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WHAT HAPPENED ELECTRO-MAGNETICALLY AT 1995 HYOGO-KEN NANBU (KOBE) EARTHQUAKE?

T. Nagao, S. Uyeda

RIKEN International Frontier Research Group on Earthquakes, c/o Earthquake Prediction Research Center, Tokai University, Japan

Occurrences of anomalous electromagnetic phenomena at varied frequency ranges, covering ELF to VHF, have been reported in relation to the Jan. 17, 1995 Hyogo-ken Nanbu $M7.2$ earthquake, by several independent research groups. Prominent pre-seismic peaks, which could have been emissions from the focal area, were observed on Jan. 9–10 in ELF, VLF, LF and HF ranges. Whether these changes were truly precursory to the earthquake is not certain, because atmospheric (thunderbolt discharge) noise also peaked on Jan. 9–10. In the earlier few hours of the earthquake, that occurred at 05:46 (Japan Standard Time), Jan. 17, anomalous changes were markedly enhanced toward the catastrophe, in agreement with many reports on unusual radio/TV noise. Anomalous transmission of man-made electromagnetic waves in VLF and VHF ranges was also detected from a few days before the earthquake, indicating the possibility that the ionosphere above the focal zone was disturbed at the final stage of the earthquake preparation process.

ЧТО ПРОИЗОШЛО В ЭЛЕКТРОМАГНИТНОМ ПОЛЕ ПРИ ЗЕМЛЕТРЯСЕНИИ В ХИОГО-КЕН НАНБУ (КОБЕ) 1995 ГОДА?

Т. Нагао, С. Уеда

Международная исследовательская группа РИКЕН по землетрясениям, Центр исследований по прогнозу землетрясений Токайского Университета, Япония

При землетрясении 17 января 1995 года в Хиого-Кен Нанбу (магнитуда 7.2) несколькими исследовательскими группами были отмечены аномальные электромагнитные явления в различных диапазонах частот от СНЧ до СВЧ. В диапазонах СНЧ, ОНЧ, НЧ и ВЧ 9–10 января перед землетрясением были зарегистрированы крупные пики, возможно представляющие собой эмиссию из очаговой области. Неясно, были ли эти вариации действительно предвестниками данного землетрясения, так как атмосферный шум (грозовые разряды) также достигли максимума 9–10 января. За несколько часов до землетрясения, которое произошло в 5:46 по стандартному японскому времени 17 января, аномальные измерения стали заметно возрастать при приближении ко времени катастрофы, в согласии со многими сообщениями о необычном радиошуме. Начиная за несколько часов перед землетрясением было замечено аномальное распространение техногенных электромагнитных волн в диапазонах ОНЧ и ОВЧ. Это показывает, что на заключительной стадии процесса подготовки землетрясения ионосфера над очаговой областью могла находиться в возмущенном состоянии.

Introduction

The City of Kobe was struck by the $M7.2$ Hyogo-ken Nanbu earthquake (Kobe EQ hereafter) at 05:46 (Japan Standard Time) of January 17, 1995. It devastated a wide area and casualties totaled over 6,000. Neither authorities nor public were prepared to such an earthquake, although some possible precursory phenomena have been claimed through post factum analyses of mainly seismicity and hydro-geochemical data (e.g., [1, 2, 3, 4]).

At the time of the Kobe EQ, several groups of scientists were independently engaged with monitoring of electromagnetic field at various frequencies at various sites in Japan. Some monitoring was being conducted to detect possible precursory phenomena to earthquakes, but some others had quite different purposes. After the Kobe EQ, they realized that anomalous phenomena that could have been precursory or co-seismic to that earthquake were observed. In this paper, we try to integrate these independent electromagnetic observations by placing them in a common time frame.

1. Observations

1.1. Three month data

Fig. 1 shows various data before and after the Kobe EQ for a three month period (December, 1884 February, 1995). Panels 1–6 are changes in varied frequency ranges, arranged downwards from lower to higher frequencies. One may observe some peaks of signals in these records. These signals, if they were really connected with the Kobe EQ, are supposed to have been in some way emitted from the focal area. On the contrary, panels 7 and 8 are related to anomalous transmission of man-made electromagnetic waves; that would need occurrence of disturbance in the ionosphere above the focal area. Panels 9 and 10 are the data on the atmospherics (thunderbolt discharge) and seismicity. Fig. 2 shows the distribution of monitoring sites at which data cited in Fig. 1 were observed. Brief explanation of each panel of Fig. 1 will be given in the following.

1.2. Panel 1 (ELF magnetic field)

Three-component geomagnetic field measurement at an extremely narrow band of 223±0.5 Hz was designed to monitor changes related to volcanic and seismic activity and had been conducted at several stations [5]. 223 Hz was chosen because it is a prime number and is not a harmonic of commercial 50 Hz or 60 Hz. Prominent peaks were observed at the stations on Jan. 10 (M. Hata, private communication). Panel 1 shows an example (EW component) at Usami station designed for monitoring the volcano-seismic activity in Izu area, about 400 km from the epicenter of the Kobe EQ (Fig. 2). Same was true for the records at Omaezaki station and Unzen station which is about 500 km from the other side of the epicenter. Although a pre-seismic signal was also reported in the lowest frequency, i. e., in the DC geoelectric field on January 5 at a site about 150 km northeast of the epicenter [6], its reliability is considered low, because the change was observed only on one out of six dipoles.

1.3. Panel 2 (VLF underground electric field)

Fujinawa and co-workers were monitoring the electric field variation at 0–0.7 Hz(DC), 0.01–0.7 Hz (ULF), 1–9 kHz (VLF) bands using the casing pipes of boreholes as antennas at several sites in Kanto-Tokai area some five hundred km east of the epicenter [7]. Panel 2 ([8]: Y. Fujinawa, private communication) is the count of VLF pulses that exceeded certain threshold values at Hasaki station (Fig. 2). Enhanced counts on Jan. 9 and 10 are notable. Although not shown in the figure, other stations revealed the same peak. There were no notable changes in the DC and ULF bands. The other strong peak in early December 1994 in panel 2, which is common to other panels, will be mentioned later. General increase of count level after the Kobe EQ may also be noteworthy.

1.4. Panels 3 and 4 (VLF and LF pulse)

Oike and co-workers had long been interested in earthquake-related electromagnetic phenomena and were monitoring electric field pulse in VLF (1–10 kHz) and LF (163 kHz) bands since 1983 at Uji station which happened to be close to the Kobe EQ epicenter (Fig. 2) (e.g., [9]). Panels 3 and 4 show prominent enhancement of pulse counts on Jan. 9 and 10 [10].

1.5. Panel 5 (Underground vertical electric field in HF range)

Enomoto and co-workers had been measuring underground electric field variations in 10 kHz–1 MHz (HF) range since 1992 at Tsukuba station (Fig. 2), about 500 km away from the epicenter (e. g., [11]). Their work was motivated by the premise that HF electric pulse may be emitted as pre-seismic micro-fracturing takes place, in the similar manner as observed in laboratory experiments: electrons are emitted from newly formed surfaces of fractured solids and generate HF electromagnetic

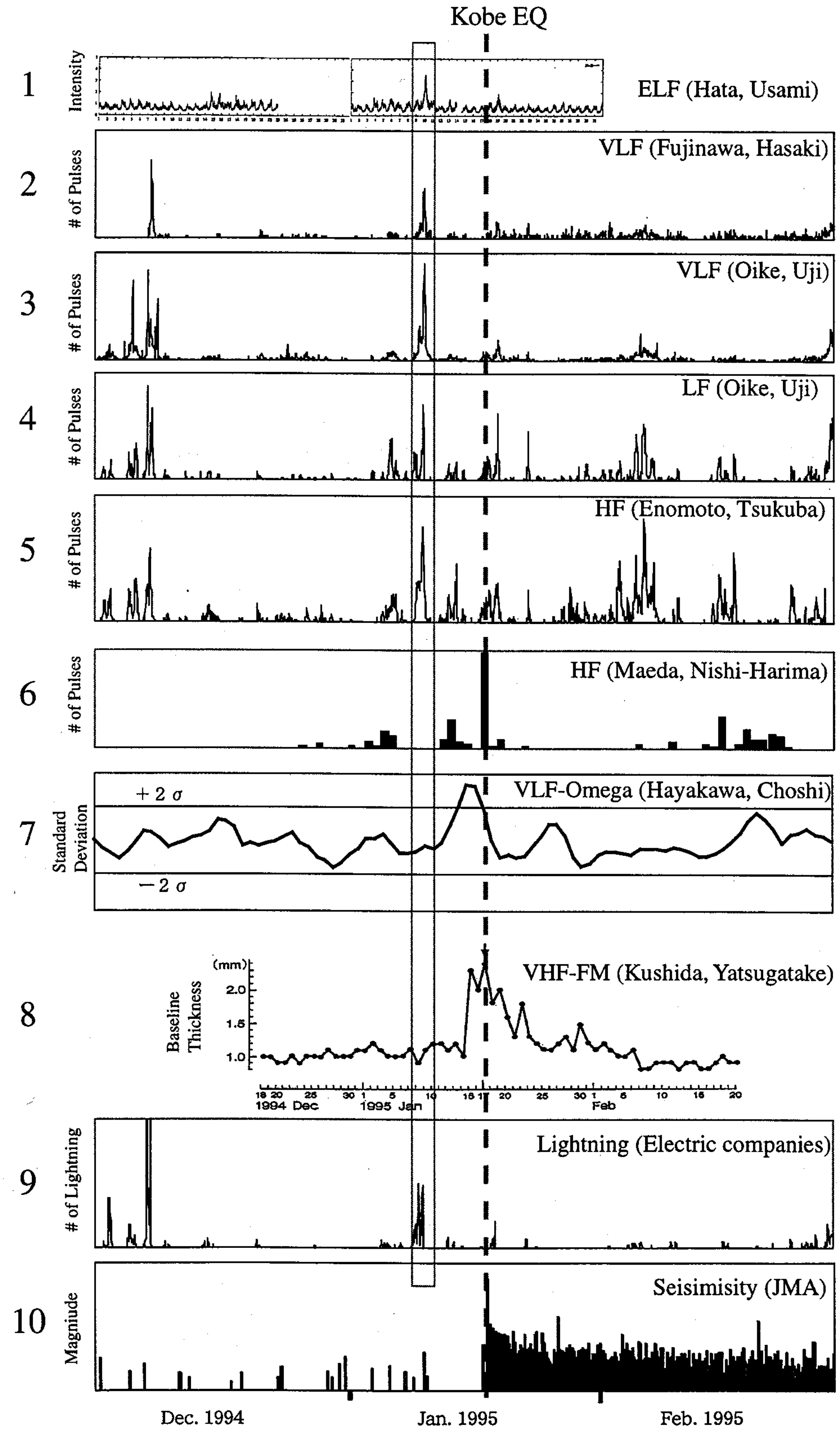

Fig. 1. Three month records around the Kobe EQ. Abbreviations for frequencies are as follows: ULF 10–100 Hz, ELF 100 Hz–1 kHz, VLF 1–10 kHz, LF 10–100 kHz, MF 100 kHz–1 MHz, HF 1–10 MHz, VHF grater than 10 MHz

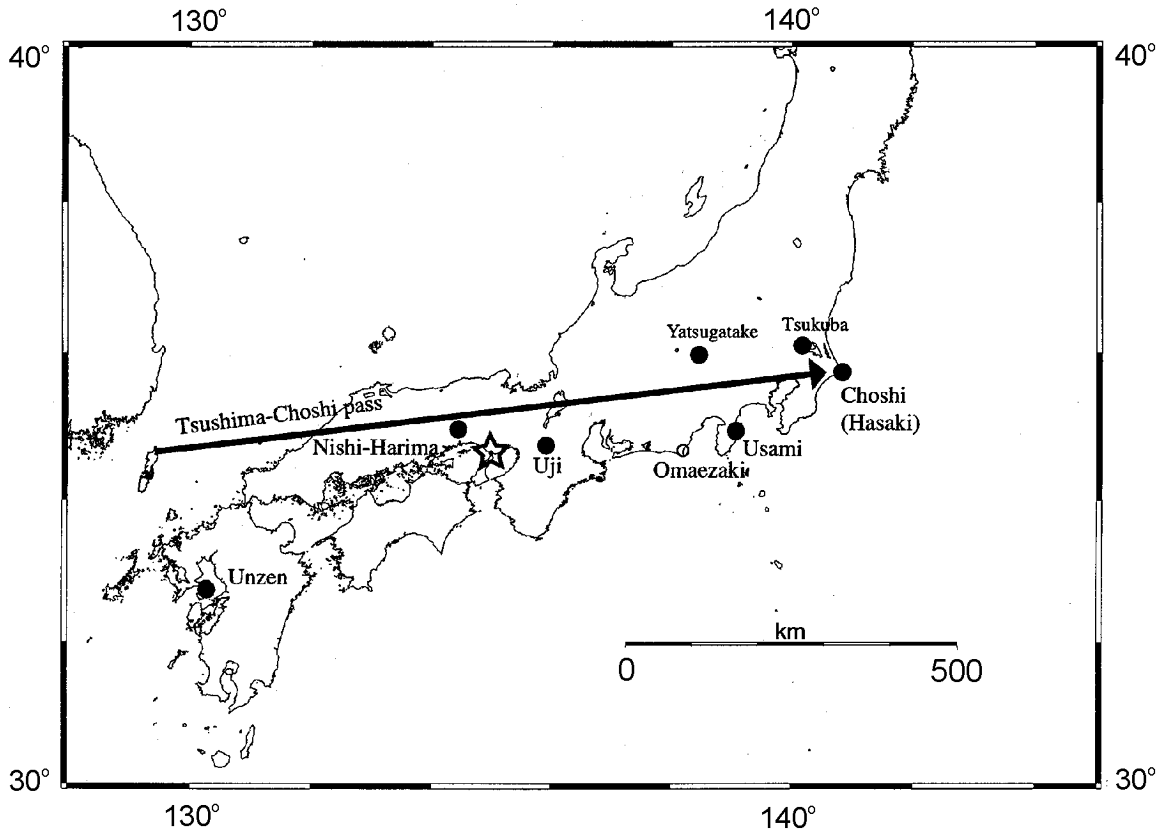

Fig. 2. Observation sites. Long arrow shows the path of Omega waves. Star is the epicenter of the Kobe EQ

pulse [12]. Panel 5 (Enomoto, private communication) indicates features very similar to those in panel 4, which were taken at much closer Uji station.

1.6. Panel 6 (VHF electromagnetic wave)

Electromagnetic waves from the planet Jupiter were being monitored at HF (22.2 MHz) band at Nishi-Harima, quite close to the epicenter (Fig. 2). Peculiar waves, suspect of emissions from the focus, were observed before dawn of Jan. 17 [13]. The measuring system is a simple interferometer with two dipole antennas, by which the direction of incoming waves could be known to some extent. On the morning of Jan. 17, pulse-like anomalous waves from an apparently fixed source in the direction of the Nojima fault started to be observed from about 05:20. Nojima fault is the surface fault that was displaced a few meters at the Kobe EQ [14].

1.7. Panel 7 (Unusual transmission of 10 kHz Omega wave)

Monitoring of VLF waves, such as Omega signals for navigation, is a well-established method for recording short-term electron density variation in the lower ionosphere. Hayakawa et al. [15] and Molchanov and Hayakawa [16] demonstrated that the transmission of Omega wave from Tsushima received at Inubo (Choshi in Fig. 2) was anomalous from several days before the Kobe EQ, the maximum anomaly being a couple of days before. The anomaly was formally equivalent to lowering the reflection height by about 2 km. Panel 7 shows the variation of the "terminator time" [16] of VLF signals.

1.8. Panel 8 (Unusual transmission of FM radio waves)

Ionosphere monitoring to receive FM radio waves from stations beyond the line of sight is a standard method for detection of meteorites; meteorites penetrating into the ionosphere cause strongly ionized plasma tubes that make distant FM waves audible. Kushida and Kushida [17] at Yatsugatake South

Base Observatory accidentally noted that their system recorded anomalous signals from a few days before the EQ. Panel 8 shows the time change of baseline thickness, which is an indicator of anomalous FM wave reception. The Kushidas have since been practicing open earthquake prediction experiments [18, 19].

Among the above monitoring efforts, those in panels 1 to 5 had been designed for the purpose of observing electromagnetic phenomena related to seismic and volcanic activities and certain claims of success had already been made before Kobe EQ (e. g., [5, 7, 9, 20, 21]). On the other hand, those in panels 6, 7, and 8 were in operation for astronomical or navigational purposes.

It may also be noted that the signals in panels 1–6 are considered as those emitted from the focal zone, whereas those in panels 7 and 8 indicate anomalous propagation of electromagnetic waves likely originated by pre-seismic disturbance of ionosphere above the focal zone.

Fig. 1 shows that there was a prominent pre-seismic signal in panels 1–5 on January 9–10, a week before the catastrophe. However, there is a serious problem, the noise due to atmospherics (thunderbolts). Panel 9 shows the atmospheric data observed by Electric Power. They are numbers of clouds to ground discharges in the area in and around Japan. There were strong atmospherics on January 9–10. The atmospheric activity was in the Japan Sea (Jan. 9) and moved into the Pacific Ocean (Jan. 10). It is possible that all or some of what looked like signals were atmospheric noise. In fact, in early December there were anomalous peaks in panels 2–5 at the times of notable atmospherics. However, ELF data (panel 1) did not show any peaks at these times. Immunity from distant atmospherics of Hata's narrow band ELF magnetic field changes has been demonstrated in other cases, too (M. Hata, personal communication). Therefore, the ELF peak on Jan. 10 could have been non-atmospherics. This may lead to a conjecture that at least some of the recorded pulses in other higher frequency ranges could also be of non-atmospherics origin. Fig. 3 shows the data of these days in expanded time scale. It can be seen that the atmospherics data and signals are not exactly simultaneously peaked; the lightning peak on Jan. 10 is lower than that on Jan. 9, whereas the peaks in ELF and VLF signals are highest on Jan. 10. The timing of all the measurements was accurate enough, so that the time difference was real. However, the atmospherics data of the power companies cover only the cloud to ground discharges and not the inter-cloud discharges that might have been even more frequent. Moreover, the areal coverage of atmospherics monitoring was limited, so that the real peak of atmospherics on Jan. 10 could have been considerably higher than the figure shows. These leave the problem fundamentally unsolved.

Fig. 4 shows the data on morning of January 17, the very day of the Kobe EQ. The signals started, though not exactly synchronously, to increase from a few hours before the catastrophe and decreased afterwards. Though not shown in Fig. 4, co-seismic changes in the telluric and magnetic fields were observed at about 10 s after the origin time at about 70–100 km from the epicenter (Electromag. Res. Group for 1995 Hyogo-ken Nanbu EQ, 1997; [22]).

There are numerous reports on radio/TV noise, lights and other macroscopic anomalies that happened at about the same time (e. g., [23]). The gist of witness documented by Yoshino [24] through interviewing a truck driver, as an example, is as follows. Early morning of Jan, 17, Mr. J. Takahashi, who was also a licensed radio engineer, was driving his truck toward Kobe from the west listening to Radio Kansai (558 kHz) as usual. At about 05 o'clock passing Higashi Kakogawa about 30 km west of Kobe, he first noticed unusual noise which increased as approaching Kobe. He tried five other available stations (550 kHz to 1. 6 MHz), but none of them were readable due to noise until he had to abandon his truck at the fierce shock that destroyed the highway he was on. When he returned to the truck after finding out what had happened about 10–20 minutes later, the radio was announcing the earthquake. There was no strong noise.

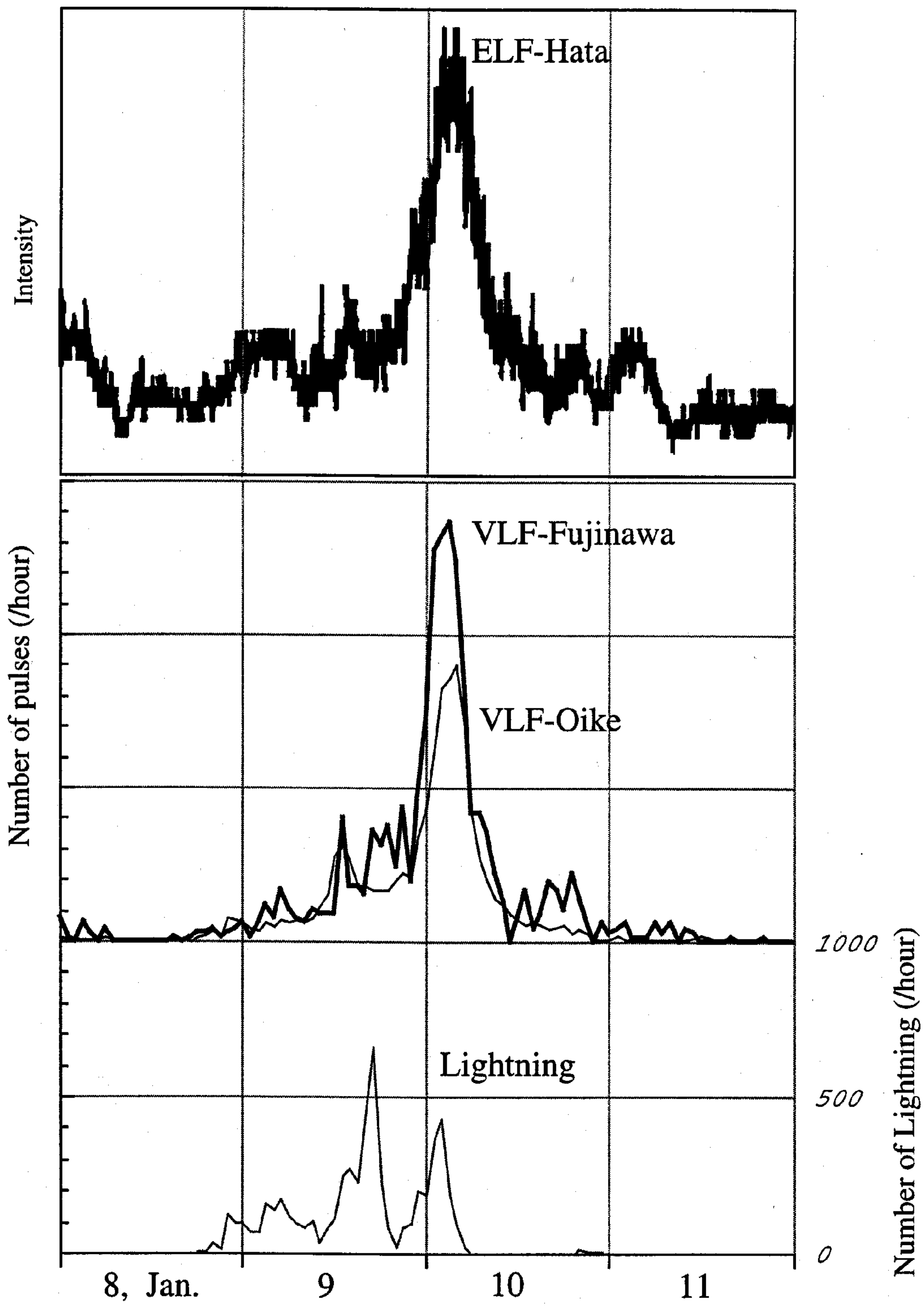

Fig. 3. Records on January 8-11, 1995. Data source (private communications from M. Hata, Y. Fujinawa and K. Oike) and Power Companies

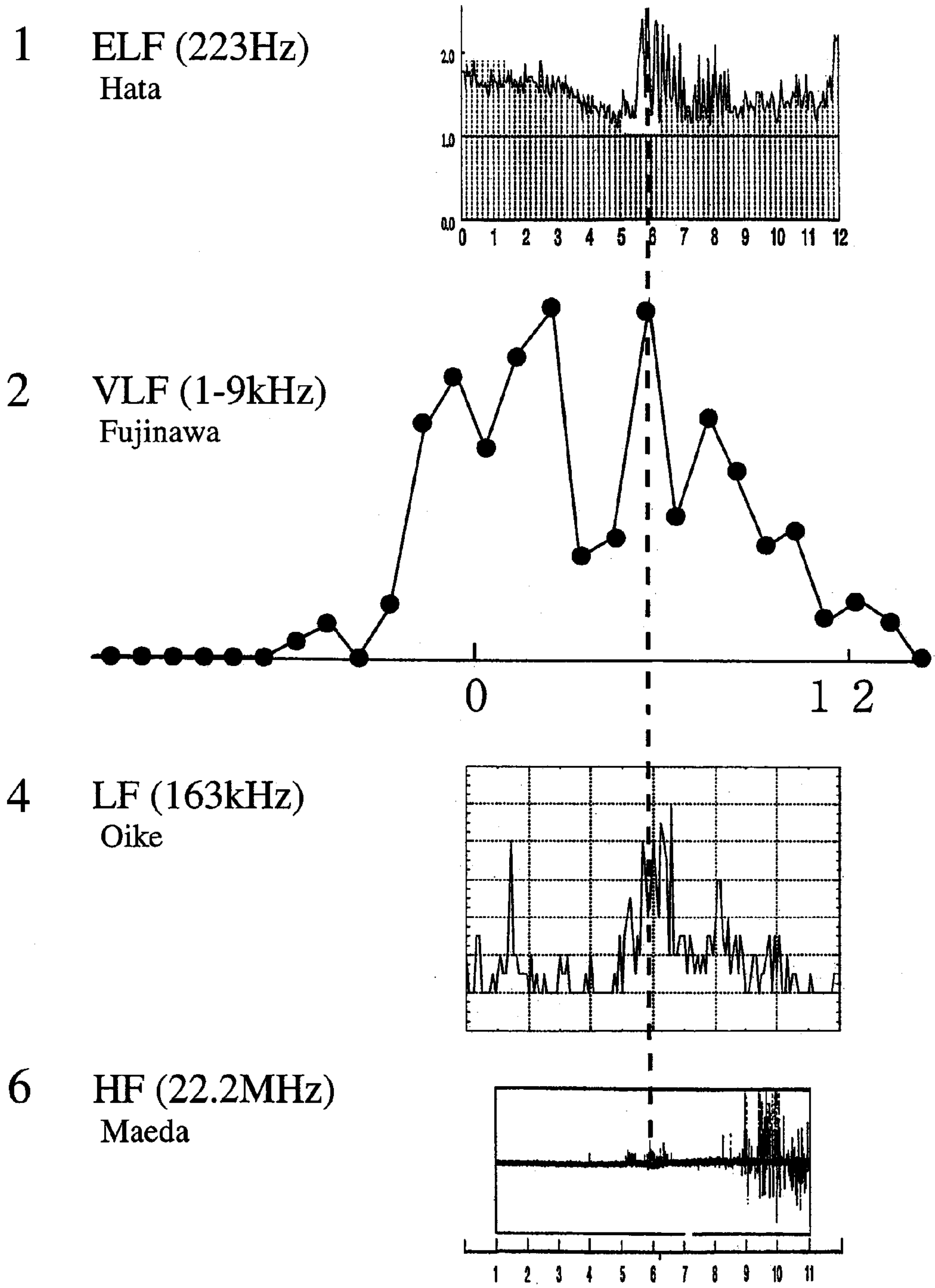

Fig. 4. Records on the morning of January 17, 1995. Dashed line shows the time of Kobe EQ. Numbers 1,2,4 and 6 correspond to those in Fig. 1.
1 (M.Hata, Private communication),
2 [8] (Fujinawa and Takahashi, 1995),
4 [26] (Yamada and Oike, 1999),
6 [13] (Maeda and Tokimasa, 1995)
In panel 6, the signals at the time of the EQ correspond to the strong peak in Fig. 1. The stronger signals from about 08 o'clock are solar effects after sunrise not included in Fig. 1

2. Discussion and Conclusion

From the reports summarized above, it seems likely that some anomalous electromagnetic phenomena took place at Kobe EQ. Phenomena on the very day are undeniable.

As to the pre-seismic phenomena, the anomalous changes of January 9–10 are suggestive. However, there is a serious problem, namely the possibility that the changes were due to atmospherics. As mentioned earlier, the existence of ELF signals that are claimed to be immune to atmospherics and the time difference of peaks in atmospherics and signals are in favor of their EQ related origin. However, the possibility for their atmospherics related origin is distinct. In fact, there are different ideas regarding the relationship between pre-seismic electromagnetic signatures and lightning (and rain), because there have been many cases where both of them were observed before EQs (e. g., [9]).

One is that pre-seismic anomaly in the atmospheric electric field induces or at least enhances lightning activity [25] and the other is that lightning (and rain) activity triggers EQs (e. g., [26]). All these indicate that there are still many unknown factors and careful accumulation of more data and detailed theoretical investigation are needed.

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