LAND SUBSIDENCE DETECTION IN AGRICULTURAL AREAS OF KONYA CLOSED BASIN BY PS-INSAR AND GNSS OBSERVATIONS

Fatma CANASLAN ÇOMUT (1), Milan LAZECKY (2), Aydın USTUN (3), Sefa YALVAÇ(4)

(1) Disaster & Emergency Directorate of Denizli (AFAD Denizli), 20 010, Turkey , Email:fatma.c.comut@afad.gov.tr
(2) IT4Innovations,VSB - TU Ostrava, 17 listopadu 15, 708 33 Ostrava, Czech Republic, Email: milan.lazecky.st@vsb.cz
(3) Kocaeli University Engineering Faculty Geomatics Engineering, 41 135, Turkey, Email:aydin.ustun@kocaeli.edu.tr
(4) Selcuk University Engineering Faculty Geomatics Engineering,42 250, Turkey, Email:sefa.yalvac@selcuk.edu.tr

ABSTRACT

The aim of this study is to determine and to monitor the areas affected by land subsidence caused by the decrease of groundwater, by using geodetic methods in Konya Closed Basin, Turkey. The GPS and InSAR techniques which complement each other perfectly will be used to deduce spatial deformations caused by the land subsidence.
The land subsidence activity in the area of Küçükköy situated at the Konya Closed Basin (KCB) of the Central Anatolia Region in Turkey has been studied using the Stanford Method for Persistent Scatterers (StaMPS) InSAR technique. Significant movements of land subsidence ranging from mm to cm per year were detected with ENVISAT ASAR data between 2003 and 2010 above the city center. Results are also compared with GNSS measurements. Estimated deformation rate of KCKY GPS station is approximately - 2 cm/yr.

1. INTRODUCTION

The decrease of groundwater caused by the rapid increase in population, global warming, over-use of water resources, and other influences is one of the most important problems of the world. The problems coming from the decrease of groundwater are not limited to loss of water resources. Depending on the decreasing water volume, a deformation and compaction are observed on aquifer systems that hold the groundwater. This effect triggers the subsidence of the land above the aquifer systems. The subsidence rate can reach tens of cm or dm level. According to the USGS database, 80% of the recorded land subsidence cases of more than 100 worldwide records are related to the groundwater decline [1]. The agricultural irrigation regions that use groundwater resources, metropolis, and mining areas are under threat as a result of land subsidence effect. Finally, the land subsidence damages structures such as roads, water channels, drainage systems, pipelines, and buildings in cities.
In this paper Konya Closed Basin is chosen for study area , which is one of the important centers of Turkey in terms of agricultural and industrial production. The water needed for the population, ecological system, and agricultural and industrial production should be gained from limited surface waters like Beyşehir Lake which capacity is not sufficient for the whole water demand. This is the reason why groundwater sources are often used for water supply. The significant decrease of the water level of the wells, distributed in the basin, and operated by State Hydraulic Works, has been observed since 1960. The extent of this decrease is more significant in the last decade. In some wells, the decreases of 1 m per year have been observed.
This paper briefly presents the results of StaMPS PS and SB InSAR processing of Envisat ASAR data for a case study in Küçükköy district (boundaries of KCB). The magnitudes of subsidence detected by these techniques are close to GNSS results. Farming of the fields for agricultural purposes makes difficult detecting surface deformations from the interferograms but the results show meaningful land subsidence effects of several cm per year caused by groundwater withdrawal in study area.

2. STUDY AREA

Konya closed basin, which is located in a 55 000 km^2 area of Anatolian peninsula, is the biggest closed basin of Turkey involving Konya, Karaman, Nigde and Aksaray provinces (see Fig.1).

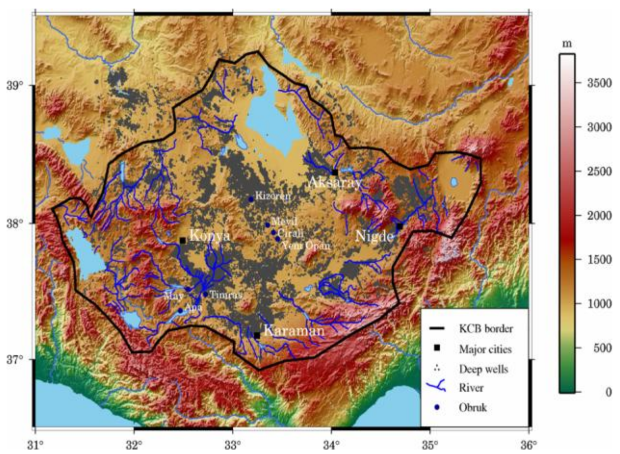

Figure 1. Konya Closed Basin [2]

The study area is entirely on the Anatolian plate and covers a limited area of Konya closed basin. It is

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assumed that the tectonic activity effect is far below the values of vertical deformations due to the land subsidence. The amount of water used at agricultural irrigation reach up to %70 of the whole country [3]. The basin has a significant water potential, but because of some reasons, small amount of rain and unconscious usage of the water, underground water levels are decreasing and the basin is faced with the risk of drought [4]. Due to the overuse of ground water, subsidence at housing site is current problem and also subsidence occurred in especially southwest part of Basin shown as Fig. 2.

Figure 2. The earth surface fissure due to land subsidence

3. VERTICAL DEFORMATION MONITORING USING GNSS MEASUREMENTS

In order to monitor land subsidence in the basin, 28 GNSS stations have been established in the first months of 2011 (Fig 4.). 10 campaign of GNSS measurements has been obtained with 3 months of interval until now. Each station has been measured at least 8 hour on consecutive days in order to check the precision of the geodetic network. GNSS data has been processed on GAMIT/GLOBK V10.4 in daily basis. The IGS (International GNSS Service) stations located near the test area about 1000 km has been used so as to defining reference frame on the ITRF system. The GLRED module of the GAMIT/GLOBK suite has been used to obtain GNSS time series for each station. Tab.1 shows subsidence rates for each stations.

Table 1. Subsidence rates at GPS stations

GPS Points	Longitude	Latitude	Subsidence (cm/yr)	SD
ABTL_GPS	32.74541	37.73688	-10.73	4.20
AKCY_GPS	33.20190	37.70016	-4.88	2.96
ALHY_GPS	32.65269	37.54085	-0.45	3.54
ALKV_GPS	32.47702	37.76996	-0.19	3.13
BELD_GPS	32.48647	37.87735	-22.45	1.74
CARK_GPS	32.55574	37.66420	-3.25	3.80
CENG_GPS	32.74926	38.03669	-6.74	3.54
CUMR_GPS	32.70461	37.58412	6.57	3.19
D114_GPS	32.58672	37.66195	8.38	3.05
DNEK_GPS	32.60985	37.32610	4.53	3.09
DVAN_GPS	32.91753	37.95494	1.99	3.17
ERKY_GPS	32.66404	37.80160	-0.59	3.60
FETH_GPS	32.75047	37.62015	-0.47	3.20
HAVD_GPS	32.55700	37.65262	3.55	2.70
ISML_GPS	33.11834	37.70911	13.65	2.91
KAMN_GPS	33.22027	37.19323	-11.87	1.88
KCKY_GPS	32.81633	37.68364	-9.52	3.52
KONY_GPS	32.39391	37.86887	-4.59	2.95
MUGR_GPS	32.68077	37.55918	-0.23	3.22
MVKM_GPS	32.51593	37.86817	-16.38	3.57
PNRB_GPS	32.58236	38.05205	-0.27	3.64
SARC_GPS	32.63991	38.07485	-2.50	3.30
SINC_GPS	32.90846	37.36879	12.45	3.36
TUTP_GPS	32.71625	38.13498	-5.73	3.47
ULMK_GPS	32.51452	37.83521	-2.28	4.38
YAZR_GPS	32.44054	37.95946	2.72	3.17

Time series of displacement in terms of local coordinates at KCKY station is presented as follows (Fig. 3):

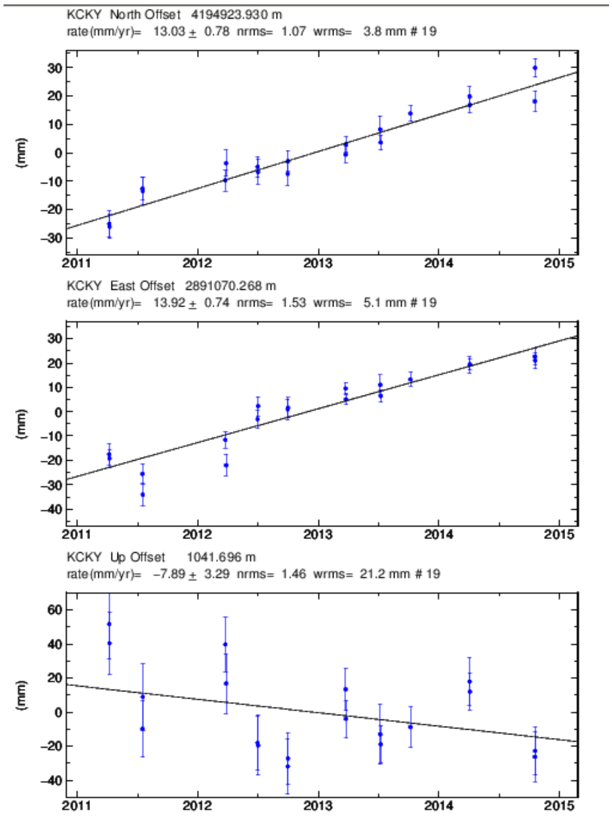

Figure 3. KCKY Stations Time Series for North East and Up Component

Finally, the GLOBK module is utilized for predicting deformation rates of ten period (2011 doy 097 -- 2014 doy 290) of the GNSS stations measurements.

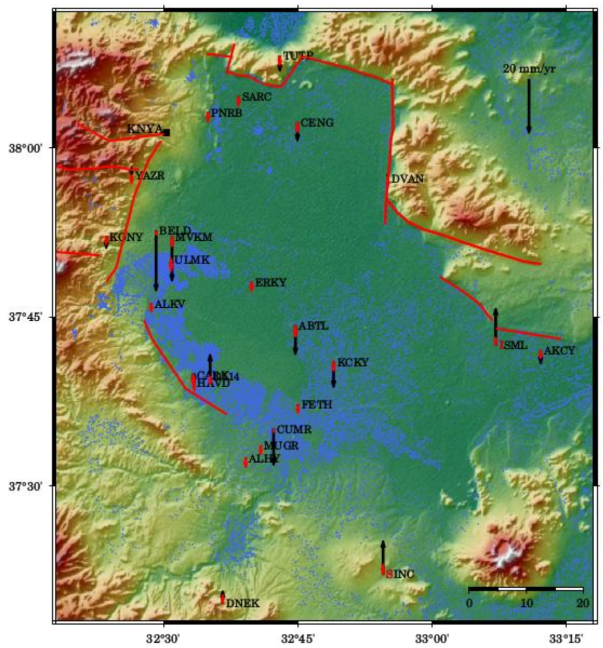

Figure 4. Kalman Filter estimating results for 10 period of GNSS measurements

4. SUBSIDENCE MONITORING USING PS-INSAR

We use the Stanford Method for Persistent Scatterer (StaMPS) to generate interferogram time series. Two stacks of ENVISAT ASAR images (Swath IS2, Incidence Angle mid-range: 23°), acquired between November 2002 and June 2010, have been independently processed through the StaMPS algorithm [5]. Each dataset consists in 15 ascending Single Look Complex (SLC) acquisitions (Track 114 and Track 343). In Fig. 5 it is shown the ground coverage of both tracks with GNSS Stations. Selection of image frames were considered especially through GPS points, and both tracks overlapping part is over almost that points.

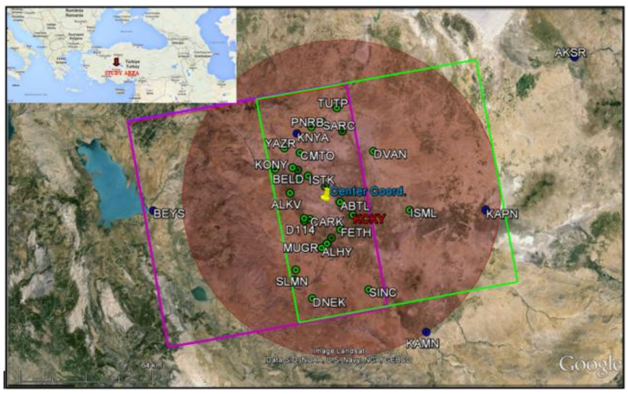

Figure 5. Purple frame (Track No: 114) and green frame (Track No: 343) refer to the ENVISAT ASAR images ground coverage, while the green points refers to GNSS Stations (including red KCKY point). Red circle is generally study area(AOI' Center Coordinate: 37°43'9.00"Lat., 32°39'6.34"Lon.). Inset shows the location of the area of interest (AOI), that includes the city of Konya (Province of Küçükköy).

From the result of PSInSAR and SB processing, subsidence occurred by decrease of groundwater can be estimated. Fig. 6 - 7 shows all results from PSInSAR and SB processing using both tracks.

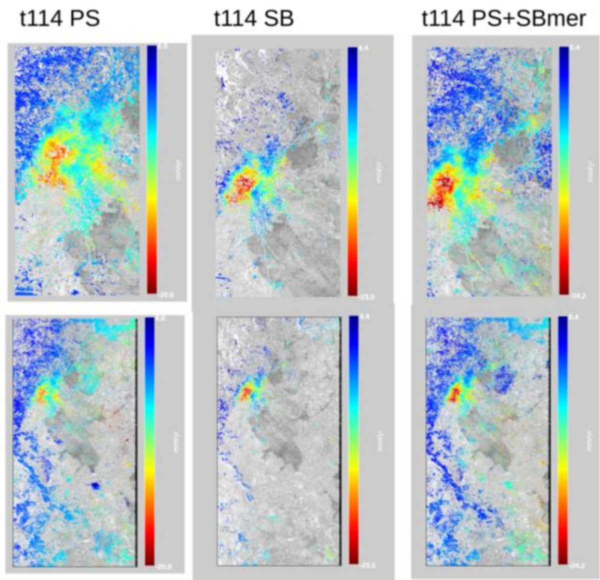

Figure 6. PSInSAR and SB results comparison for 114 track

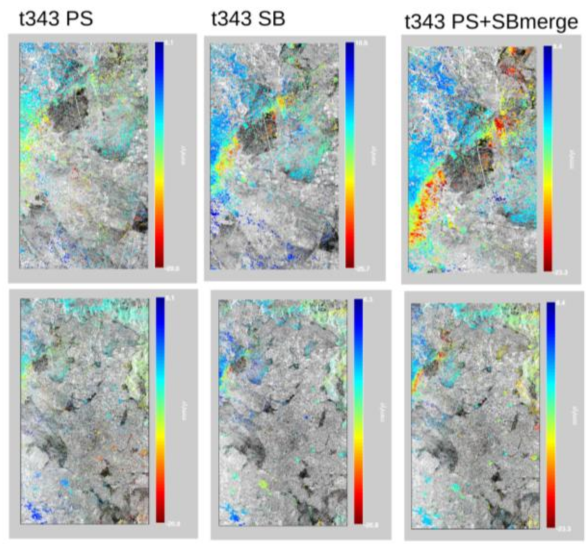

Figure 7. PSInSAR and SB results comparison for 343 track

These results are outputs of semi-automatic StaMPS processing chain and in case of need of reliability analysis, the results should be further investigated. Anyway, results from both tracks show very similar behaviour in their overlapping area.

Due to the overuse of ground water, subsidence occurred in surrounding of Konya City centre. Especially, subsidence at housing site is current problem at the northern part of Konya. InSAR results depict the extent of subsidence trough.

5. GPS AND INSAR COMPARISON

For all GPS points where can be seen from Fig.5, we have been estimated velocity (mm/year) and then we make interpolation. As a result we see the areas how they are moving, in average. The grid on the middle part in Fig. 10 is a result of interpolation from the GPS points (Tab.1). There can be seen that it corresponds relatively well with the InSAR results from Track 114 on the left and Track 343 on the right part. (the scale is almost the same, after recomputed the LOS to vertical).

Because of the thick vegetation, Persistent Scatterers cannot be detected close to KCKY GPS station, it can be clearly seen from Fig. 8 that directly in KCKY place there are no PS points because of vegetation. For this reason we have selected points from the Küçükköy village next to KCKY. There are 17 PS points including radius of 500 m.

Figure 8. PS Point over AOI

And it is shown on Fig 9., the time series (StaMPS PS+SB) of the 17 points of the Küçükköy village. We can see the general trend of the deformation that is expected to be approximately between -13 to -17 mm/year.

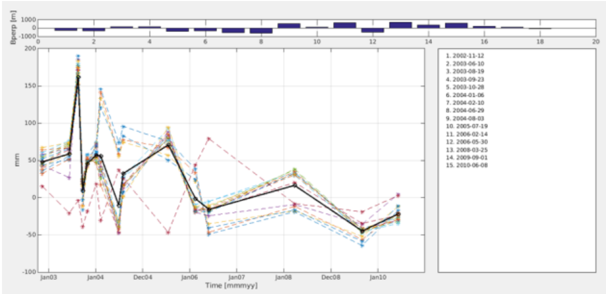

Figure 9. StaMPS PS + SB time series graph

That differences (Fig. 10) were mostly due to phase unwrapping and/or APS estimation errors within large distances of PS points. To overcome such issues in agricultural areas, application of L-band data for monitoring deformations should be tested in future work.

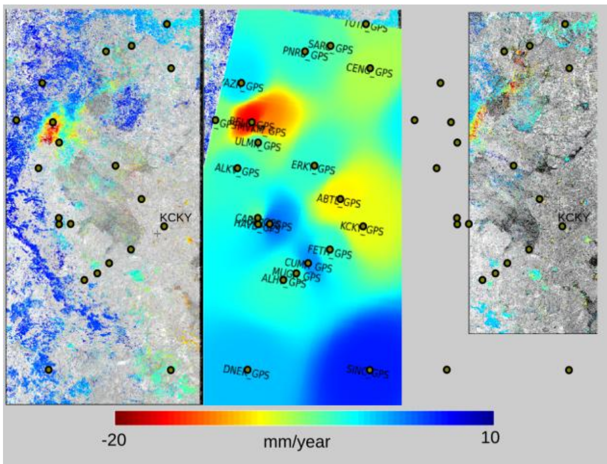

Figure 10. Differences between 114, 343 and GPS interpolation (left is 114, right is 343)

6. CONCLUSIONS

PSInSAR+SB processing with ENVISAT ASAR images brings significant results of detection of land subsidence as well as GPS studies. Especially, it is effective to detect very slow land subsidence movement at high vegetation area.

In this study we compare the StaMPS results from November of 2002 and June of 2010 with interpolated GPS velocities results. We make interpolated area from velocities and compare this interpolated area with InSAR results which generally are fit. Because of low sensitivity of InSAR to horizontal displacement, we compare only vertical movements.

Detected movements from InSAR (2003-2010) are very similar to those detected by GPS in further period (2011-2015)

The InSAR results show that C-band data indicate appropriate results and also C-band Sentinel-1 with similar resolution as Envisat should deliver reliable outputs.

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