Monitoring Mining Induced Subsidences Using GPS and InSAR

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SUMMARY

Underground mining causes subsidence effect on the earth surface. It is possible to monitor this effect by geodetic surveying methods. However, these methods have some difficulties to apply in places where topography is hilly or forestry or dense urbanization is available. These difficulties can be overcome using InSAR technique to monitor subsidence effects. In order to study the performance of InSAR on determining subsidence effects, an investigation has been carried out in Kozlu region of Zonguldak Hardcoal Basin, Turkey. Using JERS-1/SAR and RADARSAT images subsidence areas and amounts have been determined. These results obtained from InSAR have been compared those obtained from GPS observations of a geodetic control points established in the region. This comparison shows that GPS and InSAR results are consistent with each other.

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1. INTRODUCTION

In many countries that coal mining is applied, surface subsidence caused by mining activities has been carefully monitored, and some precautions intended for surface damages by the subsidence have been taken into consideration. However, subsidence is a complex event which is a result of natural and unnatural effects although it is taken place due to the underground productions. The regional behavior of this event can be investigated by observation techniques applied over the earth surface and/or under the earth. In this study, InSAR and GPS techniques are integrated to monitor the surface changes caused by the subsidence in Zonguldak city, which is the biggest hard coal basin in Turkey.

In Zonguldak Hardcoal Basin (ZHB), production activities have been continued since the year of 1848. Up to now the raw coal about 400 million ton has been extracted from the basin which has the area of 15000 km^2 whose 3000 km^2 is under the sea. In this basin, the coal seams are limited to the upper carbonifer layers. These layers, whose total thickness changes between 600-800 m, have a very complex geological structure. The coal production in the region has been carried out in the production panels with different geometrical pattern and different height, using different production techniques. Kozlu region treated in this study is one of the oldest production areas of the basin. The location of the basin and the investigation area in this basin are given in Fig. 1.

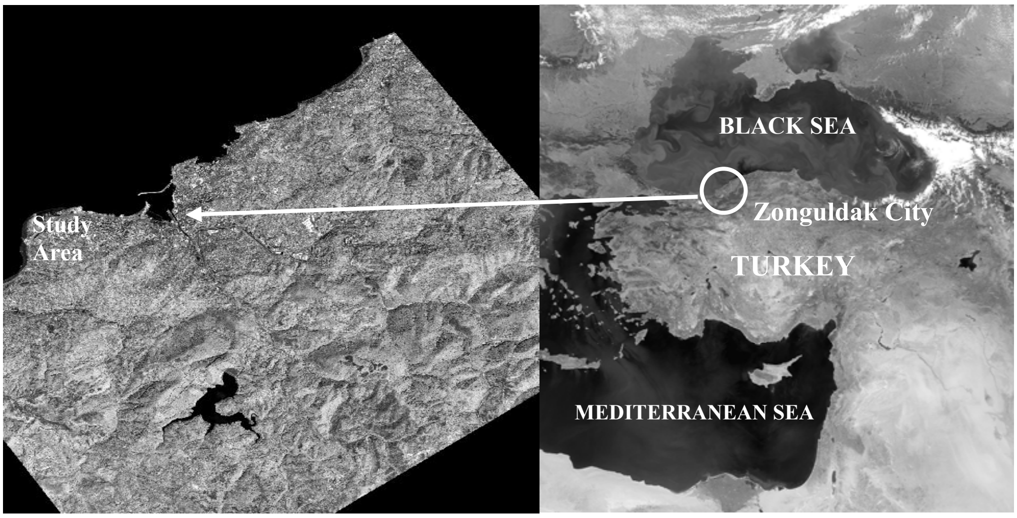


Fig.1. Location of study area

At the beginning of this study, a deformation map is formed by differential application of two different images in 1995 taken from JERS-1/SAR satellite (Fig. 2). In this map five deformation zones have been detected. The four of these zones are in the forestry area which is not appropriate to apply GPS observation technique. The only urban area which the

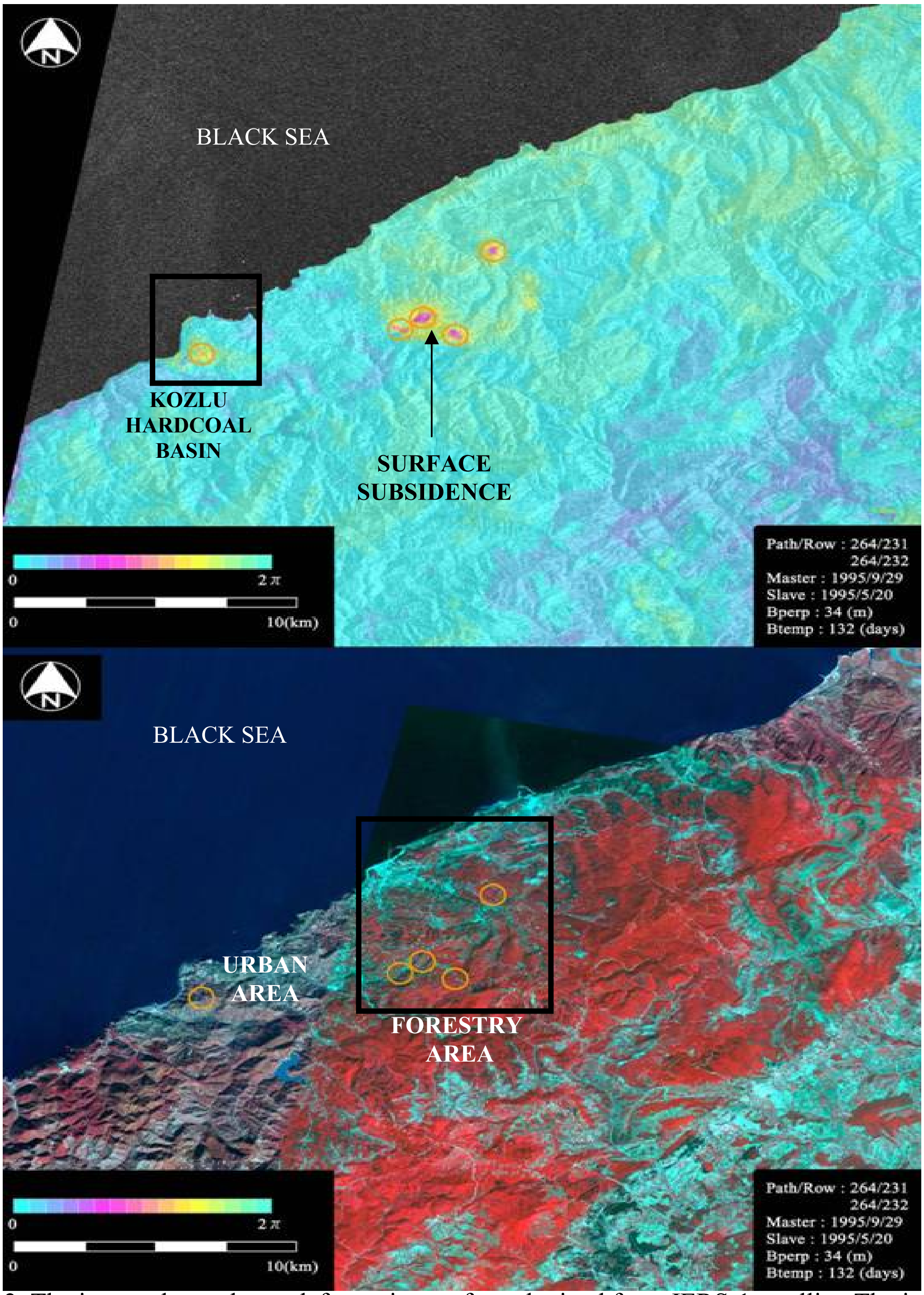


Fig. 2. The image above shows deformation surface obtained from JERS-1 satellite. The image below is ASTER infra-red image of the region.

subsidence is observed is related to the Kozlu region. In this area, a GPS network has been established to confirm the deformations detected by InSAR technique.

In addition, the digitized coal production plans are used for determining whether the deformations obtained coincide with the subsidence effect area or not. When the subsidence mechanism in the region is investigated it is observed two constitutions in the direction of and the perpendicular direction to the production (Fig.3 and Fig. 4). It is known that this mechanism is induced by the constant factors relating to geological structure and the variable factors relating to the geometry of production area (Whittaker, B. N. ve Reddish D. J., 1989).

For GPS and InSAR observations, determining the area which subsidence affects on the earth surface is an important issue. The effect area on the earth surface can be determined when the dimensional parameters of the panel constituted in the gallery mined, i.e. width and length of the panel, thickness of the gallery, and lower and upper heights of the panel, are known (Fig. 5).

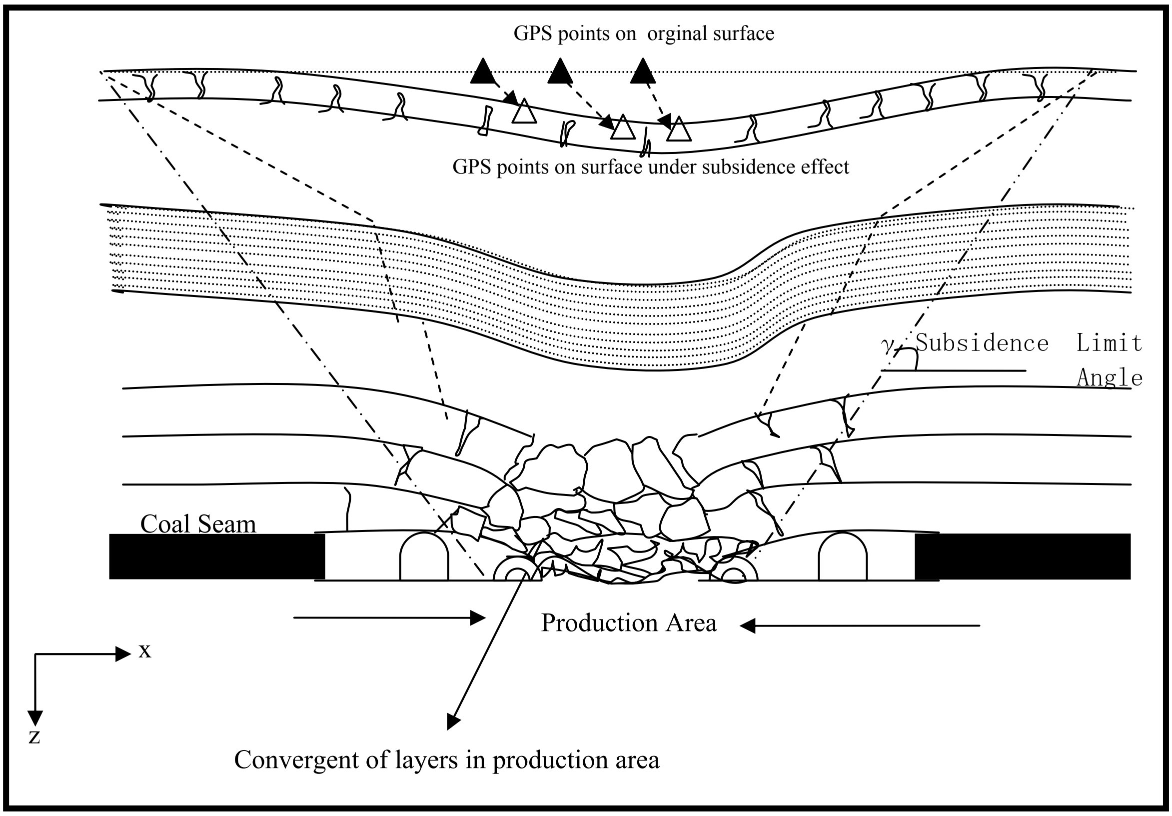


Fig.3. Subsidence constitution mechanism in the direction of production (adapted from Shadbold, C. H., 1977)

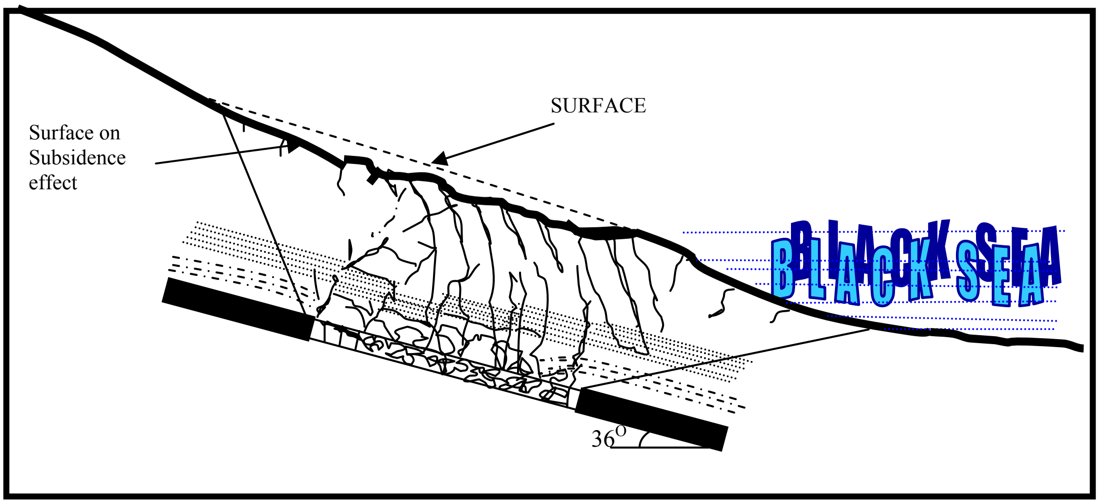


Fig.4. Subsidence mechanism in the perpendicular direction of production

2. DETERMINATION OF THE PRODUCTION EFFECTS AREAS IN KOZLU TEST AREA

In order to determine which production activities affects on the surface deformations to be obtained by InSAR ve GPS observations, underground production plans has been digitized, and effects areas of the coal productions after 1995 have determined. Fig. 6 shows the production panels and their effect areas between the heights of -200 m and -400 m between 1995 and 2001.

3. OBTAINING SUBSIDENCE EFFECTS IN KOZLU USING GPS AND INSAR TECHNIQUES

Geodetic control points on the earth surface can be deformed with time due to tectonic movements and/or underground mine productions. Observing the control points repeatedly by geodetic surveying techniques such as GPS, horizontal (v_X, v_Y) and vertical (v_H) components of deformations in relation to the point coordinates X, Y and H can be obtained. Analogously, applying differential InSAR application to radar images in two different instant, deformation vectors can be obtained.

For such an investigation, two period GPS observations in 1996 and 2003 carried out on the available network in Kozlu region have been utilized, and the first result for the subsidence effect have been obtained. After 2005 the number of the control points has been increased to obtain more detailed deformation knowledge. Fig. 7 and Fig. 8 show old and new constitutions of the geodetic network.

The deformation vectors obtained from the 1996 and 2003 observations are illustrated in Fig. 9. In order to obtain the surface deformations by InSAR technique, two images taken with an interval of 132 days in 1996 have been used, and deformation areas given in Fig. 10 have been determined. Fig. 11 shows the regression graphics of deformation slant ranges obtained from GPS and InSAR. Fig.12 also shows deformation vectors obtained from both methods, GPS and InSAR, in 2005.

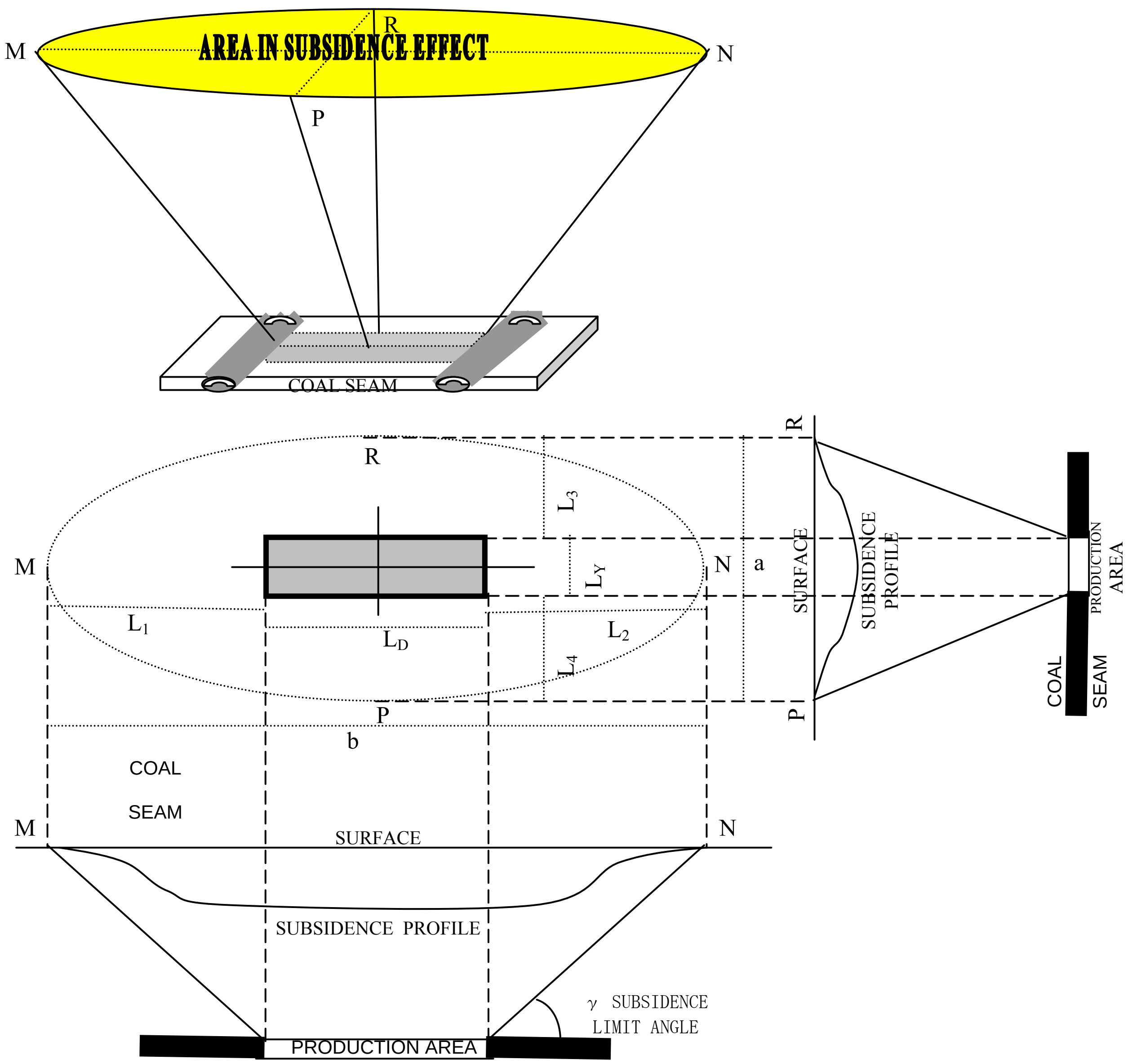


Fig.5. Subsidence constitution and its effect area from different profiles in a horizontal seam (adapted from Peng, 1992).

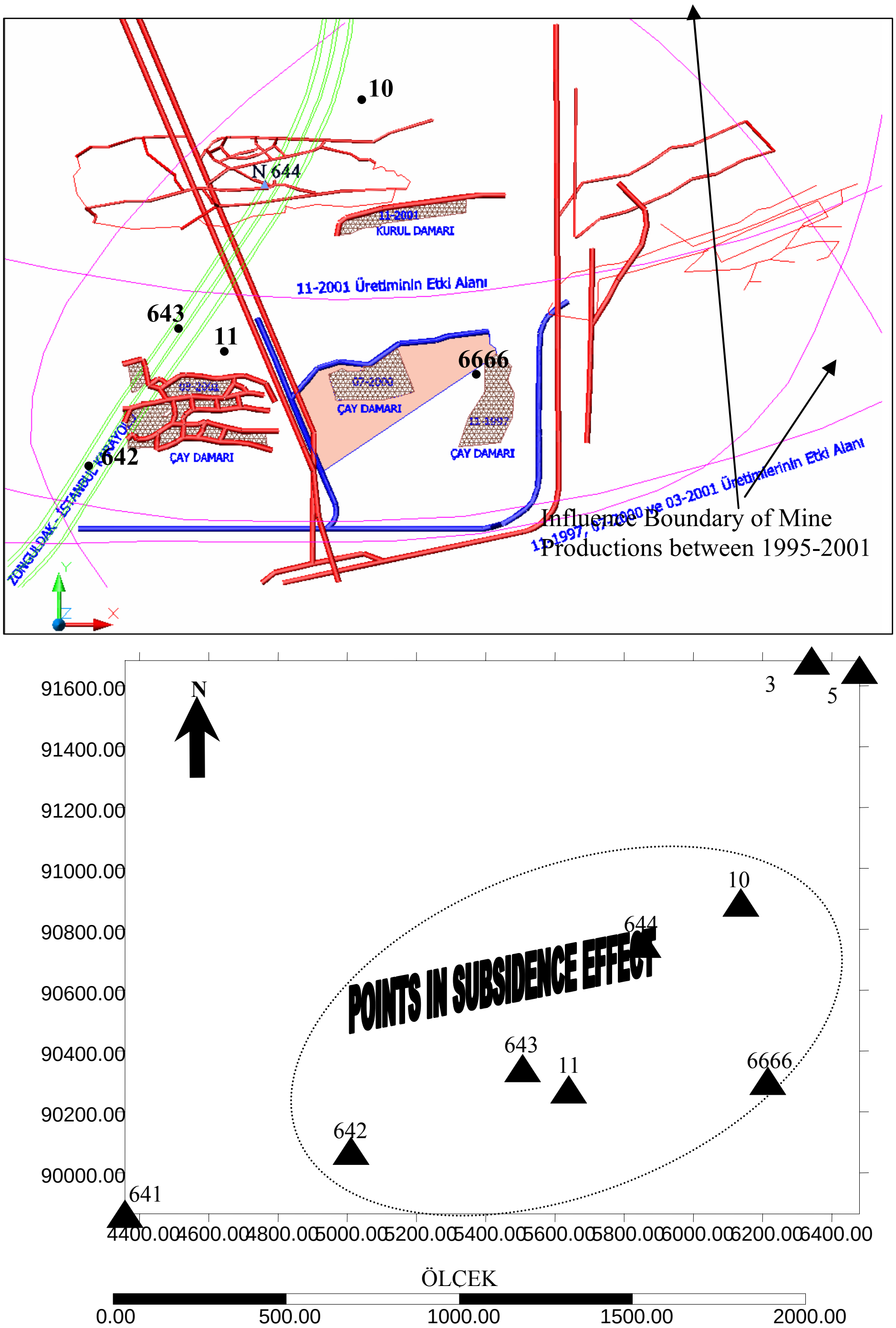


Fig.7. Control points used between1995 and 2003

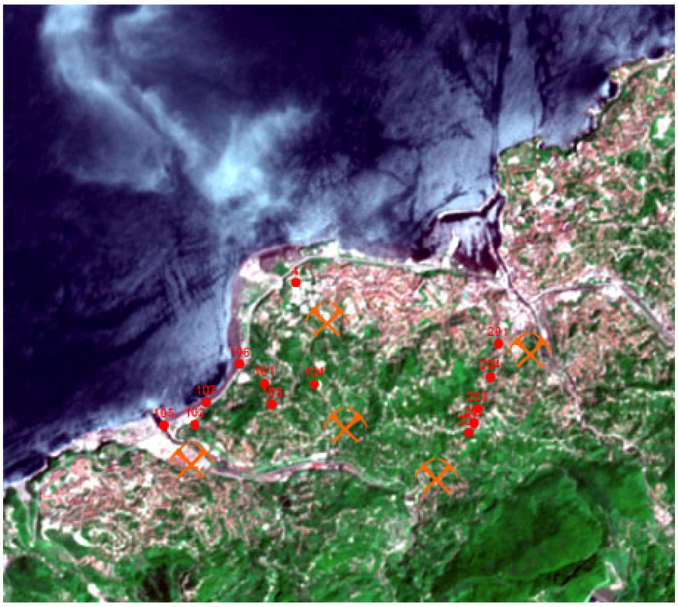


Fig.8. Extended network after 2005

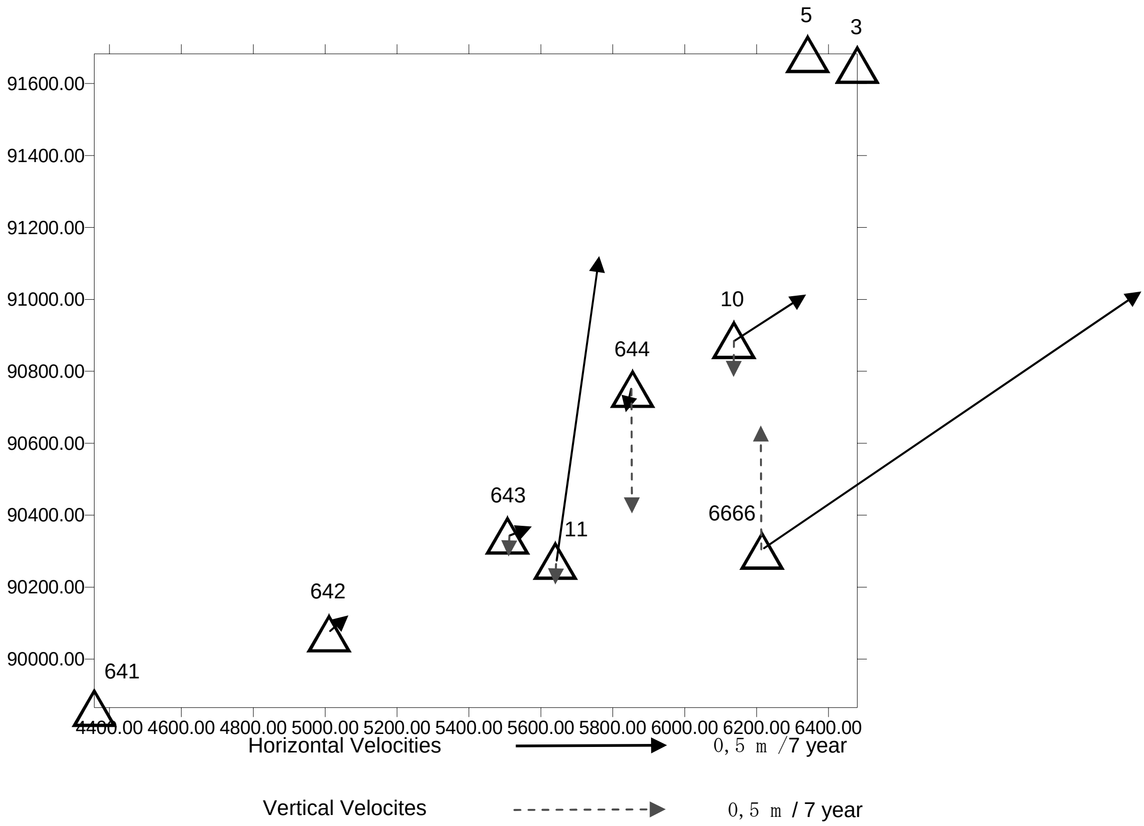


Fig.9. Deformation vectors obtained between 1996-2003

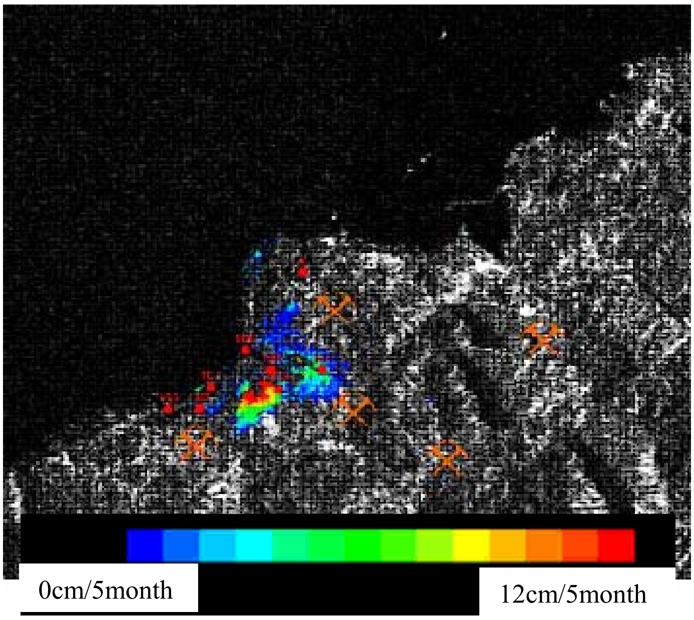


Fig. 10. Deformations obtained from InSAR in 1996

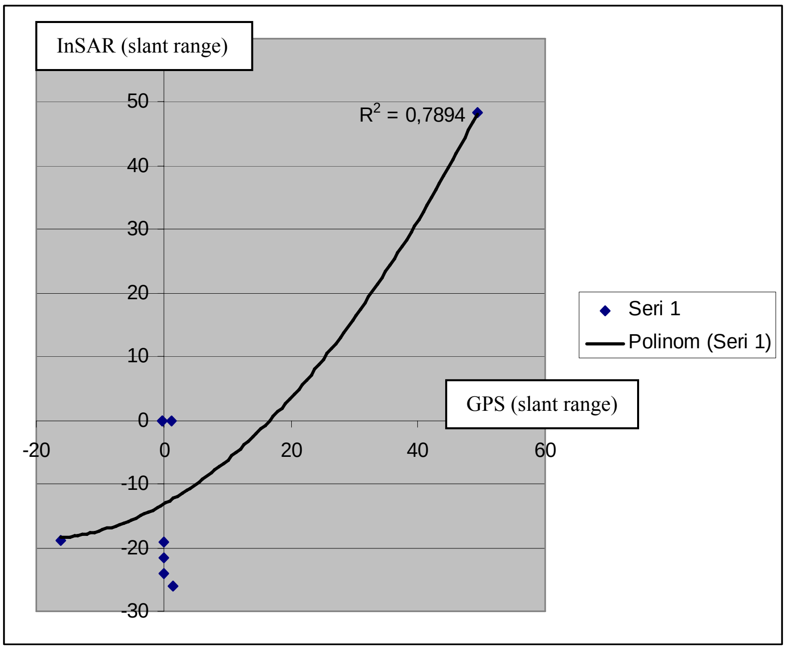


Fig. 11. Regression graphics of deformation slant ranges obtained from GPS and InSAR with an interval of 132 days in 1996

5. CONCLUSIONS

Subsidence which is an important issue of underground mining is a three dimensional deformation event which occurs due to collapsing layers from underground production plane to the earth surface. Since subsidence is a destructive event like earthquakes its advance with time must be monitored using proper methods. In this study, the subsidence effects on Kozlu region in ZHB which happen between 1996-2003 and between 2005-2006 have been investigated using GPS and InSAR techniques. In conclusion, the followings have been obtained:

- JERS-1/SAT and RADARSAT have been provided consistent results with GPS. In this way, spatial and temporal details have been possible to produce in Kozlu region.
- In the same parallel with GPS, diferential InSAR analyses have been provided to monitor the deformation in short periods such as 0-5 month
- Subsidence effects in places where GPS method can not be applied have been successfully determined by InSAR

Finally, in the light of the findings above, it can be said that high accuracy subsidence monitoring can be performed with an effective cost using InSAR technique**.**

REFERENCES

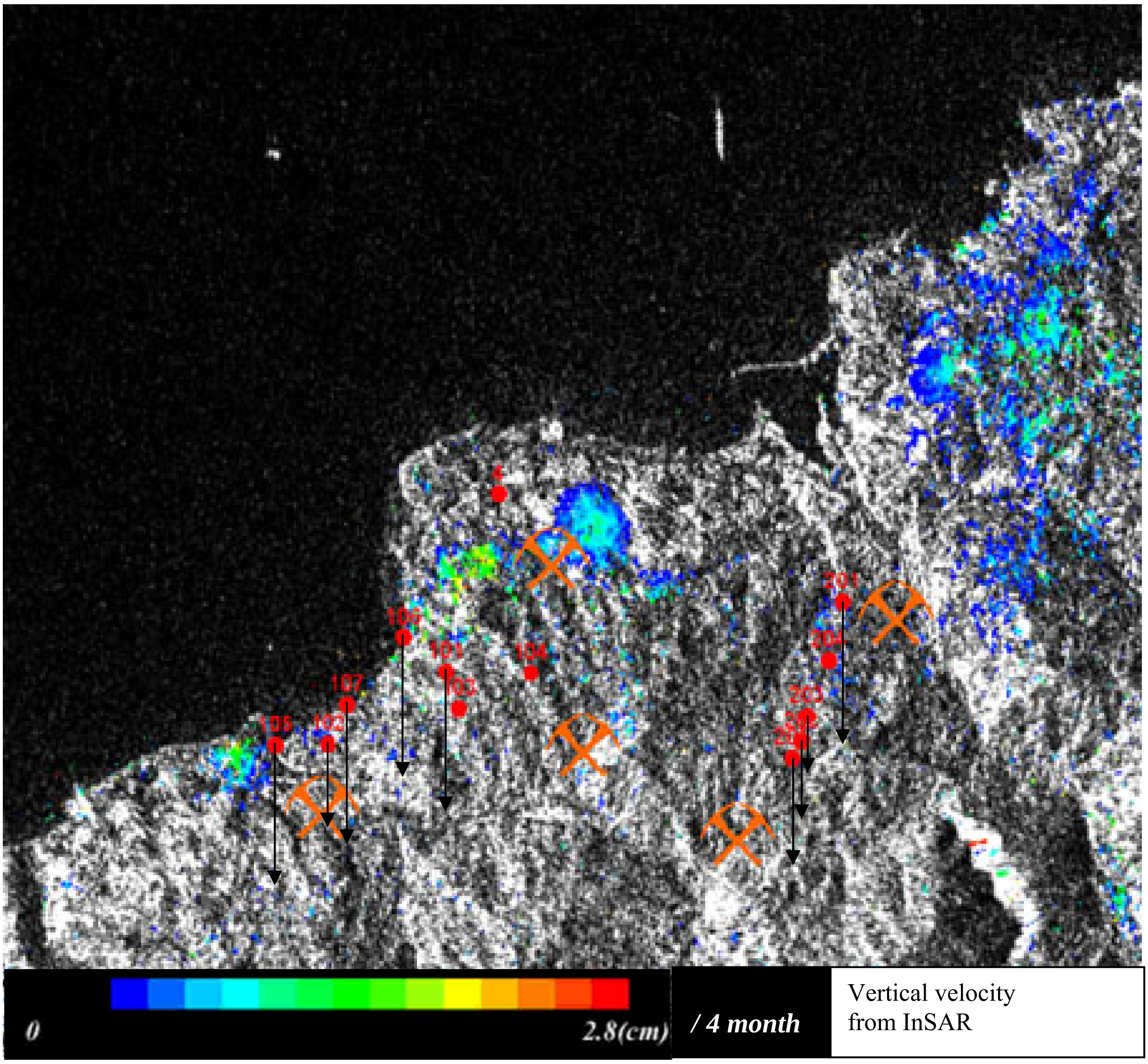
Ge, L., Rizos C., Han S. and Zebker H., (2001). *Mining subsıdence monıtorıng using the combined InSAR and GPS approach*, The 10th FIG International Symposium on Deformation Measurements, California USA.

Hirose K., Maruyama Y., Murdohardono D., Efendi A., Abidin Z. H., (2001). *Land subsidence detection using JERS-1 SAR interferometry,* 22nd Asian Confernce On Remote Sensing, Singapore

Peng, S. S., (1992). *Surface Subsidence Engineering*, 159 sh., Published by Society for mining, metalurgy, and exploration, Inc., Littelon, Colorado.

Shadbold C. H., (1977). *Minining subsidence – historical review and state-of-the-art.Proc. Conf. Large Ground Movements*, 705-748 sh., UWIST, Cardiff. Ed. J. D. Geddes, Pentech Pres, London Plymouth.

Whittaker B. N., Reddish D. J., (1989). *Subsidence occurrence, prediction and control,*528 sh., Elsecer, Amsterdam-Oxford-New york-Tokyo.



→ Vertical velocity from GPS observations 2cm / 4 month

Fig.12. Deformation vectors obtained from both methods, GPS and InSAR, in 2005

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