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The lightning initiation as a noise-induced kinetic transition

Dmitry Iudin (1,2) and Vladimir Rakov (3)

(1) Institute of Applied Physics of Russian Academy of Sciences, Nizhny Novgorod, Russia, (2) Lobachevsky State University, Nizhny Novgorod, Russia, (3) University of Florida, Gainesville, USA

It is common knowledge that observations of thundercloud electric fields have consistently yielded a peak value that is an order of magnitude weaker than the dielectric strength of air. In this work, initiation of lightning in the thundercloud is regarded as a noise-induced kinetic transition. As a source of the noise we consider the collective stochastic electric field of charged hydrometeors. Above-critical bursts of the stochastic field provide the survival of the free electrons in conditions when the RMS level of fluctuations of the field is significantly less than the air electric strength. The considered kinetic transition has several characteristic features that distinguish it from other mechanisms of lightning initiation. First, due to interaction of electron and ion components the dynamic implementation of this transition is stretched in time interval, which significantly exceeds the development time of ordinary spark discharge. In this case the rapid attachment of electrons is balanced by the processes of their liberation during negative ions destruction. Secondly, ions stochastic drift due to the fine-scale electric field fluctuations plays a significant role in the transition kinetics. From a formal mathematical point of view, this stochastic drift is indistinguishable from advection of a scalar impurity in a turbulent flow. It is shown that the effectiveness of “advective mixing” for a few degree surpasses the efficiency of conventional diffusion. Third, noise-induced explosive growth in the density of free electrons and ions is limited to spatial - temporal clusters that have a fractal structure and covering, as a result, a vanishingly small proportion of the actual area of four-dimensional space-time. As a result in the considered transition the average conductivity of the medium does not significantly change. The proposed kinetic mechanism of the initiation of the lightning discharge provides both amplification of the local electric field in a thundercloud, and self-consistent support of the discharge process under the conditions when the free electrons attachment dominates over their production in ionization process.