Using machine learning to detect and characterize long-range infrasound signals from explosions

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ORAL PRESENTATION

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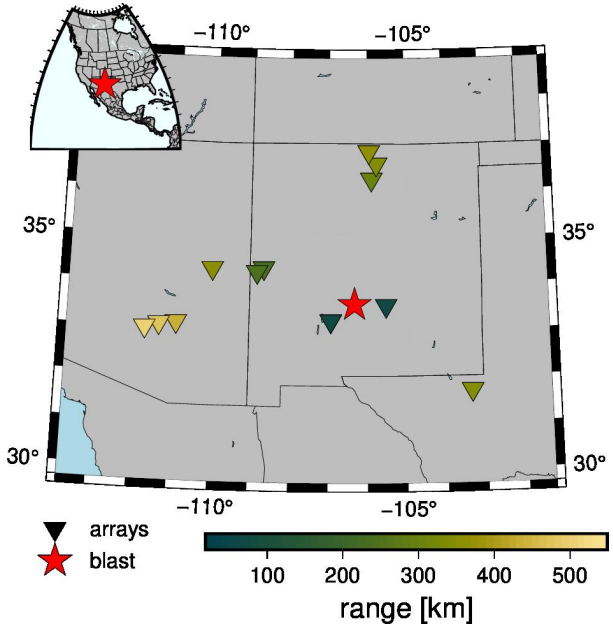
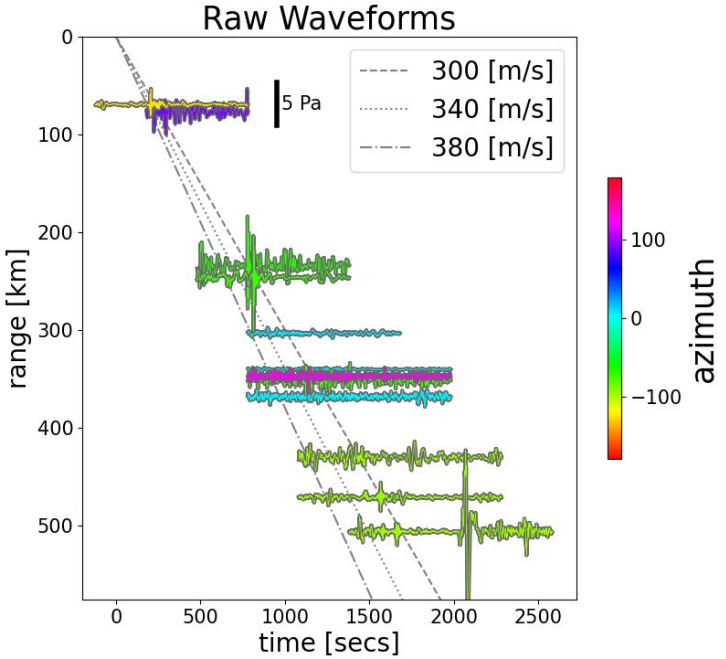
Infrasound signals can propagate 100s (sometimes 1000s) of km.





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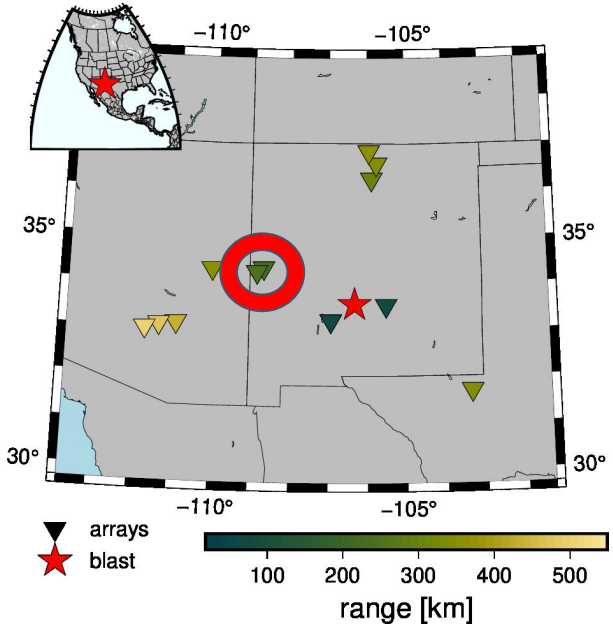

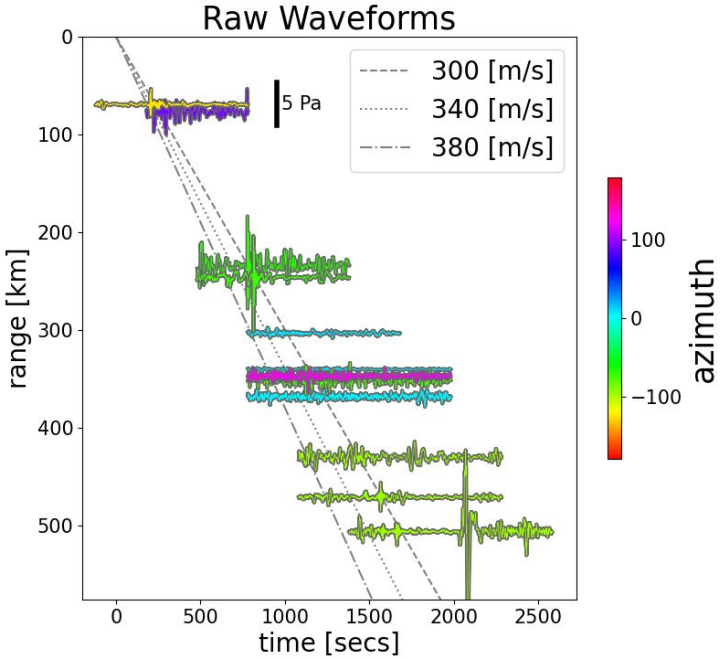

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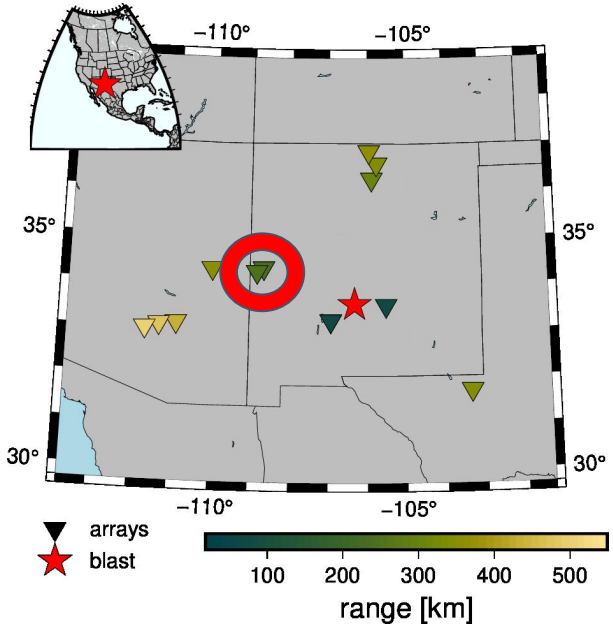

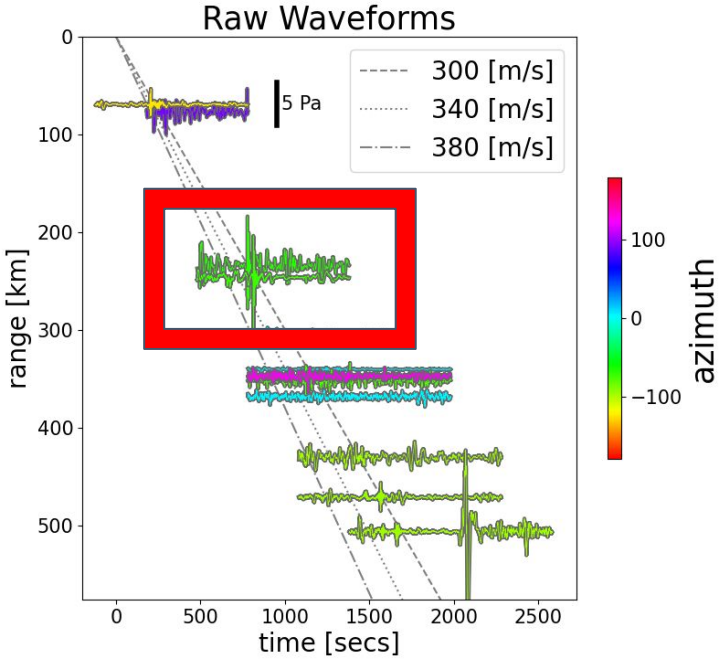

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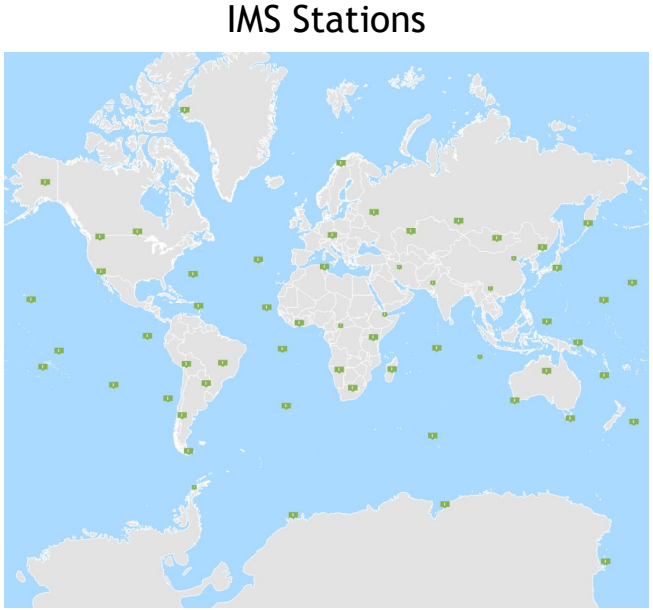
Global infrasound arrays well positioned to record explosion signals.



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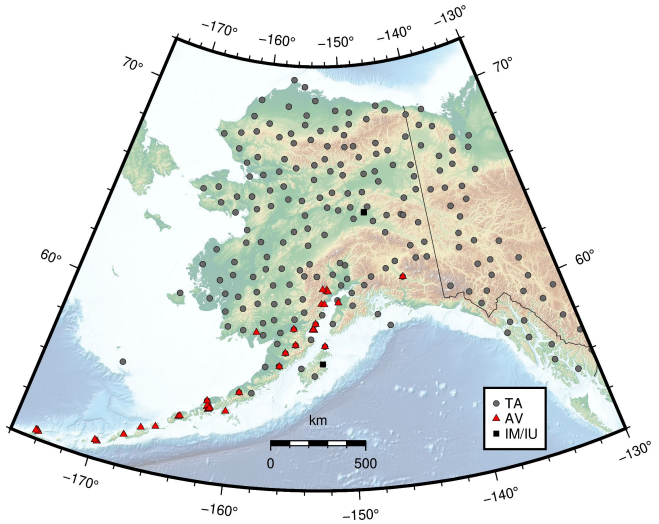
Most infrasound deployments comprise single channel microphones.

IMS Stations

TA/AVO Stations



>300 infrasound stations across Alaska

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Can we identify explosion signals from single channel infrasound data?

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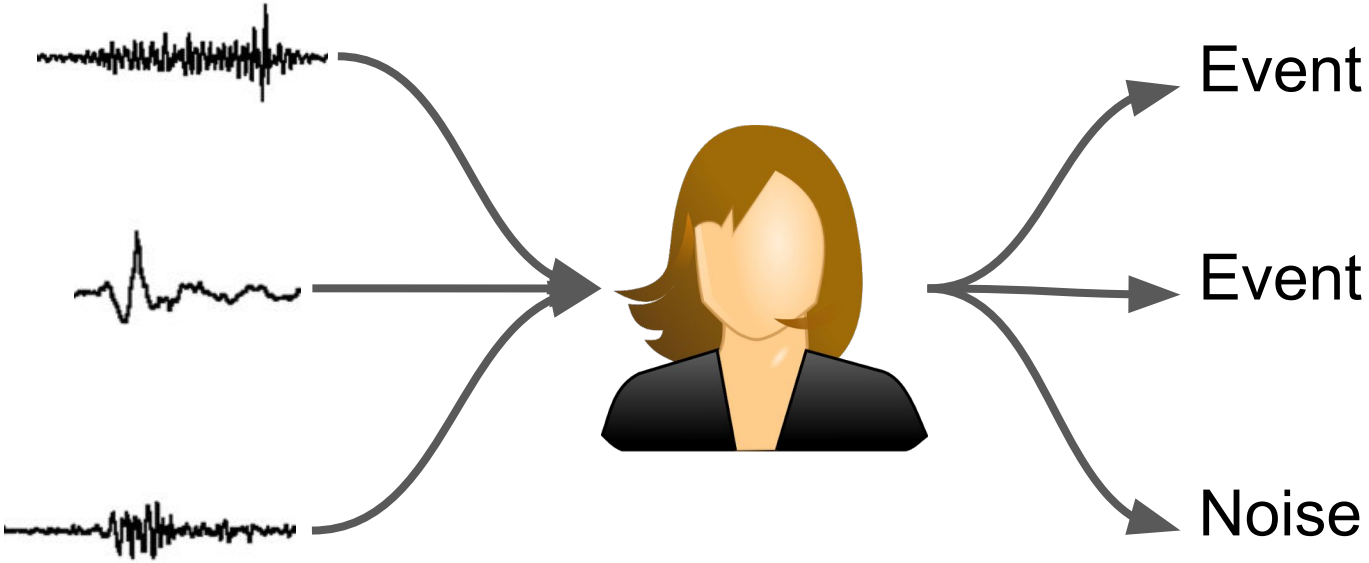
Typically, a technician is trained to identify activity.



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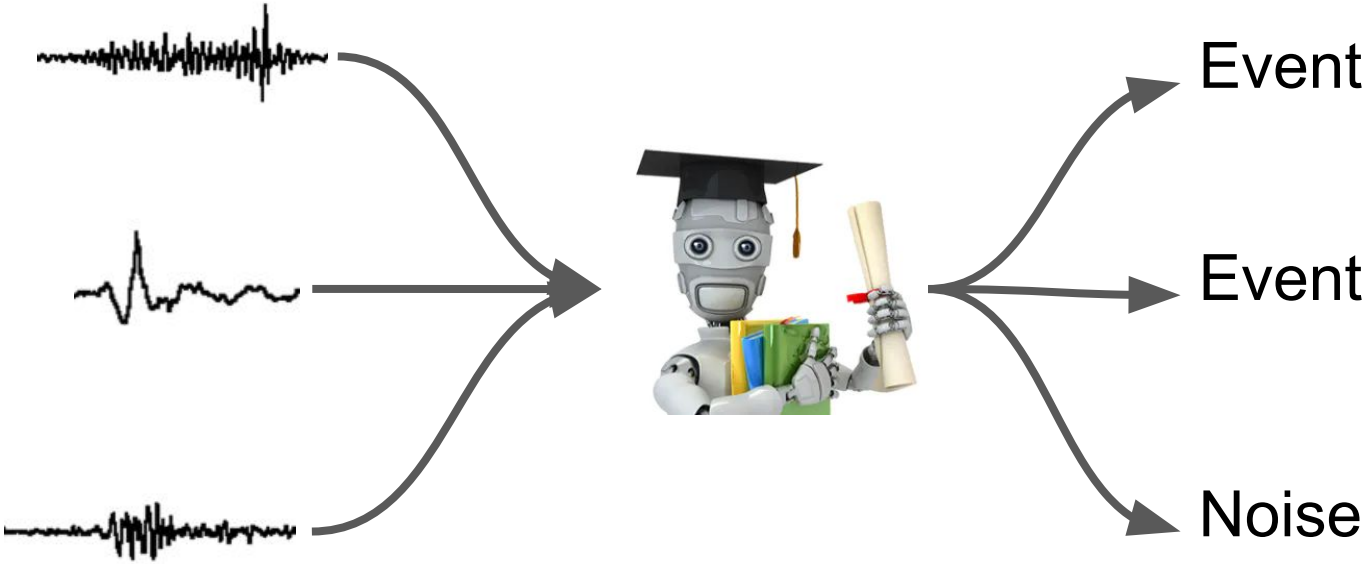
Machine learning is well suited to recognize subtle patterns associated with explosions.



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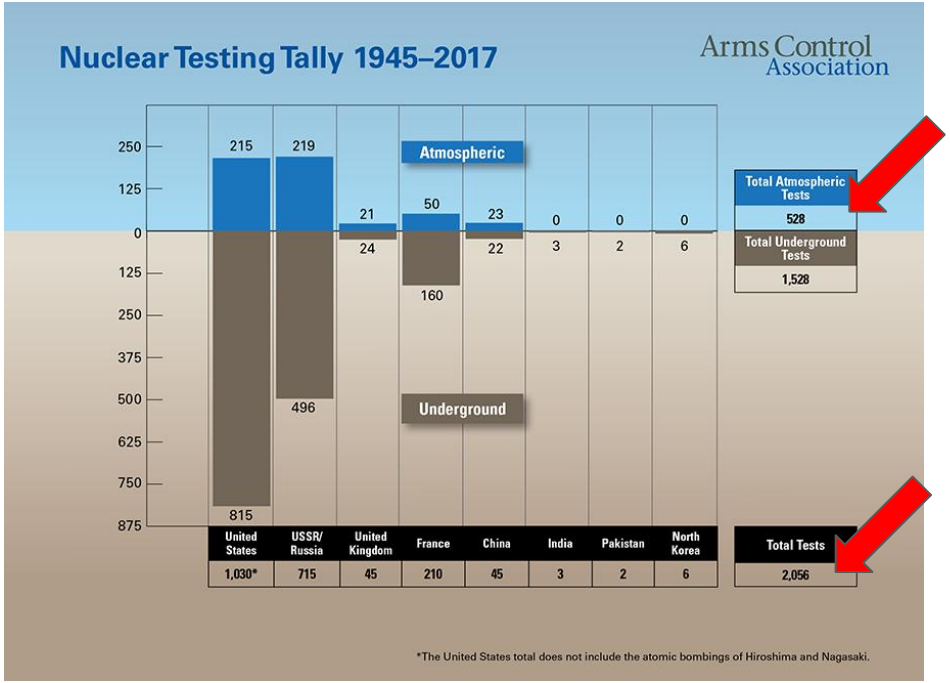
Historic infrasound data from nuclear blasts insufficient to train ML model.



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Train the ML model on a set of synthetic events.

(physics based data augmentation)

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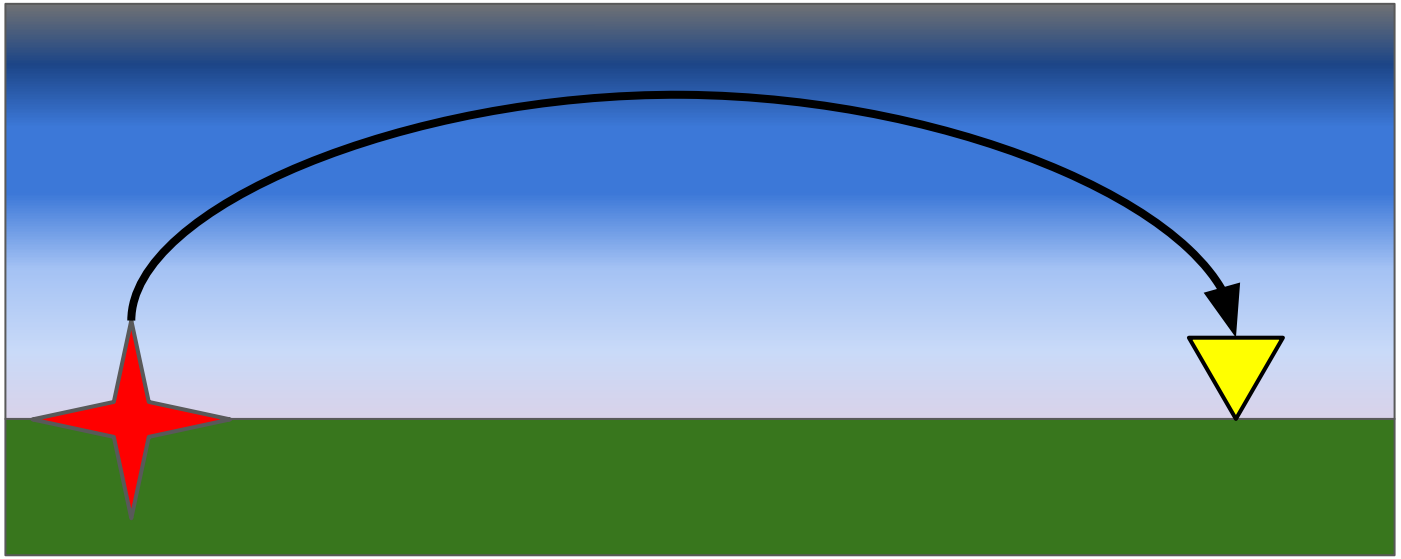
Recorded events are a function of source mechanism, propagation path, and instrument response.



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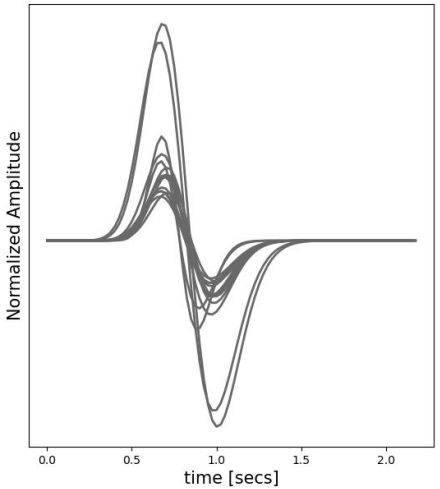
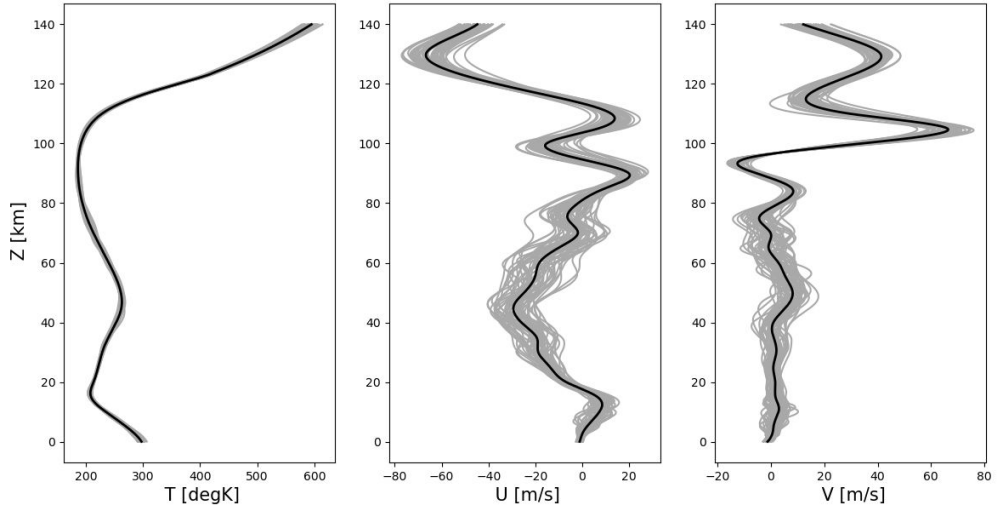
Use HRR data to model sources and atmospheres.

Sources



[Waxler & Assink, 2018]

Atmospheres



[Schwaiger et al. (2019)]

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Propagate 14 sources through 50 atmospheres in 4 directions out to 10 distances.

Generate a total of 28,000 propagated waves.

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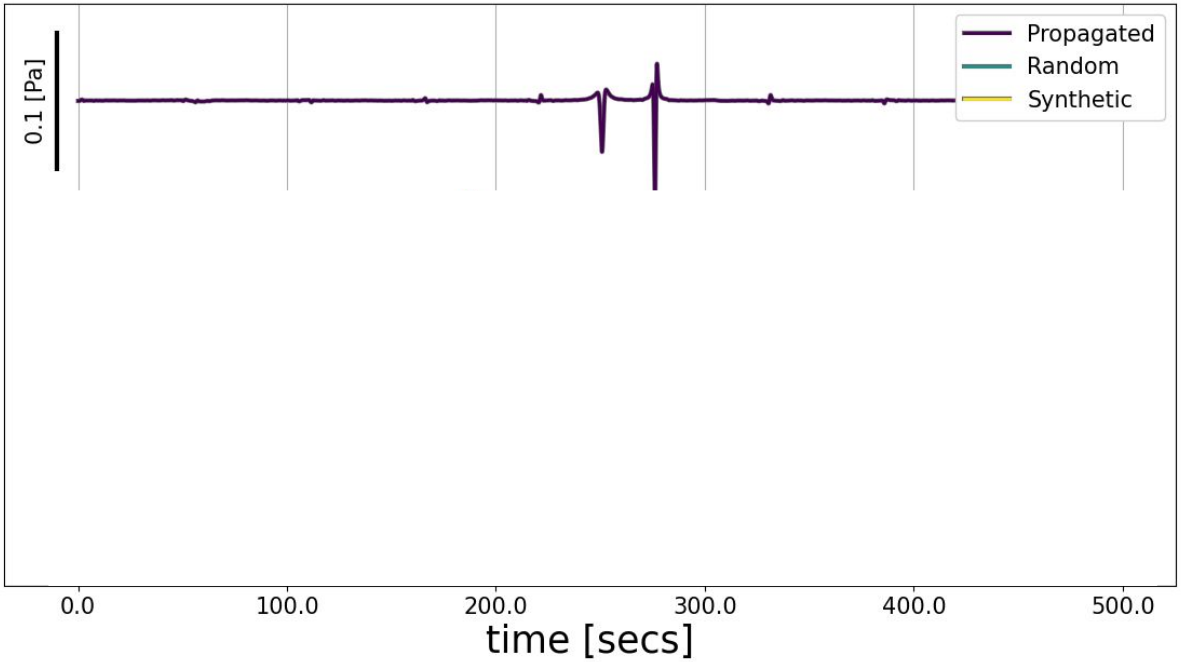
Add random recordings (noise) from the TA to propagated wave to create synthetic event.



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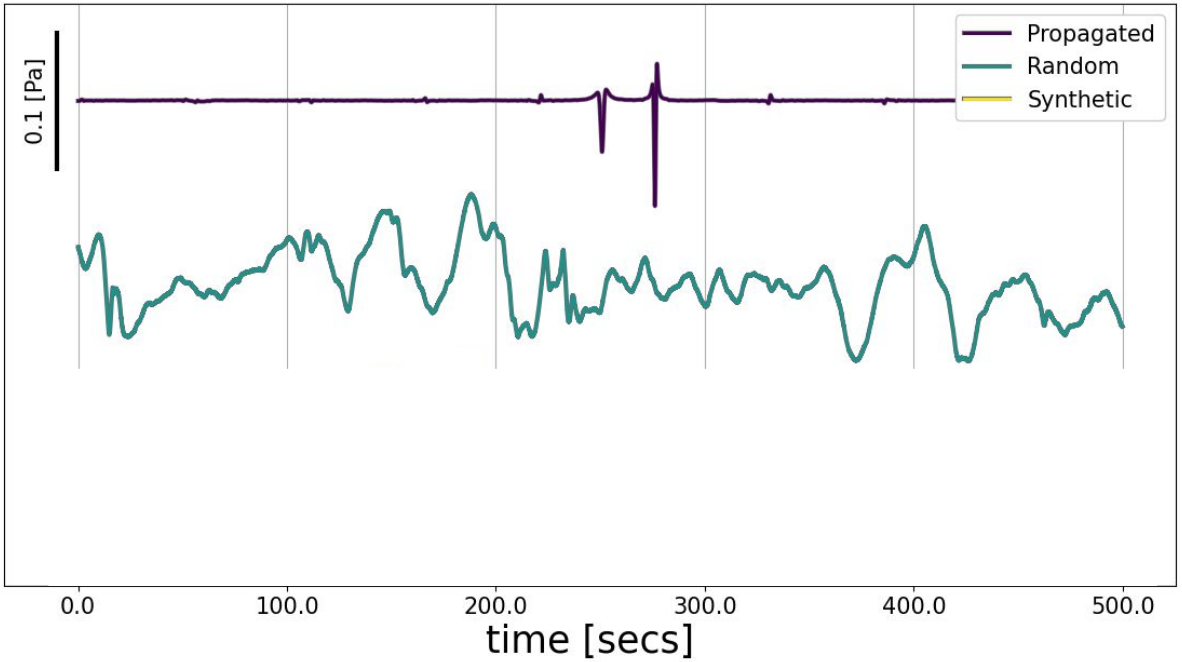

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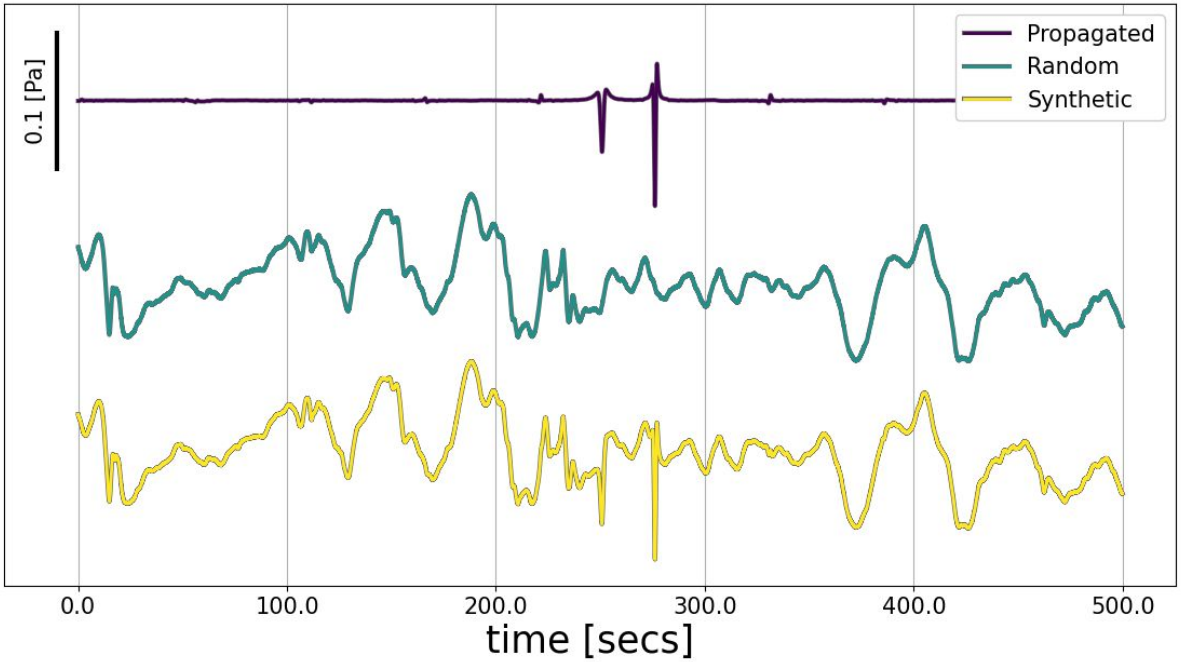

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ML model performs with overall accuracy of 90%

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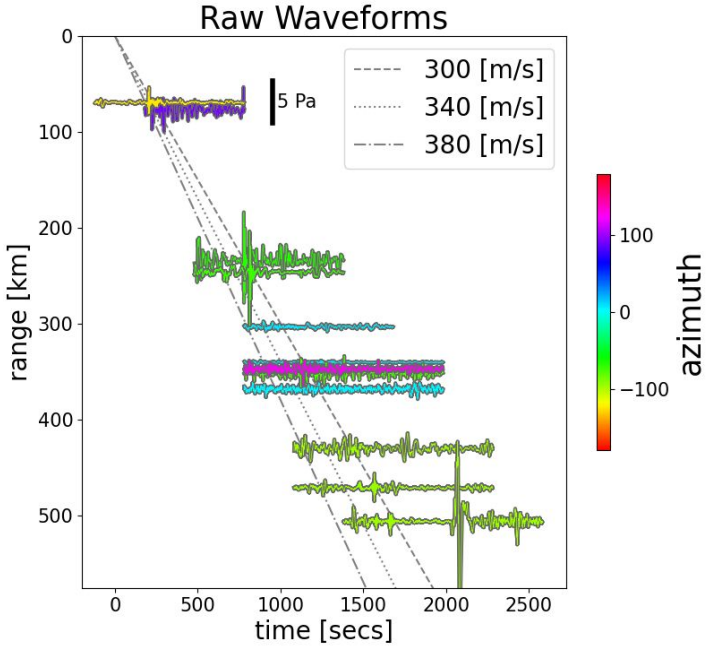
Apply ML model to HRR data.



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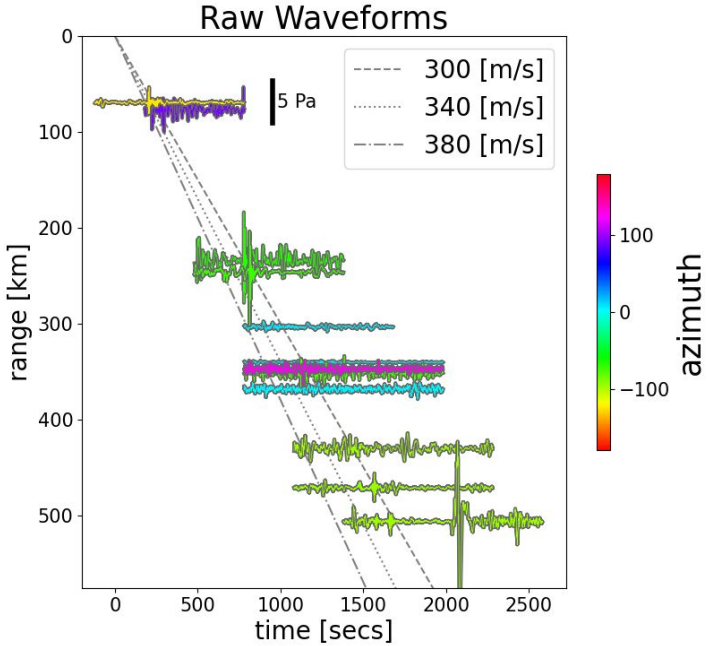

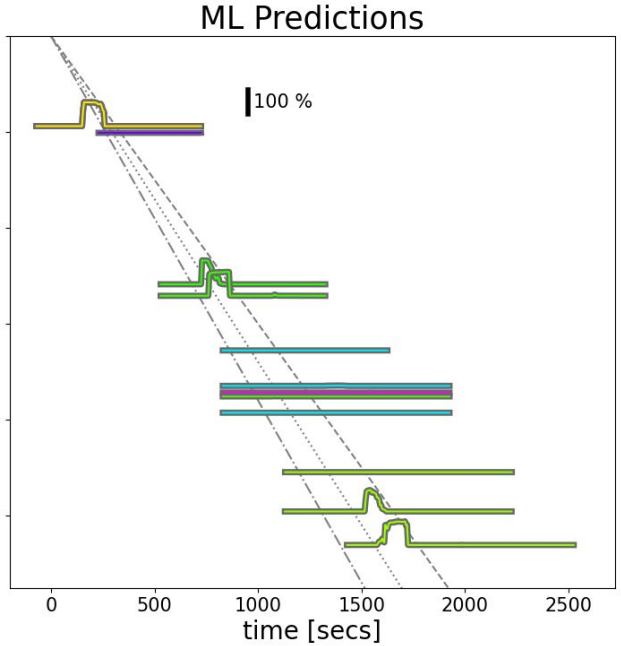

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ML model trained on synthetic data can detect real world explosions.

Research elevates the usefulness of single channel microphones.

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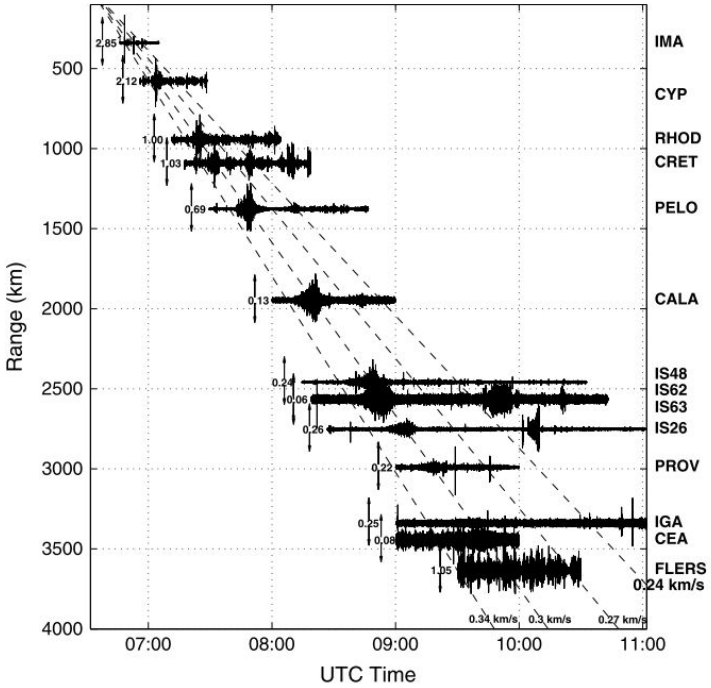
Infrasound signals can propagate 100s to 1000s of km.



[Fee et al. (2013)]

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Supervised ML relies on large training datasets.

Dataset	Classes	Instances
ImageNet	20,000	14,197,122
MNIST	9	60,000
YouTube	4,800	8,000,000
COCO	91	2,500,000

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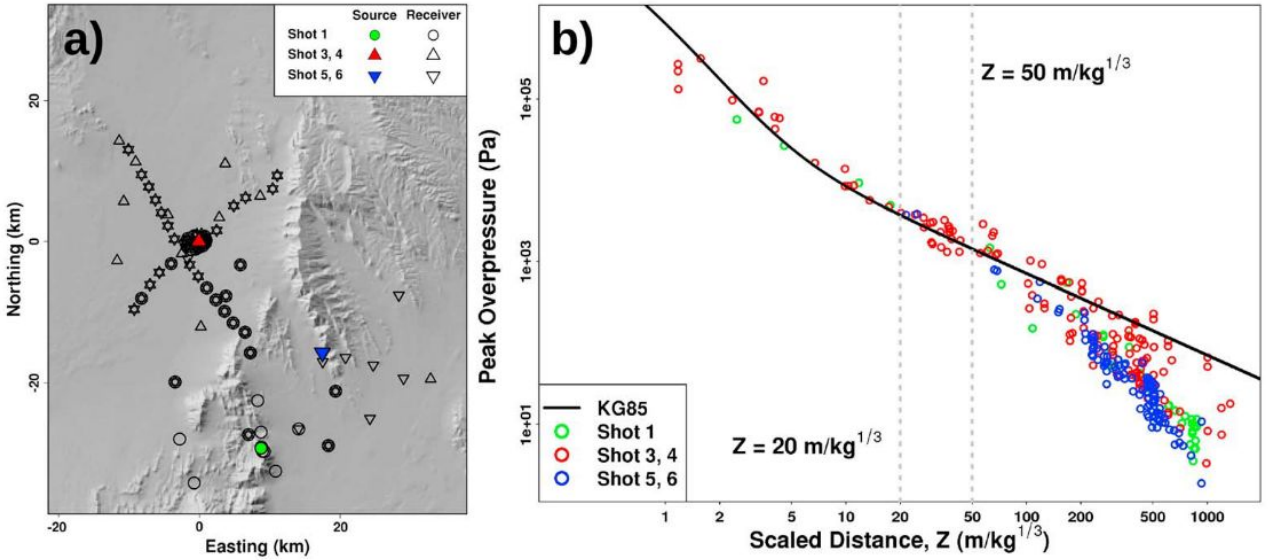
HRR was instrumented in the far and near field.



[Kim & Rodgers 2016]

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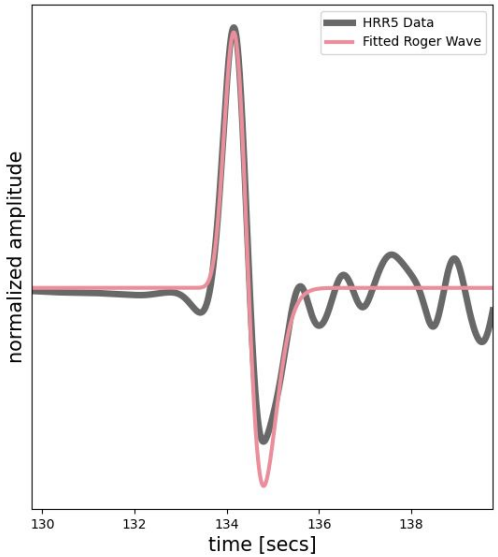
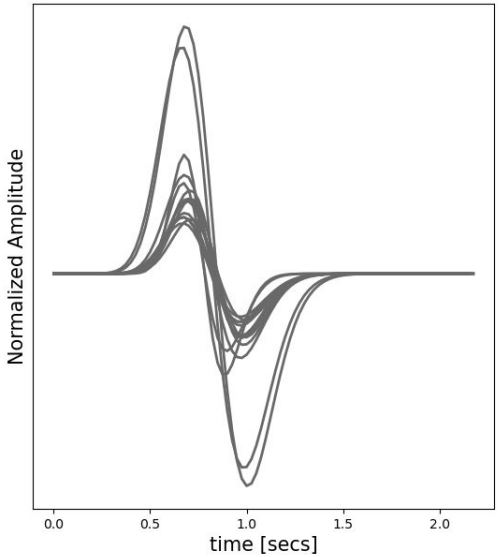
Model source time functions from HRR near field data.





[Waxler & Assink, 2018]

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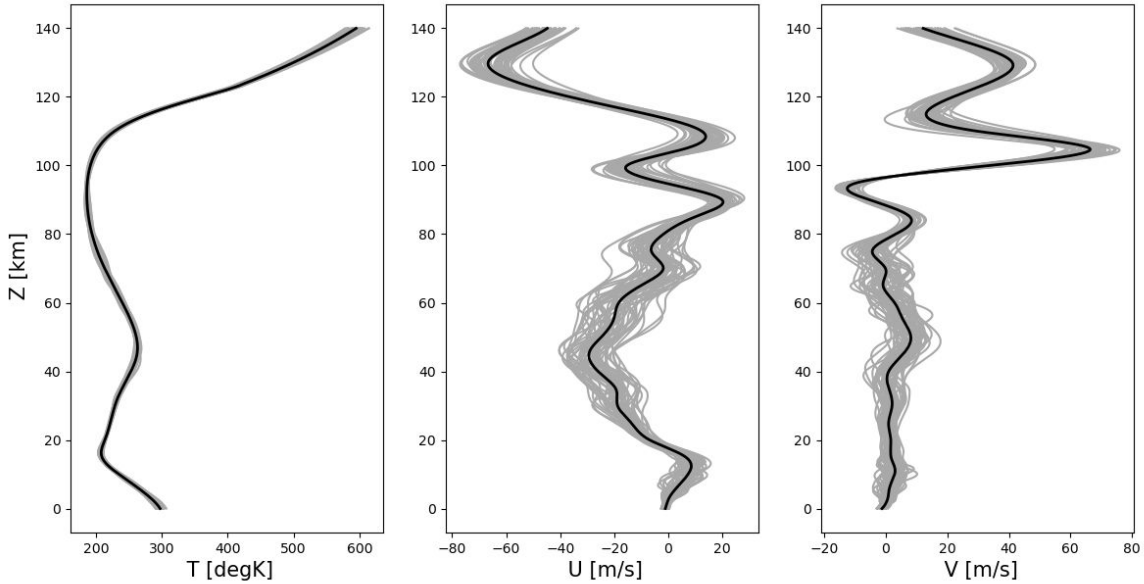
Generate a set of atmospheres by adding variance to atmosphere modeled at HRR testing site.



[Schwaiger et al. (2019)]

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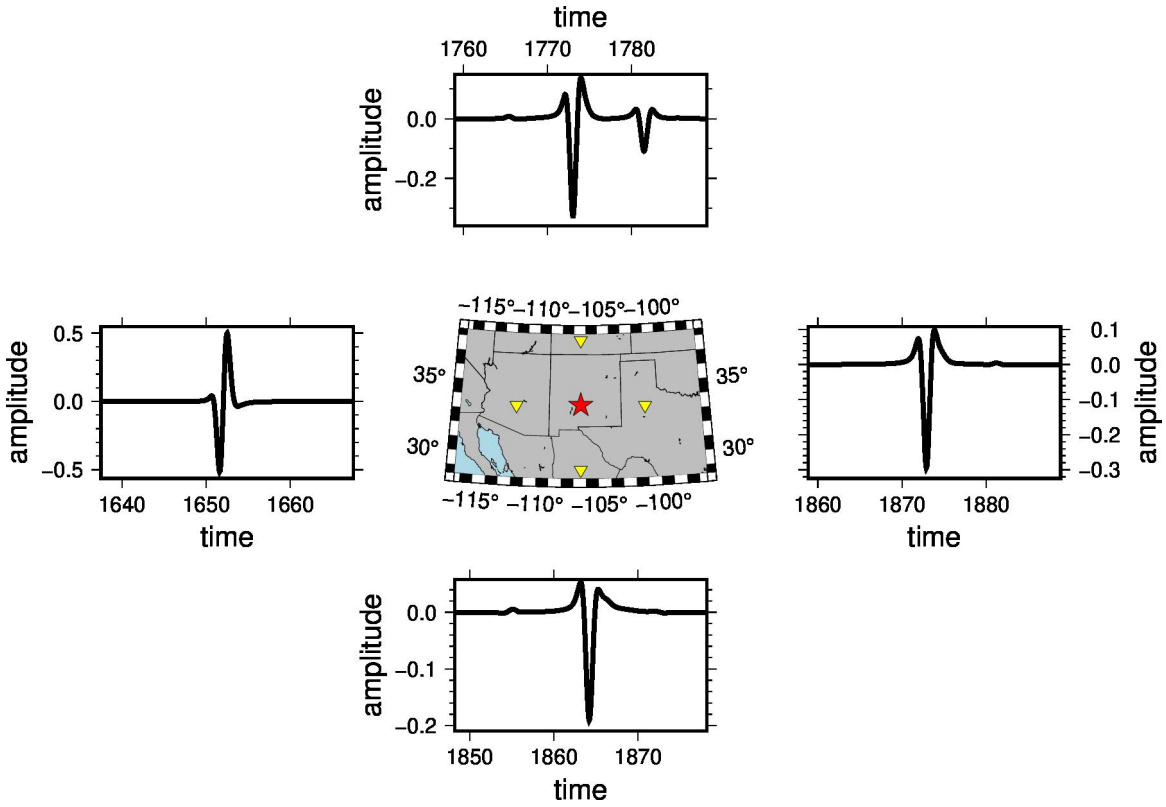
Propagated waves are a function of, among other things, propagation direction.



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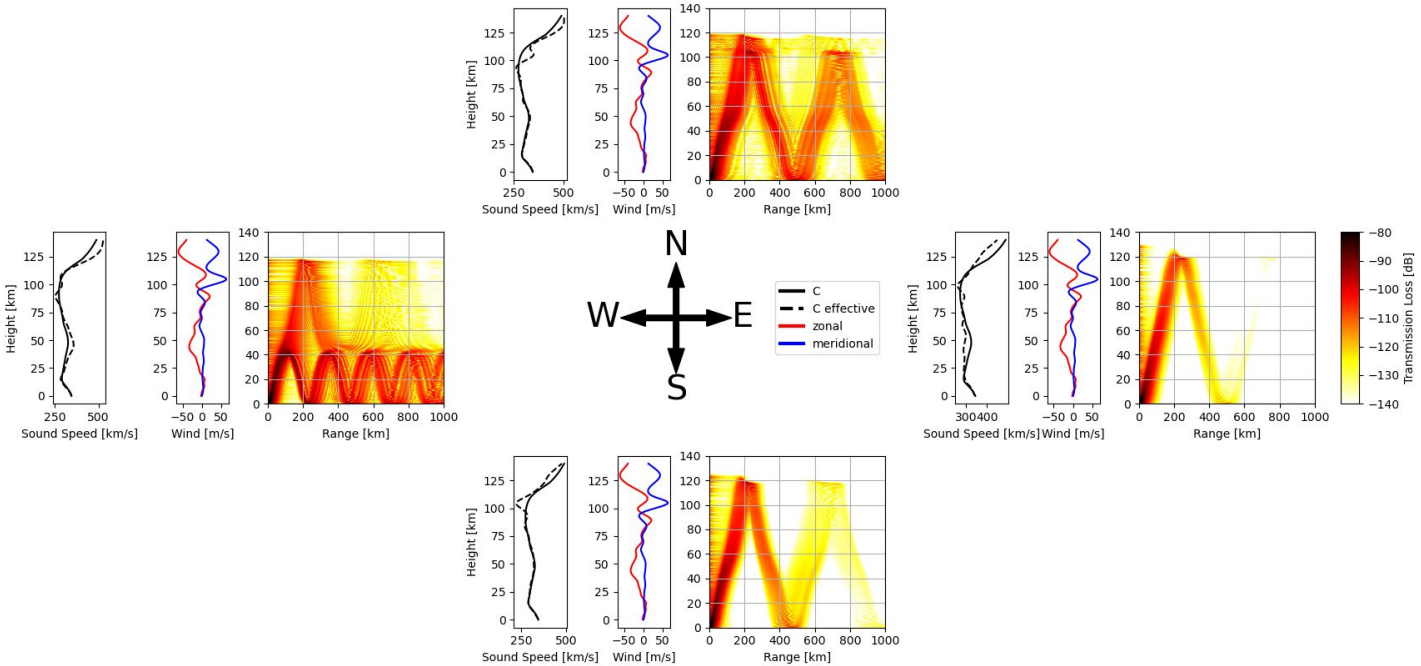
Waves propagated west experience less transmission loss.



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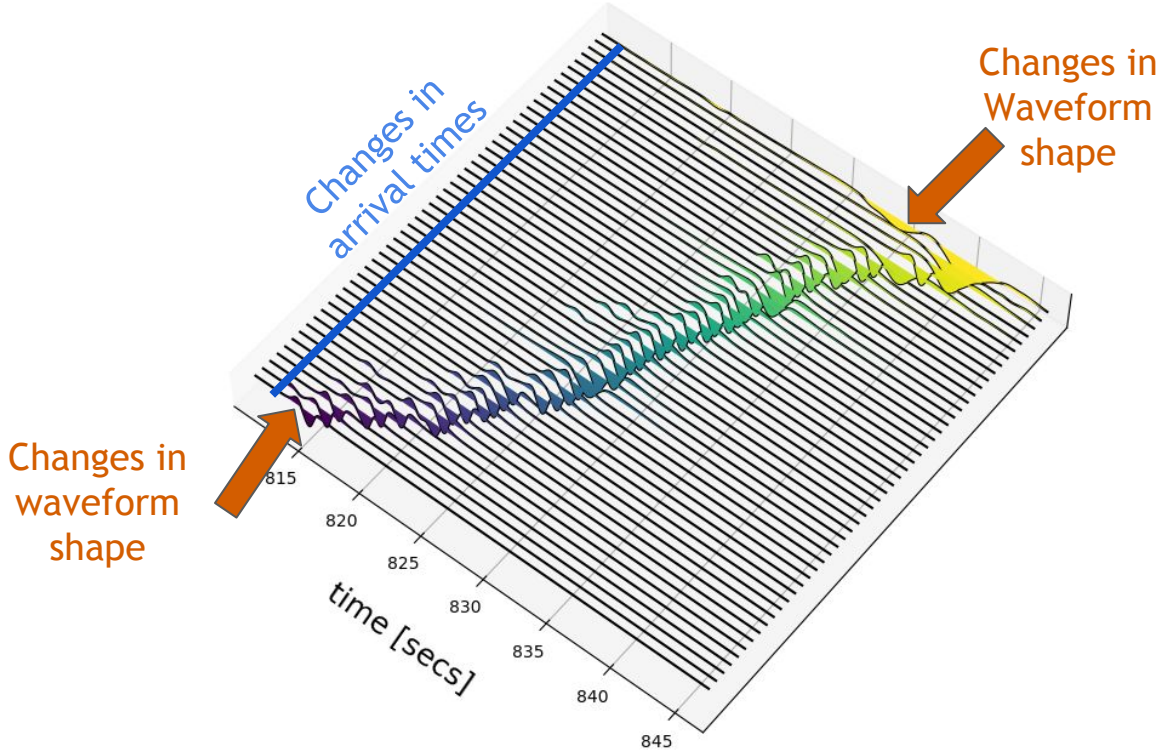
Propagated waves are a function of atmosphere.



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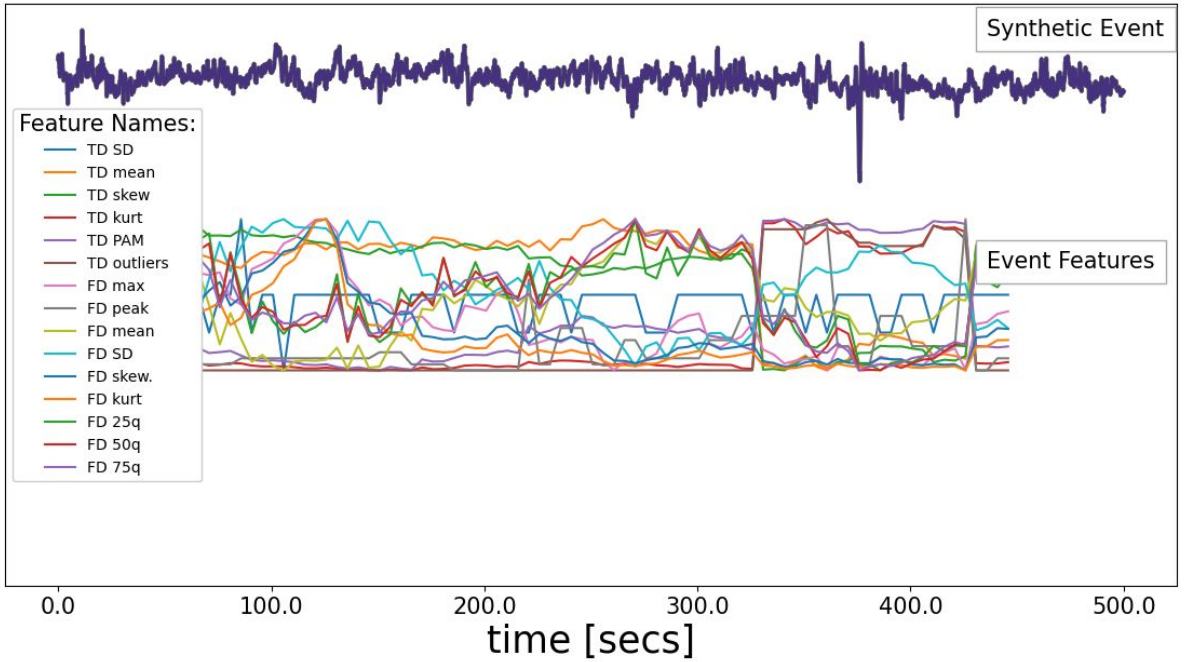
Extract features (statistics) from synthetic events and random TA recordings.



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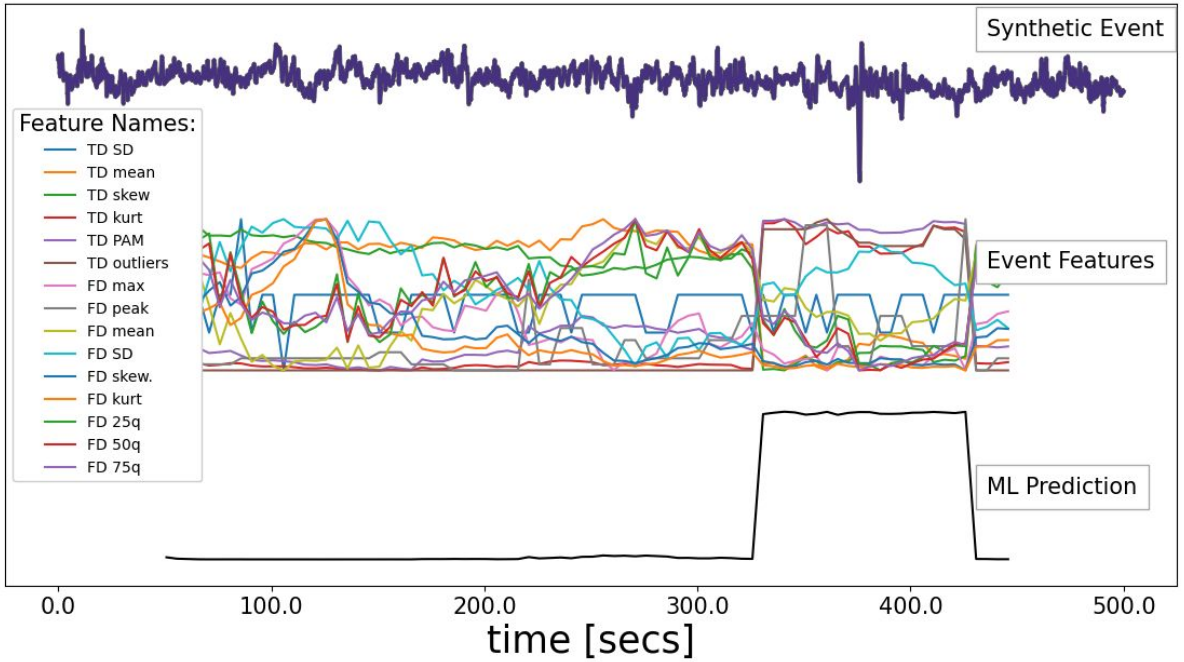
Train *vanilla* artificial neural network (ANN) on features.



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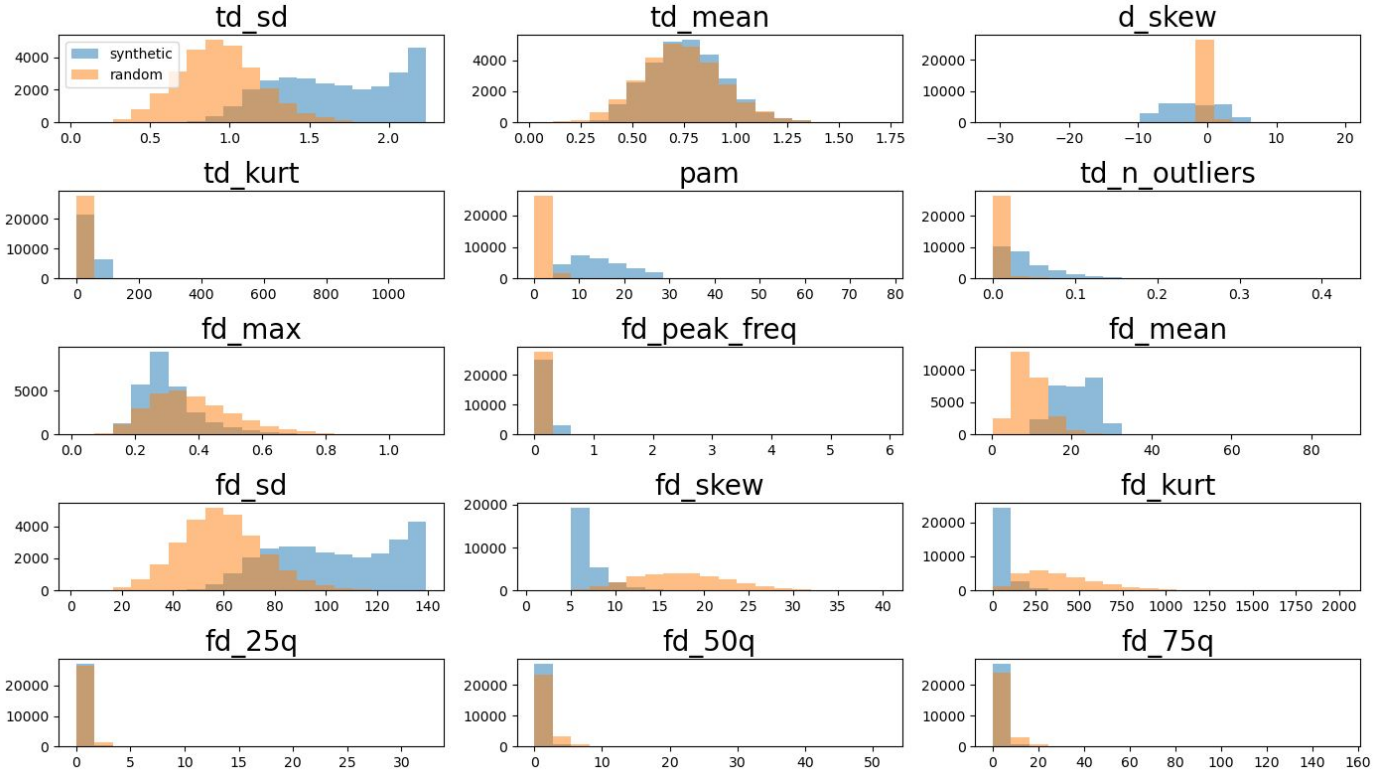

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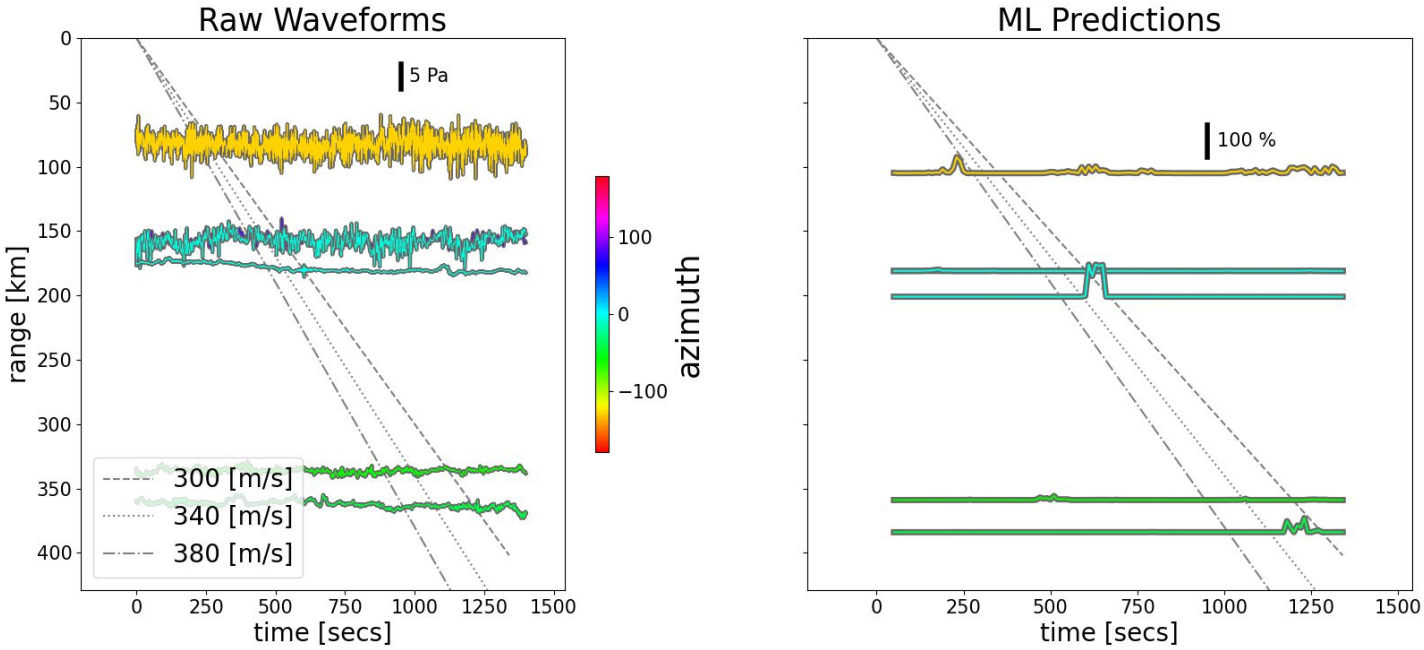
Apply ML model to HRR data from the TA.



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Conclusions:

- Generate a physics-based, synthetic training dataset of infrasound signals from explosions.
- ML model performs with overall accuracy of 90%.
- ML model performs well on synthetic and real world data.
- Research elevates usefulness of single channel microphones.

Future Work:

- Apply more advanced ML models.
- Move beyond binary explosion/no explosion classifier
- Explore yield determination.
- Integrate probabilities with arrays --> source localization.