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The ESI scale, an ethical approach to the evaluation of seismic hazard

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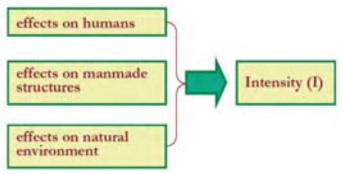
The dissemination of correct information about seismic hazard is an ethical duty of scientific community worldwide. A proper assessment of earthquake severity and impact should take into account both the effects on humans, man-made structures, as well as on the natural environment.



MICHETTI A.M., ESPOSITO E., GUERRIERI L., PORFIDO S., SERVA L., TATEVOSSIAN R., VITTORI E., AUDEMARD F., AZUMA T., CLAGUE J., COMERCI V., GURPINAR A., MC CALPIN J., MOHAMMADIOUN B., MORNER N.A., OTA Y. & ROGHOZIN E. (2007)

We illustrate the new macroseismic scale that measures the intensity taking into account the effects of earthquakes on the environment: the ESI 2007 (Environmental Seismic Intensity) scale (Michetti et al., 2007), ratified by the INQUA (International Union for Quaternary Research) during the XVII Congress in Cairns (Australia). The ESI scale integrates the traditional macroseismic scales, of which it represents the evolution, allowing to assess the intensity parameter also where buildings are absent or damage-based diagnostic elements saturate, solely on the bases of environmental effects.

The aim of this paper is to highlight the importance of the ESI 2007 scale, that can be considered "ethical" because it helps to define the real scenario of an earthquake, regardless of the country's socio-economic conditions and level of development

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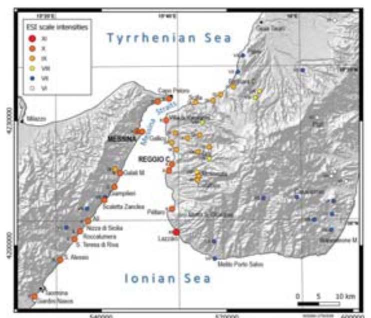
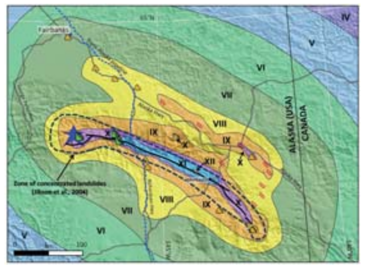
The ESI 2007 intensity scale in ten languages

- Enviromental Seismic Intensity scale - ESI 2007 **(English)**
- La scala di intensità sismica ESI 2007 **(Italian)**
- Escala medio-ambiental de intensidad sismica ESI 200 7 **(Spanish)**
- L'échelle d'Intensité Sismique Environmentale - ESI 2007 **(French)**
- ESI 2007 Intensitätsskala **(German)**
- の2007年の震度 **(ESI Japanese)**
- Шкала сейсмической интенсивности на основании природных эффектов - ESI 2007 **(Russian)**
- Η μακροσεισμική κλίμακα έντασης ESI 2007 **(Greek)**
- Seismische intensiteitschaal op basis van omgevingseffecten - ESI 2007 **(Dutch)**
- 환경진도단위-ESI 2007 (한국어)- ESI 2007 **(Korean)**

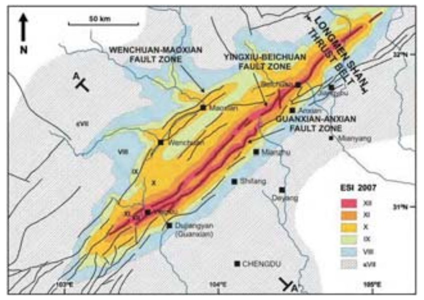
Some applications of the ESI 2007 intensity scale



The December 28, 1908, earthquake (Mw=7.1, Io=MCS XI) was the most destructive disaster of the twentieth century in Italy. The impact of the earthquake was particularly catastrophic along the southwestern Calabrian coast and along the northeastern coast of Sicily. Reggio Calabria and Messina were almost totally destroyed. Few minutes after the earthquake, both sides of the Messina Straits were inundated by a disastrous tsunami, whose effects often overprinted those directly caused by the earthquake (Comerci et al., 2015)



The November 3rd, 2002 Denali (Alaska) earthquake, (Mw=7.9, I0= MM IX) generated a surface rupture of 340 km with the maximum offset of 8.8 m horizontal displacement and 5 m of vertical displacement. The maximum ESI 2007 intensity degree based on the amount of slip is XII, but the resulting I0 is XI (Serva et alii, 2015; Comerci et al 2015).



The May 12, 2008, Wenchuan (China) earthquake of (Mw=7.9) caused primary and secondary effects in a region exceeding 50,000 km². This earthquake generated a 220-km surface rupture along the Yingxiu-Beichuan fault with a maximum vertical and horizontal displacements of 6.2 m and 4.9 m, respectively and a 72-km surface rupture along the Guanxian-Anxian fault, with a maximum vertical and horizontal displacement of 3.5 m and 1.0 m, respectively. These large primary effects clearly affected and modified the topography of the area (Lekkas, 2010).

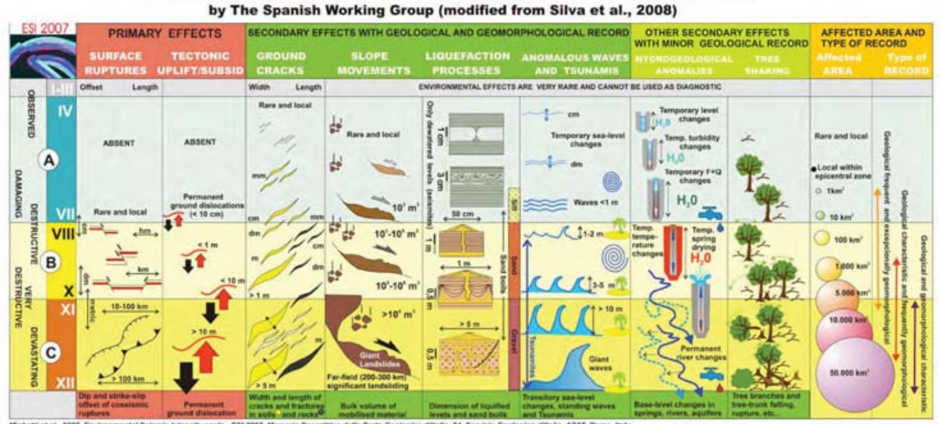
I_0	PRIMARY EFFECTS		SECONDARY EFFECTS
	Surface Rupture Length	Max Surface Displacement / Deformation	Total Area
IV	-	-	-
V	-	-	-
VI		-	-
VII	(*)	(*)	10 km²
VIII	Several hundreds meters	Centimetric	100 km²
IX	1 - 10 km	5 - 40 cm	1000 km²
X	10 - 60 km	40 - 300 cm	5000 km²
XI	60 – 150 km	300 – 700 cm	10000 km²
XII	> 150 km	> 700 cm	> 50000 km²

(*) Limited surface fault ruptures, tens to hundreds meters long with centimetric offset may occur essentially associated to very shallow earthquakes in volcanic areas.

The evaluation of epicentral intensity (I⁰) can be done only based on primary effects and on the total area affected by secondary effects (last column on the right).

The ESI scale is a 12-degree scale: each degree reflects the corresponding strength of an earthquake and the role of ground effects, evaluating the Intensity on the basis of the characteristics and size of primary and secondary effects.

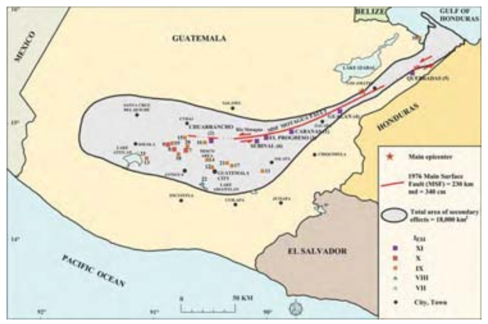
CHART OF THE INQUA ENVIRONMENTAL SEISMIC INTENSITY SCALE 2007 - ESI 07
by The Spanish Working Group (modified from Silva et al., 2008)



Michetti et al., 2007. Environmental Seismic Intensity scale - ESI 2007. Memorie Descrittive della Carta Geologica d'Italia, 74, Servizio Geologico d'Italia, APAT, Rome, Italy
Silva et al., 2008. Catalogue of the geological and environmental effects of earthquakes in Spain in the ESI-2007 Macroseismic scale. Cong. Geol. Esp. Gran Canaria, Spain

The main advantage of the ESI 2007 scale is the classification, quantification, and measurement of several known geological, hydrological, geomorphological and botanical features for each intensity degrees. The primary effects are surface faulting and tectonic uplift/subsidence and the secondary effects are ground cracks, slope movements, liquefaction phenomena, anomalous waves and tsunamis, hydrological changes, trees shaking, dust clouds and jumping stones.

Motagua Fault trace crosses the Gualan soccer field USGS



Map showing the main epicenter of the February 4, 1976, Guatemala earthquake, the Motagua surface fault and the total area of secondary effects. The intensity values according to ESI scale, have been assessed considering surface faulting, slope movements, ground cracks, liquefaction phenomena and ground settlements, (Porfido et al, 2015).

Guatemala suffered several dramatic earthquakes during the last century. The most destructive event associated with the Motagua fault, occurred on February 4, 1976 (M=7.5), that caused 23.000 deaths, and 77.200 injuries. The coseismic geological effects were remarkable displacement along a 230 km long strike-slip fault and also provoked 50.000 landslides, numerous liquefaction phenomena, ground cracks and ground deformation over an area of about 18.000 km². In spite of this, the estimated intensity was relatively low (Imax= IX MM, only in few localities). For this reason, a re-evaluation of the 1976 earthquake, taking into account the environmental effects, has been carried out.

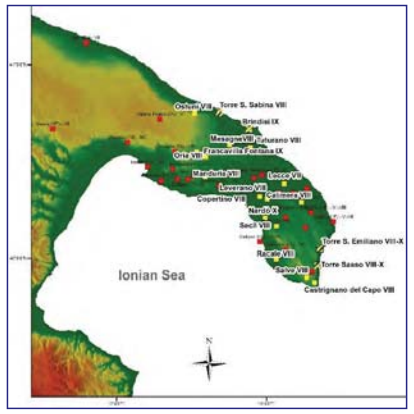
The analysis of primary and secondary effects has permitted the evaluation of seismic intensity in 24 localities, and to establish a new epicentral Intensity, characterized by Io=XI ESI. The recalculated seismic intensity is hence two degrees higher than previous estimates and definitely more consistent with the scenario of the actual damage caused by the earthquake (Porfido et al., 2015) with a better definition of the Guatemala seismic hazard.

Case studies

For an appropriate mitigation strategy in seismic areas, it is fundamental to consider the role played by seismically induced effects on ground, such as active faults (size in length and displacement) and secondary effects (the total area affecting). With these perspectives two different cases studies have been reviewed: the destructive 1976 February 4 Guatemala earthquake and the 1743 February 20 Nardò historical earthquake (Salento, Southern Italy).

The Salento peninsula was severely hit by the February 20, 1743 earthquake (I=IX MCS, M_w=7.1), considered the strongest seismic event of the area, which also generated a large tsunami. The 1743 epicenter is still very controversial due to the different locations ascribed respectively on land, near the town of Nardò, and offshore in the Ionian sea. This earthquake caused mostly severe damage in Salento, killing about 180 people, 150 of which in the town of Nardò (Lecce), and inflicted heavy damage also in Francavilla Fontana (Brindisi). The seismic event was extensively felt on the western coast of Greece, on the Malta island, in Southern Italy and in some localities of Central and Northern Italy.

Boulders on the Salento east coast (Porto Badisco -Torre S. Emiliano)



Map of the intensity values of the 1743 Salento earthquake: CFTIMED, 2007 MCS intensity values (red squares); re-evaluated MCS Intensity values in this study (yellow squares); re-evaluated ESI Intensity values in this study (yellow striped squares).

For the re-evaluation of the 1743 earthquake on the basis of ESI scale, the tsunami phenomenon along the southern Adriatic coastline of Salento has been the most important environmental effect. Accordingly, for the town of Brindisi the ESI intensity value has been raised up from VIII to IX, due to the damage of the harbour mole caused by the tsunami. Moreover, it has been possible to assess the ESI intensity values of VIII≥ I ≥ X for the localities of Torre Sasso (Tricase) and Torre Sant'Emiliano (Otranto), along the coastline of the Salento peninsula, on the basis of the tsunami blocks dimensions consisting of large boulders with a maximum weight of about 70 tons. Ground effect phenomena triggered by the 1743 earthquake also occurred in the town of Nardò where variations of the water flow rate of wells together with variations of chemical-physical properties of water were observed (Nappi et al., 2014, Nappi et al., 2015). On the bases of these results the seismic hazard of the Salento peninsula must be re-evaluated and further study should be dedicated to this area, considering also a possible revision of the seismic classification.

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