Meteorological Review of the 05 Feb 2004 Heavy Rainfall and Flooding Event

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1. Intro and Synoptic Overview

This event review will focus on the synoptic and mesoscale conditions as the event unfolded, as well as the performance of the short-term models in handling these conditions and the resultant precipitation fields. Heavy rainfall first entered Northwest Alabama during the early morning hours on Thursday February 5th, before slowly spreading eastward across the remainder of the Huntsville CWA over the next 24 hours. By 12Z that morning, much of Northwest Alabama had already received over 0.50", with parts of Lauderdale and Colbert counties seeing as much as 1 to 2 inches (see Fig. 1a). This prolonged heavy rain event eventually brought widespread rainfall accumulations of 3 to 5 inches across the entire CWA (see Fig. 1b), with some isolated higher amounts upwards of 6 to 7 inches.

On the synoptic scale, a 500 mb RUC analysis at 03Z the previous evening (see Fig. 2) shows a southern stream closed low and trough axis ejecting out of the Rockies, with a ridge axis located across the Carolinas. This places much of the southern U.S. within a favored area for heavy rainfall, with a broad southwest mid-level flow between the 500 mb trough/ridge axis providing the area with a moist, deep layer airmass. Also of note is the absence of stronger shortwaves east of the Plains, with just very weak shortwaves noted shearing eastward ahead of the main system from west Texas to near St. Louis. Thus, while these shortwaves certainly enhanced the larger scale lift, other factors likely played a more substantial role in the increased rainfall rates during this event.

A surface analysis taken at 03Z (see Fig. 3a) shows a 1000mb surface low centered across southern Texas, with a warm frontal boundary draped along the Gulf Coast and an inverted trough oriented approximately from eastern Texas to western Tennessee. IR imagery and lightning data at this time (Fig. 3b) display the large area of heavy rainfall/elevated convection ongoing along and northwest of the frontal boundary and inverted trough. The most interesting area of convection was across parts of the Arklatx region, where surface temperatures and dewpoints were only in the mid to upper 30s (Hot Springs, Arkansas temperature is 34). This would indicate that strong low level inflow is producing tremendous amounts of warm air/moisture advection and isentropic lift aloft, thus helping to release this elevated convective instability and likely enhancing the heavy rainfall northwest of the frontal boundary and inverted trough.

2. Summary of what happened and model performance

By 06Z, the area of heavier precipitation/convection had shifted eastward over the Mississippi River and remained oriented along and west of the inverted trough axis and north of the warm front (see Fig. 4). By this time, precipitation had entered northwest Alabama, with 06Z KGWX radar showing this precipitation as light to perhaps moderate in intensity at the onset (see Fig. 5). The remainder of Figure 5 compares this radar coverage to the corresponding 6-hr QPF progs taken from available 00Z model forecasts. Based on this, it's apparent that all 3 models were too slow and weak with the precipitation at the onset. The NGM is clearly the worst, with no accumulating precipitation even shown in Mississippi. Very little improvement if using the ETA, with forecasted accumulations still under 0.1" east of the Mississippi River despite the ongoing heavy rainfall across northwest Mississippi and western Tennessee. The AVN does a better job in advancing the higher QPF's eastward, but is still too slow with the onset in Northwest Alabama and is likely underforecasting the amounts in northwest Mississippi. Other moisture fields within the models showed similar "poorly resolved" results. Thus, this is another example of an inadequately forecasted overrunning situation where the models could not handle the timing or intensity of the precipitation at the onset. These problems were likely only magnified by the enormity of this particular overrunning event.

Moderate to heavy precipitation with isolated thunder continued through the morning hours of the 5th, primarily west of Huntsville. By 18Z, the surface low had lifted northeast into southern Mississippi with the attendant warm front surging northward toward the Tennessee Valley (see Fig. 6). Figure 7 compares the MSLP and QPF from the 18-hr progs of the 00Z 05-Feb AVN and ETA model runs versus that of the actual 18Z composite reflectivity and MSAS MSLP data. The AVN is slightly too far north with the surface low, but seems to have a "reasonable" handle on the location and amounts of QPF. However, the ETA continues to have difficulties, with the surface low mistakenly too far northwest and the QPF amounts substantially underforecasted east of the Mississippi River.

Figure 8 displays the current radar at 18Z along with some LAPS analysis of a few of the key heavy rainfall ingredients. A closer examination of these ingredients revealed that a strong 60-70 kt southerly 850 mb jet core was oriented across the region, with heavy precipitation continuing along and just west of the jet axis. This LLJ was inducing significant isentropic lift and moisture transport north of the surface warm front. Precipitable water values were now exceeding 1.25" (200-250% above climo), with impressive upstream and ambient K-Index values of 30 to 35. High levels of upstream instability within the warm sector were also being transported northward, providing a continued source for elevated convection. The heavy precipitation axis was also aligned with the 850 mb theta-e ridge and within an area of high theta-e advection.

Figure 9 displays the 18-hr model progs for these parameters. Both models did a decent job in showing the location of 850mb theta-e ridge axis. They also properly depicted a 60+kt 850mb jet, although the ETA appears too far north with the main jet core. The AVN correctly showed tremendous theta-e advection ongoing across the entire Tennessee Valley, while the ETA inadequately displaced the highest 850 mb theta-e advection too far north. Finally, both models displayed high ambient and upstream precipitable water values, although the AVN correctly indicates a larger swath of PW exceeding 1.5 just southwest of the Tennessee Valley.

The heavy precipitation began to shift eastward during the late afternoon and evening hours. By 00Z that evening, the surface low was near Tupelo, MS with the warm front well north of the Huntsville CWA (Fig. 10). Ongoing elevated instability and the resultant heavy convective rainfall appeared to be maximized during the evening hours as the area moved into the warm sector and within the right entrance region of a 130+ kt 250mb jet. The 00Z BHM sounding (Fig. 11) showed a decent area of elevated CAPE above 775 mb and model sounding data for the area showed similar profiles. There was also no shortage of available moisture, as the BHM sounding displayed a precipitable water value of 1.41" and a K-Index value of 33.

The 24-hr AVN prog from the 00Z 05-Feb model run remained somewhat closer to reality than did the ETA (Fig. 12). The ETA continued to place the surface low and main moisture axis too far west. However, the QPF amounts were really underforecasted by both models during this 6-hour period. As indicated by the LAPS analysis and composite radar (Fig. 13), the main moisture axis was still located along the 850 mb theta-e ridge axis and west of the 850 mb southerly low level jet core. Precipitable water continued to exceed 1.25, while K-Index values remained between 30 and 35. Each model showed decent placement of the 850 mb theta-e ridge, with the AVN displaying more accuracy in depicting the 850 mb jet location and the continued strong theta-e advection across and just north the Tennessee Valley (Fig. 14).

The surface low surges northward into the Ohio Valley through the overnight hours, with the heavy precipitation axis gradually advancing eastward ahead of the cold front. The final radar/LAPS display at 06Z (Fig. 15) shows the 850mb theta-e ridge and jet core have finally shifted east, along with the convection. Periods of moderate to heavy rainfall will taper off from west to east through the remainder of the overnight hours, before pushing east of the CWA around daybreak.

3. Final Thoughts

This event occurred within a synoptically favorable environment for sustained periods of heavy rainfall. The area was located within a broad mid level southwest flow, with a surface frontal boundary positioned to the south. As this frontal boundary lifted northward as a warm front, strong southerly low level winds brought substantial isentropic lift and moisture advection over this boundary and established an environment conducive for heavy rainfall. This deep layer moisture was indicated via extremely large PW values and K-indices through model and sounding data. The heavy precipitation was also enhanced by elevated convection, brought on primarily by the isentropic transport of upstream instability from within the warm sector. The main precipitation axis remained focused along the low level theta-e ridge and along or just west of the low level jet max, within an area of 850 mb moisture convergence and positive theta-e advection. Increased divergence within the right entrance region of the 250 mb jet also aided in increasing the convection and heavy rainfall toward the end of the event.

Overall, the models did a poor job in resolving the QPF fields, with both the timing and amounts incorrect. As with many overrunning events, the models were too slow with the precipitation onset. They were also too weak with the initial precipitation intensity, indicating a tenth or less across Northwest Alabama, when up to an inch fell in some areas during the first 6-9 hours. The ETA in particular just seemed a bit off with this event, showing inadequate QPF amounts and timing that was a good 6-12 hours behind.

However, an analysis of several model mass and thermal fields showed that the models (in particular the AVN) did an adequate job in predicting several of the parameters related to heavy rainfall. Thus, despite insufficient model QPF fields, a closer analysis of these key ingredients could significantly enhance the confidence for or against forecasting a prolonged heavy rainfall and significant flooding event. A flash flood/heavy rainfall decision tree, located next to the phone on the communications table and also attached at the end of this summary, is a useful list summarizing some of the fields that a forecaster may want to focus on leading up to these events.

(a)

(b)

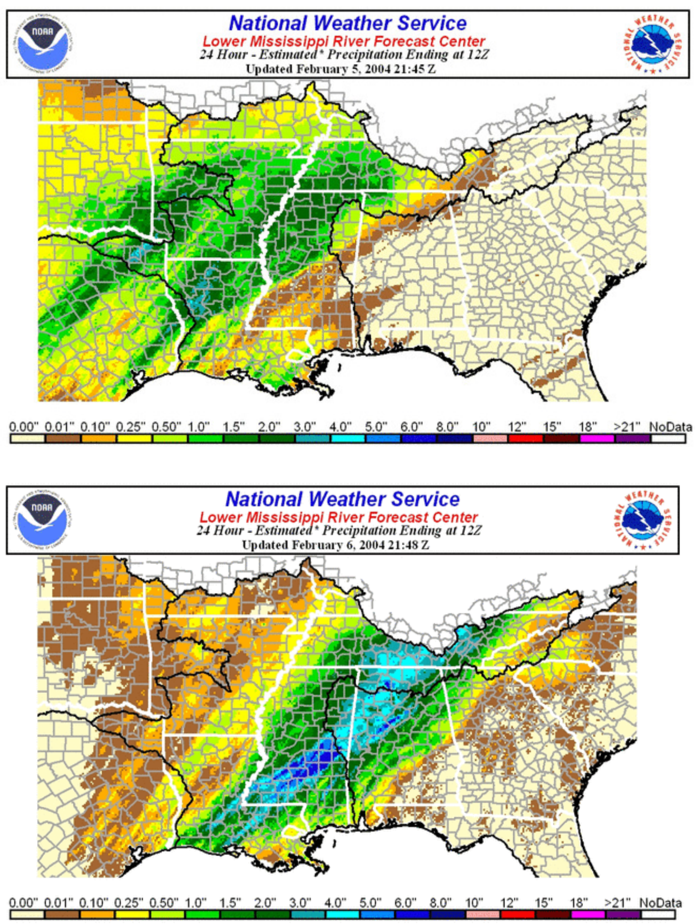


Figure 1: 24 hour estimated precipitation from the LMRFC ending at 12Z on (a) February 5th and (b) February 6th.

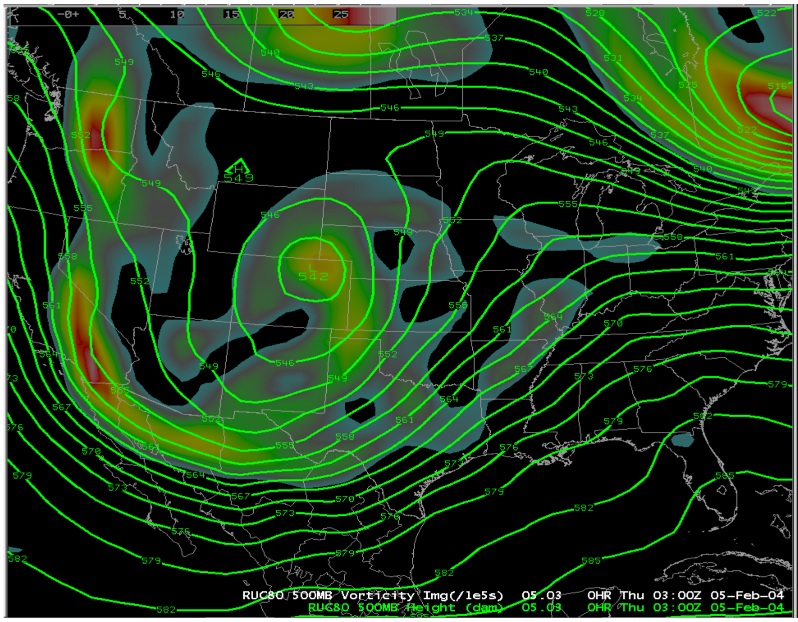
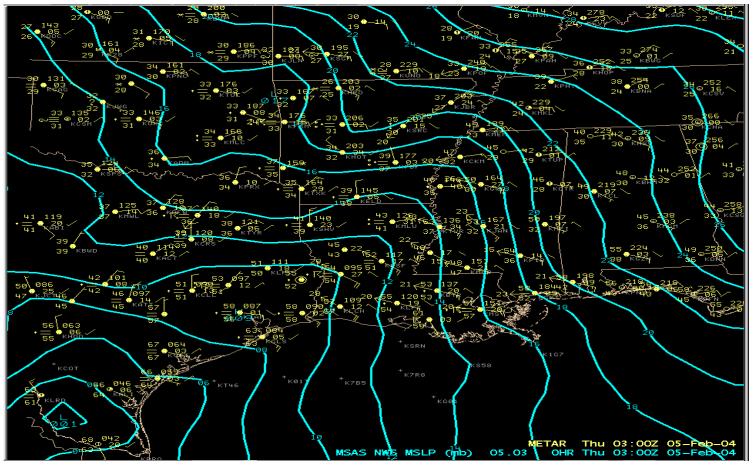


Figure 2: RUC analysis of 500 mb height and vorticity at 03Z.

(a)



(b)

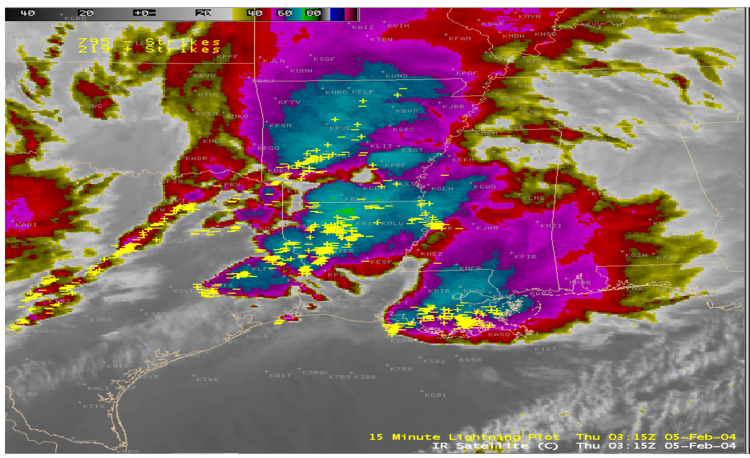
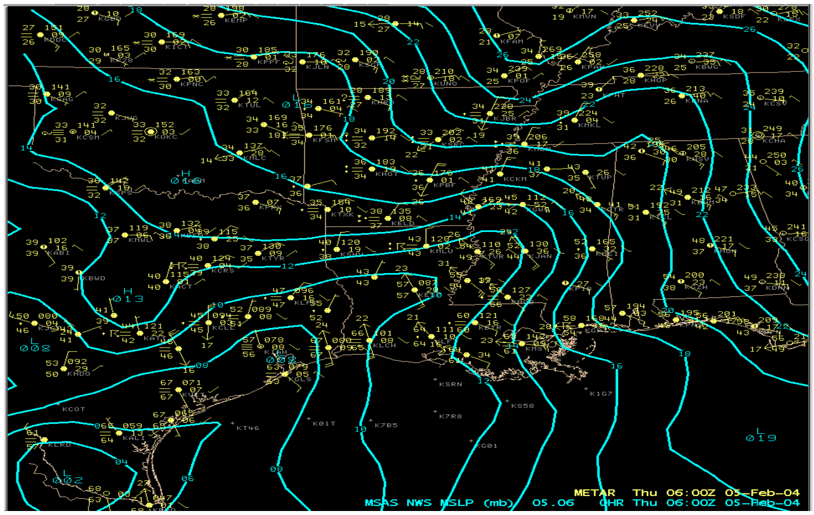


Figure 3: (a) 03Z surface analysis and (b) 03Z IR image with lightning data.

(a)



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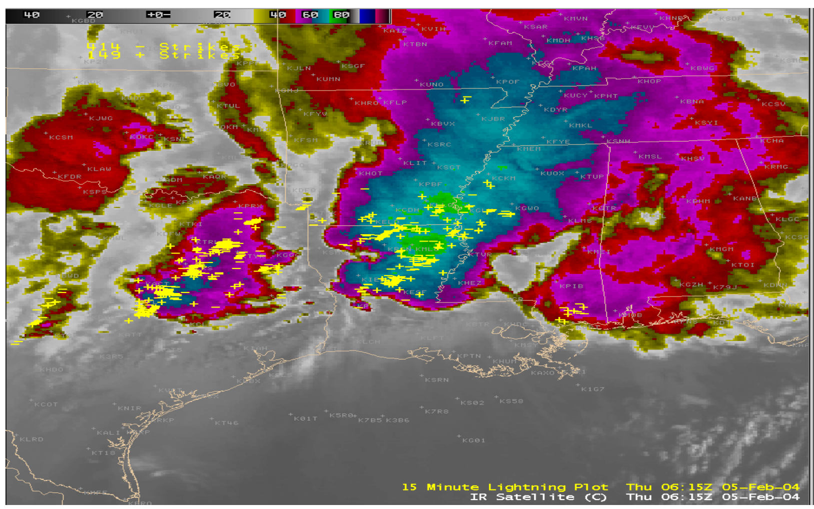


Figure 4: (a) 06Z surface analysis and (b) 06Z IR image with lightning data.

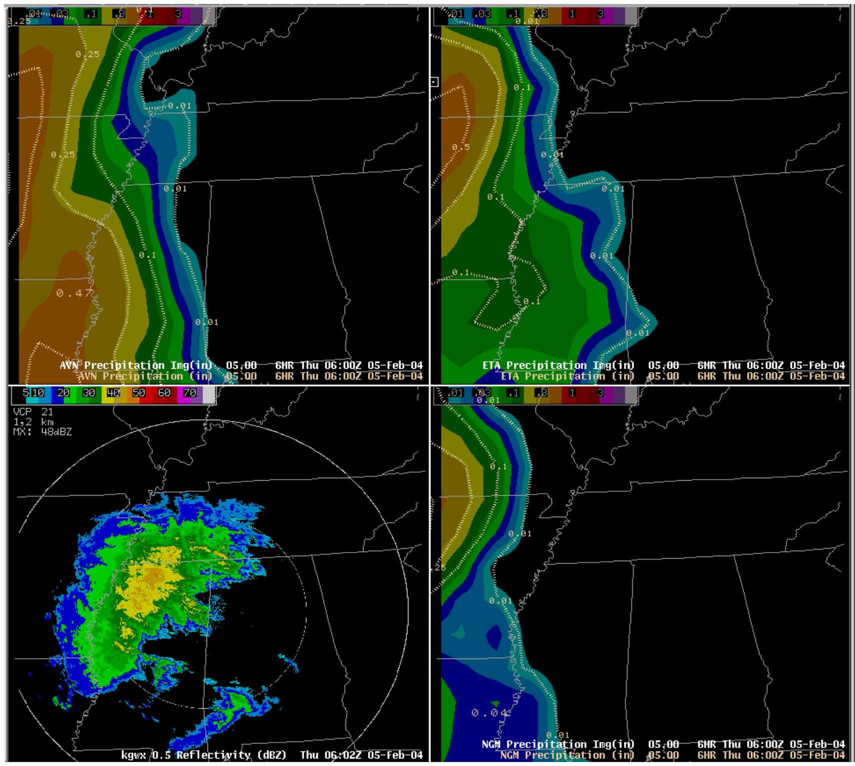
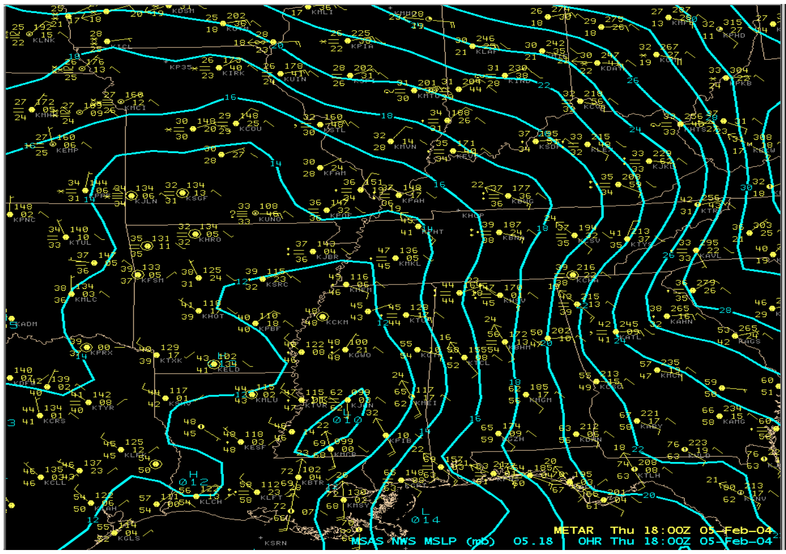


Figure 5: 6-hr qpf AVN, ETA and NGM model forecasts at 06Z and the corresponding KGWX radar image.

(a)



(b)

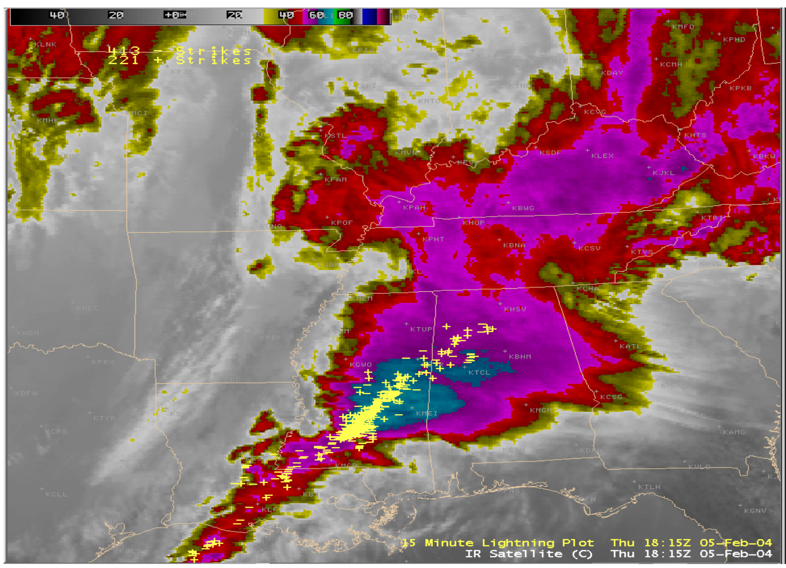


Figure 6: (a) 18Z surface analysis and (b) 18Z IR image with lightning data.

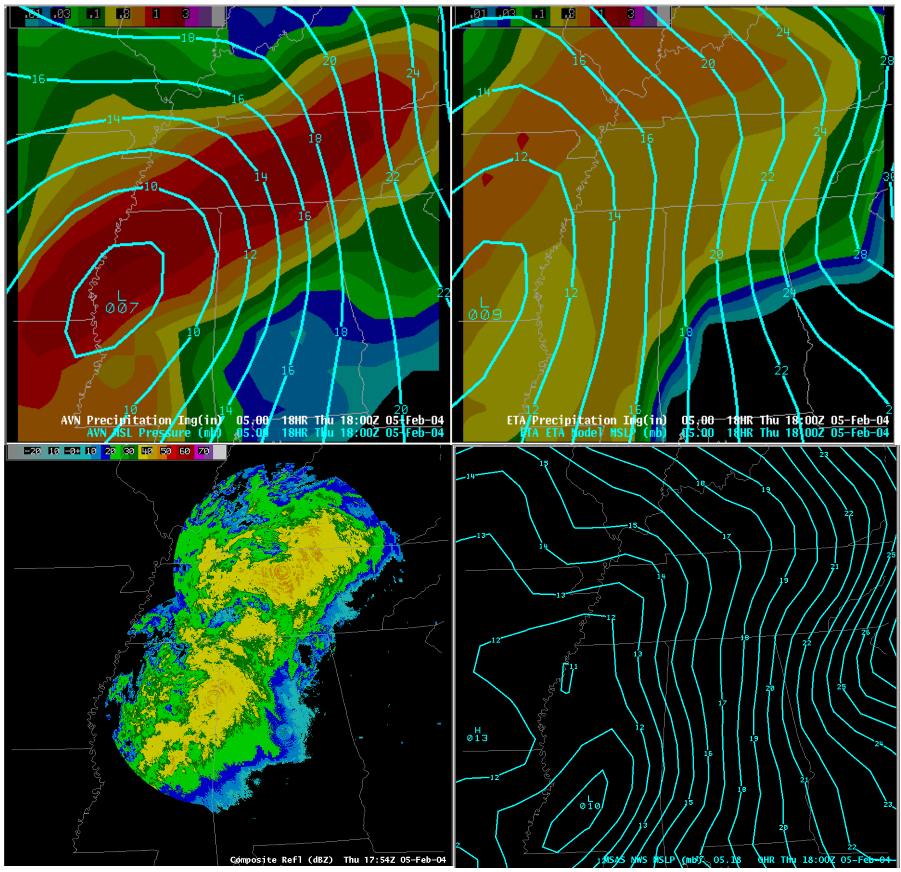


Figure 7: AVN and ETA 18-hr forecast of MSLP and precipitation (top), 18Z HTX radar and MSAS MSLP analysis (bottom).

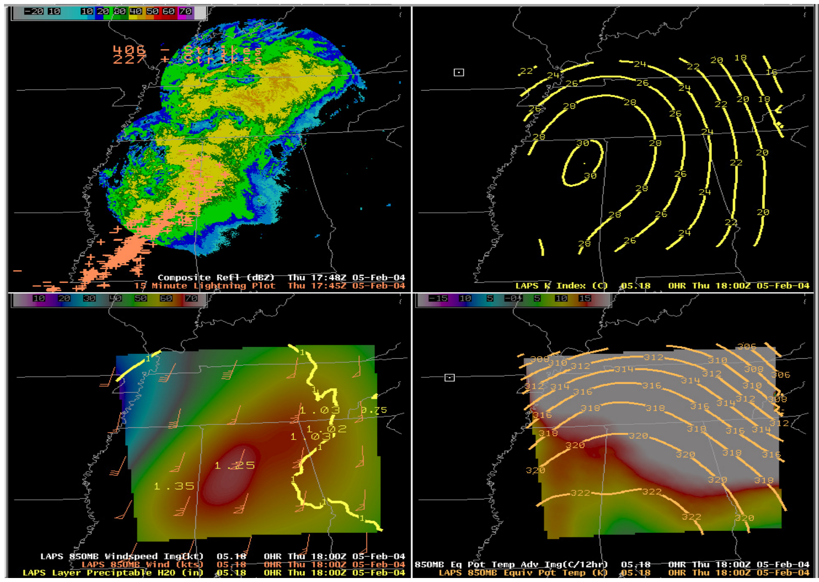


Figure 8: 18Z KHTX radar image with corresponding 18Z LAPS analysis.

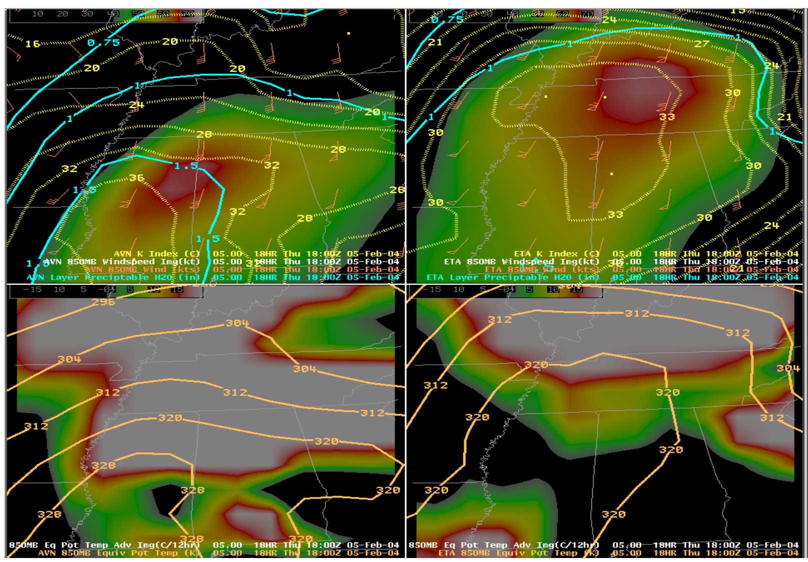


Figure 9: AVN and ETA 18-hr forecast of precipitable water, K Index and 850 mb winds (top), 850 mb theta-e and theta-e advection (bottom).

(a)

(b)

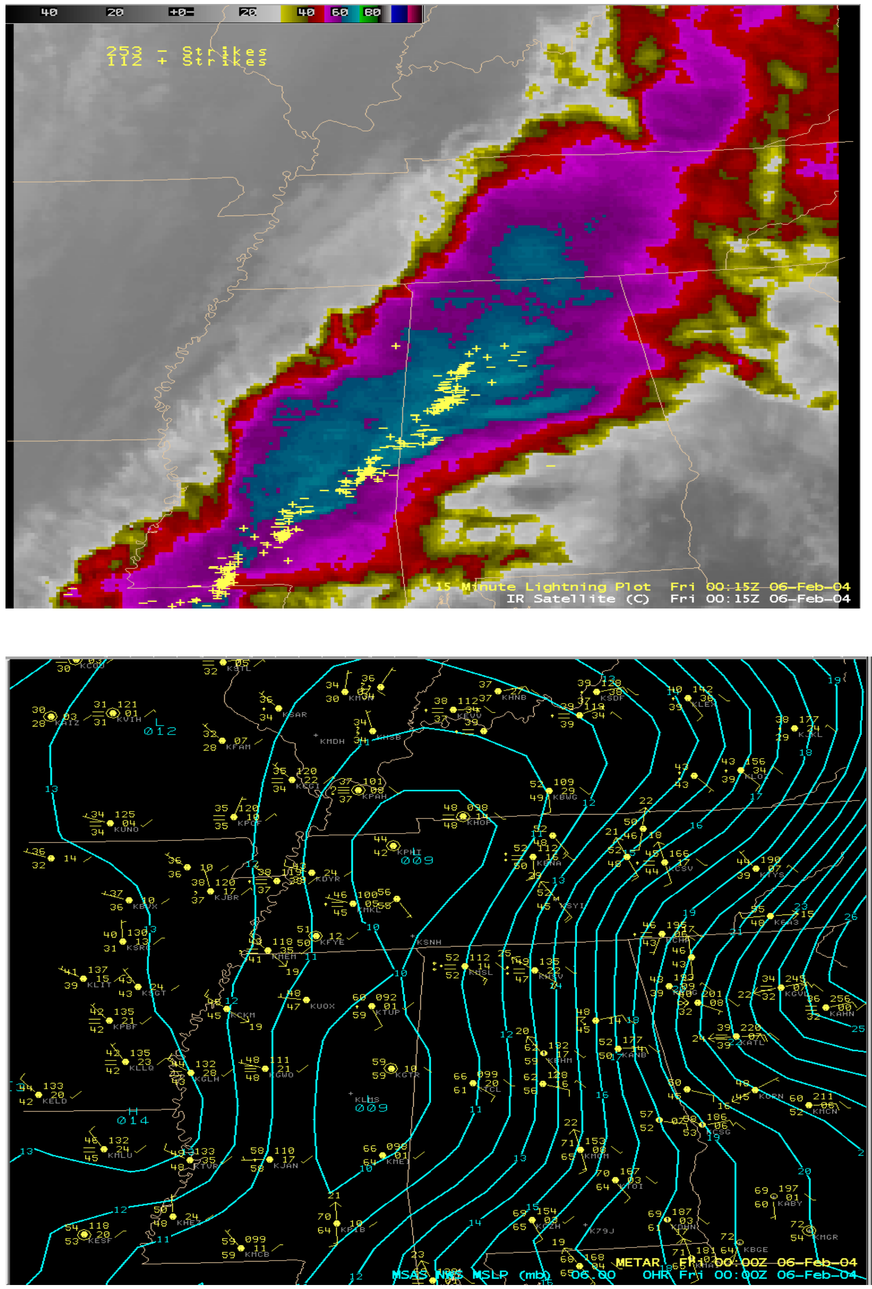


Figure 10: (a) 00Z surface analysis and (b) 00Z IR image with lightning data.

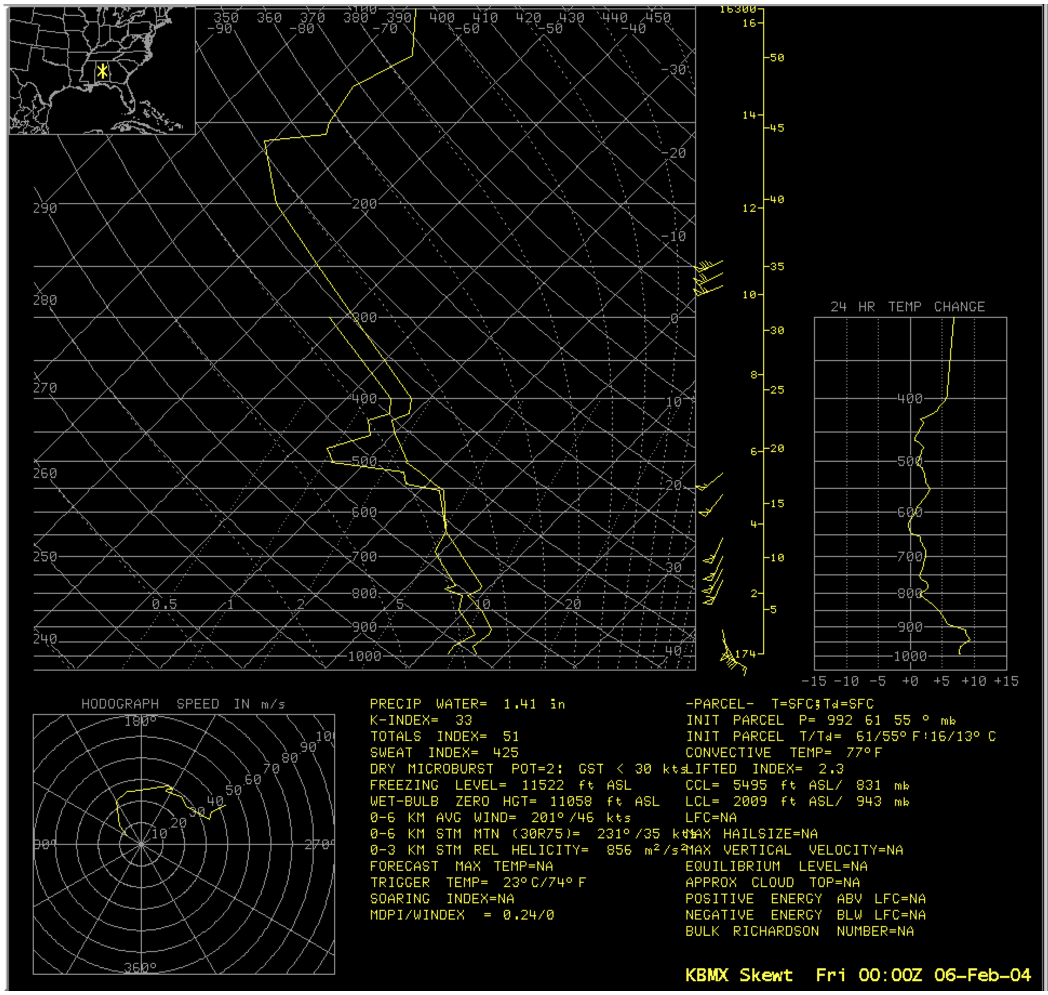


Figure 11: 00Z BHM sounding.

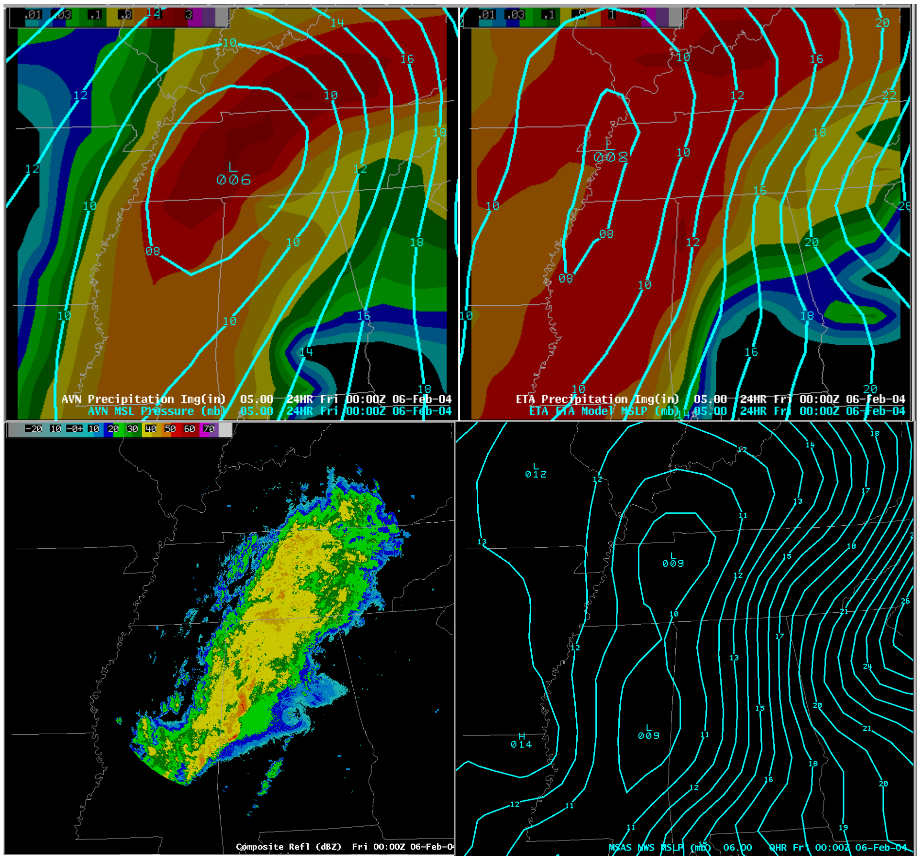


Figure 12: AVN and ETA 24-hr forecast of MSLP and precipitation (top), 00Z HTX radar and MSAS MSLP analysis (bottom).

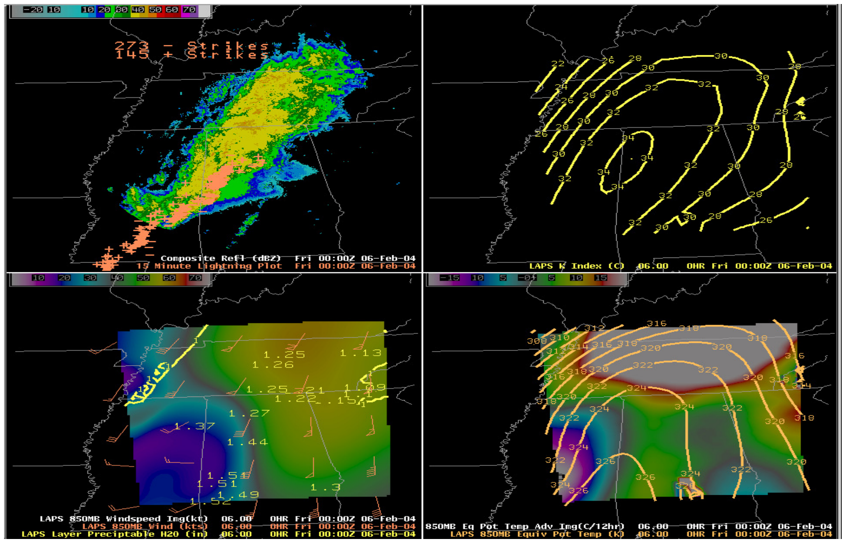


Figure 13: 00Z KHTX radar image with corresponding 00Z LAPS analysis.

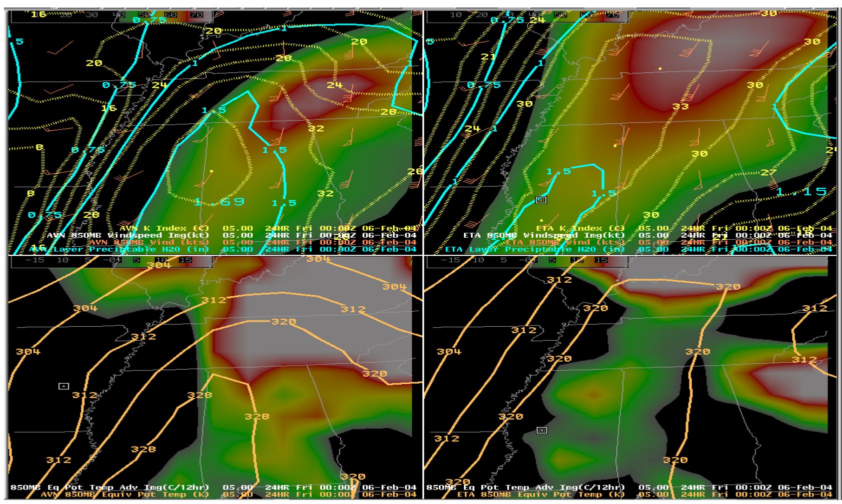


Figure 14: AVN and ETA 24-hr forecast of precipitable water, K Index and 850 mb winds (top), 850 mb theta-e and theta-e advection (bottom).

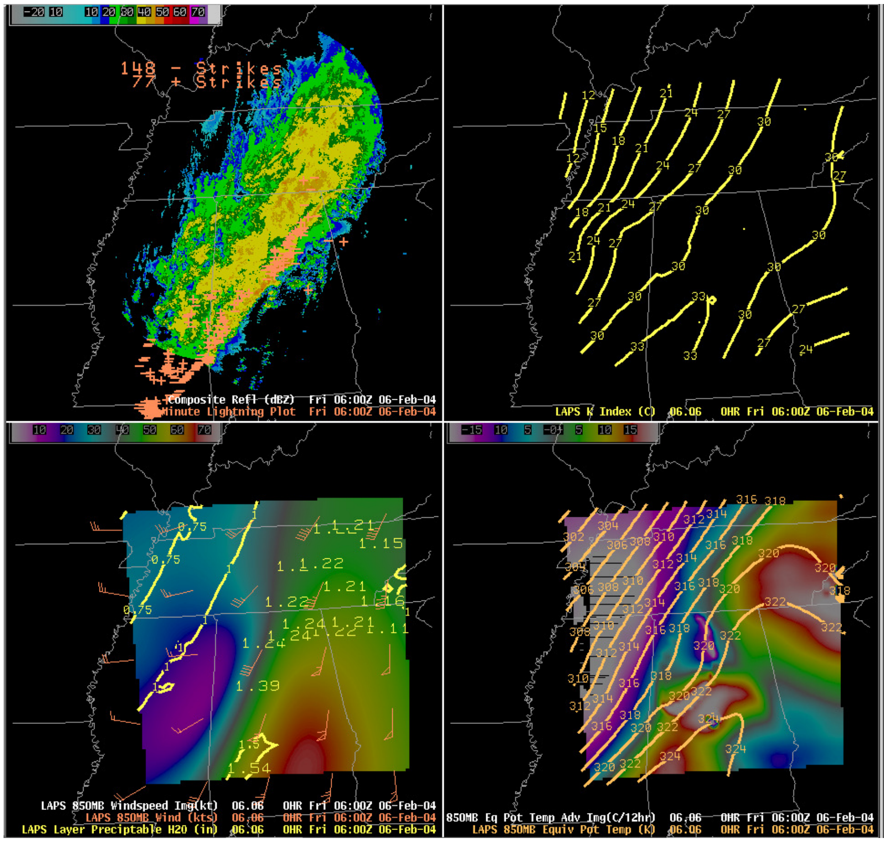


Figure 15: 06Z KHTX radar image with corresponding 06Z LAPS analysis.