Estudos (Inter) Multidisciplinares nas Ciências Exatas e Tecnologias

Henrique Ajuz Holzmann
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(Organizadores)

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APRESENTAÇÃO

Neste livro são apresentados vários trabalhos, alguns com resultados práticos, outros com métodos de desenvolvimento para o ensino de tecnologias, bem como um enfoque em energias renovais.

Um compendio de temas e abordagens que constituem a base de conhecimento de profissionais que buscam estar atualizados e alinhados com as novas tecnologias .

A obra Estudos (Inter) Multidisciplinares nas Ciências Exatas e Tecnologias aborda os mais diversos assuntos sobre a aplicação de métodos e ferramentas nas diversas áreas das engenharias a fim de melhorar a relação ensino aprendizado, sendo por meio de levantamentos teórico-práticos de dados referentes aos cursos ou através de propostas de melhoria nestas relações.

Outro ponto de grande destaque, são as novas ferramentas utilizadas em um compendio relacionado ao ensino-aprendizagem, como ferramentas tecnológicas que facilitem o entendimento e executem um link entre aluno-professor-conteúdo.

Desta forma temas e abordagens que facilitam as relações entre ensino-aprendizado são apresentados, a fim de se levantar dados e propostas para novas discussões em relação ao ensino nas engenharias, de maneira atual e com a aplicação das tecnologias hoje disponíveis.

Boa leitura

Henrique Ajuz Holzmann
João Dallamuta
Ricardo Vinicius Bubna Biscaia

SUMÁRIO

CAPÍTULO 21

STUDY OF LIGHTNING BIFURCATION AND EFFECT ON RADIATION

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Diamantina-MG

ABSTRACT: In this work radiation and lightning channel were analyzed. For this, waveforms of electric fields and lightning footage were obtained in the cities of São José dos Campos and Diamantina. The proposals of this work were: 1) comparison between waveforms of electric fields and of their derivatives for different types of return strokes; 2) perform multifractal analysis of waveforms of electric fields and of their derivatives, also for different types of return discharges. The results from the comparisons show that the waveforms of the electric fields and the waveforms of the derivatives of the electric fields of primary return strokes are different from the waveforms of the electric field and the waveforms of the derivatives of the electric fields of non-primary return strokes. This result is in accordance with the literature. In addition, for primary return strokes, no dependence of their waveforms of electric fields and of their waveforms of their derivatives on whether or not the lightning was bifurcated and on the order of the return stroke was found. Multifractal analysis revealed the multifractal character of the waveforms of the electric fields and of the waveforms of their derivatives. However, the waveforms of the electric fields and the waveforms of the derivatives of the electric fields from primary and non-primary return strokes did not show significant differences between their fractal dimension values.

KEYWORDS: Lightning Radiation, Return Stroke, Bifurcated Channel, Multifractal Spectrum.

ESTUDO DE BIFURCAÇÃO EM RELÂMPAGOS E EFEITO NA RADIAÇÃO

RESUMO: Neste trabalho a radiação e o canal de relâmpagos foram analisados. Para isso, formas de onda de campo elétrico e filmagens de relâmpagos foram obtidas nas cidades de São José dos Campos e Diamantina. As propostas deste trabalho foram: 1) comparação entre formas de onda de campos elétricos e de suas derivadas, para diferentes tipos de descargas de retorno; 2) realização de análise multifractal das formas de onda de campos elétricos e de suas derivadas, também para diferentes tipos de descargas de retorno. Os resultados provenientes das comparações mostram que, as formas de onda dos campos elétricos e as formas de onda das derivadas dos campos elétricos das descargas de retorno primárias são diferentes das formas de onda dos campos

elétricos e das formas de onda das derivadas dos campos elétricos das descargas de retorno não-primárias. Este resultado está em conformidade com a literatura. Além disso, para as descargas de retorno primárias, nenhuma dependência das suas formas de onda dos campos elétricos e das suas formas de onda das derivadas dos campos elétricos com o fato do relâmpago ser bifurcado ou não e com a ordem da descarga de retorno, foi observada. A análise multifractal revelou o caráter multifractal das formas de onda dos campos elétricos e das formas de onda das derivadas dos campos elétricos. Porém, as formas de onda dos campos elétricos e as formas de onda das derivadas dos campos elétricos, provenientes de descargas de retorno primárias e não primárias, não evidenciaram diferenças significativas entre seus valores de dimensão fractal.

PALAVRAS-CHAVE: Radiação de Relâmpago, Descarga de Retorno, Canal Bifurcado, Espectro Multifractal.

1 I INTRODUCTION

Lightning strikes are electrical discharges that occur within the cloud or between the cloud and the ground. They last about 0.5 seconds and many different electrical processes occur in this short time interval. The most intense electrical discharge, and usually the one visible to the naked eye, is called return stroke or stroke, with typical peak electric current around 35 kA and lasting a few dozens of microseconds. The return stroke emits electromagnetic radiation which is generally used in its study. Figure 1 shows an example of a waveform of the electric field of the radiation emitted by a return stroke. The path taken by the return stroke, the luminous trace usually seen with the naked eye, is called a channel and consists of a plasma at a temperature of about 5,000 K. Lightning bolts that have a single return stroke are called simple lightning. Lightning bolts that have multiple return strokes are called multiple lightning. In multiple lightning a return stroke is characterized by its order of occurrence and can be classified as first return stroke, second return stroke, third return stroke and so on. Return strokes whose order of occurrence is greater than 1 are referred to as subsequent strokes.

When lightning strikes only 1 point on the ground (Figure 2a) it is referred as single channel lightning. However, in some cases, return strokes in a multiple lightning can travel through different channels so that lightning strikes 2 or more points on the ground. This type of lightning is called bifurcated (Figure 2b). In a bifurcated lightning a given bifurcation may occur at the same return stroke, but it may occur that a bifurcation occurs involving return strokes of different orders, with the higher order return stroke usually being considered bifurcated from the lower order return stroke. So, beyond the term “bifurcated lightning” the term “bifurcated return stroke” is also used. Observations of bifurcated lightning have been made since the 1930s, but the pioneers in using video cameras in such observations were WINN et al (1973) and THOMSON et al (1984). Distances between 2 points on the ground struck by bifurcated channels have been observed ranging from a few hundred meters to a few kilometers (THOTTAPPILLIL et al, 1992). In their work, VALINE AND KRIDER (2002), studying bifurcated and single channel lightning, obtained an average number of channels equal to 1.45, besides noting that 67% of the bifurcations occurred in the second return stroke. In Brazil, FERRO et al (2012) in their study observed that 52% of bifurcation cases occurred on the second return stroke.

The complex nature of lightning channels was observed by MIRANDA and SHARMA (2016). They observed the multifractal character presented by lightning channel and the variation of this character among the various categories of lightning analyzed by them.

In this present work, when a stroke is the first return stroke to travel in a channel, such as, the first order return stroke or a subsequent return stroke which is the first stroke to travel in a given bifurcation, it is referred as primary. The other return strokes are called non-primary.

Besides the use of video cameras, another technique widely used to study lightning is the use of electric field antennas to obtain electric field waveforms from the electromagnetic radiation of lightning. These waveforms are usually analyzed in order to get lightning information. Several characteristics of lightning have been studied through analysis of electric field waveforms of lightning radiation (MIRANDA et al, 2003; MIRANDA, 2004; MIRANDA, 2008; SHARMA et al, 2011).

WEIDMAN and KRIDER (1978) were the first to use the fine waveform structure of the electric fields emitted by return strokes to distinct such discharges as bifurcated or non-bifurcated. However, WILLETT et al. (1995) were the first to use the fine structure of the waveform of the derivatives of the electric fields emitted by return strokes to make such a distinction.

According to WILLETT et al. (1995), the waveform of the derivative of the electric field of the radiation emitted by a primary return stroke is noisy after the instant of the occurrence of the electric field peak value. But, in the case of non-primary return stroke, the waveform of the derivative of the electric field is smooth or much less noisy after the instant of the occurrence of the electric field peak value.

Based on what has been exposed, this work proposed from video images and electric field waveforms of return strokes and their derivatives, to analyze the fine structure of these waveforms and verify the occurrence of bifurcated and non-bifurcated return strokes. It was also proposed to investigate whether these electric field waveforms and their derivatives exhibit multifractal characteristic.

For the implementation of these proposals the return strokes were classified into the following types or classes: first order, subsequent, primary and non-primary. The correspondent lightning discharges were classified into bifurcated or single channel.

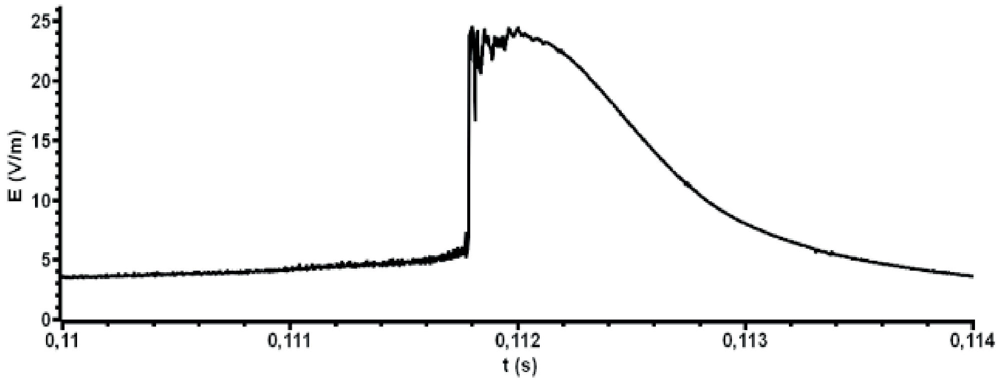


Figure 1 – Example of a waveform of the electric field (E) of the electromagnetic radiation emmitted by lightning return stroke.

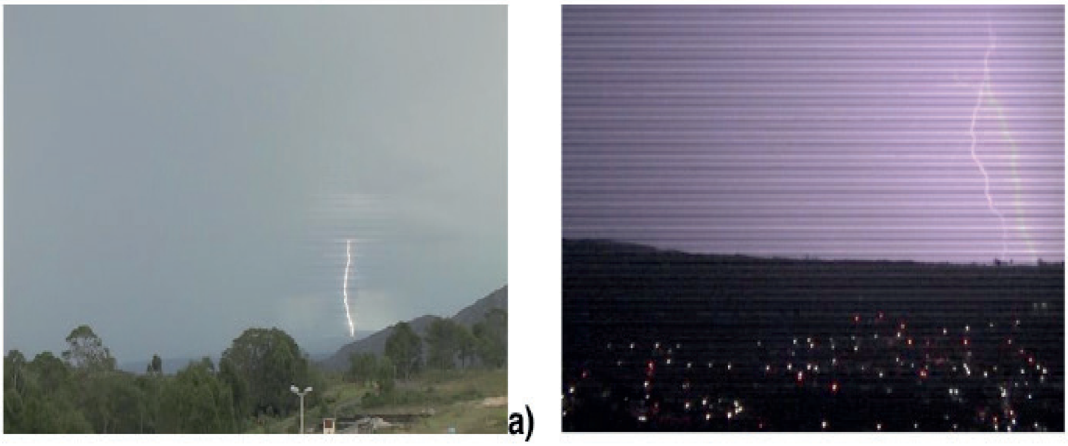


Figure 2 – a) Lightning with a single channel occurred in Diamantina. b) Bifurcated lightning occurred in Diamantina.

2 I METHODOLOGY AND INSTRUMENTATION

The methodology used in this work consisted of the following steps: 1) data acquisition; 2) data processing and analysis; 3) analysis of results and establishment of conclusions. In the first step, waveforms of radiation electric fields and lightning footage were obtained in storms occurred in São José dos Campos and Diamantina. In the second step, the derivatives were numerically calculated from the measured electric field waveforms. Both were correlated and analyzed with the filming performed. In this step, comparisons of electric field waveforms and their derivatives for primary and non-primary return strokes were performed. In addition, multifractal spectra of these waveforms were calculated. The results were also obtained. To perform this step, software was used to visualize time series and filming (frame by frame), as well as algorithms were developed for numerical calculations. In the third step, the results obtained in the second step were analyzed and the conclusions established.

Figure 3 shows the instrumentation used in this work. In Figure 3a, there is the scheme of the electric field waveform acquisition system. It consisted of a plate antenna to detect lightning radiation and send its signal to an electronic circuit to be processed.

The signal was then sent to a digital oscilloscope and sampled at a rate of 800,000 samples per second. A photo of the antenna and the electronic circuit is shown in Figure 3b. The electronic circuit was stored inside the box under the plate antenna and operated at a 70 MHz bandwidth. Figure 3c shows the camcorder used in this work.

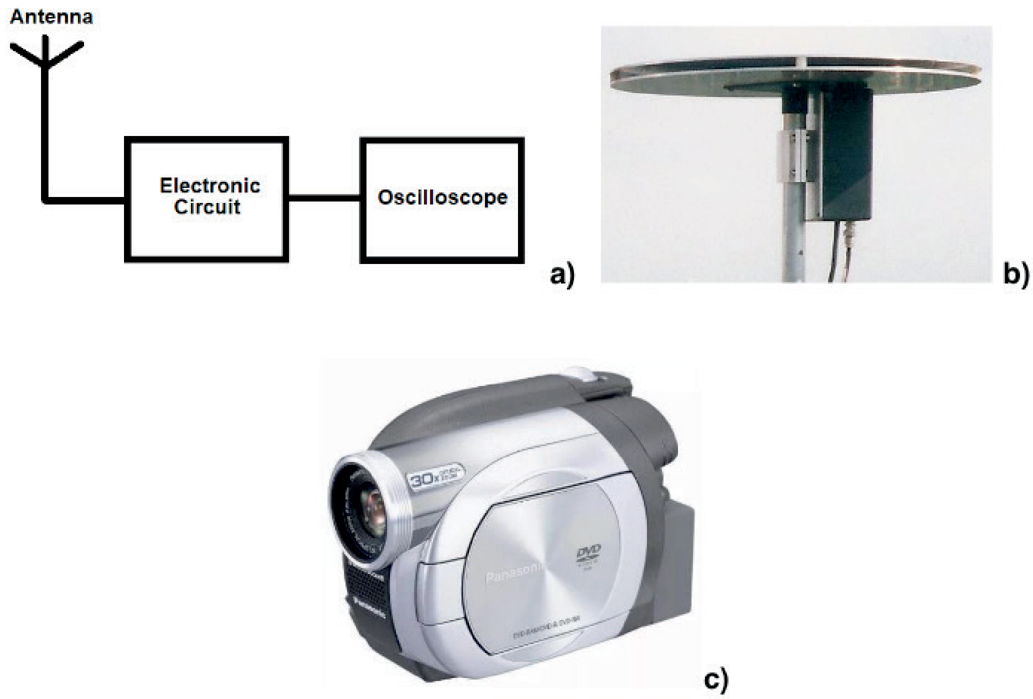
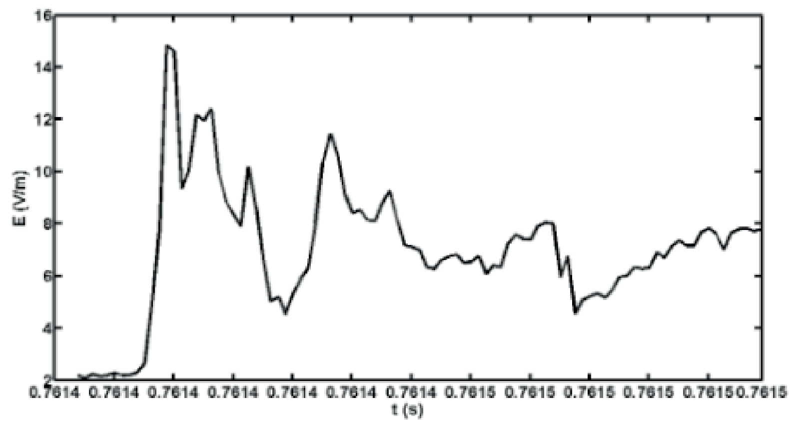


Figure 3 - a) Instrumentation scheme used in the acquisition of electric field waveforms from lightning radiation. b) Electric field sensor (plate antenna) and Processor Circuit; c) Panasonic VDR 300d camcorder.

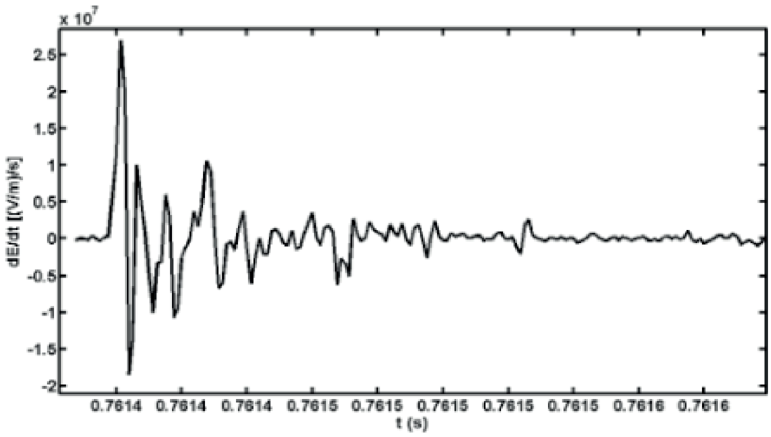
3 I RESULTS

In this work 4 lightning strikes were analyzed. Of these, 3 were bifurcated and 1 was a single channel lightning. The total amount of return strokes was 19. Of these, 4 were first order primary strokes, 4 were subsequent primary (or bifurcated) strokes and 11 were non-primary strokes.

Figures 4 and 5 show examples of primary and non-primary return strokes observed in this work. The waveform of the electric field (E) in Figure 4a and the waveform of the derivative of this electric field (dE/dt) in Figure 4b were originated from the same subsequent primary return stroke of a bifurcated lightning. Figure 5 shows the same, but for a subsequent non-primary return stroke of the same bifurcated lightning. As shown in Figures 4 and 5, all return strokes analyzed in this work, except those of the single channel lightning, exhibit behaviors similar to those evidenced by WEIDMAN and KRIDER (1978) and WILLET et al (1995), showing a noisy fine structure after the instant of the occurrence of the electric field peak value, in the case of primary strokes (Figure 4) and a smooth fine structure after this instant, in the case of non-primary strokes (Figure 5). According to them, this noisy fine structure in the waveforms of primary return strokes is due to the occurrence of branching and tortuosity in the channel. In the case of the single channel lightning, it contained 1 first-order primary return stroke and 8 subsequent non-primary return strokes, and all return strokes exhibited similar and relatively noisy fine structure after the instant of the occurrence of the electric field peak values. Waveforms of the electric fields of first order primary strokes and subsequent primary strokes were compared. A similar comparison was performed taking into account the waveforms of the derivatives of these electric fields. Either for the comparisons of the waveforms of the electric fields or for the comparisons of the waveforms of the derivatives of these electric fields, no dissimilarities were exhibited between first order primary strokes and subsequent primary strokes. The similarities observed in these waveforms, for both first order and subsequent primary strokes suggest that the characteristics of these return strokes do not depend on the order of occurrence. The waveform of the electric field of the primary stroke in the single channel lightning was compared to the waveforms of the electric fields of the primary strokes in the bifurcated channels. No dissimilarity was found in these waveforms. The same kind of analysis but taking into account waveforms of the derivatives of the electric fields also did not show dissimilarities. Thus, dependence of primary strokes with the fact of lightning being single channel or bifurcated was not found.



a)



b)

Figure 4 – a) Waveform of electric field (E). b) Waveform of the derivative of the electric field (dE/dt). Both for the same primary return stroke.

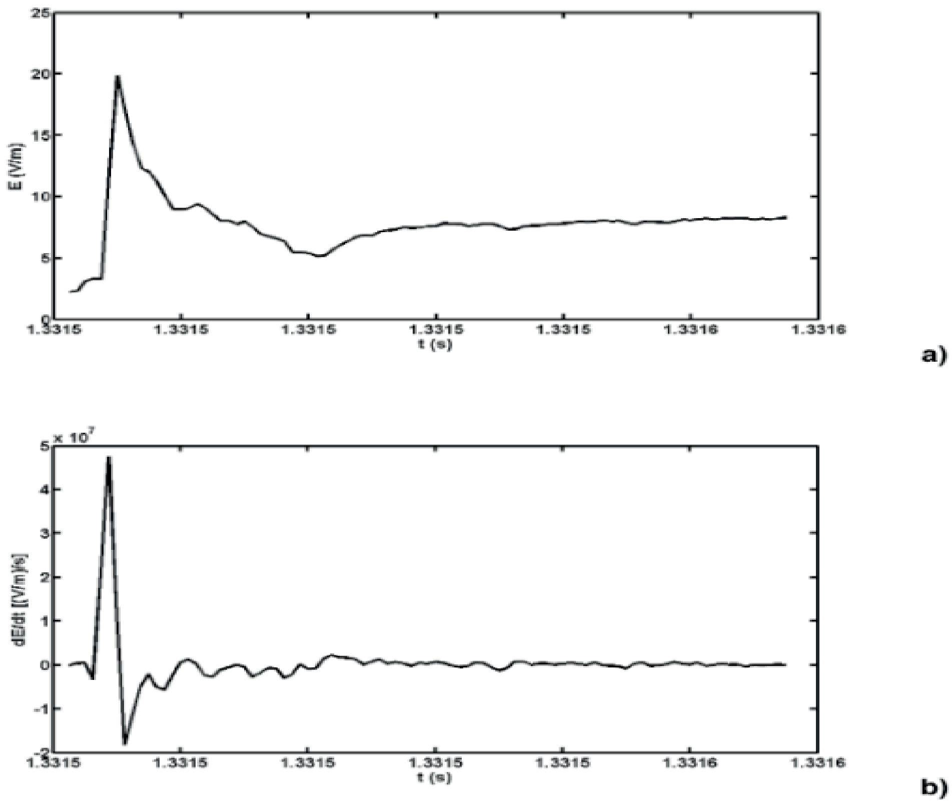
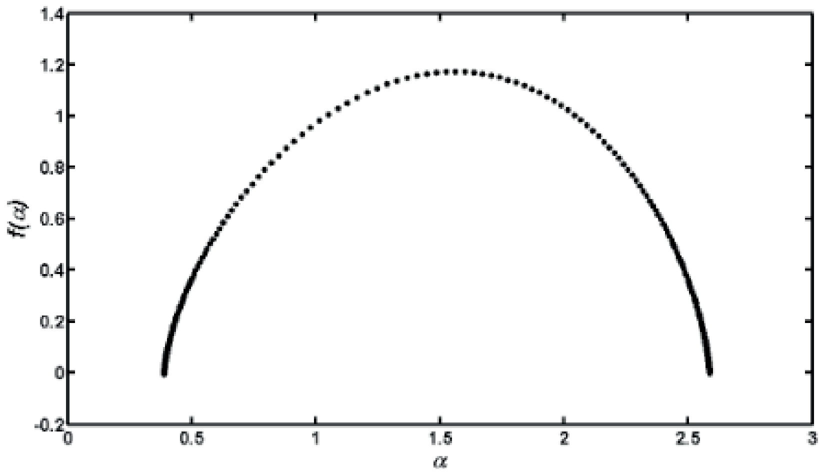
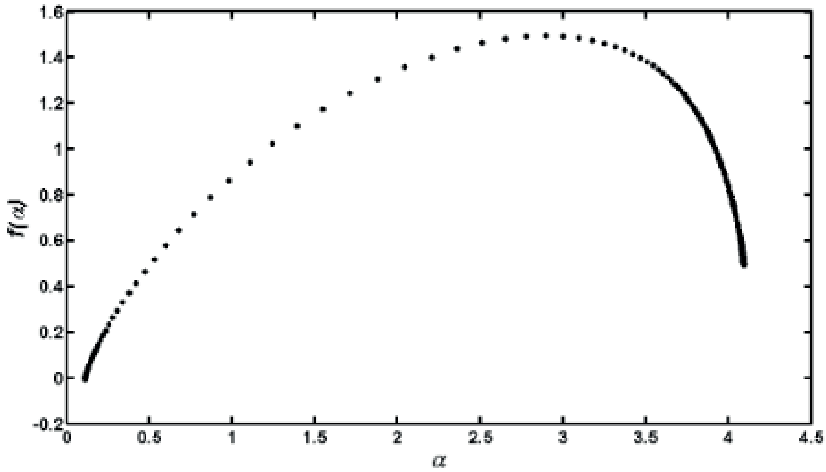


Figure 5 – a) Waveform of electric field (E). b) Waveform of the derivative of the electric field (dE/dt). Both for the same non-primary return stroke.

A multifractal analysis of the waveforms of the electric fields and their respective derivatives was performed. All return strokes which were analyzed exhibited multifractal spectra similar to those shown in Figure 6, suggesting the multifractal character of the waveforms. The spectra in Figures 6a and 6b correspond respectively to the waveforms in Figures 4a and 4b. The multifractal spectrum is a kind of distribution (f(*a*)) of singularities in the signal, arranged in sets of "intensities" (*a*). When the spectrum of the object has only one point it is a fractal object, and the singularities are in a set with a unique value of fractal dimension. However, in the case of the spectrum containing a lot of points as in Figure 6, singularities are arranged in several sets, each one with a specific value of dimension. In this case, the fractal dimension of the object is defined as the value of f(*a*) corresponding to the maximum of the spectrum.



a)



b)

Figure 6 – a) Multifractal spectrum of the waveform exhibited in Figure 4a. b) Multifractal spectrum of the waveform exhibited in Figure 4b.

Values of fractal dimensions of the waveforms of the electric fields and of the waveforms of the derivatives of the electric fields were obtained from their multifractal spectra. Table 1 shows the fractal dimension values which were obtained.

Return Stroke Type	Fractal Dimension of the Waveform of the Electric Field	Fractal Dimension of the Waveform of the Derivative of the Electric Field
First Order Primary	1.63±0.23	1.39±0.20
Subsequent Primary	1.25±0.08	1.72±0.16
Non-Primary	1.36±0.08	1.77±0.11

Table 1 - Fractal dimension values of the waveforms of the electric fields and their derivatives for the return strokes types taken into account in this work. The values are presented in the format: Mean ± Standard Error.

From the data presented in Table 1, an inference by eye (CUMMING and FINCH, 2005) suggested no significant difference in the fractal dimension values as a function of the return stroke type. However, caution should be taken when looking to these results due to the small sizes of the samples (less than 10) used to obtain the results shown in Table 1. An analysis with large samples is recommended.

4 I CONCLUSIONS

Comparisons of waveforms of electric fields of different types of return strokes were performed. The same comparisons were performed using waveforms of the derivatives of these electric fields. From these comparisons it is concluded that: 1) the primary and non-primary return stroke waveforms are not similar and observations from WEIDMAN and KRIDER (1978) and WILLET et al (1995) were confirmed in this work; 2) for the waveforms of the electric fields of primary return strokes and the waveforms of the derivatives of these electric fields, no dependence on the order of occurrence of the primary return stroke was found; 3) it was not evidenced from the characteristics of the waveforms of the electric fields and the waveforms of their derivatives, a dependence of the primary return strokes on whether lightning is single channel or bifurcated; 4) the waveforms of the electric fields and the waveforms of the derivatives of these electric fields exhibited multifractal character for all types of lightning and strokes taken into account in this work. No significant difference was found in the fractal dimension values of the waveforms (E(t), dE(t)/dt) of the different types of return strokes considered in this work.

REFERENCES

CUMMING, G.; FINCH, S. **Inference by Eye. Confidence Intervals and How to Read Pictures of Data**. American Psychologist. Vol. 60, No. 2, 170–180. DOI: 10.1037/0003-066X.60.2.170, 2005.

FERRO, M. A. S.; SABA, M. M. F.; PINTO JR, O. **Time-intervals between negative lightning strokes and the creation of new ground terminations**. Atmospheric Research. 116. 130–133. 10.1016/j.atmosres.2012.03.010, 2012.

MIRANDA, F. J.; PINTO JR., O; SABA, M. M. F **A study of the time interval between return strokes and K-changes of negative cloud-to-ground lightning flashes in Brazil**. Journal of Atmospheric and Solar Terrestrial Physics, v. 65, issue 3, p. 293-297, Feb., 2003.

MIRANDA, F. J. **Estudo das características de relâmpagos nuvem-solo negativos através da análise comparativa de observações por múltiplas técnicas** – São José dos Campos: Tese - INPE, 2004. 192p. – (INPE-12181-TDI/975), 2004.

MIRANDA, F. J. **Wavelet analysis of lightning return stroke**. Journal of Atmospheric and Solar-terrestrial Physics, v. 70. p. 1401-1407. 10.1016/j.jastp.2008.04.008., 2008.

MIRANDA, F. J.; SHARMA, S. R. **Multifractal analysis of lightning channel for different categories of lightning**. Journal of Atmospheric and Solar-Terrestrial Physics, v. 145, p. 34-44, 2016.

SHARMA, S. R.; COORAY, V.; FERNANDO, M.; MIRANDA, F. J. **Temporal features of different lightning events revealed from wavelet transform**. Journal of Atmospheric and Solar-terrestrial Physics, v. 73. p.507-515. 10.1016/j.jastp.2010.11.009, 2011.

THOMSON, E. M.; GALIB, M. A.; UMAN, M. A.; BEASLEY, W. H.; MASTER, M. J. **Some features of**

stroke occurrence in Florida lightning flashes. Journal of Geophysical Research, v. 89, n. D3, p. 4910-4916, June, 1984.

THOTTAPPILLIL, R.; RAKOV, V. A.; UMAN, M. A.; BEASLEY, W. H.; MASTER, M. J.; SHELUKIN, D. V. **Lightning subsequent-stroke electric field peak greater than the first stroke peak and multiple ground terminations.** Journal of Geophysical Research, v. 97, n. D7, p. 7503-7509, May, 1992.

VALINE, W. C.; KRIDER, E. P. **Statistics and characteristics of cloud-to-ground lightning with multiple ground contacts**. Journal of Geophysical Research, v. 107, n. D20, AAC8 (p.1-11), Oct., 2002.

WEIDMAN, C. D.; KRIDER, E. P. **The fine structure of lightning return stroke waveforms**. Journal of Geophysical Research, v. 83, n. C12, p. 6239-6247, Dec., 1978.

WILLETT, J. C.; LE VINE, D. M.; IDONE, V. P. **Lightning-channel morphology revealed by return-stroke radiation field waveforms**. Journal of Geophysical Research, v. 100, n. D2, p. 2727-2738, Feb., 1995.

WINN W. P.; ALDRIDGE, T. V.; MOORE, C. B. **Video-tape recordings of lightning flashes**. Journal of Geophysical Research, v. 78, n. 21, p. 4515-4519, July, 1973.

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