



European Flood Awareness System

DETAILED ASSESSMENT REPORT

EFAS DISSEMINATION CENTRE
Specific Contract No.4











Table of Content

1	Introduction	3
2 2.1 2.2	Description of the EFAS related work during the flood events EFAS flood forecasting EFAS flash flood forecasting	4
	_	
3	Floods in the region of Valencia, Spain	6
3.1	Description of the study area	е
3.2	Description of the flood event	7
3.3	Impacts - based on media reports	15
3.4	EFAS flood information	18
3.5		
4	Floods in the north of Italy	27
4.1	Description of the study area	27
4.2	Description of the flood event	29
4.3	Impacts - based on media reports	36
4.4	EFAS flood information	38
4.5	EFAS and national information	46
5	Conclusions	48
5.1	Summary of flood events	48
5.2	Lessons-learnt from the detailed assessment	48
5.3	Moving forward	
	- 0	

ANNEX 1

Floods in the region of Valencia, October 2018: Timeline of issuance of EFAS Flood notifications

ANNFX 2

Feedback on the EFAS notifications in the region of Valencia, October 2018

ANNEX 3

Floods in the northern Italy, October-November 2018: Timeline of issuance of EFAS Flood notifications

ANNEX 4

Feedback on the EFAS Formal Flood Notification for the Po river issued on 2018-10-03





Acronyms

AEMET	Agencia Estatal de Meteorología (Spanish State Meteorological Service)		
ASCAT	Advanced Scatterometer		
CET/CEST	Central European Time/Central European		
	Summer Time		
СНЈ	Confederación Hidrográfica del Júcar		
CoA	Condition of Access		
COMP	EFAS Computational Centre		
COSMO-LEPS	Limited Area Ensemble Prediction System		
DISS	S EFAS Dissemination Centre		
DWD	German National Meteorological Service		
ECMWF	WF European Centre for Medium-Range Weath		
	Forecasts		
ECMWF-ENS	Ensemble forecast of ECMWF		
EFAS	European Flood Awareness System		
EFAS-IS	EFAS Information System		
ERCC	European Response and Coordination Centre		
ERIC	Enhanced Runoff Index based on Climatology		
HYDRO	EFAS Hydrological Data Collection Centre		
METOP	Meteorological Operational Satellite		





1 Introduction

Floods are one of the most destructive natural hazard worldwide that causes severe economic damages and human losses. The European Flood Awareness System (EFAS) operated by the Copernicus Emergency Management Service since 2012 is the first monitoring and operational forecasting and warning system that provides a service that significantly increases the efficiency in decision-making and flood situation response, particularly in the large trans-national river basins throughout Europe. It provides complementary, added-value information (e.g. probabilistic, medium range flood forecasts, flash flood indicators, and impact forecasts) to the relevant national and regional authorities. Furthermore, EFAS keeps the Emergency Response Coordination Centre (ERCC) informed about ongoing and possibly upcoming flood events across Europe.

The weather in Europe in October 2018 was characterised by a persistent high-pressure bridge from the Azores to Russia forcing most of the low-pressure systems on northern tracks, intense precipitation events in the Mediterranean regions and a still ongoing drought in central Europe.¹

Here the EFAS detailed assessment report focuses on two flood events over autumn 2018 affecting citizens and decision-making from different water managers and users in a number of countries. The report is targeted on a situation in the region of Valencia, Spain in mid October 2018 and in the northern Italy from late October till early November 2018, and aims to provide a thorough understanding of the EFAS forecasts in terms of accuracy, time-efficient availability and effective communication of the forecasts. In addition to the hydrological forecasting skill, the report provides information about the hydrological model performance over the regions of interest, meteorological forecasts and antecedent conditions (i.e. soil moisture). The flood and flash flood generation drivers are stated for each region together with the number of EFAS notifications sent to the partners. Overall, this assessment allows identification of EFAS service limitations and leads to a number of suggestions for further service improvements.

The report is organized as follows: Section 2 introduces the EFAS flood and flash flood forecasting service. Sections 3 and 4 present the two selected events in Spain and Italy respectively. These sections provide information on the flood events, impacts (including media reports) and information based on EFAS from both a flood and flash flood perspective. Finally, Section 5 states the conclusions together with the lessons learned from this analysis, and proposes improvements of the EFAS service.

¹ https://www.efas.eu/meteorology?field_month_value=10&field_year_value=2018





2 Description of the EFAS related work during the flood events

EFAS provides complementary, flood early warning information up to 10 days in advance to national authorities, regional hydrological services and the European Response and Coordination Centre (ERCC). It currently incorporates multiple weather forecasts from two different weather services, real-time weather observations from around 13150 stations across Europe and real-time hydrological observation from more than 1500 stations.

EFAS provides a number of products, including, among others, simulated soil moisture and snow accumulation, rapid impact assessment, probabilistic river flood hazard forecasts, observed daily precipitation accumulation, flash flood hazard forecasts, average daily temperature, accumulated precipitation forecasts, and seasonal hydrological forecast outlook.

The EFAS Information System (EFAS-IS) is the interface used to access EFAS flood forecast information. In EFAS-IS, hydrological forecasts are generated and visualized using meteorological and hydrological data from ECMWF and DWD and COSMO as well as other EFAS data providers. Observations are also used as input to the LISFLOOD hydrological model.

EFAS information is produced twice a day, based on the 00:00 UTC and 12:00 UTC meteorological forecasts, and made available to all EFAS partners on EFAS-IS. Only partners, third party or research projects have access to the real-time forecasts after agreeing on and signing a Condition of Access (CoA), whereas all the information older than 30 days is freely open to the public.

The forecasters of the EFAS Dissemination Centre analyse the EFAS results twice a day, in the morning by 8:30 CET/CEST and in the afternoon by 16:00 CET/CEST. Forecasters on duty discuss the situation and what notifications should be sent via chat and in complicated cases by telephone. The notifications are logged in the EFAS interface and distributed by email including the name of the responsible forecaster who can then be contacted by the EFAS partners in case of further questions. Different criteria to send notifications are described in paragraphs below.

2.1 EFAS flood forecasting

EFAS sends out notification emails to all EFAS partners potentially concerned in case of flooding and all partners within the catchment in copy.

Criteria for *EFAS Flood Notification - Type Formal*:

- Catchment part of Conditions of Access
- Catchment area is larger than 2000 km²
- Event more than 48 hours in advance with respect to forecast date
- Forecasts are persistent (3 consecutive forecasts with more than 30 % exceeding EFAS 5-year return period threshold according to ECMWF-ENS or to COSMO-LEPS)
- At least one of the deterministic forecasts (ECMWF or DWD) exceeds also the EFAS 5-year return period threshold

Criteria for *EFAS Flood Notification – Type Informal*:

- Catchment part of Conditions of Access
- Any of the above criteria is not met (catchment size, lead time, forecast persistence, deterministic forecast exceedance) but the forecasters think the authorities should be informed. Note: The minimum catchment size where EFAS provides skilful results is approx. 1000 km². For catchment areas significantly smaller than 1000 km² no EFAS Flood Notification Type Informal should be sent.
- Any other doubt





Sending out an *EFAS Flood Notifications* is done using the EFAS cart system in <u>www.efas.eu</u>. An EFAS Notification should always be sent first to partners (before submission of the ERCC Overview). Although parts of the Notification email are composed automatically, the forecaster needs to adapt some parts of the text manually.

Request for feedback is sent to the partners only in the case of an EFAS Formal Flood Notification.

2.2 EFAS flash flood forecasting

EFAS Flash Flood Notifications are issued for the corresponding regions in the case of flash flooding. Furthermore, for a single region only one notification is issued, even if there are many catchments affected. Notification emails are sent to partners potentially concerned in case of flooding.

An event could be valid for a Flash Flood Notification using the methodology of the Enhanced Runoff Index based on Climatology (ERIC)². It is calculated on a 1 km resolution river network whose extent matches the domain of the COSMO-LEPS forecast data.

The index is calculated based on the comparison of forecasted accumulated upstream surface runoff with the mean annual maxima from a 19-year climatology series taken from COSMO-LEPS reforecast data. It is calculated for each of the 16 ensemble members in the COSMO-LEPS forecast.

Surface runoff is calculated by multiplying forecasted precipitation data, taken from the 16 member COSMO-LEPS ensemble, with the corresponding soil moisture data produced by the LISFLOOD hydrological model driven with the COSMO-LEPS meteorological data. The accumulated upstream surface runoff is then calculated for every 1 km resolution river network pixel, where the upstream area is $< 2,000 \text{ km}^2$. This calculation is performed over three different accumulation periods of 6, 12 and 24 hours, and the resulting ERIC value corresponds to the maximum over each of these three accumulation periods.

The criteria for issuing an *EFAS Flash Flood Notification* (updated and valid since 10th October 2018) were the following:

- Region is a part of CoA
- The probability of exceeding the 5-year return period magnitude of the surface runoff index (ERIC) is forecasted to be equal or greater than 10 %
- Start of the event has a lead time < 72 hours (from the run time). The start of the event is when the surface runoff index starts to increase.
- Actual lead time to the earliest predicted peak is > 0 hours (where actual lead time is the time
 difference between the current time when the forecaster analyses the forecast and the predicted
 peak of the event).

In case more than one flash flood reporting point qualifies for issuing notification based on the above criteria, the forecasters should group them according to geographic vicinity and/or start time of the event into a single EFAS Flash Flood Notification. The grouping should be done on the forecasters expert judgement, however always with the aim to reduce the number of EFAS Flash Flood Notifications sent to an EFAS partner. Clearly separated flash flood reporting points (geographically and/or with regard to the start time of the event) should be sent as distinct flash flood notifications.

For Flash Flooding no feedback from the partners is requested.

² Raynaud, D., Thielen, J., Salamon, P., Burek, P., Anquetin, S. and Alfieri, L.: A dynamic runoff co-efficient to improve flash flood early warning in Europe: Evaluation on the 2013 central European floods in Germany, Meteorological Applications, 22(3), 410–418, doi:10.1002/met.1469, 2015.





3 Floods in the region of Valencia, Spain

3.1 Description of the study area

The Valencia region is an autonomous community of Spain. It is the fourth most populated autonomous community after Andalusia, Catalonia and Madrid with more than 4.9 million inhabitants. Its homonymous capital Valencia is the third largest city and metropolitan area in Spain. It is located along the Mediterranean coast on the east side of the Iberian Peninsula. It borders with Catalonia to the north, Aragon and Castilla–La Mancha to the west, and Murcia to the south. The Valencia Community consists of three provinces, which are Castellón, Valencia and Alicante.³

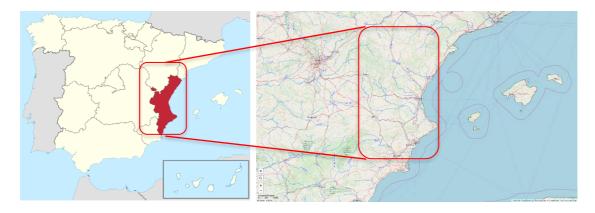


Figure 1 Map of the Valencia region in Spain

The Valencia region has a generally mild climate, heavily influenced by the neighbouring Mediterranean Sea. Still, there are important differences between areas:

- Proper Mediterranean climate (Köppen Csa): It roughly goes along the coastal plain from the northernmost border through the Benidorm area. It covers in various grades the lower inland areas. In this area, winters are cool, summers are long, dry and hot; precipitation occurs mostly during spring and autumn, usually accumulating around 600 mm with a remarkably wetter micro climate in the Marina Alta and the Safor comarques just north of Cap de la Nau cape, which accumulates an average of up to 1000 mm due to an orographic effect.
- Mediterranean to continental Mediterranean climate (Köppen Csa) and highland climate (Köppen H): These are the innermost lands and those at a higher elevation. Winters are cool to cold here, especially at night (a few days of snow are not unusual), summers mild to hot and precipitation more evenly distributed through the year.
- Semi-arid climate (Köppen BSh): It roughly goes along the coastal plain from Villajoyosa through the southernmost border of the region. Summers are hot and dry, winters are cool to mild and its most prominent feature is a very scarce precipitation, typically below 300 mm per year, which is most likely to happen during spring and autumn. The reason for this lack of precipitation is the marked precipitation shadow effect caused by hills to the west of the Alicante province.⁴

There are only two major rivers: the Segura in the Province of Alicante, whose source is in Andalusia, and the Júcar (*Xúquer*) in Province of Valencia, whose source is in Castilla–La Mancha. Both are subjected to very intense human regulation for cities, industries and, especially, agricultural consumption. The river Turia (*Túria*) is the third largest and has its source in Aragon. Most rivers

³ https://en.wikipedia.org/wiki/Valencian_Community

⁴ https://en.wikipedia.org/wiki/Valencian_Community#Climate





in the area, such as the Vinalopó, are usually short, have little discharge (due to agricultural usage, climatic reasons or both) and are often completely dry during the summer. Other rivers in the Valencia region are the Serpis and Sénia. The inland part of the territory is rocky, with some of the highest peaks in the Valencia and Castellón provinces forming part of the Iberian mountain range. The mountains in the Province of Alicante are in turn a part of the Subbaetic range. The highest peak of the Valencia community is the Calderón (1,839 m). The rather thin coastal strip is a very fertile plain mainly free of remarkable mountains. Typical of this coastal area are wetlands and marshlands.⁵

3.2 Description of the flood event

Several days of torrential rain have caused flooding in eastern and southern Spain. This rain was caused by meteorological phenomenon known as "Gota Fria" (Cold Drop) occurring in Spain during autumn months. It is experienced particularly along the western Mediterranean and as such, most frequently affects the east coast of Spain. It is a closed upper-level cyclone, which has become completely cut off from basic westerly stream. Cut-off cyclones may remain nearly stationary for days, or on occasion may move westward opposite to the prevailing flow (retrogression).

At least one person died and dozens were rescued or evacuated. The heavy rain began on 18th of October 2018, particularly in the Valencia region where Vinaròs in the Castellón Province recorded 374.6 mm in 24 hours (18-19 October; see Table 1). The Spanish State Meteorological Agency (AEMET) noted that 159.2 mm of rain in Vinaròs fell in just 1 hour. The AEMET-based map of accumulated precipitation for the period 18 – 20 October 2018 is presented in Figure 2.

Table 1 Accumulated precipitation (mm) for different regions during the period 18-19 October 2018

Temporal de Pluges / Temporal de Lluvias en la Comunidad Valenciana
Días 18 y 19 de octubre - precipitación acumulada (hasta las 21 horas del día 19)
Redes AEMET y CH Júcar

Vinaròs	374.6
Torreblanca	292.8
Alcalà de Xivert	255.6
Cervera del Maestre	255.0
El Palmar	235.2
Sarratella	220.6
Traiguera	215.6
Xert	214.2
Castellfort	214.0
Alfondeguilla	213.6
Catí	209.0
Almenara	206.6
Sot de Ferrer	191.8
Vilafamés	181.8
Atzeneta del Maestrat	174.4
Silla	171.0
Morella	169.6
Benafigos	168.4
Pina de Montalgrao	167.2
La Pobla de Benifassa	165.6
Vilafranca	161.7
Catarroja	158.0
Onda	150.4
Atzeneta del Maestrat	148.6
Vila-real	148.0
Picanya	146.2

Alcora	142.6
València-UPV	139.9
València-Viveros	138.6
Paiporta	138.0
Montanejos	137.2
Castelló	135.6
Torrent	133.0
Burriana	133.0
Sagunto (Corinto)	128.0
Sollana	126.0
Sagunt	120.4
Fredes	106.4
Montserrat (Casadalt)	106.0
Aeropuerto de València	101.0
Playa de Miramar	96.0
Segorbe	88.2
Ademuz	83.4
Miramar	80.0
Callosa d'en Sarrià	78.0
Llíria	75.2
Oliva	75.0
Turís	72.2
Chelva	70.6
Gandia	67.2
Benimodo	66.6
Polinyà	62.7

Buñol	50.6
San Vicente del Raspeig	44.0
Pego	42.8
Jávea/Xàbia	42.2
Utiel	41.4
Carcaixent	35.8
Jalance	30.2
Bicorp	24.8
Beneixama	23.0
Zarra	18.0
Xàtiva	15.0
Ontinyent	10.0
Alicante/Alacant	9.4
Alcoy/Alcoi	5.2
Fontanars dels Alforins	3.4
Benidorm	0.2
Pinoso/el Pinós	0.2
Aeropuerto de Alicante-Elche	0.1
Torrevieja	0.0
Torrelamata	0.0
Orihuela	0.0
Crevillent	0.0
Hondón de las nieves	0.0
Santa Pola	0.0
Elche/Elx	0.0
Novelda	0.0

⁵ https://en.wikipedia.org/wiki/Valencian Community#drography

⁶ http://floodlist.com/europe/floods-valencia-andalusia-spain-october-2018





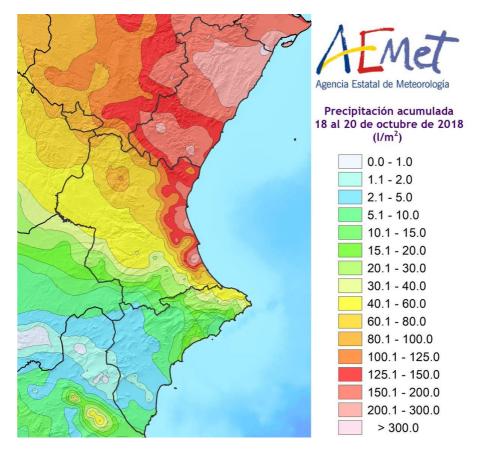


Figure 2 Map of accumulated precipitation (mm) for 18 - 20 October 2018 presented by AEMET

The high 24-hour precipitation amounts (more than 100 mm) were observed in Tortosa (Tarragona region) and in Valencia (Valencia region). More than 50 mm of precipitation were measured on some SYNOP stations also in Guadalajara region (Figure 3 and 4).

The amount of precipitation as well it location were well forecasted by the DWD and ECMWF meteorological models used in EFAS (Figure 5 and 6).

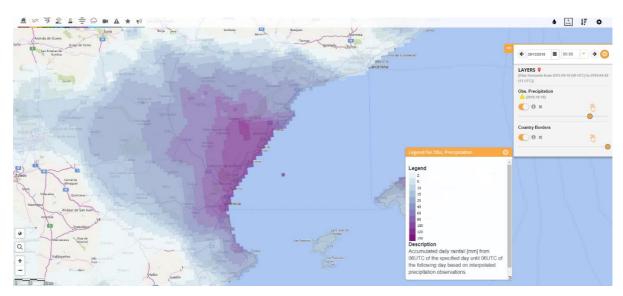
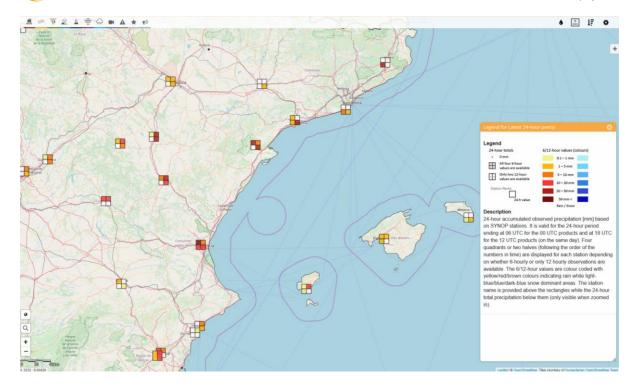


Figure 3 Accumulated daily precipitation (mm) from 2018-10-18 6:00 UTC until 2018-10-19 6:00 UTC based on interpolated precipitation observations.







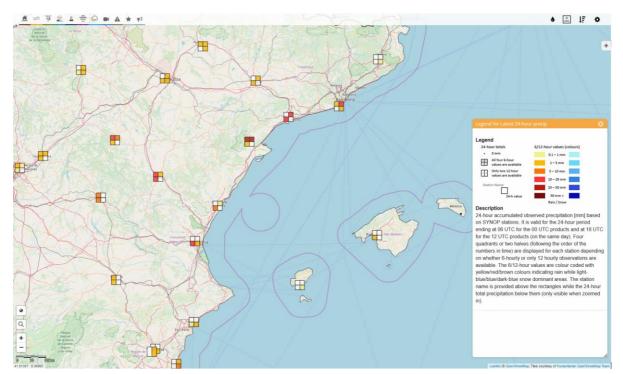
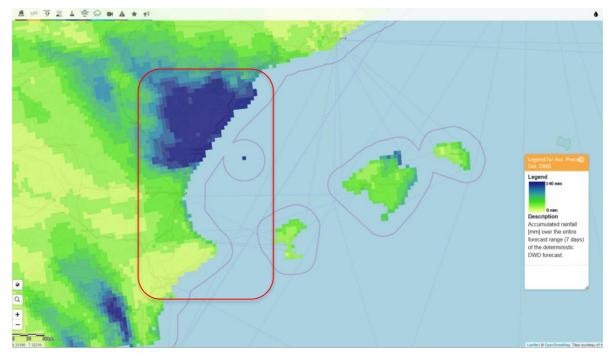


Figure 4 Latest 24-hour accumulated observed precipitation (mm) based on SYNOP stations on 2018-10-19 06:00 UTC (top) and 2018-10-20 06:00 UTC (bottom)

First signals of high precipitation appeared in the 2018-10-15 12:00 UTC model run. The deterministic meteorological models by DWD and ECMWF forecasted high precipitation for the north part of the Valencia region. The two probabilistic models by ECMWF-ENS and COSMO-LEPS indicated more than 50 % probability of exceeding 150 mm over the next 10 and 5 days respectively in the coastal area of the north of the Valencia region. Next model runs supported this forecast. The EFAS information available on 2018-10-18 is displayed in Figures 5 and 6.







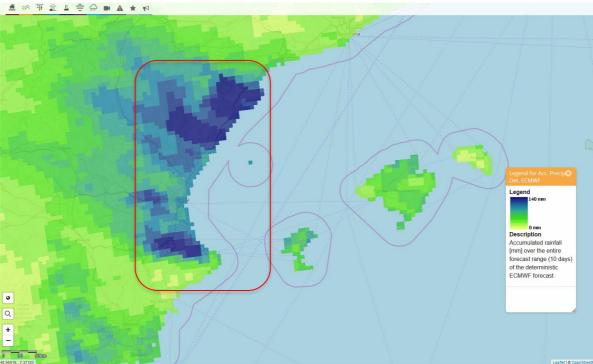
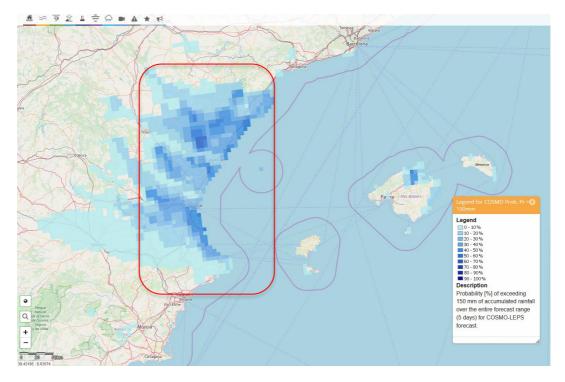


Figure 5 Accumulated precipitation (mm) over the entire forecast range: top - DWD (7 days), bottom - ECMWF (10 days) of the deterministic forecast (2018-10-17 12:00 UTC model run)







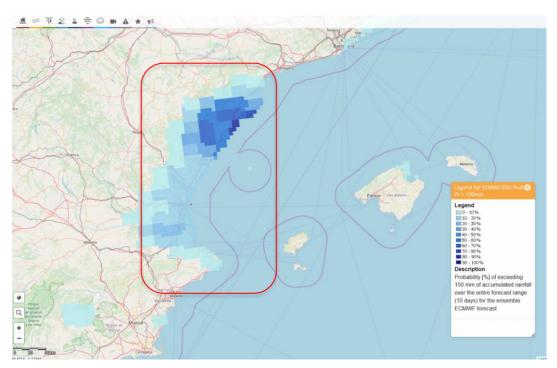


Figure 6 Probability (%) of exceeding 150 mm of accumulated precipitation over the entire forecast range: top - COSMO-LEPS (5 days), bottom - ECMWF (10 days) ensemble forecast (2018-10-17 12:00 UTC model run)

The highest predicted 6-hour precipitation was forecasted by the COSMO-LEPS for 2018-10-19 00:00 UTC (Figure 7).





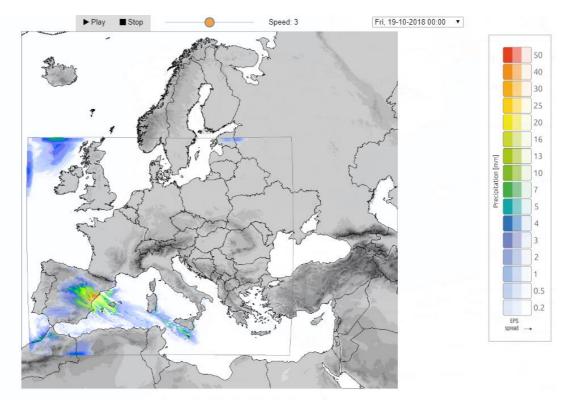


Figure 7 Precipitation COSMO-LEPS forecasts for October 19^{th} at 00:00 UTC. The model was initialized on October 16^{th} at 12:00 UTC

The soil moisture prior to the event was in near normal conditions (the definition of near normal conditions is based on a 26-year LISFLOOD model climatology) in most parts of the region. Only in its northern part, by the Ebro River estuary, the upper soil layer was much wetter than normal. The mountains in the western part had drier conditions than normal, (Figure 8a). After the event (on 19th of October), the affected area was highly wetter than normal (Figure 8b).

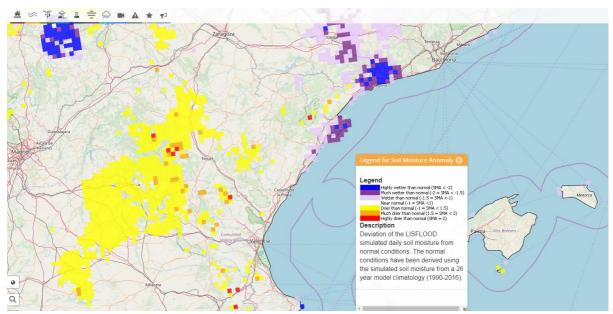


Figure 8a LISFLOOD simulated deviation of daily soil moisture from normal conditions valid for the 2018-10-17 12:00 model run (top)





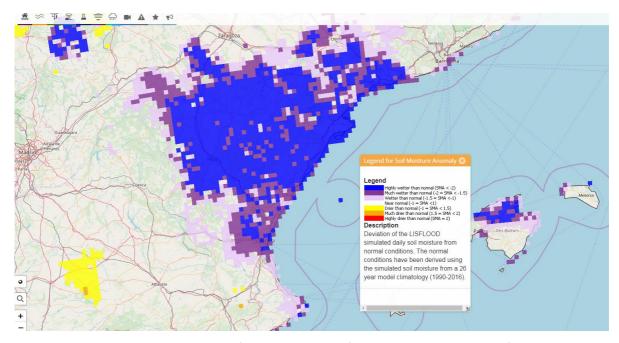


Figure 8b LISFLOOD simulated deviation of daily soil moisture from normal conditions valid for the 2018-10-19 12:00 model run

Satellite images show a less pronounced difference in soil wetness before and after the event. Figure 9a shows the relative soil moisture as result from a weighted average of three products from the advanced scatterometer (ASCAT) on board of METOP satellite. The satellite images show that the soils were saturated generally to 50 % before the event. Figure 9b shows the conditions after the event indicating a saturation of generally 80 % in the hit area.

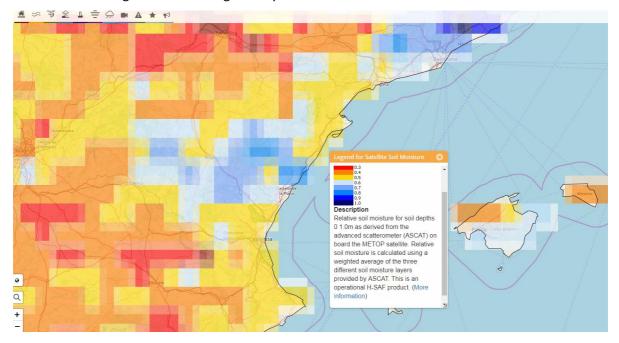


Figure 9a Relative soil moisture resulting from a weighted averaging of three soil moisture layers measured form METOP satellite for 2018-10-17





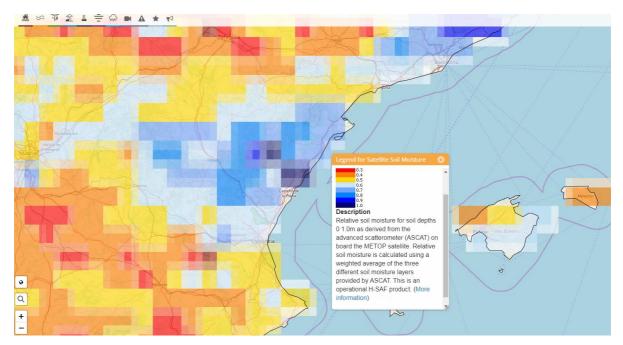


Figure 9b Relative soil moisture resulting from a weighted averaging of three soil moisture layers measured form METOP satellite for 2018-10-19

Flood extent of the EFAS 5-year return period threshold probability exceeding based on the ECMWF- ENS meteorological model forecasts valid for 2018-10-17 12:00 UTC model run is presented in Figure 10a and 10b. The highest probabilities of 5-year return period exceedance are forecasted for lower parts of the Millars and Palancia rivers for both 0-48 hours and 2-10 days ahead.

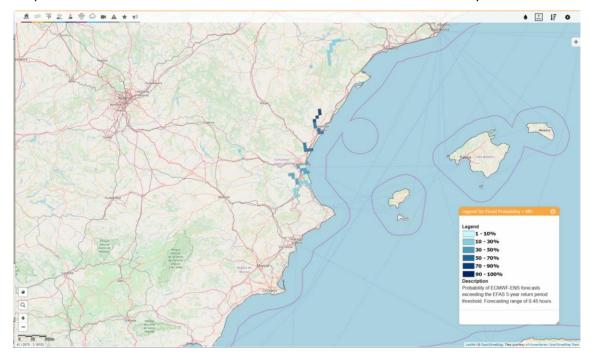


Figure 10a Flood probability exceeding the EFAS 5-year return period threshold based on ECMWF – ENS forecasts valid for 2018-10-17 12:00 UTC model run: forecasting range of 0 - 48 hours.





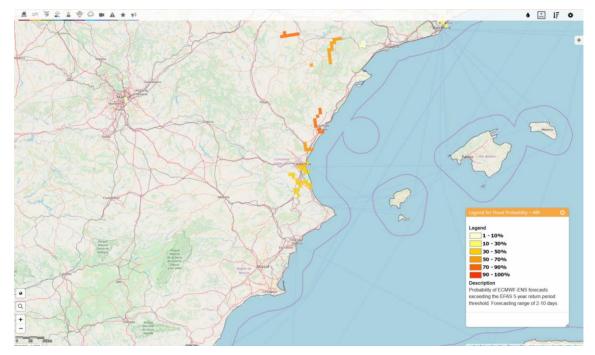


Figure 10b Flood probability exceeding the EFAS 5-year return period threshold based on ECMWF – ENS forecasts valid for 2018-10-17 12:00 UTC model run: forecasting range of 2 - 10 days.

3.3 Impacts - based on media reports

Emergency services in Valencia responded to more than 4,500 phone calls that correspond to about 4,000 incidents during the severe weather. Dozens of residents were evacuated from their homes in Benicarló, where local media said the rain had turned streets to rivers. Around 30 people were rescued from their vehicles. Further evacuations were carried out in Borriana and Alcossebre, where homes and buildings were flooded. Trains and schools in parts of the Valencia region were suspended.

3.3.1 Media example #1

"Spain: Half a million students stay home as Valencia region hit by floods"

Published on Friday October 19th (by efe-epa ⁷)

The report highlighted that about 500,000 students were given a day off on Friday after authorities in the eastern region of Valencia decided to close educational establishments as a precautionary measure following massive rainstorms as a result of two weather systems coalescing over Spain (one storm headed in from the Atlantic Ocean on the west and merged with another that travelled west across the Mediterranean Sea and affected the Iberian peninsula's East coast on Thursday with particular intensity). Added to this was a local meteorological phenomenon known as "Gota Fria" or "cold drop". The term describes a sudden drop in temperature along the Spanish east coast caused

 $^{^7\} https://www.efe.com/efe/english/life/spain-half-a-million-students-stay-home-as-valencia-region-hit-by-floods/50000263-3786102$





by the arrival in autumn of very cold polar air crossing from Russia right across the Mediterranean. The last "Gota Fria" of similar intensity took place in October 2008.

Despite the intensity of the precipitation, which caused many rivers to break their banks, flooding local roads, houses and properties, there had not been any victims (till the day of the report). The Spanish police and emergency responders rescued around 100 people in the province of Castellón and assisted nine drivers trapped in their vehicles in the past few hours. The Ford automobile plant in Almusafes (Valencia) restarted its normal production after Thursday's decision to halt operations due to the difficulty in accessing the factory and the need to pump floodwater out of the production line.

3.3.2 Media example #2

"RED ALERTS: Spain could see MAJOR flooding with up to 400mm (16 inches) of rain on east coast"

Published on Friday October 19th (by Karl Smallman ⁸)

Emergency services received many calls as the torrential rain lashed Spain with three areas on red alert for heavy rain (on Friday October 19th; see Figure 11).

The worst of the weather was expected in the areas Teruel (Aragon), Tarragona (Cataluña) and Castellon (Valencian Community) where precipitation was forecasted up to 400 mm. On Thursday October 18th fire fighters rescued at least 15 people from their cars across the province of Castellon, after flash flooding hit the region. The city activated its local flood emergency plan. The Balearic island of Mallorca that was badly hit the week before with 13 fatalities in flash floods remained on an orange alert on Friday October 19th.

On Saturday October 20th the situation improved in the east while the south took the brunt of the worst weather. In Andalusia the provinces of Almeria, Granada and Malaga (including the Costa del Sol) had orange alerts for heavy rain, as did Murcia. By Sunday October 21st the storms were expected to move away and no alerts were forecasted.



 $^{^8}$ https://www.euroweeklynews.com/2018/10/19/red-alerts-spain-could-see-major-flooding-with-up-to-400mm-16-inches-of-rain-on-east-coast/#.XLhnudhBpGE





Figure 11 Meteorological warning issued by AEMET (Spanish State Meteorological Service) on October 19, 2018

3.3.3 Media example #3

""Cold drop" wreaks havoc in Spain's eastern coast and Balearic Islands"

Published on Friday October 19th (by el País 9)

Around 30 people were rescued from their cars as torrential rain batters the country, causing flooding, traffic problems and road closures.

Spain was hit by another bout of extreme weather, with the eastern coast and Balearic Islands battered by torrential rain and flooding. The unusual conditions were the result of the *gota fría* – or "cold drop," a term used to describe a sudden drop in temperatures along the east coast caused by the arrival of very cold polar air. While the weather phenomenon is "typical" of Spanish fall weather in the Mediterranean, Spain's national weather service AEMET stated that a drop of this intensity had not occurred since October 2008.

The weather event that hit on Thursday October 18th continued to escalate on Friday in Aragón, the north of Catalonia and the south of Valencia. AEMET issued a red alert – the highest on the scale – for the provinces of Teruel, Tarragona and Castellón, an orange alert for "significant risk" for Valencia and the island of Mallorca, and a yellow alert for Zaragoza, Cuenca, Guadalajara, Soria, Barcelona and Alicante.

The cold drop caused flooding in Valencia. A total of 60 municipalities in Valencia and Castellón suspended classes because of the rain. Emergency services worked during the night due to the heavy rain.

While the extreme weather did not cause any fatalities, it led to significant problems in Castellón. Around 30 people had to be rescued from their cars across the province as the torrential rain turned streets into rivers. Around 240 mm of rain fell in Torreblanca and 235 mm in El Palmar. Homes were flooded in Alcossebre and 40 residents were forced to find shelter in a sports centre in Burriana. The rain disrupted train routes and university classes in Valencia were suspended. The Valencia region received 1,906 calls for help between 11.00 pm on Thursday and 06.00 am on Friday.

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⁹ https://elpais.com/elpais/2018/10/19/inenglish/1539938913 108964.html





3.4 EFAS flood information

The first time that EFAS forecasted a probability of flood in this region was on the 14th of October (model run 00:00). The DWD and ECMWF deterministic models predicted floods for 19th-20th and 19th-22th of October respectively. In the next model run (initialisation), the signal of deterministic models significantly decreased.

On the 15th of October (model run 00:00) the probabilistic models exceeded the critical thresholds for the first time. COSMO-LEPS exceeded the thresholds with 50 % probability (for both 5-year and 20-year return period) for the Millars river. The DWD deterministic model was under the thresholds, whilst the ECMWF deterministic model showed threshold exceedance for 19th and 20th of October. In the next model run, the signal of both deterministic and both probabilistic models significantly increased (for 5-year and also for 20-year return periods). However, the conditions for Formal/Informal Flood Notification were not fulfilled; the signal being above 30 % probability was persistent only for two model runs.

All conditions for Formal Flood Notification were met on the 16th of October (model run 00:00) as presented in Figure 12.

The Informal Flood Notification for the Millars river (based on the 2018-10-16 12:00 model run) and Coastal Catchment Western Mediterranean Sea (based on the 2018-10-17 00:00 model run) were issued on the 17th of October.

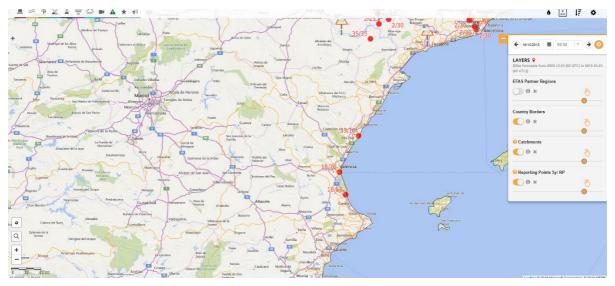


Figure 12 EFAS reporting points for the Valencia region – EFAS model run 16/10/2018 00:00 UTC.





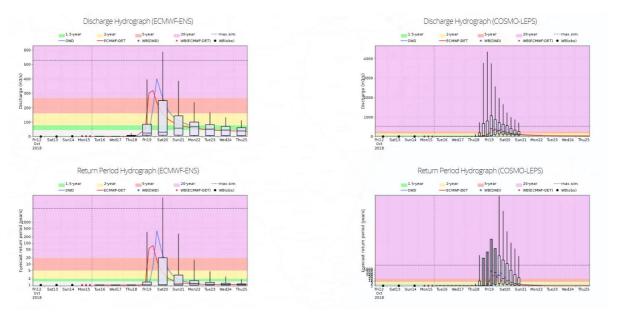


Figure 13 Forecasts of discharge hydrographs EFAS and return period hydrographs for the Millars river (EFAS model run 16/10/2018 00:00 UTC).



Figure 14 Deterministic model (DWD and ECMWF) forecasts for the South-East Coast – Millars river (EFAS model run 16/10/2018 00:00 UTC).

As shown in Figure 14 after the first signal on the 14th of October, the probability of the following two model runs decreased and were under the thresholds. From the 15th of October (model run 12:00) onwards, the signal was persistent in time.







Figure 15 ECMWF-ENS probabilistic model forecasts for the South-East Coast – Millars river (EFAS model run 16/10/2018 00:00 UTC).



Figure 16 COSMO-LEPS probabilistic model forecasts for the South-East Coast – Millars river (EFAS model run 16/10/2018 00:00 UTC).

One more Informal Flood Notification - for the Júcar river was sent on the 18th of October 2018. The EFAS model run 2018-10-16 00:00 UTC showed two persistent runs with forecasted signal above the threshold. Then the point disappeared for the following two model runs. The model run 2018-10-18 00:00 showed a signal again, and therefore a notification could be issued.

Figures 15 and 16 indicate that the LISFLOOD hydrological models forced by COSMO-LEPS meteorological forecasts, which has a high spatial resolution, predicted this situation better than the one forced by ECMWF-ENS.

Flash flood event of October 19th-20th

The first flash flood signal appeared with the 2018-10-14 12:00 model run, and increased with the next runs.

The conditions for Flash Flood Notification for the Valencia region were fulfilled on the 16th of October (model run 00:00), when the onset of the event was less than 72 hours and the signal persisted for at least the last two model runs (Figure 17).

The Flash Flood Notifications for the Castello and Valencia regions were issued in the morning of the 17th of October (Figure 18). Another Flash Flood notification for the Valencia region was issued in the afternoon of the same day.





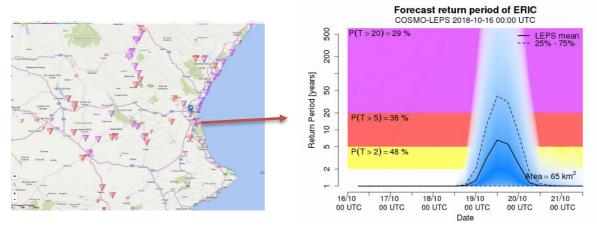


Figure 17 Forecast return period for the Valencia region (EFAS model run 16/10/2018 00:00 UTC).

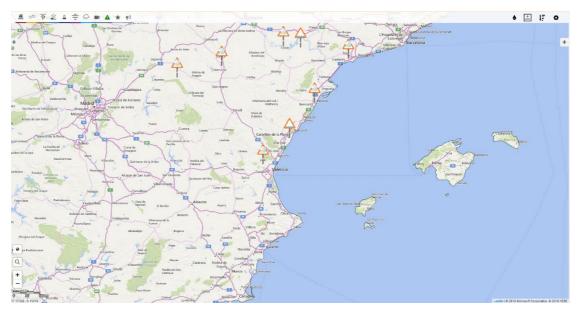


Figure 18 EFAS Flood Notifications issued for the Valencia region valid for 17/10/2018 (2018-10-16 12:00 UTC model run)

Timeline of issued EFAS flood information is available in the Annex 1.

Outputs of the new EFAS products

There are new EFAS products included in the EFAS-IS: Seasonal Outlook, Rapid Flood Mapping and Rapid Impact Assessment. Analysis of their outputs regarding studied event is described in this part of the report.

Seasonal information extracted from the EFAS Seasonal Outlook, with the forecasts being initialised in the beginning of October 2018 (see Figure 12), showed a high probability of low flows over the Valencia region. River flow anomaly is calculated from the seasonal forecast produced by forcing the LISFLOOD model with the ECMWF System 5 (SEAS5) seasonal forecast and can be found in the EFAS-IS. It has not been designed to capture flash floods and anomalies are aggregated over the large regions, therefore it cannot give adequate outlook of local events. Observed water balance confirms close-to-average flows in regional scale.





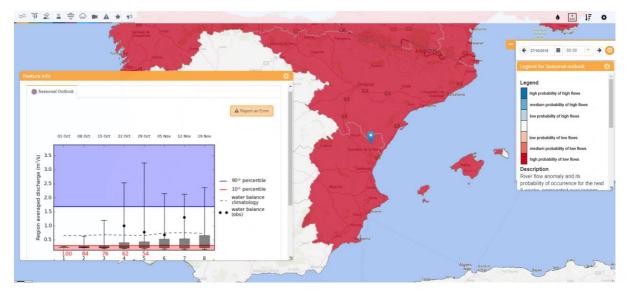


Figure 19 The EFAS Seasonal hydrological outlook for the Valencia region for October – November 2018

Estimated flood extend at 100 m resolution based on forecasted flood magnitude is shown in Rapid Flood Mapping layer. Protection levels are taken into consideration as well. If they are exceeded by a forecasted flood, flood prone areas are delineated for each river section using a Catalogue of flood hazard maps. The maximum estimated flood extend of the studied event is shown in Figure 20.

The event-based hazard maps are combined with exposure information to assess regional impacts (shown on the "Rapid Impact Assessment" layer). Considered exposure includes population, infrastructure and land cover. Impact is aggregated over NUTS regions. The level of flood risk is derived from combination of expected impact and likelihood. The highest likelihood of the forecasted event together with the highest affected population category meant also the highest flood risk in the studied region (Figure 21).





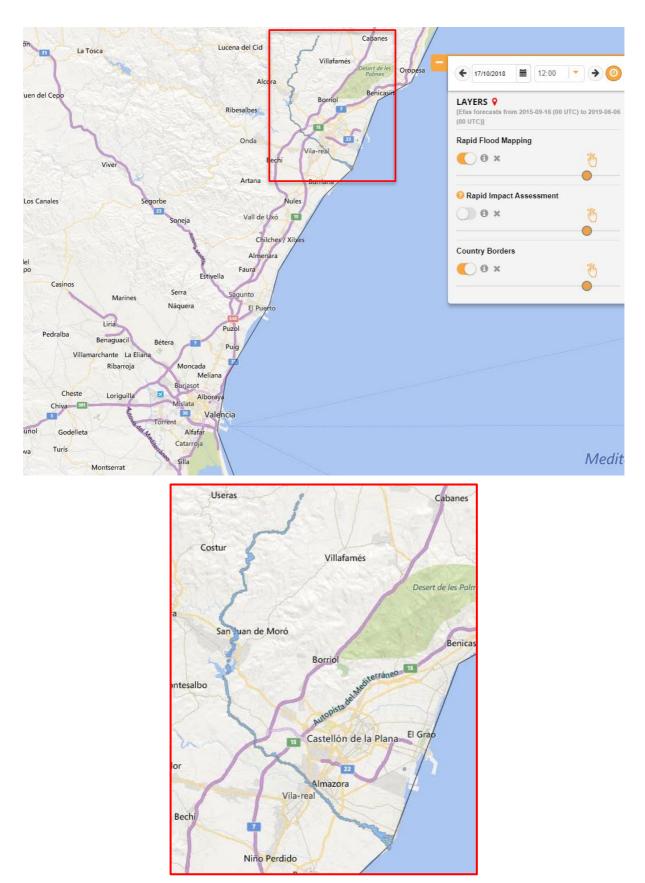


Figure 20 Rapid Flood Mapping layer: Estimated flood extend on the Millars and its tributary Rambla de la Viuda rivers (model run of 2018-10-17 12:00 UTC)





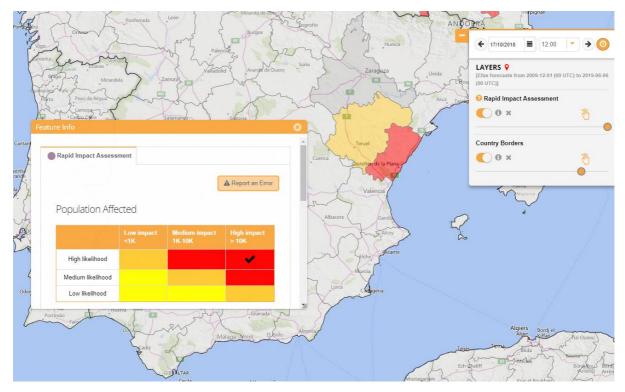


Figure 21 Rapid Impact Assessment: Flood risk in Valencia region (model run of 2018-10-17 12:00 UTC)

Relevant work of the EFAS Dissemination Centre

These extreme events in Spain indicated also possibilities for improvement in the workflows of the EFAS Dissemination Centre.

The analysis of the EFAS forecasts was very time consuming and not a straightforward task. There were many reporting and flash flood points, not only in the Valencia region, but also in Catalonia. With every model run, the forecasted signal often changed, and it was therefore necessary to check and assess many points. The assessment of forecasters on duty in some cases (regions and model runs) was not optimal, and hence the notifications were not sent timely.

The Informal Flood Notification for the Millars river and the Flash Flood Notifications for the Castellon and Valencia regions could be sent one model run earlier (in the afternoon of the 16th of October instead of morning on the 17th of October).

JRC contacted the EFAS Dissemination Centre in order to raise the focus on possible unissued notifications after the ERCC Overview was sent on the 17th of October 2018. Consequently, an Informal Flood Notification was sent for the Millars river at 10:42 am and a Corrigendum of the ERCC Overview was sent at 11:53 am.

This indicates that in such hydrologically complicated situation cooperation between the EFAS Centres is fundamental. In similarly complicated situations, forecasters and hydrological modellers of regional/local experience could exchange knowledge, which would result in improved (in terms of time and accuracy) issued notifications.





3.5 EFAS and national information

EFAS DISS conducted an interview with *Confederación Hidrográfica del Júcar* (CHJ), which belongs to the EFAS partner network.

CHJ is in charge of the management of water resources in part of the Teruel, Castellón, Cuenca, Valencia, Albacete and Alicante provinces, and two small areas of the Tarragona and Murcia provinces (Figure 22). CHJ uses meteorological information provided by the Spanish Meteorology Agency (AEMET), in addition to other systems from the ANYWHERE project funded by the Horizon 2020 program. AEMET divides the forecast warning into 4 levels (green, yellow, orange and red). In the case of an orange or red level, a technical team is put into 24/7 duty, until the warning or event ends. The duty involves the analysis of real time data and the provision of valuable information for emergency authorities. CHJ has also its own system called Automatic Hydrologic Informational System (SAIH)¹⁰, which produces precipitation and flow alerts. The system consist of a dense station network that measures among others precipitation, river flows and reservoir levels. When certain threshold levels are exceeded, the system issues automatically warnings.

EFAS information is checked by the CHJ only after receiving a notification, and mainly only as an indicator to increase awareness. In general, SAIH keeps a continuous surveillance and a technical team goes into the state of emergency preparedness. CHJ hydrologists consider EFAS forecasts adequate in general.



Figure 22 Territorial scope of Confederación Hidrográfica del Júcar

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¹⁰ http://saih.chj.es/





During flooding, there are also other authorities responsible for emergency response in the Valencia region:

- Civil Protection depending on Spanish Government Delegation in Valencia; It receives EFAS notifications.
- 112 is the institute to sort the emergency calls depending on the Generalitat Valenciana administration.

CHJ received notifications on possible flooding from AEMET and EFAS based on the same model run (2018-10-16 12:00 UTC). The EFAS forecasts were evaluated by CHJ hydrologists as adequate, as they were verified with increase water levels after intense precipitation.

The EFAS notifications are generally considered as useful by the CHJ and are not ignored. CHJ welcomes notifications from different warning systems to improve the flood management.

This event was not monitored on the EFAS interface by CHJ hydrologists, because they had their own monitoring network. However, in next events they are aiming to have a look into the EFAS to compare available forecasts, too.

The partners were also asked if they would find it more useful to receive the actual EFAS data for ingestion into their own system instead of looking at the EFAS web interface in parallel. They consider the proposal as interesting as they could use their tools, but with more information, so they could compare results from different sources.

An email acknowledging the usefulness of the EFAS forecasts/notifications for this specific flood event in Valencia/Castellon was also provided by the Spanish government (Annex 2).





4 Floods in the north of Italy

4.1 Description of the study area

The study area is in the northern Italy, which borders France in the west, Switzerland and Austria in the north, and Slovenia in the east. It is roughly delimited by the Alpine watershed, enclosing the Po Valley and the Venetian Plain.

The studied area is situated in Aosta Valley, Liguria, Piedmont, Lombardy, Emilia-Romagna, Trentino-Alto Adige, Veneto and Friuli Venezia Gulia regions (Figure 23).



Figure 23 Administrative regions in Italy (https://en.wikipedia.org/wiki/Italy#Administrative_divisions)

Most of its rivers drain into the Adriatic Sea. The waters from some municipalities drain into the Black Sea through the Drava basin - tributary of the Danube and the waters from the Lago di Lei drain into the North Sea through the basin of the Rhine. A small area on the southeast drains to the Ligurian Sea.

The Po river, Italy's longest river (652 km), flows from the Alps on the western border with France and crosses the Padan plain on its way to the Adriatic Sea. Near the end of its course, it creates a wide delta. It has a drainage area of 74,000 km², of which 45,000 km² is in mountainous environments and





29,000 km² on plains (Figure 24). Po´s biggest tributaries are the left-hand Dora Riparia, Dora Baltea, Ticino, Adda, Oglio, and those spring in the south Alpine slopes. Right-hand tributaries (the biggest one is Tanaro), which mainly spring in the northern slopes of the Tuscan–Emilian Apennines, are of smaller discharges than the left-hand tributaries.

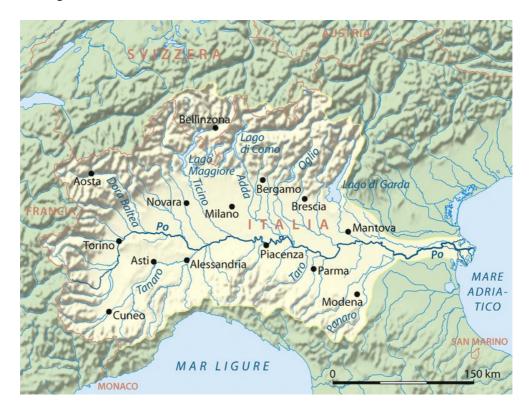


Figure 24 Map of the Po basin in Italy

Other important rivers are situated in the east of the studied area and also flow from the Alps to the Adriatic Sea: Adige (2nd longest Italian river), Brenta, Piave, Livenza, Tagliamento and Isonzo/Soča on the Italian-Slovenian border. In the north of the area of interest, there are several subalpine moraine-dammed lakes, the largest of which is Garda (370 km²). Other well-known subalpine lakes are Lake Maggiore (212.5 km²) whose most northerly section is a part of Switzerland or Como (146 km²) one of the deepest lakes in Europe.

A relatively "continental" and "four-season" version of the humid subtropical climate (Cfa according to the Köppen climate classification) can be found in the Po and Adige valleys. It is marked by hot and wet summers, while winters are moderately cold. The conformation of the plain surrounded by the Alps and the Apennines, and the influence of the Adriatic Sea cause high levels of relative humidity throughout the year. The precipitation varies between 700 and 1200 mm and is equally distributed during the year, with maximums during autumn and spring. The climate becomes increasingly warmer and more humid further south and east. Average temperatures are around 1 °C to 3 °C in January, and more than 22 °C in July and August. The alpine valleys are of cold continental climate (Dfc) with very cold winters and cool summers. Above the tree line in the Alps there is Tundra climate (ET). With increasing elevation the annual mean precipitation reaches 1200-2000 mm, whilst in the highest altitudes of the Julian Alps this can be more than 2500 mm (Figure 25).

¹¹ https://en.wikipedia.org/wiki/Climate of Italy





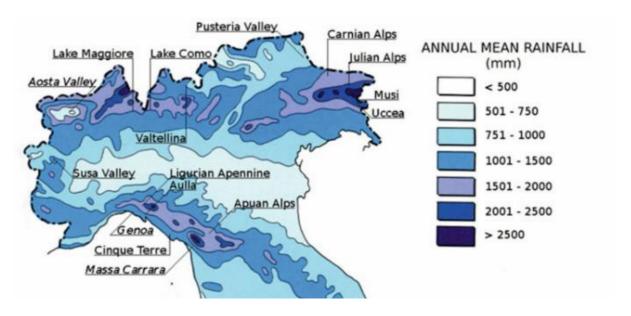


Figure 25 Annual mean precipitation for the period 1961 to 1990 in northern Italy. (Source: Fratianni, S., Acquaotta, F., 2017: The Climate of Italy. ¹²)

4.2 Description of the flood event

In the last days of October, a large trough emerged over Western Europe, reached northern Africa and induced a meridional flow over the central Mediterranean Region and central Europe with intense orographic precipitation in the southern parts of the Alps and corresponding floods. Summing up, October 2018 was characterised by a persistent high-pressure bridge from the Azores to Russia forcing most of the low-pressure systems on northern tracks, intense precipitation events in the Mediterranean regions and a still ongoing drought in central Europe. The highest precipitation amounts were measured at the western coasts of Norway and Scotland, but also in the western and central Mediterranean Region originating from convective precipitation events forced by the high sea surface temperatures.¹³

The high precipitation amounts in the Po basin were measured from October 27th to October 29th (Figure 26, 27 and 28). The highest precipitation amount (269 mm) was observed in Trento (Trentino-Alto Adige region). Similarly, high precipitation amounts (more than 190 mm) were measured in Tarvisio (Friuli Venezia Giulia region) and in Genova-Sestri (Liguria region). More than 100 mm of precipitation were observed in Passo Rolle and Bolzano in the Trentino-Alto Adige region. More than 50 mm of precipitation were observed in many SYNOP stations in Po basin in these three days.

¹² Fratianni, S.; Acquaotta, F.,2017: The Climate of Italy. In Soldati, M., Marchetti, M. (editors), 2017: Landscapes and Landforms of Italy. World Geomorphological Landscapes. Springer International Publishing AG, ISBN 978-3-319-26192-8

¹³ https://www.efas.eu/en/node/380





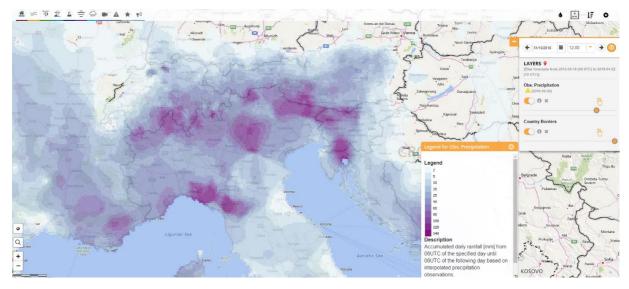


Figure 26 Accumulated daily precipitation (mm) from 2018-10-29 6:00 UTC until 2018-10-30 6:00 UTC based on interpolated precipitation observations.

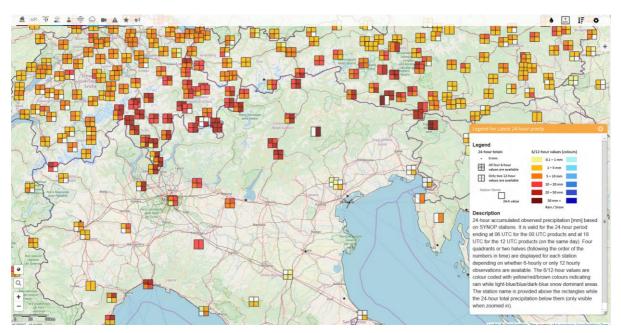


Figure 27 Latest 24-hour accumulated observed precipitation (mm) based on SYNOP stations on 2018-10-28 06:00 UTC





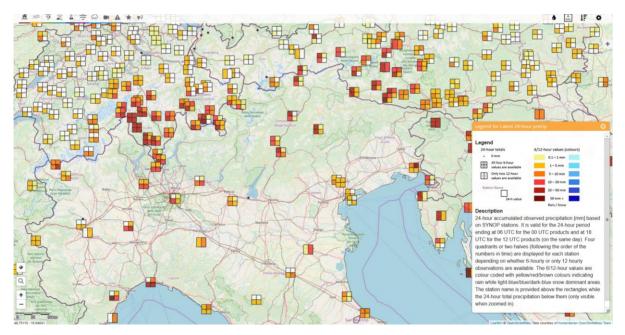


Figure 28 Latest 24-hour accumulated observed precipitation (mm) based on SYNOP stations on 2018-10-28 06:00 UTC (top) and 2018-10-29 06:00 UTC (bottom)

Precipitation was interrupted on 30th October. Precipitation on 31st October affected mostly the Western part of the area of interest. The highest precipitation amounts were observed in the Liguria region (Genova-Sestri 68 mm, Monte Settepani 111 mm, and Mondovi 50 mm).

In the following days, precipitation decreased spatially as well as volume-wise. Higher precipitation amounts affected only smaller areas. The most significant was precipitation on the 6th November, when up to 53 mm were observed in the Alps bringing a response in the upper Po and Sessia rivers.

Precipitation was well forecasted by all meteorological systems used in EFAS. Figure 29 shows the forecasted accumulated precipitation over the entire forecast range of the DWD and ECMWF deterministic models (7 and 10 days respectively).

Evidence of an adequately forecasted precipitation event from the probabilistic models is presented in Figure 30. The probability (%) of exceeding 150 mm of accumulated precipitation over the entire forecast range was very high on both the COSMO-LEPS (5 days) and-ECMWF-ENS (10 days) models.





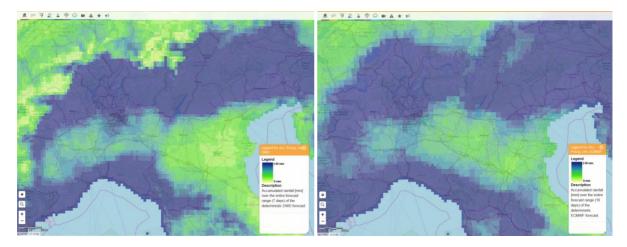


Figure 29 Forecasted accumulated precipitation (mm) over the entire forecast range: left - DWD (7 days) (2018-10-26 12:00 UTC model run), right - ECMWF (10 days) of the deterministic forecast (2018-10-23 12:00 UTC model run)

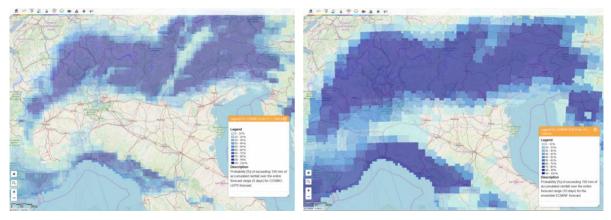


Figure 30 Probability (%) of exceeding 150 mm of accumulated precipitation over the entire forecast range: left - COSMO-LEPS (5 days), right - ECMWF (10 days) ensemble forecast (2018-10-26 12:00 UTC model run)

Figures 31-36 show the COSMO-LEPS model forecasts of the 6-hour precipitation amounts of 50 mm for October 28th until 12 UTC, October 29th until 12 UTC, and October 30th until 00 UTC. The estimated precipitation approximately corresponded to the observed amounts.

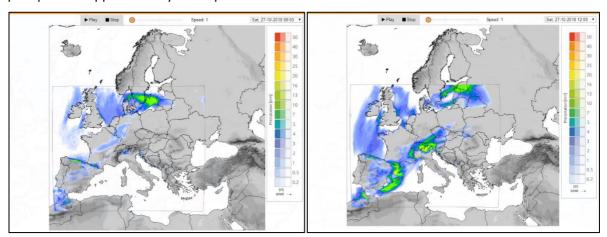


Figure 31 Precipitation COSMO-LEPS forecasts for October 27th 00:00 UTC and 12:00 UTC. The model was initialized on October 26th at 12:00 UTC.





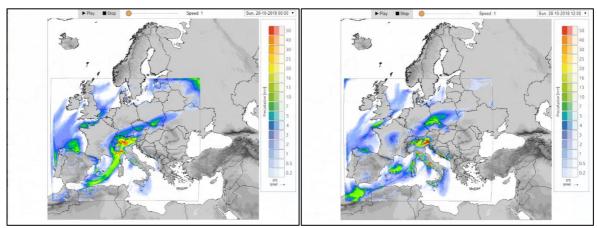


Figure 32 Precipitation COSMO-LEPS forecasts for October 28^{th} 00:00 UTC and 12:00 UTC. The model was initialized on October 26^{th} at 12:00 UTC.

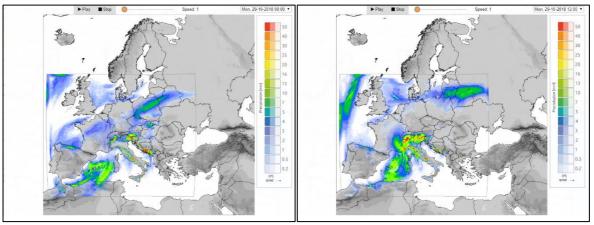


Figure 33 Precipitation COSMO-LEPS forecasts for October 29^{th} at 00:00 UTC and 12:00 UTC. The model was initialized on October 26^{th} at 12:00 UTC.

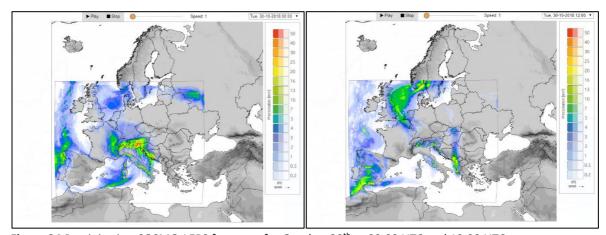


Figure 34 Precipitation COSMO-LEPS forecasts for October 30^{th} at 00:00 UTC and 12:00 UTC. The model was initialized on October 26^{th} at 12:00 UTC.





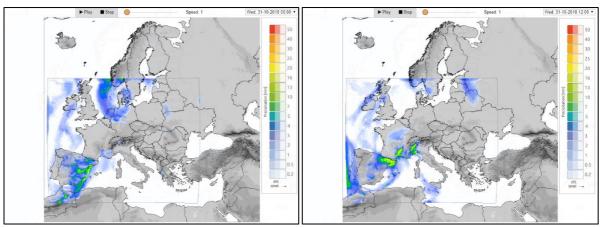


Figure 35 Precipitation COSMO-LEPS forecasts for October 31^{st} at 00:00 UTC and 12:00 UTC. The model was initialized on October 30^{th} at 12:00 UTC.

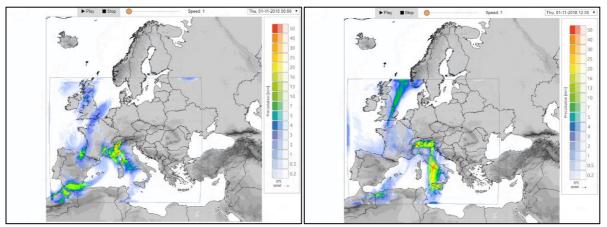
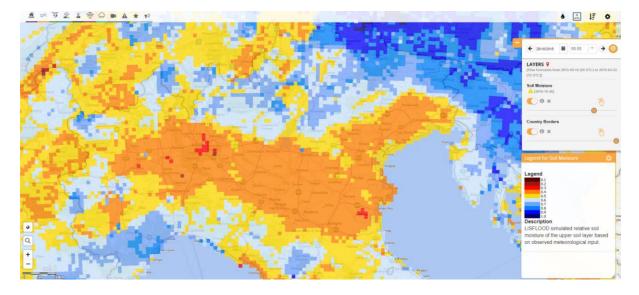


Figure 36 Precipitation COSMO-LEPS forecasts for November 1^{st} at 00:00 UTC and 12:00 UTC. The model was initialized on October 30^{th} at 12:00 UTC.

The simulated soil moisture content (LISFLOOD) is presented in Figure 37 (top). On October 26th the soil was drier than normal in the northern part of Italy, especially in the Po basin. The satellite image gives a wetter picture than the LISFLOOD simulations in EFAS (Figure 37 bottom). Prior to the precipitation event with start on October 27th, the relative soil moisture in almost all parts of Po basin was 30 to 50 %.







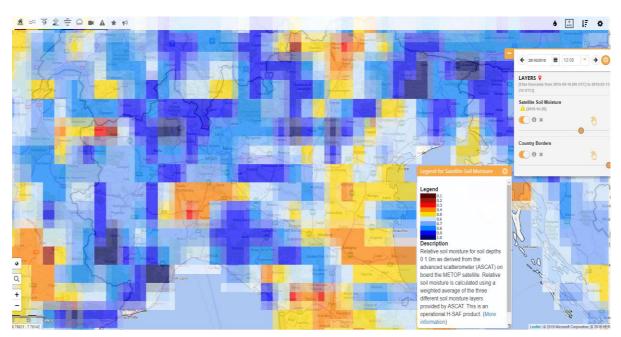


Figure 37 LISFLOOD simulated relative soil moisture of the upper soil layer based on observed meteorological input (top) and satellite soil moisture (bottom) on 2018-10-26.





4.3 Impacts - based on media reports

Storms, heavy rain and very strong winds in the end of October and beginning of November caused flash floods not only in Italy but also in Croatia, Slovenia, Bosnia and Herzegovina, France and Switzerland.

4.3.1 Media example #1

"Italy - Storms and Flooding Cause 11 Deaths"

Published on Wednesday October 31th (by Floodlist News in Europe¹⁴)

At least 11 people died in Italy after storms and severe weather swept across parts of southern Europe, bringing strong winds, rough seas and heavy rain. Croatia, Slovenia, Bosnia, France and Switzerland have all been badly affected.

Italy

Six regions of Italy – Lombardy, Veneto, Friuli-Venezia Giulia, Liguria, Trentino-Alto Adige and Abruzzo – were put on red alert due to storms, torrential rain and strong winds from the 29th of October. Heavy rain increased river levels and risk of landslides since then, with further severe weather expected. On the 30th of October, the Civil Protection issued red alerts for hydrogeological risk in the Veneto and Trentino-Alto Adige regions, and an orange alert for Liguria.

Many of the deaths in Italy were caused by wind damage, with gusts reaching 180 km/h (112 mph) in some areas. Fallen trees caused major travel disruption and schools in many cities had been closed.

The strong winds and high tide combined to cause major flooding in Venice, with over three quarters of the historic centre inundated on the 29th of October 2018. Local authorities said the high tide hit a maximum of 156 cm in the early afternoon – the fourth highest level ever recorded and the highest seen since 2008.

Heavy rain also triggered some flash flooding, causing at least 2 deaths. According to news from the ANSA agency, a woman died due to floodwaters at Dimaro in Trentino Province, Trentino-Alto Adige Region, and a man was found dead in a river near Belluno in the Veneto region.

People were forced to evacuate their homes after flooding in the town of Levanto, La Spezia province, in the Liguria region. Flooding was also reported in the Ovaro, Udine Province in Friuli-Venezia Giulia region, where a road collapsed and a factory was evacuated.

The Piave river broke its banks in parts of Veneto region in northern Italy. Evacuations were carried out in the town of San Donà di Piave as a result.

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¹⁴ http://floodlist.com/europe/italy-storm-flood-october-2018





4.3.2 Media example #2

"Italy storms kills 11 and floods inundate St Mark's Basilica, Venice"

Published on Tuesday October 30th (by Reuters in Rome¹⁵)

Heavy storms hit Italy for a third consecutive day on Tuesday, killing at least 11 people, and flooding many areas in Venice.

The lagoon city's St Mark's Square remained under water for a second day, while the adjacent St. Mark's Basilica was inundated, its baptistery totally flooded and its mosaic floors covered by 90 cm (2ft 11in) of water.

"The basilica has aged 20 years in just one day, and perhaps I am being overly optimistic about that." said Carlo Tesserin, the church's chief administrator. "It is becoming ever more difficult for us and indeed could become impossible for us to repair the damage, especially in an age of climate change."

Italian media said it was the second time in this century that the basilica had been flooded, and just the fifth time there had been such high water within the body of the cathedral in the structure's 1,000-year history.

Widespread damage was also reported in towns and cities in the north, south and centre of Italy. Many of the 11 deaths were caused by falling trees as winds as strong as 90mph whipped the country.

One of the hardest hit regions was Liguria in the northwest. The breakwater walls in the chic seaside resort of Rapallo were destroyed by pounding waves, letting in a surge of water that toppled dozens of luxury yachts and inflicted heavy damage on the port area. Local media said a yacht owned by the family of former Prime Minister Silvio Berlusconi was one of those badly damaged.

The nearby resort town of Portofino was cut off by a landslide, while a video showed the seawater pouring through the picturesque fishing village of Vernazza further to the south.

The weather was expected to improve in the coming days (next Tuesday and Wednesday) "giving the country a truce", an official from the civil protection agency told Reuters.

Meanwhile, heavy snowfall across south-central France, with up to 40cm (16in) falling in some towns and villages, caused chaos on the roads and knocked out electricity to nearly 200,000 homes, authorities said on Tuesday.

4.3.3 Media example #3

"Wild weather across Europe leaves nine dead in Italy"

Published on Tuesday October 30th (by Agence France-Presse in Rome¹⁶)

Winds of 110mph brought destruction in Italy as snow traps more than 1,000 drivers in France.

The death toll from fierce storms battering Italy rose to nine as wild autumn weather swept across many parts of Europe.

 $^{^{15}\} https://www.theguardian.com/weather/2018/oct/30/water-rises-to-three-feet-in-st-marks-basilica-after-venice-floods$

¹⁶ https://www.theguardian.com/world/2018/oct/30/wild-weather-across-europe-leaves-nine-dead-in-italy





Roads were blocked and thousands of people were left without power in southern and central Europe, as rain and violent winds sparked flooding and tore up trees.

Heavy snow fell in mountainous areas of France and Italy, trapping scores of drivers in their cars and tourists in hotels.

In Italy, where wind speeds reached 110mph (180km/h) in some areas, civil protection authorities announced a further four deaths, after confirming five people had perished on Monday.

A woman died when her home was engulfed by a mudslide in the northern region of Trentino, a man was killed by a falling tree in the northeastern region of Veneto, and a fire-fighter died during relief operations in South Tyrol.

A man was killed while kite surfing on Monday near the town of Cattolica on the Adriatic coast. The local press said strong winds blown him into rocks.

Venice was inundated by a near-record flooding and tourists were barred from St Mark's Square on Monday as local authorities said the high water peaked at 156cm. The water level has had only topped 150cm five times before in recorded history.

Italian media also reported that about 170 tourists and hotel staff were stranded by heavy snowfall at the Stelvio pass on the Swiss border.

4.4 EFAS flood information

Annex 3 lists all the EFAS flood information issued for this event, includes Issued EFAS Notifications as well as the ERCC Overviews.

Flood event of October 28th-30th

The first signs of potential flooding in northern Italy for October 28th emerged in the EFAS-IS seven days prior to the event with the 00:00 UTC forecast on October 21th. Forecasts from the 00:00 UTC model run of October 25th shows reporting points with more than 50 % probability (based on the COSMO-LEPS) for an event with more than 5-year return period in the EFAS-IS. In the next model run, the probability increased to 85-95 % on the Mincio, Brenta and Livenza rivers (Figure 38).

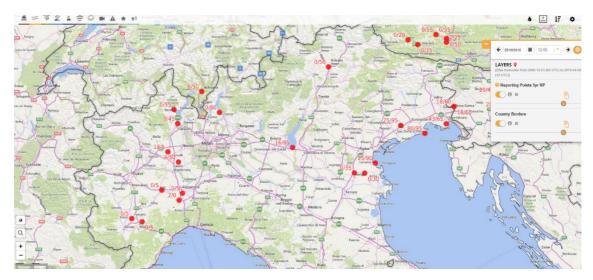


Figure 38 Reporting points for 2018-10-25 12:00 UTC model run, where the forecasted probability of exceeding the EFAS 5-year return period is > 10 %.





The first model run in which all conditions for a Flood Notification were fulfilled was the run 2018-10-23 12:00. The threshold exceedance was persistent for three model runs for the Tagliamento river and it was mentioned in the ERCC Overview on the 24th of October 2018, but no EFAS Notification was sent out as the area wasn't covered by any partner agreement at that time. The start of the event and the first peak were predicted for the 29th October.

In the morning of the 25th October, the model results from the 2018-10-24 12:00 UTC run fulfilled the criteria and the first Formal Flood Notifications for Mincio river was issued. The Livenza river (which was out of the EFAS partner network) was also added to the Overview. The forecasted start (onset) of the event was lagged and shifted to the 27th October. In the afternoon model run, another Formal Flood Notification was issued for the Adda river and the start of the event was persistent and predicted for the 28th October.

In the next day, two Formal and one Informal Flood Notifications (Informal due to the small drainage area) were issued for Ticino, Toce and Sesia river. The basins of Brenta, Adige and Isonzo, that were out of the partners region at that time, also fulfilled the criteria and this information was added to the ERCC Overview.

Informal Flood Notification for the Isonzo/Soca river was finally issued on the 27th October. Since this river basin is trans-boundary, the notification was valid for Italy and Slovenia.

All valid notifications on the 27th of October 2018 are presented in Figure 39.

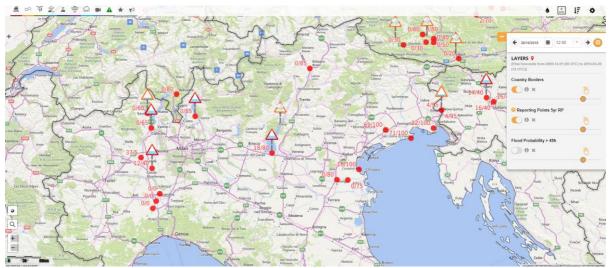


Figure 39 Issued EFAS notifications on the 27th of October 2018 (2018-10-26 12:00 UTC model run)

Formal Flood Notifications were issued driven by the COSMO-LEPS forecasts and also supported/verified by the DWD deterministic forecasts. However, results of the LISFLOOD model forced by both deterministic and probabilistic ECMWF forecasts did not exceed the critical threshold, although a rise of discharge was predicted. An example of forecasts is presented in Figure 40 for the Ticino river:







Figure 40 Forecasted hydrographs of return periods for the Ticino river (2018-10-26 12:00 UTC model run).

DWD-det and COSMO-LEPS are based on a high resolution numerical prediction model and are therefore of high forecasting skill. Precipitation in the Alps was forecasted very differently by COSMO-LEPS and ECMWF-ENS (see Figure 41); with COSMO-LEPS predicting more precipitation than ECMWF-ENS. This difference is mirrored in the hydrological response (Figure 40). The forecast forced by ECMWF-ENS hardly exceeds 1.5-year return period threshold, whereas the one forced with COSMO-LEPS exceeds the 20-year return period threshold. However, despite the DWD and ECMWF deterministic precipitation forecasts being quite similar (Figure 41), their hydrological response is vastly different (Figure 40 left), with the DWD hydrograph being much higher than the ECMWF-det one.

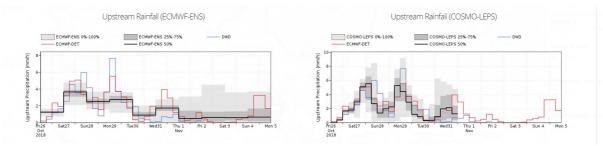


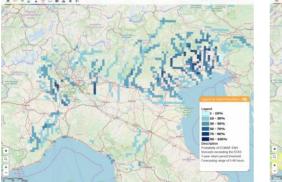
Figure 41 Forecasted upstream precipitation for the Ticino river (2018-10-26 12:00 UTC model run)

The only regions that were similarly predicted by ECMWF-DET/ECMWF-ENS and DWD-DET/COSMO-LEPS were basins on the east of north Italy (see Figure 39).

Figure 42 shows the maps of flood probability exceeding the EFAS 5-year return period threshold based on the ECMWF-ENS forecasts. The relevant map driven by COSMO-LEPS, which more accurately predicted the event, is not available in the EFAS-IS.







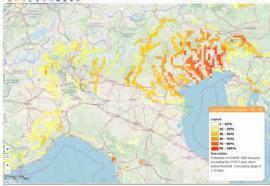


Figure 42 Flood probability exceeding the EFAS 5-year return period threshold based on the ECMWF–ENS forecasts. Left: forecasting range of 0 - 48 hours (2018-10-28 12:00 UTC model run). Right: forecasting range of 2 - 10 days (2018-10-25 12:00 UTC model run)

Flash flood events for October 28th-30th

The model run 2018-10-24 12:00 UTC indicates flash flood points in north Italy of greater than 10 % probability of exceedance of ERIC 5-year return period. Forecasts showed two peaks in the hydrograph; a small one on the 28th and a high one on the 30th of October. However, not all necessary conditions for a flood notification were fulfilled. The first peak was not always greater than 10 % probability, the lead time was more than 72 hours and/or the area was outside the EFAS partners region. Only in the morning of the 27th of October, a forecaster on duty issued (based on the model run 2018-10-26 12:00 UTC) the first Flash Flood Notification for the Verona region. A possible flash flooding for the Trento region (outside the EFAS partner region) was mentioned in the ERCC Overview. In the afternoon of the same day (hence model run of 2018-10-27 00:00 UTC), the signal decreased and the notification was deactivated.

From the model run of 2018-10-28 00:00 UTC a lot of flash flood points appeared south and east from Milan. Consequently Flash Flood Notifications for the Pavia and Verona regions were issued. The peak was predicted for the night of 29th-30th October 2018 indicating a lead time of 1.5 days. The forecast for October 29th with 18 % probability for a possible flash flood event based on the 20-year ERIC return period is showed in Figure 43.



Figure 43 EFAS ERIC reporting points and EFAS ERIC affected area valid for the 2018-10-29 00:00 UTC model run





Flash Flood Notifications for the Alessandria and Brescia regions were issued on the 29th of October 2018. The forecast showed peaks on October 29th/30th with maximum of 18 % probability of exceedance based on the 20-year ERIC return period.

Flash flood event for November 1st and 5th

The first (but still weak) sign for the intense precipitation event on November 1st emerged in the EFAS-IS with the 2018-10-30 00:00 UTC model run. In the next model run, the probability for an event with greater than the 5-year ERIC return period increased up to 22 % in reporting points in the Cuneo and Alessandria regions (Figure 44). A Flash Flood Notification was issued in October 31th.

The first signs of the precipitation event in the Cuneo region (southwest of Milan) in November 5th emerged in the EFAS-IS with the 2018-11-01 00:00 UTC model run. This forecast indicated reporting points up to 7 % probability for an event with more than 5-year return period in the EFAS-IS. In the next model run (2018-11-01 12:00 UTC), the probability increased to 16 % (Figure 45). A Flash Flood Notification was issued in November 2nd for this region.

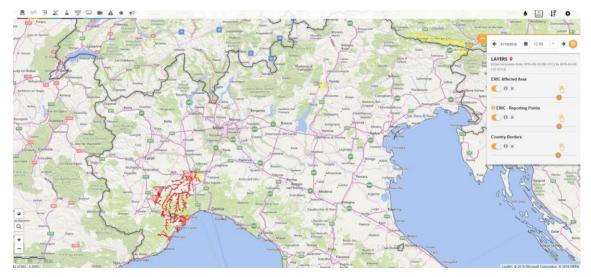


Figure 44 EFAS ERIC Reporting points and EFAS ERIC affected area valid for 2018-10-31 12:00 UTC model run

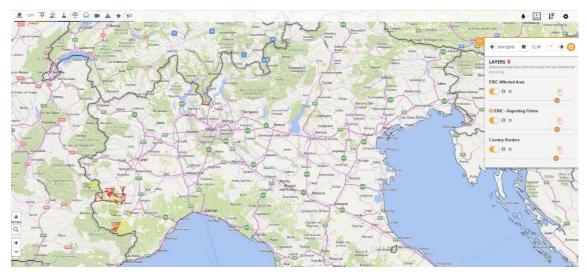


Figure 45 EFAS ERIC reporting points and EFAS ERIC affected area valid for 2018-11-01 12:00 UTC model run





Flood event for November 7th-8th

The first signs of the extreme precipitation event in the Po and Sesia rivers in November 7th - 8th emerged in the EFAS-IS with the 2018-11-01 00:00 UTC model run. The model run of 2018-11-02 12:00 UTC indicated a reporting point in the Po river with 75 % probability (based on the COSMO-LEPS meteorological input) the event to exceed the 5-year return period (see Figure 46), whilst the model run 2018-11-04 12:00 UTC indicated a reporting point in the Sesia river with 80 % probability (based on the COSMO-LEPS) to exceed the 5-year return period. A Formal Flood Notification for the Po river was issued on November 3rd and the Informal Flood Notification for the Sesia river was issued on November 5th.

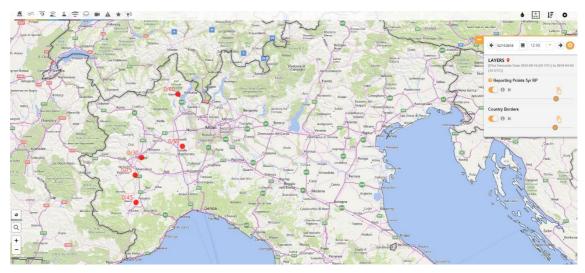


Figure 46 Reporting points for 2018-11-02 12:00 UTC model run, where the forecasted probability of exceeding the EFAS 5-year return period is > 10 %

Outputs of the new EFAS products

According to the EFAS Seasonal Hydrological Outlook, with the model being initialised in October 2018 (Figure 47), there was a high probability of low flows over the studied area. River flow anomaly is calculated from the seasonal forecasts produced by forcing the LISFLOOD hydrological model with the ECMWF System 5 (SEAS5) seasonal meteorological forecast.





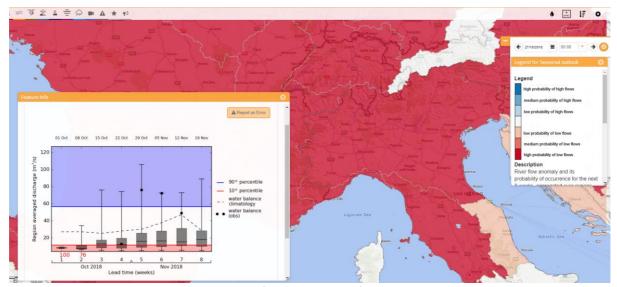


Figure 47 EFAS Seasonal Hydrological Outlook for northern Italy for October – November 2018

The Rapid Flood Mapping layer showed affected flooded areas in the eastern part of the Northern Italy, in the Piave, Livenza and Isonzo/Soča catchments (Figure 48).

This high flood risk was due to the high impact (more than 10,000 affected people) and medium likelihood (Figure 49).

It is important to mention that Rapid flood mapping and Rapid Impact Assessment are calculated based on the results of the hydrological model forced with ECMWF-ENS, which forecasted possible floods in this area.





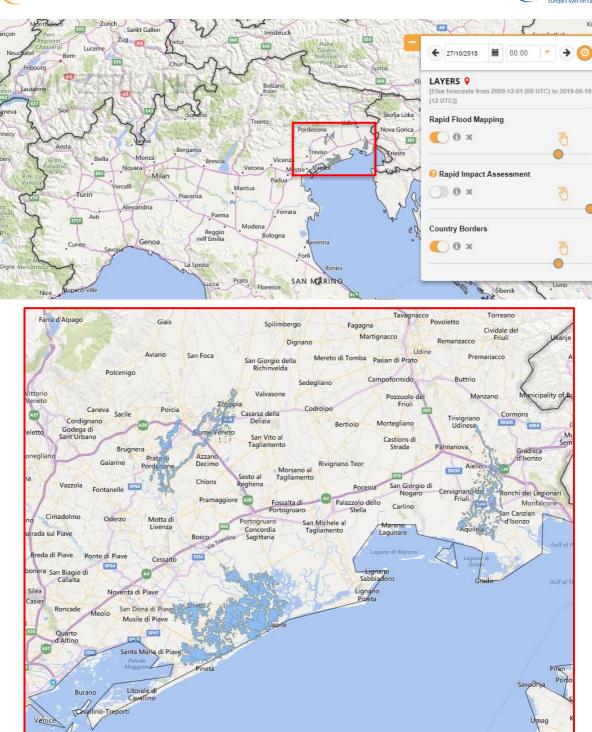


Figure 48 Results from the Rapid Flood Mapping layer showing the estimated flood extend in Piave, Livenza and Isonzo/Soča basins (model run of 2018-10-27 00:00 UTC)







Figure 49 Results from the Rapid Impact Assessment showing the flood risk in north-east of Italy (model run of 2018-10-27 00:00 UTC)

4.5 EFAS and national information

In October 2018 only the Po basin was included in the EFAS partners region. Other basins were outside this area, therefore EFAS Flood and Flash Flood Notifications could not be issued for any areas outside the Po river basin. However, flood events forecasted by EFAS were mentioned in the ERCC overviews using the same criteria as for Flood Notifications.

There are 21 regional hydrological services in Italy, each with its own website. Due the large number of websites it is impossible for the EFAS Officer on Duty to check them all during the morning hours. For this reason EFAS analysis information published on the overarching web page of the Italian Civil Protection Agency instead. Every day at 4 p.m. they publish a bulletin¹⁷ that reports on the expected evaluation of hydrogeological and hydraulic criticalities levels till midnight next day. There are three warning levels used: yellow, orange and red. Affected regions are visualised on the map and also described in more detail in the text. When warnings of orange or red level are valid, officers on duty from the EFAS Dissemination Centre include this information into the Unrestricted, public information of the ERCC Overview.

On 26th October 2018 at 16:30 CEST the national bulletin contained the first warnings for the upcoming events. Red warning levels were valid for next day (27th of October) for the Veneto region, whereas orange warning levels were valid for Lombardy, Emilia-Romagna and Trentino-Alto Adige regions (Figure 50). Later bulletins enlarged the affected area and increased the warning levels in some areas red level for Friuli Venezia Giulia, Liguria, Lombardy, Trentino-Alto Adige and Veneto regions; orange level for Emilia-Romagna and Piedmont regions; Figure 51).

Feedback requests were sent out for all five Formal Flood Notifications. However, only one feedback was returned, which was on the Formal flood notification for the Po river (issued on 3rd November 2018; Annex 4). According to this feedback, the accuracy of the EFAS forecasts in terms of location and time was accurate, whilst the magnitude of the actual event was less severe than predicted. The regional EFAS Partner stated that they were very well prepared for this event; and hence rated the added value of the notification as 1 (=No added value).

¹⁷ http://www.protezionecivile.gov.it/risk-activities/meteo-hydro/activities/prediction-prevention/central-functional-centre-meteo-hydrogeological/prediction/criticality-bulletins





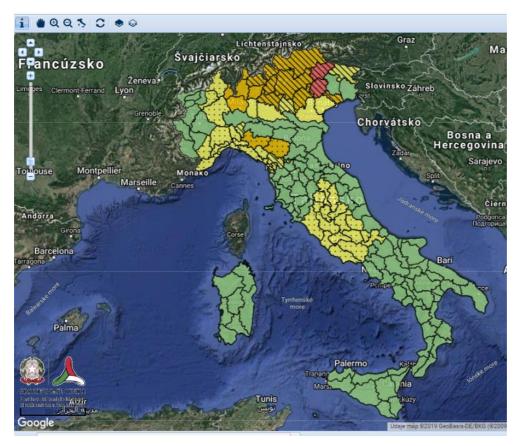


Figure 50 Bulletin of the Italian Civil Protection Agency for 27th October 2018 (issued on 2018-10-26 16:30 CEST)

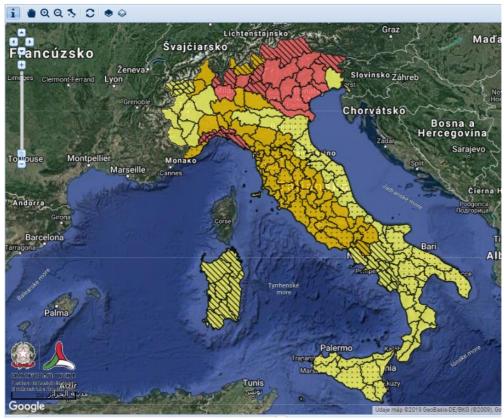


Figure 51 Bulletin of the Italian Civil Protection Agency for 29th October 2018 (issued on 2018-10-29 16:00 CEST)





5 Conclusions

5.1 Summary of flood events

Flood event in Spain

At least one person died and dozens were rescued or evacuated after the mid-October flash floods in the Valencia region. The heavy precipitation on the 18th of October 2018 hit particularly the Valencia region, where Vinaròs in the Castellón Province recorded 374.6 mm in 24 hours. Although the soil moisture conditions were rather normal, the precipitation was very intense and hence a flash flood greater than a 20-year return period occured.

The event was well predicted by EFAS. The flash flood signal firstly appeared in the 2018-10-14 12:00 UTC model run and increased in the next runs. Since the lead time was more than 72 hours, the notifications could only be issued in the morning of the 17th of October 2018 (based on the 2018-10-16 12:00 UTC run). In summary EFAS Dissemination Centre issued 3 Informal and 2 Flash Flood Notifications.

According to the EFAS partner CHJ EFAS notifications were useful. EFAS forecasts were in accordance with the information from the national system, which forecasted an event at the same time.

Flood event in Italy

Floods in the northern Italy were caused by an intensive precipitation occurring from the 27th to 29th of October 2018. The maximum amount of this 3-day event was 269 mm and was observed in Trento.

EFAS predicted the flooding 7 days in advance. The first Flood Notification was sent (hence fulfilling all necessary conditions) with 4 days lead time on the 25th of October 2018. Moreover, 5 Formal, 3 Informal and 6 Flash Flood Notifications for 8 regions were issued.

Results of the LISFLOOD model forced by COSMO-LEPS were better than the ones forced by ECMWF-ENS during this event.

5.2 Lessons-learnt from the detailed assessment

Formal Flood Notifications can be issued based on the hydrological forecasts driven by the COSMO-LEPS meteorological model since September 2017. Prior to September 2017, only Informal Notifications could be sent based on the COSMO-LEPS. However, the floods in Italy in October 2018 highlight the importance of this decision; in this case, no Formal Flood Notification would have been issued based on ECMWF-ENS forcing only.

Targeting only at the precipitation forecasts, the volumetric difference between the various meteorological models (ECMWF/ECMWF-ENS, and DWD/COSMO-LEPS) is not evident. However, the differences in the predicted hydrographs between the different models were significant. This could be due to the spatiotemporal distribution of the precipitation events. We note that the models different in spatial resolution also, which could result in better representation of the spatial characteristics of the event. This should be further investigated.

In addition, a weak persistency of flash flood signal was observed. Nevertheless, a Flash Flood Notification was initially issued and then deactivated in consequent model run (in the Verona region on the 27th of October 2018). The forecasted signal adequate for a notification occurred more frequently, and therefore the criterion for issuing a Flash Flood Notification was modified in December 2018: "If the lead time is > 48 hours (from the run time), flash flood points within the same grouped





geographic vicinity should meet the other criteria for two or more consecutive forecasts. If the lead time is shorter, a notification is issued based on only one run."

Background information in the shapefiles of the Po river basin often stated "river Po" instead of the actual name of the corresponding tributary. Such cases were noticed and reported by a forecaster on duty and changed by COMP during this specific flood event (Toce river, Sessia, Bialera Mellea, Stura di Demonte). A careful assessment of the point information can avoid sending notifications including wrong river names.

Due to an error in the CoA status, a Flood Notification for Isonzo/Soča was sent to the Italian partners. Isonzo was not a part of the EFAS partner network in that time. Note that since January 2019 the entire Italian territory is covered by an EFAS partnership.

Requests for feedback regarding all Formal Notifications were sent after the events, and only one feedback report was returned completed. It is generally expected that signing a CoA with the new national Italian partner *Dipartimento della Protezione Civile*, the EFAS Dissemination Centre will receive responses to the future Italian Formal Notifications.

Cooperation between forecasters on duty is essential, particularly during complicated situations. During internal trainings, it is expected to highlight the importance of communicating and discussing questions and challenges with experienced forecasters. In case a quick feedback is needed, it is essential to contact the other forecasters by phone, as mentioned already in the instructions to the forecasters on duty.

5.3 Moving forward

Experience from the detailed assessment of the flood events in Spain and Italy, the following recommendations are concluded for further improving the EFAS service:

Flood probability layer in the new EFAS-IS is displayed based only on ECMWF-ENS. This is an important layer that presents the flood development throughout the entire flow, from the spring to its mouth. The event in Italy highlights the need to display information also based on the COSMO-LEPS predictions, as it better predicted the flooding.

Provision of hydrological data from the Italian partner could not only assist on the LISFLOOD model verification, but assimilation of local information can improve the results on the Italian rivers. Real-time hydrographs (post-processed forecast hydrographs) could be calculated as well. The joint DISS and HYDRO visit to the Italian Civil Protection is already planned for September 2019, during such issues will be discussed.

It would be of added value to enable merging the *Latest 24-hours precipitation* layer based on the SYNOPS stations and the *Observed precipitation* layer that provides a spatial precipitation distribution based on interpolated observations. This could help forecasters and partners to better assess the initial catchment conditions. Currently the *Observed precipitation* layer is one day behind.

Grouping of the Flash Flood reporting points into a single EFAS Flash Flood Notification reduces the number of notifications sent to the partners. However, it has occurred that this rule is not always respected mainly because:

- Grouped notification cannot be deactivated for individual regions, only as groups.
- In case there are many flash flood points visualised, it is difficult to identify which points belong to the same region. Marking the already checked points in the new EFAS-IS has simplified the analysis.

It is therefore recommended to allow the deactivation of an individual region from the grouped notification, whilst a layer with regional borders would be a great help for forecasters.





We finally suggest to review whether the information *Percent of affected area susceptible to landslides* in the Flash Flood Notification e-mail is sufficient in case a single flash flood point in the same region is selected among many points by the forecaster on duty. This percentage describes the susceptibility of the drainage area of the selected point only.

ANNEX 1

Floods in the region of Valencia, October 2018: Timeline of issuance of EFAS Flood notifications

17.10.2018

EFAS Informal Flood Notifications

10:42 CEST

Spain: EFAS predicted a high probability of flooding for the **Millars** basin from Thursday the 18th of October 2018 onwards. The earliest peak was predicted for Friday the 19th of October 2018. An EFAS Informal Flood Notification was sent on 2018-10-17. It was only informal due to the large forecast uncertainty and the short forecast lead-time (< 48 hours).

12:00 CEST

Spain: EFAS predicted a high probability of flooding for the **Coastal catchment western Mediterranean sea** from Friday the 19th of October 2018 onwards. The earliest peak was predicted for Saturday the 20th of October 2018. An EFAS Informal Flood Notification was sent on 2018-10-17. It was only informal due to the large forecast uncertainty.

EFAS Flash Flood Notifications

6:07 CEST

Spain: EFAS predicted a low probability of extreme precipitation with possible flash flooding for the **Castello** and **Valencia regions**. The earliest peak is predicted for Friday the 19th of October 2018. The EFAS flash flood notification was sent on 2018-10-17.

11:53 CEST

Spain: EFAS predicted a low probability of extreme precipitation with possible flash flooding for the **Valencia** region. The earliest peak is predicted for Friday the 19th of October 2018. The EFAS flash flood notification was sent on 2018-10-17.

18.10.2018

EFAS Informal Flood Notification

13:55 CEST

Spain: EFAS predicted a medium probability of flooding for the **Júcar** river (South-East coast basin) from Friday the 19th of **October** 2018 onwards. The earliest peak was predicted for Saturday the 20th of October 2018. An EFAS Informal Flood Notification was sent on 2018-10-18. It was only informal due to the large forecast uncertainty and the short forecast lead-time (< 48 hours).





ANNEX 2

Feedback on the EFAS notifications in the region of Valencia, October 2018

From: Peter.SALAMON@ec.europa.eu <Peter.SALAMON@ec.europa.eu>

Sent: Friday, October 19, 2018 5:17 PM

To: comp@efas.eu; JRC-EMS-EFAS@ec.europa.eu; efas@rws.nl; efasofficeronduty@smhi.se;

efas@shmu.sk; efas@deltares.nl; efas.mdcc@dwd.de; hydro@efas.eu

Subject: FW: Warnings de EFAS

Dear all,

For those of you that understand Spanish see below the positive feedback (highlighted in yellow) from the Spanish government on the performance of EFAS forecasts for the flood event from yesterday/today in Valencia/Castellon.

Keep up the good work & have a nice WE!

Peter

PETER SALAMON PhD

European Commission

Directorate-General Joint Research Centre Disaster Risk Management Unit

TP 122, Via Enrico Fermi 2749 I-21027 Ispra/Italy

+39 0332 78 6013 Fax: +39 0332 78 6653

peter.salamon@ec.europa.eu

Web: https://ec.europa.eu/jrc/en/research-topic/floods?search

From: ROSA MARIA TORRES SAAVEDRA [rosamaria.torres@correo.gob.es]

Sent: 19 October 2018 12:36

To: Daniel Sempere; SALAMON Peter (JRC-ISPRA)

Cc: apenac@procivil.mir.es; xavi.llort@hyds.es; Cobo Gil, Carmen

Subject: Re: Warnings de EFAS

Hola a todos, gracias por vuestro trabajo y preocupación.

Peter, sólo decirte que las predicciones EFAS se han cumplido plenamente e incluso se han quedado un poco cortas ya que el período de retorno de 20 años se ha dado en el 80 % de los cauces de la provincia y sigue. Los daños serán muy parecidos a los de octubre de 2000 con avenidas en los principales ríos de la provincia de Castellón...con daños en infraestructuras y algunas viviendas.

El seguimiento con A4CAT y EFAS ha sido muy bueno y lo he podido seguir al minuto.





Daniel gracias por tu ayuda.

En cuanto al crowdsourcing hay que estudiarlo porque me ha parecido escaso el $n^{\rm o}$ de tweets.

Aunque localizados en la zona de mayor afectación.

He ido documentando todo. Lo veremos en Barcelona si queréis.

Rosa





ANNEX 3

Floods in northern Italy, October-November 2018: Timeline of issuance of EFAS Flood notifications

This is sort with regard to the appearance of information on possible flooding and available public information in the ERCC Overview

(ERCC Overview is published by 8:30 CEST)

24.10.2018

Information to ERCC in the Overview - riverine

Italy: EFAS predicted a high probability of flooding for the **Tagliamento** basin from Monday the 29nd of October 2018 onwards. The earliest peak was predicted for Monday 29th of October 2018. The area is out of the EFAS partner region.

25.10.2018

EFAS Formal Flood Notifications

7:21 CEST

An EFAS Formal Flood Notification has been sent for

ITALY (Po basin) - **Mincio** on 2018-10-25.

The earliest flood peak is expected for Monday 29th of October 2018.

15:25 CEST

An EFAS Formal Flood Notification has been sent for

ITALY (Po basin) - Adda on 2018-10-25.

The earliest flood peak is expected for Monday 29th of October 2018.

Information to ERCC in the Overview - riverine

Italy: EFAS predicted a high probability of flooding for **Livenza** river from Monday the 27nd of October 2018 onwards. The earliest peak was predicted for Monday 29th of October 2018. The area is out of the EFAS partner region.

26.10.2018

EFAS Formal Flood Notifications

12:25 CEST

An EFAS Formal Flood Notification has been sent for

ITALY (Po basin) - Ticino on 2018-10-26.

The earliest flood peak is expected for Tuesday 30th of October 2018.

13:10 CEST

An EFAS Formal Flood Notification has been sent for

ITALY (Po basin) - Sesia 2018-10-26.

The earliest flood peak is expected for Monday 29th of October 2018.





EFAS Informal Flood Notification

13:06 CEST

Italy: EFAS predicts a medium probability of flooding for **Toce** river from Sunday the 28th of October 2018 onwards. The earliest peak is predicted for Monday 29th of October 2018. The EFAS Informal Flood Notification was sent on 2018-10-26. This EFAS Flood Notification is only informal due to the small affected drainage area.

Information in the Overview - riverine

Italy: EFAS predicts a high probability of flooding for **Isonzo**, **Brenta and Adige** rivers from Monday the 29nd of October 2018 onwards. The earliest peak was predicted for Monday 29th of October 2018. The area is out of the EFAS partner region.

Information in the Overview - flash flood

Italy: EFAS predicts a low probability of extreme precipitation with possible flash flooding for **Verona** and **Trento regions**. The earliest peak is predicted for Sunday 28th of October 2018. The area is out of the EFAS partner region.

27.10.2018

Public information in the Overview

Italy: Warning level 3/3 has been issued for **Veneto** region and 2/3 for **Lombardia**, **Emilia Romagna** and **Trentino Alto Adige regions**.

EFAS Informal Flood Notification

8:06 CEST

Slovenia/Italy: EFAS predicts a high probability of flooding for **Soca** river (Isonzo/Soca basin) from Sunday the 28th of October 2018 onwards. The earliest peak is predicted for Monday 29th of October 2018. The EFAS Informal Flood Notification was sent on 2018-10-27. This EFAS Flood Notification is only informal due to the short forecast lead-time (< 48 hours) and the small affected drainage area.

EFAS Flash Flood Notification

7:12 CEST

Italy: EFAS predicts a low probability of extreme precipitation with possible flash flooding for **Verona** region. The earliest peak is predicted for Sunday 28th of October 2018. The EFAS Flash Flood Notification was sent on 2018-10-27.

Information in the Overview - flash flood

Italy: EFAS predicts a low probability of extreme precipitation with possible flash flooding for **Trento** region. The earliest peak is predicted for Monday 29th of October 2018. The area is out of the EFAS partner region.

28.10.2018

Public information in the Overview

Italy: Warning level 3/3 has been issued for **Veneto** and **Friuli Venezia Giulia** regions and 2/3 for **Lombardia**, **Emilia Romagna**, **Liguria** and **Trentino Alto Adige regions**.





EFAS Flash Flood Notification

13:28 CEST

Italy: EFAS predicts a low probability of extreme precipitation with possible flash flooding for **Verona** and **Pavia** regions. The earliest peak is predicted for Monday 29th of October 2018. The EFAS Flood Notification was sent on 2018-10-28.

Information in the Overview - flash flood

Italy: EFAS predicts a low probability of extreme precipitation with possible flash flooding for **Treviso** region. The earliest peak is predicted for Sunday 28th of October 2018. The area is out of the EFAS partner region.

29.10.2018

Public information in the Overview

Italy: Warning level 3/3 has been issued for Friuli Venezia Giulia, Liguria, Lombardia, Trentino Alto Adige and Veneto regions and 2/3 for Emilia Romagna and Piemonte regions.

EFAS Flash Flood Notifications

6:33 CEST

Italy: EFAS predicts a low probability of extreme precipitation with possible flash flooding for **Alessandria** region. The earliest peak is predicted for Tuesday 30th of October 2018. The EFAS Flash Flood Notification was sent on 2018-10-29.

12:51 CEST

Italy: EFAS predicts a low probability of extreme precipitation with possible flash flooding for **Brescia** region. The earliest peak is predicted for Monday 29th of October 2018. The EFAS Flash Flood Notification was sent on 2018-10-29.

30.10.2018

Public information in the Overview

Italy: Warning level 3/3 has been issued for Friuli Venezia Giulia, Liguria, Lombardia, Trentino Alto Adige and Veneto regions and 2/3 for Emilia Romagna, Piemonte, Friuli Venezia Guilia, Lombardia, Liguria and Veneto regions.

31.10.2018

Public information in the Overview

Italy: warning level 3/3 has been issued for **Trentino Alto Adige and Veneto regions** and 2/3 for **Liguria** and **Veneto** regions.

EFAS Flash Flood Notifications

6:37 CEST

Italy: EFAS predicts a low probability of extreme precipitation with possible flash flooding for **Alessandria** and **Cuneo regions**. The earliest peak is predicted for Thursday 1th of November 2018. The EFAS Flash Flood Notification was sent on 2018-10-31.





Information in the Overview - flash flood

Italy: EFAS predicts a low probability of extreme precipitation with possible flash flooding for **Savona** region. The earliest peak is predicted for Thursday 1st of November 2018. This area is out of the EFAS partner region.

1.11.2018

Public information in the Overview

Italy: warning level 3/3 has been issued for **Veneto** region and 2/3 for **Liguria, Lombardia, Piemonte, Trentino Alto Adige** and **Veneto** regions.

2.11.2018

Public information in the Overview

Italy: warning level 3/3 has been issued for **Veneto** region and 2/3 for **Lombardia** and **Veneto** regions.

EFAS Flash Flood Notification

7:29 CEST

Italy: EFAS predicts a low probability of extreme precipitation with possible flash flooding for **Cuneo** region. The earliest peak is predicted for Monday 5th of November 2018. The EFAS Flash Flood Notification was sent on 2018-11-02.

3.11.2018

Public information in the Overview

Italy: warning level 2/3 for Emilia Romagna, Friuli Venezia Giulia and Veneto regions.

EFAS Formal Flood Notifications

12:16 CEST

An EFAS Formal Flood Notification has been sent for

ITALY (Po basin) - **Po** on 2018-11-03.

The earliest flood peak is expected for Thursday 8th of November 2018.

4.11.2018

Public information in the Overview

Italy: warning level 2/3 has been issued for Emilia Romagna, Friuli Venezia Giulia and Veneto regions.

5.11.2018

Public information in the Overview

Italy: warning level 2/3 for Emilia Romagna, Veneto, Lazio and Piemonte regions.





EFAS Informal Flood Notification

12:16 CEST

Italy: EFAS predicts a medium probability of flooding for **Sesia** river (Po basin) from Wednesday 7th of November 2018 onwards. The earliest peak is predicted for Wednesday 7th of November 2018. The EFAS Informal Flood Notification was sent on 2018-11-05. This EFAS Flood Notification is only informal due to the large forecast uncertainty.

6.11.2018

none relevant information

7.11.2018

Public information in the Overview

Italy: Warning level 2/3 for Lombardia, Piemonte and Veneto regions.

8.11. 2018

Public information in the Overview

Italy: Warning level 2/3 for Emilia Romagna and Veneto regions.





ANNEX 4

Feedback on the EFAS Formal Flood Notification for the Po river issued on 2018-10-03

EFAS Formal Notification Feedback Form

#198

COMPLETE

Collector: New link - use this (Web Link)

Started: Tuesday, December 18, 2018 6:48:36 PM Last Modified: Tuesday, December 18, 2018 6:52:41 PM

Time Spent: 00:04:05 IP Address: 158.102.162.34

Page 1

Q1 Name, organisation and email

Name Sara Pavan

Organisation AIPo

Email Address sara.pavan@agenziapo.it

Q2 Which notification (region and date the notification was issued) applies to this feedback?

EFAS Formal Flood Notifications for the Po river issued on 3rd of November 2018

Q3 Was the flood event observed? (return period equal to or larger than 2 years)

Page 2

Q4 What was the severity of the event (area, water level above land, casualties, economic damage)?

Medium

Q5 What was the location of the observed flood event (e.g. river name, coordinates, etc.)?

River Po, mainly Crescentino station

Q6 Rate accuracy of EFAS information in terms of location

Pretty much as indicated in EFAS information

Q7 What was the actual lead time (i.e. days between receiving EFAS Notification and start of the event (Q>5-year RP))? If the observed event had a return period of less than 5 years, the onset of the observed event should be estimated by your best knowledge.

3





Q8 Rate accuracy of EFAS information in terms of time	o (event on predicted day)
Q9 Rate accuracy of EFAS information in terms of magnitude	- (less severe than EFAS prediction)
Q10 What was the return period of the observed flood event?	5-9 years
Q11 What caused the flood event? (If more than one cause	se, please rank the alternatives.)
snow melting	N/A
long-term raining	1
extreme rainfall	3
soil saturation	2
ice jam	N/A
dam break	N/A
Q12 If none of these was the cause, what was the reason for the flooding event?	Respondent skipped this question
Q13 Rate the added value of the EFAS notification for your organization" (1 = No added value, I was already aware of the upcoming situation; 5 = Very helpful, thanks to the notification we were prepared to face the situation)	1
Q14 If you wish to share with us any further material of the event (e.g. photos, regional/ national reports, shapefiles, etc.) please upload them here.	Respondent skipped this question
Q15 Space for further comments	Respondent skipped this question
Q17 If you wish to share with us any further material of the event (e.g. photos, regional/ national reports, shapefiles, etc.) please upload them here.	Respondent skipped this question
Q18 Space for further comments	Respondent skipped this question
Q16 If no flood, do you have an idea why the event did not occur (reservoirs, precipitation as snow, precipitation fell in other area, forecasted precipitation did not occur, snow did not melt as fast as predicted, etc)?	Respondent skipped this question