Characterizing Ionospheric Disturbances for Space Weather Hazard Mitigation

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The world relies increasingly on capabilities that are enabled or delivered by space-based systems, and there exists a need to continually refine our vulnerability assessment models and understanding of natural versus artificial threats. One area of growing global focus is monitoring and mitigating hazards for space-based systems that are highly dependent on the space atmospheric environment. For example, in 2018 the United States defined benchmarks for five space weather phenomena critical to vulnerability assessment for national infrastructure and services, and for stakeholder mitigation planning. We were invited to lead the next-phase national working group in benchmarking of ionospheric disturbances to capture physical properties of the medium and response to solar drivers; key parameters include ionospheric electron content, turbulence, and absorption that characterize the medium for radio propagation. All such values translate readily into impacts on existing and emerging technologies for users/operators.

In this context we present new methods of ionospheric characterization and parameterization to gain insight into the impact on ground- and space-based RF systems. Our approach exploits the University of Calgary Transition Region Explorer (TREx) network for geospace sensing – a federal investment in over 40 sophisticated optical, magnetic and radio instruments across Canada. Combined with our modeling tools, this is one of the world’s foremost high latitude facilities for remote sensing of the near-earth space environment. On track to be fully operational in 2020, our ground-based infrastructure includes new technologies in auroral cameras and imaging riometers. At distributed key locations within the target region, multi-constellation Global Navigation Satellite System (GNSS) total electron content (TEC)/scintillation receivers and commercial grade systems also provide multi-scale scientific observations.

We present space weather monitoring for ground-based and space-based RF systems. Our ionosphere modeling capabilities include a data driven approach to estimate the three-dimensional temporally evolving electron density distributions over regional spatial scales. Input observations can include integrated TEC for multi-constellation GNSS signals from ground-based receivers, topside over-satellite TEC from space-borne GNSS receivers (e.g. Swarm), and GNSS occulting link TEC from low-earth orbiters. We also exploit small-scale Swarm in situ plasma density observations to estimate ionospheric turbulence. We focus on two recent studies:

1) The assimilation of imaging riometer observations to provide D-region specification and
estimation of key space weather parameters for HF applications.

2) Ionospheric scintillation modeling based on turbulence key parameters for transionospheric RF signal propagation and related applications such as GNSS.

Outcomes include new approaches in space situational awareness and monitoring of space environmental conditions with improved anomaly resolution (distinguishing artificial from natural hazards) and informed mitigation.