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Streamer inception from hydrometeors as a stochastic process with a particle-based model

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In thunderstorms, streamers (as precursors for lightning leaders) can be initiated from hydrometeors (droplets, graupel, ice needles, etc.) which enhance the thundercloud electric field to values above electric breakdown; and initial electrons may come from extensive air showers [1]. Typically, streamer inception from hydrometeors is theoretically studied with deterministic fluid simulations (i.e. drift-diffusion-reaction coupled with Poisson), see [1, 2, 3] and references therein. However, electrons will only multiply in the area above breakdown, which is of the order of a cubic millimeter for hydrometeors of sub-centimeter scale. Initial electron densities, even in extreme extensive air shower events, do not exceed 10 per cubic millimeter. Hence only individual electron avalanches – with their intrinsically random nature – are entering the breakdown area sequentially. On these scales, a deterministic fluid description is thus not valid. Therefore, we developed a new stochastic particle-based model to study the behavior of the system described above, to calculate the probability of streamer inception, for given hydrometeor, electric field and initial electron density. Results show that the discharge starts with great jitter and usually off the symmetry axis, demanding stochastic approach in full 3D for streamer inception in realistic thunderstorm conditions.

The developed software will be made publically available as an open source project.

[1] Dubinova et al. 2015. Phys. Rev. Lett. 115(1), 015002.
[2] Liu et al. 2012. Phys. Rev. Lett. 109(2), 025002.
[3] Babich et al. 2016. J. Geophys. Res. Atmos. 121, 6393–6403.