Can Intraplate Earthquakes Increase the Magnitudes in Future Earthquakes?

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Background

An intraplate earthquake occurred in the east Indian Ocean on April 11, 2012 with a magnitude of Mw 8.6 resulting from the largest strike slip ever to be recorded. This earthquake was felt over 10,000 km from the epicenter and found that it can trigger new events at longer distances (Pollitz et al., 2012).

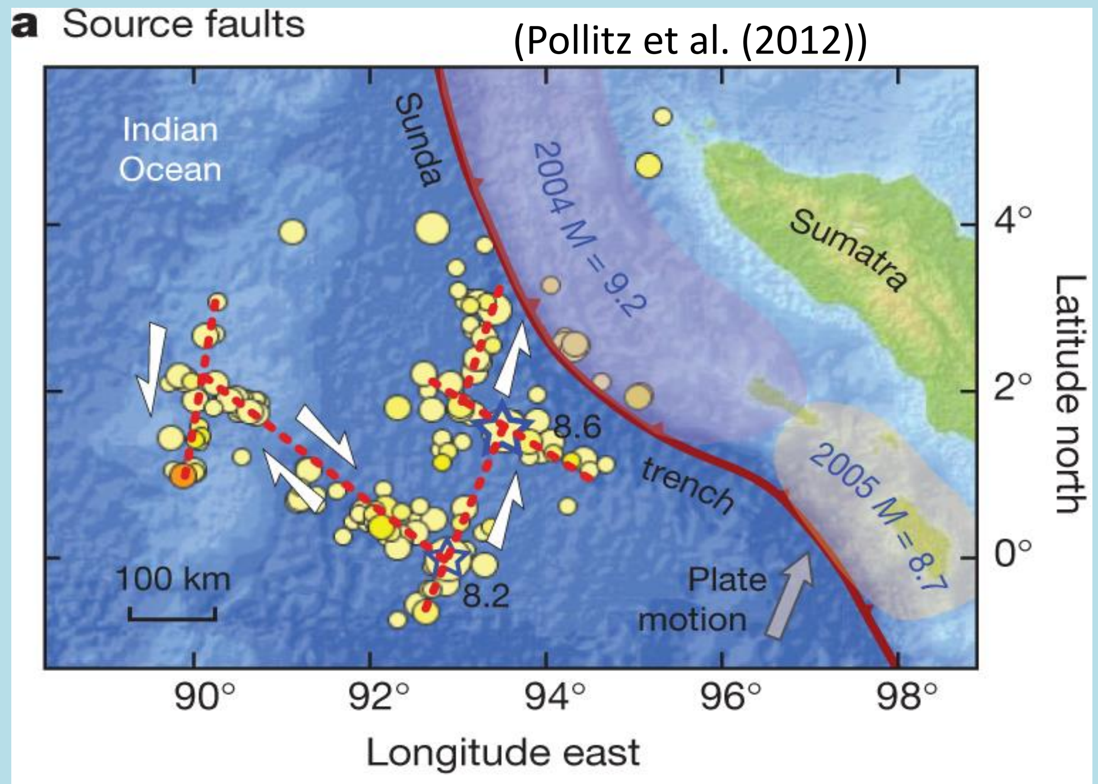


Figure (a) The inferred fault ruptures of the 11 April 2012 M=8.6 east Indian Ocean earthquake and M=8.2 aftershock.

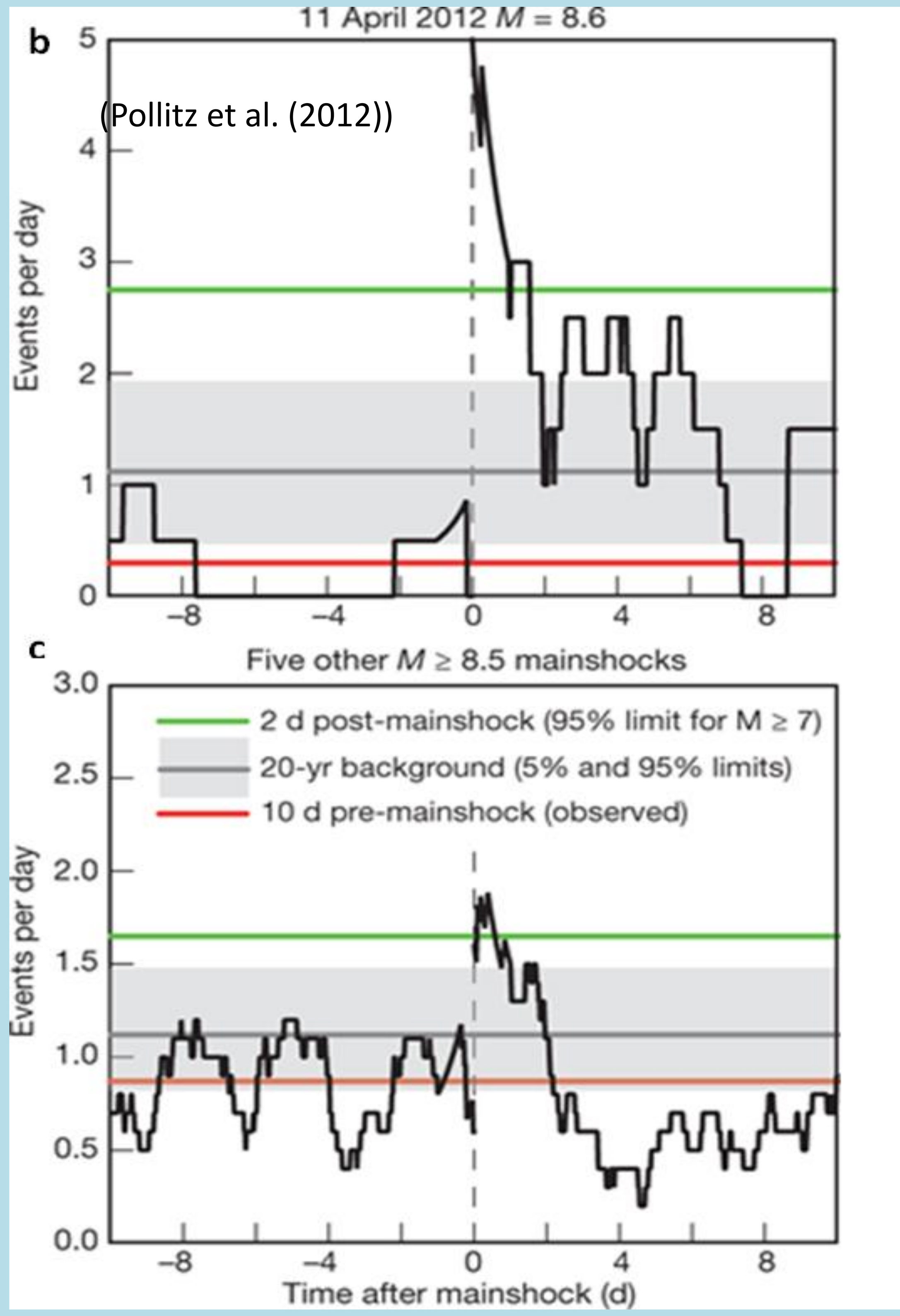


Figure (b) 11 April 2012 Mw=8.6 Indian Ocean mainshock.
Figure (c) A collection of five other mainshock with Mw≥8.5

Introduction and Hypothesis

In relation to the Indian Ocean earthquake, the Mineral, Virginia intraplate earthquake occurred on August 23, 2011 with a magnitude of Mw 5.8 resulting from a reverse fault slip. The Mineral event was the largest to shake the Eastern United States since 1897 and was felt over an extraordinary large area (Horton et al., 2012).

Shortly after the Mineral earthquake, a PhD student from the Department of Geology, Lisa Walsh, noticed seismicity rate changes from the USGS. Walsh is investigating whether there are more earthquakes after the event than before.
As complementary to Walsh's research, I propose an alternative hypothesis to the Mineral Earthquake:

- Experimental Hypothesis: The earthquakes that occurred since the Mineral Event are generally larger than before the event.
- Null Hypothesis: There is no significant difference in the magnitudes before and after the Mineral earthquake.

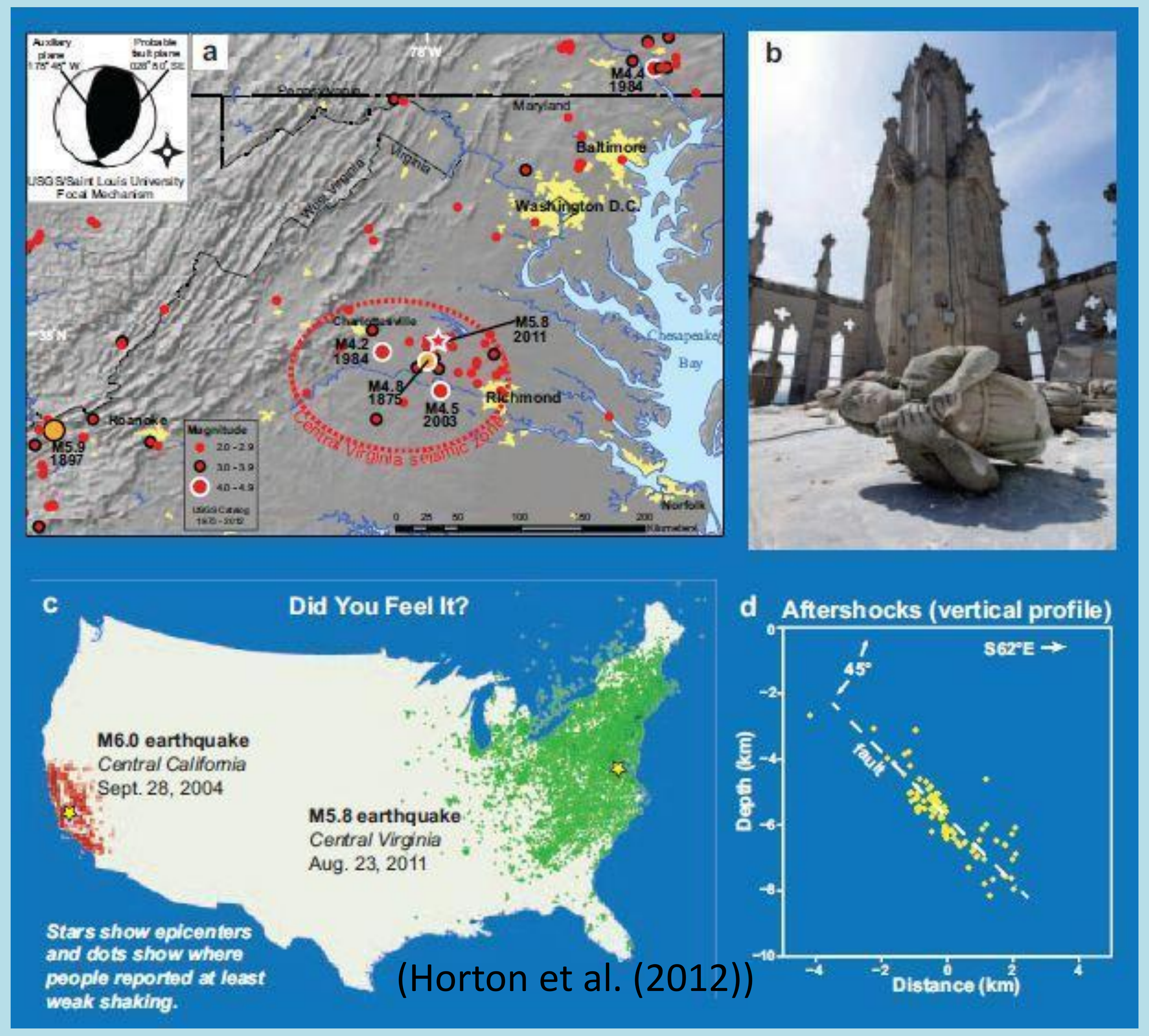


Figure (a) Mw=5.8 earthquake in the Central Virginia Seismic zone with a focal plane indicating a reverse motion on an east-southeast dipping plane. **Figure (b)** The picture depicts damage to the National Cathedral in Washington D.C. that was 135 km away from epicenter. **Figure (c)** According to USGS "Did You Feel It" data map, the earthquake was felt over an extraordinary large area in the eastern region as compared to the western region with similar depth and magnitude. **Figure (d)** The aftershocks were defined in an east-southeast dipping fault rupture plane.

Methodology and Feasibility

I downloaded the Earthquake catalogue from Incorporated Research Institutions for Seismology website (IRIS) to be parsed into the computer program Matlab. The catalogue comprised magnitudes ≥ 1.0 in a ten year duration from January 01, 2001 to August 22, 2011 before the Mineral Earthquake.
There are a number of methods that can be applied in determining the statistical level of significance of the changes in seismicity.

Gutenberg-Richter Relation

One method I applied was the Gutenberg-Richter (frequency-magnitude plot) relation to extract the magnitude of completeness where the small earthquakes are not detectable. The logarithm of the rate of earthquakes is plotted against magnitude and forms a linear array. The slope of the line fits through the array is extended to estimate about how often a large earthquake may be expected in a period of time. The relation is defined as:

$$\log_{10} N = \alpha - \beta M$$

where N is the number of earthquakes with magnitudes larger than a magnitude M in the catalogue. The parameters α and β are constants where α depends on the time span and size of earthquake catalogue and β is the slope in the frequency-magnitude plot that is often close to 1.

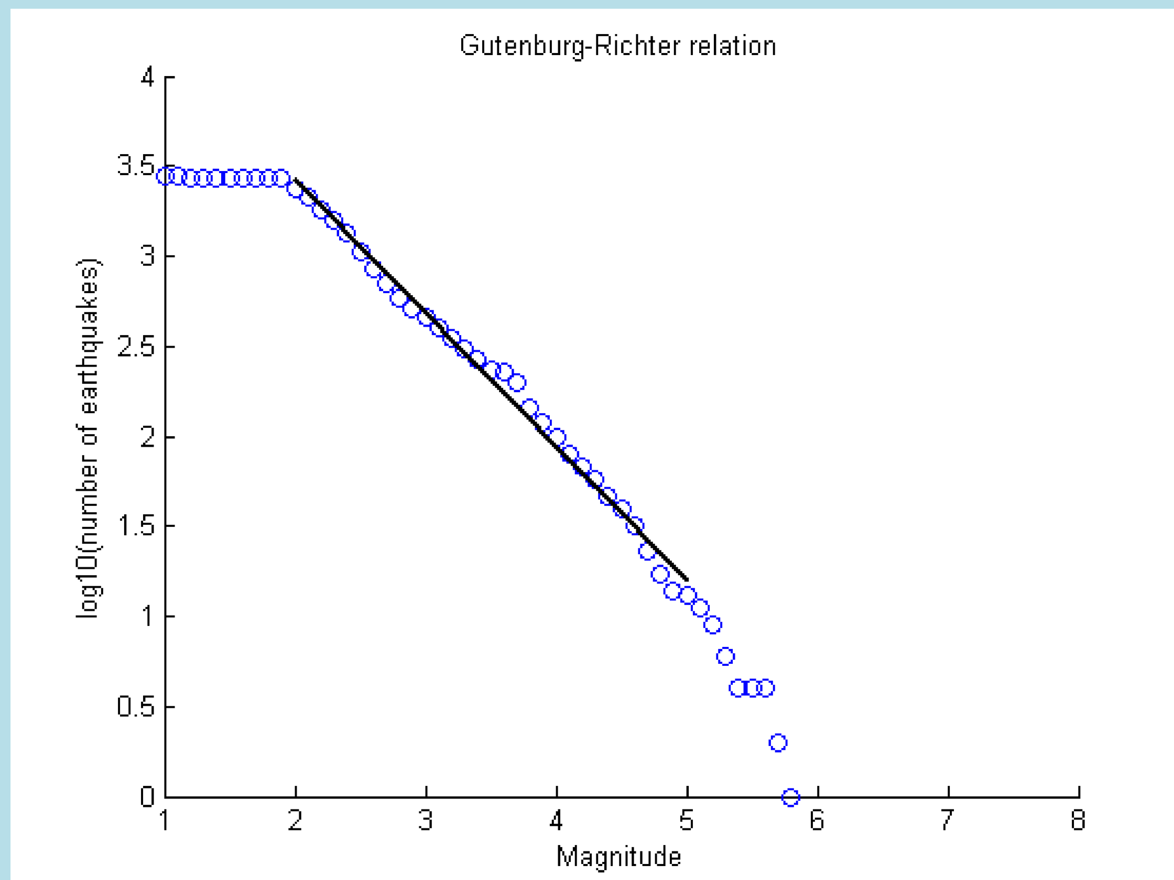


Figure 1: The magnitude of completeness is around Mw=2.0.

References

Horton, J.W. and Williams, R.A. (2012), The 2011 Virginia Earthquake: What Are Scientists Learning? EOS, Trans. Am. Geophys. U., 92, p.317-324, doi: 10.1029/2012EO330001

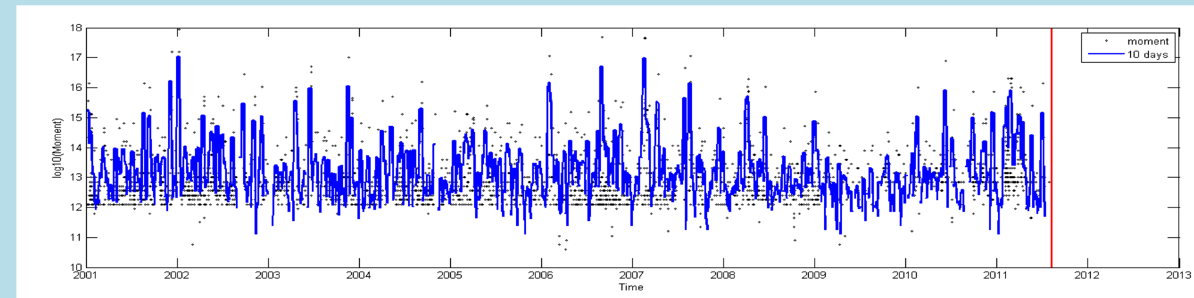
Pollitz, F.F., Stein, R.S., Selvigen, V., and Bürgmann, R. (2012), The 11 April 2012 east Indian Ocean earthquake triggered large aftershocks worldwide, Nature 490, 250-253, doi:10.1038/nature11504

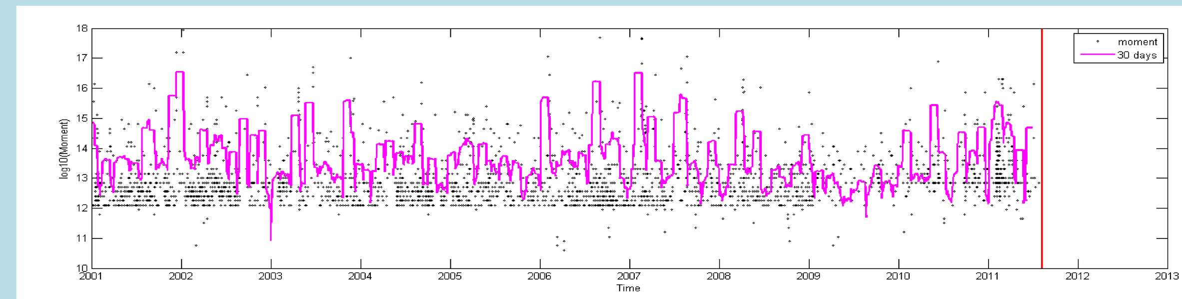
Time Series and Moving Window Average

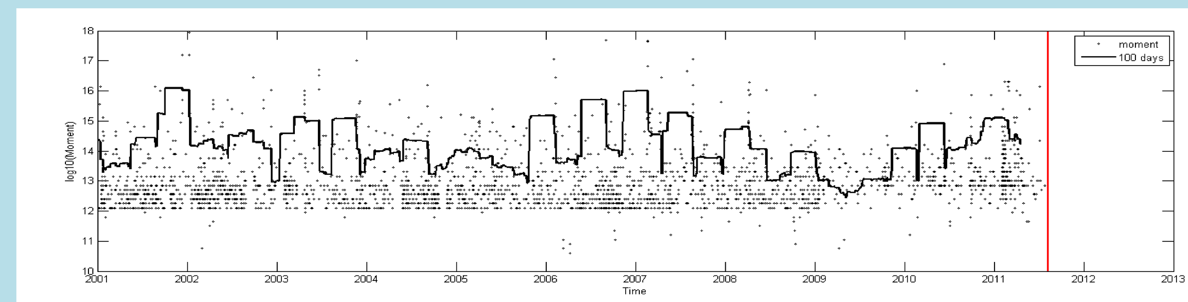
In another method, I converted the reported magnitude into seismic moment using the Kanamori equation:

$$M_o = 10^{(\frac{3}{2}Mw+9.1)}$$

where Mo is seismic moment and Mw is reported magnitude. With the calculated seismic moment, I generated a times series that plots individual seismic moment points per each event and compiled a statistical analysis of the total moment released over 10, 30, 100 day windows occurring during the ten years prior to the Mineral earthquake.







The three plot figures show the seismic moments and the 10-day, 30-day, and 100-day window moving averages in the ten year duration before the Mineral event. The red line in all three of the plots shows a break before the Mineral earthquake.
Figure 2 (top) shows the time series that is noisy for the 10-day moving average. **Figure 3** (middle) shows the time series is also noisy for the 30-day moving average. **Figure (4)** (bottom) shows the 100-day moving average is dominated by occasional large earthquakes.

Future Plans

For the Fall semester, I planned to continue working on the cumulative histogram of the average moment release rate for each window to be analyzed as an empirical statistical distribution for determining how unusual the time period after the Mineral event was in comparison with the pre-earthquake period that took place in the Central and Eastern US. Later I will repeat the analysis for separate regions and evaluate the hypothesis.

Acknowledgements

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