



European Flood Awareness System

Analysis on the CEMS hydrological data collection - 2017

CEMS HYDROLOGICAL DATA COLLECTION CENTRE

Specific Contract No.4





Environmental and Water Agency of Andalusia REGIONAL MINISTRY OF ENVIRONMENT Rediam







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1. Introduction

This report contains an analysis of the hydrological data received by the CEMS Hydrological Data Collection Centre (HDCC) for the year 2017. The HDCC is contracted by the European Commission and operated by the Agencia de Medio Ambente y Agua de Andalucia in collaboration with Soologic SL.

Throughout the year 2017 the HDCC received data from (Figure 1 and annex 1), of which two have joined this collaboration during the course of 2017. These are the Republican Emergency Management and Response Center of the Ministry of Emergency Situations of the Republic of Belarus (REMRC) and the Israel Hydrological Service - Water Authority (IHSWA). Additionally, the Federal Hydrometeorological Institute of Bosnia and Herzegovina (FHMZ BiH) and the Institute of Meteorology and Water Management Wroclaw Branch of Poland (IMGW) joined the collaboration in 2018.



Figure 1. Maps of current data providers (Annex 1).

In total the HDCC received during 2017 hydrological data for 1297 stations; of which 289 stations delivered discharge data, 217 stations water level data and 791 both discharge and water level data. The analysis on the CEMS hydrological data collection of 2017 is based on stations that have been delivering actively throughout the year 2017. Hence any station that joined the data collection after 01.01.2017 or was not active during the entire year was excluded from the analysis, which reduced the total amount of stations to be analysed to 1236.





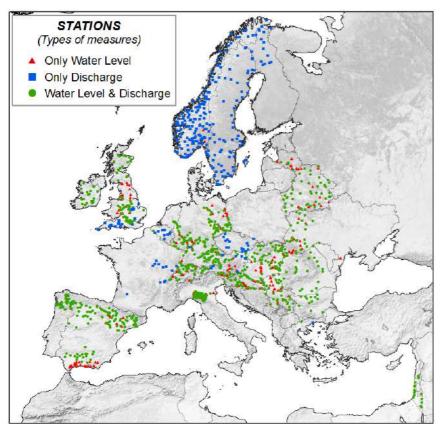


Figure 2. Spatial distribution of stations and type of variable measured.

The analyses of the CEMS hydrological data collection for the year 2017 includes four main aspects:

- 1. The analysis of the **general hydrological conditions** across Europe based on discharge observations, with prime focus on evaluating if and where there were major deviations of the average and extreme flow conditions with the regard to the past.
- 2. The analysis of **gaps within the data collection**, with focus on classification of gaps in terms of length, seasonality, distribution, status, typology and possible solutions.
- The analysis of threshold level exceedances, assesses for each station for which their own threshold level was
 exceeded (threshold provided by the data provider) the duration, magnitude, number and distribution of
 those exceedances.
- 4. The analysis of a **flood event**. The evolution of the flood event which occurred between 6-24 of December 2017 in northern Italy is studied in terms of magnitude and timing, and compared to past events in the same area.

Each of this aspects covers an individual section of this report, which is completed by an executive summary.

At this point the whole EFAS team, but in particular the HDCC would like to thank the EFAS partners and data providers that have contributed to the CEMS hydrological data collection! We like to acknowledge their dedication to the EFAS project, their commitment and the sharing of their hydrological data. In particular, we must thank them for their cooperation with the HDCC, both for the provision of data and for being proactive in responding to any questions or issues that arise concerning the data and metadata provided. Without their collaboration the delivery of this report would not be possible.





2. Hydrological conditions of EFAS gauging stations

2.1 Introduction

This report describes the hydrological conditions for the year 2017 through the analysis of the near real time data collected by the EFAS Hydrological Data Collection Centre (HDCC). The data has been analitically compared with near real time and historical data from 2016 and the period 1970-2016.

The analyses have been carried out on the discharge data collected, as it allows for a better comparison of the hydrological behaviour between stations. Although water level values are collected as well, the discharge data is an indicator of the volume of water that flows through the section of the gauge measure independently of its geometry, resulting in a better parameter for our study.

Three statistical parameters were used for the analyses: minimum, average and maximum annual discharge values. The minimum and maximum discharge values are indicators of extreme river regimes. Any variation of these parameters can be associated to either drought or flood events. At the same time, the average discharge values are indicators of the water contribution at the gauging points.

Discharge values not only depend on the hydrological conditions of a river, but on the upstream meteorological conditions, catchment area and infrastructures that might be regulating the river flow.

2.2 Assessing stations and data for analysis

In order to guarantee a minimum significance for the statistical parameters calculated, stations with low reporting rates have been discarded from the analyses. The first condition defined was for the stations selected to have been fully operational and active since January 1st 2017 to December 31st 2017. The second condition consisted in discarding stations which received less than 75% of their expected annual discharge data during 2017.

The same criterion was applied for the year 2016. An additional condition was defined for the 1970-2016 period, where only stations that accounted for at least two years of data were included. For aggregated time series, the statistical parameters are more representative the longer the aggregation period is.

As a result, a total of 934 stations met the criteria for the year 2017. Out of these, 769 stations for the year 2016 and 792 stations for historical time series 1970-2016 met the defined conditions as well.

In Figure 3 we have the spatial distribution of the hydrological gauging stations according to the length of their historical time series.

Stations belonging to the Douro and Minho river basins, located in north-western Spain, as well as to the Daugava river basin in Latvia account for less than 3 year long historical time series, while stations found across the Scandinavian, the Rhine, the Elbe, the Oder and the western Danube river basins posses historical time series more than 20 years long.





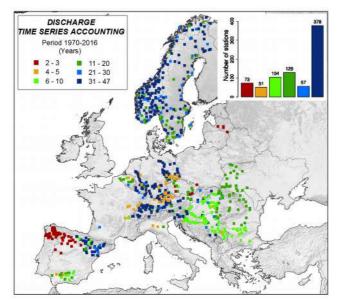


Figure 3. Spatial distribution of stations according to their historical time series.

2.3 Hydrological conditions in 2017

As previously mentioned, the analysis of extreme discharge values allows us to better understand the behavior of rivers

By observing the spatial distribution of **minima discharge values** (Figure 4), we notice that the majority of minima values are below 10 m3/s. There are a few stations along the Danube and the Rhine rivers for which the minimum discharge values are higher than 500 m3/s. There are two stations that present negative minima discharge values, which apparently are related to backwater fenomenon.

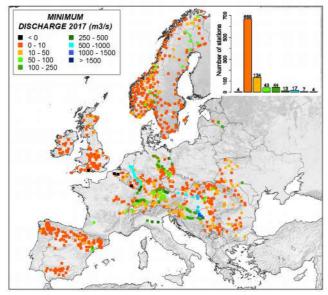


Figure 4. Spatial distribution of minimum discharge values in 2017.

Figure 5 shows the **average discharge values**. Around 40% of the stations studied present average discharge values below 10 m3/s, these are mostly present across Spain, Norway, Sweden and England. Average discharge values higher than 500 m3/s are predominant across the central area of Europe.





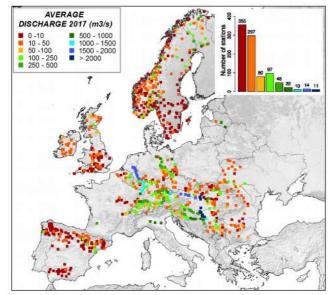


Figure 5. Spatial distribution of average discharge values in 2017.

The most frequent **maxima discharge values** (Figure 6) are in the range of 50-250 m3/s. Values below 50 m3/s are also quite abundant. The lowest maximum discharge values, near 10 m3/s, are mainly distributed across Spain, England and Scandinavian countries as well as central Europe. Values higher than 500 m3/s are found for stations across the Danube, Rhine and Po river basins.

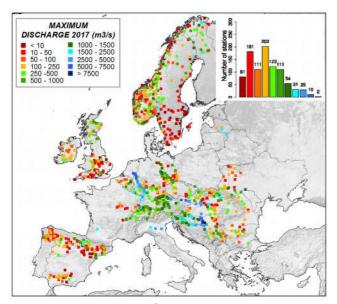


Figure 6. Spatial distribution of maximum discharge values in 2017.

2.4 Comparative analysis

In order to compare the relative variation of the minima, average and maxima values, a normalized variation index (NVI) was employed.

$$NVI_{2016} = \frac{V_{2017} - V_{2016}}{V_{2017} + V_{2016}} \tag{1}$$

$$NVI_{H} = \frac{V_{2017} - V_{H}}{V_{2017} + V_{H}} \tag{2}$$





Where V_{2017} , V_{2016} and V_H refer to the statistical parameters for 2017, 2016 and the 1970-2016 aggregated time series respectively. This index ranges between -1 and 1, with negative values indicating a decline or positive values indicating an increase when compared to the 2017 values.

The resulting NVI are distributed among the following classes:

- Extreme negative variations: NVI values between -1 and -0.6.
- Moderate negative variations: NVI values between -0.6 and -0.2.
- Small or null variations: NVI values between -0.2 and 0.2.
- Moderate positive variations: NVI values between 0.2 and 0.6.
- Extreme positive variations: NVI values between 0.6 and 1.

2.4.1 VARIATION OF HYDROLOGICAL CONDITIONS

Considering the **minima values variations between 2017 and 2016** (Figure 7a), near 65% of the stations presented small variations. Extreme positive and negative variations are present in 5% of the stations, which are scattered across Europe.

The distribution of minima values variations between 2017 and the 1970-2016 period (Figure 7b) shows that 2017 was a year with a predominance of stations (around 75%) with higher minima values compared to the historical series across Europe.

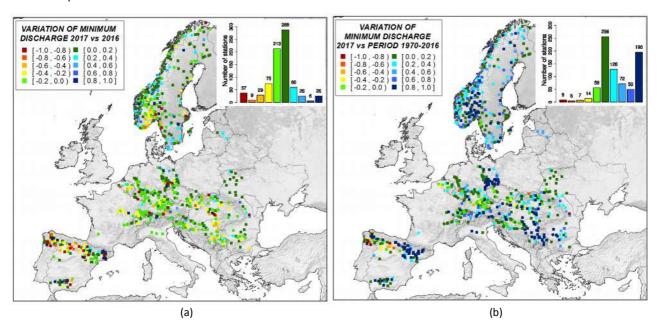


Figure 7. Spatial distribution of the 2017 minima discharge values NVI.

The spatial distribution of the **average values variations between 2017 and 2016** shows that 95% of the stations presented small variations (Figure 8a). It is important to underline that extreme positive NVI values occur for several stations across southern Scadinavian countries, Latvia (in the Daugava river basin) and for a few isolated stations across central Europe and Spain. Extreme negative variations occur across north-western Spain, in the Douro and Minho river basins.

Concerning the average values variations between 2017 and the 1970-2016 period (Figure 8b), around 95% of the stations show small variations with the exception of stations found in the Daugava river basin in Latvia which present moderate positive variations while extreme and moderate negative variations occurred for stations located in Spain.





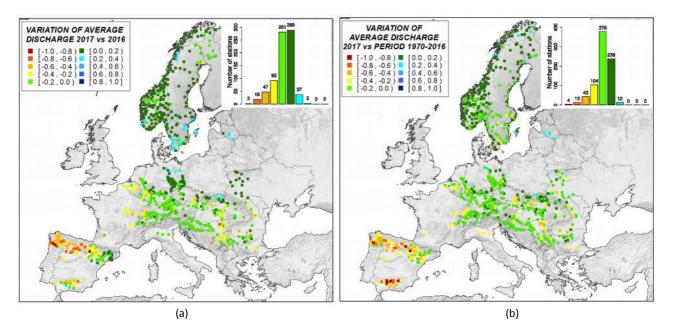


Figure 8. Spatial distribution of the 2017 average discharge values NVI.

For the **maximum values variations between 2017 and 2016** we observe that around 70% of the stations present small variations (Figure 9a). Extreme positive variations are found mainly across basins in Spain and moderated variations are present in Scandinavian countries and the Elbe, Danube, Oder, Daugava and Dnieper river basins. Extreme negative variations occur in stations across the northern and southern areas of Spain and for some stations across the Danube, Po, Rhône.

Concerning the maximum values variations between 2017 and the 1970-2016 period, in Figure 9b we observed that small variations are predominant across Europe. It should also be noted that extreme positive variations practically do not occur, while extreme negative variations are found mainly in northern and southern Spain, Scandinavian countries, the Elbe river basin and dispersedly across the rest of Europe.

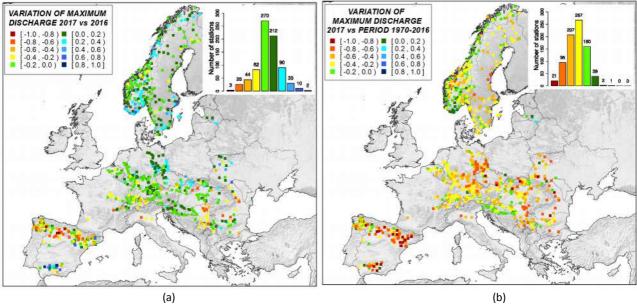


Figure 9. Spatial distribution of the 2017 maxima discharge values NVI.





3. Data Collection Gap Analysis

3.1 Initial considerations

The HDCC receives data from hydrological gauging stations that are managed by EFAS Data Providers (hereafter DPs). The data provision frequency can vary from a value provided every minute to a value provided every 24 hours. This section discusses the incidents that are related to gaps in the data transfer process. A gap occurs when a hydrological station, that provides water level and/or discharge values to the HDCC, fails to send any data during a specific period of time.

The basic gap unit considered is a single missing value. A gap ends once the reception data is resumed and the missing values are not received. Gaps will have a beginning and an end date associated to them. The importance of a gap will depend on the data provision frequency and the duration of the data transfer interruption.

If the duration of missing values for a specific station lasts more than 3 days, the DP responsible is contacted by the HDCC.

The analysis has been carried out on 1,236 stations, from 35 DPs, of which 1,125 stations presented gaps between January 1st 2017 and December 31st 2017. A total of 548,820 gaps occurred. A considerably large amount of gaps!

Considering that 98.87% of the gaps lasted less than 1 day and that 78.46% of the gaps lasted less than 1 hour, the following criteria is applied to filter out gaps which are not relevant in terms of HDCC operations:

 All gaps consisting of 10 missing values or less, and with observation frequencies (time intervals) higher than 1 hour are discarded.

With this criteria we exclude from the analysis gaps of 10 missing values and 30 minutes time interval, a gap with a maximum duration of 5 hours. This is an acceptable condition as this type of gaps do not interfere in data transfer and processing tasks of the HDCC.

Having applied this filter, the total gaps analysed are reduced to 78,820, which occurred throughout 1111 stations and the data collection for 1,820 variables, as each station can provide water level and/or discharge values.

3.2 Gap classification by duration

We define five classes of duration.

- More than 30 days
- From 10 to 30 days
- From 3 to 10 days
- From 1 to 3 days
- Less or equal than 1 day

95% of the filtered gaps have a duration less than, or equal to, 1 day (generally resulting from changes in the data delivery times and/or delays in data transmissions), 4% of the gaps last between 1 to 3 days and the remaining 821 gaps, which represent 1% and require our intervention, last more than three days long and are distributed according to Figure 10.





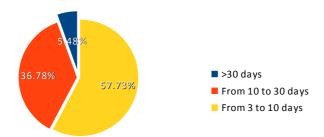


Figure 10. Gaps with more than more than 3 days duration.

The majority of these gaps range from 3 to 10 days in length. This is a result of the communications to DPs process that takes place after the detection of missing data for three days. Usually DPs are able to solve the issues within a couple of days after being contacted. Gaps that last more than 30 days are less frequent as all parties involved have been notified and have had time to solve the issues in most cases.

3.3 Gap classification by status

Once a gap occurs, several scenarios may unfold.

- FILLED: The gap is filled with the missing data sent by the data provider.
- FILLED INTERPOLATED: The gap is filled by the HDCC data interpolation process. Gaps with a duration of less than 5 days, gaps are completed by an automatic interpolation process.
- PENDING: Pending action (this applies to gaps recently detected).
- NOT FILLED: No interpolation is carried out for gaps longer than 5 days. The gap remains.

In the case of interpolated data, when the missing data from the DP is received, the new data replaces the interpolated data

Figure 11 shows the distribution of gaps according to the previous categories and their duration intervals. Most of the short duration gaps (less than 3 days) are interpolated and the series are completed. For medium duration gaps (3 to 10 days) the percentage of interpolated gaps decreases, resulting in 31.43% of the gaps being Not Filled. Gaps that last more than 10 days are not filled and will be permanent unless the DPs provide the missing values whenever they become available.

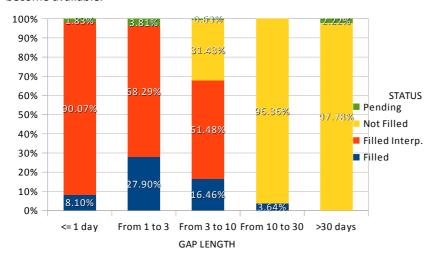


Figure 11. Percentage of gap status by gap length.





3.4 Other aspects to be considered.

As previously mentioned, for the year 2017, a total of 78,820 gaps have been analysed, which occurred across 1111 stations and involving the data collection of 1,820 variables.

These gaps add up to 2,441,050 missing values with a total of 30,397 accumulated days of gaps considering all stations and variables. The average gap length is 0.39 days and the average number of gaps per station and per variable is 43.30. For each station and variable, there is an average of 16.89 days of gaps.

Figure 12 represents the percentage of received data against expected data per month. With the box plot we observe the existing variation throughout DPs on a monthly basis as well as the mean value of the percentage of received data, which is above 90% throughout 2017, although lower values exists. This evidences the success rate of the data transfer process between the HDCC and DPs.

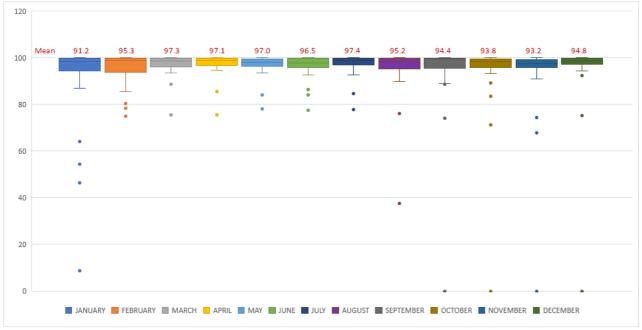
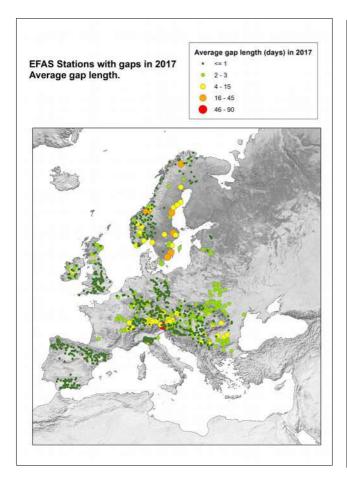


Figure 12. Box plot depicting the monthly data reception against the expected data delivery from EFAS DPs.

The maps in Figure 13 and Figure 14 shows the spatial distribution of gaps, with respect to the average gap duration (hours) and maximum gap length (days), respectively.







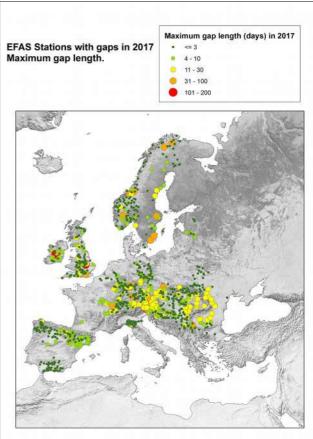


Figure 13. Average gap length in days per station.

Figure 14. Maximum gap length in days per station

3.5 Gap typology and proposal for future data collection strategy.

As indicated at the beginign of this section, the vast majority of gaps have a duration which is less than three days long. When gaps last 3 days or longer, the HDCC proceeds to analyse each case and, when necessary, communicates with the DP involved in order to identify possible solutions. This has been the case for 821 gaps.

After analyzing the gaps, the following categories have been defined. These categories are based on communications with data providers and their replies detailing the gap causes. Once a better understanding of each situation has been achieved, it is possible to propose a series of measures to help improve the data collection strategy both quantitatively and qualitatively.

The following table lists each type of gap categories, their occurrence rate and proposed solutions.





Table 1: Gap classification by typology

	% OF RECOMMENDATION /			
GAP TYPOLOGY	FURTHER INFO	OCCURANCE	POSSIBLE SOLUTION	
To be determined.	No information on this type of gap	24.60	These are the cases of the smallest gaps (from 3 to 5 days). As it is not known which might be the cause of these gaps, it is difficult to propose a solution.	
Limited resources of DP to attend data gap requests	Lack of technical personnel availability to attend data gap requests on behalf of HDCC.	23.26	No easy solution exists as it does not depend on the HDCC. Some agreement between the HDCC and Data Providers might help minimize the effort needed (data services access, etc). Otherwise this could result in the number of gaps to grow, issue should be discussed with EFAS.	
Gauging Station out of order	Usually caused by breakdown, maintenance, repairs, etc. as a consequence of lightning, floods, sensor replacement, long term breakdown	16.69	If the station has any alternative sensor with identical characteristics, those data could be an alternative.	
Readings taken only during specific hydrological conditions	Data values only obtainable under specific conditions (i.e. above a certain water level).	13.40	For this kind of issues our proposal, whenever possible, is to look for an alternative station. In case this is not possible, it would be advisable to find out if missing values can be calculated from the station rating curve in order to complete	
Lack of reply from Data Provider.	DP usually reply to HDCC communications, but on certain occasions we don't receive replies.	9.69	These issues rely enterely on the DP. A meeting between HDCC and DP to analyse the situation is highly recommended.	
Extreme Meteorological Conditions beyond sensor capacity.	Extreme Meteorological Conditions that obstructs the correct functioning of the sensor. Frozen rivers are the most common cases in this category.	4.14	We need to consider if the extreme meteorological conditions are odd and very rare situations or if they occur on a regular or frequent basis. If the events are regular and frequent, either an alternative station or a different placement would be	
Communications Failure between Sensor and DP	Communications Failure between Sensor and the facilities responsible for the data collection and transmission.	3.90	This relies on the DP (data collection and transmission personnel). Quick communications help minimize the impact of missing data.	
Technical issues between DP and HDCC	Issues concerning the Data Collection service between Data Providers and the HDCC: Delays in data transfers from DP to HDCC, changes in IP directions, problems with the servers etc.	2.31	Improving communications with DPs to achieve a more efficient and faster solution. (Prompt communications when missing data is detected or when IP directions are changed)	
Delay due to stations requiring a manual intervention	Delay in the data collection of stations which require a manual intervention of personnel as well as lack of personnel to obtain the data.	1.22	HDCC always procures to maintain quick communications with DPs when no data is being received.	
Data Sensor Failure	The sensor presents some kind of anomaly that causes for wrong or unexpected data to be sent (i.e -9999 values).	0.61	The solution is repairing the sensor, or replacing it with a new one. This solution depends directly on the DP.	
Modification of time interval.	Some DP modify data time intervals. This influences the amount of data reception. As a result they are considered as gaps. They are usually quickly resolved by updating the time intervals.	0.24	This is a common cause for gaps. The first step is to communicate with DPs in order to determine a stable time interval. Another alternative is to define a fixed observation frequency and interpolate data when time intervals are	

Figure 15 shows the number of gaps for each category classified by gap duration.





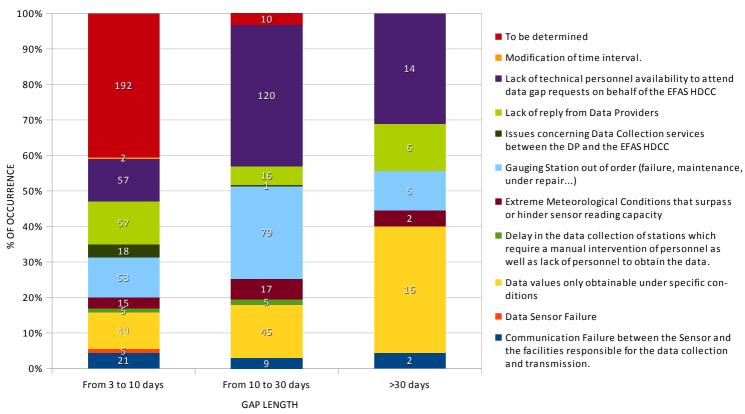


Figure 15. Number of gaps by duration and typology. Percentage of occurrence.

The following considerations may result useful as well:

- If a specific station presents gaps repeatedly, a alternative station could be proposed as a replacement. It could be a station located nearby. Or it may be considered to be removed from the system.
- When delays occur repeatedly for a specific DP or station, a possible solution to avoid the gaps, could be to
 increase the response time for data collection process. We consider the response time as the time frame
 expected before considering the data is missing. This measure would allow for presumed missing data, that
 might be automatically completed in the following data transfer, to be avoided.
- For gaps that are of less than 1 hour long or those which are a result of time interval variations (irregular data delivery), these could be avoided by normalizing the data series (i.e. aggregating data to 1 hour operational tables).





4. Analysis of Exceedance events

In this section we analyse the threshold level exceedance events for EFAS hydrological stations, according to their occurence, severity and duration in 2017.

A threshold level is defined as a value established for a specific gauging station for monitoring the rise in water level or discharge values. This allows the management authorities responsible of a gauging station network to be able to plan and implement necessary measures to mitigate risks related to the rise in the river level and possible effects on the immediate surrounding and downstream areas.

For this analysis an event is defined as each time a measured discharge or water level value exceeds any of the threshold levels of the station that registered it. The event duration will be considered from that point in time until the values measured at that station drop below the lowest threshold level defined for the station.

4.1 General description

A total of 1236 stations actively transferred data to the HDCC throughout 2017. Out of these, threshold levels for water level and/or discharge values are defined for 808 stations, representing 65% of the total stations.

Out of these, 343 stations (42%) had their threshold levels exceeded during 2017, resulting in 940 events registered; 96% of them were events that lasted less than 1 day.

In Figure 16 we have a spatial representation of stations and exceedances.

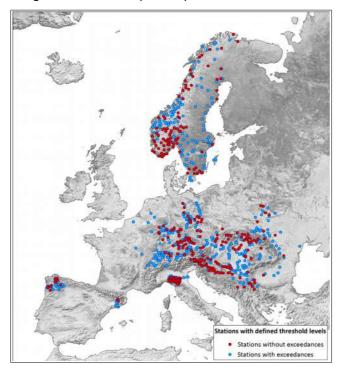


Figure 16. Stations with and without threshold levels exceedances.

From a water body perspective, 48% of the rivers across Europe accounted for stations that registered threshold exceedances events. When considering the European basins, 51% were affected by threshold exceedances events. The distribution of the threshold exceedances events covered 83% of the EFAS countries. In Table 2 we have a summary.





Table 2. Summary of threshold exceedances in 2017, considering different spatial scales: station, river, basin and country and station location.

	Station	River	Basin	Country
Threshold Levels established	808	447	142	18
Threshold Levels exceeded	343	216	72	15

If we study the duration of threshold levels exceedances, 88% of the stations had less than 10 days with exceedances events.

The remaining 12% recorded more than 10 days of events, the majority (78%) located across the Danube basin (see Figure 17). The stations with the longest exceedance events are:

- Station Kiskore felso, located along the Tisza River with an event duration of 222.5 days (the longest lasting event in 2017)
- Stations Jasenovac and Slavonski Kobas which are located along the Sava River that accounted for accumulated durations of 79.5 and 66.3 days respectively.
- · Station Lubeshiv along the Stokhid River, in the Dnieper basin, with 66 days of accumulated duration
- Stations located on the Latorica River and the Ossiach Lake that registered accumulated event durations of more than 51 days.

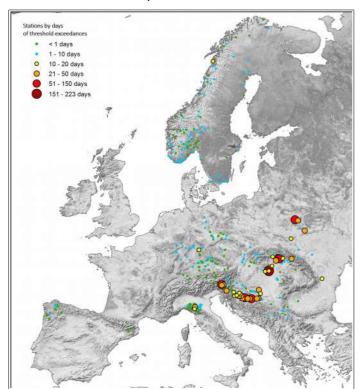


Figure 17. Duration of exceedances events by station.

The basins with the most exceedances events registered are: The Danube, The Po, The Rhine and the Elbe basin.

The Danube basin accounts the most events, stations and days with threshold exceedances. If we consider the





percentage of stations with exceedances compared to the total stations of a basin, the Po basin is the one with the largest percentage of stations exceeding their threshold levels and it is also the one with the highest average of events by station (see Table 3).

Table 3. Basins with the highest number of exceedances: Total number of stations with threshold levels defined, per basin; number of station with threshold exceedances; Percentage of stations which have exceeded their threshold levels per basin; Duration of exceedances per basin; Number of events per basin.

Basin	N. Station	N. Station with exceedances	% Station with Exceedances	Duration (days)	N. Events
Danube	306	145	47	325	413
Po	71	44	62	40	208
Rhine	85	19	22	23	51
Elbe	39	15	38	13	23

4.2 Highest threshold level exceedances

This section focuses on the stations that surpassed their highest threshold level in 2017. The aim is to identify the most severe events in terms of the levels exceeded (see Figure 18).

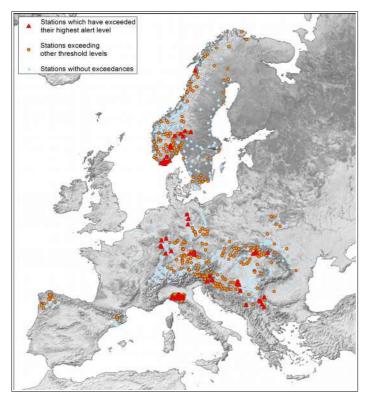


Figure 18. EFAS Stations that exceeded their highest threshold level in 2017.

59 stations surpassed their highest threshold level, with events of different durations.

Of these, 68% of the stations are located across the Danube (37%), the Po (20%) and the Rhine (11%) river basins.

The remaining 32% are found across the Elbe, Glomma, Skien, Tovdal, Mandal, Lygna, Drammen, Strandåvassbotn,





Søgneelva, Nidelva, Otra and Dal river basins.

As the following figure indicates, most of the "highest level" events lasted less than 1 day. The longest events (more than 5 days) occurred just for a few stations spread across the Danube basin located on the Danube, Sava, Juzna Morava and Krasna rivers, the Rhine and Lahn rivers (Rhine Basin) as well as for a station on the Strandvassbotn river (Norway) (see Figure 19).

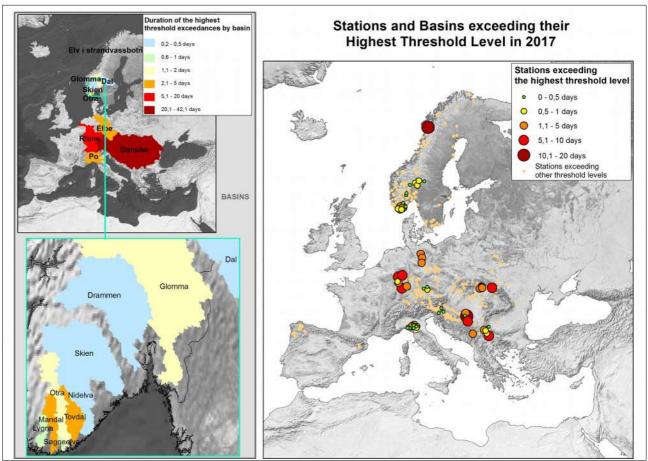


Figure 19. Stations and river basins with exceedances of their highest threshold level in 2017.

4.3 Maximum Duration of Exceedances

Figure 20 shows the classification of exceedances according to their maximum duration in days. Most of the stations (86%) recorded events shorter than 5 days. The longest lasting events (more than 5 days) mainly occurred for stations located in the Danube basin, with a record duration of 222,5 days (01.04.2017 – 08.11.2017) on the Tizsa River.





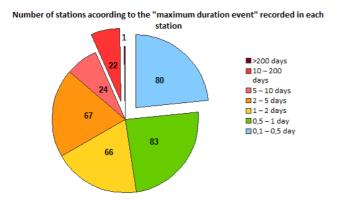


Figure 20. Pie chart ilustrating the number of stations according to the maximum duration of events recorded for each station.

As we initially described, 940 threshold level exceedances events were recorded during 2017. In Figure 21 we have the geographical distribution of the number of events per station as well as a classification of stations by their event frequency. As can be appreciated, most stations recorded less than 5 events throughout the year.

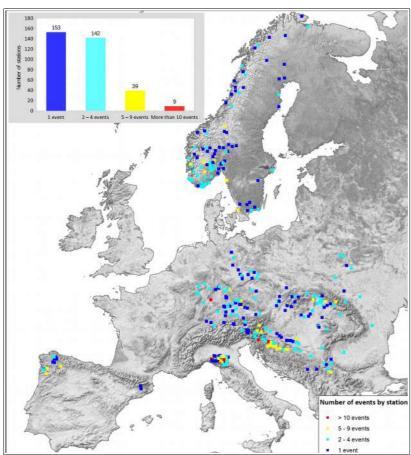


Figure 21. Map showing the stations classified by number of events and including a bar chart with the amount of stations by number of exceedance events.

For a clearer image of the threshold level exceedances, the average duration of the events has been calculated for each station, see Figure 22. The average duration of exceedances events in 2017 is of 1 day.





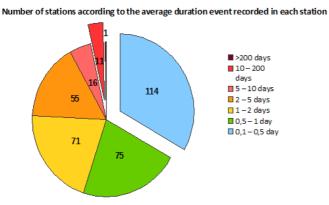


Figure 22. Pie chart showing the number of stations in accordance to the average duration of the exceedances event by station.

In Figure 23 we have the distribution of stations and their average duration. The maximum average values are distributed across the rivers found in the Danube and Dnieper basins: Tisza, Stokhid, Latorica, Bodrog, Styr, Horyn, Lake Wörth, Faak Lake and Sava rivers.

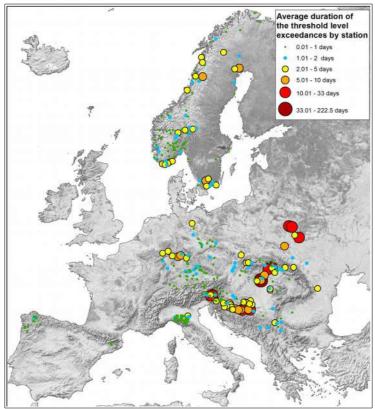


Figure 23. Average duration of events for EFAS stations in 2017.





5. Extreme study cases

In this section we describe a flood event which occurred in northern and central Italy, during the period from the 6th of December to the 24th of December 2017, through the assessment of the real time data received by the HDCC.

Many European and global media covered this flood event¹ and the Copernicus Rapid Mapping service was activated to produce the flood delineation and impact mapping²

Near real time discharge data were not available for this event and the information employed for the assessment of the event is the real time water level data registered for the affected area. The data has an observation frequency of 30 minute.

Although absolute water level values may not be an indicator of water volumes, they are a valid indicator for analyzing the event together with the threshold exceedances information available.

5.1 General description

The floods resulted in the evacuation of hundreds of civilians. Snow, rain and low temperatures were persistent from the 11th of December, affecting ground and air transport services as well as communications services. The heavy rainfall caused damages throughout the regions of Emilia-Romagna, Liguria and Tuscany. The Enza River flooded parts of the village Lentigione and affected many households. Hundreds of people in Colorno required evacuation due to the Parma River overflow as well.

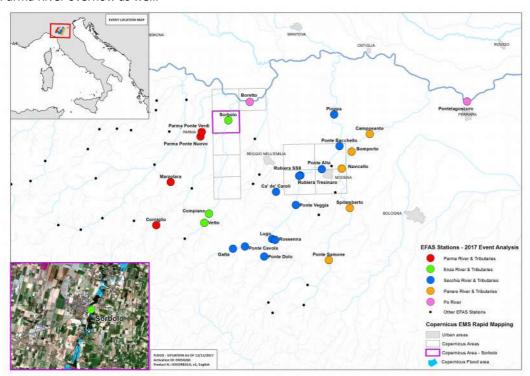


Figure 25. Copernicus image and location map for the gauging stations affected by the floods.

Figure 25 shows the 10 areas of interest covered by Sentinel 1A/B. The inset is an example of the flood delineation for

1 News

http://www.euronews.com/2017/12/12/evacuations-ordered-as-severe-flooding-sweeps-northern-italy and the sum of the sum

https://www.times of malta.com/articles/view/20171213/world/heavy-rain-triggers-flooding-in-northern-italy. 665545

https://watchers.news/2017/12/12/major-flooding-after-rivers-overflow-in-emilia-romagna-italy/linear-rivers-overflow-in-emilia-romagna-italy/linear-rivers-overflow-in-emilia-romagna-italy/linear-rivers-overflow-in-emilia-romagna-italy/linear-rivers-overflow-in-emilia-romagna-italy/linear-rivers-overflow-in-emilia-romagna-italy/linear-rivers-overflow-in-emilia-romagna-italy/linear-rivers-overflow-in-emilia-romagna-italy/linear-rivers-overflow-in-emilia-romagna-italy/linear-rivers-overflow-in-emilia-romagna-italy/linear-rivers-overflow-in-emilia-romagna-italy/linear-rivers-overflow-in-emilia-romagna-italy/linear-rivers-overflow-in-emilia-romagna-italy/linear-rivers-overflow-in-emilia-romagna-italy/linear-rivers-overflow-in-emilia-romagna-italy/linear-rivers-overflow-in-emilia-romagna-italy/linear-rivers-overflow-in-emilia-rivers-overflow-

https://flood observatory.colorado.edu/Events/2017 Italy 4551/2017 Italy 4551.html

2 http://emergency.copernicus.eu/EMSR260





the area of Sorbolo and the Enza River. The location map also shows the stations from which data was obtained. The stations colored are the ones which were employed for this study case. The stations were divided into five groups according to main river they are located on: Parma (red), Enza (green), Secchia (blue), Panaro (orange) and Po (pink).

5.2 Flood Event Evolution Analysis

The following variables were employed for the study:

- Daily maximum water level values and their comparison to threshold levels defined by the hydrological authority of the Po basin. . The authority provides three threshold levels. These where renamed to TL1, TL3 and TL4.
- A Normalized Variation Index (NVI)³, as described in section 1, is used to analyze the increase or decrease of the maximum daily water level compared to the maximum water level registered on December 6 (considered as the beginning of the event). It is calculated as a difference between both values, divided by their sum:

$$NVI = \frac{Max \ WL day \ D - Max \ WL origin \ day}{Max \ WL day \ D + Max \ WL origin \ day}$$

To present the NVI on a map, the values were divided into 6 levels. Figures 25 and 26 show the evolution of the index and threshold levels for the main days of the event (from December 9th to December 14th).

The 11th and 12th of December 2017 are the days where the strongest increase in water level values were registered, with the highest values being reached at Camposanto and Bomporto (on the Secchia river) as well as in Ponte Alto and Lugo (on the Panaro river). The values registered along the Secchia river surpassed the highest threshold values (TL4). Water level values along the Secchia river started to decrease on December 13th 2017.

The water level was above the first threshold (TL1) level for most stations between December 11th and 13th. No threshold levels were exceeded at the following 5 stations: Pontelagoscuro and Boretto, located on the Po River, and Marzolara, Rossenna and Ca' de' Caroli as these are located on smaller tributaries rivers.

Alternatively, the station with the longest duration in threshold exceedances is Ponte Alto, on the Secchia river, which accounted for a total duration of eight days.

In the area affecting the city of Parma, the TL4 values were exceeded for the stations Parma Ponte Verdi, Vetto, Sorbolo, Ponte Veggia, Ponte Alto, Ruviera SS9, Rubiera Tresinaro, all located along the Enza and Secchia rivers. The stations located on the Panaro River only had their TL1 and TL3 values surpassed.

³ Normalized Variation index provides a value always between -1 and 1, which allows to compare, in a simple and objective way, the variation produced in different stations. "0" represents the non-variation between the initial date and the day being compared.





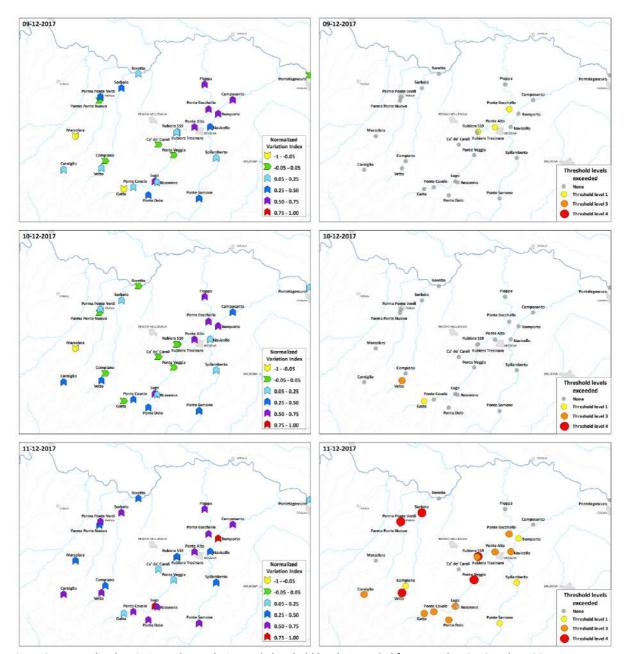


Figure 25. Normalized Variation Index evolution and Threshold levels exceeded for December 9, 10 and 11, 2017.

From the previously mentioned stations, it should be noted that the values registered by Parma Ponte Verdi (Parma river, in the city centre), Sorbolo (Enza river) and Ponte Veggia (Secchia river) directly exceeded their maximum level (TL4). The station Ponte Veggia (Secchia river) which is located upstream presents infrastructures that controls the water flow and could have had an effect on the sudden rise in water level.





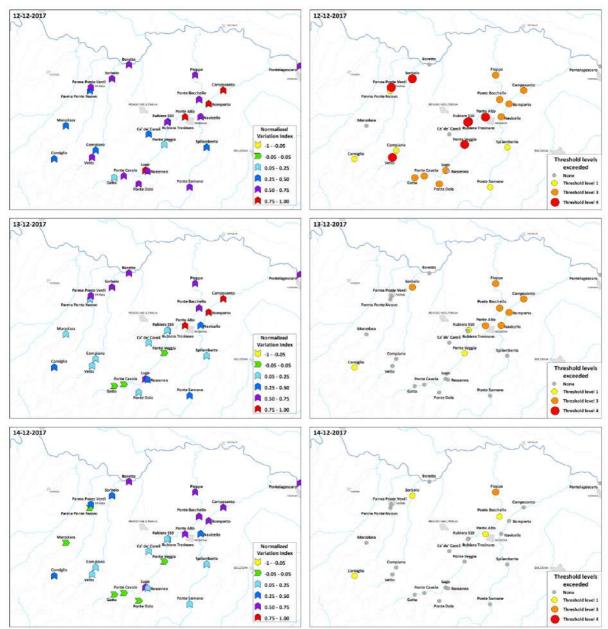


Figure 26. Normalized Variation Index evolution and Threshold levels exceeded for December 12, 13 and 14, 2017.

Figure 27 shows the NVI time series for all the stations analyzed during the event, grouped by rivers. It can be observed that NVI values that exceed 0.5 are linked to the exceedances of TL3 values for almost all the stations except the following:

- Ponte Veggia (Seccha river): NVI is near 0.1 yet the threshold level exceeded is TL4. NVI is very low because water level values for this station are very high, near 10 meters before the start of the flood event and near 13m on the day with maximum levels registered. The station is located in the middle of the city of Sassuolo and a water level rise of 3 meters is more than enough to surpass TL4.
- Gatta (Secchia river): NVI does not score high values because the water level was already high before the flood event occured. The results here show the high dependence of the NVI to the reference level used, which is the water level value of day 6.





- Rossenna (Secchia river): The opposite phenomenon is observed for this station. NVI is high but no threshold levels are exceeded.
- Pontelagoscuro and Boretto (Po river): NVI is high for both stations. The Water level difference is almost 4
 meters during the event, but it falls short to exceed any threshold levels.

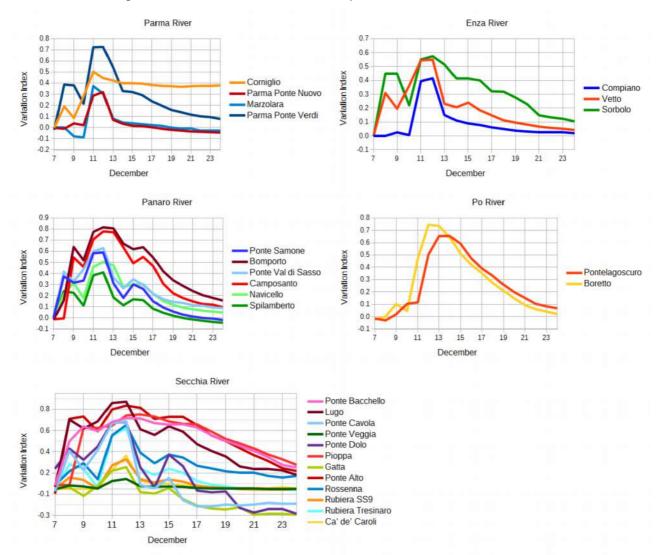


Figure 27. Normalized Variation Index of stations grouped by rivers.

5.3 Comparison with past floods

Only three years before, on January 18th 2014, a flood event occurred in the same area affecting the Panaro and Secchia rivers. In order to compare the progress of both events, the analysis is carried out with real time water level values (m) for both periods and the same stations (location map in Figure 24). The hydrographs of Figure 28 show the "event time" (X axis) centered on the moment in which the maximum value is reached for the two events (considered as value "0"). Negative values of "event time" represent the time before the maximum water level is reached, and the positive values represent the time after having reached the maximum water level. Each unit of "event time" is measured according to 30 minutes, which is the real-time data collection interval for these stations.





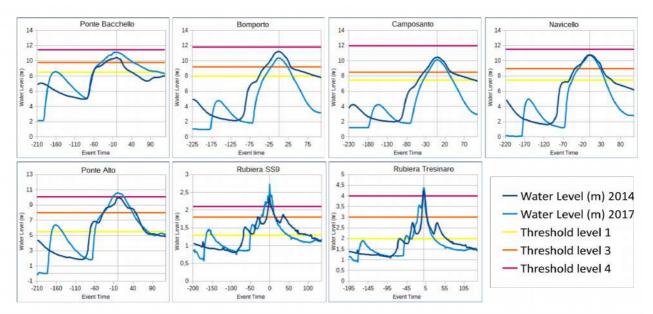


Figure 28. Hydrographs of real time Water Level values and threshold Levels. Events of 2014 and 2017.

The behavior and peak water levels for both events are remarkably similar, although some differences exist. In the case of 2017, all stations present a considerable increase and slight decrease in the water level shortly before reaching the peak event values, which did not happen in 2014. Also in 2017 the recession of water level is much quicker for all stations, except for Ponte Bacchello, when compared to 2014.

On February 10, 2016 another flood event was registered in the same area, this time along the Enza river. The comparison of the hydrographs can be seen in Figure 29. The hydrographs confirm that the event in 2016 has been of a lesser magnitude than 2017. Regarding the behavior prior to the maximum values of the event, for 2016, Vetto and Sorbolo stations also show a quick increase and recession of water levels before the maximum is reached, but of a lesser magnitude than the one in 2017 and closer to occurrence of the maximum value of the event.

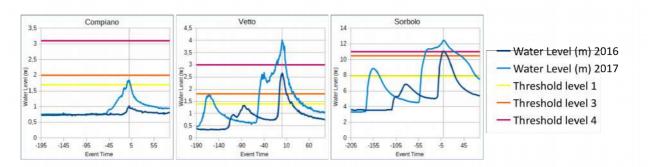


Figure 29. Hydrographs of real time Water Level values and threshold Levels. Events of 2016 and 2017.





Conclusions

As a result of the analysis on the data provided by the EFAS partners throughout 2017, we would like to showcase the following considerations in order to summarise each one of the sections discussed in this report.

In general terms the minima, average and maxima discharge values registered in 2017 are relatively similar to the same values for 2016. However, it is worth noticing that the Minho and Douro river basins in northen Spain, as well as the Guadalquivir basin in Southern Spain, have registred lower values than in 2016 and throughout the historical period 1970-2016. On the other hand, an increase of maxima values compared to 2016 has been registered in stations across southern Norway.

When comparing values with the historical time series for the period 1970-2016, with the exception of the previously mentioned stations in the Spanish river basins, we found small variations for minima and average values, while the maximum values registered in 2017 have remained below those registered during the historical period.

Regarding the data collection gap analysis, a high number of gaps [548,820] were detected for 2017, most of which presented a duration less than 1 hour and the majority occurring due to time interval variations (irregular delivery of data). A measure proposed that would help mitigate the effects of the data gaps consists in normalizing the data series to a specific time interval for all partners, whenever possible (i.e. 1 hour operational tables).

Data gaps that have a duration less than 5 days are filled by the EHDCC data interpolation process. However gaps that present longer durations are only completed if the data is provided by the authorities responsible of the hydrological data provision upon request from the EHDCC.

The cause of data gaps was identified in 75% of the cases and solutions have been proposed accordingly. However, for the remaining 25% of the cases the causes remain unknown.

Considering the Exceedances events registered throughout 2017, we have that the average duration of events is of one day. Most of the stations exceedances lasted less than 10 days. We found that 65% of the events registered during 2017 were located across the Danube, the Po, the Rhine and the Elbe river basins, respectively affecting 47%, 62%, 22% and 38.5% of the stations that are located within their catchment areas.

The Danube basin presented the highest number of threshold level exceedance days, reaching a total of 325 days, followed by the Po basin with 40 days. The stations that recorded the highest amount of exceedance days (over 10 days) are located along the Tisza River, Sava River, Latorica River and Ossiach Lake (the Danube Basin), Secchia River (Po basin) and Stokhid River (The Dnieper basin).

The most extreme events, refering to the highest threshold level exceeded by stations, are also located in the Danube, Po, Rhine and Elbe basins. The stations that stand out in terms of extreme event duration are located across the Danube, Sava, Juzna Morava and Krasna Rivers, in the Danube Basin, across the Rhine and Lahn River (Rhine Basin) and the Strandvassbotn River (Strandvassbotn Basin).

With regards to the analysis performed on the real time data available during the flood event that occured in Italy during 2017 and comparing them to the real time values for the affected area and available to the HDCC since May 8th 2012, the water level values registered are the highest ever reached for the main rivers affected (Parma, Enza and Sechhia rivers).

As a final consideration we would like to outline the usefulness of the hydrological real time information provided by EFAS partners, which has allowed for the analysis of this extreme case. This study can be applied to any other event in the regions for which real time information and data is provided to the EFAS System.





Annex 1: Data provider list

Agency name	Country
Federal Ministry of Agriculture, Forestry, Environment and Water Management	Austria
Hydrological Information Centre	Belgium
Service public de Wallonie	Belgium
Federal Hydrometeorological Institute	Bosnia and Herzegovina
National Institute of Meteorology and Hydrology	Bulgaria
Meteorological and Hydrological Service of Croatia	Croatia
Estonian Environmental Agency	Estonia
Finnish Environment Institute	Finland
Ministère de l'Ecologie et du Développement Durable Service Central d'Hydrométéorologie et d'Appui à la Prévision des Inondations	France
Bundesanstalt fuer Gewaesserkunde	Germany
Ministry of Rural Development, Environment and Agriculture of the Federal State of Brandenburg	Germany
Hessisches Landesamt für Umwelt und Geologie	Germany
Landesamt für Umwelt, Wasserwirtschaft und Gewerbeaufsicht Rheinland - Pfalz	Germany
Landesamt für Umwelt, Gesundheit und Verbraucherschutz	Germany
Bayerisches Landesamt für Umwelt	Germany
Hungarian Hydrological Forecasting Service (OVSZ), General Directorate of Water Management (OVF)	Hungary
Office of Public Works of Ireland	Ireland
Servizio Idro Meteo Clima	Italy
Latvian Environment, Geology and Meteorology Centre	Latvia
Czech Hydro	Meteorological Institut
Rijkswaterstaat Institute for Inland Water Management and Waste Water Treatment	Netherlands
Norwegian Water Resources and Energy Directorate, Hydrology Department	Norway
Institute of Meteorology and Water Management Wroclaw Branch	Poland
Institutul National de Hidrologie Si Gospodarire A Apelor	Romania
Republic Hydrometeorological Service of Serbia	Serbia
Slovak Hydrometeorological Institute	Slovakia
Environmental Agency of the Republic of Slovenia	Slovenia
Automatic System of Hydrological Information for the Ebro River Basin	Spain
Government of Andalusia - Regional Ministry for the Environment and Spatial Planning, Environmental Information Network	Spain
Confederación Hidrográfica del Miño - Sil	Spain
Catalan Water Agency	Spain
Confederación Hidrográfica del Duero	Spain
Swedish Meteorological and Hydrological Institute, core services department	Sweden
Federal Office for the Environment	Switzerland
State Emergency Service of Ukraine - Ukrainian Hydrometeorological Center	Ukraine
UK Met Office - Flood Forecasting Centre	United kingdom
Scottish Environment Protection Agency	United Kingdom