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Diagnostic Analysis on a Heavy Rainfall Associated with the Northeast Cold Vortex and Atmospheric River

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Atmospheric rivers (ARs) are narrow and instantaneous corridors of water vapor extending from the tropical ocean to the mid-latitudes with roughly 300-500 km wide and thousands of kilometers in length (Zhu and Newell,1998; Ralph et al,2004). ARs are responsible for heavy precipitation in many regions and at present identifying and tracking ARs are mainly depend on Eulerian or Lagrangian methods (Bao et al, 2006; Gimeno et al,2012; Garaboa et al, 2015). Cutoff lows (COLs) are isolated cyclonic vortices in the middle and upper troposphere developed from a deep trough in the westerly (Palmén and Newton,1969; Gimeno et al,2007). COLs significantly contribute to extreme precipitation events when accompanying ARs, which means moisture within the lower to middle troposphere is sufficient (Hirota et al, 2016). The northeast cold vortex (NECV) that cause heavy natural hazards in the North and Northeast China is a cutoff low essentially.

Based on the FNL reanalysis and HYSPLIT model driven by NCEP GDAS data, this study examined a heavy rainfall associated with NECV and ARs over the northeast China occurred on July 25, 2016.The results indicated that the heavy rainfall occurred in a favorable synoptic pattern, NECV, the Okhotsk blocking high,the low at the east of Japan,upper- and low-level jet played important roles in the process.There were two ARs that both originated from the Western Pacific and coupled with deep wet layers during this event.However,one of the two ARs flowed northward to the northeast China through the East China sea and the Yellow Sea and the other flowed northeastward through the South China Sea with considerable moisture.The AR was a bridge of the interactions between the synoptic systems of low- and mid-latitudes.ARs provided favorable moisture condition for the heavy rainfall by entraining abundant moisture from tropical regions to mid-latitudes directly.The convergence of moist air from tropical origin and dry air from the circulation of NECV induced intense ascending motions in surrounding regions,which was the main dynamic uplift mechanism of the intense rainfall.Analysis of the trajectory tracking reveals that the most significant moisture sources of the heavy rainfall were the Western Pacific,the South China Sea,the Bay of Bengal and the Eurasia.Furthermore,the moisture within the lower and middle troposphere was mainly transported by the south atmospheric river and the southwest atmospheric river separately.