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Combining Seismic and Acoustic Event Catalogs to Better Understand the Nature of Individual Events

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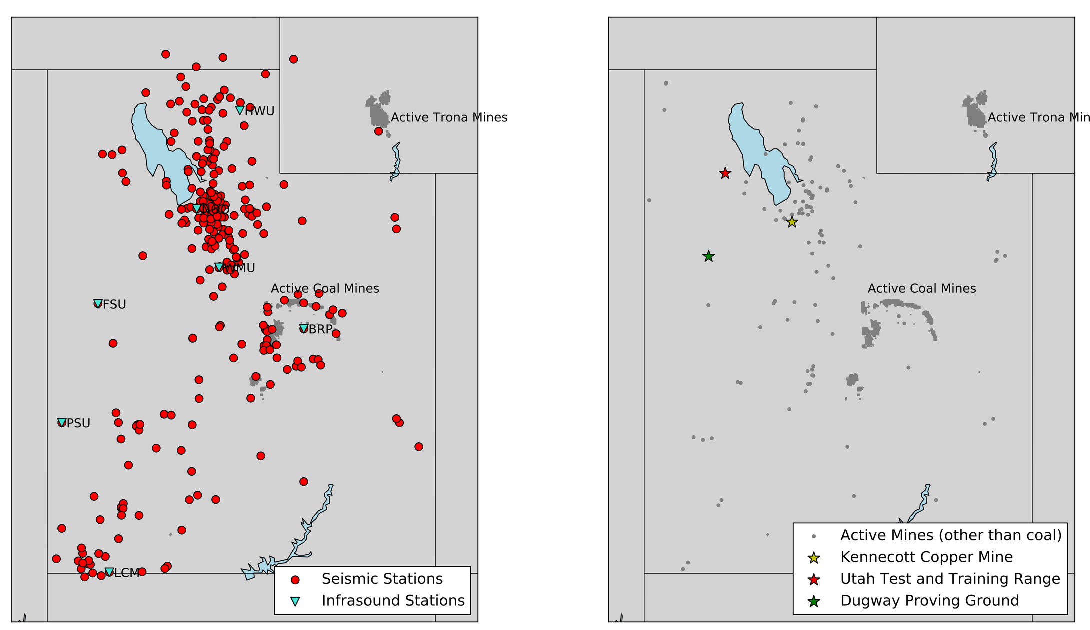
Abstract

We present a combined catalog of seismic and acoustic events within the vicinity of Utah in 2011. Focusing on the Bingham Copper Mine, an area with many mining blasts, we group seismoacoustic events. For events detected at multiple acoustic arrays, grouping was based on origin time and location. For events detected at only one acoustic array, grouping was based on trace velocity and backazimuth. Here we quantify differences in origin time and location, comparing these to event type and magnitude estimated from seismic data. Ultimately, we show that the use of a combined seismoacoustic catalog leads to a better understanding of the nature of individual events.

Introduction

In 2011, 318 seismic stations and 9 infrasound arrays were operating in Utah. The state is tectonically active and has many mines, creating an opportunity to record seismoacoustic signals from a variety of sources. Two separate event detection algorithms, developed at Sandia National Laboratories, were available for use in detecting seismic and acoustic events in Utah. The two algorithms created two separate event catalogs, one for seismic events and another for acoustic events.



(a) Station Coverage (b) Active Mines

Figure 1: (a) Station coverage map and (b) active mining locations for Utah from Jan-Jun 2011.

Our question was: **Will merging the two individual catalogs give us insight into the nature of individual events?**

Detection Methods

Seismic Events

Seismic events are formed using a Waveform Correlation Event Detection System (WCEDS). The system uses back-projection based on (a) travel time predictions for different seismic phases or (b) an empirical stack based off of prior event catalogs. Events occur as peaks in a multivariate function. A peak search method is performed and once a peak is found the event hypothesis is saved into an event database [1].

Acoustic Events

Acoustic events are formed in a different way. First, Fisher's method is used to combine detectors. Association is then done using a grid-based search method, with the grid being defined by the user. Geiger's method is used to determine location by creating a matrix of partial derivatives that allows us to solve for changes in location using least squares minimization. Error is calculated by finding the eigenvalues and eigenvectors of the variance-covariance matrix. Once event information is gathered it is saved into an event database.

Creating a Combined Catalog

First, we attempted to create a seismoacoustic catalog consisting of only events found in both seismic and acoustic catalogs. Seismoacoustic events were formed based on origin time and location. However, the smallest origin distance threshold required to form seismoacoustic events was 100 km, meaning that event origins were within at most 100 km of one another. This limited the accuracy and number of events in the seismoacoustic catalog, so we also created a complementary combined catalog of all seismic and acoustic events. This combined catalog allowed for comparison with ground truth event information provided by the University of Utah Seismograph Stations (UUSS) and the United States Geological Survey (USGS).

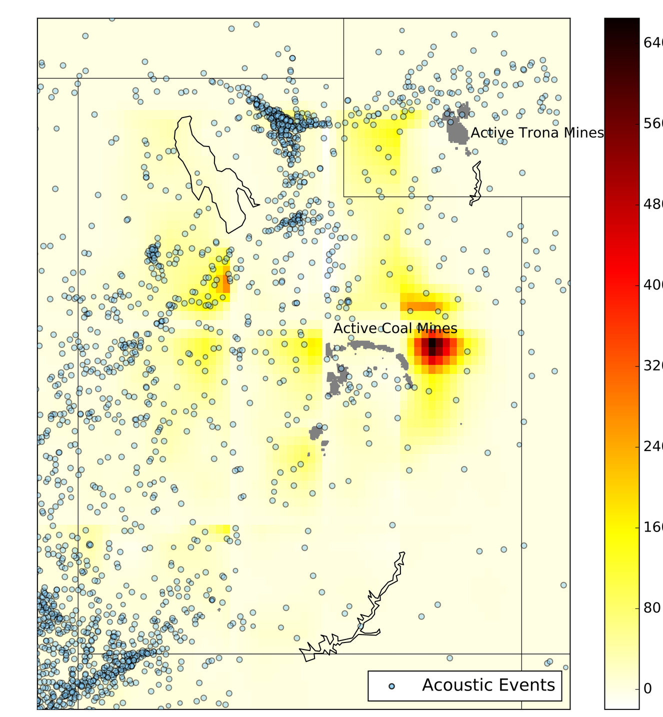


Figure 2: Combined catalog of all seismic and acoustic events in Utah from Jan-Jun 2011.

Results

Catalog (Utah region, Jan-Jun 2011)	Number of Events	Number of Ground Truth Events
Ground Truth (UUSS and USGS)	48	48
Seismoacoustic	6	0
Combined Seismic and Acoustic	15974	15
Seismic	11780	15
Acoustic	4194	0

Focus Area - Kennecott Copper Mine

The Kennecott Copper Mine is an active mine that frequently uses explosions in its operations. While we do not have ground truth on all of these explosions, this location serves as a known source. Therefore, we chose to first focus the on this area to test the combined catalog method.

(a) Seismoacoustic detections (b) Combined catalog

Figure 3: (a) Seismoacoustic detections and (b) a combined catalog of seismic and acoustic events at Kennecott Copper Mine in Utah from Jan-Jun 2011.

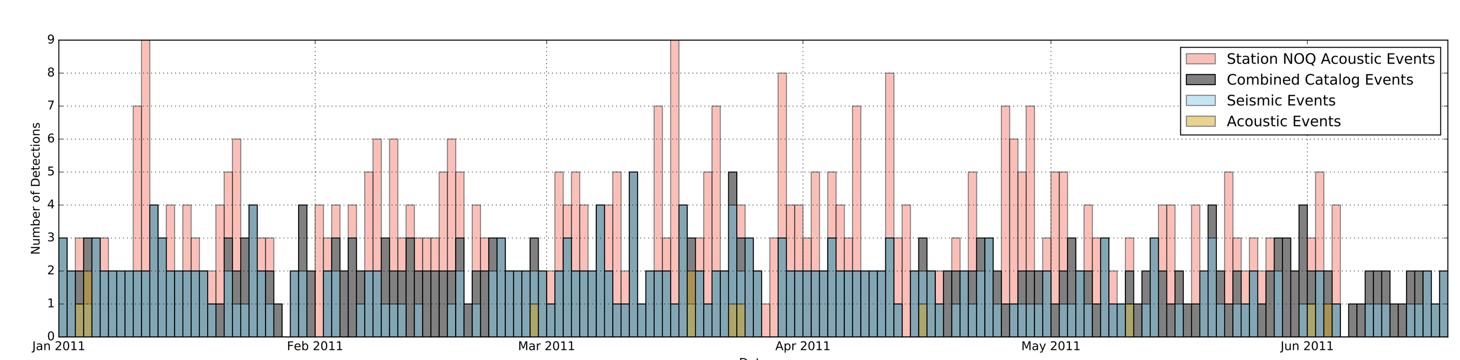
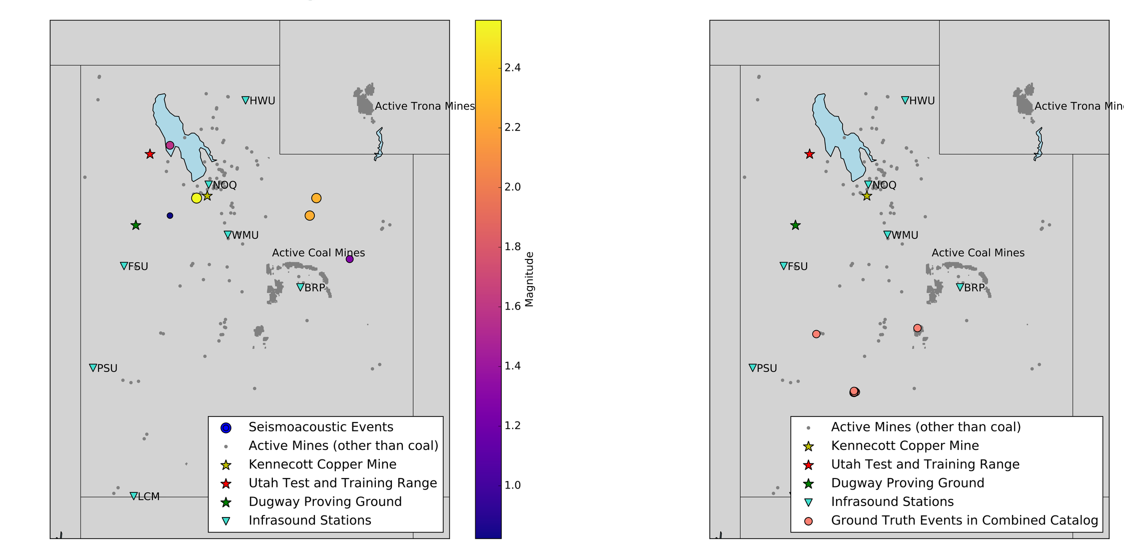


Figure 4: Histogram of single station events, seismoacoustic events, seismic events, and acoustic events at Kennecott Copper Mine from Jan-Jun 2011.

Regional Area - Utah

We created the two catalogs shown in *Figure 5*: (a) a seismoacoustic catalog and (b) a combined catalog of all seismic and acoustic events. Seismoacoustic events have an average location difference of 65 km and a standard deviation of 21 km. Seismoacoustic events are likely a result of military testing and mining activity. We then compared the combined catalog to ground truth events. 15 of the 48 ground truth events were found in the combined catalog, all but two of which were part of the January 3, 2011 Circleville earthquake sequence [2]. The other two ground truth events are likely due to mining activity in the region. The presence of ground truth events in the combined catalog is due to the seismic contribution of events.



(a) Seismoacoustic Detections (b) Ground Truth Detections in Combined Catalog

Figure 5: (a) Seismoacoustic detections and (b) detections verified by ground truth events in the combined catalog for Utah from Jan-Jun 2011.

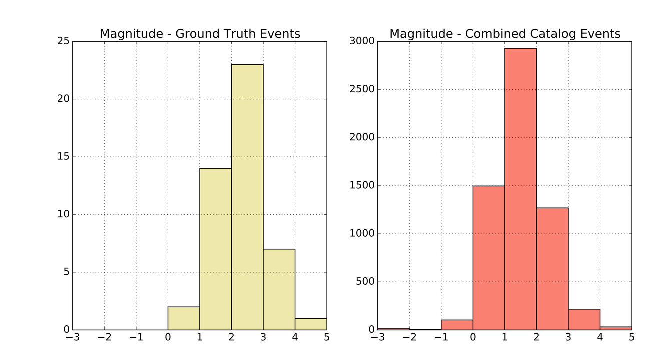


Figure 6: Distribution of (a) ground truth and (b) combined catalog event magnitudes.

Conclusions

1. Forming a solely seismoacoustic catalog is limiting due to the loss of numerous events.
2. The seismic and acoustic catalogs complement each other by adding events into the combined catalog that would otherwise be undetected.
3. Focusing on single acoustic stations may provide more events.
4. There is a need for a larger ground truth event catalog with a lower magnitude of completeness and more mining blast events.

Future Research

1. Create a more extensive ground truth catalog for Utah in 2011.
2. Investigate the possibility of discrimination using the probability of an event being a blast give its presence in the seismoacoustic catalog.
3. Compare presence and lack of detections to the detection quality analysis done by Park and Stump, 2015 [3].
4. Incorporate detection uncertainties into merging thresholds that form the seismoacoustic catalog.

References

[1] Stephen Arrowsmith, Christopher Young, Sanford Ballard, Megan Slinkard, and Kristine Pankow. Pickless event detection and location: The waveform correlation event-detection system (wceds) revisited. *Bulletin of the Seismological Society of America*, 106(5):2037–2044, 2016.

[2] Stephen J Arrowsmith, Relu Burlacu, Kristine Pankow, Brian Stump, Richard Stead, Rod Whitaker, and Chris Hayward. A seismoacoustic study of the 2011 january 3 circleville earthquake. *Geophysical Journal International*, 189(2):1148–1158, 2012.

[3] Junghyun Park and Brian W Stump. Seasonal variations of infrasound detections and their characteristics in the western us. *Geosciences Journal*, 19(1):97–111, 2015.

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