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NSHA Seismic Zoning for the Territory of Kosovo

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Abstract: Recent lessons learnt from the latest destructive earthquakes including earthquakes, provided new insights on the seismic destruction that emphasized the need to take action and revise and improve the procedure for Seismic Hazard Assessment (SHA). In fact, the need of establishment of formal procedure for consistent and proper collection and evaluation of SHA results, so, community may benefit from the scientific studies and may not be misled by the existing incorrect hazard assessment results. In fact, recent destructive earthquakes demonstrate that a single hazard map cannot meet the requirements from different end-users. Therefore, for NDSHA is need to du NSHA seismic zoning.

Key words: Hazard, seismic, earthquake, seismogene zone, emphasized, requirements

INTRODUCTION

Seismic hazard assessment can be performed following a Neo-deterministic Approach (NDSHA) which allows to obtain a realistic description of the seismic ground motion due to an earthquake of given distance and magnitude. The procedure for neo-deterministic seismic zoning is based on the calculation of synthetic seismograms (Al-Attar, 2007). It can be applied also to areas that have not yet been hit by a catastrophic event in historical times but are potentially prone to it.

In the NDSHA approach, the definition of the space distribution of seismicity accounts only for the largest events reported in the earthquake catalogue at different sites as follows. Earthquake epicenters reported in the catalogue are grouped into cells, assigning to each cell the maximum magnitude recorded within it. A smoothing procedure is then applied to account for spatial uncertainty and for source dimensions. Only cells located within the seismogenic zones are retained and if the resulting magnitude (Berril and Davis, 1980). In each cell is lower than 5 a magnitude 5 (Berge-Thierry *et al.*, 2003) is assigned by default. This choice is based on the hypothesis that wherever a seismogenic zone is defined, damaging earthquakes may occur and the value of 5 is conventionally taken as the lower bound for the magnitude of damaging earthquakes. This procedure for the definition of earthquake locations and magnitudes for NDSHA makes the method pretty robust against uncertainties in the earthquake catalogue which is not required to be complete for magnitudes lower than 5. The neodeterministic method allows to quantitatively model the effects of an earthquake which may happen in the future and therefore is a very effective technique in seismic hazard assessment, even in the regions with scarce or no historical or instrumental information available.

The NDSHA is based on modeling techniques, developed from knowledge of the seismic source process and of the propagation of seismic waves, that can realistically simulate the ground motion due to an earthquake by means of synthetic seismograms. At the regional scale a set of sources is defined in the tectonically active areas of the considered region. From these sources and once the physical properties of average structural models have been defined, wave propagation is efficiently modeled with the modal summation technique and broadband synthetic seismograms are generated at the free surface on a predefined grid of points covering the study region. Such kind of large set of realistic time series constitutes a valuable database that can be used by civil engineers for the reliable definition of the seismic input when designing seismo-resistant structures. A summarizing view of the expected ground shaking can be easily produced for the considered region by mapping the

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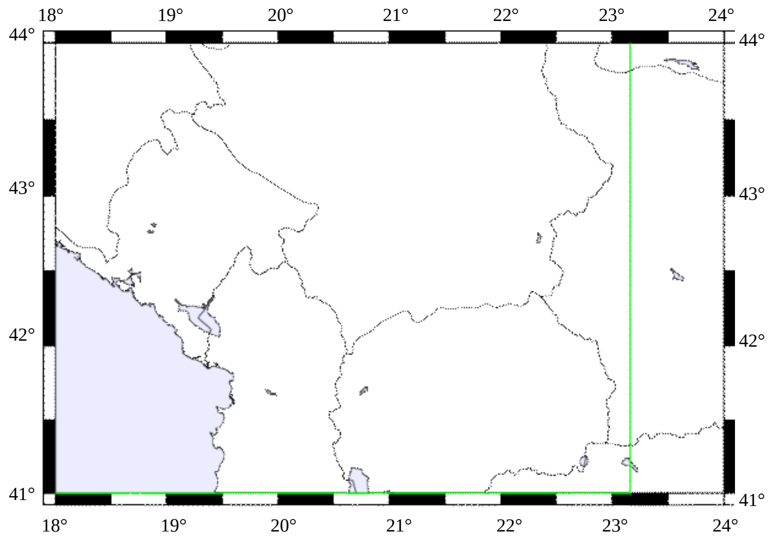

Fig. 1: Considered region is within the green border lines

peak values extracted from the synthetic seismograms in terms of displacements, velocities and accelerations. The NDSHA methodology is still evolving and the computer codes are being constantly improved, since, the original implementation to better fit the need of producing realistic ground shaking maps and ground shaking scenarios at different scale levels by incorporating all relevant progresses in the knowledge of geological processes and their numerical modeling (reduction of epistemic uncertainty). Among the most relevant changes recently implemented to the algorithm are (Gvishiani *et al*., 1977; Capdeville, 2005):

- Code optimization which leads to a speedup in the computations by a factor of about 6
- The possibility to consider very realistic source models that account for the rupture characteristics at the fault, directivity included
- The option to consider sources distributed not only within the seismogenic zones but also in the nodes identified by the morphostructural zonation (Gvishiani *et al*., 1977)
- The option to compute the synthetic seismograms with a maximum frequency content of 10 Hz
- The option to compute ground shaking maps also for the vertical component

The flow chart of the current implementation of the procedure is shown in Fig. 1. In any modelling, the quality of the results depends on the quality of the input data. In the following, the results of several different variants of the input data and of the execution parameters have been mainly obtained with:

- The adoption of different seismogenic zones (Aliaj *et al*. 2004) and earthquake catalogs
- The inclusion of the nodes in the definition of the considered sources
- The choice of the structural models used for wave propagation
- The choice of the cutoff frequency in the computation of synthetic seismograms (Capdeville, 2005)

MATERIALS AND METHODS

Input data: The considered region for which the calculations were performed is shown on Fig.1 and it includes territory of Kosovo and parts of neighboring countries that are characterized with existence of seismic zones that have significant seismic activity that also affects the seismic hazard potentioal of Kosovo. This region includes the significant seismic sources of Peshkopeja in Albanija, Debar and Skopje in Macedonia, Kopaonik and Kraljevo in Serbia (Fig. 1).

The sources are distributed within the seismogenic zones shown in Fig. 2 and they are treated as Size Scaled Point Sources (SSPSs). Sources belonging to the same seismogenic zone share the representative focal mechanism associated with the zone itself (Fig. 3). The study area has been subdivided in to 16 regions. For NDSHA assessment for the territory of Kosovo, that is represented with the poligon given on Fig 4, two different calculations were performed, first using devision of the considered region in $0.2°\times0.2°$ cells and the second case when the territory was devided in $0.1°\times0.1°$ cells

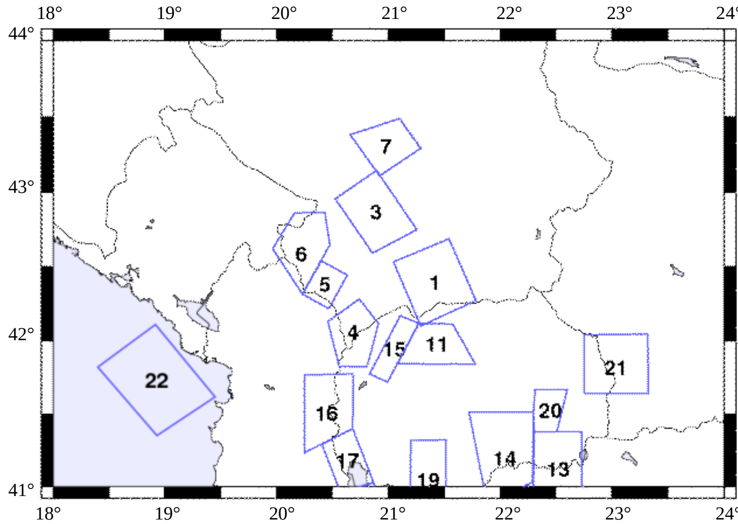

Fig. 2: Seismic zones included in the calculations

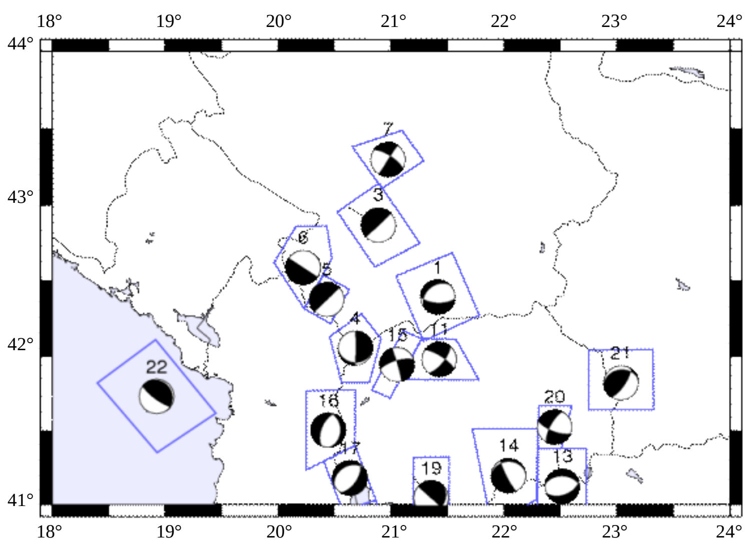

Fig. 3: Representative focal mechanism associated with the seizmogene zones

(Fig. 5 and 6). In this way the number of points in which the computation of synthetic accelerograms will be performed is defined.

RESULTS AND DISCUSSION

Smoothed seismicity: For the calculations of seismicity of the region using the neo-deterministic procedure, following input data were used:

- The part of the earthquake catalog BS-HAZ prepared for the wider region of SE region (events till 2003) updated with the events relevant for the region of Kosovo up to 2012
- The seismogenic zones defined for the territory of Kosovo as well as the seismic zones in border regions with neighboring countries that have significant contribution to the overall seismic hazard
- The focal mechanisms for earthquakes originating from all seismic sources that are included in the analysisq
- 1D layered an elastic bedrock models prepared for territory of Kosovo

In the NDSHA approach, the definition of the space distribution of seismicity accounts only for the largest

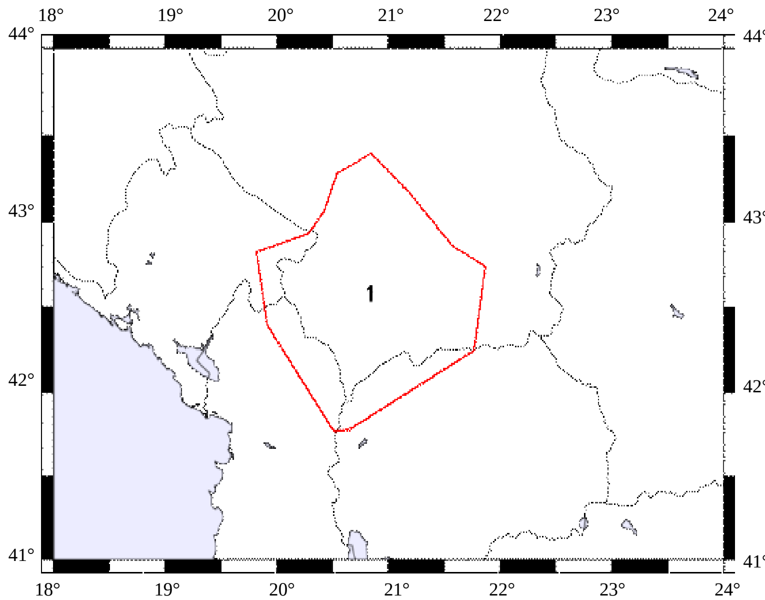

Fig. 4: Poligon representing the region considered in the computation

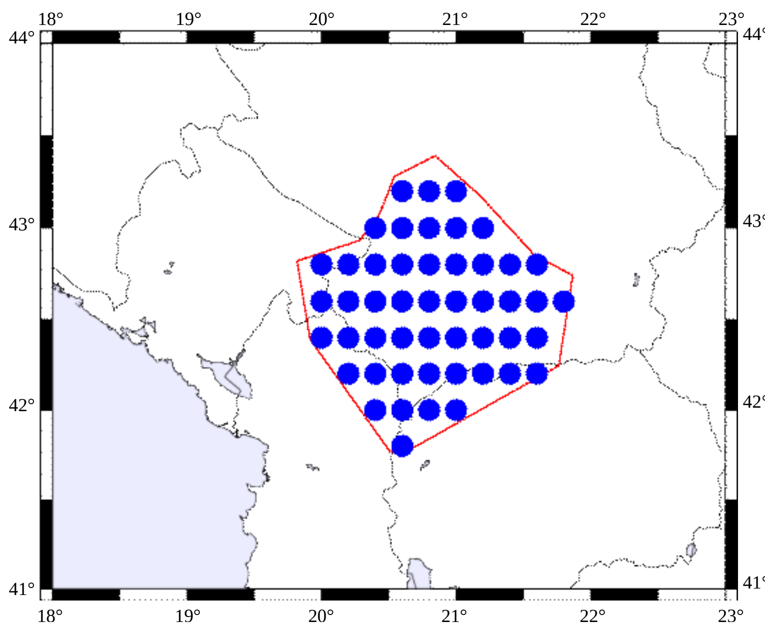

Fig. 5: Grid points for which the ground shaking will be computed for 0.2°×0.2° cells

events reported in the earthquake catalogue at different sites. Earthquake epicenters reported in the catalogue are grouped into 0.2°×0.2°/0.1°×0.1° cells, assigning to each cell the maximum magnitude recorded within it. A smoothing procedure is then applied to account for spatial uncertainty and for source dimensions. Only cells located within the seismogenic zones are retained. This procedure for the definition of earthquake locations and magnitudes for NDSHA makes the method pretty robust against uncertainties in the earthquake catalogue which is not required to be complete for magnitudes lower than 5. A double-couple point source is placed at the center of each cell with a focal mechanism consistent with the properties of the corresponding seismogenic zone and a depth which is a function of magnitude (Fig. 7-9). Further on, the smoothed seismicity for each seismogenic

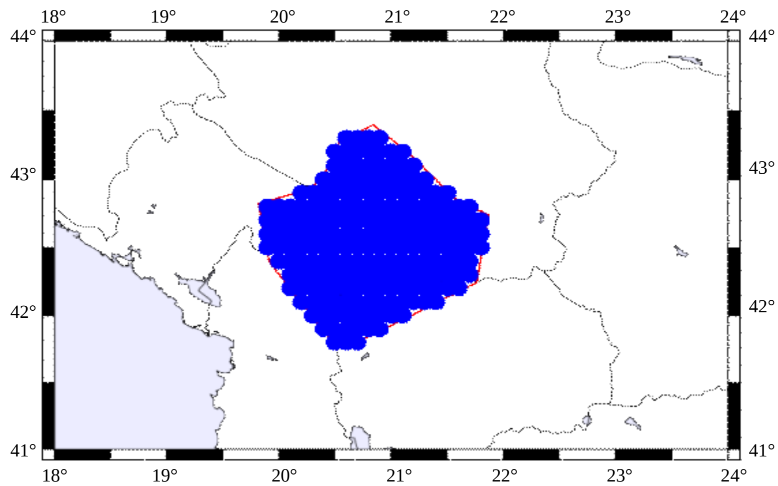

Fig. 6: Grid points for which the ground shaking will be computed for 0.1°×0.1° cells

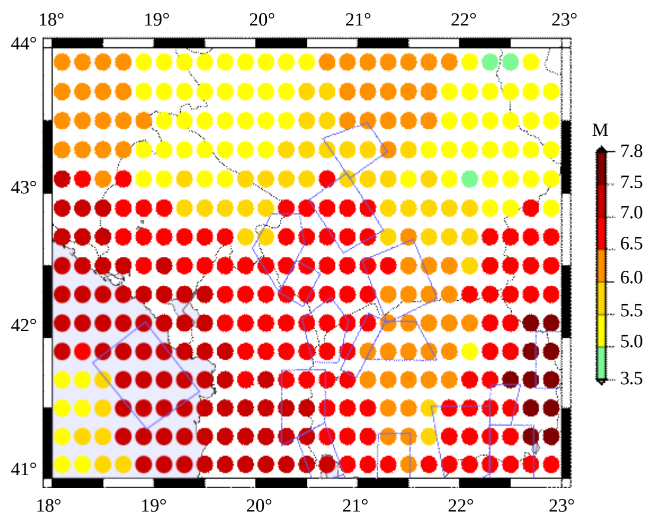

Fig. 7: Smoothed seismicity for 0.2°× 0.2° cells for the region as a whole

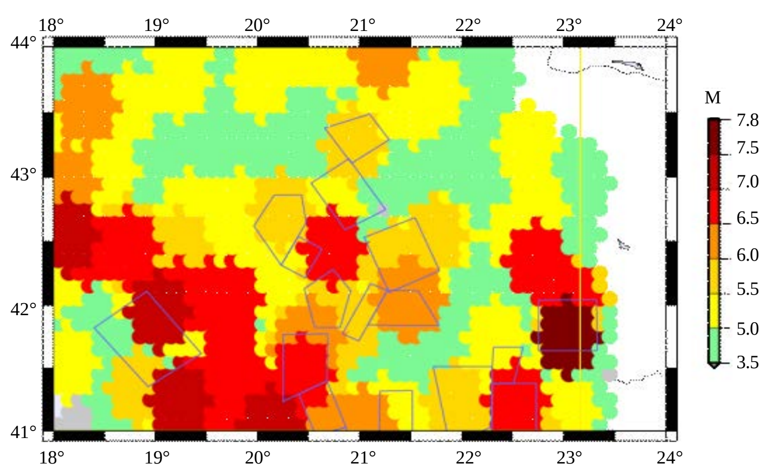

Fig. 8: Smoothed seismicity for 0.1°×0.1° cells for the region as a whole

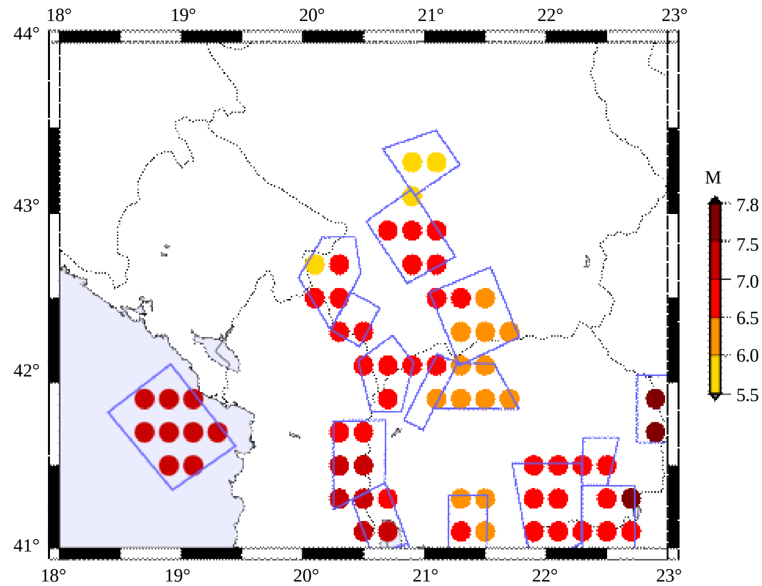

Fig. 9: Smoothed seismicity within seismogenic zones (sources) for 0.2°×0.2° cells

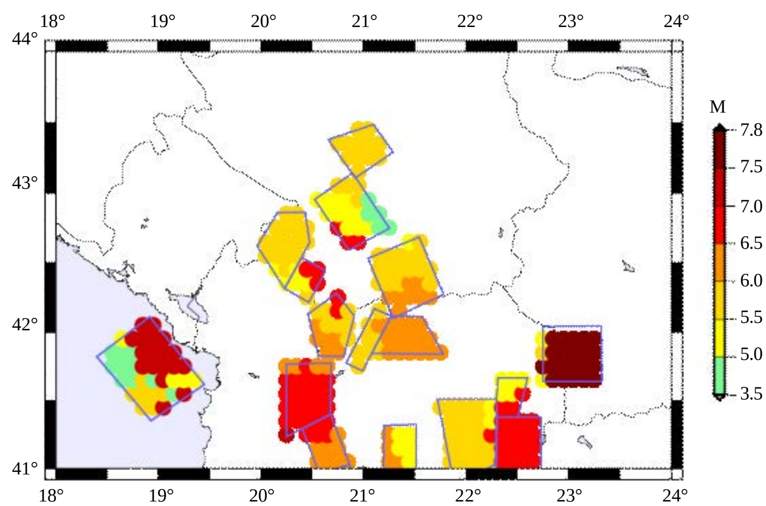

Fig. 10: Smoothed seismicity within seismogenic zones (sources) for 0.1° ×0.1° cells

zone that was taken into account to participate in seismic hazard was calculated and presented on Fig. 9 and 10 for both cases, respectively.

CONCLUSION

The input data are as follows catalogue of earthquakes for the territory under investigation, structural models for the crust and upper mantle under the separate seismogene zones and the fault-plane solutions for the referenced earthquakes with the (best) reliable seismological data.

Synthetic seismograms are computed using method of normal mode summation (up to 1 Hz) for receiver sites on 0.2°×0.2°/0.1°×0.1° (two cases) and scaled to the magnitude of the maximum expected earthquake. The second important element is that there are no such types of maps that are the basis for urban planning in seismically active regions as is the territory of Kosovo in this case. The neighboring countries (Macedonia, Bulgaria, Albania and Greece) have deterministically elaborated seismic hazard maps already for a longer period of time. This will cover the "gap" in this part of the Balkan Peninsula. Such an analysis was done for this region for the first time. Its upgrading will be done after a certain period of time. The practical limits to the use of PSHA analysis for adequate structural design and in general for seismic risk mitigation are clearly outlined by the comparative analysis of PSHA and NDSHA estimates.

The estimates of seismic hazard obtained according to the NDSHA and to the probabilistic (PSHA) approaches have been compared for the Kosovo territory. The NDSHA provides values larger than those given by the PSHA in high-seismicity areas and in areas identified as prone to large earthquakes while lower values are provided in low-seismicity areas.

Besides the standard NDSHA estimates, the flexibility of the neo-deterministic approach permits to account for earthquake recurrence and eventually allows for the generation of ground shaking maps at specified return periods (i.e., probability of exceedance). This permits a straightforward comparison between the NDSHA and the PSHA maps which provide the hazard estimates in terms of probability of exceedance of a given threshold of ground motion at a specific site.

One of the most important advantages of the NDSHA approach is the capability to incorporate in a rather straightforward way, the newly available geophysical data and new advanced methods in seismological and geophysical data analysis. The proposed approach complements the traditional approach to seismic hazard estimates, since, it supplies routinely updated information that can be useful in assigning priorities for timely mitigation actions and hence it is particularly relevant for civil defence purposes.

To define the physical properties of the source-site paths, the territory is divided into cells, each characterized by a structural model composed of flat, parallel anelastic layers that represent the average lithosphere properties at regional scale. Synthetic seismograms are then computed by the modal summation technique for sites placed at the nodes of a grid with step $0.2°\times0.2°/0.1°\times0.1°$ that covers the national territory, considering the average structural model associated to the regional polygon that includes the site. Seismograms are computed for an upper frequency content of 1 Hz which is consistent with the level of detail of the regional structural models and the point sources are scaled for their dimensions using the spectral scaling laws. To test the stability of the results, the neo-deterministic procedure has been executed several times adopting different input data sets for the definition of the source and of the structural properties.

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