Modeling of Iranian Crust Deformation in 2007 Using Satellite Geodetic Observations

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Abstract

In this study, using the data of Iran's permanent geodynamic network in two six-month APECs in ۲۰۰۷, a two-dimensional model of surface deformation of the Earth's crust in Iran will be presented. For this purpose, two methods of numerical solution, one finite element and the other method of relative distance changes, have been used to calculate the strain tensor. In the finite element method, the results obtained depend on the shape of the element. Of course, this issue should be studied in practice and the results should be compared. This method gives the same answer to the hypothesis that the deformation is homogeneous in the desired element only for homogeneous networks with any type of elementation. The resulting strain for the center of gravity of all the elements was the same size and in the same direction, indicating the homogeneity of the deformation in the lattice.

Keywords: finite element, geodynamics, Iran, tensor.

1. Introduction

Observing crustal movements is a difficult and important task in geodynamics and geodesy. The need to observe crustal deformation is due to the fact that there is a risk of large earthquakes in many places on the planet, and these observations are used to detect aftershocks on fault plates and stress accumulation in weak areas. By continuous observations of deformation in earthquake-prone areas, it is possible to discover how the crustal movement process in each earthquake period and to estimate impending landslides.

2. Finite Element Method

In this method, the grid is divided into a set of elements and for each element, the deformation tensor is calculated. The finite element is based on the fact that in each element, the deformation is homogeneous and this is one of the important disadvantages of this method because in any continuously heterogeneous environment, the strain components change from one point to another and the results obtained from this method, It differs from their actual amount.

Each element consists of n vertices. The deformation is determined for the point P or the center of gravity of the element.

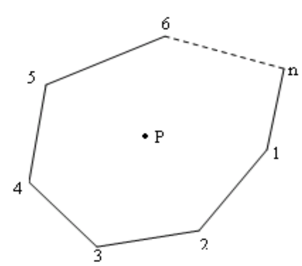

Fig.1. The element used in the finite element method

In two-dimensional analysis of deformation, the components of the displacement vector for the center of gravity of the element can be obtained from the following linear relations [4]:

$$u_j = \left(\frac{\partial u}{\partial x}\right)x_j + \left(\frac{\partial u}{\partial y}\right)y_j + a + r_{ij} \tag{1}$$

$$v_j = \left(\frac{\partial v}{\partial x}\right)x_j + \left(\frac{\partial v}{\partial y}\right)y_j + b + r_{ij} \tag{2}$$

$$i = 1, \quad j = 1, 2, 3, \ldots, n$$

In the above formulas, a and b are constant values, $(X_j^{(1)}, Y_j^{(1)})$ The broken coordinates of the vertices of the elements in the first APEC and $(X_j^{(2)}, Y_j^{(2)})$ The broken coordinates of the vertices are in the second APEC. (ui,vi)

The components of the displacement vector are for the vertices of the element that are obtained from the difference of the coordinates of the divisors of the points in two time periods, and rij is the vector of the remainder of these displacements.

$$u_j = X_j^{(2)} - X_j^{(1)} \tag{3}$$

$$v_j = Y_j^{(2)} - Y_j^{(1)} \tag{4}$$

x_j and y_j are obtained from the difference between the coordinates of the vertices of the element and the center of gravity.

$$x_j = X_j - X_i \tag{5}$$

$$y_j = Y_j - Y_i \tag{6}$$

Using formulas (1-3) and (2-3), for an element with n vertices, the unknowns of the problem (deformation parameters) can be obtained by solving the n2 equation and 6 unknowns. To reach the answer, the element must consist of at least three points. The matrix of observations and unknowns is as follows.

$$\mathbf{V} = \mathbf{AX} - \mathbf{l} \tag{7}$$

$$\mathbf{X} = \begin{bmatrix} \frac{\partial u}{\partial x} & \frac{\partial u}{\partial y} & \frac{\partial v}{\partial x} & \frac{\partial v}{\partial y} & a & b \end{bmatrix}^T \tag{8}$$

$$\mathbf{l} = \begin{bmatrix} u_1 & v_1 & u_2 & v_2 & u_3 & v_3 \end{bmatrix}^T \tag{9}$$

Using these displacement components, the strain tensor parameters can be calculated.

$$e_{xx} = \frac{\partial u}{\partial x}, \quad e_{yy} = \frac{\partial v}{\partial y}, \tag{10}$$

$$e_{xy} = e_{yx} = \frac{1}{2}\left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}\right)$$

$$\mathbf{e} = \begin{bmatrix} e_{xx} & e_{xy} \\ e_{yx} & e_{yy} \end{bmatrix} \tag{11}$$

3. Data Used and Analysis of GPS Data

Using the 2-dimensional isoparametric strain analysis method and also the coordinates obtained from the stations of the geodynamic network of Iran in two time periods, the strain values for all stations of the above network are calculated and the results are shown in Figures 4 and 5. In both figures, the eigenvalues of the strain tensor are plotted with pairs of vectors pointing in the same direction (pressure) and in the opposite direction (expansion). The existing focal mechanisms of earthquakes that occurred during the observation period of this study show a deformation regime consisting of compaction throughout the Iranian plateau except for two stations in the southeast of the country. This confirms the pressure calculated in two APECs and confirms the location of all stations on this network (except for 2 stations in the southeast).

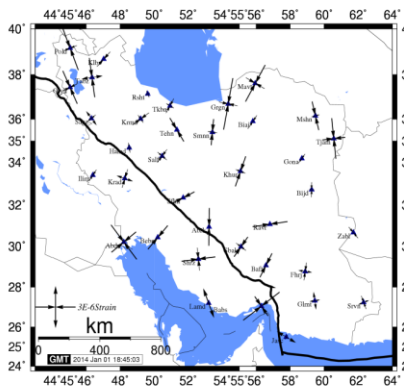

Fig.4. Main values of strain at geodynamic network stations in Iran for the first ٦months of ٢٠٠٧

Also, in Figure 5, the results of strain analysis are compared with the natural topography of Iran. According to this figure and the results obtained from geodetic observations, it can be seen that in most mountainous areas we face the issue of pressure. This issue can be seen in the stations close to the fault belt of Iran and also in the stations with high altitude.

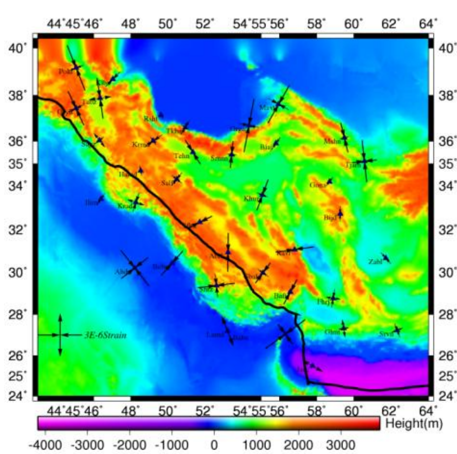

Fig.5. The main values of strain in the first ٦months of 2007 in Apok with topographic map of Iran

In order to evaluate the values of strain within the geodynamic network of Iran and ٢D isoparametric method, as mentioned at the beginning of this chapter, strain analysis was performed in two ٦-month epochs in 2007. Figure ٦shows the strain values obtained for the second half of 2007 for Epoxy. According to this figure, it can be concluded again that in this ٦-month period, the majority of strains on the stations of the geodynamic network of Iran are as pressure strains. (Fig. 6)

For further analysis of the results obtained from the two-dimensional isoparametric method, the values of strain obtained on the network stations along with the topography of Iran are given in Figure 7. Due to the shape and the fact that no major earthquake has occurred in the Iranian region in this ٦-month epoch, the strains obtained from the above method are almost consistent with the topography of the Iranian region and in most mountainous areas is a compressive strain. (Fig. 7)

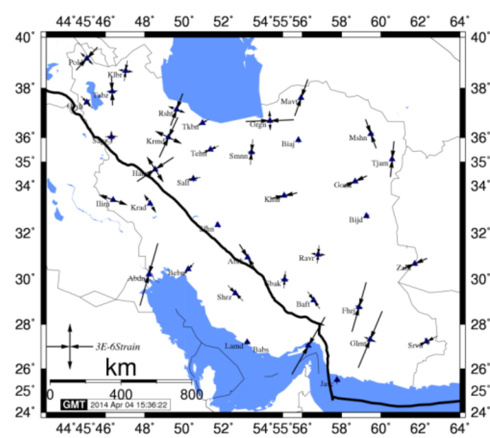

Fig.6. Main values of strain at geodynamic network stations in Iran for the second half of 2007 for OPOK

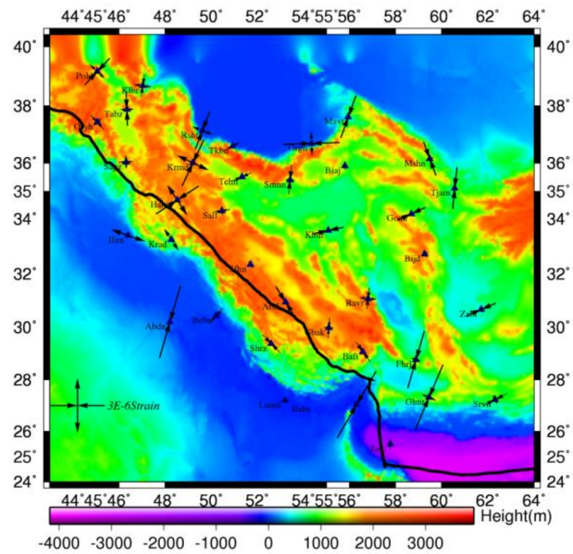

Fig.7. Main values of strain in the second half of 2007 in Apok with topographic map of Iran

For two observational APECs from to 2008, the strain tensor element containing 35 triangular elements for the center of gravity of each element was calculated using the finite element method. Figure 8 shows how the above elementation for the geodynamic network of Iran. (Fig. 8)

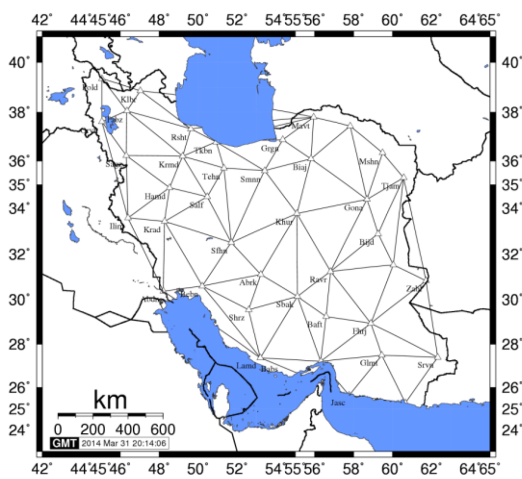

Fig.8. Triangular elements considered for the geodynamic basis network of Iran

The strain tensor components are calculated for the centers of each element using the method described in the previous chapter. The results of this calculation can be seen in Figure 9. According to this figure, it can be seen that most regions of Iran are compact. Of course, areas can also be seen in the figure that have a lot of expansion. The results seem to be strongly dependent on the type of elementation. (Fig. 9)

In order to evaluate how the strain in the Iran region was changed by the finite element method, this method was also calculated for the second 6-month period of 2007. Of course, it is necessary to pay attention to the fact that this method is assumed to be homogeneous deformation within each element and also has a strong dependence on the type of elementation. Figure 10 shows the results for the finite element strain analysis for the second 6 -month period. (Fig. 10)

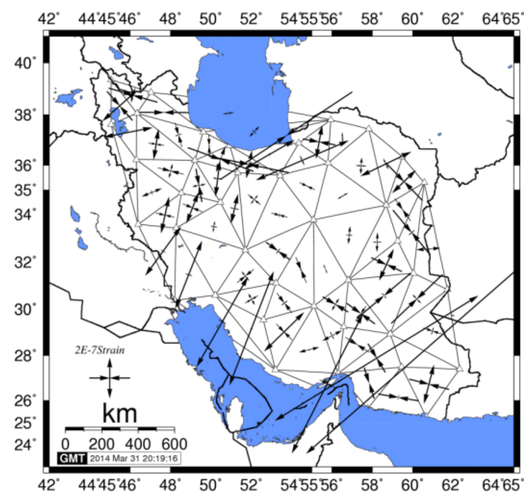

Fig.9. Strain tensor components for the centers of each triangular element in the first ٦months of ٢٠٠٧

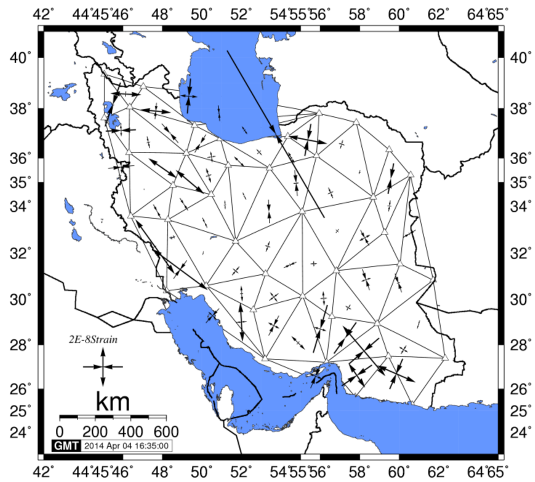

Fig.10. Strain tensor components for the centers of each triangular element in the second ٦-month period of 2007

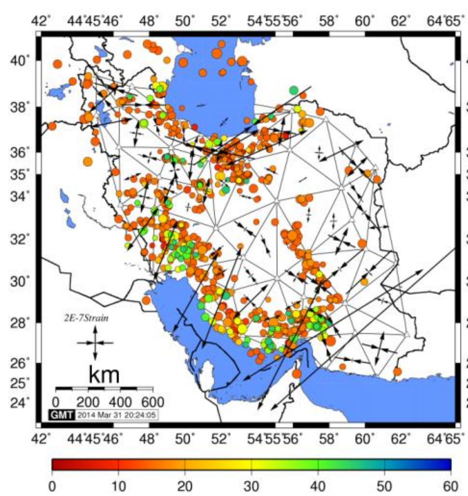

Fig.11. Distribution of earthquakes in Iran between 2001 and 2008 based on the depth of the earthquake

It should be noted that the assumption in this method is the homogeneity of the deformation in the region. Iran is an earthquake-prone region and suffers from many earthquakes in the long APECs of this region, and this causes a lot of deformation and inhomogeneity in the region, so that in the observation APEC used earthquakes with a depth of less than 100 km, minimum 1.7 and maximum005 /006has occurred. For this reason, it is recommended to use shorter APCs for a few months to calculate the strain tensor in Iran. Figure 11 shows the distribution of earthquakes in Iran in the period between 2001-2008 based on the depth of earthquakes.

Conclusion

In the finite element method, the results obtained depend on the shape of the element. Of course, this issue should be studied in practice and the results should be compared. This method gives the same answer to the hypothesis that the deformation is homogeneous in the desired element only for homogeneous networks with any type of elementation. The resulting strain for the center of gravity of all the elements was the same size and in the same direction, indicating the homogeneity of the deformation in the lattice. The finite element method seems to be inappropriate for regions with heterogeneous deformation such as Iran and is not dependent on APEC observation time. This statement is the result of calculations made in this article and further investigation can prove the accuracy of this statement.

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