Web based macroseismic survey of 2009 L'Aquila earthquakes sequence

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Introduction

A macroseismic survey system, based on a web questionnaire, was fully running during L'Aquila 2009 sequence. Reported effects were statistically analyzed to extrapolate Mercalli-Cancani-Sieberg and European Macroseismic Scale intensities. The final result was the definition of the intensity degrees, with the evaluation of the associated uncertainty. Maps of macroseismic intensity were displayed on-line in almost real time and continuously updated in case of availability of new data. Three major earthquakes are here presented as their macroseismic intensity field, showing the ability of the method in giving fast and reliable results. Quantity and quality of data allow further investigations like definition of attenuation patterns and anomalous intensity areas.

Many seismic institutions collect intensity data through the web. The INGV online questionnaire, based on voluntary collaboration of common people, is reachable at the address **www.haisentitoilterremoto.it**. It is online since 1997. During 2007 it was re-designed to report the effects on a single person and location. In this way the judgment of the individual is not erroneously extended to a whole community (as previously done), avoiding data interpretation problems [1]. The use of web-based macroseismic surveys grew up with the wide diffusion of Internet connections. It presents several positive features: almost real time results, low cost survey, fast evaluation of earthquake severity, positive feedback between seismic institutions and people. Large amount of data, even for very small events, allows statistical evaluation of intensities.

Assigning the intensity to a questionnaire, we assume that the compiler and the observed building belong to the wider and thus the most probable category of people (*many* of the EMS scale) [2-3]. If this is not fulfilled, this intensity could vary at the most ±1 degree. This error becomes negligible when averaging intensity values from the same place [3].

Intensity maps are produced and displayed when, for a seismic event, more than five questionnaires are compiled. They consist of the geographical distribution of intensities averaged for each town or village. In order to quantify the error associated to the mean intensity, we use the Kalman iterative procedure [4], that appears very suitable when an on-time evaluation and its corresponding reliability are needed. Using our database we estimated the standard deviation of the intensity distribution pertaining to each town. The standard deviations were quite small, lower than 1 degree. Even assuming a standard deviation of 1 degree, the Kalman filtering procedure provides an error associated to the commune intensity of ±0.4 - ±0.3 degrees (respectively with 5 and 15 questionnaires).

Since 2007 more than 106000 questionnaires were compiled providing more than 1000 intensity maps, the majority belonging to earthquakes of magnitude in the range 2-4. The most frequent intensity value assigned to a questionnaire was the III-IV degree. We received even questionnaires of felt effects in Italy of some Greek events with high magnitude.

Voluntary compilation of questionnaire has the risk to represent people that felt the quake the most, introducing a sort of positive bias to the data. To overcome this drawback we introduced a group of permanent compilers. When an event occurs, we send an e-mail asking to compile our questionnaire, receiving data even from people who didn't feel the quake. Up to now we count more than 7200 subscriptions.

Macroseismic intensity analysis

The first analyzed event is the M_l 5,8 occurred on April 6, 2009 (1:32 UTC) near L'Aquila (figure 1). The shock was widely felt throughout Italy and, in the epicentral area, EMS intensity reached X-XI. In just one hour after the event, using our real time mapping with the first 700 questionnaires, we were able to well approximate the current macroseismic field. The sole significant exception was represented by the field close to the epicenter: heavy damages, communication connections failure and people's high fear and suffering, prevented the compilation of questionnaires. This lack of data defined the most severe and highly damaged area, useful for first aid organization. Up to now, for the mainshock, we count more than 11000 compiled questionnaires averaged over 1363 towns or villages. For the whole sequence, we have recorded more than 65000 questionnaires. In the city of L'Aquila and in some villages, many buildings collapsed or were seriously damaged. Figure 1 clearly shows the area of VI EMS with a circular shape of 25 km in radius around the instrumental epicenter (red star); highest intensity degrees, although present into the questionnaire data, were town averaged with lower intensities in the filtered macroseismic field. It is worth to note that the highest intensity zone of L'Aquila, evaluated by macroseismic experts, was referred to the older center town only [5]. Nevertheless, our data allow us to downscale the macroseismic field up to the home addresses.

Intensity data have been filtered in space using a moving window average of 30 km in radius. The area of the V degree is not symmetrically related to the epicenter, having an elongation toward East: the V lower boundary is distant from epicenter about 35 km through West, 85 km through East. This geometry of V degree area closely reflects the spatial distribution of PGA [6]. Low boundaries of the III degree are missing due to the poor data density of the far field data set. We show in Figure 2 the intensity attenuation with hypocentral distance. Dots represent the average intensity calculated within a distance bin of 10 km wide. Red line is the good data fit obtained through the function $I = -0.87\,Ln(D) + 8.27$.

The event of April 7, 2009 (17:43 UTC, M_l 5.3), the strongest aftershock recorded, received more than 3300 questionnaires. Filtered field is shown on Figure 3. Corresponding intensity areas are reduced in extension compared to the main shock, reflecting the lower magnitude. Highest intensities are markedly anisotropic: VI EMS degree is located toward North – NorthWest in respect to instrumental epicenter, V EMS degree is elongated toward South – East.

The event of April 9, 2009 (00:52 UTC, M_l 5.1) received 2200 questionnaires. The VI intensity degree is not more represented in the filtered field. The V and IV EMS are elongated through North side in respect to instrumental epicenter.

Conclusions

An advantage of our procedure is the possibility to statistically analyze data in almost real time. Due to fast data collecting, we were able to significantly distinguish aftershocks separately. Reported intensities are compared with those derived from traditional macroseismic survey, showing the reliability of web-based method [2-3]. Our analysis is not limited to the highest intensities area, but it is easily extended to more peripheral field portions. We quickly obtain good results at a very low cost in terms of funding and time. Medium-high magnitude events receive a bigger surface extension analysis, by the inclusion of areas interested by low intensity effects, usually disregarded by direct inspection for evident cost reasons. Web-based survey is able to investigate intensity attenuation. The shapes of intensity degrees are in agreement with PGA estimation [6].

Acknowledgements

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http://www.unich.it/geosis/rif/Ameri-etal_INGV_MI.pdf

Figures and captions

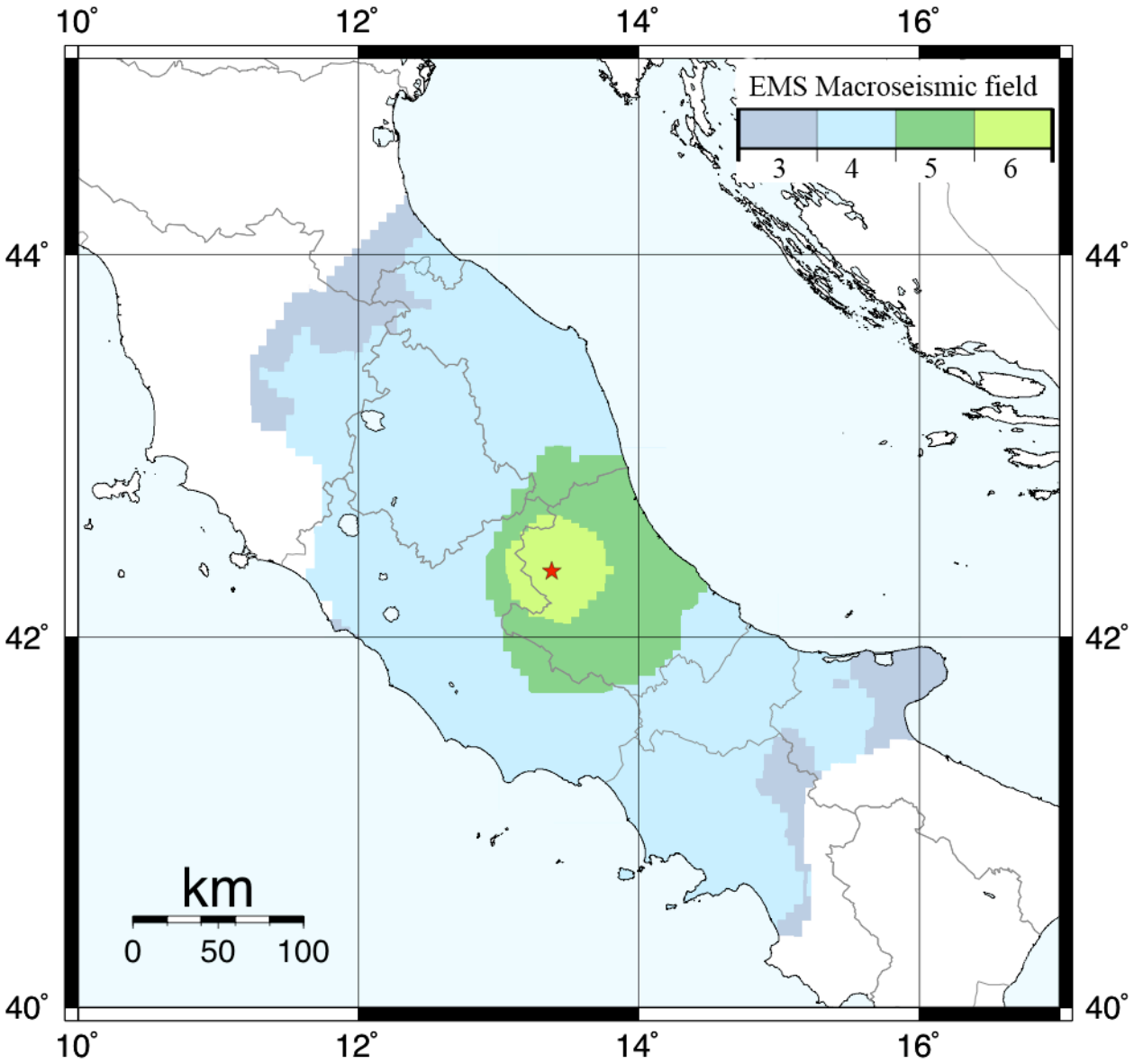

Figure 1

Filtered macroseismic intensity field of April 6, 1:32 UTC, M_l = 5.8, obtained with 11295 questionnaires.

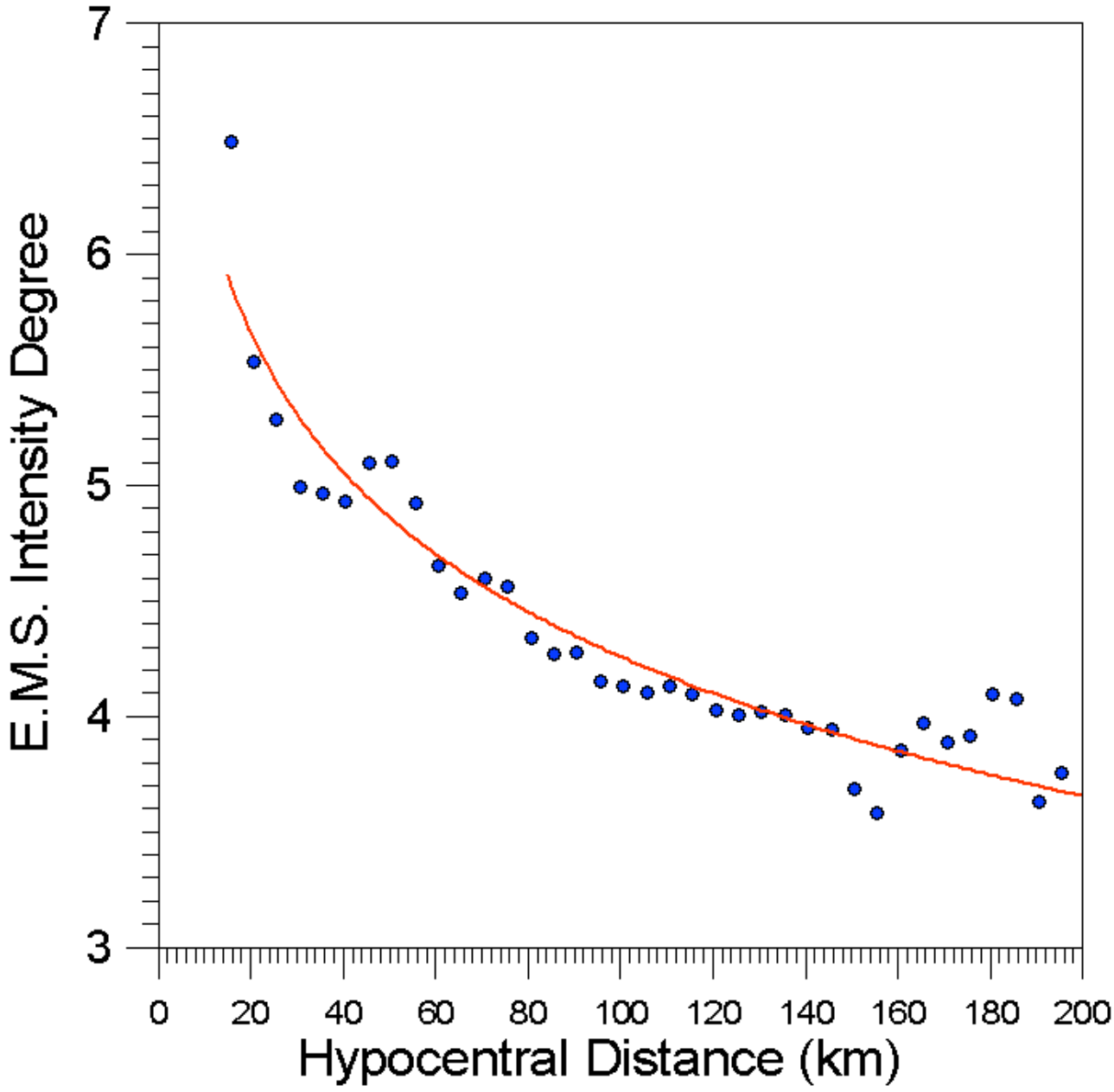

Figure 2

Earthquake of April 6, 1:32 UTC. Intensity attenuation with hypocentral distance.

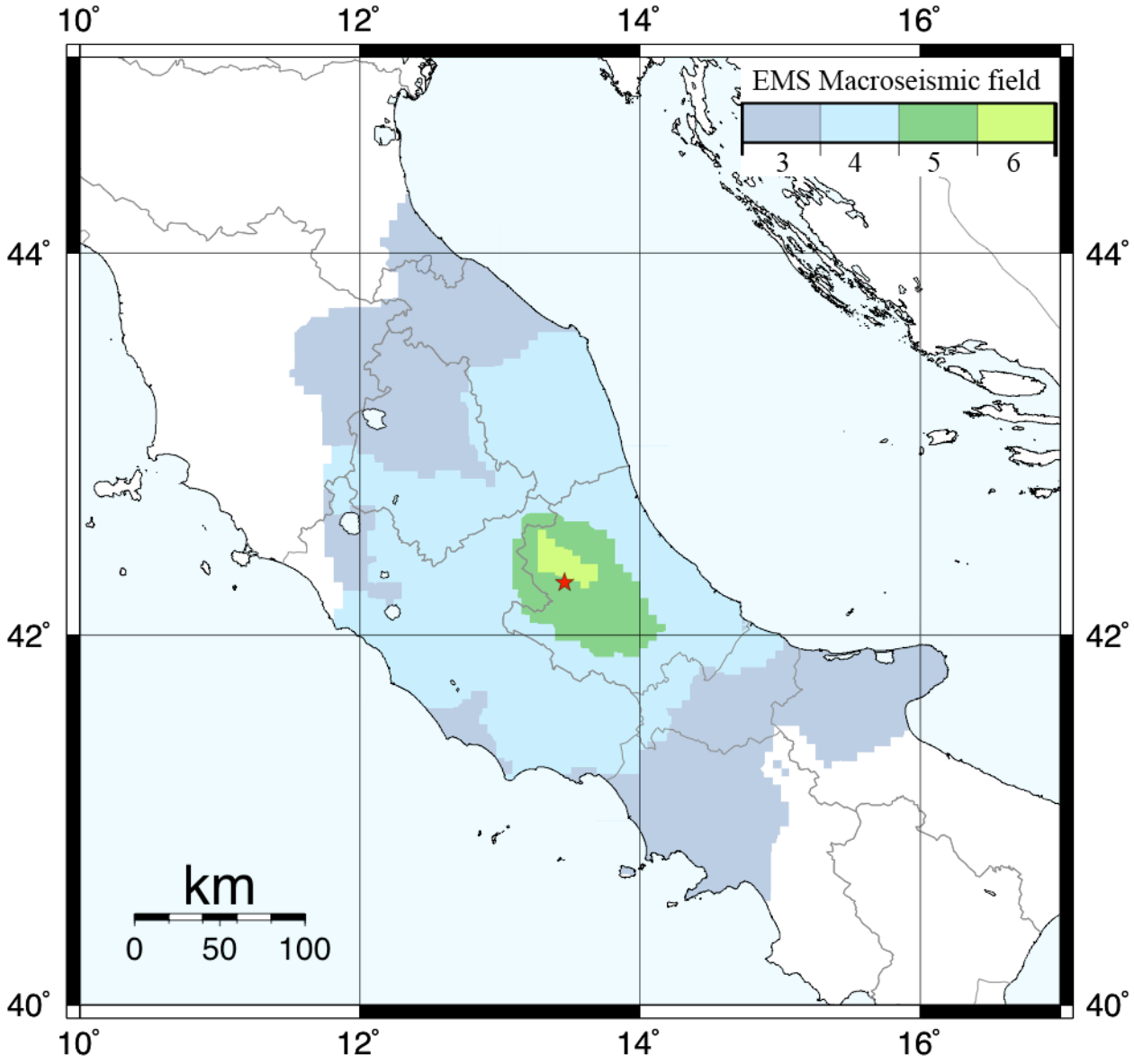

Figure 3

Filtered macroseismic intensity field of April 7, 17:47 UTC, M_l = 5.3, obtained with 3398 questionnaires.

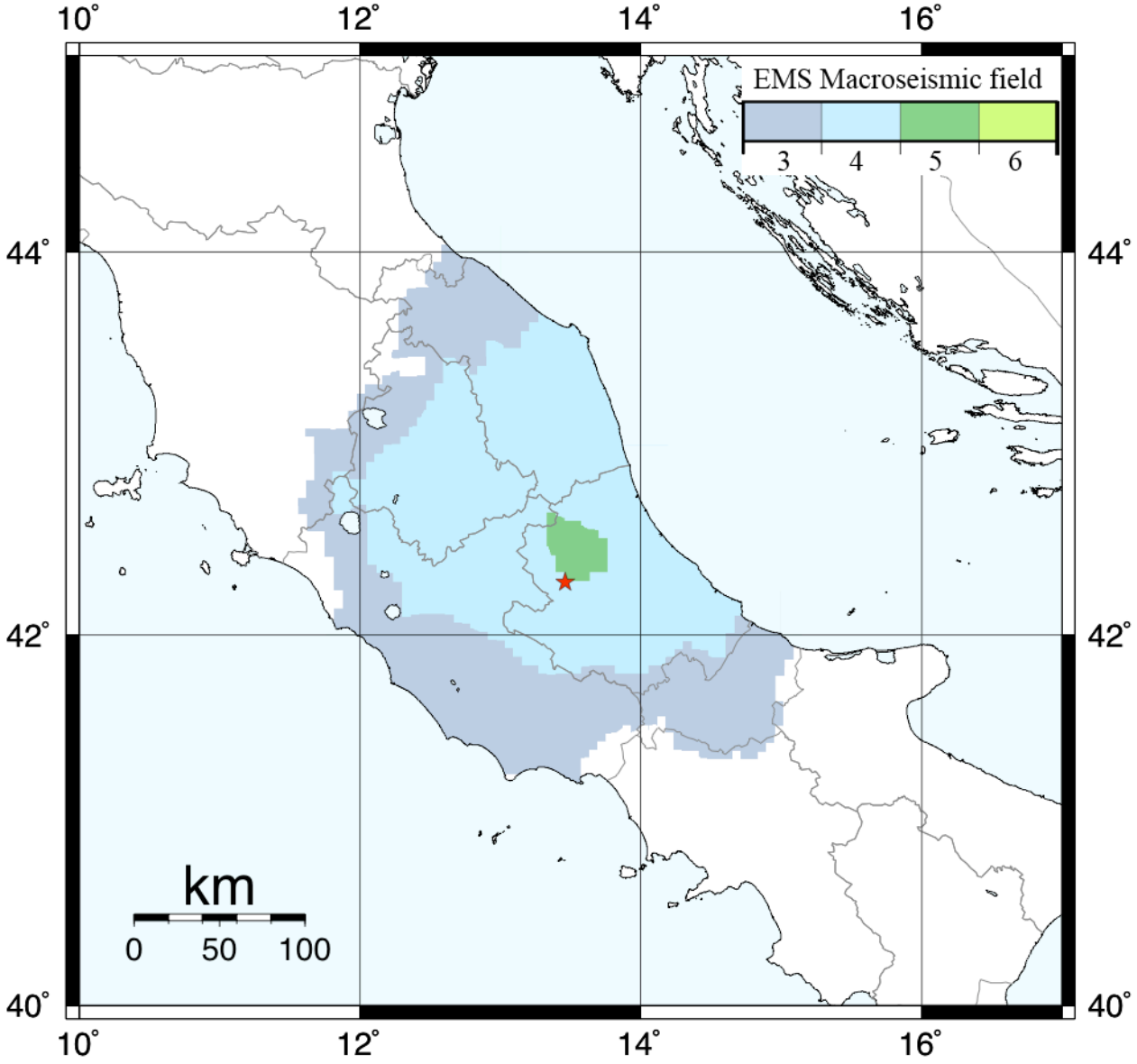

Figure 4
Filtered macroseismic intensity field of April 9, 00:52 UTC, M_l = 5.1, obtained with 2246 questionnaires.