Recent Developments in Understanding Natural-Hazards-Generated TEC Perturbations: Measurements and Modeling Results

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Natural hazards, including earthquakes, volcanic eruptions, and tsunamis, have been significant threats to humans throughout recorded history. The Global Positioning System satellites have become primary sensors to measure signatures associated with such natural hazards. These signatures typically include GPS-derived seismic deformation measurements, co-seismic vertical displacements, and real-time GPS-derived ocean buoy positioning estimates. Another way to use GPS observables is to compute the ionospheric total electron content (TEC) to measure and monitor post-seismic ionospheric disturbances caused by earthquakes, volcanic eruptions, and tsunamis.

Research at the University of New Brunswick (UNB) laid the foundations to model the three-dimensional ionosphere at NASA's Jet Propulsion Laboratory by ingesting ground- and space-based GPS measurements into the state-of-the-art Global Assimilative Ionosphere Modeling (GAIM) software. As an outcome of the UNB and NASA research, new and innovative GPS applications have been invented including the use of ionospheric measurements to detect tiny fluctuations in the GPS signals between the spacecraft and GPS receivers caused by natural hazards occurring on or near the Earth's surface. This continuing research is expected to provide early warning for tsunamis, earthquakes, volcanic eruptions, and meteor impacts, for example, using GPS and other global navigation satellite systems. We will demonstrate new and upcoming applications including recent natural and accidental hazards that generated TEC perturbations to perform state-of-the-art imaging and modeling of earthquakes, tsunamis and meteor impacts.

We will show examples for early detection of natural hazards generated ionospheric signatures using ground-based and space-borne GPS receivers. We will discuss recent results from the U.S. Real-time Earthquake Analysis for Disaster Mitigation Network (READI). By studying the propagation properties of ionospheric perturbations generated by natural hazards along with applying sophisticated first-principles physics-based modeling, we are on track to develop new technologies that can potentially save human lives and minimize property damage. It is also expected that ionospheric monitoring of TEC perturbations might become an integral part of existing natural hazards warning systems.