Measuring and attributing geomorphic and sedimentary responses to modern climate change: challenges and opportunities

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The societal importance of understanding physical landscape response to rapidly progressing anthropogenic climate change is very high. Detecting geomorphic and sedimentary signals of modern climate change is essential for management decisions affecting human health and safety, infrastructure, economics, energy–food–water security, and ecosystems. This presentation examines challenges in measuring and attributing the influence of contemporary climate change on geomorphic and sedimentary systems, and opportunities for improving these efforts.

Foremost among the challenges to detecting modern climate-change impacts are short and incomplete records. Because anthropogenic climate change accelerated substantially after around 1970, its detection often requires robust, high-resolution data from before and after that time. For some purposes a small number of data points can be informative (documenting glacier extent using photographs taken decades apart), whereas investigations of other processes require daily or at least sub-annual data (fluvial sediment fluxes; documenting landslide patterns). Direct measurements rarely continue long enough, with consistent sampling frequency and methods, to resolve signals at the level of detail needed to detect or attribute change to climatic effects. Isolating signals in ‘noisy’ natural systems is notoriously difficult; individual extreme events (floods, storms, fires) can remain apparent for decades, obscuring more subtle change. Climatic influence also must be disentangled from land-use and tectonic effects. Data availability is commonly biased toward places with human land use, either because land uses motivated the site selection or because people witnessed and reported disasters. Variable connectivity and storage in sediment-routing systems (e.g., floodplains or dams in river basins) also affects climate signal detection downstream.

However, the scientific community has opportunities to make useful progress. Data are needed from many more locations, at greater spatial and temporal resolution, to resolve the nature and extent of ongoing climate-change effects. This can be done by establishing and continuing time-series measurements with consistent methods and frequency. We can utilize paleo-records wherever possible, such as studying high-sedimentation-rate lake deposits instead of relying on laborious in-stream sediment-flux measurements. Optimal research sites are those with little human land-use influence and a high signal-to-noise ratio—high sensitivity to climatic change (high-sediment-yield, low-storage catchments; steep slopes with little stabilizing vegetation) and places where warming has been fastest, e.g., high-latitude and high mountain settings. For certain landscape processes, it is useful to establish a global list of sites likely to respond earlier and more strongly than other locations, as has been done recently in the landslide community. We can better define the role of superimposed, cascading landscape disturbances and their relative timing and seasonality (e.g.,
fires, storms, and growth and senescence of vegetation). We encourage sharing data and methodological improvements across disciplinary and national boundaries and building a community network/platform to synthesize such improvements. There are instances where sufficient data exist to detect recent climatic influence but where no signal is apparent yet. Thus, reporting of both negative and positive results, that highlight climate-change effects or lack thereof, is essential to demonstrating rates, regional patterns, and nuances of process.