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Title: DETECTION, LOCATION AND ANALYSIS OF SEISMIC EVENTS AT INTERMEDIATE AND LOW FREQUENCIES: COLLABORATIVE RESEARCH WITH URS & UC SANTA BARBARA

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Abstract

We have developed a simple, yet powerful, method to locate worldwide earthquakes and determine their size. This method continuously maps global surface waves at very long periods into to a three-dimensional space spanned by the geographic coordinates and origin time. Because our system uses very long period surface waves and operates continuously, it can determine reliable magnitudes and locations even for great or "slow" earthquakes and experiences few operational problems in real time due to its constant load approach. In collaboration with staff at the National Earthquake Information Center (NEIC), we have installed a proof of concept prototype of our software at the NEIC and integrated it with their seismic waveform retrieval system. We have tested this prototype on months of waveform data, by comparing our results with established earthquake catalogs. We have found that the method performs well for worldwide earthquakes down to a magnitude of 5.5 and also shows promise in indicating the rupture propagation of great earthquakes.

Investigations Undertaken

We have developed a very simple but powerful method of locating earthquakes using surface waves. Our locator carries out a simple continuous mapping of the surface wave arrivals from different stations and different periods onto a (global) grid, using group velocity based travel time corrections. The first step is akin to the traditional method of measuring dispersion using a sliding window, which results in a spectrogram with amplitude as a function of period and arrival time (Figure 1). These spectrograms can then be mapped into origin time and distance for every individual station. This time-distance function will show localized maxima for every time-distance pair corresponding to a seismic event. In our current algorithm, we continue with a final mapping of this function into a three-dimensional space spanned by the geographic coordinates and origin time. Seismic events are then identified as local maxima of this mapped function, both in space as well as time.

This method has several advantages over conventional short period locators:

1. it can determine a reliable moment magnitude even for great earthquakes
2. it provides a good first estimate of centroid location and time, which can give a quick indication of source finiteness and directivity
3. it will indicate the enhanced long period seismic energy of tsunami earthquakes, events for which moment (and thus tsunami generating potential) are underestimated using body wave techniques
4. it can act as independent back-up of traditional near real-time location methods, which occasionally miss or underestimate earthquakes
5. it is potentially able to detect very long period events, bridging the gap between geodetic and high-frequency seismic monitoring
6. due to continuous operation it is less susceptible to operational problems

Furthermore, this system has potential for further development, as indicated by similar methods used to determine regional moment tensors and rupture models.

Results

We have implemented a proof of concept prototype of our locator software at the National Earthquake Information Center and integrated it with their seismic waveform retrieval system. We have tested the locator on several months worth of waveform data (Figure 2) and compared the results to the real-time USGS catalog and, for those events for which this catalog did not provide complete information, the Global CMT catalog. We have found that the software performs well and is able to locate global events reliably and quickly, down to a magnitude of about 5.5. Furthermore, the magnitudes determined by this system also compare well to those of the final catalog, even for slow ridge events, tsunami earthquakes and earthquakes larger than magnitude 8 (Figure 3). Initial tests indicate that the magnitude threshold may be lowered considerably by including shorter period (< 100 seconds) surface waves in the analysis. The locator results for the great Sumatra earthquake also indicate that it shows promise in locating the centroid of energy release as a function of time for very large earthquakes, and thus determining some of the first order rupture characteristics of these events.

Non-technical Summary

We have implemented software at the National Earthquake Information Center that quickly and reliably locates global earthquakes down to a magnitude 5.5 and determines their magnitude. The method employed continuously projects seismic energy back to the source region and thus represents a new way of using the wave field produced by earthquakes. We have shown that this system can provide completely automatic, near real-time, location and magnitude for worldwide large earthquakes and performs particularly well for events greater than magnitude 7.0, which have proven to be problematic for other systems in the past. Initial tests show that this method also shows promise in locating earthquakes down to smaller magnitudes and in indicating the propagation of the rupture for very large earthquakes.

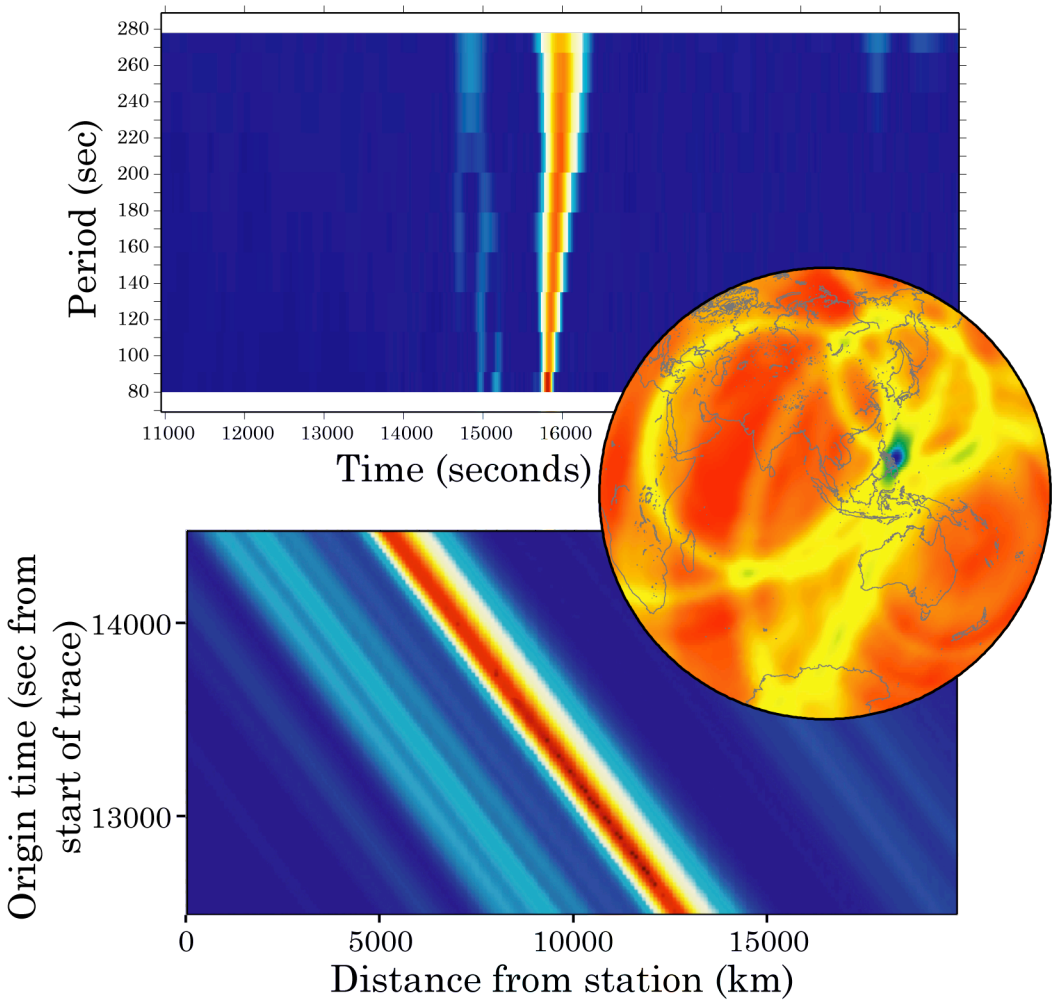
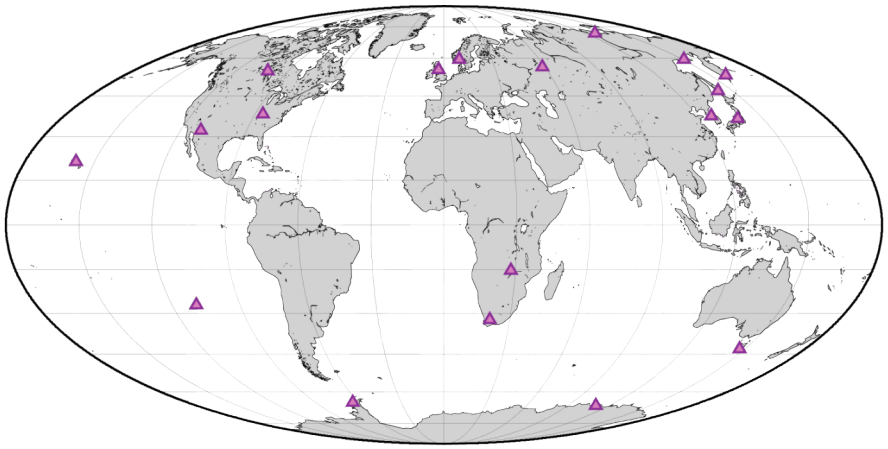
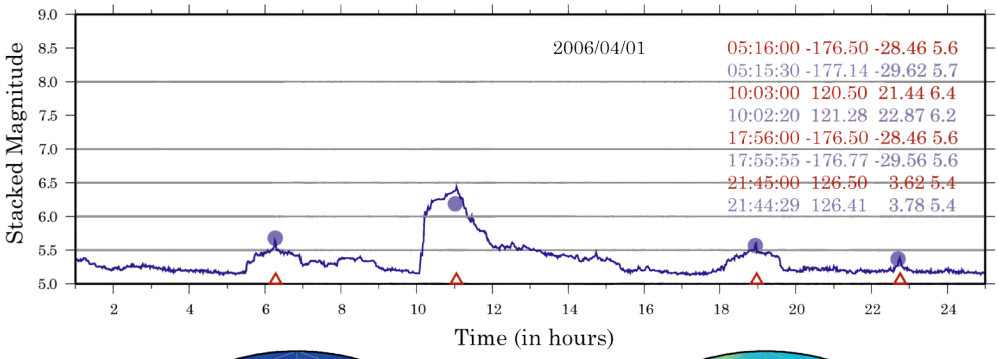


Figure 1: Different stages of locator. Top panel shows spectrogram with surface wave arrivals and dispersion clearly visible. Transformation to distance and origin time is shown in bottom panel. Stacked results for 6 stations are shown in map indicating detection of event in the Philippines.




Stacked Magnitude
Time (in hours)
2006/04/01
05:16:00 -176.50 -28.46 5.6
05:15:30 -177.14 -29.62 5.7
10:03:00 120.50 21.44 6.4
10:02:20 121.28 22.87 6.2
17:56:00 -176.50 -28.46 5.6
17:55:55 -176.77 -29.56 5.6
21:45:00 126.50 3.62 5.4
21:44:29 126.41 3.78 5.4

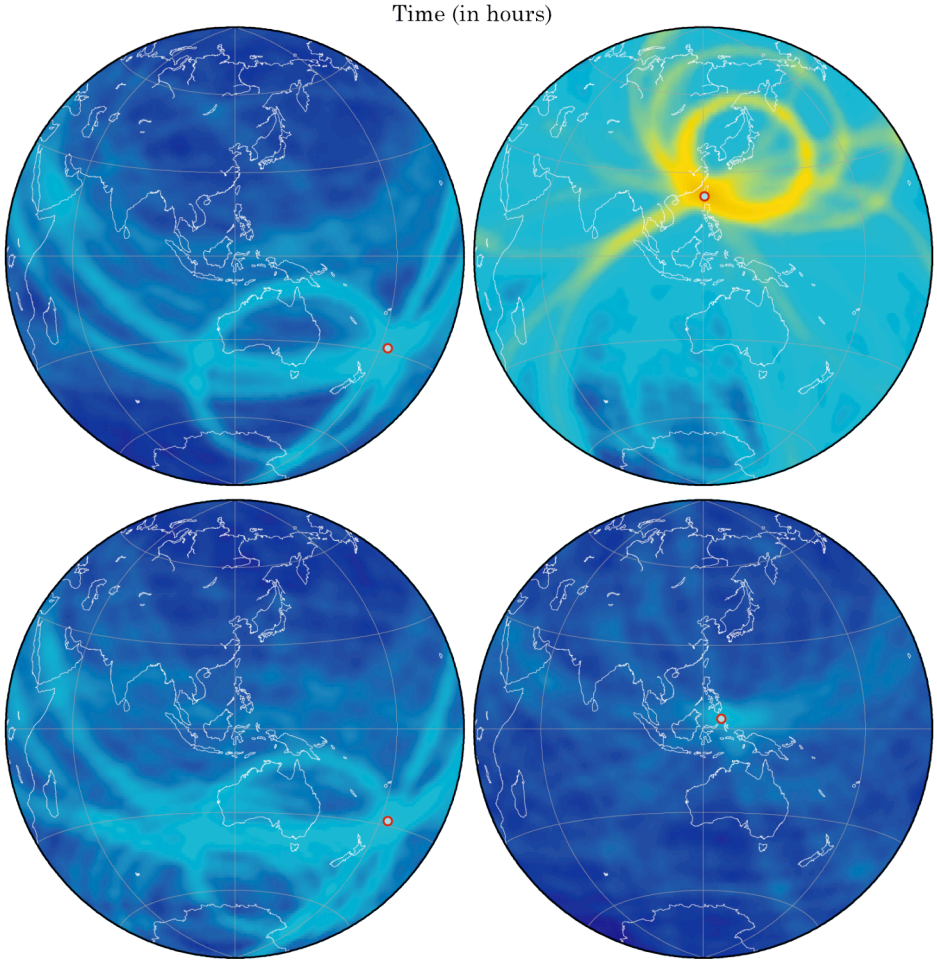


Figure 2 (previous page): Locator results for one day of data. Top panel shows locations of stations used. Stacked waveform time trace is shown in middle panel, with the stacked spatial functions shown in the bottom panel for the four detected events. Purple colors show magnitude and origin time from PDE catalog, red colors indicate locator results.

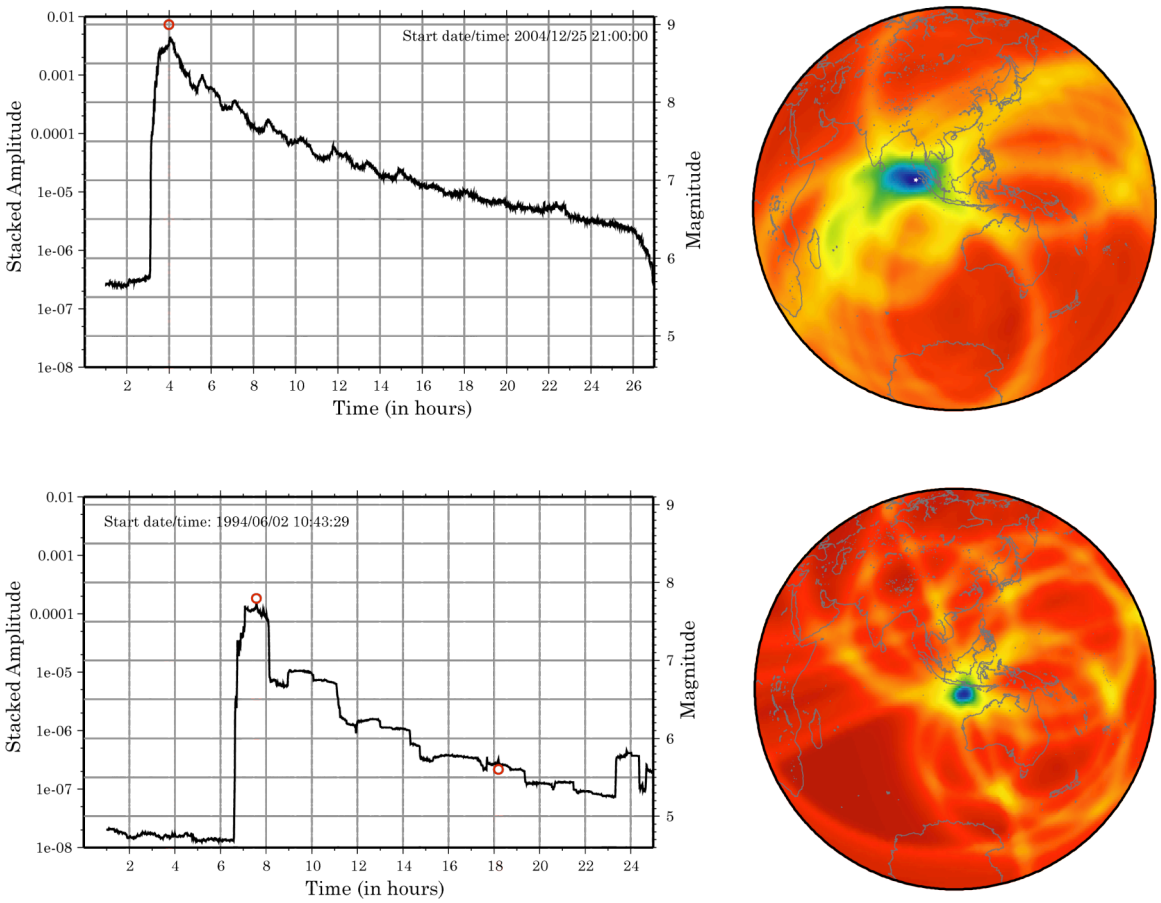


Figure 3: Locator results for the 2004 Sumatra-Andaman earthquake (top panels) and the 1994 slow Java earthquake (bottom panels), carried out with aim of obtaining rapid locations as well as magnitudes using a time-lag of only 1800 and 900 sec respectively and data from only 8 stations. Magnitudes for these events are still somewhat underestimated, but better reflect their true size than the results from other rapid methods available at that time.