Temporal Investigation of Effects on Coastal Structures of Subsidence Caused by Undersea Mining in Zonguldak Hardcoal Basin Using InSAR and GNSS Approach

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SUMMARY

InSAR and GNSS are effective tools to measure the amount of ground deformation caused by subsidence in populated areas. PALSAR and RADARSAT are two important radar missions in the monitoring of deformations by Interferometric SAR (Rodriguez E. et al 1992, Raucoules D. et al 2007). This achievement is due to the fact that PALSAR uses L-band microwave which is less affected by vegetation and atmosphere (Deguchi T. et al 2006, Nga A.H. et al 2008). In this study, we determined ground deformation and temporal changes induced by coal mining development in terms of environment using InSAR technique with C- and L-band SAR data, and then tried to verify the accuracy using GNSS measurement data. All this techniques are used for real-time monitoring of subsidence in coastal zones of Kozlu region of Zonguldak Hardcoal Basin- ZHB.

In this area; 11-15 cm negative vertical displacements and 12-25cm horizontal displacements were determined from processing of the GNSS measurements between 2005 and 2008. Later on tree period precise leveling survey methods and GNSS company are realized, and 3,2cm-10,3cm negative vertical and 1,2cm-15,3cm horizontal displacements are determined between 2008-2010. Also, -5,6cm slant range displacement caused in coastal zone in 456 day between 24.07.2005 and 23.10.2006 from sixteen RADARSAT SAR images. In period between 2007 and 2011, firstly -6cm slant range displacement for 460 day between 24.09.2006 and 28.12.2007 and -20cm slant range displacement for 828 day between 06.12.2007 and 13.03.2010 from ALOS PALSAR SAR images has been determined. High correlation is established in annual scale from comparison of results. In this study, in addition to the mining subsidence effect on some of the coastal structures in this field are investigations and makes some proposals using subsidence surface counters.

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1. INTRODUCTION

An important part of hardcoal production in Zonguldak Hardcoal Basin-ZHB of the Turkey from the populated Kozlu area towards the under Black Sea between -400m and -600m levels is carried out, and every day 2000-3000 tons raw hardcoal extracted (figure1). Also, most of the important coastal structures as the marina, the coastal highway, river port, parks and recreation areas, open market, bus station apartment buildings and filling station etc. located on this region.

Undersea mining production in Kozlu area of ZHB causes displacement and deformation in the soil and earth surface depending upon mining and geological factors. The deformations in the overburden cause damage also in the coastal structures and undersea topography. The damages appear in the structures by the active subsidence, which emerges while the underground mining activities continue, and the residual subsidence which emerges after the mining production. The type of the soil, the topography of the ground, environmental factors such as the site of the structure in the subsidence impact area, the dimensions of the structure, the type of the structure, the type of the foundation and the load-bearing system of the structure, the material used in the structure are also effective on the damage occurred in the structure except for the mining subsidence effects. Determine and repair of the damages occurred during and after the mining activities are in the field of the mining subsidence engineering. This engineering discipline includes the subjects such as forecast, control, damages and measurement of the mining subsidence.

2. VERIFICATION OF SAR and GNSS / LEVELING DATA

In this research; InSAR and GNSS techniques are used for temporal monitoring of subsidence zones in Kozlu coastal region of ZHB. In analysis of RADARSAT data, temporal change of ground deformation was measured by using 15 pairs whose baselines were less than 500 m between 2006 and 2008. RADARSAT is C-band microwave sensor and it is difficult to provide high coherence between master and slave image in densely vegetated areas (Akcin et al 2010). Consequently, fringe with spatial continuity was observed only in the urban district in this study area. Deformation of over 5,5cm per 15 months in slant range direction was detected in the urban area located near Kozlu mining region. The location of deformation extracted by RADARSAT is at the extension of existing mining tunnel and it corresponds to the currently ongoing mining activity. -5,6 cm slant range displacement caused in coastal zone in 456 day between 24.07.2005 and 23.10.2006 from sixteen RADARSAT SAR images. In the Figure 2, temporal subsidence development in the Kozlu coastal zone has been shown.

Figure 1. Location of Zonguldak and Kozlu region.

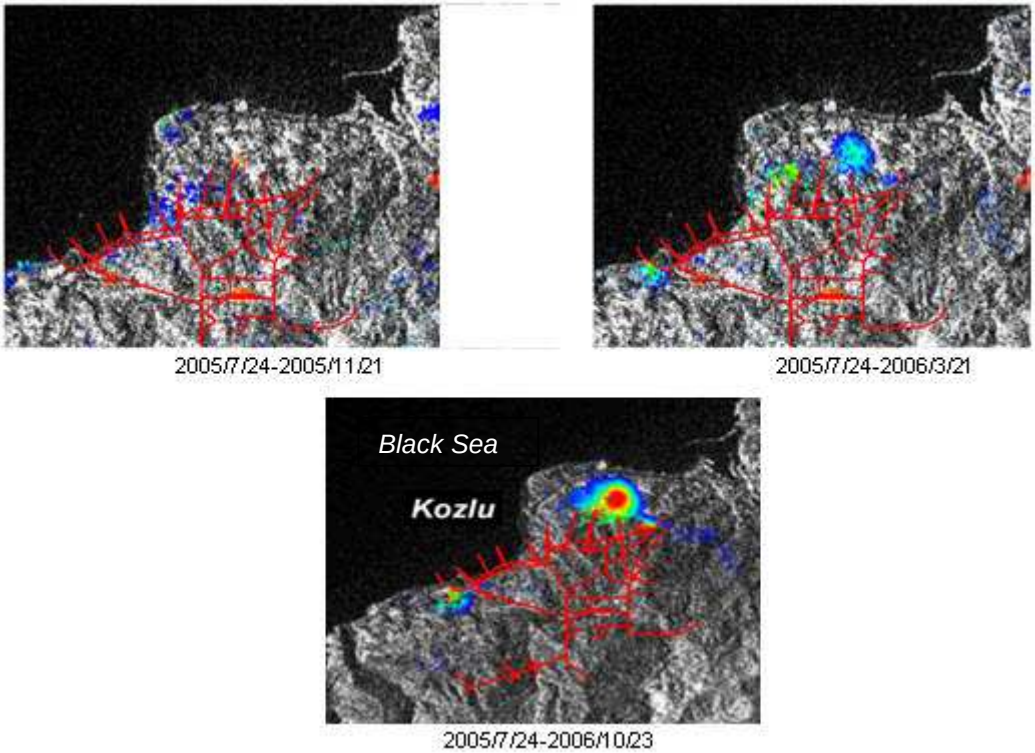

Figure 2. Temporal subsidence development from RADARSAT SAR image in environmental of underground tunnels.

Another measure deformation in Kozlu coastal zone is realized by periodic observation PALSAR SAR image. In the result of analysis using PALSAR data, local deformation was detected firstly -6cm slant range displacement for 460 day between 24.09.2006 and 28.12.2007,and secondly -20cm slant range displacement for 828 day between 06.12.2007

and 13.03.2010. In Figure 3, deformation firings determined with PALSAR SAR image and subsidence contours are given.

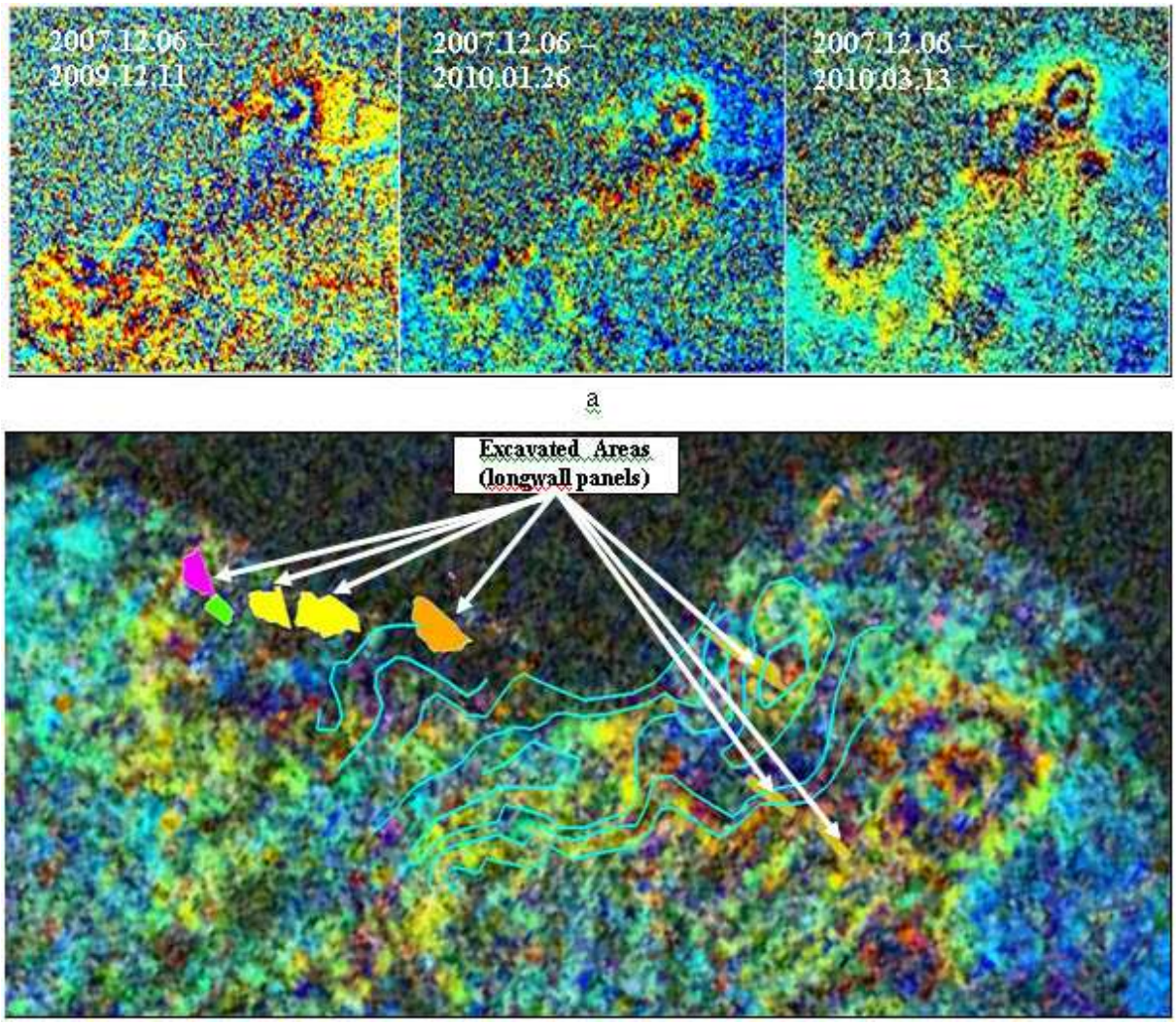

Figure 3. Temporal (a) and total changes (b) between 2007/12/06 and 2010/03/13 of deformations using PALSAR image series on Kozlu coastal zone of ZHB.

In order to comprehensive of InSAR results, firstly 15 deformation monitoring points later totally 36 ground check point for GNNS and leveling measurements were installed within the coastal zone in Kozlu region. In these points, periodical control observations synchronized with production in longwall panels were realized. For observed dates post processing by statistical adjustment was done. In this area; 11-15cm negative vertical displacements and 12-25cm horizontal displacements were determined from processing of the GNSS measurements between 2005 and 2008. Later on tree period precise leveling survey methods and GNSS company are realized, and 3,2cm-10,3cm negative vertical and 1,2cm-15,3cm horizontal displacements are determined between 2008-2010. Determined subsidence counters by

leveling for 2008-2010 period shown in Figure 4. Also; morphological comparison of subsidence contours derived from InSAR and leveling given in Figure 5.

Figure 4. Subsidence counters from GNNS and leveling in period 2008-2010.

Figure 5. Morphological comparison of subsidence contours delivered from InSAR and Leveling.

3. INVESTIGATION OF SUBSIDENCE INDUCED DAMAGES IN STRUCTURES

Structures like sea port, river port, marine and high way, buildings or undersea topography within the area affected by underground mining operations caused subsidence under the influence with a continuously changing and finally diminishing magnitude and direction (Can E. et al, 2011). It stays undamaged resisting or accommodating the aforementioned effect or sustains slight or great damage that can result from emerging differences in slope, displacement and strain to the surface in which the building is positioned by the subsidence

effect. Aside from the magnitude of subsidence effects, there are peripheral and structural factors that play crucial roles in this damage such as type of ground, topographic construction position of structure in the affected area, dimensions and shapes of buildings, type of basic structural system and properties of construction materials. For example; if The longitudinal axis of structure is not to be positioned parallel to subsidence contours on the surface, it can be damage (Figure 6 and 7). Accordingly, suitable and unsuitable located buildings in coastal zone of Kozlu Region have been investigated and shown in Figure 8 and 9.

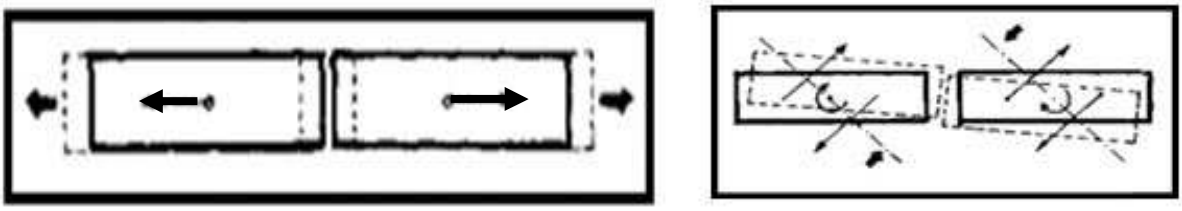

Figure 6. Effect on axis of structure of impact forces depending on the subsidence (Erol A. 1987).

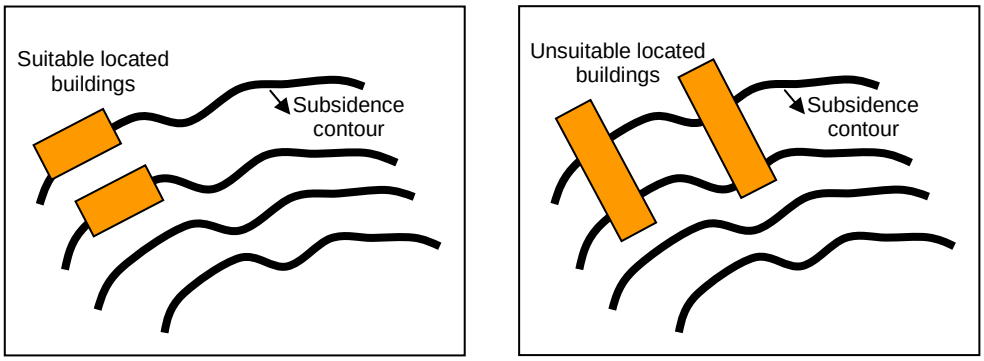

Figure 7. Relationship of subsidence contours with and without suitable positioning of buildings.

4. CONCLUSIONS AND FURTHER WORKS

By using GNSS / Leveling, RADARSAT and PALSAR data, undersea mining induced land deformation was detected in the costal zone of Kozlu region in ZHB Following findings were obtained from the study:

Figure 8. Unsuitable located buildings in investigated areas.

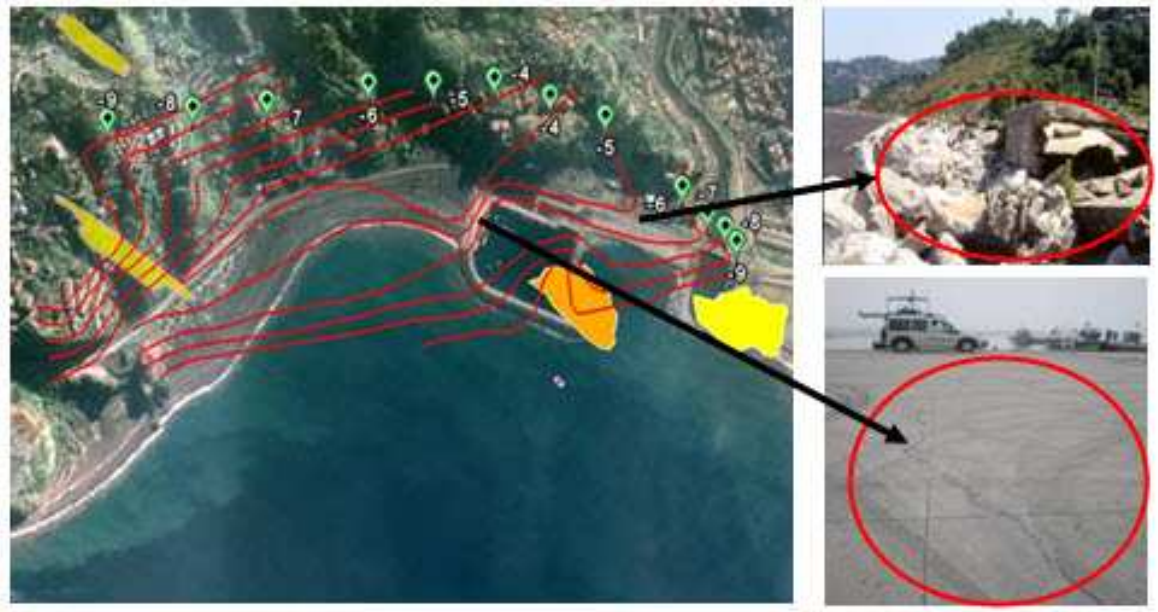

Figure 9. Unsuitable located seaport, river port and highway in investigated areas.

- In the results of RADARSAT data obtained between 2005 and 2008, two local surface displacements were detected in the coastal zones of Kozlu region. The amount of deformation was approximately 4.4 cm/year in slant range direction surrounds coastal structure and buildings.
- In the results of PALSAR data obtained between 2006 and 2010, totaly 26cm deformation in slant range direction determined. For the PALSAR data; 11.8 cm in slant range direction has been accepted to 15.1cm. (Ge L. et al 2001). However, 26 cm slant range transformed to 33.3cm in vertical direction.
- Morphological relationship between subsidence contours from InSAR and leveling are found compatible. Also; location of any buildings and structures are unsuitable in this field.
- In the future; these research will continued with ENVISAT SAR image and GNNS / leveling measurement.

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