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REFINING INFRASONIC DETECTION ALGORITHMS USING GROUND TRUTH EVENTS

Fransiska K. Dannemann Dugick[1,2], Philip S. Blom[1], and Brian W. Stump[2]

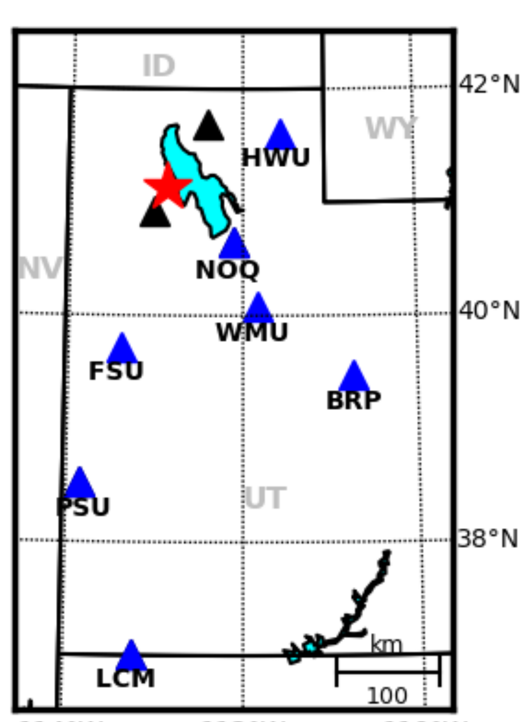
[1] Los Alamos National Laboratory, EES-17, Los Alamos, NM, [2] Southern Methodist University, Dallas, TX

ABSTRACT

In 2012, 53 missile motor or propellant explosions were conducted at the Utah Test and Training Range at varying yields. These events are examples of ground truth where knowledge of a facility combined with seismic data produces well constrained source locations and event times so that the event may be considered ground truth for infrasound purposes. Prior infrasound event catalogs in the western US suggest that UTTR is a major source of infrasound signals in the region (Park *et al.*, 2014, Walker *et al.*, 2011). Despite this, only 5 of the identified ground truth events were present in the published 2010-2012 Western US Bulletin; suggesting that either current state-of-the-art methodologies for detecting signals of interest fail to identify signals from large explosive events, or association and location methodologies fail to produce event location estimates. This study identifies both data limits as a result of noise and propagation path effects as well as failures in automatic detection and association procedures. These results provide the basis for improvements in detection methodologies with the goal of improving network performance.

OVERVIEW

This study seeks to systematically evaluate the detection performance of a regional infrasound network in the presence of a variable signal propagation and noise environment.



Locations of acoustic arrays (solid triangle) within the SMU-UU seismo-acoustic network. Blue triangles represent arrays used in this study, while black triangles represent arrays in the network but not used in this study due to data availability. The red star denotes the location of UTTR, the source of ground truth events.

REFERENCES

Arrowsmith, Stephen J., et al. "The F-detector revisited: An improved strategy for signal detection at seismic and infrasound arrays." *Bulletin of the Seismological Society of America* 99.1 (2009): 449-453.

Blom, Philip, and Roger Waxler. "Impulse propagation in the nocturnal boundary layer: Analysis of the geometric component." *The Journal of the Acoustical Society of America* 131.5 (2012): 3680-3690.

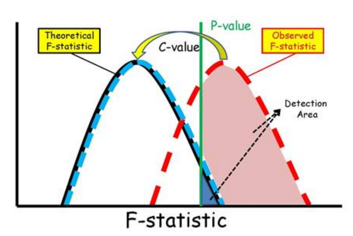
Park, Junghyun, et al. "Automatic infrasound detection and location of sources in the western United States." *Journal of Geophysical Research: Atmospheres* 119.13 (2014): 7773-7798.

Walker, Kristoffer T., et al. "Western US Infrasonic Catalog: Illuminating infrasonic hot spots with the USArray." *Journal of Geophysical Research: Solid Earth* 116.B12 (2011).

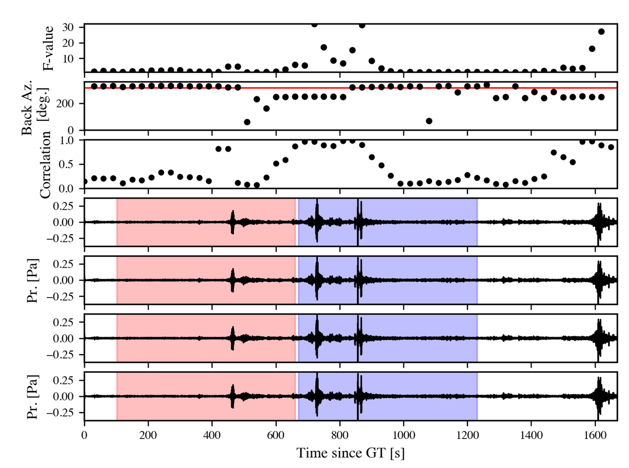
CONTACT INFORMATION

Fransiska K. Dannemann Dugick
fransiska@lanl.gov
fdannemann@smu.edu
S41E-0585

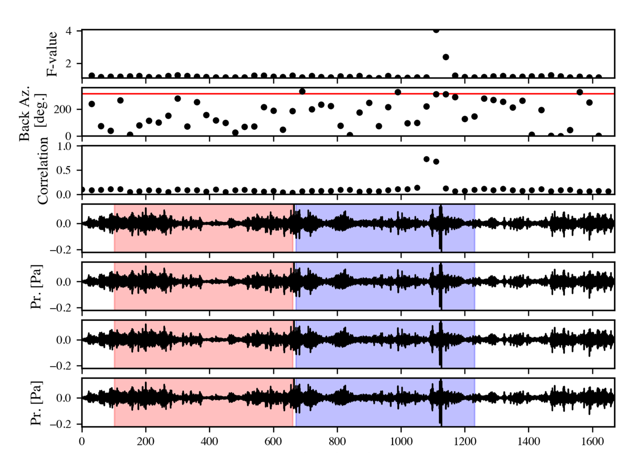
AUTOMATIC SIGNAL DETECTION



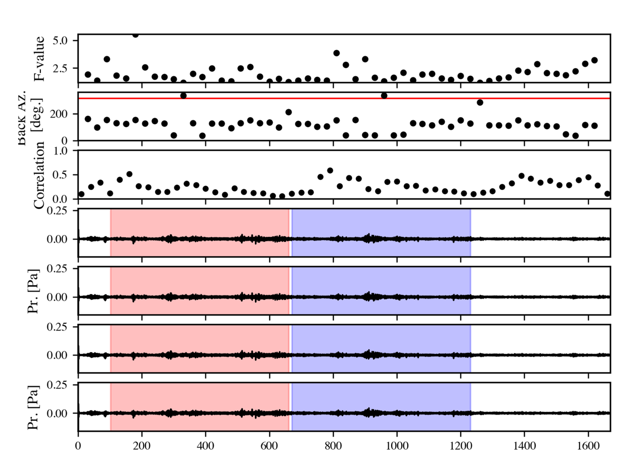
Data is processed using the Adaptive F-Detector (Arrowsmith *et al.*, 2009) to establish a baseline of automatic detector performance across the network. Figure from Arrowsmith *et al.*, 2011.



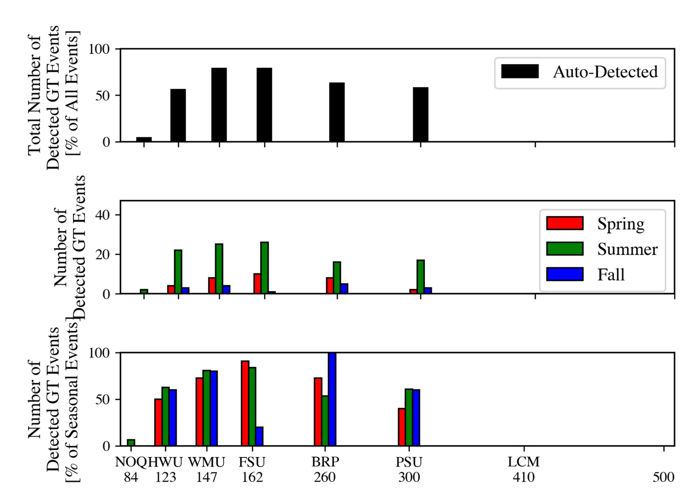
Data example for an **automatically detected** signal on 2012-04-09T17:59:00 UTC. Signal of interest is detected due to low background noise and high signal correlation, leading to a large increase in F-value.



Data example for a signal on 2012-06-25T17:44 UTC that was **missed by the auto detector but identified in analyst review.** Signal is missed due to increased background noise, which reduces SNR and leads to a low SOI F-value.



Data example for a signal on 2012-08-06T19:36 UTC that was **missed by the auto detector and not identified in analyst review.** Signal is missed due to a combination of correlated background noise and low SOI strength.



A comparison of the total number of automatically detected GT events across the network shows a relationship between automatic detector performance and station distance from the [stationary] source.

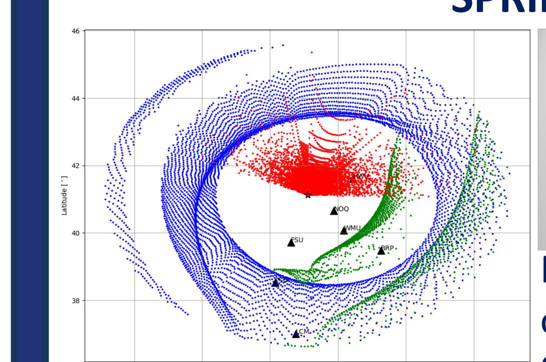
Missed detections are reviewed to quantify the phenomena contributing to a missed detection across the network:

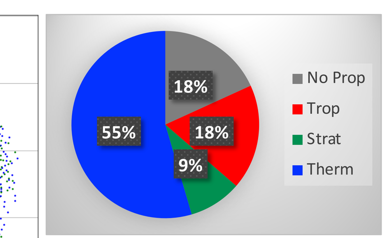
1. **high noise immediately prior to or during the expected arrival time which masks the signal of interest,**
2. **a lack of atmospheric conditions favorable to propagation from the source to the receiver.**

PROPAGATION ANALYSIS

Ray-tracing through realistic atmospheric models was conducted following methods presented by Blom and Waxler (2012). Seasonal phase arrivals at **BRP** are shown as a percentage of all seasonal predicted arrivals.

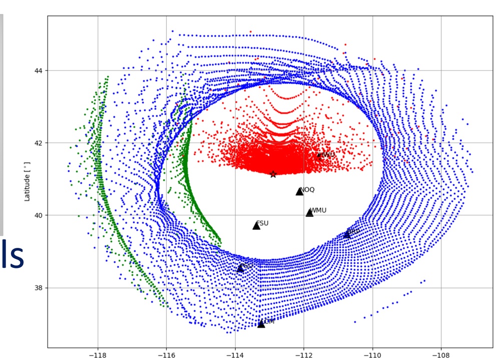
SPRING

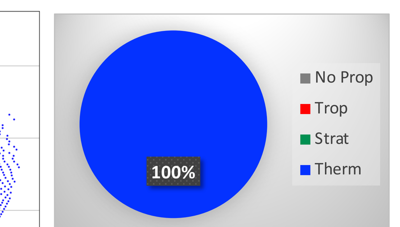




Predicted ray arrivals on 2012-04-09T18:00:00 UTC

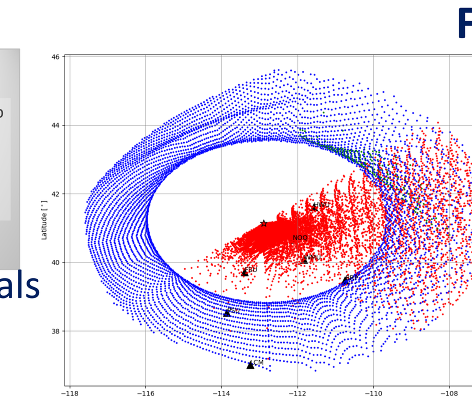
SUMMER

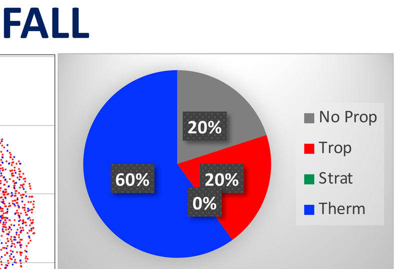




Predicted ray arrivals on 2012-06-25T17:00:00 UTC

FALL



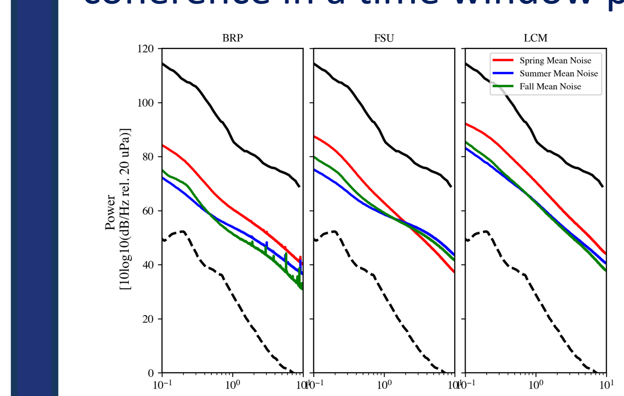


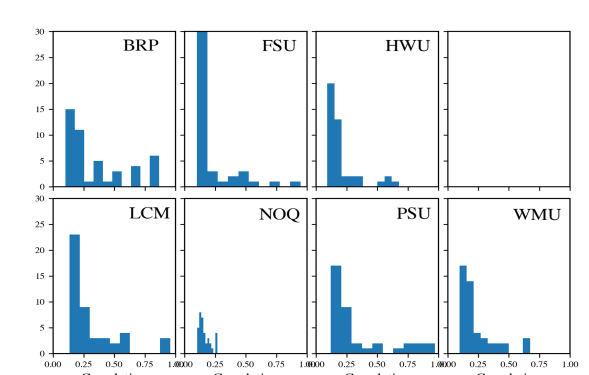
Predicted ray arrivals on 2012-10-03T19:00:00 UTC

Arrivals across the network are dominated by tropospheric and thermospheric phases.
In the case of thermospheric arrivals, an assessment of the attenuation and predicted signal amplitudes is needed to determine whether a signal will be observable at the station of interest.

NOISE ANALYSIS

Noise models were developed to examine temporal (seasonal) and spatial trends in noise variability across the network.
Time periods with either coherent or incoherent noise were identified through a correlation analysis identifying the maximum coherence in a time window prior to predicted signal arrival.



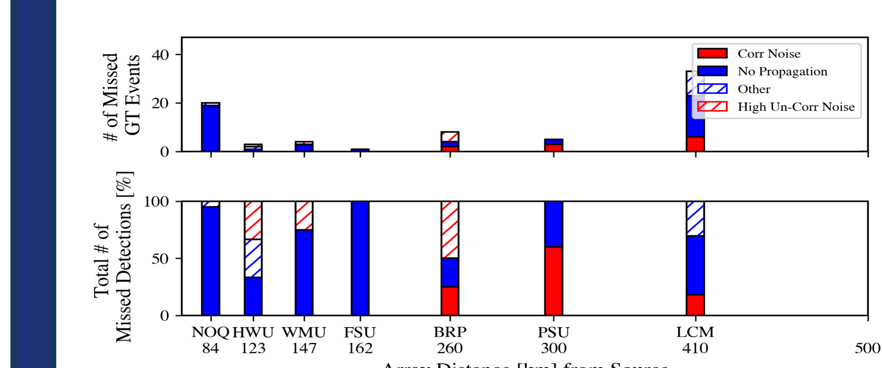


While mean noise falls within established IMS noise models, it is generally high across the network and is comprised of both coherent and incoherent components.

RESULTS

Missed detections were assigned one of four possible criteria:

1. Low to no predicted propagation ,
2. High correlated noise prior-to or at the time of predicted signal arrival,
3. High, uncorrelated noise prior-to or at the time of predicted signal arrival ,
4. Undetermined reasons for missed detections.



These results provide the basis for quantifying network detection performance of GT events.

CONCLUSIONS

An automatic detection catalog was produced as a means of determining baseline AFD performance across the network. **An analyst review of waveform data suggests that the AFD misses signals of interest in the presence of both correlated and uncorrelated background noise. Additional signals may be missed due to poor or low propagation from the source to the receiver.**

Propagation analysis suggests that arrivals from events at UTTR consist of predominantly tropospheric and thermospheric phases. **In the case of thermospheric arrivals, detections may be missed due to attenuation and decreasing signal amplitudes with distance from the source.**

Noise analysis demonstrates that average noise across the network varies both temporally and spatially. While noise falls within the IMS high and low background noise limits, it is generally high across the network. In particular, noise at LCM and NOQ is significantly higher that noise at the other stations. Background noise is both coherent and incoherent; the number of coherent background noise sources varies as a function of station location.

Time periods with missed detections were evaluated to quantify phenomena contributing to missed detections. Missed detections are primarily attributed to the propagation effects discussed above, but are also shown to be due to high noise. **This suggests that detection performance is driven by propagation effects due to network design, i.e. stations located either too close to the source to receive a signal, or far enough from the source that any propagating signal is too attenuated to be detected at the station.**

Finally, AFD performance is evaluated as a function of the percentage of automatically detected events with clearly modeled propagation from source to receiver. **The AFD is able to successfully detect signals within the presence of correlated and uncorrelated noise an average of 50% and 49% of the time** across the network, respectively.