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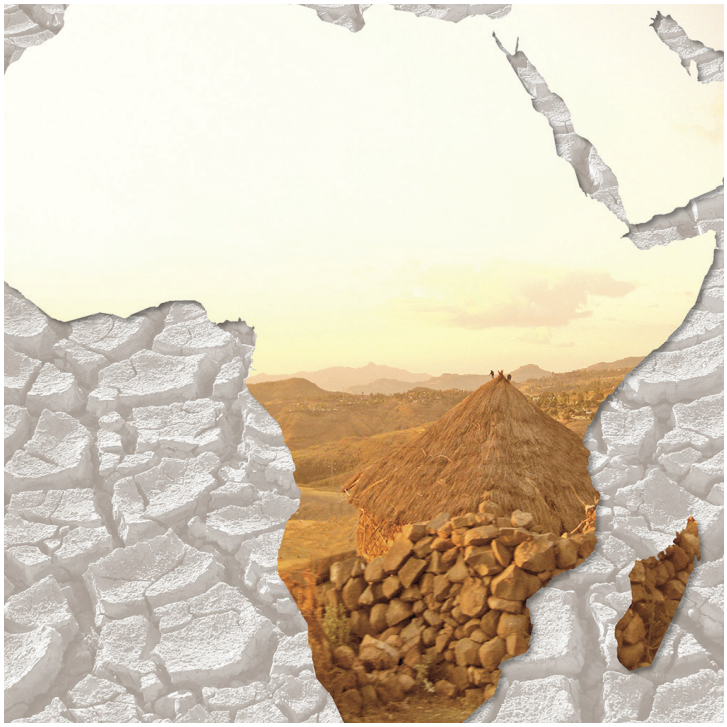
METEOROLOGY

The European Flood Awareness System (EFAS) at ECMWF: towards operational implementation



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The European Flood Awareness System (EFAS) at ECMWF: towards operational implementation

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Together with national and regional hydro-meteorological services and small-to-medium sized enterprises, ECMWF is currently establishing the operational services for the European Flood Awareness System (EFAS). ECMWF will be hosting the Computational Centre for EFAS which is envisaged to be fully operational in the second half of 2012. This follows many years of research and development on ensemble-based, probabilistic hydrological prediction, during which ECMWF has been increasingly interacting with national and international institutes that are developing hydrological prediction systems. The close collaboration with the European Commission's in-house science service, the Joint Research Centre, that developed EFAS over the past decade has been particularly fruitful.

This article describes how EFAS started in 2002 as well as the stakeholders and partners. The set-up of the operational phase of EFAS is described along with ECMWF's role. It is demonstrated that the EFAS system is skilful and the advantages for the Member States of ECMWF are highlighted.

Background

The need for a European-wide flood alert system was recognised in 2002 when, following a decade of severe natural disasters including record floods, the European Commission funded several initiatives related to flood risk management acting on the four major phases of the disaster cycle: prevention, preparedness, crisis management and recovery. Regarding prevention there have been several important developments.

- The EU flood directive (http://floods.jrc.ec.europa.eu/eu-floods-directive) requires countries to map those areas at risk of flooding.
- The development of the European Flood Awareness System (EFAS) was initiated to improve preparedness for floods by increasing warning times up to 10 days and by providing catchment-based overviews across Europe.
- Crisis management in Europe has been greatly enhanced through the establishment of the European Community Mechanism with its Monitoring and Information Centre (MIC, http://ec.europa.eu/echo/civil_protection/civil/prote/mic.htm).
- The establishment of an EU solidarity fund provides financial support during the recovery phase for those countries exceptionally hit by disasters.

Administratively at the EC level, the operational EFAS has been inserted into the Emergency Management Service of the Global Monitoring of Environment and Security (GMES) programme which enters its GIO (GMES Initial Operations) phase from 2011–2013. The objective of the GMES Emergency Management Service is to support users in the field of crisis management by providing them with information based on space (satellite) data combined with other sources of data. It addresses natural disasters (e.g. floods, forest fires, earthquakes, tsunamis, volcanoes, landslides and storms) and man-made disasters (e.g. industrial, nuclear accidents and terrorism attack), both inside and outside the EU.

EFAS has developed into a unique system that serves two purposes. It provides:

- The European Commission with harmonized overview information about forecast and ongoing floods across Europe (i.e. for the preparation and management of aid during a flood crisis).
- National hydrological services and water authorities with medium-range and catchment-based flood information thereby raising their preparedness for future flood events by complementing information from their local and regional systems.

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EFAS has developed in strong collaboration with a variety of organisations. These fall into four broad categories.

- National meteorological services, consortia (e.g. LAM consortia) and NWP centres.
- National hydrological services.
- Private sector.
- European and international organisations.

Box A gives some information about the contributions made by the stakeholders and partners of EFAS.

Initial operations phase of EFAS

This initial operations phase of EFAS (2011–2013) involves four centres:

- EFAS dissemination centre
- EFAS computational centre
- EFAS hydrological data collection centre
- EFAS meteorological data collection centre

The overall coordination of the project and the contract management of these four centres remain with the European Commission's Joint Research Centre (JRC). This will also continue to provide off-line development and research support for improving the operational services.

The role of the individual centres is described in Box B.

Stakeholders and partners of EFAS

A

National meteorological services, consortia (e.g. LAM consortia) and NWP centres

- ECMWF's medium-range weather forecasts are key inputs for EFAS. Currently use is made of forecasts and re-forecasts of surface data from the high-resolution model (with geographical resolution of about 16 km) and Ensemble Prediction System (EPS, with a geographical resolution of about 32 km). With 104 single forecasts a day, the ECMWF products constitute the bulk input of the probabilistic EFAS.
- Deutscher Wetterdienst (DWD, Germany) provides deterministic predictions of surface variables as input to EFAS (COSMO-EU, with a geographical resolution of 7 km, and DWD-GME, with a geographical resolution of 30 km). They are an important part of the combined hydrological ensemble prediction system as they introduce a different meteorological model to the hydrological ensemble system.
- The Limited Area Ensemble Prediction System developed within the international COSMO Consortium (COSMO-LEPS, run at ECMWF by the COSMO members: Germany, Greece, Italy and Switzerland) provide limited-area ensemble predictions of surface variables (with a geographical resolution of about 7 km). They are an important part of the combined hydrological prediction system, in particular over mountainous terrain within the COSMO-LEPS domain. The COSMO-LEPS modelling framework uses a version of the DWD model and drives it with initial conditions from the ECMWF EPS.

National Hydrological Services

- Currently 30 services, which are responsible for more than 80% of all trans-national river basins in Europe, have agreed to receive EFAS information for testing purposes and provide feedback to improve the system.
- 27 water authorities provide hydrological discharge and water level data for EFAS in realtime.

Private sector

- Commercial companies, small and medium-sized enterprises or commercial arms of national institutes have been involved in EFAS. Examples are Atkins Ltd (data collection and database set-up), PCRaster (provider of specialized GIS software) and several consultancies working with JRC to support their developments.

European and international organisations

- WMO hosts the Global Runoff Data Centre (GRDC) which was involved in collection of real-time river discharge for EFAS.
- The Monitoring and Information Centre (MIC) in the European Commission in Brussels is the operational heart of the Community Mechanism for Civil Protection in Europe. The MIC receives EFAS information for improved aid management. Any country affected by a major disaster – inside or outside the EU – can launch a request for assistance through the MIC.
- The European Earth monitoring programme GMES (Global Monitoring for Environment and Security) addresses emergency response for floods in Europe through EFAS.

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B

Roles of the four EFAS centres

EFAS dissemination centre

The EFAS dissemination centre will analyse the EFAS results provided by the EFAS computational centre, investigate any on-going floods in Europe and issue early flood warnings to partners of the EFAS network. Furthermore, feedback on flood forecasts and performance of the system will be collected and reviewed at the EFAS annual meetings organised in close collaboration with the JRC. The EFAS dissemination centre is the most visible part of the EFAS chain and is led by the Swedish Meteorological and Hydrological Institute (SMHI) in collaboration with the Slovakian Hydrological and Meteorological Institute (SHMU) and Rijkswaterstaat (RWS, The Netherlands).

EFAS computational centre

The EFAS computational centre will be responsible for the transfer of the EFAS computational tasks from a research and development environment into operations with a guaranteed 24/7 support, together with associated testing and support for further research and development. This role will be performed by ECMWF. – for more details see the section concerning 'Operational EFAS at ECMWF'.

EFAS hydrological data collection centre

The EFAS hydrological data collection centre will manage an existing network of data providers for real-time hydrological observations, set up the data collection system for discharge and water level, implement quality control on the real-time data and provide the data in an agreed format for EFAS, operating with guaranteed 24/7 support. This task will be performed by a consortium based in Andalusia (Spain) formed by ELIMCO SISTEMAS (private company) and the Environmental Information Network of Andalusia (REDIAM) (public sector).

EFAS meteorological data collection

The EFAS meteorological data collection centre will manage an existing network of data providers for real-time and historic meteorological observations, set up the data collection system for surface observations, implement quality control on the real-time and historic data time series and provide the data in an agreed format for EFAS. This part of the is managed by the JRC through exiting framework contracts.

EFAS performance in the past

The performance of EFAS has been assessed using a range of verification metrics, both in a statistical sense based on several years and for selected key events.

Information about hits and false alarms for all EFAS warnings are collected for flood events throughout the year and presented during the EFAS annual meeting to all partners. Figure 1 shows such a statistic for the last four years and illustrates that there have been many more hits than false alarms. Here a 'hit' is counted if EFAS has issued an alert to a partner organisation and somewhere within the catchment flooding has been reported. A 'false alarm' is counted if flooding was predicted but not observed or, if in the days following the warning, EFAS has forecast a decreasing probability for flooding. In some cases, feedback from the partners could not yet be collected or was not provided. Clearly, 2010 was a busy year for the EFAS forecasters with almost twice as many alerts sent out as in previous years. Although this is mostly due to the many floods that took place in 2010, it also reflects that alerts are sent out with lower probabilities in order to achieve longer lead times. Average warning lead times ranged between 6 to 3 days.

A more objective, statistical approach to evaluate the skill of EFAS has been completed for a period of ten years within the framework of the SAFER (Services and Applications For Emergency Response) project. This analysis showed that the skill has been progressively increasing over the past ten years due to improved NWP inputs and higher-resolution observational networks used to calculate the initial conditions (*Pappenberger et al.*, 2010).

The Central European floods in May/June 2010 serves as an example how the different actions at the EU level worked, for the first time, hand in hand to provide improved flood and crisis management. Figure 2 shows the EU actions on the floods. The triangles indicate river basin authorities which received EFAS alerts with at least a 3 day lead-time warning, at some locations up to 6 or 7 days. Clearly, EFAS forecasts picked out the Vistula, Odra, and Danube tributaries as being at risk of flooding affecting Poland, Germany, Czech Republic, Austria, Hungary, Slovakia and Romania.

For the first time, the Monitoring and Information Centre (MIC) received EFAS information on a daily basis and used it to prepare aid actions in advance and so was prepared when Poland (19 May) and Hungary (25 May) requested international assistance through the MIC (indicated by MIC-PL and MIC-HU in Figure 2). Also, although EFAS is primarily designed to provide early flood warnings, EFAS information helped MIC to keep an overview of what was reported in terms of flooding and whether second flood waves were predicted.

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Figure 3 gives an example of an EFAS forecast associated with the May/June floods. This shows which rivers were expected to be affected by flooding. Also shown is a hydrograph indicating that the rate of flow reaches a peak on the sixth day. During February 2012 the high amounts of accumulated snow raised fears that suddenly raising temperatures could lead to severe snow melt floods. Public information on the possibility of widespread flooding, such as the one issued by the UN News Centre (http://www.un.org/apps/news/story.asp?NewsID=41310) on the possibility of sudden thaw in the Danube, made both EFAS partners and the MIC look to EFAS for a more detailed assessment of the probability for floods 3 to 10 days in advance.

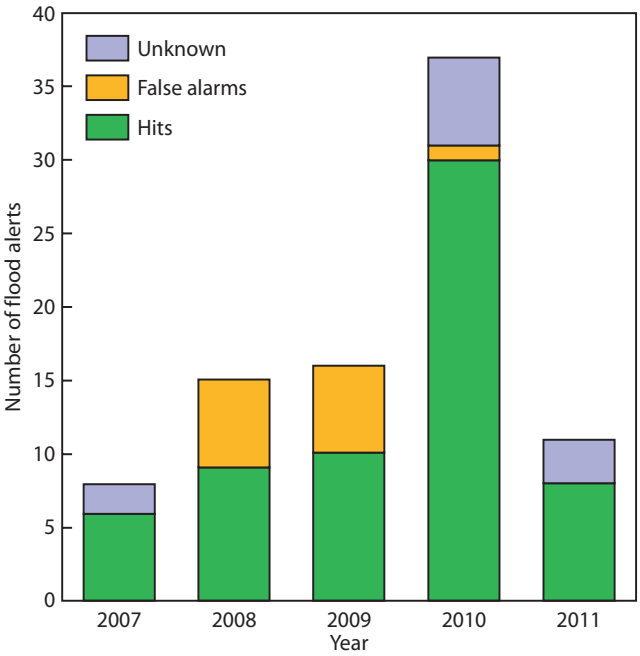

Figure 1 Hits and false alarms from EFAS flood alerts from 2007 to 2011. Note that there are more hits than false alarms and that in 2010 more than twice as many alerts were issued compared with previous years.

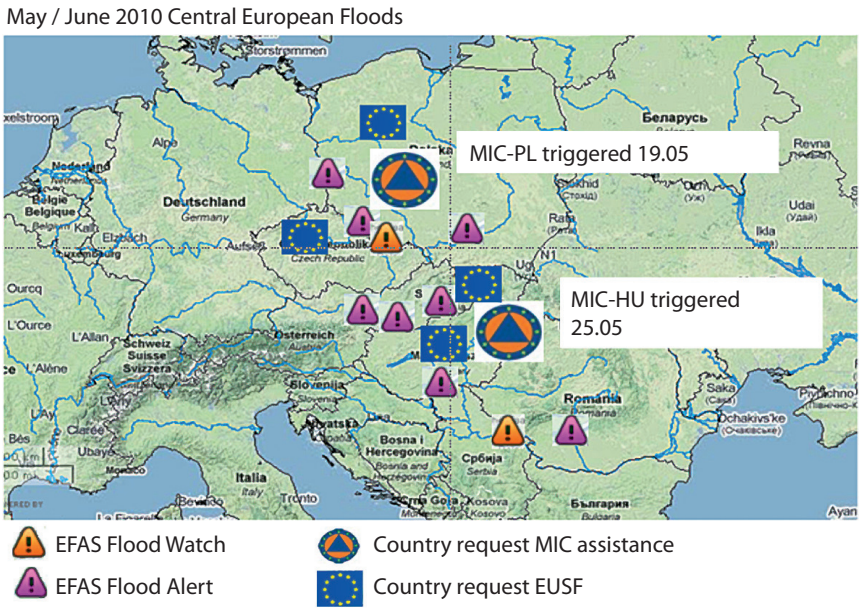

Figure 2 EU actions on the May/June floods in 2010. The triangles refer to flood watches and flood alerts. An 'EFAS Flood Alert' is issued when a probability of exceeding critical flood thresholds are forecast more than 2 days ahead in a river basin which is covered with an existing EFAS Memorandum of Understanding (MoU). An 'EFAS Flood Watch' is issued when a probability of exceeding critical flood thresholds are forecast in a river basin but the forecast event does not satisfy the rules laid out in the MoU (e.g. regarding warning lead time, size of river basin, or location of event). The other symbols indicate where a country requests MIC assistance or support from the European Solidarity Fund.

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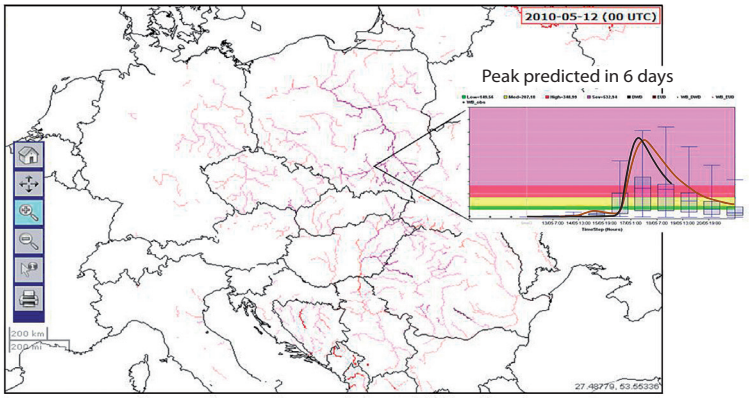

2010-05-12 EFAS FLOOD ALERT for PL – Vistula river basin and tributaries (San and Wiskola)
National EFAS partner and MIC informed on 12-05-2010

Figure 3 EFAS forecasts from 00 UTC on 12 May 2010. All rivers which maybe affected by flooding are shaded in red and purple. Also shown is a hydrograph, which predicts a peak in 6 days. The box plots on this hydrograph represent EPS forecasts: the black line shows the ECMWF high-resolution forecast and the brown line the DWD forecast. The green area indicates the low flood warning level, the yellow the medium, the red the high and the purple the extreme flood warning level.

Operational EFAS at ECMWF

The pre-operational version of EFAS has been set-up on a 5×5 km^2 grid and a 6-hour time step for the ECMWF high-resolution and COSMO-LEPS (COSMO Limited Area Ensemble Prediction System) forecasts and a daily time step for the initial conditions and the ECMWF EPS (Ensemble Prediction System) runs. The lead time is set to 10 days for the medium-range forecasts and 5 days for the LEPS forecasts. Temperature forecasts are corrected for height above ground while precipitation is not corrected.

From a content point of view, the future operational set-up will be considerably enhanced. The most important changes are as follows.

- All forecasts will be running on a 6-hour time step including all those from the EPS.
- Lead times will be 15 days instead of 10 days and twice a week monthly forecasts will be run.
- Weather forecasts will be pre-processed before being input to the hydrological model (e.g. bias corrections for temperatures and precipitation are going to be performed).
- Skill scores for past performance will be calculated automatically.

Another major feature is the availability of a fully independent test environment. During the research phase the disk space and computing time was limited and therefore testing was restricted to a few months of comparison between old and new set-ups. However, the computational centre at ECMWF now has the capability of running extended tests and comparisons with previous versions.

From a technical point of view, the major task of running EFAS within an operational environment splits into implementing a data acquisition suite, integrating the JRC-EFAS system into a workflow software (SMS or ecFlow) and deploying the web infrastructure (EFAS-IS).

Data acquisition suite

EFAS requires a wide variety of input data. Some meteorological input parameters are produced by the NWP models running at ECMWF; these are ECMWF and COSMO-LEPS ensemble forecasts as well as ECMWF deterministic forecasts. In addition DWD routinely provides the latest regional deterministic forecasts.

EFAS also requires the acquisition of observational data:

- Observations collected by the JRC MARS (Monitoring Agricultural ReSources) project.
- Observations from SYNOP stations acquired via the DWD.
- Discharge observations from European Terrestrial Network for River Discharge.

These observations are used to derive initial conditions for the hydrological forecasts and in the post-processing of the forecast discharge rates.

The NWP forecasts and observations from external providers (JRC and DWD) are acquired by the ECMWF data acquisition suite. Its task is to regularly contact external FTP servers and fetch any new data. The retrieved files are stored on the file system of the LINUX cluster for use by the operational EFAS. The data is also stored permanently in the ECMWF Data Handling System.

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Workflow software

ECMWF currently uses SMS (Supervisor Monitor Scheduler) as a workflow software to manage the operational and research work. SMS is an application that enables users to run a large number of programs which may have dependencies on one another. It provides a controlled environment with reasonable tolerance of both hardware and software failures, combined with good restart capabilities. Furthermore it is a very good tool for running different versions of the EFAS suite (e.g. the operational EFAS system at ECMWF and an identical EFAS shadow system at the JRC for development).

Figure 4 shows the experimental set-up of the EFAS suite which is run on the ECMWF LINUX Cluster. The suite is set up using three main families: a make family ('make') that installs the EFAS software and initializes the computations, a main family ('main') which computes the forecast and a lag family ('lag') for archiving and distribution of results. Forecasts in the main family are currently run twice daily at 00 and 12 UTC driven by the ECMWF EPS ('eue'), ECMWF high-resolution forecast ('eud'), DWD forecasts ('dwd') and COSMO LEPS ('cos', 12 UTC only). Forecasts are (where appropriate) directly triggered from other suites running at ECMWF. For example, the EFAS/ECMWF implementation using COSMO forecasts is directly triggered from the COSMO suite running at ECMWF; this allows a more timely delivery of the EFAS forecast. In addition to executing the forecasts, the suite performs large parts of the pre-processing of input data and post-processing of results.

ecFlow is a new workflow software, also written by ECMWF, which will replace SMS over the next 18 months (see *ECMWF Newsletter No. 129*, 30–32). To a large extent it is backward compatible and will be available freely from ECMWF early in 2012. All EFAS suites will be migrated to use ecFlow in line with the migration of the other operational suites running at ECMWF.

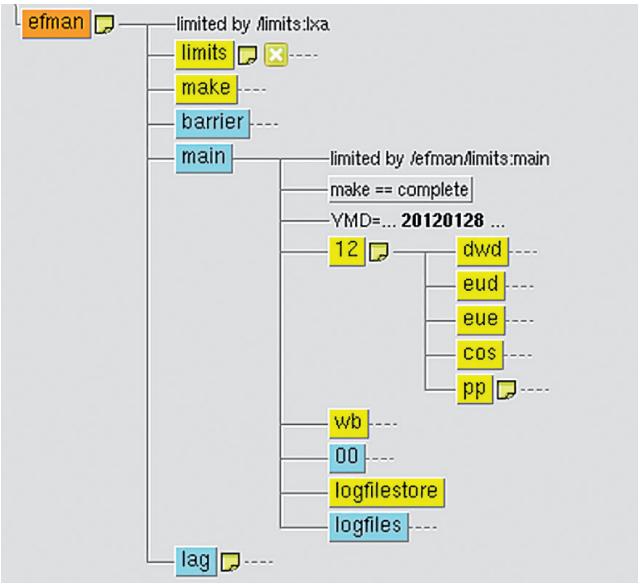

Figure 4 A diagram of the experimental EFAS suite. See the text for information about the components of the EFAS suite.

The EFAS Information System (EFAS-IS)

The EFAS-IS (http://efas-is.jrc.ec.europa.eu) is a password protected web-portal where EFAS partners (such as National Hydro-Meteorological Services, the MIC) can browse, in an easy and intuitive way, different aspects of the most recent or past forecasts as spatially distributed information. An example is shown in Figure 5 which displays the reporting points where the maximum discharge is expected within the next 5 days or more. Also indicated are when the maximum discharge is expected and the highest alert level exceeded by a certain forecast.

In addition, maps with different contents (e.g. maps with the flood probability of different meteorological models, precipitation forecasts and combined probability maps) can be activated or overlaid with other shapes such as land use or urban areas to see whether the flooding is forecast to occur in a potentially vulnerable area. Critical points in the river channels (i.e. pixels showing an increased probability of flooding over various forecasts) are linked to time series of flood threshold exceedances in order to provide more detailed information. ECMWF will install the EFAS-IS and fulfil administrator duties, such as insert new users, keep references up to date and follow up the forum discussions.

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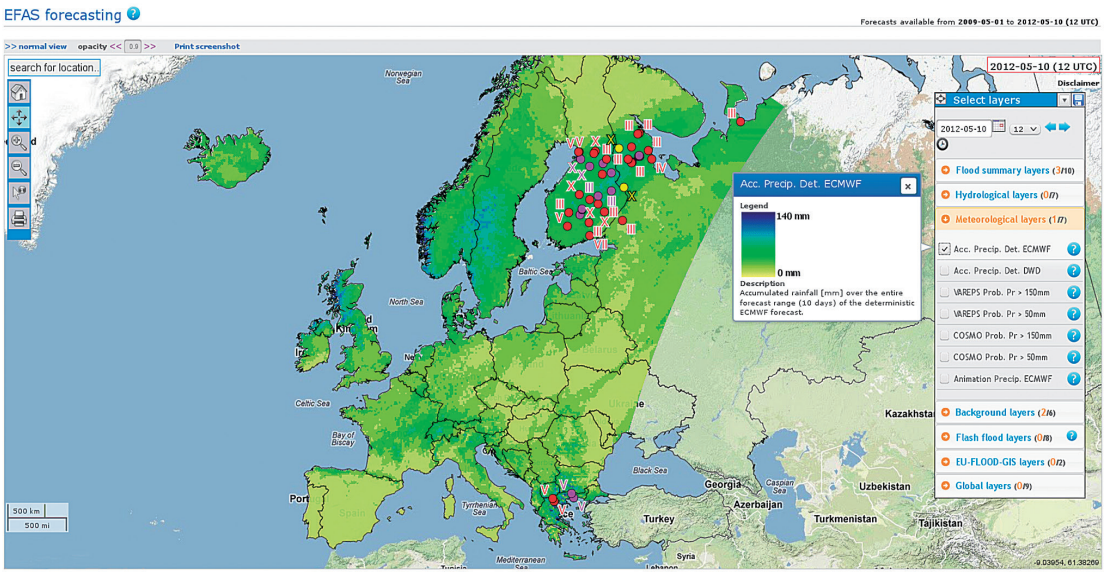

Figure 5 Screenshot (DATE) of EFAS-IS displaying reporting points where the maximum discharge is expected within the next 5 days or more. Roman numerals denote when the maximum discharge is expected. The colours indicate the highest alert level exceeded by a certain forecast (purple being extreme and red being high).

Benefits of an operational EFAS

The following are some of the key benefits of an operational EFAS for the Member States' national hydrological services.

- Timely information on possible flood situations across Europe more than 3 days in advance, based on multiple medium-range weather forecasts. This allows the national services to compare their own results against another reference model and complement their systems with information derived from different NWP inputs.
- Consistent and coherent probabilistic meteorological and hydrological predictions, allowing users not only to estimate the most likely scenario but also the probability of occurrence of any event of interest.
- Increased interactions between institutions developing meteorological and hydrological numerical prediction systems.
- Participation in EFAS as an exchange platform for information, methods and data.

The European Commission is going to directly benefit from a consistent, harmonized and timely overview of ongoing and forecast floods across Europe, including access to expert knowledge on floods through the EFAS activity and forecaster team.

Benefits are not restricted to the hydrological community. In fact, an operational EFAS has tangible benefit for the meteorological NWP communities.

EFAS produces real-time simulations of hydrological processes not just for individual catchments, but across Europe with a resolution of 5 km. Therefore, EFAS simulations can be used for verification of NWP models. This allows the identification of deficiencies in the NWP system, especially in the land surface representation. For example, in the case of ECMWF, certain components of the EFAS hydrological model can be used to improve the land surface model HTESSEL, leading to a better representation of surface fluxes and freshwater flux into the oceans. Along the same lines, some components of HTESSEL could be adopted by the EFAS system. Such synergy would accelerate these developments within ECMWF's core activities.

NWP systems are steadily moving towards higher resolutions (closer to the 5-km resolution of EFAS), making the coupling of meteorological and hydrological modelling components possible, also for operational NWP systems. Furthermore, EFAS fosters increased awareness and use of ECMWF products within the hydrological user community.

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EFAS has become a distinctive means for the meteorological centres to verify the skill of their NWP models with regards to hydrologically-relevant surface variables. For example, the collection of river discharge measurements across Europe allows the verification of integrated spatial and temporal surface variables. EFAS predicts extremes in river flows which can be used to verify the quality of ECMWF's forecast data in cases when heavy rainfall leads directly to fluvial flooding. This supports one of ECMWF's main goals of providing early warnings for severe weather.

In summary, EFAS has developed into a unique tool for forecasting floods across Europe that is embedded in a large network of hydrological and meteorological services as well as civil protection agencies. The operational phase of EFAS that is starting soon will not only help to improve the preparedness for floods across Europe and its crisis management, but also be a very useful tool to improve NWP models through European-wide verification of the hydrological response to the meteorological model outputs.

Further reading

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