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PHYSICS OF LIGHTNING INITIATION AND PROPAGATION

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Electrical Structure of Thundercloud

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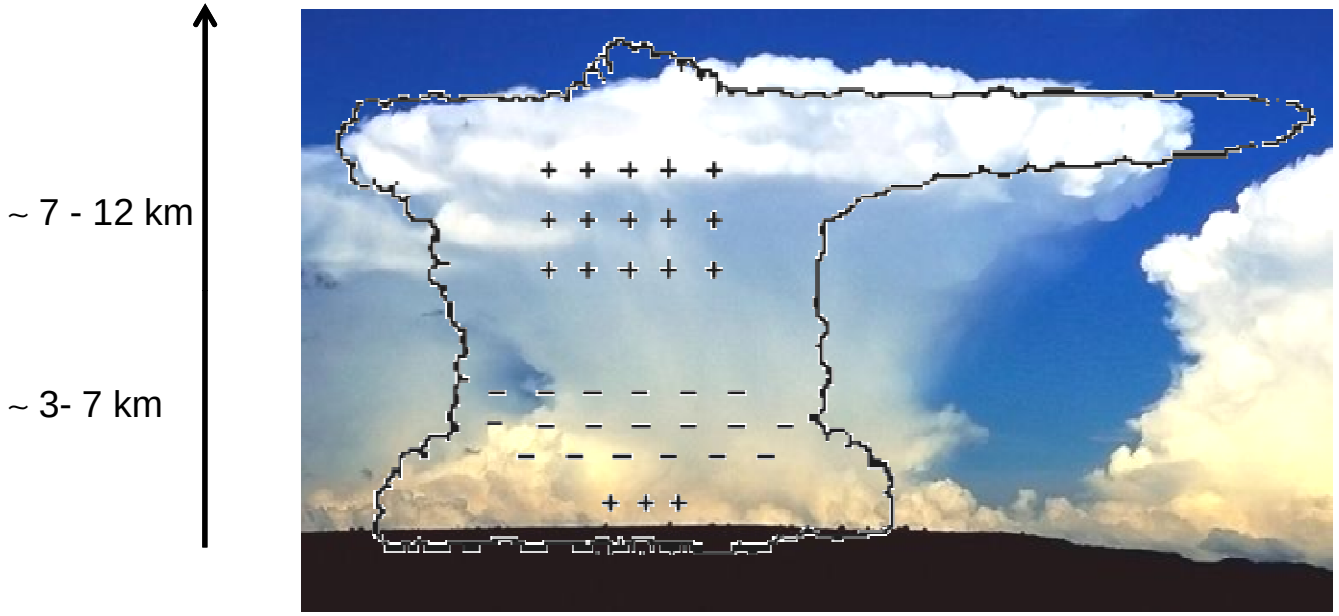
Electrical Structure of Thundercloud



Electrical Strucuture of Thundercloud – Cumulonimbus (2 or 3 charge centers)

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Preliminary Breakdown and Leader Initiation

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Preliminary Breakdown and Leader Initiation

Lightning initiation is due to the formation of streamers inside the thundercloud (charge centers), caused by the high electric fields which exist therein (between 0.1 to 1 MV/m).

The propagation of these streamers leads to the recombination of charges in the cloud and to the formation of an electrical channel from where a lightning leader starts its development.

Preliminary Breakdown and Leader Initiation

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So far, there is no total clarity regarding the way in which the streamers are formed inside the cloud.

However, the major discussion and controversy is focused on the way in which they propagate, since there are two main conceptual models :

I. Unipolar concept
II. Bipolar concept

Leader Propagation

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Leader Propagation

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I. Unipolar concept

It assumes that a unipolar and unidirectional leader channel emanates from the charge center of the cloud toward ground and that the electrical charge is transferred from the cloud to the leader channel.

Nevertheless, there is no physical explanation for this transfer mechanism, and the “unipolar” term concerns only a theoretical assumption which does not strictly represent the real leader physics. This concept is the most widely used in the literature.

Leader Propagation

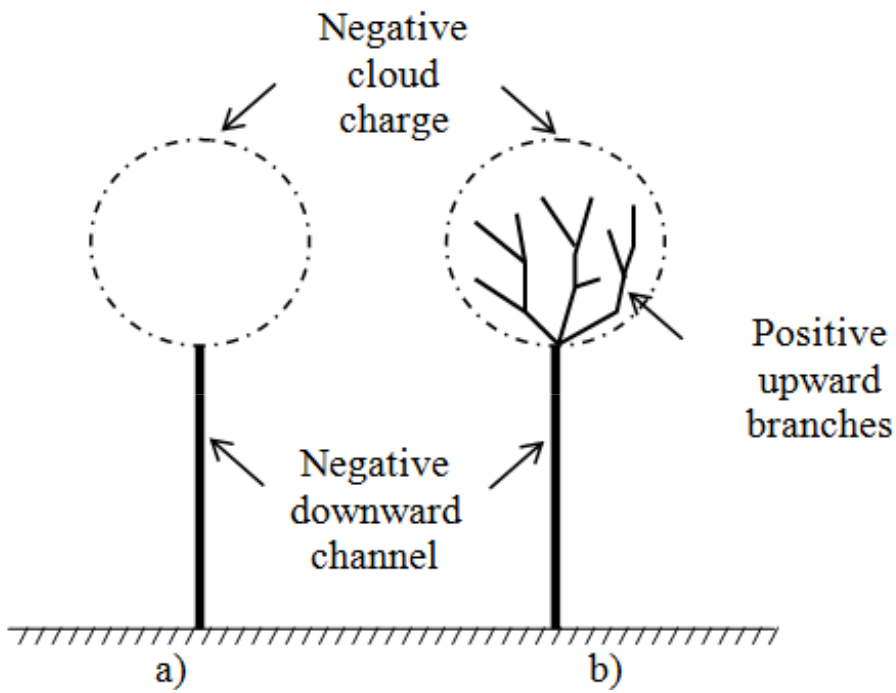
I. Bipolar concept

It considers a bipolar and bidirectional leader moving in opposite directions: one toward ground and other penetrates into the cloud.

The charge deposited on each channel has the same magnitude but opposite polarities, something which means that the net charge on the bipolar leader is zero and there is no charge transfer from the cloud to the leader.

The bipolar concept makes sense physically and is a better approach to the real phenomenon; also its propagation mechanism has been verified through field measurements of rocket triggered lightning and experiments with aircrafts

Leader Propagation



Conceptual models of leader propagation

a) unipolar / unidirectional b) bipolar / bidirectional

Tortuosity and Branching of the Leader Channel

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Tortuosity and Branching of the Leader Channel

Two interpretations of this random lightning behavior are:

i. Lightning leader path is guided by the variations of the external electric field and the local field at leader tip. These variations can be caused by the presence of space charge pockets along the leader trajectory and by the horizontal displacement of sections of charge inside the cloud. This may modify the electric field in the region in front of the leader tip and cause the random change of direction of the next step.

Tortuosity and Branching of the Leader Channel

ii. The instability of the plasma channel leads to the random appearance of spikes or peaks on its surface. These produce an electric field enhancement along their trajectory, which originates the appearance of other leader tips. When this happens, the tip whose growth and development is closest to the direction of the external electric field will have the highest probability to survive and to hinder the growth of the others, due to the repulsive action of the charges. However, if more than one tip propagate successfully, a branching of the leader occurs.

Tortuosity and Branching of the Leader Channel

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According to the studies on natural negative discharges carried out by Hill and Idone (1968/1988), the tortuosity is independent of the step length and height.

Hill found that the distribution of the change of direction with respect to the direction of propagation is Gaussian and its absolute value is between 15° and 21° with a mean of 17.3°.

In addition, the mean absolute value of the change of direction found by Idone was 17°, which agrees very well with Hill's results.

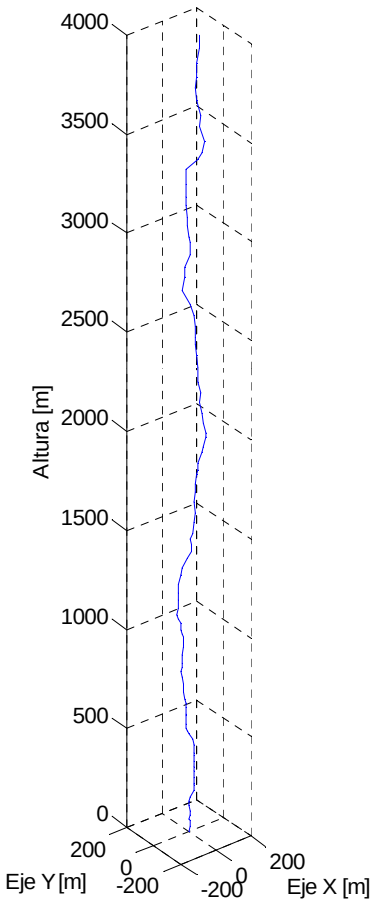
Tortuosity and Branching of the Leader Channel

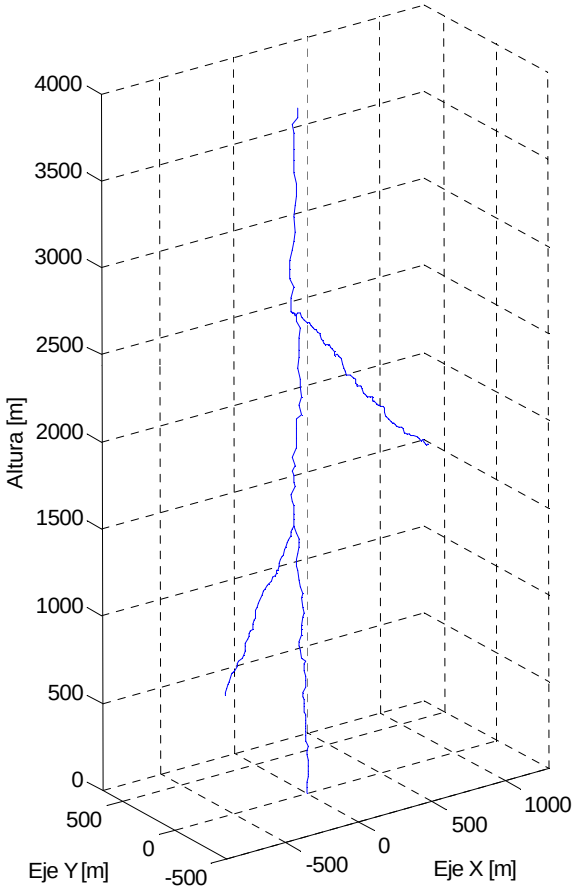
Eriksson analyzed the branches of 159 natural discharges, for a total of 575 branches (1979).

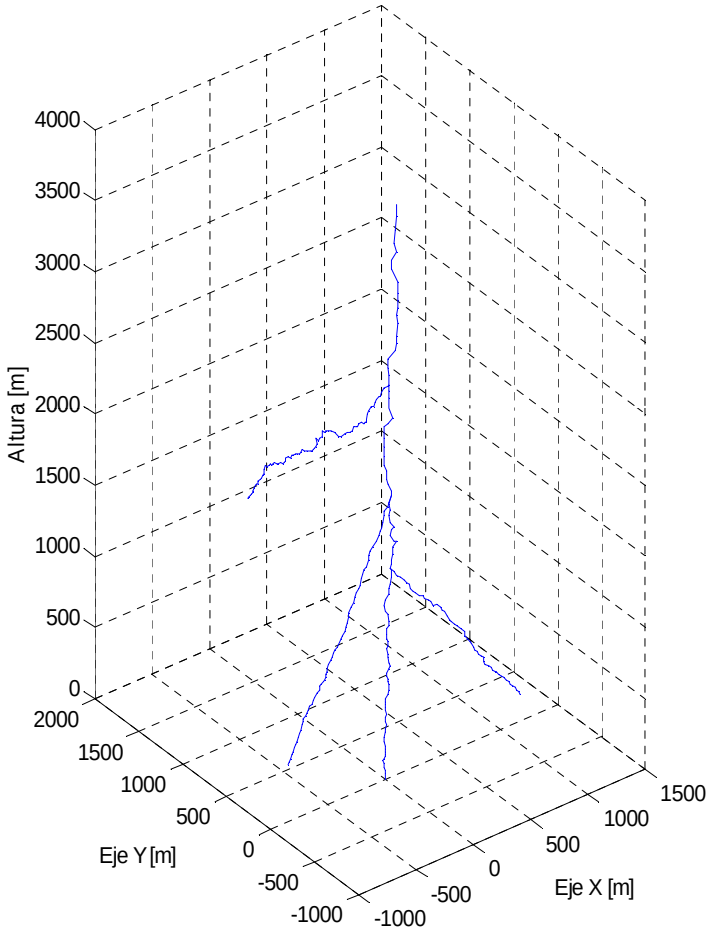
He found that 50% of the discharges exhibit 2 and 3 branches, and only 12% do not show any branching. Moreover, his measurements of the deviation angle of the branches with respect to the main direction of propagation, showed a typical branching angle of 45°.

Eriksson also found that the branching interval increases with height. In other words, the branches are closer to each other in the lower part of the leader.

Tortuosity and Branching of the Leader Channel







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Conclusions

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✓ It is only over the last two centuries that scientist have carried out studies and interpretations of this phenomenon in order to develop the knowledge of its nature.

✓ Recent developments and measurements contributes to the understanding of lightning and it is necessary to update the models and concepts regarding its initiation and propagation.

✓ The better understanding of this natural phenomenon , the more effective the protection and mitigation of its effects

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