REDUCING IONOSPHERIC DECORRELATION EFFECTS IN INSAR DATA USING ACCURATE COREGISTRATION

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1. INTRODUCTION

Interferometric synthetic aperture radar (InSAR) is now routinely used to generate topographic data and to study geophysical phenomena, such as crustal deformation, ice motion and structure, and vegetation canopy depths [1]. In this study, we show that ionospheric disturbances can distort InSAR phase and correlation maps, and, further, that accurate image coregistration can compensate for ionospheric propagation variations and significantly improve the interferometric coherence. Specifically, spaceborne synthetic aperture radar (SAR) instruments illuminate the Earth's surface with a sequence of narrowband microwave pulses and receive the backscattered echoes from these pulses. Both the transmitted and received signals propagate through the ionosphere, which causes the phase to be advanced by an amount proportional to the total electron content (TEC) along the propagation path [2]. Therefore, an azimuth gradient in the TEC results in a range-dependent azimuth phase gradient being added to the phase histories of the pixels being imaged. These phase gradients are equivalent to Doppler shifts, and thus they cause azimuth offsets between the actual and imaged positions of the pixels. Because of temporal variations in the ionosphere, these offsets are different in the two SAR images of an interferometric pair. As a result, when the offset between the two images is described using a low-order polynomial function of range and azimuth position, there are regions where the two images will not be correctly coregistered. These regions often form “azimuth streaks” which can be particularly salient in coherence images [3].

2. METHOD

Here we measure the range and azimuth offsets at a dense, uniformly-spaced grid of locations using amplitude cross-correlation to improve coherence in InSAR pairs affected by ionospheric artifacts. The range and azimuth offsets between the two SAR images are functions of position, and the measurements represent samples of these functions. The offset measurement grid spacing is an input parameter to our software, which means denser grid spacing can be used for cases of greater offset variability. Because the amplitude cross-correlation measurements are susceptible to outliers and noise, we median filter and low-pass filter the measurements to obtain a more accurate representation of the average offset variation with position. The offsets are not necessarily band-limited functions of position, so we use bilinear interpolation to estimate the actual range and azimuth offset for each pixel in the first SAR image. Finally, we coregister the second image in the pair to the first image using a 9x9 point 2-dimensional sinc interpolation kernel.

We have applied this method to data acquired over Greenland, in which prominent streaks of low coherence are common. It is necessary to compensate for the misregistration if we are to measure the correlation accurately, a necessary step for interpretation of volumetric scattering and its application to estimation of snow accumulation rates. The ionospheric azimuth streaking artifacts are greatly reduced using accurate image coregistration. For efficiency, we have parallelized the execution of this software, so that the coregistration takes about 1 minute using 8 computing threads for an 80 km long scene.

3. RESULTS

We tested this method using L-band SAR data from the PALSAR instrument on the ALOS spacecraft. We show the results from a scene in the interior of the Greenland ice sheet in Figure 1. Common InSAR software packages such as ROI-PAC represent the range and azimuth offsets between the two SAR images of an interferometric pair as a low-order polynomial function of position. Figures 1.a and 1.c show the interferogram and coherence images generated using a low-order polynomial function to represent the offsets. The most prominent “azimuth streak” artifact is indicated by the red outline. In contrast, the interferogram and coherence images shown in Figures 1.b and 1.d demonstrate that interferometric fringes are much more clearly visible and coherence is improved using our accurate coregistration method. Figure 2 shows the azimuth and range offsets that we use in the resampling process. To further quantify the improvement in coherence, Figure 3 shows histograms of the coherence values in this image, using both the low-order polynomial offset fit and our accurate coregistration method. Whereas the low-order polynomial fit results in many pixels with coherence below 0.5, almost all the pixels have coherence greater than 0.5 using our method.

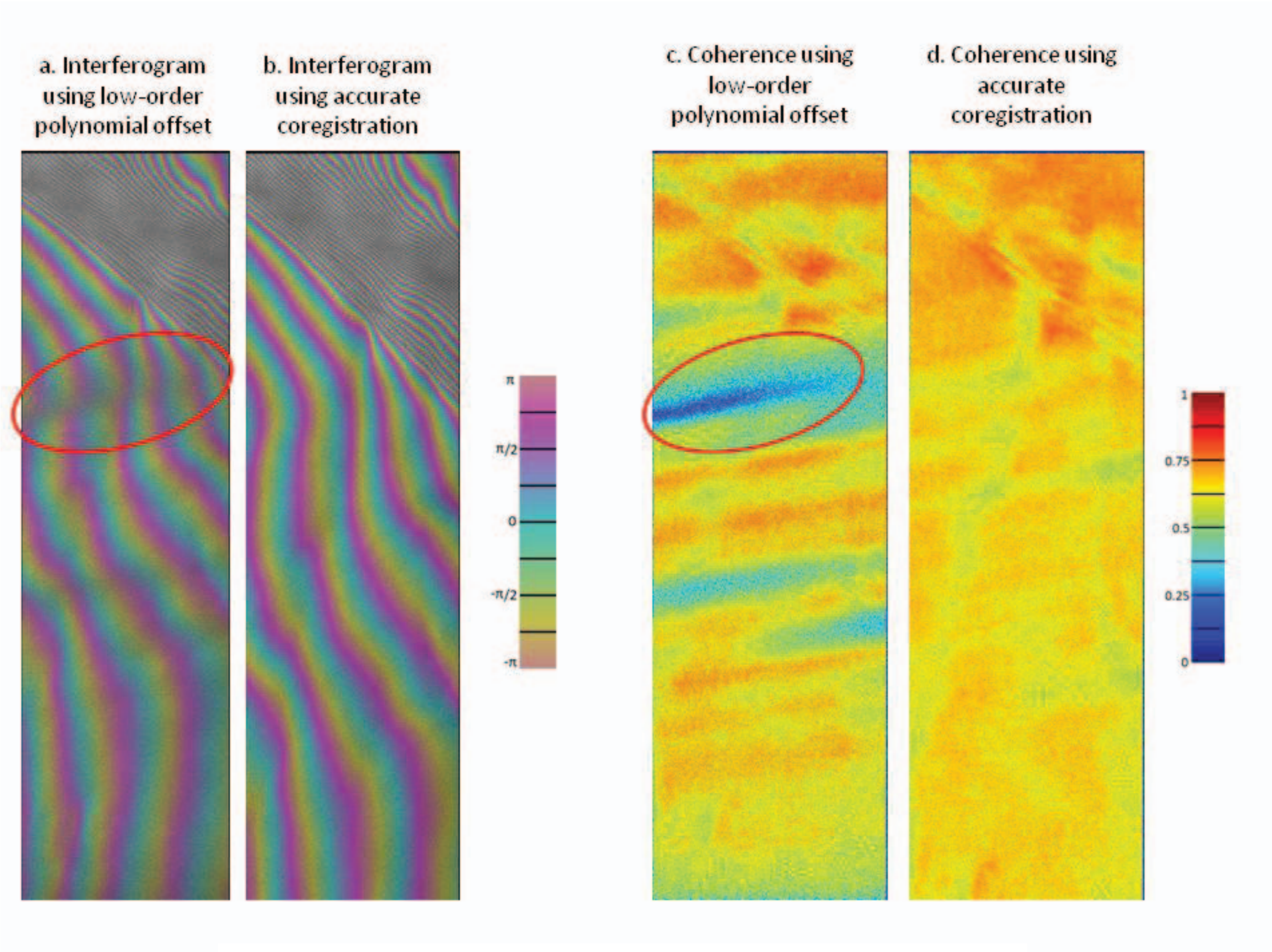
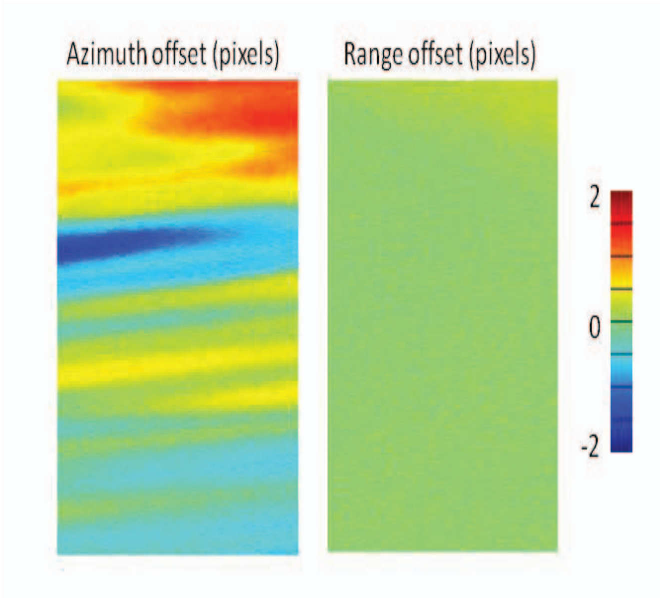


Figure 1: Interferograms and coherence images

4. DISCUSSION

We observe spatial variation of offsets between interferometric pairs of ALOS SAR data, and we note that there is much more variation in the azimuth offsets than in the range offsets. This is likely due to ionospheric propagation effects. We have shown that we can achieve high coherence in spite of these effects using accurate image coregistration. Simple models of ionospheric wave propagation indicate that the spatial TEC variation also affects the phase of the interferogram [4]. In these scenes we estimate that there is less than a single fringe of ionospheric phase variation over an 80 km ALOS interferogram. Because estimating azimuth offsets at a dense grid of locations using amplitude cross-correlation can be computationally time-consuming, we also note that these same offsets can be estimated using multiple aperture interferometry [5]. One disadvantage of our method is that it is less robust to outliers in the offset measurements than the commonly used low-order polynomial fit method. This can be addressed, for example, by using signal processing techniques to identify outliers and smooth the offset fields before they are used in the resampling software.



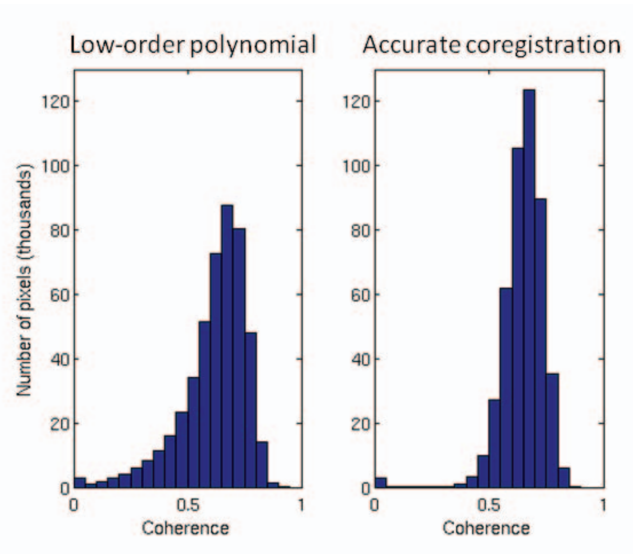


Figure 2: Azimuth and range offsets

Figure 3: Coherence histograms

5. REFERENCES

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