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Effects of precipitation patterns on catchment erosion considering unsaturated zone hydrology

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Geomorphological models are based on simplifying hydrological assumptions due to the computational limitations. The runoff generation method used in these models is generally the Hortonian excess rainfall. This assumption does not take into account the response of unsaturated zone to the dry intervals and precipitation event's duration and looks only at the intensity of the precipitation events. It also implies that the smaller intensity precipitations does not incise or erode the river. This study compliments previous work by investigating the 3D transient response of the unsaturated zone, river flow and erosion power to different precipitation patterns of fixed total precipitation. The catchment of interest is 150km2 with a relief of 900m located in the south of Germany. The total amount of surface shear from runoff is computed as a measure of effectiveness of the incision and bedrock erosion. The sensitivity of the erosion on the surface is calculated with sampling multiple precipitations of the varying intensity, duration and dry intervals using using a 3D transient hydrologic model called Hydrogeosphere. Three types of experiments are designed where in each experiment, one precipitation characteristic (i.e. duration) is kept constant and the other two precipitation parameters are allowed to vary (i.e. intensity and dry intervals). The number of events are varied, but produce a fixed total precipitation amount of 700 mm over six months. An exponential probability distribution for the intensity, duration and dry intervals was explored in 300 simulations. These precipitation events are simulated and the shear stress over the stream is sampled every half hour.

Model results show that the combined effects of intensity, duration and dry intervals on shear stress over the river is significant even with the total fixed precipitation. Experiment I consists of events with small mean intensities and long durations. These events are less effective in eroding the channel despite producing comparatively large hydrograph peaks and discharges. Experiment II has intense precipitations and mean precipitation durations derived from the historic recored. These events produce large runoffs and large surface erosion on the river channel. Experiment III consists of intense precipitations with short durations. These events produce surface erosion which is larger than Experiment I, and smaller than Experiment II. The peaks in discharge for Experiment III are much smaller than the other cases and base flow is swamped by the rising and falling hydrograph limbs. Though the hydrograph peaks are small in experiment III, the resulting total shear force is comparable to Experiment II. The differences in shear stress can be up to thirty percent larger than simulations with a constant precipitation rate.

The total ex-filtration(subsurface feeding the river) is one order of magnitude smaller than total infiltration and total evapotranspiration. The model clearly demonstrate that the annual river discharge is not the only measure to consider for the erosion in catchments. As climatic changes in geologic times are inevitable, variations in precipitation patterns will follow and erosive power of the river will change depending on the changes in precipitation patterns. Results obtained here imply that for longer (decadal to geologic) time scales, different climate states will influence erosional efficiency such that estimating catchment erosion from mean annual discharge may be problematic.