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Research on Lightning in the Physics Department of the University of Colombo

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The Physics Department of the University of Colombo is at present engaged in a Research Programme on Lightning in collaboration with the Sri Lanka Meteorological Department and the University of Uppsala, Sweden.

As a start, relatively inexpensive devices called Lightning Flash Counters are being used to investigate the patterns of lightning that occur in the neighbourhood of Colombo. In particular, it is hoped to use these instruments to estimate the annual incidence of Cloud to ground lightning strokes in the Colombo area. This information would be valuable in estimating the risk from lightning strikes to a particular structure like a television antenna for example. It is hoped also to extract an important parameter of lightning through this research, namely the ratio of intra cloud lightning flashes to cloud to ground flashes.

A lightning flash counter is triggered by the Electric field change that results from a lightning discharge. In the case of an intra-cloud discharge the effect in the tropics is essentially due to the discharge of an electrical dipole with its negative charge at an altitude of about 5km and its positive charge at a higher altitude of about 10km. Experimental evidence gathered over the years by various researchers suggest that in this type of discharge currents of the order of 120 Amperes flow between positive and negative charge concentrations in a cloud for about 250 milliseconds, neutralising about 30 coulomb of charge. There is evidence to show that superposed on this flow of current there are short bursts of current where the current rises to about 1400 Amperes for short periods of about 1 millisecond. If the electric field in the vertically downward direction is regarded as positive, an intra-cloud discharge causes a positive field change at the earth's surface at close distances within about 9km from the discharge measured horizontally, but it causes a negative field change beyond 9km. Also, due to the relatively low level of currents and rate of change of currents involved, the electric field change due to an intracloud discharge is dominantly electrostatic in nature. This is in contrast with a cloud to ground stroke where very much larger currents of a much more impulsive nature are involved which give rise to radiation field changes which are appreciable.

In a cloud to ground flash, at first a narrow column of negative charge lowers towards the ground from the cloud base and when the column comes to within about a 100 metres from the ground, narrow columns of positive charge rise from pointed earthed structures like trees, bushes, blades of grass, man-made structures like telegraph and electric lines, lightning conductors, television antenna, etc. If one of these upward travelling positive columns makes contact with the downcoming negative column from the cloud, the result is spectacular. The negative charge on the downcoming column from the cloud, which amounts to about 5 coulombs is discharged violently to Earth in a few micro-seconds, with the discharge current peaking at values of the order of 20,000 to 100,000 Amperes. The discharge is accompanied by a bright flash of lightning and a loud clap of thunder.

The electric field change caused by this type of discharge is positive at all distances from the discharge. The electrostatic field change is like a step voltage change. The magnitude of the change drops off as the cube of the distance from the discharge. Accompanying the electrostatic field change is a radiation field due to the very large rates of change of current involved. The radiation field drops off only as the first power of the distance. Thus beyond about 20km distance it is the radiation field change that dominates and this field change is appreciable at distances extending to about 60km.

The Lightning Flash Counters being used in the present investigation are two types called the VO3 counter and the VO4 counter designed by the Institute of High Voltage Research, University of Uppsala, Sweden and gifted to us. Both these counters use identical vertical antennae. In both counters, basically a voltage V_o (t) fed to the antenna gives a voltage V_o (t) through a filter circuit to the base of a 2N 914 transistor. If V_o (t) exceeds 0.58 volt at any time there is a count. After a count, there is a dead time of 1 sec before the counter is ready to register again. The antenna filter circuits are so designed that a sinusoidal signal at V_i (t) of fixed amplitude but variable frequency, gives a sinusoidal signal of maximum amplitude, V_o (max) say, at a frequency f_o, with the response dropping off on either side of f_o such that the mplitude of V_o at a frequency mf_o is the same as the amplitude of V_o at a frequency f_o/m where m is a real positive number. In particular, the response drops to 10/17 of its maximum value when $m=5$. For the VO3, f_o = 500Hz and for the VO4, it is 10kHz. The threshold of counting of the VO3 is for a sinusoidal input signal of frequency 500Hz and amplitude 15 Volt to the antenna and the threshold for the VO4 is for an input signal of frequency 10kHz but the same amplitude of 15 Volt.

When a VO3 and VO4 are operated together, a characteristic counting pattern is observed as a thunderstorm approaches from a distance. The VO4 starts counting first. As the storm approaches closer the VO3 begins to register in coincidence with the VO4. When the storm is close enough for thunder to be distinctly heard, that is within about 10km, the VO3 counting rate overtakes the VO4 counting rate rather dramatically. When the storm is within about 5km distance, the VO4 counting rate picks up and catches up with the VO3 rate. The pattern then repeats itself in reverse order as the storm recedes from the counters.

We have interpreted this counting pattern on the basis that the VO4 registers cloud to ground strokes through the radiation field at distances beyond about 20km. Within 20km the VO3 begins to register ground strokes through the electrostatic field change. When the storm approaches within 10km, because of the field reversal of the electrostatic field change caused by inter-cloud flashes, which was explained earlier, the VO3 starts registering intra-cloud flashes as well. When the storm is almost directly overhead the VO4 is also sensitive to the electrostatic field change caused by intracloud flashes and so its counting rate picks up and catches up with the VO3 rate.

Counting data from the two counters have been collected for a continuous period of almost two years. These counts are being correlated with visual and aural reports of thunderstorms sent in on an hourly basis 24 hours a day from meteorological substations and Physics A-level school teachers and students scattered all over the country. From the analysis of this data and on the basis of the interpretation of the counting pattern of the counters given earlier, it is possible to deduce the average number of intra-cloud flashes strong enough to trigger the counters per ground flash and the average number of cloud to ground flashes per year hitting the ground within a distance of roughly 10km from the counters. The analysis done so far indicates that there are at least 10 intracloud flashes per ground flash in the Colombo area and that annually there are about 2000 lightning hits to ground within a radius of about 10km in the Colombo area.