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RESEARCH

Converting PSH estimates in terms of ground motion intensity into macroseismic intensity estimates

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Abstract Methodological aspects relative to the conversion of probabilistic hazard evaluations in terms of ground motion intensity into hazard in terms of macroseismic Intensity. As a first step, the probabilistic relationships between ground motion intensity and macroseismic intensity are critically re-examined to account for the different formal properties of these two dimensions of the earthquake intensity. Then these relationships are coherently considered in the conversion of hazard curves by accounting for the inherent binning of macroseismic intensity values and of their inherent probabilistic nature. It is shown that approximate procedures currently used to provide this conversion may provide biased outcomes when the dispersion of values relative to ground motion intensity corresponding to macroseismic Intensity is dismissed or not properly accounted for. The impact of this possible bias is evaluated by considering the seismic hazard at reference site condition at the city of L'Aquila in Central Italy.

Keywords Macroseismic intensity · Seismic hazard · Ground motion intensity · Bayesian approach

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1 Introduction

Probabilistic seismic hazard (PSH) estimate represents a basic element of most advanced building codes (e.g., Eurocode 8, CEN 2005). Being mainly devoted to assessing seismic loads to be considered in anti-seismic design, PSH outcomes are expressed in terms of ground motion intensity (e.g., Peak Ground Acceleration, PGA) or response spectra ordinates (e.g. Kramer 1996). However, ground motion intensity cannot be easily used for evaluating the global impact of an earthquake on a settlement (e.g., Kaestli and Faeh 2006) and the Macroseismic Intensity appears much more effective on purpose. This intensity measure has been largely used since the beginning of modern seismology (Musson et al. 2010; Tertulliani 2019) to characterize the impact of earthquakes on a settlement. To this purpose, a discrete set scenario (twelve in more recent scales) is defined and ordered by an increasing level of severity: several descriptive indicators (relative to the effects on people and manufacts) are considered to identify the relevant scenario among the ones in the scale. In terms of seismic risk assessment, these scenarios can be used to evaluate the global impact of future earthquakes at any site and this information could be of main importance for communication and supporting prevention policies. However, PSH maps in terms of Macroseismic Intensity are generally not considered for normative purposes and not implemented in the reference seismic codes. Moreover, these maps are developed by following methodological approaches (e.g., D'Amico and Albarello 2008) not fully compatible with standard Cornell-McGuire procedures for PSH assessment (Cornell 1968; McGuire 1978). In the last years, the problem of evaluating reliability of PSH estimates implemented in the seismic codes and other applications has received increasing attention (e.g., Albarello and D'Amico 2015; IAEA, 2024). Since these estimates mainly concern events characterized by average return times of the order of hundreds of years, the comparison of the PSH outcomes with observations must rely on the historical records and thus on Intensity data. This implies that standard PSH outcomes must be 'converted' in intensity to make the above comparison possible (e.g., Salditch et al. 2024).

This conversion, however, presents possible drawbacks when performed without necessary cautions accounting for the respective characteristics of macroseismic intensity and ground motion intensity (Kuehn and Scherbaum, 2010). In the following, the respective characteristics of ground motion and macroseismic intensities are shortly overviewed and a coherent formalized procedure in the Bayesian perspective is delineated to provide to convert PSH estimates in ground motion intensity into PSH in terms of macroseismic intensity by also accounting for the inherent uncertainty. An example is also provided relative PSH at the town of L'Aquila (in Central Italy).

2 Macroseismic intensity vs. ground motion intensity

Formal differences at first. Ground motion intensity (e.g., Peak Ground Acceleration, PGA in the following) is expressed in terms of a continuous positive variable (ideally a real number) with no upper limit: thus, a metric is defined in the domain of possible values. Macroseismic Intensity is discrete, ordinal and defined over a finite support: to make these features more explicit, Intensity degrees are generally expressed with Latin numbers (from I to XII). This also makes explicit the lack of any metric relative to the relationship between intensity degrees: actually, differences between degrees are not defined and in principle meaningless (how the difference between two scenarios including several quite heterogeneous effects can be assessed and interpreted?).

In the practice of Intensity assessment, intermediate degrees (e.g., VIII-IX) represent uncertain assessments due to the lack of information and no scenario is assumed to correspond to something between two contiguous degrees. As an example, writing VIII-IX means that effects relative to Intensity VIII can be clearly identified while those relative to intensity IX have been achieved only partially. Managing these situations may be troublesome and will be considered in some detail in the following.

Ground motion intensity and macroseismic intensity are also representative of different areal domains. While ground motion intensity represents ground shaking at the scale of a single building at most, macroseismic intensity refers to seismic effects relative to an extended area (at the scale of a settlement as a minimum). Finally, while any ground shaking only represents seismic motion at the ground surface (eventually at rock conditions), macroseismic Intensity also includes social aspects (human reactions), site effects, soil structure interactions, manufacts vulnerability, etc..

Anyway, since ground shaking is ultimately responsible for all these effects, any positive correlation is generally expected (at least in a statistical sense) between macroseismic Intensity and ground motion intensity. Since the last years of the XIX century (Holden 1888) a monotonic relationship was assumed between ground motion acceleration and macroseismic intensity. Mimicking the Weber-Fechner law (Fechner 1860) relative to stimulus–response in physiology, the monotonic relationship was established between Intensity and the logarithm of ground acceleration (Cancani 1904). This position is generally assumed as valid today (see, e.g., Gomez-Capera et al. 2020; Oliveti et al. 2022; Gallahue and Abrahamson 2023).

3 Probabilistic formulation of Intensity-Ground motion relationships and their implementation in PSH assessment

The approach here proposed is in line with the one described by Kuehn and Scherbaum (2010), with the difference that the Bayesian perspective has been more coherently adopted. Due to the inherent differences between ground motion and macroseismic intensity listed above, no one-to-one deterministic correspondence is expected to exist between macroseismic intensity (I_{ms} in the following) and any ground motion intensity G (when in logarithm, G_{lg} in the following). Due to the empirical nature of the expected relationship, probabilistic parametrization is mandatory. In the following, the relationships connecting I_{ms} and G_{lg} will be assumed in the forms $p\left(I_{ms}|G_{lg}\right)$ and $p\left(G_{lg}|I_{ms}\right)$ respectively representing the conditional probability density of a value I_{ms} when ground shaking is G_{lg} and vice-versa. To account for the different formal properties of macroseismic and ground motion intensities, one has

$$p\left(I_{ms}|G_{lg}\right) = p\left(I_{ms}\right)\frac{p\left(G_{lg}|I_{ms}\right)}{\sum_{J} p(J)p\left(G_{lg}|J\right)} \tag{1}$$

(where summation in the denominator is extended to all the macroseismic intensity bins) and

$$p\left(G_{lg}|I_{ms}\right) = p\left(G_{lg}\right)\frac{p\left(I_{ms}|G_{lg}\right)}{\int_{-\infty}^{\infty} p(x)p\left(I_{ms}|x\right)dx} \tag{2}$$

In a Bayesian perspective, the terms $p\left(I_{ms}\right)$ and $p\left(G_{lg}\right)$ can be interpreted as any prior probability distributions relative to I_{ms} and G_{lg} respectively. The above relationships imply that $p\left(I_{ms}|G_{lg}\right)$ and $p\left(G_{lg}|I_{ms}\right)$ cannot be determined independently one from the other and that the prior distributions play a major role in this joint determination. Orthogonal regression techniques have been proposed (e.g., Zanini et al. 2019; Oliveti et al. 2022) to jointly determine $p\left(I_{ms}|G_{lg}\right)$ and $p\left(G_{lg}|I_{ms}\right)$. Anyway, these procedures do not solve the problem relative to the implicit assumption of any metrics in the macroseismic intensity scale and of neglecting the inherent binning of macroseimic intensity values. Problems arising when this last element is not appropriately considered become evident in hazard estimates. Hazard in terms of macroseismic intensity is defined as the probability $H\left(> I_{ms}\right)$ that any value I_{ms} is exceeded during exposure time. This probability can be inverted to obtain a reference macroseismic intensity I_{ref} corresponding to a fixed exceedance probability a, i.e., $I_{ref}=H^{-1}(a)$. When macroseismic intensity is assumed to be a continuous variable, I_{ref} will be a real number (e.g., 8.45): this value may correspond to intensity (VIII) by truncation to the closest bin, to Intensity VIII-IX (how to interpret it?) or to intensity IX by rounding to the upper closer value. It is worth noting that jumping from VIII to IX is not negligible in terms of the expected impact of the earthquake (e.g., in terms of percentage of damaged buildings) and the choice between the alternative possibilities listed above lacks any sound motivation. A similar discussion is also provided by Kuehn and Scherbaum (2010) and Cataldi et al. (2021). It is worth to note that, except these two last contributions, the problem of combining ordinal discrete Intensities and ideally real valued ground motion measures is generally ignored, while most attention is devoted to dealing with possible statistical biases in the regression procedure (e.g., Gallahue and Abrahamson 2023).

In general, due to the inherent binning of empirical probability density distribution of Intensity values $p\left(G_{lg}|I_{ms}\right)$ can be determined by considering G_{lg} values within each Intensity bin without any further assumption (e.g., Gomez-Capera et al. 2020). On the contrary, the empirical definition of $p\left(I_{ms}|G_{lg}\right)$ would require any statistical artifact to manage real valued G_{lg} data and ordinal discrete I_{ms} data. To avoid these troubles, $p\left(I_{ms}|G_{lg}\right)$ can be obtained via equation [1] from $p\left(G_{lg}|I_{ms}\right)$. This approach will be considered in the following.

The probabilistic formulation provided above also allows a coherent application of empirical relationships between macroseismic Intensity and ground motion intensity within PSH assessment procedures. In general, the most common outcome of PSH is provided in the form of probability $H\left(> G_{lg}\right)$ that the ground motion intensity value G_{lg} will be exceeded in the exposure interval (Cornell 1968). The corresponding hazard curve $H\left(> I_{ms}\right)$ in terms of macroseismic intensity can be obtained by considering that

$$P\left(> I_{ms}|G_{lg}\right) = \sum_{J>I_{ms}} p\left(J|G_{lg}\right) \tag{3}$$

And then

$$H\left(> I_{ms}\right) = \int_{-\infty}^{\infty} h(x)P\left(> I_{ms}|x\right)dx \tag{4}$$

where $h(x)$ is the probability density function corresponding to the hazard function $H\left(> G_{lg}\right)$. It is worth noting that the use of [3] and [4] allows accounting for the dispersion of the G_{lg} values relative to each I_{ms}. This aspect could be important when any correspondence between $H(G_{lg})$ and $H(I_{ms})$ must be established by preserving the internal coherence of the analysis.

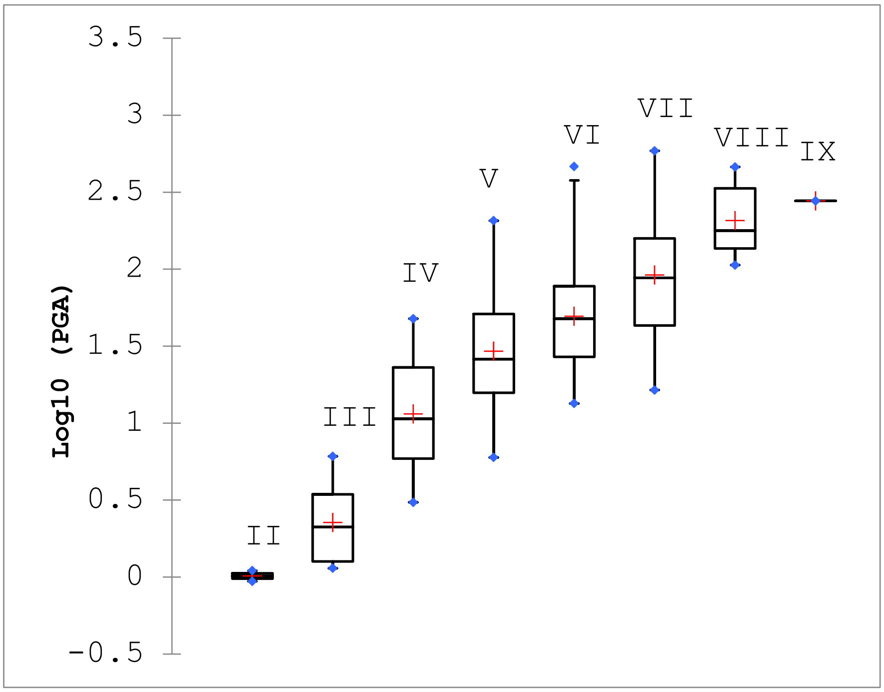

Fig. 1 Box-Whisker plot representation of G_{lg} values (Log10 of PGA in cm s^{-2}) in each I_{ms} bin (at the top of the corresponding box plot in Latin numbers relative to the corresponding MCS bin). The box includes the values in between first and third percentile of the distribution of the data in the bin. The horizontal bar within the box indicates the median and the cross indicates the average. The vertical 'whiskers' extend to 1.5 times the difference between the corresponding quartile and the median

4 The case of Italy

Gomez-Capera et al. (2020) examined most recent macroseismic and accelerometric databases available in Italy to select a reliable set of Intensity values in the scale MCS (Sieberg 1932) and accelerometric data to parameterize possible conversion relationships. They collected 240 pairs after a careful check of situations where accelerometric records can be considered representative (in terms of closeness, similar seismo-stratigraphical and morphological situation, etc.) of the settlements where Intensity was assessed. Among these data, a single univocal intensity value was assessed in 150 cases, being the remaining ones relative to uncertain assessments. The frequency distribution of data results quite uneven among the Intensity values (see Gomez-Capera et al 2020). In the following, the XII MCS scenario, never assessed in Italy (Locati et al. 2022), have been discarded.

To proceed, the G_{lg} values with uncertain attribution to the I_{ms} bins must be solved in some way. With respect to Kuehn and Scherbaum (2010), a different approach has been considered to manage uncertain attributions. To this purpose, the distribution of G_{lg} values corresponding to uncertain I_{ms} attribution have been compared with those relative to the closest I_{ms}. The Kolmogorov Smirnov test indicates that the distribution of G_{lg} values relative to the cases IV-V MCS and V-VI MCS are significantly different ($p < 0.05$) from those relative to the V MCS bin. Thus, the relevant accelerometric values have been attributed respectively to the bins IV MCS and VI MCS. In the other cases, no significant difference is revealed, possibly due to the small dimensions of the samples. Since the main purpose of the study concerns seismic hazard assessment, a conservative approach has been adopted by merging the G_{lg} values with uncertain I_{ms} values to the nearest bin corresponding to upper uncertainty limit (e.g. VII-VIII MCS to VIII MCS). In Fig. 1, the distribution of G_{lg} values relative to each I_{ms} bin is reported. The main statistics related to the same bins are reported in Table 1.

The Lilliefors test (Lilliefors 1967; Dallal and Wilkinson 1986) has been considered to assess Normality of G_{lg} values in each I_{ms} bin including at least 10 G_{lg} values (i.e., relative to degrees from IV to VII MCS). By considering a significance threshold of 0.05, except in the case of the V MCS bin, the hypothesis of normality cannot be rejected. The distribution of G_{lg} data in the V MCS bin is slightly skewed towards higher values with respect to what is expected in the case of normality: in other words, there is a light exceedance of larger G_{lg} values with respect to expectations. As stated above, none of the uncertain Intensity values were included in this bin and thus the skewness cannot be attributed to these uncertain attributions. This could be the genuine effect of the lack of continuity between the lower part of the MCS scale relying on subjective effects only (< VI) and the higher one where effects on buildings become increasingly important. Anyway, for the sake of simplicity, the normality hypothesis has been tentatively accepted for all the bins.

A clear monotonic (whether not linear) increase of average G_{lg} values increasing I_{ms} appears evident. On the other hand, dispersion relative to large samples seems quite similar. The Levene test (Levene 1960) carried out on the most populated bins (from IV to VII MCS bins), reveals that the hypothesis that all the samples have been drawn by populations with the same variance (but different average) cannot be excluded at a 5% confidence level. Thus, this hypothesis has been tentatively accepted.

4.1 Empirical estimate of $p\left(G_{lg}|I_{ms}\right)$

As one can see in Table 1, sampling is quite uneven among the considered I_{ms} bins and in some cases quite insufficient for a reliable statistical estimate of the average G_{lg} value relative to the bin. To reduce this problem, average values relative to less constrained bins (less than 10 values) have been tentatively extrapolated from the averages relative to most populated bins (in the range IV to VII MCS) by an empirical equation: this should be considered as very rough proxy in the present lack of satisfactory sampling. By considering a cardinal value the ordinal I_{ms} value, the least squares best fitting equation in the logarithmic form proposed by Gomez-Capera et al. (2020) is obtained by only considering the average G_{lg} values relative to bins in the range [IV, VII] MCS in the form.

$$\mu' = 3.69log_{10}I_{ms} - 1.16 \tag{5}$$

This relationship has been tentatively adopted only to extrapolate average G_{lg} values relative to poorly sampled bins (less than 10 evaluations). Since the homoscedasticity hypothesis cannot be rejected, standard deviation *s'* relative to all the bins has been estimated by considering deviations from the average within the bins with at least ten G_{lg} values (IV to VII MCS) and results equal to 0.358 (close to the value 0.35 relative to the standard deviation of the data estimated by Gomez-Capera et al. 2020). A similar approach to assess standard deviation including poorly sampled bins has been also adopted by Kuehn and Scherbaum (2010). In Table 1, the values m' and s' relative to all the Intensity bins are reported.

Table 1 Distribution of the Intensity-PGA values available for statistical analysis Gomez-Capera et al. 2020). N is the number of data considered in each Intensity bin (in the MCS scale), μ and σ respectively represent average and standard deviation of G_{lg} = Log10 PGA (where PGA is in cm s^{-2}). The last two columns report averages and standard deviations finally adopted (see text for details)

Macroseismic Intensity Bin (MCS)	N	μ (G_{lg})	σ (G_{lg})	μ'(G_{lg})	σ'(G_{lg})
I	0	-	-	−1.159	0.358
II	2	0.007	0.049	−0.047	0.358
III	5	0.324	0.325	0.603	0.358
IV	38	1.045	0.344	1.045	0.358
V	60	1.467	0.387	1.467	0.358
VI	92	1.693	0.330	1.693	0.358
VII	32	1.961	0.403	1.961	0.358
VIII	8	2.289	0.245	2.177	0.358
IX	2	2.484	0.058	2.366	0.358
X	0	-	-	2.535	0.358
XI	1	2.748	-	2.688	0.358

4.2 Empirical estimate of $p\left(I_{ms}|G_{lg}\right)$

The relationship [2] can be used to compute the probability density function $p\left(I_{ms}|G_{lg}\right)$ to be used via equations [3] and [4] to obtain a hazard curve in Intensity from the one in G_{lg}.

By considering results described above, the probability distribution density relative to $p\left(I_{ms}|G_{lg}\right)$ can be defined as follows.

$$p\left(I_{ms}|G_{lg}\right) = \frac{p\left(I_{ms}\right)\mathcal{N}\left[\mu\prime\left(I_{ms}\right),\sigma\prime\left(I_{ms}\right)\right]}{\sum_{J}p(J)\mathcal{N}[\mu\prime(J),\sigma\prime(J)]} \tag{6}$$

where $\mathcal{N}\left[\mu\left(I_{ms}\right),\sigma\right]$ indicates the normal probability density distribution with parameters $\mu\prime\left(I_{ms}\right)$ and $\sigma\prime\left(I_{ms}\right)$ as reported in Table 1. The choice of the prior

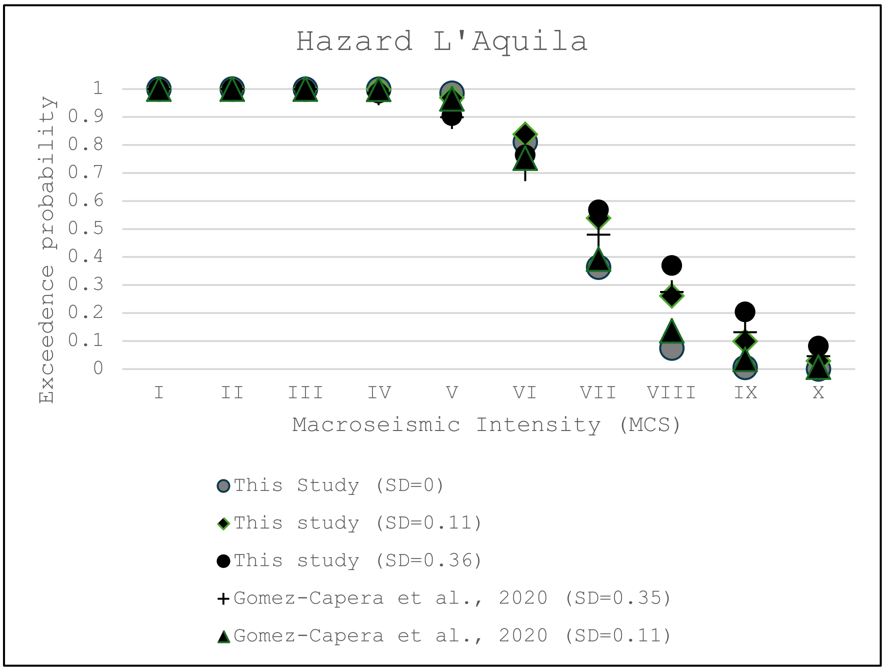

Fig. 2 Hazard curves in terms of Macroseismic Intensity (MCS scale) corresponding to the hazard curve at the town of L'Aquila (Central Italy) by considering different conversion rules and standard deviation estimates (SD) relative to probability distribution $p(G_{lg}|I_{ms})$. The Hazard curves obtained by considering the parameterizations by Gomez-Capera et al. (2020) are also reported for comparison

is a critical aspect. Kuehn and Scherbaum (2010) suggest using the relative frequency of intensity bins within the data sample, by implicitly assuming that the considered data sample is representative of the whole population of possible Intensity values, which seems to be unrealistic: e.g., the number of low intensity values are clearly under sampled with respect to the possible number of sites experiencing none or weak effects during an earthquake. In alternative, one could consider as a prior the relative frequency of I_{ms} value in a comprehensive repository (e.g., Locati et al. 2022). In this case, however, it will appear evident that lowest intensities dominate the sample (87% of records after 1900 concerns I_{ms} <VI MCS) despite the incompleteness of the repository relative to low Intensity records (see, e.g., Pasolini et al. 2008). In the case that this kind of prior is assumed, outcomes of [6] will largely privilege low intensity values for a given G_{lg} by providing under conservative estimates. In this regard, a more conservative approach is assuming a uniform prior, which corresponds to the Bayes-Laplace 'principle of insufficient reason' in the lack of arguments for choosing 'ex-ante' among alternative I_{ms} values (Jeffreys 1961). In this last case one has.

$$p\left(I_{ms}|G_{lg}\right) = \frac{p\left(G_{lg}|I_{ms}\right)}{\sum_{J=1}^{12}\mathcal{N}[\mu\prime(J),\sigma\prime(J)]} \tag{7}$$

This last position has been adopted in the following.

4.3 The case study of L'Aquila

To illustrate the feasibility of this procedure, we examine the hazard curve relative to the L'Aquila city in Central Italy, struck by a destructive earthquake in 2009 (Ameri et al. 2011). The respective hazard curve $H(G_{lg})$ is obtained from the refence hazard map of Italy (Stucchi et al. 2011) relative to the ground motion in PGA and an exposure time of 50y at reference site conditions. The corresponding $h(G_{lg})$ probability density function to be used in equation [4] has been obtained by following Albarello and Paolucci (2024).

Outcomes relative to the application of equations [1, 3, 4, 5 and 7] and parametrizations in Table 2 are reported in Fig. 2. In the same figure, the hazard curve in terms of I_{ms} obtained by considering the parameterizations proposed by Gomez-Capera et al. (2020) considering the two estimates of the standard deviation they propose (0.11 and 0.35) is reported for comparison. It is worth noting that the Hazard curve in intensity is inherently discrete. Thus, to preserve the conservative approach here adopted, the real values of I_{ms} obtained from the equations provided by Gomez-Capera et al. (2020) have been discretized by rounding to nearest higher value. The Hazard curves obtained by disregarding uncertainty affecting conversion are also shown… As one can see, the standard deviation relative to the normal distribution $p\left(G_{lg}|I_{ms}\right)$ plays a major role: by increasing standard deviation from 0 to 0.36 a monotonic increase of hazard is obtained: when standard deviation increases, the values of the exceedance probabilities relative to the larger I_{ms} values monotonically increase making more probable the occurrence of these major events. As an example, the highest Intensity value characterized by an exceedance probability larger than 10% (corresponding to a 475y return time in the standard approaches) increases from VII MCS to IX MCS when the standard deviation increases from 0 to 0.36.

5 Conclusions

A formally coherent probabilistic procedure in the Bayesian perspective is presented to infer hazard curves in terms of Macroseismic Intensity from the hazard computed in terms of ground motion intensity. Different from previous approaches, which simply assimilate ground motion parameters and Intensity data, the procedure accounts for the peculiar nature of Intensity data, which are discrete, ordinal (no metric is explicitly defined) and defined over a finite support. In principle, these differences prevent the use of common regression procedures to parameterize relationships between the two considered kinds of parameterizations. The approach here proposed is in line with the one by Kuehn and Scherbaum (2010) and applied to Italy by Cataldi et al., (2021) aiming at overcoming these formal difficulties. With respect to the study by Cataldi et al., a different approach has been here considered to manage Macroseismic Intensities based on specific statistical assessments with a conservative attitude. Another important difference concerns the choice of the prior probability considered in the Bayesian inference of the Macroseismic Intensity from ground motion parameters: the choice here considered of the uniform prior may be debatable but is anyway coherent with the conservative position generally held in hazard estimates.

The relevant outcomes are proposed as a benchmark for approximate less coherent procedures (e.g., resulting from standard regression analyses).

The case study here considered shows that the key element to avoid possible biases in the application of approximate procedures is the correct estimate and implementation of dispersion relative to ground motion intensity corresponding to each Intensity bin. As expected, the increase of dispersion directly reflects in a hazard increase. When this element is not accounted for (e.g., a one-to-one correspondence is considered between ground motion and Intensity values) the hazard in Intensity results dramatically underestimated.

Other critical issues must be addressed. The present study relies on a relatively poor database relative to many I_{ms} bins. Future studies are necessary to improve this dataset and reduce incompleteness of the data and avoid empirical extrapolations. Recently Oliveti et al., (2022) proposed a larger dataset that has not been considered here because its inherent heterogeneity of the Macroseismic Intensities implemented in the database by mixing I_{ms}values expressed in MCS and EMS98 (Grünthal 1998) scales. Ideally, mixing data relative to different scales should be avoided and best procedure should be returning to the original data and reassign values in the desired intensity scale (Ambraseys et al. 1983; Grünthal 1998). Problems arising when data from different scales are compared are widely discussed in Musson et al. (2010). The congruence of estimates provided by two scales is controversial depending on the approach considered to estimate possible discrepancies (e.g., Graziani et al. 2015; Vannucci et al. 2021). As an example, one can compare the different positions about the compatibility of MCS and EMS98 degrees assumed by Musson et al. (2010) and by Vannucci et al., (2024) as concerns Intensity values in the range [V, VIII], which represent the main part of the data considered in the present analysis. Another important aspect should be considered. Most of Italian data considered for seismic hazard assessment have been determined based on historical documents in the lack of any possible evaluation of building vulnerability, which is important for EMS98 assessment. This implies that MCS estimates dominate the catalogue. Thus, since the present study is mainly devoted to the conversion of PSH outcomes in Italy into macroseismic intensity values, it appeared more coherent the use of MCS data only, by preferring the the use of the poorer but homogenous dataset by Gomez-Capera et al. (2020) to the more extended (and potentially more heterogeneous) data set by Oliveti et al. (2022). The present paper is mainly methodological in character and focused on the conversion of PSH estimates, exploring the possible impact of eventual heterogeneities in the considered data set is beyond the scope of the present study.

Finally, an important issue concerns the possible effect of cumulative damage for macroseismic intensity values greater than I = 6 when seismic sequences occur: the presence of cumulate macroseismic effects could potentially bias the conversion procedures relative to I_{ms} and G_{lg}. In particular, larger I_{ms} values can result in correspondence of relatively small ground motion when the effects on buildings weakened by previous earthquakes or reactions of people stressed by seismic swarms are considered in the Intensity assessment. It is worth noting, however, that when hazard assessment is of concern, the main interest is on the largest expected effects. This implies that considering the cumulative effects as representative of macroseismic intensity is in line with the generally conservative position adopted in hazard assessment.

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Author contribution Being a single Author all the parts of the manuscript are under his full responsibility.

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Data availability Data will be available on request to the Author.

Declarations

Competing interests The authors declare no competing interests.

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