Introduction

The relationship between stress perturbations and the advancement or suppression of future earthquakes is an ongoing area of research in active tectonics. Studies of earthquake triggering provide insight into the state of stress on a fault and the conditions prior to and during an earthquake nucleation sequence. Static triggering results from the elastic deformation and stress changes due to slip on a fault during an earthquake. In the near-field, a static stress transfer of ~0.1 MPa has been shown to influence regional earthquake activity by promoting or suppressing earthquakes (Stein, 1999). In the far-field; i.e., at distances where static stress changes are negligible, studies of dynamic triggering examine the effects of a stress pulse on critically stressed faults and the subsequent change in seismic activity (Freed, 2005). Dynamic triggering refers to changes in earthquake activity due to the transient stress perturbation during the passage of seismic waves. Separating the effects of static vs. dynamic stress changes is necessary to advance the understanding of global earthquake interaction (Felzer and Brodsky, 2005; Richards-Dinger et al., 2010; van der Elst and Brodsky, 2010) and requires investigating seismicity more than 2–3 rupture lengths from the mainshock.

Beyond the traditional aftershock zone, the largest transient stress perturbation from a remote earthquake occurs during the passage of the surface waves. Surface waves are capable of instantly triggering low magnitude earthquakes \((M<5)\), as well as non-volcanic tremor, and sometimes increasing activity in the subsequent days to weeks after the seismic waves have passed (Hill et al., 1993; Pankow et al., 2004). Rarely observed is the immediate triggering of \(M>5.0\) earthquakes beyond the aftershock zone (Parsons and Velasco, 2011), which suggests that larger-magnitude events are not susceptible to transient stress changes (Parsons et al., 2012). Recent observations of large magnitude earthquakes \((M>8)\) promoting \(M>5.5\) aftershocks in the far-field has prompted seismologists to continue the investigation into dynamic stresses and the relationship to earthquake nucleation (Gomberg and Sherrod, 2014; Pollitz et al., 2012).

In this study we examine global seismicity of \(M\geq5.5\) events in the months following the passage of large-amplitude surface waves in regions beyond the aftershock zone. Our goal is to investigate the triggering potential of \(M\geq7.5\) and a possible threshold for triggering \(M>5.5\) events. This study develops a systematic method that examines all \(M>7.5\) events in 35 years using the Global Centroid Moment Tensor catalog (http://www.globalcmt.org/) establishing global earthquake rates following the largest events. The techniques of this study allow us to characterize enhanced or suppressed activity following a stress perturbation and to consider the activity related to different fault mechanisms of either mainshocks or trigger candidates.

Figure 2.20.1: The region of elevated strain is indicated in the figure for two separate mainshocks. The importance of scaling the magnitudes is shown by the extent of large-amplitude surface waves for two events that cover very different regions of the globe. Shaded regions indicate the area for event selection before and after each mainshock. The exclusion zone is a radial region spanning 2.5 fault lengths from the mainshock and is shown in white. The distal limit is scaled to the magnitude using the estimated seismic wave amplitude relative to the maximum strain threshold. The top figure indicates the region for a \(M7.6\), with an exclusion zone of 230 km and selecting events out to a radial distance of 3600 km. The bottom figure is showing a \(M7.9\), with an exclusion zone of 500 km and selecting all events to a radial distance of 5900 km.
Summary

This study incorporates only far-field seismic activity following $M \geq 7.5$ mainshocks using all $M \geq 5.5$ events in the catalog. Our method builds on the results by Parsons and Velasco (2011) that indicate no increase in $5 < M < 7$ events following $M \geq 7$ mainshocks beyond 1000 km. We study the triggering potential by separating $M \geq 7.5$ mainshocks by fault mechanism and develop a rate curve using a two-day moving average. The rate curve for each mainshock is then stacked and normalized by the total number of mainshocks. Our method is scaled spatially, using a region of elevated strain that is unique to each mainshock and determined using empirical wave amplitudes (Figure 2.20.1). This allows us to consider only far-field activity occurring in regions that are dynamically strained during the passage of seismic waves. We adopt a threshold of $\geq 0.1$ $\mu$strains that is previously shown to trigger activity in seismically active areas (Peng et al., 2010; Pollitz et al., 2012; van der Elst and Brodsky, 2010) to define the region of interest in this study.

The results shown in Figure 2.20.2 represent the stacked rate curves for four $M \geq 8.0$ strike-slip events. This curve excludes the 2012 $M_{w}6.8$ east-Indian Ocean event that produced a 10 day increase in global earthquake activity of $M \geq 5.5$ events (Pollitz et al., 2012). We remove the event, which is also the largest strike-slip event on record, in order to establish the triggering potential of other large-magnitude strike-slip earthquakes. A rate increase above the 95% confidence interval is observed following time zero but additional pulses of activity are present at other points in time. Using this approach, we are continuing to examine far-field earthquake activity for different mechanisms and magnitude thresholds. The initial findings indicate that dynamic triggering of $M \geq 5.5$ events is only observed following the very largest; i.e., $M \geq 8.5$, earthquakes on record.

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References


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