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Bayesian Approaches for Non-Linear Ionosphere Modelling – Concept and Strategies

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Tomography is a well-known procedure for determining the distribution of a physical quantity from a set of path integrals through the region containing the unknown distribution. This inverse procedure is commonly used for medical imaging, oceanic and geological surveying, and more recently ionospheric characterization. However, in contrast to medical applications the ionospheric tomography must be performed with relatively few measurements. We apply a physics-motivated approach, i.e. we introduce for the electron density profile Ne (h) a mathematical function which describes the height-dependency as „good as possible“, but also in a simple and interpretable manner. To be more specific, we apply a Multi-Layer-Chapman model to represent the electron distribution along the height. Hence, for each layer of the ionosphere Chapman-functions depending on the values Nm as the maximum electron density of each layer, hm as the altitude of the maximum electron density and the scale height H describe the electron density.

The parameters of the Chapman model are defined as functions of B-splines which leads to a complex and large-scale non-linear model definition. Instead of applying a classical non-linear Kalman filter for the estimation of the unknown parameters, we have focused on modern approaches. Modern sequential Bayesian estimators, for instance unscented, ensemble Kalman and particle filters have been gaining attraction and widely used to solve different scientific problem ranging e.g. from meteorology, atmosphere modelling to geology, robotics and target tracking to handle severe non-linearity and non-Gaussian model definitions. Those estimators can offer a superior approach to classical estimators e.g. Kalman filter. The sequential Bayesian estimators can exhibit different performances according to many factors, e.g. scaling of the problem, computational load, probabilistic characteristics of measurement and dynamic models. Therefore, the estimator is required to be selected carefully.

Within this study, we have investigated concepts and strategies for the solution of non-linear ionospheric electron density modelling in terms of modern sequential Bayesian estimators. We revealed the pros and cons of the estimators for the ionosphere modelling according to the aforementioned factors.