Thundercloud electric field fine structure and lightning initiation

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It is well known that the amplitude of the electric field measured in a thundercloud, is an order of magnitude less than the threshold value, which is necessary for the conventional electrical breakdown of air. This fact turns the lightning initiation question in one of the most intriguing problem of thunderstorm electricity. In this work, initiation of lightning in a 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. The intensity of the noise is equal to the product of hydrometeors concentration with the variance of their charge magnitude. Above-critical bursts of the stochastic field provide the appearance of elevated-conductivity areas and turn the cloud medium into a strongly inhomogeneous random mixture of highly conductive areas with poorly conducting, almost dielectric regions. Thus we reduce the consideration of lightning initiation to the dielectric breakdown problem in random conductor-insulator composites. The sensitivity of the dielectric breakdown field on the conductor fraction in the material is caused by the formation of conductive percolation clusters which act as equipotential for an applied quasi-static electric field. For a given applied field, a larger and larger local field is concentrated across the space between relatively large conductive clusters. The breakdown field is of order the inverse of the linear dimension of the largest of these percolation clusters. Since the size of the clusters diverges as the volume fraction of conductor tends to the percolation threshold value, the breakdown field tends to zero in this limit. In addition, the average breakdown electric field decreases logarithmically with the linear dimension of the system when the volume fraction of good conductor is below the percolation threshold. 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.

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