Arctic TEC Mapping Using Integrated GNSS-R and Ground-based GNSS Observations

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Our recent research has demonstrated the feasibility of spaceborne Global Navigation Satellite System (GNSS) reflectometry (GNSS-R) measurements as a new data source to improve the accuracy, resolution, and coverage of ionospheric total electron content (TEC) at high latitudes, including the polar caps and auroral ovals.

The high latitudes provide a direct path for solar wind and magnetospheric disturbances to impact the Earth's ionosphere. TEC at the high latitudes is essential for capturing ionospheric structures which impact navigation and radio communication system performance. Current high latitude TEC observations are limited in spatial resolution, update rate, and accuracy due to the sparsity of GNSS receivers over oceans, inaccessible terrains, and GNSS satellite orbit inclination constraint. Our analysis of Spire Global CubeSat data has shown that GNSS signals reflected over sea ice and calm water surface can be processed to retrieve slant TEC at a fraction of TEC unit precision and better than 1km spatial resolution at a 50 Hz rate. The reflection signal utilization is especially high over sea ice which covers the polar caps and large areas of the Arctic and Antarctic.

However, the slant TEC includes contributions from the incident and reflection ray path, whose ionospheric piercing points can be separated by hundreds of kms. We have developed an algorithm that integrates the direct signal and reflection signal measurements from GNSS-R CubeSats and available ground-based receivers to derive vertical TEC maps. This presentation will show results obtained from simulated ionosphere based on the NeQuick-2 model, simulated GNSS-R constellations, and actual IGS ground monitoring stations over the Arctic. The performance of the vertical TEC map retrieval is evaluated for varying numbers of CubeSats, different levels of space weather activities, and several update time intervals. The results show that the inclusion of GNSS-R measurements drastically improves the accuracy and update rate of the vertical TEC map at the high latitudes especially under active space weather conditions.