Use of radar rainfall estimates for hydrometeorological analysis of flash flood events

Marco Borga[1], Francesco Zanon[1]

[1] University of Padova, Padova, Italy.

1 Introduction

Flash floods are localized phenomena that occur in watersheds of few hundred kilometres or less, with response times of a few hours or less (Creutin and Borga, 2003). Such basins respond rapidly to intense rainfall because of steep slopes and impermeable surfaces, saturated soils, or because of human- (i.e., urbanization) or fire-induced alterations to the natural drainage.

Implementation of flood warning systems and community self-help programs is one of the most effective ways to mitigate the flash-flood risk. In many instances, these are the only affordable and sustainable risk mitigation approaches. Unfortunately, flash-flood warning is hampered by a number of limitations, including our limited knowledge of atmospheric and hydrologic generating mechanisms of this type of flood. Lack of knowledge is related to the fact that flash floods develops at time and space scales that conventional observation systems of rain (rain gauge networks) and discharge in rivers are not able to monitor. Since the small basins prone to flash-floods are rarely gauged, response to flash-flood generating storms must be generally predicted without prior hydrological model calibration. Furthermore, the dominant processes of runoff generation may change with the increase of storm severity, and therefore the understanding based on analysis of moderate flood events may be questioned when applied to forecast the response to extreme storms. In this sense, flash flood forecasting exemplifies the ungauged basin problem under extreme conditions.

Radar rainfall estimates have the potential to address flash flood monitoring, improving both the understanding of fundamental scientific questions, including extreme storms and runoff production mechanisms, and the 'distributed' monitoring of flash flood hazard. This presentation addresses some of the developments in the use of radar rainfall estimates for flash flood analysis, and identifies a number of new research issues in this direction. The development of a European network of long-term hydrometeorological observatories, aimed at the creation of a detailed data-set for flash flood events, is specifically emphasised.

Correspondence to: Marco Borga.

marco.borga@unipd.it

2 Specific issues of radar rainfall estimation for flash-flood-generating storms

There are a number of issues which characterise radar rainfall estimation for flash-flood-generating storms, including:

- extreme rainfall rates and accumulations;
- high space and time variability;
- scarcity of rain gauges for rainfall product generation and validation.

Furthermore, flash-flood-generating storms may be enhanced by orography, with the difficulties of radar observations in hilly and mountainous terrain.

The effects of the extreme rainfall setting and of the high space and time variability on radar rainfall estimation have been examined by several researchers (Sanchez-Diezma et al., 2001; Krajewski and Smith, 2002 and references cited therein; Delrieu et al., 2005). This work has shown that well maintained conventional radar systems can estimate rainfall at ground level, even under extreme conditions, provided that a number of precautions are taken, and in particular:

- the siting of the instrument and its scanning protocol is carefully selected and analysed.
- the quality of the instrument is routinely checked.
- the signal processing takes into account the physics of the instrument as well as the properties of the atmospheric and ground targets. A downstream control of the radar rainfall processing can rely on rain-gauge measurements at ground level using a variety of methods.

The scarcity of rain gauges available in flash flood conditions makes it compulsory the use of radar error correction procedures accounting for the physics of the signal processing and of the atmospheric properties, rather than the statistical 'merging' of radar and raingauge data.

When these precautions are taken, different studies have shown that radar-based rainfall estimates are reliable and may be used as input in rainfall-runoff models for flood and flash-flood modelling and forecasting (Dolcinè et al., 2001; Borga et al., 2000; Borga, 2002; Delrieu et al., 2005; Corral et al., 2005). These very positive results should not be hiding some weaknesses:

- Most of these results never had the opportunity to be *coherently validated over a significant number of flash floods events*. The use of *specific experiments* or of limited operational radar data sets is insufficient to test complex combinations of algorithms, especially if high rain intensities are of interest.
- Very few results have been *translated into operational hydrologic applications*.

Furthermore, so far we cannot answer numerous basic questions about radar-rainfall estimation error structure, particularly for flash flood generating storms. What is the probability distribution of the rainfall estimation errors? Are they dependent in space and time from pixel to pixel and from scan to scan? How do they depend on the rainfall regime?

It is clear that the growing impact of flash flood hazard, the potential shown by radar estimates and the above questions form a research agenda for the upcoming years. We advocate that a central role in the research agenda is plaid by the development of a European network of long-term Hydrometeorological Observatories for flash flood monitoring.

3 Development of a European network of long-term Hydrometeorological Observatories (HOs) for flash flood monitoring

The HydrometeorologicalObservatories (Hos) are cooperative structures, linking together hydrometeorological monitoring services, operational forecasting centres and research centres. The common objective of the HO is to observe flash flood by combining:

- conventional hydrometeorological monitoring;
- weather radar observations;
- complementary information acquired from field surveys executed during the days following the event.

Post event field surveys mainly focus on river flood discharges at small scales, compensating the usual lack of runoff data (due to sparsity of the hydrometric network and to its fragility during extreme flood events).

The main motivation for the development of a HOs European network is to observe these locally rare events wherever they occur in a region (with area ranging from 10 000 to 50 000 km^2) and not only in places where refined observation system actually exist.

Using this observation strategy to enhance understanding of flash flood processes supposes harmonization across the HOs domain. This includes substantial research efforts aimed at improving rainfall estimation under extreme storms.

There are two reasons why establishing such a network is timely. The first is operational: several European countries have completed or are going to complete their national weather radar coverage. This provides ground for a common European-wide initiative focused on improving flash flood observation and analysis. The second one is scientific: the network will permit us to advance knowledge on radar rainfall estimation for extreme storms and on flash flood hydrometeorological processes.

A central aspect in the development of the network is the involvement of end users and stakeholders. This will provide opportunities for the diffusion of radar-rainfall products into a diverse array of meteorologic and hydrologic applications.

A first network has been already established in the frame of the EU Integrated Project *FLOODsite* (6th Framework Program). This will be integrated in the next years (*HYDRATE* project) to form the network of six HOs shown in Fig. 1.

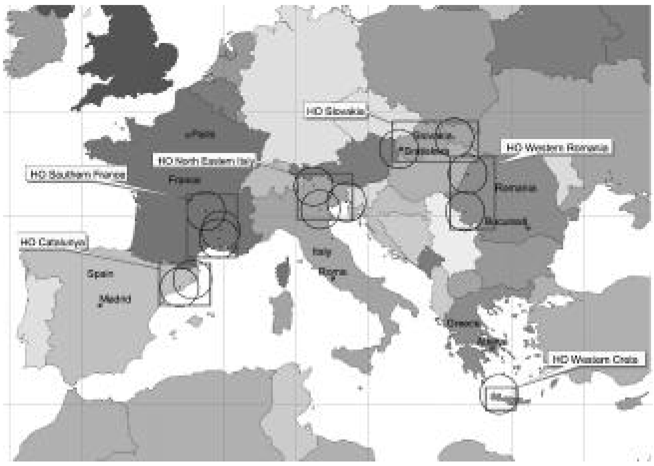

Fig. 1. Locations of the six European Hydrometeorological Observatories. Radar sites and radar coverage (at 120 km) are also shown.

The presentation will provide a summary of first results obtained from the implementation of this flash flood observation strategy.

We are looking forward to joining other hydrometeorological pilot areas, with the aim of exploring different flash flood settings. Flash flood monitoring will thus reveal its greatest potential as an umbrella under which a rich spectrum of concepts and tools can be explored.

Acknowledgements: This work was supported by the European Community's Sixth Framework Programme through the grant to the budget of the Integrated Project *FLOODsite*, Contract GOCE-CT-2004-505420.

References

Borga, M. 2002: Accuracy of radar rainfall estimates for streamflow simulation. *Journal of Hydrology*, 267, 26-39, 2002.

Borga, M., Anagnostou, E. N., and Frank, E., 2000: On the use of real-time radar rainfall estimates for flood prediction in mountainous basins, *Journal of Geophysical Research-Atmospheres*, 105(D2), 2269-2280.

Corral, C., M. Berenguer, R. Sánchez-Diezma, D. Sempere-Torres, 2005. The use of processed radar data for hydrological purposes in the Besòs catchment. *Geophysical Research Abstracts, Vol. 7, 09763, 2005.*

Creutin, J.D., and Borga, M., 2003: Radar hydrology modifies the monitoring of flash flood hazard. 10.10002/hyp.5122, *Hydrological Processes*, 17, 7, 1453-1456, 2003.

Delrieu, G., Ducrocq, V., Gaume, E., Nicol, J., Payrastre, O., Yates, E., Kirstetter, P. E., Andrieu, H., Ayral, P. A., Bouvier, C., Creutin, J. D., Livet, M., Anquetin, A., Lang, M., Neppel, L., Obled, C., Parent-du-Chatelet, J., Saulnier, G. M., Walpersdorf, A., and Wobrock, W., 2005: The catastrophic flash-flood event of 8-9 September 2002 in the Gard region, France: a first case study for the Cévennes-Vivarais Mediterranean Hydro-meteorological Observatory. *Journal of Hydrometeorology*, 6, 34-52.

Dolciné, Andrieu, H., Sempere-Torres, D., and Creutin, D., 2001. Flash Flood forecasting with a coupled precipitation model in a mountainous Mediterranean basin. *Journal of Hydrologic Engineering (ASCE*). 1: 1-10.

Krajewski, W.F., and Smith, J. A. 2002. Radar hydrology: rainfall estimation. *Adv. Water Resour.*, 25, 1387–1394.

Sánchez-Diezma, R., Sempere-Torres, D., Creutin, J.D., Zawadzki, I., Delrieu, G. 2001. Factors affecting the precision of radar measurement of rain. An assesment from a hydrological perspective. *30th International Conference on Radar Meteorology, Munich, Germany, 19-24 July 2001. 573-575.*