Diagnostic analysis of a heavy rainfall event over Beijing on July 21-22, 2012

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Introduction

Disastrous rainfall pounded Beijing on July 21-22, 2012. The Chinese capital was soaked by the heaviest rainfall in 61 years, causing widespread havoc and killing at least 79 people. Unfortunately, the weather forecast underestimated the rainfall and the issue of the rainstorm warning was delayed.

Objective

To investigate the causes of the extreme event from both the synoptic and mesoscale conditions:
- Diagnosis of synoptic circulation
- Analysis of physical parameters (thermodynamic and moisture)
- Mesoscale features and the effect of topography

Data

- Conventional observation data
- FY-2E Satellite image and Beijing Doppler radar data
- CMORPH merged automatic gauge data (0.1° x 0.1°, hourly)
- NCEP GFS 6-h 0.5° x 0.5° analysis data
- WRF-RUC 3km hourly output data

Synoptic overview

Surface observations with 3-h accumulated precipitation. Surface pressure continued to fall until 18 UTC, July 21, when a cold front passed Beijing. Thus, the heavy rainstorm was mainly caused by precipitation in the warm area of the front.

Forecast 500hPa mean sea level pressure and 1000hPa thickness from Beijing and China. The 500hPa weather map overlies with the 200hPa wind vector. Beijing is located in the front of the 500hPa trough and the right backside of the 200hPa jet (black arrow).

Physical diagnosis

Time series of area averaged relative vorticity (left) and vertical velocity (right) over 39° N-41° N, 115° E-117.5° E. Strong ascent occurs and extends high into the upper level.

Moisture condition

The 500hPa moisture flux at 12 UTC, July 21 indicate strong water vapor transport by both northwesterly flow and southeasterly flow.

Thermal condition

The sounding plot (left) at 116° E, 40° N using WRF-RUC output data at 21UTC, July 20 and the corresponding sounding parameters (right).

The sounding plot shows that before the rainfall starts, dry intrusion occurred in the middle level, accompanied by the low-level advection of warm and moist air. By 03 UTC, July 21, low-level moisture has increased, contributing to a rather low lifting condensation level (LCL) and increasing the precipitation water (PWAT) from 50mm to 70mm. The Showalter Index (SHOX) has increased slightly from -0.3 to 0.0, indicating weak instability. In contrast, the convective available potential energy (CAPE) has increased sharply from 1136 to 3121 J/kg. Accordingly, from the cross section plot at 06 UTC, July 21, low-level moisture increases into a layer almost 10km thick. High equivalent potential temperature extends to lower levels over Beijing area, which favors the occurrence of convective heavy rainfall.

Mesoscale features

Mesoscale convective complex (MCC)

The FY-2E infrared images at 09UTC (left) and 12UTC (middle), July 21. And the corresponding hourly precipitation (mm) from CMORPH merged automatic gauge data at 12UTC (right).

Mesoscale convergence and topographical effect

At 12 UTC, July 21, a northeast-southwest linear zone of enhanced radar reflectivity (Fig. A) spreads across Beijing. Also, from the corresponding surface map (Fig. B), the relatively dry and cold northwesterly flow encounters the warm and moist southwesterly flow at the convective convergence line. Meanwhile, the distribution of the 700hPa relative humidity (Fig. C) indicates a relatively dry area along with the convergence zone. The general tendency for convergence to form in lines is perhaps associated with these characteristics.

The effect of the topography

Low-level wind direction coupled with the northeast-southwest topography (Fig. D) increases precipitation on the windward side.

Summary

Mesosynoptic conditions met the necessary requirements for the extreme rainstorm event over Beijing on July 21-22, 2012. High rainfall rates with a relatively long duration lead to the extreme heavy precipitation:
- Favorable circulation background
- Strong ascending and adequate water vapor
- Mesoscale convergence and topographical enhancement
- Tropical precipitation features
- Slow-moving system

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Reference