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High-precision and high-resolution VTEC maps based on Multi-Scale B-spline Representations and near real-time GNSS observations

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The Ionosphere Associated Analysis Centers (IAAC) of the International GNSS Service (IGS) provide ionosphere information in terms of global ionosphere maps (GIM) representing the vertical total electron content (VTEC) as a function of latitude, longitude and time. The GIMs are typically provided with a spatial resolution of 2.5° in latitude and 5° in longitude for snapshot maps with a temporal resolution of 2 hours. In the recent years investigations have been initiated to reduce the grid spacing to 1° x 1° with a temporal resolution of 15 minutes. In order to justify higher spatial resolutions, the spectral resolution of the empirical VTEC model should also be adjusted accordingly.

Since the ionospheric observations from space-geodetic missions are distributed rather unevenly over the globe, an appropriate modelling approach has to be used to achieve the proposed resolution limits for GIMs. Most of the IAAC rely their modelling strategy on spherical harmonic expansions which are generally not suitable for representing data of a heterogeneous global distribution. As a consequence, the resolution of GIMs has not been increased in the last years.

Unlike most of the IAAC, the modelling approach in OPTIMAP is based on localizing basis functions; the unknown model parameters are estimated via Kalman filtering (KF). To be more specific, polynomial B-splines are used representing latitudinal variations in VTEC, trigonometric B-splines are representing longitudinal variations. B-spline functions allow the generation of a multi-scale-representation (MSR) based on B-spline wavelet functions. The basis feature of a MSR is to split the target function in to a smoothed signal, i.e. a low-pass filtered version and a number of detail signals, i.e. band-pass filtered versions. Hence the MSR of VTEC adapts the spatial model resolution to the data distribution and thus, fulfills the request for higher resolution GIMs.

Within this study, we compare GIMs of (1) different spectral resolution levels by applying the MSR and (2) different temporal resolutions using different KF step sizes. For that purpose we use the well-known dSTEC analysis, also known as self-consistency analysis and discuss the results.