EFFECTS OF PHOTOIONIZATION ON THE DYNAMICS OF POSITIVE AND NEGATIVE STREAMERS IN SPRITES

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Sprites are large luminous discharges, which appear in the altitude range of ~40 to 90 km above large thunderstorms [e.g., Sentman et al., GRL, 22, 1205, 1995]. Recent telescopic imaging of sprites revealed an amazing variety of generally vertical fine structure with transverse spatial scales ranging from tens to a few hundreds of meters [Gerken et al., GRL, 27, 2637, 2000; Gerken and Inan, 107, 10.1029/2002JA009248, 2002]. Also recently, it has been demonstrated that sprites often exhibit a sharp altitude transition between the upper diffuse and the lower highly structured regions [Stenbaek-Nielsen et al., GRL, 27, 3827, 2000; Pasko and Stenbaek-Nielsen, GRL, 29, 10.1029/2001GL014241, 2002; Gerken and Inan, 2002]. The appearance of the fine structure and the vertical stratification in sprites has been interpreted in terms of positive and negative streamer coronas, which are considered as scaled analogs of small scale streamers, which exist at high atmospheric pressures at ground level [e.g., Pasko et al., GRL, 25, 2123, 1998; Raizer et al., J. Phys. D Appl. Phys., 31, 3225, 1998; Petrov and Petrova, Tech. Phys., 44, 472, 1999; Pasko et al., GRL, 28, 3821, 2001; Pasko and Stenbaek-Nielsen, 2002].

In this talk we report results from a new two-dimensional model recently developed at Penn State for studies of dynamics of positive and negative streamers for a wide range of air pressures corresponding to streamer dominated regions of sprites. The model utilizes a modified Scharfetter-Gummel algorithm for solution of electron convection-diffusion equation [Kulikovsky, J. Comput. Phys., 119, 149, 1995] and accounts for effects of photoionization on the streamer dynamics [e.g., Kulikovsky, J. Phys. D: Appl. Phys., 33, 1514, 2000, and references therein]. Using the model, we studied double-headed streamers initiated at sprite altitudes from single electron avalanches and calculated the full time dynamics of optical emissions (without the steady state assumption) from 1st and 2nd positive bands of N_2, 1st negative and Meinel bands of N_2^+ and 1st negative bands of O_2^+. The model results indicate that the effects of photoionization significantly modify the streamer scaling properties as a function of air pressure, leading in particular, to a factor of three wider streamer structures at altitudes >30 km, when compared to the previously discussed similarity laws [Pasko et al., 1998]. The primary reason for the observed differences is that the effective quenching altitude of the excited states that give photoionizing radiation is about 24 km. The quenching of these states is therefore negligible at altitudes >30 km, leading to a substantial enhancement of the electron-ion pair production ahead of the streamer tip due to the photoionization, when compared to the ground level, and resultant widening of the streamer filaments. In our talk we will present results of a comparison of the model outputs with the recent telescopic imaging of sprites [Gerken et al., 2000; Gerken and Inan, 2002] and discuss parameterizations allowing the evaluation of the effective streamer radius at different altitudes in the streamer dominated regions of sprites.