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3-D Ionosphere Modeling by B-Splines and Spherical Harmonics

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On the one-hand side modern satellite navigation and positioning systems require the use of precise and high resolution ionosphere correction models. On the other side the precise measurements of modern space geodetic techniques allow the study of ionosphere variations with an unprecedented accuracy. The characteristics of the ionosphere are described by the electron density distribution and its functionals such as the vertical total electron content (VTEC).

Usually VTEC is modeled globally by a spherical harmonic expansion up to specific degree n (e.g. n = 15) for fixed time intervals (e.g. 2 hours). However, it is well-known that spherical harmonic models are not suited for representing data of heterogeneous density and quality. As a consequence, data gaps as in case of the evaluation of GNSS observations cannot be handled appropriately.

In this paper we present two different approaches for modeling VTEC generally depending on space and time. The first and more traditional one is based on a system of 3-D base functions defined as the tensor product of spherical harmonics for longitude, latitude and endpoint-interpolating B-spline functions for the time. In the second, alternative approach we define the 3-D system of base functions as tensor products of trigonometric B-spline functions for the longitude and two sets of endpoint-interpolating B-spline functions for latitude and time, respectively. We introduce both approaches mathematically and discuss advantages and disadvantages. Whereas spherical harmonics are global base functions, the localizing feature of B-splines functions allows the use for global and regional applications. Thus, data gaps can be handled appropriately. Furthermore, B-spline functions can be used to create a multi-scale analysis of VTEC, which can be used for data compression. We apply and compare the two methods with respect to both, simulated VTEC and real GNSS data.