A dual band 3D lightning locating system

1. Introduction

The characteristics of lightning activity are highly related to the dynamical and microphysical processes in thunderstorm. The observation of lightning can give us some insight into the evolution of the electrical structure, dynamic process and cloud microphysical process in thunderstorm. In addition, lightning is an important phenomenon in severe weather. The study on lightning detection can contribute to the monitoring and warning of weather disaster.

The lightning locating systems could be divided into VLF/LF and VHF system based on different focuses on frequencies. In general, the VLF/LF band is sensitive to long-scale current surges such as return stroke, and the VHF band is more capable of imaging the breakdown processes occurring over short distances. Therefore, most of the existing VLF/LF lightning locating systems are designed to locate return strokes and Intra-Cloud (IC) processes that bear pulse-type waveforms, provide 2D or 3D location results to track thunderstorm or describe a particular lightning process. Since the VLF/LF waveforms not only contain the information of time and amplitude but also mean a physical quantity introduced by a certain lightning process, when a lightning discharge is located, the type, strength and polarity of the discharge also can be determined [1-6]. Meanwhile, the VHF systems are usually used to map detailed paths while discharges break through the air and this is helpful to understand detailed charging structures and evolutions of thunderstorm [7-11]. Some of the VLF/LF network can also give 3D lightning images that are remarkably similar to those created by VHF mapping systems, but the linkage between the two is still under debate [12-15]. Both lightning locating results of the two kinds of systems are highly complementary, the combination of which would be helpful to study lightning occurrences and its physics. But by now, there was no lightning locating system that working in VLF/LF and VHF bands simultaneously and could provide 3D dual-band lightning location results continuously.

The technologies used to locate lightning discharge are roughly categorized into Differential Time of Arrival (DTOA) method and Direction Finding (DF) method. Since the advent of Global Positioning System (GPS), the location accuracy of DTOA system had been tremendously improved and nowadays it is more common to be used for such purpose. In VLF/LF band, DTOA technology can be used to locate IC flash unlike Magnetic Direction Finding (MDF) method which are mainly designed to locate return stroke [16]. In VHF band, the existing DTOA systems can locate lightning discharges with time resolution of tens of microsecond [9, 17], and are more economical and easier to give continuous 3D lightning observation throughout entire thunderstorm process than interferometric systems.

Recently, a Dual-band Lightning Locating System (DULLS) was designed and deployed in Chongqing, China. DULLS was upgraded from the original VLF/LF network [18], worked in VLF/LF and VHF bands, used high stability GPS modules for timing and DTOA method for 3D locating, can identify the type of lightning and provide some physical parameters such as the polarity and strength of a discharge. This system and some preliminary observation will be introduced in this article.

2. Instruments and Data

As shown in Figure 1a, the dual-band sensor includes two parts: receiving and processing. The bandwidth of VHF receiver is 6 MHz, the center frequency of which can change from 30 to 300 MHz with a step size of 1 MHz. The center frequency used in Chongqing is 266 MHz to decrease electromagnetic interference. The output center frequency of the VHF receiver is 15 MHz. The VLF/LF receiver is similar to the circuit used in a fast electric field change meter with a decay time constant of 1 ms, is design to measure the electric field change caused by lightning. The processing module is made up of a high-speed A/D card with 14 bits resolution, a GPS...
time. The segment AB in (a), and L

graves. The densities of VHF and VLF/LF source altitudes versus time

respectively. The lightning activity increased first and then decreased. Figure 2a and b give

August 31, 2014, was made up of 14 dual

network from January 2014, which is made up of 14 dual

simulated by Monte Carlo method when error of timing is set to 100 ns.

and the vertical estimated errors of the VHF results at the altitude of 7 km

According to the simulation results, the error of DULLS is

The maximum of site spacing is about 128 km and the minimum of that is

signals are 100 μs and 1 ms

Figure 2

(a)

(b)

(c)

Figure 3

(a)

(b)

3. Observation results and analysis
different. From 19:00 to 1:00 the next day, the VHF sources mainly distribute at altitudes of 5~15 km, centered around 10 km; the VLF/LF sources mainly occurred below 5 km, a small portion of them occurred at altitudes of 5~15 km, centered below 1 km. From 1:00 to 3:00, the distribution of VHF and VLF/LF sources were nearly unchanged, while the lightning activities were increasing. The lightning activities became intense from 3:00 to 6:00. During this time, the region of high VHF source density around 10 km remain and growing strong, while another strong lightning intensity core appeared around 5 km altitude and gradually became the region of the highest lightning discharge density in this storm. Accordingly, a region of high VLF/LF source density also appeared around 5 km, but the highest VLF/LF source density was still below 1 km altitude. It is thought that the VHF radiation of negative breakdown process is stronger than that of positive breakdown process [9], thus the region of high VHF radiation source density can partly reflect the position of positive charge center in a thunderstorm. Hence, the distribution feature of the VHF radiation sources in this thunderstorm may indicate that the main positive charge center was at an elevation of about 10 km before 03:00, then a new positive charge center appeared at a height of about 5 km. According to this instance, the VHF location results mainly reflect IC discharges; the VLF/LF location results mainly reflect return stroke, while also describing some IC discharges.

Figure 3 shows the composite radar reflectivity and dual-band lightning location results within a radar scanning time at 04:36 on August 31, in which the radar reflectivity is moving from southwest to northeast. The black and blue points represent VHF and VLF/LF radiation sources respectively. As shown in Figure 3a, both VHF and VLF/LF radiation sources occurred in the strong echo region in the front of the storm, covering almost the same region. Figure 3b shows a profile of the radar reflectivity and the lightning location results within 1 km of the profile. According to this figure, VHF sources were mainly above 3 km, clustered at the altitude of 5 km; VLF/LF sources occurred at several altitude levels. These distribution features are consistent with the cases in Figure 2.

Besides giving the distribution of lightning activity continuously and tracking thunderstorm, DULLS also can describe the time-space evolution of a lightning by using the dual-band location results and the waveforms recorded by the sensors. Figure 4 gives an IC flash occurred at 04:38:20 on August 31.

Figure 4 (a) Fast electric field change waveform; (b) VHF and VLF/LF sources altitude versus time; (c) east-west vertical view of the sources; (d) VHF source number distribution along height; (e) plan view; (f) north-south vertical view.

Figure 5 Similar to Figure 4 but gives a CG occurred at 04:40:22 on August 31. This CG flash had 5 return strokes, lasted for about 1 s.
4. References


