Application of Geodetic tools for crustal deformation monitoring in Iran (Insight from GPS technique)


Geodesy and Geodynamics Dept
National cartographic center of Iran
Email: nankali@ncc.org.ir
Tel: 66071092

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 a continuous GPS network is used to better understand the tectonic deformation and to compare with the campaigns results. Since early 2005, National Cartographic Center of Iran (NCC) is establishing a continuous GPS network of 113 stations named Iranian Permanent GPS Network for Geodynamics (IPGN). This network 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 (Sella et al., 2002 ; 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).
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 geohazard 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 introduces IPGN and final results from analysis center.

2) Network Configuration

The network consists of two parts: the base network and regional networks. The base network consists of 41 stations 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

Regional networks are in Tehran, Tabriz, and Mashhad areas and the distance between the stations is about 25-30 km. Tehran, as the capital with 12 million 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 parts according to geological and geodetical parameters. Fig 3.
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

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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
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

**Fig 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. Downloaded 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 coordinates 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.
Conclusion:

IPGN (Iranian Permanent GPS Network) has been showing enormous information about crustal deformation (plate motion-activity of active faults), and 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.

Fig 8-GPS Velocity Filed estimated with respect to Eurasia
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GEONET, GPS Earth observation network in Japan, report of GSI in Japan 2004

SCIGN, South California integrated GPS network. 2006 internet report