Analysis of the November 11th, 2003 Convective Snow Banding Event in Western Montana Using the Weather Event Simulator

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Introduction and General Meteorological Conditions

Banded convective precipitation is quite common over western Montana and the mountains of northern Idaho during cold air advection situations. The convection often initiates in orographically favored regions and advects downstream developing into bands parallel to the mean 850-700mb flow as mid level cold air advection steepens lapse rates below 700 mb. Typically the mean 850-700 mb flow is nearly unidirectional from the west though northwest and at least 20 kts, although banding has occurred with mean windflow from the southwest through north through east. These precipitation bands are often a significant forecast issue during the cold season, as they can produce locally heavy snow in the valleys. Snowfall rates of up to 3 inches per hour have been observed. Given the nature of the bands, they can persist along the same track for several hours producing significant local snowfall accumulations. Most persistent banding situations typically produce local snowfall accumulations of 2 to 5 inches. Though every winter during stronger events, snowfall of 8+" inches are reported. The impact of the heavy snow can be significant if a persistent heavy band develops over a populated area. These events generally occur in post frontal environments with the models often ending precipitation much too quickly. The other issue is detecting situations where heavy snow bands may be occurring, but is not easily detectable. Due to the location of the Missoula radar, on top of a mountain at 8000', the beam overshoots the snow bands over most of our CWA. At times visible imagery can be used to locate bands during the daytime if higher clouds are not present. In an effort to improve forecast of these events, and to determine where bands might be favored in certain situations, several banding events have been investigated over the past 2 winters. One of the strongest banding events in the past few years occurred on November 11th, 2003. Details of this event were analysed using the Weather Event Simulator to compare features of this event with previous events.

Event Description and Comparison with Other Banding Events

During the early morning of November 11th, 2003, an upper trough and associated cold front moved through western Montana. By 18 UTC, the cold front moved into far eastern Montana with strong west northwesterly flow developing above 800 mb across western Montana (Fig 1). Mid level cold air advection resulted in a deep moist well mixed layer below a modest stable layer at 400 mb as indicated by the Missoula Eta BUFR Sounding at 18 UTC (Fig 2). Following the trough passage an upper ridge was building into the Pacific Northwest with warm air advection developing aloft (Fig 3). At this time, widespread heavy snow bands were already occurring as indicated by the 1733 UTC Missoula composite reflectivity product (Fig 4). Snowfall rates of up to 3 inches per hour were reported with the heaviest bands. Visible satellite imagery at 1800 UTC (Fig 5), indicated the bands were initiating well upstream over northern Idaho along the leading edge of the Clearwater Mountains and intensifying downstream into western Montana. The imagery also shows bands that the Missoula radar is overshooting. Satellite and radar loops often show the initiation points of the convection can persist for several hours. This gives the appearance that the bands are "anchored" to a given point, even if the mean windflow changes direction by 10 or 20 degrees. At times the anchor points can clearly be traced to a particular terrain feature. Other times, they seem to be related to a pattern of interference among the various bands.

The convective bands persisted through the afternoon into the evening hours only slowly weakening with time. The Missoula Eta BUFR Sounding at 00 UTC on the 12th (Fig 6) indicates the forecasted stable layer has lowered to around 530 mb as warm air advection at high levels began to move into the region with the upper ridge. Conditions remained moist and well mixed below the stable layer. The trend in decreasing intensity and coverage continued through 06 UTC. The Missoula Eta BUFR Sounding at 06 UTC (Fig 7) indicates the stable layer continue to lower to about 660 mb. The mean wind in the 850-700 mb layer has also diminished. The 0529 UTC Missoula composite reflectivity product (Fig 8) still shows locally heavy snow bands, but the intensity and coverage are greatly diminished. The 06 UTC MesoEta (Fig 9, Fig10) continues to show the upper level features progressing to the east. The banding continued to weaken as the inversion height lowered through the early morning hours.

Local snowfall accumulations of 2 to 5 inches were common with as much as 10 inches at one mountain location. Despite the intensity and duration of this event, overall snowfall totals were not as high as they could have been as the bands were not persisting over the same location for any length of time. The 850 mb to 700 mb windflow was not unidirectional with height with the 850 mb being about 20 degrees more westerly. Often in this situation, the bands orient themselves with the 700 mb windflow, but translate downstream with the 850 mb wind. Thus, the bands did not persist over any given location for a prolonged period.

Summary and Comparison with Other Events

Many of the elements seen in this banding event are similar to previous events investigated. It appears the primary factors in the development and character of convective banding in western Montana, are the existence and height of a stable layer, the 850-700mb mean wind, the lapse rates below the stable layer, and available moisture below the stable layer. A time height of MesoEta forecast data for Missoula (Fig 11) clearly indicates the descending stable layer as the upper ridge builds in from the west with the shrinking moist well mixed layer. The stable layer acts to force downward vertical motions on either side of the convective cores as opposed to venting the updraft air at a higher level in the atmosphere. This organizes the convection in rolls which are advected downstream by the mean wind forming the bands. The organization of the bands is strengthened by the low and mid level divergent/convergence that is enhanced by the convective rolls. Heavy snow showers still occur when a stable layer does not exist. In these situations the convection does not organize into bands, but into varied patterns of individual cells. Despite the intense snowfall rates inside these showers, they typically do not persist over a given location for a long enough period to result in significant accumulations. There are situations where the individual cells do train along the same path, resulting in locally heavy snows. With the importance of the stable layer in organizing the convection into bands, the most significant banding situations seems to occur with a building ridge following a trough passage. As the ridge builds in aloft a stable layer develops and descends with height, as this case illustrates. Typically the strongest bands occur with the stable layer between 500 and 600 mb. As the stable layer descends, the bands weaken with time and the spacing between the bands is reduced. More numerous bands may develop as the stable layer shallows (note the weak closely spaced bands on the 0529 UTC composite reflectivity northeast of the radar (Fig 8) . With a moist stable layer below 700 mb, persistent general light snow or flurries often results with little definition between the precipitation bands.

850 to 700 mb mean wind speeds of 30 to 50 kts seem to favor the heavier bands. With winds below 25 kts, the bands tend to be weaker and less numerous. With winds above 60 kts, downslope effects begin the dominate in the valleys, weakening the bands over the valleys. The lapse rate below the stable layer also appears to play a role in how the convection organizes. As the timeheight (Fig 11) indicates in the November 11th case, the forecasted average lapse rates below the stable layer were about 7 to 8 C /km. This range seems to favor the stronger bands. With more unstable conditions, lapse rates approaching 9 C/km, the convection often organizes into individual cells . If a stable layer is present in this situation, the individual cells may train along the same path or develop broken bands. For lapse rates between 5.5 and 7 C/km , weaker more numerous bands often develop.

Subjectively, it does appear that certain band anchor points and band tracks are favored given a particular 850-700 mb mean wind and the lapse rate within the unstable layer. A few examples: In west to west southwest flow a band often develops from north of Lolo Peak, south of Missoula, to the east across the Bitterroot Valley to the Sapphire Mountains. In west northwest flow a band often develops from near Alberton to near Potomac, (northwest through east of Missoula). With northwesterly flow, the I-90 corridor through Missoula seems to be favored. More investigation will be required to objectively determine the important parameters which effect specific band locations.

Figure 1

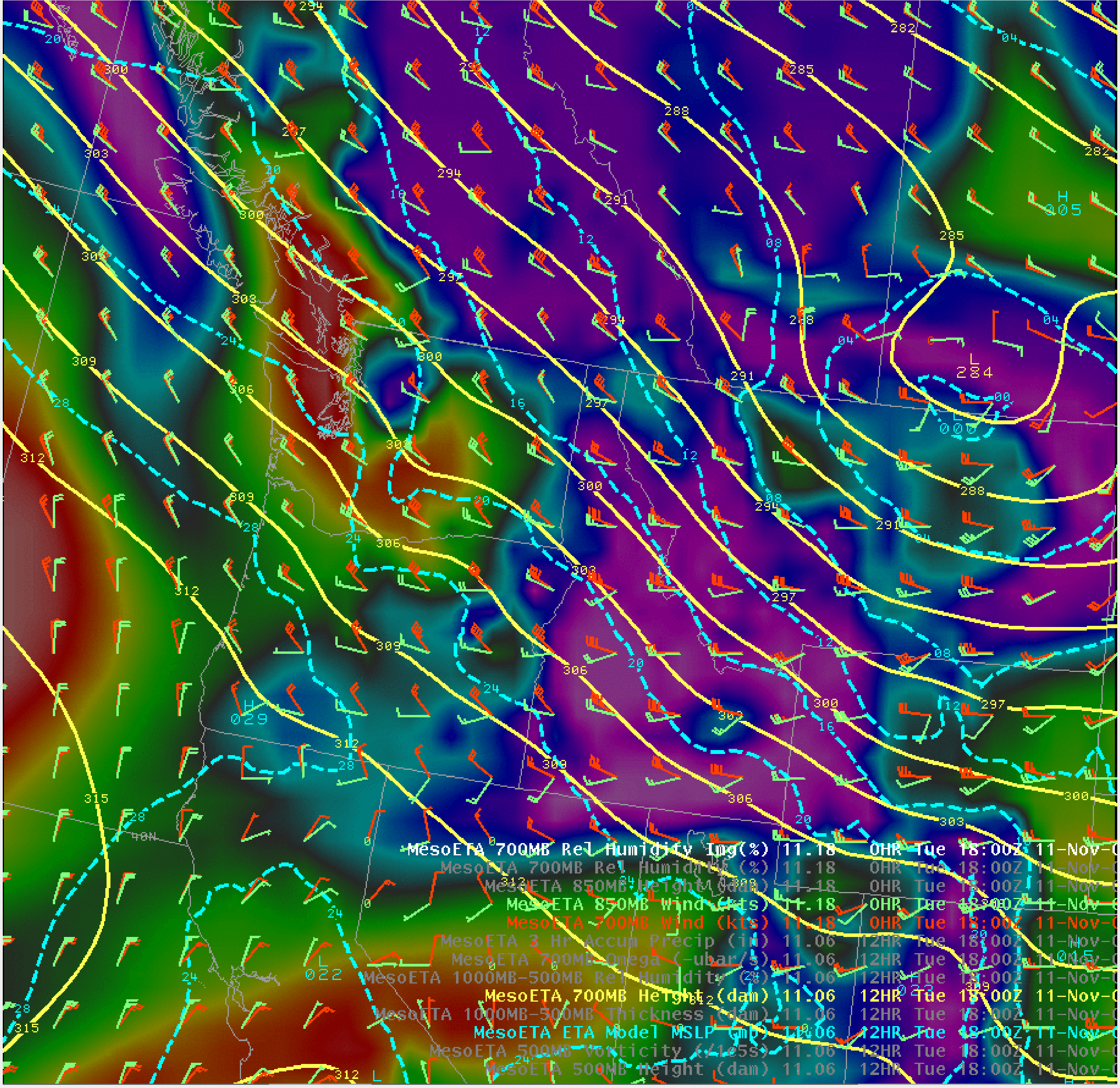

Figure 2

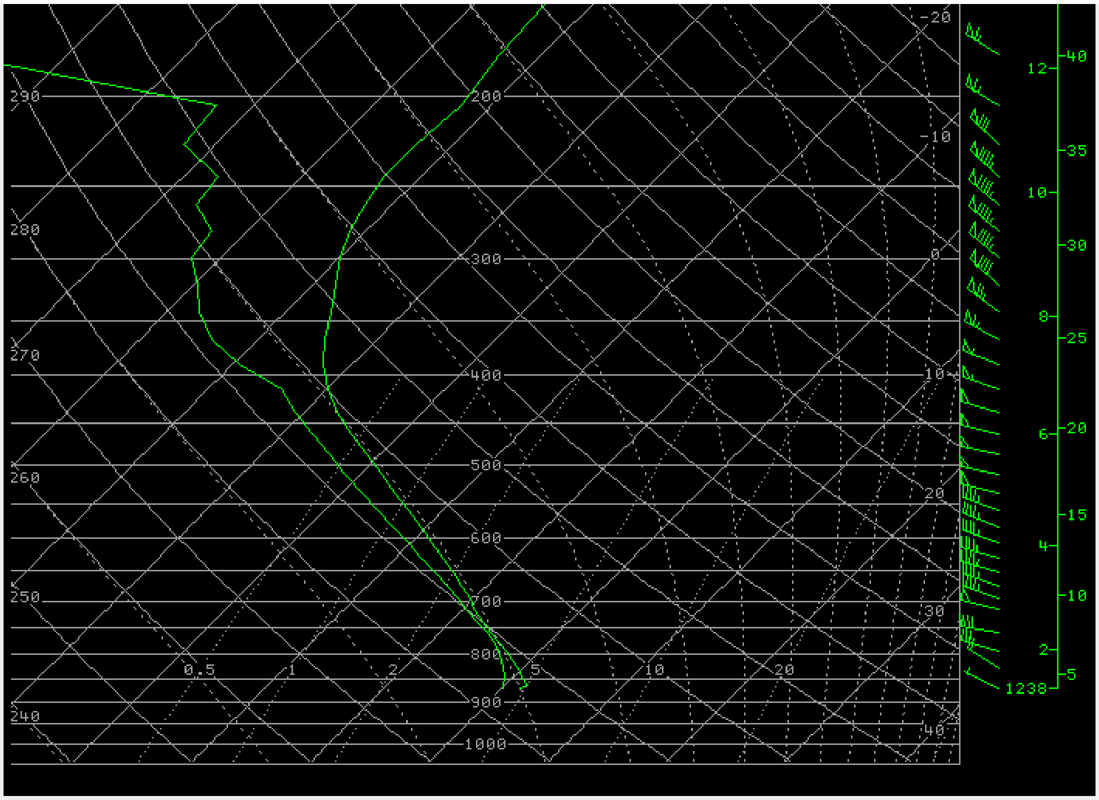

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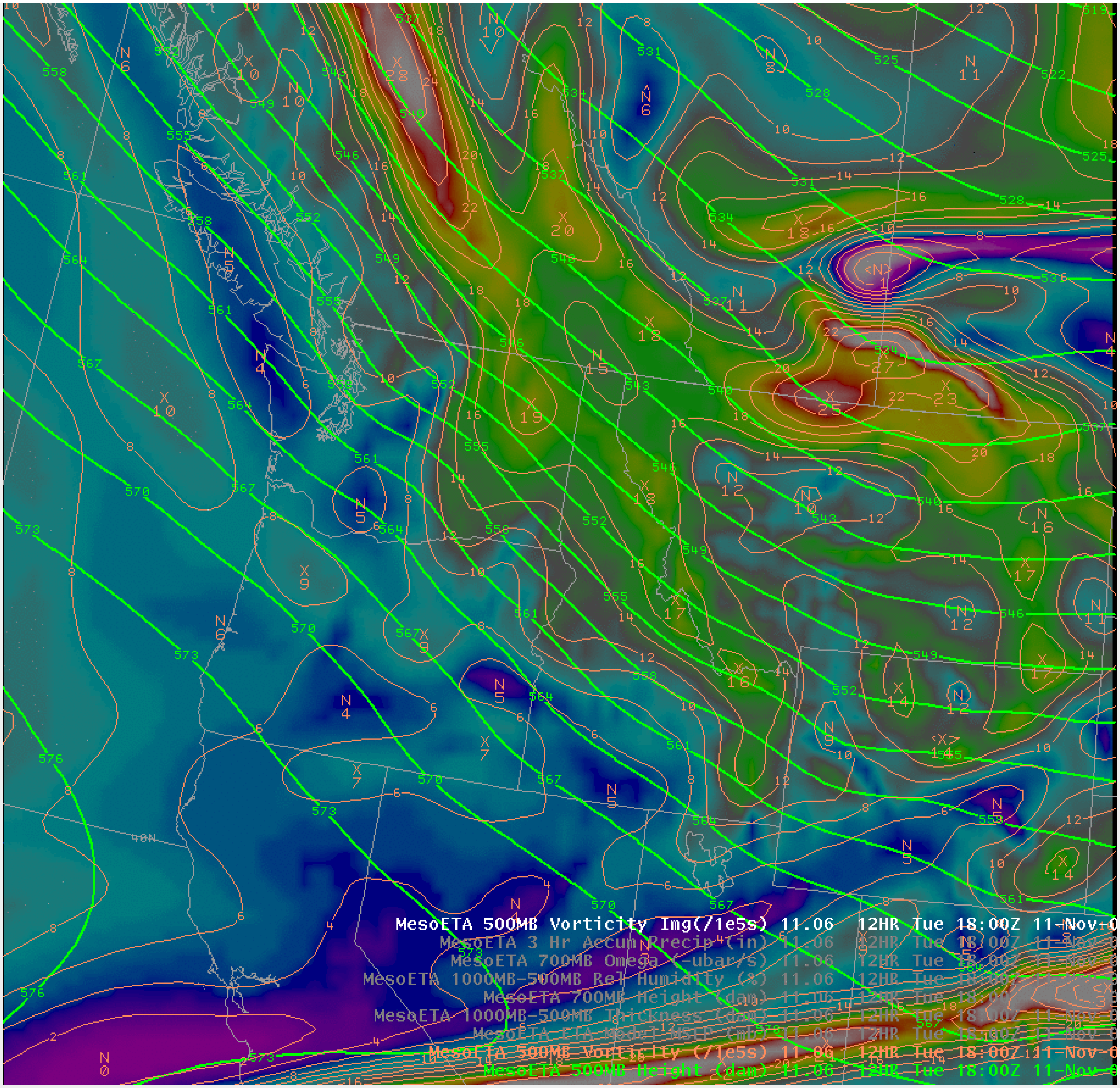
Figure 3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MesoETA 3 Hr Accum Precip (in) 11.06 12HR Tue 18:00Z 11-Nov-0
MesoETA 700MB Omega (-ubar/s) 11.06 12HR Tue 18:00Z 11-Nov-0
MesoETA 1000MB-500MB Rel Humidity (%) 11.06 12HR Tue 18:00Z 11-Nov-0
MesoETA 700MB Height (dam) 11.06 12HR Tue 18:00Z 11-Nov-0
MesoETA 1000MB-500MB Thickness (dam) 11.06 12HR Tue 18:00Z 11-Nov-0
MesoETA ETA Model MSLP (mb) 11.06 12HR Tue 18:00Z 11-Nov-0
MesoETA 500MB Vorticity (/1e5s) 11.06 12HR Tue 18:00Z 11-Nov-0
MesoETA 500MB Height (dam) 11.06 12HR Tue 18:00Z 11-Nov-0
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Figure 4

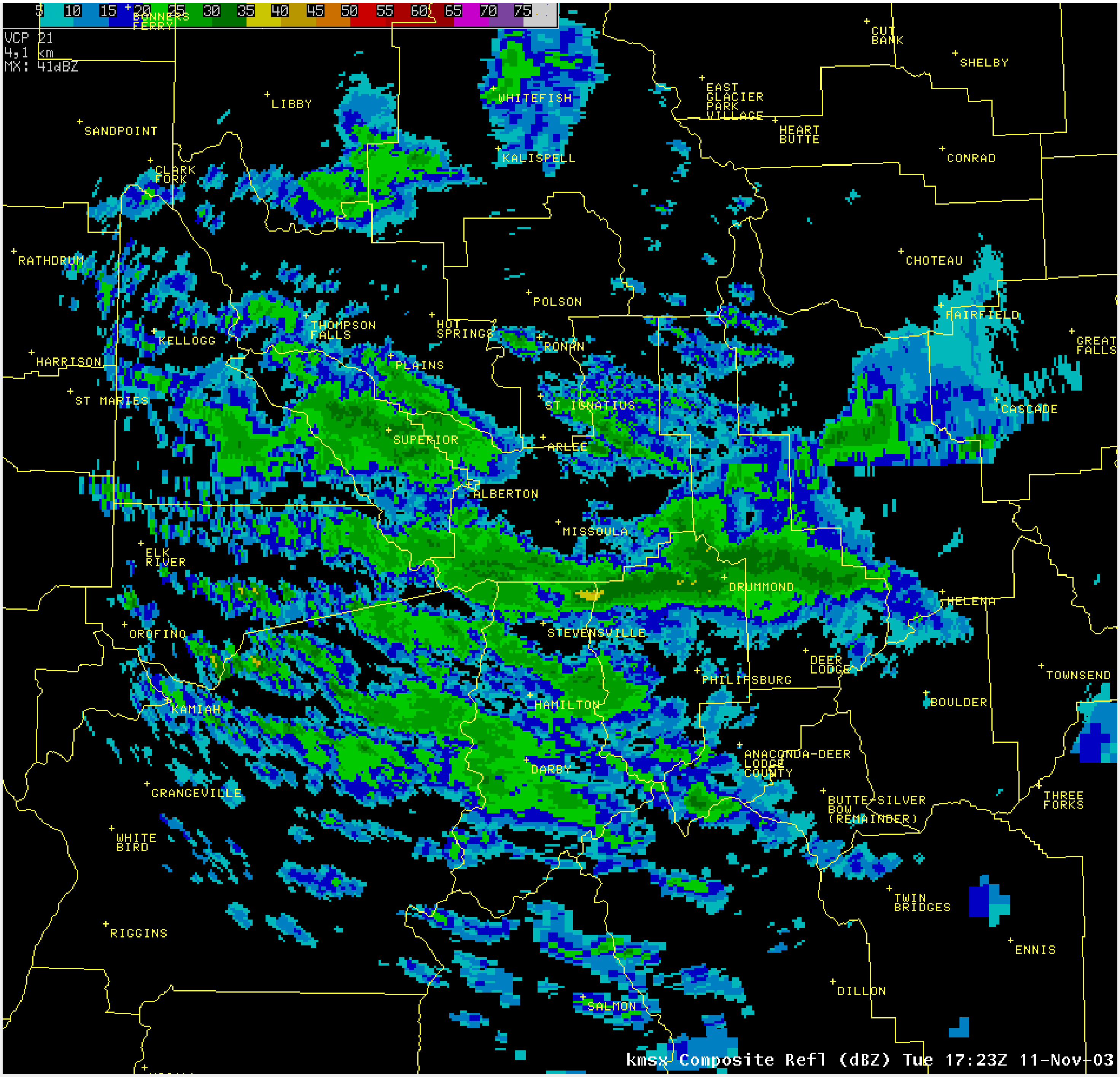
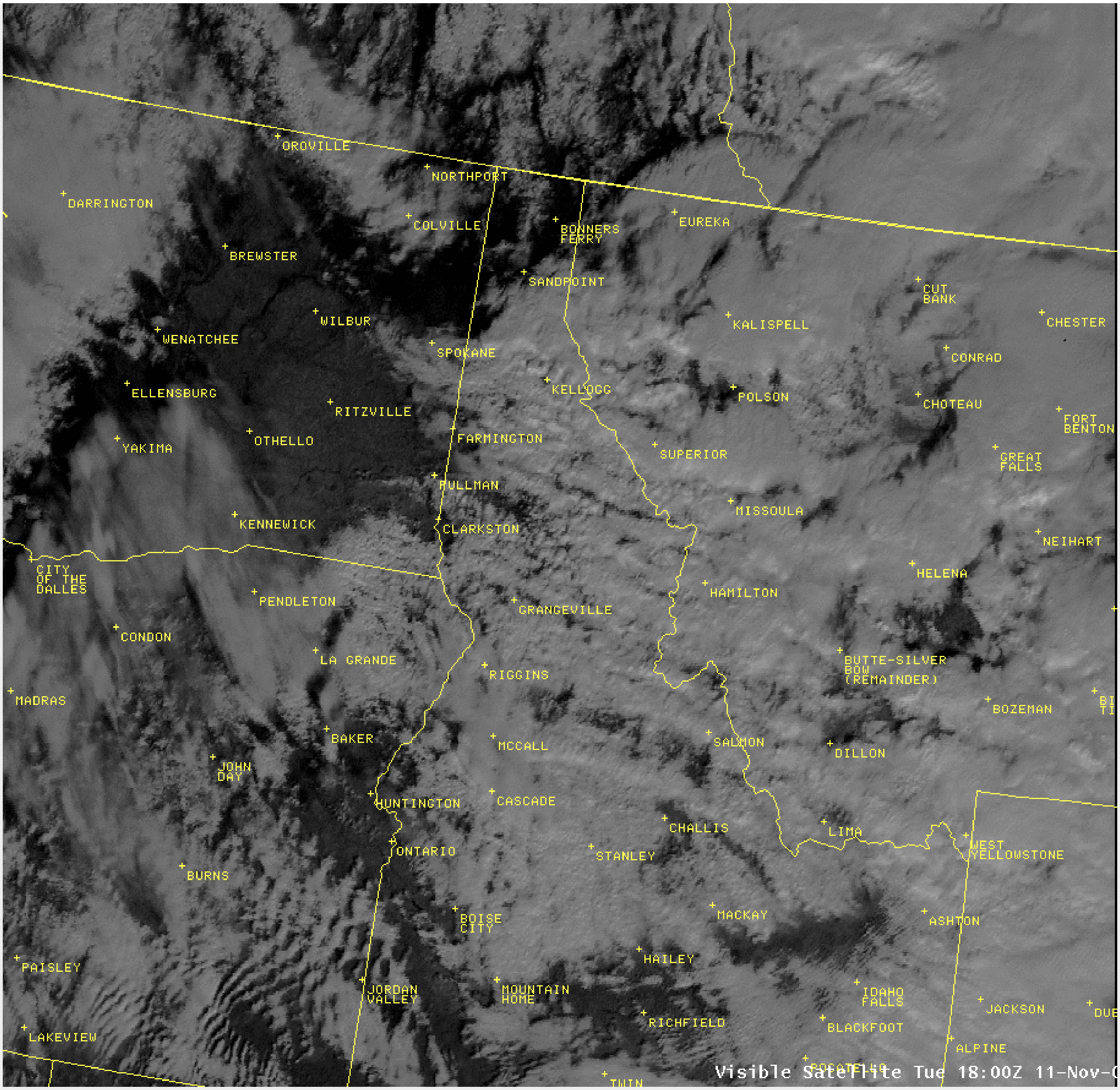

5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
VCP 21
4.1 km
MX: 41dBZ
BONNERS FERRY
CUT BANK
SHELBY
LIBBY
WHITEFISH
EAST GLACIER PARK VILLAGE
SANDPOINT
HEART BUTTE
KALISPELL
CONRAD
CLARK FORK
RATHDRUM
CHOTEAU
POLSON
FAIRFIELD
THOMPSON FALLS
HOT SPRINGS
KELLOGG
RONAN
GREAT FALLS
HARRISON
PLAINS
ST MARIES
ST IGNATIUS
CASCADE
SUPERIOR
ARLEE
ALBERTON
MISSOULA
ELK RIVER
DRUMMOND
HELENA
OROFINO
STEVENSVILLE
DEER LODGE
PHILIPSBURG
TOWNSEND
KAMIAH
HAMILTON
BOULDER
ANACONDA-DEER LODGE COUNTY
DARBY
GRANGEVILLE
BUTTE-SILVER BOW (REMAINDER)
THREE FORKS
WHITE BIRD
TWIN BRIDGES
RIGGINS
ENNIS
DILLON
SALMON
kmsx Composite Refl (dBZ) Tue 17:23Z 11-Nov-03

Figure 5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NORTHPORT
DARRINGTON
COLVILLE
BONNERS FERRY
EUREKA
BREWSTER
SANDPOINT
CUT BANK
WILBUR
KALISPELL
CHESTER
WENATCHEE
SPOKANE
CONRAD
KELLOGG
ELLENSBURG
POLSON
RITZVILLE
CHOTEAU
FORT BENTON
FARMINGTON
OTHELLO
YAKIMA
SUPERIOR
GREAT FALLS
PULLMAN
MISSOULA
KENNEWICK
CLARKSTON
NEIHART
CITY OF THE DALLES
HELENA
PENDLETON
HAMILTON
GRANGEVILLE
CONDON
BUTTE-SILVER BOW (REMAINDER)
LA GRANDE
RIGGINS
MADRAS
BOZEMAN
BI TI
BAKER
MCCALL
SALMON
DILLON
JOHN DAY
HUNTINGTON
CASCADE
CHALLIS
LIMA
WEST YELLOWSTONE
ONTARIO
STANLEY
BURNS
MACKAY
ASHTON
BOISE CITY
HAILEY
PAISLEY
JORDAN VALLEY
MOUNTAIN HOME
IDAHO FALLS
JACKSON
DUE
RICHFIELD
BLACKFOOT
LAKEVIEW
ALPINE
POCATELLO
TWIN
Visible Satellite Tue 18:00Z 11-Nov-0

Figure 6

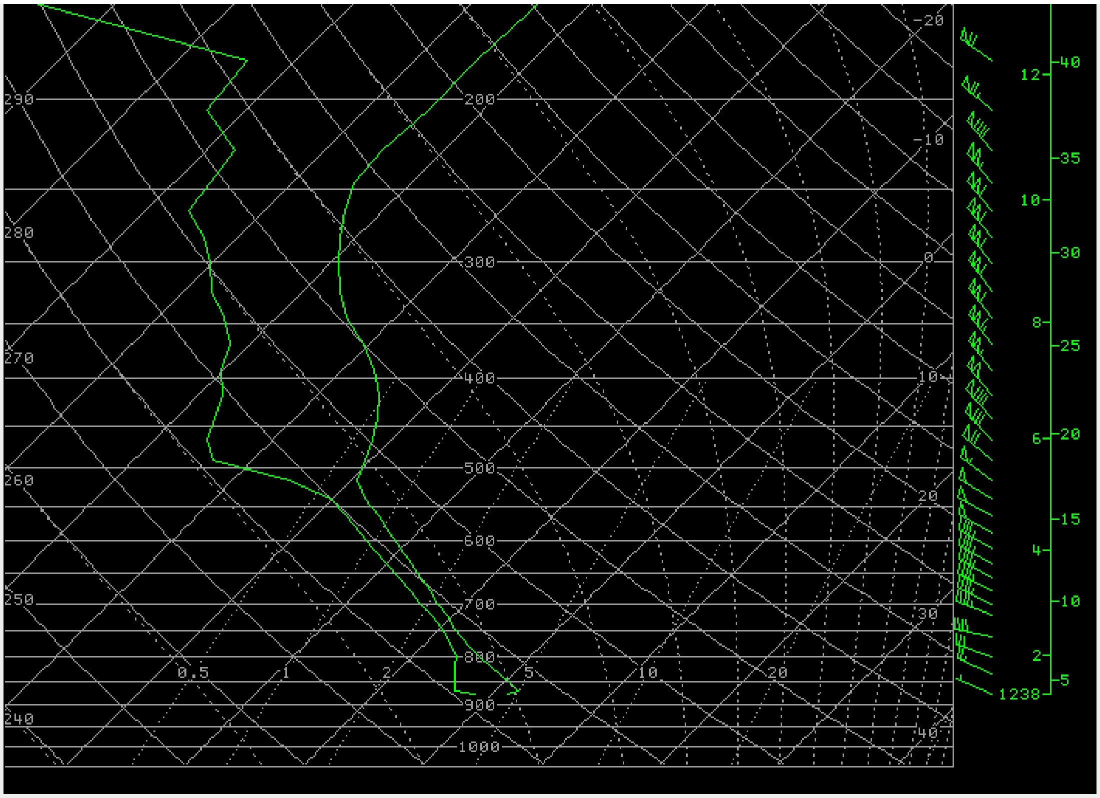


Figure 7

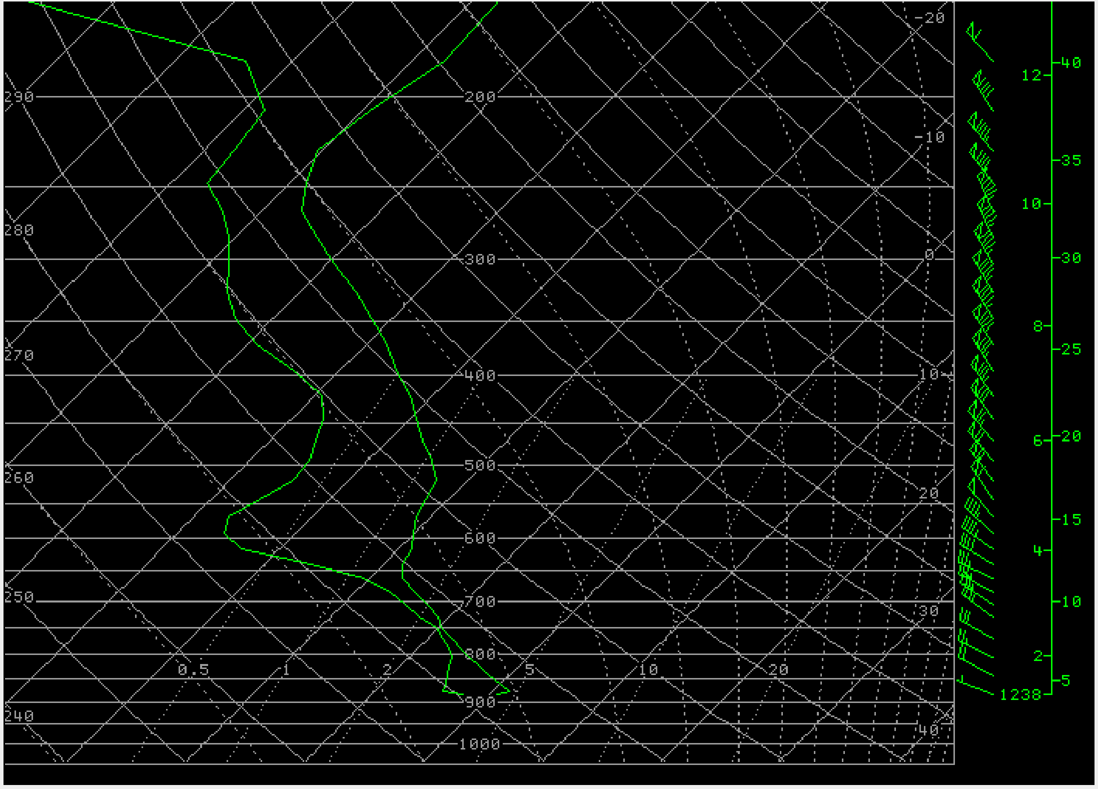
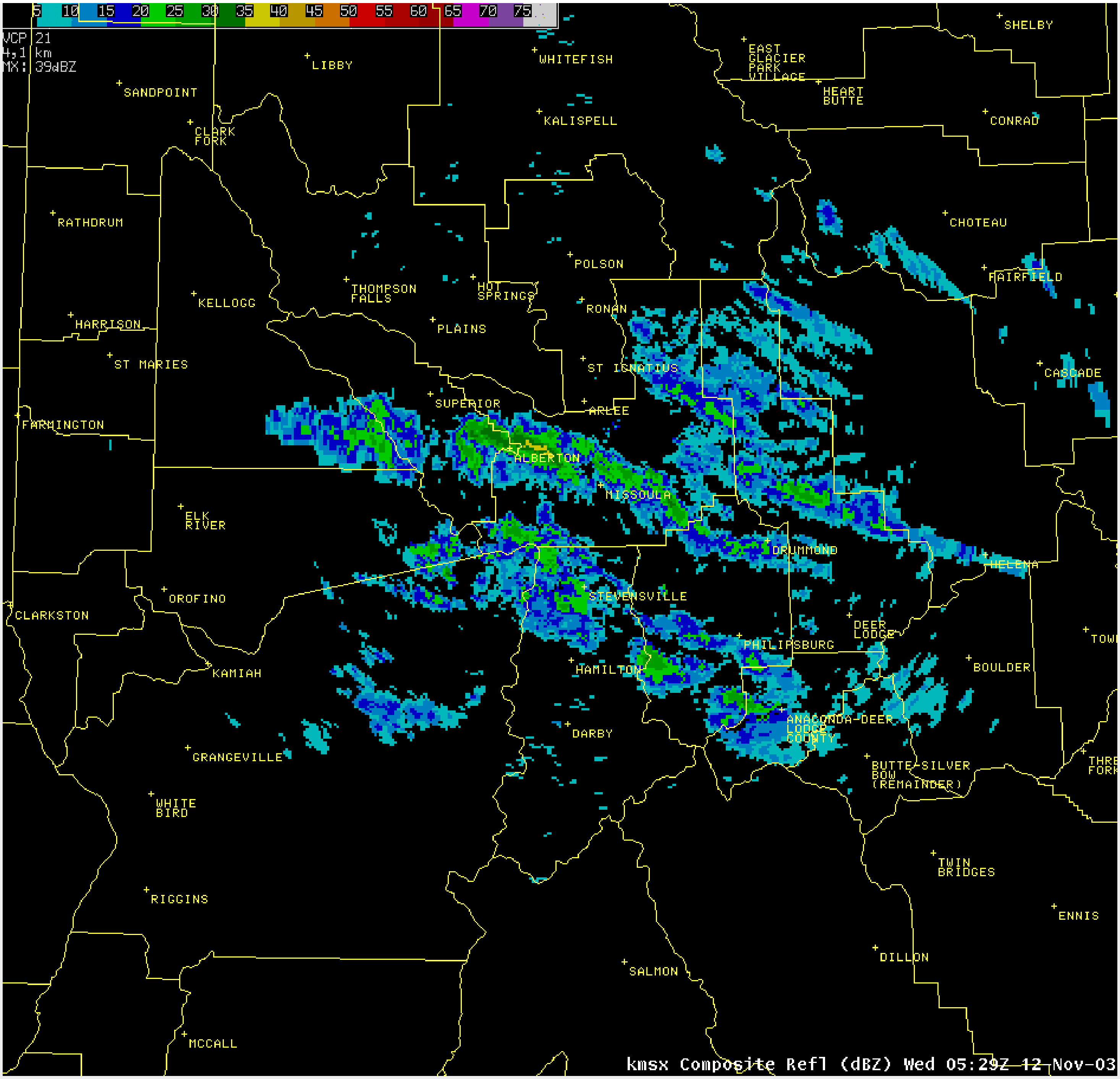


Figure 8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VCP 21
4.1 km
MX: 39dBZ
SHELBY
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WHITEFISH
EAST GLACIER PARK VILLAGE
SANDPOINT
HEART BUTTE
CLARK FORK
KALISPELL
CONRAD
RATHDRUM
CHOTEAU
POLSON
FAIRFIELD
THOMPSON FALLS
HOT SPRINGS
KELLOGG
RONAN
HARRISON
PLAINS
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ST IGNATIUS
CASCADE
SUPERIOR
ARLEE
FARMINGTON
ALBERTON
MISSOULA
ELK RIVER
DRUMMOND
HELENA
OROFINO
STEVENSVILLE
CLARKSTON
DEER LODGE
PHILIPSBURG
BOULDER
KAMIAH
HAMILTON
ANACONDA-DEER LODGE COUNTY
DARBY
GRANGEVILLE
BUTTE-SILVER BOW (REMAINDER)
WHITE BIRD
TWIN BRIDGES
RIGGINS
ENNIS
DILLON
SALMON
MCCALL
kmsx Composite Refl (dBZ) Wed 05:29Z 12 Nov-03

Figure 9

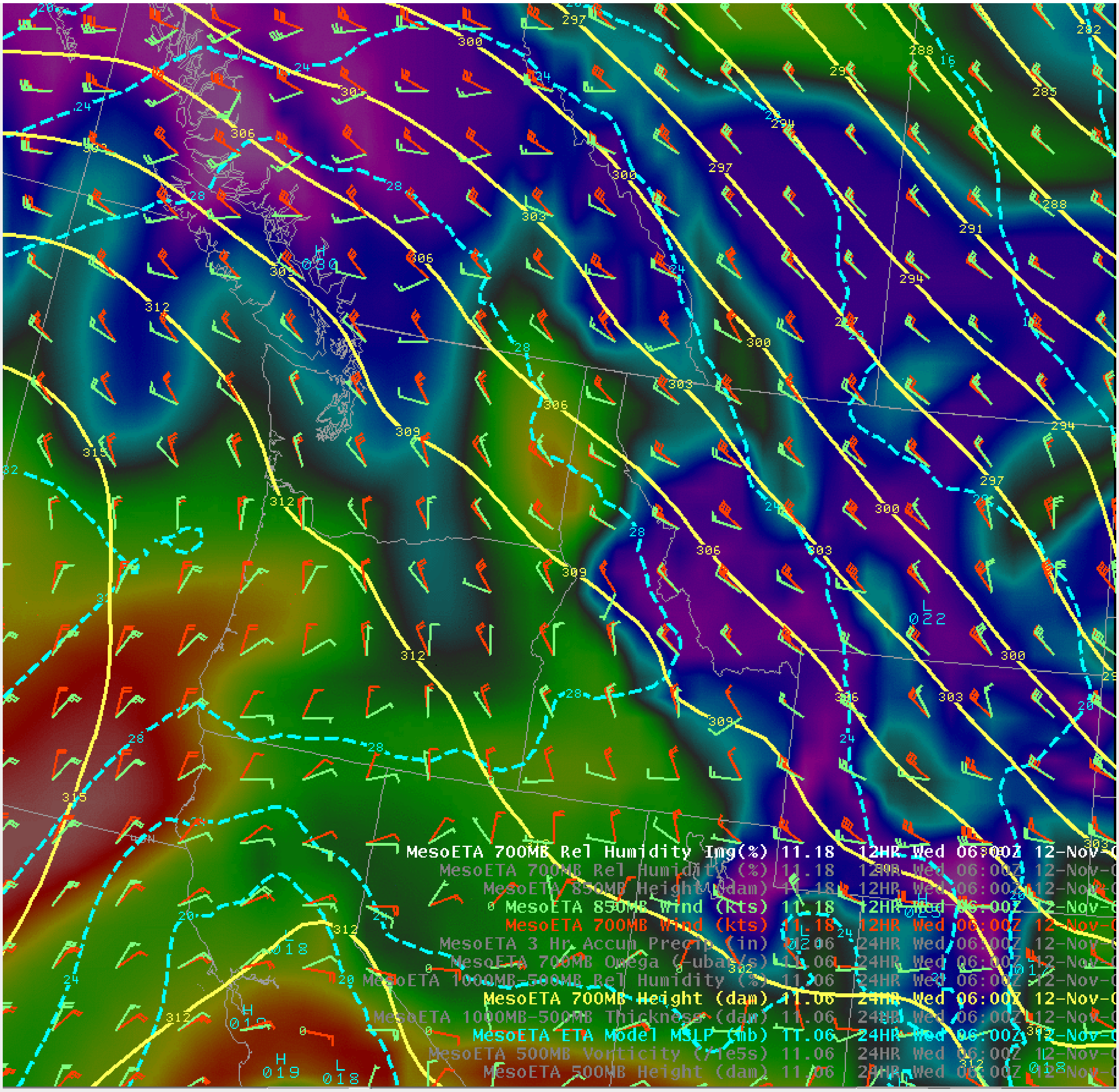
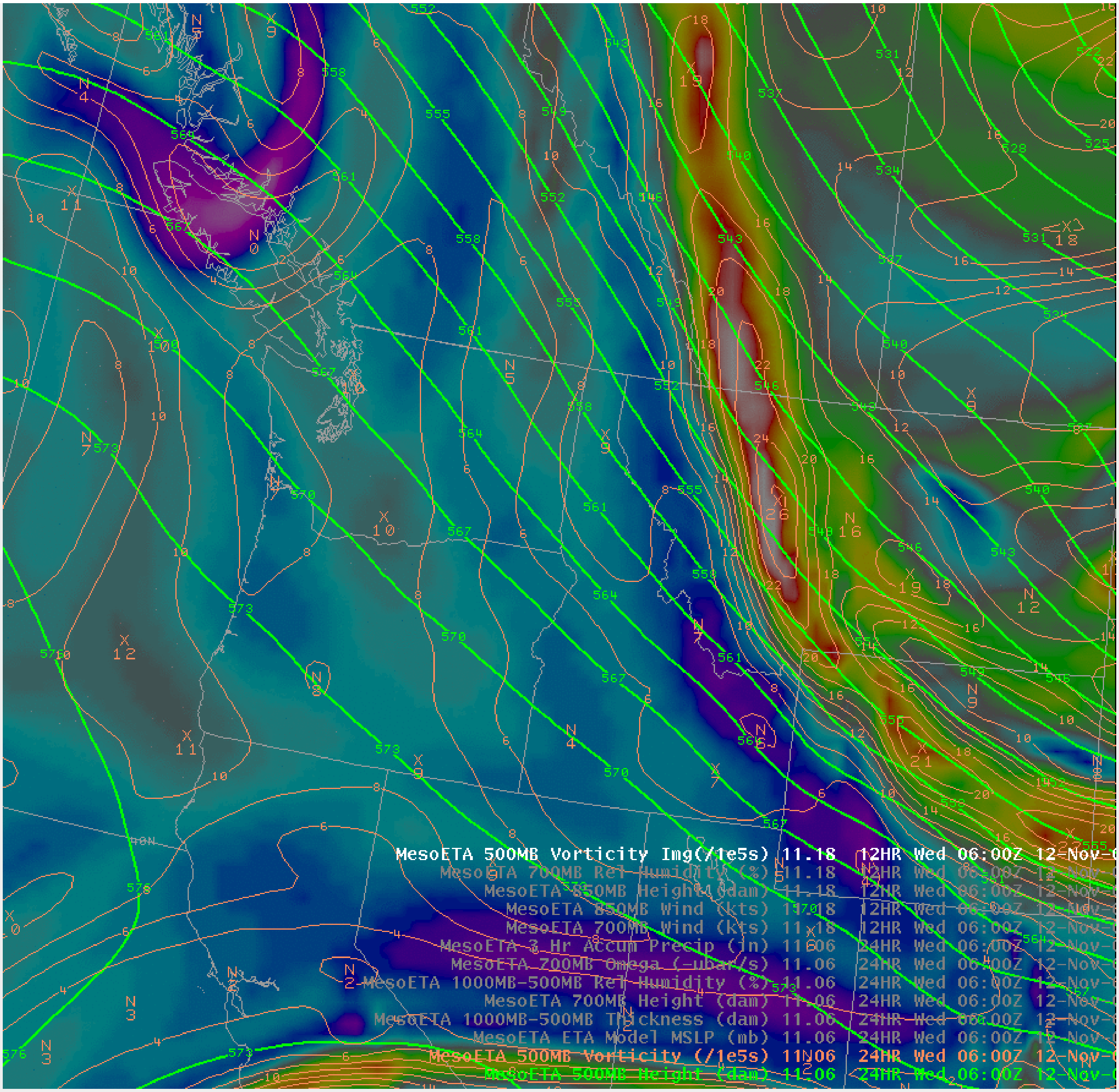

MesoETA 700MB Rel Humidity Img(%) 11.18 12HR Wed 06:00Z 12-Nov-
MesoETA 700MB Rel Humidity (%) 11.18 12HR Wed 06:00Z 12-Nov-
MesoETA 850MB Height (dam) 11.18 12HR Wed 06:00Z 12-Nov-
MesoETA 850MB Wind (kts) 11.18 12HR Wed 06:00Z 12-Nov-
MesoETA 700MB Wind (kts) 11.18 12HR Wed 06:00Z 12-Nov-
MesoETA 3 Hr Accum Precip (in) 11.06 24HR Wed 06:00Z 12-Nov-
MesoETA 700MB Omega (-ubar/s) 11.06 24HR Wed 06:00Z 12-Nov-
MesoETA 1000MB-500MB Rel Humidity (%) 11.06 24HR Wed 06:00Z 12-Nov-
MesoETA 700MB Height (dam) 11.06 24HR Wed 06:00Z 12-Nov-
MesoETA 1000MB-500MB Thickness (dam) 11.06 24HR Wed 06:00Z 12-Nov-
MesoETA ETA Model MSLP (mb) 11.06 24HR Wed 06:00Z 12-Nov-
MesoETA 500MB Vorticity (/1e5s) 11.06 24HR Wed 06:00Z 12-Nov-
MesoETA 500MB Height (dam) 11.06 24HR Wed 06:00Z 12-Nov-

Figure 10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MesoETA 700MB Rel Humidity (%) 11.18 12HR Wed 06:00Z 12-Nov-0
MesoETA 850MB Height (dam) 11.18 12HR Wed 06:00Z 12-Nov-0
MesoETA 850MB Wind (kts) 11.18 12HR Wed 06:00Z 12-Nov-0
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MesoETA 500MB Vorticity (/1e5s) 11.06 24HR Wed 06:00Z 12-Nov-0
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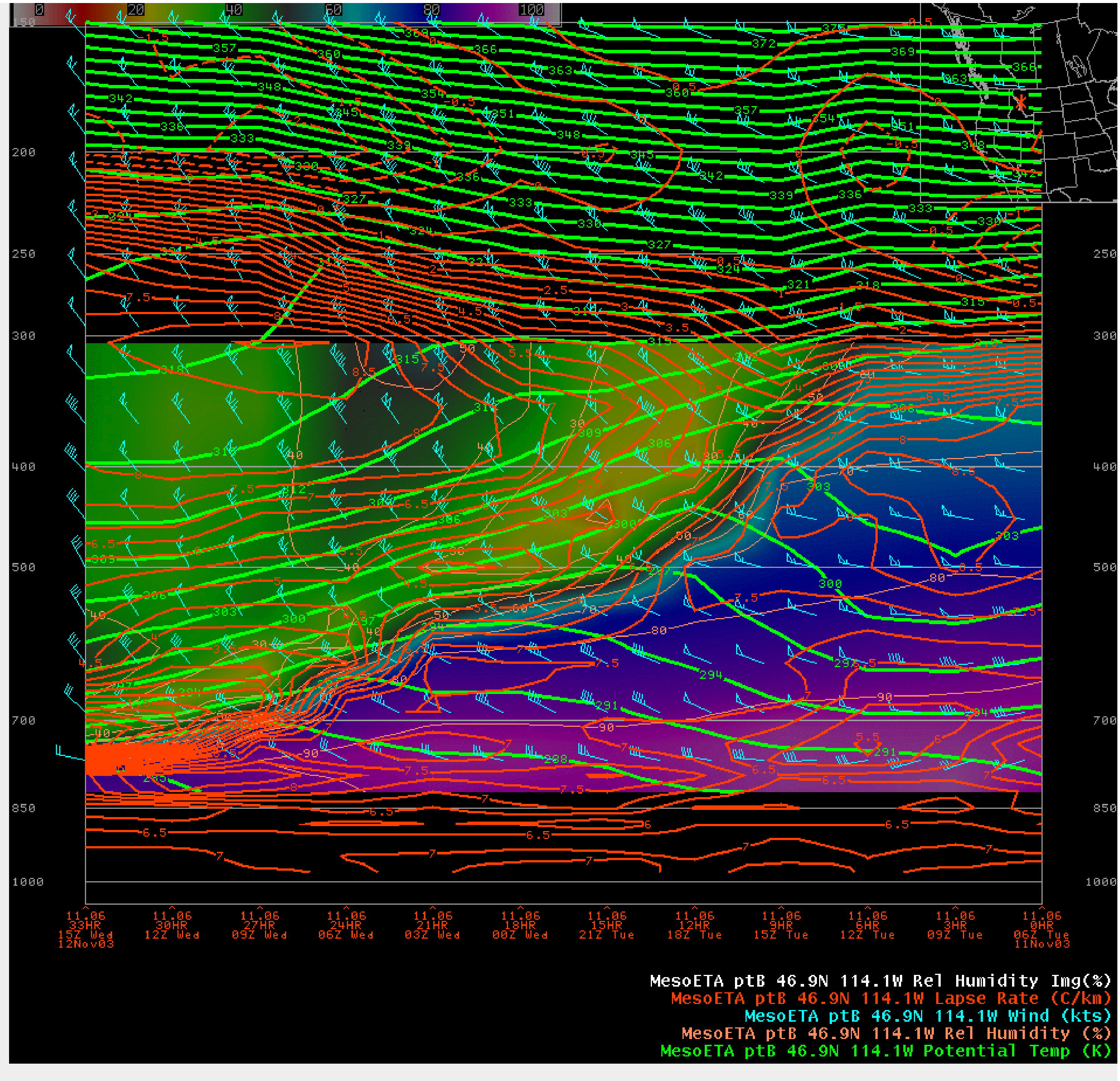
Figure 11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MesoETA ptB 46.9N 114.1W Rel Humidity Img(%)
MesoETA ptB 46.9N 114.1W Lapse Rate (C/km)
MesoETA ptB 46.9N 114.1W Wind (kts)
MesoETA ptB 46.9N 114.1W Rel Humidity (%)
MesoETA ptB 46.9N 114.1W Potential Temp (K)