Lightning Parameterization in Cloud Numerical Models: Description and Results from BRAMS and a 1-D cloud models

Rachel Albrecht¹, Carlos Morales¹, Edmilson Freitas¹, Maria A. Silva Dias¹,², Walt Petersen³

¹Universidade de São Paulo, São Paulo, Brazil
²Centro de Previsão de Tempo e Estudos Climáticos, Cachoeira Paulista, Brazil
³Marshall Space Flight Center-NASA, Huntsville, USA
(rachel@master.iag.usp.br)

Abstract - Numerical schemes of cloud electrification and lightning leader have been implemented into two numerical models at the University of São Paulo: the mesoscale Brazilian Regional Atmospheric Modelling System (BRAMS), and the one-dimensional cloud model of Ferrier and Houze (1989). Both cloud models have electrical charge separation based on non-inductive collisions between ice particles found in various laboratory studies. The resulting electric field is calculated at each time step and a lightning is triggered when this local field overcome the breakeven electric field. In the 1D cloud model, the lightning leader propagates bi-directionally (upward and downward), neutralizing charges along the channel until the electric field reduces to 15 kVm⁻¹. In the BRAMS model, the lightning leader is propagated bi-directionally towards two main exceeding net charge regions until the magnitude of the electric field reduces to 20 kVm⁻¹. At this point the lightning leader is branched into streamers where the total net charge density is greater then 0.5 nCm⁻², and the charges are neutralized along the whole lightning path. These models were used to simulate thunderstorm conditions observed during the wet and dry-to-wet seasons of southwestern Amazon. Both models were able to simulate the literature known tripolar and dipolar structures of thunderstorms, and more complicated multipolar structures.

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BRAMS (3-D) cloud model
Dynamic Model (Walko et al., 2000)
BRAMS is based on the 5.04 CSU-RAMS model + implementations
Cloud microphysics (Tripoli and Cotton, 1981)
water vapor, cloud droplets, rain, graupel, hail, aggregated, snow, pristine ice (gamma distributions)

Charge transfer (Takahashi, 1984) and Lightning leader (MacGorman et al., 2001) mc

Results: BRAMS cloud model
Temporal evolution and vertical distribution of the total liquid water content mixing ratio (\(q_t\)) and net charge density (\(Q_{nw}\)) at the grid point x=150 km and y=150 km.

Maximums of net charge density (\(Q_{nw}\)), the electric field (\(E\)), mixing ratios of graupel+ hail+ pristine+ snow+ aggre., cloud water+ rain (LWC), and vertical velocity (w) at x=150 km, y=150 km and z from 4.5 to 7.0 km of height. The dashed black line indicates when lightning has occurred.

Results: 1-D cloud model
Temporal evolution and vertical distribution of the charge densities of the four ice hydrometeors, \(Q_{nw}\) (nCm⁻²) (ice crystals - i, snowflakes - s, graupel - g, and hail - h), as well as the net charge density (\(Q_{nw}\)), and the lightning leader parameterized.

BRAMS Dynamic Model (Walko et al., 2000)
Cloud microphysics (Tripoli and Cotton, 1981)
water vapor, cloud droplets, rain, graupel, hail, aggregated, snow, pristine ice (gamma distributions)

1-D cloud model
Dynamic Model (Ferrier and Houze, 1989)
cylindrical coordinates, axial symmetric, variable radius
Cloud microphysics (Petersen, 1989)
water vapor, cloud droplets, rain, graupel, hail, snow, ice crystals (monodisperse and exponential distributions)

Diagnostics taken from MacGorman et al. (2001)

Temporal evolution and vertical distribution of the charge densities of the four ice hydrometeors, \(Q_{nw}\) (nCm⁻²) (ice crystals - i, snowflakes - s, graupel - g, and hail - h), as well as the net charge density (\(Q_{nw}\)), and the lightning leader parameterized.

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