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Combination of physics-based and empirical models to improve ionosphere and plasmasphere density profiles

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The ionosphere conditions may affect communication and global positioning systems, as electromagnetic waves propagation can be deviated or even interrupted when passing through a charged medium. In fact, many space-based technologies and services are impacted by the conditions in the ionosphere and plasmasphere. Hence, the study of upper atmospheric layers and inner magnetosphere is critical to the development of models to predict the electron content daily and seasonal variation, and possibly to reduce technological vulnerabilities. Additionally, it is important to improve existing models to better agree with available observations. The ionospheric models are generally developed empirically or based on physical/chemical processes. The former infers analytical or statistical functions to describe the known variations in ionization. The latter uses numerical solutions to evolve the main equations related to the ionization, although usually outputs from other sub-models supply missing information, such as geomagnetic fields and solar radiation. While physics-based models can provide details of ionospheric structures and its originating processes, empirical models provide estimations regardless of those details. In this work, we propose a possible hybrid solution through combination of a physics-based and an empirical model output to achieve a better overall solution for ionosphere and plasmasphere regions. The idea is to join the bottom side ionosphere estimates from Sheffield University Plasmasphere Ionosphere Model - Data Assimilation and Visualization System (SUPIM-DAVS) with topside ionosphere estimates from NeQuick topside analytical formulation. The proposed approach also considers F2 peak density (NmF2) and height (hmF2) from SUPIM-DAVS to estimate the topside analytical modeling parameters. Experiments have shown this solution improves the SUPIM-DAVS outputs in the topside ionosphere and plasmasphere. It reduced an observed inadequate electron concentration decay with height, which was leading to an overestimation in total electron content (TEC) values. Moreover, perturbations in profiles for altitudes above 10,000km in low-latitudes were avoided. Therefore the hybrid solution provides smoother and sharper ionospheric density profile decay, specially for electron concentration in the plasmasphere.

When considering a solar cycle from 2011 to 2021 it was observed a coherent reduction of high altitudes ionosphere and plasmasphere contribution to TEC, which better agrees with TEC data from the global International GNSS Service (IGS). The root mean squared error between the proposed solution and IGS TEC maps was as low as 2.64 TECU.