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Altitude distribution of large and small-scale equatorial ionospheric irregularities sampled by the Swarm Echo satellite

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Variations in ionospheric electron density, so-called irregularities, produce rapid fluctuations on propagating communication and navigation signals, which can be severe near the magnetic equator and in the polar regions. This may result in positioning error. Due to sparse sampling, our knowledge of the vertical distribution of small-scale irregularities is limited. In this study, we examine the vertical distribution of multi-scale scintillation-inducing irregularities in the low-latitude ionosphere. In four sets of novel experiments, we sampled altitudes from 330-1280 km in the 18-24 MLT sector using the Swarm Echo GAP-O GPS receiver with its antenna oriented toward zenith. In order to identify multi-scale irregularities both above and at the satellite's position, we utilize high-sample-rate GAP-O amplitude and phase measurements along with a measurement of net current onto the surface of the IRM sensor on board, which serves as a proxy for density variations. We find that amplitude scintillations on the GPS signal coincide with strong in-situ small-scale density irregularities in 74% of cases, and above 500 km of altitude in all but one instance. In addition, we show that large-scale ionospheric disturbances occur predominantly below 500 km, and down to the 330 km perigee of Swarm Echo in the 18-21 MLT sector. In contrast, small-scale variations on total electron content (TEC) are detected at all MLTs between 18 MLT and magnetic midnight and at all altitudes sampled in this experiment. However, they are more frequent in the 22-24 MLT range.