THE IMPACT OF IONOSPHERIC PATH DELAY ON GEODYNAMIC PARAMETER RETRIEVAL FROM L-BAND SAR

Franz Meyer[1], Jeremy Nicoll[2], Peter Webley[1], Jeff Freymueller[3], Mark Fahnestock[4]

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

[2] Alaska Satellite Facility, Geophysical Institute, University of Alaska Fairbanks
903 Koyukuk Dr., Fairbanks, Alaska, 99775, USA

[3] Seismology Group, Geophysical Institute, University of Alaska Fairbanks
903 Koyukuk Dr., Fairbanks, Alaska, 99775, USA

[4] Institute for the Study of Earth, Oceans, and Space, University of New Hampshire
8 College Road, Durham, New Hampshire, 03824-2600, USA

1. ABSTRACT

Ionospheric propagation effects can have significant impact on the signal properties of Synthetic Aperture Radar (SAR) systems and they increase with decreasing carrier frequency. Though distortion of multi-polarized SAR signals by the ionosphere has gained recent notoriety (see e.g. [1-3]), interferometric SAR processing can also be significantly affected by the ionosphere (see e.g. [4]). Relative range shifts, internal deformations, range and azimuth blurring, and interferometric phase errors are the most significant effects to be considered.

Ionospheric distortions of interferometric signals may complicate the analysis of slow deformation processes by means of differential SAR Interferometry (d-InSAR). The significance of ionospheric effects on d-InSAR derived deformation parameters depends on three general conditions: i) the spatio-temporal signature of the ionospheric path delay and its manifestation in the SAR observables; ii) the spatio-temporal properties of the deformation signal and the temporal sampling of this signal; iii) the sophistication of the applied d-InSAR technique and the assumptions inherent to the processing method. Therefore, an analysis of ionospheric influence on geodynamic parameter retrieval is case study specific and can not be answered in general.

The intention of this paper is to attempt an answer to the above question by focusing on two key applications of differential interferometry, namely the study of volcanic inflation and the measurement of glacier and ice sheet dynamics. The spatial extent and spatio-temporal properties of volcanic and glacial deformation signals differ significantly. Therefore, they not only pose different challenges on the applied processing routine, but are also susceptive to different scales, type, and nature of ionospheric disturbances. Hence, focusing on these two applications allows drawing specific conclusions while still retaining a certain generality in the derived results.

<u>Analysis of glacier and ice sheet dynamics:</u>

About 82% of the surface of Greenland is covered by the Greenland ice sheet, which discharges its ice masses through several large scale ice streams and outlet glaciers. As the catchments of these ice streams can cover several hundreds of square kilometers, glacier flow analysis is susceptive to a variety of ionospheric effects.

- Small scale disturbances may case interferometric phase fluctuations of spatial scales between one and 100 kilometers, and may be paired with localized loss of correlation, internal image deformation, and degradation of image resolution. While phase fluctuations impact deformation analysis from interferometric phase, loss of correlation and internal image deformation will affect glacier motion analysis from speckle or feature tracking methods.
- Medium scale ionospheric variability, which is often observed in arctic regions, will add phase fluctuations with spatial scales of about 50 km and above.
- Temporal variability connected to seasonal changes in sun position or long term variability in the solar cycle may add ionospheric induced phase ramps in range direction, eventually leading to an erroneous estimation of the spatial interferometric baseline.

Theoretical expectations of ionospheric effects in InSAR (see [1-5]) are paired with experience of appearance and statistics of the ionospheric signal observed in real SAR data (see [6]) to assess the expected impact of the ionosphere on InSAR derived ice sheet motion in a theoretical study. Both conventional two- and three-pass d-InSAR as well as speckle tracking methods will be considered. Using SAR data stemming from JAXA's L-band SAR mission ALOS PALSAR, the theoretical findings are verified over a test glacier in Greenland. Methods are proposed to separate ionospheric effects from the desired deformation signal, which are relying on ionospheric maps derived from GPS, or are taking advantage of the different spatio-temporal signature of the respective phase contributions.

Analysis of volcanic activity:

The North Pacific region is one of the most volcanically active areas in the world, with over 192 volcanoes, including over 70 that have been active in the past 3500 years. Alaska has over 92 volcanoes with over 50 historically active since 1760. Observation of Alaskan volcanoes with InSAR techniques started in the mid 1990 and matured into an important information source for studying the spatio-temporal behavior of many volcanic systems in the Alaska region. Examples of InSAR studies of Alaskan volcanoes can be found in [7-9]. As the deforming area around volcanoes is limited in size and very specific in shape, and as the temporal deformation behavior is typically highly non-linear, volcano analysis shows a different sensitivity to ionospheric influence.

- Interferometric phase fluctuations of small spatial scales paired with localized loss of correlation, internal image deformation, and degradation of image resolution are the main effects of concern. These effects are mainly due to auroral activity and their impact on d-InSAR is determined by the probability of their occurrence. The ability to correct for these effects depends on their detectability in the data.
- Medium scale spatial variability and temporal fluctuations of the ionospheric activity are of lower importance due to the limited extent of the area of deformation.

Statistical data of ionospheric turbulence in the North Pacific is combined with knowledge of the spatio-temporal deformation signature of test volcanoes in Alaska for a theoretical study. Conventional d-InSAR as well as stacking methods are considered in the analysis. The study focuses on two key aspects of volcanic deformation analysis, the detection and monitoring of the background activity (activity during non-eruptive phases) and the ability to detect the onset of increased volcanic unrest.

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] A. Gray, K. Mattar, and G. Sofko, "Influence of ionospheric electron density fluctuations on satellite radar interferometry," *Geophys. Res. Lett.*, vol. 27, no. 10, pp. 1451–1454, May 2000.

[5] F.J. Meyer, and J.B. Nicoll, "The Impact of the Ionosphere on Interferometric SAR Processing," *Proceedings of IGARSS08*, in print, July 2008.

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

[7] Z. Lu, R. Fatland, M. Wyss, S. Li, J. Eichelberger, K. Dean, and J. Freymueller, "Deformation of New Trident Volcano Measured by ERS-1 SAR Interferometry, Katmai National Park, Alaska," *Geophys. Res. Lett.*, vol. 24, pp. 695-698, 1997.

[8] Z. Lu, T. Masterlark, D. Dzurisin, R. Rykhus, and C. Wicks, "Magma Supply Dynamics at Westdahl Volcano, Alaska, Modeled from Satellite Radar Interferometry," *Journal of Geophysical Research*, vol. 108, No. B7, 2354, 10.1029/2002JB002311, 2003.

[9] Z. Lu, C. Wicks, D. Dzurisin, J. Powers, W. Thatcher, and T. Masterlark, "Interferometric Synthetic Aperture Radar Studies of Alaska Volcanoes," *Earth Observation Magazine (EOM)*, vol. 12, No. 3, 8-18, 2003.