IMPORTANCE OF MAPPING DESIGN EARTHQUAKES: INSIGHTS FOR SOUTHERN APENNINES, ITALY

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The most complete analysis for the safety level of existing civil or strategic structures such as nuclear power plants, hospital, bridges or pipelines in a earthquake prone zone, from an engineering point of view requires nonlinear dynamic analysis. This type of analysis allows to account for several characteristics of the ground shaking, such as peculiar spectral shape, cumulative damage potential, nonstationarity and special effects, such as directivity-related velocity pulses. As a consequence, it requires a detailed modeling of the structure and a proper selection of seismic input. The selection of the time series from a given database, or their simulation through ad-hoc techniques, requires that an appropriate earthquake (i.e., magnitude and source-to-site distance), defining the “design earthquake”, would be identified (Iervolino et al. 2008). In the current practice, selection of real records for seismic design of structures is based on the uniform hazard spectrum (UHS). The UHS is a multi-parameter description of ground motion generated from probabilistic seismic hazard and is made up of spectral ordinates that have the same probability of being exceeded in a given time interval depending on the limit state of interest (i.e., 10% probability of exceedance in 50 years). Once the UHS has been defined, the waveform selection proceeds with the disaggregation of seismic hazard (Bazzurro and Cornell, 1999), by magnitude (M) and distance (R). Disaggregation is based on the computation of the relative contributions to seismic hazard of different seismogenic zones characterized by their geometries, recurrence relationships and maximum magnitude. Those contributions are typically expressed in terms of probability density functions of M, R and ε (epsilon – defined as the number of logarithmic standard deviations by which the logarithmic ground motion deviates from the median predicted by an appropriate attenuation relationship) conditional to the level of spectral acceleration for which the hazard is being disaggregated is exceeded. The analysis of these PDFs, allows to define the “design earthquake” identifying some values of the variables giving the largest contribution to disaggregated hazard or considered representative in some other statistical sense (e.g., mean or modal values of M, R and ε).The study herein presented investigates the implications of mapping the design earthquake for the Campania region in the Southern Apennines (Italy) for spectral acceleration at different oscillation periods. In fact, the data made publicly available for Italy by Istituto Nazionale di Geofisica e Vulcanologia (INGV) (Gruppo di Lavoro MPS 2004), provides disaggregation for peak ground acceleration (PGA) only; on the other hand short and long period portions of the UHS may be differently contributed by M and R (Reiter, 1990).The results allow to assess how various portion of the design spectrum are differently contributed by sources in the test area and whether disaggregation for PGA is generally sufficient to obtain a representation of hazard-dominating earthquakes for structural risk assessment.

The first step in the analysis consisted in the computation of the hazard maps relative to the seismic zones shown in Fig.1. The zones have been selected from the zonation ZS9 (Meletti et al., 2008) and the main parameters are listed in Tab. 1. The hazard maps have been computed for PGA, and one spectral ordinate (Sa) at natural period T=1.0 sec for TR= 475 years return period.

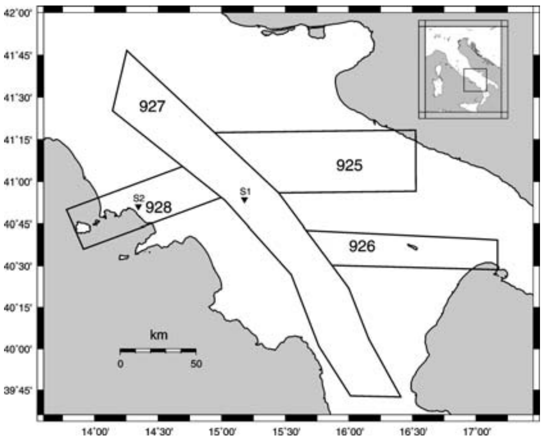

Fig. 1 – Seismogenic zones configuration for Southern Apennines, Italy.

Tab. 1 - Parameters of the selected seismic source zones shown in the Fig.1.

Zone	α (events/year)	*b*	M_{max}
925	0.17	-0.75	6.83
926	0.09	-1.38	6.14
927	0.69	-0.72	7.06
928	0.21	-0.66	5.91

A massive computation of the hazard levels has been used with a very fine sampling rate both on distance (dr=1.0 km), magnitude (dm=0.05) and ε ($d\varepsilon$=0.2). This setting parameter would avoid the problems linked with the interpolation generally used to produce the hazard maps and, from a disaggregation point of view, would limit problems linked with the selection of the bin used to collect the relative contribution of the hazard variables.

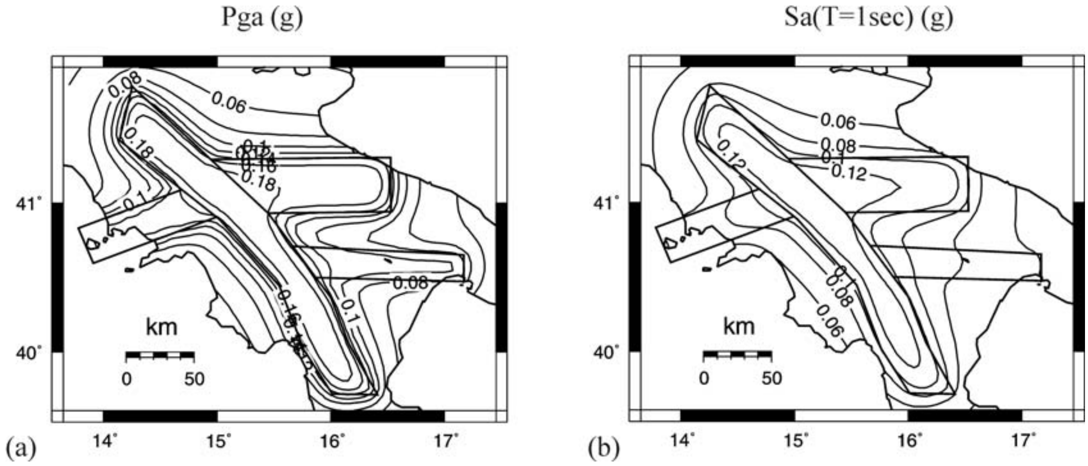

Fig. 2 – Hazard maps for Southern Apennines, Italy. Panel a shows PGA values expressed in g. Panel b shows the values of Sa(T=1 sec) expressed in g.

Panel a of Fig.2 shows the hazard map for PGA expressed in g while panel b shows the map of Sa(T=1sec). Due to the input parameters the most hazardous seismic zone is the 927. The hazard maps show larger values PGA compared with Sa(T=1sec).

After computing the hazard maps, for each site, by using the same sampling as for the hazard computation, the corresponding hazard level was disaggregated for the return period TR=475 years. The corresponding disaggregated values are reported on the map shown in Fig. 1 representing the design earthquake map.

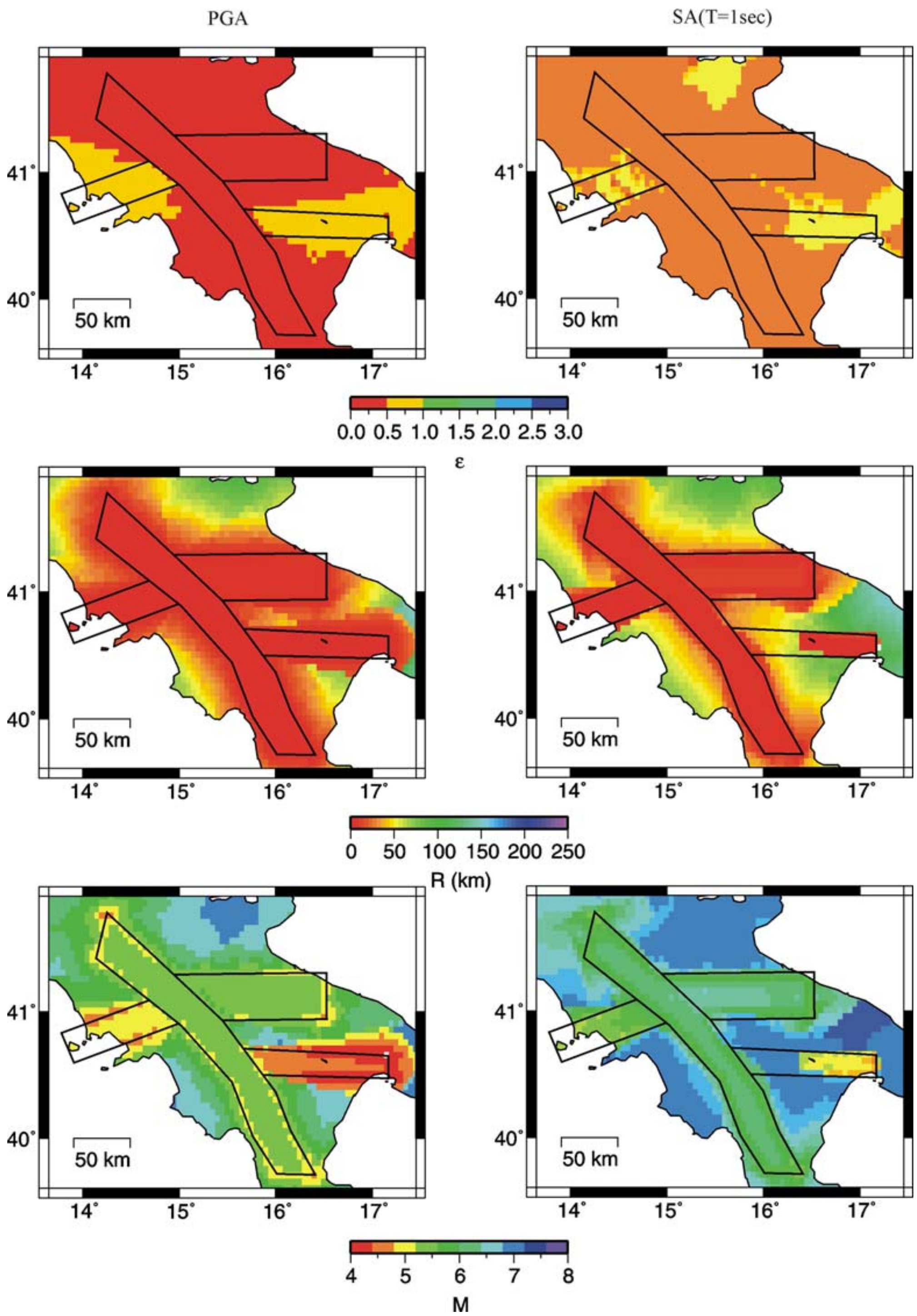

Fig. 3 – Design earthquake map obtained from the modal value of the joint PDF.

Fig. 3 shows the design earthquake map in terms of magnitude, distance and ε corresponding to the modal value of the joint PDF obtained from disaggregation. In particular, left panels refer PGA while right panels refer to Sa(T=1 sec).
The results have a strong correlation with both the geometry of the seismic zones and the maximum magnitude values selected for each zone. As general consideration, it can be noticed that, a single design earthquake cannot be selected for both PGA and Sa (T=1sec) for the study area. Looking at the design earthquake maps, the hazard variable that must be carefully analyzed is the magnitude. In particular, larger magnitude values are required to explain target values for Sa(T=1 sec) with respect to PGA. Another interesting feature enlightened from the perfomed analysis concerned the bimodality of the disaggregated PDFs. In particular, from the analysis of both joint and marginal PDFs it can be noticed that for large part of the study area two maxima exist that can equivalently explain the hazard level.

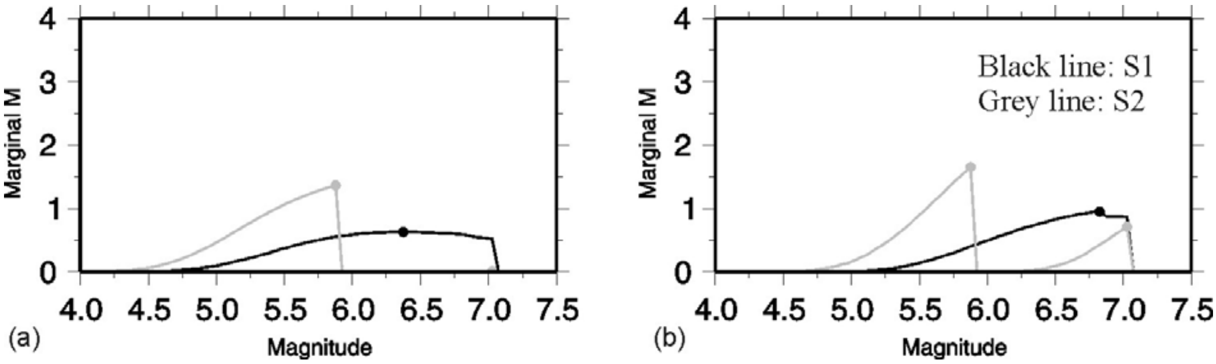

Fig. 4 – Test site analysis for bimodality of disaggregated PDFs. Sites are shown in Fig.1. Panel a refers to PGA while panel b refers to Sa(T=1sec).

As an example, Fig. 4 shows the marginal PDFs on the magnitude for the two sites reported in Fig. 1 obtained from disaggregation of PGA and Sa(T=1 sec). Particularly for Sa(T=1 sec) and site S2, a secondary maximum is present providing a contribution to the hazard a similar to that of the first maximum.

References

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