Focal Mechanism and Stress Drop Estimates of the 2018/11/30 M_L 4.5, Injection-induced Earthquake Sequence near Dawson Creek, British Columbia, Canada

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Introduction

- Globally, fluid injection operations for permeability enhancement and wastewater disposal correlate with increased seismicity [e.g., Keranen & Weingarten, 2018]
- Several potentially hydraulic fracturing induced earthquakes have been detected in northeastern British Columbia (e.g., Fig. 1)
- We use data from 15 broadband stations to study source properties of the 2018/11/30 M_L 4.5 induced earthquake near Dawson Creek, northeast British Columbia
- We aim to determine the orientations of the seismogenic faults and source properties such as stress drop values of the sequence.

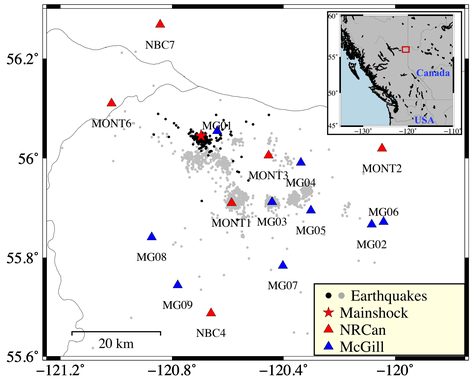

Figure 1. Map of the study area showing the 2018/11/30 seismicity sequence (black dots), all induced events from Jan. 2018 to Dec. 2018 (gray dots), and seismic stations (triangles) used in this study (see presentation IUGG19-0702 on 2019/07/17 at 11:45 AM for more details).

Methods

Moment Tensor Inversion:

- We use a probabilistic moment tensor inversion tool, *Grond* [Heimann et al., 2018] , to compute focal mechanism solutions (FMSs) of the mainshock, one foreshock, and 3 aftershocks
- *Fomosto,* a Green's Function (GF) database management tool, is used to manage GF pre-calculated with *Qseis* code [Wang, 1999; Heimann et al., 2017]
- Waveforms of both P & S waves as well as envelopes are fit in time and frequency domain simultaneously to determine optimum solutions.

Spectral Analysis:

- We follow the approach of Onwuemeka et al. [2018] to estimate seismic moment, corner frequency, and stress drop of 7 events with individual spectra and 2 events (the two largest M_L 3+ aftershock) using the spectral ratio methods [Hartzell, 1978]
- Empirical Green's Functions (eGFs) selected based on 1) similarity in the difference between S-phase and P-phase arrival times (≤ 1 *s*); 2) hypocentral separation (< 5km); and 3) cross-correlation (cc) values (≥ 0.7)
- We fit station-averaged stacked spectral ratios weighted by the cc value.

Results

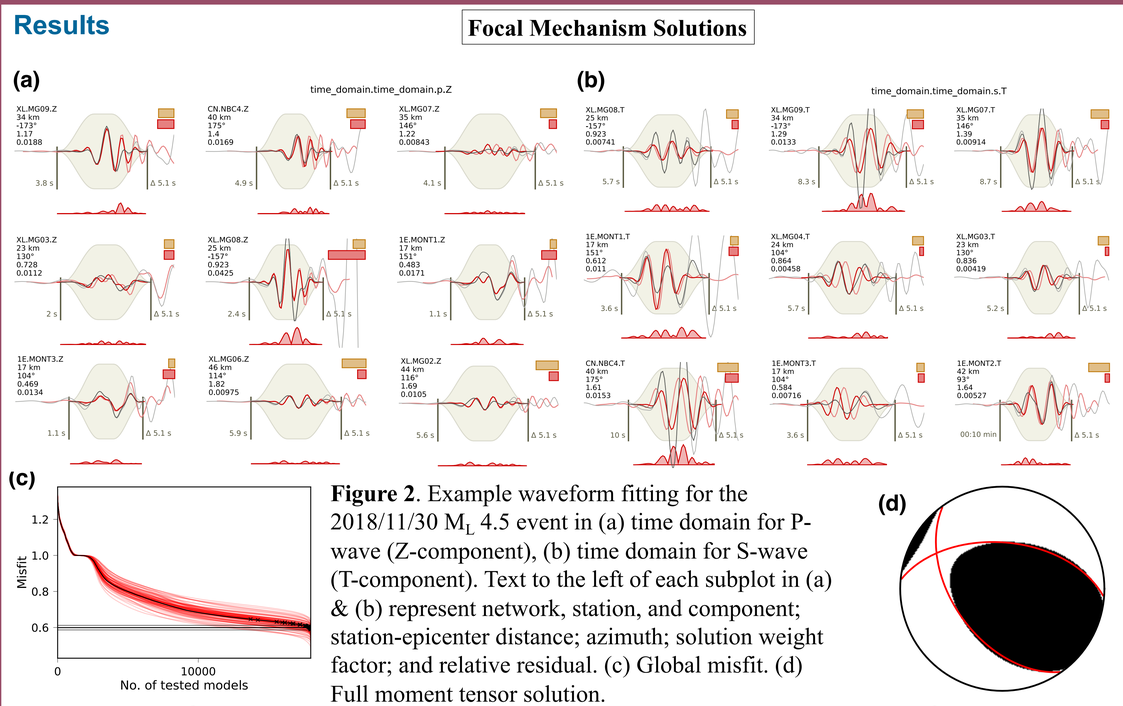

Figure 2. Example waveform fitting for the 2018/11/30 M_L 4.5 event in (a) time domain for P-wave (Z-component), (b) time domain for S-wave (T-component). Text to the left of each subplot in (a) & (b) represent network, station, and component; station-epicenter distance; azimuth; solution weight factor; and relative residual. (c) Global misfit. (d) Full moment tensor solution.

Hydraulic fracturing induced failure on NW-SE trending fault

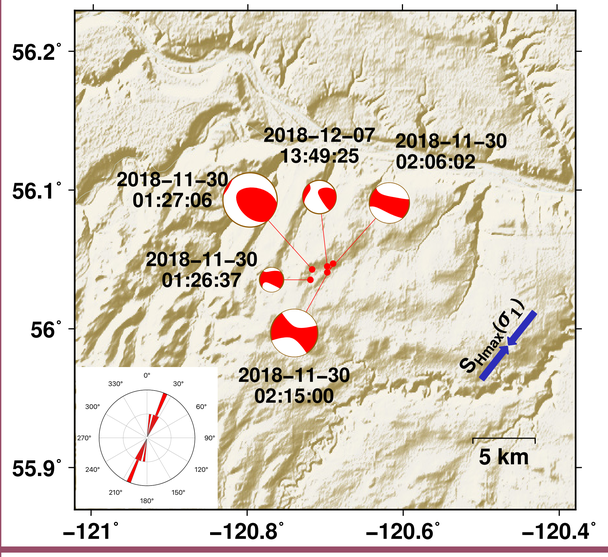

Figure 3. Map view showing focal mechanism solutions (FMSs) of the mainshock, one foreshock, and three aftershocks. Blue arrows indicate the reported maximum horizontal principal stress. Bottom-left inset shows rose diagram of P-axis trend of all FMSs.

P-axes follow the trend of the regional maximum horizontal principal stress

Spectral Analysis

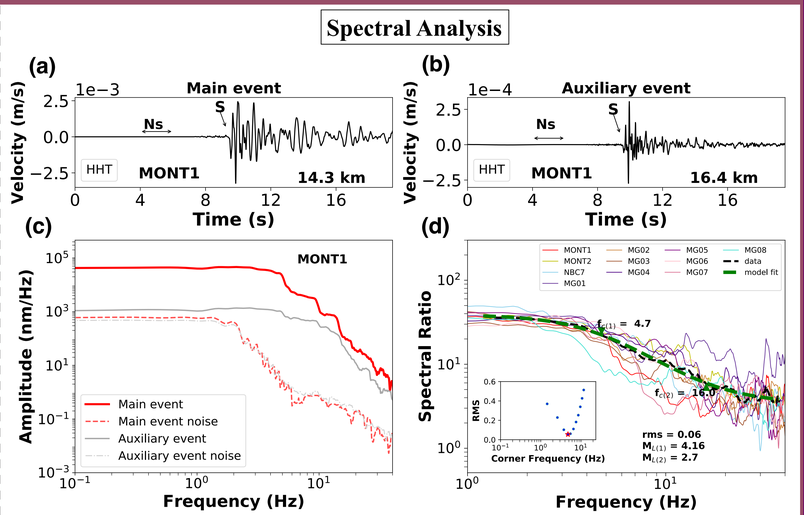

Figure 4. (a & b) Raw waveforms of an event pair. (c) Spectra of windowed event-pair signal and noise for one station. (d) Spectral ratios for the event pair color-coded by station. $f_{c(1)}$, $f_{c(2)}$, $M_{L(1)}$, $M_{L(2)}$, and rms are the estimated corner frequency and magnitude of the main event and eGF, and normalized root-mean-square error between the weighted-mean representative spectral ratio, and best-fit model, respectively.

Stress drop between ~1 and 10 MPa

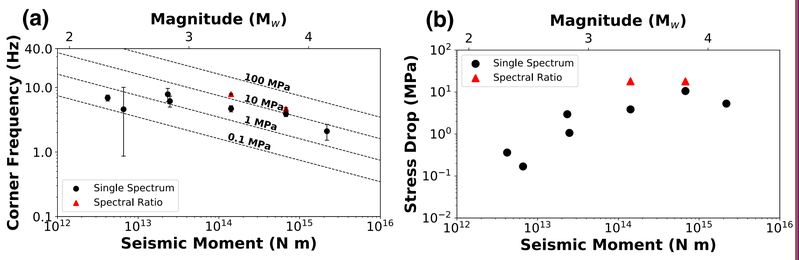

Figure 5. (a) Corner frequency versus seismic moment. (b) Stress drop versus seismic moment. Main shock stress drop was calculated using only single spectra, due to a lack of a smaller event with similar waveforms.

References

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