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P3.4 The Distribution of Precipitation over the Northeast Accompanying Landfalling and Transitioning Tropical Cyclones

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1. INTRODUCTION

Landfalling and transitioning tropical cyclones pose a significant heavy precipitation forecast challenge over the northeastern United States. The forecast challenge is heightened because the heavy rainfall distribution associated with these tropical cyclones can be modulated significantly when the poleward-moving storms interact with mobile midlatitude upper-level troughs and coastal fronts over regions of complex terrain. The purpose of this paper is to document the large spatial and temporal variability of heavy precipitation that accompanies landfalling and transitioning tropical cyclones, and to determine the physical basis for the observed rainfall distribution.

2. METHODOLOGY

A 38-storm dataset (Fig. 1) of landfalling and transitioning tropical cyclones that produced at least 10 cm (4 in) of precipitation during 1950–1998 has been constructed. The NCEP 24 h daily (1200–1200 UTC) Unified Precipitation Dataset (UPD) and the twice-daily (0000 and 1200 UTC) NCEP/NCAR reanalysis dataset (Kalnay et al. 1996; Kistler et al. 2001) were used to produce maps of storm rainfall and synoptic-scale circulation features for each of the 38 storms. The 38-storm dataset also served as the basis for the preparation of maps showing the rainfall distribution relative to the track of each tropical cyclone. The National Hurricane Center (NHC) best–track dataset at 6 h intervals (0000, 0600, 1200 and 1800 UTC) was used to define the 38 individual storm tracks.

The UPD is a gridded (0.25° x 0.25° resolution) analysis of the precipitation field. Although the UPD grids produce a reasonably accurate representation of the spatial distribution of precipitation, limitations imposed from smoothing processes lead to underestimation of maximum accumulations. A second precipitation analysis was conducted using National Climatic Data Center (NCDC) surface archives for the northeastern United States. Approximately 3500 surface stations were analyzed for each storm period (currently: 1950–1991) by Ron Horwood of NWS WFO Taunton, MA. Obvious erroneous data were removed to obtain the most accurate analyses possible.

A subset of eight storms (Fig. 1) where the precipitation distribution is possibly influenced by coastal frontogenesis was chosen from well–documented or famous cases. Detailed analyses were conducted using the four times daily (0000, 0600, 1200 and 1800 UTC) NCEP/NCAR reanalysis dataset (Kalnay et al. 1996; Kistler et al. 2001) and archived DIFAX surface charts in an attempt to elucidate both synoptic and mesoscale processes.

3. RESULTS

Hurricane Connie: 12-14 August 1955

Hurricane Connie made landfall in Cape Lookout, NC, on the morning of 12 August 1955. Subsequent to landfall, Connie slowly propagated northwestward. Precipitation fell along both sides of the storm track, with the heaviest amounts located in a narrow band extending from the Mid-Atlantic region northward to western New England (Fig. 2). Minimal interaction with a midlatitude trough embedded within the poleward displaced westerlies was indicated at 500 hPa (Fig. 3a). Diabatically induced outflow associated with the tropical convection produced western Atlantic

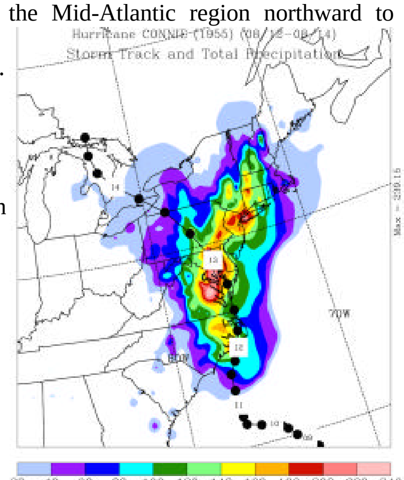

Fig. 2. Storm track relative to precipitation (mm) for Hurricane Connie: 12–14 August 1955.

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ridging at 200 hPa (Fig. 3b). In response to the upper-level ridging, propagation of an intensifying jet core to the north and east ceases for a period of time with a slight reconfiguration of the jet core to the south and west (Fig. 3b). The reconfiguration of the jet places the maximum area of upper-level divergence associated with the equatorward-entrance region of the jet near western New England (not shown). Examination of the lower levels (Fig. 3c) shows that the 925 hPa height gradient intensifies, leading to an increase in both the low-level southeasterly jet and the advection of high θ_e air into the Mid-Atlantic region. A surface analysis for 0630 UTC 13 August (Fig. 3d) shows Connie centered in the vicinity of extreme eastern Virginia. A sharp baroclinic zone draping southwest to northeast across central Maryland and southeastern Pennsylvania is colocated with an area of convergent wind flow, producing an area of coastal frontogenesis and enhanced precipitation. Figure 4 represents a more detailed precipitation analysis than in Fig. 2 with approximate positions of the coastal front analyzed every three hours. The movement of the coastal front can be seen to coincide with the axis of heaviest precipitation, while orographic modulation of precipitation is evident on the eastern slopes of the Pocono, Berkshire, Greene and Catskill Mountains.

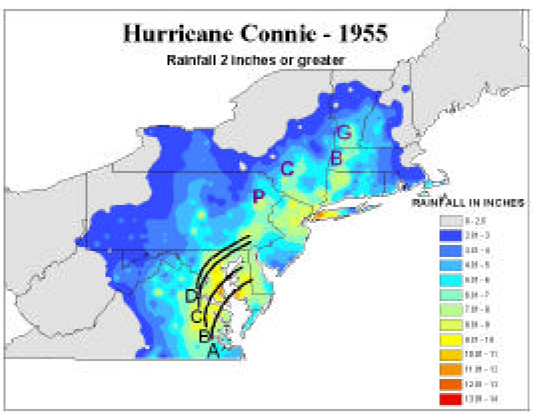

Fig. 4. Finer-resolution precipitation analysis with coastal front locations (black lines) plotted every 3 h beginning at 0030 UTC (A) and ending at 0930 UTC (D) on 13 August 1955. The Pocono, Catskill, Berkshire and Greene Mountains are denoted by a P, C, B and G, respectively.

4. SUMMARY

Hurricane Connie was investigated in an attempt to elucidate both the synoptic and mesoscale processes that were responsible for the heavy precipitation distribution. Results show that very little interaction of a midlatitude trough occurred with the tropical cyclone, such that the precipitation distribution relative to track failed to show a preference for a left of track shift. Diabatically induced outflow associated with the tropical convection resulted in western Atlantic ridging, and intensification and reconfiguration of the upper-level jet. Intensification of the low-level height gradient produced an increase in the low-level jet, and θ_e advection increased over the region as a whole. Orographic signatures were evident in the enhanced easterly flow over the Catskill, Pocono, Greene and Berkshire mountain ranges. The presence of the low-level jet and a tropical air mass provided conditions conducive for heavy precipitation forced by coastal frontogenesis in the Mid-Atlantic region, while the colocation of the low-level jet and upper-level jet–entrance region provided a situation favorable for large–scale forcing for ascent in the vicinity of western New England.

5. ACKNOWLEDGMENTS

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38 tropical cyclones producing > 10 cm (4 in) of rainfall in the northeast U.S. during the period 1950–1998

* Courtesy of David Vallee and Kermit Keeter

SEASON	STORM NAME	DATE(S)	MAX RAINFALL
1950	Hurricane Able	8/20	4 – 5 in.
1950	Hurricane Dog	9/11 – 9/12	4 – 5 in.
1952	Hurricane Able	8/31 – 9/1	—
1953	Hurricane Barbara	8/14 – 8/15	4 – 5 in.
1954	Hurricane Carol	8/31	5 in.
1954	Hurricane Edna	9/10 – 9/11	8 in.
1954	Hurricane Hazel	10/15	> 10 in.
1955	Hurricane Connie	8/12 – 8/14	4 – 8 in.
1955	Hurricane Diane	8/18 – 8/20	> 20 in.
1958	Hurricane Daisy	8/29	—
1960	Hurricane Brenda	7/29 – 7/30	—
1960	Hurricane Donna	9/12	8 in.
1961	Hurricane Esther	9/21 – 9/26	8 in.
1962	Hurricane Alma	8/28 – 8/30	6 in.
1962	Hurricane Daisy	10/6 – 10/8	14 in.
1963	Hurricane Ginny	10/29	—
1966	Hurricane Alma	6/10 – 6/11	6 in.
1969	Hurricane Gerda	9/9	4 in.
1971	Tropical Storm Doria	8/27 – 8/28	8 – 10 in.
1971	Tropical Storm Heidi	9/13 – 9/14	4 – 5 in.
1972	Tropical Storm Agnes	6/21 – 6/22	> 10 in.
1972	Tropical Storm Carrie	9/2 – 9/4	12 in.
1976	Hurricane Belle	8/9 – 8/10	5 in.
1979	Tropical Storm David	9/5 – 9/7	—
1979	Tropical Storm Frederic	9/13 – 9/14	—
1985	Hurricane Gloria	9/26 – 9/27	8 in.
1988	Tropical Storm Alberto	8/6 – 8/7	—
1988	Tropical Storm Chris	8/29 – 8/30	—
1989	Hurricane Hugo	9/22 – 9/23	—
1991	Hurricane Bob	8/18 – 8/19	8 – 9 in.
1991	Perfect Storm/Grace	10/29 – 11/01	5 – 6 in.
1995	Hurricane Opal	10/5 – 10/6	4 – 5 in.
1996	Hurricane Bertha	7/13 – 7/14	7 in.
1996	Hurricane Fran	9/7 – 9/9	—
1996	Hurricane Edouard	9/1 – 9/3	6 in.
1996	Oct. ’96 Floods/Lili	10/21 – 10/24	12 – 20 in.
1997	Tropical Storm Danny	7/26	—
1998	Oct. ’98 Floods	10/8 – 10/11	—

Fig. 1. 38-storm dataset of landfalling and transitioning tropical cyclones producing > 10 cm of precipitation in the Northeast: 1950–1998. A subset of eight storms are highlighted that are either well documented or famous, and that exhibited possible coastal frontogenesis.

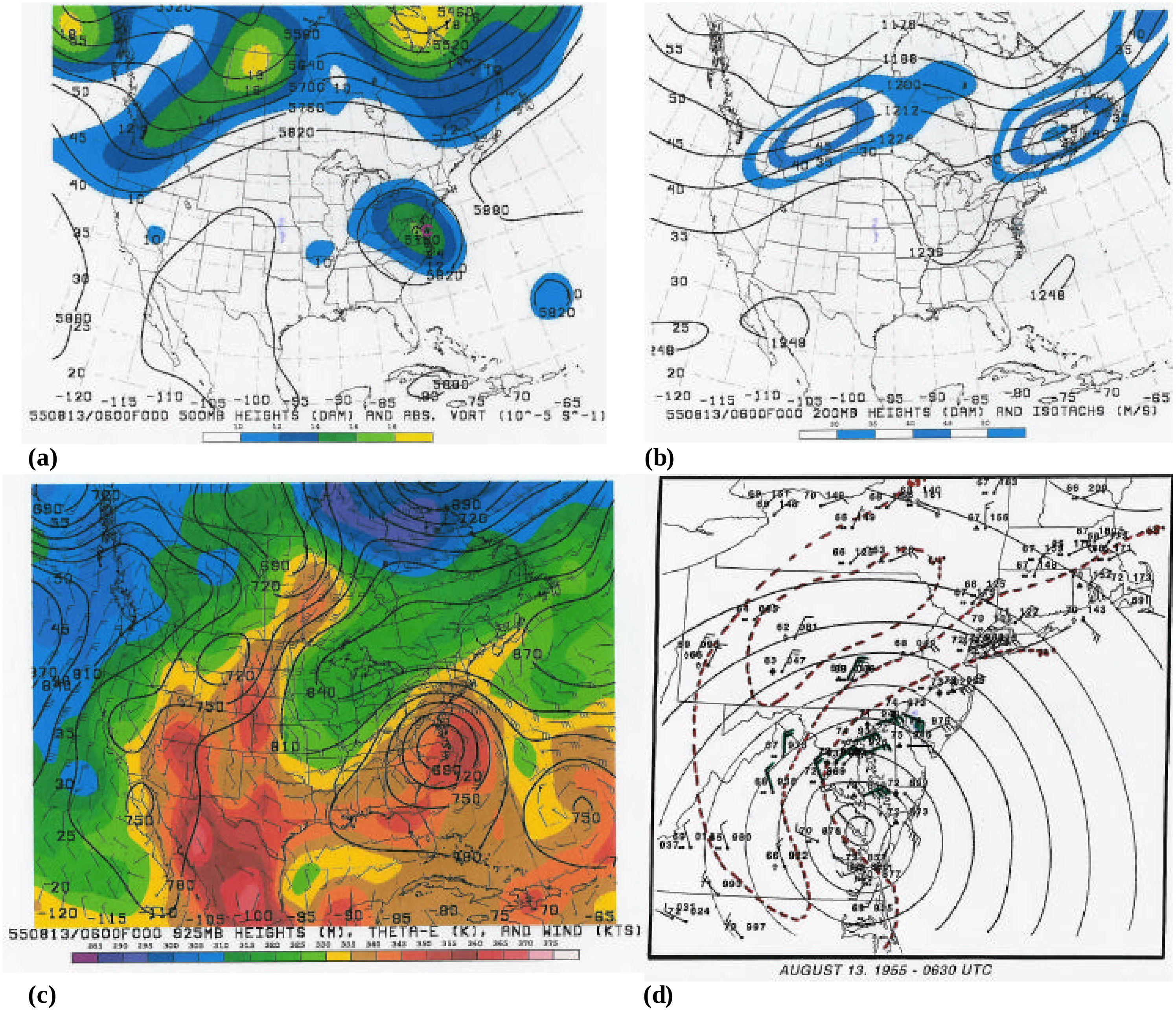

Fig. 3. Plots for 0600 UTC 13 August 1955: (a) 500 hPa heights and absolute vorticity; (b) 200 hPa heights and wind speed; (c) 925 hPa heights, equivalent potential temperature, and wind. (d) Surface analysis for 0630 UTC 13 August 1955 (adapted from Kocin 1995).