Web based macroseismic survey in Italy: method validation and results.

Sbarra Paola, Tosi Patrizia and De Rubeis Valerio

Istituto Nazionale di Geofisica e Vulcanologia, Roma, Via di Vigna Murata, 605 00143 Roma, Italy
email paola.sbarra@ingv.it
Telephone number +39 0651860276
Fax number +39 065041181

Abstract

A new method of macroseismic surveys, based on voluntary collaboration through the Internet, has been running at the Istituto Nazionale di Geofisica e Vulcanologia (INGV) since July 2007. The macroseismic questionnaire is addressed to a single non-specialist; reported effects are statistically analysed to extrapolate a probabilistic estimate of Mercalli Cancani Sieberg and European Macroseismic Scale intensities for that observer. Maps of macroseismic intensity are displayed online in almost real time and are continuously updated when new data are made available. For densely inhabited zones, we have received reports of felt effects for even very small events (M=2). Six earthquakes are presented here, showing the ability of the method to give fast and interesting results. The effects reported in questionnaires coming from three towns are carefully analysed and assigned intensities are compared with those derived from traditional macroseismic surveys, showing the reliability of our web-based method.

Keywords= Earthquakes, Macroseismic Intensity, Questionnaire, Macroseismic effects.

Introduction

Many seismic institutions and agencies all over the world, including the European-Mediterranean Seismological Centre, the U.S. Geological Survey, the British geological survey, the Swiss Seismological Service, Le Bureau Central Sismologique Français, etc (see table 1) manage web-based macroseismic surveys. Information is collected through questionnaires, compiled online by people who experienced a seismic event. Results are displayed either as maps or as tables.

In Italy, at the INGV, a web-based questionnaire has been online since 1997. The questionnaire in use up to 2006 was drawn up faithfully following the Mercalli Cancani Sieberg (MCS) (Sieberg, 1930) scale and was addressed to a large community. The compiling person was asked to give a comprehensive report of the effects on the population and buildings in his or her town. Obviously, this request cannot be fulfilled by a non-technician, so resulting intensities were frequently over-estimated. Dengler and Dewey (1998) also observed that when a single individual compiles a questionnaire, reporting effects observed by a whole community and hence not directly observed, data could be influenced by his judgment. For this reason, in the year 2007, the questionnaire was completely reformulated to address it to a single person who is asked to describe only effects directly observed. The same principle is followed in other on-line questionnaires, such as those of the U.S. Geological Survey (Wald et al. 1999) and the British Geological Survey (Musson 2007, Gilles et al. 2008). The new questionnaire consists of simple questions offering multiple-choice answers (Appendix 1), and requires a completely different evaluation method. The new procedure has been operative since June 2007 and can be found at the address **www.haisentitoilterremoto.it**. Macroseismic intensity maps are produced in real time from the analysis of the questionnaires and immediately displayed on the internet site. Both the MCS and the European Macroseismic Scale (EMS) (Grünthal 1998) are followed. The use of web-based macroseismic surveys developed in parallel with the wide diffusion of Internet connections. It presents several positive features: almost real-time results, low costs, fast evaluations of earthquake severity, positive feedback between the seismic institution and people, a large amount of data, and intensity values for even very small events. On the other hand, great care must be devoted to the design of the questionnaire and to the evaluation of answers, as compilation mistakes are possible because people are under emotional stress due to the seismic event and they are not expert.

Here we evaluate the following topics: the ability of our method to produce reliable macroseismic intensities and the comparison with traditional survey methods.

Questionnaire

The MCS and EMS macroseismic scales were designed to account for effects observed over a group of people and buildings. The operator who assesses the macroseismic intensity is usually an expert in the field, collecting information directly from a village and then evaluating the intensity through a critical analysis. The direct observation of effects by an expert is a very reliable way to collect macroseismic data, but is also very time-consuming. Particular attention must be paid to the danger of indirect data collection. There is agreement among survey experts on the low reliability of information gathered by asking one person what another has felt. The risk of introducing a bias in the data is high. For this reason, we designed our web-based questionnaire avoiding all references to a group of people or an extended area, instead asking a single person for the effects he or she felt directly. The questions follow the effects reported on the macroseismic scales. Answers of each questionnaire are then analysed by an algorithm to estimate the probabilistic intensity associated. Finally a mean value of all intensities coming from each town or village is calculated. The final result is the definition of MCS and EMS intensity degree located on the centroid of a municipality, and an evaluation of the associated uncertainty. Questions are grouped into three principal thematic sections. The first section deals with personal information, the geographic location and the association with the seismic event as recorded by the INGV seismic network. If the compiler is going to reply shortly after the event occurrence, before the INGV provides an official location, he or she is asked to specify the occurrence time. We also request a characterisation of the specific location of the observer (inside a building, in an open space, on a road near buildings), the floor number and the building storey.

The second section deals mainly with transient effects (Appendix 1) usually prevalent in medium-low degrees of the macroseismic scale. Surveying these effects is traditionally considered more difficult as it is based only on human accounts. Examples of such questions include personal reactions, movement of pictures, books and vases, animal reactions, and light furniture shake. This section also addresses the question of what the observer was doing during the earthquake (sleeping, walking, being still). This is useful to evaluate the level of shaking, as for example, it must be stronger to be felt by a walking person. The section ends with a box in which the compiler can record any other observed effect. Although this information is not used to calculate the intensity, it constitutes an open way to collect new significant descriptive elements (i.e., activation of car alarms, interruption of telephone lines): these could be in the future associated with known effects and to their intensity.

The last section inquires about building damages in a very simple way, as the compiler does not have to be an expert on building structures.

In some cases, in order to avoid ambiguity, we have introduced answers about effects not considered in the macroseismic scales. One of these cases is related to balance during the shaking. The MCS and EMS scales provide three cases: no problem, difficulty in remaining upright and falling down. During a training period of the questionnaire, we noticed that many people were selecting "difficult to keep balanced." This is an effect related to high macroseismic intensities. This answer was often in disagreement with other answers pointing to lower degrees, demonstrating a misunderstanding. To solve the problem, we introduced a new answer "dizziness," assigning it the same meaning as "no problem" when analysing the questionnaire.

Assessment of intensity degree and map creation

The analysis of a compiled questionnaire for the evaluation of the local macroseismic intensity is a delicate task. Dedicated statistical analyses have been applied in similar cases (De Rubeis et al. 1992) to determine the degree and reliability of each questionnaire. Our needs are complicated by the necessity to perform the analysis quickly and to exclude poorly-compiled questionnaires from the almost real-time macroseismic maps. For these reasons, we have designed a statistical procedure to give fast and robust results. The procedure has been applied to interpret felt effects according to the MCS and EMS scales, respectively, using the same criteria.

In the macroseismic scales, each effect can be associated to a particular degree depending on the percentage of people or buildings involved. The MCS scale does not fix precise limits on the percentage, preferring to quantify the results through adjectives like few, part, or many. A more precise quantification has been proposed (Molin et al. 2008), but a common rule is still lacking. The EMS scale gives percentage range corresponding to few, many and most even if the class limits are not strictly defined. When assigning an intensity to one questionnaire, we assume that the compiler and the observed building belong to “many”, which is the wider category, and thus the most probable one. If this is not true, and the person/building comes from the other categories, the intensity for that questionnaire can vary at most ± 1 degree. Our method determines a probabilistic intensity estimate for each questionnaire and is based on additive scores associated with the answers, assigned following these points:

- Each answer concerning an observed effect adds scores to specific intensity degrees; the observation of one effect is typically one or few degrees.
- Every answer has a potential score equal to 100. If the corresponding effect is present in more than one macroseismic degree, the score is equally divided among all considered intensities. In this case, the score added to each degree is smaller.
- An answer pointing to an explicit lack of a specific effect adds scores to degrees that exclude that effect; unanswered effects, on the other hand, do not produce scores.
- If the observer reports permanent damages in the building then all scores derived from transient effects are discarded for this questionnaire.

Table 2 shows examples of three transient effects and the assigned scores in the MCS scale.

For every question there is always an answer stating that no such effect was present as well as the answer “unable to say.” These are quite different for the analysis: the first gives scores to degrees that definitely do not produce such an effect while the latter does not assign any scores.

Scores deriving from some specific effects change depending on other variables. These variables are defined in the questionnaire (Appendix 1) in question 1 (situation variable) and 20 (structure variable). For example, stronger buildings are supposed to be less damaged by the shaking, so a particular level of damage to these buildings shifts its score to a higher intensity. The same rule is applied to the transient effect of felt vibration intensity, as its associated score may vary depending on the status of the observer: if for example the observer is still and awake then he or she can detect even a very low vibration (in table 2 an example of a person being still during the earthquake is shown). It could be possible to add another variable depending on the floor, but at this stage we are collecting this information for successive studies, without using it in the intensity evaluation. Scores pertaining to each answer are then summed, giving a total score for each degree. The resulting distribution of scores for each questionnaire varies depending on the intrinsic coherence of the given answers and on the capability of felt effects to identify a particular macroseismic degree. The maximum value of the distribution should point to the most probable intensity, but there are usually several macroseismic degrees with similar high scores. The intensity degree (I) assigned to the each questionnaire is thus calculated as follows:

$$I = \frac{\sum_{i=1}^{12} i s_i \Theta(s_i - 0.75\, max(s))}{\sum_{i=1}^{12} s_i \Theta(s_i - 0.75\, max(s))},$$

where S_i is the total score for the i^{th} degree and Θ is the Heaviside step function.

One important evaluation performed on the compiled questionnaire has to do with its reliability: a wrong questionnaire may report effects not really observed. Basically, there are two possible situations in a wrong questionnaire:

1) The compiler wrongly adds some effects not really felt. The resulting questionnaire will have a wide distribution of scores.
2) The compiler wrongly or deliberately reports several self-consistent effects not really observed. The result points to a false intensity degree, with a narrow score distribution.

To identify situation 1) we calculated the variance associated to the weighted mean intensity for available questionnaires in our database. We then defined a limit of variance as the value separating the upper 2.5% tail of the whole distribution: questionnaires having variances bigger than this value are considered wrong. This is, for example, the case of a questionnaire having answers corresponding to degrees IV and VII and for any other questionnaires having a degree range bigger than 3.

Regarding situation 2), we apply a filter based on the "square root" attenuation law (Gasperini 2001):

$$I_a = I_0 - (-0.42 + 0.45\sqrt{D}),$$

where I_0 is the epicentral intensity and D is the epicentral distance from the town reported in the questionnaire. The epicentral intensity has been estimated using the earthquake magnitude M and the empirical function (Marcelli and Montecchi 1962):

$$I_0 = (M - 1.407)/0.481.$$

If the intensity associated with a questionnaire is greater then $I_\alpha + 2.5$ or the variance is bigger than the threshold, we consider it dubious and temporarily discard it from the real-time elaboration and it is not considered for the evaluation of macroseismic intensity. These dubious questionnaires, that are only 3% of the whole database, will be manually revised for eventual specific studies.

The probabilistic intensity estimates of all questionnaires coming from a municipality are averaged to assign the intensity showed in the real-time map. The maps are produced when more than five questionnaires are compiled for a seismic event. The average of intensities is more reliable when more questionnaires are available. To quantify the error associated with the mean intensity, we use an iterative procedure, commonly adopted in engineering and statistics, that provides a quick and reliable evaluation. In particular, we use a filtering procedure belonging to the set of Kalman filter procedures (Kalman 1960). Using our database for each event, we estimated the standard deviation of the intensity distribution of all questionnaires pertaining to each town for each earthquake. This is quite small, less than 1 degree. Even assuming a standard deviation of 1 degree, the Kalman filtering procedure provides an error associated with the commune intensity of ±0.4 degrees with 5 questionnaires and an error of ±0.3 degrees with 15 questionnaires.

Displayed intensity values are located on the centroid of the municipal district area, as given by the Italian statistical agency (Istat). Since June 2007, more than 100000 questionnaires have been compiled, producing 1000 intensity maps, most belonging to earthquakes of magnitude 2-4. Analysing the whole database we note that the most frequent intensity value assigned to a questionnaire was degree III-IV. For some shallow events with magnitudes lower than 2, we obtained enough questionnaires, that allowed to produce maps. We even received questionnaires of felt effects in Italy for some high magnitude Greek events. Recently, the M=6.3 of L'Aquila and the associated sequence brought forth a huge amount of data: for the main shock we here show the macroseismic field constructed with more than 10500 questionnaires.

An additional map is routinely produced for each felt event. It shows the areas where the earthquake sound was heard. Although this particular effect does not contribute to the intensity assessment, it may be useful for epicentral location and source pattern characterisation (Tosi et al. 2000).

Data analysis and comparison

Six earthquakes are presented here. The first event was instrumentally located near the town of Rome (Figure 1) in April 12, 2008 at 5.45 UTC, with a magnitude $M_l = 3.8$; the depth was estimated at about 10 km. The highest intensity (V MCS) was estimated at the villages of Palestrina and Castel Gandolfo. Effects were felt up to the coast over a distance of 40 km from the epicenter. We received a total of 1150 compiled questionnaires, 807 of them coming from the city of Rome. The high number of inhabitants allowed a good sampling, opening the possibility of an in-depth analysis for this area. On average, Rome experienced III-IV MCS degree. The distribution of MCS values assigned to questionnaires coming from Rome is shown in Figure 2. It results that the more frequently assigned value to each questionnaire is IV MCS, but that there are also a lot of questionnaires of III MCS. Using the distribution of all effects reported by the population, we extrapolated an MCS degree following a procedure similar to a standard macroseismic survey, in order to test our real-time method. Figure 3 shows the distribution of observed severity for some effects, caused by 3 different earthquakes, in 3 cities (Roma, Rende and Crotone) . For example in Rome, considering the personal reaction of the compiler, we note that 72% reported curiosity and 28% fear. Analysing the *a posteriori* distributions of all effects MCS degree III-IV is assigned, in agreement with the result given by the real-time analysis.

In the questionnaire, we ask, as additional information, the complete address where the observation was made. In the case of events felt within a large town, like Rome, it is possible to estimate intensity in different areas or sectors, and to produce a detailed scale intensity map (Figure 4). For this event, a standard macroseismic survey was independently conducted by a team from the INGV (QUEST 2009) following the EMS scale. Their results can be compared to ours (Figure 4, Table 3), as they provide intensities for some villages and for particular areas of Rome.

In general, both methods give similar results, with the biggest differences of the order of one intensity degree (Ciampino and Casal Palocco).

A different comparison can be produced from the estimated Modified Mercalli Intensity (MMI) map (Wood and Neumann 1931) obtained by the INGV (DPC – S4 Project, 2005), following the Shake Map procedure (Wald et al. 2006) and based on instrumental accelerograph data. Since MMI and EMS scales are very similar for low intensities (Molin 1995), we directly compare values (Table 3), showing general agreement.

Newspaper articles represent another source of information. Even if these data are not as reliable as direct observations, they are frequently used to assess the macroseismic intensity, especially for past earthquakes. For the event that occurred in Rome, reports show that most people felt the earthquake. Many felt fear, doors were slamming, and there were clear vibrations of floors and frames in houses. Such effects alone denote degree V. This represents an overestimation compared with other available data, as reporters probably highlighted only the most striking effects.

On July 30 2007, a magnitude $M_l = 4.2$ event occurred near the town of Parma. The macroseismic map, built from a total of 444 questionnaires (Figure 5), shows a very peculiar field: far from the epicenter, separated by an area of no reports – indicating that earthquake effects were probably negligible – there is a large area of MCS degree III. Our procedure estimates an intensity of III–IV for the city of Parma. As for Rome, the analysis of the distribution of single effects felt in Parma agreed with MCS III-IV. The faraway amplification area, despite the low associated intensities, constitutes an interesting result. It is clearly delineated and in some areas corresponds to the boundary of the Pianura Padana sedimentary basin, but as of yet there has been no clear explanation for this amplification.

As another example of the application of our method, we refer to the earthquake that occurred on December 20 2007 near the village of Rende (Southern Italy), of magnitude $M_l = 3.7$ and at a depth of 11 km. We received a total of 156 compiled questionnaires, 61 of them referring to Rende. The intensity estimated for this village by our real-time procedure is MCS IV-V. The distribution of degrees assigned to single questionnaires shows that 25 are of MCS IV and 17 give MCS V (Fig. 6). A detailed analysis from single answers confirms the higher intensity for this town (Figure 3) compared with Rome. We note that 60% of observers felt intense shaking. Around the same percentage felt fear and 74% reported the vibration of doors and windows. These effects point to MCS IV-V.

The fourth analysed event (August 1, 2007) was located on the coast near Crotone with magnitude $M_l = 4.1$ and a depth of 10 km. The intensity map was produced with a total of 178 questionnaires distributed in 16 villages. In the town of Crotone, light damages to buildings occurred (cracks in the plaster). Out of a total of 151 questionnaires for this town, 82% felt strong shaking (Fig. 3). Moreover, furniture oscillation and moving and falling of pictures and books were reported. From these effects, we can assign on overall intensity of MCS V, in agreement with the mean value of questionnaire intensities (V MCS), even if the distribution of all values assigned to the questionnaires shows the presence of some MCS VI and very few MCS VII (Figure 7).

The next analysed event also occurred near the city of Parma, but the epicenter was further south (Figure 8), on 23 December 2008, having magnitude Ml=5.1 and a depth of 26.7 km. Due to the relatively high depth, the main shock was felt in a large territory, up to 250 km away. The highest MCS felt intensity was MCS VI but the majority are V MCS. The Padana plain played an important amplification role, enhancing the degree IV area toward the north and north-east side of the macroseismic field. Although the filtering of macroseismic data produced a consistent intensity field, we note that locally a certain data variability is observed. This shows the important role of local amplification-attenuations of intensity.

Comparing the macroseismic intensity of this event with that obtained from a standard macroseismic survey conducted by the QUEST team (direct macroseismic survey, QUEST2009), a map of differences between intensities estimated by QUEST team and probabilistic intensities given by our method has been produced (Figure 9). The map shows quite a good correspondence between the two analysed methods. Values less or equal half degree, corresponding to white points on the map, are considered to be without difference, because this is comprised in the methodology error of the determination of intensity degree. Most points have similar values with differences less than one degree; higher differences can be attributed to the poor statistics of towns that have few compiled questionnaires (fewer than 3, see Figure 9). In general, our procedure produces slightly lower MCS intensities. Conversely, the comparison with intensities reported by the USGS "did you feel it" for the same event (http://earthquake.usgs.gov/earthquakes/dyfi/events/us/2008ayaz/us/index.html) showed values that are on average lower than our corresponding EMS of half degree. The last analysed event is the recent Mw 6.3 occurred on April 6, 2009 near L'Aquila (Figure 11). The shock was felt in most of Italy and, in the epicentral area, the MCS intensity reached VIII-IX. The real-time mapping of intensities permitted us to delineate the macroseismic field, using 700 questionnaires, starting one hour after the event. We have so far received more than 10500 questionnaires for the mainshock alone, and around 60000 for the whole sequence. Analysing data versus time we note a good correspondence among the first produced maps and the final ones evidencing that answers are not biased by time or mass media or emotional reaction. In the city of L'Aquila and in some villages, many buildings collapsed or were seriously damaged. As could be expected, few people living in these villages had the opportunity to complete the internet questionnaire. For this reason, in the first maps information in the epicentral area was lacking. During the following days, we received many questionnaires even for this area, but the majority were derived from people who experienced a low level of damage, reducing the mean probabilistic intensity assigned to entire municipality by our methodology in respect to the intensity estimated by QUEST team (QUEST 2009) for the historical center of the villages in the epicentral area. The area of MCS VI in figure 11 is instead in agreement with macroseismic survey map (QUEST 2009). It is slightly elongated towards the south-east in accordance with the rupture directivity (Scognamiglio et al. 2009). In figure 12 a zoom of the epicentral area of L'Aquila earthquake is shown.

Discussion

Our web-based macroseismic survey is radically different from traditional data collection. It is based on the collaboration of volunteers and will experience growth in parallel with the diffusion of the Internet in Italy. Results are quickly displayed: usually half an hour after an event, intensity map shows a good approximation of the final macroseismic field. It is very suitable for medium-low intensities and no investigated area is previously planned, preventing biases in data acquisition.

At the beginning, we received many answers from people who felt events and very few from people who did not notice any effect. To deal with this problem, we compiled a list of interested people to be alerted immediately after the occurrence of an earthquake in their zone. This group started in December 2008, and it now has more than 7000 registered correspondent and is constantly growing. Members are volunteers, quite homogeneously distributed over the territory, who compile questionnaires even in the case of "not felt." In this way, it is now possible to outline the areas of degree II and III. Our procedure of intensity assessment is similar to that used in other institutions such as the U.S. Geological Survey and the British Geological Society. Macroseismic intensity is generally calculated considering all questionnaires coming from a zone (based on zip code or on a regular grid) and analysing scores associated with the answers. We follow some rules like that used in other institutions, such as a greater weight for an answer referring to an effect that is typical of a particular degree (USGS, Wald et al. 1999), or discarding weights associated with transient effects in the case of permanent damage (BGS, Musson 2007). One of the differences among the methods concerns the choice of the area inside which effects are counted and minimum numbers of questionnaires used for the intensity evaluation. BGS focuses on a regular grid of 5 km x 5 km with at least five questionnaires (Musson 2007). The USGS, on the other hand, assigns intensity values to the areas associated to zip codes containing at least one questionnaire (Wald et al. 1999). Our method assigns a mean probabilistic estimate of intensity to each commune area from which we received at least one valid questionnaire (i.e., not discarded by the filtering procedure), and plots on a map points of different size depending on the number of questionnaires used, because, as shown before, this is correlated with the error associated with the commune intensity. The main difference among the various methods lies in the particular score values and weights given to the answers. At present, each institution follows a subjective reasoning while interpreting the macroseismic scales, but it would be advisable, in the future, to compare these methods in order to standardise them.

Conclusions

Our macroseismic intensity data collection provides the possibility to analyse all available information with statistical procedures in almost real-time. We moreover provide, with the mean probabilistic estimate intensity for each municipality, the number of compiled questionnaires on which it is based: normally this information is not reported in traditional macroseismic field surveys.

The studied events show the coincidence of intensities obtained processing our data with two different methodologies. In the first, the real time one, the intensity assigned to a municipality is obtained calculating the mean value of all questionnaires each one with its intensity. In the second procedure, performed like a standard macroseismic survey, we estimate the intensity representative of a city considering the *a posteriori* distribution of all effects.

Agreement was found with intensities elaborated through standard methods, i.e., following investigations done by experts. Our method gives acceptable results for quickly and preliminary intensity assessment at a very low cost.

The web-based method provides more data compared to a direct survey, given by the analysis of a greater number of events of low magnitude. Moreover, medium-high magnitude events receive a bigger surface extent analysis, by the inclusion of peripheral areas affected by low intensity effects, usually disregarded by direct inspection for clear cost reasons. Web-based surveys can detect attenuation or amplification anomalies because we have e large amount of data even for low intensities. Moreover, when the spatial density is adequate, it could be possible to identify anomalies at a more detailed scale.

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Figure Captions

Figure 1

12 April 2008 Ml=3.8 depth=10 km Time (UTC)= 05:45. MCS macroseismic map produced from the analysis of 1150 questionnaires. Circles show the mean probabilistic intensity estimate localised in the commune area centroids.

Figure 2

Distribution of MCS intensity for the earthquake of 12 April 2008, assigned to questionnaires coming from the city of Rome.

Figure 3

Distribution of the severity of some transient effects observed in the cities of Rome (807 questionnaires for the earthquake of April 12, 2008 5:45 UTC), Rende (61 questionnaires for the earthquake of December 20, 2007 3:25 UTC) and Crotone (151 questionnaires for the earthquake of August 1, 2007 00:08 UTC). Y axes are expressed in percentage of total number of questionnaires.

Figure 4

EMS macroseismic map showing intensities in the city of Rome. The mean intensity value is calculated inside each mesh of a regular grid.

Figure 5

30 July 2007 Ml=4.2 depth=28 km Time (UTC) = 19:06. Macroseismic MCS map produced from the analysis of 444 questionnaires. Circles show the mean probabilistic intensity estimate localised in the commune area centroids.

Figure 6

Distribution of MCS intensity for the earthquake of 20 December 2007, assigned to questionnaires coming from the city of Rende.

Figure 7

Distribution of MCS intensity for the earthquake of 1 August 2007, assigned to questionnaires coming from the city of Crotone.

Figure 8

23 December 2008 Ml=5.1 depth=26.7 km Time (UTC) = 16:24. Macroseismic MCS map produced from the analysis of 1569 questionnaires. Circles show the mean probabilistic intensity estimate localised in the commune area centroids.

Figure 9

23 December 2008 Ml=5.1 depth=26.7 km Time (UTC) = 16:24. Map of the differences between intensities estimated by QUEST team (direct macroseismic survey) and intensities estimated using questionnaires.

Figure 10

Absolute value of differences between intensities estimated by QUEST team (direct macroseismic survey) and intensities estimated using questionnaires relative to the 23 December 2008 earthquake (shown in the map of Figure 9) plotted versus the number of compiled questionnaires used for each town.

Figure11

6 April 2009 Ml=5.8 depth=8.8 km Time (UTC) = 01:32. Macroseismic MCS map produced from the analysis of 10368 questionnaires. Circles show the mean probabilistic intensity estimate localised in the commune area centroids.

Figure12

April 6, 2009, Ml = 5.8, depth = 8.8 km, time (UTC) = 01:32. Macroseismic MCS map of epicentral area (zoom of Fig. 11). Circles show the mean probabilistic intensity estimate localised in the commune area centroids

Appendix 1

Did you feel the earthquake?

yes - no

1) what were you doing?
   a) unable to say b) sleeping c) still d) walking

2) shaking
a) unable to say b) not felt c) weak d) moderate e) strong

3) emotional reaction
a) unable to say b) curiosity c) fear

4) personal reaction (inside a building)
a) unable to say b) stood motionless or left quietly c) ran outside

5) balance
a) unable to say b) no problem c) dizziness d) difficulty to keep balance e) fall

6) how many people close to you felt the earthquake and reacted like you
a) unable to say b) I was alone c) 0 d) 1-3 e) 4-10 f) > 10

7) animal upset during the earthquake or a few minutes before
a) unable to say b) no problem c) animals indoors may have been frightened d) animals outdoors may have been frightened e) animals indoors and outdoors may have been frightened

8) hanging object
a) unable to say b) still c) swing slightly d) swing considerably

9) china and glasses
a) unable to say b) still c) rattling d) clattering together e) have broken

10) small objects
a) unable to say b) still c) have moved or fallen

11) doors and windows
a) unable to say b) still c) rattling d) opening or closing e) slamming

12) liquid in containers
a) unable to say b) still c) oscillating slightly d) oscillating or spilling out e) moving strongly f) splashes from pools

13) pictures, vases and books
a) unable to say b) still c) moving d) few falling e) many falling

14) furniture
a) unable to say b) still c) swinging d) moving e) falling or overturning

15) plants and trees
a) unable to say b) still c) plants and sprigs visibly moving d)shaking branches e) branches have broken

16) acoustic effect : rumble
a) unable to say b) not felt c) felt

17) when was the acoustic effect heard?
a) unable to say b) before the ground shaking c) during the ground shaking d) after the ground shaking

18) where did the acoustic effect come from?
a) unable to say b) from underground c) from the building d) from outside

19) other observed peculiar effect
....

Damages or effects to the building

20) structure of the building
a) unable to say b) masonry c) reinforced concrete d) wood e) steel

21) walls

a) unable to say b) no damage c) cracks in plaster only d) small cracks in walls and/or big pieces of plaster fall e) large cracks in walls f) collapse of walls

22) roof tiles
a) unable to say b) no damage c) few sliding d) all sliding

23) chimneys
a) unable to say b) no damage c) fall of few stones d) fracture f) fall

24) building
a) unable to say b) no damage c) slight damage d) moderate damage e) partial collapse f) total collapse

Institution or agency	**Link**
European-Mediterranean Seismological Centre	http://www.emsc-csem.org/index.php?lang=en&page=rye&sub=choose
U.S. Geological Survey	http://earthquake.usgs.gov/eqcenter/dyfi/
British geological survey	http://www.earthquakes.bgs.ac.uk/questionnaire/EqQuestIntroA.html
Swiss Seismological Service	http://www.seismo.ethz.ch/networks/macroseismic/macro_form_ineu.html
Le Bureau Central Sismologique Français	http://www.seisme.prd.fr/english.php#
Geological Survey of Canada	http://earthquakescanada.nrcan.gc.ca/dyfi
Central Institute for Meteorology and Geodynamics of Austria	http://www.zamg.ac.at/erdbeben/bebenbericht/index.php
Geophysical Institute, University of Zagreb (Croatia)	http://www.gfz.hr/seizmologija/upitnik.php
Environmental Agency of the Republic of Slovenia	http://www.arso.gov.si/potresi/vprašalnik/
SyNaRMa (European project)	http://gserver.civil.auth.gr/synarma/Questionare/SQ/QuestSeis.aspx

Table 1. Some other currently available web-based macroseismic questionnaires.

effects	**II MCS**	**III MCS**	**IV MCS**	**V MCS**	**VI MCS**
small objects were still	33	33	33	0	0
moderate shaking	0	0	100	0	0
doors and windows rattling	0	0	100	0	0
Total score	**33**	**33**	**233**	**0**	**0**

Tab 2. Example of assigned scores in an MCS scale if a person was still during the earthquake. In this case, the assigned intensity is IV MCS.

	Online Questionnaire	**QUEST (survey)**	**Shake Map**
Ciampino	4	5	4
Albano	4	4.5	4
Ariccia	4	4.5	4
Fiumicino	3.5	4	3
Frascati	4	4	4
Grottaferrata	4	4	4
Monte Porzio Catone	4	4	4
Tuscolano (Rome)	4	4	3,5
Laurentino (Rome)	3.5	4	3.5
Acilia (Rome)	4	4.5	3.5
Ostia (Rome)	4	4.5	3.5
Casal Palocco (Rome)	3.5	4.5	3.5

Tab 3. EMS intensities obtained using different methodologies for the April 12 2008 earthquake.

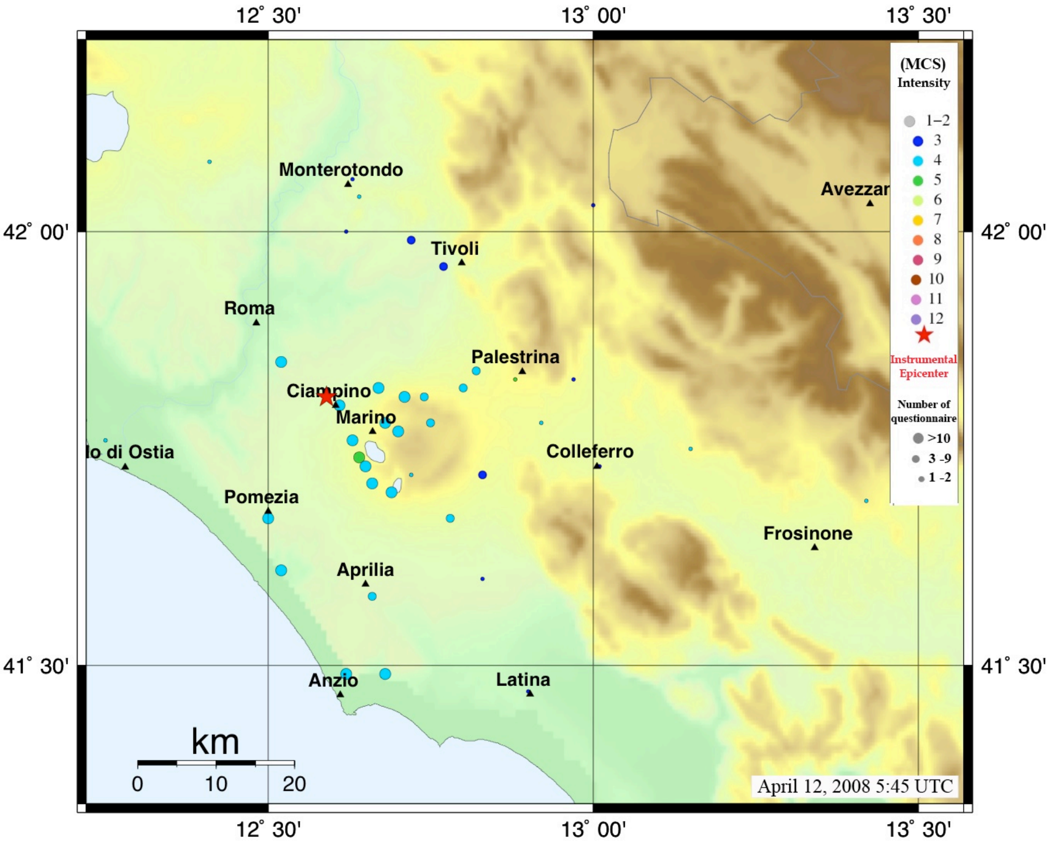
12° 30'
13° 00'
13° 30'
42° 00'
41° 30'
(MCS) Intensity
1–2
3
4
5
6
7
8
9
10
11
12
Instrumental Epicenter
Number of questionnaire
>10
3 -9
1 -2
Monterotondo
Avezzar
Tivoli
Roma
Palestrina
Ciampino
Marino
lo di Ostia
Colleferro
Pomezia
Frosinone
Aprilia
Anzio
Latina
km
0
10
20
April 12, 2008 5:45 UTC

Figure 1

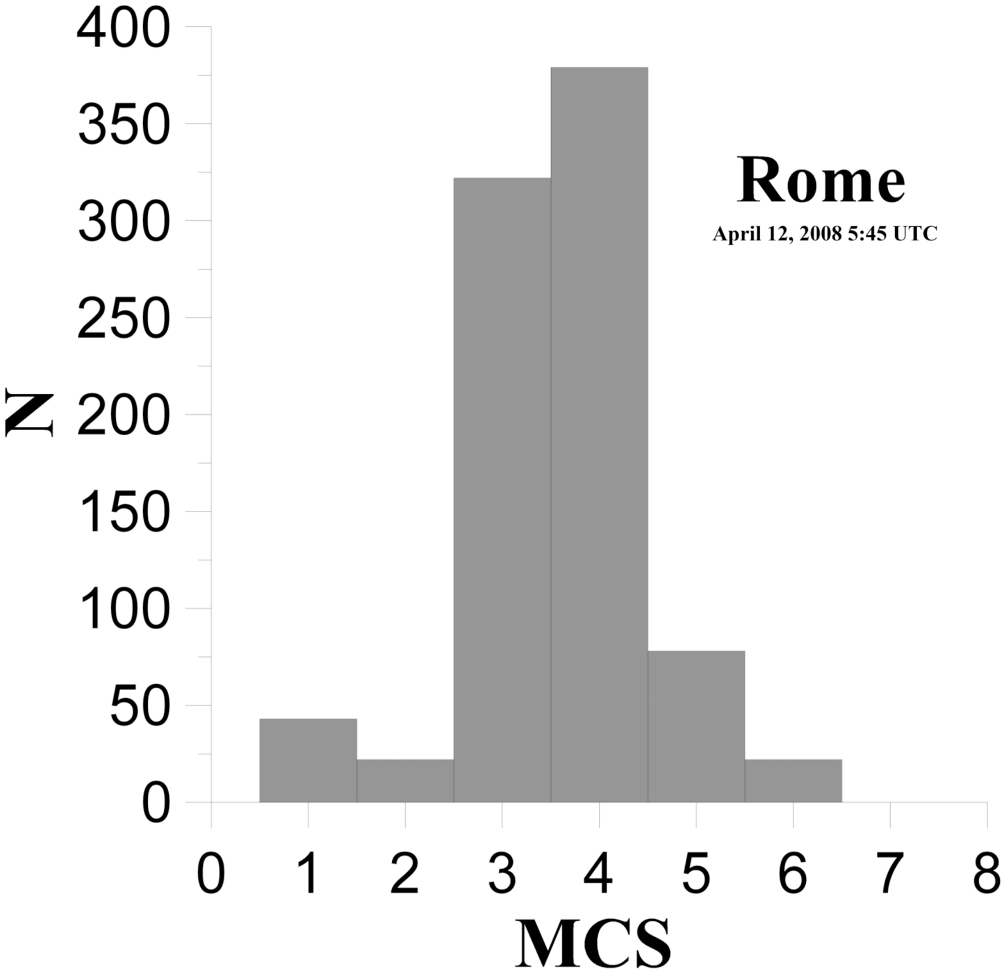
Rome
April 12, 2008 5:45 UTC
N
0
50
100
150
200
250
300
350
400
0
1
2
3
4
5
6
7
8
MCS

Figure 2

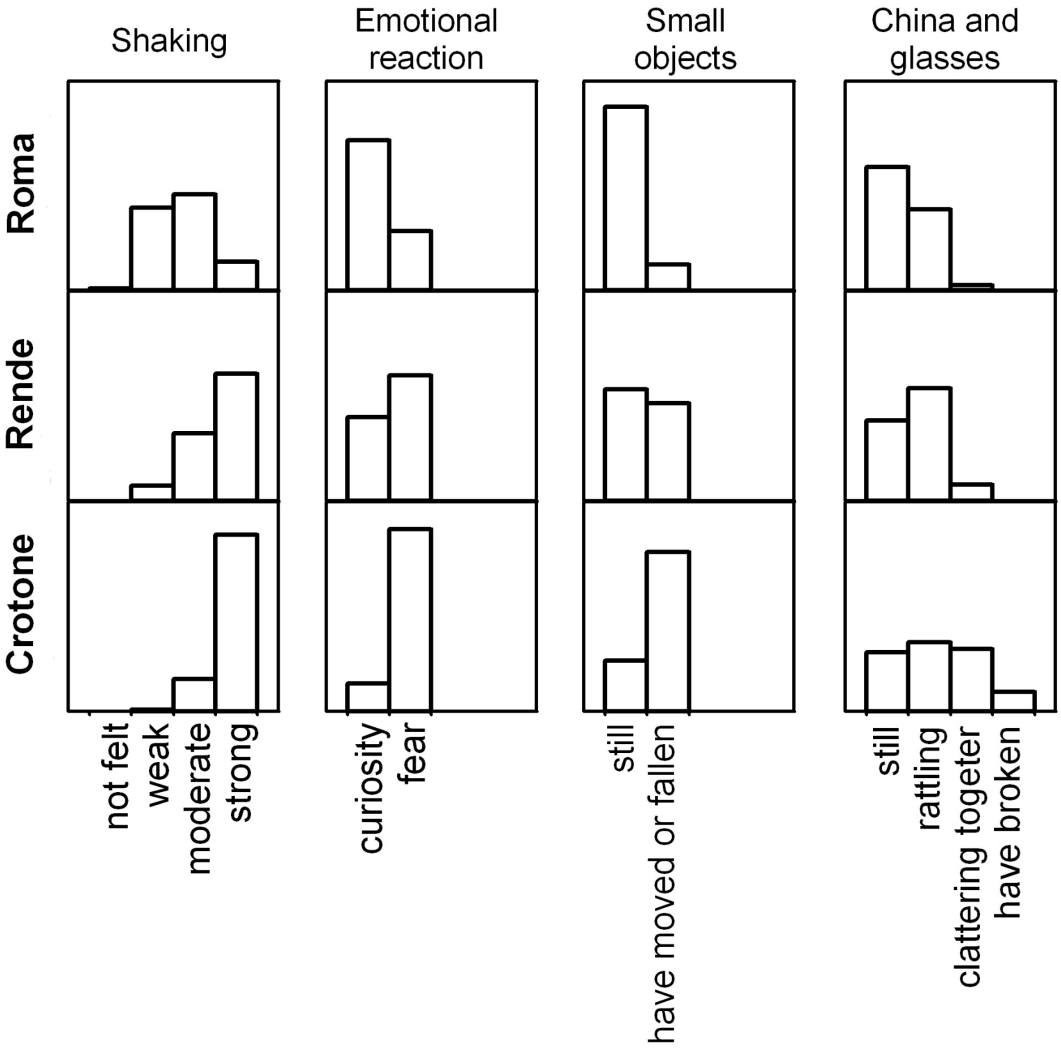
Shaking
Emotional reaction
Small objects
China and glasses
Roma
Rende
Crotone
not felt
weak
moderate
strong
curiosity
fear
still
have moved or fallen
still
rattling
clattering togeter
have broken

Figure 3

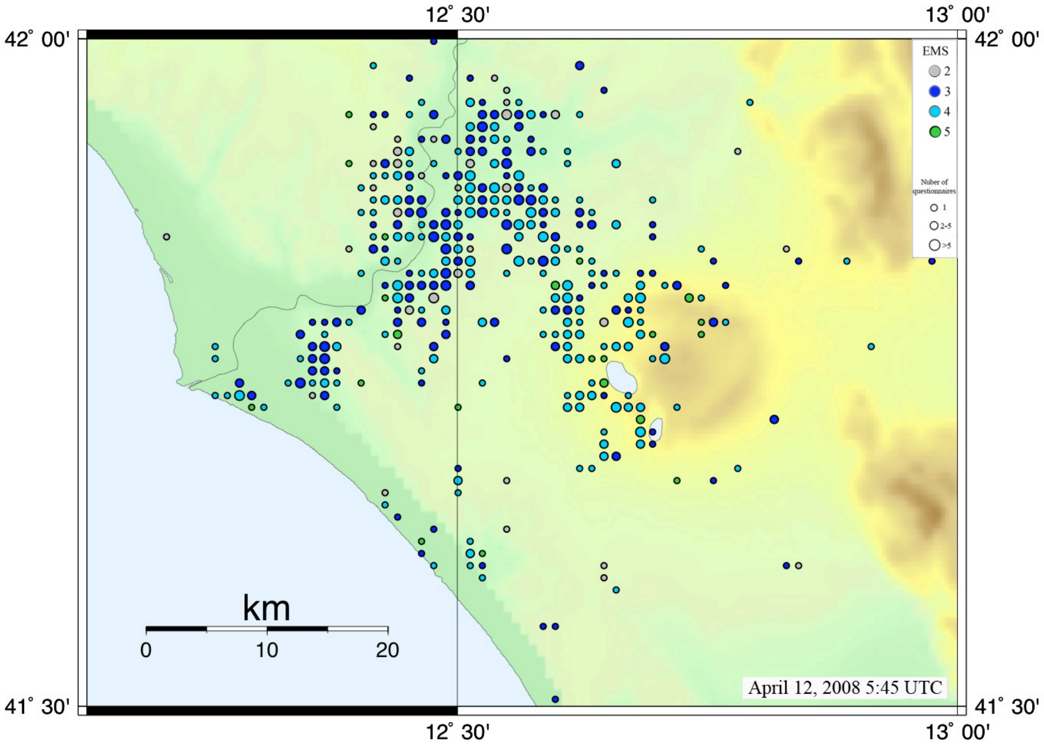

Figure 4

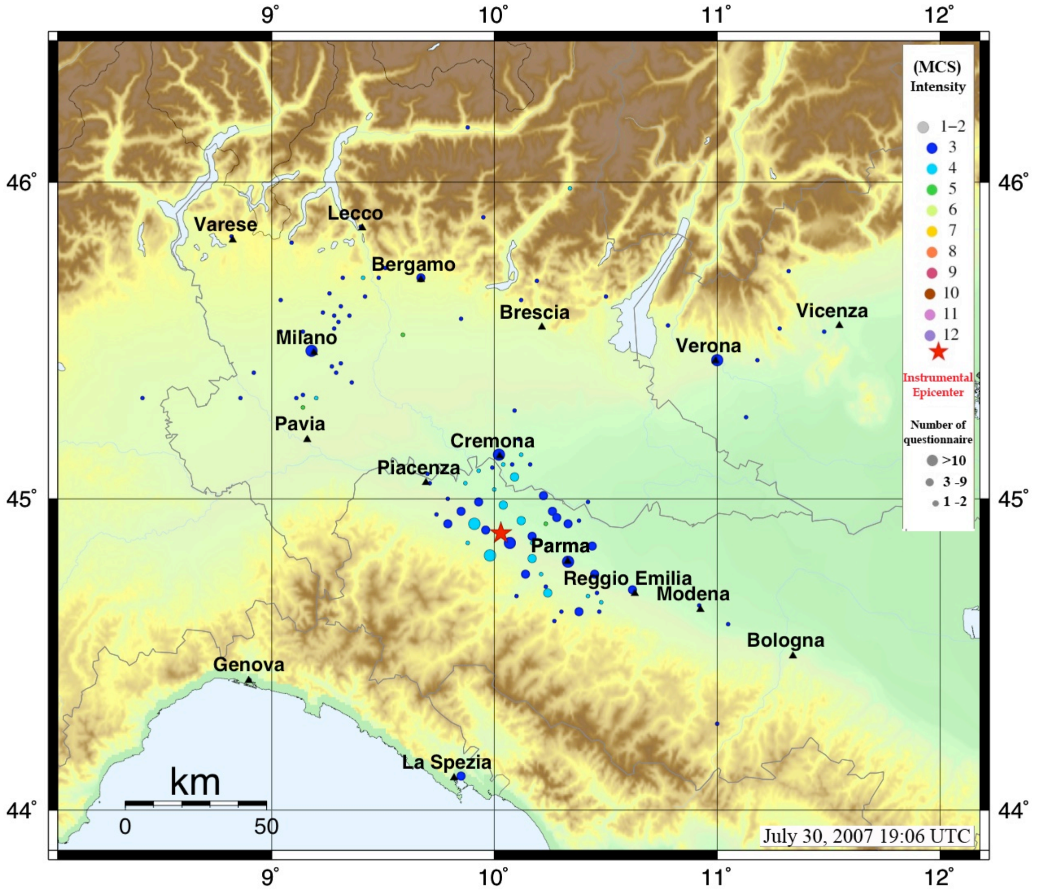

Figure 5

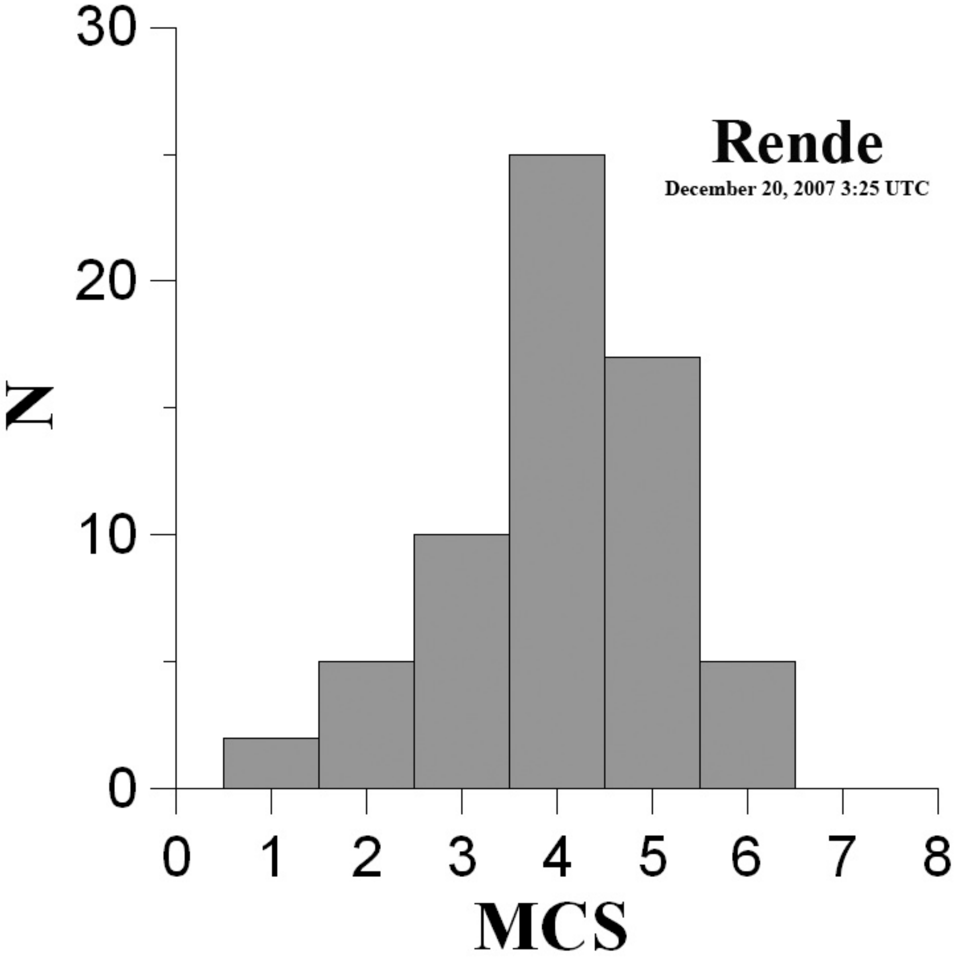

Figure 6

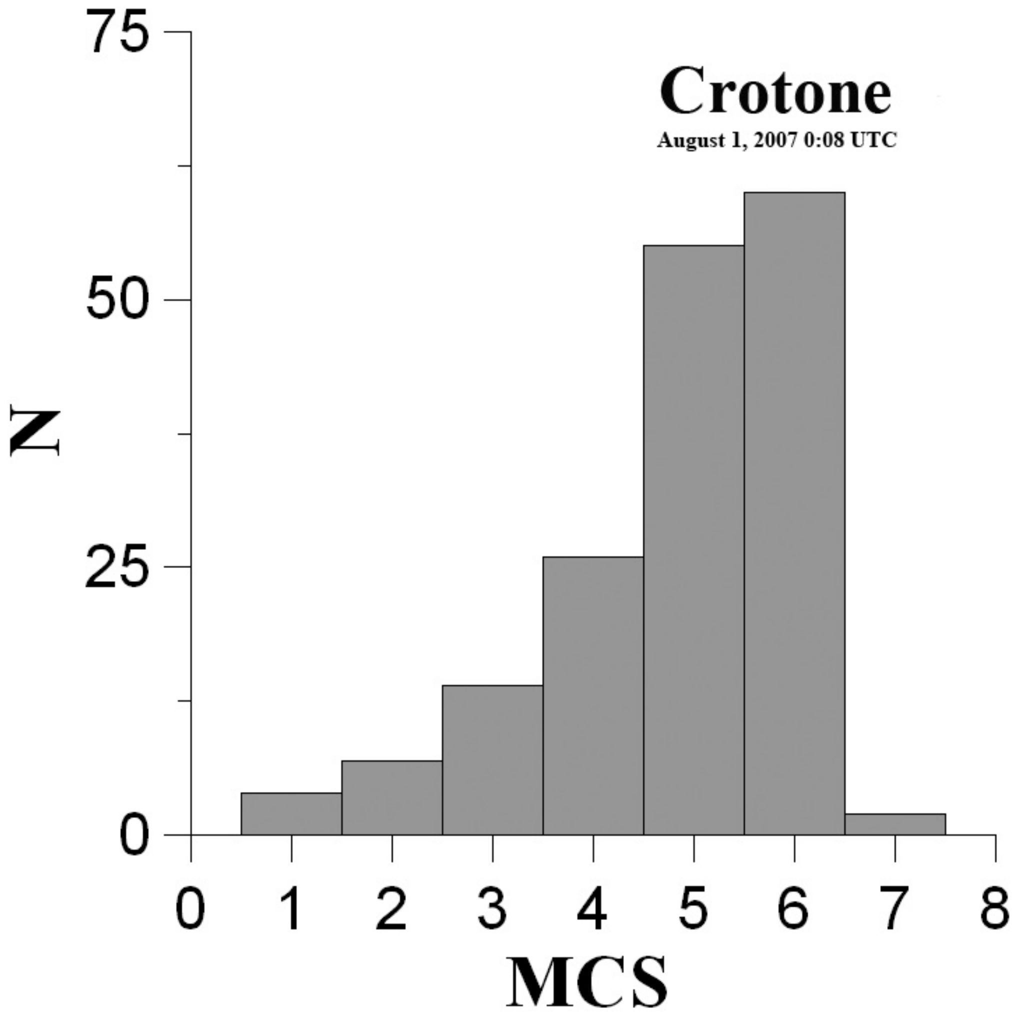

Figure 7

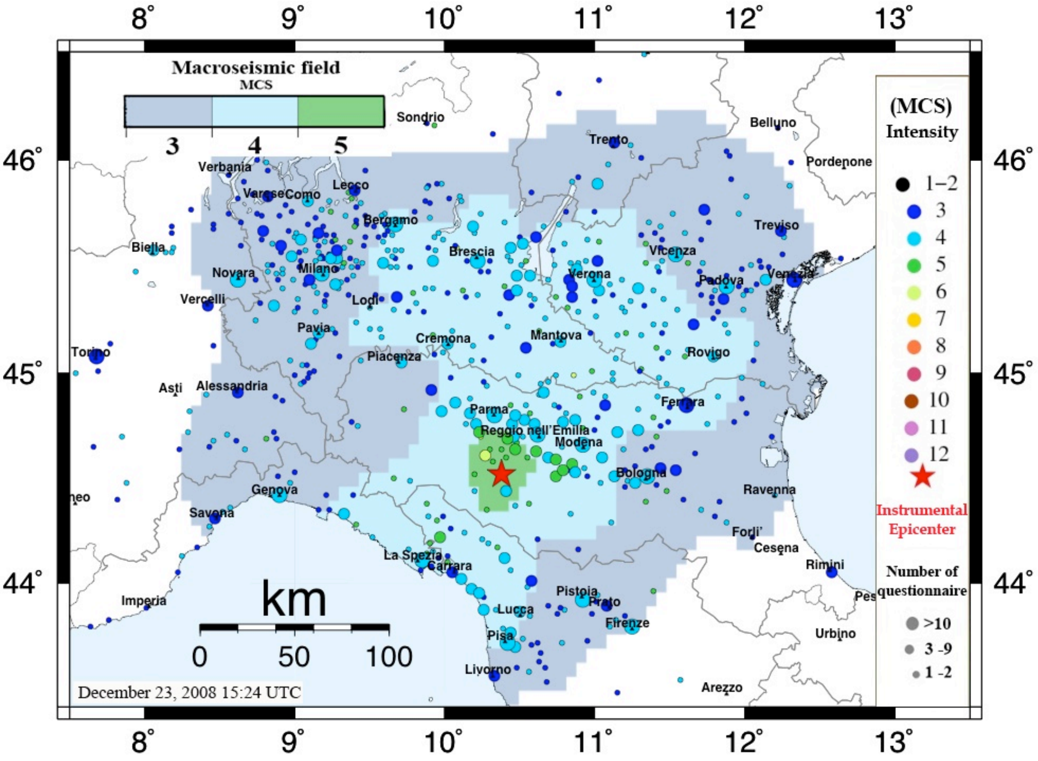

Figure 8

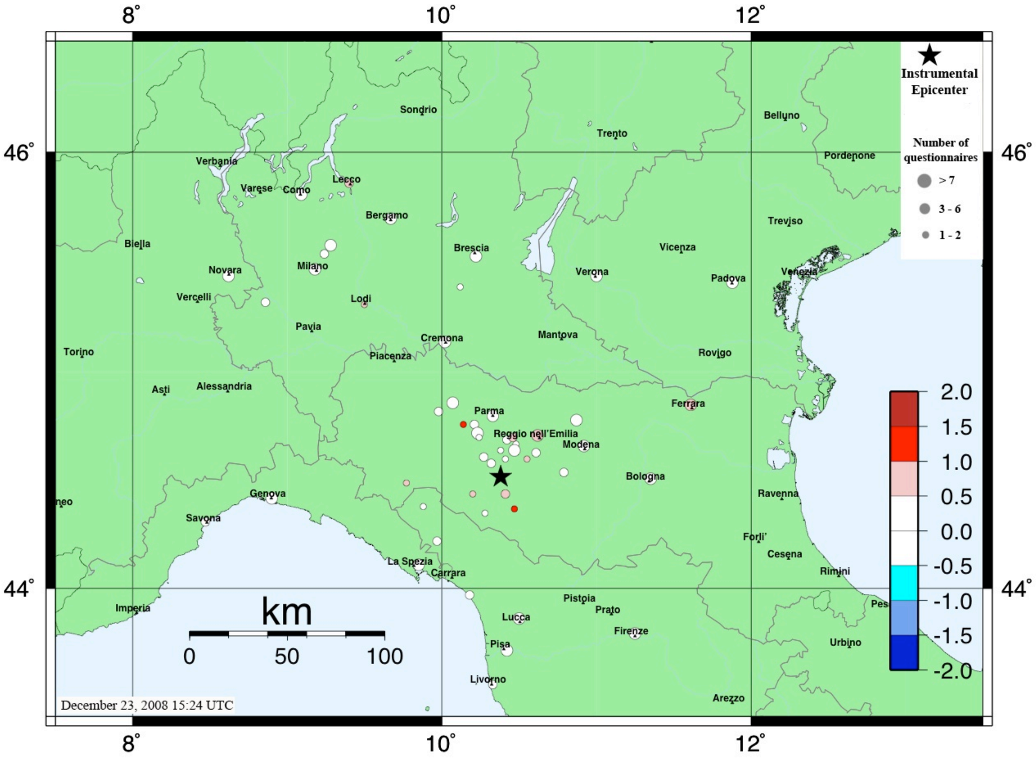

Figure 9

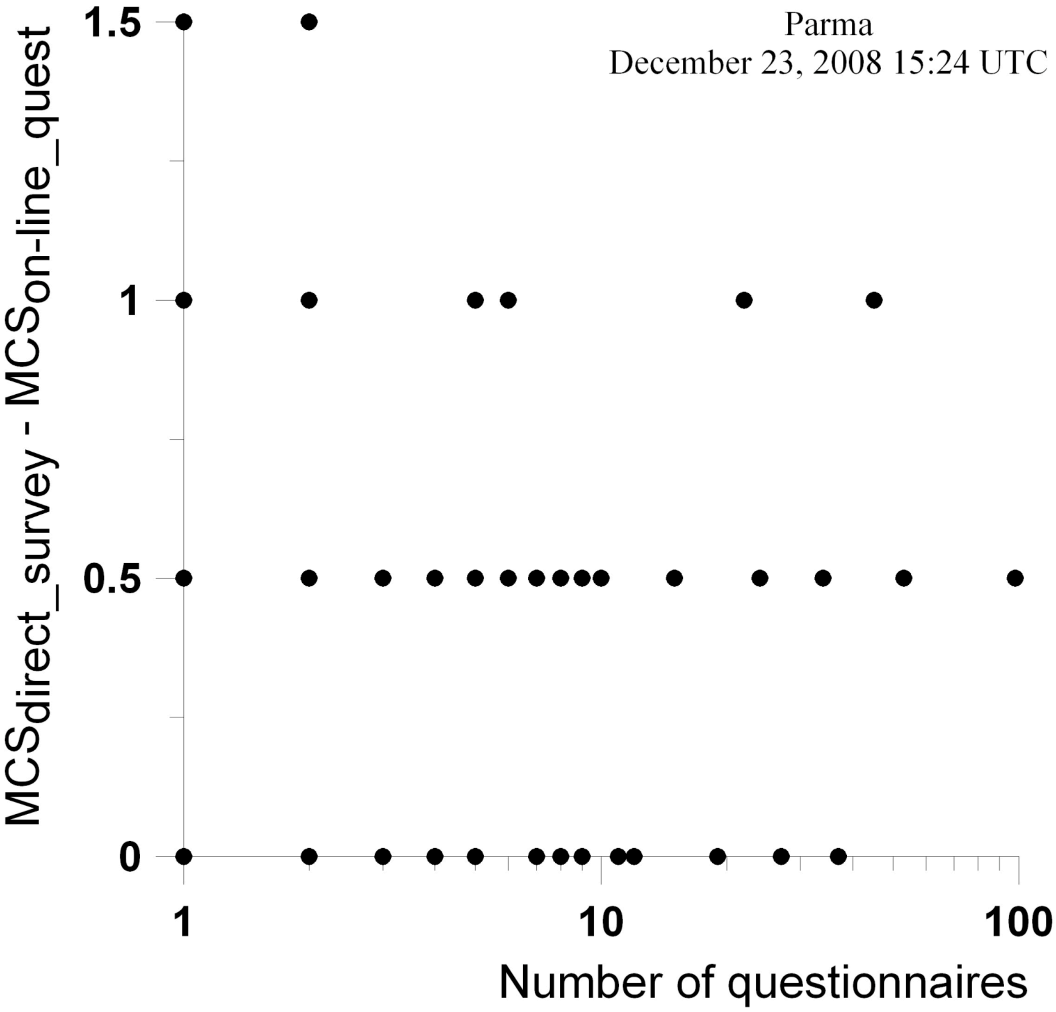
Parma
December 23, 2008 15:24 UTC
1.5
1
0.5
0
MCSdirect_survey - MCSon-line_quest
1
10
100
Number of questionnaires

Figure 10

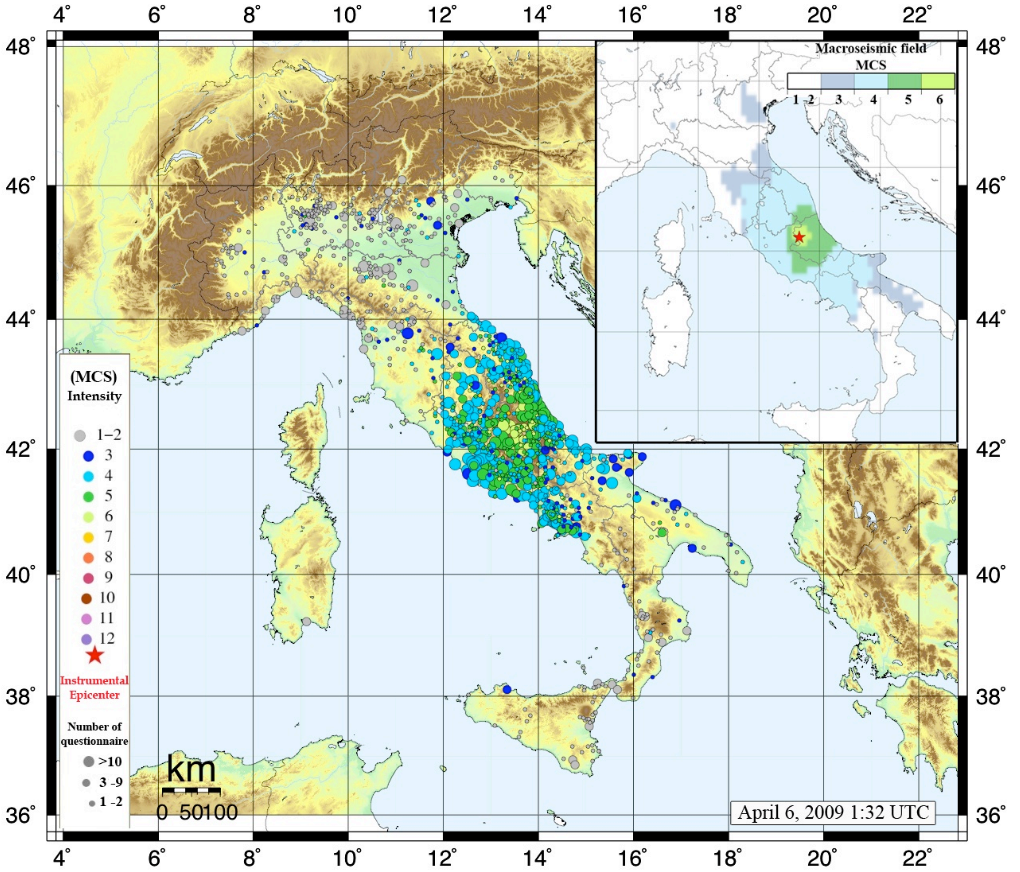
4° 6° 8° 10° 12° 14° 16° 18° 20° 22°
48° 46° 44° 42° 40° 38° 36°
Macroseismic field
MCS
1 2 3 4 5 6
(MCS)
Intensity
1–2
3
4
5
6
7
8
9
10
11
12
Instrumental Epicenter
Number of questionnaire
>10
3 -9
1 -2
km
0 50100
April 6, 2009 1:32 UTC

Figure 11

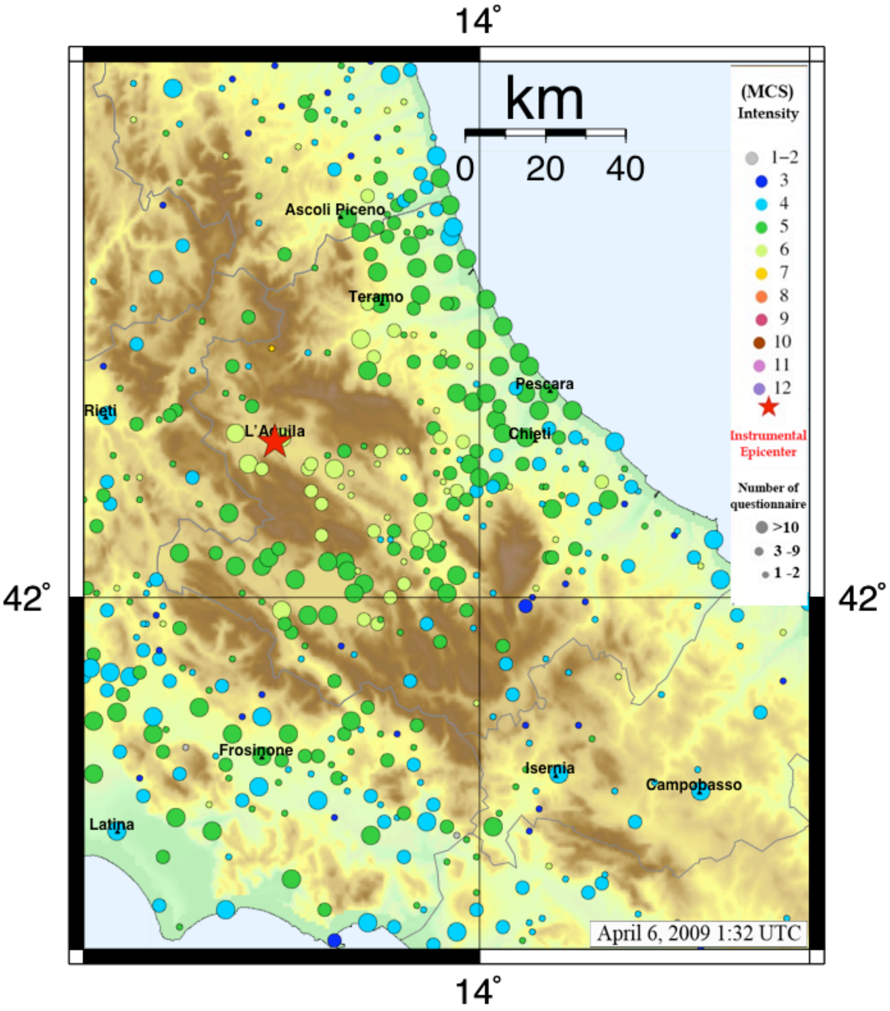
14°
km
0
20
40
(MCS) Intensity
1–2
3
4
5
6
7
8
9
10
11
12
Instrumental Epicenter
Number of questionnaire
>10
3 -9
1 -2
Ascoli Piceno
Teramo
Pescara
Rieti
L'Aquila
Chieti
42°
42°
Frosinone
Isernia
Campobasso
Latina
April 6, 2009 1:32 UTC
14°

Figure 12