Satellite Monitoring of Ionospheric Disturbances Associated With Earthquakes Over Asian Region.

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ABSTRACT

This paper presents the ionospheric disturbances observed from the micro-satellite DEMETER (Detection of Electro-Magnetic Emissions Transmitted from Earthquake Regions) over the Asian region. The DEMETER is the first micro satellite developed by CNES (French National Space Agency) for seismo-ionospheric studies. The scientific objective of the DEMETER is the detection and characterization of electro-magnetic signal associated with natural phenomena (such as earthquakes, volcanic eruptions, tsunamis) or anthropogenic activity. The scientific payload of DEMETER is composed of several sensors, which allows to measures waves in broad frequency range (DC to 4 MHz) and also some important plasma parameters. The study includes the variations of electron density, ion composition and temperature during the time of earthquakes. The variability of various electromagnetic signals observed by DEMETER during seismic activity over Asian region are presented.

INTRODUCTION

The prediction of earthquakes and volcanic eruptions remains largely an unsolved problem. The interest in ionospheric and electromagnetic phenomenon caused by lithosphere, which is related to earthquake preparation increased during last ten years. It is observed by many researchers that there is a connection between the lithosphere and the ionosphere of the earth. This connection may be established either from the ground or from the space. There is at present factual materials that shows evidence of a response in the ionosphere from seismic activity. Above the epicentre of future earthquake, there appears a macroscopic changes in the ionospheric parameters at an altitude of about 400 km to 1000 km prior to the occurrence of earthquake. Variation in ionospheric parameters such as plasma density fluctuations, change in composition and density of ion are detected were detected few days before the earthquake (Pulinets et al. 1994) . Increases as well as decreases of the critical frequencies are observed in the D, E and F regions before earthquakes. Although this phenomenon is not well understood, it could be related to a redistribution of the electric charges at the surface of the Earth and then in the Earth's atmospheric system (Parrot et al. 1993, Molchanov 1993, Parrot (1995), and Pulinets et al. 2003). Ionospheric disturbances in electron density were also observed during the time of earthquakes (Liu et al. 2001).

Electro-magnetic emissions are considered to be the most promising tool for studying ionospheric disturbances associated with earthquakes. These are the electric and magnetic perturbations caused by earthquakes and volcanic eruption and occur between few hours to few days before the main shock. It includes electromagnetic emission in a large frequency range, perturbations in ionospheric layers, and anomalies on the record of VLF transmitter signal. The generation mechanism of these electromagnetic emissions is not entirely understood. There was a hypothesis that rocks under stress emit waves at various frequencies and these waves propagates from ground and modify the ionospheric parameters (Parrot et al. 1995). The micro-satellite DEMETER has been launched in June 2004 for seismo-ionospheric studies. The scientific objective of DEMETER is to study emissions of electromagnetic waves observed during earthquakes and volcanic eruptions, disturbances in the ionosphere and the upper atmosphere. The second scientific objective of is the global monitoring of electromagnetic environment around the earth.

Asian region covers the most seismically active regions of the world. Strong and devastating are occurring in almost all the parts of this region. Two earthquakes events are taken from Asian region. The first earthquake of magnitude 5.8 occurs on 20th August 2004 near the West coast of Honshu, (36.97°N, 147.63°E) Japan. The islands of Japan lie on the Pacific Ring of Fire and form a series of clearly defined arcs. The relative motion of the North American, Eurasian, Pacific, and Philippine plates causes earthquakes in Japan as they collide near the Japanese islands. The second event of magnitude 8.7 occurred on March 28, 2005 in Sumatra region (Lat 2.07°N, long. 97.3°E) of Indonesia. In Sumatra region, the earthquakes occur due to the relative motion of Indian plate, Burmese micro plate, Sunda plate as they collide near the Sunda trench. Anamolous variation were observed in plasma parameters above the epicenter region before the seismic shock. It includes the variation of electron density, electron temperature, ion density and ion temperatures. Electromagnetic emissions of Very Low Frequency (VLF) ranges were also noticed during this period. The nighttime orbits of DEMETER are taken for observation because at night the ionosphereis calm. The local geomagnetic activity was found to be moderate during the days of observation as there were no solar flare and no

geomagnetic storms observed during that period. Therefore the ionospheric perturbations observed were independent of the solar terrestrial disturbance and the observed variation might be attributed to the seismic activity.

DATABASE AND OBSERVATION METHODOLOGY

The DEMETER is the first micro satellite developed by CNES (French National Space Agency) for seismo-ionospheric studies. It is a low-altitude satellite (h = 710 km) with a nearly polar orbit. The main scientific objectives of the DEMETER are related to the investigation of ionospheric perturbations due to seismic activity. The scientific payload of DEMETER is composed of several sensors associated to a data processing unit and a large memory in order to record the information all around the Earth independently from a telemetry station. There are two modes of operation firstly a survey mode to record low bit rate data all around the earth and secondly a burst mode to record high bit rate data above the seismic regions. Data and plots for all experiments are available through a web server (http://demeter.cnrs-orleans.fr).This satellite measures electromagnetic waves from DC to 4 MHz. Electrical Field Instrument (ICE) measures the quasi-electric components of waves. The main objective of the ICE experiment is to detect and characterize the electromagnetic perturbations in the ionosphere that are associated with seismic activity. The magnetic components of waves are measured by Magnetometer Search Coil Instrument (IMSC). For measuring the plasma parameters, Plasma Analysis Instrument (IAP) and Langmuir Probe Instrument (ISL) are used. The IAP instrument is designed to measure the main plasma parameters in the ionosphere variations of which reflect disturbances in the ionosphere. They are the density and ionic composition, temperature (range 1000K – 5000K) and velocity of dominant ions H+, He+ and O+ less than 2km/s. The ISL instrument measures the electron density of plasma (range 10^2 to 5.10^6), electron temperature (range 500K to 3000K) and the potential of the satellite (range +/-5V).

RESULTS AND DISCUSSION

1. An earthquake of Magnitude 5.5 occurred in the West coast of Honshu, (36.97°N, 147.63°E) Japan on 20th August 2004. Fig. 1 shows the half orbit (655_1) of DEMETER on 16th August 2004. This orbit is four days before earthquake. The data corresponding to this event is shown in Fig.3.From top to bottom the first and second panel shows the variation of electron density and electron temperature observed by ISL instrument. The third panel represents the density variation of H+, He+ and O+ ions observed from IAP experiment. The last panel highlights the spectrogram of electric component up to 2 KHz recorded by ICE experiment on board DEMETER satellite. The intensity of the emissions is colour coded according to the scale on the right. The data is presented as a function of the Universal time (UT), the Local time (LT), the geographic latitude and longitude and the L values are also given. The black arrow in each panel shows the position of earthquake. Fig. 3 clearly shows that the electon density and density of O+ ions increases at 12:40 UT to 12:45UT (locally night time) over the epicentre region. Regarding the electron temperature there is a clear variation in electon temperature. In the last panel we saw that there is an increase VLF emission from latitude 27 °N to 42°N that is very near to the epicentre region of the earthquakes. These ionospheric variations can be explained in terms of anomalous electric field generated near the epicentre of future earthquakes. Also the observations were taken on quiet day and the value of Kp for the whole month of August is less than 4, so these so variations might be caused due to the seismic activity.

2. An earthquake of magnitude 8.7 occurred on March 28, 2005 in Sumatra region (Lat 2.07°N, long. 97.3°E) of Indonesia. Figure 2 shows the half orbit (3842_1) of DEMETER on March 23, 2005, five days prior to the main shock. The data corresponding to this orbit is shown in Fig. 4.In Fig. 4 the top panel shows the electron density variations observed from ISL instrument, the second panel gives the density variations of H+, He+ and O+ ions. The last panel represents the spectrogrm of VLF emission. The data is presented in the same way as in the previous case. The black arrow in each panel shows the position of earthquake. Fig.4 also shows that there is a fluctuation in electron and ion density at 15 :23UT to 15 :28UT(locally night time), above the epicenter region of the earthquake. Last panel shows that the intensity of VLF emissions increases (shown by red color) above the epicenter region.In this case also the anomalous electric field generated near epicentre of earthquakes is responsible for these observed ionospheric variations as the maximum value of Kp is less than 4.5 for the whole month,so these variations were independent of the solar terrestrial disturbance and might be attributed to the seismic activity.

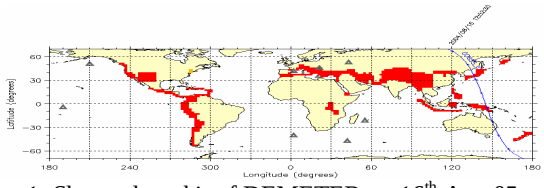

Fig. 1: Shows the orbit of DEMETER on 16th Aug.05

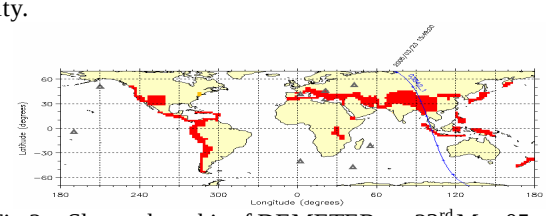

Fig 2. : Shows the orbit of DEMETER on 23rd Mar.05.

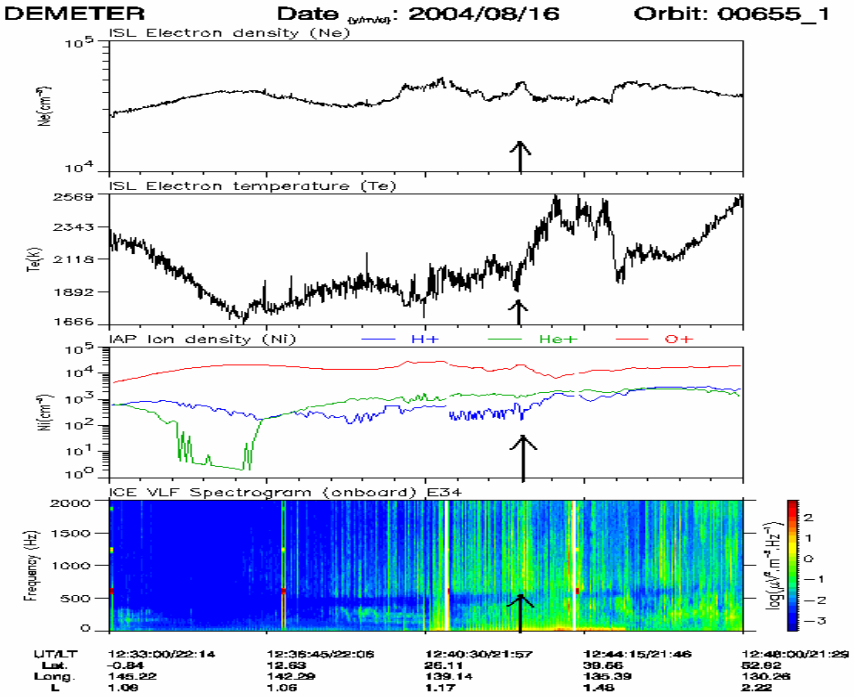

Fig. 3: From top to bottom the panels successively show the electron density, electron temperature given by ISL instrument, the ion density given by IAP instrument and the spectrogram of electric component between 0 to 2kHz from ICE instrument.

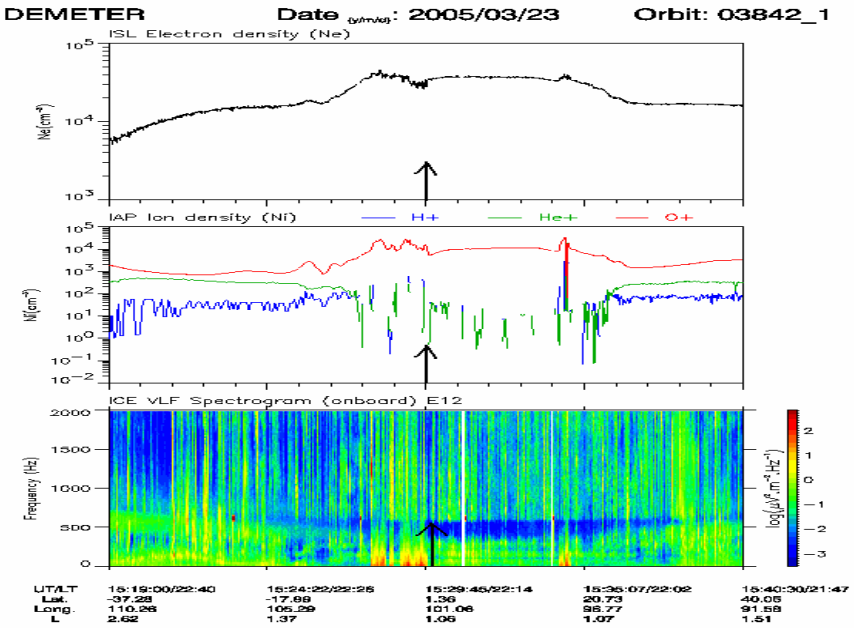

Fig. 4: From top to bottom the panels successively show the electron density given by ISL instrument, the ion density given by IAP instrument and the spectrogram of electric component between 0 to 2kHz from ICE instrument.

CONCLUSION

The ionospheric perturbations over the epicentre of future earthquakes has been discussed which includes the variations of plasma parameters and increase in the intensity of VLF emissions above the epicentre of future earthquake. The spatial and temporal variations of ionospheric parameters are very close to the future earthquakes. There is a hypothesis that anomalous electric field penetrating into the E- region of the ionosphere creates irregularities (Liperovsky et al.2000). And due to the equipotentiality of geomagnetic lines the electric field without any decay penetrates at the higher levels of the ionosphere. This effect is seen in the F region of ionosphere and in the area of maximal conductivity due to joule heating acoustic gravity waves will be generated giving rise to small-scale density irregularities within the ionosphere (Hegai et al.1997). The plasma density variations that we have observed are due to this effect. These irregularities spread along the geomagnetic field lines creating field-aligned ducts where VLF emissions of different origin (seismic origin) will be scattered. This will lead to increased level of VLF emissions within the magnetic tubes along the areas of anomalous electric field generation. The maximum value of Kp recorded for the corresponding period is moderate (4.5). So the perturbations observed were independent of the solar terrestrial disturbance and these phenomena might be attributed to seismic activity.

ACKNOWLEDGEMENT

The authors would like to thank Prof. Michel Parrot of LPCE/CNES, France for providing DEMETER data and other valuable guidance.The authors also wants to express their gratitude to Dr. Jean Louis Pincon of LPCE/CNES for his support. The authors also wish to acknowledge the Indo French Centre for the promotion of Advanced Research (IFCPAR), New Delhi for providing financial support

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