UNITED NATIONS **E/CONF.100/CRP.13**

ECONOMIC AND SOCIAL COUNCIL

Eighteenth United Nations Regional Cartographic Conference for Asia and the Pacific
Bangkok, 26-29 October 2009
Item 7(a) of the provisional agenda
Country Reports

Application of Geodetic Tools for Crustal Deformation Monitoring in Iran*

*** Prepared by Tavakoli.F, Nankali.H.R, A.Soltanpour, M.Sedighi, F.Khormi, S.Arabi, Surveying and Geodesy Department, National Cartographic Center (NCC), Iran**

Application of Geodetic Tools for Crustal Deformation Monitoring in Iran

Tavakoli.F, Nankali.H.R, A.Soltanpour, M.sedighi, F.Khormi, S.Arabi

Surveying and Geodesy Dept
National cartographic center (NCC) of Iran
farokh.tavakoli@ncc.org.ir
Tel: 66071098

Iran is one of the most tectonically active zone in Alpine-Himalayan seismic belt where has been shaken by largely destroying historical and instrumental earthquakes (Engdahl et al., 1998; Ambraseys & Melville, 1982). The shortening between Arabian and Eurasian plates in Iran is mainly distributed on Zagros and Alborz belts. Several GPS campaigns were carried out on different networks between 2000 and 2008 and provided the horizontal velocity field in Iran. In this work, for the first time we used a continuous GPS network, precise leveling, Insar, and absolute Gravimetery are used to better understand the tectonic deformation in different active part of the country. These techniques will bring us more precise information on crustal information (shortening and strike-slip rate in Iran as horizontal movements, subsidence and uplift as vertical movements) and geophysical phenomena such as ionosphere disturbances and water vapor.

Keywords: GPS-Geodynamics-Iran-Fault-Tectonic

1) Introduction:

The present tectonics in Iran results from the north-south convergence between the plates of Arabia to the south-west and Eurasia to the north-east (Jackson and McKenzie, 1984) at a rate of about 22 mm/yr (Nilfouroushan.,2003; Vernant *et al.* 2004) Fig.1. It involves a juvenile continental collision (Falcon, 1974; Berberian and King 1981) except along the Makran, its south-eastern margin, where a remnant part of the Tethys oceanic lithosphere subducts northward beneath south-east Iran (Byrne *et al*. 1992). Within Iran, most of the deformation is accommodated in the major belts (Zagros, Alborz, Kopet-Dag) and along large strike-slip faults which surround blocks (Central Iran, Lut and the southern Caspian sea) with moderate relief and seismicity (Jackson and McKenzie 1984; Berberian and Yeats, 1999).

Figure1. Topographic and active fault map of Iran and surrounding regions. Geographic and tectonic features indicated are: Afghanistan; Pakistan ; Apscheron–Balkhan sill; Cheleken; South Caspian basin ; Talesh mountains; Alborz mountains; Kopeh Dagh; Zagros mountains; Oman Line and and Makran

This convergence is accommodated almost entirely in the Alborz (6–8 mmyr^{-1}) and Zagros Mountains (6–9 mmyr-1), the remaining deformation being located somewhere in the south Caspian basin. At the southeastern margin of the Arabia-Eurasia collision zone, along the Makran, the shortening is absorbed by subduction of oceanic lithosphere beneath southeast Iran at 19.5 mm yr^{-1} (Vernant *et al*. 2004) In the Persian gulf no shortening is observed (Tatar *et al*. 2002). As previously proposed on the base of the seismicity (Jackson & McKenzie,1984) and recently confirmed by geodetic measurements (Vernant *et al.* 2004), central Iran does not significantly deform and acts as a backstop of the Zagros Mountains. Since the central Iranian block (CIB) moves at 13 mm yr^{-1} to the north relative to Eurasia, the relative velocity between the CIB and the Arabian plate is 7 mm yr^{-1} in a North-South direction. According to this situation, it is important to monitor the crustal deformation using geodetic data such as VLBI,SLR,In SAR, and GPS. Among them GPS has several advantages (continuous collection, cheaper, and more compact) and therefore it is easier to construct lots of observation stations. With the recent advance in GPS receivers technology and scientific software's (Bernese-Gamit/Globk-GIPSY OASIS) and using precise satellite orbit and clock, we can achieve the accuracy for station position their velocity for geodynamic applications.So in 2005 National Cartographic Centre of Iran (NCC) started to built a GPS permanent observation network for crustal deformation monitoring and estimating geohozard in Iran.The network consist of 113 GPS observation site which distributed in the active part at the country. To reach the goals we also benefited the studies and remark of GSI(Geological Survey of Iran) and IIEES (International Institute of Earthquake Engineering and Seismology).This article introduce IPGN and final result from analysis center.

2) IPGN Network Configuration

The network consists of two parts: base network and regional networks. The base network consist of 41 station which distributed in Zagros-Alborz-Lut-Kopet-Dag-Central Iran- Makran and east of Iran in order to monitor the total motion and geodynamics of plates boundary. Fig 2

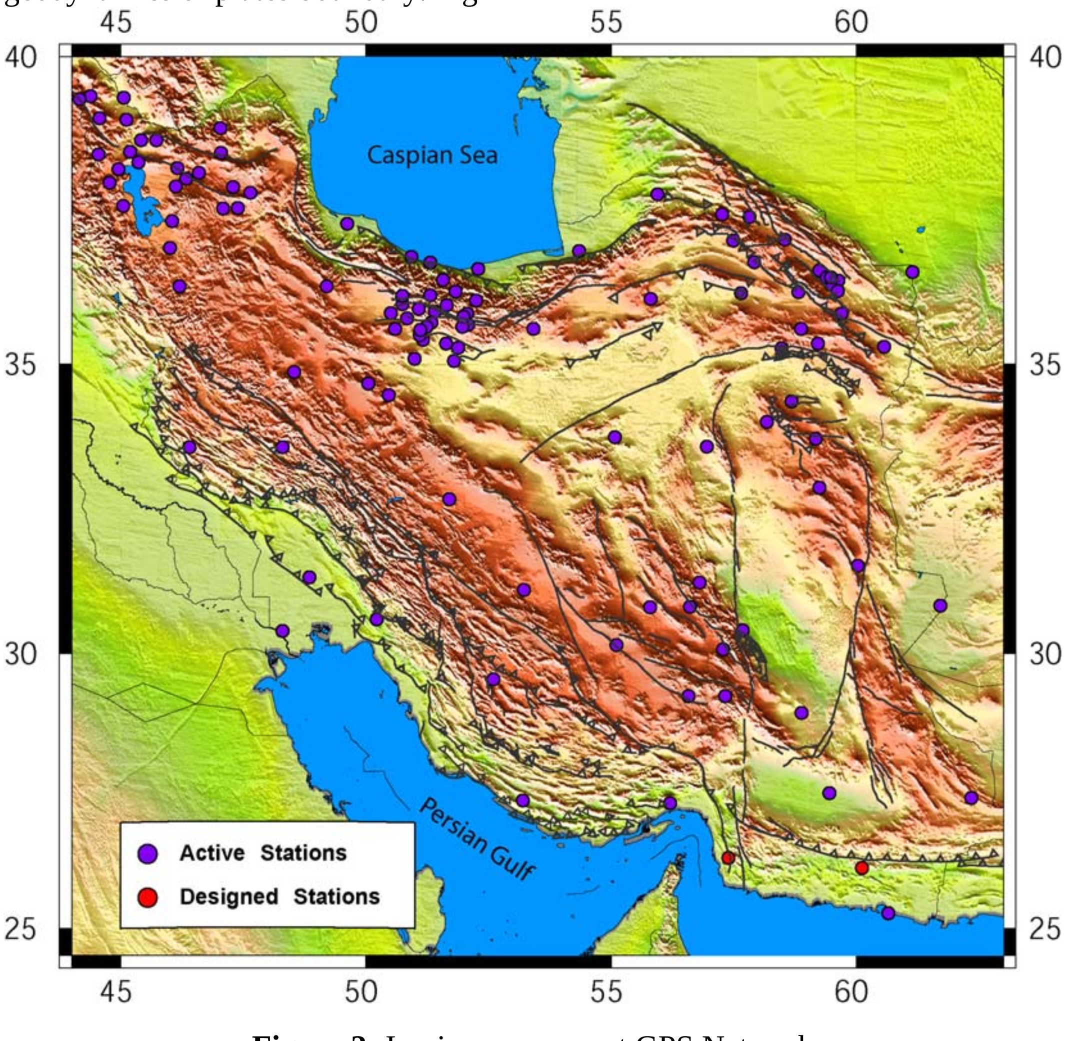

Figure 2- Iranian permanent GPS Network

Regional networks are in tehran,tabrize and mashhad areas and the distance between the stations is about 25-30 km. Tehran as the capital with 12million population located in the southern mountain foots of central alborz in a highly active zone. In order to monitor tectonic deformation in this area 25 stations are established in different part according to geological and geodetical parameters. Fig 3.

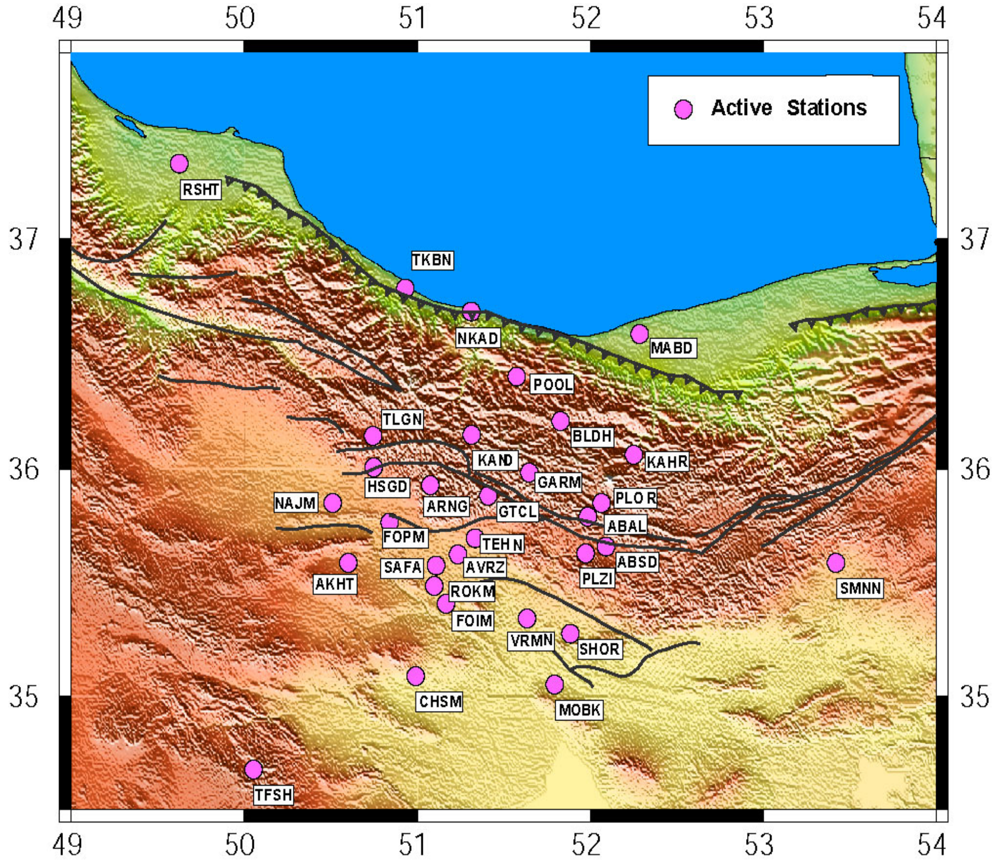

Figure 3- Tehran Network

In the western and eastern Azerbaijan and ardabil areas there are many active faults such as Tassouj and north Tabrize faults. Tabriz city is located at 100km distance from this fault and historical earthquakes with 6 to 7 Richter have occurred in this area. So in order to monitor this part 20 stations are established. Fig 4

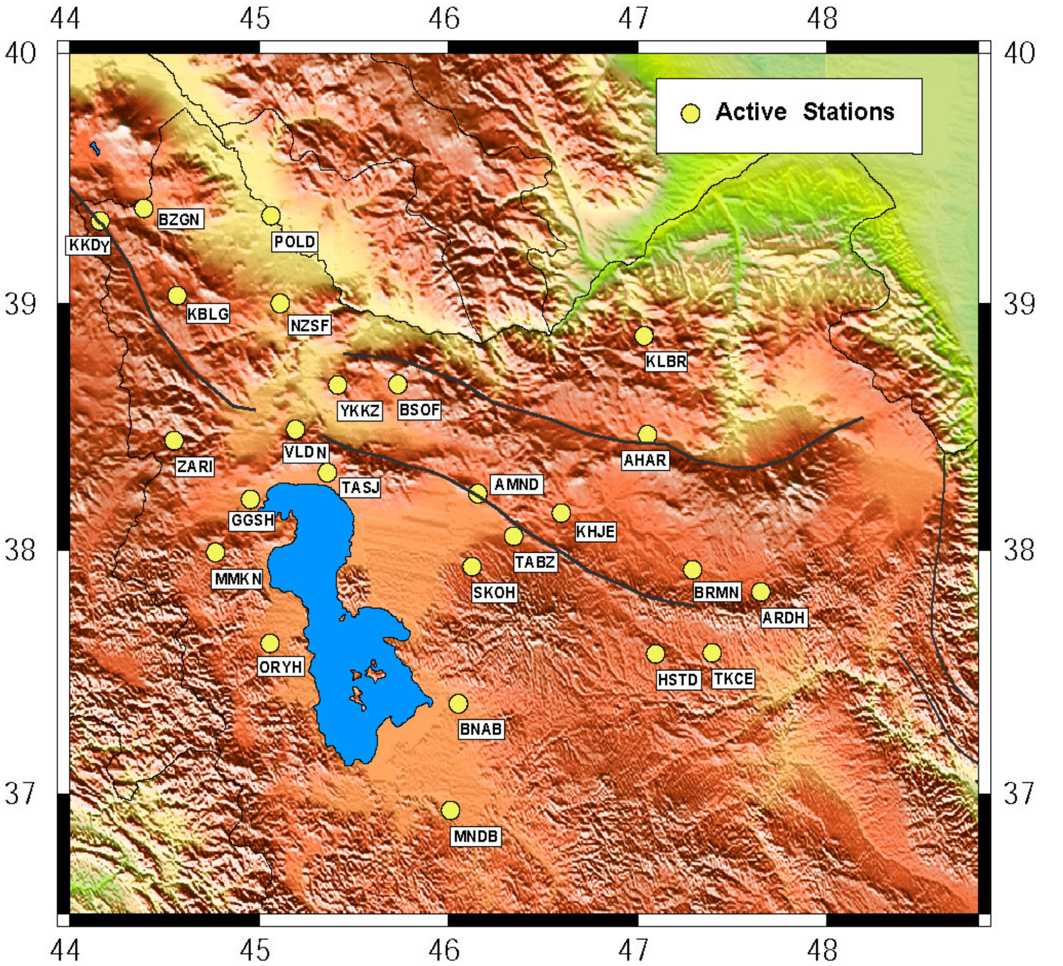

Figure 4- Tabriz Network

The 3 cities of mashhad and neishaboor and sabzevar had also historically shaken by many earthquakes which destroyed the areas and killed many people due to neishaboor dasht-bayaz and kopet-dag faults. So 21 stations are established in order to monitor the active tectonic of this area. Fig 5

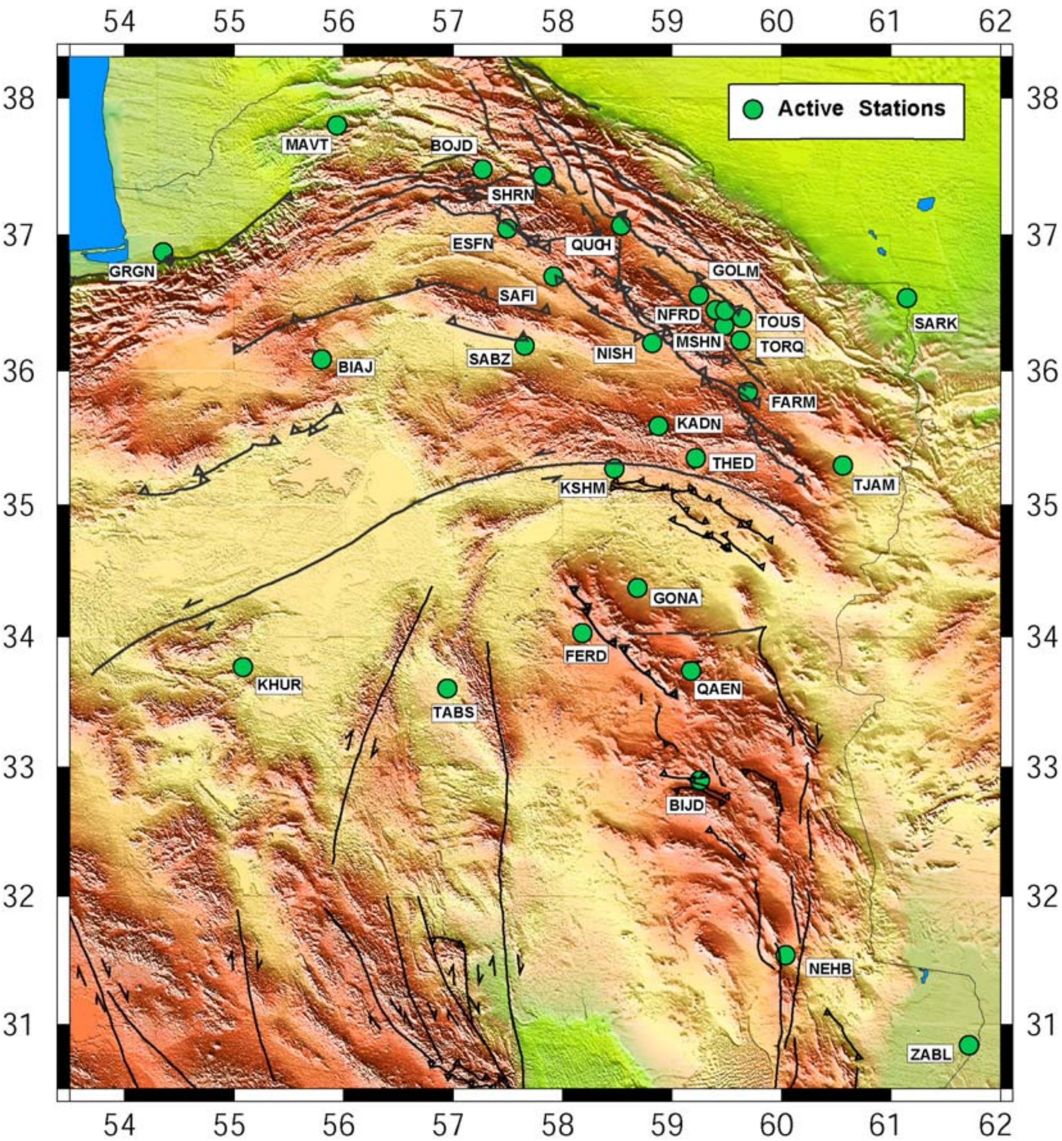

Figure 5- Mashhad Network

3) Observation Station:

The function of observational station is to receive signal from GPS satellite, to accumulate them and to communicate with data center. For this purposes each station is provided with a GPS antenna, GPS receiver, communication device and backup battery. The GPS antenna is fixed on a station pillar. The receiver and other equipment are stored in the rack near Pillar. A reinforce concrete pillar is 1.5m highs standing on the reinforced concrete base (1.20m * 1.20m)and 2m cube.The base of the pillar is reinforce concrete too. A rack near the pillar keeps the GPS receive, the modem and other instrument. A fan attach to the top of the rack is controlled to keep air condition suitable for instruments and also heather for temperature control. Cables and electric power supply and telephone line are buried underground in order to preserve diminish vibration effect by wind. Since it is expected that uneven subsidence of a pillar might occur a tilt meter installed in order to check any inclination from the initial state. 93 of the station also equipped with meteorological sensor for GPS meteorology. Fig 6

Fig 6- GPS receiver and equipment

GPS receivers installed in the rack are dual frequency from Ashtech uz12(ICGRS)and CGRS with 128 MB internal memory. All receivers are scheduled to receive dual band carrier phase data and code data every 30 seconds in daily mode (24h). Fig 7

Figure 7- GPS Station

Antenna is set on the top of the pillar covered with a radom. 85% of remote stations are equipped with modems and commercial telephone lines and 15% was setup with GSM modem. A transmission of 9600 bps is available for the connection to the data centre.

Data Centre:

The Master Data Centre for controlling the network and data analysis is settled in Tehran at National Cartographic Centre of Iran. Also we have 4 data centre in Tabriz-Mashhad-Hamedan-Ahvaz that control the operation of their observation sites, data communications, data management and send them to the Terhan for final processing. Data stored by the receivers are downloaded once per day from data centres and master data centre according to define procedure in midnight. The size of data is about 1.6mb that needs 10minutes with digital line. Down loaded data is archived into the database in RINEX format using TEQC program from unavco and compress for final archive in the FTP site of NCC on the 2 server with 300 Gb capacity

Data processing:

After archiving data, the data processing unit start network solution process of GPS data include the network and IGS stations.
The data processing unit consists of 6 engineering workstations with Linux operating system. The data are processed by precise analysis software Gamit-Globk ver 10.20 which was develop by MIT and SIO, in two steps. In the first step Gamit analyzes these data from user specified. Clusters of stations to create loosely constrained (buty ambiguity resolved) estimates of station coordinates. In the second step Globk combine these Gamit output files to create solution file in the SINEX format, containing loosely-constrained estimates for entire network. Globk is basically a kalman filter and uses the covariance matrices obtained by Gamit.
The process is performed twice: once with rapid orbit from IGS outputs and the final orbit(Precise ephemrids)after two weeks. The former is used to obtain rapid solution and the later for final solution of whole network.

Outputs and Results:

Several kinds of results obtained by routine analysis such as, time series group of coordinate's sites, time series of relative position of two site (baseline time series) displacement vector and also velocity filed. The summery of results and reports can be seen on NCC web site. (http://www.ncc.org/English/geodynamic. Fig8, Fig9 shows the time series of Tehran station and also the present velocity field which produce by GMT. The new next product strain rate map which will appear soon.

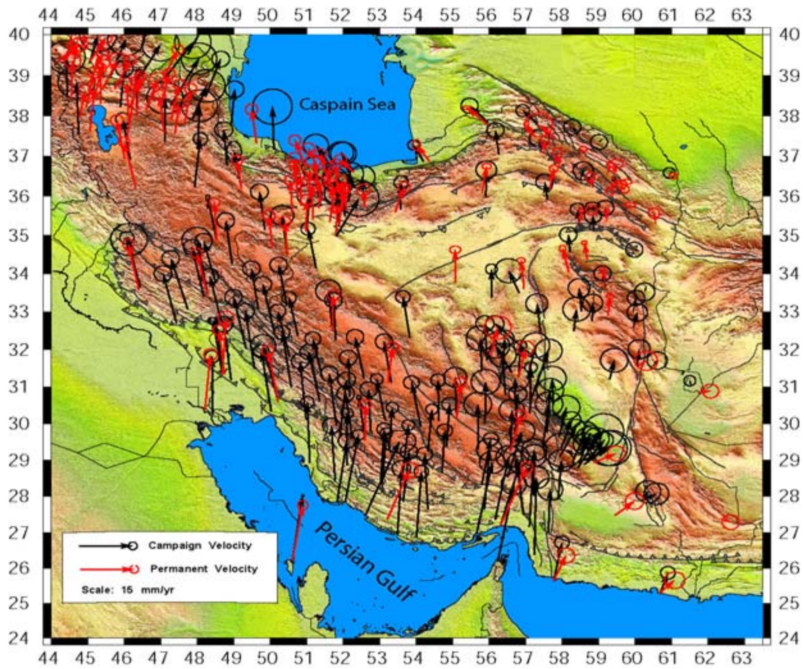

Figure 8-GPS Velocity Filed estimated with respect to Eurasia

Insar Measurement

Yazd-Ardakan plain, central Iran is an arid region with a shadow rain where extra-extraction of ground water for agriculture purpose caused a serious subsidence. We used differential interferometric SAR technique for investigating temporal and spatial behavior of surface deformations in Yazd, central Iran. This approach is based on the use of a large number of SAR acquisitions distributed in small baseline subsets; it allows the easy combination of DIFSAR interferograms computed via standard processing techniques and computation of a time sequence of deformation. Also mean rate of subsidence computed from repeated first order precise leveling network of Iran are accurately matched in the mean rate of InSAR time series (figure 9).
Based on the subsidence map generated we found 3 distinct pattern of fringes with a NW-SE elliptical-shaped bowl shape, with maximum rate of 12 cm/yr between Meybod and Zarch, with 10 cm/yr in west of Ardakan and with 6.5 cm/yr in south of Yazd, the center of province for the 2003–2006 time period (figure 9). These regions are located in cultivated land, clay flat and sand dunes (figure 10). Assessment of the groundwater level in the region revealed extra extraction of ground water for agricultural and industrial purpose is the common reason of subsidence in all 3 parts. Water level decline of as much as 15.46 m has been recorded in the region during the last three decades.

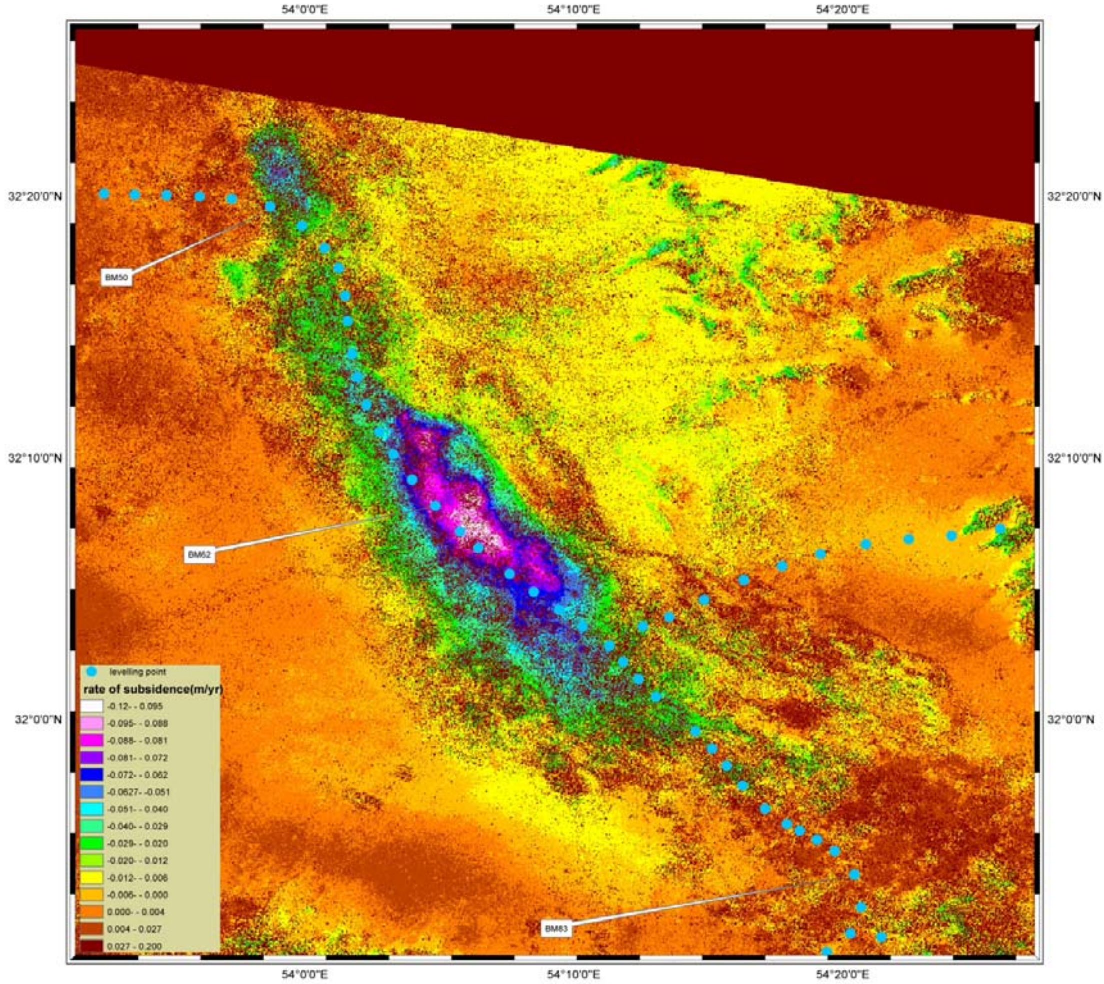

Figure 9- Rate of subsidence in Yazd-Ardakan determined by InSAR technique.

Absolute Gravimetry

Iranian zero order gravity network has been established since 2000 by measuring the stations in absolute sense using FG-5 absolute gravimeter. This network consists of 28 stations mostly monumental on bedrocks including Iranian national gravity calibration line (Figure 10). The main purposes of this network are: controlling/improving the accuracy of the gravity networks of higher order (1st, 2nd, and 3rd), making more consistency between gravity data collected by different organizations and companies and calibrating relative gravimeters used in data collection process. Since Iran is located in the Alpine-Himalayan seismic belt which is one of the most active tectonic regions of the world, zero-order gravity network is of interest to other disciplines in geosciences like geophysics, geology and geodynamic. Therefore, some stations have been selected to be measured several times in order to reveal crustal movements and/or mass changes.

Combining these measurements with GPS observations helps to distinguish between movement and mass-change induced gravity changes in such tectonic stations. Gravity changes in Tehran and Abali stations are shown in Figure 11.

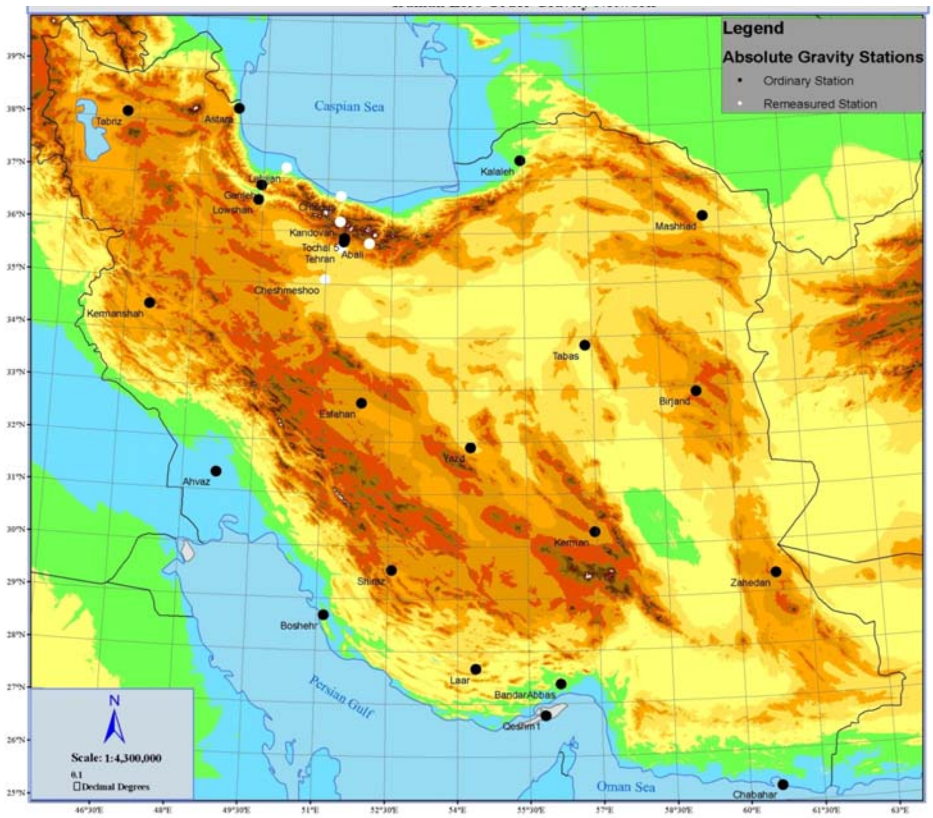

Figure 10- Iranian Zero–order Gravity Network.

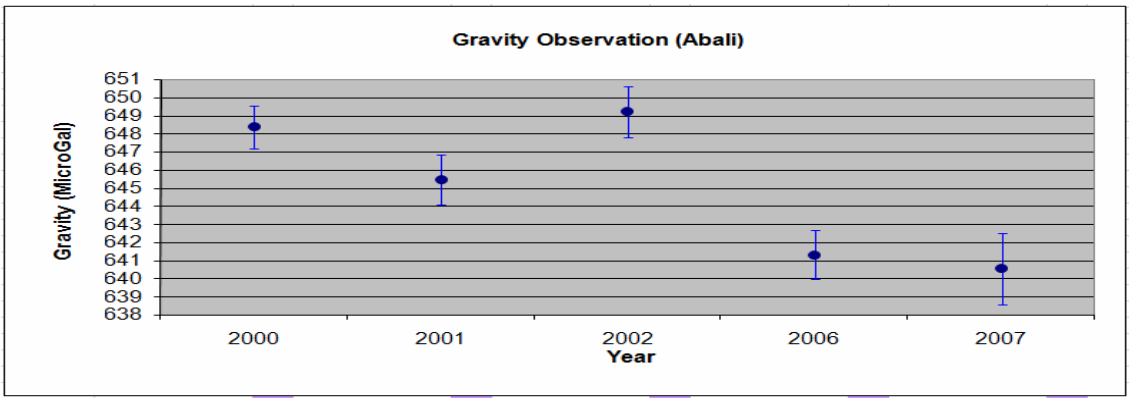

Figure 11- Gravity changes observed for Abali (Alborz) station

Precise Leveling

Based on the results from re-measurement of the first order precise leveling network of Iran (see figure 12), height changes of the leveling routs were computed. Accuracy of the results was estimated implementing Vignal formula and showed the worst quantity of 0.4 mm. Some results from re-measurement of the leveling network are depicted in Figure 13.

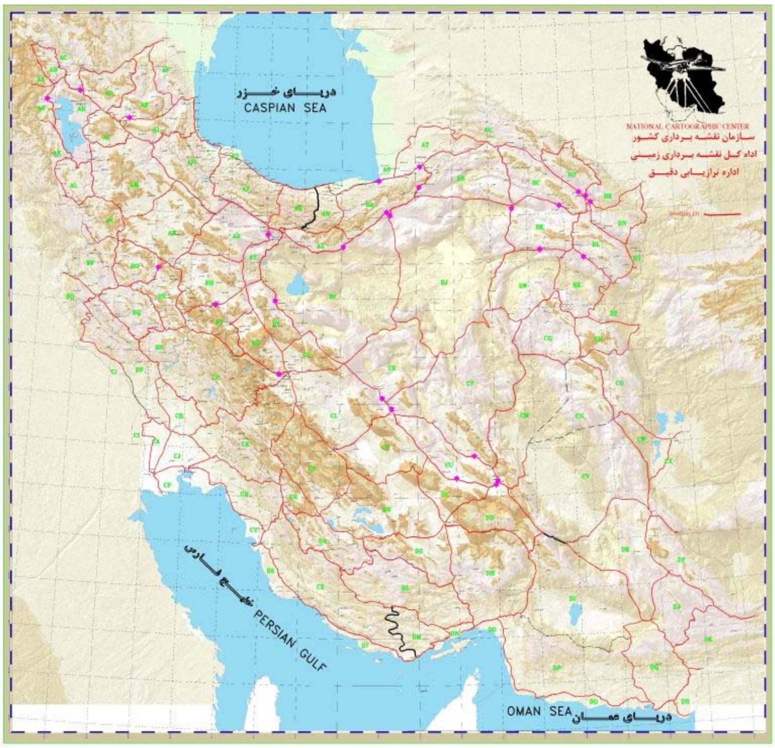

Figure12- Iranian first order levelling network

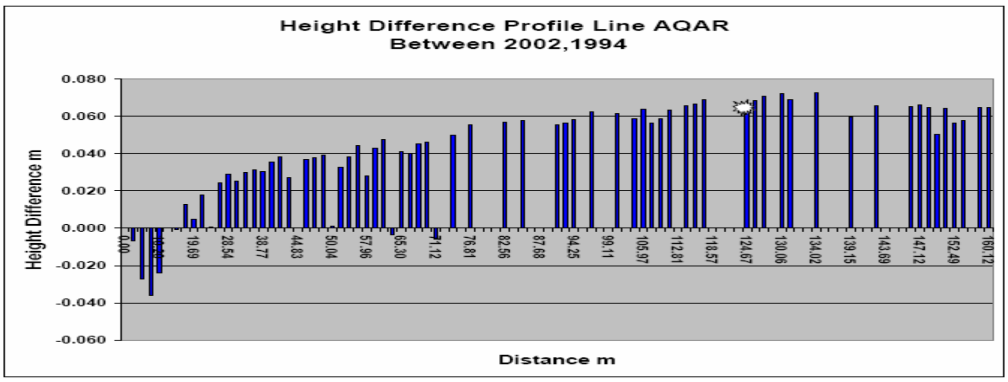

Figure 13- Height changes along the Alborz levelling rout between 1994 and 2002, derived from re-measurement of the 1st order levelling network of Iran.

Campaign GPS network for geodynamics studies

Some campaign GPS network (about 250 stations) carried out during the interseismic period in order to obtain the slip rate of the active faults. This result can be use to better understanding seismic hazard in Iran. All measurement were done by dual frequency GPS receiver and chock ring antenna and process with Gamit/Globk software.

Conclusion:

IPGN (Iranian Permanent GPS Network) and other geodetic techniques have been showing enormous information about crustal deformation (plate motion-activity of active faults, uplift, subsidence) in different part of the country. IPGN also to serve as an active controlling system for GPS surveying. The usage of this network is not limited on crustal deformation. Actually in Iran GPS metrology project is also start and this is another application of this network. The next phase of this project is real time monitoring that start this year. This system will be expanded to more than 700 permanent observation sites in the next years.

References:

Altaminmi Z, Sillard P, Boucher C(2002) ITRF2000:A new relapse of the International Terrestrial Reference Frame for Earth Science Applications. J Geophys Res: 107 doi:10.1029/2001 JB000561

De Mets c, Gordon RG,Argus DF,Stein S(1994) Effect of recent revisions to the geomagnetic reversal time scale on estimates of current plate motions. Geophys Res Lett 21:2191-2194

Herring TA (2001) Documentation for the GLOBK software version 9.5. Massachusetts Institute of Technology, Cambridge, MA .

Jackson J, McKenzie D(1984) Active tectonics of the Alpine-Himalayan Belt between western Turkey and Pakistan. Geophys J. Roy Aster Soc 77:185-264

Johansson JM,Davis JL,Scherneck HG,Milne GA,Vermeer M,Mitrovica JX,Bennett RA, Johnson B,Elgered G,Elosegui P, Koivula H, Poutanen M, Ronnang BO,Shapiro II, (2002) Continuous GPS measurements of postglacial adjustment in Fennoscandia-1. Geodetic results, j. of Geophy. R. solid-Earth 107(B8)No.2157

King RW, Bock Y(2001) Documentation for the GAMIT GPS software analysis version 10/05, Massachussetts Institute of Technology,Cambridge, MA

Matindas R(1998) The Status and Activity of the Working Group on Regional Geodetic Network of the Permanent committee on GIS Infrasturcture for Asia and the Pacific workshop on regional geodetic network, Canberra, 2-4 July 1998.

McClusky S, Balassanian S, Barka A, Demir c, Ergintav S, Geogiev I, Gurkan O,Hamburger M,hurst K, Kahle H,Kastens K, Kekelidze G, King R,Kotzev V,Lenk O,Peter Y, Prilepin M, Reilinger R, Sanli I, Seeger H, Tealeb A, Tokoz M, Veis G (2000) Global positioning system constraints on plate kinematics and dynamics in the eastern Mediterranean and Cuscause. J Geophys Res 105: 5695-5719

McClusky,S.,Reilinger, R.,Mahmound, S.,Ben Sari, D.&Tealeb, A. 2003. GPS constrains on Africa(Nubia) and Arbaia Plate motions. Geophysical Journal International, 155,126-138..

Nilforoushan, F. *et al.*, 2003. GPS network monitors the Arabia-Eurasia collision deformation in Iran, *J. of Geodesy,* **77,** 411–422.

Tatar M, hatzfeld D, Martiond J, Walperdorf A, Ghafori-Ashtainy M,Che'ry J(2002) The present-day deformation of the centeral Zagros form GPS measurements. Geophys Res Lett 29(19),doi: 10.1029/2002 GLO15427

Tavakoli,F.,etal.,2008 Distribution of the right-lateral strike–slip motion fromtheMain Recent Fault to the..., Earth Planet. Sci.Lett. (2008), doi:10.1016/j.epsl.2008.08.030

Vernant, Ph., Nilforoushan, F., Hatzfeld, D., Abbassi, M.R., Vigny, C., Masson, F., Nankali, H.,Martinod, J., Ashtiani, A., Bayser, R., Tavakoli, F.& Chery, J.(2004), persent day curstal deformation and plate kinematics in the Middle East constrained by GPS measurements in Iran and nortern Oman, Geophyscial Journal International, 157(1) ,381-398.

Vigny C, Che'ry J, Dequesnoy T, Jouanne F, ammann J, Anzidei M, Aouac JP, Barlier F, Bayer r, Briole P, Calais E, Cotton F, Duquemme F, Feigl K, Flouzat M, Gamond JF, Geiger A, Harmel A, Kasser M, Laplanche M,Le Pape M, Martinod J, Menard G, Meyer B, Ruegg JC, Scheubel JM, Scotti O, Vidal G(2002) GPS network monitors the Western Alps over a five year period: 1993-1998:Geodesy 76:63-76.

Walpersdorf, A. *et al.*, 2006. Difference in the GPS deformation pattern of North and Central Zagros (Iran), *Geophys. J. Int*, in press.

Wang Q,Zhang PZ, Freymueller JT,Bilham R,Larson KM, Lai X, You X, Niu Z, Wu J,Li Y, Liu J, Yang Z , Chen Q(2001) Present-day crustal deformation in China by global positioning system measurement. Science 294:574-577.