CROSS-INTERFEROMETRY FOR DEM CONSTRUNTION WITH ERS-ENVISAT PAIR

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ABSTRACT:

Spaceborne radar interferometry has been widely used to estimate the topography and deformation of the Earth. It is difficult to obtain coherent interferometric SAR pairs especially over coastal areas mainly because of variation of surface conditions. We carried out the experiment using a cross-interferometric pair with a perpendicular baseline of about 1.4 km, a 30 minutes temporal separation and the height sensitivity of about 6 meters. The temporal decorrelation can be reduced by the cross interferometric technique with a 30 minutes temporal separation. Accurate coregistration was performed through resampling of ENVISAT ASAR data to equivalent pixel spacing to the ERS SAR data, because of the differences of the pulse repetition frequency and range sampling rate between the two sensors. Then we estimated range and azimuth offset to a sub-pixel accuracy using image intensity cross correlation. A larger window chip size than a general case was used because it was difficult to distinguish typical features. As range bin increased, the difference of Doppler centroid also increased. It resulted in lower coherence in far range than in near range. Coherences over wetland in near and far range were about 0.8 and 0.5, respectively. The coherence was improved by applying azimuth and range common band filtering, but coherence gap still existed. ERS-ENVISAT cross-interferogram usually lost information in urban area. However, high coherence over a city in this pair was shown, because of less man-made structures than other major cities. Accuracy of the DEM constructed by the ERS-ENVISAT 30-minute pair in a coastal area is to be evaluated.

KEY WORDS: Coastal DEM, Cross interferometry, Common band filtering, Coherence, Surface conditions

1. INTRODUCTION

Coastal areas characterized by extremely low slopes are the buffer zone between landmass and ocean, and are invaluable from geologic, environmental and ecological aspects. For examples, the coastal area does function such as flood control, pollution specie, fish, habitat, and aesthetics, etc.

The digital elevation models (DEMs) of coastal areas in a time series can be utilized to estimate sediment budget or monitor changes annually or seasonally. Topographic characteristics in coastal regions change more significantly than landmass, so it is difficult to obtain coherent interferometric SAR pairs over coastal areas mainly because of dynamic variation of surface conditions. Precise coastal DEMs have recently been made using Light Detection and Ranging (White, 2002), airborne radar interferometry (Greidanus, 1999; Wimmer, 2000), and waterline method (Won, 2003). The waterline method is a useful approach in the practical application of satellite remote sensing to tidal flat environments and is to stack the extracted boundaries between seawater and exposed bottom surface in satellite images acquired under different tidal conditions. The advantages of airborne remote sensing such as LIDAR or airborne InSAR have controllable observation time, high spatial and temporal resolution. However, airborne remote sensing is neither cost effective nor operational.

Spaceborne imaging radar interferometry has been widely used to measure the topography and deformation of the Earth. There are two obstacles in repeat pass SAR interferometry in coastal regions. There are variations of coastal surface conditions and remnant surface water on the exposed bottom surface. Recently, utilization of ERS-ENVISAT interferometric pairs is taken a growing interest. Since the temporal decorrelation can be reduced by the cross interferometric technique with a 30 minutes tandem ERS-ENVISAT pair, we can overcome the obstacles referred above. The frequency differences between ERS and ENVISAT SAR can be compensated by about 2 km perpendicular baseline and common band filtering.

2. DATA PROCESSING

2.1 Dataset and Study Area

After the launch of ENVISAT ASAR, a practical demonstration of cross-interferometry has drawn an attention. Especially, a very short temporal decorrelation of a half hour and small height sensitivity allow the accurate mapping of the elevation and deformation on rolling terrains (Colesanti, 2003; Gatelli, 1994). The cross-interferometry technique was applied to a coastal region in the south-eastern Louisiana using ERS-2 SAR and ENVISAT ASAR images acquired on 26 October 2004. The coasts in the south-eastern Louisiana are covered with mainly emergent herbaceous wetlands, woody wetlands, pasture, and row crops, etc. except the urban area (Figure 1.). The cross-interferometric pair has a perpendicular baseline of about 1.4 km, a 30 minutes temporal separation, and the height ambiguity of about 6 meters. The small height ambiguity resulted in a large perpendicular baseline is favourable to generate accurate DEMs for the low slope areas.

2.2 Coregistration and Common Band Filtering

An accurate coregistration was performed with a careful consideration that sampling frequencies and pulse repetition frequencies are slightly different between ERS SAR and ENVISAT ASAR, and the number should be approximately 18.9 vs. 19.2 Mhz and 1679 vs. 1652 Hz. Resampling of ENVISAT ASAR data was performed to have equivalent pixel spacing to the ERS SAR data. Since it was difficult to distinguish typical features for the coastal areas, a larger window chip size than general cases was used for the range and azimuth offset estimation to a sub-pixel accuracy using intensity cross correlation.

The common band filtering was applied to both SAR images before generating the interferogram for the compensation of spectral shift because of the 31 MHz frequency differences between ERS and ENVISAT (Gatelli, 1994.). Moreover some ERS-2 gyroscope mode mission has been operated since Jun 2001, Doppler centroid exceeds often a half of PRF. Therefore, an azimuth common band filtering was in need.

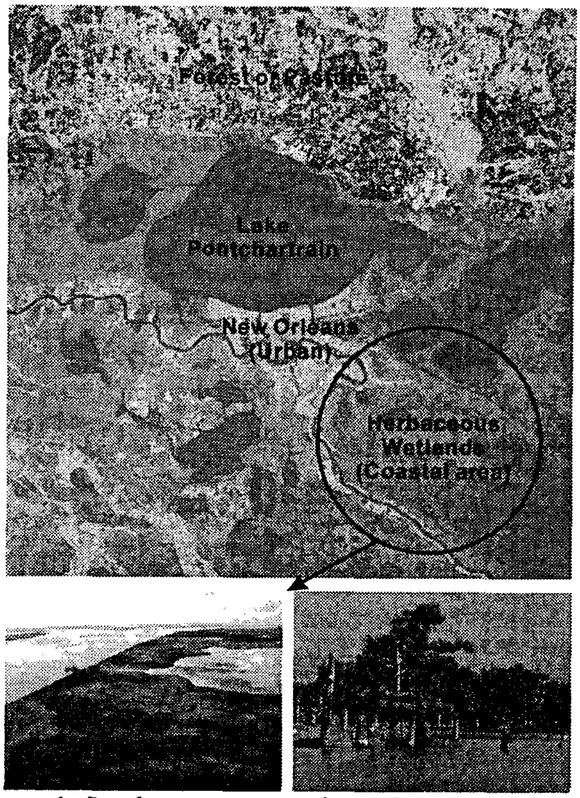

Figure 1. Landcover map over the study area.

3. THE RESULT

3.1 Interferograms

We applied the interferometric techniques with ERS pair, ENVISAT pair, and ERS-ENVISAT tandem pair over the study area. Figure 2 shows coherent phase to allow for DEM construction. But, characteristics of ERS pair and ENVISAT pair are different from that of cross-interferometric pair.

As shown in the coherence map of figure 2(a) and 2(b), the interferometric phases of ERS pair and ENVISAT pair over the coastal area are incoherent except urban and forest area. On the other hand, figure 2(c) presents good coherence over the coastal area in the cross-interferometric pair. It is caused by the temporal decorrelation resulted from the rapid variation of the surface condition covered with emergent herbaceous or woody wetlands. In general, the phase over the urban area is corrupted by random phase screen in cross-interferogram, but coherence over a city of New Orleans was about 0.5 because of less man-made structures than other major cities.

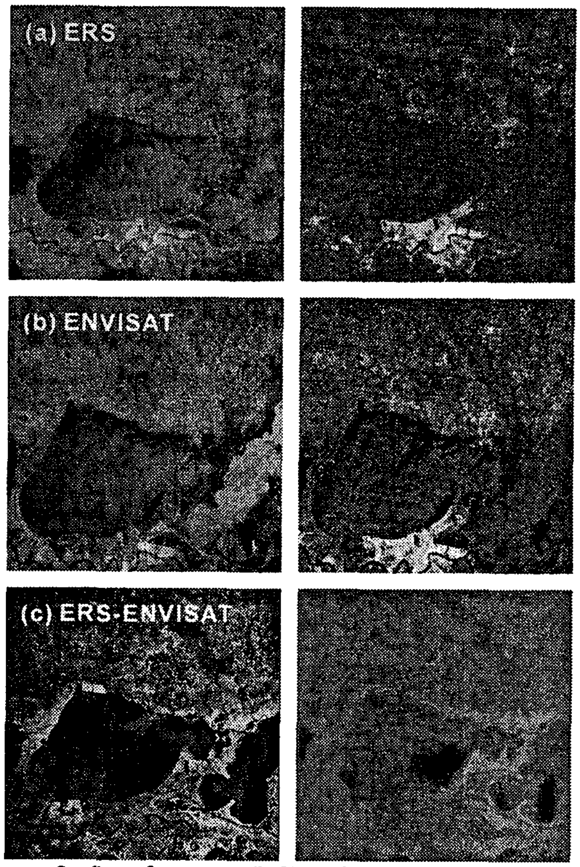

Figure 2. Interferogram (left) and coherence (right) with (a) ERS pair, (b) ENVISAT pair, and (c) ERS-ENVISAT tandem pair.

3.2 Doppler Centroid Difference and Coherence

After some ERS-2 gyroscope mode mission, no significant degradation in attitude and intensity image, and Doppler centroid stability was reported recently. For 95 % of the data, the Doppler centroid frequency is within the range of ±4500 Hz (Miranda, 2003). However, for interferometric application using ERS-2 SAR, careful attention is required in that Doppler centroid exceeds often a half of PRF.

Figure 3 shows the azimuth spectra and variation of Doppler centroid difference as range and azimuth bin increased. Relatively small Doppler centroid difference of ERS pair and ENVISAT pair was shown in Figure 3(a) and 3(b) compared with that of tandem ERS-ENVISAT pair (Figure 3(c)). In ERS-ENVISAT pair, although the 540 Hz difference in Doppler centroid was estimated, the cross-interferogram was highly coherent. As range bin increased, the difference of Doppler centroid also increased. It resulted in lower coherence in far range than in near range. Coherences over wetland in near and far range were about 0.8 and 0.5, respectively. The coherence was improved by applying azimuth and range common band filtering (Figure 4), but coherence gap still existed.

4. CONCLUSIONS

To monitor active changes in coastal areas and tidal flats, high precision DEMs are required. We attempted to construct DEMs using ERS-ENVISAT 30-minutes tandem pairs with a perpendicular baseline of 1.4 km and a height sensitivity of 6 meters over the south-eastern Louisiana and evaluated the feasibility of the spaceborne radar interferometry for the construction of DEMs in tidal flats and coastal area. The small height sensitivity is favourable to construct DEMs in low relief coastal areas

Variation of surface conditions and water remaining on the surface plays an important role for coherent phase in coastal areas. While incoherent phase was found over the coastal areas with multi-pass both ERS pair and ENVISAT pair, however the cross-interferometric pair showed coherence of about 0.8. It is enough high to construct a precise DEM. If the temporal baseline is enough short to maintain the coherent phases, we will be able to successfully construct a precise DEM for the monitoring of coastal area.

Coherences over wetland in near and far range were about 0.8 and 0.5, respectively. The gap of coherences resulted from the Doppler centroid difference. As range bin increased, the difference of Doppler centroid also increased in the applied cross-interferometric pair. The coherence was improved by applying common band filtering to both azimuth and range direction, but coherence gap still existed.

Common band filtering is essential for the qualified interferogram in cross-interferometric technique, because the Doppler centroid variability of ERS-2 SAR is very significant factor to retain coherent phase and a spectral shift cause by effect of carrier frequency difference must be compensated.

ERS-ENVISAT tandem cross-interferometry can be one of the solutions for the environment with a rapid change of the surface. Accuracy of the DEM constructed by the ERS-ENVISAT 30-minute pair in a coastal area is to be evaluated.

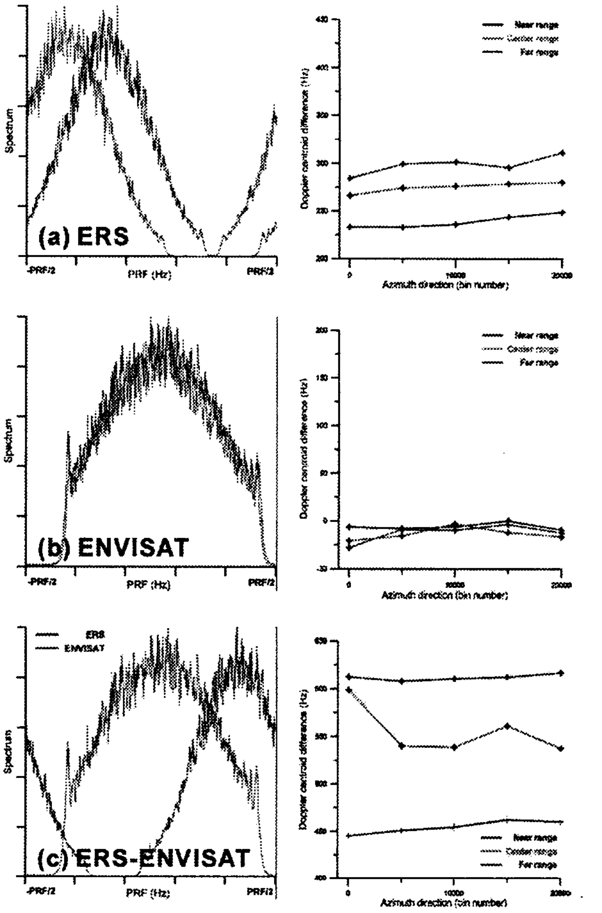

Figure 3. Azimuth spectra (left) and Doppler centroid difference (right) with (a) ERS pair, (b) ENVISAT pair, and (c) ERS-ENVISAT tandem pair.

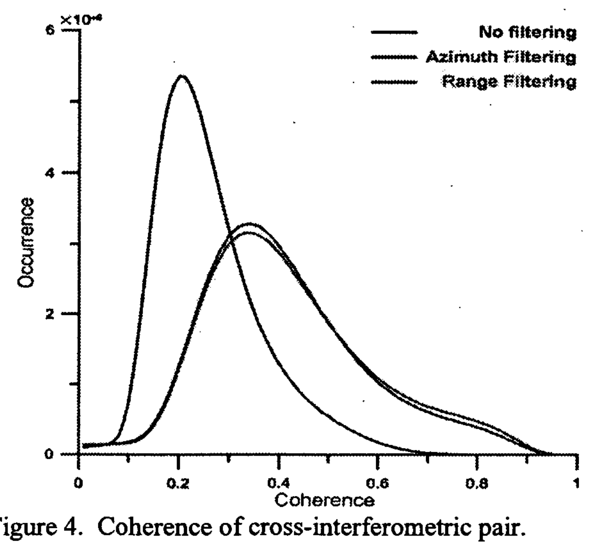

Figure 4. Coherence of cross-interferometric pair.

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