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On the Degradation in Satellite Synthetic Aperture Radar data due to Ionospheric Irregularities

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Ionospheric changes can degrade L-band Synthetic Aperture Radar (SAR) images by affecting the propagation of radio signals. However, the precise mechanisms behind these degradations remain poorly understood. This study aims to employ SAR data from the Advanced Land Observing Satellite - 2 (ALOS-2), PALSAR instrument, alongside ionospheric and geomagnetic data, to identify the ionospheric phenomena responsible for the observed degradations in the L-band SAR imagery. SAR interferograms, phase and coherence, from four distinct sites in Norway: Svalbard, Finnmark, Troms, and Møre and Romsdal, were analyzed. The phase is a phase difference between two measurements at different times. The coherence is a measure of the accuracy of interferometric phase determination. The SAR data, collected between 2020 and 2023, correspond to scenes acquired during the summer season. These locations were selected based on their geographic positioning relative to the auroral oval. The analysis was performed separately for daytime and nighttime conditions, with SAR measurements taken around 12 UTC and 22 UTC, respectively. Low coherence lines were primarily observed during nighttime, whereas during the daytime, they were mostly limited to the Svalbard region, with occasional occurrences in Troms and Finnmark. Total electron content (TEC) maps were generated using data from the International GNSS Service network and the Norwegian Mapping Authority network, which comprises over 300 GNSS receivers across Norway. To facilitate direct comparison with SAR data, the TEC maps were adjusted to align with the satellite geometries of the SAR images, such as matching slant angles. Additionally, magnetometer data and ionospheric equivalent current data from the International Monitor for Auroral Geomagnetic Effects (IMAGE) network, as well as density current data from the Active Magnetosphere and Planetary Electrodynamics Response Experiment (AMPERE), were incorporated to examine auroral and storm-time evolution during the SAR observations. Our results suggest that SAR images are influenced by multiple ionospheric phenomena. For instance, around local noon, Svalbard provides an optimal location for observing the cusp inflow region, while auroral activity plays a more prominent role during nighttime. We found that TEC data did not significantly contribute to understanding the SAR degradation. Given that ionospheric electron density structures can scatter and diffract electromagnetic waves, causing unexpected fluctuations in propagating radio signals, it is likely that small- to medium-scale ionospheric irregularities contribute to SAR image distortion. Considering this, it is reasonable to observe the absence of these effects in the TEC map data, which prompted further verification using scintillation parameters such as sigma-phi and S4 as alternative indicators. Therefore, our findings indicate that SAR can offer higher-resolution mapping of electron density distribution, at scales of tens of kilometers or smaller, when compared to GNSS measurements.

References:

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