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Abnormal infrasound signals before 92 $M \geqq 7.0$ worldwide earthquakes during 2002–2008

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ABSTRACT

In this paper, 240 abnormal infrasound signals observed at Beijing (39.87°N, 116.48°E) and 92 $M \geqq 7.0$ worldwide earthquakes during 2002–2008 are investigated. It is found that about 85% the earthquakes are preceded the signals by 1–30 days and the greater $M \geqq 7.6$ earthquakes are most likely leaded by 1–10 days. The maximum amplitude of the abnormal infrasound signal generally exceeds 8 Pa in sound pressure. The statistical analyses further indicate that the amplitude of the abnormal signals is proportional to the magnitude the associated forthcoming earthquake but inversely to the distance from that earthquake to the observation station.

1. Introduction

Earthquake prediction is a worldwide issue; scientists have been devoting time and effect on seeking an effective way and/or a reliable precursor for earthquake prediction over several decades. It has been widely accepted that whether the prediction method is valid and useful depends on the score of three factors of an earthquake, magnitude, time, and location. Mutschlecner and Whitaker (2005) indicate that an earthquake generates atmospheric infrasound (i.e. very low frequency sound) by the low-frequency oscillation of the earth's surface near the epicenter and surrounding regions. The waves then travel through the atmosphere where they are refracted by the effects of the variations of sound and wind velocities with height. They suggest that the waves are ducted back toward Earth from regions near 50 km in altitude and return to Earth at distances of about 200–250 km from the source (Mutschlecner and Whitaker, 2005). The waves are efficiently reflected from the surface and may be transmitted by multiple "bounces" to more distant regions. Two possible mechanisms have been proposed (Mutschlecner and Whitaker, 2005): Near the epicenter the infrasound is generated by the local ground motion (body waves or Rayleigh waves), and in regions far from the epicenter, the infrasound may be induced in the interaction of surface waves with topographic features, such as mountains, by a diffraction process. Although, signatures triggered by co-seismic ground motions and/or surface waves has been studied by many researchers (see papers listed in Mutschlecner and Whitaker (2005)), anomalous infrasound signals before large earthquakes have not yet been formally reported in detail.

A prototype (analog) infrasound system (Fig. 1) has been routinely operated more than 20 years at Institute of Earthquake Prediction (IEP) at Beijing University of Technology for the imminent earthquake prediction since 1982 (Li et al., 2002a–c). Based on the 20s-year observations and experiences, Li et al. (2002a–c) report that abnormal infrasound signals tend to appear several days before large earthquakes. In general, an abnormal infrasound signal follows by a worldwide $M \geqq 7.0$ earthquake about 9 days. Li et al. (2002a–c, 2008) further show that the errors of the predicted occurrence time and magnitude are less than ±4 days and ±0.8, respectively. Based on the experiences of the analog infrasound system, an advanced (digital) infrasound system was constructed in 2000 and finalized by 2002 (Fig. 1). The advanced system not only has a better sensitivity and also adding a digital recording function. Therefore to validate the existence of pre-earthquake infrasound, this paper statistically investigates abnormal signals before 92 $M \geqq 7.0$ worldwide earthquakes during a 7-year period of 2002–2008 (Fig. 2).

2. Observation and data analysis

The infrasound system consists of an infrasound sensor, power supply, and data logger. The CC-1T type of capacitive sensor is developed by Institute of Acoustics in Chinese Academy of Science (Fig. 1). The sensor has a sensitivity of 0.01 Pa with the frequency range 0.5–200 s and a dynamic range of 80 dB (Xie, 1991). Both the analog and digital systems are rather stable and long-life and

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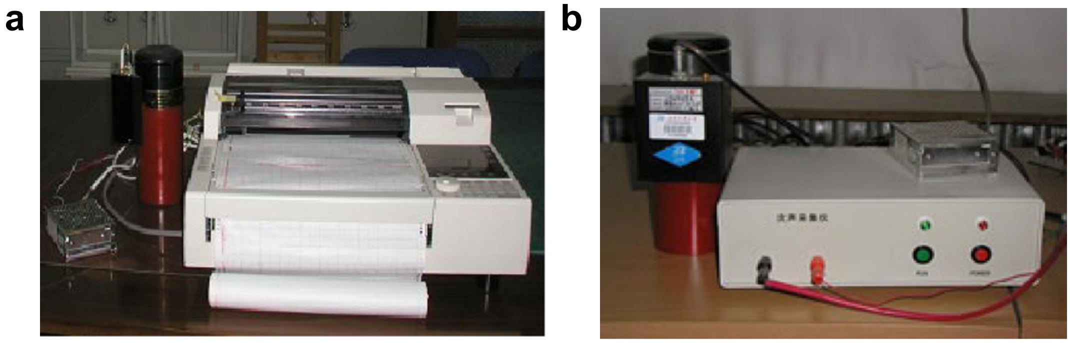

Fig. 1. The infrasound systems: (a) analog and (b) digital systems. The sensor/detector (red cylinder), power supplier (electronic box) and data logger (chart recorder or GPS/digitizer). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

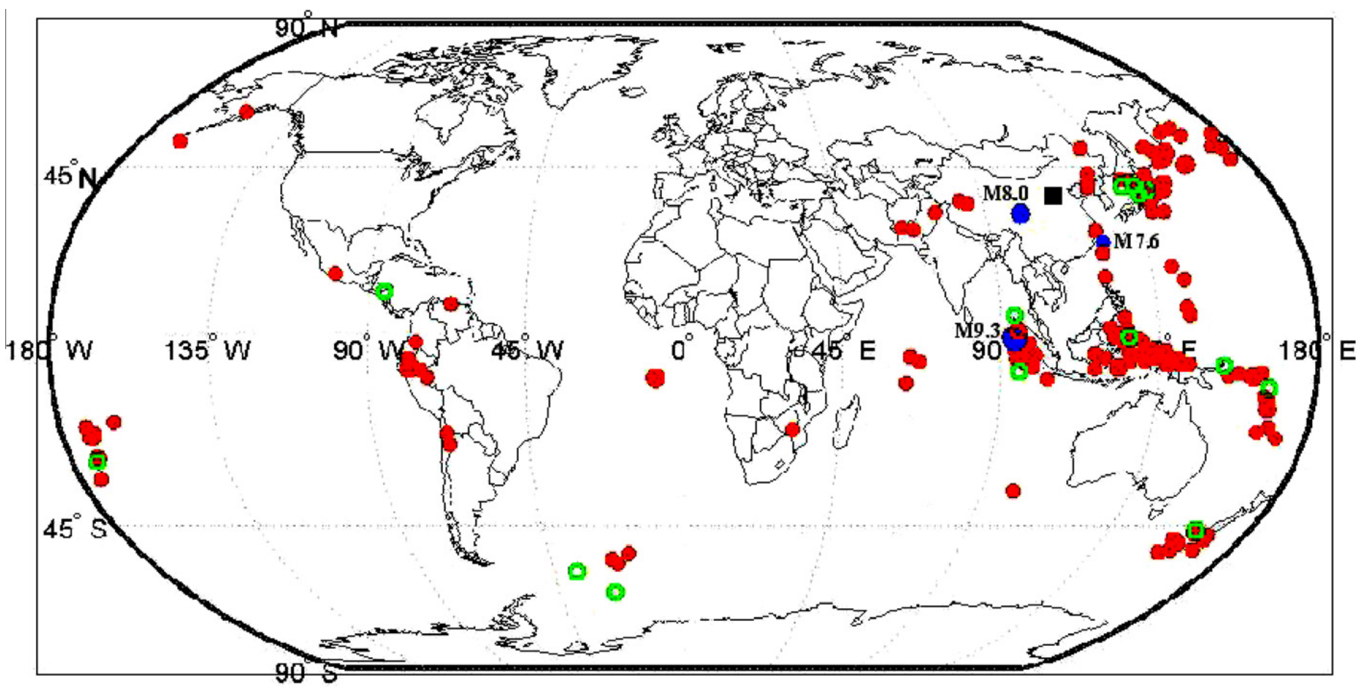

Fig. 2. Locations of 92 $M \geqq 7.0$ worldwide earthquakes during 2002–2008. The red solid and green open dots denote the earthquakes with and without preceded abnormal infrasound signals. The blue dots highlight the January 17, 1995 M7.2 Kobe Earthquake, the September 21, 1999 M7.6 Chi–Chi Earthquake, the December 26, 2004 M9.3 Sumatra Earthquake, and the May 12, 2008 M8.0 Wenchuan Earthquake. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

have been long-term continuously operated in IEP (39.87°N, 116.48°E) since 1982 and 2002, respectively.

The systems have been often registering abnormal infrasound signals before $M \geqq 7.0$ worldwide earthquakes. Fig. 3 reveals typical features of the abnormal infrasound signals of the M7.6 September 21, 1999 Chi–Chi Earthquake, the M9.3 December 26, 2004 Sumatra Earthquake (Li et al., 2006; Xia et al., 2005a,b) and the M8.0 May 12, 2008 Wenchung Earthquake (30.9°N, 103.4°E) recorded by the analog and/or digital systems. Fig. 3a and b illustrates the signals with a frequency range 0–0.02 Hz and a maximum amplitude, V_m, 1100 mV, which is equivalent to sound pressure of 8.8 Pa, appearing at 16:00–16:40BJT (Beijing local time) on day 3 (September 18) before the 21 September 1999 M7.6 Chi–Chi Earthquake. Fig. 3c and d displays the signals with a frequency 0–0.005 Hz and a maximum amplitude 2100 mV (or 16.8 Pa), at 03:00–04:00BJT on day 7 (December 19) before the 24 December 2004 M9.3 Sumatra Earthquake. Fig. 3e and f depicts that the signal with a frequency 0–0.004 Hz and a maximum amplitude 3300 mV (or 26.4 Pa) appears at 04:00–06:40BJT on day 10 before the 12 May 2008 M8.0 Wenchung Earthquake. It can be seen that the signals of the Chi–Chi Earthquake and Sumatra Earthquake are very similar except the former is in an invert-N shape while the later has an N shape. By contrast, the Wenchuan signal is much more fluctuated and superimposed with some higher frequency waves.

Usually in an abnormal signal occurs in a day. However, before some large and nearby earthquakes, such as the Wenchuan Earthquake, multi abnormal signals could be observed. For multi abnormal signals, we denote the largest one. For simplicity, we first examine the relationship between 240 days of the abnormal infrasound signal and the 92 $M \geqq 7.0$ earthquake days during the 7-year of 2002–2008 (Fig. 4). Therefore the background occurrence rate of the infrasound signals in the 7-year period is $9.4\% = 240/(365 \times 7 + 2)$. Table 1 summarizes the nearest abnormal day before the earthquake. Fig. 5 superimposes (or bins) the abnormal signals 30 days before to after the earthquakes. We further compute the