SOME RESEARCH NEEDS FOR RIVER FLOOD FORECASTING IN FP6

1. Introduction

1.1 The context of ACTIF

The Accompanying Measures activity **ACTIF** (Achieving Technological Innovation in Flood Forecasting), contract number EVK1-CT-2002-80014-ACTIF, has been established under 5th Framework Programme (FP5) to cluster the results of the FP5 research projects on flood forecasting funded under different paragraphs of the FP5 work programme. Links to these projects are available from the **ACTIF** web site http://www.actif-ec.net. **ACTIF** commenced in February 2003, with duration of 36 months.

This document summarises Research and Development (R&D) needs that have been identified by the members of the **ACTIF** steering committee following the first project workshop in Bologna (24-5 Nov 2003). The issues outlined below are intended to amplify the more general context of R&D described in the work programme of a potential 6th Framework Programme (FP6) Integrated Project on flood and drought forecasting under within the priority of global change and ecosystems.

1.2 Types of flood

Before detailing the research requirements in the area of flood forecasting, we have defined the phenomena of flash floods and other plains floods. Fluvial floods can be separated into:

- Flash floods
- Plains floods.

In addition, flooding can be caused by a variety of other mechanisms including:

- coastal flooding generated by waves and storm surges,
- catastrophic failure of infrastructure such as dams
- groundwater floods from long term accumulation of precipitation, and
- “pluvial” floods in which local drainage systems cannot evacuate intense storm rainfall.

This R&D position paper concentrates on the needs for fluvial flood forecasting research and not the other causes of floods described above.

It has been proposed by the **ACTIF** steering committee that “flash” and “plains” floods should be defined as in the following paragraphs.

1.3 Flash floods

A flash flood can be defined as a flood that threatens damage at a critical location in the catchment, where the time for the development of the flood from the upstream catchment is less than the time needed to activate warning, flood defence or mitigation measures downstream of the critical location. Thus with current technology even when the event is forecast, the achievable lead-time is not sufficient to implement preventative measures (e.g. evacuation, erecting of flood barriers). This definition decouples the concept of a flash flood from any static time-scale based definition in terms of *n* hours lead threshold time, and introduces both a location and an event specific definition for a flash flood. It is possible to identify risk areas in general, particularly settlement in upper valleys, where time to peak of rivers is known to be short. These areas should be given particular attention for applications of QPF, radar rainfall measurement and real-time hydrological forecasting.

1.4 Plains floods

Flood events that do not meet the definition of a flash flood fall within the more general category of plains floods. Plains floods have a forecast lead-time that is larger than the time-scale needed for implementing protective measures downstream. This lead-time exceeds, by definition, the time required for the implementation of the necessary downstream protective and mitigation measures. For example evacuating of a Dutch city situated on the river Rhine requires two days, while a peak discharge travelling down the river Rhine from Germany can be predicted with high accuracy up to four days ahead. It is important to take account of the variations in flood response, even in a moderately sized catchment, e.g. 10,000 km^2. Whereas the main river flood response may allow adequate time for response procedures, smaller but not "flashy" catchments may experience severe flooding on a shorter time scale, requiring specific response from the authorities (e.g. Elbe, 2002).

2. Flood forecasting research requirements

We have identified four categories of research relating to flood forecasting. These are detailed below

2.1 Plains floods.

Use of quantitative precipitation forecasting for continental and regional scale flood forecasting

Plains floods often occur in densely inhabited areas along the principal river systems in Europe. The times of concentration time of the catchments allows the use of large-scale deterministic and probabilistic Quantitative Precipitation Forecasts (QPF) from numerical weather prediction models. Regional flood management in most countries further requires the QPFs and hydrological forecasts over regional hydrological scales. A key element in this process is the downscaling of the forecasts from large-scale meteorological models to the regional hydrological scales. These in combination with Quantitative Precipitation estimates (QPE) from radar, satellites or gauges can be used to:

- Increase lead-times;
- Reduce the uncertainty band in stage and/or discharge prediction.

Research is needed on exploiting the entire range of QPE and QPF products in continental and regional scale flood forecasting. The research should complement that under the FP5 Projects CARPE DIEM, EFFS and FLOODRELIEF

Forecasting of floods caused by extreme precipitation events

A potential effect of climate change inferred from several GCM scenario simulations is an increased frequency of extreme river discharges in the future. Research is required on forecasting floods caused by extreme precipitation event conditions. In this context "extreme" may be interpreted as of annual probability of less than 1%. Alternatively, rainfalls above a given threshold of duration and accumulation (intensity) could be considered to define, characterise and provide recognition of extreme events.

Quantifying losses caused by floods

The damages caused by plains floods are significant and threaten housing areas, industrial and production infrastructure. Research is needed on quantifying losses by overlaying maps of quantities simulated through physical models (depths, duration of flood, rate of rise and flow velocities), with Geographical Information System (GIS) data on land-use, infrastructure and population density. The research should complement that proposed under the FP6 Integrated Project **FLOOD*site***.

Data assimilation techniques for use in real-time flood forecasting

Research is required on data assimilation techniques to be used in real-time operational forecasting for increasing the reliability of the lead-times of forecasts. The following issues require particular attention:

The updating of soil moisture states in the soil moisture accounting modules
The persistence of errors in these model states implies that these have a large impact on the reliability of the forecast, particularly for longer lead times. Both in-situ observations from climate stations and remotely sensed data can be utilised in reducing these errors.

The updating model states of both hydrological models and hydraulic models
Using model-independent state updating techniques, such as ensemble or unscented Kalman filtering. This will allow for state-of the-art updating to be incorporated in forecasting systems, without the requirement of using particular, vendor dependent, modelling systems.

The research should complement that under the FP5 Projects CARPE DIEM, EFFS, FLOODMAN, FLOODRELIEF and MANTISSA.

Reliability of probabilistic medium range flood forecasting

Research is required into the reliability of probabilistic medium range flood forecasting such as introduced in the **EFFS** project of FP5. The usefulness of these forecasts has been demonstrated for a large number of flood events. However, to establish the reliability and consequences of using such forecasts the reliability and *false-warning rates* must be established. To achieve this a number of events in selected river basins in Europe (across the hydrological range) must be studied where these events include both significant events as well as events that remained just below critical thresholds. Good results from demonstrating probabilistic forecasts are necessary to demonstrate effectiveness of method, and to convince end users that this is a viable operational tool. The research should complement that under the FP5 Projects EFFS, FLOODMAN, FLOODRELIEF and MUSIC.

Operational use of reservoirs and floodplain storage

Research is required into the operational use of reservoirs and floodplain storage within a flood forecasting context with the aim of reducing downstream flood peaks, given a (medium-range) forecast. This requires integration of reservoir operation rules into forecasting models, optimisation of reservoir operation and probabilistic forecasting to establish robustness of operation over a range of possible spatial and temporal precipitation and hydrological response scenarios. The research should complement that under the FP5 Projects FLOODRELIEF and MUSIC.

2.2 Flash floods.

Use of quantitative precipitation forecasting and estimates

Flash floods affect many catchments in southern Europe, surrounding the Mediterranean basin, but they are also a problem in densely populated urban areas located in many upland catchments. The short time of concentration for these cases requires maximal use of QPE and QPF techniques available, as well as excellent communication between forecasters and communities at risk. Research is needed to improve QPE and QPFs and to combine the information with the aim of increasing lead-time and decreasing forecast uncertainty. The research should complement that under the FP5 Projects Carpe Diem, MANTISSA and MUSIC.

Flash floods in urban areas

Flash floods in urban catchments are particularly devastating because of the dense concentration of economic valuable assets and infrastructure in metropolitan areas. One area of research is to link “nowcasts” of convective storm events to robust hydrological modelling and analysis to produce useful flash flood predictions in terms of timing, and the spatial and temporal distribution of the runoff. Advances in radar-rainfall estimation, using Doppler and locally based radars and two-dimensional physically based runoff modelling offer the basis to develop tools to improve flash flooding forecasting and to reduce the potential for loss of life and property damage in urban catchments. The research should complement that under the FP5 Projects MANTISSA and MUSIC.

Use of rainfall threshold methods

Research into the use of rainfall threshold methods in combination with GIS spatial and topographic information and water balance accounting is required to assist in identifying, mapping and classifying flash-flood prone areas in Europe (e.g. surrounding the Mediterranean basin) in a systematic manner. This would allow standard and benchmark criteria and tools to be developed. The research should complement that proposed under the FP6 Integrated Project **FLOOD*site***.

The impact of climate change on flash floods

The impact of climate change and related extreme events on flash-flood regime and exposure to flash flood risk requires further research. The research should be focused on extreme events for particular vulnerable areas such as the Mediterranean rim and alpine regions.

Forecasting of flash floods in ungauged catchments

Research on flash flood forecasting is required for ungauged basins, for which little or no measured data are available. The research should complement that under the FP5 Projects CARPE DIEM, FLOODMAN, FLOODRELIEF, MANTISSA and MUSIC and he FP6 Integrated Project **FLOOD*site***.

Forecasting and prevention of floods caused by ice jams

Ice jams can occur when warm temperatures and heavy rain cause a rapid thaw. The rising water breaks the ice layer into large chunks, which block narrow valley sections and structures such as bridges. Two factors which could improve warning for ice-jam floods are improved rainfall and temperature forecasts and monitoring of ice conditions along the river.

2.3 Reducing input uncertainty.

Reduction of uncertainty in estimates and forecasts of precipitation

There are currently four main precipitation measurement methods being utilised in Europe:

- Rain gauges;
- Ground-based radar measurements;
- Satellite measurements;
- Microwave links.

These measurement are either at a point (gauges), spatially distributed (radar and satellites) or limited to a straight line (microwave link). Various ongoing European FP5 projects within the **ACTIF** cluster are investigating the use of these platforms operationally to improve QPE and QPF for flood forecasting purposes. In this context research is needed on integrating the findings of these projects into more reliable precipitation products, with the aim of reducing uncertainty in the estimation and forecast. Methods of interfacing these products and techniques with continental-scale and with regional-scale flood forecasting systems are also required. The research should complement that under the FP5 Projects CARPE DIEM, EFFS, EURAINSAT, FLOODRELIEF, MANTISSA and MUSIC.

Use of quantitative precipitation forecasting and estimates to establish precipitation thresholds

Research to exploring the use of QPE and QPF products in the context of precipitation threshold methods for flash flood prediction is required. Such research is end-user driven, given that experience from interaction with end-users in previous projects has shown that critical precipitation is often preferred to discharge rates at critical locations during the decision process. Methods need to be investigated and tested systematically. The research should complement that under the FP5 Project MUSIC.

Data assimilation – real time updating of flood forecasts

Real-time flood forecasting systems allow the incorporation of new data from a variety of sources during the progress of a flood event. At present the assimilation of data into forecast models is often difficult and restricted to models run by the Meteorological Offices. However, information gathered during a storms, including automated as well as observational measurements, provide a real opportunity to improve forecasts locally. Research is required to develop various updating techniques to ensure the information content from data is maximised across source, pathway and receptor models. This would maximise the use of all data within the system models and build a real-time "learning capability" into the forecast system. The research should complement that under the FP5 Projects CARPE DIEM, FLOODMAN, FLOODRELIEF, MANTISSA and MUSIC.

Research into the use of integrated ensemble techniques

There is a requirement to develop techniques to integrate ensemble precipitation forecasts from different forecast systems ranging from "nowcasts" to regional (one to two days) to medium range (less than two weeks) to climate (greater than ten days) into a seamless and consistent set of ensemble forcing. This would allow the possibility of longer ranges of prediction if fully probabilistic and unbiased QPF products could be produced at high spatial and temporal resolution. The research should complement that under the FP5 Projects EFFS and FLOODRELIEF.

Remote sensing of hydrological parameters

Research on parameters that define the cryosphere, and the integration of these into run-off forecasts has the potential to improve both flood and drought forecasting. Monitoring snow cover extent, and in particular estimating water equivalence of a snowfield, improves hydrological run-off modelling and gives more reliable flood and drought prediction in many Alpine drainage basins in Europe and in similar cases world. Such forecasts will allow businesses, individuals and authorities to take appropriate actions to mitigate risks. In addition, other key hydrological parameters for monitoring and forecasting flood conditions, such as soil moisture, inundation extent and water levels, can be derived from satellite data. Research is needed to exploit the capabilities of recently commissioned and proposed satellite instruments for hydrological state measurement and forecasting. Such research needs to complement other activities within the EC GMES priority. The research should complement that under the FP5 Projects ENVISNOW, EURAINSAT, FLOODMAN and MUSIC

2.4 Communicating forecasting results and inherent uncertainty to the end-user community

Translation of forecasts into warnings

Experience from FP5 projects has shown that forecasting results need to be translated into a language accessible, appropriate and understandable to end-users. This particular issue requires the translation and interpretation of knowledge from the scientific and the forecasting communities into a form for the user, both for “professional partners” (emergency services) and the public, but without loss of important content. Research is needed to develop procedures visualisations, interfaces and training facilities that support the translation of the deterministic and probabilistic forecasting results into a binary “Yes/No” decision on issuing an alert, that is acceptable to the end-user community. The research should complement that under the FP5 Projects FLOODRELIEF, MANTISSA and MUSIC.

Increasing the alert level of the end user community

Research is required to increase the alert level of the end-user community by exercises (for catchment managers and emergency services combined) role-play and training personnel on past and hypothetical events that are simulated through the now available forecasting products for specific basins throughout Europe. The research should complement that under the FP5 Project MUSIC and the FP6 Integrated Project **FLOOD*site***.

Communication platforms for the dissemination of warnings to the public

Research is needed on innovative means and communication platforms for disseminating warnings to the public. This could include encouraging interaction with leading partners in the European communication equipment industry.

This document was finalised by Paul Samuels, **ACTIF** Project Coordinator from contributions of the **ACTIF** Steering Group Members.

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