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Japan Tohoku Earthquake of March 11, 2011: GPS-TEC Evidence for the Ionospheric Disturbances with Application for Early Warning

V.E. Kunitsyn (1,2), I. A. Nesterov (1), S.L. Shalimov (2), B.Yu. Krysanov (1), A.M. Padokhin (1), and D. Rekenthaler (3)

(1) Faculty of Physics, M.Lomonosov Moscow State University, Moscow, Russia (kunitsyn77@mail.ru), (2) Institute of Physics of the Earth, Russian Academy of Sciences, Moscow, Russia , (3) Earthquake Warnings, Inc, Sioux City, IA, United States

Two-dimensional distributions of the vertical total electron content in the ionosphere above the Japan undersea mega-earthquake of March 11, 2011 has been obtained with radio tomographic (RT) reconstruction using the high-temporal-resolution (2-minute) data from the Japan GPS network. A diverging ionospheric perturbation with multi-component spectral composition is identified emerging after the main shock. The disturbances in the ionospheric electron concentration were attributed to the acoustic gravity waves (AGWs) generated by the earthquake-related processes. The initial phase of this disturbance can be used as a marker in the tsunami early warning systems. The surface energy of the earthquake estimated from the amplitude of the ionospheric disturbance was found to be close with that based on the seismic data. Ionospheric responses to the Rayleigh waves and tsunami are analyzed with physical interpretation of the revealed ionospheric disturbances. Tsunami waveforms recorded with DART buoys near Japan were used as initial condition for modeling of gravity wave generation. Our previous modeling showed that several oscillation flips of the ocean surface with a period of hundreds of seconds and the velocity amplitude about 10 cm/s generate rather long wavetrains of the gravity waves (10 periods and longer) in the upper atmosphere, which propagate over long distances from the area of perturbation. Here we support this scenario by the results of modeling with the parameters of the ocean surface perturbation corresponding to the considered earthquake. In addition it was observed in the modeling that at long distance from the source the gravity wave can pass ahead of the tsunami. Experimental evidence of this finding has been discussed.