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Ionospheric Threats to the Operation of Space and Ground-based Augmentation Systems in Civil Aviation in Low Latitude Regions

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Various types of phenomena in the Earth's ionosphere at different latitude regions pose a diverse set of challenges to the performance of modern technology that we use today. The impacts are expected to be most prevalent in technology involving radio communications and global navigation satellite systems (GNSS), as the propagation of radio waves can be affected by perturbations or irregularities in the ionospheric density. Ionosphere over some latitude regions, such as that over the polar and equatorial regions, is known to be considerably more active than others. The high-latitude ionosphere, being a gateway to the magnetosphere, tends to receive a large amount of energy deposition and is generally exhibits fast ionospheric drift velocities. The low-latitude ionosphere is largely non-homogeneous due to the constant presence of the equatorial ionization anomaly (EIA) crests, and it can be severely turbulent due to the possible occurrence of equatorial plasma bubbles (EPBs) during nighttime hours. In contrast, ionosphere over the midlatitude region, where most of the developed economies are located, is known to be relatively calm except under geomagnetically active conditions. Many of the most rapidly growing economies today, however, are situated near or within the low-latitude region. Places with a high economic growth are also where modern technology is also most rapidly being adopted by the wider population. For this reason, an awareness by the public regarding equatorial ionospheric phenomena that are potentially detrimental to modern technology may become paramount. Here we present an overview of our recent efforts in characterizing and formulating ways to address low-latitude ionospheric threats to the operation of space-based and ground-based augmentation systems (SBAS and GBAS) in civil aviation by steep total electron content (TEC) gradients and amplitude scintillations associated with the occurrence of EPBs. These efforts include the development of a more accessible EPB and scintillation climatology tool, empirical characterization of equatorial ionospheric scintillation effects on tracking loop performance in GNSS receivers, and the development of a physically simplified but computationally efficient way of simulating large-scale EPB branching structures in low-latitude ionosphere.