Lightning characteristics related to radar morphology and hail distribution in linear convective systems

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ABSTRACT: Based on SAFIR3000 Lightning Location Network and radar data, 58 linear mesoscale convective systems are analyzed occurred in Beijing area from the year of 2007 to 2011. All the linear convective system are classified to six categories by radar morphologies, including leading convective lines with trailing stratiform region, leading stratiform region, leading convective lines with no stratiform region, bow echo of leading line, leading convective lines with parallel stratiform region. The results showed that linear convective systems occurred frequently in summer time over Beijing area, particularly the TS and LS mode, accounted for 58% of the linear MCSs. On average, lightning mainly located in the linear convective region, and less or no lightning located in the trailing stratiform region. The hail-produced linear MCSs generated high +CG lightning percentage than the non-hail-produced system.

INTRODUCTION

Linear mesoscale convective system usually accompanied with frequent lightning, precipitation, severe wind and hail hazard, influenced large area and lasted long duration. Parker and Johnson (2000) identified three modes of organization in mesoscale convective systems (MCSs) using the lightning information detected by National Lightning Detection Network and radar data. Generally, the linear MCSs are usually divided into three main categories including leading line trailing stratiform region (TS), leading stratiform region trailing linear convective region (LS), and leading line with parallel stratiform region (PS). Gallus et al. (2008) classified the storm into eight categories, including six kind of linear mesocale systems, most of linear-MCSs exhibited as linear convective line with trailing stratiform region. Parker et al. (2001) analyzed the CG lightning in three different types of linear MCSs and found that PS MCS generated more CG lightning than two other categories. Many researches on the relationship between the lightning and meteorological factor were usually based on the CG lightning, only accounted for small part of total lightning in the majority thunderstorms. Recent studies investigated the total lightning distribution of individual MCS (Lang et al., 2004; Dotzek et al., 2005; Ely et al., 2008). Makowsi et al. (2013) studied the lightning activity of 30 MCSs with the lightning network, satellite, radar data and found that most of lightning initiation sources were concentrated in or around the high radar reflectivity and colder cloud tops of -52℃. Liu et al. (2013a, b) analyzed the characteristic of the lightning in leading convective line systems, and obtained the relationship between the lightning and environment factors.

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By the influence of special terrain and large-scale weather systems, the linear MCSs are easily generated in summer time. Based on lightning detection network and radar data, the study analyzed the lightning activity in different mode of linear MCSs.

DATA AND METHORD

2.1 Data sources

Lightning data used this study were obtained from the SAFIR 3000 (System d'Alerte Fondre par Interferometrie Radioelectrique) lightning detection network. SAFIR 3000 Detection network consists of a central detector receiving and processing system and three stations which consists of a number of antenna arrays, apart as 120 km covered mostly Beijing area. Each detection station composed by a VHF frequency processor (110-118 MHz band) and a low frequency processor (300-3 MHz). High frequency band provide high positioning accuracy and high detection efficiency. Low frequency antennas measured the lightning activity in the direction of the long-range, which identify cloud to ground lightning characteristics through certain standards (peak current, polarity, rise and fall times). Lightning information detected by each of stations with the GPS time synchronization, the lightning signal sent to a central processing system over the WAN in real-time. Eventually, the lightning database formed by lightning discharges through technical computing intersection position.

The detected accuracy of the lightning network reached to 90%. In order to ensure the accuracy of lightning data, the lightning source radiations are selected, which occurred during 1s in 7 km range considered as a single lightning flashes. Meanwhile, the polarity of CG lightning with positive is defined as +CG lightning, and the negative polarity is regarded as –CG lightning. Cuminus et al. (1998) considered the strong and distant intra-cloud lightning (IC lightning) could be recognized as +CG lightning flashes. Therefore, the +CG flashes less than 10kA are considered as the IC lightning in this study.

Radar data

Radar information is obtained from Doppler radar located in Beijing meteorology administration. Radar scans from 0.5-3.4 ◦ degree with seven layers elevation in 6 min. The horizontal resolution of the radar observation is 1 km and the azimuth resolution rate is 1 ◦ degree. In this study, composite radar reflectivity (the maximum radar reflectivity of different elevation angle) is used to analyze the relationship of lightning and radar reflectivity.

RESULT

According to the radar morphologies, 58 cases of linear MCSs that occurred around Beijing area during 2007-2011 are classified into six category, including leading line trailing stratiform (TS), leading stratiform trailing convective line (LS), bow echo of linear MCS (BE), parallel stratiform region (PS), narrow stratiform (NS), and break line stratiform (BS). A general organization of the six morphologies are shown in Figure 1.

1) Statistical characteristic of linear characteristic

By the influence of special terrain with mountain in the northwest and the plain in the southeast, the linear MCS are easily formed in the northern of Beijing area. It is investigated that about 55% of MCSs originated from the edge of the mountain, and 45% of them formed linear MCSs. The classification of linear MCSs involved the radar morphology are determined by the mature stage of thunderstorms which the radar area exceed 10km×10 km with a maximum greater than 40 dBZ. If the radar morphology remained the same in the mature stage of event, all storm reports are attributed to that mode. If the thunderstorm came into dissipating stage and a newly system formed into another mode, that radar morphology and lightning separated into two modes. So there is no duplication of computing cases. The statistical results showed that the mode of LS and TS occupied 58% of linear MCS, all of the other cateorgies (BE, PS, NS, BS) accounted for 42% with a fair distribution and a relatively rare BE events. It is noticed that the mode of TS, LS and PS developed by supercells at the starting time.

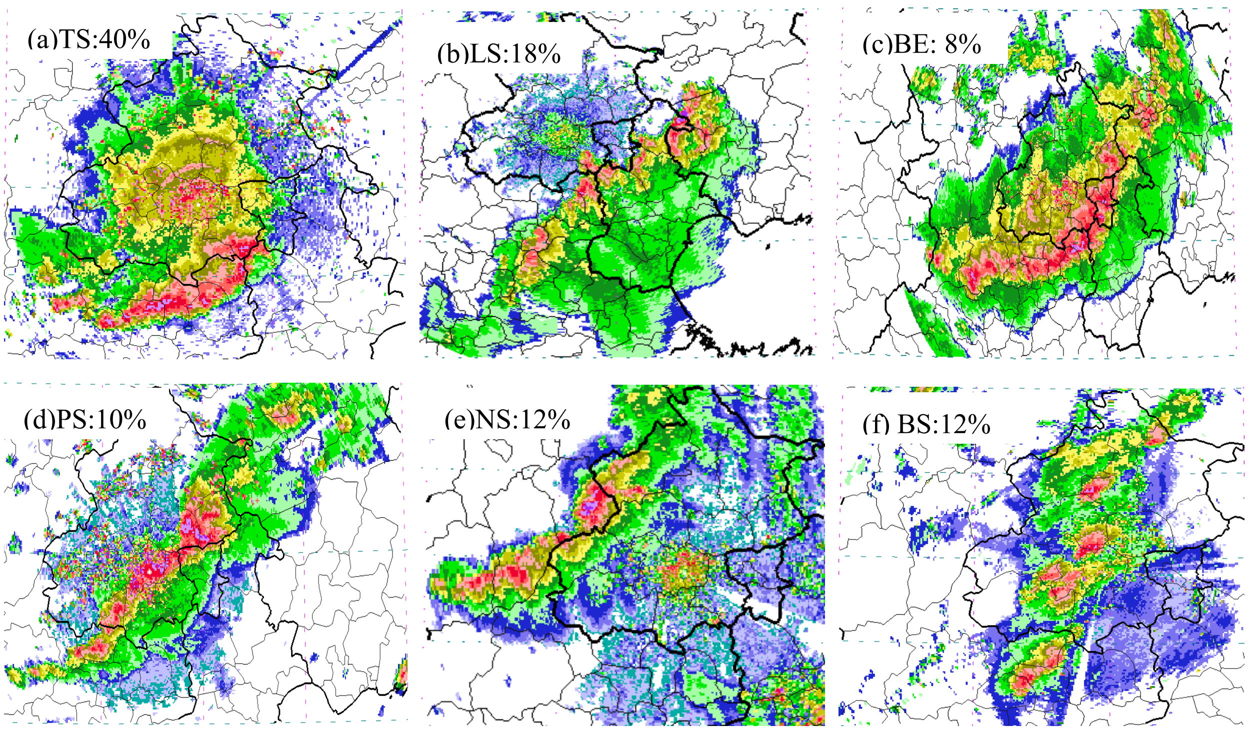


Figure 1. Linear MCS classification around Beijing area, (a) TS, (b) LS, (c) BE, (d) PS, (e) NS, (f) BS.

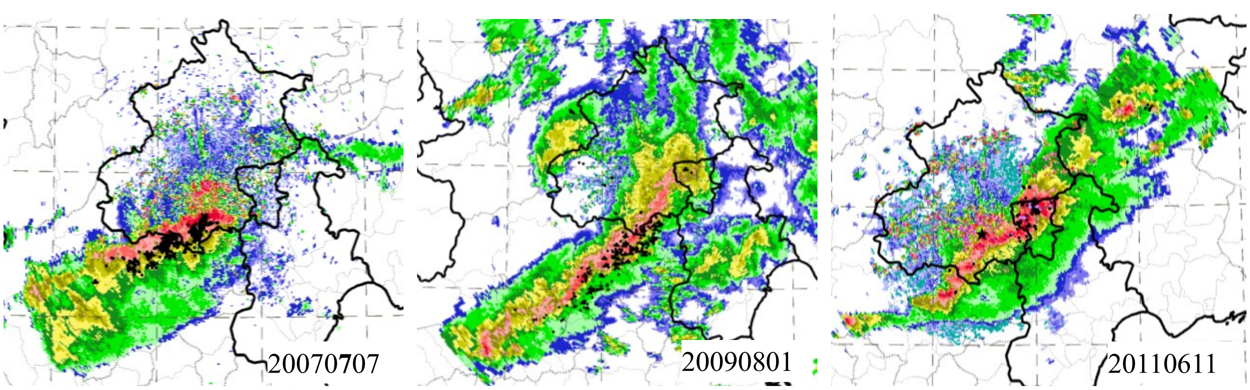
The lightning activity and hail report of linear MCSs are showed in Table 1. Ten linear MCSs are analyzed, including three TS-MCSs, three LS-MCSs and only one case from other types (BE, NS, PS, NS). Generally, the lightning frequency of TS-MCSs and LS-MCSs are larger than other modes of the linear-MCSs. Of ten linear MCSs classified six (60%) are associated with at least one report of hail, with the diameter from 0.3 to 5 cm. Hail report usually occurred in the strong radar echo just after the frequent lightning discharge ended. Therefore, the rapid increase of lightning frequency could be as an indicator of hail falling. The results showed the hail-produced linear MCSs generated high +CG lightning percentage than the non-hail-produced system.

Table 1. The cases of different linear MCS

Time	Linear MCS mode	Lightning frequency (flashes/10min)	Hail (duration, size)
2007/07/07	LS	800	5 min, 2cm
2007/07/17	TS	580	22min, 5cm
2007/07/27	LS	450	--
2007/07/31	TS	300	10min,0.8cm
2009/07/23	BE	550	5min, 1cm
2009/08/01	LS	340	15min, 0.3
2010/06/13	TS	540	--
2010/06/15	NS	280	--
2010/06/16	BS	430	--
2011/06/11/	PS	200	20min,1.3cm

2) Lightning activity of linear MCSs

The lightning imposed on composite radar reflectivity at the mature stage of different mode of linear MCS are showed in Figure 2. Usually, the mode of LS-MCS and BE-MCS influenced by the front weather system, while TS-MCS formed by the southwest airflow and PS-MCS generated by the cold vortex. Meanwhile, different mode of linear MCS presented different characteristics of lightning activity. Overall, lightning mainly distributed in the convective region within high radar reflectivity (greater than 40 dBZ), and fewer lightning located in the trailing stratiform region. With the thunderstorm developed into dissipating stage, lightning occurred in the stratiform region is gradually increased in the mode of LS, BE, PS. In this study, large scale linear MCSs corresponded to low lightning frequency (Figure 2d) and large number of lightning generated in relative small scale linear MCSs (Figure 2a and 2e) of ten cases. The +CG lightning accounted for high percentage of CG lightning in the mode of LS-MCSs, especially in the trailing stratiform region at the dissipating stage. Compared with the CG lightning location of TS-MCS, there is no CG lightning occurred in the stratiform region of the LS-MCS. It assumed that the charge density is weak in the trailing stratiform region of thunderstorm, therefore, the discharge released as IC lightning.



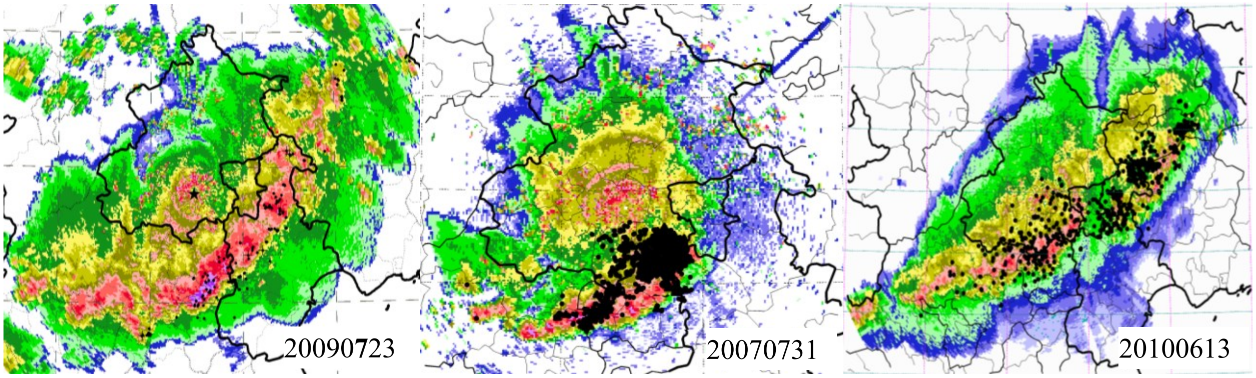


Figure 2. The composite radar reflectivity superposed within 6 min lightning in different mode. Black dots stand for lightning location.

CONCLUSIONS

Under the special terrain condition, linear MCS occurred frequently around Beijing area. Based on the radar morphologies, the linear MCS are classified into six category including TS, LS, PS, NS, BE and BS. The mode of TS-MCS and LS-MCS occupied 58% of the whole linear MCSs. It is investigated that the lightning frequency of TS-MCS and LS-MCS are larger than other mode of linear MCSs. Generally, hail falling is accompanied with the lightning increase sharply and the time of lightning frequency reached to the peak value prior to hail falling, thus the rapid increased lightning frequency can be used to indicate the hail hazard.

The differences of lightning activities are attributed to the different charge structure of linear-MCSs. Under the electrification and discharge processes of thunderstorm, the charge structure is formed by the interaction between dynamical and microphysical processes. Future works will combine the model simulation with the observation to investigate the lightning activity of the linear MCS deeply.

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