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Variation of global seismic activity with time

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1. Introduction

The original motivation for this study was that several news articles were noticed during 2023 that relate to two issues that are purported to affect global seismic activity.

The first issue is the idea, which started about fifteen years ago, that global warming has an effect on global seismic activity. Examples of news articles in 2023 which promoted this idea were [1], written soon after the Turkey-Syria earthquakes of 2023, and [2], an article that was published on the World Economic Forum website.

The second issue is the idea, which started around the mid-19th Century, that sunspot activity has an effect on global seismic activity. A modern variation of this idea was put forward in 2023 [3], which is that cosmic radiation (which is highly correlated with sunspot activity) influences global seismic activity.

The purpose of this study is to investigate these two ideas. The expectation is that global seismic activity is most likely to be random. An attempt to model the variation in global seismic activity could be made if the variation does not appear to be random.

2. Global earthquake event data

Global earthquake event data for earthquakes with magnitudes above 6 and 7 (M6+ and M7+) was downloaded in 2023 as a speadsheet file from the USGS website [4]. Event data is downloaded between specified lower and upper bound magnitude limits, so an upper bound of magnitude 10 was selected, which is higher than any earthquake that has ever occurred.

For downloading data from the USGS website, a starting year for the event data needs to be selected, and this requires some knowledge of when the earthquake event data source is likely to be complete. Information on the starting years when global earthquake event data can be regarded as complete is provided in [5], which suggests that M7+ data can be regarded as being complete from 1894, M6.5+ data from 1930, M6+ data from 1953 and M5.5+ data from 1966. The starting years used for the study were taken as 1900 for M7+ events and 1953 for M6+ events, and the end year was taken as 2022.

A program called EQcount was written which reads in the spreadsheet data and counts the number of earthquake events on an annual or a monthly basis.

The USGS spreadsheet data includes a relatively small number of non-earthquake events, virtually all of these corresponding to nuclear weapon explosion tests. There were seventy M6+ events that were recorded over the period 1973 to 2017 of this type, and zero M7+ events of this type. The EQcount program is able to identify these non-earthquake events in the input data and does not include them in the earthquake event count.

3. Investigation into the idea that global warming affects global seismic activity

3.1 Global seismic activity over complete record

Results from the EQcount program for global M7+ earthquake events over the period 1900 to 2022 and for global M6+ earthquake events over the period 1953 to 2022 are shown below in Figures 1 and 2.

Figure 1 indicates that only one or two global M7+ events per year occurred in the first four years of the 20th Century, and that such a small number of events per year has not been seen again. This raises a suspicion that the M7+ event data is not complete for the first few years of the 20th Century.

Linear fits (best fit straight lines) to the number of events versus year data are included in Figures 1 and 2. These show an upward trend, which would be consistent with the notion that global warming is causing an increase in global M6+ and M7+ earthquake activity.

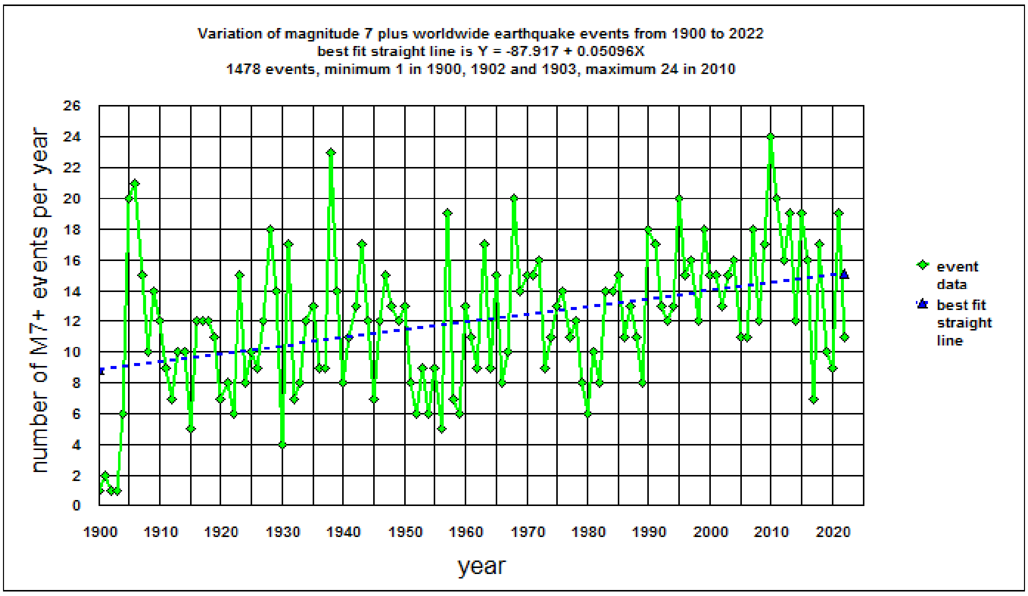

Figure 1 Variation of global M7+ earthquakes over period 1900 to 2022

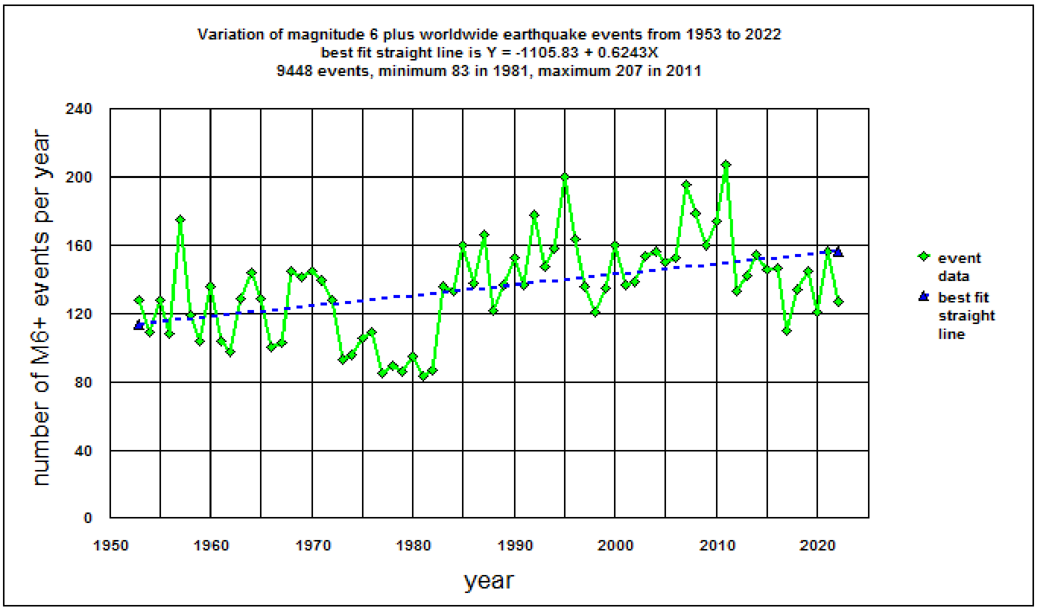

Figure 2 Variation of global M6+ earthquakes over period 1953 to 2022

3.2 Global seismic activity over more recent decades

However if global warming does cause an increase in global seismic activity, it would be reasonable to expect this to continue to be observed in more recent decades. The United Nations set up a body called the Intergovernmental Panel on Climate Change (IPCC) in 1988 in response to international concern over increasing global average temperature and increasing greenhouse gas concentrations in the atmosphere. Since 1988 there has been an upward trend in average global temperature.

When the M7+ and M6+ earthquake event data are plotted over the period 1988 to 2022, as shown in Figures 3 and 4, the trend is virtually flat, with a very slight upward trend for M7+ events and a very slight downward trend for M6+ events.

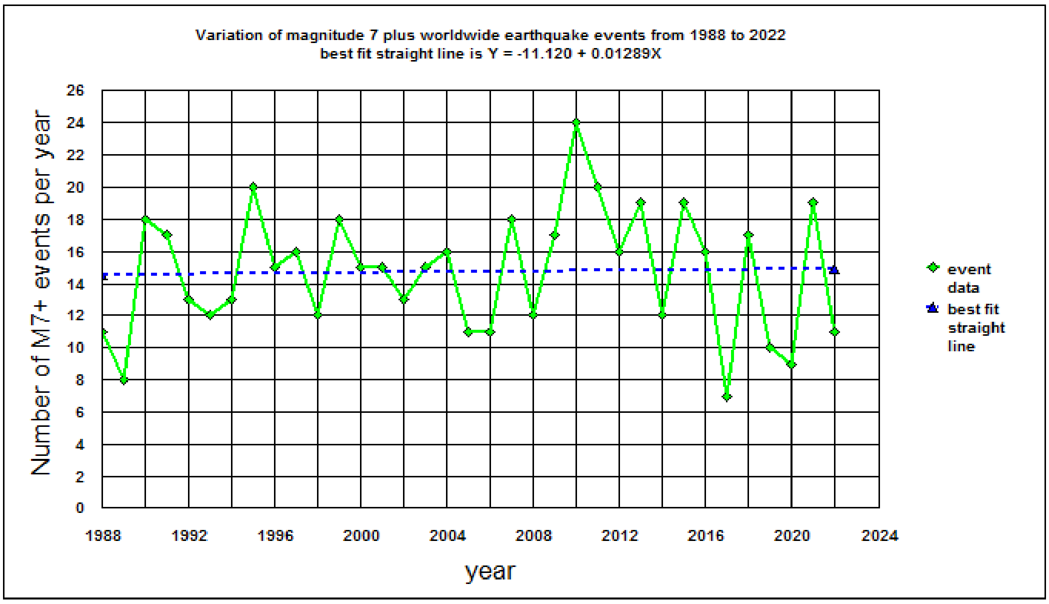

Figure 3 Variation of global M7+ earthquakes over more recent period 1988 to 2022

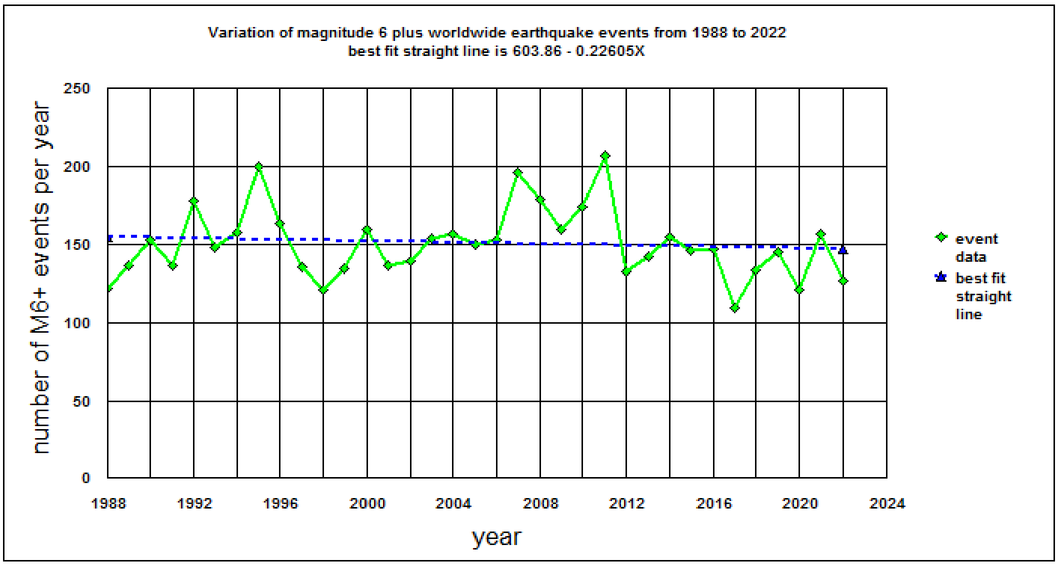

Figure 4 Variation of global M6+ earthquakes over more recent period 1988 to 2022

3.3 Global seismic activity in the 20th Century according to other investigators

The only other study that could be found in the literature for the variation of global earthquake event numbers with time, and which also provides a linear fit to the data, was an exercise carried out in 1999 by the Institute for Creation Research [6]. Figure 5 below taken from [6] shows the global M7+ earthquake event activity over the period 1900 to 1997. Figure 5 includes a broken line which corresponds to a linear fit to the data, which has a gradient estimated as being about -0.052. The figure also includes an oscillating curve which corresponds to a polynomial fit to the data.

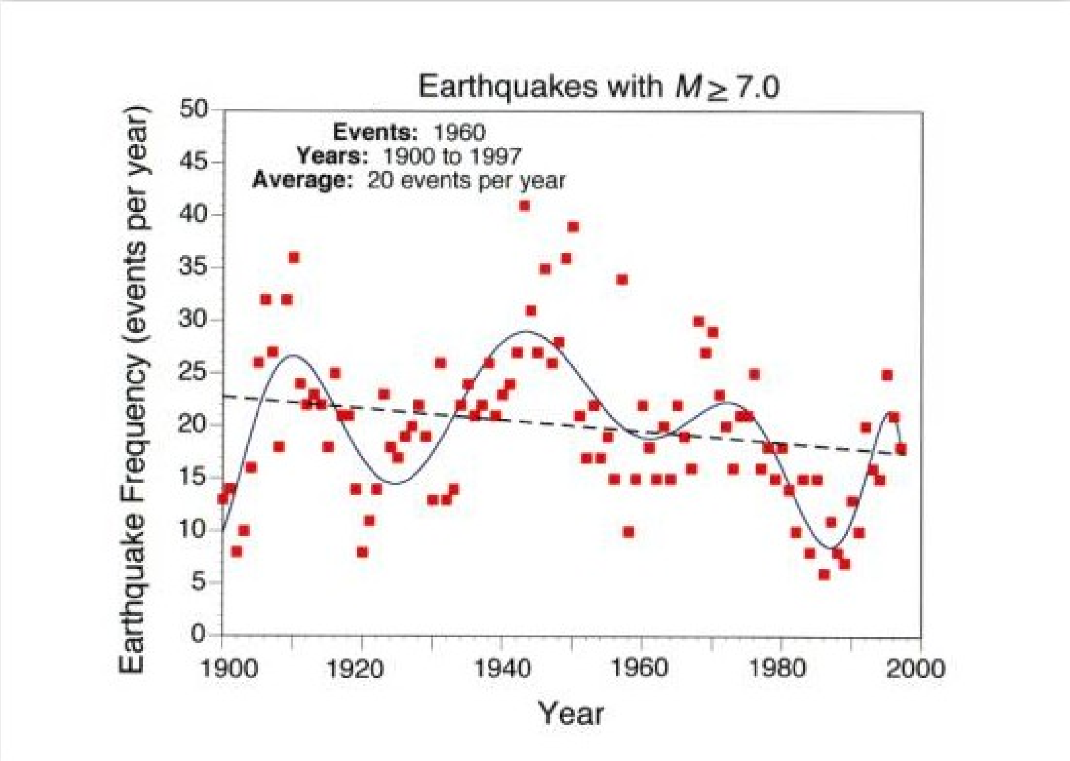

Figure 5 Variation of global M7+ earthquakes over period 1900 to 1997 according to Institute for Creation Research study

Comparison of Figure 5 with Figure 1 suggests that there has been a significant re-evaluation of the number of global M7+ earthquake events compared with data sources that were in use in the 20th Century. Figure 5 indicates a downward trend of M7+ activity in the 20th Century, whereas Figure 1 indicates the opposite, an upward trend for the 20th Century.

Using contemporary USGS data, the number of global M7+ earthquake events over the period 1900 to 1997 was 1106, with an average of 11.286 events per year. By contrast [6] gives 1960 M7+ events over the period 1900 to 1997 with an average of exactly 20 events per year. The maximum number of events occurring in Figure 5 can be estimated as 41 events occurring in the year 1943, whereas contemporary USGS data gives a maximum of 23 events occurring in the year 1938 over the period 1900 to 1997.

4. Investigation into the idea that sunspots (or cosmic rays) affect global seismic activity

4.1 Correlation between earthquakes and sunspots according to previous investigators

The correlation between global M7+ earthquakes (E) and annual mean sunspot number (N) over the period 1905 to 1964 was reported in a letter to the Physics Today magazine in 1976 [7]. Figure 6 below has been taken from [7]. The red line on the plot corresponds to a linear fit to the data with the equation E = 18.81 + 0.0188 N, and the E versus N data has a correlation coefficient of 0.129.

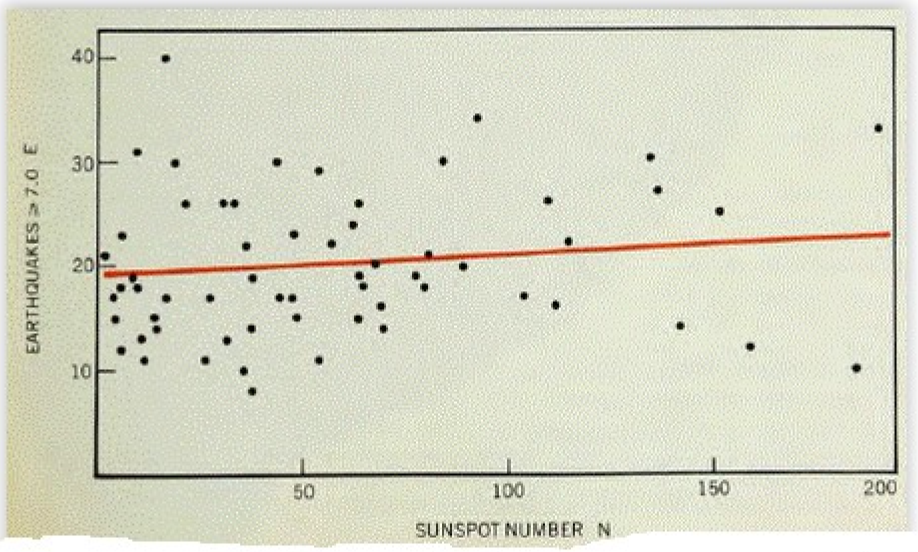

Figure 6 Scatterplot of M7+ eathquakes versus sunspots included in letter to Physics Today magazine in 1976

The global M7+ earthquake event data used in [7] seems to be consistent with the global M7+ event data that was used in the study reported in [6]. Figure 6 indicates that a maximum of 40 M7+ events occurred in one year during the period 1905 to 1964, which ties up well with the maximum of 41 events in 1943 in Figure 5. The letter [7] also quotes that there were 31 M7+ events in 1944 and 25 events in 1947, and this ties up well with Figure 5, from which 31 events can be estimated to have occurred in 1944, and 26 events can be estimated to have occurred in 1947. By contrast, contemporary USGS data gives only 12 M7+ events occurring in 1944 and 15 events in 1947.

4.2 Correlation between earthquakes and sunspots using contemporary USGS earthquake event data

An up-to-date version of Figure 6 using contemporary USGS global M7+ earthquake event data has been produced as Figure 7 below. The sunspot data used in the figure is contemporary sunspot data that was obtained from [8]. Figure 7 has about twice as many data points as Figure 6.

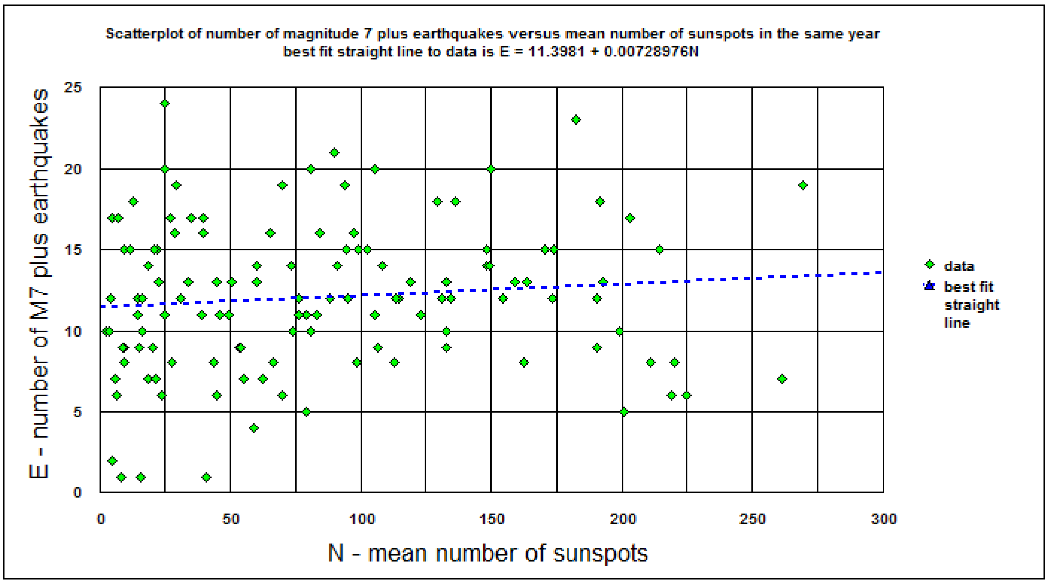

Figure 7 Scatterplot of global M7+ earthquakes versus sunspots over period 1900 to 2022

A plot for global M6+ earthquake events versus sunspots can also be determined, and has been produced as Figure 8 below.

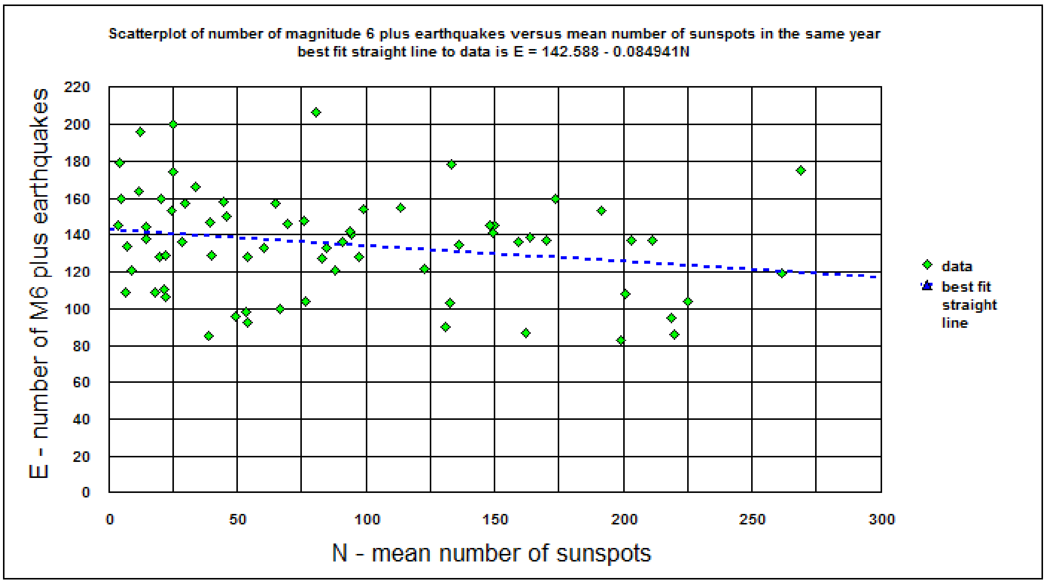

Figure 8 Scatterplot of global M6+ earthquakes versus sunspots over period 1953 to 2022

The correlation coefficients for the linear fits to the E versus N data were +0.106 for the M7+ event data and -0.218 for the M6+ event data. Correlation coefficients between -0.3 and +0.3 are generally regarded as representing no correlation or at best a weak correlation. The weak correlation that was reported in [7] is still apparent when contemporary data is used.

5. Spectral analysis of global M6+ earthquake event time series

5.1 Periodic behaviour that appears to be present in global M6+ event time series

The global M6+ event time series shown in Figure 2 does not appear to be as random as had been anticipated, and it was thought it might be useful to perform a spectral analysis of the time series. A minimum of 83 events in 1981 and a maximum of 207 events in 2011 suggests that a cycle with a half period of about 30 years, or a period of about 60 years, could be present in the data. If monthly data for counting earthquake events is used rather than annual data, the minimum number of monthly M6+ events was zero in October 1978 (the only month where zero events occurred) and the maximum number of monthly M6+ events was 73 in March 2011 (the same month that the Great East Japan earthquake of 2011 occurred), suggesting that a cycle with a half period of about 32.5 years, or a period of about 65 years, could be present in the data.

5.2 Spectral analysis methods used in study

The two spectral analysis methods that were adopted for the study are the maximum entropy spectral analysis (MESA) method and the conventional fourier analysis method.

The advantages of MESA analysis over fourier analysis are explained in [9]. MESA analysis is regarded as superior to fourier analysis for 'short' time series where cycles with periods that are similar to the length of the data record are suspected to be present, as it makes no assumptions about the data outside the data record. So MESA analysis is expected to be more accurate for identifying lower frequency or longer period cycles. Another advantage of MESA analysis is that it does not produce 'side lobes' surrounding spectral peaks whereas fourier analysis produces a sinc function as the fourier transform of a finite duration sine wave.

Coding for MESA analysis is provided in [9], but this would be difficult to use as the printing quality in downloaded PDF copies of the report is not good. Coding for MESA analysis is also provided in [10], which has been found to produce similar results to the program used in [9].

A significant disadvantage of the version of MESA analysis used in [9] and [10] is that it tends to produce very sharp spectral peaks, and the amplitude of these peaks can change substantially if the power spectrum is calculated at a set of slightly different frequencies. In the examples that are considered in [9], effectively every spectral peak, whatever its amplitude, is being assumed to be significant. The preference would be to produce a spectrum where the most significant spectral peaks can be more easily identified, which seems to be the case when a fourier spectrum is produced.

Another version of MESA analysis was found in a program called CYSTRATI that is described in [11]. Coding for the CYSTRATI program is also provided in [11]. This version of MESA analysis was found to be less prone to producing very sharp spectral peaks, and this enables the more significant spectral peaks (the spectral peaks which have the highest amplitudes) to be more easily identified.

A program called POWERSPEC was written which is based on the coding for subroutines associated with MESA analysis taken from CYSTRATI. For fourier analysis, a program called FFT which is based on coding taken from [10] has been used.

5.3 Spectral analysis results

Spectral analysis results obtained using POWERSPEC (MESA analysis) and FFT (fourier analysis) for the global M6+ event time series over the period 1953 to 2022 are shown in Figures 9 and 10 below. A modified version of the time series with its mean value adjusted to be zero was used to improve the accuracy of the spectral analysis at low frequencies. For the MESA analysis, the number of poles (called the M value in [9]) used in the analysis was 48, and the power spectrum was calculated at 1000 frequency points. For the fourier analysis, a similar number of frequency points was used, 1025, which required padding the time series with zeroes to 2048 time points.

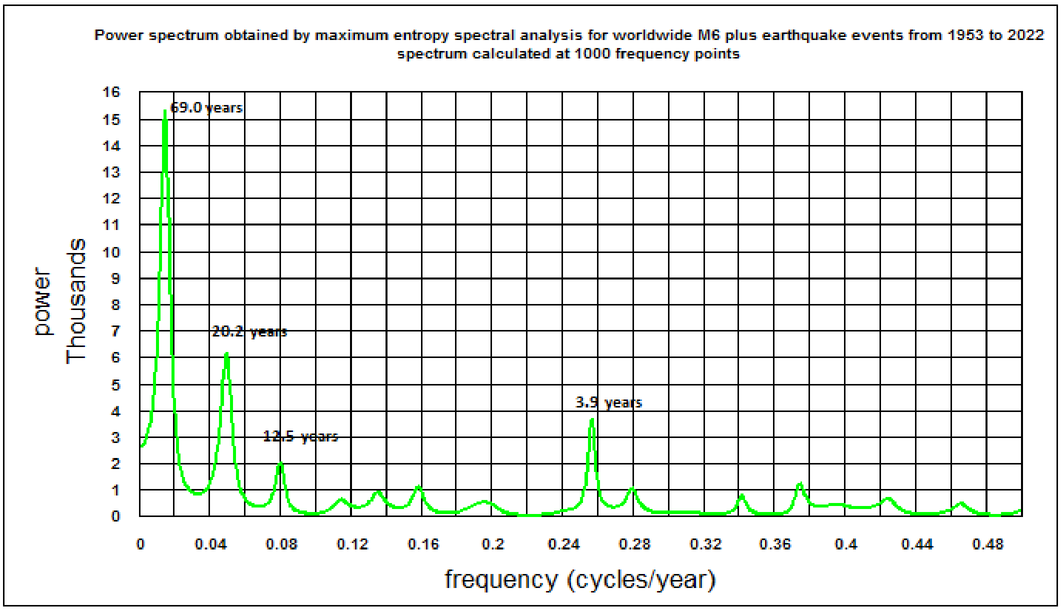

Figure 9 POWERSPEC spectral analysis plot for global M6+ earthquakes over period 1953 to 2022

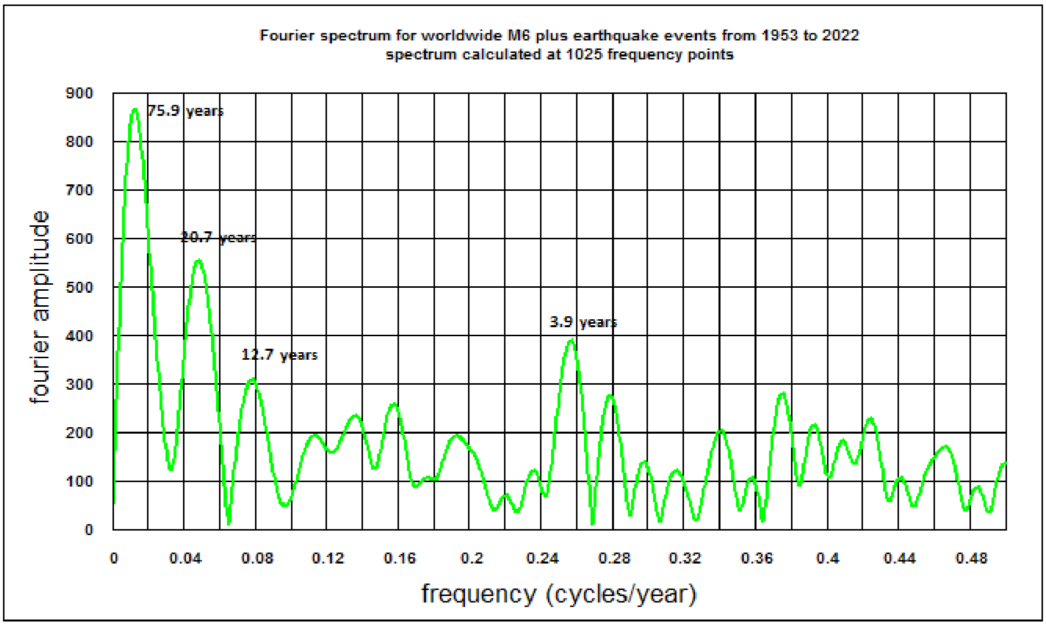

Figure 10 FFT spectral analysis plot for global M6+ earthquakes over period 1953 to 2022

Period values for the more significant spectral peaks are marked on the plots in Figures 9 and 10. Both POWERSPEC and FFT give four significant amplitude spectral peaks as being present in the time series, with period values of 69.0, 20.2, 12.5 and 3.9 years obtained by MESA analysis, and 75.9, 20.7, 12.7 and 3.9 years obtained by fourier analysis.

6. Multi-sinusoid curvefit model for representing global M6+ seismic activity

It was assumed that global M6+ seismic activity could be represented by a multi-sinusoid model of the form:

$$MS(t) = V + A_1 \cos\{2\pi(t/T_1)+\phi_1\} + A_2 \cos\{2\pi(t/T_2)+\phi_2\} + \ldots A_n \cos\{2\pi(t/T_n)+\phi_n\}$$

where A_j, T_j and ϕ_j are the amplitude, period value and phase angle of the j'th sinusoid term where j has values 1,2....n, V is a constant and n is the number of sinusoid terms or cycles.

The time t is relative time which is taken as zero for the first time value in the supplied time series data.

A program called MULTISINEFIT was written which is based around the MINPACK subroutine LMDIF [12]. MULTISINEFIT calculates the best fit for the multi-sinusoid model parameters A_j, ,ϕ_j and V for a supplied time series and a supplied set of period values T_j. The period values T_j and the number of cycles n would need to be determined in advance from a spectral analysis of the time series. The program can carry out an extrapolation of the model for future times.

For the global M6+ earthquake event time series from 1953 to 2022, taking the number of significant cycles as 4, and the set of period values for these significant cycles as $T_1 = 69.0$, $T_2 = 20.2$, $T_3 = 12.5$ and $T_4 = 3.9$, MULTISINEFIT gives the following curvefit parameters:

$V = 136.05863$

$A_1 = -24.549482$, $A_2 = -16.162028$, $A_3 = 9.7705197$, $A_4 = 11.191996$

$\phi_1 = 29.720439$, $\phi_2 = 10.797903$, $\phi_3 = -2.7570384$, $\phi_4 = 7.1478285$

A comparison of the curvefit with event data obtained using these parameters is shown in Figure 11 below. The curvefit predicts that the next time for the occurrence of low global M6+ seismic activity, similar to the low activity that was observed around the year 1980, will be around the year 2040.

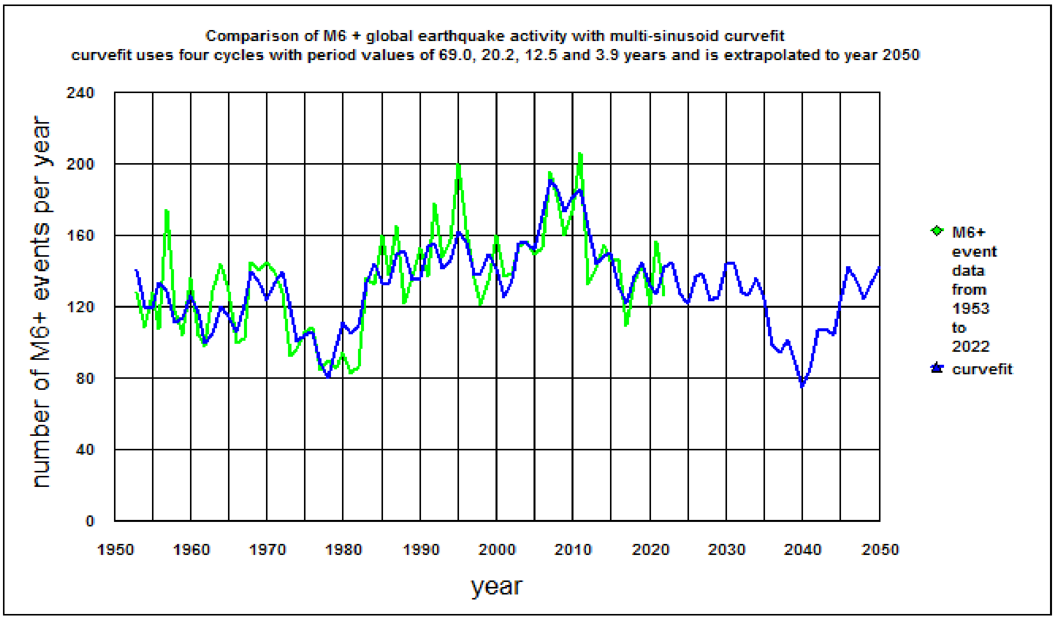

Figure 11 MULTISINEFIT curvefit and extrapolation for global M6+ earthquake activity

7. Conclusions

1 The idea that global warming affects global seismic activity, an issue which may have contributed to 'climate anxiety' amongst environmentalists, is not supported by this study. The trend line for global M6+ and M7+ seismic activity has been virtually flat since 1988, the year in which global warming became an issue of international concern and the Intergovernmental Panel on Climate Change (IPCC) was formed.

2 The idea that sunspots affect global seismic activity is not supported by this study. The correlation between annual mean sunspot numbers and the numbers of global M6+ and M7+ earthquake events would have to be regarded as being weak.

3 There seems to have been a significant re-evaluation of the numbers of global M7+ earthquake events occurring in each year according to contemporary data downloaded from the USGS website when compared with earthquake event data sources that were in use in the 20th Century.

4 Global seismic activity appears not to be as random as had been anticipated at the outset of the study. A spectral analysis of the global M6+ earthquake event time series data was carried out using maximum entropy spectral analysis and fourier analysis, and this identified four significant cycles that may be present in the data.

5 A multi-sinusoid model using four cycles produced a reasonably good curvefit to the global M6+ earthquake event time series data, and this model predicts that the next occurrence of low global M6+ seismic activity will be around the year 2040.

8. References

[1] Özdemir, İbrahim "Euroviews. Climate change is triggering more earthquakes. Big Oil's interests are a factor" https://www.euronews.com/2023/02/09/climate-change-is-triggering-more-earthquakes-big-oils-interests-are-a-factor , 9th Feb 2023

[2] Blackett, Matthew "Climate change could be triggering more earthquakes and volcanic eruptions. Here's how" https://www.weforum.org/agenda/2023/08/climate-change-trigger-earthquakes-volcanoes/ , 14th Aug 2023

[3] The Henryk Niewodniczanski Institute of Nuclear Physics Polish Academy of Sciences "The intriguing correlation between earthquakes and cosmic radiation" https://phys.org/news/2023-06-intriguing-earthquakes-cosmic.html , 15th June 2023

[4] USGS Earthquake Hazards program - Search Earthquake Catalog https://earthquake.usgs.gov/earthquakes/search/

[5] Tsapanos T M, Papazachos B C "Geographical and vertical variation of the earth's seismicity", Journal of Seismology, Vol 2, pp 183-192, 1998

[6] Austin S A, Strauss M L "Earthquakes and the End Times: A Geological and Biblical Perspective" http://static.icr.org/i/pdf/technical/Earthquakes-and-the-End-Times.pdf , Jan 1999

[7] Meeus, Jean "Sunspots and Earthquakes" Physics Today 29 (6), p 11, 1976 https://pubs.aip.org/physicstoday/article-abstract/29/6/11/430523/Sunspots-and-earthquakes?

[8] Solar Influences Data Analysis Center (SIDC), Sunspot Index and Long-term Solar Observations (SILSO) Yearly mean total sunspot number https://www.sidc.be/SILSO/infosnytot

[9] Kirk B L, Rust B W, Van Winkle W "Time series analysis by the maximum entropy method" Oak Ridge National Laboratory report ORNL-5332, Jan 1979

[10] Press W H, Teukolsky S A, Vetterling W T, Flannery B P "Numerical Recipes in Fortran 77   The art of scientific computing" 2nd edition, 1992

[11] Pardo-Igúzquiza, E., Chica-Olmo, M., Rodríguez-Tovar, F J   "CYSTRATI: a computer program for spectral analysis of stratigraphic successions" Computers & Geosciences Vol 20, No 4, pp 511-584, 1994

[12] Garbow B S, Hillstrom K E, More J J   "Documentation for MINPACK subroutine LMDIF Double precision version" Argonne National Laboratory, Mar 1980