# European Flood Alert System Post-event summary report

# The Alpine floods of August 2005

What did EFAS forecast, what was observed, which feedback was received from end-users?



Ad De Roo, Maria Helena Ramos, Jutta Thielen, Giovanni Franchello, Jens Bartholmes, Karl Wachter, Stefan Niemeyer, Milan Kalas, Giovanni Laguardia, Johan Van Der Knijff

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European Commission Joint Research Centre Institute for Environment and Sustainability

Contact information Address: TP261, 21020 Ispra (Va), Italy E-mail: <u>ad.de-roo@jrc.it</u> Tel.: ++39-0332-786240 Fax: ++39-0332-786653

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### Summary

From the 22<sup>nd</sup> until 27<sup>th</sup> August 2005, the northern Alpine region was hit by severe floods. The floods occurred in tributaries of the Rhine River in Switzerland and Austria (Vorarlberg) and in several tributaries of the Danube River in Germany (Iller, Lech, Isar), Austria (Lech, Inn, Mur, Drau/Drava, Raab/Raba) and Hungary (Mur and Raba/Raab), as well as in the German part of the Danube.

The European Flood Alert System (EFAS), under development and running in preoperational mode at the Joint Research Center (JRC) since February 2003 (De Roo *et al.*, 2003), forecasted these events in all river basins and reported in realtime to its partners' organizations in the Member States. During the period from 16<sup>th</sup> to 25<sup>th</sup> August, EFAS forecasted potential flooding in the Upper Danube (tributaries Isar, Iller, Lech) in Germany and Austria, as well as in the upper Rhine (Switzerland and Germany). Furthermore, potential flooding was forecasted in the Mur and Drava rivers in SE-Austria, Hungary, Slovenia and Croatia.

This report describes what was forecasted with the EFAS system, what was communicated to the EFAS partners' organizations (water authorities in the relevant countries), where and when the floods occurred and which feedback was received from the end-users. Lessons learnt are described at the end of the report.

Flood forecasting based on weather forecasts from ECMWF-Ensemble Prediction System (EPS), one of the key elements of EFAS forecasts, has been implemented since June 2005 pre-operationally in EFAS. For technical reasons (one corrupt input file), the probabilistic forecasts did not run during the August floods. Following a rerun of the EPS immediately after the August floods, it is demonstrated that the availability of the probabilistic forecasts might have increased the flood warning time of 1-2 days. Especially the forecasts of 16<sup>th</sup> and 19<sup>th</sup> August show an increased number of EPS above EFAS High Alert Level (HAL).





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## 1. The European Flood Alert System (EFAS)

The European Flood Alert System (EFAS) is a research activity of the DG Joint Research Centre of the European Commission (De Roo *et al.*, 2003). The aim of EFAS project is to develop a prototype of a Pan-European Early Flood Alert System. The development of EFAS started in 2002 and it will be pre-operationally tested until at least 2006. EFAS is set-up for the whole of Europe on a 5-km grid and is also tested for several pilot river basins on a 1-km grid, amongst them the Elbe and the Danube river basins. The underlying hydrological rainfall-runoff model is the LISFLOOD model (De Roo *et al.*, 2000; Van Der Knijff & De Roo, 2005). EFAS simulations are based on weather forecasts from different meteorological services. At present, these are:

**DWD**: deterministic meteorological forecasts from the *Deutsche Wetterdienst*, forecast range of 7 days, twice a day (00:00 and 12:00). The DWD uses the so-called Lokalmodell for the first 2 days of forecast with a 7-km resolution and the Global model for the remaining 5 days with a 40-km resolution.

- **ECMWF**: deterministic meteorological forecasts from the European Centre for Medium-range Weather Forecasts, forecast range of 10 days, twice a day (00:00 and 12:00). The ECMWF forecasts are based on one model only that is set-up with a grid spacing of about 40 km.

- **ECMWF-EPS**: ensemble prediction system (EPS) forecasts with 51 members from the European Centre for Medium-range Weather Forecasts. The forecast range is the same as for the deterministic ECMWF forecasts (10 days), but the spatial resolution is about 80 km. Since June 2005, the full suite of EPS forecasts is running in pre-operational mode in EFAS for the whole of Europe.

In EFAS, four thresholds are defined for flood forecasting: Severe, High, Medium and Low. The qualitative description of each level is given in the chart below. EFAS results based on the deterministic meteorological forecasts are presented in the form of **EFAS Flood Threshold Exceedance Maps**, which summarize in a concise way the spatial information given by EFAS simulations. These maps show the highest level reached at any time during a flood forecast, i.e., for the next 10 days based on ECMWF weather forecasts and for the next 7 days based on DWD forecasts. At any point inside a catchment, it is also possible to visualize the temporal daily evolution of EFAS levels according to the forecasting leadtimes. The **EFAS Forecast Diagrams** show in sequential boxes, each box representing 24 hours, the EFAS levels simulated: for each forecast date there are 7 consecutive boxes for DWD forecasts and 10 consecutive boxes for ECMWF forecasts. **EFAS-EPS Exceedance Maps** show the results based on ECMWF-EPS forecasts, which are presented as the number of simulations where discharges are predicted to exceed EFAS high and severe alert thresholds.

EFAS Level	Color	Description
S (Severe)		very high possibility of flooding, potentially severe
H (High)		seriously increased river discharges with high possibility of flooding (likely exceeding bankful conditions)
M (Medium)		significantly increased river discharges, no flooding expected
L (Low)		river discharges increased, no flooding expected





#### 2. Introduction

From the 22<sup>nd</sup> until the 27<sup>th</sup> August 2005, the northern Alpine region was hit by severe floods. The floods occurred in tributaries of the Rhine River in Switzerland and Austria (Vorarlberg) and in several tributaries of the Danube River in Germany (Iller, Lech, Isar), Austria (Lech, Inn, Mur) and Hungary (Raba), as well as in the German part of the Danube. This report describes what was forecasted using the European Flood Alert System (EFAS), under development and running in pre-operational mode at the JRC since February 2002. Furthermore, the report describes which actions were taken by the EFAS team, what was communicated to the EFAS partners' organizations (water authorities in the relevant countries), what was observed and which feedback was received from these end-users. Lessons learnt are described at the end of the report.

The aim of this report is not to give a complete post-analysis of the flood event, but rather to put together all the information produced and received by EFAS during and immediately after this important flood event, offering thus some insights into its analysis.

In Chapter 3, it is shown, on a day-to-day basis, what was forecasted and concluded using EFAS in the days before and during the floods. The detailed EFAS forecasted maps and diagrams based on the two deterministic weather forecasts of ECMWF (the European Centre for Medium Range Weather Forecasts located in Reading, UK) and DWD (the German Weather Service, located in Offenbach, Germany) are shown in Chapter 4. Although the ECMWF-Ensemble Prediction System (EPS) has been implemented pre-operationally in EFAS since June 2005, unfortunately, in the week of the flooding in August 2005, the EPS forecasts failed to run. In the week after the flood, the EPS setup was repaired and the forecasts with the EPS were re-run. In Chapter 4, it is also shown the EFAS forecasted maps based on the re-runs of the Ensemble Prediction System weather forecasts of ECMWF.

An overview of what was observed in the countries affected by floods is given in Chapter 5, followed by a comparison between the observations and the forecasts (Chapter 6). Additional detailed information on the flood extent is summarized in Chapter 7.

Rainfall is the driving motor in rainfall-runoff models. The flood forecasts strongly depend on the quality of the rainfall forecasts, which is therefore crucial for successful flood prediction. An analysis of the forecasted rainfall as compared to the observed rainfall in the Upper Danube area is described in Chapter 8.

The feedback from the National Hydrological Services is very important for the EFAS activity. Feedback forms are sent out to the EFAS partners' organizations whenever EFAS information reports are sent and after the flood event is over. These feedback reports allow the EFAS team to evaluate the correctness, usefulness and impact of the EFAS information reports sent out before and during the floods. The feedback received with respect to the August flood event is described in Chapter 9.

Finally, lessons learnt from the event are summarized in Chapter 10 and conclusions are drawn in Chapter 11.



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#### Day-to-day EFAS forecasts and actions taken 3.

Every day EFAS simulations run with ECMWF and DWD weather forecasts from the midday forecast (12:00) of the previous day and the midnight forecast (00:00) of the same day. EFAS simulations are finalized at around midday, when the forecaster on duty analyzes the situation and registers in the EFAS logbook any flooding situation being forecasted, as well as any eventual internal and external alerts (EFAS Information Reports). This chapter summarizes on a day-to-day basis the information reported in the daily EFAS logbook from 16<sup>th</sup> to 30<sup>th</sup> August for the Upper Rhine and Danube August 2005 flood event, as well as the actions that were taken internally within the EFAS team, the information that was communicated to outside end-users and the information the EFAS team got from external sources during this period. Detailed EFAS forecast results are described in Chapter 4.

#### Tuesday 16 August

(EFAS forecasts based on weather forecasts 2005081512 and 2005081600)

- EFAS logbook entry:
  - No flood problems forecasted for the next 7-10 days.
- Actions:
  - o None.
- Information from external sources:
  - o None.

#### Wednesday 17 August

(EFAS forecasts based on weather forecasts 2005081612 and 2005081700)

- EFAS logbook entry:
  - o Floods are forecasted for:
    - Upper Danube, Germany, Austria, 23/8 onwards (ECMWF).
    - Upper Danube, Hungary, 25/8 onwards (ECMWF).
  - Actions:
    - o None.
    - Information from external sources:
      - o None.

### Thursday 18 August

(EFAS forecasts based on weather forecasts 2005081712 and 2005081800)

- EFAS logbook entry:
  - Floods are forecasted for the Upper Danube, Germany/Austria, 22/8 (DWD).
  - Floods are forecasted for the Rhine, section Neckar, Germany, 24/8 (DWD).
  - Floods are forecasted for the Drava (Danube), Austria/Croatia, 23/8 (DWD).
  - Floods are forecasted for the Tisza, Hungary, 23/8.
- Actions:
  - o Internal alert.
- Information from external sources:
  - o None.

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#### Friday 19 August

(EFAS forecasts based on weather forecasts 2005081812 and 2005081900)

- EFAS logbook entry:
  - 2005081900: Upper Rhine predicted to go to High Alert Level on t-168, based on DWD, which means Thursday-Friday 25-26 August.
  - 2005081900: Upper Danube predicted to go to High Alert Level on t-168, based on DWD, which means Thursday-Friday 25-26 August.
- Actions:
  - Internal alert.
- Information from external sources:
  - o None.

### Saturday 20 August

(EFAS forecasts based on weather forecasts 2005081912 and 2005082000)

- EFAS logbook entry:
  - 2005081912: Rhine tributary in CH predicted to go to Severe Alert Level on day 4, which means Monday-Tuesday 22-23 August.
  - 2005082000: Severe Flood Alert Level predicted for several tributaries of Rhine and Danube in CH, DE, AT.
  - Rivers with forecasted floods are mainly small.
- Actions:
  - o Internal alert.
- Information from external sources:
  - o None.

#### Sunday 21 August

(EFAS forecasts based on weather forecasts 2005082012 and 2005082100)

- EFAS logbook entry:
  - 2005082012: Severe Flood Alert Levels predicted in several tributaries of Rhine (Aare) in CH and Inn in Germany; Rhine at Basel predicted to go to High Alert Level, just under the Severe Alert Level threshold.
  - 2005082100: Isar and other Danube tributaries predicted to reach Severe Alert Levels 23/8 (Tuesday); Danube at Passau just to go to Severe Alert Level on 24/8 (Wednesday).
- Actions:
  - 15:30 **External alert no.1** sent out to the Bavarian Water Authorities and the German Federal Water Authorities (BfG):
    - Potential flooding in Upper-Danube Basin + tributaries Isar, Alz<sup>1</sup>, Iller, Lech: EFAS simulates potentially hazardous situation in the Upper Danube from 23 to 27 August (tributaries already on 22 August); Discharge expected to reach high values: 23 August; Peak flow expected: 24 August.
  - No alert report sent out for the Rhine River to BfG and Baden Wuertemberg: floods were already within the 48-hour range<sup>2</sup>.

<sup>&</sup>lt;sup>2</sup> The JRC agreed with ECMWF not to report on floods forecasted with less than 2 days in advance. This condition is also included in the MoU signed with EFAS partners to prevent potential conflicting flood warnings from EFAS and the National Forecasting Systems, which typically cover the first 48 hours).





<sup>&</sup>lt;sup>1</sup> The Alz is mentioned here mistakenly as it should have been the Inn River. This is caused by an incorrect naming in EFAS and has been corrected.

- Information from external sources:
  - o DWD launched a severe weather alert ("Unwetter-warnung").

#### Monday 22 August

(EFAS forecasts based on weather forecasts 2005082112 and 2005082200)

- EFAS logbook entry:
  - The main Danube at Passau and further downstream is predicted to exceed the High Alert Level threshold, but not the Severe Alert Level threshold.
  - The Danube at Ingolstadt is predicted to exceed the Severe Alert Level threshold.
- Actions:
  - 9:20 BfG asks to forward alert reports also to their local forecasting address.
  - 9:30 CHMI (the Czech Hydro Meteorological Institute in Prague ) asks for EFAS information for the upper Elbe river basin (Vltava). Since no MoU has been established yet, only short informal information has been provided, indicating that EFAS predicts discharges in the Vltava River to reach the high alert level on 24 August, based on the DWD forecasts, but not the severe alert level.
  - o 13:05 External alert no.2 sent out to Bavaria and BfG:
    - Potential flooding in Upper-Danube Basin + tributaries Alz [read Inn], Iller, Lech. EFAS simulates potentially hazardous situation in the Upper Danube from 23 to 27 August (tributaries already on 23 August). The severe alert level is not forecasted anymore for the main Danube (discharges are back to high alert levels). Some small tributaries show persistent severe alert levels. Discharge expected to reach high alert levels: 24 August; Peak flow expected: 25 August (night of 24 and 25 August).
  - o 15:50 eInternal alert for the upper-Rhine.
- Information from external sources:
  - Lech at Augsburg forecasted by Bavarian water-authorities to go to alert level 2 ("Melde Stufe 2") on 23 August (24-hr forecast).
  - o The water level in the Iller River is still increasing.
  - The Mur River south of Graz (AT, SLO) flooding is confirmed.
  - On the upper Rhine, flood is already ongoing at Rheinfelden and Basel. The navigation in this part of the river is interrupted.

### Tuesday 23 August

(EFAS forecasts based on weather forecasts 2005082212 and 2005082300)

- EFAS logbook entry:
  - Follow-up of the situation.
- Actions:
  - 10:00 BfG asks if EFAS sees flood problems on the Rhine, especially if there is a contribution to be expected from the Mosel, based on ECMWF data.
  - 11:55 informal message sent to BfG that no problems are expected for the middle and lower Rhine.
  - o 12:40 External alert no.3 sent out to Bavaria and BfG:

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- Potential flooding in Upper-Danube Basin + tributaries Alz [read Inn], Iller, Lech; EFAS simulates potentially hazardous situation in the Upper Danube from 23 to 27 August (tributaries already on 23-24 August). The severe alert level is not forecasted anymore for the main Danube (discharge is just exceeding the high alert threshold). Some small tributaries show persistent high alert levels. Discharges are forecasted less severe compared to the previous forecasts. Discharge expected to reach high alert levels: 24 August; Peak flow expected: 25 August (night of 24 and 25 August).
- Information from external sources:
  - Event at Rheinfelden/Rhein (near Basel) evaluated as a 10-year flood (~3530 m<sup>3</sup>/s) – see Figure 1 below; forecasted peak at Maxau on 24 August to reach 770 cm, well below a 10-year flood (869 cm).

Wasserstände der letzten 7 Tage am Pegel RHEINFELDEN Stand: 30.08.2005 15:00:00





Figure 1 – Water levels at Rheinfelden. (Source: <u>http://www.hvz.baden-wuerttemberg.de/;</u> visited on 30.08.05)

- The Upper Iller River/Danube basin (Gauge Kempten) shows a 100year flood!
- The European Media Monitoring (EMM) system collects several press articles on ongoing floods (eg. website visited on 23.08.2005: <u>http://tagesanzeiger.ch/dyn/news/schweiz/532112.html</u>). Apparently, there are severe damages in Swiss traffic infrastructure; the Gotthard motorway is closed, as are all main train lines crossing the Alps (Gotthard, Loetschberg). Swiss lake levels are extremely high and local flooding with severe damages occurred during the last 24 hours in side valleys and along Reuss (Luzern), Aare (Berne), and Rhine valley (Chur). The region Lower Engadina is apparently cut off completely, as all roads and the train line have been destroyed.
- According to the Czech News received by EMM, the flood situation in the Czech Republic is serious, particularly in the southern part (upstream part of Vltava River basin, in Malse and Otava subcatchments).



#### Wednesday 24 August

(EFAS forecasts based on weather forecasts 2005082312 and 2005082400)

- EFAS logbook entry:
  - Follow-up of the situation.
- Actions:
  - 10:00 Request to ECMWF to apply Article 7 of JRC-ECMWF 0 agreement.
  - 12:00 Live interview at BBC World at their request (permission asked 0 according to JRC procedures).
  - 12:15 External alert no.4 sent out to Bavaria and BfG: 0
    - Potential flooding in Upper-Danube Basin + tributaries Alz [read Inn], Iller, Lech; EFAS simulates that the current flood waves in the Upper Danube are decreasing. High alert levels are reached only until midday tomorrow (25 August). Tributary discharges are decreasing as well. The flood wave is propagating into Austria, without reaching severe alert levels. Discharges now decreasing (peak was on 24 Aug 00:00).
  - 15:00 ECMWF provides permission to apply Art 7.
  - 15:30 External report for Bavaria forwarded to Commission services. 0
  - o 15:45 External alert no.1 sent out to Austria and Commission services:
    - Flooding in Upper-Danube Basin + tributaries Upper Danube, Inn, Mur/Mura, Raab/Raba: EFAS simulates that the current flood waves in the Upper Danube at the German/Austrian border are increasing until 24 August midday, then the flood wave propagates through Austria reaching high alert levels for next 3 days (27 August). Discharge in the upper part of Inn River is forecasted to decrease; the downstream part is still reaching high alert levels for next 36 hours. Mura River discharges are decreasing, reaching high alert levels only for one day. Raba River discharges are decreasing, not reaching high alert levels. Discharge expected to reach high alert levels: increasing/high alert levels reached next 3 days.
- Information from external sources:
  - o None.

#### Thursday 25 August

(EFAS forecasts based on weather forecasts 2005082412 and 2005082500)

- EFAS logbook entry: •
  - Follow-up of the situation.
  - Actions:
    - o Director General of JRC phones director of ECMWF to discuss conditions.
    - The Dartmouth Flood Observatory is asked to provide flood extent 0 maps based on MODIS images.
    - o 12:30 External alert no.5 (last) sent out to Bavaria, BfG and Commission services:
      - Potential flooding in Upper-Danube Basin + tributaries Alz [read Inn], Iller, Lech; EFAS simulates a continuous decrease of the current flood waves in the Upper Danube River. High alert levels are reached only until today afternoon (25 August).



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Tributary discharges in the Upper Danube catchment area are decreasing as well. The flood wave is propagating into Austria, without reaching severe alert levels. Due to continuous and consistent simulations of decreasing discharges, this is the last Information Report issued on the current flood event in southern Germany, unless the situation will be deteriorating again. Discharges decreasing (peak was on 24 Aug 00:00).

- 15:00 External alert no.2 sent out to Austria, Hungary and Slovakia and Commission services:
  - Potential flooding in Upper-Danube Basin + tributaries Upper Danube, Inn, Mura, Raba; EFAS simulates decreasing discharges in the Upper Danube River at the Austrian border. The flood wave propagates through Austria reaching high alert levels for the next 1 day (25 August, upstream area) and next 2 days (25-26 August, downstream area). In Slovakia, high alert levels will be reached for the next 2 days (25-26 August) and in Hungary, for the next 3 days (25-27 August). Discharge in the Upper Inn River is decreasing and not reaching high alert levels anymore. Countries: Austria, Slovakia, Hungary
- Information from external sources:
  - Danube at Passau reached peak discharge at Wednesday night 24 August (Figure 2).
  - In Switzerland, the situation is still problematic in the Aare basin (50to 100-year flood estimated). The Aare River together with a moderate flood from the Upper Rhein caused a 10-year flood at Basel/Rhein at the Swiss-German border. Downstream of the Rhine River, the flood is estimated as only a 2- to 5-year occurrence.
  - In Switzerland, a lot of traffic lines in the central region are still interrupted because of the flood (bridges and roads are destroyed) and of the risk of landslides. St.Gotthard and Loetschen are closed. Only the connection Bern-Zurich-Chur was reopened (railway and motorway).
  - In South Germany, in the Allgäu area (Iller River), flood was estimated as a 50- to 100-year event. On the upper Danube, it was about a 50year occurrence at the section Ulm-Ingoldstadt. Also, the upper part of the tributary Isar had a high flood alert (Garmisch - München), while on the other Bavarian Danube tributaries it was less severe. The flood level on the upper Bavarian Danube is falling; only between Regensburg and Passau the flood level is still a little bit increasing.
  - The flood peak of the greatest tributary Inn reached the Danube at Passau yesterday on late afternoon. Water levels in the Inn River are already falling very fast.
  - In Austria, the Danube is already falling in the upper part (-1m) and downstream (Vienna-Bratislava), it seems to be a little bit increasing. The discharge of about 6000 m<sup>3</sup>/s is a little bit over a 1-year flood and therefore no great flooding is expected.
  - The Raba River flood (SE Austria/Hungary) is over, but still some landslides are occurring. This flood occurrence was more or less a flash flood (estimated: 30-year flood). Many houses were destroyed and one dead person was reported.
  - The Mura River flood (also SE Austria) is over. The flood wave reached also Slovenia and Croatia, flooding some areas.





- In W-Austria (Vorarlberg), in the Rhine basin, extreme rainfalls occurred and, in some parts, flash floods of up to 100-year occurrence were observed. This area is close to the German Allgäu. The flood and a lot of landslides destroyed many houses, roads and facilities; two dead persons were reported. The situation is still problematic.
- On the upper Inn River, in the western part of Tirol, heavy rainfalls caused extreme floods and landslides,e
- For two days, all the bridges in the Inn River were closed and still it is not possible to pass Tyrol by trucks or by the motorway. Especially, a motorway bridge on the German-Austria border in Bavaria is still under survey. The water levels are however relatively low.

Wasserstände der letzten 7 Tage am Pegel PASSAU\_DONAU Stand: 30.08.2005 14:45:00



Figure 2 – Water levels at Passau. (Source: http://www.hnd.bayern.de; visited on 30.08.05)

### Friday 26 August

(EFAS forecasts based on weather forecasts 2005082512 and 2005082600)

- EFAS logbook entry:
  - Follow-up of the situation.
- Actions:
  - 15:30 External alert no.3 (last) sent out to Austria, Hungary and Slovakia:
    - Potential flooding in Upper-Danube Basin + tributaries Upper Danube, Inn, Mura, Raba; EFAS simulates decreasing discharges in the Upper Danube River in Bavaria upstream of Passau reaching high alert levels on day 1 (26 August). In Slovakia, high alert levels will be reached for the next 1 day (26 August). The flood wave propagates through Hungary, reaching high alert levels for the next 1-2 days (26-27 August). Due to continuous and consistent simulations of decreasing discharges after the flood wave has passed, this is the last Information Report issued on the current flood event, unless the situation will be deteriorating again. Countries: Austria, Slovakia, Hungary.
- Information from external sources:
  - o None.





### Saturday 27 August

(EFAS forecasts based on weather forecasts 2005082612 and 2005082700)

- EFAS logbook entry:
  - Floods in upper Danube and Rhine lasting, but decreasing.
- Actions:
  - o None.
- Information from external sources:
  - o None.

#### Sunday 28 August

(EFAS forecasts based on weather forecasts 2005082712 and 2005082800)

- EFAS logbook entry:
  - Floods in upper Danube and Rhine lasting, but decreasing.
- Actions:
  - o None.
- Information from external sources:
  - o None.

#### Monday 29 August

(EFAS forecasts based on weather forecasts 2005082812 and 2005082900)

- EFAS logbook entry:
  - None on the event.
- Actions:
  - o None.
- Information from external sources:
  - 1.5 million Euro flood damage estimated at Isar near Munich (Suddeutsche Zeitung).

### **Tuesday 30 August**

(EFAS forecasts based on weather forecasts 2005082912 and 2005083000)

- EFAS logbook entry:
  - None on the event.
- Actions:
  - o None.
- Information from external sources:
  - EMM for Bulgaria (Sofia News): The water level of the Danube has increased of 45 cm overnight, reaching 540 cm at Novo Selo, in the upper part of the Bulgarian stretch. The increase is fed by the massive floods in Central Europe and the full waters of European rivers pouring into the Danube. Civil defense authorities warned of further increase in the Bulgarian stretch in the next days, with expectations of a maximum of 800 cm. The alert level threshold in the area is 850 cm.



### 4. EFAS simulated results

#### EFAS deterministic forecasts

The maps shown in this session indicate the highest EFAS flood level simulated at any time during the forecast range of each meteorological forecast, i.e.:

- ECMWF: for the next 10 days starting from the indicated forecast date,
- DWD: for the next 7 days starting from the indicated forecast date.

In EFAS flood threshold exceedance maps, flood levels correspond to:

- Severe (pink) Severe Alert Level (SAL)
  High (red) High Alert Level (HAL)
- Medium (yellow) Medium Alert Level (MAL)
- Low (green) Low Alert Level (LAL)

For rivers with an upstream area of less than 4,000 km<sup>2</sup> any alert level is indicated in gray. A summary of EFAS forecasts is presented for the Upper Danube and the Rhine catchments.

#### Upper Danube catchment

- On the forecast of 15/08 00:00, High Alert Levels (HAL) are simulated for the Upper Danube tributary Isar in Germany. EFAS HAL are predicted for days 24-25/08, a leadtime of 9 days, but only with ECMWF deterministic weather forecasts. EFAS simulations with DWD forecasts show discharges reaching Low Alert Levels (LAL) in the same tributary. HAL are not persistent in the next EFAS simulations (15/08 12:00 and 16/08 00:00 weather forecasts).
- HAL are simulated again on the 16/08 12:00 forecast, based only on ECMWF deterministic weather forecasts. EFAS simulations show also some river reaches of the Upper Danube catchment with discharges exceeding EFAS Severe Alert Levels (SAL). For the Upper Danube tributary Isar in Germany, discharges are predicted to reach HAL on 23/08 (12:00) onwards, with thus a forecast of 7 days in advance, and they are predicted to exceed EFAS SAL at +8 days (i.e., 24/08 12:00). SAL are also simulated in the Iller River for 23-24/08 midday. Only EFAS simulations based on ECMWF deterministic weather forecast predicted these increasing discharges and the forecasts were not persistent in the next forecasts (dates: 17/08 00:00 and 12:00, 18/08 00:00).
- On the 17/08, EFAS simulations based on DWD weather forecasts only (17/08 00:00 and 12:00) predict discharges exceeding HAL in the Upper Danube River in Austria and in upper reaches of the Danube in Germany for 23/08 onwards (leadtime of 6 days). A reach of the Salzach River on the Austria/Germany border also shows HAL predicted for 22/08 onwards.
- The next simulations (based on DWD weather forecast dates of 18/08 and 19/08) show river reaches oscillating between MAL and HAL. Persistent HAL appear in EFAS simulations from forecasts 20/08 onwards in the main Upper Danube and its tributaries Lech, Isar, Inn and Salzach. HAL are predicted for

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days 23-24/08 onwards (3 to 4 days of leadtime). With the weather forecast of 21/08 00:00, EFAS simulates discharges exceeding SAL in the Lech and Isar rivers, as well as in the main Upper Danube just after the confluence with the Salzach River, for days 24-25/08, with thus 3 to 4 days in advance. Discharges were predicted to decrease from 27-28/08 onwards.

• EFAS simulations based on ECMWF deterministic weather forecasts oscillate between HAL and MAL in the Upper Danube for the forecast dates from 17 to 21 August. Persistent HAL are simulated for the Lech and Isar tributaries from the forecast of 22/08 onwards for the days 24-26/08. Discharges are predicted to decrease from 27-28/08 onwards.

#### Rhine catchment

- The first significant EFAS simulations of HAL and SAL for the Rhine catchment appeared in EFAS simulations based on 17/08 12:00 DWD weather forecasts. For the Rhine River and the Neckar tributary in Germany, HAL were predicted for days 22/08 onwards (forecasted thus with 5 days in advance), with discharges exceeding SAL at some river reaches on 23-24/08, depending to the location (see locations 10 - Rheinfelden, 9 - Strassbourg, and 8 – Mainz shown on pages 56 to 58). For the Upper Rhine in Switzerland, discharges exceeding EFAS SAL are simulated for 22/08 onwards (a 5-day leadtime) (see for example location 10 - Rheinfelden on page 58). In the following DWD weather forecasts of 18/08 and 19/08, this situation was relatively persistent, although some forecasts showed MAL in the Rhine and only short river reaches with discharges exceeding EFAS HAL. From 20/08 onwards, EFAS simulations based only on DWD weather forecasts predicted discharges reaching HAL and SAL continuously. For instance, EFAS simulations based on the forecast date of 22/08 00:00 predict discharges exceeding SAL in the main Upper Rhine for 25-26/08 (a 3-4 day leadtime). Discharges are predicted to decrease from 27-28/08 onwards.
- Basically, EFAS simulations based on ECMWF deterministic weather forecasts predicted increased discharges, but not exceeding HAL in the Upper Rhine area. EFAS simulations based on only some weather forecasts predicted discharges exceeding HAL: for instance, simulations based on weather forecasts of 18/08 predict HAL in the Neckar tributary in Germany and in the Upper Rhine in Switzerland for 24/08; simulations based on the weather forecast of 21/08 00:00 predict HAL in the Rhine River in Switzerland for 24/08.





#### 15 August EFAS forecast (2005081500)

Flood Threshold Exceedance Map based on ECMWF forecast of 2005 08 15 00:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)



Flood Threshold Exceedance Map based on DWD forecast of 2005 08 15 00:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green).







#### 16 August EFAS forecast (2005081512)

Flood Threshold Exceedance Map based on ECMWF forecast of 2005 08 15 12:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)



Flood Threshold Exceedance Map based on DWD forecast of 2005 08 15 12:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)







#### 16 August EFAS forecast (2005081600)

Flood Threshold Exceedance Map based on ECMWF forecast of 2005 08 16 00:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)



Flood Threshold Exceedance Map based on DWD forecast of 2005 08 16 00:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)







#### 17 August EFAS forecast (2005081612)

Flood Threshold Exceedance Map based on ECMWF forecast of 2005 08 16 12:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)



Flood Threshold Exceedance Map based on DWD forecast of 2005 08 16 12:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)







#### 17 August EFAS forecast (2005081700)

Flood Threshold Exceedance Map based on ECMWF forecast of 2005 08 17 00:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)



Flood Threshold Exceedance Map based on DWD forecast of 2005 08 17 00:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)







#### 18 August EFAS forecast (2005081712)

Flood Threshold Exceedance Map based on ECMWF forecast of 2005 08 17 12:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)



Flood Threshold Exceedance Map based on DWD forecast of 2005 08 17 12:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)

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18 August EFAS forecast (2005081800)

Flood Threshold Exceedance Map based on ECMWF forecast of 2005 08 18 00:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)



Flood Threshold Exceedance Map based on DWD forecast of 2005 08 18 00:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)







#### 19 August EFAS forecast (2005081812)

Flood Threshold Exceedance Map based on ECMWF forecast of 2005 08 18 12:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)



Flood Threshold Exceedance Map based on DWD forecast of 2005 08 18 12:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)

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#### 19 August EFAS forecast (2005081900)

Flood Threshold Exceedance Map based on ECMWF forecast of 2005 08 19 00:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)



Flood Threshold Exceedance Map based on DWD forecast of 2005 08 19 00:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)







20 August EFAS forecast (2005081912)

Flood Threshold Exceedance Map based on ECMWF forecast of 2005 08 19 12:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)



Flood Threshold Exceedance Map based on DWD forecast of 2005 08 19 12:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)







#### 20 August EFAS forecast (2005082000)

Flood Threshold Exceedance Map based on ECMWF forecast of 2005 08 20 00:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)



Flood Threshold Exceedance Map based on DWD forecast of 2005 08 20 00:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)







#### 21 August EFAS forecast (2005082012)

Flood Threshold Exceedance Map based on ECMWF forecast of 2005 08 20 12:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)



Flood Threshold Exceedance Map based on DWD forecast of 2005 08 20 12:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)







21 August EFAS forecast (2005082100)

Flood Threshold Exceedance Map based on ECMWF forecast of 2005 08 21 00:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)



Flood Threshold Exceedance Map based on DWD forecast of 2005 08 21 00:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)







22 August EFAS forecast (2005082112)

Flood Threshold Exceedance Map based on ECMWF forecast of 2005 08 21 12:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)



Flood Threshold Exceedance Map based on DWD forecast of 2005 08 21 12:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)







#### 22 August EFAS forecast (2005082200)

Flood Threshold Exceedance Map based on ECMWF forecast of 2005 08 22 00:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)



Flood Threshold Exceedance Map based on DWD forecast of 2005 08 22 00:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)







#### 23 August EFAS forecast (2005082212)

Flood Threshold Exceedance Map based on ECMWF forecast of 2005 08 22 12:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)



Flood Threshold Exceedance Map based on DWD forecast of 2005 08 22 12:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)







#### 23 August EFAS forecast (2005082300)

Flood Threshold Exceedance Map based on ECMWF forecast of 2005 08 23 00:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)



Flood Threshold Exceedance Map based on DWD forecast of 2005 08 23 00:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)






#### 24 August EFAS forecast (2005082312)

Flood Threshold Exceedance Map based on ECMWF forecast of 2005 08 23 12:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)



Flood Threshold Exceedance Map based on DWD forecast of 2005 08 23 12:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)







24 August EFAS forecast (2005082400)

Flood Threshold Exceedance Map based on ECMWF forecast of 2005 08 24 00:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)



Flood Threshold Exceedance Map based on DWD forecast of 2005 08 24 00:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)







25 August EFAS forecast (2005082412)

Flood Threshold Exceedance Map based on ECMWF forecast of 2005 08 24 12:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)



Flood Threshold Exceedance Map based on DWD forecast of 2005 08 24 12:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)







25 August EFAS forecast (2005082500)

Flood Threshold Exceedance Map based on ECMWF forecast of 2005 08 25 00:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)



Flood Threshold Exceedance Map based on DWD forecast of 2005 08 25 00:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)

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#### 26 August EFAS forecast (2005082512)

Flood Threshold Exceedance Map based on ECMWF forecast of 2005 08 25 12:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)



Flood Threshold Exceedance Map based on DWD forecast of 2005 08 25 12:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)

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#### 26 August EFAS forecast (2005082600)

Flood Threshold Exceedance Map based on ECMWF forecast of 2005 08 26 00:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)



Flood Threshold Exceedance Map based on DWD forecast of 2005 08 26 00:00; flood levels correspond to: severe (pink), high (red), medium (yellow) and low (green)

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# EFAS ensemble forecasts using ECMWF EPS

The ensemble weather forecasts from the Ensemble Prediction System (EPS) of ECMWF were incorporated in the pre-operational testing of EFAS in June 2005. At a daily basis, the 51 members (weather forecast variations: 50 members + 1 control) are simulated using the EFAS-LISFLOOD setup and the results are evaluated.

Unfortunately, in the week of the flooding in August 2005, following the implementation of some technical changes to the EPS setup, the EPS failed to run. This was caused by one corrupted file that was needed for the calculation. In the week after the flood, the EPS setup was repaired and it was possible to re-run the EPS forecasts from the midday weather forecasts. The results are presented below. The EPS maps show the number of simulations based on the ECMWF-EPS members exceeding the EFAS high flood threshold (EFAS HAL) at any time during the forecast range of the EPS meteorological forecasts, i.e., for the next 10 days starting from the indicated forecast date. A summary of EFAS forecasts is presented for the Upper Danube and the Rhine catchments.

#### Upper Danube catchment

In the Upper Danube catchment, a mean of about 5 to 20 EPS simulations showed discharges exceeding EFAS HAL in the forecasts of 15 to 21 August. Especially the forecasts of 16 and 19 August show an increased number of EPS above the High Alert Level (HAL). The peak was forecasted for 23-24/08, depending on location and EPS member. The tributaries Lech, Isar, Inn, Salzach and Enns were those presenting the greater number of EPS above EFAS HAL. The highest number of EPS exceeding EFAS HAL appears in the map of the forecast date 22/08, where 33 to 39 EFAS-EPS simulations predicted discharges reaching EFAS HAL for the Lech tributary. The peak was forecasted on 22/08 for the following 24 hours. Discharges were predicted to decrease from 25/08 onwards.

#### Rhine catchment

Few EFAS-EPS simulations predicted discharges exceeding EFAS HAL for the Rhine catchment. About 1 to 6 simulations reached the HAL in the forecasts of 15 to 17 August. The peak was predicted for 22-23/08, depending on EPS member and location. The tributary Neckar showed 20 to 25 EFAS-EPS simulations reaching EFAS HAL in the forecast of 18/08 for the days 23-25/08, depending on the EPS member. From 19/08 onwards, very few or none of the EFAS-EPS simulations predicted discharges reaching EFAS HAL.











EFAS-EPS High Flood Threshold Exceedance Map based on ECMWF EPS forecast from 2005 08 15 12:00



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#### 17 August EFAS forecast (EPS 2005081612)

EFAS-EPS High Flood Threshold Exceedance Map based on ECMWF EPS forecast from 2005 08 16 12:00



## 18 August EFAS forecast (EPS 2005081712)

EFAS-EPS High Flood Threshold Exceedance Map based on ECMWF EPS forecast from 2005 08 17 12:00







#### 19 August EFAS forecast (EPS 2005081812)

EFAS-EPS High Flood Threshold Exceedance Map based on ECMWF EPS forecast from 2005 08 18 12:00



## 20 August EFAS forecast (EPS 2005081912)

EFAS-EPS High Flood Threshold Exceedance Map based on ECMWF EPS forecast from 2005 08 19 12:00







#### 21 August EFAS forecast (EPS 2005082012)

EFAS-EPS High Flood Threshold Exceedance Map based on ECMWF EPS forecast from 2005 08 20 12:00



## 22 August EFAS forecast (EPS 2005082112)

EFAS-EPS High Flood Threshold Exceedance Map based on ECMWF EPS forecast from 2005 08 21 12:00







#### 23 August EFAS forecast (EPS 2005082212)

EFAS-EPS High Flood Threshold Exceedance Map based on ECMWF EPS forecast from 2005 08 22 12:00



## 24 August EFAS forecast (EPS 2005082312)

EFAS-EPS High Flood Threshold Exceedance Map based on ECMWF EPS forecast from 2005 08 23 12:00







#### 25 August EFAS forecast (EPS 2005082412)

EFAS-EPS High Flood Threshold Exceedance Map based on ECMWF EPS forecast from 2005 08 24 12:00



#### 26 August EFAS forecast (EPS 2005082512)

EFAS-EPS High Flood Threshold Exceedance Map based on ECMWF EPS forecast from 2005 08 25 12:00







#### 27 August EFAS forecast (EPS 2005082612)

EFAS-EPS High Flood Threshold Exceedance Map based on ECMWF EPS forecast from 2005 08 26 12:00



## 28 August EFAS forecast (EPS 2005082712)

EFAS-EPS High Flood Threshold Exceedance Map based on ECMWF EPS forecast from 2005 08 27 12:00





# EFAS forecast history diagrams

EFAS forecast diagrams show the temporal daily evolution of forecasted EFAS alert levels at a number of selected locations. For each forecast date (rows), sequential boxes in columns show the highest EFAS alert level reached for simulations based on both ECMWF and DWD meteorological forecasts. Each box represents a lead time of 24 hours, increasing in time from left to right. A map of locations presented below (Figure 3) indicates the points selected for the Upper Danube (locations 1 to 7) and the Rhine catchment (locations 8 to 11).



Figure 3 - Map of locations for which the daily evolution of EFAS forecast levels is presented.

From the diagrams on the next pages strong differences can be observed between the DWD based and the ECMWF based forecasts. This is due to differences in the two weather forecasts, but also due to different initial conditions. Since observed weather data were available with a time lag of 2 days or more, the intermediate time period between the last observed data and the forecast data was filled up with forecasted data. This causes differences in initial conditions that propagate during the forecast period. The results presented in this report show the simulations obtained at the time of the EFAS forecasting, without re-analysis of data accounting for updated observed initial conditions.

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## **Upper Danube catchment**

Location 1 -	nea	r Pa	assa	au ((	Geri	man	/Au	stria	n b	orde	er)							
Country:	Gerr	many	y															
MoU Status:	MoL	J exi	sts															
River:	Dan	ube		В	asin:	Dan	ube,ı	uppe	r									
Upstream Area:	7605	50 kr	m²															
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#### Location 2

Country:	Ge	rman	ıy																
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Upstream Area: 7800 km <sup>2</sup>																			
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#### Location 3

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2005082400												<u> </u>	<u> </u>		
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#### **Location 4** Country: Germany **MoU Status:** MoU exists **River:** Basin: Danube,upper Upstream Area: 4500 km<sup>2</sup> DWD 2005081600 x х х llx х Х х **ECMWF**



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MoU Status:	Мо	U ex	ists															
River:				B	lasin	: Da	nube	e,upp	er									
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DWD																		
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#### Location 6

Country:	Aus	stria													
MoU Status:	req	ueste	ed												
River:				В	asin:	Dan	ube,	uppe	r						
Upstream Area	<b>:</b> 785	575 k	m²												
DWD															
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#### Location 7

Country:	Au	stria																
MoU Status:	req	ueste	ed															
River:				В	asin:	Dar	nube,	uppe	er									
Upstream Area	: 942	225 k	m²															
DWD																		
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# **Rhine catchment**

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Country:	Ge	rman	У														
MOU Status:	Mo	U exi	sts	_													
River:			. 2	B	asin:	Rn	ine										
Upstream Area	: 100	0700	km⁻														
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#### Location 9

Country:	Germany				
MoU Status:	MoU exists	5			
River:		Basin:	Rhine		
Upstream Area:	: 46075 km <sup>2</sup>	2			
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#### Location 10 Country: Germany **MoU Status:** MoU exists **River:** Basin: Rhine Upstream Area: 34925 km<sup>2</sup> DWD 2005081600 x х х x х х х **ECMWF**







#### Location 11 Country: Switzerland **MoU Status:** MoU exists **River:** Basin: Rhine Upstream Area: 10725 km<sup>2</sup> DWD 2005081600 x х х x х Х х **ECMWF**





#### **Observed flood: information from hydrological** 5. services and websites

#### Danube in Germany up to German/Austria border

The images below (Figure 4) show the flood wave propagation in the Bavarian Danube from Oberndorf until Passau. Passau shows two peaks: an early peak due to the Inn River inflow in the Danube, followed by a second peak later on due to upstream Danube waters from mainly the Iller and the Lech tributaries.

Comparing the observed discharges shown below with EFAS forecasts, one can conclude that for the upper main Danube River (location 3, page 51) EFAS forecasted the severe alert level to occur on 23 and 24 August, while the measurements show the peak occurring on 25 and 26 August. The magnitude of the flood peak however was well forecasted by EFAS (see page 72).























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Figure 4 – Flood wave propagation in the Bavarian Danube from Oberndorf until Passau: time evolution of observed water levels (cm). (Source: www.bafg.de/php/; visited on 30.08.05).



#### Upper Rhine

Figure 5 shows the observed discharges in the Upper Rhine. At Rheinfelden/Rhein (near Basel), the observed peak discharge was estimated as a 10-year flood (~ 3530 m<sup>3</sup>/s). The observed flood peak at Maxau on 24 August (770 cm) was well below a 10-year flood (869 cm).



Figure 5 – Flood wave propagation in the Upper Rhine: time evolution of observed water levels (cm). (Source: www.bafg.de/php/; visited on 30.08.05).

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#### Danube in Austria and Hungary

Figure 6 shows the observed hydrograph for the Danube at Kienstock (Austria). Discharges did not reach by far the level of August 2002 flood (11300 m<sup>3</sup>/s). The observed flood peak for the August 2005 flood correspond to a 1-year return period flood. The Danube at Vac (Hungary, downstream Slovakian border and upstream Budapest) shows a similar response (Figure 7).



Figure 6 – Observed hydrograph for the Danube at Kienstock (Austria). (Source: <u>www.noe.gv.at/SERVICE/WA/wa5;</u> visited on 30.08.05).



Figure 7 – The Danube at Vac (Hungary, downstream Slovakian border and upstream Budapest). (Source: <u>www.vizdat.hu</u>; visited on 30.08.05).





Other information on observed flows is shown in Figures 8 to 12.



#### Raba River at the border Austria/Hungary

Figure 8 – Observed discharge (m<sup>3</sup>/s) in Raba River at the border Austria/Hungary. (Source: <u>www.vizdat.hu</u>; visited on 30.08.05).

# Mura River at the border Hungary/Croatia, downstream Austria/Slovenia



Figure 9 – Observed discharge (m<sup>3</sup>/s) in Mura River at the border Hungary/Croatia. (Source: <u>www.vizdat.hu</u>; visited on 30.08.05).







# Drava River at T.Polje (Croatia/Hungary border)

Sava River at the border Slovenia/Croatia







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Sava River at Zagreb (Croatia)





# 6. Comparison of flood forecasts and observations

Post-event reports for Germany (Holle *et al.*, 2005) and Austria (Muller & Godina, 2005) were produced by the Regional and/or National Hydrological Services. They show maps with the estimated return periods of the observed flood waves. These maps were produced by comparing observed maximum discharge with historic discharge data. They are reproduced below (Figures 13 and 14).

In Figure 15, these two maps were combined (note that the color scales used for Austria and Germany, indicated in the map, are different).

In order to compare the observed flood to EFAS forecasts, we reproduce in Figure 16 the EFAS Flood Threshold Exceedance map for the Upper Danube. This map shows the strongest flood alert levels forecasted with EFAS based on the DWD midnight weather forecast of 21 August (2005082100) for the forecasting period of 7 days, from 21 to 27 August.

When comparing Figures 15 and 16, one can see that EFAS forecasts indicated well the overall region of severe flood problems. Looking in more detail to the exact river reaches, EFAS forecasted very well the extreme floods that happened in the Iller River (Kempten and further downstream), where return periods were estimated to be more than 100 years, and around Garmisch Partenkirchen in the Upper Isar River. The 50- to 100-year return period floods in the middle part of the Isar (around Munich) and in the downstream part of the Lech (downstream Augsburg) were also well predicted by EFAS with a Severe Alert Level.

In the Inn River, however, EFAS underpredicted the flooding. EFAS simulations showed discharges reaching High Alert Levels in the German part and only Medium Alert Levels in the Austrian part, whereas in reality the return period of the observed flood was estimated to be larger than 50 years in Germany and even greater (more extreme event) in Austria.

Along the main Danube, EFAS overpredicted the flood in the river reach downstream Passau by simulating a Severe Alert Level (although only slightly surpassed in EFAS simulations), whereas the observed event was only a 1- to 5-year return period flood. Upstream Passau a High Alert Level was forecasted by EFAS, matching reasonably the observed flood, estimated to be an event of 10- to 50-year return period.

As for the Mur/Drava region in southeastern Austria, it can be concluded from Figures 17 and 18, that EFAS forecasted well the floods in the Mur River, upstream and downstream Graz, with the EFAS High Alert Level forecasted matching the observed 5- to 10-year return period flood. EFAS slightly overpredicted the floods in the Raab/Raba River, simulating discharges reaching the Severe Alert Level, whereas observed floods were associated with a return period of 5 to 10 years.







Figure 13 – Estimated return periods of the observed flood in Germany in August 2005. (Source: Holle *et al*, 2005).



Figure 14 – Estimated return periods of the observed flood in Austria in August 2005. (Source: Muller& Godina, 2005).






Figure 15 – Estimated return periods of the observed floods in Germany and Austria: combined map. (Source: Holle *et al*, 2005 and Muller& Godina, 2005).



Figure 16 – EFAS Flood Threshold Exceedance Map based on DWD weather forecast starting on 21 August (00:00) for the next 7 days: Severe alert level (pink), High alert level (red), Medium alert level (yellow) and Low alert level (green).







Figure 17 – Estimated return periods of the observed flood near Graz (Austria) in August 2005. (Source: Muller& Godina, 2005).



Figure 18 – EFAS Flood Threshold Exceedance Map for the Graz region based on DWD weather forecast starting on 21 August (00:00) for the next 7 days: Severe alert level (pink), High alert level (red), Medium alert level (yellow) and Low alert level (green).





In flood forecasting, one can also be interested in comparing observed and forecasted hydrographs (timing and magnitude of peak discharges). When comparing EFAS forecasted discharges to observed ones, one should pay attention to the following:

- EFAS forecasts are done with the 5km EFAS setup, which is only slightly calibrated and does not include reservoirs, polders, etc.
- The main strength and purpose of EFAS is on providing an advanced warning for critical or extreme floods to happen in the medium-range (3 or more days in advance). EFAS is not intending to predict water levels with accuracy of several centimeters.
- The 1-km Danube setup for EFAS, which is currently in final preparation, is meant to produce more accurate results than the 5-km setup.

Figure 19 shows EFAS simulated discharges at a point in the Danube corresponding to the location of the Hofkirchen station based on the midnight DWD weather forecasts from 20 to 25 August. The discharges simulated when observed rainfall data from JRC-MARS synoptic data is used as input (see "EFAS WB obs data" in the graph) are also shown. One can see that the simulated peak discharges from 21 August onwards compare relatively well with the observed peak discharge of 2700 m<sup>3</sup>/s.

Figure 20 shows EFAS forecasted river discharges (in m<sup>3</sup>/s) for several other locations along the main Danube, starting in Wiblingen (Germany), via Ingolstadt, Hofkirchen, Achleiten, Linz (Austria), Kienstock, Vienna/Wien, Bratislava (Slovakia) to Mohacs (Hungary).

When comparing EFAS simulations and observed peak discharges, one can see that:

- In Ingolstadt, EFAS predicted a peak of 2400 m<sup>3</sup>/s for 24 August in the morning, whereas the observed peak was of 1560 m<sup>3</sup>/s and a little later on the same day. This difference is probably due to inundations (dykebreaks), resulting therefore in a delayed and smooth observed flood peak.
- In Hofkirchen, EFAS predicted a peak of 3200 m<sup>3</sup>/s for 24 August midday, whereas the observed peak was 2700 m<sup>3</sup>/s on August 25 (18% error in magnitude).
- In Achleiten, EFAS predicted a peak of 5850 m<sup>3</sup>/s for 24 August midday, whereas the observed peak was 5750 m<sup>3</sup>/s on 24 August at 21:00 (1% error in magnitude).
- In Linz, EFAS predicted a peak of 5800 m<sup>3</sup>/s for 24 August at around 18:00, whereas the observed peak was 6000 m<sup>3</sup>/s on 24 August at 21:00 (3 % error in magnitude).
- In Kienstock, EFAS predicted a peak of 6800 m<sup>3</sup>/s for 24 August midday, whereas the observed peak was 5950 m<sup>3</sup>/s on 25 August at 06:00 (13% error in magnitude).



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Figure 19 – EFAS simulated discharges at Hofkirchen in Danube based on different midnight DWD weather forecasts (blue lines) and on JRC-MARS observed precipitation (squares).



EFAS simulations based on DWD meteorological forecasts 2005082200

Figure 20 – EFAS simulated discharges at several locations along the main Danube based on DWD weather forecast starting on 22 August 00:00 for the next 7 days.





#### 7. Flood extent map

The Dartmouth Flood Observatory (http://www.dartmouth.edu/~floods/) detects, maps, measures and analyzes extreme flood events world-wide using satellite remote sensing. Microwave and optical satellite imaging of selected river reaches are used to detect overbank flood and extreme low flow conditions.

The map shown in Figure 21 was received shortly after the flood event in August 2005. It shows flood inundation extents for Southern Germany on 24 August. Inundation maps are an important source of information to assess the severity of a flood event. The map showed in this report was the only one available immediately after the flood event. However, requests to produce more in depth maps and an overview of the August 2005 flood extent were sent to Dartmouth for future postevent analysis.



Figure 21 – Southern Germany inundation map for the August 2005 flood. (Source: http://www.dartmouth.edu/~floods/).



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# 8. Forecasted and observed precipitation

Many factors can play a role in the quality of a flood forecast, such as: the quality of the forecasted precipitation, the assessment of the initial conditions before the event (soil moisture, river discharge, snow cover, storage capacity in lakes, reservoirs and/or retention polders, groundwater conditions), the quality of the hydrologic model used in the simulation, the quality of other input data (soil data, land cover data, topographic data, river geometry), etc. Since extreme precipitation is usually at the origin of flood events, the reliability of a flood forecast depends largely on a precise rainfall forecast. In order to assess the quality of a system such as EFAS and the quality of its results, a first detailed assessment of the quality of the forecasted precipitation is therefore important.

## Observed precipitation

Figure 22 illustrates the total amount of precipitation observed over the reported area from 15 to 26 August 2005. Precipitation data come from MARS-JRC database and are based on a 50-km grid interpolation of point rain gauge data (synoptic stations) available over Europe. Maximum observed rainfall sums are shown around Bern (Switzerland) and near Garmisch-Partenkirchen (Germany).

Figure 23 shows observed rainfall as measured at selected gauging stations in Germany and Austria on 22-23 August (Rudolf *et al.*, 2005). Several stations recorded more than 100 mm of rainfall in 24 hours, with a maximum observed in Reutte/Tirol (Austria) of 189 mm in 24 hours.

Figure 24 shows a map obtained by combining high density station data and rainfall radar data for 22 August, as produced by the German Weather Service DWD (Rudolf *et al.*, 2005). It shows a widespread area of high rainfall amounts around the Austrian/German border.

Figure 25 shows the observed daily rainfall amounts for days 20 to 23 August as obtained using the JRC-MARS database. Due to the limited realtime availability of stations, the density of stations is less than the density of stations used in Figure 24. Figure 25 shows rainfall maxima on 21 August in Switzerland and in the Drava/Mur region (Austria/Hungary). On 22 August, widespread rainfall is observed in Switzerland, western Austria and southern Germany. On 23 August, high rainfall amounts around the Garmisch-Partenkirchen area are still observed.







Figure 22 – Observed rainfall (mm) accumulated from 15<sup>th</sup> to 26<sup>th</sup> August 2005 based on rainfall data from JRC-MARS database.



Figure 23 – Measured 24-hour rainfall accumulations in mm (22.8., 08 MESZ until 23.8., 08 MESZ). (Source: Rudolf *et al.*, 2005).







Figure 24 – Combined rainfall radar and station observations for 22 August 2005. (Source: Rudolf et al., 2005).



Figure 25 - Daily observed precipitation as derived from the JRC-MARS database (observed station network) for the upper Danube area and days 20 to 23 August 2005.



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#### Forecasted precipitation

Figures 26a and 26b show accumulated forecasted precipitation fields based on the DWD (Figure 26a) and the ECMWF meteorological forecasts (Figure 26b) for the 22 August 2005, interpolated onto the 5-km EFAS grid. For visualization purposes, the same color scale is used for both meteorological forecasts.

For each figure, the first row shows from left to right: a map of the area, the observed rainfall from JRC-MARS database, the estimated rainfall using the UK Met Office NIMROD data and the forecast for 22 August done on 22 August 00:00 (i.e., forecast for the next 24 hours).

The second row shows from left to right: first, the rainfall forecasted for 22 August on 21 August at 12:00 (12 hours of leadtime), then, next on its right, the forecast for 22 August done on 21 August at 00:00 (1 day of leadtime), followed by the forecast for 22 August done on 20 August at 12:00 (1.5 day of leadtime), and so on.

For the DWD forecasts (Figure 26a), the first two forecasted rainfall fields show a higher resolution since they come from the DWD local model.

One can see that both weather forecasts from DWD and ECMWF already predicted substantial amounts of rainfall for the 22 August on the 16 August 12:00 forecast (see 2005/08/16 dwdg12\_6 and 2005/08/16 eudg12\_6 in Figures 26a and 26b, respectively) in southern Germany, Switzerland and western parts of Austria, affecting the Rhine and the Upper Danube catchments. The DWD forecasts from 19 August 00:00 onwards persistently predicted high amounts of rainfall in central Switzerland and western Austria.





Figure 26a - Observed and DWD forecasted precipitation (DWD deterministic forecasts).



Figure 26b – Observed and ECMWF forecasted precipitation (ECMWF deterministic forecasts).

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#### Comparison of forecasted and observed precipitation

Figures 27a and 27b show a comparison of observed rainfall (JRC-MARS database) and DWD forecasted rainfall in the Upper Danube in Germany. Forecasts done on 20 August at 00:00 and 12:00 are considered. Figure 27a shows the time evolution of the mean areal rainfall (mm/day) and Figure 27b shows the cumulative rainfall (mm/day).

From Figure 27a, one can see that the timing of the 20 August 00:00 rainfall forecast was very good: forecasted and observed peaks occurring at approximately the same time. The 20 August 12:00 forecast however predicted the mean areal rainfall peak for 21 August, i.e., one day earlier. Figure 27a also shows that from 14-16 August, the same area received an important amount of rainfall, which was responsible for relatively wet initial conditions for the subsequent event.

Figure 27b shows that the forecasted sum of precipitation matches well the observed amount when considering the 20 August 00:00 forecast: the line of accumulated forecasted precipitation perfectly follows the line of accumulated observed precipitation until 25 August. The cumulative rainfall forecasted for the 26 August is however overpredicted when compared to the observed cumulative rainfall curve.











Figure 27b – Comparison of cumulative observed rainfall from JRC-MARS database (in red) and cumulative DWD forecasted rainfall on 20 August (in blue for the 00:00 forecast and in green for the 12:00 forecast).

Rudolf *et al.* (2005) highlighted in their report the good quality of the DWD forecast of 21 August 2005. The extract presented below (from the original report in German) reports that especially the 21 August DWD weather forecasts (which was the basis of the first EFAS alert report sent out) matched extremely well the observed rainfall.

However, several weather forecasts produced earlier than the one of 21 August were apparently also good: as, for instance, DWD 20 August 00:00 forecast and both DWD and ECMWF 16 August 12:00 forecasts.

#### Extract from Rudolf et al. (2005):

"Schon vom 21. 8. 2005 ausgehend (Modellstart 02 MESZ) berechneten die globalen Modelle GME und ECMWF Niederschlagshöhen bis zu fast 100 mm für den 22. August. Die höchsten Niederschläge wurden allerdings etwas zu weit im Osten vorhergesagt. Die GME-Vorhersagen lagen dennoch in diesem Fall auch deutlich näher an den tatsächlich eingetroffenen Verhältnissen. Die Vorhersage vom 22. 8. 2005 (Starttermin 02 MESZ) für die nächsten 30 Stunden brachte noch höhere Werte mit dem Maximum um Garmisch-Partenkirchen. Die Lokalmodelle LM und LME sagten auf Grund der feineren Maschenweite noch höhere Maxima voraus. Das Gebietsmittel ist aber fast gleich. LM und LME verbessern im Vergleich zum GME vor allem die Vorhersage für die Schweiz.

Um 22.04 Uhr konkretisierte der DWD seine Unwettervorwarnung und gab eine amtliche Unwetterwarnung für die besonders gefährdeten Städte und Landkreise wie zum Beispiel Kempten und Garmisch-Partenkirchen heraus. Der DWD warnte vor Niederschlägen von bis zu 120 Liter pro Quadratmeter im Zeitraum von 24 Stunden, von Montag, 22. 8. um 4.00 Uhr bis Dienstag, 23. 8. 2005 um 4.00 Uhr. Die Unwetterwarnung wies auf drohende Hochwassergefahren hin.





Eine Überprüfung der Vorhersagen durch die Messungen einiger Wetterwarten des DWD in der betroffenen Region ergibt: In der Summe über die drei Tage vom Sonntag den 21. bis Dienstag den 23. August wurden in Garmisch-Partenkirchen 144, in Oberstaufen 170 und in Oberstdorf 150, im Ortsteil Rohrmoos sogar 179 Millimeter Niederschlagshöhe bzw. Liter pro Quadratmeter gemessen. Die frühzeitigen Prognosen des DWD sind also eingetroffen.

Die sehr guten Vorhersagen der Niederschläge, welche im August 2005 die Überschwemmungen in Südbayern verursachten, belegen die erfolgreiche Weiterentwicklung der Modelle, der Beobachtungsnetze und der Datenassimilation (Anpassung der Modelle an die Daten). Künftig bietet der DWD ergänzende Vorhersageprodukte an, die Aussagen über die Eintrittswahrscheinlichkeit der Vorhersagen ermöglichen. Ob ein Extremereignis mit hoher Wahrscheinlichkeit auftreten wird, wird sich aber auch künftig nicht langfristig, z.B. Monate im Voraus, vorhersagen lassen. Wenn eine entsprechende Großwetterlage frühzeitig prognostiziert wird, ist Wachsamkeit geboten. Eine erhöhte Wahrscheinlichkeit für das Auftreten extremer Ereignisse wird sich öfter um einige Tage im Voraus erkennen lassen. Eine raum-zeitliche Zuordnung aber, die für hydrologische Vorhersagen notwendig ist, können die Modelle häufig erst kurzfristig erfassen."



#### Feedback from National Hydrological Services 9.

The feedback from the National Hydrological Services is very important for the EFAS activity. Therefore, feedback forms are sent out to the EFAS partners' organizations whenever EFAS information reports are sent and after the event is over. These feedback reports allow the EFAS team to evaluate the correctness, usefulness and impact of the EFAS information reports sent out before and during the floods.

## Feedback during the event

Germany - BfG:

- On Monday 22 August, the BfG confirmed the receipt of the EFAS information report of Sunday 21 August (External alert no.1) and requested to include several additional email adresses at BfG in EFAS list.
- On Tuesday 23 August, the BfG asks if EFAS sees flood problems on the Rhine, especially if there is a contribution to be expected from the Mosel, based on ECMWF data. An informal email was sent, indicating that no problems were expected for the middle and lower Rhine.

Czech Republic:

On Monday 22 August, CHMI asks for EFAS information for the upper Elbe river basin (Vltava). Since no MoU had been established yet, only short informal information was provided, indicating that EFAS predicted that the Vltava would reach the EFAS high alert level on 24 August, based on the DWD forecasts, but not the severe alert level.

## Feedback after the event

In this paragraph, some remarks received from the national centers (EFAS endusers) after the flood event are summarized.

Germany - BfG:

- EFAS alerts are interesting for BfG, but it would be more useful if early • warning was based on forecasts beyond the 2-day DWD local model.
- The maps showing the whole river system (also the unaffected parts) are found useful, but the figures have a lot of grey lines (rivers, borders), which makes them not so easy to understand at the first view. A suggestion is made to give the unaffected rivers a different color.
- Some more time and experience is needed to get used to EFAS boxes-• diagrams. Even with good printers, it is hard to distinguish some colors (pink from red) and read some legends.
- The EPS-forecasts would be very interesting because it cannot be covered from the local national forecasting centers in Germany right now.

Germany – Bavaria:

- The Bavarian water authorities received well all EFAS information reports • (external alerts) and found they were well structured, with useful information. The contents and structure of the reports are considered good, but in general the reports could be more concise.
- In addition to the current recipients, it was requested to send future reports directly to the Flood Warning Service "Hochwassernachrichtendienst" (HND).



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- At the time of receiving the first EFAS report (21.08.2005 at 15:43), the Flood Warning Service HND was already aware of the situation and reservoirs with flood retention were already ordered to empty. Consequently, if EFAS would have warned earlier, the warning would have been even more useful. In general, this type of early warning is very welcome.<sup>3</sup>
- EFAS warned for floods along the Upper-Danube, Iller, Lech, Isar und Alz [read Inn] rivers. The timing of the flood, the occurrence of the flood peak and the forecasted alert level were predicted relatively accurately in the first report. In general, the first warning had a good accuracy for Bavaria. In the consequent reports, the flood forecasts reflect the subtle changes in the weather forecast (reduction of the flood alert and then again a more extreme flood alert).
- The use and application of ECMWF data is very welcome as additional information to the Bavarian water authorities, since they do not have this data available.
- The summary information given in the EFAS reports is very clear and concise.
- Other remarks concern some improvements in the layout of EFAS reports in order to have more concise and readable information.

#### Austria:

• Feedback on EFAS reports was not received as such, but, after the flood event, Austrian authorities asked for more information to sign the MoU on EFAS with the JRC (personal communication in December 2005 at the WMO meeting in Bratislava).

Hungary:

• Hungarian recipients were extremely happy with the forecasts communicated on the Mur River and found them useful (personal communication in December 2005 at the WMO meeting in Bratislava).

Slovak Republic:

• Positive feedback was received from SMHU (Slovakian Hydro Meteorological Institute). Slovakia wants to intensify staff exchange with the JRC EFAS team for training purposes, following a first staff visit in July 2005.

Switzerland:

 EFAS reports have not been sent to Switzerland (no MoU/EFAS agreement) and, consequently, no feedback was received as well. However, in the meantime, during contacts at the WMO meeting in Bratislava, the Swiss expressed their interest in receiving this post-event report to evaluate what the added value and quality of EFAS forecast might have for the Swiss rivers, which are relatively small river systems.

<sup>&</sup>lt;sup>3</sup> If EFAS were already a fully operational system, it could have alerted earlier based on the 12:00 forecast on 20.08, and potentially even sooner, given the current research on consistence and persistence of the forecasts.



# 10. Lessons learnt

Some lessons learnt from the forecasting of the Alpine floods of August 2005 are summarized below:

- A first EFAS alert report could have been issued earlier on Saturday 20 August, if the minimum catchment size limit (currently, 30 000 km<sup>2</sup> for main rivers and 4 000 km<sup>2</sup> for tributaries) established in agreements within the EFAS project was lesser.
- A first EFAS alert report could have potentially been sent even earlier than 20 August, since previous forecasts were already showing a flood signal in the area. This improvement however requires some experienced knowledge in the interpretation of consistence and persistence of the available forecasts. The gain in leadtime without increasing false alerts is one of EFAS research topics currently under development.
- The re-runs of EFAS forecasts based on the ECMWF-EPS also give reason to believe that an even earlier warning could have been achieved. However EPS forecasts failed to run during the August flood period and, since there was no backup staff to fix the problems, the results were not available to the EFAS forecaster on duty. Changes have been implemented to prevent these problems during future flood forecasting periods.
- In case of a widespread flood concerning many different countries, like the Alpine August 2005 flood, EFAS alert reports have to include in its analysis a large number of rivers and situations. Therefore, there is a strong need to more automatically produce EFAS reports. This would help in including a larger number of sites for which forecasts are predicting EFAS high or severe alert levels, which could also correspond to a number of standard sites of special interest to the hydrological services. This is currently in phase of implementation in EFAS.
- During the August flood, EFAS simulations based on ECMWF forecasts were starting with different initial conditions than those based on the DWD forecasts. This was due to the fact that the period of missing observed weather data was longer than usual (delayed availability of data) and it was being filled in with either ECMWF or DWD forecast weather data. This issue needs improvement and is currently being addressed within the EFAS development team.
- EFAS first alert report was sent to water authorities on a Sunday. To avoid that reports do not reach the operational forecasters on time and thus to maximize the early warnings of EFAS to end-users, alert reports should be preferably send to the email addresses of the operational National or Regional forecasting centers. An automatic confirmation of the reception of EFAS emails is also important.





# 11. Conclusions

EFAS forecasted the 22-27 August 2005 Alpine flood several days in advance. An EFAS flood alert report was sent out on Sunday 21 August to the German hydrological services with whom an MoU agreement exists. On this day, based on DWD weather forecast data, EFAS forecasted a severe flood peak to occur on 24 August in the Upper Danube region. The quality of EFAS forecasts was confirmed to be well accurate by the local water authorities. In flood forecasting, the quality of the input rainfall forecast is of great importance. For this event, accurate flood forecasts were strongly related to the good quality of rainfall forecasts from the DWD. In general, the ECMWF forecasts were perceived as useful additional information, since most water authorities do not have access to those data.

Although perceived useful by the end-users, EFAS reports would have been even more useful if the EFAS system had been able to warn the national centers earlier than 21 August. Several forecasts prior to 21 August showed indications for an upcoming flood disaster. For instance, simulations using the ECMWF deterministic forecasts predicted exceedance of the EFAS Severe flood threshold in the Danube at Passau (D) for 23 August already on the 16 August noon weather forecast. For the Upper Danube tributary Isar in Germany, discharges were predicted to reach EFAS High Alert Levels on 23 August onwards, with thus a forecast leadtime of 7 days in advance. Also, discharges were predicted to exceed EFAS Severe Alert Levels at +8 days (i.e., on 24 August). Severe Alert Levels were also simulated in the Iller River for 23-24 August. EFAS forecasts based on DWD weather forecasts showed discharges exceeding EFAS High alert thresholds for the first time already in the forecasts done on 19 August.

However, persistent EFAS High Alert Levels only appeared in EFAS simulations from forecasts of 20 August onwards in the main Upper Danube and its tributaries Lech, Isar, Inn and Salzach. High Alert Levels were predicted for days 23-24 August onwards, with thus 3 to 4 days of leadtime. Based on the weather forecasts of 21 August 00:00, EFAS simulated discharges exceeding Severe Alert Levels in the Lech and Isar rivers, as well as in the main Upper Danube just after the confluence with the Salzach River, for days 24-25 August, with thus 3 to 4 days in advance. Discharges were predicted to decrease from 27-28 August onwards. It was based on this more consistent forecast that the first EFAS alert report was sent to the German water authorities. Persistence in EFAS forecasts is currently a topic under research in the JRC. The aim is to contribute to produce earlier warnings, without increasing false alarms.

The first EFAS alert proved to match very well the observed flooding. EFAS forecasts indicated well the overall region of severe flood problems. Looking in more detail to the exact river reaches, EFAS forecasted very well the extreme floods that happened in the Iller (Kempten and further downstream), where floods were associated with return periods of more than 100 years, and around Garmisch Partenkirchen in the Upper Isar River. The 50- to 100-year return period floods in the middle part of the Isar (around Munich) and the downstream part of the Lech (downstream Augsburg) were also well predicted by EFAS with a Severe Alert Level.





EFAS underpredicted the flooding in the Inn River: EFAS simulations showed discharges reaching High Alert Levels in the German part and only Medium Alert Levels in the Austrian part, whereas in reality the return period of the observed flood was estimated to be larger than 50 years in Germany and even greater (more extreme event) in Austria.

Along the main Danube EFAS overpredicted the river reach downstream Passau by simulating a Severe Alert Level (although only slightly surpassed in EFAS simulations), whereas the observed event was only a 1- to 5-year return period flood. Upstream Passau a High Alert Level was forecasted by EFAS, reasonably matching the observed flood, estimated to be an event of 10- to 50-year return period.

As for the Mur/Drava region in southeastern Austria, EFAS forecasted the floods in the Mur very well, both upstream and downstream Graz, with the EFAS High Alert Level matching the observed 5- to 10-year flood. However, EFAS slightly overpredicted the floods in the Raab/Raba with a Severe Alert Level, whereas the observed event was associated with a 5- to 10-year.flood.

EFAS simulations based on ECMWF weather forecasts oscillated between the High Alert Level and the Medium Alert Level in the Upper Danube for the forecast dates from 17 to 21 August. Persistent High Alert Levels were simulated for the Lech and Isar tributaries from the forecast of 22 August onwards for the days 24-26 August. Discharges were predicted to decrease from 27-28 August onwards.

As for the probabilistic EFAS forecasts based on the ECMWF-EPS weather forecasts (51 members), the re-run of the full EPS set right after the flood event showed a mean of about 5 to 20 simulations with discharges exceeding EFAS High Alert Level in the forecasts of 15 to 21 August. The peak was forecasted for 23-24 August, depending on location and EPS member. The tributaries Lech, Isar, Inn, Salzach and Enns were those presenting the greater number of EPS above EFAS High Alert Level. These results indicate that probably EFAS could have sent an earlier warning (before the first one sent on 21 August) based on the EPS results if they were available at the time of the forecasting.

Feedback from the national hydrological services has been in general very positive and lessons learnt during the event have been implemented in the ongoing development and testing of EFAS. The August 2005 flood event triggered also the signing of several new MoU's on EFAS project between the JRC and Member States' hydrological services throughout Europe.





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## References

De Roo, A., Gouweleeuw, B., Thielen, J., Bates, P., Hollingsworth, A. *et al.* (2003), Development of a European Flood Forecasting System. *International Journal of River Basin Management*, Vol. 1, No. 1, p.49-59.

De Roo, A., Wesseling, C. G. & Van Deurssen, W. P. A. (2000), Physically based river basin modelling within a GIS: the LISFLOOD model. *Hydrological Processes*, Vol. 4, Issues 11-12, p.1981-1992.

Holle, F.K., Vogelbacher, A. & Wilhelm, F. (2005), *Hochwasser in Bayern*. In: Hydrobrief Nr. 29, September 2005.

Müller G., R. Godina (2005), *Das Augusthochwasser 2005 in Österreich*. In: Hydrobrief Nr. 30, December 2005.

Rudolf, B., H. Frank, J. Grieser, G. Müller-Westermeier, J. Rapp, W. Trampf (2005), Hydrometeorologische Aspekte des Hochwassers in Südbayern im August 2005: Niederschlagsvorhersage, Warnung und klimatologische Bewertung des DWD. Deutscher Wetterdienst.

Van Der Knijff, J. & A. De Roo (2005), LISFLOOD – distributed water balance and flood simulation model. User manual (version December 2005). *EUR report* 22166 EN, 80 pp.



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# EUR 22154 EN – Joint Research Centre, Institute for the Environment and Sustainability

Title: European Flood Alert System - Post-event summary report: The Alpine floods of August 2005: What did EFAS forecast, what was observed, which feedback was received from end-users?

Authors: Ad De Roo, Maria Helena Ramos, Jutta Thielen, Giovanni Franchello, Jens Bartholmes, Karl Wachter, Stefan Niemeyer, Milan Kalas, Giovanni Laguardia, Johan Van Der Knijff

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Abstract

From the 22nd until 27th August 2005, the northern Alpine region was hit by severe floods. The floods occurred in tributaries of the Rhine River in Switzerland and Austria (Vorarlberg) and in several tributaries of the Danube River in Germany (Iller, Lech, Isar), Austria (Lech, Inn, Mur, Drau/Drava, Raab/Raba) and Hungary (Mur and Raba/Raab), as well as in the German part of the Danube.

The European Flood Alert System (EFAS), under development and running in preoperational mode at the Joint Research Center (JRC) since February 2003 (De Roo et al., 2003), forecasted these events in all river basins and reported in realtime to its partners' organizations in the Member States. During the period from 16th to 25th August, EFAS forecasted potential flooding in the Upper Danube (tributaries Isar, Iller, Lech) in Germany and Austria, as well as in the upper Rhine (Switzerland and Germany). Furthermore, potential flooding was forecasted in the Mur and Drava rivers in SE-Austria, Hungary, Slovenia and Croatia.

This report describes what was forecasted with the EFAS system, what was communicated to the EFAS partners' organizations (water authorities in the relevant countries), where and when the floods occurred and which feedback was received from the end-users. Lessons learnt are described at the end of the report.

Flood forecasting based on weather forecasts from ECMWF-Ensemble Prediction System (EPS), one of the key elements of EFAS forecasts, has been implemented since June 2005 pre-operationally in EFAS. For technical reasons (one corrupt input file), the probabilistic forecasts did not run during the August floods. Following a re-run of the EPS immediately after the August floods, it is demonstrated that the availability of the probabilistic forecasts might have increased the flood warning time of 1-2 days. Especially the forecasts of 16th and 19th August show an increased number of EPS above EFAS High Alert Level (HAL).







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