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The estimation of scaling exponents for extreme flows in Europe and their dependence on river network structure

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The spatial scaling of geophysical fluxes has been often observed in a variety of studies and disciplines. This process characteristic, usually referred to as “scale invariance”, arises from the non-linear interaction of different components of a geophysical system. An outstanding and very popular example of scale invariance in hydrology is represented by the observed power law relationship between discharge and drainage area. A number of studies have focused on the scaling of flow quantiles and, more recently, of extreme flow events with drainage area, reporting the existence of scale invariance in many cases of interest. The importance of these findings lies in the potential improvement and simplification of hydrological predictions, provided that the scaling exponent, α, is correctly estimated. For this reason, several studies have focused on relating α to physical basin characteristics, such as river network structure or climate, in order to provide a predictive framework for its value. However, as we show in this study, the estimation of α bears an intrinsic uncertainty due to the commonly used estimation method as well as the often limited data availability. In order to explore the physical basis of the scaling exponent it is therefore paramount to quantify the effect of the estimation uncertainty, and possibly separate it from the natural variability of α. In this study we use an extensive set of numerical simulations to assess the variability of α under controlled conditions. We then compute a set of event-based α’s for 62 European river basins on the basis of data available for approximately 700 stations. We find that for a number of basins, the variability due to estimation uncertainty is significantly smaller than the one obtained from data, suggesting an actual, physical basis of the scaling exponent. Finally, for these basins we test the hypothesis that the river network structure is the first order control on the value of α. To this end we analyse the spatial scaling of the width function peaks within the considered basins and compare it with the peak discharge scaling exponents. Our results show that for the majority of the basins the width-function scaling exponent lies within the confidence interval of the discharge-based scaling exponents, which supports the thesis that the river network structure is indeed a dominant control on the peak discharge scaling exponent. This represents a first step towards a general predictive framework for the scaling of peak discharge.