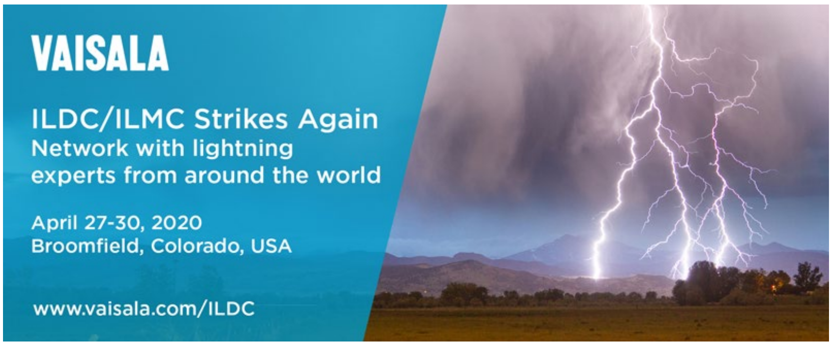

Development of Lightning Location Technology for Low-Frequency E-field Detection Array

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Abstract

In recent years, locating total lightning at the LF / VLF band has become one of the most important directions in lightning detection. Based on the attention paid to the physical process of lightning and the thunderstorm electricity, the Chinese Academy of Meteorological Sciences developed and constructed a low-frequency E-field detection Array (LFEDA) consisting of nine fast electric field change measuring instruments in Guangzhou area from 2014. At present, the LFEDA composed of 10 stations with the baseline length between approximately 6 and 70 km and run in frequency of 160 Hz–600 kHz with the sampling rate of 10MHz.

Shi et al. (2017) developed the initial localization algorithm of LFEDA system by referring to the localization method of the same kind of detection system commonly used at that time. The main step experienced matching the electric field waveforms according to their triggered times, obtaining the normalized power waveforms of each station by Hilbert transform, extracting the pulses from the normalized power waveforms, matching the pulses associated with same lightning pulse discharge events (LPDEs) by cross-correlation method, and then calculating the 3-D location and time of the LPDEs by time of arrival (TOA) technology based on non-linear least square method. Generally speaking, this work enables the LFEDA to have the capability of three-dimensional location of lightning.

In order to improve positioning ability, Fan et al. (2018) introduced empirical mode decomposition (EMD) algorithm into the analysis of lightning low frequency electric field signals. A new signal processing method and location algorithm are developed by using low-frequency filtering and high-frequency noise reduction for 1ms segment recorded waveform of electric field change and quadratic cross-correlation method of time-reduced window. It improves the accuracy of extracted peak time of pulse signal and helps to identify more pulses after Hilbert transformation, thus significantly advances the positioning accuracy of LFEDA system and the description ability of the LFEDA for lightning development channel.

However, EMD has inherent mode mixing and endpoint effects, limiting the adequacy of pulse extraction and the accuracy of pulse peak time. To solve these problems, advanced ensemble empirical mode decomposition (EEMD) is introduced into the analysis of lightning LF/VLF signals, and the mirror extension method is used to solve the endpoint effect (Fan et al., 2019). The mode mixing effect of EMD is significantly reduced by introducing uniformly distributed white noise signals into the decomposed signals during the filtering process of EEMD, allowing the shift of the signal peaks to be reduced by filtering out only the 500-600 kHz components during the filtering and de-noising process. The amplitude reduction of the pulses is also significantly weakened. Overall, compared with EMD algorithm, EEMD further improves the lightning location capability of the LFEDA.

The aforementioned works all locate the LPDEs by traditional TOA technology, which requires at least five stations for 3-D location. In recent, the time reversal (TR) technique was introduced into 3-D lightning location based on the LF lightning signals for the first time (Chen et al., 2019); this algorithm can locate the 3-D positions of LPDEs with only four-station synchronous observations, not only reducing the requirements on the number of stations, but also being of certain anti-interference ability and low requirements on time accuracy.

Topic Areas

Lightning Detection Systems Technology and Performance

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