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# Investigating and Comparing the Mid-Latitude Thermosphere-Ionosphere Response to two recent Geospheric Storms by means of Ionosonde Data

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To study the ionosphere under any condition, modern ionosondes continue to be strong performers thanks to their high accuracy, fast data acquisition and automatic scaling, making ionosonde observations suitable for integration with data from other monitoring techniques and assimilation in ionospheric models, for both scientific research and operation purposes. In the absence of routine thermosphere observations, ionosonde data can be also used to retrieve aeronomic parameters around noontime hours at mid-latitudes, where the ionospheric F-layer is formed by solar ionizing radiation, through the THERmospheric parameters from IONosonde observations (THERION) method [1, 2]. The method is based on ionosonde $f_o$F2 and bottom-side $N_e(h)$ profile observations in the F region under sunlit conditions as inputs along with standard indices of solar (F10.7) and geomagnetic (Ap) activity and can be applied to investigate thermosphere-ionosphere (T-I) coupling processes under both quiet and disturbed conditions.

In this study, the T-I response over Central Europe to the two recent severe geospheric storms that occurred in October 2024 and January 2025 is investigated and compared. Ionosonde data at the ionospheric stations of Rome (41.8°N, 25.5°E) and Juliusruh (54.6°N, 13.4°E) have been manually validated and used to study the ionospheric variability and to retrieve thermospheric parameters (neutral composition, temperature, wind) to gain a deeper insight into the processes that occurred at mid-latitude European sector during the selected storms. A comparison with thermospheric empirical models like MSISE00 is also shown to highlight the increased ability of the method in reproducing thermospheric variability in such conditions. TEC data from GNSS receivers co-located with the ionosondes have been used to better characterize the ionospheric state, while geomagnetic field data provided by the INTERMAGNET network were investigated to study the ionospheric current system variations. Interplanetary and magnetospheric conditions have been also considered to study each event in a wider context, which is unique for any storm.

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