P2.23 IMPROVING ANTICIPATION OF THE INFLUENCE OF UPSTREAM CONVECTION ON DOWNSTREAM PRECIPITATION

Christian M. Cassell[+], Gary M. Lackmann, and Kelly M. Mahoney
North Carolina State University, Raleigh, North Carolina

Gail Hartfield, Rodney Gonski, and Jonathan Blaes
NOAA/National Weather Service, Raleigh, North Carolina

1. INTRODUCTION

Operational forecasting near the US East Coast can be complicated when conditions appear favorable for cyclogenesis to occur in the Southern US or along the Southeast Coast since many large population centers are located in this region, which is near favored storm tracks. Despite tremendous advances in numerical weather prediction (NWP) and its ability to forewarn of significant weather impacts on the East Coast, in situations where organized convection associated with a midlatitude cyclone develops upstream (a situation dubbed "upstream convection", or UC), significant model errors have been observed. In UC situations, previous studies have documented that model quantitative precipitation forecasts (QPF) can be highly unreliable (e.g., Mahoney and Lackmann 2007).

Specifically, Mahoney and Lackmann (2007) suggested that large model QPF errors may be a result of poor prediction of the absolute UC speed in relation to the system-relative (cold front) speed. They presented contrasting cases in which model QPF error was related to the character of the UC: one case exhibited fast convection (FC) and the other slow convection (SC). Performing a representative case study of each scenario, it was found that the FC case resulted in a large positive model QPF bias, while the SC case resulted in a smaller, but negative, QPF bias. Additionally, the FC case was characterized by an MCS that propagated eastward much faster than the cold front, subsequently decreasing moisture transport into the downstream region (e.g., from the Carolinas to the Mid-Atlantic). The SC case was characterized by UC that moved slowly relative to the cold front, and featured the development of a southerly low-level jet (LLJ) that enhanced moisture transport into the downstream region.

Given large uncertainties that exist in model QPF when UC is present in the South, improved anticipation of the influence of UC on downstream precipitation may benefit forecasters in the Southeast and Mid-Atlantic. As noted by Mahoney and Lackmann (2007), a larger case sample is needed in order to develop a climatology that distinguishes FC and SC, as well as to relate synoptic signals to observed and predicted precipitation totals in the eastern US. The current study presents results of an extended climatology of UC events, and details the large-scale synoptic environment in which the SC and FC cases develop. The climatology uses composites of the twenty driest and twenty wettest UC cases on an area centered within a 200 km radius of Raleigh, NC.

2. METHODOLOGY

An extensive database of cool season (defined as occurring between 1 Oct and 30 Apr) UC events was collected from the period from 1 Oct 2001 – 31 Jan 2007. UC was defined as a contiguous region of radar echoes in excess of 50 dBZ persisting within an area bounded by the Gulf of Mexico to the south, the Mississippi River to the west, the southern Tennessee and North Carolina borders to the north, and the Georgia border with South Carolina and the Atlantic Ocean to the east (Fig. 1).

[+] *Corresponding author address: Mr. Christian Cassell*, North Carolina State University, Dept. of Marine, Earth and Atmospheric Sciences, Raleigh, NC 27695. E-mail: cmcasse2@ncsu.edu

Figure 1. *Schematic map of the defined UC region and precipitation study area.*

For each individual case, calculations were performed to determine the absolute speed of the UC and system-relative (cold front) speed in 12-hour intervals, using archived composite radar data from the National Center for Atmospheric Research (NCAR) and North American Regional Reanalysis (NARR, Mesinger et al. 2006) data from the Penn State University NARR display (http://www.meteo.psu.edu/~gadomski/NARR/index.html), respectively. A general qualitative analysis of the frontal (katafront vs. anafront) and 500-mb trough (digging/lifting) characteristics, as well as UC description (e.g., linear, scattered, etc.), were also noted for each case. Area-averaged NARR precipitation amounts were calculated by a computer program for each Julian calendar day, centered on a circular region within a 200 km radius of Raleigh, NC (denoted by the circular area in Fig. 1). It is noted that there exists some inherent error from using NARR precipitation data; however, a previous study (Mahoney and Lackmann, 2007) comparing manual precipitation analyses with the NARR data for the same area confirmed that the NARR precipitation analyses were sufficiently accurate for the purposes of this study.

Composites for the twenty driest and twenty wettest cases using NARR data were then constructed by first determining a zero-hour time in which the UC is generally in the same geographic area for each case. This was defined as the nearest three-hour time in which UC existed along the Mississippi/Alabama border; this time was deemed critical for UC influence on downstream QPF. The twenty driest and twenty wettest UC cases were determined within a 48-hour block of time in which the zero-hour time was identified during day 1. The area-averaged rainfall in the region was ~4 mm (~0.14") for the dry cases and ~18 mm (~0.70") for the wettest cases. While some inherent error is associated with this method, a case-by-case examination revealed only relatively minor changes in area-averaged NARR precipitation amounts by extending or reducing the 48-hour time block, and there were no exclusions or additions of individual cases by using this method compared to the *total storm* time-averaged NARR precipitation amounts (not shown).

The composites of dry and wet UC cases were constructed from NARR data spanning a period of 96 hours, with the first 48-hour period approaching the zero-hour time and the subsequent 48-hour period following the zero-hour time. Hereafter, times relative to the center time of the composite are denoted T-HH or T+HH, where HH is the offset in hours from the center time. The synoptic-scale evolution of the dry and wet composites is determined from the time of cyclogenesis in the lee of the Rocky Mountains until the parent system has departed the East Coast. Comparisons of the two composites are detailed in Section 3.

3. RESULTS

3.1. Dry composite

A composite of the 20 driest UC cases (for central North Carolina) was constructed to analyze the synoptic-scale pattern for these low-precipitation UC cases. Typically in these events, convection that existed in the upstream region dissipated or weakened before entering the Carolinas.

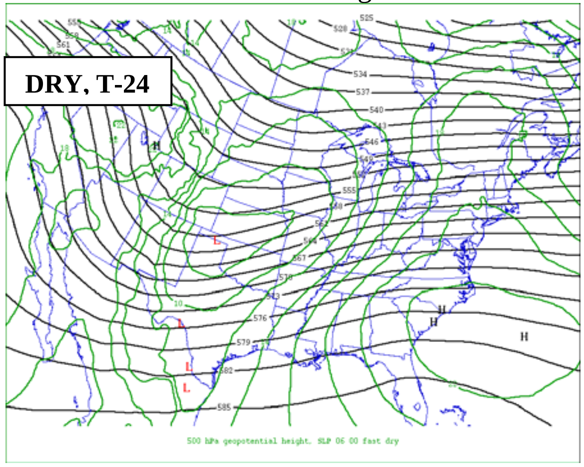

Figure 2. *Dry composite 1000-mb height (green) and 500-mb height (black) for the T-24 hour composite time.*

The synoptic-scale pattern prior to T-24 h is characterized by cyclogenesis on the Front Range of the Rockies in the vicinity of Montana or Wyoming (not shown). Warm advection (WA) and differential positive vorticity (DPVA) advection east of the upper trough provide forcing for ascent through much of the central US and a general increase in precipitation as the system begins to draw moisture from the Gulf of Mexico.

By T-24, the 500-mb trough has deepened, with a surface low strengthening over the Central Plains and a cold front extending southward through Texas (Fig. 2). The lower-tropospheric flow shows strong onshore flow along the Gulf Coast, with strong geostrophic veering evident there. By T-12, and more so at T0, the 500-mb trough begins to show a transition towards lifting as the jet streak has rounded the base of the trough. Also, there is a weakening of WA over the southern US as the 1000-mb and 500-mb heights become nearly parallel, thus limiting the forcing for ascent over the Carolinas (Fig. 3).

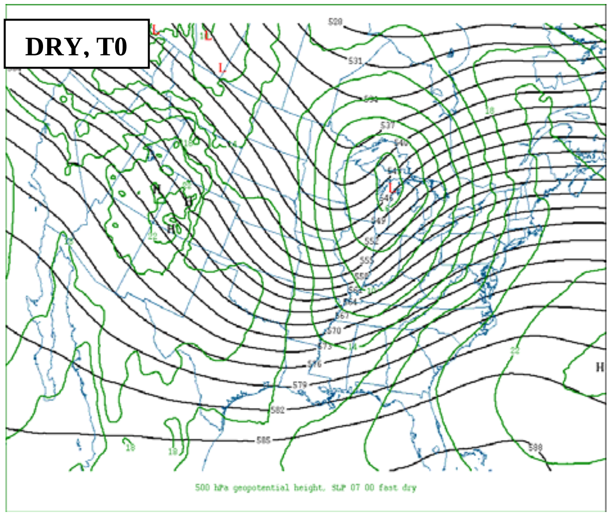

Figure 3. As in Fig. 2, but for T0 hours.

The geostrophic flow at the 1000-mb level is generally parallel to the southeast US coast, limiting onshore moisture transport (Fig. 3).

3.2. Wet composite

A composite of the 20 wettest UC cases (for central North Carolina) was performed to analyze the synoptic-scale evolution in which convection existed in the upstream region, and precipitation strengthened in intensity and/or coverage before or while entering the central Carolinas. The synoptic pattern at T-48 is not unlike that of the dry composite case, with cyclogenesis to the lee of the Rocky Mountains, ahead of an upper-level trough.

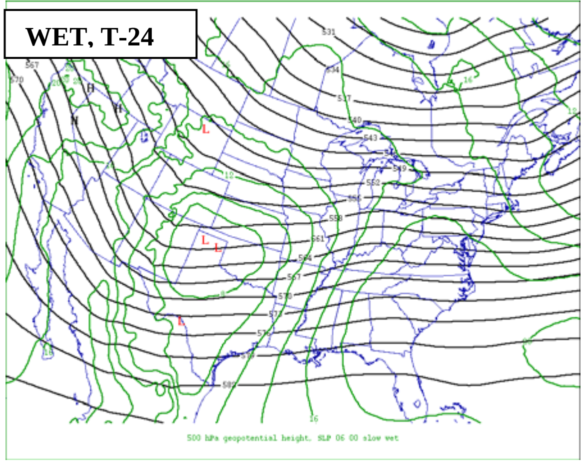

Figure 4. As in Fig. 2, but for wet composite at T-24 hours

At T-24 hours, the surface low is located in northern Texas, with strong WA and strengthening DPVA throughout the Mississippi Valley (Fig. 4). Southerly geostrophic flow along the Gulf Coast suggests ample northward moisture transport into the developing system (Fig. 4).

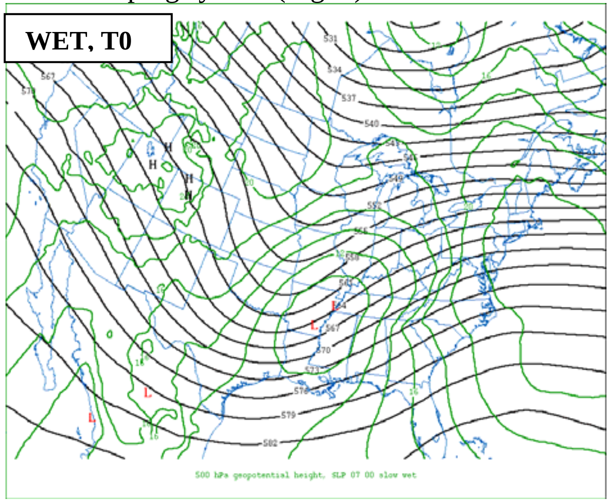

Figure 5. *Same as in Figure 1, except for the wet composite at T0 hours.*

At T0, strong forcing for ascent is evident in pronounced geostrophic veering from the Florida Panhandle northward into the eastern Great Lakes region (Fig. 5). The near-perpendicular veering orientation of 1000- and 500-mb height contours over the Carolinas is consistent with strong forcing for ascent there. Onshore flow, implied by the sea level isobars, suggests moisture influx into the interior Southeast from ***both*** the eastern Gulf of Mexico and Atlantic Ocean. This is in marked contrast to the dry composite, where little onshore flow from the Atlantic is evident. The 500-mb trough begins to take on lifting characteristics as a jet streak begins to lift out of the base of the trough and downstream 500-mb ridging continues to build. At T+12 hours, strong forcing for ascent continues in conjunction with an onshore flow to support conditions favorable for heavy rainfall over the Eastern Seaboard.

At T+24 hours, the surface low is moving up the spine of the Appalachians, with a strengthening secondary low along the coastal plain (not shown).

4. CONCLUSION AND FUTURE WORK

Composites of the 20 driest and 20 wettest (for central North Carolina) UC cases have been generated, and reveal marked differences in the synoptic-scale evolution over the eastern and southeastern US. The dry composite, like the wet composite, is characterized by cyclogenesis near the Front Range in the lee of the Rockies, followed by continued cyclogenesis in the central Plains. This is followed by a more northerly track of the surface low as the system moves northeastward through the Great Lakes region and into eastern Canada, leaving the greatest synoptic-scale forcing for ascent well north of the Mid-Atlantic region.

The wet composite shows cyclogenesis also beginning on the Front Range of the Rockies. However, as the surface low moves eastward it follows a more southerly track as a strong digging signature in the upstream region of the 500-mb trough appears, as indicated by a tightening of the height contours approaching the base of the trough. Strong synoptic-scale forcing for ascent, and lower-tropospheric flow from moisture source regions in the Gulf of Mexico and western Atlantic Ocean support increased precipitation over the Carolinas and Mid-Atlantic region. Continued strong WA and DPVA allow for substantial lift and moisture influx, enhancing downstream precipitation. Slower cold front and 500-mb trough movement allow for prolonged periods of enhanced areas of precipitation in certain favored areas in the Mid-Atlantic region.

Upon examination of the individual cases that comprised the wet composite, it was found that the FC and SC case studies from Mahoney and Lackmann (2007) did not exclusively fall in the wet or dry case sample. In other words, the track of the parent synoptic system, along with the strength of forcing over the Carolinas, appears to be a more dominant determinant of precipitation amount in this region than the speed of the UC alone. However, this study has not addressed the issue of model QPF error, and it remains to be seen whether the larger sample analyzed here will support the idea that a positive model QPF bias is more likely in FC than in SC events. The model QPF errors are likely the result of timing errors in the NAM model forecasts due to poor representation of the UC propagation speeds. Future work will examine cases characterized by large positive or negative model QPF biases.

5. ACKNOWLEDGEMENTS

This project is funded by a Subaward with UCAR under the sponsorship of NOAA/DOC as part of the NOAA Collaborative Program for Operational Meteorology, Education, and Training (COMET) Outreach Program, award number 061923 / S06-58392. We wish to acknowledge the NWS Raleigh office, and others at the NWS Forecast offices in the Southeast and Mid-Atlantic regions for helpful insights and discussions concerning the UC problem.

6. REFERENCES

Mahoney, K. M., and G. M. Lackmann, 2007: The Effect of Upstream Convection on Downstream Precipitation. *Wea. Forecasting*, **22**, 255–277.

Mesinger, F. and co-authors, 2006: North American Regional Reanalysis. *Bull. Amer. Meteor. Soc.* **87**, 343–360.