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Relationships between Seismic Activity and Electromagnetic Emissions, Atmospheric Electric Field and Local Magnetic Activities in Kamchatka

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Abstract

We examined relationships between seismic activity and VLF narrow band emissions, atmospheric electric field and local daily magnetic activities observed in the Kamchatka region. The results can be summarized as follows; (1) Precursors of atmospheric electric field and VLF narrow band emissions appeared several to 10 hours before the onset of earthquakes, of which epicenters were located within ~ 200 km from the Karimshina station. (2) The earthquakes tended to occur around the minimum of local daily magnetic (Σ K-index) and atmospheric electric field (E_z) activities in the Kamchatka region.

1. Introduction

Historically there have been extensive attention to the seismogenic electromagnetic phenomena in a wide frequency range from DC to HF, which have been studied as precursors to earthquakes with the magnitude larger than $M=5.0$ and the epicenter within ± 100 km from the observation site (and volcano eruptions) (see HAYAKAWA and FUJINAWA, 1994). However, still there is an argument on if the observed electromagnetic phenomena were really associated with the earthquakes or not, because the signal/noise ratio is not high in the urban area and there are other possibilities to excite the electromagnetic phenomena on the ground and in space. Since these electromagnetic emissions and DC variations may be a promising candidate for short-term prediction of earthquakes, we are in a position that we should accumulate more amount of convincing signatures of earthquakes.

In order to investigate relationships of atmospheric electric field and VLF narrow band emissions to seismic events observed in the Kamchatka region, the Institute of Cosmophysical Research & Radio Wave Propagation (IKIR), Russian Academy of Science, is conducting these measurements at Paratunka ($\theta=53.0^\circ$ N, $\lambda=158.3^\circ$ E, $L=2.10$) and at the Karimshina expedition point, located at 21 km south from Paratunka. Globally coordinated magnetometer network observations are also being carried out along the 210° magnetic meridian (MM) from the dip equator to high latitudes, in cooperation with more than 30 organizations from 1991 (see YUMOTO *et al.*, 1996).

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In this paper, we will introduce good relationships between seismic activity and VLF narrow band emissions, atmospheric electric field and local magnetic activities observed in the Kamchatka region.

2. Precursors of atmospheric electric field and VLF narrow band emissions

Figure 1 shows an example of precursor of atmospheric electric field observed at Karimshina ($\theta=53.0^\circ$ N, $\lambda=158.3^\circ$ E) on March 5, 1992. Peculiar negative electric field variation appeared about 11 hours before the onset of earthquake (~ 02 h LT on March 6, 1992), of which the magnitude was $M=6.1$ and the epicenter (Δ) was located about 130 km from the Karimshina station. The atmospheric electric fields were measured at Karimshina and Paratunka (not shown here) by means of the standard rotating field mill (e. g. YEBOAH

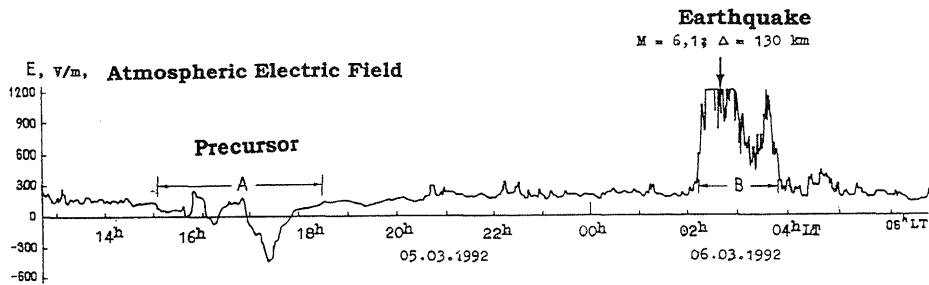


Fig. 1. A precursor of atmospheric electric field observed at Karimshina ($\theta=53.0^\circ$ N, $\lambda=158.3^\circ$ E) about 11 hours before the onset of earthquake on March 6, 1992 ($M=6.1$, $\Delta=130$ km).

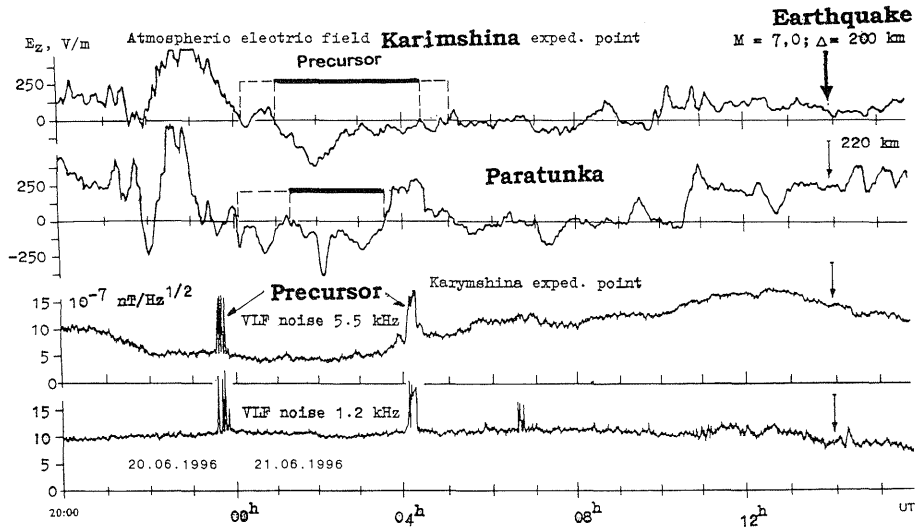


Fig. 2. Precursors of atmospheric electric fields observed simultaneously at Karimshina and Paratunka and VLF narrow band (5.5 kHz, 1.2 kHz) emissions measured at Karimshina about 12-13 hours before the onset of earthquake on June 21, 1996 ($M=7.0$, $\Delta=200$ km and 220 km, respectively).

-AMANKWAH and VAN DER MADE, 1992). The seismic events were identified at the Petropavlovsk-Kamchatsky station in Kamchatka.

Figure 2 shows another example of precursors of atmospheric electric fields and VLF narrow band (5.5 kHz, 1.2 kHz) emissions observed simultaneously at Karimshina and Paratunka about 12-13 hours before the onset of earthquake on June 21, 1996 ($M=7.0$, $\Delta=200$ and 220 km respectively). From this figure, the peculiar negative electric field variations are concluded not to be related to the local clouds above the stations, but to appear about 10 hours before the onset of earthquake. The VLF noise emissions were also found to appear around the beginning and ending times of the peculiar atmospheric electric field variation.

A precursor of VLF noise emissions at the central frequency of 1.2 kHz with 100 Hz band width was identified at Karimshina about 2 hours before the onset of earthquake on December 30, 1993 (09:43:30 UT, $K=11.5$, $\Delta=105$ km) and the aftershock (09:55:56 UT, $K=9.9$, $\Delta=125$ km) as shown in Fig. 3. K is an energetic class of seismic events defined by $K=4.6+$

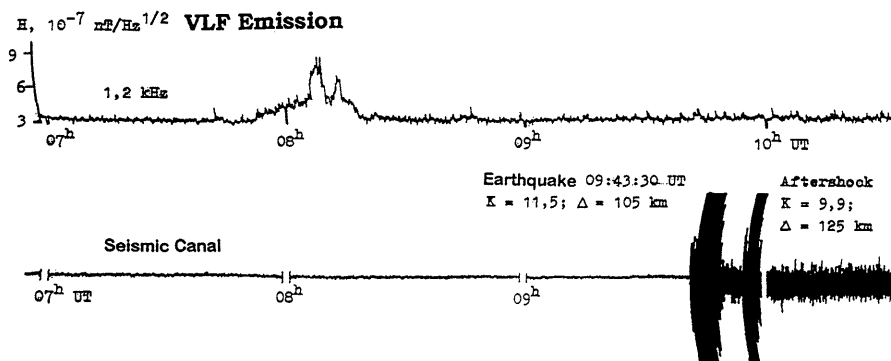


Fig. 3. A precursor of VLF narrow band emission at the central frequency of 1.2 kHz with 100 Hz band width and seismic variation registered at Karimshina about 2 hours before the onset of earthquake on December 30, 1993 (09:43:30 UT, $K=11.5$, $\Delta=105$ km) and the aftershock (09:55:56 UT, $K=9.9$, $\Delta=125$ km).

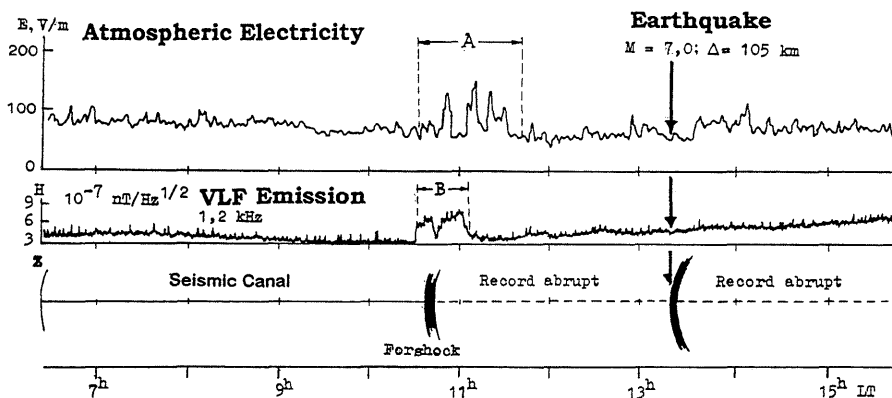


Fig. 4. Simultaneous, anomalous variations of atmospheric electric fields, 1.2 kHz VLF noise emission, and seismic variation registered at Karimshina about 3 hours before the onset of earthquake on November 13, 1993 ($M=7.0$, $\Delta=105$ km).

1.5 M. The VLF narrow band emissions were registered by means of the loop antenna at Karimshina. The data of atmospheric electric fields for this event were not available, and then not shown in the figure. Figure 4 shows simultaneous, anomalous variations of the atmospheric electric field, the 1.2 kHz VLF noise emissions, and seismic variation registered at Karimshina about 3 hours before the onset of earthquake on November 13, 1993 ($M=7.0$, $\Delta=105$ km).

Prof. Sobolev in Moscow (private communication) recently summarized the precursor times of various variations, depending on the magnitude of earthquakes; 1: deformation of

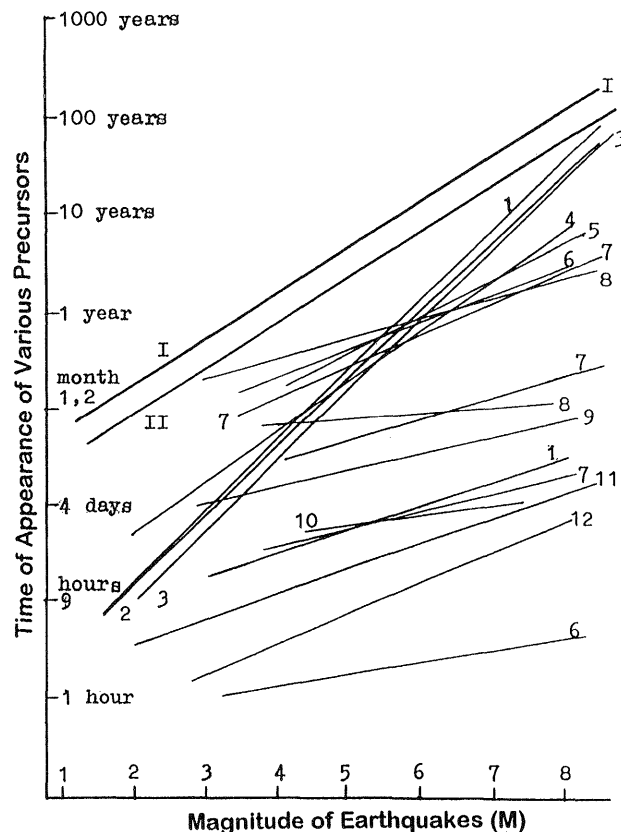


Fig. 5. The dependence of time of appearance of various precursors on the magnitude of earthquakes; 1: deformation of earthcrust, 2: geomagnetic field, 3: variations of seismic regime, 4: seismic wave velocity, 5: emission of Radon, 6: electro-conductivity of mountain rocks, 7: level of underground water, 8: debit of natural gases and fluids, 9: electrotelluric fields, 10: electromagnetic emissions, 11: forshocks, and 12: atmospheric electric field. The line I corresponds to middle periods repeating of earthquakes, and the line II to maximum time appearance of all precursors (by Sobolev, Moscow).

earthcrust, 2: geomagnetic field, 3: variations of seismic regime, 4: seismic wave velocity, 5: emission of Radon, 6: electro-conductivity of mountain rocks, 7: level of underground water, 8: debit of natural gases and fluids, 9: electrotelluric fields, 10: electromagnetic emissions, 11: forshocks, and 12: atmospheric electric field (see Fig. 5). He suggested statistically that the precursor times of electromagnetic emissions and atmospheric electric field are a few days and several to 10 hours, respectively, before the onset of earthquakes for $M \geq 5.0$. The precursor times of atmospheric electric field observed at Karimshina are well consistent with the statistics of Sobolev, whereas those of VLF narrow band noise emissions at Karimshina are not agreement with the statistics and a little bit shorter. Further measurements of the VLF noise emissions associated with the earthquakes are needed to establish the relationship between the precursor time of VLF narrow band emissions and the magnitude of earthquakes in Kamchatka.

3. Relationships of local daily magnetic and atmospheric electric field activities to onset of earthquakes

Using the superposed epoch analysis method as shown in Fig. 6, we examined relationships of local daily magnetic (ΣK -index) and atmospheric electric field (E_z) activities at

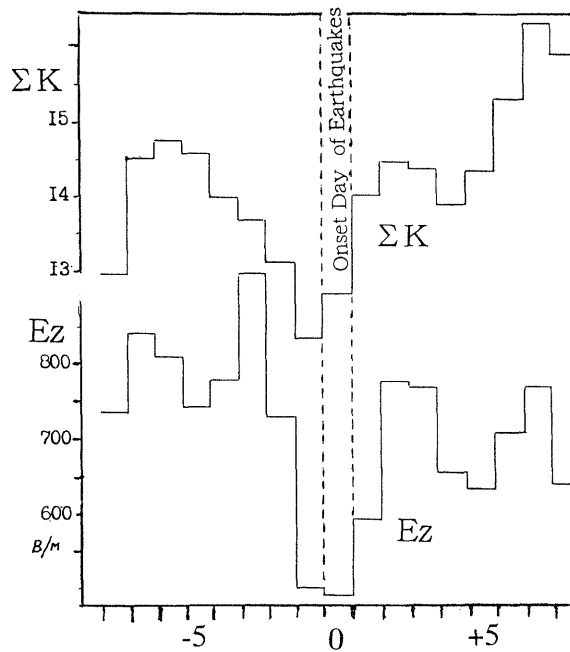


Fig. 6. Superposed epoch analysis of daily magnetic activity (ΣK -index) and atmospheric electric field (E_z) at Paratunka before and after earthquakes in 1995-1996, of which epicenters were located within ~ 200 km from the station in Kamchatka region. Day 0 (broken line) is the onset day of earthquakes.

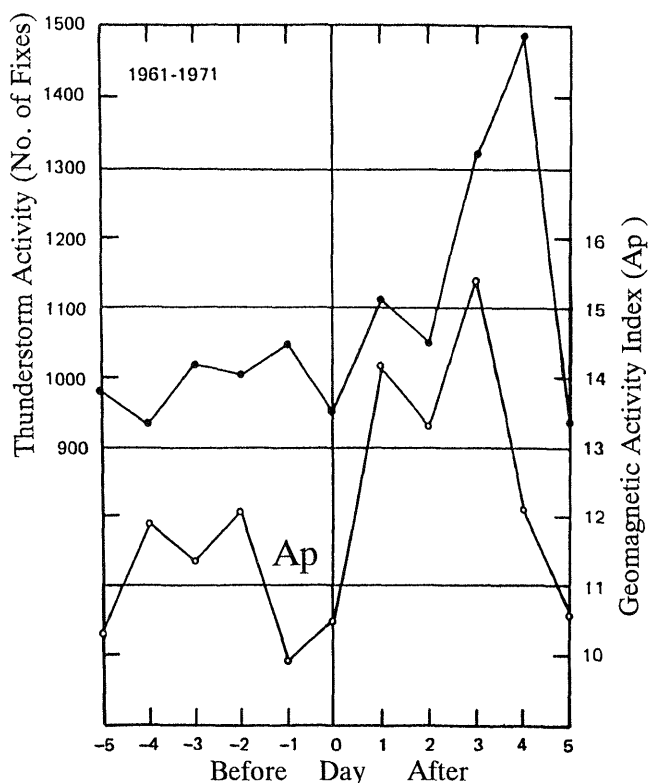


Fig. 7. Superposed epoch analysis of daily thunderstorm activity and geomagnetic activity index Ap before and after flares of class 2B or greater in years 1961-1971. Day 0 is the onset day of flares. From BOSSOLASCO *et al.* (1973).

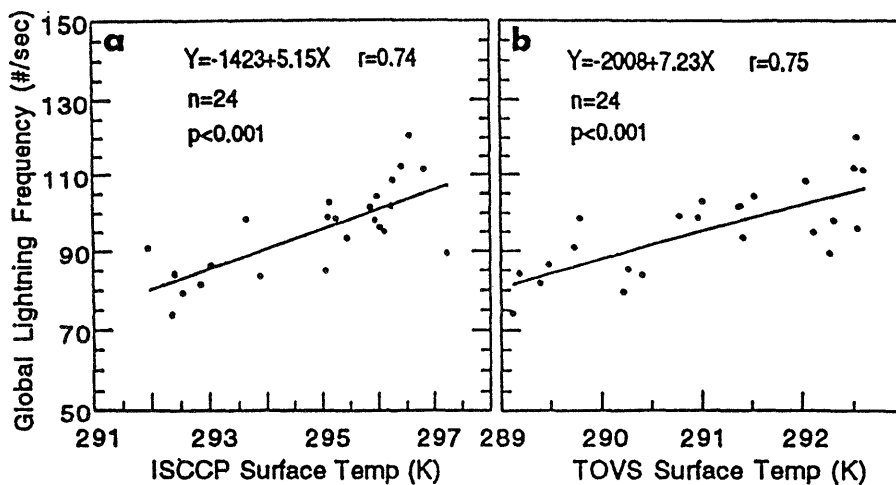


Fig. 8. The linear relationship between 15-day global mean lightning frequencies and clear sky surface temperatures obtained from the ISSCP (a) and TOVS (b) satellites, during 1990 (PRICE, 1993).

Paratunka, to the onset day of earthquakes registered in Kamchatka in 1995-1996. The local K-index was obtained by means of Fluxgate magnetometer data of the 210° MM project. We selected only the events of earthquakes in the Kamchatka region, of which magnitudes were larger than $M=5.0$ and epicenters were located within ~ 200 km from the Paratunka station. Day 0 (broken line in the figure) is the onset day of earthquakes. It is found that the earthquakes in Kamchatka tend to occur around the minimum of local daily magnetic (Σ K-index) and atmospheric electric field (E_z) activities at Paratunka as shown in Fig. 6.

On the other hand, by using the superposed epoch analysis method, BOSSOLASCO *et al.* (1973) also demonstrated a good correlation between daily thunderstorm activity and geomagnetic activity index A_p as a function of onset day of flares of class 2B or greater in years 1961-1971 (see Fig. 7). Moreover, PRICE (1993) presented a linear relationship between 15-day global mean lightning frequencies and clear sky surface temperatures obtained from the ISSCP and TOVS satellites, during 1990 (see Fig. 8).

From these observational results ; the in-phase relation between the daily magnetic and thunderstorm activities, and the linear relation between the global lightning frequency and the surface temperature, we may conclude that the earthquakes in the Kamchatka region tended to occur during the period when the local daily magnetic, atmospheric electric field and thunderstorm activities, and the surface temperature were lower. We have no ideas to explain the relationships, however, further observational studies at multiple stations and more theoretical studies are needed to interpret the relationships between the occurrence of earthquakes and the local daily magnetic and atmospheric electric field activities in Kamchatka, the global lightning frequency, and the surface temperature.

4. Summary

We investigated relationships between seismic activity and VLF narrow band emissions, atmospheric electric field and local daily magnetic activities observed in the Kamchatka region, and found the following results ;

- (1) Precursors of atmospheric electric field and VLF narrow band emissions appeared several to 10 hours before the onset of earthquakes, of which epicenters were located within ~ 200 km from the Karimshina station.
- (2) The earthquakes in Kamchatka tended to occur around the minimum of local daily magnetic (Σ K-index) and atmospheric electric field (E_z) activities at Paratunka.

However, the precursor times of peculiar VLF emissions in Kamchatka are not consistent with the statistics of Sobolev (Fig. 5), and then further measurements of the VLF emissions associated with the earthquakes are needed to establish the relationship between the precursor of VLF narrow band emissions and the earthquakes. Moreover, further theoretical studies are needed to interpret the relationships between the occurrence of earthquakes and the local daily magnetic and atmospheric electric field activities in Kamchatka.

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