INTERFEROMETRIC DETERMINATION OF SUBSIDENCES IN PRAGUE CITY (preliminary results)

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Abstract

Radar interferometry (InSAR) method uses radar images for deformation monitoring of a large area. Four ENVISAT stacks of the ASAR images acquired from 2003 till 2009 provided by ESA were processed. The processing of the whole images would be very time and memory consuming, that's why only cuts covering the area of interest were created. These cuts were coregistered to a selected master in order for all possible interferogram combinations to be created.

The examined area of interest is the built-up area of Prague city. Some subsidences occurred there in the past, mainly because of the human activity. Since several tunnels were built after 2000 and others are still under construction, there is an assumption of the deformation within examined area.

The permanent/persistent scatterers (PS) method was used for deformation detection. The processing was performed by IPTA (Interferometric Point Target Analysis) package, which is a part of the GAMMA software. Only appropriate point targets were used for further processing, while the rest of points are omitted. Almost all available images can be used compared to the conventional interferometry method in which the critical baseline requirement must be fulfilled otherwise the interferograms are totally decorrelated.

The aim of the project is the determination of the unstable areas caused either by the natural conditions or by the human activity (e.g. tunnels construction).

Keywords: radar interferometry (InSAR); subsidence; permanent scatterers (PS)

INTRODUCTION

Area description

The area of interest covers the area of Prague city. The motivation for examining this area was the fact that several landslides occurred there in the past [2]. There is an assumption that some subsidences are possible in present since several tunnels were built after 2000 and others are still under construction. Even small movement within such highly built-up area can cause large damage of buildings and constructions. IPTA method is supposed to work well here thanks to occurrence of the sufficient amount of the stable points suitable for processing (e.g. buildings, bridges, crossroads).

Data description

The data of four ENVISAT stacks of ASAR images were processed. The images acquired between 2003 and 2009 were provided by ESA – track 43 (12 scenes acquired, ascending pass), track 122 (10 scenes acquired, descending pass), track 272 (13 scenes acquired, ascending pass) and track 351 (11 scenes acquired, descending pass). The images of tracks acquired during ascending passes (from south to north) are vertically flipped and the images of tracks acquired during descending passes (from north to south) are horizontally flipped.

Only the area of interest was cut from each image because the processing of the whole scene (approx. 100 x 100 km) would be very time- and memory- consuming. The cuts (aprox. 20 x 25 km) were coregistrated to the master and radiometrically calibrated. After these steps the cuts were prepared for the processing. Unfortunately not all the images within each track were possible to coregister due to the long perpendicular baseline ($B_{\perp}$), see table 1 which summarizes the used images. IPTA method works well for the high number of the images and the insufficient number of images brought complications to the processing. But no more scenes were available for the examining area due to the conflicts with other projects.

Table 1. Data used - the perpendicular baselines were calculated with regard to the master scene (in bold typeface)

	Track 43			Track 122	
Orbit	**Date**	**$B_\perp$ [m]**	**Orbit**	**Date**	**$B_\perp$ [m]**
08113	2003-09-18	-807	09695	2004-01-07	924
10618	2004-03-11	-980	12701	2004-08-04	615
11620	2004-05-20	-1284	15206	2005-01-26	264
13624	2004-10-07	-1781	22220	2006-05-31	-205
14626	**2004-12-16**	**0**	22721	2006-07-05	1126
18133	2005-08-18	-352	**24224**	**2006-10-18**	**0**
22642	2006-06-29	-1459	25226	2006-12-27	1019
25648	2007-01-25	-1306	27230	2007-05-16	237
			35747	2008-12-31	544
			37250	2009-04-15	181
	Track 272			**Track 315**	
Orbit	**Date**	**$B_\perp$ [m]**	**Orbit**	**Date**	**$B_\perp$ [m]**
6839	2003-06-21	-8	12429	2004-07-16	627
9344	2003-12-13	1193	14433	2004-12-03	867
12350	2004-07-10	783	15435	2005-02-11	296
13853	2004-10-23	-285	22449	2006-06-16	607
15356	2005-02-05	628	**24453**	**2006-11-03**	**0**
17861	2005-07-30	926	25455	2007-01-12	1251
22871	**2006-07-15**	**0**	28461	2007-08-10	493
23873	2006-09-23	213	30465	2007-12-28	258
28883	2007-09-08	1126	35976	2009-01-16	829
29885	2007-11-17	998			
32891	2008-06-14	612			
34394	2008-09-27	367			
36398	2009-02-14	508			

Method description

IPTA (Interferometric Point Target Analysis) method is based on the principle of permanent or persistent scatterers (PS) which is implemented within the GAMMA software. The principle of the method is that not the whole scene but only appropriate points are processed. Then the process is much faster, more effective and output files are much smaller compared with the conventional interferometry method. Even the pairs with long baselines can be used because of the iterative process.

The outputs from the regression analysis includes linear deformation rate corrections, height corrections, residual phases, unwrapped interferometric phases and point quality information. These results are used to improve the model [1].

IPTA PROCESSING

Point data generation

Each track was processed separately. First the baselines were calculated with the limitation of the maximum perpendicular baseline set to 350 m. For each track several interferograms were obtained.

The candidate points were selected from coregistered SLCs and coordinates (range and azimuth pixel number) of each point were saved to the point list (plist, see Fig. 1). Selection of the appropriate candidate points is based on the low temporal variability of the SLC intensity and an SLC intensity above a threshold relative to the spatial average (minimum threshold was set to 1). The mean/sigma ratio was calculated to evaluate the temporal variability of the chosen candidate points (with minimum threshold set to 1.5) [1].

SRTM-X Digital Elevation Model (DEM) was used during the processing. The Shuttle Radar Topography Mission (SRTM) obtained elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of Earth [3]. The model was already transformed to the geometry of SAR images using the GAMMA DIFF&GEO software. DEM data were transformed to the point data stack. Also the values of target points in SLCs were extracted and written to the point data file.

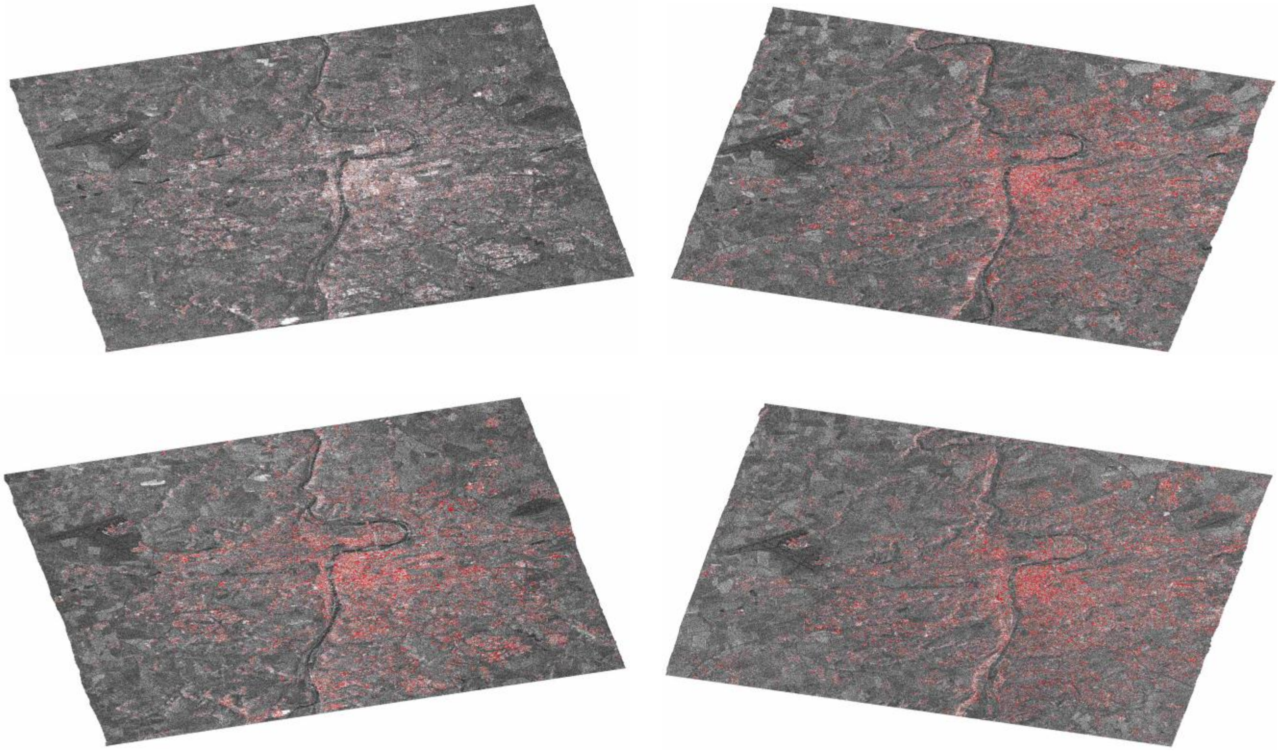

Fig. 1. The candidate point list (plist, represented by the red dots) plotted on the georeferenced image cuts – track 43 (upper left), track 122 (upper right), track 272 (lower left) and track 351 (lower right). The images are dispalyed in multilook (1 pixel in range and 5 pixels in azimuth) for easier interpretation.

Differential interferograms calculation

First the interferograms were calculated from the SLC point data. Then the simulation of the unwrapped interferometric phase was calculated. Differential interferograms were calculated by the subtraction of the unwrapped simulated phase from the complex valued interferogram.

A reference point must be determined in interferometry. This point must be either stable or its deformation must be known, because the changes are related to it. Since the examined area is assumed to be stable, then the reference points are assumed to be stable too. The selection of the reference point is very important. The amount of the processed points depends on the quality of the target point itself and on the quality of the reference point (see Table 2). All reference points are located roughly in the same place in the centre of the image.

Table 2. Reference points summary.

Track number	Size of the image [pix]		Ref. point number	Ref. point coordinates [pix]		Number of candidate points
	width	length		azimuth	range	
43	1300	5000	14934	814	2729	22784
122	1100	5000	19686	404	1974	62022
272	1100	5000	38893	693	2748	56001
351	1300	5000	22908	450	2043	72345

Regression analysis

The regression analysis was performed on the differential interferograms. The height corrections from the analysis were added to the initial heights and the pairs with the perpendicular baselines up to 500 m were added and the process was repeated. The procedure was repeated until all pairs were used.

During each iteration step the point quality is re-calculated. As a quality measure the standard deviation of the phase from regression is used. The points which is not suitable for IPTA analysis can be then detected and rejected from the process. If the phase standard deviation is smaller than 1.2 rad, the regression is said to be successful [1].

Table 3 shows the number of processed pairs with the dependency on the perpendicular baseline length for each track. Also the decreasing amount of the processed points for every iteration with the dependency on the baseline length. The temporal baseline is not important for the deformation detection and is omitted.

Table 3. Number of the processed pairs with the dependency on the perpendicular baseline length for each track. There is clearly visible the decreasing amount of the processed points for every iteration with the dependency on the baseline length.

Track 43			**Track 122**		
($B_{\perp}$) [m]	**Number of interferograms**	**Number of the processed points**	**($B_{\perp}$) [m]**	**Number of interferograms**	**Number of the processed points**
350	7	22692	350	14	47192
500	14	20177	500	24	29297
600	14	20103	600	27	27225
700	16	20237	700	30	27274
800	16	20183	800	34	24025
900	18	20135	900	38	20260
1000	22	18837	1000	40	18200
all	28	12668	all	45	14440
Track 272			**Track 351**		
($B_{\perp}$) [m]	**Number of interferograms**	**Number of the processed points**	**($B_{\perp}$) [m]**	**Number of interferograms**	**Number of the processed points**
350	27	26985	350	17	59777
500	37	19415	500	22	54517
600	46	16104	600	25	55553
700	54	12114	700	30	50698
800	58	12598	800	31	51102
900	61	11161	900	33	50151
1000	67	10359	1000	35	48379
all	78	7795	all	36	47122

RESULTS

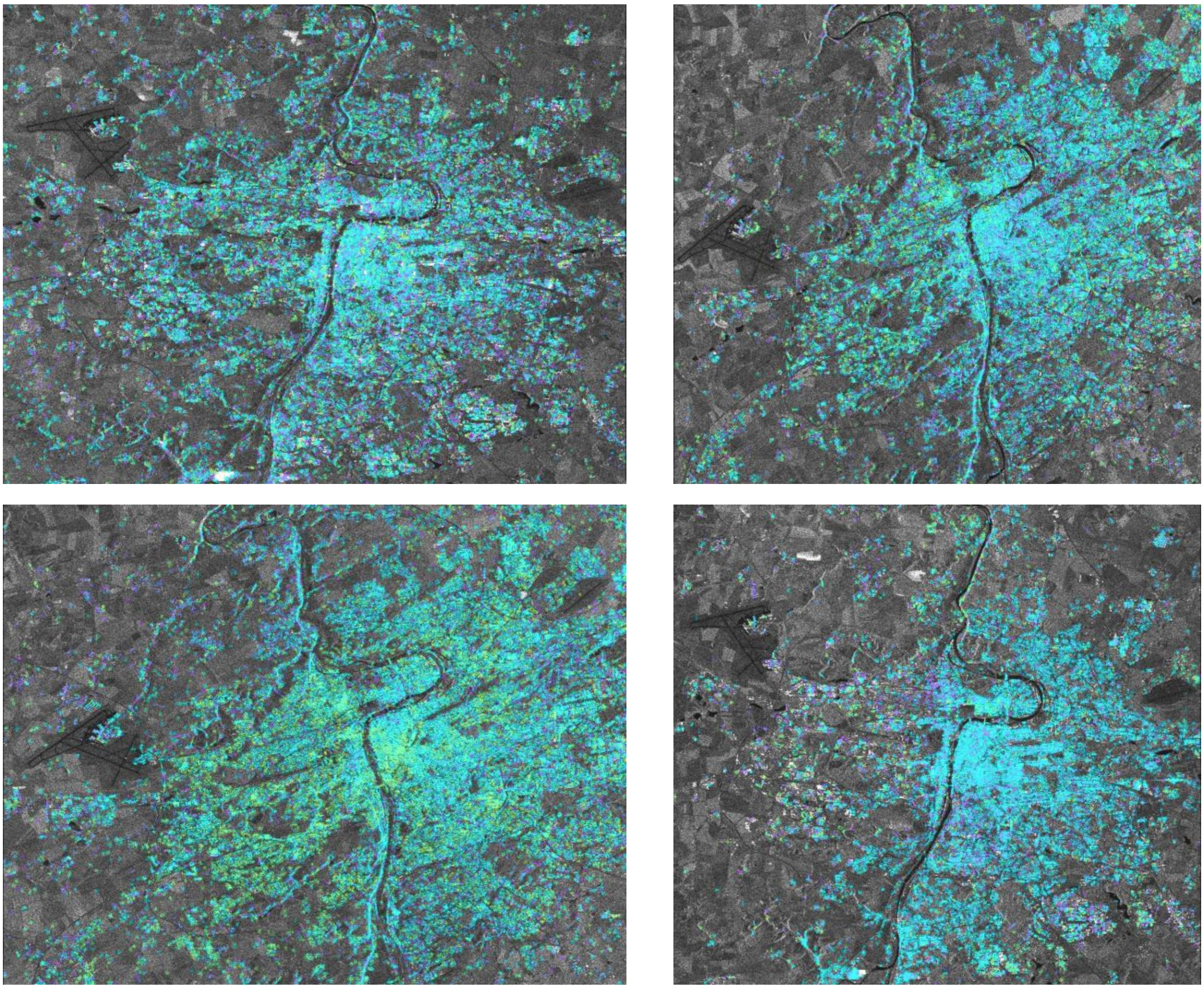

Fig. 2. Resultant linear deformation rate for each track - track 43 (upper left), track 122 (upper right), track 272 (lower left) and track 351 (lower right). The images are displayed in multilook (1 pixel in range and 5 pixels in azimuth) for easier interpretation. One colour cycle corresponds to the 0.05 m/year relative linear deformation rate.

Fig. 3. Colour scale for the deformation map, with the edges of ± 2.5 cm/year.

Suspicious areas

The histograms showing the number of points related to the deformation rate were plotted (see Fig. 4). There are two ascending (43 and 272) and two descending (122 and 351) tracks among which the deformations can be compared. A suspicious area was discovered in the track 272 but since there is not enough images in track 43, the area was not found there and cannot be compared.

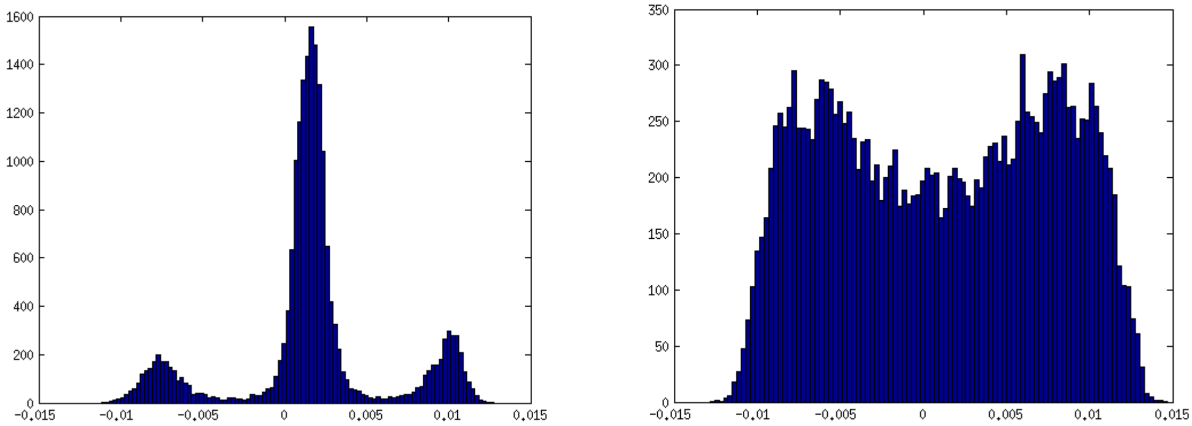

Fig. 4. Example of the histograms showing the number of points (vertical axis) related to the deformation rate (with removed zero value points, horizontal axis) – track 272 (left) and track 43 (right).

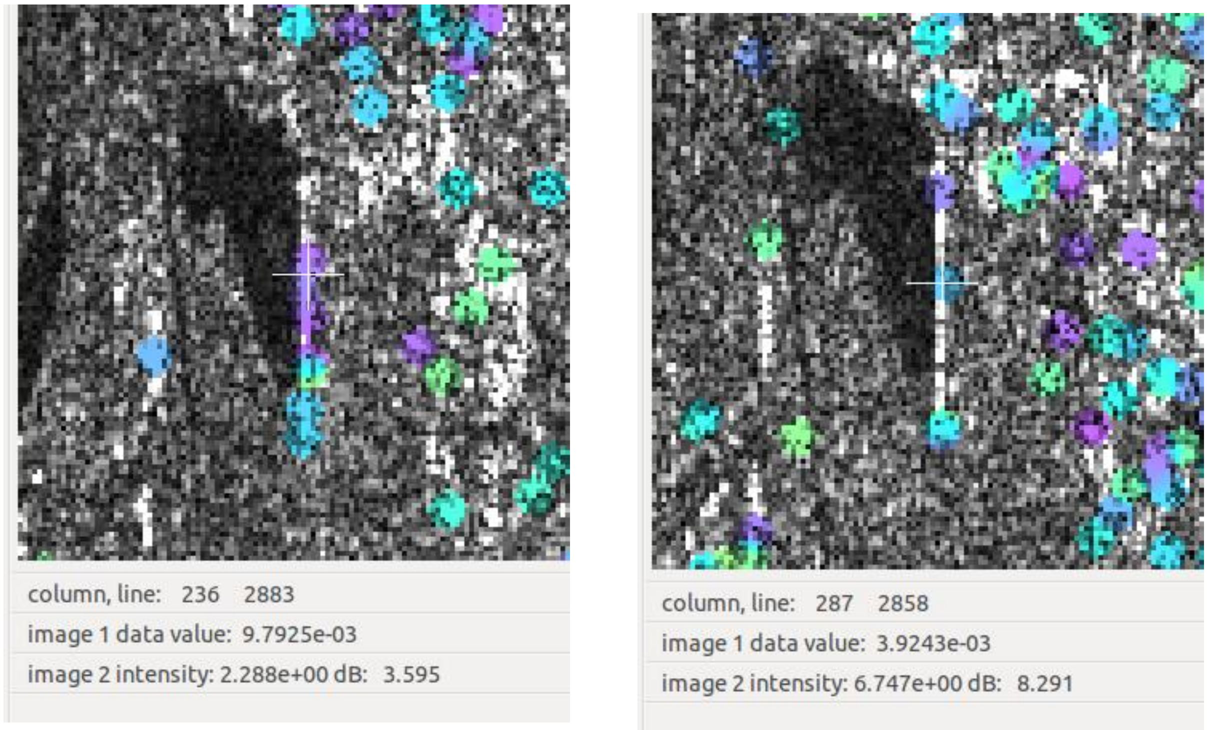

Fig. 5. The detail of the linear deformation rates of the retention basin Jiviny dam. On the left image there is a detail with the processed points and its values for the track number 272 and on the right image there is a detail for the track number 43.

FUTURE WORK

The deformation maps will be thoroughly researched and well interpreted. The final deformation maps from various tracks will be compared for better results interpretation. The process of the estimation and subtraction of the atmospheric influence will be implemented and maybe some interferograms will be excluded from the process. Also ERS 1 and ERS 2 image will be ordered and processed.

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