Multi-constellation GNSS TEC measurements

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Total electron content (TEC) is a key parameter to study the impact of the ionosphere on radio wave propagation and TEC is measured by calculating the difference in carrier signal delays between different frequency radio signals. Global Navigation Satellite System (GNSS) constellations are commonly used for TEC measurements. Through differencing both carrier phase and pseudorange observables from the receiver between two frequency bands, the smoothed TEC can be calculated along the path between the GNSS satellite and receiver. Historically, dual-frequency GPS or Glonass receivers are widely used for TEC measurements. Currently, there are 12 Galileo satellites and 21 Beidou satellites in orbit with more planned to be launched. In this work, multi-frequency multi-constellation GNSS receivers are used to measure the TEC. Compared with previous single/dual-constellation TEC measurements, tracking more constellations greatly increases the number of ionospheric piercing points to be measured, which potentially improves the measurement accuracy. A new technique for determining the vertical TEC from GPS, Glonass Galileo, and Beidou constellations was developed with the ultimate goal of developing a higher-accuracy TEC monitoring and ionospheric effects analysis technique.

Calculations are validated by benchmarking with other currently available TEC software including GPStk as well as Rinex GPS-TEC. By comparing the measured vertical TEC from GPS, Beidou, and Galileo constellations with Klobuchar, CIM (Compass Ionospheric Model) and NeQuick TEC model respectively, the quality of each TEC model on positioning accuracy correction for single frequency GNSS user can also be evaluated. Moreover, the quantity of integrated multi-constellation TEC and single-constellation TEC are compared and characterized based on other benchmark TEC measurements, including the World-wide GPS Receiver Network in MIT Madrigal Database. The Root Mean Square (RMS) of 24-hour period TEC discrepancies are used to characterize the measurement consistency between different constellations, and potentially distinguish the measurement accuracy of integrated multi-constellation from previously individual constellation TEC measurements.