P0.98 **COMPOSITE ANALYSIS OF HEAVY-RAIN-PRODUCING ELEVATED THUNDERSTORMS IN THE MO-KS-OK REGION OF THE UNITED STATES**

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1. INTRODUCTION

Most elevated thunderstorms in the United States occur in the Midwest, with a maximum in eastern Kansas (Colman 1990) (Figure 1). These storms occur above a stable layer near the surface, essentially cut-off from surface-based instability (Corfidi et al. 2006).

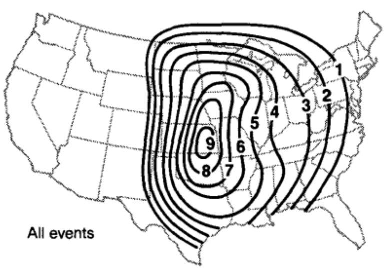

Figure 1. *The number of elevated thunderstorms (reports/station) identified over the 4-year period from September 1978 through August 1982 (Figure and caption taken from Colman 1990).*

This composite analysis looks at the environmental conditions conducive for the development of heavy-rainfall-producing elevated thunderstorms and mesoscale convective systems. Corfidi et al. (2006) called for additional study of elevated convection of the kind proposed here.

Events included in this study produced over two inches of rainfall in 24 hours. Cases were collected for five different National Weather Service county warning areas (Figure 2): Kansas City/Pleasant Hill (EAX), Springfield (SGF), Tulsa (TSA), Wichita (ICT), and Topeka (TOP). This study hopes to gain a better understanding of the environment for these storms, which will help in forecasting when these systems will produce heavy rainfall.

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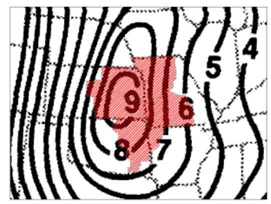

Figure 2. *Colman's (1990) elevated thunderstorm climatology (Figure 1) overlaid with chosen NWS county warning areas.*

2. DATA AND METHODOLOGY

Cases were chosen by first looking at daily precipitation charts (U.S. Unified Daily Precipitation Analyses). These spanned a 24-hour period from 12Z to 12Z. Events collected for this study occurred during warm season months from April through September, over our model data range, from 1979 to 2012. Dates were chosen if there was precipitation recorded greater than two inches within a boundary of a county warning area (CWA).

From the list of dates for each CWA, North America Regional Reanalysis grid files were then downloaded from the National Operational Model Archive & Distribution System and converted to GEMPAK files for plotting. In order to find the time of the event, three-hourly rainfall was plotted until the highest accumulation was found corresponding to the precipitation maximum on the daily precipitation map.

Once the event time was found, two-meter equivalent potential temperature (θ_e) was plotted with the three-hourly accumulated precipitation to see if the maximum was on the cold side of a surface boundary. The second criteria that allowed a case to be considered elevated was looking at a model sounding taken from the coordinate of the local precipitation maximum within the CWA. If there was a stable layer inversion near the surface, the case was elevated.

The evaluation process in this analysis is based on the criteria Colman (1990) used for his elevated convection events. He used surface observations of temperature, dewpoint temperature, and wind to prove the thunderstorm was on the cold side of a frontal boundary. In the study performed here, model two-meter θ_e was used to show the location of the surface front, instead. This also satisfied Colman's criteria that the environment on the warm side of the surface front has a higher θ_e than the environment on the cool side.

This method produced a list of elevated thunderstorm events with coordinates for each case from its local precipitation maximum. These lists were used to generate composites for each CWA. For these composites, software developed at Saint Louis University overlaid the precipitation maximum coordinate from each case over the centroid of the CWA. The environmental conditions were then averaged and a composite grid file was produced.

The composite grids were used to make plots in GEMPAK showing typical environment for heavy-rain-producing elevated thunderstorms in each region.

3. ANALYSIS

Analyses are presented for EAX (Fig. 3), SGF (Fig. 4), TSA (Fig. 5), ICT (Fig. 6), TOP (Fig. 7), which are all quite similar. Looking 250 mb (subfigure *a* in each), there typically was a jet streak positioned to the north-northeast of the event region. This places the region in the right-entrance of the jet streak, under the maximum of divergence aloft. The region also is located just upstream of a 250-mb ridge axis.

At 850 mb (subfigure *b* in each), a low-level jet is found, characterized by a local maximum of 20-25-kt winds. The convective region is found in the left-exit region of the low-level jet, and on the nose of the jet in the region of maximized convergence. This is also shown by the 850-mb equivalent potential temperature advection maximum (subfigure *c* in each), which either lies over the centroid of each region, or just north.

1000-500-mb thickness (subfigure *d* in each), illustrates a region of weak warm-air advection through the column, while diffluent thickness, found over the region as well, is a preferred location for heavy-rainfall development (explained further in Funk 1991). Assisting in the development of heavy rainfall, precipitable water values greater than 1.6” (and even 1.8” in EAX) are found in over the environment, showing ample moisture through the column.

Even though parcels lifted from the surface would show little to no CAPE due to the low-level stable layer, most-unstable CAPE (MUCAPE) which is lifted from the layer with the highest equivalent potential temperature (subfigure *e* in each), shows the convective potential above the stable layer. The environment for elevated convection in these five CWAs was found to have between 1000-1500 J kg^{-1} of MUCAPE, indicating a fairly unstable environment aloft. This is supported by K-Index values > 35 over the region as well.

Overall, the elevated thunderstorms that produced heavy rainfall were typically forced by the cooperation of the lower-level and upper-level jets. This is shown very well by the cross-sections (subfigure *f* in each), through each environment depicting θ_e, scalar-normal wind, ageostrophic wind vectors, and mixing ratio. The low-level jet advects warmer, moist air over the surface boundary, generating elevated instability and lift. Lifted air is then incorporated into the direct thermal circulation from the upper-level jet, which is generating upward motion over the region under its right-entrance. Convergence above the surface boundary, enhanced lift from both the upper-level and lower-level jets, and elevated instability guide the production of these storms, and ample moisture in the environment provide the fuel for the generation of heavy rainfall.

4. SUMMARY

This study found similar results to previous studies performed by Moore et al. (2003) and Schumacher and Johnson (2005). Elevated thunderstorms that produce heavy rainfall tend to be given enhanced elevated lift by the cooperation of lower-level and upper-level jet streaks, in a region of maximized convergence with a divergence maximum found aloft in the right-entrance of the upper-level jet. Ample moisture through the column provides the fuel for the development of efficient precipitation, and the advection of warmer (higher equivalent potential temperature) air over the cooler stable layer near the surface generates the elevated instability for convective mixing to occur.

Aknowledgements

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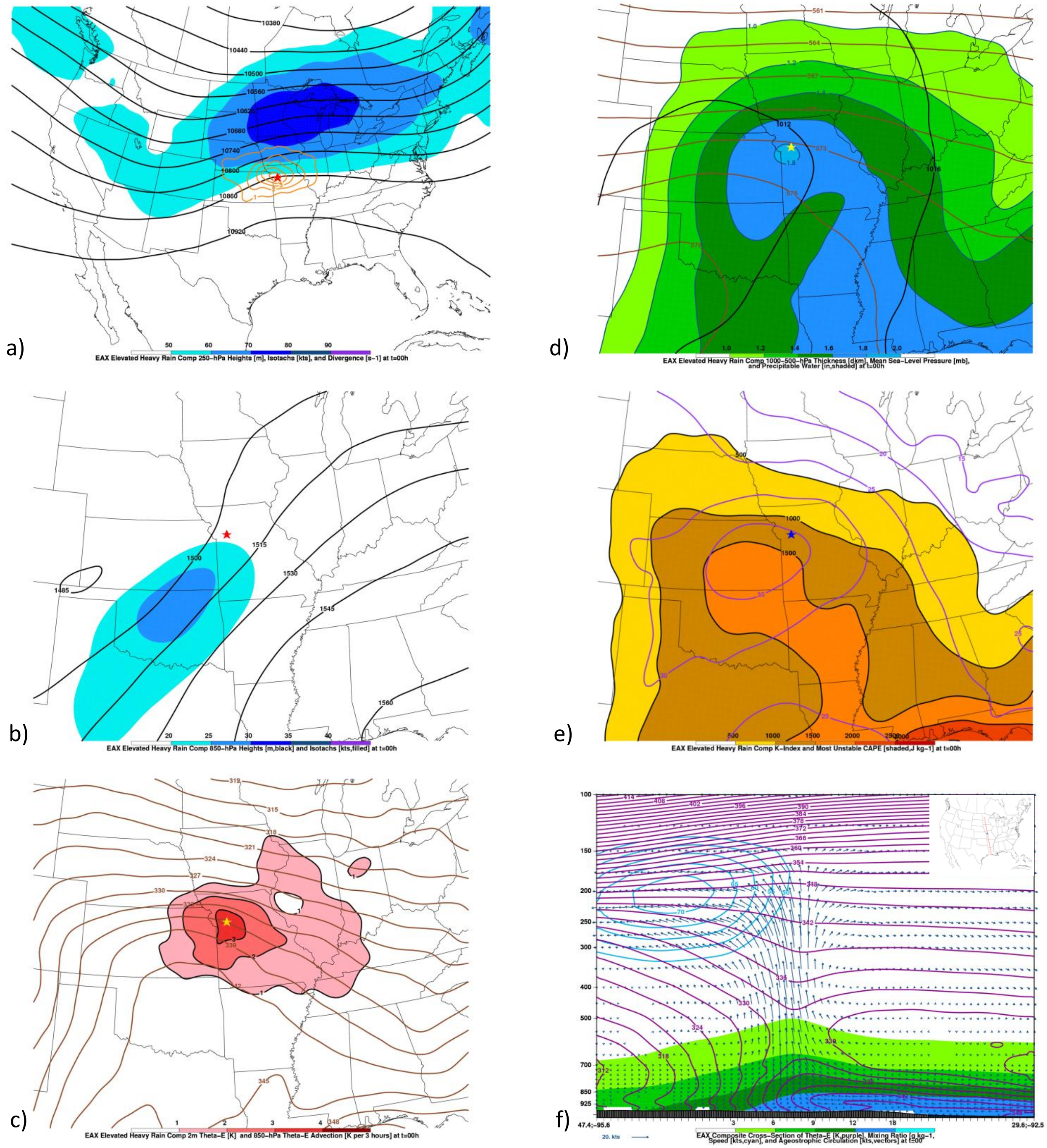

Figure 3. *Plots from the composite grid file generated from events which occurred in the Kansas City/Pleasant Hill, Mo. National Weather Service county warning area. The star in each plot shows the location of the centroid of the CWA. From top left: (a) 250-mb geopotential heights (black), winds (color-filled), and divergence (orange); (b) 850-mb geopotential heights (black) and wind (color-filled); (c) 850-mb equivalent potential temperature advection (color-filled) and 2-meter equivalent potential temperature; (d) 1000-500-mb thickness (brown), mean sea level pressure (black), and precipitable water (color-filled); (e) most-unstable cape (color-filled) and k-index; (f) cross-section (location depicted by red line on map in top-right corner) showing equivalent potential temperature (purple), scalar-normal wind (blue), mixing ratio (color-filled), and ageostrophic wind vectors (navy).*

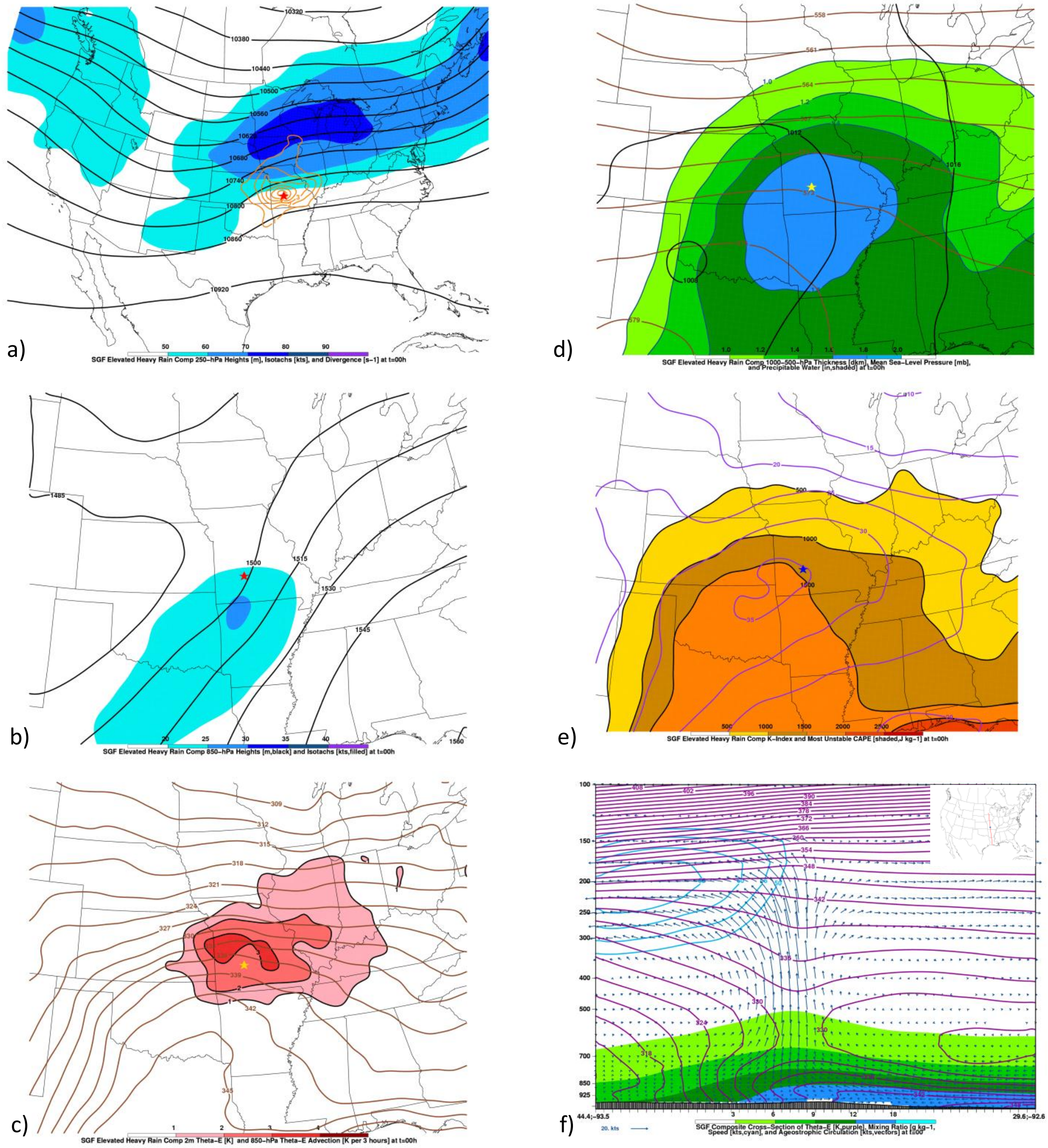

Figure 4. *Plots from the composite grid file generated from events which occurred in the Springfield, Mo. National Weather Service county warning area. The star in each plot shows the location of the centroid of the CWA. From top left: (a) 250-mb geopotential heights (black), winds (color-filled), and divergence (orange); (b) 850-mb geopotential heights (black) and wind (color-filled); (c) 850-mb equivalent potential temperature advection (color-filled) and 2-meter equivalent potential temperature; (d) 1000-500-mb thickness (brown), mean sea level pressure (black), and precipitable water (color-filled); (e) most-unstable cape (color-filled) and k-index; (f) cross-section (location depicted by red line on map in top-right corner) showing equivalent potential temperature (purple), scalar-normal wind (blue), mixing ratio (color-filled), and ageostrophic wind vectors (navy).*

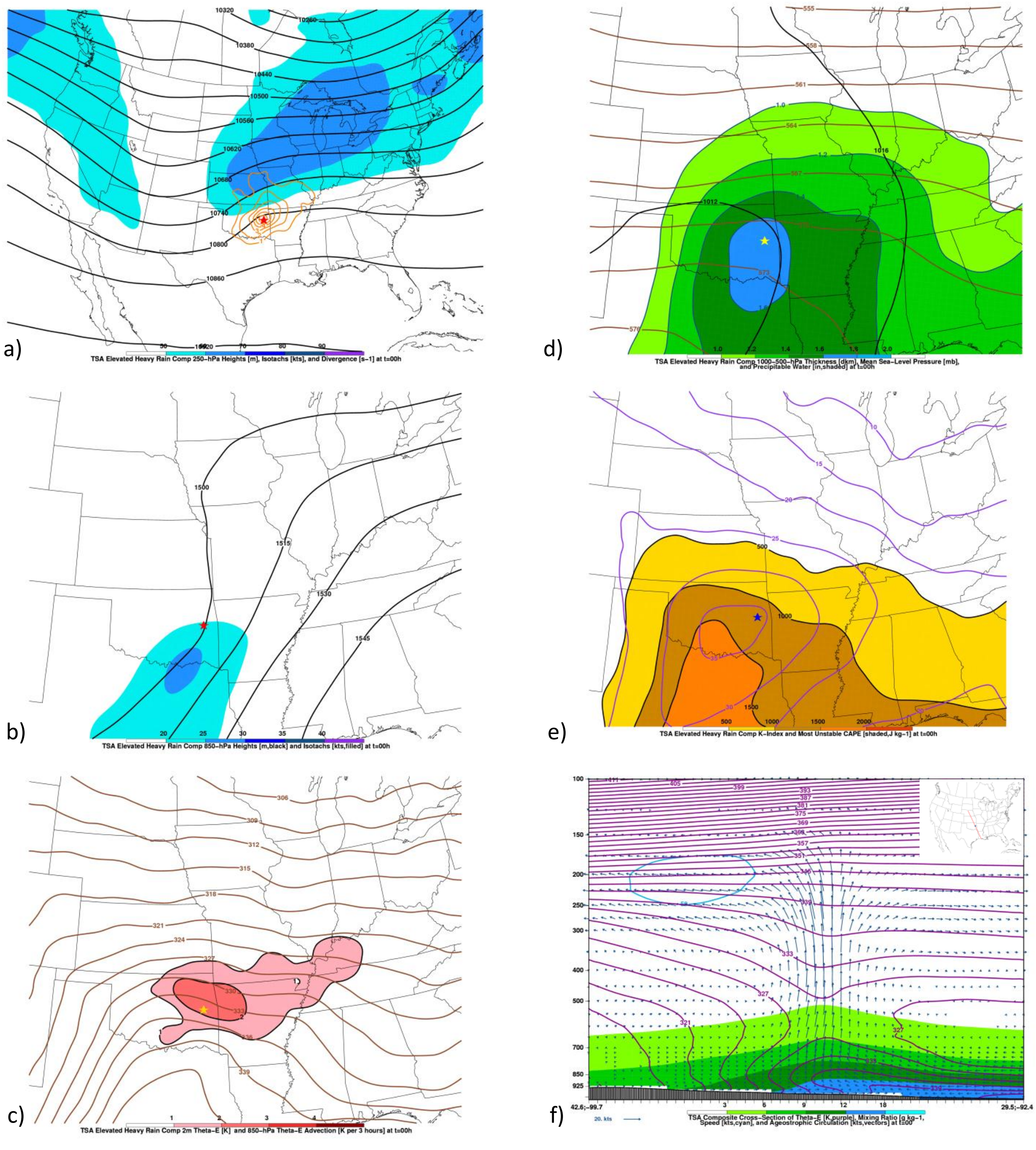

Figure 5. *Plots from the composite grid file generated from events which occurred in the Tulsa, Ok. National Weather Service county warning area. The star in each plot shows the location of the centroid of the CWA. From top left: (a) 250-mb geopotential heights (black), winds (color-filled), and divergence (orange); (b) 850-mb geopotential heights (black) and wind (color-filled); (c) 850-mb equivalent potential temperature advection (color-filled) and 2-meter equivalent potential temperature; (d) 1000-500-mb thickness (brown), mean sea level pressure (black), and precipitable water (color-filled); (e) most-unstable cape (color-filled) and k-index; (f) cross-section (location depicted by red line on map in top-right corner) showing equivalent potential temperature (purple), scalar-normal wind (blue), mixing ratio (color-filled), and ageostrophic wind vectors (navy).*

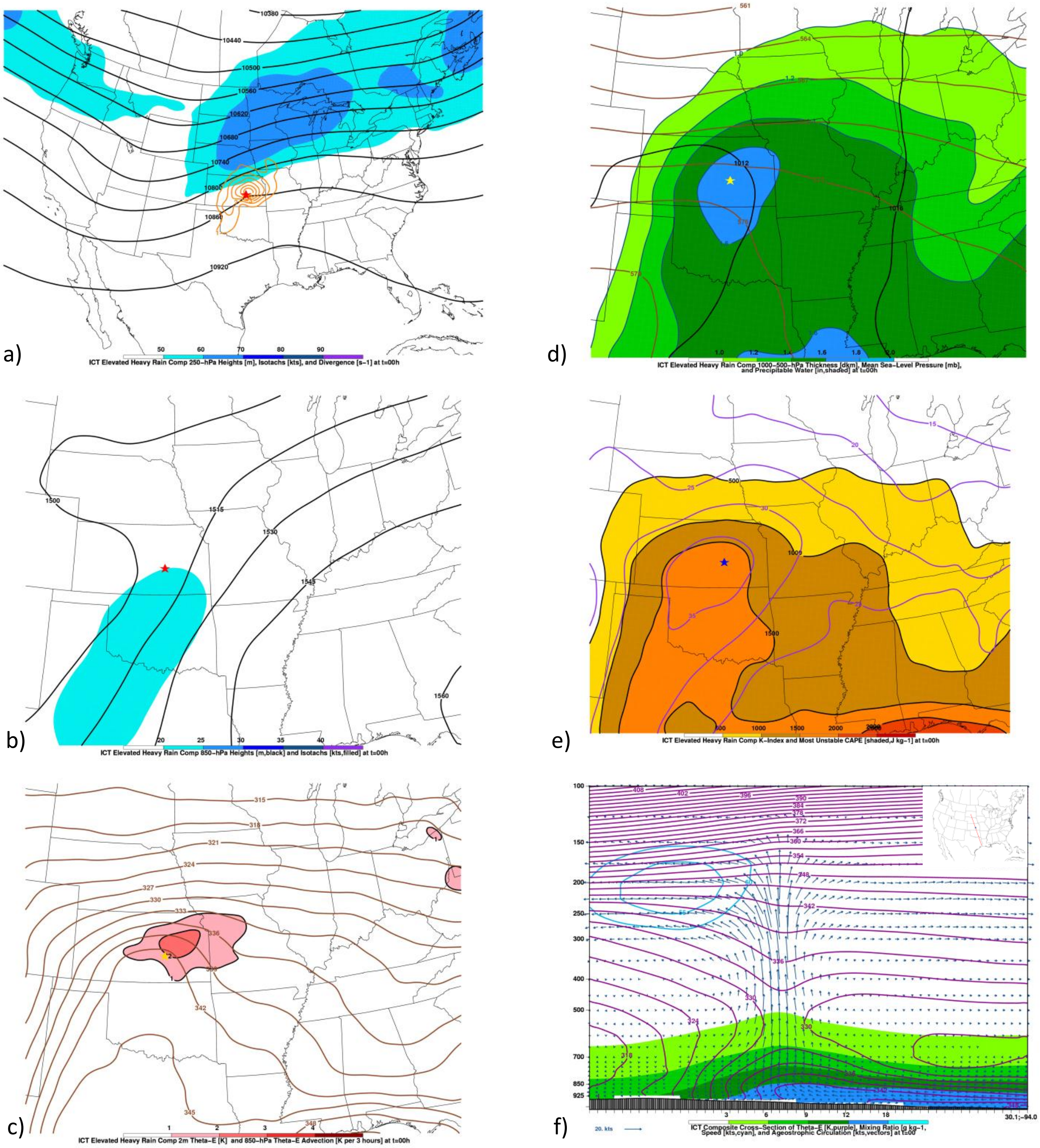

Figure 6. *Plots from the composite grid file generated from events which occurred in the Wichita, Ks. National Weather Service county warning area. The star in each plot shows the location of the centroid of the CWA. From top left: (a) 250-mb geopotential heights (black), winds (color-filled), and divergence (orange); (b) 850-mb geopotential heights (black) and wind (color-filled); (c) 850-mb equivalent potential temperature advection (color-filled) and 2-meter equivalent potential temperature; (d) 1000-500-mb thickness (brown), mean sea level pressure (black), and precipitable water (color-filled); (e) most-unstable cape (color-filled) and k-index; (f) cross-section (location depicted by red line on map in top-right corner) showing equivalent potential temperature (purple), scalar-normal wind (blue), mixing ratio (color-filled), and ageostrophic wind vectors (navy).*

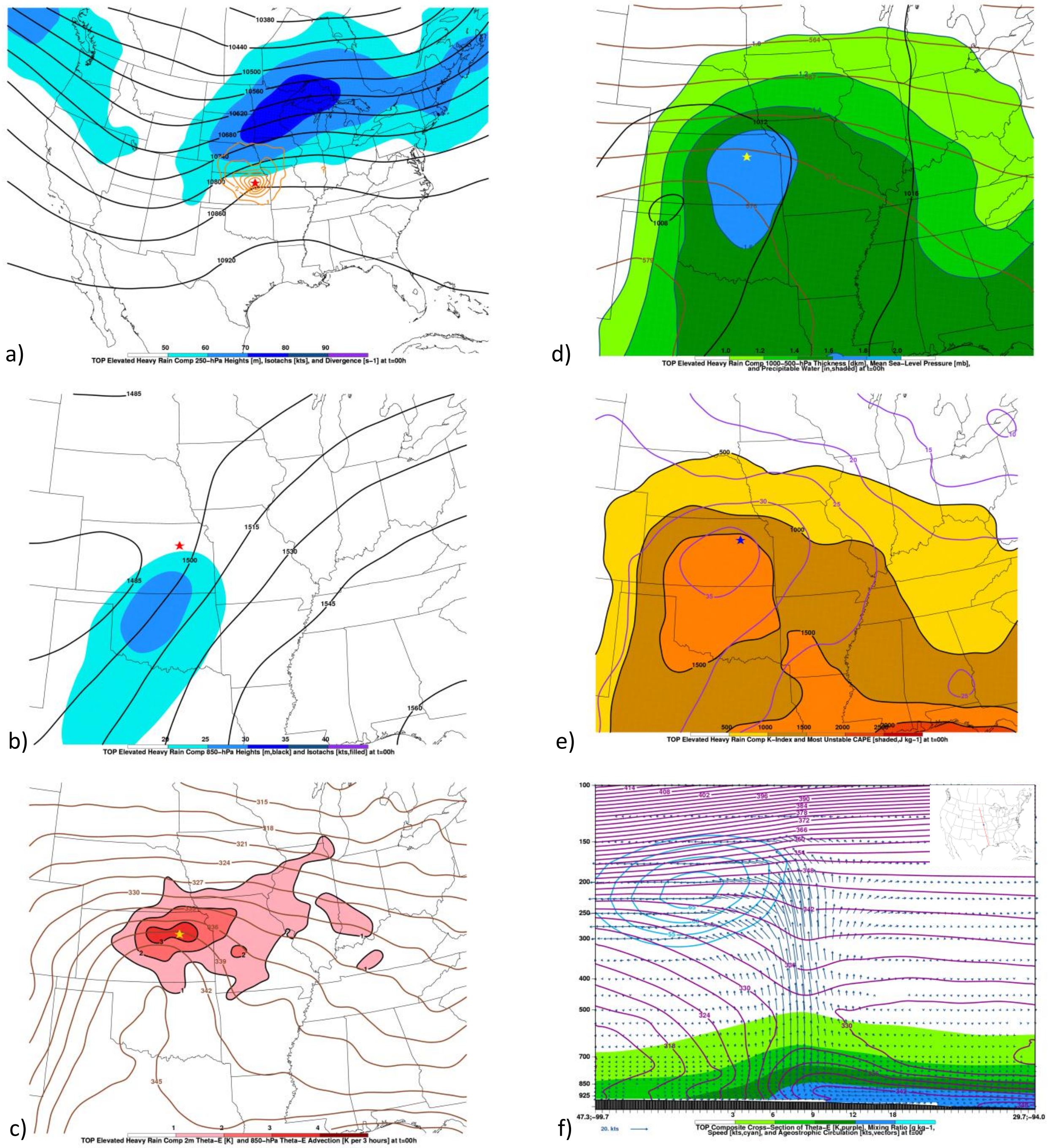

Figure 7. *Plots from the composite grid file generated from events which occurred in the Topeka, Ks. National Weather Service county warning area. The star in each plot shows the location of the centroid of the CWA. From top left: (a) 250-mb geopotential heights (black), winds (color-filled), and divergence (orange); (b) 850-mb geopotential heights (black) and wind (color-filled); (c) 850-mb equivalent potential temperature advection (color-filled) and 2-meter equivalent potential temperature; (d) 1000-500-mb thickness (brown), mean sea level pressure (black), and precipitable water (color-filled); (e) most-unstable cape (color-filled) and k-index; (f) cross-section (location depicted by red line on map in top-right corner) showing equivalent potential temperature (purple), scalar-normal wind (blue), mixing ratio (color-filled), and ageostrophic wind vectors (navy).*