Heavy Rainfall Forecast Problems

Extreme weather has an enormous impact on all facets of transportation. According to the Weather Information for Surface Transportation (WIST; 2005), there are:

1) Approximately 3.9 million miles of public roadways.

2) 122,000 miles of major railroad tracks.

3) Over 26,000 miles of commercially navigable waterways.

4) Nearly 5,300 public-use airports.

5) 28% of all highway crashes and 19% of all fatalities are directly or indirectly related to adverse weather conditions.

6) Weather-related crashes have an estimated annual economic impact of nearly 42 billion USD.

Heavy rainfall is just one type of treacherous weather event, but has the potential to cause a variety of socioeconomical problems:

1) Loss of or reduced visibility.

2) Flooding or flash flooding.

Both occur quickly on small time scales and are potentially deadly. According to WIST (2002), as visibility decreases the speed of traffic also decreases, especially when traffic flow increases (e.g., during the local rush hours). The faster the reduction of visibility, the quicker traffic must slow to prevent accidents. According to the National Oceanic and Atmospheric Administration (2006), every year flooding costs an average of over 2 billion USD in damages and causes over 100 fatalities. As areas become more populated and are covered with impermeable structures and surfaces, such as buildings and roads, the amount of strom-water runoff increases (Kelsch 2002). Consequently, modest rainfall episodes can become potentially dangerous flash flood situations.

Research Objective

The objective of the present study is to investigate proximity soundings (observation and model analysis) that sampled the environment within which a heavy rainfall event initiated or developed to better understand critical parameters (moisture, instability, wind shear, etc) and how those particular parameters are associated with differing rainfall amounts.

Heavy rainfall is defined as rainfall accumulations of 4 inches or more in a 24-h period from one precipitation system. The event must have occurred in the central United States from March through September for the years 2003 through 2005. This accumulated 46 observed and 33 model analysis soundings.

The 4-inch dataset is compared to two additional datasets:

1) One comprised of days where 1-2 inches of rainfall occurred, following the same guidelines as the 4-inch dataset. Totaling 73 observed and 47 model analysis soundings.

2) One comprised of days where no rainfall occurred within 24-48 hours of the nominal sounding time. Totaling 491 observed soundings.

Therefore, it is anticipated that forecasters will have the opportunity to recognize a potential heavy rainfall situation utilizing key sounding parameters rather than a light rainfall episode before it becomes a surprise storm for the community.

Examining the Preconvective Heavy Rainfall Environments Utilizing Observational and Model Analysis Proximity Soundings

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Domain and Definition of Proximity

Area within the black outline illustrates the domain for this study.

Spatial Criteria:

Soundings must be within 250 km of the region that received the greatest rainfall accumulation.

Temporal Criteria:

Soundings must be within 6 hours prior to convection affecting the region that received the greatest accumulation of rainfall.

Quality Control:

No major boundaries must exist between the soundings and the area of heavy precipitation within the 250 km spatial region.

Contaminated (i.e., outflow, precipitation) soundings were removed.

Suspect soundings with CAPE values greater than 5000 $J kg^{-1}$ were removed.

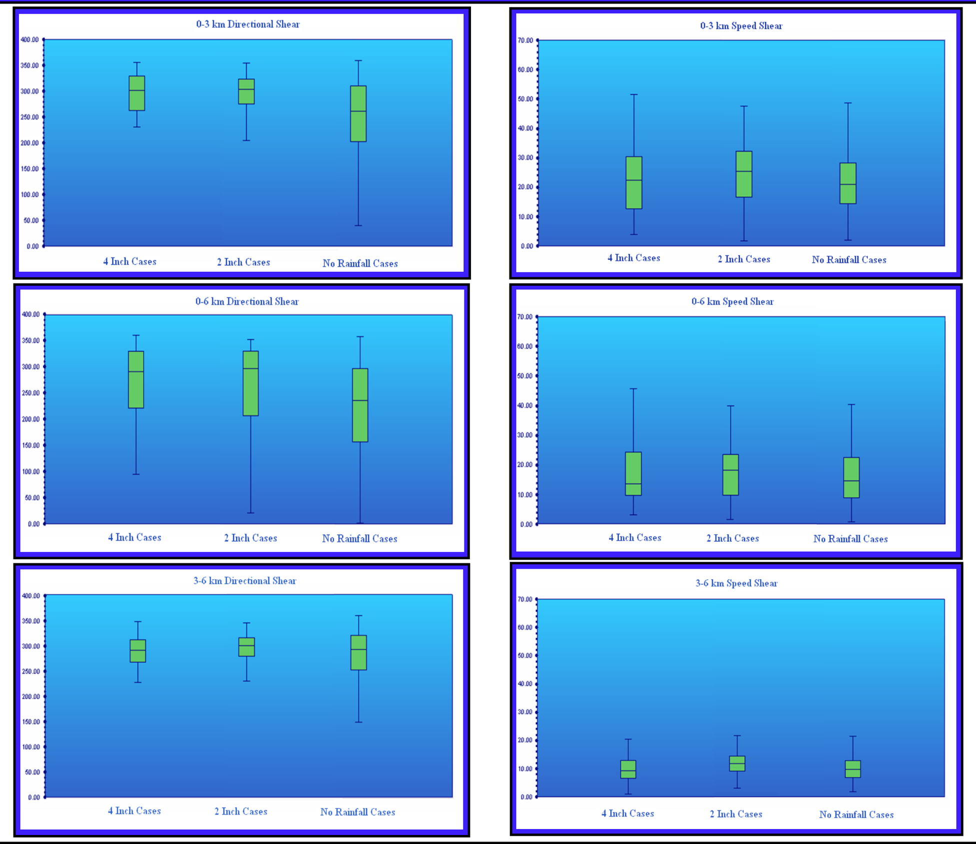
Justification of Proximity Criteria:

Beyond 250 km, there are numerous large-scale boundaries and potential contamination sources that limit the availability of other soundings.

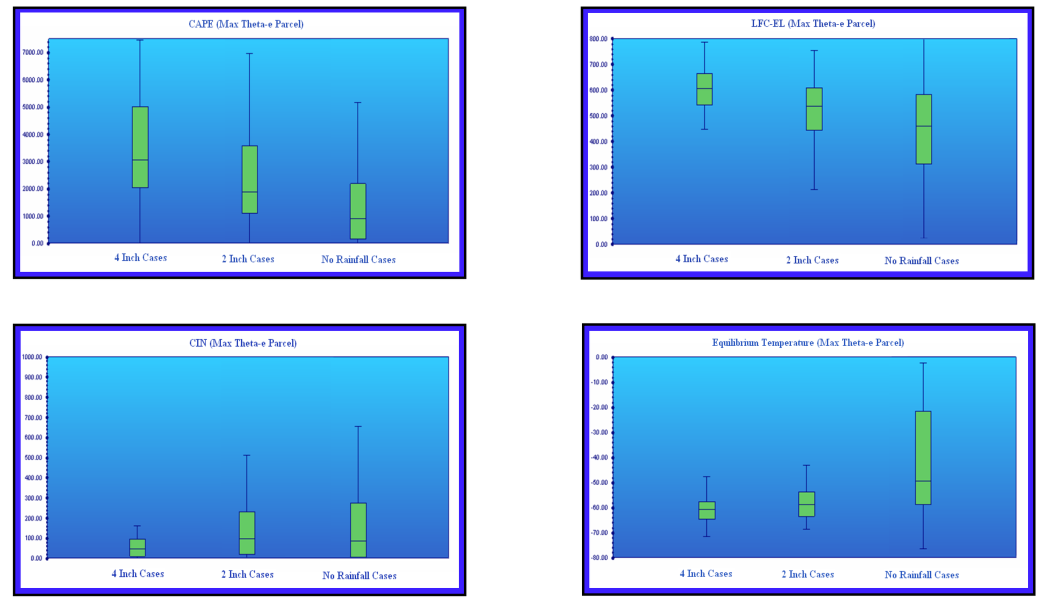
Cutting the spatial criteria in half drastically reduces the dataset, which would question the statistical significance of the results. 20 years would be needed to obtain the same number of soundings in the current dataset.

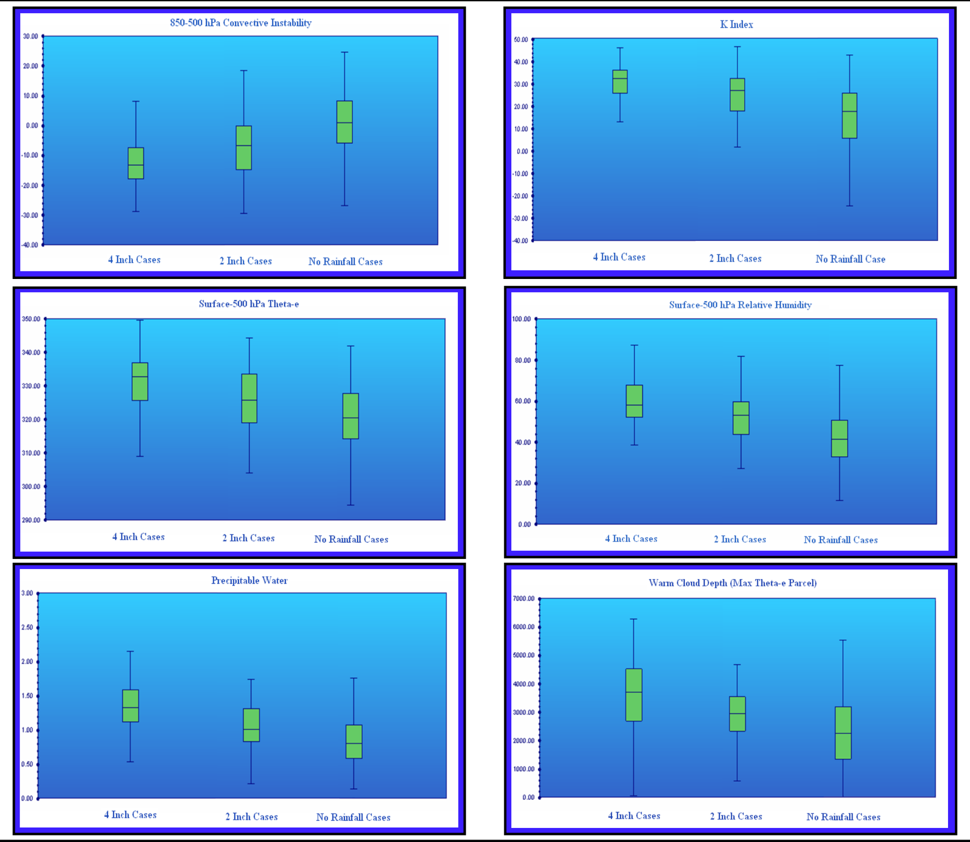
Beyond 6 hours, there are very few cases (12) that could be considered for this particular study. These 12 cases add no significant difference between categories.

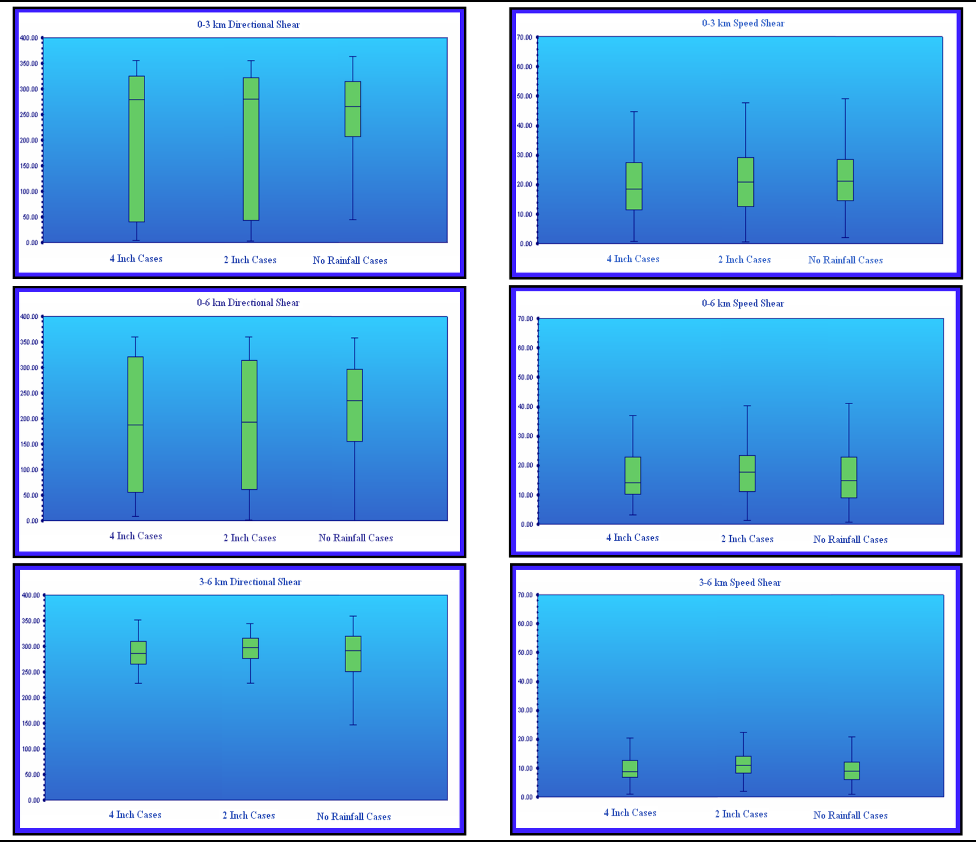
Cutting the temporal criteria reduces the dataset by 40-50%.



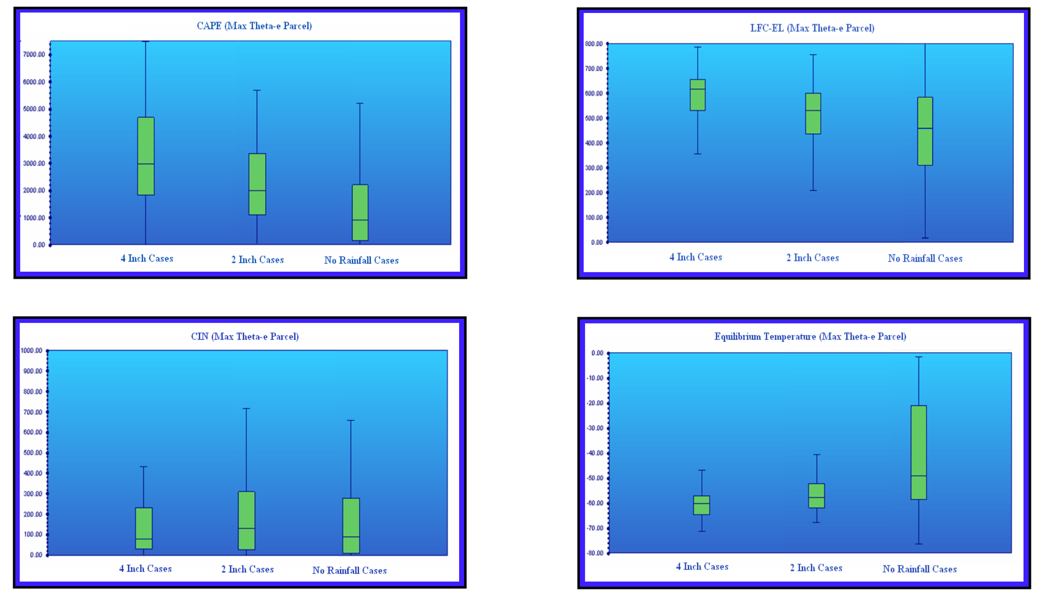
Parameters Associated with Observational Soundings

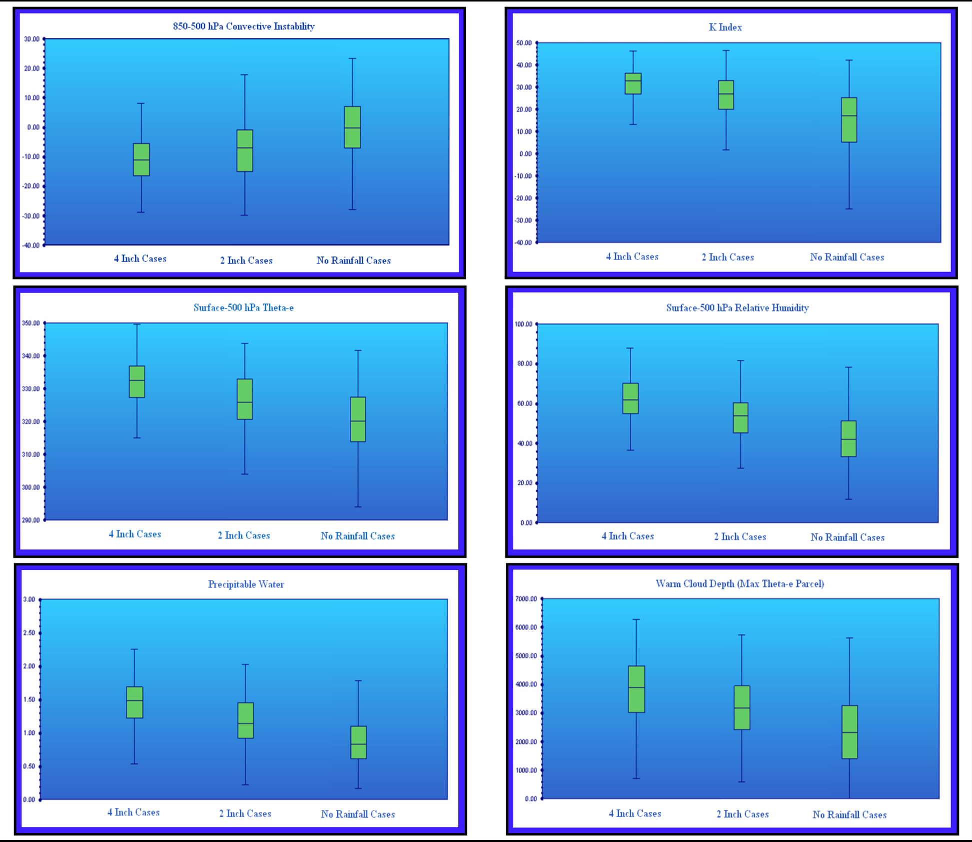






Parameters Associated with Observational and Rapid Update Cycle Version 2 Soundings





Summary and Conclusions

1) Wind direction tends to be from the north over a relatively large layer.

2) Wind speeds tend to be relatively strong near the surface, but weaken with height.

3) While there is great spread, the mean maximum theta-e CAPE values increase from the no rainfall category to the 4 inch category.

4) The mean maximum theta-e CIN, equilibrium temperature, and 850 to 500 hPa convective instability values decrease from the no rainfall category to the 4 inch category.

5) The distance between the LFC and EL tends to be greater in the heavier rainfall cases.

6) K index, precipitable water, surface to 500 hPa relative humidity, surface to 500 hPa equivalent potential temperature, and warm cloud depth tend to increase in the heavier rainfall events.

While the wind shear parameters do not appear to illustrate a significant impact on this study, they do depict the common thought that stronger low-level wind speeds could potentially aid in the low-level convergence. The decrease in wind speeds with height illustrates that upper-level winds are not necessarily strong enough to advect these heavy precipitation cells to other regions, thus prolonging the accumulation. The wind direction illustrates that these events tend to be located on the northern side of a surface boundary.

The increase in CAPE and decrease in CIN values illustrates an atmosphere more condusive for convective activity. The decrease in the equilibrium temperature and increase in the distance between the LFC to EL allows for a greater region of instability, thus the increase in CAPE values.

The K index, precipitable water, surface to 500 hPa relative humidity, surface to 500 hPa equivalent potential temperature, and warm cloud depth values illustrate a warm more moist atmosphere than lighter precipitation events. The increase in the warm cloud depth values shows that heavier rainfall events rely on warm cloud precipitation processes to produce greater accumulations.

Future Research

1) Further check for a statistically significant difference between the three categories using the Mann-Whitney test statistic.

2) Compare and contrast the combination of several parameters to help illustrate differences between categories.

3) Devise a normalized heavy precipitation parameter equation to help guide forecasters in identifying a potentially dangerous heavy rainfall event for the community.

4) Break down the dataset into elevated versus surface-based rainfall events. Then compare synoptic settings with Maddox (1979).