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Acoustic signal proxies for explosive yield and scaled depth of burial during the Source Physics Experiment

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Introduction

Phase I of the Source Physics Experiment (SPE) consisted of **non-nuclear chemical explosions in granite.** The experiment was designed to produce **a high quality, multiparameter geophysical data set** to facilitate the development of **physics-based models** of signals from buried explosions. Infrasound characterization emerged as one of the primary goals of the experiment, and an eight element acoustic network was deployed for that purpose. With six explosions complete and four more taking place in the next year, infrasound's utility as a buried explosive source discriminant can now be explored systematically.

Network

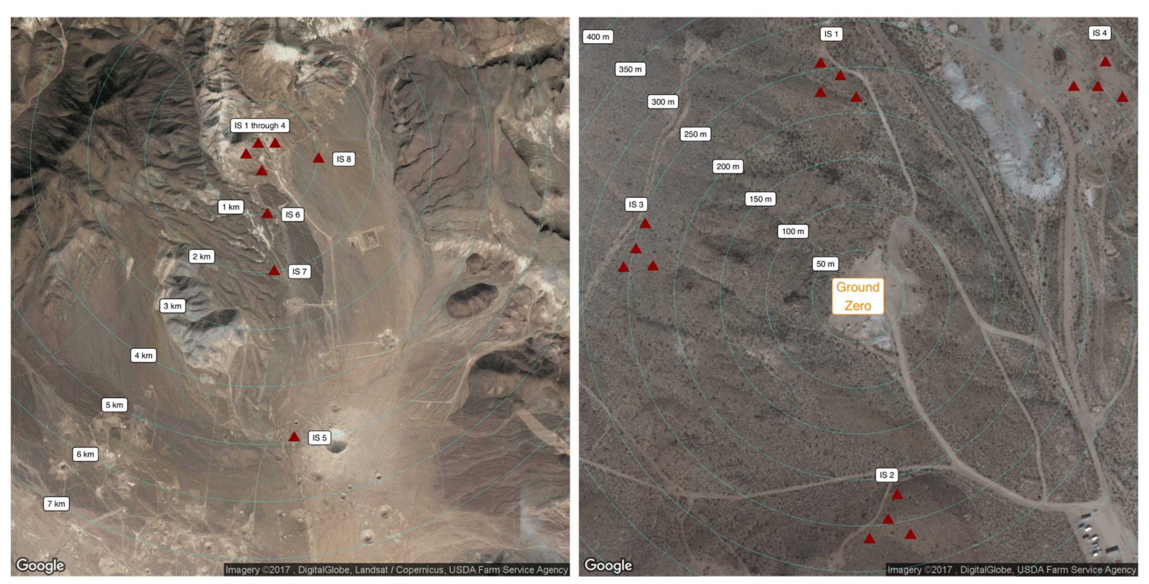

Figure 1: Far view of the eight infrasound stations deployed during the SPE (left) and close up view showing individual array elements (right).

Infrasound sensors were placed 200 m to 5 km from the explosion epicenter. Each station consisted of four sensors approximately 30 m apart. Sensors consisted of Inter-mountain Labs microphones (SPE-1 and SPE-2) replaced with Hyperion microphones (SPE-3 through 6). Wind mitigation consisted of porous hoses and high frequency shrouds. Most microphones at stations IS-1 through IS-4 were replaced with seismically decoupled versions for SPE-5 and SPE-6.

Acknowledgments

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Wave Forms

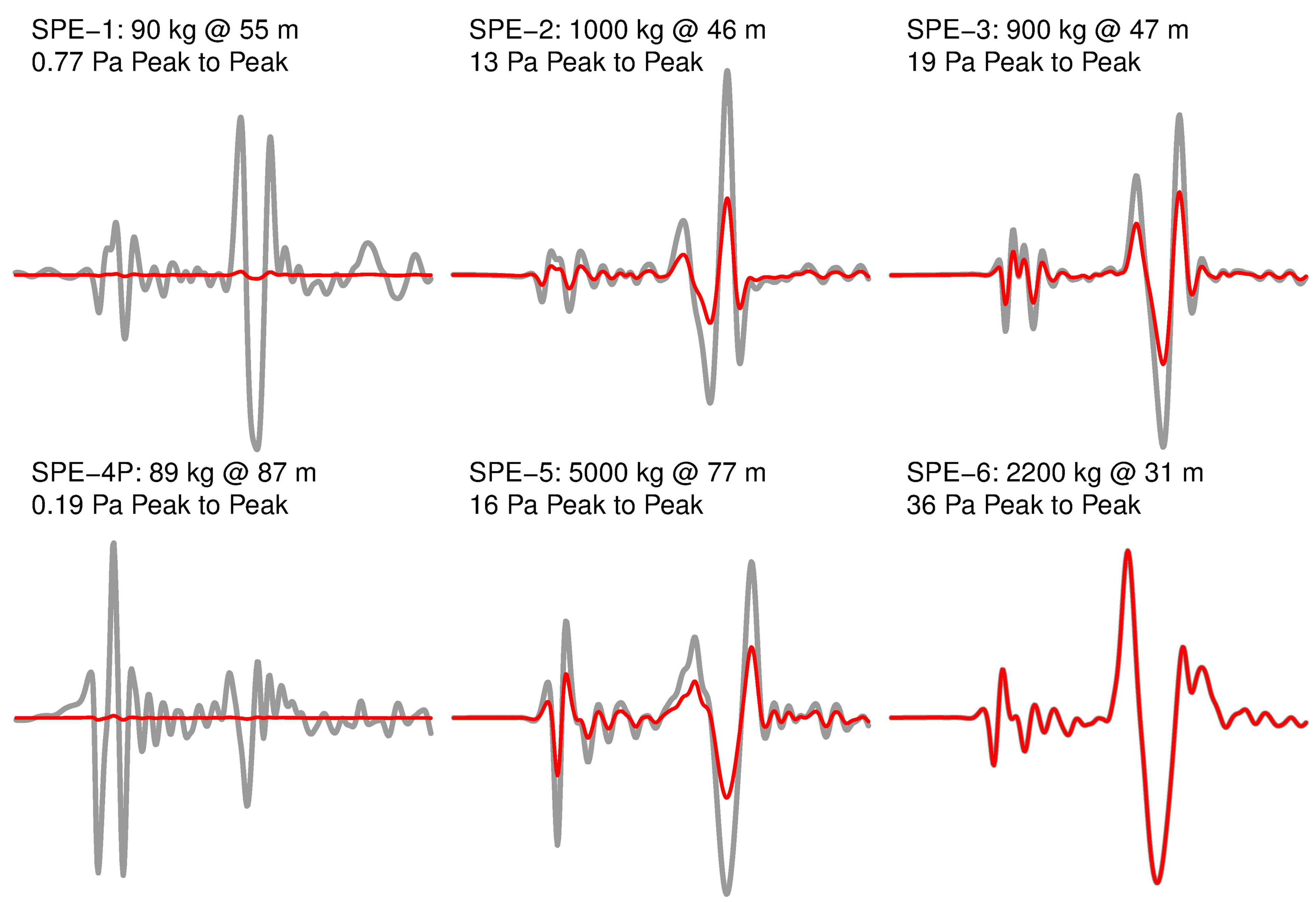

Figure 2: Infrasound recorded at station IS-3, approximately 250 m from the epicenter. The red line is scaled to the maximum amplitude recorded during the series. Shot weights are in TNT equivalent.

Signal Characteristics

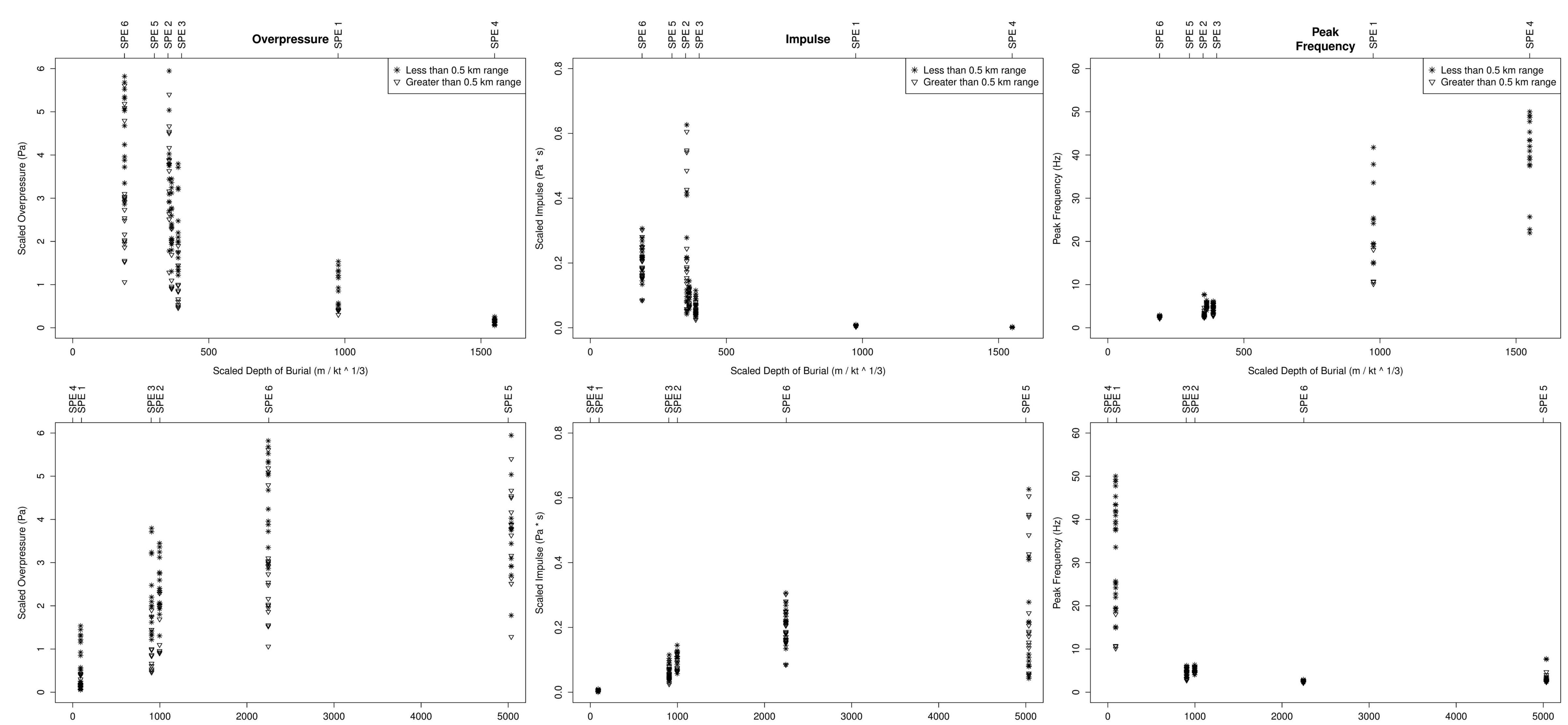

Figure 3: Overpressure, impulse, and peak frequency for each sensor that had an identifiable signal. Overpressure and impulse were scaled to 1 km from the epicenter assuming a geometrical attenuation of $1/r$, where r is distance from source.

Waveforms (Figure 2) and signal parameters (Figure 3) show systematic differences with yield and scaled depth of burial. The overpressure, impulse, and peak frequency of each arrival sheds light on the surface ground motion that gave rise to the signal.

Empirical Models

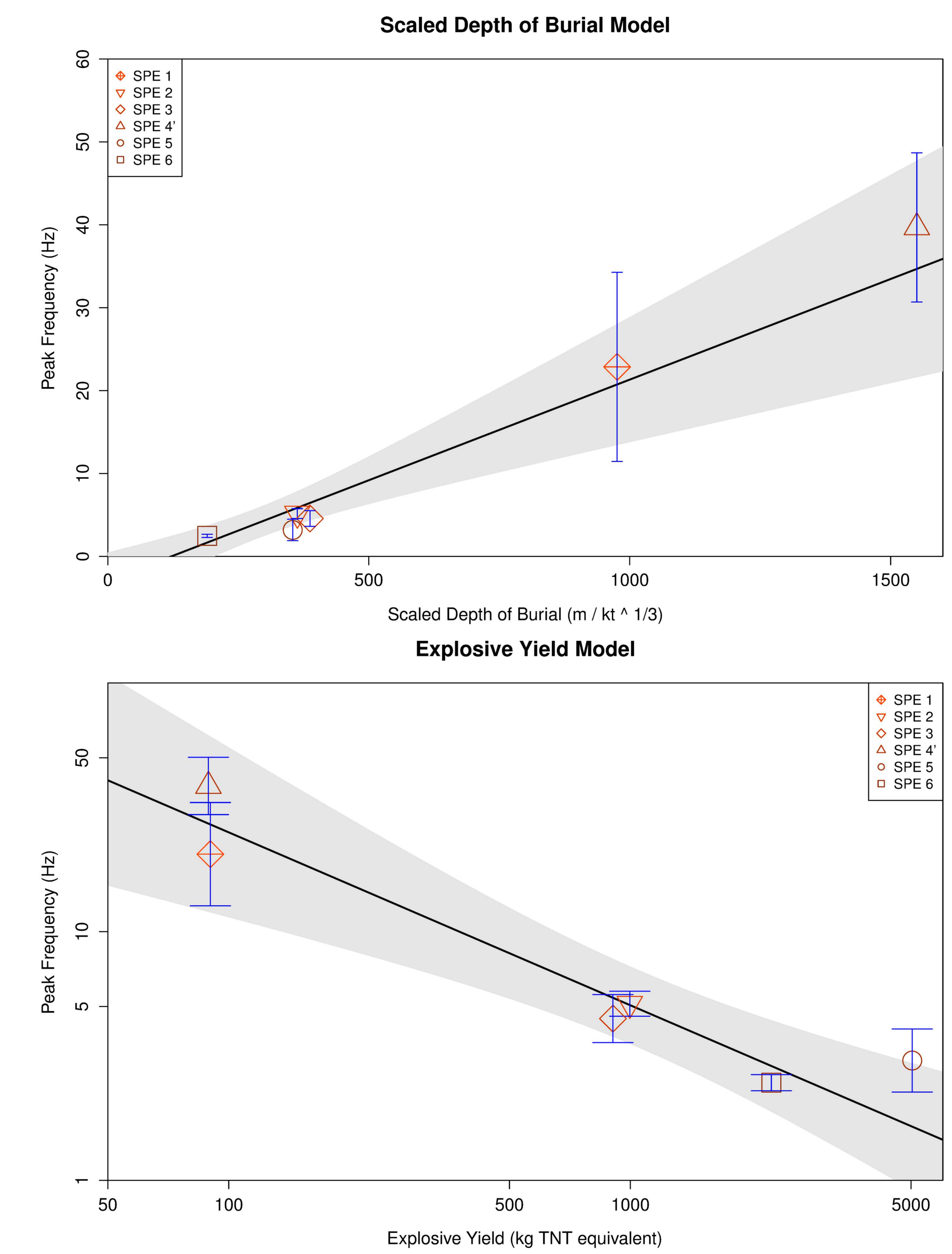

Figure 4: Least squares regression models relating peak frequency of the infrasound wavelet to explosive yield and scaled depth of burial. The gray region is the 95% confidence interval and error bars show the standard deviation of frequency measurements for each shot.

The velocity structure of the lower atmosphere exerts a strong effect on overpressure and impulse measurements even at ranges of less than ten kilometers, making them unreliable proxies for source characteristics. Peak frequency may be a more consistent metric since it is less sensitive to atmospheric variability. Indeed, a reasonable linear model can be constructed for frequency and scaled depth of burial (Figure 4, top) and logarithmic model for explosive yield (Figure 4, bottom). At present, extrapolating beyond the data limits (or in different substrates) is discouraged pending more detailed analysis.

Summary

Despite infrasound signals reported from buried volcanic, chemical, and nuclear explosions, its potential for source characterization remains poorly known. The SPE Phase I results reported here suggest that peak frequency may provide information on the scaled depth of burial and explosive yield, although the extent to which this can be extrapolated to events of different sizes is unclear. However, even simple regression models suggest that the acoustic waveform preserves useful information on the source itself. The upcoming Phase II experiment (in dry alluvium) will provide additional constraints on this hypothesis.