EGU23-3281, updated on 27 Apr 2024
https://doi.org/10.5194/egusphere-egu23-3281
EGU General Assembly 2023

Library of simulated gamma-ray glows and application to previous airborne observations

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Gamma-Ray Glows (GRGs) are bursts of high-energy radiation that are emitted by thunderclouds and have a duration of seconds to minutes. These radiation sources are extended over several to tens of square kilometers. GRGs have been observed from detectors on the ground, in aircraft, and on balloons. In this paper, we present a Monte-Carlo model that can be used to study the production and propagation of GRGs. We compare our model to one developed by Zhou et al. (2016) and find small differences between the two. We have also created a library of simulations that is available to the community. Using this library, we were able to reproduce five previous GRG observations from five airborne campaigns: balloons from Eack et al. (1996) and Eack et al. (2000), and aircraft from the ADELE (Kelley et al. 2015), ILDAS (Kochking et al. 2016), and ALOFT campaigns (Østgaard et al. 2019).

Our simulation results confirm that the flux of cosmic-ray secondary particles at a given altitude can be enhanced by several percent or even several orders of magnitude due to the effect of thunderstorms' electric fields. These results explain the five observations we studied and will be useful for the upcoming ALOFT-2023 campaign. While some GRGs can be explained solely by the MOS process, the strongest GRGs observed require electric fields significantly larger than the RREA threshold value (E_th). Some of the observations also came with in-situ electric field measurements that were always lower than E_th, but these measurements may not have been taken from the regions where the glows were produced. This study supports the idea that some thunderstorms must have electric fields with magnitudes of at least E_th on a kilometer scale.

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