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Tidal triggering evidence of intermediate depth earthquakes in the Vrancea zone (Romania)

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Abstract. Tidal triggering evidence of intermediate earthquakes in the Vrancea region (Romania) is investigated. The Vrancea seismic zone is located in the bend region of the South-Eastern Carpathians (45°–46° N, 25.5°–27.5° E) and is known as one of the most active seismic zones in Europe. We selected earthquakes occurred between 1981 and 2005 from the RomPlus catalog provided by the Institute of Earth Physics of Bucharest with $Mw \geq 2.5$ and focal depths between 60 and 300 Km.

We assigned a tidal component phase angle for each event which is computed from the earthquake occurrence time. Then the phase angle distribution was obtained by stacking every angle value in a 360 degree coordinate. Main lunar and solar semidiurnal tidal components $M2$ and $S2$ are considered. The phase angle distributions are tested by Permutation test which are introduced for the first time to a tidal triggering study. We compared results with classical Schuster's test. Both tests produce one value, p_p for Permutation test and p_s for Schuster's test, which represent the significance level for rejecting the null hypothesis that earthquakes occur randomly irrespective of tidal activities $M2$ and $S2$ phase distribution are random for the complete data set. However, when we set up a one year window and slide it by 30 d step, significant correlations were found in some windows. As a result of the sliding window, data set systematic temporal patterns related to the decrease of the p_p and p_s values seem to precede the occurrence of larger earthquakes.

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1 Introduction

Although the amplitude of the tidal stress change is two or three orders smaller than the stress drop of earthquakes, the tidal stress rate could be comparable to the tectonic stress rate and generally larger than this. It is reasonable to expect tidal triggering of an earthquake when the stress in the focal area is near the critical level (Tanaka et al., 2006).

At the intermediate seismic focal depth levels (60 km<focal depth<300 km), the gravitational force is the main outside force which could affect the dynamic process of the inner Earth. Its systematic variations are controlled by the lunar-solar attraction forces on each terrestrial point. It can be calculated through the precisely defined periods of the earth tides that vary from few hours (e.g. diurnal and semi-diurnal waves) to years (Melchior, 1978). Earth tides are deeply modulated signals which depend on the Sun and Moon's orbital parameters. For the main position on orbits, declination, ellipticity, and positions of the nodes, each is related to the absolute sidereal reference. Local and regional heterogeneities lead to a different response from one zone to another in accordance with the geological and tectonic background and it could also be influenced by the regional characteristics of the mantle-crust interface with a viscous coupling mechanism.

In summary, the response of a seismic zone to tidal periodicities depends on its specific geology, tectonic history and stress accumulation mechanisms in this region. The tidal modulation tendencies in seismic activity could help explain some aspects of the physical mechanism of rupture forming. A remarkable number of studies have been devoted to the possibility of triggering of earthquakes by earth tides. Most have reported negative conclusions about the correlation between the earth tide and earthquake occurrence (Schuster, 1897; Knopoff, 1964; Simpson, 1967; Shudde and Barr, 1977; Heaton, 1982; Curchin and Pennington, 1987; Rydelek et al., 1992; Vidale et al., 1998). However, many

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