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Insights into fluvial seismology and bedload transport in a Himalayan river

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A number of studies over the past years have established that seismic data can be used to observe fluvial activity, and that the amplitude of high frequency (>1 Hz) seismic noise in near-river stations can be related to river discharge and bedload transport. Recent theoretical models of seismic noise generation by flow turbulence and bedload impacts provide a framework for understanding how fluvial processes combine to produce observed seismic signals. We use data from a network of seismometers installed in the Bhote Koshi River valley from spring 2015 through fall 2018 to test these models and explore the seismic signals generated by a monsoon-dominated mountain river with typical discharges ranging from approximately 30 to 300 m3/s. We first use a series of event case studies to explore the relationships between fluvial processes and the seismic noise generated in different frequency ranges. These events include temporary damming of the river by an upstream landslide, a local tributary debris flow causing channel constriction, and the aftermath of a glacial lake outburst flood.

We find that a reduction in discharge leads to reduced seismic noise over a wide range of frequencies (1-80 Hz), but in near-river (<100 m) stations, the most affected parts of the spectra are a sharp peak at 2-5 Hz and a broad peak at 10-15 Hz. Both of these frequency ranges are sensitive to discharge, but appear to reflect different processes in the river, as they respond in different ways to changes in channel geometry. At even higher frequencies, seismic noise is sensitive to both bedload transport and water discharge. Events that caused an increase in sediment supply in the river are associated with a change in the shape of the frequency spectra and the development of a broad hump at 30-50 Hz, supporting model predictions that this frequency range is sensitive to bedload transport. However, throughout much of the observation period, this 30-50 Hz hump is not visible and noise in this frequency range appears to be dominated by turbulent flow, even in stations 20-50 m from the river, possibly reflecting limited bedload transport at rates well below the river's transport capacity. We then use the existing theoretical models to do a Monte Carlo inversion of the seismic data for water depth and bedload flux over the 2015 monsoon season. The inverted water depth is consistent with pressure gauge data, but we have lower confidence in the bedload flux inversion. Our observations from the Bhote Koshi illustrate the viability of seismic monitoring of discharge, but highlight the difficulty of seismic detection of bedload transport in rivers that are well below transport capacity.