ITALIAN MACROSEISMIC INTENSITY ATTENUATION MODEL
AS A FUNCTION OF MW AND DISTANCE
A.A. Gómez Capera\textsuperscript{1}, M. Santulin\textsuperscript{2}, M. D’Amico\textsuperscript{1}, V. D’Amico\textsuperscript{2}, M. Locati\textsuperscript{1}, L. Luzi\textsuperscript{1}, M. Massa\textsuperscript{1},
C. Meletti\textsuperscript{2}
\textsuperscript{1} Istituto Nazionale di Geofisica e Vulcanologia, sezione di Milano, Italy
\textsuperscript{2} Istituto Nazionale di Geofisica e Vulcanologia, sezione di Pisa, Italy

Introduction. Following the goal of CPS (Centro di Pericolosità Sismica, Center for Seismic Hazard) that is to develop a new Italian seismic hazard map, we propose an updated macroseismic intensity attenuation model for the whole Italian territory and Sicily (without Mount Etna area) that can be applied for computing PSHA in terms of macroseismic intensity. The adopted methodological criterion is focused on developing a new macroseismic intensity attenuation model calibrated as a function of the moment magnitude (Mw) rather than the epicentral intensity (I\textsubscript{0}). The standard deviation, related to a normal distribution of residuals macroseismic data, is given and can be used to model the uncertainty of ground shaking in hazard studies.

Current knowledge status. Regarding PSHA studies in terms of macroseismic intensity, the most recent macroseismic intensity attenuation models for the whole Italian territory are proposed in literature by Pasolini \textit{et al.} (2008) and Gomez Capera \textit{et al.} (2010). Both models were developed in the frame of a seismological project (agreement INGV-DPC 2004-2006/Project S1), and both using the same datasets (DBMI04, Stucchi \textit{et al.}, 2007 and CPTI04, CPTI Working Group, 2004) adopted for assessing the national reference seismic hazard model (MPS04, MPS Working Group, 2004). The two attenuation models adopt different functional forms to evaluate the intensity attenuation with distance and source parameters. Moreover, they are focalized on different spatial and source size range and consequently on higher and lower intensities. A more recent, but not published, attenuation intensity model was calibrated for Italy in the frame of the module NA4 “Distributed Archive of Historical Earthquake Data” of the EC FP6 NERIES Project (Gomez Capera \textit{et al.}, 2009) and CPTI11 (Rovida \textit{et al.}, 2011; Gomez Capera \textit{et al.}, 2008) for determining earthquake parameters from macroseismic data. The relationship developed by NA4 was disregarded as it could be improved by using a larger dataset.

The prediction equation proposed in this work is based on the most recent and publicly available datasets, compiled in the framework of the new Italian hazard map, the version 2015 of the Italian Macroseismic Database (DBMI15, Locati \textit{et al.}, 2016) and the 2015 version of Parametric Catalogue of Italian Earthquakes (CPTI15, Rovida \textit{et al.}, 2016), and this allowed to developed new studies.

Input data. A dataset of 16,261 Macroseismic Data Points (MDPs) related to a set of 118 earthquakes occurred in the time window 1908-2013 with reliable instrumental location and moment magnitudes (Mw) was used to calibrate the coefficients of the macroseismic intensity attenuation relation. The so-called “input calibration dataset” is the input data carefully selected for addressing a series of general conditions: 1) earthquake in CPTI15 covering the largest possible magnitude range and 2) spatial distribution, and having good quality 3) instrumental Mw, 4) epicentral locations, and 5) set of MDPs from DBMI15.

An additional subset of events called “validation dataset”, was then selected with the same criteria, and was used to test the attenuation model developed in this study.

Input data selection criteria. In order to derivate a macroseismic intensity attenuation model a careful selection of set of MDPs and earthquakes was carried out considering diverse criteria (Gomez Capera, 2006; Gomez Capera \textit{et al.}, 2010):
- earthquakes relative to the volcanic area of Mount Etna were removed because the attenuation pattern in this zone is different from active crustal regions (Ciccotti \textit{et al.}, 2000);
- MDPs with intensity $I < 3$ were discarded to avoid data incompleteness;
- events with cumulated effects due to damaging aftershocks were removed;
- events with focal depth $> 33$km were discarded;
- off-shore and cross-national earthquakes were also discarded due to incomplete distribution of MDPs and ill-constrained epicenter location;
- events characterized by low $I_0$ and/or small $M_w$ because the study will be focused on strong earthquakes;
- events with few MDPs were removed, because these could bias the regression analysis;
- carefully considering those MDPs associated to places identified as special cases by DBMI, such as TE (large territory), IB (isolated building), SS (small settlement), MS (multiple settlement), DL (deserted locality), AL (absorbed locality), CQ (city quarter), because the statistical nature of intensity might not be full filled;
- carefully considering those non-conventional macroseismic intensities by DBMI (e.g. Felt, Damage, etc).

After the application of these selection criteria, the resulting set of macroseismic intensities is made of 16,261 MDPs related to 118 events (i.e. input calibration dataset, Fig. 1) that occurred from 1908-2013.

**Modelling and conclusions.** A typical functional formula is chosen in the present study to model the attenuation of Italian macroseismic intensity data as a function of epicentral distance and $M_w$ using five free parameters:

\[ I = a - bR - c \log R + dM_w \]

with $R = (x^2 + (e)^2)^{0.5}$ i.e. $x$ is the epicentral distance.

The model parameters ($a$, $b$, $c$, $d$, $e$) are determined through a non-linear least squares method using KaleidaGraph software (Synergy Software, 2014) and the calibration dataset. The calibrated model assumes a point source and an isotropic macroseismic field, centered at the instrumental epicenter. The between-events residual (also called inter-event residual or inter-event term, Al Atik et al., 2010) was computed to obtain the best possible performance earthquake-to-earthquake variability of the calibrated macroseismic intensity attenuation model that is:

\[ I = (1.8125 \pm 0.10329) - (0.0038551 \pm 0.000266)R - (2.6096 \pm 0.066535) \log R + (1.4206 \pm 0.0066)M_w \]

with $R = (x^2 + (9.87)^2)^{0.5}$.

Tab. 1 summarizes the range of the calibrated model.

<table>
<thead>
<tr>
<th>Time range</th>
<th>No Events</th>
<th>No MDPs</th>
<th>Mw Range</th>
<th>x (km) Range</th>
<th>h (km) focal depth</th>
<th>I Range</th>
<th>lxx / Io Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>[1908-2013]</td>
<td>118</td>
<td>16,261</td>
<td>[3.82-7.10]</td>
<td>[0.11-634]</td>
<td>$h&lt;33$</td>
<td>[3-11]</td>
<td>[5-11]</td>
</tr>
</tbody>
</table>

The calibrated macroseismic intensity attenuation model (Figs. 2 and 3) is characterized by $\Delta I$-residuals (observed –predicted) as Gaussian curves (normal distributions, Gomez Capera, 2006). The calibrated macroseismic intensity attenuation is characterized by a lower standard deviation ($\sigma=0.75$) than the one reported in Gomez-Capera et al. (2010), and resulting in better quality fit factors for each calibrated attenuation coefficient. A validation process will be the next phase of this study.
Fig. 1 - Input earthquakes for the IPE calibration: 118 post 1900 (1908-2013) events (3.82 ≤Mw≤7.10).

Fig. 2 - Plot in 3D of I(MCS)=1.8125-(0.0038551*R-2.6096±*LogR+1.4206Mw with R=(x^2+(9.87)^2)^0.5, where x is the epicentral distance (km), Mw the moment magnitude (the 16.261 MDPs are black dots),
Fig. 3 - 2D plot of I(MCS) as function of epicentral distance for different Mw classes with the standard deviation =0.75: a) linear scale; b) log. scale.

References


