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Predicting the 2019 M7 Strong Earthquake in California

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Abstract

The U.S. Geological Survey has estimated a 99% chance of a magnitude 6.7 earthquake in California in the next 30 years from 2008. In this paper, Fourier transform, mode analysis and commensurability analysis are used to study the earthquake cycle in California and predict the future strong earthquake. The analysis shows that the strong earthquake in California is most likely to occur in 2019, and the prediction was sent to the relevant institutions of United States in 2018. In July 2019 an M7.1 earthquake occurred in California, which proved our prediction to be correct.

Keywords

California, Earthquake Prediction, The Fourier Transform, Commensurability

1. Introduction

California is the state with the most severe earthquake disaster in the United States. Therefore, earthquake prediction in this area is particularly important. The U.S. Geological Survey (USGS) has made two famous earthquake predictions in California. One is for the Parkfield area in southern California. They found that the earthquake in this area has a cycle of about 22 years. The last earthquake occurred in 1966, so they predicted the next earthquake may occur around 1988 (1983-1993) with probability of 95% [1] [2]. The actual earthquake occurred in 2004, 11 years later than expected and this proved that the earthquake prediction was a failure [3]. The second time is the long-term probability prediction of the California earthquake. In 2008, USGS reported that the probability of an M6.7 earthquake in California in the next 30 years is 99% (https://www.sciencedaily.com/releases/2008/04/080414203459.htm). Because the forecast period is as long as 30 years, the actual disaster mitigation significance of this forecast is not great. Here we propose a new method to predict which year will have the greatest probability of earthquake occurrence during the period, and reduce the time from 30 years to 1 year, which is helpful for disaster reduction and prevention.

2. Regional Seismic Data

The historical seismic data of the California area was downloaded from the website of the US Geological Survey (https://earthquake.usgs.gov/earthquakes/search/). A total of 14 strong earthquakes of M6.7 or above occurred from 1900 to 2018 (see **Table 1**). The distribution is shown in **Figure 1**.

3. Earthquake Prediction Methods and Result Analysis

3.1. Forecast the Year of Earthquake

3.1.1. Fourier Transform

Fourier transform can get the main period of a time series [4]. Wang Xiang *et al.* (2010) used the Fourier transform method to compare the quasi-periodicity of the time-magnitude series of 30 $M_S \geq 5.0$ earthquakes which occurred in the border area of Shanxi, Hebei and Mongolia from 1494 to 2009 [5]. The results show that the earthquake sequence in the area has a cycle of 11 years and 8.6 years. In this paper, Fourier transform is performed on the sequence of strong earthquakes in the California area, and the main earthquake periods are 5 and 9 years (**Figure 2(a)**, **Figure 2(b)**).

Taking the five recent earthquakes in California in 1989, 1992, 1994, 1999 and

Table 1. Sequence of strong earthquakes in California, USA from 1900 to 2018.

No.	Year	Month	date	Lat	Lon	M
1	1906	4	18	37.7	−122.5	7.9
2	1915	11	21	32	−115	7
3	1918	4	21	33.7	−117	6.8
4	1925	6	29	34.3	−119.8	6.8
5	1927	11	4	34.8	−120.7	6.9
6	1940	5	19	32.8	−115.4	6.9
7	1952	7	21	34.9	−118.9	7.5
8	1956	2	9	31.8	−116.2	6.8
9	1983	5	2	36.2	−120.3	6.7
10	1989	10	18	37	−121.8	6.9
11	1992	6	28	34.2	−116.4	7.3
12	1994	1	17	34.2	−118.5	6.7
13	1999	10	16	34.6	−116.3	7.1
14	2010	4	4	32.2	−115.3	7.2

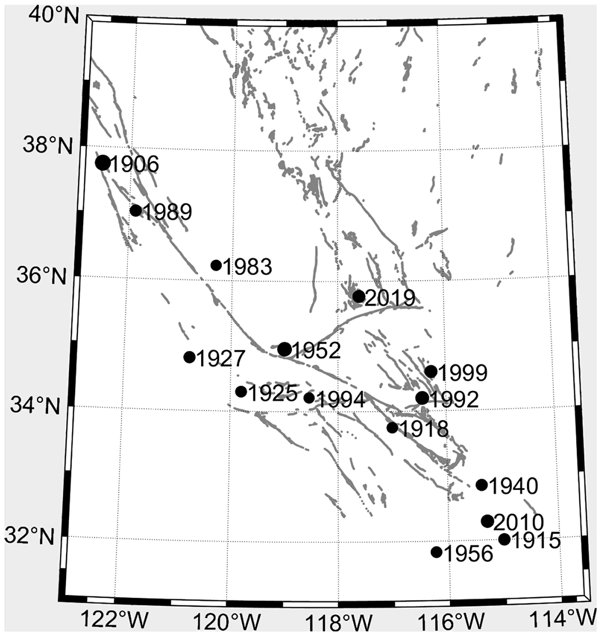

Figure 1. Distribution of strong earthquakes in California, USA from 1900 to 2018 (the gray solid line is the regional faults).

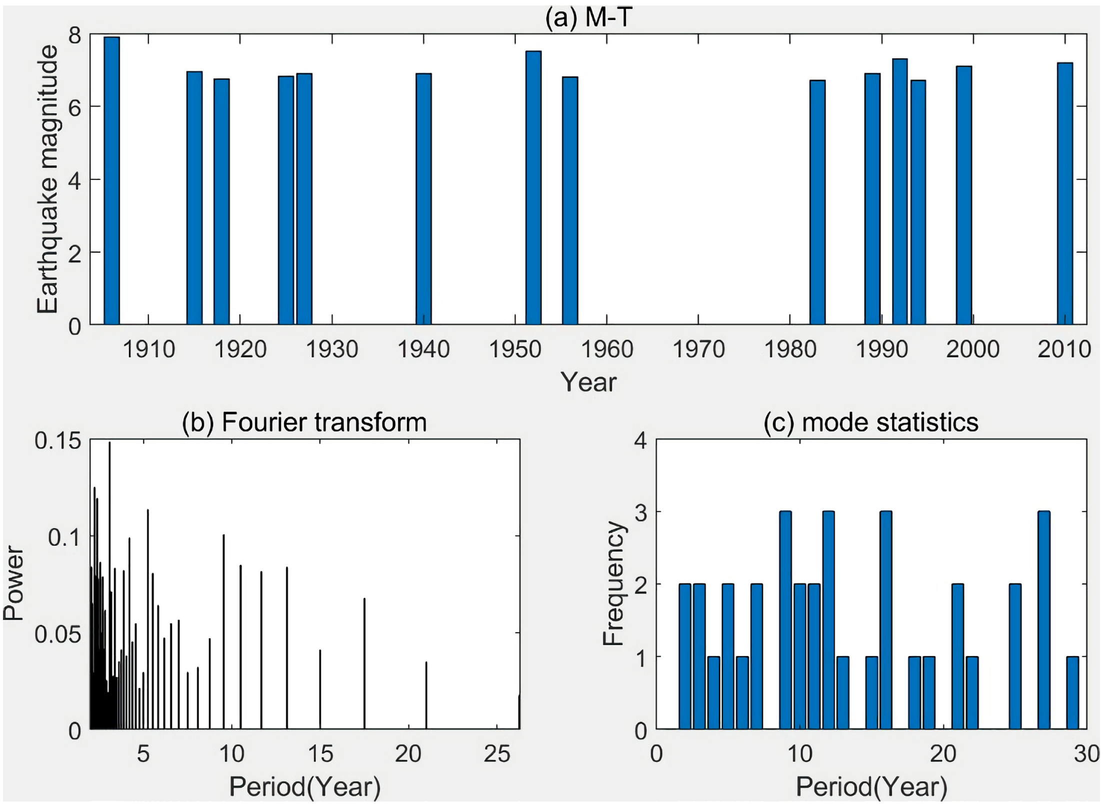

Figure 2. (a) Strong earthquake sequence in California, USA, and (b) its Fourier transform and (c) mode statistics.

2010 as the starting point, the calculations are based on 5-year and 9-year cycles respectively. The results are as follows:

1) Calculation based on 5-year cycle
1989 1994 1999 2004 2009 2014 2019 2024
1992 1997 2002 2007 2012 2017 2022 2027
1994 1999 2004 2009 2014 2019 2024
1999 2004 2009 2014 2019 2024
2010 2015 2020 2025 2030
2) Calculation based on 9-year cycle
1989 1998 2007 2016 2025 2034
1992 2001 2010 2019 2028 2037
1994 2003 2012 2021 2030
1999 2008 2017 2026
2010 2019 2028 2029

The statistics result shows that 2019 is the most frequent year which appears 5 times, while for other years (2015-2035) they appear only 1-3 times (**Figure 3**).

3.1.2. Mode Analysis

The mode is the value that appears most frequently in a data sequence, and reflects the value that has an obvious central tendency point on the statistical distribution of the data. In this paper, we subtracted the data of the earthquake sequence in California to obtain the data sequence of the interval between earthquakes. The frequency statistical analysis was performed, and the earthquake period was extracted. The result is shown in **Figure 2(c)**. It can be seen that in the sequence of strong earthquakes in California, the most frequent cycles are 9, 12, 16, and 27 years, and here we used these cycles to forecast.

1) 9 years cycle
1989 1998 2007 2016 2025 2034
1992 2001 2010 2019 2028 2037
1994 2003 2012 2021 2030
1999 2008 2017 2026
2010 2019 2028 2029
2) 12 years cycle

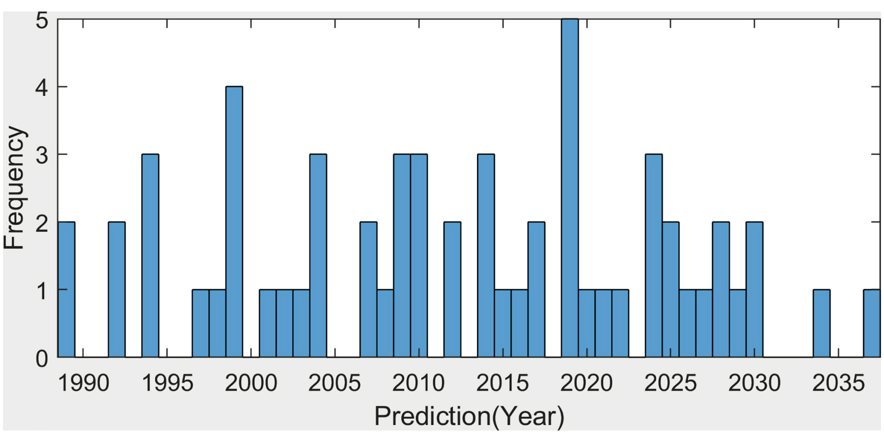

Figure 3. Earthquake prediction based on Fourier transform.

1989 2001 2013 2025

1992 2004 2016 2028

1994 2006 2018 2030

1999 2011 2023

2010 2022

3) 16 years cycle

1989 2005 2021

1992 2008 2024

1994 2020

1999 2015

2010 2026

4) 27 years cycle

1989 2016

1992 2019

1994 2021

1999 2026

2010 2037

According to statistical analysis, after M7 earthquake in southern California in 2010, the most frequent years are 2016, 2019, 2021, 2026 and 2028. Because there is no strong earthquake in 2016, so 2019 is the next most likely years (**Figure 4**).

3.1.3. Commensability Analysis

The commensurability of the earthquake sequence is an expansion of the earthquake periodicity, namely the mixed law that appears after periods of different lengths are superimposed on each other, which reflects the objective periodic order of strong earthquakes in the region, and it is valuable for earthquake prediction [6]. With the commensurability method, in 2006 Long Xiaoxia predicted that the next possible $M_s \geq 6.7$ earthquake in the Sichuan-Yunnan area was 2008, and the result was an M8.0 earthquake occurred in Wenchuan County, Sichuan Province on May 12, 2008 [7]. In 2008 Yan studied the trend of strong earthquakes in western China based on commensurability, and predicted that the

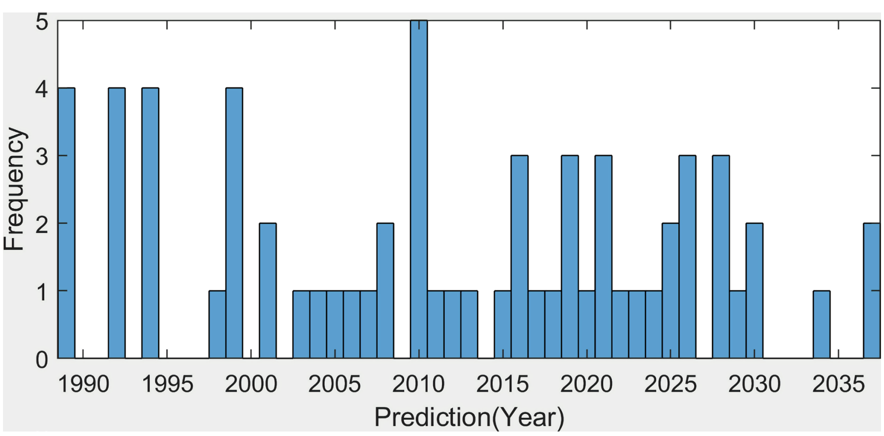

Figure 4. Earthquake prediction based on modal analysis.

next possible $M_s \geq 7.2$ earthquake in the Sichuan-Yunnan seismic zone would be 2010. As a result, a M7.1 earthquake occurred in Yushu, Qinghai on April 14, 2010 [8]. Here we use the quaternary commensurability method to predict the sequence of strong earthquakes in California. The formula is $X_a + X_b = X_c + X_d$, where X_a, X_b, X_c, and X_d are the earthquake occurrence years. The results show that 2019 is the year with the highest probability of earthquakes from 2015 to 2022 (see **Figure 5**).

3.2. Estimation of the Earthquake Month

We plot the month of 14 California earthquakes on the wind rose map. The most frequent are 5 times for April and October, 4 times for May and November, and 2 times for January and July which show obvious clustering. The above earthquake months are opposite each other, separated by half year, and appear as a straight line on the earth's orbit, which conforms to the 180-day periodic law we discovered [9]. In terms of frequency, most earthquakes occurred from April to July, and the fact is the strong earthquakes in 2019 occurred in July. At the same time, July, April, and October showed a vertical distribution. Therefore, based on the month of the historical earthquake, it is possible to estimate the month of the earthquake (**Figure 6**).

3.3. Estimation of the Epicenter Location

Earthquake migration is a phenomenon that earthquake shows a directional migration within an earthquake zone. Studies have shown that the earthquake has an orderly migration phenomenon on the Qilianshan fault zone, Xianshuihe fault zone and north-south seismic zone in many country [10]. In **Figure 7**, we list the migration process of earthquakes in California in terms of longitude and latitude. For latitude, there have been two earthquakes in California in history that occurred near the latitude about 32˚, and then went northward to 33.7˚ and 36.2˚. The M7 earthquake in 2010 occurred at N32˚, so it is speculated that the next earthquake should be around N34˚ - 36˚. The actual latitude of the strong earthquake that occurred in July 2019 is 35.7˚, which is consistent with the estimation. For longitude, there are 4 earthquakes that the longitude changes from

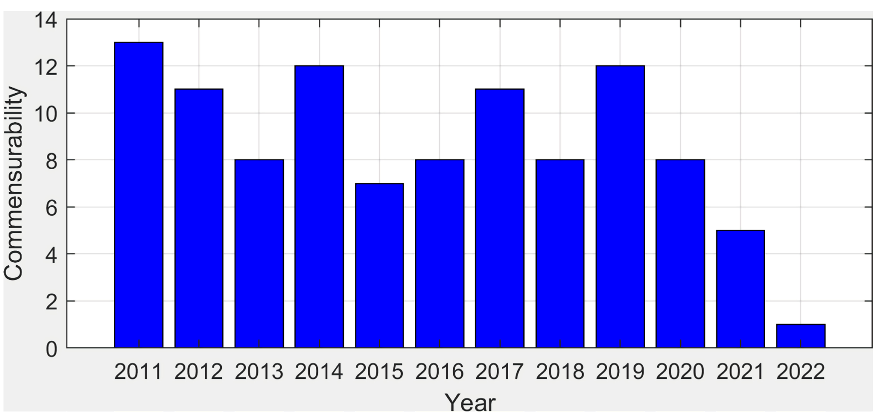

Figure 5. Earthquake prediction based on commensurability.

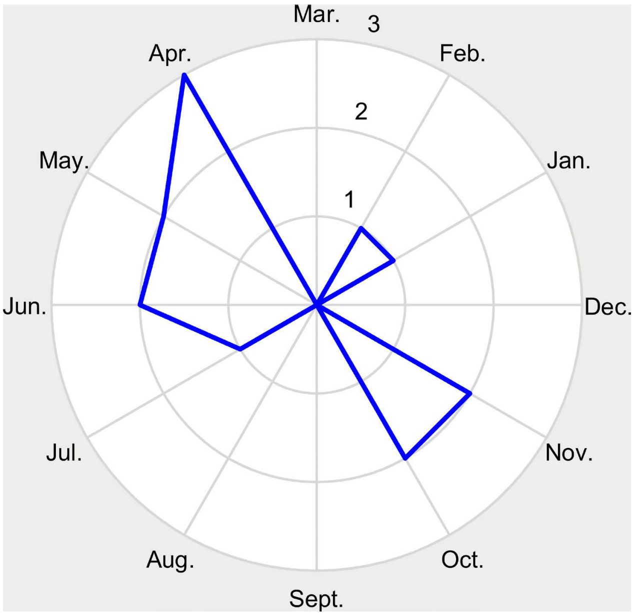

Figure 6. Wind rose map of the month of earthquakes.

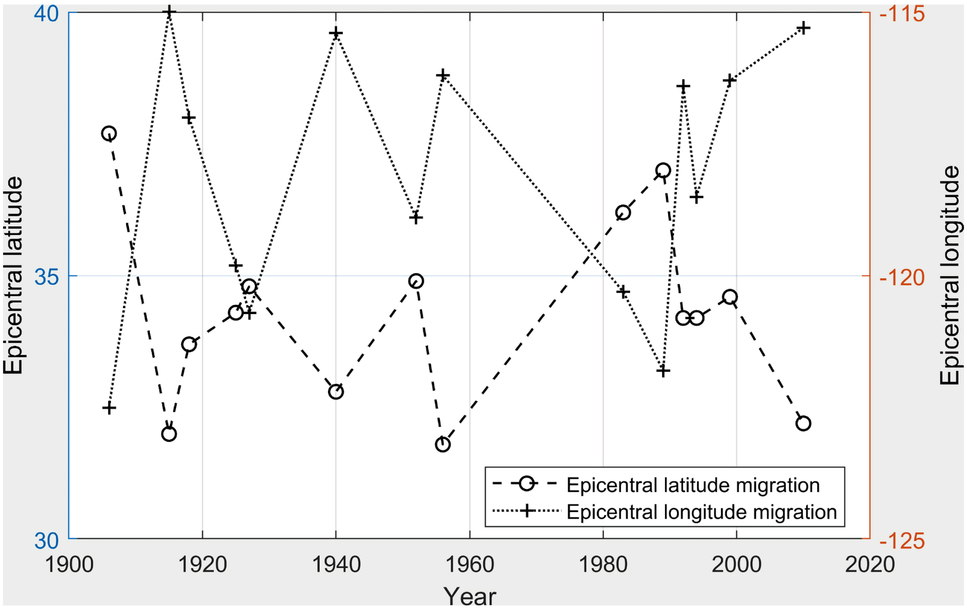

Figure 7. The epicenter shift pattern of the California earthquakes.

−115˚ to −117˚, from −115.4˚ to −118.9˚, from −116.2˚ west to −120.3˚, and from −116.4˚ to −118.5˚, and all the 4 earthquakes moved from east to west. The longitude of the strong earthquake in 2010 is −115.3˚. According to the above rules, it is speculated that the next strong earthquake will also move westward, possibly between −120˚ and −117˚. The actual longitude of the strong earthquake in July 2019 is −117.6˚, which is consistent with the estimation.

4. Conclusions

In 2018 we used Fourier transform, mode analysis, and commensurability analysis and predicted that California is most likely to have a strong earthquake of M6.7 or above in 2019, and the prediction was sent to the White House government, California Office of Disaster Mitigation, U.S. Geological Survey and other related agencies in 2018 and received their receptions. An M7.1 earthquake occurred in California on July 6, 2019. The facts have proved our prediction.

The method of USGS scientists can only give the probability of earthquake occurrence in the next 30 years. Our method can predict the earthquake occurrence period within 1 year, which shortens the time window greatly and is of great significance to disaster reduction and prevention in California. Through the month prediction analysis and the epicenter migration analysis, it is found that the law of California earthquakes is clear, and it is possible to use this law to predict the location and month of future strong earthquakes, which provides the possibility for disaster reduction and prevention.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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