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MTT41-04 会場:203 時間:5 月 26 日 09:45-10:00

地震波によって励起されたインフラサウンドのイオノゾンデによる波面追跡と熱圏の電波-音波計測
Radio acoustic sounding of the thermosphere by ionosonde tracking of infrasound wavefronts launched by seismic waves

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It is well known that atmospheric waves excited by intense earthquakes induce ionospheric disturbances. At remote distances greater than ~500 km, Rayleigh waves are the major source of infrasounds that propagate upward in the atmosphere. Acoustic waves interact with the ionospheric plasma through collision between neutral particles and ions. Ionospheric disturbances caused by Rayleigh waves near the low frequency part of the Airy phase (a period of several minutes) are detected as a change in the total electron content since the wavelength of induced acoustic waves in the thermosphere is comparable to the ionospheric slab thickness. On the other hand, Rayleigh waves near the high frequency part of the Airy phase (a period of several tens of seconds) cause distortion of ionogram traces, which is characterized by a multiple cusp signature (MCS). The vertical separation of the ledge corresponding to each cusp is the wavelength of the infrasound in the thermosphere. Thus, the MCS ionogram is considered to be a snapshot of the wave that propagates upward.

We conducted rapid-run operation of ionosonde with a frame rate of 1 min at Kazan, Russia. After the 2010 M8.8 Chile earthquake (epicentral distance was 15,162 km), ionospheric disturbances showing MCSs in ionograms were observed for several tens of minutes. The seismogram obtained at Obninsk near Moscow, Russia (epicentral distance was 14,369 km) recorded Rayleigh waves with a period of ~17 s responsible for the ionospheric disturbances showing MCS (the seismogram was shifted by the time corresponding to the difference of epicentral distances between the two locations by assuming a Rayleigh wave speed of 3 km/s). The vertical wavelength of the acoustic wave launched by the Rayleigh waves was 8.5~12 km in the thermosphere. The sound speed calculated by a model was 500~700 m/s at the height of the bottomside ionosphere and wavefronts should propagate 30~42 km upward during the intervals of ionograms, which is smaller than the bottomside depth of the ionosphere. Thus, we could track acoustic wavefronts between consecutive MCS ionograms.

This observation bears an analogy with radio acoustic sounding system (RASS), in which atmospheric perturbation induced by acoustic sounds is tracked by a radar technique and the sound speed (and corresponding virtual temperature) at high altitudes is remotely measured. In a like manner, we compared the sound speed estimated by the MCS analysis and that calculated by the MSIS thermospheric model. The determined sound speed (and corresponding temperature) was slightly higher than the model.

キーワード: イオノゾンデ, カスプ構造, 2010 チリ地震, レーリー波, インフラサウンド, 熱圏
Keywords: ionosonde, multiple cusp signature, 2010 Chile earthquake, Rayleigh waves, infrasounds, thermosphere