RUNOFF FROM SMALL BASINS STUDIED FROM A MULTIFRACTAL VIEW POINT

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The process of watercourse flow is known to be extremely non-linear and variable in time and space, since it depends very much on climatic regimes (particularly rainfall) and complex rainfall-runoff processes occurring over a variety of time scales and across drainage basins. No satisfactory detailed modelling of the complexity of the processes involved and their interactions has yet been achieved, either in mathematical terms or with respect to field data availability at suitable temporal and spatial scales. Moreover, empirical scale truncations are made often (i.e. one scale is studied independently of the others).

One major issue is the characterization of extreme discharges. On the one hand, often there are no discharge records for extreme flood events, and on the other hand, many models fail to adequately describe the violent behaviour of watercourse flows. This matters because the estimation of the probability of exceeding certain large events is highly important to hydrological studies and engineering design, since extreme discharges often lead to flooding that can endanger property and human life. The conventional models frequently used for this type of study, i.e. models developed within non-scaling frameworks, usually involve only weak variability (e.g. exponential probability tails). Moreover, in these frameworks, two or more different distributions are often required to fit different regimes such as the "low-flow", the "regular" and the "extreme" events. These are all factors that limit the full statistical characterization of river and stream discharges.

This work explores an alternative approach to studying this process, developed within a scaling framework. Multifractal theory and models are used for this purpose. In general terms, in a given process multifractal theory allows us to mathematically investigate the presence of invariance of properties maintained across scales. This theory has been used to study many different natural processes and systems. Scale-invariance leads to a class of scaling rules (power laws) characterized by scaling exponents. This allows the relationship of variability between different scales to be quantified.

In this work discharge data from small drainage basins located in mainland Portugal are analysed. The basins have different geometric, geological, climatic, and land use characteristics. Their area ranges from about 10 km^2 to 200 km^2. The rainfall regime in this territory and its strong seasonality make the surface flow regimes observed in the drainage network highly irregular. The typical time resolution of the flow rate records is daily and hourly. The time span of the records is more than 40 years for the majority of the data sets.

The multifractality of the watercourse flow process is investigated by testing the scaling behaviour of the probability distributions of the flow rates and their statistical moments. The data investigated exhibit scaling behaviour across a significant range of scales. The empirical multifractal scaling exponent functions expressing the statistical properties of the flow rates for different scales are described using a multifractal model based on Lévy random variables. This is called universal model and it is based on only three parameters.

Results show that the particular signature of a runoff process can be characterized by multifractal parameters. This signature results from the combined effect of the various non-linear processes involved in the rainfall-runoff transformation. Note that multifractal theory offers a single framework to deal with different flow regimes simultaneously.

Special attention is dedicated in this study to the statistics of extreme events, which are explored across a wide range of scales. These statistics exhibit probability distributions with heavy tails. This type of statistical behaviour has important implications for estimating extreme discharges, which may affect current practices in engineering design: compared with the behaviour predicted when exponential tails are considered, these statistics typically lead to a larger flow rate estimate for the same return period.