

REFINEMENT OF THE BOTTOM-SIDE VTEC SCALING PARAMETER FOR CORRECTING IONOSPHERIC PATH DELAYS IN SENTINEL-1 DATA

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The ionization of Earth's upper atmosphere by particles of the solar wind and solar radiation is a known major source of data disturbance with Synthetic Aperture Radar (SAR) satellites, typically operating in the micro-wave regime between 1.2 GHz (L-band) and 9.5 GHz (X-band). Dominated by the approximately 11-years solar cycle, the impact of ionosphere dynamics on SAR satellites spans from minor degradation of precise orbit solutions to frequency-dependent path delays in the radar measurements, causing significant errors of up to several meter when geolocating SAR image data, as well as errors in interferometric SAR processing [1][2][3][4].

The vertical Total Electron Content (vTEC) maps, generated from Global Navigation Satellite System (GNSS) measurements of the global geodetic station networks, see e.g. [5], are a well-established data source for observing and modelling ionospheric delay effects in a wide range of applications, including the SAR. However, because the GNSS-based vTEC maps provide the integrated effect of the entire ionosphere condensed into a thin spherical layer, additional considerations are required for the SAR satellites still operating within the upper layers of the ionosphere, which extends to approximately 1500km above the Earth's surface. Consequently, the total vTEC result has to be separated for the relevant sub-satellite vTEC result in order to reliably correct the SAR measurements.

Solutions to this problem have been discussed and investigated by the SAR community, which involve fixed scaling factors linked to the orbit height, or scaling factors derived from series of SAR measurements, or accounting for an in-situ top-side vTEC observed by the GNSS receiver on-board the satellite [4][6]. For the Sentinel-1 (S-1) mission, operating a C-band SAR payload with 5.405GHz center frequency and orbiting at an average 712km altitude, we originally derived and tested a fixed factor of 0.9 [7], implying that 90 percent of a given total vTEC result are applicable to its SAR measurements. This method was sufficient to achieve a range geolocation accuracy with S-1 of better than 4 cm after calibrating the sensor timings [8]. However, with the onset of the latest solar cycle #25 in 2022, we began to observe low cm-level systematic effects in our assessment of S-1 data geolocation quality with globally distributed test sites, which we perform on a regular basis within the framework of S-1 SAR Mission Performance Cluster (SAR-MPC) [7]. These systematic effects were attributed to limitations in the applied fixed scaling factor.

In this contribution we will report on different methods to improve the scaling factor for S-1 and attain more consistent long-term results with the SAR data. We compare model-driven ionospheric bottom-side scaling factors based on the 3-D ionospheric model NEDM2020 [8], which vary with space and time, with an updated empirical data-driven scaling factor that was derived from the mission-long time series of S-1 geolocation data over calibration sites. Based on these validation results, we will also discuss an update to the S-1 Extended Timing Annotation Dataset (ETAD), which contains timing correction data for S-1 data and is generated at an operational level for each SLC product since mid-2023 [7][8]. These corrections also include the ionospheric path delays, which presently apply the fixed 0.9 scaling factor, and which will be improved according to our evaluation results.

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