Title: The Optical Characteristics of Lightning

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Accomplishments to Date:

Optical signals (0.4 to 1.1μm) radiated by Florida lightning were recorded in correlation with wideband electric field signatures. The amplitudes and time-behavior of the early portion of the signals produced by return strokes indicate that this lightning process produces a space- and time-averaged peak radiance on the order of 4 to 13 x 10^5 watts per meter of channel.

Integrals of the Poynting vector of the electromagnetic (EM) field radiated by return strokes indicate that the peak EM power is on the order of 3 to 20 x 10^9 watts at the source. When this peak EM power is produced, the optical power is at least 2 orders of magnitude smaller, hence an upper limit to the radiative efficiency of the channel at this time is about 1%. From these measurements we also infer that at the time of the initial current peak, (1) the total voltage drop on the high-current portion of a return stroke must be at least 2 to 7 x 10^5V in first strokes and 2 to 4 x 10^5V in subsequent strokes, (2) the total resistance of the high-current channel must be at least 6 to 20 Ω in subsequent strokes, and (3) the energy that is required to form the propagating tip of the channel must be at least 10^2 to 10^3J/m.

Recent analyses of the light signals radiated by dart leaders indicate that a small but important fraction of these signals exhibit an unusually large peak output per unit length of channel, i.e. values that are comparable to or even exceed those of the subsequent return stroke.

Data derived from a large network of electric field mills and alightning locating system have been used to obtain the average diurnal variation of summer lightning in Florida. When the statistics of lightning are compared with the statistics of thunder on the same days, good agreement is found between the start times and the times of peak activity; however, the thunder stop times tend to lag the lightning by 1 to 2 hours. The diurnal variations over the Atlantic Ocean and the Gulf of Mexico are substantially less than over land. Over land, the diurnal variation is such that a DMSP satellite can, at best, detect 0.0007, 0.0004, and 0.0028 of the actual discharges at midnight, dawn, and dusk, respectively. If there were no diurnal variation this satellite would detect about 0.0014 of the actual number.

Current and Future Activities:

We have established a cooperative experiment on the radiative properties of long sparks in air with members of the High Voltage Institute at the University of Uppsala, Sweden. We plan to analyze optical data that are produced by long sparks (whose power and energy inputs are known) to determine better the power and energy balance of these processes and ultimately lightning.

Efforts are also being made to understand how the rates of lightning activity in various thunderstorms relates to the total Maxwell current that is being generated by these storms. The results are expected to make an important contribution to our understanding of the thunderstorm as a source in the global circuit.

Publications:

"The Optical Power Radiated by Lightning Return Strokes" J. Geophys. Res., 88, 8621-8622, 1983 (with C. Guo).

"The Peak Electromagnetic Power Radiated by Lightning Return Strokes," J. Geophys. Res., 88, 8471-8474, 1983 (with C. Guo).

"Anomalous Light Output from Lightning Dart Leaders" Trans. Am. Geophys. Union, 64, 662, 1983 (Abstract with C. Guo).

"Average Diurnal Variation of Summer Lightning Over the Florida Peninsula" to be pub. Mon. Wea. Rev., 1984, (with L. M. Maier and M. W. Maier).