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Imaging ionosphere using single-frequency GNSS data onboard nanosatellite missions

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The Earth's ionosphere is of considerable importance for medium- and long-range high-frequency communication, positioning, and over-the-horizon radar systems. Positioning and communication applications require new capabilities to understand, model, and predict the ionosphere's characteristics, including electron density profiles and total electron content (TEC), on a global scale. Geodetic observations are crucial for understanding the structure of the ionosphere. Nanosatellite technology has recently grown in importance for a wide range of applications, including communication, technological demonstration, heliophysics, astrophysics, earth research, and planetary science. The goal of this study is to assess the potential for reconstructing the 3D ionospheric characteristic by means of simultaneous measurements from nanosatellite constellations that are equipped with low-cost GNSS receivers.

In this paper, we present a novel ionospheric imaging technique based on a tomography-based modelling approach, using four Astrocast nanosatellites placed in a "string-of-pearls" pattern in December 2022. The investigation found up to 1800 radio occultation events during the 14-hour observation period. To estimate electron density fields, the ionospheric excess phase was extracted from the GPS L1 code and phase measurements and integrated into a tomographic system together with ray-traced signal paths. The findings of this study highlight the potential of this cutting-edge observation technique for three-dimensional sensing of the ionosphere, providing significant opportunities for future atmospheric investigations.

Keywords: STEC, nanosatellites, tomography technique, GNSS radio occultation measurements