ULF GEOMAGNETIC ANOMALY ASSOCIATED WITH EARTHQUAKES AROUND IZU ISLANDS, JAPAN 2000.

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Electromagnetic phenomena are recently considered as a promising candidate for short-term earthquake prediction (e.g. Hayakawa and Fujinawa 1994; Hayakawa 1999). There have been accumulated a lot of evidence of precursory signatures in a wide frequency range from DC to VHF. The ULF range is one of the most promising phenomena, because convincing evidences have been reported (Fraser-Smith et al., 1990; Kopytenko et al., 1993; Hayakawa et al., 1996, 1999, 2000). The purpose of this report is to find out any ULF geomagnetic signature for Izu Islands Earthquakes in July, 2000.

On June 26, 2000, an official alarm was issued for imminent volcanic activity of volcano Oyama, Miyake-jima Island (34.09°N, 139.51°E) by the Japan Meteorological Agency based on increased occurrences of small earthquakes under the island. In the next morning, at several km west of the island, there was an indication of undersea eruption and the seismic swarm activity started almost simultaneously. After a while, a large scale depression at the summit the volcano occurred on July 8. The depression kept growing. Although the last major volcanic event was on August 29, 2000, toxic gas emission is still continuing.

Earthquake epicenters also migrated from the island first westward and then northwestward. The migration of foci is considered as related with a large-scale dike intrusion or migration of magma. There are five large earthquakes (M > 6) during this activity. They occurred on July 1, July 9, July 15, July 30, and August 18 with magnitude M = 6.4, 6.1, 6.3, 6.4 and 6.0, respectively.

The ULF geomagnetic data observed at Izu and Boso Peninsulas in Japan have been investigated. Three stations are closely distributed in both peninsula (Seikoshi (34.85°N, 138.82°E), Mochikoshi (34.89°N, 138.86°E), Kamo (34.86°N, 138.83°E) for Izu peninsula, Kiyosumi (35.16°N, 140.15°E), Uchiura (35.16°N, 140.10°E), Unobe (35.21°N, 140.20°E) for Boso peninsula). The inter sensor distance is about 5 km. Torsion type magnetometers with three components are in operation there. The sampling rates are either 50 Hz or 12.5 Hz. The rough epicentral distances are about 80-100 km for Izu stations and about 130-150 km for Boso stations. Fig.1 shows the stations and earthquakes.

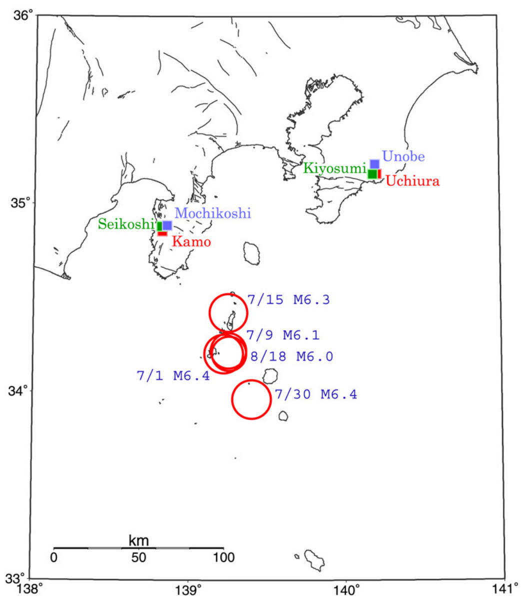

Fig. 1. The map of stations and large earthquakes during earthquake swarm at Izu Islands, 2000.

In order to extract any ULF signature of Izu Islands earthquake swarm, the principal component analysis (PCA) has been performed. The NS component has been used for this analysis. We analyzed data from February, 2000 to February, 2001 to investigate the long-term variations from different sources (geomagnetic variation, man-made noise, and the other sources (like earthquake related ULF emissions)).

The procedure of PCA is as follows. First, the ULF waveform data are down sampled and they are fed to numerical narrow-band pass filters without delay. We adopt PCA to the time series data observed at closely separated stations. Let us consider the time series data (30 minutes) observed at the three stations are given by $\boldsymbol{y_1} = [y_1(t_1), y_1(t_2), \ldots\ldots, y_1(t_{1800})]^T$, $\boldsymbol{y_2} = [y_2(t_1), y_2(t_2), \ldots\ldots, y_2(t_{1800})]^T$, and $\boldsymbol{y_3} = [y_3(t_1), y_3(t_2), \ldots\ldots, y_3(t_{1800})]^T$. Then, the data matrix $\boldsymbol{Y} = [\boldsymbol{y_1}, \boldsymbol{y_2}, \boldsymbol{y_3}]^T$ is obtained, where T means transpose. Then, we calculate the variance matrix $\boldsymbol{R} = \boldsymbol{Y}\boldsymbol{Y}^T$. Then eigenvalue decomposition of $\boldsymbol{R}$ have been done, $\boldsymbol{R} = \boldsymbol{V}\boldsymbol{\Lambda}\boldsymbol{V}^T$ where $\boldsymbol{\Lambda}$ is eigenvalue matrix with λ_1, λ_2 and λ_3 and $\boldsymbol{V}$ is the eigenvectors matrix whose column is $\boldsymbol{v}_1$, $\boldsymbol{v}_2$, and $\boldsymbol{v}_3$.

In this paper, we discuss the temporal evolution of the amplitude of each eigenvalue at a particular frequency of 10 mHz. The result showed that the largest component (sqrt (λ_1)) had a clear correlation with the geomagnetic activity which is described in Ap index. Therefore, the first principal component is reasonably considered to be the effect of geomagnetic variation (Fig.2). The second largest component (sqrt (λ_2)) showed a clear daily variation reminiscent of human activity: high at work hours, low at lunch time, night time and weekends (Fig.3). The weakest third component (sqrt (λ_3)), which was about an order of magnitude smaller than the first, is the third possible noise candidate and earthquake related ULF emissions is possible to be included in this component. Fig.4 indicates the nighttime variation of sqrt (λ_3). During nighttime, little effect of human activity is expected. This would be possible to detect weak earthquake related ULF emissions, if they exist. The noise level of sqrt (λ_3) begins to increase from the end of March, 2000. A sharp decrease of in the intensity of sqrt (λ_3) about 10 days before the first large earthquake on July 1, followed by an abrupt increase a few days before the first large earthquake. Very Similar behaviors are noticed for both the second and third earthquakes on July 9 and July 15. This kind variation cannot been seen with the geomagnetic variation. Therefore, the temporal evolution in sqrt (λ_3) at night is highly likely to reflect that of earthquake related ULF emissions with Izu Islands earthquake swarm. Similar results have been obtained for data observed at Boso peninsula.

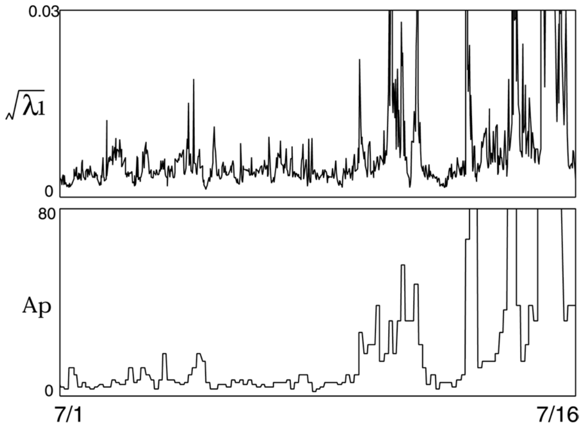

Fig. 2. The variation of sqrt(λ_1) and Ap index

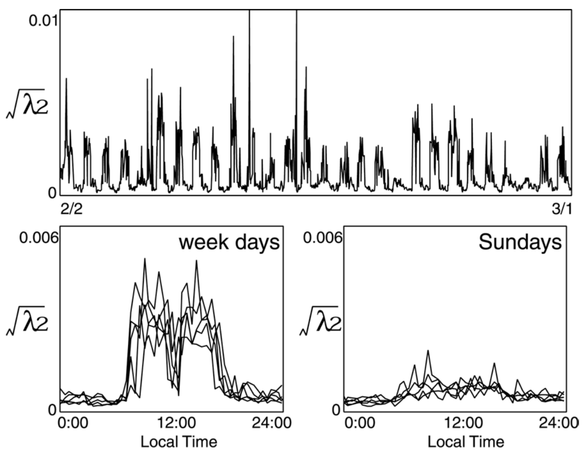

Fig. 3. The variation of sqrt(λ_2)

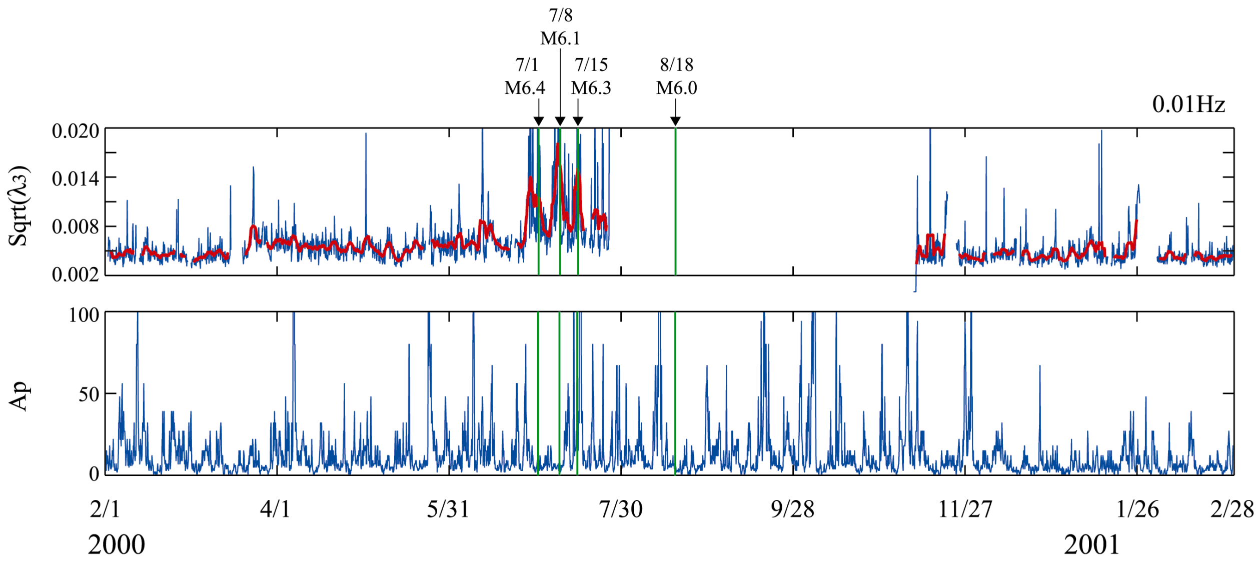

Fig. 4. The variation of sqrt(λ_3)

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