



Real-time regional VTEC modeling based on B-splines using real-time GPS, GLONASS and GALILEO observations

Eren Erdogan¹, Andreas Goss¹, Michael Schmidt¹, Denise Dettmering¹, Florian Seitz¹, Jennifer Müller², Barbara Görres³, and Wilhelm F. Kersten³

¹Technical University of Munich, German Geodetic Research Institute, München, Germany (eren.erdogan@tum.de)

²German Space Situational Awareness Center (GSSAC), Germany

³Bundeswehr Geoinformation Centre (BGIC), Germany

The project OPTIMAP is at the current stage a joint initiative of BGIC, GSSAC and DGFI-TUM. The development of an operational tool for ionospheric mapping and prediction is the main goal of the project.

The ionosphere is a dispersive medium. Therefore, GNSS signals are refracted while they pass through the ionosphere. The magnitude of the refraction rate depends on the frequencies of the transmitted GNSS signals. The ionospheric disturbance on the GNSS signals paves the way of extracting Vertical Total Electron Content (VTEC) information of the ionosphere.

In OPTIMAP, the representation of the global and regional VTEC signal is based on localizing B-spline basis functions. For global VTEC modeling, polynomial B-splines are employed to represent the latitudinal variations, whereas trigonometric B-splines are used for the longitudinal variations. The regional modeling in OPTIMAP relies on a polynomial B-spline representation for both latitude and longitude.

The VTEC modeling in this study relies on both a global and a regional sequential estimator (Kalman filter) running in a parallel mode. The global VTEC estimator produces VTEC maps based on data from GNSS receiver stations which are mainly part of the global real-time IGS network. The global estimator relies on additional VTEC information obtained from a forecast procedure using ultra-rapid VTEC products. The regional estimator makes use of the VTEC product of the real-time global estimator as background information and generates high-resolution VTEC maps using real-time data from the EUREF Permanent GNSS Network. EUREF provides a network of very dense GNSS receivers distributed alongside Europe.

Carrier phase observations acquired from GPS, GLONASS and GALILEO constellations, which are transmitted in accordance with RTCM standard, are used for real-time regional VTEC modeling. After the acquisition of GNSS data, cycle slips for each satellite-receiver pair are detected, and ionosphere observations are constructed via the linear combination of carrier-phase observations in the data pre-processing step. The unknown B-spline coefficients, as well as the biases for each phase-continuous arc belonging to each receiver-satellite pair, are simultaneously estimated in the

Kalman filter.

Within this study, we compare the performance of regional and global VTEC products generated in real-time using the well-known dSTEC analysis.