INTENSITY ATTENUATION WITH DISTANCE FOR LARGE SUBDUCTION EARTHQUAKES: A PERSPECTIVE BASED ON EARTHQUAKE GROUND EFFECTS FROM THE 16 APRIL 2016, MW 7.8 PEDERNALES EARTHQUAKE (ECUADOR)

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Introduction. Macroseismic data are valuable tools in both delineating the earthquake damage distribution and deriving source parameters for historical events (e.g., Sibol et al., 1987; Musson, 1996; Bakun and Wentworth, 1997; Pettenati et al., 1999; Gasperini et al., 1999, 2010; Hough et al., 2000).

Nevertheless, intensity reliability for seismic hazard assessment can be particularly problematic along subduction zones and in particular in South America, where i) datasets are
limited in time, ii) macroseismic fields are inherently incomplete because lacking the offshore areas, iii) intensity data points tend to be strongly clustered along the coast or in the major valleys, therefore iv) site effects might be the controlling factor, due to loose sediments and shallow water table, and v) dynamic parameters of engineering structures and building codes significantly changed in the last 30-40 years.

As a matter of fact, the introduction of the Environmental Seismic Intensity scale (ESI-07; Michetti et al., 2007; Serva et al., 2016) provides nowadays a tool addressing these issues and yielding improved intensity metrics. The distribution of Earthquake Environmental Effects (EEEs) is not dependent on settlements location, and environmental response to large earthquakes is stable over extensive time windows.

Starting on the day after the mainshock, we mapped in the field and compiled all the available observations on earthquake environmental effects (EEEs) caused by the Mw7.8 subduction earthquake that hit the coastal region of Ecuador on 16 April 2016 (Pedernales earthquake). These effects include: i) permanent ground deformation, ii) open cracks, iii) liquefaction, iv) landslides, and v) tsunami waves.

We use these observations to evaluate the macroseismic field of the Environmental Seismic Intensity - ESI-07 scale and compare our results with published macroseismic data collected using traditional, damage-based, intensity scales.

Methods. We grouped the 298 ESI-07 intensity sites into intensity data points (IDPs) taking into consideration local geomorphological settings. Next, we draw isoseismal maps based on visual interpolation of the intensity data points. For traditional intensity data collection (i.e., EMS-98 and MM scales), we used mainly the information provided by Geophysical Institute of Ecuador (IGEPN), which includes an intensity map.
Intensity regression with distance and comparison with previous events was tested through a GIS-based approach. In order to calibrate a distance-based attenuation equation, we analyzed a calibration dataset of published macroseismic fields for large instrumental subduction earthquakes between Ecuador and Chile (Mw = 7.7 - 8.3).

For each earthquake, first we digitized in a GIS environment the instrumental epicentral location and the macroseismic field and then, following the approach proposed by Bakun and Wentworth (1997), we investigated the epicentral distance of each isoseismal area. Since the distribution and the amount of data are not comparable among all the events (i.e., number and density of IDPs for each subset), we adopted a modified version of the procedure originally proposed by Bakun and Wentworth (1997), using the published isoseismals as input data instead of the originally listed IDPs. Then, we calculated distance statistics of the sampled points belonging to each isoseismal (i.e., median, average and standard deviation) and, as suggested by Bakun and Wentworth (1997), we used the median of distance to calculate an attenuation equation. Median values have the considerable advantage to automatically smooth the effect of outliers (i.e., sites showing site amplification phenomena). We used a linear regression for attenuation relationship, as in Bakun and Wentworth (1997).

**Results.** We found systematic difference in the assessed earthquake intensity between ESI-07 and traditional scales and in the intensity attenuation with distance. A comparison of our dataset with macroseismic data of six, instrumental, large subduction earthquakes occurred between Ecuador and Chile, suggests that for the Pedernales earthquake the ESI-07 works better in the near field whereas damage-based scales are more reliable in the far field.

![Fig. 2 - Macroseismic fields for the 2016 Pedernales earthquake (Mw 7.8): a) Regional map of the EMS-98 IDPs; b) Isoseismal map for EMS-98 scale; c) Isoseismal map for ESI-07 scale. Legend: ESM Esmeraldas, MUI Muisne, MOM Mompiche, PED Pedernales, SIS San Isidro, CAN Canoa, BDB Boca da Briceño, TOS Tosagua, POR Portoviejo, JIP Jipijapa.](image-url)
Following the analysis of the damage distribution and EEEs triggered by the Pedernales earthquake, we observe a systematic distance-dependent difference of macroseismic fields as derived from EMS-98 and ESI-07 scales. Near field values and epicentral intensity are ca. one degree lower in EMS-98, while ESI-07 values are more consistent with epicentral intensities recorded by previous similar subduction events. This observation, even if not necessarily systematic, has been done in other case studies (Mosquera - Machado et al., 2009; Papanikolaou et al., 2009; Di Manna et al., 2012) and it can be ascribed to an underestimation of traditional macroseismic scales in the near field, at least for strong earthquakes occurred in the last decades.

Underestimation of traditional intensity scales in the near field, can possibly be ascribed to a considerable improvement of building parameters with time, including recent economic development and the introduction of building codes, resulting in an overall less vulnerable built environment. Conversely, since ESI-07 scale is, by definition, less sensitive to moderate shaking effects, as experienced in the far-field areas (e.g., Papanikolaou et al., 2009), here traditional scales work better in depicting the overall macroseismic field. Nevertheless, to our knowledge, a quantitative comparison with traditional intensity scales, in terms of attenuation regressions, has never been tried before, neither for large subduction earthquakes.

These results strongly suggest that, in the future, EEEs should be considered to evaluate the earthquake macroseismic field, as initially suggested by the pioneers of macroseismic investigation (e.g., Sieberg, 1930; Wood and Neumann, 1931; Richter, 1958; Medvedev et al., 1964).

References


