About the Intensity of Strokes in Negative Lightning Flashes

I.R.C.A. Pinto*
O. Pinto Jr.*
J.H. Diniz**
A.M. Carvalho**

*Instituto Nacional de Pesquisas Espaciais - INPE
**Companhia Energética de Minas gerais - CEMIG

Negative cloud-to-ground lightning flashes were recorded by a lightning positioning and tracking system (LPATS) in the region of the Mount Agulhas Negras (altitude of 2787 m) in Brazil, during the winter and summer season of 1993. The dependence of the stroke peak-current on the order of the stroke, the flash multiplicity and the season was investigated. It was found that subsequent strokes tend to be less intense than first-order strokes and that first-order strokes tend to be more intense in multiple stroke flashes. It seems that the larger is the multiplicity, the higher is the intensity of the first-order stroke. The above results are more evident during the winter season. It was also found that the geometric mean of the first-order stroke peak-current increases in the winter season. The dependence of the results on the high altitude of the observation site was also investigated. Apparently, the high altitude of Mount Agulhas Negras has an effect on the lightning intensity during the summer season.

INTRODUCTION

The peak-current intensity of negative cloud-to-ground lightning flashes has been studied for several authors in terms of stroke order (Fisher and Uman, 1972; Berger et al., 1975; Tiller et al, 1976; Rakov and Uman, 1990), latitude (Orville, 1990; Pinto et al., 1997), and season (Orville et al., 1987). Rakov and Uman (1990) have found that in general subsequent strokes are less intense than first-order strokes in multiple flashes. Also they found that first-order strokes in multiple stroke flashes are larger than strokes in single flashes by a factor of 1.3. Orville (1990) and Pinto et al. (1997) have found that negative flashes tend to be more intense at lower latitudes. Orville et al. (1987) have investigated the characteristics of negative lightning flashes as a function of season. They found that negative flashes tend to be more intense and present lower multiplicity in the winter season. Reap (1986) has investigated the influence of terrain elevation on the frequency and time of maximum lightning occurrence for the summer season in the western United States. He found that the higher is the terrain elevation, the higher is the mean number of lightning strikes and the earlier is the hour of maximum lightning activity. No information on lightning intensity was available.

In this paper we present the results of observation of 913 negative flashes in the region of Mount Agulhas Negras (22°23' S, 44°52'W, peak altitude of 2787 m), located in the frontier between the states of Minas Gerais and Rio de Janeiro, in the southeastern region of Brazil. The observations were made by a lightning positioning and tracking system (LPATS) during the winter (665 flashes) and summer (248 flashes) season of 1993. The system is described in detail by Pinto et al. (1996). The results are compared with similar data obtained in the same periods for the whole state of Minas Gerais.

RESULTS

During the 1993 summer season 248 negative lightning flashes were observed in a region of 12.5 km around the summit of the Mount Agulhas Negras. About 68% of the flashes were single flashes. The average multiplicity of multiple flashes was 2.5. During the winter season of 1993, 665 negative flashes were observed in the same region. Almost same percentage of single flashes (64%) and average multiplicity (2.6) were observed.

Table 1 shows the median peak-current values of first-order strokes in negative single and multiple flashes for winter and summer season. Median values are also presented for last-order strokes in multiple flashes and first-order strokes of multiple flashes with high multiplicity, here defined arbitrarily as those having five or more strokes. Also shown in Table 1 is the median values for all first-order strokes observed. In order to test the significance of the differences shown in Table 1, we have used the t-statistic to compare different median values assuming a log-normal distribution for the peak-current. We have also assumed that the population variances are the same (Rakov and Uman, 1990) and can be estimated from the sample variances.

Table 2 shows the results of the comparison of the median values showed in Table 1. Only cases where the significance level was equal to 0.02 or less are shown. This value was arbitrarily adopted as the limit for belief. Although not statistically significant at 0.02 significance level, the comparison between the median peak-current first-order strokes of all flashes with four or less strokes and those with five or more strokes (significance level of 0.07) seems to indicate that the larger is the multiplicity, the higher is the intensity of the first-order stroke. To

date, no data on such a relationship is available in the literature. A larger data set of high multiple flashes (five or more strokes) is necessary to prove or not this tendency.

Discussion and Conclusions

From the analysis of the results presented in Tables 1 and 2 we conclude that subsequent strokes tend to be less intense than first-order strokes, first-order strokes tend to be more intense in multiple stroke flashes, and that first-order strokes in winter flashes tend to more intense than those in summer flashes.

The first two results were observed in both seasons, although they were more evident in the winter season, perhaps due to the large data sample in this season. They were also observed by Rakov and Uman (1990) from electric field measurements in Florida, and seem to be independent on the altitude. The last result is in agreement with the observations of Orville et al. (1987) along the east coast of the United States. However they are in contrast with the result obtained by Rocha et al. (1997) and Pinto et al. (1986) for the whole state of Minas Gerais in the same winter and summer season, respectively. The results show that the negative first-order strokes are less intense in the winter. While the median peak-current of winter first-order strokes in the Mount Agulhas Negras is almost the same that in the state of Minas Gerais, the value in the summer (22.5 kA) is much lower than the value for the whole state (33kA). This fact suggests that the high altitude of Mount Agulhas Negras may have some influence in the intensity of negative flashes in the summer season. Clearly a more complete study is necessary in order to identify all aspects related to the seazonal and geographical variation of the intensity of negative first-order strokes.

Acknowledgments.

We would like to thank Armando Cazzeta Filho and Carlos Alexandre Meireles do Nascimento from CEMIG for supporting in the data aquisition.

References

Berger, K., Anderson, R.B., and Kroninger, H. Parameters of lightning flashes, Electra, 80:3402-3406, 1975.

Ficher, R.J., and Uman, M.A. Measured electric field risetimes for first and subsequent lightning return strokes, J. Geophys. Res., 77:399-406, 1972.

Orville, R.E. Peak-current variations of lightning return strokes as a function of latitude, Nature, 343:149-151, 1990.

Orville, R.E., Weisman, R.A., Pyle, R.B., Henderson, R.W., and Orville Jr., R.E. Cloud-to-ground lightning flash characteristics from June 1984 through May 1985, J. Geophys. Res., 92:5640-5644, 1987.

Pinto, O., Jr., Pinto, I.R.C.A., and Lacerda, M. Are equatorial lightning flashes more intense?, J. Atmos. Terr. Phys., in press, 1997.

Pinto, O., Jr., Gin, R.B.B., Pinto, I.R.C.A., and Mendes Jr., O. Cloud-to-ground lightning flash characteristics in southeastern Brazil for the 1992-1993 summer season, J. Geophys. Res., 101:29627-29635, 1996.

Rakov, V.A., and Uman, M.A. Some properties of negative cloud-to-ground lightning flashes versus stroke order, J. Geophys. Res., 95:5447-5453, 1990.

Reap. R.M., Evaluation of cloud-to-ground lightning data from the western United States for the 1983-84 summer seasons, J. Climate Appl. Meteor., 25:785-799, 1986.

Rocha, R.M.L., Pinto, I.R.C.A., and Pinto, O., Jr.,Cloud-to-groundlightningflash characteristics in the southeastern Brazil in the winter season, in this issue, 1997.

Tiller, J.A., Uman, M.A., Lin, Y.T., Brantley, R.D., and Krider, E.P. Electric field statistics for close lightning return strokes near Gainesville, Florida, J. Geophys. Res., 81:4430-4434, 1976.

Table 1: Median peak-current values in kA of negative cloud-to-ground flashes.

	SUMMER		WINTER	
	median peak current	number of flashes	median peak current	number of flashes
Single Flashes	22.1	168	23.9	424
First-order Stroke-Multiple Flashes	23.2	80	26.2	241
First-order Stroke-Flash with five or more Strokes	24.9	4	32.0	16
Last Stroke Multiple Flashes	21.5	80	21.2	241
All First-order Strokes	22.5	248	24.7	665

Table 2: Significance level associated with the differences in the median peak-current values presented in Table 1 (only cases with significance level of 0.02 are shown).

	Significance Level
All single strokes vs all first-order strokes in multiple flashes	0.02
All first-order strokes in summer flashes vs all first-order strokes in winter flashes	0.0009
All first-order strokes in multiple flashes vs all last-order strokes in multiple flashes	$<10^{-7}$