Studies of Ionospheric Structure using the GPS Occultation Experiment (GOX) on the COSMIC Satellite Constellation

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The six-satellite Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC, also known as FORMOSAT-3) was launched from Vandenberg, AFB, CA on April 14, 2006. Each satellite carried three instruments: the GPS Occultation Experiment (GOX), a dual-frequency GPS receiver; the Tiny Ionospheric Photometer (TIP), a compact ultraviolet photometer; and the Tri-Band Beacon (TBB), a three-frequency radio beacon. The three instruments provide complementary ionospheric measurements that are useful for studying scintillation and ionospheric structure, especially at nighttime, when the TIP measurements are made. The Naval Research Laboratory has been using the COSMIC instruments for a researching a variety of ionospheric physics topics.

The focus of this talk will be on studies of ionospheric structure and evolution performed using the GOX occultation measurements. The GOX slant total electron content (TEC) measurements were used to study how accurately ionospheric models reproduce the measured ionospheric state. This study selected a 75 day period in 2012 and compared the slant TECs measured by the GOX and the precise orbit determination (POD) receivers along lines-of-sight between the COSMIC and GPS satellites to slant TECs calculated by integration along those same lines-of-sight through SAMI3, GAIM-GM, IRI-2007, IRI-2011, and NeQuick models. All models performed reasonably well, with typical differences between the measurements and calculated TECs of <15% and with a few TECU (TECU: TEC unit = 10^{16} electrons-m^{-2}) additive biases. The GAIM-GM model showed the best overall performance, but this is expected for a data assimilation model. However, all models underestimated the topside plasma distribution. We have also investigated large-scale ionospheric structure using tomographic inversion of the radio occultation data and found similar results to the TEC study. The GOX electron densities derived by Abel inversion of the slant TEC measurements were used to study the effects of sudden stratospheric warming (SSW) on the electron density distribution in the ionosphere. SSWs have been shown to affect the ionosphere via coupling of planetary waves generated in the polar cap into the low-latitude ionosphere where they interact non-linearly with the tides to modulate the vertical ion drift. Statistically significant differences in the electron density distribution were found during the major SSWs of January 2009 and February 2010; the 2009 event showed the semi-diurnal variation seen in previously studied events that were driven by a wave-2 planetary wave, while the 2010 event showed a diurnal variation that was more consistent with driving by a wave-1 planetary wave. We also present and discuss the advantages and limitations of the GPS occultation technique.