5.5 LARGE-SCALE ENVIRONMENT AND DIURNAL CYCLE OF U.S. WARM SEASON PRECIPITATION EPISODES

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1 INTRODUCTION

In the Central U.S., a large portion of the warm season precipitation falls from organized, mesoscale regions of deep convection. When warm season rainfall observations are viewed in time-longitude space over the U.S., one sees coherent, eastward propagating precipitation entities that span the entire eastern two thirds of the continent and last longer than 24 h. The precipitation is often associated with deep convection that regularly initiates in the early evening hours near 105 W and tracks eastward toward the Mississippi River Valley during the nocturnal hours. The longevity of these precipitation episodes exceeds that of an individual convective system and is often attributable to a succession of mesoscale convective systems (MCSs). Understanding the lifecycle of these precipitation episodes may lead to better 6-24 h forecasts of warm season precipitation, especially downstream from ongoing events. In this study, we take a closer look at the large-scale environment of these precipitation episodes for a 7-day period in late July 1998. With composites of Rapid Update Cycle-2 (RUC-2) analyses at different phases of the diurnal cycle, we will characterize the large-scale environment of the precipitation episodes.

2 PRECIPITATION

In late July 1998, the central U.S. was host to a succession of MCSs that propagated around the periphery of a midtropospheric ridge centered over Texas. For several days, precipitation was relegated to a narrow corridor north of an east-west oriented stationary front, with very little variation in diurnal timing. Composites of hourly precipitation reveal a persistent pattern of convective initiation near the lee of the Rocky Mountains in the evening, rapid eastward propagation overnight, and subsequent dissipation in the lower Mississippi River Valley (Fig. 1).

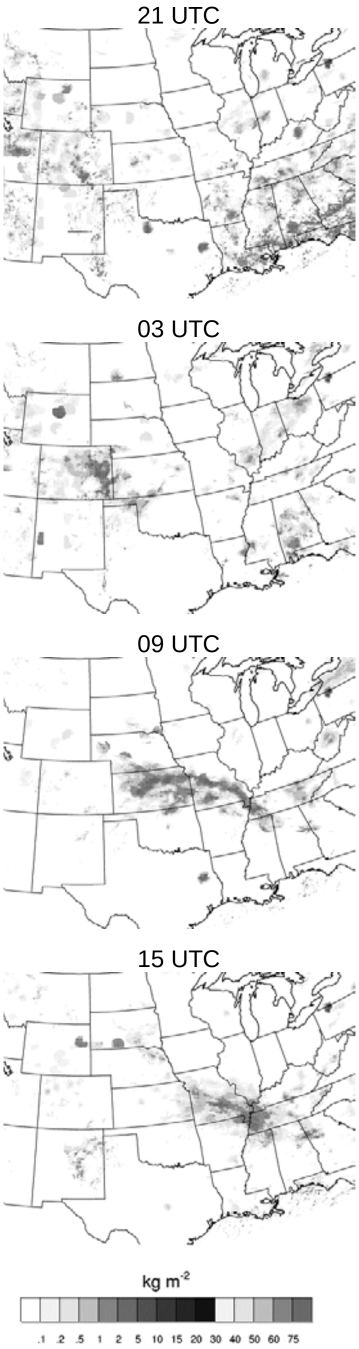

Fig. 1. Average 1-h accumulated rainfall composites centered on 21, 3, 9, and 15 UTC for the time period between 22 July, 20 UTC and 29 July, 18 UTC. Rainfall data from GCIP/EOP NCEP/CPC 4 km multi-sensor analyses at http://www.joss.ucar.edu/cgi-bin/codiac/dss?21.049.

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3 UPPER-LEVEL COMPOSITES

The average height of the 300 mb pressure surface from 23-30 July, 1998 (Fig. 2) was created by compositing all available 0, 3, 6, . . . , and 21 UTC RUC-2 analyses for that time period. From north of a ridge in southwest Canada, the jet stream dips southward into the northeast U.S. while a cut-off low spins off the western U.S. coast. The standard deviation of temperature and height was small for the broad region south of the jet stream. The central U.S. precipitation episodes appeared largely independent of short-waves or transient disturbances in the westerlies, as their storm track was somewhat displaced from the jet stream and its associated synoptic-scale lifting.

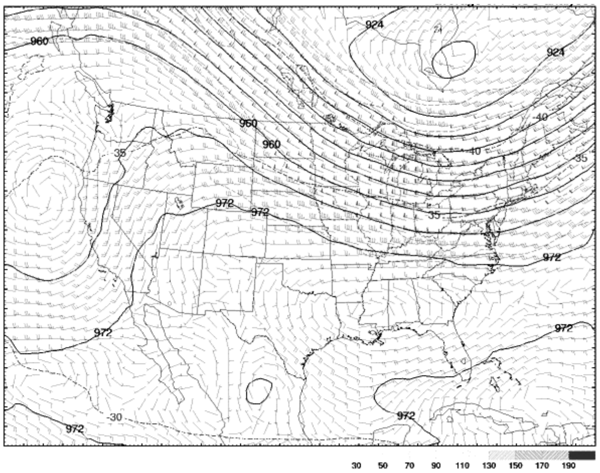


Fig. 2. Average 300 mb height (dm; solid contours), wind (kts; barbs and hatched contours), and temperature (C; dashed contours) using RUC-2 analyses from 23 to 29 1998.

Moving lower in the atmosphere, the 500 mb RUC-2 composite (Fig. 3) shows high relative humidity over the 4-corners region of the southwest U.S. associated with the N. American monsoon. The subtropical moisture was drawn northward by a mid-tropospheric ridge centered over Texas. The ridge axis extends from Texas northwestward into the intermountain West.

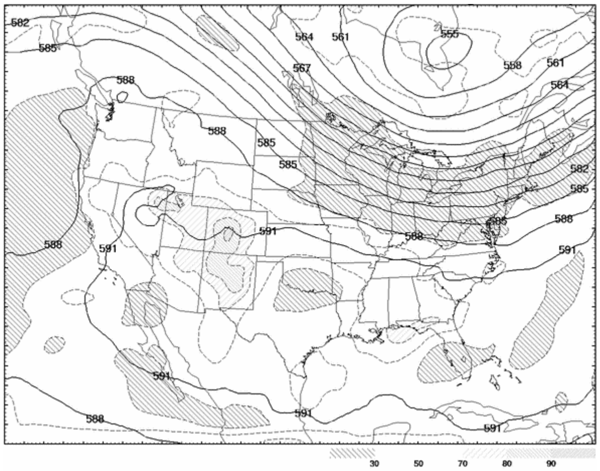


Fig. 3. Average 500 mb height (dm) and relative humidity (%; hatched contours) from RUC-2 analyses, 23 to 29 July 1998.

At the surface, an east-west oriented front draped across the Southern Plains separated contrasting air masses. The boundary remained stationary throughout the period, as the upper-level winds were primarily parallel to the front. The nocturnal MCSs helped maintain the temperature contrast by opposing the warm, humid southerly flow with cool thunderstorm downdrafts. Fig. 4 shows the wind shift and dramatic temperature contrast on either side of the surface boundary during the afternoon of 25 July 1998.

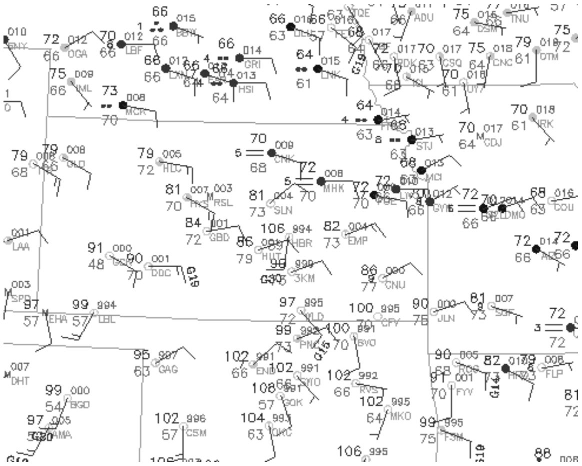
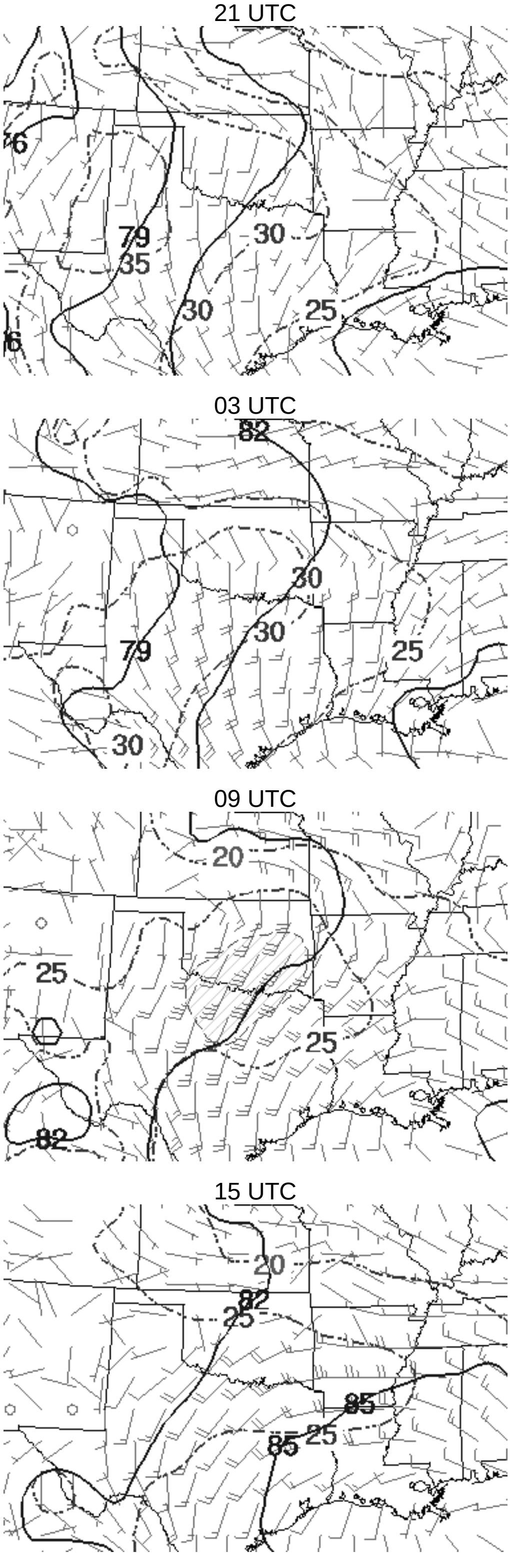


Fig. 4. Surface analysis from 23 UTC, 25 July 1998 depicting temperature (F) and wind (kts) contrast across stationary front in southern Kansas.

4 LOW-LEVEL JET

The multi-day RUC-2 composites exhibited a strong diurnal signal in low-level wind over the Southern Plains. Average low-level winds in OK were light and southerly in the mid- to late afternoon, but by nightfall they rapidly evolved into a classic low-level jet (Blackadar, 1957; Bonner, 1968) after the surface boundary layer stabilized. Consistent with the inertial oscillation of the ageostrophic wind, the jet veered to primarily westerly by morning.


21 UTC

03 UTC

09 UTC

15 UTC

Fig. 5. Average 925 mb height (dm; solid contours), wind (kts; barbs and hatched contours), and temperature (C; dashed contours) for various times using RUC-2 analyses from 23 to 29 July 1998.

One can see the interplay between the low-level jet and the frontal zone in the vertical cross-sections shown below (Fig. 6). These north-south cross-sections are perpendicular to the front and show potential temperature along with meridional wind and pressure vertical velocity. As unsaturated air south of the front was advected northward at 900 mb, it was lifted sharply along the isentropic surface until it reached its level of free convection near 40° N. From there, it ascended moist-adiabatically in deep convective updrafts. The stationary front served as an efficient lifting mechanism where it intersected the strong low-level jet.

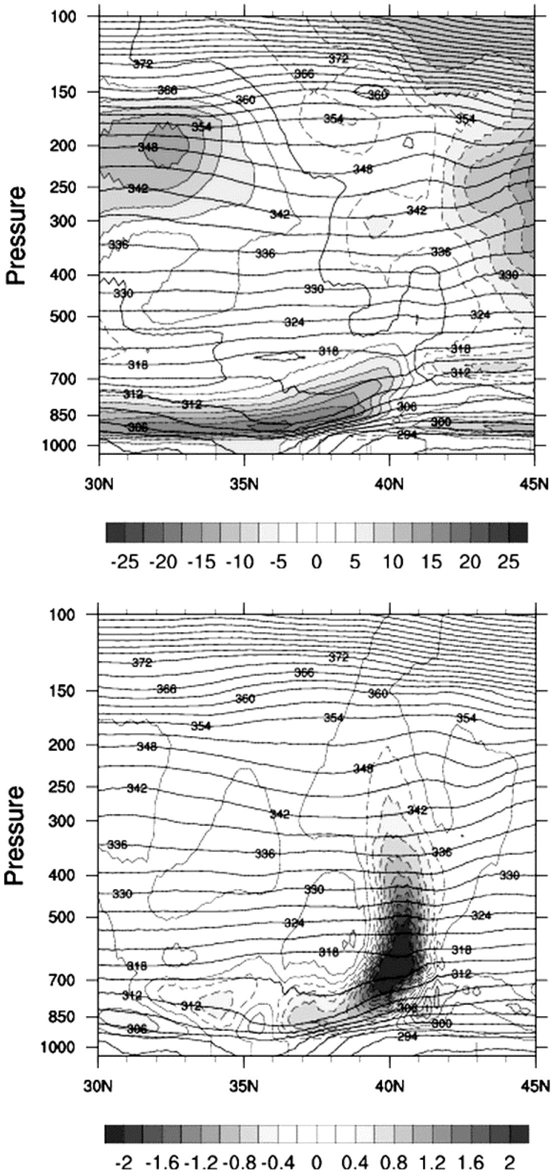


Fig. 6. Vertical cross-sections through 98° W of potential temperature (contours every 3 K), meridional wind (m/s; shaded contours; upper panel) and pressure vertical velocity (Pa/s; shaded contours; lower panel) from the 26 July 1998, 9 UTC RUC-2 analysis.

5 CONCLUSIONS

The upper-level flow pattern was relatively static from 23 to 30 July 1998, and the multi-day composite in Figure 2 is quite representative of any particular time within that period. The variation of temperature and pressure-level height was very small south of the average polar jet stream position. The primary track of the precipitation episodes was within a deep layer of confluent winds from 700 mb to 300 mb that stretched across the northern edge of the midtropospheric ridge centered over Texas.

Composites of hourly precipitation exhibited strong longitudinal dependence on the diurnal cycle. However, despite the strong diurnal signal in observed rainfall, the signal was much less evident in the composites of upper-level wind, temperature and height derived from the RUC-2 analyses. There are several likely reasons. Deep convection is notoriously difficult to represent in numerical models, especially when a large fraction of the convection is unresolved. The cumulus parameterization may not accurately convey the influence of deep convection to its large-scale environment. In addition, the daily suite of RUC-2 analyses is nudged toward reality by rawinsonde data only twice a day. In between, the model relies primarily on its own limited physics packages and parameterizations. Furthermore, the wind and height field associated with the precipitation episodes may be too local to affect the composites. A moderate displacement of a couple hundred km in the track of the precipitation episode from one day to the next could easily smear the signal in the composite results. Recreating composites centered on the precipitation centroid could help alleviate the latter problem.

The precipitation episodes from 23 to 29 July 1998 were likely supported by the low-level jet and its interaction with the east-west oriented frontal zone. The stationary front across the southern Plains served as a "stepping-stone" for air parcels, lifting them to their level of free convection as they streamed northward within the low-level jet. As the low-level jet veered from southerly to southwesterly, the main region of precipitation shifted eastward following the nose of the jet. As the cross-frontal component of the low-level jet decreased towards daybreak, the intensity of the precipitation episodes likewise diminished.

6 REFERENCES

Blackadar A.K., 1957: Boundary layer wind maximum and their significance for the growth of nocturnal inversions. *Bull. Amer. Meteor. Soc.*, **38**, 283-290.

Bonner, W. D., 1968: Climatology of the low-level jet. *Mon. Wea. Rev.*, **96**, 833-850.