Geophysical Research Abstracts
Vol. 19, EGU2017-13105-1, 2017
EGU General Assembly 2017

Modulation of erosion rates of uplifting landscapes by long-term climate change: Experimental investigation

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Whether climatic variations play a major role, or not, in setting the erosion rate of continental landscapes is key for demonstrating the influence of climate on the tectonic evolution of mountain belts, as expected from analytical, numerical and analog modelling approaches. These models actually demonstrate that any modification in surface erosion rate that would affect significantly the gravitational loading of the continental crust might change its state of stress and consequently its deformation. However field evidences of these interactions has proved challenging to demonstrate unambiguously, the question of the climatic control on erosion efficiency at the geological time-scale being among the most critical issues.
Here, we investigate how a change in precipitation influences the erosional dynamics of a landscape on the basis of an experimental approach where we surveyed the erosion by runoff of water of laboratory-scale landscapes that evolved under the combination of uplift and rainfall forcings (e.g. Bonnet and Crave, 2006). The experimental facility used is a modified of a device initially developed in the Geosciences Rennes laboratory and now set up in the Geosciences Environnement Toulouse laboratory. Following early experiments of Bonnet and Crave (2003) where the effect of a sudden drop in precipitation was investigated, we consider here the impact of decreasing rainfall events of finite duration on the erosive response of a landscape forced by a constant uplift (10 mm/h) and initially at steady-state (SS1). We performed several experiments with the same amplitude (from 160 to 60mm/h) but with different duration of rainfall drop (Tp: 0, 60, 300, 500, 700 min).
As predicted theoretically and already observed in numerical and experimental modelling studies, a sudden drop of precipitation rate (Tp=0) induced a decrease of the mean erosion rate of the landscape (E), resulting in surface uplift. Then, landscape mean elevation stabilized to a higher value as it recovered a new steady-state (SS2). On experiments with a gradual (linear) decrease of precipitation of finite duration (Tp>0), we observe that the onset of surface uplift and of decrease in erosion rate is delayed with regard to the onset of precipitation change and occurs only after a period where landscapes remain very close steady-state. The duration of this delay differs between experiments and increases linearly with Tp. Beyond this delay, the mean erosion rate then drops to a minimum value, while knickpoints migrate in the drainage system following the mechanism described by Whipple and Tucker (1999). We observe that the amplitude of the drop in mean erosion rate decreases with Tp, experiments with the longest duration of precipitation drop showing a damped erosional response, representing only about 20 % the uplift rate value (Tp=700 min). As a perspective we anticipate that experiments with longer Tp would ultimately not show any significant erosional response to precipitation variations.