STUDYING THERMAL ANOMALY BEFORE EARTHQUAKE WITH NCEP DATA

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ABSTRACT:
Thermal anomaly before earthquake was widely studied with satellite data such as NOAA/AVHRR and MODIS. A big disadvantage is that satellite thermal sensor can not penetrate thick clouds to retrieve surface temperature, so some thermal anomaly information was lost. Until now many research showed that the distance between thermal anomaly and future epicenter is too far that it is difficult to estimate the possible epicenter with these anomalies. Here we introduced NCEP Reanalysis data which was widely used in atmosphere research area, and found the thermal anomalies before earthquakes. According to this anomaly we can verify the possible epicenter within a reasonable spatial error of about 1 degree. This promising method is easy, quick and low cost compared with the traditional geophysical method. If other geophysical method is combined with this method together, the accuracy may be promoted.

1. INTRODUCTION

In 1980's Russian scientists found some short lived thermal anomalies from satellite image before earthquake in central Asia (Gorny et al., 1988). Since then many scientists began to study this thermal anomaly with satellite data in China, Japan, India, Iran and Algerian earthquakes (Qiang et al., 1990; Xu et al., 1991; Tronin, 1996; 2002; Saraf et al., 2004; Ouzounov & Freund, 2004). The short-lived thermal anomalies typically appear 7–14 days before an earthquake, affect several thousands or tens of thousands square kilometres, displayed a positive deviation of 2–4K or more and disappeared a few days after the event.

A big disadvantage of this method is that satellite thermal sensor can not penetrate thick clouds to retrieve surface temperature. So continuous temperature data can not be retrieved and some thermal anomaly information was lost. This leads to difficulties in predicting earthquake with satellite thermal data. Here we used temperature data provided by National Centers for Environmental Prediction (NCEP) and found that NCEP can also detect thermal anomaly before earthquake. This data is generated with satellite data and weather station observation data every six hours and they can provide thermal information continuously, which showed a big advantage than single satellite data. With these data we may verify the possible epicenter within a reasonable spatial error of about 1 degree. This provides a promising method in predicting earthquake.

2. DATA AND METHOD

The National Centers for Environmental Prediction (NCEP) of NOAA provided global air temperature, humidity, pressure, sea surface temperature and so on every six hours with 1 degree resolution. NCEP used a state-of-the-art analysis method to perform data assimilation with ground weather station data and satellite data. These data has no such problem as clouds cover or interpolation, it is continuous and this provides a reliable data base to analyze thermal anomaly before earthquake. In this The National Centers for Environmental Prediction (NCEP) of NOAA provided global air temperature, humidity, pressure, sea surface temperature and so on every six hours with 1 degree resolution. NCEP used a state-of-the-art analysis method to perform data assimilation with ground weather station data and satellite data. These data has no such problem as clouds cover or interpolation, it is continuous and this provides a reliable data base to analyze thermal anomaly before earthquake. In this research we use the subtraction method to get the temperature difference of the same time in 2 days. If there existed an isolated high temperature area within the low temperature background, and the high temperature area existed more than 6 hours, we considered it as an earthquake thermal anomaly. If the thermal anomaly was caused by meteorological factor, the temperature gradient must change gradually in a large area, not in an isolated area. According to this anomaly, we may predict the future epicenter.

3. EARTHQUAKE EXAMPLE

3.1 Example 1

A M6.7 earthquake occurred at 37.281°N, 136.602°E at 00:41:57 (UTC) March 25, 2007 (USGS). The NCEP data showed that surface air temperature increased about 6.2K at N37.5°, E136.5° at 18:00 (UTC) March 23 compared to the temperature of March 22 (Figure 1). The areas without obvious temperature increase are shown with grey, blue and green, and the area with higher temperature is shown with yellow and red. We can see that the high temperature center corresponded to the future epicenter well. Their distance is about 25km. We checked the temperature from February 25 to March 25, and found no other similar thermal anomaly, so we considered that this temperature increase at March 23 was caused by earthquake. According to the USGS earthquake catalogue, there are 23 earthquakes bigger than M4.5 in December 25 2006 to March 25 2007 in N32-42°, E131-141°. The M6.7 earthquake is the only one that located in the thermal anomaly area, the rest 5 small earthquakes are the aftershock occurred on the same day (Figure 2).The air temperature of the closet weather station to the epicenter (about 28km away) showed that it got its maximum with 14.7°C at 24:00 (local time) and still increased to 14.9°C at 01:00 (local time) on March 25, even bigger than that at 14:00 (Figure 3).

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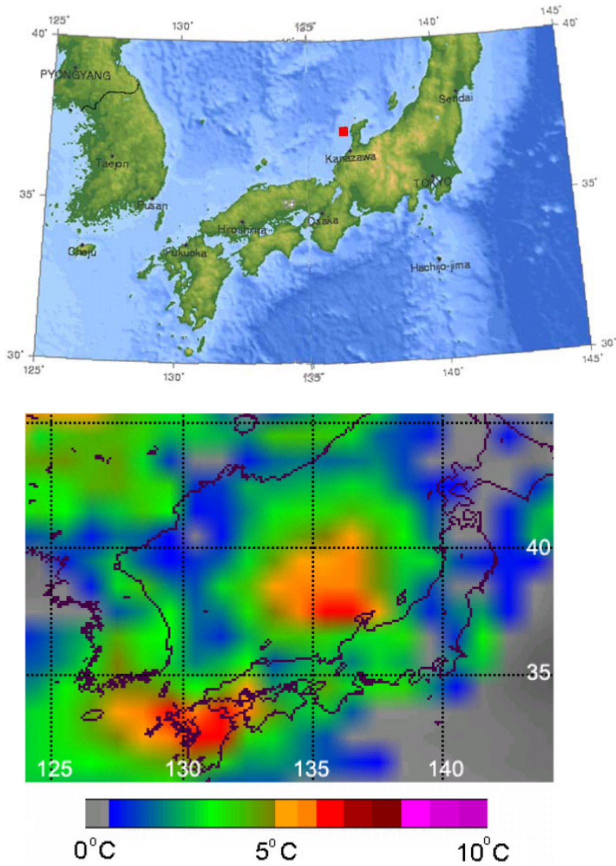

Figure 1. The location of M6.7 earthquake of Japan (USGS) and the temperature anomaly before this quake

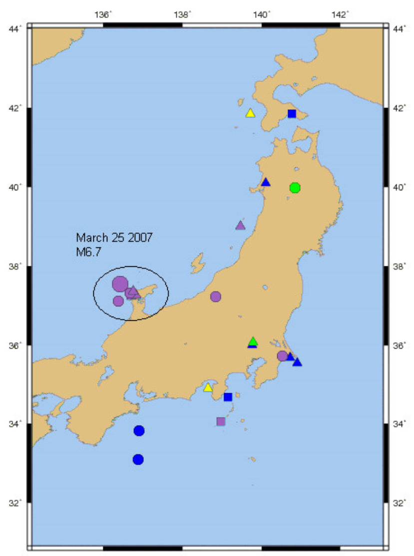

Figure 2. All earthquakes bigger than M4.5 from December 25 2006 to March 25 2007 in N32-42^{o}, E131-141^{o}

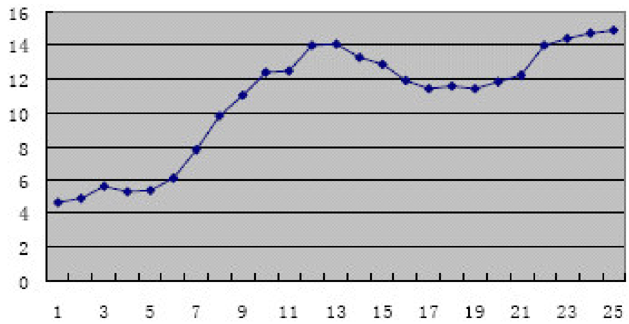

Figure 3. Air temperature change of Wajima weather station (N37^{o}23.5', E136^{o}53.7') on April 24

3.2 Example 2

Three earthquakes with M6.3, M6.5, M6.0 occurred at N25.7, E125.1 on April 20, 2007 according to Chinese Seismic Bureau. The magnitude reported by USGS is M5.7, M6.2 and M5.9. This does not affect our research. The NCEP data showed that surface air temperature increased about 3.5K at N25.5°, E125.8° (see the blue point in figure 4) at 12:00 (UTC) and 8k at 18:00 (UTC) April 17 (see the red point in figure 4). The air temperature data measured by JMA (Japan Meteorological Agency) (Miyako-jima weather station: N24°47.6'，E125°16.6') which is about 100km away from the epicenter, showed that the daily day-night difference temperature got to its maximum on April 20, and this was the maximum value in March, April and May. So we considered that this is a clear anomaly caused by earthquake.

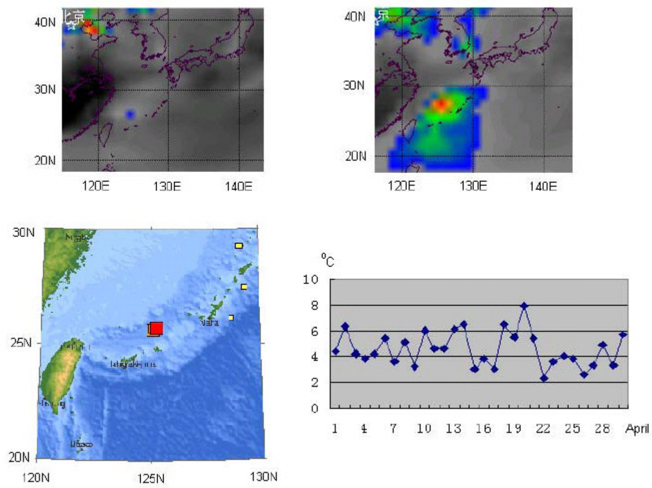

Figure 4. The thermal anomaly in April 17 (top) the location of three earthquakes in April 20 (USGS), and the temperature change of Miyako-jima weather station

3.3 Example 3

The same thermal anomaly appeared 16 days before the M4.9 earthquake occurred at 11:41 February 25, 2007(Figure 5). The temperature around the future epicenter increased about 5K.

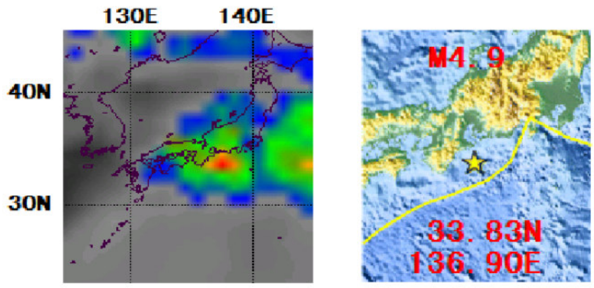

Figure 5. The location of M4.9 earthquake of Japan (USGS) and the temperature anomaly before this quake

3.4 Example 4

The most interesting picture is the temperature change before the three Sumatra earthquakes occurred on February 8, 11 and 12 in 2007 with M5.0, M5.7 and M5.0 respectively. Four high temperature centers appeared on January 16 2007, and the right three centers corresponded to the three epicenters well (Figure 6). This phenomenon is the first time that appeared in our one year's research. So we consider that this is a clear anomaly.

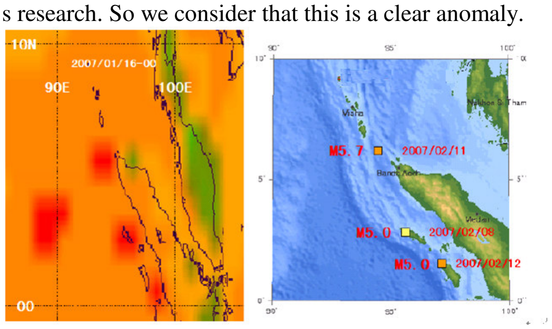

Figure 6. Three earthquakes around Sumantra and three temperature anomalies correspond to their epicenter espectively

Usually there exist many thermal anomalies in NCEP data, and of course not every thermal anomaly corresponded to one earthquake. NCEP provided a quick, easy method to make early warning in global coverage with very low cost compared with traditional geophysical method. This early warning is coarse, so we need other data such as active fault position, earthquake history data, geophysical data and so on to reduce the false alarm. In March and April 2007 we used this multi-method and made 30 early warnings. The average latitude error is $0.89^{o}\pm0.71$ and longitude error is $0.94^{o}\pm0.77$. 66.7% of latitude and 63.6% of longitude is less than 1 degree. In the 30 examples there existed one false alarm that the earthquake did not occur.

4. DISCUSSION AND CONCLUSION

In this research we first introduced NCEP data into earthquake early warning area and found that thermal anomaly before earthquake can also be detected with NCEP data. Because satellite sensor can not get land surface temperature when there exists thick clouds, this will lead to data discontinuity, while NCEP can provide continuous data, so here NCEP showed an advantage over satellite data. This research showed that NCEP can also detect thermal anomaly as satellite data. It is free and easy to process; it is widely used in atmosphere research while people in earthquake research seldom used it. So here our first aim is to introduce this new data source to earthquake researcher.

Second, of course there existed many thermal anomalies in NCEP data, and not every thermal anomaly corresponded to one earthquake, but on the contrary, in our 30 examples, if there is an earthquake, there existed thermal anomaly before this quake. So NCEP provides an easy, early, and coarse warning. In the Parkfield experiment, hundreds of sensors with millions of dollars were distributed in a small area. Parkfield mode can not be applied into the whole earth everywhere due to its expensive price. NCEP data and satellite data may be the hope to resolve global earthquake prediction problem.

Third, how to reduce the false alarm of NCEP data is still need to be improved. We think that any sole data, any sole method, can not solve earthquake prediction fully. NCEP data, together with fault position, earthquake history, geophysical data and so on may be used to reduce false alarm. Our 30 examples showed that the average distance error between thermal anomaly and epicenter is within about 1 degree. While in previous researches the distance is about 100-1000km away, and the possible epicenter is difficult to be verified from the large areas of thermal anomaly found in satellite image. In this research we reduced the distance to about 1 degree which is limited by out data source. Though the mechanism of the thermal anomaly is not clear, it still provide some useful information about impending earthquake. If this method is combined with other geophysical methods, maybe it will produce an estimate of future epicenter within reasonable distance error.

5. ACKNOWLEDGEMENTS

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