Principles of Lightning Detection

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Basic principles of lightning detection in the VLF/LF and VHF frequency regime will be reviewed. We explain what kind of EM signals can be measured that are emitted during a lightning discharge. Besides the well-known cloud-to-ground strokes, a particular focus is given to the recognition and locating of pulses that are emitted inside thunderclouds, and to the discrimination of discharges that connect to ground or remain inside the clouds. Modern measurement techniques are presented, whereby both research systems and operational networks with direction finding, interferometry, and time-of-arrival are subject of the discussion. Results from scientific campaigns are shown that have been carried out in various parts of the world.

1. General

Lightning discharges are generally recognized due to their emission in the optical range and the accompanying thunder. In fact, the EM emission covers a wide range of frequencies from Schumann resonances (a few Hz) to the visible spectrum (several 100 THz). Most detection systems utilize VLF/LF (1 – 300 kHz) around the maximum power near 10 kHz, or VHF (some 10 – 100 MHz).

The discharge process is complex and involves many different steps. Basic descriptions can be found in standard textbooks [1]. For example, stepped leader processes develop a channel whereby many VHF signals are emitted, either as pulse trains or distinct pulses, measurable by interferometry (DF, direction finding) or time-of-arrival (TOA) techniques, respectively [2, 3]. When a channel connects positive and negative charge reservoirs a stroke occurs that can be measured by VLF/LF methods [3], employing either DF and/or TOA.

While strokes that connect to ground (return strokes, CG) are quite well understood, another large class of impulsive events takes place inside clouds (IC strokes). Signal characteristics of CG and IC strokes are mostly different, but also overlap to an extent that renders reliable discrimination difficult. Occurrence of IC strokes will be discussed in detail.

2. Lightning location networks

Automated lightning detection networks have reached a high standard and are used in many parts of the world. We will describe several networks that operate in either the VLF/LF or VHF range and employ somewhat different techniques. Typical results are shown, along with some limited data comparisons. Most critical network features are

- detection efficiency for CG and IC events
- discrimination between CG and IC
- location accuracy and scatter of locations

These features will be scrutinized, based on data from operational systems. In addition, data from research campaigns will be presented, e.g. from a project in Florida, and from DLR work in Brazil, Africa, and Australia, focussing on the recent CHUVA campaign that was carried out in the Sao Paulo area in Brazil. The results allow interesting comparisons of various lightning location networks.

3. Research topics

Although extensive and reliable knowledge has been assembled, many questions about lightning discharges remain open. For example, the initiation process is not yet understood: notably, IC strokes can occur after channel formation by stepped leaders, but they can also occur directly without any measurable prior EM activity. There is a wealth of other topics under investigation and some of them will be addressed.

4. References

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