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The influence of the brittle-ductile transition zone on aftershock and foreshock occurrence

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The organization in time, space and energy of aftershocks is characterized by scaling behaviors with exponents which are quite universal. At the same time, deviations from the universal behavior are sometimes observed and they have been proposed as a tool to discriminate aftershock from foreshock occurrence. Here we show that the change in rheological behavior of the crust with increasing depth, from velocity weakening to velocity strengthening, represents a viable mechanism to explain statistical features of both aftershocks and foreshocks. More precisely, we present a model of the seismic fault described as a velocity weakening elastic layer elastically coupled to a velocity strengthening visco-elastic layer. The model has only two parameters: one controls the degree of heterogeneities of the static friction force and the other quantifies the stress transferred between the two layers. We show that the statistical properties of aftershocks in instrumental catalogs are recovered at a quantitative level without any fine-tuning. This robustness provides a justification for the universality of aftershock phenomenological laws and supports our modelling assumptions. We also find that synthetic foreshocks mimic those observed in instrumental catalogs, opening the way for subtle forecasting tools.