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[Invited Lecture]

Space weather influence and multifaceted observations of natural hazards events inferred from sub-ionospheric VLF/LF electric fields and satellite magnetic measurements

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Abstract: Monitoring of the ionosphere enables the detection of changes that are related to numerous processes on Earth. However, space weather, primarily solar radiation, has a very significant influence on the atmospheric layers. Variations caused by these influences can be affected by some processes on Earth, which can be used to detect relevant terrestrial processes. On the other hand, the strong influence of solar radiation can mask changes due to processes on Earth. Therefore, it is important to examine the impact of space weather on the detection of changes in signals associated with natural hazards. Natural hazards events like earthquakes or volcanic eruptions could significantly excite lithosphere – atmosphere

– ionosphere coupling (LAIC) up to high altitudes with different physical processes. However, the impacts of specific phenomena are complex and the details are still difficult to disentangle.

This study considers selected earthquakes (USGS catalogue) with magnitude M ≥5.5 related to LAIC coupling processes based on the combining of ground-based sub-ionospheric VLF/LF electric field measurements from the INFREP network and complementary low earth orbit (LEO) satellite magnetic field measurements. Ground-based and space borne observations require temporal and spatial proximity to the events.

We investigate electric field narrowband VLF/LF transmitter signals propagating in the ionospheric waveguide and detected by two INFREP receiving stations in Belgrade (Serbia) and Graz (Austria). It encloses areas along the radio paths from the lithosphere and up to the ionospheric D/E-layers. The analyses are carried out in the time- and frequency-domain and are restricted to European sites due to the INFREP network infrastructure. Complementary magnetic field measurements are obtained by ESA's three satellite Swarm mission at ~500 km altitude (ionospheric F-region). Case studies like the 29.12.2020 earthquake, M6.4, Petrinja, Croatia, and the 06.02.2023 Turkey-Syria earthquake sequence with M7.5 and M7.8 events, indicate a coupling via waves from the lithosphere and up to the LEO satellite orbits.

Statistically significant robust results, in both the VLF/LF electric field variations and satellite magnetic field measurements, are obtained for strong earthquakes. In order to observe these tricky interactions, one needs continuous VLF/LF measurements in a network structure and satellite-based resources as well as scientific cooperations.

Keywords: Natural hazards events, VLF/LF transmitter measurements, Swarm magnetic field observations, INFREP network

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