8.5A An Evaluation of Precipitation Distribution in Landfalling Tropical Cyclones

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1. Introduction

A current rule of thumb for forecasting precipitation in landfalling tropical cyclones is based on a simple algorithm where the maximum 24-h precipitation (in inches) is forecast by 100/v, where v (in m.p.h.) is the translational speed of the cyclone. This algorithm, however, provides little insight as to the precipitation distribution and intensity that can be expected in a landfalling tropical cyclone. Furthermore, several recent cases (Danny 1997, Dennis, Floyd, and Irene 1999) show that precipitation distribution and intensity can be drastically altered by interactions with mid-latitude troughs and jet streaks which often result in extratropical transitions (ET). Occasionally, these interactions produce catastrophic rainfalls as illustrated by Hurricane Floyd in September 1999. While several papers have been written concerning extratropical transitions (i.e. Palmen 1958, DiMego and Bosart 1982b, and Bosart and Lackman 1995), the focus of this paper will be to use a potential vorticity (PV) perspective in an attempt to understand the precipitation distribution in landfalling tropical systems.

2. Data and Methodology

Synoptic-scale data are taken from the National Centers for Environmental Prediction Reanalyses on a 2.5^0 x 2.5^0 latitude-longitude grid. The Unified Precipitation Data set (UPD) on a 0.25 x 0.25 latitude-longitude grid was used to evaluate the precipitation distribution associated with several landfalling tropical cyclones. A description of the UPD can be found at www.cdc.noaa.gov/cdc/data.unified.htm. This data set is used primarily to discern precipitation structure relative to the cyclone track. Storm relative composites are constructed based upon the precipitation distribution relative to the cyclone track. Storms used in the composites constructed below all exhibit a shift in the primary precipitation region to the NW quadrant of the storm. A second requirement for inclusion in the composites is a considerable meridional component in cyclone motion. Cyclone tracks are defined by the National Hurricane Center's best track data. Whenever best track data was not available, 925 hPa vorticity in the Reanalysis grids was used to track the cyclone.

3. Results and Discussion

Figure 1 shows the storm-relative composite upper- and lower-tropospheric PV structure of eight land-falling tropical cyclones. The cyclones used in computing the composite include Hazel (1954), Carla (1961), Agnes (1972), Frederic (1979), Chris (1988), Andrew (1992), Earl (1998), and Floyd (1999). All cyclones are positioned relative to Floyd (1999), with the initial position occurring 12 h prior to the shift in precipitation to the NW quadrant of the storm. Storm positions are then plotted every 12 h ignoring differences in the rate of propagation.

A single primary upper-level PV anomaly is located approximately 1500 km northwest of the tropical cyclone (Fig. 1a). Upper-tropospheric flow across the tropical cyclone is still relatively weak at this point. Twelve hours later, the scale of the lower-level PV anomaly increases as it elongates to the NW, while the upper-level PV anomaly propagates to the southeast (Fig. 1b) The scale of the lower-level PV anomaly continues to increase over the next twelve hours, concomitant with partial superposition of the PV anomalies (Fig. 1c). By this time, some anticyclonic curvature along the leading edge of the upper PV anomaly has become apparent due to latent heating associated with the primary precipitation region. By 24 h after the precipitation has shifted, the upper-level PV anomaly exhibits considerable anticyclonic curvature, as the tilt of the trough becomes more neutral (Fig. 1d). Strong upper-level flow across the lower-level PV anomaly at this point suggests that the remnant tropical cyclone circulation is now clearly embedded in a strong baroclinic zone. This last time period also tends to coincide with the classification of the system as an extratropical cyclone by NHC.

Another common feature of this type of extratropical transition is the coupling of the cyclone to the jet-entrance region of a jet streak embedded in the southwesterly flow ahead of the upper-level trough (Fig. 2). Initially, the composite jet streak has a magnitude of approximately 40 m s^{-1} (Fig. 2a). In the equatorward-entrance region (EER) of this jet streak is an area of strong divergence associated with both the outflow of the tropical cyclone as well as the EER itself. As this divergence maximum propagates northward, the aerial extent of the jet streak increases as the flow becomes more southerly along the coast in response to the anticyclonic outflow from the tropical cyclone (Fig. 2b). Twelve hours after the precipitation shift has occurred, the jet has reached its maximum magnitude of over 50 m s^{-1}, as the wavelength between the trough/ridge couplet decreases (Fig.2c). Eventually, the magnitude of the divergence in the EER and the magnitude of the jet streak decreases as the storm undergoes ET (Fig. 2d).

It is hoped that the strength of these composites based primarily on precipitation distribution will help provide a forecast paradigm for precipitation distribution in landfalling tropical cyclones. Future results will also present composite structures of storms with the heaviest precipitation both along and to the right of the cyclone track.

4.Acknowledgements

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5. REFERENCES

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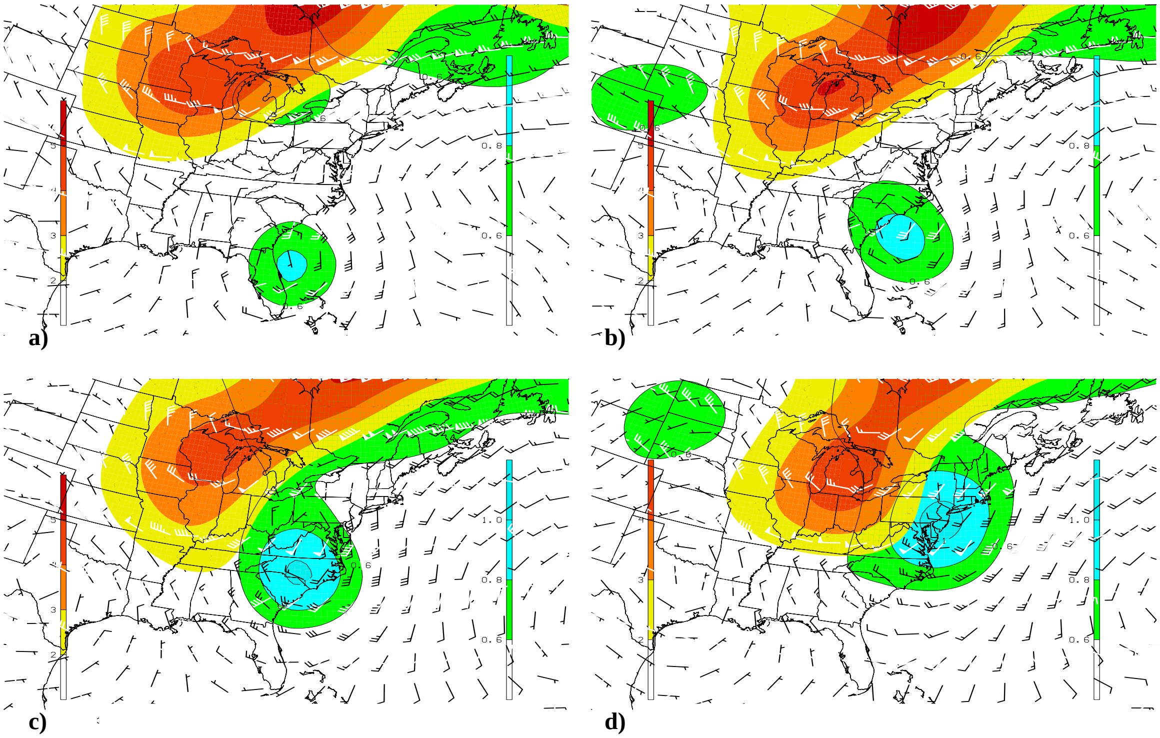

Figure1. 850-700 hPa PV (shaded in cool colors every 0.2 PVU starting at 0.8 PVU) and wind (dark barbs-knots) and 300-200 hPa PV (shaded in warm colors every 2 PVU starting at 2 PVU) and wind (white barbs-knots) for a) -12 h.from precipitation shift to the NW quadrant, b) -00 h, c) +12 h, and d)+24h.

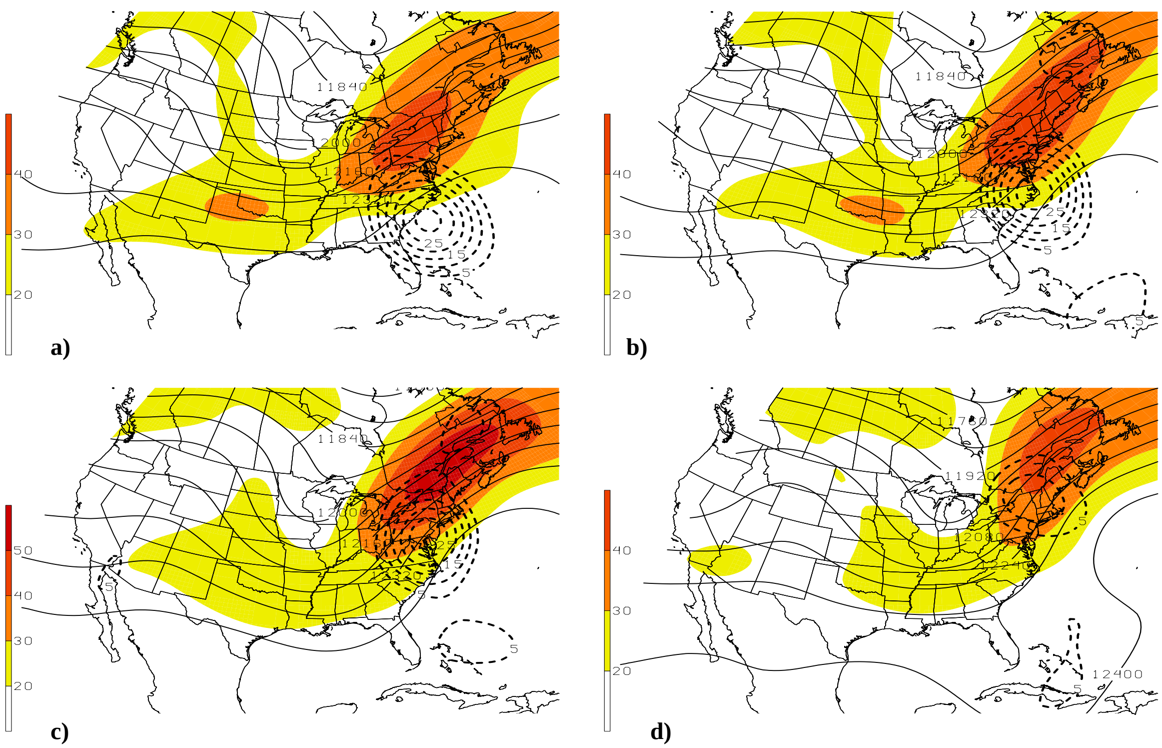

Figure 2. 200 hPa heights (solid black lines), isotachs (shaded every 10 m s^{-1} knots starting at 20 m s^{-1}) and divergence (dashed black lines contoured every 5 x 10^{-6} s^{-1}) for a) -12h from precipitation shift to the NW quadrant, b) -00 h, c) +12 h, and d) +24 h.