DEVELOPMENT OF NATIONAL LIGHTNING DETECTION NETWORK AND ITS APPLICATION IN CHINA

Meng Qing[1] Ding Haifang[2] Zhang Yijun[1] Xu XiaoFeng[2]
Yuan Jiashuang[1] Zhu Xiaoyan[1] Yao Wen[1] Lv Weitao[1]

1.Chinese Academy of Meteorological Sciences
2.China Meteorological Administration
46 Zhongguancun Nandajie,Beijing, 100081,P.R. China
Direct: 86 10 68408146
Fax: 86 10 68408941
E_mail:mengqing@cams.cma.gov.cn

ABSTRACT

Nowadays there is a growing worldwide awareness of the need for the automatization of atmospheric detection and sensing to lightning flashes. National Lightning Detection Network (NLDN) in China has being established by China Meteorological Administration (CMA) through sharing the sources of regional lightning detection network. The developed of NLDN in China make it available to provide real-time lightning flashes data and to meet the need of operational lightning detection.

In China there are some regional Lightning Detection Network at most provinces and areas, which is designed for CG lightning detecting, while SAFIR 3000 lightning observation have been installed at some places, which is designed for total lightning flashes detecting. It is necessary for the development the NLDC that network consists of homogenous lightning detection sensors that provides both time-arrival and direction-of arrival measurements. Only with same communication data protocol and flow, detection and status data format, Network Control Center (NCC) of NLDN may processes and archives individual strokes data transmitted form remote sensors.

Weather forecasters in both public and private sectors use real-time lightning maps and individual lightning strike characteristics from the NLDN to closely monitor thunderstorm development, strength, and paths for more accurate severe weather forecasting and for issuing warnings. The preliminary lightning warning software system is developed base on regional network data ,which may provide nowcasting and warning lightning product 0~2h in advance.

Keywords: NLDN NCC Lightning warning lightning detection

1. Introduction

Over the past 15 years, CMA has researched on Lightning Detection System (LDS) and performed field experiment with LDS equipment and sensor. There are a lot separate regional lightning network in some provinces or areas in China,.For example ,in the south Shenzhen, Jiangxi and Fujian areas, in the east Shanghai and Hubei areas,in the west ,Guizhou and Yunnan Privince,in the north, Beijing and Heilongjiang areas have setup their regional lightning detection network. Figure1 show lightning observation data at 18::00 to 19:00 on Aug.1th, 2006.1(a) and 1(b) give a instances, observation data was detected by separate regional lightning network in China .

Although, there is a Network Control Center (NCC) for each regional lightning detection network., the NLDN has not been providing real- time, continental-scale information on cloud-to-ground (CG) lightning to research and operational users in China now. CMA will make separate regional network to share data to establish the NCC for operational NLDC. This network has undergone improvement the sensor and regular improvements during its lifetime. The intent of this paper is to provide research on how CMA NLDN® may become the most reliable lightning information system monitoring cloud-to-ground lightning activity across most provines in China, 24 hours a day, 365 days a year.

The strong convection, precipitation and lightning activities are often produced in thunderstorms. A lot of significant research results on the relationship among them have been revealed with the applications of lightning location system.

There are a significant relationship between severe weathers such as hail, heavy precipitation and tornado, which often occur in supercell thunderstorms, and temporal and spatial characteristics of lightning discharges. In this paper, the basic algorithms for warning method of lightning are analyzed, lightning warning production, comparison and its effect evaluation are discussed.

2 . NLDN operational overview

NLDN consists of more han 100 remote, ground-based lightning sensors，which instantly detect the electromagnetic signals given off when lightning strikes on earth's surface .Lightning Sensor send raw data via transmit link to NCC. Within seconds, the NCC's central analyzers process information on location, time, polarity, and the amplitude of each stroke . Lightning information is sent to users across the country.

For China, the existing condition and state of NLDN may see from Figure1 that observation data was detected by separate regional lightning network in China is not meet the need of operational lightning detection, that means when and where lightning activities occur, the observation data may be not presented.

2.1Network of lightning sensors

In China ,NLDN consists of more than 100 remote, ground-based Lightning Sensors that specializes in cloud-to-ground lightning sensing with lightning efficiency and excellent accuracy in location and lightning parameters using combined LF magnetic direction finding and time-of-arrival lightning sensing technology. The technical information operational show in Table 1 as below:

Table 1 Equipment technical information operational of Lightning Sensors installation in NLDN

feature	Specifications
Lightning Type	Cloud-to-ground(CG) flashes and strokes
Network Detection Efficiency	>90% for CG
Network Median Location Accuracy	500m CG stroke
Nominal Baseline Between Sensors	15 to 350 km
LF Band	1kHz-350kHz

2.2Network Control Center (NCC)

Lightning sensors instantly detect the electromagnetic signals given off when lightning strikes the earth's surface. Individual stroke reports are transmitted from the remote sensors to a central station via the transmittal links. The link sites forward data via dedicated communications links to the Network Control Center (NCC) in Beijing, Here the data are processed and archived, and the results are forwarded to customers via some type data links within 30-40 seconds. CG stroke and flash data are also available via the Internet, and limited (survey level) information of the occurrence and frequency of cloud discharges is expected to be available via the Internet in the next stage of establishment of NLDN in China.

NLDN flash data provides time, location, polarity, amplitude of each cloud-to-ground lightning flash. Within seconds, the NCC's central analyzers process information on location, time, polarity, and amplitude of each stroke.

2.3 Data communication System

In Communications data flow, sensors send raw data to the NCC, from NCC lightning information is sent to customers across the country via special designed communication link.. It is necessary that the lightning sensor communications links operated or employed in the NLDN have proven to be more reliable that any other communications method and to avoid to occasional congestion in the data links, which caused the data from some sensors to arrive at the NCC too late to be used in real-time processing. As part of the upgrade, the downlink sites and the links between these sites and the NCC were upgraded in an effort to minimize this problem. Although weather-related communication failures can still lead to data delays and possibly missed events in real-time, this data congestion has largely been eliminated from the NLDN. Differences between the real-time and reprocessed data archives are now in the range of 1 to 2 percent. in the NLDN.

3. Lightning Warning and applications

In U.S.A and Canadian reporting locations and detailed characteristics for flashes and strokes .The flash data provides time, location, polarity, amplitude of each cloud-to-ground lightning flash. However, there can be up to 20 return strokes that make up a flash and these strokes often strike the earth in different locations up to several kilometers apart. CLDN stroke data provides time, location, polarity, and amplitude of these strokes, providing the very detailed data needed for in-depth lightning analysis and lightning incident investigations. Flash data is most often used for general trending of lightning events; stroke data is critical for understanding specific incidents.

Weather forecasters in both public and private sectors use real-time lightning maps and individual lightning strike characteristics from the CLDN to closely monitor thunderstorm development, strength, and paths for more accurate severe weather forecasting and for issuing warnings. Lightning is a fast and accurate indicator of severe weather and can also help identify hazardous weather. Improvements in the NLDN have been motivated primarily by the applications that require lightning data. Although the first application, early detection of lightning-caused forest fires., more and more NLDN users include Meteorology, aviation, Electric power, telecommunications and other government agencies. – rely on NLDN lightning data to tell which facilities are at increased risk from thunder-storms. now some applications for NLDN lightning Information as below:

- Weather forecasting: Help predict severe weather for public warning
- Electric power utilities: Pre-position field crews for approaching storm threats and to improve engineering and design with lightning analysis
- Air traffic control: Re-route aircraft around hazardous thunderstorms
- Airports: Suspend high-risk activities like fueling during lightning threats
- Insurance and arson: Investigate lightning as the cause of property damage or fire
- Power-sensitive manufacturing and processing operations: Prepare for storm-caused power outages by switching to back-up power early
- Hazardous materials handling: Warn personnel working near explosives and flammable materials to evacuate
- Forestry: Dispatch crews to suspected fire starts for more successful initial attack
- Golf and outdoor recreation: Warn players to seek safety from storms
- Launch facilities: Monitor for safest weather conditions for shuttle and satellite launches

Over the 3 years, Chinese Academy of Meteorological Sciences (CAMS) found The Laboratory of Lightning Physics and Protection Engineering (LLPPE), which Lightning Forecasting and Warning is the most important research fields. LLPPE has proposed and implemented the lightning warning method, which is integrating multiple observation data, multiple parameters and multiple algorithms. The preliminary lightning Nowcasting and warning system (CAMS-LNWS) software is developed. In this system, many observation data such as the surface electrical field mill, cloud-to-ground lightning location system, SAFIR interferometer system, radar, satellite, sounding data, etc., the forecasting product of synoptic situation, and the numerical simulation of thunderstorm electrification and discharge model are used.

The main contributions are following: the framework and modular design of the lightning warning method is finished; two basic algorithms are implemented: one is area identification, tracking and extrapolating algorithm, and the other is decision tree algorithm, both of which are successfully applied in some warning modules; the lightning warning system can provide the 0~12h thunderstorm activity potential prediction, and 0~2h nowcasting and warning of lightning, which can be showed in several ways such as lightning occurrence probability, the track and forecasting of lightning activity region, the lightning region of interesting for lightning activities, and so on.

For provide and issuance the lightning warning production and services, LLPPE set up Lightning detection information website as figure2 (http://lightning.cma.gov.cn/). The lightning detection information and warning production are automatically created by CAMS--LNWS on website per 15min to 1h. Figure3 shows the lightning detection information and lightning warning production produced by CAMS_LNWS and CAMS_LDAS on July 23th ,2006 in Beijing.(a)-(d) is lightning warning production at 18:00(local time) for occurrence probability of lightning activities 15min. to 1 hour in advance.Tthe graph filled in blue, yellow, orange and redmeans the different level occurrence probability of lightning activities.(e) is lightning warning production at 18:00 (local time) for track and forecasting of lightning activities 1 hour in advance,the purple circle and black arrow means the movement region and direction of lighting activities.(f) is lightning detection information for locations of lightning discharges detected by SAFIR 3000 network at 18::00 to 19:00 (local time).

For verified the warning result and its effect, the evaluation method is adapted to comparesion of lightning warning production with lightning detection information. Figure4 shows lightning warning production superimposition on Lightning observation data.the graph filled in blue, yellow, orange and red show the different level occurrence probability of lightning activities 15min. in advance produced by CAMS_LNWS on Aug 1th,2006 in Beijing at 16:30 and 17:00 (local time).The Green dots show lightning for locations of lightning discharges detected by SAFIR 3000 network at 16:30 to 16:45 (local time) and 17:00 to 17:15 (local time) in Beijing.

From analysis of comparison results and validation studies, CAMS_LNWS have the expect ability of lightning warniing and better effect for lightning activities in beijing areas.

4.Summary and future plans

Based on now regional Network consists of heterogeneous of lightning detection sensors that provides both time-of-arrival and direction-of-arrival measurements, and improvements in the data processing algorithms have also been implemented. According to the need meso-scale observation , the performance analysis and comparison results will help us to design the network of distribution of lightning sensor of NLDN in China , to choose the stability, reliability and practicability of Lightning detection sensor and communication system ,and to develop its application on lightning warning method and services product with NLDN lightning data in China. Performance projections indicate the ability to detect discharges in most regions of the network. The largest improvements in the NLDN detection capability are in regions near the edge of the network, Verification of NLDN performance characteristics will continue.

The improved detection of small events has resulted in an ability to detect some cloud discharges but some cloud pulses are misclassified as CG strokes. It is clear that the current IC:CG classification methods in the NLDN need to be improved, and more sophisticated classification methods are being examined by Vaisala. Vaisala also plans to add an “ambiguous” category for events that cannot be clearly identified as “cloud” or “cloud-to-ground” pulses. Although this is not intended to be a long-term solution, it can provide the user with additional information that might be useful in warning applications, and the “ambiguous” events can be removed for users that require a “cloud-free” dataset.

CLDN performance is measured in two ways: location accuracy and detection efficiency. Median stroke location accuracy, or the typical margin of error for locating a cloud-to-ground strike, is scientifically validated at 500 meters. The entire network and every sensor in the network are continuously monitored to ensure data quality and proper operation.

The artificial rocket-triggered lightning experiments have been a key source of ground truth for several years, and should continue to provide useful information. At Conghua region in Guangdong, LLPPE conducted an experiment field experiment for artificial rocket-triggered lightning on summer reason in 2006.study will complete its analysis of data acquired and will continue to make video studies. These and other investigations will continue to ensure that NDLN performance characteristics are properly validated.

China Meteorological Administration (CMA) continually has invested in development of operational National Lightning Detection Network (NLDN) and expand its applications on disastrous weather forecasting and lightning protection during next 5-10 years.

Acknowledgment This work was supported by Ministry of Science and Technology of the People's Republic of China under contract 2003BA904B10 and by China Meteorological Administration under contract CMATG2006M12 .

References

Cummins, K.L., M.J. Murphy, E.A. Bardo, W.L. Hiscox, R.B. Pyle, and A.E. Pifer, 1998a: A combined TOA/MDF technology upgrade of the U.S. National Lightning Detection Network, *J. Geophys. Res.*, 98, 9035-9044.

Cummins K. L., E. P. Krider, M. D. Malone, 1998b: The U.S. National Lightning Detection Network and Applications of Cloud-to-Ground Lightning by Electric Power Utilities, IEEE Transactions on Electromagnetic Compatibility, Vol. 40, No. 4, pp. 465-480.

Demetriades, N.W.S., M.J. Murphy, and K.L. Cummins, 2002: Early results from the Global Atmospherics, Inc., Dallas-Fort Worth Lightning Detection and Ranging (LDAR II) research network. 6th Conf. on Integrated Observing Systems, Amer. Meteorol. Soc., Orlando, FL, 202-209.

Idone, V.P., D.A. Davis, P.K. Moore, Y. Wang,

R.W. Henderson, M. Ries, and P.F. Jamason, 1998b: Performance evaluation of the U. S. National Lightning Detection Network in eastern New York, 2, Location accuracy. *J. Geophys. Res.,* 103, 90579069.

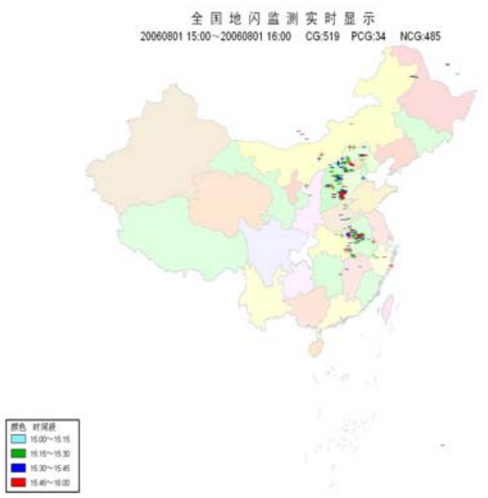
Jerauld, J., V.A. Rakov, M.A. Uman, K.J. Rambo, D.M. Jordan, K.L. Cummins, and

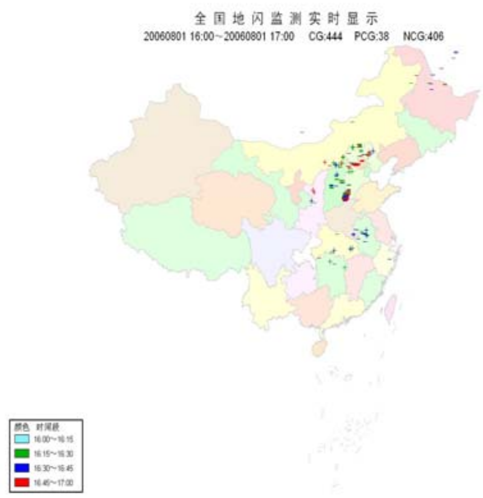
J.A. Cramer, 2005: An evaluation of the performance characteristics of the U.S. National Lightning Detection Network in Florida using rocket-triggered lightning. *J. Geophys. Res.*, 110, doi:10.1029/ 2005JD005924

Kehoe, K.E. and E.P. Krider, 2004: NLDN performance in Arizona. 18th International Lightning Detection Conf., Vaisala Oyj, Helsinki, Finland, paper 50 (CD-ROM).

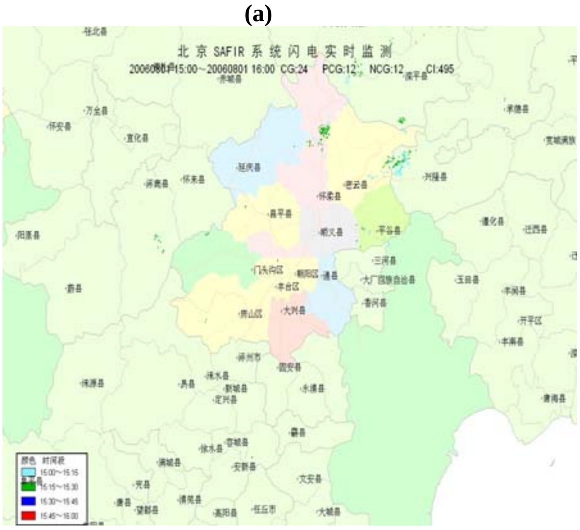
Rakov, V.A., 2005: Evaluation of the performance characteristics of lightning locating systems using rocket-triggered lightning”, Proc. of Int. Symp. on Lightning Protection (VIII SIPDA), Sao Paulo, Brazil, Nov. 21-25.

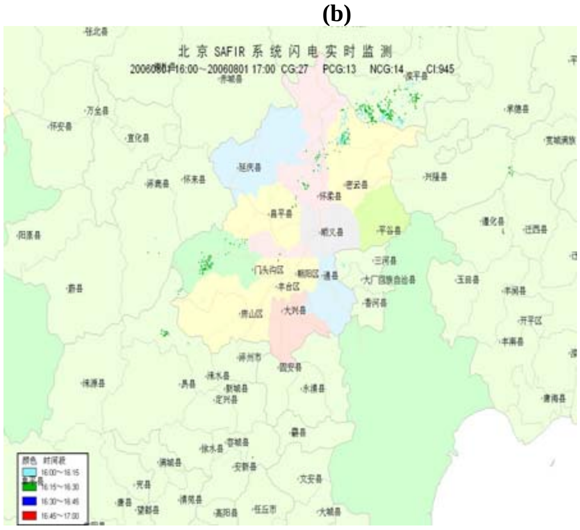
Z-I Kawasaki,K.Yamamoto,K.Matsuura, et al., 1994: "SAFIR operation and evaluation of it’s performance", Geophysical Research Letters , 21(12),1133-1136





(a) **(b)**





(c) **(d)**

Figure1 lightning observation data at 18::00 to 19:00 on Aug.1th, 2006.

(a)and (b) detected by separate regional lightning network in China .(c)and (d) detected by SAFIR 3000 network in Beijing areas

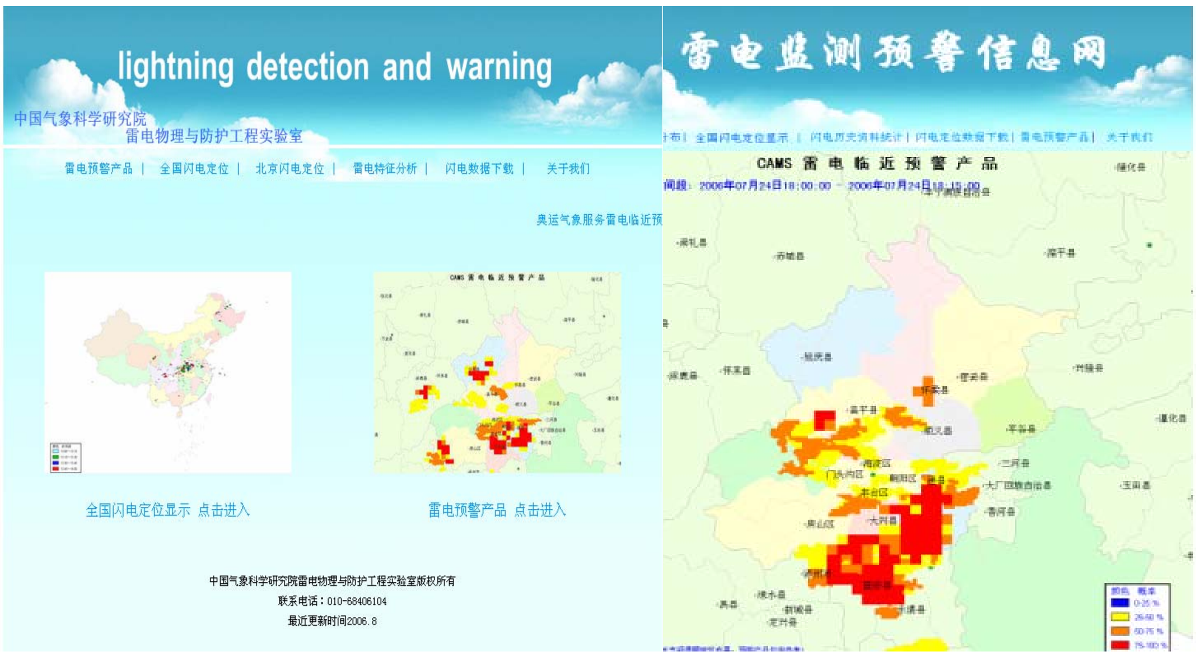


Figure2 lightning detection information and lightning warning production on website (http://lightning.cma.gov.cn/) supported by CAMS Lab of lightning Physics and Protection

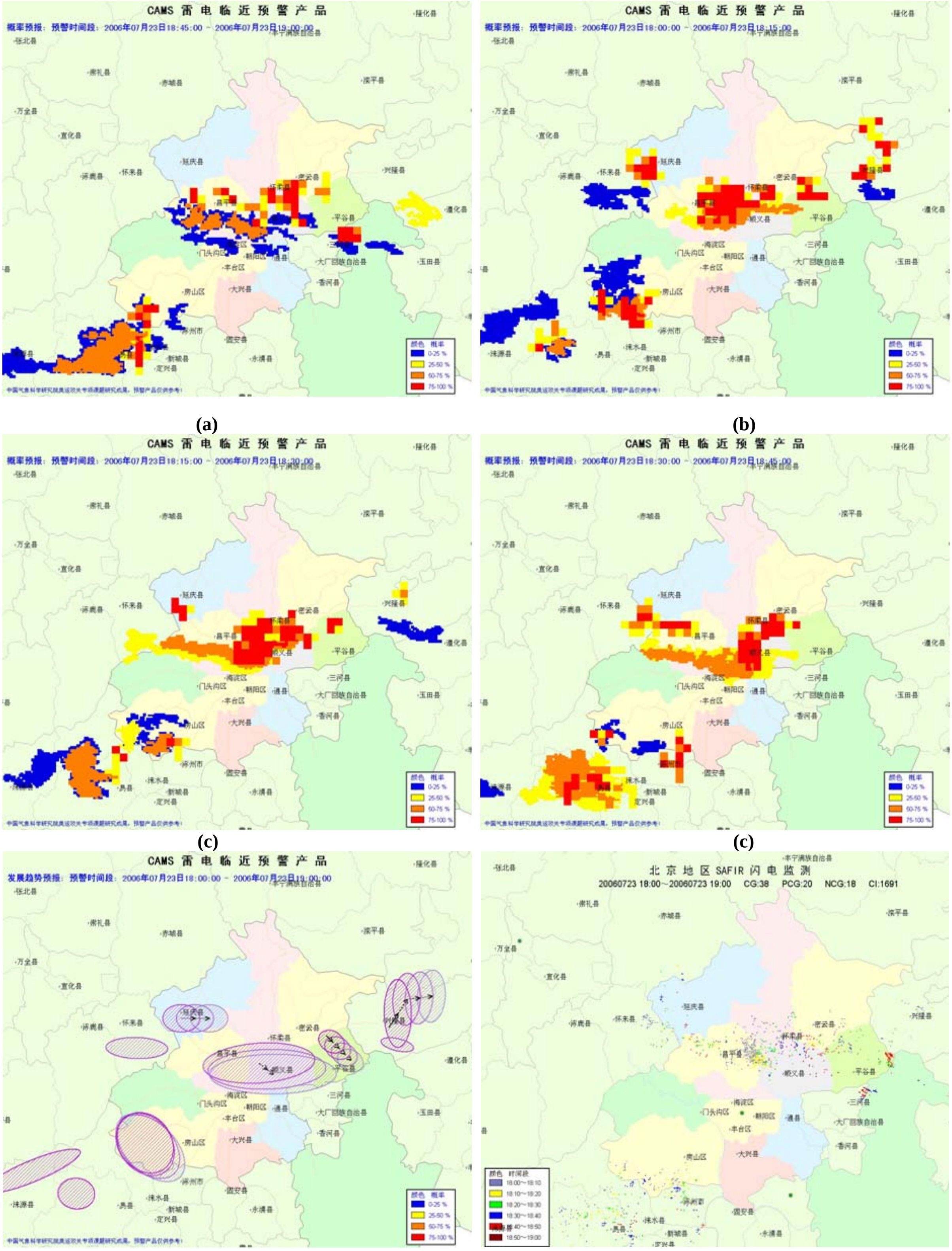


Figure3: lightning detection information and lightning warning production produced by CAMS_LNWS and CAMS_LDAS on July 23th ,2006 in Beijing. (a)-(d) lightning warning production at 18:00(local time) for occurrence probability of lightning activities 15min. to 1 hour in advance, graph filled in blue, yellow, orange and red means the different level occurrence probability of lightning activities (e) lightning warning production at 18:00 (local time) for track and forecasting of lightning activities 1 hour in advance,the purple circle and black arrow means the movement region and direction of lighting activities.(f) lightning detection information for locations of lightning discharges detected by SAFIR 3000 network at 18::00 to 19:00 (local time).

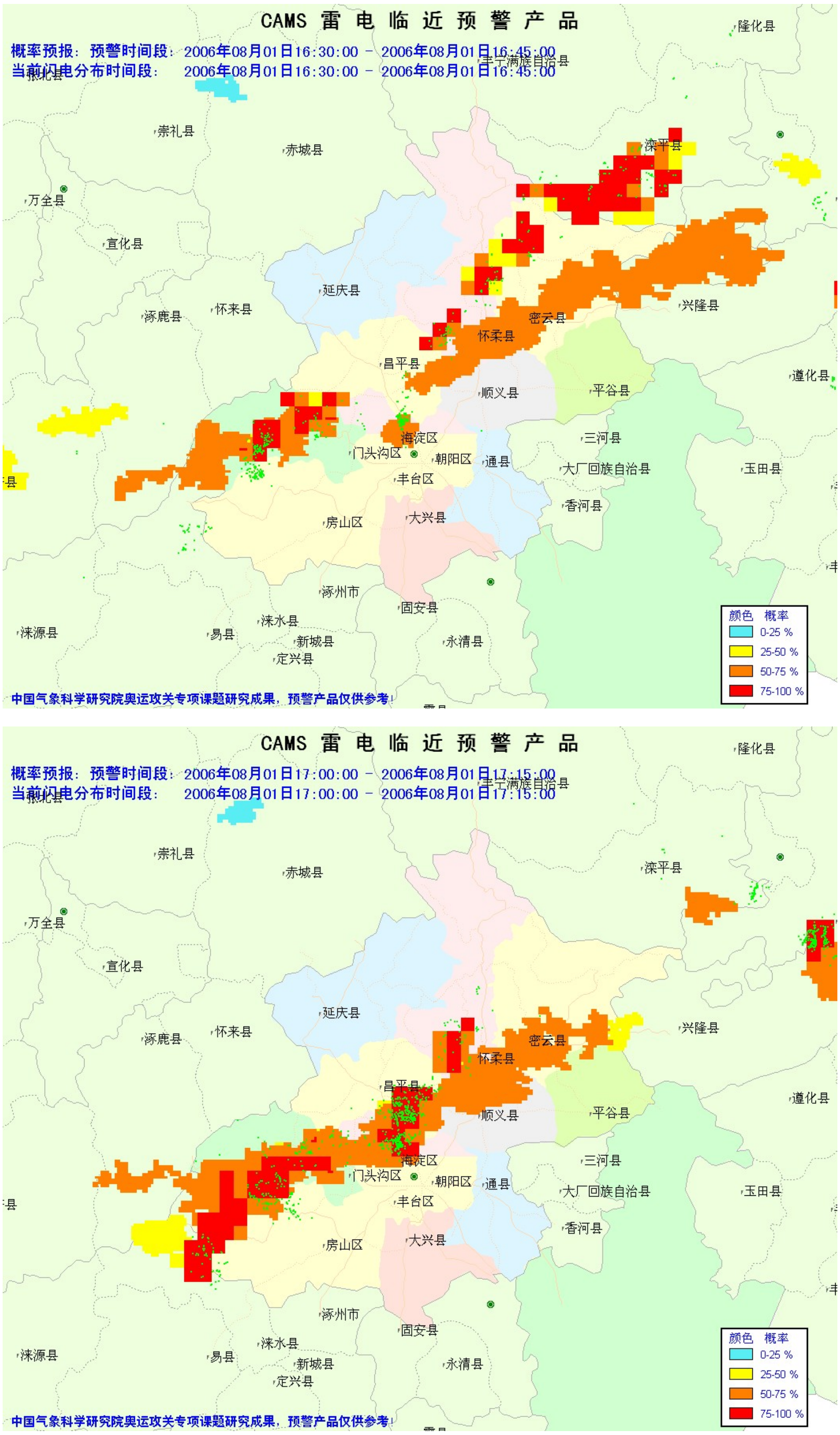


Figure4: lightning warning production superimposition on lightning detection information. Graph filled in blue, yellow, orange and red show the different level occurrence probability of lightning activities 15min. in advance produced by CAMS_LNWS on Aug 1th,2006 in Beijing at 16:30 and 17:00 (local time).The Green dots show lightning for locations of lightning discharges detected by SAFIR 3000 network at 16:30 to 16:45 (local time) and 17:00 to 17:15 (local time) in Beijing.