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A plan of earthquake forecast network for the Kanto (Tokyo) district: A few hazard combating approaches.

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Abstract

This short paper presents a plan of coordinated observations of multi-parameters associated with earthquakes (EQs) in the Kanto (Tokyo) district. This coming network is composed of VLF/LF monitoring of the lower ionospheric perturbations and monitoring of the upper ionospheric perturbations, atmospheric perturbations, lithospheric effects etc. The new network will be of potential use not only in the scientific elucidation of the mechanism of lithosphere-atmosphere-ionosphere coupling, but also in the accuracy improvement of real short-term EQ forecast especially for the Kanto district.

Key words: 1; Earthquake prediction.2; ionospheric perturbations. 3; VLF/LF network. 4; ULF/ELF waves.

1. Introduction

There has been established a recent consensus that electromagnetic phenomena do occur prior to an earthquake (EQ) which would be invaluable for short-term EQ prediction [e.g., Hayakawa (Ed) 2012., 2013; Hayakawa 2015., Sorokin et al., 2015], because there has been enormous progress in the field of seismo-electromagnetics all over the world during the last two decades since the 1995 Kobe EQ.

A few electromagnetic precursors have already been reported as promising candidates for short-term EQ prediction (Hayakawa 2015). The most convincing one among them is the ionospheric perturbation not only in the lower part (D/E layer), but also in the upper F region. Hayakawa et al., [2010] have established a statistical correlation of lower ionospheric perturbations with EQs based on the long-term VLF/LF propagation data. Also, the similar statistical correlation has been obtained for the upper iono-spheric perturbations by Liu [2009] on the basis of ionosonde VHF sounding data during 10 years. Further it seems that some other precursors are ready to reach the level of statistical correlation with EQs, including DC earth current [Varotsos, 2005], ULF electromagnetic radiation [Hayakawa et al., 2011; Hattori, 2013] (these two being lithospheric effects), ELF radiation [Ohta et al., 2013; Schekotov et al.,2013], VHF radiation [Sorokin et al., 2015] (these two being atmospheric radiation), and ULF depression (as an indicator of seismo-ionospheric perturbation) [Schekotov et al., 2006, 2013].

Initially based on the collaboration with the UEC VLF/LF network, we established, in 2010, a private venture (named Earthquake Analysis Laboratory (EAL)) releasing the EQ forecast information to a closed society through any kinds of media (PC, mobile phones and smart phones). But, since there were frequent no-observation periods in the university network due to several reasons, we have established our own network composed of 8 VLF/LF receiving stations in Japan. After the experience of having released EQ forecast to the public during four years, we have learned of a few important lessons. The first lesson is that it seems impossible for us to detect EQs at any place in Japan by our network with a limited number of receivers. For example, as related to the recent EQs on April 14 and 16, 2016 in Kumamoto area of Kyushu Island, we have issued prospectively the information that an EQ would happen in the Kyushu Island. The time and place of our prediction were good, but the predicted magnitude was smaller than the actual one. The second lesson is that the people who received such EQ information were faced with a problem of how to treat the information and how to respond to it. So that, our EQ forecast is not useful enough without further providing the solutions on how to react to such EQ prediction information.

The first lesson seems very clear to everybody, because there will be an EQ at any place of Japan. This is a commonly accepted idea, but we have re-confirmed it just after the 2016 Kumamoto EQs. One of the authors (MH) has just resigned the post of advisor of the first venture company (EAL), and then as our next step we would like to establish a very new network for any EQs in the Kanto (Tokyo) district. To strict the area of our interest is one possible way to resolve the first problem. As you know, Tokyo is a highly populated city, and is located in a seismically active area with a lot of active faults. So, our private venture (university-originated) (Hayakawa Institute of Seismo Electromagnetics (Hi-SEM)) established in 2011, will take the principal responsibility to pay particular attention to severe EQs in the Kanto district expected to take place in near future based on the national medium-term EQ forecast.

2. Instrumentations for EQ prediction in Tokyo area

From the standpoint of research on seismo-electromagnetics and EQ prediction, it is recently agreed that multi-parameter observation is highly required for short-term EQ prediction; that is, coordinated measurements of different seismogenic phenomena. Correspondingly, we have installed and will install different observational items, and we list them in the following starting from the upper atmosphere and going down to the lithosphere.

2.1 Ionospheric perturbations

2.1(a) A network of subionospheric VLF/LF signals for the study of lower ionospheric (D/E layer) perturbations

This is the most important element for this Tokyo EQ forecast network, because it is the most established tool for short-term EQ prediction [Hayakawa and Hobara, 2013; Rozhnoi et al., 2013]. The LF transmitter with call sign of JJY (40kHz, Fukushima) is the main target in the Tokyo area, so that several receivers for this transmitter signal are established; one in Chiba (e.g., Togane), one in Izu peninsula (e.g., Ito), one in Hamamatsu, and others in Tottori and in Hokkaido. Figure 1 illustrates the Tokyo network of subionospheric VLF/LF signals to find precursory ionospheric perturbations in the Kanto district. As in our previous network, we design our receivers to be able to receive simultaneously signals from other transmitters (JJI transmitter in Miyazaki and three foreign transmitters (NWC (Australia), NPM (Hawaii) and NLK (Seattle, USA).

2.1(b) Monitoring network of upper ionosphere (F region)

There is a station at Kokubunji (west Tokyo) of vertical VHF sounding of the upper ionosphere (so-called ionosonde), whose data on foF2 are available regularly and which will be used for monitoring seismo-ionospheric perturbations [e.g., Liu, 2009]. Figure 2 shows the location of Kokubunji and its possible monitoring region.

A new project will be carried out to detect the obliquely incident waves of the above Kokubunji VHF transmitter signals at two remote stations in Ise-shima (Mie prefecture) and at Sendai. These VHF receiving stations are plotted in Figure 2 as well, together with the possible monitoring areas indicated by circles (with radius of 100km) because those oblique VHF signals can provide us with the information in the upper ionosphere around the mid-point between the transmitter and receiver.

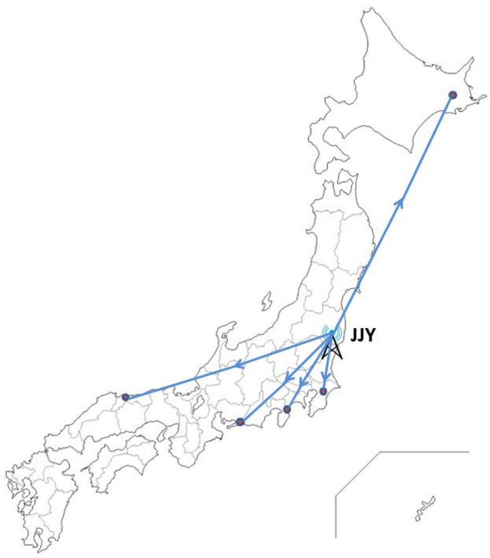

Figure 1. A VLF/LF network with the target of JJY transmitter (Fukushima, 40kHz) signals. Five receiving stations, and the JJY transmitter.

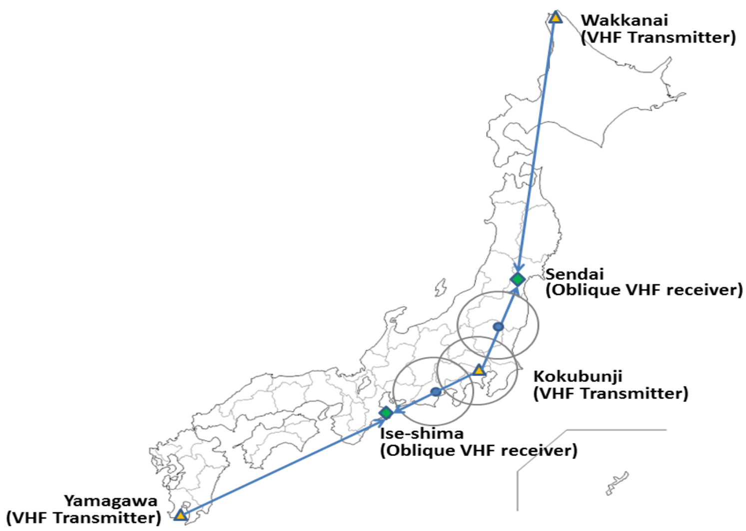

Figure 2. A network of monitoring of the upper ionosphere (F region). A VHF transmitter located in Kokubunji, and the reception at remote stations of Ise-shima and Sendai of its oblique VHF transmitter signals. Possible monitoring regions are plotted with circles (radius of 100 km).

As a conclusion, we can monitor not only the ionosphere above Tokyo, but also two other regions, west and north of Tokyo. These receivers for oblique VHF transmitter signals are newly developed, which will be the first attempt for the study of EQ prediction.

The simultaneous monitoring of both the lower part and F-region of the ionosphere is the first attempt, so a comparison of ionospheric characteristics between those two regions will be of essential importance in understanding the coupling of ionospheric perturbations between the lower and upper parts of the ionosphere.

2.1(c) The use of ULF depression

This phenomenon is characterized by the depression of horizontal components of ULF magnetic field [Schekotov et al., 2006] as a signature of lower ionospheric perturbation [Schekotov et al., 2013], just like the perturbation in subionospheric VLF/LF signals [Hayakawa et al., 2010]. Because the main part of ULF waves observed on the ground is of magnetospheric origin, those waves suffer from the enhanced absorption when penetrating through the perturbed lower ionosphere prior to an EQ. This phenomenon is not so popular in the academic society, but we understand that this effect is very convincing and sensitive to seismogenic influence [Schekotov et al., 2013].

Figure 3 illustrates the possible locations of ULF/ELF sensors; Asahi (near Chosi) and Matsushiro (in Nagano prefecture). A few more will be installed shortly at possible positions, Izu peninsula and Chichibu area. The frequency range of these ULF/ELF sensors is in a range from 0.01 Hz to 50 Hz because their sampling frequency is 100 Hz [Ando et al., 2005]. The ULF range of their whole frequency band is used to study such a depression of horizontal components of ULF waves of magnetospheric origin, which will be compared with the results by subionospheric VLF/LF propagation anomalies.

2.2 Atmospheric radiation and atmospheric effect

Schekotov et al., [2007] were the first that reported on the ELF seismogenic radiation in the frequency range of 1~10Hz, and there have been a few additional reports on these precursory ELF impulsive emissions even for the 2011 Tohoku EQ [Ohta et al., 2013; Schekotov et al., 2016]. The ELF range of those ULF/ELF sensors can be used to study the ELF seismogenic radiation.

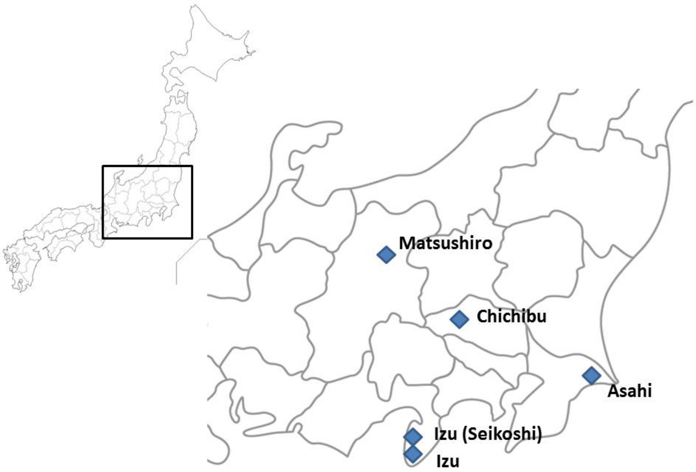

Figure 3. Location of ULF/ELF receivers. Observations at Asahi and Matsushiro are in operation, and a few more stations will be established shortly.

A few stations have already been installed and they are in operation (Asahi and Matsushiro stations). A few more will be installed shortly in the Izu peninsula and at Chichibu. The simultaneous use of ELF data at a few stations will enable us to locate the source of such seismogenic ELF radiation by means of triangulation [Schekotov et al., 2007, 2016; Ohta et al., 2013], and so this principle will enable us to pinpoint a coming EQ (such as a possibility to distinguish between the EQs in the Ibaraki prefecture or in the Odawara area).

The ELF radiation is supposed to be generated by the seismogenic lightning effect due to the generation of those EQ effects in the atmosphere [Schekotov et al., 2013]. The condition of near-the-ground atmospheric effect can be monitored with the reception of line-of-sight VHF signals. In Chofu we will receive signals from the four VHF transmitters (FM transmitters) on the North, South, East and West of Chofu. The VHF signal information will provide us with the near-the-ground atmospheric condition.

2.3 Lithospheric effect

Seismogenic ULF radiation is known to reflect the condition of the lithosphere at the focal region of a coming EQ [e.g., Hayakawa et al., 2011] since the three historical events which are the 1987 Spitak, the 1988 Loma Prieta, and the 2003 Guam EQs. In our opinion this effect is the second important phenomenon for short-term EQ prediction, and a recent statistical study by Hattori [2013], has indicated statistically that the occurrence probability of ULF emissions is higher prior to an EQ than after the EQ.

Again, the direction finding may be useful on the basis of observations at a few stations with different techniques [Ohta et al., 2005; Kopytenko et al., 2006; Hayakawa et al., 2011], and any kind of direction finding techniques will be utilized in our coming Tokyo network.

Furthermore, we will utilize the so-called critical analyses for those seismogenic ULF emissions to identify whether an anomaly in ULF magnetic changes might be due to the precursory critical condition of lithospheric nonlinear process. Fractal analyses have been used extensively by our group [Gotoh et al., 2004; Smirnova et al., 2004; Ida et al., 2005, 2006; Ida and Hayakawa, 2006; Hayakawa and Ida, 2008], and recently we have performed another critical analysis like natural time analyses for a particular 2011 Tohoku EQ and succeeded in finding pre-EQ criticality for this EQ [Hayakawa et al., 2015]. These critical analyses will give us an answer whether an anomaly in ULF noise is really EQ-related or not, so that it will be of potential importance in understanding the mechanism of seismogenic ULF emissions as a fracturing process.

3. Coordination of multi-disciplinary parameters

As shown in the previous section, the physical parameters we observe are seen to cover the whole range from the lithosphere, atmosphere and ionosphere, so that a comparison of temporal and spatial evolutions of various seismogenic parameters will be used to elucidate the mechanism of lithosphere-atmosphere-ionosphere coupling (a few hypotheses have been proposed [Pulinets and Boyarchuk, 2004; Molchanov and Hayakawa, 2008; Devi et al., 2012; Hayakawa, 2015].

4. Outlook of this network

We believe that the network proposed in this paper with special reference to EQs in the Kanto (Tokyo) region, is the first attempt of very multi-disciplinary observations of seismogenic effects. As is seen from the coming network composed of several observational items, the Kanto district does not mean only the central Tokyo, but it may cover the central Japan down to Hamamatsu in the west and down to Sendai in the east. This coming network will help a lot in resolving the mechanism of lithosphere-atmosphere-ionosphere coupling as the main academic target of EQ predictology. Better understanding of those mechanisms will surely lead to drastic improvement in the accuracy of short-term EQ prediction (time, place, and magnitude) in the Kanto district.

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