A Downslope Windstorm Induced by Precipitation in a Post-convective Rain Region Investigated Using the Weather Event Simulator

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Introduction

On September 1st 2004, a shortwave trough and associated cold front moved through the Missoula forecast area producing several severe thunderstorms with large hail and damaging winds. A few unconfirmed funnel clouds were also reported by the public. The convection was well forecasted and produced few surprises. However, the event did produce a significant unforecasted downslope wind event in the Bitterroot Valley south of Missoula. Although there were several aspects of the convection that would make for an interesting study, this paper will concentrate on the details of the downslope wind event.

Brief Synoptic Overview and Model Assessment

Overall the models performed well with the synoptic evolution of this event. The ETA at 02/0000 UTC indicates a shortwave trough at 500 mb (fig 1) approaching the region from the west with a double jet structure at 300 mb (fig 2). A subtropical jet from northern California across to southwest Montana and a polar jet from southern Oregon to eastern Washington, produced a region of significant upper level diffluence across western Montana

At 700 mb (fig 3), the ETA indicates the mid level front with a wind shift and an increase in mid level moisture behind the front. A pressure trough at the surface at 02/0000 UTC and wind shift at 850 mb indicates the frontal position just south and east of Missoula (fig 4), though the model was in error in moving the front through western Montana a little too quickly.

An ETA model sounding at Missoula (fig 5) prior to the frontal passage at 01/2100 UTC indicates moderately unstable conditions with a forecast CAPE of nearly 1000 J/Kg, significant speed shear, and modest helicity. The model sounding depicted actual conditions fairly well, except surface winds were light southeasterly. Adjusting for the actual surface winds resulted in a modest increase in the helicity over the model output. An ETA model sounding from Salmon, Idaho (fig 6) for the same time, indicated conditions are quite a bit drier than further to the north. Actual conditions at Salmon were even drier then the model sounding indicated.

Given current conditions and the model forecasts, an active thunderstorm day was expected. With better available moisture to the north, storms that did develop were expected to produce large hail and in particular locally gusty winds due to the strong mid level flow in advance of the front. While in the south, a very dry sub cloud with layer steep lapse rates to above 600 mb would favor isolated high based storms with dry-microbursts. However, no thought was given to the potential for a downslope wind event. Conditions were too unstable in the low and mid levels, and the model forecasted flow was only 20-25 kts at ridgetop.

The Event

Thunderstorms began to develop over northwest Montana and central Idaho ahead of the cold front by 01/1900 UTC. Convection continued along and ahead of the front throughout the afternoon as seen on visible satellite imagery at 01/2100 UTC (fig 7). Several cells produced large hail up to 1 ½" and local winds gusts to 65 mph. A few cells exhibited significant rotation and a few unconfirmed funnel clouds were reported. Over southwest Montana isolated convection did develop over the higher terrain. Radar indicated that a few of these cells could have produced locally gusty winds; however this could not be confirmed.

Around 01/2200 UTC, two strong cells moved through the northern Bitterroot Valley and the Missoula Valley. Wind gusts in excess of 60 MPH were reported in Missoula. Precipitation with the convection cooled surface temperatures from the low to mid 80s °F in the valleys to the 60s °F. Over the higher terrain west of the Bitterroot Valley temperatures dropped from the mid 70s °F to the 50s °F, resulting in stabilization of atmosphere below 10000 feet msl. In addition, a large post convective stratiform rain region developed behind the initial convection and ahead of the mid level cold front. A composite reflectivity radar image at 01/2247 UTC (fig 8) from the Missoula Point Six radar shows the convection that just moved through the Missoula area and the broad region of precipitation, with a few embedded convective cells, approaching Missoula and the Bitterroot Mountains from the southwest.

At 01/2254 UTC, a call was received from a weather spotter on the west side of the Bitterroot valley west of Hamilton with winds gusts over 70 MPH. Initially it was thought that this was a late report from the convection that moved through the area 50 minutes earlier. Then at 01/2310 UTC, a call from the Ravalli County Sheriff's Office was received of power lines and trees down on the west side of the Bitterroot Valley from west of Hamilton northward with very strong winds occurring at the present time. The 01/2247 UTC (fig 9) 0.5 degree base velocity product indicated a few pixels > 60 kt inbound wind component at about 12,000 feet just southwest of Hamilton on the eastern edge of the precipitation region (note red arrows). Assuming a wind direction of about 220 degrees, the estimated true windspeed is approximately 75-85 kts.

By 01/2312 UTC (fig 10) and 01/2317 UTC (fig 11) the narrow region of strong inbound winds expanded and spread north along the west side of the valley. It became apparent by this time from radar loops of reflectivity and velocity that a mountain wave induced downslope windstorm was in progress. Conditions prior to the convection were unfavorable for a downslope wind event due to unstable conditions from the surface to above 600 mb upstream of the mountains. However, the precipitation produced by the convection, substantially stabilized the airmass upstream of the Bitterroots. This stabilization along with VWP estimated 40-50 kts southwesterly flow at ridgetop level created conditions favorable for a mountain wave induced wind event to develop. The actual ridge top winds were 20 kts higher then forecast by the ETA. The true extent of the winds was not clear from radar, as the strong downslope flow caused the precipitation to dissipate, resulting in a sharp eastern edge of the velocity returns. In addition, the elevation of the 0.5 degree beam is 8000 to 10000 feet above the valley floor in this area.

Another indication of a wave induced downslope windstorm is the weak flow on the velocity plots over the north-south oriented Bitterroot Mountains (figs 10 and 11). A visible satellite image from 02/0000 UTC (fig 12) indicates a band of mainly cirriform cloud tops extended from southwest to northeast across the Bitterroot Mountains. In the image, a subtle thin region in the clouds just downstream and oriented parallel to the Bitterroots can be seen is associated with the mountain wave (note red arrow). Note the easterly surface wind at Hamilton, indicating a lee side low pressure area on the west side of the valley induced by the local downslope warming.

The highest wind gusts during the event occurred between 01/2250 UTC and 02/0015 UTC and between 02/0140 UTC and 02/0210 UTC (note the 01/0154 UTC (fig 13) base 0.5 degree base velocity product), with several reports over 70 MPH with the strongest report of 83 MPH west of Stephensville in the northern Bitterroot Valley. The winds diminished following the passage of the mid level front around 03/0300 UTC.

Conclusions

This event was unique in that it occurred during a convective situation. There is no record of a similar event occurring in the Storm Data Bulletins, or from long time forecasters at Missoula, following widespread convective activity. In addition, this event was detectable by radar. With more typical downslope events the flow is often westerly, thus perpendicular to the radar beam radial, making detection by radar very difficult even when precipitation is occurring.

Despite the north-south orientation of the Bitterroot Mountains, true downslope wind events reaching the valley floor are not common, even during the winter with strong mid level flow. Although lee gaps in the cloud cover often occur associated with strong westerly flow near ridgetop, it is thought that the distance between the Bitterroot Range and the downstream Sapphire Range may be too small for the winds to reach the valley floor during the more typical stable situations of winter. The accelerated flow separates from the surface higher up on the west slopes of the valley. When strong westerly winds do occur on the valley floor, it is most often in situations with unstable conditions below 700 mb, resulting in non-accelerated downslope winds and evanescent downstream wave development.

Linked Figures

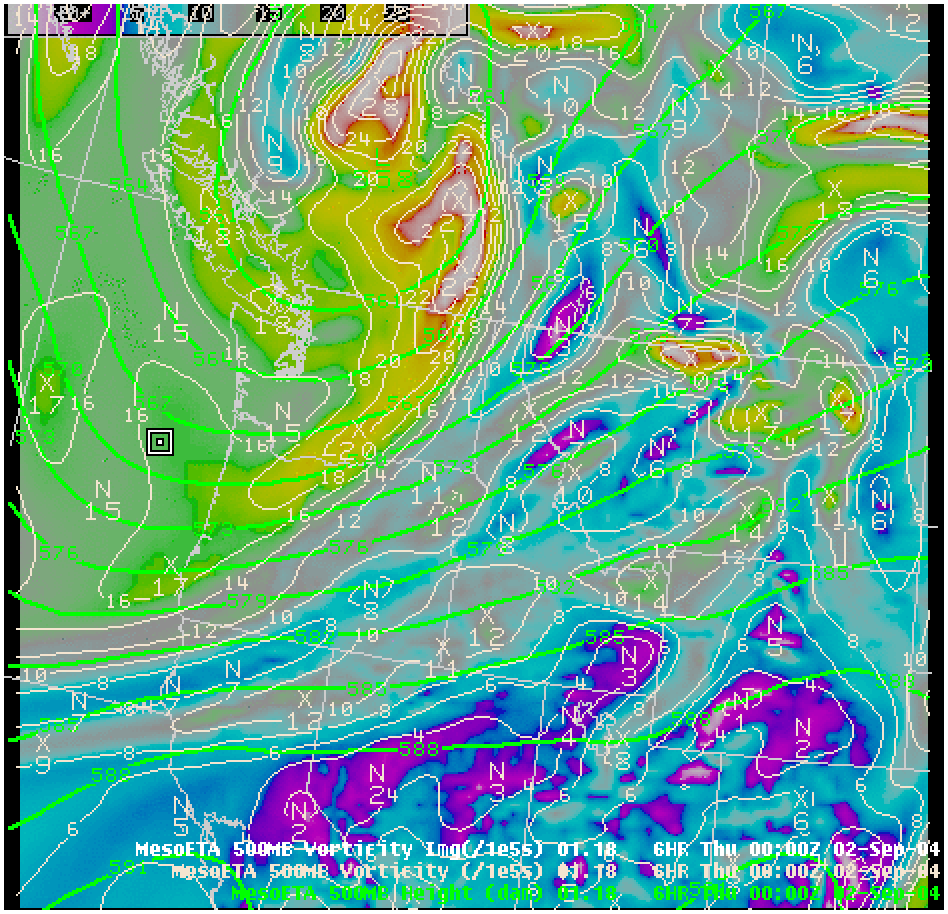

Figure 1. ETA 09/01/04 forecast valid 02/0000 UTC – 500 mb Heights and Vorticity

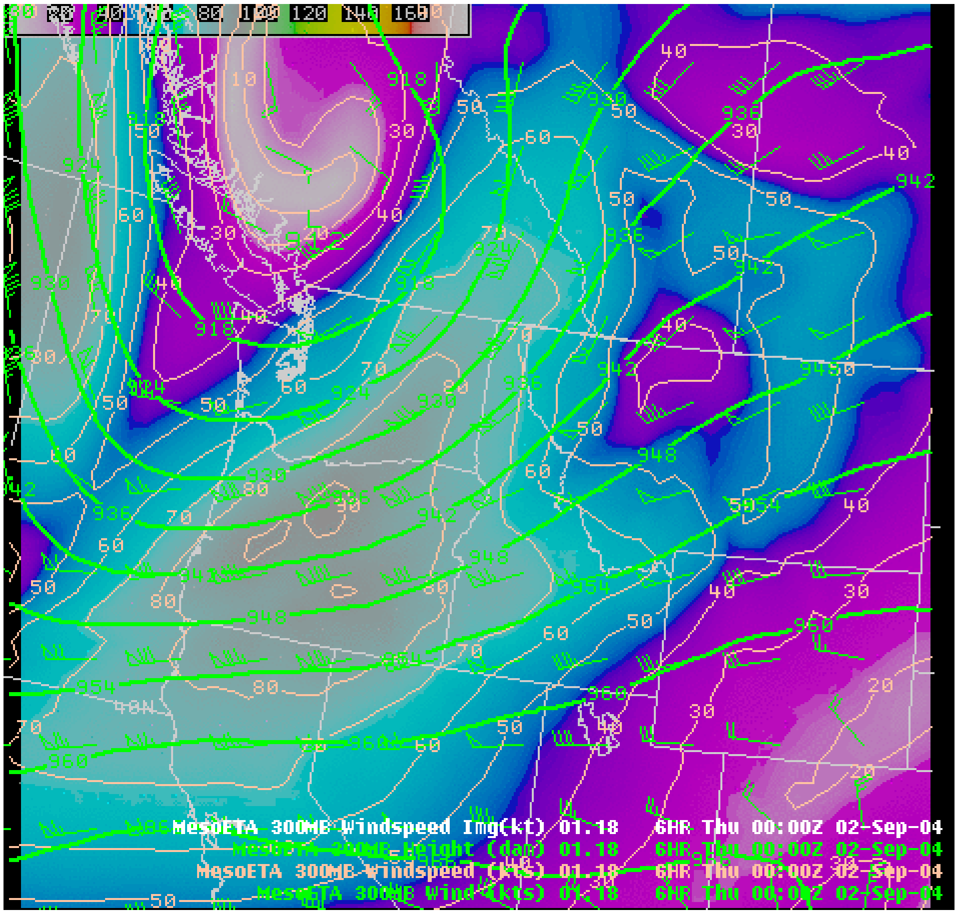

Figure 2. ETA 09/01/04 forecast valid 02/0000 UTC – 300 mb Heights and Wind

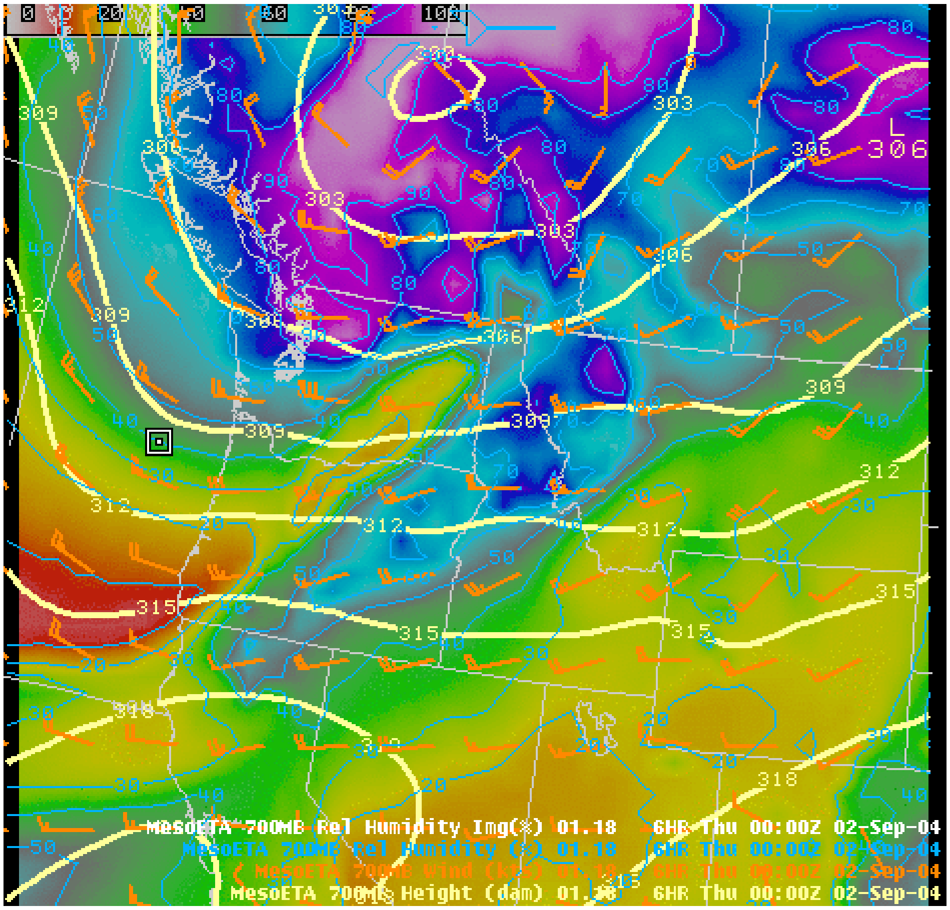

Figure 3. ETA 09/01/04 forecast valid 02/0000 UTC – 700 mb Heights, Wind, and RH

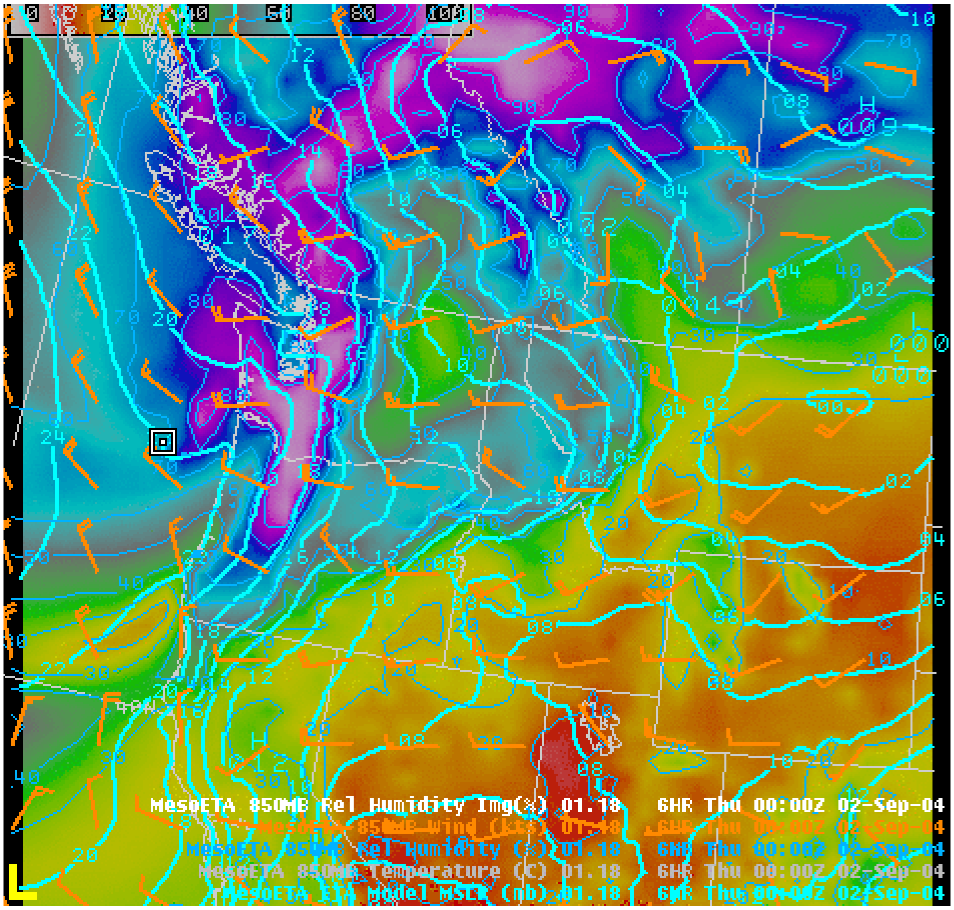

Figure 4. ETA 09/01/04 forecast valid 02/0000 UTC – MSLP, 850 mb Wind and RH

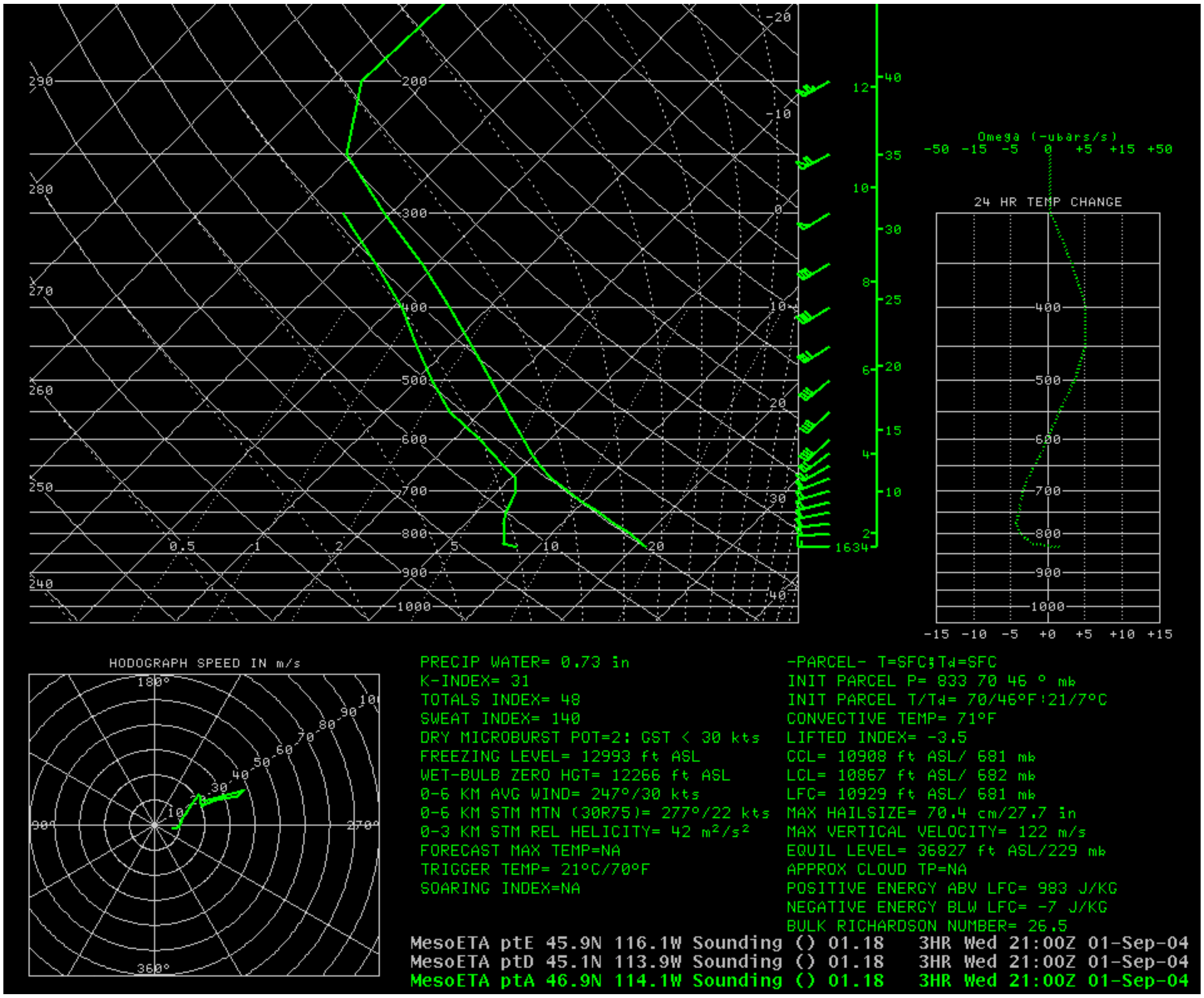

Figure 5. ETA 09/01/04 forecast valid 01/2100 UTC – Sounding for Missoula, Montana

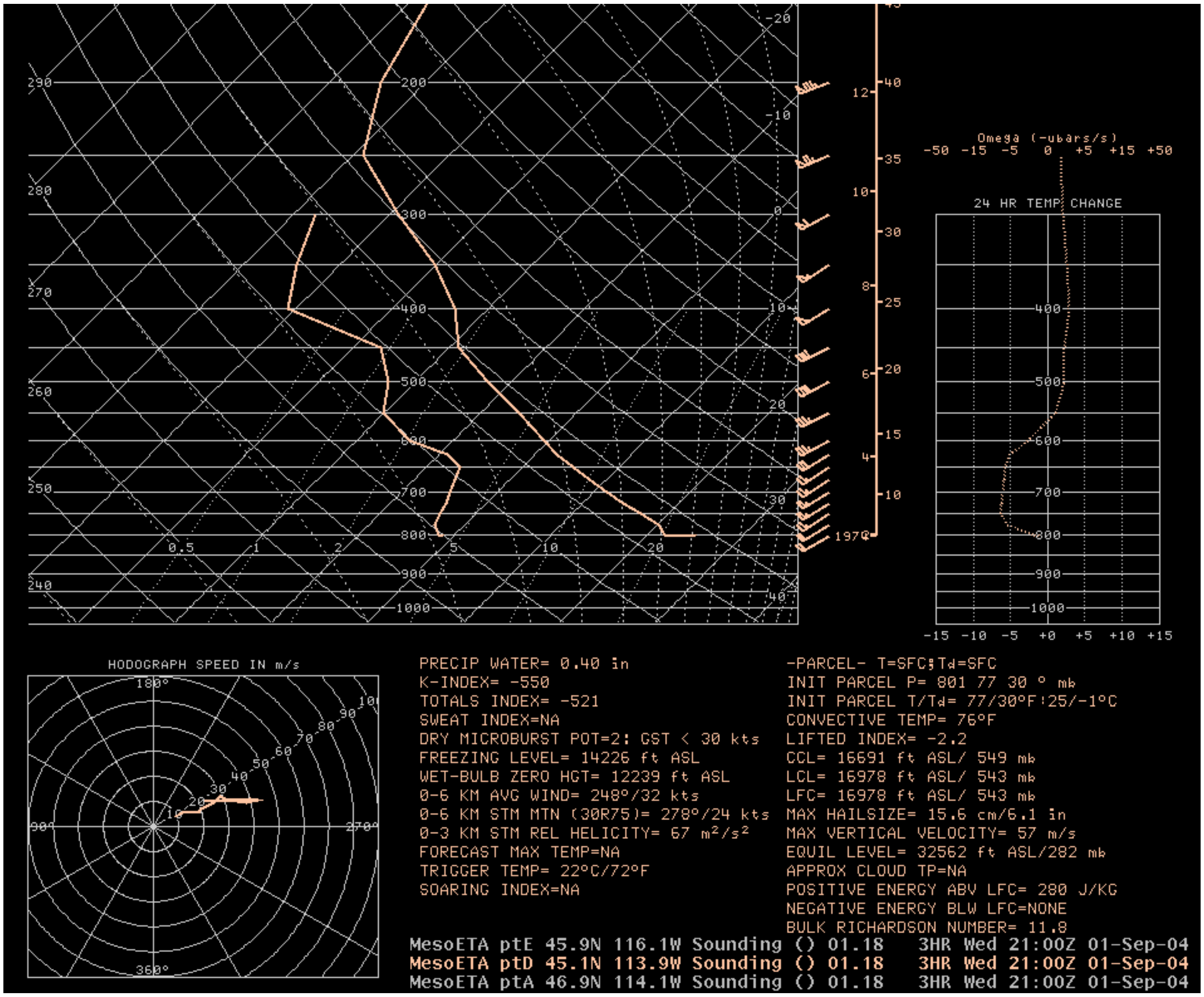

Figure 6. ETA 09/01/04 forecast valid 01/2100 UTC – Sounding for Salmon, Idaho

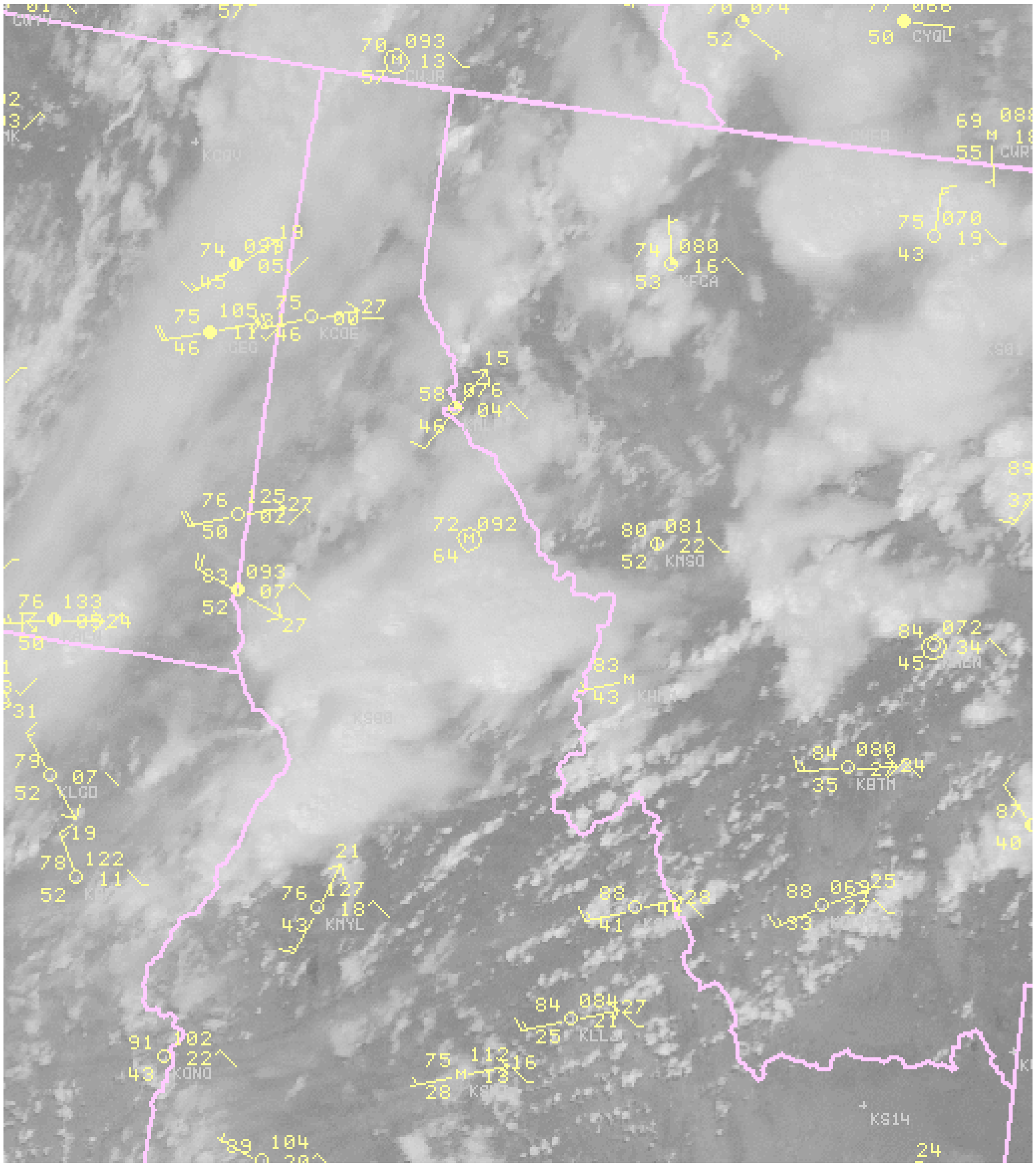

Figure 7. 01/2100 UTC Visible Satellite Imagery and 01/2100 UTC Surface observations

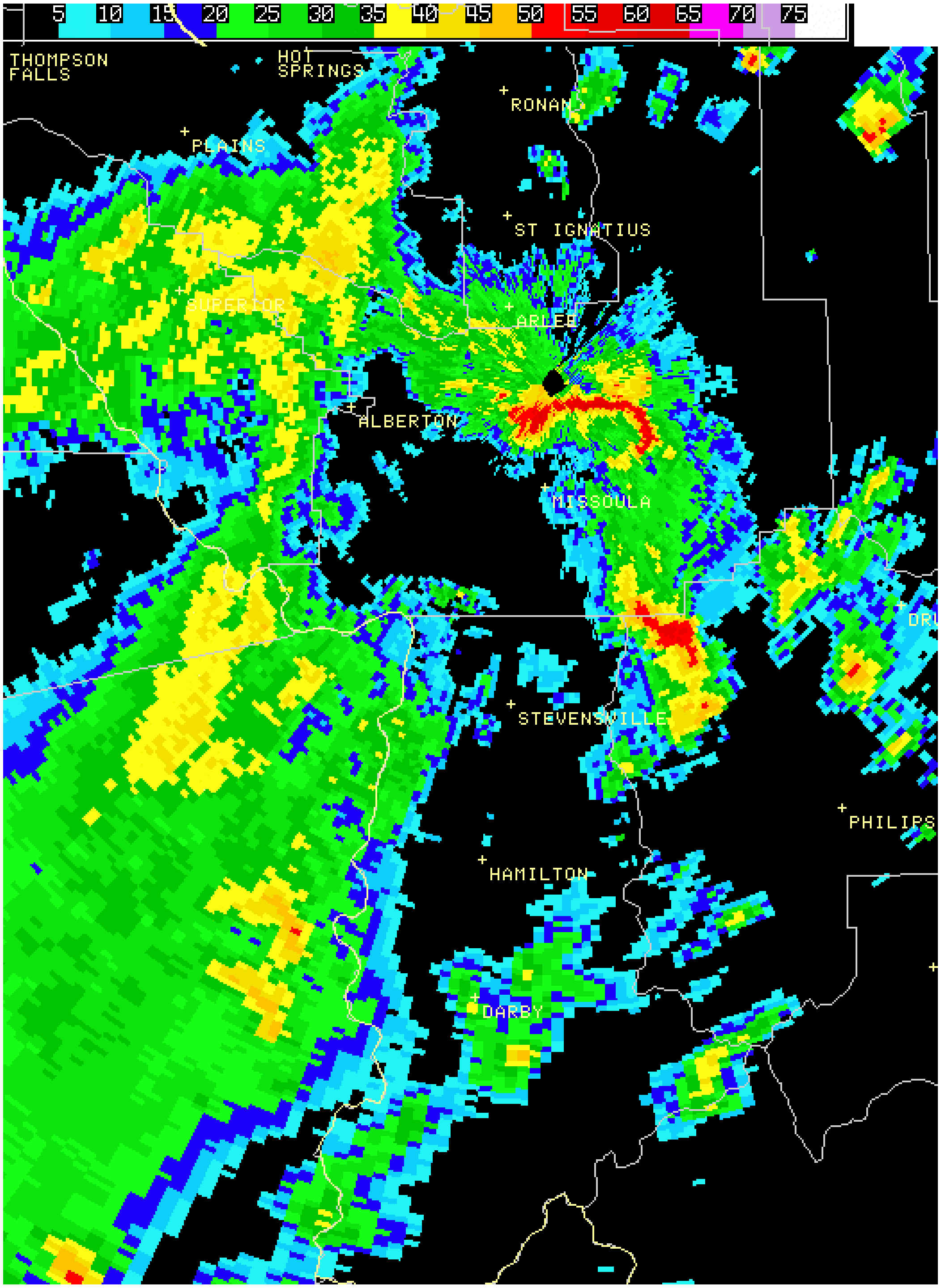

Figure 8. KMSX radar Composite Reflectivity image – 01/2247 UTC

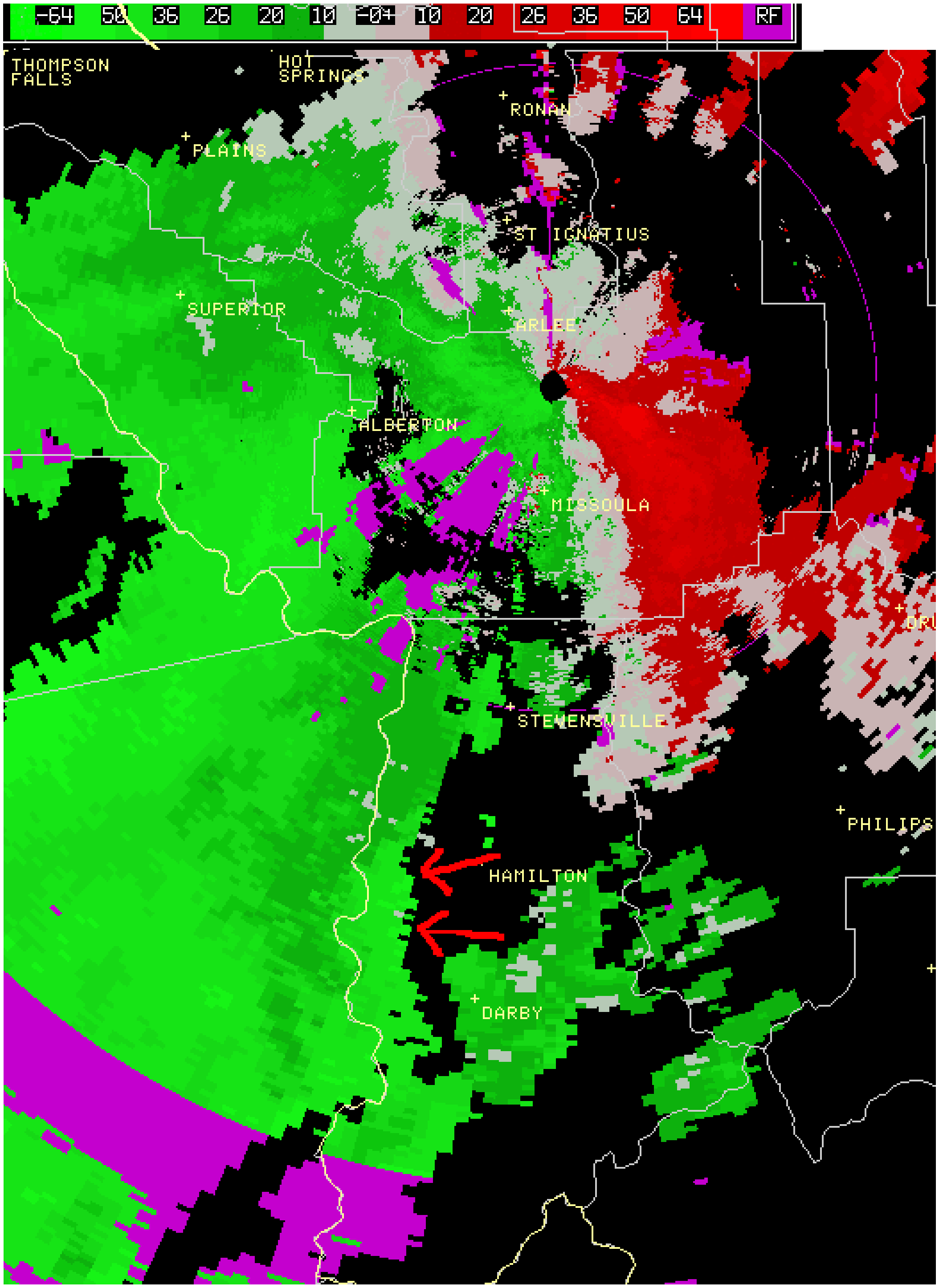

Figure 9. KMSX radar 0.5 degree Base Velocity image – 01/2247 UTC

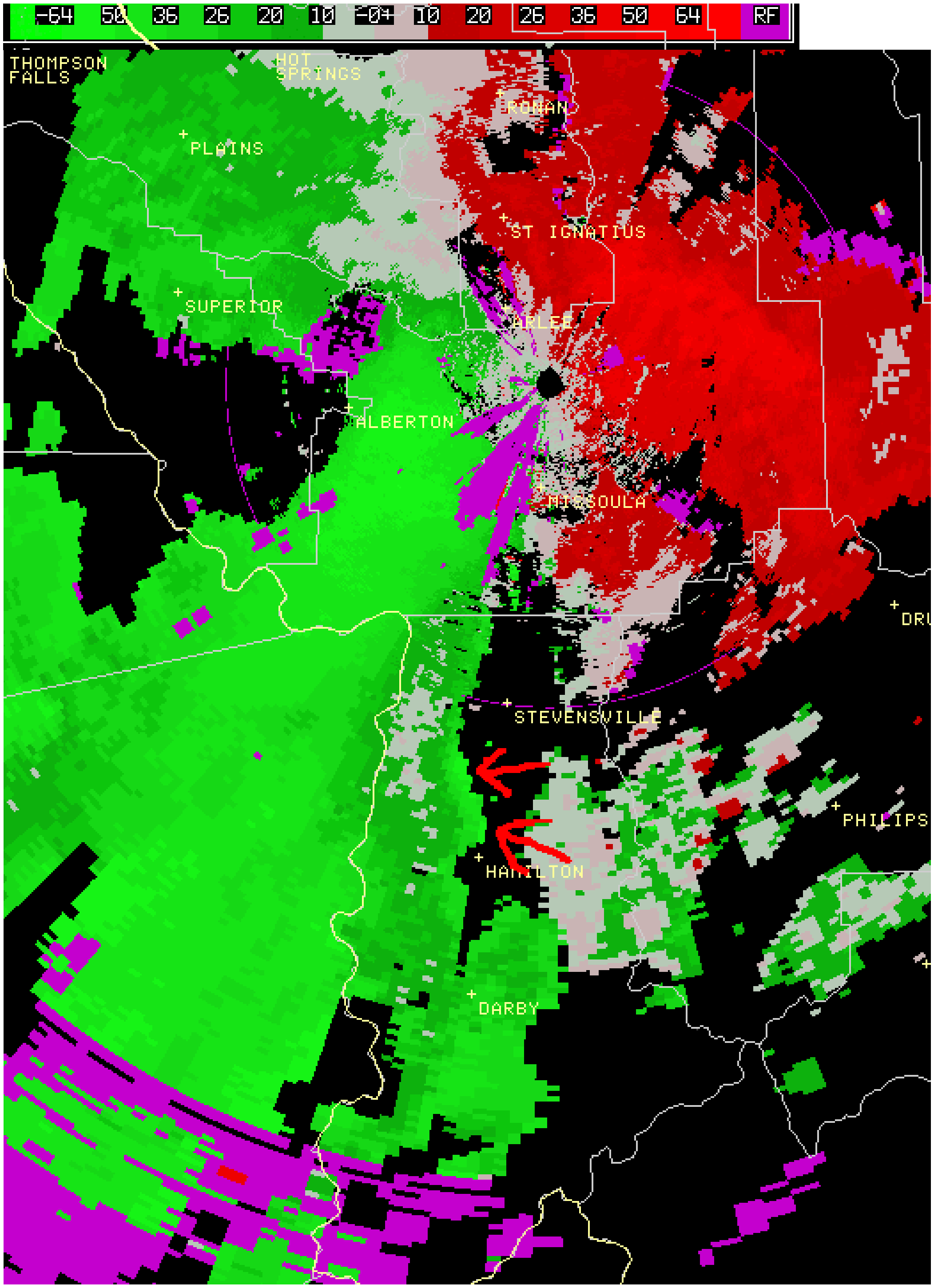

Figure 10. KMSX radar 0.5 degree Base Velocity image – 01/2312 UTC

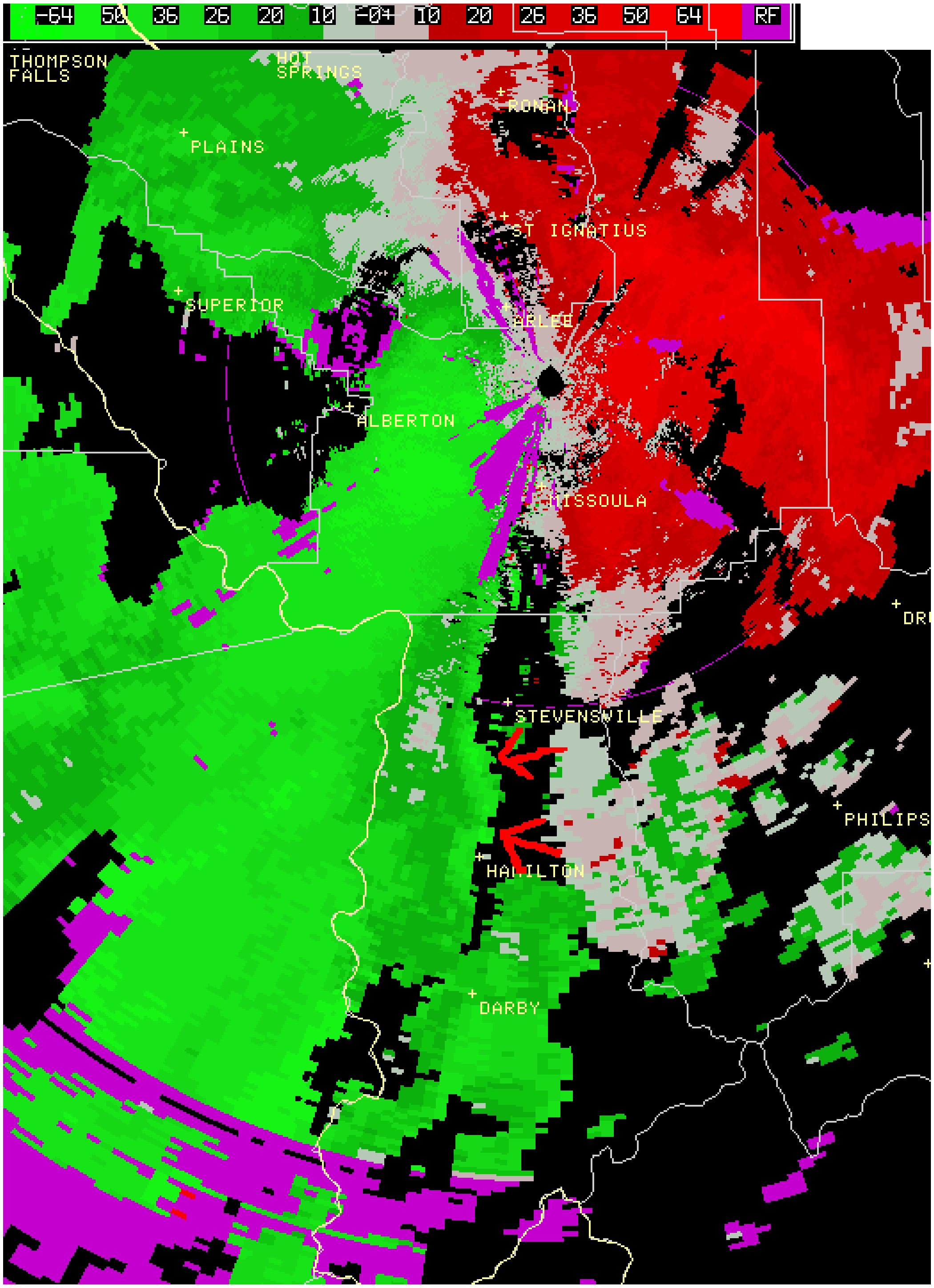

Figure 11. KMSX radar 0.5 degree Base Velocity image – 01/2317 UTC

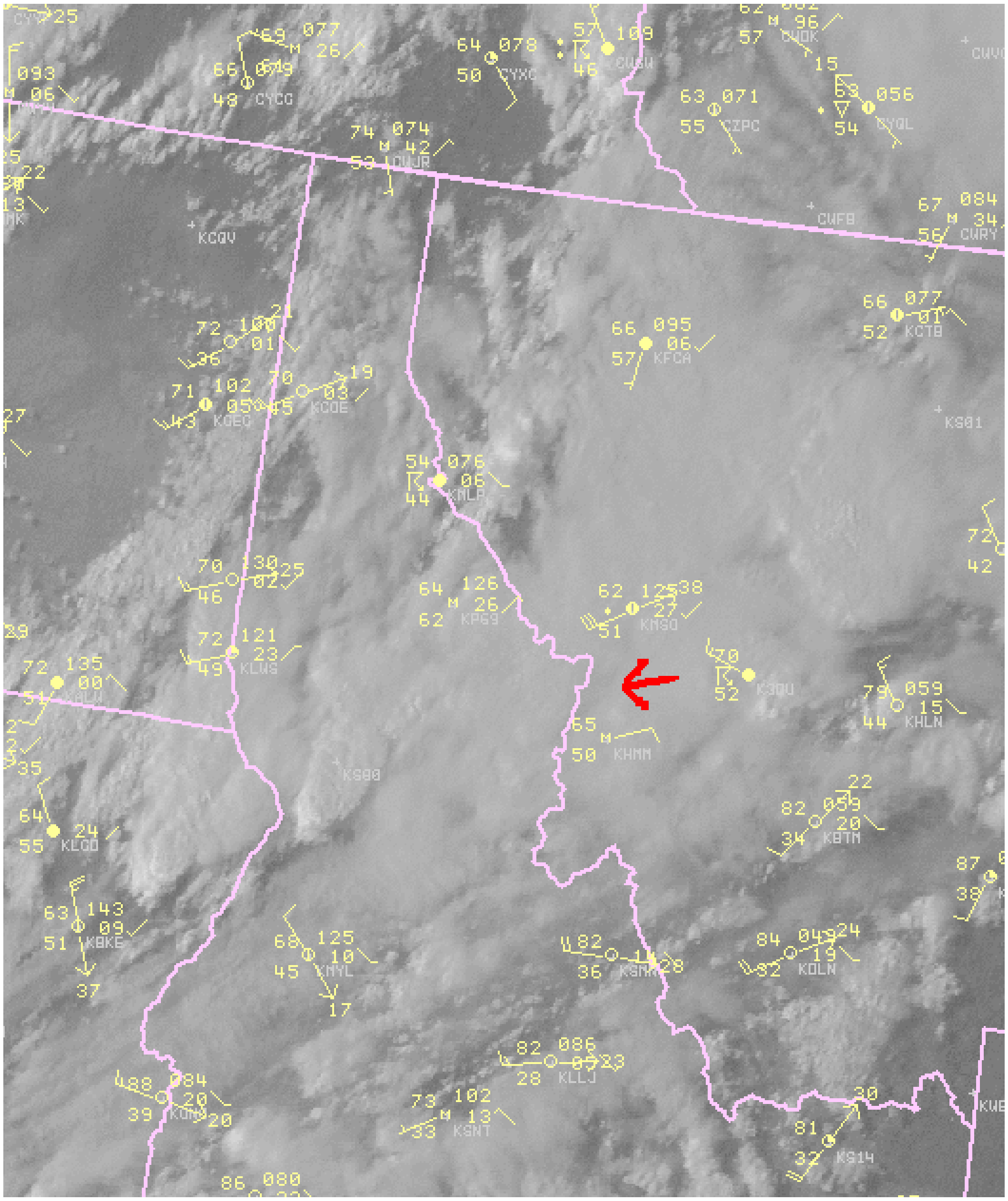

Figure 12. 02/0000 UTC Visible Satellite Imagery and 02/0000 UTC Surface observations

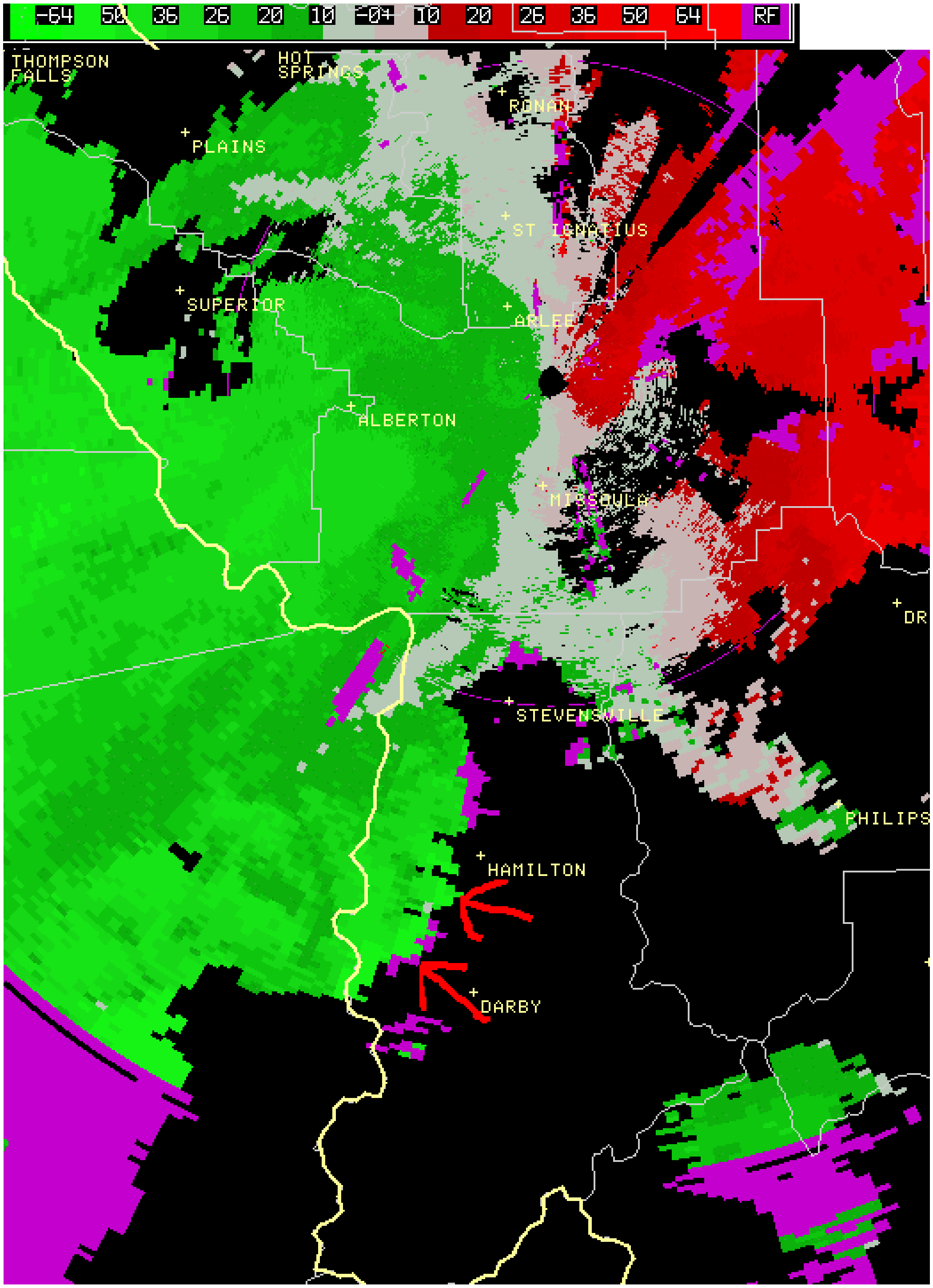

Figure 13. KMSX radar 0.5 degree Base Velocity image – 02/0154 UTC