VOLCANIC AND SEISMIC ACTIVITIES DURING THE SOLAR HIBERNATION PERIODS

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Abstract: A massive number of strong earthquakes and volcanic eruptions occurred during the Maunder Minimum or Little Ice Age (1645 to 1715) worldwide. Both magmatic and seismic activities dwindled dramatically after the end of the Maunder Minimum. The Dalton Minimum shows some regional variations; seismically still quiet in Japan and Turkey, whereas in some other regions including India, Indonesia, continental North America and northern South America very strong earthquakes occurred. Indonesia’s Tambora volcano erupted in this solar low period.

Magmatic and seismic events became active worldwide after the closure of the Dalton; this trend has continued until today with a conspicuous rise since 2000 when the 206- and 361-year solar cycles started to decline sharply. The recent spate of unusually strong natural disasters (earthquakes, volcanic eruptions, and extreme weather events) has occurred during the rapidly declining period of this longer solar cycle – probably comparable to the earliest stage of the Maunder Minimum.

This paper confirms the remarkably heightened magmatic and seismic events during the major solar hibernation periods in the past. This fact prompts us to prepare for more severe catastrophic natural disasters in the coming two to three decades or even longer as the solar hibernation deepens further.

Keywords: earthquakes, volcanic eruptions, solar hibernation, Maunder Minimum, Dalton Minimum

Introduction

On 14 June 2011 the National Science Foundation’s National Solar Observatory sent a shock wave round the world by announcing that the Sun would be heading into a more dormant period with activity during the next 11-year solar cycle (cycle 25) greatly reduced or even eliminated (http://www.boulder.swri.edu/~deforest/SPD-sunspot-release/SPD_solar_cycle_release.txt). Should this forecast be correct, this means the Earth has entered a solar hibernation period similar to the Maunder Minimum from 1645 to 1715 (Eddy, 1976).

The arrival of a major solar cycle low period (cycles 24 and 25) has been predicted and strongly advocated by John Casey (2008) along with many other earlier researchers including Komitov and Kaftan (2003), Schatten and Tobiska (2003), Landscheidt (2003) and Archibald (2006). Against the global warming alarmists, Casey warned that the arrival of a solar hibernation period in the coming 20 to 30 years comparable to the Maunder or Dalton Minimums, which would result in prolonged deeply cold weather. Some of the coldest years will destroy crops and produce catastrophic food shortages. He later warned (2010) of the increase in large volcanic and seismic events in the solar cycle trough periods comparable with the Dalton Minimum, their ill-effects on global climate and food production, and social disruption.

His advocacy was supported by Choi and Maslov (2010). Based on an exhaustive study of earthquakes and comparison with solar cycle, they showed an inverse or anti-correlation between seismic activity and the solar cycle; when the Sun is active (rising and peak phases of the cycle) seismicity becomes low, but when the Sun becomes inactive (trough and declining period), more of the largest earthquakes occur.

The above underlying understanding prompted the authors to examine global tectonic activity during the major solar low periods – Maunder and Dalton Minimums. The first area chosen was in the Molucca Sea, Indonesia, because the region is expected to have a major shallow earthquake sometime around late 2012 (Choi, 2010). The study was expanded to other regions where historical archival data are available. This paper briefly describes our main findings to stimulate discussion on the intriguing tectonics and related planetary interaction.
Volcanism in the Indonesian region since 1960

Molucca Sea

Volcanoes in the Molucca Sea region form the chains of islands on both sides of the Sea: the Sulawesi-Sanghihe islands in the west and the Halmahera chain in the east. Fig. 1 was compiled from the Smithsonian Institution’s Global Volcanism Program website (http://www.volcano.si.edu/world/) for each chain, and compares the results with the published solar cycle taken from the NASA website with emphasis on major solar cycle trough periods (highlighted in blue).

![Volcanic eruption history in the Sulawesi-Sanghihe Island chain and Halmahera Islands around the Molucca Sea.](image)

The above figure shows that large volcanic eruptions took place during the Maunder and Dalton Minimums in the Molucca Sea region: The strongest volcanism in the region (VEI 5) occurred during the Maunder Minimum (Tongkoko and Gamkonora). The Dalton Minimum period roughly coincides with the starting period of magmatic reactivation which has continued until today in many volcanoes. In the Sulawesi-Sanghihe chain, volcanoes south of Karangetan are active, but its northern volcanoes, Banua Wuhu and Awu, are inactive at this moment. In the Halmahera islands all volcanoes except for the southernmost one (Makian) are currently active at the end of 2011.
Lesser Sunda, Java and Sumatra Islands
For comparison with the above Molucca Sea region, the volcanic history of Lesser Sunda, Java and Sumatra Islands was studied (Figs. 2-4). In all regions some volcanoes were active during the Maunder Minimum, such as Merapi in Java and Krakatau. Merapi, Raung and Tengger Caldera in Java were active during the Dalton Minimum, and so were Tambora (1815, VEI 7), Sangeang Api, Agung, and Bartur in Lesser Sunda, whereas there was no recorded activity in volcanoes in Sumatra during both the Maunder and Dalton troughs. Interestingly in all regions of Indonesia volcanoes became active after the end of the Dalton Minimum.

Figure 2. Volcanoes in the Lesser Sunda Islands. Note the eruption of Tambora in 1815 (VEI 7 – strongest in world history) in the middle of Dalton and Agung in 1963 (VEI 4) which also occurred in the declining period of the solar cycle 19 (see Fig. 6).
Figure 3. Volcanoes in Java Island. Note periodic, intensive eruptions of Merapi during the early half of the Maunder Minimum, and a series of eruptions starting from the Dalton Minimum period in the eastern half of Java.
Figure 4. Volcanoes in Sumatra. No strong eruptions above VEI 3 have been recorded in Sumatra except for Krakatao, which also erupted during the Maunder Minimum. Another interesting trend is the start of small eruptions after the Dalton Minimum.

Quantitative analysis of volcanic and seismic activities in the Celebes-Molucca Sea region

To analyze the available data in a quantitative way, Fig. 5 was produced. It represents the energy level of volcanic and seismic activities in the Celebes-Molucca Sea region, an area bounded by latitudes 0.00
and 10.00N and longitudes 120.00 and 130.00E – roughly covering the area shown in Fig. 1. The energy level is expressed in the form of volcanic and earthquake points; the calculation methods are shown in the figure caption. It is clearly seen that volcanoes were very active during the Maunder Minimum – represented by Tongkoko and Gamkonora volcanoes in the middle of the low period. A most outstanding event during the Dalton Minimum was the Awu volcano eruption in 1812 – also in the middle of the low period. Otherwise the activity level remained relatively low throughout the Dalton. Volcanic activities gradually increased after the Dalton low period, notably after 1980s in the region.

Historical earthquakes in the region are archived on the Utsu-WEQ website (http://iisee.kenken.go.jp/cgi-bin/utsu/result.cgi). However, compared to the volcanoes, relatively few reliable historical earthquake records are available, particularly for the period before 1840. Yet the limited data show that the total energy level of earthquakes for each five-year interval was quantitatively expressed in the form of the total number of M6.0 quakes at the bottom of Fig. 5. It is interesting to note that there is a distinctive peak between 1890 and 1930. The period coincides with a minor but notable peak in volcanic activity too, suggesting heightened activity in the Earth’s outer core during this period. However, after 1970 there is no clear correlation between earthquake and volcanism; the study area needs to be expanded for meaningful analysis.

![Figure 5. Volcanic and seismic activities in the Indonesian region in comparison with the solar cycle in the Celebes-Molucca Sea region. Calculation method of volcanic points: Each eruption was given the following points: Level 0 (VEI 0) = 1 point, Level 1 = 100 points, Level 2 = 1,000 points, Level 3 = 10,000 points, Level 4 or greater = 100,000 points. Five-year total points are indicated in the figure. Data source: Smithsonian National Museum of Natural History, http://www.volcano.si.edu/world/find_regions.cfm, 2011, and Volcanic Alert Level (WOV) (http://www.wovo.org/). Note extreme highs in the middle of the two solar minima. Earthquake points: Based on magnitude (which is on a logarithmic scale), all earthquakes with magnitude 6.0 or greater were converted to the number of M6.0 quakes and the total number of M6.0 was counted; for example, an M7.0 quake = 32 M6.0 quakes, an M8.0 quake = 32 x 32 (= 1024) M6.0 quakes, and an M8.7 quake = 12 x 32 x 32 (= 12,288) M6.0 quakes.](image-url)
As seen above, the following trends in volcanic and seismic events are observed in the Indonesian region: 1) very strong and intensive activities during the Maunder Minimum, 2) much subdued but still marked activities during the Dalton Minimum, 3) renewed, continuous activities after the end of Dalton, and 4) very high level of activity after 2000. It is also of note that the observed spike in earthquake activity in the first decade of the 1900’s correlates strongly with the “Centennial Cycle” solar minimum described by Casey (2008) and his subsequent forecast of increased seismic activity during major solar minima or ‘solar hibernations’.

**Historic seismicity and volcanism, and their relation to the solar cycles of the world**

To see global trends in the solar cycles and seismicity/volcanism we searched for references for some selected regions: Japan, India and Turkey, where historical records are available. The results are displayed in Fig. 6.
As clearly shown in the above figure, the most intensive activities are recorded during the Maunder Minimum throughout the world. After the end of the Maunder, many regions entered a quiescent period until the start of the Dalton low, but in South America in particular strong earthquakes continued. In general the Dalton period saw renewed activity in both seismicity and volcanism, though showing local variance - some areas such as Japan and Turkey remained seismically quiet. In the post-Dalton era, seismicity was renewed in Japan and Turkey. In all regions the heightened activity trend has continued until today. These trends are harmonious with those of volcanoes in Indonesia as discussed earlier.

**Worldwide earthquake energy level fluctuation during the Maunder and Dalton Minimums**

**Maunder Minimum**

To see global seismicity trends during the solar hibernation periods we retrieved historical quakes recorded on the Utsu-WEQ site. The results for the Maunder period are shown below (Fig. 7). To show them in a quantitative manner, as done in the Celebes-Molucca Sea region, all M6.0+ earthquakes were converted to the total number of M6.0 quakes.

![Figure 7. Frequency of earthquakes during the Maunder Minimum. Data source: Utsu-WEQ website, http://iisee.kenken.go.jp/cgi-bin/utsu/result.cgi. See the caption to Fig. 6 for conversion method.](image)

If we set the major earthquake frequency peaks at around 7,000 (Figs. 7 and 8), the years 1647, 1668, 1700, 1716, and 1730 become the peak years, separated by intervals of 21, 32, 16 and 14 years. Among them exceptionally high energy years are 1700 and 1716, which are equivalent to over 25,000 M6.0 quakes.

The start of the Maunder Minimum is 1645 (Eddy, 1976). However, it seems more reasonable to take 1646 as the starting year, as the very strong energy release occurred in 1647. On the other hand, the end of the Maunder is generally taken to be 1715; but because 1716 is one of the highest energy peaks during the Maunder, it appears more natural to place the end of the Maunder in 1716.

**Dalton Minimum**

The Dalton low period’s energy level fluctuation is shown below (Fig. 8). The Dalton’s starting year cannot be clearly defined by the earthquake energy level. But one possible year is 1795, before the curve started to rise in 1796. Regarding the end year of the Dalton, we consider 1828 is a better choice than 1830 based on the rapid energy drop seen in 1828. This year also corresponds to the rising period of solar activity (Fig. 6).
Discussion
Stothers (1989) extensively studied volcanic catalogs compiled by Simkin et al. (1981) and Newhall and Self (1982). He ably summarized many preceding studies on volcanic eruption and solar cycles. Based on statistical analysis, he detected two weak eruption cycles - 11 and 80 years; the incidence of volcanic eruptions is slightly greater around the time of solar minimum than at any other phase. Both Stothers (1989) and Fairbridge (1980) noted the abnormally high volcanic eruption numbers during the Maunder Minimum; this is supported by elevated acidity in Greenland deep ice cores covering the years from 533 to 1972 AD (Hammer et al., 1980) during this protracted solar minimum.

In his well-researched book, Casey (2011) summarized the effect of cold climate on humans and society especially during the Dalton Minimum, and warned of the imminent arrival of a cold climate in the coming 20 to 30 years. Our current study strongly supports his conclusions; the prolonged Maunder-type cold period if it occurs, will surely be accompanied by remarkably heightened volcanic and earthquake activities in the coming several decades.

The heightened tectonic and magmatic events during the solar low period as documented here are harmonious with the earthquake-solar cycle anti-correlation proposed by Choi and Maslov (2010). A reasonable explanation for this fact must be addressed urgently. One of the hints comes from Gregori (2002), who considers the Earth to be a leaky capacitor or a battery which is charged when solar activity is strong, but discharges energy when solar activity declines. However, further studies of various facets including cosmic ray effects, microwave background radiation, etc. are needed to get a clearer picture of this intriguing phenomenon.

Relationship between the solar minima and earthquake energy cycle
In general, very strong seismicity peaks with over 10,000 M6.0 quakes (including worldwide trends, Fig. 6, and other published data) have a cycle of about 40 years, and other minor peaks 10 to 20 years (Tsunoda, 2010). These trends are maintained regardless of the solar cycle fluctuation pattern. However, if examined more closely, during the low cycles the number of peaks increases, which is especially well observed during the Maunder Minimum (Fig. 7). Therefore, the Earth’s energy level during the solar low periods is undoubtedly higher than during the solar high periods. Also it is worth noting that, when viewed in terms of the total energy level fluctuation or the VE process (Tsunoda, 2010), while the start and the end of the Maunder are clearly defined, those of the Dalton are unclear.

All available data presented here seem to suggest that the recent unusually strong volcanic and earthquake activities especially after 2000 are comparable with those which occurred during the early stage of the Maunder Minimum. This is the time when the longer solar cycles, both 206- (Casey, 2008)
and 361-year cycles (Sonnett and Finney, 1990), have started to sharply decline. We tentatively set the year 2008 (lowest trough before the rise of the solar cycle 24) to be the starting year of the Current Minimum. It well matches the 206-year cycle after the start of Dalton and the 361-year cycle after the start of the Maunder.

Conclusions

This preliminary study shows heightened volcanic and seismic activities during the major solar hibernation periods since 1600. Because the Earth is likely to have a Maunder-type inactive solar cycle period in the coming decades, we will have more numerous catastrophic magmatic and seismic disasters coupled with unusually severe weather events.

Acknowledgements: We sincerely thank to the following colleagues: John Casey of Space and Science Research Corporation, USA for his thorough review and helpful comments; Cliff Ollier of the University of Western Australia for editorial comments; T.E. Girish of University College, Trivandrum, India and Valentino Straser, Italy for collecting earthquake references; David Pratt for polishing English; and Dongwon Kim of Raax Australia Pty Ltd. for compilation of historic Indonesian volcano data.

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