August 19th, 2003 Severe Convective Wind Event in Western Montana using the Weather Event Simulator

Mike W. Johnson and Gene Petrescu, WFO Missoula, MT

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Introduction

During the late afternoon of August 19th 2003, a line of thunderstorms moved through western Montana producing high winds and lightning which resulted in moderate to severe fire behavior on numerous local wildfires and created at least 30 new lightning-caused fire starts. In addition, strong winds tore down trees and tree limbs; which in turn produced minor structural damage, brought down power lines, and caused one personal injury. As an example of the impact to fire fighting efforts, the Fish Creek Fire Complex grew 10,000 acres from 19 Aug to 20 August and several other fires experienced rapid growth as a result of these thunderstorms.

The weather prior to events on the 19th was relatively benign. In particular, a weak upper-level trough was located over central Montana on August 17-18. This pattern effectively shunted monsoonal moisture east of western Montana and allowed a relatively stable, hot, and dry air-mass to dominate. At the surface, a persistent thermal trough extended from New Mexico northward through the Idaho panhandle. This relatively dry and benign weather pattern changed on the 19th as an upper-level trough approached from the Pacific Ocean providing a tap into mid- and high-level moisture as well as increased ageostropic flow from an advancing jet streak.

Event Description

As shown in Figure 1, the 500mb low at 1800 UTC (as depicted by the GFS model) was located west of San Francisco with the trough axis extending northward into British Columbia. Southwest flow prevailed at this altitude and extended eastward from the Pacific coast into central Montana. In addition, a jet streak was located in north central Oregon, though placed slightly too far north by the model as evidenced by clearing on water vapor imagery and not coincident with model height fields. Also, notice that convection is occurring at this time in the right rear and left front quadrant of the jet streak.

Several features favoring possible severe thunderstorm development were evident by the morning of the 19th: First, low level instability seemed assured - due to a diurnally persistent thermal trough predicted by the Mesoeta model to extend through central Idaho and into western Montana by afternoon (see Figure 2). Also shown are predicted 700mb winds, which would produce a storm movement of 30 to 35 knots from the southwest. Second, mid- and high-level moisture was moving up from the base of the trough off the California coast, providing a moisture source to the region (see Figure 3). This figure also shows convection in right rear of jet streak noted from Figure 1 had increased and moved into north central Idaho. In addition, the GFS and Mesoeta models are shown to be producing similar placements of major features as seen by the 500mb height fields depicted in the figure. Third, the vertical thermodynamic profiles predicted an unstable afternoon environment favorable for convective growth and relatively long-lived storms - given daytime heating, the influx of upper-level moisture, and the influence of increased winds aloft.

Figures 4 & 5 show the 00:00 UTC Eta buffer forecast soundings for Missoula (MSO) and Kalispell (FCA). Significant features for MSO and FCA respectively from these soundings include: a 0-6km wind shear of 25 to 35kts; Microburst Potential of <30kts, an Equilibrium Level of 35,800 to 36,000ft; Convective Available Potential Energy (CAPE) of 708 to 897 J/Kg; a Lifted Index (LI) of -3.3 to -4.0; and Precipitable Water of 0.53 to 0.69 inches. In addition, note that the poor resolution of model topography in the Missoula County Warning Area can negatively impact model-derived convective parameterization and microburst potential. For example, the MesoEta model surface for MSO is approximately 1000 ft higher than the actual elevation. Depending on surface temperature and dewpoint, this discrepancy can influence the model-derived calculation of the level-of-free-convection; which in turn leads to errors in calculated CAPE and LI. In addition, microburst potential is often underestimated when surface conditions are dry and near surface lapse rates are adiabatic. For this day, the near surface lapse rate was at least adiabatic, and the low-level environment was very dry. In fact, Figure 6 shows observed dewpoint depressions at 23:00 UTC ranging from 45 to 50 degrees Fahrenheit. Therefore, since convective indices and microburst potential were underestimated by the models; adjustments to the convective analysis were critical; particularly in north central Idaho and southwest Montana. Nevertheless, both the MesoEta and GFS models did a good job of locating general regions where convection would grow. Figure 7 shows a plan view of predicted late afternoon CAPE that lies roughly along the location of the thermal trough shown in Figure 2. In summary, the most impressive features from these soundings (after adjusting for topography-induced errors) are moderate convective indices, good speed shear, and moderate microburst potential.

By 23:00 UTC on the 19th, radar and visible satellite imagery indicated convection developing over the Clearwater mountains of Idaho, with the most significant feature being a line of storms with up to 50dBZ returns east of Grangeville Idaho moving the towards the northeast at about 30kts (see Figure 8-9). Notice also the smoke plumes from large fires west-, east-, and south-of-Missoula are clearly evident. Changes in the intensity and coverage of these returns can be used as a proxy for changes in fire behavior. By 23:57 UTC, the aforementioned line of storms had rapidly intensified into a weak bow echo with possible rear inflow notch and most significant growth located near the northern and southern edges (see Figure 10). A comparison of visible satellite imagery from 23:00 UTC (Figure 9) to imagery at 00:00 UTC (Figure 11) shows the rapid intensification of convection west of Missoula. As the storm approached Missoula at 00:38 UTC, the northern end of the squall line passed directly over the Fish Creek Fire Complex just southwest of Alberton MT. A 45-dBZ return was located over the fire area at this time as shown by the 0.5-degree-reflectivity-product (Figure 12) while the 0.5-SRM-product indicated a mesocyclone directly over the fire (see Feature A, Figure 13). In addition, an area of low-level convergence can be seen just west of Lolo MT - at the leading edge of the bow echo (see Feature B, Figure 13). As this storm swept over the Missoula and Bitterroot valleys, trees were reported blown down onto power lines near Hamilton. In addition, winds blew trees over in Missoula downing power lines and damaging two vehicles. One downed tree injured a passing bicyclist. By 01:43 UTC, the intensity of the squall line had weakened considerably (see Figure 14). Nevertheless, the advancing gust front downed trees in Rock Creek Canyon (20 miles east on Missoula) and blew tents down at the Boles Fire Camp (25 miles northeast of Missoula). In addition, convection developed to the northwest of Missoula and intensified over the next hour, producing an estimated wind gust of 59 knots near Dixon MT, where a barn sustained significant damage.

Summary

The post analysis of this event through the Weather Event Simulator was very instructive. Even though long-lived squall lines and bow echoes are a fairly rare occurrence in this region, key environmental differences existed between this event and our more typical pulse storms. These differences, if correctly identified, should allow identification of these types of storms long before they actually develop. The case is instructive in allowing forecasters to recognize events leading to a change from a dry unstable environment; which existed prior to the 19th of August; to the mid-level-moist and unstable environment that existed on the 19th. These conditions were caused by the approaching upper level trough, which allowed increased mid- and upper-level moisture to enter the region. Finally, the case specifically points to the importance of jet-streak dynamics and what can happen through the introduction of significant shear to a moist unstable atmosphere.

Figure 1

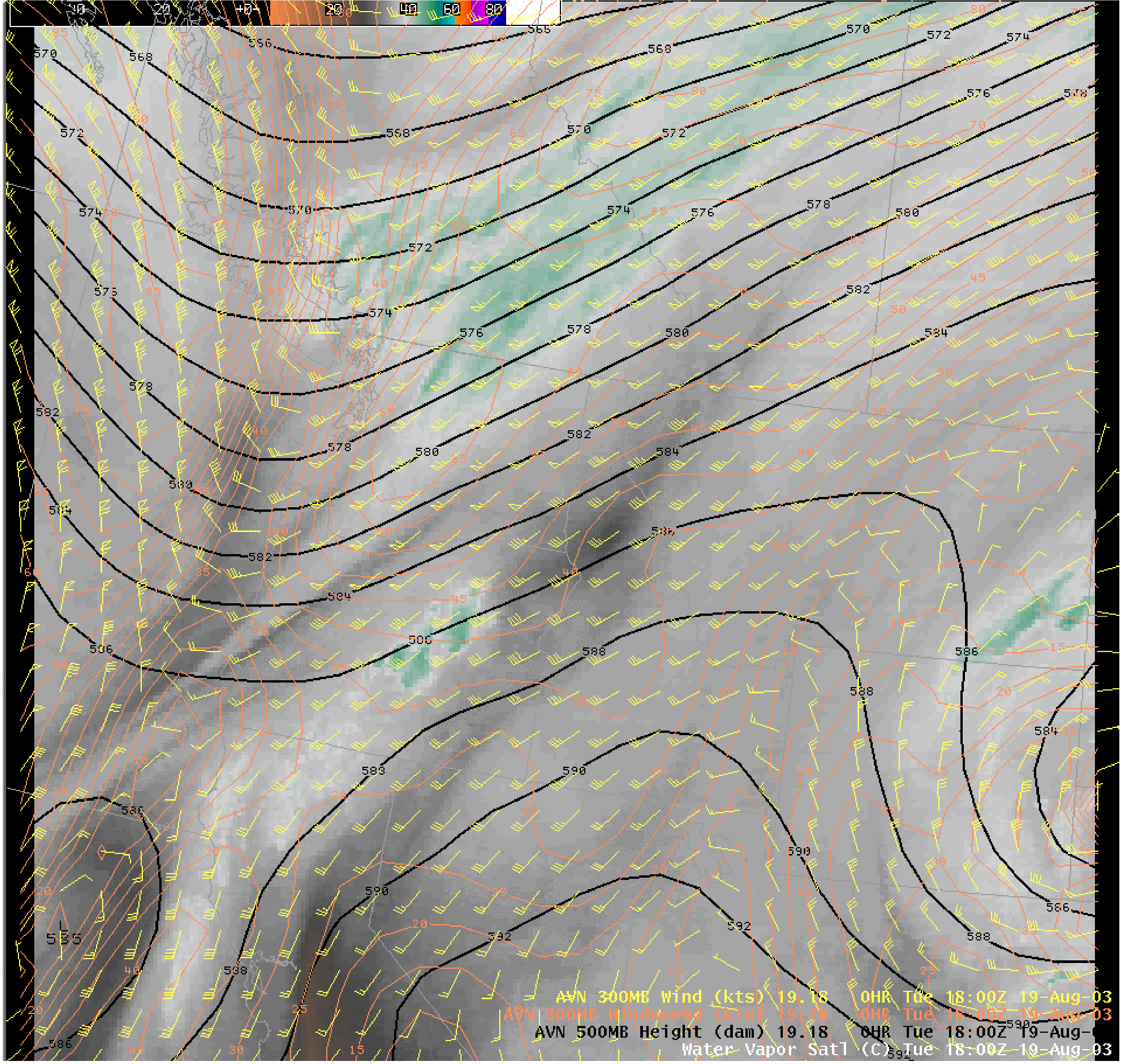


Figure 2

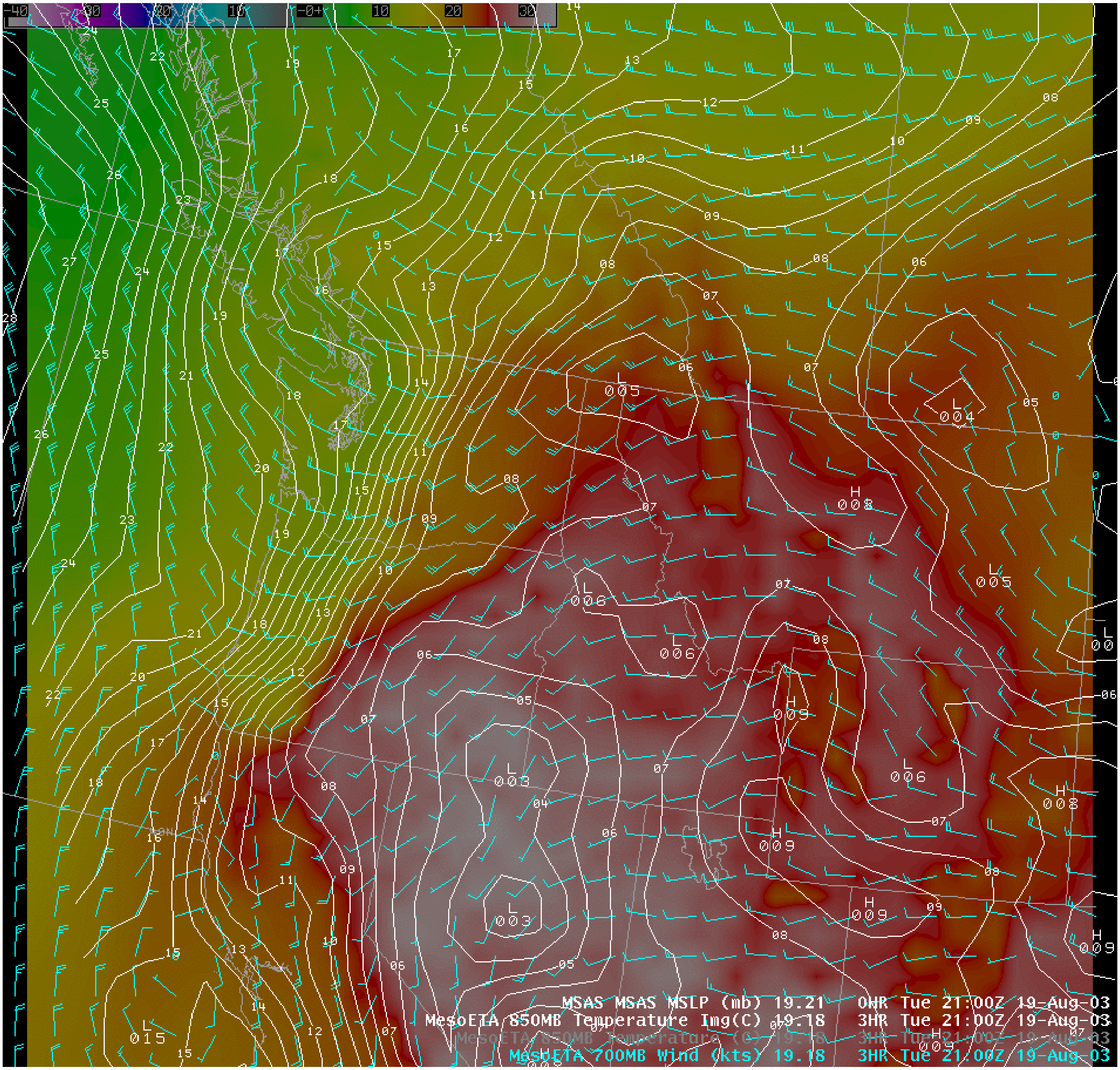

-40
-30
-20
-10
-0+
10
20
30
MSAS MSAS MSLP (mb) 19.21 0HR Tue 21:00Z 19-Aug-03
MesoETA 850MB Temperature Img(C) 19.18 3HR Tue 21:00Z 19-Aug-03
MesoETA 850MB Temperature (C) 19.18 3HR Tue 21:00Z 19-Aug-03
MesoETA 700MB Wind (kts) 19.18 3HR Tue 21:00Z 19-Aug-03

Figure 3

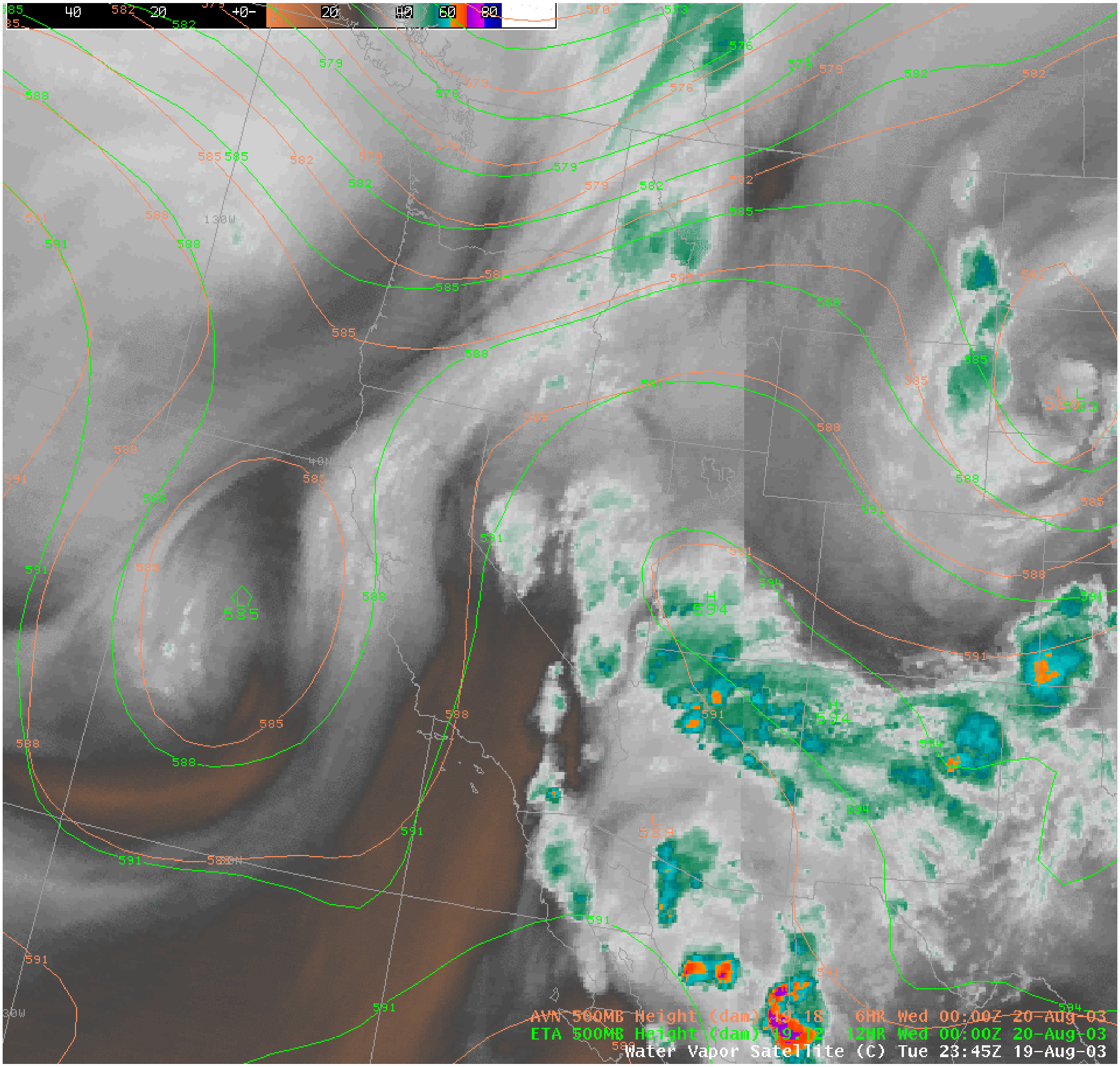
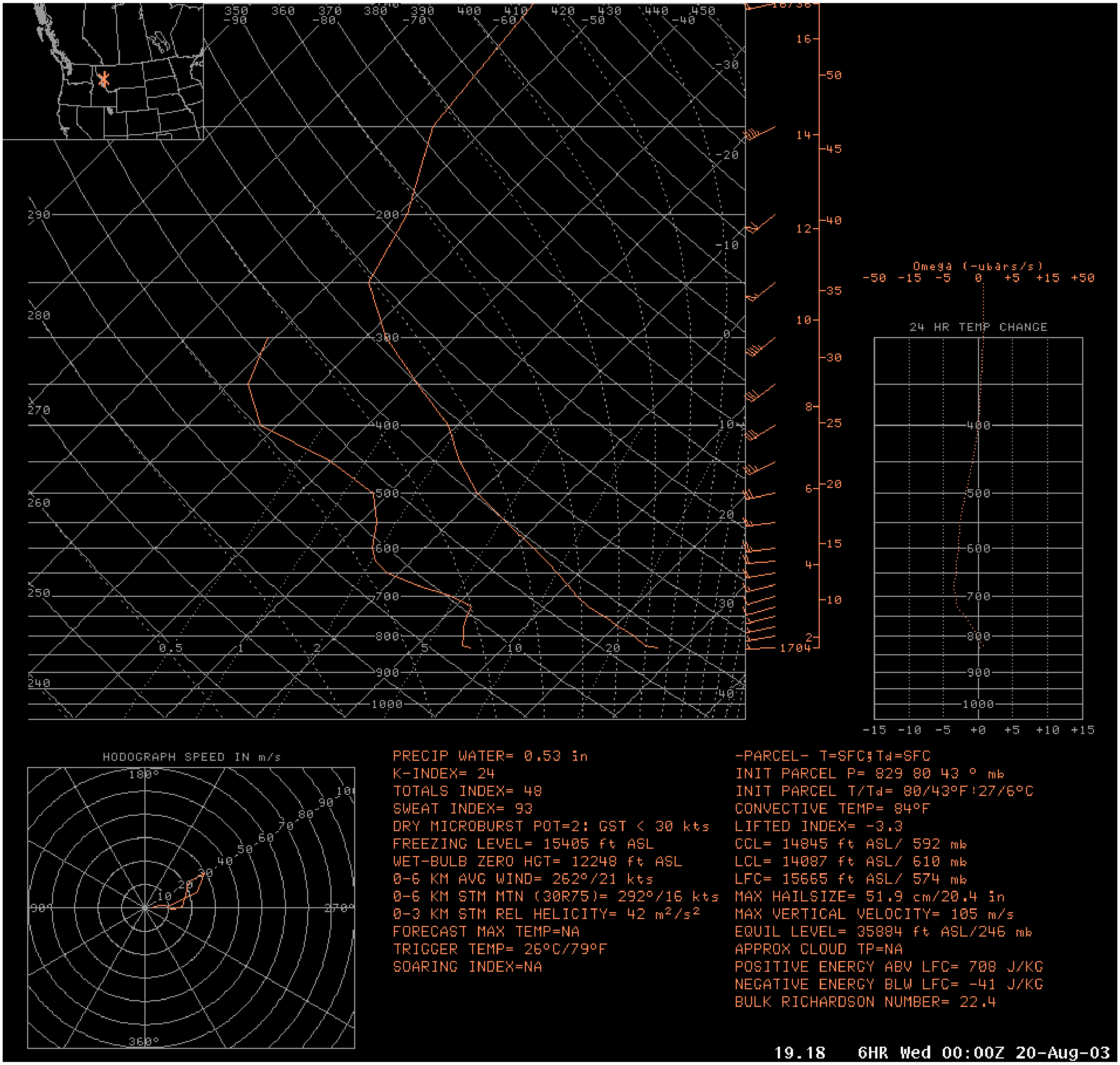

40
20
+0-
20
40
60
80
130W
40N
L
585
H
594
L
588
AVN 500MB Height (dam) 19 18 6HR Wed 00:00Z 20-Aug-03
ETA 500MB Height (dam) 19 12 12HR Wed 00:00Z 20-Aug-03
Water Vapor Satellite (C) Tue 23:45Z 19-Aug-03

Figure 4



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PRECIP WATER= 0.53 in                  -PARCEL- T=SFC;Td=SFC
K-INDEX= 24                            INIT PARCEL P= 829 80 43 ° mb
TOTALS INDEX= 48                       INIT PARCEL T/Td= 80/43°F!27/6°C
SWEAT INDEX= 93                        CONVECTIVE TEMP= 84°F
DRY MICROBURST POT=2: GST < 30 kts     LIFTED INDEX= -3.3
FREEZING LEVEL= 15405 ft ASL           CCL= 14845 ft ASL/ 592 mb
WET-BULB ZERO HGT= 12248 ft ASL        LCL= 14087 ft ASL/ 610 mb
0-6 KM AVG WIND= 262°/21 kts           LFC= 15665 ft ASL/ 574 mb
0-6 KM STM MTN (30R75)= 292°/16 kts    MAX HAILSIZE= 51.9 cm/20.4 in
0-3 KM STM REL HELICITY= 42 m²/s²      MAX VERTICAL VELOCITY= 105 m/s
FORECAST MAX TEMP=NA                   EQUIL LEVEL= 35884 ft ASL/246 mb
TRIGGER TEMP= 26°C/79°F                APPROX CLOUD TP=NA
SOARING INDEX=NA                       POSITIVE ENERGY ABV LFC= 708 J/KG
                                       NEGATIVE ENERGY BLW LFC= -41 J/KG
                                       BULK RICHARDSON NUMBER= 22.4

                                          19.18   6HR Wed 00:00Z 20-Aug-03
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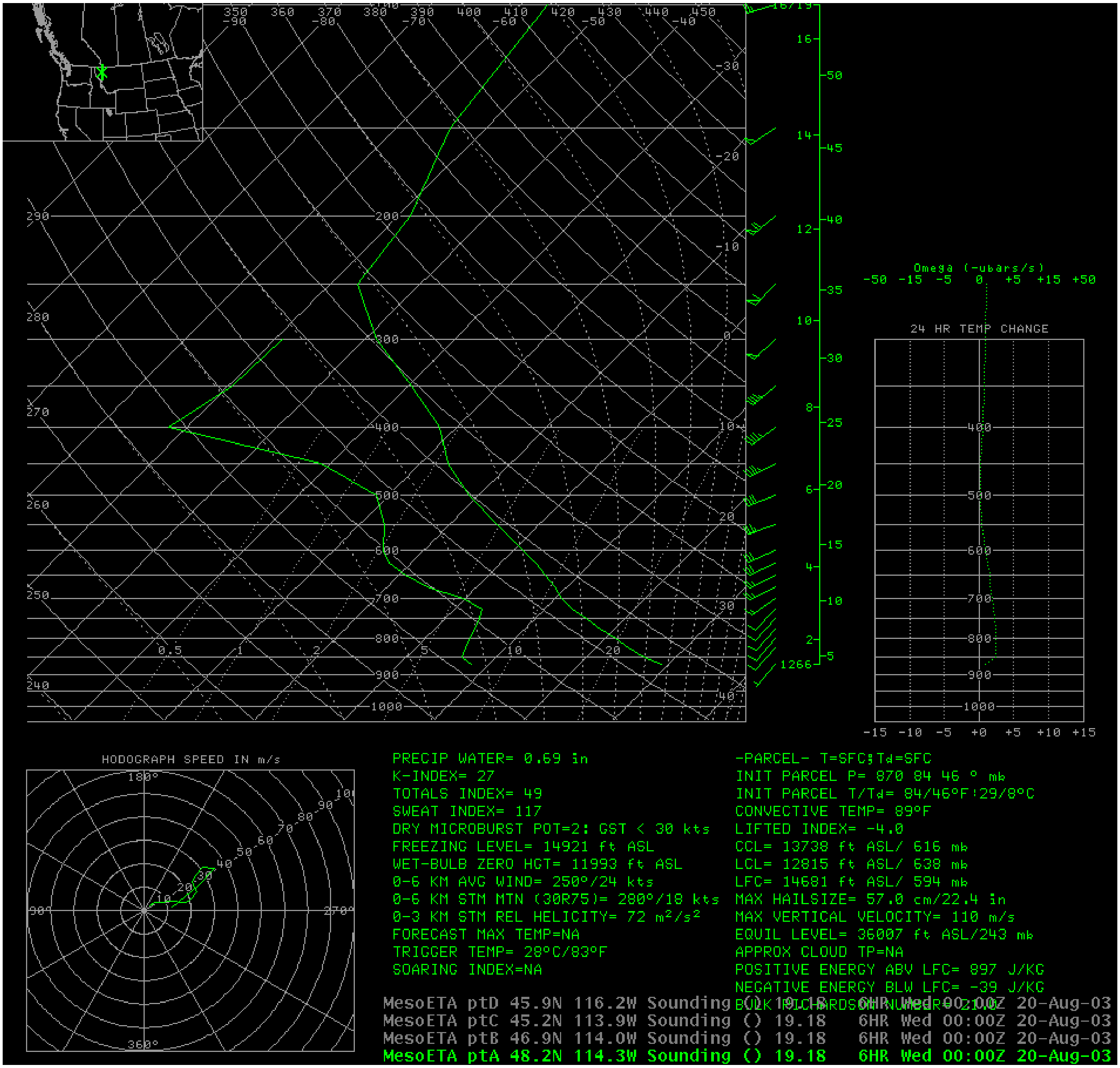
Figure 5



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PRECIP WATER= 0.69 in                    -PARCEL- T=SFC;Td=SFC
K-INDEX= 27                              INIT PARCEL P= 870 84 46 ° mb
TOTALS INDEX= 49                         INIT PARCEL T/Td= 84/46°F:29/8°C
SWEAT INDEX= 117                         CONVECTIVE TEMP= 89°F
DRY MICROBURST POT=2: GST < 30 kts       LIFTED INDEX= -4.0
FREEZING LEVEL= 14921 ft ASL             CCL= 13738 ft ASL/ 616 mb
WET-BULB ZERO HGT= 11993 ft ASL          LCL= 12815 ft ASL/ 638 mb
0-6 KM AVG WIND= 250°/24 kts             LFC= 14681 ft ASL/ 594 mb
0-6 KM STM MTN (30R75)= 280°/18 kts      MAX HAILSIZE= 57.0 cm/22.4 in
0-3 KM STM REL HELICITY= 72 m²/s²        MAX VERTICAL VELOCITY= 110 m/s
FORECAST MAX TEMP=NA                     EQUIL LEVEL= 36007 ft ASL/243 mb
TRIGGER TEMP= 28°C/83°F                  APPROX CLOUD TP=NA
SOARING INDEX=NA                         POSITIVE ENERGY ABV LFC= 897 J/KG
                                         NEGATIVE ENERGY BLW LFC= -39 J/KG
                                         BULK RICHARDSON NUMBER= 21.0
MesoETA ptD 45.9N 116.2W Sounding () 19.18   6HR Wed 00:00Z 20-Aug-03
MesoETA ptC 45.2N 113.9W Sounding () 19.18   6HR Wed 00:00Z 20-Aug-03
MesoETA ptB 46.9N 114.0W Sounding () 19.18   6HR Wed 00:00Z 20-Aug-03
MesoETA ptA 48.2N 114.3W Sounding () 19.18   6HR Wed 00:00Z 20-Aug-03
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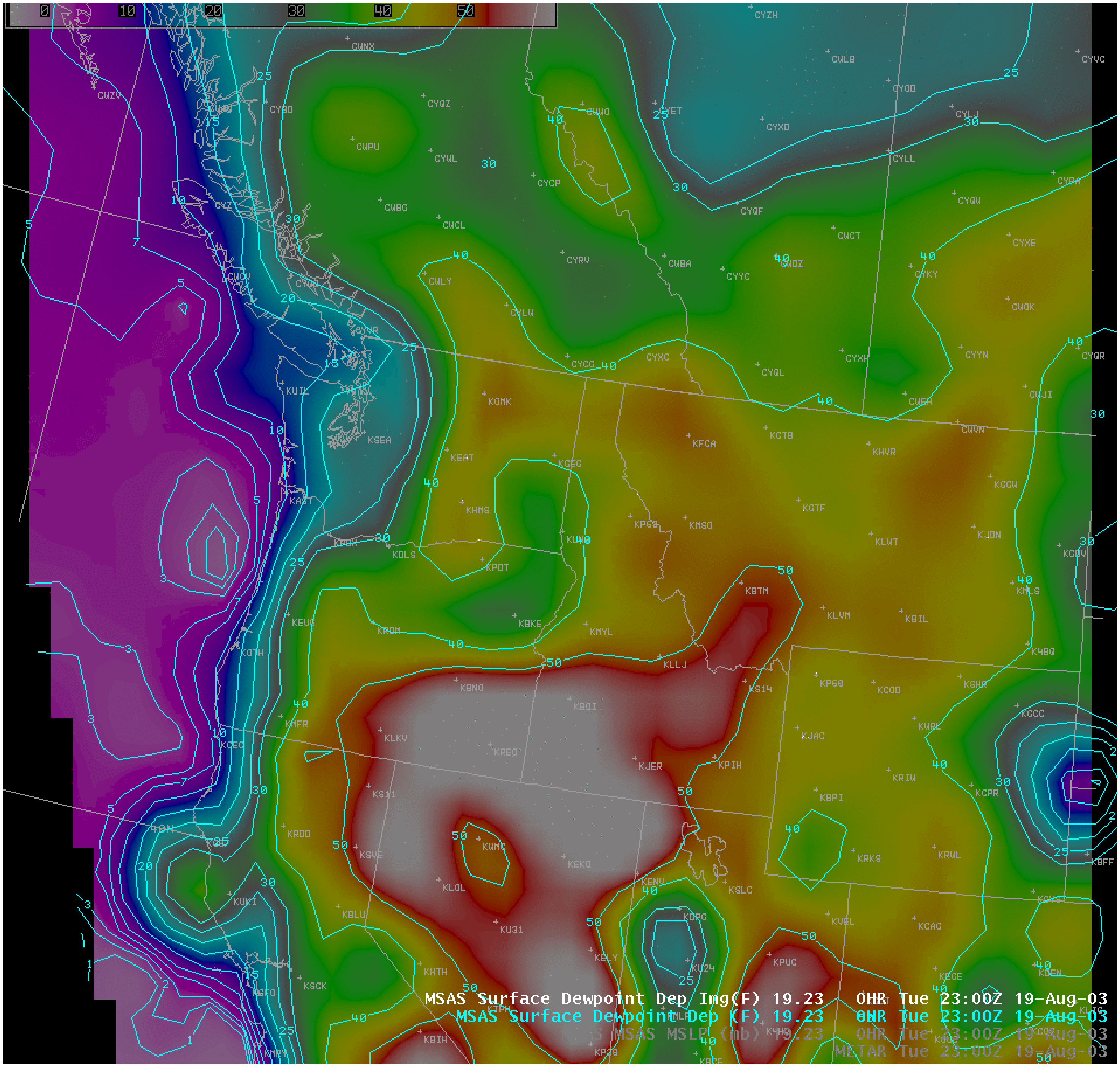
Figure 6


0
10
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MSAS Surface Dewpoint Dep Img(F) 19.23 0HR Tue 23:00Z 19-Aug-03
MSAS Surface Dewpoint Dep (F) 19.23 0HR Tue 23:00Z 19-Aug-03
MSAS MSLP (mb) 19.23 0HR Tue 23:00Z 19-Aug-03
METAR Tue 23:00Z 19-Aug-03

Figure 7

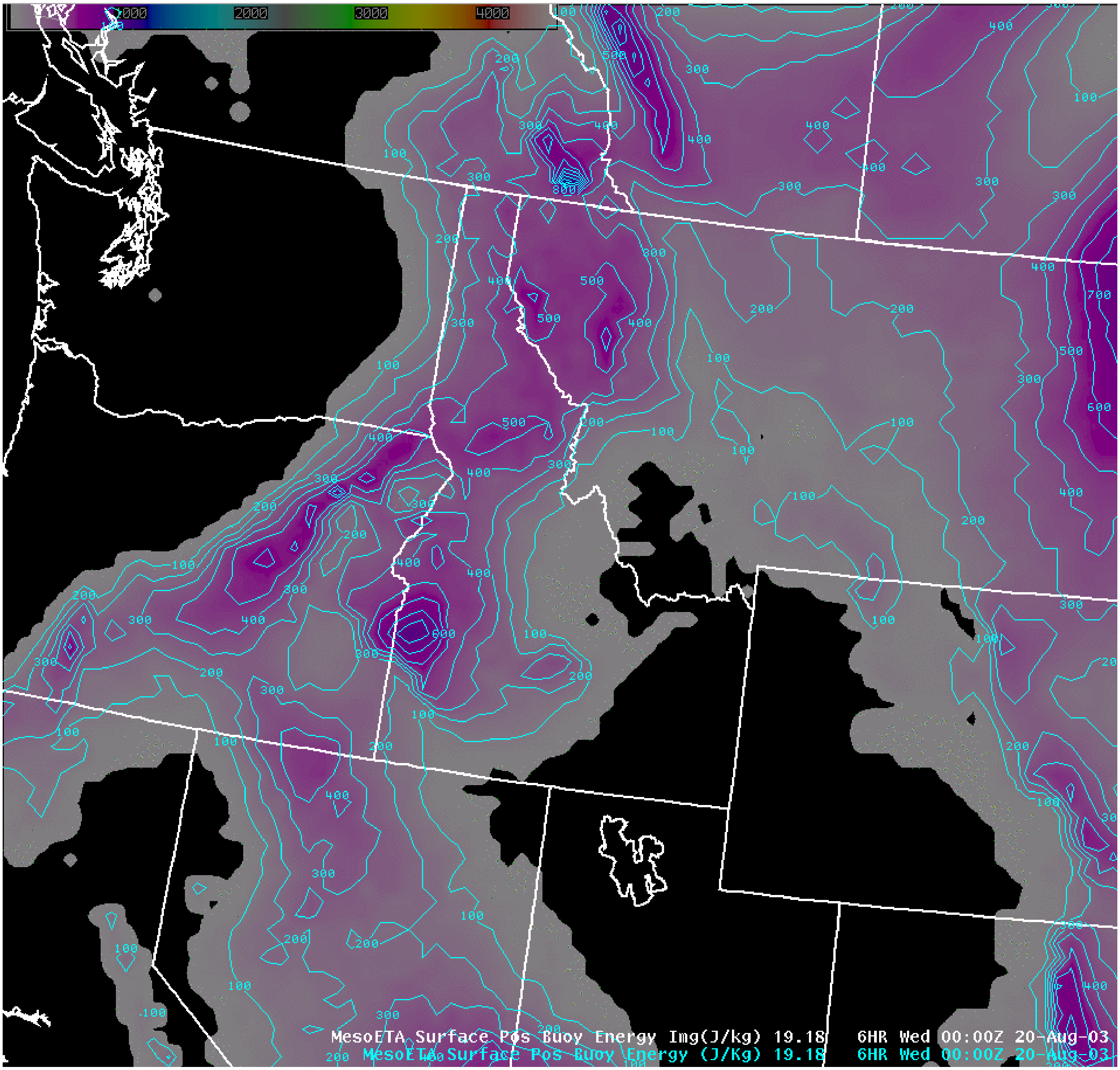
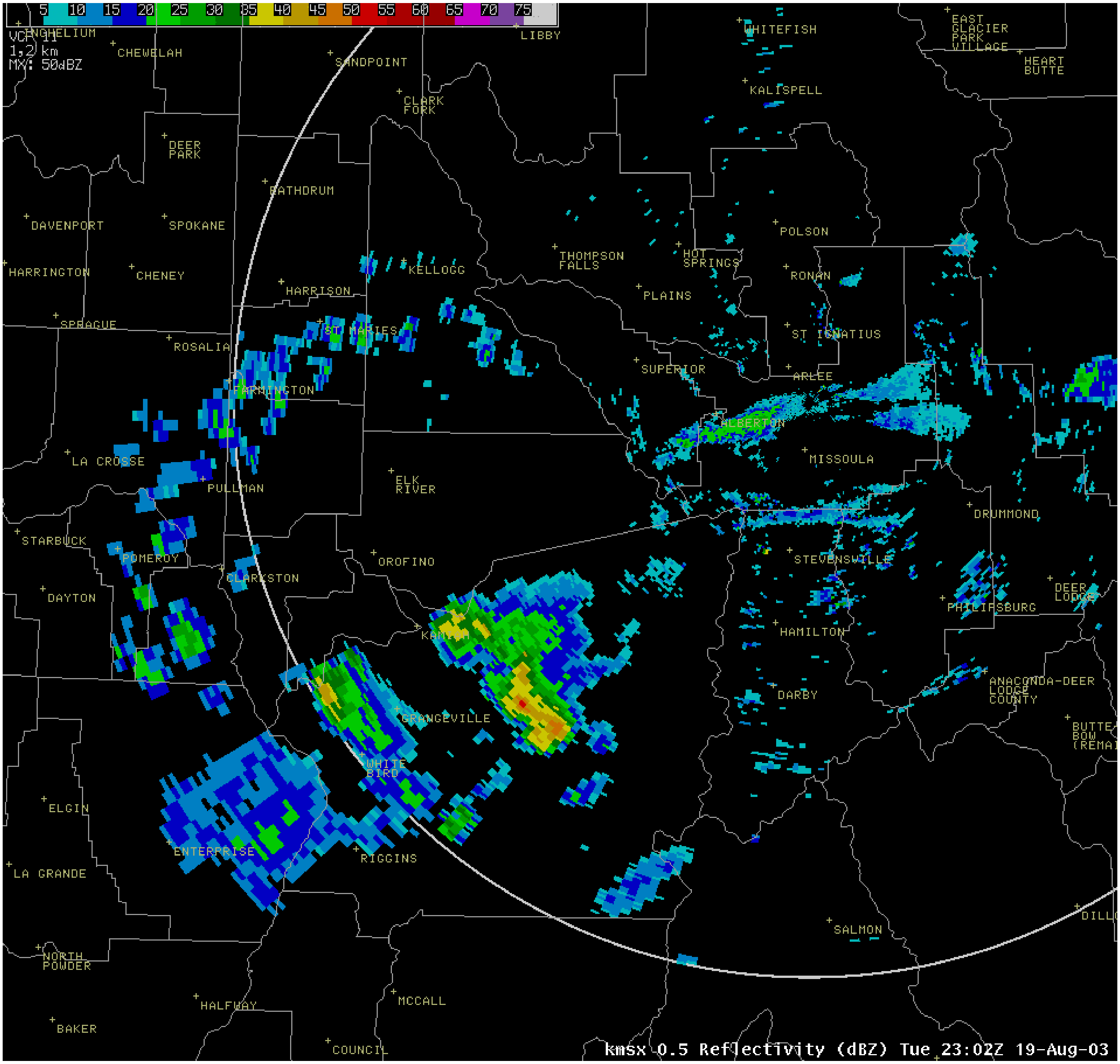

1000
2000
3000
4000
MesoETA Surface Pos Buoy Energy Img(J/kg) 19.18 6HR Wed 00:00Z 20-Aug-03
MesoETA Surface Pos Buoy Energy (J/Kg) 19.18 6HR Wed 00:00Z 20-Aug-03

Figure 8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VCP 11
1,2 km
MX: 50dBZ
CHEWELAH
SANDPOINT
LIBBY
WHITEFISH
EAST GLACIER PARK VILLAGE
HEART BUTTE
KALISPELL
CLARK FORK
DEER PARK
RATHDRUM
DAVENPORT
SPOKANE
POLSON
HARRINGTON
CHENEY
KELLOGG
THOMPSON FALLS
HOT SPRINGS
RONAN
HARRISON
PLAINS
SPRAGUE
ROSALIA
ST MARIES
ST IGNATIUS
SUPERIOR
ARLEE
FARMINGTON
ALBERTON
LA CROSSE
PULLMAN
ELK RIVER
MISSOULA
DRUMMOND
STARBUCK
POMEROY
CLARKSTON
OROFINO
STEVENSVILLE
DAYTON
DEER LODGE
PHILIPSBURG
KAMIAH
HAMILTON
DARBY
ANACONDA-DEER LODGE COUNTY
GRANGEVILLE
BUTTE-BOW (REMAI
WHITE BIRD
ELGIN
ENTERPRISE
RIGGINS
LA GRANDE
DILL
SALMON
NORTH POWDER
HALFWAY
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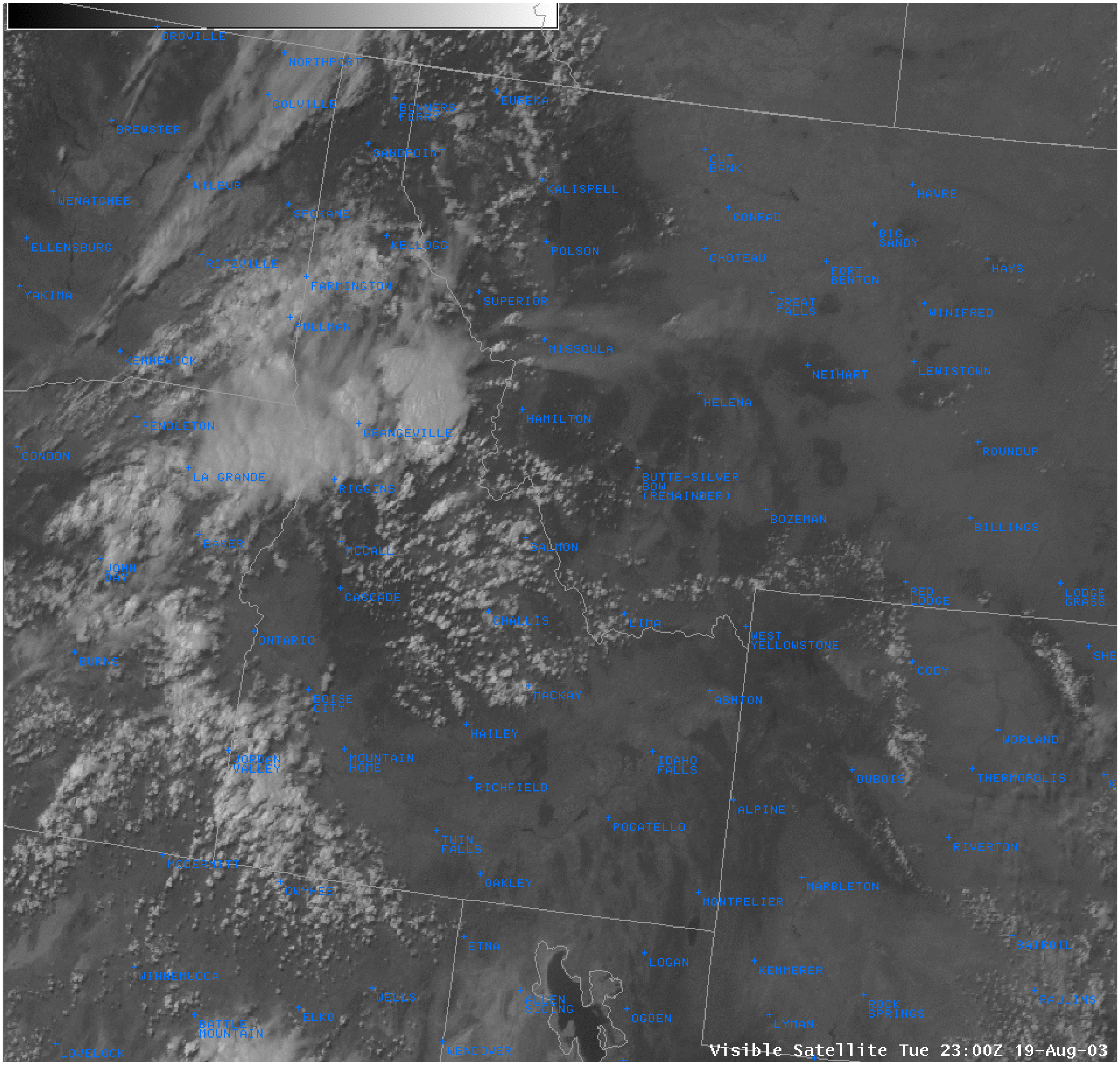
BAKER
COUNCIL
kmsx 0.5 Reflectivity (dBZ) Tue 23:02Z 19-Aug-03

Figure 9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NORTHPORT
COLVILLE
BONNERS FERRY
EUREKA
BREWSTER
SANDPOINT
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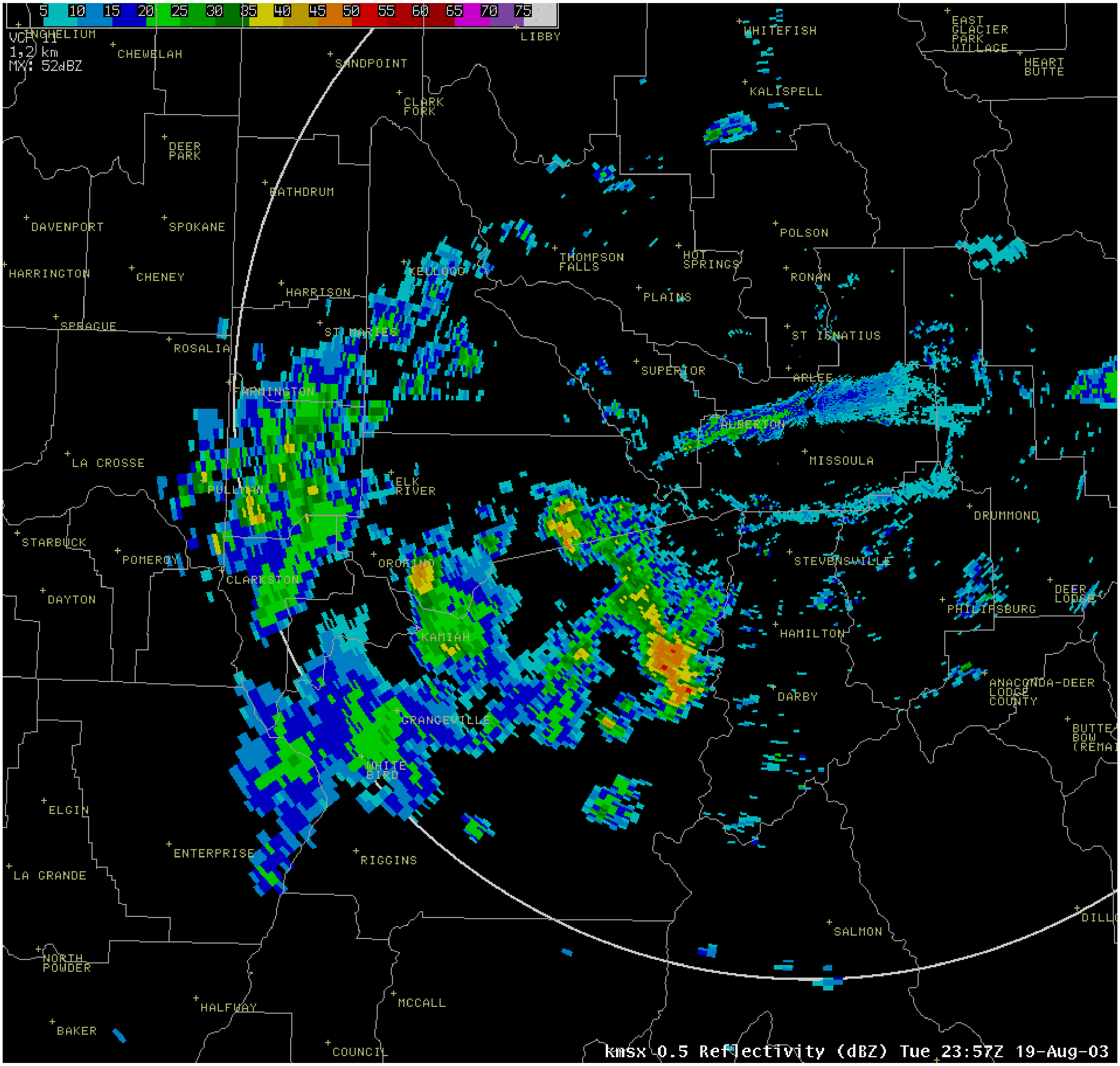
WILBUR
KALISPELL
HAVRE
WENATCHEE
SPOKANE
CONRAD
BIG SANDY
ELLENSBURG
KELLOGG
POLSON
CHOTEAU
FORT BENTON
HAYS
RITZVILLE
FARMINGTON
YAKIMA
SUPERIOR
GREAT FALLS
WINIFRED
POLLMAN
MISSOULA
KENNEWICK
NEIHART
LEWISTOWN
HELENA
HAMILTON
PENDLETON
GRANGEVILLE
CONDON
ROUNDUP
LA GRANDE
RIGGINS
BUTTE-SILVER BOW (REMAINDER)
BOZEMAN
BILLINGS
BAKER
MCCALL
SALMON
JOHN DAY
RED LODGE
LODGE GRASS
CASCADE
CHALLIS
LIMA
WEST YELLOWSTONE
ONTARIO
BURNS
SHE
CODY
BOISE CITY
MACKAY
ASHTON
HAILEY
WORLAND
JORDAN VALLEY
MOUNTAIN HOME
IDAHO FALLS
DUBOIS
THERMOPOLIS
RICHFIELD
ALPINE
POCATELLO
TWIN FALLS
RIVERTON
MCDERMITT
OWYHEE
OAKLEY
MARBLETON
MONTPELIER
ETNA
BAIROIL
LOGAN
WINNEMUCCA
KEMMERER
WELLS
ALLEN SIDING
ROCK SPRINGS
RAWLINS
ELKO
OGDEN
BATTLE MOUNTAIN
LYMAN
LOVELOCK
WENDOVER
Visible Satellite Tue 23:00Z 19-Aug-03

Figure 10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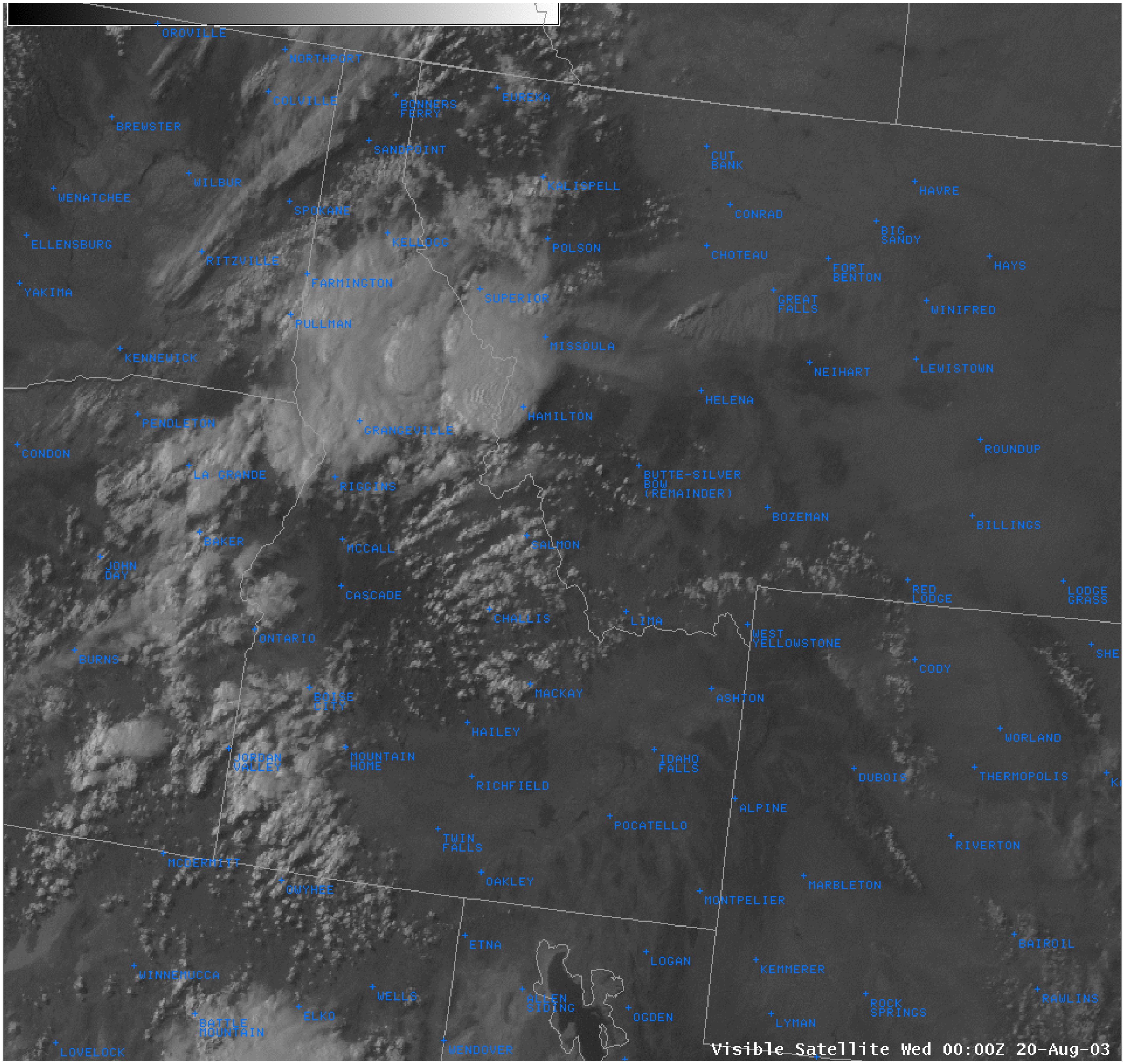
VCP: 11
1.2 km
MX: 52dBZ
ENGHELIUM
CHEWELAH
SANDPOINT
LIBBY
WHITEFISH
EAST GLACIER PARK VILLAGE
HEART BUTTE
KALISPELL
CLARK FORK
DEER PARK
BATHDRUM
DAVENPORT
SPOKANE
POLSON
HARRINGTON
CHENEY
KELLOGG
THOMPSON FALLS
HOT SPRINGS
RONAN
HARRISON
PLAINS
SPRAGUE
ST MARIES
ST IGNATIUS
ROSALIA
SUPERIOR
ARLEE
FARMINGTON
ALBERTON
LA CROSSE
MISSOULA
PULLMAN
ELK RIVER
DRUMMOND
STARBUCK
POMEROY
OROFINO
STEVENSVILLE
CLARKSTON
DEER LODGE
DAYTON
PHILIPSBURG
HAMILTON
KAMIAH
ANACONDA-DEER LODGE COUNTY
DARBY
GRANGEVILLE
BUTTE-BOW (REMAI
WHITE BIRD
ELGIN
ENTERPRISE
RIGGINS
LA GRANDE
DILL
SALMON
NORTH POWDER
HALFWAY
MCCALL
BAKER
COUNCIL
kmsx 0.5 Reflectivity (dBZ) Tue 23:57Z 19-Aug-03

Figure 11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COLVILLE
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HAVRE
WENATCHEE
SPOKANE
CONRAD
BIG SANDY
ELLENSBURG
KELLOGG
POLSON
CHOTEAU
FORT BENTON
HAYS
RITZVILLE
FARMINGTON
YAKIMA
SUPERIOR
GREAT FALLS
WINIFRED
PULLMAN
MISSOULA
KENNEWICK
NEIHART
LEWISTOWN
HELENA
PENDLETON
HAMILTON
GRANGEVILLE
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ROUNDUP
LA GRANDE
BUTTE-SILVER BOW (REMAINDER)
RIGGINS
BOZEMAN
BILLINGS
BAKER
SALMON
MCCALL
JOHN DAY
RED LODGE
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CASCADE
CHALLIS
LIMA
WEST YELLOWSTONE
ONTARIO
BURNS
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CODY
MACKAY
ASHTON
BOISE CITY
HAILEY
WORLAND
JORDAN VALLEY
MOUNTAIN HOME
IDAHO FALLS
DUBOIS
THERMOPOLIS
RICHFIELD
ALPINE
POCATELLO
RIVERTON
TWIN FALLS
MCDERMITT
MARBLETON
OAKLEY
OWYHEE
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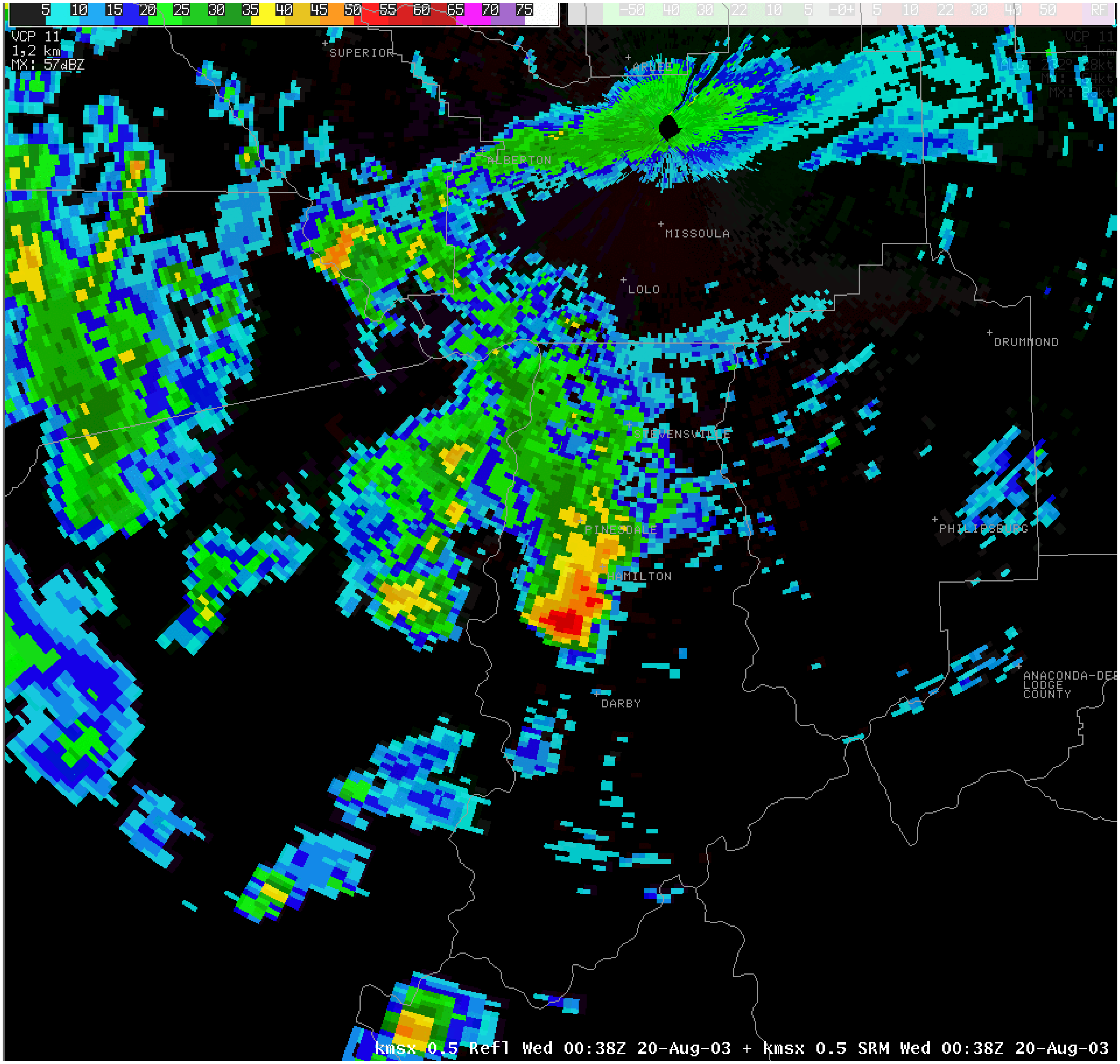
ETNA
BAIROIL
LOGAN
KEMMERER
WINNEMUCCA
WELLS
BLUE SIDING
RAWLINS
ROCK SPRINGS
ELKO
OGDEN
LYMAN
BATTLE MOUNTAIN
LOVELOCK
WENDOVER
Visible Satellite Wed 00:00Z 20-Aug-03

Figure 12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-50
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22
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10
22
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RF
VCP 11
1,2 km
MX: 57dBZ
SUPERIOR
ARLEE
ALBERTON
MISSOULA
LOLO
DRUMMOND
STEVENSVILLE
PINESDALE
HAMILTON
PHILIPSBURG
DARBY
ANACONDA-DEE
LODGE
COUNTY
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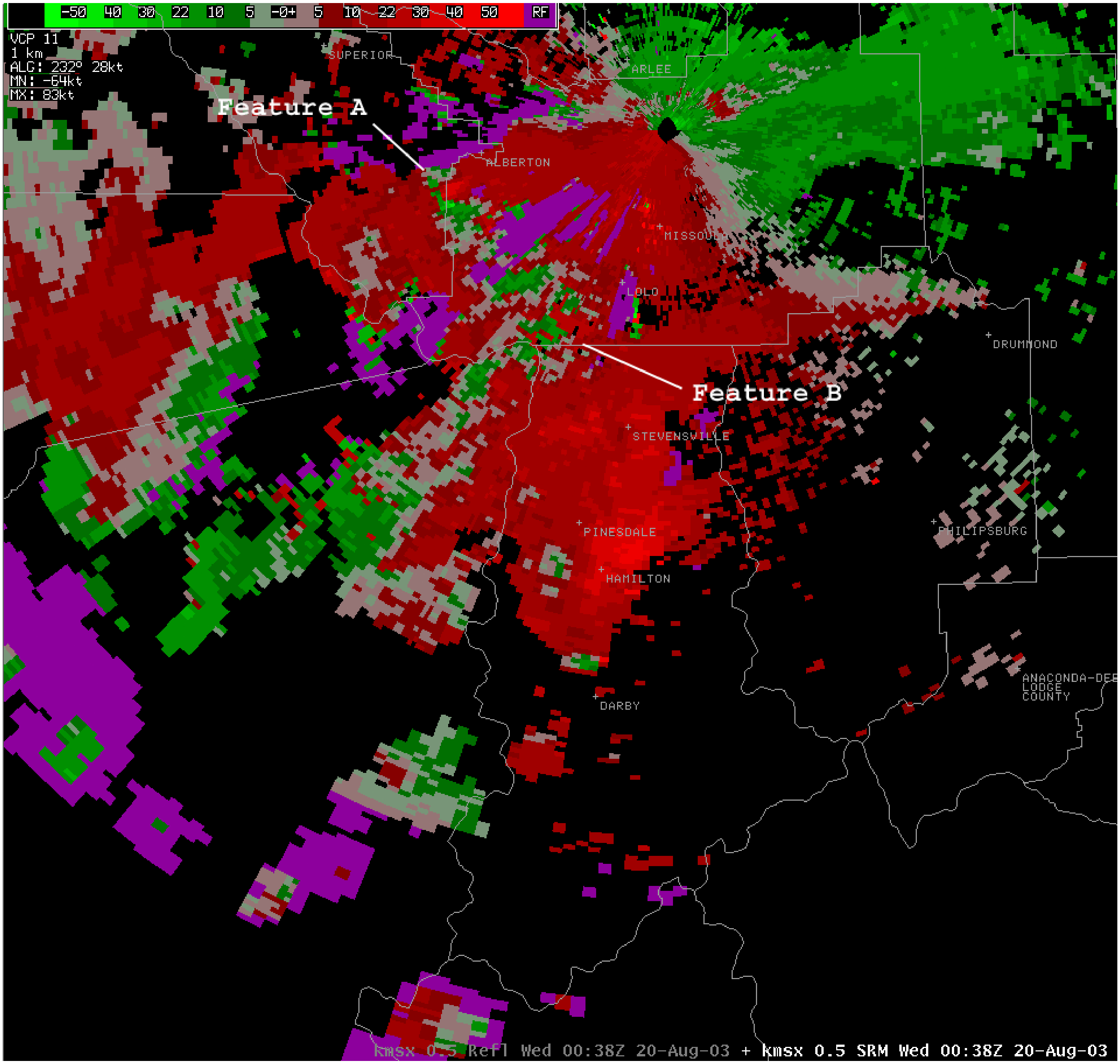
Figure 13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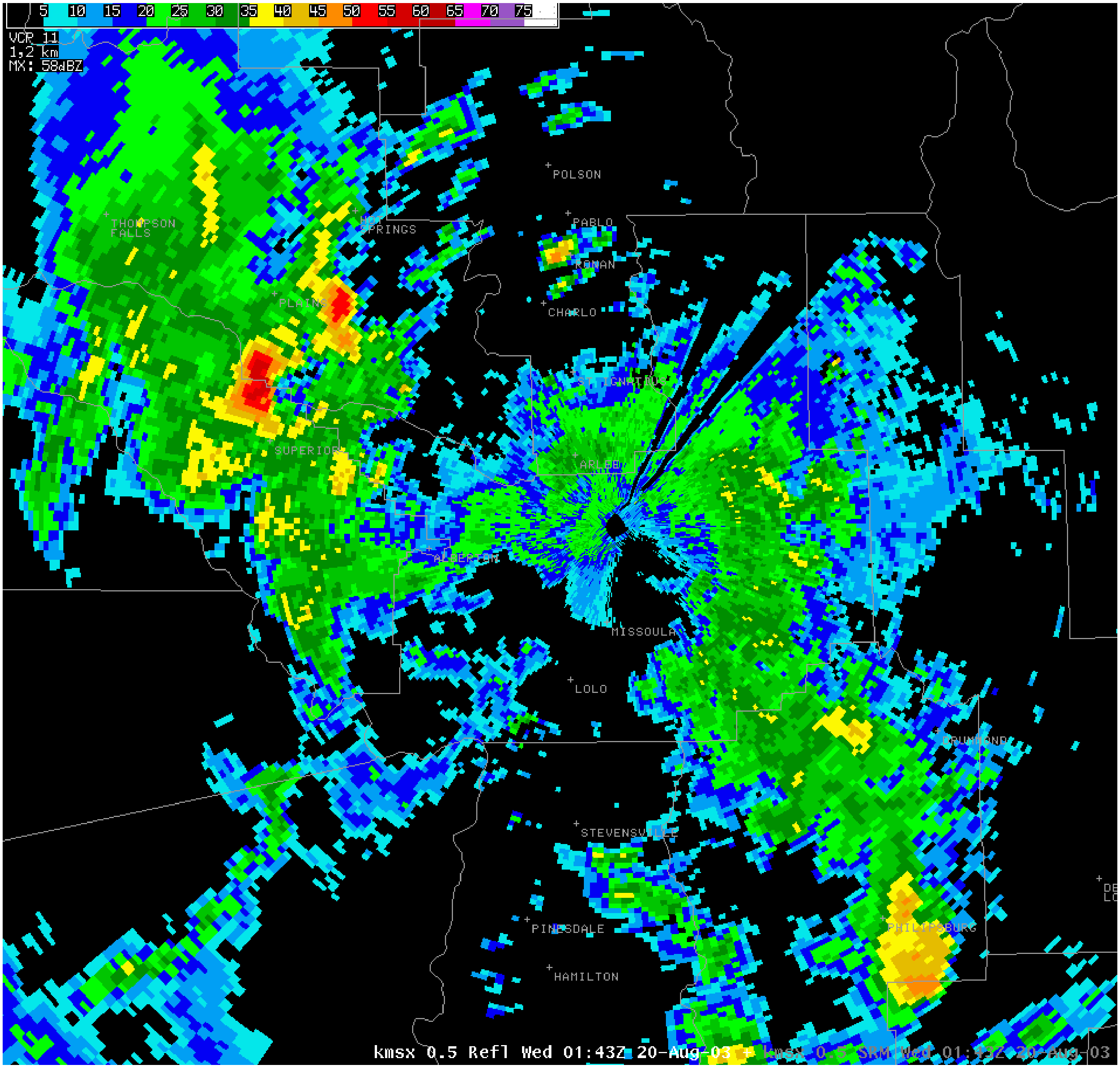
VCP 11
1 km
ALG: 232° 28kt
MN: -64kt
MX: 83kt
Feature A
Feature B
SUPERIOR
ARLEE
ALBERTON
MISSOULA
LOLO
DRUMMOND
STEVENSVILLE
PINESDALE
HAMILTON
PHILIPSBURG
ANACONDA-DEE
LODGE
COUNTY
DARBY
kmsx 0.5 Refl Wed 00:38Z 20-Aug-03 + kmsx 0.5 SRM Wed 00:38Z 20-Aug-03

Figure 14



5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
VCP 11
1.2 km
MX: 58dBZ
POLSON
PABLO
RONAN
CHARLO
THOMPSON FALLS
HOT SPRINGS
PLAINS
ST IGNATIUS
SUPERIOR
ARLEE
ALBERTON
MISSOULA
LOLO
DRUMMOND
STEVENSVILLE
PHILIPSBURG
PINESDALE
HAMILTON
kmsx 0.5 Refl Wed 01:43Z 20-Aug-03 + kmsx 0.5 SRM Wed 01:43Z 20-Aug-03