The GPS segment of the AFRL-SCINDA global network and the challenges of real-time TEC estimation in the equatorial ionosphere

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Abstract: The estimation of Total Electron Content (TEC) in the equatorial ionosphere using GPS presents a number of challenges due to the presence of strong spatio-temporal density gradients and scintillation of the satellite signals caused by F-region irregularities. In this paper we describe a methodology for real-time calibrated TEC estimation in the presence of scintillation and a highly structured ionosphere. The inter-frequency biases of the GPS satellites are assumed known; we use estimates provided by the Center for Orbit Determination in Europe (CODE). The inter-frequency bias associated with a particular receiver is estimated late at night when the ionosphere is minimally structured, using an iterative approach that minimizes the variance of verticalized TEC measured along the different satellite links. The nightly estimated receiver bias is shown to be insensitive to the assumed centroid height used in the single-layer approximation of the ionosphere. It is also relatively stable on a night to night basis, deviating from its running average most when nighttime gradients in density are largest (commonly associated with geomagnetic activity and/or equatorial spread F). A 14 day running average of the bias is used to minimize the effect of this variability on the calibrated TEC. The effectiveness of the technique is illustrated by comparing the calibrated TEC estimated using two GPS receivers connected to the same antenna. During quiescent ionospheric conditions the difference in TEC estimated with the two receivers is generally less than a couple of TECU, despite their substantially different internal biases. During scintillating conditions, the TEC from the two receivers exhibit substantial differences due to receiver errors in the measurement of pseudorange and phase, unless strict quality control techniques are applied to exclude this data from the analysis. Methods for the automated detection of receiver error due to scintillation are presented and are shown to yield reliable TEC estimates. The GPS segment of the AFRL-SCINDA network currently includes 7 dual-frequency receivers that monitor equatorial scintillation and TEC in the Pacific, South American, Indian, and East Asian sectors. Several additional deployments are planned, particularly in Africa and Asia. The TEC data provided by these sensors are expected to be made publicly available and should make a valuable contribution to space weather monitoring and forecast models, since much of the dynamics of the storm-time ionosphere originates in the equatorial region and other GPS networks tend to sparse in this area.

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