CLIMATOLOGICAL EVALUATION OF PARAMETERS FOR A MORE REALISTIC LIGHTNING MODELLING

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ABSTRACT

Lightning consists of a high current, transient atmospheric electric discharge with path length of about several kilometers. Due to its importance for human environment, several researchers have developed numerical simulations for different aspects of atmospheric electrodynamics. Thus, for a realistic modelling of lightning trajectory and its behavior, researchers need to use experimental data as parameters in their numerical simulations and to compare with the numerical outputs. This work contributes to this goal with the following experimental results: (a) ratio among different polarities of lightning flashes; (b) lightning distribution related to multiplicity; (c) stroke distribution related to current amplitude in lightning flashes; and (d) nature of relationship between consecutive strokes in multistroke lightning flashes concerned to interstroke time interval. To achieve these results a preliminary climatological analysis of lightning was developed using southeastern Brazil stroke data.

Keywords: Lightning - Atmospheric Electricity - Climatology

1. INTRODUCTION

Due to the importance of lightning flashes in Nature and in human environment, several researchers developed models for different aspects of atmospheric electrodynamics (Anderson and Freier, 1969; Takagi et al., 1986; Dellera and Garbagnati, 1982; Takeuti et al., 1993; Kawasaki et al., 1989; Mendes et al., 1998). Lightning consists basically of a high current (~ kA), transient atmospheric electric discharge with path length of about several kilometers. It is a consequence of the great amount of electric charge (~ 10-100 C) accumulated in the thunderclouds (cumulonimbus) and it occurs when the electric field exceeds locally the electric air insulation (> 400 kV/m) - (Volland, 1984; Uman, 1987). Researchers dealing with a realistic modelling of lightning trajectory and its behavior need to use experimental data as parameters in their numerical simulation and to compare with the numerical outputs.

The aim of this paper is to present some information on the study of the atmospheric behavior and to allow lightning modelling in a more realistic manner. From a "true model" one should obtain all the real characteristics of phenomena, but at the beginning only some features have been pursued. Thus the basic questions proposed are:

- In general, lightning flashes are made of only one electrical discharge (stroke), but there are lightning with several strokes (feature called multiplicity). (a) When a model simulates a great amount of lightning flashes, what kind of multiplicity distribution should it present for the flashes?
- Depending on the polarity of charge source (negative or positive) from where lightning starts, a lightning is classified into negative polarity category, positive polarity category or bipolar polarity category (Bipolar ground flashes are multistroke flashes having different polarities). (b) What statistical polarity ratio should a lightning simulation tests to obtain an adequate physical mechanism?

– Lightning is a transport of charges presenting in time a peak of current related to every stroke. (c) What stroke peak current distribution should a simulation reproduce statistically? (d) What kind of relationship is there between the stroke current amplitude in a multiple stroke and interstroke time interval?

This work represents an attempt to answer these questions.

2. DATA AND CLIMATOLOGICAL ANALYSIS

During last decade, large-scale detection and location systems have been used in different parts of the world to determine the general characteristics of cloud-to-ground lightning flashes. One of those systems, Lightning Position and Tracking System (LPATS), is based on time-of-arrival of lightning electric signature (LPATS technology) - (Bent and Lyons, 1984). In September of 1988, in a pioneer work, the Companhia Elétrica de Minas Gerais-CEMIG installed this system in the state of Minas Gerais in southeastern Brazil (Carvalho et al., 1995). There are only two systems in South America, the other one was installed recently by Sistema de Meteorologia do Paraná-SIMEPAR, Paraná, BR, in 1996. The CEMIG-network covers a total area of about 1,400,000 km^2, comprising the state of Minas Gerais and part of neighboring states (Diniz et al., 1996).

The LPATS records on a continous basis the strokes occurred during thunderstorms. Information records are date, time, sensors used to resolve stroke, latitude, longitude and estimated peak-current amplitude. The October-April (warm season) stroke data used in this work was from 1988-1989 to 1994-1995. In this period the system worked with four sensors under the same technical condition. To take advantage of estimated global efficiency of LPATS (> 70%), the region of strokes was limited to latitude 14^o-23 ^{o}S and longitude 39^o-52 ^{o}W. The positive strokes with current amplitude less than 15 kA were cut off to avoid data contamination by non-cloud-to-ground lightning (Zaima et al., 1997). In the data analysis the following empirical criteria were adopted for the time and distance between strokes to recuperate lightning flashes from stroke records (computational process called lightning classification - Mendes and Domingues, 1998): subsequent strokes in a flash were considered to be within 500 ms of the previous stroke and within 2s and 10 km of the first stroke (Gin et al., 1997). Same criteria were adopted by Cook and Casper (1992). No restriction was imposed on the polarity of subsequent strokes.

In order to evaluate some parameters to be used in lightning modelling, this work deals with this database and obtains some typical features. Figure 1 presents the ratio of negative, positive and bipolar cloud-to-ground lightning flashes. Figure 2 presents the lightning distribution concerned to the number of strokes per flash (multiplicity). Figure 3 presents the stroke distribution relative to the estimated current amplitude for only-one stroke flashes and for the first two strokes in multistroke flashes. At last, Figure 4 presents for consecutive strokes in a multistroke lightning the interstroke time interval related to the difference of current amplitude between them. Through these results this work also contributes to a first, preliminary picture of the climatology of lightning for this region of Brazil.

3. RESULTS AND CONCLUSION

Figure 1 presents the ratio among the different polarities (negative: 71.6%, positive: 27.4%, and bipolar: 1.0%) of cloud-to-ground lightning flashes integrated from 1988-1989 to 1994-1995 in the case of southeastern Brazil. In order to obtain a similar result as output, a lightning simulation needs to investigate and to test what physical mechanisms produce this output.

A more realistic model must produce statistically a similar lightning distribution related to multiplicity according to Figure 2, and a similar stroke distribution with current amplitude in lightning flashes according to Figure 3. Single lightning and the two first stroke distribution is presented in the latter figure.

From Figure 4, as an example of the behavior of each thunderstorm in this data set, the conclusion was that there is no increasing/decreasing relationship for the multistrokes lightning flashes between stroke current amplitude and interstroke time interval. A similar result was obtained for all periods in the data set and also obtained with positive flashes.

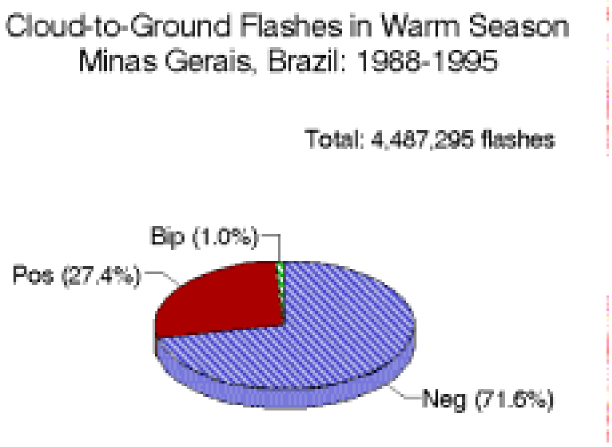

Fig. 1 - Ratio among the different polarities of Cloud-to-Ground Lightning Flashes integrated from 1988 to 1995 in the southeastern Brazil region.

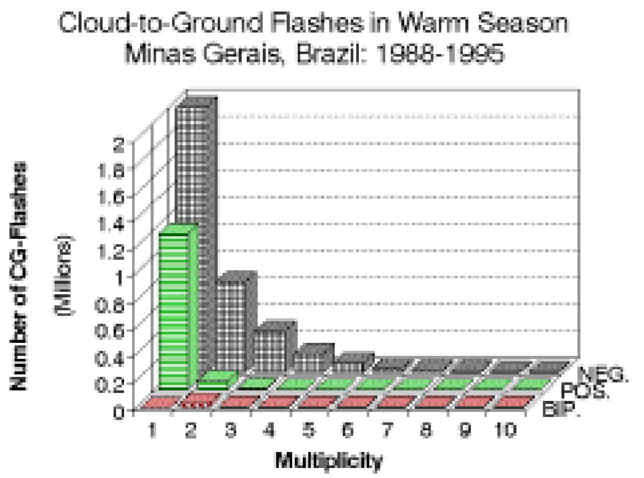

Fig. 2 - Cloud-to-Ground Lightning distribution related to multiplicity (number of strokes per flash).

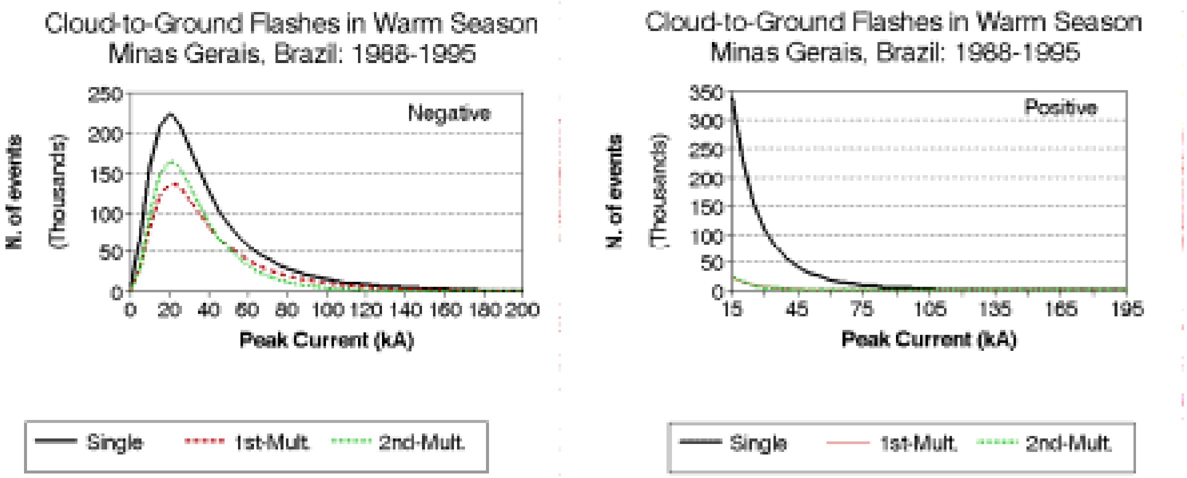

Fig. 3 - Stroke distribution with current amplitude in lightning flashes for negative and positive polarity, respectively. Single lightning and the two first strokes in the multistroke lightning are presented..

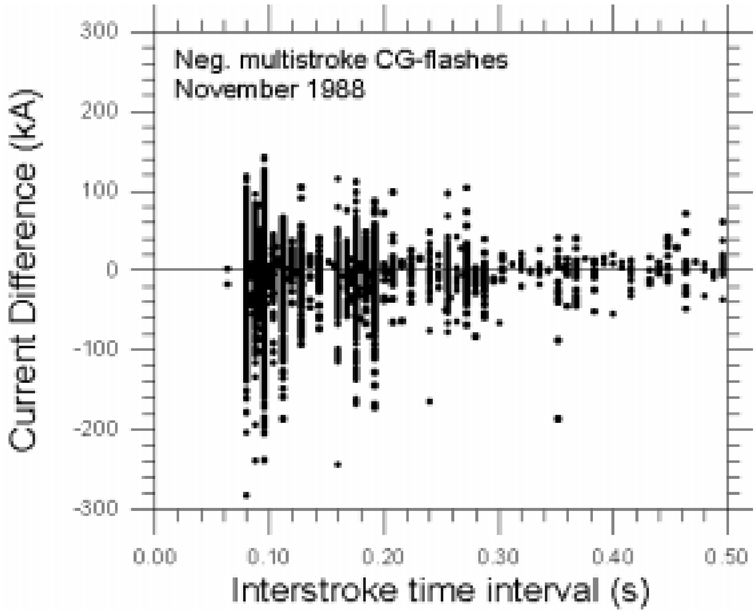

Fig. 4 - Example of the difference of current amplitude related to interstroke time interval for consecutive strokes in multistroke lightning flashes. A similar result was obtained for all periods in the data set and also obtained with positive flashes.

Although this work had been done for the warm season period (South Hemisphere), based in the monthly stroke distribution for Minas Gerais calculated by Diniz et al. (1996), the results obtained are representative of the annual lightning variation. In another recent study, the results presented in Figure 1 have been found by Mendes et al. (1988) using a numerical simulation that consider an exponentially increasing air conductivity with height. It was not necessary a strong wind-shear (producing a tilted electrical dipole) like at Japan (Takagi et al., 1986).

The analyses of multiplicity distribution (Figure 2) and stroke current distribution (Figure 3) suggest us to examine the following questions: What is the percentage of the positive lightning flashes originated from the lower positive charge center in cumulonimbus? Is it possible to obtain a density probability function for stroke distribution related to peak-current lightning flashes? Those questions are already under investigation.

Although, it is a preliminary climatological analysis, this work aims not only to provide information for a more realistic lightning modelling but also to extend the knowledge about lightning features in a worldwide sense.

Acknowledgements

The authors thank CEMIG by Ground-Strike data and keeping this important operative apparatus (LPATS). Rosangela B. B. Gin thanks to FAPESP for grants and support (Proc. N. 96/06961-5).

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