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DIRECTIVITY EFFECTS OF STRONG GROUND MOTIONS FROM VRANCEA SUBCRUSTAL EARTHQUAKES

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This study deals with the analysis of the measures of horizontal ground motion which are not dependent on the orientation of the in-situ seismic sensors. Beyer and Bommer (2006), Boore et al. (2006) and Boore (2010) have defined or tested new measures which combine the horizontal components (response spectra or the recorded time series) of the ground motion. Some of these measures are applied in this study on a strong ground motion database which consists of over 300 horizontal components recorded in Romania, Bulgaria and Moldova during several Vrancea subcrustal earthquakes (Table 1). The database was assembled for the BIGSEES national research project (http://infp.infp.ro/bigsees/default.htm). The aim of the study is to investigate whether there is any directivity or regional pattern visible on the horizontal components of the strong ground motion and to relate the measures of the horizontal ground motion with the earthquake rupture propagation direction.

It is noteworthy the fact that usually the rupture of typical subcrustal Vrancea earthquakes propagates on the NE-SW direction which is parallel to the Carpathian Mountains. However there are some seismic events, (e.g. the earthquake of May 31, 1990) which reveal ruptures propagating on a perpendicular direction to the Carpathian Mountains.

Analysis of focal mechanisms of the strongest Vrancea earthquakes shows a thrust type of motion, with horizontal compression and vertical extension Radulian et al. (2000). The predominant type of motion is characterized by the NE–SW oriented rupture plane and maximum compression in the perpendicular direction. This is the typical mechanism for all the earthquakes with magnitude ~ 7 or larger. As we consider smaller events, the majority of them preserves the reverse faulting type with principal axis of extension close to vertical, while the orientation of the principal axis of compression shows a larger variety (Enescu 1980; Oncescu 1987). Note for example the fault plane solution of the second shock in May 1990 which shows practically a complementary solution with the rupture plane oriented perpendicularly to the solution typical observed in Vrancea. Radulian et al. (2000) shows the predominance of reverse faulting mechanisms for earthquakes with $M_W \geq 5.0$. Nevertheless, there is one case of a normal fault earthquake from 1945 and of two strike-slip events from 1950 and 1981.

Table 1. Characteristics of the earthquakes and strong ground motion database

Earthquake date	Lat. N	Long. E	M_W	h (km)	No. of horizontal components
30.08.1986	45.52	26.49	7.1	131	80
30.05.1990	45.83	26.89	6.9	91	102
31.05.1990	45.85	26.91	6.4	87	72
27.10.2004	45.84	26.63	6.0	105	132

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A striking feature of the radiation pattern of the Vrancea earthquakes is the azimuthal dependence of the seismic wave attenution with the lowest attenuation toward NE and the highest attenuation toward NW. This particular radiation is supported by both historical and instrumental data. It is invariably observed for major events, but it is frequently reported for smaller events, as well.

The recordings come from four seismic events with $M_W \geq 6.0$ produced in the past 30 years in the Vrancea subcrustal seismic source. The characteristics of the earthquakes and the number of analysed horizontal components for each earthquake are given in Table 1.

The distribution of the the peak ground acceleration (*PGA*) vs. the epicentral distance of the recording seismic stations is shown in Figure 1.

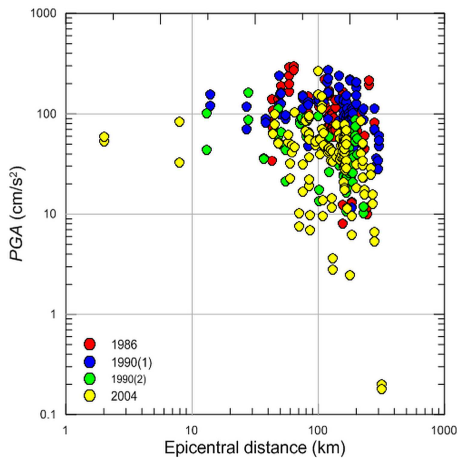

Figure 1. Distribution of peak ground acceleration with the epicentral distance of the recording seismic station

Figure 2 shows the median ratio of the largest spectral acceleration (taken from the response spectra of the two horizontal components) – SA_{larger} to the geometric mean of the response spectra from the as-recorded horizontal components – SA_{GM}.

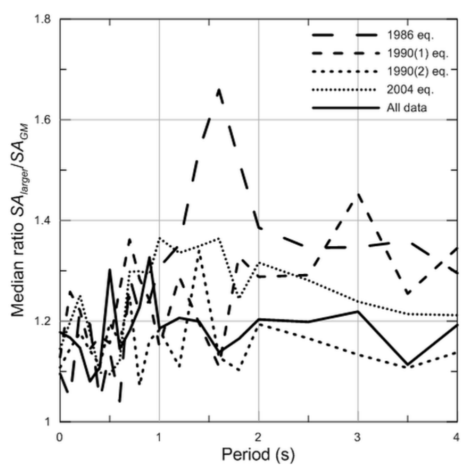

Figure 2. Distribution of peak ground acceleration with the epicentral distance of the recording seismic station

In order to check whether any directional pattern is noticeable, several maps showing the direction corresponding to *RotD100* (Boore, 2010) for T = 0.0 s are plotted for each earthquake in the database in Figure 3. In the four figures a zoom with the results for the recording seismic stations situated in Bucharest is also given. The position of the earthquake epicenter is marked on the maps with a half red circle.

The computation for the waves propagating from hypocenter toward SW (Romanian Plain) indicates mainly radial motion for 1990 (1), 1990 (2) and 2004 events and transversal motion for 1986 event which is to a certain extent in agreement with *PGA* maximum direction values. For the waves propagating from hypocenter toward SE (Dobrogea region) the radiation pattern shows mainly radial motion for 1986, 1990 (1) and 2004 events and transversal motion for 1990 (2) event which is slightly in better agreement with the *PGA* maximum direction estimates. Finally, for the waves propagating from hypocenter toward NW (Transylvania region) the radiation pattern shows mainly transversal motion for 1986 and 2004 events (for which there are available a few observation data) and once again the *PG*A direction estimates are better reproduced.

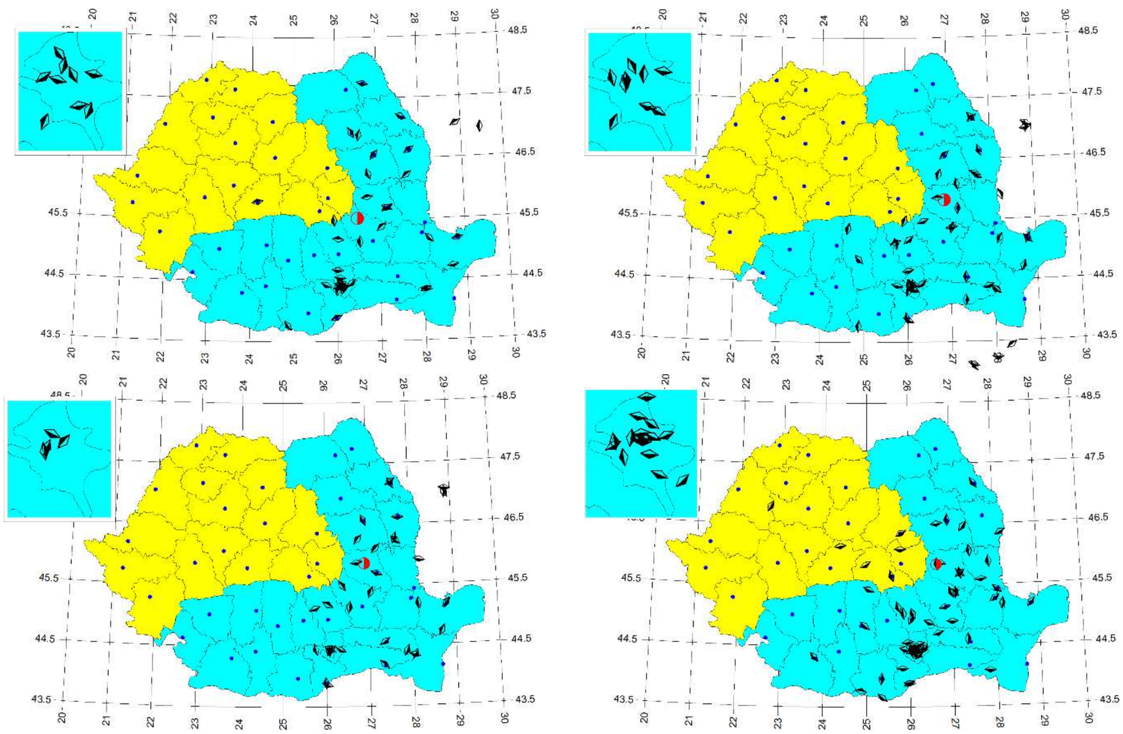

Figure 3. Direction of *RotD100* for *PGA* (*T* = 0.0 s) for the for the August 30, 1986 earthquake (*top left*), for the May 30, 1990 earthquake (*top right*), for the for the May 31, 1990 earthquake (*bottom left*) and for the October 27, 2004 earthquake (*bottom right*). Upper left corner zoom is for Bucharest

Some of the results obtained in this study will be incorporated in the future seismic hazard assessment of Romania, leading thus to a more realistic quantification of the seismic hazard levels.

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