Geomagnetic pulsations caused by the Sumatra earthquake on December 26, 2004

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Published in: Geophysical Research Letters
DOI: 10.1029/2005GL024083
Publication date: 2005

Citation for published version (APA):
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1. Introduction

A long period Pc5 pulsation was observed at Phimai in Thailand, shortly after the origin time of the Sumatra earthquake on December 26, 2004. The localized nature and the period of oscillations suggest that the long period magnetic pulsation was generated by dynamo action in the lower ionosphere, set up by an atmospheric pressure pulse which propagated vertically as an acoustic wave when the ocean floor suddenly moved vertically. It is speculated that a Pc3 type pulsation observed at Tong Hai in China, 10 degrees north of Phimai in latitude, was the result of magnetic field line resonance with a magnetosonic wave generated from the electric and magnetic fields of the dynamo current caused by the Earthquake.


2. Observations

In the following, ‘ALat.’ means magnetic Apex latitude defined by VanZandt et al. [1972] which is suitable for analyzing ionospheric phenomena near geomagnetic equator; N and E are geographic latitude (North) and east longitude, respectively. Fluxgate magnetometers at Phimai (15.2N, 102.6E, 7.0ALat.) in Thailand, Tong Hai (24.0N, 102.7E, 16.6ALat.) in China and Aso (32.9N, 131.0E, 25.5ALat.) in Japan were in operation with a sampling rate of 1 second at the time of the Sumatra earthquake. The earthquake origin time was 00:58:53UT (Universal Time) when the three observatories were in the sunlit hemisphere where the ionosphere is conductive.

Figure 1 shows the geomagnetic measurements from Phimai and Aso for the period from 00:30UT to 02:30UT on December 26, 2004. H, D and Z indicate magnetic north, east and downward components in nanoteslas (nT), respectively. The vertical dotted line indicates the origin time and the vertical solid line indicates the onset time of a long period (about 3.6 minutes) pulsation at Phimai. At Aso, no similar pulsation is seen. Although it is not shown here, there was also no pulsation with similar frequency at other Chinese stations such as Urumqi (43.8N, 87.7E, 38.3ALat.) or Lanzhou (36.1N, 103.8E, 29.7ALat.).

Figure 2 shows the data from Tong Hai for the period from 01:08UT to 01:20UT. Although the longitudes at Phimai and Tong Hai are almost the same and the difference in latitude is only 10 degrees (i.e., about 1000 km), the oscillation with a period of 3.6 minutes is not appreciable there. However, we see a Pc3 type oscillation with a period of about 30 seconds. We have checked the data from other stations such as Phimai, Lanzhou, Urumqi and Aso, however none of them showed Pc3 activity at the time.

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0094-8276/05/2005GL024083
measurements from Phimai and Aso, we subtracted the fluctuation at Aso from Phimai normalizing the amplitude with the amplitude ratio between them before the earthquake, i.e., we multiplied the fluctuation at Aso by 0.667 and subtracted it from the data at Phimai for H and D. For the vertical component (Z), we did not subtract the fluctuation observed at Aso because it depends largely upon the conductivity structure of the Earth at the observation site. Figure 3 shows the H, D and Z variations at Phimai processed as described above and Figure 4 shows their spectra calculated with MEM (Maximum Entropy Method). These figures indicate that there was a localized long period pulsation with a period about 3.6 minutes at Phimai.

3. Discussion

Geomagnetic oscillations with a period of 3.6 minutes are normally categorized to Pc5 or Pi3 [e.g., Saito, 1978]. However, in middle or low latitudes, these pulsations are normally observed in much wider area both in latitude and longitude, or on a global scale. If it is a normal Pc5 pulsation generated by external sources, the amplitude is, in general, larger at higher latitudes. However, there was no Pc5 with the period of 3.6 minutes at Aso or Tong Hai or at other Chinese stations. There was some Pc5 activity, mainly in the D component, both at Phimai and Aso with periods other than 3.6 minutes and the amplitude was larger at Aso than that at Phimai suggesting an external source. By subtracting the fluctuations in the Aso data, normalized with the amplitude ratio (i.e., 0.667) as explained in previous section, the 3.6 minutes oscillation appears clearly in Figure 3 and the spectral peaks at the frequency become sharp. Perhaps this is a Pi2 type pulsation with a longer period which is generated at magnetospheric substorm onset. However, it is known that the amplitude in the H component is almost the same in low and middle latitudes for Pi2 pulsations [e.g., Osaki et al., 1996]. On the other hand, if the oscillation comes from sensor tremor caused by the passage of seismic wave, it should appear mainly in the Z component because the magnetic inclination at Phimai is...
Figure 5. A schematic drawing of the possible generation mechanism of pulsations caused by the earthquake. An electric field oscillation generated by the dynamo is mapped to the ionosphere over Phimai (PHI) along geomagnetic field lines and causes current to flow. The dynamo current (J) and electric field (E) launch a magneto-sonic wave which may cause the Pe3 type short period oscillation at Tong Hai (THJ).

Acknowledgments. The observations at Phimai are partly supported by Kyoto University Active Geosphere Investigations for 21st Century COE program and a grant from Heiwa Nakajima Foundation. We thank the Bureau of Royal Rainmaking Agriculture and Aviation, Thailand, for their help in the construction and maintenance of the Phimai observation site.

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