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The Impact of Rainfall Spatial Variability on the Hydrologic Response

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We study the influence exerted by the spatial variability of rainfall on the response of hydrological systems. In particular, we seek to determine the spatial scales at which rainfall variability may be expected to play a relevant role in shaping the main features of hydrographs generated in basins of varying characteristics. The analyses are performed using models based on the geomorphological theory of the hydrologic response which have been extensively validated and shown to reproduce observed hydrographs under different hydrologic conditions in a wide variety of real basins. Numerical experiments are performed in which the spatial resolution of the input rainfall fields is coarse-grained from 100 m to 50 km by i) simple averaging of the high-resolution fields and ii) by an averaging procedure which ensures strict conservation of the rainfall volume on the catchment. The variation in the resulting hydrographs shows that rainfall variability does not significantly influence flood response for basin areas up to about 3500 km^2, provided that the rainfall volume at each time interval is preserved. We then interpret the results of our analyses in terms of the travel time distributions arising as a result of characteristic basin geomorphological and rainfall structures. We use the Jensen-Shannon divergence measure to characterize differences in travel time distributions sampled by idealized, disk-shaped, rainfall events of different sizes. We show that because the total travel time of a water parcel is dominated by the travel time within the hillslope even for quite large basins (e.g. $8000\,km^2$) it is the scale of the hillslope that largely determines the effects of rainfall heterogeneity: If the the typical size of the hillslope is smaller than the characteristic size of rainfall structures, these effectively sample all possible residence times and the flood response of

the catchment does not depend on the specific rainfall distribution occurred. In larger basins (i.e. larger than $10^3\ km^2$), or in peculiarly elongated ones, the travel time in the channels is expected to be an important part of the total travel time. In this case the response of a catchment will thus be controlled also by the detailed spatial distribution of rainfall.