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# Discharge height of lightning narrow bipolar event and its relationship with thundercloud

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Narrow bipolar event (NBE) is one of the most special types of lightning discharge events. In order to study the characteristics of NBE, two experiments using VLF/LF lightning location network in Guangzhou and Chongqing of China were carried out, and thousands of both polarities of NBEs were recorded.

In order to accurately determine the discharge height of NBE, we developed a method employing ionospheric reflection pair of NBE. The VLF/LF signal produced by NBE is reflected between the ionosphere and the ground, producing ionospheric reflection pulse and ground-ionospheric reflection pulse. With simultaneous observations of the NBE by multiple stations, 3-D location of the NBE can be determined by time delays between the original signal of the NBE and its ionospheric and ground-ionospheric reflection signals. This method proves to be much more accurate than traditional time-of-arrival (TOA) technique.

With this method, discharge heights of thousands of NBEs were calculated. In Guangzhou, there are a total of 1318 and 625 height results for +NBEs and -NBEs. The geometric means (GMs) of discharge height are 12.1 km and 17.3 km. In Chongqing, there are a total of 5489 and 1400 height results for +NBEs and -NBEs with GMs of 9.9 km and 17.5 km. An interesting result of our calculation is that very few NBEs are above 19 km. The highest results in Guangzhou and Chongqing are 19.6 km and 19.9 km, but there are only 0.31% of NBE in Guangzhou and 0.26% of NBE in Chongqing that are above 19 km, all of which are negative polarity.

Distribution of NBE discharge height shows that +NBEs and -NBEs occur in two different altitudes, with -NBEs mostly higher than +NBEs. Most +NBEs occur between 8 and 16 km while most -NBEs occur between 16 and 19 km. On the basis of such distribution and discharge polarities of positive and negative NBEs, we conclude that +NBEs are probably produced between the main negative charge layer and the upper positive charge layer while -NBEs are probably produced between the upper positive charge layer and the screening negative charge layer at the cloud top.

In order to further study the relationship between NBE and thundercloud, we utilized observations of two thunderstorms producing more -NBEs than +NBEs by conventional S-band Doppler weather radar. The result shows that bursts of -NBEs are clearly related with strong convection within the thunderstorm. When large number of -NBEs are produced, 30-dBZ reflectivity height is higher than 15 km, indicating the thundercloud top is even higher, probably comparable to the discharge height of -NBE.

Keywords: Narrow bipolar event, Intracloud lightning discharge, lightning discharge height, convective strength, lightning location network