Analysis of feedbacks between hydrologic response and long-term drainage basin evolution

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Abstract. Basin topography and network structure are known to impact hydrologic response. Because hydrologic response dictates rates of erosion and sediment movement, the reverse is also true. Here we use simple landscape evolution theory to examine how the size and duration of storm events may impact the long-term evolution of a basin. We present a model for the distribution of peak discharges throughout a basin as a function of the ratio of storm duration to basin concentration time. This model is coupled with a long-term basin evolution model. Analytical results and numerical simulations predict that when all else is equal, basins will grow to be less concave and more elongated as the ratio of storm duration to flood-wave travel time decreases. This implies a scale dependence to basin form, and may explain the weak scale dependence observed in natural basins. The degree of impact on form depends on the degree of nonlinearity in geomorphic response, which is not well known but can be placed within reasonable bounds using current sediment transport and bedrock erosion theory. Analysis of storm size effects predicts similar consequences. In particular, the ratio of basin diameter to characteristic storm diameter influences the frequency and magnitude of flood peaks, and thereby the geomorphic response. The result of these connections is a self-organizing mechanism through which, over time, basin geometry and runoff response co-adapt to the prevailing storm regime. It follows that any sustained change to that regime will produce a corresponding geomorphic reaction. This raises the question of whether the signatures of changes in average storm size and duration over the Neogene have been imprinted in drainage basin morphology and erosion patterns.

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