Alternative Ionospheric Correction Algorithms for Satellite-Based Augmentation Systems in Low-Latitude Region

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The ionospheric correction algorithms have been characterized extensive latitude region of the ionosphere where benign conditions usually exi States Federal Aviation Administration's (FAA) Wide Area Augme (WAAS) for civil aircraft navigation is focused primarily on the Conte States (CONUS). Other Satellite-Based Augmentation Systems (SBAS) include the European Geostationary Navigation Overlay Service (EGNOS) and the Japanese Global Navigation Satellite System (MSAS). Researchers are facing a more formidable challenge in addressing the ionospheric impact on navigation using SBAS in other parts of the world such as the South American region or India. At equatorial latitudes, geophysical conditions lead to the so-called Appleton-Hartree (equatorial) anomaly phenomenon, which results in significantly larger ionospheric range delays and range delay spatial gradients than is observed in the CONUS or European sectors.

In this paper, we use data from the South American region to perform a quantitative assessment of WAAS-type ionospheric correction algorithms in this region. For the study, we accessed a world-wide network of 400+ dual-frequency GPS receivers. The network includes: 1) the Continuously Operating Reference Sites (CORS) in the United States; 2) stations in and near South America as part of the Brazilian Network of Continuous Monitoring of GPS (RBMC), operated by the Brazilian Institute of Geography and Statistics (IGBE); and (3) sites included in the International GPS Service (IGS) global network. Data sets have been selected to include both a quiet and storm days. To provide ground-truth and calibrate GPS receiver and transmitter inter-frequency biases, we processed the GPS data using Global Ionospheric Mapping (GIM) software developed at the Jet Propulsion Laboratory to compute calibrated high resolution observations of ionospheric total electron content (TEC).

In our investigations, we initially assessed the WAAS's planar fit algorithm in the equatorial region where the spatial gradients and the absolute slant TEC are known to be the highest in the world. We found that in Brazil the dominant error source for the WAAS planar fit algorithm is the inherent spatial variability of the equatorial ionosphere with ionospheric slant range delay residuals as high as 15 meters and root-mean square residuals for the quiet day of 1.9 meters. This compares to a maximum residual of 2 meters in CONUS, and 0.5 meter RMS. We revealed that ionospheric gradients in Brazil are at the 2 meter over 100 km level. Contrary to results obtained for CONUS, we discovered that a major ionospheric storm had a small impact on the planar fit residuals in Brazil. Based on these results, we expect that a WAAS-type planar fit algorithm applied to Brazil will result in significantly reduced availability of Lateral

Navigation/Vertical Navigation (LNAV/VNAV) service, particularly near solar maximum during daytime and evenings.

In this study we will investigate other alternative algorithms to augment or replace the WAAS algorithm in Brazil. This includes fitting higher order surfaces to the data. Initial assessment of fitting e.g., a quadratic surface to the data provides us improvement in the accuracy of ionospheric corrections. In addition to large ionospheric delays and gradients in the equatorial region, users will also be exposed to 15-20 meter level large depletions or "bite-outs" due to plasma bubbles. We will evaluate these effects and determine the density of ground stations necessary to detect these structures so that full integrity of the corrections is maintained.