Traveling Ionospheric Disturbances Triggered the 26 December 2004 Mw9.3 Sumatra Earthquake and Associated Indian Ocean Tsunami

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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. Recently, many coseismic ionospheric disturbances (CIDs) have been reported. In this paper, ionospheric disturbances triggered by vertical surface motion of seismic waves of the Mw9.3 earthquake originated in the Indian Ocean off the western coast of northern Sumatra at 00:58 UT on 26 December 2004 have been presented. Two giant ionospheric disturbances at 01:19 and 04:10 UT are observed by a network of digital Doppler sounders in Taiwan (Figure 1). The first disturbance excited mainly by Rayleigh waves, which consists of a packet 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±70 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 (Figure 2). 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. Results further show that the iononami, which has maximum height of about 8.6-17.2 km, periods of 10-20 minutes, and horizontal wavelengths of 120-240 km, travel away from the epicenter with an average horizontal speed of about 700 km/hr (190 m/s) in the ionosphere.

References

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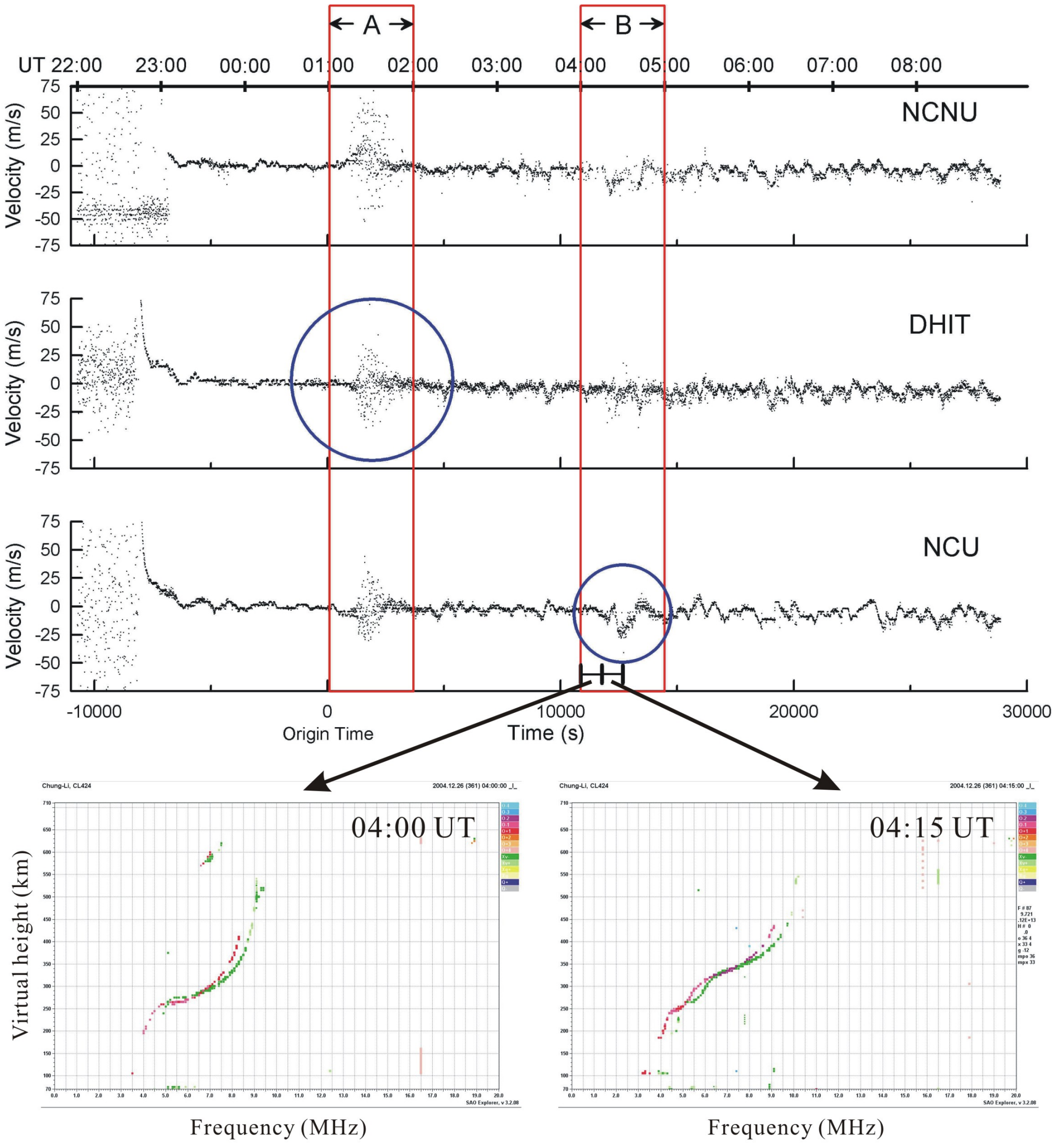

Figure 1. Top: Digital Doppler sounder records of the ionospheric disturbance obtained at stations in Taiwan. Bottom: ionograms recorded by a co-located ionosode at 04:00 UT and 04:15 UT.

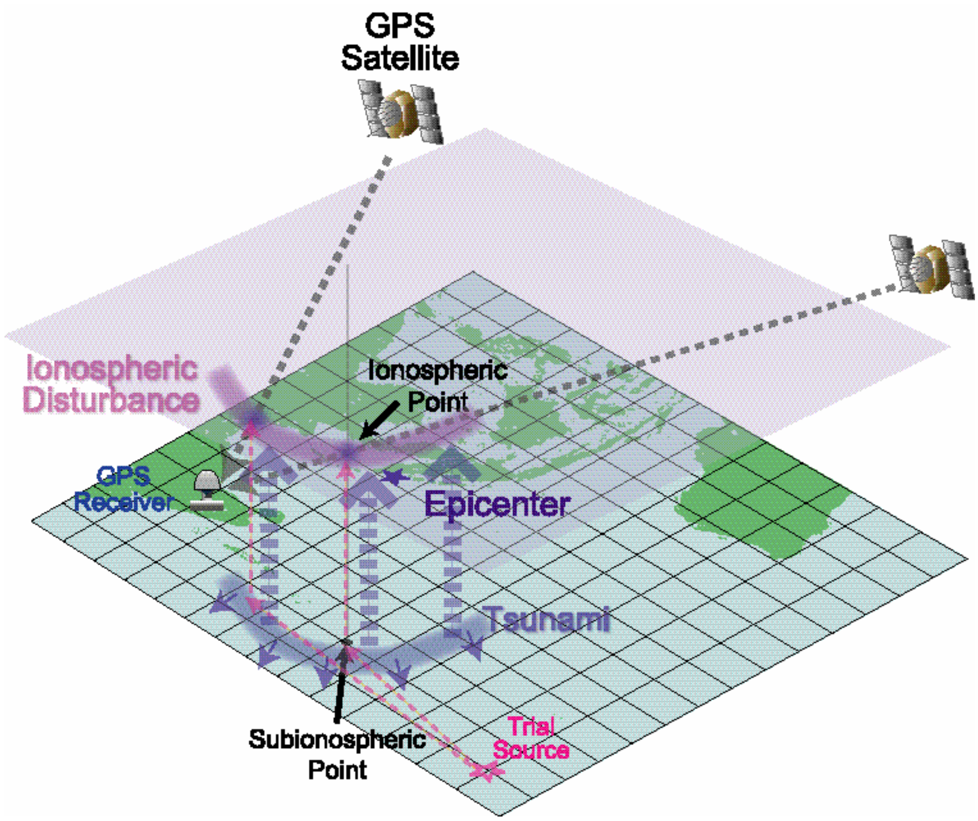

Figure 2. Tsunami activated by an earthquake travels away from the epicenter (dark blue star) along the ocean surface (blue curve) and launches atmospheric gravity waves (blue dashed arrows) which then propagate into the ionosphere and trigger the TID (purple curve). The slant TEC (grey dashed arrow) is the integration of electron density along the path from a GPS satellite to a ground-based receiver. The vertical component of the slant TEC at the intercept (or ionospheric point) of the slant path on the ionospheric surface is termed a vertical TEC (grey line). Each ionospheric point acting as a monitoring station can be employed to detect TIDs. The footprint of monitoring station on the earth surface is termed subionospheric point. The grid for the ray tracing method is 1°x1° latitude by longitude. The solid and open stars denote the epicenter and trial source (pink star), respectively.