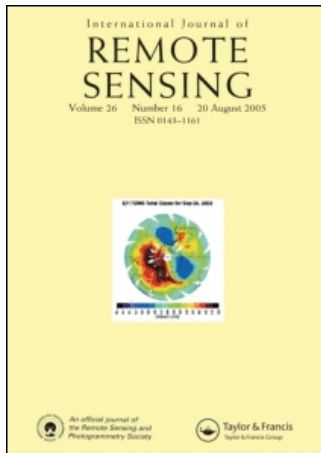


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Cloud anomaly before Iran earthquake

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Cloud anomaly before Iran earthquake

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In the 1980s Russian scientists found a thermal anomaly before an earthquake and abnormal cloud above an active fault. In the following 20 years, thermal anomalies were widely studied, however abnormal cloud was seldom reported. Here geostationary satellite sensor data was used to study the abnormal cloud above the Iran active fault. The linear traces with high temperature in thick clouds spread along the main tectonic structures. Sixty-nine days later a M6.3 earthquake occurred close to the abnormal clouds. The same clouds appeared on 25 December 2005 and 64 days later a M6.0 earthquake occurred. In these two cases, the abnormal clouds indicated the rough area of the future epicentre. If geophysical measurement data, satellite thermal data and abnormal cloud data are combined, it is possible that it will contribute to earthquake studies.

1. Introduction

In the 1980s Russian scientists found some short-lived thermal anomalies from satellite images before an earthquake in central Asia (Gorny *et al.* 1988). Since then many scientists have studied this thermal anomaly with satellite sensor data in Chinese, Japanese, Indian, Iranian and Algerian earthquakes (Qiang *et al.* 1990, Xu *et al.* 1991, Tronin 1996, Nosov 1998, Tronin *et al.* 2002, Ouzounov and Freund 2004, Saraf and Choudhury 2004, 2005). The short-lived thermal anomalies typically appear 7–14 days before an earthquake, affect several thousands or tens of thousand square kilometres, display a positive deviation of 2–4 K or more and disappear a few days after the event. However, it seems that few scientists noticed the other research put forward by Morozova (1997). She found some abnormal linear clouds above an active fault. A linear hole trace in a large thick cloud was observed by Russian satellite on 25 May 1984. She considered that the gas emitted from the earth rushed up to the sky, eroded the cloud, and formed the linear trace. This was called earth degassing and it was an good example of atmosphere–lithosphere coupling. Until now many researchers explained the thermal anomaly before an earthquake with the earth degassing hypothesis. Tadanori (2003) also observed an upward tornado-type seismic cloud over the epicentre region before the M7.2 Nanbu earthquake of 17 January 1995.

The above two methods—the thermal method and the cloud method—were all put forward by Russian scientists; while the former was widely studied, the latter was seldom reported. Maybe the reason was that the latter was difficult to quantify, while the former could be quantified easily. Here we studied the abnormal clouds over the Iran fault with geostationary satellite sensor data.

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2. Data and methods

Earthquake data is derived from Incorporated Research Institutions of Seismology supported by the US National Science Foundation. Meteosat-5 geostationary satellite data are derived from the Dundee Satellite station, and MODIS data are downloaded from Land and Atmospheres Archive and Distribution System of NASA (LAADS). The time resolution of Meteosat-5 geostationary satellite thermal infrared data is 1 h, so we can see the rapid change of clouds in a short time period. MODIS can not track this rapid change due to its low time resolution. However, it can give a detailed snapshot because its spatial resolution (250 m) is higher than geostationary satellite sensor data (about 5 km).

Thermal anomaly can be detected by comparing land surface temperature (LST) at different times, and LST is easily quantified. If the LST in one area is obviously higher than its average, it may be considered as a thermal anomaly. But how to quantified a cloud anomaly? Here we provide a new method to find this abnormal cloud. We put the cloud image series into a computer animation, and observe the cloud movement. When the clouds pass over an active fault, the cloud shape will change somewhat. According to this change we can identify the abnormal clouds.

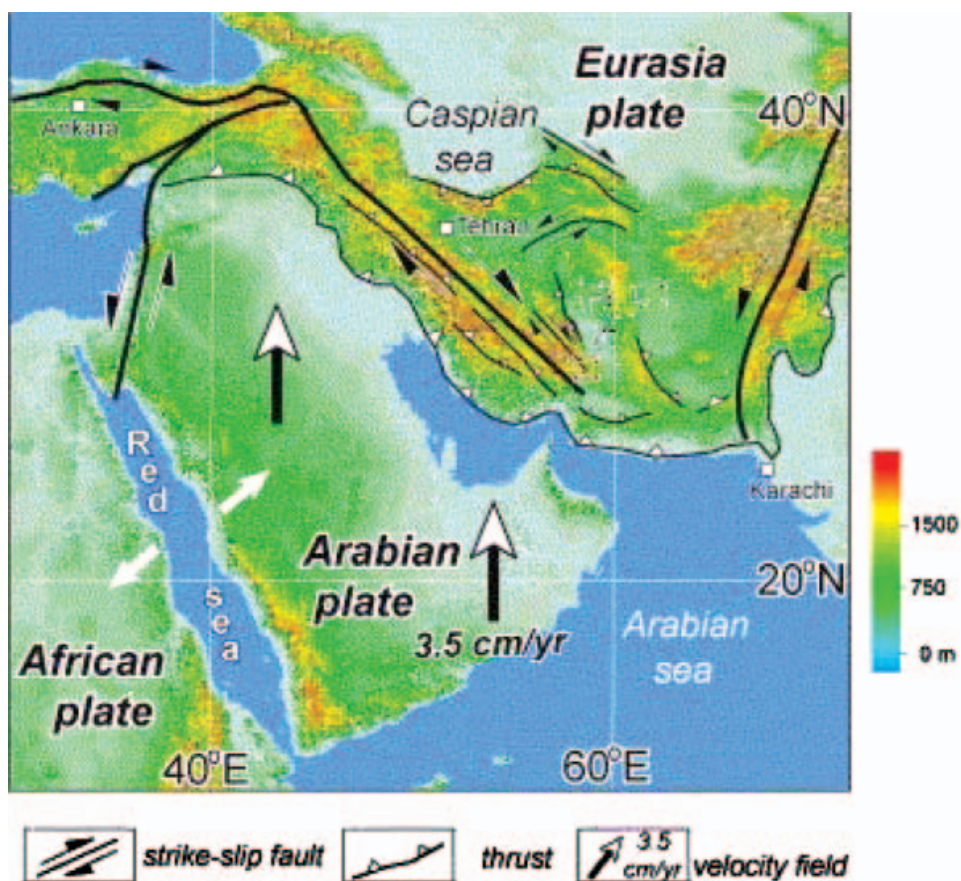


Figure 1. Sketch map of the Iran main fault.

3. Meteosat-5 data analysis

Figure 1 shows the main faults in Iran and the Arabian area. An active fault is located in south Iran and extends north-west to south-east. Figure 2 shows the image series of clouds movement on 15 December 2004. The white colour represents clouds with low temperature (about 240 K), and the black colour represents warm surface with a temperature of about 300 K. A black trace appeared in thick clouds at 07:00 UTC, it became clear at 10:00 and disappeared at about 14:00. The anomaly is that the black trace stayed there for about 7 h and did not move with wind. Current meteorology theory can not explain why the cloud is stationary under the wind blow. The clouds moved from west to east, while it could not cover the black trace. This meant warm atmosphere exited, when the cloud passed here, the liquid or solid water in cold cloud changed to invisible water vapour. So the land surface is visible as figure 3 shows. Two small black traces can be seen clearly at 09:00. All the traces spread from north-west to south-east, the same as the tectonic direction. Sixty-nine days later a M6.3 earthquake occurred at 30.74° N, 56.87° E. This is the only earthquakes bigger than M6.0 in 25–35° N, 50–60° E from 12 December 2004 to 12 November 2005.

On 26 December 2005 the same cloud appeared at the same place. A main black trace, together with two small traces, spread along the tectonic structure and stayed there for hours. Sixty-four days later, a M6.0 earthquake occurred at 28.12° N,

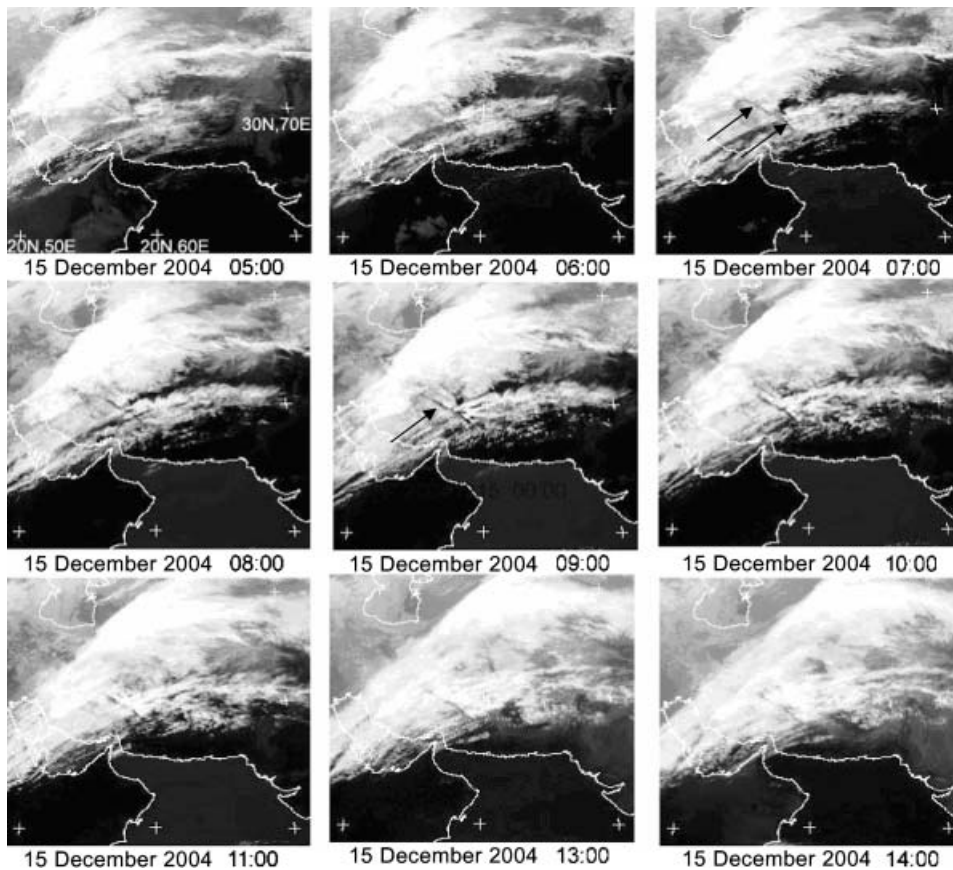


Figure 2. Cloud series images of Iran on 15 December 2004.

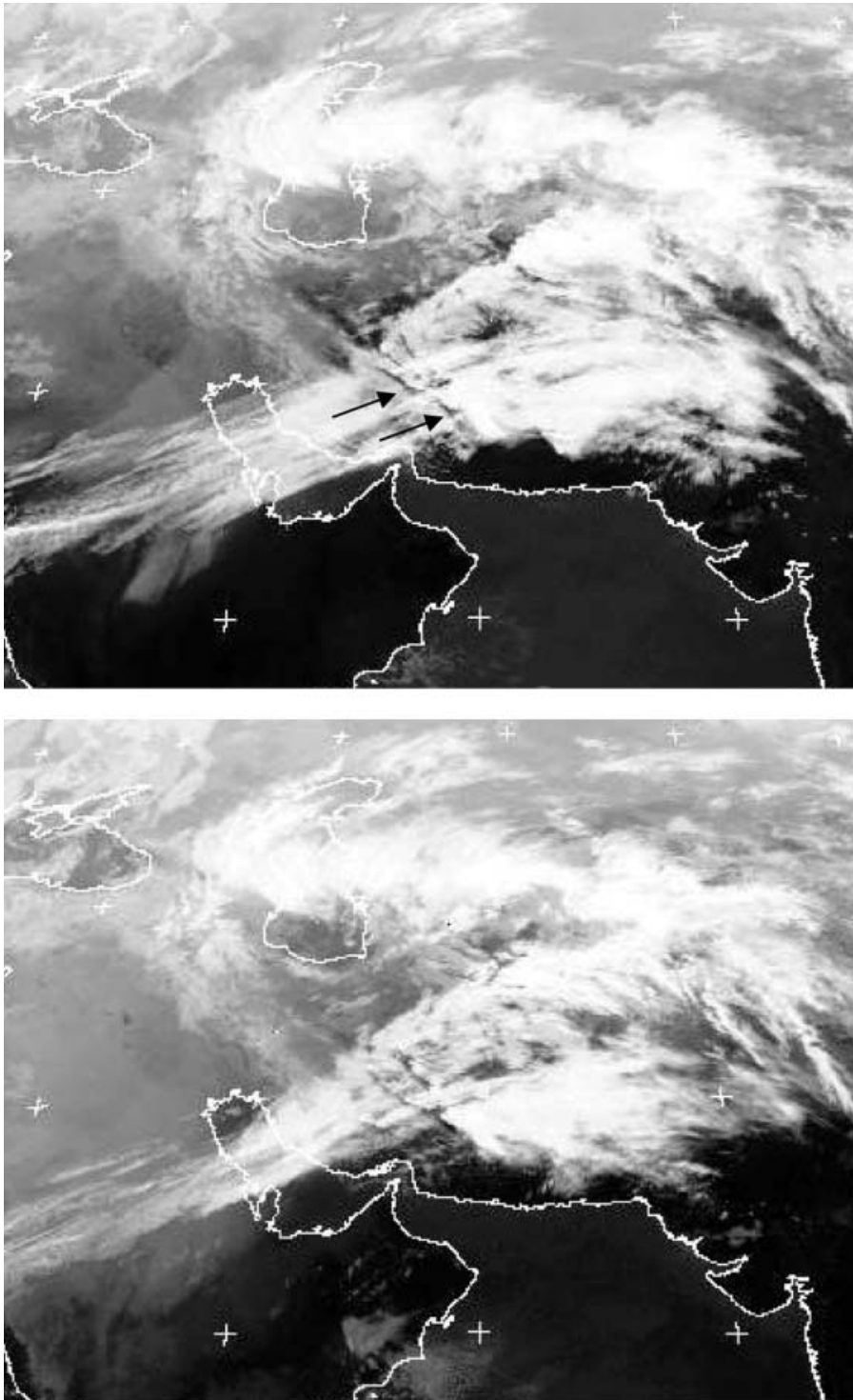


Figure 3. Cloud images of Iran on 26 December 2005. (a) 06:00 h, (b) 09:00 h.

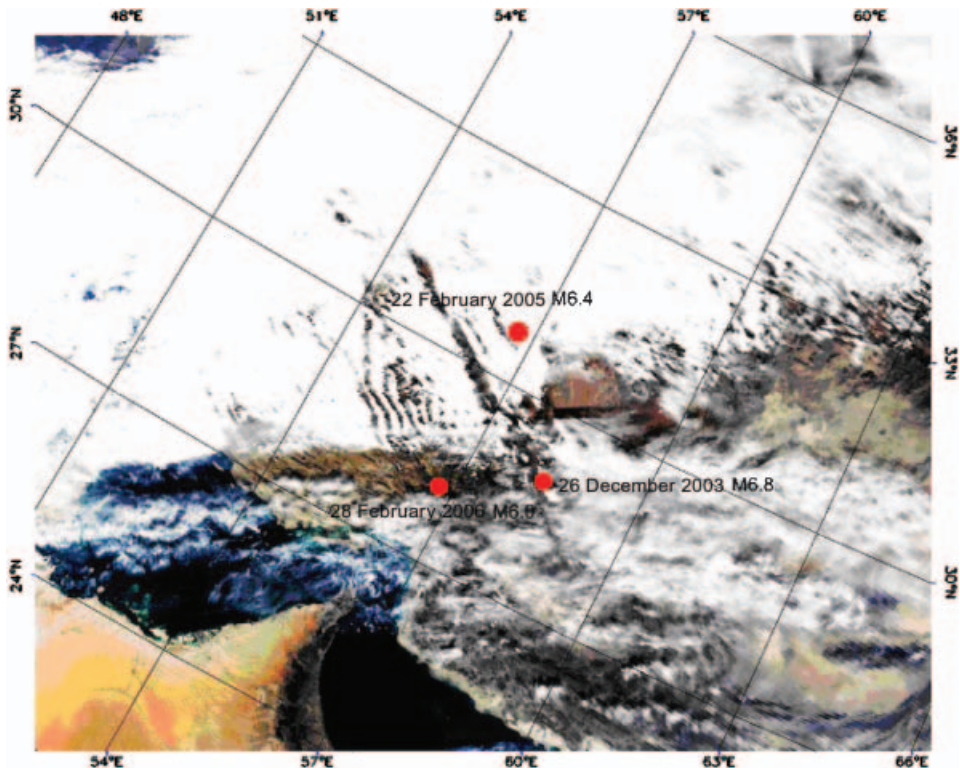


Figure 4. MODIS true colour image of Iran cloud, derived at 07:05, 15 December 2004.

56.86° E. This was the only earthquakes bigger than M6.0 in 25–35° N, 50–60° E from 26 December 2005 to 26 December 2006. We downloaded Meteosat-5 cloud images from 27 December 2005 to 28 February 2006, and found no similar clouds. This meant that the earthquake on 28 February 2006 was the only earthquake corresponding to the abnormal clouds on 26 December 2005. Note that the periods from the cloud appearance to earthquake occurrence were 69 days and 64 days. These periods are very similar.

4. MODIS data analysis

MODIS data derived at 07:05, 15 December 2004 showed more details of cloud anomaly than Meteosat-5 image due to its high spatial resolution. There were two small corridors above the main corridor, and six below. Three earthquakes are denoted with red dots (figure 4). Their distances to the main corridor are about 90 km and 150 km, respectively. The M6.8 Bam earthquake is located exactly in the main corridor. In Tronin's researches thermal anomaly is about 200–1700 km away from the epicentre (2002).

5. Cloud anomaly before the 26 December 2003 Bam earthquake

In Swapnamita and Saraf's research, they found a thermal anomaly before the 26 December 2003 Bam M6.8 earthquake. Figure 5 shows the thermal anomaly around Bam, however, it seems that they did not notice the clouds close to Bam. The cloud

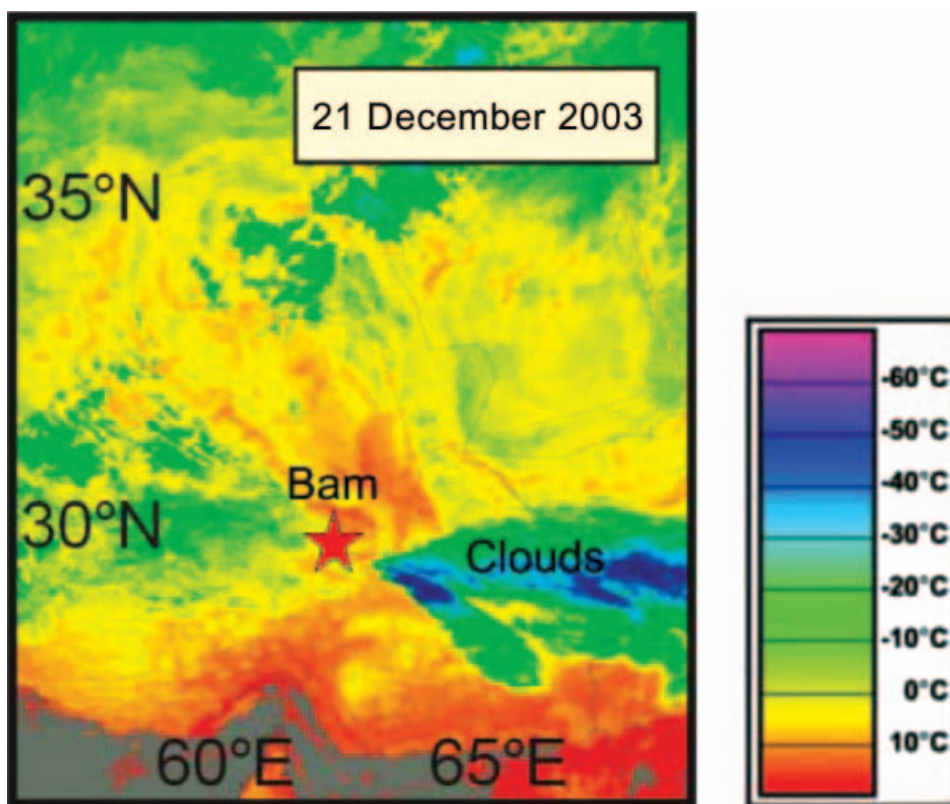


Figure 5. Thermal anomaly around Bam on the night of 21 December 2003 (Swapnamita *et al.* 2006). Note the strange clouds at the right side of Bam.

head pointed exactly at Bam; is there any relation between cloud and earthquake? Because the time resolution of the Advanced Very High Resolution Radiometer (AVHRR) data that Saraf used is low, it is impossible to identify these abnormal clouds with AVHRR data. Figure 6, provided by Shou (2004), showed the cloud movement. We can see that the cloud head stayed close to Bam, and did not move with wind, while its tail moved with wind. This is a clear difference between an earthquake cloud and a meteorology cloud. A reasonable explain is that stresses may build up in tectonically active regions; these stresses may bring about sub-surface degassing. Upon their escape to the atmosphere, these gases may be cooled and formed into clouds that can be seen. As there existed a stable gas source, this cloud seemed to be stationary around the future epicentre. It looks very much like smoke emitted from a chimney. Liperovsky *et al.* (2005) constructed a model that proposed that aerosols, increased ionization velocity and upstreaming air flows above an active fault could lead to abnormal electric fields, infrared emissions and abnormal clouds. This model showed that abnormal clouds can be formed above an active fault.

6. Result and discussion

In this paper we used geostationary satellite sensor data and found abnormal clouds related with seismic activity. Two earthquakes occurred 69 and 64 days after the

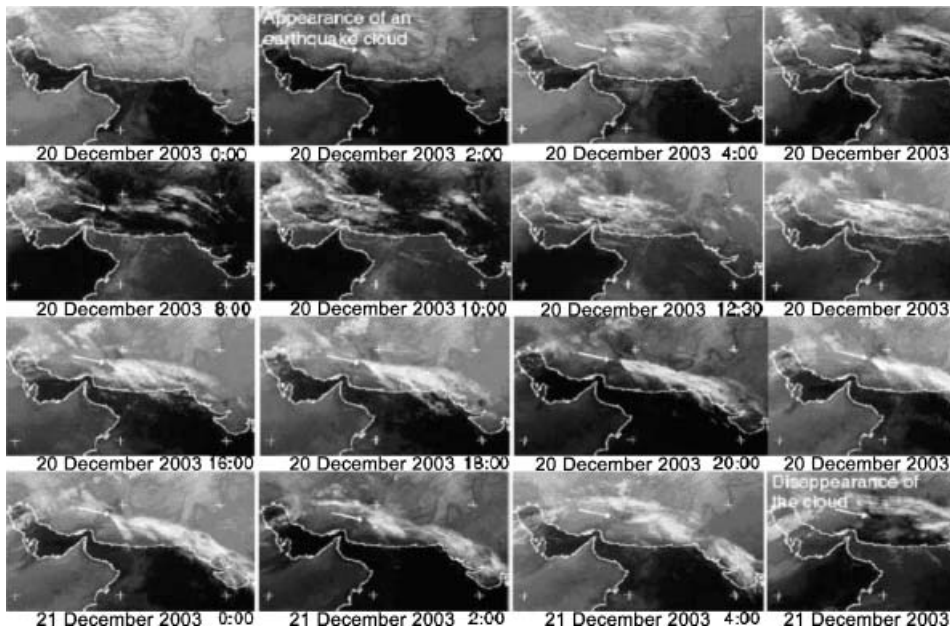


Figure 6. Cloud images of Iran for 20 and 21 December 2003 (Shou 2004).

abnormal cloud appearance, respectively. We considered that cloud anomaly and thermal anomaly were both related with the earthquakes. Their mechanism is still unknown, although some rock cracking experiments have been carried out to try to explain the anomaly. Qiang's earth degassing theory (1990), Freund's P-holes theory (2002), or Liperovsky's ionization theory (Liperovsky *et al.* 2005), whichever it is, it is beyond this paper's scope. Sometimes thermal data can not be used due to thick clouds, while the cloud anomaly method can be used in any weather conditions. If the two methods, thermal anomaly and cloud anomaly, are combined together with other geophysical methods, it will help the study of earthquake. Of course it will take a long time to predict earthquakes with satellite sensor data.

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