Application of PSInSAR technique for Monitoring Surface Deformation over Coastal Area of Incheon

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인천연안지역의 지표변위 관측을 위한 인공위성 SAR 자료의 활용

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Abstract : Many industrial fields were constructed on the reclaimed land which was used to be a tidal land. Because the industrial fields stand on weak basement, they are likely to be influenced by surface subsidence. Therefore, the surface subsidence monitoring is required for civil protection. In this study, a novel method to monitor land displacement, PSInSAR technique, was applied to monitor the land subsidence of Incheon Port, which happened a decade ago. Although the land was reclaimed more than 20 years ago, quite a bit of deformation was observed during six years. The maximum subsidence rate reached to 30 mm/year. JERS-1 data was exploited in this study.
Keywords : Radar interferometry, PSInSAR, Reclaimed land

요약 : 다수의 공업단지가 갯벌을 매워 조성된 간척지 위에 건설되었다. 공업단지들이 이렇듯 연약한 지반 위에 있기 때문에 지반침하에 의한 영향을 받을 가능성이 클 것으로 생각된다. 지반침하를 관측하는 일은 공공 방재를 위해서도 필요한 일이다. 본 연구에서는 새롭게 개발된 지표 변위 관측 기법인 영구산란체법(PSInSAR technique)을 이용하여 인천항 연안에서 10여 년 전 발생했던 지표변위를 관측하였다. 해당 지역은 이미 20년 전에 간척이 완료된 지역임에도 불구하고 6년 동안 상당한 변위가 관찰되었다. 지반침하 속도가 최고에 달하는 곳은 3mm/년에 이르기도 했다. 연구에는 JERS-1의 자료가 사용되었다.
주요어 : 간섭레이더, 영구산란체법, 간척지

1. Introduction

A lot of portion of the tidal flat along west coast has been reclaimed and used for ports, industrial and residential area. Especially Incheon port and its hinterland is mostly reclaimed land. Such area has a potential of land subsidence. Permanent scatterer interferometric SAR (PSInSAR) technique was applied to observe the surface displacement over that area.

PSInSAR technique is a novel method to monitor surface displacement based on radar interferometry. PSInSAR technique was widely applied to monitor the landslide of urban area (Ferretti *et al.*, 2001), seismic fault motion (Colesanti *et al.*, 2003), groundwater discharge (Ferretti *et al.*, 2000). PSInSAR technique can use all SAR images acquired over that area. For reliable result, more than 20 SAR images are required. Because space borne SAR imaging has been continued since early 1990's, we can exploit enough SAR images which are usable in PSInSAR technique. PSInSAR technique deals with only stable scatterers which are spatially sparsely distributed. The deformation rate and DEM error is calculated for each PS and we can get spatial deformation field by interpolation.

In most cases PSInSAR technique is applied to urban area. In Korea, Kim (2003) had applied PSInSAR technique to monitor the land subsidence of Busan area. The urban structures do not change their shape with time. In addition, many urban structures resemble to corner reflector. This is why PSInSAR technique is popular in monitoring the subsidence of urban area. In this study, we applied PSInSAR technique to monitor the land subsidence over Coastal Harbor area of Incheon Port, which was reclaimed in early 70's. We assumed linear deformation model and SRTM DEM was used as in external DEM.

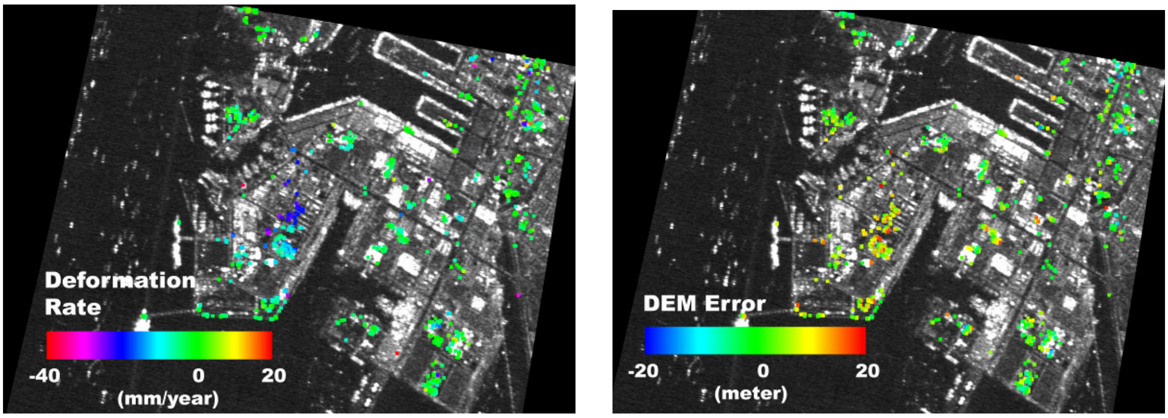
2. PSInSAR Method and Used Data

One can make a series of differential interferograms resampled to common master coordinate. Then for some selected PS's, one can make a matrix formula. (Ferretti *et al.*, 2001)

$$\mathbf{\Delta\Phi} = \mathbf{\Phi}_{\text{phase ramp}} + \vec{B}\Delta\vec{q}^{T} + \vec{T}\vec{v}^{T} + \mathbf{APS} + \mathbf{E}_{\text{dec}} \quad (1)$$

The phases of PS's in a same differential interferograms are written in a row and the phases of the same PS's each in interferograms are written in a column.

$\mathbf{\Phi}_{\text{phase ramp}}$ term represents additional phase terms caused by orbit inaccuracy. If the processing area is small, it shows linear change in space. The $\Delta\vec{q}$ term is the DEM error of the position of PS's and $\vec{v}$ is the line of sight direction movement rate of each PS's. $\vec{B}$ and $\vec{T}$ are terms to convert the effect of DEM error or velocity to phase dimension. $\mathbf{APS}$ and $\mathbf{E}_{\text{dec}}$ are the residual terms. $\mathbf{APS}$ term has spatial correlation but $\mathbf{E}_{\text{dec}}$ term is fully random. There is no explicit method to find the



(a) (b)

Fig 1. The position of PS’s and their (a) deformation rate and (b) DEM error

unknowns because the phase values are wrapped. Instead, iterative scheme is used to solve equation (1) and to find the unknown terms, such as $\vec{v}$, $\Delta\vec{q}$ and $\mathbf{APS}$. We can map the deformation field using elements of $\vec{v}$ term and their positions.

JERS-1 SAR data of path 238 / row 89 was used in this study. There are 27 images in the archive. The time span of the acquisition is about 6 years between Sep. 1992 and Oct. 1998. Considering the normal baseline and acquisition time, the 11^{th} image was selected as a master scene. Twenty six interferograms were made but only 23 interferograms were used because the 3 interferograms were severely suffered from low coherence owing to long baseline. SRTM DEM was used as external DEM.

3. Results

Total 1370 PS’s were detected in study area and the PS density is 190points/km^2. We imposed coherence threshold 0.8. The position of PS with their deformation rate and DEM error are shown in Fig. 1a and Fig. 1b. Maximum subsidence is observed over the center of the peninsular. Maximum deformation rate reached to 30 mm/year. The eastern part of the maximum subsidence is oil tank and apartment complex where many PS are detected and gradual change of deformation rate is observable. On the other hand, the western part of the maximum subsidence is open field for piling freights, PS’s are rarely observed. The area of significant subsidence is restricted to the center of peninsular but the hinterland of South Harbor also shows moderate to low deformation rate. The deformation was damped toward landward direction. The PS’s on Little Moon’s Tail Island and coal pier show no deformation. The former is a natural island and no deformation was observed. The latter is built relatively recently. The construction might have done more firmly. The deformation records of representative PS’s are given in Fig. 2.

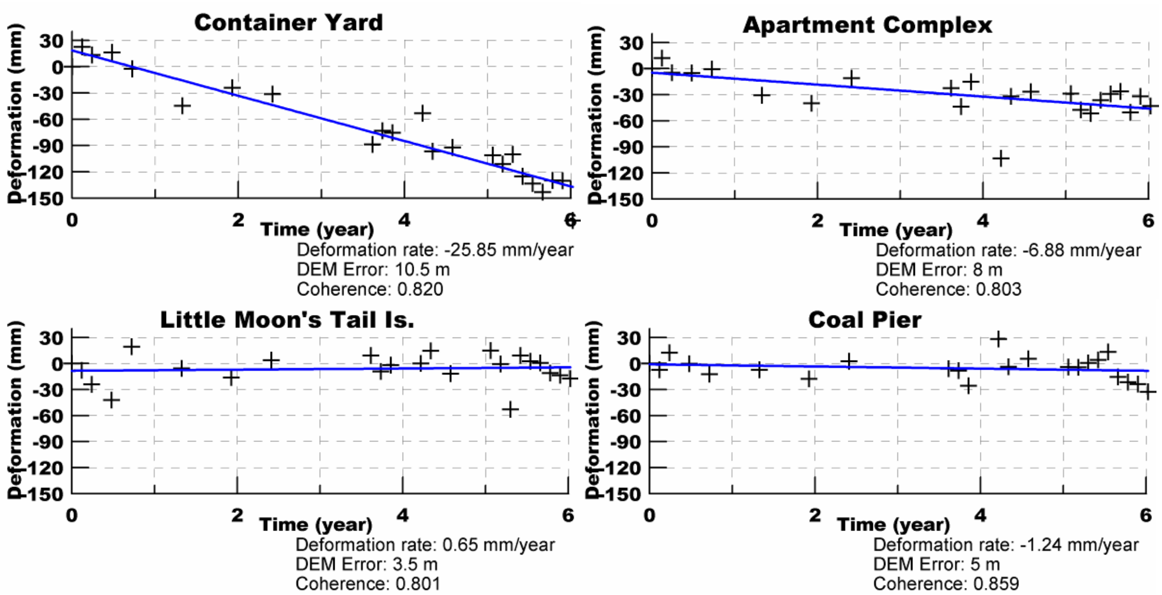


Fig. 2. The deformation records of selected points.

4. Conclusion

The land subsidence over reclaimed land was observed and its deformation rate was calculated using PSInSAR technique. The study area was a tidal flat and reclaimed about 30 years ago. The SAR images were acquired 20 years after the completion of reclamation. It was unexpected result because reclaimed land settles on in some years. Reclamation of adjacent region might trigger additional subsidence but the cause is not certain.

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