O2.4-123

Source discrimination and yield determination using high-frequency waveform coda envelopes

Brent Delbridge, Jonas Kintner, Richard Alfaro-Diaz, Loïc Viens

Los Alamos National Laboratory | EES 17 (National Security Earth Science)

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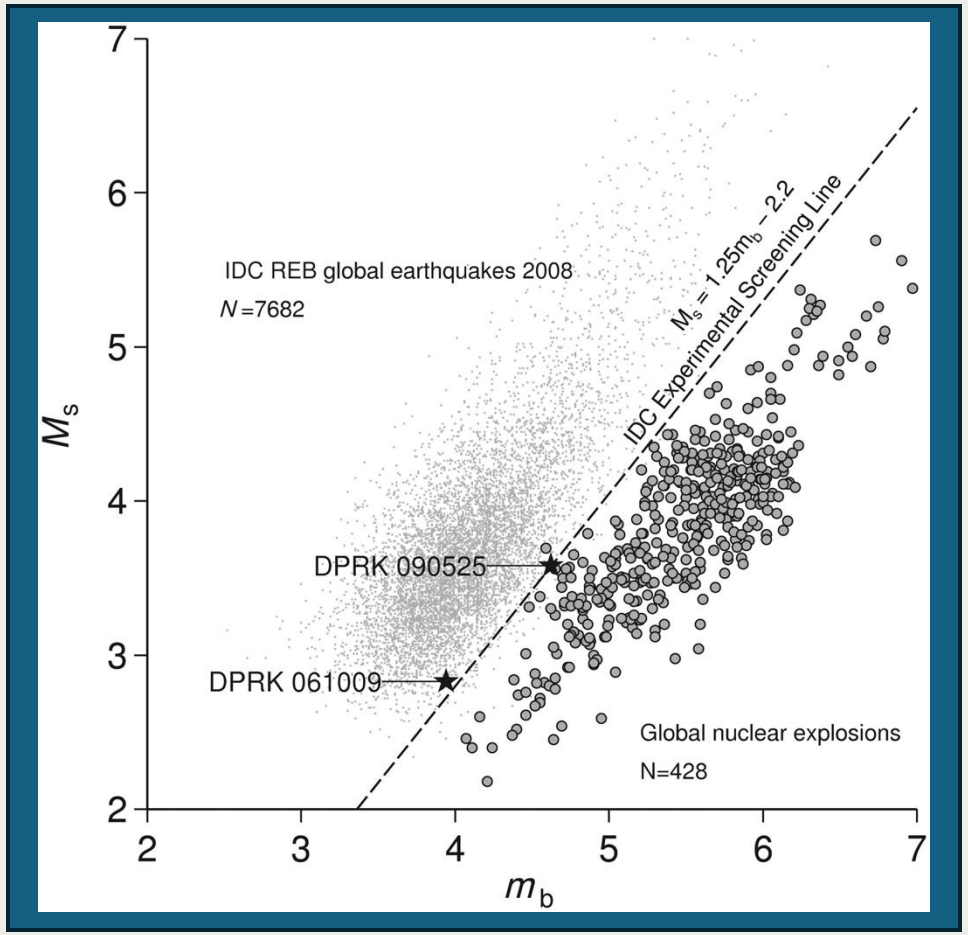
O3.5-435

Motivation:

North Korean (DPRK) tests highlight:

- Unexpected behavior in discriminant performance
- Difficulties with precise yield estimation using *mb* and other measures of source size



Selby et al., (2012)

"Improve discrimination and yield estimation methods applicable in regional and teleseismic domains, in order to be more definitive in identifying underground events of nuclear and non-nuclear origin."

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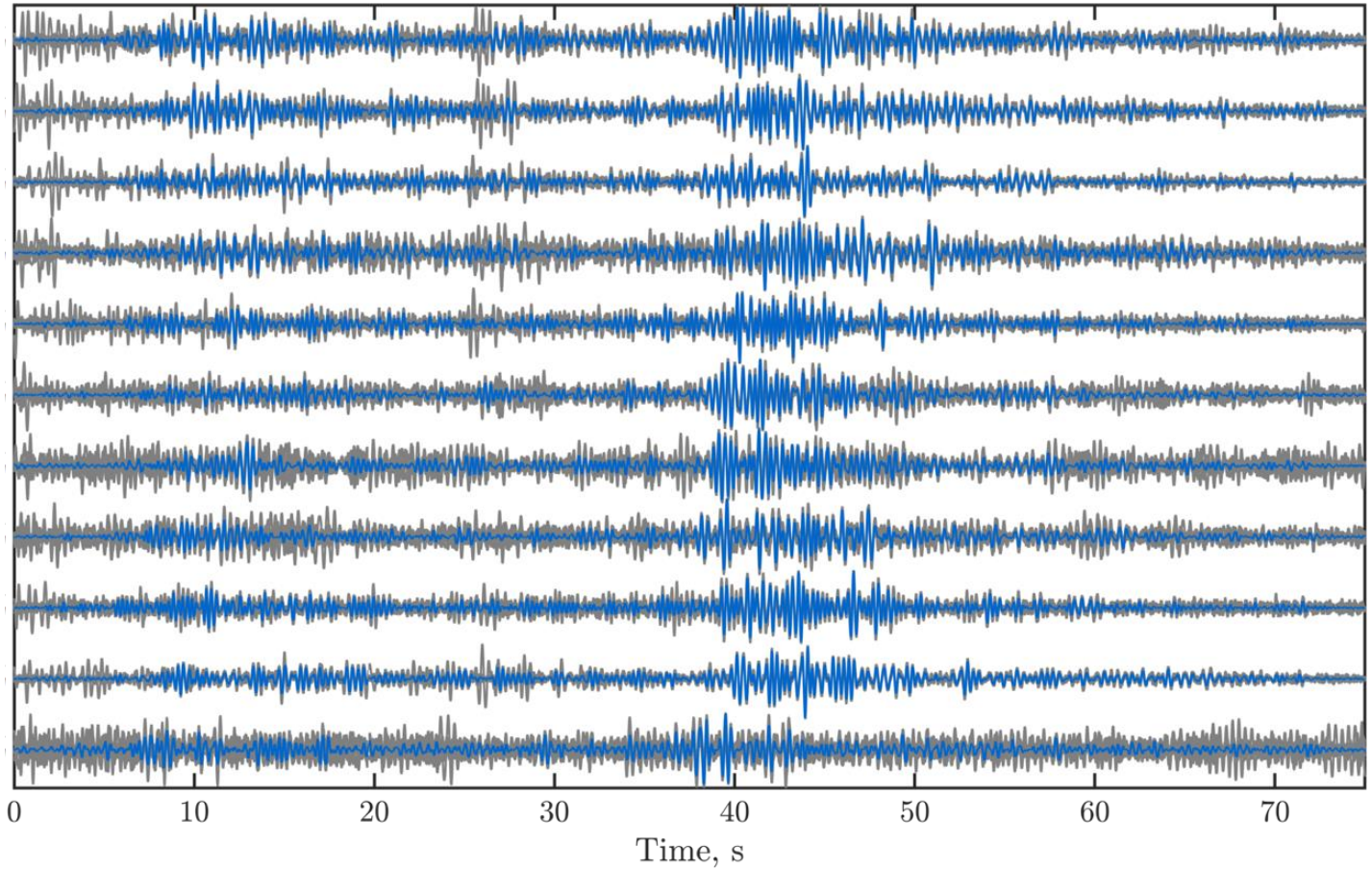
Motivation:

Why are smaller events and regional distances more difficult?

1.) Low signal-to-noise ratios

Need improved uncertainty quantification



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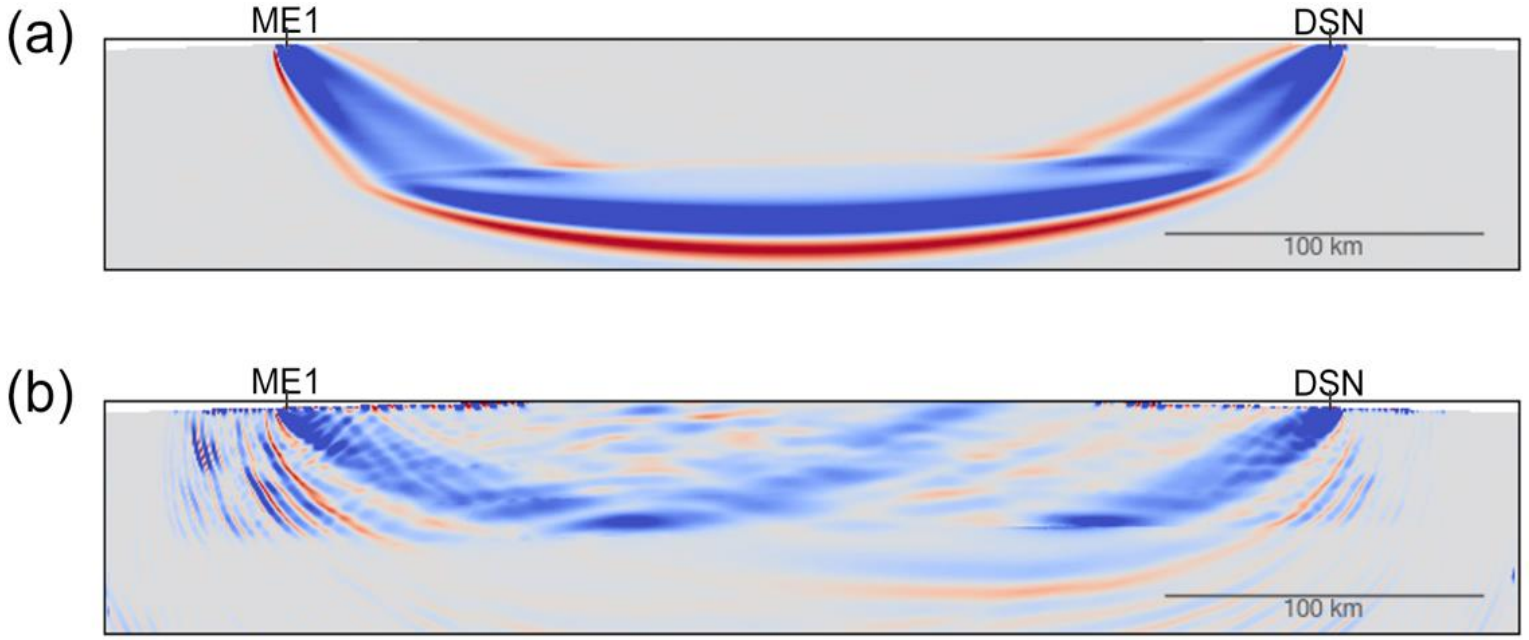
Motivation:

Why are smaller events and regional distances more difficult?

1.) Low signal-to-noise ratios

2.) Complex Wave Propagation

Need new high frequency models



Nelson et al. 2023, BSSA

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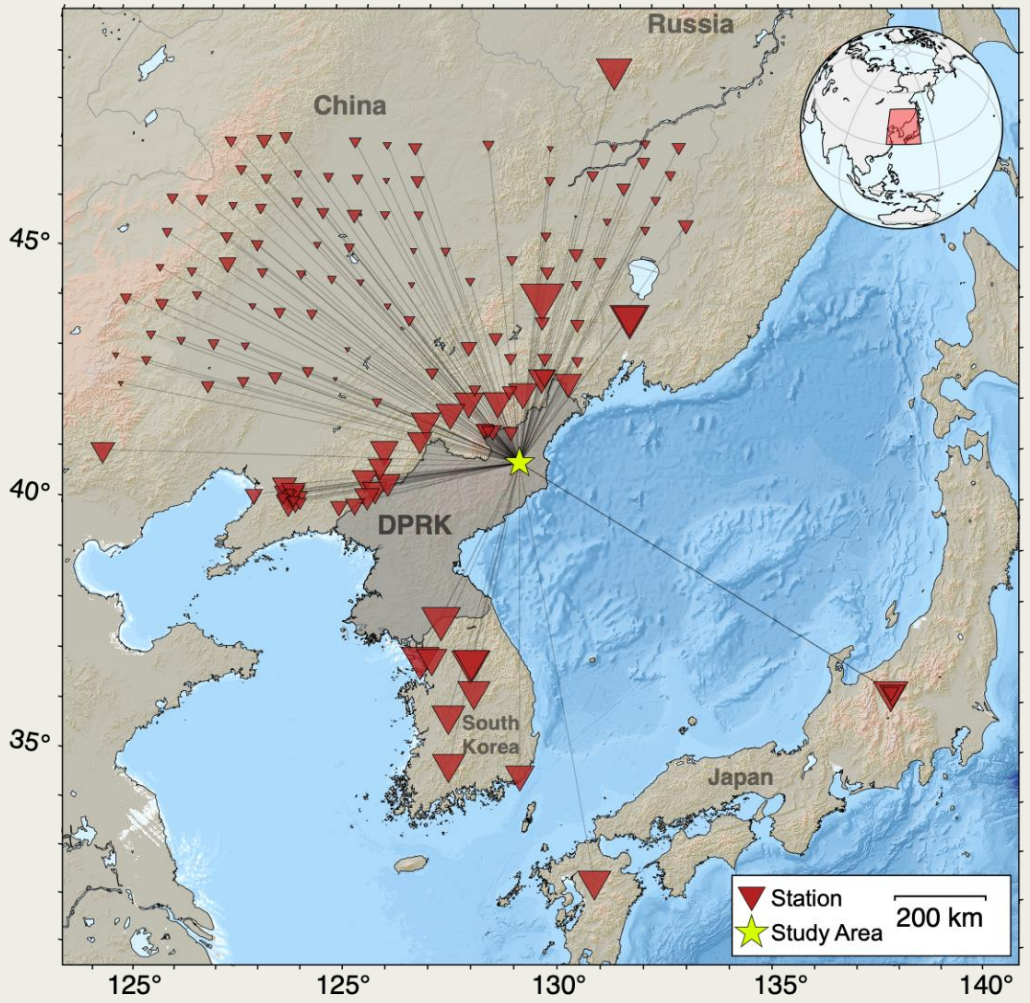
Approach:

Demonstrate source discrimination and characterization methods that do not require any *a priori* calibration, or “ground truth” measurements.



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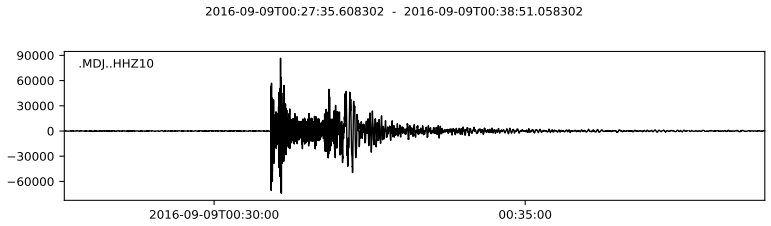
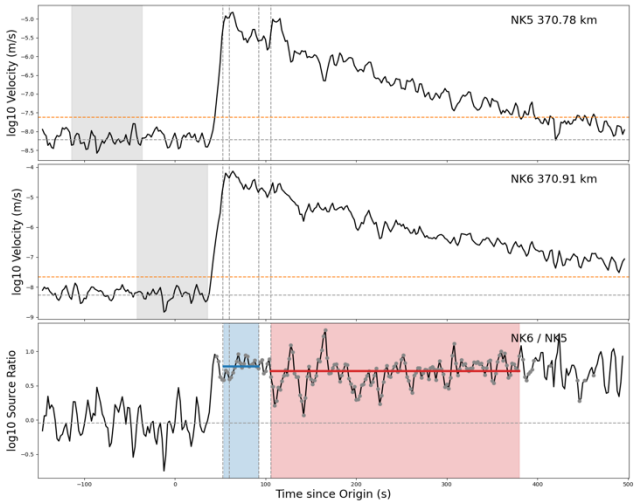
Approach:

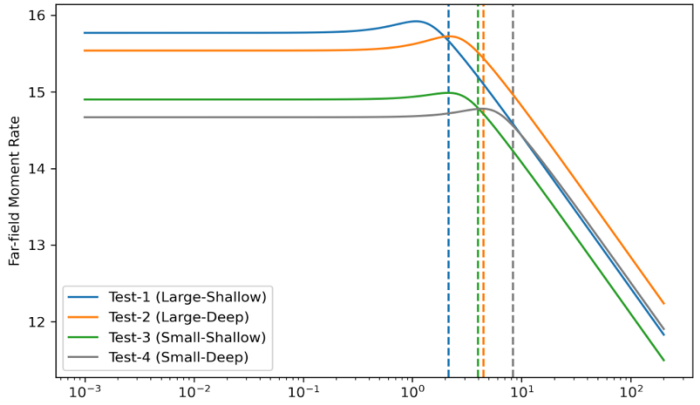
Use ratios of narrow-band envelopes of measured seismic coda waves to remove path and site effects to isolate seismic source information.

Seismic Observations





Source Models



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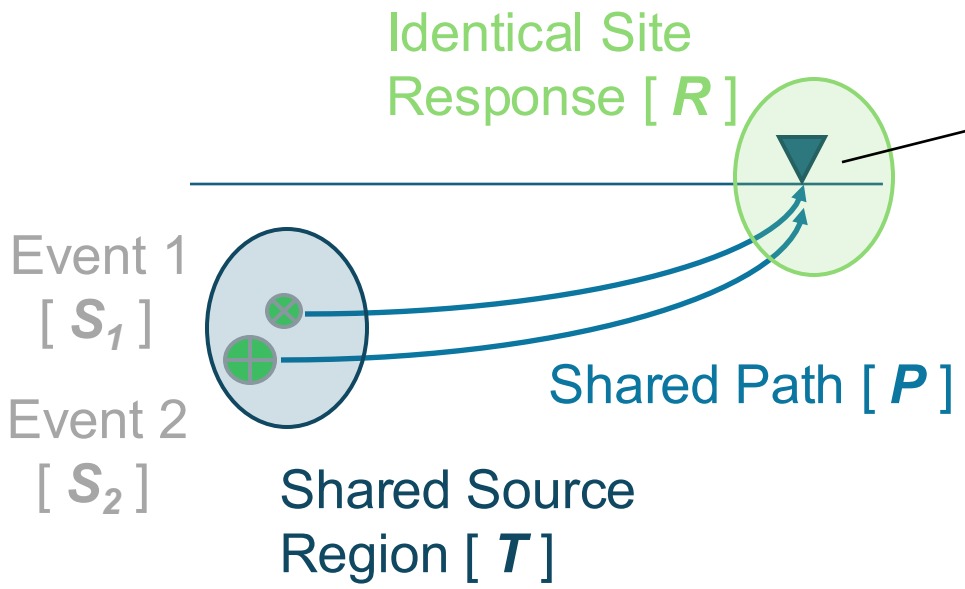
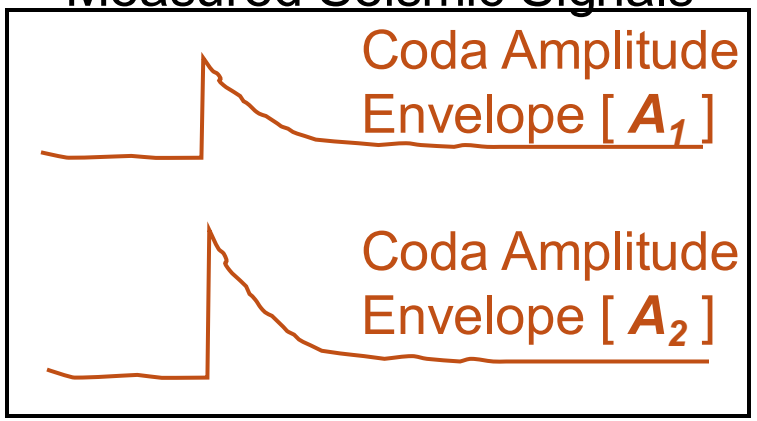
Body-wave Coda Spectral Ratios



Measured Seismic Signals



Coda Envelope Ratios

$$\frac{A_2}{A_1} = \frac{S_2 * T * P * R}{S_1 * T * P * R} = \frac{S_2}{S_1}$$

Modeled Coda Amplitude Envelope

$$A_i = S_i * T * P * R$$

Taking the ratio removes **path** and **site effects**, allowing observation of the relative source ratios

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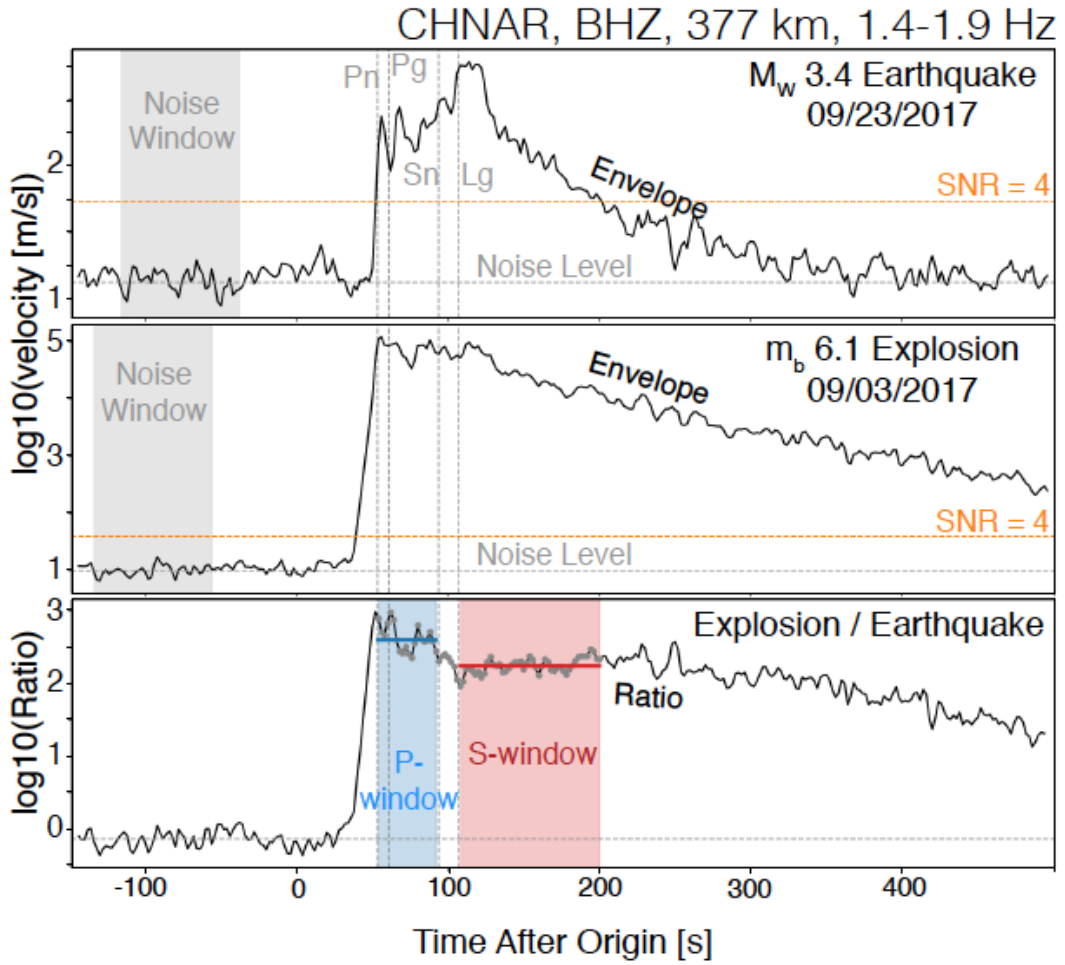
Body-wave Coda Spectral Ratios

1. Compute narrow-band envelopes for a pair of events recorded on the same station
2. Estimate noise level cutoffs
3. Take the pointwise ratio of the two envelopes
4. Estimate the median of within the P & S windows, respectively



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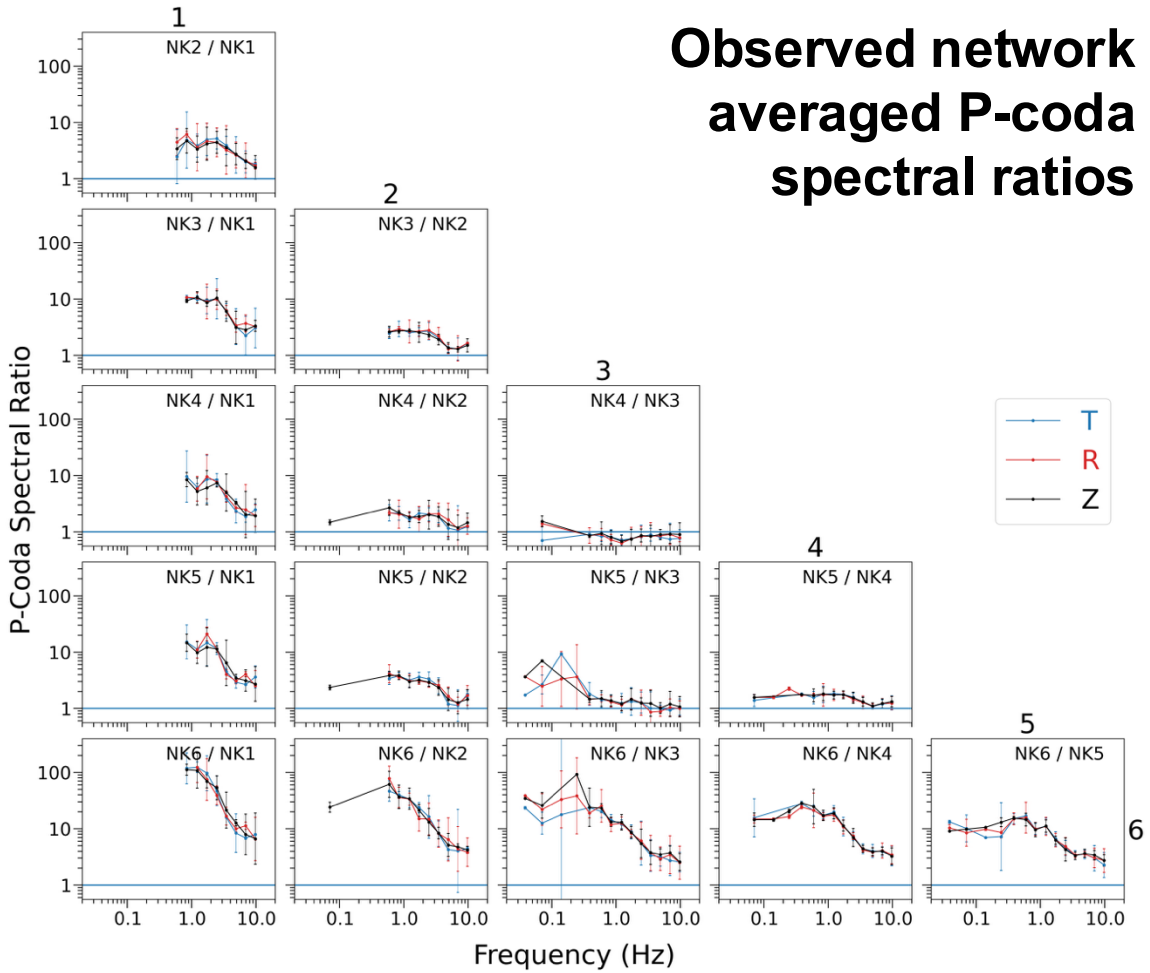
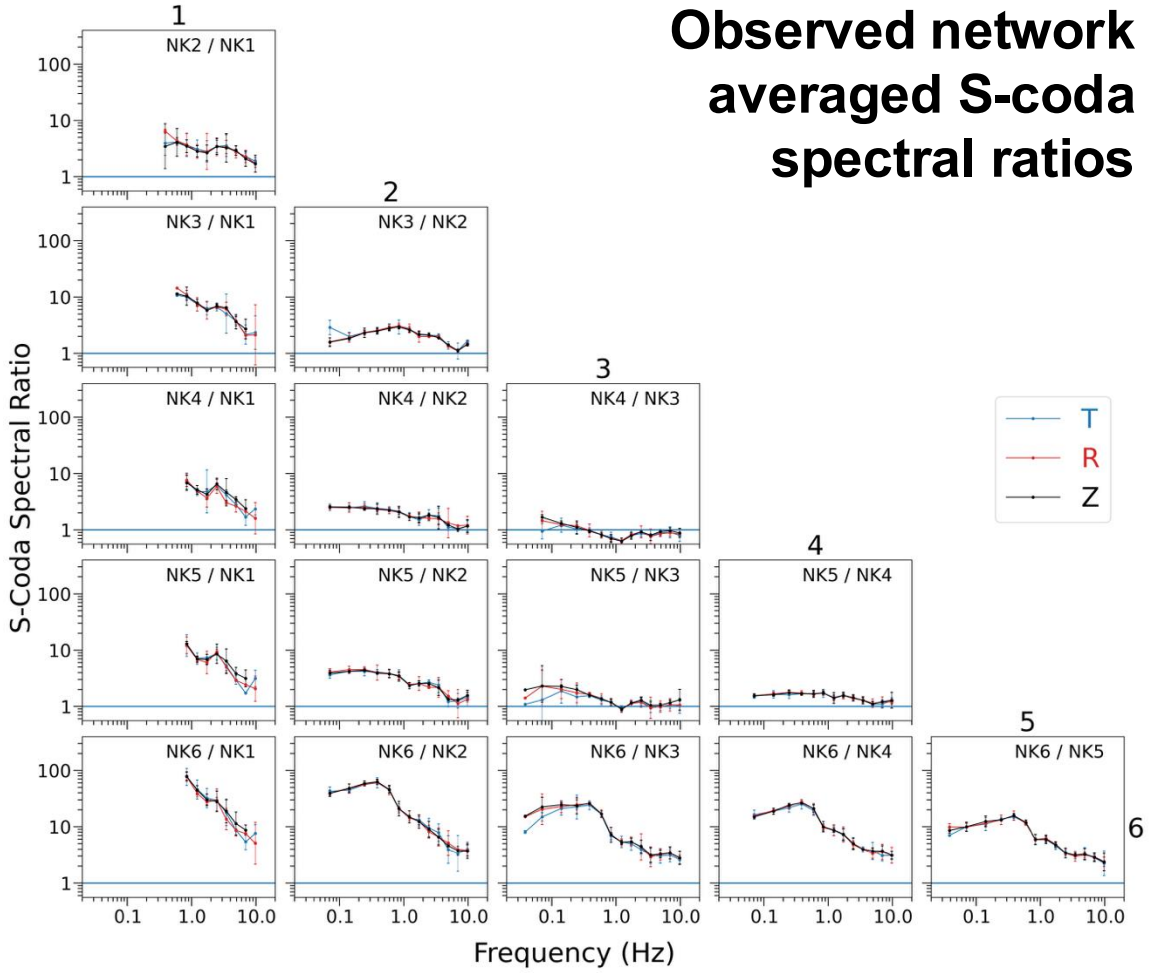
DPRK Coda Spectral Ratio Results

Observed network averaged P-coda spectral ratios



Observed network averaged S-coda spectral ratios



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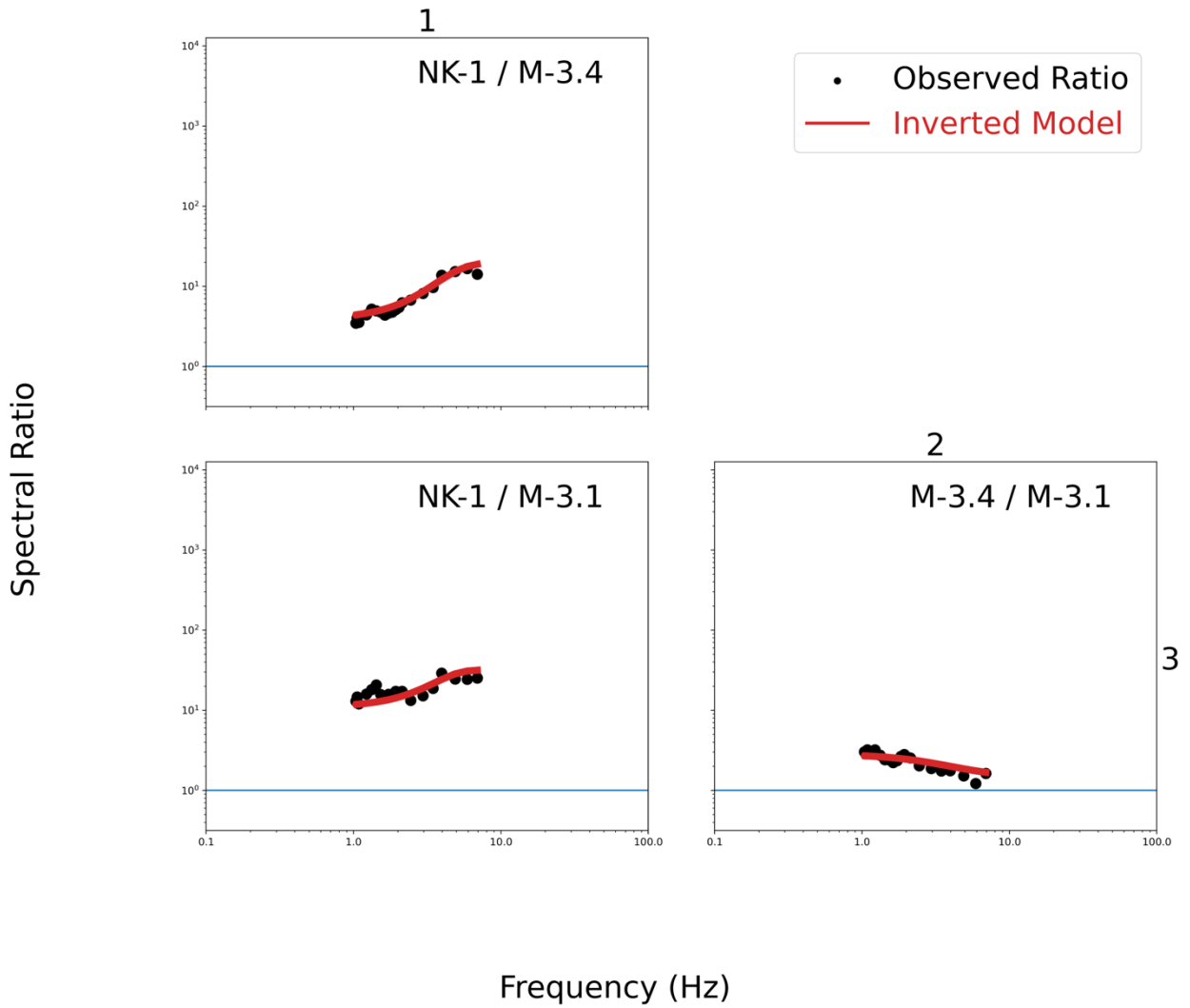
DPRK Coda Spectral Ratio Results

Without any *a priori* calibration, we can obtain a robust estimate for the yield and depth of burial.



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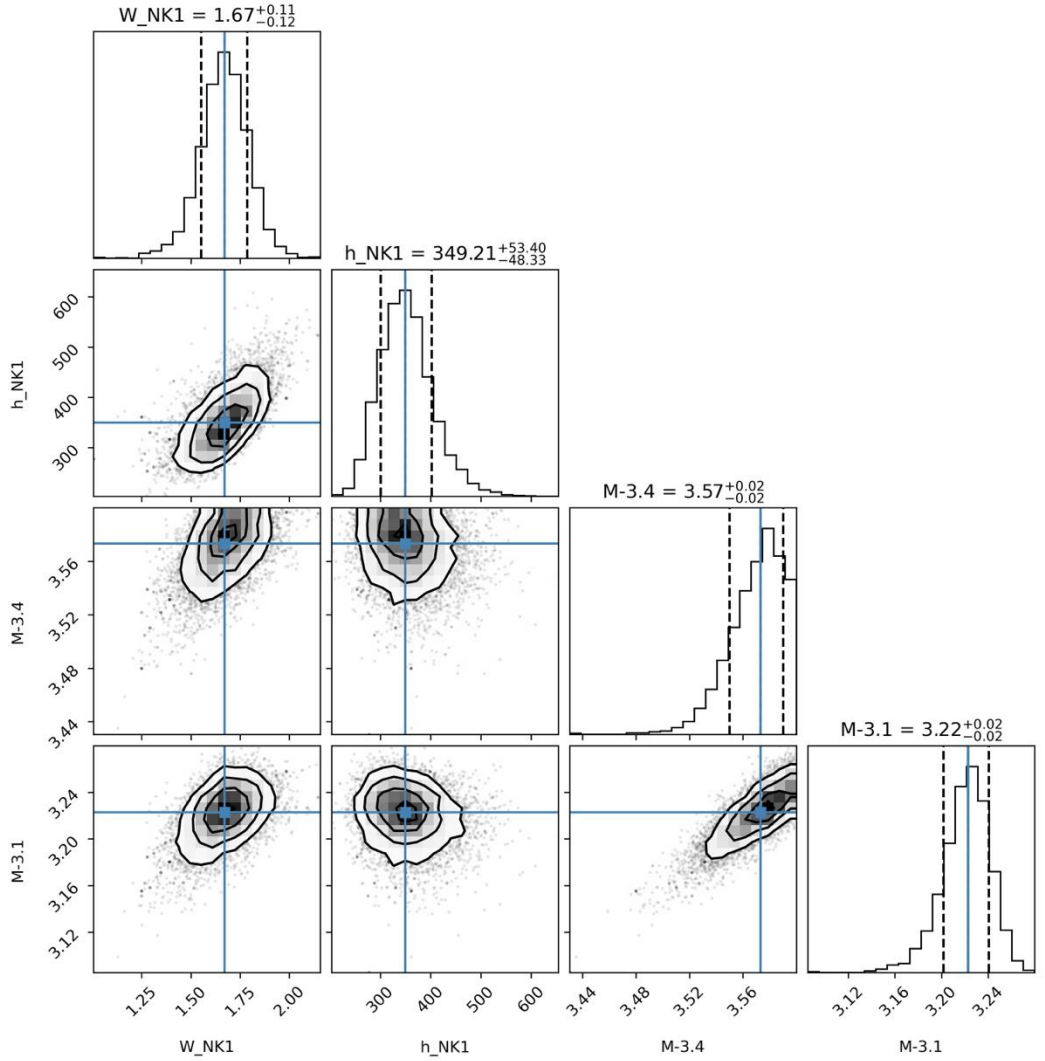

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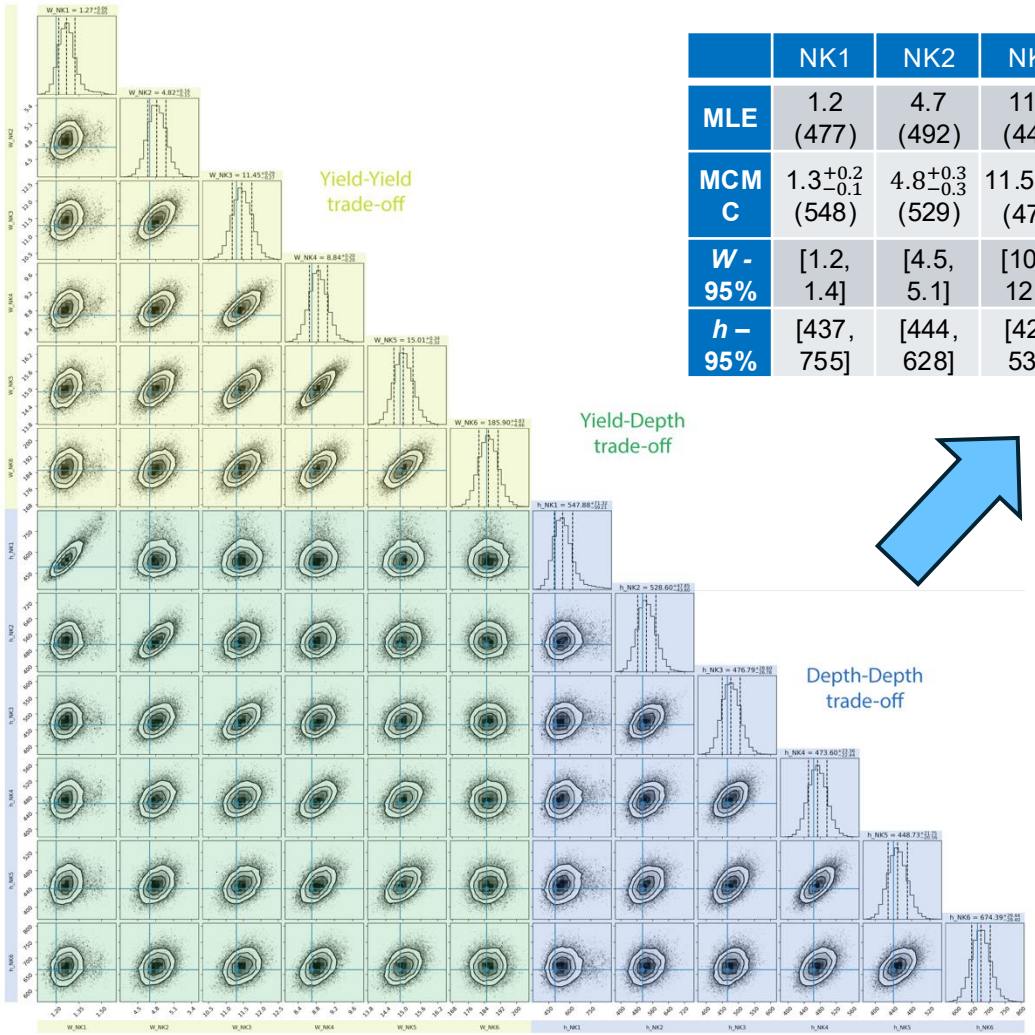
DPRK Coda Spectral Ratio Results

The yields and depth of burial estimates are commensurate with previously determined seismic source parameters.

The method also provides quantitative uncertainties



	NK1	NK2	NK3	NK4	NK5	NK6
MLE	1.2 (477)	4.7 (492)	11.1 (447)	8.6 (450)	14.6 (429)	183.7 (662)
MCMC	$1.3^{+0.2}_{-0.1}$ (548)	$4.8^{+0.3}_{-0.3}$ (529)	$11.5^{+0.6}_{-0.5}$ (477)	$8.8^{+0.4}_{-0.4}$ (474)	$15.0^{+0.7}_{-0.6}$ (449)	$185.9^{+9.8}_{-9.2}$ (674)
W - 95%	[1.2, 1.4]	[4.5, 5.1]	[10.9, 12.0]	[8.5, 9.3]	[14.4, 15.7]	[176.7, 195.7]
h – 95%	[437, 755]	[444, 628]	[425, 535]	[430, 521]	[409, 493]	[618, 735]

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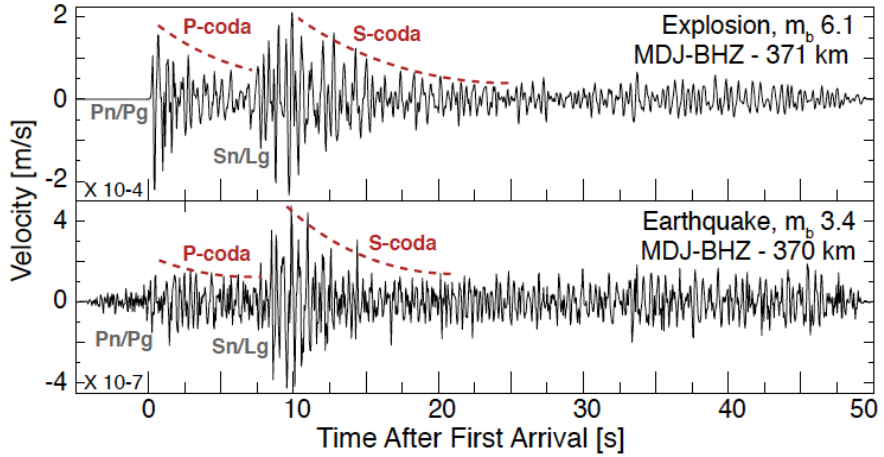
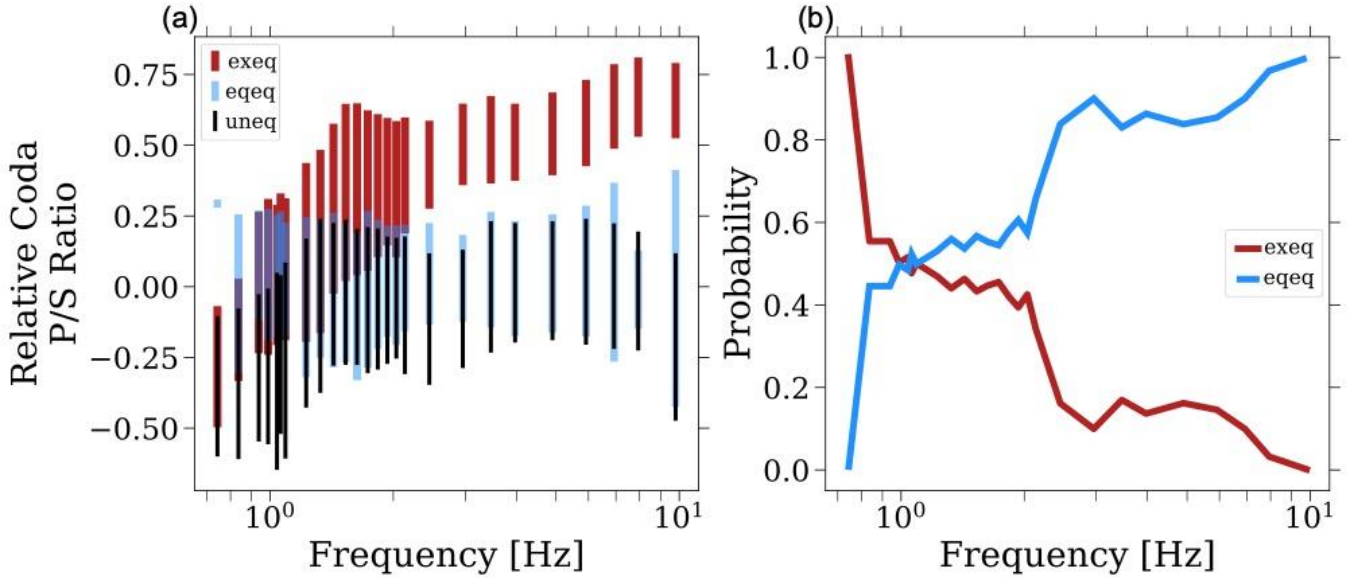
DPRK Coda Spectral Ratio Results

This discriminant can be thought of as **a network averaged P/S source ratio** that doesn't require calibration.





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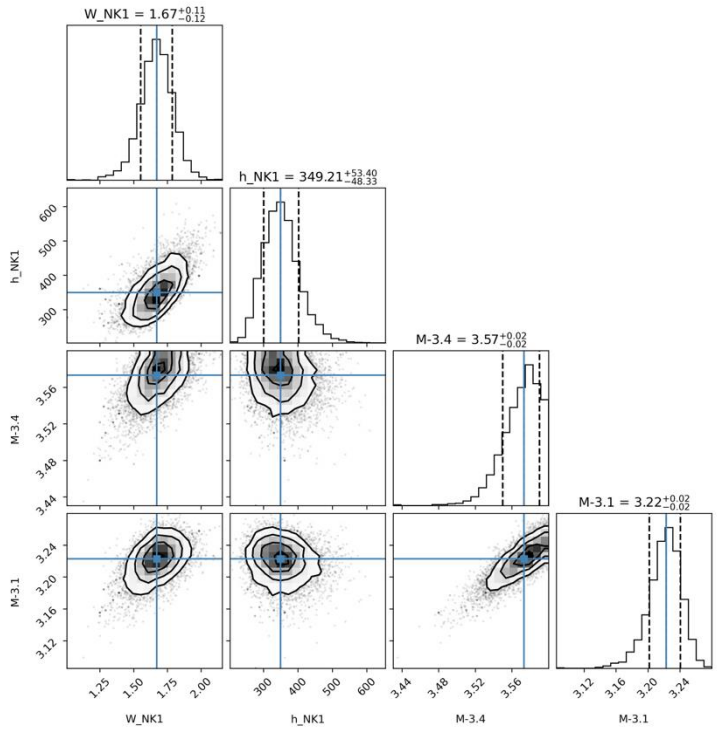
Conclusions:

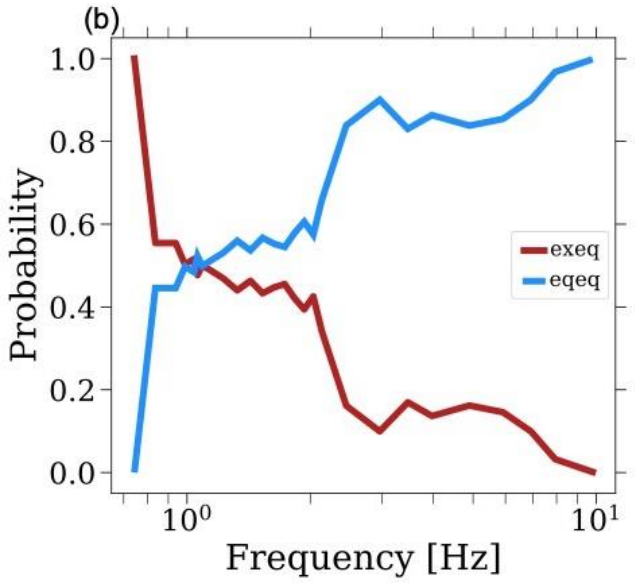
We show here that if a nuclear test of sufficient yield (>1 kT) were conducted that this method can characterize the source type and provide a robust estimate of the yield and depth of burial without requiring any station or site calibrations, and is applicable to a wide range of source yields.

The only requirements of this method is that there be a nearby earthquake and that both seismic sources be well recorded by a shared set of station channels.

Yield and DoB



Source Type Discrimination



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