Relationship Between Ionosphere VTEC and Space Weather Indices for Machine Learning-based Model Development

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Space weather can be the source of severe disturbances in the ionosphere, which can influence the performance and reliability of GNSS (Global Navigation Satellite Systems) technology and applications. In order to forecast and minimize these effects, accurate corrections need to be provided. This goal can be achieved by employing a precise model to describe the complex chain of space weather processes and the non-linear spatial and temporal variability of the Vertical Total Electron Content (VTEC) within the ionosphere, as well as, to include a forecast component considering space weather events in order to provide an early warning system. This is a challenging but important task of high interest for the GNSS community.

Artificial intelligence applications, such as Machine Learning (ML), are able to find and learn patterns from historical data to solve problems, which are too complex and/or too vast for humans. To develop an effective and high performance ML algorithm special consideration needs to be given to the selection of the input data. Data need to be selected in order to have sufficient information to describe and predict ionosphere VTEC variability accurately. Therefore, the study of space weather impacts for the integration of space weather information in forecast ionosphere models is of crucial importance.

In this study, the relationship between various indices, describing space weather and space climate, and ionosphere VTEC variability in different latitudes during longer time periods within the solar cycle 24 is examined. Conditions in space weather are described by solar wind, the magnetic field and plasma data, energetic proton fluxes, geomagnetic and solar activity indices provided by worldwide distributed observatories. VTEC data are derived from GNSS measurement from permanent stations, belonging to the EPN (EUREF Permanent Network) and the IGS (International GNSS Service) networks and selected in latitudinal range from 0° to 60°N. The period from year 2014 to year 2017 is used to relate space weather indices to VTEC variability, as well as, to train the ML model. In addition, periods of intense geomagnetic storms caused by different sources (coronal mass ejections and high-speed streams of solar wind from coronal holes), occurred during different seasons in this period are analyzed. The evolution and severity of storms are investigated in relation to the conditions in the solar activity, solar wind speed, interplanetary magnetic field and geomagnetic field together with their impact on the ionosphere VTEC. Obtained results of this investigation will be presented, as well as the methodology, goals
and challenges for ML model development including preliminary results of an initial ML model.