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Lunar Phases of 2016 Kumamoto Earthquakes

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1. Introduction

The authors found that giant earthquakes are occurring at specific lunar phases for each subduction zone (Fujii et al., 2015). Lunar phases of 2016 Kumamoto Earthquakes were examined although the finding was basically for giant earthquakes ($M_w \geq 8$ by definition) which were mainly occurring at subduction zones.

2. Dangerous lunar phases before 2016 Kumamoto Earthquakes

Dangerous lunar phases at which earthquakes concentrate was not identified for earthquakes ($M \geq 5.5$) from Jan. 1, 1923 to just before the large foreshock on Apr. 14, 2016, whose seismic intensity scale by Japan Meteorological Agency at Kumamoto is more than or equal to 3 and whose epicenter names include "Kumamoto" or "Oita" (Fig. 1).

Dangerous lunar phases from the day 9.77 to 13.12 in delay from spring tide can be seen if only the events whose epicenter names include "Kumamoto" are selected ("Before 2016 Kumamoto" in Fig. 2) with p of 3.88%. p is the probability that m or more earthquakes within the total n earthquakes occur in a specific lunar phase period under a random null hypothesis which assumes that the earthquake occurrence is a random process. The random null hypothesis is rejected and the dangerous lunar phases are statistically meaningful if p is less than a threshold value which is usually set at 5%.

p becomes 5% by setting the duration of the dangerous lunar phase at 5.05 days. The next earthquake with $M5.5$ or more can occur during the delay from spring tide of the day 8.07 (13.12 - 5.05) to 14.82 (9.77 + 5.05). This period will be called as "possibly dangerous lunar phase" later for simplicity.

The epicenter names of the earthquakes in the above analysis however are Kumamoto-ken Aso or Kumamoto-ken Amakusa & Ashikita (Table 1) and no earthquakes which has epicenter name of Kumamoto-ken Kumamoto occurred at least from Jan. 1, 1923. The earthquakes whose epicenter name is Kumamoto-ken Kumamoto from one year before the large foreshock (#13) seems becoming inactive (Fig. 3) and dangerous lunar phase cannot be identified (Fig. 4).

3. Dangerous lunar phases of 2016 Kumamoto Earthquakes

The lunar phases of the first two events are slightly earlier than the possibly dangerous lunar phases from the previous

earthquake history. The rest of the earthquakes including the mainshock are however within the possibly dangerous lunar phases.

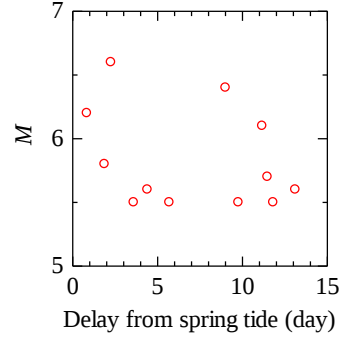


Fig. 1 Delay from spring tides for earthquakes ($M_w \geq 5.5$) from Jan. 1, 1923 to just before the large foreshock on Apr. 14, 2016, whose seismic intensity scale by Japanese Meteorological Agency at Kumamoto is more than or equal to 3 and whose epicenter names include "Kumamoto" or "Oita" (#1 - #12 in Table 1).

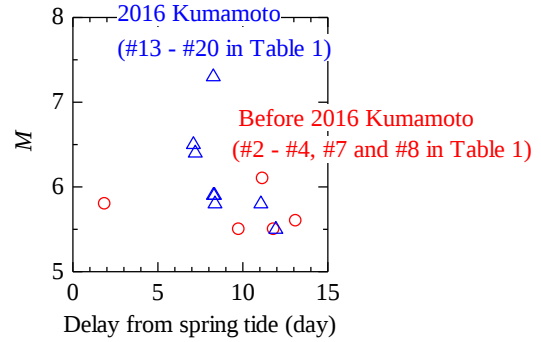


Fig. 2 Delay from spring tides for earthquakes ($M_w \geq 5.5$) from Jan. 1, 1923 to May 11, 2016 whose seismic intensity scale by Japanese Meteorological Agency at Kumamoto is more than or equal to 3 and whose epicenter names include "Kumamoto".

Japan Meteorological Agency thought the foreshock was a mainshock and urged people to take care for big aftershocks. Many people thought that there would be no larger earthquakes and returned to their homes after the foreshocks and some of them were killed by the collapses of their houses by the mainshock. The fatality could have been significantly reduced if people had known that there had been possibly dangerous

lunar phases for Kumamoto and had continued to be evacuated in safe places instead going back to their damaged houses.

4. Updating the dangerous lunar phases

The dangerous lunar phases can be calculated as the day 7.09 to 13.12 with p of 0.039% for the 13 earthquakes (#2 - #4, #7, #8, #13 - #20). The duration of possibly dangerous lunar phases can be 9.76 days with p of 5% or 8.27 days with p of 1%. The possibly dangerous lunar phases are the day 3.36 to 16.85 for the 5% case or the day 4.85 to 15.36 for the more reliable 1% case.

5. Concluding remarks

The possibly dangerous lunar phase could have saved many human lives. The authors will further study the application of the dangerous lunar phase concept although the concept is basically only for giant earthquakes at subduction zones.

The authors send their condolences to the victims of the earthquakes and are hoping early recovery of Kumamoto from the earthquake damages.

Acknowledgement

Lunar phases were calculated with Lunar Phase Calendar (<http://koyomi8.com/>). The authors express their gratitude.

Reference

Fujii, Y., Kodama, J. and Fukuda, D. (2015), Giant Earthquakes are Occurring at Lunar Phases Specific to Each Subduction Zone, Proc. ISRM Congress 2015 (The 13th. International Congress of Rock Mechanics), Paper 513.

Table 1 List of the earthquakes for the analyses. #1 - #12: before Kumamoto 2016, #13 and #14: forshocks, #15: mainshock, and #16-#20: aftershocks up to May 12, 2016 (Source: Japan Meteorological Agency, <http://www.data.jma.go.jp/svd/eqdb/data/shindo/index.php>)

Number	y	m	d	h	m	M	Area	Delay from spring tide
1	1929	1	2	1	40	5.5	Oita-ken Seibu	5.70
2	1931	12	21	14	47	5.5	Kumamoto-ken Amakusa & Ashkita	11.82
3	1931	12	22	22	7	5.6	Kumamoto-ken Amakusa & Ashkita	13.12
4	1931	12	26	22	42	5.8	Kumamoto-ken Amakusa & Ashkita	1.88
5	1947	5	9	23	5	5.5	Oita-ken Seibu	3.60
6	1950	9	16	21	48	5.6	Oita-ken Nambu	4.41
7	1975	1	22	13	40	5.5	Kumamoto-ken Aso	9.77
8	1975	1	23	23	19	6.1	Kumamoto-ken Aso	11.17
9	1975	4	21	2	35	6.4	Oita-ken Seibu	9.01
10	1983	8	26	5	23	6.6	Oita-ken Hokubu	2.26
11	2006	6	12	5	1	6.2	Oita-ken Seibu	0.84
12	2015	11	14	5	51	5.7	Oita-ken Seibu	11.48
13	2016	4	14	21	26	6.5	Kumamoto-ken Kumamoto	7.09
14	2016	4	15	0	3	6.4	Kumamoto-ken Kumamoto	7.20
15	2016	4	16	1	25	7.3	Kumamoto-ken Kumamoto	8.26
16	2016	4	16	1	45	5.9	Kumamoto-ken Kumamoto	8.27
17	2016	4	16	3	3	5.9	Kumamoto-ken Kumamoto	8.33
18	2016	4	16	3	55	5.8	Kumamoto-ken Kumamoto	8.36
19	2016	4	18	20	41	5.8	Kumamoto-ken Kumamoto	11.06
20	2016	4	19	17	52	5.5	Kumamoto-ken Kumamoto	11.94

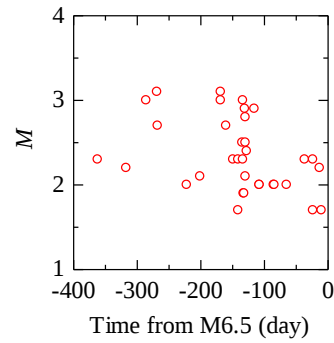


Fig. 3 Earthquakes from one year before the large foreshock (#13) to just before it whose epicenter name is Kumamoto-ken Kumamoto.

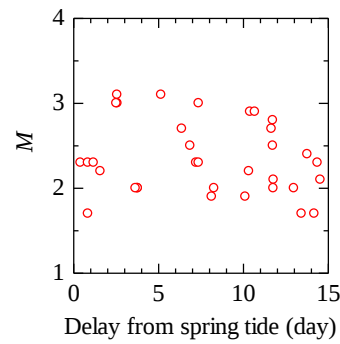


Fig. 4 Delay from spring tide for the earthquakes from one year before the large foreshock (#13) to just before it whose epicenter name is Kumamoto-ken Kumamoto.