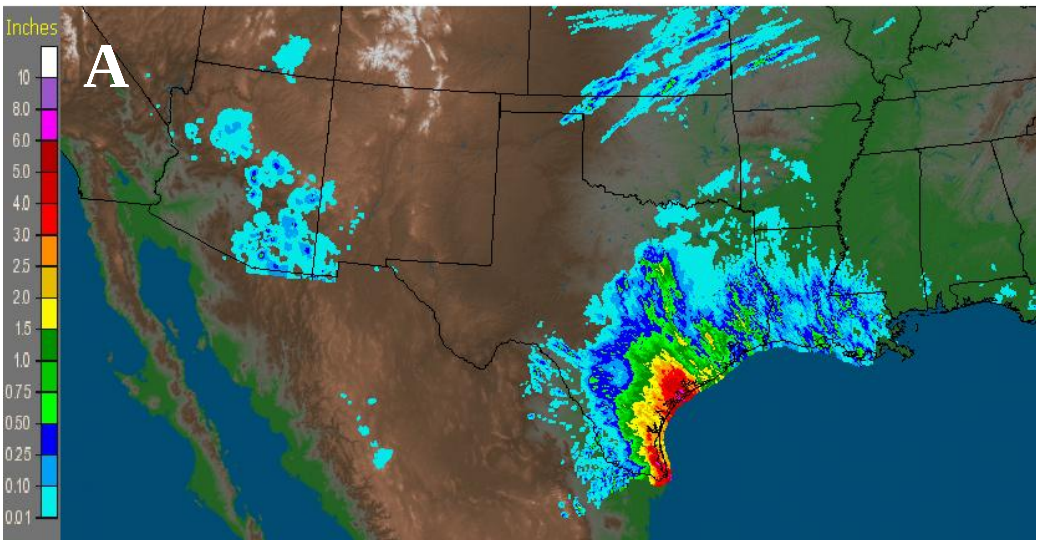
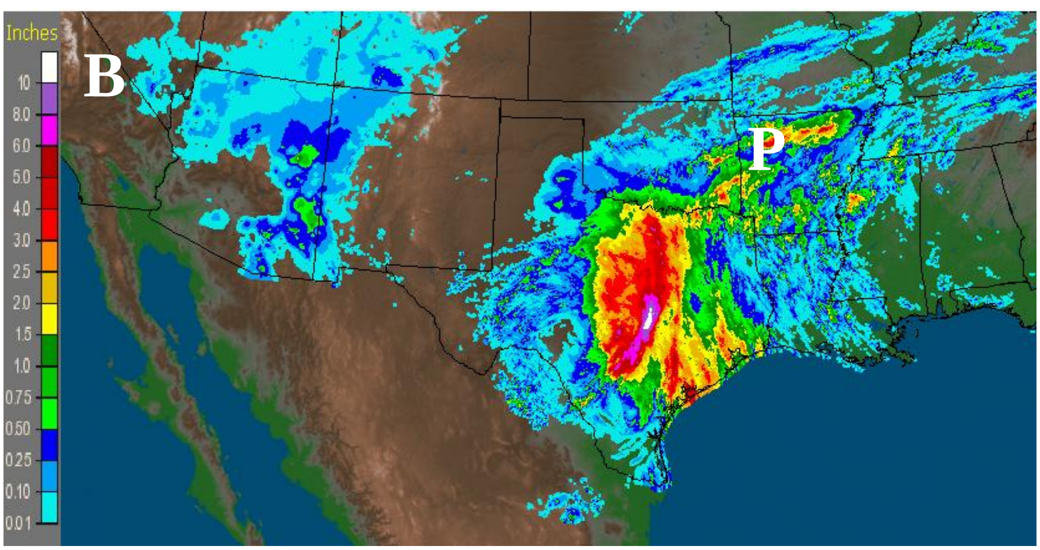
Event Review: Tropical Storm Hermine
By: Mike Soltow, HPC Meteorologist

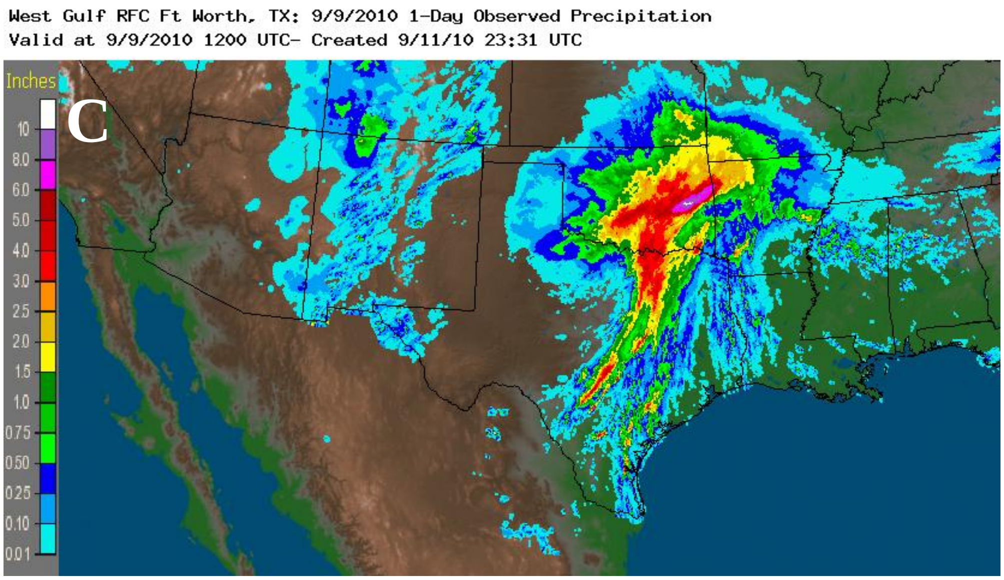
Overview: From September 6 through September 9, 2010, rains associated with Tropical Storm Hermine fell across much of the Southern Plains and the Lower Mississippi Valley. Texas was the hardest hit, with several locations, many in the Austin area, receiving over 10 inches of rain from the event. The highest total observed during the event was 15.62 inches at Georgetown, TX, which is about 25 miles north of Austin. Figures 1a-d show the observed daily rainfall evolution during the event.

West Gulf RFC Ft Worth, TX: 9/7/2010 1-Day Observed Precipitation
Valid at 9/7/2010 1200 UTC- Created 9/9/10 23:31 UTC



West Gulf RFC Ft Worth, TX: 9/8/2010 1-Day Observed Precipitation
Valid at 9/8/2010 1200 UTC- Created 9/10/10 23:31 UTC





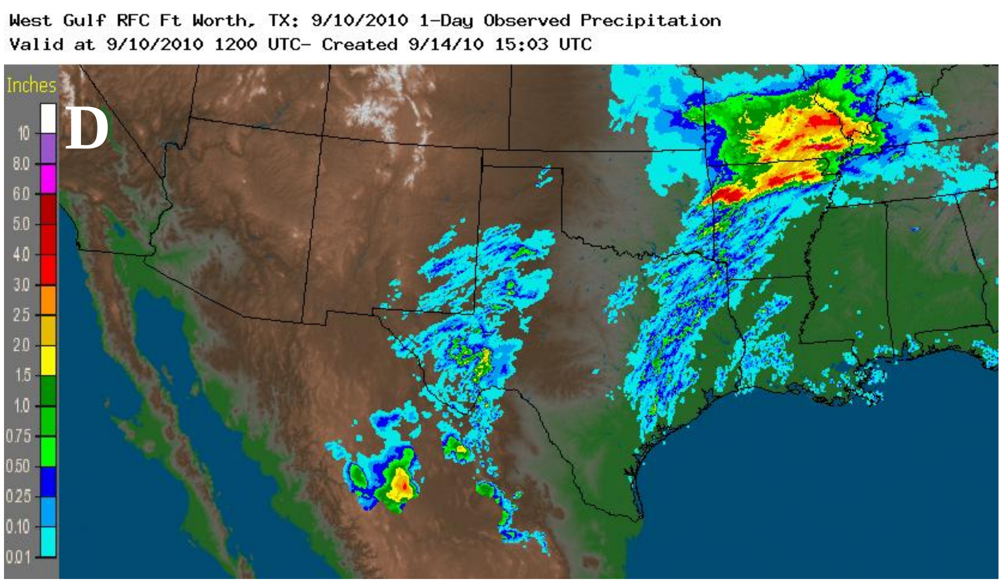


Figure 1: Observed 24 rainfall from 7 am to 7am on a) September 6-7, b) 7-8, c) 8-9, and d) 9-10, 2010.

Texas received the bulk of the rainfall on September 6 and 7 (Figs. 1a,b) as Hermine moved northward through the state. However, on Sept. 7-8 there is another area of rainfall to the north of the storm in Oklahoma and Arkansas (Fig. 1b), which occurred before the storm reached these states. This feature, which is labeled with a P in Figure 1b, is known as a predecessor rainfall event, or a PRE (Galarneau et al., 2010). Rainfall totals with this feature generally ranged from 1 to 3 inches, with a few areas receiving greater amounts. This helped to boost the rainfall totals across Oklahoma and Arkansas, as Hermine's main area of rainfall passed over these states during the next two days (see Figures 1c and 1d).

Flash flooding was common with this storm, but most of the mainstream river flooding was confined to Texas, which was due to both the larger rainfall totals over Texas as well as the distribution of the rainfall over Oklahoma and Arkansas. Most of the rainfall north of the Red River fell over the large reservoir complex of Lake Eufala and Kerr Reservoir, so only one mainstream river flood occurred in this region. On the other hand, rivers from the Gulf Coast north to the Dallas/Ft. Worth metro area reached flood stage. In addition to the rainfall, twelve tornadoes were reported in Texas, southern Oklahoma, and southwestern Arkansas with this storm.

Storm History and Timeline

Figure 2 below shows the track of Hermine. Hermine began as Tropical Depression Ten, which formed in the northern Bay of Campeche around 10 PM CDT on September 5, 2010. By 4 AM the next morning, this depression had strengthened enough to be named Tropical Storm Hermine. The storm then tracked northwest before making landfall along the northern Gulf coast of Mexico around 8:30 PM CDT on September 6. Hermine then turned to the north-northwest and tracked through central Texas before weakening to a tropical depression at around 7 PM on September 7. Hermine then gradually curved to the northeast and tracked into Oklahoma. Hermine lost its tropical characteristics and became a remnant low at around 4 AM on September 9, and then finally dissipated around 4 AM on September 10.

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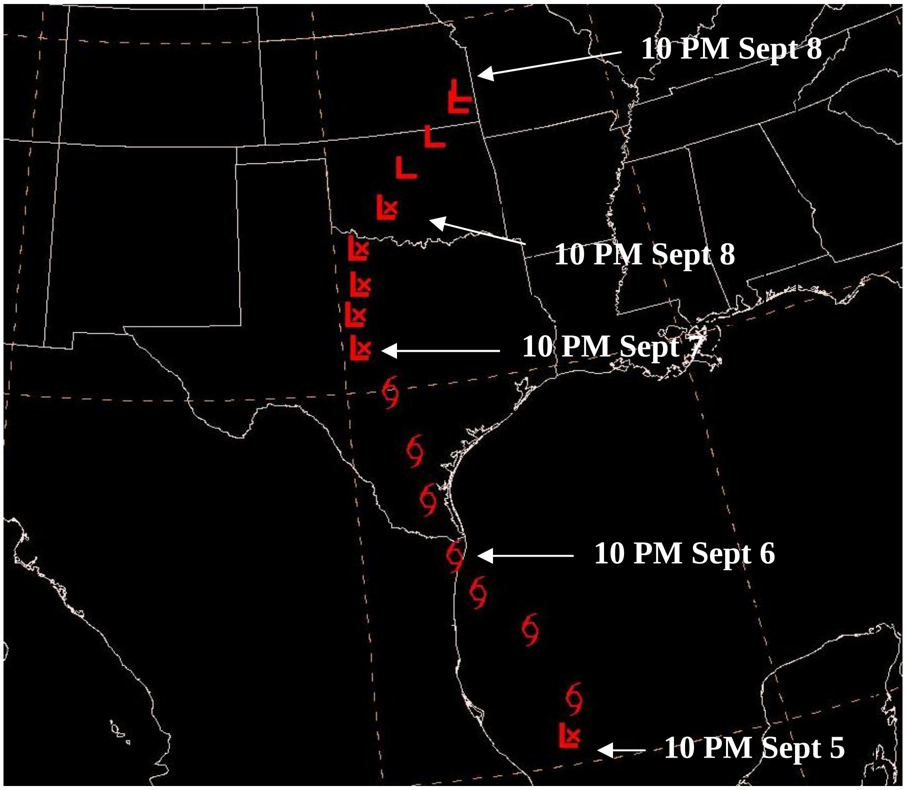

Figure 2: Storm track of Hermine (Circle = Tropical Storm, Lx = Tropical Depression, L = Remnant Low)

The initial rainbands associated with Hermine began to move over the south Texas coast at around 7 PM on September 6. As Hermine moved ashore and into Texas overnight, the rainfall began to intensify, particularly around 3 AM on September 7. Rain then continued to move across central Texas as the storm continued north.

By around 10 AM on September 7, a large area of rainfall had developed to the north of the storm, and was centered over southeast Oklahoma. This was the predecessor rainfall event, or PRE, that was discussed in the overview. This feature will be discussed in greater detail in the next section.

As Hermine moved further north and began to weaken, the precipitation shield began to change its structure, and no longer had the appearance of a classic tropical cyclone. In fact, at around 12 AM on September 8, a strong line of thunderstorms began to develop south of the storm center (Fig. 3). The band shows up quite nicely as a narrow strip of high reflectivities stretching to the south of the main precipitation shield. This line of convection kept the rainfall going over locations such as Austin, TX, which helped make the rainfall totals so high across those areas. Notice the narrow area of large rainfall totals in central Texas shown in Fig. 1b, coinciding with this band of convection.

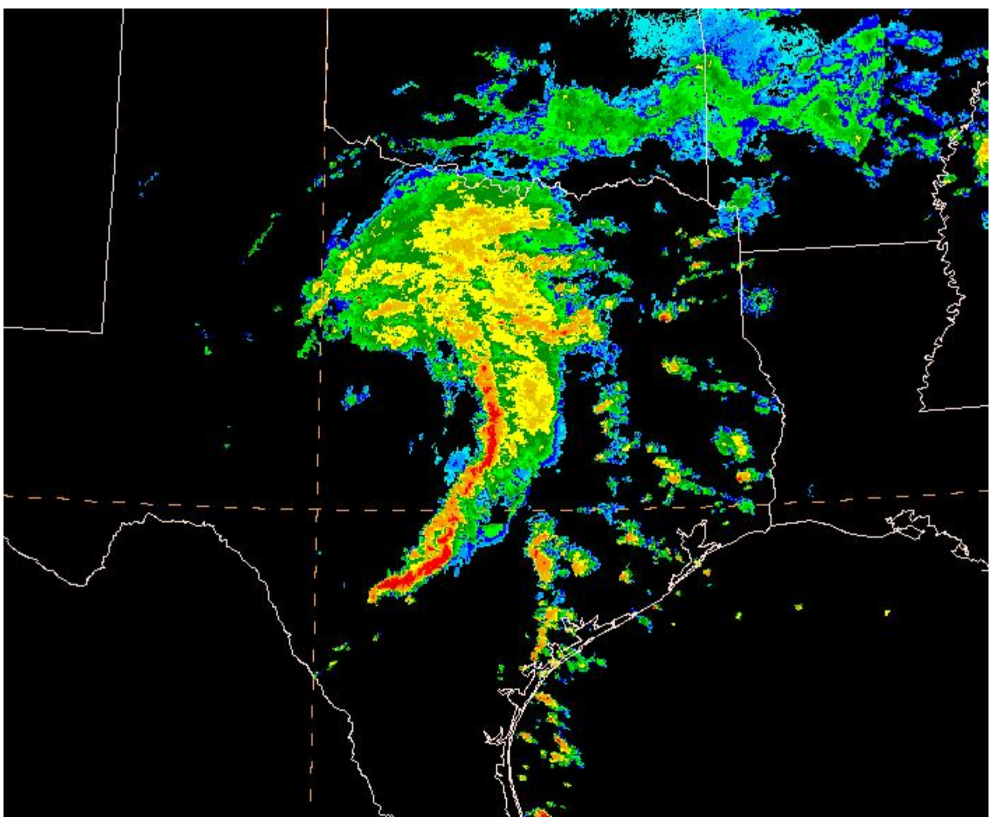

Figure 3: Radar imagery from 1 AM CDT on September 8, 2010. Notice the long band of convection that developed to the south of Hermine.

Examining surface data from this timeframe can provide some insight into the reasons for convective initiation this far south of Hermine. Fig. 4 shows the SPC mesoanalysis plot of surface wind, mixing ratio, and moisture convergence from 1 AM on September 8.

The location of Hermine at this time is indicated with an H. The plot shows that most of southeast Texas was covered by strong southeasterly winds that originated in the Gulf of Mexico. This flow met areas of drier air wrapping around the western side of Hermine, creating areas of convergence. This showed up in the analysis as a thin strip of moisture convergence stretching to the south of Hermine, which was at roughly the same location as the band of convection.

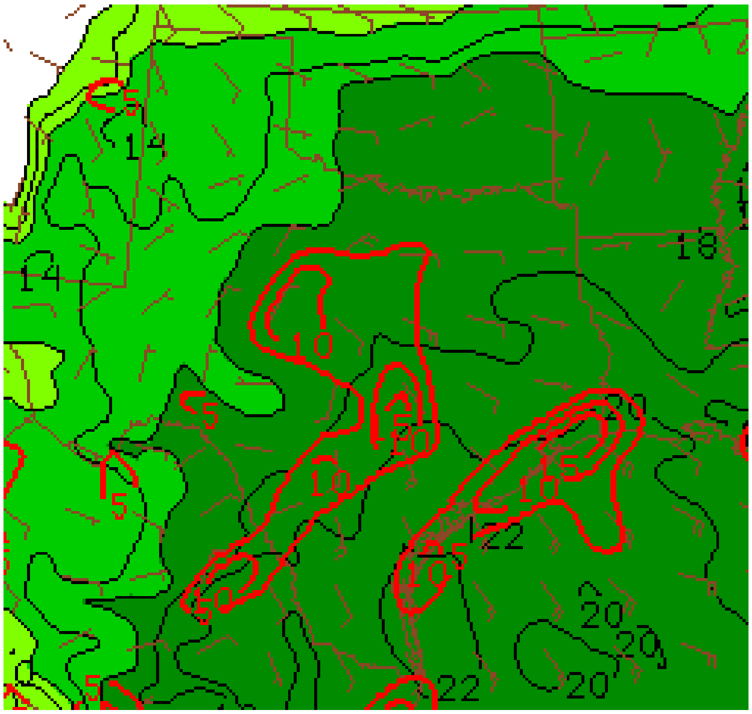

Figure 4: Surface moisture convergence (red lines), wind barbs, and mixing ratio (color fill) at 1 AM CDT on September 8, 2010. Source: SPC Mesoanalysis

The resulting convergence and moisture discontinuity created a strong enough boundary to initiate convection in the unstable environment near Hermine. This boundary set up near the Balcones Escarpment and remained relatively stationary for several hours, indicating that the terrain may also have provided forcing that helped initiate this band of convection. Regardless, because this boundary moved very little, heavy rain was able to persist for an extended period of time over a narrow area of central Texas.

Analysis of the PRE

The following two images show the national radar overlaid on the HPC surface analysis at 10 AM, and 1 PM CDT on September 7, 2010.

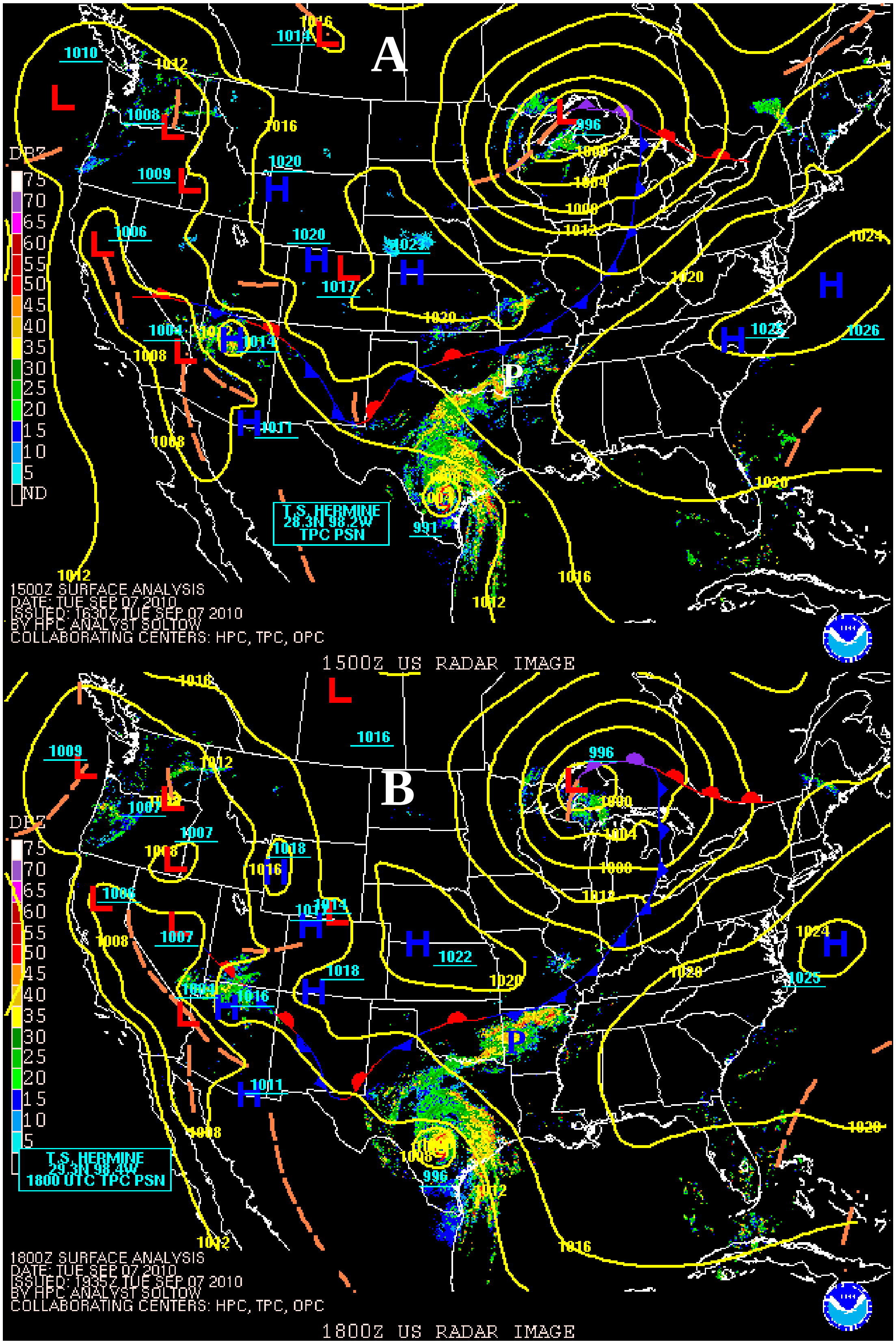

Figure 5: National radar imagery and HPC surface analyses from a) 10 AM and b) 1 PM CDT (1500Z and 1800Z, respectively) on September 7, 2010. The PRE location is marked with a P.

The small area of rainfall that develops to the north of the main precipitation shield is the PRE that was discussed earlier (this feature is labeled with a P in Figure 5). This section will examine the synoptic setup that contributed to this feature's development.

The 250 hPa analysis from 1 PM on September 7 (Fig. 6) shows a high pressure system over the Gulf of Mexico, as well as a jet streak centered over the Upper Midwest. The location of the PRE at 1 PM is indicated with a P, and the center of the jet streak is labeled with a J.

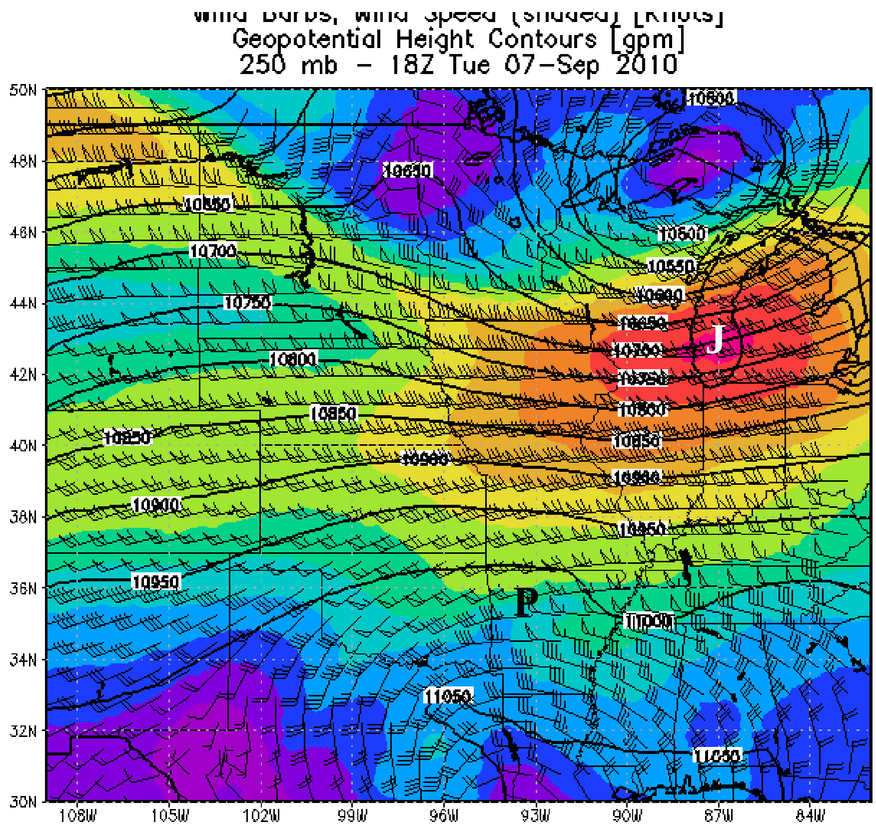

Figure 6: 250mb winds, and isotachs at 1 PM CDT on September 7, 2010, as analyzed by the NARR. The location of the PRE is labeled with a P, and the center of the jet streak is labeled with a J.

Notice that the PRE is located near the right entrance region of the jet streak over the Upper Midwest, which is a favorable region for enhanced lift. Further down, at 850 mb (analysis shown in Fig 7), we can see more synoptic support for the PRE.

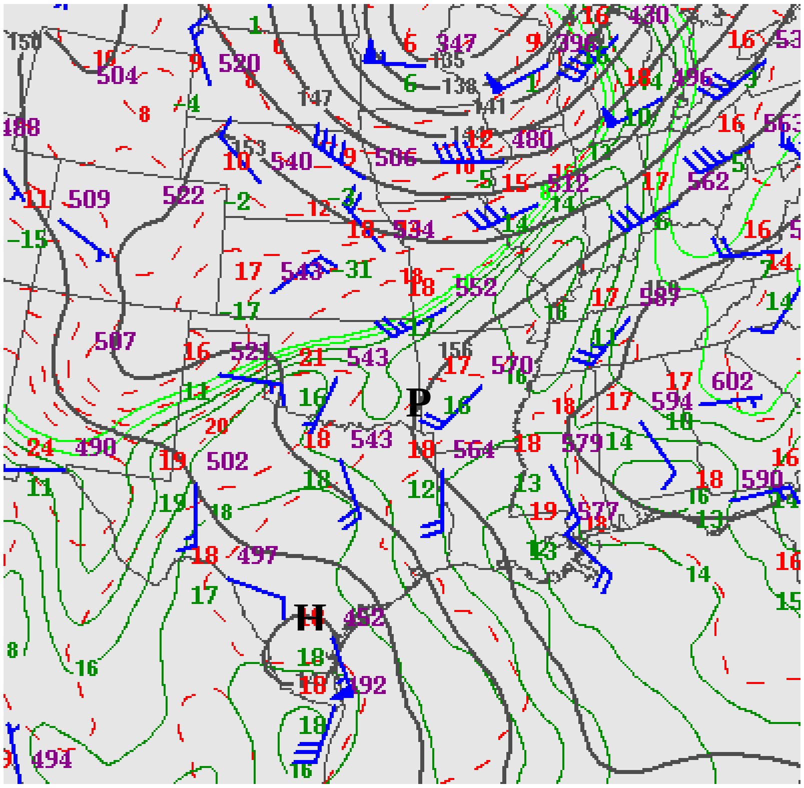

Figure 7: 850mb winds, heights (black lines), and temperatures (green lines) at 7 AM CDT on September 7, 2010. The location of Hermine at 10 AM is indicated with an H, while the location of the PRE at 10 AM is indicated with a P. Source: SPC

A baroclinic zone was draped across the center of the country that corresponds to the surface front from the 7 AM surface analysis in Figure 5. In addition, southerly winds are evident across Texas, and over Hermine, suggest that moisture was being transported northward from Hermine towards this baroclinic zone. In order to confirm this, a 24 hour backward trajectory from the PRE's location at 1 PM CDT on September 7 to 1 PM on September 6 was created using NOAA's HYSPLIT model. Using the NAM12 as a base for the model, a plot was created for an air parcel 1500m above sea level (~850 mb) at this location. The resulting trajectory (Fig. 8) shows that the air arriving in northern Arkansas at 1 PM on September 7 was located in the Gulf of Mexico 24 hours earlier.

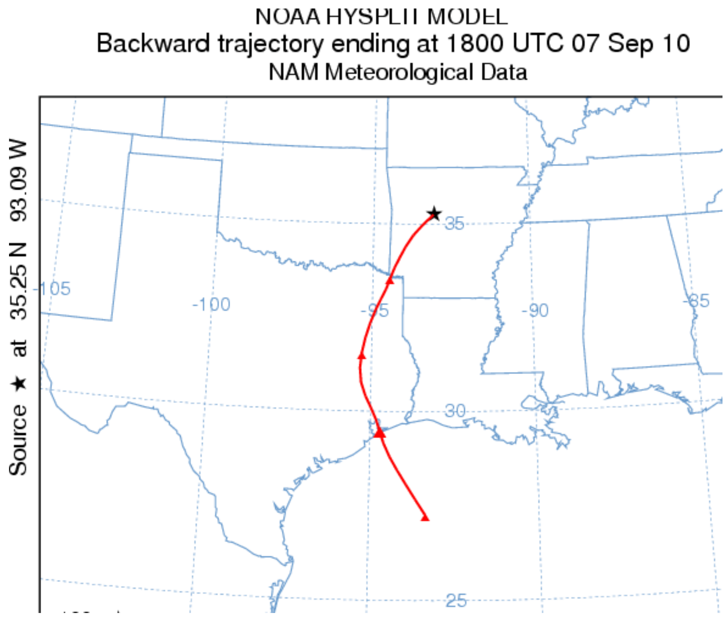

Figure 8: 24 hour backwards trajectory of an air parcel 1500m ASL at the PRE's location at 1 PM CDT on September 7, 2010. Source: NOAA HYSPLIT model

At 1 PM on September 6, Hermine was centered off the coast of Mexico, well south of this point. However, the tropical moisture associated with Hermine extended well to the north of the storm's center, as evidenced in the satellite image below (Fig. 9) and precipitable water analyses (not shown).

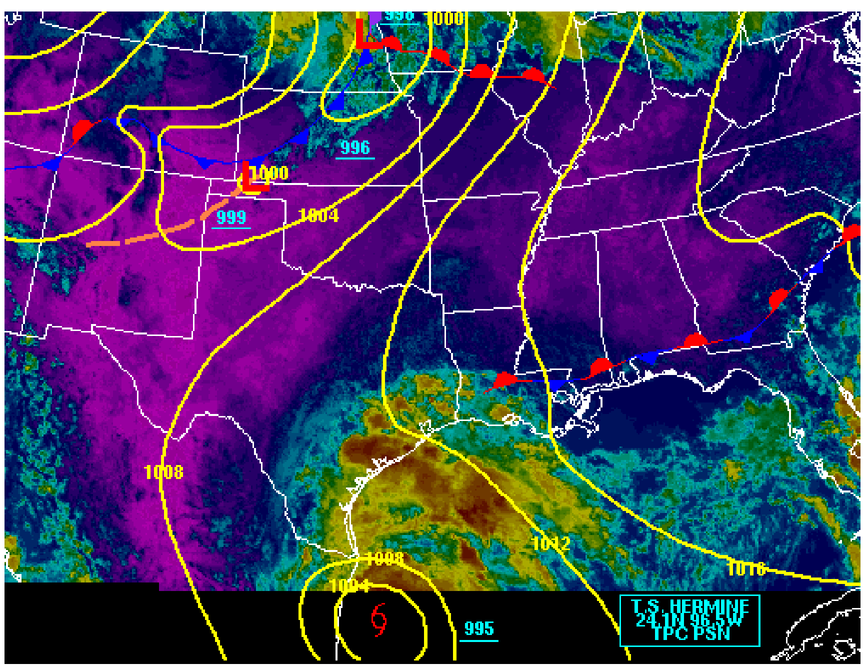

Figure 9: Surface analysis and IR satellite image at 1 PM CDT on September 6, 2010.

Notice the cloud shield extending well north of Hermine's center. Upon reexamining Figure 8, we can see that the end of the trajectory is in this cloudy region over the western Gulf, suggesting that the air parcels at the PRE's location did indeed originate in a region of rich tropical moisture associated with Hermine. This moisture was then advected northward along the trajectory in Fig. 8 towards the baroclinic zone, where it was forced upwards. The jet dynamics discussed earlier further contributed to the lift in this region, and the combined effect was heavy precipitation.

Conclusion

Tropical Storm Hermine had a significant impact on the south central United States as it moved through the region from September 6 – 9, 2010. Tornadoes and wind damage created problems across the region, but the main impacts of the storm resulted from the storm's heavy rainfall, especially across Texas. While the main precipitation shield certainly resulted in a large amount of rain across the region, smaller features also played a significant role in generating flooding. A favorable synoptic setup at the mid and upper levels of the atmosphere acted to develop a predecessor rainfall event across Oklahoma and Arkansas. In addition, a zone of convergence located near the Balcones Escarpment led to the initiation of an intense, stationary band of thunderstorms and heavy rainfall over central Texas after Hermine had already moved to the north. These features combined to produce several days of heavy rainfall and flooding across the region.

References:

Galarneau, Thomas J., Lance F. Bosart, Russ S. Schumacher, 2010: Predecessor Rain Events ahead of Tropical Cyclones. *Mon. Wea. Rev.*, **138**, 3272–3297.