On the reliability of the size assigned to historical earthquakes

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ABSTRACT: Standard statistical comparisons have been made between the mean magnitudes, mean epicentral intensities and mean seismicity rates of large ($M>6.6$) Aegean shocks listed in four catalogs of the 19th and 20th centuries. The most prominent result is a significant ($a=0.01$) excess by 0.67-1.05 degrees (MM) of the mean epicentral intensity in one of the two historical catalogs examined, which implies a systematic intensity overestimation.

1 INTRODUCTION

Although vastly incomplete and highly inaccurate, historical earthquake data are extremely useful in studies of seismicity, seismic hazard assessment and earthquake prediction. The Greek experience constitutes a good instance of this notion (Papadopoulos and Kijko 1991). For this reason, examining the reliability of the size assigned to historical earthquakes is of special importance. This problem has been statistically examined by analysing data sets of large earthquakes which occurred in the Aegean and surrounding regions during the 19th and 20th centuries.

2 METHOD AND DATA

Our method of analysis is based on two main assumptions: (1) the instrumental data of the 20th century are more reliable with respect to the 19th century macroseismic data, (2) the seismicity rate is constant over relatively long time intervals (80-100 years). Under these assumptions we compare the mean magnitudes, $\bar{M}$, the mean epicentral intensities, $\bar{I}$, and the mean seismicity rates, r , of the 19th and 20th centuries earthquakes.

Statistical comparisons have been made in the sense of accepting or rejecting, at a certain significance level, a , the null hypothesis Ho: $\bar{M}_i$ (or $\bar{I}_i$ or r)$=\bar{M}_j$ (or $\bar{I}_j$ or r) and its alternative hypothesis H_1 :
$\bar{M}_i$ (or $\bar{I}_i$ or r) $\neq \bar{M}_j$ (or $\bar{I}_j$ or r_j), where
$i=1,2,3,4$, $j=1,2,3,4$ and $i \neq j$ in each hypothesis. The z-test and t-test have been applied for large ($n>30$) or small ($n \leq 30$) statistical samples, respectively.

Four catalogs for the earthquakes of the Aegean and adjacent regions have been utilised as data sources; two for the 19th century (1800-1900): PC (Papazachos and Comninakis 1982) and PP (Papazachos and Papazachos 1989), and two for the 20th century (1901-1985): CP (Comninakis and Papazachos 1986) and MA (Makropoulos et al. 1989). Only data for shallow earthquakes ($h < 70$ km) have been analysed.

The number of earthquakes reported during the 18th and 19th centuries increases quasi-exponentially with time (Papadopoulos 1988) which implies a vast incompleteness in the earthquake sample available. The completeness of the 19th century data set has been tested by examining the non-linear structure of the magnitude-frequency relation for the PP catalog which is a modification of the PC one. Figures 1 and 2 show that this data set is incomplete for $M \leq 6.6$ for both time intervals examined: 1800-1870 and 1853-1900. The t-test indicates that in both diagrams the difference between the b-values found for the two time intervals is significant at the level of $a=0.01$ (Table 1). As a consequence we consider that the data of the 19th century are complete only for $M > 6.6$. This is the lower magnitude threshold involved in the analysis of the four catalogs used. Calculation of b-values has been made by the least-squares method. M is the surface-wave magnitude determined instrumentally in the CP and MA catalogs and analogically from macroseismic observations in the PC and PP catalogs .

3 RESULTS

3.1 Difference between the mean sizes

The significance of the difference betwee.. $\bar{M}$ and $\bar{I}$ of large ($M > 6.6$) earthquakes listed in the four catalogs has been
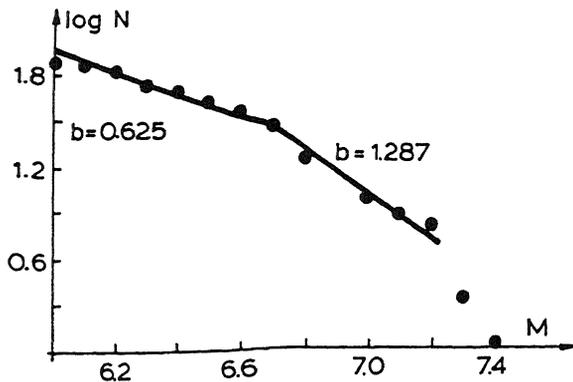
Figure 1. The magnitude-frequency relation for the time interval of 1800-1870 of the PP catalog.
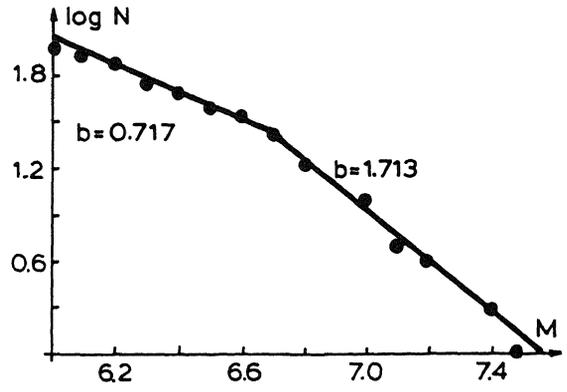

Figure 2. The magnitude-frequency relation for the time interval of 1853-1900 of the PP catalog.

checked by examining the validity of the hypothesis Ho and H_1 on the basis of the z-test (Table 2). The intensities cited in the catalogs PC, PP and CP are according to the modified Mercalli-Sieberg scale . Intensities are not cited in the MA catalog.

Table 1. Papameters involved in the t-tests applied to the magnitude-frequency relations of Figures 1 and 2.

	Time	Interval
	1800-1870	1853-1900
M < 6.7		
n	7	7
b	0.625± 0.0007	0.717± 0.042
M= 6.7-7.2		
n	5	7
b	1.287± 0.128	1.713± 0.085

Any intensity scale provides only integer values of intensity. Several authors , however, use non-integer values, e.g. in a decimal form, for intensities either observed in the field or calculated from formulas relating intensity with other seismological parameters (e.g. Evernden 1975). The decimal form of intensities has been adopted for the purposes of the present study.

The total number of z-tests performed is nine; six for the $\bar{M}$ difference and three for the $\bar{I}$ difference. According to these tests the six $\bar{M}$ differences as well as the $\bar{I}$ differences between the PP and CP catalogs are not significant at the a=0.01 level. However, the $\bar{I}$ difference between the catalogs PC - PP and PC - CP appears to be significant at the same level. This means that the mean epicentral intensity assigned to large earth-quakes in the PC catalog is significantly

overestimated by 0.67-1.05 degrees with respect the PP and CP catalogs. We do not attribute this difference to the reduced earthquake resistance of the 19th century buildings. What seems more reasonable is the systematic intensity overestimation because of misinterpretation of the historical documents containing macroseismic descriptions. This suggestion is based on the fact that although the PP catalog covers also the 19th century, its $\bar{I}$-value is significantly lower, with respect to that of the PC catalog , obviously because of the careful reexamination of the existing documents. On the contrary, no significant difference between the $\bar{I}$-values of the PP and CP catalogs has been found.

Table 2. Parameters involved in the z-tests performed for the difference between mean magnitudes and mean intensities in the four catalogs used.

Catalog	n	$\bar{M}$	$\bar{I}$
PC	41	6.943± 0.299	9.610± 1.137
PP	37	6.883± 0.232	8.946± 1.104
CP	40	7.000± 0.256	8.564± 1.252
MA	37	7.008± 0.251	———

3.2 Difference between the mean seismicity rates

The mean seismicity rate, r= dN / dt (in events / yr), has been determined by re-gression analysis for each one of the four catalogs, where dN is the cumulative number of earthquakes at time dt after the beginning of the catalog. The r-values found for

M > 6.6, and the number, (n), of points dN/dt involved are 0.469+ 0.098 (30), 0.447+ 0.024 (29), 0.452+ 0.019⁻(29) and 0.477+ 0.049 (28) for the catalogs PC, PP, CP and MA, respectively.

The significance of the difference between the seismicity rates has been considered as an alternative approach of our problem. The performance of six t-tests showed that the hypothesis Ho is accepted at a=0.01 in five cases, while only in one case the hypothesis Ho has been rejected. This is the case of the difference between the r-values of the catalogs PP and MA which means that the number of earthquakes recorded per time unit in the 20th century is, according to the MA catalog, significantly larger than the number of earthquakes reported per time unit in the PP catalog. A plausible explanation may rely on the poor reporting of aftershocks in the PP historical catalog.

4 CONCLUSIONS

Results of standard statistical tests performed for examining the significance of the difference between the mean magnitudes, mean epicentral intensities and mean seismicity rates of four Aegean catalogs of large (M > 6.6) earthquakes of the 19th and 20th centuries imply that:

(1) No significant differences, at the a=0.01 level, have been detected for the mean earthquake magnitudes.

(2) A significant (a=0.01) excess, by 0.67-1.05 degrees (MM), of the mean epicentral intensity reported in the historical catalog of Papazachos and Comninakis (1982), with respect the mean epicentral intensities reported in the revised historical catalog of Papazachos and Papazachos (1989) and in the present century catalog of Comninakis and Papazachos (1986), indicates a systematic overestimation of the epicentral intensities listed in the first catalog.

(3) The significantly (a=0.01) larger seismicity rate in the present century catalog of Makropoulos et al. (1989) with respect the seismicity rate in the historical catalog of Papazachos and Papazachos (1989) is possibly explained by the poor reporting of aftershocks in the last catalog.

REFERENCES

Comninakis, P.E. & B.C. Papazachos 1986. A catalogue of earthquakes in Greece and the surrounding area for the period 1901 - 1985. Univ. Thessaloniki Geophys. Lab. Publ. : 1, 167 pp.

Evernden, J.F. 1975. Seismic intensities , "size" of earthquakes and related parameters . Bull. Seismol. Soc. Am. 65 : 1287 - 1313.

Makropoulos, K.C. , J.K. Drakopoulos &

J.B. Latousakis 1989. A revised and extended earthquake catalogue for Greece since 1900. Geophys. J. Intern. 98 : 391 - 394.

Papadopoulos, G.A. 1988. Statistics of historical earthquakes and associated phenomena in the Aegean and surrounding regions. In P. Marinos & G. Koukis (eds.), The Engineering Geology of Ancient Works, Monuments and Historical Sites: 1279 - 1283. Rotterdam : Balkema.

Papadopoulos, G.A. & A. Kijko 1991. Maximum likelihood estimation of earthquake hazard parameters in the Aegean area from mixed data. Tectonophysics 185: 277-294.

Papazachos, B.C. & P.E. Comninakis 1982. A catalogue of historical earthquakes in Greece and surrounding area, 479 B.C. - 1900 A.D.. Univ. Thessaloniki Geophys. Lab. Publ. : 5, 24 pp.

Papazachos, B.C. & K. Papazachos 1989. The earthquakes of Greece. Thessaloniki : Ziti, 356 pp.