Determination of Hazardous Subsidence in the Mining Region of Ukraine with the ERS SAR Interferometry

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Abstract – The Krivoy Rog iron-stone basin is an strained ecologically mining area of Ukraine. A withdrawal of plenty stone masses from deep and their displacement to another place cause the significant changes of both a visible stationary local topography and its slowly deformation also. Most informative method for monitoring of these processes is the satellite radar interferometry for estimation of a digital elevation model (DEM) and analysis of small deformations existent in the Krivoy Rog city's area, which is placed over the mining cavities here and there. Three Tandem ERS-1/2 SAR SLCI descending images were processed with the SARscape 2.2 software. The paper shows results of the analysis of one fragment which includes the urban settlement areas along a river, opencast mines, reservoirs, road and railway systems.

Keywords: interferometry, coherence, DEM, opencast, shaft.

1. INTRODUCTION

Krivoy Rog was developed historically as a mining company town on base of the extraction of ore. It is situated along the river on area of 15,000 km sq. (18x84 km approximately). The opencasts and shaft minings are adjoining with the town directly. Productive infrastructure includes large open pits with extension more than 2 km, dumps by height of tens meters and the technological water setting-basins of area up to 24 km sq.

The conventional geodetic methods (lasermeters, GPS) are not able to provide an uniform assessment of state of a variable landscape. The uncontrolled derelict open and underground minings lead to unexpected change of environment.

The interferometry (INSAR) (Prati, 1994) from the Synthetic Aperture Radar (SAR) data for recurring determination of the topography and the differential interferometry (DINSAR) to monitor anticipated surface movements is a cost-effective tool obviously. The capability of the technology was already shown in (Hartl, 1994), (Raucoules, 1999), (Crosetto, 2004).

This work was carried out within the framework of the European Space Agency AO358 Project to study of the Antarctic and Ukrainian regions with the ERS1/2 SAR data.

2. THE STUDY AREA AND DATA USED

Map from the ESA/Eurimage DESCW Catalog with the study area in Ukraine is shown in Fig. 1. It is covered completely by the ERS scene with the frame #2640 along the 21 descending track. ERS1 and ERS2 have implemented 36 expositions during 1991-2003. We selected

The Tandem pair including scenes of ERS1 (22.10.1996, orbit 27564) and ERS2 (23.10.1996, orbit 7891). The Baseline between satellites is 193.1 m. These data were used to compute DEM. An appropriate third scene to determine deformations was identified from the ERS2 orbit 43963 of 17.09.2003. The Baseline between satellites of 22.10.1996 and 17.09.2003 is 45.2 m.

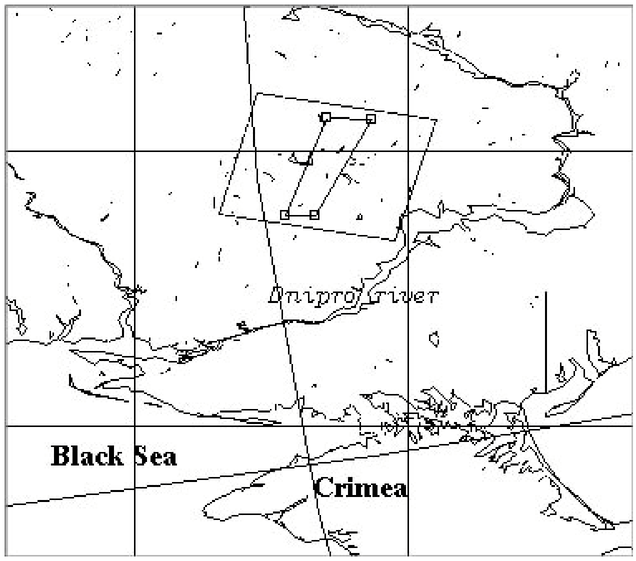

Figure 1. DESCW map of the Krivoy Rog test area and location of the ERS1/2 frame 2640.

The fragment of the halftone amplitude image of ERS2 is shown in Fig. 2. More bright hue corresponds to more intensive backscattered signals. A central part of the city pertains to such areas. Dark areas are the water basins (reservoir, lodgements, rivers), where is lacking in reflection signals. The impaired signals owing to vegetation causes the shadowy areas also. Regular agricultural sites, located northward from the reservoir, are shown by bright hue.

The ERS Tandem mission provides a high similarity between the images. However the difference is visible in the small localised region southward from the reservoir. It is explained by the atmosphere artifacts (rainfall) of 23.10.96. Due to this the shoreline is blurry in this region in the image this date. The meteorological data confirms this event.

We thank ESA/ESRIN for releasing the ERS SAR SLCI data and CREASO GmbH/SARMAP for the SARscape Demo software.

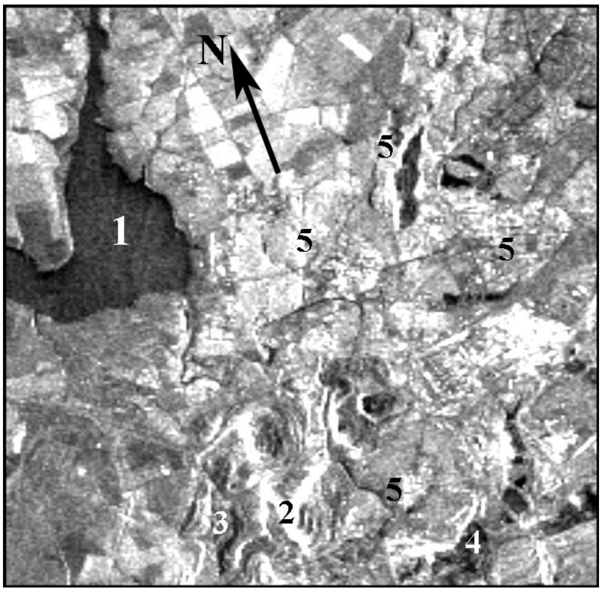

Figure 2. Georeferenced intensity image of the test area of 22.10.1996. 1 – reservoir, 2 - opencast, 3 – terrace, 4 – lodgement, 5 – urbanized territories.

3. PROCESSING AND INTERFEROMETRIC RESULTS

The next stage of the processing is calculation the coherence between two images which were co-registered to 1/10 of a pixel. Coherence indicates the correlation between images and the capability to assess areas which are appropriate for topographic information. Different reflective properties of the land surface and artifacts above affect the coherence values. Coherence was calculated using an average window size of 3 in slant range and 15 in azimuth samples (5 looks, 60x60 m). As we see in Fig. 3, the coherence over the whole test area is quite high. Values more than 0.33 are 61%. Low values less than 0.2 are for the region with rainfall between the scenes. The coherence of the water basins is near zero.

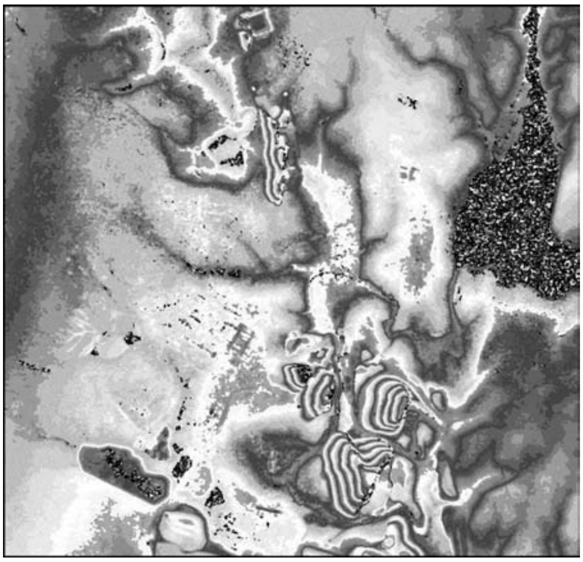

Figure 3. Georeferenced coherence image of the test area.

The coherence is considered when a quality of the interferogramme is evaluated for generation of DEM. Fig. 4 shows the phase interferogramme of the area after removing of the synthetic interferogramme calculated by orbit data and with respect to an ellipsoid plain in the test area. Topography in this area varies within a range of 55-60 m approximately. Moreover, elevations in the opencasts and terraces regions mount to 170 m. In respect that the baseline between satellites is about 193 m, one fringe forms a corresponding change of height about 52 m.

Figure 4. Phase interferogramme (non georeferenced) of the test area.

Relative topography as the product of the interferometry is shown in Fig. 5. This result is in a good correspondence with the actual elevation in the area.

Figure 5. Relative topography of the test area. Contour interval is 10 m.

4. CONCLUSION

The continuation of the work will be on base of the detail reference DEM to identify the deformation of the land surface in areas of the derelict shafts.

5. REFERENCES

PH. HartlHartl, K.-H. Thiel, X. Wu, Y. Xia, “Practical application of SAR-interferometry; experiences made by the Institute of Navigation,” Processing Second ERS-1 Symposium – Space at the Service of our Environment, Hamburg, Germany, 11-14 October 1993, ESA SP-361, vol. II, p.p. 717-722, January 1994.

C. Prati, F. Rocca, “Use of the spectral shift in SAR interferometry,” Processing Second ERS-1 Symposium – Space at the Service of our Environment, Hamburg, Germany, 11-14 October 1993, ESA SP-361, vol. II, p.p. 691-696, January 1994.

D. Raucoules, C. Carnec, “DEM derivation and subsidence detection on Hanoi from ERS SAR interferometry,” Second ESA International Workshop on ERS SAR Interferometry: ‘FRINGE99 - Advancing ERS SAR Interferometry from Applications towards Operations’, held in Liege, Belgium
10–12 November 99, ESA Publications Division, SP-478, CD-ROM.

M. Crosetto, B. Crippa, O. Monserrat, M. Agudo, E. Biescas, “Land subsidence measurement with SAR inteferometry data,” Abstract and Programme Book – 2004 Envisat & ERS Symposiu, Salzburg, Austria, 6-10 September 2004, Session 3B1: Subsidence, Abstract No. 443