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Methods and Outcomes for Recent Evaluations of Commercial Radio Occultation Total Electron Content

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Global Navigation Satellite System (GNSS) Radio Occultation (RO) is a remote sensing technique that uses GNSS signals of opportunity to estimate parameters of the Earth's atmosphere. For example, a multi-frequency GNSS receiver placed on a satellite in low-Earth orbit can be used to measure the total electron content (TEC) along the ray path between it and the GNSS satellite. Currently, near real time RO measurements are provided by the COSMIC-2 mission as well as an increasing number of commercial providers. The data available from commercial providers has significant scientific and operational potential, especially given their coverage of higher latitudes that are not visited by COSMIC-2. Orion Space Solutions (OSS) has a long history of evaluating commercial RO data utility, beginning with data from Spire and expanding to GeoOptics and PlanetiQ. As part of the US Air Force's Commercial Weather Data Pilot (CWDP), we recently assessed the impact of PlanetiQ data on ionospheric specification. In addition, for NASA's Commercial Smallsat Data Acquisition New Vendor Onramp Evaluation (CNVOE) program, we are evaluating GeoOptics ionospheric data to determine whether it can support NASA's earth science research and application goals. We will present several methods and outcomes of these past and current evaluations.

For CWDP, we assessed the quality of ionospheric TEC data collected by PlanetiQ's GNOMES-2 satellite beginning in late 2021. The quality was investigated with respect to the elevation angle and minimum altitude, comparing those to COSMIC-2 and other commercial providers. Next, we examined the geographic coverage and receiver performance statistics. PlanetiQ TEC data was also compared to other space-based and ground-based measurements and models like ionosondes, incoherent scatter radars (ISRs), the international reference ionosphere (IRI) climatological model, and an assimilative model: IDA4D. In these comparisons, the PlanetiQ RO data is Abel inverted to yield electron density profiles rather than TEC data. When comparing the data to both models, a qualitative assessment was followed by a quantitative assessment. While there was substantial variance in this comparison, the agreement is better with IDA4D than with IRI, which is expected for an assimilative model. We also ran IDA4D without and with the PlanetiQ measurements and compared the results to independent observations. We performed an Observing System Simulation Experiment (OSSE) to provide additional insight into the utility of ingesting PlanetiQ data. By comparing the resulting analysis to the original truth model, we quantified the impact of observations from the GNOMES-2 satellite orbit. In all aspects of overall data evaluation, PlanetiQ data was found to be accurate and high quality. Notably, OSS discovered a TEC leveling error that would have caused significant negative impact on Air Force operations, had it gone unnoticed. The data is now fixed and could be ingested for operational ionospheric specification.

For CNVOE, our newer methods of data evaluation combine examining the ease of use, including accuracy and completeness of metadata; assessing the quality, accuracy, and coverage; and evaluating the potential impact on ionospheric specification. The quality of GeoOptics relative and absolute TEC data is assessed along with elevation angle and altitude coverage. To quantify the absolute TEC accuracy, we compare the average overhead (elevation>60 degrees) TEC with COSMIC-2 for regions where the two providers overlap in latitude and local time. The agreement in average overhead TEC each day in the common regions gives a measure of absolute TEC accuracy. Only overhead TEC is used to minimize the effect of horizontal gradients. To quantify the relative accuracy, we Abel invert the TEC data to yield electron density profiles and compare these to ionosonde data, as we did for CWDP. OSS has a well-developed pipeline to invert RO data and compare it to any nearby ionosondes. Differences between the ionosonde and RO electron densities will be more indicative of relative TEC accuracy when the tangent point is close to the ionosonde.

In this presentation, we will share results of our data evaluations, as well as comment on our methods of evaluation and on the scientific and operational utility of the commercial RO data.