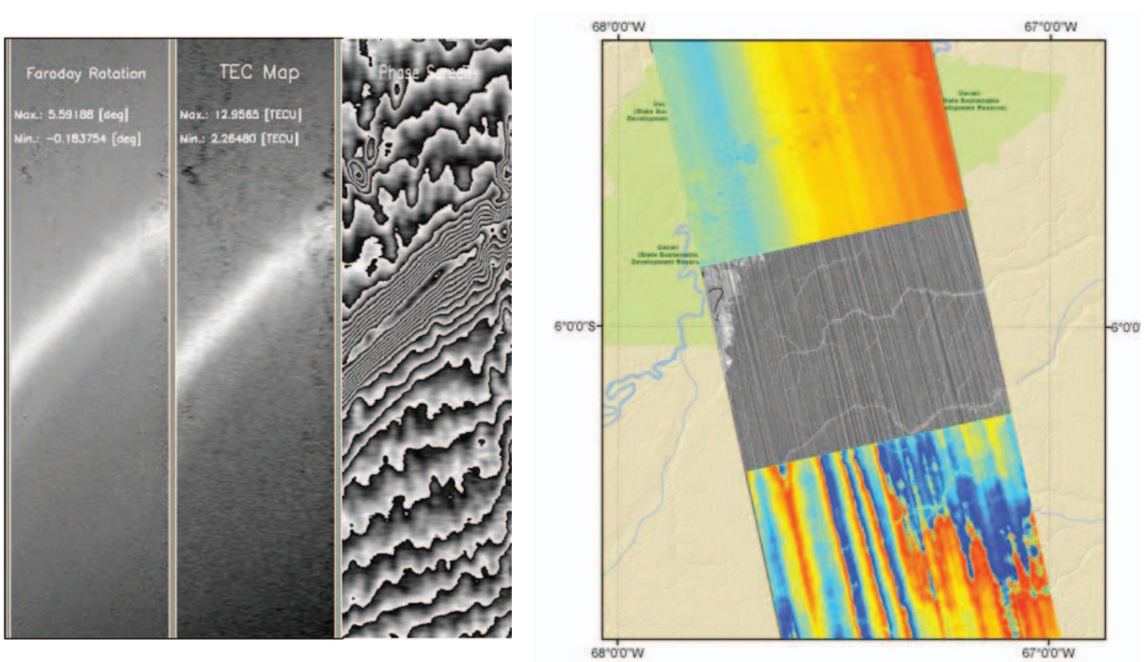
A REVIEW OF IONOSPHERIC EFFECTS IN LOW-FREQUENCY SAR – SIGNALS, CORRECTION METHODS, AND PERFORMANCE REQUIREMENTS

Franz Meyer[1)]

[1)] Earth and Planetary Remote Sensing, Geophysical Institute, University of Alaska Fairbanks
903 Koyukuk Dr., Fairbanks, Alaska, 99775, USA

1. ABSTRACT

It is well known that the impact of ionospheric propagation effects on the signal properties of L-band SAR systems is significant. Recent theoretical analyses of ionospheric distortions in L-band SAR data have indicated many effects that are likely to affect the quality of SAR, interferometric SAR (InSAR), and polarimetric SAR (PolSAR) data (see, e.g., [1] - [5]). Small scale ionospheric irregularities with spatial scales smaller than a SAR image are of most concern for SAR and InSAR, as they affect image geometry and image focus, and add phase screens to interferograms. PolSAR data is affected by all spatial scales of ionospheric delay, which introduces Faraday rotation, a rotation of the polarization vector of transmitted signals. Several examples have been published in recent years ([5], [6]) that confirm the presence of ionospheric effects by unambiguous detection of total electron content (TEC), including TEC gradients. Some



a) b)

Figure 1: a) Example of ionospheric effects caused by aurora activity in sub-arctic regions (l.t.r.: Faraday rotation estimate, derive TEC maps, predicted ionospheric phase screen); b) example of ionospheric effects caused by ionospheric bubbles in equatorial regions (top to bottom: unwrapped InSAR phase, stripes in amplitude image, ionospheric signal in wrapped InSAR phase).

examples of ionospheric effects in SAR and InSAR are shown in Figure 1. Figure 1a) shows aurora-related localized TEC enhancement that can be identified in Faraday rotation maps derived from quad-pol data. Figure 1b) presents effects on SAR amplitude and phase caused by ionospheric bubbles in equatorial regions.

A variety of methods for correcting ionospheric effects in SAR and InSAR have since been published by several authors. These methods can be grouped into i) range split-spectrum based ([7], [8], [2]), and ii) azimuth auto-focus based techniques ([8], [4]). These methods differ in sensitivity, areas of applicability, requirements, and accuracy.

With this paper a review of ionospheric signals in low-frequency SAR systems together with signal properties, the significance of the ionospheric effects is provided. In addition to existing information, the spatial structure of iononspheric delay signals is presented. This structure information is derived from a combination of high-resolution GPS and existing L-band SAR observations and is an important parameter for InSAR applications. A summary of available methods for ionospheric correction is presented and requirements for ionospheric correction are derived. The performance requirements developed in this paper extend the research published in [9] to a large range of upcoming satellite missions operating in L- and P-band. The proposed requirements can serve as a benchmark for a performance assessment of ionospheric correction methods and will help defining their suitability for operational implementation. Based on these requirements the performance of available ionospheric correction methods is evaluated and recommended correction methods are presented for different applications of SAR. These applications include SAR imaging, SAR polarimetry, SAR interferometry, and ionospheric research. All findings are exemplified with real L-band SAR data. An outlook including suggestions for future work concludes the paper.

2. REFERENCES

[1] A. Freeman, and S. Saatchi, “On the Detection of Faraday Rotation in Linearly Polarized L-Band SAR Backscatter Signatures,” Trans. On Geoscience and Remote Sensing, vol. 42, No. 8, pp. 1607–1616, 2004.

[2] F. Meyer, R. Bamler, N. Jakowski, and T. Fritz, “The Potential of Low-Frequency SAR Systems for Mapping Ionospheric TEC Distributions,” Geoscience and Remote Sensing Letters, vol. 2, no. 4, pp. 560–564, 2006.

[3] Z.-W. Xu, J. Wu, and Z.-S. Wu, “A Survey of Ionospheric Effects on Space-based Radar,” Waves in Random Media, vol. 14, pp. 189–273, 2004.

[4] F. Meyer and J. Nicoll, "The Impact of the Ionosphere on Interferometric SAR Processing**,"** Proceedings of IGARSS'08 Conference, 2008, Boston, vol. 2, pp. 391–394.

[5] F. Meyer and J. Nicoll, "Prediction, Detection, and Correction of Faraday Rotation in Full-Polarimetric L-Band SAR Data," IEEE Trans. Geosci. Remote Sens., 46, 10, 3076-3086. 2008a.

[6] F. Meyer and J. Nicoll, "Mapping Ionospheric TEC using Faraday Rotation in Full-Polarimetric L-Band SAR Data," Proceedings of EUSAR'08, 2, 23-26. 2008b.

[7] Rosen, P.A., Hensley, S., Zebker, H.A.; Webb, F. H., Fielding, E. J., "Surface deformation and coherence measurements of Kilauea Volcano, Hawaii, from SIR C radar interferometry,“ *Journal of Geophysical Research*, vol. 101 (E10):23,10923,126, doi:10.1029/96JE01459.

[8] Schneider, R.Z. and K. Papathanassiou, "Ionospheric Correction by Means of Coherent Scatterers," *Proceedings of EUSAR'08*, vol. 3, 105–108, 2008.

[9] Meyer, F., "Performance Requirements for Correction of Ionospheric Signals in L-band SAR Data," *Proceedings of EUSAR'10 Conference*, Aachen, to be published, 2010.