ABSTRACT

ScanSAR is a type of SAR imaging technology, in which SAR switches its antenna look angle cyclically to cover several subswaths and therefore to achieve a very wide coverage. Compared with the conventional strip-map mode, ScanSAR has lots of advantages due to its wide swath coverage and moderate resolution. The disastrous Wenchuan earthquake happened on May 12, 2008 caused large scale land deformation far beyond the coverage of a single strip-map mode acquisition. On the other hand, ScanSAR interferometry is an attractive option to monitor the deformation, which is implemented using a pair of L-Band ALOS PALSAR ScanSAR acquisitions in this paper. Firstly each subswath is processed until the differential interferogram is generated, then subswath interferograms are mosaicked together to form the entire scene. The ultimate differential interferogram gives an overall view of the land deformation caused by the earthquake.

1. INTRODUCTION

ScanSAR employs burst acquisition pattern to cover several subswaths in slant range by trading off azimuth resolution. The burst gap in a subswath is used to image other subswaths. The Phase Array Type L-band Synthetic Aperture Radar (PALSAR) instrument, boarded on the Advanced Land Observing Satellite (ALOS), can acquire ScanSAR dataset with a swath coverage as large as 350km and a ground resolution of 100m. One advantage of PALSAR is its 23.6 cm wavelength, which means better penetration to the earth and consequently better coherence for interferometry applications. It is very important to our case study, as the C-band acquisitions shows extremely low coherence in Wenchuan area and nearly can not be used to do interferometry.

ScanSAR has already been implemented in the early launched spaceborne sensors, such as Envisat ASAR and Radarsat-1. People can find many ScanSAR interferometric results using these datasets. This is true especially for Envisat ASAR because of its enhancement in ScanSAR interferometry and the publication of Single Look Complex (SLC) of ScanSAR acquisitions. First ALOS PALSAR ScanSAR interferometry result can be found in [1]. In this paper, we will introduce our ScanSAR interferometry processing technique. The good coherence of L-band data and the large coverage of ScanSAR mode make the PALSAR ScanSAR acquisitions the best choice to monitor the displacement of Wenchuan earthquake, which occurred on the Longmen Shan fault zone, a convergent zone with a dextral component, separating the Sichuan basin from the eastern margin of the Tibetan plateau [2]. The deformation monitored using strip-map data has already been reported in [2]. However, results from adjacent tracks are not consistent with each other well. Therefore, it is meaningful and proper to use ScanSAR interferometry.

ScanSAR interferometry requires precise time and orbit control. Although synchronization is not well planned in ALOS mission, a pair of acquisitions completely covering the fault zone is chosen with enough synchronization and relative short baseline for interferometry. The ultimate differential interferogram shows satisfactory result and gives an overall view of the land deformation caused by the earthquake, compared with that of strip-map mode.

2. ALOS PALSAR ScanSAR datasets

As we have mentioned above, the L-band echoes show much higher coherence than that of C-band. In addition, longer wavelength of L-band also allows much longer
critical baseline. In ScanSAR mode, the chirp bandwidth of PALSAR is 14 MHz in the range direction. The critical baseline as a function of incidence angle is shown in Fig. 1.

ALOS PALSAR ScanSAR mode is comprised of two types: WB1 and WB2 mode. WB2 is not well calibrated and PALSAR seldom works in this mode, therefore, WB1 is the favourite for ScanSAR interferometry. The WB1 mode data, usually comprised of 5 subswaths, can achieve swath width as large as 350 km, which is much larger than the 70 km swath width of PALSAR strip-map mode. In this study, we have collected 10 scenes of WB1 mode datasets. Among these datasets, a pair of them is chosen to do further research. Another advantage of WB1 acquisitions in this case study is that the Longmen Shan fault zone, parallel to the diagonal, lies in the center of the scene, which further enables the chosen scene to perfectly cover it. Some important parameters of the datasets are summarized in Tab. 1.

Compared with strip-map mode data, the unique parameter to be considered for ScanSAR interferometry is its azimuth scanning pattern synchronization, which can be defined as [3]:

$$\frac{N_{synchronized}}{N_{burst}}$$

(1)

In ScanSAR interferometry, enough synchronization should be guaranteed in order to keep good coherence between master and slave image. The synchronization of the pair chosen from subswath1 to subswath2 is 82%, 80%, 78% and 78%, respectively. It is proved to be sufficient to generate satisfactory interferogram.

### Table 1. Selected important parameters of the interferometric pair

<table>
<thead>
<tr>
<th>Date</th>
<th>Jan. 3rd, 2008 - May. 20th, 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Path</td>
<td>124</td>
</tr>
<tr>
<td>Perpendicular Baseline [m]</td>
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</tr>
<tr>
<td>Orbit Direction</td>
<td>D</td>
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<tr>
<td>Wavelength [cm]</td>
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<tr>
<td>Range Sampling Frequency [Hz]</td>
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<tr>
<td>Range Bandwidth [Hz]</td>
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<tr>
<td>I/Q Bias</td>
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<tr>
<td>Polarization</td>
<td>HH</td>
</tr>
<tr>
<td>PRF</td>
<td>1683.502 – 2358.491</td>
</tr>
</tbody>
</table>

### Figure 2. The overall processing flow of ScanSAR interferometry.

Until now, several algorithms have been devised to focus the raw echoes of burst mode data, such as the Modified SPECAN Algorithm, the Short IFFT Algorithm, the Extended Chirp Scaling Algorithm and the simple Full-Aperture Algorithm. We use Full-Aperture Algorithm [4] to focus the raw burst echoes. Although it is computationally inefficient, it can make use of current strip-map algorithms with minor modifications. The principle of this method is that burst gaps of each subswath are padded with zeros and standard high precision algorithm can be used to compress ScanSAR raw echoes just as strip-map mode. The first problem being considered is the correct estimation of Doppler Centroid and it is also the fundamental of Range Cell Migration Correction (RCMC) and Azimuth Compression. Some prior proposed algorithms for the strip-map mode data are no longer suitable to ScanSAR, as full Doppler bandwidth required by these algorithms is not available in a ScanSAR system, but the CDE (Correlation Doppler Estimator) [5] remains applicable [6]. Besides, the CDE algorithm is performed in time domain and computationally efficient. Therefore, it is applied to the Doppler Centroid Estimation and sufficiently large estimation window is adopted. To our experience, it is more precise to use linear fit rather than quadratic fit to determine the relationship between range and Doppler Centroid Frequency. In implementation, we firstly use a
linear fit to cull the estimated values with gross errors, after that the remaining values are used to make a second linear fit. The result of Doppler estimation of subswath1 is displayed in Fig. 3. The SLC focused using full-aperture algorithm will show a strong periodic modulation affecting the quality of the image. However, a subsequent low pass filter, such as multi-looking, will remove the phenomenon [4]. However, in the case of ALOS PALSAR, there is another problem. The timing precision of PALSAR is 1 millisecond, while the PRF of the subswaths varies from 1577.3 Hz to 2386.6 Hz. Therefore, we can not pad zero-lines according to the time difference of last line of last burst and the first line of current burst because this may cause an error of several lines of each pad and may resultantly cause coregistration errors. Instead, we use the beginning and the ending time of the whole scene to determine how many lines should be padded between adjacent bursts. To improve the coherence of the interferometric pair, a step called synchronization selection should be performed in most of the cases. If the same point on the ground is imaged from the same along-track positions both times [7], then these echoes are synchronized and therefore coherent. Other echoes should be removed. The strategy we used is as follows: after the compression of raw echoes, slave image is coregistered to the master image. If both of the corresponding raw lines in master and slave are not zeros, they are synchronized echoes and kept for further processing. Other lines should be removed by means of replacing them with zero-lines. Note that, the raw burst images have already been padded with zeros in order to use Full-Aperture algorithm. However, the removal of echoes also leads to the reduction of image quality. Here, we recommend that if the coherence is good enough to generate satisfactory interferogram, synchronization selection is not necessary to be performed. The problem of processing each subswath rather than the whole scene is that, the adjacent subswath interferograms will show a minor difference in the overlap region. To remove the difference and improve the precision of these regions, a method named overlap region smoothing as shown in the blue rectangular of Fig. 2 is proposed in [8]. This method is very effective and an interferogram with much higher quality can be generated. Other processing steps are the same with that of strip-map data and will not be discussed any more in this paper.

4. RESULT AND DISCUSSIONS

The differential interferogram completely reflects the large scale land deformation in Fig. 4. Preliminary comparison with the result of strip-map interferometry suggests the correctness of our result. The long time baseline, the seasonal difference and the wet environment of this area seriously affected the coherence of the interferometric pair. It has been shown that C-band datasets nearly can not generate useful fringes. Even the SRTM has many holes in this area. In this pair, we can see that the Chengdu plain still shows enough coherence with clear fringes, whereas the eastern margin of the Tibetan plateau in the west of fault zone shows extremely low coherence because of the thick forest. The upper-left corner still shows good coherence, in spite of the presence of forest. However, the overall coherence of this pair is not as good as that of strip-map mode reported in the relating literature [2] [9] [10]. The longer temporal baseline is to be blamed for that, in our opinion. The coarser azimuth resolution may also cause the degradation of the coherence.
Figure 4. ScanSAR differential interferogram of Wenchuan earthquake.
5. FUTURE WORK
We will do more research on the precise estimation of Doppler centroid and ScanSAR focusing algorithms in order to generate high quality image. Additional validation of the differential interferogram should be implemented in the future.

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