Western Region Technical Attachment
NO. 04-05
June 18, 2004

August 29, 2002 South Central Montana Flash Flood Event

By Albert Richmond and Sally A. Springer
National Weather Service Billings, Montana

Introduction

On the 29th of August 2002, a series of thunderstorms developed over south central Montana and northern Wyoming (Fig 1). The first in the series of these storms developed along a nearly stationary surface boundary. Thunderstorms continued to redevelop along the boundary for several hours. Five to eight inches of rainfall was estimated by WSR-88D within a three-hour period in the vicinity of this boundary, which resulted in a flash flood event (Fig. 2). The flash flooding took place in a rural area of Treasure County. A sheriff deputy from Treasure County MT went to the area of concern and reported several rural roads were flooded along with nearby fields.

Numerical guidance received earlier in the day, poorly predicted where the thunderstorms would develop. Models developed convection along a surface trough, which was forecast to be too far east. In addition, forecast soundings and hodographs also suggested that the storms would move quick enough to prevent flash flooding. However, further analysis of satellite, radar, surface observations, along with Aircraft Communications Addressing and Reporting System (ACARS), showed a flash flood potential just as the convection began to develop. This paper will provide an overview of the synoptic and mesoscale environment that lead to the development of this flash flood event. Since numerical models did not indicate the possibility for flash flooding for this event, the focus of this paper will be on how observational data could have been used alone to recognize flash flood potential.

Pre-storm Synoptic and Mesoscale Environment and Numerical Model Assessment

Analysis of the water vapor imagery revealed a nearly stationary upper level low-pressure system over Southeast Idaho on 28 Aug, 2002, through early on the 29th. During the afternoon of the 28th, convection developed to the north and east of the upper level low in a diffluent region aloft. The convection eventually weakened overnight on the 28th through the morning of the 29th. . An upper level trough approaching the Pacific Northwest coast on the 29th caused the Southeast Idaho upper low to accelerate to the east toward southwest Montana. As a result, the diffluent region associated with convection the prior day, shifted over south central Montana on the 29th (Fig 3). Numerical models forecast the movement of this upper low and diffluent region fairly well.

In the morning of the 29th a surface trough was moving north through southern Montana. MAPS Surface Analysis System (MSAS) analysis of equivalent potential temperature revealed a moisture maximum along with surface convergence extending along the trough axis. However, precipitable water was only about 125 percent of normal. Numerical models moved this surface trough north of the flash flood area and focused most of the convection along this axis during the afternoon of the 29th , and not in the region of diffluent flow associated with the upper level low.

A modified 1259Z ACARS sounding, using the expected maximum temperature and respective dew point, revealed a weak cap would be present late on the 29th near Billings. The wind profile on the 1259Z ACARS also showed the atmosphere was weakly sheared and favored storms moving northeast around 15 knots (Fig 4). The 12Z Eta on the 29th forecast sounding also indicated a weakly sheared environment at 13Z and was in fairly good agreement with ACARS (Fig 5). The Eta forecast for the afternoon maintained the weak shear and favored mean storm motions from the south around 15 knots with right movers heading east around 10 knots. Left moving storms were forecast by the ETA to move much more rapidly. The Eta forecast valid for 13Z showed considerably more moisture below 700mb than the 1259Z ACARS. However, the near surface dew point on ACARS was considerably lower than Billings ASOS. Therefore, the ACARS moisture profile was likely not representative. The 12Z Eta forecast precipitable water to increase from 0.72 inches at 13Z to 0.90 inches by 00Z on the 30th (not shown).

Near Storm Environment, Numerical Model Assessment, and Evolution of Thunderstorms

A surface analysis at 22Z on the 29th revealed the surface trough extended from 40 miles north and east of Billings into the southeast corner of Montana. A moisture axis as depicted by surface dew points extended along the trough axis from South Dakota to near Billings (Fig 6). The dew point values were slightly higher than depicted by the Eta and analyzed by MSAS.

A boundary (boundary 1) of unknown origin was apparent on KBLX 88D five miles east of Billings at 22Z (Fig. 7). This boundary remained nearly stationary from late morning through early afternoon. KBLX 88D VWP showed the wind profile west of the boundary was south to southeast just above the surface to 5000 feet (750mb) and southwest from 5000 feet to 15000 feet (750mb to 600mb) (Fig. 8). The flow was slightly stronger than the Eta forecast, but overall the Eta handled the wind profile well.

Two regions of convection developed and moved into south central Montana between 21Z and 22Z. One area of convection developed southeast of Billings near Fort Smith, but weakened shortly after developing. This convection produced an outflow boundary (Boundary 2), that moved north between 5 mph and 10 mph, through northern Big Horn County. The other area of convection developed over the higher terrain southwest of Billings. Around 22Z, an outflow boundary (boundary 3) produced by this convection became apparent on KBLX-88D moving northeast at 25 mph. Another boundary of unknown origin (boundary 4), organized just to the north of boundary 3 and was progressing northwest at less than 5 mph. (Fig. 9). None of these boundaries could be seen in visible or infrared satellite imagery due to extensive cirrus.

Boundary 1 moved slowly west through 2300Z, passing west of the Billings airport between 2230Z and 2300Z. As it did, a deeper southerly flow became established over Billings. A 2308Z ACARS showed the flow was southeast from the surface to 675mb with southerly flow above 675mb to 400mb (Fig. 10). Since the ACARS flight descended into the airport from the east, this wind profile is likely very representative of the convection occurring along boundary 3-4. A hodograph generated from the ACARS sounding indicated mean storm motions from the southeast around 12 knots with nearly stationary right movers, slower than indicated by the Eta. The ACARS also revealed lifting parcels with a dew point around 50F resulted in no cap. Thus, convergence produced by low level boundaries was sufficient enough to initiate convection. The weak wind profile, lift along low level boundaries, diffluent flow aloft with no cap, were clear clues to a potential heavy rain event despite the lack of abundant moisture (Maddox et al 1980). These clues were available to forecasters just as the convection was developing.

Boundaries 2, 3 and 4 continued moving at the same rate through 2315Z. However, boundary 3 merged with boundary 4 by 2315Z (Fig. 9). Shortly before the merger, a thunderstorm likely initiated by boundary 3, developed between the two boundaries over Treasure County. This storm split within 30 minutes of developing with the left mover heading north while the right mover drifted slowly east as denoted by the arrows on (Fig. 11.).

Between 2315Z and 0115Z, thunderstorms with very heavy rain developed to the southwest along boundary 3-4. As this convection built back to the southwest, boundary 2 approached Treasure County and enhanced the initiation of new convection. KBLX 88D VWP (Fig.12) revealed that the wind profile behind boundary 2 was drastically different than ahead of the boundary and no longer favored slower moving storms. In addition, surface dew points dropped 20F behind the boundary (Fig. 13). Therefore, observational analysis at 2330Z revealed the nearly stationary convection over Treasure County would begin to dissipate or begin to move more rapidly after boundary passage.

Radar estimated five to eight inches of rain over Treasure County between 2230Z on the 29th and 0200Z on the 30th (Fig. 2). VIL densities occasionally reached 1 $g*kg^{-1}feet^{-1}$ between 2330Z and 0115Z, which suggest some hail contamination, took place. Unfortunately, there were no gauge reports to verify the rain or hail amounts. Law enforcement officials reported several flooded fields and roads.

Conclusion

For models to produce reliable quantitative precipitation forecasts (QPF), they must accurately predict the development and evolution of convection (Phillip, Stensrud 1998). This is typically not accurately done in a mesoscale flash flood event. As Kuo et al. (1996) showed, the intensity of precipitation is extremely sensitive to the choice of cumulus parameterization scheme. Thus the cumulus parameterization scheme, impacts how well a numerical model will predict flash flood events. The inability of numerical models to resolve meso-scale features such as outflow boundaries, also limits the ability of the models to accurately predict the QPF of a flash flood event. Therefore, numerical models will not usually be able to directly predict a flash flood event via QPF forecast. Numerical models have a greater ability to predict parameters that are conducive for flash flooding such as moisture content and wind shear, diffluent flow aloft, which forecasters can use to access flash flood potential.

The 29 August 2002 12Z Eta QPF did not indicate a flash flood event. In addition, some of the parameters conducive to flash flooding were not depicted well by the Eta. These include the erroneous movement of the theta-E ridge out of the area and a storm motion faster then observed.

Because of numerical model limitations and errors, observational data was instrumental in showing the true potential for this flash flood event. WSR-88D along with ACARS, showed the steering flow favored enhancement of slower right moving storms whereas the Eta forecast did not. WSR-88D and ACARS also showed that slow moving outflow boundary interactions would take place, with little to no cap. Thus observational data showed a favorable environment existed for flash flooding while the Eta did not. This case serves as a good example of the importance of knowing the actual atmospheric conditions through analysis of observational data such as radar and ACARS. By understanding the true flash flood potential, warning meteorologists are better equipped to provide earlier warnings when thunderstorms first begin to redevelop over the same location rather than react to the first reports of flash flooding.

References

Maddox, Robert A., Faye Canova, L. Ray Hoxit, 1980: **Meteorological Characteristics of Flash Flood Events over the Western United States.** *Monthly Weather Review*: Vol. 108, No. 11, pp. 1866–1877.

Spencer, Phillip L., David J. Stensrud, 1998: **Simulating Flash Flood Events: Importance of the Subgrid Representation of Convection.** *Monthly Weather Review*: Vol. 126, No. 11, pp. 2884–2912.

Kuo, Ying-Hwa, Reed, Richard J., Liu, Yubao. 1996: **The ERICA IOP 5 Storm. Part III: Mesoscale Cyclogenesis and Precipitation Parameterization**. *Monthly Weather Review*: Vol. 124, No. 7, pp. 1409–1434.

Figures

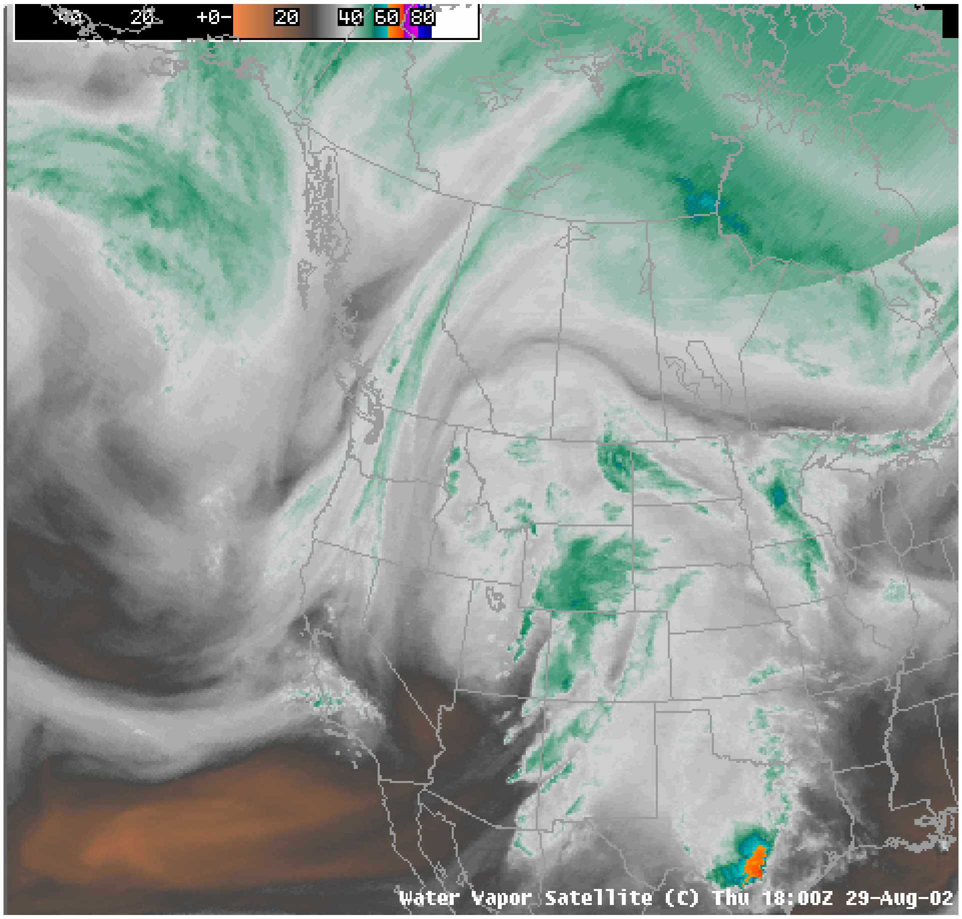

Figure 1

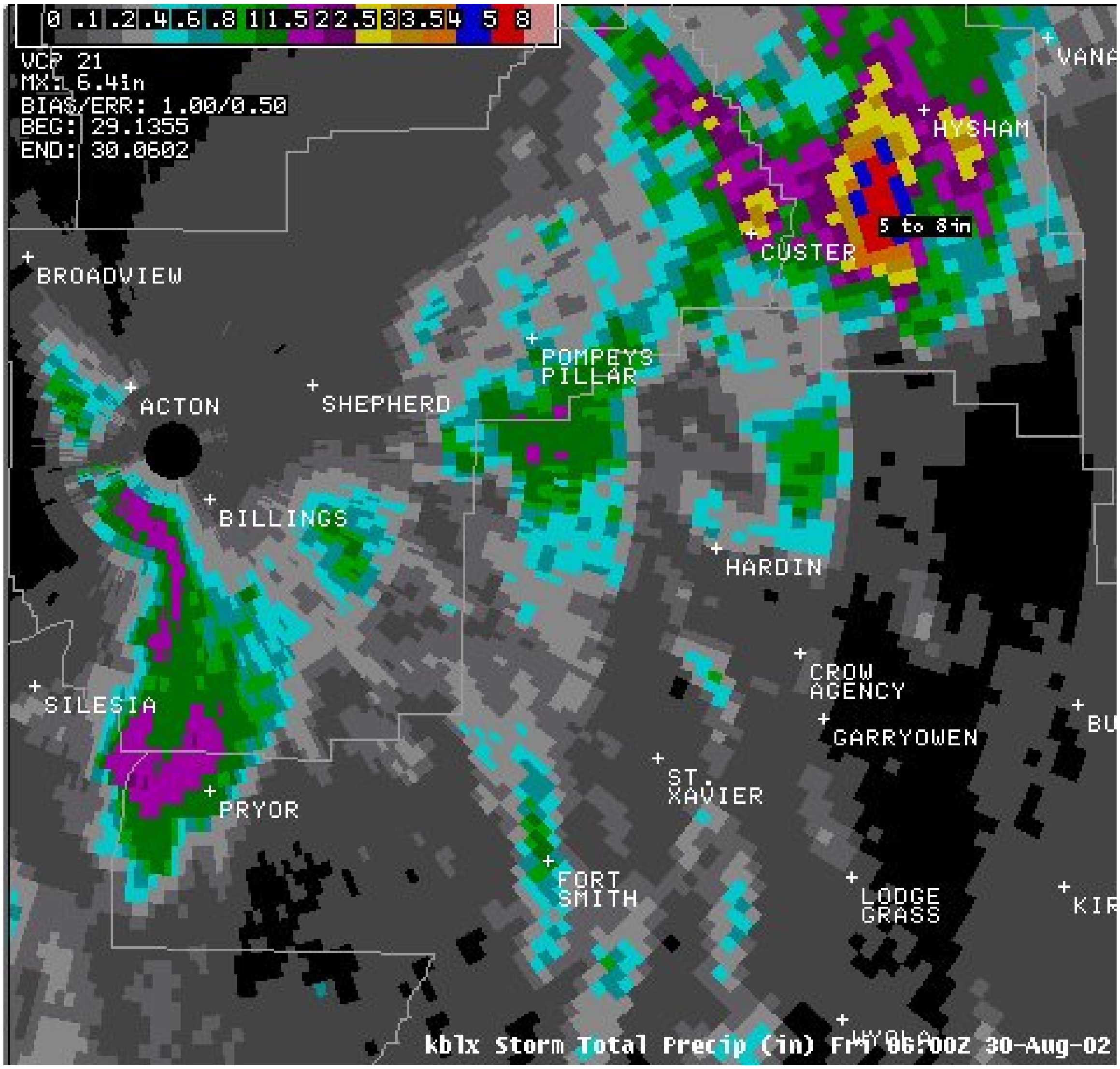
0 .1 .2 .4 .6 .8 1 1.5 2 2.5 3 3.5 4 5 8
VCP 21
MX: 6.4in
BIAS/ERR: 1.00/0.50
BEG: 29.1355
END: 30.0602
VANA
HYSHAM
5 to 8in
CUSTER
BROADVIEW
POMPEYS PILLAR
ACTON
SHEPHERD
BILLINGS
HARDIN
CROW AGENCY
SILESIA
GARRYOWEN
BU
ST. XAVIER
PRYOR
FORT SMITH
LODGE GRASS
KIR
WYOLA
kblx Storm Total Precip (in) Fri 06:00Z 30-Aug-02

Figure 2

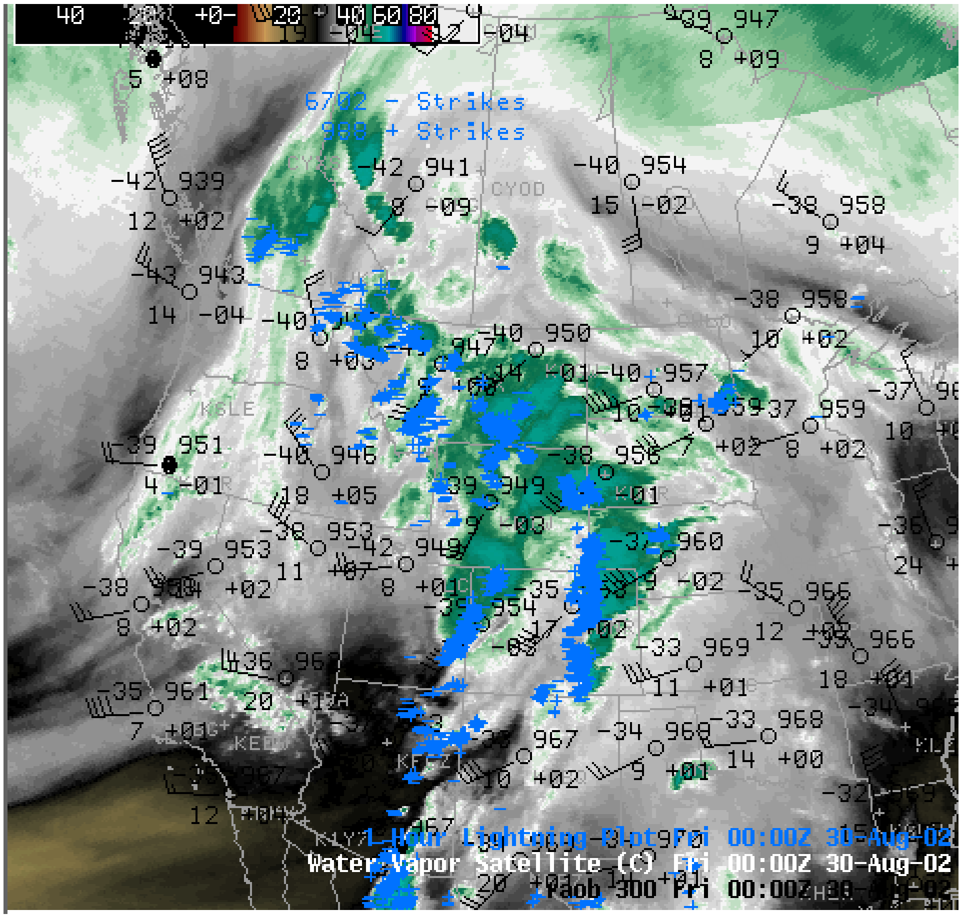
40
+0-
20
40 60 80
6702 - Strikes
988 + Strikes
1-Hour Lightning Plot Fri 00:00Z 30-Aug-02
Water Vapor Satellite (C) Fri 00:00Z 30-Aug-02
Raob 300 Fri 00:00Z 30-Aug-02

Figure 3

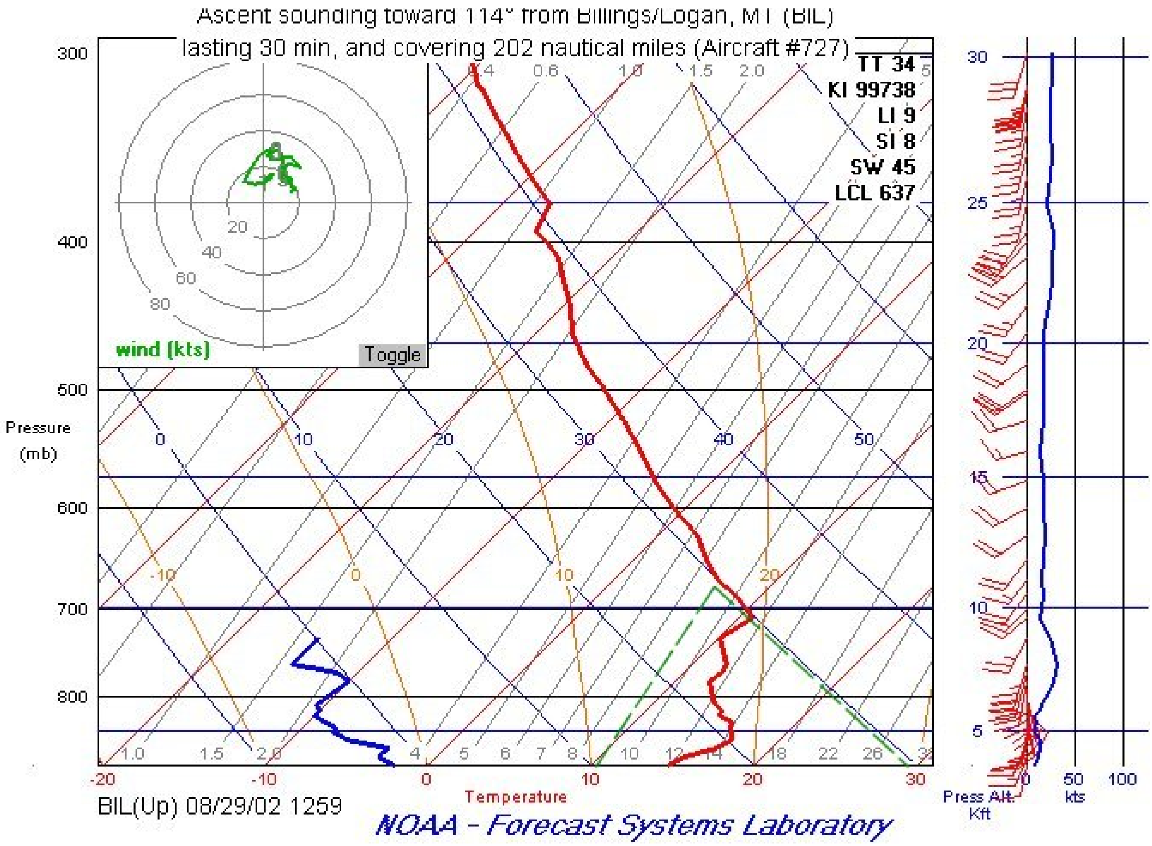

Figure 4

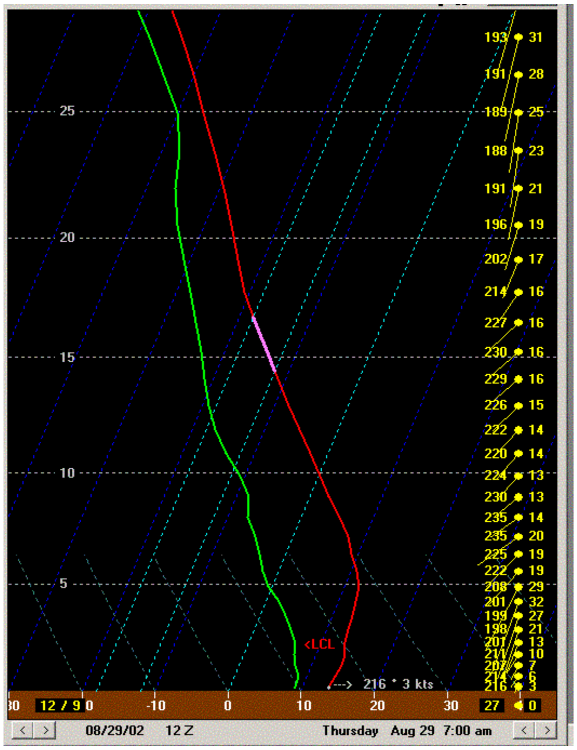

Figure 5

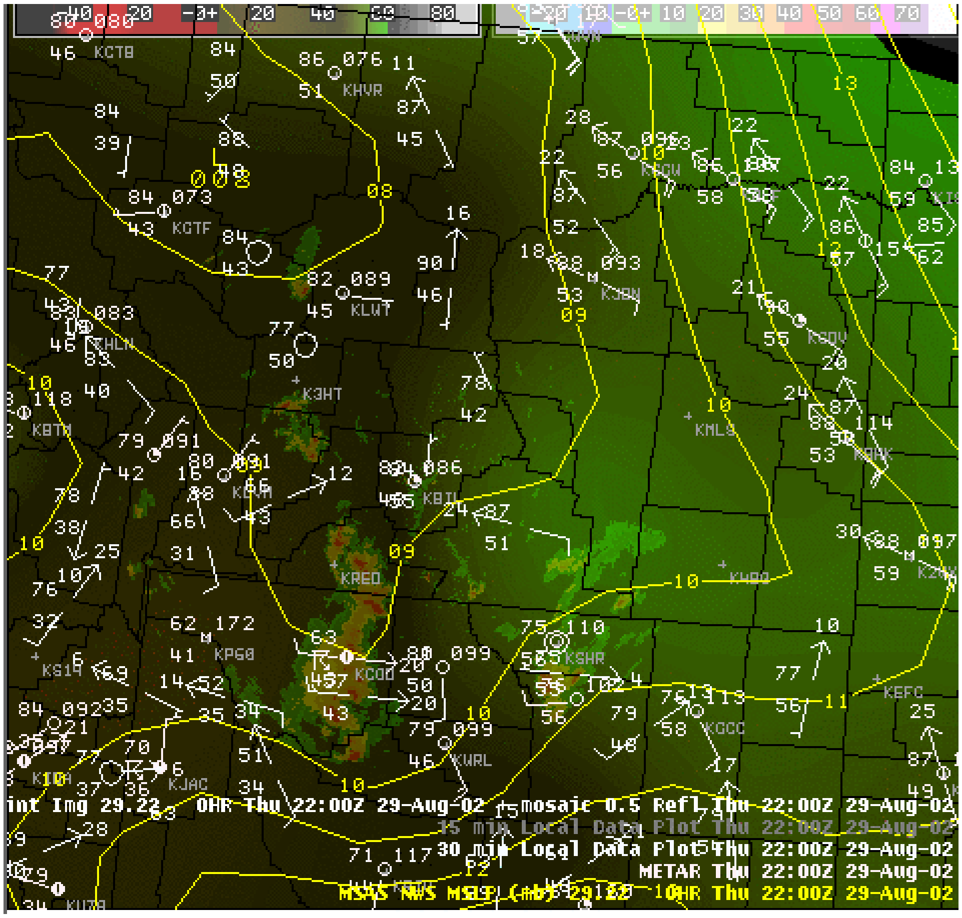

Figure 6

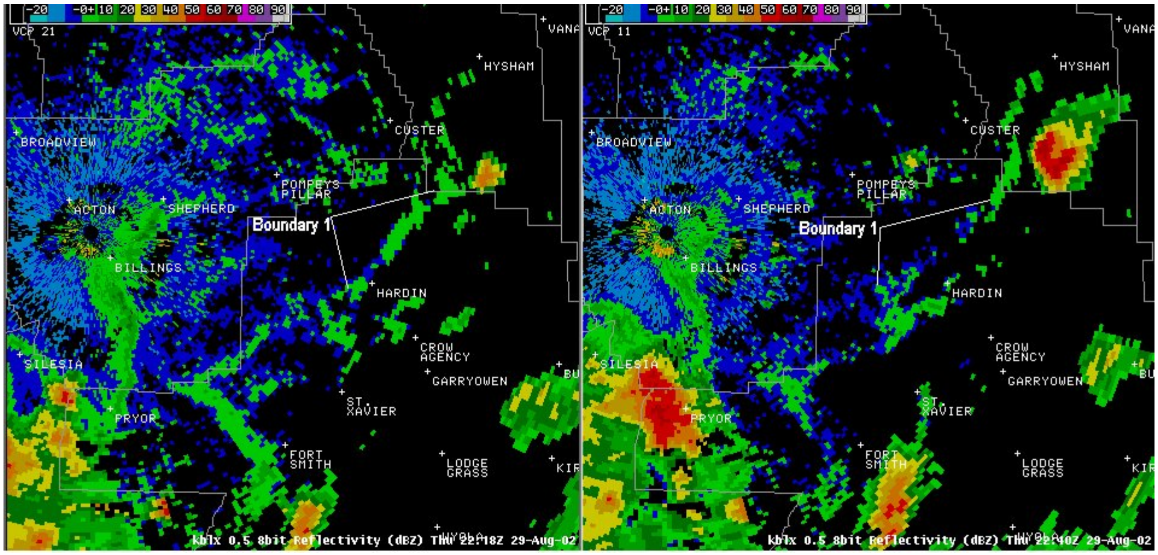

Figure 7

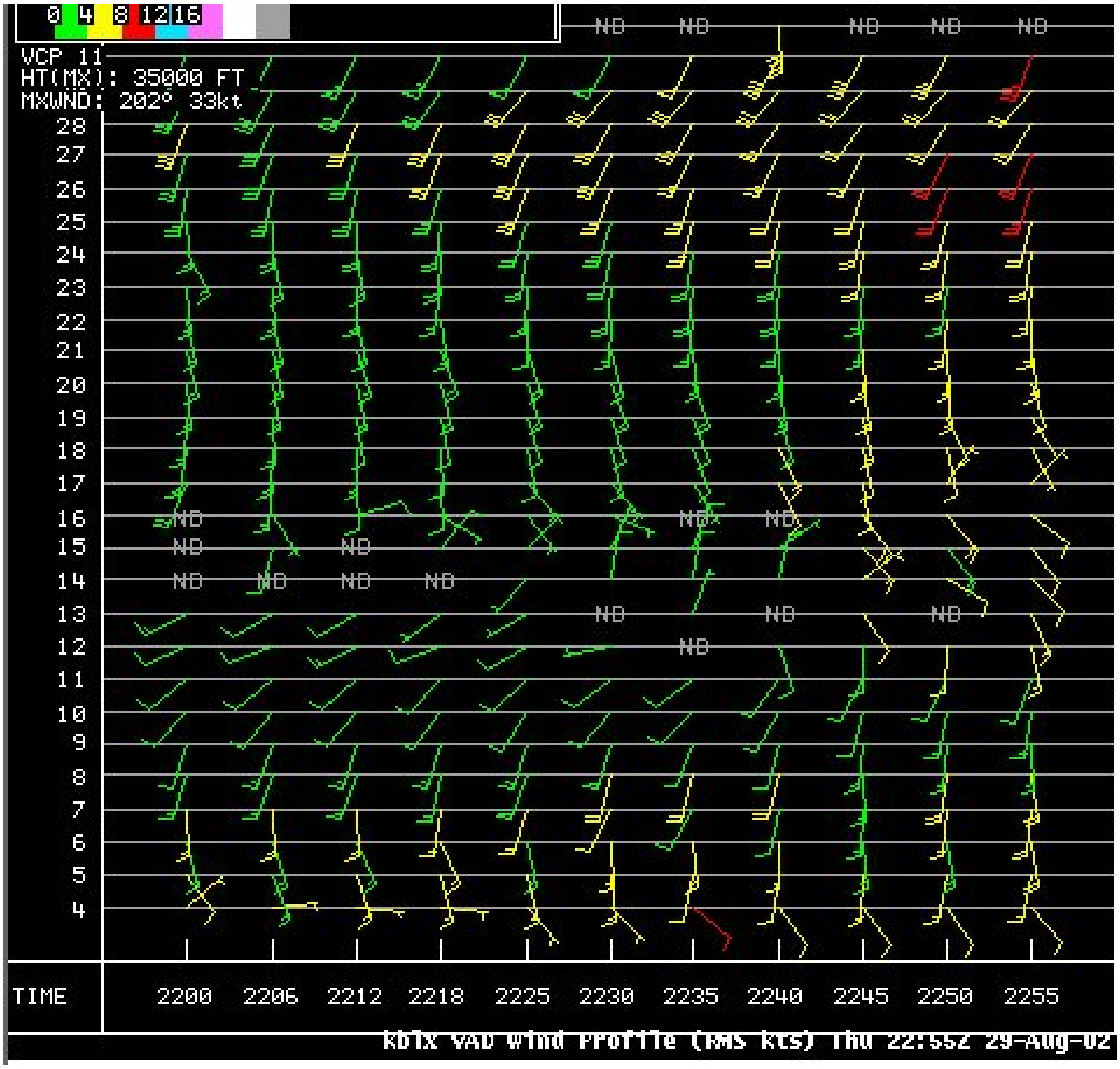

Figure 8

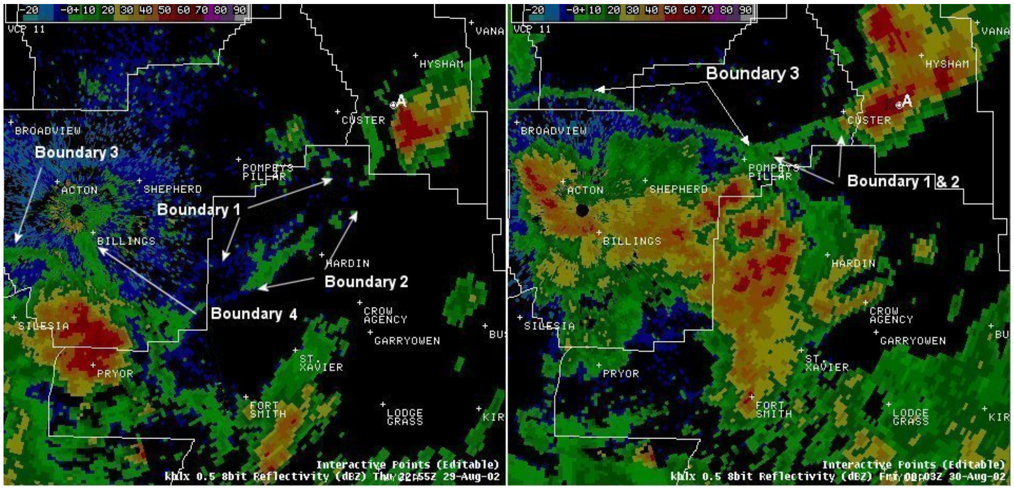

Figure 9

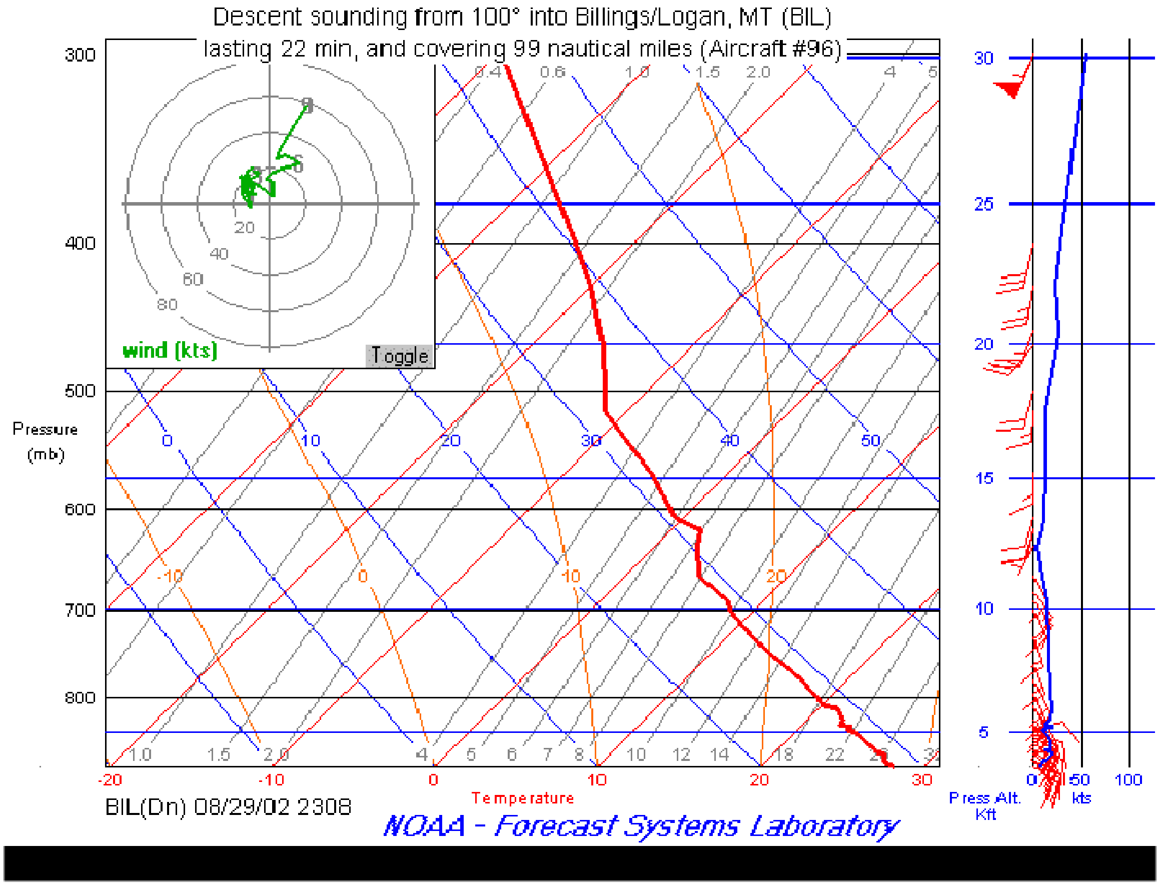

Figure 10

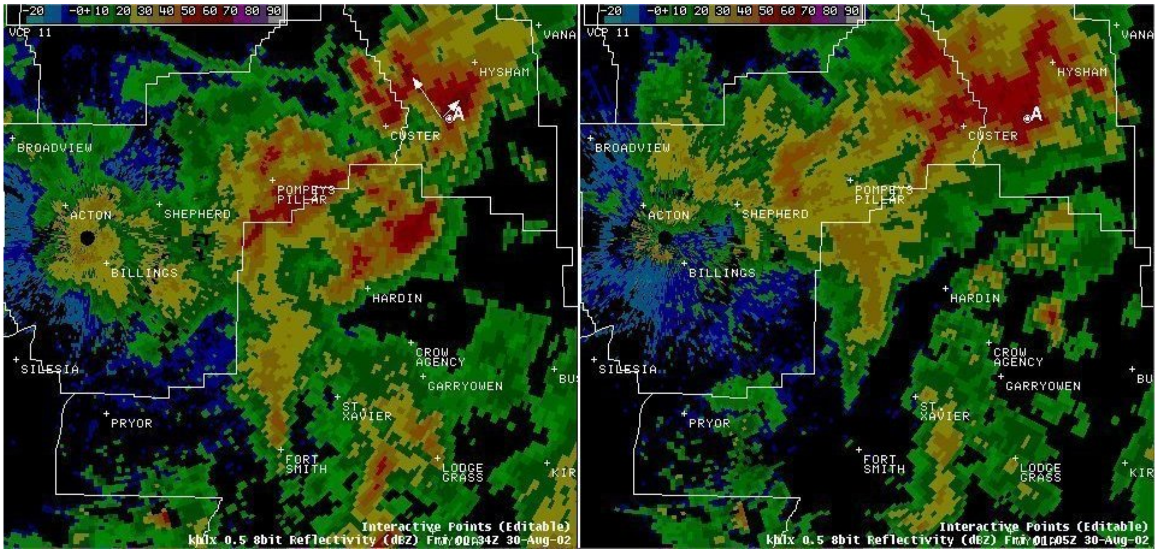

Figure 11

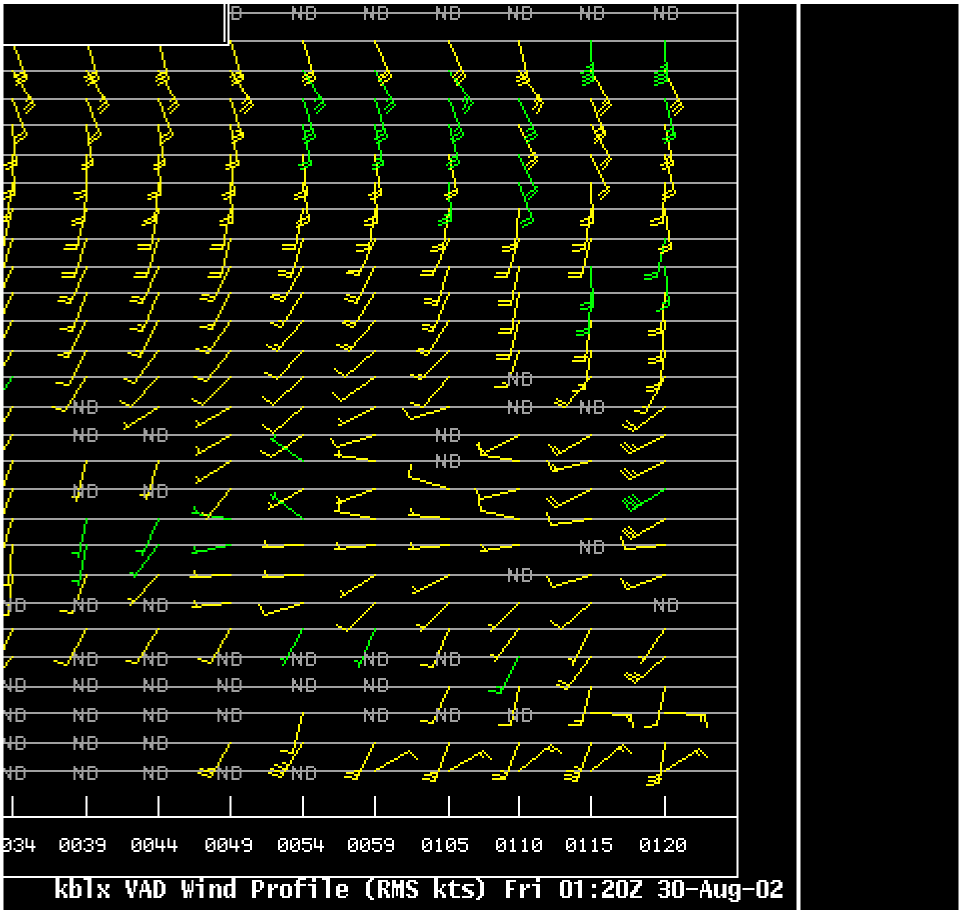
ND
034
0039
0044
0049
0054
0059
0105
0110
0115
0120
kblx VAD Wind Profile (RMS kts) Fri 01:20Z 30-Aug-02

Figure 12

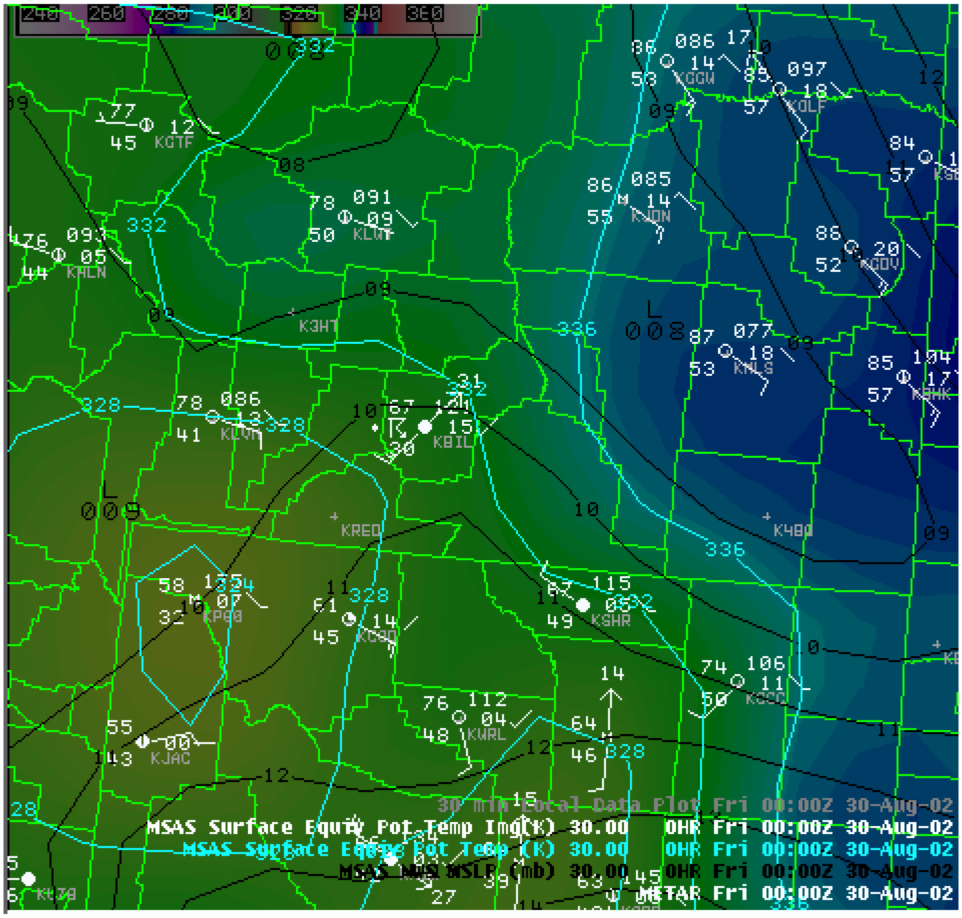
240 260 280 300 320 340 360
30 min Local Data Plot Fri 00:00Z 30-Aug-02
MSAS Surface Equiv Pot Temp Img (K) 30.00 0HR Fri 00:00Z 30-Aug-02
MSAS Surface Equiv Pot Temp (K) 30.00 0HR Fri 00:00Z 30-Aug-02
MSAS NWS MSLP (mb) 30.00 0HR Fri 00:00Z 30-Aug-02
METAR Fri 00:00Z 30-Aug-02
KCTB
KGGW
KOLF
KSDY
KJDN
KGDV
KHLN
KLWT
K3HT
KMLS
KBHK
KLVM
KBIL
KRED
K4BQ
KPOD
KCOD
KSHR
KGCC
KWRL
KJAC
L
008
009
332
336
328

Figure 13