Global Analysis of Fireball Events (2017–2024): Spatiotemporal Distribution, Energy Correlations, and Trajectory Modeling.

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Abstract

This study provides a comprehensive analysis of the radiated optical and impact energies of fireball events, aiming to elucidate spatial, temporal, and energy-related patterns. Utilizing a dataset of nearly 1,000 fireball occurrences from the Center for Near-Earth Object Studies (CNEOS) archives, we examine critical metrics such as altitude, velocity, radiated energy, and impact energy. Through comprehensive statistical analyses, uncertainty propagation, and trajectory simulations, we uncover the global distribution of fireball events and their interrelationships, emphasizing the correlation between radiated and impact energies. The study models energy dissipation over time due to atmospheric drag, combining these dynamics into the analysis of fireball behavior. Our findings indicate a reasonable positive correlation between radiated optical energy and impact energy, validating the use of radiated energy as a reliable proxy for estimating impact potential. Additionally, mass estimates based on radiated energy provide further insights into fireball characteristics and their energy dissipation rates. The spatial distribution reveals significant clustering in regions with advanced sensor networks, suggesting detection biases, while the temporal analysis highlights consistent meteoroid influx, with seasonal peaks corresponding to known meteor showers. This research advances meteor science by identifying key trends in the distribution and energy characteristics of fireballs, offering new insights into meteoroid dynamics, atmospheric entry behaviors, and potential hazards. The dataset, detailing attributes such as radiated optical energy, calculated impact energy, altitude, velocity at peak brightness, and energy dissipation patterns, supports ongoing investigations into meteoroid impacts and their broader implications for planetary defense.