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Comparison of Earth-fixed and Sun-fixed regional VTEC modeling strategies using GPS observations

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Modeling of the ionosphere has been a highly interesting subject within the scientific community due to its effects on the propagation of electromagnetic waves. Numerous modeling studies have been proposed depending on several reference systems. The ionosphere is relatively stable in a Sun-fixed system as the Sun is the main source for its ionization. Therefore, the ionosphere is often modeled in a Sun-fixed reference frame where it can be assumed as static for a certain modeling period. On the other hand, the ionosphere is highly variable in an Earth-fixed reference frame due to the diurnal motion of the Earth. Thus, the models in an Earth-fixed frame should either consider the time dependency or be used instantaneously, i.e. epoch-specific. In this study Vertical Total Electron Content (VTEC) of the ionosphere, which is obtained from the observations of ground based Global Positioning System (GPS) receivers, is modeled with three approaches: 3D (three dimensional) B-spline model in an Earth-fixed reference frame depending on geodetic latitude, geodetic longitude and time and 2D B-spline and spherical harmonic models in a Sun-fixed frame depending on geodetic latitude and Sun-fixed longitude. For all approaches, VTEC is split into two as a reference and a correction term. The reference is computed from low level solutions of the relevant methods while the correction term is obtained with higher level solutions. The parameters for the corresponding linear systems of equations, i.e. unknown model coefficients and differential code biases (DCB) of the receivers, are calculated with least squares estimation. Tikhonov regularization is employed to stabilize the ill-conditioned problems in parameter estimation stage. The models are applied to a real data set which is obtained from ground based GPS receivers over Europe. Carrier phase observations are used to reduce the noise level of pseudorange measurements. Results indicate that B-spline models give more successful results for regional VTEC modeling. Especially, 3-D B-spline solutions represent the temporal change in the ionosphere more successfully than 2-D solutions. On the other hand, it is observed that the length of the modeling period has considerable effect on the results of Sun-fixed VTEC models, especially for the periods of high ionospheric activity.

Keywords: Ionosphere Modeling, GPS, B-splines, Spherical Harmonics