Integrating Faults and Past Earthquakes into a Probabilistic Seismic Hazard Model for Italy

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ABSTRACT

Italy is one of the most seismically active countries in Europe. M derate to strong earthquakes, with magnitudes of up to ~7, have been recorded on many of active faults in historical times. In our model, we used two categories of earthquake sources. The first involves active faults, and fault slip rates were used to quantify the seismic activity rate. We produced an inventory of all fault sources, with details on their geometric, kinematic and energetic properties. The parameters are used to compute the total seismic moment rate for each fault. We evaluated the magnitude-frequency distributions of each fault source using two models, a characteristic Gaussian model centred on the maximum magnitude and a Truncated Gutenberg-Richter model. The second earthquake source category involves distributed seismicity, and a fixed-radius smoothed approach and a historical catalogue were used to evaluate seismic activity. Under the assumption that deformation is concentrated along faults, we combined the earthquakes derived from the geometry and slip rates of active faults with the earthquakes from the spatially smoothed earthquake sources and assumed that the smoothed seismic activity in the vicinity of an active fault gradually decreases by a fault-size driven factor. We computed horizontal peak ground acceleration maps for return periods of 475 and 2,475 yr. Our model is characterized by areas that are more hazardous and that correspond to mapped active faults. We think our model represents an advance for Italy in terms of input data (quantity and quality) and methodology in the field of the fault-based regional seismic hazard modelling.

1. FAULT SOURCE

The model proposed here combines a fault source model based on over 110 faults (Fig.1 and Fig. 2) with 86 fault sources (Fig. 3) and a distributed source model. For each fault source, the maximum magnitude and its uncertainty has been derived by applying scaling relationships, and the rates of seismic activity have been derived by applying slip rates to seismic moment evaluations and balancing this seismic moment over two magnitude-frequency distributions (Fig. 2).

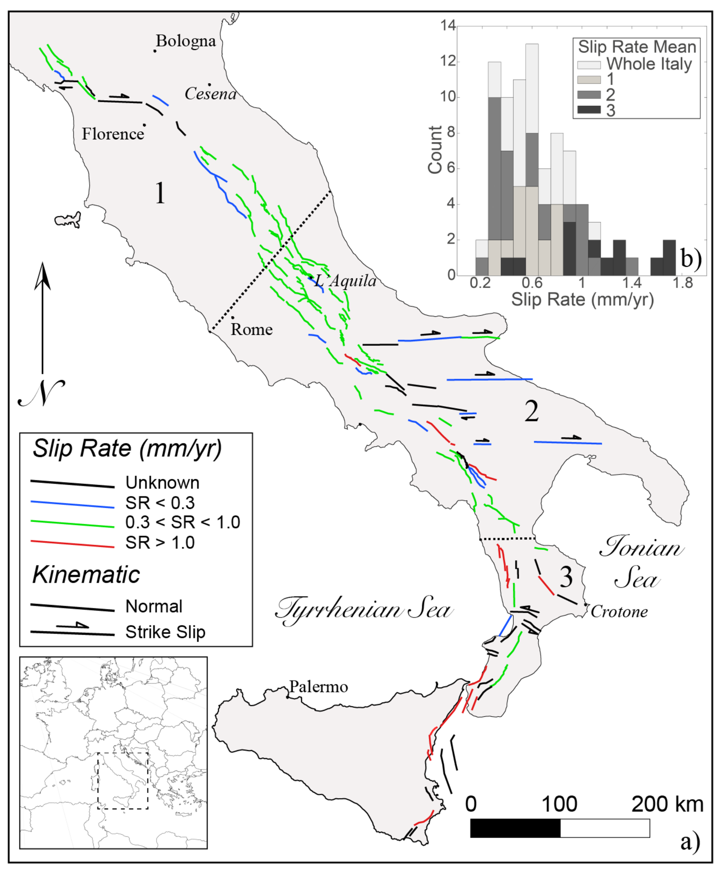


Fig. 1 a) Map of normal and strike-slip active faults used in this study. Colour scale indicates slip rate. **b)** Histogram of slip rate distribution for the whole study area and for three sub-sectors. The numbers 1, 2 and 3 are for the Northern Apennines, Central-Southern Apennines and Calabria-Sicilian coast regions, respectively. The dotted black lines are the boundaries of the regions.

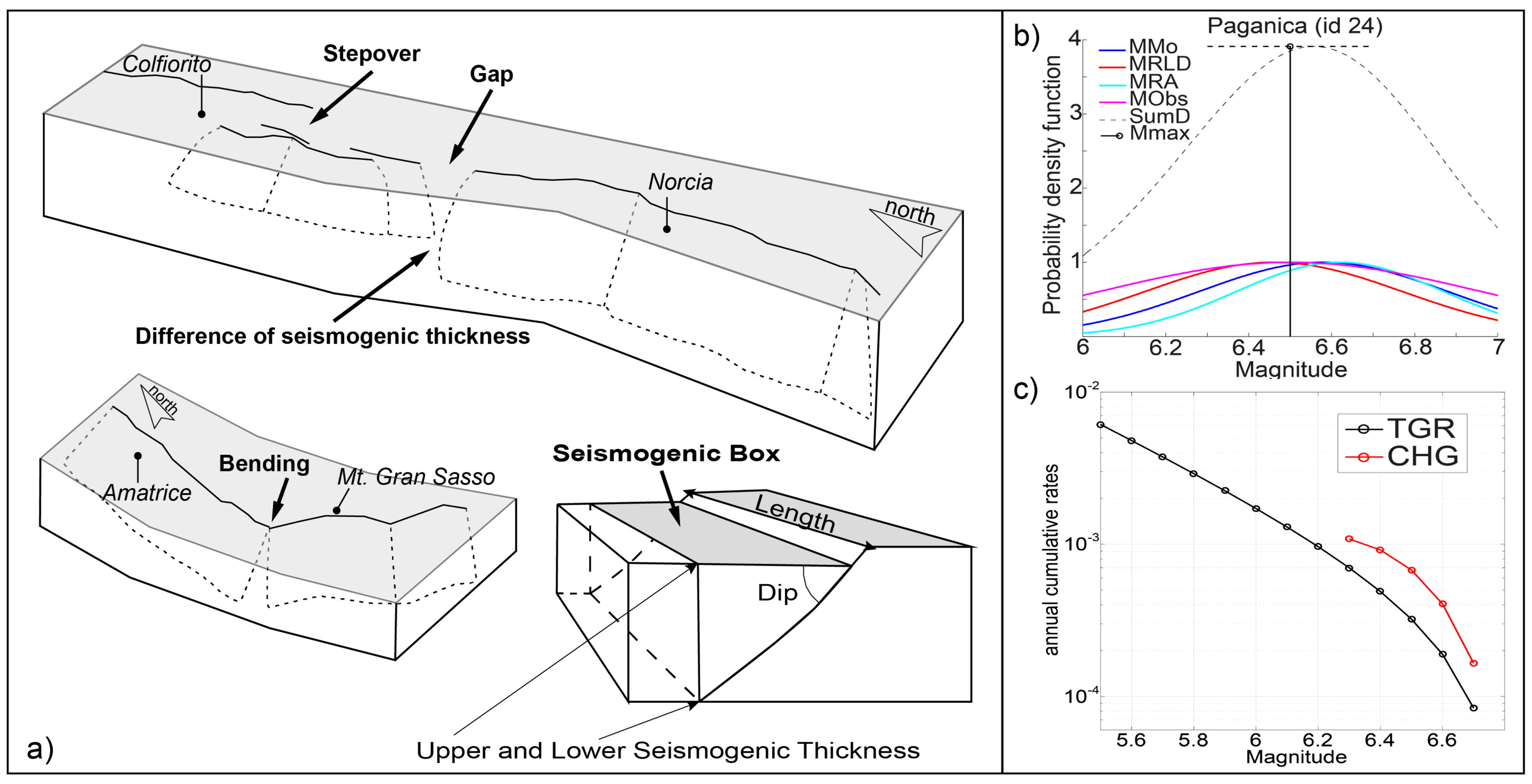


Fig. 2 a) Conceptual model of active faults and segmentation rules adopted to define a fault source and its planar projection, forming a seismogenic box [modified by Boncio et al., 2004]. **b)** Example of FiSH code output (see Pace et al., 2016 for details) for the Paganica fault source, showing the combination of magnitude estimates from empirical relationships and observations, both of which are affected by uncertainties. In this example, four magnitudes are estimated: MMo (blue line) is from the standard formula (IASPEI, 2005); the maximum subsurface fault length (MRLD, red line) and maximum rupture area (MRA, cyan line) are from the empirical relationships of Wells and Coppersmith (1994) for length and area, respectively; and Mobs (magenta line) is the largest observed moment magnitude. The black dashed line represents the summed probability density curve (SumD), the vertical black line represents the central value of the Gaussian fit of the summed probability density curve (Mmax), and the horizontal black dashed line represents its standard deviation (σMmax). **c)** Comparison of the magnitude–frequency distributions for the Paganica source, which were obtained using the Characteristic Gaussian model (CHG, red line) and the Truncated Gutenber-Richter model (TGR, black line).

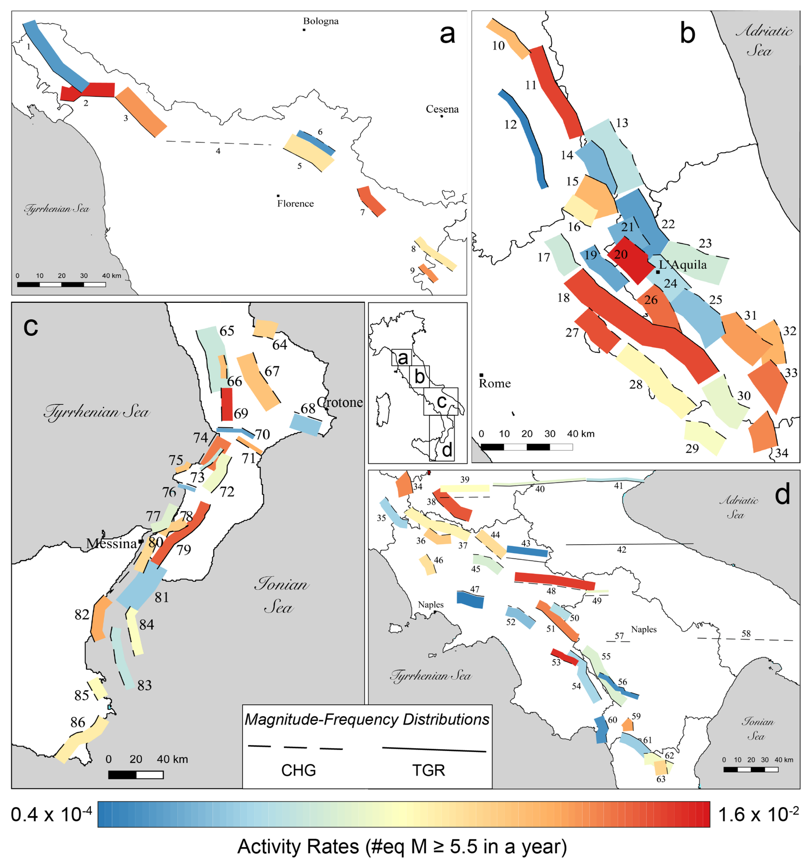


Fig. 3 Maps showing the fault source model as seismogenic boxes (see Fig. 2a). Colour scale indicates activity rate. Solid and dashed lines (in correspondence of the uppermost edge of the fault) are used to highlight our choice between the two end-members of magnitude-frequency distributions adopted here for the so-called Mixed model.

2. DISTRIBUTED SOURCE

To account for unknown faults, a distributed seismicity model has also been applied following the well-known Frankel (1995) methodology for the calculation of seismicity parameters.

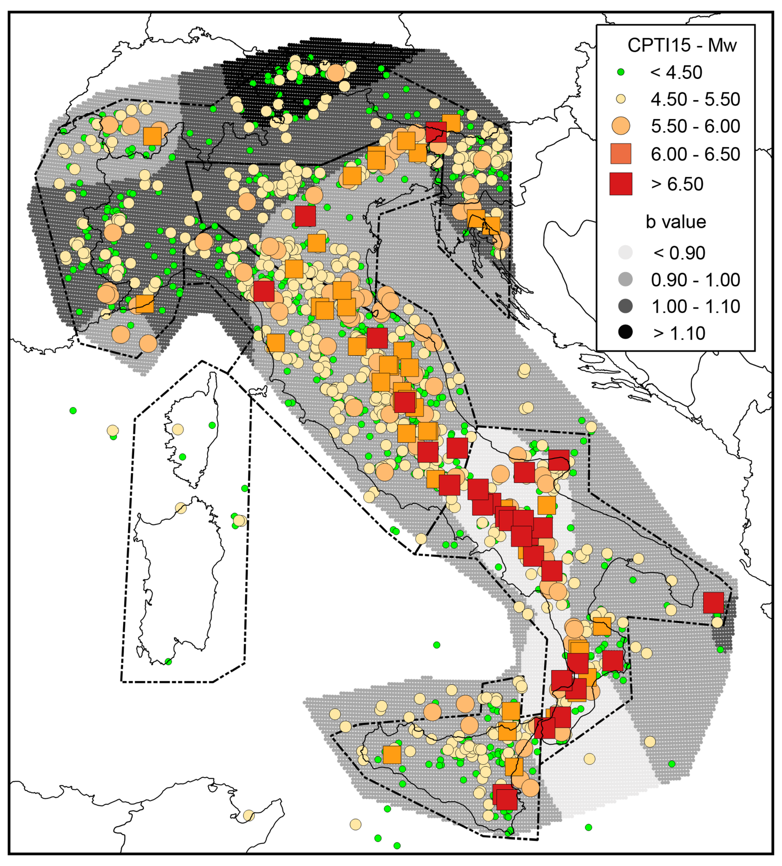


Fig. 4 Historical earthquakes from the most recent version of the historical parametric Italian catalogue (CPTI15, Rovida et al., 2016), the spatial variation in b-values and the polygons defining the five macroseismic areas used to assess magnitude completeness intervals.

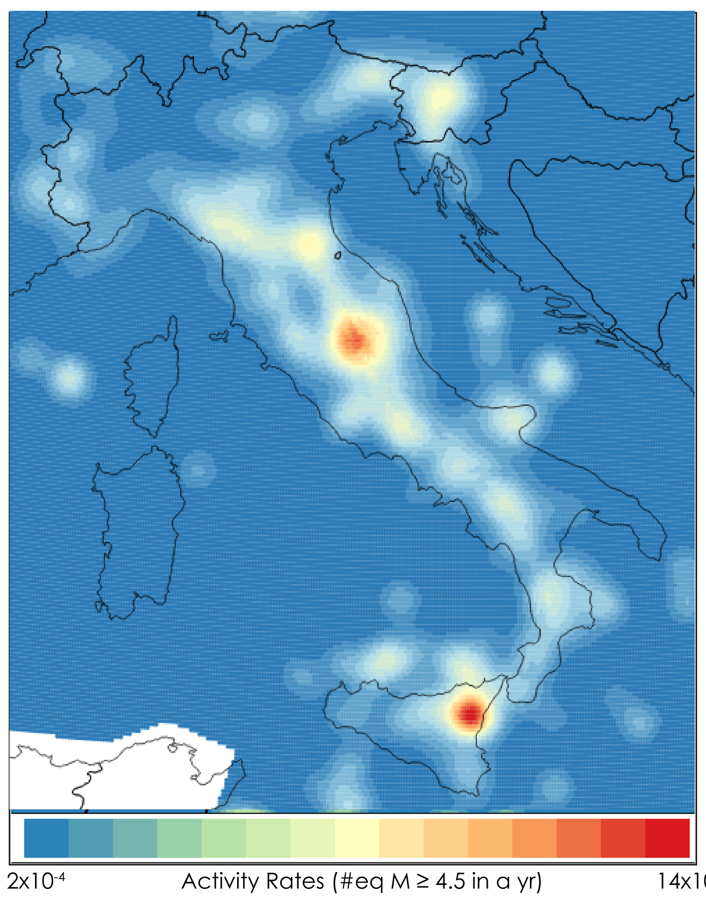


Fig. 5 Earthquake rates computed for a 0.05° latitude/longitude spacing grid following the standard approach proposed by Frankel (1995) using the last italian earthquake catalog (CPTI15). The grid is made by 45,602 nodes and for each node we computed a Truncated Gutenberg-Richter magnitude frequency distribution to obtain the seismicity rates.

3. MAGNITUDE-FREQUENCY DISTRIBUTION

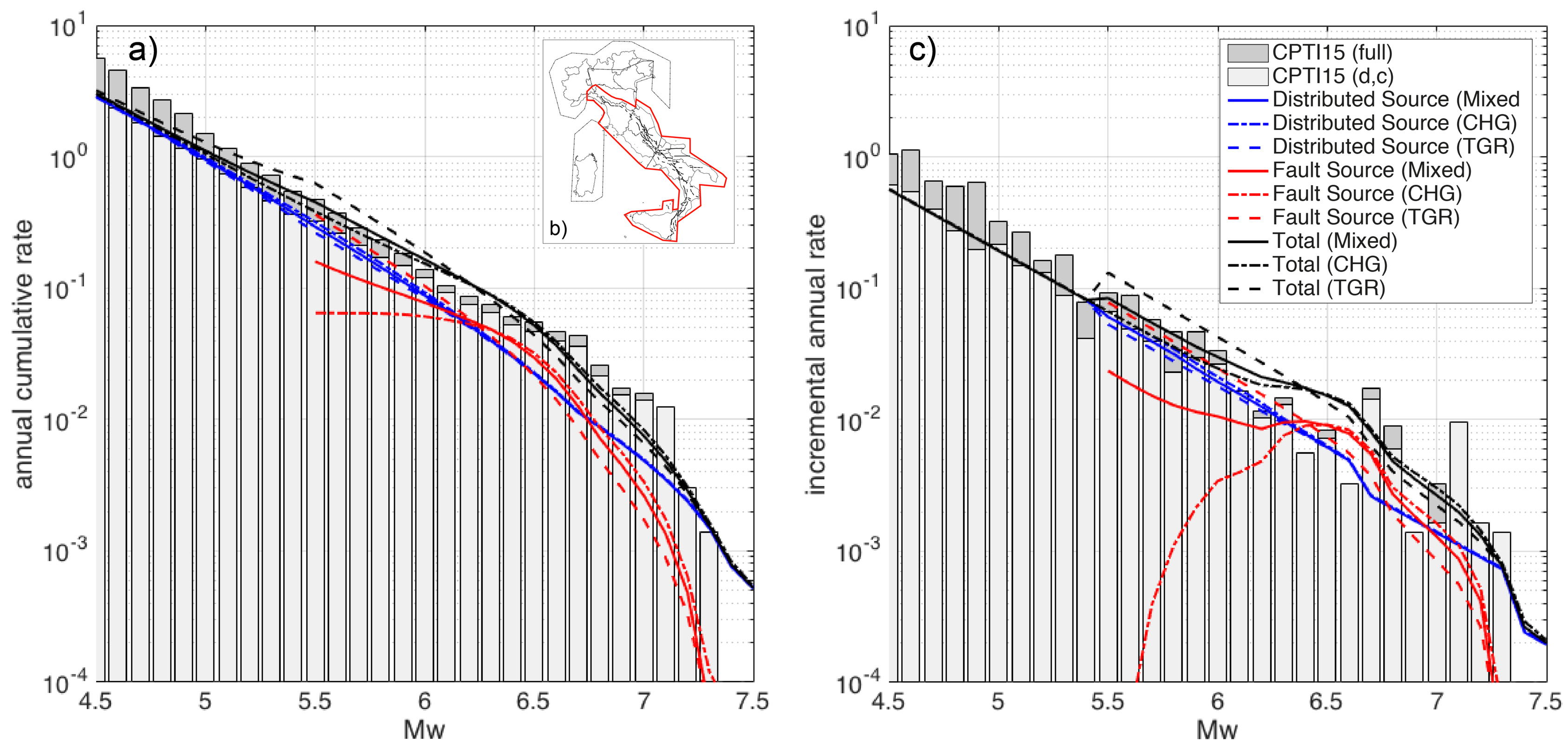
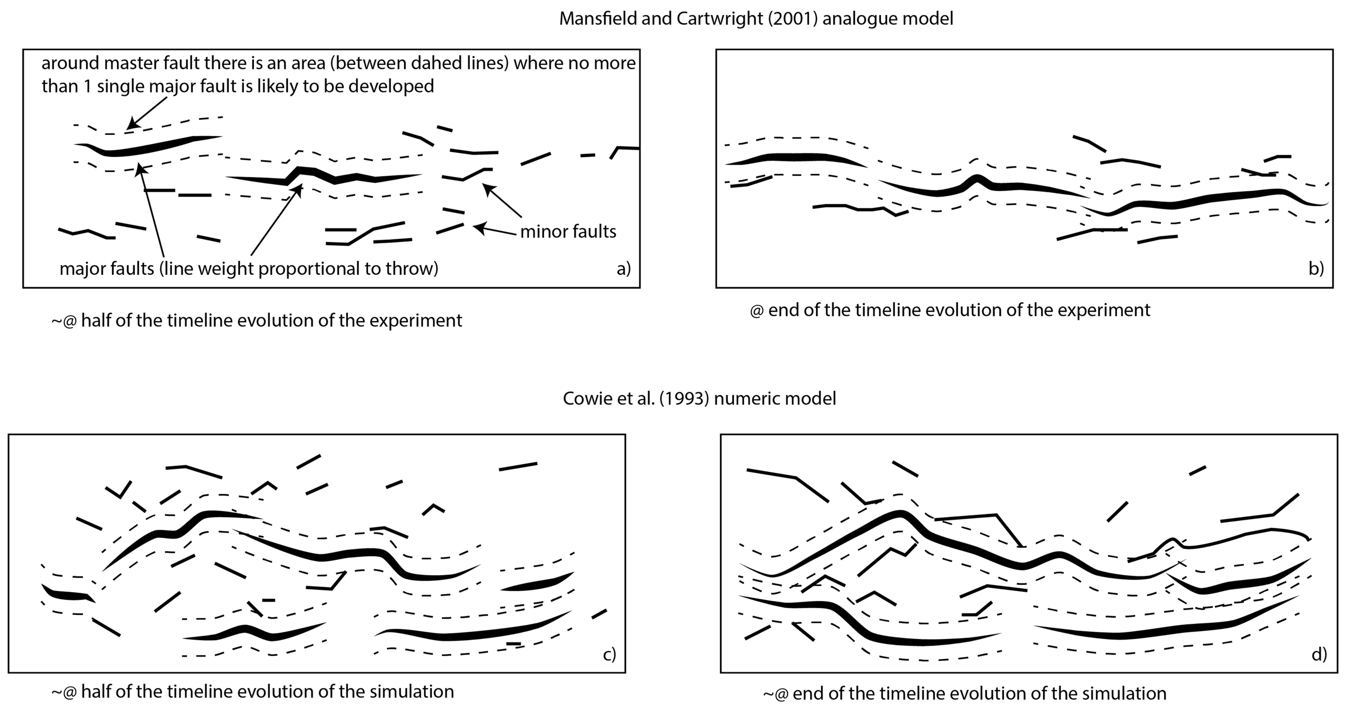
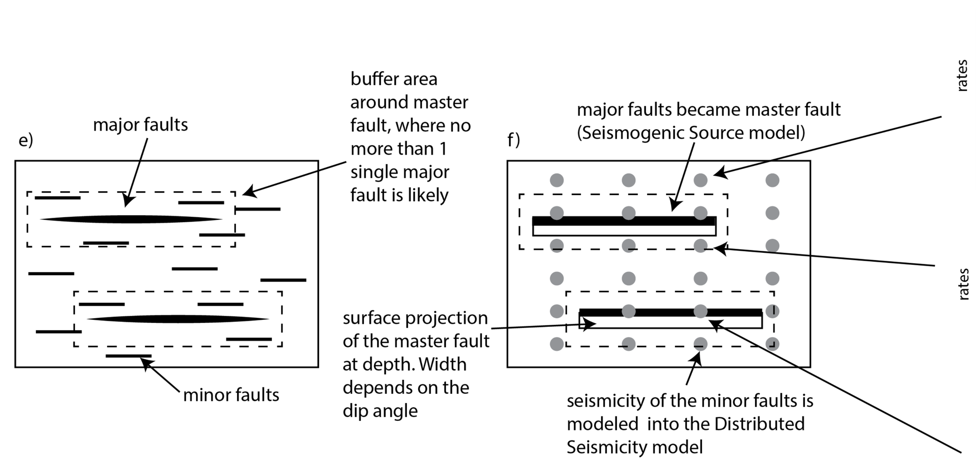


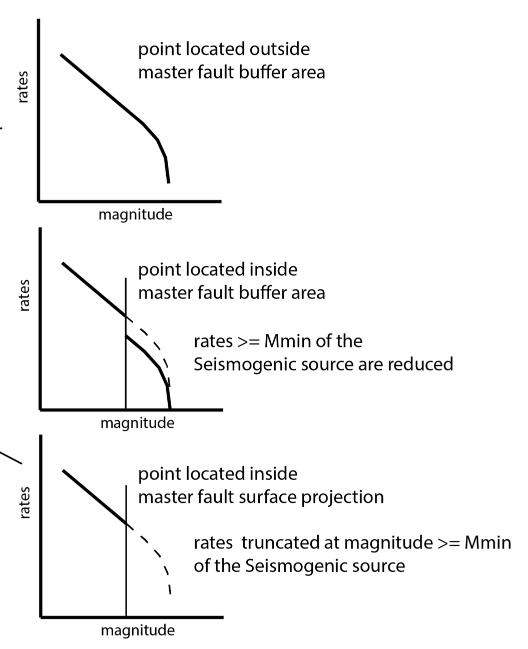
Fig. 6 a) annual cumulative rate and c) incremental annual rate computed for the red bounded area in b). The rates have been computed using: (i) the full CPTI15 catalogue; (ii) the declustered and complete catalogue (CPTI15 (d, c) in the legend) obtained using the completeness magnitude thresholds over different periods of time given by Stucchi et al. (2011) for five large zones; (iii) the distributed sources; (iv) the fault sources; and (v) summing fault and distributed sources (Total).

4. HOW TO COMBINE THE TWO SOURCE INPUTS

Fig. 7 The fault sources and distributed sources have been integrated via a new approach based on the idea that deformation in the vicinity of an active fault is concentrated along the fault and that the seismic activity in the surrounding region is reduced.







5. RESULTS

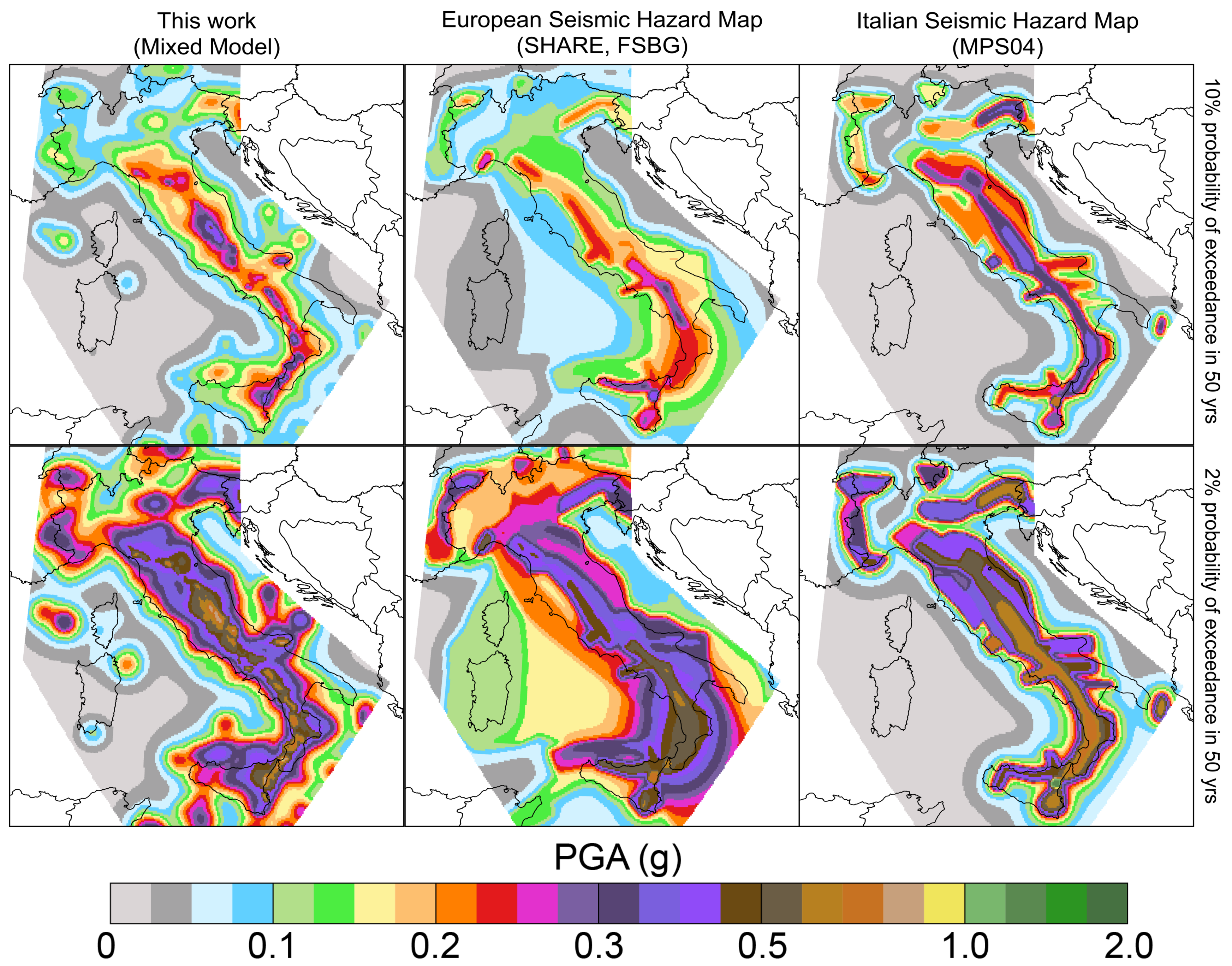


Fig. 8 Seismic hazard maps expressed in terms of Peak Ground Acceleration (PGA) and computed for a latitude/longitude grid spacing of 0.05° based on site conditions. The figure shows a comparison of our model (Mixed model, on the left), the SHARE model (FSBG logic tree branch, in the middle) and the current Italian national seismic hazard map (MPS04, on the right). The same GMPEs (Akkar et al. 2013, Chiou et al., 2008, Faccioli et al., 2010 and Zhao et al., 2006 and Bindi et al. 2014), were used for all models to obtain and compare the maps.

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