ANNALI DI GEOFISICA, VOL. XXXVII, N. 3, June 1994

Detection capability of the Italian network for teleseismic events

Rosalba Di Maro and Alessandro Marchetti
Istituto Nazionale di Geofisica, Roma, Italy

Abstract
The future GSE experiment is based on a global seismic monitoring system, that should be designed for monitoring compliance with a nuclear test ban treaty. Every country participating in the test will transmit data to the International Data Center. Because of the high quality of data required, we decided to conduct this study in order to determine the set of stations to be used in the experiment. The Italian telemetered seismological network can detect all events of at least magnitude 2.5 whose epicenters are inside the network itself. For external events the situation is different: the capability of detection is conditioned not only by the noise condition of the station, but also by the relative position of epicenter and station. The ING bulletin (January 1991 - June 1992) was the data set for the present work. Comparing these data with the National Earthquake Information Center (NEIC) bulletin, we established which stations are most reliable in detecting teleseismic events and, moreover, how distance and back-azimuth can influence event detection. Furthermore, we investigated the reliability of the automatic acquisition system in relation to teleseismic event detection.

Key words *teleseismic detections – network detection capability*

1. Introduction

The Istituto Nazionale di Geofisica (ING) seismological network consists, at present, of 74 stations mostly equipped with vertical short-period seismometers (Di Maro, 1994). Most stations are connected with the Rome Data-Center by dedicated telephone lines (blue in fig. 1), the remainder by other kinds of links (green). The analog signals are digitized at the Data Acquisition Center.

Figure 2 shows the hardware of the automatic acquisition system at ING. The telephone lines are connected to demodulators with a maximum of eight channels per line.

From this point on, the system has two parallel branches: there are two analog/digital converters and two computer systems that provide identical, simultaneous processing of data in order to guarantee continuity of service.

The software of the system is outlined in fig. 3. On the digitized data the power spectrum is calculated for every 5 s time interval. The spectrum is sectioned into eight bands, from 0.2 Hz to 8.0 Hz. The ratio between the short time average and the long time average calculated on the spectral amplitude is compared with a threshold (*e.g.* 3.5) for every band.

The noticeable attenuation introduced by the transfer function (from sensor to demodulator) from 1.0 Hz down, and the fact that the detection algorithm must work independently for each station, suggested that the best way to detect the greatest number of events (teleseismic and otherwise), would be to analyse data in the frequency domain.

If the algorithm were to detect teleseis-

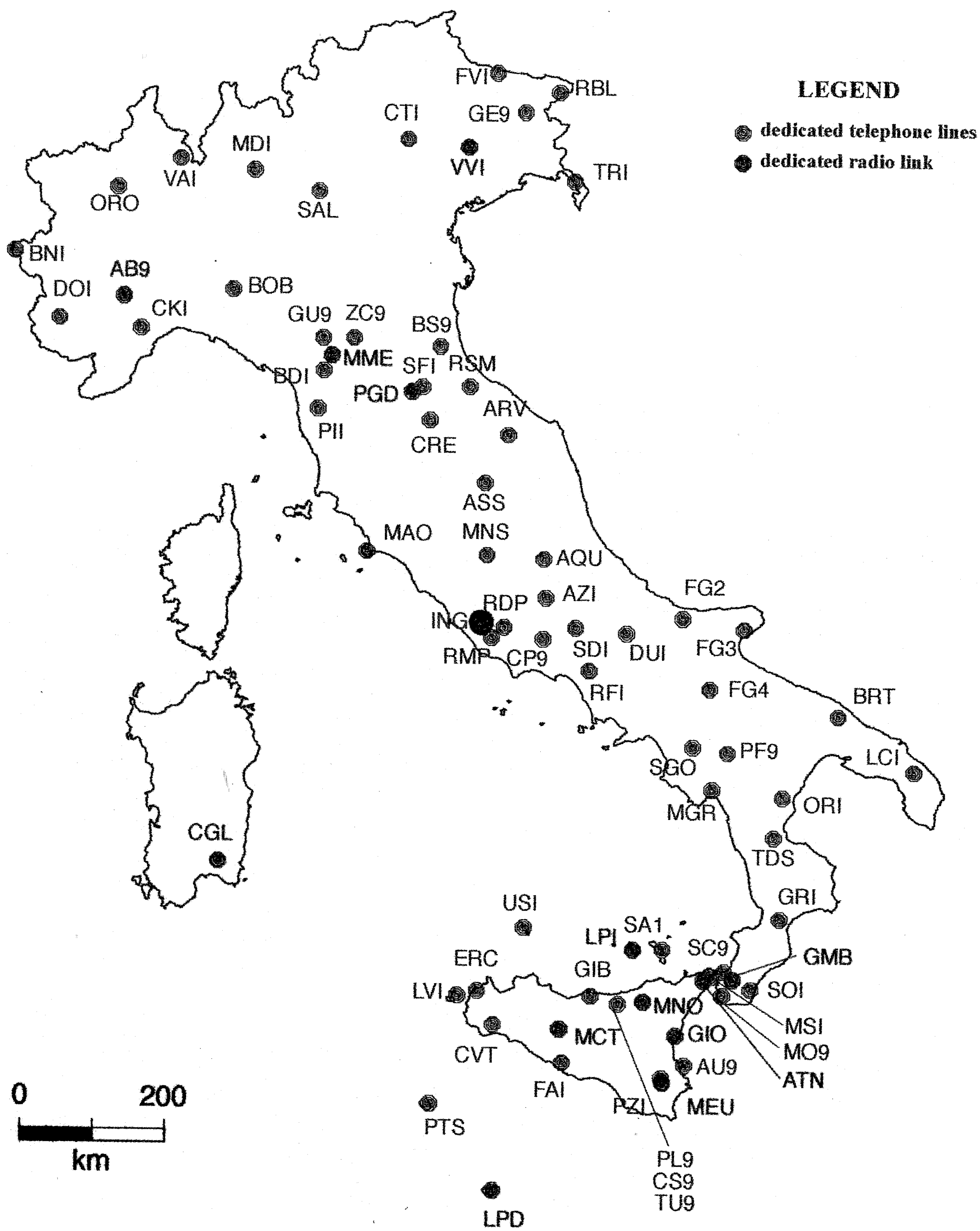

Fig. 1. Italian telemetered seismological network. In the map are distinguished the stations connected by dedicated telephone lines from those connected by dedicated radio links. The ING National Data Center is indicated by another symbol.

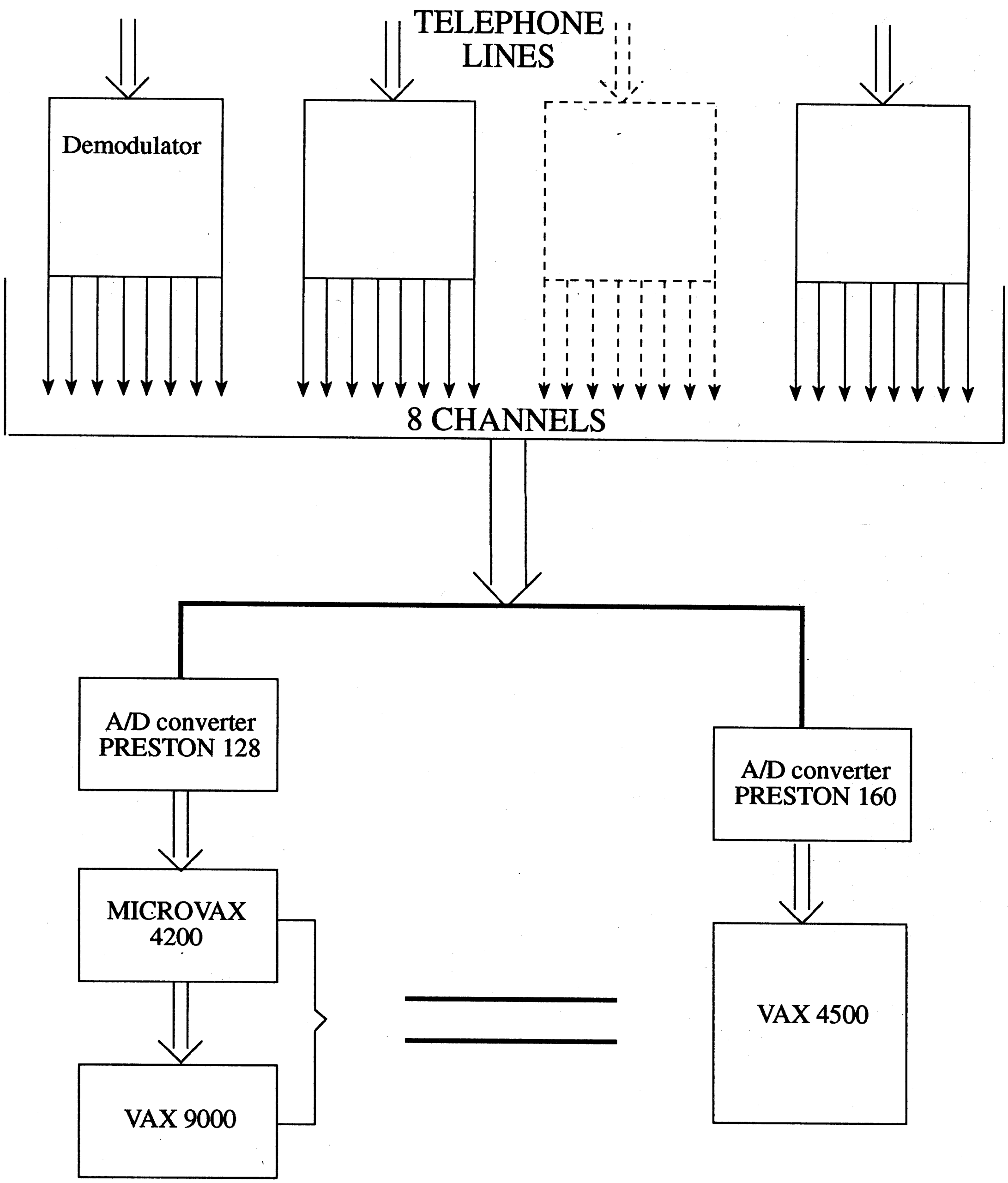

Fig. 2. Hardware of the ING automatic acquisition system.

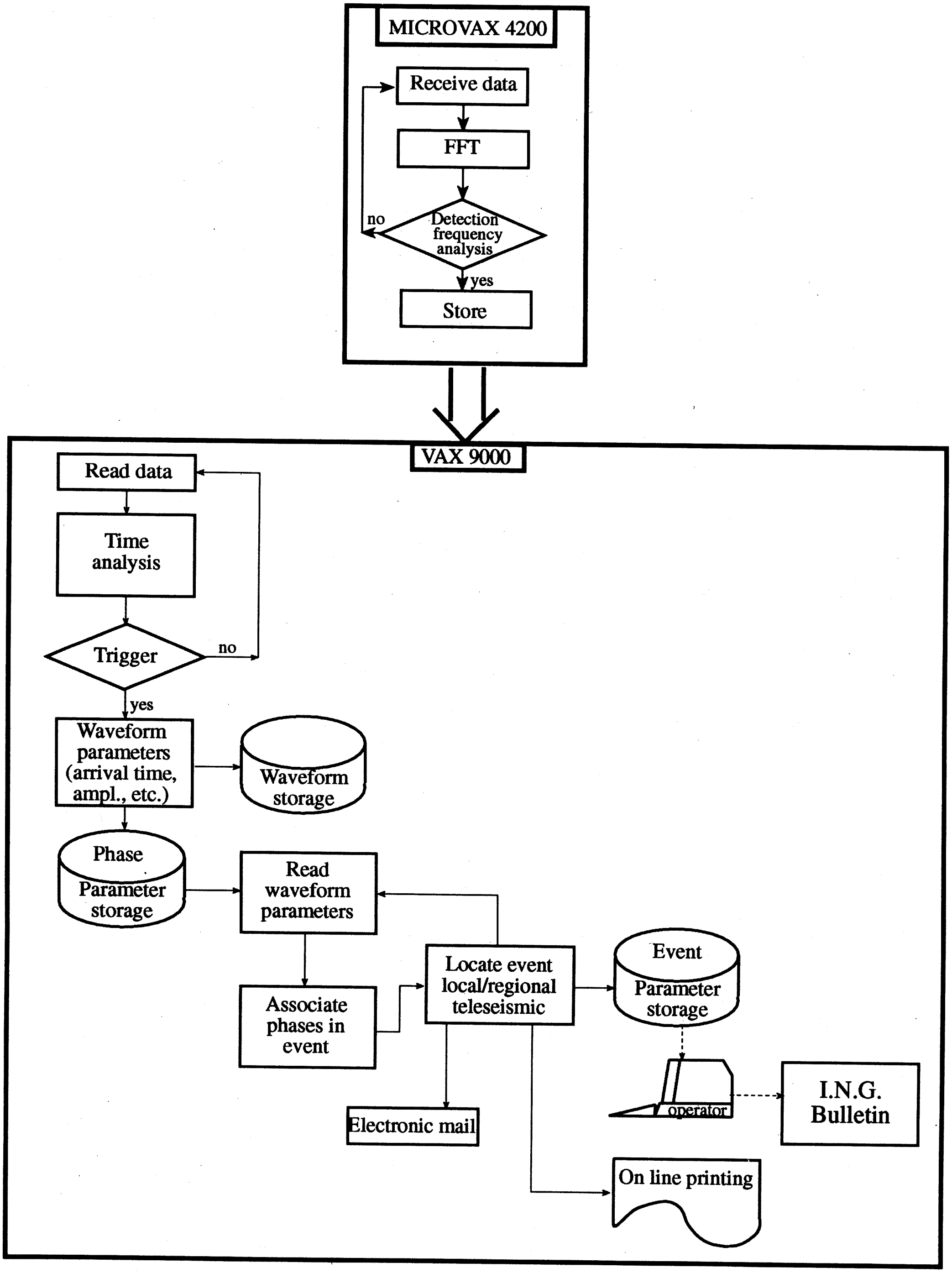

Fig. 3. Software of the ING automatic acquisition system.

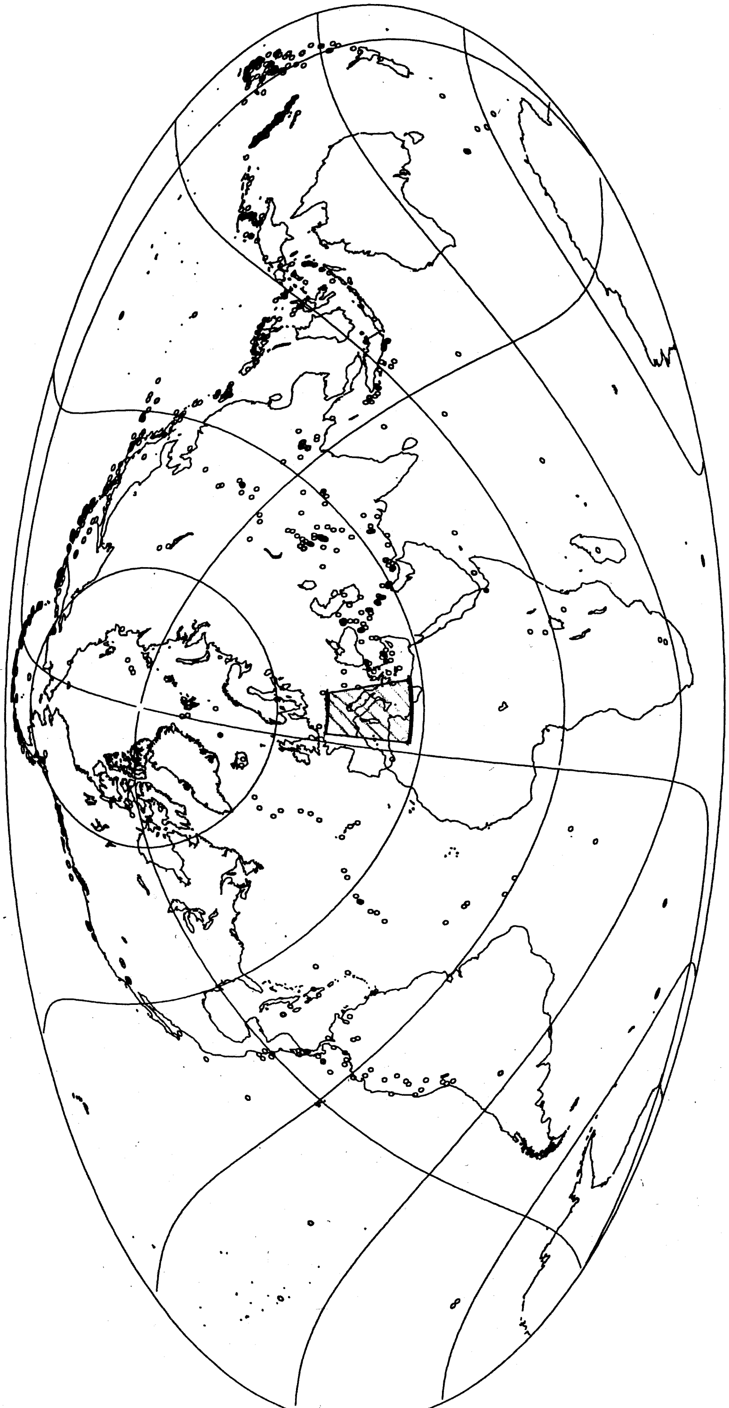

Fig. 4. Map of teleseismic events recorded by the ING automatic acquisition system from January 1991 to June 1992. The shadowed area, including Italy and the border region, was excluded from our analysis.

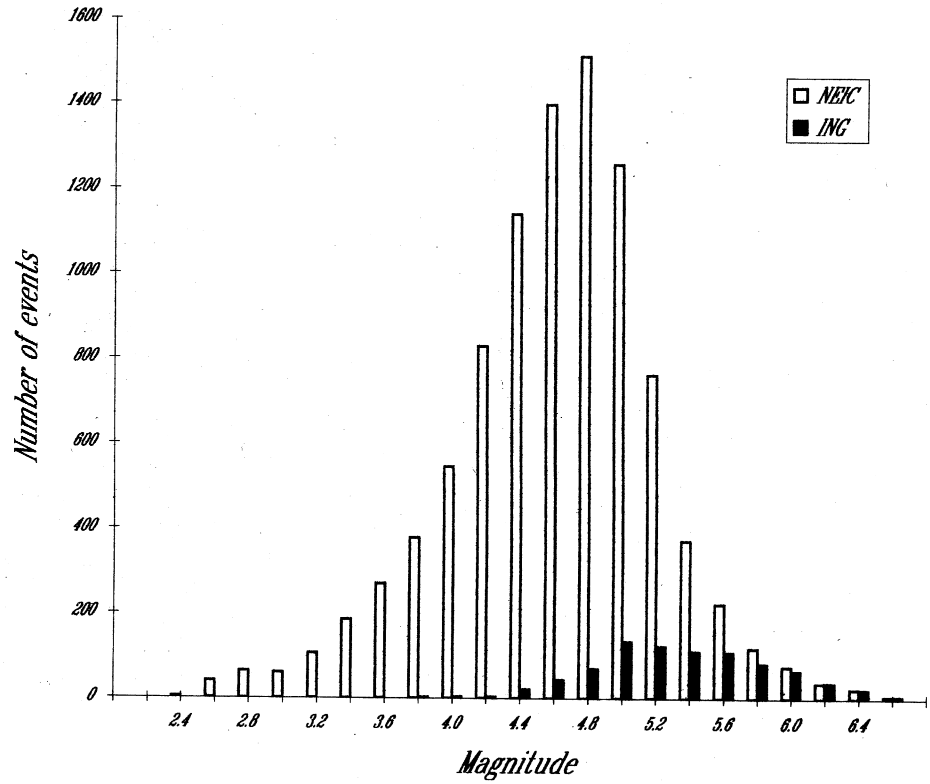

Fig. 5. Magnitude distribution of events reported by NEIC and ING bulletin from January 1991 to June 1992.

mic events only, the alternative way would be to filter data in a convenient frequency range, to analyse it in a time domain with an STA/LTA algorithm, to acquire it if a coincidence criteria is satisfied (*e.g.* when the noiseless stations detect a probable event). Obviously our network has to detect regional events principally, so the present algorithm is a good compromise between the necessity of recording both teleseismic and regional events and the speed of calculation.

The relevant signal is stored when a detection is declared. The trigger algorithm is performed in the time domain, comparing a threshold with the rate between the short time average and long time average. When a trigger is declared the parameters relative to the phase, together with the waveform itself, are stored and are then accessible for off-line analysis (Basili *et al.*, 1988 a,b, 1990).

In order to associate different arrival times from different stations to a single event, the list of the most recently recorded phases is continuously examined.

Finally, the event is located and the location is printed out approximately seven minutes after the first arrival time occurred. The National Earthquake Information Center (NEIC) and other international agencies are then notified via electronic mail.

An operator analyses, on a daily basis, all the signals again and revises them if necessary. For Italy and the border region only, other arrival times are added if the relevant signals are present only on the

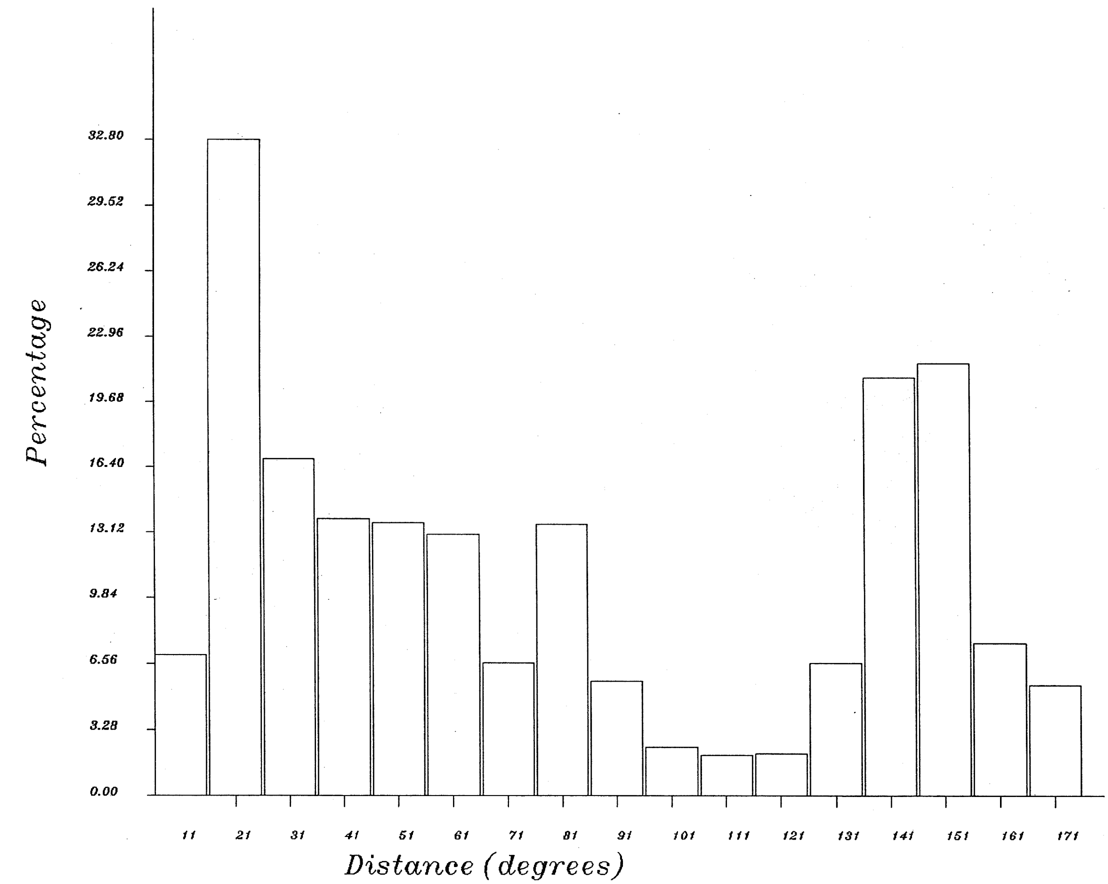

Fig. 6. Percentage of events recorded by ING referred to NEIC data versus distance.

seismograms of the continuous analogic acquisition, and the location quality is checked. For external events only the correctness of the arrival time established by the automatic acquisition system is checked.

The ING publishes a periodic bulletin with the locations of all local and regional events and the teleseismic arrival times (ING, 1991, 1992).

2. Data set

As we mentioned above, the ING telesismic data set comes from the automatic acquisition system only. In fact, for events occurring at any point in the world, except Italy and border region, our convention is not to perform the location and not to read other arrival times from seismograms. So, from the whole set of seismic data, with about 4000 located events, ranging from January 1991 to June 1992, we selected approximately 900 teleseismic events. Figure 4 shows the event distribution and the region we excluded from our considerations.

As reference, we considered the NEIC bulletin (NEIC, 1991, 1992). Excluding Italy and the border region, in the same period the NEIC International Data Center collected data for about 9000 located events in all parts of the world. Figure 5 shows the

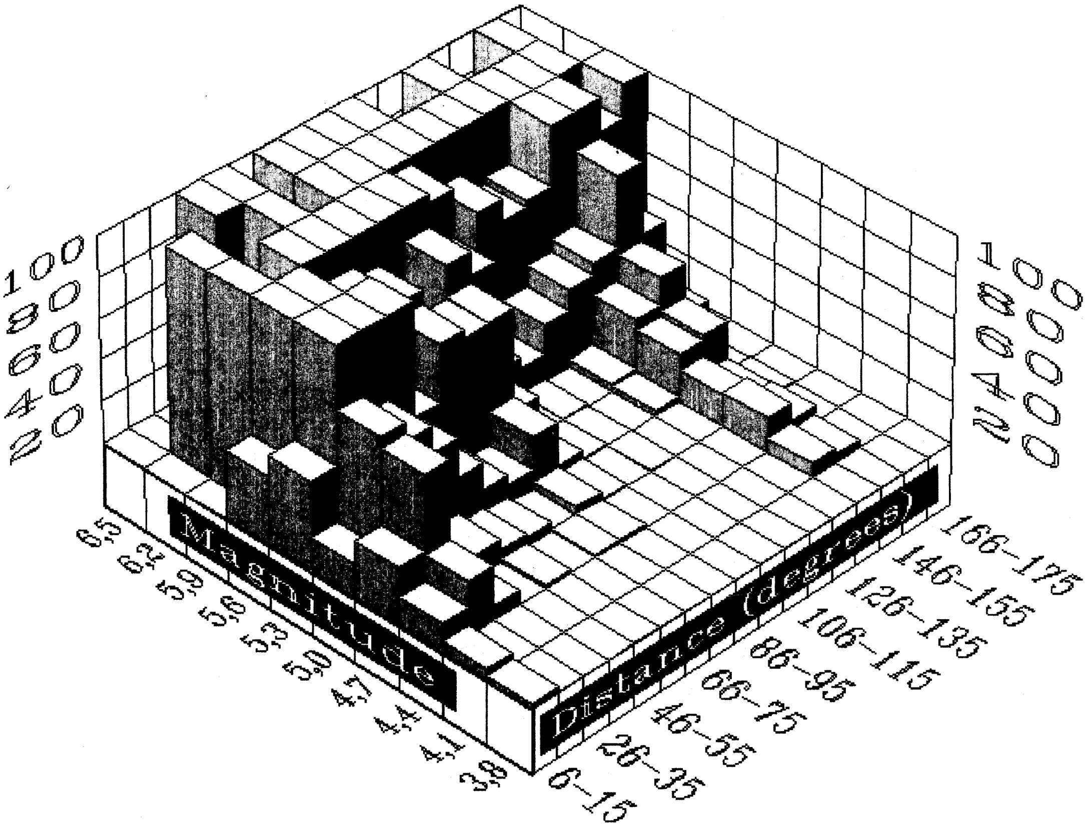

Fig. 7. Relation between magnitude and distance. Each class is referred to NEIC data.

number of events reported by the NEIC bulletin and, in black, the number of events reported by the ING bulletin. From this figure it is clear that the contribution of a regional network to the detection of teleseismic events with magnitude less than 6.0 is poor. All events of magnitude over 6.2 were recorded except one with magnitude 6.4. This event occurred on the west coast of Irian (New Guinea) at a critical distance (about 116°) from Italy. Since it occurred in the same region, about three minutes after another event with magnitude 5.9, which was recorded, it is likely that the trigger algorithm did not work because of the high value of LTA. Furthermore, for an International Data Center, such as NEIC, which collects data from about 5000 stations distributed everywhere, the completeness for events with magnitude less than 4.8 is questionable.

3. Data analysis and conclusions

In order to determine how the relative position between station and epicenter can influence the detection algorithm, we calculated how distances and back-azimuth of recorded events were distributed.

Figure 6 shows the percentage of events recorded versus distance; the influence of the shadow zone ($100° < \Delta < 135°$) is clear: at greater distances, from 135° to 155°, seis-

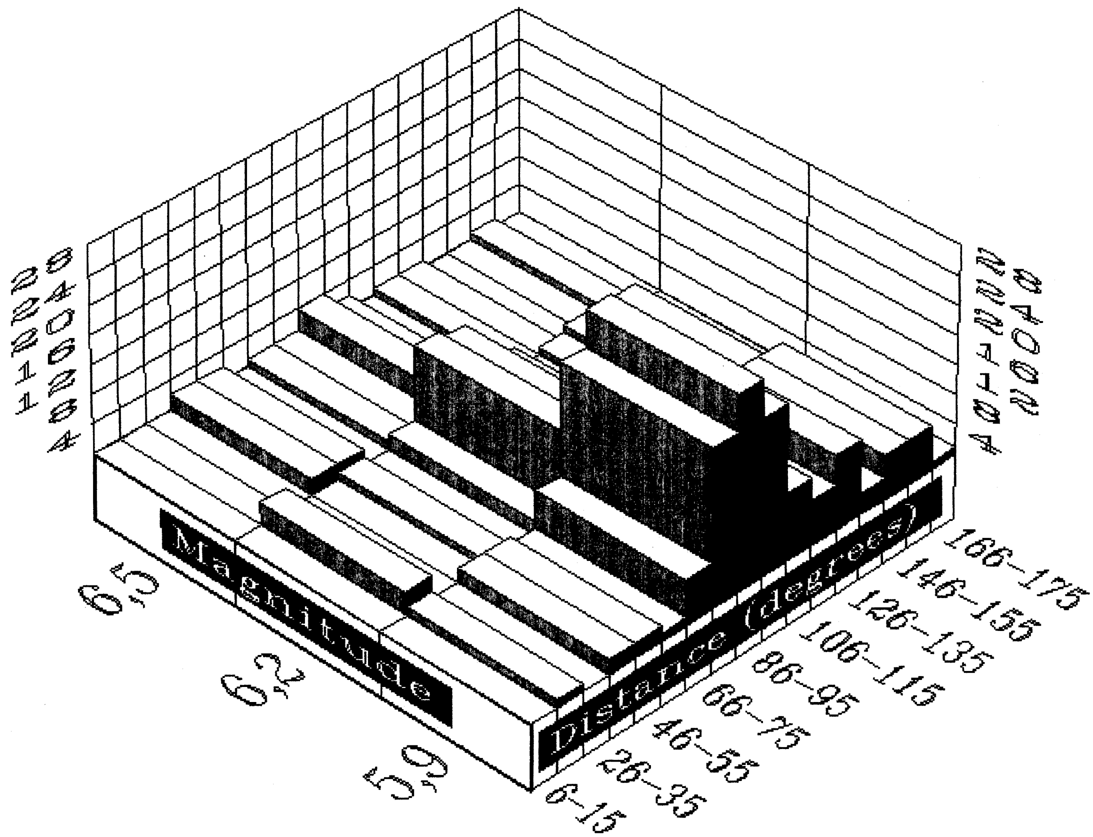

Fig. 8. Number of major events occurred in the world as reported by NEIC bulletin.

mic waves are better recorded than those generated in the shadow zone.

Actually the first step of distance includes earthquakes felt in the border region, and the selection criteria to eliminate regional events worked in two different ways: for our bulletin we could select events whose phases were reported as *P* or *PKP*, so many events in the border region were excluded from the data base because the phases were reported as *Pn* instead of *P*. For the NEIC bulletin we excluded earthquakes that occurred in the Italian and border regions. In this way it seems that the nearest events were recorded by the network more poorly than the more distant ones but in effect it is just a consequence of a different selection criteria.

We can affirm that, with respect to distance, the detection algorithm works well, recording better the nearest and most impulsive events. Now we control how magnitude can influence the detection of events at a certain distance from our network. Figure 7 shows that, for magnitude over 6, detection is quite independent of distance. To confirm this, see fig. 8, which shows the number of events occurred in the world (reported by NEIC bulletin) with magnitude equal or greater than 5.8. The maximum occurred at distances close to the shadow zone for our network; in spite of this we recorded all the events. For lower values, the trend is irregular: under 90°, events with magnitude over 5.3 are well detected. Over 90° detection is unreliable.

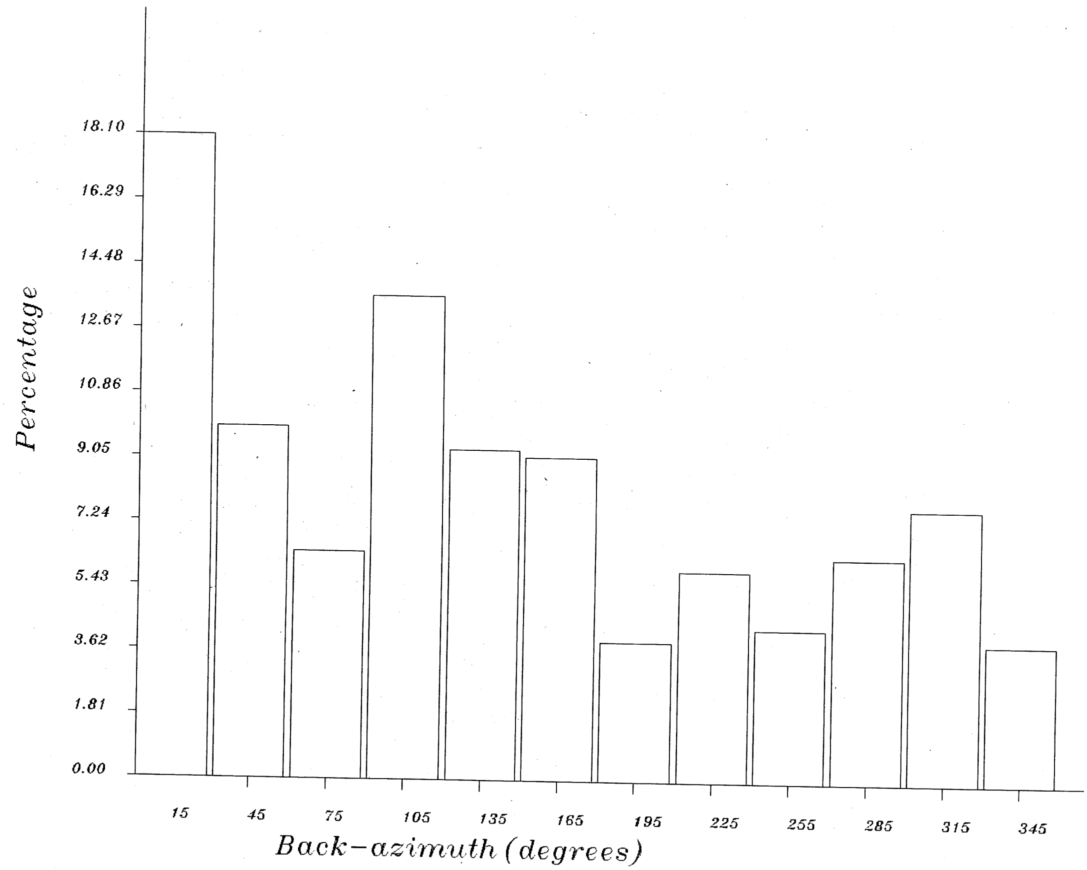

Fig. 9. Percentage of events recorded by ING versus back-azimuth. Each class is referred to NEIC data.

Analysing the percentage of events recorded versus back-azimuth (fig. 9), it is possible to define some privileged directions, such as the first and the third interval, with respect to the others. The tridimensional histogram in fig. 10 confirms that for magnitude over 6.0 the algorithm works well, independently of back-azimuth as well as distance. For lower magnitudes, waves coming from azimuth less than 40° and between 75° and 111° are better detected than the others. It means that we recorded eastern events better than western ones. Obviously it is impossible that this is an effect of the detection algorithm, rather than an amplification effect due to the particular ray paths.

A brief analysis was conducted on the number of stations recording the same events. This number was variable. If we analyse events above magnitude 6.0, we can affirm that in the best cases about 70% of stations recorded a given event. So we can conclude that a large fraction of the total number of station suffered some failures.

The best cases are not, of course, the rule. Because of the variability in the number of stations recording a single event, we

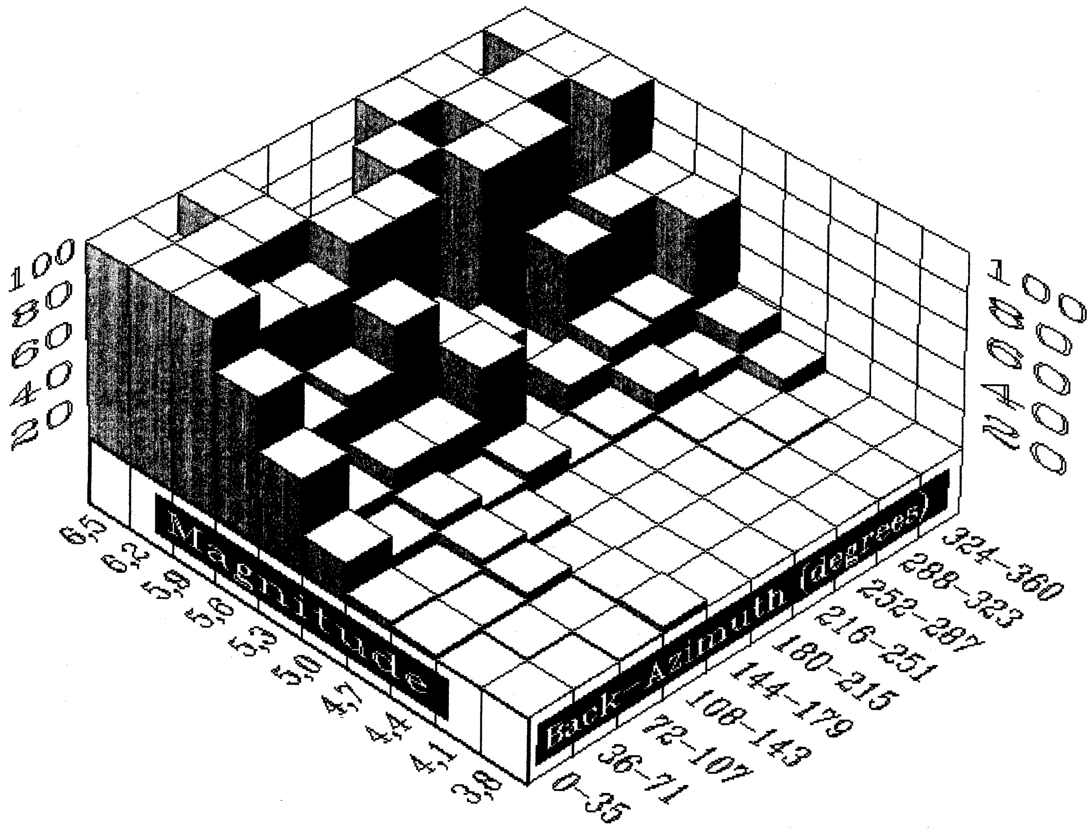

Fig. 10. Relation between magnitude and back-azimuth. Each class is referred to NEIC data.

can just affirm that at least three stations are able to record any event with magnitude 6.0 or more.

In order to define the best group of stations in relation to *P* and *PKP* detection we prepared two maps: the first, in fig. 11, shows, station by station, the percentage of *P* and *PKP* detections for events with magnitude 6.0 and over. The second, in fig. 12, shows the same for *P* detections only (distances less than 90°). To comment these two figures we have, as reference, the last map in fig. 13, which shows the percentage of time each station worked during the whole period. Both figures show that for the detection of teleseismic events, the situation is better in the northern part of Italy. For the *P* waves alone we have five stations (FVI, BNI, CKI, MME, BDI) that recorded over 90% of events.

Background noise, often connected with the geology of the site where the station is located, and the reliability of communication links are important factors in this result.

Obviously, if noise were reduced, the detection algorithms could work better than now. One possibility is to improve the automatic acquisition system introducing *ad hoc* filters to reduce background noise in the teleseismic frequency band. These filters would be different, from station to station.

Table I resumes the above mentioned

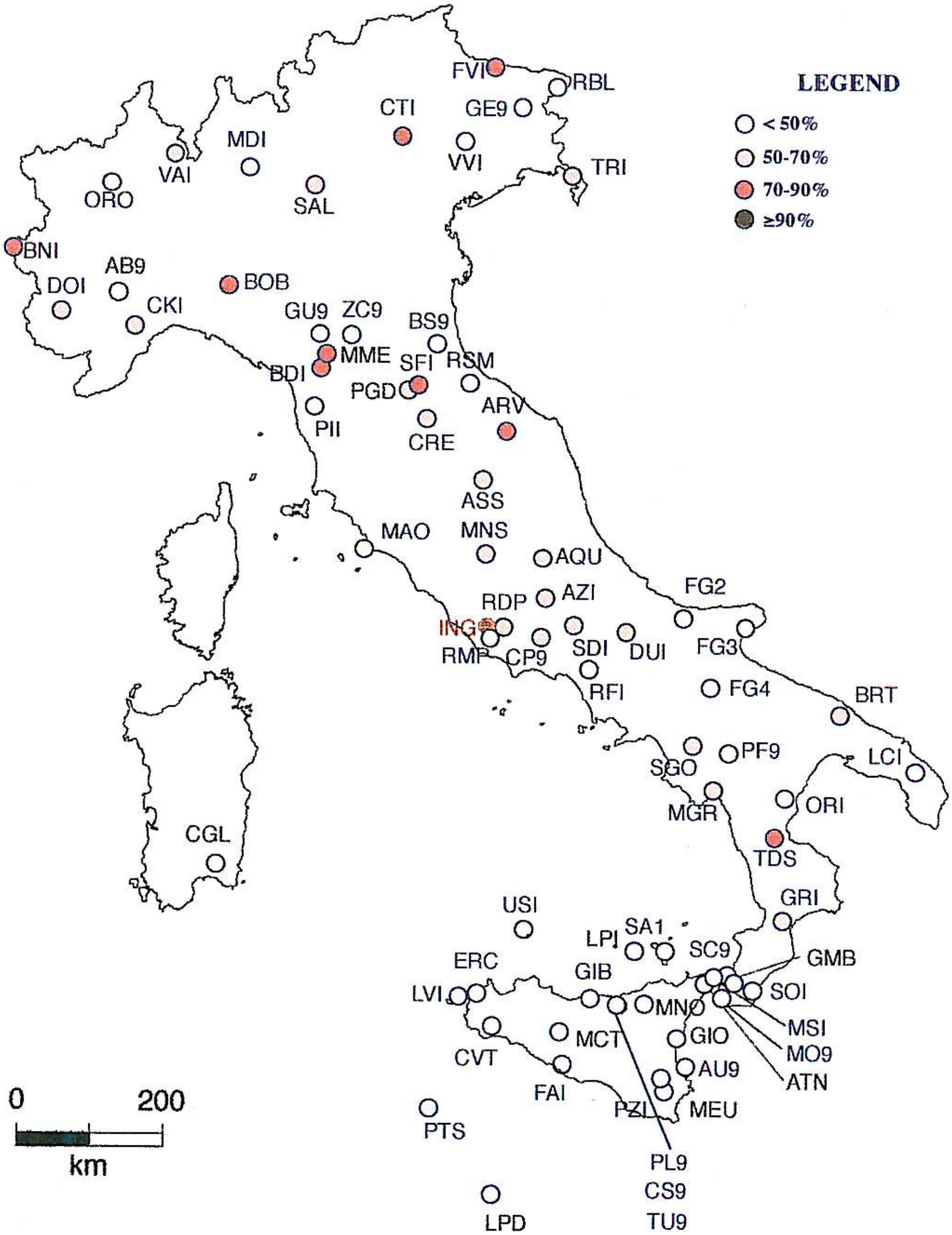

Fig. 11. Network capability with respect to the detection of teleseismic events ($M_b \geq 6.0$). The different colours correspond to different class of percentage.

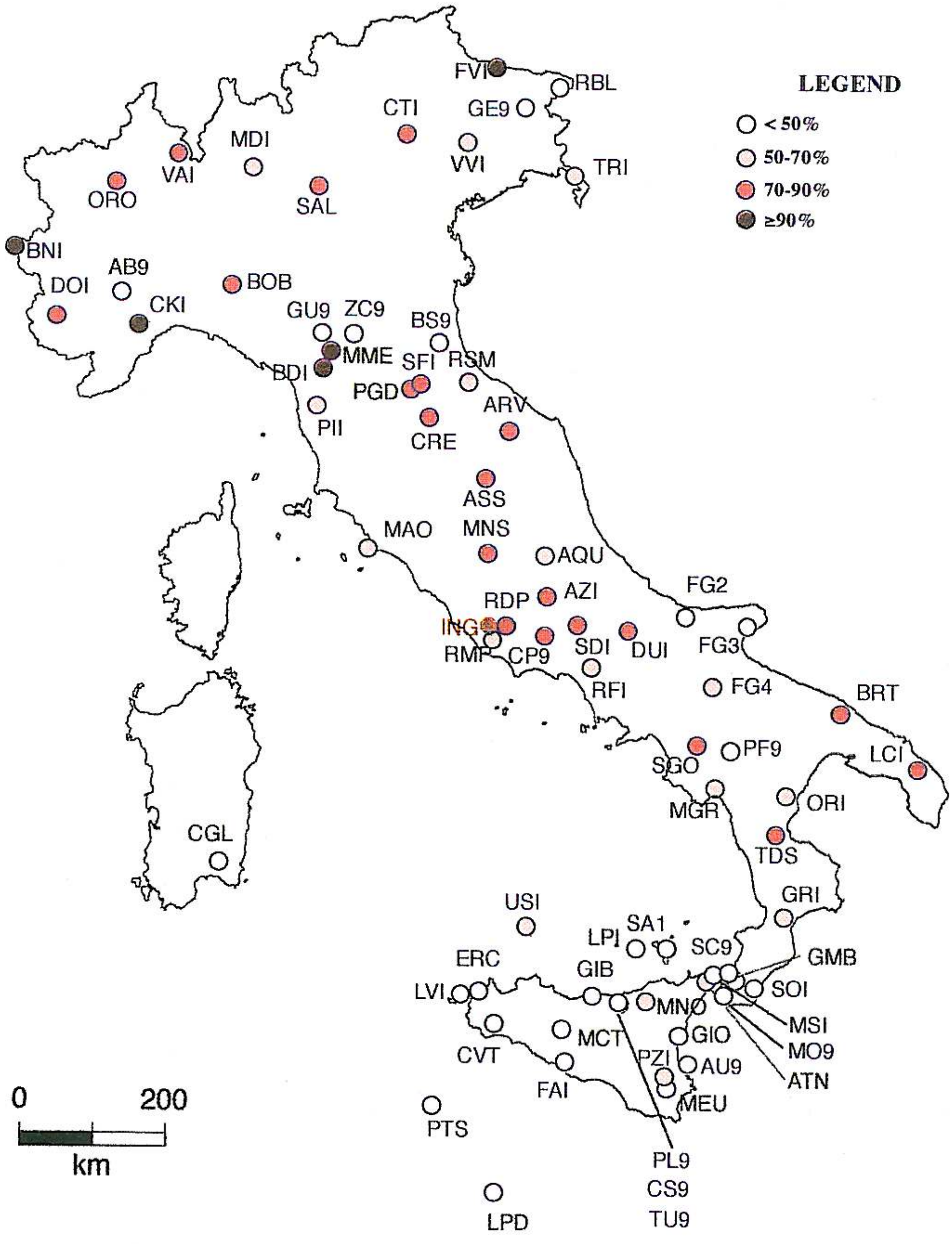

Fig. 12. Network capability with respect to the detection of events occurred at distance less or equal to 90° ($M_b \geq 6.0$). The different colours correspond to different class of percentage.

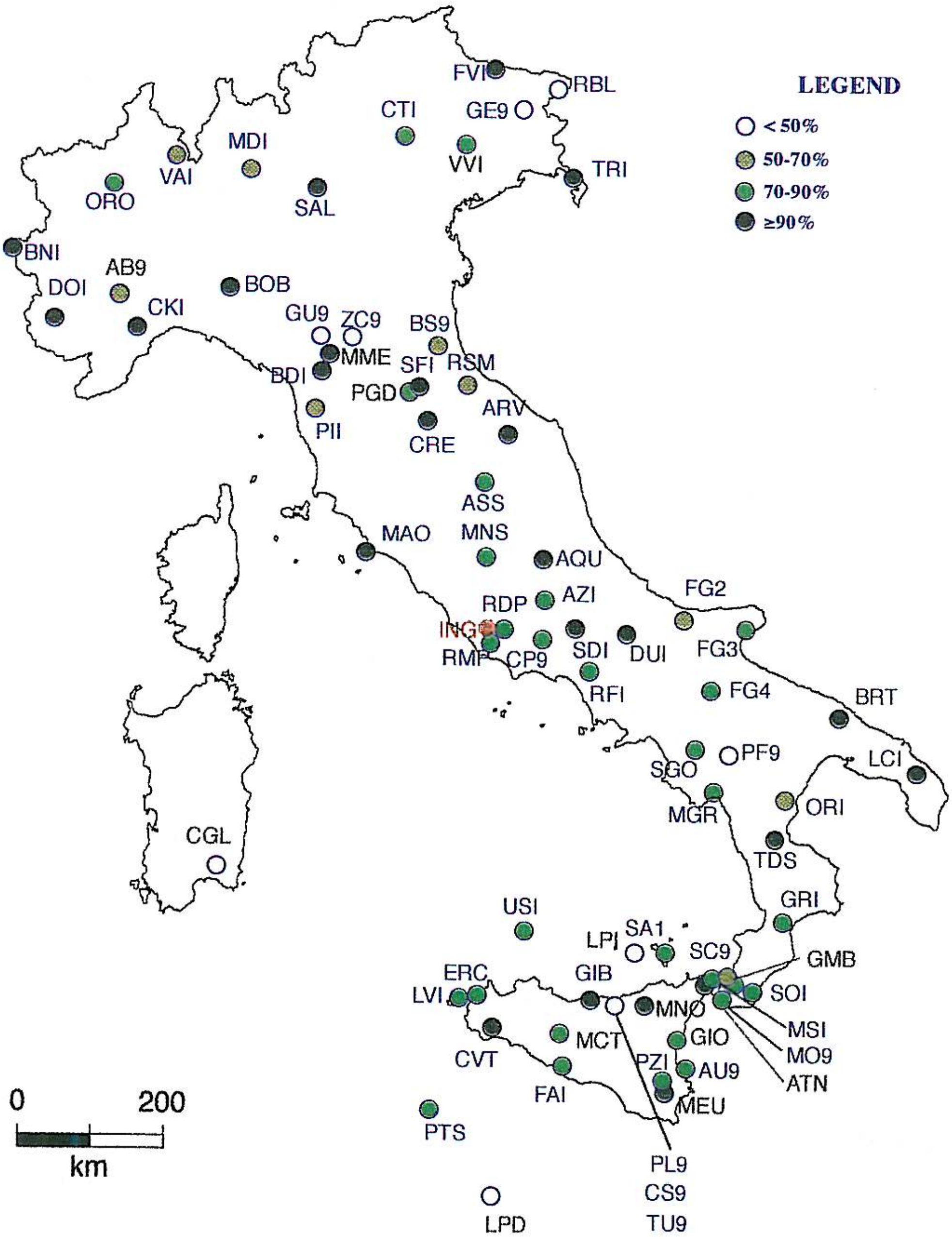

Fig. 13. Working days percentage of the ING network from January 1991 to June 1992.

Table I. Reliability of the ING automatic acquisition system. In the first column are reported station codes, in the second are indicated the connections with ING Data Center (tl: telephone lines; rl: dedicated radio links). In the third are collected the working days percentages. In the last two columns are reported the percentages of detections with respect to *P* + *PKP* phases and *P* phases only ($M_b \geq 6.0$).

Station code	Connections	Working days percentage	Percentage of detections	
			P + *PKP*	*P*
BNI	tl	97	84	94
CTI	tl	90	84	89
FVI	tl	90	80	95
BDI	tl	95	79	91
SFI	tl	94	77	81
ARV	tl	97	75	84
MME	rl	94	73	95
TDS	tl	90	73	85
BOB	tl	93	72	89
CKI	tl	97	69	92
VAI	tl	70	69	79
SDI	tl	93	67	77
ASS	tl	90	64	81
SAL	tl	96	63	88
PGD	rl	88	63	86
SGO	tl	78	63	78
CRE	tl	92	60	76
MGR	tl	74	60	70
BRT	tl	97	59	71
MNS	tl	79	58	80
DUI	tl	92	58	71
TRI	tl	94	58	70
AQU	tl	95	54	67
AZI	tl	75	53	73
DOI	tl	91	52	75
GRI	tl	73	52	51
CP9	tl	84	51	71
RDP	tl	80	50	76
ORO	tl	88	50	74
LCI	tl	96	49	73
VVI	rl	79	48	69
RMP	tl	90	46	69
MO9	tl	84	46	58
PII	tl	64	45	58
PZI	tl	85	43	60

Table I. (*continued*) Reliability of the ING automatic acquisition system. In the first column are reported station codes, in the second are indicated the connections with ING Data Center (tl: telephone lines; rl: dedicated radio links). In the third are collected the working days percentages. In the last two columns are reported the percentages of detections with respect to $P + PKP$ phases and P phases only ($M_b \geq 6.0$)..

Station code	Connections	Working days percentage	Percentage of detections	
			$P + PKP$	P
MDI	tl	64	43	60
RFI	tl	83	42	51
MAO	tl	91	41	63
ORI	tl	63	37	56
RSM	tl	64	37	52
USI	tl	89	36	54
FG4	tl	89	36	53
MNO	rl	94	36	50
SOI	tl	79	36	34
AU9	tl	73	34	48
ATN	rl	92	33	49
GIB	tl	95	29	48
CVT	tl	91	27	49
FG3	tl	86	27	47
SA1	tl	70	27	45
MEU	rl	92	26	41
FAI	tl	78	26	36
GU9	tl	23	26	33
FG2	tl	61	22	32
GMB	rl	87	21	31
ERC	tl	84	20	29
SC9	tl	70	20	28
AB9	rl	50	17	24
PTS	tl	78	14	29
CGL	rl	49	14	21
MCT	rl	80	14	17
PF9	tl	20	14	9
BS9	tl	57	10	19
GIO	rl	72	8	9
LPI	rl	26	7	8
RBL	tl	14	7	8
MSI	tl	88	1	2
LVI	tl	79	0	0

results for events with magnitude 6.0 and over. Stations with a working time below 1% were excluded.

The stations are sorted versus the detection capability with respect to teleseismic earthquakes. The poor reliability of southern stations is connected to the major instability of connections and in some cases, for example in Sicily, to the sea vicinity, which causes a high background noise.

The first ten stations will be recommended as reference for future work on teleseismic events because of the good values of detection rate both for *P* and *PKP* waves. Visual reading of analog signals would furtherly increase the number of detected events for those stations.

For the last group of stations that did not show a good detection rate, in spite of the high number of working days, the possibility is to examine their detection capability with respect to regional events, and, if it is also insufficient, changing the place in a less noisy one.

In conclusion, the ING acquisition system is able to detect just major events as any other regional network. We have to remember that the detection algorithm operating at our Institute is set up to detect regional events principally. The use of data provided by the best stations in the world or, better than that, the use of many arrays that are able to improve the signal to noise ratio, allows to record earthquakes, anywhere occurred, with magnitude 4.8 approximately. It would seem that the superior capability of an international network composed by a selected set of low noise stations makes the regional ones unnecessary. On the contrary, the use of a regional network is related to its capacity of recording and locating regional and local events with magnitude ranging from 2.5 and 4.5. In this respect regional networks could contribute to a global system of data exchange, reducing the magnitude threshold and the location errors in some areas of specific interest.

REFERENCES

BASILI, A., R. CONSOLE and F.M. MELE (1988a): Automatic detection and location of teleseismic events at the Italian Seismological Center, in *Proceedings of the Conference on Nuclear Test Ban Verification, Linkoping, Sweden, May 17-19 1988*, edited by E.B. BJORCK, Borgstroms, Motala, Sweden.

BASILI, A., R. CONSOLE and F. MELE (1988b): Automatic procedures for seismic event location, in *Proceedings I Seminar on the Prediction of Earthquakes, Lisbon, Portugal, 14-18 November 1988*, United Nation Economic Commission for Europe, Report Sc. Tech./Sem. 16, R. 36.

BASILI, A., E. BOSCHI, R. CONSOLE, F. MELE and G. SMRIGLIO (1990): Seismological analysis with automatic processing for the Italian telemetered network, in *I Workshop on MEDNET «The broadband network for the Mediterranean», September 10-14, 1990*, edited by E. BOSCHI, D. GIARDINI and A. MORELLI, CCSEM, Erice, 353-366.

DI MARO, R. (1994): Problematiche connesse con il calcolo della funzione di trasferimento dei sismografi in uso presso la rete sismica nazionale centralizzata dell'Istituto Nazionale di Geofisica, *ING Internal Report* N. 551.

ING Seimic Bulletin (Internal Report) (January 1991 - June 1992).

NEIC Monthly listing: *Preliminary determination of epicenter* (January 1991 - June 1992).