# A New Insight towards Earthquake Prediction

*Messele Zewdie Ejeta, Ph.D., P.E.*

## Abstract

A new analysis of over a century of the world's recorded major earthquakes ($M \geq 7.0$ where M is the Richter magnitude scale) and solar eclipse events was conducted using the number of days between the occurrences of the two sets of events as a determinant variable for earthquake predictability. The result shows a remarkable relationship between these sets of events, as evidenced by a Gaussian distribution of the determinant variable, which has a mean of 11.6 days. In hindsight, the recorded major earthquakes during the last over 100 years could have been predicted to occur, on average, within a few days of the occurrences of solar eclipse events. A closer analysis of reported earthquakes around the January 15, 2010, solar eclipse event shows that on average, these reported earthquakes occurred within 2.65 days of the alignment or proximate alignment of the earth, moon, and sun. Solar eclipse events and the phases of the movement of the moon around the earth are used as proxies for deciphering the alignment or proximate alignment of the earth, moon, and sun. Based on this premise and the resulting analysis, it is inferred that the near coincidental occurrences of major earthquake events when the earth, moon, and sun are aligned or closely aligned in the earth-moon-sun space, and possibly other celestial objects, points to the utility of the inverse-square law in Newton's universal law of gravitation for earthquake prediction. This discovery is poised to bring the predictability of earthquakes within a close reach and signals enormous implications for policy and decision makers. Towards this end, this insight highlights the need for the creation of a vector field in the sun-moon-earth space and a further characterization of historical earthquakes and their locations in relation to the concurrent positions of these celestial objects in this vector field, a subject of an ongoing investigation.

## Introduction

In January 2010, at least three notable natural phenomena have occurred: the tragic earthquake in Haiti on January 12, 2010, an annular solar eclipse on January 15, 2010, (NASA, 2010), and a severe thunderstorm patterns over the western United States with a strong upper level jet of very high velocities during the third week of the same month. After the prediction of the severe thunderstorm over the western United States, the National Weather Service issued a rare tornado warning for Northern California's Contra Costa County.

The minimization of the enormous societal and economic impacts due to naturally occurring hazardous disasters have long been challenges to policy and decision makers. Earthquake is one of the natural hazards that disrupt California's costly infrastructure systems (California Natural Resources Agency, 2009). Empirical earthquake predictions that attempt to narrow prediction time windows from several years down to months have the potential to lead to the reformulation of disaster preparedness (Davis, et al., 2010). The Seismological Grand Challenges Writing Group recently identified 10 basic challenges in seismology that need to be put at the forefront of research on earth systems (Lay, et al., 2009). Thus, the commitment for better predictions of natural disasters to minimize their impact on the society and built environment continues to attract the interests of policy and decision makers.

Many questions about the causes of earthquakes have remained not fully explained. An interpretation of the processes responsible for tremor generation is yet to be determined (Thomas, et al, 2009). Non-volcanic tremor that was discovered nearly a decade ago has led to the suggestion that seismic energy can be generated from a region of the earth that was previously thought incapable of generating it (Obara, 2002). Shelly, et al (2007) suggest that non-volcanic tremor is a weak, extended duration seismic signal observed episodically on some major faults, often in conjunction with slow slip events. They further suggest that tremor may hold the key to understanding fundamental processes at the deep roots of faults, and could signal times of accelerated slip and hence increased seismic hazard. The motions of plate tectonics give insight into both the locations and average recurrence interval of future large earthquakes on plate boundaries, yet they give no insights into where and when earthquakes will occur within plates (Stein and Liu, 2009). A further study by Shelly (2010) demonstrates a systematic recurrence of tremor, thus suggesting a potential for monitoring detailed time-varying deformation. The study hasn't yet provided a prognostic capability for earthquake prediction. One of the latest research reports by Grant and Halliday (2010) that is based on monitoring common toad population prior to and after the April 6, 2009, earthquake in Italy suggests that this population responded to an impending earthquake by fleeing their spawning habitat five days prior to the earthquake event. However, they conclude that it is unclear what environmental stimuli these animals responded to in advance of the event.

Panakkat and Adeli (2008) broadly group prediction efforts in the last nearly two decades into theoretical geophysics, heuristic genetic algorithms, and statistical and mathematical approaches that are based on historical earthquake catalogs in seismic regions. Despite the complexity of these undertakings, they recommend that the scientific community pursue earthquake prediction vigorously in view of the necessity for emergency management and hazard preparedness. Hiroshi and Masakuzi (2002) studied the effects of earth tides on earthquake occurrences using a numerical simulation approach. In their simulation, starting from different initial stresses, fault planes were stressed by constantly increasing tectonic and cyclic tide loads and observed that the simulated earthquake occurrence is strongly controlled by the change of the tide stress relative to stress accumulation. The study thus suggests possible triggering of earthquakes by earth tides but did not provide a procedure for earthquake prediction. According to Diacu (2009), the efforts of mathematical models at predicting natural disasters such as earthquake have been hardly dependable.

A recent study by this author on the traditional assumption of stationarity in hydrology suggests that a conceivable relationship exists between solar eclipse trajectories over two years and wet and dry spells in Northern California. Further analysis of over a century of earthquake and solar eclipse events shows a strong association between these two events. This further analysis reveals that from nearly 350 recorded major earthquakes that have happened since 1901, the average gap between solar eclipse events and major earthquakes is about 11.6 days; nearly half of them occurred within 45 days of recorded solar eclipses. Furthermore, the analysis of these occurrences by taking into consideration the new and full lunar cycles as proxies for the evolving and decaying solar eclipse events significantly reduces the gap. Specifically, this further analysis was done using the recorded earthquakes around the January 15, 2010, solar eclipse event and during the four lunar cycles that encompass it. The result of this further analysis shows that on average, these reported earthquakes occurred within 2.65 days of the alignment or close alignment of the earth, moon, and sun (Figure 1). In general, there is a strong observed relationship between reported earthquakes and shorter distances between the earth, moon, and sun as formulated by Newton's universal law of gravitation and evidenced by the association between historical solar eclipse occurrences and major earthquakes. It is evident that when these celestial objects are aligned, the resultant distance between these objects is smaller, which implies greater resultant gravitational forces on these objects, according to Equation 1:

$$F = G.m_1.m_2/r^2 \qquad (1)$$

where F is the magnitude of the gravitational force between two point masses, G is the gravitational constant, $m_1$ is the mass of the first point mass, $m_2$ is the mass of the second point mass, and r is the distance between the two point masses.

## Data Sources and Analysis

Historical solar eclipse data for 1901 to January 2010 were obtained from the National Aeronautics and Space Administration's (NASA) Eclipse website (NASA, 2010). Recorded worldwide historical earthquakes are available from the United States Geological Survey's (USGS) Historic World Earthquakes website (USGS, 2010). According to this USGS data set, there have been nearly 350 recorded and documented major earthquakes ($M \geq 7.0$) since 1901.

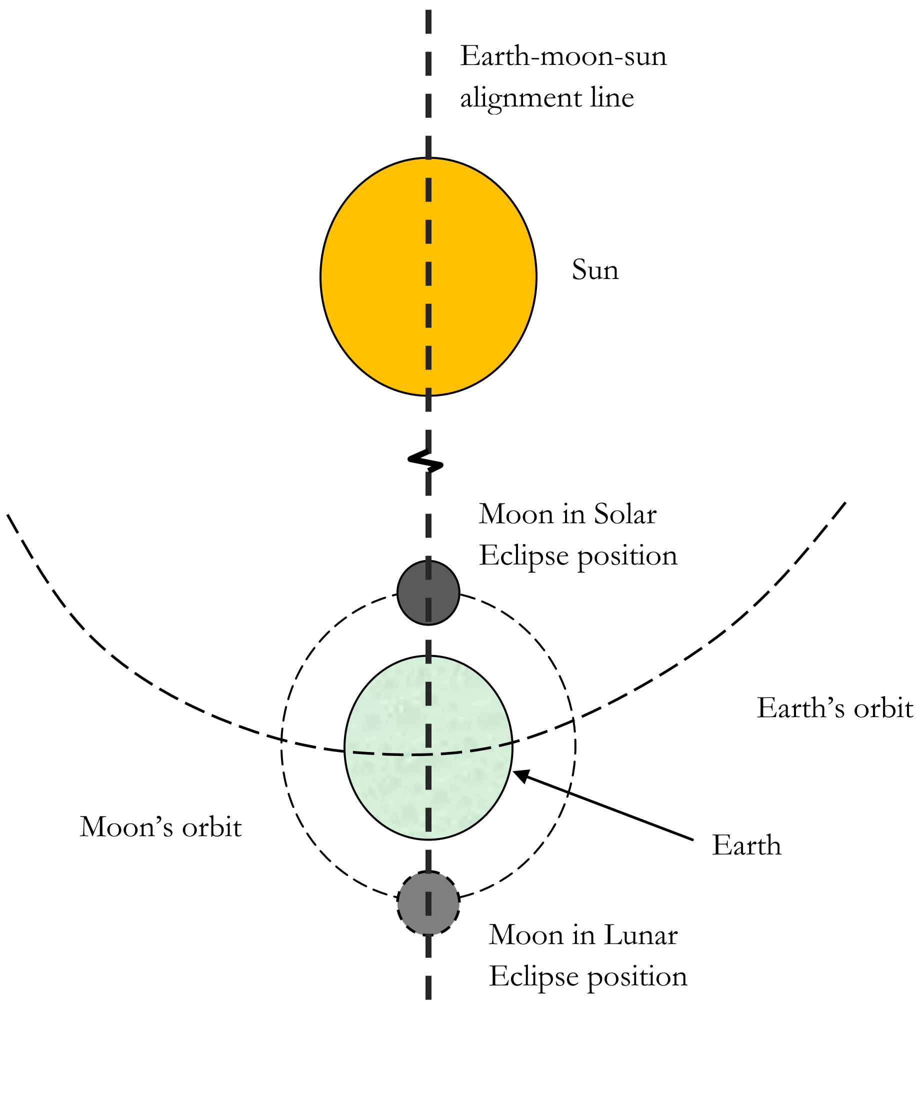


Figure 1. Schematic depiction of the earth-moon-sun alignment (not to scale)

Using these two data sets, this study analyzed the association of recorded solar eclipse events with major earthquakes during the 1901 to January 2010 period. The number of days between solar eclipse and major earthquake events was computed for each recorded earthquake during this period. A statistical characterization of this derived data has shown a remarkable relationship between the two sets of events. Figure 2 illustrates the number of days between solar eclipse events and between solar eclipse and major earthquake events.

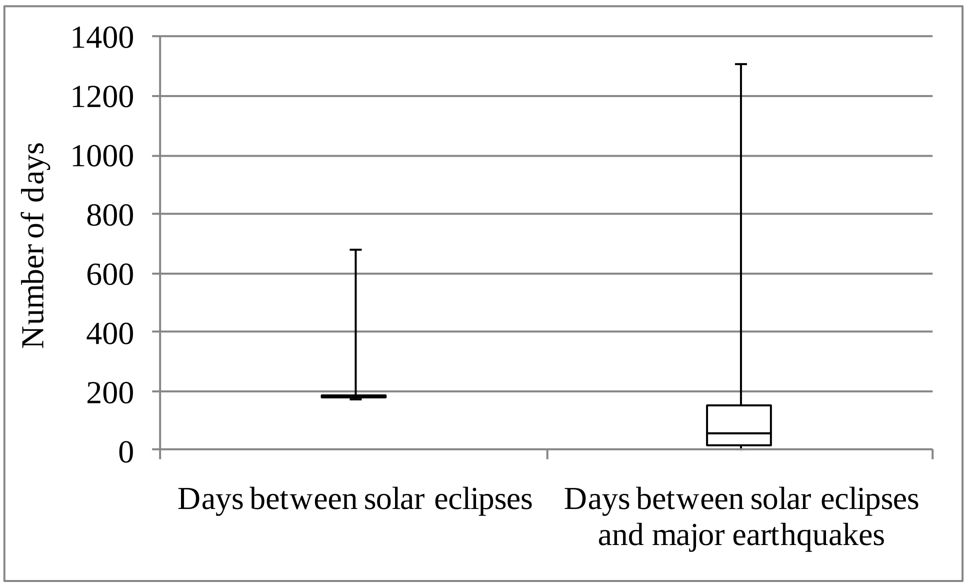


Figure 2. Box plots showing the frequencies of solar eclipse events and the gap between solar eclipse and major earthquake events for the 1901 to 2010 period

While the number of days between solar eclipse events is predictable (about 177 days in general), the average gap between the occurrence of solar eclipse and major earthquakes is very narrow as shown in the second box plot in Figure 2. This gap, which has a mean of 11.6 days and standard deviation of 104 days, is normally distributed as shown in Figure 3 and Figure 4. The outlying number of days between solar eclipse and major earthquake events in the second box plot in Figure 2 shows an absence of a recorded major earthquake between 1981 and 1985. The USGS has no data for a major earthquake during this period, which incidentally is the wettest spell over the western United States in over a century. It is arguable that large number of days between major earthquakes may not necessarily mean the absence of this class of earthquakes. This is because not all the terrestrial and oceanic parts of the earth are equipped to record earthquakes. In addition, the absence of a solar eclipse in a given period may not necessarily mean a lack of a close alignment of the moon and sun relative to the earth during that period. Thus, it is arguable that some of the bigger gaps may likely be minimized if such close alignments are taken into account.

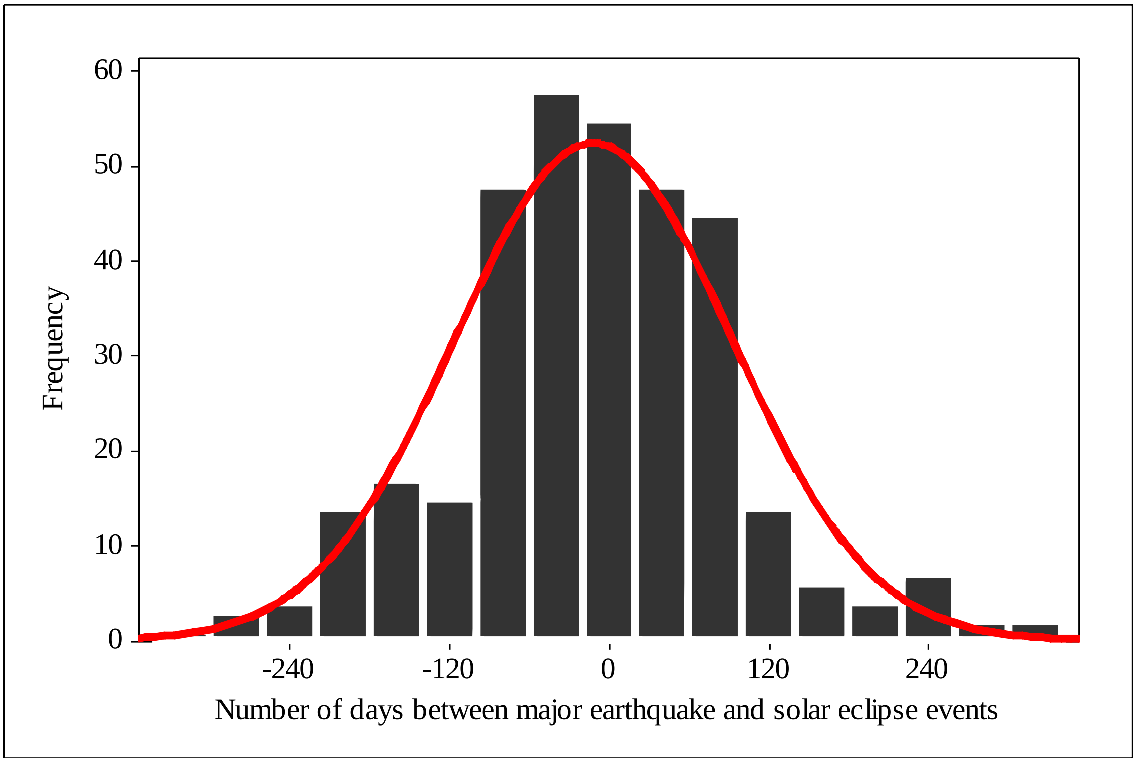


Fig. 3. Frequency distribution and normal distribution fit of the number of days between major earthquake and solar eclipse events for the 1901 to 2010 period

The Gaussian distribution in Figure 3 is, therefore, a preliminary characterization of the occurrence of major worldwide earthquakes relative to those of solar eclipse events during a period of over a century. Thus, this distribution points to a useful tool for earthquake predictability. As a selected sample illustration, the numbers of days between solar eclipse events and selected major earthquakes during the 2001 to 2010 period are presented in Table 1. According to this data set, on average, these selected earthquakes during the last decade occurred within about 2.6 days from the recorded solar eclipse events.

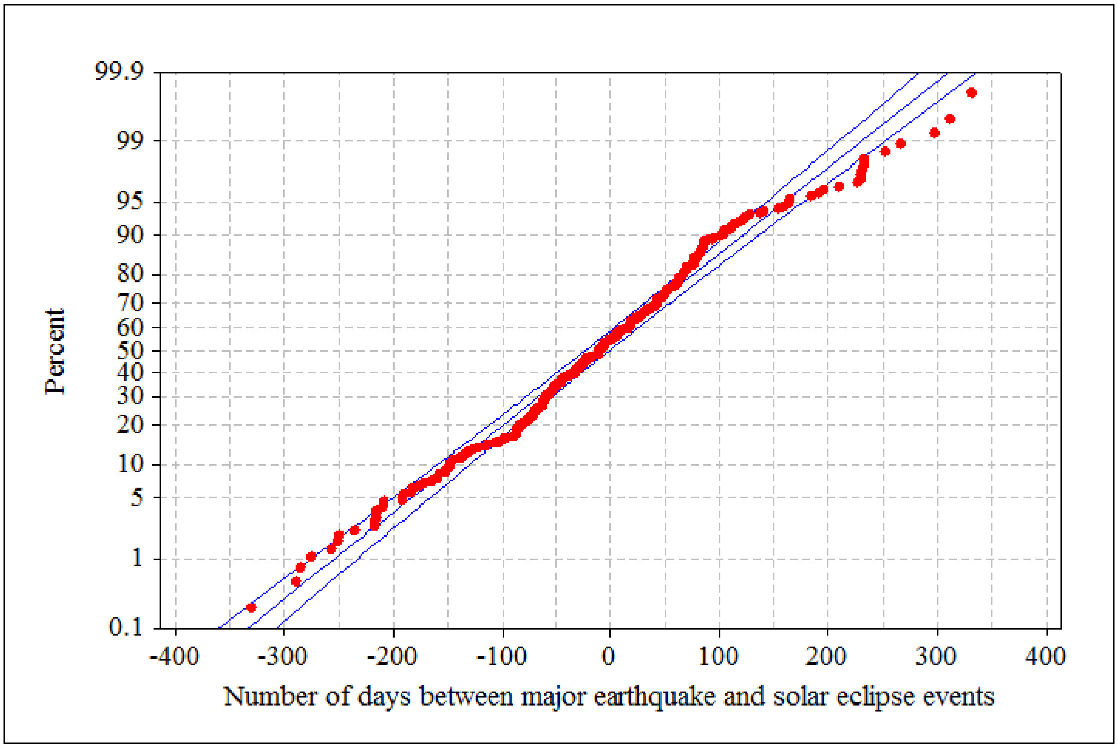


Fig. 4. Probability plot showing the number of days between major earthquakes and solar eclipse events for the 1901 to 2010 period

By focusing on all recorded earthquake events during about four lunar cycles around the January 15, 2010, solar eclipse (November 15, 2009, to March 15, 2010), it was found that, on average, these reported earthquakes occurred within 2.65 days of the alignment or proximate alignment of the earth, moon, and sun. For the purpose of this analysis, a proximate alignment of the earth, moon, and sun is assumed to have occurred about 15, 30, 44, and 59 days before and after the solar eclipse event. This assumption is based on the 29.5 days of full lunar cycle and the nearly 15 days between new moon and full moon phases. It should be noted that these three celestial objects get nearly aligned twice during a full lunar cycle. Table 2 shows the results of this focused analysis.

Table 1. Gaps (in day) between solar eclipse and selected major earthquake dates during the 2001 to 2010 period

| Solar eclipse date | Earthquake date, location, and magnitude | | | Gap (days) |
|---|---|---|---|---|
| | Date | Location | Magnitude | |
| 1/15/2010 | 01/12/2010 | Haiti | 7.0 | -3 |
| 7/22/2009 | 07/15/2009 | Near South Island, New Zeland | 7.8 | -7 |
| 1/26/2009 | 01/15/2009 | Kuril Islands, Russia | 7.4 | -11 |
| 8/01/2008 | 07/19/2008 | Honshu, Japan | 7.0 | -13 |
| 2/07/2008 | 02/20/2008 | Simeulue, Indonesia | 7.4 | 13 |
| 9/22/2006 | 08/20/2006 | Scotia Sea | 7.0 | -33 |
| 3/29/2006 | 04/20/2006 | Koryakia, Russia | 7.6 | 22 |
| 10/03/2005 | 10/08/2005 | Pakistan | 7.6 | 5 |
| 10/03/2005 | 09/26/2005 | Northern Peru | 7.5 | -7 |
| 4/08/2005 | 03/28/2005 | Northern Sumatra, Indonesia | 8.6 | -11 |
| 11/23/2003 | 11/17/2003 | Rat Islands, Aleutian Islands, Alaska | 7.8 | -6 |
| 5/31/2003 | 05/26/2003 | Halmahera, Indonesia | 7.0 | -5 |
| 6/10/2002 | 06/28/2002 | Northern China | 7.3 | 18 |
| 6/21/2001 | 06/23/2001 | Near the Coast of Peru | 8.4 | 2 |
| Average gap (days) | | | | -2.6 |

## Discussion

Various past studies on earthquake phenomenon have envisaged prognostic capabilities for its occurrences so that the damage this natural hazard causes may be minimized. This new study has attempted to show that the alignment of the moon and the sun relative to the earth has left yet another footprint in earthquake occurrences. In light of the finding of this novel association, it is also possible that the suggested predictive capability of male toad population behavior (Grant and Halliday, 2010) to impending earthquake may be linked to the gradual approach of the alignment or close alignment of the earth, moon, and sun that the amphibian population is sensitive enough to in one way or another. The new observation of the strong relationship between the alignment of these celestial objects, as recorded through solar eclipse events and major earthquake events of over a century has enormous implications for policy and decision makers. Projected solar eclipse dates through the end of the 21$^{st}$ century are available from NASA and can be used to predict future earthquakes around the globe. In essence, this novel uncovering of the association between the two events will go a long way in setting in motion a more detailed characterization and accurate prediction of earthquakes. The analysis

Table 2. Number of days from the January 15, 2010, solar eclipse and proximate earth, moon, and sun alignment dates

| Date of earthquake | Location and magnitude of earthquake (in brackets) | Number of days from the 1/15/2010 solar eclipse date | Number of days of proximate alignment date to the 1/15/2010 solar eclipse date | Gap (days) |
|---|---|---|---|---|
| 3/15/2010 | Biobío, Chile (6.7) | 59 | 59.00 | 0.00 |
| 3/14/2010 | Indonesia (6.5) | 58 | 59.00 | 1.00 |
| 3/14/2010 | Honshu, Japan (6.3) | 58 | 59.00 | 1.00 |
| 3/8/2010 | Eastern Turkey (6.1) | 52 | 59.00 | 7.00 |
| 2/27/2010 | Offshore Maule, Chile (8.8) | 43 | 44.25 | 1.25 |
| 1/12/2010 | Haiti region (7.0) | -3 | 0.00 | 3.00 |
| 1/10/2010 | Offshore Northern California (6.5) | -5 | 0.00 | 5.00 |
| 1/3/2010 | Solomon Islands (7.1) | -12 | -14.75 | 2.75 |
| 12/30/2009 | Baja California, Mexico (5.9) | -16 | -14.75 | 1.25 |
| 12/19/2009 | Taiwan (6.4) | -27 | -29.50 | 2.50 |
| 11/24/2009 | Tonga (6.8) | -52 | -59.00 | 7.00 |
| 11/17/2009 | Queen Charlotte Islands region (6.6) | -59 | -59.00 | 0.00 |
| Average gap (days) | | | | 2.65 |

presented herein appears poised to bring us to the verge of bringing within reach the predictability of disasters from this natural phenomenon and hence minimizing its damage. The transfer of gravitational force between these three celestial objects to the earth's plate tectonics may well be through tidal dynamics, which is already known to be affected by the phases of the moon and the alignment of the earth, moon, and sun. Towards that end, this new insight points to the need for the creation of a vector field in the earth-moon-sun space and a further characterization of earthquakes and their locations on earth relative to the positions of these celestial objects in this vector field, a subject of an ongoing investigation.

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