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GEOGRAPHICAL INFORMATION SYSTEMS – AN INTEGRAL PART OF THE EUROPEAN FLOOD ALERT SYSTEM (EFAS)

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Over the past ten years we have observed the development of powerful early warning and decision support systems for natural and man-made hazards such as forest fires, tsunamis, floods, oil spills, chemical releases in air and water and many more. Their development became feasible through the revolutionary increase in computing and network power over the past years and the advanced Geographical Information System (GIS) analysis tools that are now available. Traditionally GIS was rather associated with static data such as topography, forest areas, urban areas or infrastructure, occasional satellite images, allowing to assess current situations and to make projections for the future – but all in a rather static way. The incorporation of dynamic data sets such as remotely sensed data (vegetation cover, snow cover), gridded weather forecasts (precipitation, temperature, evapotranspiration), and weather station observations, nowadays usually received at high frequencies, into a GIS environment forms the basis of effective operational decision support tools. GIS allows this information to be displayed easily and to be combined with other information locally or through internet applications, making GIS based applications very powerful and useful communication tools.

An example of an early warning system that has recently been developed with a strong GIS component is the European Flood Alert System (EFAS). Severe river floods with trans-national dimensions and important socio-economic impact are not uncommon in Europe. It has been estimated that between 1998 and 2002 floods in Europe caused about 700 deaths, the displacement of about half a million people and at least 25 billion Euros in insured economic losses (EEA, 2003). The Elbe and Danube floods in 2002 (Brázdil *et al*., 2005; Yiou *et al*., 2006, Toothill, 2002), were a wake-up call for the National flood forecasting centres as well as for the European Commission that effective flood management requires coordinated actions among countries sharing the same river basin. It also highlighted that a spatial overview of ongoing and upcoming flood events on European scale that could be used for effective international aid and crisis management does not exist.

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The European Commission reacted by promoting new strategies for flood prevention and protection, with a focus on coordinated actions among countries sharing the same river basin (European Commission, COM(2002) 481) promoting also the effective use of Geographical Information Systems for flood hazard and flood risk mapping. In 2002 the development of a European Flood Alert System (EFAS) was launched to increase preparedness for floods through novel approaches in flood forecasting applied to entire river basins and Europe as a whole. Specifically, EFAS provides flood forecasting information on catchment level for the whole of Europe with warning times up to 10 days. Since its launch it has matured to a pre-operational system providing twice a day complementary flood forecasting information to currently 24 EFAS partner organisations responsible for about 80% of the major trans-national river basins in Europe (Thielen *et al*., 2008, Bartholmes *et al*., 2008, Ramos *et al*., 2007, and http://efas.jrc.it) (figure 1).

A European wide flood alert system would not be possible without a strong geographic information system (GIS) component. Therefore, EFAS has been developed on two important pillars: one is the state-of-the-art of meteorological weather inputs, the other a strong GIS environment. For the first pillar, forecasting data including full weather ensemble prediction systems (Buizza *et al*., 1999, Buizza *et al*. 2007) from the European Centre for Medium-Range Weather Forecasts (ECWMF – http://www.ecmwf.int), the German weather service (DWD, http://www.dwd.de) and the COSMO-LEPS consortium (Marsigli *et al*., 2005) are incorporated into the system. With the recently integrated COSMO_LEPS, EFAS now runs a total of 68 different weather forecasts through the system for each flood forecast providing a probability distribution of possible flood events up to 10 days in advance.

The second pillar is a strong geographical information system capable to make use of the existing spatial data sets relevant for hydrological processes and to provide estimates of streamflow at any point along the river system. For this purpose the GIS-based hydrological rainfall-runoff-routing model LISFLOOD (van der Knijff and de Roo, 2007, de Roo *et al*., 2000) was developed at the DG JRC, with a specific focus on simulating floods in large, transnational river basins encompassing a variety of applications including flood forecasting, and assessing the effects of river regulation measures, land-use change and climate change on hydrological processes. To fulfill these objectives the dynamic GIS language PCRaster (http://pcraster.geo.uu.nl) and the Python scripting language were used. The PCRaster environmental modelling language is a high-level computer language that uses spatio-temporal operators with intrinsic functionality especially developed for the construction of spatio-temporal models. This has the advantage that models such as LISFLOOD can be programmed and structured with a strong geographical component allowing on one hand to assimilate easily any useful spatial information into the model and on the other hand to easily overlay model results with other geographical information, e.g. urban areas, road, snowcover maps, etc. A number of European data and information layers necessary to describe the multi-catchment environment are readily available at the DG JRC. This includes most soil and land-use related parameters as well as hydro-geomorphological features which can be obtained from existing data sets such as the Soil Geographical Database of Europe (King *et al*. 1997, Lambert *et al*., 2003), the HYPRES database on hydraulic soil properties (Wösten *et al*. 1999), the CORINE land use database (CEC 1993), and pan-European river network databases (Hiederer and De Roo, 2003; Vogt *et al*., 2007).

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In addition to spatial layers and meteorological forecasts, EFAS also requires hydrological and meteorological information from the European Member States. The most important data are the historic and real-time rainfall, temperature and river flow observations from hydrological and meteorological station networks. These data are needed to calibrate and validate the system, and also to calculate the initial conditions at the onset of a flood simulation and to calibrate the model on historic events. Other information that can be approximated but would nevertheless improve the quality of the EFAS forecasts considerably are for example river dimensions, relational information between level height and discharges, but also the position and size of lakes, reservoirs and their operating rules. Collecting these data on European scale is a major challenge. In order to achieve data collection on European scale the JRC has launched the European Flood Geographical Information System (EU-FLOOD-GIS) project and the European Terrestrian Network for river discharge (ETN-R). The EU-FLOOD-GIS project consists of a metadata catalogue listing information on available hydrological and meteorological data in Europe, an access restricted database containing historic hydrological and meteorological time series data in a harmonized format as well as other spatial data including for example river cross sections or flood extent vectors, and a data collection module that collects station data in real-time, performs quality checks and data processing to standard units before the data are inserted into the database. The EU-FLOOD-GIS has been designed to hold different types of geographical data ranging from point data, grids, flood extent polygons and cross section data and other information and will be major contribution not only to EFAS but also for other EC research related to floods, droughts, and climate change. The ETN-R project focuses on the collection of near real-time river discharge data over Europe and quality checking of the data which are also incorporated into the EU-FLOOD-GIS.

Finally, a very important part of EFAS concerns the dissemination and visualization of the latest flood hazard information. This is done via the EFAS information system (http://efas-is.jrc.it). EFAS-IS is a password protected web interface, which uses as its main tools PHP, PHPMapScript, and MapServer (http://mapserver.gis.umn.edu/), a development environment for building spatially-enabled internet applications. EFAS members can browse in a very easy and intuitive way different aspects of the most recent or past forecasts as spatially distributed information. Maps with different contents, e.g. maps with the flood probability of different meteorological models, precipitation forecasts, combined probability maps, etc., can be activated or be overlaid with other shapes such as land use or urban areas to see if the flooding is forecasted 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.

EFAS has been successfully providing flood forecasts in a pre-operational mode twice a day now to all partners since 2005. Feedback to EFAS is very positive, in particular because of the clear and concise visualization products developed. With the availability of more detailed spatial information via the data collection projects EU-FLOOD-GIS and ETN-R and the constant improvement in the GIS based hydrological model, EFAS will increase its role in serving as a common platform to support National flood forecasting centers. Furthermore, an update of the EFAS information system is foreseen in the near future, using the latest development in web-based Geographical Information Systems, Web 2.0 concepts, and document management systems to increase user-friendliness and visualization of the EFAS products. The roadmap for an operational

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EFAS is currently being discussed and it is expected that by 2010 the system will be ready for transfer.

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FIGURAS

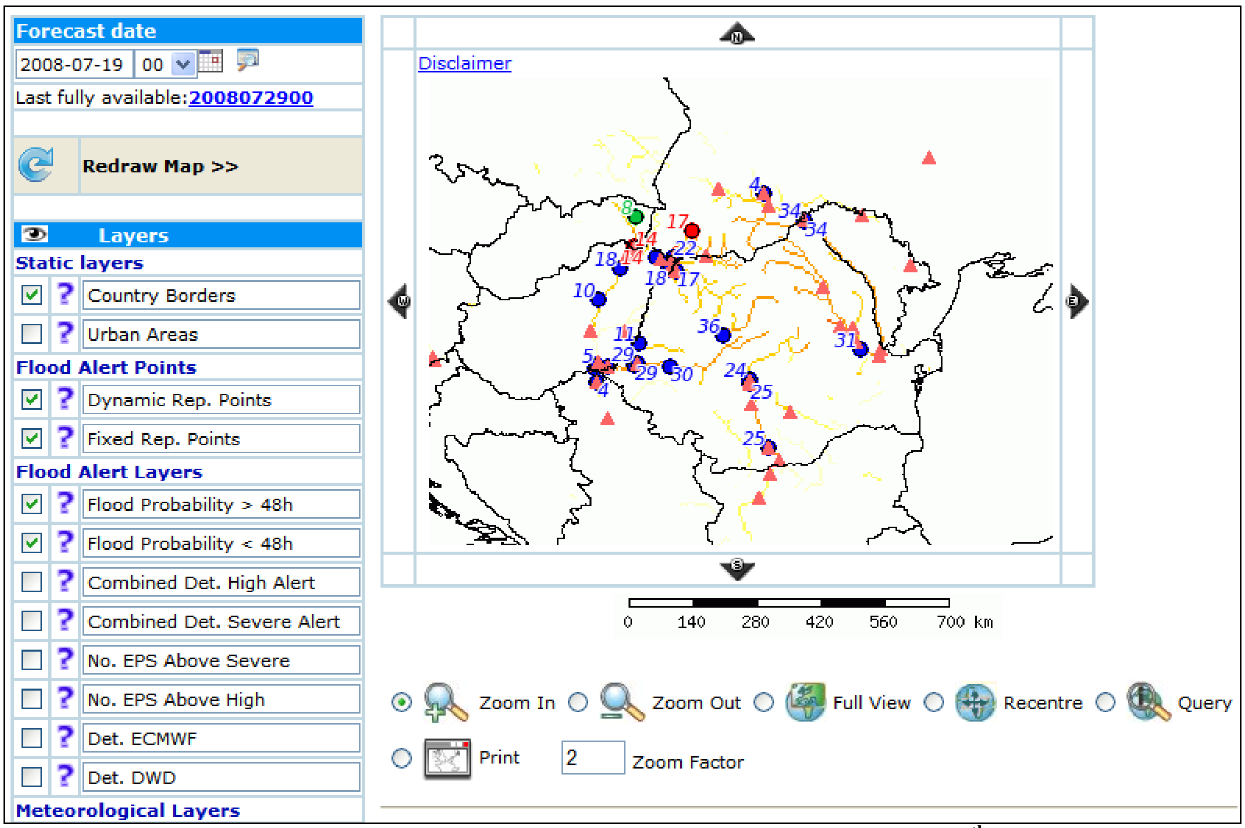

Figure 1: Screenshot from the EFAS-IS webpage from the forecasts of 19th July, 7-9 days before the severe flooding in Romania, Slovakia, southern Poland, Ukraine and Moldova. The webpage illustrates at first glance which river stretches are expected to exceed the EFAS high alert threshold in more than 3 days. The reporting points indicate the number of EPS exceeding the EFAS high alert. By clicking on the reporting points, the time series of threshold exceedances are also displayed. The user can activate any other layers, e.g. rainfall maps, main rivers, urban areas or topography, any time.