P1.2 **AN OVERVIEW OF THE SUMMER 2007 EXCESSIVE RAIN EVENT IN THE SOUTHERN PLAINS**

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1. INTRODUCTION

The year 2007 was historic for the state of Oklahoma in terms of annual precipitation. After Oklahoma experienced drought during 2005 and 2006, record-setting precipitation fell across much of the state. On 17 October 2007, Oklahoma City officially surpassed its annual rainfall record; a new record of 56.95 inches, 21.97 inches above average, fell in 2007. This year was marked by a number of atypical weather events that contributed to the extreme rainfall experienced in much of the state.

During the extended rainfall event (hereafter, ERE) of 19 June to 7 July 2007 that affected Oklahoma, Kansas, and Texas, precipitation recorded by the Oklahoma Mesonet was up to 800% above normal (Fig. 1). As a result, major flooding affected a large portion of the state. Most notably, Lake Texoma overflowed its spillway for only the third time in history on 10 July 2007.

Mesoscale vortices played a major role in the ERE. The initial mesoscale convective vortex (MCV; e.g., Johnston 1981; Menard and Fritsch 1989) developed from squall-line convection on 19 June 2007. MCVs typically have warm-core low-pressure characteristics (e.g., Johnson 1986; Zhang and Fritsch 1987, 1988; Bartels et al. 1997), and last at most a couple of days (Zhang and Fritsch 1988; Menard and Fritsch 1989; Johnson and Bartels 1992). However, during the ERE, an MCV-generated circulation persisted for ten consecutive days. We hypothesize that the initial MCV most likely dissipated around 22 June 2007; a new MCV, which became identifiable on 25 June, initiated in the vicinity of the original MCV. This new MCV then transitioned into a long-lived warm-core low-pressure system that remained in Kansas, Oklahoma, and Texas for approximately ten days.

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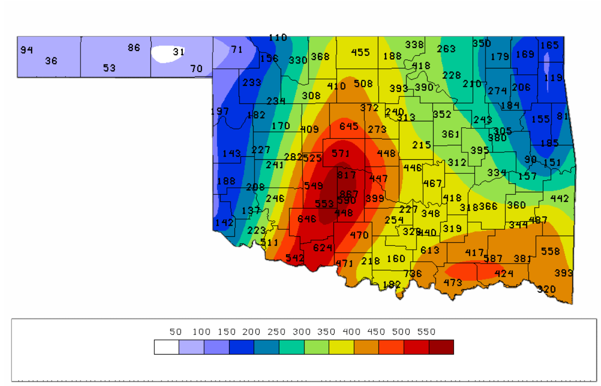

Fig. 1. Percent of normal rainfall for the period 19 June to 7 July 2007 recorded by the Oklahoma Mesonet.

This paper will present observational data from the ERE to explain how and why this event occurred. Section two will discuss the setup and initiation of the ERE. Section three will describe the evolution of the ERE. Section four will discuss the possible causes for the behavior observed during the ERE on multiple meteorological scales. Finally, section five will summarize the findings.

2. ERE SET-UP AND INITIATION

2.1 *Pre-event environment*

During the period 1 May to 18 June 2007, much of Oklahoma and Texas experienced above normal rainfall. In Texas, many locations had nearly twice their average rainfall, including Dallas (KDFW), Denton (KDTO), Abilene (KABI), and Lubbock (KLBB). Del Rio (KDRT) and Waco (KACT) received nearly three times their average rainfall for the 49-day period. Central Oklahoma also experienced above average precipitation, with many Oklahoma Mesonet (Brock et al. 1995) sites reporting 100 to 240% of their average accumulations (Table 1).

The unusually moist conditions in the weeks preceding the ERE played an important role in this event. The Atmospheric Radiation Measurement (ARM) program (Stokes and Schwartz 1994) measures soil moisture and surface heat flux over portions of Kansas and Oklahoma using the energy balance Bowen ratio (EBBR) instrument (Yucel et al. 1998). Persistent and abundant rainfall resulted in above average values of soil moisture, observed in EBBR measurements in central Oklahoma (Fig. 2a). This resulted in a prevalence of latent heat flux over sensible heat flux in boundary layer transport preceding the ERE (Fig. 2b).

Mesonet	May 1-June 18 rainfall	Normal rainfall	Percent of Normal
Altus	4.1	7.41	55.35%
Bessie	9.63	6.75	142.67%
Copan	17.96	8.06	222.94%
Freedom	8.73	6.17	141.49%
Grandfield	7.85	6.65	118.01%
Hugo	8.68	8.46	102.62%
Inola	8.89	8.30	107.16%
McAlester	6.49	8.84	73.38%
Medford	9.41	7.56	124.47%
Minco	17.83	7.71	231.20%
Norman	19.86	8.38	237.11%
Cheyenne	8.42	6.75	124.67%

Table 1. Accumulated rainfall for the period of 1 May – 18 June 2007 for selected sites from the Oklahoma Mesonet.

2.2 *ERE initiation*

At 1200 UTC 19 June 2007, a diffuse boundary was situated across southern Oklahoma. Surface temperatures across the state were between 22–26 C , with surface dew-point temperatures between 21–24 C. At 700 hPa a low-amplitude shortwave trough was present over northeastern Colorado. At 500 hPa there was weak northwesterly flow with anti-cyclonic curvature, while at 250 hPa a shortwave trough was located over the Northern Plains. Steep mid-level lapse rates above a nearly saturated boundary layer led to morning surface-based CAPE of approximately 2000 J kg^{-1} (Fig. 3a).

At 1800 UTC 19 June, a confluence zone was evident in northwest Kansas, with surface temperatures in northeast Kansas near 27 C and in southwest Kansas around 30C. The shortwave trough and weak surface convergence centered in northwest Kansas contributed to convective initiation in this area. In Oklahoma, instability had increased substantially and surface based CAPE was now in excess of 6000 J kg^{-1} (Fig. 3b). However, weak mid-level subsidence, coupled with a lack of defined low-level surface boundaries, prevented convective initiation in central Oklahoma.

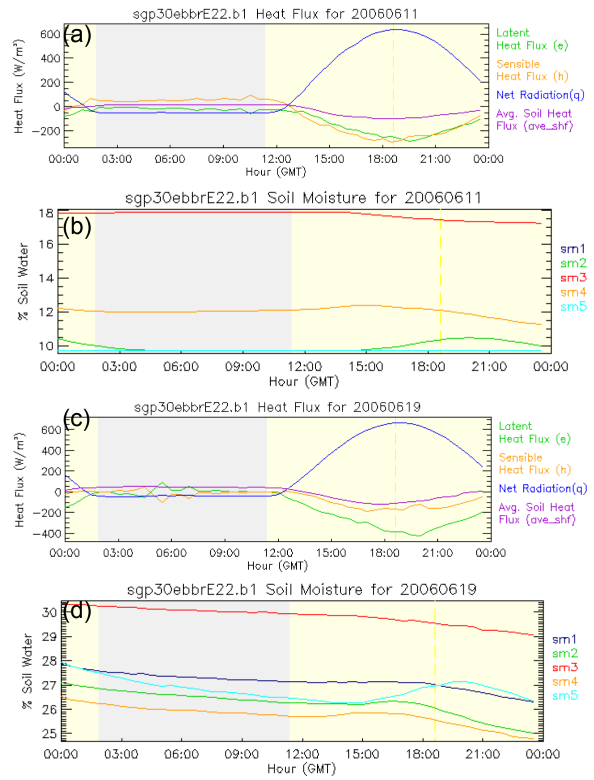

Fig. 2. Surface fluxes (a) and soil moisture (b) observed for a representative day in June 2006 by the EBBR instrument located near Cordell, OK. Same for a representative day in June 2007 in (c) and (d).

At 0000 UTC 20 June, a confluence boundary, previously in Kansas, had shifted southward into northern Oklahoma. This boundary, coupled with a thermal ridge and moisture axis located in central Oklahoma, appears to have contributed to convective initiation in northern Oklahoma. The mid-level shortwave trough progressed into central Kansas within weak northwesterly flow, typical of MCS events (e.g., Johns 1984; Stensrud and Fritsch 1993). In the Texas panhandle, convection initiated ahead of a dryline situated along the New Mexico border at approximately 0130 UTC. The soundings from Amarillo, TX (KAMA) (not shown) and Norman, OK (KOUN) (Fig. 3c) indicate a non-existent and weakened cap, respectively, and mid-level subsidence also had weakened in Norman. Meanwhile, convective instabilities remained strong at both locations.

During the evening of 19 June 2007, a

large mesoscale convective system (MCS; Houze 1993) swept through Oklahoma and much of Texas, with widespread reports of severe hail and wind. The MCS began as at least three separate thunderstorm complexes (Fig. 4a). The area of convection that initiated in north-central Kansas progressed southward, producing large hail and a few tornadoes in southwest Kansas, before merging with the storms in north-central Oklahoma around 0330 UTC 20 June 2007. The storms in the Texas panhandle progressed southeast before merging with the storms in Oklahoma at approximately 0530 UTC.

At this juncture, radar reflectivities were continuous, but with two distinct portions to the combined MCSs (Fig. 4b). The northeastern portion progressed through southeast Oklahoma and decayed. The southwestern portion, located primarily in Texas, contained a strong bow-echo that paralleled the Red River through the night. The bow-echo separated from the quasi-linear convection to the southwest, and that convection propagated to the Rio Grande River. Meanwhile, the bow-echo weakened after producing an 82-kt wind gust in Wichita Falls, TX. By 1200 UTC 20 June 2007, a MCV is identifiable within radar reflectivity in central Oklahoma (Fig. 4c).

3. THE ERE

3.1 *The first MCV*

On 1200 UTC 20 June 2007, a mid-level circulation, identifiable at 500 hPa, was located over central Oklahoma in the region where the stratiform precipitation from the overnight MCS dissipated. The circulation was also present at low-levels, as indicated from radar reflectivities. The low-level circulation was consistent with the location of the mid-level circulation. There was a convective minimum throughout the day, but convection re-initiated around the MCV by 2000 UTC in southwest Oklahoma.

By 0000 UTC 21 June, upper-air analyses (not shown) confirm that the MCV had moved into southwest Oklahoma. The KOUN 500-hPa temperature was warmer by 2 C than all adjacent sites, suggesting a warm-core structure. The MCV remained over southwest Oklahoma, sustaining convection throughout the night.

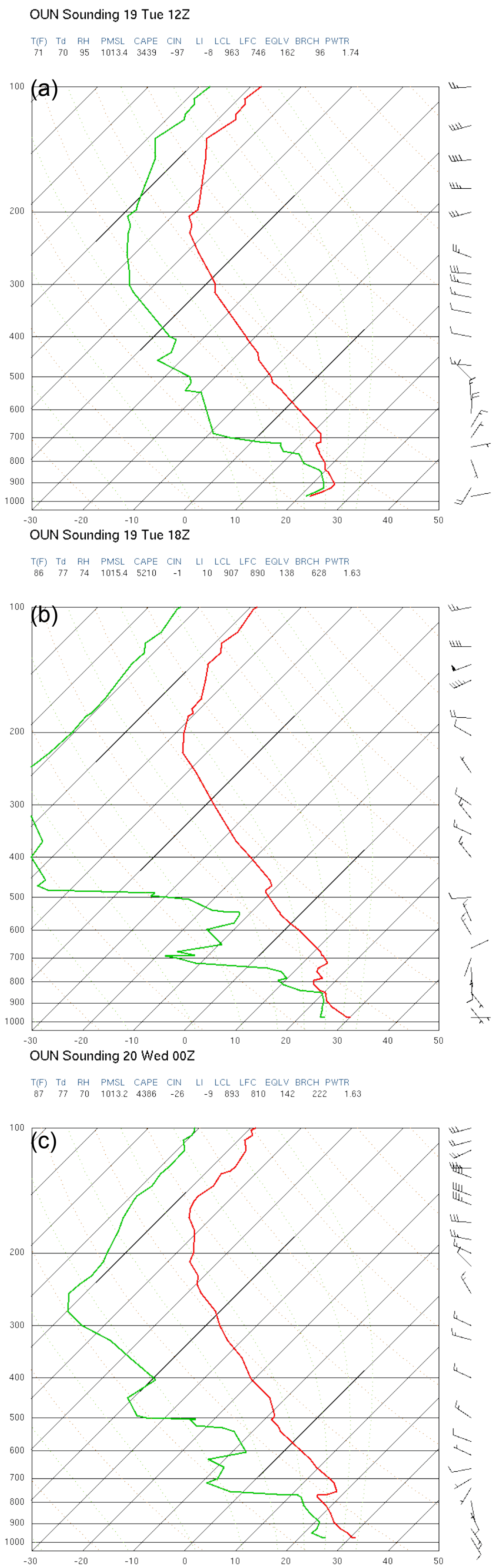

Fig. 3. KOUN soundings for 19 June 2007 (a) 1200 UTC, (b) 1800 UTC, and (c) 20 June 2007 0000 UTC.

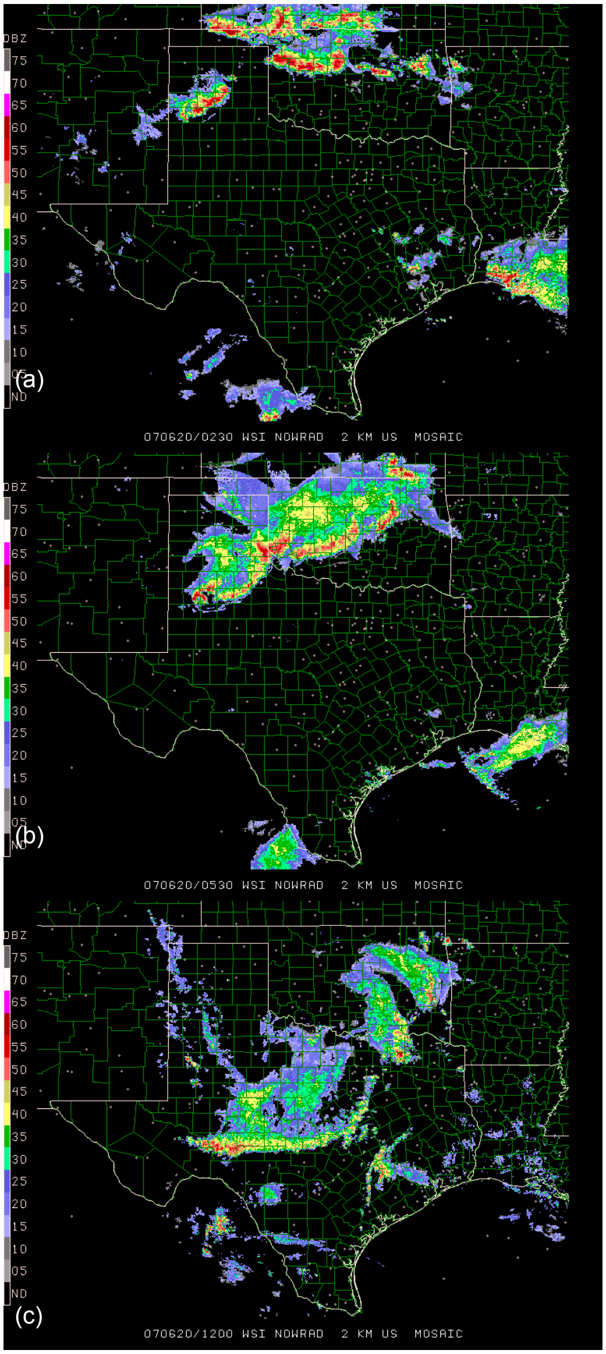

Fig. 4. Radar composite over the SGP for 20 June 2007 at (a) 0230 UTC, (b) 0530 UTC, and (c) 1200 UTC.

A shortwave trough was situated over the central Rockies at 0000 UTC 22 June. This shortwave began to move into the Central Plains overnight and began to interact with the MCV located over southwest Oklahoma and northwest Texas. The MCV moved east out of southwest Oklahoma as it phased with the shortwave trough. The convection associated with the MCV dissipated completely by 1600 UTC. Thereafter, the MCV is not discernible in radar or satellite imagery.

Over the next two days, convection formed over the Southern Great Plains in association with two shortwave troughs that moved through the area. At no point did this convection form long-lived MCVs. It is not until 24 June that convection in the Southern Great Plains (SGP) produced another long-lived MCV.

3.2 *The second MCV*

Convection initiated around 1800 UTC 23 June along a surface confluence boundary in central Oklahoma, aided by a shortwave trough aloft. The convection moved southwestward into southwest Oklahoma and then shifted southward into Texas. By 1000 UTC on 24 June, an MCV appeared in radar reflectivity near Childress, TX. Convection then dissipated by 1200 UTC, but redeveloped by 1600 UTC, likely in association with the MCV. Widely scattered thunderstorms continued to develop in northwest Texas, making it difficult to identify any potential MCV in the radar reflectivity. Beginning at 1200 UTC 24 June, the flow at 500 hPa indicates a weak circulation, which strengthened during the next 24 hours. By 1200 UTC 25 June, a clearly identifiable MCV was present in the radar reflectivity in northwest Texas, along with a mid-level circulation at 500 hPa.

During the day on 25 June, convection surrounded the center of the MCV. By 0000 UTC 26 June, much of the convection had dissipated, except for the area around the MCV. After sunset, thunderstorms weakened throughout the SGP, but redeveloped by 0800 UTC near the center of the MCV as it moved northward into central Oklahoma. Two distinct areas of convection developed by 1600 UTC and rotated around the MCV. At this point the spatial scale of the MCV appears to have increased substantially.

Between 1800 UTC 26 June and 1200 UTC 27 June, the MCV transitioned into a fully tropospheric warm-core circulation (WCC). The mid-level circulation at 500 hPa had increased and was associated with temperatures 2 C warmer than the surrounding region. At this time the circulation was also evident at 700 hPa and to a lesser extent at 850 hPa. In association with this lower tropospheric circulation, there was anti-cyclonic flow at 250 hPa.

The WCC continued to organize through 27

June, and by 0000 UTC 28 June, a surface circulation is observed in northern Oklahoma. At this time the WCC was well-defined, and temperatures were approximately 2 C warmer near its center throughout the entire troposphere. At this point, the WCC began to move southward into northern Texas.

By 0000 UTC 29 June, the WCC was located in western-north Texas, with the strongest mid-level flow on its eastern side. The system moved northeast, re-entering Oklahoma by 0000 UTC 30 June. Around 0000 UTC 1 July, the ridge that had been in place to the east began to break down, and the ridge to the west pushed slightly eastward. After two days in northern Oklahoma, the WCC, now with the strongest mid-level flow on its western side, moved back to the southwest into northern Texas.

As it moved southward, the WCC began to weaken, and by 1200 UTC 2 July, the circulation was no longer identifiable at 850 hPa. Despite weakening, the WCC remained discernable in central Texas because no upper-level shortwave trough was in the region to kick it out. An upper-level jet streak moved into the Pacific Northwest on 2 July, and over the western ridge by 6 July. This jet streak finally suppressed the ridge in the Southeast, allowing the WCC to phase with a shortwave trough as it rapidly moved eastward through the south-central United States. The WCC lost warm-core characteristics by 8 July.

4. DISCUSSION

From a research and operational perspective, several questions arise from this uncommon event. First, why were MCSs so frequent during this time? Second, why did the two MCVs evolve so differently? Third, what factors may have influenced the upscale growth of the second MCV into a WCC? Finally, what were potential influences on the movement of the WCC?

4.1 *Favorable MCS environments*

Throughout the ERE, the environment over the SGP and southern High Plains was favorable for the daily regeneration of mesoscale convective systems (MCSs). Before the event spring rainfall provided abundant surface moisture, which remained present throughout the ERE. Abundant surface moisture remained over the SGP because of a stagnant synoptic pattern, maintaining a deep, moist boundary layer favorable for frequent convective events. This pattern consisted of weak mid- and upper-level flow atop similarly weak but persistent low-level southerlies, resulting in high-instability, low-shear environments frequently observed in MCSs (e.g., Parker and Johnson 2000).

4.2 *Differences in MCV longevity*

Two separate MCV events evolved quite differently during the ERE, as described in section 3. The initial MCV lasted for approximately two days, whereas the second MCV transitioned into a WCC that persisted for more than 10 days. The first MCV weakened in response to an approaching shortwave trough on 22 June. This shortwave trough was able to move the MCV out of the region owing to the lack of a sub-tropical ridge located in the southeast United States. Conversely, the MCV that began on 24 June did not get kicked out shortly after its formation. The development of a sub-tropical ridge east of the SGP prevented shortwave troughs from moving the MCV out of the area. Subsequently, the MCV was able to develop into a WCC. The WCC could only be swept out of the area following the breakdown of the eastern ridge.

4.3 *Upscale growth of MCV*

There were multiple factors that aided in the transition of the MCV into a WCC. First, a deep, moist boundary layer was present, which allowed for convection to reinforce the warm-core system frequently through release of latent heat. Latent heat release contributed to the development of upper-level divergence. Ambient vertical shear was weak, allowing the MCV to persist beneath the upper-level divergence. Within this environment the spatial scale of the system increased substantially, coinciding with a dramatic increase in the areal coverage of convection, a strengthening upper-level anti-cyclone, and nearly persistent convection.

4.4 *WCC movement*

The SGP were bounded by two subtropical highs, one to the east and one to the west; there was also a persistent long-wave blocking pattern to the north. As a result, shortwave troughs in the stronger flow to the north could not dictate the movement of the WCC that developed on 24 June. Consequently, the movement of the WCC appeared erratic, looping around Oklahoma, Kansas, and Texas. However, we hypothesize that the movement of the WCC was largely driven by internal system dynamics, including the daily redevelopment of convection. This movement was evident in the oscillation of stronger mid-level flow between the east and west side of the system as it moved north and south, respectively (Fig. 5).

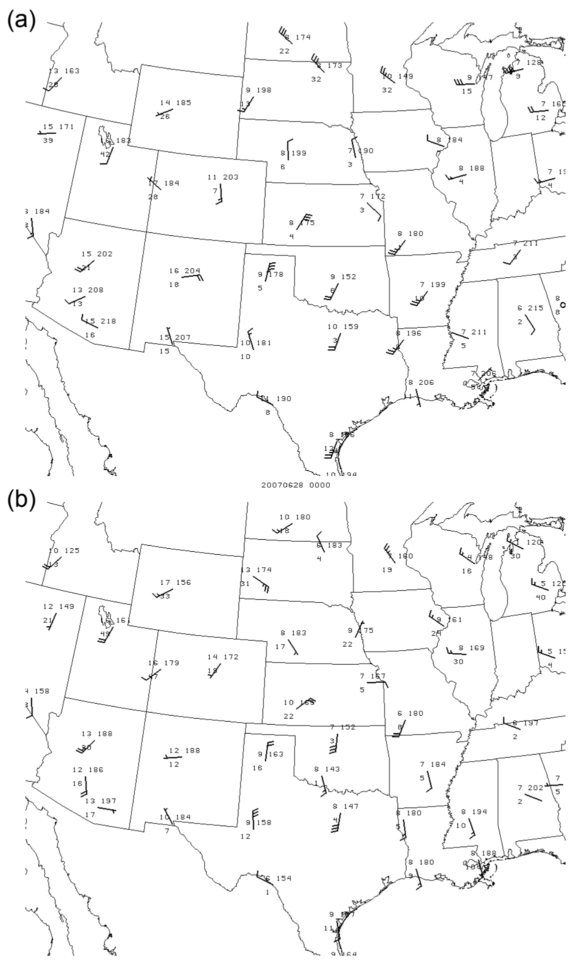

Fig. 5. 700 mb observations valid at (a) 0000 UTC 28 June 2007 and (b) 1200 UTC 29 June 2007.

5. CONCLUSION

The ERE was a result of the interaction between convection, MCVs, and an unusually tropical and stagnant synoptic environment over the SGP. This setup was aided by frequent and abundant rainfall during the weeks preceding the ERE and resulted in an extended period of widespread convective rainfall during the ERE. During the peak of the ERE, ridging to the east and west of the SGP prevented shortwave troughs from halting the upscale growth of a MCV, allowing transition to a WCC. The WCC only dissipated when the ridge to the east weakened sufficiently to allow shortwave trough interaction.

With this theoretical framework in mind, it is reasonable to examine the numerical predictability of high-impact meteorological events like the ERE. In future work, we will investigate the capability of numerical models to perform such forecasts of this case. In doing so, we intend to verify and refine the ERE conceptual model.

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