INSAR FOR EARLY WARNING OF POSSIBLE HIGHWAY INSTABILITY OVER UNDERMINED AREA OF OSTRAVA

Milan Lazecký[(1)], Michal Kačmařík[(2)], Petr Rapant[(3)]

[(1)] VŠB-TUO, 17. listopadu 15, 708 33 Ostrava, Czech Republic, Email: espiritocz@gmail.com
[(2)] VŠB-TUO, 17. listopadu 15, 708 33 Ostrava, Czech Republic , Email: michal.kacmarik@vsb.cz
[(3)] VŠB-TUO, 17. listopadu 15, 708 33 Ostrava, Czech Republic , Email: petr.rapant@vsb.cz

ABSTRACT

A part of czech highway D1 connecting Ostrava with Prague and Poland, is built over an undermined area of Ostrava-Svinov. Since the end of 2010, this part of the highway is fully operational. Because of undermining, a subsidence can be expected, however with a very slow rate since the mines are no more active in this area. Several TerraSAR-X images from 2011 are investigated interferometrically in order to estimate a precise deformation model. Subjects of interest are movements of newly built highway bridges, banks and close neighbourhood. Existing C-band multitemporal InSAR processing results of ERS and Envisat are available from an earlier period that reveil a slow trend of residual subsidence. In this project, InSAR will be investigated as a tool for an early warning for highway stability.

1. INVESTIGATED AREA

The project of continuation of D1 highway to pass through Ostrava (the project was called D47) started with construction works already in October 2003. On December 2007 the highway was publicly opened. In 2014 the highway should establish a connection between Prague and Polish Silesia, i.e. the highway will run across almost the whole Czech Republic. Around 20 km passage of the highway between Ostrava and Bohumín is built over an undermined area. Black coal mining was performed during the whole 20th century. The last mine in the area has stopped its activities in 1994, the neighbouring area is still subsiding nowadays, even that in much slower rate. The aim of the project was to confirm any effect of subsidence on the highway itself. The area of interest is chosen to be the part of D1 near to closed mines as depicted in Fig. 1 (left to right): Oderský Mine, Svinov Mine and Jan Šverma Mine.

Figure 1. Investigated part of highway leading through three closed mines in Ostrava-Svinov

2. DATA AND METHODOLOGY

Previous work as demonstrated in [4] showed the proper abilities of satellite SAR interferometry for monitoring subsidence due to mining in the region. Disponible datasets of ERS-1, ERS-2 ranging 1995-2001 and Envisat ranging 2003-2010 were DInSAR processed by Doris [3] and filtered using an adapted NL-Mean algorithm [1]. Multitemporal processing was performed using StaMPS [2]. Only two available Alos Palsar acquisitions from 2008 with 46 days temporal baseline had to be processed using GAMMA [6]. An SRTM model was used to remove topographical content from interferograms.

To register fine deformations on the highway, in a short temporal window, 4 TerraSAR-X Spotlight acquisitions in about a monthly step (June-September 2011) were ordered and processed using Doris – an attempt of multitemporal processing failed (see further). Since especially vertical settlement of highway pillars is to be investigated, acquisitions of as vertical incidence angle mode as possible (27.7°) were ordered in VV polarisation mode.

3. PREVIOUS PROCESSING RESULTS

The area was first investigated using lower-resolution C-band data of ERS-2 and Envisat. Area of highway surroundings can often preserve a high coherence. From DInSAR between 2009-12-07 – 2010-09-13 (280 days) there was no significant deformation detected directly on the highway - however the signal in the neighbourhood was strongly decorrelated and potential deformations in that area cannot be properly evaluated from DInSAR.

According to the processing of 48 ERS-2 SAR images, the undermined area was subsiding per 7-8 mm/year in average (estimated by StaMPS) during first years after the Jan Šverma Mine closure, i.e. in 1996-2000. Graph describing this subsidence trend w.r.t a possibly stable reference point in 1 km distance is shown in Fig. 2.

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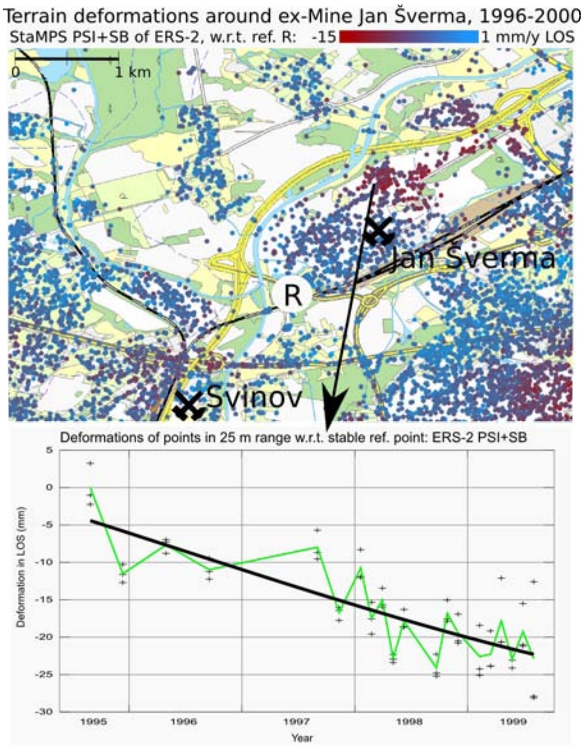

Figure 2. Results of ERS-2 StaMPS processing around ex-Mine Jan Šverma and graph of deformations of PS points of selected area (diameter 25 m), 1996-2000

4. TERRASAR-X PROCESSING ISSUES

Processing of TerraSAR-X (TSX) data was problematic. First of all, no actual sufficiently precise DEM was available for a topography removal from such interferogram of cca 1x1 m spatial resolution. Fig. 3 describes some relevant parameters of the data.

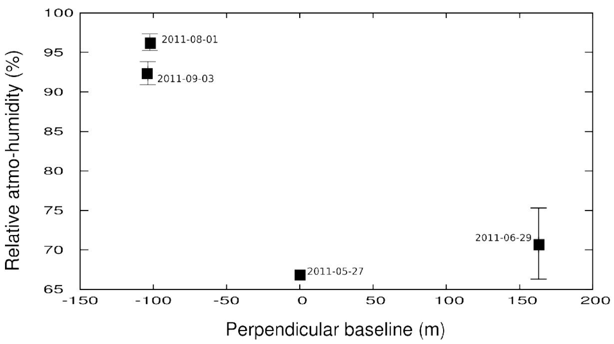

Figure 3. Characteristics of TerraSAR-X acquisitions: Perpendicular baselines, Relative humidity

The short wavelength of TSX is very sensitive to atmospheric moisture, clouds and rain as well. There is no known general behaviour of temporal distribution of moisture during the day. However as can be observed from Fig. 3, an ascending track could be more profitable w.r.t. atmosphere humidity – the descending acquisitions were taken in the morning time at around 5:09 UTC while the ascending mode would scan at 16:25 UTC. Within such levels of relative atmospheric humidity (information in Fig. 3 were gathered from two precise meteorological stations installed in cca 4 km range), the X-band should be strongly affected by local delays [5]. It is possible that during acquisition of 2011-08-01 a mild rain of around 1 mm/hour occured (as was also confirmed using meteo radar data).

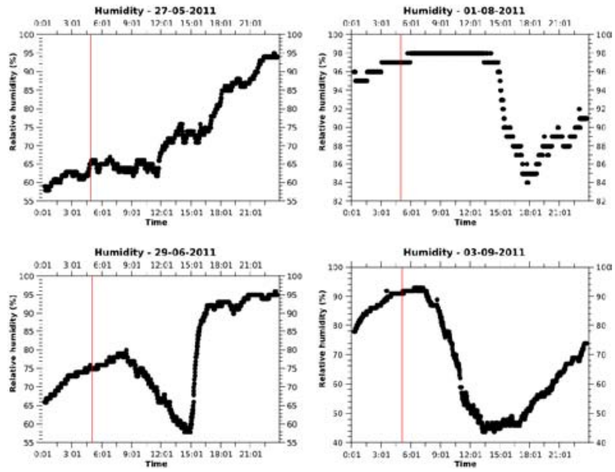

Figure 4. Distribution of relative humidity per acquisition days

According to Fig. 3, only an interferogram between 2011-08-01 and 2011-09-03 doesn't include significant topographical phase contributions (due to very short perpendicular baseline of 4 m). However since these two images are strongly affected by atmospheric moisture, the interferogram suffers by a high overall decorrelation and have to be processed by a proper filtering.

Unfortunately, attempts of a multitemporal processing using StaMPS failed, probably due to small number of acquisitions. StaMPS include algorithms to estimate so-called spatially uncorrelated look angle errors that refer directly to DEM errors – topography induced phase (which is related to perpendicular baseline) can be estimated and removed. More proper acquisitions should be available.

5. TERRASAR-X RESULTS

Since the topography phase couldn't be removed properly from interferograms of Bperp=100-265 m (height ambiguity of -37 to -14 m), only an interferogram between 2011-08-01 and 2011-09-03 could be interpreted. By visual inspection of combinations within full 4 months range (2011-05-27 and 2011-09-03) and each 1 month difference, no signs of evolving deformation were found. On the other hand, mentioned interferogram of Bperp=4 m and Btemp=33 days may depict some subsidence on the highway bridge and the part of highway leading towards the area of closed Svinov Mine – see Fig. 5. Because of strong weather variations between both acquisition times, the phase is prone to decorrelation as well as objects are prone to changes due to weather only (the detected movement may be caused by a temporal dilation only). To provide a more confident interpretation about deformations on the highway, a multitemporal processing using more acquisitions should be performed.

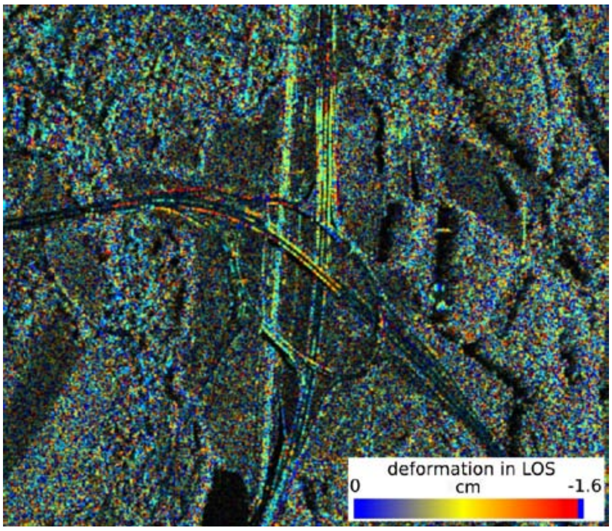

Figure 5. Interferogram of TerraSAR-X between 2011-08-01 and 2011-09-03 (phase on intensity)

6. CONCLUSIONS

Usage of InSAR for early warnings of highway instabilities over undermined (or otherwise affected) areas are site specific. For a proper investigation, fine resolution data are strongly recommended. Tested spotlight data of TSX shows a highly coherent phase within highway structures. Even that the X-band wavelength is very sensitive to meteorological conditions, the data can be considered optimal for a continuous monitoring of highway settlement.

The advantage of InSAR, against typical geodetical approaches of highway monitoring, is an investigation of the whole area at once, in temporal periods that are sufficient for these purposes (TSX revisit time is 11 days).

The preliminary result show a proper potential of the methodology for highway stability monitoring. For a complete actual deformation overview and proper conclusions, more high resolution data should be acquired.

7. Acknowledgements

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8. REFERENCES

1. Deledalle, Ch. A., F. Tupin, and L. Denis. "A non-local approach for SAR and interferometric SAR denoising". In: IEEE International Geoscience and Remote Sensing Symposium, IGARSS'10. Honolulu: IEEE International, 2010. isbn: 978-1-4244-9564-1.

2. Hooper, A. "A multi-temporal InSAR method incorporating both persistent scatterer and small baseline approaches". In: Geophysical Research Letters 35 (2008). issn: 0094-8276.
doi: 10.1029/2008GL034654.

3. Kampes, B. M., R. F. Hanssen, and Z. Perski. "Radar interferometry with public domain tools". In: Fringe Workshop. Frascati: ESA, 2003, p. 6.

4. Lazecký, M. "Monitoring of Terrain Relief Changes using Synthetic Aperture Radar Interferometry: Application of SAR Interferometry Techniques in a Specific Undermined Ostrava-Karviná District" PhD thesis. Ostrava: VSB-TUO, 2011.

5. Li, Z. "Correction of atmospheric water vapour effects on repeat-pass SAR interferometry using GPS, MODIS and MERIS Data". PhD thesis. University College London, 2005.

6. Wegmüller U., Werner C., Strozzi T., and Wiesmann A. "Monitoring mining induced surface deformation". In: Geoscience and Remote Sensing Symposium, 2004. IGARSS'04. Proceedings. 2004 IEEE International. Vol. 3. IEEE. 2004, pp. 1933–1935.