Analysis of the June 28-29 2001 Severe Weather Event in Southeast Montana using the Weather Event Simulator

Donald Moore WFO Billings, Montana

Introduction

In a typical severe weather event in Montana, afternoon convection usually fires over the higher terrain of south central and southwest Montana and spreads east into the Dakotas by late evening. However, in the summer of 2001 there were many days in which the majority of thunderstorm development took place over WFO Billings CWA well after sunset. Late evening on 28 Jun 2001 to early morning on 29 Jun 2001 was one such instance.

Isolated to scattered thunderstorms developed in the afternoon on the 28th over the northwestern part of the CWA and continued through sunset. Around 11 PM thunderstorm development increased which resulted in widespread convection by midnight over the eastern half of the CWA. The storms began to decrease in coverage and intensity around 3 AM. The severe weather, which started shortly before 5 PM and ended around 3 AM, consisted of hail up to baseball size and flash flooding. In addition, two funnel clouds were reported.

This was a well advertised severe weather event and the development of severe thunderstorms came as no surprise to forecasters. However, the intensity and coverage of thunderstorms well after dark was not anticipated before the start of the event. Predicting the latter half of the severe weather event was particularly difficult to forecasters, not only because the storms fell outside of the traditional time of development, but also because the greatest instability was greater than originally thought. Since one of the more challenging aspects of this severe weather event was determining the extent of the severe thunderstorms, this paper will focus on the factors that contributed to the severe thunderstorm development after dark.

Meteorological Conditions and Thunderstorm Evolution

Southwest flow aloft was established over the Northwest on 28 June 2001 as an upper level trough was situated over the eastern Pacific (Fig. 1). An 850mb to 700mb thermal ridge and moist axis was nosing up from Wyoming and into Montana ahead of the trough (Fig. 2). This pattern was not too different from the positively tilted trough pattern that Evenson and Johns noted in 1995 as being associated with severe weather over the Northwest. The 28 June 2001 12Z Eta accurately predicted a weak surface front would extend west to east across northern Wyoming and into the Plains at 6 PM on the 28th (Fig. 3). Low level northeast to east flow north of the frontal boundary combined with strong southwest flow aloft produced nearly 80kts of surface to 6 km shear. The 12 hour forecast of surface based CAPE from the Eta was also fairly accurate north of the frontal boundary and indicated surface based CAPE values from 500 J/KG over the western part of the CWA to around 2000 J/KG over the eastern half. However, surface based convective inhibition (CIN) ranged from 15 J/KG to 40 J/KG at 6 PM on the 28th (Fig. 4). As a result, a weak short wave trough moving through northwest Montana (Fig. 1) was able to generate isolated to scattered thunderstorms.

Since significant shear was present, a few of the storms that did break the cap took on supercell characteristics on the afternoon of the 28th. Several outflow boundary interactions took place with the supercells. Horizontal vorticity on the cold side of these boundaries, as described by Markowski et. al. (1998) was able to help a few funnel clouds to form. One of the funnel clouds formed between Roundup and Broadview when a supercell crossed over an outflow boundary produced by another supercell (Fig. 5). The funnel cloud never developed into a tornado, possibly because the 2 km height of the lifting condensation level (LCL) and level of free convection (LFC) was too high (Davies 2002).

Forcing from the short wave trough moving through northwest Montana exited the area by sunset. However, the Eta forecast isentropic ascent to increase significantly north of the frontal boundary, particularly over southeast Montana around 06Z on the 29th and then shift into the Dakotas by 12Z (Fig. 6). Since nocturnal inversions developed by 06Z, elevated instability played an important role in controlling where the isentropic ascent would be able to initiate new convection. This is an important fact considering elevated CAPE lifting from near 800mb was three times greater than surface based CAPE (Fig. 7). In addition, the Eta forecast soundings indicated less than 10 J/KG of CIN from parcels lifting from 800mb with CAPE values equal to the afternoon surface based CAPE.

Thunderstorms rapidly developed shortly before 06Z on the 29th in response to the isentropic lift, little CIN, and large elevated CAPE. Many thunderstorms quickly split shortly after developing due to the straight line hodograph between 800mb and 400mb or around 2km to 6km (Fig. 8). However, after the thunderstorms began to moisten up the atmosphere below 800mb, some storms evolved into right movers. This suggests these thunderstorms likely became surface based or near surface based and was able to make use of much greater shear occurring below 800mb.

The wet bulb temperature on the 12Z Eta forecast sounding (blue line in Fig. 7), valid for 29 June 2001 at 06Z, showed that if enough evaporative cooling took place, the modified temperature profile could become nearly moist adiabatic from 800mb to the surface (Fig. 7). Thus, the Eta suggests elevated convection that developed over southeast Montana could have modified the environment enough to favor near surface based convection. Supercells in this environment would have had a greater ability to produce tornadoes. Although, a tornado was not reported.

Discussion

A key point from this case to consider for future events is the level in which instability is occurring. A plan view of model surface based CAPE or lifted index during a nocturnal event may not be representative of the true environment. In the case presented, elevated cape was analyzed at numerous levels for different points across the CWA. This technique allowed forecasters to identify the greatest instability that was present, regardless if the instability was surface based or not. By knowing the level of the greatest instability, forecasters could determine what type of forcing could initiate convection. In this case, low level inversions at 06Z would have inhibited thunderstorm development from surface based forcing. Meanwhile, forcing at the base of the layer of instability, such as isentropic ascent at 800mb, had a much greater chance of initiating convection.

Knowing if elevated thunderstorms could become surface based has a tremendous impact on the type of warnings that should be considered for strongly rotating supercells. If supercells are elevated in nature, tornado development becomes extremely difficult and warnings should focus on the hail threat. However, if evaporative cooling from the thunderstorms could modify the environment to favor surface based convection, the likelihood of tornadoes increases.

Analysis of the change of wet bulb temperatures with height is a good starting point to determine if elevated convection could evolve into surface based convection.

[Davies J. M, 2002: On Low-level On Low-Level Thermodynamic Parameters Associated with Tornadic and Nontornadic Supercells, Preprints, Severe Local Storms Conference, San Antonia, TX.]

Evenson, E. C. and R. H. Johns: 1995: Some Climatological and Synoptic Aspects of Severe Weather Development in the Northwestern United States. Natl. Wea. Dig., 20, 34-50.

Markowski, P. M, E. N. Rasmussen, and J. M. Straka, 1998: The Occurrence of Tornadoes in Supercells Interacting with Boundaries during VORTEX-95. Wea. Forecasting, 13, 852-859.

Figure 1

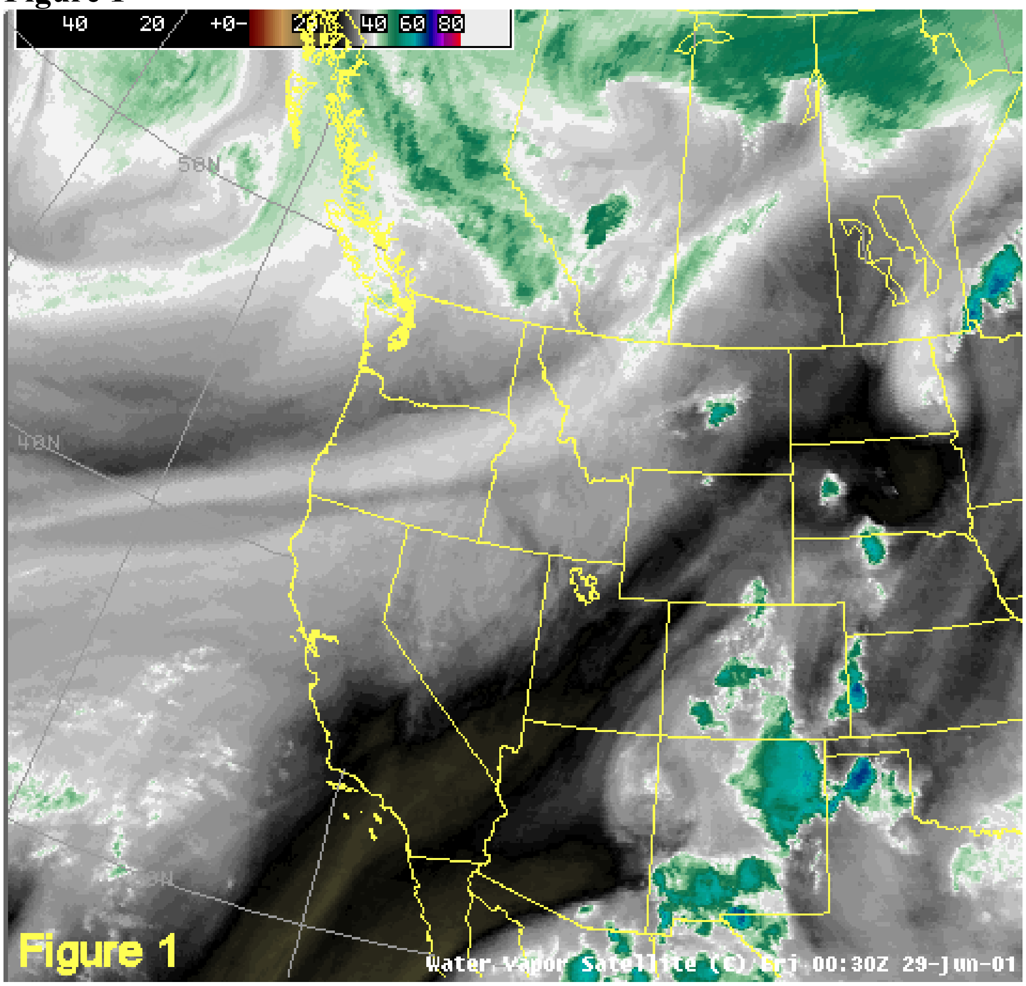


Figure 2

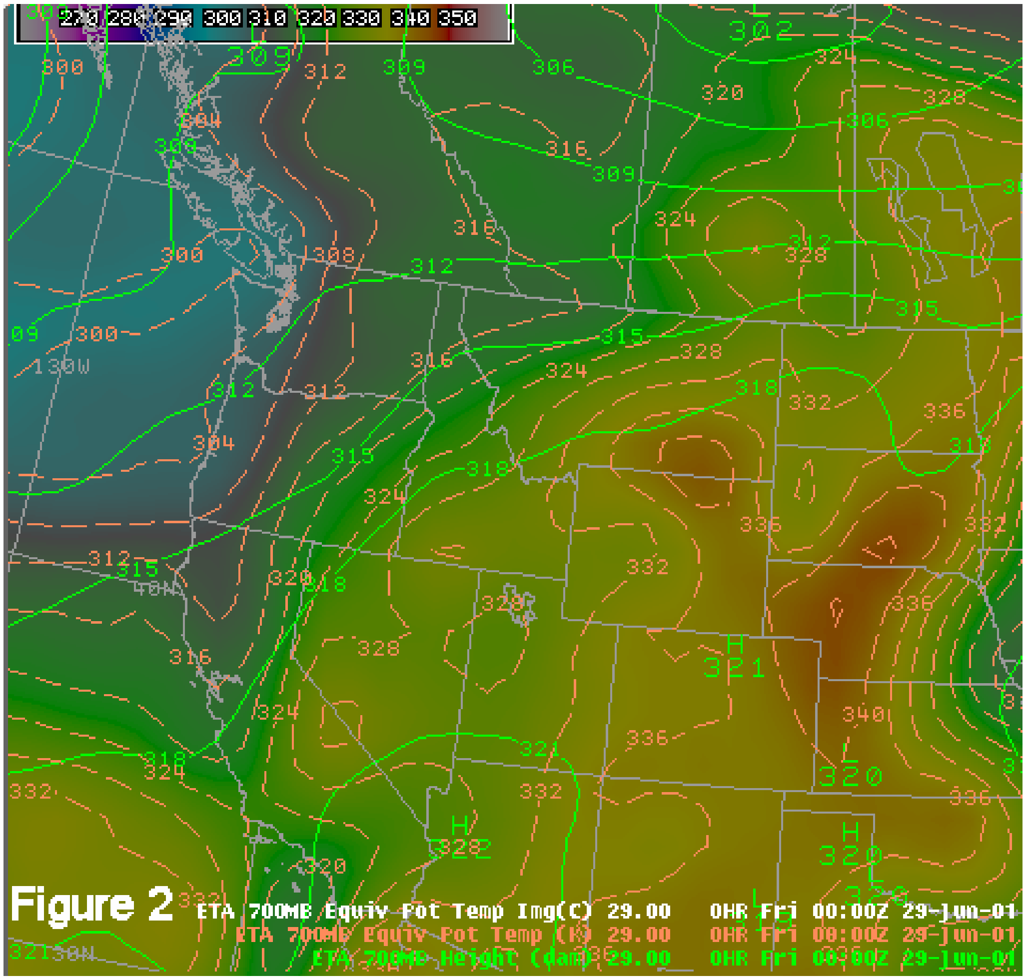

270 280 290 300 310 320 330 340 350
Figure 2
ETA 700MB Equiv Pot Temp Img(C) 29.00 0HR Fri 00:00Z 29-Jun-01
ETA 700MB Equiv Pot Temp (K) 29.00 0HR Fri 00:00Z 29-Jun-01
ETA 700MB Height (dam) 29.00 0HR Fri 00:00Z 29-Jun-01

Figure 3

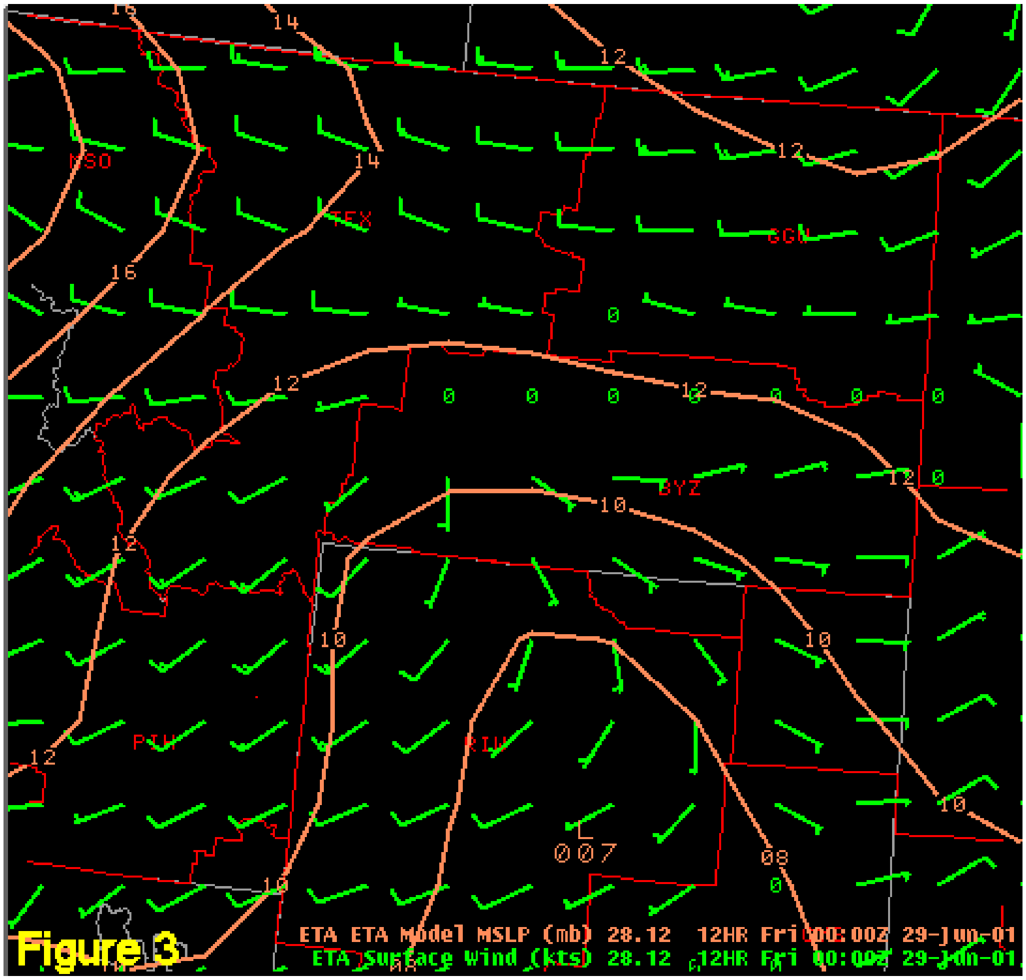
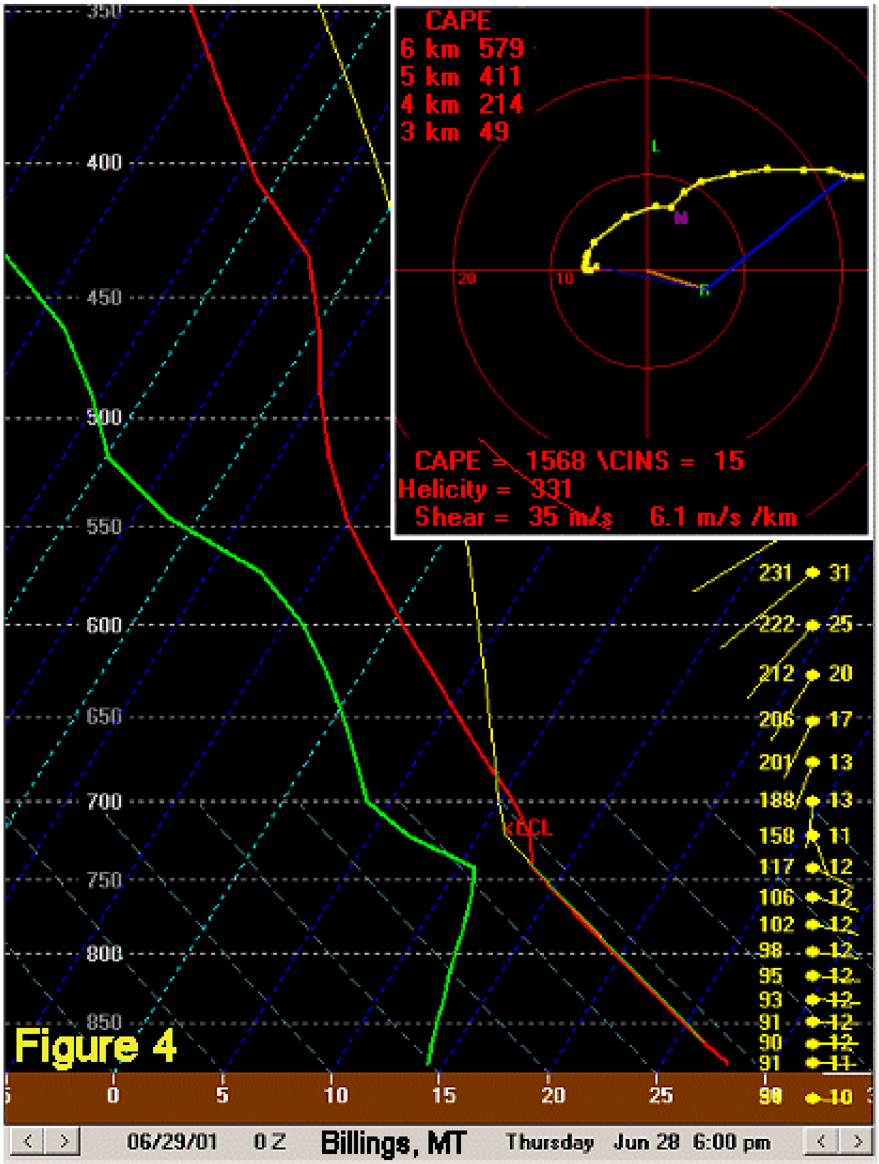
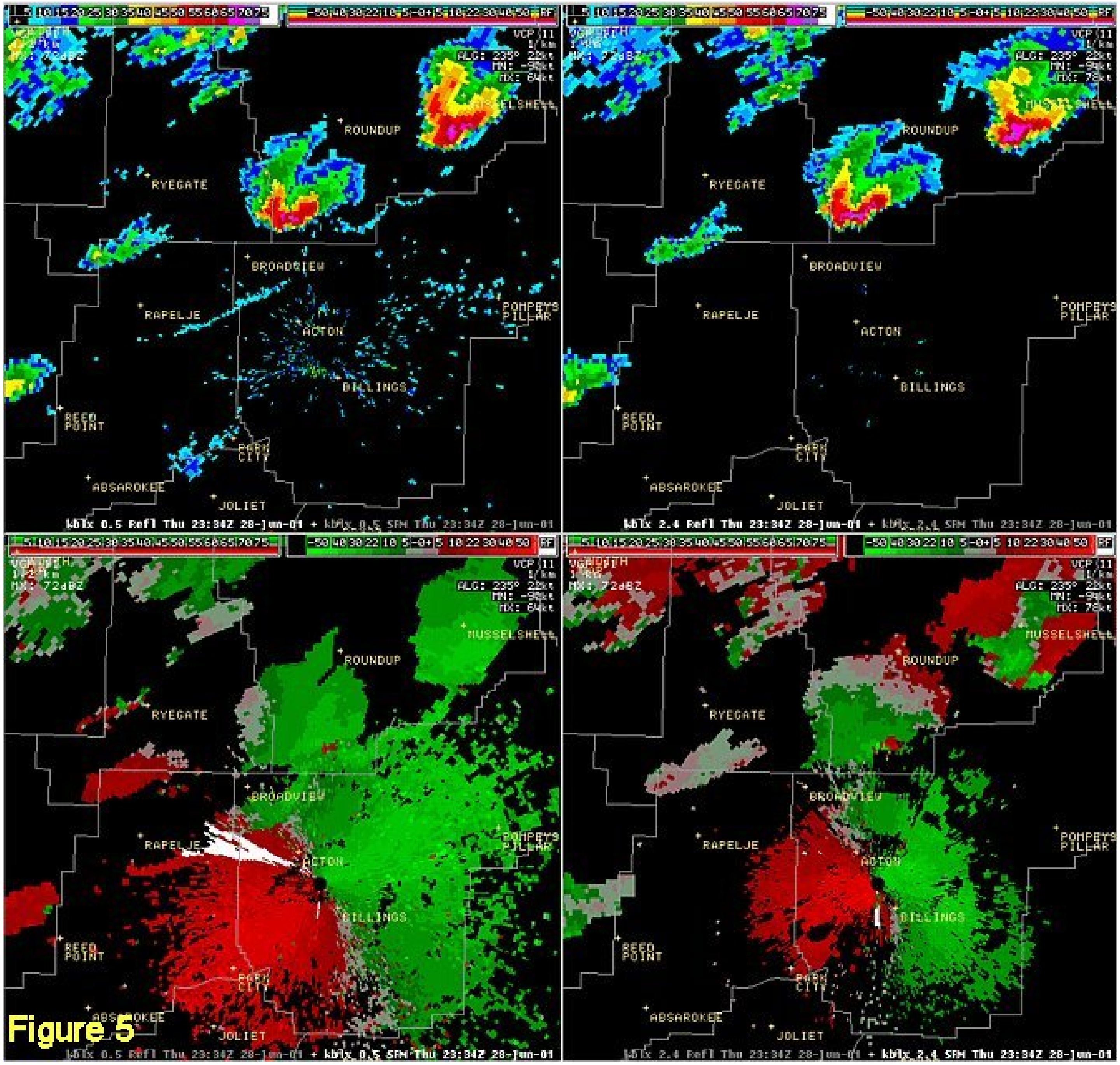

MSO
BYZ
PIH
RIW
ETA ETA Model MSLP (mb) 28.12 12HR Fri 00:00Z 29-Jun-01
ETA Surface Wind (kts) 28.12 12HR Fri 00:00Z 29-Jun-01
Figure 3

Figure 4



CAPE
6 km 579
5 km 411
4 km 214
3 km 49
CAPE = 1568 \CINS = 15
Helicity = 331
Shear = 35 m/s 6.1 m/s /km
LCL
Figure 4
06/29/01 0 Z Billings, MT Thursday Jun 28 6:00 pm

Figure 5



ROUNDUP
RYEGATE
BROADVIEW
RAPELJE
ACTON
BILLINGS
POMPEYS PILLAR
REED POINT
PARK CITY
ABSAROKEE
JOLIET
MUSSELSHELL
Figure 5
kblx 0.5 Refl Thu 23:34Z 28-Jun-01
kblx 2.4 Refl Thu 23:34Z 28-Jun-01
kblx 0.5 SRM Thu 23:34Z 28-Jun-01
kblx 2.4 SRM Thu 23:34Z 28-Jun-01

Figure 6

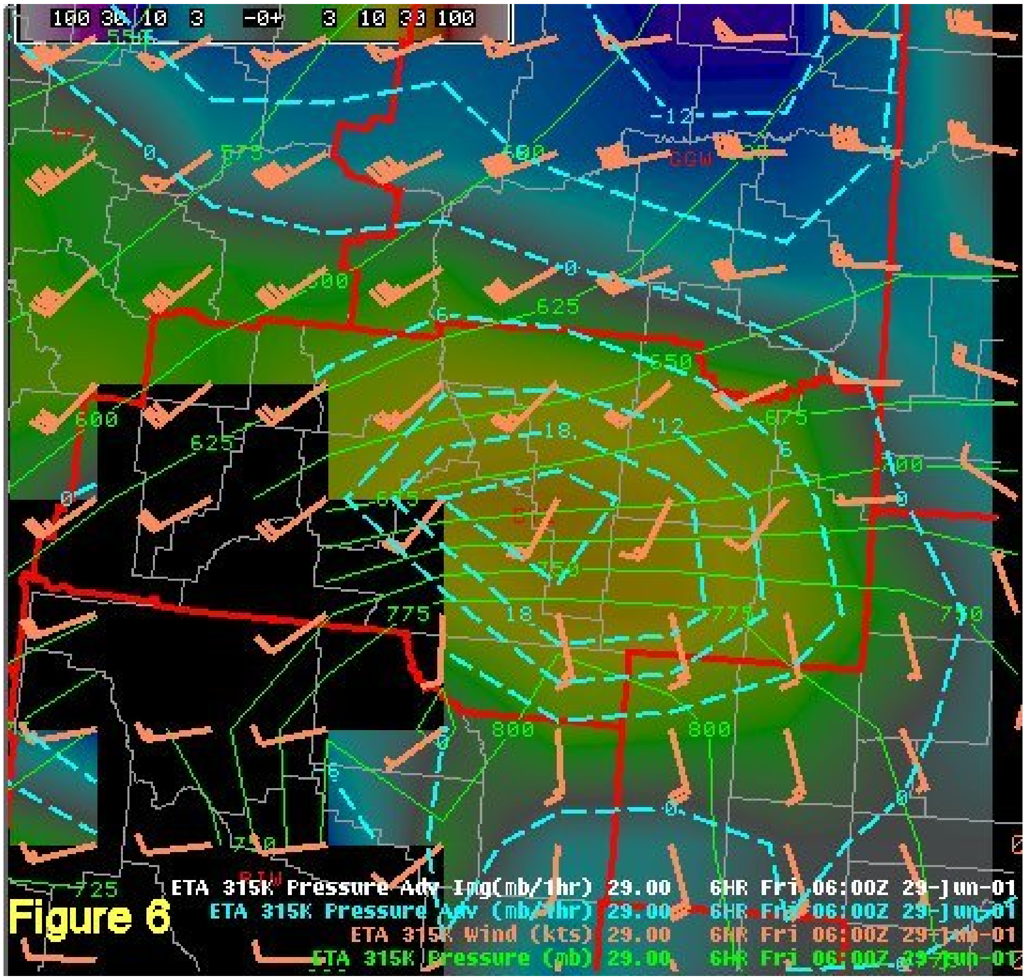
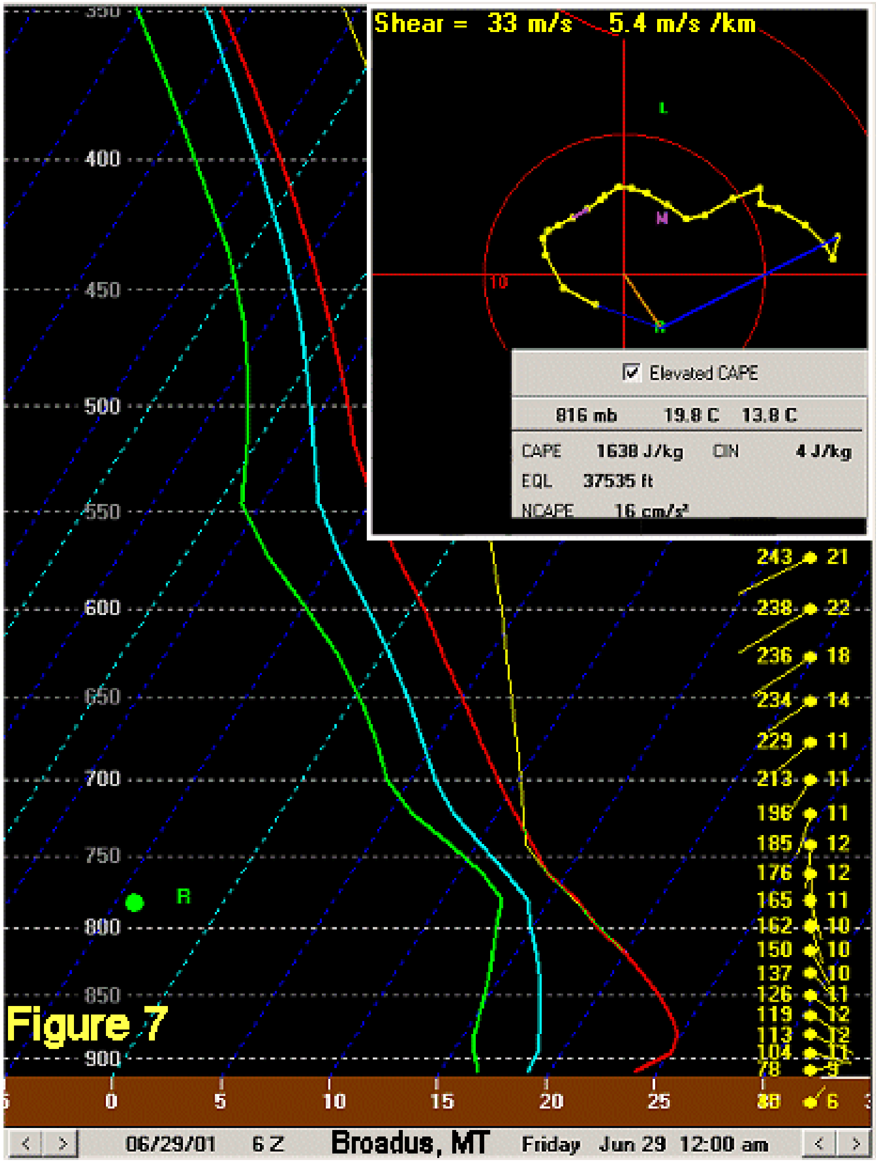


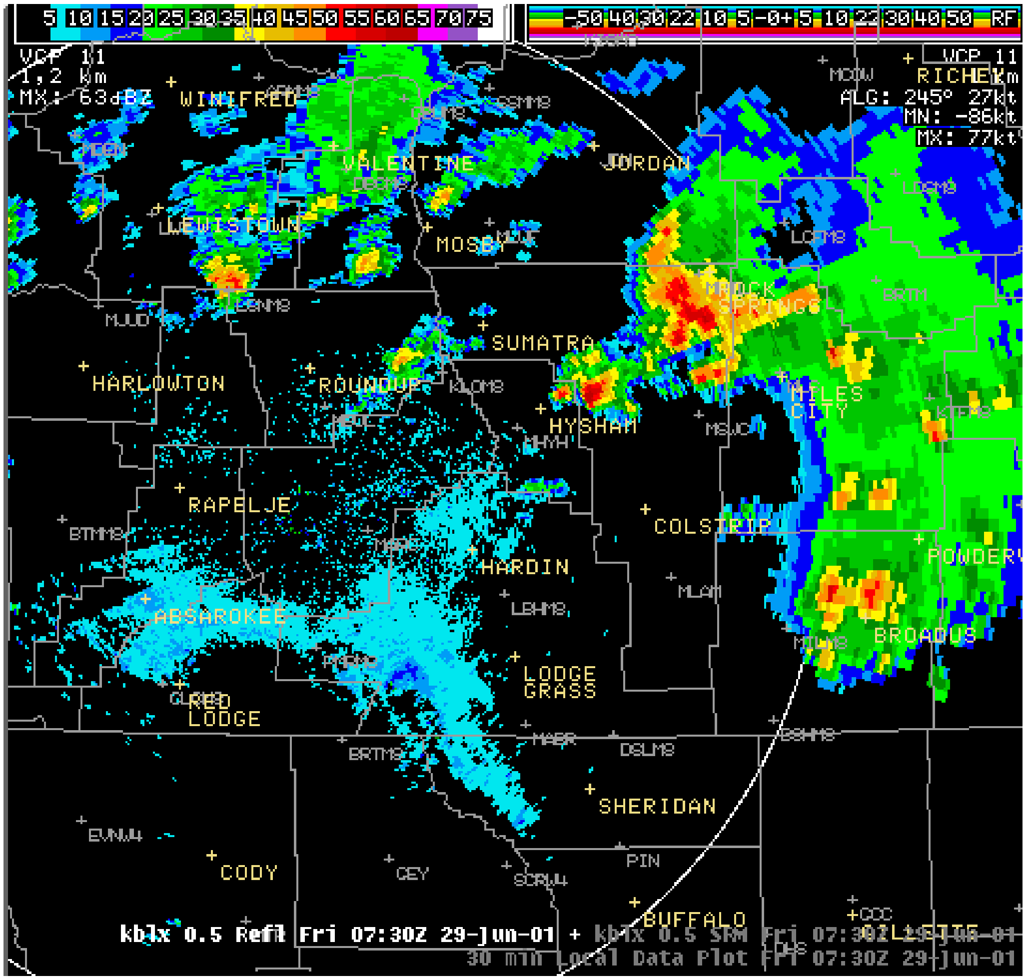
Figure 6
ETA 315K Pressure Adv Img(mb/1hr) 29.00 6HR Fri 06:00Z 29-jun-01
ETA 315K Pressure Adv (mb/1hr) 29.00 6HR Fri 06:00Z 29-jun-01
ETA 315K Wind (kts) 29.00 6HR Fri 06:00Z 29-jun-01
ETA 315K Pressure (mb) 29.00 6HR Fri 06:00Z 29-jun-01

Figure 7



Shear = 33 m/s 5.4 m/s /km
Elevated CAPE
816 mb 19.8 C 13.8 C
CAPE 1638 J/kg CIN 4 J/kg
EQL 37535 ft
Figure 7
06/29/01 6 Z Broadus, MT Friday Jun 29 12:00 am

Figure 8


5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
-50 40 30 22 10 5 -0+ 5 10 22 30 40 50 RF
VCP 11
1,2 km
MX: 63dBZ
ALG: 245° 27kt
MN: -86kt
MX: 77kt
WINIFRED
VALENTINE
JORDAN
RICHEY
LEWISTOWN
MOSBY
MILES CITY
SUMATRA
HARLOWTON
ROUNDUP
HYSHAM
RAPELJE
COLSTRIP
HARDIN
ABSAROKEE
LODGE GRASS
RED LODGE
BROADUS
SHERIDAN
CODY
BUFFALO
kblx 0.5 Refl Fri 07:30Z 29-Jun-01 + kblx 0.5 SRM Fri 07:30Z 29-Jun-01
30 min Local Data Plot Fri 07:30Z 29-Jun-01