GNSS Radio Occultations as a key instrument for topside ionosphere climatology

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There are several techniques to remotely sense ionospheric properties in the 3d domain. Most of them are based on the radar approach and have principal limitations. In particular, the most reliable data source for the ionosphere and plasmasphere consists from the small number of incoherent scatter radars with a relatively short duration of experiments. In fact, only radio occultation (RO) techniques allows us to solve the task of the global specification of ionospheric electron density in the 3d domain. This technique has been most successfully implemented by the COSMIC mission. The COSMIC satellite constellation provided continuous global synoptic measurements over long and still ongoing operation time from 2006 up to today — more than one solar cycle. Together with results of another RO mission - GRACE – currently, there are available several million ionospheric electron density profiles at the COSMIC Data Analysis and Archive Center (CDAAC, http://www.cosmic.ucar.edu/cdaac/) database. Depending on the constellation state, it produced up to 1500-2500 high-quality soundings of the ionosphere and atmosphere per day, uniformly distributed around the globe.

The correct representation of the topside ionosphere (above the F2 layer peak), plasmasphere, and total electron content in temporal and spatial domains is still an open question for both empirical and first principal ionospheric models. Currently, RO is a single and unique data source to specify electron density above the F2 layer peak on a global scale.

In this study, we demonstrate how COSMIC RO electron density profile (EDP) product contributes to fill gaps in understanding of the topside ionosphere/plasmasphere climatology. The combination of the RO EDPs with ground-based and satellite-based GPS observations allows us to gain new knowledge about plasma redistribution in the ionosphere-plasmasphere system. We derived and analyzed electron content estimates in several representative altitudinal intervals for the ionosphere and the plasmasphere from the COSMIC GPS radio occultation, ground-based GPS, precise orbit determination (POD) GPS receivers on board GRACE, GOCE, TerraSAR-X, and Swarm satellites as well as Jason-2 altimeter and POD GPS observations. It was revealed that long term changes in the global distributions of topside electron density and variation of the plasma redistribution in different altitudinal ranges as solar activity changes. It is highlighted that electron density has a considerable impact in the topside ionosphere and plasmasphere to the vertical GPS TEC values especially for low solar activity periods and night time.

The performance of empirical ionospheric models (IRI and NeQuick) was assessed in order to develop recommendations for the improvements of the topside ionosphere and plasmasphere representation by these models.

Keywords: COSMIC, ionosphere, plasmasphere, radio occultation, TEC, empirical models