On the ability of the ESA Swarm satellites to simultaneously detect Extremely Low Frequency whistlers originating from the same lightning strike

Pierdavide Coïsson*(1), Janusz Mlynarczyk(2), Gauthier Hulot(1), Louis Chauvet(1), Martin Jenner(1), Jerzy Kubisz(3), Vladimir Truhlik(4) Dalia Burešová(4) and Jaroslav Chum(4)

(1) Université de Paris, Institut de physique du globe de Paris, CNRS, F-75005, France, http://www.ipgp.fr

(2) AGH University of Science and Technology, Department of Electronics, Krakow, Poland

(3) Astronomical Observatory, Jagiellonian University, Krakow, Poland

(4) Institute of Atmospheric Physics of the Czech Academy of Sciences, Prague, Czechia

1 Extended Abstract

The penetration of lightning energy into the ionosphere at Extremely Low Frequencies (ELF) at the altitude of Low Earth Orbits (LEO) has not yet been systematically studied. It strongly depends on both the local Earth magnetic field and on the ionospheric plasma distribution. The European Space Agency (ESA) Swarm mission, though initially designed to study slowly varying magnetic fields, provides an opportunity to carry such studies. It embarks Absolute Scalar Magnetometers, that can be run in burst-mode during dedicated campaigns when the sampling rate is raised from 1 Hz to 250 Hz [1] This mode was originally intended only for instrument calibration purposes, but the initial in-orbit calibration and validations activities at the beginning of 2014 revealed that whistlers signals could be detected quite frequently. Starting from 2019 it was therefore decided to conduct regular one-week burst-mode campaigns every month. This is currently achieved on two satellites: Alpha orbiting at an altitude of 450 km and Bravo at an altitude of 500 km. Since their respective polar orbital planes drift in local time at different speeds, their relative position changes during the course of the mission. We already acquired data progressively covering all local time sectors and constructed a database of detected events allowing the study of diurnal variation of whistler activity. At the end of 2021 the orbital planes of these satellite became almost co-planar, with the two satellites orbiting in counter-rotation. We took advantage of this unique configuration to conduct several synchronous ASM burst-mode acquisition sessions and analyse simultaneous whistler detections by both satellites. Often, when the satellites gets close to each other, both satellites can detect whistler signals generated by the same lightning strike. Occasionally, however, only one satellites detects a clear signal. To understand and characterise the lightning strikes that produced these whistlers, we make use of the World Wide Lightning Location Network (WWLLN) [2] and the World ELF Radiolocation Array (WERA) [3]. We present a number of remarkable events and analyse the detectability of the ELF portion of the lightning strikes at LEO altitudes. We plan to continue this activity as long as the Swarm mission is in operation. Additional data are next to be made available by the future NanoMagSat mission, which will monitor continuously both the intensity and the three orthogonal components of the magnetic field up to 800 Hz using three nanosatellites.

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," *Earth, Planets and Space*, **67**, 1, 57, 26, April 2015, doi: 10.1186/s40623-015-0231-1.

[2] Hutchins, M. L., R. H. Holzworth, C. J. Rodger, and J. B. Brundell, "Far-field power of lightning strokes as measured by the World Wide Lightning Location Network", *Journal of Atmospheric and Oceanic Technology*, **29**. 8, 1, August 2012, pp. 1102–1110, doi:10.1175/JTECH-D-11-00174.1.

[3] Mlynarczyk, J., A. Kulak, and J. Salvador, "The accuracy of radio direction finding in the extremely low frequency range," *Radio Science*, **52**. 10, 20, September 2017, pp. 1245-1252, doi:10.1002/2017RS006370