Characteristic of Compact intracloud discharges on Qinghai-Tibet plateau and Northern part of China

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ABSTRACT: In this work, the Compact intracloud discharges (CIDs) were observed and analyzed in high time resolution in inland plateau and Northern plain in China using a time of arrival lightning mapping system working on dual band. A total of 236 CIDs are documented northern part of China. The CIDs were classified as isolated type and lightning associated type. Of between, 32 occurred in isolation and 204 occurred in association with either IC or CG lightning discharges. No apparent difference among all types CIDs has been found on rise time, etc. The CIDs occurred at a height ranging from 7 km to 16 km with a peak power ranging from 12 kW up to 781 kW in the 267–273 MHz passband. In inland plateau of China, 284 CIDs are observed. And the positive CIDs occupied 88%, negative CIDs occupied 12%. The parameters (ex. rise time, etc) of CIDs in Qinghai-Tibet plateau are similar to that in eastern plain in China. There are no pair pulses of reflection in 98% CIDs which much less than that in eastern plain in China. Roughly, CIDs can be characterized with an average rise time of 1.5μs, an average main peak width of 4.0 μs, an average of broadband EFC duration of 20.0 μs and VHF duration of 10.0 μs, respectively.

1. INTRODUCTION

Compact intracloud discharges (CIDs), a name first given by Smith et al. (1999), refers to a temporally isolated, short-lived (about 10-20μs) discharge event (Le Vine, 1980) that exhibits strongest Radio Frequency (RF) radiation and higher amplitude in low frequency (LF)/ very low frequency (VLF) wave band than ordinary intracloud (IC) lightning and cloud to ground (CG) lightning processes (Jacobson and Light, 2003; Smith et al., 1999; Willett et al., 1989). Such discharge event has also been called Narrow Bipolar Pulse Events (NBEs) by Jacobson and Light. (2003) and Zhu, et al., (2010). Since its discovery, many authors have performed related researches to better understand it (e.g., Rison et al., 1999; Jacobson and light., 2003; Wiens et al., 2008; Nag, et al., 2010a, 2010b, 2010c; Zhang et al., 2010; Zhu, et al., 2010a, 2010b). In this study, we have documented and analyzed 236 CIDs that occurred in a severe thunderstorm in Northern part of China and 284 CIDs in inland plateau of China. We found that although there are many CIDs which are either isolated or as the initial breakdowns of lightning discharges, similar to those reported by previous authors (e.g., Rison et al., 1999; Smith et al., 1999; Nag, et al., 2010a, 2010b,

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2010c), there are also many CIDs embedded in ordinary lightning discharges (Nag, et al., 2010a, 2010b, 2010c). This paper reports our results.

2. INSTRUMENTS

In this work, the Compact intracloud discharges (CIDs) were observed and analyzed in high time resolution in inland plateau and Northern plain in China using a time of arrival lightning mapping system working on dual band [Zhang et al., 2010]. The system was set to catch a 1.2 s continuous waveforms of radiation in VHF-band (with its band width from 267 MHz to 273 MHz) and Broad Electric Field Change signal (EFC, with band width of 10 MHz and time constant of 100 μs) for one lightning discharge which that pulses amplitude exceed the threshold. Seven receiver of this system distributed over an area of about 15 km diameter and uses the arrival times to locate the sources of the radiation. In addition, a GPS clock (±25 ns in time accuracy) was set at each station to synchronize all of equipment. The signals out puts from all the systems were digitized and recorded by computers. All stations were linked via broad-band wireless net work system. Data collection in each station was either controlled by central station or free operation. Calculation shows that the horizontal error and altitude error are related to baseline of this network, and both increase with distance.

Fig. 1 The Antennas of LMS

3. CIDS IN NORTHERN CHINA PLAIN

1）Isolated CID

32 isolated type CIDs were recorded during the storm in Northern China Plain. For all the 32 isolated CIDs, we have performed a statistical study on their rise time, width of the main peak, broadband EFC

duration, VHF duration, and the results are shown in Fig. 2a, 2b, 2c, 2d, respectively. As seen in this figure, the rise time of isolated CIDs ranges from 0.7 μs to 2.8 μs with an average of 1.5 μs; the width of the main peak ranges from 1.7 μs to 8.7 μs with an average of 5.1 μs; and the average broadband EFC duration and VHF duration is 23.2 μs and 13.0 μs respectively.

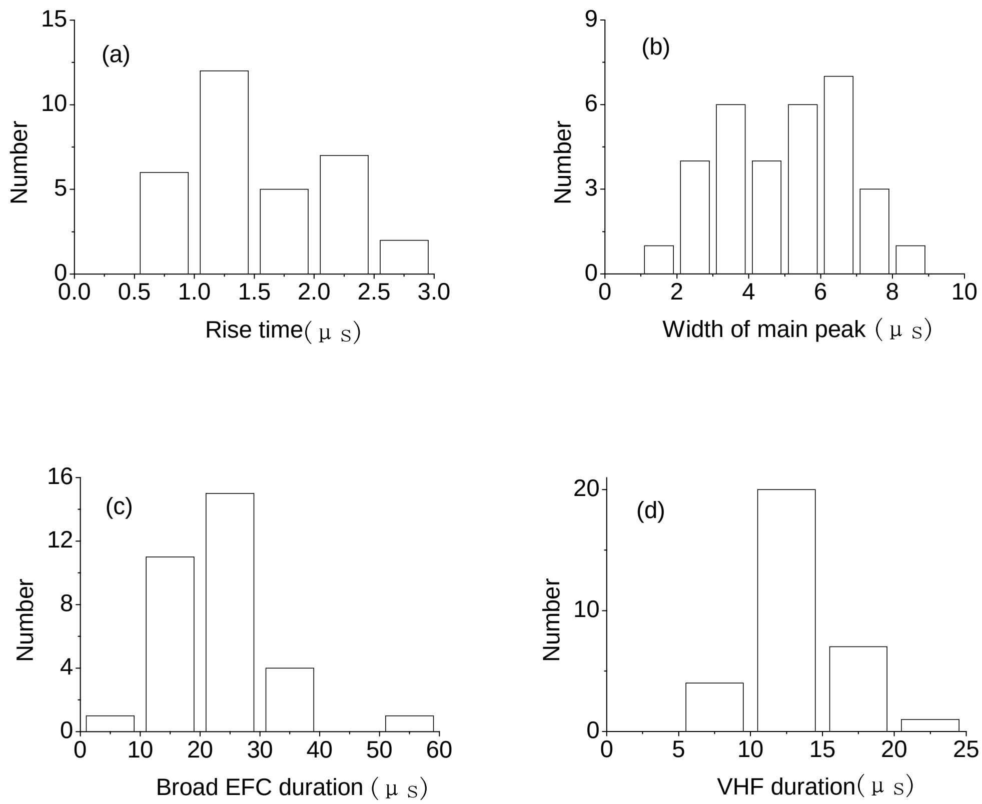

Fig. 2 Typical waveforms of CID VHF radiation (a) and broadband electric field change (b) recorded in this study.

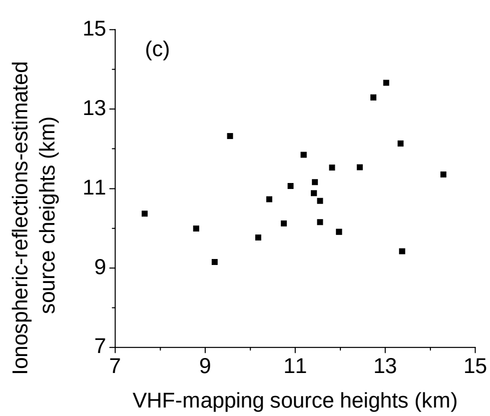

Fig. 3 The scatter plot of VHF-mapping source heights versus ionospheric-reflections-estimated source heights.

In this study, we were able to locate all 32 isolated CIDs, with 22 in three dimensions and 10 in two dimensions. The isolated CIDs typically occurred at a height of around 11 km with a peak power ranging from 24.1kW to 242.3kW. Seen from the Fig. 3, the heights of 21 isolated CIDs were located using both VHF-mapping method and inferred method from ionospheric reflection. And there are some differences between heights from these two location methods, but in most cases, the VHF-mapping heights are general accord with those inferred from the ionospheric reflections.

2）Lightning-discharge-associated CID

Among the 204 CIDs that were associated in time with ordinary lightning discharges, 130 were the initial event of the subsequent lighting discharges; 72 occurred during ordinary lightning; and 2 occurred as the terminating event of their preceding lightning discharges.

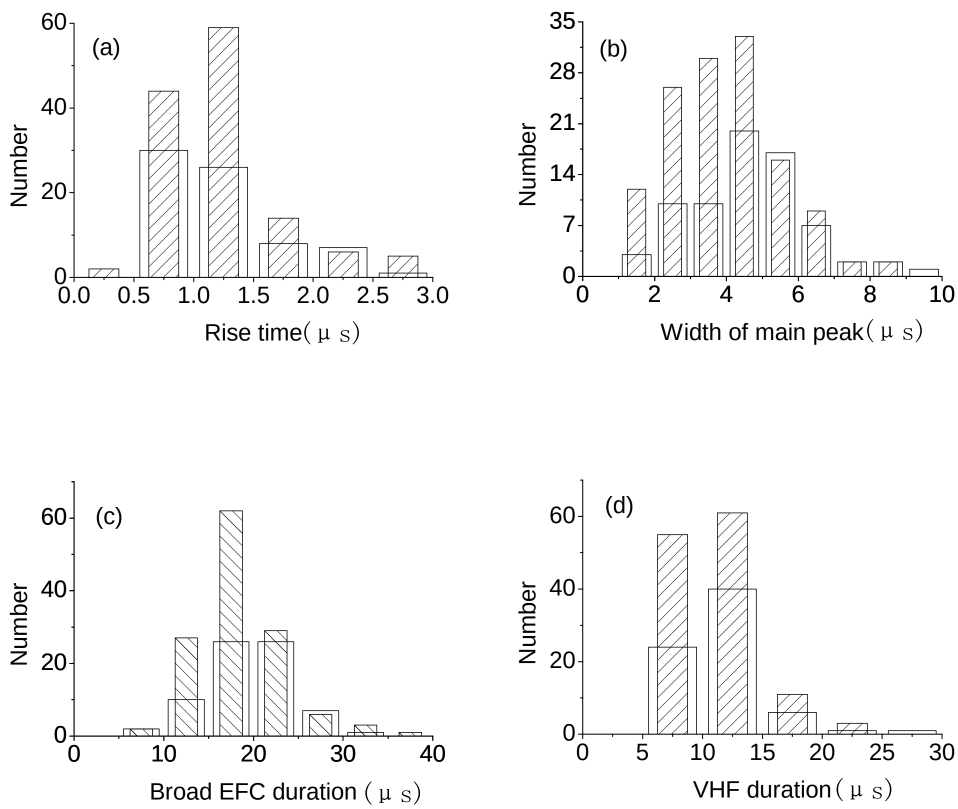

Fig. 4 Histograms of lightning-discharge-associated CID rise time (a), width of the main peak (b), broadband EFC duration (c), VHF duration (d). The "▨" in the figure is for the CID acting as the first pulse in a lightning discharge, and the "□" is for the CID embedded in a lightning discharge.

For all 204 lightning-discharge-associated CIDs, similar statistics as done for isolated CIDs have been performed, and the results are shown in Fig. 4a, 4b, 4c, and 4d, respectively. As seen in these Fig. 4, the rise time of the CIDs that occurred as the first pulse in a lightning discharge ranges from 0.3 μs to 2.9 μs with an average of 1.2 μs, while that of CIDs embedded in lightning discharge ranges from 0.6 μs to 2.8

μs with an average of 1.2 μs; the main peak width of the former ranges from 1.5 μs to 8.4 μs with an average of 3.9 μs and that of the latter ranges from 1.4 μs to 9.4 μs with an average of 4.6 μs; the average broadband EFC duration of the two types of CIDs are 18.7 μs and 19.6 μs, respectively; VHF radiation durations of the former and the latter are 10.9 μs and 11.9 μs, respectively.

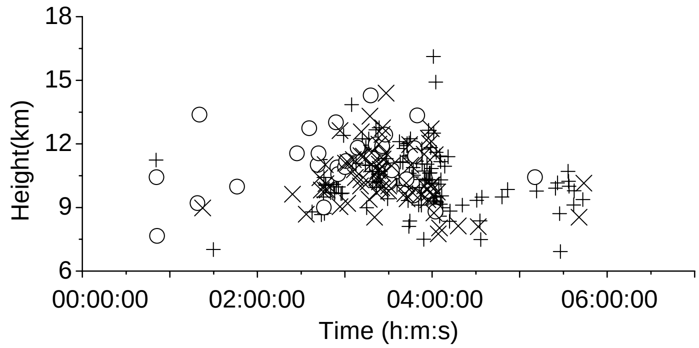

Fig. 5 The time evolution of the CIDs height. The "+" denotes the CIDs acting as first radiation source of a lightning discharge (the number is 130); The "×" represents the CIDs embedded in a lightning discharge (the number is 72); the "○" is for isolated CIDs(the number is 32)

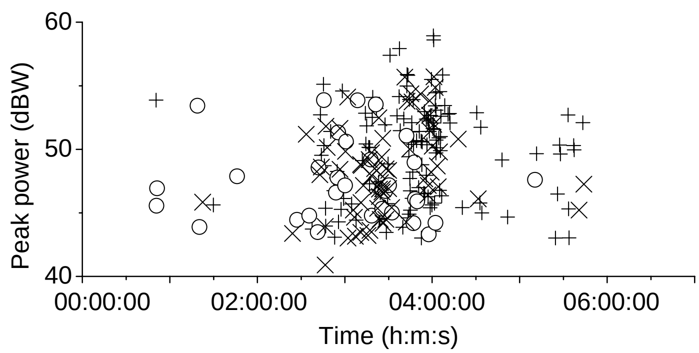

Fig. 6 The time evolution of the CIDs peak power. The "+" denotes the CIDs acting as first radiation source of a lightning discharge (the number is 130); The "×" represents the CIDs embedded in a lightning discharge (the number is 72); the "○" is for isolated CIDs(the number is 32).

4. CIDS IN INLAND PLATEAU

In inland plateau of China, 284 Compact Intracloud Discharges (CIDs) are observed and analyzed. And the positive CIDs occupied 88%, negative CIDs occupied 12%. The statically results of EFC waveform show that the rise time ranging from 0.3 to 6.2 μs and average value is about 2.1 μs, the lasting time ranging from 3.5μs to 45.8μs and average value is about 19.7 μs, the width of main peak ranging from 0.8μs to 12.8 μs and average value is about 5.4 μs. The VHF radiation lasting time ranging from 1.0 μs to 37.9 μs and average value is about 9.6 μs. Total 106 CIDs are three dimensional located using LMS, and there are only 7 negative CIDs. The 3D location results indicate that the height of CIDs ranging from 3 km to 18 km. And average heights are about 7.3 km and 8.2 km for positive and negative CIDs.

5. CONCLUSIONS

Roughly, CIDs can be characterized with an average rise time of 1.5μs, an average main peak width of 4.0 μs, an average of broadband EFC duration of 20.0 μs and VHF duration of 10.0 μs, respectively. The rise time, width of the main peak, broadband EFC duration, VHF duration of CIDs in Qinghai-Tibet plateau are similar to that in eastern plain in China. The CIDs occurred at a height ranging from 7 km to 16 km with a peak power ranging from 12 kW up to 781 kW in the 267-273 MHz passband. There are not pair pulses of reflection in 98% CIDs which much less than that in eastern plain in China.

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