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Multi-instrument analysis of MSTIDs generated by extreme tropospheric events in Europe

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The Earth's ionosphere is known to be a very dynamic medium. Its plasma density at any location can change significantly even on a short timescale, for example due to wave-like disturbances, called traveling ionospheric disturbances (TIDs), mainly related to atmospheric gravity waves (AGWs) propagating in the neutral atmosphere which could be caused by the geomagnetic and lower atmospheric forcing. AGWs can transfer energy and momentum between different layers of the atmosphere, e.g. from the troposphere up to the thermosphere/ionosphere, and change their properties due to the coupling between neutral and ionized particles. Possible candidates in the troposphere for the sources of AGWs include high mountains, tectonic activity, jet streams, cyclones, fronts and convective systems. TIDs with a wavelength of 100-500 kilometers and a propagation speed of 100-300 m/s are classified as Medium Scale Traveling Ionospheric Disturbances (MSTIDs). The presence of MSTIDs can cause serious issues in the high accuracy positioning of the navigational systems, like Global Positioning System (GPS) or Global Navigation Satellite System (GNSS) networks. Furthermore, their impact on HF signal propagation and, through it, on civil air traffic control (on Over The Horizon Radars) is also significant.

The main purpose of the T-FORS project is the development and validation of new models in order to forecast and provide alerts for TIDs several hours ahead, considering a broad range of observations of the solar corona, the interplanetary medium, the magnetosphere, the ionosphere and the atmosphere. The present paper focuses on extreme tropospheric events, intensive cold fronts with large convective systems leading to high lightning activity, which passed the European region and could trigger MSTIDs. Data of European ionosondes, Continuous Doppler Sounding System (CDSS) Measurements, and detrended TEC from GNSS measurements were investigated. In addition, meteorological data (e.g. temperature, pressure measured at different levels, jet stream, CAPE index and lightning activity for the convection) were used for reference in the analysis. The presence of MSTIDs and their propagation properties for these events were determined and compared with the results of the climatological model. During the most intense periods of the events, stations close to the front's passage observed very high MSTID activity compared to the climatology, primarily characterized by extremely distorted traces on the ionograms. The presence of MSTIDs in Central Europe was confirmed by CDSS data. The current study will support the identification of parameters that can be considered as early indicators of intense MSTID activity, and the determination of the alert criteria for disturbed periods when the observed perturbations exceed the climatology.