STUDIES ON LIGHTNING FLASHES BY USING FRACTAL ANALYSES AND METHODS OF GEOMETRICAL STATISTICS.

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ABSTRACT: Several objects in the Nature present non-regular random shapes, irregular trajectories, complex dynamics, or are randomly scattered in space. Lightning flashes are considered in this category. In this work some fractal analysis techniques and geometrical statistic methods were chosen and presented to be applied in specific features of lightning. The results were interpreted trying to relate them to the electrodynamics properties of the lightning or the atmosphere.

INTRODUCTION

Several objects in the Nature present non-regular random shapes, irregular trajectories, complex dynamics, or are randomly scattered in space. Lightning flashes, which consist of transient atmospheric electric currents, are considered in this category. In general the investigation of the random and fractal behaviors could be supposed to reveal some hidden physical processes or mechanisms related to those objects (Stoyan and Stoyan, 1995; Vechi et al., 1994; Ott, 1993; Takayasu, 1990; Tsonis and Elsner, 1987).

Nowadays several electromagnetic techniques for lightning detecting are available. Those tools are for remote monitoring, so complex features of lightning flashes are lost. The use of visual documentation for the analysis of this kind of phenomenum could help to identify important aspects of detected lightning or, anyway, non-detected lightning. Surely the specifically generated knowledge will improve the lightning detector networks and, on the other hand, allow the adequate use of the information in weather nowcasting. The values obtained from imagery analyses will also be used as parameters in lightning numerical simulations, which allow to investigate the atmospheric electrodynamics and the relationship between atmospheric electric discharges and atmosphere.

Thus in this work some fractal analysis techniques and geometrical statistic methods were chosen and presented to be applied in specific features of lightning. The results could be interpreted trying to relate them to the electrodynamics properties of the lightning or the atmosphere.

DATASET AND METHODOLOGY

The analyzed data are images taken from lightning events in several conditions. The imagery devices are conventional cameras (30 frames per second) or high speed camera (500 frames per second). Photography could help too. Each of them presents advantages and disadvantages related to allowed pixel resolution (for spatial characterizations) and time resolution (for dynamical analyses). However a new order of comprehension on lightning flashes is expected to arise from these persistent efforts.

The proposed methodology consists of the integrated use of information on channel characterization, imagery fractal analyses, stroke/lightning geometrical statistics and discharge-feature time analyses. The features which should be analyzed are: (a) branching which is supposed to be related to the electric breakdown and atmospheric conductivity, (b) tortuosity which is supposed to be related to atmospheric conductivity and space charge, (c) current intensity peak, multiplicity, time lag, and stroke/lightning clusters which are supposed to be related to charge storage processes, atmospheric conductivity and the thermo-electrodynamics of convective cells. This study deals with the first two parts of the methodology.

The box counting fractal analysis can apply filters in the image treatment (Russ, 1998), in order to emphasize features of the channel. In this study, three filters are used. The first one is the gradient find edge (GFE), which emphasize the frontier of the channel; the second is the Laplacian find edge (LFE), which emphasize the channel; and the third is Sobel find edge (SFE), which emphasize the channel. In principle the fractal dimensions are not the same, although the examined object is the same. The reason is that the analyzed features are different. For each image, due to the differences in brightness and background, it is necessary to define the threshold values for the treatment. The box counting dimensions could be used as indices for branching. If the index are close one, there is no branching, and the value close 1.7 is common values for laboratory discharge that are very branched (Takayusu, 1990).

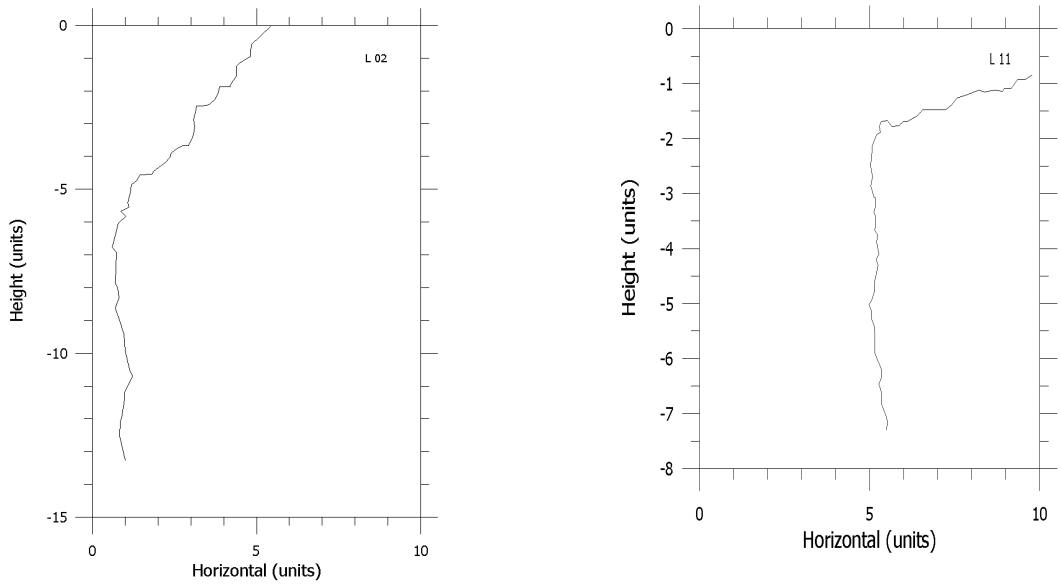
RESULTS AND DISCUSSION

Taking into account part of the methodology (channel characterization and counting box method for fractal analysis), preliminary results are presented.

The following figures are related to analysis of the main channels of the first strokes of lightning events. Although they have similar visual path behavior, they represent different physical aspects. The first one (case a) is a cloud-to-ground lightning and the second one (case b) present cloud-to-ground and cloud-to-cloud behavior “simultaneously”. Figure 1 presents these 2D-channel paths. The units are image pixels, in this sense the most

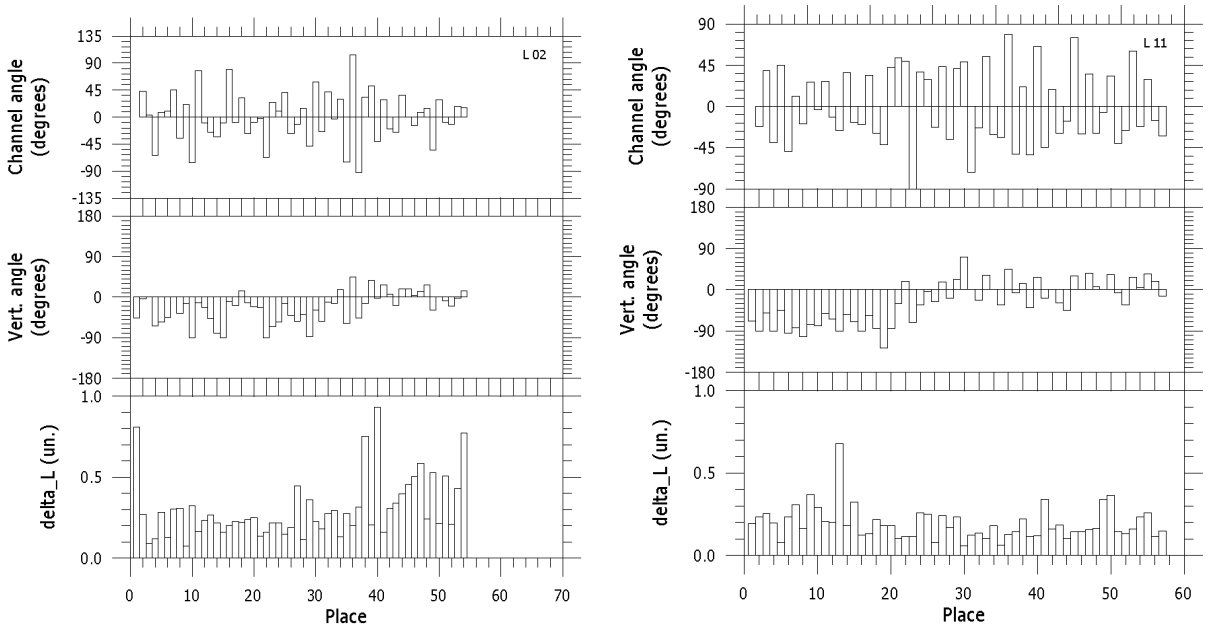
important information is the fluctuation, not the absolute values. Figure 2 presents step length, angle with the vertical and angle between consecutive steps related to the position of lightning. The channel angle establishes an index for the ambient disturbance due to the conductivity and space charge. Both channels have a similar fluctuation value, on the other hand the histogram of these angles presents a modal distribution and a bimodal distribution, respectively (Figure 3). In this last case, very few angles occur near 0^o, and in both cases they occur between $[-90^o,90^o]$. The vertical angle indicates how vertical is the step-path. The second path is less vertical than the first one. It is related to the natural path in the atmosphere, in this sense the difficulty to reach the ground is higher in the second case. The third aspect presented in Figure 2 and 3 is the linear step length. It indicates a local disturbance in the ambient like the channel angle index indicates. In this case, the lower values of the step length indicate difficult in the path development. In the histogram of this aspect, it is observed that very long length is not so common and the cloud-to-ground flash (case a) seems to have the highest step length. Other aspect is that there are modes in both cases. In Figure 4 the lightning flash of case b is presented. It is noticed that it has a branch connected to ground and other branch connected to other place in the cloud. The complete lightning presented complex behavior, nevertheless it is usual in nature (according to the image dataset). Figure 5 applies filters in order to emphasize lightning features and allow to obtain the fractal dimensions and Table 1 presents these results. The fractal dimension is about 1.5, i. e., branching is detected and value is high.

This kind of analysis is being applied to a large imagery database with the purpose of statistics consistence and find boundary values for the classifying lightning flashes.



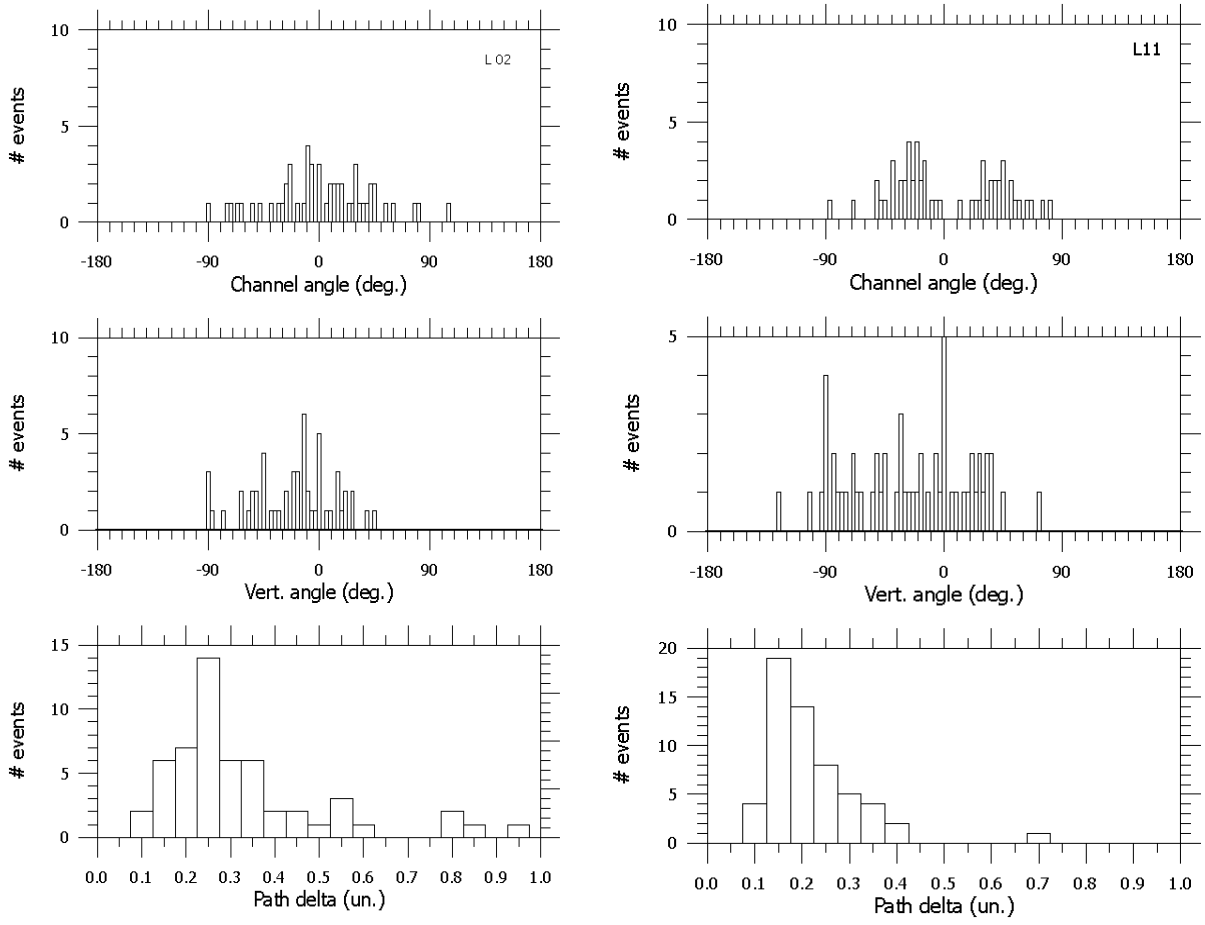
(a) (b)

Fig. 1 – The main channels of the first strokes of lightning events.



(a) (b)

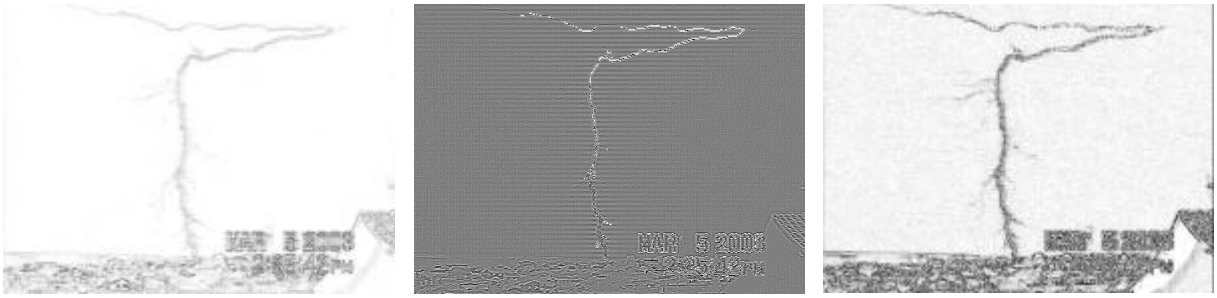
Fig. 2 – The horizontal coordinate place is the step from top (zero) to bottom with the related step length, angle with the vertical and angle between consecutive steps.



(a) (b)

Fig. 3 – Histograms of step length, angle with the vertical and angle between consecutive paths.

Fig. 4 – The complete lightning presented complex behavior. Flash presented a branch connected to ground and a branch connected in other place in the cloud (case b).



(a) (b) (c)

Fig. 5 – Filters in order to emphasize channel features: (a) GFE, (b) LFE and (c) SFE.

Table 1 – Box Counting fractal dimensions

Case:	***GFE***	***LFE***	***SFE***
(a)	1.51±0.01	1.48±0.03	1.51±0.01
(b)	1.58±0.01	1.42±0.02	1.55±0.01

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