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Stress shadows – a controversial topic

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The spatial correlation between the positive Coulomb stress changes and the subsequent seismic activity has been firmly confirmed in many recent studies. If, however, the static stress transfer is a consistent expression of interaction between earthquakes one should also observe a decrease of the activity in the zones of negative stress changes. Instead, the existence of stress shadows is poorly evidenced and may be questioned. We tested the influence of the static stress changes associated with the coseismic slip of the 1995 Mw6.5 Kozani-Grevena (Greece) earthquake on locations of its aftershocks. The study was based on a detailed slip model for the main shock and accurate locations and reliable fault plane solutions of an adequate number of the aftershocks. We developed a statistical testing method, which tested whether the proportions of aftershocks located inside areas determined by a selected criterion on the static stress change could be attained if there were no effect of the stress change due to the main shock on aftershock locations. The areas of stress change were determined at the focus of every aftershock. The distribution of test statistic was constructed with the use of a two-dimensional nonparametric, kernel density estimator of the reference epicenter distribution. The tests highly confidently indicated a rise in probability to locate aftershocks inside areas of positive static stress change, which supported the hypothesis on the triggering effect in these areas. Furthermore, it was evidenced that a larger stress increase caused a stronger triggering effect. The analysis, however, did not evidence the existence of stress shadows inside areas of negative stress change. Contrary to expectations, the tests indicated a significant increase of the probability of event location in the areas of a stress decrease of more than or equal to 5.0 and 10.0 bar. It turned out that for areas of larger absolute stress change this probability increased regardless of the sign of the change though distinctly more in areas of positive than of negative change. In the case of seismicity accompanying underground mining exploitation the coseismic stress changes expressed in terms of the Coulomb failure function are at least of one order smaller than those for earthquakes. Furthermore, they are only a small component of the total stress field variations in mining rockmass, which are mainly controlled by the mining process. Nevertheless, our studies of the induced seismicity in the Rudna mine in the Legnica-Głogow Copper District in Poland showed that the influence of the Coulomb stress changes on locations of subsequent events was statistically significant. We analyzed series of seismic events quantifying the triggering and inhibiting effect by the proportion of events in the series whose locations were consistent with the stress increased and stress decreased zones, respectively. It was found out that more than 60 per-cent of the analyzed seismic events occurred in areas where stress was enhanced due to the occurrence of previous events. The significance of this result was determined by comparing it with 2000 results of the same analysis carried out on the random permutations of the original series of events. The test indicated that the locations in positive stress changes areas were preferred statistically significantly when the stress changes exceeded 0.05 bar. However, no statistically significant inhibiting effect of negative static stress changes, within the considered range of these changes, was ascertained. Here we present details of these two studies and discuss possible reasons behind the negative conclusions on the existence of stress shadows.