

RESEARCH ON THE LINEAR AND NONLINEAR METHODS OF CORRECTING BASELINE ERRORS ON SAR INTERFEROGRAMS

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ABSTRACT:

In this paper, the precise orbit and the coarse orbit are both used to compare the characteristics of the baseline errors on interferograms. To eliminate the fringes caused by baseline errors, a linear algorithm which is done on interferograms and a nonlinear algorithm which is performed on phase-unwrapped maps are both used. The unwrapped phase values are decreased greatly after baseline errors are eliminated using bilinear method. The results show that the standard deviation (STD) is decreased from 10.9 radians to 3.1 radians. In nonlinear method, a quadratic function is used to fit the surface of the phase-unwrapped map, then the fitted surface is subtracted. STD is decreased from 10.9 radians to 2.8 radians. The results show that the nonlinear method is a little effective than the linear one.

1. INTRODUCTION

Repeat-pass interferometric synthetic aperture (InSAR) requires orbital satellite state vectors to estimate baseline vector, reduce flat earth effects, and geocode. However, the orbits are difficult to determine with enough precision to satisfy the need of InSAR. The orbit errors will propagate directly into the topography height and deformation maps. Because the ultimate products of InSAR are relative such as height or deformation, to fully correct the residual interferometric fringes, the required absolute orbit accuracy would need to be on the order of 1mm, which is far below the current satellites's precision (about 5-10cm, ESA ENVISAT satellite).

Hanssen (2001) has explained in detail how orbit errors affect the baseline and how baseline errors influence the reference phase. The baseline vector can be described conveniently in three representations:①parallel/perpendicular, ②horizontal/vertical, and ③baseline length/angle.

$$\overset{U}{B} = (B_{\parallel}, B_{\perp}) = (B_h, B_v) = (B, \alpha) \quad (1)$$

where $\overset{U}{B}$ =baseline vector

B_v = perpendicular baseline

B_{\perp} = parallel baseline

B_h = horizontal baseline

B_v = vertical baseline

α = orientation angle

The phase errors in interferogram come only from the propagation of the orbit errors in the satellite's across-track and radial directions. The relationship between baseline vector errors and across-track/radial errors can be given by:

$$\begin{aligned} \sigma_{B_v} &= \sqrt{\sigma_{radial,1}^2 + \sigma_{radial,2}^2} \\ \sigma_{B_h} &= \sqrt{\sigma_{xtrack,1}^2 + \sigma_{xtrack,2}^2} \end{aligned} \quad (2)$$

Where σ_{radial} = radial orbit error

σ_{xtrack} = across-track error

In this paper, the characteristics of baseline errors are studied, and linear and nonlinear methods are introduced to reduce these errors. The precise orbit (from Delft University) and the coarse orbit in SAR SLC product are both used to compare the baseline errors on interferograms.

2. ALGORITHMS

Massonnet and Feig (1998) proposed a method similar to the tie-point method proposed to diminish those baseline errors for topography height estimation. However, this method can only reduce the parallel component error vector, and cannot correct the perpendicular one, still leaving residual errors. Another problem that constrains the tie-point method is the atmospheric effect, which causes additional phase gradients.

In this paper a bilinear algorithm and a nonlinear algorithm are used to eliminate the baseline errors on interferograms and phase-unwrapped maps. The linear algorithm is done on

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interferograms, on which the fringes caused by baseline errors is first estimated with FFT in range and azimuth direction and then eliminated. The nonlinear algorithm is performed in phase-unwrapped maps, where a quadratic surface function is used to fit the trend of unwrapped phase and then the trend is subtracted. The quadratic function can be described by:

$$f(x, y) = a_1 + a_2 \cdot x + a_3 \cdot y + a_4 \cdot xy + a_5 \cdot x^2 + a_6 \cdot y^2 \quad (3)$$

where $a_n (n = 1 \cdots 6)$ = polynomial coefficients
 x, y = coordinates in range and azimuth directions.

3. RESULTS

To verify the effectiveness of linear and nonlinear methods for mitigating the baseline errors, ESA Envisat ASAR data at Bam area are selected. The selected image pairs and baselines are as follows.

Master	Slave	Temporal Baseline	Perpendicular Baseline
9192	6687	-175 days	475 m
9192	9693	475 days	530 m

Table 1. SAR images pair and baselines

The data was processed by DORIS software with two-pass differential method, in which SRTM3 DEM was used to remove the topographic effects. The results are as follows.

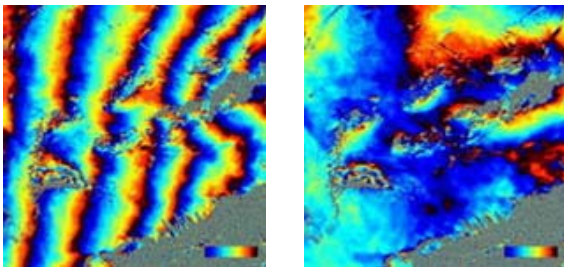


Figure 1.

Figure 2.

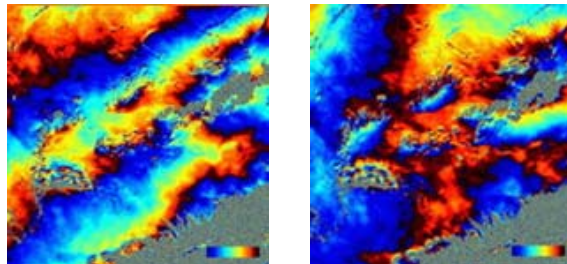


Figure 3.

Figure 4.

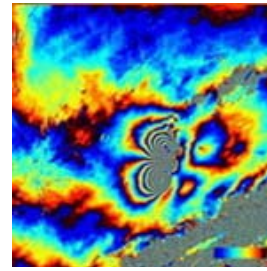


Figure 5.

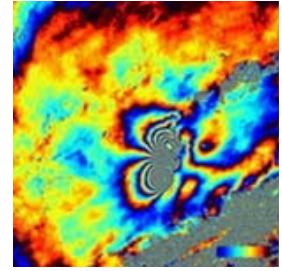


Figure 6.

Figure 1. Interferogram (9192-6687,coarse orbit used)
 Figure 2. Residuals of Fig.1 after subtracting bilinear fringes
 Figure 3. Interferogram (9192-6687,precise orbit used)
 Figure 4. Rresiduals of Fig.3 after subtracting bilinear fringes
 Figure 5. Interferogram (9192-9693,precise orbit used)
 Figure 6. Residuals of Fig.5 after subtracting bilinear fringes

From the comparison of interferogram between Figure 1. and Figure 3., we can see that the pattern of fringes mainly takes on the characteristics of linear trend. The fringes on Figure 1 and Figure 3. are mainly ascribed to baseline errors, for no obvious deformation takes place during the 175 days of SAR images acquirement. The pattern difference between them are only due to the difference of the orbit accuracy: Figure 1. with precise orbit and Figure 3. with coarse one. Figure 1. is generated during BAM earthquakes, on which the butterfly-look fringes are very clear. However the three other linear fringes cannot be due to earthquakes, and they should be due to the baseline errors. If the linear fringes are not eliminated, they will affect the interpretation of the earthquakes. Maps Figure 2, Figure 4, and Figure 6 are respectively the results of Figure 1, Figure 3, Figure 5 after subtracting the linear fringes estimated from FFT spectrum.

The fringes caused by baseline errors can be removed in two methods. One is bilinear method, which is performed on interferograms, the other is nonlinear method performed on phase-unwrapped maps. The results of both methods are as follows.

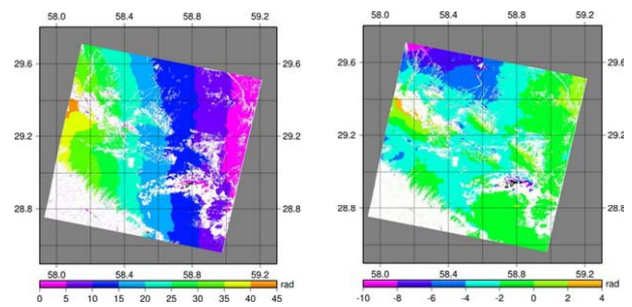


Figure 7.

Figure 8.

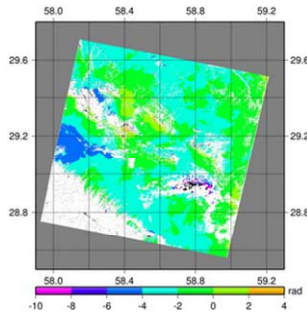


Figure 9.

Figure 7. Unwrapped phase map of B (masked area with coherence less than 0.15)

Figure 8. Unwrapped phase map of E (masked area with coherence less than 0.15)

Figure 9. Residuals of F after removing the fitted quadratic surface

According to Figure 1, one fringe in azimuth direction and six ones in range direction are simulated. After removing the simulated fringes in range and azimuth direction from Figure 1 (bilinear method), few fringes remains, as is shown in Figure 2. The unwrapped phase results of Figure 1 and Figure 2 are respectively presented in Figure 7 and Figure 8. Evidently, the unwrapped phase values are decreased greatly after baseline errors are eliminated using bilinear method. The results show that the standard deviation (STD) is decreased from 10.9 radians (Figure 7) to 3.1 radians (Figure 8). In nonlinear method, a quadratic function is used to fit the surface of the phase-unwrapped map, then the fitted surface is subtracted, as is shown in Figure 9. STD is decreased from 10.9(Figure 7) radians to 2.8 radians(Figure 9).

The residuals in Figure 8 and Figure 9 may be caused by atmospheric delay errors, unwrapping errors, and uncomplete removal of linear fringes.

4. CONCLUSIONS AND DISCUSSIONS

According to the results above, we can see that the fringes on interferograms caused by baseline errors can be reduced greatly with both the bilinear method and nonlinear method. From the comparison of STD of Figure 8 and Figure 9, we can find that nonlinear method is a little effective than the linear one. However, which one is used depends on the patterns of the fringes on the interferogram. If the fringes are presented nonlinearly, the former is used, or the latter.

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