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Ionospheric manifestations of earthquakes and tsunamis in a dynamic atmosphere

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Observations of the ionosphere provide a new, promising modality for characterizing large-scale physical processes that occur on land and in the ocean. There is a large and rapidly growing body of evidence that a number of natural hazards, including large earthquakes, strong tsunamis, and powerful tornadoes, have pronounced ionospheric manifestations, which are reliably detected by ground-based and satellite-borne instruments. As the focus shifts from detecting the ionospheric features associated with the natural hazards to characterizing the hazards for the purposes of improving early warning systems and contributing to disaster recovery, it becomes imperative to relate quantitatively characteristics of the observed ionospheric disturbances and the underlying natural hazard. The relation between perturbations at the ground level and their ionospheric manifestations is strongly affected by parameters of the intervening atmosphere. In this paper, we employ the ray theory to model propagation of acoustic-gravity waves in three-dimensionally inhomogeneous atmosphere. Huygens' wavefront-tracing and Hamiltonian ray-tracing algorithms are used to simulate propagation of body waves from an earthquake hypocenter through the earth's crust and ocean to the upper atmosphere. We quantify the influence of temperature stratification and winds, including their seasonal variability, and air viscosity and thermal conductivity on the geometry and amplitude of ionospheric disturbances that are generated by seismic surface waves and tsunamis. Modeling results are verified by comparing observations of the velocity fluctuations at altitudes of 150–160 km by a coastal Dynasonde HF radar system with theoretical predictions of ionospheric manifestations of background infragravity waves in the ocean. Dynasonde radar systems are shown to be a promising means for monitoring acoustic-gravity wave activity and observing ionospheric perturbations due to earthquakes and tsunamis. We will discuss the effects of the background ionospheric disturbances and uncertainty in atmospheric parameters on the feasibility and accuracy of retrieval of the open-ocean tsunami heights from observations of the ionosphere.