Geophysical Research Abstracts
Vol. 12, EGU2010-14173, 2010
EGU General Assembly 2010

Spatial moments of catchment rainfall and their use to quantify the influence of spatial rainfall variability on runoff response

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The concept of flow distance, i.e. the distance along the runoff flow path from a given point to the outlet, provides a natural metric to examine the spatial rainfall distribution, as already been observed by *Woods and Sivapalan* (1999). Variability measures based on this metric may be particularly useful when examining the influence of spatial rainfall variability on flood response modelling. Linear runoff routing through branched channel networks imposes an effective averaging of spatial rainfall excess at equal flow distance, in spite of the inherent spatial variability. This implies that rainfall organisation measured along the river network by using the flow distance coordinate may be a significant property of rainfall spatial variability when considering flood response modelling. Spatial moments of catchment rainfalls provide a description of overall spatial rainfall organisation, as a function of the rainfall field $R(u)$ value at position u and of the flow distance $d(u)$ between the position u and the catchment outlet measured along the river network. The principal objectives of this work are: (1) to investigate the statistical properties of the spatial moments of catchment rainfall; (2) to analyse the use of these moments to quantify the sensitivity of distributed rainfall-runoff models to rainfall spatial variability; and (3) to examine the dependence of the spatial moments of rainfall catchment on the relative contribution of hillslope and channels to the average response time. The investigation focuses on a set of 25 extreme flash flood events observed across Europe during the period 1994-2007 for which high-resolution data enabling identification and analysis of the hydrometeorological causative processes (including high quality radar rainfall observations) have been collected. The size of the study catchments range from 36 to 2000 km^2. The analysis reported here shows that neglecting the spatial rainfall variability results in a considerable loss of simulation Nash-Sutcliffe (*NS*) efficiency even for catchment less than 100 km^2 in size. Moreover, it is shown that these rainfall statistics, used in combination, are able to isolate and describe the features of rainfall spatial variability which have significant impact on runoff simulation. The analysis shows also that increasing the hillslope contribution to the overall response time decreases the runoff response modeling sensitivity to spatial rainfall variability. These characteristics are emphasized in elongated catchments and for cases of strong convection enhanced by orographic uplifting.