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Traveling ionospheric disturbance studies enabled by advanced ground-based radio techniques

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The traveling ionospheric disturbance (TID) is a common form of upper atmospheric variability as an ionospheric manifestation of atmospheric acoustic-gravity waves (AGWs). There are many different sources and mechanisms associated with AGW excitation; thus TIDs have different wave properties and space and time scales. This study focuses on mid-latitude large scale TIDs caused by geospace storms as well as other sources such as the solar eclipse and the solar terminator. Using the densely distributed GNSS network yielding 2-D differential total electron content maps as well as height-resolved electron density measurements by incoherent scatter radars (ISRs) at Millstone Hill and Arecibo, we cross-check TID detection methods and physical significance of ionospheric disturbance information in different ionospheric variables, and, in particular, we characterize both horizontal and vertical propagation properties of TIDs, allowing for presenting quasi 3-D ionospheric disturbances. This study is featured with using unprecendented high temporal-spatial coverage over the continental US provided by 2000+ GNSS receivers, along with highly accurate electron density height profiles with the high temporal-height resolution derived using the ISR plasma-line technique.