Spatio-temporal structures of aftershock sequences

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Aftershocks are a vivid example of the result of a trigger impact on the lithosphere. Wherein the main shock acts as an obvious trigger, which triggers the process of discharging accumulated tectonic stresses in the local area of the earthquake source, and the aftershocks are elementary acts of this process. We proceed from the concept of nonstationarity of rocks in the focal area, which is its most important property.

This report is devoted to the results of studying the features of the reaction of a nonlinear dynamic system - the focal zone - on a trigger impact - the main shock, and the selection of empirical formulas describing the spatial-temporal evolution of aftershocks. The data from the world USGS/NEIC catalog of earthquakes from 1973 to 2014 (https://www.usgs.gov) and regional catalogs of earthquakes in Northern California from 1968 to 2007 (http://www.ncedc.org) and Southern California from 1983 to 2008 (https://www.scec.org) have been used.

The paper analyzes the generalized (cumulative) spatial distributions of aftershock sequences, depending on the magnitude of the main shock, obtained by studying a large number of main shocks. The resulting spatial distributions remind the Omori law. Empirical formulas describing these dependencies are proposed.

Examples of the evolution of aftershock sequences are considered not only in space, but also in time. It is shown that after the main shock in the focal zone a "wave" of activation shows up, which spreads from the epicenter of the main shock to the periphery of the focal zone. An estimate of the propagation rate of such activation was made. On average, it is about 5-10 km/h.

It is shown that in the process of relaxation of accumulated stresses in the focal zone, its "deactivation", in the space-time of aftershocks evolution, a similarity of the wave structure is observed. We believe that one of the possible approaches for describing such a structure could be the introduction of the diffusion term $D\nabla^2 n$ into the differential equation of aftershocks evolution, where D is a parameter that has the physical meaning of the diffusion coefficient. In this case, an association arises with the Fisher-Kolmogorov-Petrovsky-Piskunov equation known in mathematics. In the context of the space-time distribution of aftershocks, in which wave structures, found empirically, arise, it is interesting in that it has self-similar solutions in the form of propagating nonlinear waves. In the two-dimensional model of the FKPP equation by natural way gets an explanation the sometimes observed variable velocity propagation of the wave of the focal zone activation.

Thus, we can conclude that the earthquake source "cooling" after the main shock is an inexhaustible spring of the richest physics.

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