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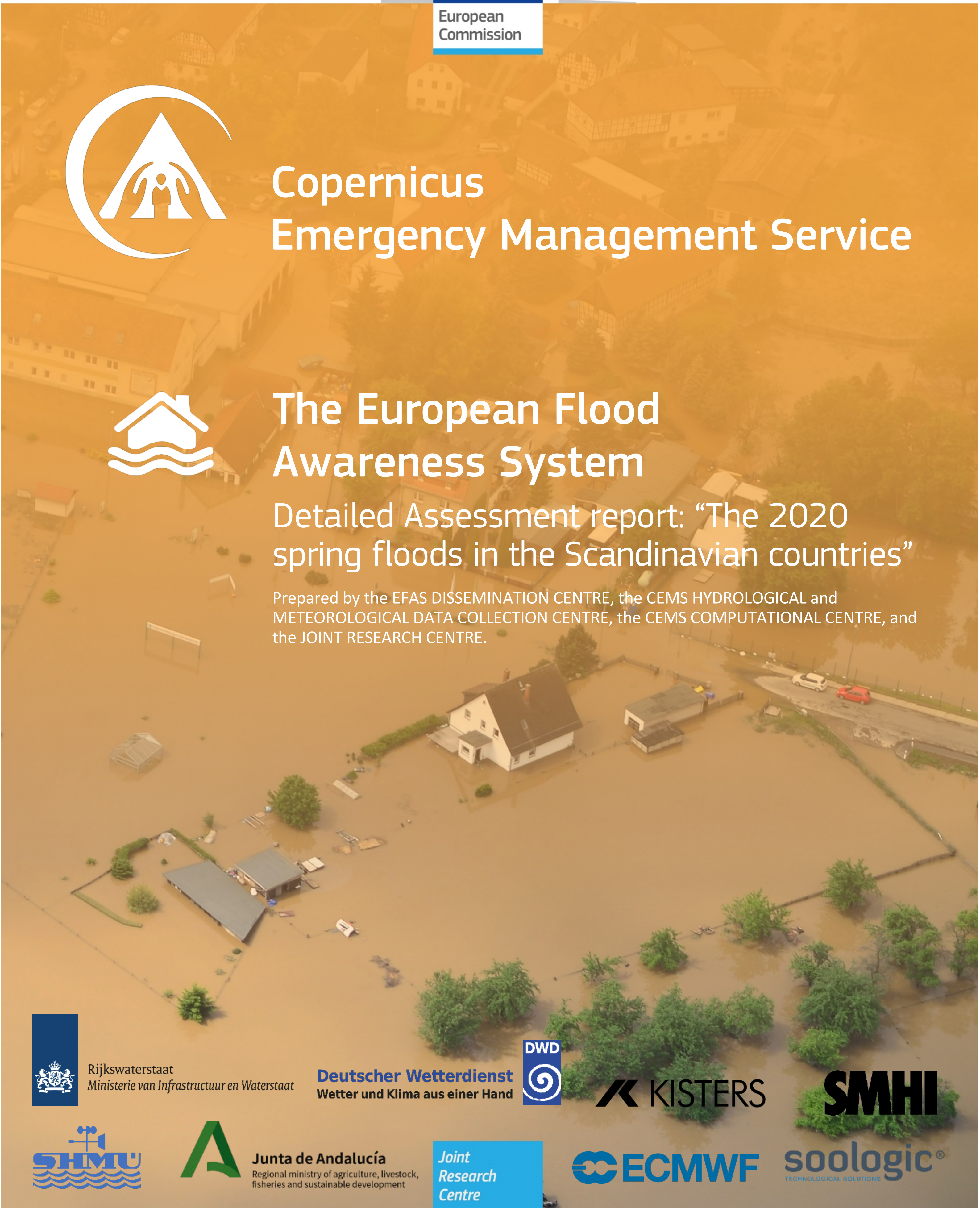

Copernicus Emergency Management Service

The European Flood Awareness System

Detailed Assessment report: “The 2020 spring floods in the Scandinavian countries”

Prepared by the EFAS DISSEMINATION CENTRE, the CEMS HYDROLOGICAL and METEOROLOGICAL DATA COLLECTION CENTRE, the CEMS COMPUTATIONAL CENTRE, and the JOINT RESEARCH CENTRE.

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Contents

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
NRT	Near Real-Time
NVE	Norwegian Water Resources and Energy Directorate
NWP	Numerical Weather Predictions
RP	Return period
SWE	Snow Water Equivalent
SMHI	Swedish Meteorological and Hydrological Institute
SYKE	Finnish Environment Institute

1 Introduction

Flooding is one of the most destructive hazards and accounts for large economic damages and human losses worldwide. The European Flood Awareness System (EFAS, https://www.efas.eu/) operated by the Copernicus Emergency Management Service (CEMS) operationally monitors and forecasts floods across Europe since 2012. EFAS forecast supports preparatory measures before major flood events, particularly in the large trans-national river basins and throughout Europe.

EFAS provides early warning information up to 10 days in advance, while the EFAS Information System (EFAS-IS) is the interface used to access the forecast information including a variety of products. EFAS provides complementary, added-value information (e.g. probabilistic, medium-range flood forecasts, flash flood indicators, and impact forecasts) to the relevant national and regional authorities. The EFAS forecasters access the hydro-meteorological information, discuss the situation, summarize it and finally disseminate it by email to National authorities, regional hydrological services and the European Response and Coordination Centre (ERCC).

The present document is a detailed assessment report which aims to evaluate the performance of EFAS for the flood events during the spring season of the year 2020 (end May to end July) for the Scandinavian countries of Finland, Norway and Sweden. In Scandinavia high flows occur in the months of May to July, with the snow melting being the main hydrological driver. In addition, strong precipitation events can significantly increase the flow response leading to potential floods. The performance will be evaluated in terms of timing, magnitude, lead time and missed events. In this report, the usefulness of the system from the user's perspective is also analysed. In addition to the EFAS notifications, this report presents the national flood warnings during the 2020 spring flood period as disseminated to the public through the national webpages. Overall this assessment allows to evaluate the accuracy of the EFAS forecasts and disseminated notifications, with the aim of shaping suggestions for further service evolutions.

The report is organized as follows: section 2 includes a general description of the events. Section 3 analyzes data from available stations. Section 4 presents the public information about the flood events, while section 5 describes and 6 evaluates the EFAS forecast and information from the EFAS-IS. Finally, section 7 presents conclusions and recommendations.

2 Description of the flood event

2.1 The study area

Scandinavia is a subregion in Northern Europe. Here, the study area is the Scandinavian countries within the EFAS system, which refer to Finland, Norway, and Sweden. The geography of Scandinavia is extremely varied, consisting of the Scandinavian mountains, the low areas in the archipelagos of Sweden, Finland and Norway. These countries also have many lakes and reservoirs for the hydropower production. The climate varies from north to south and from west to east, including humid continental climate, subarctic climate, and alpine climate in the mountains. The climate in these country makes it possible for snow to be accumulated mainly in the winter months (December till February), however especially in the northern part of the countries snow can be accumulated earlier than December and later than March. The temperature increase above zero degrees starting during the spring season can lead to floods, which are called spring floods. The magnitude of the spring floods is largely depending on the quantity of accumulated snow, the pattern in which the temperature increase, and the amount of runoff coming from rainfall in addition to the snow melting process.

2.2 The meteorological situation leading to the event

This section describes the overall meteorological situation prior and at the beginning of this event. The data were taken from the EFAS Meteorological Data Collection Centre (MDCC) data base, if no other source is given.

Starting position

Since the beginning of the hydrological year 2020, which started in October 2019, a precipitation excess accumulated till May 2020 in large parts of northern Scandinavia (Figure 2.1). Some regions in Norway and Finland received over 100 mm more precipitation from October 2019 till May 2020 than the long-term average (based on data from 1990-2013). On the other hand, precipitation totals in northern Sweden mountains were below the long-term means.

As shown by the station “Rovaniemi Airport” within the affected area in Finland, on a monthly basis, October 2019 and December 2019 till February 2020 were significantly wetter than normal while March 2020 was around normal and November 2019 and April 2020 were slightly drier than usual (Figure 2.2)

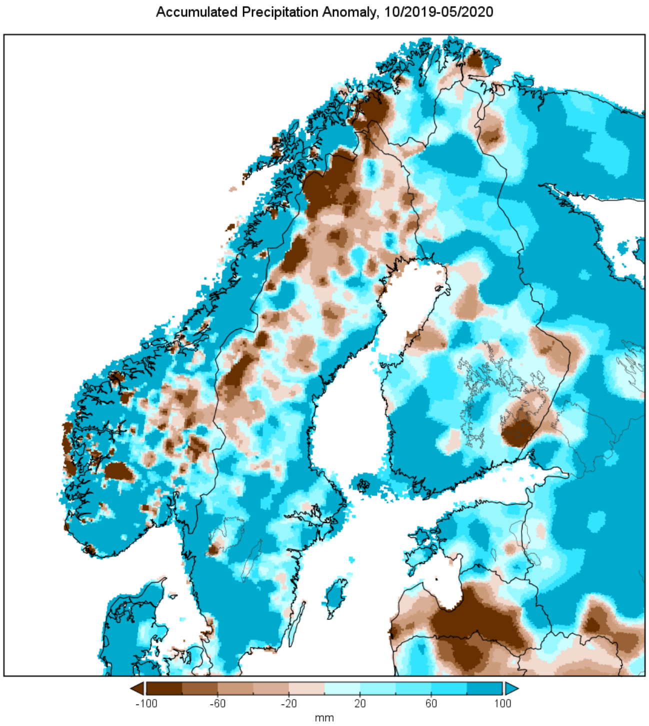


Figure 2.1: Accumulated precipitation anomaly from October 2019 till May 2020 relative to long-term means 1990-2013.

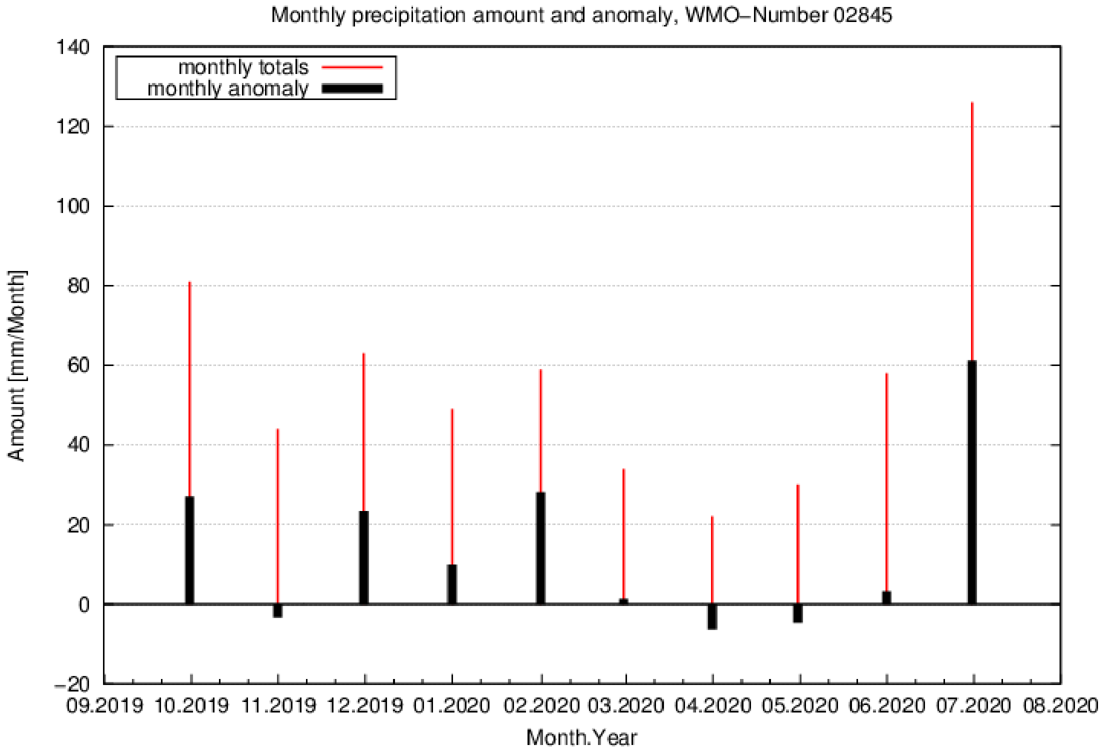


Figure 2.2: Monthly precipitation total and anomaly for station "Rovaniemi Airport" (WMO-Number 02845) in Finland (source: https://www.cpc.ncep.noaa.gov/products/timeseries/).

Daily mean temperatures were below normal in October 2019 and November 2019, above normal, but mostly below zero degree Celsius, from December 2019 till March 2020 and again below normal in April 2020 and May 2020 till May, 22nd (Figure 2.3, for a station in Finland). Daily mean temperatures below zero degree Celsius were reported until end of April 2020 (Figure 2.4). Therefore, until then the majority of the received precipitation was accumulated as a snowpack.

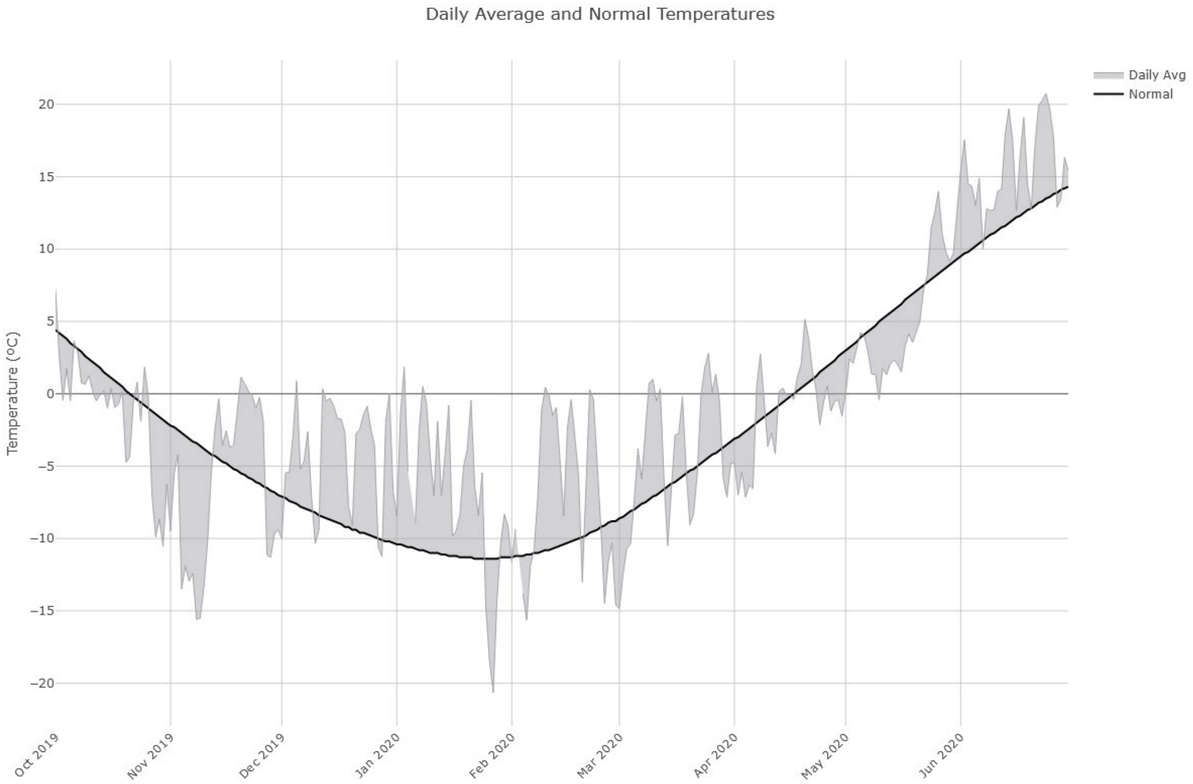


Figure 2.3: Daily mean and average daily mean temperature for station " Rovaniemi Airport " (WMO-Number 02845) in Finland (Source: https://www.cpc.ncep.noaa.gov/products/timeseries/).

During the event

The widespread floods were mainly triggered by a steep temperature increase, which caused a rapid snowmelt. Daily mean temperature timeseries at the station “Rovaniemi Airport” are depicted in Figure 2.4 for the event. While daily mean temperatures were only slightly above zero degrees Celsius till May, 21st, they increased in the following six days by eleven degrees Celsius from below normal to above normal temperatures. This increase was caused by two consecutive low-pressure systems over the northern Atlantic Ocean which adverted subtropical warm air masses far to the north.

Monthly precipitation amounts were around normal in May 2020 and in June (see Figure 2.2). Precipitation totals in July 2020 were above normal in Finland and Northeast Sweden, locally by as much as twice the precipitation amount as the normal (information found at the bulletin/EFAS-IS, not shown here).

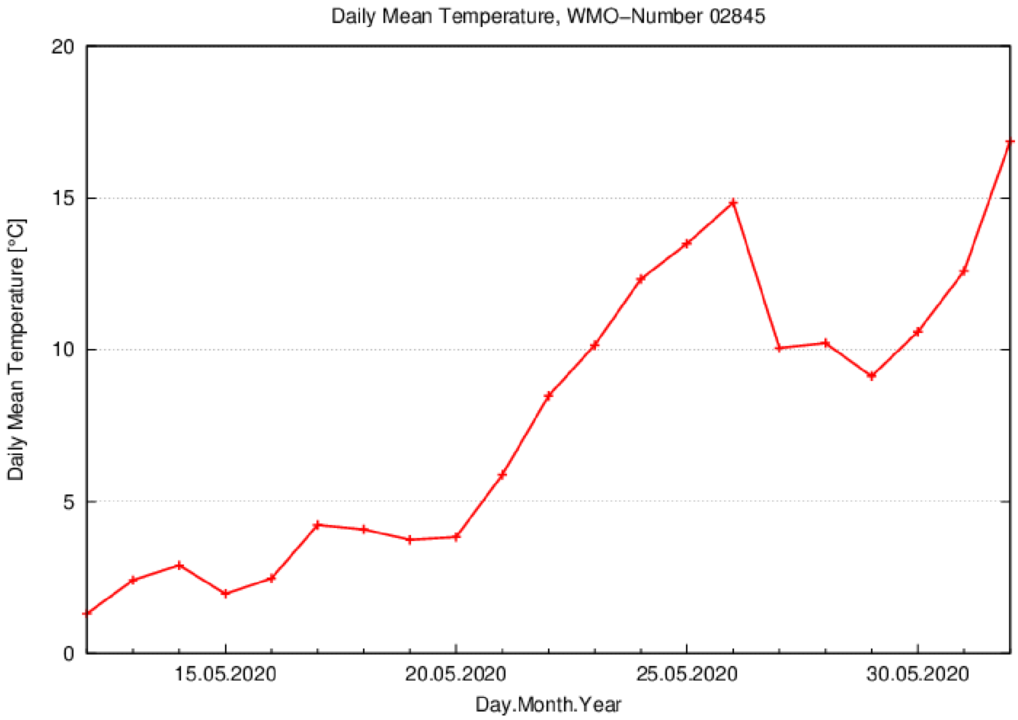


Figure 2.4: Mean daily temperature for station " Rovaniemi airport" (WMO-Number 02845) in Finland, during the days the flood event starts.

2.3 Description of reported flood and their impact

2.3.1 Description of the flood event

Information in the EFAS-IS during the event showed a large amount of water equivalent snow (larger than 250 mm, Figure 2.5) just before a steep increase in temperature starting at the end of May (Figure 2.6), while temperature prevailed above zero the rest of the spring. The last combination resulted in snow melting which in turn lead to a series of EFAS flood warning notifications for the Scandinavian region starting on the 23rd of May. Precipitation intensified the magnitude of the flood temporary, see for example precipitation during the 29th and 30th of May, and the 7th, 8th and 9th of June in Figure 2.7. In general, the observed (spatially interpolated at the 5km grid) precipitation reached a maximum of 25 mm per day with the exception of few small areas where it reached up to 40 mm.

In general, the first affected area by the 2020 spring flood in Scandinavia was the central and northern Finland, and successively extended to Norway (spread around the country) and west-central and northern parts of Sweden. Depending on the location within the Scandinavian region, the 5-year return period (RP) threshold was exceeded anytime between the 25th of May to the end of June, when almost all the snow had melted for the three countries (Figure 2.5).

EFAS predicted discharge exceeding the 20-year RP for 15 notifications, located all over the affected area, of which six are presented in Figure 2.8. In the next sections of this report, it is shown that the 2020 event is one of the largest spring floods in recent years. The snow melting event exceeded of the highest national threshold for discharge in Finland and Norway.

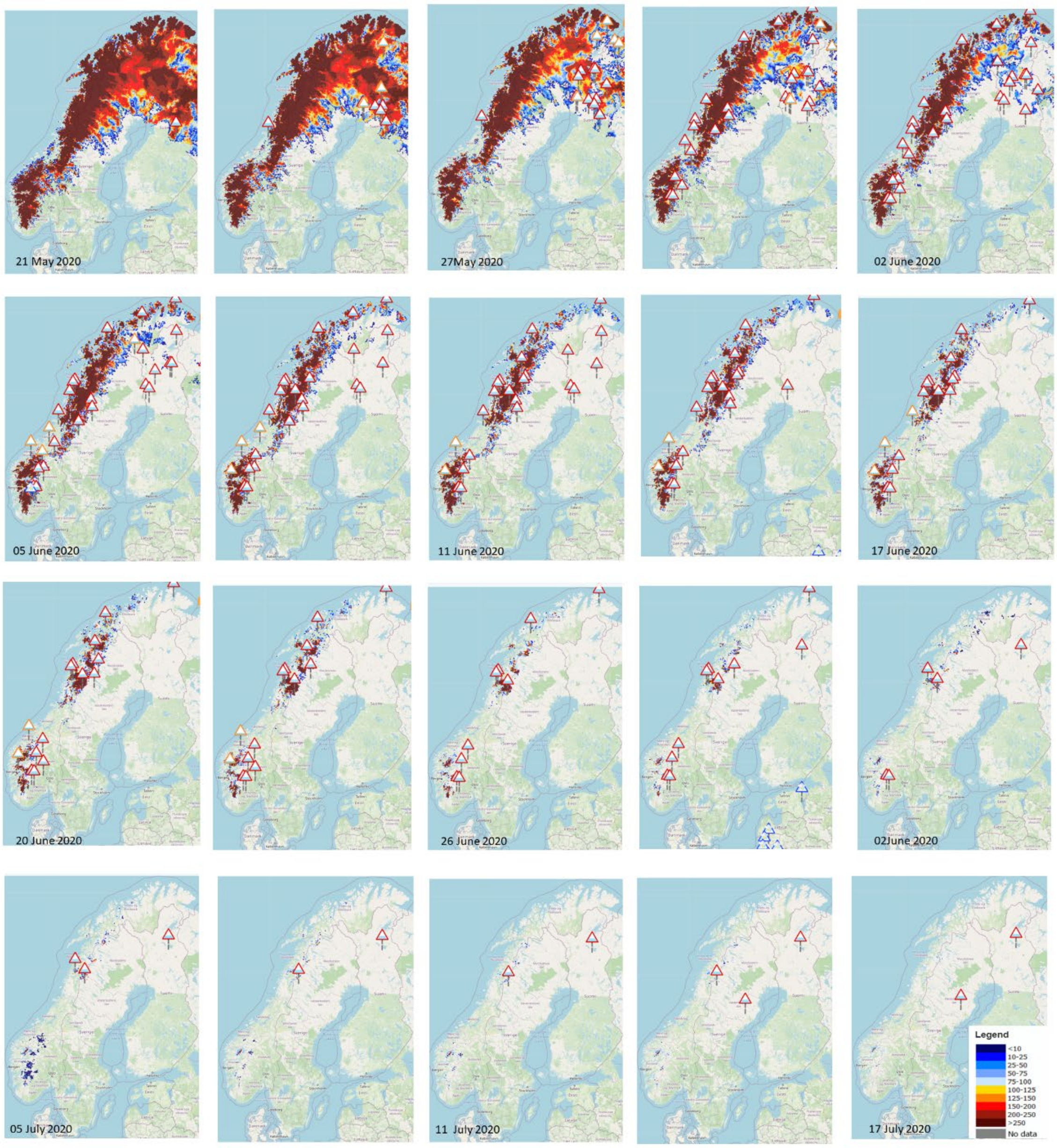


Figure 2.5: Evolution of EFAS issued flood notifications at intervals of 3 days. The background shows the LISFLOOD simulated amount of snow (mm; snow water equivalent) based on observed meteorological input.

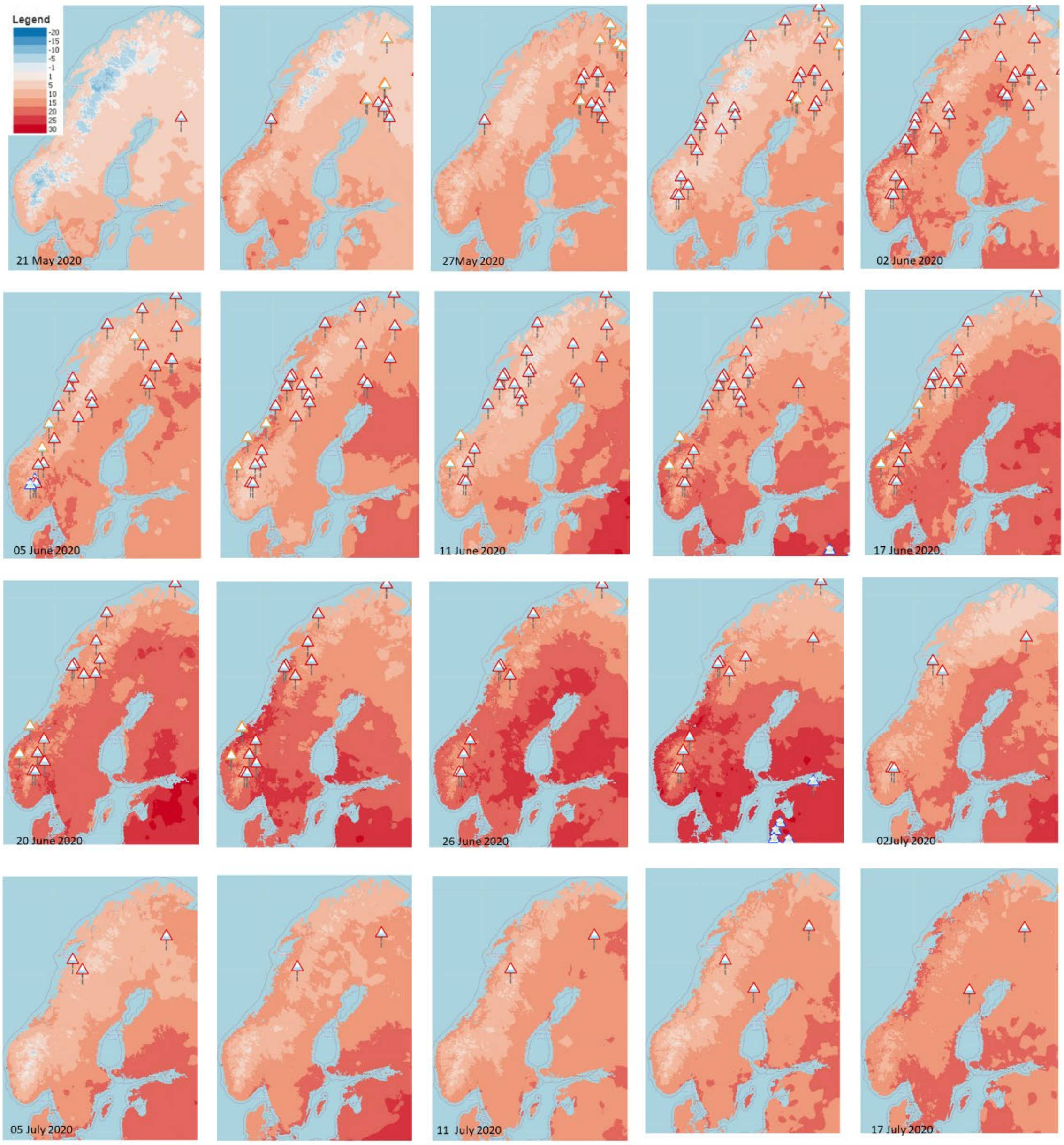


Figure 2.6: Evolution of EFAS issued flood notifications at intervals of 3 days. The average observed daily temperature is shown in the background.

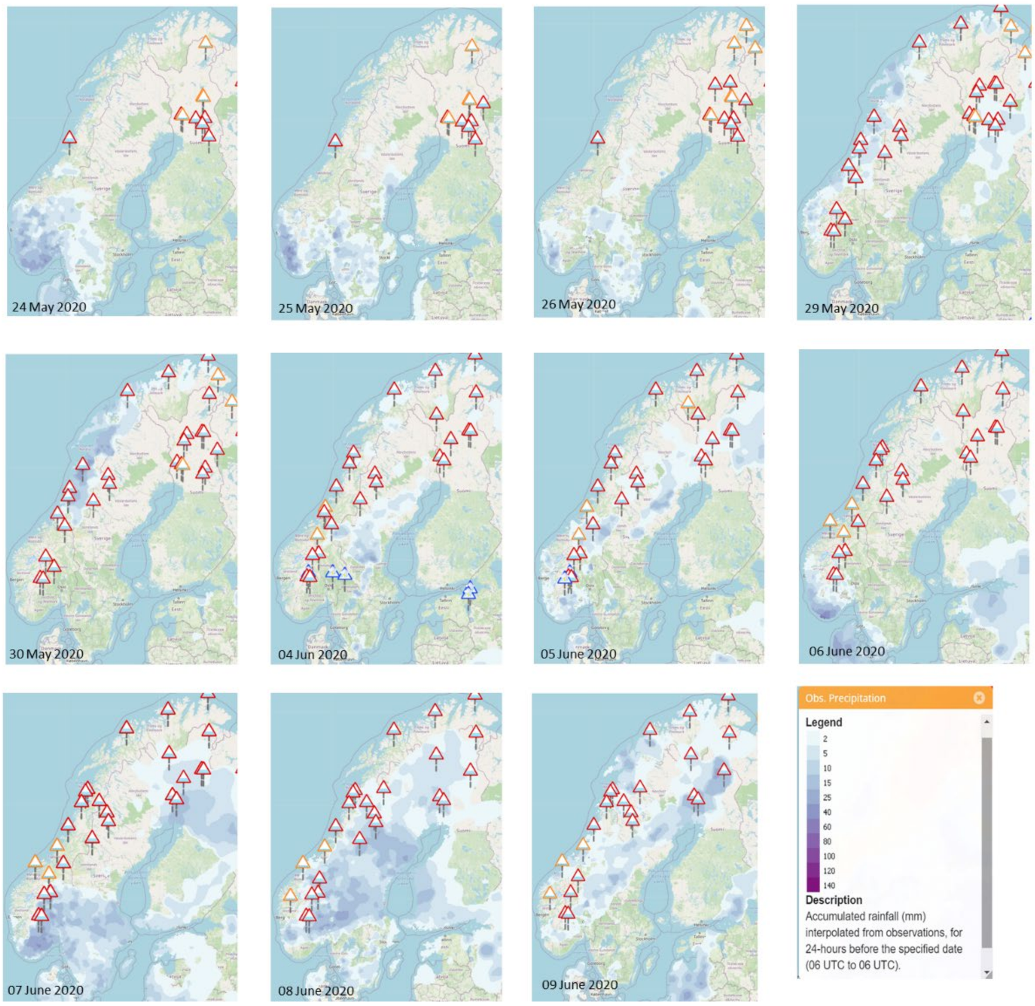


Figure 2.7: Distribution of daily accumulated precipitation for selected days when the accumulation was significant. Issued EFAS notifications are also shown.

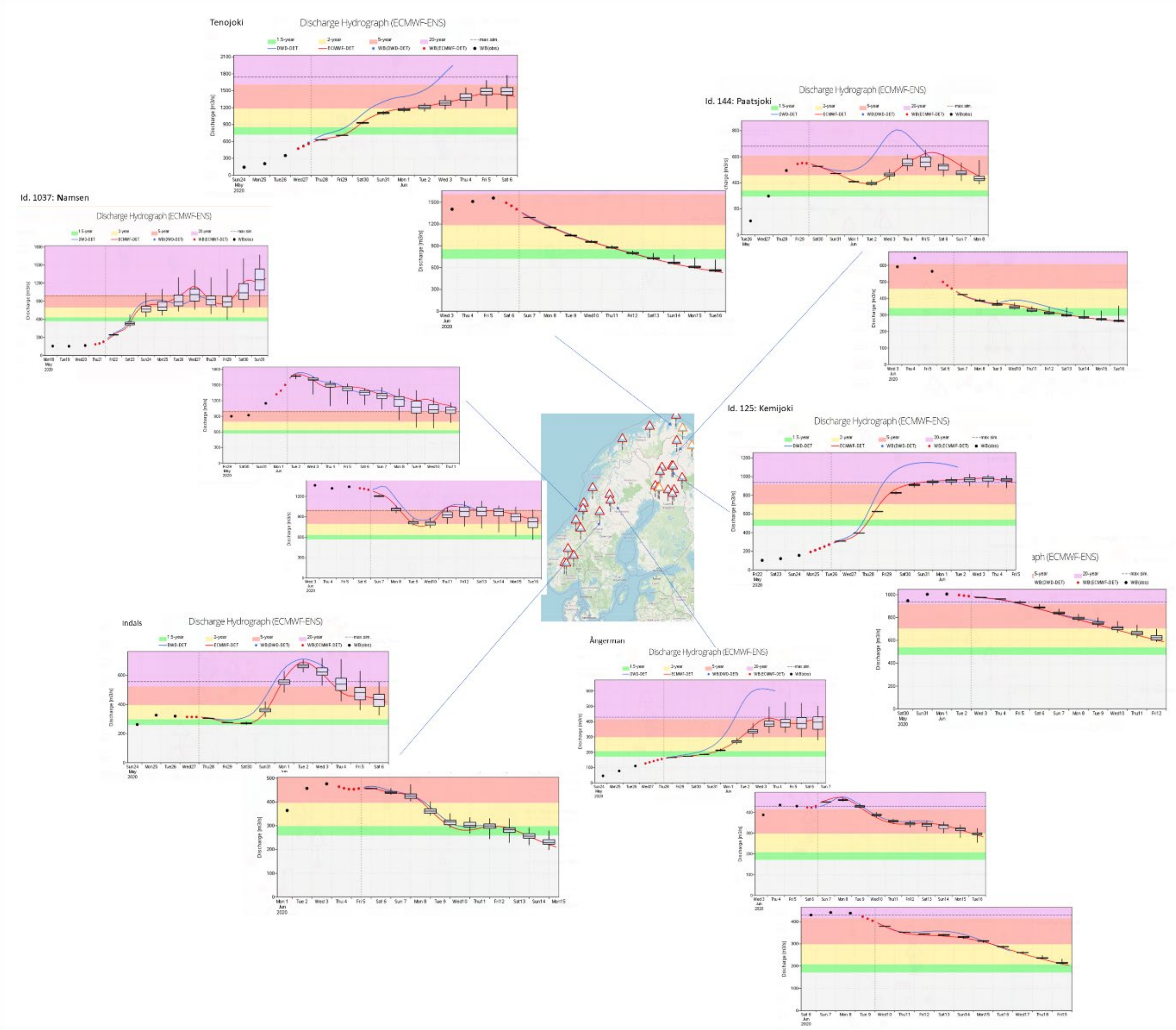


Figure 2.8: EFAS forecasted hydrographs for some of the most critical 2020 spring floods in Scandinavia; black dots represent LISFLOOD forced with observations (precipitation, temperature).

2.3.2 Impacts - based on media reports

Finland

Media reports 1 and 2 in Annex 1 show that the snow melting event was forecasted way ahead on time. This allowed the preparation of mitigation measures so that institutions, municipalities and those in control of reservoirs cooperated and smoothed down the high flows. As they reported later “many of the efforts paid off” (see Media report 3 in Annex 1). Nevertheless, the consequences of the spring flood in Lapland included evacuations, and roads and houses being affected (Media report 4 in Annex 1), see an example in Figure 2.9.

Figure 2.9: Picture taken at Lånestranden in Rovaniemi on the 31st May.

Norway

Media report 5 (Annex 1) mentioned that the likelihood of large spring floods was somewhat reduced in Norway due to the warm weather at the beginning of May; the actual flood could have been more severe if part of the snow would not melt earlier. Consequences reported in the media on the 8th of June includes evacuations of some homes in and around Norway's northern city of Alta (Figure 2.10) and the E6 highway being affected (see Media report 6 and 7 in Annex 1).

Figure 2.10: Picture taken at Alta in Finnmark on the 8th of June.

Sweden

On the 3rd of June small local problems were reported in Sweden as consequences of flooding (report 8 in Annex 1, made by the Swedish Civil Contingencies Agency). On the 10th of June local problems were specifically described at, among others, the Hemavan Tärnaby airport and at a bridge along the way 322 which was at risk of falling. In general, the affected area had a low population density, but have touristic visitors. Measures for the dissemination of information at different centers were taken. The last report on the spring flood in Sweden occurred on the 8th of July.

3 Hydrological analysis on the in-situ observations

3.1 Introduction

To analyze the hydrological situation in the Scandinavian countries, EFAS provides information at gauging stations from three different Data Providers: Norway (NO-1002: Norwegian Water Resources and Energy Directorate), Sweden (SE-1014: Swedish Meteorological and Hydrological Institute) and Finland (FI-1011: Finnish Environment Institute). There is a total of 230 gauging stations with discharge values to be analyzed, but after a first preliminary analysis the study focused on 114 gauge stations that show a notable increase in flow for the period of the event (May 19th to July 31th). See Figure 3.1.

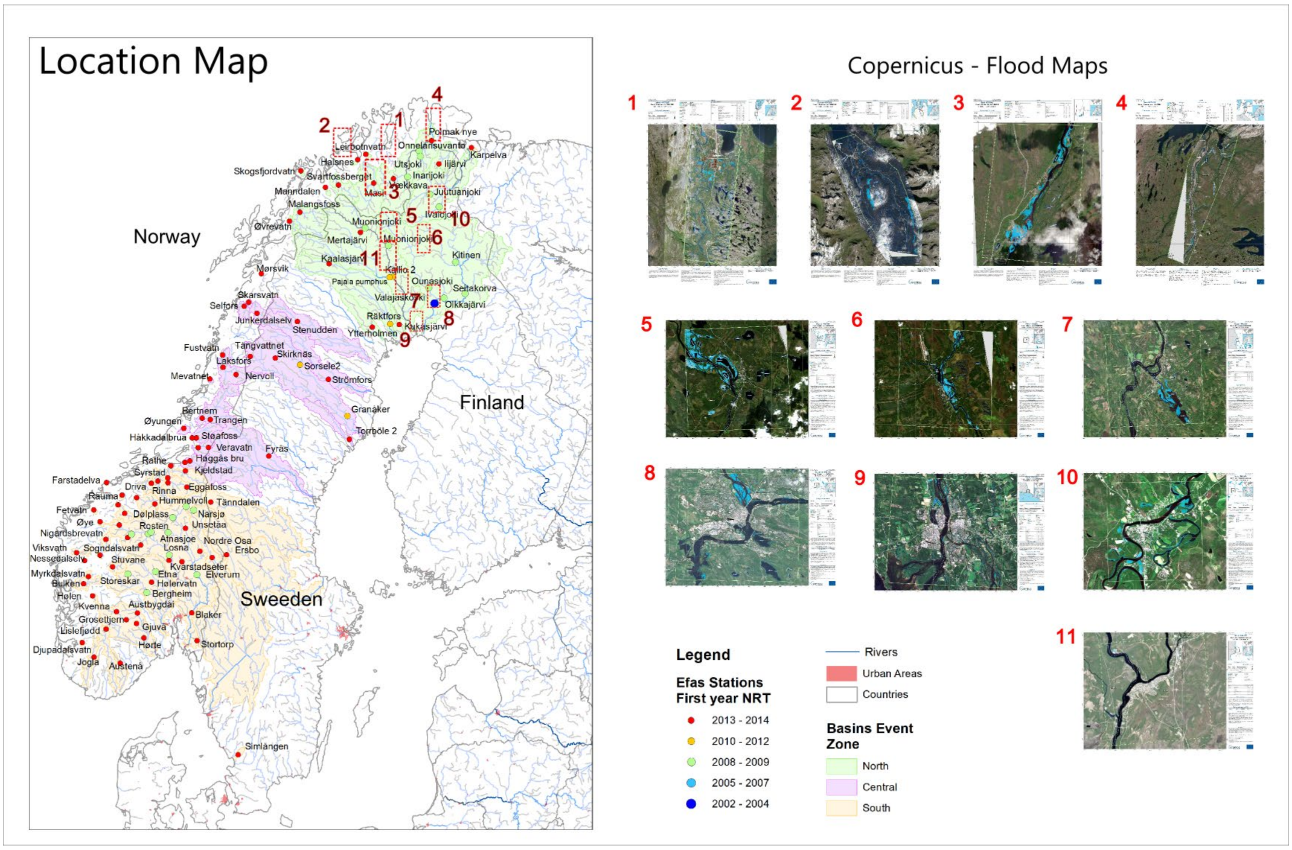


Figure 3.1: Location map with the EFAS stations selected, including the year of the first Near Real-Time data, and areas with Flood Maps made by Copernicus.

3.2 Methodology

The hydrological analysis is based on three different indicators. To make it easier to interpret the results, we present maps and calendar matrices, showing the indicators for each zone (North, Central and South, see in Figure 3.1) and their progression over time.

3.2.1 Normalized Variation Index (NVI)

The NVI is an indicator for the daily evolution of the event. It is for each day f calculated as a difference between the maximum observed discharge of day f of the event (D^f_{max}) and the maximum discharge on the day before the event starts (D^i_{max}), divided by their sum:

$$NVI = \frac{D^f_{max} - D^i_{max}}{D^f_{max} + D^i_{max}}$$

The NVI provides values between -1 and 1, allowing a relative comparison in a simple and objective way. Zero value represents the non-variation between the initial date and the day being compared with, while positive and negative values represent increasing and decreasing flows, respectively. For the present flood analysis, the NVI is grouped into four classes: <0, 0-0.3, 0.3-0.75 and >=0.75. Negative values were grouped into a single class since this analysis focuses on floods, hence positive NVI values; see Figure 3.2 (1) for an example of an NVI analysis. In addition, for each station the number of days per NVI class were computed and for the highest class (NVI >0.75) the following grouping was done: 0 days, 1-20 days, 21-40 days, 41-60 days and >60 days to show it in a diagram and in a map (Figures 3.3, 3.6 and 3.9).

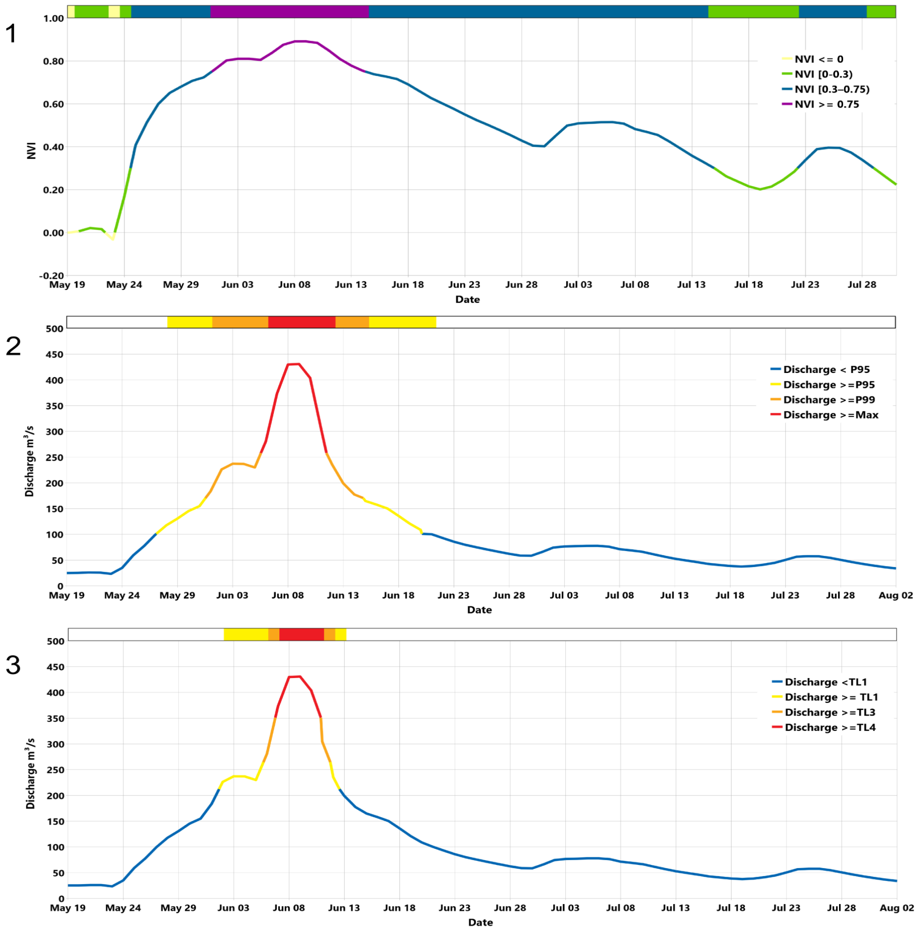


Figure 3.2: Vækkava" station: 1) Example of NVI analysis. 2) Example of percentile analysis. 3) Example of a threshold level exceedance evaluation.

3.2.2 Percentiles

Percentiles are useful to assess the severity of the flood event in a historical perspective. Four levels were chosen based on the 95th, 99th and Max percentiles: < P95, P95-99, P99-Max, >Max (Figure 3.2 (2)). The 95th and 99th percentiles represent floods that are exceeded on average 18 and 4 days per year, respectively, and the Max represents the value that has never been exceeded before. Also, the 99th percentile is not necessarily exceeded every year, although the annual frequency of exceedances will depend on the catchment size. The percentiles for each station were obtained from real-time data (daily aggregated maximum), where data is available from (at least) 2014, however many stations have data from 2008 (see in Figure 3.1).

Figure 3.2 (2) shows an example of the percentile evaluation. As for the NVI, also here the number of days per percentile was computed, and the number of days exceeding the 99th percentile and the Maximum were plotted on a map per zone (Figure 3.4, 3.7 and 3.10).

3.2.3 Exceedance of station-specific thresholds

The threshold exceedance analysis was done only for the stations located in Norway and Sweden, because in Finland the stations are not provided with threshold levels. There are four threshold levels defined in the EFAS System, but these Providers only uses three. EFAS then orders them as Level 1, Level 3 and Level 4 (TL1, TL3 and TL4). The three levels can be referred to as: Activation, Pre-alert and Alert Threshold, respectively.

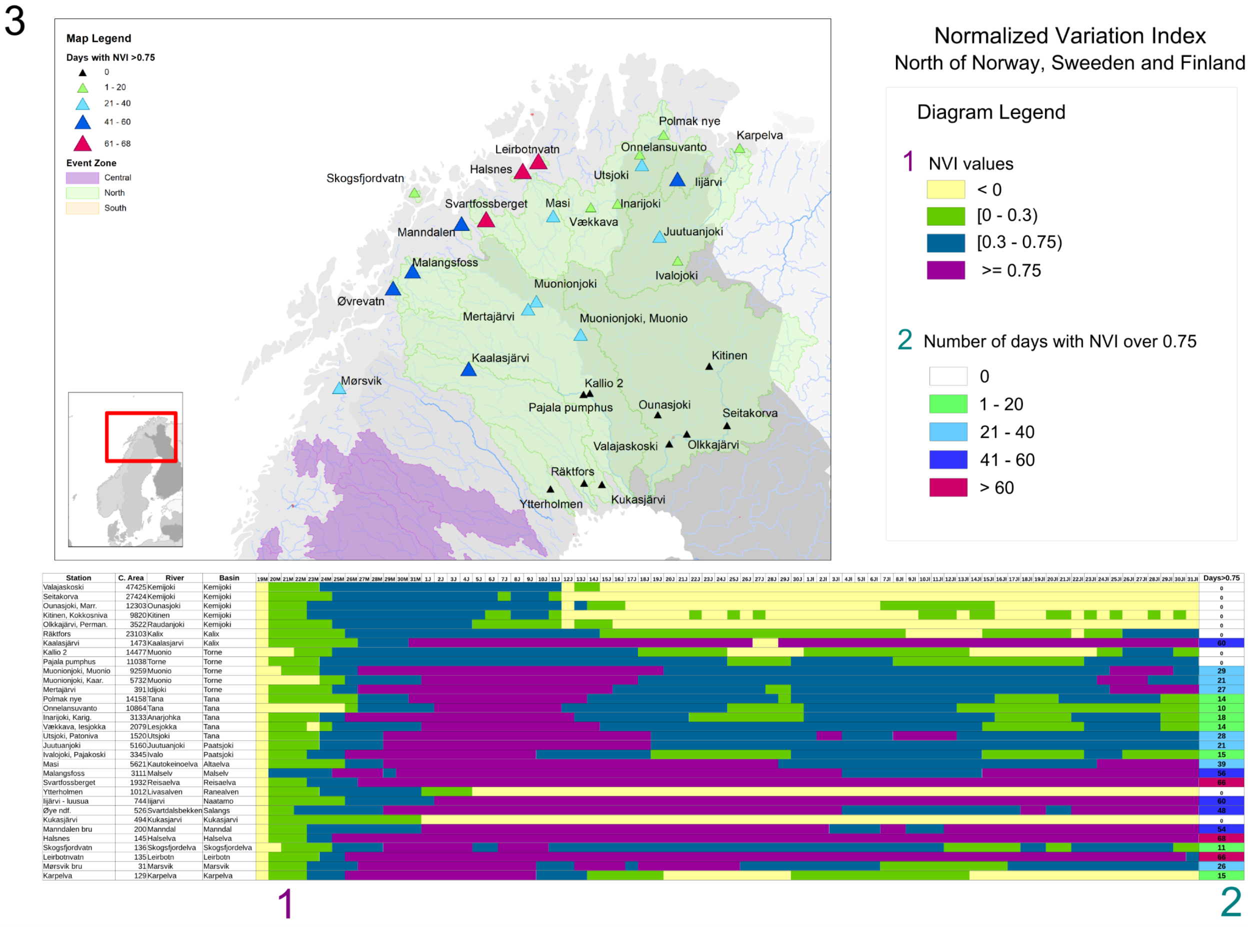
Figure 3.2 (3) shows an example of a threshold level exceedance. The number of days above each threshold is further used as an indicator for the severity of the event and has been plotted in a calendar matrix and mapped by zones in Figures 3.5, 3.8 and 3.11.

3.3 Results

3.3.1 North zone

To facilitate the analysis and interpretation of the NVI, a map-diagram composition was created at the basin level. It is composed of three parts: 1) a calendar matrix showing the NVI value for each day and stations, 2) the number of days within the highest NVI class per station, and 3) a map with this last value for each station (Figure 3.3).

A total of 31 stations have been analyzed for the time period between May, 19th and July, 31th of 2020. The highest number of days with values over 0.75 can be found in the north of Norway (Leirbotnvatn, Halsnes and Svartfossberget stations). In the south area the event is not as high as in the rest or the studied domain. The stations show an increase in discharge but it does not reach an NVI of 0.75. This happens mainly in Kemijoki, Kalix and Torne basins (see in the top of the diagram in Figure 3.3).



Station	C. Area	River	Basin	Days>0.75
Valajaskoski	47425	Kemijoki	Kemijoki	0
Seitakorva	27424	Kemijoki	Kemijoki	0
Ounasjoki, Marr.	12303	Ounasjoki	Kemijoki	0
Kitinen, Kokkosniva	9820	Kitinen	Kemijoki	0
Olkkajärvi, Perman.	3522	Raudanjoki	Kemijoki	0
Räktfors	23103	Kalix	Kalix	0
Kaalasjärvi	1473	Kaalasjarvi	Kalix	60
Kallio 2	14477	Muonio	Torne	0
Pajala pumphus	11038	Torne	Torne	0
Muonionjoki, Muonio	9259	Muonio	Torne	29
Muonionjoki, Kaar.	5732	Muonio	Torne	21
Mertajärvi	391	Idijoki	Torne	27
Polmak nye	14158	Tana	Tana	14
Onnelansuvanto	10864	Tana	Tana	10
Inarijoki, Karig.	3133	Anarjohka	Tana	18
Vækkava, Iesjokka	2079	Lesjokka	Tana	14
Utsjoki, Patoniva	1520	Utsjoki	Tana	28
Juutuanjoki	5160	Juutuanjoki	Paatsjoki	21
Ivalojoki, Pajakoski	3345	Ivalo	Paatsjoki	15
Masi	5621	Kautokeinoelva	Altaelva	39
Malangsfoss	3111	Malselv	Malselv	56
Svartfossberget	1932	Reisaelva	Reisaelva	66
Ytterholmen	1012	Livasalven	Ranealven	0
Iijärvi - Iuusua	744	Iijarvi	Naatamo	60
Øye ndf.	526	Svartdalsbekken	Salangs	48
Kukasjärvi	494	Kukasjarvi	Kukasjarvi	0
Manndalen bru	200	Manndal	Manndal	54
Halsnes	145	Halselva	Halselva	68
Skogsfjordvatn	136	Skogsfjordelva	Skogsfjordelva	11
Leirbotnvatn	135	Leirbotn	Leirbotn	66
Mørsvik bru	31	Marsvik	Marsvik	26
Karpelva	129	Karpelva	Karpelva	15

Figure 3.3: NVI analysis for the North Zone. 1) Calendar matrix showing the evolution of NVI levels. 2) The number of days with NVI > 0.75 by river and station. 3) Map of stations representing the number of days with NVI > 0.75 grouped in 5 classes.

To facilitate the results of the percentile analysis (see Figure 3.4), the map-diagram composition includes four sections: 1) a calendar matrix showing the percentile reached for each day and stations, 2) the number of days over the 99th percentile per station, 3) the number of days over the Maximum per station, and 4) a map with these two last values for each station.

From the 31 stations, 28 overpassed the 99th percentile and 17 of them exceed the Maximum, with Polmak nye, Masi, Onnelansuvanto and Iijärvi having the highest number of days above the Maximum.

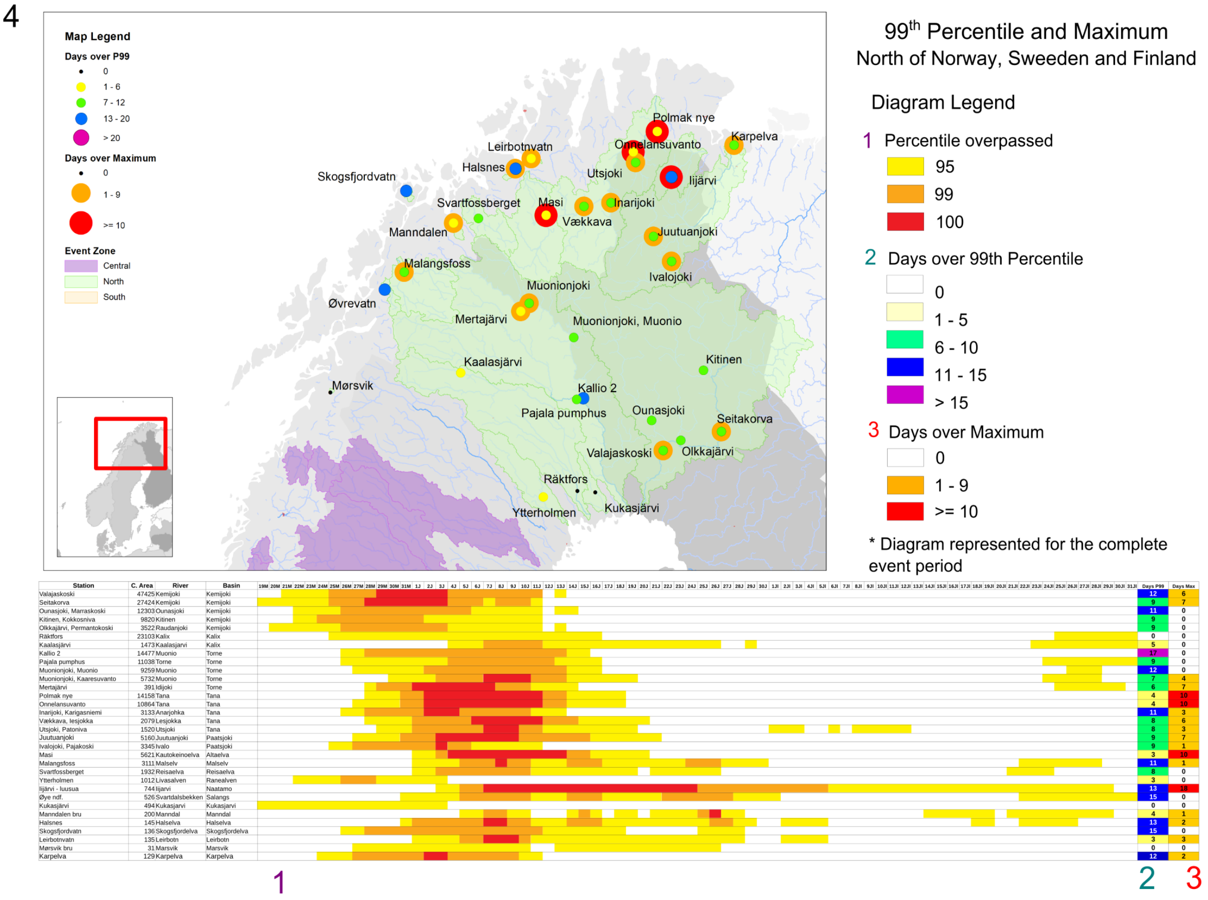
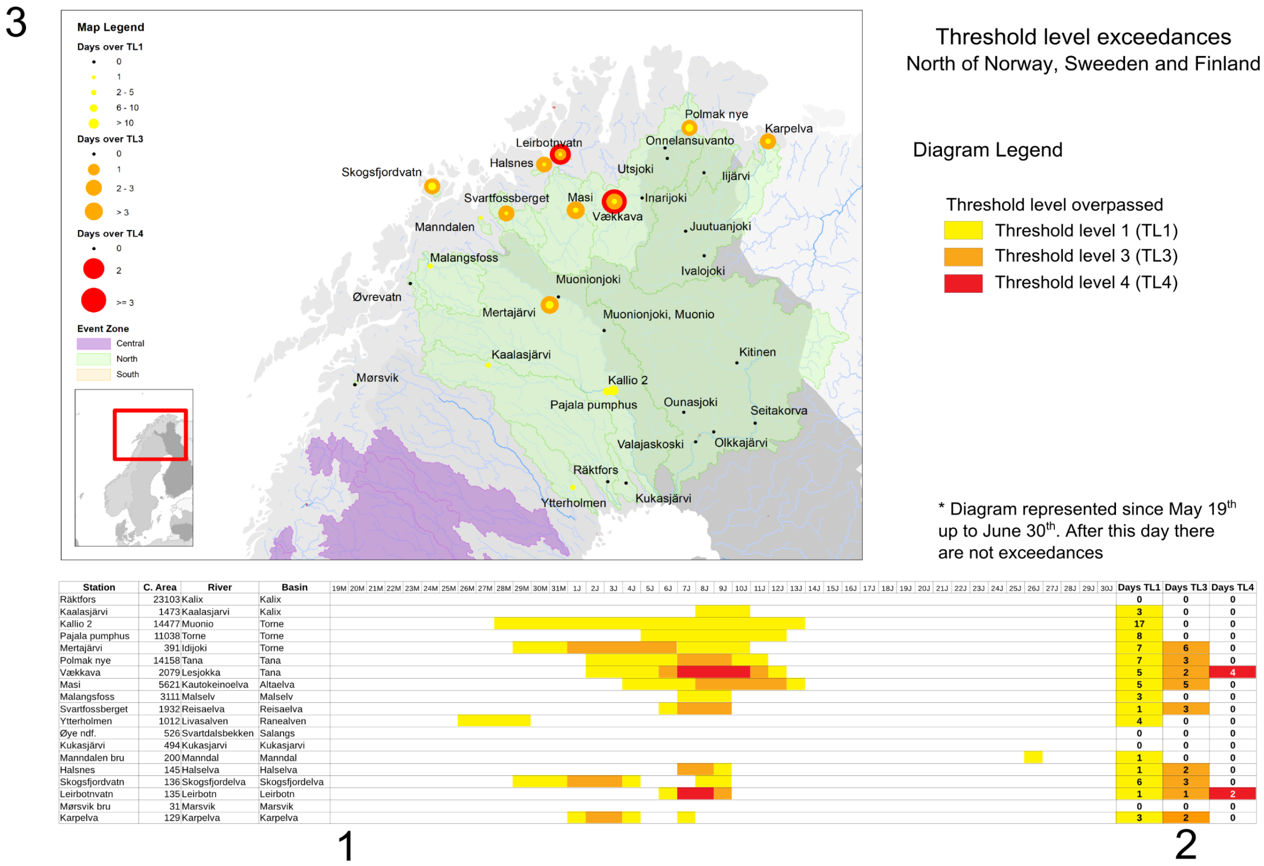


Figure 3.4: Percentiles analysis for North Zone. 1) Calendar matrix showing the evolution of Percentile levels. 2) The number of days with Maximum Daily Discharge (MaxD) > P99 by river and station. 3) The number of days with MaxD > Maximum by river and station. 4) Map of stations representing the number of days with MaxD > P99 grouped in 5 classes and MaxD > Max grouped in 3 classes.

Regarding the exceedance of threshold levels, it is necessary to clarify that only 18 out of the 31 stations contain threshold levels defined in EFAS System. Considering this, the area with exceedances of the highest level is again northern Norway. Leirbotnvatn and Vaekkava stations are the ones that overpass TL4, but 14 of the 18 stations overpass TL1 and 8 overpass TL2 (see results in Figure 3.5).



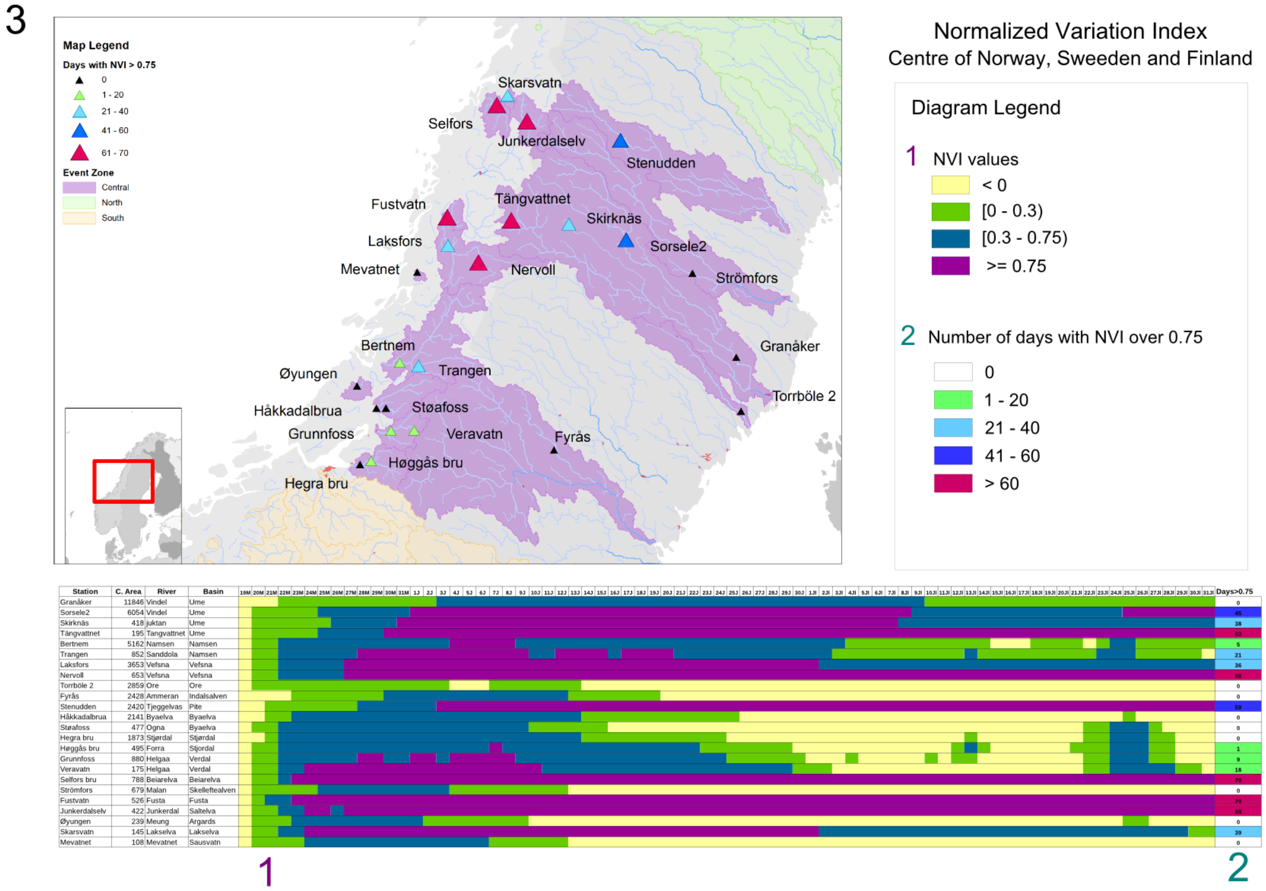
* Diagram represented since May 19th up to June 30th. After this day there are not exceedances

Station	C. Area	River	Basin	19M	20M	21M	22M	23M	24M	25M	26M	27M	28M	29M	30M	31M	1J	2J	3J	4J	5J	6J	7J	8J	9J	10J	11J	12J	13J	14J	15J	16J	17J	18J	19J	20J	21J	22J	23J	24J	25J	26J	27J	28J	29J	30J	Days TL1	Days TL3	Days TL4
Räktfors	23103	Kalix	Kalix																																												0	0	0
Kaalasjärvi	1473	Kaalasjarvi	Kalix																					🟨	🟨	🟨																					3	0	0
Kallio 2	14477	Muonio	Torne										🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨																		17	0	0
Pajala pumphus	11038	Torne	Torne																		🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨																			8	0	0
Mertajärvi	391	Idijoki	Torne											🟨	🟨	🟨	🟧	🟧	🟧	🟧	🟧	🟧	🟨	🟨	🟨	🟨																					7	6	0
Polmak nye	14158	Tana	Tana															🟨	🟨	🟨	🟨	🟨	🟧	🟧	🟧	🟨	🟨																				7	3	0
Vækkava	2079	Lesjokka	Tana															🟨	🟨	🟨	🟨	🟧	🟥	🟥	🟥	🟥	🟧	🟨																			5	2	4
Masi	5621	Kautokeinoelva	Altaelva																	🟨	🟨	🟨	🟨	🟧	🟧	🟧	🟧	🟧	🟨																		5	5	0
Malangsfoss	3111	Malselv	Malselv																				🟨	🟨	🟨																						3	0	0
Svartfossberget	1932	Reisaelva	Reisaelva																			🟨	🟧	🟧	🟧																						1	3	0
Ytterholmen	1012	Livasalven	Ranealven								🟨	🟨	🟨	🟨																																	4	0	0
Øye ndf.	526	Svartdalsbekken	Salangs																																												0	0	0
Kukasjärvi	494	Kukasjarvi	Kukasjarvi																																												0	0	0
Manndalen bru	200	Manndal	Manndal																																							🟨					1	0	0
Halsnes	145	Halselva	Halselva																				🟧	🟧	🟨																						1	2	0
Skogsfjordvatn	136	Skogsfjordelva	Skogsfjordelva											🟨	🟨	🟨	🟧	🟧	🟧	🟨				🟨	🟨																						6	3	0
Leirbotnvatn	135	Leirbotn	Leirbotn																			🟨	🟥	🟥	🟧																						1	1	2
Mørsvik bru	31	Marsvik	Marsvik																																												0	0	0
Karpelva	129	Karpelva	Karpelva														🟨	🟧	🟧	🟨			🟨																								3	2	0

Figure 3.5 Threshold exceedance analysis for the North Zone. 1) Calendar matrix showing the evolution of thresholds exceedance. 2) The number of days overpassing the maximum threshold by river and station. 3) Map of stations showing the number of days exceeding the maximum threshold level.

3.3.2 Central zone

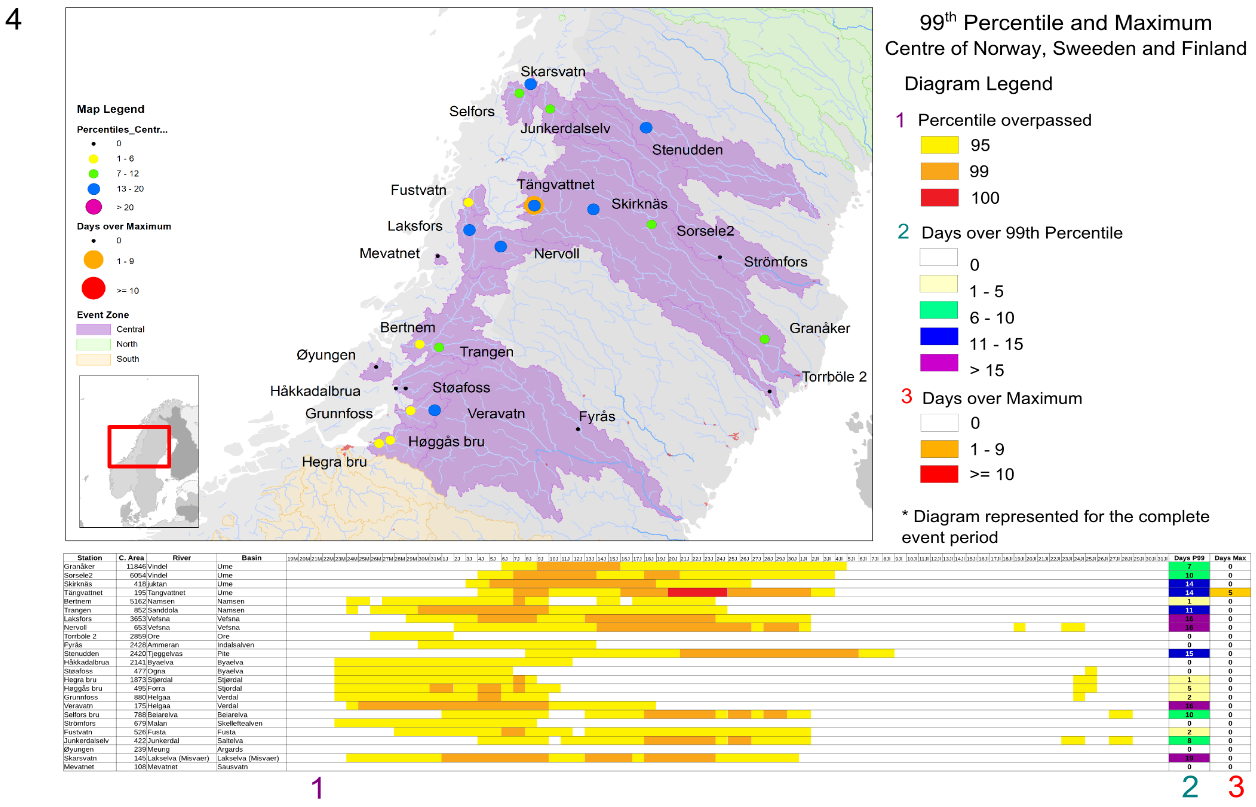
Here 24 stations were analyzed for the Central zone for the time period between May 19th and July 31th, 2020. The most remarkable are located in Norway (See Figure 3.6). Selfors and Fustvatn stations remain for 70 days with NVI greater than 0.75, being followed by Junkerdalselv (68), Nervoll (66) and Tängvattnet (63). For the Swedish stations, the increase of discharge values is smaller than in the stations mentioned above, however Stenudden and Sorsele stations present NVI values greater than 0.75 during a high number of days (59 and 45, respectively).



Station	C. Area	River	Basin	Days>0.75
Granåker	11846	Vindel	Ume	0
Sorsele2	6054	Vindel	Ume	45
Skirknäs	418	juktan	Ume	38
Tängvattnet	195	Tangvattnet	Ume	63
Bertnem	5162	Namsen	Namsen	5
Trangen	852	Sanddola	Namsen	21
Laksfors	3653	Vefsna	Vefsna	36
Nervoll	653	Vefsna	Vefsna	66
Torrböle 2	2859	Ore	Ore	0
Fyrås	2428	Ammeran	Indalsalven	0
Stenudden	2420	Tjeggelvas	Pite	59
Håkkadalbrua	2141	Byaelva	Byaelva	0
Støafoss	477	Ogna	Byaelva	0
Hegra bru	1873	Stjørdal	Stjørdal	0
Høggås bru	495	Forra	Stjordal	1
Grunnfoss	880	Helgaa	Verdal	9
Veravatn	175	Helgaa	Verdal	18
Selfors bru	788	Beiarelva	Beiarelva	70
Strömfors	679	Malan	Skelleftealven	0
Fustvatn	526	Fusta	Fusta	70
Junkerdalselv	422	Junkerdal	Saltelva	68
Øyungen	239	Meung	Argards	0
Skarsvatn	145	Lakselva	Lakselva	39
Mevatnet	108	Mevatnet	Sausvatn	0

Figure 3.6: NVI analysis for the Central Zone. 1) Calendar matrix showing the evolution of NVI levels. 2) The number of days with NVI > 0.75 by river and station. 3) Map of stations representing the number of days with NVI > 0.75 grouped in 5 classes.

Regarding the percentile analysis, only two of the 24 stations do not overpass the minimum percentile considered (95th percentile); Øyungen and Mevatnet, two of the stations with a smaller catchment area, in Norway. Fyrås and Torrböle-2 stations only overpass the 95th percentile, and the other 20 stations overpass the 99th percentile. Tängvattnet, Laksfors and Nervoll stations located in larger areas show more remarkable exceedances; the first one is the only one with Maximum exceedance, during 5 days (Figure 3.7).

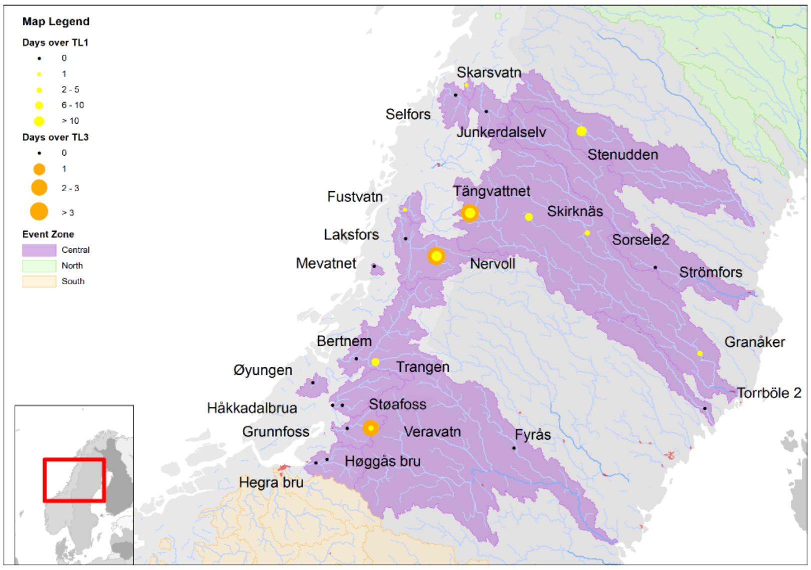


Station	C. Area	River	Basin	Days P99	Days Max
Granåker	11846	Vindel	Ume	7	0
Sorsele2	6054	Vindel	Ume	10	0
Skirknäs	418	juktan	Ume	14	0
Tängvattnet	195	Tangvattnet	Ume	14	5
Bertnem	5162	Namsen	Namsen	1	0
Trangen	852	Sanddola	Namsen	11	0
Laksfors	3653	Vefsna	Vefsna	16	0
Nervoll	653	Vefsna	Vefsna	16	0
Torrböle 2	2859	Ore	Ore	0	0
Fyrås	2428	Ammeran	Indalsalven	0	0
Stenudden	2420	Tjeggelvas	Pite	15	0
Håkkadalbrua	2141	Byaelva	Byaelva	0	0
Støafoss	477	Ogna	Byaelva	0	0
Hegra bru	1873	Stjørdal	Stjørdal	1	0
Høggås bru	495	Forra	Stjordal	5	0
Grunnfoss	880	Helgaa	Verdal	2	0
Veravatn	175	Helgaa	Verdal	16	0
Selfors bru	788	Beiarelva	Beiarelva	10	0
Strömfors	679	Malan	Skelleftealven	0	0
Fustvatn	526	Fusta	Fusta	2	0
Junkerdalselv	422	Junkerdal	Saltelva	8	0
Øyungen	239	Meung	Argards	0	0
Skarsvatn	145	Lakselva (Misvaer)	Lakselva (Misvaer)	19	0
Mevatnet	108	Mevatnet	Sausvatn	0	0

Figure 3.7: Percentiles analysis for the Central zone. 1) Calendar matrix showing the evolution of Percentile levels. 2) The number of days with Maximum Daily Discharge (MaxD) > P99 by river and station. 3) The number of days with MaxD > Maximum by river and station. 4) Map of stations representing the number of days with MaxD > P99 grouped in 5 classes and MaxD > Max grouped in 3 classes.

Finally, as can be seen in Figure 3.8, there are not exceedances of TL4 in the central area, and only three stations exceed TL3. In decreasing order of number of days and catchment area these are Tängvattnet, Nervoll and Veravatn stations.

3

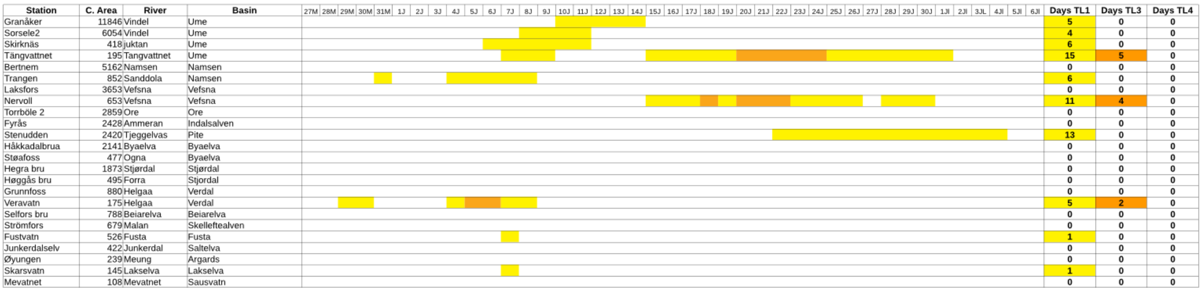


Threshold level exceedances
Centre of Norway, Sweeden and Finland

Diagram Legend

Threshold level overpassed
🟨 Threshold level 1 (TL1)
🟧 Threshold level 3 (TL3)

* Diagram represented since May 27th up to July 6th. After this day there are not exceedances



Station	C. Area	River	Basin	27M	28M	29M	30M	31M	1J	2J	3J	4J	5J	6J	7J	8J	9J	10J	11J	12J	13J	14J	15J	16J	17J	18J	19J	20J	21J	22J	23J	24J	25J	26J	27J	28J	29J	30J	1Jl	2Jl	3JL	4Jl	5Jl	6Jl	Days TL1	Days TL3	Days TL4
Granåker	11846	Vindel	Ume															🟨	🟨	🟨	🟨	🟨																							5	0	0
Sorsele2	6054	Vindel	Ume													🟨	🟨	🟨	🟨																										4	0	0
Skirknäs	418	juktan	Ume											🟨	🟨	🟨	🟨	🟨	🟨																										6	0	0
Tängvattnet	195	Tangvattnet	Ume												🟨	🟨	🟨						🟨	🟨	🟨	🟨	🟨	🟧	🟧	🟧	🟧	🟧	🟨	🟨	🟨	🟨	🟨	🟨	🟨						15	5	0
Bertnem	5162	Namsen	Namsen																																										0	0	0
Trangen	852	Sanddola	Namsen					🟨				🟨	🟨	🟨	🟨	🟨																													6	0	0
Laksfors	3653	Vefsna	Vefsna																																										0	0	0
Nervoll	653	Vefsna	Vefsna																				🟨	🟨	🟨	🟧	🟨	🟧	🟧	🟧	🟨	🟨	🟨	🟨		🟨	🟨	🟨							11	4	0
Torrböle 2	2859	Ore	Ore																																										0	0	0
Fyrås	2428	Ammeran	Indalsalven																																										0	0	0
Stenudden	2420	Tjeggelvas	Pite																											🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨			13	0	0
Håkkadalbrua	2141	Byaelva	Byaelva																																										0	0	0
Støafoss	477	Ogna	Byaelva																																										0	0	0
Hegra bru	1873	Stjørdal	Stjørdal																																										0	0	0
Høggås bru	495	Forra	Stjordal																																										0	0	0
Grunnfoss	880	Helgaa	Verdal																																										0	0	0
Veravatn	175	Helgaa	Verdal			🟨	🟨					🟨	🟧	🟧	🟨	🟨																													5	2	0
Selfors bru	788	Beiarelva	Beiarelva																																										0	0	0
Strömfors	679	Malan	Skelleftealven																																										0	0	0
Fustvatn	526	Fusta	Fusta													🟨																													1	0	0
Junkerdalselv	422	Junkerdal	Saltelva																																										0	0	0
Øyungen	239	Meung	Argards																																										0	0	0
Skarsvatn	145	Lakselva	Lakselva														🟨																												1	0	0
Mevatnet	108	Mevatnet	Sausvatn																																										0	0	0

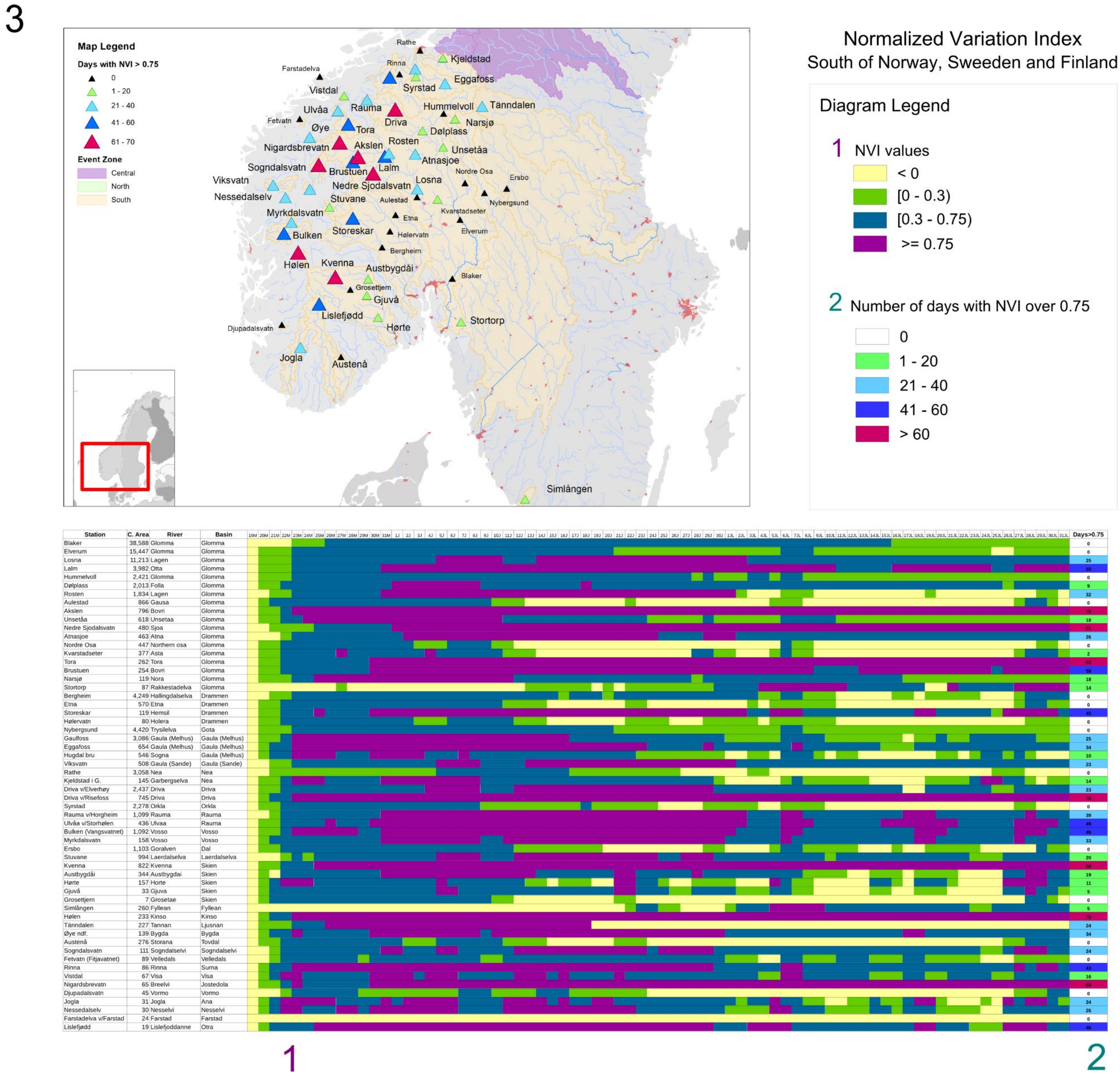
1

2

Figure 3.8: Threshold exceedance analysis for the Central Zone. 1) Calendar matrix showing the evolution of thresholds exceedance. 2) The number of days over passing the maximum threshold by river and station. 3) Map of stations showing the number of days exceeding the maximum threshold level.

3.3.3 South zone

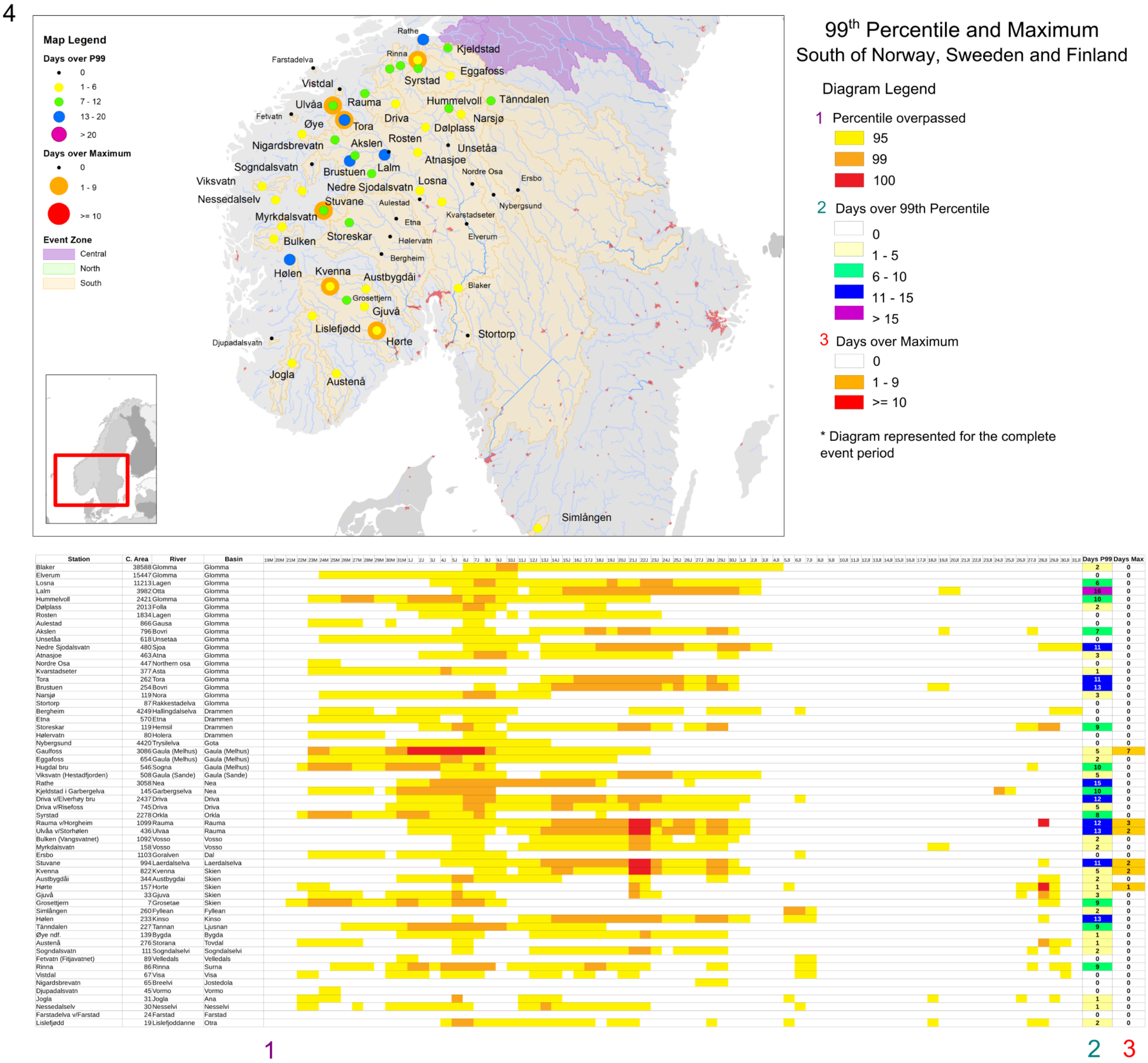
There were more stations in the south zone to be analysed. A total of 59 stations, with 42 of which have exceedances of the NVI 0.75 value, while seven stations located in Norway are the ones with more than 60 days with NVI > 0.75, and three of them are in the Glomma basin (Akslen, Nedre Sjodalsvatn and Tora). The remaining three are Driva (Driva basin river), Kvenna (Skien basin river) and Hølen (Kinso river). See details in Figure 3.9.



Station	C. Area	River	Basin	Days>0.75
Blaker	38,588	Glomma	Glomma	0
Elverum	15,447	Glomma	Glomma	0
Losna	11,213	Lagen	Glomma	25
Lalm	3,982	Otta	Glomma	55
Hummelvoll	2,421	Glomma	Glomma	0
Dølplass	2,013	Folla	Glomma	9
Rosten	1,834	Lagen	Glomma	32
Aulestad	866	Gausa	Glomma	0
Akslen	796	Bovri	Glomma	70
Unsetåa	618	Unsetaa	Glomma	18
Nedre Sjodalsvatn	480	Sjoa	Glomma	61
Atnasjoe	463	Atna	Glomma	26
Nordre Osa	447	Northern osa	Glomma	0
Kvarstadseter	377	Asta	Glomma	2
Tora	262	Tora	Glomma	63
Brustuen	254	Bovri	Glomma	58
Narsjø	119	Nora	Glomma	18
Stortorp	87	Rakkestadelva	Glomma	14
Bergheim	4,249	Hallingdalselva	Drammen	0
Etna	570	Etna	Drammen	0
Storeskar	119	Hemsil	Drammen	45
Hølervatn	80	Holera	Drammen	0
Nybergsund	4,420	Trysilelva	Gota	0
Gaulfoss	3,086	Gaula (Melhus)	Gaula (Melhus)	25
Eggafoss	654	Gaula (Melhus)	Gaula (Melhus)	34
Hugdal bru	546	Sogna	Gaula (Melhus)	10
Viksvatn	508	Gaula (Sande)	Gaula (Sande)	23
Rathe	3,058	Nea	Nea	0
Kjeldstad i G.	145	Garbergselva	Nea	14
Driva v/Elverhøy	2,437	Driva	Driva	23
Driva v/Risefoss	745	Driva	Driva	70
Syrstad	2,278	Orkla	Orkla	0
Rauma v/Horgheim	1,099	Rauma	Rauma	39
Ulvåa v/Storhølen	436	Ulvaa	Rauma	49
Bulken (Vangsvatnet)	1,092	Vosso	Vosso	46
Myrkdalsvatn	158	Vosso	Vosso	33
Ersbo	1,103	Goralven	Dal	0
Stuvane	994	Laerdalselva	Laerdalselva	20
Kvenna	822	Kvenna	Skien	68
Austbygdåi	344	Austbygdai	Skien	19
Hørte	157	Horte	Skien	11
Gjuvå	33	Gjuva	Skien	5
Grosettjern	7	Grosetae	Skien	0
Simlången	260	Fyllean	Fyllean	5
Hølen	233	Kinso	Kinso	70
Tänndalen	227	Tannan	Ljusnan	24
Øye ndf.	139	Bygda	Bygda	34
Austenå	276	Storana	Tovdal	0
Sogndalsvatn	111	Sogndalselvi	Sogndalselvi	24
Fetvatn (Fitjavatnet)	89	Velledals	Velledals	0
Rinna	86	Rinna	Surna	43
Vistdal	67	Visa	Visa	16
Nigardsbrevatn	65	Breelvi	Jostedola	64
Djupadalsvatn	45	Vormo	Vormo	0
Jogla	31	Jogla	Ana	24
Nessedalselv	30	Nesselvi	Nesselvi	26
Farstadelva v/Farstad	24	Farstad	Farstad	0
Lislefjødd	19	Lislefjoddanne	Otra	46

Figure 3.9: NVI analysis for the South zone. 1) Calendar matrix showing the evolution of NVI levels. 2) The number of days with NVI > 0.7 by river and station. 3) Map of stations representing the number of days with NVI > 0.7 grouped in 5 classes.

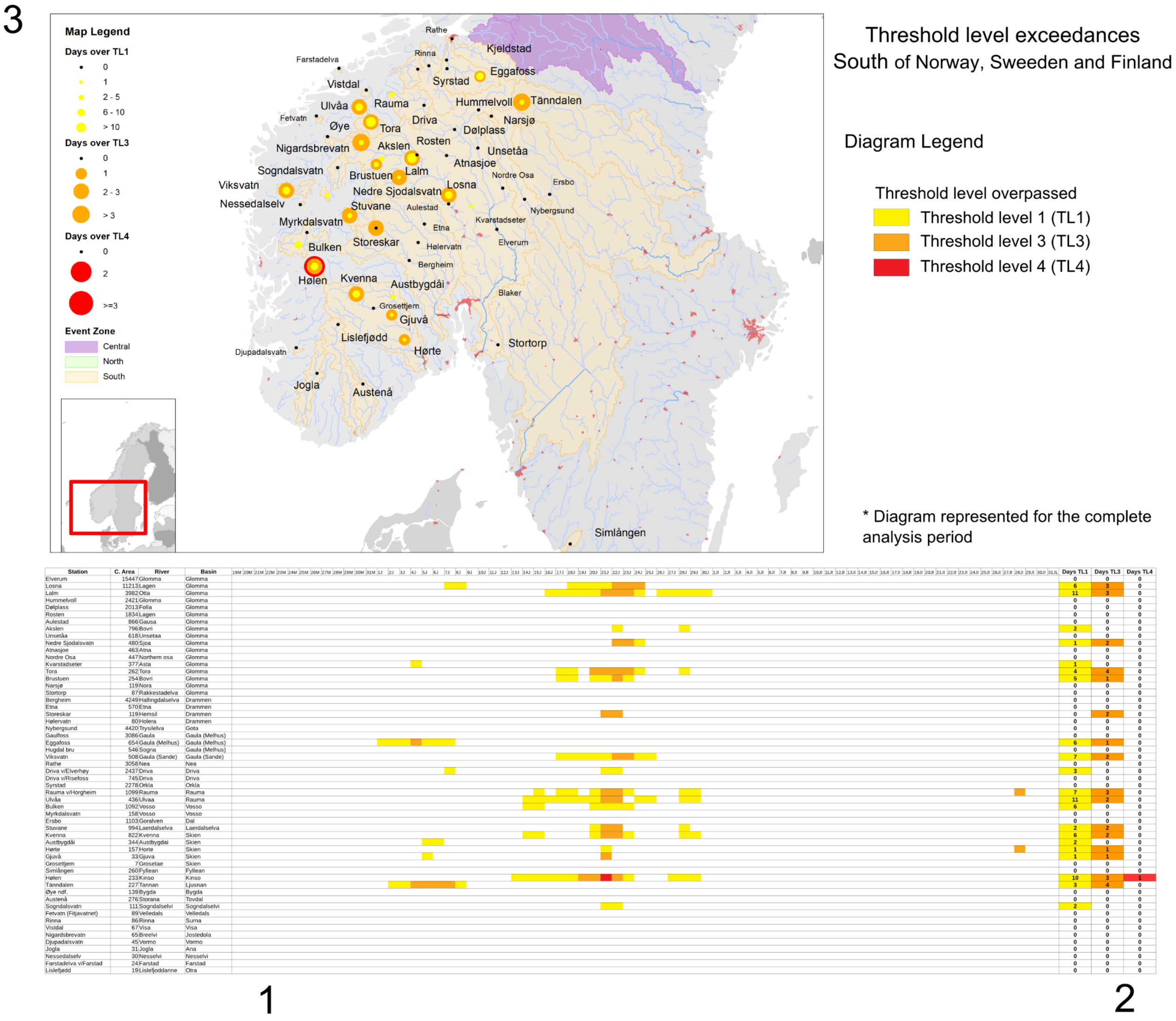
The percentile exceedances are lower than those of the North zone. Only 7 stations exceed the Maximum, and they do so for a short period of days. The only station with exceedances of 7 days is Gaulfoss, on the Gaula River. The other stations are: Rauma and Ulvåa, on the Rauma river, Stuvane, on the Laerdalselva river, Hørte, on the Skien river and Karpelva on the Karpelva river. Despite this, only 16 out of the 59 stations do not exceed the 99th percentile. Most of them are located in the southeast of Norway and southwest of Sweden, while the remaining stations overpassed percentiles although not as high as in the north (see Figure 3.10).



Station	C. Area	River	Basin	Days P99	Days Max
Blaker	38588	Glomma	Glomma	2	0
Elverum	15447	Glomma	Glomma	0	0
Losna	11213	Lagen	Glomma	6	0
Lalm	3982	Otta	Glomma	16	0
Hummelvoll	2421	Glomma	Glomma	10	0
Dølplass	2013	Folla	Glomma	2	0
Rosten	1834	Lagen	Glomma	0	0
Aulestad	866	Gausa	Glomma	0	0
Akslen	796	Bovri	Glomma	7	0
Unsetåa	618	Unsetaa	Glomma	0	0
Nedre Sjodalsvatn	480	Sjoa	Glomma	11	0
Atnasjoe	463	Atna	Glomma	3	0
Nordre Osa	447	Northern osa	Glomma	0	0
Kvarstadseter	377	Asta	Glomma	1	0
Tora	262	Tora	Glomma	11	0
Brustuen	254	Bovri	Glomma	13	0
Narsjø	119	Nora	Glomma	3	0
Stortorp	87	Rakkestadelva	Glomma	0	0
Bergheim	4249	Hallingdalselva	Drammen	0	0
Etna	570	Etna	Drammen	0	0
Storeskar	119	Hemsil	Drammen	9	0
Hølervatn	80	Holera	Drammen	0	0
Nybergsund	4420	Trysilelva	Gota	0	0
Gaulfoss	3086	Gaula (Melhus)	Gaula (Melhus)	5	7
Eggafoss	654	Gaula (Melhus)	Gaula (Melhus)	2	0
Hugdal bru	546	Sogna	Gaula (Melhus)	10	0
Viksvatn (Hestadfjorden)	508	Gaula (Sande)	Gaula (Sande)	5	0
Rathe	3058	Nea	Nea	15	0
Kjeldstad i Garbergelva	145	Garbergselva	Nea	10	0
Driva v/Elverhøy bru	2437	Driva	Driva	12	0
Driva v/Risefoss	745	Driva	Driva	5	0
Syrstad	2278	Orkla	Orkla	8	0
Rauma v/Horgheim	1099	Rauma	Rauma	12	3
Ulvåa v/Storhølen	436	Ulvaa	Rauma	13	2
Bulken (Vangsvatnet)	1092	Vosso	Vosso	2	0
Myrkdalsvatn	158	Vosso	Vosso	2	0
Ersbo	1103	Goralven	Dal	0	0
Stuvane	994	Laerdalselva	Laerdalselva	11	2
Kvenna	822	Kvenna	Skien	5	2
Austbygdåi	344	Austbygdai	Skien	2	0
Hørte	157	Horte	Skien	1	1
Gjuvå	33	Gjuva	Skien	3	0
Grosettjern	7	Grosetae	Skien	9	0
Simlången	260	Fyllean	Fyllean	2	0
Hølen	233	Kinso	Kinso	13	0
Tänndalen	227	Tannan	Ljusnan	9	0
Øye ndf.	139	Bygda	Bygda	1	0
Austenå	276	Storana	Tovdal	1	0
Sogndalsvatn	111	Sogndalselvi	Sogndalselvi	2	0
Fetvatn (Fitjavatnet)	89	Velledals	Velledals	0	0
Rinna	86	Rinna	Surna	9	0
Vistdal	67	Visa	Visa	0	0
Nigardsbrevatn	65	Breelvi	Jostedola	0	0
Djupadalsvatn	45	Vormo	Vormo	0	0
Jogla	31	Jogla	Ana	1	0
Nessedalselv	30	Nesselvi	Nesselvi	1	0
Farstadelva v/Farstad	24	Farstad	Farstad	0	0
Lislefjødd	19	Lislefjoddanne	Otra	2	0

Figure 3.10: Percentiles analysis for the South zone. 1) Calendar matrix showing the evolution of Percentile levels. 2) The number of days with Maximum Daily Discharge (MaxD) > P99 by river and station. 3) The number of days with MaxD > Maximum by river and station. 4) Map of stations representing the number of days with MaxD > P99 grouped in 5 classes and MaxD > Max grouped in 3 classes.

There are 57 stations in the south area with threshold levels defined in EFAS System. Only one of them, exceed the three levels: Hølen, on the Kinso river, level TL4 was overpassed during only one day, TL3 and TL1 were exceeded during three and ten days respectively. However, the exceedances of TL3 are mainly in Norway, with fifteen stations overpassing TL3. In Sweden only the Tänndalen stations on the Tannan river exceeded the thresholds (Figure 3.11).



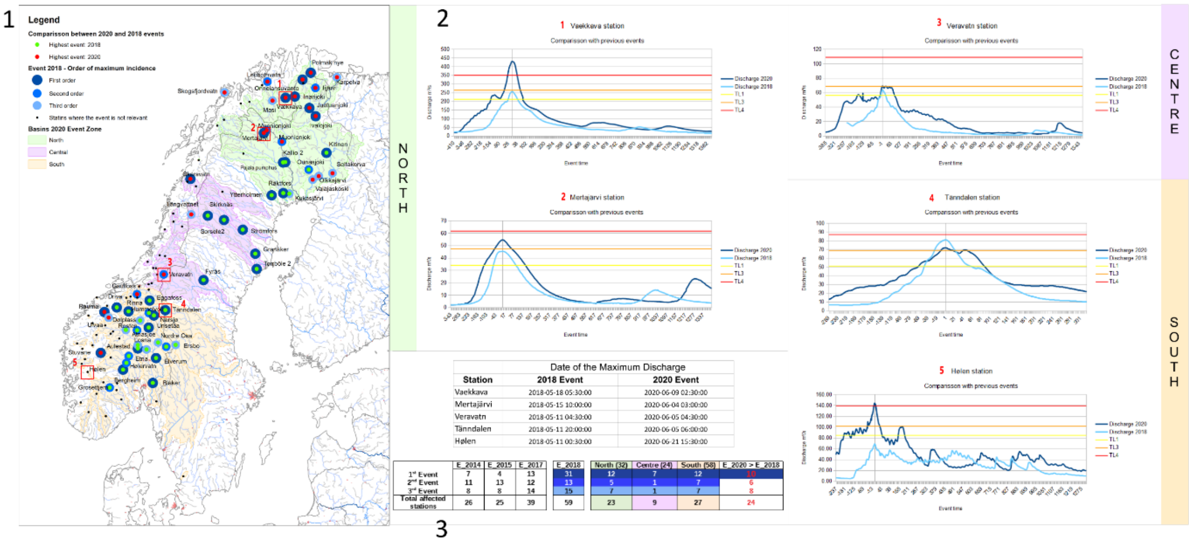
Station	C. Area	River	Basin	Days TL1	Days TL3	Days TL4
Elverum	15447	Glomma	Glomma	0	0	0
Losna	11213	Lagen	Glomma	6	3	0
Lalm	3982	Otta	Glomma	11	3	0
Hummelvoll	2421	Glomma	Glomma	0	0	0
Dølplass	2013	Folla	Glomma	0	0	0
Rosten	1834	Lagen	Glomma	0	0	0
Aulestad	866	Gausa	Glomma	0	0	0
Akslen	796	Bovri	Glomma	2	0	0
Unsetåa	618	Unsetaa	Glomma	0	0	0
Nedre Sjodalsvatn	480	Sjoa	Glomma	1	2	0
Atnasjoe	463	Atna	Glomma	0	0	0
Nordre Osa	447	Northern osa	Glomma	0	0	0
Kvarstadseter	377	Asta	Glomma	1	0	0
Tora	262	Tora	Glomma	4	4	0
Brustuen	254	Bovri	Glomma	5	1	0
Narsjø	119	Nora	Glomma	0	0	0
Stortorp	87	Rakkestadelva	Glomma	0	0	0
Bergheim	4249	Hallingdalselva	Drammen	0	0	0
Etna	570	Etna	Drammen	0	0	0
Storeskar	119	Hemsil	Drammen	0	2	0
Hølervatn	80	Holera	Drammen	0	0	0
Nybergsund	4420	Trysilelva	Gota	0	0	0
Gaulfoss	3086	Gaula	Gaula (Melhus)	0	0	0
Eggafoss	654	Gaula (Melhus)	Gaula (Melhus)	6	1	0
Hugdal bru	546	Sogna	Gaula (Melhus)	0	0	0
Viksvatn	508	Gaula (Sande)	Gaula (Sande)	7	2	0
Rathe	3058	Nea	Nea	0	0	0
Driva v/Elverhøy	2437	Driva	Driva	3	0	0
Driva v/Risefoss	745	Driva	Driva	0	0	0
Syrstad	2278	Orkla	Orkla	0	0	0
Rauma v/Horgheim	1099	Rauma	Rauma	7	3	0
Ulvåa	436	Ulvaa	Rauma	11	2	0
Bulken	1092	Vosso	Vosso	6	0	0
Myrkdalsvatn	158	Vosso	Vosso	0	0	0
Ersbo	1103	Goralven	Dal	0	0	0
Stuvane	994	Laerdalselva	Laerdalselva	2	2	0
Kvenna	822	Kvenna	Skien	6	2	0
Austbygdåi	344	Austbygdai	Skien	2	0	0
Hørte	157	Horte	Skien	1	1	0
Gjuvå	33	Gjuva	Skien	1	1	0
Grosettjern	7	Grosetae	Skien	0	0	0
Simlången	260	Fyllean	Fyllean	0	0	0
Hølen	233	Kinso	Kinso	10	3	1
Tänndalen	227	Tannan	Ljusnan	3	4	0
Øye ndf.	139	Bygda	Bygda	0	0	0
Austenå	276	Storana	Tovdal	0	0	0
Sogndalsvatn	111	Sogndalselvi	Sogndalselvi	2	0	0
Fetvatn (Fitjavatnet)	89	Velledals	Velledals	0	0	0
Rinna	86	Rinna	Surna	0	0	0
Vistdal	67	Visa	Visa	0	0	0
Nigardsbrevatn	65	Breelvi	Jostedola	0	0	0
Djupadalsvatn	45	Vormo	Vormo	0	0	0
Jogla	31	Jogla	Ana	0	0	0
Nessedalselv	30	Nesselvi	Nesselvi	0	0	0
Farstadelva v/Farstad	24	Farstad	Farstad	0	0	0
Lislefjødd	19	Lislefjoddanne	Otra	0	0	0

Figure 3.11: Threshold exceedance analysis for the South Zone. 1) Calendar matrix showing the evolution of thresholds exceedance. 2) The number of days overpassing the maximum threshold by river and station. 3) Map of stations showing the number of days exceeding the maximum threshold level.

3.4 Comparison with previous events

For the comparative study of previous events in the 114 stations affected by this event, an analysis of the Near Real-Time (NRT) data up to 31 December 2019 has been carried out. The three most outstanding peaks (or events) of each station have been selected, establishing a ranking of events per station (1st, 2nd and 3rd) according to the maximum value reached. As a result of this analysis it is possible to highlight 4 spring snowmelt events, due to their extension or high number of stations affected (see Figure 3.12 (3)): spring 2014, which stands out in 26 stations; spring 2015, which stands out in 25 stations; spring 2017, which stands out in 39 stations; and finally spring 2018, which stands out in 59 stations, of which a total of 31 had the highest peak discharge observed in the available record. The 2018 event could therefore be considered the largest and most intense in the recent past, and has been selected for comparison with the 2020 event. However, comparing the extent of the events, the 2020 event could be classified as the largest event in the entire Scandinavian territory in recent years.

For the 31 stations located in the northern zone, the 2018 event affected 74% of them (23) and is the most representative in almost 40% (12). In the central zone (with 24 stations), it is the most representative for 30% of the stations (7) and in the south (with 59 stations) it stands up in 20% of the stations (12). Figure 3.12 (1) represents a map with the stations that present the 2018 event, indicating the order of importance of this event in each station.



Date of the Maximum Discharge		
Station	**2018 Event**	**2020 Event**
Vaekkava	2018-05-18 05:30:00	2020-06-09 02:30:00
Mertajärvi	2018-05-15 10:00:00	2020-06-04 03:00:00
Veravatn	2018-05-11 04:30:00	2020-06-05 04:30:00
Tänndalen	2018-05-11 20:00:00	2020-06-05 06:00:00
Hølen	2018-05-11 00:30:00	2020-06-21 15:30:00

	E_2014	E_2015	E_2017	E_2018	North (32)	Centre (24)	South (58)	E_2020 > E_2018
1st Event	7	4	13	31	12	7	12	10
2nd Event	11	13	12	13	5	1	7	6
3rd Event	8	8	14	15	7	1	7	8
Total affected stations	26	25	39	59	23	9	27	24

Figure 3.12: 1) Map with locations for the 2018 event, including the order of importance by station. 2) Comparison, in five stations, between the events of 2020 and 2018. 3) Ranking table of previous events. Zone breakdown of the 2018 event and comparison with the 2020 event.

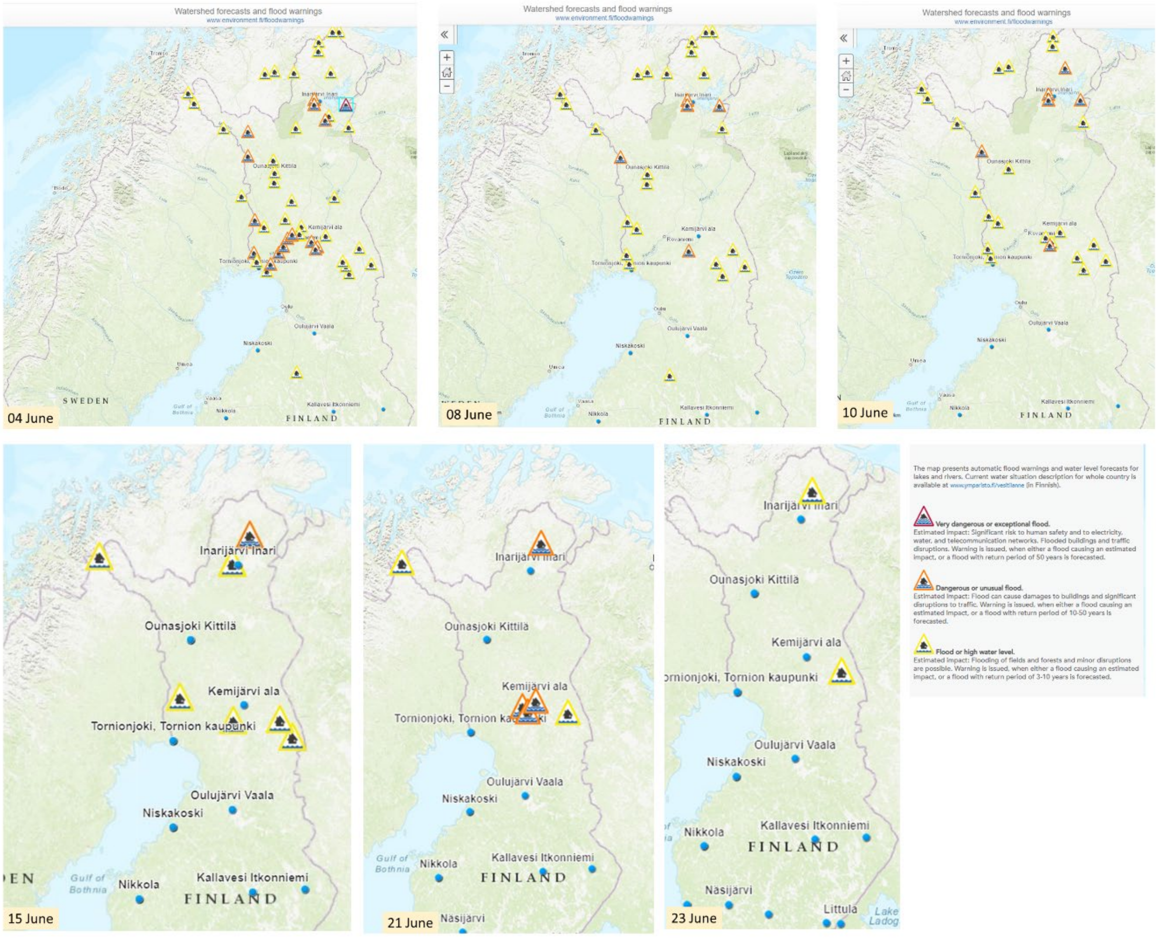
In Figure 3.12 (2) there is also a graphical representation for some selected stations in the three zones. The selection has been made based on the stations with exceedances of the threshold levels in the 2020 event. To facilitate the visual comparison, the hydrographs of both events were overlaid with each other and aligned at their respective peaks (event time = 0). The negative and positive values of "event time" represent time before and after arrival the peak discharge, respectively.

Regarding the intensity of both events, Figure 3.12 (1) shows in red the 24 stations where the 2020 event exceeded the 2018 event and in green the 35 where the 2018 event is still more intense. It is important to note that 10 stations show the 2020 event as the most intense, among which are stations the Vaekkava and Mertajärvi, depicted in Figure 3.12 (2) in hydrographs 1 and 2 respectively.

4 Public information about the flood event

4.1 Finland

Information at the Finnish Environment Institute (SYKE) website for flood warning (Figure 4.1) showed approximately 20 stations with a level associated to a *dangerous or unusual* flood (level 2 out of 3) during the most intensive period of the snow melting (4th June to ~21st of June). One station went over the level for *very dangerous or exceptional* flood (level 3 out of 3) on the 4th of June. The number of active stations decreased to two at the end of June, while at the end of July only one station was active. There were no reports at floodlist.com.



The map presents automatic flood warnings and water level forecasts for lakes and rivers. Current water situation description for whole country is available at www.ymparisto.fi/vesitilanne (in Finnish).

Very dangerous or exceptional flood.
Estimated impact: Significant risk to human safety and to electricity, water, and telecommunication networks. Flooded buildings and traffic disruptions. Warning is issued, when either a flood causing an estimated impact, or a flood with return period of 50 years is forecasted.

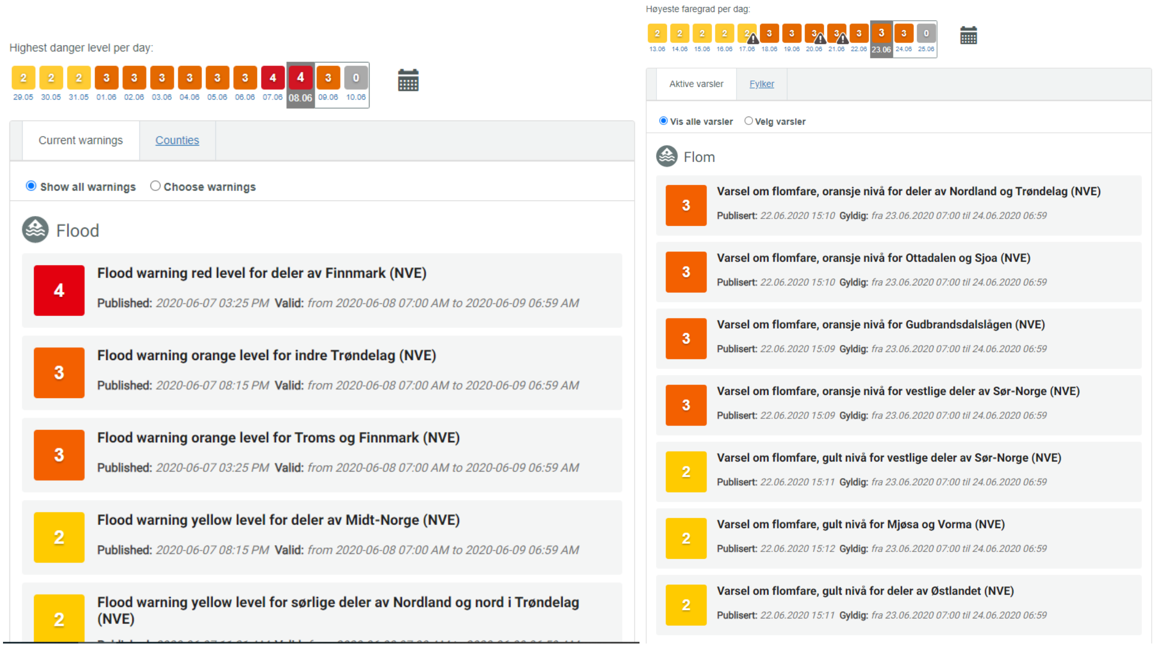
Dangerous or unusual flood.
Estimated impact: Flood can cause damages to buildings and significant disruptions to traffic. Warning is issued, when either a flood causing an estimated impact, or a flood with return period of 10-50 years is forecasted.

Flood or high water level.
Estimated impact: Flooding of fields and forests and minor disruptions are possible. Warning is issued, when either a flood causing an estimated impact, or a flood with return period of 3-10 years is forecasted.

Figure 4.1: Screenshots of the Finnish Environment Institute (SYKE) website for flood warnings. Yellow, orange and red triangles indicate warning level 1, 2 and 3 respectively.

4.2 Norway

Information from the Water Resources and Energy Directorate (NVE) website for flood warning showed stations above the orange level (3 out of 4) almost every day from 4th June until 2nd July. Among the days with the most intensive forecast was the 8th of June with 2 orange stations (level 3 out of 4) and 1 red station (level 4 out of 4). The highest level (4 out of 4) was active for 3 days at Finnmark, see Figure 4.2 (left). The 22nd and 23rd June can also be considered intense with a total of 4 stations above the orange level, see Figure 4.2 (right). There were no reports at floodlist.com.



4 **Flood warning red level for deler av Finnmark (NVE)**
Published: *2020-06-07 03:25 PM* **Valid:** *from 2020-06-08 07:00 AM to 2020-06-09 06:59 AM*

3 **Flood warning orange level for indre Trøndelag (NVE)**
Published: *2020-06-07 08:15 PM* **Valid:** *from 2020-06-08 07:00 AM to 2020-06-09 06:59 AM*

3 **Flood warning orange level for Troms og Finnmark (NVE)**
Published: *2020-06-07 03:25 PM* **Valid:** *from 2020-06-08 07:00 AM to 2020-06-09 06:59 AM*

2 **Flood warning yellow level for deler av Midt-Norge (NVE)**
Published: *2020-06-07 08:15 PM* **Valid:** *from 2020-06-08 07:00 AM to 2020-06-09 06:59 AM*

2 **Flood warning yellow level for sørlige deler av Nordland og nord i Trøndelag (NVE)**

3 **Varsel om flomfare, oransje nivå for deler av Nordland og Trøndelag (NVE)**
Publisert: *22.06.2020 15:10* **Gyldig:** *fra 23.06.2020 07:00 til 24.06.2020 06:59*

3 **Varsel om flomfare, oransje nivå for Ottadalen og Sjoa (NVE)**
Publisert: *22.06.2020 15:10* **Gyldig:** *fra 23.06.2020 07:00 til 24.06.2020 06:59*

3 **Varsel om flomfare, oransje nivå for Gudbrandsdalslågen (NVE)**
Publisert: *22.06.2020 15:09* **Gyldig:** *fra 23.06.2020 07:00 til 24.06.2020 06:59*

3 **Varsel om flomfare, oransje nivå for vestlige deler av Sør-Norge (NVE)**
Publisert: *22.06.2020 15:09* **Gyldig:** *fra 23.06.2020 07:00 til 24.06.2020 06:59*

2 **Varsel om flomfare, gult nivå for vestlige deler av Sør-Norge (NVE)**
Publisert: *22.06.2020 15:11* **Gyldig:** *fra 23.06.2020 07:00 til 24.06.2020 06:59*

2 **Varsel om flomfare, gult nivå for Mjøsa og Vorma (NVE)**
Publisert: *22.06.2020 15:12* **Gyldig:** *fra 23.06.2020 07:00 til 24.06.2020 06:59*

2 **Varsel om flomfare, gult nivå for deler av Østlandet (NVE)**
Publisert: *22.06.2020 15:11* **Gyldig:** *fra 23.06.2020 07:00 til 24.06.2020 06:59*

Figure 4.2: Screenshots of the Water Resources and Energy Directorate (NVE) website for flood warning on the 8th June 2020 (left) and on the 23rd June (right). Yellow, orange and red colors indicate warning level 1, 2 and 3 respectively.

4.3 Sweden

The Swedish Meteorological and Hydrological Institute (SMHI) issued several warnings (level 2 out of 3, which indicates exceedance of the 10-year RP) for the north-west of the country between 4th June to 3rd of July (Figure 4.3). Warning level 1 out of 3 were issued until the 24th July. Discharge values in the river network at different parts of the country were clearly larger than the mean value for the specific days in the months of June and July (blue areas in Figure 4.4). There were no reports at floodlist.com.

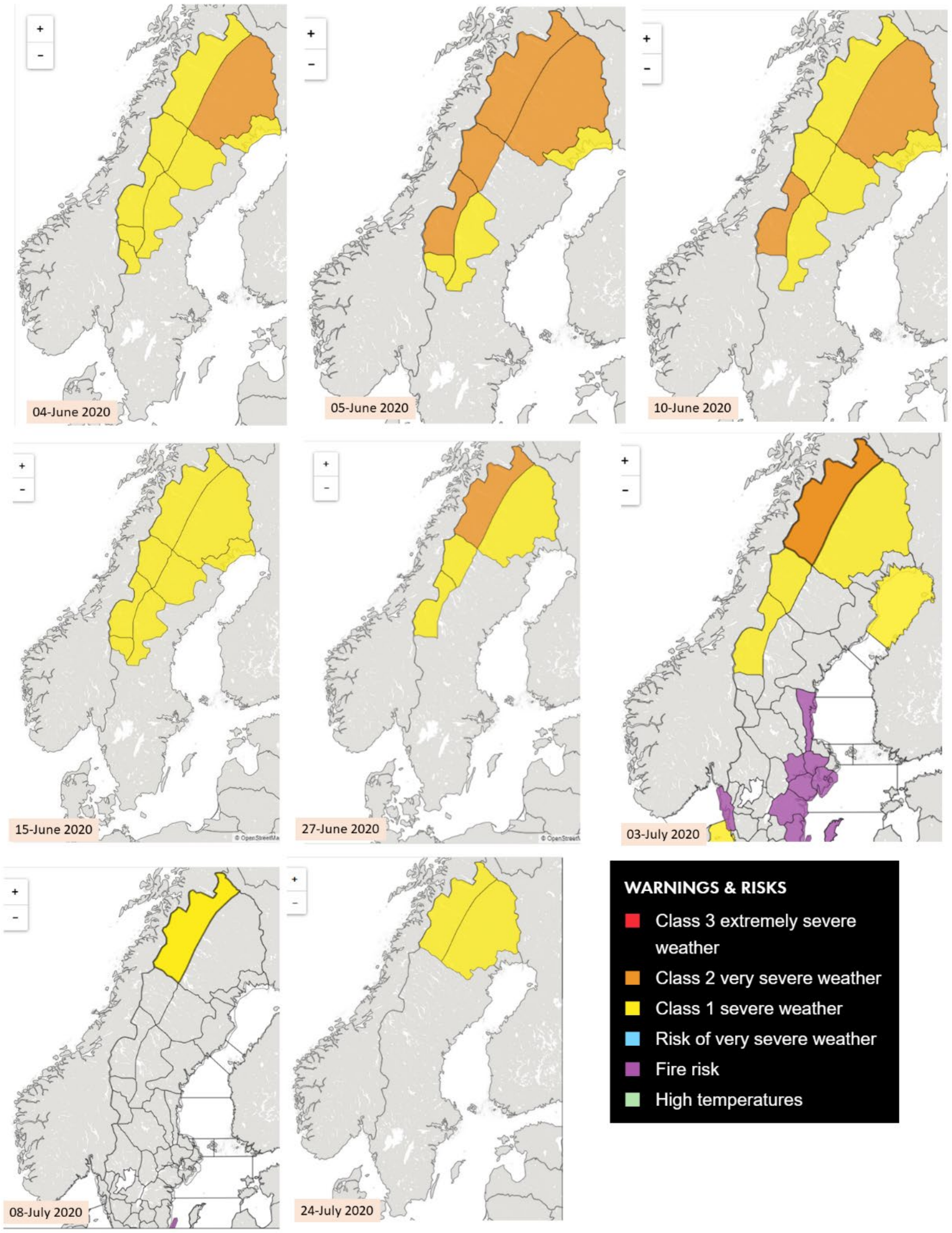


Figure 4.3: Screenshots from the Swedish Meteorological and Hydrological Institute (SMHI) website for flood warnings during the 2020 spring flood period.

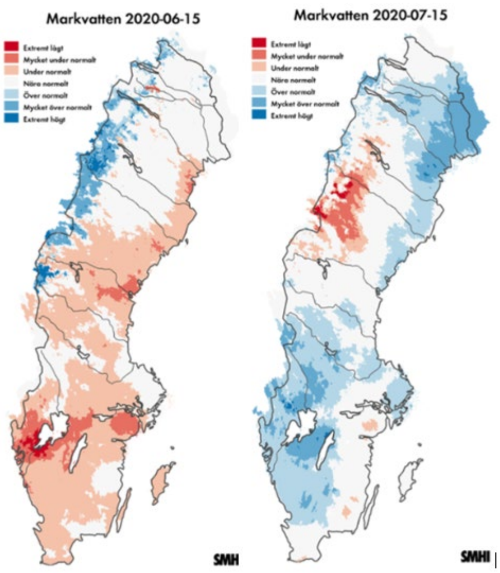


Figure 4.4: Discharge variation in relation to the mean value for the same day. Blue (red) colors indicate above (below) normal conditions.

5 EFAS forecast and information

5.1 Background information about EFAS

EFAS forecasts are computed at the European Centre for Medium-Range Weather Forecasts (ECMWF, UK) and then disseminated twice a day by three Centers located at different countries. The hydrological forecasts are generated using meteorological and hydrological data from ECMWF and DWD as well as other EFAS data providers. More specifically, the system incorporates weather forecasts from two different weather services, real-time weather observations from around 15,000 stations across Europe and real-time hydrological observation from more than 1900 stations. Observations are used to calibrate, validate and generate the forecast through the hydrological model LISFLOOD.

EFAS version 3.6 was operational until the 15th October 2020 (currently the improved version EFAS 4.2 is operational). EFAS produces information twice a day, based on the 00:00 UTC and 12:00 UTC meteorological forecasts, and the information is made available to all EFAS partners using EFAS-IS. EFAS-IS is the interface where a number of products are visualized, including simulated soil moisture, snow accumulation, observed temperature and precipitation averages, rapid impact assessment, probabilistic river flood hazard forecasts, flash flood hazard forecasts, accumulated precipitation forecasts, and (sub-)seasonal hydrological forecast outlook. Only partners, third party or research projects have access to the real-time forecasts after agreeing on and signing a Condition of Access (CoA), whereas all the information older than 30 days is freely open to the public.

The forecasters for the EFAS Dissemination Centre analyses the EFAS results twice a day, in the morning by 8:30 CET/CEST and in the afternoon by 16:00 CET/CEST. Forecasters on duty discuss the situation and what notifications should be sent via the communication platform and in complicated cases by telephone. The notifications are logged in the EFAS-IS 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.

The criteria used in EFAS 3.6 to send notifications are described in below.

Criteria for EFAS Flood Notification - Type Formal:

- Catchment part of Conditions of Access.
- Catchment area is larger than 2000 km^2.
- Event more than 48 hours in advance with respect to forecast date.
- Forecasts are persistent (3 consecutive forecasts with more than 30 % exceeding EFAS 5-year return period threshold according to ECMWF-ENS or to COSMO-LEPS).
- At least one of the deterministic forecasts (ECMWF or DWD) exceeds also the EFAS 5-year return period threshold.

Criteria for EFAS Flood Notification – Type Informal:

- Catchment part of Conditions of Access.
- Any of the above criteria is not met (catchment size, lead time, forecast persistence, deterministic forecast exceedance) but the forecasters think the authorities should be informed. Note: The minimum catchment size where EFAS provides skillful results is approx. 1000 km2. For catchment areas significantly smaller than 1000 km^2 no EFAS Flood Notification – Type Informal should be sent.
- Any other doubt.

The following rules are also followed before deciding for a notification:

- If an EFAS Flood Notification has been sent already for a tributary there is no need to send another one if a new reporting point appears further downstream in the same tributary (i.e. the flood wave is travelling downstream)
- If an EFAS Flood Notification has been sent for a tributary and a new reporting point appears further downstream located in the main stream a notification should be sent.
- If an EFAS Flood Notification has been sent for major river and a new reporting point appears further downstream a notification should be sent if the new reporting point is located in another country.
- If an EFAS Flood Notification has been sent for a specific reporting point and the forecasted discharge falls below the EFAS high threshold and then rises again above the EFAS high threshold this can be considered a new event and a new notification should be sent.

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

A request for feedback is automatically integrated in the Formal Flood notification email sent to the partners.

5.2 EFAS forecast during the event

5.2.1 EFAS timeline of the event

A timeline for the issued notifications is shown in Table 5.1. Flow above the 5-year RP was firstly forecasted on the 22nd of May for the Norwegian river Namsen and the high discharge values were the result of a combined effect of rainfall and snow melting. Both the DWD and ECMWF predictive systems forecasted a steep increase in temperature (see Figure 5.1) leading to a number of reporting points associated merely with snow melting on the 23rd of May. Consequently, a total of 5 notifications were issued which later increased to a total of 14 on the 27th; all of them in Finland (see green rows in Table 5.1).

One of the first notifications in Finland (River Iijoki) forecasted 2 days ahead on time an exceedance of the 5-year RP with the event starting on the 25th of May. The period during which a notification was active varied from 3 to 36 days (Table 5.1), while the short lead time of the forecast led to two of the informal flood notifications.

The EFAS sub-seasonal outlook (river flow anomaly and its probability of occurrence for the next six weeks, aggregated over regions) predicted a high probability of high flow in the affected areas already from the 20th of April (Figure 5.2). The EFAS seasonal outlook (river flow anomaly and its probability of occurrence for the next eight weeks, aggregated over regions) predicted high probability of high flow in the affected areas starting from the 1st of May (Figure 5.3).

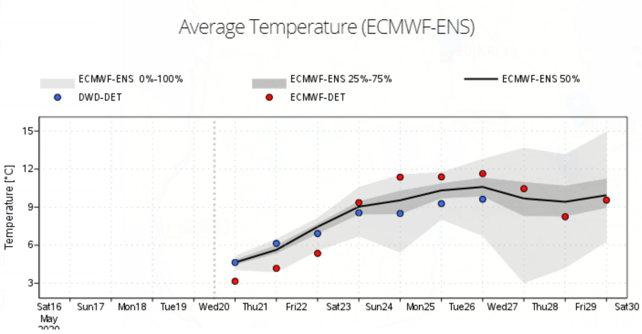


Figure 5.1: EFAS Forecasted temperature at a station near the Rovaniemi airport on the 20th of May 2020.

Table 5.1: Issued EFAS formal/informal notifications during the 2020 spring flood for the Scandinavian region (countries are differentiated by colour).

No	Station ID	Country	Basin	River	Station Name	Area [km2]	PointID	Sent on	Disable on	Duration (days)	Type of warning
1	-99	NORWAY	Norway	Namsen	Not a station	6200	DH000201	2020-05-22	2020-06-17	26	Formal
2	1999	Finland	Oulujoki-Iijoki	Kuivajoki	LUUJOKI HAARAN ALA PUOLELLE	1350	SH000161	2020-05-23	2020-06-01	9	Informal Because of the small affected area
3	124	Finland	Kemijoki	Jumiskonjoki	Jumisko	1300	SH000068	2020-05-23	2020-05-26	3	Informal because of the small affected area
4	2885	Finland	Iijoki	Iijoki	Vaatajansuvanto	4150	SM000155	2020-05-23	2020-06-01	9	Formal
5	2887	Finland	Iijoki	Livojoki	Livojoki Hanhikoski	2150	SM000155	2020-05-24	2020-05-30	6	Formal
6	2886	Finland	Iijoki	Jaurakkajarvi	Jaurakkajarvi-luusua	2550	SH000160	2020-05-24	2020-06-03	10	Formal
7	2000	Finland	Simojoki	Simojoki	SIMO	3125	SH000154	2020-05-24	2020-06-01	8	Formal
8	-99	Finland	Finland (Gulf of Bothnia)	Kemijoki, above Ounasjoki	Not a station	3125	DH000066	2020-05-24	2020-05-26	2	Formal
9	-99	Finland	Patsojoki	Paatsjoki	Not a station	2725	DH000031	2020-05-24	2020-05-29	5	Informal due to the short lead time
10	2888	Finland	Oulankajoki	KOUTAJOKI	Oulankajoki	2100	SH000106	2020-05-25	2020-06-04	10	Formal
11	-99	Finland	Finland (Gulf of Bothnia)	Luiro	Not a station	4925	DH000053	2020-05-26	2020-06-08	13	Formal
12	131	Finland	Kemijoki	Meltausjoki	Unari luusua	1175	SH000086	2020-05-26	2020-06-04	9	Formal
13	125	Finland	Kemijoki	Kemijoki	Kemihaara	10 325	SH000074	2020-05-27	2020-06-13	17	Formal
14	132	Finland	Kemijoki	Ounasjoki	Ounasjoki, Marraskoski	12 900	SH000102	2020-05-27	2020-06-07	11	Formal
15	319	Norway	Drammen	Snarum	Sklfoss	5100	SH000405	2020-05-28	2020-06-04	7	Formal
16	-99	Norway	Moel	Moel	Not a station	2525	DH000291	2020-05-28	2020-07-03	36	Formal
17	307	Norway	Glomma	Glomma	Hummelvoll	2450	SH000295	2020-05-28	2020-06-08	11	Formal
18	-99	Norway	Hallingdalselva	Hallingdalselva	Not a station	2325	DH000379	2020-05-28	2020-07-01	34	Formal
19	-99	Norway	Temijoki	Tenojoki	Not a station	15 800	DM000001	2020-05-28	2020-07-01	34	Formal
20	1099	Norway	Gaula (Melhus)	Gaula (Melhus)	Gaulfoss	3200	SH000269	2020-05-28	2020-06-05	8	Formal
21	1982	Norway	Altaelva	Altaelva	KISTA	6250	SH000019	2020-05-28	2020-06-10	13	Formal
22	1114	Norway	Vefsna	Vefsna	Laksfors	3575	SH000184	2020-05-28	2020-06-20	23	Formal
23	-99	Sweden	Indals	Indals?lven	Not a station	2475	DH000230	2020-05-28	2020-06-09	12	Formal
24	1132	Norway	Byaelva	Byaelva	Hkkadalbrua	2125	SH000155	2020-05-29	2020-06-04	6	Formal
25	-99	SWEDEN	Angerman	Angerman	Not a station	3000	DH000204	2020-05-29	2020-06-16	18	Formal
26	-99	SWEDEN	Angerman	Vojman	Not a station	2300	DH000120	2020-05-29	2020-06-16	18	Formal
27	134	Finland	Kemijoki	Kemijoki	Isohaara	52 475	SH000151	2020-05-29	2020-06-16	18	Formal
28	1107	Norway	Malselv	Malselv	Malangsfoss	2975	SH000050	2020-05-29	2020-06-27	29	Formal
29	144	Finland	YES	Paatsjoki	Paatsjoki	Kaitakoski	14 575	2020-05-30	2020-06-14	15	Formal
30	136	Finland	Torne	Muonio	Muonionjoki, Muonio	9250	SH000063	2020-05-31	2020-06-12	12	Formal
31	1966	Sweden	Torne	Torneaelven	KUKKOLANKOSKI OEVRE	39 975	SH000146	2020-05-31	2020-06-12	12	Formal
32	297	Norway	Drammen	Begna	Bagn	2975	SH000365	2020-06-03	2020-06-09	6	Formal
33	-99	NORWAY	Norway	Coastal zone	Not a station	2100	DH000155	2020-06-04	2020-07-02	28	Formal
34	317	Norway	Glomma	Lagen	Rosten	1825	SH000315	2020-06-04	2020-06-08	4	Informal due to the small affected area
35	1076	Norway	Nea	Nea	Rathe	3050	SM000249	2020-06-04	2020-06-10	6	Informal due to the short forecast lead-time.
36	-99	NORWAY	Norway	Rana	Not a station	3975	DH000152	2020-06-06	2020-07-07	31	
37	1075	Norway	Rauma	Rauma	Rauma v/Horgheim	1125	SH000287	2020-06-06	2020-06-24	18	Informal due to the small affected area.
38	-99	SWEDEN	Umelrven	Ume?lven	Not a station	3175	DH000184	2020-06-07	2020-07-16	39	Formal
39	1056	Norway	Vosso	Vosso	Bulken (Vangsvatnet)	1075	SH000372	2020-06-08	2020-06-26	18	Informal due to to the small affected area.
40	301	Norway	Glomma	Lagen	Eide	7925	SH000328	2020-06-08	2020-06-30	22	Formal
41	-99	SWEDEN	Skellefte	Skellefte	Not a station	3075	DH000136	2020-06-08	2020-06-20	12	Formal
42	1195	Sweden	Pite	Tjeggelvas	Stenudden	2375	SH000060	2020-06-10	2020-06-24	14	Formal
43	-99	SWEDEN	Lullmlven	Stora Lule	Not a station	2350	DH000045	2020-06-10	2020-06-26	16	Formal
44	-99	SWEDEN	Umelrven	Vindel	Not a station	3050	DH000164	2020-06-16	2020-06-22	6	Formal
45	319	Norway	Drammen	Snarum	Sklfoss	5100	SH000367	2020-06-20	2020-06-24	4	Formal
46	1195	Sweden	Pite	Tjeggelvas	Stenudden	2375	SH000060	2020-06-29	2020-06-30	1	Formal
47	-99	FINLAND	Finland (Gulf of Bothnia)	Luiro	Not a station	3625	DH000031	2020-06-29	2020-07-29	30	Formal
48	2897	Sweden	Umeliven	Umeliven	HARRSELE KRV	13650	SH000176	2020-07-12	2020-08-06	25	Formal

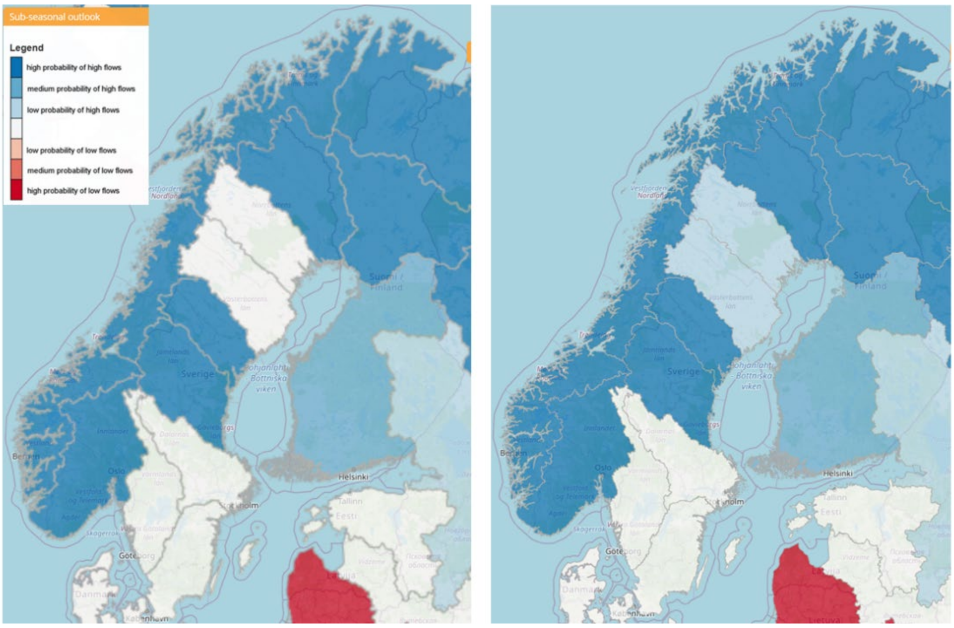


Figure 5.2: EFAS river flow anomaly and its probability of occurrence for the next six weeks, aggregated over regions for the 20th April 2020 (left) and 29 April 2020 (right) initializations. This is based on the EFAS sub-seasonal outlook product.

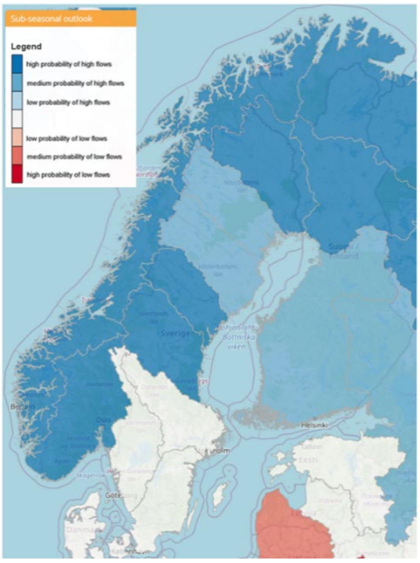


Figure 5.3: EFAS river flow anomaly and its probability of occurrence for the next eight weeks, aggregated over regions (forecasts initialized on the 1st of May 2020). This is based on the EFAS seasonal outlook product.

6 Verification

6.1 Verification of EFAS forecasts

6.1.1 Meteorological situation

6.1.1.1 Snow

EFAS modelled larger amount of snow water equivalent for Norway (specially along the west coast) and Finland (northern part) than the other parts of Scandinavia (see Figure 2.5). This result agrees with the analysis of observed precipitation prior to the event (see section 2.2, and specifically Figure 2.1 and 2.2). Furthermore, different media reports in Finland and Norway (see Media report 1 and 5 respectively in Annex 1) referred to an unusual high amount of snow for winter in 2020.

6.1.1.2 Effect of forecasted precipitation and temperature errors on forecasted discharge

The combined effect that errors in temperature and precipitation from the meteorological forecasts have on the medium-range discharge forecasts was analyzed for 6 EFAS notification points (see Annex 2), which are those that were associated with the most severe flooding.

Based on the analysis in Annex 2, it can be summarized that the ECMWF meteorological forecasts could persistently forecast the precipitation and temperature conditions from 4 to 9 days ahead on time. The forecasted time to peak agreed quite well with the time obtained later when the model was run with the observed input data; differences were negligible except for one point in Sweden where the overprediction was about 50%. The hydrological predictions always achieved with time a correct value as a result of the model (initial conditions) update with the meteorological observations. The persistence of the DWD forecast was inferior in comparison to the ECMWF forecast persistence for 4 out of 6 stations. The DWD forecasts usually overestimated the peak by at least 15% for all the cases. By inspecting the stations with problems in persistence, it appeared that the DWD system tended to forecast a higher (plus 2-3 °C) temperature leading to an increased amount of snowmelt.

For the local case in Finland, the pattern of EFAS 3.6 forecasted temperature (10 days ahead on time; see Figure 5.1) agree well, but also locally with the observed temperature from a station in Finland (Figure 2.4); differences of max 3 °C can be observed between the DWD and ECMWF forecasts. The temperature at the station measured about 3 °C higher than the temperature in the EFAS information/forecast (for both DWD and ECMWF), which could be the result of local variations. In general, it seems that forecasted temperature for ECMWF was slightly better and more persistent than that for DWD.

6.1.2 EFAS flood hazard forecasting

6.1.2.1 Medium-range forecasting

In terms of timing

Table 6.1 presents a summary of the performance of the EFAS forecast for the stations where notifications were sent and had discharge observations during the event. An evaluation was done for the forecasts 6 and 2 days before the observed peak; 6 days was chosen here to make it possible to identify the peak of the forecasted event, this might not have been possible if chosen the maximum lead time (10 days). For the notifications analyzed in Table 6.1, EFAS forecasted the time of the peak to be earlier than the actual observation for almost all the predictions i.e. for 6 or 2 days before the peak, for both DWD and ECMWF. The ECMWF and DWD systems estimated the peak to be too early, with an average of 3 and 2 days respectively when the forecast was 6 days before the observed peak. For the 2 days lead time, the forecast of the correct time of the peak improved for DWD and decreased slightly for ECMWF.

The result of this analysis is also supported by EFAS partners' input. It was mentioned in one reported point (see Annex 3) that the forecasted time of the peak was about 3 days too early. In addition, a comment from a partner in Norway pointed out that the partner experienced EFAS to have a faster response when comparing with the local observations (see Annex 4).

In terms of peak magnitude

For the analyzed stations in Table 6.1, underprediction is shown for most of the stations using both the DWD and ECMWF forecasts. The forecasted magnitude of the peak did not change significantly when the lead time to peak was shorter, i.e. from 6 to 2 days or even when using real observed input data (column Diff Obs Input data). This shows that the meteorological predictions were somewhat persistent and that in fact the errors were caused by the hydrological model. The forecasts from 6 days lead time led to an average underprediction of 28% and 25% for ECMWF and DWD respectively. The underprediction improved for the 2 days lead time and resulted into 21% for both systems.

In terms of spatial extent

Figure 3.4 shows a total of 17 stations in north Scandinavia that reached discharge values larger than the maximum measured in the historical (at least 6 years) records. Together in the central and northern part of Scandinavia 7 stations reached the maximum (Figure 3.9 and 3.10). Particularly, values in the north of Finland and Norway experienced maximum values in more than 10 days (red circles in Figure 3.4).

Based on a visual evaluation, it can be concluded that notifications sent by EFAS (See for example Figure 2.6) cover all the areas with high flows (exceeding the 99th percentile) as shown in Figure 3.4, 3.7 and 3.10. EFAS notifications are not sent to all stations with high flows, since according to the criteria to send EFAS notifications, only one notification per tributary is sent unless a new reporting point appears downstream in a main stream or in another country. Comparison of Figure 3.5, 3.8, 3.11 and 2.6 indicate that all stations where observed discharge exceeded a threshold level were covered by the EFAS notifications.

Analysis at stations that reached the highest alert level

Analysis of the discharge exceeding the national threshold levels (only available for Norway and Sweden) shows that the highest Level (TL4) was exceeded for 3 stations; 2 in the north (Leirbothnvatn and Vaekkava in Norway), none in central, and 1 in the south zone (Holen in Norway) (Figure 3.7, 3.10 and 3.13 respectively). Inspection of the EFAS forecasts for the Vaekkava station (Figure 6.1) shows that while the magnitude of the peak was near the observation, the time of the peak was about 7 days too early. The stations Leirbothnvatn and Holen were not analyzed here as the drainage area is smaller than the threshold set in EFAS, i.e. 2000 km^2.

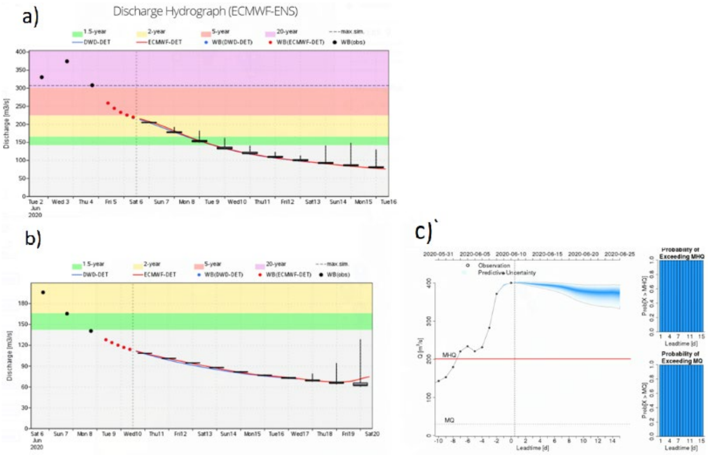


Figure 6.1: EFAS forecasts for station Vaekkava for the: a) 6th of June, and b) 10th of June. c) shows the observation when discharge reached a maximum peak.

Although information on exceedance levels is not available for Finland, from the national service is shown that one station near the lake Inarijärvi exceeded the highest warning level from the 4th to the 6th of June (Figure 4.1). The location of the station in the national system agrees well with the location of the EFAS station with ID 144, named Kaitakoski in the basin Paatsjoki (Figure 2.8). The forecasted time of the peak was on the 3rd of June based on DWD and on the 5th of June based on ECMWF, which agrees well with the time when the station exceeded the highest level in the national system. The station went over the 20-year RP which indicates that probably the forecasted magnitude was close to the observations.

None of the stations in Sweden reached the highest level according to the observations. The highest level in Sweden is associated with return periods larger than 50 years. Although some stations exceeded the 20-year RP in EFAS, these would be classified as second level (TL3 in Figure 3.5, 3.8 and 3.11) which agrees with locations where Level 2 (from 10 to 50-year RP) was exceeded in the national system (Figure 4.3).

Table 6.1: Evaluation of the EFAS forecast performance in terms of time of the peak and peak magnitude for both DWD and ECMWF, for 6 and 2 days prior to the observed peak.

Station ID	Date of maximum peak											Maximum discharge (m^3/s)										
	Daily obs	EFAS 3.6	ECMWF (6 days before)	DWD (6 days before)	ECMWF (2 days before)	DWD (2 days before)	Diff (days) ECMWF (6 days before)	Diff (days) DWD (6 days before)	Diff (days) ECMWF (2 days before)	Diff (days) DWD (2 days before)	Diff Obs input data	Daily obs	Obs input data	ECMWF (6 days before)	DWD (6 days before)	ECMWF (2 days before)	DWD (2 days before)	Diff (%) ECMWF (6 days before)	Diff (%) DWD (6 days before)	Diff (%) ECMWF (2 days before)	Diff (%) DWD (2 days before)	Diff Obs input data
132	31-maj	30-maj	03-jun	29-maj	30-maj	30-maj	3	-2	-1	-1	-1	1275.8	1292.6	1050	1500	1300	1300	-18	18	2	2	1
136	11-jun	05-jun	05-jun	05-jun	05-jun	05-jun	-6	-6	-6	-6	-6	1185.8	674.7	700	700	700	700	-41	-41	-41	-41	-43
307	08-jun	04-jun	04-jun	04-jun	07-jun	07-jun	-4	-4	-1	-1	-4	259.1	252.9	260	275	252	252	0	6	-3	-3	-2
317	08-jun	02-jun	11-jun	09-jun	07-jun	07-jun	3	1	-1	-1	-6	194.8	86	80	100	85	82	-59	-49	-56	-58	-56
1056	23-jun	20-jun	20-jun	22-jun	21-jun	21-jun	-3	-1	-2	-2	-3	410.1	347	400	400	400	400	-2	-2	-2	-2	-15
1075	23-jun	18-jun	18-jun	18-jun	18-jun	18-jun	-5	-5	-5	-5	-5	419.1	217.2	250	240	230	230	-40	-43	-45	-45	-48
1076	09-jun	07-jun	09-jun	07-jun	08-jun	08-jun	0	-2	-1	-1	-2	354.2	375.4	320	325	400	450	-10	-8	13	27	6
1099	08-jun	02-jun	02-jun	02-jun	02-jun	07-jun	-6	-6	-6	-1	-6	848.6	518.5	500	510	500	650	-41	-40	-41	-23	-39
1107	09-jun	08-jun	12-jun	08-jun	06-jun	07-jun	3	-1	-3	-2	-1	638.3	364.6	330	375	340	340	-48	-41	-47	-47	-43
1114	08-jun	02-jun	02-jun	02-jun	02-jun	07-jun	-6	-6	-6	-1	-6	997.8	919.4	910	1050	910	920	-9	5	-9	-8	-8
1132	08-jun	08-jun	06-jun	06-jun	09-jun	08-jun	-2	-2	1	0	0	269	152	150	160	160	170	-44	-41	-41	-37	-43
Average							-2.1	-3.1	-2.8	-1.9	-3.6	Na						-28	-21	-25	-21	-26

6.1.2.2 EFAS sub-seasonal outlook

The sub-seasonal outlook forecast skill was quite good for predicting above normal conditions six weeks ahead on time starting on the 20th of April. As also shown for the 29th of April (Figure 5.2), this match well the widespread of the flood through the three countries for the weeks around the 1st to the 8th June in the medium-range forecast products (Figure 2.6 and Table 5.1)

Specifically, for Sweden, Figure 4.4 shows that flows above normal conditions matches quite well the prediction of the sub-seasonal outlook. However, EFAS predictions are at the regional level and consequently it is not possible to see in a better spatial resolution the affected areas, as in the local data from the national service.

6.1.2.3 EFAS seasonal outlook

The EFAS seasonal forecast service produced accurate predictions (i.e. flow above normal conditions agreed well with the observed flood development) when the Lisflood model was initialized on the 1st of May. Thus, during the 2020 spring event in the Scandinavian region, there was no high benefit from using the 8-weeks ahead seasonal outlook. The 6-week ahead sub-seasonal prediction product outperformed the seasonal outlook product by providing an accurate forecast earlier in time. Differences in the performance of the sub-seasonal and seasonal forecasts have to do with: (1) high forecast quality for the ECMWF extended-range prediction system in comparison to the ECMWF SEAS5 seasonal prediction system, and (2) frequent initialization of the LISFLOOD model using the ECMWF extended-range forecasts, i.e. model is initialized every week.

6.2 Verification of the EFAS service

From a survey answered by the partners in the Scandinavian region (see Annex 4) it was found as a common view that getting an email with notification was a fast and simple way to get information from EFAS, whilst partners agree that they do not see a need for more information from the EFAS system. Partners did not express a wish for a change in the criteria for sending formal notifications. Note that one out of three partners did not use the forecasting system, while the other two use the service, but conditionally.

6.2.1 On the accuracy and usefulness of EFAS

From the reported points (see Table A3.1 in Annex 3) during the 2020 spring flood, a total of 5 points were reported for Sweden and 1 for Finland. The average added-value score was 1.4, with a value of 1 indicating “No added value, I was already aware of the upcoming situation” and a value of 5 indicating “Very helpful, thanks to the notification we were prepared to face the situation”. The reported point for Finland indicated that the event started 3 days later than the EFAS predicted time. At one reported point in Sweden, it was indicated the peak to be at least 3 days earlier and much less severe than in the EFAS predictions. Note that these results are driven by analysis of few points, which are most located in Sweden, and hence conclusions might be biased.

The EFAS partners in Finland assessed that the information was mainly relevant and most of the time in line with their national system. EFAS notifications are important as they help partners avoiding missing information on possible events in their local service.

The EFAS partner in Norway do not use the EFAS service for their daily warning system, since they consider their local system to be better tailored to the Norwegian hydrological conditions. A general comment from the Norwegian EFAS partner is that the LISFLOOD model does not perform well for fast responding events, i.e. EFAS can tend to have too quick response than the observations. However, they value EFAS with regard to having easily accessible and user-friendly information at a European level.

The EFAS partner in Sweden used the information from the notification as a confirmation of the extreme hydrological conditions. However, the national warnings are based on the national service which is considered to perform better. The national service incorporates more observations, especially at river systems whose response depends on dam regulations.

6.3 Performance of EFAS 3.6 versus 4.0

6.3.1 Introduction

EFAS 3.6 was operational for the duration of the 2020 spring floods, however, EFAS 4.0 was launched in October 2020, and this report presents a good opportunity for a brief evaluation of the comparative performance of the two models. Version 4.0 constituted a complete upgrade of the EFAS hydrological modelling system, notably including a 4-fold increase in the temporal resolution (from daily to 6-hourly), as well as a recalibration and an upgrade of some static fields, amongst other significant improvements.

The performance of the two model versions was evaluated for all stations listed in Table 6.2. This meant a total of 26 stations were included, with 11 of those having discharge observations available for the study period (last column in Table 6.2). Though the core study period is from 20th May to 31st July, this evaluation examines data from the 1st May, to gain an insight into the conditions (particularly those related to snow) prior to the onset of the flooding.

Alongside this, an assessment of the EFAS 3.6 and 4.0 forecasts was conducted. To compare the magnitude, timing, and presence of reporting points for both EFAS 3.6 and EFAS 4.0, forecast discharge hydrographs for a selected date (peak in observations) were examined. The performance of both forecasts was evaluated alongside the observations and model outputs to provide context for the flood event. A subsection is dedicated to this summary analysis of the forecast performance, with a more detailed evaluation of the forecasts at all 11 stations with observations given in Table 6.4.

Table 6.2: Summary characteristics of study stations, including the hydrological model performance (as measured by the modified Kling-Gupta Efficiency [KGE'] score) associated with EFAS 3.6 and 4.0 for stations with appropriate observational records. A KGE' score of 1 indicates a perfect agreement between simulations and observations.

Station ID	**Station Name**	**River**	**Catchment**	**Provided Drainage Area (km^2)**	**Model Drainage Area (km^2)**	**KGE score EFAS 3.6**	**KGE score EFAS 4.0**	**KGE score difference**	**Obs.**
125	Kemihaara	Kemijoki	Kemijoki	8538	10325	0.76	0.8	0.04	No
131	Unari luusua	Meltausjoki	Kemijoki	1198	1175				No
132	Ounasjoki, Marraskoski	Ounasjoki	Kemijoki	12303	12900	0.55	0.86	0.31	Yes
134	Isohaara	Kemijoki	Kemijoki	50683	52475	0.65	0.84	0.19	No
136	Muonionjoki, Muonio	Muonio	Torne	9259	9250	0.23	0.64	0.41	Yes
297	Bagn	Begna	Drammen	2976	2975				No
301	Eide	Lagen	Glomma	7969	7925				No
307	Hummelvoll	Glomma	Glomma	2421	2450				Yes
317	Rosten	Lagen	Glomma	1833	1825				Yes
319	Skalfoss	Snarum	Drammen	5126	5100	0.58	0.71	0.13	No
1056	Bulken (Vangsvatnet)	Vosso	Vosso	1092	1075	0.63	0.73	0.1	Yes
1075	Rauma v/Horgheim	Rauma	Rauma	1099	1125				Yes

1076	Rathe	Nea	Nea	3057	3050				Yes
1099	Gaulfoss	Gaula (Melhus)	Gaula (Melhus)	3086	3200	0.71	0.72	0.01	Yes
1107	Malangsfoss	Malselv	Malselv	3110	2975	0.39	0.54	0.15	Yes
1114	Laksfors	Vefsna	Vefsna	3653	3575	0.6	0.79	0.19	Yes
1132	Hkkadalbrua	Byaelva	Byaelva	2141	2125				Yes
1966	Kukkolankoskioevre	Torneaelven	Torne	33930	39975	0.9	0.84	-0.06	No
1982	Kista	Altaelva	Altaelva	6187	6250	0.65	0.63	-0.02	No
1999	Luujoki Haaran Ala Puolelle	Kuivajoki	Oulujoki-Iijoki	1352	1350	0.71	0.78	0.07	No
2000	Simo	Simojoki	Simojoki	3141	3125	0.67	0.8	0.13	No
2885	Vaatajansuvanto	Iijoki	Iijoki	4101	4150	0.44	0.44	0	No
2886	Jaurakkajarvi-luusua	Jaurakkajarvi	Iijoki	2588	2550	0.74	0.74	0	No
2887	Livojoki Hanhikoski	Livojoki	Iijoki	2151	2150	0.77	0.79	0.02	No
2888	Oulankajoki	KOUTAJOKI	Oulankajoki	2113	2100	0.84	0.79	-0.05	No
2897	Harrsele KRV	Umeliven	Umeliven	13624	13650	0.38	0.3	-0.08	No
Average						0.62	0.71	0.09	No

6.3.2 *Analysis of EFAS performance (EFAS 3.6 versus 4.0)*

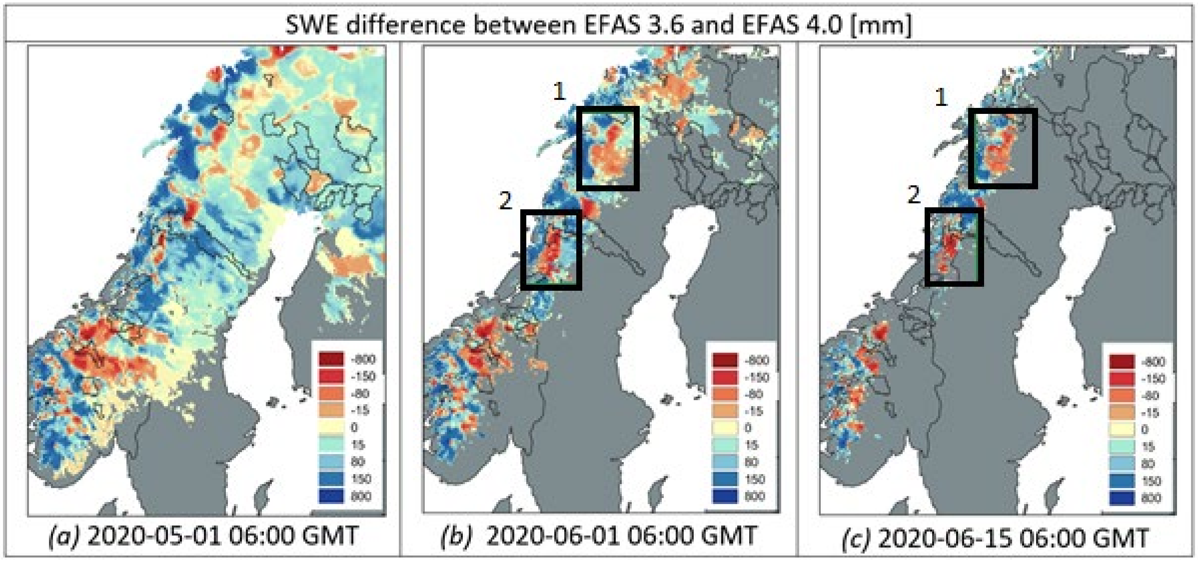
6.3.2.1 Comparison between model simulations, and observations where applicable

An evaluation of the performance of EFAS 3.6 and 4.0 was conducted through comparison of the models’ simulations of discharge and other key components of the hydrological cycle. Where possible, this simulated discharge has been compared against observed discharge. Stations where this is the case are indicated in the final column of Table 6.2. The other simulated variables examined alongside discharge are precipitation, temperature, snowmelt, and snow water equivalent (SWE). Whilst statistical analysis is beyond the scope of this evaluation, it is possible to make qualitative statements on the timing and magnitude of the floods, highlight any missed events, and offer plausible reasons for any findings.

Snow Water Equivalent (SWE) comparison

The flood events analyzed in this report have a strong snow component, for this reason in this subsection we present a general overview of the SWE status for EFAS 3.6 and 4.0. Given the scope of this section to highlight the discrepancies between the two models, the SWE is presented as the arithmetic difference between EFAS 3.6 and EFAS 4.0.

Prior to the onset of the event (Figure 6.2(a)), EFAS 3.6 has a higher content of SWE over the study area generally, with some exceptions along the Scandinavian mountains where the biggest differences are found. By the start of June most of the snow at low/medium altitudes has completely melted Figure 6.2(b); in some areas (box 1 and box 2 in Figure 6.2(b) where SWE is still present there is more in EFAS 4.0 than EFAS 3.6 compared to the initial SWE differences observable in Figure 6.2(a). On the 15th of June (Figure 6.2(c)) snow is present only at very high altitudes with the SWE differences having the same pattern as in Figure 6.2(b).



(a) 2020-05-01 06:00 GMT (b) 2020-06-01 06:00 GMT (c) 2020-06-15 06:00 GMT

Figure 6.2: SWE (snow water equivalent) difference between EFAS 3.6 and EFAS 4.0 before the onset of the event (a), during the event (b) and few days before the snow completely melted (c). In the blue areas EFAS 3.6 has higher SWE compared to EFAS 4.0, and red areas are where EFAS 4.0 has a higher content of SWE.

Discharge comparison for stations with observations available

Figure 6.3 shows the observed discharge and model simulations for all 11 stations with observations (as indicated in Table 6.2). These stations can be divided into those where the two model versions perform similarly, and those where they do not. EFAS 3.6 and 4.0 can be said to perform broadly similarly in terms of timing and magnitude at all 11 stations, with the exception of Stations 317 (Rosten), 1076 (Rathe), and 1132 (Hkkadalbrua). However, their broadly similar performance at these eight stations is not invariably a good one when compared to the observed discharge. This is particularly true of Stations 136 (Muonionjoki, Muonio), 1075 (Rauma v/Horgheim), and 1107 (Malangsfoss) where the discharge simulated by both EFAS 3.6 and 4.0 was a considerable underestimation compared to the observations. Information on the timing and magnitude of the observed and simulated peak river discharge at each station is available in Table 6.3. For the other five stations that show generally good agreement between model versions (IDs 132, 307, 1056, 1099 and 1114), this information indicates that one model does not consistently outperform the other in simulating both the timing and magnitude of peak discharge. Interestingly though, except for station 1099 (Gaulfoss), EFAS 3.6 does better predict the magnitude of the discharge than EFAS 4.0 (Table 6.3). However, it is worth noting that a more accurate prediction of the timing and/or magnitude of peak river discharge does not mean that the model performs better overall throughout the study period. This is acknowledged as a limitation of this evaluation.

Regarding the three stations where the models do not perform similarly (IDs 317, 1076, and 1132), again one model is not consistently better at capturing the timing and magnitude of the observed discharge. However, it is clear in Figure 6.3 that EFAS 3.6 more accurately captures the magnitude of the flooding at the Rathe station (ID 1076), with a value of 375 m^3/s, slightly above the observed peak (354 m^3/s) whilst EFAS 4.0 has a sizeable underestimation (257 m^3/s) (Table 6.3). Interestingly however, the timing is the same in both models, peaking two days early (07/06, observed peak 09/06). At Rosten (ID 317), EFAS 4.0 captures the flow fluctuations discernible in the observations, but considerably overestimates the magnitude, with a peak of 298 m^3/s compared to just the 195 m^3/s observed (Table 6.3). Meanwhile version 3.6 captures neither the fluctuations in the flow nor the severity, with a peak discharge of just 86 m^3/s. Lastly, at the Hkkadalbrua station (ID 1132), the models have a similar magnitude of peak river discharge (152 m^3/s and 144 m^3/s in EFAS 3.6 and

4.0 respectively), but very different timing. EFAS 3.6 correctly predicts the date of the highest river discharge as being on 08/06, whilst EFAS 4.0 peaks 16 days early on 24/05.

Table 6.3: The date on which the highest discharge value was recorded in observations and in EFAS 3.6 and 4.0, and the value itself.

	Timing of highest peak						Maximum discharge recorded (m^3/s)					
Station ID	**Daily obs**	**EFAS 3.6**	**EFAS 4.0**	**3.6 diff**	**4.0 diff**	**Better timing**	**Daily obs**	**EFAS 3.6**	**EFAS 4.0**	**3.6 diff**	**4.0 diff**	**Better magnitude**
132	31/05	30/05	28/05	1	3	3.6	1275.8	1292.6	1211.9	-16.8	63.9	3.6
136	11/06	05/06	03/06	6	8	3.6	1185.8	674.7	596.0	511.1	589.8	4
307	08/06	04/06	07/06	4	1	4	259.1	252.9	236.7	6.2	22.5	3.6
317	08/06	02/06	03/06	6	5	4	194.8	86.0	298.2	108.8	-103.5	4
1056	23/06	20/06	21/06	3	2	4	410.1	347.0	301.5	63.0	108.5	3.6
1075	23/06	18/06	19/06	5	4	4	419.1	217.2	264.0	201.9	155.1	4
1076	09/06	07/06	07/06	2	2		354.2	375.4	257.4	-21.3	96.8	3.6
1099	08/06	02/06	01/06	6	7	3.6	848.6	518.5	798.0	330.1	50.7	4
1107	09/06	08/06	08/06	1	1		638.3	364.6	325.1	273.7	313.2	3.6
1114	08/06	02/06	07/06	6	1	4	997.8	919.4	861.1	78.5	136.7	3.6
1132	08/06	08/06	24/05	0	14	3.6	269.0	152.0	144.0	117.0	125.0	4
	Averages			3.6	4.4		623	473	481	150	142	

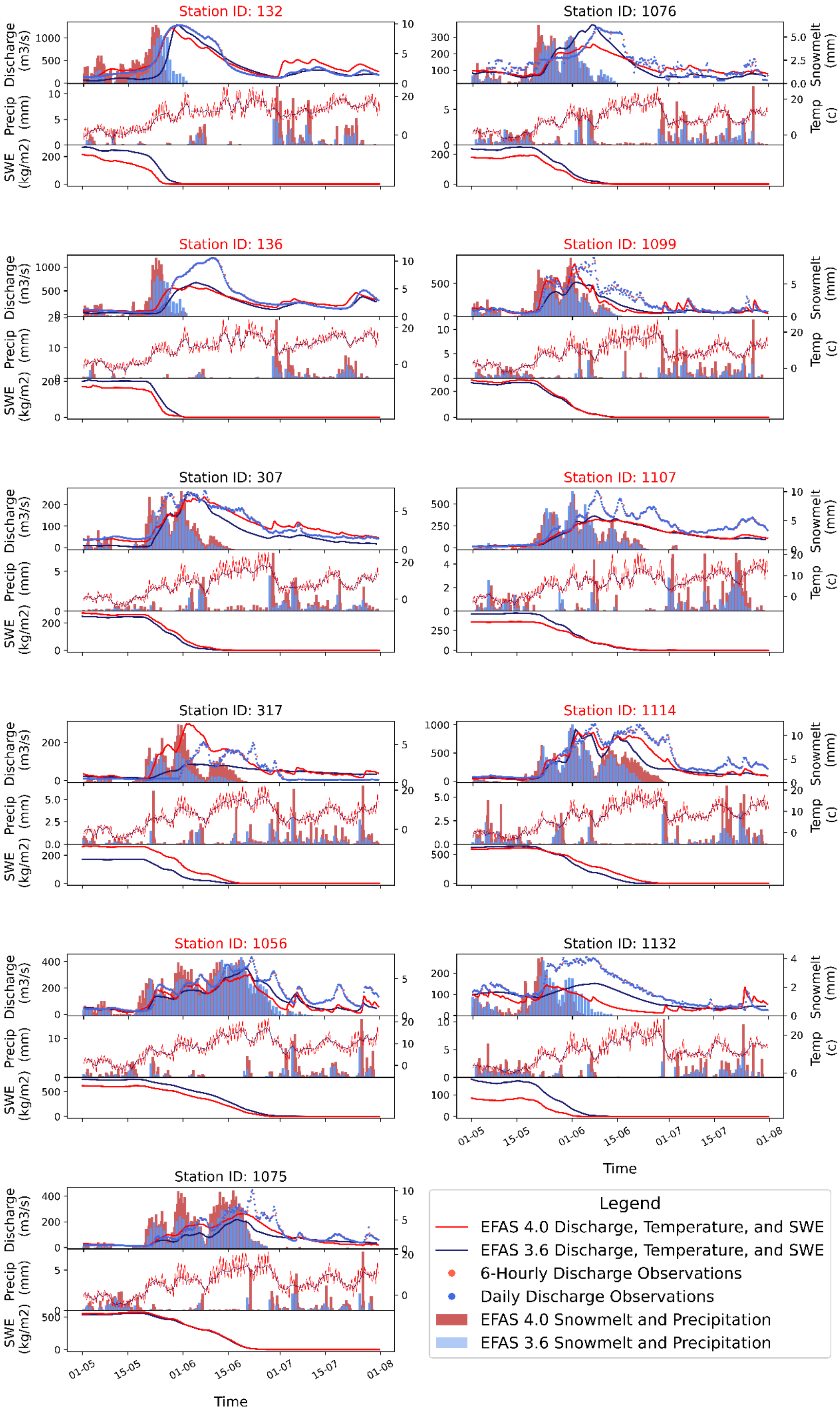


Figure 6.3: Graphs for the study stations with observations from Table 6.2. Each plot shows the simulated and observed discharge and snowmelt (top subplot), the precipitation and temperature (middle subplot), and the snow water equivalent (SWE) (bottom subplot). Station IDs are colored by KGE' score, with red (blue) indicating a higher (lower) score for EFAS 4.0 compared to 3.6, and black indicating no KGE' score was calculated for that station. Temperature, snowmelt, and SWE values represent the mean value of the model cells upstream of that station.

To detect any spatial patterns in model accuracy in simulating the timing and magnitude of peak river discharge, the information in Table 6.3 was categorized and plotted (Figure 6.4). There does not appear to be a pattern in the northern half of the study area, though this is limited by only three stations having observations. However, it is reasonable to say that south of the Trøndelag region in Norway (i.e. Station 1099 and below), EFAS 4.0 appears to better predict the timing of the peak flooding. Even at Station 1099 (Gaulfoss), EFAS 4.0 is only a day earlier than 3.6 (01/06 vs 02/06, observed peak 08/06).

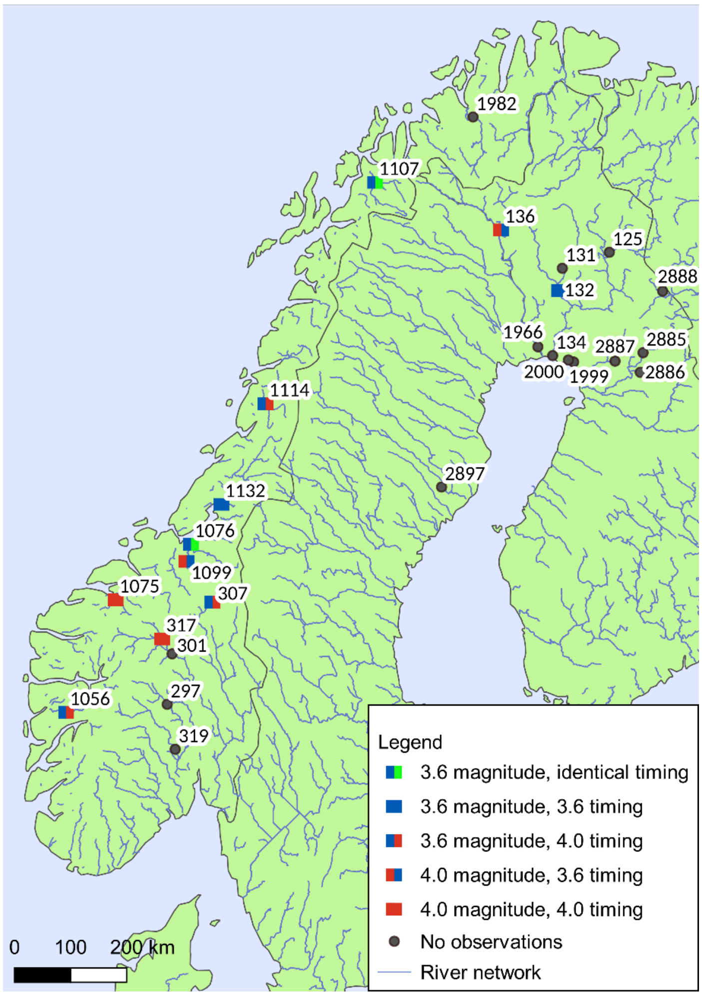


Figure 6.4: Qualitative assessment of the timing and magnitude of peak river discharge in the two model versions when compared to observations. The categories show by color whether version 3.6 or 4.0 more accurately simulated both the magnitude (left rectangle) and the timing (right rectangle) of the flooding

Discharge comparison for stations with no observations available

This evaluation primarily focuses on the stations with discharge observations available, as without these it is not possible to determine which model version most closely mimicked the observed peak river discharge. Despite this, they are still worth briefly examining and discussing, and so Figure 6.5 shows the simulated discharge and other variables for the stations without observations (as indicated in Table 6.2). The model versions are in good agreement about the timing and magnitude of the simulated discharge for seven out of the 15 stations (IDs 1966, 1982, 1999, 2000, 2885, 2887, 2888). With the exception of stations 1966 (Kukkolankoskioevre) and 2887 (Livojoki Hanhikoski), EFAS 4.0 consistently predicts a slightly higher peak discharge than EFAS 3.6 for these stations. The timing is very similar across these stations, with river discharge peaking in the second half of May. An exception is station 1966, which peaks in the beginning of June.

The extent to which EFAS 4.0 and 3.6 disagree about the discharge at the other eight stations varies, some show more obvious differences (IDs 134, 301, 319, and 2897), whilst others show slightly less obvious differences, primarily in magnitude (IDs 125 and 131) or timing (IDs 297 and 2886). For stations 125 (Kemihaara) and 131 (Unari luusua), neither model is higher at both stations, with EFAS 4.0 (3.6) predicting a higher peak discharge at station 125 (131). However, for both stations where timing is main difference (IDs 297 and 2886), EFAS 4.0 is earlier than 3.6, with it showing an earlier rise to peak discharge levels than in 3.6.

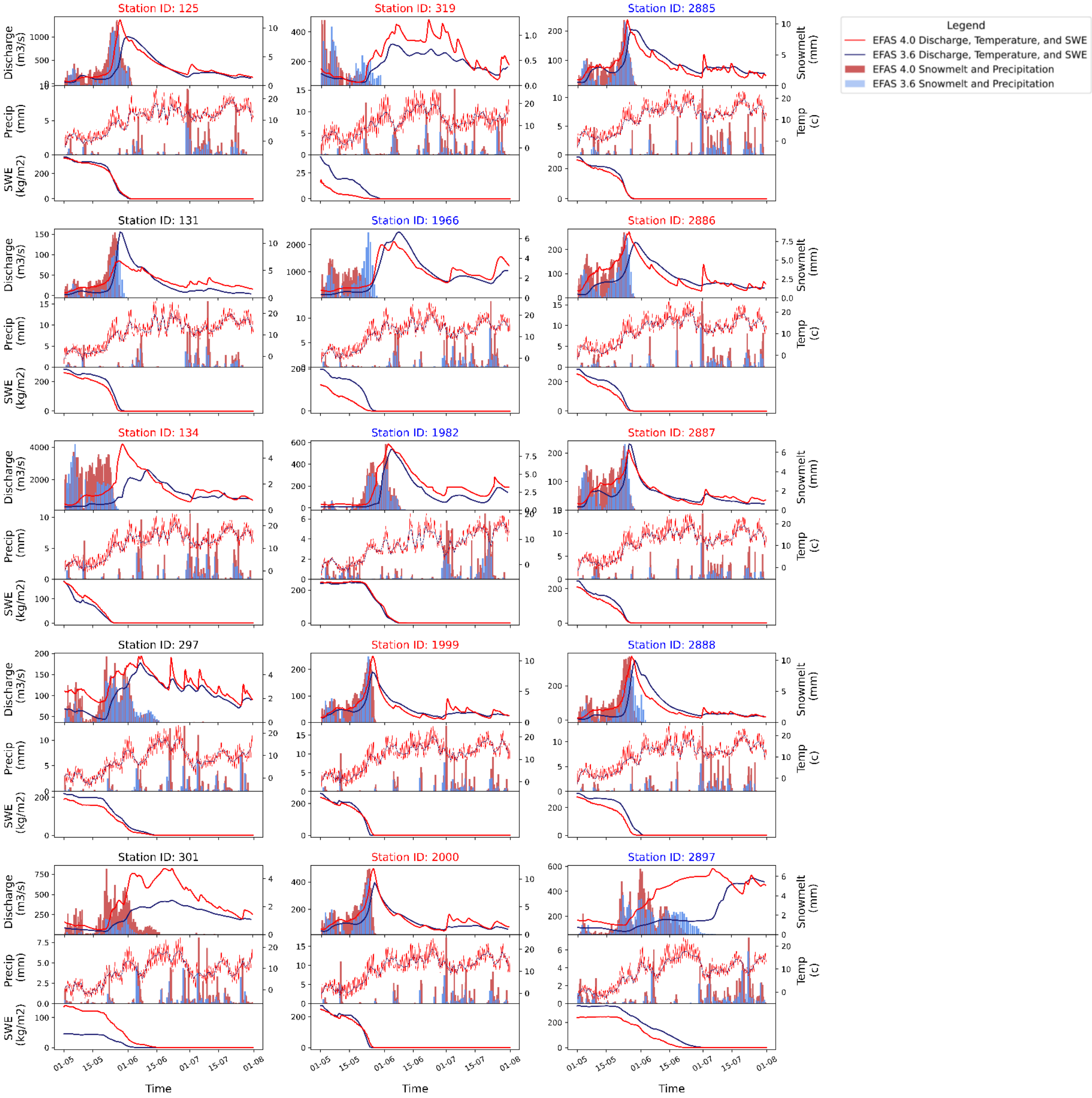


Figure 6.5: Graphs for the study stations without observations from Table 6.2. Each plot shows the simulated discharge and snowmelt (top subplot), the precipitation and temperature (middle subplot), and the snow water equivalent (SWE) (bottom subplot). Station IDs are colored by KGE score, with red (blue) indicating a higher (lower) score for EFAS 4.0 compared to 3.6, and black indicating no KGE score was calculated for that station. Temperature, snowmelt, and SWE values represent the mean value of the model cells upstream of that station.

6.3.2.2 Commentary on results

As stated in the introduction, it is possible to offer plausible explanations for some of the findings described in the preceding sections. Firstly, it should be noted that some differences in discharge between the model versions can be attributed to the higher levels of precipitation of EFAS 4.0 (e.g. due to spatial interpolation and elevation correction for the new finer temporal resolution). This mostly occurs throughout July and is the likely cause of the small increases in EFAS 4.0 discharge observed at many stations during this time (e.g. Stations 131, 132 and 297) (Figure 6.3 and 6.5). Furthermore, it is one of several identified potential causes for the differences observed at Station 1132, with higher levels of precipitation in EFAS 4.0 in early May (Figure 6.3). It is reasonable to expect different levels of precipitation between the models, as EFAS 4.0 included a methodological change to the way precipitation data are created.

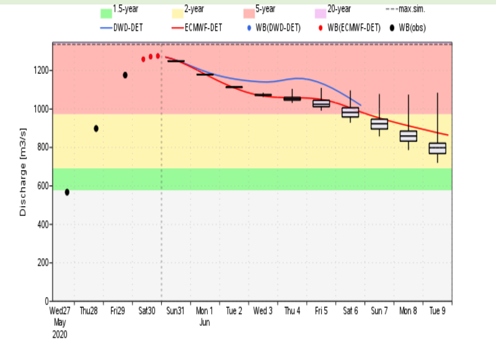
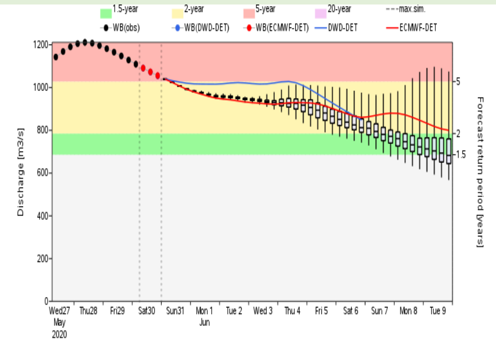
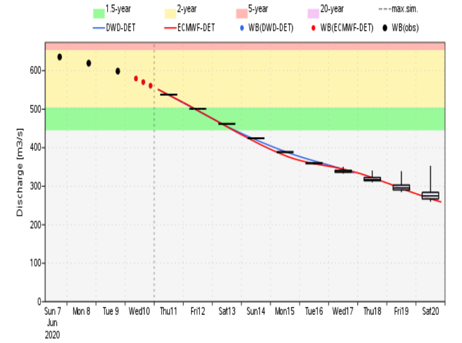
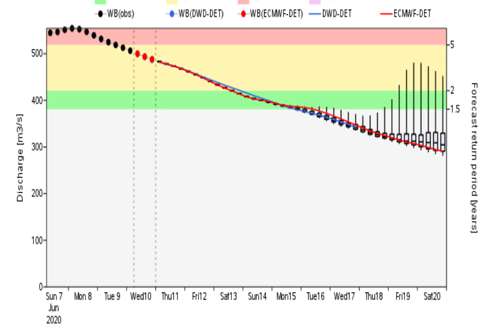
Another key consideration is the increased temporal resolution of EFAS 4.0. With a 6-hourly timestep, it is now able to capture diurnal temperature variations, whilst EFAS 3.6 has only a daily average. In LISFLOOD, if the temperature is below the 'TempSnow' threshold (usually 1°C), any precipitation will fall as snow. Overall, this can have two effects. Firstly, any precipitation falling during the colder night-time temperatures in EFAS 4.0 will fall as snow, which could lead to a higher SWE and thus higher snowmelt. However, it also means that if there are large diurnal temperature variations, precipitation falling during the day will be captured as snow in EFAS 3.6 (as the significant drop in night-time temperatures would give a daily average below the 'TempSnow' threshold), whereas it would fall as rain in EFAS 4.0. Overall, this could explain why SWE differs substantially in EFAS 3.6 and 4.0 at the beginning of the study period, as shown in Figure 6.2(a) and Figures 6.3 and 6.5. Though a plausible cause of the differences in the model versions at these locations, further investigation is required to better understand these impacts and their influence. Furthermore, the data in the months preceding study period should also be examined to better understand the accumulation of SWE in both model versions, as Figure 6.2 highlights that this differs considerably.

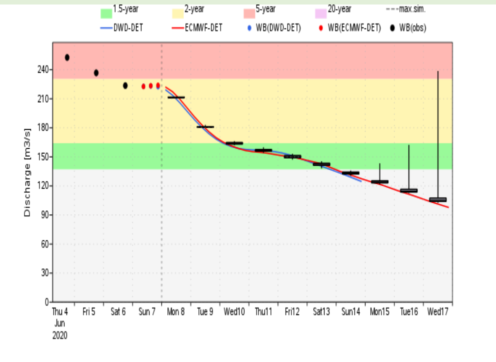
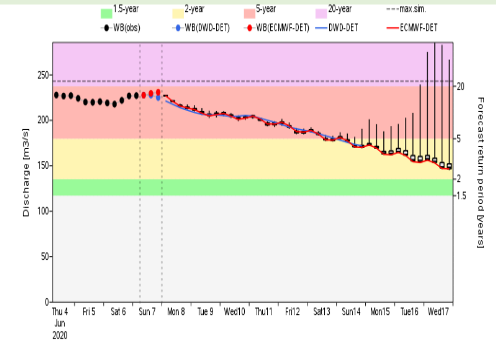
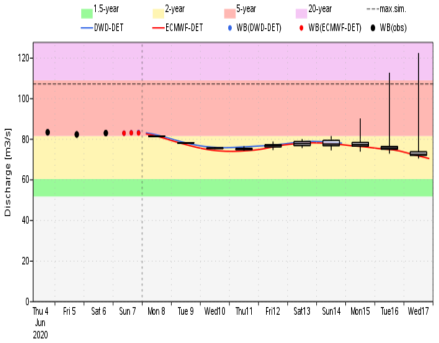
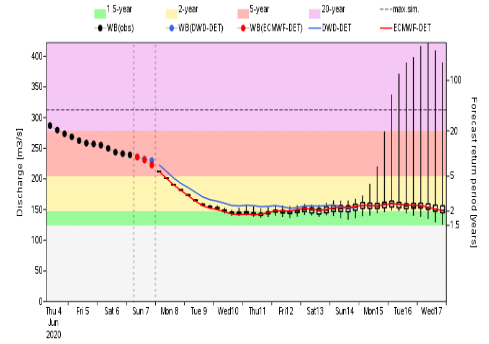
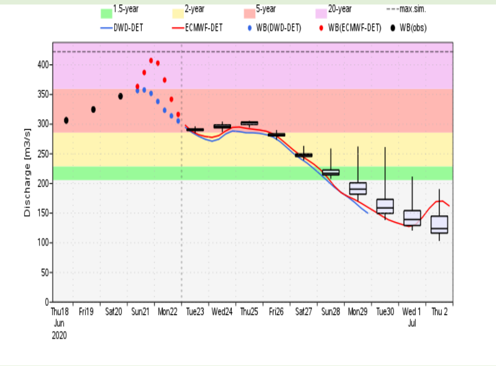
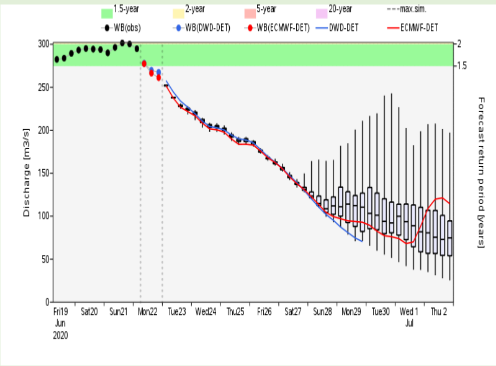
An attempt was made to identify potential causes of the underestimation of simulated discharge compared to observations that occurred at four stations (IDs 136, 1075, 1107 and 1132). The stations do not have a clear geographical pattern (Figure 6.4). Interestingly however, for all these stations except Muonionjoki, Muonio (ID 136), an inspection of the nearby upstream areas revealed reservoirs not currently accounted for in EFAS. However, one would expect this to result in overestimations of the discharge, not underestimations, and so this finding remains unexplained, but warrants further investigation outside of this report.

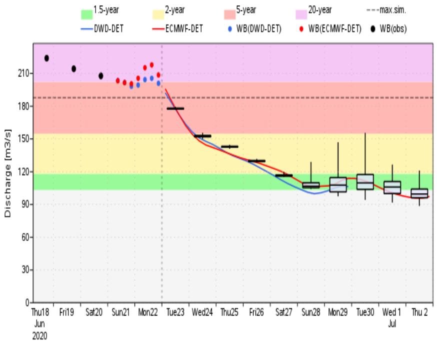
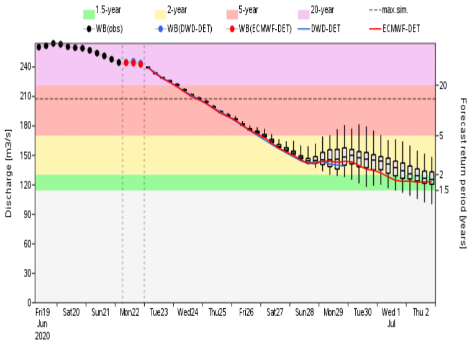
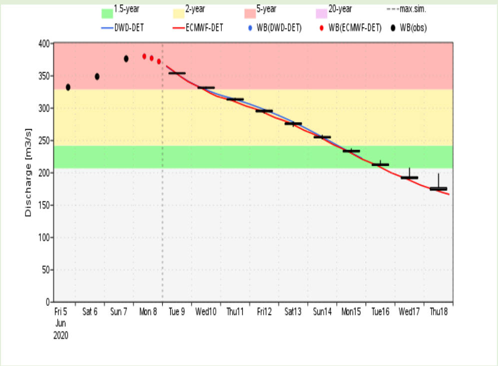
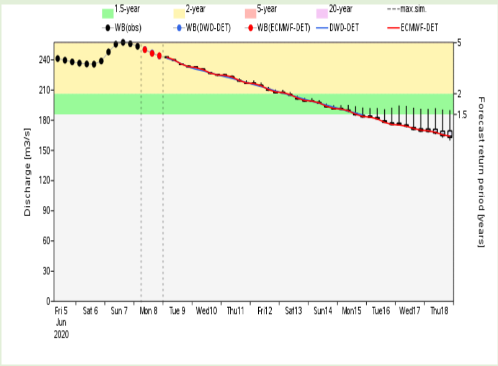
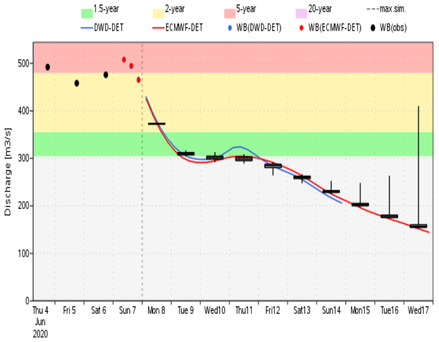
6.3.3 Analysis of EFAS forecast performance (EFAS 3.6 versus 4.0)

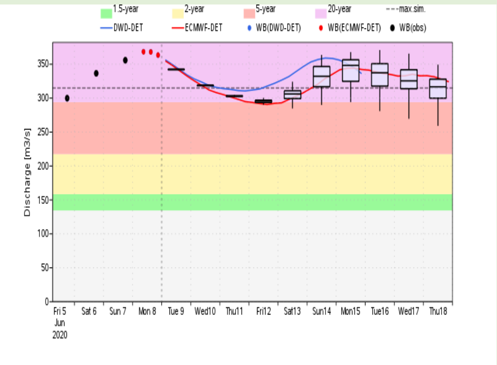
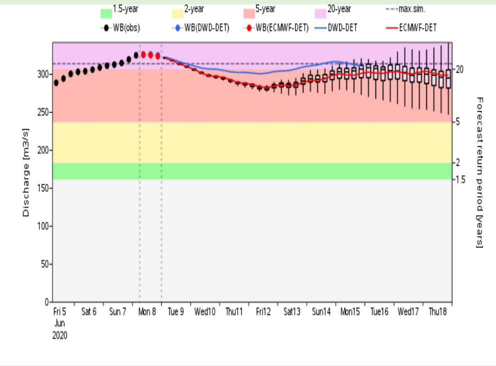
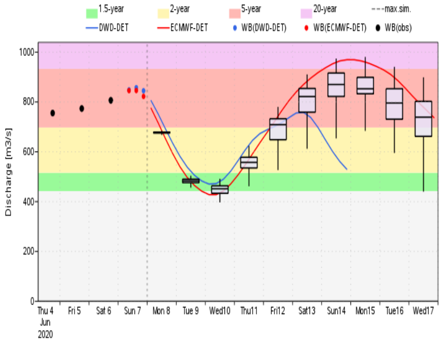
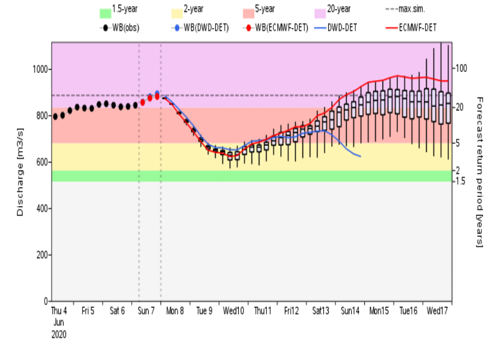
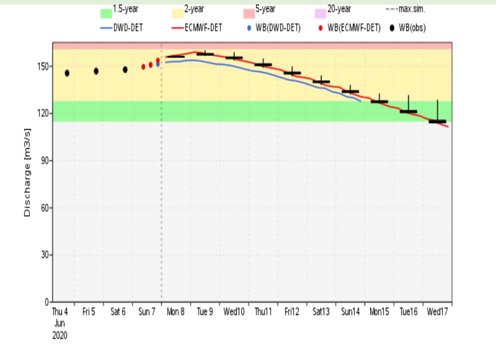
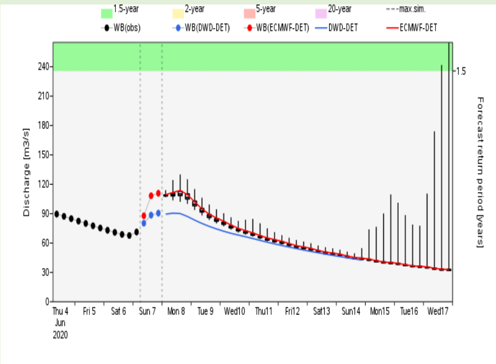
Table 6.4 illustrates the comparisons of EFAS 3.6 and 4.0 forecasts for all 11 stations with observations for the period of spring flooding in Scandinavia. Discharge hydrographs for all stations for EFAS 3.6 and EFAS 4.0 were selected by using the peak date from the observations (given in Table 6.3), allowing for the direct comparison of the forecasts. Used in conjunction with the observation plots in Figure 6.3, the hydrographs were analyzed to determine if both forecasts were broadly in agreement (or not) with regard to the performance predicting the flood magnitude and timing, and the presence of active reporting points on EFAS-IS. Corresponding to the observations and model outputs, seven out of 11 stations were found to have broadly similar performance between EFAS 3.6 and 4.0 forecasts. The remaining four stations showed contrasting forecasts, either displaying different timing, magnitudes or reporting points on EFAS-IS for the forecast dates.

Table 6.4: Comparison of EFAS 3.6 (left column) and EFAS 4.0 (right column) discharge hydrographs for a specified date where the flood peak was found in observations. Hydrographs were visually inspected alongside observations of discharge and model simulations to determine context for the EFAS forecasts. The 'Agree?' column highlights if both forecasts were broadly similar/ in agreement (or not) when predicting discharge magnitude and timing for the flood event in Scandinavia from May to July 2020.

ID	Peak date in obs	EFAS 3.6 Forecast	EFAS 4.0 Forecast	Agree?
132	31/05	Captures discharge quite accurately (EFAS 3.6 overestimates by 16.72m3/s). Close coherence with observations. Timing of the peak with EFAS 3.6 is one day early when compared with peak in observations. 	Captures discharge but underestimates by 63.9m3/s (a larger difference than EFAS 3.6 magnitude). Peak in EFAS 4.0 is on 28/05 which is 3 days before actual observed peak. 	Yes
136	11/06	EFAS 3.6 underestimates the peak of the flood. The timing of the peak flow in EFAS 3.6 is inaccurate but performs marginally better than EFAS 4.0. 	EFAS 4.0 underestimates the peak of the flood but has a slightly better capture of the magnitude of discharge over the EFAS 3.6 simulations. The timing of the flood in EFAS 4.0 underestimates when the peak will be by over a week. 	Yes
307	08/06	EFAS 3.6 captures discharge magnitude well. Peak of EFAS 3.6 discharge occurs on 04/06/2020 which is 4 days before the actual observed peak. EFAS 3.6 flood waters drain too quickly compared to observations.	EFAS 4.0 captures discharge well (slight underestimation compared to EFAS 3.6). EFAS 4.0 captures the timing of peak height of flood waters better than EFAS 3.6. Flood waters drained more accurately with EFAS 4.0 in comparison to the observed drainage.	Yes

				
317	08/06	EFAS 3.6 model output underestimates the flood peak. EFAS 3.6 also inaccurately times the flood peak to be about a week early. 	EFAS 4.0 model overestimates the flood peak (marginally closer to observations than EFAS 3.6 but still is inaccurate). The timing of the flood peak in EFAS 4.0 is also too early but performs slightly better than EFAS 3.6. 	No
1056	23/06	EFAS 3.6 captures discharge magnitude well, but underestimates slightly when compared to observations. Timing of peaks are early by about 2 or 3 days. EFAS 3.6 model drains more steadily and more in line with observations of discharge after flood peak. 	EFAS 4.0 model underestimates flood magnitude. However, timing of flood peaks is better with EFAS 4.0 forecast. EFAS 4.0 model drains at a faster rate than both EFAS 3.6 and the observed drainage after flood peaks. For the date of highest peak in observations (23/06) there is no reporting point exceeding the flood return periods defined in EFAS 4.0 (point appears as tiny blue point, where a real-time post-processed forecast hydrograph is available). 	No
1075	23/06	EFAS 3.6 performs poorly when predicting the magnitude of flood waters. Peaks are underestimated by approximately 250m3/s. Timing of flood peak with EFAS 3.6 is early.	EFAS 4.0 magnitude is underestimated considerably, by approximately 200m3/s. The timing of flood peak is predicted more accurately with the EFAS 4.0 simulation.	Yes

				
1076	09/06	The EFAS 3.6 model estimates the peak of the flood to be on 07/06 (slightly early but the same as EFAS 4.0). The magnitude of the flood is slightly overestimated by EFAS 3.6 simulations but are more accurate than EFAS 4.0. The 3.6 model drains more quickly than seen in observations. 	The EFAS 4.0 model estimates the peak of the flood to be on 07/06 (slightly early but the same as EFAS 3.6). Magnitude is underestimated by EFAS4.0. Drainage after flood event is more in line with the observations, draining at a slower rate. 	No
1099	08/06	EFAS 3.6 is marginally better at estimating the timing of the flood peak compared to the EFAS 4.0 simulation. EFAS 3.6 underestimates the peak magnitude of flow considerably (in the order of 330m3/s). Drainage occurs at a faster rate for EFAS 3.6 than is seen in the observations. 	EFAS 4.0 captures the magnitude of the flood event quite well and only underestimates slightly. There is rapid drainage in EFAS 4.0 simulations and flows recede to a much lower magnitude following the flood peak when compared to observations. 	Yes
1107	09/06	The EFAS 3.6 model estimates the peak of the flood to be on 08/06 (slightly early but the same as EFAS 4.0). Poor performance when estimating magnitude of flood for EFAS 3.6 model. Output underestimates the flood peak by ~270m3/s.	The EFAS 4.0 model estimates the peak of the flood to be on 08/06 (slightly early but the same as EFAS 3.6). EFAS 4.0 underestimates the peak of the flood by about 310m3/s. Again, a poor	Yes

			performance when estimating magnitude of flood for this station. 	
1114	08/06	EFAS 3.6 captures magnitude of flood event sufficiently and performs better than EFAS 4.0. All peaks for this period are underestimated slightly in terms of magnitude for this station. EFAS 3.6 model drains quickly after first flood peak. The timing of flood peaks is inaccurate with EFAS 3.6. 	EFAS 4.0 underestimates the magnitude of flow more than the EFAS 3.6 simulation. EFAS 4.0 model also drains quickly after flood event but is an improvement on 3.6. The timing of flood peaks is improved with EFAS 4.0 simulations. 	Yes
1132	08/06	The EFAS 3.6 model output underestimates the flood peak by 117m3/s, the model showing poor performance when estimating magnitude for this station and flood event. However, the timing of the flood peak by the EFAS 3.6 model is accurate. 	EFAS 4.0 model output also underestimates the flood. The timing of the peak in flow is inaccurate by 16 days (predicted for 24/05). For the date of highest peak in observations (08/06) there is no reporting point exceeding the flood return periods defined in EFAS 4.0 (point appears as tiny blue point, where a real-time post-processed forecast hydrograph is available). 	No

6.3.3.1 Evaluation of EFAS 3.6 and 4.0 forecasts

The evaluation of the EFAS forecasts for all 11 stations with observations returned results in line with the model evaluations. For seven of the 11 stations with observations (132, 136, 307, 1075, 1099 1107 and 1114), the discharge hydrographs from both EFAS 3.6 and EFAS4.0 were found to be broadly similar in terms of timing and magnitude of the floods, with only slight differences between forecasts (see Table 6.4 for details). There were active reporting points present on EFAS-IS for these seven stations during the specified date of the peak in observations, which suggests that both forecasts were largely accurate for the flood period at these locations.

In contrast, the remaining four of 11 stations with observations were found to have discrepancies when comparing EFAS 3.6 and EFAS 4.0 forecast discharge hydrographs, so differences can be more easily analyzed (see Table 6.4 for details). Station 317 (Rosten) showed contrasting under- and overestimates for the discharge magnitude for EFAS3.6 and EFAS4.0, respectively. Timing of the forecast output for this station also showed disagreement, with both forecasts predicting the flood peak too early (EFAS 4.0 proved marginally more accurate than its counterpart for timing of flood). Station 1056 (Bulken (Vangsvatnet)) shows the forecasts were not in agreement. There was no presence of an active reporting point at the time of the peak in observations (23/06) for EFAS 4.0 on EFAS-IS. The forecast for EFAS 4.0 underestimates the magnitude of the flood but more accurately captures peak timing seen in the observations when compared to EFAS3.6. For station 1076 (Rathe) contrasting over- and underestimates for the discharge magnitude was found for EFAS 3.6 and EFAS 4.0 forecasts, respectively. Drainage rates following the peak flood period also illustrate differences in the forecasts, with EFAS 4.0 draining more slowly in line with observations than EFAS 3.6. Finally, station 1132 (Hkkadalbrua) also did not provide an active reporting point for EFAS 4.0 for the specified peak date in the observations. Here, the most prominent feature of difference is the timing of the forecasts. EFAS 3.6 captures the peak observed accurately, while EFAS 4.0 missed the event by estimating the flood peak to be earlier by 16 days (predicted for 24/05 when observed peak was 08/06).

A visual analysis of the EFAS 3.6 and EFAS 4.0 forecast discharge hydrographs was not performed for the remaining 15 stations without observations. An accurate flood peak date on which to base the selection of hydrographs could not be determined accurately without observations, thus would not add value to the analysis in this report.

7 Conclusions

7.1 Summary of the flood event

A steep temperature increase caused by two consecutive low-pressure systems set the start of the 2020 spring flooding in the Scandinavian countries (here the report focuses on Norway, Sweden and Finland). Snow melting started first in central and northern Finland, and successively extended to Norway (all along the country), and west-central and north parts of Sweden. The most intensive period, with many stations experiencing high flows, was at the beginning of June 2020.

Based on information from the national services, a total of three stations reached the maximum alert level (discharge exceeding the threshold for the highest return period) in Norway, one station in Finland, and none in Sweden. The severity of the flood was larger in the northern regions of Finland and Norway, where for many stations discharge exceeded the maximum observed value in the analyzed record; e.g. the magnitude of the peak was clearly larger than the one during the severe spring flood in 2018. Particularly in Norway, high flows were observed continuously for more than 60 days at about 15 stations. In most of them, river discharge exceeded the maximum discharge previously observed for 1-9 days, while for three stations the maximum discharge was exceeded for more than 10 days. The national services provided an early forecast of the event that allowed measures to be taken in advance. For example, municipalities cooperated with companies in charge of regulating the reservoir so that the flood-peak magnitude could be reduced. Among the consequences of the 2020 spring flood included evacuations, and effects on roads and houses.

7.2 Lessons learnt from the detailed assessment

The analysis of the performance of the EFAS forecast, for 6 days before the observed peak, shows that the time of the peak was forecasted to occur earlier (about 2.5 days) than the observation, while the magnitude of the peak was underestimated by approximately 26%. The forecast performance did not change when assessing the forecast for 2 days before the observed peak. The LISFLOOD performance analysis based on observed meteorological inputs shows similar results; the model tended to predict an earlier and lower peak. Particularly, one notices that ECWMF forecasts are accurate (at least for most of the analyzed points) in predicting precipitation and temperature already 4 to 9 days ahead in time. Thus, errors in the forecasts are associated with errors in the hydrological model, i.e. modelled processes and initial hydrological conditions. Despite issues with timing and magnitude, notifications sent by EFAS cover all the areas with high flows and where observed discharge exceeded the national threshold levels. Assessment of the long-range forecasts showed that the sub-seasonal outperformed the seasonal outlook forecast by showing a more accurate forecast earlier in time. Nevertheless, this was expected due to the more frequent initialization of the sub-seasonal product (i.e. once a week) in comparison to the seasonal product (i.e. once a month).

From a total of 48 formal and informal flood notifications sent, feedback for only 6 was received not allowing for a detailed feedback analysis on the notifications. However, in a survey with the three EFAS partners in the affected river basins, the partners stated that they mainly use their national service for the public warnings and that two of the partners have been using EFAS forecasts as confirmation to the forecasts from the national system. All three partners agreed that getting an email with the notifications is a fast and simple way to get notified about an upcoming event.

Finally, in this report, a brief evaluation provides an initial insight into how both EFAS 3.6 and 4.0 perform for the 2020 spring floods. Though this topic would benefit from a more comprehensive investigation, some clear differences are already evident, such as how the diurnal temperature variations (or lack thereof) can influence the state of precipitation (liquid or solid) and hence river discharge simulated by the two model versions. Furthermore, given that some stations have large differences in SWE at the beginning of the study period, it would be beneficial to examine the period before the event more thoroughly. Regarding the analysis of forecasts, it proved difficult to assess and discuss the intricacies between EFAS 3.6 and EFAS 4.0 when both performed well, as the differences are slight.

7.3 Moving forward

Based on the detailed assessment of the 2020 spring flood event in Finland, Norway and Sweden the following recommendations are made for further improving the EFAS service:

- The drivers for the poor discharge forecast skill in term of both timing and magnitude need to be analyzed and better understood. Specifically, at the northern parts of Scandinavia, processes are controlled by snow accumulation/melting. Consequently, issues associated with the amount of snow at the beginning of the event and model structural hypotheses, e.g. processed on snow melting and flow routings, need to be re-evaluated and potentially refined.
- Estimations of snow water equivalent are subject to large uncertainty, e.g. the initial amount of snow for EFAS 3.6 and 4.0 differed largely. However, data assimilation (close to near real time) of snow water equivalent can improve the initial conditions and thus the skill of the discharge forecasts. In addition, data assimilation of discharge at more stations over Scandinavia has the potential to improve the forecast skill, especially if more stations associated with dam regulations are incorporated in the EFAS system.
- Model performance can in general be improved by calibration of the parameters and improvements in the structure. For example, the model structure could include energy-based modules for snow accumulation and melting processes, since these might be more appropriate for snow-dominated river systems in northern Europe.
- Modifying the criteria for officers on duty to consider the model performance (at stations with near real time discharge observations) and discharge forecast skill (that varies as a function of lead time) before issuing notifications can improve the quality of the EFAS service. This would result into EFAS notifications which are not only driven by raw hydrological forecasts but also on expert knowledge from the officers on duty that includes/tailors the understanding of model performance and forecast skill.

Table of Figures

Annexes

1 Media reports

Finland

Media report 1
https://watchers.news/2020/06/01/rapid-melting-of-extraordinary-snow-loads-threatens-finnish-lapland-communities-brace-for-worst-floods-in-50-years/

Media report 2
https://thebarentsobserver.com/en/ecology/2020/05/barents-region-prepares-flooding-after-snowiest-winter-years

Media report 3
https://www.kemijoki.fi/viestinta/tiedotteet-ja-uutiset/tulvakevat-2020-osoitti-luonnon-ja-yhteistyon-voiman.html

Media report 4
https://www.iltalehti.fi/kotimaa/a/daf036a4-eb0c-4f66-937c-2a1c715b1e6a

Norway

Media report 5
https://norwaytoday.info/news/eastern-norway-will-probably-escape-the-worst-floods/

Media report 6
https://www.vg.no/nyheter/innenriks/i/4qMzWV/storflom-i-finnmark-sikre-gjenstander-og-hold-dere-inne

Media report 7
https://www.newsinenglish.no/2020/06/08/floodwaters-rise-in-northern-norway/

Sweden

Media report 8
https://www.msb.se/sv/aktuellt/avslutade-handelser-och-insatser/hoga-floden-2020/

2 Analysis of the effect of forecasted precipitation and temperature errors on forecasted discharge

Here, some of the notifications where EFAS forecasted a return period above the 20-year RP (see Figure 4.9) were analyzed to assess the effect of precipitation and temperature forecasted error on the forecasted discharge. This was done by calculating the difference between the earliest forecasted peak discharge and the one obtained afterwards when the model was forced with observations (precipitation, temperature, WB(obs) in EFAS-IS).

Note that when analyzing the ECMWF predictions, the interquartile range, i.e. 25-75% percentiles, was considered; however, the only available deterministic value considered was for the case of DWD.

Id. 144 Paatsjoki (Finland): the peak of the event was predicted 4 days ahead by ECMWF, while DWD timing was one day too early. The range for the predicted discharge values for the ensemble ECMWF forecast was persistent. The DWD deterministic forecast overestimated the peak by about

15% three days before the event, but slowly approached the observation after the peak (in comparison to when the model was run with the observations).

Id. 125 Kemijoki (Finland): the peak of the event was predicted correctly by ECMWF 5 days ahead, while DWD timing was one day too early. The range for the predicted discharge values for the ensemble ECMWF forecast was quite accurate. The DWD deterministic forecast overestimated the peak by about 15% even three days before the event, but slowly approached the observation around the time of the peak. Overestimation of discharge and early time of the peak was likely due to an overestimation of the temperature by DWD at the beginning of the event (Figure A2.1)

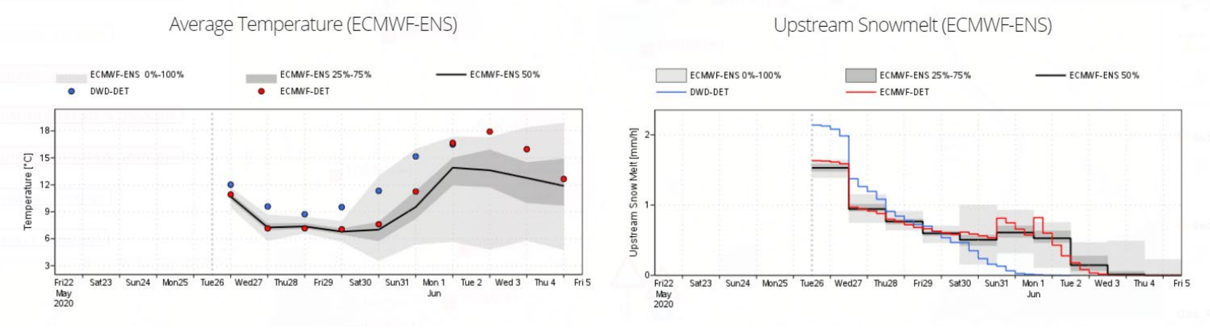


Figure A2.1 Forecasted temperature and snowmelt in EFAS for the 26th of May 2020

Id. 1037, Namsen (Norway): the predictions from ECMWF and DWD systems were similar, and the forecasted timing was correct to a large extent. The peak was forecasted around nine days ahead in time. The ECMWF ensemble and DWD forecasts were overpredicting discharge for about 300 m^3/s (about 21%) at the beginning, which later improved with an overprediction of about 7%.

Tenojoki (Norway): the timing for both ECMWF and DWD systems was correct. The range for the predicted discharge values for the ensemble ECMWF forecast was quite accurate. The peak was forecasted around 7 days ahead in time. The DWD deterministic forecast overestimated the peak by about 30% three days before the event, but slowly approached the observation after the peak. The discharge overestimation was probably due to the overestimation of temperature at the beginning of the event (Figure A2.2).

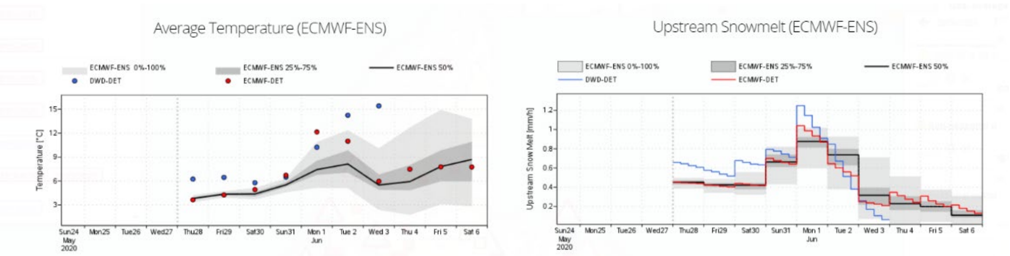


Figure A2.2 Forecasted temperature and snowmelt in EFAS for the 28th of May 2020

Ångermani (Sweden): the time of the peak of the event was predicted correctly by ECMWF 6 days ahead, while DWD timing was one day too early. The range for the predicted discharge values for the ensemble ECMWF forecast was quite accurate. The DWD deterministic forecast overestimated the peak by about 30% still two days before the peak, but slowly approached the observation around the time of the peak.

Indals (Sweden): the peak of the event was predicted correctly by both ECMWF and DWD 6 days ahead. Both ECMWF and DWD overestimated discharge around the peak by about 50%. Two days before the peak, the overestimation was about 30% and 40% for ECMWF and DWD respectively.

The reason for this overprediction cannot be identified simply by analyzing the data available in EFAS.

3 Feedback from partners (reported points)

Table A3.1 Issued notifications during the 2020 spring flood for which partners within Scandinavia provided feedback.

No	Country	Basin	River	Area [km2]	PointID	Sent on	Location accuracy	Peak time accuracy	Magnitude accuracy	Time accuracy	Return period	Lead time accuracy (days)	Added value
29	Finland	Torne	Muonio	9250	SH000063	2020-05-31	Unanswered	Unanswered	Unanswered	Start >= 3 days later than predicted	5-9 years	9	3
37	Sweden	Umelrven	Ume?lven	3175	DH000184	2020-07-12	Unanswered	Unanswered	Unanswered	Unanswered	Unanswered	Unanswered	1
41	Sweden	Pite	Tjeggelvas	2375	SH000060	2020-06-10	Unanswered	Unanswered	Unanswered	Unanswered	Unanswered	Unanswered	1
42	Sweden	Lullmlven	Stora Lule	2350	DH000045	2020-06-10	Unanswered	Unanswered	Unanswered	Unanswered	Unanswered		1
43	Sweden	Umelrven	Vindel	3050	DH000164	2020-06-16	Unanswered	Unanswered	Unanswered	Unanswered	Unanswered	Unanswered	1
45	Sweden	Pite	Tjeggelvas	2375	SH000060	2020-06-29	In the region but not in an adjacent catchment	Peak >=3 days earlier than predicted	Peak much less severe than predicted	Start 1-2 days earlier than predicted	2-4 years	0	3
												Average added value	1.4

4 Feedback from partners (survey)

A survey was sent to partners of Finland, Norway and Sweden. Feedback was received and presented below. Questions are shown in black and responses from the partners are shown in italics.

Finland (based on one answer):

1. Did the EFAS partner monitor the event on the EFAS interface? Which products were used? Was any of the layers in EFAS-IS more useful than others?

We get email for warnings and used only that info.

2. Were the EFAS notifications relevant and sent on time? Is there a need to improve the lead time for the notifications?

They were mostly relevant and in time. Actually, I remember only correct ones.

3. How good/bad were the EFAS forecasts in comparison to the national forecasts and/or observations?

EFAS forecast (emails) were mostly correct and in line with the national system.

4. What should be done to improve EFAS forecasts and notifications? E.g. Would the EFAS partner find it more useful to receive the actual EFAS data for ingestion in their own system instead of looking at the EFAS web interface?

This system now is at least easy to use and do not take extra time or effort from us. Good way to continue at the moment.

5. Is there a need for additional information useful for the EFAS partner?

Not at this time.

6. Could changes in the criteria for issuing notifications improve the service

Probably not.

7. Other general suggestions?

None at the moment.

8. What are the lessons learnt about EFAS?

Take care that we do not miss any event in the national system.

Norway (based on one answer):

1. Is the EFAS information not used by the partner, explain why.

EFAS It is ***not*** *used in the "daily" flood/landslide warning service in our warning team.*

We experience that in periods of low pressure (storms) weather systems where a lot of precipitation has been forecast in the form of rain or snowmelt, we see that the accuracy of the forecasts is better on our own models. I have focus on the spring flood 2020 (end May – end July), but mine comments are in general for the whole hydrological year. This may be due to several reasons - but we may believe that EFAS's models have a higher level (degree) of soil- and groundwater index which leads to a faster response to the water flow in the watercourse. That is, a too quick response than what we see happening. Below is an example from December last year. EFAS's figures (forecasts) can be seen on the left.

EFAS Flash Flood Notification*

Country(ies): **NORWAY**
Region(s): **Vest-Agder, Aust-Agder, Telemark, Vestfold**
Earliest predicted peak: **Monday, 14th of December 2020 - 18:00**
Percent of affected area susceptible to landslides: **Very High: 0%, High: 12%, Moderate: 24%**
Forecast date: **2020-12-12 12 UTC**
Comment: -

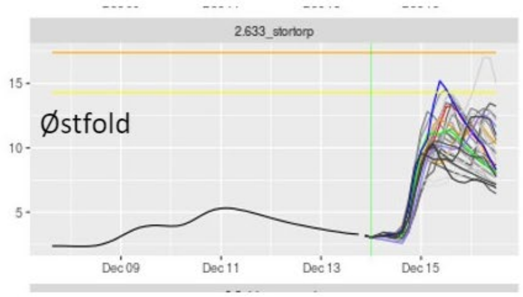
This is the only notification you will receive for this event! Please follow the evolution of the event on EFAS.

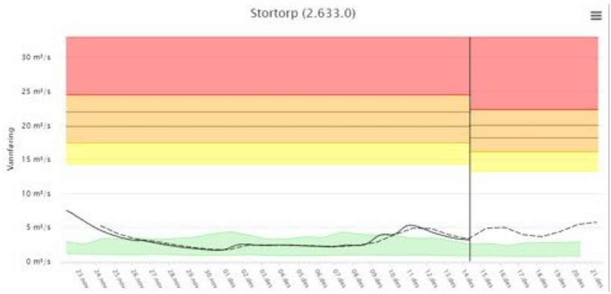
EFAS Flash Flood Notification*

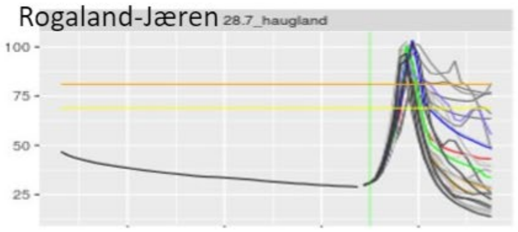
Country(ies): **NORWAY**
Region(s): **Ostfold, Akershus**
Earliest predicted peak: **Tuesday, 15th of December 2020 - 12:00**
Percent of affected area susceptible to landslides: **Very High: 0%, High: 3%, Moderate: 8%**
Forecast date: **2020-12-13 12 UTC**
Comment: -

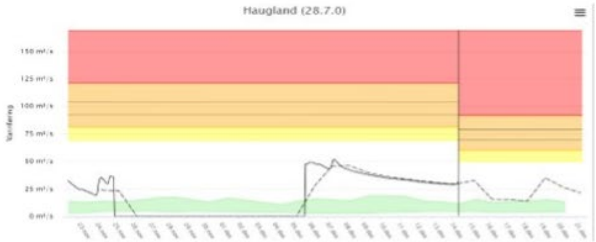
This is the only notification you will receive for this event! Please follow the evolution of the event on EFAS.

EFAS FORECASTER ON DUTY









2. What are the lessons learnt about EFAS?

But - having said that (above), we are grateful for what EFAS has of the hydrological forecasting system for Europe. In addition, we are impressed with how EFAS presents data and forecasts for so many watercourses and countries in Europe. It is a system that can certainly be followed up and desired by several forecasting services. Thanks.

Below I will give some general comments about The Norwegian Planning and Building Act states that development is not allowed, unless safety is at an "acceptable level", with local municipalities responsible for ensuring that this is the case. NVE offers guidance to local municipalities in the form of flood inundation maps, maps showing areas at risk of quick clay landslides and gives expert advice to municipal land use plans.

NVE has also developed a national guideline defining acceptable safety levels with respect to floods and other hazards related to rivers. The safety levels are differentiated related to hazard type and type of asset. A stepwise procedure for assessing the hazards has been designed to fit with the planning process and levels typical for a local municipality.

If you want more comments and more answers, just get in touch again.

Sweden (based on three answers):
Partners perspective

The EFAS notifications are used only as a confirmation to the information in the National forecast system. Reason that the system is not used as a main source is because in Sweden we have a *comprehensive forecasting system with two hydrological models in place that incorporates numerous stations also from hydropower companies and other private data providers. When EFAS notifications are received we double-check with the in-house system and trust that one. Our warnings are based on our own system.*

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