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RESEARCH ON EXPERIMENT AND EVALUATION OF LIGHTNING NOWCASTING AND WARNING SYSTEM

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ABSTRACT

Chinese Academy of Meteorological Sciences developed a Lightning Nowcasting and Warning System (CAMS_LNWS), which integrating multiple observation data, multiple parameters and multiple algorithms. In the lightning nowcasting and warning method, many observation data such as radar, satellite, lightning monitoring system, surface electrical field mill, sounding data, etc., are used. During 2008-2009 summer, Operational experiment about CAMS_LNWS taking part area all around Beijing, In order to make an objective assessment of the effect of the Lightning Nowcasting and Warning System, three indicators, POD (Probability of Detection), FAR (False Alarm Rate) and TS (Threat Score) are used in the evaluation method.

The experiment results showed that CAMS_LNWS may runs steadily and enables its sharing on internet. It is shows that CAMS_LNWS have favorable forecasting ability for regional lightning activity and the forecasting accuracy came up to internal advanced level from analysis of comparison results and validation studies.

Keywords: Lightning, Nowcasting Warning, Experiment, Evaluation

1. INTRODUCTION

The Lightning Nowcasting and Warning System (CAMS_LNWS) was developed by the Laboratory of Lightning Physics and Protection Engineering (LiP&P), Chinese Academy of Meteorological Sciences (CAMS). In view of strong convection weather in the local areas, the system proposed a lightning characteristic diagnose and nowcasting scheme in typical region, and adopted a multi-data, multi-parameter and multi-algorithm lightning nowcasting method, its foundation is the analysis of lightning space-time distribution characteristics and radar echo characteristics of thunderstorm monomer in local region. The CAMS_LNWS integrated observation data from radar, satellite, lightning detection system, ground electric instrument and sounding instrument with synoptic pattern forecasting products and 2-D charge-discharge model, and employed algorithms of region recognition, region tracing, extrapolation and Decision Tree algorithms. The CAMS_LNWS system was

designed by framework and modularization and applied integrated warning methods in the warning program. CAMS_LNWS can identify, track and extrapolate the potential areas and yield lightning nowcasting and warning products，which supplies products of Lightning Occurrence Probability, Moving Trend of Lightning Activity Area and Lightning Occurrence Probability of Key Area automatically. Designed in modular structure, the system provides plenty parameter interfaces and human-machine interaction function, and can be applied and promoted to a variety of occasions and areas.

2. OPERATIONAL EXPERIMENTS

From 2006-2009 ， the CAMS_LNWS has been promoted for operational use in China. Presently, Beijing, Shanghai, Hubei, Yunnan, Henan, Chongqing, Qingdao, Liaoning, Hei Longjiang et al. have realized the localization of CAMS_LNWS, and began to carry out lightning warning services for local area. Additionally, the CAMS_LNWS played an very important role in lightning forecasting service for 2008 Beijing Olympics Games. In Beijing and its vicinal area, strong convections happened frequently during summer months when the Olympics Games hold. In order to protect the stadiums and facilities form lightning strokes, the CAMS_LNWS worked 24 hours every day and renewed the warning products every 15 min automatically. Warning products were published via China Meteorological Administration (CMA) website, which achieved real-time sharing. During the Beijing Olympic Games, the CAMS_LNWS produced and uploaded 16992 lightning warning products, and released early warning signals for 279 times.

At the same time operational experiments have been held for evaluation of accuracy of the warning products with he CAMS_LNWS .For Lightning Nowcasting and Warning System, the evaluation was based on comparison of predicted and observed results from several thunderstorm processes , and adoption of the 3 parameters, which includes Probability of Detection (POD), False Alarms Rate (FAR) and Test Score (TS) as evaluation index.

Through the drill of meteorological service for Beijing Olympic and the operational promotion in national wide, operational experiments and evaluation work for lightning warning products was conducted in order to improve forecasting and diagnosing techniques and establish a quick-response operational system for lightning warning service.

3. CASES AND ANALYSIS

3.1 Case 1

3.1.1 The weather state and lightning activity

On the early evening of 8th August 2008, influenced by local convective cloud and warm cluster, thunderstorm occurred in fractional area of Beijing. In spite of the large distribution, the rainfall scattered in different directions and Precipitation in southwest and northeast district reached thundershower which would influence to Olympics Games. From the observation of Lightning locating by SAFIR systems in Beijing area, the Strong lightning occurred simultaneously. Figure 1 shows the lightning locating result in Beijing area from 17:00~23:00 on 8th August, 2008 detected by SAFIR system. From the lightning distribution in different time period we can see that, lightning activity area presented southwest- northeast distributions. It moved from west to east with two activities of Fangshan and Miyun Haidian in suburb, and passed to urban area of Beijing at 19:15.

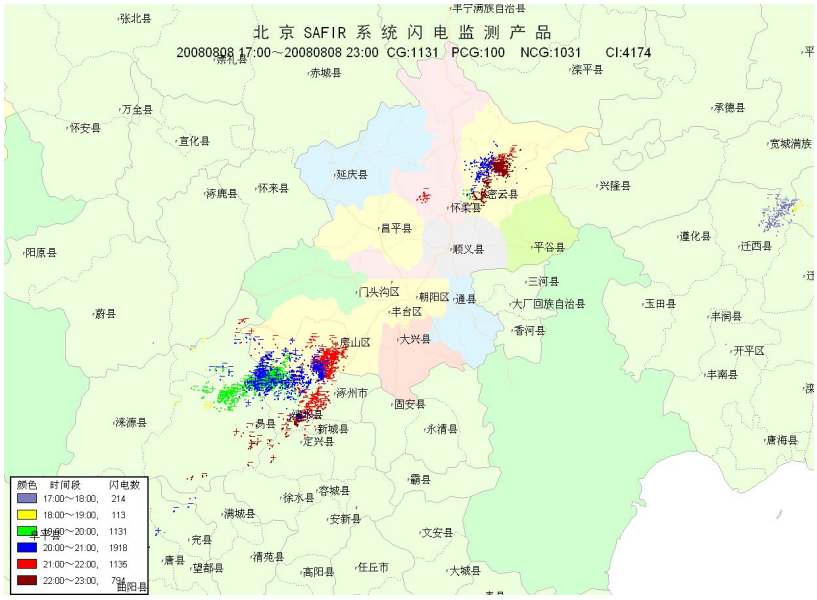
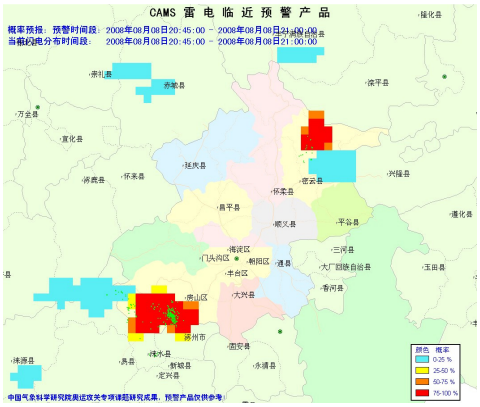


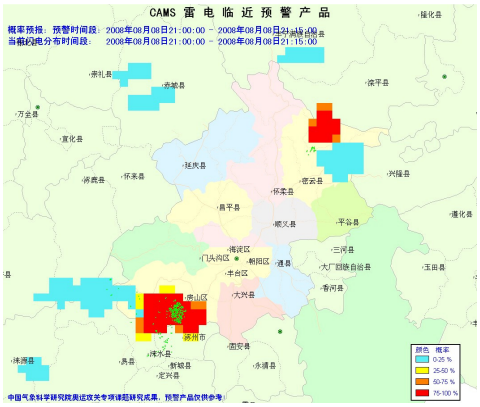
Fig. 1 Lightning locating result of 17:00~23:00 on 8th August, 2008 detected by SAFIR systems in Beijing area.

3.1.2 Analysis and evaluation

The CAMS_LNWS gives the lightning occurrence probability results of 21:00~22:00 at 21:00. Figure2 provides four images of every 15 min from 21:00 to 22:00. As Figure3 show, results suggest that,potential lightning activity region forecasted by the CAMS_LNWS is consistent with real lightning occurrence region observed by lightning locating systems. We also evaluated the forecasting results given by the CAMS_LNWS in 0-15 minutes periods and listed them in Table 1.

As for several important thunderstorms including 8th August (Figure 1), CAMS_LNWS did the forecasting and warning timely and precisely. The system released warning signals 97 times for Beijing and its vicinal area, and supplied essential warning reference information for Beijing Weather Forecast Station.





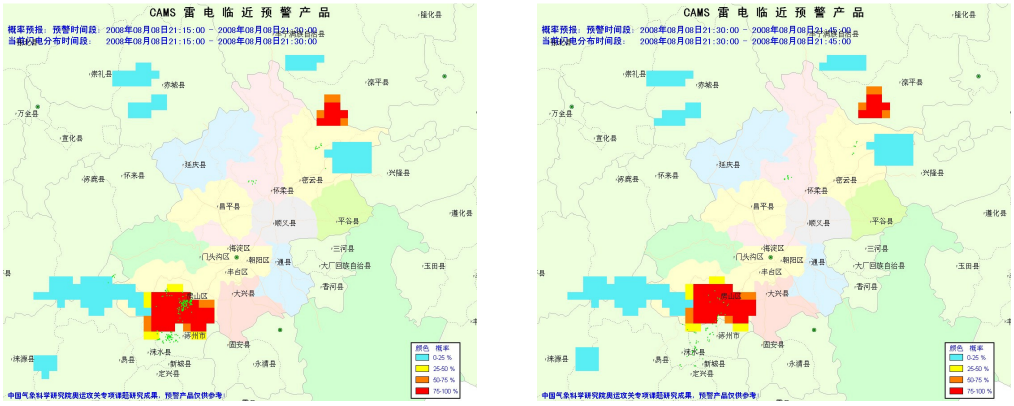


Figure 2. Lightning occurrence probability products given by the CAMS_LNWS for 20:45~21:45 on 8 August 2008, overlaid by observed lightning. Time period of four images are: upper left panel 20:45~21:00, upper right panel 21:00~21:15, lower left panel 21:15~21:30, lower right panel 21:30~21:45. Green dots indicate lightning locating results by the SAFIR 3000 system.

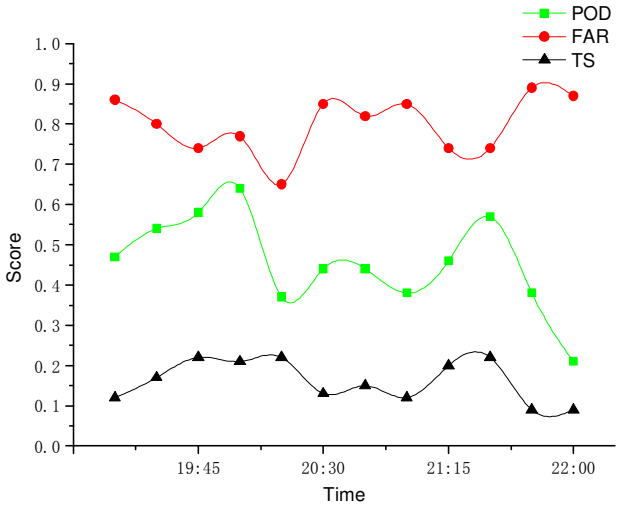


Figure 3. Evaluation results of nowcasting products for 17:00~22:45 on 8 August 2008. POD is probability of detection, FAR is false alarm rate and TS is testing score. X-axis is time and Y-axis is evaluation value for the parameters. Time interval is 15 min.

Table 1. Median and extreme of evaluation parameters of 0~15minute forecast results

	POD	FAR	TS
Median	0.26	0.86	0.09
Extreme	0.64	0.00	0.22

3.2 Case 2

3.2.1 The weather state and lightning activity

August 1st, 2009 from afternoon to night, it was a meso-β scale thunderstorm weather process in Beijing area, due to high-altitude eastward trough and the effect of convergence in front of trough (Figure 4). According to automatic weather station data, the average precipitation was 15mm in Beijing and the maximum precipitation in Xiwengzhuang Observatory was 66.9mm.

According to the monitoring system of CG lightning, lightning activity moved from northwest to southeast obviously. It began from 3:00pm and achieved to a maximum extent at about 4:30pm, then decreased from 6:00pm and ended at 7:00pm. The lighting activity showed a zonal distribution from northwest to southeast and mainly located in Huairou, Yanqing, Changping, Mentougou, Fangshan, Haidian, Shijingshan, Fengtai and Shunyi (figure 5).

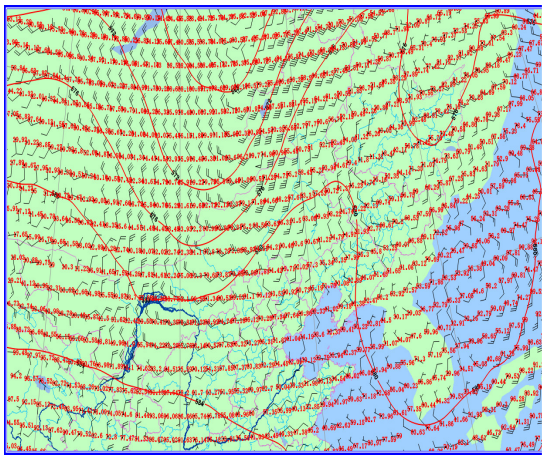


Figure4. superposition chart with the situation of 500hpa height field, 700hap wind field and 700hpa humidity field at 8:00 am on August 1st, 2009

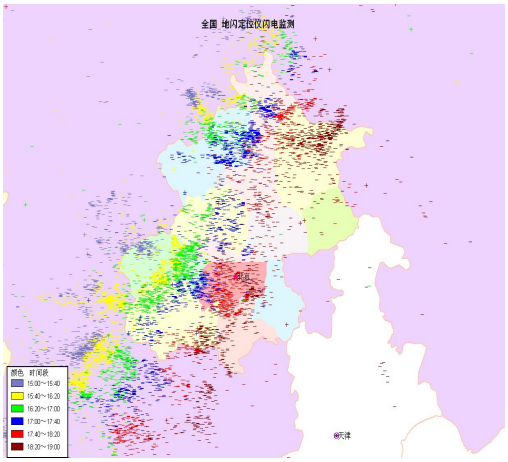
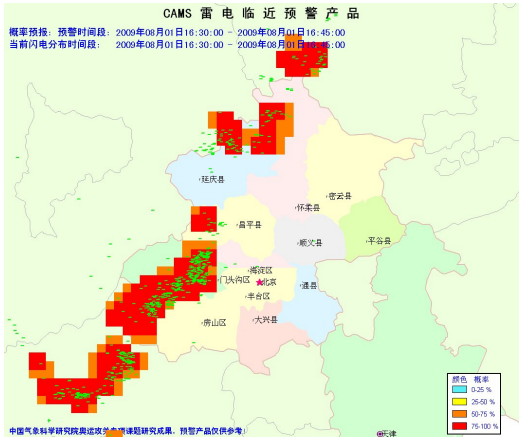


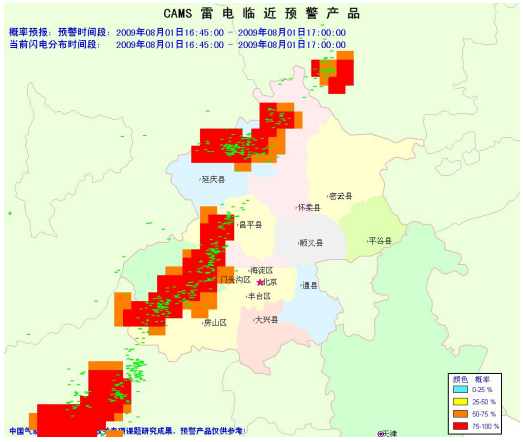
Figure 5. The distribution image of the temporal variation of lightning in Beijing on August 1st, 2009.

3.2.2 Analysis and evaluation

The CAMS_LNWS system has a good relationship on spatio-temporal variation by comparing lightning observation data with forecast result (Figure 6). To further illustrate the effect of forecast, TS score was introduced and presented in Table 2, which the number of sample points are 21. Figure 7 shows the curves of each evaluation parameters along with time, which represents 0~15minutes evaluation results of forecast products.

It shows that CAMS_LNWS system have a good forecast effect for local weather process, was drawn from the following aspects. First of all, 0~15minutes lightning probability forecasts were consist with the measured lightning locations. Secondly, the system got an ideal TS score in this weather process.





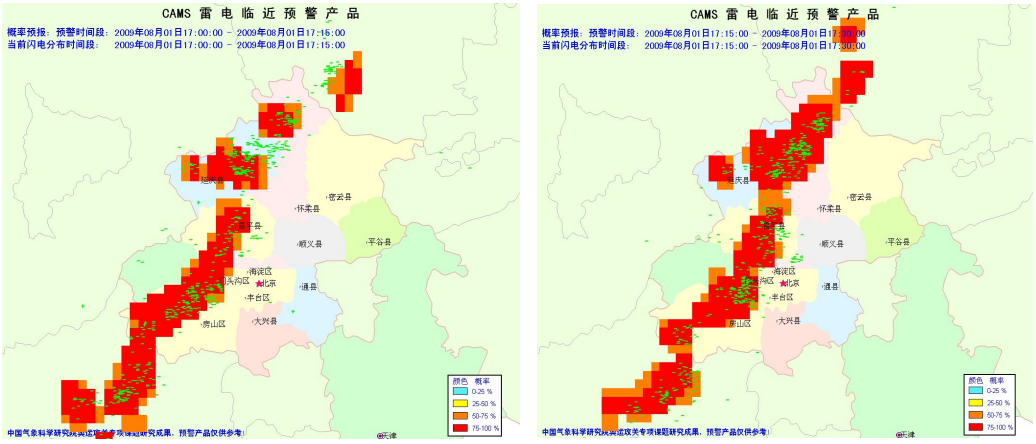


Figure 6. Superposition chart of 16:30 ~ 17:30 lightning probability forecasts and lightning location information in Beijing area on August 1st, 2009. (Green points stand for real CG lightning)

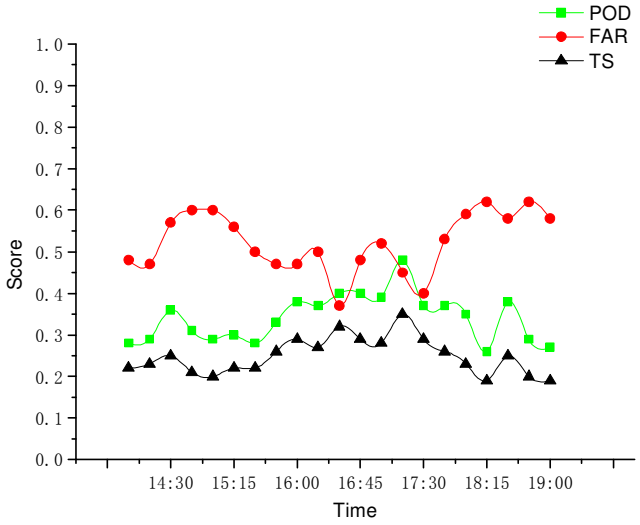


Figure 7. Evaluation curves of 2:00pm~7:00pm on August 1st, 2009.

Table 2. Median and extreme of evaluation parameters of 0~15minute forecast results

	POD	FAR	TS
Median	0.35	0.52	0.25
Extreme	0.48	0.37	0.35

3.3 Case 3

3.3.1 The weather state and lightning activity

On June 16th, there was a large range and medium precipitation accompanied by lightning in Beijing due to the eastward trough, of which the convergence in front influenced this area. Figure 8 shows real weather situation at 8:00am that day. The information, water vapour was brought by the southwest air current front of the pressure at 700hpa, could be understood from the image. According to the monitoring system of CG lightning, the CG lightning first appeared sporadically in urban areas at 8:30am and then the lightning activity

strengthened and moved from southwest to northeast thereafter and achieved maximum at 11:30am while ended at 2pm(Figure 9).

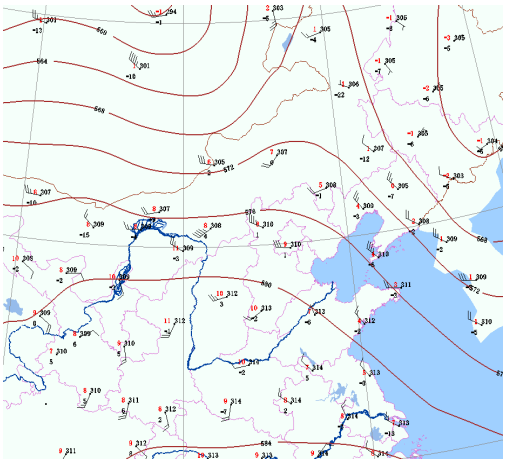


Figure 8. superposition chart with the situation of 500hpa height field, 700hap wind fieldat 8:00 am on June 16th, 2009 .

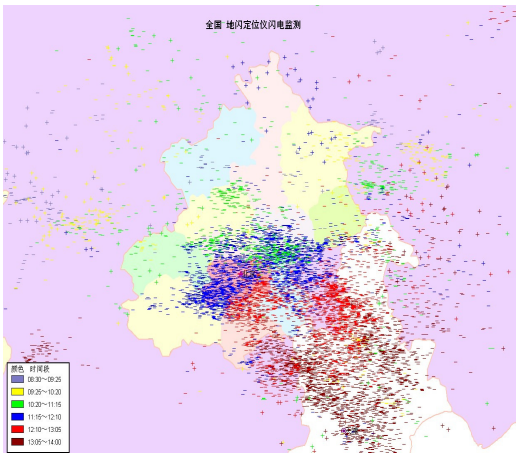
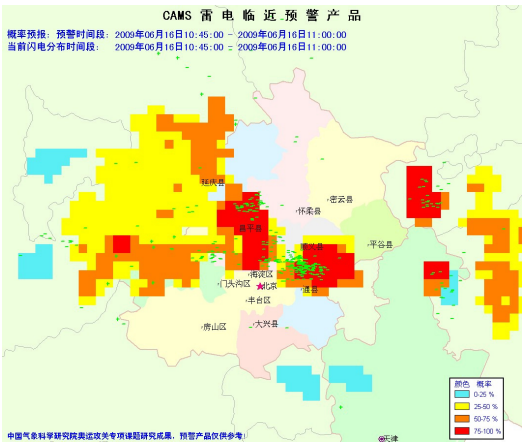


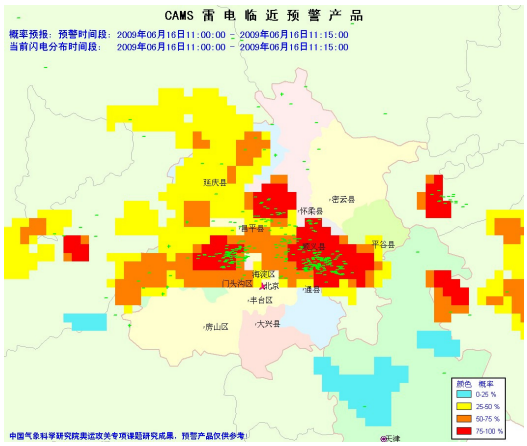
Figure9. The distribution of the temporal variation of lightning in Beijing on June 16th, 2009

3.3.2 Analysis and evaluation

As the case of August 1st, the result of this system was satisfactory. Figure 10 shows superposition chart of 10:45am ~ 11:45am lightning probability forecasts and lightning location information in Beijing area on June 16th, 2009. During this time, the 75%~100% lightning probability forecasts has a good effect of superposition with measured lightning (Figure 11).

The result of TS score showed that the system had a satisfactory performance in this weather process and presented in Table 3. It indicated that the high level POD brought out an ideal TS score despite the system got high level FAR. Table 3. Median and extreme of evaluation parameters of 0~15minutes forecast result, which the number of sample points are 14. Figure 8 shows the curves of each evaluation parameters along with time, which represents 0~15minutes evaluation results of forecast products.





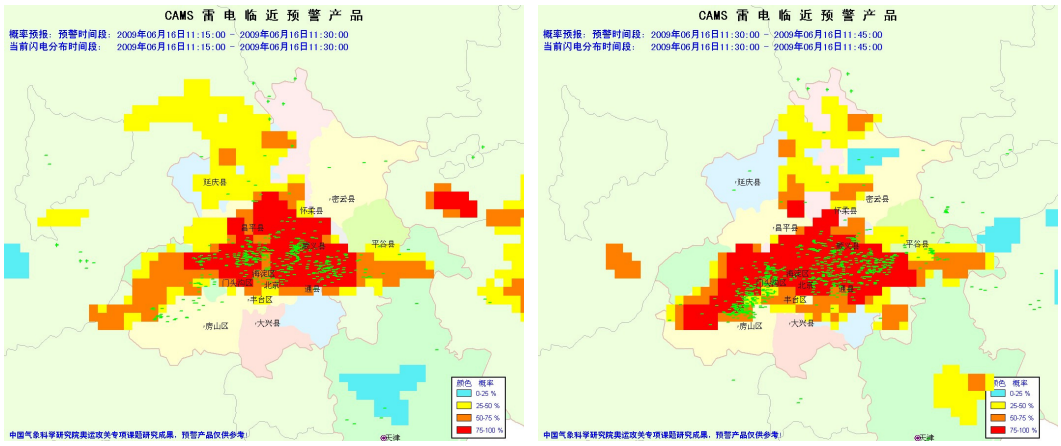


Figure 10. Superposition chart of 10:45am ~ 11:45am lightning probability forecasts and lightning location information in Beijing area on June 16th, 2009.

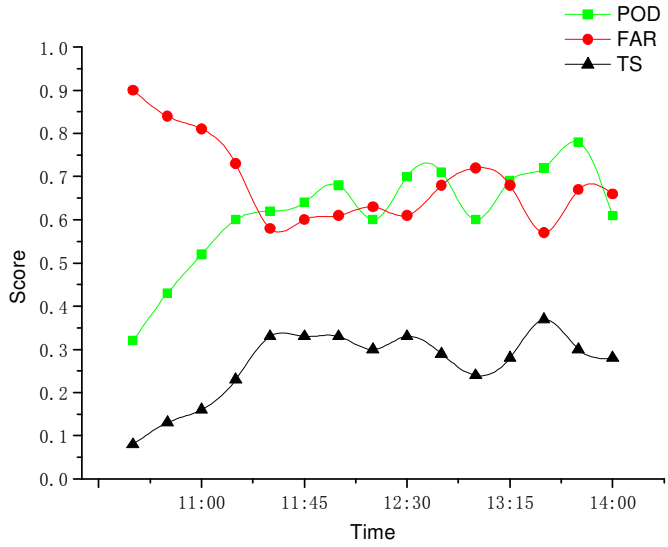


Figure 11. Evaluation curves of 10:30am~1:45pm on June 16th, 2009.

Table 3. Median and extreme of evaluation parameters of 0~15minutes forecast result,

	POD	FAR	TS
Median	0.64	0.68	0.30
Extreme	0.78	0.57	0.37

4. DISCUSSIONS AND CONCLUSION

Through evaluating many thunderstorm processes in 2008 at Beijing region , the results show: POD of 15min exceeds 50%, TS up to 0.19, POD of 45~60min up to 27%. the CAMS_LNWS had a good forecasting and warning ability for lightning activities in local and its vicinal area . The CAMS_LNWS works steadily and provides variety of products. It can read multi-source detection data on time, yield warning products automatically and display them repeatedly

When lightning activity regions are complex, the CAMS_LNWS has worse forecasting results compared to simple lightning activities. Because the forecasting method is based on region recognize, tracking and extrapolation Generally, POD

decreases with the warning time while FAR increases with it. For the warning time within 30 min, POD is above 50% and FAR is less than 80% and the result is acceptable. As for warning time of 30 min to 1 hour, POD decreases to about 30%, and FAR increases to above 85%. It is because of the accuracy and time-effectiveness of the extrapolation method.

The operational experiments and promotion work of the CAMS_LNWS are still in progress now. In the future, we will carry out in-depth studies to reveal the evolution characteristics of lightning activity in different areas, set up a regional lightning warning model, and further improve the regional lightning nowcasting index and algorithm. We will also consider coupling of charge-discharge model of thunderclouds with meso-scale model to promote our scientific understanding of lightning activities with different micro-physical and dynamical processes in cloud. A 0~6 hour numerical forecasting method for lightning activity will be developed in order to improve lightning forecasting effect and progress the national lightning detection, forecasting and warning service ability to a new level.

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REFERENCES

Wang Fei, Zhang Yijun, Zhao Junzhuang, et al. The Prelimiary Application of Radar Data to the Lightning Warning of Isolated Storm Cells. , Journal of Applied Meteorological Science, 2008， 19(2): 153~160.

Zheng Dong, Zhang Yijun, Lu Weitao, et al. Atmospheric Instablity Parameters and Forecasting of Ligthning Activity. Plateau Meteorology, 2005，24(2): 198~203.

Meng Qing, Lu Weitao, Yao Wen, et al. Application of Detection Data from Electric Field Meter on Ground to Lightning Warning Technique. Meteorological Monthly, 2005，31(9): 30~33.

Ma Ming. A study of the relationship between lightning activity and climatic variation. Ph.D. Thesis, University of Science and Technology of China,2004

Tan Yongbo. Numerical simulation of the relationship of the lightning discharge with the space charge and potential distribution in thundercloud. Ph.D. Thesis, University of Science and Technology of China,2006.

Dixon, Mlig., and G. Wiener. TITAN: Thunderstorm Identification, Tracking, Analysis, and Nowcasting—A Radar-based Methodology. Journal of Atmospheric and Oceanic Technology, 1993, 10: 785~797.

Xu Xiaofeng. Lightning Induced Disasters and Its Detecting and Forecasting. Meteorological Monthly, 2004, 30(12): 17~21.

Mansell, E.R., C.L. Ziegler, and D.R. MacGorman, 2007: A Lightning Data Assimilation Technique for Mesoscale Forecast Models. Mon. Wea. Rev., 135, 1732–1748.

Bridenstine P., C. Darden, J. Burks, S. J. Goodman: The Application of Total LightningData in the Warning Decision Making Process. Conference on the

MeteorologicalApplications of Lightning Data, San Diego, CA, January 2005.

Mazany, R.A., S. Businger, S.I. Gutman, and W. Roeder, 2002: A Lightning Prediction Index that Utilizes GPS Integrated Precipitable Water Vapor. Wea. Forecasting, 17, 1034–1047.

Gremillion, M.S., and R.E. Orville, 1999: Thunderstorm Characteristics of Cloud-to-Ground Lightning at the Kennedy Space Center, Florida: A Study of Lightning Initiation Signatures as Indicated by the WSR-88D. Wea. Forecasting, 14, 640–649.

Feng Guili, Qie Xiushu, Zhou Yunjun. A Case Study on Characteristics of Lightning Activity in a Mesoscale Convective System. Plateau Meteorology, 2006,(2).

Richard, Philippe. Thunderstorm monitoring and lightning warning, operational applications of the Safir system. The 1991 International Aerospace and Ground Conference on Lightning and Static Electricity, Volume 1 6 p (SEE N91-32599 24-47).

Goodman, S.J., Predicting thunderstorm evolution using ground based lightning detection networks, NASA Tech. Memo, TM-10352, 210 pp., 1990.