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Stress Drop Mapping in the Northern Chilean Subduction Zone

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Introduction

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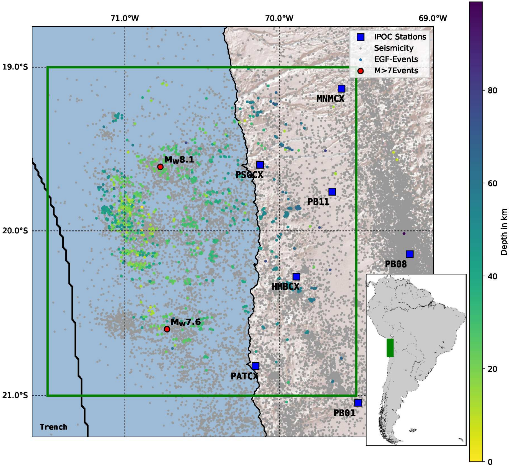
- Earthquake source parameter scaling is fundamental for understanding the mechanics of earthquake rupture.
- The parameter **stress drop** relates rupture dimension to seismic moment which makes it a central parameter for source description.
- The Northern Chilean subduction zone has been monitored by the IPOC network for more than ten years. The subduction zone produced a vast amount of seismic activity and a **huge catalog** was compiled including over 100000 events, published by Sippl et al. 2018.
- We apply the **spectral ratio approach** to investigate stress drop of interface seismicity in the rupture region of the 2014 $M_W 8.1$ Iquique event.



Research area northern Chile. Seismicity catalog from Sippl et al. 2018, highlighted are 3201 events which were selected for this study color coded with depth. Red circles are the 2014 Iququie main event and its largest aftershock; blue squares are IPOC stations.

Stress Drop - Computation

Brune type stress drops are computed using:

$$\Delta\sigma = \frac{7}{16}\left(\frac{f_c}{k\beta}\right)^3 M_0$$

β is shear wave velocity at the source

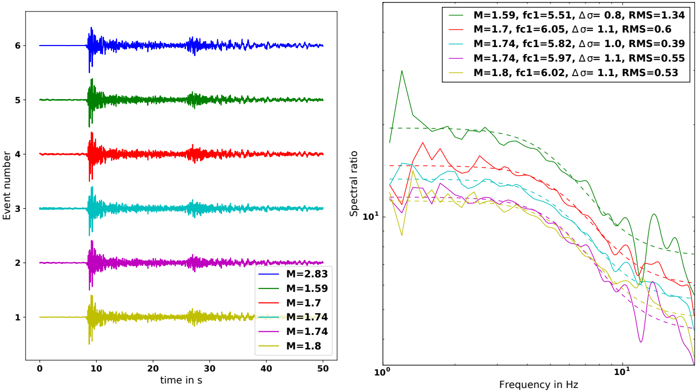
$k = 0.32$ is a standard value introduced by Brune, 1970

M_0 is seismic moment

We estimate f_c with the **spectral ratio** approach (e.g., Abercrombie, 2014):

$$\frac{u(f)}{u_{EGF}(f)} = \frac{\Omega_0}{\Omega_{0EGF}}\left(\frac{1+(f/f_{c_{EGF}})^{\gamma n}}{1+(f/f_c)^{\gamma n}}\right)^{\frac{1}{\gamma}}$$

where n is spectral falloff, γ is model dependent ($\gamma = 1$: Brune,1970, $\gamma = 2$: Boatwright,1981).



Empirical Green's function family. One target event on top with five EGFs found by template matching. Spectral ratios computed with corresponding colors. From the ratio f_c is computed and stress drop can be calculated. Note the consistency of f_c and stress drop estimates using the different EGFs. Figures taken from Rakau, 2019

Processing and Examples

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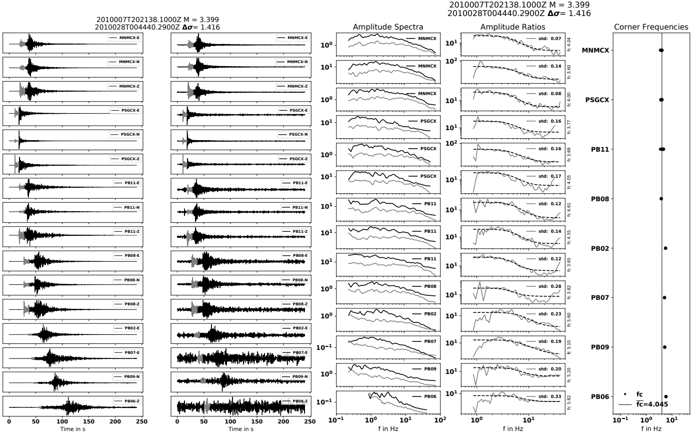
Event selection

→ 9071 templates from catatlog by Sippl et al., 2018
→ Template matching at IPOC station PB11
→ Time span 2008-2016
→ $cc \geq 0.8$, $\Delta M \geq 1$
→ 3201 event pairs found

Processing

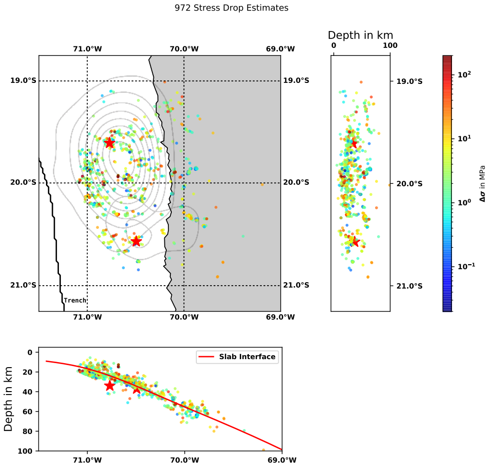
→ Detrend
→ Integrate to Dispacement
→ Bandpass filter (0.8–40Hz)
→ Spectral Smoothing (Konno and Ohmachi, 1998)
→ Spectral Ratio
→ Boatwright spectral model fit
→ Averaging of trace wise obtained f_c
→ Computation of stress drop

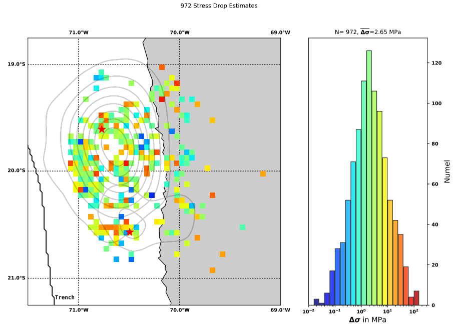
→ Repeat for all events, P and S phase
→ Average redundant results with median



From left to right: Seismic traces from target event and EGF. Selected P phase is highlighted. Spectra and spectral ratios with Boatwright fit. Estimated f_c for each station. Spherical average using median, indicated by vertical line gives $f_c = 4Hz$ resulting in a stress drop of 1.4MPa.

Results I

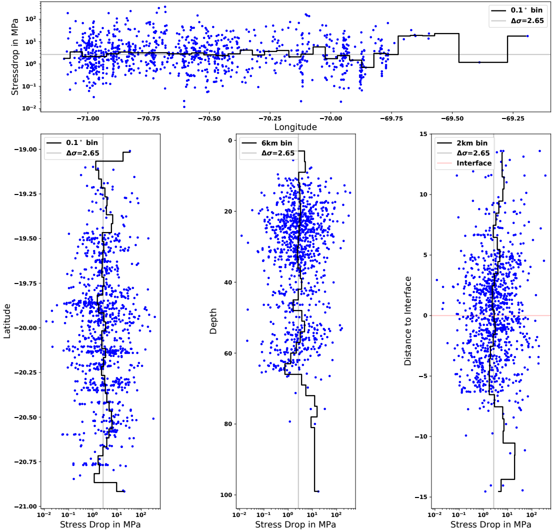


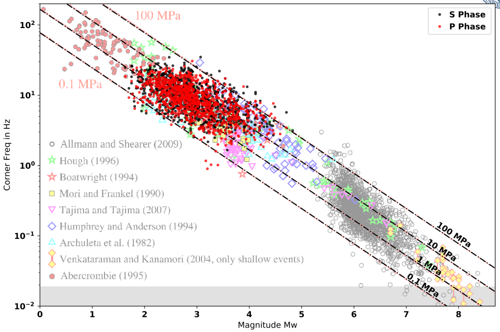


left: Stress drop distribution in map view and side views. Color indicates magnitude of stress drop. Red stars indicate the hypocenters of the $M_W 8.1$ Iquqiue event and its biggest aftershock ($M_W 7.6$). Slip distribution from Schurr et al 2014 is underlain in grey.

right: Cell wise averaged stress drop distribution and histogram. Note the log–normal distribution with the overall median of 2.65MPa.

Results II





left: Stress drop variation in four spatial sections. W–E, N–S, Depth, Distance to Interface. Note, the absence of a large scale lateral trend as well as no depth dependence. A tendency of increased stress drop with distance to the interface and some small scale variability is found.

right: P and S phase based stress drop results plotted over a collection of studies from Allmann and Shearer, 2009. Our results cover a similar range as those from the included authors (0.1–100MPa).

Conclusions

- Spectral ratio method provides reasonable stress drop estimates for a large group of events (972).
- Estimates span a range from 0.1 to 100 MPa and show log–normal distribution with a median of 2.65MPa.
- Slight spatial dependencies are observed such as increased stress drop with distance to interface.
- No increase of stress drop with depth was identified.
- Temporal variability is found associated with the Mw8.1 Iquique event (not shown).
- The computed stress drops do not corroborate the earthquake rupture scale invariance hypothesis but reveal a dependency of stress drop and seismic moment.
- We find indications for possible correlation with inter–plate locking.
- We hypothesize that the seismotectonic regime is the paramount factor for significant offsets between stress drop for different groups of events.

Acknowledgments and Bibliography

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Several figures from this contribution are included in similar versions into a manuscript submitted to JGR-solid Earth: Folesky et al. 2020

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