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Earthquakes can be Predicted

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Abstract

The aim of this research is to discover a reliable and scientific precursor that is theoretically able to predict all earthquakes, within specified parameters, within a few days, in this case within two days, of the earthquakes - this is more efficient than having a prediction window of months or years.

This method has accurately predicted 14 out of 15 earthquakes within specified parameters of location, magnitude and depth, with no false predictions-this is a success rate of 93%. Deviations in the times for a simple pendulum to complete 30 oscillations were analysed and these deviations were used to make earthquake predictions. This is related to plate motion and changes in 'g'.

The parameters of earthquakes predicted include those that occurred in north-eastern Colombia, of magnitude M 4.0 and higher, and depth 100 km or more. Also included in the predictions are earthquakes of similar magnitude, originating at depths of 25 km and more in Antigua and Barbuda, Montserrat and Guadeloupe. Another parameter is that for an earthquake to be accurately predicted it must not occur within 24 hours of the previous one. These earthquakes were predicted within two days of their occurrences.

In addition to predicting earthquakes, the data supports the rebound theory, since deviations in times for 30 oscillations return to zero within a day or two after an earthquake-this allows for calculations of rebound velocities. The data also shows that there is a net transfer of lithospheric matter away from the observation point at St. Augustine, Trinidad. This method can be applied anywhere on earth-it is simple to set up, inexpensive, scientific and reliable.

Keywords: Earthquake prediction; Gravity; Simple pendulum; Tectonic plates; Plate motion; Density; Mass

Introduction

In Seismology, the terms earthquake prediction and earthquake forecasting initially were used interchangeably. However, in more recent times, when analyzing earthquakes, these two terms are defined differently. Earthquake prediction is now generally accepted to be more rigorous than earthquake forecasting, i.e. an earthquake prediction is more specific that an earthquake forecast. There are various definitions for earthquake prediction but Nishenko used the definition: 'Earthquake prediction refers to the specification of the expected magnitude, geographic location and time of occurrence of a future event with a high probability and sufficient precision that the ultimate success or failure of a prediction can be evaluated'. This definition does not include a method of validation of the prediction.

A definition of earthquake forecasting is the probabilistic assessment of general earthquake hazard, including the frequency and magnitude of damaging earthquakes in a given area over years or decades [1]. After many decades of searching for reliable methods of earthquake prediction, none has so far been found. In fact, there have been so many unsuccessful attempts that some are of the opinion that it is inherently impossible [2-4] to predict earthquakes.

Among the few so-called successful predictions that have been rejected by the scientific community is one that occurred in Haicheng, China. A medium-term prediction was issued in June 1974 and an M7.3 occurred in February 1975. It was deemed that this so-called prediction was not reliable since it relied heavily on foreshocks, which are not a reliable indicator of impending earthquakes. An official publication in 1988 claimed that there were 1328 deaths and 16,980 were injured [5]. In any case, the predicted earthquake occurred eight months after the prediction.

Another so-called successful prediction was done by Bakun and Lindh [6]. They observed that there was a pattern of earthquakes along the Parkfield section of the San Andreas Fault about every 22 years and predicted one to occur in 1988, or up to 1993 for the latest. The USGS then created a network to monitor signs of an expected earthquake. The expected date of 1988, and also 1993, went and nothing happened. Eventually, there was an M6 event in 2004, but without any noticeable precursors. This 1988-expected seismic event was based on a regular pattern of approximate M6 earthquakes that had occurred in this location from 1857 to 1966 [6]. The pattern was so regular over this extended time that a dense network was set-up, ready to record any precursors. According to the Economist "never has an ambush been more carefully laid for such an event" [2].

Earthquakes have been difficult to predict as they occur because of sudden release of stress in rocks that make up Earth's lithosphere. The lithosphere's behavior due to changing stresses are non-linear, and this further complicates doing predictions. In addition, the high and unknown variability of the lithosphere's composition, features, strength and temperatures further complicate predictions. Also, many earthquakes occur far beneath Earth's crust, oftentimes more than 100 km and sometimes as deep as 700 km. Earthquakes sometimes occur in clusters but the clusters are very irregular. Sometimes large earthquakes follow smaller ones but here again there is no uniformity and hence no predictability.

There have been attempts to identify precursors but so far all such attempts have been unreliable and generally recognized only after the

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seismic event. The IASPEI (International Association of Seismology and Physics of the Earth's Interior) has defined a precursor as "a quantitatively measurable change in an environmental parameter that occurs before the main shocks and that is thought to be linked to the preparation process for the main shocks". Among precursors that have been applied to predicting earthquakes are emissions of radon gas, changes in magnetic field, unusual animal behavior, changes in resistance of rocks, changes in groundwater levels, emission of radio waves, temperature changes in rocks, preshocks and changes in the ratio of primary to secondary seismic wave velocities. None of these precursors are reliable-they have been observed before earthquakes at some times and not at others and there is no basis to scientifically apply them to predicting earthquakes.

Earthquake-predicting is very relevant in today's world where being able to make accurate predictions eliminates the guess factor and makes people feel safer in the same way that predicting hurricanes allows people more time to make necessary preparations. Relocating people from the vicinity of an impending earthquake can save lives and property.

Theory

Some researchers are of the opinion that earthquake-prediction is impossible while others think that with improved knowledge and technology we may, sometime in the future, be able to make predictions. For example: recent research suggests to us that this belief to predict earthquakes is incorrect, according to Geller et al. [2]. Another article states that the leading seismologists of each era, except for a brief period in the 1970's, have generally concluded that earthquake-prediction is not feasible [7]. Also, it was mentioned that there are strong reasons to doubt observable and identifiable precursors exist [8]. Varotsos claim to be able to predict earthquakes in Greece, based on geo-electrical signals, but this has been shown to be invalid [9] - some of the signals were found to be of industrial origin and there was no compelling evidence that linked the geo-electrical signals to earthquakes. However based on scientific data, probabilities can be calculated for potential future earthquakes. For example, scientists estimate that over the next 30 years the probability of a major earthquake occurring in the San Francisco Bay area is 67% and 60% in Southern California.

The small-angle approximation for a simple pendulum is given by:

$$\approx 2\pi\left(\frac{L}{g}\right)^{1/2},$$

where T is the period and L the length of the simple pendulum. It shows that 'T' is inversely proportional to the square-root of 'g'. An angle of 3° was used throughout the data-collecting phase. Since the pendulums were timed for 30 oscillations: $t=30T=60\pi (L/g)^{1/2}$, and an increase in t corresponds to a decrease in g, for a particular length L. Values of t=30T were analyzed, not values of 'g', since the stop watch used was calibrated to hundredths of a second-dividing by 30 and multiplying by π to find 'g' would introduce approximation errors. In addition, dividing by 30 to get 'T' would imply that the fluctuations in 'T' would be smaller than those in't'. Additionally, mass plays no role in the equation, $t=30T=60\pi (L/g)^{1/2}$, since gravitational mass and inertial mass are equal as stated in the 'equivalence principle' and they cancel each other in equations used to derive $T=2\pi (L/g)^{1/2}$ for small angles [10].

Method

The method involved measuring the times for 30 oscillations of 3 simple pendulums of different lengths. The theory that was used to make these predictions is based on the relationship between T and g of a simple pendulum. A constant time indicates no imminent earthquakes while increasing or decreasing times indicate an earthquake within two days. The data predicted earthquakes in the north-eastern region of Colombia, Antigua and Barbuda, Montserrat and Guadeloupe.

The northern coast of Trinidad lies in the Caribbean plate while the remainder lies in the South American plate. The South American and Nazca plates are convergent and so their motions result in increased densities and hence increased masses, which result in increased values of g and decreased times for 30 oscillations. One the other hand, Antigua and Barbuda, Montserrat and Guadeloupe are moving away from the observation point in St. Augustine, Trinidad and this result in decreased densities and masses and hence smaller values of 'g' and consequently larger values of times for 30 oscillations. Trinidad and Tobago is located near the south-east corner of the Caribbean Plate, slightly off the north-easterly tip of South American. Collected data are in agreement with plate motion and accurately make earthquake predictions. Readings taken with longer pendulums and at multiple locations and at more regular intervals can thus predict earthquakes (times, locations and magnitudes) with higher accuracy.

The lengths of the pendulums were as follows: pendulum 1 was 2.1960 m long, pendulum 2 was 2.0120 m long and pendulum 3 was 1.4960 m long. Every time in Tables 1 and 2 is an average found from three values – 30 oscillations were timed three times in all cases. Each pendulum has an average base time for 30 oscillations: deviations from this average base time indicate impending earthquakes. Earthquakes that are deeper and greater in magnitude are easier to detect since more lithospheric matter is involved and a bigger effect is generated on the value of 'g'.

Results and Analysis

Table 1 shows the average times for 30 oscillations for the 3 pendulums from 13 January, 2016 to 15 March, 2016. Also shown are details of earthquakes during this period. The same thing was done for Table 2, for the period 12 April, 2016 to 18 May, 2016. Time increases and decreases from base times can be observed by looking at the columns for average times in Tables 1 and 2 – these deviations occurred within two days before the corresponding earthquakes. In column 5 of Table 1, NC stands for Northern Colombia, Gu stands for Guadeloupe and Ma is used for Martinique.

Predictions can be made from the data in Tables 1 and 2. A prediction is made whenever two or all three of the pendulums simultaneously show increasing or decreasing times. All times are the local times in Trinidad and Tobago. Sometimes, earthquakes were predicted even when they were outside of the stated parameters. One such instance was an earthquake that was predicted on 20 January, 2016 and occurred on 21 January, 2016. Its depth was only 31 km, as seen in Table 1- the parameters in the second paragraph of the 'Abstract' section stated a depth of 100 km or more for north-eastern Colombia.

Blank cells in Tables 1 and 2 are due to no timing being done on those days - these are shown as breaks in Figures 1 and 2. Figures 1 and 2 shows the same data from Tables 1 and 2 respectively, but in a more visual form. Figure 1 shows times and earthquake particulars from Table 1 for the period 01/13/2016 to 03/15/2016, for pendulum 1 alone, since patterns in times for 30 oscillations are similar for all three pendulums. The connection among moving plates, changes in t=30T and earthquake prediction in this research worked well in predicting earthquakes.

DATE	Time (s)	Time (s)	Time(s)	Earthquake Date	DATE CON'TD	Time (s)	Time (s)	Time (s)	Earthquake Date
MM/DD (2016)	Pend 1	Pend 2	Pend 3	Magnitude Depth (km) Location	MM/DD (2016)	Pend 1	Pend 2	Pend 3	Magnitude Depth (km) Location
01/13	89.00	85.19	73.64		02/15	89.02	85.25	73.60	
01/14	88.97	85.16	73.61	M4.6,10, NC	02/16	89.00	85.24	73.64	
01/15	88.97	85.16	73.62		02/17	89.01	85.22	73.63	M4.4,15,NC
01/16	89.00	85.19	73.61		02/18	89.00	85.25	73.64	
01/17	89.00	85.22	73.67		02/19	89.03	85.25	73.64	
01/18	89.00	85.25	73.67		02/20	89.03	85.26	73.62	
01/19	89.00	85.25	73.68		02/21	89.00	85.25	73.65	
01/20	88.91	85.20	73.59		02/22	89.00	85.25	73.67	
01/21	88.87	85.12	73.55	M4.9,31, NC	02/23	89.05	85.25	73.66	
01/22	88.94	85.17	73.56		02/24	89.03	85.25	73.66	
01/23	88.91	85.18	73.56		02/25	89.04	85.26	73.66	
01/24	None	None	None	M4.4,148,NC	02/26	89.03	85.25	73.66	
01/25	88.95	85.07	73.63		02/27	88.97	85.22	73.62	
01/26	89.00	85.16	73.62		02/28	88.95	85.22	73.62	M4.6,157,NC
01/27	89.00	85.19	73.63		02/29	89.03	85.26	73.66	
01/28	89.00	85.25	73.61		03/01	89.04	85.25	73.65	
01/29	89.00	85.16	73.60		03/02	89.05	85.28	73.68	
01/30	89.01	85.20	73.60		03/03	89.06	85.26	73.67	
01/31	89.01	85.26	73.67	M4.8,116,Gu	03/04	89.05	85.25	73.66	
02/01	89.02	85.26	73.65		03/05	89.05	85.26	73.68	
02/02	89.00	85.25	73.60	M4.9,48,Ma	03/06	89.05	85.27	73.68	
02/03	88.99	85.25	73.60		03/07	89.05	85.25	73.66	
02/04	89.00	85.24	73.64		03/08	89.05	85.25	73.67	
02/05	89.00	85.25	73.63		03/09	89.03	85.22	73.60	M5.0,144,NC
02/06	89.00	85.24	73.63	M4.3,147,NC	03/10	89.06	85.29	73.69	
02/07	89.00	85.25	73.65		03/11	89.05	85.26	73.66	
02/08	88.94	85.16	73.60		03/12	89.03	85.26	73.68	
02/09	88.92	85.12	73.60		03/13	89.04	85.25	73.66	
02/10	88.94	85.19	73.58	M4.3,154,NC	03/14	89.04	85.26	73.65	
02/11	89.03	85.20	73.66	M4.8,165,NC	03/15	89.06	85.25	73.65	
02/12	89.03	85.25	73.55		-------	-------	------	------	
02/13	89.03	85.25	73.60		-------	-------	-------	------	
02/14	89.03	85.25	73.60		----------	-------	-------	------	

NC=North eastern Colombia; Gu=Guadeloupe; Ma=Martinique

Table 1: Table of pendulum average times for 30 oscillations and earthquake details.

Date	time (s)	time (s)	time (s)	Earthquake Date
MM/DD/YYYY	pendulum 1	pendulum 2	pendulum 3	Magnitude, Depth, Location
04/12/2016	89.25	85.4	73.7	
04/13/2016	89.25	85.4	73.7	
04/14/2016	89.25	85.4	73.7	
04/15/2016	89.25	85.4	73.71	
04/16/2016	89.25	85.4	73.7	
04/17/2016	89.25	85.4	73.7	
04/18/2016	89.25	85.4	73.7	
04/19/2016	89.21	85.35	73.66	Mw3.4, 144 km, North Colombia
04/20/2016	89.25	85.4	73.7	Mw4.3, 140 km, North Colombia
04/21/2016	89.25	85.41	73.71	
04/22/2016	89.25	85.4	73.71	
04/23/2016	89.25	85.4	73.71	
04/24/2016	89.25	85.41	73.71	
04/25/2016	89.22	85.4	73.68	M4.6, 122 km, North Colombia
04/26/2016	89.25	85.4	73.7	
04/27/2016	89.25	85.42	73.7	
04/28/2016	89.25	85.41	73.7	
04/29/2016	89.23	85.4	73.7	
04/30/2016	89.21	85.37	73.66	M4.5, 162 km, North Colombia

05/01/2016	89.25	85.4	73.7	
05/02/2016	89.25	85.4	73.7	
05/03/2016	89.25	85.41	73.71	
05/04/2016	89.25	85.4	73.7	
05/05/2016	89.25	85.4	73.7	
05/06/2016	89.25	85.41	73.72	
05/07/2016	89.31	85.44	73.75	
05/08/2016	89.25	85.41	73.7	M4.9, 34 km, Antigua and Barbuda
05/09/2016	89.29	85.44	73.78	M4.9, 25 km, Guadeloupe
05/10/2016	89.3	85.46	73.78	
05/11/2016	89.26	85.42	73.72	
05/12/2016	89.25	85.41	73.72	
05/13/2016	89.25	85.42	73.71	
05/14/2016				
05/15/2016	89.25	85.41	73.71	
05/16/2016	89.22	85.38	73.69	
05/17/2016	89.2	85.37	73.69	M3.6, 181 km, North Colombia
05/18/2016	89.25	85.4	73.72	

Table 2: Table of pendulum average times for 30 oscillations and earthquake details.

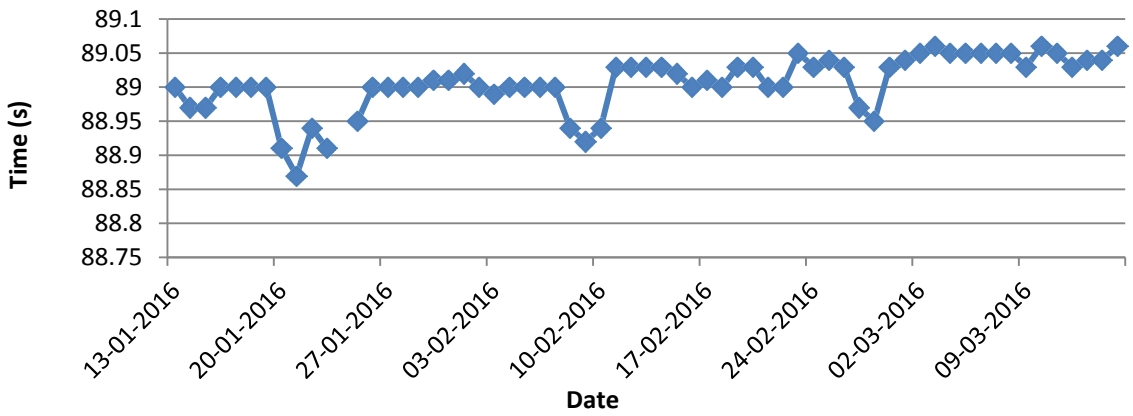

Figure 1: Peaks represent earthquakes that were predicted two days before they occurred in Antigua and Barbuda, Guadeloupe and Martinique.

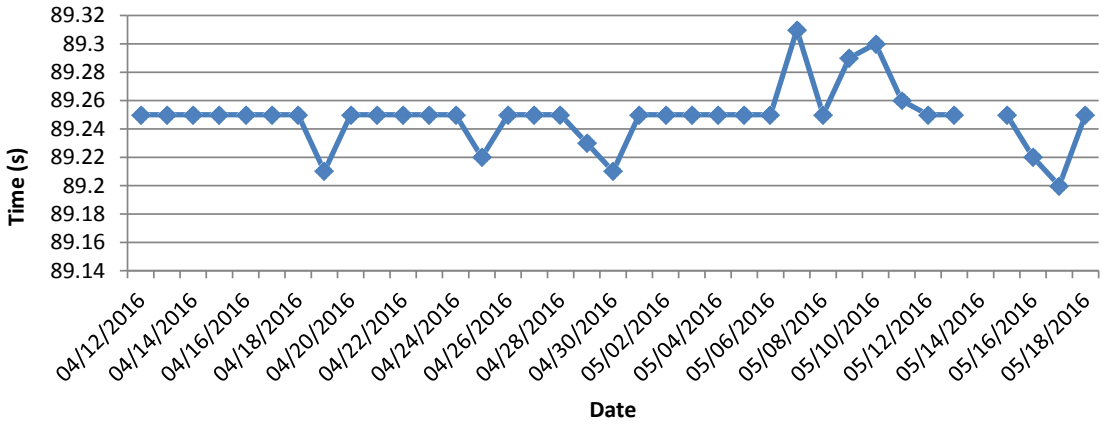

Figure 2: The two crests represent increasing values of t=30T – they predicted the earthquakes that occurred in Antigua and Barbuda and Guadeloupe.

For Figure 1, peaks represent earthquakes that were predicted two days before they occurred in Antigua and Barbuda, Guadeloupe and Martinique while troughs represent earthquakes in Northern Colombia that were also predicted two days before they occurred. As an example,

consider Table 1, where times started decreasing on 02/08/2016 and an M4.3 earthquake occurred two days later on 02/10/2016 – this is shown in Figure 1 by decreasing times forming a trough. Another example is the decrease in t=30T from 02/27/2016, shown by the trough in Figure 1 which predicted the M4.6 earthquake of 02/28/2016.

Figure 2 shows the data from Table 2, from 04/12/2016 to 05/18/2016. The four troughs show decreasing values of t=30T – they predicted earthquakes in Northern Colombia. The two crests represent increasing values of t=30T – they predicted the earthquakes that occurred in Antigua and Barbuda and Guadeloupe.

Referring to Figure 2, as an example, Table 2 shows values of t=30T decreasing from 04/29/2016 – this predicted the M4.5 North Colombia earthquake of 04/30/2016. Continuing with Figure 2, it is seen that there are four troughs and two crests predicting a total of six earthquakes. However, Table 2 contains seven predicted earthquakes. This is because the earthquakes on 04/19/2016 and 04/20/2016 occurred about twelve hours apart and the resolution of the method does not allow for separate predictions of two earthquakes that happen less than a day apart - this is one of the stated parameters, in the 'abstract' section. Hence the first one was predicted and not the second.

Conclusion

The data in Tables 1 and 2 have clearly shown that earthquakes can be predicted one or two days in advance. Increasing a pendulum's length will result in detection of smaller and shallower earthquakes that are further away. Hence, by installing pendulums throughout Earth's surface, it should be possible to detect non-micro earthquakes everywhere. Epicentres of predicted earthquakes can be located by triangulation methods or by knowing the directions in which the tectonic plates are moving i.e. whether they are divergent or convergent.

In this research, earthquakes were accurately predicted from one to two days in advance for Antigua and Barbuda, Guadeloupe, Martinique and north-eastern Colombia, when they occurred within the specified parameters of magnitude and depth.

This method of earthquake prediction bypasses the intricate details of the mechanisms involved in earthquake formation. Researchers have been looking for a reliable and scientific precursor and this paper clearly shows that deviations in t=30T is such a precursor. In addition, a justification is given for the connection between deviations in t=30T and occurrence of earthquakes – changes in densities, mass and 'g' due to plate motions.

Fourteen out of fifteen earthquakes, within specified parameters, were accurately predicted one or two days before earthquakes occurred. There were no false predictions. The success rate was 93% for predicting earthquakes in North-eastern Colombia, Montserrat, Guadeloupe and Antigua and Barbuda. Thus, changes in the time for a simple pendulum to perform 30 oscillations are a reliable and scientific precursor. Predictions are made when t=30T increases or decreases – there is no need for a mathematical formula since predictions should be theoretically 100% accurate. The theory says that changes in t=30T should increase as the magnitude of an earthquake increases but all earthquakes in Tables 1 and 2 are less than M5, so it was not possible to get data for M5 and larger earthquakes.

Some stand-out features of this method of earthquake prediction are that the theoretical probability of a predicted earthquake occurring is 100%; earthquakes are predicted one or two days in advance; the method is uncomplicated and inexpensive; it can be applied anywhere and the theory that supports time deviations for oscillations of a simple pendulum and plate tectonics is well established.

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