AN ANALYSIS OF SURFACE SUBSIDENCE IN CHIBA USING PSInSAR TECHNIQUE

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ABSTRACT:

Currently, surface subsidence has become an important problem what we are facing. Because of complex topography, uneven distribution of rainfall, and the fast development of urbanization, many cities of the world have undergone surface subsidence disaster, such as Chiba, Paris, Tokyo, Beijing. The surface subsidence has occurred in Chiba since the early twenty-first century. The surface subsidence seriously threatens the safety of human life and property. In order to monitor surface subsidence, people have done a lot of research, and time-series InSAR technique with its better coverage, lower cost and high measurement accuracy advantages shows great potentiality for monitoring surface subsidence. Time-series InSAR technique can be applied for analysis of subtle surface subsidence which occurred consistently for a long term period. This paper uses time-series InSAR technique, Permanent Scatterers Interferometric SAR (PSInSAR), to monitor surface subsidence of Chiba. The used dataset consists of thirty-four Envisat ASAR images from September 2006 to August 2010. For the experimental results, this paper uses GPS data to verify the reliability of the results, and the results can provide information for local government to prevent the occurrence of surface subsidence.

1 Introduction

Currently, surface subsidence has become an important problem what we are facing. Because of the frequent occurrence of natural disasters, such as earthquakes, volcanoes, and the rapid development of urban construction, the formation of surface subsidence phenomenon increases , and the urban ground surface deformation is more prominent , the surface subsidence seriously threat to the safety of human life and property.

As an earth observation, synthetic aperture radar interferometry (InSAR) has opened up a new research direction for monitoring surface subsidence [1]. And InSAR has some advantages, such as better coverage and lower cost, and it can work for al-weather condition to monitor surface subsidence. It has become a hot international research. With the in-depth study of InSAR technique, differential interferometry technique (DInSAR) was born [2]. DInSAR technique shows amazing advantage in monitoring earthquakes, volcanoes, landslides and other surface deformation, but in monitoring the slow surface deformation, such as the urban surface subsidence, it is impacted by time decorrelation, space decorrelation and atmospheric delay. To solve this problem, researchers proposed time series InSAR technique [3], such as the Permanent Scatterers Interferometric SAR technique (PSInSAR) and Small Baseline Subset technique (SBAS) [4]. And PSInSAR technique achieved better results in urban surface subsidence monitoring applications.

In this paper, we adopt PSInSAR technique to carry out surface subsidence monitoring experiment, then analysis the results of the experiment, and verify the reliability of the results.

2 Principle and data processing of PSInSAR technique

2.1 Principle of PSInSAR technique

PSInSAR technique is the innovation and development of DInSAR technique. PSInSAR technique is a time series technique, and it adds the amount of time on the basis of conventional DInSAR technique [5]. PSInSAR technique uses many SAR images, at least 20 scenes, covering the same area.

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Because of the more images, we will acquire the more reliable results. One of the images is selected as the public master image, others are slave images to match the public master image space and carry out interference treatment. And then a selection model is adopted to elect a sufficient number of PS points, which have highly steady radar scattered characteristics. By making analysis about phase of points, the PS point deformation results are obtained. Finally an interpolation method is used to get deformation results throughout the study area. Currently, PSInSAR technique has been widely applied to urban surface subsidence monitoring [6], [7].

2.2 The study area and experimental data

Chibal is located in Japan's Kanto region, and it contains the Kanto Plain and Boso Peninsula. It is a long and narrow peninsula that is about 96 km east-west and 129 km north-south. Figure 1 shows the position of the study area, where is in the red box.

Chibal is a coastal city, which is near the Pacific Ocean. Since the unconsolidated soil is the main basement of Chibal area, there are some possibilities of potential subsidence risk. Along with the rapid development of the city and the increase in population, the city need more and more water resource. Over-exploitation of water resource caused the surface subsidence of Chibal, and the surface subsidence has occurred in Chiba since the early twenty-first century.

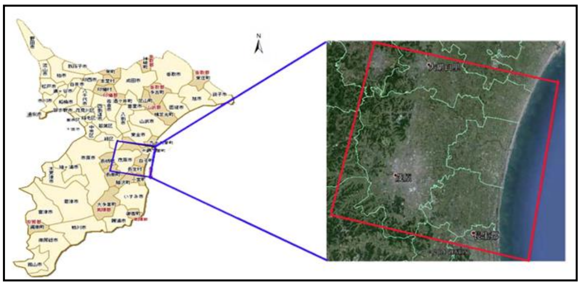

Figure 1 The study area

Envisat is one of sun-synchronous polar orbit earth monitoring satellites, which is launched in 2002. It can provide SAR image data for the oceans, atmosphere, land and other applications and carries a C-band ASAR sensor that it's revisit cycle is 35 days. The used dataset consists of thirty-four scenes Envisat ASAR images from September 2006 to August 2010. Table 1 shows the SAR data information.

Table 1 The parameters of Envisat ASAR

NO.	Sensor	Date	Orbit	Mode
1	ASAR	20060904	23589	IMS
2	ASAR	20061009	24090	IMS
3	ASAR	20061113	24591	IMS
4	ASAR	20061218	25092	IMS
5	ASAR	20070122	25593	IMS
6	ASAR	20070507	27096	IMS
7	ASAR	20070611	27597	IMS
8	ASAR	20070716	28098	IMS
9	ASAR	20070820	28599	IMS
10	ASAR	20070924	29100	IMS
11	ASAR	20071029	29601	IMS
12	ASAR	20071203	30102	IMS
13	ASAR	20080107	30603	IMS
14	ASAR	20080211	31104	IMS
15	ASAR	20080317	31605	IMS
16	ASAR	20080421	32106	IMS
17	ASAR	20080526	32607	IMS
18	ASAR	20080630	33108	IMS
19	ASAR	20080804	33609	IMS
20	ASAR	20080908	34110	IMS
21	ASAR	20081013	34611	IMS
22	ASAR	20081117	35112	IMS
23	ASAR	20081222	35613	IMS
24	ASAR	20090302	36615	IMS
25	ASAR	20090511	37617	IMS
26	ASAR	20090720	38619	IMS
27	ASAR	20090928	39621	IMS
28	ASAR	20091207	40623	IMS
29	ASAR	20100215	41625	IMS
30	ASAR	20100322	42126	IMS
31	ASAR	20100426	42627	IMS
32	ASAR	20100531	43128	IMS
33	ASAR	20100705	43629	IMS
34	ASAR	20100809	44130	IMS

2.3 Data processing

Data processing mainly includes the public master image selecting, interferogram generation, PS point recognition and subsequent processing.

The public master image selection is affected by time baseline, normal baseline and Doppler centroid frequency difference. The paper uses the minimum sum of the absolute value of three baselines model to select the public master image (showing in table 2), then selects 4 August 4, 2008 image as the public master image, and generates 33 interferograms.

This paper uses coherence coefficient threshold model to elect a sufficient number of points and obtains the distribution of PS points, as shown figure 3 (green dots for the PS points).The number of identified target PS points is 12948, and the PS points mainly concentrates in urban and residential areas, such as buildings, roads, rock. But farmland and vegetation coverage area exist a small amount of PS points.

Table 2 shows situation about the public master image selecting.

NO.	Data	$\sum\|T\|$ /day	$\sum\|B_{\perp}\|$ /m	$\sum\|F_{DC}\|$ /Hz	The absolute value of three baselines
1	20060904	23450	12847.092	290.315	36587.407
2	20061009	22330	21684.222	218.732	44232.954
3	20061113	21280	29796.034	232.566	51308.6
4	20061218	20300	8160.812	182.035	28642.847
5	20070122	19390	18466.404	270.257	38126.661
6	20070507	16870	9259.358	239.782	26369.14
7	20070611	16100	10255.228	974.298	27329.526
8	20070716	15400	8486.107	188.159	24074.266
9	20070820	14770	8339.058	198.444	23307.502
10	20070924	14210	11537.317	671.119	26418.436
11	20071029	13720	8741.703	367.752	22829.455
12	20071203	13300	10531.931	188.311	24020.242
13	20080107	12950	17267.077	212.712	30429.789
14	20080211	12670	10479.819	181.379	23331.198
15	20080317	12460	10641.933	510.049	23611.982
16	20080421	12320	10498.67	180.178	22998.848
17	20080526	12250	9131.518	269.083	21650.601
18	20080630	12250	8205.802	340.721	20796.523
19	20080804	12320	8157.322	181.279	20658.601
20	20080908	12460	9758.097	216.409	22434.506
21	20081013	12670	9344.207	196.437	22210.644
22	20081117	12950	9429.701	267.45	22647.151
23	20081222	13300	13522.783	185.638	27008.421
24	20090302	14140	9193.473	184.055	23517.528
25	20090511	15120	8790.098	207.515	24117.613
26	20090720	16240	8181.883	180.185	24602.068
27	20090928	17500	18411.47	205.54	36117.01
28	20091207	18900	9248.616	183.663	28332.279
29	20100215	20440	14416.858	185.68	35042.538
30	20100322	21280	8357.415	372.607	30010.022
31	20100426	22190	9582.427	328.453	32100.88
32	20100531	23170	8447.811	228.34	31846.151
33	20100705	24220	8476.02	329.742	33025.762
34	20100809	25340	13248.227	269.717	38857.944

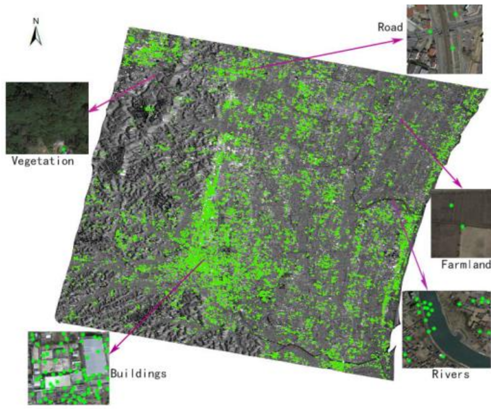

Figure 3 The distribution of Envisat ASAR’s PS

After obtaining PS points deformation results, the paper utilizes Kriging to interpolate, and finally gets deformation results throughout the study area. The subsidence rate and distribution of Envisat ASAR’s PS and the subsidence rate of Envisat ASAR are shown in figure 4 and figure 5, and right of the figure is a deformation rate allocation table.

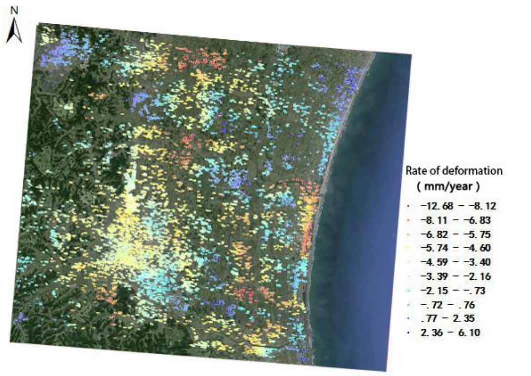

Figure 4 The subsidence rate and distribution of Envisat ASAR’s PS

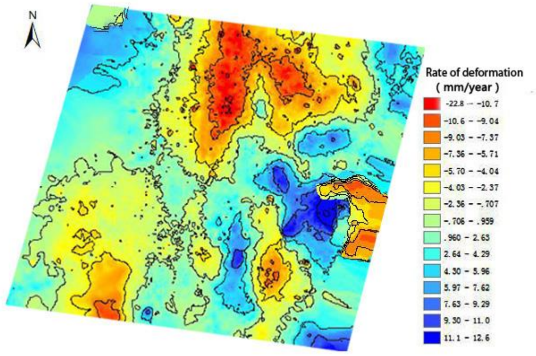

Figure 5 The subsidence rate of Envisat ASAR

3 Results and discussion

To observe temporal variations of Chibal, 33 interferograms were generated and the subsidence rate of the study area was obtained. Figure 5 displays the satellite LOS surface deformation rate generated using PSInSAR technique, where the red represents the settlement area and the blue represents the raised area. There are two forms of deformation: subsidence and uplift, and the maximum subsidence rate reaches 12.68mm/year. First, it is clear that there are two primary sedimentation funnel, which is located in the northern part of the study area. Groundwater extraction and human engineering activities are the main causes of this phenomenon. Because building activities increases in the central and southwestern of the study area, it results in the emergence of a small funnel in the area. However, uplift phenomenon appears in the northwest and southeast of the study area. It mainly dues to temporal decoherence caused by vegetation cover in the northwest and atmospheric delay caused by atmospheric humidity in the southeast coastal areas.

In order to verify the reliability of the experimental results, this paper uses settlement information of GPS points to compare with the experimental results. Because GPS data is original data, GPS data needs to be related to treatment to obtain GPS deformation rate corresponding to the SAR image time series. Then, it needs to find a PS point near the GPS point, compare GPS deformation rate with PS deformation rate and obtain rate line chart (Figure 6). It can be found from figure 6 that the PS point has a more consistent trend settlement with the GPS point, and the surface deformation obtained by PSInSAR technique is reliable.

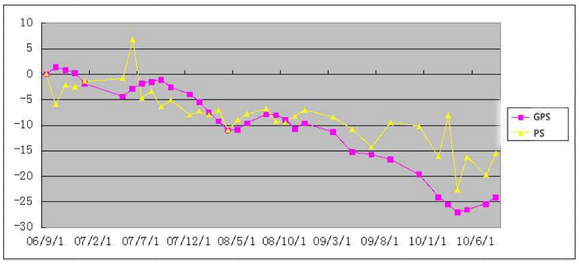

Figure 6 The subsidence rate of GPS and PS

4 Conclusions

PSInSAR technique allows measuring the average deformation trend of the city area. We explored the temporal variations of surface at the Chibal city. To make PSInSAR monitoring surface subsidence experiment, this paper uses the minimum sum of the absolute value of three baselines model to select the public master image, and generates the interferograms; then uses coherence coefficient threshold model to elect a sufficient number of points, makes the analysis about phase of points, obtains PS points deformation results; Finally makes interpolation to get deformation results throughout the experimental area. By analyzing the results, it finds that there are three serious subsiding districs in experimental area, which are located in eastern, northern and southwestern of study area, and the maximum subsidence rate reaches 12.68mm/year. Finally, this paper uses GPS data to verify the reliability of the results.

Acknowledgements

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References

Paul A, Rosen, 2000. “Synthetic Aperture Radar Interferometry”, Proceeding of the IEEE, 88, pp. 333-382.

Vijay Kumar, G. Venkataraman, Y. S. Rao, 2008. “Spaceborne InSAR technique for study of Himalayan Glaciers Using Envisat ASAR and ERS data”, IEEE International, Vol. 4, pp. 1085-1088.

Qingli Lou, Daniele Perissin, Yuanzhi Zhang, Youliang Jia, 2014. “L-and X-Band Multi-Temporal InSAR Analysis of Tianjin Subsidence”, Remote Sensing, 6, pp. 7933-7951.

Feifei Qu, Qin Zhang, Zhong lu,etc, 2014. “Land subsidence and ground fissures in Xi’an, China 2005-2012 revealed by multi-band InSAR time-series analysis”, Romote Sensing of Environment, 155, pp. 366-376.

D. Perissin, A. Ferretti, 2007. “Urban target recognition by means of repeated spaceborne SAR images”, IEEE Transactions on Geoscience and Remote Sensing, Vol. 45, pp. 4043 – 4058.

Crosetto M, Monserrat O, Iglesias R, Crippa B, 2010. “Persistent scatterer interferometry: Potential, limits and initial C-and X-band comparison”, Photogramm. Eng. Remote Sensing. Vol. 76, pp. 1061–1069.

Liu G.X, Jia H.G, Zhang R, Zhang H.X,Jia H.L, 2011. “Exploration of subsidence estimation by persistent scatterer InSAR on time series of high resolution TerraSAR-X images”, IEEE J. Sel. Top. Appl. Earth Obs. Remote Sensing. Vol. 4, pp. 159–170.