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Signal Bursts observed by low Earth Satellite during Seismicity

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Abstract- Every year, the world is hit by a large number of earthquakes, which result in enormous damage, not only in terms of mortality rate but also adversely weaken the socio-economical spine of any nation. Recent years have evidenced a comprehensive study about seismic activities and the various phenomena associated to such events. An interesting and relatively nascent subject related to earthquakes is the generation of Ultra Low Frequency and the Extremely Low Frequency emissions, that account for changes in the electric and the magnetic field prior to moderate as well as strong earthquakes. This paper attempts to emphasize on and discuss the association of ULF and ELF waves in context to the seismic activities. Also some of the intricate causes pertaining to generation mechanism of such electric burst are discussed.

Index Terms- DEMETER, Earthquakes and Electric Field Variation.

I. Introduction

The study of electro-magnetic emissions during a seismic event has attracted a large number of physicists and seismologists. Among the electro-magnetic emissions during earthquakes, the Ultra low frequency (upto 10 Hz.) and the Extremely low frequency (3Hz. to 3kHz.) prove as an effective mode to study the precursors associated with moderate as well as large scale earthquakes. These emissions propagate up to the ionosphere (Gokhberg et.al., 1983, 1984; Molchanov, 1991). Observations made by low altitude satellites also show enhancement in the ELF signals over seismically active regions.
Despite the involvement of high frequency emissions, this paper presents the ULF and ELF variations associated with seismic activity as they possesses a greater skin depth. The ELF and ULF measurements started recently in Seikoshi station have detected the precursory anomalies for large earthquakes (M>6.0) near Izu Island. The Guam earthquake of 1993 and California quake of 1989 are other such evidences of ULF and ELF emissions. This paper presents the electric field data recorded by a low altitude satellite during a recent Indonesian earthquake (3.68 °S, 135.46 °E, 07:36 hrs. UTC and 100 kms. from Enarotali) that measured 6.1 on the Richter scale .

Generation mechanism of Electro- Magnetic emissions:

The primary mechanisms for the generation of electric and magnetic field changes during earthquakes include effects such as piezoelectricity, tribo-electricity, the electro kinetic effect and micro-fracturing. These phenomena are briefly discussed below.

Piezoelectric effect: The mechanism is based on the phenomena that opposite sides of certain piezoelectric crystals become oppositely charged when stress is applied to them in certain crystallographic directions. It happens due to subtle displacement of ions in the structure (Finkelstein et.al., 1973). This causes a voltage (piezo-voltage) to generate and it is expected that similar processes of indentation in tectonic plates due to their differential motion could lead to electromagnetic emissions.

Tribo-electric effect: it describes the phenomena that when crystals are violently rubbed or abraded sparks may be observed. In the process, current is generated referred to as the tribo electricity and cause the disturbed electric and magnetic fields.

Electro kinetic effect: The role of active fluid flow in the earth's crust as a result of dislocation or volcanic activity can generate electric and magnetic fields (Fenoglio et.al., 1995). Such variations in the electric and magnetic fields result from fluid flow through the crust in presence of an electric double layer at the solid liquid interface.

This double layer consists of ions enclosed to the solid face along with the equivalent ionic charge of opposite sign distributed in the liquid phase near the interface. Fluid flow in this system transports the ions in the direction of the flow of fluid and in turn results an electric current.

Micro-fracturing: When stress from a rock under high uniaxial compression are released suddenly a micro crack is generated with emission of electrons from the atoms giving rise to the distribution of oppositely charged particles (electrons and ions) near the tip of the generated crack. With the consequent increase in stress, two micro cracks are nucleated at the end points of the initial crack. They grow in both directions and finally cause an axial splitting. The negative charges exist in the middle and the positive charges at the ends. Such a distribution of charges, is equivalent to a moving electric quadripole which is sufficient to generate electric and magnetic fields.

Project DEMETER (Detection of Electro-Magnetic Emissions Transmitted from Earthquake Regions):

In order to encourage studies related to large number of earthquakes and related phenomena simultaneously, the French scientists have launched a microsatellite 'DEMETER' (Detection of Electro-Magnetic Emissions Transmitted from Earthquake Regions) mainly to study and investigate the ionospheric perturbations associated with major geophysical hazards such as volcanic eruptions and earthquakes.

The mission was proposed by ***Laboratoire de Physique et Chimie de l'Environnement*** (***LPCE***)-***Environment Physics and***

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Chemistry Laboratory. It is also equipped with instruments to detect the electro magnetic field variations linked with seismic occurrences.

Magnetic field component measurements: The 'Instrument Magnetometre Search Coil' (IMSC) has been used to measure the three components of the magnetic field upto 18 kHz. The value of the corresponding magnetic field is given by the current circulating in a spiral coil around a metallic core. The 3 antennas supporting the tri axial measurement of the magnetic field are mounted according to three orthogonal axes at the end of 1m arm.

Electric field component measurements: The 'Instrument Champ Electrique' (ICE) is utilized for making the electric field measurements upto 3MHz. The three components are obtained by measuring the potential difference between the electrodes.

II. Observations

In this paper, the electric field variations measured by **DEMETER** satellite that occurred during the earthquake in the Irian Jaya region in Indonesia (**3.68 °S, 135.46 °E, 07:36 hrs. UTC** and **Ms=6.1** 100 kms. from Enarotali) have been presented for the ELF range.

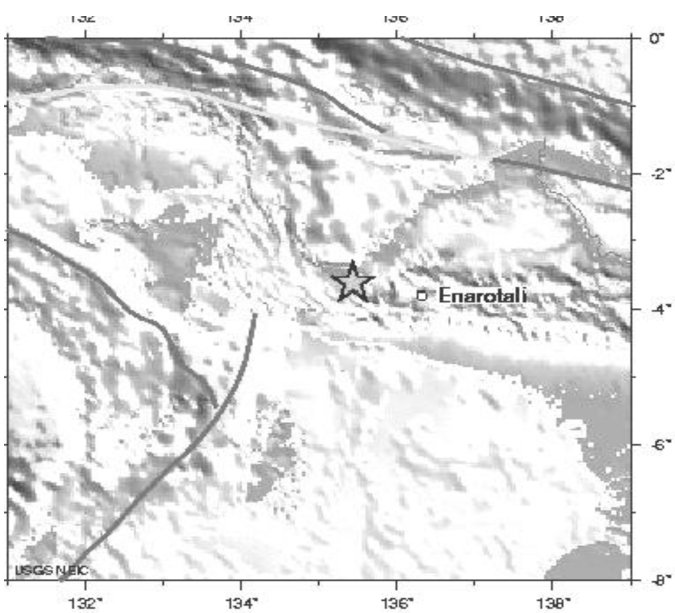
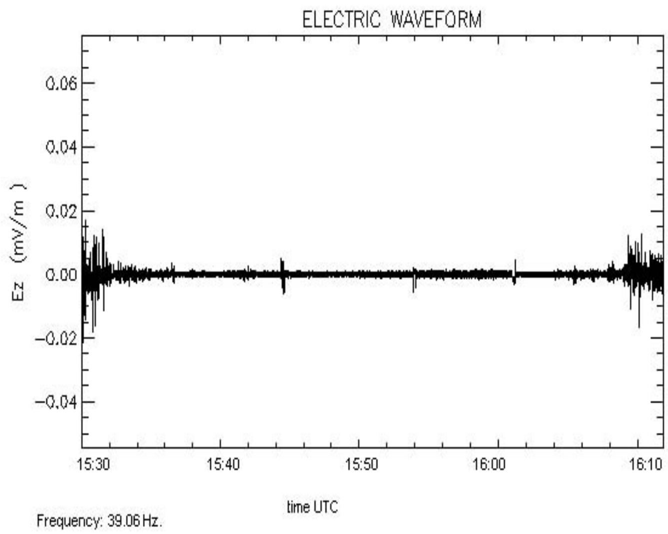


Fig.1 Earthquake location (3.68 °S, 135.46 °E, 07:36 hrs. UTC and Ms=6.1) (courtesy: NEIC)

The electric field component fluctuations have also been shown. The corresponding orbit numbers for 26 Nov.04 and 28 Nov. 04 are 2140 and 2168 respectively.



26/11/04 data

Fig.2 Plot showing ELF electric field for Ez component two days before earthquake over the same region.

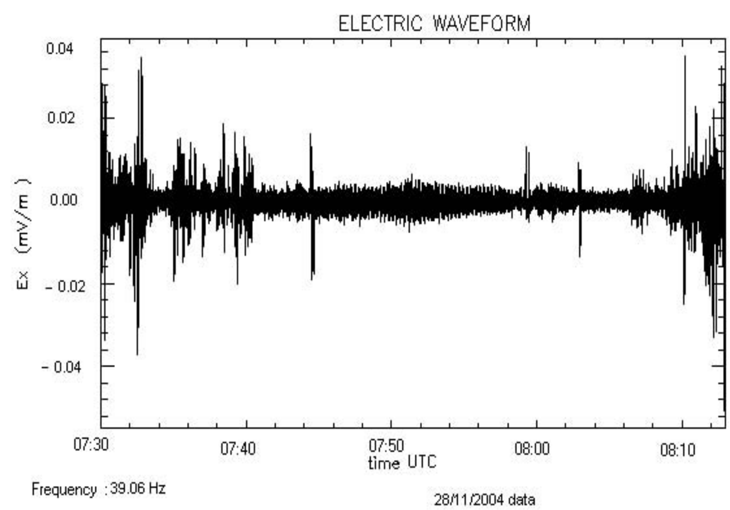


Fig. 3(a) Plot showing ELF electric field bursts during earthquake for Ex component during the time of the Indonesian earthquake.

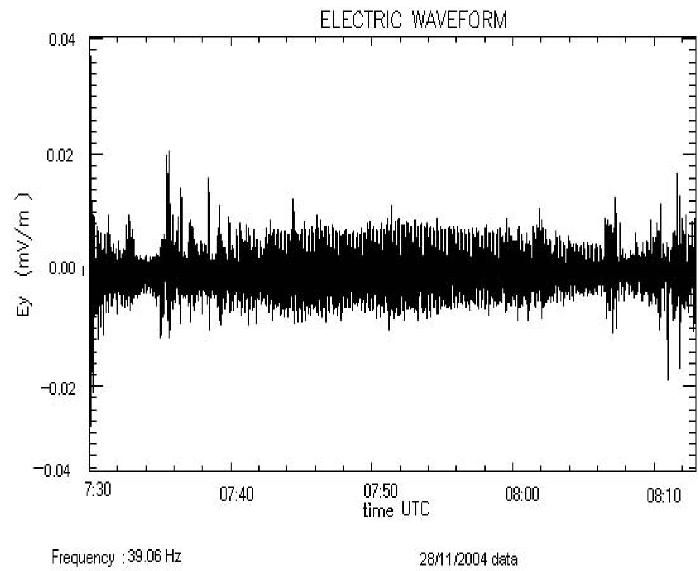


Fig. 3(b) Plot showing ELF electric field bursts during earthquake for Ey during the time of the Indonesian earthquake.

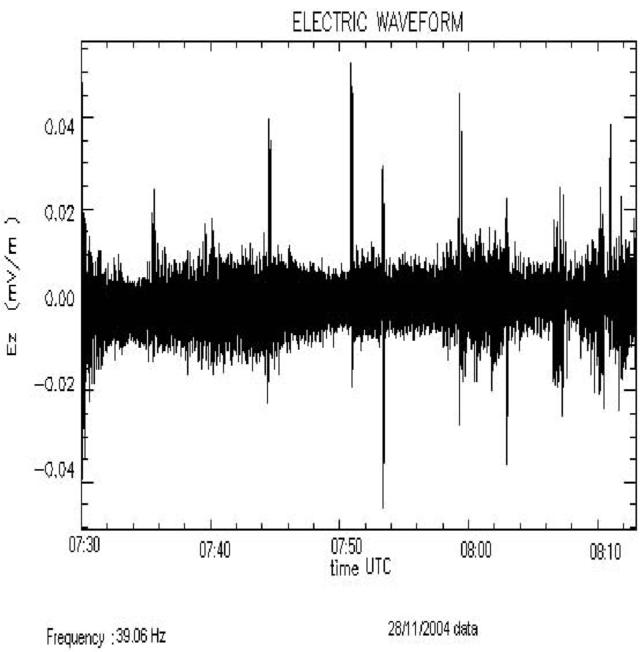


Fig. 3(c) Plot showing ELF electric field bursts during earthquake for Ez during the time of the Indonesian earthquake.

III. Results and Discussions

Fig. 2 indicates the data of electric field for the vertical Ez component two days before the earthquake (26 November 2004, 15:30 UTC). Fig.3(a), 3(b) and 3(c) illustrate the ELF electric field for the Ex, Ey and Ez components respectively around the 40 Hz. range (ELF) which was observed by the DEMETER satellite over the Irian Jaya region in Indonesia just before the time of occurrence of earthquake (**Ms=6.1**). One could observe that there were no extraordinary variations in the Ez component (Fig. 2) during the pass of satellite. However, significant noise bursts in the ELF (around 40 Hz.) were observed in Ex and Ez components during the occurrence of the seismic activity on 28 Nov. 2004 {Fig. 3(a) and 3(c)}. The earthquake occurred on 28 November 2004 at 07:36 hrs. UTC and during this period the Ex component shows enhancement in the signal. Thereafter, sudden variations in the vertical Ez component occur for some significant point of time in the form of bursts suggesting, the association of ULF-ELF emissions with the seismic activity in the Irian Jaya region of Indonesia.

IV. Conclusions

Electro-magnetic emissions in the ULF and ELF range are very common in the ionospheric region. But moderately strong earthquakes also suggest the involvement of such emissions that could occur before, during or after seismic activities. The Indonesian earthquake justifies one such example where the magnitude is large enough to cause electric field perturbations in the ELF range. One of the main scientific objectives of Project DEMETER is to study and analyze the association of electro-magnetic field emissions with earthquakes by capturing a larger number of seismic activities globally.

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