Dynamic-microphysical-electrical Processes in Severe Thunderstorms and Lightning Hazards

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ABSTRACT: As National Key Basic Research Program (973 Program) of China support by Ministry of Science and Technology, Storm973 (Dynamic-microphysical-electrical processes in severe thunderstorms and lightning hazards) Project aims to answer the following three major scientific questions based on coordinated observations: 1) how dynamic, microphysical, and electrical processes interact in the severe thunderstorms in North China? 2) how lightning initiates, propagates, and causes hazards? and 3) how to assimilate special observation data and incorporate them into forecasting model of severe thunderstorms? Comprehensive observations on severe thunderstrom in Beijing and rocket-triggering-lightning experiments in Shandong and Guangdong will be conducted in coordinance during the project execution from 2014-2018.

INTRODUCTION

Severe thunderstorms are usually produce heavy rainfall, wind, hail, lightning and possibly tornadoes. They are major precipitation processes and often lead to flooding and disastrous consequences in northern China with Beijing and Tianjin involving. However the forecast of severe thunderstorm in the region is very difficult because of its nonlinear interactions with the environmental dynamic and thermodynamic field in multi-scales（Yi et al. 2011; Xiao et al., 2013）. One of the more intriguing severe storm types is the leading-line and trailing stratiform mesoscale convective systems (Liu et al., 2010; 2013; Zheng et al., 2010).

Storm973 (Dynamic-microphysical-electrical processes in severe thunderstorms and lightning hazards) Project, as National Key Basic Research Program of China supported by Ministry of Science and Technology, is a five-year program and have been launched since March of 2014 with a joint effort of several institutes from Chinese Academy of Sciences, China Meteorological Administration, and four universities. The project is desired to 1) establish a comprehensive observational dataset of severe thunderstorms in northern China; 2) reveal the interaction between dynamic, microphysical, and electrical processes in severe thunderstorms and the associated mechanism; 3) clarify the physical mechanism of lightning occurrence and development, effect of electromagnetic radiation, and hazard causes; 4) achieve the parameterization of lightning in numerical models, the assimilation and application of lightning data, and the forecasting and early warning for severe thunderstorms and lightning hazards.

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Storm973 Project will carry out six major research subjects to achive the aforementioned goals, including 1) Comprehensive integration of detection systems for thunderstorm and coordinated observations; 2) Dynamic processes and evolution of severe thunderstorms; 3) Cloud microphysical processes and their effects on electrical structure in severe thunderstorms; 4) Incloud charge distribution and mechanism of lightning initiation and propagation in severe thunderstorms; 5) Physical processes of lightning development and hazard causes; and 6) Data assimilation of special observations, forecast and early warning methods of severe thunderstorms and lightning hazards.

COORDINATED OBSERVATIONS

During Storm973 Project, the field campaigns will be carried out in Beijing, Shandong, and Guangdong from 2014-2018. The intensive observation period is arranged from 2015-2017 in Beijing. To detect severe thunderstorms around Beijing, Storm973 will use two C-band multi-parameter radar, one C-band mobile multi-parameter radar and Beijing Lightning Network (BLNet) which currently contans 10-station slow and fast antenna. The campaign will make use of 3D lightning VHF radiation source location through cooperation. The campaign will also integrate with the meteorological operational networks of S-band Doppler radar, cloud-to-ground (CG) lightning, rain gauge and automatic meteorological station. The thunderstrom detection field campaign of pre-Storm973, mainly tested C-band multi-parameter radar and BLNet, was conducted in Beijing from 1 July to 30 August 2013. During this field experiment, three kinds of storm systems were documented: squall lines, cold fronts and local convective systems. Figure 1 shows a layout of E-field sensors of BLNet. An example of lightning detection result for a thunderstorm for July 7, 2013 is shown in Figure 2. Dynamical, microphysical characteristics (such as hydrometeor identification and ice/water mass) and precipitation are inferred from the C-Polarization and operational S-band radars.

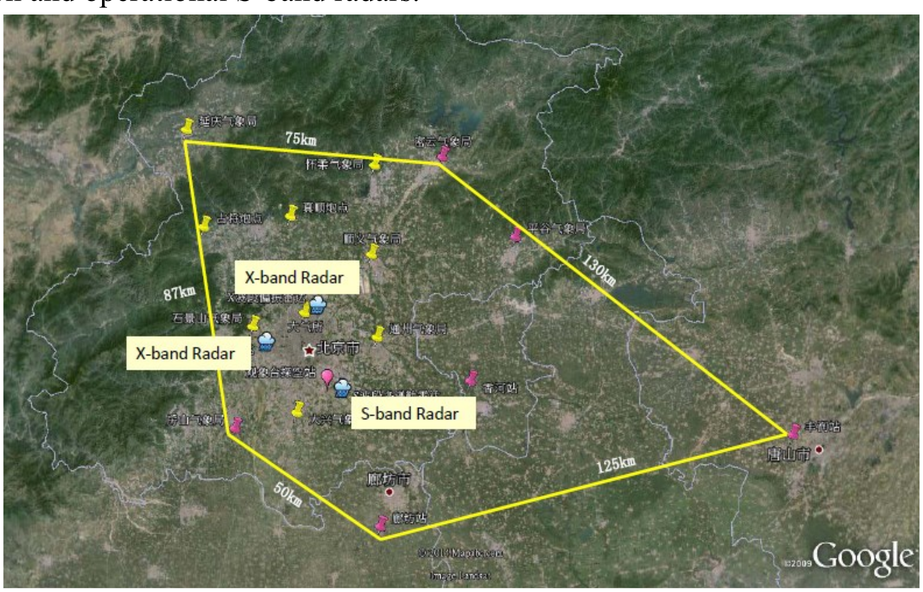

Figure 1. Layout of BLNet (yellow pins) in 2013.
The BLNet will be upgraded to 15 stations as shown in pink pins in 2014.

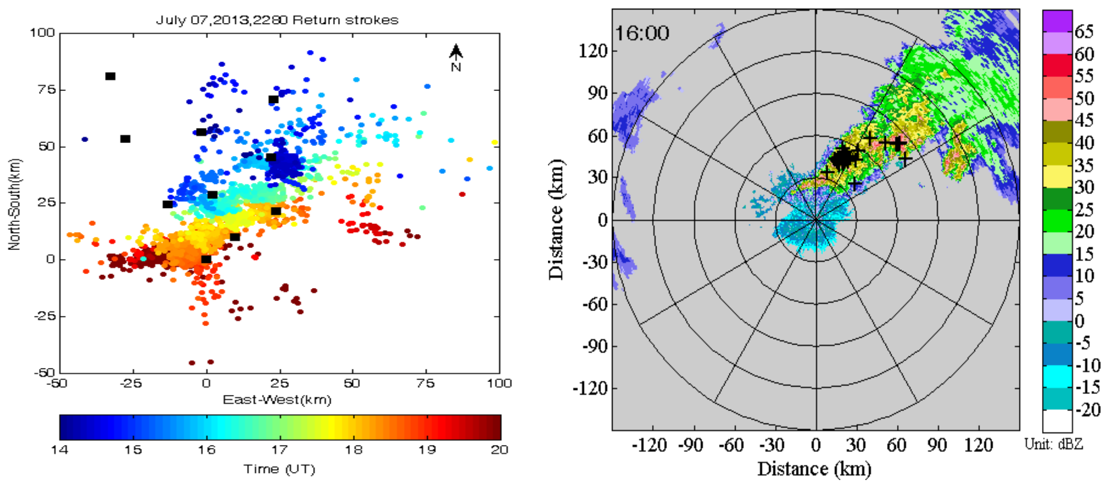

Figure 2. Lightning 2D locations of a thunderstorm on July 7, 2013. Left panel: all return strokes; right pannel: IC radiation pulses in 6 minutes after radar echo at 1600

Rocket-triggered lightning and high structure-initiated lightning observation will be conducted both in Shandong and Guangdong taking the advantage of the existing plateform in both sites (Qie et al., 2009; Zhang et al., 2014), with emphasizing lightning physical process and its effets on surface objectives (Lu et al., 2014). In particular, the field campaigns in Beijing and Shandong (with about 300 km apart) will be coordinated with a specific purpose to achieve the comprehensive observations of various types of thunderstorms including that might produce transient luminous events in the mesosphere. Figure 3 shows radar echoes of a squall line passing over Beijing and producing a sequence of sprites on July 31, 2013.

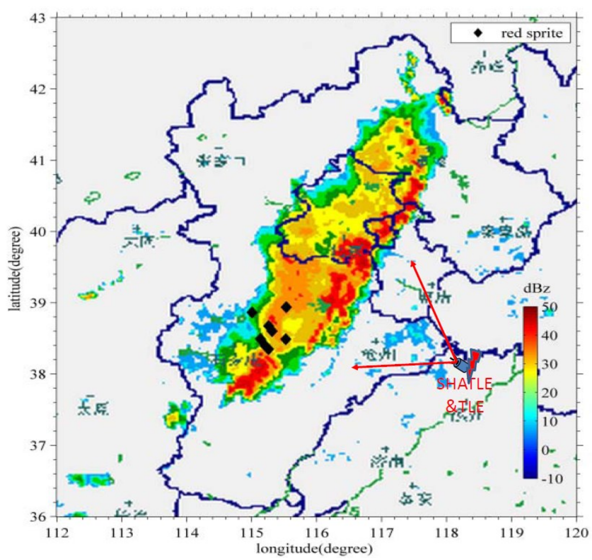

Figure 3. Radar echoes of a squall line passing over Beijing on July 31, 2013. Black quadrangles shows the 2D loctions of parent +CG of sprites.

SUMMARY

With an objective to prevent and mitigate meteorological hazards in China, the five-year Storm973 program meets the major national demands in the following three aspects: 1) improve the capability to monitor lightning and severe thunderstorms with high spatial and temporal resolution; 2) enhance the forecasting and early warning skills of severe lightning-hazard-producing thunderstorms; and 3) enhance the defense techniques and coping capacity against lightning.

During Storm973 project, the field campaigns will be carried out in Beijing, Shandong, and Guangdong continously. Lightning detection demonstrates outstanding advantages of high-precision, long-distance coverage, and free from the influence of terrain. With the development of state-of-the-art lightning detection technologies and the accumulation of high-quality lightning location data, lightning assimilation techniques and their application in numerical weather prediction models, aiming to improve the forecasting skill of precipitation, will become a major scientific effort in the future.

ACKNOWLEDGMENTS

This work is supported by National Key Basic Research Program (973 Program) of China (Grants Nos. 2014CB441401, 2014CB441405, 2014CB441406).

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