Preseismic Lithosphere-Atmosphere-Ionosphere Coupling Associated With Earthquake

Preliminary Mission Analysis for Nano-Satellite Observation

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***Abstract*—We propose an satellite observation to investigate preseismic lithosphere-atmosphere-ionosphere (LAI) coupling. Preliminary mission analysis shows that it is possible to prove not only a statistical correlation but also causation between earthquake and ionospheric anomaly even by three dedicated nano-satellites. The observation of proposed satellite constellation promotes a comprehensive understanding of LAI coupling.**

Keywords—Earthquake; Precursor; Lithosphere-Atmosphere-Ionosphere Coupling; Satellite

I. Nonseismological Earthquake Precursors

Preseismic atmospheric and ionospheric disturbances as well as preseismic geo-electric potential anomalies and ultra-low-frequency (ULF) geomagnetic variations observed on the ground have been reported. Both the phenomena have been found since the 1980s and a number of papers have been published [1]. Since most of the reported phenomena transiently appear with accompanying quiescence before the mainshock, this prevents us to intuitively recognize a correlation between the anomaly appearance and the earthquake occurrence (Fig. 1). Some of them, however, showed that anomalies monotonically grew into the mainshock, of which a variation supports the concept of seismic nucleation process under the pre-earthquake state. For instance, preseismic ULF geomagnetic variation in 1989 M7.1 Loma Prieta earthquake, USA, was observed 7 km distance from the epicenter [2]. This variation started two weeks before the mainshock, and further enhancement was observed a few hours before. After the mainshock, the variation gradually decreased. This report is still contradictious partly because the signal enhancement might be due to malfunctions of the instrument such as amplifier failure [3]. However, this report has been significant as a pioneering study. As a similar variation, Heki reported that ionospheric electron density monotonically enhanced tens of minutes prior to the subduction mega-earthquake [4]. However, this preseismic enhancement is apparent variation attributed to tsunamigenic ionospheric hole [5], namely wide and long-duration depletion of ionospheric electron after tsunami-excited acoustic waves reach the ionosphere [6]. Since the tsunamigenic ionospheric hole could be simulated [7], the reported variations are high-possibly pseudo phenomena. Thus, there are barely a few reports which show the preseismic monotonic variation supported by the concept of the seismic nucleation process.

As far as we discuss the preseismic geoelectromagnetical and atmospheric-ionospheric anomalies, preseismic transient events from a few weeks to a few hours prior to the mainshock are paid attention to for the precursor study.

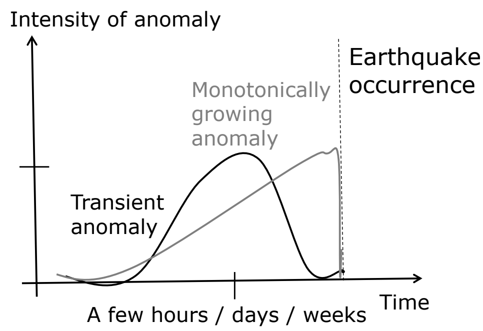

Fig. 1 Two types of time-series of reported precursors

II. Methodology For Study

In order to identify precursors from a number of anomalies, one has to show a statistical significance of correlation between the earthquake and the anomalies, to elucidate the physical mechanism, or to conduct both statistical and physical approach. Since many speculation of the physical mechanism have been hardly verified so far, a statistical approach has been unique way to promote the research. After the 2000s, several papers showing robust statistical results have arisen. In this paper, we focus on publications satisfying the following identification criteria: 1) A candidate of precursor, namely anomaly, is quantitatively defied. 2) Two time-series of anomalies and earthquake are constructed within the fixed thresholds such as a minimum magnitude, a region, and a lead-time. 3) To obtain a statistical correlation, a statistical process which includes four relations considering all combination among earthquake - no earthquake versus anomaly and no anomalies (TABLE I) is applied, *e. g.*, phi correlation. 4) For correlations under various thresholds the results keep consistency. 5) Large anomalies appear before large earthquakes.

One of papers based on the identification criteria, which concerns preseismic geoelectrically anomalies, is introduced as an educative example. VAN method in Greece, *i. e.*, Geo-electric potential difference measurement for precursor study in Greece, has been often discussed in the point of view of success and failure performance for practical prediction [9] to show a correlation and then less number of papers shows the statistical correlation with satisfying the identification criteria [10], so that the phenomena had been controversial. However, recent related study in Kozu-Island, Japan which satisfied the criteria showed the robust correlation [11]. Therefore, the preseismic geoelectric anomalies are expected to be a precursor.

TABLE I. CORRELATION IN FOUR-WINDOWS

	Earthquake occurrence	No Earthquake
Anomaly appearance	High rate means expected precursors.	Anomalies caused not by earthquake but by other reasons should be shown.
No anomaly	Not candidate of precursor	Normal state should be known.

III. LITHOSPHERE-ATMOSPHERE-IONOSPHERE COUPLING

Preseismic lithosphere-atmosphere-ionosphere coupling has been intensively discussed (See [12]). According to review based on the identification criteria with considering recent publications, plausible precursors have been found, which are tropospheric anomaly [13], nighttime ionospheric disturbance in D region [14], daytime electron depletion in F region [15], nighttime decrease of background intensity of VLF electromagnetic waves possibly attributed to ionospheric disturbance in D region [16][17] as shown in Fig. 2. Although these reported anomalies are plausible from a statistical correlation, we note that the results are controversial because of no repeated results [18], optimistic statistical process [19], and residual variation due to magnetic storm [20].

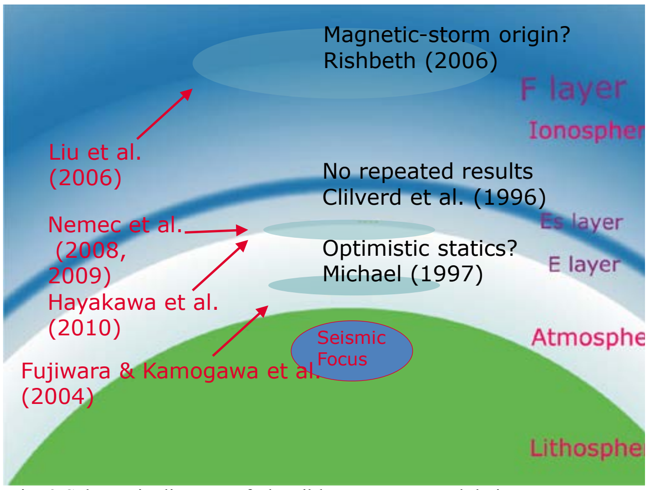

Fig. 2 Schematic diagram of plausible precursors and their arguments

IV. SATTELITE OBSERVATION

In general, it is difficult to show a statistical correlation between the precursor and the large earthquake, because of infrequent occurrences of the large earthquake. In particular, to prove the causation required by the identification criteria 5 needs a number of much larger earthquakes, which are further less number according to Gutenberg- Richter relation. In addition, the events of earthquakes in the ocean and far from the ground observation site might be undetectable. Supposing that a number of precursors are detectable on the ground-based station, it might take the long term of thousand years. Theses plausible atmospheric-ionospheric precursors last for a few hours to a few days before the mainshock. Therefore, some of precursors are detectable by satellites because the orbit sampling of satellite is less than the duration of the precursors. Moreover, the satellite observation can cover the whole of a region of active seismicity, when the inclination of satellite is more than 60 degrees.

Here we focus on preseismic intensity decrease of VLF electromagnetic waves during the nighttime which is observed by sun-synchronous DEMETER satellite [16][17]. The phenomena appeared within 4 hours before the mainshock with more than magnitude 5.0 occurred inside 500 km epicentral distance from the sub-satellite point. From this orbit, more than 100 events with the magnitude of more than 5.5 are observable during 2.5-year operation (Fig. 3). If we simultaneously launch three dedicated and low-cost nano-satellites to detect this precursor as a piggyback, an increase of orbit intervals due to perturbations to the satellites expands the number of observable events to contribute to a statistical analysis. In other words, the comparison between the results of more than magnitudes 6 and 5, required by the identification criteria 5, provides a conclusion of the causation between the earthquake and the detected anomalies.

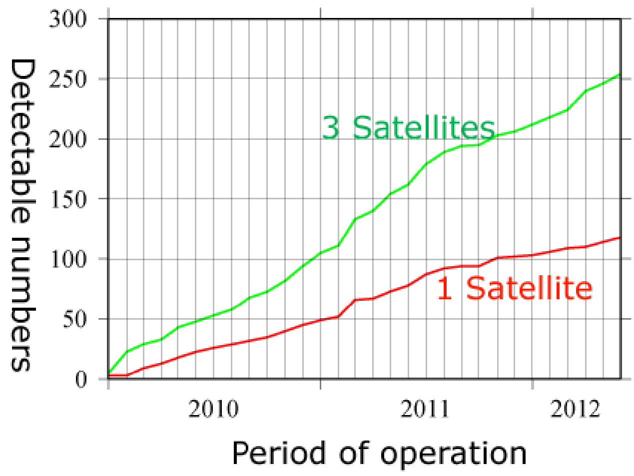

Fig. 3 The detectable number of events with magnitude of more than 5.5 for one and three nano-satellites.

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