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An Alternate Method for Earthquake Source Characterization through Empirical Mode Decomposition and Spectral Analysis of Strong-Motion Records

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1. Introduction

- Occurrence of a large number of earthquakes along the Japan Trench leads to ruptures with varying frequencies.
- Energy release is traditionally represented using the moment rate function (MRF), from teleseismic models.
- We use strong-motion data to obtain an "energy release function" that represents frequency-dependent energy release.

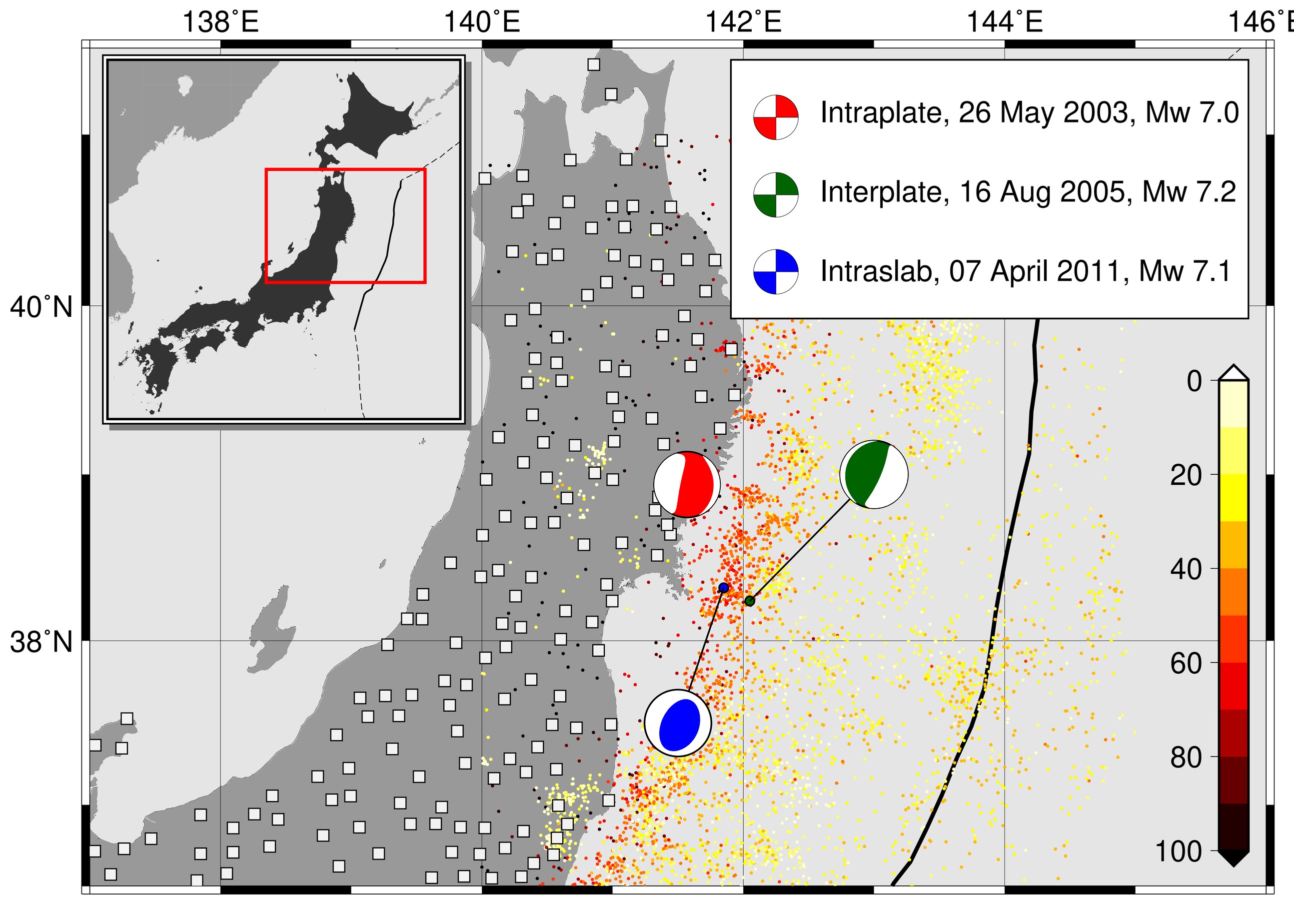


Figure 1: Earthquakes used in this study (focal mechanisms), background seismicity (circles), and KiK-net stations (squares).

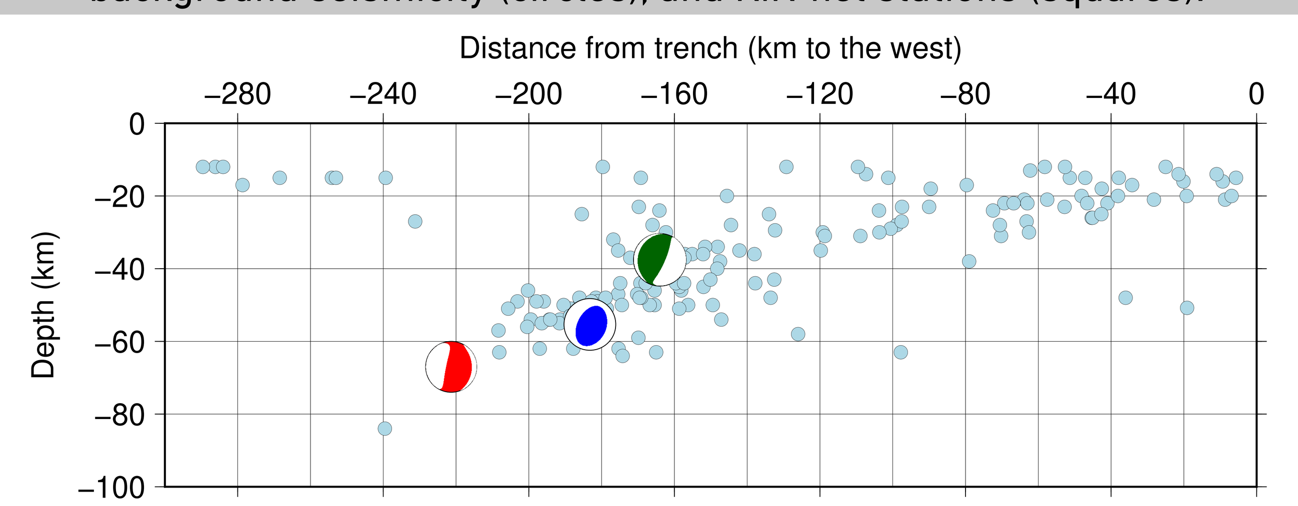
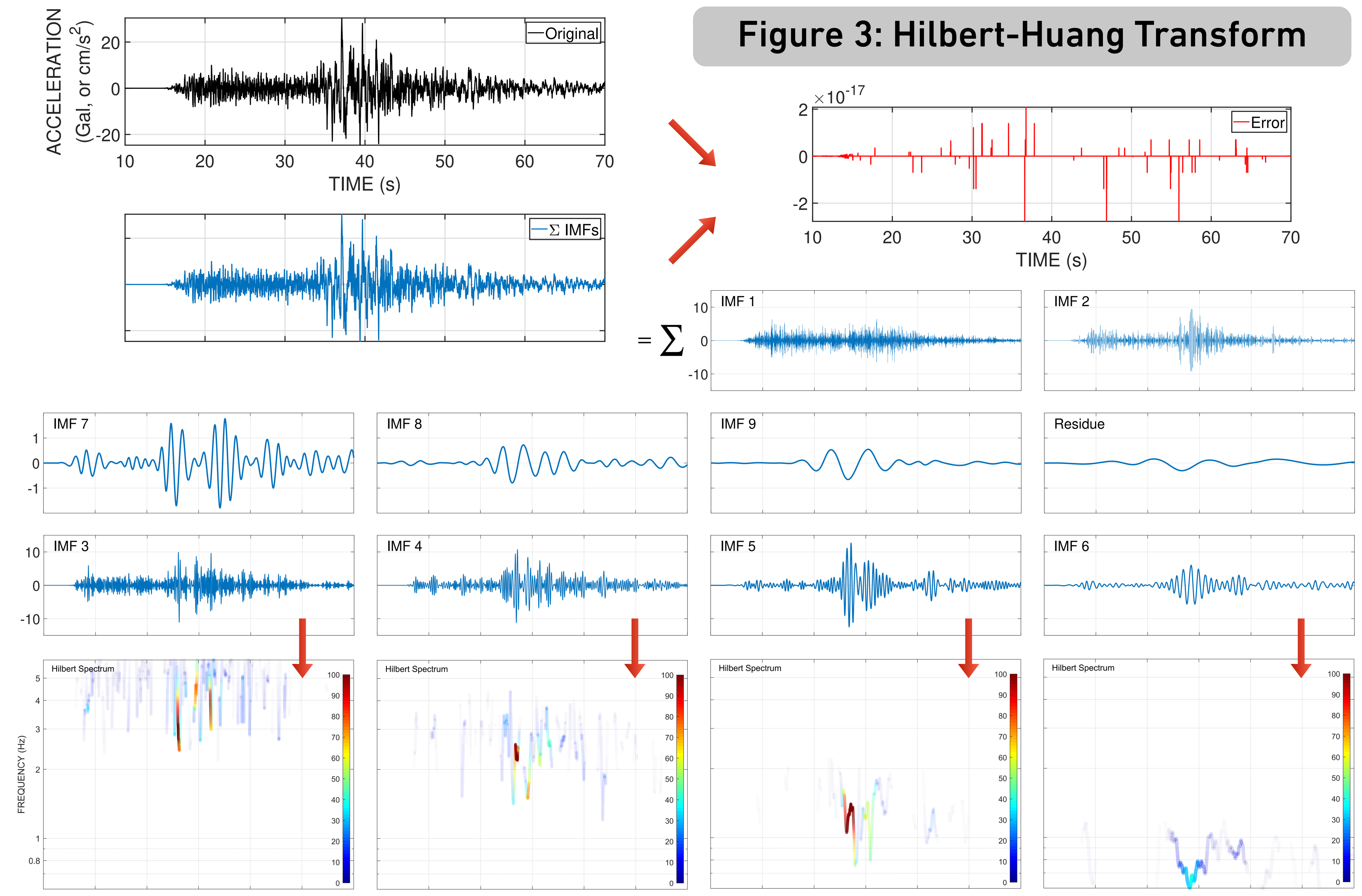


Figure 2: Cross-section showing the subduction of the Pacific slab beneath Japan and the trend of earthquakes. Blue and green beach balls represent the Tohoku (2011) and Miyagi (2005) earthquakes.

2. Methodology

- Hilbert-Huang Transform (HHT) is used to develop spectra that capture the temporal distribution of energy and ranges of frequencies. HHT is a combination of Empirical Mode Decomposition (EMD) to derive Intrinsic Mode Functions (IMFs) and Hilbert Spectral Analysis (HSA).
- A combination of IMFs within the frequency band (0.1 to 3 Hz) used; mostly represents the teleseismic source inversion (0.01 to 2 Hz).
- Hilbert Transform gives instantaneous frequencies as functions of time and resolves energy release at finer scale.

Figure 3: Hilbert-Huang Transform



3. Results

Shape of the spectra generally mimics the moment rate function (MRF). For energy release with a single pulse, the spectrum generates the shape of the MRF. Sub-events come out as independent pulses.

3.1. Intraslab, 2011-04-07, Mw 7.1, Lat 38.32, Long 141.85, 55.3 km

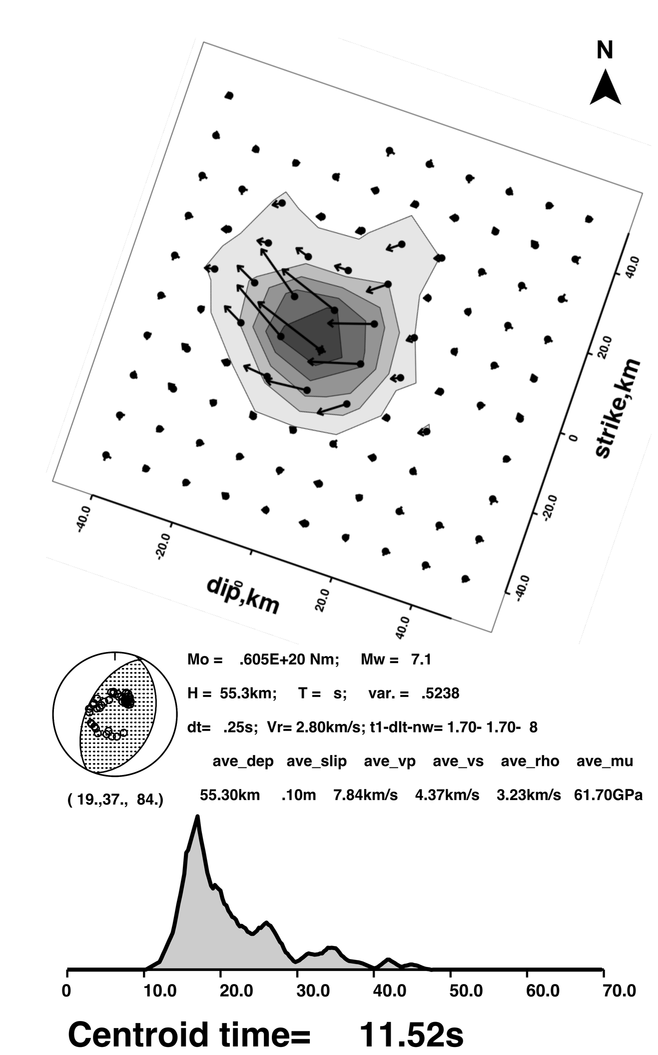


Figure 4: Waveform Modelling. Slip, focal mechanism, source parameters, and MRF.

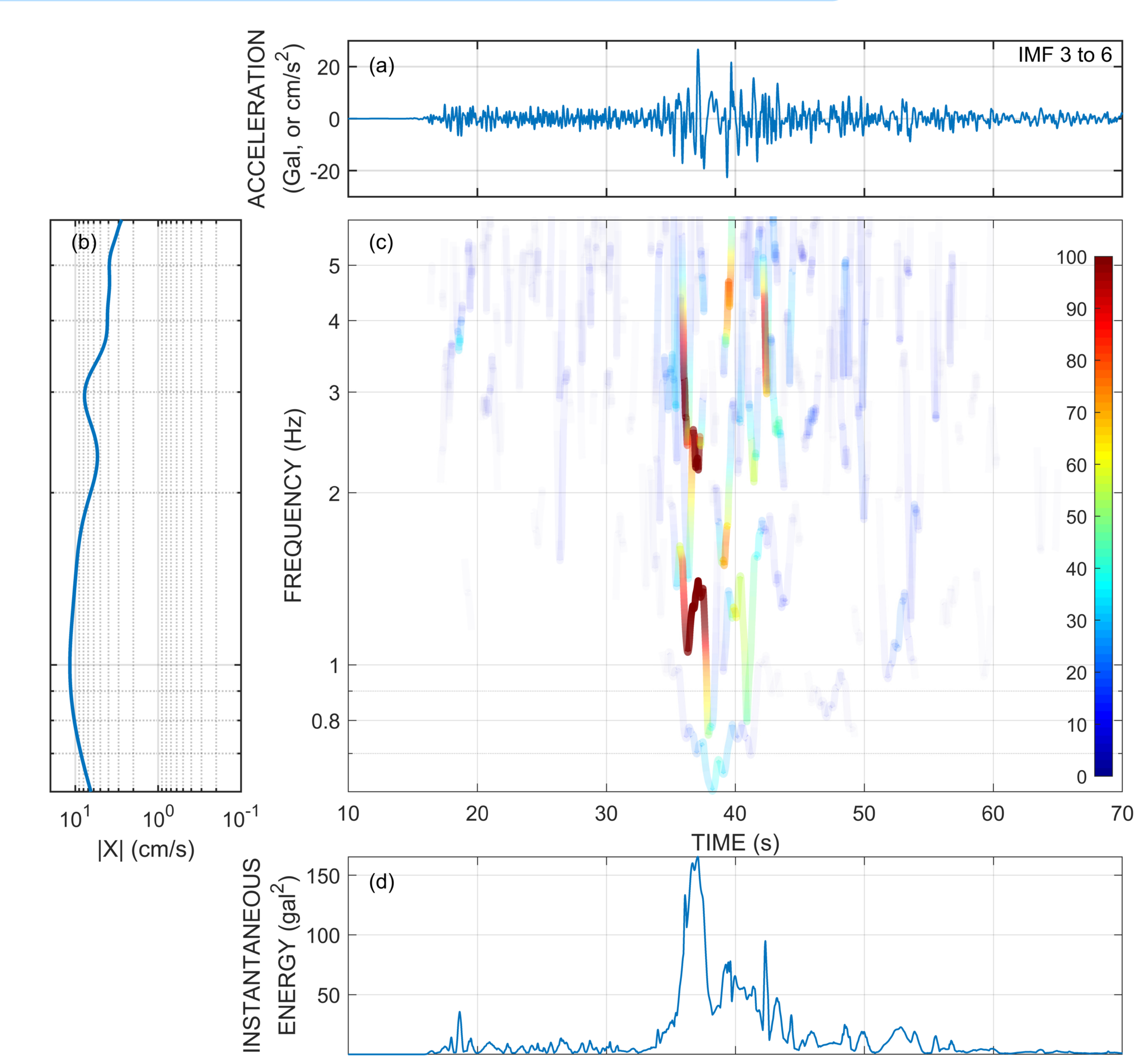


Figure 5: HHT-based (a) time, (b) frequency, (c) energy-frequency-time distribution. (d) "Energy release function"; mimics the MRF.

Sources of Data: Strong-motion data from KiK-net, Japan (NIED). Focal mechanisms, earthquake locations from GCMT. Background seismicity from ISC.

3.2. Interplate, 2005-08-16, Mw 7.2, Lat 38.24, Long 142.05, 37.5 km

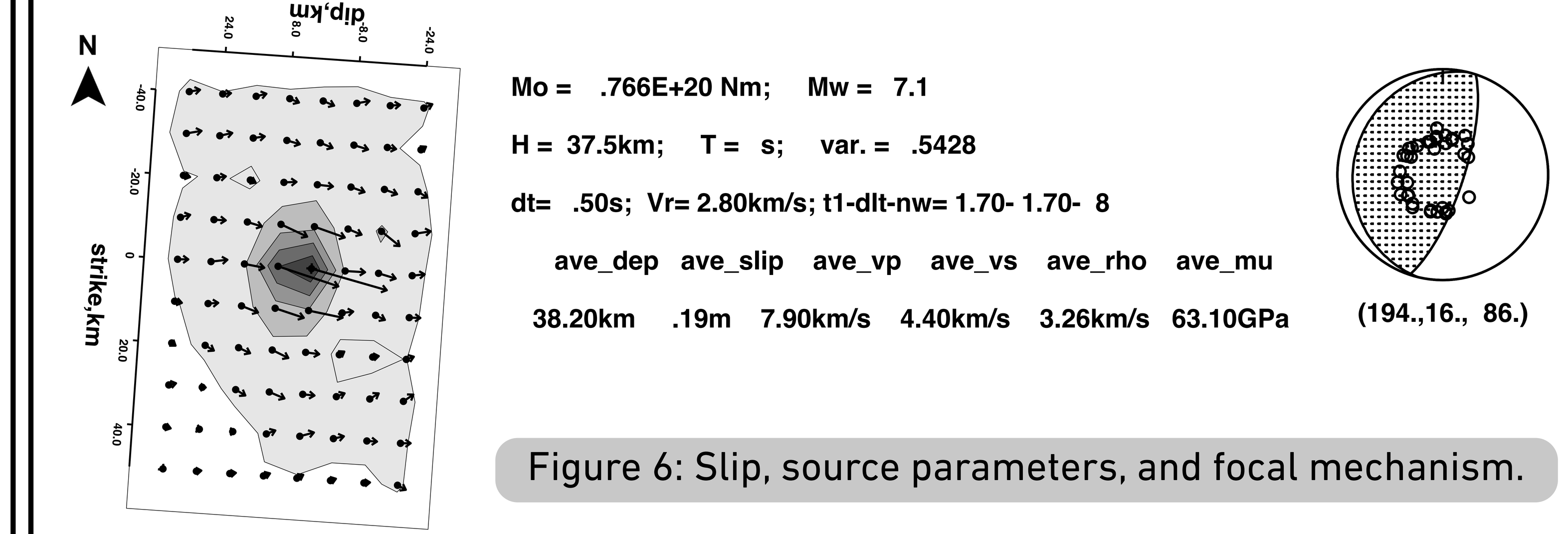


Figure 6: Slip, source parameters, and focal mechanism.

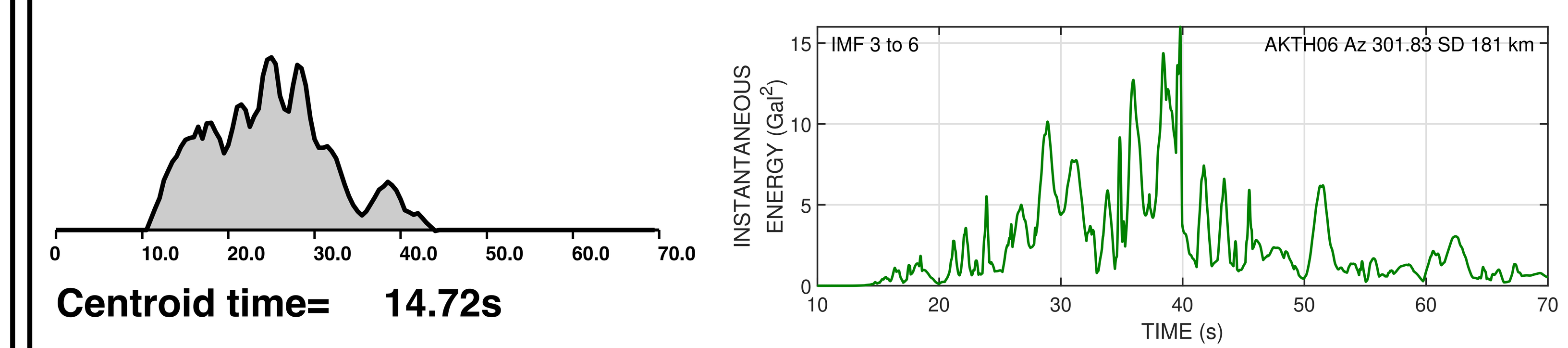


Figure 7: Moment rate function and energy release function.

3.3. Intraplate, 2003-05-26, Mw 7.0, Lat 38.94, Long 141.57, 67 km

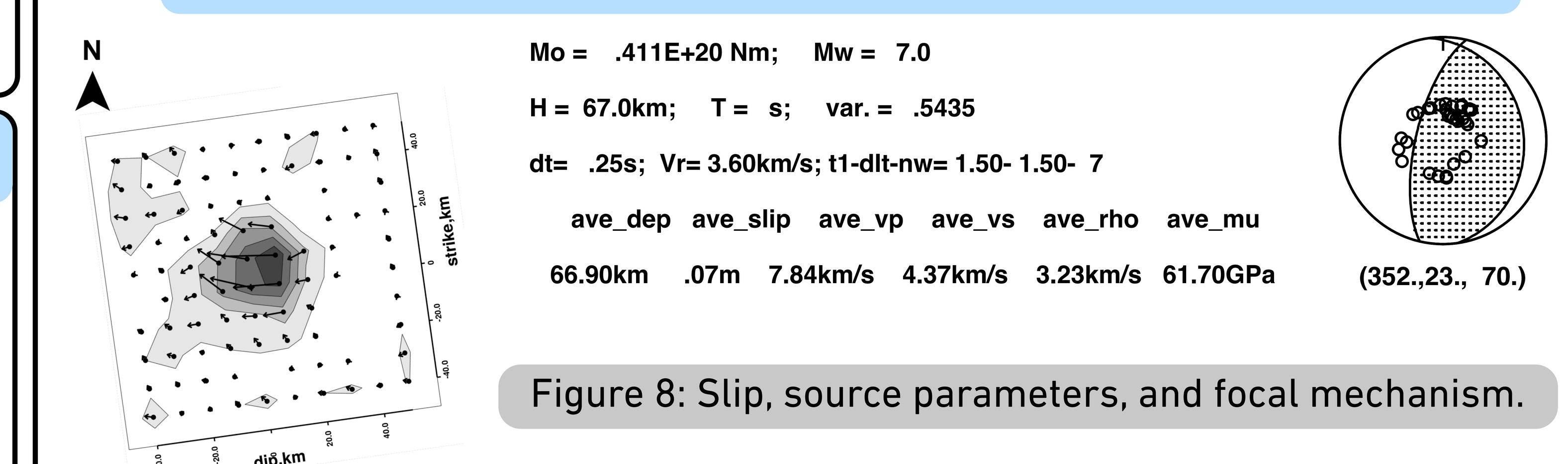


Figure 8: Slip, source parameters, and focal mechanism.

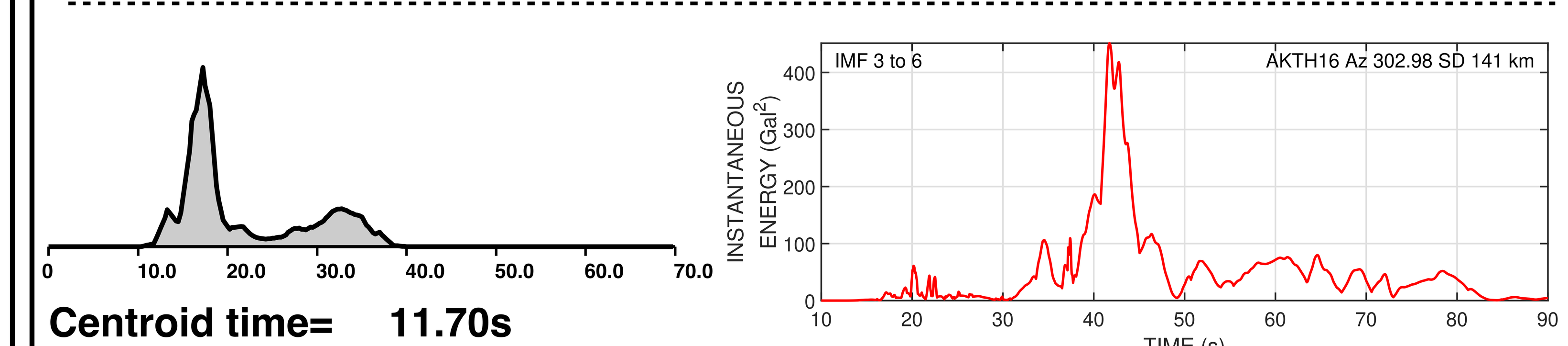


Figure 9: Moment rate function and energy release function.

4. Conclusions

- Obvious advantage of the HHT method is that it skips the assumptions of slip, elastic moduli, fault geometry, velocity models required for source modelling.
- Ability to represent an earthquake source based on its frequency content and temporal distribution could be critical for predicting shaking effects.

5. References

- Huang NE et al., 1998. Proc. R. Soc. London Ser. A 454:903–95
- Huang NE et al., 2001. Bull. Seism. Soc. Am. 91, 1310–1338
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