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Modelling uncertainty in short-term catchment erosion rates

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Several studies have presented the discrepancies between erosion rates measured over different timescales for catchments worldwide. We focus on those comparing short term erosion rates spanning 10^0 to 10^1 years, obtained by river load sampling and from sedimentation rates in reservoirs and lakes, and long term erosion rates spanning 10^3 to 10^4 years, obtained by cosmogenic nuclide dating. Conflicting relationships exist between short and long term rates for different regions of the world. Short term rates exceed long term rates by orders of magnitude in some regions, whilst in others the opposite relationship occurs, notably in glaciated basins. Elsewhere short and long term rates appear to be in equilibrium.

Two fundamental problems exist with the short term erosion rates used in such comparisons. The first is the assumption that sediment yield is representative of the erosion rate. Sediment storage may significantly modulate the transfer of sediment from source to sink and may result in both temporary decreases and increases in sediment yield, thus affecting the calculated erosion rates. The second problem is the inability to capture the long term behaviour of the system in the short sampling window. For the comparison of short and long term erosion rates it is therefore important to quantify the possible uncertainty in the published short term rates resulting from these two factors.

We use a simple conceptual model, based on the linear reservoir theory, to quantify the uncertainty in catchment sediment yield and thus erosion rate. In particular we investigate how uncertainty is a function of statistical characteristics of the external forcing, formalized here as a stochastic event-based process, and the storage capacity of the catchment, as determined by the mean residence time of sediment in the system. We take several catchments for which short and long term erosion rates are available. For each catchment a time-series of sediment output is generated with a long term mean validated with the observed long term erosion rate. We then repeatedly sample from the time-series, with a sampling window that represents the short-term erosion rate record length, to obtain a probability distribution of erosion rates. Our results show how sampling record length, the nature of external forcing and sediment residence time interact to produce uncertainty in short-term erosion rates observed in different catchments worldwide, raising questions about comparisons made between these and long term erosion rates and interpretations based on these comparisons.