



Sandia
National
Laboratories

Extending Waveform Correlation Techniques to Broad Regional Monitoring: Processing over 3 years of MKAR data



Megan Slinkard*¹, Stephen Heck¹, Dorth Carr¹, Christopher Young¹, Paul Richards², Natalya Mikhailova³ | Sandia National Laboratories¹, Lamont-Doherty², KNDC³

INTRODUCTION

Waveform correlation techniques have garnered increasing attention in the last few years, as their value in detecting and classifying repeated events has been demonstrated again and again. In this research, we show the potential in extending waveform correlation techniques to broad regional monitoring for the benefit of nuclear monitoring. The CTBTO's International Monitoring System has a sparse network of stations which monitor the globe; we show the ability of waveform correlation to aid catalog completeness.

MOTIVATION AND OBJECTIVES

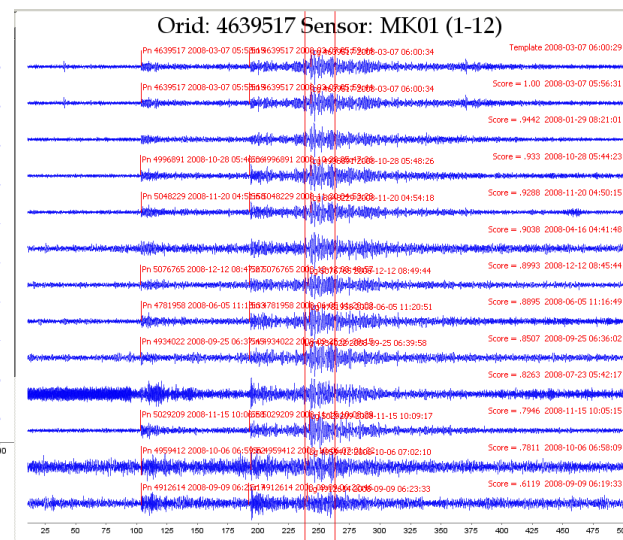
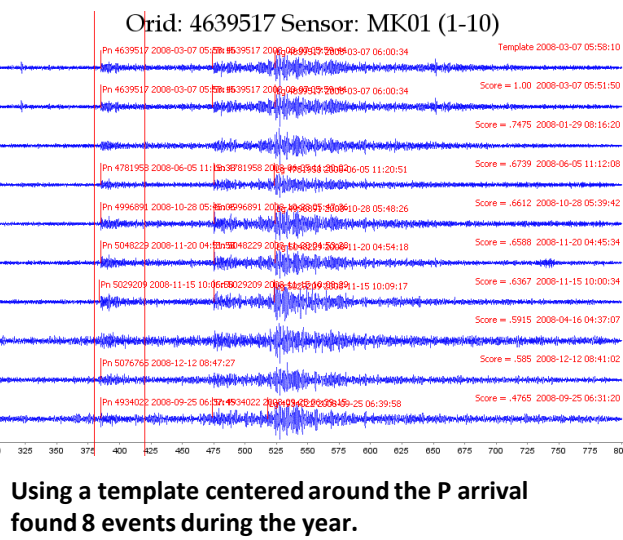
Comparing the CTBTO's LEB catalog to a regional catalog from Kazakhstan which covers central Asia, we note the potential for waveform correlation to enhance the completeness of the LEB catalog.

STATION SELECTION

For this phase of the project, we focused on the benefits of using waveform correlation on just one station. To determine which LMS network station to use for our study, we calculated for each station the percent of events in the LEB catalog (in 2008, in our region) which had Lg arrivals. MKAR was the clear winner, observing 95% of the LEB events (figure 2). We perform correlation on each element of MKAR's 9 element array.

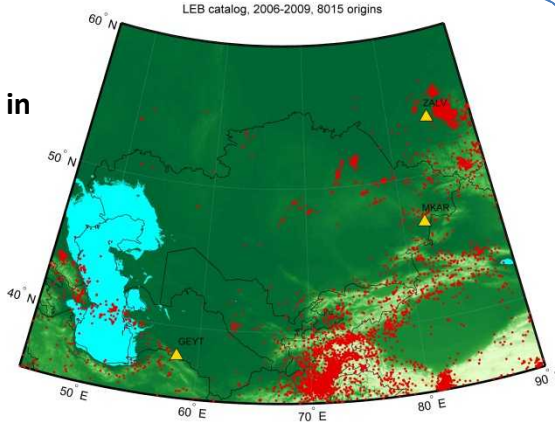
TEMPLATE SELECTION

Template selection is a critical aspect of a well functioning waveform correlation system. The first question to ask is which phase of an arrival to use as the template. We compared using templates formed from P arrivals, Lg arrivals, and P through Lg in our region of interest. Specifically, we found 99 events with both good P and good Lg arrivals; we made templates from these 99 events, set the correlation threshold right at the cusp on consistently getting good matches, processed one year of data, and compared the results.

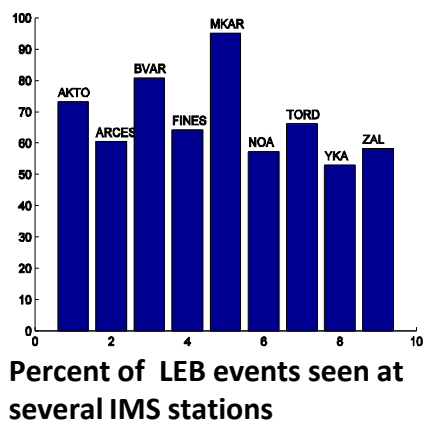
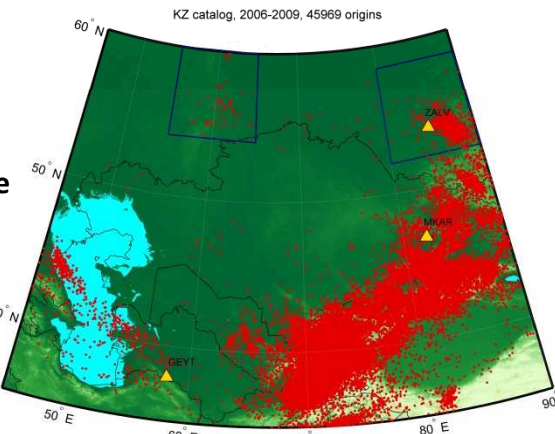


The Lg templates found significantly more matches than P templates: 750 compared to 322, with 293 found by both. We suspect this is due to Lg's higher signal to noise ratio. (P through Lg performed comparable to just using Lg; since just using Lg is computationally more efficient, we decided to use Lg templates.)

The LEB catalog had 8015 origins in a 3 year period



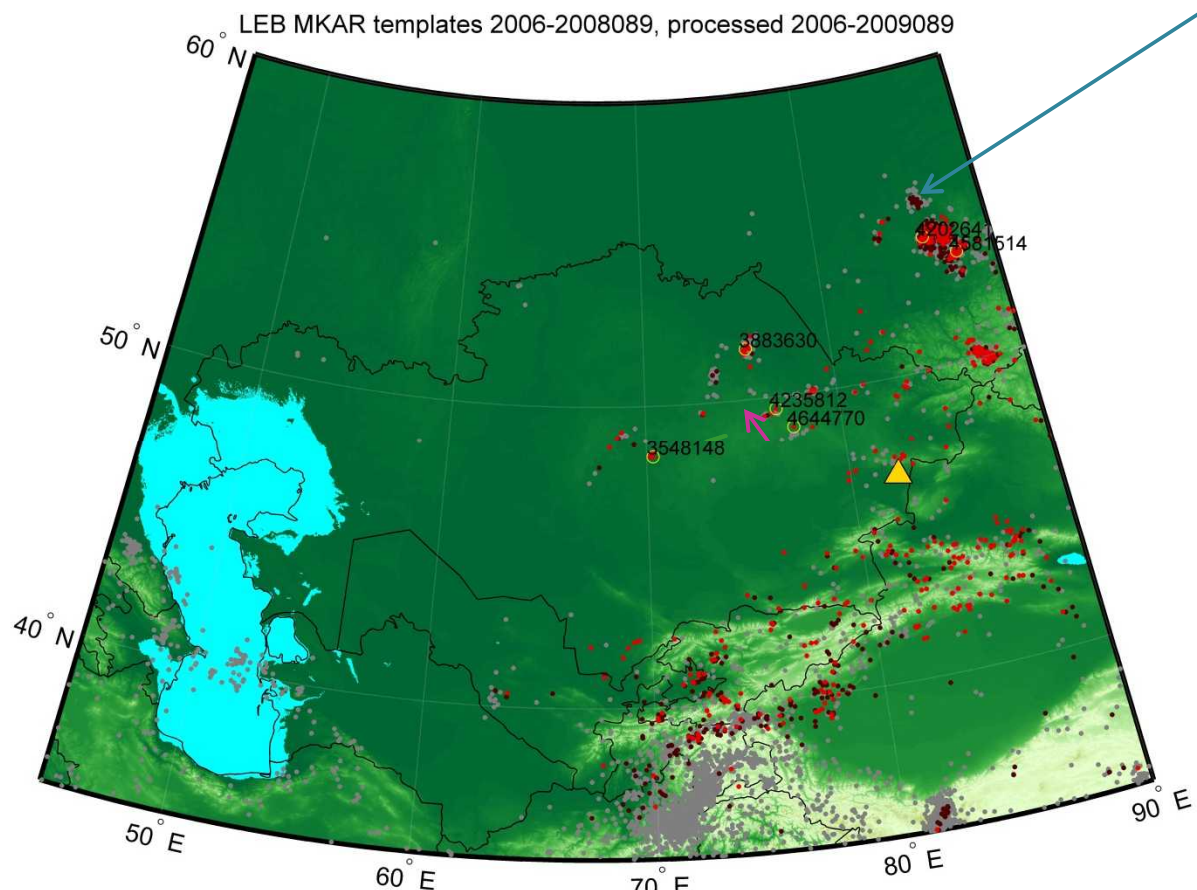
The KZ regional catalog had over 45000, AFTER mining events were removed (except for mining events in the two boxed regions in Russia)



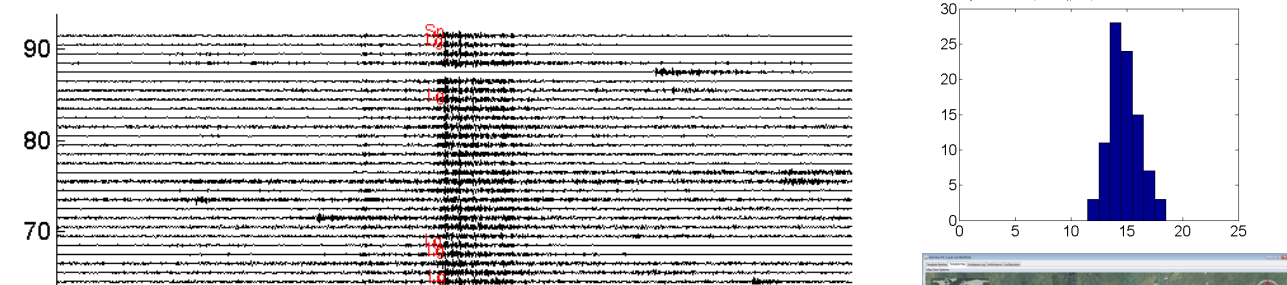
Dates WCD Ran	1/1/2006 – 4/1/2009 (3.25 years)
<div><div>Templates formed</div><div>Raw data processed</div></div>	The first 2.25 years overlapped with the period used to make the template library; the last year was processed to study the value of using archival data for templates.
2006/1/1	2008/3/30
2009/3/30	
Stations used	MKAR
Array elements used	9
Templates: acquisition dates	1/1/2006 - 3/30/2008 2.25 years; 502 templates Included earthquake swarm in March 2008
Templates: lat/lon box	lat : 35- 60 lon : 45- 90

Typical families of similar events are plotted, showing waveform plots and a histogram of the time of day at which the events occurred (to help distinguish mining families from earthquake families). In the waveform plots the top waveform is the template; below it are detected events, sorted by correlation value. The first detection is always the template finding itself; this serves as a nice sanity check, and is not counted in our detection statistics.

Geographic Distribution of Waveform families

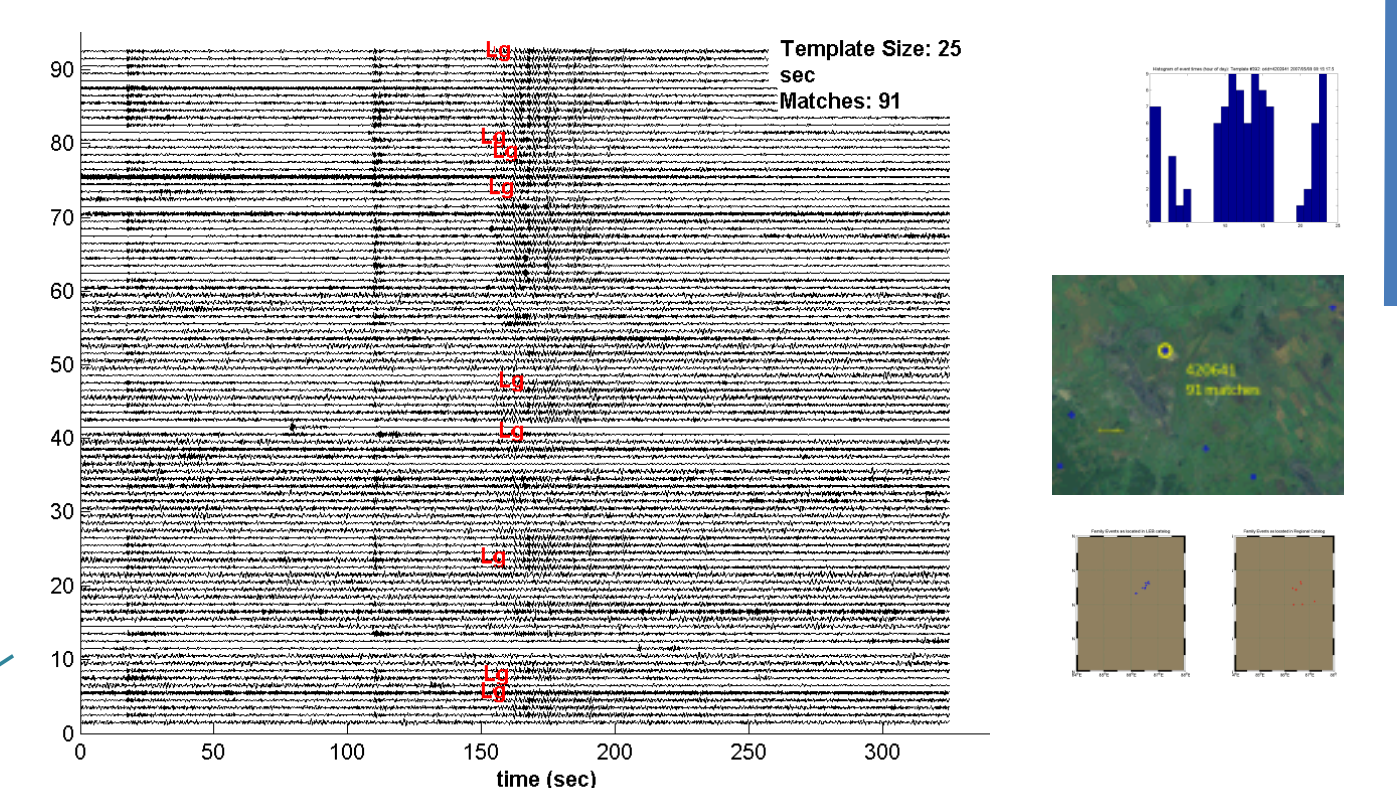


Family found by Orid 3883630

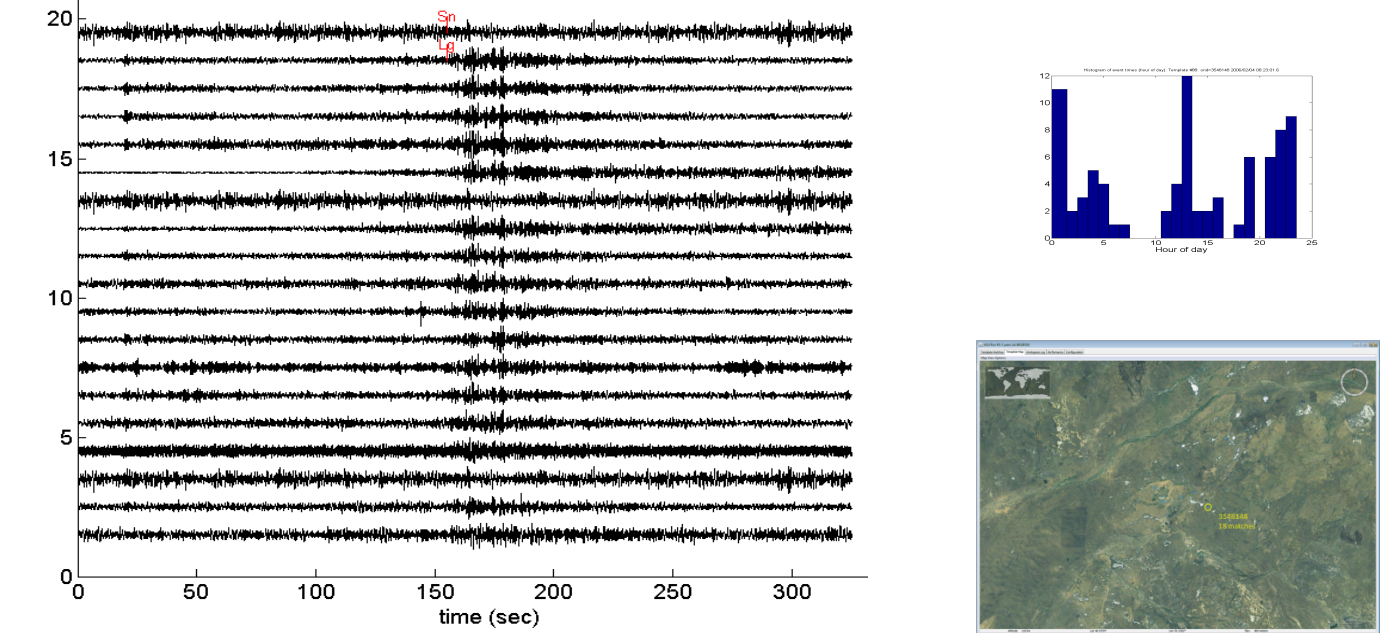


RESULTS

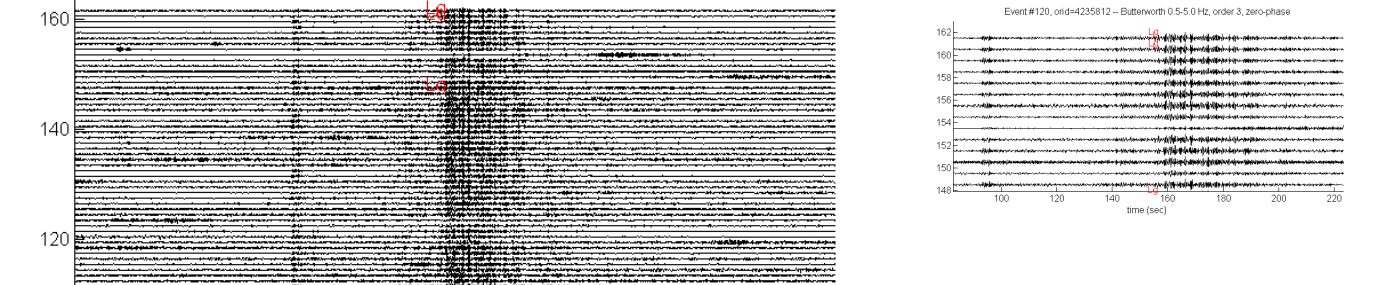
Family found by Orid 4202641



Family found by 3548148

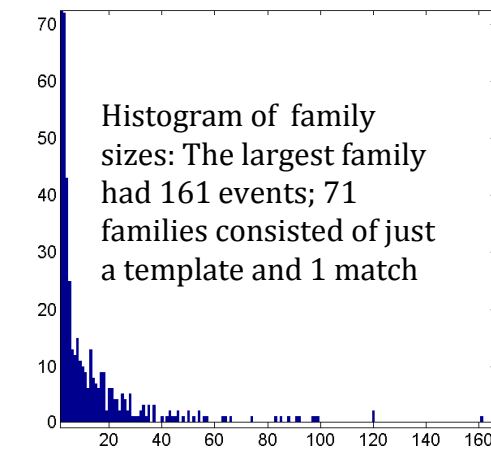


Family found by Orid 4235812

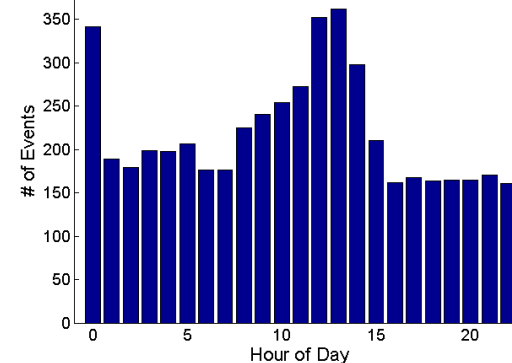


RESULTS SUMMARY

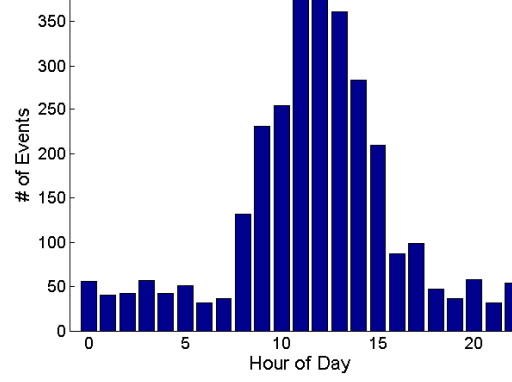
Number of Detections (made by the 180 of the 501 templates that found matches)	Number of detections matched with events in the LEB Catalog	Number of detections matched with events in the Regional Catalog	Detections validated in EITHER catalog	# Detections thought to be Mining / earthquakes
5364	429 (2131 total events in the LEB catalog)	450 (catalog had mining events removed, except for in the boxed regions!)	659	At least 2952 mining events; probably less than 1399 earthquakes



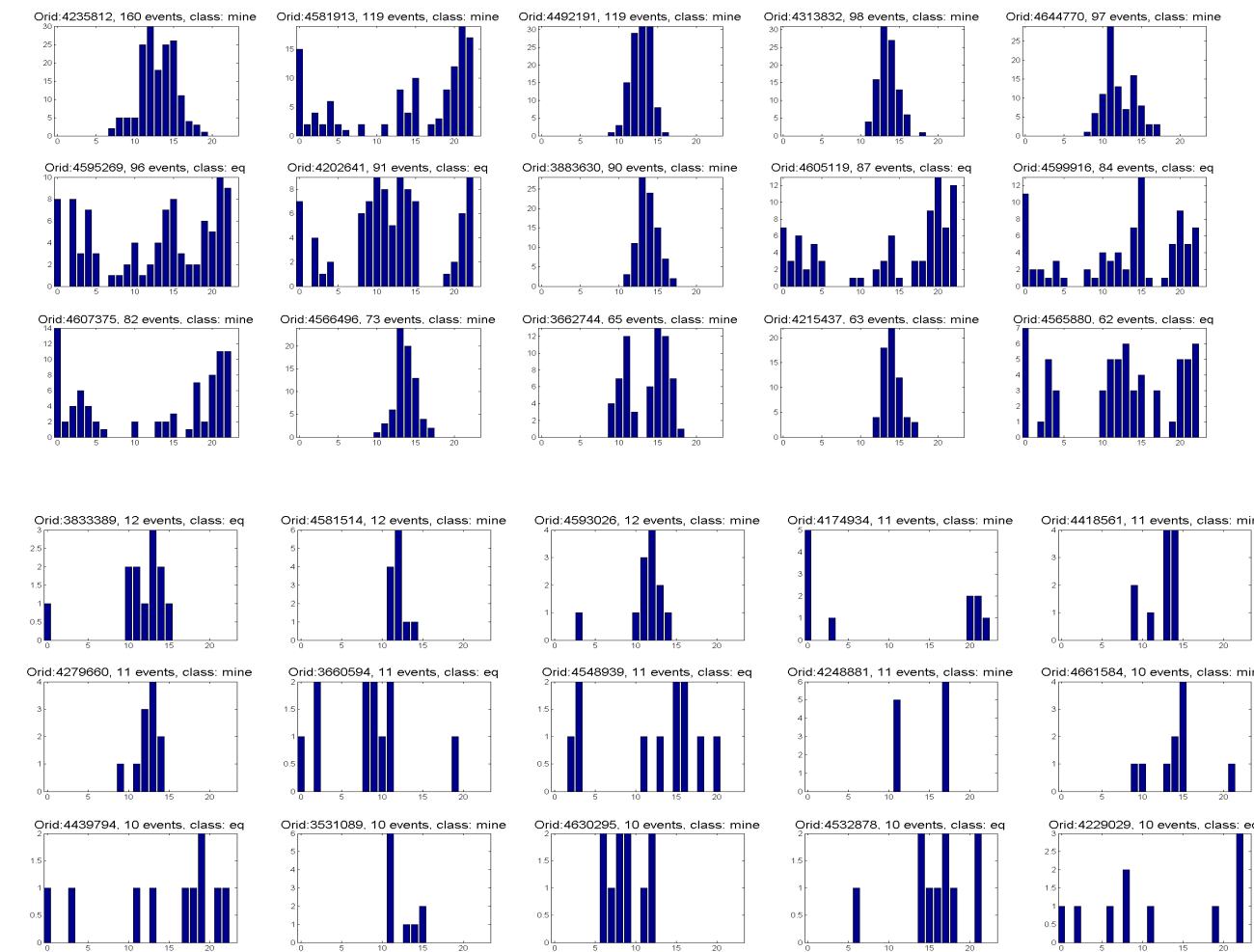
LEB events also in KZ, 2006-2009



LEB events not in KZ, 2006-2009



Histograms of the hour of day during which events occurred help us classify families as mining or earthquake families. Our large families were generally classified as mining



SUMMARY

We performed waveform correlation on 3 years of data for station MKAR in central asia using 501 templates.