Study of thunderstorm characteristic with SAFIR lightning and electric field meter observations in Beijing Areas

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1. Introduction

A field experiment with SAFIR system during summer seasons in 2005 is organized with the observation of lightning observation with SAFIR 3000 system, meteorological radar and other meteorological detection data, especially installation the network of electric field meter. A network of ten EFM sensor and central processor unit were installed around Beijing areas from August in 2005.

There is an obvious but largely unmet need for information to help those in charge of outdoor activities to assess the possibility of a near by lightning strike before the first strike has occurred and at the end of storms when the time between successive lightning flashes can be tens of minutes. Electric field related to lightning close to storm were measured in Beijing city Zone. The aim of this campaign was the study of thunderstorm characteristic with lightning and electric field meter observations, and development the lightning warning technique with the detection data from the electric field meter on ground is based on the network observation of the electric field meters. Through detection electric filed on the ground produced by the electric charge center in the thunderstorms on automatic, continuous and real time mode, the lightning warning technique can provide the information about development of the charge center and position and movement of lightning activity in thunderstorm on the detection domain. With the combine of detection from Lightning location system, the lightning warning way may give the more whole information for lightning detection and warning.

In this paper, the observed data of strong thunderstorms are analyzed and typical lightning characteristics at beginning, mature and dissipation stage of thunderstorm and the relationship between lightning and convection are discussed. This study presents a comparison between the occurrence of thunderstorm as identified by SAFIR and the properties of change of atmospherics electric field measured by electric field meter. The results indicate that good correlation between SAFIR location distributions, electric field change and radar echo data. The purpose of the comparison is to identify thunderstorm prediction indices, suitable for Beijing 2008’s Olympics games and demands for lightning detection operation and its application in CMA.

Electric field near earth’s surface increases significantly in magnitude with overhead charged clouds, so EFM may be helpful for warning prior to first strike and clear indication when local danger has passed. The establishment of method and technique of lightning warning for severe weather through study on the characteristics of thunderstorm in summer reason at Beijing areas, make it is possible for providing the information of lightning information and products of lightning warning for Olympics games occasion, communication and computer equipments through application to public meteorological services network for Beijing 2008’s Olympics Games.

2. Measurement Network

Figure1 shows the operational coverage of EFM Network sensors, there are 10 sensor
respectively situate around Beijing city zone, at AWS (automatic Meteorological Station) sites served for Olympics Games Sport Place (OGSP) . EFM measurement site locations over Beijing OGSP Network adapt a new observation method of combine to AWS data acquisition, which the EFM is a sensor of AWS, central processor unit may get the electric field data for both EFM sensors from data loggers. The data loggers for each site were time synchronized by a GPS network time service offered from central processor unit per hour, and the data were send about per minute by GPRS or CDMA communication mode. The central processor may display the status of each sensor is and save the electric field data. The details of functions about EFM network and sensors are shown in table 1 and table 2 below.

Table 1                Data Acquisition of EFM Network Specifications

<table>
<thead>
<tr>
<th>Function</th>
<th>Techniques Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAQ Memory</td>
<td>2MB</td>
</tr>
<tr>
<td>Sample Rate</td>
<td>1/sec</td>
</tr>
<tr>
<td>Communication Mode</td>
<td>GPRS or CDMA</td>
</tr>
<tr>
<td>Communication rate</td>
<td>Send 60 data to center computer for each station</td>
</tr>
<tr>
<td>Sensor status</td>
<td>Center computer display the station number of online</td>
</tr>
<tr>
<td>Timing Accuracy</td>
<td>GPS Time service: 1pps</td>
</tr>
<tr>
<td></td>
<td>Center computer give the time service to each DAQ per hour</td>
</tr>
<tr>
<td>Date Display</td>
<td>Center computer update the data for each EFM sensor and draw the map of EFM data.</td>
</tr>
<tr>
<td>Data Save</td>
<td>Center computer save a EFM data file for each station per hour</td>
</tr>
</tbody>
</table>

Table 2                Electric Field Meter Specifications

<table>
<thead>
<tr>
<th>Function</th>
<th>Techniques Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detection Rang</td>
<td>20km</td>
</tr>
<tr>
<td>Measurement Rang</td>
<td>±50kV/m</td>
</tr>
<tr>
<td>Resolution</td>
<td>±5V/m</td>
</tr>
<tr>
<td>Accuracy</td>
<td>&lt;10%</td>
</tr>
<tr>
<td>Electrical Interface</td>
<td>RS-232 (DB-9).</td>
</tr>
<tr>
<td>Sample Rate</td>
<td>1/sec</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>AC 220V±%10 ; DC 9V; &lt;6W</td>
</tr>
<tr>
<td>Programmability</td>
<td>Microprocessor controlled with data storage capability</td>
</tr>
<tr>
<td>Site Calibration</td>
<td>Pre-determined site calibration with standard EFM Sensor</td>
</tr>
<tr>
<td>Environmental</td>
<td>-20 to 50 °C, 0 to 100% RH</td>
</tr>
</tbody>
</table>

3. **Observation and analysis**

Nowadays EFM Beijing OGSP Network have operated and observed several thunderstorms in the filed experiment. More than 20 days data of electric field, SAFIR lightning, echo pattern of
Doppler weather radar and the normal meteorological detection in 2005 summer season are obtained.

For Beijing areas, all eyes are on city zone for a significant rain event during whole day on Friday, August 12th, 2005. According to the weather situation report, on effect of warm and wet air current from the outer edge of subtropical high pressure, together with southward weak cold air come from Mongolia, Beijing areas produce some heavy rains across most parts of city-zone and suburb. The rain ride into upstate from the south-west by early Friday and across city-zone thereafter. Parts of westem suburb pick up over 51mm and city-zone pick up 24.5mm precipitations by late Friday. Figure 2 shown precipitation distribution of 24 hours during 00:00 to 22:00 (UTC) on August 12th, 2005 in Beijing areas. There three storm system affect Beijing areas on the whole day. The rain has increased dramatically from City-zone to Pinggu location at the eastern of suburb, a more strong severe thunderstorms with lightning activities develop on the early are analyzed below.

The thunderstorm with small echo which had strongest intensity of more than 40dBz started to develop in the southwest and moved to the northeast of observation area of EFM Beijing OGSP Network. The lasting time was about 2hours. Figure 3-1 shows thunderstorm with lightning discharges locations 22903 IC and 2851 CG records at plan and altitude from 08:00 to 09:40 LT(00:00 to 01:40 (UTC)) on August 12th, 2005. Lightning location are presented by different colors to shows the movement of lightning activity per 18 minutes as color palette. The figure 3-2 show the development of lightning discharges on spatial and temporal about same storm. The storm produced more than 8,000 lightning radiation events for 2 hours. The different panels show respectively the view. (a) height-time plots; (b) north-south vertical projections; (c)height distribution of number (N) of radiation events; (d)latitude—longitude plan views; (e)least-west vertical projections. The changes of color from purple, blue, green, yellow, ed and brown in the figure indicate the variation of IC and CG discharges events with time.

From Figure 3-2(d), it was seen that lightning radiation sources started (purple), at about 00:00(UTC), moving to northeastward, distributed vertically at altitude of 10-15km. Comparing figure3-2(b) and(e), at maturity period, the height of lightning discharges became lower with the development of storm. The figure3-2(c) present most of lightning radiation sources appeared at 10-12km. The movements of storm show variation of structure on electric charge and lightning characteristics. The figure3-2(d) also pointed, a few lightning discharges appeared in the right-top, on higher altitude, it may proved that the beginning of development about another storm cell. This indicates that the more increasing of lightning discharges, the more developing intensively of thunderstorm.

Figure 4 shows the comparison between lightning discharges and radar echo. It was seen the lightning data (red dots) superimposition on a radar echo map from 00:00 to 01:40 (UTC) on August 12th, 2005. To get each superimposition map, Radar echoes are overlayed with lightning data gathered beginning 3 minute before the time of Radar observation, and ending 3 minutes after. Form Figure 4(a)–(g), it can be observed that there are several storm cells in the echo, which had strongest intensity echo over 40dBz. It is believed that the echo may corresponded lightning data during respective time period and SAFIR network may seen as an indication on thunderstorm and help for lightning warning in Beijing region.

Figure 5 shows the comparison between lightning discharges and EFM data during growth, decay and advection of electric charge distribution overhead. It was seen the lightning data (red dots) superimposition on a EFM map during same time period. There are many lightning discharges from the southwest one moved up to north, while more lightning discharges passed, electric file data seemed to become the strong near EFM sites at Beijing city-zone. At 08:00(LT) as 00:00(UTC), the lightning discharges begin to enter the city-zone, from Figure 5(a) to (c), it is noticed that on the southwest EFM sites, electric filed data also become more great which value is 15kv/m-20kv/m; After half of an hour, while lightning discharges location record reached the high frequency, 2-minutes total lightning flashes rate rose from less 500 to more 1000 from figure6-1. And the electric filed data on center of city-zone changed to he high value which is 20kv/m-25kv/m from Figure6-1 and 6-2, it is indicate the EFM data are associated with intense convection. The distribution of electric data is associated with the radar echo on temporal and spatial characteristics in strong storm updraft region. After 09:20(LT) as 01:20(UTC), from Figure5(f) lightning discharges passed the city-zone, intro-cloud lightning discharges decreased as dissipation stage of thunderstorm, the electric filed data form EFM also dropped down. Compared with Figure4(a)-(f), these lightning discharge sources, together with electric field data, are a good indicator for variation of strong...
convection at the beginning, mature and dissipation stage of thunderstorm.

4. Discussions and Conclusion
Based on the observation data analyzed above, we may get the relation between thunderstorm and Atmospheric electric field observation:

1. Electric field near earth's surface increases significantly in magnitude with overhead charged clouds, EFM measurement site locations over Beijing OGSP Network can detect the thunderstorm development, and may be helpful for warning prior to lightning activities and clear indication when local danger has passed.

2. With comparison of relationship between radar echo, variation of lightning characteristics during summer 2005 in Beijing areas, electric field observation data were associated with the movement of lightning discharges and radar echo in the development of thunderstorm. The result indicates that electric field observation data were increasing and the thunderstorm was developing intensively, EFM value normally appeared at 15kv/m-25kv/m. Atmospheric electric field observation are a good indicator for variation of strong convection and may provide the information of lightning warning on electric field changes development of thunderstorm.

3. 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 EFM network. There are a significant relationship between severe weathers such as hail, heavy precipitation which often occur in Supercell thunderstorms, Mesoscale Convective Complexes, and characteristics of atmospheric electric field changes. The atmospheric electric field parameter is one of important factors in warning and forecasting severe weathers. Especially, the results are of general significance and can be referred in morning and forecasting severe weathers. However, further researches and observations are needed.

4. Electric field meter along with lightning detector or network of electric field meters provide the most faithful lightning warning, atmospheric electric field useful yet under-utilized meteorological parameter. Further study of lightning warning has been improvement in Project on lightning detection, warning and forecasting for Beijing 2008's Olympic Games base on more detection data.

5. Here we only discuss the main reasons for lack of perfect observation data and suggest some resolutions:
   a) Among the more than 60 days of lightning data, we just get few perfect or good data, obviously all detection sites usually are in the lack of power supplies and poor communication conditions, especial for the begining of experiments, center processor unit Beijing EFM OGSP Network equipments rarely have received above 10 sensors data simultaneity. In fact, we can not obtained many electric field observation data for all thunderstorm in summer 2005. In this case, it seemed too few to find comparison samples between electric field observation data and the lightning, radar echo data in thunderstorm passing through operational coverage of Beijing EFM OGSP Network EFM network sensors.
   b) Although the two experiment period, it is difficult to describe the performance of Beijing EFM OGSP Network. In the face of such a situation, the efficiency way is to improve the power and communication conditions on sensor sites. After available experiment, performance evaluation should be organized for Beijing EFM OGSP Network function in detection site calibration, although each EMF sensor is be calibration with standard EFM Sensor. For Beijing EFM OGSP Network, it is very convenience to new observation method of combine to AWS data acquisition, but EFM measurement sites locations on city-zone where see many great building and under construction building, and the installing environment is complex for site calibration of electric field observation. It is difficult to description the effect of landform and hypsography around the EFM detection site. Shield of electric charge in air is another parameter for the calculation of calibration. The first study is to find the way of normalization process for the electric field observation data from different sites. It is helpful for us to select the optimum equipments for atmospheric electric field observation that need the
requirement of meteorological operation. On the other hand it is valuable to criterion the build of local EFM network and lay down the next development strategies.

c) Concerning electric field observation data for application on thunderstorm warning, the method of thunderstorm warning and prediction should be studied by analysis the observation data and comparison with radar echo data and lightning data integrated the corresponding projects.

Acknowledgment

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

References

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Figure 1: EFM measurement site locations over Beijing OGSP Network and operational coverage of EFM network sensors

Figure 2: Precipitation distribution of 24 hours during 00:00 to 22:00 (UTC) on August 12th, 2005 in Beijing areas (unit: mm). Red circle is the Beijing city zone.
Figure 3-1 Locations of 25754 lightning discharges detected by SAFIR network from 00:00 to 22:00 (UTC) on August 12th, 2005. Lightning location are presented by different colors to shows the movement of lightning activity as color palette. Pink circle is the Beijing city-zone and suburb.

Figure 3-2: Lightning radiation evens during 00:00 to 22:00 (UTC) the storm on August 12th, 2005. The changes of color from purple, blue, green, yellow, ed and brown in the figure indicate the variation of IC and CG discharges evens with time. The different panels show respectively the view. (a) height-time plots; (b) north-south vertical projections; (c) height distribution of number (N) of radiation events; (d) latitude—longitude plan views; (e) least-west vertical projections.
Figure 4: Lightning data superimposition on a radar echo map from 00:00 to 01:40 (UTC) on August 12th, 2005. Lightning data (Red dots) are gathered on a 6 minutes time frame centered around EFM data observation time. (a)–(f) respectively indicate the different time of EFM observation (blue value).

Figure 5: Lightning data superimposition on an EFM data map from 00:00 to 01:40 (UTC) on August 12th, 2005. Lightning data (Red dots) are gathered on a 6 minutes time frame centered around EFM data observation time. (a)–(f) respectively indicate the different time of EFM observation (blue value).
Figure 6-1: Lightning frequency distribution per 2 minutes from 07:50 to 09:40 (LT) as 00:00 to 01:40 (UTC) on August 12th, 2005. Red stick are IC, green stick is CG.

Figure 6-2: a EFM data distribution at site 1# to 4#, and 8# to 10# from 07:50 to 09:40 (LT) as 00:00 to 01:40 (UTC) on August 12th, 2005.