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Seismo-ionospheric Precursors Probed by Global Navigation Satellite System during the 12 May 2008 M8.0 Wenchuan Earthquake

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ABSTRACT

The global ionospheric map (GIM) is used to observe variations in the total electron content (TEC) of the global positioning system (GPS) associated with 35 M≥6.0 earthquakes occurred in China during a 10-year period of 1 May 1998-30 April 2008. The statistical result indicates that the GPS TEC above the epicenter often pronouncedly decreases on day 3-5 before 17 M≥6.3 earthquakes. The GPS TEC of the GIM and electron density profiles probed by six micro satellites of FORMOSAT3/COSMIC (F3/C) are further employed to simultaneously observe seismo-ionospheric anomalies during an Mw7.9 earthquake near Wenchuan, China on 12 May 2008. It is found that GPS TEC above the forthcoming epicenter anomalously decreases in the afternoon period of day 6 to 4 and in the late evening period of day 3 before the earthquake, but enhances in the afternoon of day 3 before the earthquake. The spatial distributions of the anomalous and extreme reductions and enhancements indicate that the earthquake preparation area is about 1650km and 2850km from the epicenter in the latitudinal and longitudinal directions, respectively. The F3/C results further show that the ionospheric F2-peak electron density, NmF2, and height, hmF2, significantly decreases approximately 40% and descends about 50-80km, respectively, when the GPS TEC anomalously reduces.

Figure 1 displays the GPS TEC above the Wenchuan epicenter isolated from the GIM database, and the upper (enhancement) and lower (reduction) anomalies appearing before and after the earthquake. The Dst index shows that the geomagnetic activity is relatively quiet. It can be seen that the GPS TEC anomalously reduces during 06:00-10:00UT (the afternoon period of 13:00-17:00LT; LT=UT+7hours) on 6, 7, and 8 May as well as 14:00-17:00UT (the late evening period of 21:00-24:00LT) on 9 May 2008. Meanwhile, there is a GPS TEC anomalous enhancement occurring in the afternoon period of 9 May 2008. In general, the reduction anomaly day occurs more frequently before than after the Wenchuan earthquake.

Figure 2 displays that severe reduction and extreme minimum in the GPS TECs generally occur near the north and/or east side of the Wenchuan epicenter but slight enhancement in the west side at 06:00UT on 6, 7, and 8 May 2008, as well as at 14:00UT on 9 May 2008. Note that the local time of 06:00 and 14:00UT at the Wenchuan area are the afternoon period of 13:00LT and the late evening period of 21:00 LT, respectively. To remove the local time effects, again sequences of GIMs at the fixed global times of 13:00 and 21:00LT on the four days are also examined. Overlaps (or superimposition) of the extreme minima observed at 06:00UT or global fixed

13:00LT on 6, 7, and 8 May 2008 shown in Figure 2 confirms that the GPS TEC significantly reduces around the epicenter in the afternoon period of day 6 to 4 before the Wenchuan earthquake.

Figure 3 resents electron density profiles observed over the epicenter during the afternoon period of 13:00-17:00LT on 6, 7, 8, and 9 May and the late evening period 21:00-24:00LT on 9 May, together with the associated references. The F3/C GOX observations demonstrate that the ionospheric NmF2 in the afternoon period on 6, 7, and 8 of May and in the late evening period of 9 May are significantly less than their associated medians by about 30-50%. Moreover, it is found that the F2-peak height, hmF2, descends from about 300 km to 250-220 km altitude which is approximately 50-80 km lower than the associated median on the four anomalous days. By contrast, at 10:00UT on 8 May 2008 the NmF2 significantly enhances but the hmF2 remains the same as the associated median at about 300km altitude when the GPS TEC of the GIM around the epicenter significantly enhances.

Key words: global ionospheric map (GIM), FORMOSAT-3/COSMIC, temporal precursor, spatial precursor.

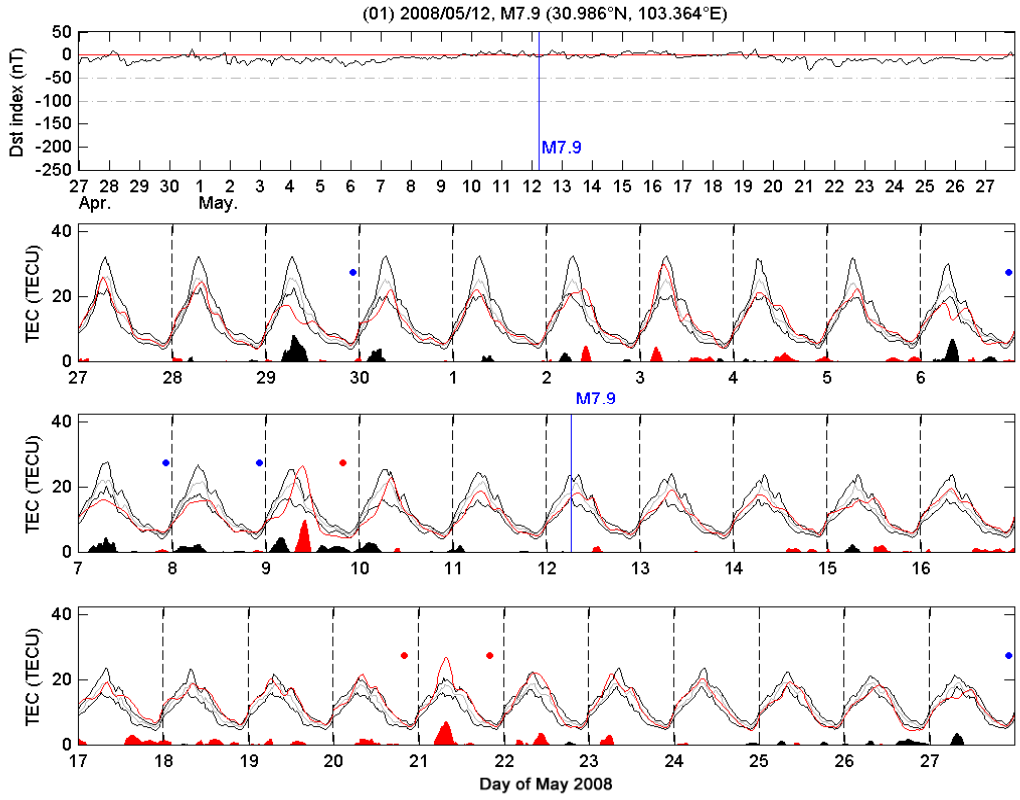

Figure 1. A time series of GPS TEC right above the Wenchuan epicenter extracted from GIMs in May 2008. The Mw7.9 Wenchuan earthquake occurred at 06:28:01 UT on Monday 12 May 2008. The top panel displays variations of the Dst index, which shows the geomagnetic activity being generally quiet. The red, gray and two black curves denote the observed GPS TEC, associated median and upper/lower bound (UB/LB), respectively. Red and blue dots represent the upper and lower anomalous days identified by the computer routine, respectively. The LB and UB are constructed by the 1-15 previous days moving median (M), lower quartile (LQ), and upper quartile (UQ). Here, LB=M-1.5(M-LQ) and UB=M+1.5(UQ-M). Red and black shaded areas respectively denote differences of O-UB and LB-O, where O is observed GPS TEC. [1]

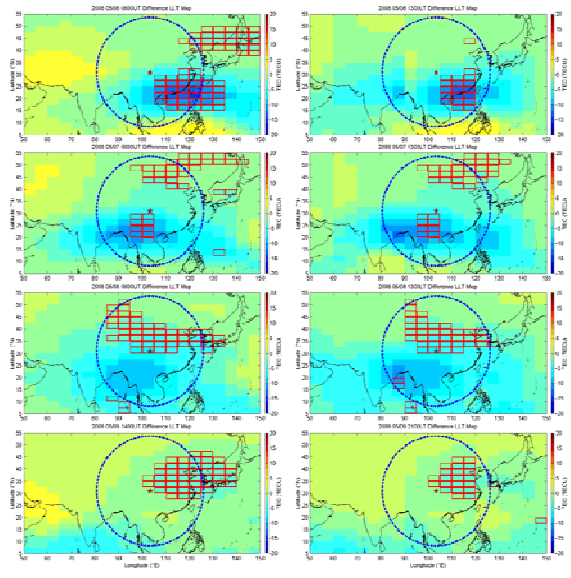

Figure 2. The ionospheric GPS TEC anomalies of the GIMs observed on day 6 to 3 prior to the Wenchuan Earthquake. The left and right columns are GIMs of the universal time and global fixed local time, respectively. The top three panels are the difference between the observations and the associated medians at 06:00UT and global fixed 13:00LT on 6, 7, and 8 May 2008 (from top to down), respectively. The color denotes the difference of the TEC on the observation day to the associated median, and the red grids represent the extreme decreases. The bottom panels are at 14:00UT and global fixed 21:00LT on 9 May 2008. It can be seen that the ionospheric GPS TECs around the epicenter significantly reduce. [1]

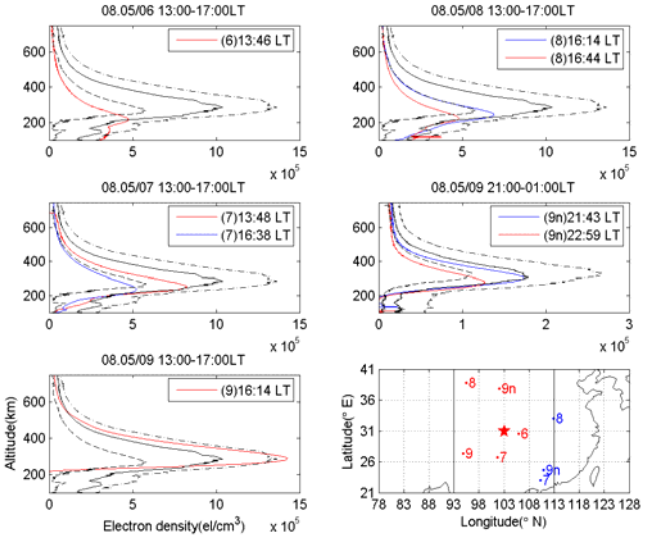

Figure 3. The ionospheric electron density profiles above the epicenter observed on day 6 to 3 before the Wechuan Earthquake by FORMOSAT3/COSMIC satellites. The two panels are the vertical profiles of electron density observed during 13:00-16:00LT on 6, 7, and 8 May (day 6, 5, and 4 before) as well as 21:00-24:00LT on 9 May 2008 (day 3 before the earthquake), respectively. The left bottom is the vertical profiles of electron density observed during 13:00-16:00LT on 9 May 2008 (day 3 before the earthquake). The right bottom panel displays locations of the vertical profiles where the star and numbers denote the epicenter and days of May, and "n" indicates nighttime (i.e. late evening). The red curves represent the observed profiles while the solid and dashed curves in each panel are the associated median and upper/lower quartiles of the same local time period during 21 April – 5 May 2008 (7 to 22 days before the earthquake). [1]

References:

[1] Liu, J.Y., Y.I. Chen, C.H. Chen, C.Y. Liu, C.Y. Chen, M. Nishihashi, J.Z. Li, Y.Q. Xia, K.I. Oyama, K. Hattori, and C.H. Lin, (2009). Seismo-ionospheric GPS total electron content anomalies observed before the 12 May 2008 Mw7.9 Wenchuan earthquake, Journal of Geophysical Research, doi:10.1029/2008JA013698.

Acknowledgements: The global ionosphere map (GIM) of the total electron content (TEC) constructed with about 200 of worldwide ground-based receivers of the GPS is routinely published in a 2-hour time interval (ftp://cddisa.gsfc.nasa.gov/pub/gps/products/ionex). The data for this study are available at Taiwan Analysis Center for COSMIC (TACC) and COSMIC Data Analysis and Archival Center (CDAAC). Dataset name: ionPrf.