Correlating Multi-Phenomenology Measurements with Blast Design in a Copper Mine

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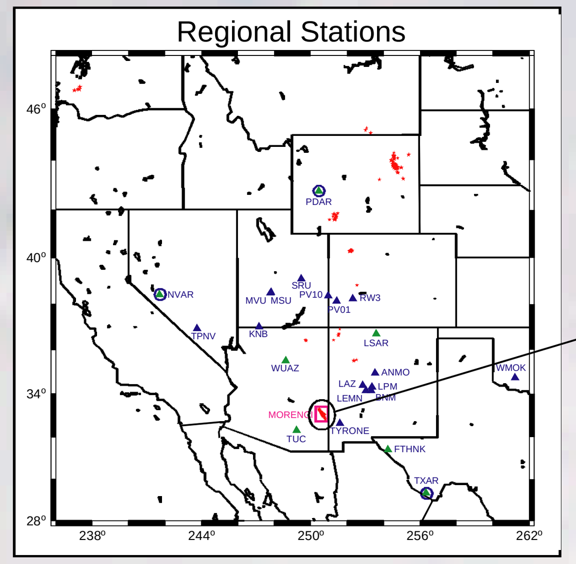
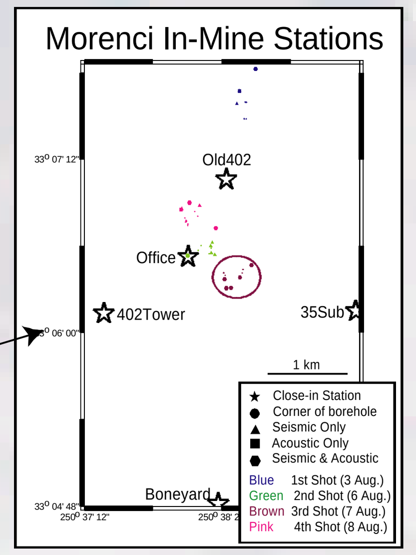
Study Philosophy

A study has been undertaken to quantify physical processes associated with mining explosions that generate seismic and infrasonic waves. Experimental components included in-mine blast diagnostics, in-mine seismic and infrasound instruments, and regional seismic and infrasound stations and arrays. In-mine and regional stations are diagramed below.

This poster focuses on amplitude scaling effects of seismic and infrasound signals from different blasts within a single mine.



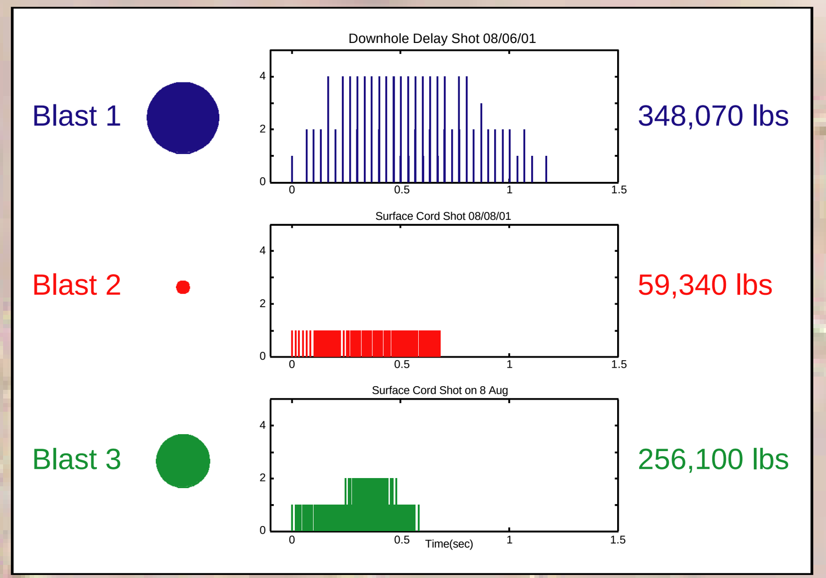


The Mine

The cooperating mine was the Morenci Mine operated by Phelps-Dodge in SE Arizona. The scale of the operation is illustrated below. The mine produces over 25% of all US copper. Three to five blasts are detonated daily. During July and August, 31% of the events in the USGS Mine Event List were from this mine. Regional magnitudes for these events ranged from 2.4 to 3.1.

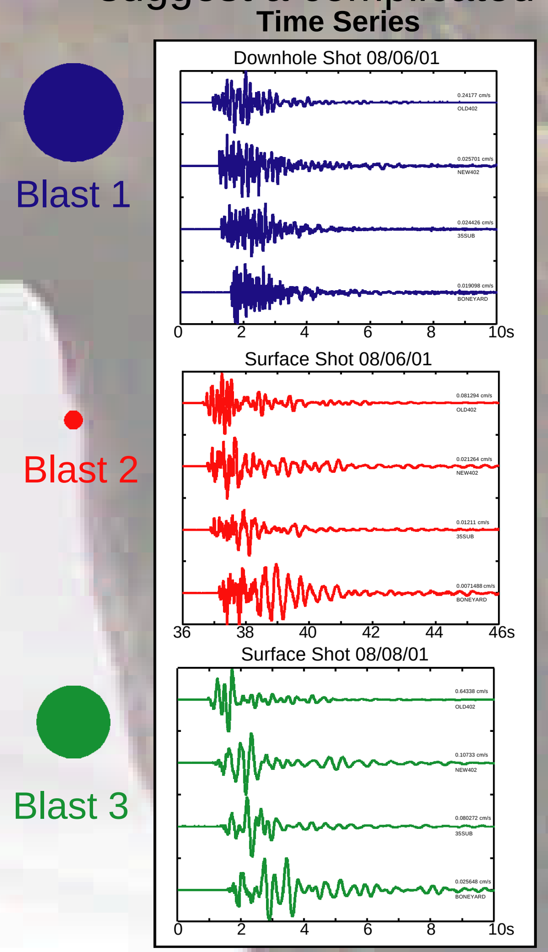
Explosive Sources

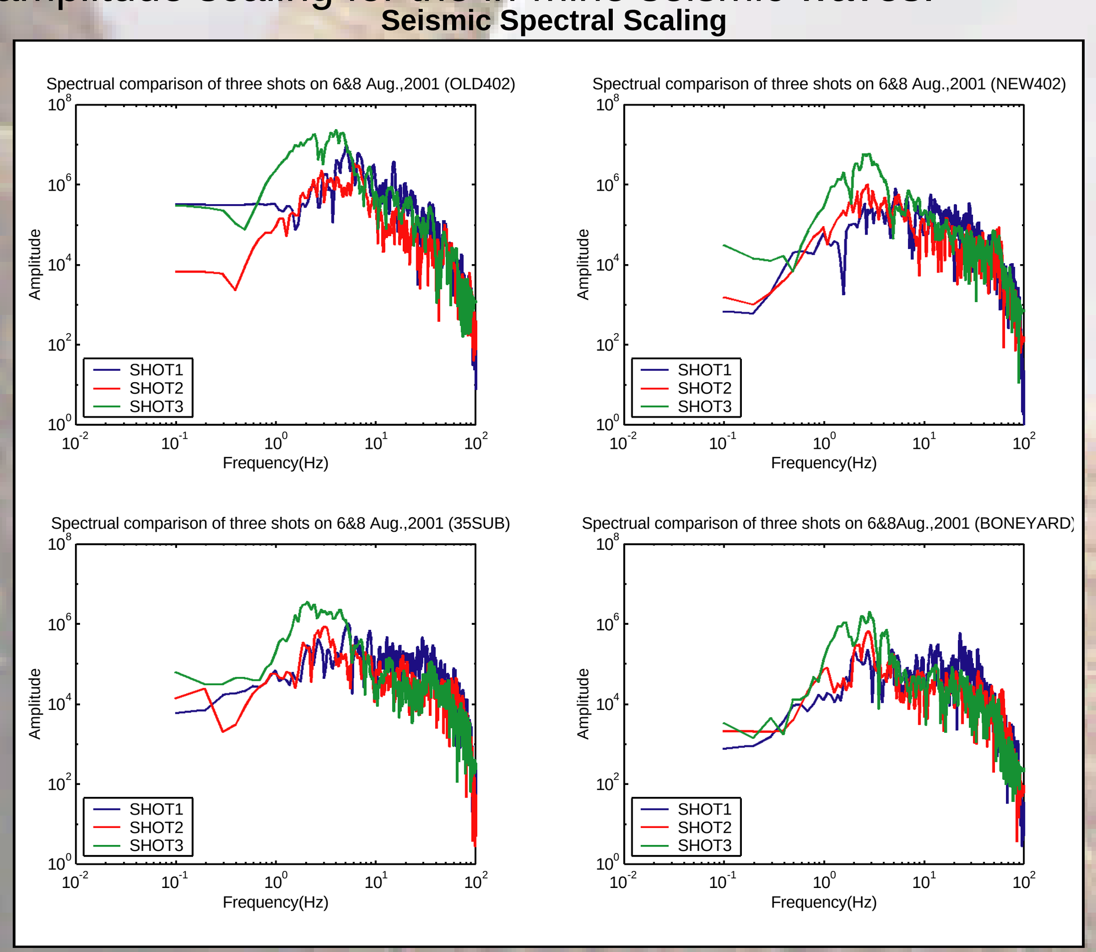
This analysis focuses upon the details of three blasts. Individual blast size is characterized by the radius of each circle below. The source time delays are represented as an impulse series. Two blasts (green and red) use short delay times while the largest blast (blue) uses long delay times.



In-Mine Seismic

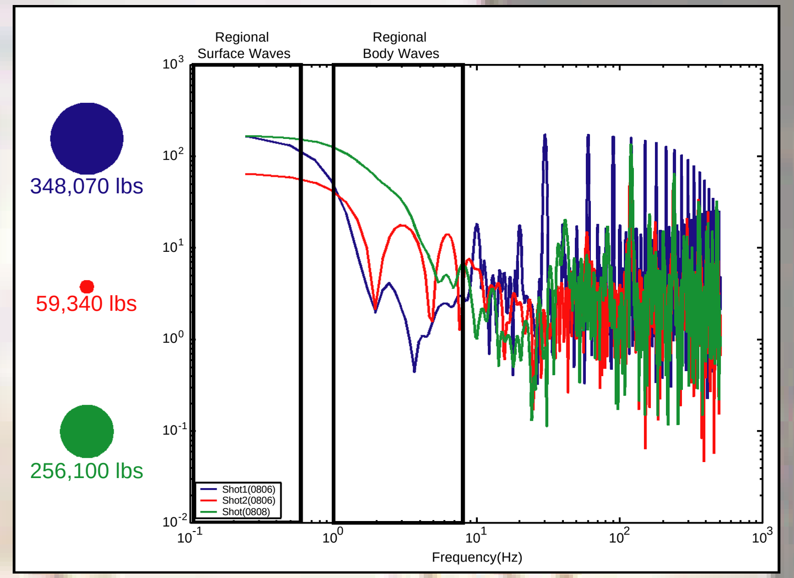
The in-mine vertical velocity records and spectra for 4 stations are plotted below. Blast 3 (green) is the largest at frequencies below 5 Hz. Blast 1 (blue) included the largest amount of explosives, produces the smallest amplitudes at mid periods but dominates at high frequencies. These data suggest a complicated amplitude scaling for the in-mine seismic waves.



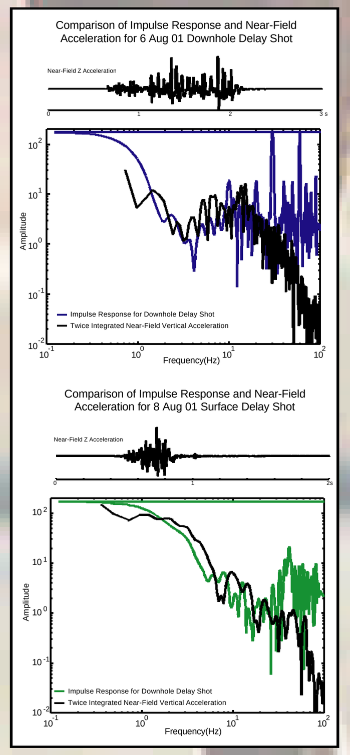


Seismic Source Model

The spectra from each explosion's impulse series are compared to quantify frequency dependent scaling introduced by a combination of intershot delay times and total source duration. The largest explosion, Blast 1 (blue), is predicted to have the smallest amplitudes in the 1-10 Hz band. It is only at the very longest periods that the peak amplitudes reflect the total amount of explosives. Blast 1 also has the largest amplitudes at high frequency, consistent with the in-mine observations.

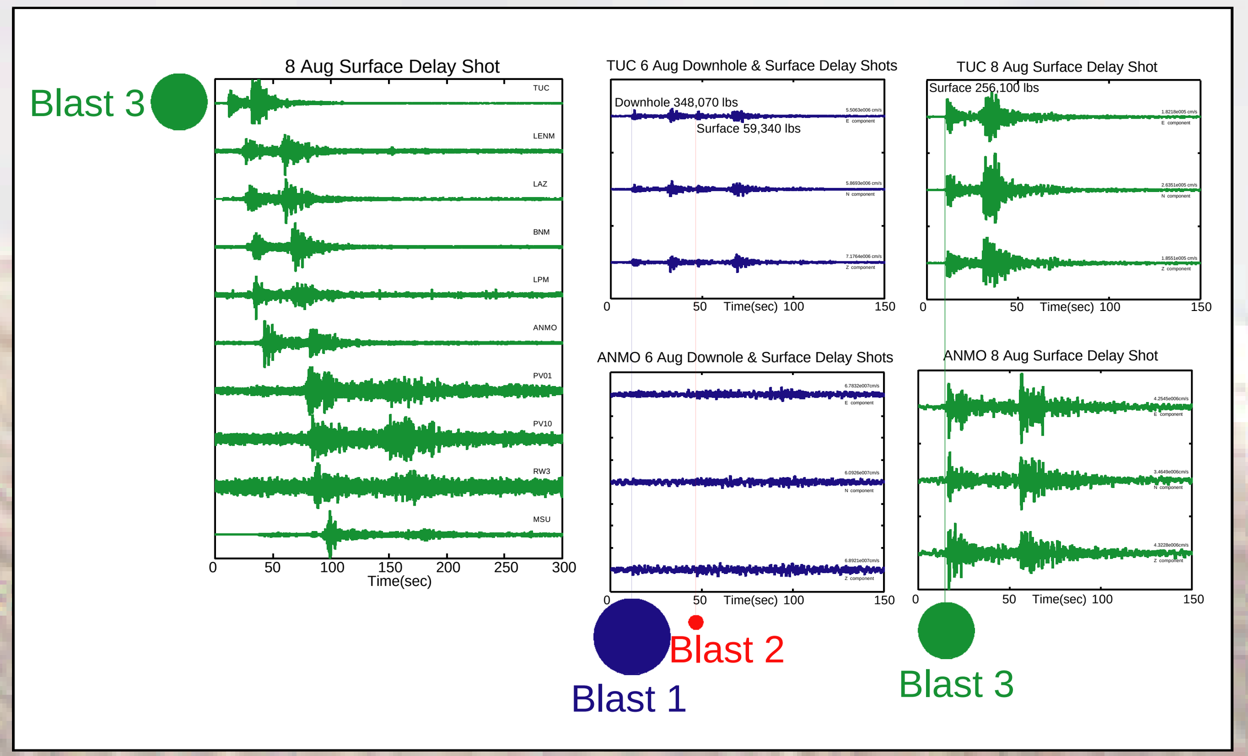


Near-source accelerograms provided in-mine documentation of blast timing. The spectra of the design shot times are compared with the displacement spectra determined from acceleration measurements. The similarity of the spectra up to 20 Hz suggests that source timing effects are responsible for a decrease in amplitude for the largest shot. Above 20 Hz, the spectra diverge since the impulse time series does not include the corner frequency of the individual blasts.



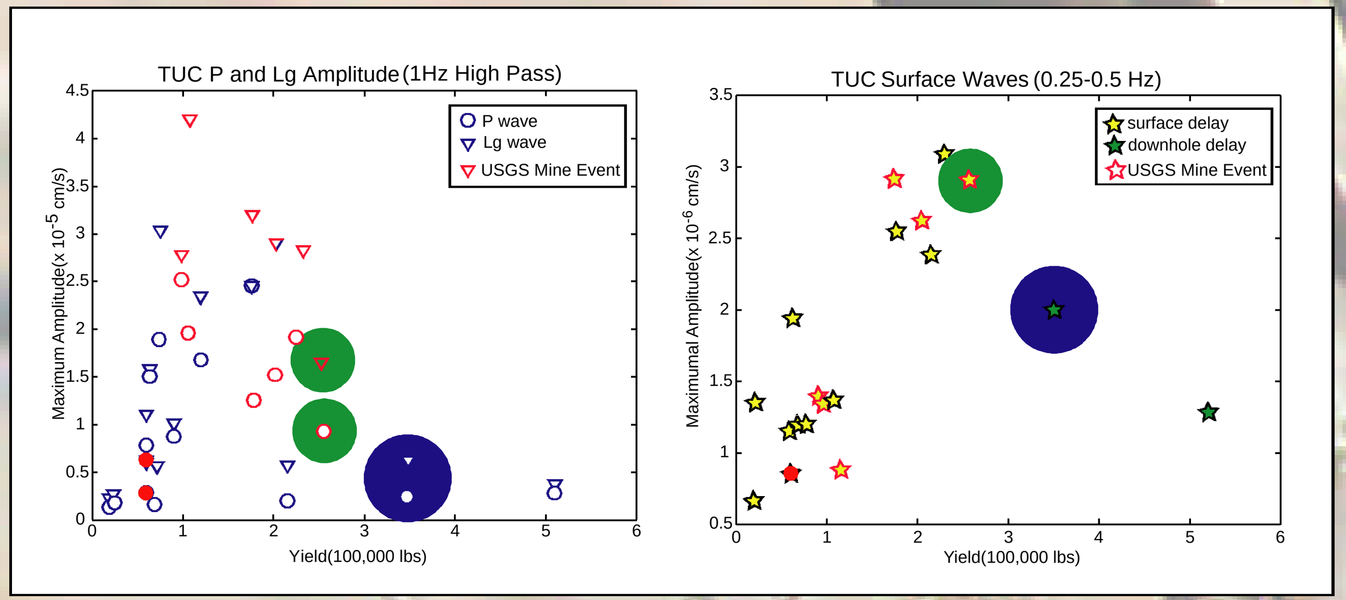
Regional Seismic

A regional record section is reproduced from 100 to 700 km for Blast 3. Relative waveform comparisons are made between the three shots at TUC and ANMO. The shot of largest yield, Blast 1 (blue), does not appear above background at ANMO and is barely seen at TUC with amplitudes similar to Blast 2 (red) despite Blast 2's much smaller yield (7 times). The relative sizes of the regional signals from the three blasts follows that observed in-mine and modeled with design delay times for the blasts.



Regional Amplitude Scaling ?

Based upon the analysis of the three blasts we do not expect peak amplitudes of regional signals at high frequency to be related to total explosive yield. The modeling suggests that at the longer periods there may be a relation between peak amplitude and total amount of explosives. In order to check this prediction, peak amplitudes of P and Lg waves were determined in the 1-10 Hz band and peak surface wave amplitudes were determined in the 0.25-0.50 Hz band. All events from the mine for a one week period were included. The three focus blasts are identified by blue, red and green circles. The high frequency (1- 10 Hz) peak amplitudes do not increas with charge size. The two events with the largest amount of explosives have among the smallest regional amplitudes. The 0.25-0.50 Hz surface wave amplitudes increase with total amount of explosives except for the two, long-duration shots. These results are consistent with the source models and in-mine observations.

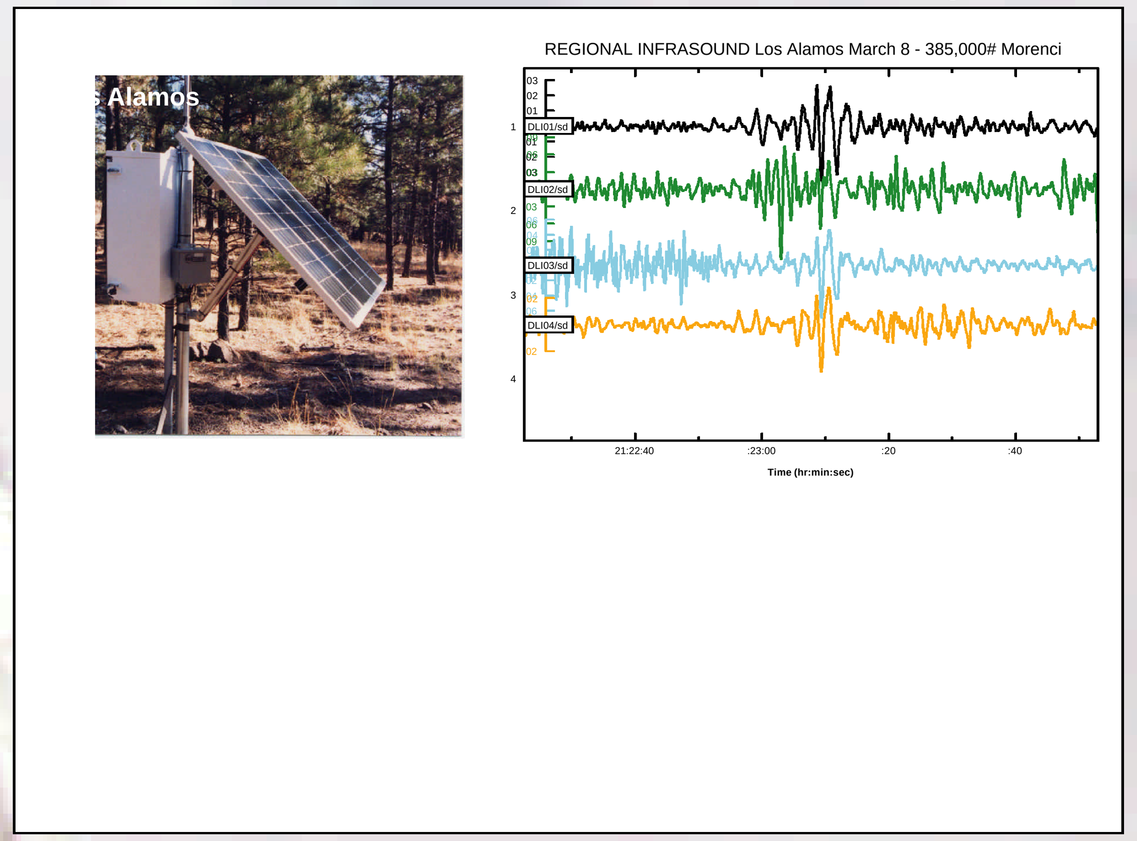


Regional Infrasound

Regional infrasound signals from the blasts at Morenci were analyzed. We have focused on two time periods, February and August, in order to assess the effects of seasonal winds on signal amplitude and detection.

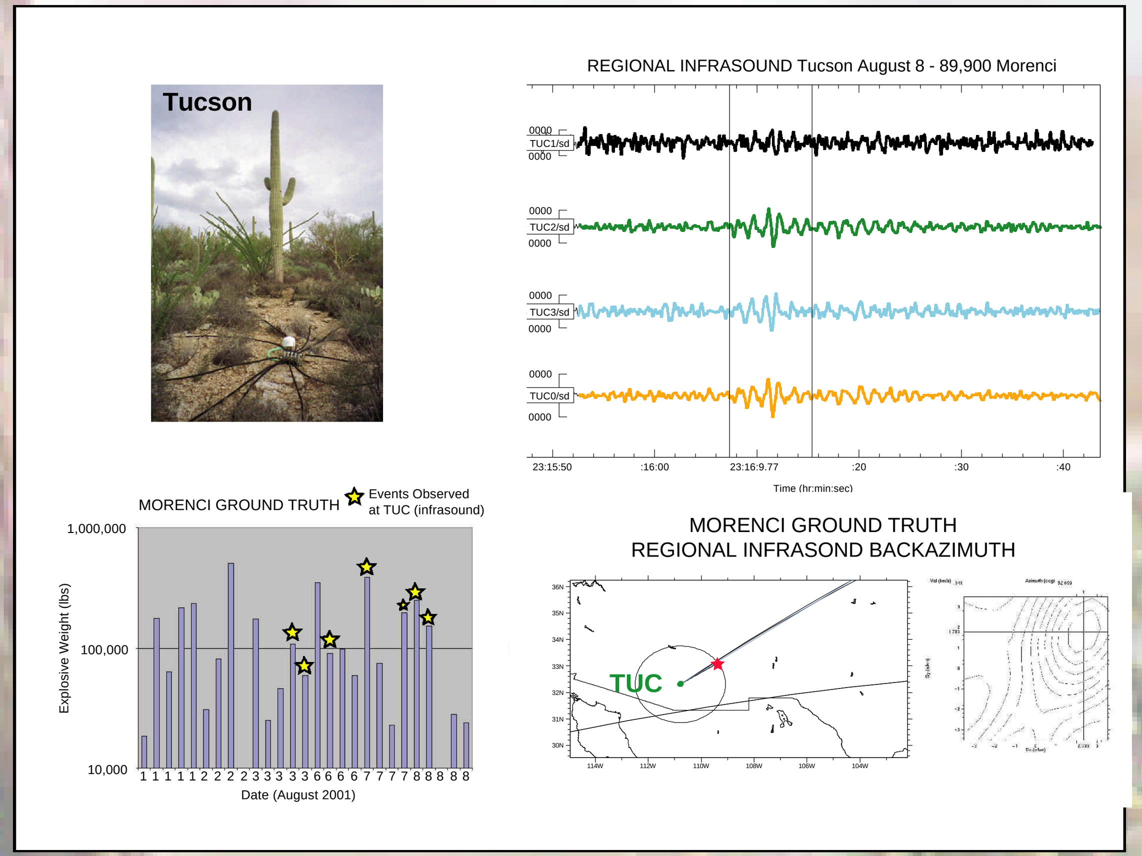
February

7 of 25 ground truth events at Morenci were observed at Los Alamos to the northeast along the prevailing wind direction. Only explosions above 100,000 lbs were observed although not all.



August

None were observed at Los Alamos against the prevailing winds. 7 of 25 events were observed for paths to the southwest to Tucson.



These observations suggest that seasonal winds dominate the infrasound observations in this case.

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