SPECIAL CONSIDERATION ON THE RADARSAT REPEAT-PASS SAR INTERFEROMETRY

Kim, Sang-Wan*, Joong-Sun Won* and Wooil M. Moon**
***Department of Earth System Sciences, Yonsei University**
****Department of Geology, Seoul National University**
E-mail: sangwan@geors.yonsei.ac.kr
Fax) +82-2-392-6527

Abstract — SAR interferometry (InSAR) using the space-borne Synthetic Aperture Radar (SAR) have recently become one of the most effective tools monitoring surface changes caused by landslides, earthquakes, subsidences or volcanic eruption. This study focuses on examining the feasibility of InSAR using the RADARSAT data. Although the RADARSAT SAR with its high resolution and variable incidence angle has several advantages for repeat-pass InSAR, it has two key limitations: first, the orbit is not precisely known; and second, RADARSAT's 24-day repeat pass interval is not very favourable for retaining useful coherence.

In this study, two pairs of RADARSAT data in the Nahanni area, NWT, Canada have been tested. We will discuss about the special consideration required on the interferometric processing steps specifically for RADARSAT data including image co-registration, spectral filtering in both azimuth and range, estimation of the interferometric baseline, and correction of the interferogram with respect to the "flat earth" phase contribution. Preliminary results can be summarized as: i) the properly designed azimuth filter based upon the antenna characteristic improves coherence considerably if difference in Doppler centroid of the two images is relatively large; ii) the co-registration process combined by fringe spectrum and amplitude cross-correlation techniques results in optimal matching; iii) the baseline is not always possible to be estimated from the definitive orbit information.

1. Introduction

The concept on satellite repeat-pass Synthetic Aperture Radar (SAR) Interferometry (InSAR) is well-established based on various SAR data. The RADARSAT system with its variable incidence angles and resolution modes is very useful better used to generate interferometric DEM and coherence map. Also, RADARSAT's fine-resolution beam modes allow large baselines in the range of about 6 km due to their high chirp bandwidth(30MHz) and large incidence angles[1]. If the surface is stable over the time span between passes, we could extract the information on the topographic height by InSAR technique. Furthermore, Differential InSAR (DInSAR) offers the opportunity to measure small scale spatial displacements.

In this paper, We discuss the interferometric processing of RADARSAT data. Suitable InSAR image pairs is first evaluated in the study area. We discuss the registration of two interfering SAR images though 2D interpolation based on imaging geometry. We then analyze the effects on the data spectra in azimuth and range. Finally, the estimation of baseline from the RADARSAT definitive orbit data is discussed with respect to reliability.

2. RADARSAT Data and Study Area

We have used four SAR data acquired over the Nahanni area, NWT, Canada, which has been known to be seismically active for many years. All of the images are acquired in descending orbits and F3 beam mode. Further descriptions on all cases that can be used as

Table 1. RADARSAT images of the Nahanni area.

Dates of pairs	Time interval	Beam mode	Baseline	Look angle
Dec. 09, 1997 Jan. 02, 1998	24	F3	1023.6 m	42.4°
Dec. 09, 1997 Feb. 19, 1998	72	F3	1735.4 m	42.4°
Dec. 09, 1997 Mar. 15, 1998	96	F3	709.7 m	42.4°
Jan. 02, 1998 Feb. 19, 1998	48	F3	2038.1 m	42.4°
Jan. 02, 1998 Mar. 15, 1998	72	F3	1010.8 m	42.4°
Feb. 19, 1998 Mar. 15, 1998	24	F3	990.2 m	42.4°

pairs with each other are given in Table 1. Among the image pairs, Dec. 9/Jan. 2 and Feb. 19/Mar. 15 pairs are chosen as InSAR test pairs. The others show severe temporal decorrelation so that interferometric fringe can not be formed. In addition, the long baseline(about 2 ㎞) of Jan. 2/Feb. 19 pair and the large difference(about 200 ㎐) of Doppler centroid in Dec. 9/Feb. 19, and Dec. 9/Mar. 15 pairs, as shown in Fig. 5, lead to more decorrelation effect.

3. InSAR Processing

The first step in InSAR processing is to co-register the complex image pairs. The bandpass filterings for azimuth spectral overlap in azimuth direction and baseline decorrelation in the range are followed.

3.1 Co-Registration

We attempted to co-register the two images using the following procedure:

1. Implement manual rough registration by selecting some tie points through visual inspection of each amplitude images.
2. Using amplitude correlation[2] and spectrum correlation or fringe spectrum[3], the offsets of a sub-pixel accuracy on equally spaced grid points are searched in the both range and azimuth direction.
3. Grid points that show low correlation in amplitude correlation and low signal-to-noise ratio (SNR) in spectrum correlation may be unreliable and thus are excluded before the further processing.
4. The exact tie points estimated from two methods are combined together and used to do the 2D interpolation of the slave image based upon a certain wrapping model.

In this research, we develop and use the warping model as follows.

$$\begin{pmatrix} r' \\ a' \end{pmatrix} = \begin{pmatrix} \sin\theta & \cos\theta \\ -\cos\theta & \sin\theta \end{pmatrix} \begin{pmatrix} Sr & 0 \\ 0 & Sa \end{pmatrix} \begin{pmatrix} r \\ a \end{pmatrix} - \begin{pmatrix} \Delta r \\ \Delta a \end{pmatrix},$$

where r and a are range and azimuth pixel in master image, respectively, and r' and a' in slave image. Sr and Sa are scaling factors along range and azimuth. Δr and Δa are constant shifting values. And then θ is a rotation angle. Sr is nearly a constant related to the ratio of the different pixel spacing due to the incidence

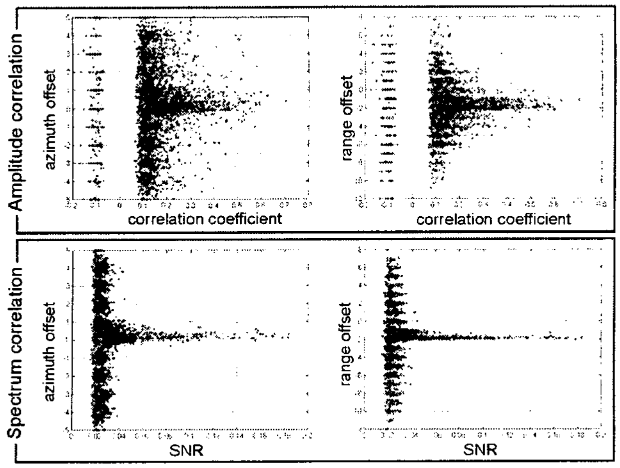

Fig. 1. The offsets of Dec. 9/Jan. 2 pair.

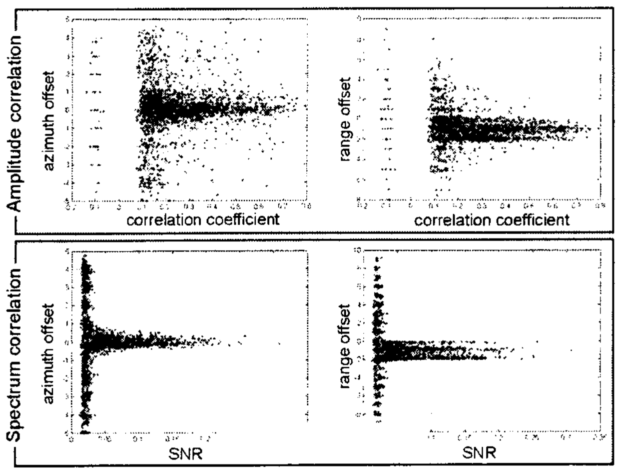

Fig. 2. The offsets of Feb. 19/Mar. 15 pair.

angle differences on the registrated points. *Sa* can be caused by the discordance of PRF.

The resulting offsets after apply the algorithm above to two InSAR pairs(Dec. 9/Jan. 2, Feb. 19/Mar. 15) are shown in Fig. 1 and 2. The offsets with lower correlation coefficients than 0.2 and lower SNR's than 0.03 are randomly distributed. Also, we can conclude that the method of spectrum correlation is more reliable. This method, however, sometimes give little tie points due to spectral decorrelation, which is not enough to make an accurate warping model. Therefore, the combination of the two methods is strongly recommended. Though we actually perform 2D interpolation from the presumed warping model, fitting of the estimated offsets(Fig. 3 and 4) is shown very well that each offsets is linearly relevant to azimuth and

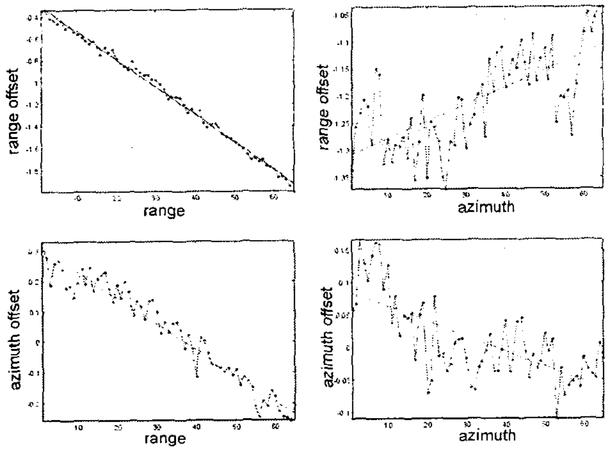

Fig. 3. Fitting offets estimated from Feb. 19/Mar. 15 pair.

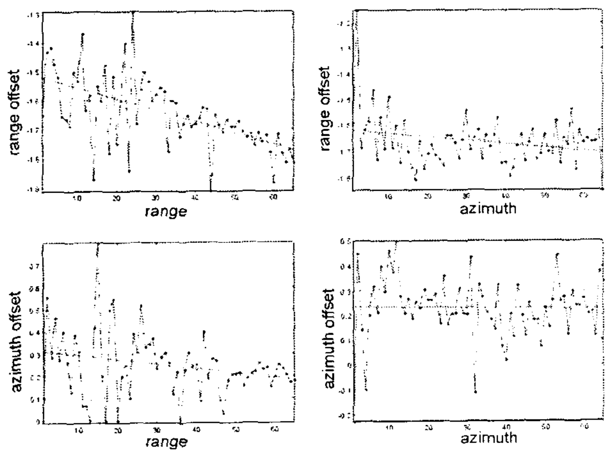

Fig. 4. Fitting offsets estimated from Dec. 9/Jan. 2 pair.

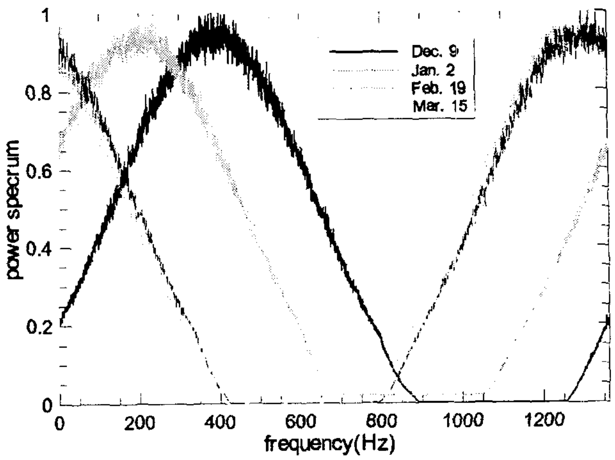

Fig. 5. Azimuth spectra of the four images before spectral bandpass filtering.

range directions. These plots also offer a opportunity to judge image rotation.

3.2 Azimuth-Filtering

RADARSAT can have large effective squint angles because RADARSAT is not operated in a yaw-steering mode to compensate for Earth rotation[4]. Fig. 5 shows the azimuth power spectra of four images. The spectral correlation can be improved by an azimuth bandpass filtering, because only the common part of both image spectra is used for interferometry. The filter is composed of the azimuth spectral envelope weighted by a Kaiser-Bessel window and the antenna beam pattern weighting. The applied result of the azimuth filtering to Dec. 9/Jan. 2 pair is shown in Fig. 6. The coherence

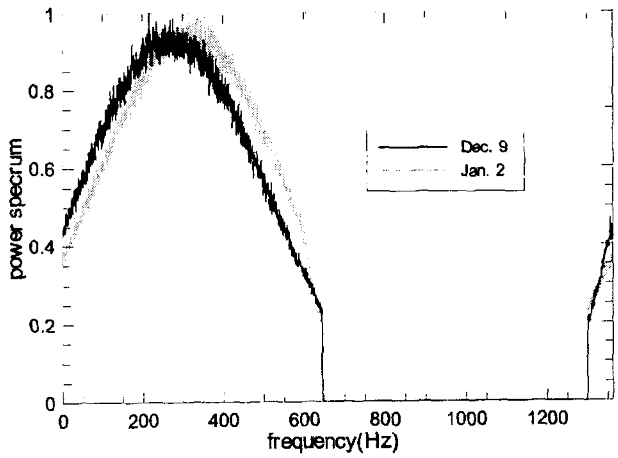

Fig. 6. Azimuth spectra of the Dec. 9/Jan. 2 pair after azimuth spectral bandpass filtering.

of that pair characterized by a large non-overlapping portions of the two image spectra increases considerably(Fig. 6).

3.3 Range-Filtering

We are interested in the relative band shift between the two range data spectra. The frequency shift of range spectra arises from RADARSAT's large quint angles[5]. This relative band shift can be easily observed in interferogram's spectrum because that is the linear cross-correlation of the two spectra[6].

3.4 Baseline Estimation and Earth Flattening Correction.

The time-variant InSAR baseline is calculated from the definitive orbit data given by RADARSAT Inc. The orbit propagation can be performed using analytical graphics' Satellite Tool Kit (STK) by specifing the platform position data to be nearby aquisition time. Then, We correct interferogram for the expected phase contribution of a topographically flat, ellipsoidal Earth. Fig. 7(b) is obtained after processing up to post-filtering. We, however, fail to generate proper fringe line out of Dec. 9/Jan. 2 pair as shown in Fig. 7(a). Fig. 7(a) is only a primitive interferogram before earth flattening correction. That may be happened by a uncertainty of the orbit. Accordingly, a set of suitable tie points are required.

4. Conclusions and Discussion

The optimal co-registration results from 2D interpolation using a proper warping model

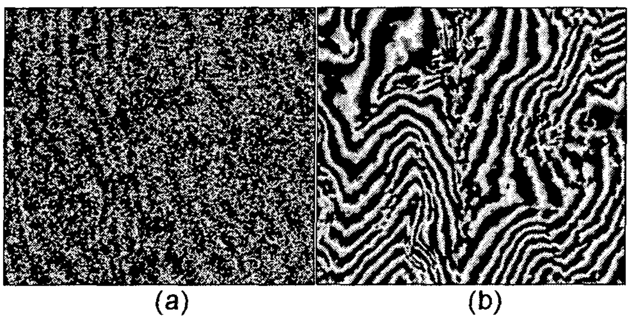

Fig. 7. Interferogram of (a) Dec. 9/Jan. 2 pair (b) Feb. 19/Mar. 15 pair.

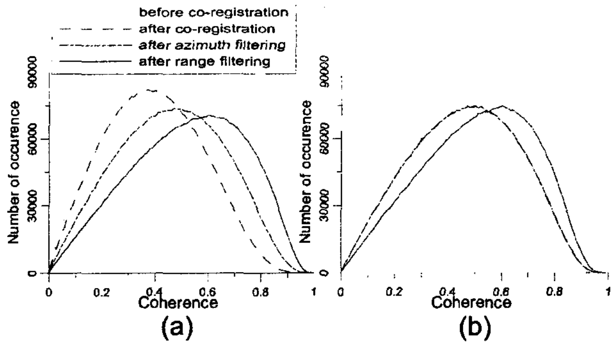

Fig. 8. Coherence histogram of (a) Dec. 9/Jan. 2 pair (b) Feb. 19/Mar. 15 pair.

computed from automatically collected tie points. Since RADARSAT's imaging geometry has a large squint angle, the removal of decorrelation due to spectral misalignment is very important in InSAR processing. In each processing step, a variation of coherence histogram is shown in Fig. 8. Coherence is improved as each step applied. The effect of an azimuth filtering is negligible in Feb. 19/Mar. 15 pair because its difference of Doppler centroid is very slight. Generally, coherence of the RADARSAT data pair over the study area is very poor. Since data aquisitions are in the middle of winter in the Canadian north, this may be caused by the surface with thick snow and snow drift. Earth flattening correction for Dec. 9/Jan. 2 pair results in a destruction of primitive interferogram unexpectedly. Therefore, for a more accurate DEM generation and DInSAR applications we must try another methods such as using Ground Control Points and so on.

Reference

[1] Vachon, P. W., D. Geudtner, A. L. Gray and R. Touzi, 1995, ERS-1 Synthetic Aperture Radar repeat-pass interferometry studies: Implications for RADARSAT, *Can. J. Rem. Sens.*, 21(4), pp. 441-445.

[2] Kwoh, L. K., E. C. Chang, W. C. A. Heng and H. Lim, 1994, DTM Generation from 35-Day repeat ERS-1 interferometry, *Proceeding* of the 1994 Int. Geo. of Rem. Sens. Symp., pp. 2288-2290.

[3] Gabriel, A. K. and M. R. Goldstein, 1988,

Crossed orbit interferometry: theory and experimental results from SIR-B, *International Journal of Remote Sensing*, 9(5), pp. 857-872.

[4] Geudtner, D., P. W. Vachon, K. E. Matter and A. L. Gray, 1998, RADARSAT Repeat-Pass SAR Interferometry: Results Over An Arctic Test Site, ADRO Project #500

[5] Rocca, F., C. Prati and A. Monti Guarnieri, New algorithms for processing SAR data, ESA-ESRIN Contract No. 1998/88/F/FL(SC)

[6] Gatelli, A., M. Guarnieri, M. Parizzi, C. Pasquali, C. Prati and F. Rocca, 1994, The wavenumber shift in SAR interferometry, *IEEE Trans. Geo. Rem. Sens.*, 32(4), pp. 855-865.