Geophysical Research Abstracts
Vol. 19, EGU2017-17797, 2017
EGU General Assembly 2017

The response of the Earth's surface and the regolith to climatic perturbations

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The regolith is a major component of the critical zone in part because it is the main fresh water reservoir that is necessary for the development and sustainability of many ecosystems. Along its upper surface, the regolith is subjected to a wide range of erosional and transport processes. Along its based, chemical and physical processes combine to transform intact bedrock into a porous medium through water is able to flow. If we wish to understand how the regolith and thus the critical zone respond, over geological time scales, to changes in climate, tectonic uplift and/or erosion, it is therefore important that we not only identify the processes responsible for its formation and evolution, but that we develop adequate parameterisations of these processes to evaluate the spatial and temporal scales at which they are susceptible to respond to external forcing.

To address part of this problem, we have investigated how surface processes, including fluvial and glacial erosion, as well as chemical weathering that controls the propagation of a chemical front at the base of the regolith, respond to periodic variations in climate forcing. To do so we have used existing and relatively well established parameterisations of these processes to predict their response time scales to external perturbations. These analytical solutions have been tested using numerical models that are based on similar parameterisations (equations). We show that each of these processes can only respond to climate forcing over a range of periods that is set by the response time scale(s) of the process. For each process, we also compute the shape of the gain and lag functions. The gain tells us how the climate forcing might be amplified or damped as a function of the forcing period, while the lag function informs us on whether the response of the system is in phase or not with the forcing.

We conclude by showing how important such an approach is to study not only under which conditions the regolith and, consequently, the critical zone are sensitive to climate perturbations, but also to decipher the geological record and derive from it useful constraints on the hypothesised links between climate, erosion and tectonics.