RECENT TECTONIC FEATURES OF MID-SEGMENT OF THE NORTH ANATOLIAN FAULT USING GPS AND INSAR TECHNIQUES

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Abstract

The one of the major fault system all over the world is the North Anatolian Fault (NAF). There have been lots of destructive earthquakes on the NAF. The important part of the NAF is central part (mid-NAF) such as from Ladik to Ilgaz. In its central and eastern part, the NAF has an asymmetric fish bone structure consisting of an east-trending main branch and splines veering southwestward, towards the interior parts of Asia Minor. Main branch and the splines of the NAF dissected the Anatolian Plate into fault-bounded continental blocks.

The GPS campaigns were carried out in order to describe earthquake potential and block kinematics in study area by financial support of TUBITAK and ITU.

GPS observations were carried out between 2000 and 2004. The data from campaigns were processed by using GAMIT/GLOBK software.

The Radar images were obtained to expand velocity field relating to study area and to define deformation independent from GPS stations. Obtained radar images were processed by InSAR (Interferometric Synthetic Aperture Radar) technique using ROI_PAC (Repeat Orbit Interferometry Package) and DIAPASON (Differential Interferometric Automated Process Applied to Survey of Nature) software. The deformation occurred between acquired times of two images was determined from interferogram of the image pair belonging to mid-NAF by eliminating noise, topographic and orbital effects. The InSAR results and GPS products were processed altogether.

Introduction

The Anatolian plate started to escape westward about 5Ma along two strike-slip faults the Northern and the Eastern Anatolian Transform faults (NAF and AEZ, respectively). Within the NAF zone (NASZ), there are different offshoots (splines) that leave the main branch of the NAF and extend into the interior parts of Anatolia. As a result of differential movements along both the main branch and the offshoots, these fault-delimited blocks display different rotations as indicated by palaeomagnetic data (Isseven and Tüysüz, 2006). In this paper, the sutudy has been focused the biggest offshoots to display the sharing of movements between blocks in NASZ by using GPS and InSAR technique.

Main branch of the NAF forms the northern boundary of the westward moving Anatolian plate. Most part of the main branch in the study area was broken during the 1943 Tosya earthquake (M=7.6, surface rupture was 260 km in length, Barka, 1996). The longest offshoot, the Sungurlu Fault, leaves the main trunk in the town of Niksar to the east and extends southwestwards. Eastern part of Sungurlu Fault was broken during the 1939 Erzincan earthquake (M=7.9, surface rupture was 370 km long, Barka, 1992 and 1996). The Çaldag, Osmancık, Gumus, Merzifon and Amasya blocks located between the Sungurlu Fault and the main branch are separated from each other by secondary faults, which are also active as indicated by historical and instrumental earthquake records (Eyidogan et al., 1991; Ambraseys and Finkel, 1995).

GPS Data

The Central NAF GPS network (MID-NAF) was designed to control the movements of both the main branch of the NAF and the block-bounding active faults described by Isseven and Tüysüz (2006) using 16 force-centered stations.

GPS measurements were started with 16 well-distributed stations in August 2001 and repeated in following four years. During both the third and the fourth campaigns SNGR and IHGZ stations were run as throughout the campaign in order to link our measurements together to International GPS Service for Geodynamics (IGS) network. The duration of the measurements was about 8 hours per day with an interval of 30 seconds and all sites were observed in three consecutive days.

Pseudo-range and phase GPS data has been analyzed using GAMIT software as single-day solutions (King and Bock, 2003). Station coordinates, satellite orbits, 13 tropospheric zenith delay parameters per site, phase ambiguities using doubly differenced phase measurements are solved while applying loose a priori constraints to all parameters.

The IGS final orbits, IERS earth orientation parameters are used In addition to our sites, 7 IGS stations in the first campaign and 11 IGS stations around the region in the second, third and fourth campaigns are incorporated into the analyses to serve as ties to ITRF2000.

Finally, reference frame for our velocity estimates were defined by using generalized constraints for transformation parameters (McClusky et al., 2000).

Block Model

The GPS velocity field has been well-determined and modeled for central of the NAF. In our study, the center of the NAF has been modeled with using DEF-NODE software (McCaffrey, 2002). The software can calculate the three-plate problem of slip partitioning using spherical Euler poles to describe both the kinematics of block motions and the relative slip on block-bounding faults. Backslip can apply to estimate the contribution of fault locking to the total velocity field.

The software uses the input parameters such as long term slip rate, locking depth, the location and dip angel of faults, seismologic data and GPS velocity vectors. The input parameters were described that, locking depth was obtained from seismological data as 16 km. The faults' locations were determined from filed study and morphology, seismicity, mapped faults and historical earthquakes. The dip angle was taken the vertical because the chi2 reaches up to minimum value upon the angle was vertical.

The deformation is fit well by arctangent function explained in Savage and Burford (1973) as a characteristic of elastic strain accumulation. This illustration is given in Fig.1 and Fig.2. The profile is especially affected from two faults extended in our region that are main brunch of the NAF and Sungurlu faults.

Slip Rate

The geological slip rate reported in literature ranges from 20.5±5.5 to 27±7 mm/yr (Kozaci, 2007, Reilinger 2006, Hartleb, 2003 and Hubert-Ferrari, 2002). It is difficult to compare the present-day rates of faulting and long-term geological rates because of the large uncertainties on most geological estimates (Reilinger, 2006). However, the reported geological slip rate gives a good coherence as compared with GPS-derived slip rates (Fig.2).

The GPS-derived slip rate of the Mid-NAF acquired from this project rages from 18.7±1.6 mm/yr to 21.5±2.1mm/yr on main brunch of the NAF as shown Fig.2. On the Sungurlu fault, it has a small slip rate against to main brunch that is approximately 3±2mm/yr.

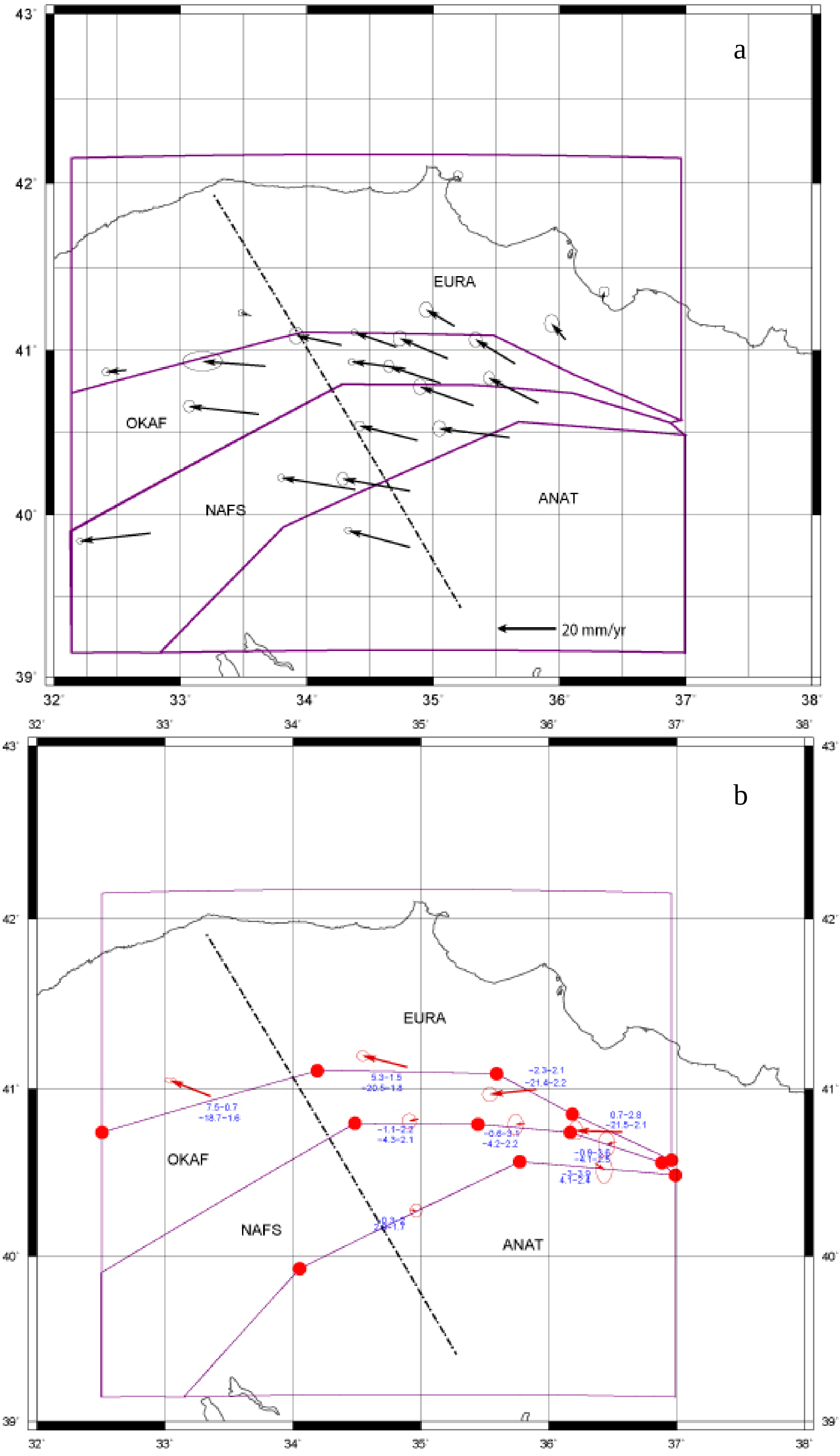

Figure 1. Upper figure (a) shows the GPS velocity vector field according to Eurasia fix in ITRF00, the lower figure (b) indicates the GPS-derived slip vectors on the main brunch of NAF, Laçin and Sungurlu faults from north to south respectively. The abbreviations are

ANAT: Anatolian block, EURA: Eurasian block, OKAF and NAFS are the interior block delaminated by local faults. In the lower (b) figure the slip rate has two values, the uppers are the normal components and the lowers are horizontal components and the red points indicate characteristic points of the faults. The dashed line shows profile location across to faults.

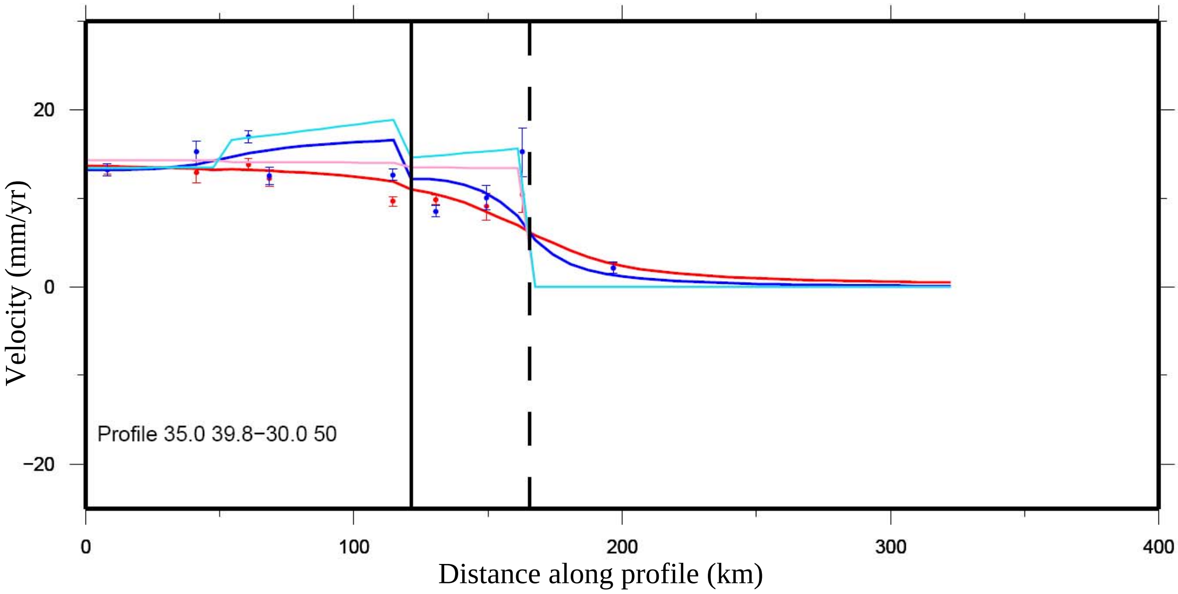

Figure 2. The plot showing GPS velocities parallel to the main brunch of the NAF and Sungurlu fault as illustrated with dashed line in Fig.1. The dashed line in this figure represents to main brunch and solid line shows the Sungurlu fault. The bold blue line for strain accumulation, light blue line for unlocking time deformation, the bold red line for perpendicular deformation of the fault and light red line for unlocking time deformation of perpendicular to fault are derived from GPS velocities.

InSAR

The InSAR (Synthetic Aperture Radar Interferometry) technique is a useful tool for describing deformation according to GPS and other terrestrial systems. In this study, to determine the deformation of mid-NAFZ, the technique has been used. The numbers of frames used in process are 9 from 1993 to 2000 in two orbits that are 0819-Ascending and 2781-Descending.

The data have been processed by ROI_PAC and DIAPASON software using two images on the same orbit and one DEM (Digital Elevation Model) belonging to the exactly same area. This process strategy was explained Zebker and Goldstein (1986).

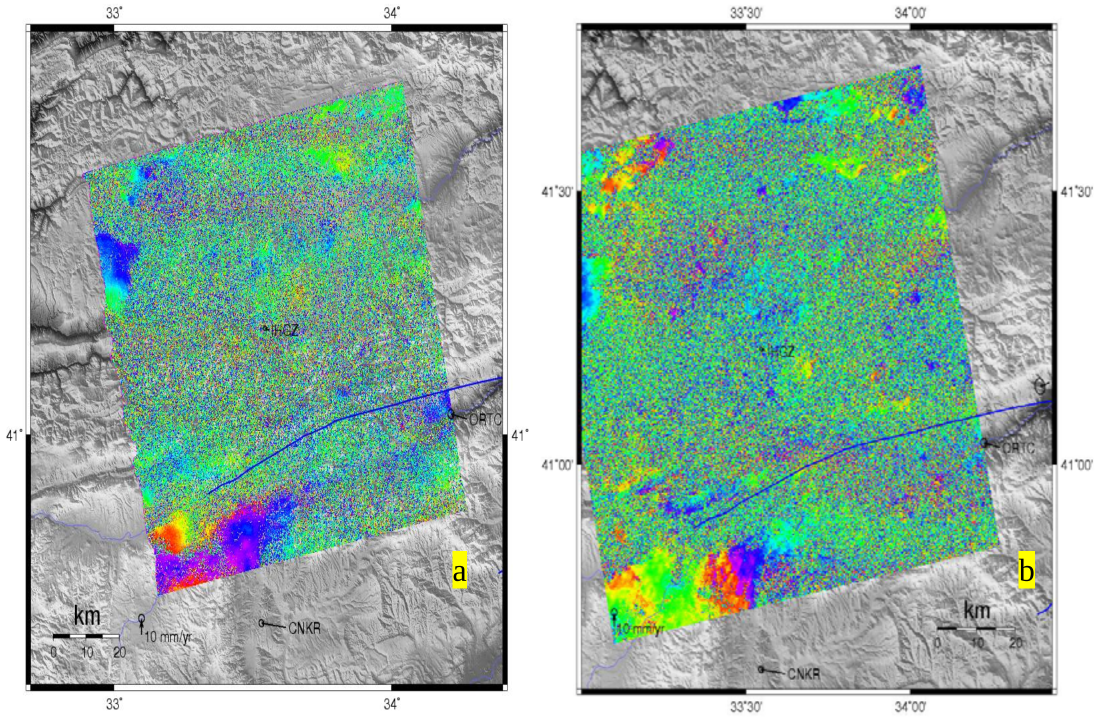

Figure 3. The results of the InSAR process have been illustrated. The right picture (a) has two different date data (930611-990510) data processed by ROI_PAC. The left picture (b) has also two different date data (970609-990719) evaluated by DIAPASON.

Conclusion

After evaluating the GPS and InSAR data, the extended velocity field of mid-NAF was obtained. To calculate the strain accumulation from new extended velocity field, the profile which is perpendicular to faults was selected as explained in Gomez (2007). As a result;

1. Mid-NAF is active as much as the other site of the NAF.
2. The results obtained from GPS data were confirmed and extended by using InSAR data.
3. The deformations in the center of the study area were dispelled largely by main branch of the NAF, when the profile results were examined.
4. The Sungurlu fault is also active but its velocity is slower than the main brunch of the NAF.
5. Çankırı basin is one of the most active areas as can be seen from InSAR and GPS results (Fig. 3).

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