SECOND EUROPEAN CONFERENCE ON EARTHQUAKE ENGINEERING
AND SEISMOLOGY, ISTANBUL AUG. 25-29, 2014

1
2

DISCRIMINATING AMONG DISTINCT SOURCE MODELS OF THE 1908 MESSINA STRAITS EARTHQUAKE BY MODELLING INTENSITY DATA THROUGH FULL WAVEFIELD SEISMOGRAMS

1

Vincenzo CONVERTITO[1] and Nicola Alessando PINO[2]

1
2

The mitigation of seismic risk requires an ever deeper knowledge of both recent seismicity and historical earthquakes for the evaluation of their impact. In this respect, macroseismic intensities are the only available data for most historical earthquakes and often represent the unique source of information for crucial events in the definition of seismic hazard. Here we present the results of a recent paper by Convertito and Pino (2014) aimed at getting insight into source characteristics by reproducing the observed intensity field of 1908 Messina Straits earthquake (M_W=7.1). By considering that the present population in the area is in excess of 700000, with 500000 in the Messina urban area and 190000 in Reggio Calabria, with constructive quality of the buildings far from the optimal, the determination of a reliable fault model is not trivial nor it represents an academic dispute.

In this study, we focused on the simulation of the macroseismic field associated with large events, by computing the broad-band ground motion produced by realistic seismic sources. We applied this technique to the source of the 1908 Messina Straits event and pointed at discriminating among distinct published fault models. In particular, we tested three distinct fault models deduced from the analysis of geodetic data. The first model was proposed by Boschi et al. (1989). The second is a slightly modified version of the one by De Natale and Pingue (1991), derived by using their slip distribution and the focal mechanism published by Capuano et al. (1988). This latter is very similar to the one by De Natale and Pingue (1991), with planes orientation differing by only a few degrees. The third was recently published by Aloisi et al. (2013) (hereinafter indicated as M1, M2 and M3, respectively). The first two are almost comparable, while the third one displays very different fault plane dimension and dip orientation. The main features of three models are listed in Table 1 while their surface projections are shown in Figure 1.

Table 1. Fault plane geometry, depth of the fault top (DFT), and focal mechanism of the tested models

Model	L(km)	W(km)	DFT(km)	Stike(°)	Dip(°)	Rake(°)
M1	45	18	3	11	29	-90
M2*	45	24	3	349	42	-121
M3	29	12	0.171	188	60	-77**

* The fault dimensions correspond to the area of non-null slip in the De Natale and Pingue (1991) model.
** This value is derived from the strike-slip and dip-slip component given by Aloisi et al. (2013).

Starting from the static slip distribution, we developed kinematic source models for the investigated fault and compute full waveform synthetic seismograms at 100 selected sites. We used the 1-D structural model proposed by Barberi et al. (2004). The density value ρ in each layer was

[1] Dr. habil., Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Vesuviano, Naples, vincenzo.convertito@ov.ingv.it
[2] Dr., Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Vesuviano, Naples, alessandro.pino@ov.ingv.it

obtained by using the empirical relation by Brocher (2005), whereas the anelastic attenuation was set through the quality factor *Q* values by using the function proposed by Tuvè et al. (2006).
We converted both peak-ground acceleration (PGA) and peak-ground velocity (PGV) computed from the synthetics to macroseismic intensity, by means of specific empirical relations for the Italian region (Faenza and Michelini, 2010). By comparing the original data separately with PGA- and PGV-based intensity fields, we discriminated among the tested faults and determine the best values for the investigated kinematic parameters of the source. We also performed a misfit analysis for the best source model, in order to investigate the dependence of the results on the selected parametrization. In particular, for each selected source model, we have investigated the effect of: rise-time, rupture velocity, nucleation point position and slip distribution.

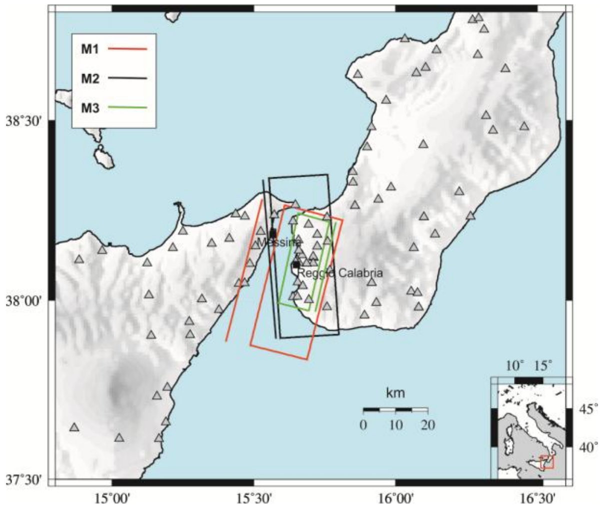

Figure 1. Geographic map showing the Messina Straits area. The 100 sites selected for the analyses presented in this study are also represented (triangles). The rectangles indicate the surface fault projection of the three investigated models for the source of the 1908 earthquake: M1 (Boschi et al. 1989) (red); M2 (Capuano et al. 1991; De Natale and Pingue 1991) (black); M3 (Aloisi et al. 2013) (green), while the color lines indicate the intersection of the upward prolongation of the fault with the Earth's surface.

The results of the analysis indicate that, among the tested models the one characterized by an east-dipping fault, with strike oriented NS slightly rotated clockwise, i.e. M1, better explains the observed macroseismic field of the 1908 Messina Straits earthquake. Besides, the fracture nucleated at the southern end of the fault and ruptured northward, producing considerable directivity effects. This is in agreement with the published results obtained from the investigation of the historical seismograms (Pino et al. 2000). We also determined that for all the models the best rise-time value is 1.4 s, whereas the rupture velocities providing better fit are always larger than 2.6 km/s. For the best model, we evaluated the dependence on the parametrization by using an approach similar to seismic hazard deaggregation. in which, during the computation, the contribution of each model to the hazard is saved to build a joint a-posteriori probability density function (Bazzurro and Cornell 1999; Convertito et al. 2009).

Our study confirms the great potential of the macroseismic data, demonstrating that they contain enough information to constrain important characteristics of the fault, which can be retrieved by using complex source models and computing complete wavefield. Moreover, we also show that the simultaneous comparison of both PGA- and PGV-based synthetic macroseismic fields with the original intensities provides tighter constraints for discriminating among different source models, with respect to what attainable from each of them.

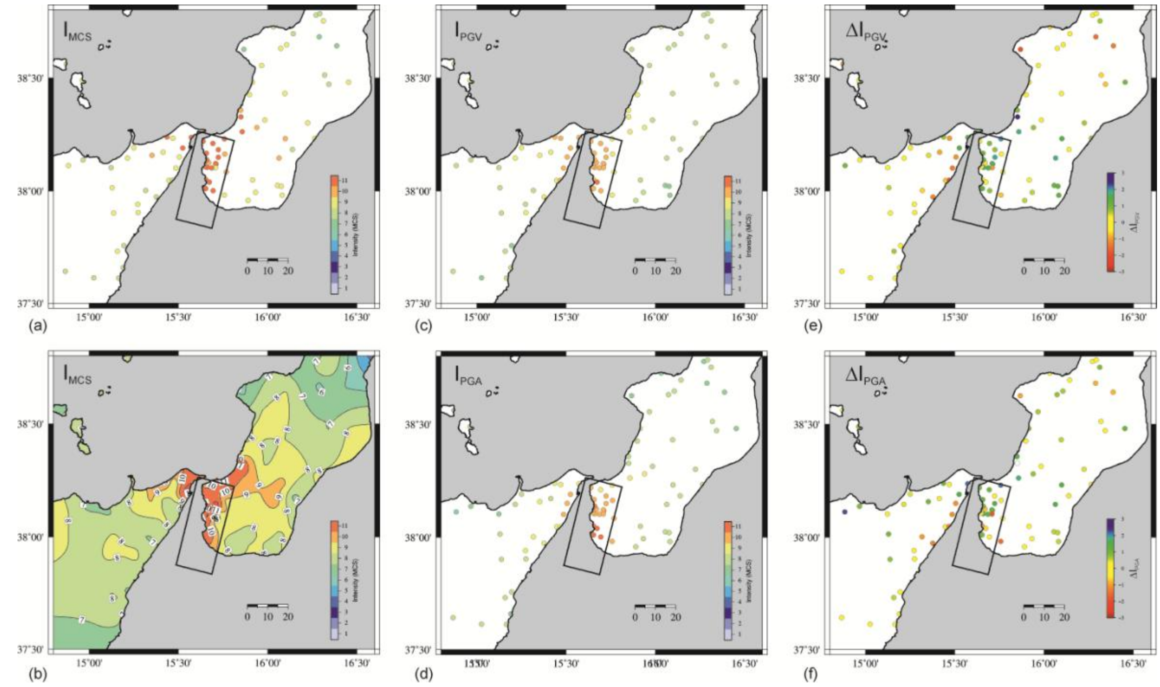

Figure 2. Observed and simulated data: (a) original macroseismic intensities; (b) interpolated original macroseismic intensities; (c) intensities obtained from the simulated PGV relative to the best model M1; (d) same as (c), for PGA; (e) difference between original intensities and those obtained from the simulated PGV relative to M1; (f) same as (e), for PGA. The black rectangle represents the surface fault projection for M1.

1

2

REFERENCES

1

Aloisi M, Bruno V, Cannavò F, Ferranti L, Mattia M, Monaco C and Palano M (2013) “Are the source models of the M 7.1 1908 Messina Straits earthquake reliable? Insights from a novel inversion and a sensitivity analysis of levelling data,” *Geophys J Int*, 192, 1025-1041, doi: 10.1093/gji/ggs062.

Barberi G, Cosentino M, Gervasi A, Guerra I, Neri G and Orecchio B (2004) “Crustal seismic tomography in the Calabrian Arc region, south Italy,” *Phys Earth Planet Inter*, 147(4), 297–314, doi: 10.1016/j.pepi.2004.04.005.

Bazzurro P and Cornell CA (1999) “Disaggregation of seismic hazard,” *Bull Seism Soc Am*, 89, 501-520.

Convertito V, Iervolino I anf Herrero A (2009) “Importance of mapping design earthquakes: insights for the Southern Apennines, Italy,” *Bull. Seismic. Soc. Am.*, 99, 2979-2991; doi:10.1785/0120080272.

Convertito V and Pino NA (2014) “Discriminating among distinct source models of the 1908 Messina Straits earthquake by modelling intensity data through full wavefield seismograms,” *Geophys J Int,* DOI:10.1093/gji/ggu128.

Boschi E, Pantosti D and Valensise G (1989) “Modello di sorgente per il terremoto di Messina del 1908 ed evoluzione recente dell’area dello Stretto,” *Atti VIII Convegno G.N.G.T.S.*, Roma, 245–258.

Brocher T (2005) “Empirical relations between elastic wavespeeds and density in the Earth’s crust,” *Bull Seism Soc Am*, 95, 2081– 2092, doi:10.1785/0120050077.

Capuano P, De Natale G, Gasparini P, Pingue F. and Scarpa R (1988) “A model for the 1908 Messina Straits (Italy) earthquake by inversion of leveling data,” *Bull Seism Soc Am*, 78, 1930–1947.

De Natale G and Pingue F (1991) “A variable slip fault model for the 1908 Messina Straits (Italy) earthquake, by inversion of leveling data,” *Geophys J Int*, 104, 73–84, doi:10.1111/j.1365-246X.1991.tb02494.x.

Faenza L and Michelini A (2010) “Regression analysis of MCS intensity and ground motion parameters in Italy and its application in ShakeMap,” *Geophys J Int*, 180, 1138-1152, doi:10.1111/j.1365-246X.2009.04467.x

Pino NA, Giardini D and Boschi E (2000) “The December 28, 1908, Messina Straits, southern Italy, earthquake: Waveform modeling of regional seismograms,” *J Geophys Res*, 105, 25473–25492, doi:10.1029/2000JB900259.

Tuvè T, Bianco F, Ibáñez JM, Patané D, Del Pezzo E and Bottari A (2006) “Attenuation study in the Straits of Messina area (Southern Italy),” *Tectonophysics*, 421, 173-185, doi:10.1016/j.tecto.2006.04.005.