URSI GASS 2023, Sapporo, Japan, 19 – 26 August 2023

Evaluating the Impact of Commercial Radio Occultation Measurements of the Ionosphere with Data Assimilation and Observing System Simulation Experiments

Ian Collett*, Joseph Hughes, Geoff Crowley, and John Noto
Orion Space Solutions, Louisville, CO, USA; e-mail: ian.collett@orionspace.com; joe.hughes@orionspace.com; geoff.crowley@orionspace.com; john.noto@orionspace.com

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 has led a number of efforts to evaluate the quality and impact of commercial RO data provided by Spire, GeoOptics, and PlanetiQ. For example, 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 to this CWDP work, we will also touch on several other past and current evaluations.

For CWDP, we evaluated TEC data collected by PlanetiQ's GNOMES-2 satellite beginning in late 2021. Two complementary methods were used. First, to assess the impact of the real data, we ran a data assimilation model without and with the PlanetiQ measurements, and compared the results to independent observations. Second, we performed an Observing System Simulation Experiment (OSSE) to provide additional insight into the utility of ingesting PlanetiQ data. An OSSE synthesizes measurements from a truth model of the ionosphere rather than using real data, so the characteristics of the real data may not be perfectly represented. However, an OSSE allows us to quantify improvement at all places and times. In either case, a key component of the impact assessment is Orion Space Solutions' Ionospheric Data Assimilation Four-Dimensional (IDA4D) model, an ionospheric data assimilator that has been developed and validated over the past two decades. The IDA4D model combines a background electron density model with observations to produce a global time-varying 3D ionospheric electron density specification, called the analysis. IDA4D can ingest measurements of many types; in this study, the RO measurements are ingested as slant TEC.

To assess the impact of the real data, two IDA4D model runs are performed over a period of four consecutive days in December 2021. Run 1 ingests RO data from COSMIC-2 as well as measurements made by ground-based ionosondes and GPS receivers. Run 2 ingests the same measurements as run 1, except with the additional inclusion of the PlanetiQ RO data. By comparing the electron density specifications from the background, run 1, and run 2 to independent measurements, we have quantified the impact of adding the PlanetiQ data and its impact relative to the other ingested data. The OSSE study is performed in a similar way but with the use of synthetic observations. Orion Space Solutions has developed a first-of-its-kind capability for streamlining OSSEs in the ionosphere: the OSSE Tool (OSSET). OSSET synthesizes measurements of various types from an ionospheric truth model and hands them off to IDA4D for ingestion. The synthesized RO measurements contain realistic representations of effects such as leveling errors and cycle slips. By comparing the resulting analysis to the original truth model, we can quantify the impact of observations from the GNOMES-2 satellite orbit. Although OSSET was used in this study to synthesize observations for an existing sensor, we note that OSSET can also be used to assess the impact of future or hypothetical observing systems.

Our impact assessment for CWDP shows that assimilating PlanetiQ data improves the ionospheric specification, with a larger impact at higher latitudes. The positive impact demonstrated here is for a single satellite, and we expect that increases in coverage brought on by additional PlanetiQ satellites (or other RO satellites with comparable data quality) will continue to have a positive impact on the ionospheric specification.