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Real-Time TEC-Based Tsunami Detection with VARION Algorithm and Stand-Alone GNSS Receivers

Various natural hazards, such as tsunamis and earthquakes, can produce acoustic-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 using continuously operating ground-based receivers from the Global Navigation Satellite Systems (GNSS). Here, we present results using a new algorithm, also known as VARION (Variometric Approach for Real-Time Ionosphere Observation). For the first time, we estimate slant TEC variations generated by tsunamis using real-time data streams from the NASA's GDGPS system, which is a robust real-time GNSS monitoring and augmentation system capable of tracking GPS, Galileo, GLONASS and BeiDou constellations.

Specifically, we study the 2016 New Zealand tsunami event using 1-Hz real-time data recorded from several GNSS receivers with multi-constellation tracking capabilities located in the Pacific region. We compare estimates of TEC variations obtained using multiple constellations. We observe TEC perturbations with amplitudes up to 0.8 TEC units that correlate well in time and space with the propagating tsunami waves. The efficiency of the real-time TEC estimation using the VARION algorithm has been demonstrated for the 2012 Haida Gwaii tsunami event. We conclude that the integration of different satellite constellations is a crucial next 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.