InSAR PS Adaptive Detection and its Application in Beijing Area

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Abstract—**PS InSAR (Permanent Scatters for Interferometry Synthetic Aperture Radar) was proposed at first by A. Ferretti & al. in 2001 [1]. In this technique, stable natural reflectors or permanent scatters are detected and studied over long temporal series of interferometric SAR images, in order to detect topographic changes. Although this technique is relatively new, results have already demonstrated remarkable potentials; it has proved to be a powerful tool for exploring the slow movement of the Earth surface. We present in this paper the results obtained using PS INSAR technique to analyze the subsidence of the area of Beijing city, China. An adaptive PS detection method is introduced, aiming at improving the reliability of the selected PS points using a small data set. Finally, the limitation of this linear approach is analyzed and the future work is designed.**

*Keywords-**Permanent Scatter detection; SAR interferometry, Digital Elevation Model; ERS; Line of Sight velocity; Subsidence; Urban areas applications***

I. INTRODUCTION

Permanent Scatters SAR Interferometry (PSInSAR) has gradually become a well-known technique in the field of Radar Remote Sensing. Since it was introduced in 2001[1], it has proved to be a powerful tool to explore the subsidence of topography. It has been in these recent years an active topic for both research and development applications.

Terrain subsidence is a geophysical phenomenon, which appears more and more frequently around urban areas. The subsidence is most of the time a result of the activities that surround the cities: water pumping, underground constructions, etc. The results of PS processing in measuring the subsidence have demonstrated an extremely high accuracy, i.e up to few millimeters [1][2].

The main goal of this paper is to apply PS technique in the area of Beijing, China, to measure the subsidence rate of the city in the recent years. The contribution of this paper is to propose a new approach for PS point selection adaptive to the amplitude values of the used SAR images. In section II the PS technique is described and some processing details are given. In section III our method for adaptive PS selection is described. A new concept named "Amplitude Filter" is introduced, adding more constraints on PS detection. The processing results of our experimental area are presented in section IV. The final section concludes and draws the main lines of future work.

II. RECALL ON PS TECHNIQUE

In InSAR theory, it is well known that the interferometric phase can be expressed as:

$$\phi(x,y) = \phi_r(x,y) + \phi_\mu(x,y) + \phi_a(x,y) + \phi_\sigma(x,y) \qquad (1)$$

Where: $\phi_r(x,y)$ is decided by the acquisition geometry; $\phi_\mu(x,y)$ is caused by the terrain motion; $\phi_a(x,y)$ is the APS (Atmospheric Phase Screen) and $\phi_\sigma(x,y)$ is random phase noise.

The flat phase decided by the slant range position can be removed in the step of flattening when generating interferograms. The topographic term, however, can be derived from the elevation, which is estimated from a given DEM file. The subtraction of the topographic phase is also called *differential interferograms generation*, or *zero baseline steering* [1]. The resulting formulation is then:

$$\Delta\phi(x,y) = \phi_a(x,y) + \Delta\phi_q(x,y) + \phi_\mu(x,y) + \phi_\sigma(x,y) \qquad (2)$$

The expression of each term of (2) has been detailed in [1]. Readers can find in [7] an efficient iterative algorithm to solve this matrix system.

In PS-InSAR technique, a large set of SAR images (generally more than 20) are used. Different from DInSAR (Differential SAR Interferometry), this technique only works on a reduced set of pixels that coherent over long time. These pixels of the sub-set are called PSs. In practice, topographic phase subtraction in (2) is applied only at PS points.

The selection of PS points is extremely important since the quality of the PSs can affect the final results of the LOS velocity calculation, the estimation of APS, etc. Up to now two approaches can be explored for the purpose of PSs selection.

One is the coherence approach, and the other is the amplitude approach. In the next section we will introduce a new algorithm, which is more strict and suitable for smaller set of SAR images.

III. PS Detection: An Adaptive Method

The problem is how to detect stable point scatters from a set of images. Related works can be found in [2][9]. Two different methods have been proposed: the coherence approach and the amplitude approach. In the coherence approach, pixels that exhibit high coherence values in all interferograms are selected as PS candidates. However, when estimating coherence, a spatial correlation window must be used, leading to a spatial average effect. This is indeed an undesirable effect since we expect PS points to locate targets on the ground having a size close to or smaller than the pixel resolution.

Here we use the amplitude approach. A.Ferretti has proposed a measure of phase stability [1]

$$D_A = \frac{\sigma_A}{m_A} \quad (5)$$

In (1) m_A and σ_A are the mean and standard deviation of the amplitude values of a given pixel over all the set of images. A.Ferretti & al. has proved that when many SAR images are available, the amplitude dispersion can be safely considered as the phase dispersion.

From experimentation, we noticed that some pixels with low amplitude values, in lakes areas for example, also exhibit the stable amplitude value characteristic. That means, at these pixels, although the mean amplitude value is low, the standard deviations are lower, resulting in a low amplitude dispersion value, thus these pixels would be selected as PSs. But indeed these pixels, since they also are of low coherence, should not be retained.

For this reason, we developed the concept of “Amplitude Filter”, adding an adaptive threshold to the processing of PSs detection. On one hand we use the amplitude dispersion as one estimator. On the other hand, we consider the amplitude values of the pixels. Only the pixels with the amplitude values larger than a certain threshold have the chance to be selected as PSs.

The problem is how to define an amplitude threshold. It is not suitable to define an absolute value since the amplitude value is affected by many factors –backscattering coefficient, noise, etc. However, we can define a relative value, i.e. relative to the spacing average of the whole area of interest. Let’s at first ignore the threshold for amplitude dispersion and consider the following strategy: For each pixel, calculate the average amplitude over all the available images. Thus we get an “average amplitude image”. Create a histogram of this “image” in an inversed sequence, with large values ahead and small values behind. Then we can declare that only a certain percentage of pixels ahead have the chance to be selected as PSs. The choice of the percentage of pixels selection determines the threshold for amplitude. The percentage value is obtained empirically. From our experimentation, 5 percent provides satisfying results.

In summary, an “Amplitude Filter” of 0.5 means only 0.5 percent of pixels with highest amplitude values has the possibility to be selected as PSs. Other pixels are “filtered out”. Notice the amplitude value is the average over all the available images.

IV. Experimental Results

Our application site is Beijing area, China, centered at longitude of 116.35 E and latitude of 39.9 N, for which we wish to estimate the subsidence rate. The image set includes 13 ERS1,2 , from 1995 to 1999. Table.1 gives the data list.

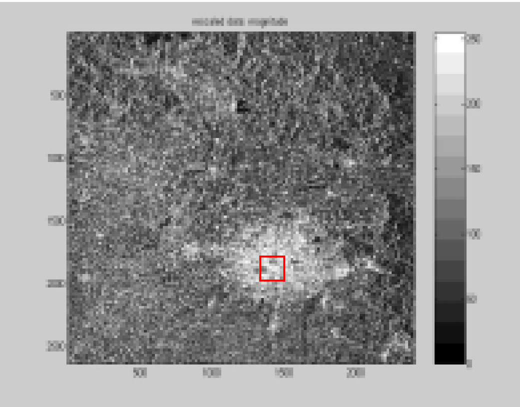
TABLE I. List of ERS1,2 SAR Images

SAT(ERS1/2)	Orbit	Date	Normal Baseline (m)	Temporal Baseline (day)	Height Ambiguity (m)
ERS2	17607	19980902	0	0	--------
ERS2	03579	19951227	198.6	-980	44.3917
ERS2	06585	19960724	90.8	-770	97.0946
ERS2	07086	19960828	-882.4	-735	-9.9911
ERS2	12096	19970813	-80.9	-385	-108.9764
ERS2	12597	19970917	-786.5	-350	-11.2094
ERS1	32771	19971021	-499.7	-316	-17.6430
ERS2	16104	19980520	93.6	-105	94.19
ERS2	16605	19980624	153.7	-70	57.3597
ERS2	17106	19980729	-245.1	-35	-35.9698
ERS2	18108	19981007	379.8	35	23.2127
ERS2	21615	19990609	52.5	280	167.9274
ERS2	22617	19990818	1044.3	350	8.4422

For the restriction of APS model, we select a small area of $5x20km^2$ (illustrated by the small square in the amplitude image of figure 1). Using Doris software [5][6], 12 interferograms are created and the flat phase is removed. In the step of PS detection, experiment and comparison are done without “Amplitude Filter”, and with an “Amplitude Filter” of 1 and 5. Finally we use the “Amplitude Filter” of 5 and 467 PS points are selected. Figure 2 shows the increase of detected PSs with the change of “Amplitude Filter”. PSs distributions for selected without “Amplitude Filter” and with “Amplitude Filter” of 1 and 5 are illustrated in Figure 3.

By using SRTM3 data, the topographic phase is estimated and removed. With our modified algorithm and after a few iterations the LOS velocity is estimated. Figure 4 shows the LOS velocity of PS points overlapped on one of the SAR amplitude image. The dark rings outside show the positions of PSs, and the gray level inside the ring expresses the value of LOS velocity, ranging from about –8 mm/year to 6 mm/year.

Another site is selected a little North to the former, with a central longitude of 116.35 and latitude of 39.97. We use the same images set; the area of interest is 1200x300 pixels, or about 5x6km^2. In a similar way, the interferograms are created and the PSs are detected. Figure 5 shows the selected PSs with the change of the "Amplitude Filter".



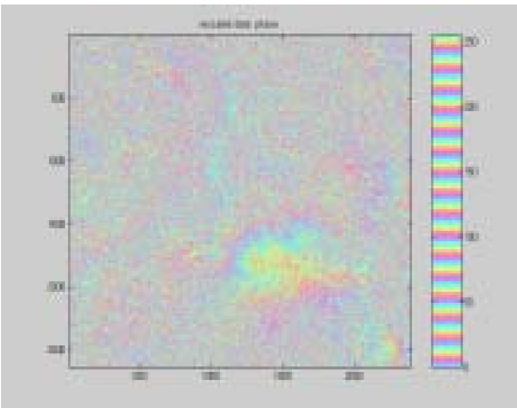


Figure 1. Up: Amplitude image on the area covering Beijing Down: Associated interferogram from SAR-ERS images acquired at 98/09/02 and 99/06/09, after flattening.Normal Baseline: 52.5m, Height Ambiguity:167.2 m

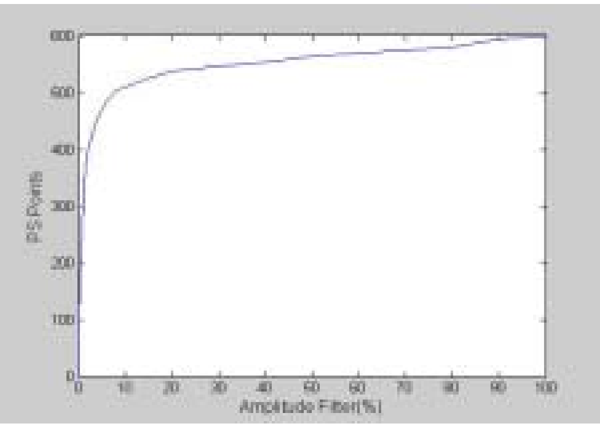
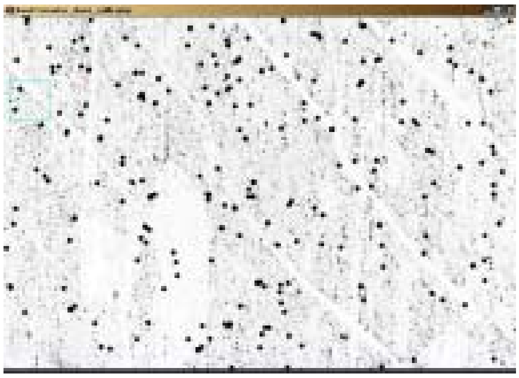
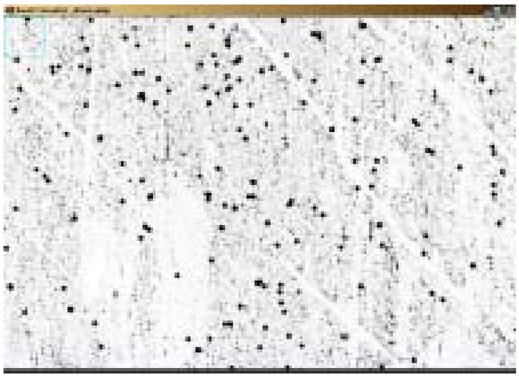


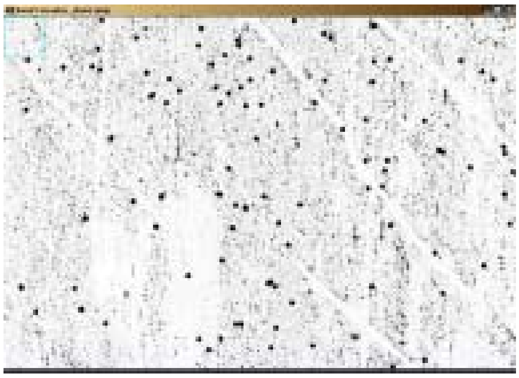
Figure 2. The number of PS points with the change of Amplitude Filter



3.a. No Amplitude Filter (600 PSs)



3.b. Amplitude Filter 5 (467 PSs)



3.c. Amplitude Filter 1 (305 PSs)

Figure 3. Comparisons of PS distribution for different Amplitude Filter threshold values on Site 1

V. Conclusions and Further Work

PS technique has proved to be a unique tool for the analysis of subsidence. We have proposed a new scheme for PS point selection, based on an adaptive threshold approach, in order to solve the problem of site-dependant threshold evaluation.

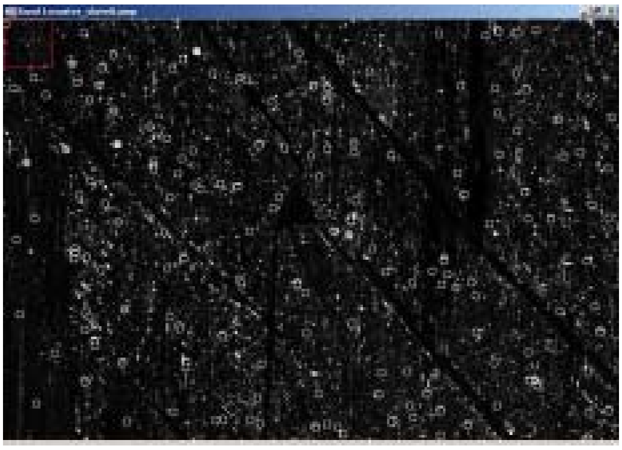
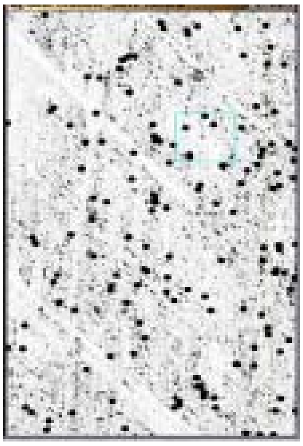
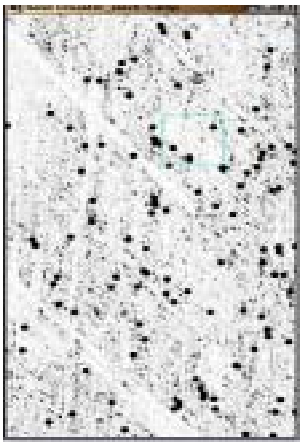


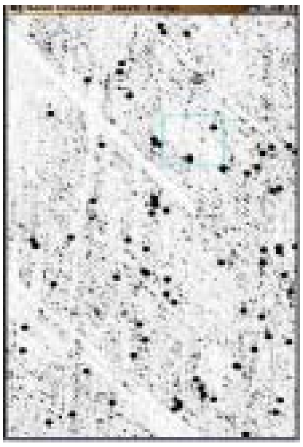
Figure 4. LOS velocity computed at each PS point superimposed on one SAR amplitude image



5.a: No Amplitude Filter(442 PSs)



5.b Amplitude Filter 5(338 PSs)



5.c Amplitude Filter 1(237 PSs)

Figure 5. PS distribution for different Amplitude Filter threshold values on Site 2

However, our test case and experiments over Beijing city show certain limitations. In particular, it has been done with a limited number of images: this is in contradiction with most literature which advice to use a set of more than 20 images; it therefore forgives us from any direct interpretation of the computed subsidence rate values. Other limitation concerns the model itself: the terrain motion may not be linear, although it is a basic assumption of (4). We may need to work out on more sophisticated model..

In order to increase the data set, we will make use of ENVISAT images. We are presently working on cross-interferometry and PS points from cross-interferograms.

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