Geophysical Research Abstracts,
Vol. 10, EGU2008-A-05595, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-05595
EGU General Assembly 2008

Couplings between internally-driven tectonic processes and surface erosion

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The link between tectonics, climate and erosion has been the subject of much attention for more than twenty years now. Numerical models have long ago predicted that there should be a link between these processes. Typically, the results of numerical models of crustal deformation and more recently mantle flow show much variations depending on the assumed surface erosion efficiency and thus the climate. The main reason for these couplings and potential feedbacks, between erosion and tectonics in particular, is directly linked to the assumed crustal and/or mantle rheology and relies on whether the stresses generated by surface topography gradients (and their evolution through time) are similar in magnitude to the stresses needed to drive crustal deformation. Observational evidence has been sought in terms of correlation in space and time between precipitation, erosion rate and tectonic activity, and, may be more adequately, in terms of related changes among any of these three processes. So far, very few (if any, according to some) case studies have been presented that clearly identify such couplings, at least at the scale of an orogenic belt.

Here we present the results of relatively simple computations that quantify the efficiency of surface processes in modifying tectonic processes somewhat regardless of the assumed crust and/or mantle rheology. Our work is based on the simple postulate that crustal deformation and mantle flow are driven by internal lateral density differences and, under the assumption that there is no inertia in the Earth on the scale of tectonic processes, these stresses must, in larger part, be compensated by those created by surface topography gradients. From this simple consideration, one must accept that changing surface topography must have an important feedback on the rate at which the underlying tectonic processes take place. To demonstrate this point, we show the results of simple internally-driven flow experiments coupled with first-order surface processes models. We simply demonstrate that the rate of tectonic movements is strongly affected by the rate of surface processes as long as those are capable of transferring mass along the Earth's surface at a rate that is comparable to the rate of deformation driven by internal density gradients. Consequently, the effectiveness of surface processes being strongly related to surface slope, we demonstrate that a strong feedback between surface and tectonic processes is plausible at the scale of small orogen and less likely at a larger continental scale.