IONOSPHERIC DISTURBANCES ASSOCIATED WITH TONGA M_W7.9 EARTHQUAKE—RESULTS FROM LANGMUIR PROBE INSTRUMENT ONBOARD DEMETER SATELLITE

Ze-Ren-Zhi-Ma[1], ZHANG Xue-Ming[1], SHEN Xu-Hu[1]i, Liu Jing[1], Xiong Pan[1],Kang Chun Li[2]

1. Institute of Earthquake Science, China Earthquake Administration, Beijing, 100036, China
2. China Earthquake Networks Center,Beijing,100036,China

ABSTRACT

Nowadays more and more evidences proved that ionospheric disturbances associated with strong earthquake do truly exist, with the development of earthquake observations from space, showing that perturbation of strong earthquake is not merely limited in lithosphere, but also can interaction with atmosphere, ionosphere and even magnetosphere. Even though, the coupling mechanism between Lithosphere, Atmosphere and Ionosphere（LAI） is poorly understood about how the ionosphere is perturbed by the strong earthquake activity in the lithosphere, but an increasing number of studies about ionospheric disturbances associated with seismic activity are carried out(M.Parrot, 2009, S.Bhattacharya et al.2009,Xue Min Zhang et al.2009), especially after the first micro satellite DEMETER) successfully launched by CNES (French National Space Agency).

The DEMETER Satellite is devoted to the study of ionospheric perturbations in relation with the seismic activity, volcanoes and human activity, and to detect the electromagnetic environment of global scale. Authors in this paper mainly employ Ne (electron density), and Te (electron temperature) data of Langmuir Probe Instrument (ISL) onboard DEMETER, to study the variations of electron density, electron temperature associated with strong earthquakes. 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)（Lebreton J P et al.2006）.

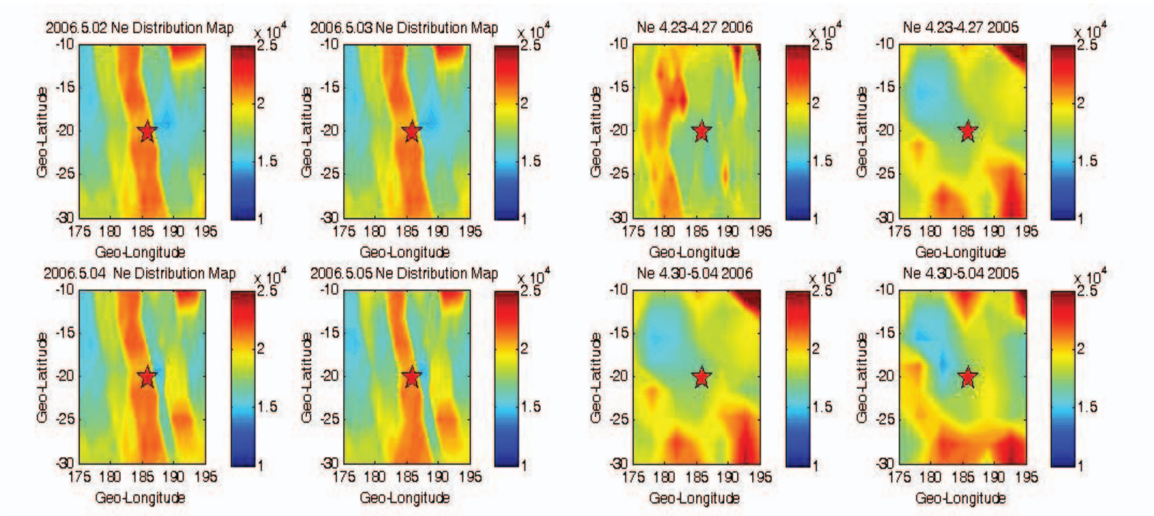
For each earthquake, we chose the orbits which pass over in an area about LAT0±10°，LON0 ±10° (LAT0 and LON0 means the geo-latitude, geo-longitude of the epicenter respectively),including four months data before earthquakes and two months data after

earthquakes. There are three steps to reprocess raw data before analysis. Firstly, the bad orbits affected by man-made operations are deleted based on the data related event file provided by the Demeter scientific task center. The data related event file contains all the events that can affect or corrupt the Demeter data. Secondly, geomagnetic condition is also taken into account, because the disturbances from solar activity, planetary magnetic field and so on, may cover the anomalous information associated with strong earthquakes (Zhang X M, 2009). So when geomagnetic disturbance indices arrived at the level of $Dst \leqslant -30nT$, $Kp \geqslant 3$, $AE \geqslant 200nT$, the orbits affected by geomagnetic disturbance will directly discarded. Thirdly, some sharp change of data in short time is usually generated from the payload itself or Calibration signals, should not be taken into analysis. So we eliminate this kind of noises by computer program.

Here the Mw 7.9 Tonga earthquake which occurred on 3 May 2006(UTC) is one of case study. Hundreds of orbits data from 1 April to 11 May 2006 is collected and reprocessed. The Mw7.9 Tonga earthquake case study show that electron density is relatively lower before 28 April, while began to enhance from 28 April, and got the highest at 2 May, one day before earthquake occurred. Until 6 May after 3 days of the main shock, the electron density began to decline. For deeply study the precursors associated with earthquake, we collected revisited orbits of some particular orbits to build the normal background without strong earthquakes.

The DEMETER satellite orbit was designed as solar synchronous circular orbit, with declination 98.23°, with a revisited period of 16 days from 2005 to 2008.Using revisited orbits at epicenter area can compare data at the same place at the same local time of after every 16 days, to study the spatial and seasonal variation. About three and half hours before the Mw 7.9 Tonga earthquake at 3 May 2006, and fifteen hours after in 4 may 2006, the DEMETER happen to fly above the epicenter, the orbit number is 09768UP(before shock) and 09872UP(after shock) respectively, here UP means up orbit recorded at local nighttime. The revisited orbits about the two orbits from 1 January 2005 to 1 July 2006, about one and a half years, are analyzed to find the normal variation without earthquakes at the same place. The results shows that the electron density became higher than normal ones before earthquake, with variations of up $20000cm^{-3}$ to $30000cm^{-3}$, meanwhile electron temperature got lower than normal ones with variations of up 1000K to 1500K.

Using 5 days as time window and 1 day for step size from 1 March to 1 July 2006, Ne data and Te data has been scanned respectively in research area, to study their temporal and spatial evolution. The results show that Ne distribution occurred high value from 28 April to 8 May, lasting 10 days during the time of the earthquake, with the highest value at 30 April. The temporal and spatial evolution of Te is opposite to Ne. Fig.1.A illustrated evolution of Ne during the Tonga earthquake. We also collected the data of the same time one year before, in order to compare temporal and spatial evolution of electron density and electron temperature in the study area. Fig.1.B illustrated Ne distribution in normal days without earthquake, taking the results of ones from April 23rd 2006 to April 27th 2006, from April 23rd 2006 to April 27th 2005, from April 30th 2005 to May 4th 2005 as examples. The image is approximately same without earthquake days like Fig.1.B. The results of this paper also support the conclusions of Pulinets et al (2003), the ionosperic disturbance generally occurred in a week before strong earthquake.



(A) (B)

Fig.1 The temporal and spatial evolution of Ne during earthquake (A) and normal days without earthquake (B)

The hypothesis about coupling mechanism of LAI proposed by Hayakawa (2004) explained how the ionosphere is perturbed by the strong earthquake activity. The hypothesis demonstrated there are three channels between LAI, chemical channel, acoustic channel and electromagnetic channel respectively. Through chemical channel, the geochemical quantities, such as surface temperature, radon emanation etc change the conductivity of the atmosphere, thus result in the perturbation of ionosphere through the atmospheric electric field (Pulinets and Boyarchuk, 2004). As for acoustic channel, the perturbations in the lithosphere, such as disturbance of temperature, pressure of earthquake preparation area excites the atmospheric oscillations traveling up to the ionosphere (Molchanov et al, 2001). Through electromagnetic channel, the electromagnetic radiation (in any frequency range) generated in the earthquake preparation area propagate up into the ionosphere, resulting in ionospheric disturbance by heating or ionization. The increasing of Ne before earthquake may result from the production of gravity acoustic wave. While there accompanies accumulation and emission of electric signals, so electrons and ions are constructed rapidly and interact intensively. It is known that the coupling mechanism between LAI is complex, and multi-kinds of measurements at ground, atmosphere and ionosphere, even in magnetosphere should be strengthened in future for further understanding the coupling mechanism from seismic source to ionosphere.

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