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Modeling continuous seismic velocity changes due to ground shaking in Chile

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In order to investigate temporal seismic velocity changes due to earthquake related processes and environmental forcing, we analyze 8 years of ambient seismic noise recorded by the Integrated Plate Boundary Observatory Chile (IPOC) network in northern Chile between 18° and 25° S. The Mw 7.7 Tocopilla earthquake in 2007 and the Mw 8.1 Iquique earthquake in 2014 as well as numerous smaller events occurred in this area.
By autocorrelation of the ambient seismic noise field, approximations of the Green's functions are retrieved. The recovered function represents backscattered or multiply scattered energy from the immediate neighborhood of the station. To detect relative changes of the seismic velocities we apply the stretching method, which compares individual autocorrelation functions to stretched or compressed versions of a long term averaged reference autocorrelation function. We use time windows in the coda of the autocorrelations, that contain scattered waves which are highly sensitive to minute changes in the velocity.
At station PATCX we observe seasonal changes in seismic velocity as well as temporary velocity reductions in the frequency range of 4-6 Hz. The seasonal changes can be attributed to thermal stress changes in the subsurface related to variations of the atmospheric temperature. This effect can be modeled well by a sine curve and is subtracted for further analysis of short term variations.
Temporary velocity reductions occur at the time of ground shaking usually caused by earthquakes and are followed by a recovery. We present an empirical model that describes the seismic velocity variations based on continuous observations of the local ground acceleration. Our hypothesis is that not only the shaking of earthquakes provokes velocity drops, but any small vibrations continuously induce minor velocity variations that are immediately compensated by healing in the steady state.
We show that the shaking effect is accumulated over time and best described by the integrated envelope of the ground acceleration over 1 day which is the discretization interval of the velocity measurements. In our model the amplitude of the velocity reduction as well as the recovery time are proportional to the size of the excitation. This model with the two free scaling parameters for the shaking induced velocity variation fits the data in remarkable detail. Additionally, a linear trend is observed that might be related to a recovery process from one or more earthquakes before our measurement period.
For the Tocopilla earthquake in 2007 and the Iquique earthquake in 2014 velocity reductions are also observed at other stations of the IPOC network. However, a clear relationship between the ground shaking and the induced velocity reductions is not visible at other stations. We attribute the outstanding sensitivity of PATCX to ground shaking to the special geological setting of the station, where the material consists of relatively loose conglomerate with high pore volume.