8th Workshop on Non-Linear Dynamics and Earthquake Prediction
3 - 15 October, 2005

Earthquake Catalogs Analysis: Examples from Different Data Sets

Antonella Peresan
Universita di Trieste
Dipartimento di Scienze della Terra
Via E. Weiss 4
34127 Trieste
Italy

These are preliminary lecture notes, intended only for distribution to participants
CN algorithm and long-lasting changes in reported magnitudes: the case of Italy

A. Peresan, G. F. Panza, and G. Costa

SUMMARY
Prediction methods based on seismic precursors, and hence assuming that catalogues contain the necessary information to predict earthquakes, are sometimes criticised for their sensitivity to the unavoidable catalogue errors and possible undeclared variations in the evaluation of reported magnitudes. We consider a real example and we discuss the effect on CN predictions, of a long-lasting underestimation of the reported magnitudes.

Starting approximately in 1988, the CN functions in Central Italy evidence an anomalous behaviour, not associated with TIPs, that indicates an unusual absence of moderate events. To investigate this phenomenon, the magnitudes given in the catalogue used, which since 1980 is defined by the INGV bulletins, are compared to the magnitudes reported by the global catalogue NEIC (National Earthquake Information Centre, USGS, USA) and by the regional LDG bulletins issued by the Laboratoire de Detection et de Geophysique, Bruyeres-le-Chatel, France.

The comparison is performed between the INGV bulletin and the NEIC catalogue, considering the local, $M_L$, and duration, $M_d$, magnitudes, first within the Central region, and then extended to the whole Italian territory. To check the consistency of the conclusions drawn from INGV and NEIC data, the comparison of local magnitudes is extended to a third data set, the LDG bulletin.

The differences between duration magnitudes $M_d$ that are reported by INGV and NEIC since 1983 appear quite constant with time. Starting in 1987, an average underestimation of about 0.5 can be attributed to $M_d$ reported by INGV for the Central region; this difference decreases to about 0.2 when the whole Italian territory is considered. The anomalous behaviour of the CN functions disappears if a magnitude correction of +0.5 is applied to $M_d$ reported in the INGV bulletin. However, such a simple magnitude shift cannot restore the real features of the seismic flow, and INGV bulletins are not suitable for CN algorithm application.

Key words: earthquake catalogues, earthquake prediction, Italy, regionalization.

INTRODUCTION
CN is an intermediate-term earthquake prediction algorithm based on the quantitative analysis of premonitory phenomena, which can be detected in the seismic flow preceding the occurrence of strong earthquakes (Gabrielson et al. 1986; Keilis-Borok & Rotwain 1990). The quantification of the properties of the seismic flow is performed by means of a set of functions of time (Table 1), which evaluate variations in the seismic activity, seismic quiescence and space-time clustering of events. The normalisation of the functions allows us to apply CN to regions with different seismic activity (Keilis-Borok 1990; Rotwain & Novikova 1999).

The CN algorithm has been applied to the monitoring of seismicity in Central Italy since 1990 (Keilis-Borok et al. 1990; Costa et al. 1996; Peresan et al. 1998a). The analysis of the time behaviour of CN functions for the different regionalizations defined for Central Italy (Fig. 1) allowed us to observe the common anomalous flat values of some functions (see $Z_{max}$, $S_{max}$, Sigma, $K$ and $G$ in Fig. 2), starting approximately in 1988. The flat trend of the functions, never observed before, indicates the absence of moderate events and hence evidences an unusual decrease in the seismicity rate, suggesting the need to check for possible changes in the magnitudes reported by the catalogue used.

Until July 1997 the catalogue used for CN monitoring in Italy was the CC1996 (Peresan et al. 1997). This catalogue is composed of the revised PFG catalogue (Postpischl 1985) for the period 1900–1979, and since 1980 we have updated it with the bulletins distributed by the Istituto Nazionale di
Table 1. Definition of the time functions used in the CN algorithm for the quantification of the properties of the seismic flow (from Koles-Borok et al. 1996). The magnitude thresholds $m_1, m_2, m_3$ that allow the normalization of the functions are fixed according to the average yearly frequency of the main shocks that occurred within the region during the learning period (1954–1986). For the Central region (the dark grey in Fig. 1) $m_1 = 4.2, m_2 = 4.5, m_3 = 5.0$, corresponding to the standard yearly average frequencies $n_1 = 3.0, n_2 = 1.4, n_3 = 0.4$.

| $N_1(t)$ | Number of main shocks with $M \geq m_1$ that occurred in the time interval $(t - 3 \text{ yr}, t)$. |
| $N_2(t)$ | Number of main shocks with $M \geq m_2$ and origin time $t$. |
| $N_3(t)$ | Number of main shocks with $M \geq m_3$ and origin time $t$. |

$K(t) = K_1(t) = K_2(t) = K_3(t) = 1$, where $K_1(t)$ is the number of main shocks with $M \geq m_1$ and origin time $t$, $K_2(t)$ is the number of main shocks with $M \geq m_2$ and origin time $t$, and $K_3(t)$ is the number of main shocks with $M \geq m_3$ and origin time $t$.

$G(t)$ is the ratio between the number of the main shocks with $M \geq m_3$ and origin time $t$ and the number of the main shocks with $M \geq m_1$. Only main shocks with origin time $t$ in the interval $(t - 1 \text{ yr}, t) \leq t \leq t$ are considered.

$\Sigma_{\text{mag}}(t) = 2 \times 10^{4.5 \beta - \alpha}$, the main shocks with $m_1 \leq M \leq m_2 - 0.1$ and origin time $(t - 3 \text{ years}) \leq t \leq t$ are included in the summation; $\alpha = 4.5, \beta = 1.00$.

$S_{\text{mag}}(t) = \max (|S|, |N_1|, |N_2|, |N_3|)$, where $S$ is calculated as $\Sigma_{\text{mag}}$ for the events with origin time $(t - 3 \text{ yr}, t) \leq t \leq t$.

$Z_{\text{mag}}(t) = \max (Z_1, Z_2, Z_3)$, where $Z_1$ is calculated as $S$, but with $\beta = 0.5$ and $N_1$ is the number of earthquakes in the sum.

$N_1(t)$ Number of main shocks with $M \geq m_1$, which occurred in the time interval $(t - 10 \text{ yr}, t - 7 \text{ yr})$.

$q(t) = 2\Sigma_{\text{mag}}(t) \max (0, \text{Sin} - n_1)$, where $n_1$ is the average annual number of main shocks with $M \geq m_1$.

$B_{\text{mag}}(t)$ Maximum number of aftershocks for each main shock counted within a radius of 50 km for the first 2 days after the main shock.

---

Table 2. Data set used for the catalogue comparison. For each agency the following are indicated the period of time, the kind of catalogue, and how the data are made available.

<table>
<thead>
<tr>
<th>Agency</th>
<th>Period</th>
<th>Type</th>
<th>Medium</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1985–1986</td>
<td>Digital ING bulletin</td>
<td>floppy disk</td>
</tr>
<tr>
<td></td>
<td>1987–1997</td>
<td>Digital ING bulletin</td>
<td>ftp</td>
</tr>
<tr>
<td></td>
<td>1990–1997</td>
<td>Earthquake Hypocentres Data Files</td>
<td>ftp</td>
</tr>
</tbody>
</table>

The ING bulletins contain two estimations of magnitudes: the local magnitude $M_L$ and, since 1983, the duration magnitude $M_D$. The NEIC global catalogue reports the magnitudes $m_1$ and $m_3$, both computed by NEIC, plus two values, $M_1$ and $M_2$, that correspond to magnitudes of a different kind contributed by different agencies. From a previous analysis of the NEIC catalogue (Peresan & Rotwarin 1998) we observed that, for the Italian area, both $M_1$ and $M_2$ are mainly $M_L$, and that $M_2$ is 10 times more frequent than $M_3$. Furthermore, ING is among the contributors to the PDE and it supplied information for more than 600 events, from 1997 to 1997, as can be observed by listing the events with network code ROM reported in the PDE catalogue. Most of these events have magnitudes below 4.0, especially when $M_1$ is considered, while about 100 of them have $M_3 > 4.0$. The bulletins distributed by LDG contain two magnitude values, mainly corresponding to $M_1$ and $M_2$.

In order to perform the magnitude comparison, the events common to the different catalogues are identified according to the following rules: (a) time difference $\Delta t \leq 1 \text{ min}$; (b) epicentral distance $\Delta \text{Lat} = \Delta \text{Lon} \leq 1^\circ$ for the comparison with the global catalogue (Storchak et al. 1998). No limitation is imposed on magnitude or depth differences.

The analysis is performed by evaluating, for a fixed type of magnitude, the quantities

$$\Delta M = M(C1) - M(C2).$$

© 2000 RAS, GJI 141, 425–437
which are the differences between magnitudes of the same type reported in the catalogues C1 and C2 for each of the common earthquakes.

The comparison between ING and NEIC estimations is performed considering Ms and Mh separately among the events for which Ms and Mh are reported in both the catalogues. The events contributed to NEIC by ING, which represent a relatively small fraction of the set of common events (less than 10 per cent), are obviously excluded from the analysis. Initially, the comparison is focused on the Central region (Fig. 1) and the yearly average values $\Delta M_L$ and $\Delta M_H$ are evaluated from the common events contained in the area monitored using the CN algorithm. Subsequently, the comparison between the ING and NEIC catalogues is enlarged to the whole Italian territory and its surroundings, as shown in Fig. 9.

To check the consistency of the conclusions drawn from ING and NEIC data, the comparison of Ms is extended to a third catalogue, and the ING and NEIC Ms are compared directly with the Ms reported by the LDG bulletins. Since the LDG is among the NEIC contributors for the area analysed, the NEIC events with magnitude code LDG are obviously excluded when performing the comparison between LDG and NEIC data.

Changes in reported magnitudes for Central Italy

The analysis of the behaviour of CN functions in Central Italy allows us to identify the anomalous flat trend of some of the functions (Fig. 2), starting approximately in 1988. Such a flat trend indicates an unusual absence of moderate events.

To look for an explanation for this anomaly we focus our attention on the magnitude variations within the Central...
region currently used for the monitoring of seismicity (in dark grey in Fig. 1). The sub-catalogue of earthquakes common to ING and NEIC contains about 800 events. The operating magnitude for CN monitoring is chosen from the Italian catalogue CCI1996, and hence from ING bulletins, according to the priority order $M_1, M_2$ (Costa et al. 1996; Perna et al. 1998). Therefore, local magnitudes play a relevant role in the CN analysis of seismicity. Hence, as a first stage, we study the discrepancies among the $M_1$ values reported in the two catalogues, i.e. the quantity

$$\Delta M_1 = M_1(\text{NEIC}) - M_1(\text{ING}). \quad (2)$$

The histograms of $\Delta M_1$ are plotted for three contiguous ranges of magnitude (Fig. 3), chosen to correspond to the CN magnitude thresholds for Central Italy. The events with $M_1 < 3$ are not used by CN, the events with $3 \leq M_1 < 4.2$ are included only in the counting of aftershocks, and those with $M_1 \geq 4.2$ can enter into the calculation of functions. For most of the events, $\Delta M_1 > 0$, while a secondary peak around $\Delta M_1 = 0$ can be seen in Fig. 3 for the smaller events.

In order to detect a possible undeclared long-lasting change in the estimation of the reported $M_1$, the time behaviour of the yearly average of $\Delta M_1$ is analysed considering only earthquakes with $M_1(\text{NEIC}) \geq 3$. The yearly number of such events is around 30-35, with two exceptions: there were 83 earthquakes in 1980 (mainly associated with the Irpinia event of 1980 November 23) and only four events in 1987.

The time distribution of $\Delta M_1$ yearly averages, shown in Fig. 4(a), indicates the presence of a major discontinuity in 1987. The average $\Delta M_1$, estimated using eq. (2) for two

---

**Central Region**

**Figure 3.** Histograms of the number of events versus $\Delta M_1$ for three contiguous ranges of magnitude in the Central region (dark grey area in Fig. 1).
Figure 4. Yearly average of (a) $\Delta M_L$ and (b) $\Delta M_L'$ obtained for the NEIC and ING catalogues, considering the common events that occurred within the Central region (Fig. 1). Error bars correspond to the 95 per cent confidence interval of the mean.

subsequent periods of time, excluding the year of transition, 1987, are as follows (the error corresponds to the 95 per cent confidence interval of the mean):

- (1980-1986) $\Delta M_L = 0.13 \pm 0.05$,
- (1988-1997) $\Delta M_L = 0.64 \pm 0.04$.

According to these average results, assuming $M_L(\text{NEIC})$ as a uniform reference value, an underestimation of about 0.5 can be assigned to the $M_L$ values reported by ING since 1987.

A similar analysis, performed by replacing $M_L$ with $M_L'$ in eq. (2), does not evidence a significant change for $M_L(\text{ING})$. The relevant uncertainty associated with the value of $\Delta M_L'$ (Fig. 4b) for the years 1985 and 1991 is mainly due to the reduced sample size (only two events in 1985 and four in 1991). The average magnitude difference for the whole period 1983-1995 for which the sample is available is estimated to be $\Delta M_L' = 0.30 \pm 0.04$.

CN: A DETECTOR OF ANOMALOUS VARIATIONS IN REPORTED MAGNITUDES

In order to understand whether the variations found in reported magnitudes can account for the anomalous behaviour of the CN functions observed in the Central region, the quantity $D = 0.5$ is added to the $M_L$ reported by the ING bulletin, beginning in 1987. $M_L$ values do not need to be modified because no significant time variation has been detected. CN is then applied to the Central region using the 'corrected' catalogue and following the standard procedure of forward monitoring of seismicity: learning is not repeated and the parameters are kept unchanged. The time diagram obtained is shown in Fig. 5 and clearly indicates that the anomalous behaviour of some CN functions, shown in Fig. 2, is no longer present.

Obviously, this magnitude transformation cannot be used to correct the catalogue and the magnitude revision must be...
Figure 5. Time diagrams of the CN functions obtained for the Central region using the 'corrected' catalogue, in which the quantity $D = 0.5$ is added to $M_L(ING)$ beginning in 1987.

performed using all the available information (especially concerning variations in the acquisition system), not only that provided by the catalogue itself. Furthermore, a simple magnitude shift, estimated from a limited sample, cannot restore all the properties of the real seismic sequence.

Several tests performed by systematically increasing or decreasing the operating magnitude in the catalogue used for CN monitoring (Peresan & Rotwain 1998) show that the functions $G$, $\Sigma$, $Z_{max}$ and $S_{max}$ (Table 1) are sensitive to long-lasting major magnitude underestimations of about half a magnitude unit: they become abnormally constant for relatively long periods of time, while the function $q$ keeps very high values, but do not cause any TIP activation. On the other hand, magnitude overestimations lead to unusually high values, especially for the functions $N_2$ and $N_3$, that can be used to identify and therefore discard possible TIPs declared by CN.

EXTENSION OF THE ANALYSIS TO THE WHOLE ITALIAN REGION

The magnitude differences have also been analysed within the Northern and Southern regions defined for the application of CN to the Italian territory (Peresan et al. 1998a). In the Northern region, the results are in very good agreement with those obtained for the Central region and, on average, an increase of $+0.5$ is observed for $M_L$ in 1987. The variation in reported $M_L$ does not affect the CN functions in the Northern region as clearly as in the Central region because the Italian catalogue (Postpischl 1985) covers an area that, towards the north, follows the Italian border and consequently is incomplete for CN application. This incompleteness has been filled in by Costa et al. (1996) and Peresan et al. (1998a) with data provided by two other catalogues: AL FOR (Catalogo della Alpi Orientali) (1987) and NEIC, thus reducing the influence of $M_L(ING)$ in the computation of CN functions in the Northern region. The small number of common events, and hence the insufficient sample size, does not allow any conclusive analysis in the Southern region.

The analysis of the NEIC catalogue performed by Peresan & Rotwain (1998) for the Italian area showed that for the magnitudes $M_L$ and $M_a$ contributed to NEIC by other agencies, $M_L$ is 10 times more frequent than $M_a$. From Fig. 6 it is seen that the total yearly number of common events varies quite significantly with time. The number of common events...
considerably increases after 1988, for both $M_c$ and $M_s$, especially when the smaller earthquakes are considered.

The frequency distributions of $\Delta M_c$ and $\Delta M_s$ versus NEIC magnitude are analysed to evaluate their possible correlation with the earthquakes size (Fig. 7). The linear correlation between $\Delta M_c$ and $M_c$ (NEIC) appears quite weak, while the correlation is significant for $\Delta M_s$ versus $M_s$ (NEIC), the correlation coefficient being about 0.7 (significant at $p < 0.05$).

The distributions of $\Delta M_c$ and $\Delta M_s$ are rather different, as can easily be seen from their histograms constructed for three contiguous intervals of magnitude (Fig. 8). The values of $\Delta M_c$ appear normally distributed around mean values increasing with $M_s$. However, the histograms of $\Delta M_s$ are centred around $\Delta M_s = 0$, with a tail towards positive values. It seems that the set of common events can be divided into two subsets: (a) events with $\Delta M_s$ distributed around zero; and (b) events with $\Delta M_s$ distributed around 0.5.

A detailed analysis, suggested by the bimodal distribution of $\Delta M_s$, shows that the events giving $\Delta M_s = 0$ are fairly localized in space (Fig. 9). The peak in the $\Delta M_s$ histograms is due to the coincidence of $M_s$ (ING) with the $M_s$ contributed to NEIC by some local networks, mainly from GEN (IGG network, Dipartimento Scienze della Terra, Università di Genova, Italy), LDG (Laboratoire de Détection et de Geophysique, Bruyères-la-Chalet, France), TTG (Seismological Institute of Montenegro, Podgorica, Yugoslavia) and TRI (OSS, Osservatorio Geofisico Sperimentale, Trieste, Italy), following the standard station codes used by NEIC. Indeed, the data reported by some local networks are used by ING to integrate the information collected by the Italian network (Fig. 8).

Fig. 6 indicates that the size of the sample becomes relatively stable for magnitudes larger than 3.0, although the yearly number of common events generally increases in 1988. Hence, in this step of the analysis also, the time behaviour of the
yearly average of $\Delta M_0$ and $\Delta M_4$ is evaluated using only earthquakes with NEIC magnitude larger than 3.0.

The yearly average values of $\Delta M_0$ and $\Delta M_4$ are shown in Fig. 10. The remarkable uncertainties on the average value of $\Delta M_4$ during the year 1983 and, similarly, of $\Delta M_0$ in 1985 are due to the large dispersion of the reported values rather than to the sample size. For the whole period 1983–1997, the yearly average of $\Delta M_0$ appears almost constant around a mean value.
of $0.30 \pm 0.02$ (Fig. 10a), in very good agreement with the results obtained for the Central region. Therefore, this analysis seems to confirm that since 1983, when they started to be reported, there have been no changes in the $M_L$ values provided by ING. A linear relation between the $M_L$ reported by the two agencies can be estimated by orthogonal regression of $M_d$(ING) versus $M_d$(NEIC) using the set of common events, as follows:

$$M_d$(ING) = 0.7M_d$(NEIC) + 0.8.

According to this relation, the events with $M_d$(ING) $\geq 3.0$ are on average underestimated with respect to $M_d$(NEIC), while smaller events are overestimated.

The diagram of the yearly average $\Delta M_L$ (Fig. 10b), however, seems to indicate the presence of two main discontinuities: the first in 1987 and the second in 1994. The average $\Delta M_L$, estimated for the three contiguous periods of time, are as follows (the error corresponds to the 95 per cent confidence interval of the mean):

- (1980–1986) $\Delta M_L = 0.08 \pm 0.05$,
- (1988–1993) $\Delta M_L = 0.10 \pm 0.04$,
- (1995–1997) $\Delta M_L = 0.17 \pm 0.06$.

The $\Delta M_L$ increase observed during 1987 appears less relevant within the whole Italian area than for the Central region.
Figure 9. (a) Space histogram of the number of common events used for $\Delta M_1$ evaluation. (b) Space distribution of events with $\Delta M_1 = 0$. The two histograms are plotted using the same linear scale. The maximum number of common events is indicated as a reference.

(Figs 10b and 4b). This reduction of $\Delta M_1$ can be explained by the inclusion of the $M_1$ values contributed to both NEIC and ING by some of the neighbouring local networks, located near to the French and Slovenian borders and along the Croatian coast.

**COMPARISON WITH MAGNITUDES FROM LDG BULLETINS**

The use of eq. (2) for $M_1$ reported by the catalogues ING and NEIC gives positive values for $\Delta M_1$. To check the conclusions...
drawn from the analysis of ING and NEIC data, the comparison of magnitudes is extended to the LDG bulletin.

The comparison between ING local magnitudes and those reported by LDG bulletin is performed within the time interval 1980-1996. About 1000 common events are selected from these regional catalogues according to the following rules: (a) time difference $\Delta t \leq 1$ min; (b) epicentral distance $\Delta \text{lat} = \Delta \text{lon} \leq 0.1$.

The bimodal distribution of $\Delta M_L$ observed in the comparison with the NEIC catalogue (Fig. 8) becomes even more marked when the ING and LDG magnitudes are considered. Nevertheless, most of the events with $\Delta M_L \approx 0$ have $M_L (\text{LDG})$ lower than 3.0. Hence, considering only events with magnitude larger than 3.0 allows us to exclude a large part of such events, whose magnitudes have very probably been provided by the same agency, while permitting us to keep events for which magnitude determinations can be considered quite reliable in regional catalogues.

The yearly average values of $\Delta M_L$ for the pairs of catalogues LDG–ING and NEIC–LDG have been estimated and are plotted in Fig 11. The number of common events used for such estimations increases in time from about 10–15 events per year up to 30–40 events per year, and this is also apparent from the corresponding reduction of uncertainties. The average values obtained from eq. (2) for the pair of catalogues LDG–ING is always significantly greater than zero, even

Figure 10. Yearly average of (a) $\Delta M_L$ and (b) $\Delta M_L$ for the NEIC and ING catalogues. Only events with magnitude greater than 3.0 have been considered. Error bars correspond to a 95 per cent confidence range on the calculated average. The $\Delta M_L$ minimum in 1994 is explained by the very large number of events with magnitudes coinciding with those provided by the local networks, mainly the JGG network.
with fluctuations in time (Fig. 11a). The differences $\Delta M_1$ estimated for the pair of catalogues LDG-ING and for the two intervals of time indicated in brackets give the following average values:

- (1983–1986) $\Delta M_1 = 0.18 \pm 0.08$,
- (1988–1996) $\Delta M_1 = 0.44 \pm 0.04$.

These values are in good agreement with those computed, for the whole Italian territory, comparing $M_1$ from the NEIC and ING catalogues.

The average values $\Delta M_1$ calculated for the global catalogue NEIC and the regional bulletins LDG (about 1200 common events) are always close to zero (Fig. 11b) and, on average, are

- (1980–1986) $\Delta M_1 = 0.03 \pm 0.06$,
- (1988–1996) $\Delta M_1 = 0.08 \pm 0.03$.

This comparison seems to confirm the relative uniformity of the reference catalogues NEIC and LDG, despite the heterogeneous origin of $M_1$ (NEIC).

A series of magnitude comparisons focused on the Central region, excluding from NEIC the events contributed by LDG or comparing directly ING and LDG, essentially confirms observations made comparing the ING and NEIC catalogues.

According to Bath (1973), we have to expect errors as large as $\pm 0.3$ units in a calculated magnitude; nevertheless, the differences $\Delta M_1$ between the ING and the two catalogues considered have been, even after averaging, equal to or larger than $+0.3$ since 1987. Giardini et al. (1997) stated that local magnitudes are generally of poor quality with respect to the seismic moment, and this study indicates that they can even be inhomogeneous within the same bulletins. Unfortunately, $M_1$ is the basic instrumental magnitude in the Italian catalogue, while $M_L$ has only been reported since 1983.
CONCLUSIONS

Prediction methods based on seismic precursors are sometimes criticized for their sensitivity to the unavoidable catalogue errors and undetected changes in the evaluation of the reported magnitudes (Habermann 1991; Habermann & Cremer 1994; Peresan 1995b). This study provides a real example, showing the effects of long-lasting systematic magnitude underestimation on CN predictions.

The absence of moderate events detected by CN functions, and consequently the unusual decrease of the seismicity rate showing the effect of a magnitude term. (Elahert et al. 1991; Uabermann 1994) may be explained by the existence of a real, long-lasting effect on the evaluation of the reported catalogue magnitudes. A comparative study between the ING and NEIC catalogues, within the area corresponding to the Central region, may help to check for possible systematic errors in the reported magnitudes. The absence of moderate events detected by CN functions and consequently the unusual decrease of the seismicity rate within the Central region used for the CN monitoring in Italy lead us to check for possible systematic errors in the reported magnitudes. A detailed comparative analysis focused on $M_1$ and $M_2$, has been performed between the NC and NEIC catalogues, within the area corresponding to the Central region. The magnitude differences $\Delta M_2$ appear quite stable in time and small, while a variation of about 0.5 has been found in $\Delta M_1$, starting in 1987. This difference decreases to about 0.2 when the analysis is extended to a wider area, including the whole Italian territory, but there is always an underestimation of the $M_1$ value, given by ING with respect to NEIC. The comparison extended to a third catalogue, the LGD bulletin, confirms such underestimation.

The robustness of the CN algorithm has been successfully tested with respect to the partial replacements in the catalogue, provided the homogeneity of data is preserved (Peresan & Rotwain 1998), and with respect to the short-term inadvertent changes in the catalogue. Therefore, our study indicates that a careful analysis of CN functions allows us to find major long-lasting undetected changes in the reported magnitudes, and may permit us to separate such effects from the anomalies in the catalogue. The CN algorithm CN, which does not seem to affect the results of predictions (Peresan et al. 1996).

ACKNOWLEDGMENTS

We are grateful to Prof. I. M. Rotwain and V. I. Kossobokov for their relevant contribution in the catalogue analyses. We wish to thank Profs. G. Molichia and T. Kostrow for the useful discussions and their invaluable suggestions. This research has been supported by MURST (40% per cent and 60% per cent funds), by CNR (contracts numbers 96.0296.PF54 and 97.00507.PF54) and by INTAS (94-0232).

REFERENCES


