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Validation of ionospheric products derived from the EUMETSAT Radio Occultation receivers on board Metop satellites

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This contribution presents an overview of the Space Weather activities performed in the framework of the Metop Radio Occultation (RO) missions run by EUMETSAT. In particular, it will provide a summary about the ionospheric products (ionospheric bending angles profiles, scintillation profiles and topside TEC) that EUMETSAT plans to generate and make available to the users, as well as the results obtained by an in-depth validation activity.

The GNSS (Global Navigation Satellite System) Receiver for Atmospheric Sounding (GRAS) instrument on-board the Metop-A/B/C satellites of the EUMETSAT Polar System (EPS) programme is a Radio Occultation receiver. It exploits measurements collected in a limb sounding geometry to derive information about the bending angle, temperature and humidity profiles in atmosphere. It was developed with the focus to collect measurements for the neutral atmosphere monitoring only and all the system aspects (antennas, vertical sounding range, channels allocation, tracking strategy, etc.) where optimized for that purpose.

Metop-A reached its end-of-life and was deorbited in November 2021. In the framework of its end-of-life testing campaign during summer 2020, EUMETSAT approved the extension of the GRAS vertical measurement range into the lower and mid ionosphere (up to 300 km and up to 600 km) for a two months' period experiment. The experiment was successful and demonstrated a negligible impact to the operativity of the instrument for the neutral atmosphere profiling, in particular extending the measurement range to 300 km. Thanks to the excellent results achieved also for the ionosphere monitoring, in February 2022 also the GRAS receivers on-board Metop-B and -C have been configured to permanently collect data to 300 km. EUMETSAT is going to provide operationally ionospheric occultation products to the users, starting from Q2/Q3 2023.

In order to validate the products associated with the GRAS ionospheric observations and to evaluate the impact of their assimilation into ionospheric models, EUMETSAT funded a study called GIMA ("Assessment of GRAS Ionospheric measurements for Ionospheric model assimilation"). The study, ran by the German Aerospace Centre (DLR) together with Universitat Politècnica de Catalunya (UPC-IonSAT) addressed the following analysis:

- Assessment of the quality of the dual frequency bending angle profiles, amplitude and phase scintillation indices profiles generated by EUMETSAT, through comparison against independent measurements;
- Assessment of the quality of the topside Total Electron Content (TEC) data generated by EUMETSAT from Metop-A, -B, -C observation, through comparisons against independent measurements;
- Processing of RO observations truncated at 600 km and 300 km into vertical profiles of electron density with a new inversion technique developed by DLR, and validation against independent measurements;
- Evaluation of the potential impact of assimilating GRAS data into a 4D ionospheric model. Additionally, assessment of the suitability of topside TEC data for data assimilation.

The validation of bending angle and scintillation indices profiles has been quite challenging, in particular when performed against co-located similar products derived by other RO missions (COSMIC-2 and Fengyun-3D) flying in different orbits. The new DLR algorithm for retrieving electron density profiles from GRAS truncated measurements performed very well, in particular when almost all the ionospheric F peak density is covered by the measurements. Of course, if measurements are not covering F layer, or covering only its bottom-side, any retrieval and extension to the topside hardly succeeds. Finally, a consistent positive impact of the GRAS data in two independent tomographic ionospheric data assimilation models has been demonstrated.