Statistical method for detecting changes in earthquake focal mechanism distribution by triangle diagram

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In this study, we propose the statistical method for determining whether the distributions of two groups of focal mechanisms, plotted on triangle diagrams [Frohlich (1992, 2001)], are indistinguishable.

Let Pt, Pp, and Pn to be the plunge angles of the T, P, and N axes, respectively. These satisfy

$\sin^2 Pt + \sin^2 Pp + \sin^2 Pn = 1$.

The above equation describes surface of an octant of a unit sphere, since the variables; x=sinPt, y=sinPp, and z=sinPn, are positive. Frohlich (1992, PEPI) presented plotting the variables on the oblique Gnomonic projection, centered at $x^2=y^2=z^2=1/3$, and evaluating features of the focal mechanism distribution. Because a focal mechanism is plotted within an equilateral triangle on this projection, this chart is called the triangle diagram. Moreover, Frohlich (2001, GJI) proposed dividing a triangle into H^2 (i=1,..., H^2) equilateral sub-triangles, and derived the distribution of the frequency within each sub-triangle.

In order to determine whether the frequency distributions of two groups (g=1, 2) are equal, we compare two models:

Model 0: The frequency distributions of two groups are equal. p(i|g)=f(i);

Model 1: They aren't equal. p(i|g)=f(i|g),

where p(i|g) denotes the probability that each mechanism of group g result in i-th sub-triangle. Let n(g) represent the total number of the mechanisms of group g, and n(g, i) the number of mechanisms of group g lying in i-th sub-triangle. Then the probability P for getting the mechanism distribution follows the multinomial distribution,

P =[n(1)! {Prod p(i|1)^n(1, i)} / {Prod n(1, i)!}] [n(2)! {Prod p(i|2)^n(2, i)} / {Prod n(2, i)!}],

where Prod means the product of sequence terms of the index i. The number of parameters of Model 0 is H^2-1, and another is 2(H^2-1). Then, we derive the AIC (Akaike Information Criterion) values of two models:

AIC(0)=(-2){K + Sigma L(0, i) } + 2(H^2-1),

AIC(1)=(-2){K + Sigma L(1, i) } + 4(H^2-1),

where

L(0, i)= { n(1, i) + n(2, i) } log[{ n(1, i) + n(2, i) } / { n(1) + n(2) }],

L(1, i)= n(1, i)log{ n(1, i) / n(1) } + n(2, i)log{ n(2, i) / n(2) },

Sigma means the summation of sequence terms of the index i, and K denotes common terms of two models. In the model selection, when an absolute value of the AIC difference of two models is greater 2, the model having lower AIC is better. For example, if D_AIC =AIC(0)-AIC(1) is greater 2, the distributions of two groups are different.

We apply this method to focal mechanism data. Group 1 (G1) consists of m mechanisms in the aftershocks of the 2004 Mid Niigata prefecture Earthquake in the Seismological and Volcanological Bulletin of Japan. We rotate all G1 with rotation angle r around N axis of the mainshock, and let them G2. In this experiment, the D_AICs are calculated under the various values of r and m, while H^2 is fixed at 16. As a result, when m is 32, 64, and 128, D_AIC is greater 2 with r more than 40, 35, and 20 degree, respectively.

Next, we investigate the activity in the source region of the Earthquakes East of the Kuril Islands of 2006 and 2007. 253 earthquakes are analyzed for the period from August 1977 to August 2008 in the Global CMT catalogue. G1 consists of 64 mechanisms which is the first part of the dataset. G2 consists of 32 mechanisms. The head event of G2 changes sequentially, and we get the time series of D_AIC. First, D_AIC was negative. However, it was gradually increasing, and became positive. When the EQ I (2006/11/15, Mw8.3, thrust type) occurred, D_AIC was the largest. Afterwards, it was steadily decreasing, and returned to negative after the occurrence of the EQ II (2007/1/13, Mw8.1, normal type). In fact, after the EQ I, the activity of normal type earthquakes was activated at the seaward region of the Kuril trench, and after the EQ II, it was rapidly deactivated. Consequently, we conclude that temporal variation of D_AIC reflected the change of focal mechanisms distribution.