Available online at www.sciencedirect.com

SCIENCE DIRECT®

Journal of Geodynamics 41 (2006) 462–470

JOURNAL OF GEODYNAMICS

http://www.elsevier.com/locate/jog

The current strain distribution in the North China Basin of eastern China by least-squares collocation

J.C. Wu[a,b,∗], H.W. Tang[a], Y.Q. Chen[a], Y.X. Li[c]

[a] *Department of Land Surveying and Geo-Informatics, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong*
[b] *Department of Surveying and Geo-Informatics, Tongji University, Shanghai, China*
[c] *First Crustal Deformation Monitoring Centre, China Seismological Bureau, Tianjin, China*

Received 3 May 2005; received in revised form 2 January 2006; accepted 27 January 2006

Abstract

In this paper, the velocities of 154 stations obtained in 2001 and 2003 GPS survey campaigns are applied to formulate a continuous velocity field by the least-squares collocation method. The strain rate field obtained by the least-squares collocation method shows more clear deformation patterns than that of the conventional discrete triangle method. The significant deformation zones obtained are mainly located in three places, to the north of Tangshan, between Tianjing and Shijiazhuang, and to the north of Datong, which agree with the places of the Holocene active deformation zones obtained by geological investigations. The maximum shear strain rate is located at latitude 38.6°N and longitude 116.8°E, with a magnitude of 0.13 ppm/a. The strain rate field obtained can be used for earthquake prediction research in the North China Basin.

Keywords: GPS; Strain; Least-squares collocation; North China Basin

1. Introduction

The current crustal deformation of China is divided into two parts by the north–south seismic zone which occurs along the longitude 105°E (Ma, 1989). The crustal deformation of the western part is more active and one order larger than that of the eastern part (Shen et al., 2000, 2003). Many investigations have studied the western China crustal deformations which are mainly controlled by the Indian Plate colliding with the Eurasian Plate (Molnar and Tapponnier, 1975; Pelzer et al., 1989; Northrup et al., 1995; Royden et al., 1997). Because of smaller magnitudes and sparse GPS data available in eastern China, the study of the current crustal deformation in eastern China is mainly limited to some active zones, such as the North China Basin, Taiwan island, etc. (Wu, 1999; Wu et al., 2003a; Yu et al., 2003). However, in eastern China there is a heavy population. More and more GPS surveys are conducted in this area including some continuous GPS stations. After 2001 and 2003 GPS surveying campaigns conducted by the State Seismological Bureau, there are more than 400 GPS station velocities available in eastern China. About half of the GPS stations are located in the North China Basin, which is one of the most active crustal deformation areas of eastern China. In this paper, we use these GPS velocities in the North China Basin to study its current crustal deformation pattern.

∗ Corresponding author. Fax: +86 21 65986737.
E-mail address: jcwu@mail.tongji.edu.cn (J.C. Wu).

0264-3707/$ – see front matter © 2006 Published by Elsevier Ltd.
doi:10.1016/j.jog.2006.01.003

Because the velocities obtained may be contaminated by observation errors, the obtained deformation patterns based on these velocities may be biased from the truth. El-Filky and Kato (1999) applied the least-squares collocation method to obtain a continuous displacement field based on the discrete observation stations in Tohoku district, Japan. This method can filter out the short wavelength movements caused by the observation errors (El-Filky and Kato, 1999). In this paper, we applied the least-squares collocation method to 154 GPS station velocities in the North China Basin. A continuous velocity filed is formulated and the strain rate distribution on a grid size of about 12 km (0.1°) is calculated. The results are compared with the conventional discrete triangle method.

At first, we present a brief introduction of the conventional discrete triangle method and the least-squares collocation method; then results on the strain rate distribution by each method are calculated and compared. Based on geological investigations and neotectonic movements, the obtained strain rates distribution is discussed and interpreted.

2. Methods and horizontal strain rate distribution

2.1. Discrete triangle method

Under the assumption of uniform infinitesimal strain, the horizontal strain components can be calculated by the horizontal displacements of three points of a triangle. Supposing the displacements of the three points to be $A : (u_A, v_A)$, $B : (u_B, v_B)$, and $C : (u_C, v_C)$, then the strain components can be calculated by (Eringen, 1980):

$$\left.\begin{aligned} u_B - u_A &= \Delta x_{AB}\varepsilon_{xx} + \Delta y_{AB}\varepsilon_{xy} + \Delta y_{AB}\omega \\ v_B - v_A &= \Delta x_{AB}\varepsilon_{xy} + \Delta y_{AB}\varepsilon_{yy} - \Delta x_{AB}\omega \\ u_C - u_A &= \Delta x_{AC}\varepsilon_{xx} + \Delta y_{AC}\varepsilon_{xy} + \Delta y_{AC}\omega \\ v_C - v_A &= \Delta x_{AC}\varepsilon_{xy} + \Delta y_{AC}\varepsilon_{yy} - \Delta x_{AC}\omega \end{aligned}\right\} \tag{1}$$

where Δx_{AB}, Δy_{AB}, Δx_{AC}, and Δy_{AC} are coordinate increments of sides AB and AC, respectively, ε_{xx}, ε_{xy}, and ε_{yy} are the three components of the plane strain tensor, and ω is the differential rotation (clockwise rotation is positive). They are defined as:

$$\left.\begin{aligned} \varepsilon_{xx} &= \frac{\partial u}{\partial x} \\ \varepsilon_{yy} &= \frac{\partial v}{\partial y} \\ \varepsilon_{xy} &= \frac{1}{2}\left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}\right) \\ \omega &= \frac{1}{2}\left(\frac{\partial u}{\partial y} - \frac{\partial v}{\partial x}\right) \end{aligned}\right\} \tag{2}$$

where u is the displacement in x direction and v is the displacement in y direction.

As long as the three points A, B, and C are not on a line, there is a unique solution for Eq. (1). Noting that

$$d = [\,u_B - u_A \quad v_B - v_A \quad u_C - u_A \quad v_C - v_A\,]^T \tag{3}$$

$$x = [\,\varepsilon_{xx} \quad \varepsilon_{yy} \quad \varepsilon_{xy} \quad \omega\,]^T \tag{4}$$

then Eq. (1) can be written as a matrix:

$$Ax = d \tag{5}$$

where

$$A = \begin{bmatrix} \Delta x_{AB} & 0 & \Delta y_{AB} & \Delta y_{AB} \\ 0 & \Delta y_{AB} & \Delta x_{AB} & -\Delta x_{AB} \\ \Delta x_{AC} & 0 & \Delta y_{AC} & \Delta y_{AC} \\ 0 & \Delta y_{AC} & \Delta x_{AC} & -\Delta x_{AC} \end{bmatrix} \tag{6}$$