Machine Learning assisted Characterization of Ionospheric Scintillation Signatures in High Latitudes according to Irregularities

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The underlying assumption for this study focusing on ionospheric scintillation signatures deems that certain types of ionospheric irregularity structures contribute differently to scintillation in the significant regions in the high latitudes. Different irregularity mechanisms such as shear instabilities, steep density gradients, or electron precipitation create diverse structuring in various scale sizes and thus are expected to cause distinct scintillation signatures. Based on this hypothesis, a supervised Machine Learning model was trained to classify events according to the region they were recorded in as either auroral oval or polar cap events. The database's high-rate (50 Hz) event time series segments were extracted from five different geomagnetic storms and several stations. They underwent filtering, data cleaning, and event detection techniques to avoid biases in the signatures. First, the time series were clustered according to their correlation and then classified into auroral oval and polar cap signatures by a decision tree approach.

Using SSUSI DMSP and the SWARM electron energy flux measurements significantly reduced the resolution of the labels of the source regions for the scintillation signatures. The database created by the supervised Machine Learning analysis was extended beyond the GNSS phase and amplitude time series to contain plasma drift, electron energy flux, electron density, and other parameters as available in a reasonable resolution. Instead of an entire time series as an input feature, this method uses parameters that describe the properties of the time series, like spectral index and Fresnel frequency. Performing a principal component analysis quantified the impact of each parameter, and only the most influential features were included. In the next step, an extensive analysis of the ionospheric conditions and dynamics around the events led to an understanding and, finally, identification of the dominant irregularity mechanism that created their signature. This research lays the groundwork for a training database to connect signatures of ionospheric scintillation in high latitudes with their predominant irregularity mechanisms, predict their occurrence, and extract their physical parameters.