Close correlation between solar and seismic activities

A.M. Eigenson
Ivan Franko Lviv National University (Ukraine)
Bar Ilan University (Israel)

e-mail: aleksey.eigenson@gmail.com

Abstract
Large earthquakes in the last 260 years are compared with the epochs of minima of 11-year cycles of Solar activity. We use the data from 352 earthquakes of magnitude 7 and larger. Close correlation between earthquakes and the minima of solar cycles is shown, with the correlation coefficient of 0.9998. Maximal number of earthquakes shows 11-year periodicity. The number of earthquakes increases with time and reaches its currently largest number in the last Solar cycles, corresponding to the decrease of Solar activity in cycle 23. Furthermore, we analyse the data of large volcanic eruptions in the last 400 years. Similarly to earthquakes, the volcanic eruptions show the correlation with the minima of Solar activity, with the correlation coefficient of 0.9994. The volcanic eruptions also tend to increase with time, corresponding to the decrease of Solar activity. The found correlation between solar and seismic activities opens the possibility of prognosis because the Solar activity may be predicted for many years forward.

Key words: seismology, earthquakes, volcanic activity, solar activity, prognosis.

Recently, D.Grishchenko (2015) published the data of large earthquakes in the “Fire Circle” and pointed out that intervals between them are 22 years on average. This number is thought-provoking, and my further investigation revealed a very close correlation between the earthquakes and years of the minima of 11-year cycles of solar activity.

We first recall that geophysical responses are not exactly connected with absolute extrema of Solar activity but rather with the epochs of these extrema (Eigenson, 1963). These epochs may continue during some years. We also recall that the 22-year Solar cycle is not simply the sum of two 11-years cycles, but has an important feature. Namely, in a given 11-year cycle the sunspots have one polarity, but in the next cycle this polarity changes the opposite. Moreover, according to O.A.Golubchina (2014), the increase of radiation from the polar regions of the Sun is seen at the minima of activity in the millimeter range. So we can speak about the influence of the activity of Solar electromagnetic field on earthquakes. Indeed, the lithosphere plates in the viscous magma in the upper mantle have the own magnetic field, and the electromagnetic radiation of the Sun in the minimum of its activity may play the role of a “trigger” provoking the earthquakes.

The comparison of Solar and Earth events is shown in Table 1 in the Appendix where we included the earthquakes of magnitude no less than 7. The comparison is also illustrated in Fig. 1. The first column is the number of Solar activity cycle, the second shows the year of absolute minimum, followed by the month of minimum in that year, the year of the earthquake, the month of the earthquake, the location of earthquake and finally the magnitude. We use the most complete catalogue of earthquakes in the last 260 years (http://earthquake.usgs.gov) as well as available published data (https://en.wikipedia.org/wiki/Lists_of_earthquakes). Our compilation includes 24 Solar cycles and 352 different earthquakes in total.

Figure 1 and inspection of Table 1 in the Appendix show that earthquakes closely follow the epochs of Solar activity minima (the calculated coefficient of correlation between the years of minima and earthquakes is 0.9998).

We note that plotting the random data in Figure 1 is expected to give a certain correlation. For this reason, we have performed a simulation where we have compared two time series, the years of Solar minima and random numbers distributed by the Poisson law (the distribution of earthquakes in the last 5 cycles in Table 1 and Fig. 3 is close to the Poisson distribution). We have considered ten different realizations of random number series and have calculated the correlation coefficients for each realization. The calculated coefficients are in the range 0.11-0.54. These are considerably smaller than the coefficient calculated for the actual data in Figure 1, implying that the correlation between the Solar and Earth events is highly significant. This is the main

conclusion of this article.

The correlation between the earthquakes and the minima of solar activity can also be illustrated by another method. This method involves plotting a graph constructed by superposing different epochs. We plot the number of earthquakes as a function of the number of years from the minima of solar activity (zero corresponds to the minima of Solar activity). This graph is shown in Figure 2 and illustrates that most earthquakes occur at the minima of solar activity.

We note that the number of earthquakes increases with time. This increase is consistent with the known picture of varying Solar activity over the last century.

It's interesting to compare the number of earthquakes with the values of Wolf numbers W. The comparison is shown in Table 2 for the last 5 cycles. We observe a sharp increase of the number of earthquakes in the last two cycles where W decreases. It would be interesting to re-visit this point in future studies using a larger set of data.

We now turn our attention to volcanic eruptions. No definitive estimations of past eruptions are available, hence we use the available data of volcanic activity extending to 1610 and available published data (see, e.g., earth-chronicles.ru/news/2013-12-16-56152; https://en.wikipedia.org/wiki/Types_of_volcanic_eruptions; ria.ru/spravka/20130826/958101173.html). The data of early Solar activity is taken from (Eigenson et al, 1948).

The results are given in the second table in the Appendix where the first two columns are year and month of Solar activity minima, the next two columns are year and month of eruptions, followed by the name and location of eruptions. In Figure 3, we compare the years of Solar and Earth events and, similarly to earthquakes, observe a strong correlation between the two, with the coefficient of correlation of 0.9994. The intervals between eruptions approximately correspond to multiples of 11 years. Similarly to our earlier analysis of earthquakes, we have performed a simulation of random number sequences and found that the correlation coefficients are significantly smaller than 0.9994, pointing to the significance of the correlation between the Solar and Earth events.

Our result opens a possibility for prognosis of seismic activity because Solar activity can be predicted for many years in the future. For example, if this trend continues, the next largest number of major earthquakes will occur around 2018 and 2029. The value of Wolf number forecasted elsewhere is predicted to be 4 in 2018.

We note recent strong earthquakes in Nepal and Chile (2015) and that the next Solar minimum will be in 2018. We can suppose that these earthquakes occur in the epoch of this minimum.

We also note that using our correlation and the existing data on past earthquakes extending into ancient times one could gain insights into the cycles of Solar activity in the past.

We recall that the ideas about influence of Solar activity on earthquakes was proposed many years ago by M. S. Eigenson (1948,1963). These ideas have been discussed since (see, e.g., S.Maus et.al. (2001), Thebault et.al. (2010) and Campbell (2009) for discussion and review). Related discussions can also be found in S-I.Akasofu and S.Chapman (1972) and H.Berg (1957) as well as in the investigations of G.Katterfeld and G.F.Landersgausen (1962) and B.L.Lichkov (1965).

We note that from the mathematical point of view, the sequences of events on Sun and Earth can be represented by the time series and can therefore be treated by the corresponding methods (see e.g. Anderson, 1973; Brillindger, 1975; Terebizh, 1992; Vityazev, 2001) including a new approach using pattern recognition theory as discussed recently by the author (Eigenson, 2015).

In summary, we have found close correlation between the epochs of Solar activity and seismic activity including earthquakes and volcanic eruptions. Both earthquakes and volcanic eruptions show 11-year periodicity similar to that of Solar activity. The found correlation between solar and seismic activities open the possibility of prognosis because the Solar activity may be predicted for many years forward.

Acknowledgments

I am grateful to K.A.Trachenko, Kh.Meliksetyan, N.N.Samus, A.V.Kendzera, E.A.Ostrovsky, I.V.Stasyuk, R.E.Gladyshevskii, M.Varukh, N.N.Pavlun, V.V.Furman, Yu.V.Lyakhov, A.S. Voloshinovsky, R.E.Rykaluk, Ya.S.Yatskiv, I.V.Popadyuk, L.M.Khazan, G.S.Pavlov, Ya.A. Nagovitsyn,V.Yu.Terebizh, V. A. Gagen-Torn, D. Karasik, I.A.Yeremenko, T. L. Gulyaeva, I. S. Veselovsky and to the participants of the conference “Solar and Solar-Terrestrial Physics” (St.-Petersburg, Pulkovo, October, 2015) for discussions. I am also grateful to the participants of scientific seminars of the Departments of Astrophysics (V.A. Gagen-Torn)

and Earth Physics (V.S. Semenov) of St.- Petersburg University for critical remarks.

References

Akasofu, S I & Chapman S., 1972. Solar-terrestrial physics.
Anderson, T. 1973. Statistical analyses of time series, John-Wiley&Sons.
Berg, H. 1957. Solar-Terrestrische Beziehungen in Meteorologie und Biologie, Geest Portig K.-G.,Leipzig.
Brillindger, D. 1975. Time series. Data and theory, Holt, Rienehart and Winston.
Cane, R. P., 2002. Solar Physics, 205.
Eigenson. A. M., Visnyk of Lviv University, in press.
Eigenson, M. S., 1963. Solntse, pogoda i klimat (in Russian). English translation: Sun, weather and climate, . Holt, Rienehart and Winston.
Eigenson, M. S., Gnevyshev, Ol, A. I. & Rubashov B. M., 1948. Solnechnaya aktivnost i ee zemnye proyavlenia (in Russian). English translation: Solar activity and it's terrestrial manifestations, OGIZ, Moscov, Leningrad.
Golubchina, O. A., 2014. Solar and solar- terrestrial physics. (in Russian) St.-Petersburg.
Grishchenko, D., 2015. Vselennaya, prostranstvo, vremya (in Russian), 2, 28. English translation: Universe, space, time. (Kiev, February issue).
Gulyaeva, T. L., 2014. Development in Earth Science, 2, 14.
Katterfeld, G.& Landersgausen G. F., 1962. Soveshchanie po problemam astrogeologii. (in Russian). English translation: Conference on astrogeology, p. 7.
Landersgausen, G. F. Periodichnost geologicheskikh sobutii (in Russian), English translation:Periodicity of geological events. Op.cit.,p.145
Lichkov, B. L., 1965 K osnovam sovremennoy teorii Zemli (in Russian). English translation: On the base of modern theory of Earth.
Maus S., 2002. Geophys.Res, 29
Terebizh, V. Yu., 1992. Analiz vremennykh ryadov v astrofizike (in Russian). English translation: Analysis of time series in astrophysics.
Thebault, E. et.al. Space Sci Rev. 22 July, 2010.
Vityazev, V. V., 2001. Analiz neravnomernyh vremennyh ryadov (in Russian). English translation: Analysis of irregular time series.

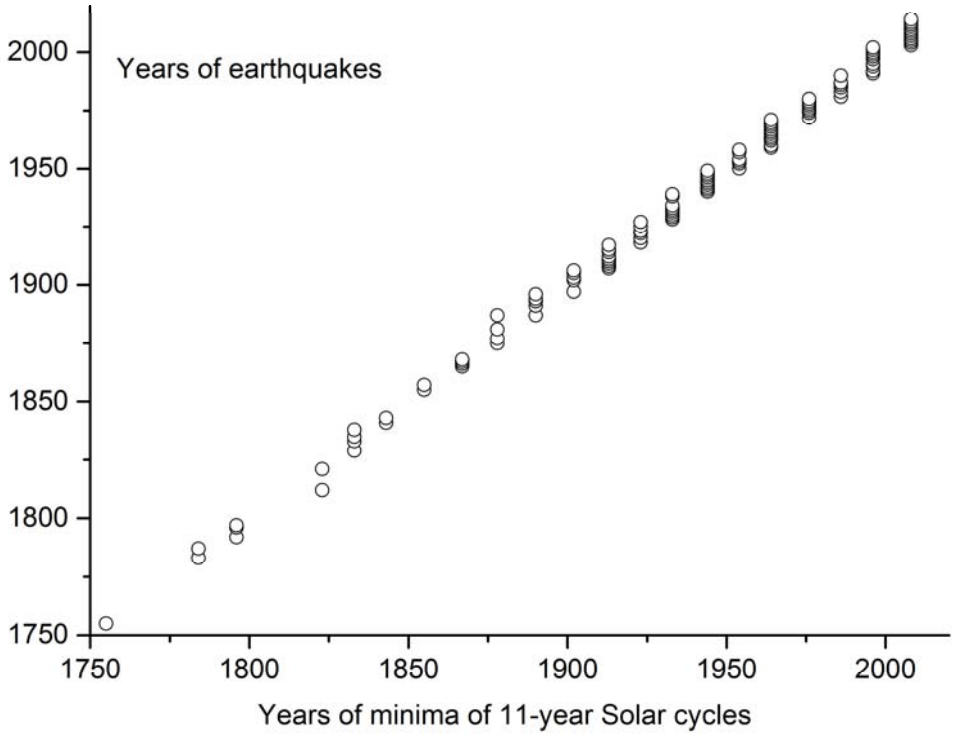

Fig.1. Correlation between the years of minima of Solar 11-year cycles and years of earthquakes.

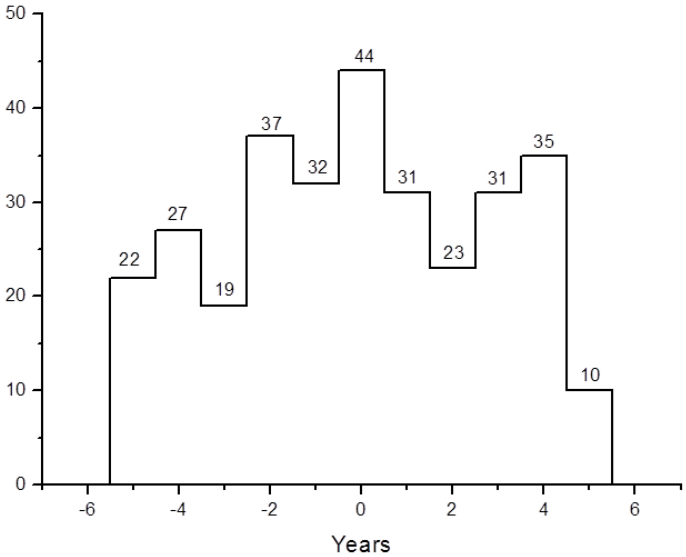

Fig. 2. Number of earthquakes as a function of the number of years from the minima of solar activity (zero corresponds to the minima of Solar activity). The graph is constructed by superposition different epochs of solar activity.

Table 2.

Cycle	Year of min.	W min.	Number of earthquakes in the cycle
20	1964	15	30
21	1976	13	20
22	1986	13	8
23	1996	10	40
24	2009	4	114

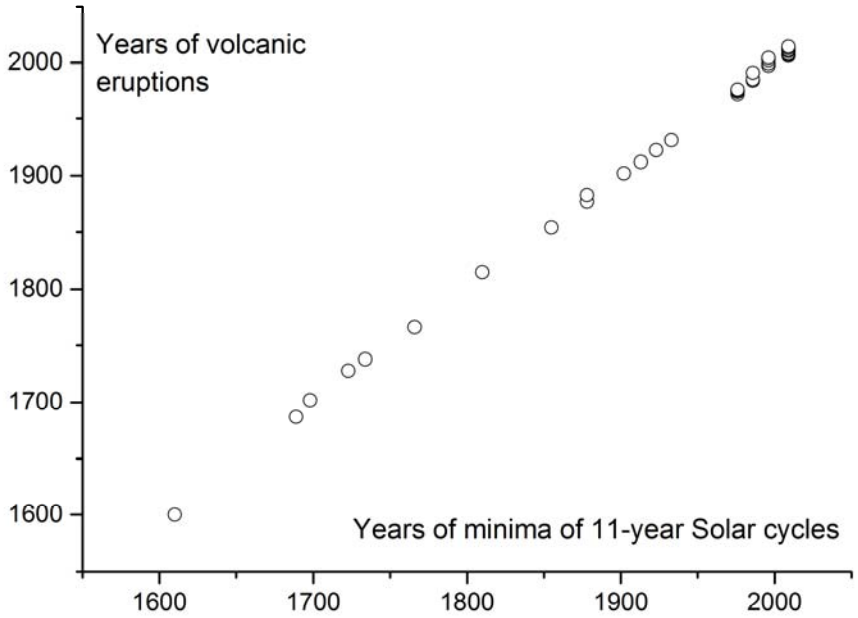

Fig.3. Correlation between the years of minima of Solar 11-year cycles and years of volcanic eruptions.

APPENDIX A

Solar activity and earthquakes

Cycle number	Solar.min.	Date of earthquake Year Month	Location of earthquake	Magnitude
1	1755 XI			
		1755 06	Iran	
		1755 11	Portugal	8,7
4	1784			
		1783 02	Italy	
		1787 05	Puerto Rico	8.0
5	1796 V			
		1792 05	Kamchatka	8.0
		1796 05	Moldavia	7.0-8.0
		1797 02	Ecuador	
7	1823 V			
		1812 03	Venezuela	7.7
		1821 05	Moldavia	7.0-8.0
		1821 07	Camana, Peru	8.2
		1821 11	Moldavia	7.0
8	1833 XI			
		1829 11	Moldavia	7.0-8.0
		1833 05	India	7.5
		1833 09	China	8.0
		1833 11	Indonesia	9.2
		1835 02	Chile	8.2
		1838 01	Moldavia	7.0
9	1843 VII			
		1841 05	Kamchatka	8.4
		1843 02	Leeward Islands	8.3
10	1855 V			

		1855 01	New Zealand	8.0
		1857 01	California	8.0
11	1867 III			
		1865 04	Moldavia	9.0
		1866 11	Moldavia	7.0
		1867 06	Kazakhstan	7,3
		1868 08	Peru	9.0
12	1878 XII			
		1875 05	Colombia	7.3
		1877 05	Chile	8.3
		1881 -	California	7.9
		1887 05	Mexico	7.4
13	1890 III			
		1887 06	Kazakhstan	7.3
		1891 10	Japan	8.0
		1893 08	Moldavia	7.0
		1893 09	Moldavia	7.0
		1894 03	Moldavia	7.0
		1894 07	Turkey	7.0
		1894 08	Moldavia	7.0
		1894 09	Moldavia	9.0
		1896 06	Japan	8,5
14	1902 II			
		1897 06	India	8.3
		1902 04	California	8.2
		1902 04	Azerbaigan	6.9
		1902 04	Guatemala	7.5
		1903 04	Turkey	7.0
		1903 05	Turkey	5.8
		1903 08	Greece	8.3
		1905 04	India	7.5
		1905 07	Mongolia	8.4
		1905 09	Italy	7.9
		1906 01	Ecuador	8.8
		1906 08	Chile	8.2
15	1913 VII			

		1907 04	Mexico	7.7
		1907 10	Tajikistan	8.0
		1908 12	Peru	8.2
		1908 12	Italy	7.2
		1909 01	Iran	7.3
		1910 04	Taiwan	7.6
		1911 01	Kyrgyzstan	7.8
		1911 02	Tajikistan	7.4
		1911 06	Mexico	7.7
		1911 06	Japan	8.1
		1912 08	Turkey	7.8
		1914 10	Turkey	7.0
		1915 01	Italy	7.0
		1917 07	China	7.5
16	1923 VIII			
		1918 02	China	7.3
		1918 10	Mona Passage	7.5
		1918 12	Canada	7.0
		1920 06	Taiwan	8.0
		1920 12	China	7.8
		1922 11	Chile-Argentina	8.5
		1923 02	Kamchatka	8.5
		1923 03	China	7.3
		1923 09	Japan	7.9
		1925 03	China	7.1
		1927 03	Japan	7.6
		1927 05	China	7.6
17	1933 IX			
		1928 12	Chile	7.6
		1929 05	Iran	7.4
		1929 05	Canada	7.0
		1929 11	Canada	7.2
		1930 05	Iran	7.2
		1931 01	Mexico	7.8
		1931 02	New Zealand	7.9
		1931 08	China	8.0
		1932 06	Mexico	8.1
		1932 12	China	7.6
		1933 03	Japan	8.4
		1933 08	China	7.4
		1933 11	Canada	7.4
		1934 01	India - Nepal	8.1
		1934 03	Moldavia	9.0
		1938 02	Indonesia	8.5

		1939 12	Turkey	7.8
18	1944 II			
		1940 05	Peru	8.2
		1940 11	Romania	7.3
		1941 04	Australia	7.2
		1942 08	Guatemala	7.9
		1942 08	Peru	8.2
		1942 11	Turkey	7.6
		1942 12	Turkey	7.3
		1943 04	Chile	8.2
		1943 09	Japan	7.4
		1943 11	Turkey	7.6
		1944 01	Argentina	7.4
		1944 02	Turkey	7.4
		1944 12	Japan	8.1
		1945 01	Japan	7.1
		1945 11	Pakistan	8.0
		1946 06	Canada	7.3
		1946 08	Dominican Rep	8.0
		1946 11	Peru	7.3
		1946 12	Japan	8.1
		1947 08	Iran	7.3
		1947 11	Peru	7.3
		1948 05	Peru	7.4
		1948 05	China	7.3
		1948 06	Japan	7.3
		1948 10	Turkmenistan	7.3
		1949 07	Tajikistan	7.5
		1949 08	Canada	8.1
19	1954 IV			
		1950 08	Tibet	8.6
		1950 04	Kamchatka	8.6
		1950 08	Tibet	8.6
		1952 03	Japan	8.1
		1952 11	Kamchatka	9.0
		1953 03	Turkey	7.3
		1953 08	Greece	7.1
		1953 12	Peru	7.4
		1954 03	Spain	7.9
		1954 04	Greece	7.1
		1957 01	California	7.9
		1957 03	Alaska	9.1
		1957 04	Turkey	7.1
		1957 06	Stanovoy, Russia	7.6

		1957 07	Iran	7.1
		1957 07	Mexico	7.9
		1957 12	Mongolia	8.1
		1957 12	Iran	7.1
		1958 01	Peru	7.3
		1958 11	Kuril Islands	8.3
20	1964 X			
		1959 04	Taiwan	7.5
		1960 01	Peru	7.5
		1960 05	Chile	7.9
		1960 05	Chile	9.5
		1962 05	Mexico	7.0
		1962 09	Iran	7.1
		1963 10	Kuril Islands	8.5
		1964 03	Alaska	9.2
		1964 06	Japan	7.5
		1964 10	Turkey	7.0
		1965 01	Indonesia	7.6
		1965 02	Chile	7.0
		1965 03	Afghanistan	7.8
		1965 03	Chile	7.4
		1965 03	Greece	7.1
		1965 04	Alaska	8.7
		1965 08	Mexico	7.3
		1966 03	China	7.0
		1966 10	Peru	8.1
		1967 07	Turkey	7.3
		1968 05	Japan	8.2
		1968 05	New Zealand	7.1
		1968 08	Mexico	7.1
		1968 08	Iran	7.3
		1969 02	Morocco	7.8
		1969 12	Guadeloupe	7.2
		1970 05	Peru	7.9
		1970 06	Canada	7.0
		1970 07	Colombia	8.0
		1971 07	Chile	7.5
21	1976 VI			
		1972 01	Taiwain	7.5
		1972 04	Iran	7.1
		1972 04	Taiwain	7.2
		1974 07	Panama-Colombia	7.3
		1974 10	Peru	8.1

		1974 10	Leeward Islands		7.5
		1975 02	China		7.0
		1976 06	Indonesia		7.1
		1976 02	Guatemala		7.5
		1976 07	China		7.5
		1976 08	Philippines		7.9
		1976 11	Turkey-Iran		7.3
		1977 03	Romania		7.2
		1977 11	Argentina		7.4
		1978 09	Iran		7.8
		1979 12	Ekuador		7.9
		1980 01	Portugal		7.2
		1980 10	Algeria		7.7
22	1986 IX				
		1981 07	Iran		7.3
		1983 10	Turkey		7.3
		1985 03	Chile		7.8
		1985 09	Mexico		8.0
		1986 08	Moldavia		7.0
		1987 03	Colombia-Ecuador		7.0
		1990 06	Iran		7.4
		1990 07	Philippine		7.7
23	1996 V				
		1991 04	Costa Rica		7.6
		1992 09	Nicaragua		7.6
		1992 12	Indonesia		7.8
		1994 06	Bolivia	200	8.2
		1995 05	Sakhalin		7.1
		1997 05	Iran		7.3
		1997 07	Venezuela		7.0
		1997 10	Fiji Islands		7.8
		1997 12	Kamchatka		7.8
		1998 05	Taiwan		7.5
		1998 07	Papua New Guinea		7.0
		1998 01	Loyalty Islands		7.5
		1998 01	Chile		7.1
		1998 03	Balleny Islands		8.1
		1998 07	Papua New Guinea		7.0
		1998 08	Ecuador		7.2
		1999 02	Santa Cruz Islands		7.3
		1999 05	Papua New Guinea		7.1
		1999 06	Mexico		7.0
		1999 08	Turkey		7.6
		1999 09	Taiwan		7.6

			1999 09	Mexico	7.5
			1999 11	Turkey	7.2
			2000 06	Indonesia	7.9
			2000 06	South Indian Ocean	7.9
			2000 11	Papua New Guinea	8.0
			2001 01	Philippines	7.5
			2001 01	El Salvador	7.7
			2001 01	India	7.6
			2001 06	Peru	8.4
			2001 07	Peru	7.6
			2002 01	Vanuatu Islands	7.2
			2002 03	Afghanistan	7.4
			2002 03	Philippines	7.5
			2002 03	Taiwan	7.1
			2002 06	China	7.3
			2002 08	Fiji Islands	7.7
			2002 09	Papua New Guinea	7.6
			2002 10	Indonesia	7.6
			2002 11	Indonesia	7.4
			2002 11	Kuril Islands	7.3
24		2008	VII		
			2003 01	Solomon Islands	7.3
			2003 01	Mexico	7.6
			2003 05	Indonesia	7.0
			2003 05	Japan	7.0
			2003 06	Brazil	7.1
			2003 07	Carlsberg Ridge	7.6
			2003 08	Scotia Sea	7.6
			2003 08	New Zealand	7.2
			2003 09	Japan	8.3
			2003 09	South. Siberia	7.0
			2003 10	Japan	7.0
			2003 12	Loyalty Islands	7.3
			2004 02	Indonesia	7.0
			2004 02	Indonesia	7.3
			2004 07	Indonesia	7.3
			2004 09	Japan	7.2
			2004 10	Nicaragua	7.0
			2004 11	Indonesia	7.5
			2004 11	Colombia	7.2
			2004 11	South Island, N.Z.	7.1
			2004 11	Indonesia	7.1
			2004 11	Japan	7.0
			2004 12	Macquarie Isl.	8.1
			2004 12	Indonesia	9.1

2005 02	Celebes Sea	7.1
2005 03	Banda Sea	7.1
2005 03	Indonesia	8.6
2005 06	Chile	7.8
2005 07	India	7.2
2005 08	Japan	7.2
2005 09	Papua New Guinea	7.6
2005 09	Peru	7.5
2005 10	Pakistan	7.6
2005 11	Japan	7.0
2006 01	Sandwich Islands	7.4
2006 01	Banda Sea	7.6
2006 02	Mozambique	7.0
2006 04	Koryakia, Russia	7.6
2006 12	Taiwan	7.1
2006 05	Tonga	8.0
2006 05	Kermadec Islands	7.4
2006 07	Indonesia	7.7
2006 08	Scotia Sea	7.0
2006 11	Kuril Islands	8.3
2007 01	Kuril Islands	8.1
2007 03	Vanuatu	7.1
2007 04	Solomon Isl.	8.1
2007 08	Vanuatu	7.2
2007 08	Peru	8.0
2007 09	Santa Cruz Isl.	7.2
2007 09	Indonesia	7.9
2007 01	Molucca Sea	7.5
2007 08	Indonesia	7.5
2007 09	Indonesia	8.5
2007 09	Mariana Islands	7.5
2007 09	New Zealand	7.4
2007 10	North. Mariana Isl.	7.2
2007 11	Chile	7.7
2007 11	Windward Isl.	7.4
2007 12	Fiji Islands	7.8
2008 02	Indonesia	7.4
2008 02	Indonesia	7.2
2008 03	China	7.2
2008 04	Macquarie Island	7.1
2008 04	Loyalty Islands	7.3
2008 05	China	7.9
2008 06	South Sandwich Isl.	7.0
2008 07	Sea of Okhotsk	7.7
2008 07	Japan	7.0
2008 11	Sea of Okhotsk	7.3

2008 09	New Zealand	7.0
2008 11	Indonesia	7.4
2009 01	Indonesia	7.7
2009 01	Kuril Islands	7.4
2009 02	Indonesia	7.2
2009 02	Kermadec Isl.	7.0
2009 03	Tonga	7.6
2009 05	Honduras	7.3
2009 07	New Zealand	7.8
2009 08	Japan	7.1
2009 08	India	7.5
2009 09	Indonesia	7.0
2009 09	Samoa Islands	8.1
2009 09	Indonesia	7.5
2009 10	Vanuatu	7.7
2009 10	Santa Cruz Isl.	7.8
2009 11	Fiji	7.3
2010 01	Solomon Isl.	7.1
2010 01	Haiti	7.0
2010 02	Chile	8.8
2010 05	Indonesia	7.2
2010 07	Philippines	7.3
2010 09	New Zealand	7.0
2011 01	Pakistan	7.2
2011 03	Japan	9.0
2012 01	Indonesia	7.3
2012 03	Chile	7.1
2012 03	Mexico	7.4
2012 04	Sumatra	8.2
2012 09	Costa Rica	7.6
2013 01	Alaska	7.5
2013 02	Santa Cruz	8.0
2013 02	Columbia	7.0
2013 04	Indonesia	7.2
2013 04	Iran	7.8
2013 04	China	7.0
2013 05	Sea of Okhotsk	8.2
2013 07	Sandwich Islands	7.2
2013 09	Pakistan	7.4
2013 10	Philippines	7.2
2013 10	Japan	7.3
2013 12	Atlantic Ocean	7.8
2014 04	Chile	

APPENDIX B

Solar activity and volcanic eruptions

Solar min epochs		Volcanoes eruptions		Volcano name	Location
Year	Month	Year	Month		
1610		1600		Huaynaputina	Peru
1689		1687		Orisaba	Mexico
1698		1702		Changbaishan	Chine
1723		1728		Sangai	Ecuador
1734		1738		Cotopashi	Ecuador
1766	6	1766	10	Mayon	Philippines
1810	12	1815	4	Tambora	Indonesia
1855	5	1854		Renir	USA
1878	12	1877		Lulyalyaco	Chile
		1883	7	Krakatoa	Indonesia
1902	2	1902	2	St.-Maria	Guatemala
		1902	5	Mon-Pele	Guadeloupe
1913	8	1912	6	Novarupta	Alaska, USA
1923	8	1922		St.-Maria	Guatemala
1933	9	1931	12	Merani	Indonesia
1976	6	1972		Kluchevskaya sopka	Kamchatka, Russia
		1974		Kluchevskaya sopka	Kamchatka, Russia
		1975		Sangai	Ecuador
		1976		Cotopashi	Ecuador
1986	9	1984		Mauna Loa	Hawaii, USA
		1985	11	Ruis	Columbia
		1991	6	Pinatubo	Philippines
1996	5	1997	6	Pinatubo	Philippines
		1999	2	Sufrier	Guadeloupe
		1999	2	St.-Maria	Guatemala
		2002	1	Nyiratonco	Congo
		2002	2	Redaut	USA
		2002	9	Etna	Italy
		2004		Etna	Italy
2009	1	2006	5	Merani	Indonesia
		2006	6	Merani	Indonesia
		2007		Etna	Italy
		2008		Etna	Italy
		2010	4	Gecla	Iceland
		2010	8	Pakaya	Guatemala
		2010	10	Merani	Indonesia
		2010	10	Tungurauya	Ecuador
		2010		Kluchevskaya sopka	Kamchatka, Russia
		2010	2	Sufrier	Guadeloupe
		2011		Etna	Italy
		2011	5	Gecla	Iceland
		2011	6	Pueyue	Chile

2013	9	Rokatenda	Indonesia
2014	10	Ontake	Japan