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Electron transport and simulation of negative streamer dynamics in the atmosphere of Titan

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In this work we investigate the possible occurrence of lightning in the atmosphere of Titan, which is the largest of Saturn's satellite. The Titan's atmosphere is mainly composed of N_2 and CH_4, and traces amounts of H_2, HCN, C_2H_2, C_2H_6, as well as of other hydrocarbons and nitriles. Atmospheric chemistry suggests the presence of lightning on Titan. Since streamers form the initial stages of lightning, we here investigate the streamer dynamics in N_2-CH_4 mixtures.

As a first step, we investigate electron transport in N_2-CH_4 mixtures. Available cross sections for electron scattering in N_2 and CH_4 are tested through a series of comparisons between swarm data calculated by a multi term theory for solving the Boltzmann equation and by Monte Carlo simulations, and available experimental data. The duality of transport coefficients, e.g., the existence of two different families of transport coefficients, the bulk and the flux, is discussed and demonstrated. Calculations have also been performed in time-dependent electric and magnetic fields aiming to understand the response of electrons towards the electromagnetic pulses generated by lightning discharges.

We here investigate negative streamer dynamics in N_2-CH_4 mixtures using the first-order (or classical) fluid model combining the equation of continuity for electrons and ions as well as the drift-diffusion approximation for electrons, and Poisson's equation including the effect of space charges. The fluid equations are closed, assuming the local-field approximation. In addition, we present a fluid model based on the hydrodynamic approximation and assume that the electron collisional term in the continuity equation can be expanded in terms of gradients of the electron number density. Both models are numerically implemented in a 1.5-dimensional setup with a particular emphasis on the correct implementation of transport data in streamer models. We also focus on the influence of the percentage of CH_4 on streamer properties. Among many important points, we find that the front velocity and the level of background ionization are increased for an increasing fraction of CH_4 in the mixture.