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A contrast study on the characteristics of the cloud-ground lightning and the surrounding conditions in two typical intense convective weathers occurred in Hubei province

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Abstract: Based on the data of lightning location network including 13 sensors in Hubei province and weather radar, 30 events with short-time heavy rain and 6 events with hail and strong wind are analyzed to investigate the characteristics of lightning polarity and frequency in these two kinds of synoptic processes with strong convection, as well as the spatial configuration of lightning and radar echoes. The result shows that

(1) in strong convections with hail, thunder and strong wind, the frequency of positive cloud-to-ground (PCG) flashes is comparable with or even greater than that of negative cloud-to-ground (NCG) flashes. The result of six events shows that PCG flashes account for 45%-87% of all the cloud-to-ground (CG) flashes. In strong convections with heavy rain, PCG flashes are much fewer than negative ones. Statistics of 30 events shows that PCG flashes account for 0-14% of all the CG flashes.

(2) Difference between total lightning frequency in strong convections with heavy rain and that in strong convections with hail and strong wind is also obvious. 3 events of both kinds of strong convections are analyzed and the result shows that as much as 50 flashes happened in 10 minutes in strong convections with heavy rain, which is much higher than the frequency of 6-23 flashes in 10 minutes in strong convections with hail, thunder and strong wind.

(3) Analysis of superposition of lightning and radar echoes shows that in synoptic processes with heavy rain, lightning locations agree well with areas of high radar echoes, and they tend to concentrate, while in strong convections with hail, thunder and large wind, flashes do not occur in areas of high radar echoes but scatter in the downwind of strong radar echoes of hail.

1. Summaries

Along with the development of the lightning detection measurement such as lightning location technology and high speed and capacity data gathering skills, the lightning monitoring materials' utilization in the short-time forecast of intense convective weather has made some research achievement. Xueqiufang[1] pointed out that the ground-flash frequency of the positive and negative polarity is unequal in different weathers (such as hailstone and rainstorm) during her research on the relationship between the lightning activities in Beijing area and the intense Convective weather , at the same time the positive polarity's proportion in the hailstone is higher than the rainstorm. Meng [2-3] made a contrast analysis of SAFIR 3000 detetion data and radar echo, found both of them have a well correspondence and the lightning detective system has a prominent outstanding in the intense convective weather 's detetion and warning. Zhang [4] analyzed the lightning characteristics in super-monomer thunderstorms using American three-dimensional lightning detective system data, revealed the existence of the lightning hole and loop and their time-space distribution is unanimous with the ascent and sink airstream areas in thunderstorms.

The ADTD lightning location and detective system which is exploited by Hubei province in 2006 obtained large quantities of cloud-ground fiash data, offering advantageous conditions in analyzing the characteristics of thunderstorms in intense convective weather cases occurred in Hubei province. Wangxueliang[5] made a research on the lightning's time-space distribution characteristics in the field of polar distribution, diurnal and monthly change , intensity and flash density. This text will use the ADTD data in Hubei province to make a contrast analysis of the characteristics in cloud-ground lightning's polarity proportion and the configuration characteristics between lightning and radar echo , at the same time compare two typical intense convective weathers'(one is intense short-time precipitations and the other is hailstone and thunderstorm weather cases)surrounding conditions . The focus is on revealing the lightning activities' characteristics and the main influency factor during the intense convective weather's process, so as to provide a valuable reference to make forecasters well carry out the analysis and short-time approaching warning of the intense convective weather.

2.Simple description of cases

This text selected 30 intense short-time precipitation calamities occured in Hubei province between 2006-2009 and 10 hailstone and rainstorm weather cases which are mainly caused by hail and wind. All courses appear disaster weather features, for example :the hail diameter is above 2 centimeter and the instantaneous wind force is higher than 10 level.

3. Characteristics of cloud-ground lightning

3.1 Characteristics of the positive ground lightning

This text made a statistical analysis of the occurrence time, amounts and proportion of the positive and negative ground lightning in each intense convective weather. The results indicated that the positive ground lightning's occurrence proportion presented an obvious differences in two intense convective weather categories, the proportion in the hailstone and rainstorm cases was obviously higher. Table 1 shows that the negative ground lightning occupied majority in the 30 intense short-time precipitation cases , the proportion of the positive ground lightning was only 0-13.6%; contrastly, the frequencies of the positive and negative ground lightning were nearly equal in the hailstone and rainstorm cases, the proportion of the positive ground lightning was 44. 9-87%, even exceed the the proportion of the negative ground lightning.

Macgorman [6]、Perez [7] analyzed the reasons cased the higher proportion of the positive ground lightning in the hail and thunderstorm cases. One is the declining upward stream made the positive electric charge layer lie upside in the weak echo areas and expose directly on the ground which is beneficial to the occurrence of the positive ground lightning. The other is the secondary positive electric charge areas' appearance was melted in the decline courses of the bigger aragonites and hails according to the principle of "temperature's difference makes electricity", formed a conformation of the external carried negative electric charge and the internal carried positive electric charge. Because of the bubble released in the procedure of ice-melting would split on the water surface, the small water drips sputtered from the surface would take away some negative electric charge which made the left aragonites and hails carry positive electric charge. But in the precipitation intense convective weather cases, the negative electric charge's vast occupation was possibly caused by the large distance between the positive electric charge layer lied in the over-cloud and the negative electric charge layer lied in the under-cloud areas, the distance between the negative electric charge layer and the ground was too small, additionally the vertical shear was not big in the intense precipitation, all that made the positive electric charge can't remove away from the negative electric charge and expose directly on the ground. Moreover, there had not enough ice phase particles, the remaining solid particles couldn't conform a secondary positive electric charge areas which can generate numerous negative cloud-ground lightnings.

3. 2 Frequency of cloud-ground lightning

This text separately selected 3 cases in the two intense convective weathers, confronted and analyzed their frequency of ground lightning characteristics' difference.

The cases selected were below: large rainstorm occurred in Xiangfan, 21-22 6 2006, which was mainly precipitation; large rainstorm occurred in Xianning, 22 4 2007 and rainstorm occurred in Jinshan, 3 5 2008; hailstone occurred in Dawu, 15 4 2007 which was mainly hail and thunderstorm; two hailstone and thunderstorm cases separately occurred in Xiangfan, 11 5 2008 and Zhijiang, 3 6 2008.

We choosed 10 minutes as a unit, made a frequency statistics of the positive, negative and total ground lightning, the results(figure 1) showed that the frequency of ground lightning in precipitation cases was obviously higher than the hail and thunderstorm cases. The precipitation cases' max numbers of the cloud-ground lightning's frequency were all above 50 times in 10 minutes while the hail and thunderstorm cases' max numbers were only 6-23 times in 10 minutes. Also the occurrence proportion of the positive ground lightning presented an obvious differences between the two intense convective weather categories.

Macgorman [8] brought forward the "uplift electric charge mechanism" to explane the smaller cloud-ground lightning in the hailstone and thunderstorm weather cases:(1) the intensive upward stream rapidly lift other particles except the largest particles to a high level; (2) the intensive upward stream made the particles can't remain in a fixed level, so there had not enough times for the particles' growing, obtaining and separating electrical charges which caused the lack of the positive and negative electric charges in a given layer. (3) the temperature of the intensive upward stream core was higher than the weak ones, that made the ice-courses generating electric charge occur on a higher place. The three reasons above jointly restrictd the occurrence of the cloud-ground lightning.

3. 3 The corresponding relationship between cloud-ground lightning and radar echo

The superposive confrontation of the cloud-ground lightning and radar echo showed that the ground lightning is well unanimous with the forceful radar echo areas in precipitation cases .but the ground lightning mainly located in the rear of the forceful radar echo areas in the hailstone and thunderstorm cases . Figure 2a showed that the negative ground lightning took main part in the rainstorm occurred in Jinshan, 3 5 2008, and the cloud-ground lightning's intensive occurent areas display a good coincidence with the forceful radar echo areas. Figure 2b, c, d respectively showed the hailstones occurred in Dawu, 15 4 2007, the hailstone and thunderstorm occurred in Wuhan, 27 7 2007 and the hailstone occurred in Xiangfan, 6 6 2009. We can know that: first of all, this weather's frequency of cloud-ground lightning was lower and didn't located in the forceful radar echo areas but fragmental scattered in the anvil cloud in the direction of the down windstrem.This is possibly related with the incline construction of the convective clouds.

4. Analysis and contradistinction of the surrounding conditions

This text based on the two selected intense convective weather cases, choosed the TlgP air-detective data which is mostly approach to the intense convective weather cases' occurance space, calculated the physical quantities such as the whole layer humidity, K index ,the corrected K index, 0 and -20degree layer's altitude, $T_{850-500}$, the severe weather threat index SWEAT, free convective layer's thickness（EL-LFC）,0-3km shear, convective inhibition CIN, gale index VV, 0-6km shear and convective available potential energy CAPE, so as to analyze and juxtapose the surrounding conditions' characteristics in the two selected intense convective weather cases.

The surrounding conditions' differences in the two intense convective weather cases (were mainly showed below)can be obtained from the table:

(1) The precipitation intense convective weather cases' whole layer humidity, K index and the corrected K index are all obviously higher than the hailstone and thunderstorm weather cases.

(2) The hailstone and thunderstorm weather cases' stratification thickness of 0 degree is lower about 1000m according to the distribution situation of the stratification thickness of 0 degree and -20 degree.

(3) The $T_{850-500}$ value in the precipitation weather cases and in the hailstone and thunderstorm weather cases are about 24.7□and 29□, indicating that if the vertical direction's temperature diversificate much severer , the hailstone and thunderstorm weather will take place much easier.

(4) The severe weather threat index is a composite index which can reflect to the atmosphere humidity, temperature and vertical wind shear. The severe weather threat index in the precipitation cases is higher than the hailstone and thunderstorm cases, the average value are 260.8and 201. This statistical results are possibly related with the atmosphere humidity's condition in the precipitation weather cases.

(5) Because of the hailstone and thunderstorm weather cases' higher free convective altitude and lower balance altitude, the free convective layer's thickness is relatively smaller. Simultaneously, the average value of 0-3km and 0-6km wind shear are larger than the precipitation cases. Certain intensitive vertical wind shear will accelerate the continuous development of the vertical upward motion and the conformation of the multi-monomers storm. And a higher intensitive vertical wind shear can also yield dynamic pressure gradient force in the side flank of the intensive windstorm, causing a coordination of upward airstream and the vertical vorticity in the windstorm's side flank, and lead to a whirling upward motion so as the conformation of the super-monomers and the development of the organizational convection[9].

(6) The gale index VV, free convective altitude LFC and 0-6km shear didn't display a steady and obvious discrepancy, only passed the significant inspection of 10% and

20%, the gale index VV represented a better instructive effect in the hailstone and thunderstorm cases, its value was higher than the precipitation cases .

(7) The value of convective inhibition CIN and convective available potential energy CAPE behaved larger in the precipitation cases.

Furthermore, we can know from the above inspection that the showalter index SI, lifting index LI ,storm strength index SSI, the maximum upward velocity Wm and the convective temperature Tg all had no obvious discrepancy in the significant inspection and didn't pass the significant inspection of 20%. They had the intense convective weather cases' collaborative feature such as the showalterindex SI and lifting index LI were all negative ,the stratification layer was unsteady and had higher storm strength index, the maximum upward velocity and convective temperature.

5. Conclusions

This text selected 30 intense short-time precipitations and 10 hailstone and rainstorm weather cases, analysed and juxtaposed the characteristics and the surrounding conditions of the cloud-ground lightning, the results show that:

(1) The negative ground lightning occupied vast majority of the precipitation intense convective weather cases, the flash frequency is numerous and the max cloud-ground lightning frequency number is above 50 times in 10 minutes. Contrastly, the flash frequency is small and the frequencies of the positive are nearly equal to negative ground lightning even exceed the the proportion of the negative ground lightning in the hailstone and thunderstorm weather cases.

(2) The cloud-ground lightning concentratly scattered and their occurent areas display a good coincidence with the forceful radar echo areas in the precipitation intense convective weather cases. Contrastly, the cloud-ground lightning's occurent areas were not located in the forceful radar echo areas but fragmented scattered in the anvil cloud in the direction of the hailstone's down windstrem.

(3)The precipitation intense convective weather cases have a better whole layer humidity feature, higher K index compared with the hailstone and thunderstorm cases. Simultaneously, the $T_{850\text{-}500,}$ 0-3km and 0-6km wind shear , gale index VV represent a better instructive effect in the hailstone and thunderstorm cases.

(4) The value of SI and LI have no distinct discrepancy in the two intense convective weather cases.

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Table 1 The characteristics of the cloud-ground lightning in two typical intense convective weathers occurred in Hubei province in 2006-2009

Weather	projects	positive lightning's Proportions	positive lightning's numbers	negative lightning's numbers	appearance date and weather conditions
precipitation	average	2.8%	32	1123	30 cases in all,21 in 2006,5 in 2007, 4 in 2008
	max	13.6%	23	143	29,6,2006, 16:30-18:10, rainstorm attack Dangyang,the max Precipitation is 119.7mm.
	min	0%	0	125	27,6,2006,04:00-07:00,rainstorm attack Yingshan,the Precipitation in 3 hours is 84mm.
hailstone and thunderstorm	average	67.5%	27	13	10 cases in all, 1 in 2006, 3 in 2007, 4 in 2008, 2 in 2009
	max	87%	22	4	15,4,2007,15:00-18:00,hailstoneattackGaodian,fengdian,xuanhua,daxing,sanli,lvwang,sigu,dongxin in dawu,the max diameter is 4cm and accompanied 6-7 level gales and thunder
	min	44.9%	22	27	11,5,2008,22:00-24:00, gale and hailstone attack Xiangyang,zaoyang,yicheng,xiangcheng,fancheng in xiangfan,the max hailstone likes the sizes of ping-pong

Table 2 the chart of the Physical quantity index in two intense convective weathers

surrounding Parameters	Illustrious levels	Mainly precipitation	Mainly hailstone and thunderstorm
the whole layer humidity	1%	5680.3g/kg	2833.0 g/kg
K index		39.1□	29.4□
the corrected K index		45.8□	35.3□
0 degree layer's altitude		5124.9m	4149.2m
-20degree layer's altitude		8590.5m	7094.7m
T850-500		24.7□	29□
the severe weather threat index SWEAT	5%	260.8	201
free convective layer's thickness（EL-LFC）		625.0hPa	385.6hPa
0-3km shear		7.1m/s	11.0m/s
convective inhibition CIN		111.6J/kg	419.1J/kg
gale index VV	10%	19.4	29.1
0-6km shear	20%	10.3m/s	15.6m/s
convective available potential energy CAPE		1252.5J/kg	719.7J/kg

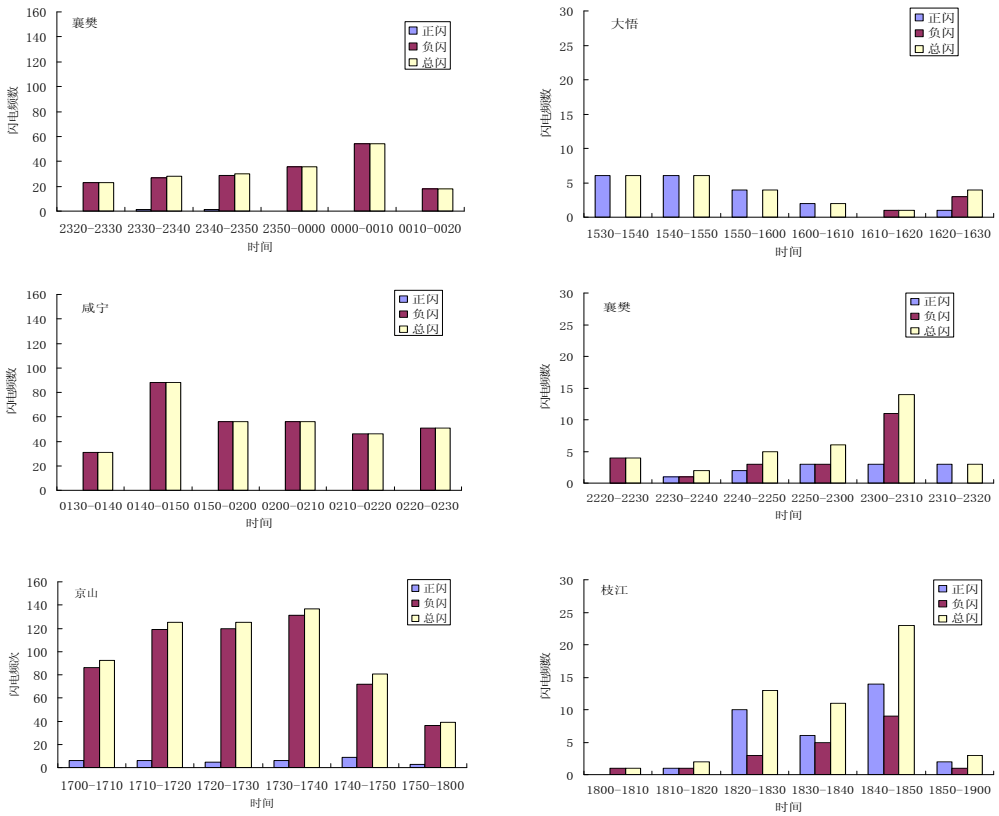

Figure 1　Frequency of cloud-ground lightning's time-distribution(left：the precipitation weathers；right：the hailstone　and thunderstorm weathers）

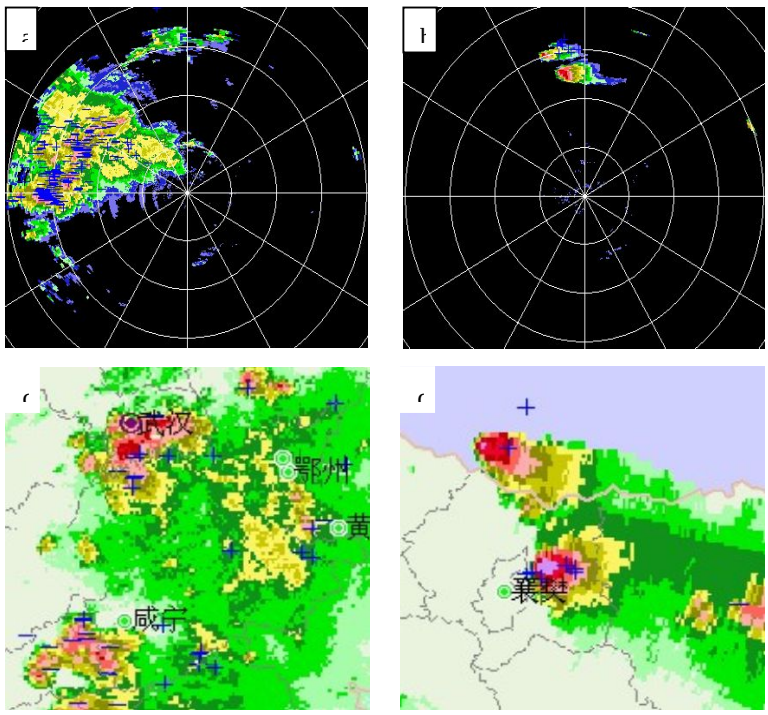

Figure 2　The picture of the relationship between cloud-ground lightning and radar echo（a: intensive precipitation weathers；b、c、d: the hailstone　and thunderstorm weathers）