Use of whistlers detected by Swarm satellites to validate IRI

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Natural electromagnetic signals generated during lightning discharges cover all radio frequency bands and propagate around the Earth. They first cross the neutral atmosphere, where the lower part of the spectrum can propagate at very long distances. They are also able to penetrate into the ionosphere, where their dispersion increase progressively due to the presence of magnetised plasma. Their propagation path is also strongly controlled by the Earth magnetic field. They can be detected as whistlers by satellites on low orbits, like those of the European Space Agency (ESA) Swarm constellation. Swarm satellites are on polar orbits, drifting in local time of about one hour every ten days. Even if this mission was not originally designed for measuring electromagnetic signals, its instruments can sense the magnetic field at Extremely Low Frequencies (ELF), during burst-mode campaigns of the Absolute Scalar Magnetometer (ASM) [1]. These campaigns are being conducted every month since 2019 on Swarm Alpha and Bravo satellites, for a duration of one week. Few sessions had already been conducted in 2014, providing additional data at maximum solar activity conditions.

We developed algorithms to detect and characterise whistlers in the frequency band between 20 and 125 Hz [2]. Most of these whistlers reach Swarm satellites from below, after crossing the lower layers of the ionosphere and the topside up to the orbital altitudes: $\sim$ 450 km for Swarm Alpha, $\sim$ 500 km for Swarm Bravo. We estimated the propagation path of whistlers using ray-tracing simulations, and we produced synthetic dispersions. These dispersions depend on the modelled ionospheric plasma distribution. Swarm satellites also provide in-situ electron density measured by the Electric Field Instrument (EFI) Langmuir probes [3]. This local measurement is an experimental constraint for the topside ionosphere. We validated our simulation approach using experimental ionospheric profiles, from ionosondes close to Swarm whistler detections, mostly at low latitudes. We then compared Swarm's dispersions with synthetic dispersions computed using different options for International Reference Ionosphere (IRI) model profiles [4], including the NeQuick topside and the latest cor2 option, introduced in IRI-2020.

References

[1] Léger, J.-M., T. Jager, F. Bertrand, G. Hulot, L. Brocco, P. Vigneron, X. Lalanne, A. Chulliat, and I. Fratter, "In-flight performance of the Absolute Scalar Magnetometer vector mode on board the Swarm satellites," 26, April 2015 *Earth, Planets and Space*, **67**(1), 57, doi: 10.1186/s40623-015-0231-1.

[2] Coïsson, P., V. Truhlik, J. Mlynarczyk, G. Hulot, L. Brocco, O. Bonnot, P. Vigneron, D. Burešová, J. Chum, P. Rzonca, and A. Kulak, "Observation and modelling of whistlers in the ELF as observed by Swarm satellites during regular ASM burst sessions" *EGU General Assembly 2021*, online, 19–30 Apr 2021, EGU21-12740, https://doi.org/10.5194/egusphere-egu21-12740, 2021

[3] Knudsen, D. J., J. K. Burchill, S. C. Buchert, A. I. Eriksson, R. Gill, J.-E. Wahlund, L. Åhlen, M. Smith, and B. Moffat, "Thermal ion imagers and Langmuir probes in the Swarm electric field instruments," 2, February 2017 *Journal of Geophysical Research: Space Physics*, **122**(2), 2655–2673, doi:10.1002/2016JA022571.

[4] Bilitza, D., M. Pezzopane, V. Truhlik, D. Altadill, B. W. Reinisch, and A. Pignalberi, "The International Reference Ionosphere model: A review and description of an ionospheric benchmark," 13, September 2022 *Reviews of Geophysics*, **60**(4), e2022RG000,792, doi:10.1029/2022RG000792.