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Quantifying the uncertainty in the Soil Conservation Service flood hydrographs: a case study in the Azores Islands

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Abstract

Flash flooding is characterised by a rapid flooding phenomenon caused by intense rainfall. Despite being an extreme event with high uncertainty, the rainfall-run-off process is often regarded as deterministic (rather than stochastic). In this paper, the Soil Conservation Service (SCS) flood hydrograph uncertainty is quantified based on the Total Error Framework (TEF), and introduced into the model by applying perturbation in the input data and model parameters. The random perturbation component is stochastically modelled. A sensitivity analysis was carried out on the stochastic model parameters, using a real case study in the Azores (Portugal). The results showed that the flood hydrograph uncertainty varies over time, with its largest deviations occurring at the beginning of the flooding because of the uncertainty associated with the SCS method curve number parameter (correlation coefficient R^2 of 0.86). Rainfall uncertainty was responsible for the uncertainty in the hydrograph peaks' magnitude ($R^2 = 0.93$) while uncertainty in the propagation velocity was responsible for the uncertainty in the peaks' time ($R^2 = 0.97$).

Introduction

Flash flooding is mainly caused by intense rainfall events. Because the time scale is generally short, measured in hours or minutes, accurate flooding measurements are difficult to obtain. In addition, uncertainty is always present, regardless of the model used, and propagates from many sources. While some recent studies take uncertainty in the rainfall-run-off process into consideration either in the model parameters (e.g. Sen and Altunkaynak, 2005) or in the rainfall spatial distribution (e.g. Dodov and Foufoula-Georgiou, 2005), most authors see the rainfall-run-off process as deterministic, (often) disregarding events with lower probability. Quantification of uncertainty is essential to ensure data usability and to overcome the pitfalls of deterministic approaches. Nevertheless, it must be mentioned that not all sources of uncertainty can be accounted for (e.g. Deletić *et al.*, 2009).

Gathering site-specific flash flooding data is extremely important for improving model prediction capability and making cities and societies more resilient to these events. Some authors have compiled important information on flooding incidents, including the floods in St. Maarten, NA, in August 2005 (Vojinović and Van Teeffelen, 2007), in Mumbai, India, in July 2005 (Gupta, 2007) and in Keighley, UK, in October 2000 (Leandro *et al.*, 2009). Important advances have recently been made in modelling these events (Maksimović *et al.*, 2009) and quantifying their risk (Dawson *et al.*, 2008). However, despite documentation being available in some cases, flash flooding is not sufficiently well understood, and data are often either incomplete or bad quality (e.g. Hunter *et al.*, 2008; Leandro *et al.*, 2011). Uncertainty quantification can help to mitigate the effect of the lack of good data by providing further understanding of the model results.

The Soil Conservation Service (SCS) dimensionless hydrograph (SCS, 1972) is often used to study the rainfall-run-off process, including floods (e.g. Shib *et al.*, 2005) and flash floods (e.g. Gabellani *et al.*, 2008), by the hydrologic modelling community (e.g. Ponce and Hawkins, 1996; Yahya *et al.*, 2010). It is a synthetic unit hydrograph in which discharge and time scale are expressed by ratios of peak discharge and time of rise of the unit hydrograph. The method requires rainfall records and soil characteristic parameters [curve numbers (*CNs*)] to compute abstractions from the rainfall and the catchment's time of concentration (*tc*), in order to estimate the flood peak. Most of the difficulties in applying uncertainty to these models lies in (1) characterising each parameter stochastically (Eagleson, 1970; Raymond, 1997;