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The performance of empirical and physics based ionosphere models

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Since the ionosphere impacts the propagation characteristics of radio waves, the estimation of the true state ionosphere (three-dimensional (3D) electron density) is an important task for many communication and navigation applications. Because the global data coverage is quite inhomogeneous and especially over the oceans it is rather sparse, modelling has to support the observations.

In our study, we will assess the performance of different ionosphere models based on the comparison with measurements. Both, physics based models and empirical models will be tested, to demonstrate and compare their different capabilities. As representatives, we are using the Coupled Thermosphere Ionosphere Plasmasphere electrodynamics (CTIPe) model, the Thermosphere Ionosphere Electrodynamics General Circulation Model (TIE-GCM) and the “TUM-Model”.

CTIPe and TIE-GCM models are global 3D time - dependent physics based nonlinear, numerical codes. They estimate the thermosphere-ionosphere conditions mainly based on solar wind, interplanetary magnetic field (IMF) and solar irradiance proxies. CTIPe has been developed to support operational nowcasting and forecasting algorithms for space weather. TIE-GCM is a research model. The “TUM model” is a 3D empirical “physics-motivated” model of the electron density. Mathematically it is defined as a linear combination of altogether four Chapman functions, each related to one of the four layers of the ionosphere, and an exponential function for the plasmasphere. The corresponding model parameters, e.g. the height hmF2 of the maximum value of the electron density within the F2 layer, are represented as series expansions in B-spline functions and estimated from space-geodetic observation techniques such as GNSS (terrestrial and space-borne).

In a case study of the St. Patrick’s Day storm 2015, the models will be compared against the critical frequency of the F2 layer and the height of maximum electron density measured by different ionosondes around the globe, as well as measurements of the Total Electron Content (TEC) derived from ground based Global Navigation Satellite System (GNSS) measurements. This validation work is a first step in preparation of data assimilation studies in the INSIGHT-II project funded by the German Science Foundation (DFG).