4th URSI AT-RASC, Gran Canaria, 19-24 May 2024

Swarm-Variability of Ionospheric Plasma (Swarm-VIP) models of the topside ionosphere

Luca Spogli (1,8), Alan G. Wood (2), Yaqi Jin (3), Jaroslav Urbář (4), Elizabeth E. Donegan-Lawley (2), Lasse B. N. Clausen (3), Golnaz Shahtahmassebi (5), Lucilla Alfonsi (1), James T. Rawlings (5), Antonio Cicone (6,1), Daria Kotova (3), Claudio Cesaroni (1), Per Høeg (3), Gareth D. Dorrian (2), Luke D. Nugent (2), Sean Elvidge(2), David R. Themens (2), María José Brazal Aragón (7), Pawel Wojtkiewicz (7) and Wojciech J. Miloch (3)

(1) Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy
(2) Space Environment and Radio Engineering (SERENE) group, University of Birmingham, Birmingham, UK
(3) Department of Physics, University of Oslo, Oslo, Norway
(4) Institute of Atmospheric Physics of the Czech Academy of Sciences, Prague, Czech Republic
(5) Department of Physics & Mathematics, Nottingham Trent University, Nottingham, UK
(6) Università Degli Studi Dell'Aquila, L'Aquila, Italy
(7) GMV Innovating Solutions, Warsaw, Poland
(8) SpacEarth Technology, Rome, Italy

The ionosphere of Earth is a dynamic system exhibiting intricate variability in both time and space, characterized by an apparent randomness or quasi-randomness in the physical parameters defining its state. This complexity arises from nonlinear interactions among the various sub-systems comprising the near-Earth environment. The imperative to model changes in the ionosphere over space and time is not only rooted in our quest to comprehend the environment and the governing physical principles but also holds significant relevance for technologies and applications where the ionospheric effects play a crucial role.

The "Swarm Variability of Ionospheric Plasma" (Swarm-VIP) project, funded by the European Space Agency (ESA) under the "Swarm+4D-Ionosphere" framework, has developed statistical models to characterize the variability of plasma in the topside ionosphere using data from the Swarm constellation [1, 2]. These models predict electron density, its gradients in three horizontal spatial scales (20, 50, and 100 km along the satellite orbit, which is approximately aligned with the North-South direction), and the level of density fluctuations, serving as a proxy for meso-scale irregularities affecting Global Navigation Satellite Systems (GNSS) signals. Employing Generalised Linear Modelling, the Swarm-VIP models provide global coverage and independence from Swarm data by incorporating various parameters and proxies of helio-geophysical conditions. Predictions are expressed as functions of specific variables grouped into six families: solar activity, solar wind, geomagnetic activity, location (geographical and geomagnetic), and daily/seasonal variations.

The versatility of the Swarm-VIP models makes them valuable for supporting existing ionospheric models and proxying the impact of ionospheric irregularities on GNSS signals at medium-to-large scales. This contribution outlines the model formulation, validation, and performance assessment, demonstrating their capability to reproduce known climatological variability and depict ionospheric weather, as observed by ground-based GNSS receivers. Furthermore, the models exhibit superior representation of ionospheric variability compared to the Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIE-GCM) in specific latitudinal regions and under certain conditions.

[1] A. G. Wood, E. E. Donegan-Lawley, L. B. N. Clausen, L. Spogli, J. Urbář, Y. Jin, G. Shahtahmassebi, L. Alfonsi, J. T. Rawlings, A. Cicone, D. Kotova, C. Cesaroni, P. Høeg, G. D. Dorrian, L. D. Nugent, S. Elvidge, D. R. Themens, M. Aragón, P. Wojtkiewicz and W. J. Miloch, "Statistical Models of the Variability of Plasma in the Topside Ionosphere: Part 1: Formulation and Optimisation", J. Space Weather Space Clim., swsc230022, 2024.

[2] L. Spogli, Y. Jin, J. Urbář, A. G. Wood, E. E. Donegan-Lawley, L. B. N. Clausen, G. Shahtahmassebi, L. Alfonsi, J. T. Rawlings, A. Cicone, D. Kotova, C. Cesaroni, P/ Høeg, G. D. Dorrian, L. D. Nugent, S. Elvidge, D. R. Themens, M. Aragón, P. Wojtkiewicz and W. J. Miloch, "Statistical Models of the Variability of Plasma in the Topside Ionosphere: Part 2: Performance assessment", J. Space Weather Space Clim., swsc230023, 2024.