International Beacon Satellite Symposium BSS-2016
Trieste, Italy

Evaluation of Different GPS Calibration Techniques

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ABSTRACT

The total electron content (TEC) obtained by the many Global Navigation Satellite Systems (GNSS) now in operation has become a very important data source not only for scientific analysis but also for the validation of other ground and space measurements and of theoretical and empirical models of the ionosphere and plasmasphere. When using slant TEC (sTEC) and vertical TEC (vTEC) from GNSS satellites, one has to keep in mind that these are not direct measurements but quantities derived from the raw data involving several data analysis steps and calibration methods that vary from data analysis group to data analysis group. These calibration steps have to account for receiver and transmitter biases, multi-path corrections, slant-to-vertical transformation, and other error sources. Small differences between the vTEC world maps produced by the different GPS data analysis centers underline this point [1]. Direct comparisons between GIM TEC maps and TOPEX/Jason altimeter measurements above the oceans also show systematic differences and limitations in accurately representing well-known ionospheric structures such as the equatorial anomaly, the Weddell Sea Anomaly, and the longitudinal wave structure [2]. During the 2015 ‘Workshop and Conference on NeQuick Latest Developments and Advance Uses’ at ICTP these limitations were noted again and the need was stressed for highly accurate TEC data for model validations. Particular attention has been given to TEC calibration techniques and comparison among them was initiated using NeQuick [3] simulated scenarios as “known” ionosphere. This presentation reports first results from this validation effort.

We have used simulated RINEX files generated using NeQuick calculated slant TEC data to test three different GNSS calibration schemes. The Azpilicueta-Brunini calibration scheme [4,5] was developed as part of LPIM (La Plata Ionospheric Model) [4,5]. It is based on the geometry-free combination (L4) carrier-phase leveled to code and the assumption of constant

calibration terms for at least one day. The slant TEC is mapped with the standard mapping function and the vertical TEC is geographically modeled with polynomial functions or spherical harmonics. The temporal variations of the coefficients are modeled with periodic functions. This method of Seemala and Valladares [6] uses the combination of both phase and code values at L1 and L2 frequencies to eliminate the effect of clock errors and tropospheric water vapor to calculate absolute values of slant TEC. The differential satellite bias corrections published by University of Bern are used. The receiver bias is calculated by minimizing the TEC variability between 0200 and 0600 LT (when spatial variability is less) or for the entire data of day (depending on data length). The resultant slant TEC is converted to vertical TEC using the single shell mapping function assuming 350 km altitude for the centroid of the ionosphere. The Single-Station Arc-Offset method of Ciraolo et al.[7] forms the geometry-free combination L4 is for each arc from the observations in the RINEX files. L4 gives TEC, which is expanded by a Vertical Equivalent 2-D function of time and horizontal coordinates, plus an arc unknown offset. Standard Least Square methods are used to estimate the unknown coefficients of VEQ expansion and the arc offsets.

The data were simulated for the three African GPS ground stations located at Dakar (Senegal), Toro (Nigeria), and Libreville (Gabon) as listed in Table 1. These stations were

Location	***Station ID***	***Network***	***Geographic Latitude***	***Geographic Longitude***
Dakar, Senegal	DAKA	AFREF/IGS	14.75	343.51
Toro, Nigeria	CGGA	NIGNET	10.12	9.12
Libreville, Gabon	NKLA	AFREF/IGS	0.35	9.67

Table 1 Stations for which GPS data were simulated

chosen considering that they are under the effect of the Ionospheric Equatorial Anomaly, a critical region of the ionosphere dominated by significant temporal and spatial gradients. For the validation exercise equinox conditions with a F10.7 solar flux of 193 units were used (day 300, 301, and 302 of year 2013).

Each team used their calibration method with the provided simulated data and their sTEC results were then compared back to the NeQuick reference data. Our presentation will discuss the results of this validation exercise and determine which of the three techniques gave the best results for the three station case study.

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