The fingerprints of earthquake stress release variations: examples from Japan and New Zealand

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The amount of stress released during earthquakes is a fundamental characteristic of the earthquake rupture process. As such, it represents a key parameter for improving our understanding of earthquake source physics and for reliable ground motion prediction. Large earthquake populations usually show variations in stress release as large as three orders of magnitude, but the underlying mechanisms have remained largely elusive, and particularly the dependence of stress release on earthquake size is still a matter of debate.

In this presentation we investigate these issues of stress drop variability using two extraordinary datasets from different tectonic backgrounds and discuss the stress drop variations within these datasets as well as potential common or dissimilar features.

The first one originates from Japan, which is a tectonically highly active region, and encompasses earthquakes of a wide magnitude range and spatial coverage. Stress drop estimates derived from these data indicate that stress release variations of crustal earthquakes in Japan are strongly correlated with heat flow variations, indicating that they are thermally controlled. In contrast, subcrustal events depict highest stress release in regions of strong subduction-interface coupling and overall less pronounced variability as compared with crustal earthquakes. Stress release is overall only weakly dependent on earthquake size, but at local scales (i.e., within individual earthquake sequences) the dependence can be very strong and apparently varies with stress regime.

The second dataset originates from the Canterbury earthquake sequence in New Zealand, which began with the 2010 Mw 7.1 Darfield earthquake and is one of the most notable and well-recorded crustal earthquake sequences in a low-strain-rate region worldwide. Ground motions in Canterbury during the aftershock sequence were partially severe, in particular during the 2011 Mw 6.2 Christchurch event, and a range of contributing factors are invoked in the explanation of these ground motions, such as high stress drop sources, regional geological structures and variable site effects (including strong liquefaction effects). A clearer understanding of these particular influences on the observed ground motions, in particular also of the source characteristics, is therefore crucial in assessing on-going seismic hazard in the region and informing the rebuild process. The source spectra for the Canterbury study indicate generally higher than average stress drops (median value ~5 MPa) compared for instance to crustal earthquakes in Japan, and on average close to self-similar behaviour. Moreover, significant lateral stress drop variations are observable.

Compared to the overall stress drop variability of large earthquake datasets, a common feature of these datasets is that the stress release variability on local scale (i.e., within smaller regions respectively individual earthquake sequences) tends to be smaller by a factor of two to three, a finding that is of key significance in the endeavor to reduce the uncertainties in future ground motion predictions.