MATEC Web of Conferences **189**, 11001 (2018) https://doi.org/10.1051/matecconf/201818911001
*MEAMT 2018*

# A method of identifying and analyzing Outgoing Long-wave Radiation anomalies before earthquake

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**Abstract.** A large amount of anomalous information will appear before the earthquake, but it is difficult to identify and analyze valuable anomalous information from large-scale data. To solve this problem, this paper presents a method of pre-earthquake Outgoing Long-wave Radiation (OLR) anomaly identification and analysis based on quantum walking algorithm. The National Oceanic and Atmospheric Administration (NOAA) data are used to process and analyze the OLR data before and after the 6 major earthquakes in 2017 in western China.The results show that different degrees of thermal infrared anomalies have appeared before and after these large earthquakes. In this paper, we also analyze and discuss the similarities and differences of these changes by combining geological conditions and other factors.

## 1 Introduction

China is a country with many earthquakes. In particular, in the western part of China, many earthquakes occur each year, posing a serious threat to people's lives and property in the western region.And satellite remote sensing technology is widely used by scientists to the research on the relationship between thermal infrared remote sensing and earthquakes. They hope to excavate useful pre-earthquake anomaly information and achieve more accurate prediction earthquake.

Zhang et al. [1] proved that there are obvious characteristic cycles and amplitudes and thermal anomaly distribution before and after the major earthquakes through the geostationary satellite remote sensing infrared temperature data. Kong et al. [2] used the geometric moving average martingale algorithm to analyze the change process of OLR data of NOAA satellite remote sensing, and anomaly the OLR data before Wenchuan earthquake and Lushan earthquake. In [3], eddy current calculation and wavelet transform were used to detect the anomalies of OLR data before earthquakes. Reference [4] conducted anomalous detection of OLR data and Total Electron Content (TEC) data by using the standard deviation threshold method and the quaternary-decay method in the Nepalese earthquake in 2015. The results show that in the vicinity of the epicenter within 3 days of the earthquake, satellites Remote sensing OLR abnormal increase phenomenon. At the same time, the TEC in the ionosphere near the epicenter shows significant positive anomalies and magnetic

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conjugation. However, although OLR data has been used as a new index of earthquake precursors anomalies, most of the existing achievements are mainly based on the research methods of geography, and the analysis of the results is mainly based on manual observation. Therefore, the experimental results are directly influenced by experts in the field and the influence of experience has great uncertainty on the judgment of the related anomalies before the earthquake.

Some researchers have started to use the anomaly detection algorithm in data mining to analyze earthquake anomalies. For example, Alarifi A S N proposed an artificial intelligence prediction system based on artificial neural network.It can predict the magnitude of future earthquakes in the northern Red Sea through data acquisition, preprocessing, feature extraction and neural network training[5]. Marzocchi et al. [6] used Bayesian estimation method to analyze seismic data to construct the overall earthquake prediction. Xiong et al [7] used wavelet transform to detect anomalies of OLR data before the earthquake. However, there are relatively few studies on the analysis of pre-earthquake anomalies based on the quantum walking algorithm, which is robust and is a feasible algorithm.

The main contributions of this paper are as follows: In this paper, Anomaly Identification and Analysis based on Quantum Walking algorithm for OLR data (AIAQW) is proposed based on Martingale theory [8]. The data mining algorithm applied to the field of earthquake research. In this paper, we take 6 earthquakes above 5.0 of magnitude that occurred in western China in 2017 as an example. By using this method, we can identify the thermal infrared anomaly characteristics and then analyze the data by signal amplification to find the anomalies before the earthquake. And through space comparison, look for the correlation between OLR data and earthquakes. The results show that proposed method is suitable for identifing and analyzing of pre-earthquake OLR anomalies. At the same time, it has an important reference for applying the data mining algorithm in the field of geography science.

# 2 Theory and method

## 2.1 Related data sources

In this paper, the OLR data of 2.5 ° longitude× 2.5 ° latitude grids provided by the NOAA of the United States is applied to study the 6 earthquakes of magnitude 5.0 above that occurred in western China in 2017:the earthquake in Zhongba, Yangbi, Tashkurgan, Jiuzhaigou, Jinghe and Kuche.Three earthquakes in Xinjiang are located in the same fault zone, which are used to monitor the existence and variation of thermal anomalies at different times in the same area . The other three earthquakes are used to compare thermal anomalies at different times in different regions . OLR data is divided into daytime data and nighttime data.In order to minimize the interference of daytime human activities and environmental factors such as sunlight, this paper uses nighttime data [9]. Specific earthquake related data shown in table 1:

**Table 1.** Seismic correlation information.

| Date(y-m-d) | Latitude(。N) | Longitude(。E) | Depth(km) | Magnitude(JMA) | Location |
|---|---|---|---|---|---|
| 17-02-01 | 30.67 | 83.34 | 8.0 | 5.0 | Zhongba |
| 17-03-27 | 25.89 | 99.80 | 12.0 | 5.1 | Yangbi |
| 17-05-11 | 37.58 | 75.25 | 8.0 | 5.5 | Tashkurgan |
| 17-08-08 | 33.20 | 103.82 | 20.0 | 7.0 | Jiuzhaigou |
| 17-08-09 | 44.27 | 82.89 | 11.0 | 6.6 | Jinghe |
| 17-09-16 | 42.11 | 83.43 | 6.0 | 5.7 | Kuche |

## 2.2 AIAQW method

In this paper, the pre-earthquake OLR anomaly identification and analysis based on discrete quantum walking algorithm. The principle of anomaly recognition based on quantum walking algorithm is as follows:

First, suppose that the coin operator is $U_C$ , the conversion operator is $U_S$ , and the evolution operator is $U$ . According to

$$U = U_S \bullet (I_P \otimes U_C) \tag{1}$$

calculate evolution operator [10].

At each step, the coin particles undergo a Hadamard transform, and then the moving particles move in the corresponding direction according to the state of the coin particles. Select the n data points before the current monitoring data point, and after the step, the whole state of the quantum walking is

$$|\psi_t\rangle = (U)^t \, |\psi_0\rangle \tag{2}$$

wherein, $|\psi_0\rangle = |P_0\rangle |C_0\rangle$ , $|P_0\rangle$ said the initial state of walking, $|C_0\rangle$ represents coin particles. Calculate the characteristics of the state of quantum stroll for each data point and obtain the feature sequence of state probability distribution of the current data point according to the walk of quantum.

Then, process the signature sequence obtained in the first step. Dataset $Z = \{z_1, \cdots, z_{i-1}\}$ represents historical data, $z_i$ representing the currently calculated data point. Obviously, when the activity of the geological plate is relatively stable, the sample distribution in $Z$ should be maintained at a relatively stable level with some similar characteristics between the samples. Therefore, the data set $Z \cup z_i$ can be treated as a time series.

As described above, let $m$ be the mean of all the data points in the set $Z \bigcup \{z_i\}$ .

Then the anomaly score is defined as the difference between this point and other points, that is, the degree of offset of $z_i$ for $m$ is as shown in equation (3):

$$s_i = s(Z, z_i) = \left\| z_i - m \right\| \tag{3}$$

where $\|\bullet\|$ defines the Euclidean distance measure. Based on the above definition, we define $\hat{p}_{i,k}$ to measure the data smoothness of the current point corresponding to $z_i$ . Calculated as shown in equation (4):

$$\hat{p}_{i,k}(Z \bigcup \{z_n\}, \theta_n) = \frac{\#\{j | s_j > s_i\} + \theta_{i,k} \#\{j | s_j = s_i\}}{i} \tag{4}$$

where $\#\{\ \}$ is a function that returns the number of samples that satisfy a given condition, $\theta_{i,k}$ is a parameter selected in the range (0,1), and $i = 1,2,\cdots n$ , $s_j$ is the point $z_j, j = 1,2,\cdots,i$ anomaly score calculated by equation (3).

Then, combined with Martingale's theory [8], calculate the degree of probability change $CD$ of data points according to equation (5):

$$CD_n^{(\varepsilon)} = \frac{\sum_{k=1}^{100} \prod_{i=1}^{n} (\varepsilon \hat{p}_{i,k}^{\varepsilon-1})}{100} \tag{5}$$

First calculate the corresponding Martingale value of each data point by calculating $\prod_{i=1}^{n} \varepsilon \hat{p}_{i,k}^{\varepsilon-1}$ , and then calculate $CD$ . According to [11], let $\varepsilon = 0.82$ and initialize $CD_0 = 1$ . Calculate the abnormality of each data point separately.

It can be seen from the calculation of equation (5) that the larger the $CD$ value, the more obvious the OLR anomaly before the earthquake.

Due to the severe crustal movement before and after a major earthquake, the OLR data may fluctuate in a short period of time. At this point, the $CD$ value increases rapidly in a short period of time, which may result in uncontrollable results. To solve this problem, a threshold $h$ is set as a stop parameter in this algorithm. The stop rule is as shown in equation (6):

$$CD_n \geq h \quad (6)$$

When a certain data point satisfies the condition of Eq. (6), the abnormality degree is very large. At this time, re-initialize the second step, and continue to calculate the remaining features of quantum stroll at each point to obtain a new feature sequence and calculate the remaining points abnormality.

## 3 Experimental results and analysis

The red vertical line in the following figures indicates the time of the earthquake. Experimental results show that:

1) Results of the Zhongba earthquake as shown in figure 1, a month before the earthquake, the epicentral region began to show anomalies and continued to the day of the earthquake. There were still abnormalities after the earthquake. The author believes that a wave anomaly appears again after the earthquake anomalies disappeared should be related to the 3.6 magnitude earthquake that occurred on July 16 in Zhongba.

The results of the earthquake in Yangbi County of Yunnan Province are shown in figure 2. Two months before the earthquake, the epicentral region began to show obvious anomalies and continued to the day of the seismogenic shock. There were still abnormalities within a short period of time after the earthquake. After 3 months there is a peak again. The occurrence of this anomaly coincides with the time period of the Lijiang earthquake in Yunnan Province on June 21, and the Yangbi and Lijiang are located in the same fault zone. Therefore, it is due to the earthquake.

The result of the earthquake in Jiuzhaigou, Aba Prefecture, Sichuan Province, is shown in figure 3. A small peak appeared between the 100th and 150th days. This period of time is not within the scope of this anomaly. The authors speculate that this may be due to a sudden temperature change or other factors. Two months before the earthquake, the epicentral region began to show obvious anomalies and reached the maximum anomaly value within one week before the earthquake. The anomaly disappeared about two months after the earthquake. This anomaly should be caused by aftershocks of the earthquake.

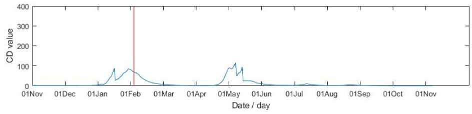


**Fig. 1.** Anomal value CD for each data point in Zhongba (2017-02-01).

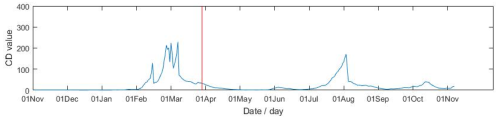


**Fig. 2.** Anomal value CD for each data point in Yangbi (2017-03-27).

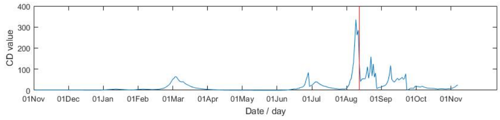


**Fig. 3.** Anomal value CD for each data point in Jiuzhaigou (2017-08-08).

Based on the above three earthquake cases, it can be concluded that before and after the earthquake, OLR data near the epicenter will be significantly abnormal changes. This further confirms the OLR data contains a large number of seismic anomalies. However, the abnormal trend can not be seen simply from the original OLR data images. This also shows the applicability and effectiveness of the proposed method based on quantum strolling algorithm for pre-earthquake OLR anomaly identification and analysis.

2) In order to further verify that the OLR anomalies between the earthquakes in the same fault zone would interfere with each other, the author takes the Xinjiang Region's districts of Taxkorgan on May 11, Jinghe on August 9, Kuche County on September 16 earthquakes are compared. The results shown in figure 4- 6.

There was a significant anomaly 6 months before the earthquake in Jinghe County. However, an earthquake occurred in Tashkurgan County three months before the Jinghe earthquake and another peak within two months after the earthquake in Taxkorgan County. During this period 5.7 earthquake occurred in Kuche area. OLR abnormalities coincide in time, to further demonstrate the author's guess.

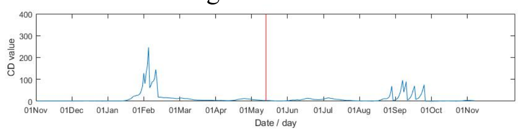


**Fig. 4.** Anomal value CD for each data point in Tashkurgan(2017-05-11).

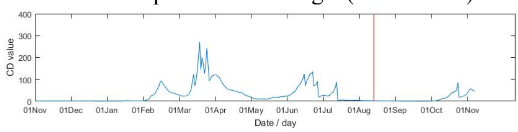


**Fig. 5.** Anomal value CD for each data point in Jinghe(2017-08-09).

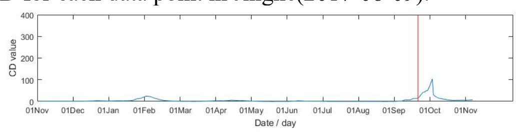


**Fig. 6.** Anomal value CD for each data point in Kuche(2017-09-16).

3) In order to further explain that the more the anomaly is, the more obvious the anomaly is, the more obvious the AIAQW extraction method proposed in this paper is. The author takes the Jiuzhaigou earthquake in Aba, Sichuan Province as an example, The results are shown in figure 7. The red vertical line on the way represents the earthquake time, the light cyan curve shows the abnormal value of the grid in the epicenter, and the other curves are the anomalies of 8 grids in the peripheral area.

As can be seen from figure 7, the CD values of grids 3, 4 and 9 which are close to the earthquake center exceed 300 and show obvious anomalies; the 5th grid value where the earthquake center is located is the largest with the most obvious anomalies; the CD value of grids 6,8 is greater than 100, less than 200; CD value of grid 7 is less than 100, the smallest anomaly. The experimental results show that the closer to the earthquake center, the more obvious anomalies.

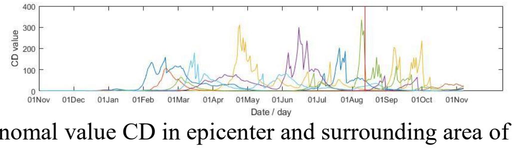


**Fig. 7.** Comparison of anomal value CD in epicenter and surrounding area of Jiuzhaigou earthquake.

## 4 Conclusion

This paper proposes a method of pre-earthquake OLR anomalies identification and analysis based on the quantum walk algorithm and uses this method to analyze anomal OLR data near the epicenter before and after the occurrence of 6 MS 5.0 earthquakes that occurred in western China in 2017 to explore the correlation between OLR data and earthquakes. It can be seen from the results that the OLR data contains abundant earthquake information. Meanwhile, the anomalous change of OLR data before the earthquake is closely related to the spatial location and geological conditions of the earthquake area. In addition, we can find from the experimental results in this paper that even if the original OLR values are not obviously anomalous, their corresponding anomal values will change a lot during the period before and after the earthquake. Compared with other traditional algorithms, the proposed method can objectively describe the anomalies of the data before and after the earthquake. The larger the value, the greater the abnormalies in the current data point. This not only further confirms that OLR data contains pre-earthquake anomaly information, but also provides a great possibility for the analysis of OLR data by using the quantum walking algorithm to predict earthquake. In this paper, some preliminary laws have been found between the anomal value corresponding and the OLR anomaly by using the proposed method. However, more seismic data needs to be collected and more comprehensive experiments conducted to further explore the correlation between the degree of change of anomalous values and seismic-related parameters such as seismogenic mechanism, seismogenic time, GPS, etc. .This is also the next research direction of this article.

## Acknowledgments

This work is partially supported by National Natural Science Foundation of China Youth Project (41601477), Fujian Province Pilot Project(2015Y0054), Fujian Provincial Natural Science Foundation(2016J01280).

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