Seismic velocity recovery following the 2015 Mw 7.8 Gorkha earthquake, Nepal: Towards a coupled vision of damage and hydrological-induced velocity variations

Luc Illien1, Christoph Sens-Schönfelder1, Christoff Andermann1, Odin Marc2, Kristen Cook1, and Niels Hovius1

1Helmholtz Center GeoForshungsZentrum Potsdam, Postdam, Germany (lillien@gfz-potsdam.de)
2CNRS, Geosciences Environnement Toulouse, France

Following the passage of seismic waves, most geomaterials experience non-linear mesoscopic elasticity (NLME). This is described by a drop in elastic moduli that precedes a subsequent recovery of physical properties over a relaxation timescale. Thanks to the development of seismic interferometry techniques that allows for the continuous monitoring of relative seismic velocity changes $\delta v$ in the subsurface, observations of NLME ($\delta v_{NLME}$) in the field are now numerous. In parallel, a growing community uses seismic interferometry to monitor velocity changes induced by seasonal hydrological variations ($\delta v_{hydro}$). Monitoring of these variations are often independently done and a linear superposition of both effects is mostly assumed when decomposing the observed $\delta v$ signal ($\delta v = \delta v_{NLME} + \delta v_{hydro}$). However, transient hydrological behaviour following co-seismic ground shaking has been widely reported in boreholes measurements and streamflow, which suggests that $\delta v_{hydro}$ may be impacted by the transient variation of material properties caused by NLME. In this presentation, we attempt to characterize the relative seismic velocity variations $\delta v$ retrieved from a small dense seismic array in Nepal that was deployed in the aftermath of the 2015 Mw 7.8 Gorkha earthquake and that is prone to highly variable hydrological conditions. We first investigated the effect of aftershocks in computing $\delta v$ at a 10-minute resolution centered around significant ground shaking events. After correcting $\delta v$ for NLME caused by the Gorkha earthquake and its subsequent aftershocks, we test whether the corresponding residuals are in agreement with the background hydrological behaviour which we inferred from a calibrated hydrological model. This is not the case and we find that transient hydrological properties improve the data description in the early phase after the mainshock. We report three distinct relaxation time scales that are relevant for the recovery of seismic velocity at our field site: 1. A long time scale activated by the main shock of the Gorkha earthquake (~1 year) 2. A relatively short timescale (1-3 days) that occurs after moderate aftershocks. 3. An intermediate timescale (4-6 months) during the 2015 monsoon season that corresponds to the recovery of the hydrological system. This timescale could correspond to an enhanced permeability caused by Gorkha ground shaking. Our study demonstrates the capability of seismic interferometry to monitor transient hydrological properties after earthquakes at a spatial scale that is not available with classical hydrological measurements. This investigation demands
calibrated hydrological models and a framework in which the different forcing of $\delta v$ are coupled.