Automated Detection of Small Seismic Events using the Transportable Array

John D. West & Jeffrey S. Lockridge
School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287

Matthew J. Fouch
Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015

School of Earth & Space Exploration
Arizona State University

S33B-2560

Introduction

Here we report preliminary results from a new method of detecting local small-magnitude seismic events using arrays of seismometers. Initial results are from the USArray Transportable Array (TA) [www.usarray.org] (Figure 1) recorded in Arizona during 2006-2008, and are compared with a published catalog of small seismic events [Lockridge et al., 2012] for verification. Our initial test spans 10 days in August 2007, during which the catalog contains 126 local seismic events or mine blasts. We can detect all cataloged events during the test period, but require further development on methods to avoid false detections.

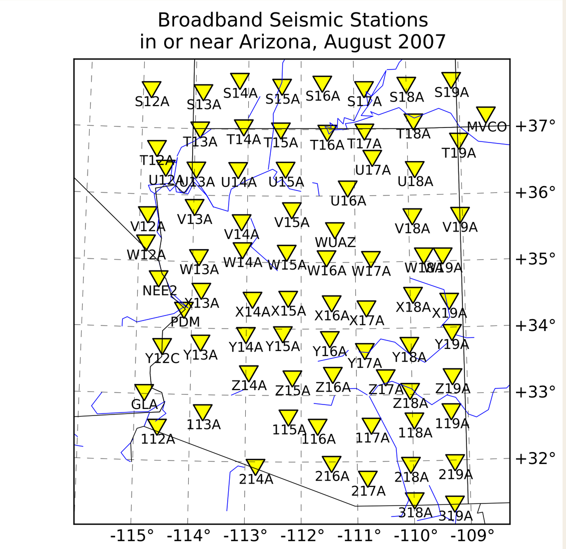


Figure 1: Map of the broadband stations used in this study.

Methods

We create new Integrated Ground Motion (IGM) time series by obtaining 40 sample/sec broadband seismic data from the IRIS Data Management Center (DMC) [www.iris.edu/dms/dmc], deconvolving the instrument response, filtering over 4 bands, and integrating the area under the absolute value of the waveform in successive 15-second windows [Magee, 2010]. We further compute a short term/long term ratio by comparing each IGM value to the average of IGM values for the previous 15 minutes (Figure 2).

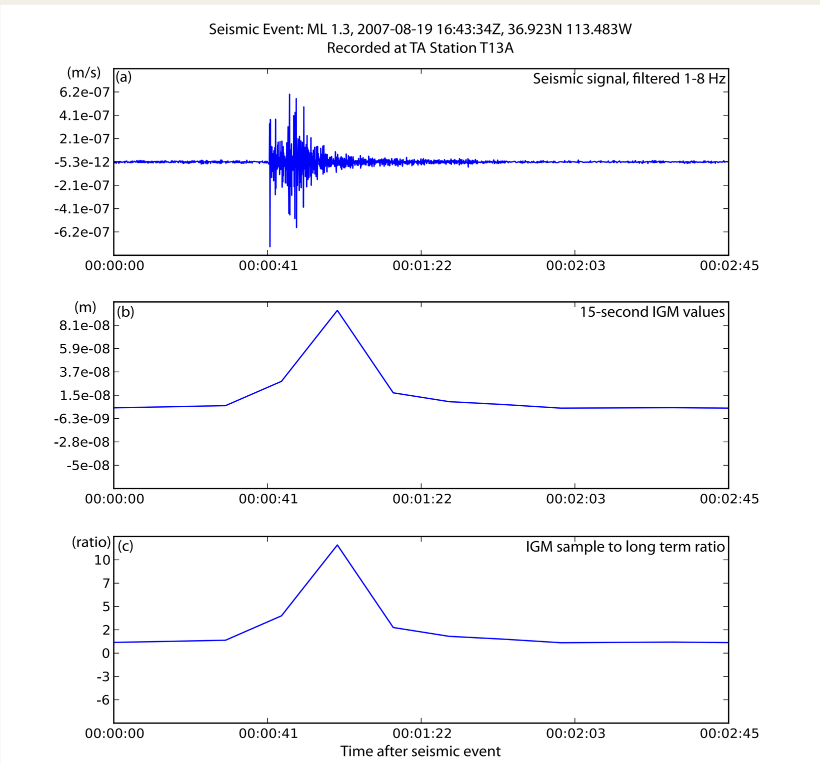


Figure 2: Example of seismic waveforms from various steps in our processing methodology. (a) 40 sample/sec broadband seismic data, with the instrument response removed and filtered over a 1-8 Hz bandpass. (b) 15-second IGM time series derived from the time series above. (c) Short term/long term ratio of individual IGM samples to the average of the previous 15 minutes.

We employ automated cluster detection techniques to locate circular regions containing multiple stations exhibiting high IGM ratio values. Cluster detection is performed for each 15-second slice of the seismic array. We reject any clusters which persist for fewer than 3 successive 15-second time periods, and record each detected cluster as a latitude/longitude location and a radius. All processing was carried out using the EMERALD application for seismic processing [West & Fouch, 2012] (Figure 3).

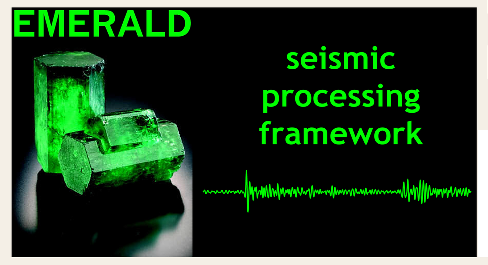


Figure 3: EMERALD [emerald.dtm.ciw.edu] is a visual web application for seismic data processing, currently in beta test with initial release planned for spring of 2013. We are actively recruiting new beta users; contact john.d.west@asu.edu.

Results and Conclusions

Results: Example seismic event (Figure 4) and mine blast (Figure 5) show the location of the event or mine blast from the catalog, and the sequence of circular clusters detected for each. For these examples, the average of the cluster centers are approximately 40 and 20 km, respectively, from the epicenters listed in the catalog. At the current stage of development, this technique detects numerous false clusters from transient high values at separated and presumably unrelated stations (Figure 6). Future enhancements of the cluster detection algorithm will focus on reducing or eliminating these false detections.

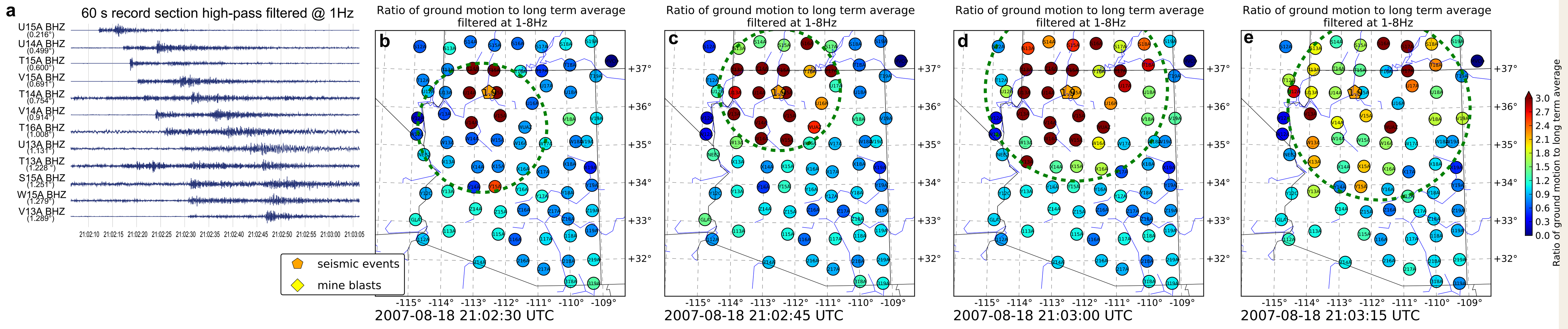


Figure 4: Seismic Event 2007-08-18 21:02:06 UTC, ML 1.9, epicenter lat/long 36.433/-112.544 is shown as a record section (a), and with circular clusters calculated at subsequent 15-second intervals (b-e). Note that the center of the circular cluster in (b) is offset due to a high value at station Y15A. Future improvements in the algorithm will help eliminate this issue.

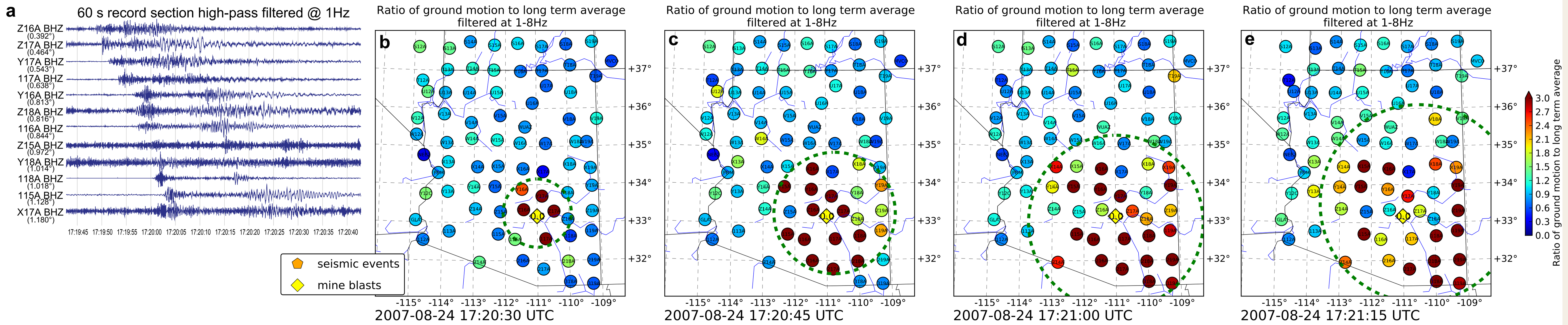
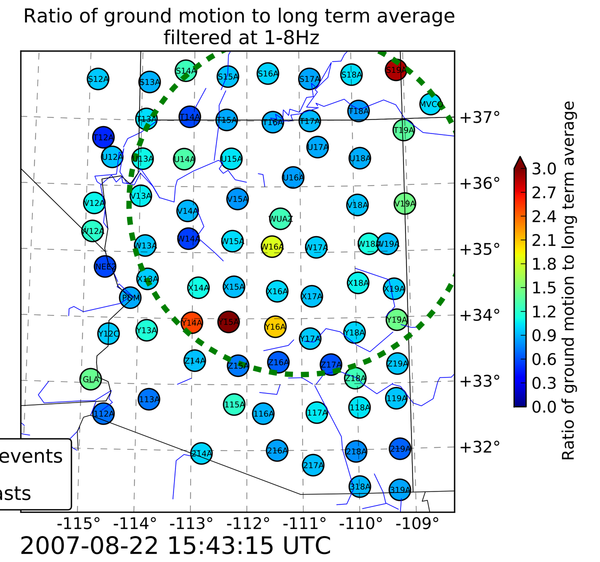


Figure 5: Mine blast 2007-08-24 17:19:41 UTC, epicenter lat/long 33.169/-111.006 is shown as a record section (a), and circular clusters calculated at subsequent 15-second intervals (b-e).

Implications: This technique is potentially useful in a number of lines of scientific inquiry which involve statistical analysis of catalogs of small seismic events, such as investigation into triggering of local seismicity by remote earthquakes. It may also prove useful as a labor-saving method for developing seismic event catalogs, by identifying approximate times and locations of events for further analysis. We also anticipate that it will allow for automated detection of seismic signals which do not include a discernable P-wave arrival.

Conclusions: We have outlined a method for detecting seismic events occurring within the bounds of a large seismic array, such as a state-wide array or the TA. This method is still under development and we will continue to work to increase its effectiveness and reduce the number of false detections.

Figure 6: This is a cluster detected by our algorithm which does not appear to be associated with a seismic event, but is instead detecting a number of unrelated high-signal stations. This is related to the problem noted in Figure 4b, and will be a focus of future development.



Acknowledgements

Financial support for this work came from National Science Foundation grant EAR-0548288 (MJF EarthScope CAREER grant) and the Carnegie Institution of Washington's Department of Terrestrial Magnetism. Productive discussions with Ed Garnero, Angela Magee, Amanda Clarke, and Ramon Arrowsmith are gratefully acknowledged.

References

Lockridge, Jeffrey S., M.J. Fouch, & J R. Arrowsmith, Seismicity within Arizona during the deployment of the EarthScope USArray Transportable Array, *Bull. Seis. Soc. Am.*, **102**, doi: 10.1785/ 0120110297, 2012.

Magee, Angela, A New Method for Identifying Triggered Seismicity: Two Examples from the Western United States, Masters Thesis, Arizona State University, 2010.

West, John .D., & M.J. Fouch, EMERALD: A Web Application for Seismic Event Data Processing, *Seismol. Res. Lett.*, **83 (6)**, doi:10.1785/0220110138, 2012