Seismoacoustic Single Infrasound Station Yield Estimation: Calculating Both Seismic and Acoustic Yields from Infrasound Data

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1. Introduction

Background:

Ground motion and and air pressure data are crucial in monitoring natural and man-made phenomena.

Seismic and infrasonic data exhibit a **trade-off** in calculated explosion **yields** and **height of bursts (HOB).**

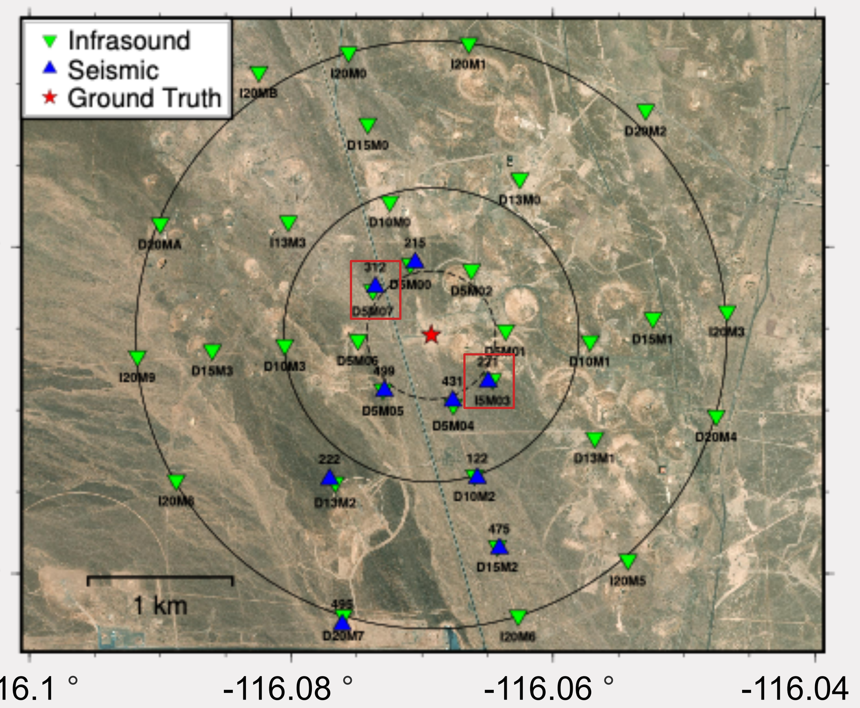
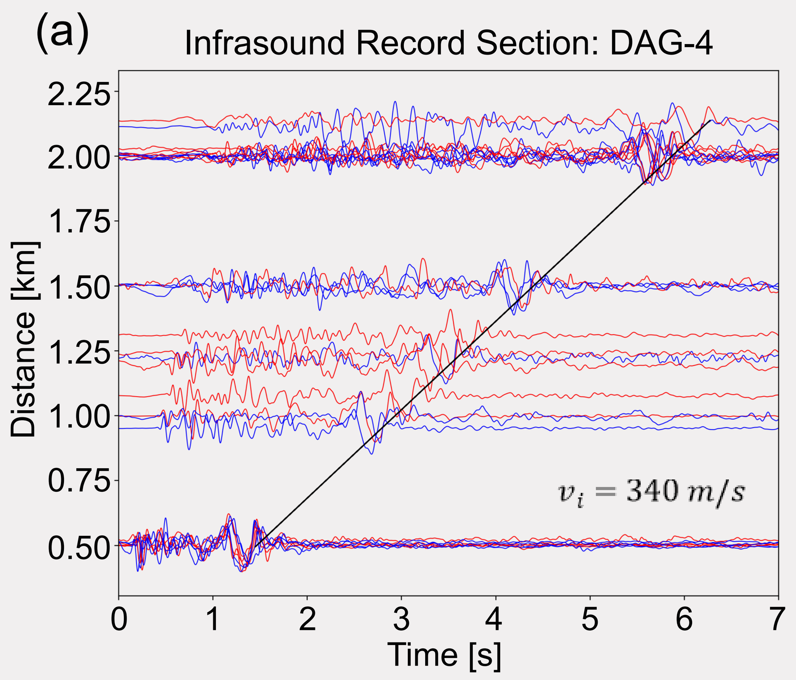


Figure 1: Infrasound (green) and seismic (blue) stations located in Nevada, relative to the explosion ground truth (red). Dashed circle: minimum strong shock regime. Solid circle: labeled with increments of 1km.

Here we utilize converted local infrasound (CLI) [Macpherson et al., 2023] and the Ford method [Ford et al., 2021] to estimate **Seismoacoustic Single Infrasound Station Yield (SASSY)** from a buried chemical explosion.

(a)



(b)

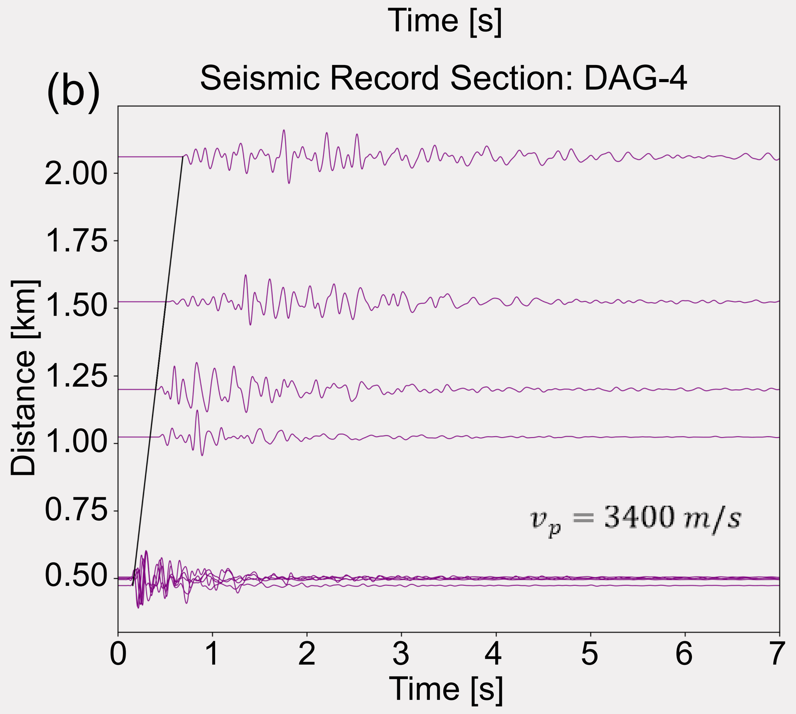


Figure 2: Record sections showing normalized amplitude bandpass filtered between 1 – 20 Hz For infrasound, wave propagation towards the West is in red, East is in blue. Time axis is in seconds, since origin time.

Data:

The fourth chemical explosion of the Source Physics Experiment Phase II Dry Alluvium Geology (DAG) series recorded by the Hyperion microbarometers and Large-N seismic array – **DAG-4** [Larotonda & Townsend, 2021].

Ground Truth (GT)	
Yield:	HOB:
10,357 kg	**-51.6 m**

Motivation:

- Test **CLI** validity to **proximate seismic arrival**
- **Minimize the uncertainty** of yield and HOB: combining seismic / CLI with infrasonic data applications
- **Increase** the number of **available observations** with CLI

2. Converted Local Infrasound (CLI)

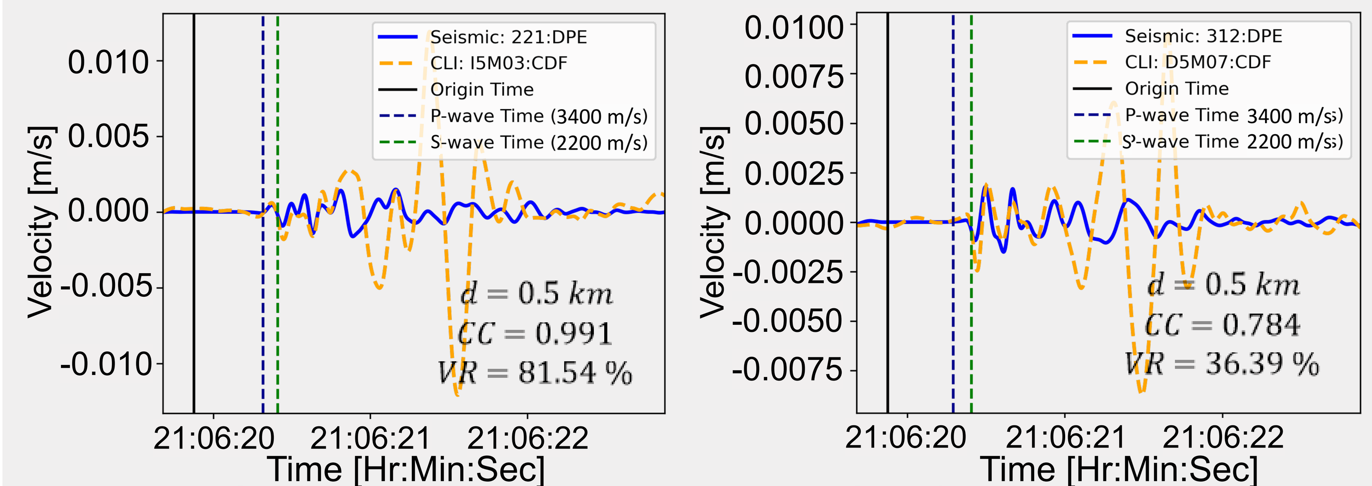


Figure 3: CLI (orange dashed) and seismic waveform (blue) at co-located stations, filtered between 0.5 – 5 Hz. Distance d indicates the station's distance away from GT. Correlation coefficient (CC) and variance reduction (VR) measures the likeness between CLI and seismic. CLI conversion equation (1) on the right.

- Seismic activity recorded by the infrasound sensors, allowing for CLI conversion

$$v_z(t) = \frac{\Delta p(t)}{\rho c} \quad (1)$$

- Macpherson showed CLI can act as a proxy for seismic arrivals
- CLI shows higher CC and VR values at ~0.5 km
- CC and VR results are mixed at further distances
- CC: phase similarity
- VR: amplitude similarity

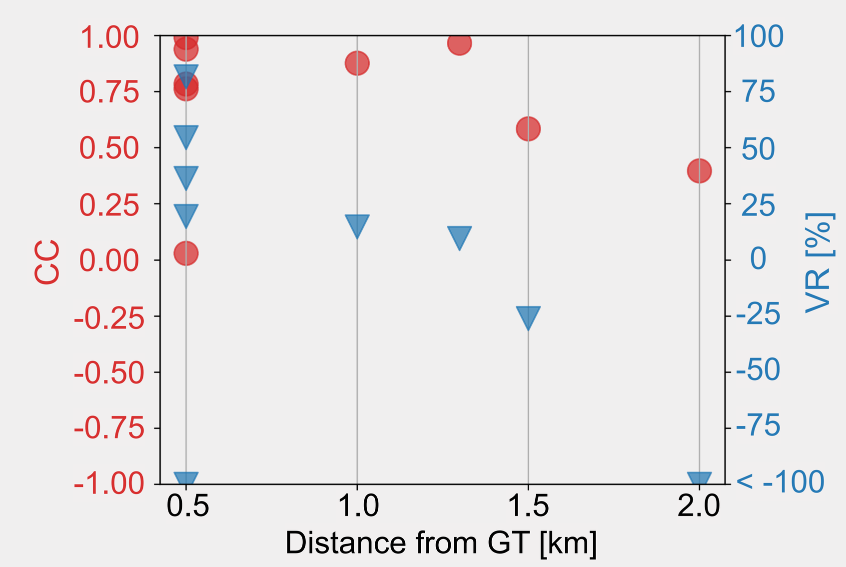


Figure 4: CC (red) & VR(blue) values plotted against distance away from GT.

3. Yield and HOB Calculation

- Ford empirical model predicts seismic displacement and acoustic impulse for a given HOB and yield [Ford et al., 2021]
- Likelihood of yield and HOB found by subtracting observed calculations from predicted calculations and assuming gaussian distribution
- Joint yield found by multiplying seismic and infrasound likelihoods

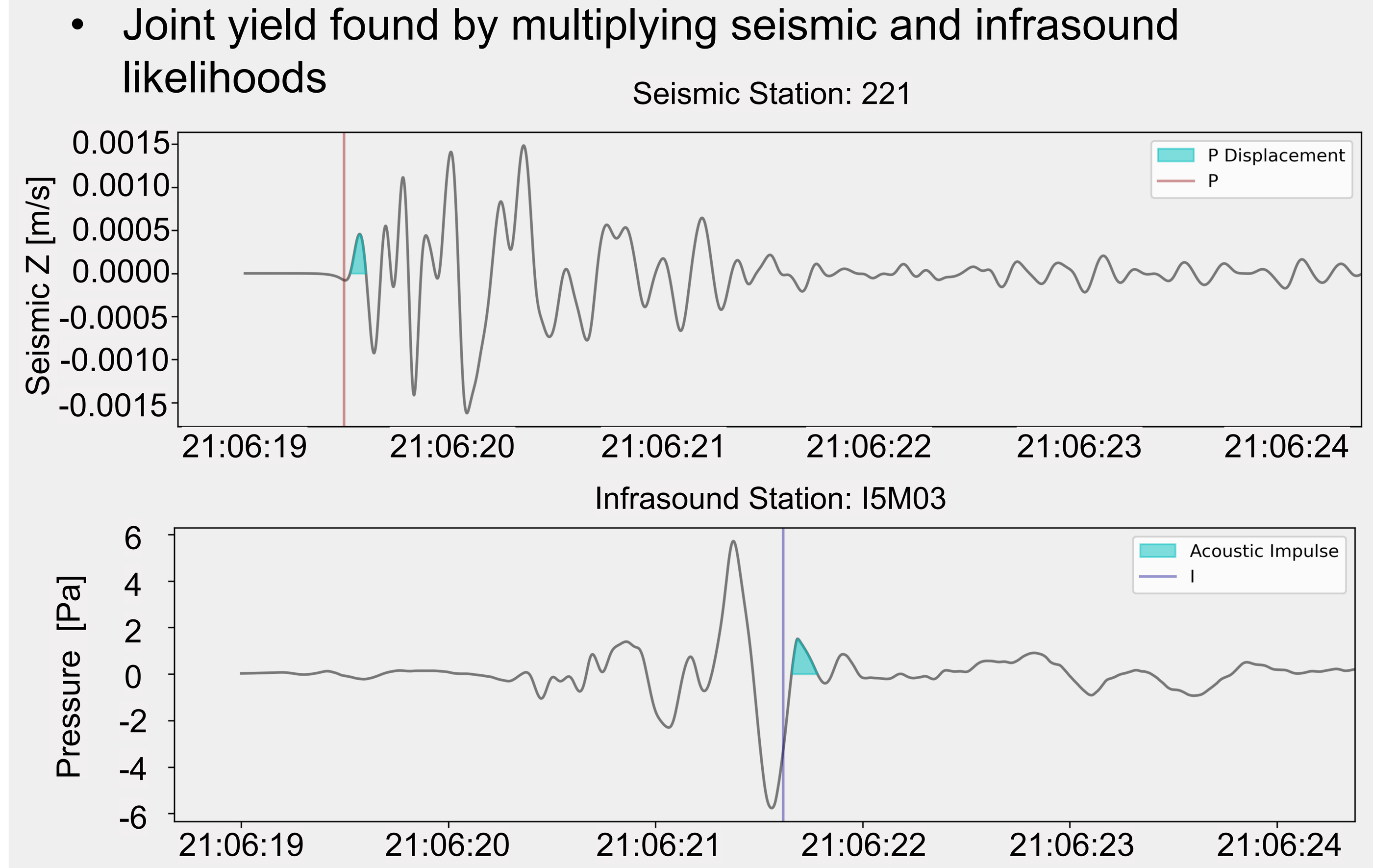


Figure 5: Seismic P impulse and acoustic overpressure picks and area under the curve of the station pair I5M03 – 221 for calculating seismoacoustic yields. Data bandpass filtered between 0.5 to 5 Hz to be consistent with Ford et al., 2020.

4. Results

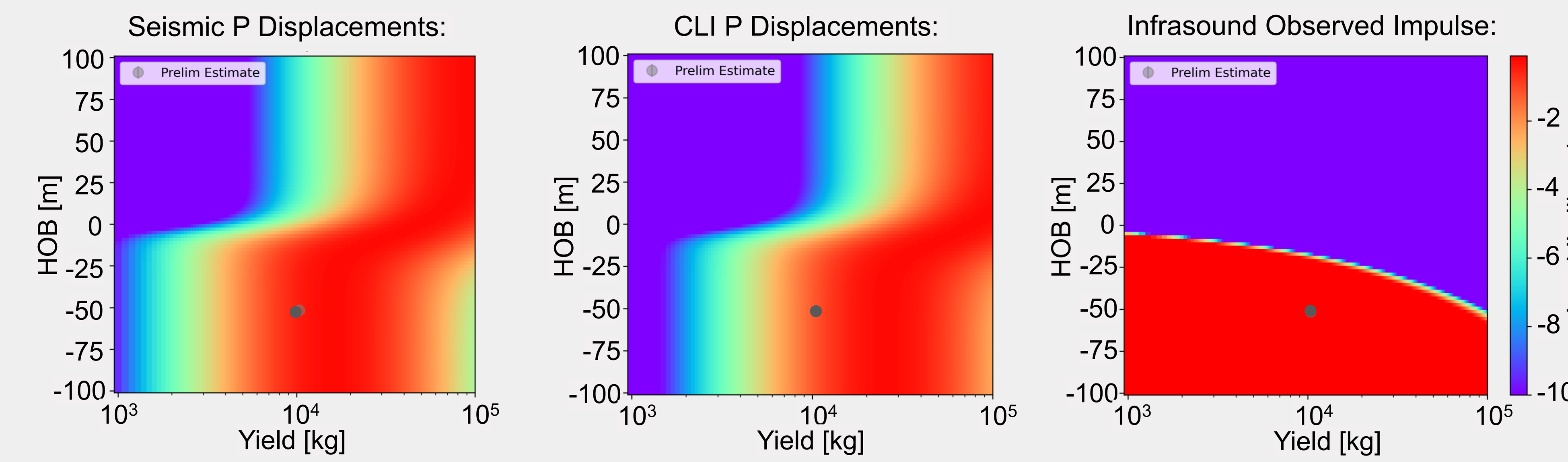


Figure 5: Seismic, CLI, and infrasound yield / HOB likelihoods at station pair I5M03 - 221. The color mesh indicates the yield / HOB likelihoods at a given estimate. The known GT is marked with a gray circle.

- SASSY method attempts to mitigate trade-off of yield / HOB estimation accuracies
- Ford prediction of acoustic impulse poorly fits recorded infrasound data, so we opt to focus on the seismic / CLI instead

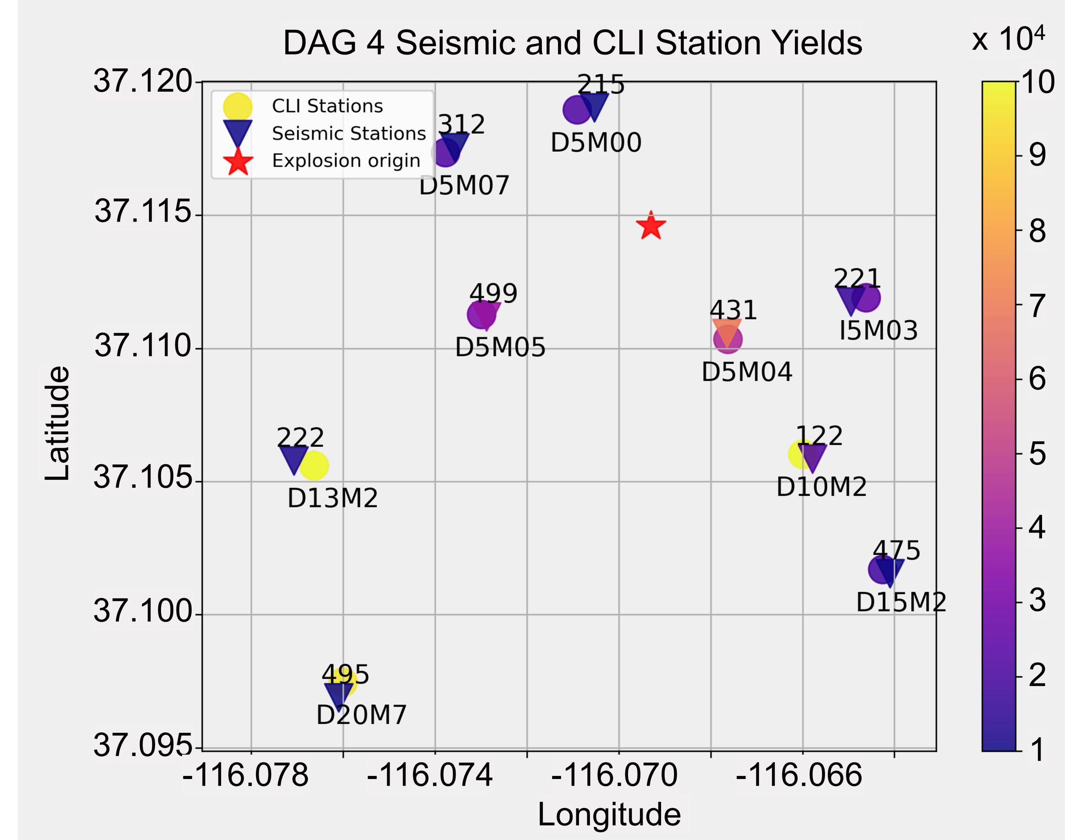


Figure 7: Colored seismic and CLI yield comparison at a HOB index closest to -51.6 m.

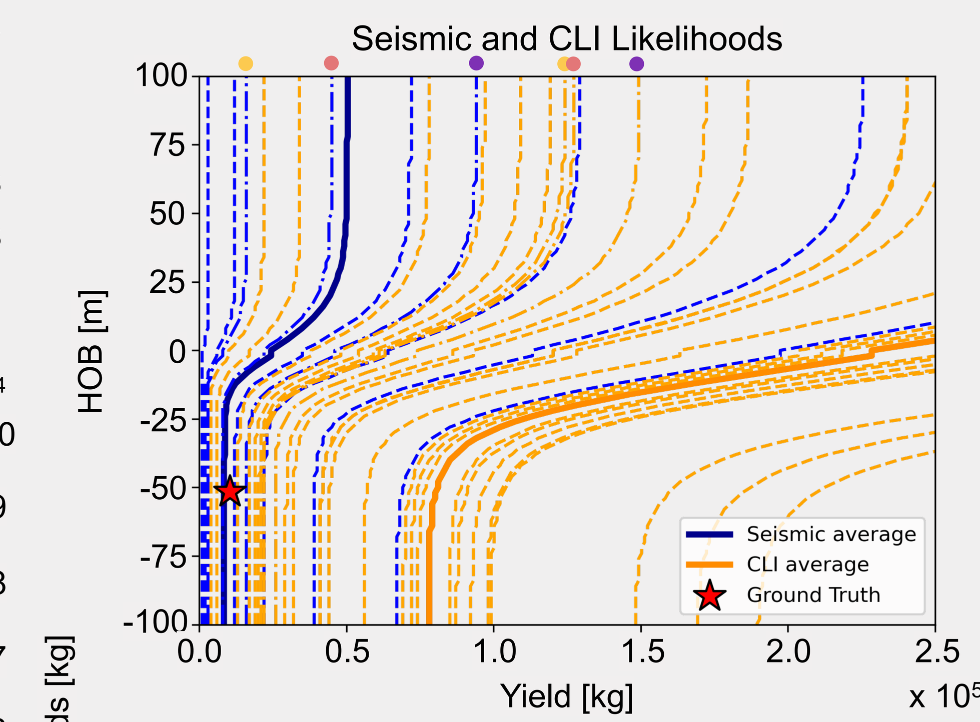


Figure 6: Bolded solid lines represents the average of the maximum likelihood yield / HOBs. Dashed lines represent single station likelihoods.

- Primary contribution to the infrasonic signal is the spall source, which the Ford model does not accurately capture [Berg & Poppeliers, 2022]
- CLI maximum likelihood curve exhibits higher yields overall when compared with the seismic yields at co-located stations

5. Conclusion

Discussion:

- The **SASSY method shows promise**, but further verification on other datasets is needed
- Utilizing both **seismic / CLI and acoustic** data helps **mitigate yield / HOB trade-offs**
- **CLI** appears to **work as a proxy,** however, frequency range, wind noise, and other sources can complicate the arrivals
- **CLI typically over estimates yield**
- Small differences in CLI P displacements leads to large variations in yield estimations

Future work:

- Test SASSY method with other datasets at varying known yields and HOBs.
- Compare yield/HOB estimation accuracy for both near surface and buried explosions
- Take into account possible wind noise to filter out with a signal to noise ratio filter
- Utilize more robust infrasound forward models
- Building a database of local infrasound

References

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