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A GPS Network Densification in Saudi Arabia in Support of Geophysical Investigations in the Region

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Abstract:

Current investigations of the motions of the Arabian and its neighbouring plates are primarily based on GPS measurements obtained in the surrounding areas of the Arabian plate, with few stations actually located on the Arabian plate itself in the kingdom of Saudi Arabia [Reilinger, et al., 2006]. In order to advance the knowledge of the dynamics of the Arabian plate and its intra-plate deformations, the General Directorate of Military Survey (GDMS), through a collaboration with the Institute of Engineering Surveying and Space Geodesy (IESSG), densified the GPS network in Saudi Arabia, covering nearly two thirds of the tectonic plate.

Since July 2002, a network of 32 GPS stations has been established at locations of the Saudi Arabia geodetic network. At all of these GPS stations a concrete pillar has been used as the monument and the locations have been selected in order to give the broadest distribution of observing sites. During 2005, 27 additional GPS stations in Hejaz and Asser Mountains in the south-western part of Saudi Arabia, have been established, with the GDMS GPS network now comparison a total of 59 stations.

This poster will show the new GPS network in Saudi Arabia established by GDMS and will present the initial results from episodic campaigns in March 2003 and March 2005. The preliminary estimates of absolute and relative Arabian plate motions inferred from the GPS network and a detailed comparison of the results based on the Bernese GPS software versions 4.2 and 5.0 will be presented as well.

Geological Setting:

The Arabian plate is 25–30 million years old [*Rodgers, et al.*, 1999]. It is surrounded by the African (Nubian, Somalia) plate on the west and southwest, the Eurasian plate on the north and the east and the Indian plate on the southeast.

The geological history of the Arabian plate has not been investigated widely, especially the uppermost part of the Mantle, but a number of research projects have been carried out on selected areas of the Arabian plate to study and investigate the geology of the Arabian Crust. The Arabian plate divides into two main parts, namely, the Arabian shield, which covers one third of the plate on the west along the Red Sea and the Arabian platform, which covers two thirds of the plate on the east [*Sanvol et al.*, 1998; *Al-Amri*, 1999]. Seismology studies show that the Arabian shield thickness ranges from 39 – 51 km [*Badri*, 1991; *Al-Amri*, 1999; *Al-Damegh et al.*, 2005]. The shield is gradually thinning towards the Red Sea where new oceanic crust is forming. The platform is covered by phonerozoic sediments and the thickness averages 45 km, gradually thickening towards the Zagros Mountains, where continental collision is taking place of the ???. The uppermost mantle thickness averages 51 km [*Al-Amri*, 1999]. The total displacement has been estimated to be about 107 km since the Oligocene, with an annual rate of about 5 cm over the last 7 to 10 million years [*Grünthal et al.*, 2006].

The seismology record shows activity along the Arabian plate boundary, especially along the Zagros Mountains on the east, the Gulf of Aden on the southwest, along the Gulf of Aqabah and Dead Sea transform (a left-lateral fault system) on the northwest and several places along the spreading axis of the Red Sea [*Al-Damegh et al.*, 2005].

Figure 1. The geological map of the Arabian plate [*Saudi Geological survey*, 2006]

The GPS Networks:

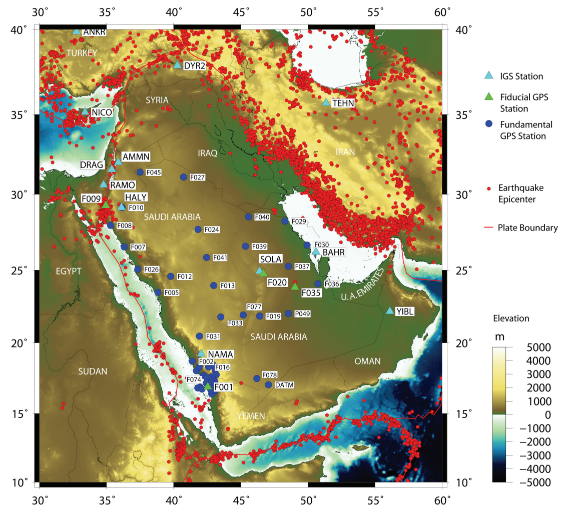
The Saudi Arabian Network: Thirty-two stations from the Saudi Arabian geodetic network were selected for observation (figure 2). Three episodic campaigns (March 2003, March 2005 and March 2007), with a two-year span between each, were planned.
The selection criteria for these stations were as follows:

- Evenly distributed within Saudi Arabia;
- Monuments already available and thought to be stable; and
- Suitability for geophysical applications.

During each campaign four stations (F001, F009, F020 and F035) were observed continuously (Fiducial stations). The rest of the stations were observed for between one and five days (fundamental stations) .

The South – West Saudi Arabia Network: The Arabian plate large scale deformation test using 2003 and 05 data show that there are crustal deformations in the tectonically active south-western part where the Hejaz and Asser mountains are formed. Hence, 27 additional stations in that area are observed for one day every year for three years (January 2006,07,08) to deduce the crustal deformations in this part.

Figure 2. The Saudi Arabian GPS networks. Plate boundaries were taken from Bird (2003) and earthquake information was obtained from the USGS Earthquake Hazards Program (http://earthquake.usgs.gov/). Earthquakes shown include events since 1973 with M > 4.0.



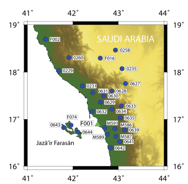


Figure 3. The South-west Saudi Arabia Network

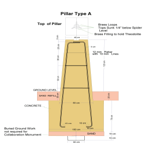


Figure 4. GPS station monument specification

Figure 5. One of the field crews on reconnaissance

Initial results:

The Initial results of the horizontal absolute and relative velocities of the regional network stations were based on absolute and relative Euler poles computed using BSW (V4.2) [*Hugentobler et al. , 2001*] . Two reference frame implementations have been investigated, which have been denoted as BSW(4.2) SOL1 and SOL2.

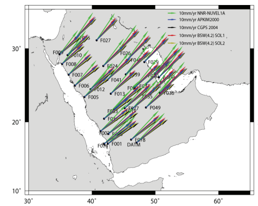


Figure 6. Absolute velocities

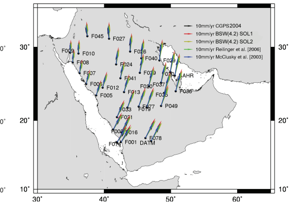


Figure 7. Relative velocities

The best agreement to the initial results of this study was found to be with the CGPS 2004 [*Prawirodirdjo and Bock*, 2004] and APKIM2000 [*Drewes and Angermann* , 2001] for the absolute results and Reilinger et al. [*2006*] for the relative results.

Migration to BSW (V5.0) [*Hugentobler et al. , 2005*] :

Fiducial stations: the velocity differences at the fiducial stations between BSW (V4.2) and BSW (V5.0) are very small as shown in figure 8, with maximum differences of 0.7 mm/yr in the East component at F001 and 0.7 mm/yr in the North component at F020. The minimum differences were 0.1 mm/yr in East component at F020 and 0.5 mm/yr in North component at F001.

Fundamental stations: the velocity differences at the fundamental stations between BSW (V4.2) and BSW (V5.0) were from 0.1 to 2.1 mm/yr in the East component and 0.1 to 1.9 mm/yr in the North component.

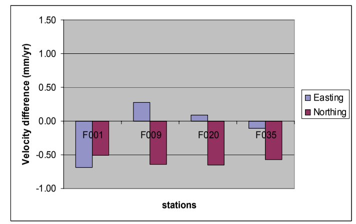


Figure 8. Velocity differences at the fiducial stations

Conclusions:

- Since 2003 a network of 59 GPS stations has been established in Saudi Arabia for investigations into plate motion and crustal deformation.
- For the Saudi Arabian network campaigns were carried out in March 2003 and 2005 and a further campaign is planned in for March 2007.
- For the South-West Saudi Arabian network a campaign was carried out in January 2006 and a further two campaigns are planned in January 2007 and 2008.
- The best agreement to the initial results of this study was found to be with the CGPS2004 and APKIM 2000 models for the absolute results and Reilinger et al. [*2006*] for the relative results.
- The velocity differences between results based on BSW V4.2 and V5.0 are at the level of sub millimetre per year at fiducial stations and at the level of up to 2 millimetres per year at the fundamental stations.

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