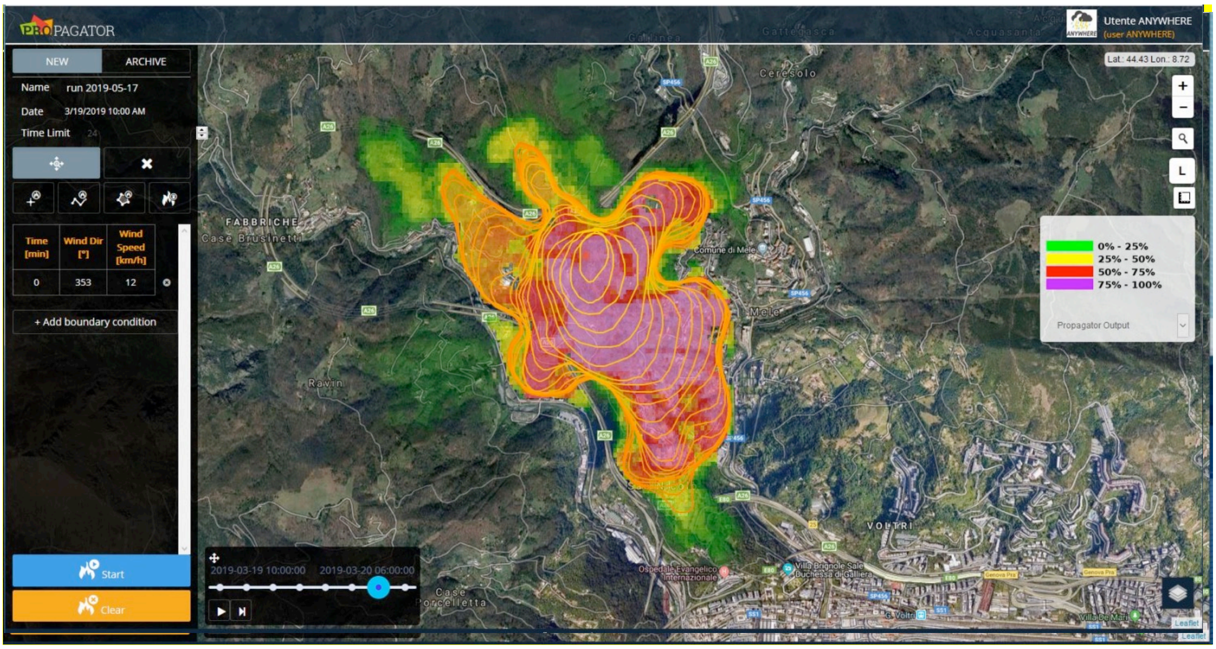


Figure 13. PROPAGATOR simulation of the WUI fire spread forecasted by the A4Lig system trough is Forest Fire models and algorithms. This map simulated the possible final path of the event and was generated just at the beginning of the fire. Its output helped the civil protection and the local fire fighters in prioritizing their actions to protect the most exposed people and relevant infrastructures.

2.5.3 Main impacts of the event

Thanks to the intervention of fire brigade personnel and volunteers the fire was limited and has surrounded inhabited areas and the highway that connects Genoa with west

Liguria in the direction of France. Fortunately, there were no major effects thanks to the timely intervention and to the wind conditions that finally changed.

2.6 Forest Fire (WUI Fire), 25-26 March 2019, Cogoleto - Liguria

2.6.1 Description of the event

Fire in Cogoleto on the 25 March 2019 at 11 p.m. a fire started and flared up on the heights of Cogoleto, in the Capieso area.

In the night between Monday and Tuesday the flames, driven by the strong wind, quickly headed towards the coast, then moving towards the west. On site Firefighters, Civil Protection, Carabinieri, Local Police, volunteers and public assistance, in a desperate struggle against the gusts that reached the speed of 100 km/h.

Some families were evacuated from their homes, since the flames were blown by the wind near some houses: 47 people were taken to the local school but almost all of them were able to return to their homes in the morning. Unfortunately, two houses were damaged by fire. Some tenth of hectares were damaged.

The causes of the fire are related to a power line failure. Due to the strong wind a cable from an electrical aerial power line collapsed on the vegetation generating a short-circuit that started the fire

This point of origin was also confirmed by those who first called the single emergency number 112 the 25th of March around 11.30pm.

During the night some small bonfires also flared up on the coast, due to burning embers flown with the wind from the woods towards the sea.

The emergency was managed by over 50 units of the Fire Brigade with the help of the volunteers, coordinated by the Dos (operations director of rescue) to ensure a contrast to the propagation of the flames and ensure the protection of people and property on the hills.

From dawn started also the launches of Canadair (fire-fighting airplanes) coordinated by the Dos, the fire-fighting actions on the hill between Cogoleto and Lerca continued throughout the morning.

The 26th of March at 20:00 the largest part of the event was managed even if the event ended completely only one week later.

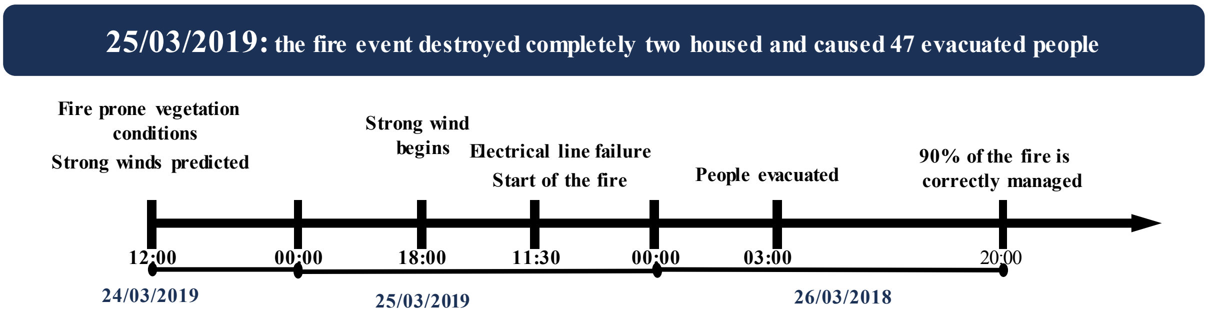


Figure 14. Timeline of the wildland-urban interface fire event that happened the 25th and 26th of March 2019 in Cogoleto (Liguria).

2.6.2 ANYWHERE tools and products used

Few days before the event the MH-EWS with its forest-fire products was providing information at European scale as well as at regional level on the increased forest fire hazard in the pilot site area, especially in the western part of Liguria (see Figure 16 and Figure 17).

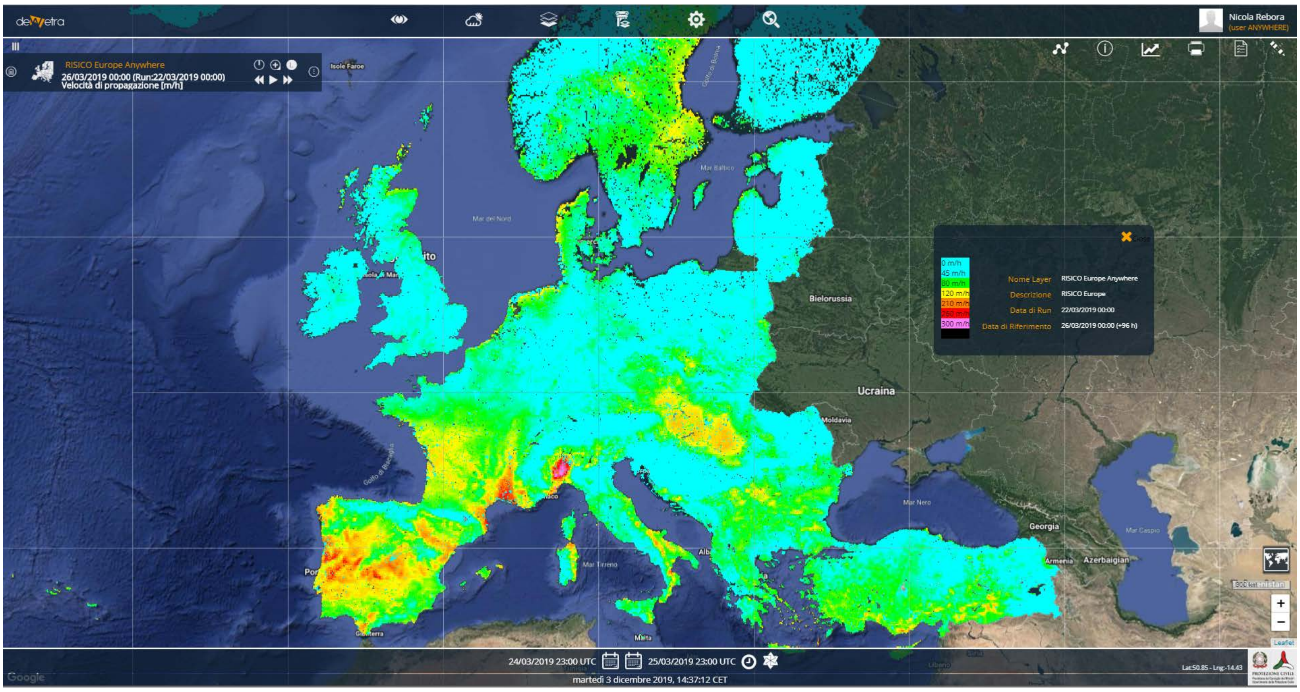


Figure 15. The RISICO model initialized the 22nd of March 2019 at 00:00 was forecasting a high Forest fires rate of spread in the southern part of Europe and particularly the rate of spread reached its maximum values (300 m/h) in the north-western part of Italy.

From the closest weather station (Figure 17) it was possible to observe a strong decrease of the moisture and an increase of the wind speed, all these conditions increased the fire hazard. The failure of the electrical line that started the fire happened due to the strong winds effects.

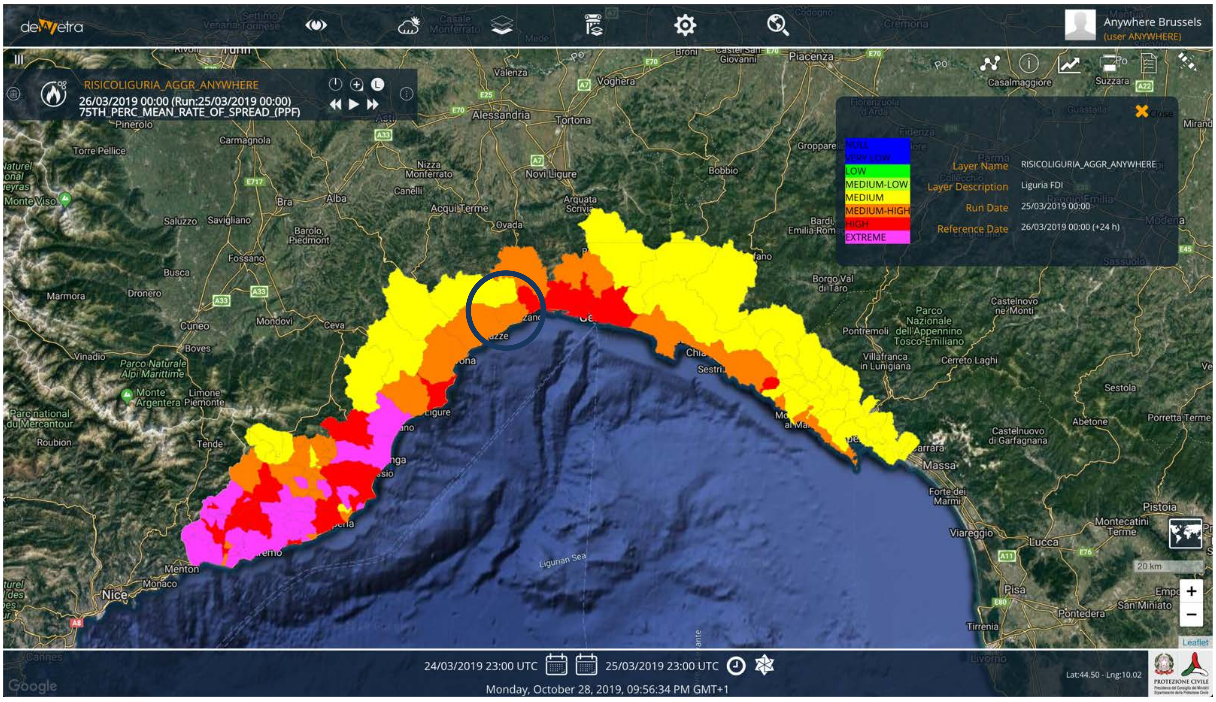


Figure 16. Fire hazard prediction using the RISICO model (specific for the Liguria pilot site) available also at European scale through the MH-EWS. The Cogoleto area were the fire started is indicated by the blue circle.

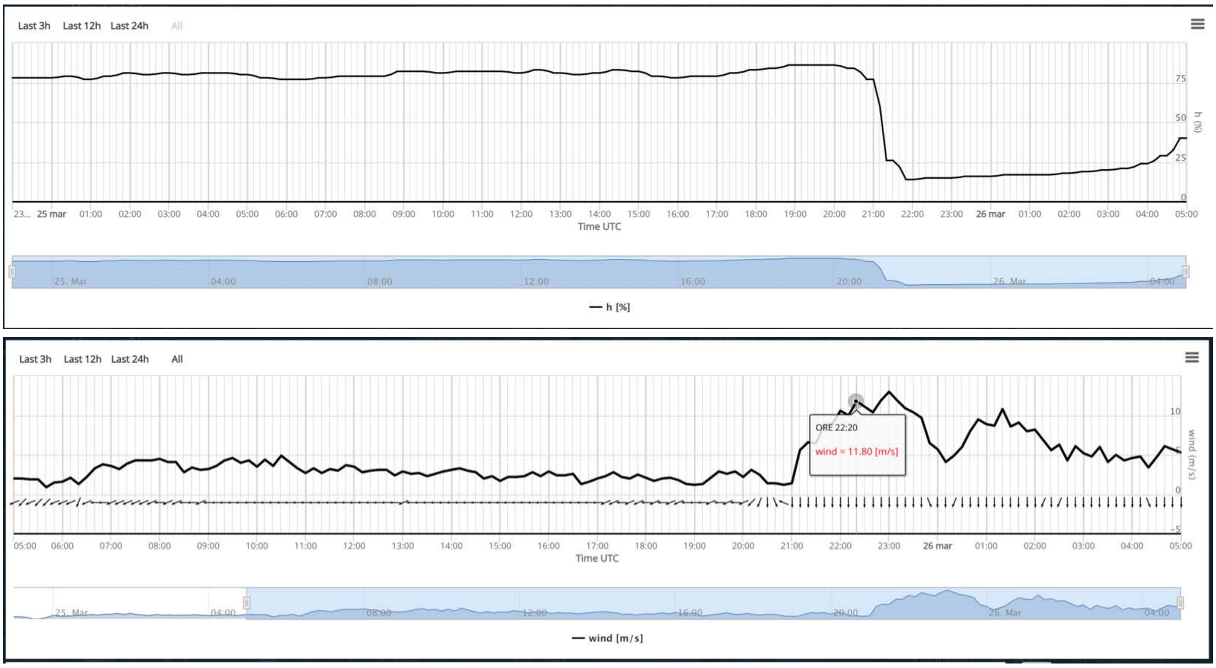


Figure 17. Relative Humidity (upper panel) and wind velocity (lower panel) available in A4Lig from a weather station close to Cogoleto in Liguria. It is possible to see, in correspondence of the forest fire event a strong decrease of the moisture and an increase of the wind speed, all these conditions increased

the fire hazard. The failure of the electrical line that started the fire happened probably due to the strong winds.

The simulation done with Propagator (fire propagation model available in the MH-EWS) at the beginning of the Cogoleto WUI fire already provided a good evaluation of the area interested by the event (Figure 18).

Figure 18. Real-time simulation of Propagator initialized with the ignition area that has been reported at the beginning of the Cogoleto fire event by Liguria Regional firefighters and with the wind conditions observed trough the weather stations available in A4Lig.

2.6.3 Main impacts of the event

In the following we report in a chronological order the main impacts of the WUI fire in Cogoleto (Figure 19Figure 20Figure 21).

26/03/2019 @00:42 highway section closed due to fire in the direction of Ventimiglia - On the A10 Genoa-Ventimiglia: the section between Arenzano and the activity of the Savona coplanar company has been closed in the direction of Ventimiglia to due to two fires adjacent to the highway. At the place of the event there are the emergency vehicles and the staff of Autostrade per l'Italia (highway manager).

26/03/2019 @0:55 in the Capieso area the Fire Brigade proceeded to evacuate the inhabitants, the flames were approaching in a dangerous manner the inhabited area.

26/03/2019 @1:05: people rescue operations have finished, Capesio area is isolated.

26/03/2019 @1:15: the highway was completely closed between Savona and Arenzano, traffic blocked also towards Genoa.

26/03/2019 @1:29: unbreathable air due to the fire smoke was detected in the center of Cogoleto, the ashes where enveloping the town.

Figure 19. Image of the Cogoleto WUI fire, 26 March 2019 at 2:30.

Figure 20. WUI forest fire event seen from the Cogoleto beach.

26/03/2019 @1:32 The message comes from the President of the Liguria Region, Giovanni Toti: Great fire in Cogoleto. The Fire Department is on site. The Civil Protection of Liguria is monitoring the situation with the Prefecture of Genoa. Families evacuated as a precaution. The strong wind is fueling the fire.

Figure 21. WUI forest fire event seen from the Cogoleto city center.

26/03/2019 @2:07 firefighters are assisting the inhabitants in the area close to the fire, the electric power was interrupted. As a precaution, some areas have been sprayed with water.

26/03/2019 @2:44 the flames have reached the highway that is connecting Genoa to Savona.

26/03/2019 @2:29 some citizens have moved away from the Ponentina town due to the dense and acre smoke that is enveloping Cogoleto.

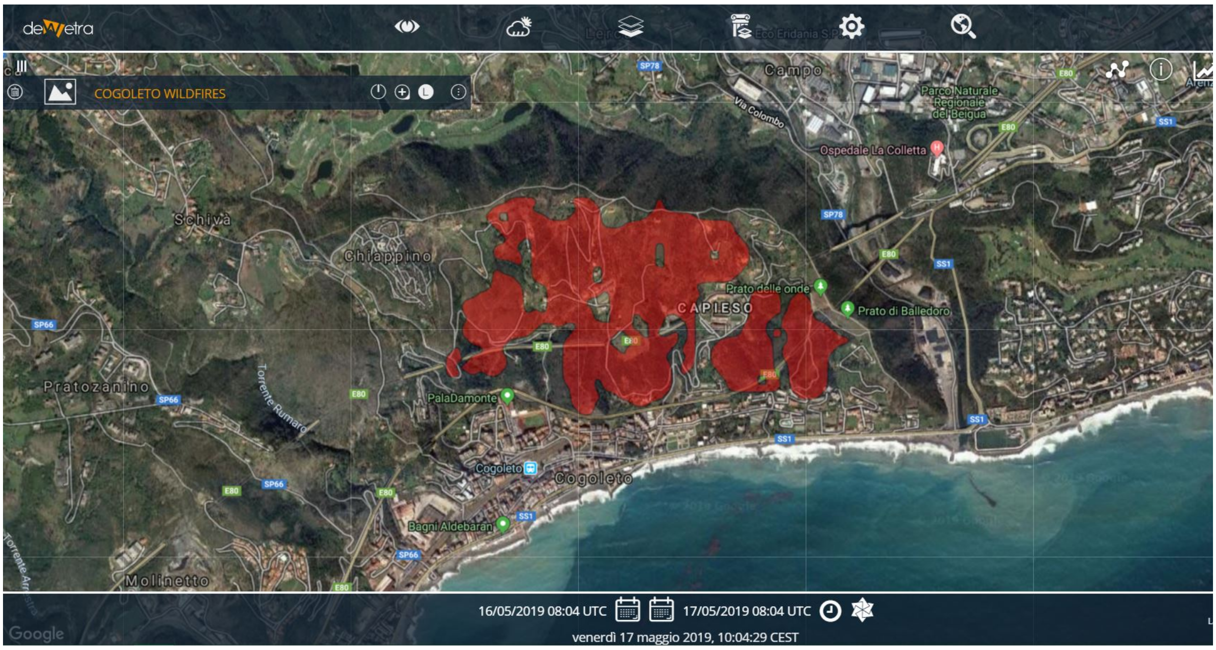


Figure 22. Observed burned area by the WUI forest fire in Cogoleto. The image was made available within A4Lig the week after the event.

2.7 Flash Flood/Heavy Rain and local flooding, 15 October 2019, Genoa

2.7.1 Description of the event

Between 14 and 15 October the region was affected by an intense event characterized by two distinct phases: a prefrontal phase, with stationary and persistent phenomena, and a frontal passage with rapidly evolving thunderstorms. The scenario at the synoptic scale that characterized the first phase of the event (prefrontal) saw the presence of a large gap on Western Europe, hampered in its movement towards the East by an anticyclonic promontory extended over the Central Mediterranean. Liguria, being on the border of the two baric structures, was exposed to an intense southern flow that carried very moist and unstable masses of air over the region. The beginning of precipitation occurred around 21 UTC (local 23 hours) following the formation of a convergence line on the ground between air masses with opposite thermodynamic characteristics, favored by a moderate baric gradient between the Po and the Ligurian Sea: on one side warm and humid air carried by intense sirocco currents, on the other fresh and relatively drier air coming from the Po Valley, exiting from the Apennine valleys.

In the following images (Figure 23Figure 24Figure 25) are reported the most significant cumulative in 10 minutes estimated by the radar of Settepani (SV) that highlight the persistence and stationarity of the phenomena. It is observed how the precipitations have developed along the convergence zone and the system has assumed the typical characteristics of a self-healing storm. A determining factor for the persistence and stationarity of the phenomena was the flow at medium tropospheric levels, directed parallel to the ground convergence line, of moderate intensity and between 30 and 40 km/h. The dynamics at the local scale just described have favored persistent precipitations for several hours on the Genoese West, made locally more intense due to the contribution of the lifting. Between 19 UTC on 14 October and 07 UTC rainfall also occurred with thunderstorms with very high quantities on B and D and very strong intensities on B, C and D. The largest accumulations occurred between 19 UTC of 14 October and 07 UTC of 15 October between the provinces of Genoa and Savona, with maximum point values above 400 mm/12h (463 mm/12h in Mele, 440 mm/12h in Fiorino).

2.7.2 ANYWHERE tools and products used

During the event both the monitoring tools that merge radar data with those of the rain gauge network and the hydrological nowcasting tools were used. In particular, nowcasting tools were used in the early morning hours on the small basins to have a forecast on possible localized flooding and on the evolution of the river basin response. Based on these indications, the Mayor and the executive operations center made some decisions about the opening or closing of schools in the Municipality.

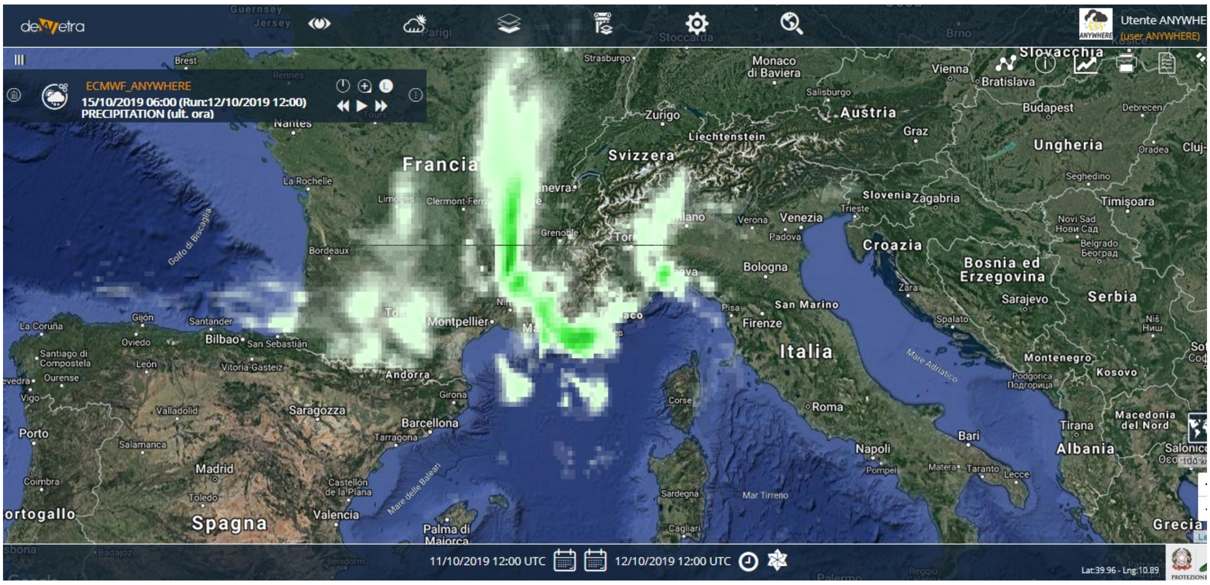


Figure 23. Precipitation prediction of the ECMWF model available in A4Lig through the MH EWS. The model indicates few days in advance the possible intense precipitation (in figure the 1h accumulation arrives at maxima of 50 mm/h).

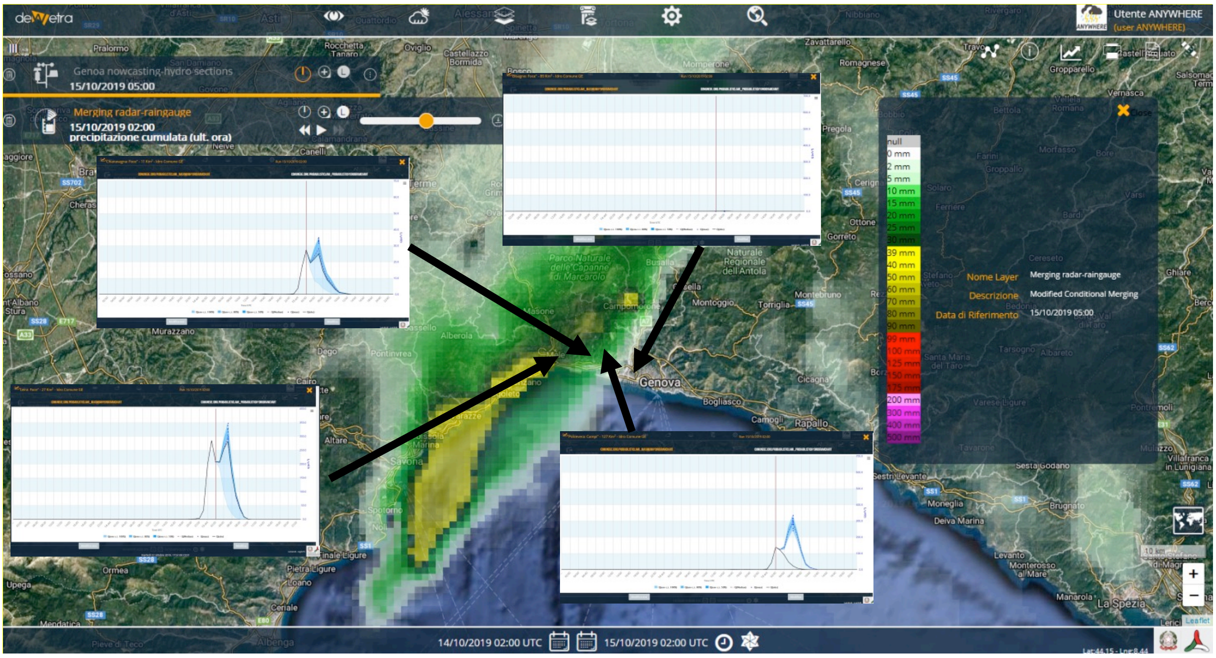


Figure 24. During the rainfall event the situation were monitored also using A4Lig tools. At 4:00 AM of 15th of October the amount of the cumulated rainfall in the western part of the municipality were significant. The use of hydro nowcasting tool showed for the next 2-3 hour there would be a high probability of flooding of some small catchment basins in the western part but not in the eastern part of the city

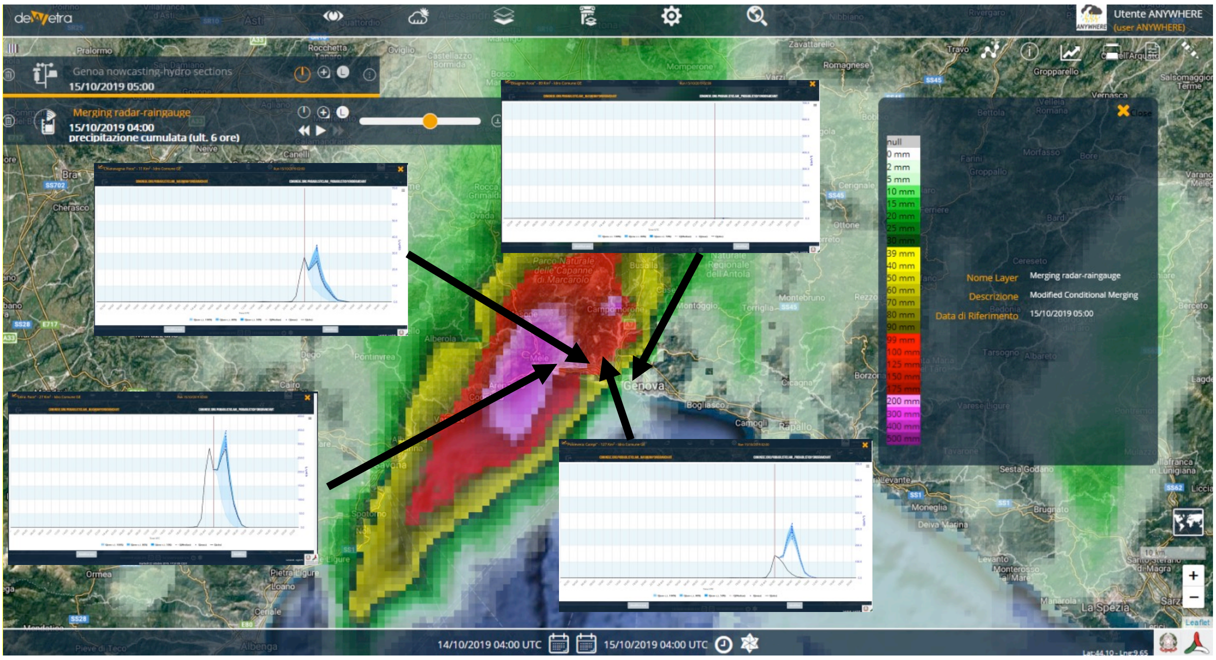


Figure 25. The rainfall map generated by merging radar and raingauges observations at the end of the event shows that the hydro-nowcasting tool correctly predict the effect of the fallen rain (almost 400mm in 8 hours) in the western part of the city.

2.7.3 Main impacts of the event

The event had the main consequences in the central-western part of Liguria. Many local flooding and failures of the secondary drainage network were registered. As a consequence, the main roads of the area experienced local flooding with a high impact on the traffic.

In this case, however, monitoring the weather conditions through A4Lig and using nowcasting tools during the event allowed for taking more aware decisions. Based on A4Lig data and nowcasting product the Genoa Mayor, Marco Bucci, supported by the CDG operational center decided to concentrate all the emergency efforts only in the western part of the Genoa city (Figure 26). As an example, the schools located on the eastern part of the city remain open while schools in the western part were closed to decrease the number of people potentially exposed to the event and to decrease the congestion of the traffic.

Figure 26. The Mayor of Genoa taking decisions for the 15 October event using also the A4Lig outputs.

2.8 Results and discussion

2.8.1 Lesson leant

During the ANYWHERE project the active involvement of the stakeholders, starting from the first phase of the project and following a co-ownership approach was crucial for designing and implementing A4EU systems that were in line with the requirements of the operational partners.

On the other hand, during the A4EU-A4Lig implementation, due to a continuous dialog between operational partners and system developers, CDG and ARPAL were able to use an operational tool, on a day by day basis, that had empowered the regional and local systems to be connected, both in terms of data and models, with the EU-level products and algorithms of the MH-EWS. These features, defined since the beginning of the project, increased the capability of anticipating the events and/or increased the awareness related to many hazards considered by the MH-EWS also at regional and local level.

2.8.2 Overall evaluation

The Municipality of Genoa (CDG) and ARPAL, as main pilot site stakeholders, have increased their response capacity in front of high-impact weather-related events trough the information available and trough the tools developed in ANYWHERE.

In the following are reported the main points that evaluate the experience of the Liguria pilot site and the possible follow-up:

1. The development of A4Lig has led to a **stable tool** with great potential
2. The use of this kind of tools would in the coming years be **the basis of the emergency management procedures** in our Region characterized by high natural risks.
3. The A4Lig multi-hazard platform is very useful in emergency room **to monitor the situation and to increase the decision-makers awareness** of high-impact weather events.

Considering the potential of A4Lig, **the municipality of Genoa intends to further develop these tools in the next year** by including its use in emergency management procedures.

3 Results of the A4EU (A4Cat) demonstration - Catalan pilot site (Spain)

3.1 Institutions leading Catalan Pilot Site operations

The General Directorate of Civil Protection of the Catalan Department of Interior (INTC) and the Catalan Water Agency (ACA) will be the users of the system. HYDS is leading the implementation of the A4EU system in the Catalan Pilot Site.

INTC and ACA are guiding the implementation to ensure that the developed system fulfils their needs. UPC-CRAHI also takes an active role supervising the floods products and the overall concept of the implemented system.

The operation of A4Cat was be done by INTC and ACA. HYDS, UPC-CRAHI and Wageningen University (WUR) supported it during all demonstration and use the continuous feedback to iteratively improve the system.

3.2 Pilot site description and A4Cat main features

Barcelona is the capital city of the autonomous community of Catalonia. Catalonia is one out of 17 autonomous communities of Spain. It covers an area of 32.000 km², located in the north-east of the country and generates 25% of Spain's GDP.

About 3.5 million out of the 7.5 million inhabitants of Catalonia live in the metropolitan region of Barcelona, which is by far the largest city in the region. The average population density is 234 inhabitants/km² but it is distributed very heterogeneously as very few people live in the mountainous areas along the border with France and Andorra.

Figure 27: Topographic map of Catalonia

The topography, and consequently also the climate, is very diverse. The lowest areas are located at sea level along the Mediterranean coast; the highest peaks of the

Pyrenees in the North West reach elevations of up to 3.148 m as (*Pica d'Estats*). The Catalan Coastal mountain range runs parallel to the coast line with elevations up to 1,712 m (*Turó de l'Home*) followed by the Catalan Central Depression in the West (Figure 27).

- The **main hazards** that affect Catalonia are: Hazardous material transport (road)
- Floods (heavy rains, rivers overflow, waves)
- Wind
- Forest fires
- Snowstorms (high vulnerability)
- Earthquakes (high vulnerability)
- Droughts
- Critical infrastructures: Chemical plants
- Critical infrastructures: Nuclear plants (3 reactors)

The main features of A4Cat are:

- Web Viewer of georeferenced information (including both MH-EWS products and local products, as well as impact information and impact summaries). Possibility to change background maps according to necessity.
- Secure internet remote access (SaaS).
- General functionalities and interfaces (data inputs and outputs management, connection to MH-EWS, database user management system and authentication).
- Visualization of the local vulnerability layers (flooding areas, critical points, infrastructures, etc.)
- Real-time crossing with the hazard forecasts ("activation" of critical elements forecasted to be at risk) and provision of key information to support warning and decision making.
- The access to the platform A4Cat is stable, most of the time, which allows a proper use of it.
- User-friendliness platform.

3.3 Main hazards faced during the operational period

Since 1st October 2018, the A4Cat platform has been used for decision-making in the emergency management room of Catalonia (CECAT). During this period different emergencies have had to be faced, but above all those related to intense rains and strong floods. The most significant episodes were:

- Flood event, October 2018 in the South of Tarragona.
- Flood event, October 2019, in the South of Catalonia and North Barcelona.
- Drought study, special development.

The attached table briefly describes the events that we will explain below. It is necessary to make a note about the special case of drought. It is a study that has been developed at the request of the ACA that has shown another way to take advantage of the resources available in A4Cat.

The WUR, HYDS and ACA institutions developed a focus on how to use A4Cat drought products to forecast reservoir volumes, which is key information for water supply planning and management in the city of Barcelona. It is clear that the results are long-term and under study. The details on the drought algorithms and methodology used during the demonstration period in the Catalonia pilot site are gathered in ANNEX 1.

Table1. Summary of the events reported with an overall evaluation of the A4EU-A4Cat system.

Hazard	Location/Date	Short description
Flood	South Tarragona, October 2018	Cut roads Suspension of school transportation Suspension of train traffic More than 500 calls to 112 (12 hours)
	South Tarragona and North Barcelona, October 2019	7 people killed (5 identify, 2 still searching) 3 people injured in a campsite 2 buildings destroyed Isolated houses > 12 hours > 40 cut roads > 30.000 people without electric supply Rail traffic affected 3500 calls to the 112
Drought	Catchment areas	Forecast reservoir volumes

3.4 Flood, 19TH October 2018

3.4.1 Description of the event

Between the 18th and 20th of October there was an episode of rain with a risk of strong intensity and accumulation in the south counties of Catalonia. On Thursday 18th

CECAT issued a release activating the emergency plan in alert phase due to the severity of the forecast:

- concerning accumulation, expected for the 19th, low probability of accumulation of more than 200mm in 24h in the southern regions
- concerning intensity, expected for the 19th, high probability of exceeding 20mm in 30min also in the southern regions

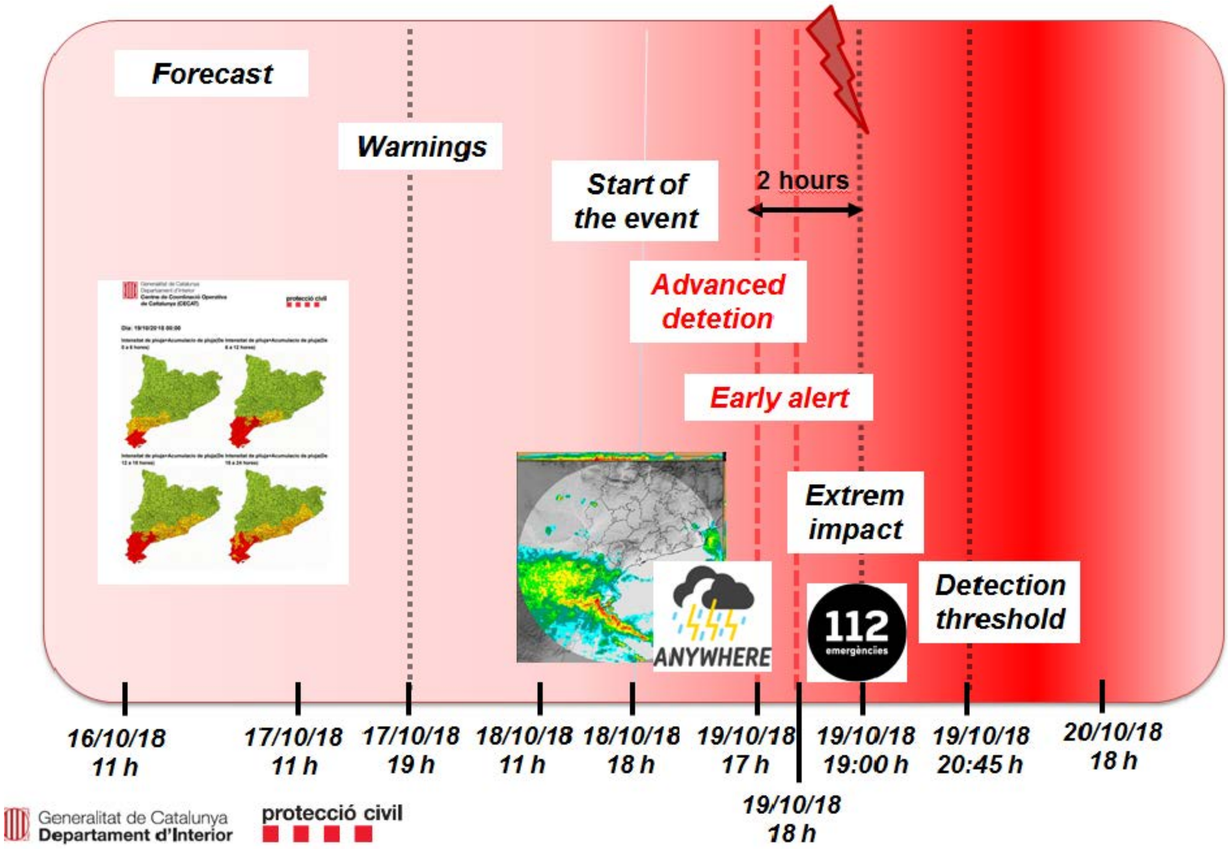


Figure 28. Timeline of the 19th October 2018 flood event.

Chronology of key actions on the 19th afternoon related to the A4Cat:

- 17:15h, monitor the evolution of the phenomena with A4Cat, rain and river warning advanced detection.
- 17:50h, CECAT broadcasted an update of the alert based on A4Cat Warnings.
- 18:00h, A4Cat rain and river warning advanced detection confirmation, one hour and a half before the incidents occurred on the field.

3.4.2 ANYWHERE tools and products used

A few days before the phenomenon began, as can be seen in Figure 29, the meteorological service of Catalonia issued warnings related to the intensity and accumulation in the southern area of Tarragona. It coincided with the ECMWF forecast for the 19th.

When the event started, all the nowcasting products were used from CECAT to monitor the evolution of the storm. Thanks to the fact of having all the products in a single application it allows to work in a more agile way. The lower part shows a radar image (product Radar 30 min accumulation SMC). This image was 1 hour and half before the incidents on the field started.

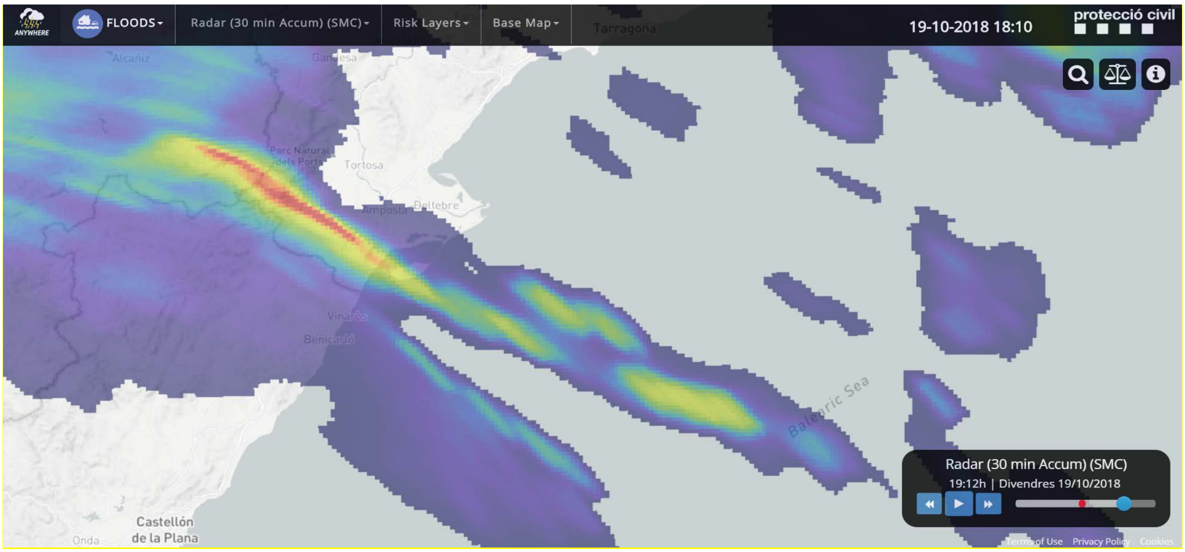


Figure 29. Radar (30 min accumulation SMC). Screenshot at 18:10, storm movement forecast at 19:12 (advance detection)

After checking the radar, we consult the products: Rainfall warning (SMC) and River Warning (SMC). The following images (Figure 29 and Figure 30) show the warnings for that day at 6 p.m.

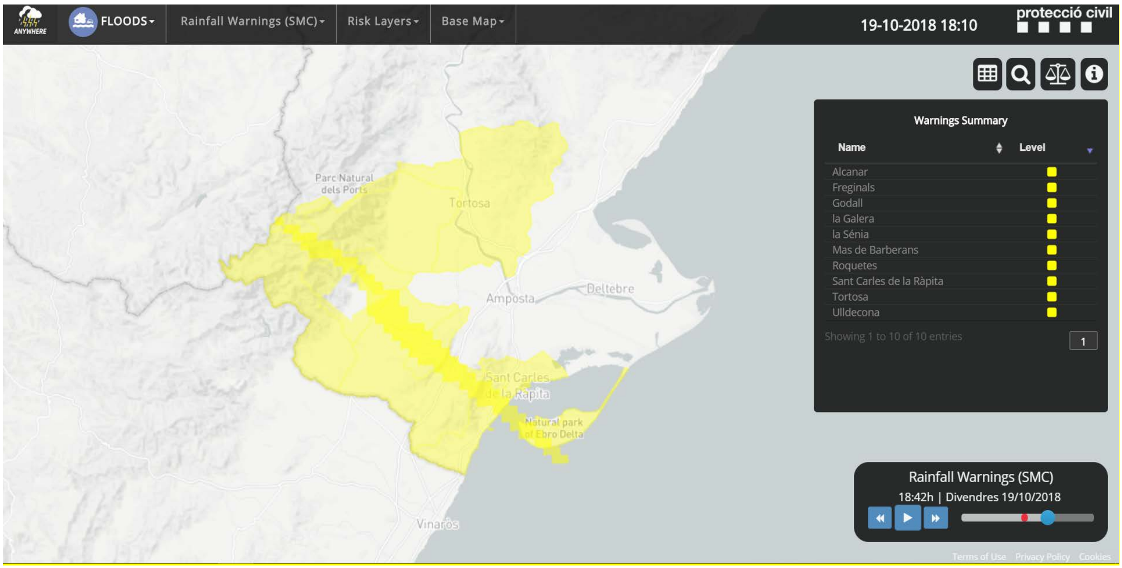


Figure 30. Rainfall warning product (SMC). Screenshot at 18:10h, expected impact at 18:40h.

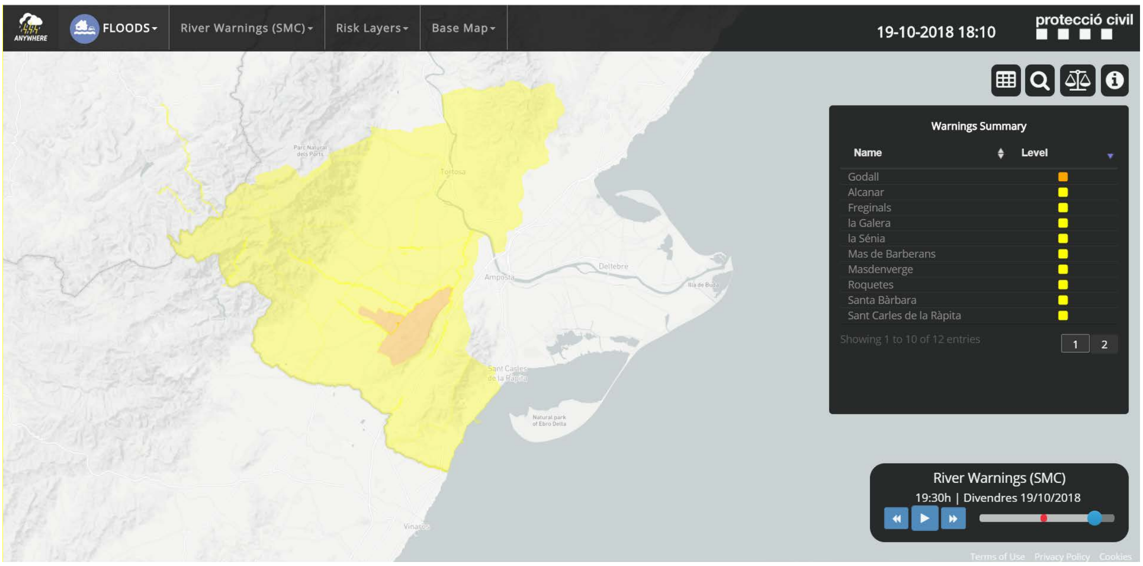


Figure 31. River warning product (SMC). Screenshot at 18:10h, expected impact at 19:30h (Early alert)

In addition, after updating the release with the information coming from the A4Cat, the pluviometer, river gauges and reservoir was consulted as well.

3.4.3 Main impacts of the event

The main impact of the event was (see Figure 33):

- Road affectation: 4 cut roads and 2 more affected
- Suspension of school transport in the municipality of Ulldecona and the region of Montsià
- Electricity supply cut-off for more than 2 hours in Sant Carles de la Ràpita (around 14.000 inhabitants)
- Long-distance trains between Barcelona and Valencia cut short due to flooding at Vinarós station
- More than 500 calls to the 112 centre (see Figure 32)

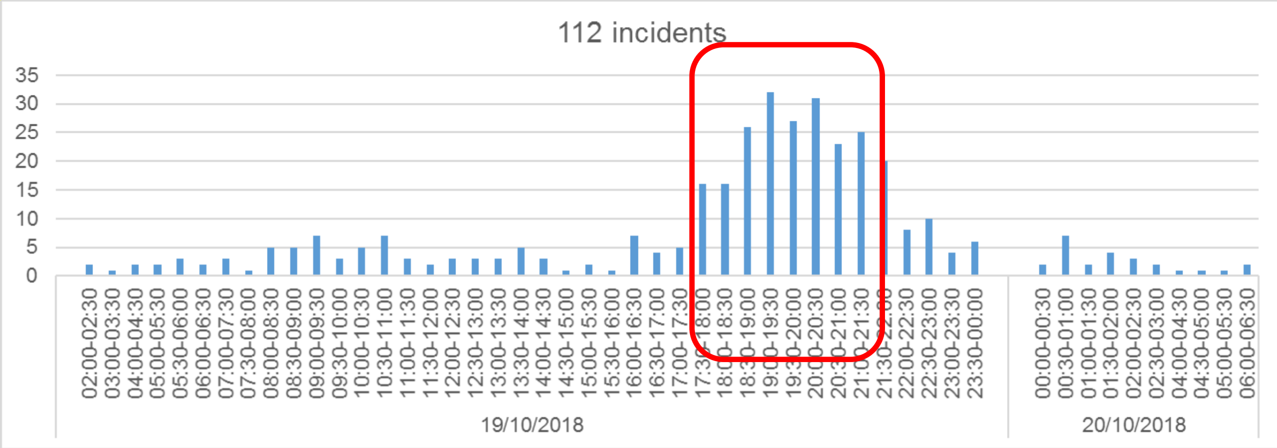


Figure 32. 112 calls related to the 19th October 2018 event.

Figure 33. Some pictures from the affected zone. The photograph at the bottom left is consistent with the river warning showed in Figure 31.

3.5 Flood, 22nd-23rd October 2019

3.5.1 Description of the event

During the 22nd and 23rd of past October, Catalonia was hit by an extreme phenomenon in different parts of the territory (in the Figure 34 it is shown a map with the affected areas). In some areas there were exceptional registers of rain (293 mm to Prades of which 188 mm in 3 hours and half) and river heads (growing from 0.5 to 3.5 m in 5 minutes to Francolí in Montblanc) equivalent to return periods of 50 years.

In this regrettable episode, in addition to material damage such as 2 buildings destroyed, 6 houses affected, cuts in electricity supply and telephone lines, traffic cuts in more than 40 roads (including highways) and cuts in railway traffic. Moreover, 10 people were affected of different severity: 5 people were killed, 2 people are still missing and 3 were injured.

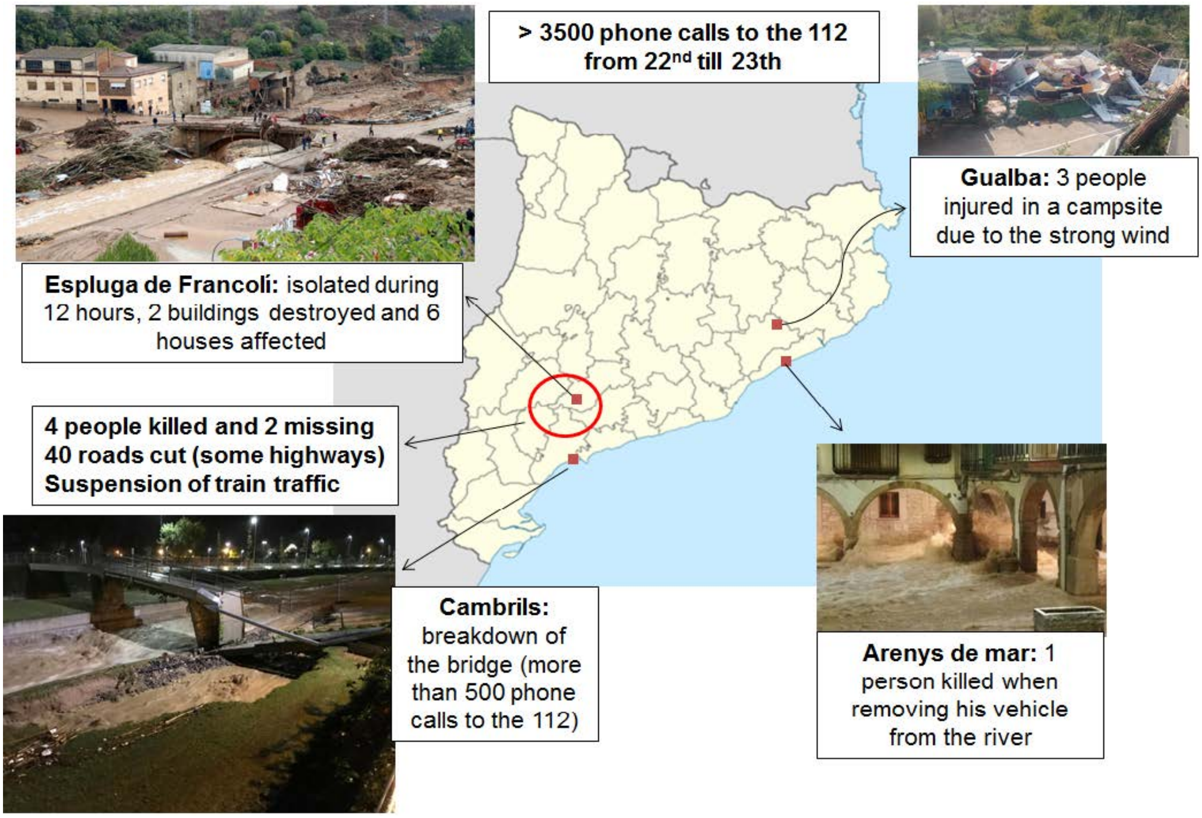


Figure 34. Most affected areas and main consequences related to the 22nd-23rd October 2019 event.

In the scheme of the evolution of the event it is showed that from October 18th, 5 days before the start of the floods, thanks to the platform EFAS (European Flood Awareness System) an episode of flash floods is predicted in the coast and pre-coastal of Tarragona and Barcelona.

Due to the severity of the phenomenon from day 21th the emergency plan begins in pre-alert phase to prepare the operational strategy. Municipalities, emergency services and citizens are warned based on data obtained from the EFAS and A4Cat platforms.

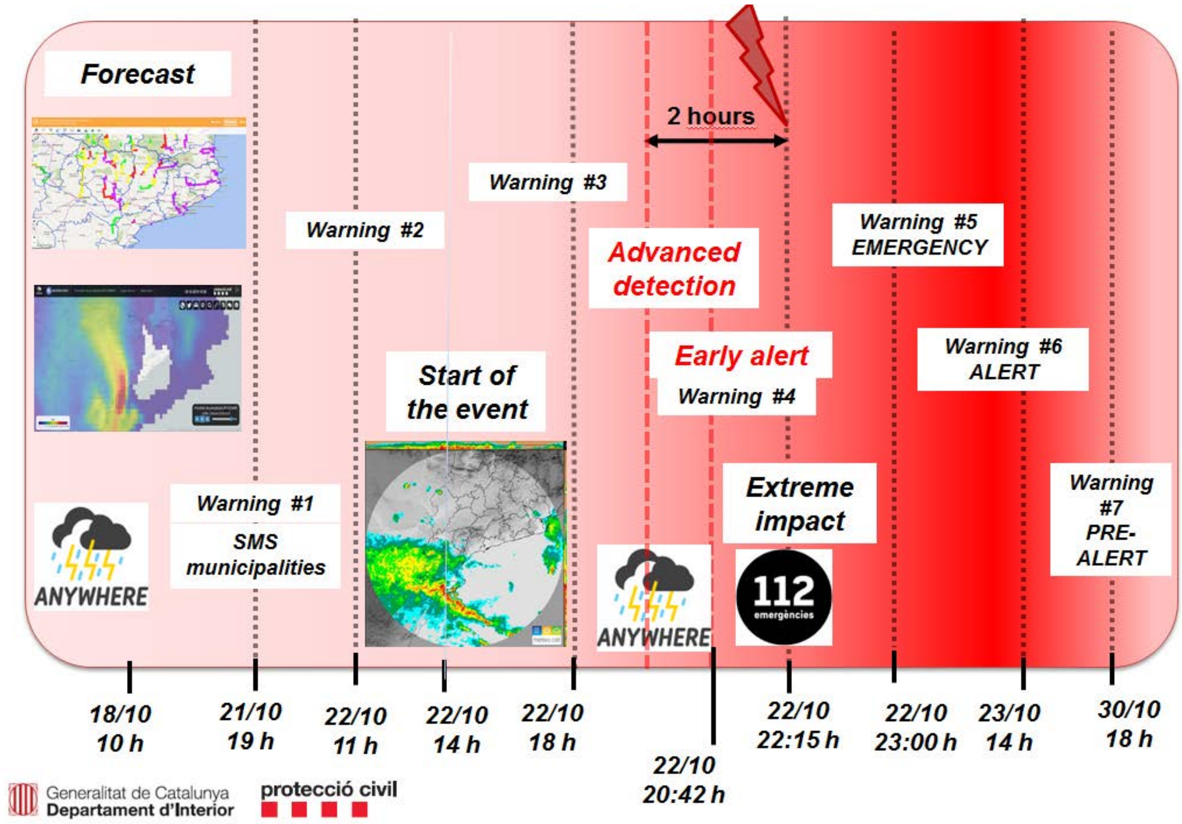


Figure 35. Timeline of the 22nd-23rd October 2019 flood event.

As the event approaches and the incidents begin, the message is modulated to the population, requiring at certain times that they do not move and remain confined at home. This warning could be advanced thanks to the 20:42h alert of the product A4Cat river warning Opera (product showed in Section 3.5.2)

In this episode, it was necessary to activate the emergency plan in the highest phase due to the severity and simultaneity of the incidents.

3.5.2 ANYWHERE tools and products used

In this episode, the need to have products for strategic operational readiness, medium-term forecast and useful products during the impact of the phenomenon (nowcasting products) is evident. As we have commented in previous point, in this case it was the first time that the hydro meteorological prediction tools of the European platform EFAS was used.

<u>EFAS products used during this event are reported in the following figures:</u>

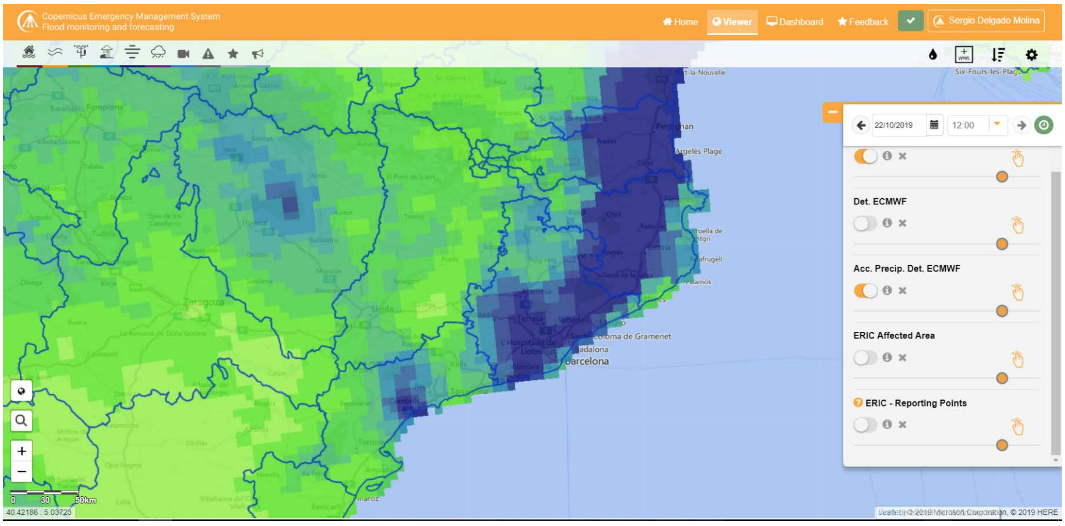


Figure 36. Accumulated Precipitation Deterministic forecast ECMWF (EFAS)

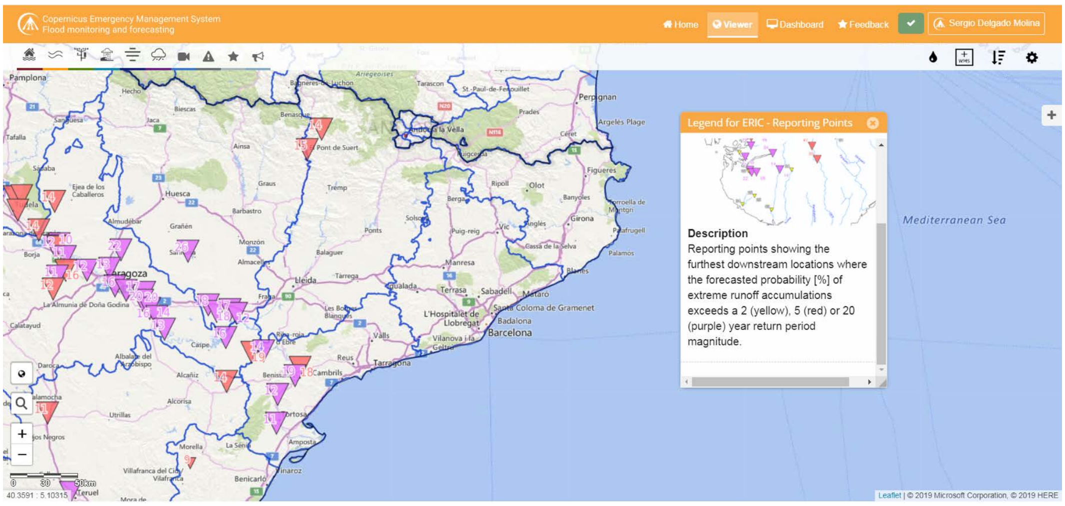


Figure 37. ERIC Reporting points (EFAS)

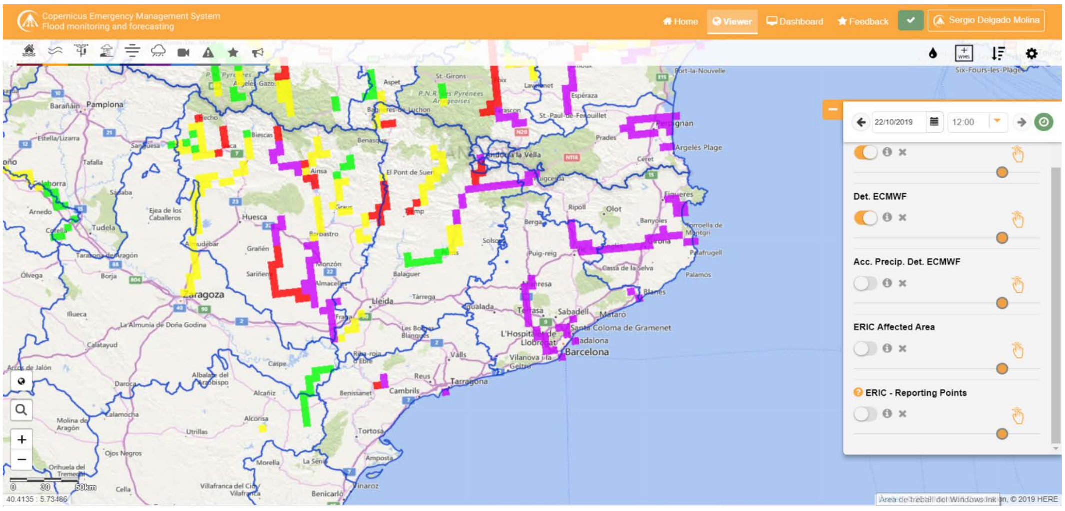


Figure 38. Discharge forecasted using deterministic ECMWF forecasting (EFAS)

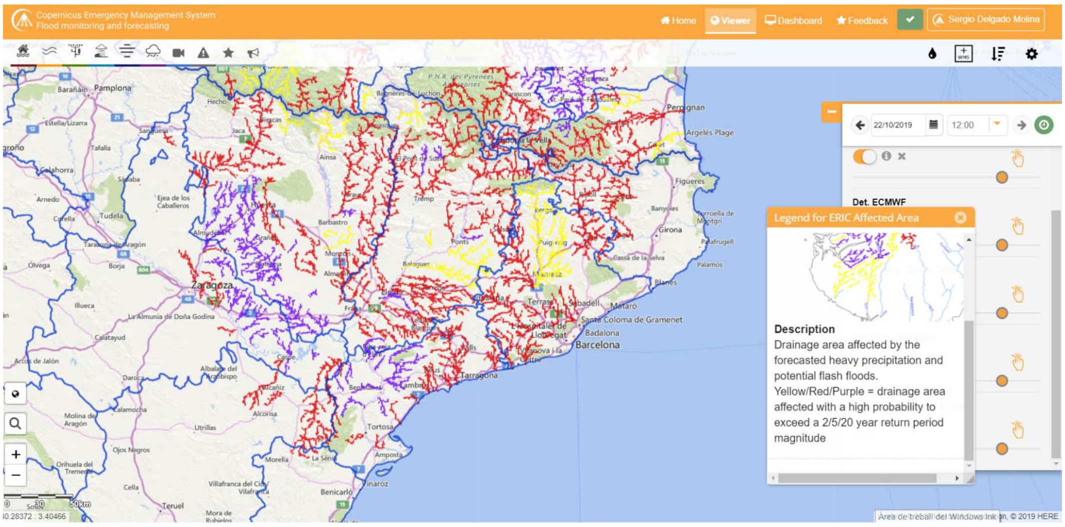


Figure 39. ERIC affected area (EFAS)

During the event, the nowcasting tools used were:

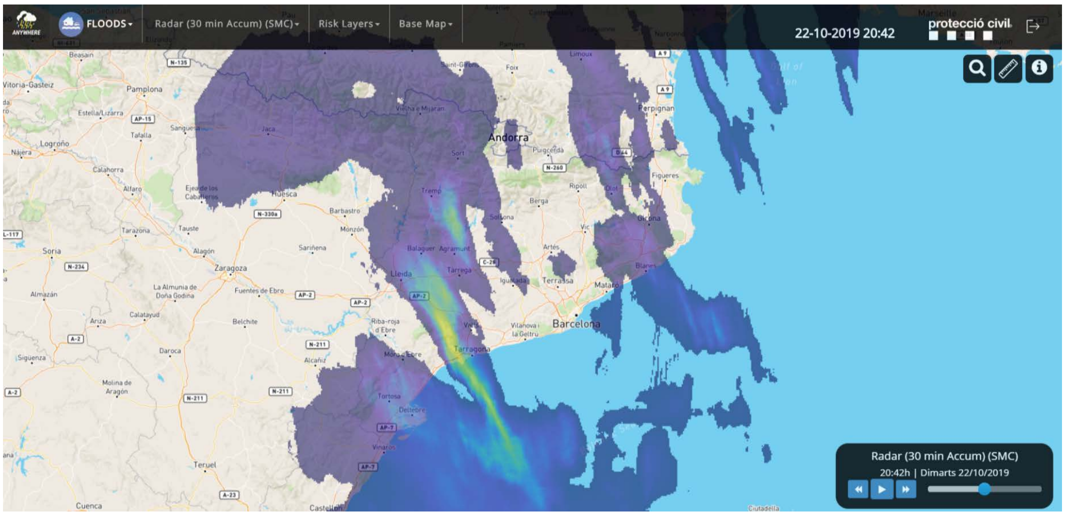


Figure 40. Radar 30 min accumulation SMC at 20:42

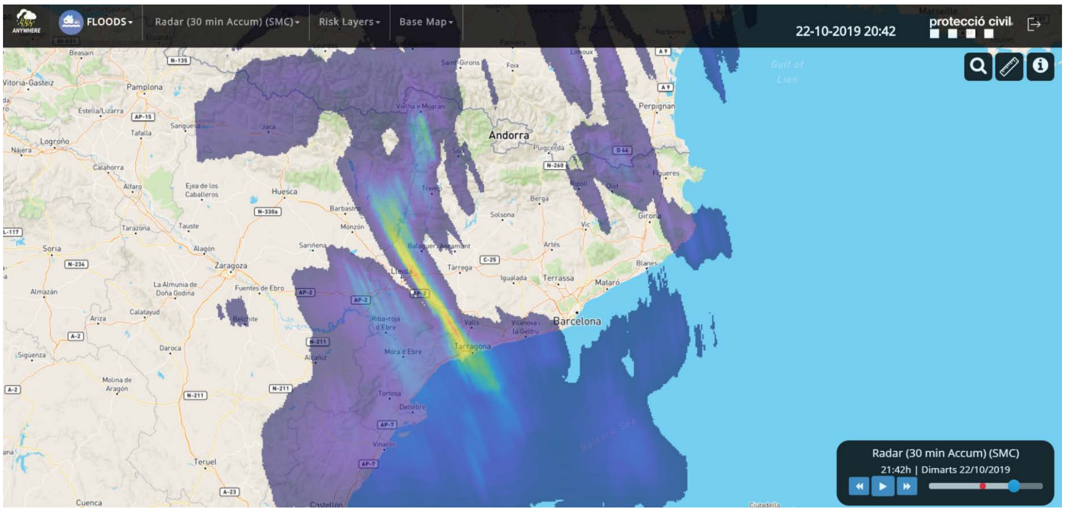


Figure 41. Radar 30 min accumulation SMC at 20:42 but with a forecast of one hour ahead.

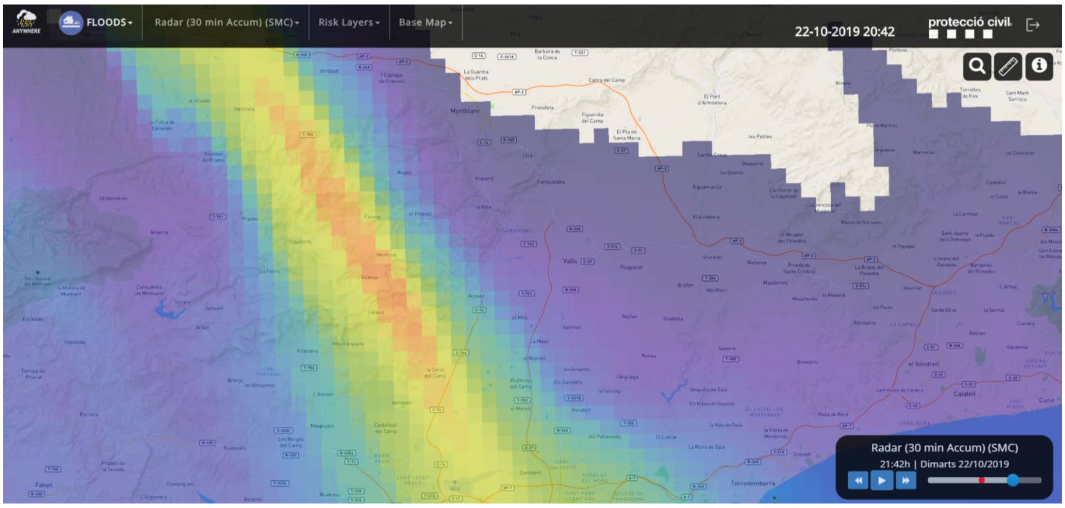


Figure 42. Radar 30 min accumulation SMC at 20:42 but with a forecast of one hour ahead zoom on Conca de Barberà county

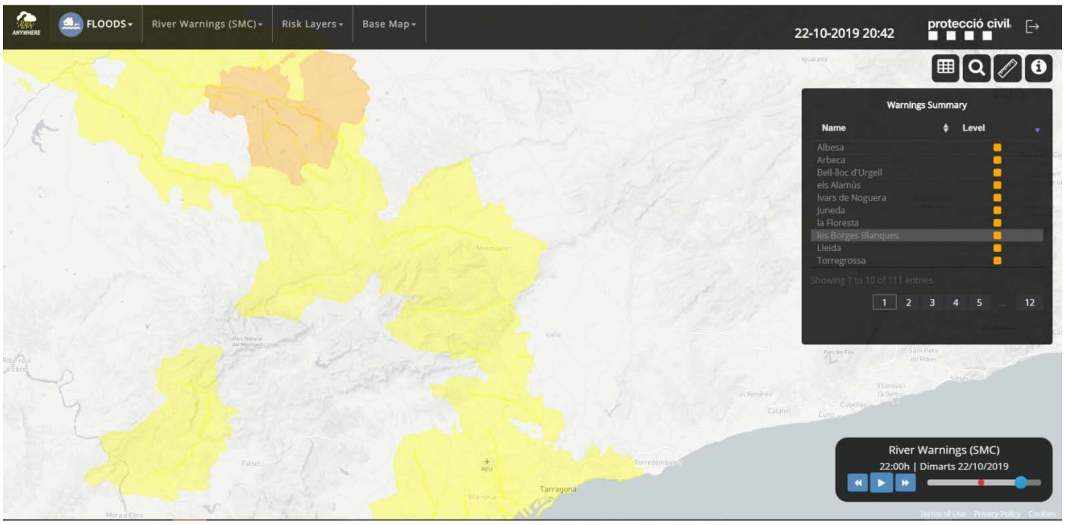


Figure 43. River warning SMC.

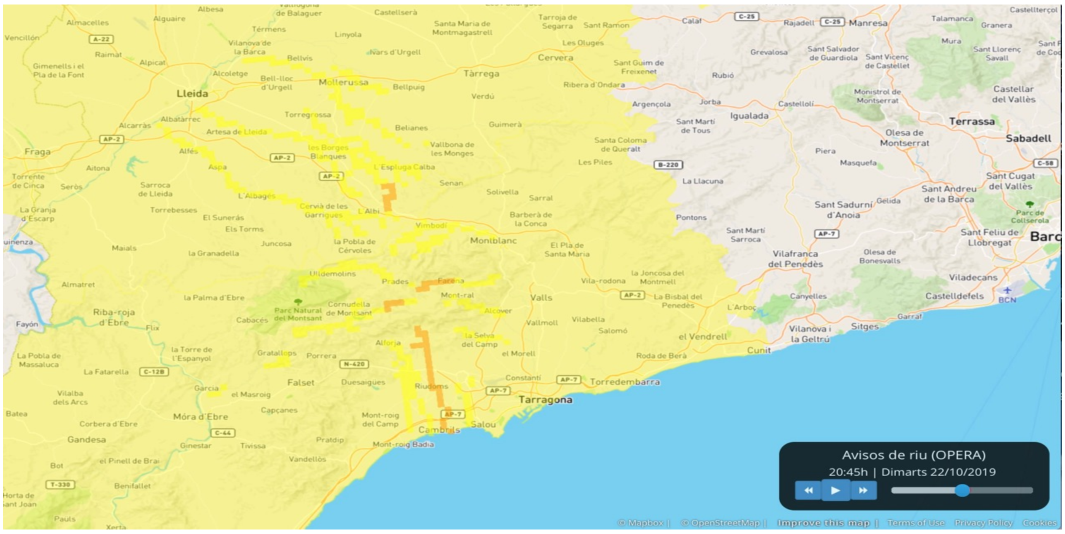


Figure 44. River warning Opera (2 hours ahead)

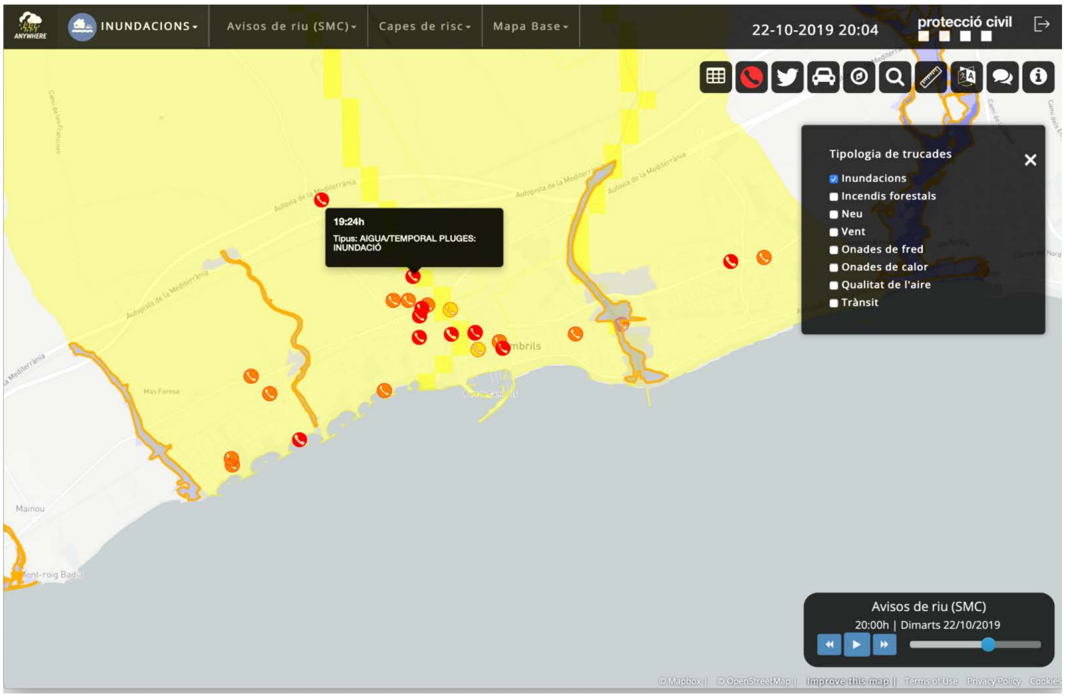


Figure 45. Combination of river warning and calls to 112 at 20h for the municipality of Cambrils. All the small rivers were in orange

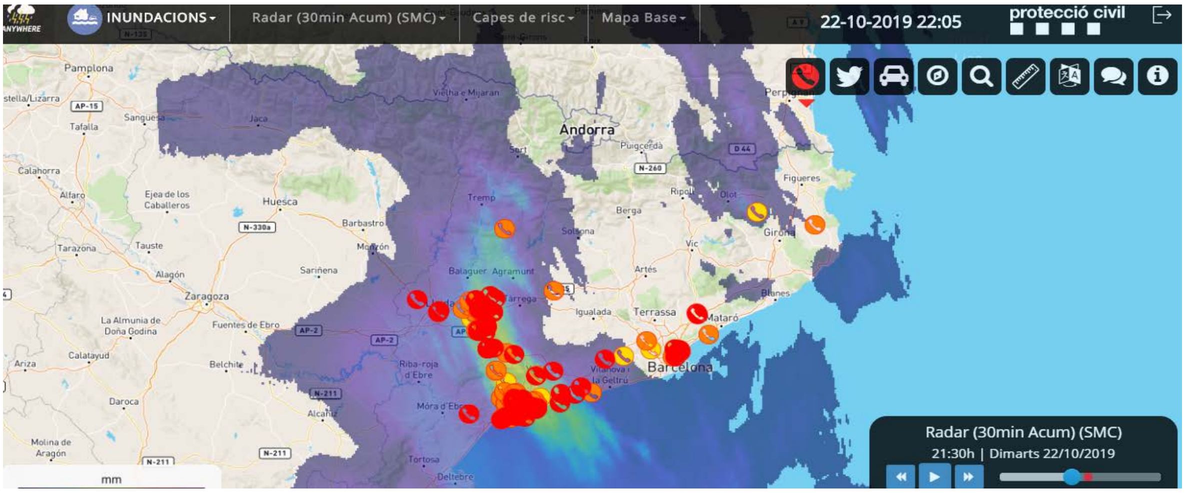


Figure 46. Combination of radar and 112 calls at 21:30h.

The most important achievement is that all this information was used in the documents broadcasted from CECAT to municipalities and emergency services.

3.5.3 Main impacts of the event

A brief summary of the main incidences derived from this event are:

- 7 people killed (5 identified, 2 still missing)
- people injured in a campsite
- 2 buildings destroyed
- Isolated houses > 12 hours
- 40 cut roads (including highways)
- 30.000 people without electric supply
- Rail traffic affected
- >3500 calls to the 112

The following graph represents the number of calls received (x-axis), time of the event and CECAT warnings. This graph reinforces the need for early warning systems to minimize the effects of heavy rains and river overflows.

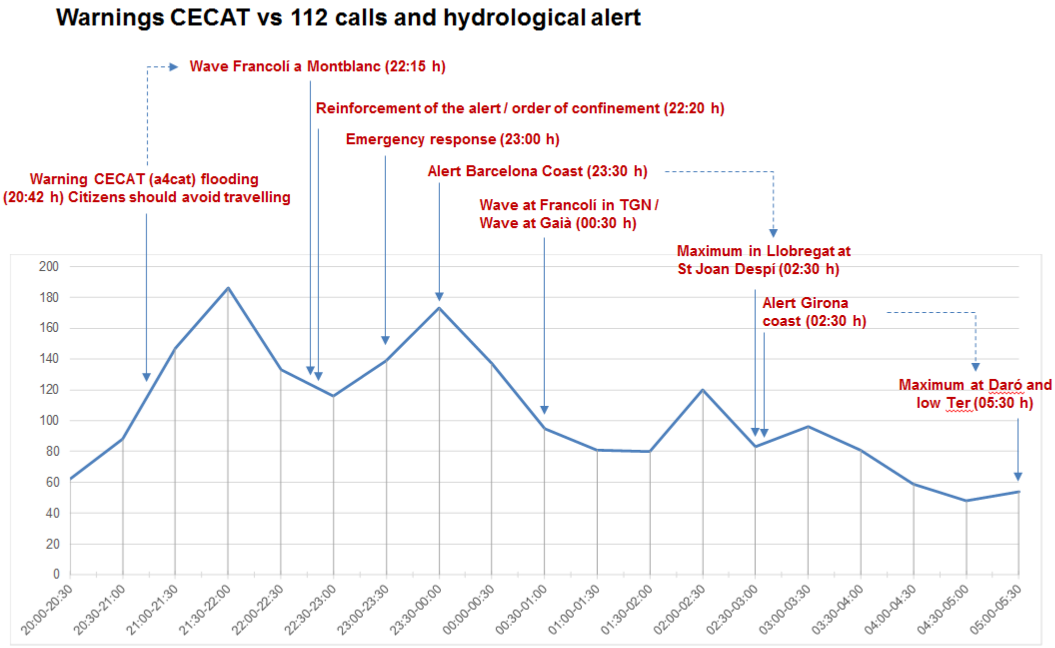


Figure 47. Graph represents number of calls received, time of the event and CECAT warnings

Figure 48. Pictures from the affected zones.

Figure 49. Pictures from the affected zones.

3.6 Drought

In Catalonia, rainfall is characterized by substantial irregularity and high year-on-year variability, a result of the typically Mediterranean climate. The highly climate variability makes Catalonia particularly vulnerable to periods of drought.

Catalonia has suffered various moderate and extreme droughts last decades. One of the most significant drought affected Catalonia and the whole Iberian Peninsula was droughts in between 1944 and 1950. This period of drought led to water supply restrictions in numerous towns at various times. In 1953, just 3 years after, rainfall occurred only half of the normal. This led to other restrictions in May, where only 70% of all houses in Barcelona received water supply. Other most notable drought years were in 1973, 1985, and 2008, where Catalonia suffered from extreme droughts that led to significant supply restrictions. In these years, the water supply was on the verge of being cut off to Barcelona until the next rainfalls.

3.6.1 Description of the event

Due to the tremendous effect of drought on water supply for Barcelona, WUR, HYDS, and ACA developed an approach on how to use the A4Cat drought products to forecast reservoir volumes, which is **key information** for water supply planning and management for Barcelona city. Special training was not carried out because there was no extreme drought event during the project lifetime. However, all parties developed the approach in close contact. Hand on demonstration of the products was held during the final project meeting in Brussels on 29 November 2019.

3.6.2 ANYWHERE tools and products developed

Training background

Every 6 months, the Catalan Water Agency (ACA) invites all end-users of each river basin to a meeting called the “Release Commission”. The objective of the meeting is: 1) to explain the use of water over the past 6 months, and 2) to achieve an agreement with the end-users on the use of water for the next 6 months taking into account the prediction of water availability in the reservoirs.

To show the predicted reservoir volumes for the next months, ACA provides a graph showing the probability of reservoir volumes using different percentiles. The graph is called a Spaghetti diagram or forecasted volume diagram (e.g., Figure 50). The Spaghetti diagram is compiled using two premises:

- Inflow to the reservoir is calculated based on a probabilistic analysis of past inflow, which is presented as Min, P5, P15, P25, and P50. For example, P5 means that with a probability of 5% the forecasted reservoir volume will be lower than the indicated number.
- Outflow from the reservoir is determined based on the agreement within the end-users during the Release Commission meeting.

During the meeting, the end-users can decide to save or release more water (lower outflow or higher outflow, resp.) based on their needs for the next 6 months. Saving more water will lead to higher reservoir volume than releasing more water. The Spaghetti diagram will help the end-users to decide during the meeting whether they want to save or release more water. If the Spaghetti diagram shows that the reservoir volume will reach the drought thresholds in the next few months (yellow colour), the end-users may agree to save more water. Thus, the end-users, mainly farmers, can decide about contingency actions for the next months. One should note that the water saving procedures will be automatically applied, without consulting the end-users, if the observed volume of the reservoir reaches the drought thresholds.

The Spaghetti diagram is prepared by ACA by using a probability analysis of the past reservoir volumes. This means that the reservoir volume is predicted in a similar manner as the Ensemble Streamflow Prediction (ESP) concept[1]. Our study submitted to Environment Research Letters (ERL)[2] about seasonal drought forecasts shows that the dynamical forecasts provided by the ANYWHERE project have higher skill than the

[1] Day, G. N. (1985): Extended streamfow forecasting using NWDRFS. J. Water Res. Plan. Man., 111(2), 157-170.

[2] Sutanto, S. J., Wetterhall, F., and Van Lanen, H. A. J.: Hydrological drought forecasts outperform meteorological drought forecasts, Environ. Res. Lett., under review.

ESP. The dynamical forecasts, therefore, open a new insight to be used in predicting the reservoirs volume.

The objective of the training was to forecast the reservoir volume based on seasonal dynamical forecasts. The outcome of the forecasting approach intends to help the end-users, especially ACA, to improve their planning and preparation for the next drought periods.

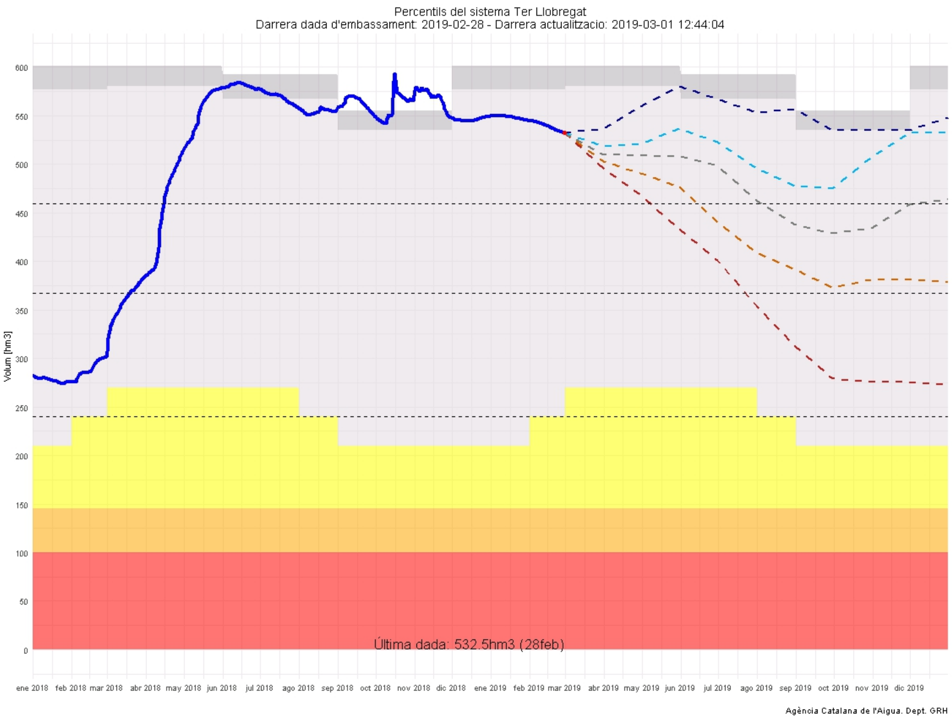


Figure 50. An example of a Spaghetti diagram for the Llobregat reservoir. The reservoir volume levels (dashed lines) are forecasted from February to December 2019 for Min (dark brown), P5 (light brown), P15 (green), P25 (light blue), and P50 (dark blue). Yellow, orange, and red areas indicate the drought thresholds for alert, exceptional, and emergency conditions, respectively.

3.6.3 Methods

Two different approaches for the reservoir volume forecasting were developed. The starting point for these approaches was the so-called: (i) Categorical approach using the Standardized Precipitation Index (SPI)[3], and (ii) Seasonal flow forecast approach. We called the two approaches: (i) the SPI approach, and (ii) the Water Balance approach. The products used in both approaches were obtained from the ANYWHERE MH-EWS, i.e. A4Cat. We retrieved the forecasted Standardized Precipitation Index (SPI) and forecasted discharges with lead-time up to 7 months from the ANYWHERE

[3] McKee, T. B., Doesken, N. J. and Kleist, J.: The relationship of drought frequency and duration to time scale, in: Proc. of 8th Conf. on Applied Climatology, Anaheim, California, 17–22 January 1993, Boston, American Meteorological Society, 179–184, 1993.

archive to predict the reservoir volume percentiles at the start of each month. We used data from a 15 months period (October 2017 to December 2018).

3.7 Results and discussion

During the different episodes managed, we have verified that products related to floods and intense rains associated with convection rains do not always give the best results. On the other hand, for the rains generated by low pressure systems in the upper levels of the atmosphere that have been completely separated from the zonal flow in height (called DANA or cold drop) they do give good results, both medium-term and nowcasting products.

In the case of the floods of October 2019 it is necessary to emphasize the anomalous functioning of the local radars, to underestimate the amount of rain, and the good functioning of the Opera radars thanks to which the different warnings were obtained.

The most important achievement is that all this information was used in the documents broadcasted from CECAT to municipalities and emergency services.

As the event approaches and the incidents begin, the message is modulated to the population, requiring at certain times that they do not move and remain confined at home. This warning could be advanced thanks to the 20:42h alert of the product a4cat river warning Opera (product showed in Section 3.5.2).

In this episode, it was necessary to activate the plan in the highest phase, emergency, due to the severity and simultaneity of the incidents.

Moreover, the need to have products for strategic operational readiness, medium-term forecast and useful products during the impact of the phenomenon (nowcasting products) is evident. As we have commented in previous point, in this case it was the first time that the hydro meteorological prediction tools of the European platform EFAS was used.

In the case of A4Cat drought products to forecast reservoir volumes as key information for planning and managing water supply in the city of Barcelona, we have already explained that the results will be medium and long term. Anyway, you will find in the annex of this document the two approaches used to do this study, the SPI and the water balance approach, and also the results and conclusions.

4 Results of the A4EU (A4Finn) demonstration– Savo and Karelia (Finland)

4.1 Institutions leading South Savo Pilot Site operations

The operation of A4Finn/A4EU has been done by ISTIKE with the support of Ministry of the Interior (FMoI) and Finnish Meteorological Institute (FMI). FMoI and FMI have been guiding the implementation to ensure that the developed system fulfills their needs.

ISTIKE follows and monitors changes in the operating environment that enable it to respond quickly and with the field units to changing situations. ISTIKE does not replace the own management organizations of the four rescue services, but it supports them. ISTIKE can provide information to municipalities in the regions, cooperative authorities and other actors in various situations of disruption and forward various notifications to responsible persons.

The main functions of ISTIKE are to monitor the current security and safety situation status in the Rescue Services of Eastern Finland and to communicate the changes to the competent rescue services, municipalities and other authorities.

Other key tasks include:

- Supporting the Rescue Commander on duty and obtaining information in accordance with the Rules of Procedure
- Accident communication to support the Rescue Commander in charge
- Active monitoring and evaluation of the situation disturbances (Rapid Risk Assessment)
- Documentation
- Supporting the operation of the Regional Command Centers
- Communicating information to municipal management teams
- Other duties assigned by the Rescue officer on duty

FMI due to its operational role in producing the national forecast will also have a role of supervision and control to ensure a seamless integration of the forecast products available at regional level. AIRBUS supported the operational partners during the demonstration period and used the provided continuous feedback trying to improve the system.

4.2 Pilot site description

The regional partner for FMoI is South Savo Regional Rescue service, which runs ISTIKE (a Finnish acronym for Eastern Finland Joint Situation Centre) with three other regional rescue services; North Savonia, North Karelia (equals the area of the Regional State Administrative Agency of Eastern Finland) and South Karelia (part of the

Regional State Administrative Agency of Southern Finland) (see Figure 51). This region is sparsely inhabited with 692.000 inhabitants on an area of 67.953 km², i.e. 1/4 of the average population density in Finland. As a side remark, this is the only pilot site where the regional respectively local civil protection authorities, which tested A4Finn, are not part of the ANYWHERE consortium.

Finland is politically strongly decentralized resulting in a multi-level governance system. As an example, the local level provides the main source of finance for the Regional Rescue Services, which is the operational Rescue Authority. Nationally there are 22 regional services in Finland, which are regulated and supervised by the national level (Ministry of the Interior, FMoI).

Multi-actor governance with shared responsibilities and tasks characterizes the emergency management sector in Finland. A good example related to weather-induced hazards is the operation of the main multi-hazard early warning system called LUOVA. This system under the control of Ministry of Transport and Communications has been in use since early 2012. There are three authoritative organization's that mainly provide information for the system. The Finnish Meteorological Institute is in charge of the round-the-clock on-call duty the system demands as well as weather and sea-related warnings. The University of Helsinki's Institute of Seismology provides information on earthquakes and the Finnish Environment Institute (SYKE) is in charge of waterway flood-related warnings. The objective of LUOVA is to support the formation of situational pictures by providing as reliable and pre-analysed advance information as possible.

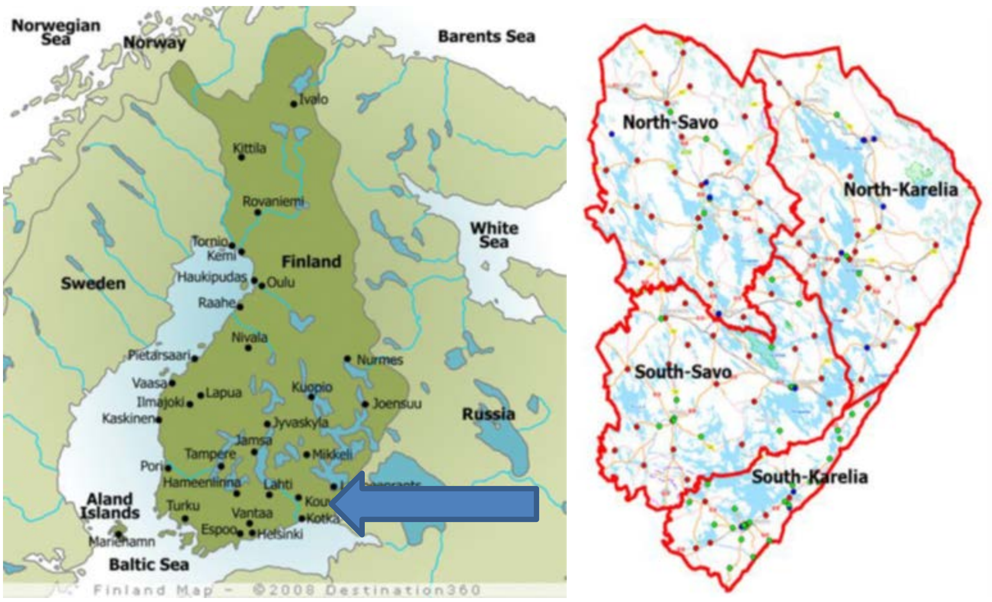


Figure 51. A4Finn pilot site at ISTIKE – East and South-East Finland Rescue Services Joint Situation and Coordination Centre area (source: ISTIKE)

The A4Finn pilot site area is sparsely inhabited and there are large seasonal variations in the population, it almost doubles in summer time due to big number of summer cottages in the region, which is famous for the high density of post-glacial lakes. Areas around the lakes are mostly covered by forest. Due to shallow soils in this area covered by glaciers during the last ice age, the roots of the trees are likewise shallow and prone to be falling during storms. Climatologically the region has high accumulation of the snow, and therefore the hazards connected to snow load cause significant impacts to forest as well as to the population in rural areas.

The main natural hazards in the pilot site are:

- Strong winds associated with extra-tropical cyclones and convective storms
- Thunderstorms
- Snowstorms
- Storms and snowstorms often result in (large-scale) power outages due to falling trees.
- Heavy rain
- Floods

4.3 Main hazards faced during the operational period

Here two snow storm events and one peatland fire event are describe**d**, which occurred during the operational period of October 2018- September 2019.

4.4 Winter storm January, 29-30, 2019

4.4.1 Description of the event

During this event, south and middle part of Finland recorded high snow accumulation, approx. 50 cm in snow depth and a heavy snowfall was forecasted covering the whole country. In A4Finn the situation on Jan 30, 3:00 pm was that North Karelia region had an orange alert, whereas North Savo, South Savo and South Karelia had yellow alert (Figure 52). The same state of alerts continued till the next day. The increased risk levels were based on the combined of indicators in the weather products: freezing rain probability was on yellow level and crown snow on yellow level, the combination created an orange level for North Karelia. North Karelia rescue department raised its preparedness, stated the command readiness, contacted other stakeholders and enhanced the monitoring of situation picture. Other ISTIKE rescue departments monitored the development of the situation and enhanced monitoring of situation picture.

4.4.2 ANYWHERE tools and products used

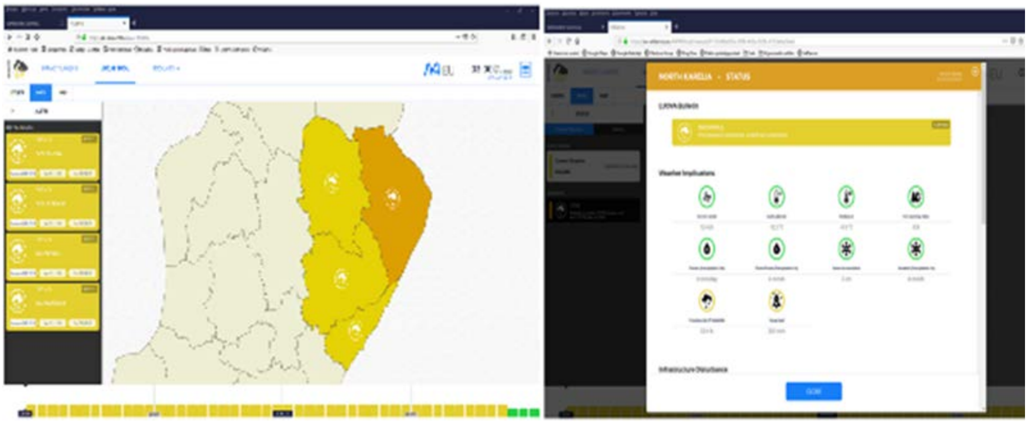


Figure 52. A4Finn tool showing the increased risk levels ISTIKE region for the January, 29-30, 2019 winter storm. At left is shown with a snowfall symbol it is indicated that FMI released a LUOVA-bulleting alerting from the coming situation. At right are shown the weather products and their values, and with a colour coding the values that are higher than the defined threshold values for increased risk.

4.4.3 Main impacts of the event

Fortunately, the snowfall accumulation was smaller than forecasted and therefore no more or more severe impacts than usual were faced. The impact was weaker than expected.

4.5 Winter storm, February 3-4, 2019

4.5.1 Description of the event

After the previous snow event, a second low-pressure system was forecasted to progress from Poland towards the western part of Finland bringing again more snow to the pilot site. There was potential for extreme heavy snowfalls. As now the crown snow load amounts were already significant in eastern Finland, it was possible for the snowfall to induce significant interruptions in electricity distribution. FMI LUOVA-bulletin was given and higher risk levels were expected in about 30 hours ahead because of combined impact of snowfall intensity, snowfall accumulation and crown snow load as indicated in Figure 53. The civil protection at ISTIKE increased readiness level. In the end, no big hazards were encountered as snowfall was weaker than expected.

4.5.2 ANYWHERE tools and products used

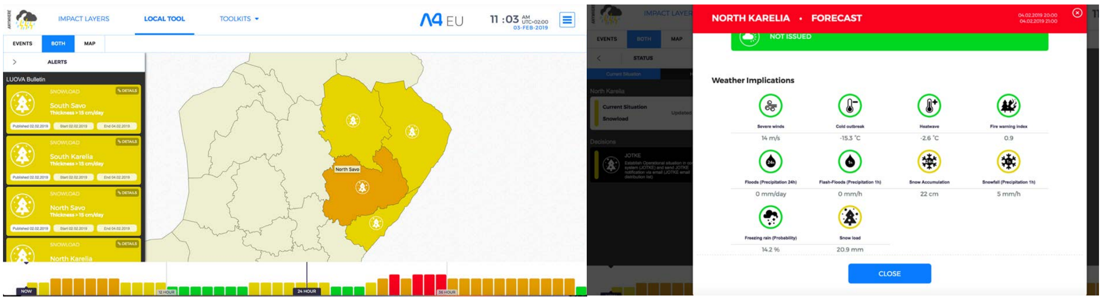


Figure 53. A4Finn tool showing the increased risk levels ISTIKE region for the February 3-4, 2019 winter storm. At left is shown with a snowfall symbol it is indicated that FMI released a LUOVA-bulleting alerting from the coming situation. At right are shown the weather products and their values, and with a colour coding the values that are higher than the defined threshold values for increased risk.

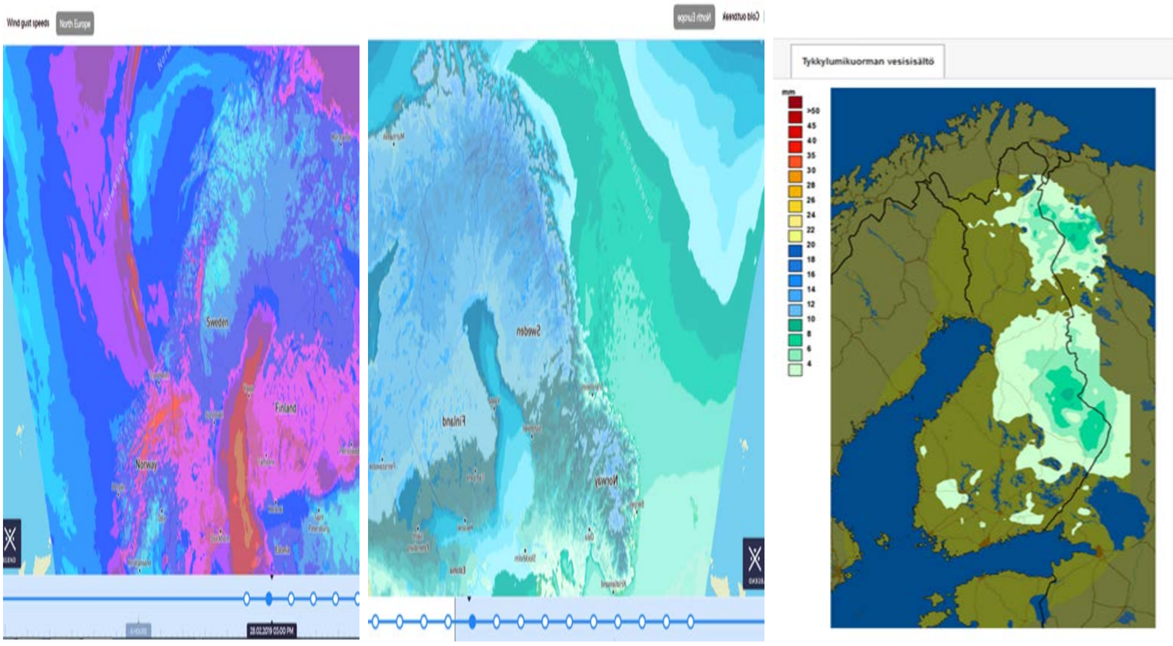


Figure 54. Other products that were available for ISTIKE. From left, wind gust and cold outbreak products on A4EU platform and crown snow load accumulation presented by FMI Ilmanet platform.

4.5.3 Main impacts of the event

Although no severe consequences were occurred, there were impacts for the society.

- Liquid Water Equivalent (LWE) precipitation: 5-15 mm
- Wind gusts: 11-17 m/s
- Households without electricity ca. 6000
- Rescue Departments interventions ca. 160

4.6 Suursuo bog fire in Taipalsaari June 10-14, 2019

4.6.1 Description of the event

This event was the biggest fire in South Karelia region in 30 years. The Suursuo peat production area covered 370 ha, and was divided in 10 sections. The fire started in section 2 (area 117 ha) and spread for many sections and the nearby forest. The weather had been warm and dry, there were several proceeding hot days on June 6 – 9, and temperatures were as high as 30°C. On the week of the bog fire the daily temperatures were 16°C - 22°C. The forest fire index was 7.6. (above the warning level of 4.0) and on the week of the bog fire forest fire index was between 4.6–5.4. The ignition day was windy, gusts of 15 m/s were observed. Typical summer wind condition prevailed on following days and the gusts were under 11 m/s. The wind direction changed drastically in between the operation causing new spread of the fire. There was no rain forecasted and, in the end, only slight rain at the end of the week.

As shown in Figure 55. The forest fire warning has been set, therefore South Karelia region has yellow alert. Two events were set to the A4Finn tool: Large scale emergency (peat bog fire) and large audience event to mimic a large-scale emergency. The combined effect increased the risk levels to red.

4.6.2 ANYWHERE tools and products used

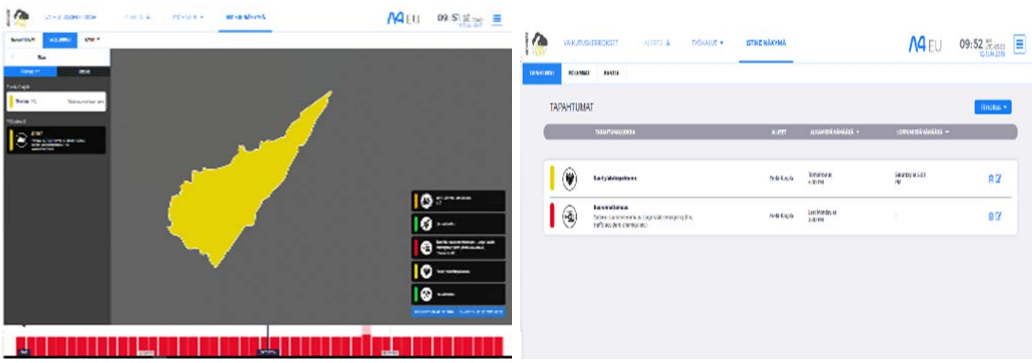


Figure 55. The South Karelia region had a yellow warning level because of the forest fire index and the increased risk level resulted from the infrastructural events added manually for the tool.

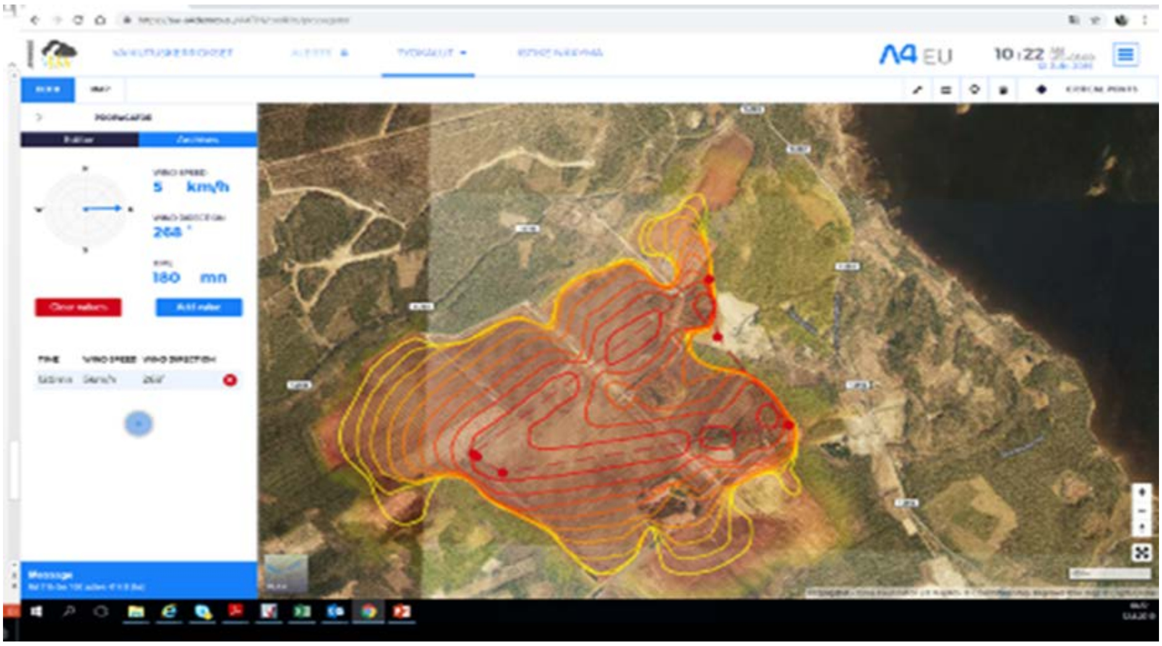


Figure 56. The fire Propagator toolkit, developed by CIMA and available within the MH-EWS, was tested during the fire event. This picture shows the estimated burned area as estimated by Propagator algorithm.

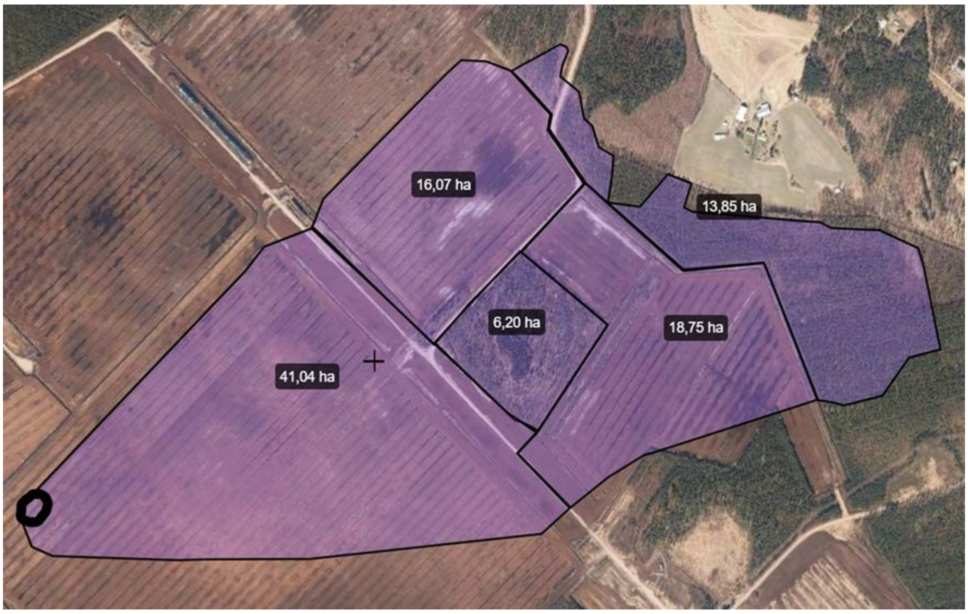


Figure 57. Actual burnt area after the event. The shape of the area interested by the event was well predicted by the model, even if overestimated.

4.6.3 Main impacts of the event

Peat production area and surrounding forest were burned 96ha between 10th and 14th June 2019. South Karelia Rescue Department got assistance from other Rescue Departments, authorities (Finnish Defense Forces and The Finnish Border Guard) and voluntary organizations and other resources from VAPO (Peat bog operator) authorities. Altogether 500 persons participated to the fire fighting. There were no casualties due to the fact that the region located in rural area.

4.7 Results and discussion

In the test events, as shown above, the A4Finn tool did show skill in reporting the coming increased risk level and did correctly improved the preparedness level of the rescue services. Luckily all the shown cases didn't have dramatic consequences. In overall, the tool was reacting to weather induced risks accordingly, though based on user feedback the wind gust product triggered the increase of levels too easily and this threshold needs to be re-adjusted. Besides these events, there were few other, which should showed increased risk levels, in few, the risk levels were reacting accordingly, and in some others, the tool was unfortunately no working because of IT issues.

Since Oct 2018, A4Finn constantly suffered short-term malfunctions for several reasons (e.g. disruptions of data flow from MH-EWS, missing data files, new users cannot login, login interruptions, malfunction of the IT structure i.e. network). In ISTIKE it was decided that until the tool reached the maturity of being almost operational, the older version with the excel files will be the main tool and the A4Finn would acting as a secondary tool for testing. In the beginning of year 2019 a new training date was defined for A4Finn for the whole operational staff. The tool has mainly been tested/used by few persons during the year 2019.

Due to the delays in the development and the uncertainty of the availability of the tool, it decreased the interest of operators in trying it. It was tested, however it did not replace the older system as a primary tool. The overall experience was that, as it was in the different platform than the other tools, the use was burdensome. From its functionality, the end-users found the Progagator to be useful and research work to implement it for the Scandinavian forest type were pursued. One of the main wishes was that end-users would have liked to have the tool presented with higher resolution on a map with reactive features. This was not possible with AIRBUS implementation, hence FMI realized a higher resolution product, which could be presented on a map in A4EU. This product was finalized in July 2019, so it could not be evaluated during the operational stage, as it was not part of the training held earlier that year. An example of the tool output is shown in Figure 58. This implementation will be developed further in later stage. During the summer period 2019 FMI and FMoI collected feedback from the usability and accuracy of the A4Finn tool. These are reported in the report D6.4 and D1.4 (WP1 final evaluation).

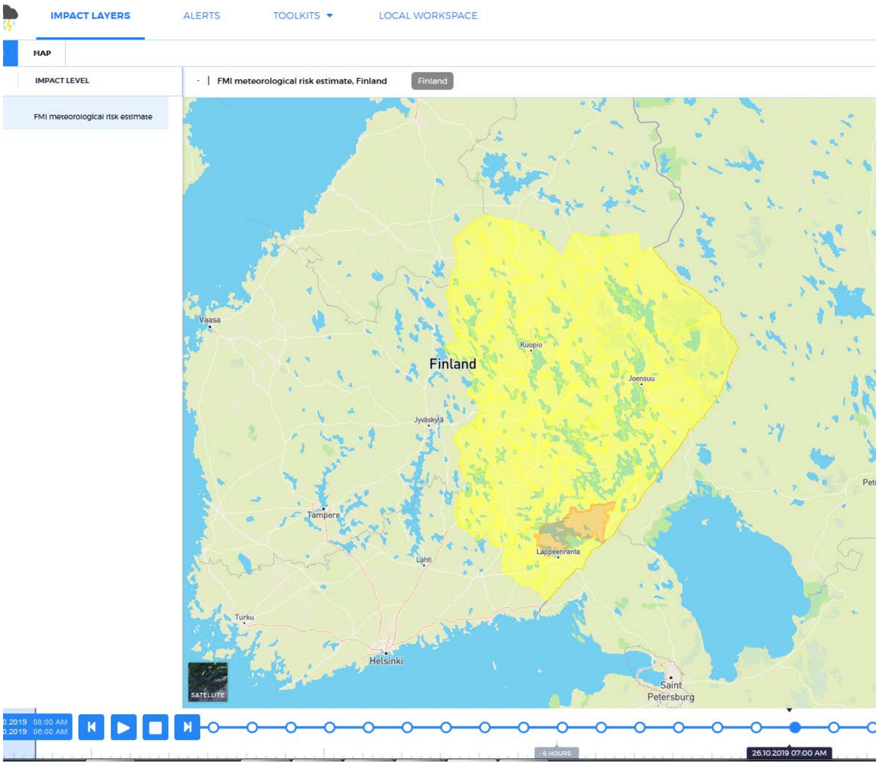


Figure 58. The fine resolution implementation of the A4F inn tool in A4EU.

5 Results of the A4EU (A4Alps) demonstration - Canton of Bern, (Switzerland)

5.1 Institutions leading Alps Pilot Site operations

AIRBUS is leading the development and the implementation of A4EU platform in the Swiss Pilot Site, so called A4Alps.

It was planned that the Canton of Bern (local organizations, regional and cantonal experts) will be the user of the platform. However, A4Alps never reached the status where the rollout to the local level was possible. Thus, ANYWHERE partners where the only users of A4Alps up until the end of the project in Fall 2019.

The roles within A4Alps where defined as follows:

- The Canton of Bern is guiding the development and the implementation to ensure that the developed platform fulfils their needs.
- AIRBUS will support it during all demonstration and use the continuous feedback to improve the platform iteratively MH-EWS products available in the implementation
- Four different institutions represent the Swiss pilot site: The University of Geneva is the formal lead representing the scientific community; the two SMEs Meteodat and Geo7 are covering the private sector; while VOLBE represents the end-users. AIRBUS is in charge of implementing the A4EU prototype in Switzerland, called A4Alps

5.2 Pilot site description

The Canton of Bern is one of 26 cantons of Switzerland and has about one million inhabitants. With almost 6.000 km^2 it is the second largest Canton and covers almost all landscape types of Switzerland such as the high Alps, the Prealps, the Plateau and the Jura. The altitude ranges from 400 m a.s.l. up to 4273 m a.s.l. The 352 municipalities of the Canton of Bern are divided into 8 districts. Tourism is very important. Every year there are 3 Mio. guest-nights, most of them (75%) in the Bernese Oberland.

Which hazard is typical in a region is highly dependent on the landscape. In mountainous areas snow avalanches, rock fall, debris flows and landslides dominate. In the Prealps landslides, debris flows and floods are the major hazards, whereas in the Plateau mainly floods and in the Jura rock fall and floods are predominant. Forest fires are quite frequent (about 60 per year), but usually quite small in extension. Hazard maps exist in different levels of detail throughout the whole area of the Canton of Bern for the predominant gravitational hazards (floods, landslides, rock fall, and avalanches).

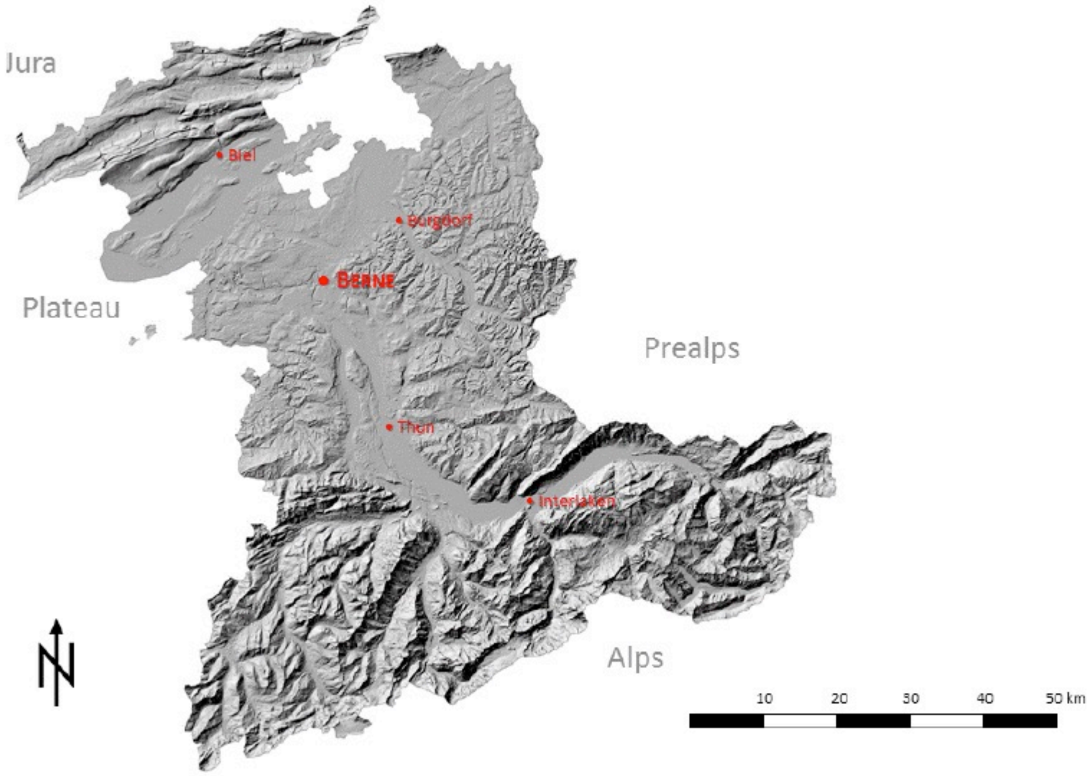


Figure 59. Relief map of the canton with the main landscape types.

An event register is kept up-to date with information containing maps of the impacted area, description of the event and photos for all the events which occurred in the last decades.190.000 persons are living in potential hazardous areas (20% of the population) and almost 700 km of major roads are crossing hazardous areas (26% of the total road network length).

The main hazards that affect the Canton of Bern are:

- Rock fall
- Debris flows
- Landslides
- Floods
- Avalanche
- Forest fires

5.3 Main hazards faced during the operational period

Since autumn 2018, the A4Alps prototype has been running in its final form. On one hand, it contains data from European models (A4EU) and the other hand data from specific Swiss models (A4Alps). Each Swiss model has a simplified overview mode and an expert mode displaying more detailed data. A4Alps is used as a complementary tool to already existing platforms in Switzerland (especially the "*Gemeinsames*

Informationsplattform Naturgefahren" short GIN) for decision makers mainly at national and cantonal level.

So far, all models desired by the Canton of Berne have been implemented on the platform with the following two exceptions:

- A4Alps: Due to technical difficulties of the model developer, the module for the disposition of mass movements from permafrost could not yet be placed to A4Alps by AIRBUS. Even though the model developer was working hard to solve the problems, the time run out so that AIRBUS could not integrate the model into A4Alps within the project time.
- A4EU: At the moment, the flash flood module by CRAHI adapted to Switzerland (50m resolution) could up to today not be set up properly and therefore is - yet integrated into the platform by AIRBUS – not displaying valid data.

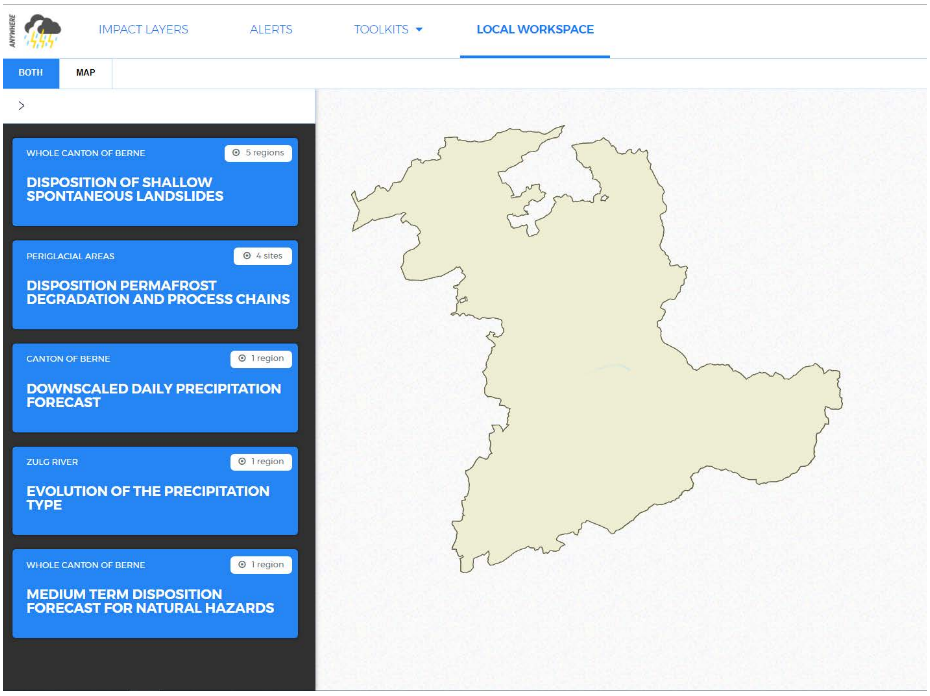


Figure 60. A4Alps current view

During the pilot phase, there have been no real critical situations (lack of severe and precipitation driven processes/situations) in which the benefit of both the different products and the platform could not be tested properly. Therefore, it is not possible to make a clear statement regarding the benefit of the platform.

On the basis of potentially critical weather conditions, which could have evolved to hazardous events, some tools have already been tested. Namely, two A4Alps products: the now casting module of the Zulg catchment and the medium-term forecast of heavy precipitation. In both cases, there is great potential for an added value in the hazard assessment of natural hazards.

The European products from A4EU are based on models with mesh sizes between 5 and 18 km (e.g. EFAS, Snowfall). Tests have shown that this resolution was too coarse to obtain useful information due to the fine topography of the Swiss Alps with its very strong relief. Thus, the entirety of the products integrated in the MH-EWS showed to be of little use for the local application. Especially, as national data with higher resolution are available.

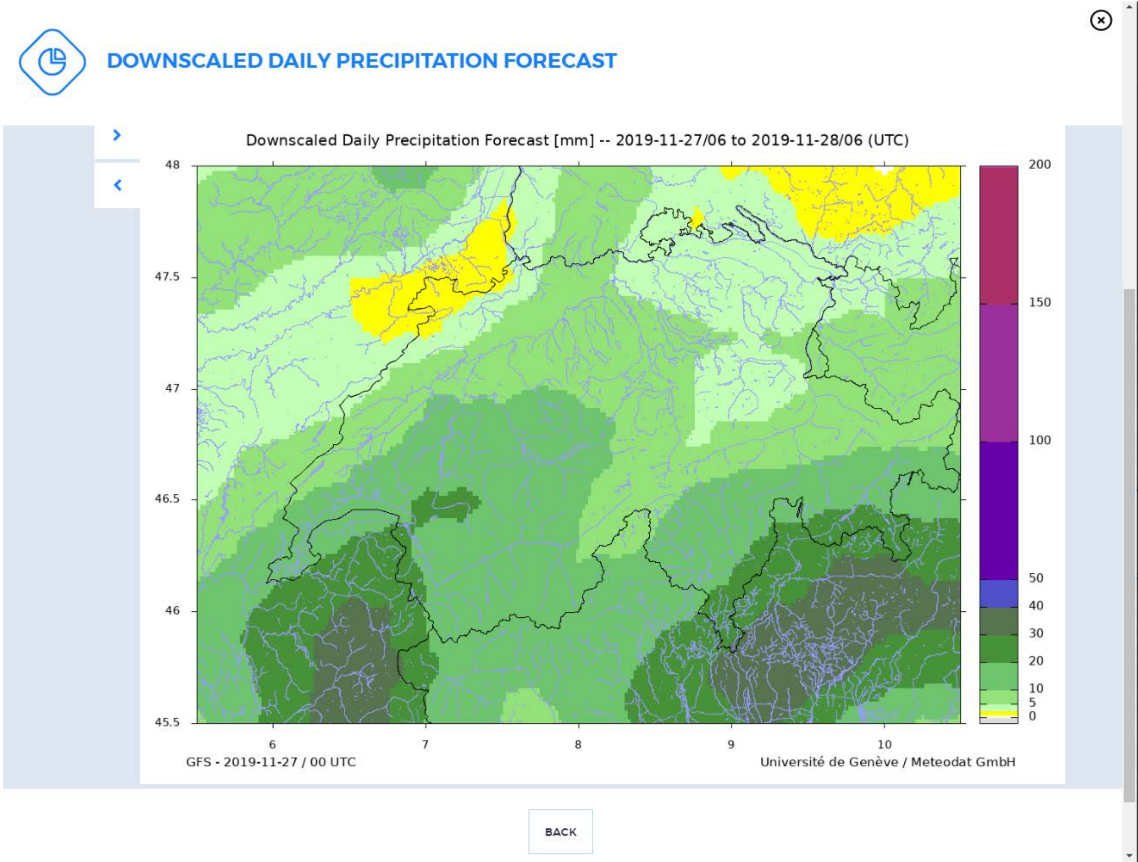


Figure 61. A4Alps: medium-term forecast of heavy precipitation.

5.4 Main features of A4Alps

The A4Alps platform by AIRBUS is mostly stable. Often the access to the platform was limited or data was not displayed, which is intolerable for the intended purpose of the instrument. Especially, as these interruptions are not only of short period but can last up to several days. Unfortunately, this has been several times the case in the past year. We've addressed the problem multiple times. First, we were reassured that they were working on a solution. In Leipzig (10th meeting) AIRBUS stated that a 24/7 operations cannot be guaranteed. Especially if interruptions occur on weekends and on national holydays trouble shooting can take several days.

On one hand the information of the data from the A4Alps part is very good. This is due to the fact that VOLBE was in direct contact with the model developers and were thus able to specify the concrete requirements such as graphs, time steps, color scales, among others. These needs were consolidated in a document for the improvement of the A4Alps products (called "A4Alps 2.0", summer 2018), including mock-ups and a priority list of the implementation, showed to be a valuable tool of communication. AIRBUS was able to implement these requirements well. The role of an end-user providing frequent feedback showed to be curial – yet not always successful as it seemed that the understanding of the operators' workflow in an emergency was never achieved. Thus, the need for simple details e.g. legends, units, date stamps where difficult to communicate toward the developers.

On the other hand, the user-friendliness of the data from the A4EU part can be improved in many parts. This, however, is primarily due to the data supplied by the model operator and not to the work of the platform developer. As the use and applications of this data showed to be very limited for Switzerland and work force had to be well focused, the Canton of Berne did not make further improvements request regarding the visualisation of these data.

5.5 Debris flow, Biregrabe, 21 July 2018

A Debris flow occurred on the 21.07.2018 at the Biregrabe (Färmel).

Figure 62. Image of the Debris Flow.

Due to the local A4Alps tools, the event could have been foreseen. As the platform was still in an early access, the data was retrieved only in hindsight. Yet, the pan-European MH-EWS had no available data. The situation was managed without the use of the ANYWHERE platform (see Figure 63 and Figure 64).

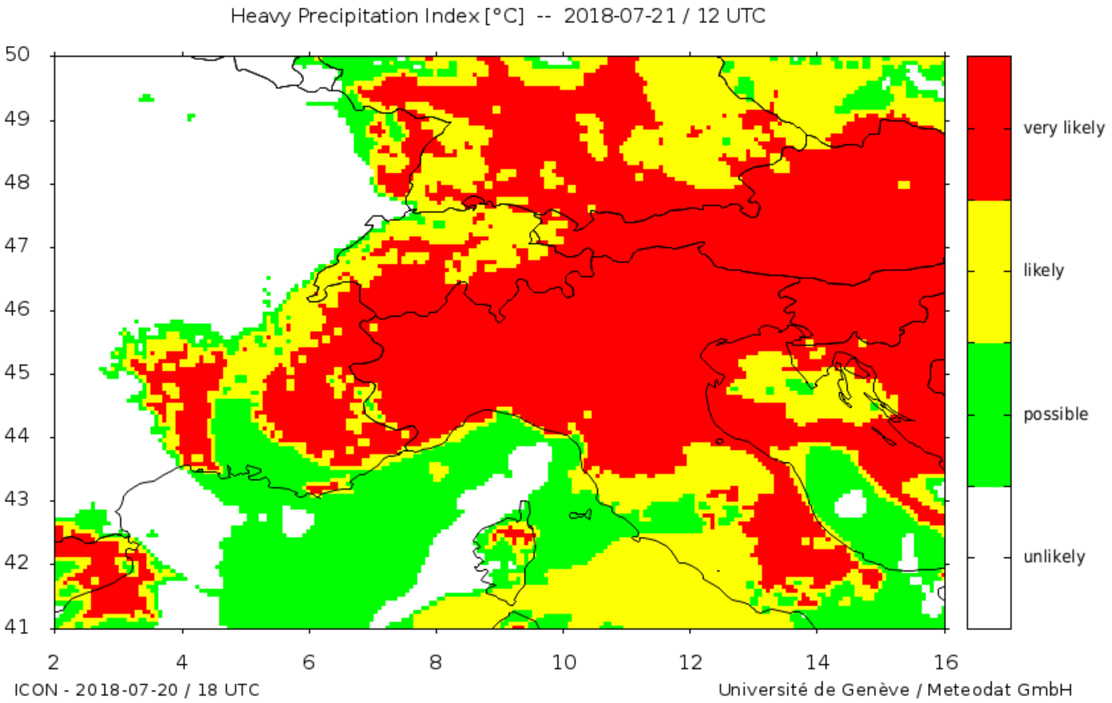
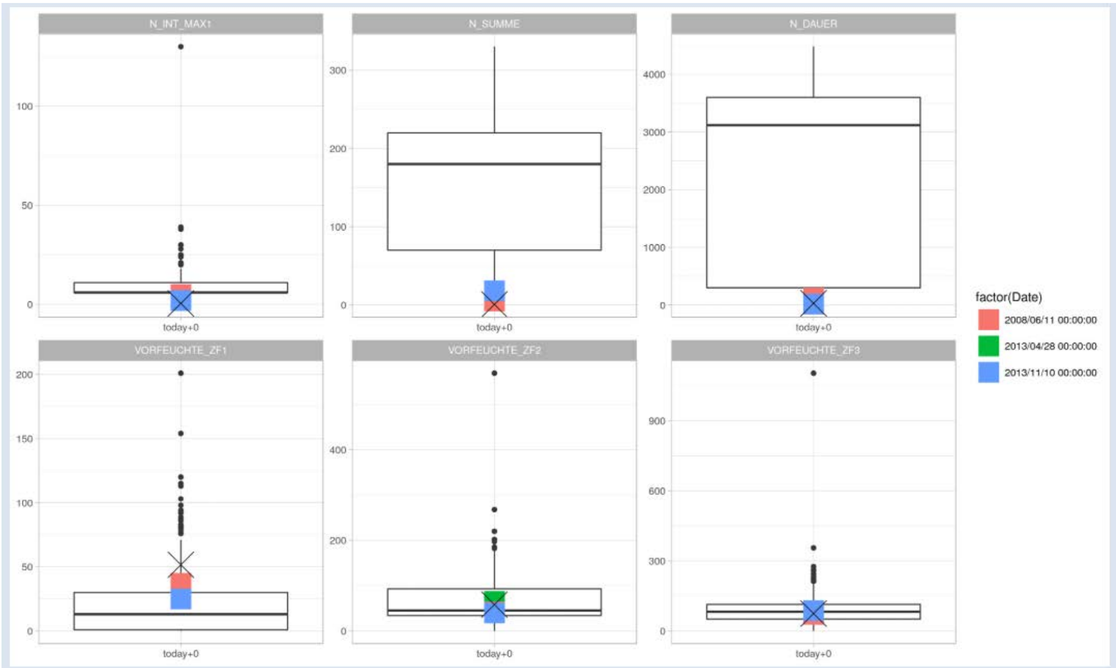


Figure 63. Heavy precipitation Index.



Box Whisker plots indicate the distribution of different variables within the geodatabase of the Canton of Bern. For each day with precipitation test-data are shown as black cross and k nearest neighbours are shown as colored squares (further details on panel).

Figure 64. Disposition Landslides for 2018/07/21 of the A4Alps, shallow landslide disposition tool.

5.6 Heavy-Snow and Non-Heavy Snow Events, January 2019

At mid-January 2019 a national warning for heavy snowfall and consecutive high avalanche danger was issued.

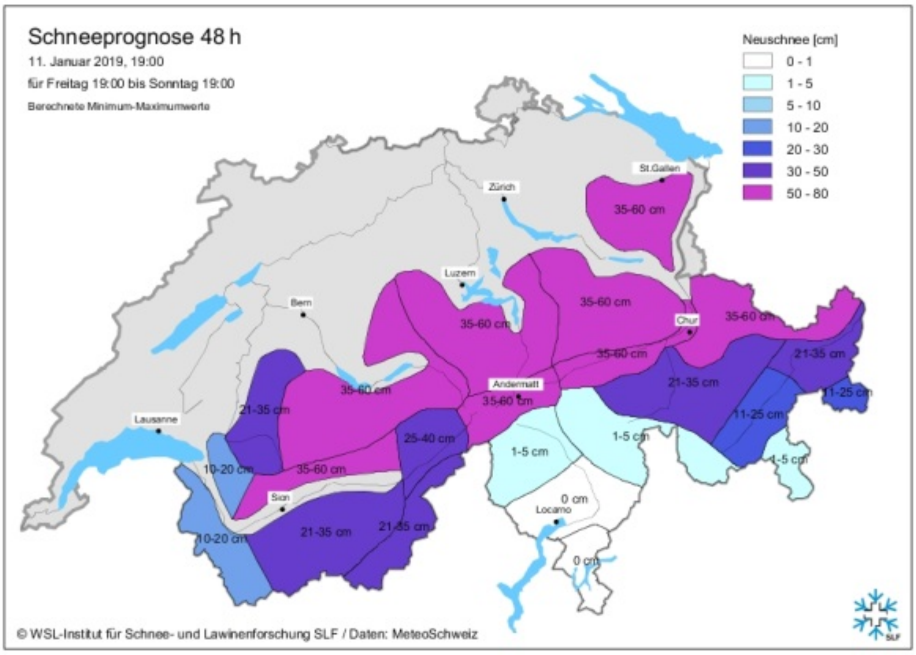


Figure 65. Forecast of New-Snow accumulation over 48h (SLF).

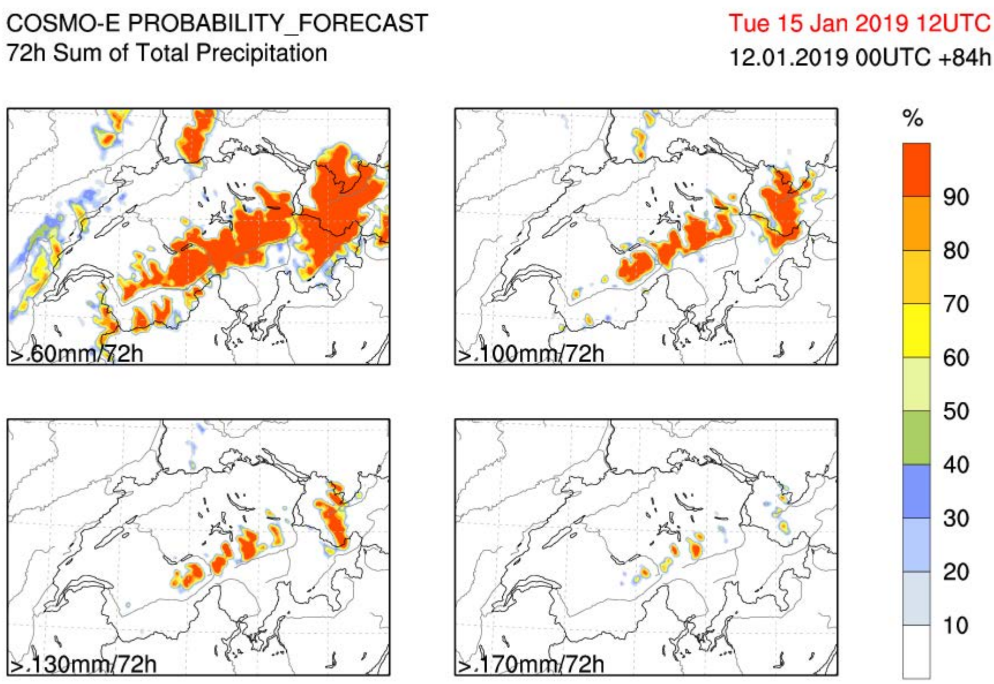


Figure 66. Forecast of Precipitation sum within 3 days.

The local tools of A4Alps where perfectly capable of detecting and correctly predict the heavy Snow-Event (see Figure 67 and Figure 68).

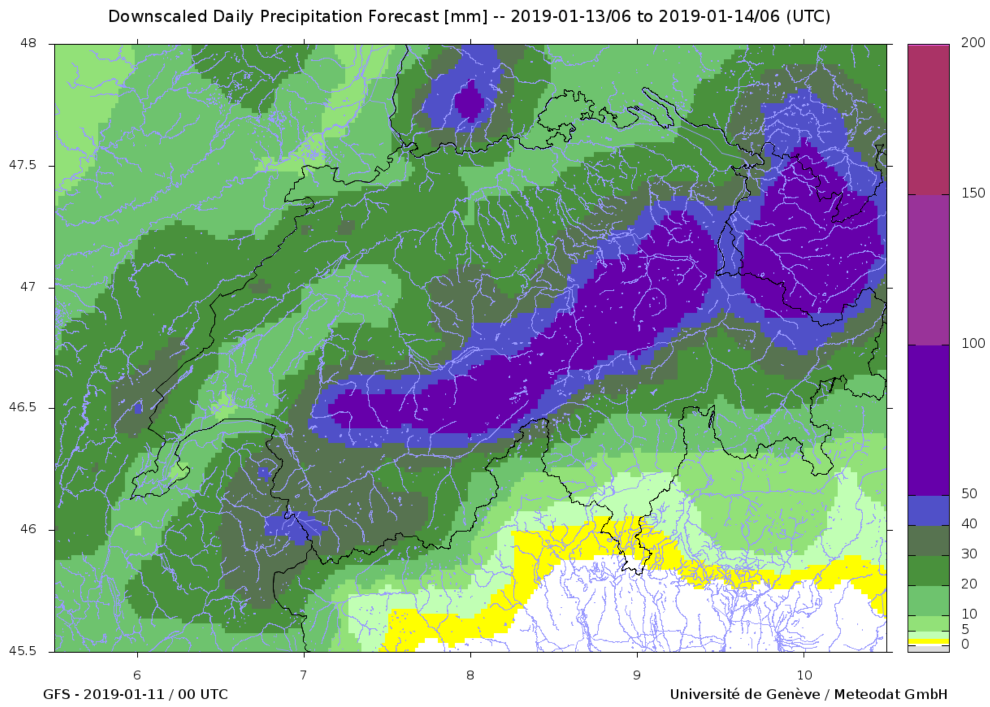


Figure 67. Appropriate forecast of an Event (True Positive) A4Alps.

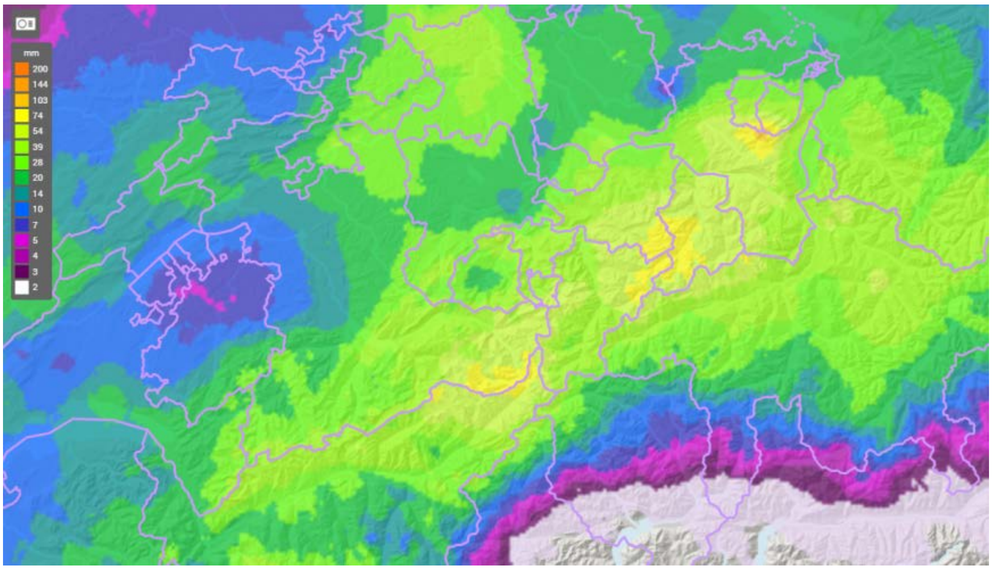


Figure 68. Effective Precipitation Sum (hindsight)

At the end of January 2019, the A4Alps tools provided information that the upcoming snowfall will not be so heavy as predicted by the national weather services. Thus, no measures had to be taken, which was also a very valuable piece of information (see Figure 69 and Figure 70).

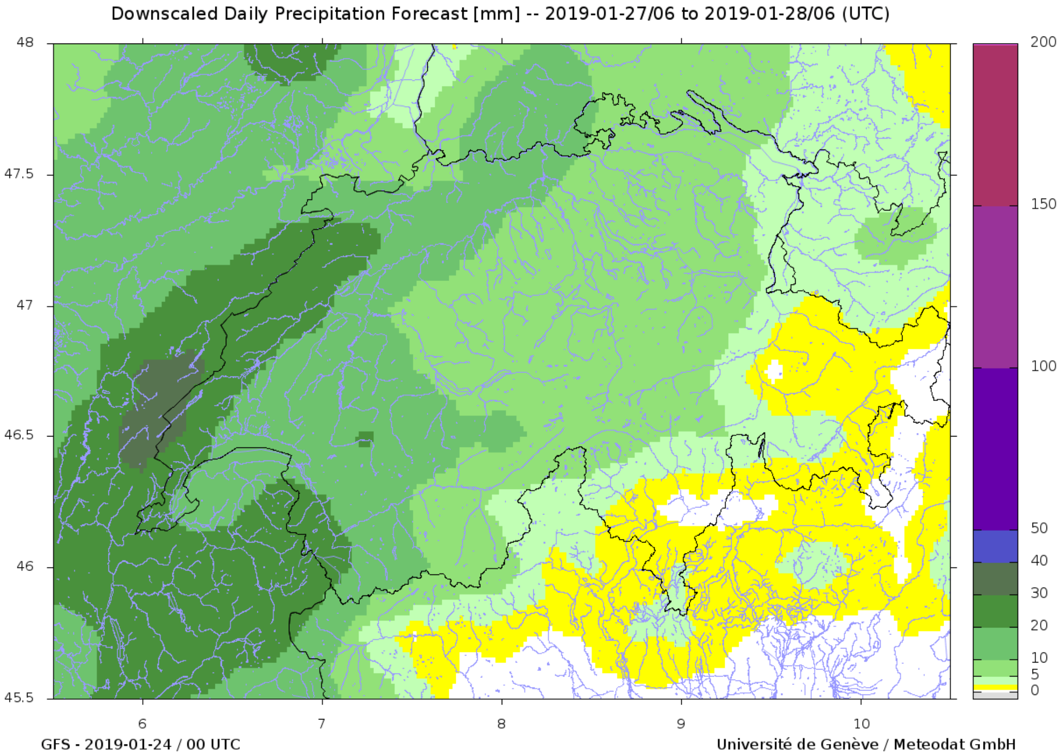


Figure 69. Appropriate forecast of a NO-EVENT (True Negative) of A4Alps.

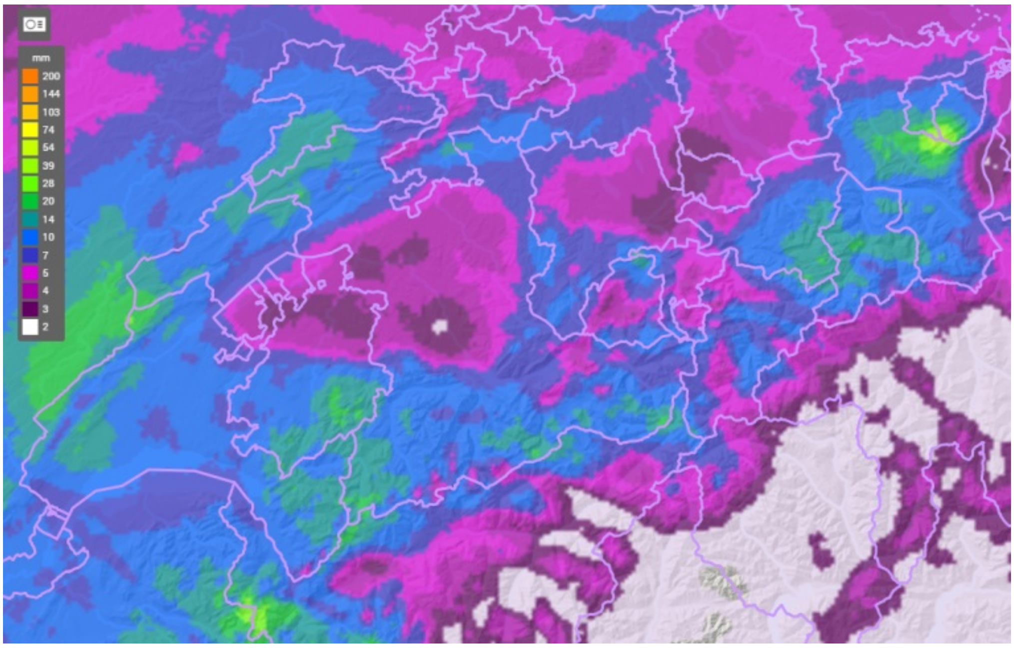


Figure 70. Effective Precipitation Sum (hindsight)

5.7 Results and discussion

As pointed out during the meetings in November 2018 in Barcelona and again in Leipzig, the storage of data (archive/history) on the platform is not solved. Data export by the user during an acute phase is not possible for capacity reasons. Only a part of the data is stored for a few weeks or months, but a wide-ranging data set in the past is not available. Additionally, it is merely impossible for the users to request all the original data directly from the many model operators. The effort would be immense. For the operational use of the platform, this is a rather small deficiency. If, however, the quality of the platform and the models should be assessed, e.g. for evaluation of past events during the pilot operational phase, with this precondition this will only be possible to a very limited extent.

The accessibility of the platform must be massively improved. AIRBUS has to find a solution for this. After 2017, the collaborators of AIRBUS have been very helpful and tried to improve the visualisation of the data as quickly as possible, if we hint to improvements. However, the accessibility of the platform as well as the overall usability is insufficient.

The ANYWHERE project showed once more that communication is key. Here, the understanding of the operators' workflow and needs by the developers showed to be crucial. The lack of such an understanding – assumed to be due to background – was a major hurdle. With all good intent and willingness, the "language barrier" (not only German – English – French but foremost "natural hazard expert" to "IT expert") was challenging and to the end not contenting.

Moreover, it showed that a pan-European platform is hardly to be developed within 3 years' time. As already different threshold showed not to be applicable over large scales (e.g. 5cm of new fallen snow is in norther Europe considered to be start of winter, in southern Europe a catastrophic event for the commuters and general traffic), the focus on impact based evaluation was not achievable. Apparently, the same algorithms are often not applicable and easily transferable to other sites even if not evident at first glance. Examples here are the Italian wild fire propagation model (called 'Propagator') or the Spanish flash flood run-off model. The topography, different vegetation (difference in species of conifers with different fire behaviour or the vegetation cover withhold precipitation run-off) and scale (temporal and special resolution) are hindering a pan-European MH-EWS.

6 Results of the A4EU (A4Nor) demonstration – Rogaland (Norway) sub-pilot site

6.1 Institutions leading Rogaland Pilot Site operations

The pilot site was led by Stavanger University Hospital, represented by RAKOS (The Regional Centre for Emergency Medical Development and Research).

RAKOS has the role to ensure common guidelines for actions in the acute medicine field and to oversee education and development in prehospital services. RAKOS is therefore very close to the action part of a crisis intervention and thanks to the connection with the police and fire department; and it represents the natural link between the different services that are involved during a major crisis.

AIRBUS led the implementation of A4EU in the pilot site (A4Nor), Sintef developed and implemented the local toolkit for the Rogaland Pilot site, called ARA (Risk-Assessment tool).

6.2 Pilot site description and A4Nor main features

The Norwegian pilot site focus is on Rogaland county (*fylke*). The county is located in the South West of Norway around the city of Stavanger.

Stavanger municipality (Figure 71) is located on a peninsula on the southwest coast of Norway and it is characterized by fjords, beaches and islands.

The municipality has an urban area of 77.98 km2 with a population of 133000, and a density of 1900 inhabitants/km2.

Figure 71. Stavanger municipality area

Sauda municipality (Figure 72) covers an area of 546 km2 and it has a population of 4,760. The population density is 9.4 inhabitants/km2. Sauda is located in the valleys and mountains surrounding the Saudafjorden. Outside of the main valley, most of the municipality has a very mountainous terrain. Sauda municipality can be reached by two-hours boat from Stavanger and it has just one road (FV520) that connect the municipality with the surrounding area; near the road there is a waterfall that can influence the road situation in case of heavy rain and snow melting. The mountains surrounding the village of Saudasjøen contain one of the biggest ski resorts on the west coast of Norway. Sauda municipality is located on flat land, a delta created by the rivers that empty into the fjord just outside the town center.

Figure 72. Sauda municipality

The two municipality have real differences both in number of inhabitants and in the land topography. Therefore, the main natural hazards for the Norwegian pilot site are:

- Storm surges
- Heavy rain
- Floods
- Strong wind

The Norwegian emergency management system is based on three levels: national level, regional level and local level. In general, operational activities are carried out by the local institutions nearest to the location of the event, very often by the municipality Situation awareness office. If the resources available are not sufficient, the local institution in charge asks for help to the other actor involved in the Norwegian emergency management system.

The A4EU platform used here represents a general A4EU platform able to be used by any potential emergency institution and control centre in the European Union. The A4EU platform represents the 5th version of the A4EU platform with generic capacities.

6.3 Main hazards faced during the operational period

During the operational period the weather situation in the western coast of Norway was mild and without any extreme event communicated by the Met Office.

The main hazards faced during the operation period were:

- Strong wind in 15/12/2018: wind gusts of 25-30 m/s were expected to hit Rogaland region and both municipality involved. The severity level was yellow, that means a moderate situation that requires vigilance and local damages with minor consequences can be expected.
- Strong wind 12/03/2019: wind gusts of 27-30 m/s were expected to hit Rogaland and Hordland. The severity level was yellow, that means a moderate situation that requires vigilance and local damages with minor consequences can be expected.
- Moderate forest fire in 10/04/2019: Moderate forest fire danger from 10/04/2019. Due to grass dryness after a dry winter time the danger for forest fire has been detected.

The information was available in the newspaper and local television, the severity was defined by the Met Office and available in the app.

No one was injured during the event and some local traffic delay was registered. Precautions were taken in order to avoid any kind of injury to the people.

6.4 Main features of A4Nor

The main features use during the events occurred in the operation period were:

- PRD 10 - 10-meter wind gust index
- PRD 141 Rate of Spread (ROS)

Both features gave the chance to follow the events from the beginning and throughout their development.

6.5 Strong wind, 15/12/2018

6.5.1 Description of the event

The event was communicated and available on the Met Office app. the day before, the 14/12/2018.

The event consisted in expected wind gust between 25 and 30 m/s in Rogaland. The event was expected to last around 24 hours, from Saturday 15th December 2018 hr. 19:00 to Sunday 16th December 2018 hr. 16:00.

The picture below shows the information available on the Met Office website and app, the same information was shared by the national and local television.

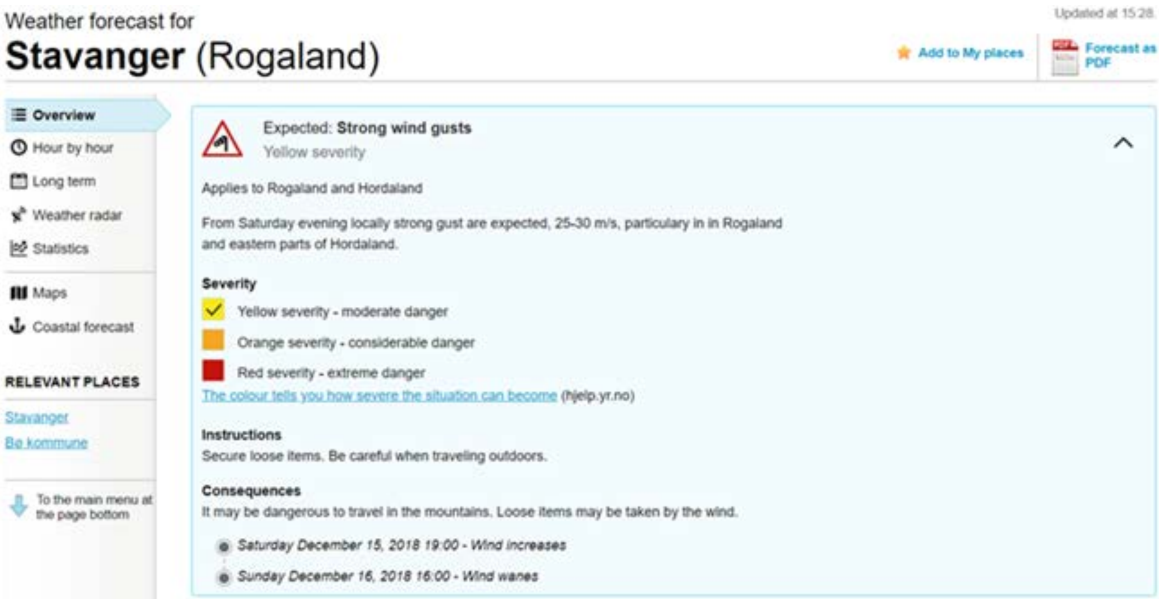


Figure 73. Strong wind gust– Met Office information

The situation was monitored by the local institution and general information about safety measure was communicated to the inhabitant.

6.5.2 ANYWHERE tools and products used

The ANYWHERE products used during the event was PRD10-10 meters wind gust.

The pictures below show the event followed throughout the event, both municipalities were hit by the wind.

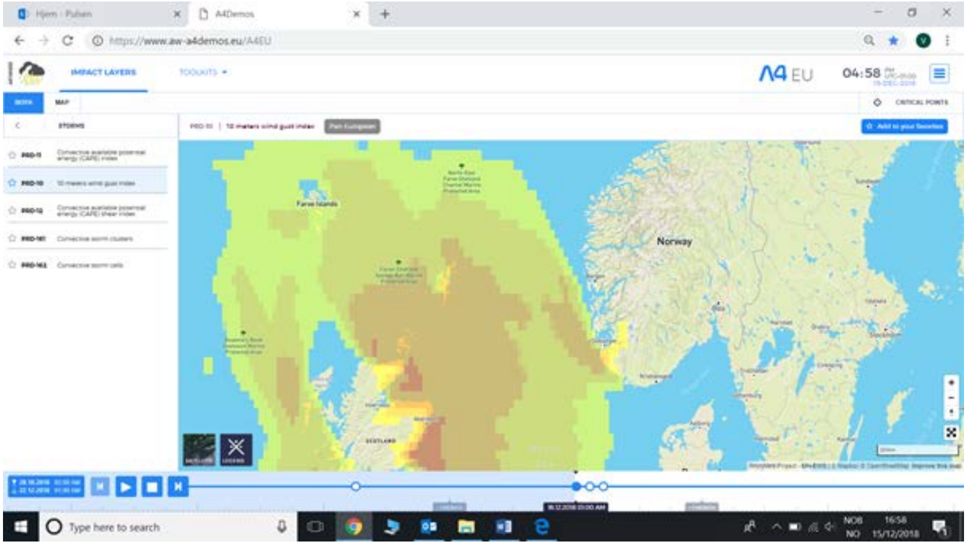


Figure 74. PRD10 – 10 meter wind gust

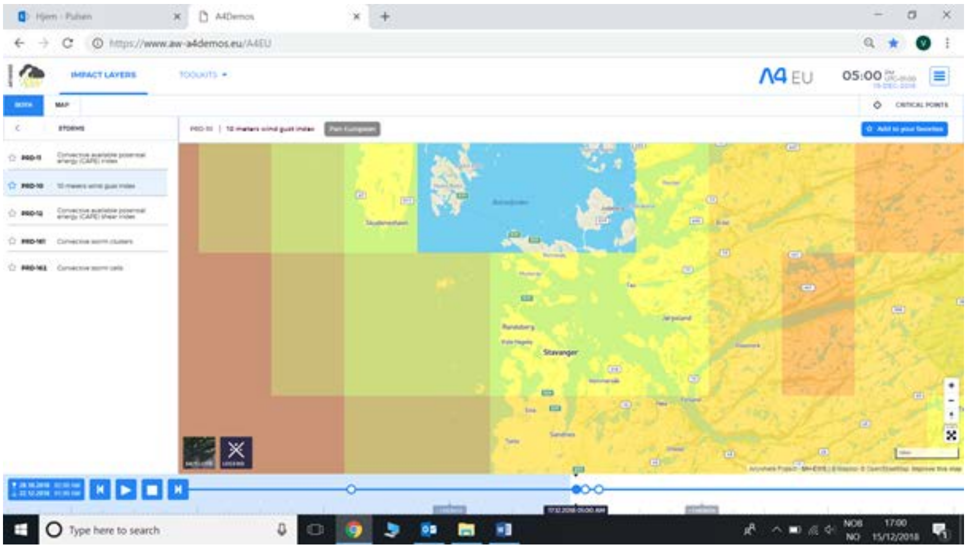


Figure 75. PRD10 – 10 meter wind gust

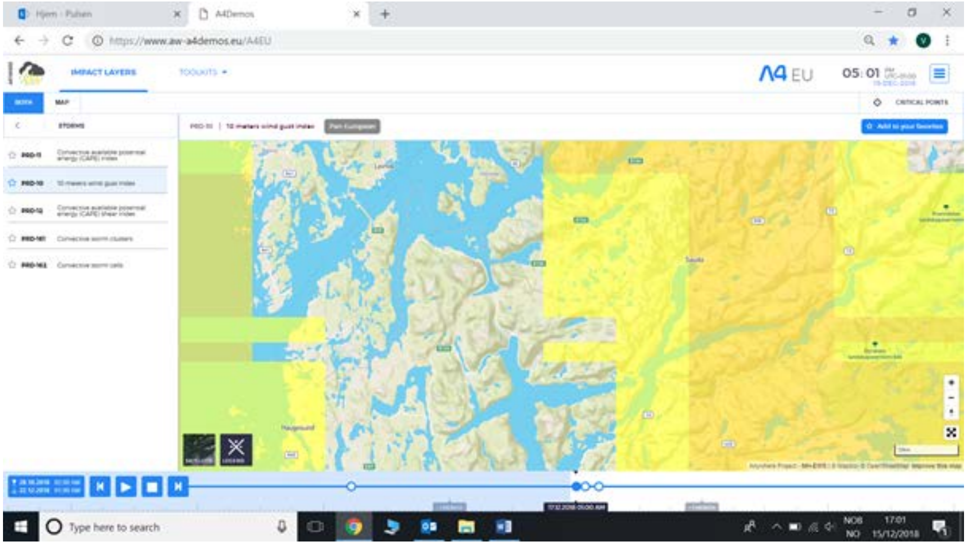


Figure 76. *PRD10 – 10 meter wind gust*

6.5.3 Main impacts of the event

The instructions given to the population by the institution were:

- Secure the lose items;
- Avoid walking in the mountains and outdoor;
- Drive safely.

The main impacts and consequences were:

- Lose items left unattended by the population taken by the wind;
- Tree branches on the road and transported by the wind
- Problem with the local train traffic due to tree branches on the line, the issue was solved in some minutes;
- Chance of ferry transportation disruption.

Luckily during such event no one was injured or killed.

6.6 Strong wind, 12/03/2019

6.6.1 Description of the event

The event was communicated ad available on the Met Office app. the day before, the 11/03/2019.

The event consisted in expected wind gust between 27 and 30 m/s in Rogaland and Hordland. The event was expected to last around 12 hours, from Tuesday 12th March 2018 hr. 10:00 to Tuesday 12th March 2018 hr. 22:00. The severity level was defined as Yellow, moderate risk and consequences.

The picture below shows the information available on the Met Office website and app, the same information was shared by the national and local television.

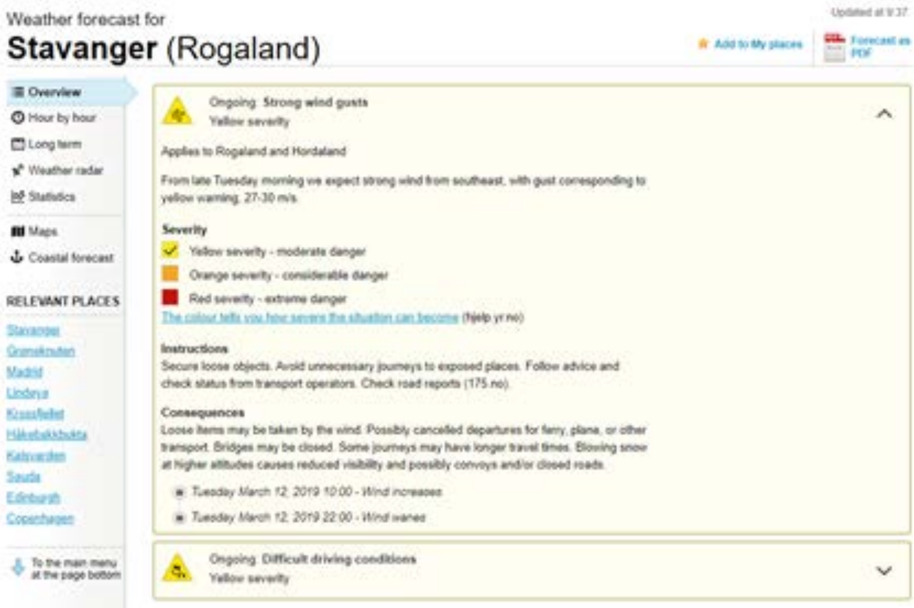


Figure 77. Strong wind gust– Met Office information.

6.6.2 ANYWHERE tools and products used

Also in this case the product used to follow the event was the PRD10 - 10 meters wind gust.

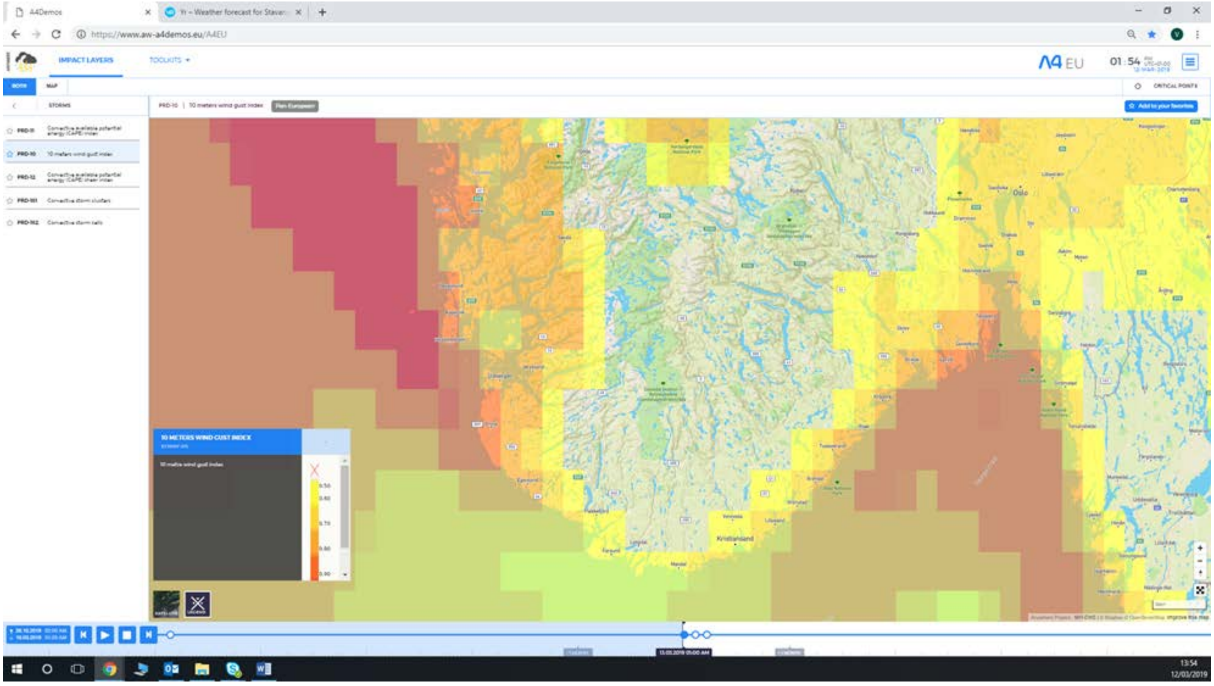


Figure 78. *PRD10 – 10 meter wind gust*

6.6.3 Main impacts of the event

The instructions given to the population by the institution were:

- Secure the lose items;
- Avoid walking in the mountains and outdoor;
- Drive safely due to reduced visibility caused by snow and lose items on the road.

The main impacts and consequences were:

- Lose items left unattended by the population taken by the wind;
- Tree branches on the road and transported by the wind;
- Problem with the local train traffic due to tree branches on the line, the issue was solved in some minutes;
- Chance of ferry transportation disruption;
- Plane disruptions;
- Closed bridges.

Luckily during such event no one was injured or killed.

6.7 Moderate forest fire danger, 10/04/2019

6.7.1 Description of the event

The day before the event a moderate forest fire danger has been communicated to the population.

The danger, as reported in the picture below, started the 10th April 2019 and the end was not defined due to the good weather situation of the dryness of the period. The severity level was defined as Yellow, moderate risk and consequences.

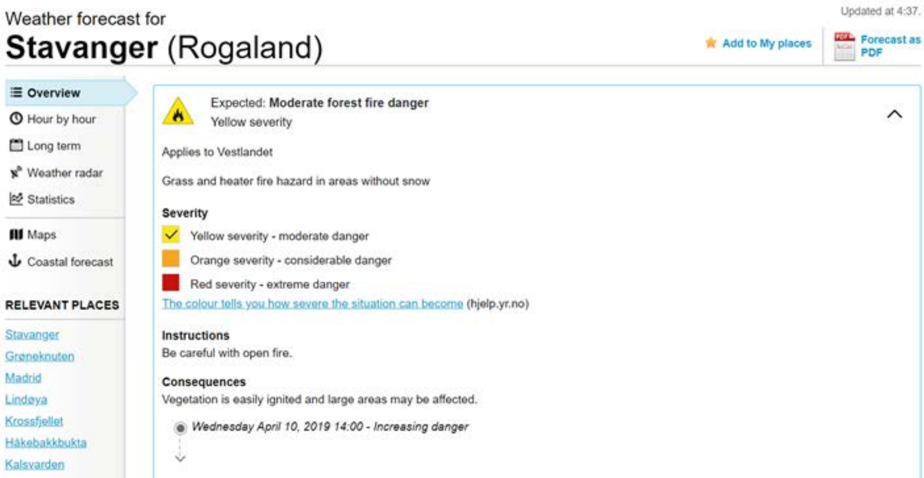


Figure 79. Moderate forest fire danger level – Met Office information

6.7.2 ANYWHERE tools and products used

During this event the situation was followed using the PRD141 – Rate of Spread (ROS)

The pictures below show the use of the product to have a better understanding of the degree of fire spreading in two-days window.

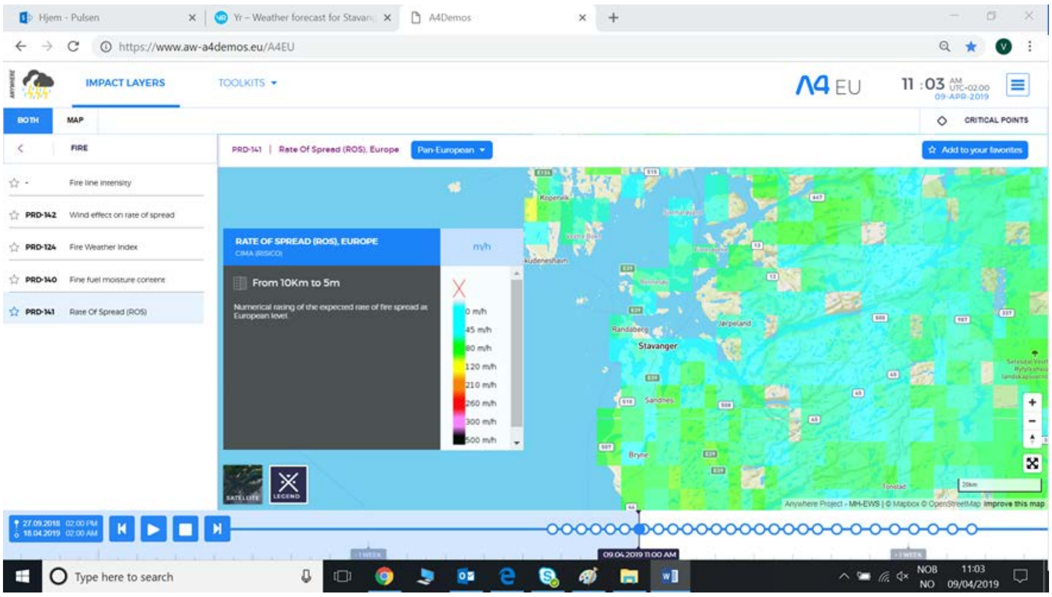


Figure 80. PRD 141 Rate of spread forecasted 09/04/2019 h.11:00

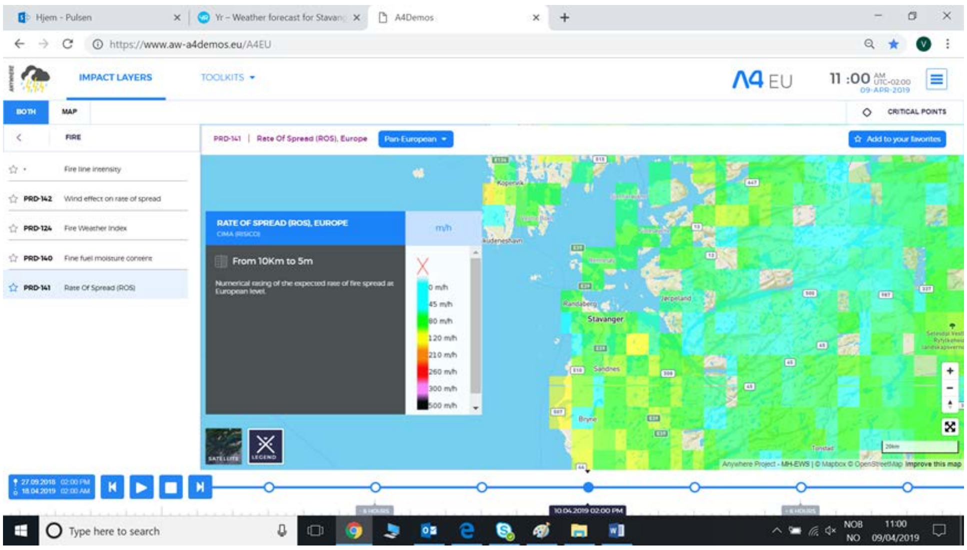


Figure 81. PRD 141 Rate of spread forecasted 10/04/2019 h.14:00

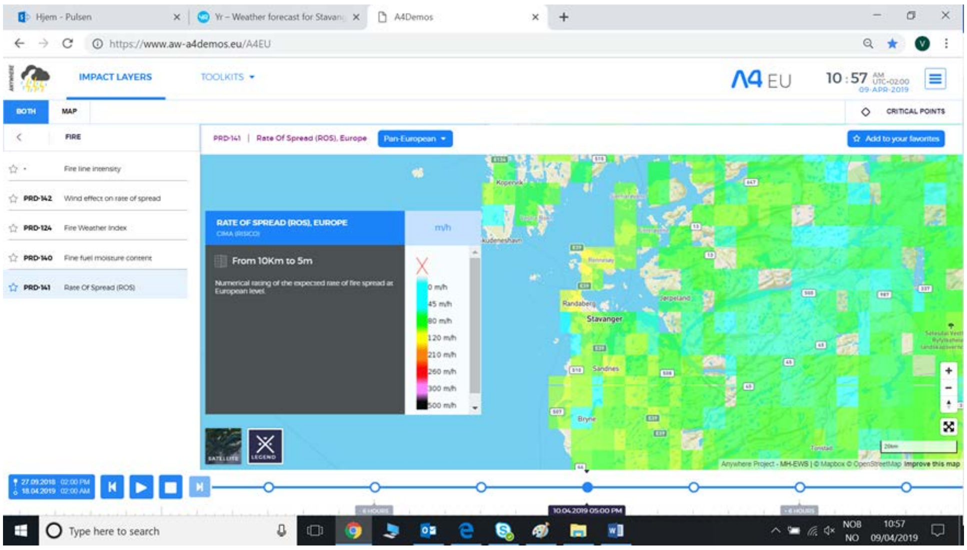


Figure 82. PRD 141 Rate of spread forecasted 10/04/2019 h.17:00

6.7.3 Main impacts of the event

Luckily no major impact was detected during this event, except that all the open fires were forbidden.

6.8 Results and discussion

The data available by the platform provided an improved understanding of the events happened during the operational test period.

The complete implementation of the platform would have been performed in the two municipalities if a direct warning system to the end users would be available. Nowadays the platform is considered as an added element to use in the decision-making process. Moreover, the delays and the drawbacks during the development of the platform made the fully implementation in the municipalities even less possible.

Unfortunately, the good weather condition of the operation period did not make possible to test the ARA toolkit, developed for Stavanger municipality by Sintef. The same happened for the Marine storms products.

7 Results of the A4EU (A4Cor) demonstration – Corsica (France) sub-pilot site

7.1 Institutions leading Corsica Pilot Site operations

The operation of A4Cor have been done by the *Service d'Incendie et de Secours de la Haute-Corse* (SIS2B) as end user with the support of Predict-Services, developer of the A4Cor platform during all demonstration activities and use the continuous feedback to iteratively improve the system. Some improvements be done during the first stage of the demonstration activities.

Figure 83. SIS2B operational activities

7.2 Pilot site description and A4Cor main features

Corsica is a French region located in the centre of the western Mediterranean. It represents the *Collectivité de Corse* (Territorial community of Corsica). Its prefectures are Bastia and Ajaccio. Following the 2015 territorial reform, the 2 departmental councils of Corsica (*Haute-Corse and Corse-du-Sud*) merged on 1st January 2018 with the Territorial Authority of Corsica, which already exercises the powers of a region with a special status, to form the Corsican Authority. The climate of a large part of Corsica is Mediterranean: hot and dry in summer, mild and rainy in winter.

However, the island also experiences nuances of the alpine climate, especially in winter. It is not uncommon to see the peaks of snow-covered mountains until May-June.

The population is estimated at about 330,000 inhabitants and the area is 80,000 km². It should be noted that this population is greatly increased with tourism, particularly in summer.

The particular situation of Corsica leads to different behaviors that must be taken into account in risk management by the authorities and especially by the rescue services:

The first one is that rescue services have to deal with 3 main types of population:

- The natives, who have always lived there and have already faced catastrophic events;
- Newcomers, who have lived there for 5 or 10 years and who think they have a good knowledge of the area;
- Tourists, who are here for a short stay and whose main reason for being here is to make a success of their holidays.
- It is easy to understand that these populations do not react in the same way to disasters.

In the early hours of a major incident, Corsica must rely solely on its own resources to manage the incident. Reinforcements can only be made (at this date)

- by means of reinforcements arriving by boat from France or, in the case of a request for assistance from the European Union,
- by means not yet clearly identified by the European Civil Protection Force.

Whole Corsica territory is subject to natural hazards like:

- Forest fires, wildfires,
- Flash floods,
- Marine submersion, strong waves and tsunami,
- Strong winds,
- Storms,
- Snowfalls,
- Heat waves

Figure 84. The A4Cor pilot site area defined by the whole territory of Corsica island

A4Cor is a web-based system to display information about different hazards gathered with local vulnerability layers and impact on critical points and sensitive hotspots. A4Cor provide to SIS2B lot of predictions of the impacts of a weather induced event. Different data provided by the MH-EWS at European and National level and by Predict Services at regional level.

The A4Cor platform is accessible from a single screen integrating all the elements useful for anticipating and managing a crisis related to an operation induced by a severe weather event.

7.3 Main hazards faced during the operational period

As the development of the platform was severely delayed due to various problems encountered during the first phase of the project, the test period was shortened and the platform's operational launch was slightly delayed.

However, it began in the first days of October 2018.

Fortunately, although this is to be welcomed for the ANYWHERE project, climatic events have followed one another rapidly, starting in October 10th 2018.

Like almost the entire Mediterranean arc, Corsica was hit by very severe climatic disturbances that generated very heavy rainfall on the island.

We then experienced other stormy events and in the last days of October the Adrian storm (https://twitter.com/i/status/1056926660426170368) swept across the island with winds measured at over 200 km/h.

So SIS2B were quickly able to implement the platform in its operational room and its command centre.

Figure 85. Images of the A4Cor platform helpfully used in real conditions at SIS2B Command and Control Centre. *Source SIS2B*

User operators had already been trained in the use of the new tools during the test phase and this made it easier to get started during real events, which are gathered at Table 2).

Table 2. Table showing the main hazard occurred in the Corsica pilot site during the demonstration period.

Type of hazard	Location	Short description of the meteo event
Flash floods	Porto Vecchio	**October 2018** General description of the phenomenon: This episode triggered the passage of several departments in the south and south-east quarter of France into orange "Rain-flood" and "Storms" vigilances on the part of Météo-France. The first vigilances were triggered on Sunday 7 October at 1600 and continued on these areas bordering the Mediterranean from the Balearics to the Gulf of Genoa until the end of the day on Thursday 11 October. Another event of the same type occurred on October 16th on the oriental cost of the island.
	Taglio Isolaccio	
	Whole island	**July 15th 2019** From Monday 15 at 0600, Météo-France places the department of Haute-Corse on orange "Storms" and "Rain-Flood" vigilance, which is extended to 1400 in Corse-du- Sud. By the end of the morning, thunderstorms with little mobility had begun to appear in the north of the island, particularly in Cap Corse and on the eastern side of the Haute-Corse department. These storms

Type of hazard	Location	Short description of the meteo event
		were very rainy and windy, bringing a lot of rainfall (120mm in 1 hour at Bastia with a local record of 30 mm in 6 minutes). A waterspout phenomenon that subsequently made landfall between Bastia and Ville-di-Pietrabugno was also observed. Thunderstorms remained strong until early in the night from Monday to Tuesday, developing over much of the Island, before gradually fading as they shifted eastward.
Wind storm	Whole island	**October 28th-30th 2018** From Sunday 28th at 1219, Météo-France places the departments of Corsica and Alpes-Maritimes on orange "Flood Rain" alert, accompanied by yellow "Wave-Submersion" alert on these same coasts, due to the Adrian storm. At 1600 this yellow vigilance is extended to the Var with an orange vigilance "Storms" then "Flood rain". On Monday 29th, Corsica went into red alert "violent wind" due to the exceptional nature of this storm. All vigilance is lifted on Tuesday 30th.
Forest fire	Calenzana	**February 23th 2019** Weather conditions: very dry air and wind In connection with high pressures, the axis of which extends from the Pyrenees to central Europe and a depression circulating over the eastern Mediterranean, a very strong, relatively cool and very dry northeast wind is developing from northern Italy to Corsica. Corsica is placed on yellow vigilance with strong winds from Friday 22nd at 4 pm to Sunday 24th at 4 pm. The wind gradually strengthens in the morning of Saturday 24th to reach a peak in the night from Saturday to Sunday. Gusts reach more than 100 km/h at many stations, in Cap Corse, on the hills but also in Balagne and in the extreme south-east with a maximum of 138 km/h at La Chiappa. When crossing Corsica, a particular and very frequent phenomenon occurs in mountain areas: the foehn effect. The air that arrives on a relief is lifted and then lowered downwind of the relief. The adiabatic compression that occurs then (by going down the side of the mountain, the pressure increases), leads to a warming and especially a drying of the air mass sometimes spectacular on the slopes and valleys downwind of the mountains. On many sites, humidity falls in the afternoon of Saturday 23rd and remains extremely low throughout the night until Sunday 24th afternoon. We note spectacular falls as in Renno where we find 70% at 2pm and 13% at 3pm.

Type of hazard	Location	Short description of the meteo event
		There are minimum humidities of around 20% on the **eastern facade exposed to the northeast wind and humidities of less than 10% due to foehn effect on many mountain posts or on the western facade and** sometimes even less than 5%, which is excessively dry. In Ajaccio on 23 February and Sampolo on 24 February, 5% and even 4% in Renno on 24 February, for the first time under the 5% mark in 26 years and the opening of the station. Maximum temperatures are not significant in the order of 15°C with a maximum of 19°C in Calvi due to the foehn effect in the afternoon. At night, the minimum temperatures are between 3 and 10°C and are negative at altitude.

7.4 Flood, October 2018

7.4.1 Description of the event

PortoVecchio and surrounding areas have more issues exposed to floods than the north of Corse du Sud department, besides Porto Vecchio presents a flatter relief with rivers and streams capable of overflowing into the plain.

Furthermore, north of Corse du Sud still keeps its dense vegetation, while Porto Vecchio is urbanized with considerably reduced infiltration areas.

The Taglio Isolaccio region in Casinca, located south of Bastia, experienced the same event as Porto Vecchio, with the same climatic phenomenon.

However, SIS2B did provide feedback on the November 2015 event; we will see below how it was used.

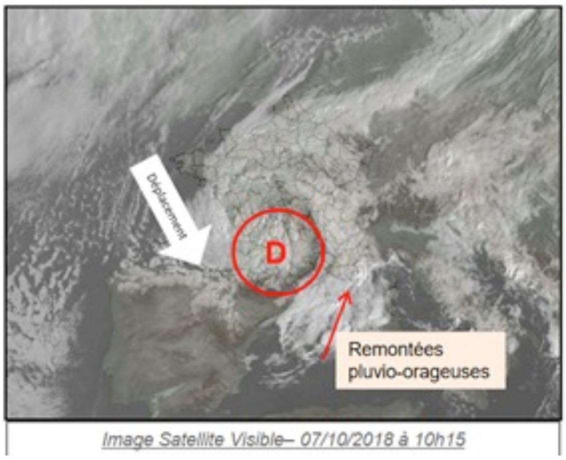


Figure 86. Images of the general situation (*source Meteo-France*

This event is characterized by an active depression that crossed the country on the weekend of 06-07/10 before moving on to Spain. This system caused rainstorms to rise early in the week over the southeast coast before moving up to France and then evacuating to Italy on Thursday, 11/10.

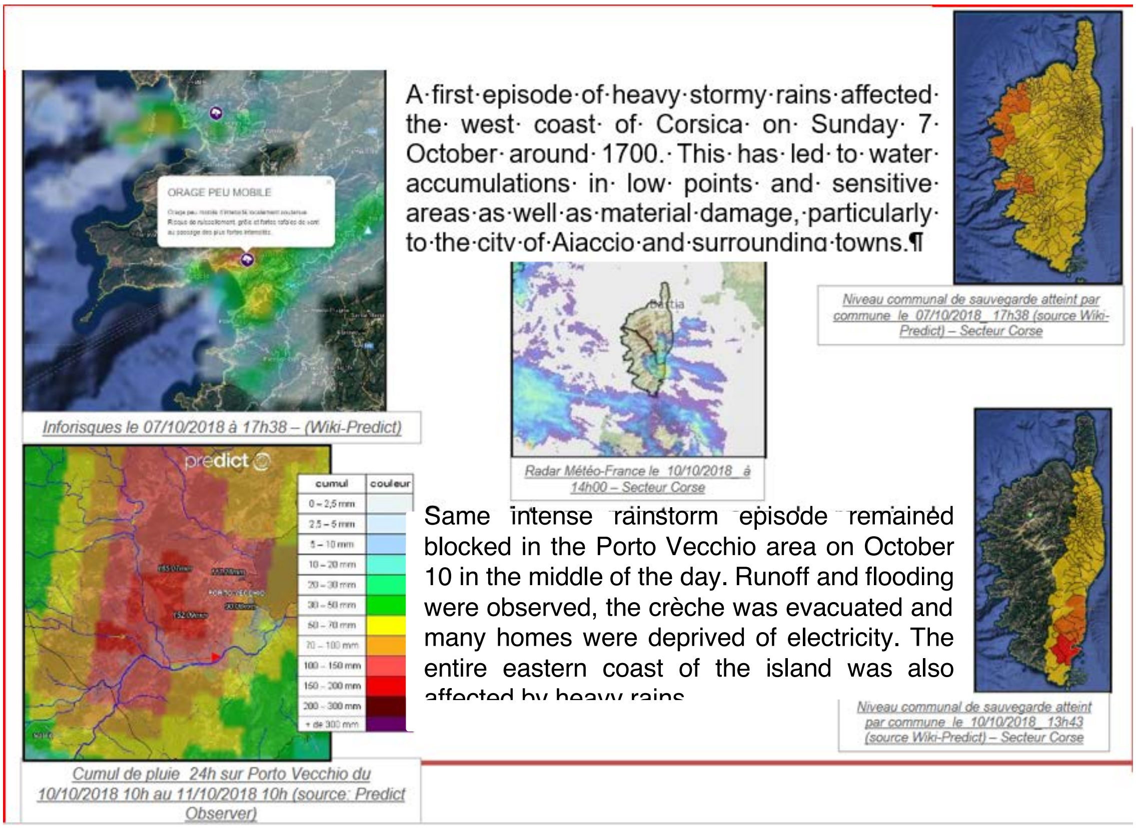


Figure 87. description of the event (source Predict-Services)

The rise of the system has resulted in continuous locally sustained and mobile precipitation generating significant totals, particularly in the PACA region, which have resulted in local heavy flooding, particularly on the coast of the Var on Wednesday 10th October to Thursday 11th October.

7.4.2 ANYWHERE tools and products used

As for the Flashflood products, Alesani river should have reacted as Fiume Alto, but the product has not taken into consideration the presence of Alesani dam, upstream the plain, whose lac of about 49 ha is enough to cushion the peak flood.

Furthermore, Fiume Alto river basin also presented more issues exposed to floods than the other rivers in the region**.**

An important element was that SIS2B had feedback on the same type of event that occurred in October 2015.

For the operational preparation of the 2018 event we used the A4Cor platform and the 2015 feedback. (Abstract: *Friday morning, after a strong rain event, a huge wave came out of the river, le Fium'Alto, and fell on the plain of Folelli, located in the commune of Penta-di-Casinca. The damage, both material and psychological, were significant. Two* *houses and 60 cars were swept into the sea. Up to 90 homes were flooded. Vineyards were ravaged*)

Firefighters used their feedback from this 2015 event.

They also used the platform A4Cor available from a few weeks ago in the Command & Control Center of SIS2B. Due to the ease of use of the platform, which includes a large part of the preventive forecasting tools, operational decision-making was facilitated.

The mayors of municipalities Venzolasca, Penta di Casinca, Castellare di Casinca, Taglio-Isolaccio, and Sorbo-Ocagnano have been prompted to activate their communal safety plan and to take all necessary preventive measures. Many damages were avoided in particular because car parks had been purged of vehicles preventively; the population properly alerted by mayors and local civil protection plans had been activated.

Firefighters better deployed resources on the field as close as possible due to the precise forecasting of the event.

Some videos available displaying the effects and consequences of this episode are available below:

- https://www.qwant.com/?q=inondations%20penta%20di%20casinca%202018&t=videos&o=0:40de6dbf6d4d650e3b7a00cbc5c666d1
- https://www.qwant.com/?q=inondations%20penta%20di%20casinca%202018&t=videos&o=0:2b6cad66f9eb6b97a0ff1ec89ec39a19

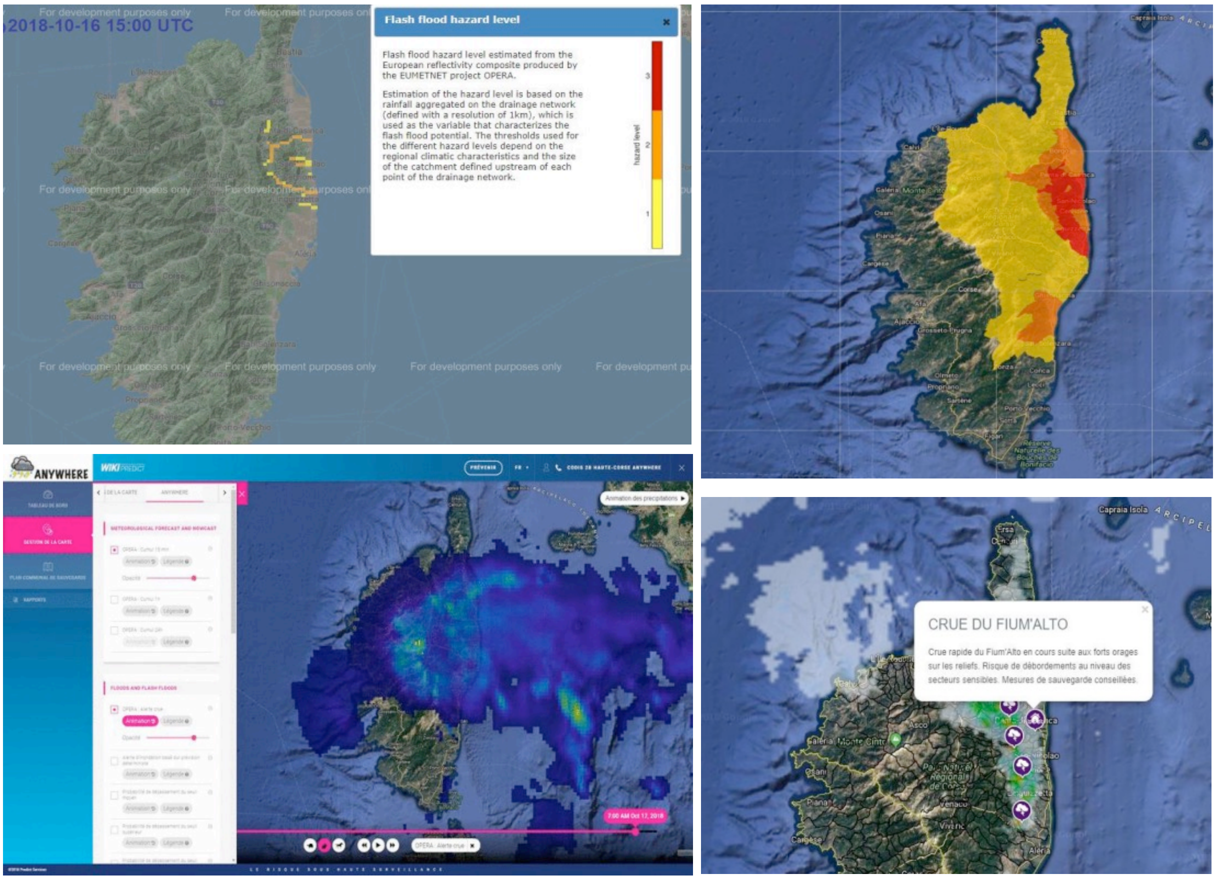


Figure 88. description of the October 2018 flood e vent, (*source Predict-Services*)

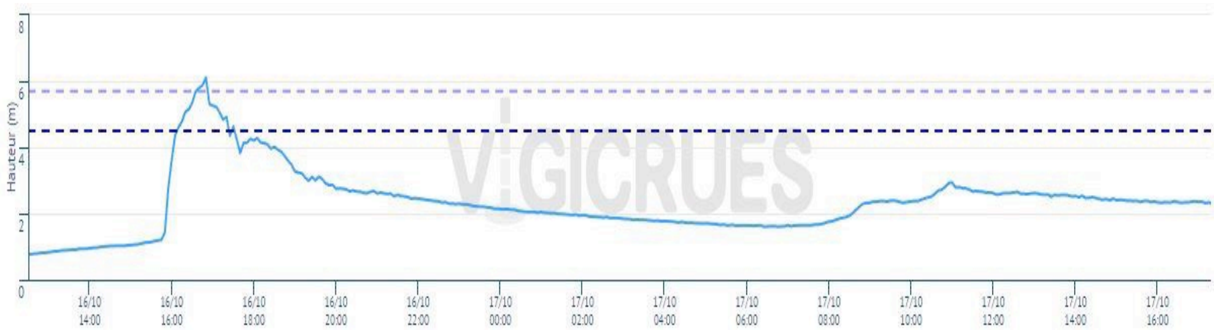


Figure 89. Taglio Isolaccio Acqua Citaja bridge Fiumalto river (source Vigicrues)

During the preparation stage and the incident management time SIS2B used a lot of ANYWHERE's MH-EWS products like OPERA's river warnings:

- OPERA: river warning,
- Refined river warning,
- Flood alert level issued by a deterministic forecast,
- Total probability of exceeding medium alert threshold,

- Total probability of exceeding high alert threshold.

7.5 Wind storm, 28th to 30th October 2018

7.5.1 Description of the event

From Sunday 28th at 12:19, Météo-France places the departments of Corsica and Alpes-Maritimes on orange "Flood Rain" alert, accompanied by yellow "Wave-Submersion" alert on these same coasts, due to the Adrian storm.

At 16:00 this yellow vigilance is extended to the Var with an orange vigilance "Storms" then "Flood rain".

On Monday 29th, Corsica went into red alert "violent wind" due to the exceptional nature of this storm. It was the first time that whole Corsica was placed in red alert. On Monday, an active low called "Adrian" rose off Corsica causing exceptional winds with peaks of up to 200km/h on exposed headlands, heavy swells and heavy rainfall. Many damages associated with these phenomena have been identified: uprooted trees, destroyed boats, damaged vehicles, blown roofs, submerged wharves and harbors, flooded neighborhoods, power cuts, runoffs, etc.

All vigilance is lifted on Tuesday 30th.

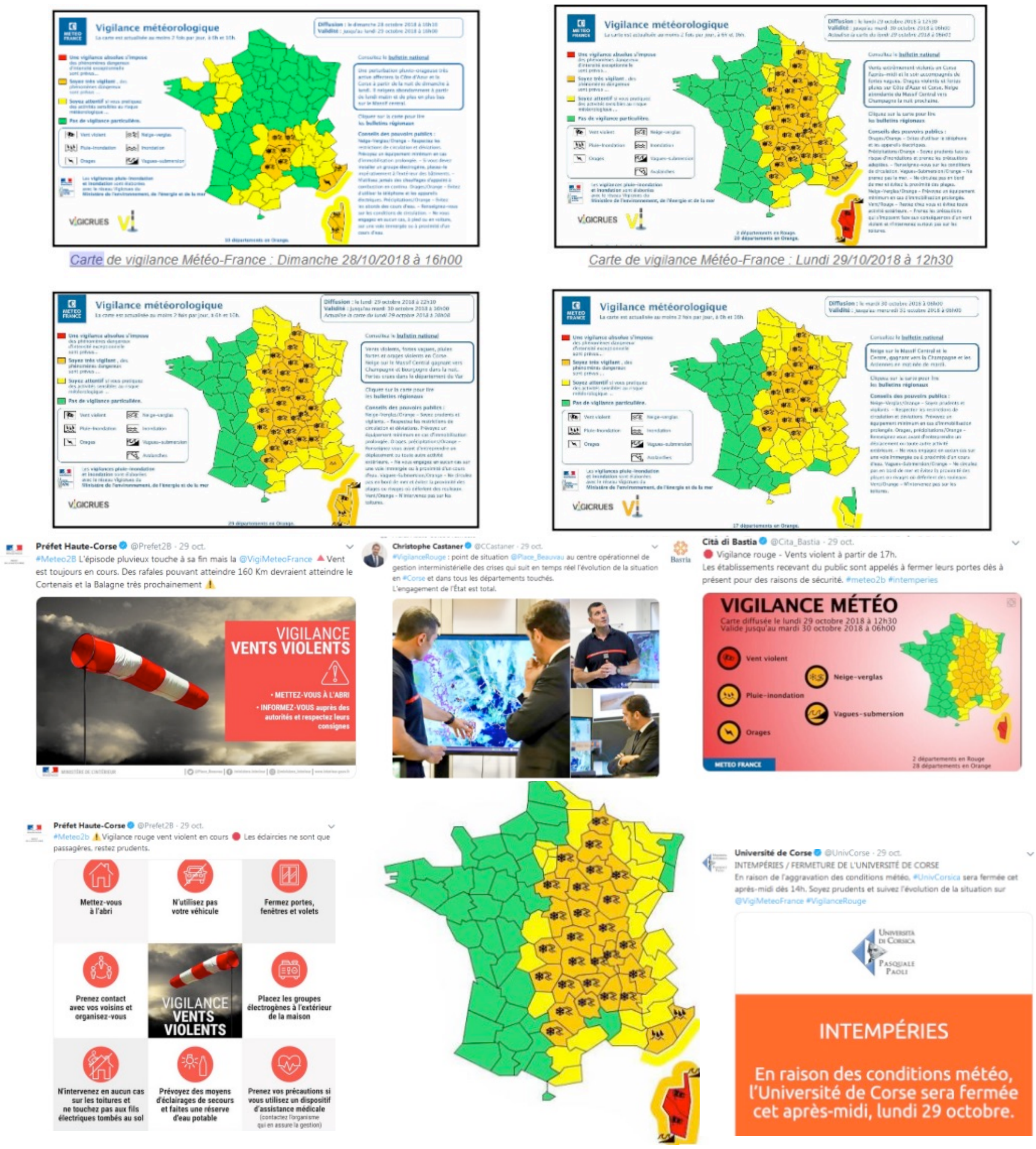


Figure 90. Alert issued by the national system reported the 29th of October at 10h30 UTC (source Météo-France).

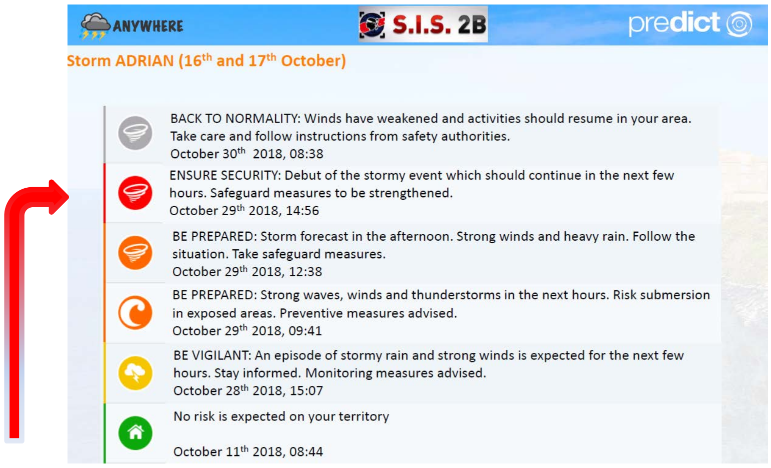


Figure 91. the event's rise to prominence (source Predict Services)

Corsica is very often exposed to very strong winds (some people says that wind is native from Corsica). One of the characteristics that the use of the A4Cor platform tools has shown is that the very accurate forecast predicted that very high winds, accompanied by heavy rains, would affect areas where these high winds had not yet been recorded. Therefore, the alert of the municipalities could be carried out directly by Predict Services, which had notified the Command and Control Centre at the same time.

During the planning meeting at the prefecture, all these elements were communicated to the authorities. The decision to impose a blockade on the island was facilitated:

- Closed schools, high schools and universities
- Establishment receiving the public closed
- Transportation by train, ferries or aircraft suspended

These were very strong measures and it was so difficult to decide but probably avoided much higher human damage.

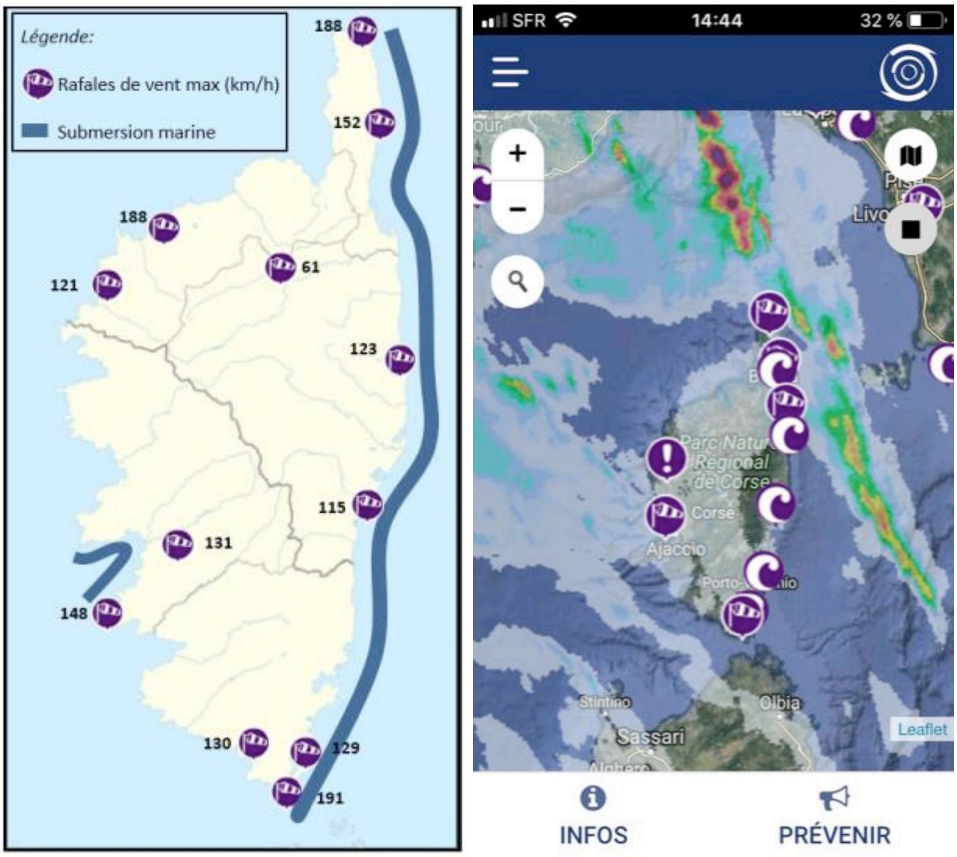


Figure 92. Screenshots of the A4Cor app (source SIS2B Predict Services)

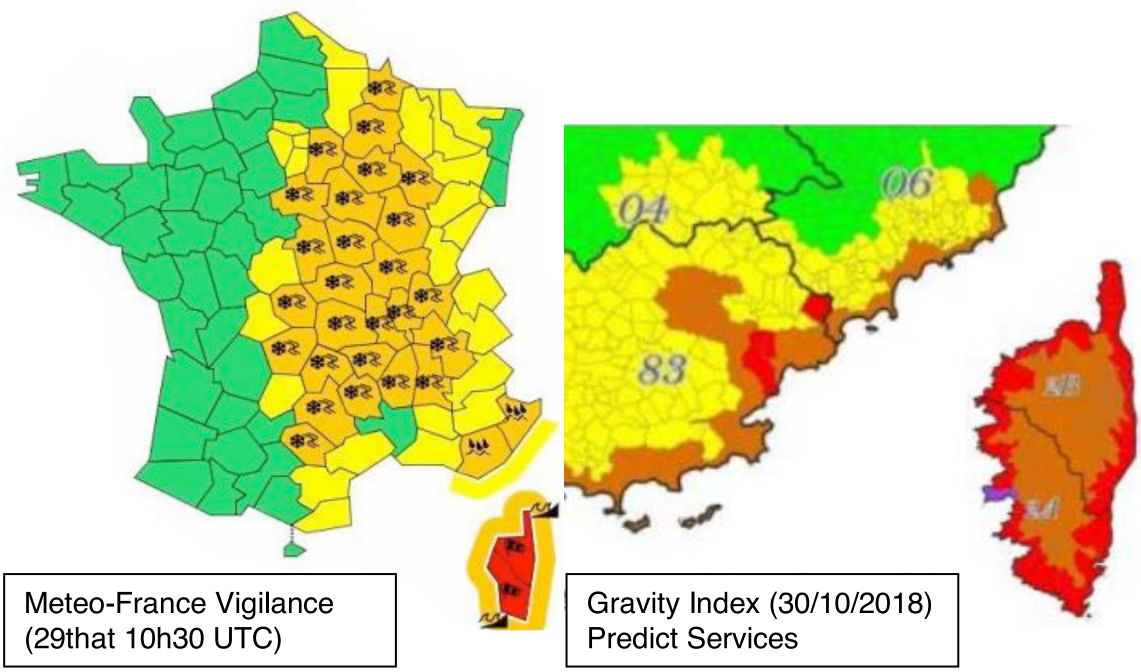


Figure 93. Comparison of delivered data (source Meteo-France/ Predict Services)

7.5.2 ANYWHERE tools and products used

During the preparation stage and the incident management time SIS2B used a lot of ANYWHERE's MH-EWS products like:

- Wind Gust Index
- Local Civil Protection Plans & impacts
- OPERA: river warning, Refined river warning, Flood alert level issued by a deterministic forecast, Total probability of exceeding medium alert threshold, Total probability of exceeding high alert threshold.

7.5.3 Main impacts of the event

During the storm, no human casualties were reported on the island, but several injuries were reported, mainly from "flying" objects. Some of them were severely injured. However, many homes were deprived of electricity for long hours. The main damage caused by the Adrian storm has been identified in coastal areas where the wind has been strong for a long time. The urbanized part of these coasts suffered greatly from this storm.

The economic impact has certainly been strong because the blockade of the island has paralyzed the economy.

Figure 94. Images of the impacts (*open data source from local and national media*)

7.6 Forest fire February 23th - 28th 2019

7.6.1 Description of the event

In the evening of 23 February 2019 around 2000 a forest fire broke out near the village of Calenzana. Météo-France had forecast a strong NE'ly wind.

At this time of year, the danger of forest fires is not very pronounced in Corsica; moreover, the NE'ly wind is not typically the most dangerous, even if in winter we have to fear it.

However, the winter drought had weighed more on the vegetation and, despite the snow overhanging the village, the fire developed very quickly in relatively low vegetation and by taking advantage of the very steep upward slope.

The fire will cover nearly 1000 hectares at night, taking advantage of very severe weather conditions. Indeed, we were able to record a relative humidity value of 8% (Temperature 14°C) at midnight and 15% (Temperature 13°C) at 0930 on the data from the nearest weather station (Calvi airport).

This unlikely situation allowed the fire to spread in the same way as in the middle of summer.

October 24

Heure	Temps	Température	Biométéo	Pluie	Humidité	Pt. de rosée	Vent moyen (raf.)	Pression	Visibilité
08h		10.2 °C		0 mm/1h	15%	-15.4 °C	40 km/h (68.4 km/h)	1030.3hPa ↗	60 km
07h		10.3 °C		0 mm/1h	13%	-17 °C	32 km/h (72 km/h)	1029.5hPa =	60 km
06h		11.3 °C		0 mm/1h	9%	-20.5 °C	50 km/h (82.8 km/h)	1028.9hPa =	60 km
05h		11.4 °C		0 mm/1h	8%	-21.8 °C	32 km/h (79.2 km/h)	1029.7hPa ↗	60 km
04h		11.2 °C		0 mm/1h	9%	-20.6 °C	40 km/h (75.6 km/h)	1029.4hPa ↗	60 km
03h		11.7 °C		0 mm/1h	8%	-21.6 °C	40 km/h (72 km/h)	1028.9hPa ↗	60 km
02h		12.6 °C		0 mm/1h	9%	-19.5 °C	36 km/h (86.4 km/h)	1028.7hPa ↗	60 km
01h		13.0 °C		0 mm/1h	8%	-20.6 °C	43 km/h (93.6 km/h)	1027.7hPa ↗	45 km

October 23

Heure	Temps	Température	Biométéo	Pluie	Humidité	Pt. de rosée	Vent moyen (raf.)	Pression	Visibilité
00h		13.6 °C		0 mm/1h	8%	-20.1 °C	47 km/h (86.4 km/h)	1026.8hPa ↘	60 km
23h		13.6 °C		0 mm/1h	8%	-20.1 °C	40 km/h (86.4 km/h)	1026.7hPa ↗	25 km
22h		13.4 °C		0 mm/1h	8%	-20.3 °C	36 km/h (86.4 km/h)	1026.9hPa ↗	60 km
21h		13.1 °C		0 mm/1h	7%	-22.1 °C	50 km/h (86.4 km/h)	1027.0hPa ↗	55 km
20h		12.8 °C		0 mm/1h	9%	-19.4 °C	40 km/h (75.6 km/h)	1026.6hPa ↗	40 km
19h		12.5 °C		0 mm/1h	15%	-13.5 °C	25 km/h (68.4 km/h)	1026.7hPa ↗	60 km
18h		13.6 °C		0 mm/1h	20%	-9 °C	32 km/h (68.4 km/h)	1026.2hPa ↗	55 km
17h		14.5 °C		0 mm/1h	23%	-6.4 °C	36 km/h (64.8 km/h)	1025.6hPa ↘	45 km

Figure 95. Meteo data recorded in the weather station of Calvi in the night 23th to 24 th (source Infoclimat)

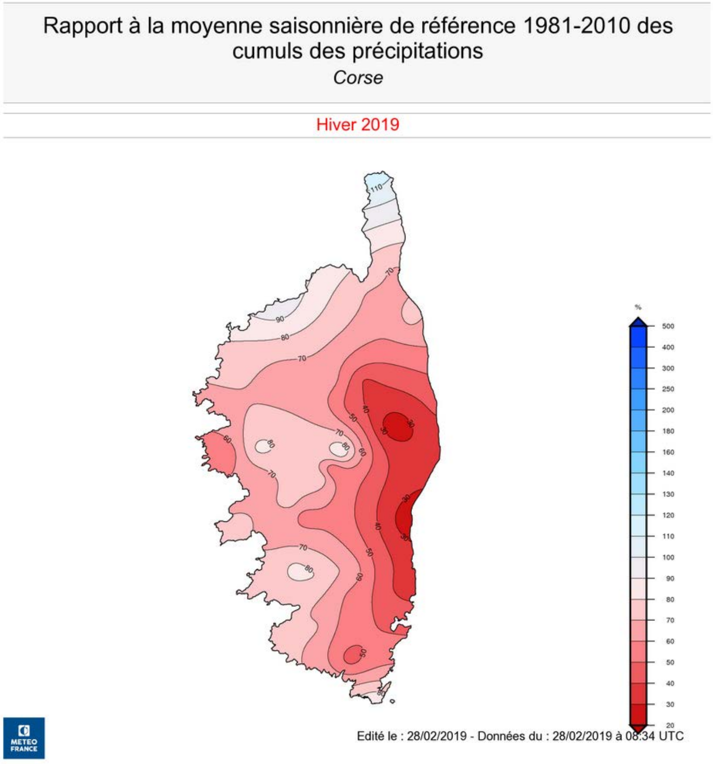


Figure 96. Ratio to average cumulative rainfall totals in Corsica (*source Meteo-France*)

After about twenty days without rain but especially in connection with strong winds and extremely low air humidity, dead vegetation, brush and shrubs of the scrubland, are extremely sensitive to fire. Any source of heat, sometimes in connection with agricultural work or eco-cups, the leftovers of which can sometimes cover several days or with falls from electric poles, can trigger fires which will then be fanned and propagated by very strong winds and by slope effects.

Mountain areas also have the particularity of being difficult for forest fire-fighting vehicles to access and the combined action of water bombers is often decisive. Aggravating circumstances, aerial treatment can only be carried out during the day and violent gusts and turbulence make aerial control very difficult. Fires started at the end of the day and at night in mountainous areas are therefore extremely difficult to deal with by the combined action of land and air assets.

These winter fires are frequent in the mountains, in Corsica. The island has already suffered violent fires in early January 2018 due to strong winds and violent Foehn effects during the passage of the “Fionn depression” (*Chiatra/Sant’Andrea di Cotone,1-4 January 2018*).

For many years, Météo-France has provided assistance dedicated to forest fire-fighting services throughout the year and more specifically for the summer season when forest fires are more numerous and more virulent.

This assistance is available at the national level as well as in the southwest and Mediterranean regions where services are dedicated to this issue.

The data from the site specializing in forest fires in "Météo-France-Valabre" are therefore not available in February. In addition, SIS2B had chosen to integrate ANYWHERE's "Forest Fire" tools into the A4Cor platform only to prepare for the summer season when the risk is very high, preferring to focus on using more profitable tools in winter.

SIS2B therefore did not benefit from specific forecasting tools for this event.

On the other hand, we used the Propagator simulator *a posteriori* to try to understand the rapid development of this fire, but it was finally the meteo survey data that allowed us to understand that the fire had benefited from conditions almost identical to those usually encountered in summer.

This reinforces our belief that successive intense climatic events should encourage us to be ready to face at any moment.

It also reminds us of the uncertainty in any decision making, even if it is argued by scientific data.

7.6.2 ANYWHERE tools and products used

SIS2B had chosen to integrate ANYWHERE's "Forest Fire" tools into the A4Cor platform only to prepare for the summer season when the risk is very high, preferring to focus on using more profitable tools in winter. So, SIS2B did not use any A4Cor or A4EU tools during this event.

7.6.3 Main impacts of the event

The Calenzana fire crossed part of the village but caused no human casualties, no injuries and most of the herds were saved in their entirety. No residential or farm buildings were affected, destroying 1174 hectares of vegetation consisting of scrubland and especially coniferous trees in the Sambuccu forest, which had already been affected by a fire in August 1982. The very uneven terrain, the development of the night fire (nearly 1000 hectares burned in the first night) and the absence of water bombers on the island at this time of year made the work of the firefighters very difficult.The Bonifato forest was the main environmental issue in the South of the fire. Thanks to hard work in the mountains, sometimes in the snow, the control services managed to protect it by stopping the progression at an altitude of 1600 meters. Only a few hectares of this forest of more than 3000 hectares, emblematic of the region, have been affected.

Figure 97. Delineation map of Calenzana forest fire (source EMS Copernicus)

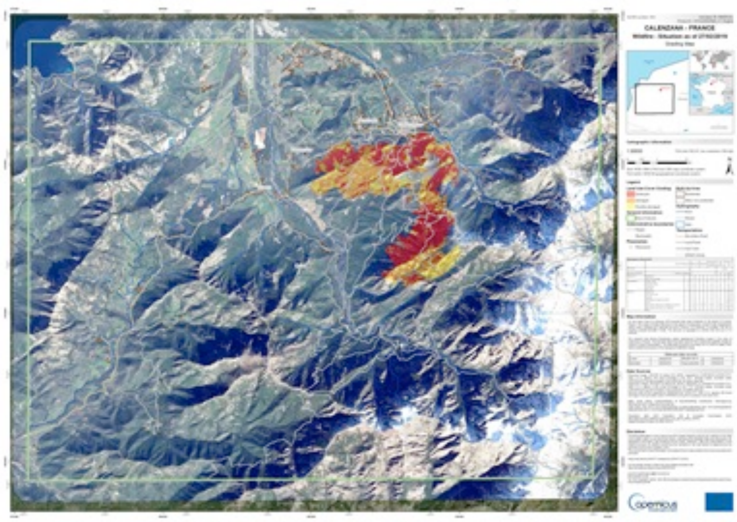


Figure 98. Grading map of Calenzana forest fire (source EMS Copernicus)

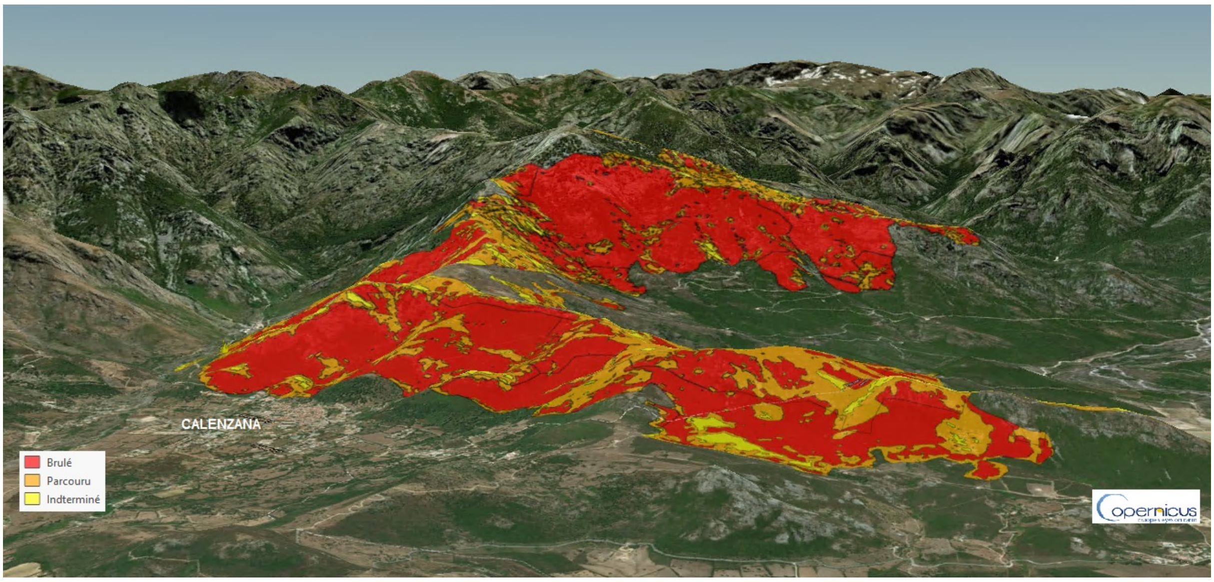


Figure 99. 3D model grading map of Calenzana forest fire (source EMS Copernicus)


Figure 100. Images of Calenzana forest fire (*source SIS2B*)

Figure 101. Images of Calenzana forest fire (*source SIS2B*)

7.7 Results and discussion

7.7.1 Lessons learnt

In recent years, climate change has caused both powerful and unusual events. Everything shows that this situation will continue and that no country or region of the world is spared. As rescue services, first responders dealing with this new paradigm, we must learn from all these events, we must talk to our European colleagues and we must very quickly accept to break out of our well-trained habits and face up to them.

To face up to better defend our territories against these increasingly powerful events, to face up to not put us in greater danger and above all to face up to **save lives** and protect our fellow citizens. This can only be done by changing our methods and aggregating our knowledge; it will only be possible by adapting our means of anticipation and by benefiting from all the decision-making support technology available. This reinforces our belief that successive intense climatic events should encourage us to be ready to face at any moment like to deal with flashflood in summer or forest fires in winter. It also reminds us of the **uncertainty** in any decision making, even if it is argued by scientific data.

7.7.2 Overall evaluation

The ANYWHERE project is for SIS2B the first H2020 project whose results will impact our working method. 34 organizations belonging to 12 European countries, 12 operational emergency management authorities covering different level of management (national, regional and local), 13 research, development and innovation organizations and 9 Small and Medium Enterprises and Industries: what a complex but really successful challenge.

It is comparable to a high-level organization and it has been managed with the principles used in High Reliability Organizations, such as a nuclear aircraft carrier! Diversities and even divergences have emerged. Between the visions of researchers and responders, between too broad visions and very local needs but always managed in the interest of the project. And this was possible because all the partners believed in the project; all had the will to succeed.

The development of this A4Cor platform can be considered as a success story. We had at SIS2B to get people to accept, to make our needs understood, we can say that we have reached the end of this project with a tool that will be useful to our Command and Control Centre and that will facilitate the task of operators and officers in charge of preparing the response to events. As SIS2B we want also to continue this work and improve the tools we have been using for more than a year in real conditions. The systems developed need to evolve and we will be able to evolve them through our feedback to do even better tomorrow, to provide improved tools to those who will replace us for the good of people dealing with the risks posed by climate change across Europe.

8 Results of the A4EU (A4CENEM) demonstration - Spain

8.1 Institutions leading Spain Pilot Site operations

A4CENEM is the web-based system developed for the National Directorate of Civil Protection and Emergencies (DGPCE) in Spain as national end-user. Nevertheless, the development is also aiming at other regional end-users. The DGPCE operational centre is CENEM (National Center of Emergencies) as the main control center but there are other institutions and actors involved in the development and use of the platform. The pilot site involved institutions are identified in the next table:

Table 3. A4CENEM involved institutions

PHASE	Leading Institution
Implementation of A4CENEM	HYDS
Training	HYDS/DGPCE
Supervision/Control	HYDS/DGPCE/AMAYA
Operation	CENEM AMAYA, 112 VALENCIA, 112 BALEARES, 112 MURCIA, 112 ANDALUCÍA JUCAR WATER AGENCY
Data Providers	GUADALQUIVIR W.A, JUCAR WATER AGENCY EBRO WATER AGENCY CATALAN WATER AGENCY NATIONAL METEOROLOGICAL AGENCY (AEMET), NATIONAL TRAFFIC DEPARTMENT

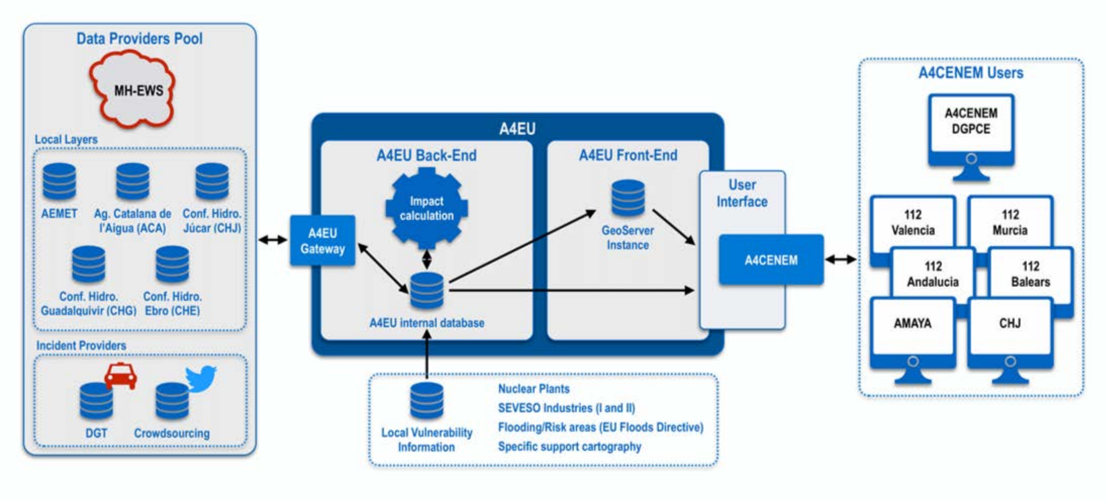


Figure 102. A4CENEM scheme

A4CENEM became operational in October 2018, but in the meantime DGPCE tested A4Cat and it was noticed that could be useful at a national level. No specific training was made while deploying the platform due to the fact that this pilot site was not foreseen initially. A quick start guide could be of use. A latter training was held on March 2019 at the ENPC (Spanish National Civil Protection School)

8.2 Pilot site description and A4CENEM main features

Spain is one of the 28 countries of the European Union. It is located on the southwest of Europe separated from the North of Africa by the Strait of Gibraltar, geographically limiting with France and Portugal. It occupies most of the Iberian Peninsula (around 80%). Next to the peninsula it has two archipelagos: Canary Islands and Balearic Islands, and two autonomous cities of Ceuta and Melilla located in Africa.

Spain is 505,990 km² wide. The capital of Spain is Madrid. It has a total population of 46,528,966 people, being the most populated autonomous communities: Andalusia with 8,409,657, Catalonia with 7,441,176 and Madrid with 6,475,872. The population density is 92 inhabitants / km², but it is distributed very heterogeneously. The majority of the population is distributed in the periphery of the country and in the Community of Madrid.

The topography and consequently also the climate are very diverse in Spain, the average altitude is 660 meters above sea level.

The highest peaks are the Teide 3,718 m (in the Canary Islands), Mulhacen 3,478.6 m and Pico Aneto 3,404 m. The mountainous systems are numerous, almost half of the national territory. Pyrenees (northeast limit), Betic Systems (southeast), Cantabrian Mountains and Central system.

In addition, the most important depressions are those of the Guadalquivir River and the Ebro River.

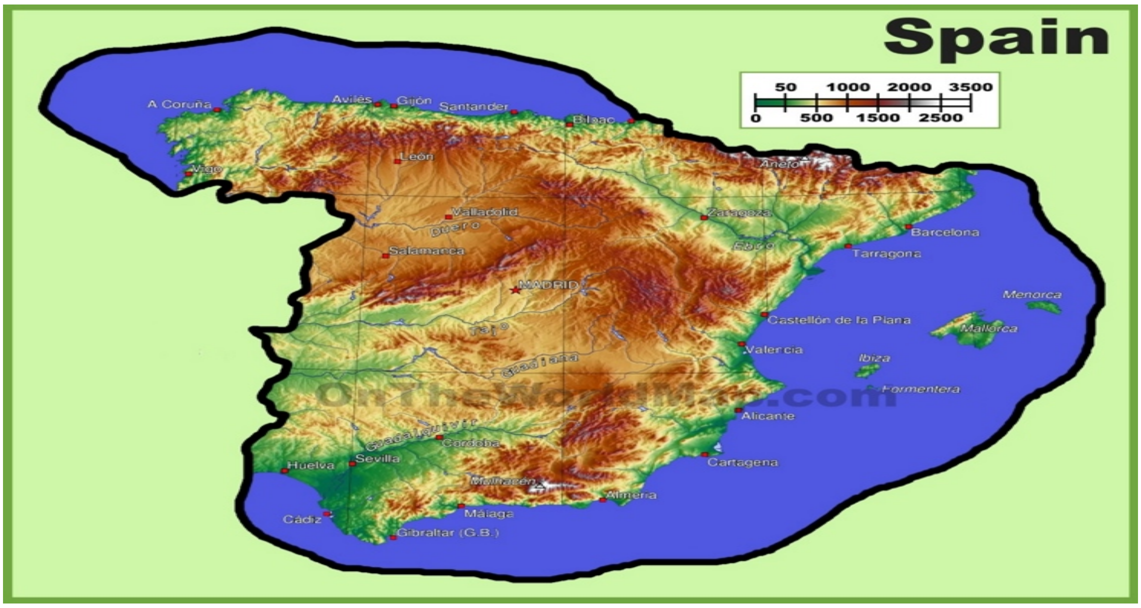


Figure 103. Pilot site area entire Spain physical map

The **main natural hazards** that affect Spain are:

- Floods (heavy rains, rivers overflow, waves)
- Winds.
- Forest fires.
- Snowstorms.
- Earthquakes.

The Spanish civil protection is organized in 3 levels, according to the 3 administrations:

- National government.
- 17 Autonomous communities (regional governments).
- 8.118 Municipalities.

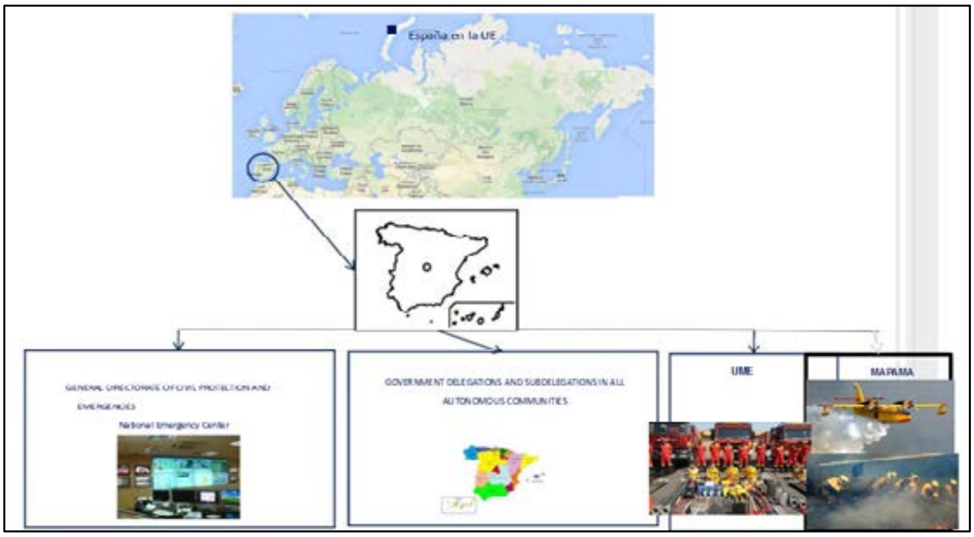


Figure 104. Organization of Spanish Civil Protection at state level

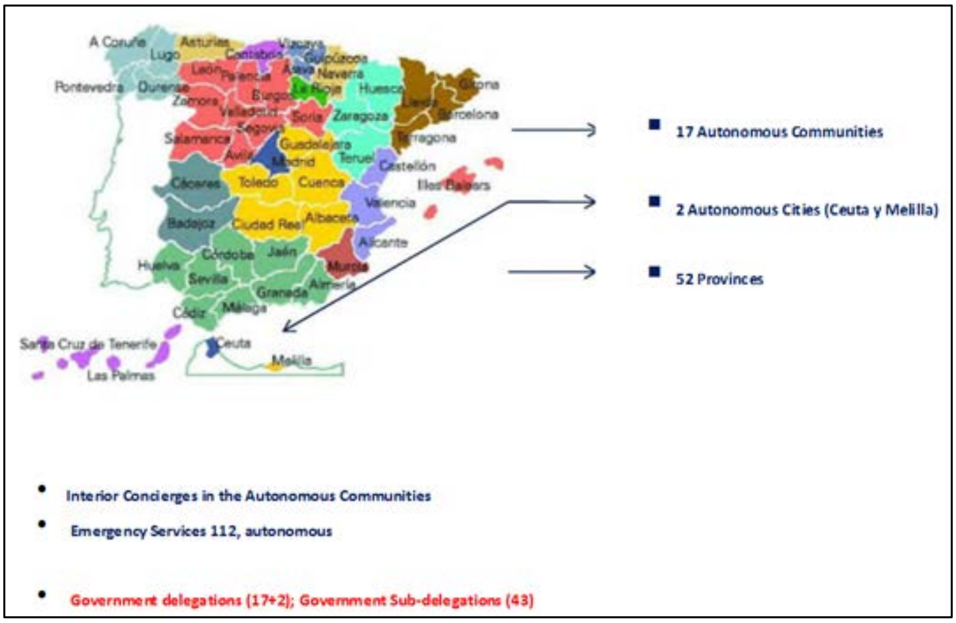


Figure 105. Organization of Spanish Civil Protection at Autonomous communities level.

Figure 106. Organization of Spanish Civil Protection at local level

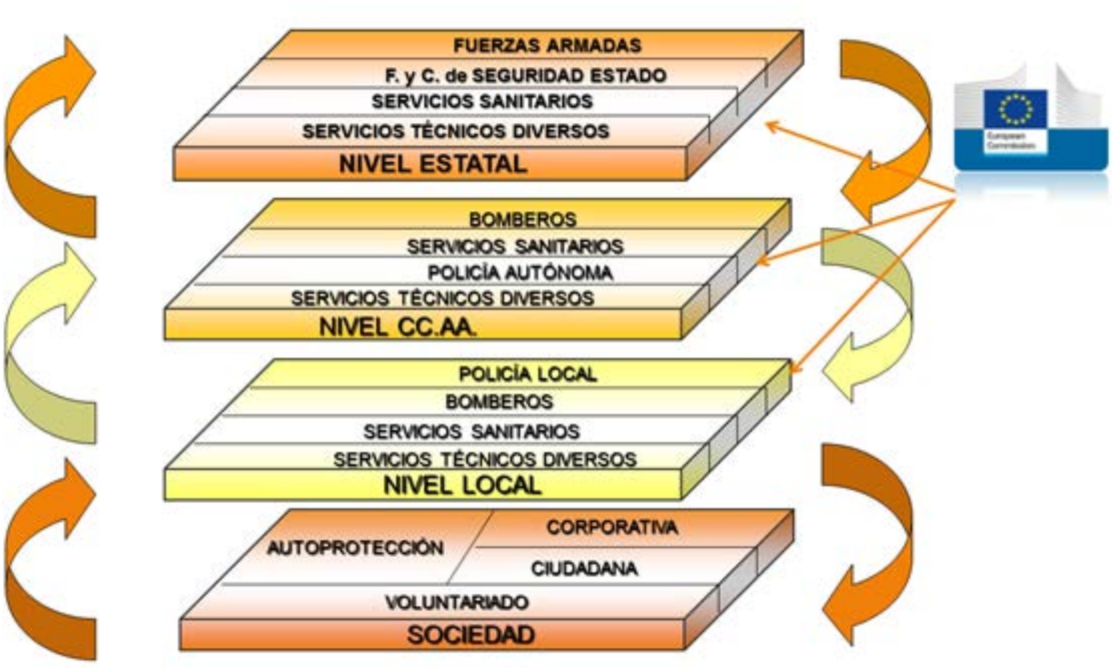


Figure 107. Participants and Spanish Civil Protection System

<u>A4CENEM Main features:</u>

- Web Viewer of georeferenced information (including both MH-EWS products national, regional and local products, as well as impact information and impact summaries). Possibility to change background maps according to necessity at national or regional level.
- General functionalities and interfaces (data inputs and outputs management, connection to MH-EWS, database user management system and authentication).
- New local layers provided by national organizations (AEMET, Water Agencies: Ebro, ACA, Júcar and Guadalquivir).
- Visualization of the national, regional and local vulnerability information (flooding areas from EU Floods Directive, strategic critical points such as nuclear plants and Seveso Industries - I and II, infrastructures, etc.)
- Real-time crossing with the hazard forecasts (“activation” of critical elements forecasted to be at risk) and provision of key information to support warning making or request extraordinary resources.
- New incidents provider, not only crowdsourcing, coming from Spanish Traffic Department.

8.3 Main hazards faced during the operational period

During the operational demonstration period the system was used and tested in supporting DGCPE during emergencies. Here we report the two main events, related to floods, in which the use of A4CENEM was relevant. These events interested different areas of Spain and having A4CENEM in place helped in understanding and proactively respond to:

- Flood event: 17th-23rd April 2019 on Levante coast (Valencia, Murcia, Baleares)
- Flood event: 9th-15th September 2019 on Levante coast (Valencia, Alicante, Murcia, Almeria, Malaga, Granada)

8.4 Flood, 17th-23rd April 2019

8.4.1 Description of the event

During the week from 17th to 23rd April 2019 there was an Atlantic squall that brought to the Iberian peninsula a drop in temperatures, rain and strong winds specially in Murcia and the south of the Valencia region where have been registered 170 litres per square metre. Balearic Islands also suffered heavy rains and strong gusts of wind.

This situation resulted as the worst in the area for the last 50 years left flooded streets, closed ports, fallen trees, wounded people, traffic cuts, etc.

A4CENEM has been operated by CENEM, Government Delegation of Valencia, Júcar Water Agency and 112 Valencia to monitor the event complementing their legacy systems and to validate the tool for decision-making.

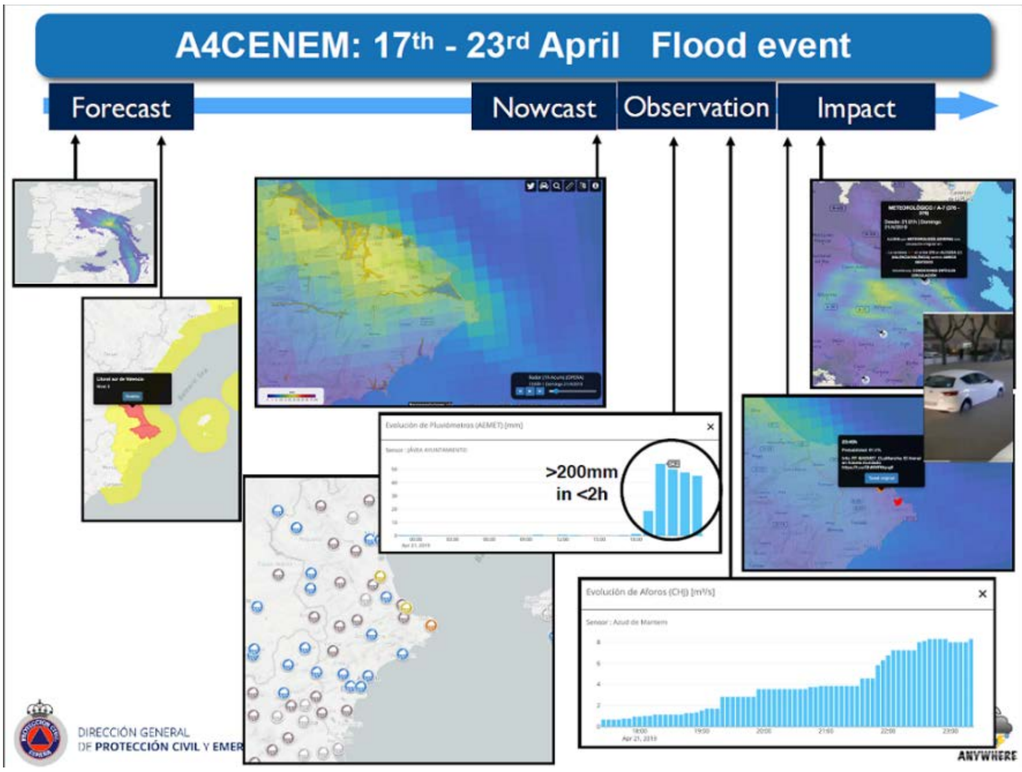


Figure 108. Timeline of the April flood event.

8.4.2 ANYWHERE tools and products used

Several days ahead an EFAS flood warning was issued to activate the monitoring of the event. The warning was also supported by the forecasted distribution of precipitation over the areas coming from the ECMWF (European Centre for Medium-Range Weather Forecasts) models and lastly confirmed three days before the event by AEMET (*Agencia Estatal de Meteorología*) with the National weather forecast warnings.

The first and third products were also available in the pre-existing legacy systems but not in a single screen and as a comprehensive tool.

Once the event begun the nowcasting tools come to front as the most useful. Products using OPERA radar information like precipitation evolution and OPERA rain and river warnings combined with information observed in rain stations and river gauges allowed to monitor the event correctly.

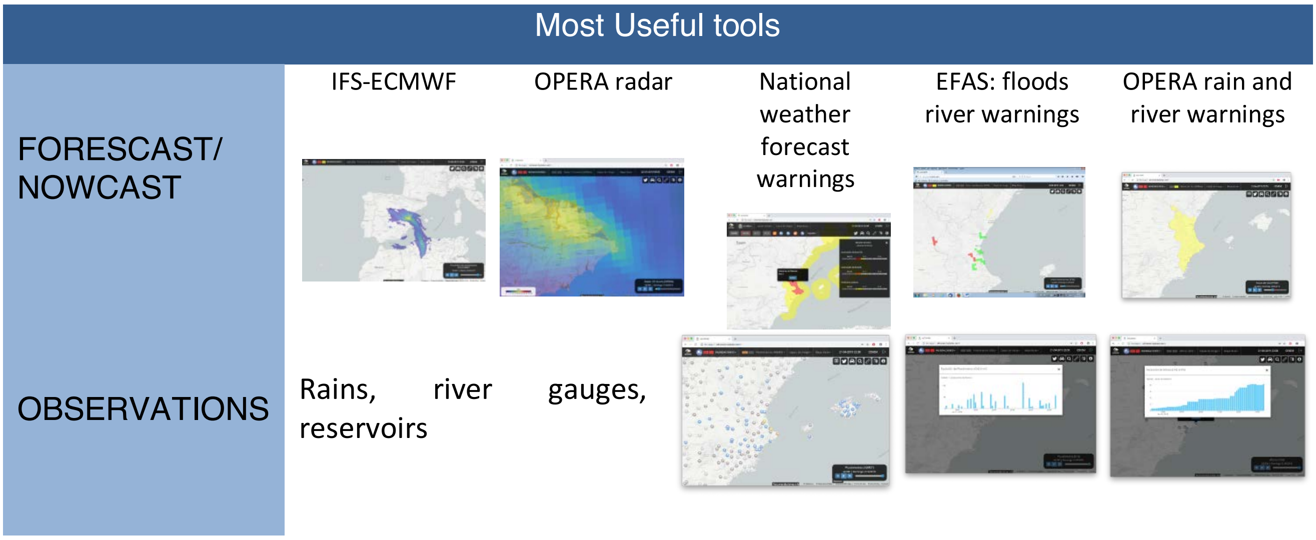


Figure 109. Most useful tools during the flood event in April 2019

8.4.3 Main impacts of the event

The impact could be estimated using the risk layers (national and regional) included in the A4CENEM tool (See Figure 110). Moreover, impact information obtained by crowdsourcing and provided by National Traffic Authority proved also their usefulness (see Figure 111).

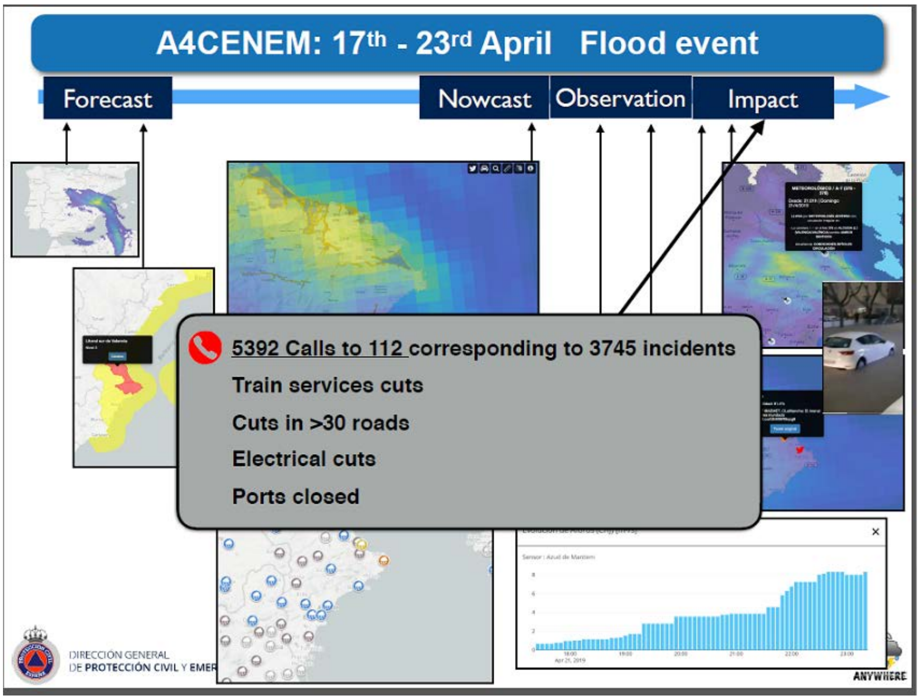


Figure 110. Impacts of the April flood event

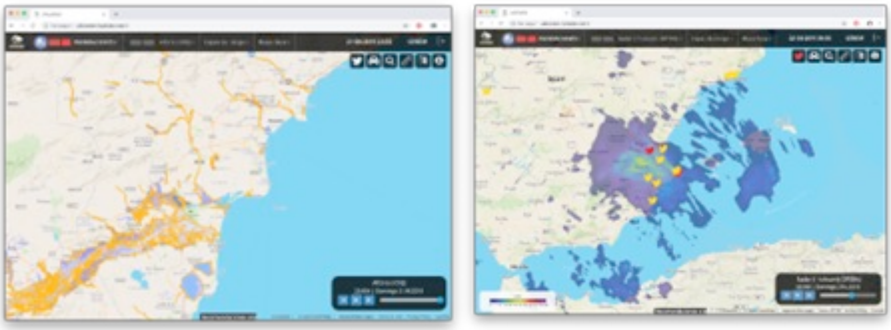


Figure 111. Impact layers included carthography of flood prone areas, incidents registered in the national traffic authority system and flood related information obtained from the crowdsourcing.

8.5 Flood, 9th-15th September 2019

8.5.1 Description of the event

During the week of September 9th to 15th there was a meteorological situation known as “DANA” (Isolated Depression in High Levels of the Atmosphere) or “*gota fría*” in Spanish that entered during the afternoon of the 9th by the northwest of the Peninsula and was moving towards the Eastern Coast, remaining stationary between the peninsular southeast and north Africa during the following days. As of Saturday 14th, the “DANA” made a change of trajectory towards the central region of Spain affecting Madrid and part of Castilla-La Mancha on September 15th.The Mediterranean area was affected, with heavy rains frequently accompanied by storms, of strong or very strong intensity, intense winds and poor state of the sea, for several days. Exceptional rainfall was reached, accumulating in 48 hours, 452 l/m^2 in Beniarrés, 425 l/m^2 in Orihuela and 339.2 l/m^2 in Onteniente (See Figure 112).

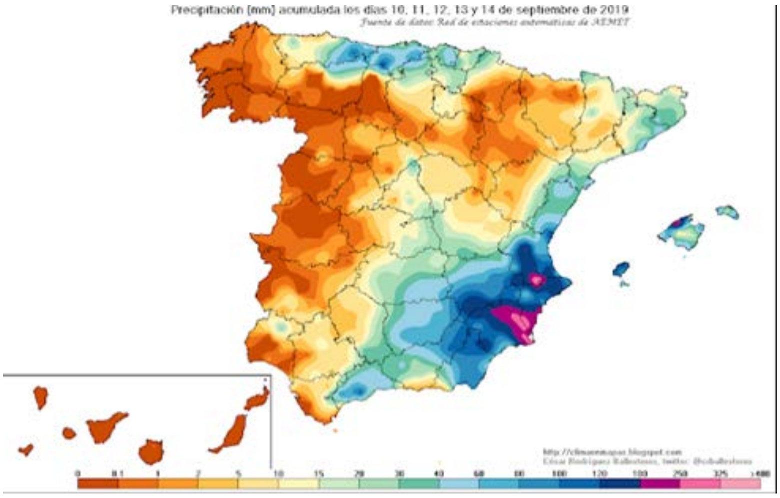


Figure 112. Total precipitation accumulation from 10th September to 13th September.

The episode, which began producing damage mainly due to intense rainfall, began to generate serious damage due to the overflows of large rivers such as Segura.

Alterations also occurred in some dams: Bellús (Valencia), Santomera (Alicante) and Almansa (Albacete). In the case of the lower part of Segura basin, the conditions of the territory itself that in some areas have altitudes lower than the Segura riverbed (Almoradí and Orihuela) favouring the flooding and the isolation of some of the municipalities.

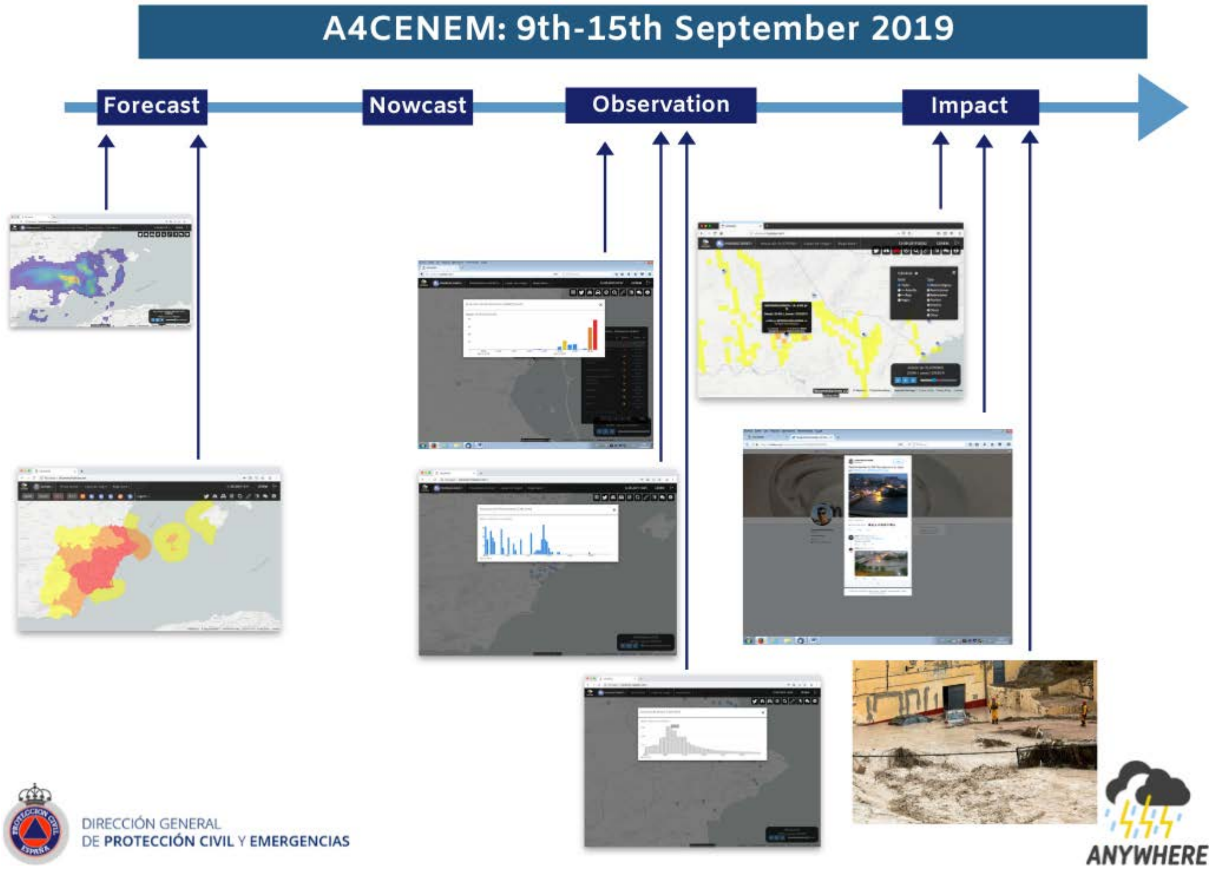


Figure 113. Timeline of the September flood event in terms of tools and models used in the different phases of the emergency.

Starting from the forecast and throughout all the event the evolution and impacts generated by the extreme meteorological situation could be followed using A4CENEM in the different control centers.

Many MH-EWS impact forecasting products were used. One product fits better than others in each of the phases so the products use evolved during the event.

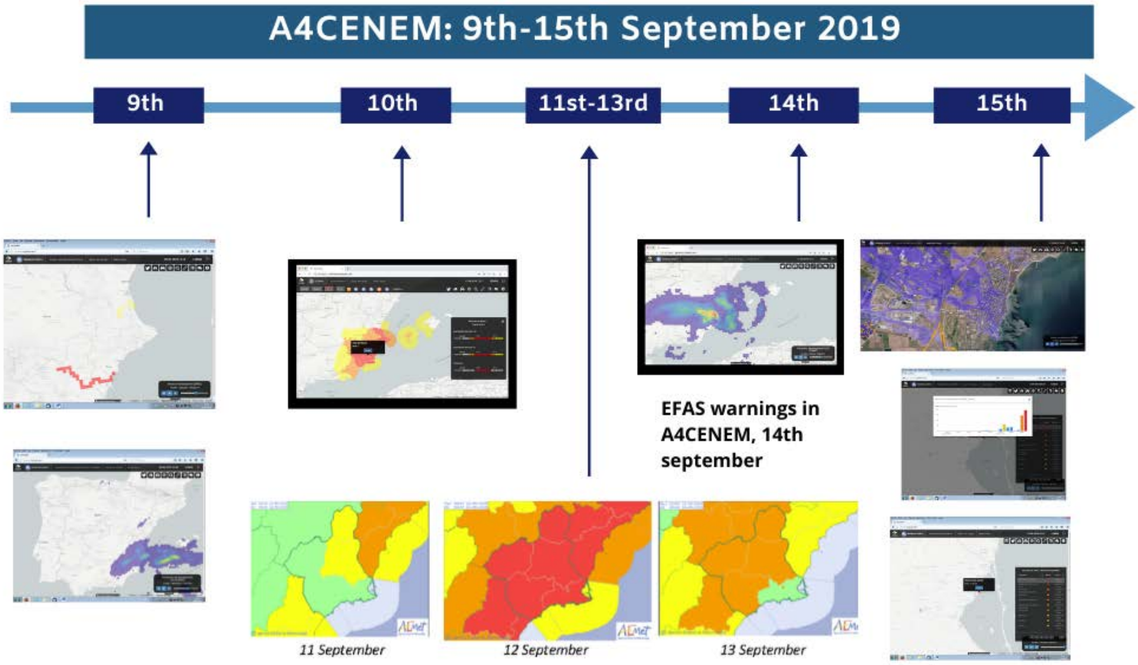
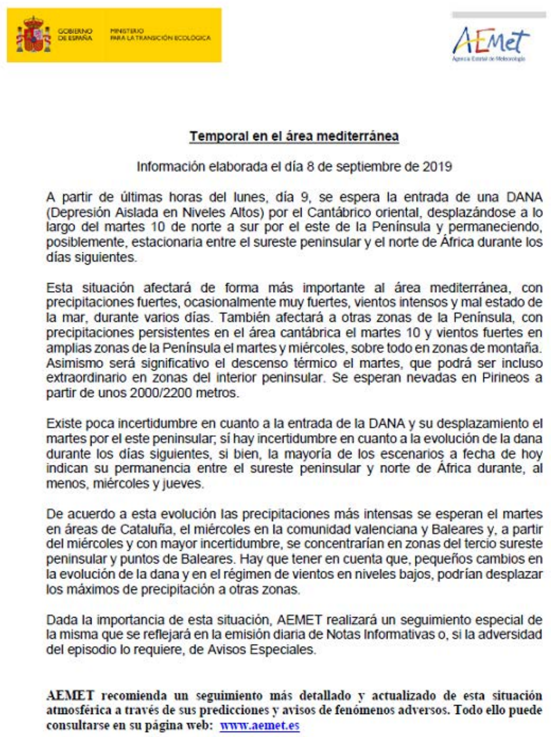


Figure 114. Timeline of the September flood event in terms of European tools warnings.



Temporal en el área mediterránea

Información elaborada el día 8 de septiembre de 2019

A partir de últimas horas del lunes, día 9, se espera la entrada de una DANA (Depresión Aislada en Niveles Altos) por el Cantábrico oriental, desplazándose a lo largo del martes 10 de norte a sur por el este de la Península y permaneciendo, posiblemente, estacionaria entre el sureste peninsular y el norte de África durante los días siguientes.

Esta situación afectará de forma más importante al área mediterránea, con precipitaciones fuertes, ocasionalmente muy fuertes, vientos intensos y mal estado de la mar, durante varios días. También afectará a otras zonas de la Península, con precipitaciones persistentes en el área cantábrica el martes 10 y vientos fuertes en amplias zonas de la Península el martes y miércoles, sobre todo en zonas de montaña. Asimismo será significativo el descenso térmico el martes, que podrá ser incluso extraordinario en zonas del interior peninsular. Se esperan nevadas en Pirineos a partir de unos 2000/2200 metros.

Existe poca incertidumbre en cuanto a la entrada de la DANA y su desplazamiento el martes por el este peninsular; sí hay incertidumbre en cuanto a la evolución de la dana durante los días siguientes, si bien, la mayoría de los escenarios a fecha de hoy indican su permanencia entre el sureste peninsular y norte de África durante, al menos, miércoles y jueves.

De acuerdo a esta evolución las precipitaciones más intensas se esperan el martes en áreas de Cataluña, el miércoles en la comunidad valenciana y Baleares y, a partir del miércoles y con mayor incertidumbre, se concentrarían en zonas del tercio sureste peninsular y puntos de Baleares. Hay que tener en cuenta que, pequeños cambios en la evolución de la dana y en el régimen de vientos en niveles bajos, podrían desplazar los máximos de precipitación a otras zonas.

Dada la importancia de esta situación, AEMET realizará un seguimiento especial de la misma que se reflejará en la emisión diaria de Notas Informativas o, si la adversidad del episodio lo requiere, de Avisos Especiales.

AEMET recomienda un seguimiento más detallado y actualizado de esta situación atmosférica a través de sus predicciones y avisos de fenómenos adversos. Todo ello puede consultarse en su página web: www.aemet.es

Figure 115. AEMET (National Meteorological Agency) warnings.

AEMET (National Meteorological Agency) warnings were issued on 8th September asking for monitoring the event in the following days.

The register of different emergency levels for the flood emergency plan in Murcia region shows one day in advance activation for the Segura River based on the forecasted precipitation coming from the ECMWF products on 9th September.

Date	Time	Emergency INUNMUR	DAMS	Emergency Plan
10 Sept	19.30	Pre- emergency		
11 Sept	18.00	Level 0		
12 Sept	13.00	Level 1		
	19.20	Level 2		
13 Sept	14.00		Santomera	Scenario 1
14 Sept	01.35		Ojós	Scenario 1
	15.00			Scenario 0
16 Sept	15.20		Santomera	Scenario 0
19 Sept	18.00	Level 1		
04 Oct	20.00	Level 0		

Figure 116. Timeline of the emergency plan activated: Santomera dam declares Scenario 1 of the Self-Protection Plan

On 13th September, the Santomera dam declares Scenario 1 of the Self-Protection Plan and it is necessary to evacuate the population of Siscar (1200 people).

A4CENEM sent warnings one day before the general information arrives that helped in the decision making in operational centers and prepare extraordinary resources for 12th sept: National government sent resources from UME (Emergency Military Units), Red Cross and activated Copernicus EMS service (see Figure 117 and Figure 118).

Figure 117. UME (Emergency Military Units), Red Cross support in the areas affected by the September flood event.

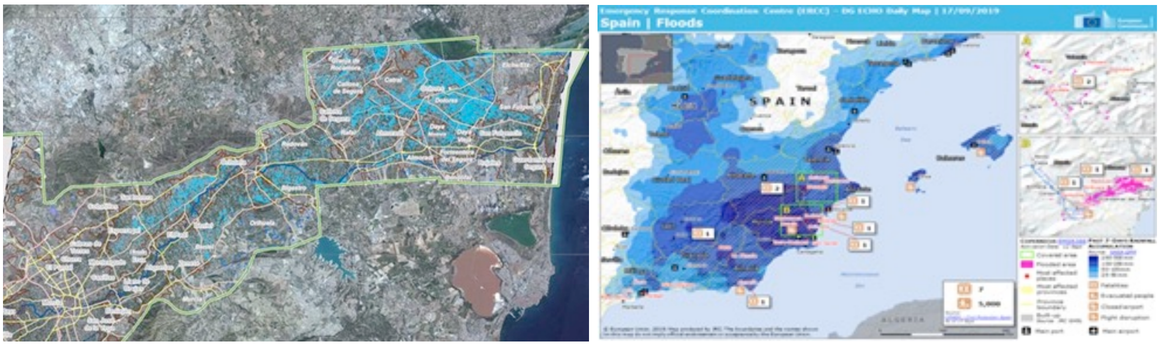


Figure 118. Copernicus maps and ERCC activation during the September flood event.

8.5.2 ANYWHERE tools and products used

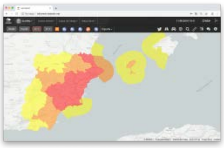
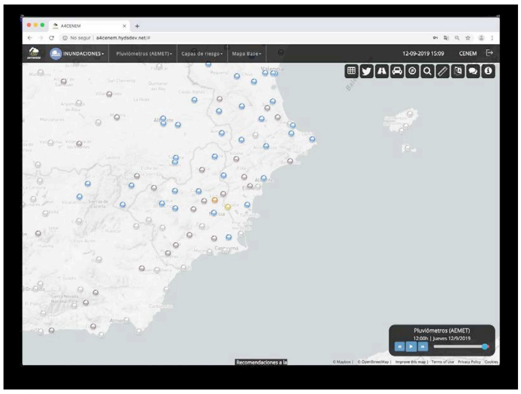
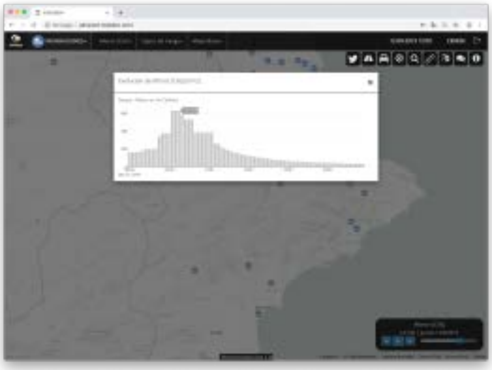
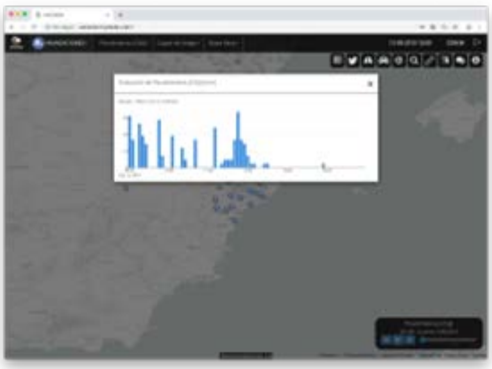
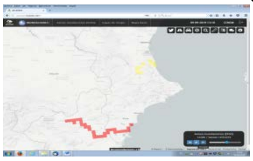
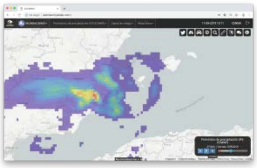
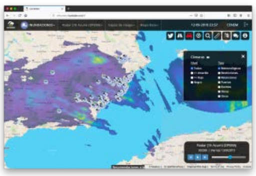
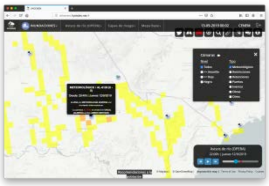
<table>
<tr><th colspan="2">MOST USEFUL TOOLS</th></tr>
<tr><th>FORECAST/NOWCAST</th><th>OBSERVATION</th></tr>
<tr><td>National weather forecast warnings
</td><td rowspan="5">Rains, river gauges, reservoirs


</td></tr>
<tr><td>EFAS: floods river warnings
</td></tr>
<tr><td>IFS-ECMWF
</td></tr>
<tr><td>OPERA radar
</td></tr>
<tr><td>OPERA rain and river warnings
</td></tr>
</table>

Figure 119. Main A4CENEM products used during the September flood event.

8.5.3 Main impacts of the event

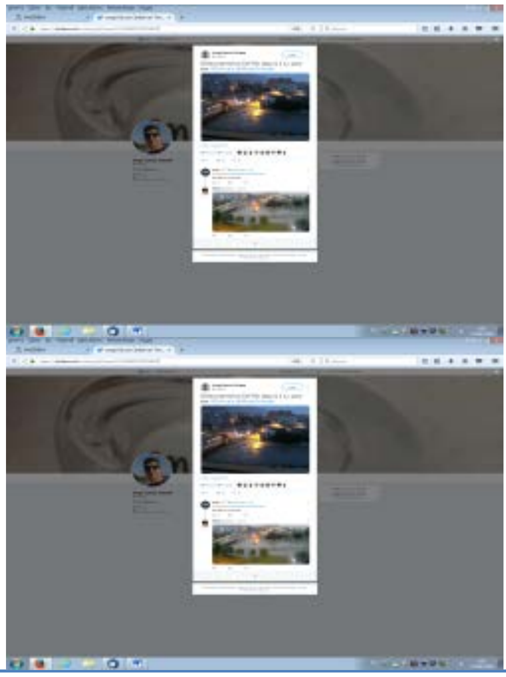
The event had main impacts in terms of both casualties, injured and evacuated people and in terms of critical infrastructures damages and disruptions (Table 4). In Figure 120 are represented the main impacts as seen by the A4CENEM system.

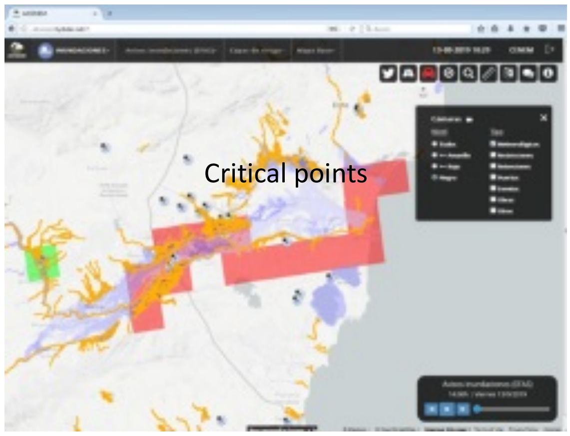
Table 4. Most important consequences related to Civil Protection.

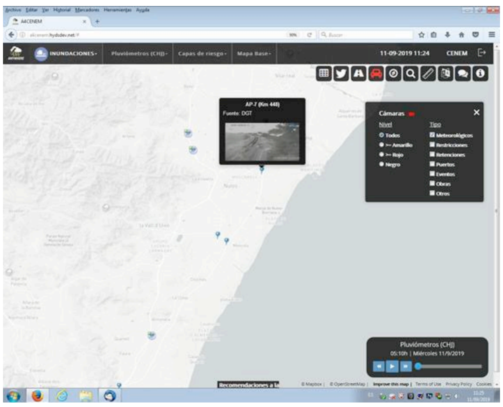
	Albacete	Alicante	Almería	Granada	Illes Balears	Málaga	Murcia	Valencia	TOTAL
Casualties	2	3	1	1					**7**
Wounded								3	**3**
Evacuees	60	5.000	60				>1.500		**>6.620**
Hosted		593	56				>400		**>1.049**
Rescued	44	1.135	3	YES	14		YES		**>1.196**
Interruption of educational services	1 town	283.000 pupils	6 towns		19 towns		WHOLE REGION	55.000 pupils	
Power outages		852 users			YES	YES	YES	155 users	**>1.007**
Water cut		4 municip.					SI		
phone outages		SI							
Closed airports			1				1		**2**
Closed ports					1			2	**3**
Railway courts	YES	YES					YES	YES	
Road closures	YES	YES	YES	YES	YES		YES	SI	
Overflows	YES	YES		YES	YES		YES	SI	

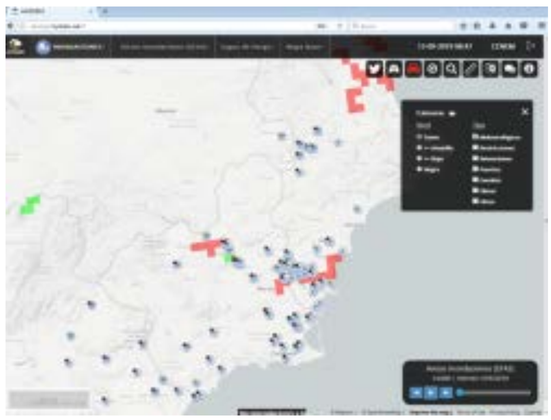
IMPACT	

CROWDSOURCING information









DGT information

Figure 120. Main impacts as reported by the A4CENEM system

8.6 Results and discussion

8.6.1 Lessons learnt

After the event, the entities operating the system filled in a questionnaire to validate A4CENEM:

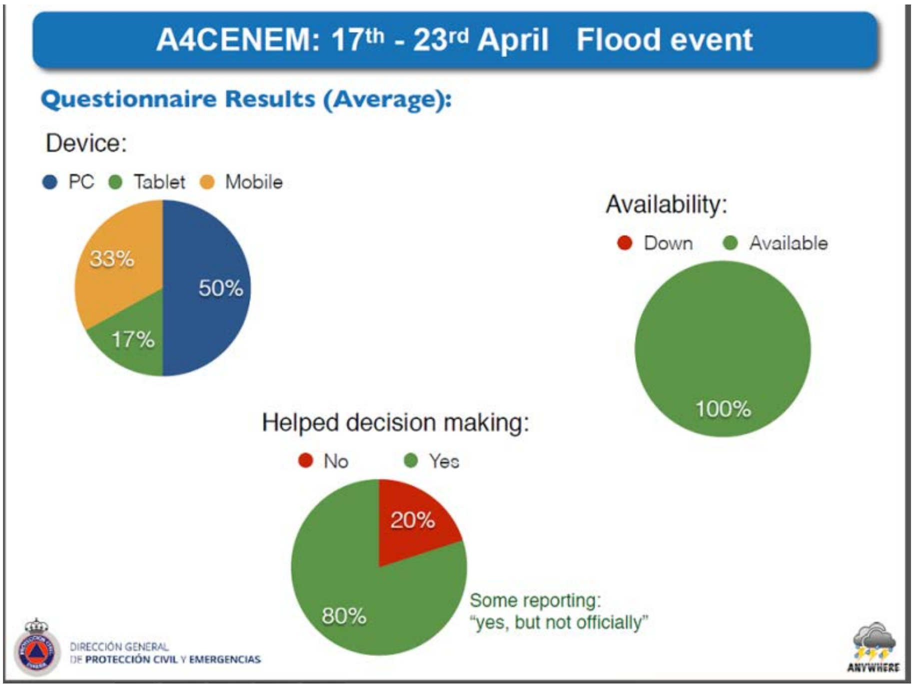


Figure 121. Internal questionnaire results related to the A4CENEM system.

Related to the devices used, 50% of tester used the computer, 33% used the mobile and 17% used the tablet.

Availability to access to A4CENEM was 100%.

The help in decision making, corresponds to a “yes” with 80% and a “no” 20%. Some specific reports set that “yes, but not officially”.

Specific results related to flood events:

- The better tools for all of end users are the related to forecast: European forecasted warnings for precipitation (IFS-ECMWF) and for floods (EFAS). It is also very useful the national rain accumulation warnings from AEMET. A4CENEM has designed a new and very visual tool of graphics with the AEMET data for the next three days and the table to access it is very intuitive.
- Some products of current information are also estimated. Water Agencies and AEMET provided new sensors data from rain and river gauges, allowing us to have a lot of data in real time. Graphics are very useful to see the period of flooding.

- It is also appreciated crowdsourcing information and national traffic information because it shows us quasi real time images and videos of the affected area, and provide the possibility of quick checking the real status avoiding eventual false alarms.
- Related to the risk layers, A4CENEM is being used not only by technicians but also by operators that are not able to completely understand all the provided information, which implies the need for a short specific training. This shows that the platform is easy to use and the wiki and the palette help in its use.
- The location of critical points on the maps is highly appreciated to send quickly new warnings. In A4CENEM there are two steps, national critical points from Seveso industries, nuclear plants and national infrastructures and regional critical points for 112 Valencia related to schools and hospitals.

8.6.2 Overall evaluation

The A4CENEM platform has proved to be a useful tool for the management of weather-induced emergencies and for improving the preparedness before the event occurrence, supporting and enhancing the decision-making. The MH-EWS forecasting products as well as the rest of included sources of information embedded (sensors, critical points, etc.) provide accurate information about the expected impact in time and space. From a National point of view, A4CENEM enables more time available for the operators to deal with the required coordination with the rest of involved authorities.

The following table shows the main strong points and drawbacks (aspects to be improved) regarding the A4CENEM platform.

Table 5. A4CENEM Strong points and aspects to be improved

STRONG POINTS	Device versatility	Easy access to a lot of information in a single viewer	Intuitive use. Doesn´t request too much training	Good forecast / Nowcast warnings	Rains and evolution	Useful for a better managing the emergency
WEAK POINTS	Essential to include historic data	Review specific cartography Little information on EFAS products.	Improve wind information	Improvements in forest fires tools	Include layer overlay capacity	Underuse of the platform: mainly used for floods. Other risks still pending

9 Conclusions

The approach followed in ANYWHERE, starting from the definition of a co-ownership framework (see WP1 activities and deliverables), and passing through the more technical aspects faced in WP3 and WP4 allowed to run for 12 months real operational demonstration activities. In the 7 pilot sites the different implementation of the A4EU, even if with a different level of accuracy and pilot site satisfaction, have shown how the A4EU systems have reached an overall Technological Readiness Level (TRL) of 7 reaching in some cases TRL 8.

In Figure 122 are shown at a glance the 7 A4EU systems operationally used in the ANYWHERE pilot sites.

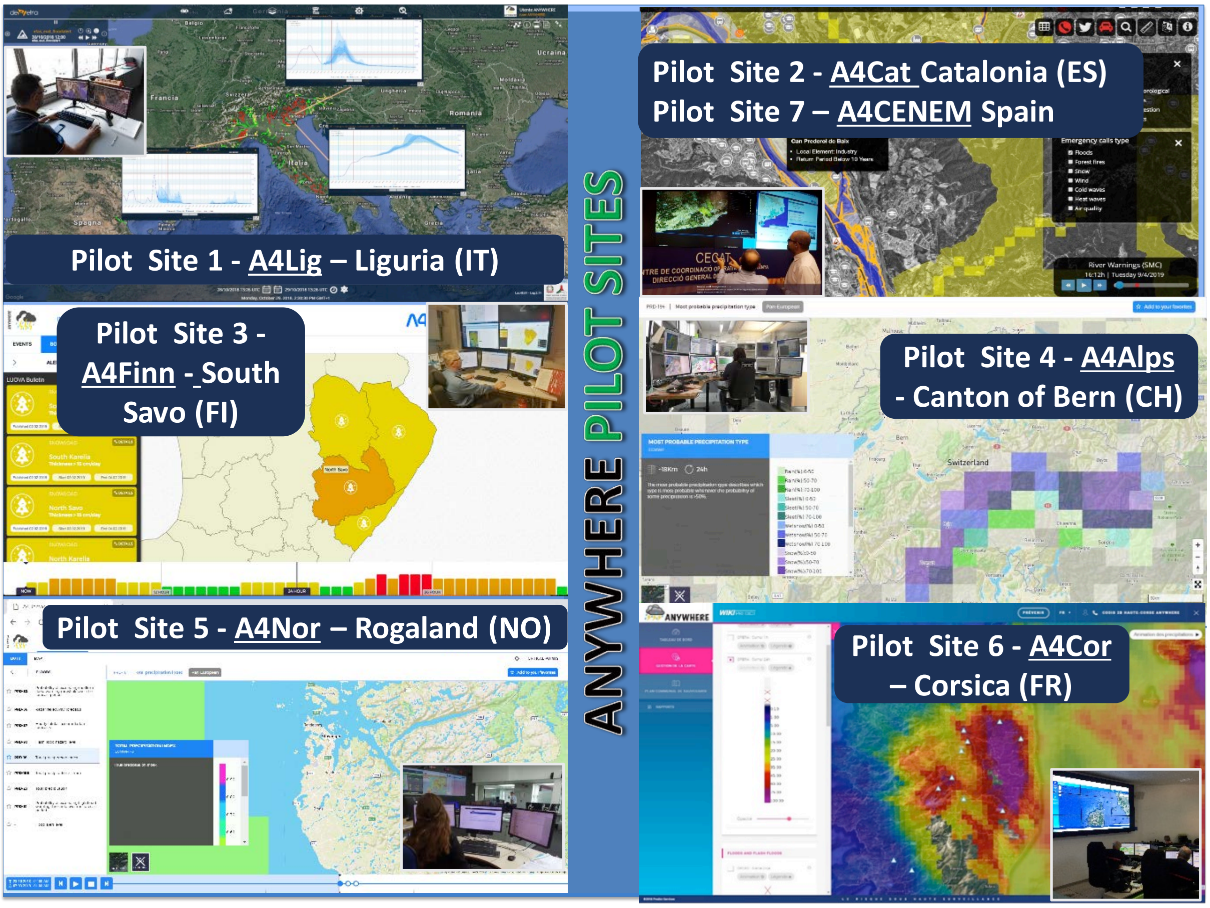


Figure 122. Image showing at a glance the different A4EU system implemented in the seven pilot sites and operationally used during the demonstration period (1st October 2018 – 30th September 2019) and are still used after the end of this period as results from the pilot site partners reported in this deliverable

In this deliverable, all the pilot sites users have shown the maturity of the A4EU systems implemented through the selection of many different real examples of operational use for supporting the emergency management related to high-impact weather events in different areas of Europe.

The results presented in this deliverable also show how the ANYWHERE approach that involved, since the beginning of the activities, the end-user in the definition of more efficient decision support system for emergency management was successful.

It shall be remarked the fact that many A4EU systems implemented are planned to be used operationally by the involved operational end-users also after the end of the project.

10 Acronyms

ACA: *Agència Catalana de l'Aigua*

AEMET: Agencia Estatal de Meteorología

AMAYA: *Agencia de Medio Ambiente y Agua de Andalucía*

ARA: Risk-Assessment Tool

ARPAL: Meteo-Hydrological Centre for Civil Protection – Liguria Region

CDG: *Comune di Genova*

CENEM: Centro Nacional de Emergencias (Spanish Emergency Control Centre)

CECAT: Emergency Control Centre of the Civil Protection of Catalonia (INTC).

CIMA: *Centro Internazionale in Monitoraggio Ambientale* - Fondazione CIMA

CHG: Guadalquivir river basin managers (*Confederacion Hidrográfica del Guadalquivir)*

CHJ: Júcar river basin managers (*Confederacion Hidrográfico del Júcar*)

CRAHI: *Centre de Recerca Aplicada en Hidrometeorologia* (UPC)

DANA: Isolated Depression in High Levels of the Atmosphere

DGPCE: Spanish General Directorate for Civil Protection and Emergencies

EFAS: European Flood Awareness System

ECMWF: European Centre for Medium-Range Weather Forecasts

ENPC: Spanish National Civil Protection School

ESP: Ensemble Streamflow Prediction

ERL: Environment Research Letters

FMI: *Ilmatieteen Laitos* (Finnish Meteorological Institute)

FMoI: Finnish Ministry of the Interior

GENCAT: *Generalitat de Catalunya* (Catalan Regional Government)

HSUH: Helse Stavanger HF

HYDS: Hydrometeorological Innovative Solutions

ICGC: *Institut Cartogràfic i Geològic de Catalunya*

INTC: *Departament d'Interior* (GENCAT)

ISTIKE: joint Situation Awareness Centre (SAC) for regional Rescue Services Eastern Finland

MH-EWS: Multi Hazard Early Warning System

RAKOS: Regional Centre for Emergency Medical Development and Research (Norway)

SAC: Situation Awareness Centre

SaaS: Software as a Service

SINTEF: Stiftelsen Sintef

SIS2B: *Service d'incendie et de secours de la Haute-Corse*

SMC: Catalan Meteorological Service

SPI: Standardized Precipitation Index

VOLBE: *Direction de L'economie publique du Canton de Berne*

UPC: *Universitat Politècnica de Catalunya*

WP: Work Package

WUR: Wageningen University

11 ANNEX 1 – Drought algorithms and methodology used during the demonstration period in the Catalonia pilot site

11.1 The SPI approach

SPI has been already used by ACA and MeteoCat to monitor meteorological drought in Catalonia. For this reason, we explored using the forecasted SPI as a basis for reservoir volume forecasts. We classified the forecasted SPI values into 5 classes as follows: super dry (SD) for Min percentile, dry (D) for 5th percentile, normal (N) for 15th percentile, wet (W) for 25th percentile, and super wet (SW) for 50th percentile (see Table 5). The SPI category indicates in which direction the reservoir volume will move. For example, if the forecasted SPI = -0.8 then it implies that the reservoir will move towards D (Dry) conditions, which means towards the P5 reservoir volume.

Table 6: SPI categories and its values categorized as reservoir percentiles.

No	Reservoir Percentile	SPI category	SPI value
1	Min	Super dry (SD)	SPI<-1
2	5 (P5)	Dry (D)	-1≤SPI<-0.2
3	15 (P15)	Normal (N)	-0.2≤SPI≤0.2
4	25 (P25)	Wet (W)	0.2<SPI≤1
5	50 (P50)	Super wet (SW)	SPI≥1

The prediction of the reservoir volume based on the SPI approach is as follows (see also Figure 123):

1. The forecast in a certain month (e.g. October 2017) starts with the retrieval of the forecasted SPI[4] from the archive for all grid cells located upstream of the reservoir. First, this was done for the first month in the forecast (October 2017) and next for the second month (November 2019) and so on, until seventh month (April 2018). Forecasts have a lead-time of up to 7 months.
2. Calculate for each of the seven months the spatially-averaged forecasted SPI using the SPI of that month from all grid cells located upstream of the reservoir (Figure 123; column 8-13). For example, the forecasted SPI in October 2017 for December 2017 is 0.03.

Transform for each of the seven months the forecasted spatially-averaged SPI values into SPI categories (

(

3. ; Figure 123; column 14-19), that is, Categorical Classification. For example, this means N (Normal) for December 2017.

[4] We have used the median of the ensemble.

4. Calculate the reservoir volume following the reservoir percentile values, which are specified by ACA.

	1	2	3	4	5	6	7	8	9	10	11	12	13
No	Date	LLOBREGAT						SPI					
		VOLUME [hm3]						SPI-3 forecasted in					
		MIN	P5%	P15%	P25%	P50%	Observed	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18
1	Jul-2017	172.5	172.5	172.5	172.5	172.5	172.5						
2	Aug-2017	152.9	152.9	152.9	152.9	152.9	152.9						
3	Sep-2017	137.1	137.1	137.1	137.1	137.1	137.1						
4	Oct-2017	120.7	123.1	127.2	129.9	140.1	123.0	-0.56					
5	Nov-2017	106.5	109.4	117.7	124.4	145.4	111.7	-0.26	-0.3				
6	Dec-2017	91.3	100.6	109.5	116.4	160.2	103.6	0.03	0.19	-0.91			
7	Jan-2018	84.3	94.9	106.5	116.3	169.5	102.2	0.53	0.65	0.03	-0.28		
8	Feb-2018	77.1	91.1	104.0	114.7	178.6	124.6	0.73	0.66	0.78	0.41	0.66	
9	Mar-2018	69.4	85.4	99.7	116.5	181.7	159.1	1.30	1.18	1.18	1.21	1.04	1.26
10	Apr-2018	77.8	90.7	108.9	122.8	190.4	193.5	1.19	1.35	1.03	0.95	0.83	0.96
11	May-2018	83.1	100.4	121.4	131.6	203.1	208.7		1.23	1.00	1.03	0.72	1.25
12	Jun-2018	78.0	94.7	125.1	134.9	206.1	210.5			0.99	0.94	1.03	0.89
13	Jul-2018	68.8	88.0	118.8	129.6	207.1	205.1				0.85	0.85	0.79
14	Aug-2018	57.6	84.1	108.7	117.8	200.2	202.5					0.46	0.17
15	Sep-2018	52.5	91.9	103.6	117.6	200.9	198.0						0.11
16	Oct-2018	76.4	93.9	113.8	125.1	210.7	206.7						
17	Nov-2018	83.8	97.4	117.1	136.7	210.7	203.1						
18	Dec-2018	78.5	95.8	116.1	128.3	210.7	203.2						

	14	15	16	17	18	19	20	21	22	23	24	25
No	Drought class						LLOBREGAT					
	SPI-3 forecasted in						FORECASTED VOLUME [hm3]					
	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18
1							172.5	172.5	172.5	172.5	172.5	172.5
2							152.9	152.9	152.9	152.9	152.9	152.9
3							137.1	137.1	137.1	137.1	137.1	137.1
4	D						123.1	123.0	123.0	123.0	123.0	123.0
5	D	D					109.4	109.2	111.7	111.7	111.7	111.7
6	N	N	D				109.4	109.3	102.9	103.6	103.6	103.6
7	W	W	N	D			112.8	112.7	105.9	97.9	102.2	102.2
8	W	W	W	W	W		111.2	111.0	110.0	107.8	100.5	124.6
9	SW	SW	SW	SW	SW	SW	144.7	144.5	143.5	141.3	134.0	127.6
10	SW	SW	SW	W	W	W	153.5	153.3	152.3	111.9	104.6	98.2
11		SW	SW	SW	W	SW		166.0	164.9	152.1	113.4	138.3
12			W	W	SW	W			130.8	118.0	150.6	104.3
13				W	W	W				112.6	112.4	98.9
14					W	N					100.6	88.4
15						N						83.3
16												
17												
18												

Figure 123: Example of reservoir volume calculation using the SPI approach for the Llobregat reservoir Numbers in columns 2-7 are provided by ACA. The other are computed through the SPI approach. Yellow-marked in column 2-7 and column 20-25 is observed volume

For Step 4, we used the following equation for the calculation of the reservoir volume:

$$V_{f(i)} = V_{o/f(i-1)} + (Va_{(i)} - Vb_{(i-1)})/m \qquad (1)$$

where $V_{f(i)}$ is forecasted reservoir volume for month *i*, $V_{o/f(i-1)}$ is observed or forecasted reservoir volume for month *i*-1 (observed volumes are used for the lead times 1), $Va_{(i)}$ is percentile reservoir volume associated with the SPI category month *i*, $Vb_{(i-1)}$ is percentile reservoir volume associated with the SPI category month *i*-1, *i* is lead-times from 1 to 7 months, and *m* is a relaxation factor.

For Step 4, we distinguished two cases for the calculation of the reservoir volume. In the first case the forecasted SPI categories are the same in two successive months, $a = b$ (e.g., D to D and SW to SW; Fig. 22 column 14, row 4-5 and row 9-10, respectively). This reflects a rather steady situation. In that case we assume $m = 1$.

For example (C stands for column and R stands for row):

V(C20R5) = V(C20R4) + V(C3R5) – V(C3R4)

109,4 = 123,1 + 109,4 – 123,1

In case forecasted SPI categories deviate in two successive months, $a \neq b$ (e.g., D to N, N to W; Fig. 22 column 14, row 5-6 and row 6-7, respectively) non-steady conditions occur. In that case we assume $m = 2$.

For example:

V(C20R6) = V(C20R5) + (V(C4R6) – V(C3R5))/2

109,4 = 109,4 (109,5-109,4)/2

The above-mentioned approach has to be repeated a number of times to find the best accumulation period for the SPI. For the Llobregat and Ter reservoirs, the SPI-3, i.e. rainfall accumulated over 3 months, appeared to be the best choice. This is based upon an intercomparison of predicted and observed reservoir volumes (columns 20-25 versus column 7, see Figure 124 for an example) using correlation analysis.

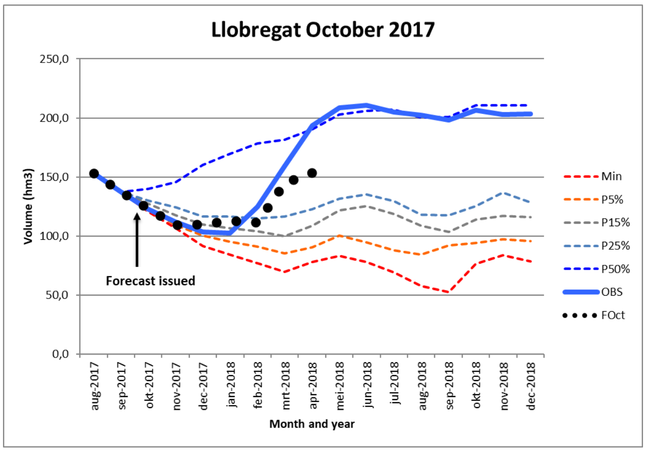


Figure 124: Llobregat reservoir volumes, re-forecasted using the SPI-3 approach with a lead-time of up to 7-month, initiated in October (FOct), and observed reservoir volumes.

In summary, the SPI approach uses the forecasted SPI, which is categorized, as an indicator how the reservoir volume in terms of reservoir percentile values moves from one month in the future to the next month.

11.2 The water balance approach

The second approach, i.e. the Water Balance approach, provides another technique to forecast the reservoir volume. In this method, the volume of the reservoir is forecasted from the difference between observed/forecasted volume for the previous month (*V*), inflow (*I*), and outflow (*O*) (see Equation 2). The reservoir volume in the previous month is obtained from the measurement done by ACA for the first forecast month (LT=1) and from the forecasts for the other lead times (LT=2-7 months). Inflow to the reservoir is obtained from the forecasted discharge[5] (1 month to 7 months ahead) of the discharge station upstream of the reservoir. Outflow is estimated from the percentile outflows (Min, P5, P15, P25, or P50), which are provided by ACA.

$$V_{f(i)} = V_{f/o(i-1)} + I_{f(i)} - O_{p(i)} \qquad (2)$$

Where $V_{f(i)}$ is forecasted reservoir volume month *i* (e.g., Figure 125 C24R4), $V_{f/o(i-1)}$ is forecasted or observed reservoir volume month *i*-1 (Figure 125 C24R3), $I_{f(i)}$ is forecasted inflow at a lead-time of *i* (Fig. 24 C21R4), $O_{p(i)}$ is percentile reservoir outflow month *i* (Figure 125 C8R4) associated with the re-forecasted or observed reservoir volume month *i*-1 ($V_{f/o(i-1)}$, Fig. 24 C24R3), and *i* is lead-times (LTs) from 1 to 7 months.

Since the real outflow of the reservoir in the forecast mode (1-7 months ahead of the forecast date) is not known, we used the percentile outflow, which is provided by ACA, based on the previous forecasted or observed volume. For example, to forecast the reservoir volume for April 2018 (C24R10) in October 2017 (initiation date), we selected

[5] We have used the median of the ensemble

the outflow of -11.00 Hm³ (C8R10) because the previous reservoir volume, which is 96.23 Hm³ (C24R9) is closer to the volume of P5%, 90,68 Hm³ (C13R10) than to P15%, 108,86 Hm³ (C14R10).

A bias correction of forecasted discharge must be carried out since there is a difference between modeled discharge (LISFLOOD SFO) and observed discharge (in-situ observation, e.g., at Guardiola and Ripoll discharge stations). The monthly correction values were calculated from the difference between average monthly discharge values estimated from the LISFLOOD Simulation Forced with Observed (SFO) and observations, from 1990 to 2018. Then, these values are added to the forecasted discharges (Figure 125 C17-20) considering the representative month, resulting in bias corrected discharge forecasts (Figure 125 C21-23).

No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Date	Llobregat-Guardiola														
		INFLOW [hm3]					OUTFLOW [hm3]					VOLUM [hm3]				
		MIN	P5%	P15%	P25%	P50%	MIN	P5%	P15%	P25%	P50%	MIN	P5%	P15%	P25%	P50%
1	Jul-2017											172.5	172.5	172.5	172.5	172.5
2	Aug-2017											152.9	152.9	152.9	152.9	152.9
3	Sep-2017											137.06	137.06	137.06	137.06	137.06
4	Oct-2017	1.55	3.97	8.06	10.75	20.93	-17.92	-17.92	-17.92	-17.92	-17.92	120.70	123.11	127.20	129.89	140.07
5	Nov-2017	2.98	3.43	7.64	11.72	22.50	-17.18	-17.18	-17.18	-17.18	-17.18	106.50	109.37	117.66	124.43	145.38
6	Dec-2017	3.53	8.90	9.57	9.67	32.49	-18.76	-17.70	-17.70	-17.70	-17.70	91.26	100.57	109.53	116.39	160.17
7	Jan-2018	6.44	7.73	10.33	13.32	22.76	-13.40	-13.40	-13.40	-13.40	-13.40	84.29	94.90	106.46	116.31	169.53
8	Feb-2018	5.01	8.35	9.75	10.52	21.27	-12.17	-12.17	-12.17	-12.17	-12.17	77.13	91.08	104.03	114.65	178.63
9	Mar-2018	5.49	7.56	8.98	21.66	22.81	-13.27	-13.27	-13.27	-19.77	-19.77	69.36	85.37	99.75	116.55	181.67
10	Apr-2018	19.42	16.30	19.57	20.37	23.76	-10.98	-11.00	-10.46	-14.15	-14.98	77.79	90.68	108.86	122.76	190.45
11	May-2018	19.63	25.02	27.88	27.90	32.61	-14.29	-15.29	-15.29	-19.10	-19.95	83.13	100.41	121.45	131.56	203.10
12	Jun-2018	13.25	12.66	25.70	25.43	25.84	-18.35	-18.35	-22.04	-22.04	-22.87	78.03	94.72	125.10	134.95	206.07
13	Jul-2018	9.96	11.04	15.24	17.04	23.47	-19.17	-17.77	-21.58	-22.44	-22.44	68.82	87.99	118.77	129.55	207.11
14	Aug-2018	10.08	18.54	16.18	14.48	20.20	-21.25	-22.45	-26.25	-26.25	-27.11	57.64	84.08	108.69	117.78	200.20
15	Sep-2018	8.73	21.93	11.31	16.19	17.77	-13.82	-14.15	-16.41	-16.41	-17.04	52.55	91.86	103.59	117.55	200.92
16	Oct-2018	36.39	17.58	28.61	25.98	32.81	-12.57	-15.54	-18.41	-18.41	-19.26	76.36	93.90	113.79	125.12	210.72
17	Nov-2018	21.94	17.94	20.71	28.94	21.40	-14.47	-14.47	-17.37	-17.37	-18.20	83.83	97.37	117.13	136.70	210.72
18	Dec-2018	8.73	12.59	16.92	10.34	22.84	-14.11	-14.12	-17.93	-18.78	-18.78	78.45	95.83	116.13	128.25	210.72

No	17	18	19	20	21	22	23	24	25	26
	Llobregat-Guardiola									
	Forecasted Inflow (discharge)				Forecasted Inflow (corrected)			VOLUM [hm3]		
	Oct-17	Nov-17	Dec-17	Jan-18	Oct-17	Nov-17	Dec-17	Oct-17	Nov-17	Dec-17
1								172.5	172.5	172.5
2								152.9	152.9	152.9
3								137.1	137.1	137.1
4	5.02				5.56			124.74	124.2	124.2
5	3.52	3.27			8.41	8.16		115.97	115.20	112.7
6	5.25	4.03	3.1167		11.57	10.36	9.44434	109.84	107.86	104.46
7	8.41	10.70	3.9714	5.0755	13.36	15.65	8.92085	111.03	110.10	99.97
8	3.39	12.58	6.5937	4.4423	4.60	13.79	7.79996	103.46	111.72	95.60
9	4.70	20.23	8.2464	11.006	6.03	21.56	9.57869	96.23	113.51	91.91
10	21.89	17.99	15.964	16.906	24.12	20.22	18.1962	109.35	123.27	99.11
11		32.79	21.708	22.685		40.46	29.3865		148.44	113.21
12			7.7868	11.411			14.8371			109.69
13				3.4101						
14										
15										
16										
17										
18										

Figure 125. Example of reservoir volume calculation using the Water Balance approach for the Llobregat reservoir. Numbers in columns 2-16 are provided by ACA. The other are computed through the Water Balance approach. Yellow-marked in columns 12-16 and 24-26 is observed volume.

In summary, the water balance approach uses the forecasted discharge and outflow, as an indicator how the reservoir volume moves from one month in the near future to the next month (up to 7 months ahead). We propose to use the volume ($V_{f/o(i-1)}$) from the previous month to determine the percentile outflow ($O_{p(i)}$). Alternatively, the forecasted discharge ($I_{f(i)}$) could also have been used to determine the percentile outflow. For example, the forecasted discharge of 5.56 Hm^3 in October 2017 with 1-month lead-time (Figure 125 C21R4) is close to P5% inflow, 3.97 Hm^3 (Figure 125 C3R4). In that case, we would have selected the P5% as an outflow, 17.92 Hm^3 (C8R4).

11.3 Results and discussion

11.3.1 The SPI approach

Figure 126 shows the re-forecasted reservoir volumes using the SPI approach for Llobregat and Ter reservoirs with a lead-time of 7 months, which are plotted together with the observed volumes for the period spanning from October 2017 to July 2019. In general, the SPI approach can reasonably well forecast the observed reservoir volumes, especially for lead-times 1 to 4 months. However, forecasts initiated from December 2018 onwards for the Ter reservoir show that the forecasts are not able to predict the decrease of the reservoir volume for a lead-time of 1 month and higher f). The deficiency of the forecasts initiated in December 2018 is not seen for forecasts initiated in December 2017. Although the forecasts could not produce the observed volume in a similar magnitude for December 2017, at least it shows the increase of the reservoir volume for the coming months. Please keep in mind, the observed reservoir volume in the Ter reservoir from December 2018 onwards is close to lower percentile (Min), which is categorized as a rare event.

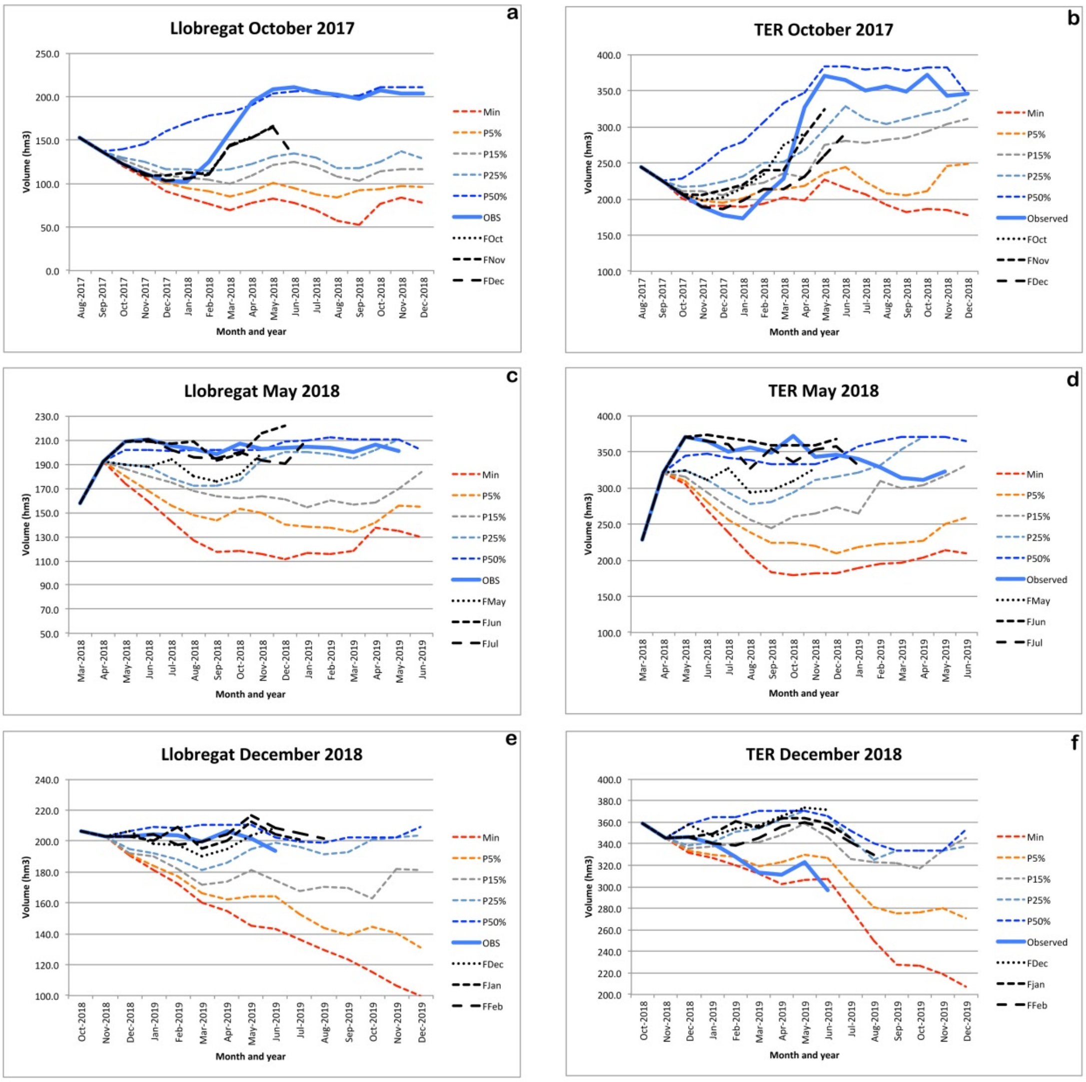


Figure 126: Figure 25: Llobregat and Ter reservoir volumes, re-forecasted using the SPI-3 approach with a lead-time of up to 7-month: a) Llobregat reservoir volume forecasts initiated in October (FOct), November (FNov), and December 2017 (FDec), c) Llobregat reservoir volume forecasts initiated in May (FMay), June (FJun), and July 2018 (FJul), and e) Llobregat reservoir volume forecasts initiated in December 2018 (FDec), January 2019 (FJan), and February 2019 (FFeb). b, d, and f) same as a, c, and e, respectively but for the Ter reservoir

11.3.2 The water balance approach

The reservoir volume re-forecasts using the Water Balance approach (Figure 127) show that the method cannot predict the reservoir volume as well as the SPI approach. Re-forecasts using the Water Balance approach initiated from October 2017 onwards (Fig. 26 a and b) show that the water balance approach cannot predict the sharp increase of observed reservoir volume. For re-forecasts, initiated from May 2018 onwards (Fig. 26 c and d), the Water Balance approach shows better results than the prediction initiated from October 2017. Unlike the SPI approach (Figure 126e), volume re-forecasts for the Llobregrat reservoir, based on the Water Balance approach initiated from December 2018 onwards (Figure 127e), show that the re-forecasts overestimate the decrease of the reservoir volume for all lead times. The re-forecasted volume drops from close to P50 to P5. On the other hands, re-forecasts initiated from December 2018 onwards for the Ter reservoir show unreasonable results for the forecasted volume (Figure 127f). This indicates that the re-forecasts produce higher discharge than the observed one.

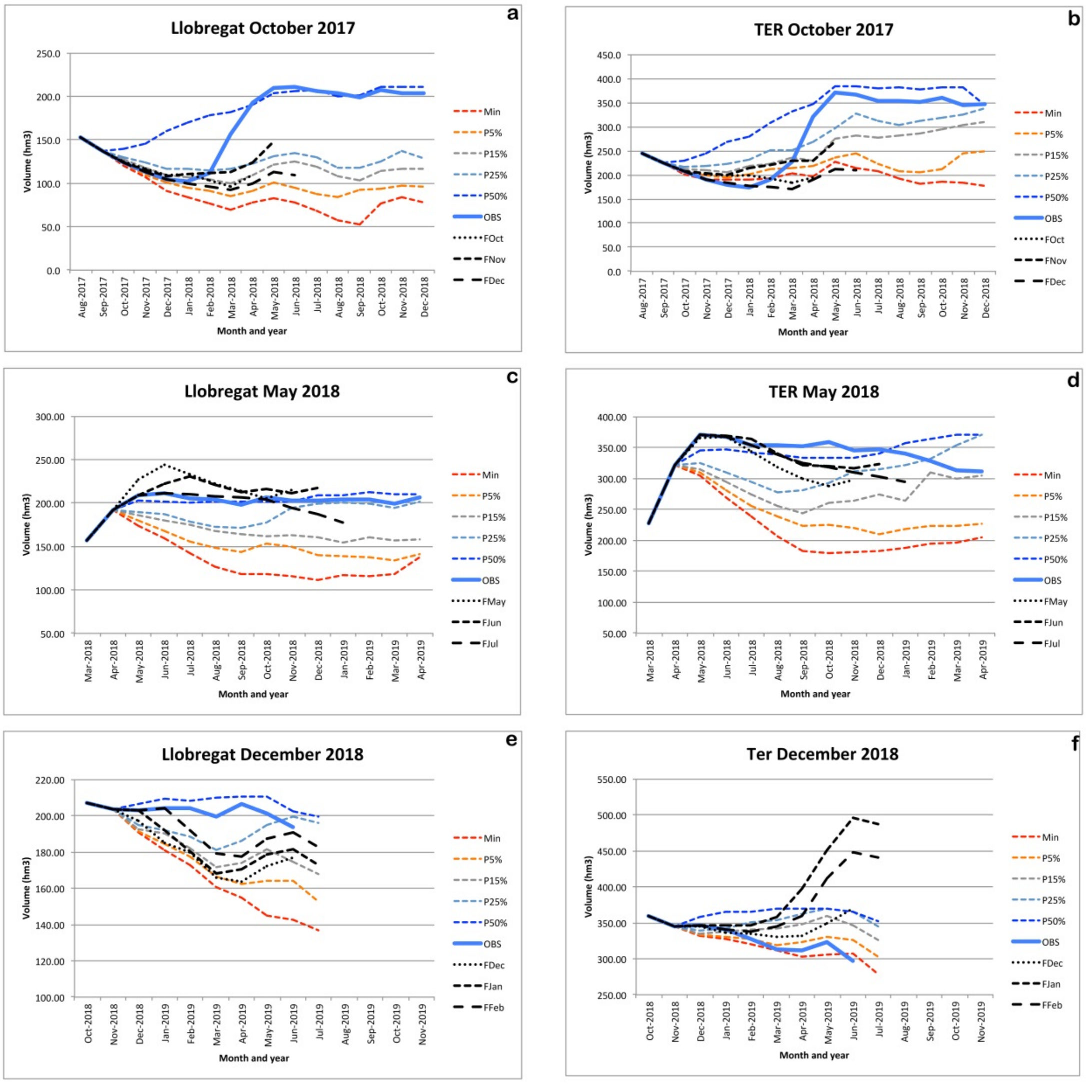


Figure 127: Llobregat and Ter reservoir volumes, re-forecasted using the Water Balance approach with a lead-time of up to 7 months: a) Llobregat reservoir volume forecasts initiated in October (FOct), November (FNov), and December 2017 (FDec), c) Llobregat reservoir volume forecasts initiated in May (FMay), June (FJun), and July 2018 (FJul), and e) Llobregat reservoir volume forecasts

initiated in December 2018 (FDec), January 2019 (FJan), and February 2019 (FFeb). b, d, and f) same as a, c, and e, respectively but for the Ter reservoir

11.3.3 Discussion

Two approaches to forecast the reservoir volumes were developed using the forecasted SPI and forecasted discharge. It seems that the SPI approach produces better results than the Water Balance approach. The SPI approach is relatively easy to be used and implemented in the ANYWHERE A4Cat. This approach only requires the forecasted SPI-3 as a drought index and a Spaghetti diagram, which are available each month from the ANYWHERE MH-EWS and ACA, respectively.

The Water Balance approach, on the other hand, produces lower prediction skill than the SPI approach. The main issue in using this approach is that this method requires an adequate estimate of the outflow for the coming months (up to 7 months ahead). An adequate estimate of the outflow for the first months in the forecast can reasonably be determined since ACA and end-users decide about the amount of outflows. Furthermore, we did not account for inflows coming from other streams (than the Guardiola for the Llobregat and the Ripoll for the Ter reservoir) upstream of the dams and losses from the reservoirs, such as open water evaporation and possible subsurface leakage. We neglected the possible additional inflow from small rivers since we assume that the contribution is relatively small. A reasonable estimate of open water evaporation can be obtained from the ANYWHERE MH-EWS since this variable is forecasted every month. Another issue in the assessment of the skill of the reservoir volume forecast using the Water Balance is uncertainty in observed reservoir volumes and discharge.

To conclude, the SPI approach can be used to adequately forecast the reservoir volumes, up to 1-3 months ahead, depending on the season. This method is rather straightforward and easy to be used. For the moment, the Water Balance approach still needs further verification regarding the outflow and possible other losses from the reservoir. We suggest to use the SPI approach and later the Water Balance approach might be used as a complementary approach. Training on the use of the drought forecasts has been carried out (WUR, ACA and HYDS). The script to obtain the SPI-3 values upstream of the reservoir as well as the excel file to transform the SPI-3 index into reservoir volume are ready to be used offline or implemented in A4Cat.