The influence of hillslope diffusion on relief at different scales

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The linear diffusion equation is the simplest approach to include hillslope processes in landform evolution models addressing scales above the hillslope scale. The diffusivity quantifies the ratio of diffusive flux and slope gradient and may vary strongly depending on climate and lithology.

The combination of fluvial erosion and hillslope diffusion has been addressed in several studies. Here we focus on the effect of hillslope diffusion superposed to fluvial bedrock incision on the relief at different scales defined by the window size over which the relief is taken. As diffusion smoothes the surface, hillslope diffusion always reduces the mean relief at small scales. In return, hillslope diffusion increases the sediment supply to the rivers, so that fluvial erosion rates must grow in order to maintain an equilibrium with a given uplift rate. Therefore, hillslope diffusion leads to an increase in channel slopes and thus to higher elevations in the respective upstream area. This effect is reflected in an increase in large-scale relief. Both the decrease in small-scale relief and the increase in large-scale relief show a nonlinear dependence on the diffusivity.

The small-scale relief with hillslope diffusion scales almost linearly with the relief scale, while it grows less rapidly with the relief scale for purely fluvial systems. The effect of hillslope diffusion becomes most clear if the semivariogram of the elevations is considered. Hillslope diffusion introduces a point of inflection in the semivariogram. The location of this point of inflection can probably be used for quantifying the ratio of diffusivity and fluvial erodibility and thus the influence of hillslope diffusion on relief for real topographies.