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Swarm-VIP-Dynamic: Ionospheric Variability, Irregularities, and Predictive Capabilities for the Dynamic Ionosphere

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Variability and structuring of the Earth's ionosphere depend on many variables and forcing from above and below. Coupling of the ionosphere with the Earth's magnetosphere and the solar wind, as well as to the neutral atmosphere, makes the phenomena in the ionosphere highly dynamic. This can be seen at different spatiotemporal scales, ranging from planetary down to decameter spatial scales, and from solar cycle down to daily and hourly temporal variations. Thus, modelling of the whole ionosphere and capturing its full dynamic range are a challenging task.

Satellite-based measurements can form a basis for ionospheric models where various spatiotemporal scales can be addressed, and they can significantly contribute to our efforts within the context of space weather modeling. The European Space Agency's Swarm mission, which is a constellation of three identical satellites in polar orbits, has been successful in providing high-quality in situ data over many years. This dataset allows for both space weather and climatological studies. Recently, with the Swarm-VIP models it was demonstrated that the Swarm mission can successfully address ionospheric variability at larger scales in relation to geophysical proxies [1,2].

The new Swarm-VIP-Dynamic project focuses on the variability, irregularities, and predictive capabilities for the dynamic ionosphere, including short time scales. In this project, we develop a suite of models for capturing the ionosphere structuring and dynamics at various spatiotemporal scales. In addition to the Swarm data, we use a significant number of datasets from other satellites and from ground-based instruments for validation and to explore the added value of space instrumentation with various observation and sampling characteristics. We also test the feasibility of the models to be used in a real-time environment. We present the Swarm-VIP-Dynamic project, its background and model concepts, initial results, as well as prospects of further development in the context of space weather and predicting ionospheric space weather effects.

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: 1. Development 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: 2: Performance Assessment", J. Space Weather Space Clim., swsc230023, 2024.