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Evaluation of the potential for sprite occurrence above thunderstorms using a 2D electrostatic model

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We present results from a simple 2D model of the mesospheric electric field for several thunderstorm charge configurations. The model assumes a simple dipole structure with a screening charge above cloud-top. The charge centers are modeled as horizontal disks with a Gaussian charge density distribution. We solve the Poisson equation numerically, using a second order central finite difference scheme. A relaxation method is used over a grid of 90 x 300 points with a 1-km interval. We convert the computed electric potential at each grid point to the electric field and compare it to the breakdown field, thus mapping the regions where there exists a possibility for sprite initiation. This model allows the study of various thunderstorm cell configurations, with multiple cells and with different polarities. Four main charge configurations are examined: (1) a summer thunderstorm cell, (2) a winter cell, (3) simultaneous lightning from two summer cells, and (4) a summer cell with an inverse dipole. The results highlight the difference in the charge moment change (CMC) threshold needed for sprite generation in winter and summer cells. The effects of the presence of neighboring thunderclouds at different relative stages of development are presented, particularly with respect to the likelihood of sprite formation and the displacement of sprites from the parent flash. In addition, we show how the orientation of the electric field changes with altitude, potentially explaining the optical observations of sprite tendril curvature toward the cloud.