Pre-earthquake and Co-seismo Ionospheric Signatures Observed in Taiwan

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The ionosphere can be affected by a variety of disturbances including, for example, solar disturbances, geomagnetic storms, severe weather, volcanoes, and earthquakes. Although the ionosphere is primarily affected by solar and magnetospheric activities, ionospheric anomalies appearing before earthquakes and ionospheric disturbances triggered by vertical surface motion of seismic waves have been observed. In this paper, both pre-earthquake ionospheric anomalies (PEIAs) and coseismic ionospheric disturbances (CIDs) observed in Taiwan are presented. The PEIAs in the total electron content (TEC) of the global positioning system (GPS) and the maximum electron density of the F2 layer (NmF2) appearing before the Chi-Chi earthquake (Mw7.6, 1747 universal time (UT), 20 September 1999) are examined in Taiwan. Results show that the NmF2 and GPSTEC anomalously decrease during 10:00-20:00 local time (LT) of 17 and 18 September 1999, which are 4 and 3 days before the Chi-Chi earthquake, respectively. It is found that the GPS TEC around the Chi-Chi epicenter significantly decrease on 17 and 18 September 1999. A statistical analysis is carried out to examine the PEIAs in the plasma frequency of the F2 peak foF2 and 184 earthquakes with magnitude M!=5.0 during 1994-1999 in the Taiwan area. Results confirm that the ionospheric foF2 significantly decreases during the afternoon period within 5 days before the earthquakes. Meanwhile, the PEIA appearances increase with the earthquake magnitude, but decrease with the distance from the epicenter to the ionosonde station suggest that the PEIA is energy related. On the other hand, many coseismic ionospheric disturbances (CIDs) have been observed in Taiwan. An Mw9.3 earthquake originated in the Indian Ocean off the western coast of northern Sumatra at 00:58 UT on 26 December 2004. Two giant ionospheric disturbances at 01:19 and 04:10 UT are observed by a network of digital Doppler sounders in Taiwan. The first disturbance excited mainly by Rayacket of short-period Doppler shift variations, results in vertical ionospheric fluctuations with a maximum velocity of about 70 m/s and displacement of about 200 m. The second disturbance, in a W-shaped pulse propagating at a horizontal speed of 360 m/s, is attributable to coupling of the atmospheric gravity waves (AGW) excited by broad crustal uplift together with the following big tsunami waves around the earthquake source zone. The accompanying ionosonde data suggest that the AGW in the atmosphere may have caused the ionosphere to move up and down by about 40 km. Meanwhile, ionospheric tsunami disturbances (iononami) of the 26 December 2004 M9.3 Sumatra earthquake are detected by the TEC of ground based receivers of GPS in the Indian Ocean area. It is found that the tsunami waves triggered atmospheric disturbances near the sea surface, which then traveled upward with an average velocity of about 730 m/s (2700 km/hr) into the ionosphere and significantly disturbed the electron density within it.Resul???