A STATISTICAL SURVEY OF IONOSPHERIC EFFECTS ON L-BAND SAR DATA

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1. ABSTRACT

Recent theoretical analyses of ionospheric distortions in low-frequency SAR signals have indicated many effects that are likely to affect the quality of SAR, interferometric SAR (InSAR), and polarimetric SAR (PolSAR) data (see [1-5]). Faraday rotation, relative range shifts, internal deformations of the image amplitude, range and azimuth blurring, and interferometric phase errors are some of the most significant effects. These distortions affect the quality of SAR data used for other purposes, but they also provide a unique opportunity to study ionospheric events at a fine resolution over large areas.

The current challenge in identifying and quantifying these ionospheric effects is not doubt that they exist; some well-known examples [5,6] show unambiguous detection of total electron content (TEC), including TEC gradients. The current problem is their scarcity. Only a few examples have been found to demonstrate TEC and TEC gradients. Some progress in predicting their occurrence has been made, by using global models derived from global GPS measurements [5,6], but the temporal and spatial scale of these models often do not have the resolution to capture these unstable and ephemeral ionospheric events. Quantification, including statistical analysis, has especially been limited.

The Alaska Satellite Facility, designated by the Japanese Aerospace and Exploration Agency (JAXA) as Americas ALOS Data Node (AADN), has archived hundreds of thousands of synthetic aperture radar (SAR) images from the advanced land observing satellite (ALOS) PALSAR instrument. This L-band SAR instrument can be operated in a variety of modes, including 3 stripmodes: single polarization, dual polarization, and full or quad polarization. The PALSAR acquisition strategy has focused on mapping and repeat pass surveys, emphasizing full coverage of land masses. This methodical coverage, including multiple repeat passes, would likely be useful in surveying ionospheric events.

The purpose of this paper is to survey a large number of images for ionospheric anomalies and estimate their frequency. A large dataset will also make possible trending and prediction based on acquisition season, location, time of day, and beam mode differences.

The survey will occur as part of a larger effort to create browse products for all PALSAR holdings at the AADN. In addition to the browse product, data will be processed using the detection techniques shown in [5,6] and as described briefly below:

Changes in TEC from azimuth sub-look: Variations of the ionospheric total electron content (TEC) within a SAR image translate into varying phase properties of the azimuth chirp. If two non-overlapping azimuth sub-looks are extracted from the original SAR data, then relative azimuth shifts between these sub-looks, detected by cross-correlation techniques, are proportional to the second derivative of the ionospheric TEC. This method can be applied to single, dual and quad polarization data.

TEC from cross-channel correlation: Dual-pol mode is exploited by recognizing that the HH-HV correlation is significantly impacted by small changes in Faraday rotation, which is proportional to ionospheric electron density over the course of a single SAR image. If reflection symmetry can be assumed, the complex cross-correlation between the two channels of a dual-pol system is dependent on the Faraday rotation angle [1]. Deriving TEC from channel correlation is not a straightforward approach and can be solved only if *a priori* knowledge about surface types is available or assumed.

TEC from Faraday rotation: Linearly polarized full-polarimetric SAR data is transformed to a circular basis and adequate smoothing is applied. Faraday rotation is derived from the phase difference between the Right-Left and Left-Right channels of the circular polarized scattering matrix. With Faraday rotation estimated, and the magnetic field assumed to be uniform, then absolute TEC can be estimated. The accuracy of the approaches is strongly dependent on the quality of the polarimetric image calibration and the correctness of the applied model.

Variations in amplitude: A small number of images with anomalous stripes have been observed over equatorial regions. These are striped variations in amplitude oriented magnetic North to South. While it is not clear the mechanism behind these fluctuations in amplitude, they have been identified in Amazon and other rainforest regions around the globe [7]. Data will be initially examined visually, as properly sampled images reveal the anomaly readily. When datasets have been identified, they will be re-processed into phase images to show the effect on phase.

The survey will include all AADN holdings of PALSAR data that have been processed to a browse product by the summer 2009. Data will be analyzed for trends and correlations to other datasets, such as models and *in situ* measurements, as well as predicted increases in solar, and therefore ionospheric, activity.

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