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Preface

Flash floods: Observations and analysis of hydro-meteorological controls

1. Introduction

Understanding the hydro-meteorological processes that control flash flooding is extremely important from both scientific and societal perspectives. On the one hand, flash floods rank highly among natural disasters in terms of the number of people affected and the number of fatalities. The potential for flash flood casualties and damage is increasing in many parts of the world due to the social and economic pressures on land use. Also, as the planet warms and the hydrological cycle intensifies, there is the possibility that flash floods increase (Huntington, 2006). On the other hand, the analysis of flash flood processes is important scientifically because these events often reveal aspects of hydrological behaviour that either were unexpected on the basis of weaker responses or highlight anticipated but previously unobserved behaviour (Smith et al., 1996, 2005; Delrieu et al., 2005; Archer et al., 2007; Braud et al., 2010). Flash floods are associated with short, high-intensity rainfall rates, mainly of convective origin that occur locally. Runoff rates often far exceed those of other flood types due to the rapid response of the catchments to intense rainfall, modulated by soil moisture and soil hydraulic properties. Characterising catchment response during flash flood events, thus, may provide new and valuable insights into the rate-limiting processes of extreme flood response and their dependency on catchment properties and flood severity (Carpenter et al., 2007). Moreover, local flood-producing processes may be analysed more easily in the typical small scale flash flood basins than in larger catchments where the regional combination of controls can be more important (Merz and Blöschl, 2008a,b).

However, the small spatial and temporal scales of flash floods, relative to the sampling characteristics of conventional rain and discharge measurement networks, make these events particularly difficult to observe. In an investigation of 25 major flash floods that occurred in Europe in the last 20 years, only about one half of the cases were properly documented by conventional stage measurements (Marchi et al., 2010). In many cases, the rivers were either ungauged or the streamgauge structures were damaged by the event. Furthermore, even when reliable stage observations are available, extrapolation of the rating curve and changes in the cross section geometry during the flood, often render the discharge estimates highly uncertain (Di Baldassarre and Montanari, 2009). Similar considerations apply to the rainfall estimation, as the spatial and temporal scales of the events are generally much smaller than the sampling potential offered by even dense raingauge networks (Anagnostou et al., 2006). As these events are locally rare, they are also difficult to capture during classical field-based experimentation, designed to last a few months over a given region, or in experimental catchments with drainage areas of a few square kilometres (Borga et al., 2008).

Flash floods, therefore, place the ungauged basin problem under rather extreme conditions. Process understanding is required for flash-flood risk management, because the dominant processes of runoff generation may change with the increase of storm severity, and therefore, the understanding based on analysis of moderate floods may be questioned when used for forecasting the response to extreme storms (Blöschl and Zehe, 2005; Collier, 2007). However, process understanding and learning from past events is hampered by the observational difficulties of flash floods.

The recognition of the poor observability of flash floods has stimulated the development of a focused monitoring methodology in the last decade, which involves post-flood surveys, use of weather radar observation re-analyses and hydrological modelling (Creutin and Borga, 2003; Carpenter et al., 2007; Gaume and Borga, 2008; Costa and Jarrett, 2008; Bouilloud et al., 2009). The implementation of this observation strategy has led to an improved characterisation of flash floods, both at the individual event scale (Hicks et al., 2005; Delrieu et al., 2005) and at the regional, multi-event scale (Costa and Jarrett, 2008; Gaume et al., 2009). Statistical regional procedures have been developed which may explicitly incorporate data from post-flood surveys to improve the estimation of extreme quantiles (Gaume et al., 2010). Ongoing research focuses on understanding how the data generated by this observational methodology may be used, for instance, to discriminate between various hypotheses of runoff generation under flash flood conditions (Braud et al., 2010) and, more generally, to identify patterns of predictability (Blöschl, 2006).

2. Overview of the special issue

This special issue of the Journal of Hydrology on "*Flash floods: Observations and analysis of hydro-meteorological controls*" includes 21 articles, which are organised into four main themes: (i) monitoring of flash flood-related processes; (ii) regional analysis of flash flood regimes; (iii) representation of space–time and process variability in flash flood models; (iv) hydro-meteorological models for flash flood forecasting and warning.

In the first theme on *Monitoring of flash flood-related processes*, two papers (Anagnostou et al., 2010; Bouilloud et al., 2010) deal with the use of weather radar observations for rainfall estimation at the space and time scales of concern for flash flood monitoring. Kirstetter et al. (2010) propose a methodology for characterising the error structure of quantitative precipitation estimates by radar. Flow rate measurements under flash flood conditions represent a challenging problem. The paper by Le Coz et al. (2010) conducts

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comprehensive performance tests for assessing and improving the quality of the Large-Scale Particle Image Velocimetry technique applied to measurements of flash-flood peak discharges. Gourley et al. (2010) provide a description of a survey-based data collection methodology for studying the impacts and characteristics of flash floods. The question of the free and unrestricted exchange of hydro-meteorological data is particularly important for advancing process understanding and developing better management policies for locally rare events, such as flash floods. The paper by Viglione et al. (2010) provides a detailed analysis of the mechanisms and barriers that limit the access to hydro-meteorological data in Europe.

In the second theme on *Regional analysis of flash flood regimes*, two papers (Parajka et al., 2010; Koutroulis et al., 2010) analyse the differences in the long-term regimes of extreme precipitation and floods in the Alpine-Carpathian range and in Crete, respectively. Seasonality indices and atmospheric circulation patterns are used in these papers to understand the main flood-producing processes. Gaume et al. (2010) propose a method for using major flash flood events in ungauged catchments to investigate flash flood regimes and to reduce the uncertainties in estimating regional flood quantiles The paper by Marchi et al. (2010), which characterises the rainfall–runoff relationships of 25 extreme flash floods in Europe, marks the transition from the monitoring and analysis themes to the modelling themes.

In the third theme on *Representation of space–time variability in flash flood models*, two papers (Anquetin et al., 2010; Zoccatelli et al., 2010) focus on the influence of space–time aggregation of rainfall and soil variability on the modelling of flash floods in France and Romania, respectively. Braud et al. (2010) and Zanon et al. (2010) combine data from post-flood surveys and distributed hydrological models to investigate the main hydrological controls – and the corresponding space–time variability – on runoff response in the flash flood context. The paper by Viglione et al. (2010) outlines an analytical framework that quantifies the effects of flood event space–time variability on catchment storm response. A second paper by Viglione et al. (2010) provides a development of the analytical framework and quantifies the contributions of the space–time variability of rainfall, runoff coefficients, hillslope and channel routing to the flood response. They also propose a dimensionless response number that represents the joint effect of runoff coefficient and hydrograph peakedness on the flood peaks.

The fourth theme on *Hydro-meteorological models for flash flood forecasting and warning*, focuses on four fundamental issues: use of Numerical Weather Prediction models and procedures for extending forecast lead times, forecasting in ungauged basins, estimating initial soil moisture, and assessing predictive uncertainty. Rossa et al. (2010) assimilate carefully checked radar-rainfall derived quantitative precipitation estimates into a numerical weather prediction model (NWP) and assess the potential of the method to extend forecast lead times for an extreme flash flood. Rozalis et al. (2010) use an uncalibrated hydrological model to simulate flash floods in a small Mediterranean catchment in Israel in order to better understand the various factors influencing flash flood response. Vincendon et al. (2010), use the ISBA land surface model to provide the initial soil moisture conditions to an event-based version of TOPMODEL. The coupled model is then used to simulate flash floods in the Mediterranean. The same problem is approached by Javelle et al. (2010) by combining two indices: a 'climatic' temporal index, calculated in each cell using an uncalibraed soil moisture accounting scheme, and a spatial 'statistical' index giving the average saturation state usually encountered before a flood. The flash flood guidance system (FFGs) is an operational, deterministic system that recommends the issuing of flash flood warnings if a precipitation threshold for a given basin and time period is exceeded (Georgakakos, 2006; Norbiato et al., 2008). Villarini et al. (2010) consider the effects of both radar-rainfall and flash flood guidance uncertainties on the FFGs. The errors in the FFG are accounted for by quantifying the uncertainties due to the estimation of the hydraulic and terrain characteristics, and the hydrologic model parameters and initial state.

We are looking forward to establish a demanding level of international discussion with this special issue that will hopefully lead to further research and improved flood risk management.

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M. Borga
Department of Land and Agroforest Environments,
University of Padova, Italy
Tel.: +39 049 8272681; fax: +39 049 8272686
E-mail address: marco.borga@unipd.it

E.N. Anagnostou
Civil and Environmental Engineering,
University of Connecticut, Storrs, CT, USA

Institute of Inland Waters, Hellenic Centre for Marine Research,
Anavissos, Greece

G. Blöschl
Institut für Wasserbau und Ingenieurhydrologie,
Technische Universität Wien, Vienna, Austria

J.-D. Creutin
Laboratoire d'Etude des Transferts en Hydrologie
et Environnement – LTHE, Grenoble, France