Modification of a method of Galanopoulos for determining earthquake risk

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Summary. — A method for the determination of earthquake risk basing on the energy–frequency–relation proposed by Galanopoulos is modified.

Riassunto. — Nella nota viene modificato il metodo per la determinazione del rischio legato ad un terremoto, metodo già proposto precedentemente da A. G. Galanopoulos e basato sulla relazione che intercorre tra energia e frequenza.

In the relation

$$\lg N = a - bM \qquad [1]$$

between earthquake magnitude M and annual number N of earthquakes of the magnitude class with centre M the coefficient a appears to depend mainly on the energy release in the considered region Γ with area G, whereas b depends on the mean depth of the focus in Γ. After reducing [1] to a general standard area G^* the accordingly transformed relation [1] informs us about the relative frequency of such earthquakes. Supposing all earthquakes have equal depth, then a measure of the earthquake risk would be found by this. To compensate the actual variation of the mean focal depth and the variability of b connected with it Galanopoulos (¹) proceeds as follows.

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$$\lg N' = a_0 - b_0 M \qquad [2]$$

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substitutes [1] where b_0 is a fixed reasonable value, possibly 0.8. The formulas [1] and [2] are connected by postulating that the magnitude M_0 corresponds to a certain value N_0 in both cases

$$M = M_0 \longrightarrow N'(M_0) = N(M_0) = N_0 \ . \qquad [3]$$

Therefore from [1] and [2] follows

$$a_0 = a \frac{b_0}{b} + \left(1 - \frac{b_0}{b}\right) \lg N_0 \ . \qquad [4]$$

In the next step Galanopoulos (1) gets to the frequency N'^* related to the standard area by thinking the earthquake events being distributed homogenously in Γ and $\Gamma^* \subset \Gamma$, too. That means

$$\frac{N'^*}{N'} = \frac{G^*}{G}$$

whence

$$\lg N'^* = a'^* - b_0 M \ , \qquad a'^* = a_0 + \lg \frac{G^*}{G} \ . \qquad [5]$$

Now we consider two regions Γ_1 and Γ_2, the intersection of which need not be empty, with $a_1 \neq a_2$, but having equal parameters a'^*, b

$$a'^*_1 = a'^*_2 \ , \qquad b_1 = b_2 \neq b_0 \ . \qquad [6]$$

For such regions it holds naturally

$$\frac{N_1}{N_2} = \frac{G_1}{G_2} \ . \qquad [7]$$

[6] helps with [5], [4], [7], and [1] to

$$0 = a'^*_1 - a'^*_2 = \left(1 - \frac{b_0}{b_1}\right) \lg \frac{N_{01}}{G_1} \frac{G_2}{N_{02}} \ .$$

Therefore

$$\frac{N_{01}}{G_1} = \frac{N_{02}}{G_2} = n_0$$

is a quantity which must be chosen uniquely for all regions Γ and N_0 cannot be independent of Γ. With this condition we get

$$a'^* = \frac{b_0}{b} (a - \lg n_0 G) + \lg n_0 G^*$$

as modified measure of earthquake risk in the sense of Galanopoulos.

The last term is an arbitrary number independent of a, b and G, suitably defined to zero:

$$n_0 G^* = 1 \ . \tag{8}$$

Therefore we finally get:

$$a'^* = \frac{b_0}{b}\left(a - \lg \frac{G}{G^*}\right) . \tag{9}$$

The values of b_0 and G^* must be chosen definitly and according to reality, possibly in conformity with Galanopoulos as

$$b_0 = 0.8 \ , \qquad G^* = 10^4 \ \mathrm{km}^2 \ .$$

The arbitrariness in choosing b_0, G^* and $n_0 G^*$ can be comprehended as a foible of the method. Another difficulty is that the investigated region Γ cannot be defined without free choice. Moreover, there remains the open question mentioned also by Galanopoulos to which degree the basing relation [1] fits to reality.

Furthermore, we consider the difference between a'^* and the analogous quantity after Galanopoulos who generally postulates

$$N_0 = n_0 G = 1 \ , \tag{10}$$

instead of [8] where N_0 is defined in [3] and who, therefore, gets

$$a^* = \frac{b_0}{b}\, a + \lg \frac{G^*}{G} \tag{11}$$

The difference

$$a'^* - a^* = \left(1 - \frac{b_0}{b}\right) \lg \frac{G}{G^*}$$

to [9] depends on the chosen values b_0 and G^* and of course on b and G. In Tab. I in the paper of Galanopoulos, this difference does not exceed the amount of 0.11 in the case of South California where $a = 5.25$, $b = 0.86$, $G = 29.61\, G^*$, and $a^* = 3.41$, $a'^* = 3.52$.

Finally, we can see at a consequence of [10] that this postulate is unsuitable. Let Γ_1 and Γ_2 be two regions with equal relative quantities a^* and b, b different from b_0:

$$a^*_1 = a^*_2 \ , \qquad b_1 = b_2 \neq b_0 \ .$$

This leads with [11] and [1] to

$$\frac{N_1}{N_2} = \left(\frac{G_1}{G_2}\right)^{b_1/b_0}$$

contradictory to the natural condition [7] because of $b_1 \neq b_0$.

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REFERENCES

(1) Galanopoulos A. G., *On Quantitative Determination of Earthquake Risk.* " Annali di Geofisica ", **XXI**, 2, 193-206, (1968).