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Reliability of Catalogues of Historic Earthquakes When More Than One Is Available

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COMPARISON OF FIVE DIFFERENT EARTHQUAKE'S CATALOGUES OF THE SAME SEISMIC REGION

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ABSTRACT OF THE CONTENT OF THE CATALOGUES

ENEL, Catalogue of Italian earthquakes, (on magnetic tape), Ente Nazionale Energia Elettrica, Roma,1975.

The ENEL (Ente Italiano Energia Elettrica, Italian Agency for Electric Energy) catalogue was prepared by Geotecneco for ENEL. The catalogue contains 20067 earthquakes; it covers the period from the year 1000 through 1975. Among other parameters the catalogue gives the maximum Intensity recorded in the MCS scale, the coordinates and the time (when availble).

(CNEN)Carrozzo M.T., De Visentini G., Giorgetti E., Iaccarino E., General catalogue of Italian earthquakes, CNEN, Roma, RT/PROT; (73) 12, 1973.

The CNEN Catalogue was compiled at Comitato Nazionale Energia Nucleare (now ENEA Ente Nazionale Enrgie e Ambiente). It contains 10604 earthquakes. Among other parameters the catalogue gives the maximum Intensity recorded in the MSK scale, the coordinates and the time (when available). It covers the time interval from the year 0 through March 1971.

CNR, Catalogo dei terremoti italiani dall'anno 1000 al 1980, D. Postpischl Ed., Graficoop, Bologna, 1985.

The CNR catalogue was prepared by Progetto Geodinamica for the Consiglio Nazionale delle Ricerche (National Research Council). Among other parameters the catalogue gives the maximum Intensity recorded in the MCS scale, the coordinates and the time (when available). The catalogue covers the period from the year 1000 through 1980.The number of events is 37211.

(ING) Boschi E., Gasparini P., Ferrari G., Guidoboni E., Smriglio G., Valensise G., Catalogo dei forti terremoti in Italia dal 461 a.C. al 1980, Istituto Nazionale di Geofisica, Roma, 1995.

The catalogue ING was prepared by the the Istituto Nazionale di Geofisica in cooperation with SGA (Storia Geofisica Italiana) and concerns 346 of the strongest and most well documented Earthquakes occurred in Italy from 461 a.D. to 1980. For each earthquake the catalogue gives the description of the events through the documents on the earthquake, the estimate of the coordinates of the epicenter, the time (when available), the maximum intensity recorded and the intensity at the epicenter in the MCS scale.

(NT4.1)Molin D., Monachesi A., Rebez A. and Zerga A., NT4.1 un catalogo di terremoti di area italiana al di sopra della soglia del danno, Stucchi M and Camassi R. Eds., Consiglio Nazionale delle Ricerche, Gruppo Nazionale Difesa dai Terremoti, Milano, DTP printer, 1997.

The NT4.1 catalogue was prepared at Gruppo Nazionale Difesa dai Terremoti and it contains the earthquakes which casued some tangible damage and for which it was possible to prepare a string of parameters. It covers the temporal window from the year 1000 through 1980. The catalogue does not contain aftershocks nor foreshocks. The number of events listed is about 2400 and includes 95% of the destructive earthquakes (Intensity larger or equal to VII) of the Italian area. Among other

parameters the catalogue gives the Intensity at the epicenter in the MCS scale, the maximum Intensity recorded, the coordinates and the time (when available).

Content of the catalogues

The knowledge of the seismicity of a region is based on the records of the past earthquakes retrieved from instrmental data or from direct analysis of the damage caused by earthquakes in modern times or in cronicles for what concerns the recent and remote past.

This information is generally assembled in documents called Catalogues of earthquakes of the region.

For each earthquake the catalogues contain an array of numerical information and, sometimes, a descritpion of the event. The array of numerical information consists of the epicentral coordinates, the depth, the epicentral intensity, the maximum intensity or the isoseismal lines with their average radiae, the depth, the Magnitude and the time of occurrence with the year the month, the day, the hour, the minute and the seconds. Often part of the information on the time is missing to the extreme that only the year of occurrence is certain while the more detailed time informations are missing, this is a frequent case for the earthquakes occurred befor the year 1000.

The time information is of extreme inportance for deciding the identification of the events to be compared in the different catalogues, especially when many events occurred in few days.

The Intensity scales used are the Mercalli Cancani Sieberg (MCS) or the Medvedev Sponheuer Karnik (MSK) which is identical with the MCS and the Mercalli modified (MM) scales respectively, only the text has been rearranged and supplemented (Karnik 1969, 1971).

The Magnitude has been measured beginning in the 1950s and, for the catalogues of Italian earthquakes, concerning the earthquakes with intensity IX or larger, is known and given in an irrelevant number of cases. The scale of the magnitude is mostly local.

The description of the event is mostly based of chronicles of damage suffered by the constructions often retrieved from the documents used for assignement of money for the reconstrucion or by the general chronicles.

Sometimes the errors in the coordinates are estimated.

The catalogues considered in this study are the following:

CNEN (1973), ENEL (1975), CNR(1985), ING (1995) and NT4.1 (1997) which contain events ranging from 460 a.D. to almost the present. However, since the time interval covered by all of the catalogues covers only the time interval from the year 1000 to 1968, this study is limited to this period.

In order to be able to handle in a simple manner the information needed for the comparison of the catalogues we limited the comparison to the largest events and selected in all the five catalogues only the earthquakes which are listed with intensity X in at least one of the five catalogues. These earthquakes form a set of 93 events which can be handled numerically almost without the use of a PC and using only a bit of patience.

Aims of the study

The catalogues of earthquakes are the basis of the study of the seismicity. The longer is the time interval covered by the catalogues the stronger are the statistical properties of the study. Unfortunately only the large earthquakes are recorded in the chronicles of the past, as a consequence the number of events per year is decreasing with increasing time from the present and one of the task is therefore to study the completeness of the catalogue establishing time interval from the present to the past in which the catalogue may be considered complete for each Intensity.

The time interval in which the catalogue is complete relative to a given Intensity is obviously an increasing function of the Intensity or, given the intensity, the time interval is decreasing with decreasing intensity. In the case of the catalogue ENEL, for instance, it is estimated that it is complete for the intensity VI only from the end of the past century.

However in the present study we are not concerned with completeness since we consider only the events which have intensity X or larger in at least one of the catalogues and occurred after theyear 1000 a.D.. This implies that the largest majority of the events did not escape being considered other catalogues with the earthquakes of large Intensity. The case when one of these earthquakes is not considered in another catalogue is very rare but is occurs.

The main concern of this study are the precision of the Intensities of the earthquakes based on the Intensities which are assigned to the event in the different catalogues and also the relative consistency of the five catalogues.

The precision will be obtained with standard methods bases on the computation of the standard deviation; however other indirect methods will be used bsed on the comparisons of the different catalogues through the computation of the numebr of events which have the same evaluation of the Intensity in the different catalogues.

The consistency will be studied through the computation of the number of events having the same evaluation in the diffferent catalogues considered in groups of different number and also computing the number of earthquakes which have the same evaluation in all the possible couples of catalogues.

The problem of the precision of the time and of the coordinates, the latter of relevance for what concerns the concentration of the seismicity of the region, are not considered here.

The functionals considered for the catalogues

The functionals which we would like to consider are several.

The first obvious functional is the average Intensity of each catalogue.

Then follows the average standard (sd) deviation of the Intensities of the earthquakes of the catalogues referring each event to its mean value in the evaluations given set of catalogues.

Another functional is the standard deviation of each catalogue referring each event to the mean value of the catalogue.

One more is the mean absolute value of each catalogue referring each event to its mean value.

The standard deviation of the Intensities and its variation in time.

The first functional to consider in order to establish the precision of the Intensity of the events in the catalogues is the average Intensity of each earthquake considering only the events with assigned non nil intensity in all the catalogues This reduces the number of events considered to 78; the resulting average intensities are shown in Table 1.

Then we estimated the average intensity of each event, with assigned non nil intensity in all the catalogues, and proceeded to the computation of the standard deviation (sd) of the intensities recorded whose mean is 0.47 units of intensity.

In order to establish if there is a variation in time of the sd , the mean of the sd in successive time intervals, containing about the same number of events, is presented in table 2 and indicates that there could be a decrease of the means of the sd with increasing time. The figure 1 shows graphycally the straight line obtained with the least square method fit to the data of table2.

A second functional to consider in order to establish the precison of the Intensities is the [redacted] sd [redacted] of the intensity of the events of each catalogue relative to the average Intensity in [redacted] the catalogue[redacted].

The [redacted] standard deviations are shown in table 1 were the average value of the intensities of each catalogue have also been presented.

It is to be noted in table 1 that the [redacted] standard deviation[redacted] in the catalogues is alwais larger than the sd of all earthquake's Intensities.

Construction of the tables of the number of coincident evaluation in the catalogues.

Indirect indications of the precision of the Intensities are also obtained by computing the number of events having the same intensity in a given number of catalogues. The table 3 shows the results of this investigation. These results are not too ecouraging when noting that only about 2/3 of the earthquakes have the same intensity in only three of the five catalogues. It is to be noted that the same evaluation in only three catalogues, in general, is not acceptable to make a sound decision.

The five catalogues considered in this study are, in order of publication date, CNEN (1973), ENEL (1975), CNR(1985), ING (1995) and NT4.1 (1997). They cover different time intervals, however all cover at least the time interval from the year 1000 a.D. through 1968, which was considered in the studies of Caputo (1981, 1986-87) and of Bella et al. (1990) as well as in the present study.

A comparison of the first two catalogues appeared (CNEN and ENEL) was made by Caputo (1981). Then came the comparison of the firsts three catalogues (Caputo 1986-87) and finally the comparison of the first four catalogues (Bella et al. 1990). Except for the latter work the comparison of the catalogues, especially those of Caputo (1981, 1986-87) did not have an elaborate procedures concernign the precision; the work of Caputo (1981) was mainly concerned with completeness and the seismic risk. The work of Bella et al. (1990) was more elaborate than the others and concerned only with the comparison but, due the limited number of catalogues available the sd of the intensities was not estimated; also the mean absolute deviation in each catalogue was not estimated .

Moreover the ING catalogue used by Bella et al. (1990) was preliminary and has been revised. The version used in the present study is the final one.

However a number of tables with the estimate of the number of events having the same Intensity in a given number of the catalogues was prepared in all the previous work but the events considered in the catalogues used in these studies are different from those of the catalogues considered is this study.

We will present here both results; however for consistency reasons we will first present the results obtained from the data resulting considering all five catalogues used in this study. The results obtained in the previous study will folllow.

In Table 4 we present comparatively the results of the computations made using the five catalogues considered here considering them 4, 3, and 2 at the time following the order of their appearence.

It is easily noted in table 4 that the number events considered in the successive groupings of catalogues is an increasing function of the number of catalogues. But also the number of coincident evaluations in at leat two catalogues is an increasing number of the number of the catalogues. The same is valid for the number of coincidences in at least three and at least four catalogues. These results are obviously to be expected because the addition of a catalogue increases the probability of an additional coincidence.

On the contrary the number of events having the same evaluation in all the catalogues considered in the successive studies is decreasing with increasing number of catalogues. Also this result is to be expected because the addition of a catalogue increases the probability of a disagreeing opinion. In the existing five catalogues there are only 9 earthquakes with the same intensity in all the catalogues. Of the events which were recorded as large in all the five catalogues only one has different evaluation of Intensity in all the catalogues, namely that occurred in North Italy on January 3rd 1117.

Although the addition of new catalogues changes the set of events considered and the catalogue ING used by Bella et al. (1990) was preliminary and different form that used here it is still worthwhile to make a comparison of the results obtained in the present study with those obtained in the previous studies.

Concerning the table 4 the percentual values in the columns of ENEL, CNEN, CNR, ING, of ENEL, CNEN , CNR, of ENEL,CNEN may be compared with the percentual values of the tables of previous works done in this field whose presentation will follow.

We begin with the study of the ENEL and CNEN catalogues made by Caputo (1981). The difference with the results of the present study are irrelevant for what concerns the number of coincident evaluations.

Follow the results of the study of Caputo (1986-87) on the ENEL, CNEN and CNR catalogues shown in table 6, which indicates that, only 24%, of the 72 earthquakes considered in all three catalogues, are listed with the same Intensity. 24% earthquakes are listed with the same intensity in the three catalogues in agreement with 23 % of table 4 of the present study. The average Intensities in the three catalogues are very close to those of table 1 with the exception of that of CNEN which is 0.21 units of Intensity larger in the study of Caputo (1981) than in the present study.

We note that the largest number of coincident evaluations is in the couple ENEL, CNR which reaches here 51%.

The slight disagreements between table 4 and table 5 concerning the catalogues of ENEL and CNEN (Caputo 1981)is only apparent because the number of events considered in the two studies is different since the addition of the CNR catalogue introduced events with Intensity X which were considered with Intensity IX in the other two catalogues. It should be noted that, since in the note of Caputo (1981) the comparison of the catalogues is treated only marginally and no indication is given on the use of the catalogues or on the limitations introduced, this discrepancy is insignificant.

Then comes the work of Bella et al. (1990) summarized in table 7 where one may note again that the number of coincident evaluations in at least two catalogues is an increasing number of the number of the catalogues. Although the addition of new catalogues changes the set of events considered and the catalogue ING used by Bella et al. (1990) was preliminary and different form that used here it is still worthwhile to make a comparison of the results obtained in the present study with those obtained in the previous ones especially with this one which deals with four catalogues.

In the table 7 it is to be noted that the largest number of coincident evaluations is in the couple ENEL, CNR which, however, here reaches only 50% instead of the 51 % of the study of Caputo (1986-87).

The table 8 shows the results obtained using the sets of data of the five catalogues considered here and computing the numbers of coincident evaluations of I in the 10 combination of the five catalogues taken two at the time. We note that here again the couples of catalogues which have the largest percentual number of coincident evaluations of I are ING and NT4.1, with 60%, and ENEL and CNR, with 51%, which is slightly more than the value 50% found by Bella et al. (1990) with four catalogues, and thus confirming it, and confirming also the 51% of coincident evaluations obtained by Caputo in 1981 who used only the three catalogues ENEL, CNEN and CNR then available.

It is to be noted in tables 6,7,8 and 9 that the catalogues CNR, ENEL and NT4.1 reach the largest total number of coincident evaluations of I with all the other catalogues issued.

Finally table 9 summarizes the number of coincident evaluations in the grouping of increasing number of catalogues, of the set of five catalogues in the form used in this study, considering them in order of appearance so the percetnual values appearing in the table may be compared with the previous work of other authors on the same catalogues.

Table 1 . Average intensity in the five catalogues ING, ENEL, CNEN, CNR, NT4.1 after removing the events whose intensity was not evaluated in all the catalogues or which were ignored in at least one catalogue. Are left 78 earthquakes.

	Average Intensity	~~Average absolute deviations~~ sd in each catalogue
ENEL	IX.731	0.532
CNEN	X.038	0.633
CNR	IX.737	0.754
ING	IX.833	0.705
NT4.1	IX.777	0.757

Table 2 . Time variation of the standard deviation (sd). The time intervals are selected in order to have about the same number of events in each of them. The standard deviation(sd) is in units of Intensity.

From year to year	Number of earthquakes	standars deviation	
1117-1328	10	0.67	
1348-1542	10	0.52	
1542-1659	10	0.49	
1661-1789	10	0.44	
1695-1789	9	0.45	
1791-1846	10	0.45	
1851-1908	10	0.45	
1910-1968	9	0.31	sd = 1.127-0.0003908 t (year)

The average of the standard deviations of the Intensities of 78 earthquakes given in the five catalogues, in the time interval 1000 - 1968 is 0.47 units of Intensity. The equation indicates a tentative least square fit of the sd versus the time center of the 8 time intervals considered.

Table 3. Number of earthquakes having the same evaluation in at least the number of catalogues given to the left when considering the five catalogues ING, ENEL, CNEN, CNR, NT4.1. after removing (columns A) the events whose intensity was not evaluated in all the catalogues or which were ignored in at least one catalogue. Are left 78 earthquakes. In the columns B are the number of events using the catalogues without removing events (93 events).

	B	A
In at least two catalogues	92 or 99%	77 or 99%
In at least three catalogues	59 or 632%	67 or 67%
In at least four catalogues	21 or 231%	26 or 26%
In all catalogues	9 or 10%	9 or 12%
Different in all catalogues	1 or 1%	1 or 1%

Table 4. Number of earthquakes having the same evaluation in at least the number of catalogues given to the left considering the catalogues indicated on top of the table

	ENEL CNEN CNR ING NT4.1		ENEL CNEN CNR ING		ENEL CNEN CNR		ENEL CNEN	
Total number of events	93		93		93		93	
In at least two catalogues	92	99%	90	97%	70	75%	43	46%
In at least three catalogues	59	63%	38	41%	27	29%	--	--
In at least four catalogues	21	23%	11	12%	--	--	--	--
In 5 catalogues	9	10%	--	--	--	--	--	--
Different in all catalogues	1	1%	3	3%	23	25%	50	54%

Table 5.Number of earthquakes which have the same evaluation in the two catalogues crossing in the column and row of the number. The results are from Caputo (1981) who used 76 earthquakes having intensity X or more in at least one of the catalogues considered. To the right of the principal diagonal is the result in percent of the 76 events considered, to the left is the number of the earthquakes. The comparison would be significant with table 1 for the average Intensities.

	CNEN	ENEL
CNEN		38%
ENEL	29	

	Average Intensity
ENEL	IX.713
CNEN	X.236

Table 6 .Number of earthquakes which have the same evaluation in the two catalogues crossing in the column and row of the number. The results are from Caputo (1986-87) who used 72 earthquakes having intensity X or more in at least one of the catalogues considered. The last column of the table gives the total number of coincident evaluation, of the catalogue in the row, with all the others; in brackets is the ratio to the number of events).To the right of the principal diagonal is the result in percent of the 72 events considered, to the left is the number of the earthquakes. 24% of the earthquakes have the same Intensity in the three catalogues.

	ENEL	CNEN	CNR	Total
ENEL		40%	51%	66(0.92)
CNEN	29		31%	51(0.71)
CNR	37	22		59(0.82)

	Average Intensity
ENEL	IX.76
CNEN	X.25
CNR	IX..59

Table 7. Number of earthquakes which have the same evaluation in the two catalogues crossing in the column and row of the number. The results are from Bella et al. (1990) who used 58 earthquakes having intensity X or more in at least one of the catalogues considered. The last column of the table gives the total number of coincident evaluation, of the catalogue in the row, with all the others; in brackets is the ratio to the number of events).To the right of the principal diagonal is the result in percent of the 58 events considered, to the left is the number of the earthquakes.

	ENEL	CNEN	CNR	ING	Total
ENEL		40%	50%	45%	78(1.3448)
CNEN	23		39%	29%	62(1.0690)
CNR	29	29		38%	73(1.2586)
ING	26	17	22		

Table 8. Number of earthquakes which have the same evaluation in the two catalogues crossing in the column and row of the number. The last column of the table gives the total number of coincident evaluation of the catalogue in the row with all the others; in brackets is the ratio to the number of events. In the list are present 95 earthquakes.To the right of the principal diagonal is the result in percent of the 95 events considered, to the left is the number of the earthquakes.

	ENEL	CNEN	CNR	ING	NT4.1	Total
ENEL		46%	51%	27%	29%	142(1.53)
CNEN	43		37%	24%	18%	117 (1.26)
CNR	47	35		27%	44%	148(1.59)
ING	25	32	25		60%	128(1.38)
NT4.1	27	17	41	56		141(1.52)

Table 9 Summary of the previous tables of coincidences.

	ENEL	CNEN
ENEL		38%
CNEN	29	

	ENEL	CNEN	CNR	Total
ENEL		40%	51%	66(0.92)
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