Studying Ahar Faults Movement in Earthquake 11 Agoust 2011 Based on GPS Observations

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Abstract

The calculation of recent crustal movements and the associated crustal deformation rely on a geodetic measurements with repetition cycles of years or decades and modern GPS permanent networks. We describe processing of GPS data from stations around the Ahar-Varzeqhan earthquakes. The maximum horizontal displacement calculated was Ahar-Varzeqhan earthquakes 27.93 and 15.35 cm white 0.24 cm RMSE. The right lateral fault south of Ahar (Ahar-Varzeqan earthquakes fault plane) according to the coseismic displacement field is evident, Field observations and previous research confirmed that the amount of movement and right lateral fault. To study the future can be compared and assessed using data from InSAR movement interseismic, coseismic and postseismic in the region and review the results of the GPS.

Keywords: Earthquake, Ahar, GPS, Faults, Movement

1. Introduction

Following the event, two consecutive earthquakes occurred at 16:53 and 17:04 on Saturday, 11 August 2012 , with a magnitude of 6.2 and 6, respectively, in the area around Ahar, Warzghan and Haris cities in East Azerbaijan. Unfortunately, at least 300 of our compatriots died and more than 2500 were injured in these two earthquakes. The central extent of these two seismic events was located in an area with a high concentration of rural population, and therefore more than 150 villages suffered damage from 20 to 100 percent.[3]

Among the influencing parameters in the occurrence of an earthquake in a region is the sliding rate of the region. Examining the slip rate of the region is one of the cases that can be used to estimate the release rate of seismic energy in the region.

In order to estimate the exact rate of slippage in this area, accurate and calculating tools such as Global Positioning Systems or (GPS) can be used. [1]

2. Methods and Data Processing

Slip tendency analysis, valuable tool for evaluating the reactivation of a fault and seismic hazard assessment. This analysis provides useful tool to quantify the potential slip ,on the known or unknown faults in the known or hypothetical stress field [10]. In addition to identifying potential faults for the reactivation can be used for the potential slip, also determined Focal mechanism that using this to check the compatibility between mechanism and geological structures of the [3]. Perform this analysis in the case of a fault and in a series of faults can be done. Slip potential into the regional tension, depends on the friction coefficient, fault plane [2].Analysis of possible reactivation of pre-existing weak pages slip is critical on many branches of geology.Analysis of reactivation slip in estimating seismic hazard is also very important, because it provides a means by using it can be quantified known or unknown potential slip faults and known or presumed in [4] the stress field.Reactivation of the fault to slip depends on the frictional resistance against slip [5]. Usually it is assumed that after the shear failure in the rock, adhesion were not seen,so the reactivation condition of the Navier - Coulomb for fault-free adhesive that can be expressed as follows:

$$\tau = \mu\left(\sigma_n - p_f\right) \tag{1}$$

That the shear and normal stresses τ ,σ_n and acting respectively at fault, μ is the coefficient of sliding friction and pore fluid pressure is p_f.

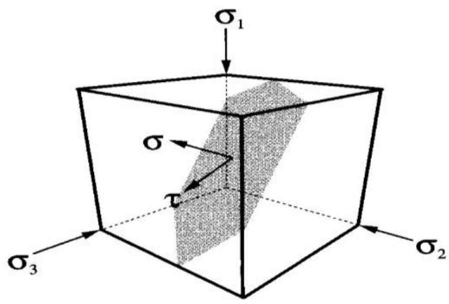
Relation (1) only in the brittle crust that is affected by frictional processes are applicable.

Slip tendency analysis,is a method for predicting possible directions instability of faults and tectonic in different activity [2].Coulomb stress changes caused by one or more earthquakes can cause subsequent earthquakes.Slip tendency analysis of faults to identify fault-prone will help to calculated Coulomb stress changes for the next big earthquake. In this study Tabriz's active fault slip tendency, calculated by using regional tensions GPS observations with Berny's software. geometry of Known fault and the coefficient of friction between 0.2 to .0.8 with the probable mechanism of deep earthquakes is calculated by Matlab software[11].

1.2 The tendency slip

According to Moho stress σ = σ_n- p_f, which considers the effect of pore pressure, critical condition to slip on weak pre-existingfaults can be written as follows:

$$\mu = \tau/\sigma \tag{2}$$



The normal stress σ_n, and shear stress τ, on a desired level of tension in the field defined by the main compressive stresses σ_1, σ_2, σ_3

Tend to slip is defined as the ratio of shear stress to normal stress on the surface:

$$T_s = \tau/\sigma \tag{3}$$

So it is clear that slip tendency is equal of coefficient sliding friction. The fault pages where likely to slip,are pages closed toμ whit high proportion of shear stress to normal stress.Slip tendency analysis is based on the truth that failure dip criterion are the coefficient friction of a range that usually covers between 0.2 to 0.85.By fixing the ratio of stress difference (Moho diameter) range of compounds (μ, ɵ) is created when landslides are possible.In an area with a certain rock, presumption a certainμ, determines the optimum angle slip [6]. Relation (4) that is the most appropriate formula for the maximum compression ratio failure page. In this page the slip tendency is maximum: $T_s = T_s^{max}$.

$$2\theta = \tan^{-1}(1/\mu) \tag{4}$$

2.2 Input and output variables

According to the theory of slip tendency, the fault pages susceptible to reactivation justify the stress tensor, the stress of φ (Or the difference between the principal stresses R) the coefficient friction is μ and the pore fluid pressure p_f (by using effective stress is considerd implicitly). Input parameters required for analysis are as follows:

1. The main tension direction;
2. The ratio of stress difference R
3. The geometry of the fault system (known) and
4. The coefficient of friction (8 / 0-2 / 0)

The right coordinate system defined main tension directions shown by X_1, X_2, X_3 .

The direction of each main axis defined according to Azimuth and dip. Azimuth ψ in the horizontal plane in degrees clockwise is measured from north within origin

$$360^o \gg \psi \gg 0^o$$

or

$$180^o \gg \psi \gg -180^o$$

Dip δ is measured in the vertical plane perpendicular to azimuth within

$$90^o \gg \delta \gg 0^o$$

The main stress values shown with σ_1, σ_2, σ_3 and according to our definition: σ_1≥σ_2≥σ_3. Conventionally used in geology compressive stresses are positive, so the main tension compression sorted from highest to lowest.[7] R is used in tension difference to place the main stress levels is sufficient for slip tendency analysis. Faults are considered flat and it is assumed that they have no interaction. For those determined with azimuth and tilt.

2.3 Using GPS observation to calculate Tensor stress by Berenese software

Bernese software, is an advanced tool to achieve accurate values in geodetic applications. The accuracy of the results of this software is better than other processors for large networks.The processing of this software includes more than 100 programs that are written in FORTRAN language. Each project is a set of observations that must be processed. In this way, each of the measures will be processed in the form of independent projects. In this article, GPS observations processing were performed by using the Bernese v4.2 software[8].

3. Discussion

Using the mentioned software, the time series of the GPS stations related to the 8 studied stations in the Azerbaijan region have been plotted. The following figures show the changes in the north-south (N), east-west (E), height (U) component, which is the result of the final processing of the data on a daily basis, it should be noted that in the figure Below each of the points shows the position of each GPS station on one day of the year, by comparing each of the points with other points, you can understand the amount of station displacement. The dispersion of the vertical component of the time series is more than the flat components, and part of it can be related to the error of the GPS devices in measuring the vertical components [9].

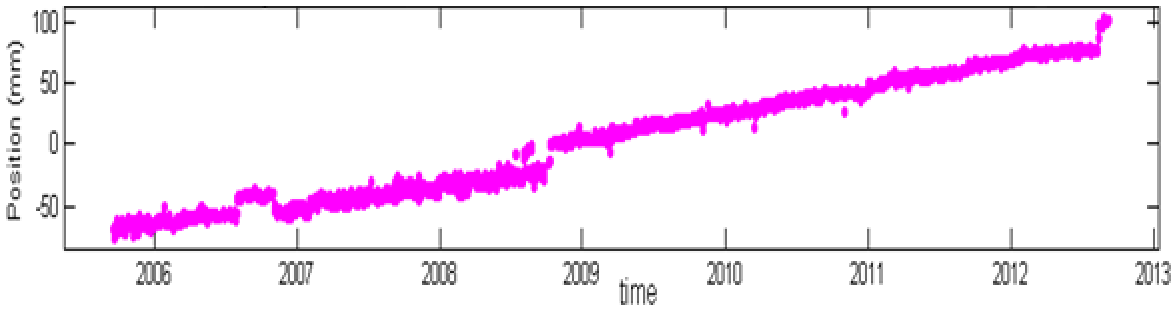


Fig.1. North-South component of the time series of Ahar station

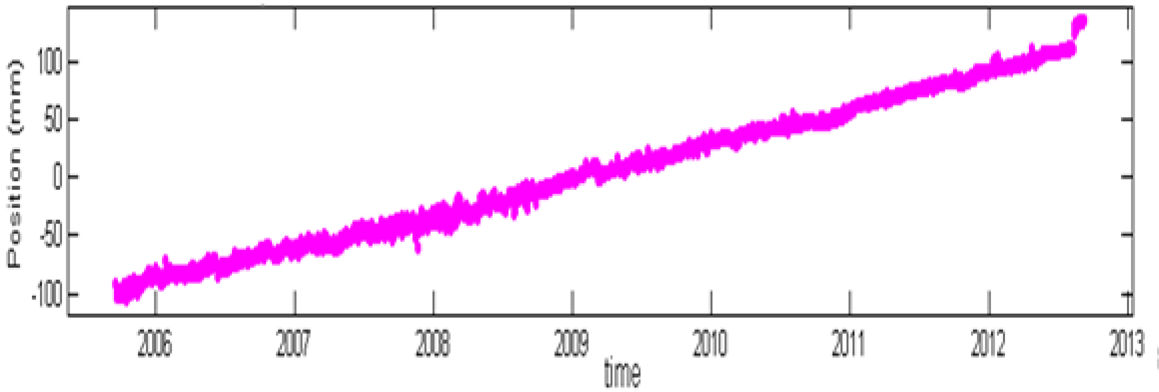


Fig.2. East-West component of the time series of the last station

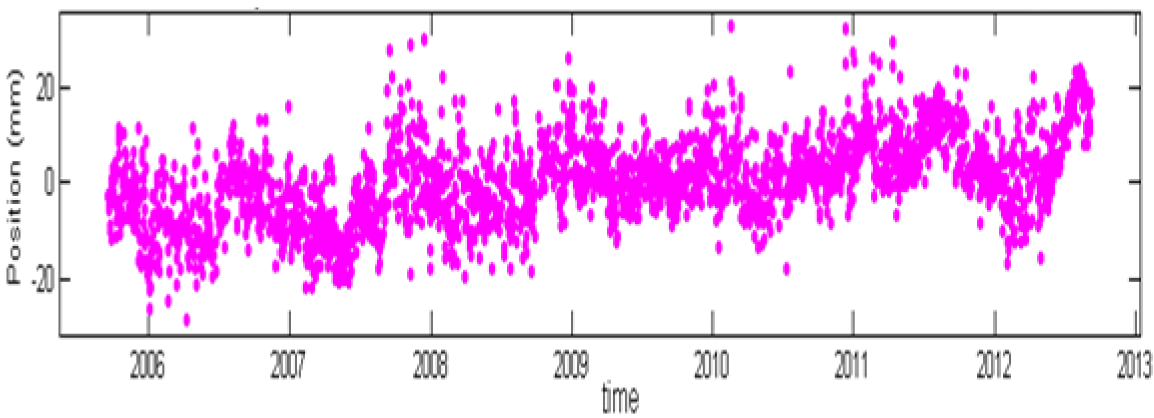


Fig.3. The height component of the time series of the last station

3.1 Interpretation of the vertical component of time series:

It has been observed by examining the vertical component of the time series of Azerbaijan geodynamic network stations. Figure (1) shows the speed vectors of the investigated stations. In almost all the stations, a linear and regular displacement towards the northeast has been observed. The velocity magnitude of the stations varies between 1.1 and 13.2 mm per year. The lowest displacement is related to Ahar station with 14.11 mm per year and the largest displacement is related to Behrman and Hashtroud stations with 13 mm per year. The reason for this displacement is the Saudi Plate force, this force is towards the northeast and causes the displacement. The area under study goes in this direction. The azimuth component of the velocity vector shows the decrease of the velocity vector from west to east. The force of the Arabian plate is in the northeast direction and the Eurasian plate is in the northwest direction, whatever from west to east. Let's go, the force of the Eurasian plate increases and the effect of the Arabian plate decreases, so the amount of deviation to the east caused by the Arabian plate decreases, and as a result, the eastern component of the velocity vector decreases. Also, the velocity values from the south it decreased to the north and this is due to the rigidity of the Eurasian plate.

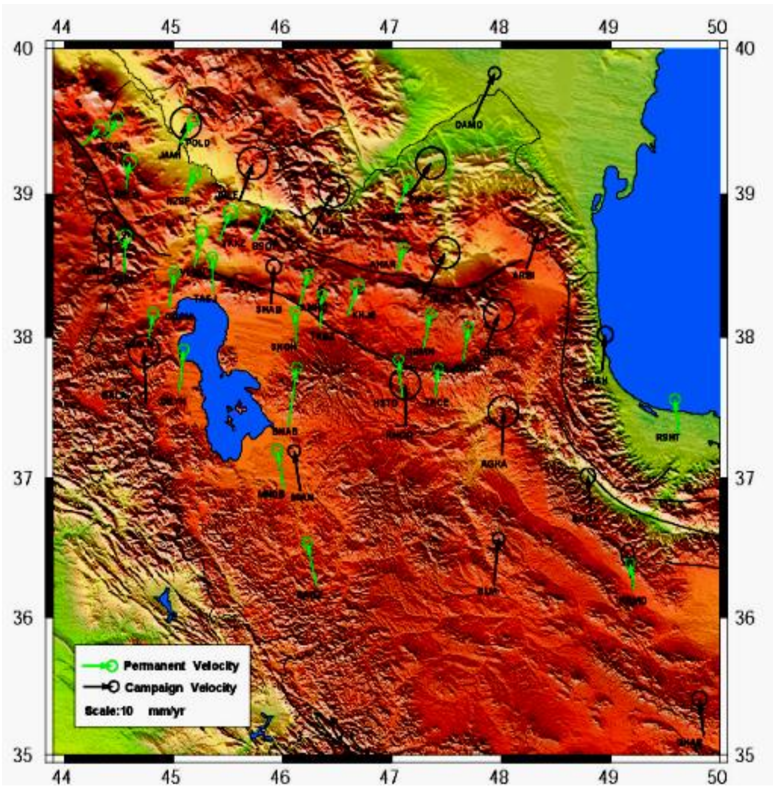


Fig4. The movement speed of the stations using GPS data, the speeds have been measured relative to Eurasia

Figure (4) shows the movement of Ahar station, before the earthquake, the displacement vector was towards the southeast, and during the earthquake, it shows an offset, then the displacement vector moved to the northwest, which it is called the displacement caused by an earthquake. The created offset shows that the earthquake affected this station and this displacement is 2 cm.

4. Conclusion and Recommendations

The results obtained from the preliminary analysis of the time series of the permanent GPS stations have shown the displacement of the crust in the region after the earthquake. And the comparison of displacement values with the oval dimensions of the obtained errors also shows that these values are significant and can be accepted as displacement. And the magnitude of the speed is between 11.4 and 13.2 mm per year. The azimuth component of the velocity vector varies between 2.6 and 1.27 degrees, also the direction of the displacement vectors indicates that the Ahar-Varzghan fault is right and the elevation changes indicate an uplift in the northern part of the fault at the stations of Ahar, Amand, and Tabriz. It is not confirmed in all the stations, also due to the low accuracy of the height component, it is not possible to give a definitive opinion on this matter. The displacement of 2 to 4 centimeters GPS indicates the amount of displacement during the earthquake in the amount of 2 to 4 centimeters.

It is necessary to answer this question, how the occurrence of an earthquake may lead to subsequent earthquakes? The occurrence of an earthquake is associated with a fault or break in the earth's crust. For this purpose, the failure criterion in the elastic medium of the earth's crust, or the Coulomb failure criterion, should be investigated. Analysis of Coulomb stress changes has been used in many seismic regions of the world. These studies show that the location and speed of subsequent earthquakes are affected by the changes in static stress caused by historical earthquakes in that region. In this research, the effect of Coulomb stress changes between fault systems in Ahar-Varzghan region has been studied. The parameters of earthquakes from the Institute of Geophysics of Tehran University in this area have been collected from various sources in order to calculate the Coulomb stress. The results show that more than 80% of the earthquakes occurred in the region where the Coulomb stress increased by -5 to 5 times. Also, the calculation of the Coulomb stress changes on strike-slip fault planes show that the faults that are in the same direction as the optimal geometry are prone to rupture and create earthquakes due to the increase in Coulomb stress caused by earthquakes, and are considered high-risk areas for future earthquakes.

By using analytical models to determine deformation according to fault geometry, earth physics, the amount and type of fault slip due to earthquakes, it is possible to calculate the deformation field of the earth's crust with appropriate accuracy. To be more precise, better modeling is done. Analytical models also have disadvantages; the effect of earth's sphericity, surface topography, and lateral inhomogeneity of the earth is usually not considered in modeling.

Of course, some of these factors, such as the sphericity of the earth, can be neglected for events close to the earth's surface. One of the advantages of analytical modeling of deformation is the possibility of observing deformation at any desired point on the surface or underground. In analytical methods, fault geometry is used in order to study crustal deformation, this problem provides a good insight into the behavior of the earth's crust due to the slippage of a specific type of fault. Among the features of analytical modeling method, we can mention the discussion of earthquake risk prediction in engineering studies. So that according to the length and type of fault in the region, the magnitude of earthquakes that may occur can be predicted, and then using experimental models that determine the relationship between the magnitude of the earthquake and the amount of slippage of the fault, the model can be used. Constructing a possible displacement field due to fault slip in the region.

The results show that the majority of aftershocks occur in the region of increased Coulomb stress from 0.1 to 0.8 bar and the absence or occurrence of a small number of aftershocks in the areas of decreased Coulomb stress. The occurrence of any earthquake can change the distribution of the Coulomb stress in the region and this will cause the movement of the Coulomb stress changes, although the movement stress is small, it can bring the surrounding faults to the breaking point even after a long period of time. According to the discussed content, the resulting model can be used as a tool for warning before the occurrence of an earthquake or predicting an earthquake. The accuracy of the model depends on the accuracy of its input parameters

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