ERI Research Report

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Exploring the impact of lateral stress drop variations on ground motion and seismic intensity observations

I would first like to thank my host, Dr. Hiroe Miyake, and the International Office staff at ERI for their dedication, allowing me to have a memorable stay at ERI. My time here in Tokyo in general and at ERI in particular has been a great experience. I had highly fruitful discussions with my colleagues at ERI and was also given the great opportunity to visit many researchers at various other institutions (NIED, DPRI, AIST, University of Tsukuba).

While at ERI, I have been working on improving the understanding of the link between earthquake stress drop estimates from classical seismological measurements (moment – corner frequency) and ground motion variability. Indeed, the amount of stress released during earthquakes is a key parameter for the understanding of earthquake rupture physics and the generation of ground motions. Cotton et al. (2013) pointed out that there is a serious discrepancy between the stress drop variability as expected from the between-event variability of ground motion prediction equations, and the variability of seismologically measured stress drop estimates. The former is generally lower by a factor of about 3, and this discrepancy has profound implications, since the assumed stress drop variability impacts the predicted ground motion variability, which in turn impacts the predicted hazard level.

Japan is an ideal case for investigating these issues, and based on the recently published extensive work on seismological stress drop estimates in Japan (Oth, 2013), we investigated the link between ground motion parameters variability and stress drop variability in-depth and within a consistent framework, avoiding the need to mix stress drop estimates from various different studies which might be biased relative to each other due to various methodological assumptions.

We used the extensive K-NET and KiK-net accelerometric networks, operated by the National Research Institute for Earth Science and Disaster Prevention (NIED). KiK-net combines surface/down-hole sensor pairs at each station, which is a particular asset in our endeavor. We then calculated the equivalent JMA seismic intensities for the recordings and focussed on crustal, inland earthquakes.

A non-parametric regression analysis was applied in order to separate attenuation with distance, source terms and site terms in a simple ground motion model. The site terms provided indications that site effects represent a very strong factor in determining the observed intensity levels, with up an average of around + 1.5 JMA intensity units amplification (ranging up to 2.5 to 3 for some specific sites).

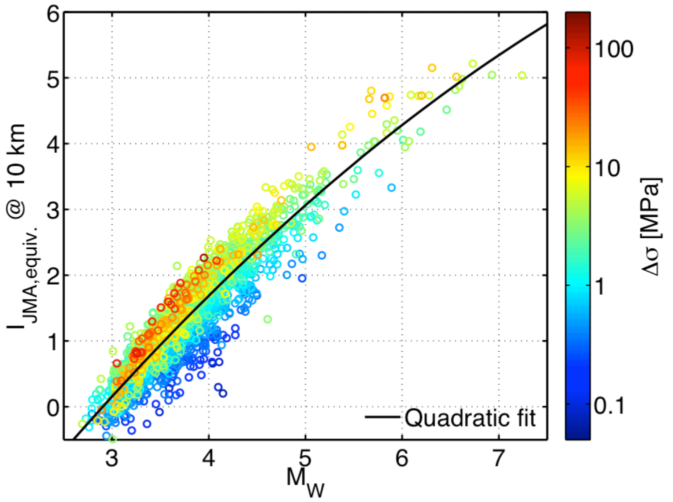

Figure 1: Source terms (i.e., equivalent JMA intensity at 10 km distance) derived from non-parametric regression.

The focus of this study was however the variabiliy of the source terms. The non-parametric regression approach allows to extract average source terms for each earthquake, which are essentially attenuation and site-corrected ground motion estimates at a given reference distance (10 km in our case). Figure 1 shows these source terms versus magnitude color-coded with the stress drop estimates derived by Oth (2013). The source terms show a clear dependence on stress drop level, with higher stress drop earthquakes depicting on average higher source terms. However, different stress drop ranges show reasonably large overlaps.

These overlaps indicate that this stress-drop-dependence is however not that trivial. In order to get a better understanding of this issue, we calculated the so-called between-event variability (relative to an average scaling relation with magnitude, shown as black line in Figure 1) and invesitgated this between-event variability as a function of stress drop and region.

The main results are shown in Figure 2. For all of Honshu, the between-event residuals belong to the same family, showing a clear dependence on stress drop, ranging between +/- 1 units. The same holds true for Kyushu, but Kyushu forms a second family with significantly higher stress drops (Oth, 2013). This second family is a peculiar feature which is subject of further research and can most likely be explained by several issues combined. As a general outcome, stress drop clearly reflects in the ground motion variability, but in view of the possibility to obtain several families as shown in Figure 2, it may not be that straightforward to actually estimate stress drop variability from the between-event residuals variability, as is at present discussed in the literature.

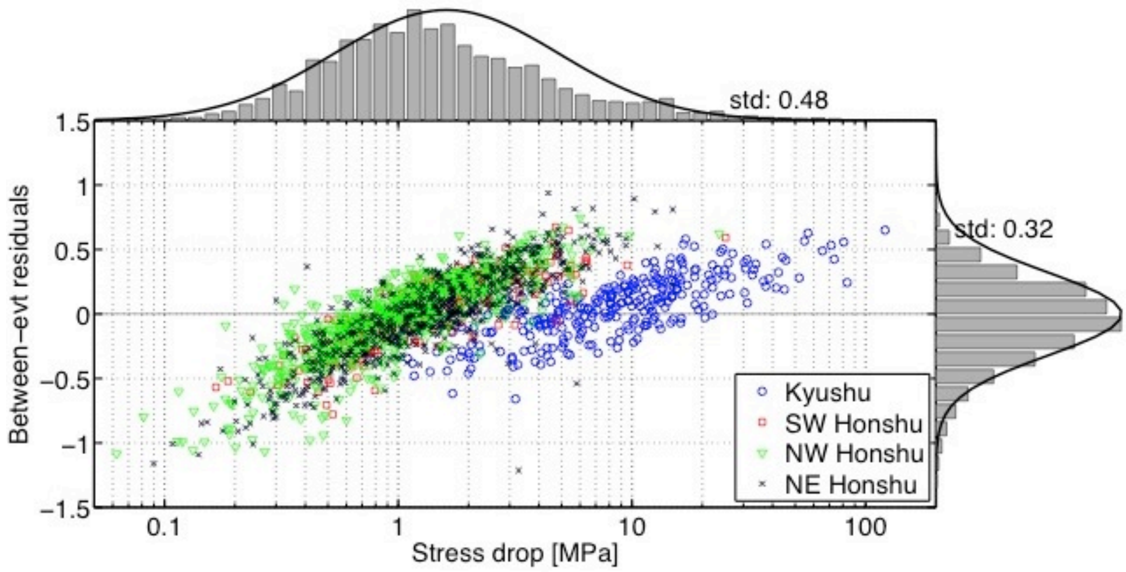

Figure 2: Equivalent JMA intensity between-event residuals (see also Figure 1) vs. stress drop, color-coded depending on region.