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Traditionally regarded as a relatively stable environment for satellite navigation, the mid-latitude ionosphere has exhibited increasingly frequent and severe disruptions during the current solar cycle. In this study, we investigate the diverse ionospheric processes responsible for these disturbances and quantify their impact on GNSS signal integrity and positioning performance.
Using high-rate (1 Hz) observations from geodetic GNSS receivers across the United States, we characterize the spatiotemporal evolution of ionospheric irregularities produced by several key processes, including the Mid-Latitude Trough (MIT), substorm-driven disturbances, and the poleward expansion of Equatorial Plasma Bubbles (EPBs) during geomagnetically active periods. To assess their operational impact, we analyze the resulting GNSS positioning errors. Our results show that these ionospheric irregularities can lead to frequent cycle slips, reductions in the number of tracked satellites, and deep signal amplitude fades, all of which degrade signal tracking and positioning performance. These findings demonstrate that mid-latitude ionospheric variability represents an emerging threat to the reliability of modern navigation systems. Incorporating mid-latitude ionospheric dynamics into space weather monitoring and mitigation frameworks will be essential for improving the resilience of GNSS-dependent infrastructure.
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