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A warming-induced rainfall heterogeneity accelerates landscape evolution

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The hydro-morphological response of a catchment is highly dependent on rainfall properties, including rainfall intensity, storm duration and frequency, and the timing of those events. Furthermore, rainfall spatial variability impacts streamflow, erosion, and sediment transport, and is explored primarily in the context of heavy rainfall triggering floods and rapid morphological changes on hillslopes and in channels. In order to examine the potential effects of warming on hydro-morphological responses, we first examined how changes in air temperature are affecting the spatial structure of rainfall. We observed that heterogeneity increases as temperatures rise. Then, we investigated the sensitivity of fast hydro-morphological responses to increasing temperatures and rainfall heterogeneity scenarios by simulating an extreme rainfall event that occurred in August 2005 in the Kleine Emme stream in Switzerland. The results show that rainfall heterogeneity has a greater impact on erosion processes than simply intensifying high rainfall intensities. We also looked at how changes in rainfall patterns affect landscape evolution over hundreds of years at the catchment scale. Multiple realizations of hourly rainfall fields, each with a different spatial distribution but identical in all other respects, were simulated using a stochastic weather generator, and the impact of the storm heterogeneity on catchment morphology was assessed using a landscape evolution model (CAESAR-Lisflood). We found that erosion and deposition rates increased and net erosion and deposition areas changed (increased and decreased, respectively) when the rain became less uniform in space. Increasing temperatures and rainfall heterogeneity resulted in longer, deeper, and more branched gullies. The results of these studies indicate that heterogeneity in rainfall spatial patterns accelerates landscape development even when rainfall volumes and temporal structures are identical.