Geophysical Research Abstracts
Vol. 16, EGU2014-5857, 2014
EGU General Assembly 2014
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Debris flow fans as sensitive recorders of glacial-interglacial climate change in the south-western United States

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Tectonics and climate are major forces shaping the morphological evolution of the landscape, and are recorded geomorphically and stratigraphically over response timescales that may vary across several orders of magnitude. Although the responses of geomorphic systems to tectonic perturbations have been well studied in recent years, far less is understood about the effects of climate change. A number of landscape evolution models predict that the sediment flux and grain size distribution exported from mountain catchments to alluvial fan systems may be highly responsive to glacial-interglacial climate changes. This implies that the sedimentology of alluvial fan deposits should record important information about how eroding mountain landscapes have reacted to past climate changes. However, a lack of targeted, empirical field data means we have not yet tested model hypotheses or constrained the magnitudes, mechanisms and characteristic timescales with which these systems have responded to climate variability in the past. This is a key challenge for building accurate landscape evolution models with predictive powers, and understanding how climatic information is recorded by geomorphic systems.

In this study, we present a new, detailed stratigraphic record from 8 mapped and dated debris flow fans in southern Owens Valley, California. These fans have a continuous depositional record extending back more than 150 ka, which we use to examine how the sediment grain size and flux from Sierra Nevada catchments has varied as a function of high amplitude climate change during the last glacial-interglacial cycle. We find that this sedimentological data is highly correlated with the palaeoclimate record, with depositional events becoming significantly larger in size and 2-3 times coarser in grain size as the climate warmed and dried. The quantitative relationships that we identify between high frequency climate change and sustained responses in the sedimentology of these catchment-fan systems reveals that they are highly sensitive to climate forcing with a relatively rapid response timescale of $\leq 10^4$ years. This is faster than many current landscape evolution models hypothesize. We demonstrate that a climatic signal is measurable and consistent across 8 discrete catchment-fan systems in Owens Valley, and discuss the implications of this for signal shredding by autocyclic fan processes. This is one of the first detailed, empirical tests of the sensitivity of fan deposition to climate variability over time, in a region where the palaeoclimate record is very well constrained. Our findings confirm that climate changes are expressed in alluvial fan sedimentology, making it possible to calibrate landscape evolution models using new field data with a high spatial and temporal resolution.