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Real-Time Detection of Tsunami Ionospheric Disturbances with a Stand-Alone GNSS Receiver: An Integration of GPS and Galileo Systems

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Tsunamis can produce gravity waves that propagate up to the ionosphere generating disturbed electron densities in the E and F regions. These ionospheric disturbances are studied in detail using ionospheric total electron content (TEC) measurements collected by continuously operating ground-based receivers from the Global Navigation Satellite Systems (GNSS). Here, we present results using a new approach, named VARION (Variometric Approach for Real-Time Ionosphere Observation), and for the first time, we estimate slant TEC (sTEC) variations in a real-time scenario from GPS and Galileo constellations. Specifically, we study the 2016 New Zealand tsunami event using GNSS receivers with multi-constellation tracking capabilities located in the Pacific region. We compare sTEC estimates obtained using GPS and Galileo constellations. The efficiency of the real-time sTEC estimation using the VARION algorithm has been demonstrated for the 2012 Haida Gwaii tsunami event. TEC variations induced by the tsunami event are computed using 56 GPS receivers in Hawai'i. We observe TEC perturbations with amplitudes up to 0.25 TEC units and traveling ionospheric disturbances moving away from the epicenter at a speed of about 316 m/s. We present comparisons with the real-time tsunami model MOST (Method of Splitting Tsunami) provided by the NOAA Center for Tsunami Research. We observe variations in TEC that correlate well in time and space with the propagating tsunami waves. We conclude that the integration of different satellite constellations is a crucial step forward to increasing the reliability of real-time tsunami detection systems using ground-based GNSS receivers as an augmentation to existing tsunami early warning systems.