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Seismological Field Observation of Mesoscopic Nonlinearity

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Noise based observations of seismic velocity changes have been made in various environments. We know of seasonal changes of velocities related to ground water or temperature changes, co-seismic changes originating from shaking or stress redistribution and changes related to volcanic activity. Is is often argued that a decrease of velocity is related to the opening of cracks while the closure of cracks leads to a velocity increase if permanent stress changes are invoked. In contrast shaking induced changes are often related to "damage" and subsequent "healing" of the material. The co-seismic decrease and transient recovery of seismic velocities can thus be explained with both - static stress changes or damage/healing processes. This results in ambiguous interpretations of the observations.
Here we present the analysis of one particular seismic station in northern Chile that shows very strong and clear velocity changes associated with several earthquakes ranging from Mw=5.3 to Mw=8.1. The fact that we can observe the response to several events of various magnitudes from different directions offers the unique possibility to discern the two possible causative processes. We test the hypothesis, that the velocity changes are related to shaking rather than stress changes by developing an empirical model that is based on the local ground acceleration at the sensor site. The eight year of almost continuous observations of velocity changes are well modeled by a daily drop of the velocity followed by an exponential recovery. Both, the amplitude of the drop as well as the recovery time are proportional to the integrated acceleration at the seismic station. Effects of consecutive days are independent and superimposed resulting in strong changes after earthquakes and constantly increasing velocities during quiet days thereafter.
This model describes the continuous observations of the velocity changes solely based on the acceleration time series without individually defined dates of events associated with separately inverted parameters. As the local ground acceleration is not correlated to static stress changes we can exclude static stress changes as causative process. The shaking sensitivity and healing process is well known from laboratory experiments in composite materials as mesoscopic nonlinearity. The sensitive behavior at this station is related to the particular near surface material that is a conglomerate cemented with gypsum - so called gypcrete. However, mesoscopic nonlinearity with different parameters might be a key to understand velocity changes also at other sites.