European Flood Awareness System

DETAILED ASSESSMENT REPORT

EFAS DISSEMINATION CENTRE

Specific Contract No.3

Table of Content

Acronyms

CoA	Condition of Access
DHMZ	Croatian Meteorological and Hydrological Service
DWD	Germany's National Meteorological Service
ECMWF	European Centre for Medium-Range Weather Forecasts
EFAS	European Flood Awareness System
ERIC	Enhanced Runoff Index based on Climatology
LVGMC	Latvian Environment, Geology and Meteorology Centre
NVE	Norwegian Water Resources and Energy Directorate
NWP	Numerical Weather Predictions

1 Introduction

Flooding is the most devastating natural hazard worldwide, affecting entire countries and causing severe economic and human losses. The European Flood Awareness System (EFAS) operated by the Copernicus Emergency Management Service provides a technical forecasting service and warning capabilities crucial to increase the effectiveness of flood disaster response and enhance efficiency in preparedness-relevant decision-making. There are different drivers (e.g., antecedent catchment conditions, precipitation and its spatiotemporal properties, catchment physiographic characteristics) that contribute to flood generation, yet with a regionally variable impact to citizens and economy. It is therefore important to understand the flood generation drivers and assess the (added-value) skill of the EFAS service on predicting major events.

The weather in Europe at the beginning of autumn 2017 was influenced by several intense low pressure systems, resulting in intense precipitation events and further into flash floods. Here the EFAS detailed assessment report focuses on three such flood events over autumn 2017 affecting citizens and decision-making in a number of countries. The assessment is targeted towards Latvia (18th Sept., and 8-9th Oct.), Croatia (11-12th Sept.) and Norway (between Sept. 30th and Oct. 3rd), 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 region of interest, meteorological forecasts and antecedent conditions (soil moisture). The flash flood generation drivers are stated for each region and event together with the number of EFAS notifications sent to the partners. Overall, this assessment allows identification of service limitations and leads to a number of suggestions for further service improvements.

The report is organized as follows: Section 1 is the introduction to the report. Section 2 introduces the EFAS flash forecasting service. Sections 3 to 5 present the three flash floods events in Latvia, Croatia and Norway respectively. These sections provide information on the flood events, impacts (including media reports) and information from EFAS. Finally, Section 6 states the conclusions together with the lessons learned from this analysis and proposals for improvements of the EFAS service.

2 Description of the EFAS related work during the flood

The European Flood Awareness System 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 three different weather services, real-time weather observations from more than 5000 stations across Europe and real-time hydrological stations from more than 500 stations.

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

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

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 has access to the system after signing a Condition of Access (CoA).

2.1 EFAS flash flood forecasting

EFAS sends out warning emails to all EFAS partners potentially concerned in case of flooding and all partners within the catchment in copy. Due to the nature of probabilistic forecasting, not every EFAS notification will be followed by flooding. For Flash Flood notifications, the probability threshold has been set to 35%, which should correspond – statistically – to about 1 flash flood out of 3 notifications. Furthermore, the notification threshold is based on 20 year return period ERIC threshold. Request for feedback is sent to all partners following only EFAS Formal Flood Notifications. For Flash Flooding no feedback is requested, and hence in these three case studies, there is not feedback on the flash floods.

Flash flood warnings are generated using the methodology of the Enhanced Runoff Index based on Climatology (ERIC) [1]. 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 data. The accumulated upstream surface runoff is then calculated for every 1 km resolution river network pixel, where the upstream area is < 2,000 km^2. This calculation is performed over three different accumulation periods of 6, 12 and 24 hours, the resulting ERIC value corresponds to the maximum over each of these three accumulation periods.

The forecasters of the EFAS Dissemination Centre analyses the EFAS results every morning and discuss the situation and what notifications should be sent. The information is 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. There are different

[1] 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.

criteria to send Notifications, and given that the events of interests are Flash Flood, the criteria for issuing an EFAS Flash Flood Notification are the following:

- Catchment part of CoA
- The probability of exceeding the 20 year return period magnitude of the surface runoff index is forecasted to be equal or greater than 35%
- 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 analyzes the forecast and the predicted peak of the event)

3 Flash floods in Latvia

3.1 Description of the study area

Latvia is largely covered by lowland plains and moderate hills (Figure 1). More than half of the area is covered by forest. There are over 12,500 rivers/tributaries in Latvia with a total length of 38,000 km. The major rivers are: Daugava, Lielupe, Gauja, Venta, and Salaca. Latvia has 2,256 lakes with an area of more than 1 ha with their total area being 1,000 km^2, whilst the agricultural area is 29%[2]. Latvia experiences fairly severe winters, which begin in mid-December and end in mid-March. Average daily temperature in winter is of -6°C but extreme temperatures can reach --30°C. Snow is also a contributing factor, with snow cover lasting an average of 82 days, with an average of 177 frost-free days. July and August[3] are the warmest months, with average temperature around 16°C. Average annual rainfall is about 570 mm, with an average of 180 rainy days per year.

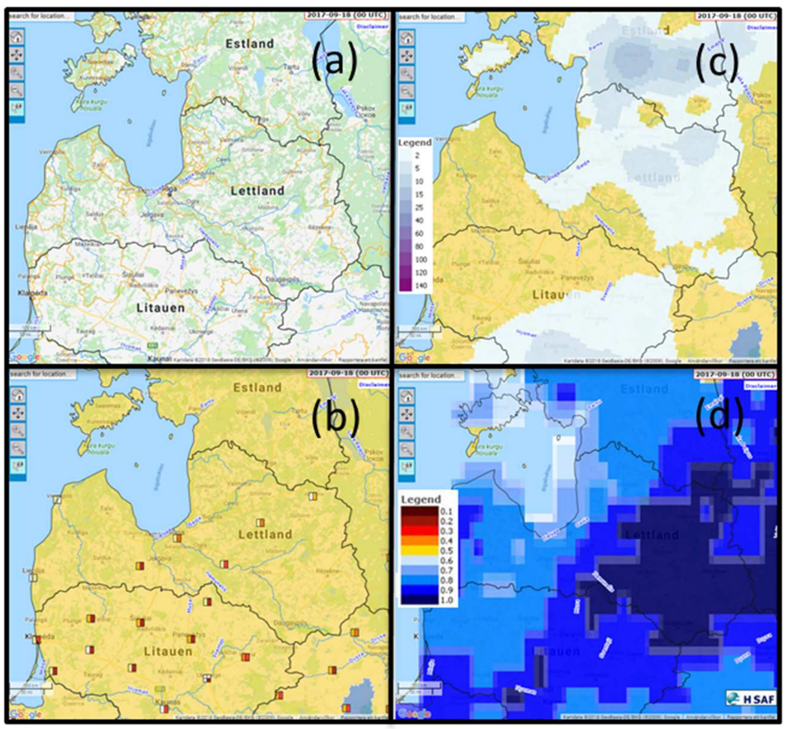

Figure 1. (a) Map of Latvia, (b) the SYNOP precipitation stations, (c) interpolated daily precipitation observations [mm] on 2017-09-18 (darker colors indicate higher precipitation amounts), and (d) relative soil moisture on 2017-09-18

3.2 Description of the flood event

In Latvia the flash flood event originated from a rainy end of August with more intense precipitation in the beginning of September. The first flash flood event occurred on September 18th and was followed by more intense precipitation on October 8th to 9th. On September 17th the soil was almost saturated in the eastern part of Latvia (Figure 2). The western part of the country was drier, especially the coastal areas. The satellite image gives a wetter picture than the LISFLOOD simulations in EFAS. Before the precipitation on October 8th to October 9th the soil moisture in almost all parts of Latvia was 70 to 90% (see Figure 3).

[2] https://en.wikipedia.org/wiki/Latvia

[3] http://www.riga.climatemps.com/graph.php

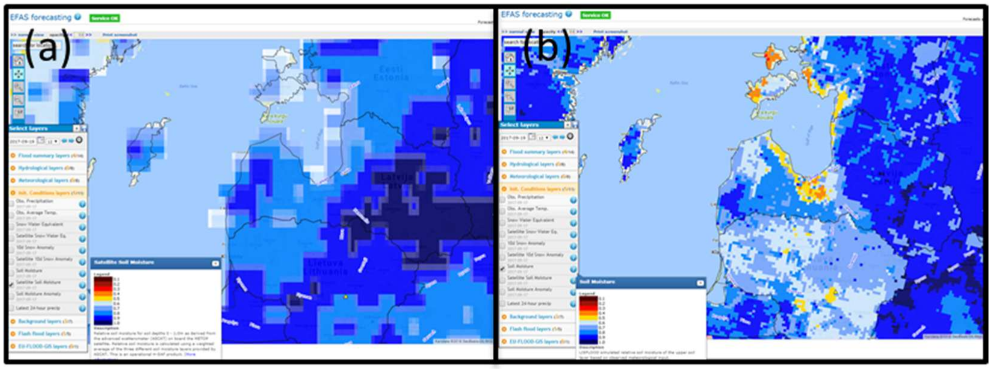

Figure 2. (a) Satellite soil moisture for September 17th, and (b) simulated soil moisture (LISFLOOD) for September 17th from EFAS-IS.

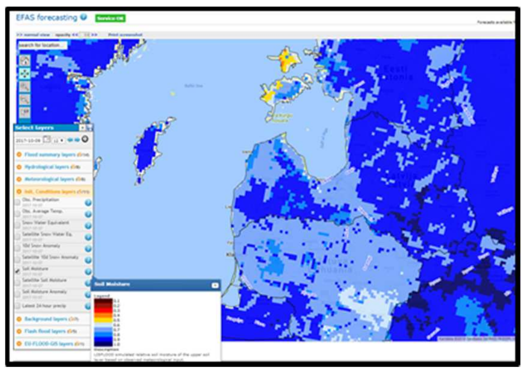

Figure 3. Simulated soil moisture (LISFLOOD) for October 7th from EFAS-IS.

The flash flooding in central and in the north of Latvia on September 18th and in the north- west of Latvia on October 8th and 9th was caused by intense precipitation. Augstasils in eastern Latvia received 131 mm precipitation during 4 days starting on the September 9th [4]. Until the flood event, the month September had fairly little precipitation. August on the other hand was wet with river flooding in Latgale and eastern Vidzeme regions [5].

On September 17th 18:00 UTC COSMO-LEPS precipitation forecast (mm/6h) showed up to 30 mm precipitation per 6 hours in Latvia but only little precipitation in the coastal area in northern Kurzeme region (see Figure 4). In particular, Dobele station in eastern Zémgale region (central area of the country) got 49 mm on September 18th according to the Latvian Environment, Geology and Meteorology Centre (LVGMC) which matches the precipitation forecasts in Figure 4.

The COSMO-LEPS precipitation forecast (mm/6h) for the period October 8th to 10th showed no big signs of the high precipitation volumes in the beginning of October. According to data from LVGMC, Ventspils station in northern Kurzeme region (western Latvia) got about 26 mm on October 8th, 6 mm on October 9th and 11.4 mm on October 10th. Liepāja in south-west of Kurzeme region got 28.8 mm on October 8th, 11.3 mm on October 9th and 5.8 mm on October 10th.

[4] www.AccuWeather.com

[5] www.baltic-course.com

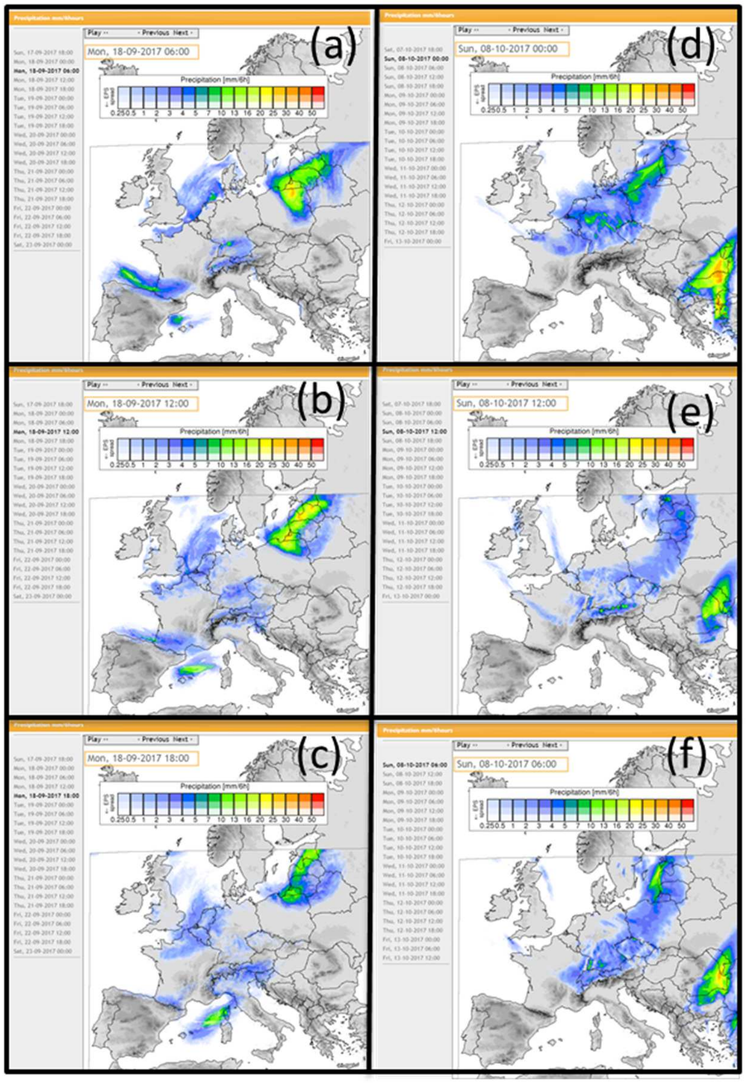

Figure 4. Precipitation forecasts: (a-c) model initialized on September 17th at 18:00 UTC and forecasting the September 18th event at 06:00, 12:00 and 18:00 UTC respectively, (d-e) model initialized on October 7th at 18:00 UTC and forecasting the October 8th event at 00:00 and 12:00 UTC respectively, and (f) model initialized on October 8th at 06:00 UTC and forecasting the first 6 hour precipitation.

3.3 Impacts - based on media reports

The night between September 18th and 19th heavy precipitation across Latvia caused damage on roads and on crops. Kalnciems south west of Riga got more than the month's rainfall in a day and a half. In river Vaidava at Ape in northern Latvia the water lever increased by 1.2 m in one day.[6]

3.3.1 Media example #1

"Latvian farmers estimate flood damage at 50-60 mln euros"

Published on Wednesday September 20th

[6] https://eng.lsm.lv/article/weather/weather/more-rain-more-flooding-more-disruption.a250650/

(by Xinhua| 2017-09-20 00:35:44|Editor: huaxia [7])

"*The damage Latvian farmers have suffered from this fall's heavy rainfalls and subsequent flooding has reached an estimated 50 to 60 million euros (59 to 72 million U.S. dollars)*" the head of the Latvian farmers' association said on public television.

The association's head Juris Lazdins said that around 80% of grain crops might have been harvested already, but that 20% remain on the fields, and most probably, many of them will be lost due to the bad weather conditions. The farmers still hope though that the rain will subside and at least part of the crops can be saved, he continued.

"*Under EU rules, farmers can apply for EU assistance if their losses reach a certain percentage of gross domestic products. In Latvia's case, the loss would have to be roughly 140 million euros to qualify for the assistance*" Lazdins said.

According to Lazdins, Latvia, along with its Baltic neighbors Lithuania and Estonia could still claim EU compensations as a particular region hit by a natural disaster.

Farmers have been struggling to harvest their crops in all Latvia this year. The Latvian agriculture ministry had considered on applying to the European Commission for assistance together with Estonia and Lithuania.

3.3.2 Media example #2

"More rain, more flooding, more disruption"

Published on Tuesday September 19th

(by eng.lsm.lv *(Latvian Public Broadcasting)* [8])

Continued heavy rain overnight from September 18 to 19 has seen water levels rising across Latvia, more damage to crops and continued traffic problems. Areas affected by flooding will likely spread on Tuesday, while impassable roads and landslides are also to be expected, LVGMC warns.

The fastest rise in water levels has been in the River Vaidava at Ape in northern Latvia, where the water level has risen by 1.2 meters since Monday and continues to rise sharply. Many other rivers are also recording a rise of one meter over the usual level.

Meanwhile at Kalnciems to the south of Riga, it took just a day and half for the normal monthly rainfall amount to be exceeded. State roads directorate spokeswoman Anna Kononova, told LTV's Morning Panorama news show September 19 that overnight the situation on the roads has not changed significantly - two local roads in Vilaki and Livani districts are still closed. On Monday some sections of road section in Ogre district near Meņģeli, were flooded too. Forecasters are holding out an olive branch of hope as jokes about preparing an ark flood social media with promises that the weekend weather will be warm and sunny.

3.3.3 Media example #3

"Rivers overflowing in Latvia, more areas threatened by floods"

Published on Tuesday September 19th

(by [9])

[7] http://www.xinhuanet.com/english/2017-09/20/c_136621917.htm

[8] https://eng.lsm.lv/article/weather/weather/more-rain-more-flooding-more-disruption.a250650/

[9] http://www.leta.lv/eng/home/important/133C8A79-052C-FA67-080F-EE0D706BD720/

Photo 1. Flooded area in Latvia.

Water levels are rising in the rivers of Latvia, and many floodplains have already been flooded, according to Latvian Environment, Geology and Meteorology Center. In the Daugava basin, water level has increased the most in the Ogre River - 1.3 meters since Monday. Water levels are also rising fast in the Maza Jugla and Liela Jugla rivers.

Floodplains along the Aiviekste River have been flooded since August, and the water level in the river has increased another 20 to 24 centimeters over the past 24 hours. Floodplains in the lower reaches of the Dubna have been flooded again this week. The water level has also increased in other Daugava basin rivers, including by almost one meter in the Pededze.

Floodplains in the upper reaches of the Gauja have also been flooded. The water level in the Vaidava has risen 1.6 meters since Monday and in Tirza River at Lejasciems - 1.3 meters. Water levels in the Lielupe and Venta have increased by more than one meter sine Monday. The water level in the Barta has increased 2.5 meters since last Tuesday.

Water levels in the small rivers in Zemgale, Vidzeme and Latgale provinces are expected to rise by another meter today, while water levels in the rivers near Riga by about a half-meter. Water levels in the Gauja and Lielupe will also increase at least half-a-meter today, hydrologists predict.

3.4 EFAS flash flood information

Flash flood event of September 13th

Signs of the intense precipitation event in Latvia emerged in EFAS-IS on September 10th with the 00:00 UTC forecast. A probability of 14% to 20% was forecasted in Vidzeme region for a precipitation event causing a runoff that would exceed the 20 year return period. For the Pieriga region the probability for a runoff exceeding the 20 year return period was 16%. The event was forecasted to start on September 13th around 06:00 UTC. Only the 12:00 UTC forecast on September 12th exceeded the 35% likelihood, i.e. the forecast showed 41% likelihood for an event exceeding the 20 year return period in Vidzeme region. No notification was sent for the event on September 12th to 13th, because during the analysis (morning September 13th) the event had already passed.

Flash flood event of September 18th

The first signs of the intense precipitation event on September 18th emerged in EFAS-IS on September 15th at 12:00 UTC forecast. Flash flood reporting points with low probability for a 5 year event emerged for Vidzeme and Pieriga regions. In the next model run/forecast at 00:00 UTC the probabilities were slightly higher than in the previous day and continued to increase at the 12:00 UTC forecast. The forecast on September 17th 00:00 UTC clearly indicates a flash flood in Vidzeme, and Pieriga regions of the Aiviekste river (Figure 5), with the probability for an event of greater than 20 years return period being up to 66% and 40% respectively. Based on this forecast a flash flood notification for Pieriga and Vidzeme regions was sent on September 17th 13:50 CEST. The next forecast shows an 81% probability for flash flooding in the upstream region of the Gauja river. The next two model runs/forecasts confirmed the signal. The probabilities were high up to 66% in the northern part of the Vidzeme region but no notification was issued for the upstream region until after the 12:00 UTC run when the probability was up to

91% for an event exceeding the 20 years return period threshold (in this case the peak was forecasted to reach a 500 years return period value) for the Gauja river. The event peak was predicted for September 18th (Figure 5). In addition, the 17th Sept. 00UTC run showed a 49% probability of flash flooding for the Kurzeme region. High probabilities were also similarly predicted for the Zemgale region at the September 17th 12:00 UTC run. Notifications were not issued, because EFAS-IS considered those points/regions as outside of EFAS partner regions.

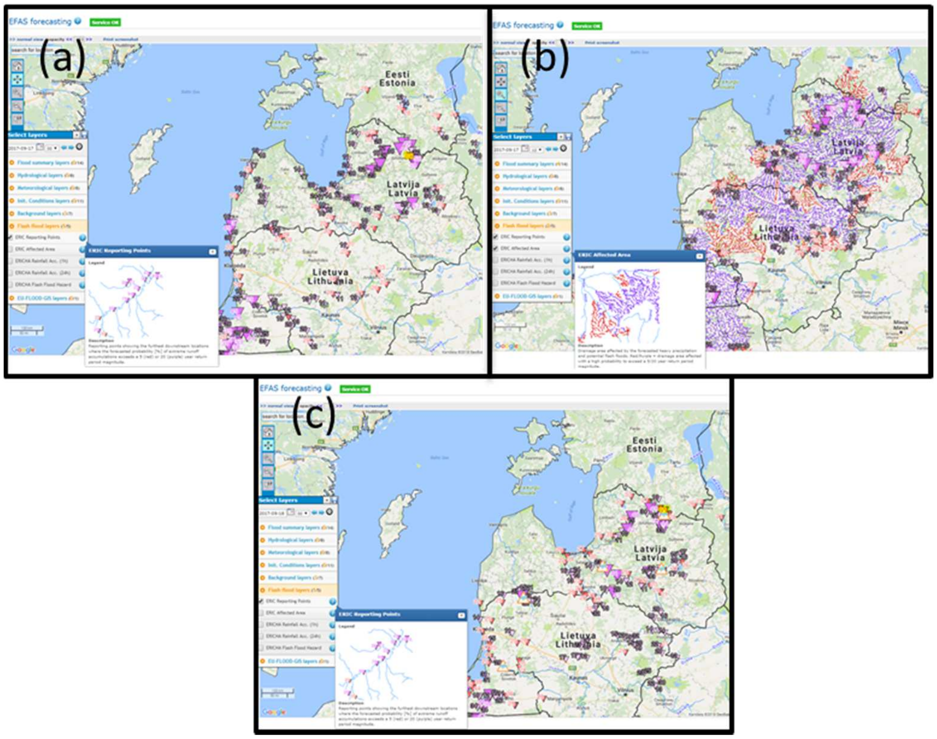

Figure 5. The forecast on: (a) September 17th 00:00 UTC with max 66% probability highlighted in yellow, (b) forecasted affected area from EFAS-IS for September 17th 12:00 UTC, and (c) September 18th 00:00 UTC with flash flood notifications for rivers Ogre, Aiviekste and Gauja, and max 60% probability for river Gauja marked with yellow.

Flash flood event of October 8th to 9th

The first signs of the precipitation event on October 8th to 9th emerged in EFAS-IS with the 00:00 UTC forecast October 7th. The date for the event was estimated to be October 8th on the coast in Kurzeme but to a later date for the area north of Riga. Then with the 00:00 UTC forecast on October 8th the risk for a big precipitation event was no longer there. Only with the 12:00 UTC forecast October 9th (Figure 6 (d)) when the precipitation storm already was ongoing a new reporting point showing 53% probability for an event with more than 20 year return period emerged in EFAS-IS. In the next model run/forecast the probability had risen to 66% in a reporting point south of the situation for the notification. The forecast was for October 10th for a flash flood on the coast north of Riga. A flash flood notification was issued on October 10th. The forecasted affected areas in EFAS-IS for the September and October events are shown in Figure 6.

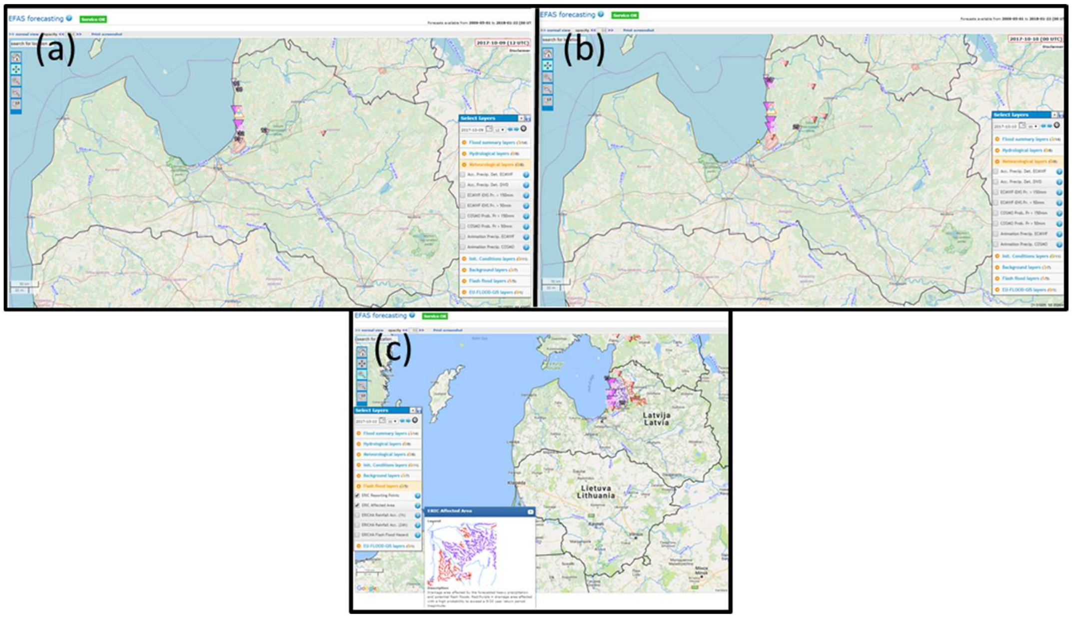

Figure 6. The forecast on: (a) October 9th 12:00 UTC with max 53% probability, (b) October 10th 00:00 UTC with max 66% probability, and (c) forecasted affected area from EFAS-IS for October 10th 00:00 UTC.

The list of Flash Flood Notifications issued by the Dissemination Centre is given in Table 1.

Table 1. Flash Flood Notifications for the Latvia event.

#	Date of ERCC overview	Comments	Number of notifications issued
1	2017-09-18	EFAS predicts a high probability of extreme precipitation with possible flash flooding for Pieriga Region and Vidzeme Region. The earliest peak is expected on Monday 18th of September 2017 12:00 UTC. The EFAS Flash Flood Notifications were sent 2017-09-17.	3
2	2017-10-10	EFAS predicts medium probability of extreme precipitation with possible flash flooding for the Pieriga region. The earliest peak is predicted for Wednesday 11th of October 00:00 UTC. An EFAS Flash Flood Notification was sent on 2017-10-10.	1

4 Flash floods in Croatia

4.1 Description of the study area

The hilly northern parts and the flat plains of Slavonia in the east are traversed by major rivers such as Sava, Drava, Kupa and Danube (Figure 7). The central and southern regions near the Adriatic coastline and islands consist of low mountains and forested highlands. Karst topography makes up about half of the country. There are many deep caves in Croatia. Forty nine caves are deeper than 250 m of which fourteen are deeper than 500 m and three deeper than 1,000 m.[10] Zadar has a monthly average of 105 mm precipitation in September.[11]

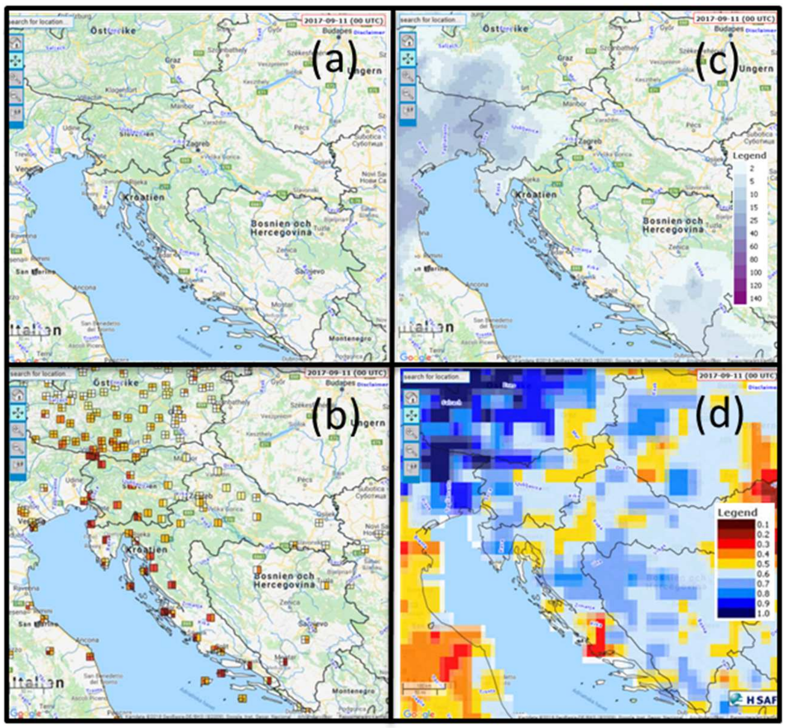

Figure 7. (a) Map of Croatia, (b) the SYNOP precipitation stations, (c) interpolated daily precipitation observations [mm] on the 2017-09-11 (darker colors indicate higher precipitation amounts), and (d) relative soil moisture on the 2017-09-11.

4.2 Description of the flood event

From September 11th to 12th torrential rainfall close to 280 mm in 24 hours fell in Zadar at the Dalmatian coast in Croatia. A well developed low pressure system was formed in the Gulf of Genoa the day before the storm, and the precipitation that fell resulted in a flash flooding. There were dry soil conditions for Zadar at the end of August (see Figure 8) and in the first part of September. Three days of precipitation in Zadar before the rainstorm on September 11th increased the soil moisture content to around 50%.

[10] https://en.wikipedia.org/wiki/List_of_caves_in_Croatia

[11] https://en.wikipedia.org/wiki/Zadar

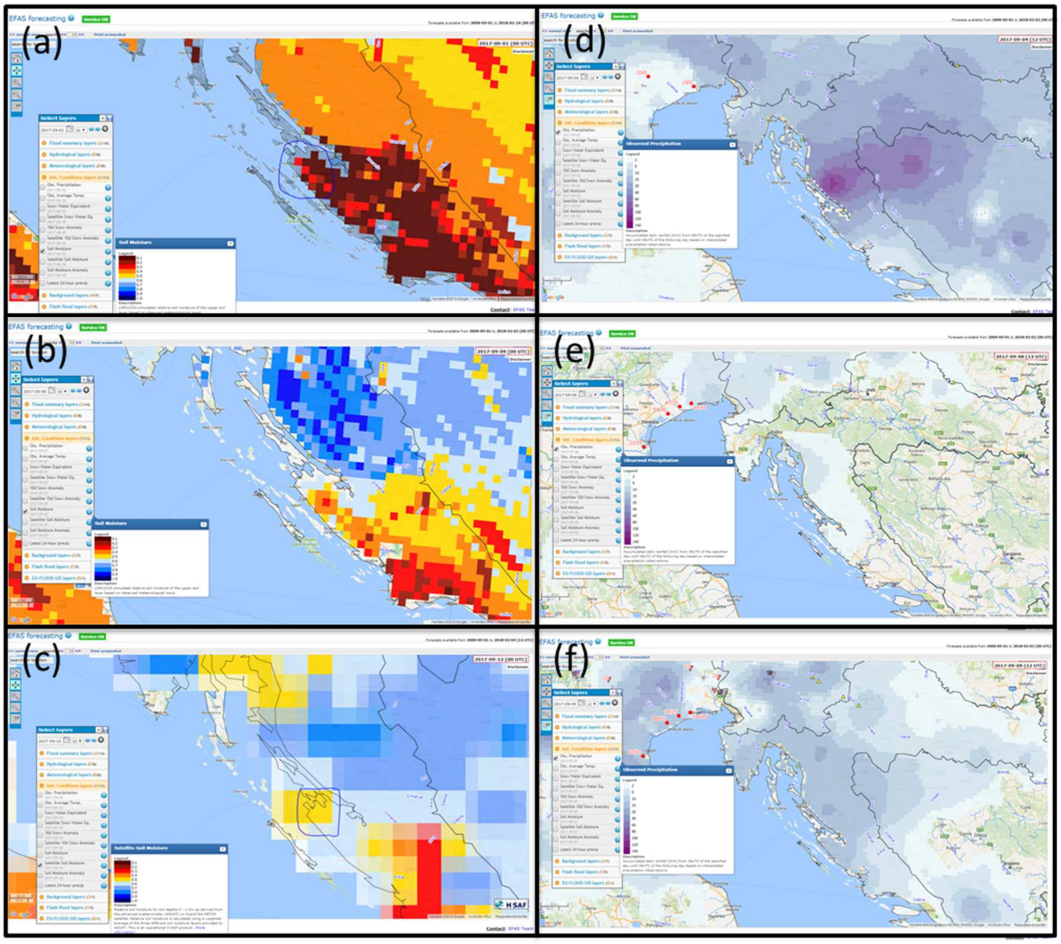

Figure 8. (a-b) Modelled soil moisture (LISFLOOD) for August 30th and September 7th (Zadar encircled by a blue circle), (c) Soil moisture from satellite for September 10th (Zadar encircled by a blue circle), (d-f) accumulated daily precipitation for September 2nd, 6th and 7th respectively from EFAS-IS.

Rainfall levels recorded by the Croatian Meteorological and Hydrological Service (Državni hidrometeorološki zavod; DHMZ):

279.6 mm in 24 hours Zadar Airport - September 11 to September 12, 2017	213.4 mm in 24 hours Zadar City - September 11 to September 12, 2017

The reasons for the formation of this mesoscale convective system were [12]:

- Continuous flow of moist air from the south in the lower layers of the atmosphere.
- Very high instability caused by very warm Adriatic sea (surface temperature of 25 °C), consequently high moisture levels in the low layers, warm advection in lower layers and cold advection in higher layers.
- Strong deep layer wind shear.
- Convergence of southeast and southwest winds in the Adriatic, which helped lift warm, moist air.

[12] https://www.eumetsat.int/website/home/Images/ImageLibrary/DAT_3760829.html

The COSMO-LEPS precipitation animation in EFAS-IS (Figure 9) shows maximum 20 mm in 6 hours for September 11th until 18 UTC and after 18 UTC about 5 mm in 6 hours, which is less than a quarter of the precipitation that actually fell. Still about 65 mm precipitation during one day is significant.

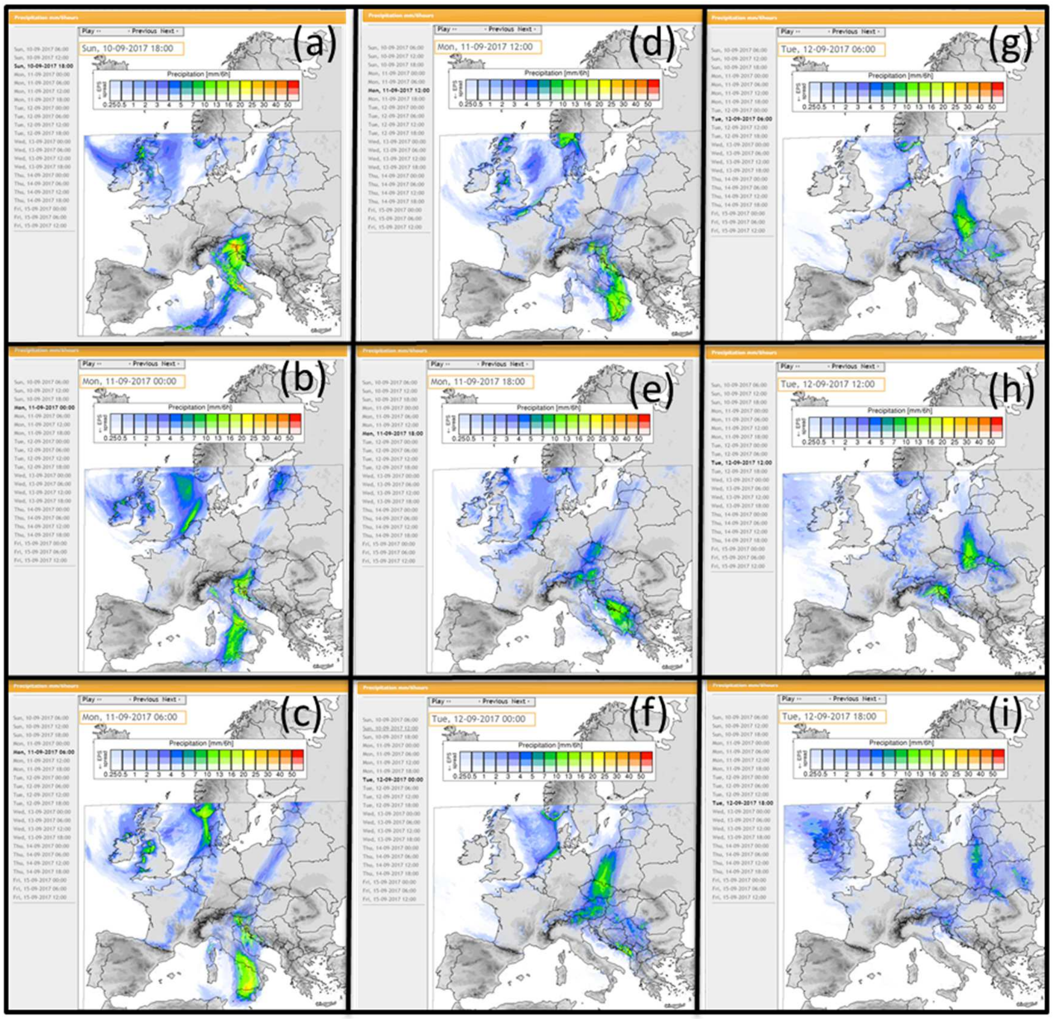

Figure 9. Precipitation COSMO-LEPS forecasts for (a) September 10th at 18:00 UTC, (b-e) September 11th at 00:00, 06:00, 12:00, 18:00 UTC respectively, (f-i) September 12th at 00:00, 06:00, 12:00, 18:00 UTC respectively. The model is initialized on September 10th at 06:00 UTC.

4.3 Impacts - based on media reports

Many roads, schools and hospitals in Zadar were closed as a result, whilst a bridge was completely destroyed by raging flood water. Local emergency services received over 1,000 calls for assistance. Authorities and emergency services have helped drain 127 flooded buildings September 11th to September 12th.

Local media claims that 242 mm fell in just 4 hours. According to DHMZ, 279.6 mm fell in 24 hours to 12 September. DHMZ says the average rainfall for the month of September in Zadar is 105 mm. In particular, there has been quite some strong spatial precipitation variability, with a meteorological station in Zemunik (Zadar airport) measuring 265mm/6h and in Zadar town measuring 188mm/6h. According to DHMZ an event of 6 hours duration and 100 years return period is 187 mm.

4.3.1 Media example #1

"Heavy Rain and Flash Flood Hits Zadar"

Published on Monday September 11th

(by Sonja Babic [13])

The report highlights that:

Roads, cellars, business premises, buses, schools are flooded.

More rain fell in 2 h than in the previous 2 months -190 liters per square meter.

- Parts of Zadar hospital have been flooded as well as Krešimir Ćosić sports hall.
- The heavy rain caused a traffic collapse and has left few neighborhoods without electricity and water and with phone lines and the internet cut off.
- All the ground floor business premises located at Relja, Jazine and Lipotica are ruined and the situation is similar elsewhere in the city.
- A shopping center Supernova suffered substantial damage; the water filled the underground garage and captured the cars.

4.3.2 Media example #2

"Croatia – Floods in Zadar After 280mm of Rain in 24 Hours"

Published on Tuesday September 12th

(by Richard Davies [14])

Torrential rainfall of almost 280 mm in 24 hours fell in Zadar, Croatia, causing damaging floods in the city. Many roads schools and hospitals in Zadar were closed as a result. Local media report that a bridge was completely destroyed by raging flood water. Local emergency services received over 1,000 calls for assistance. Since yesterday authorities and emergency services have helped drain 127 flooded buildings.

Local media say that 242 mm fell in just 4 hours. According to DHMZ, 279.6 mm fell in 24 hours to 12 September. DHMZ says the average rainfall for the month of September in Zadar is 105 mm.

Other areas in the Balkans also recorded heavy rain between 11 and 12 September. Tirana in Albania recorded 72 mm in 24 hours and Mostar, Bosnia Herzegovina recorded 50 mm. The recent rain comes just 2 days after deadly floods stuck in Italy after 250 mm of rain fell in just 2 hours in the city of Livorno, Tuscany. At least 6 people died in the floods.

4.3.3 Media example #3

"Croatian Coastal Towns Hit by Heavy Floods"

Published on Tuesday September 12th

(by Sven Milekic [15])

[13] https://www.total-croatia-news.com/news/21914-heavy-rain-and-flash-flood-hits-zadar

[14] http://floodlist.com/europe/croatia-floods-zadar-september-2017

[15] http://www.balkaninsight.com/en/article/croatian-coastal-towns-heavily-flooded-09-12-2017

Record rainfall on Monday left the region around the Croatian coastal town of Zadar under water, depriving local people of electricity, safe drinking water and transport. Heavy rains that started early on Monday morning continued through the day, flooding the region around the Croatian coastal town of Zadar, along with the nearby islands of Ugljan, Pasman and Dugi Otok. Zadar was worst hit on Monday morning and afternoon, when by 2pm 340 liters of rain per square meter had already fallen – three times as much as the September average for the region. By the end of the day, it was predicted that Croatia's record of 350 liters per square meter in 24 hours had probably been broken.

Although some roads are still partially under water, and there is still no electricity in some neighborhoods, the situation has normalized and schools opened their doors on Tuesday. The situation looked worst in the medieval coastal town of Nin, near Zadar, where a large portion of the town under deep water. There is no electricity in the town, and the authorities have warned its inhabitants that the water is not safe for drinking.

The military meanwhile has sent an amphibious vehicle to help to transport people who might have been cut off by the rising waters. The authorities on Monday evening evacuated workers from the Cromaris fish processing company and from Solana Nin, a salt-producing factory that has existed in the town from medieval times. Nin mayor Emil Curko said on Tuesday that the town would need help from the state.

"*We expect help from the government and the wider community because Nin can't cope with this [alone]*" Curko said, adding that the water was slowly ebbing away and that no locals were trapped in their homes. "*We'll only see what the situation is when the water retreats. The damage is great, two old bridges from the 16th and 18th century have been destroyed*" he added.

Hundreds of firefighters and soldiers are actively engaged in pumping out the water in the region. Croatian Prime Minister Andrej Plenkovic, accompanied by a few ministers, visited Zadar on Monday afternoon, touring the flooded areas and inspecting how the authorities are fighting the floods.

"*All that can be done is being done, it is difficult to have a preparatory plan for such an amount of precipitation falling at once. The most important thing is that nobody has been harmed*" Plenkovic said.

"*After the extraordinary circumstances we faced this summer, after heavy droughts and fires, we have now faced floods. I thank all the firefighters and volunteers who helped to repair the damage*" he added.

Croatian President Kolinda Grabar Kitarovic also visited Zadar on Monday afternoon to see the flood damage firsthand.

"*Full respect to the firefighters, it seems that after the fires in the summer, they now have to deal with the other side of their job*" Grabar Kitarovic said.

"*I can't believe that in a matter of hours the rain caused so much material damage. We were also in Nin where the situation looks like after a hurricane*" she added.

4.4 EFAS flash flood information

The intense precipitation that fell between the 11th and 12th September in Zadar area was not forecasted in the EFAS-IS (Figure 10). This is probably due to the inadequate COSMO-LEPS based precipitation forecasts which did not predict sufficient precipitation volume to generate flash floods. It seems that even the 65 mm of precipitation during this one day, as forecasted in COSMO-LEPS, were not sufficient to exceed the ERIC indicator thresholds. The spatial distribution of the precipitation event is another factor for this miss of flash flood; the event had a very local character as this was a typical convective storm which current NWP models have difficulties in capturing.

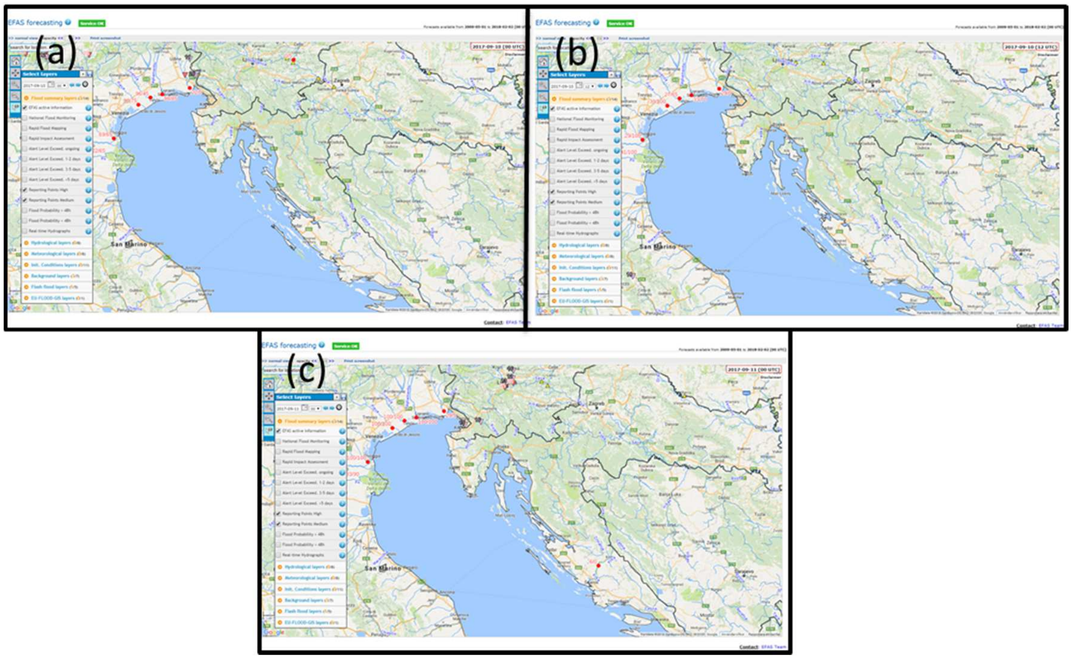

Figure 10. The forecasts for flash flooding on (a-b) September 10th 00.00 and 12.00 UTC respectively, and (c) September 11th 00.00 UTC.

5 Flash floods in Norway

5.1 Description of the study area

Vest-Agder is the southernmost county in Norway (Figure 11). The county extends inland from the North Sea and its arm, the Skagerrak. The county has a hilly surface. The highest point in the region is 1,507 m. From the coast there are six valleys that stretch north into the county. About 31 fjords are located there. The northern part of the county is mountainous and sparsely settled, while the central upland moors are used for pasturing. The Gulf Stream touches the coast of Vest-Agder. The coastal areas and the valley slopes are suitable for agriculture. Agriculture is still a main industry. The county is characterized by acidic soil with a lot of bush forest dominated by pine and juniper, and many places reach the coniferous forest all the way to the sea. Vest-Agder has nine large rivers.[16]

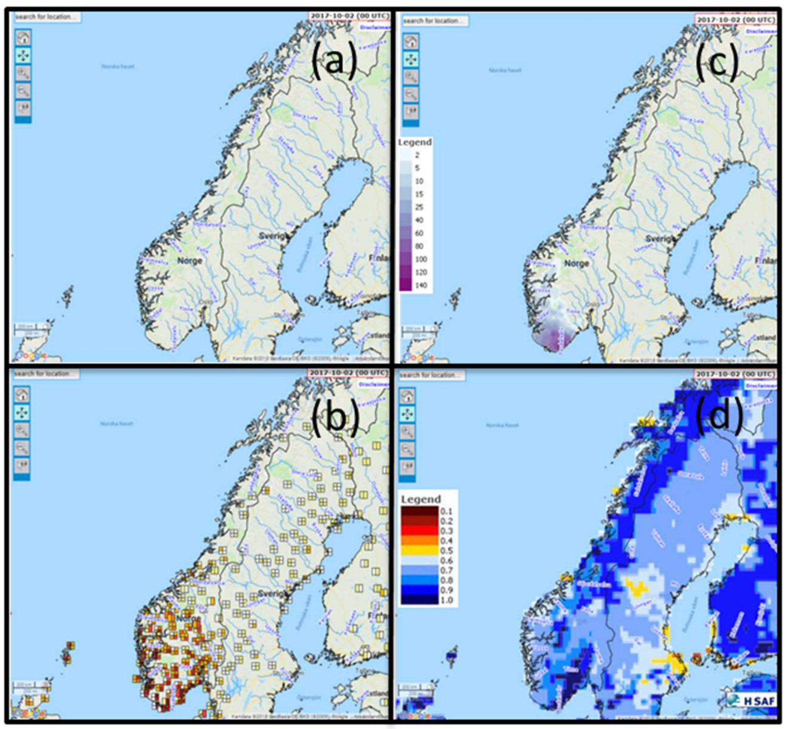

Figure 11. (a) Map of Norway, (b) the SYNOP precipitation stations, (c) interpolated daily precipitation observations [mm] on the 2017-10-02 (darker color indicates higher precipitation amount), and (d) relative soil moisture on the 2017-10-02.

5.2 Description of the flood event

In the southern part of Norway between September 30th and October 3rd close to 300 mm precipitation fell causing massive flash flooding and impact on houses and roads. The Norwegian Water Resources and Energy Directorate (NVE) describes the flooding in a report [17]. The simulated soil moisture content (LISFLOOD) is presented (Figure 12). In the western part of the affected area, the soil moisture was drier than normal, whereas it was wetter than normal in the eastern part of the area due to precipitation earlier in September. In the affected area, the water content in the soil is about 70 %. LISFLOOD results were in agreement with the data from

[16] https://en.wikipedia.org/wiki/Vest-Agder

[17] Norges vassdrags- og energidirektorat (NVE) report (2017). Report on "Flommen på Sørlandet 30.9 – 3.10.2017".

NVE. The soil moisture content by satellite observations (Figure 12 (c)) on September 27th is higher than the modelled.

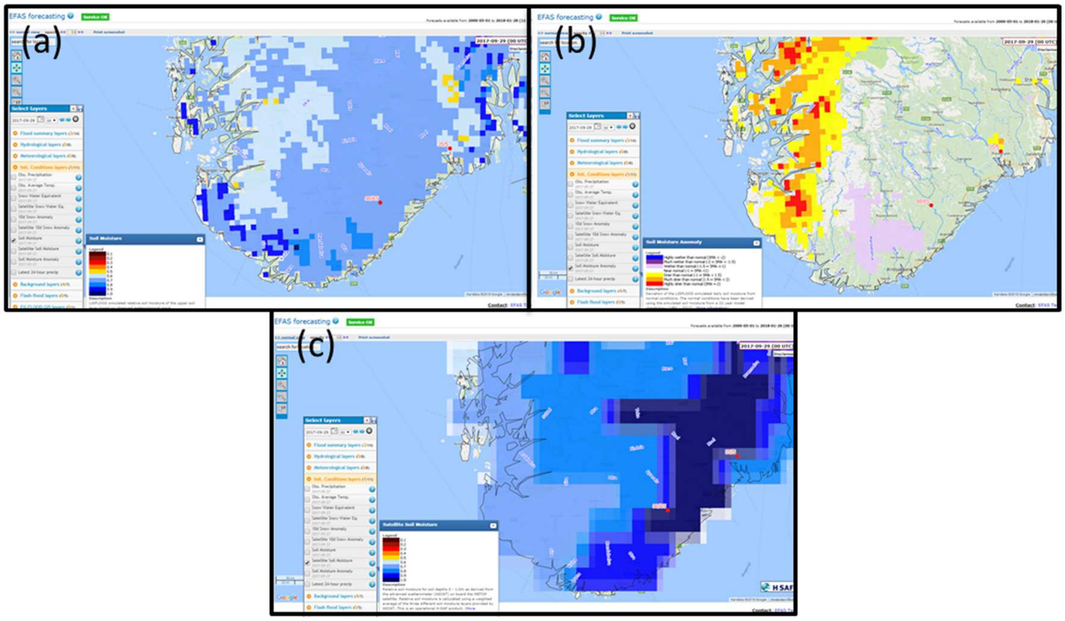

Figure 12. Soil moisture products on September 27th for: (a) LISFLOOD modelled soil moisture, (b) LISFLOOD modelled soil moisture anomaly, and (c) soil moisture from satellite observations.

From September 30th to October 2nd as much as 281.8 mm precipitation fell in Senumstad, a village in Aust-Agder county (Figure 13). Nearly as much precipitation as in Senumstad fell in Mestad in Oddernes in Vest-Agder close to Kristiansand. In three days 280.6 mm was observed in Mestad. The precipitation in these two places had a return period of more than 100 years. Other stations where the precipitation had a return period of more than 100 years were Åseral with 280 mm in 3 days and Kvåvik with 226.4 mm in 3 days. These are situated in Vest-Agder. In Aust-Agder also another station had a precipitation of more than 100 years return period. This was in Dovland where 226.4 mm was observed in three days. More than 200 mm precipitation in three days was observed in 13 stations mainly covering the southern halves of the counties Aust-Agder and Vest-Agder (Ref: "Flommen på Sørlandet 30.9 – 3.10.2017" by NVE). The stations mentioned above are located in the same area as the flash flood reporting points in EFAS-IS.

Figure 13. Map showing the location of referred precipitation stations in the affected area.

Precipitation forecasts based on COSMO-LEPS from September 28th 06:00 UTC show that an intensive rainstorm was going to hit the southern part of Norway on September 30th. The forecast was correct both in time and space (see Figure 14).

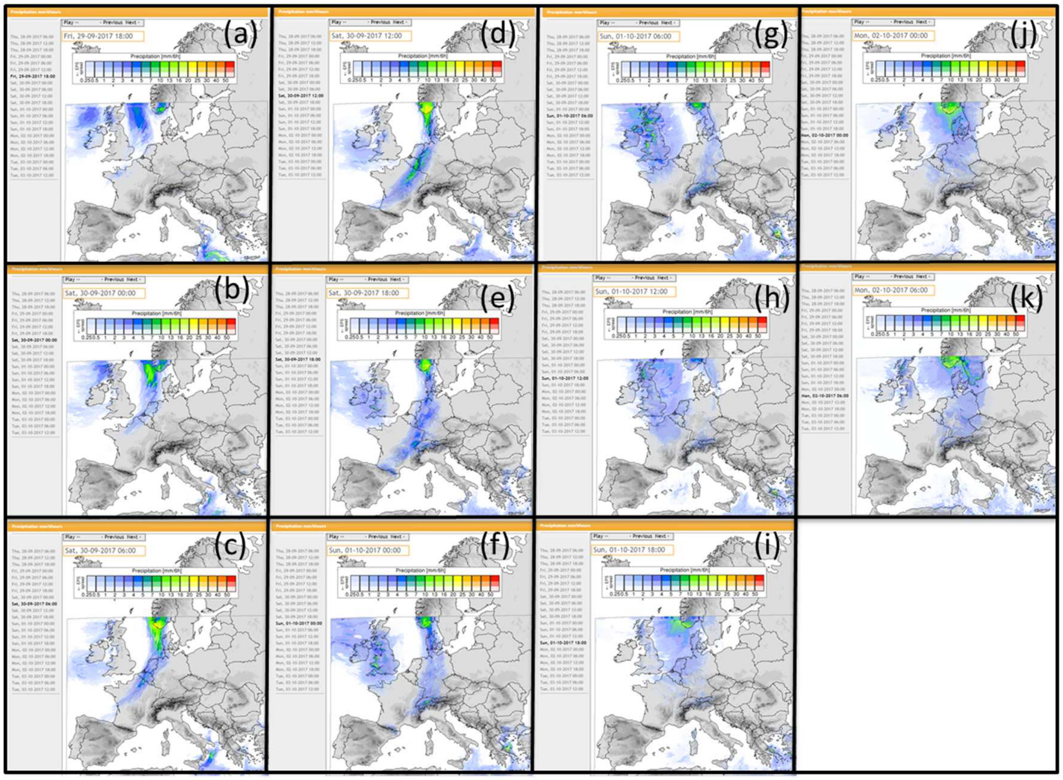

Figure 14. Precipitation COSMO-LEPS forecasts for (a) September 29th at 18:00 UTC, (b-e) September 30th at 00:00, 06:00, 12:00, 18:00 UTC respectively, (f-i) October 1st at 00:00, 06:00, 12:00, 18:00 UTC respectively, (j-k) October 2nd at 00:00, 06:00 respectively. The model is initialized on September 28th at 06:00 UTC. Note that COSMO-LEPS data stop at 60° north.

5.3 Impacts - based on media reports

Damages after the flood are among the worst seen in Norway after a flood. Reported damages were 3300 to a value of 500 million NOK (52 million EUR). Eighty percent of the damages were on private buildings. Between 40 and 50 roads had to be closed down [18]. In the city of Lyngdal (Vest-Agder county) many people watched their houses being flooded, whilst an escape was set back as the driving conditions were difficult and a number of main roads were closed due to the overflow.

The Road Administration stated that they don't even know the exact number of closed roads, but believe it is close to 70 in the Vest-Agder county. A small community, Dragsholt, was nearly destroyed by the flooding of the Tovdal River, which left its mark also on the city of Kristiansand.

One of the evacuated from Dragsholt, Lena Juul, once on dry land spoke to reporters, terrified, explaining how the water was halfway to the ceiling, and that she could only be rescued by boat. Several of others followed her in this survivalist enterprise.

A number of other minor communities in the Vest-Agder County experienced the same destiny, including Jaren, and Farsund and Lista located southwest of Kristiansand and Lindesnes on the eastward side from Kristiansand.

[18] Norges vassdrags- og energidirektorat (NVE) report (2017). Report on "Flommen på Sørlandet 30.9 – 3.10.2017".

The city of Lyngdal experienced catastrophic destruction; rivers Tovdal and Otra destroyed every building, home or factory and any other object that stood in their way.

The government agency, Norwegian Water Resources and Energy Directorate (NVE), and other city officials issued a number of warnings regarding the severity of the weather and its consequences, including landslides and mudslides, and though the flood was inevitable, the only thing they could do is make sure no life is lost.

In order to do so, the police and other officials made statements of how dangerous it would be to use cars or any other traffic vehicle since already a number of cars were thrown into the torrent.

When it comes to details of how massive this flood is, according to the NVE, since 1890, when the agency first started keeping data, there are no records of such massive precipitation levels and floods. According to their reports, around 300 mm (11.8 inches) of precipitation fell during the weekend until Tuesday, October 3.

Photo 2. Drangsholt as posted by Nikola Pajtic [19] on October 04, 2017. (The photo is published with permission by photographer Sten Arne Brunsby).

5.3.1 Media example #1

"Flood in Sørlandet 29.9 – 2.10.2017"

Published on Tuesday October 3rd

(by NVE (also reused in other web-news) [20])

Photo 3. Flooded area in Sørlandet.

[19] www.watchers.news

[20] http://www.varsom.no/nytt/nyheter-flom-og-jordskred/flommen-pa-sorlandet-29-9-2-10-2017/

Landslides caused problems on many places, and boat was a more natural way of transport than car. In Telemark there were fewer problems but also here landslides occurred and the rivers were flooded. The rivers in Sørlandet are still flooded, but the water lever is on the way down.

Damages and closed roads

The water caused problems for many and there were many damages. Everything from rail, to factories, to houses and stables were affected in the areas that were most exposed. Many houses got water in the cellars, some houses are damaged by landslides and many had to be evacuated from their homes – both by a result from the flooding and by the risk of landslides. Fortunately, people and cattle have managed to escape danger, but some near-misses have been recorded.

In Agder 40 – 50 roads were closed at the same time during the weekend and Monday it was still not possible to drive on the roads. Also in Telemark and in Rogland roads were closed because of flooding and landslide.

Lygna

v/Møska (Skolandsvatnet): Peak on Monday at 135 m^3/s. The biggest flood in the period of observation from 1970. The flood in December 2015 was almost the same size.

v/Tingvatn: Peak on Monday at 177 m^3/s. The third biggest flood in the period of observations from 1920. In 2015 and 1992 the flood was bigger.

Feda v/ Refsti:

Peak on Monday evening at 135 m^3/s. This year's flood was the fourth biggest since observation started in 1890. There was a bigger flood there in 2015.

Audna v/Gaupefossen:

Peak on Monday at 260 m^3/s which is the second biggest flood in the period of observation that started in 1988, slightly passed by the flood in 2015

Manndalselva v/ Kjølemo:

Peak on Monday at 800 m^3/s. The exact culmination will be measured later. One might have to go back to 1892 to find a flood around the same level. Otherwise the flood in 1987 of 700 m^3/s is the second biggest until now.

Otra v/Heisel:

Highest peak on Sunday with more than 1250 m^3/s. The discharge decreased to 870 m^3/s on Monday night, a new peak on Monday afternoon, just below 1200 m^3/s. The biggest flood since 1933 that was 1400 m^3/s.

Tovdalselva v/Flaksvatn:

Peak on Monday morning with water level at 8.24 m, definitely the highest in the period of observation from 1900. This year's flood was 1.5 m higher than the highest until now (1959).

Arendalsvassdraget v/Rygene:

Peak on Monday afternoon at around 860 m^3/s. The biggest flood since 1987. The flood in 2015 was almost as big as this year's flood.

5.3.2 Media example #2

"Flood Struck Southern Norway"

Published on Monday October 2nd

(by The Nordic Page [21])

Many people have had to leave their homes because of landslides and flood in Southern Norway. The Road Administration has lost the track of the number of closed roads.

Many people have had to leave their homes because of landslides and flood in Southern Norway. The Road Administration has lost the track of the number of closed roads.

Several places in southern Norway report serious incidents associated with the storm and heavy rain. In Lyngdal, around 20 people were evacuated after a river flooded on Monday.

Agder police published a warning on Monday to drivers about very difficult driving conditions in the region.

A number of roads in the Agder counties are closed due to floods. There have also been several serious damages related to the storm in recent hours

5.3.3 Other Media examples

http://www.newsinenglish.no/2017/10/02/flooding-inundates-southern-norway/

http://earth-chronicles.com/natural-catastrophe/flood-in-norway-2.html

http://emergency.copernicus.eu/mapping/ems/copernicus-ems-monitors-impact-floods-norway

http://www.mn.uio.no/geo/english/research/projects/icemass/news/floods-in-southern-norway-seen-by-sentinel.html

https://www.climatechangepost.com/norway/river-floods/

5.4 EFAS flash flood information

Already from September 27th 00:00UTC, there were clear signs in EFAS-IS that a precipitation storm was going to occur in the most southern part of Norway although the probabilities were low still (Figure 15). The forecast of September 28th 00:00 UTC indicates that the event would have a return period of 20 years or higher with probabilities over 50% in two places. In the forecast of September 29th 00:00 UTC, the probability was close to 90% for two places with a return period of 500 years and around 80% probability for many other places. The September 30th 00:00 UTC forecast indicated a 100% probability for an extreme precipitation with a return period of more than 500 years on the Norwegian south coast. In the forecast of September 29th 00:00 UTC, the onset of the event was forecasted for September 30th and peaking on October 1st at 00:00 UTC. Results were accurate with event precipitation being as forecasted. The area was not at the time an EFAS partner area and hence no flash flood notification was issued.

[21] https://www.tnp.no/norway/panorama/flood-struck-southern-norway

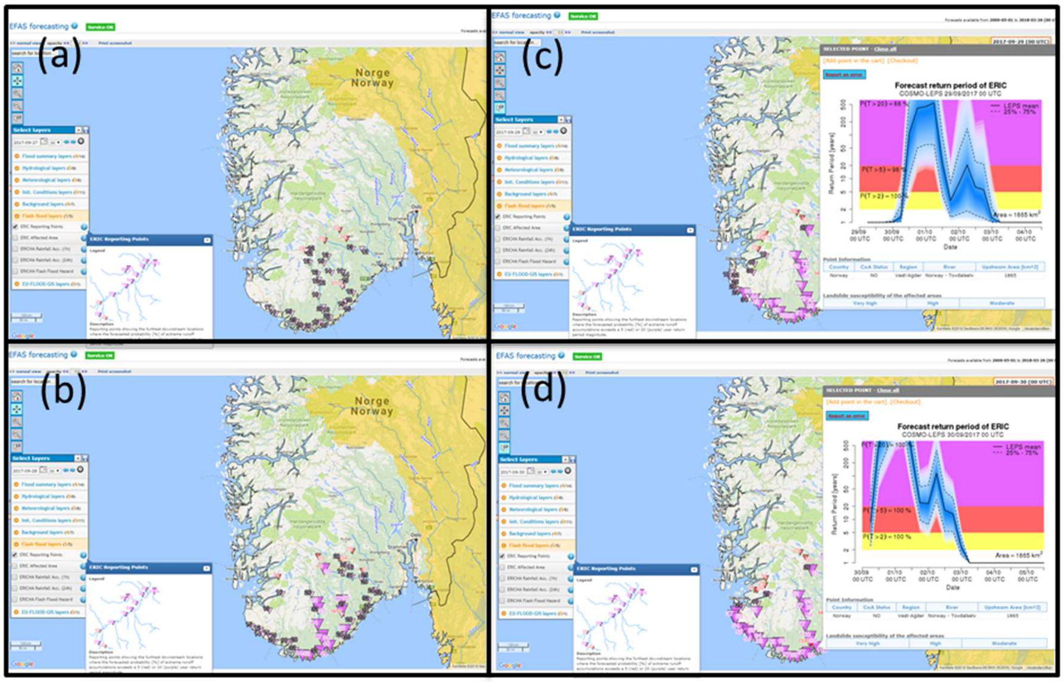

Figure 15. Forecasts in EFAS-IS on: (a) September 27th 00:00 UTC, (b) September 28th 00:00 UTC, (c) September 29th 00:00 UTC, and (d) September 30th 00:00 UTC.

6 Conclusions

6.1 Summary of events

Latvia event

The heavy precipitation that started already on September 9th resulted into almost complete soil saturation (LISFLOOD model states), and hence the upcoming intense precipitation would simply result into immediate runoff generation and flash flood. In particular, the soil moisture in the affected areas was high with a soil moisture content up to saturation which together with the end of the growing season means little uptake of the precipitation of soil and plants.

Two notifications were issued the day before the flooding and a third the same day. The third notification was issued for the region Louna-Eesti, Ape county (this point of notification is at a region that belongs to Estonia, but represents all upstream areas as similar high probability points existed upstream) that was mentioned above. This notification should have been issued at the same time as the first two notifications since the probability was over the threshold, i.e. up to 66 % probability in the area for a return period of over 20 years for the forecast of September 17th 00:00 UTC. It is probable that the precipitation caused rapid rise of water level in tributaries to Gauja and Daugava rivers but not in these two big rivers themselves.

Croatia event

According to the map of precipitation forecasts neither COSMO-LEPS nor ECMWF forecasted Zadar to be hit with intense amounts, with only the exception of the September 10th, 03:00 UTC forecast from ECMWF for September 11th 12:00 UTC. In this model initialization the precipitation reaches 40 mm in 3 hours. According to the ECMWF forecast for the Istria peninsula in north western Croatia, the peninsula is hit by a quite significant precipitation event, but no reporting point emerged for this area either.

The model used for flash flood forecasts is COSMO-LEPS. The satellite images show the evolution of the low pressure system starting the day before in the Gulf of Genoa and moving towards the Adriatic sea (e.g. see the animation here). The path of the precipitation storm is basically well forecasted in the COSMO-LEPS but misses Zadar. Also the precipitation was substantially underestimated.

Another complication for forecasting is that the storm system was formed only the previous day. Due to the rapid evolution of the system and the fact that the magnitude of the precipitation storm was not forecasted in EFAS-IS, no notification was issued.

Before the torrential rainfall the soil moisture content in Zadar area modelled by LISFLOOD was 50% as well as the observed soil moisture based on the satellite data. After the flash flood, the soil moisture content, given by the satellite observation, increases by 20% and the modelled soil moisture by 30% before the event and 46% and 47% after the event.

Norway event

EFAS-IS performed well in forecasting the flash flood event in southern Norway both in space and time and in 3 days of lead time. As the affected area was not within the Condition of Access area at that time, no notification was issued for the event.

6.2 Lessons learned

Europe has a strong hydro-climatic gradient and all three areas lie in different climatic regions. Latvia has a mix of temperate continental climate/humid continental climate and temperate oceanic climate. Zadar has a mix of warm oceanic/humid subtropical climate and warm Mediterranean climate. The most southern part of Norway has a mix of temperate continental climate/humid continental climate and temperate oceanic climate.

Latvia and the south of Norway experience precipitation throughout the year. Zadar has more a character of autumn precipitation, though the rainiest months occur in September, October and

November with fairly the same average precipitation in these three months, i.e. just over 100 mm. Kristiansand on the Norwegian south coast is also characterized by high precipitation in September, October and November with an average of 165 mm in October and November. The wettest months in Latvia on the other hand are July and August with an average rainfall of 78 mm.[22]

All three precipitation storm events occurred during or close to the rainiest season in each area. The precipitation storms in Norway and Zadar were intense with daily precipitation exceeding the average precipitation for the month; however the flooding in Latvia seems to be driven also by saturated soil moisture.

Moreover LISFLOOD modelled soil moisture slightly differs from satellite based soil moisture for the same day. For the events in Latvia and Norway, the satellite image indicated a wetter soil than the LISFLOOD modelled soil. This is similar for Zadar; however the satellite image was taken three days after the model initialization. In the case that LISFLOOD generally predicts a (slightly) biased soil moisture (as indicated here, wetter soil, and assuming that satellite observations are representing the “true” values), a refinement to the model parameters affecting soil moisture (soil evaporation, field capacity etc.) is recommended, whilst another approach could be towards implementing a data assimilation scheme coupling soil moisture satellite observations to LISFLOOD model states.

The intense precipitation in Latvia during September 18th was forecasted 3 days in advance in EFAS-IS. The timing and the location was accurate. A notification was hence issued correctly. However, the other event in Latvia (October 8th - 9th) and the event in Zadar (September 11th – 12th) were not notified accurately. This was due to the difficulty in forecasting the timing of the intense precipitation event and also predicting the correct path of the storm. Note that for the event in Zadar, the timing was right but not the exact path of the most intense precipitation. High resolution Numerical Weather Prediction (NWP) models could address some of these challenges. Such NWP models can predict better the precipitation intensities, however due to the stochastic nature of weather, predicting the core of intense precipitation storms still remains a challenge. For Norway both the timing and the path of the precipitation storm were correctly forecasted.

The Norwegian flash flood event was a result of a severe low pressure system. The return period of the observed amount of daily precipitation in many stations was about 100 years but only in 4 out of 16 stations the discharge reached a 100 year return period or more (Source: NVE). There has also been a station (i.e. Flaksvatn in Tovdalsvassdraget) that showed the recurrence period being 500 years according to preliminary calculations by NVE.

For Norway the evolution of the system was seen three days in advance. There was a strong stationary high pressure over Finland affecting the winds from the south to pass and rise and fall when meeting the Norwegian mountains. The evolution of the system was slower and clearer in the Norwegian case than in the rapid Zadar case.

Overall, for Latvia and Norway the forecast gave time for acting. For Zadar this was not the case due to a difficult meteorological situation limiting the potential to forecast precipitation intensity and location. For Norway and Latvia the timing of the event was right on target as well as the geographical location. Also the forecasted intensity was correct.

6.3 Moving forward

Results from this report show that for the investigated events there is a (slight) difference in the soil moisture between satellite observations and the LISFLOOD model. Although satellite data are for a number of reasons characterized by errors, there is useful information content in such products, which can be used to ‘inform’ (or even constrain) the states of the LISFLOOD model. In general, satellite data are widely used for quantifying the physical parameters in surface waters. Particularly since the launch of commercial high-resolution satellites, the monitoring capabilities have been significantly increased, supporting an unbeatable temporal and spatial monitoring resolution. Here we suggest that satellite products (similar to those provided in

[22] www.climatestotravel.com

EFAS-IS) are valuable in water monitoring and modeling for: 1) a priori parameter estimation (refine LISFLOOD model parameters), and 2) data assimilation (improving the model states prior to forecasting). The suggestion is to use such products for improving the EFAS service by pointing towards model structural inconsistencies (systematic differences can be used to identify possible improvements in model structure and/or parameterization), and hence ensuring results from a “right for the right reasons” LISFLOOD model. To further judge model credibility, ‘observed’ variables other than river discharge can be used, for instance from the current soil moisture satellite products. Satellite products can be used as reference to calibrate the LISFLOOD parameters that control specific fluxes and flowpaths.

Another suggestion, yet technically challenging, would be to provide forecasts at a fine temporal resolution. In the Zadar case, it is expected that the situation could have been improved by shorter time steps and multiple model runs allowing added value from refined initial model conditions and meteorological forecasts. Though such service development depends on the availability of NWP models, forecasts from high resolution NWP models (assuming that such systems are available) could for instance be used only in cases that an event of significant impact is forecasted; hence providing more detailed information. The challenges are still there as flash flooding events are often associated with “cloudbursts” (where a large amount of precipitation falls during a short time from small-scale convective cumulus-nimbus clouds) [23]. The state-of-the art NWP models are now at the model resolution where individual convective elements are explicitly resolved by the model dynamics. It is generally fundamentally not possible to predict the position of an intense localized storm in time and space to the same level of accuracy as the position of a synoptic-scale low pressure center. Radar based nowcasting tools (ERICHA) and high resolution NWP models could be a way of moving forward addressing the need for better initialization and meteorological forecasts respectively.

Finally, there is no evidence that an automated approach to issue EFAS Flash Flood Notifications can contribute to improvements in the response time. On the contrary such automated approach leaves out expert judgement, which in the events of interests, has shown to respond adequately. From an officer’s on duty perspective driving the EFAS disseminations, the presentation of the ERIC indicators seem appropriate, with generally a small risk that the current visualization approach of the ERIC forecasts could be skipped. This relates to forecasted points (EFAS probability triangles) which could overlap in the case of multiple notifications. However, such an incident was not occurred to and be reported by any officer on duty. From a partner’s perspective, there have been suggestions (personal dialogues) to reduce the number of notifications sent for the same event but at slightly different location. Yet, this is a subjective suggestion and could vary between partners.

[23] Olsson, J., Pers, B. C., Bengtsson, L., Pechlivanidis, I., Berg, P., & Körnich, H. (2017). Distance-dependent depth-duration analysis in high-resolution hydro-meteorological ensemble forecasting: A case study in Malmö City, Sweden. Environmental Modelling & Software, 93, 381–397.

Annex 1 - Feedback from operational services on EFAS forecasts

For the case of Croatia an EFAS Formal Flood Notification was issued by the EFAS Dissemination Centre and a feedback was given by DHMZ. The feedback is attached below.

EFAS Formal Notification Feedback Form

#73

COMPLETE

Collector:	Old link, don't use (Web Link)
Started:	Wednesday, October 18, 2017 10:17:20 AM
Last Modified:	Wednesday, October 18, 2017 11:33:31 AM
Time Spent:	01:16:10
IP Address:	161.53.81.2

Page 1

Q1 Name, organisation and email

Name	[redacted]
Organisation	**DHMZ**
Email Address	[redacted]

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

Missed event in Zadar and its county, Adriatic region, on 11.09.2017.

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

Yes

Page 2

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

Zadar county (Zadar, Nin, Starigrad Paklenica, islands Ugljan and Dugi otok) was hit with thunderstorms on 10/11.9.2017. that formed severe flash flooding. Economic damage was > 2.000.000 € (waste water treatment plant, county and local roads severely damaged, highway was closed for hours...)

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

The town of Zadar (44.11972, 15.24222) and Zadar county

Q6 Rate accuracy of EFAS information in terms of location

In the wider region

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.

Respondent skipped this question

1 / 3

EFAS Formal Notification Feedback Form

Q8 Rate accuracy of EFAS information in terms of time	**Not known**
Q9 Rate accuracy of EFAS information in terms of magnitude	**Not known**
Q10 What was the return period of the observed flood event?	**Respondent skipped this question**

Q11 What caused the flood event? (If more than one cause, please rank the alternatives.)

snow melting	**N/A**
long-term raining	**N/A**
extreme rainfall	**1**
soil saturation	**N/A**
ice jam	**N/A**
dam break	**N/A**
other	**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)	**Respondent skipped this question**
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

ERIC and ERICHA both didn't show anything.

Page 3

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)?

On meteostation Zemunik (Zadar airport) was measured 265 mm/6h, in Zadar town 188 mm/6h.
For period 1961-2010 precipitation for 6 hrs duration and RP of 100 yrs is 187 mm.

2 / 3

EFAS Formal Notification Feedback Form

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

3 / 3