Advancing Our Understanding on Ionospheric Threats to SBAS/GBAS Operations Over North and South America

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Adverse space weather events and disturbed ionospheric conditions may present an unfavorable environment for the operations of space-based augmentation systems (SBAS) and ground-based augmentation systems (GBAS) in aviation. In midlatitude regions, plumes of storm-enhanced density (SED) are the main source of steep ionospheric gradients that affect the performance of SBAS/GBAS; whereas equatorial plasma bubbles (EPBs) are the main source of steep ionospheric gradients that can threaten SBAS/GBAS operation in low-latitude regions. Here we present an overview of our research work on ionospheric threats to SBAS/GBAS in North and South America during Solar Cycle 24 – the United States and Brazil in particular.

Overall reductions in the coverage area of Wide Area Augmentation Systems (WAAS) over the United States and Canadian airspace were identified during geomagnetically disturbed periods, in which geomagnetic storms with more negative values of disturbance storm time (Dst) index often result in a greater degree of coverage area reduction. In terms of geography, airspace over Canada and Alaska (closer to the auroral oval) experienced more instances of WAAS LPV coverage reduction compared to the conterminous United States (CONUS). The number of WAAS LPV coverage reduction cases over the United States and Canada reached a peak in 2014-2015, which also coincided with the maximum of Solar Cycle 24 in terms of sunspot numbers.

Meanwhile, magnitudes of gradients in total electron content (TEC) over the Brazilian airspace were found to follow a double-power-law distribution. This double-power-law distribution exhibits a break at approximately $|\nabla TEC| = 200$ mm/km at GPS L1 frequency, and a final cutoff around $|\nabla TEC| = 800$ mm/km. Furthermore, the exponents of this double-power-law distribution appear to vary systematically with the progression of the solar cycle (with the average sunspot numbers as its indicator). Such variation of the exponents caused the tail of the double-power-law distribution to extend further during the maximum of the solar cycle, causing more frequent occurrence of ionospheric TEC gradients with extreme magnitudes over the area.

Although the occurrence of EPBs in general follows a rather well-defined seasonality and local time certainty, the extreme magnitudes of TEC gradients associated with EPBs (in excess of 800 mm/km at GPS L1 frequency) pose a set of difficult challenges for the operations of SBAS/GBAS in equatorial and low-latitude regions. In addition, the annual number of days with EPBs over low-latitude regions can be expected to be more numerous than the annual number of geomagnetically disturbed days that lead to the appearance of SEDs over midlatitude regions. These circumstances point to the need for civil aviation authorities to be better informed regarding the present state of scientific knowledge on EPB occurrence patterns both as a function of season and as a function of geomagnetic activity.

References

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