Predicting High Winds in Livingston, Montana – A Weather Event Simulation

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Introduction

Surface winds in Livingston, Montana are greatly impacted by the terrain. The Yellowstone River Valley south of Livingston, termed the Paradise Valley, is surrounded by mountains 3000 feet above the valley floor on the east and west sides (see Fig. 1). During the cold season, the air that flows into the Paradise Valley originates from northeast Idaho and Yellowstone National Park. This airmass is typically cold and stable from flowing over snow covered ground. Because the terrain surrounding the Paradise Valley is steep, the cold and stable air becomes trapped in the valley and can be 3000 feet deep when a mountain top capping inversion is present.

When zonal flow aloft is established over Montana, a lee side surface trough will set up and increase the surface pressure difference from northeast Idaho to central Montana. This increase in the surface pressure gradient forces the stable air to flow out of the Paradise Valley and into Livingston. As the air exits the Paradise Valley, the terrain support for a deep cold airmass ends. In response, the collapsing cold air accelerates. Sustained winds in this regime can exceed 55 mph at Livingston, even in the presence of weak flow aloft. If the airmass exiting the Paradise Valley is not stable, this acceleration will not take place. Instead, mixing to winds aloft and channeling will play a greater role in the strength of the winds in Livingston. Determining the strength of the surface winds as a result of a collapsing cold airmass or mixing to stronger winds aloft can be an extremely difficult forecast challenge.

On January 24th and 25th 2002 a slightly stable airmass was situated over Yellowstone Park and into the Paradise Valley while a lee side surface trough became established over central Montana. The surface pressure gradient, which is known to be an important factor (see Fig. 2 and Fig. 5), was very high as a result. Since the airmass was not particularly stable, surface winds in Livingston through 9pm on the 24th remained below high wind criteria (sustained 50mph and/or gusts to 70mph) except during the climatologically favored time, 10am to noon (see Fig. 3).

Forecasters in the evening were faced with the challenge of determining if winds would again reach high wind criteria. The simulation developed for this event mimics the job of an evening shift forecaster who needs to predict if high winds will be observed overnight into the 25th. To accomplish this task, forecasters need to make use of recent research to 1) Understand why winds remained below high wind criteria through the afternoon and early evening of the 24th; 2)Asses how the stability of the air exiting the Paradise Valley will change; and 3) Predict how the pressure difference across the area will be modified by the synoptic and mesoscale environment. This paper will briefly discuss some of the specifics of these parameters along with model performance.

Meteorological Environment and Model Assessment

A flat upper tropospheric ridge was slowly progressing east over the Northern Rockies on the 24th, which resulted in a surface lee side trough over Central Montana (see Fig. 4 and Fig 5). Warming from 700-500mb helped maintain low level inversions from northeast Idaho into the Paradise Valley. This combined with snow covered ground allowed for a 1040mb surface high to become established over the area (Fig. 5). The 25 January 00 UTC Eta initialized the overall pattern fairly well and picked up on a upper tropospheric wind maximum moving east through extreme southern Canada (Fig. 6). Despite the approach of this wind maximum between 00 UTC and 06 UTC, the Eta depicted surface pressure rises across central Montana from 00 UTC to 06 UTC and then pressure falls from 06 UTC to 18 UTC. Meanwhile, consistent surface pressure falls were forecast in northeast Idaho through 18 UTC. In reality, steady pressure falls were observed over central Montana and northeast Idaho through 18Z, creating a constant pressure gradient through the morning of the 25th as opposed to the weakening one shown by the Eta.

Temperatures at 700mb associated with the upper tropospheric ridge brought a capping inversion to the Paradise Valley (see Fig. 7). A comparison between the Eta and radiosonde observations revealed the Eta 700mb temperature was one degree too cold at both Riverton and Great Falls, suggesting the capping inversion in the ridge axis was likely a stronger than the Eta.

The combination of a tight surface pressure gradient and strengthening capping inversion helped produce high winds in Livingston overnight on the 24th through noon LST on the 25th. Sustained winds consistently exceeded 50 mph between 5 and 11 am LST with gusts as high as 75 mph. The mountain top inversion present overnight on the 24th weakened by noon LST on the 25th while the surface pressure gradient decreased significantly. The response was a weakening of the winds, despite 700mb flow being stronger than the day before (see Fig. 8).

Discussion

Accurately predicting Livingston winds in this simulation required forecasters to understand how mesoscale influences, such as upper level wind maximum, will impact surface pressure tendencies. Forecasters also needed to determine how mountain top inversions will evolve and influence wind acceleration potential in the lee of the Paradise Valley. The lack of high winds in Livingston during the afternoon through early evening was a result of low stability preventing much acceleration to take place in the lee of the Paradise Valley. As the mountain top inversion strengthened, the surface flow quickly responded by exceeding high wind criteria for several consecutive hours. Once stability decreased in the afternoon of the 25th and pressure differences across the Paradise Valley lowered, winds again subsided. Knowing the climatology of the high winds in Livingston also proved useful since high winds on the 24th and 25th decreased shortly afternoon 12pm LST, which is climatologically favored.

Not only did this simulation give forecasters additional experience in predicting important controlling mechanisms for strong winds in Livingston, but it also helped forecasters become more aware of problems with the plan view display of the Eta in AWIPS. Since the true resolution of the Eta is not displayed in AWIPS, the Eta 700mb temperature depiction in this case shows a large bulls eye of cold air extending more than 50 miles away from Yellowstone National Park including over the Paradise Valley. For example, the plan view of the Eta display in AWIPS shows 700mb temperatures around -8C at 25 January 06Z UTC over Livingston while the BUFR data from the same model run shows -6C (See Fig. 9 and Fig. 7). In reality, the 700mb cold pocket is likely confined closer to the higher terrain. Understanding this problem helps minimize forecast errors.

Figure 1

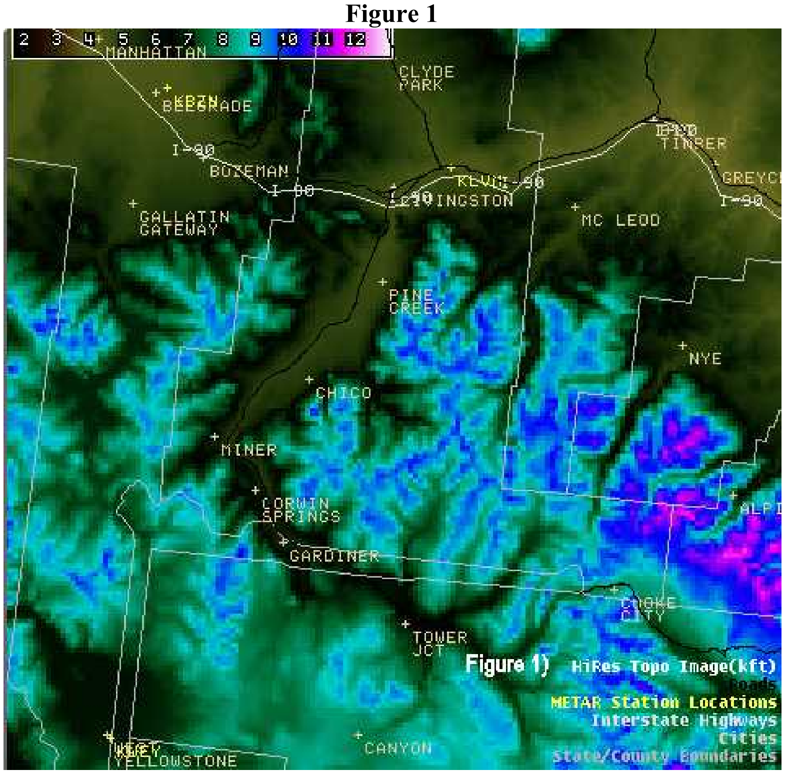

Figure 2

Altimeter difference from Idaho Falls, ID to Lewistown, MT
vs
Livingston, MT Sustained Wind Speed
1996-2001

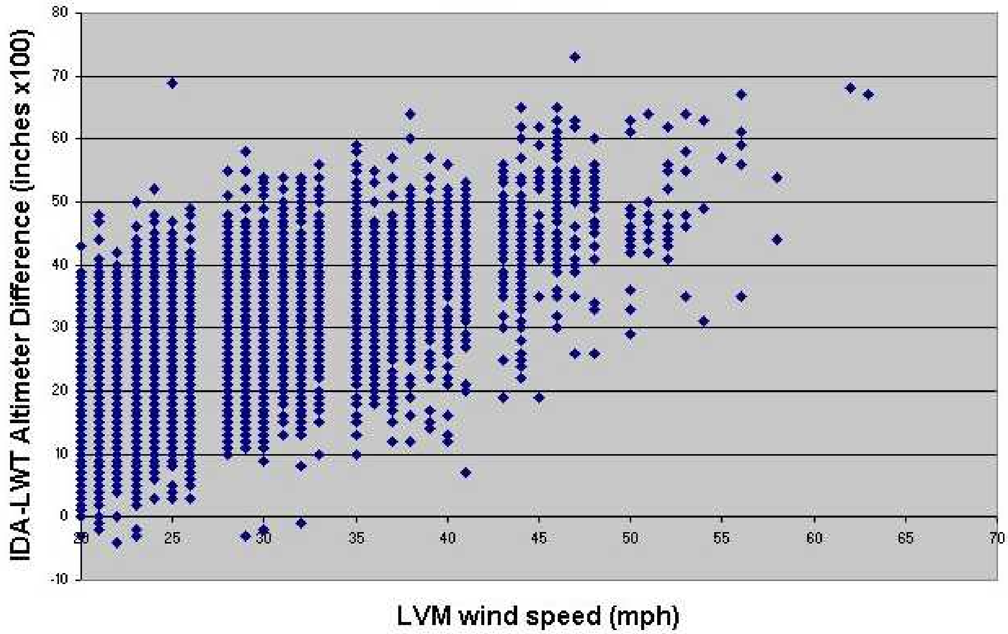

Figure 2). Idaho Falls to Lewistown altimeter setting difference against Livingston wind speed is shown. Multiple observations may be represented by a single dot since thousands of observations are included. There is a tendency for wind speeds to increase as the pressure difference increases.

Figure 3

Frequency of 50+ mph Livingston Observations by Time
Data from 1996-2000

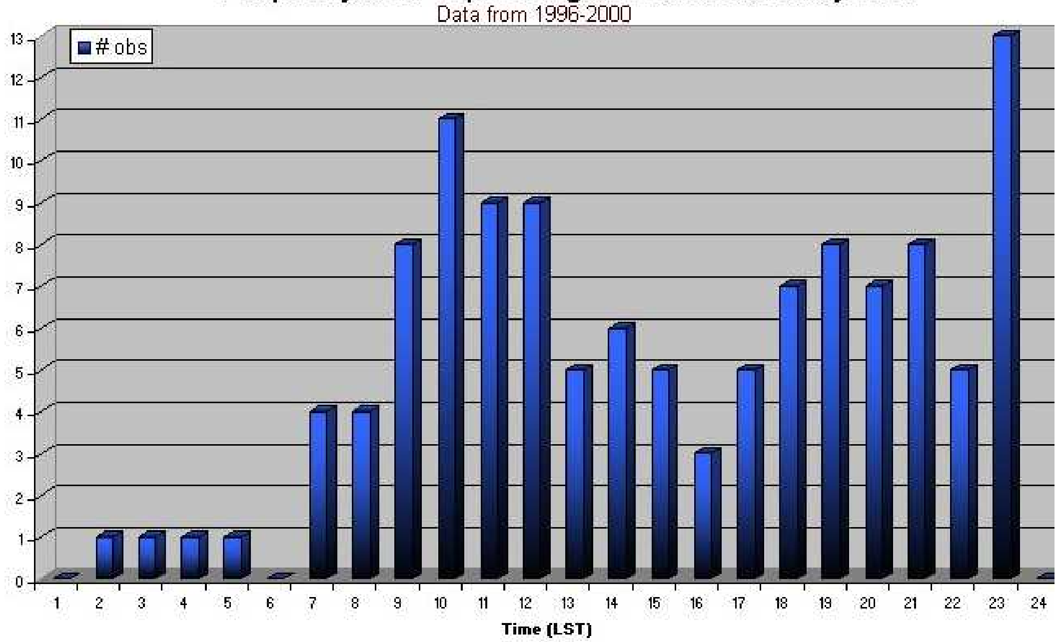

Figure 3) Frequency of Livingston metar observations reporting greater than 50 mph winds. Observations from 12 am to 6 am were not available until 1999. The data strongly suggest there is a tendency for high winds to occur from 9 am to noon and after 10 pm. Notice the lower tendency for high winds through the afternoon.

Figure 4

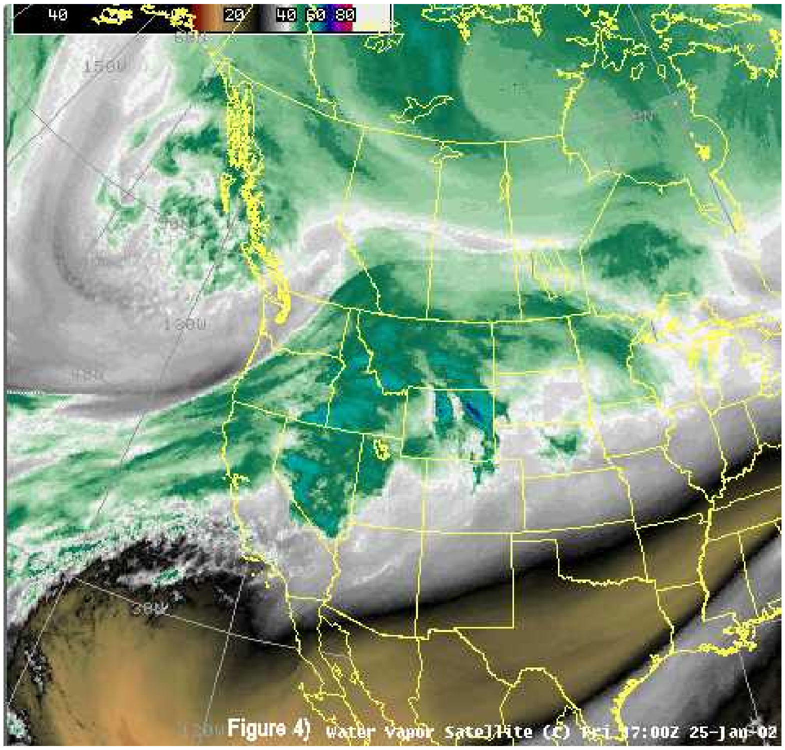

Figure 5

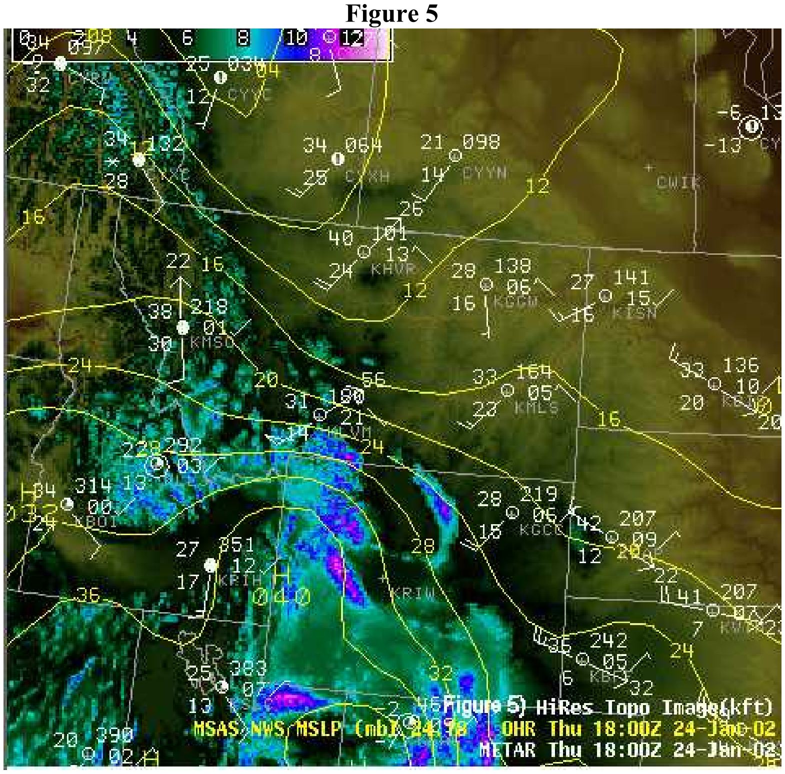

Figure 6

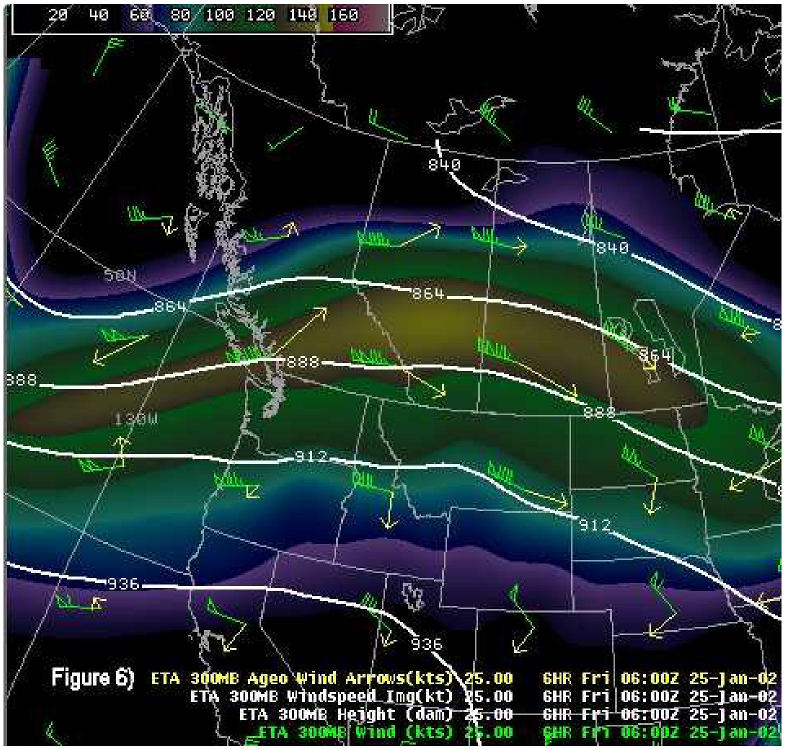

Figure 7

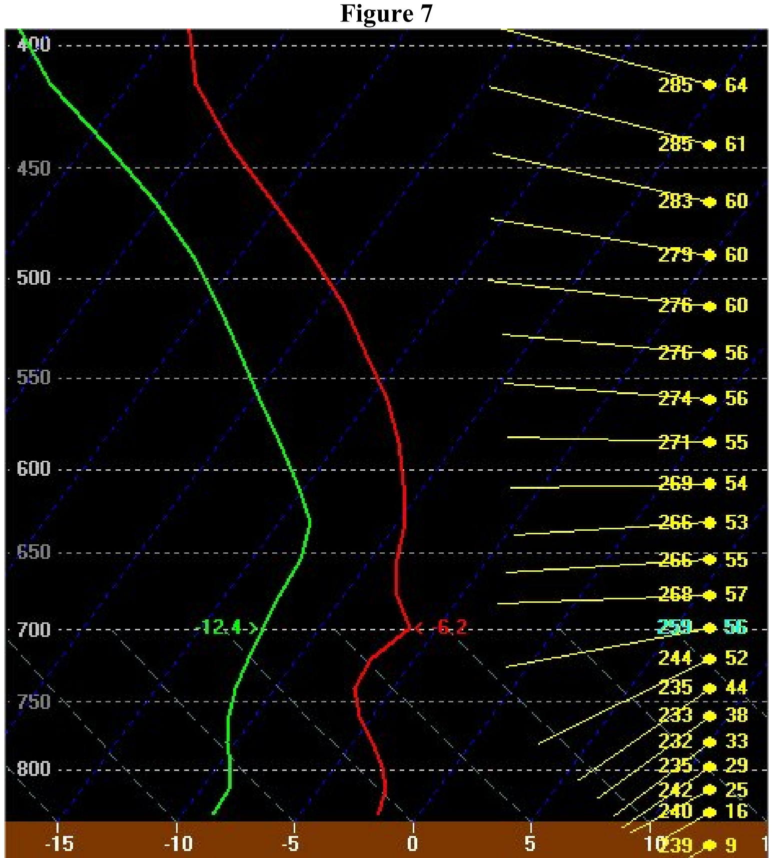

Figure 7) Eta 6 hour forecast sounding for Livingston, MT valid for 1/25/02 06 UTC

Figure 8

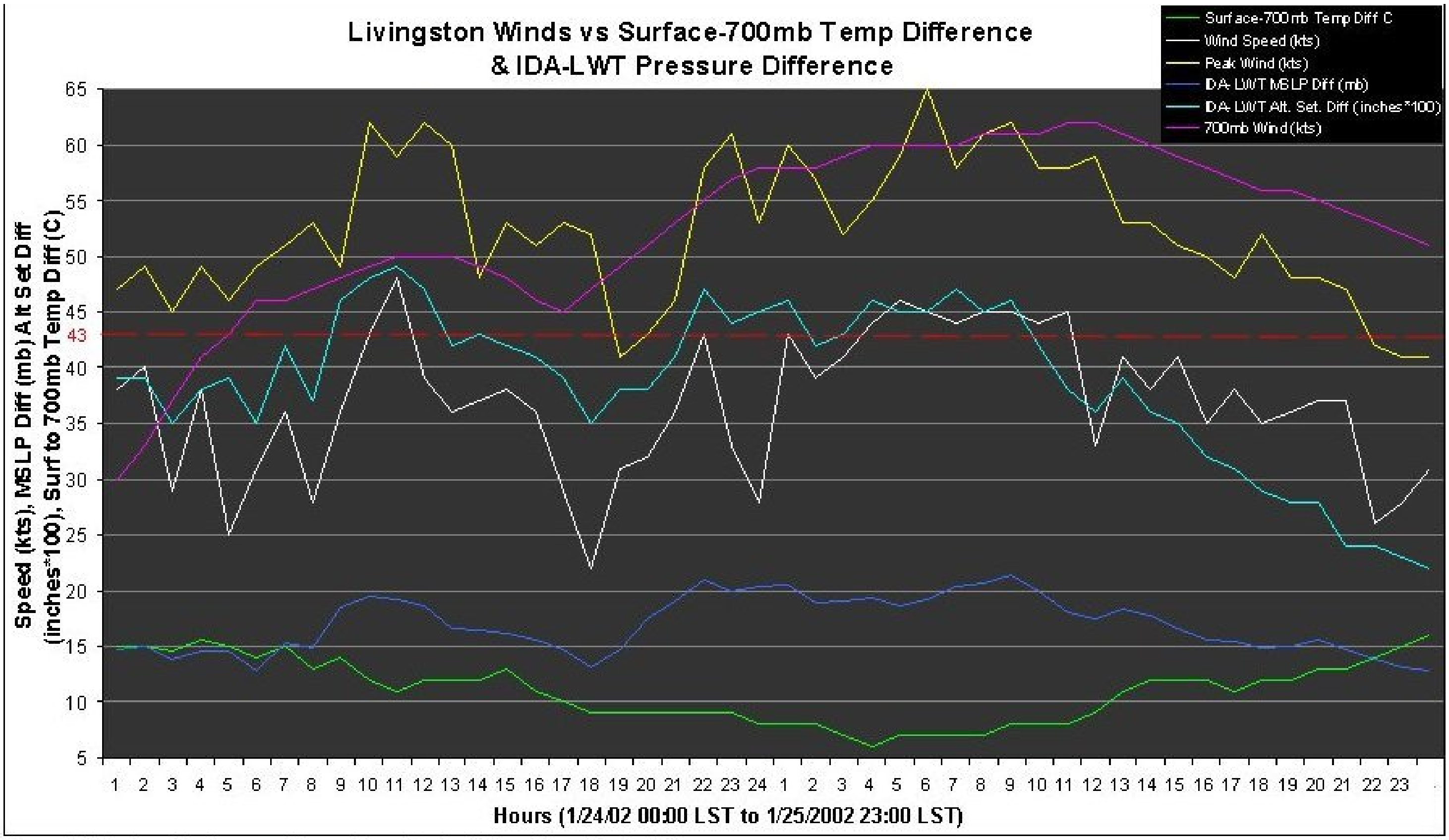

Figure 8) Depicted in the graph from 12am 24 Jan 02 to 11pm 25 Jan 02 are:
1) The Livingston (LVM) surface to 700mb temperature difference (green); 2) LVM sustained wind speed (white);
3) LVM peak wind gusts; 4) Idaho Falls (IDA) to Lewistown (LWT) mean sea level pressure difference (blue);
5) IDA to LWT altimeter setting difference (cyan); 6) LVM 700mb wind speed from the most recent Eta BURF data.

The red dotted line denotes high wind criteria for sustained winds. Notice the LWT-IDA pressure difference briefly increased when high winds were reported on the 24th. The pressure difference again increased by 12am on the 25th. This occurred while the surface to 700mb temperature difference was decreasing. The strong winds ended on the 25th as the stability and pressure difference decreased, despite 700mb winds remaining above 50 kts.

Figure 9