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Climate signals lost and found in the sediment archive

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The volume, locus and characteristics of sedimentary deposits record the response of the Earth's surface to an ever-changing climate and tectonic history. However, the sediment routing system that links the eroding landscape to down-system depositional sink can transform climatic and tectonic signals. This means that inverting the sedimentary archive for tectonic or climatic signals it is a non-trivial task, since process and product are non-linear. Here we tackle this challenge using an idealised 2-D model of catchment erosion and fan deposition, where we can vary tectonic and climatic parameters to investigate the sensitivity of simple sediment routing systems to external forcing. Finally we apply the insight gained from the model to interpret field examples from the Tremp Basin, Spanish Pyrenees.

We calculate the grain size distribution of gravel clasts down-system using a similarity approach, with fan architecture calculated by sediment budget balance. For the simple case of constant catchment rainfall followed by a single stepped increase in precipitation, the response recorded within the basin is the deposition of a coarse conglomerate sheet that extends down the length of the fan. The catchment/fan system then returns to topographic steady state with a response time of $\sim$ 1 Myr, producing a short-lived deposition of large gravel clasts down the length of the system.

This time scale of basin response is considerably larger than climate oscillations due to the eccentricity of the Earth's orbit. By forcing the eroding landscape with periodic changes in precipitation equivalent to the long eccentricity cycle (400 kyr) we find that the response recorded in the sedimentary basin to the climate change is strongly buffered by the landscape system. Shorter periodic changes in climate (100 kyr) are also highly buffered because the time scale of the climate oscillation is an order of magnitude less than the response time of the catchment. In these cases, our model system reaches a new pseudo-steady state on a time scale equal to the response time of the catchment/fan system, with fan architecture and sediment calibre similar to a scenario with constant precipitation. Additional increases in the magnitude of the oscillating rainfall signal are damped down-system and lost, as the sediment routing system can adjust more rapidly to change.

These results suggest that the Earth's landscape is highly buffered to high amplitude changes in climate and that such signals are likely to transform during propagation through the sedimentary routing system. Our results indicate that extensive sheet conglomerates, such as that at the Paleocene-Eocene boundary in the Tremp Basin, Spain, can be explained by a rapid and sustained increase in precipitation, with amplitude significantly larger than background climate oscillations and we argue that insights from this model can be applied widely to invert tectonic and climatic signals in the sedimentary record.