

The Ground Flash Fraction Retrieval Algorithm Employing Differential Evolution: Simulations and Applications

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The ability to estimate the fraction of ground flashes in a set of flashes observed by a satellite lightning imager, such as the future GOES-R Geostationary Lightning Mapper (GLM), would likely improve operational and scientific applications (e.g., severe weather warnings, lightning nitrogen oxides studies, and global electric circuit analyses). A Bayesian inversion method, called the Ground Flash Fraction Retrieval Algorithm (GoFFRA), was recently developed for estimating the ground flash fraction. The method uses a constrained mixed exponential distribution model to describe a particular lightning optical measurement called the Maximum Group Area (MGA). To obtain the optimum model parameters (one of which is the desired ground flash fraction), a scalar function must be minimized. This minimization is difficult because of two problems: (1) Label Switching (LS), and (2) Parameter Identity Theft (PIT). The LS problem is well known in the literature on mixed exponential distributions, and the PIT problem was discovered in this study. Each problem occurs when one allows the numerical minimizer to freely roam through the parameter search space; this allows certain solution parameters to “interchange roles” which leads to fundamental ambiguities, and solution error. A major accomplishment of this study is that we have employed a state-of-the-art genetic-based global optimization algorithm called Differential Evolution (DE) that constrains the parameter search in such a way as to remove both the LS and PIT problems. To test the performance of the GoFFRA when DE is employed, we applied it to analyze simulated MGA datasets that we generated from known mixed exponential distributions. Moreover, we evaluated the GoFFRA/DE method by applying it to analyze actual MGAs derived from low-Earth orbiting lightning imaging sensor data; the actual MGA data were classified as either ground or cloud flash MGAs using National Lightning Detection NetworkTM (NLDN) data. Solution error plots are provided for both the simulations and actual data analyses.

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