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Trends and Aberrations in the Measured Fluvial Erosion Response to Global Paleoclimate Change

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Quaternary climate change between glacial and interglacial cycles has resulted in temporal and spatial variations in precipitation that have the potential to impact erosion. Over the past decades many studies have sought to quantify how climate change impacts erosion by, for example, measuring cosmogenic nuclide concentrations in modern and paleo (via terraces) river sediments. However, interpretations from these studies are often complicated by uncertainties in how much precipitation has changed in different parts of the world and over what time scales these changes occur. To address these complications, we perform a sensitivity analysis of how spatial and temporal variations in Quaternary precipitation can change fluvial erosion, and how well existing cosmogenic nuclide data can constrain these changes.

Our methods include an integration of: (a) a high resolution ($\sim$ 80 x 80 km) global atmospheric general circulation model (ECHAM5), (b) a detachment-limited fluvial erosion model, (c) a model of predicted cosmogenic nuclide determined erosion rates for transient fluvial erosion histories, and (d) a comparison of results from (c) to a recent inventory of > 3,000 globally distributed cosmogenic nuclide catchment average erosion rates (OCTOPUS data set). The general circulation model predicted precipitation changes are evaluated between pre-glacial (Pliocene, $\sim$3 Ma), full glacial ($\sim$21 ka), and interglacial (Middle Holocene, $\sim$6.5 ka) to present day time slices. Catchment average fluvial erosion rates and cosmogenic nuclide determined erosion rates are predicted for different catchment sizes, rock erodibilities, and tectonic settings (i.e. rock uplift rates). Globally predicted changes in fluvial erosion are used to predict catchment average cosmogenic nuclide erosion rates. The predicted cosmogenic nuclides rates are then used to determine the cosmogenic nuclide integration time scales, i.e. the time required to erode $\sim$1 m of regolith, or the timescale over which changes in erosion rates are averaged. The modeled integration timescales are compared to integration times estimated from the observed cosmogenic nuclide data in the OCTOPUS database to identify which samples are likely to contain a signal of climate change driven erosion.

Results indicate that global precipitation variations can change fluvial erosion by > +/- 100 % of the initial erosion rate. Individual geographic locations (on almost every continent) demonstrate increases and decreases in catchment erosion rates between pre-glacial to glacial, and glacial to interglacial time periods. Furthermore, modeled cosmogenic nuclide integration time scales from climate driven changes in erosion are much longer than the simpler, estimated integration time scales of most of the existing cosmogenic nuclide data. This means that past climate driven transients in catchment erosion are only partially recorded in existing data. Taken together, these results demonstrate that although significant increases and decreases in Quaternary fluvial erosion are expected to exist around the world, the magnitude of change in erosion rates are often not (or only partially) detectable with existing cosmogenic nuclide data. Thus, while many trends in climate change driven erosion exist, we are most commonly observing, at best, only approximations of the 'true' change in fluvial erosion.