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Predicting sediment fluxes over tectonic gradients in the Ecuadorian Andes using an incision-driven geomorphological model

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Erosion of uplifting areas controls the evolution of the earth surface and produces the majority of terrestrial sediments. Despite great advances in the assessment of sediment yield (SY), most of the existing models might be called exogenic as they rely on statistical relationships between state variables (e.g. topography and lithology) and external drivers (e.g. climate and hydrology). While exogenic models have been successfully used to predict contemporary sediment fluxes, they do forego an essential property of geomorphic systems. The primary cause of topography building is tectonic uplift. Erosion is, to a large extent, a response to this uplift, mainly driven by river incision and mass wasting.

In this contribution we evaluate whether a direct representation of the uplift-erosion interplay under the form of a numerical Landscape Evolution Model (LEM), allows to better explain spatial variations in erosion rates than an exogenic statistical model. The LEM we used (TTLEM_Sed) allows to simulate spatially variable rainfall, sediment routing and landslide formation. We selected the highly transient Paute catchment in the Southeastern Ecuadorian Andes as a study area. Cosmogenic Radio Nuclide (CRN) derived erosion rates are used to calibrate the models because CRN derived erosion rataes integrate the short-term temporal variability associated with contemporary SY measurements. In a first step, we identify the critical processes needed to realistically simulate millennial landscape evolution in the Paute catchment and discuss the simulation of landslides in the area. Second, we optimize model parameters both for the statistical model and the LEM, highlighting the presence of non-linear river incision. Third, we compare the performance of the statistical modelling approach with the performance of TTLEM_Sed. We found that TTLEM_Sed is capable to better explain the CRN derived erosion patterns in comparison to a classical, statistical approach. Moreover, sequential runs with TTLEM_Sed allowed to identify the role of different driving factors such as precipitation. Contrary to the statistical analysis, suggesting a controlling role of precipitation on erosion rates, the integration of spatially variable precipitation does not significantly alter modelled results from TTLEM_Sed in the Paute catchment.

We conclude that TTLEM_Sed explains the variability in measured erosion rates at least as good as an 'exogenic' statistical model. Moreover TTLEM_Sed not only allows to simulate landscape dynamics at different spatial and temporal scales but also allows to identify the role of physical drivers such as precipitation on earth surface evolution.