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CSI SNOW EVENT OVER WASATCH FRONT MARCH 4,1999

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Introduction

During the early morning hours of March 4, 1999, a small, but unexpected, snow event took place along the Wasatch Front and adjacent mountains. Snowfall totals of 1-2 inches were common along the valleys and benches with up to 6 inches in the mountain valleys and ski areas.

The mechanism responsible for this snow event appears to be Conditional Symmetric Instability (CSI). This is at least the second CSI event in the Salt Lake City forecast area this season. Since the ability to detect banded winter precipitation first became possible with the installation of the KMTX radar in 1994, an average of two to three CSI events have been observed each winter. Although these events are not common, they do occur each year and are inevitably underforecast.

This Technical Attachment will briefly discuss the characteristics of CSI, and then present graphics and imagery from the March 4 snow event to illustrate how these events actually appear in real data, and to allow forecasters who did not work this event to see what happened.

CSI - General Characteristics

Conditional Symmetric Instability is not easy to visualize physically. Basically, the idea is that a parcel may be stable with respect to vertical displacement (convective stability) and the parcel may be stable with respect to horizontal displacement (inertial stability), but the parcel can be unstable when it travels upward along a slantwise path. This is why CSI is sometimes called slantwise convection.

Generally, the conditions for CSI are met in areas to the north of a shallow front. This can be either a warm-front or shallow cold-front. The region north of a shallow front is usually characterized by a convectively stable environment, and conditions that are near saturation. Another typical feature is the presence of a jet (and usually it is jet entrance region) just north of the area. This provides the anticyclonic horizontal shear that is typical of inertially unstable regions. The jet also provides the strong vertical shear found in CSI events. Finally, CSI is nearly always found near regions of frontogenesis. The frontogenesis produces a "secondary" circulation that often results in a larger-scale band of precipitation. The narrow, and often multiple-parallel bands seen in the radar data are the result of CSI, and will often be found embedded in the larger frontogentic band of light precipitation.

The March 4, 1999 Event

Clicking on the hyperlinks that are embedded in the following text will load imagery and graphics into another browser window so that you can look at the imagery/graphics and follow along in this text. After clicking on the first link, a new browser window will pop up over this one...just move it slightly to the side so you can see this one again, then you can switch back and forth between them. This document is on the NWSFO Salt Lake City web site at: **(http://www.wrh.noaa.gov/Saltlake/projects/csi_990304/csi_990304.html)**

The infrared imagery from 0815z IR (Fig. 1) and 1200z IR (Fig. 2) show a high cloud band over northern Utah. Notice the surface observations over the area indicate the surface front is well south of this cloud band, with northerly surface winds at Green River and Milford.

The radar reflectivity from 1208z 0.5 degrees (Fig. 3) and 1249z 0.5 degrees (Fig. 4) show the embedded narrow bands of heavier snow associated with CSI. The 1249z radar imagery is a particularly good example of multiple parallel bands aligned parallel to the thermal wind, which in most cases is the same orientation as the jet. The bands go right across the mountain ranges, which can be seen as areas of no echo due to the ground-clutter suppression employed. Most of the accumulation from this event came from these types of bands.

The MSAS analysis (Fig. 5) shows that northern Utah was clearly post-frontal. A RUC frontogenesis analysis (Fig. 6) 700 mb shows there was strong frontogenesis over the area where the precipitation developed. The RUC isotach analysis (Fig. 7) jet across southern Utah and another across Idaho and Wyoming. The IR image suggests the RUC isotach analysis at this level did not completely capture the jet streak associated with the cloud band that is just brushing northern Utah. Typically, areas of CSI are found on the anticyclonic side of the jet, so this case is somewhat more complicated since there are two distinct jets over the area.

The above-discussion indicates that many of the ingredients necessary for CSI were present. There are a number of ways to diagnose CSI with cross-sections, but the best method is to draw a cross-section perpendicular to the thermal wind (usually perpendicular to the jet), and compare the slope of theta-e surfaces to those of pseudo-angular momentum (called M-surfaces). In areas in which theta-e surfaces are steeper than M-surfaces, and the atmosphere is near saturation, CSI bands are likely to develop. Although the CSI bands are quite small-scale, the operational NWP models and analyses are capable of showing regions of CSI in cross-sections. Creating these cross-sections is very easy in AWIPS via the volume browser. The M-surfaces can be found in the fields section of the volume browser under the heading of Geostrophic Momentum at the bottom of the "basic" list.

The baseline (Fig. 8) used in this case is oriented as shown. A cross-section at 0900z (Fig. 9) and a cross-section at 1200z (Fig. 10) from RUC analyses show the theta-e surfaces are slightly steeper than the M-surfaces in a nearly a saturated region near Salt Lake City. In the 09z cross-section, note the 309 degree theta-e line crosses the 15 M-surface, and at 12z the 303 theta-e line crosses the 10 M-surface. If theta-e is decreasing with height, or if the theta-e lines are vertical, then upright convection will dominate rather than CSI, but in this case, the theta-e surfaces are not even close to vertical. Thus, the atmosphere is stable with respect to upright convection. These cross-sections are typical of what you should expect to see in a CSI event. One can think of a parcel following an M-surface in this region. In areas where the theta-e surface is steeper than the M-surface, the parcel will be moving through decreasing theta-e. It can be thought of as analogous to convective instability except along a slanted path.

Summary

The key elements necessary for CSI were present in this event. Bands of CSI-induced precipitation are found to the north of shallow fronts, but on the anticyclonic side of jets. Frontogenesis is also typically present.

Over northern Utah, these conditions occur when a shallow, and usually dry, cold front moves south into the state and either slows down or stalls across central Utah. A dry cold front did move south through northern Utah during the afternoon of March 3. The 700 mb frontogenesis, well to the north of the surface frontal position at 12z March 4, shows that the front was indeed quite shallow in this event. The secondary circulation, induced by this frontogenesis, likely provided the vertical motion necessary to saturate the environment. Being on the north side of the shallow front ensures that the lower troposphere will be stable with respect to upright convection. Northern Utah was on the anticyclonic side of a jet, and the satellite imagery suggests there was a jet streak on a smaller scale, than resolved by the RUC, that moved by just north of Salt Lake City. This provided the shear environment necessary for CSI.

The dryness associated with these fronts is likely one of the key reasons these events are very difficult to forecast. Forecasters are likely to be focusing on the precipitation potential with and immediately behind the front, and the CSI bands may not develop until much later. Whenever the aforementioned elements are present, it is worthwhile to draw some cross-sections of theta-e, M-surfaces, and relative humidity and look for the possibility of CSI banding. These bands will nearly always concentrate precipitation and produce intensities and amounts much greater than what the general pattern would suggest is possible.

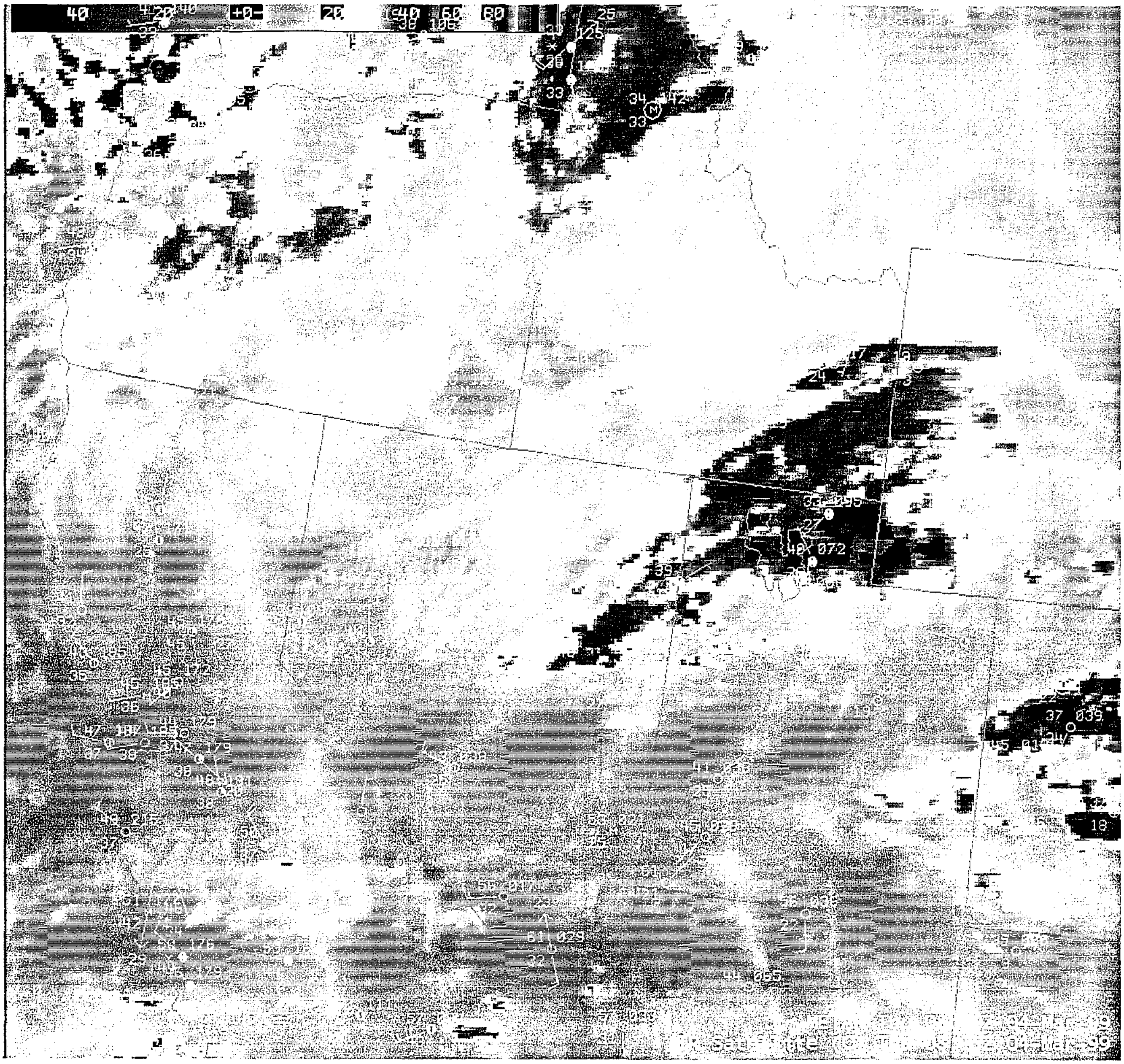

Fig. 1 - Infrared imagery from 0815Z IR

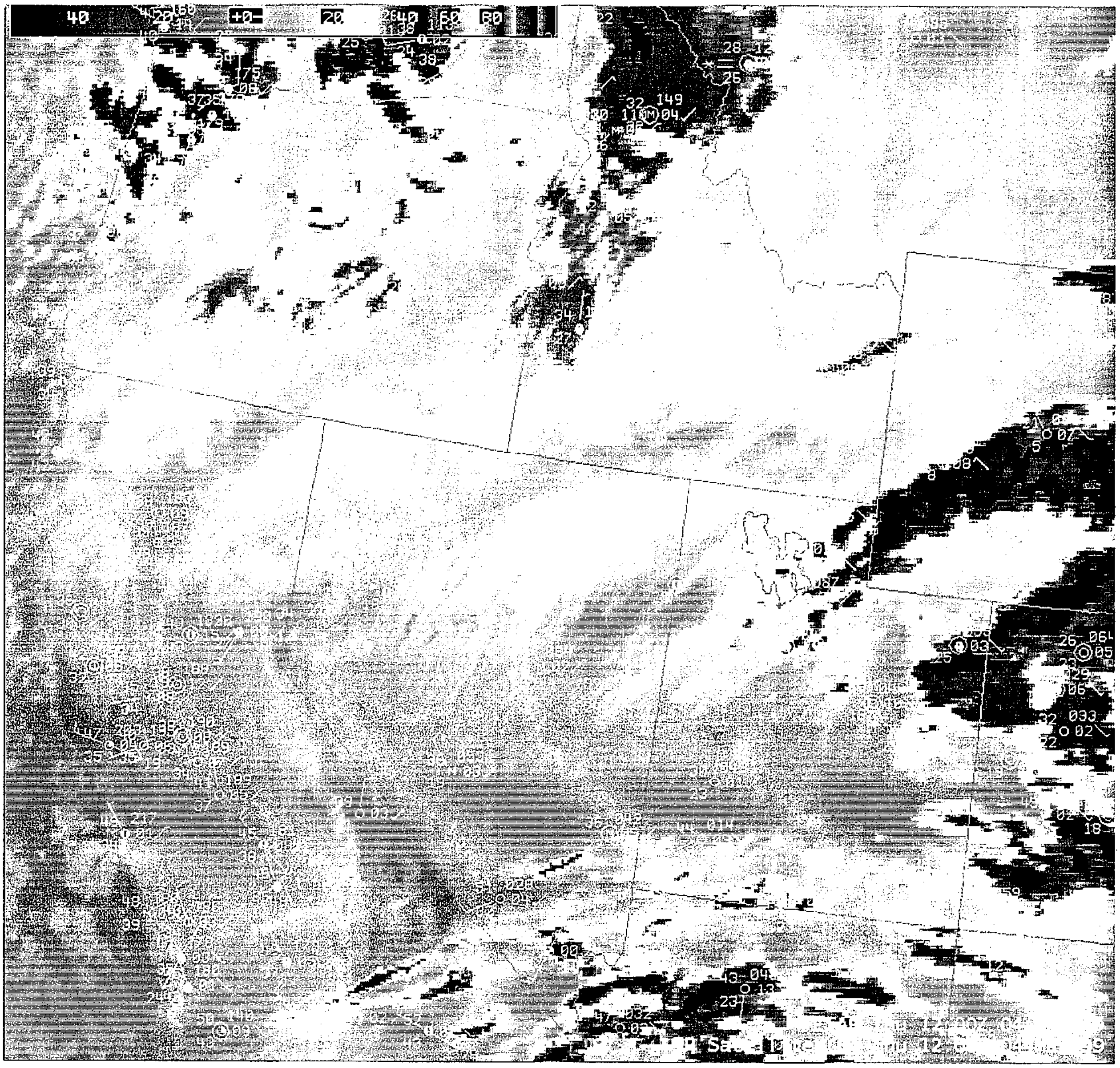

Fig. 2 - Infrared Imagery from 1200Z IR

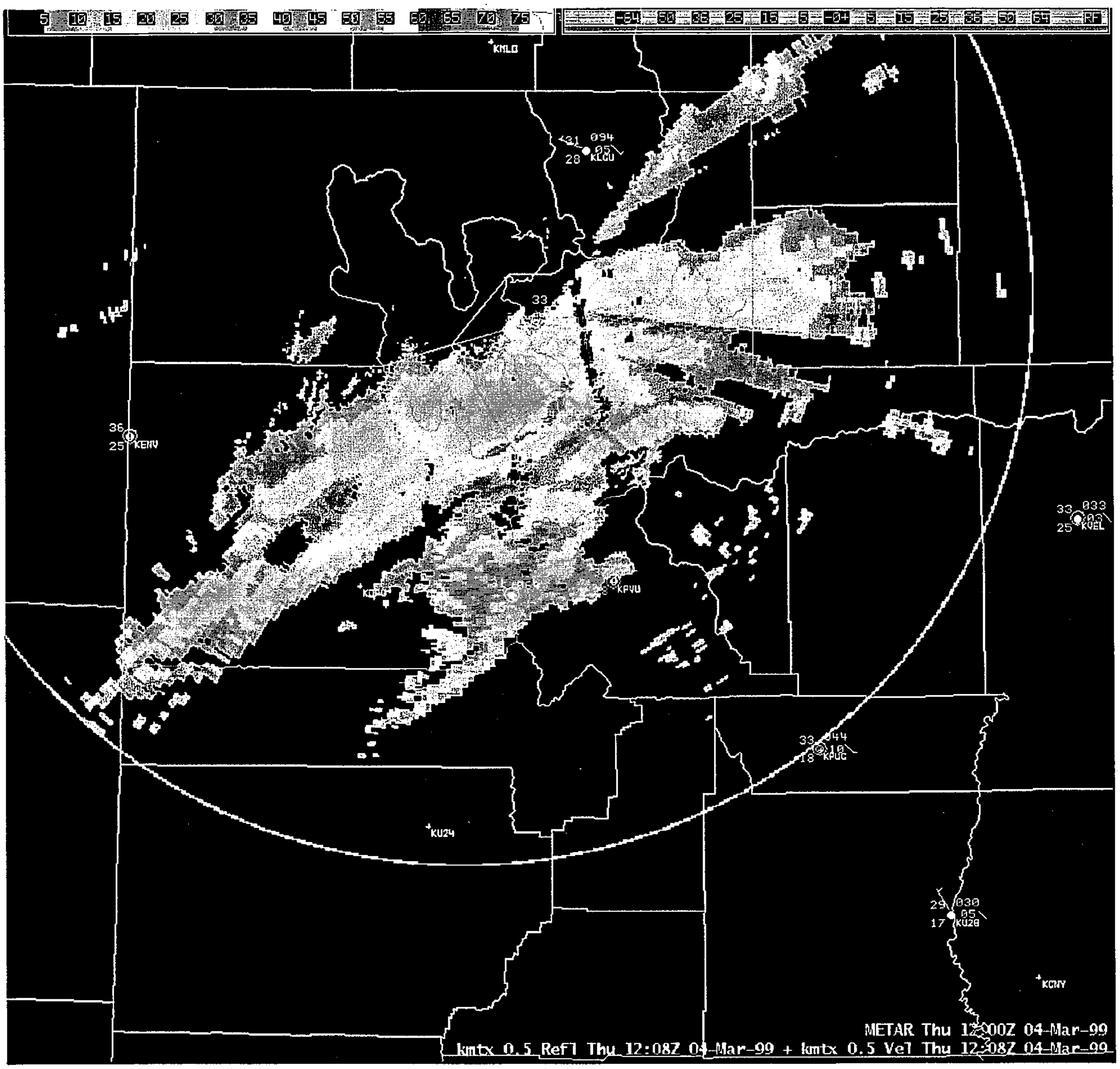

Fig. 3 - The radar reflectivity from 1208Z - 0.5 degrees

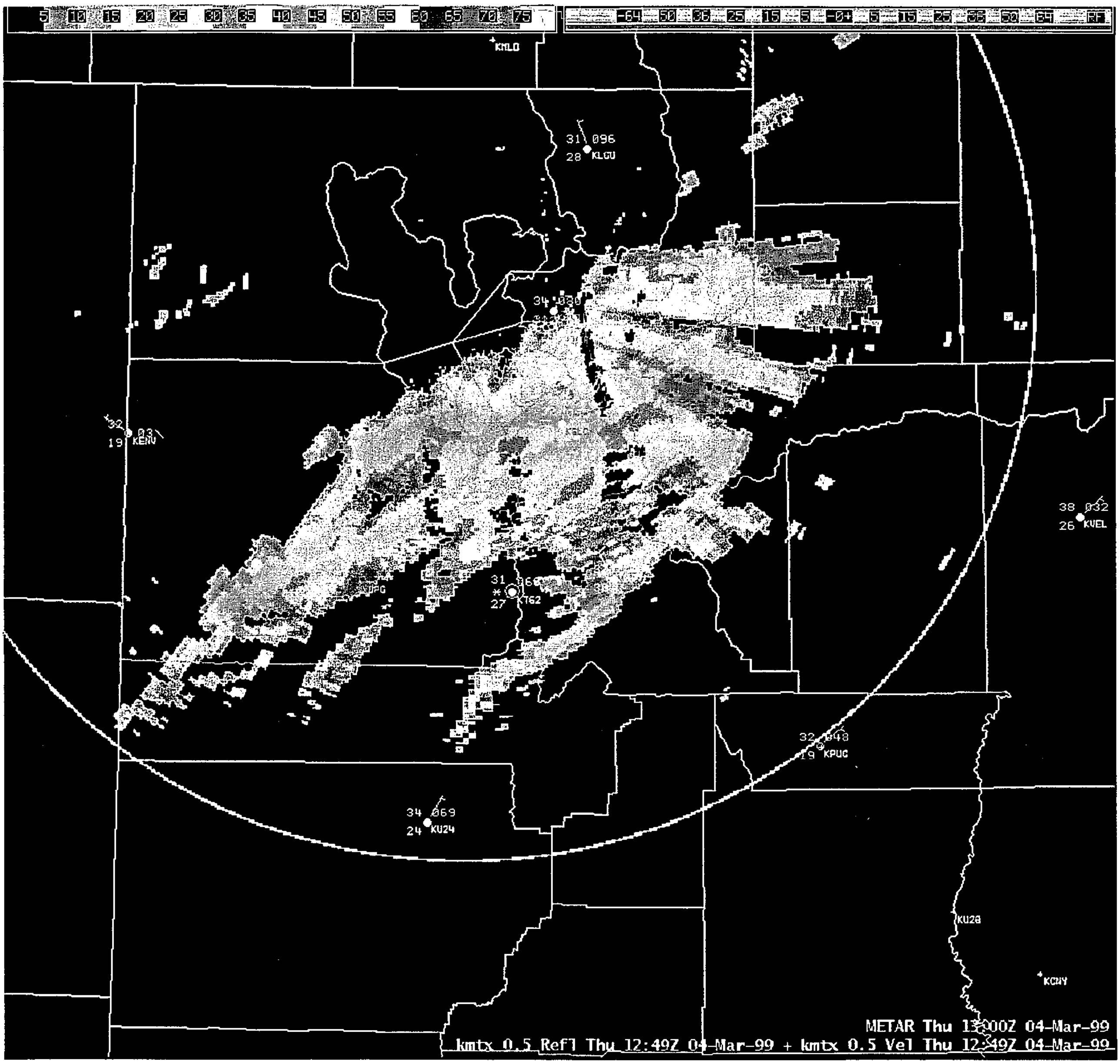

Fig. 4 - The radar reflectivity from 1249Z - 0.5 degrees

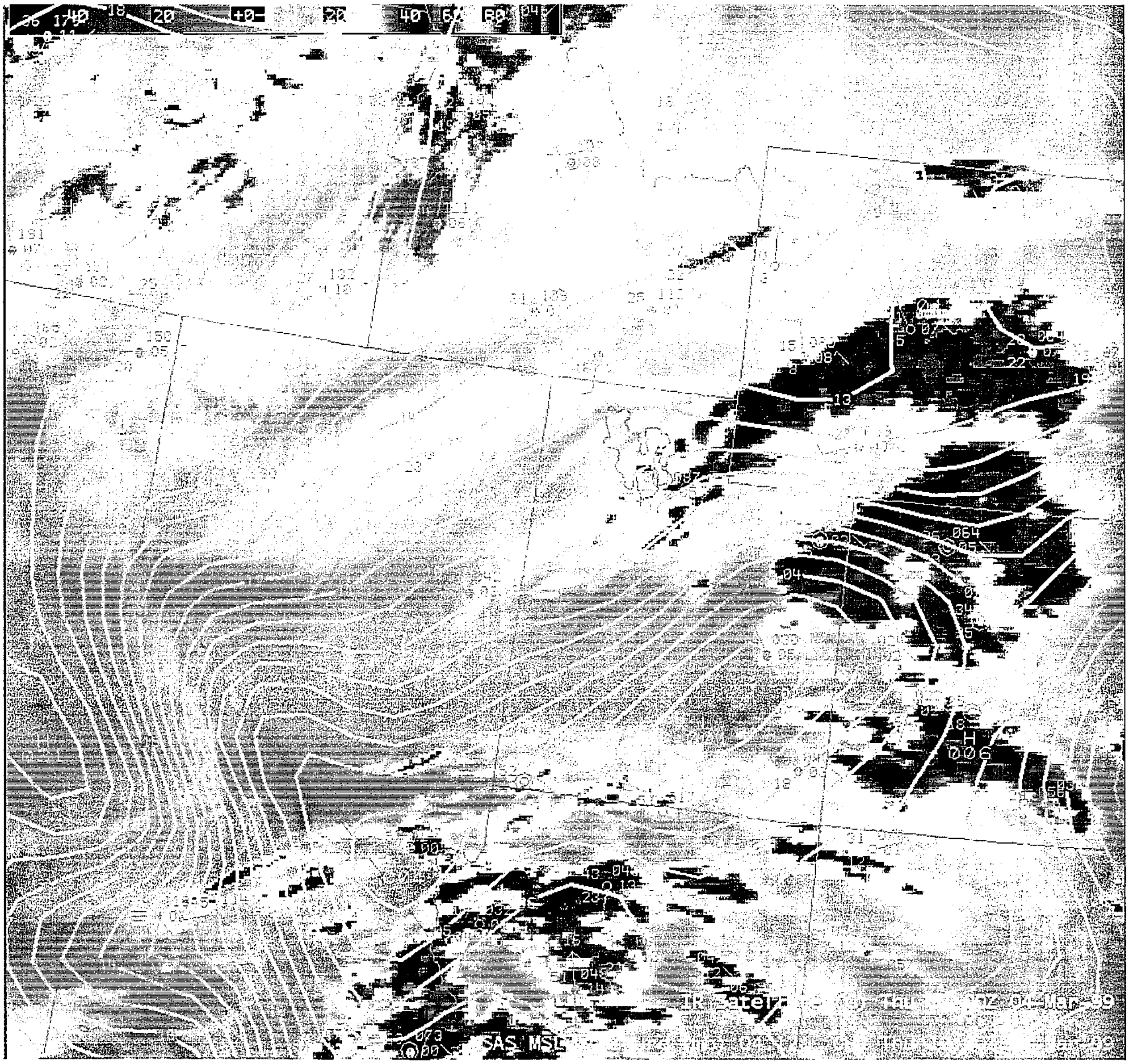

Fig. 5 - The MSAS analysis shows that northern Utah was clearly post-frontal.

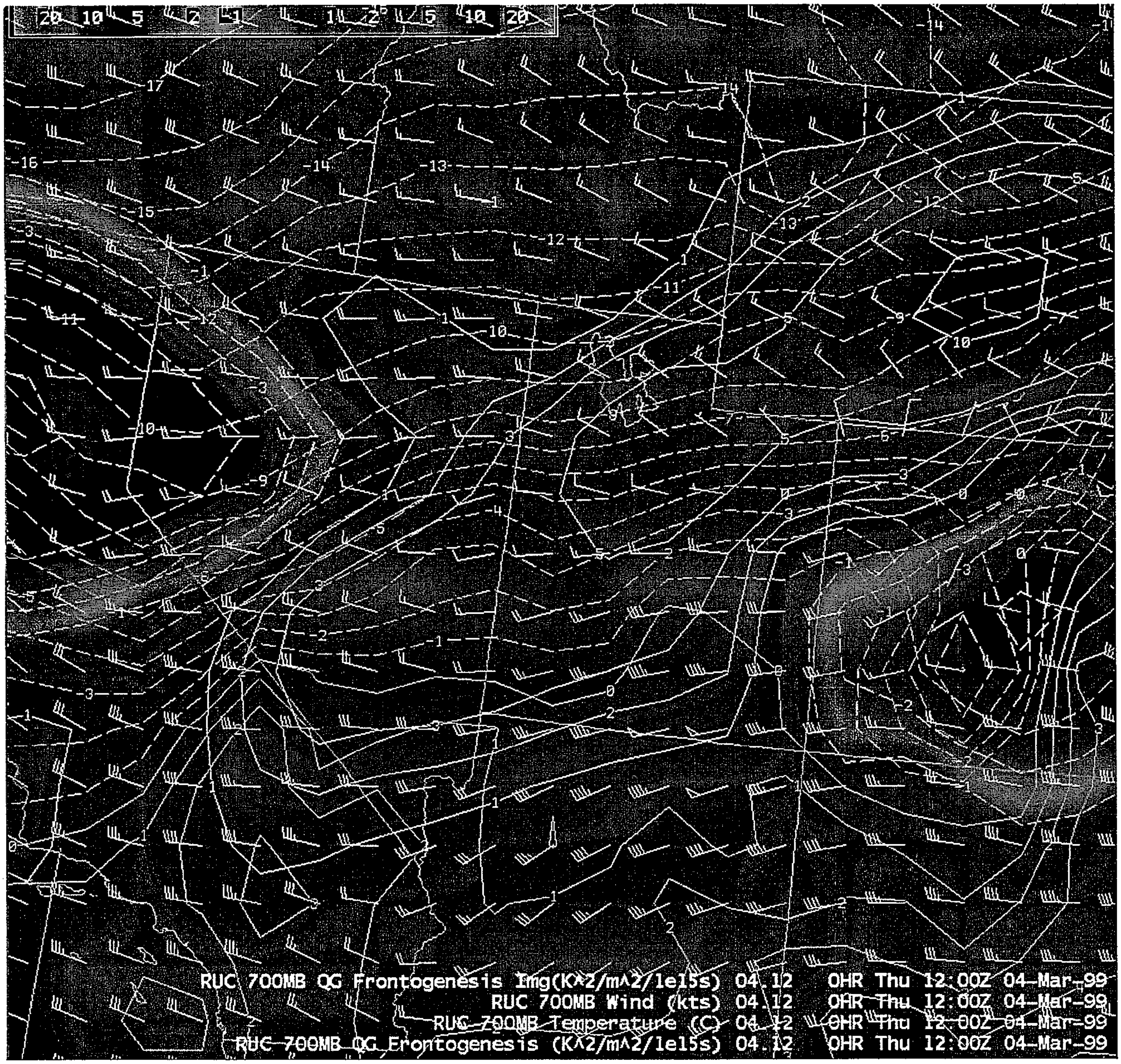

Fig. 6 - A RUC frontogenesis analysis - 700 mb

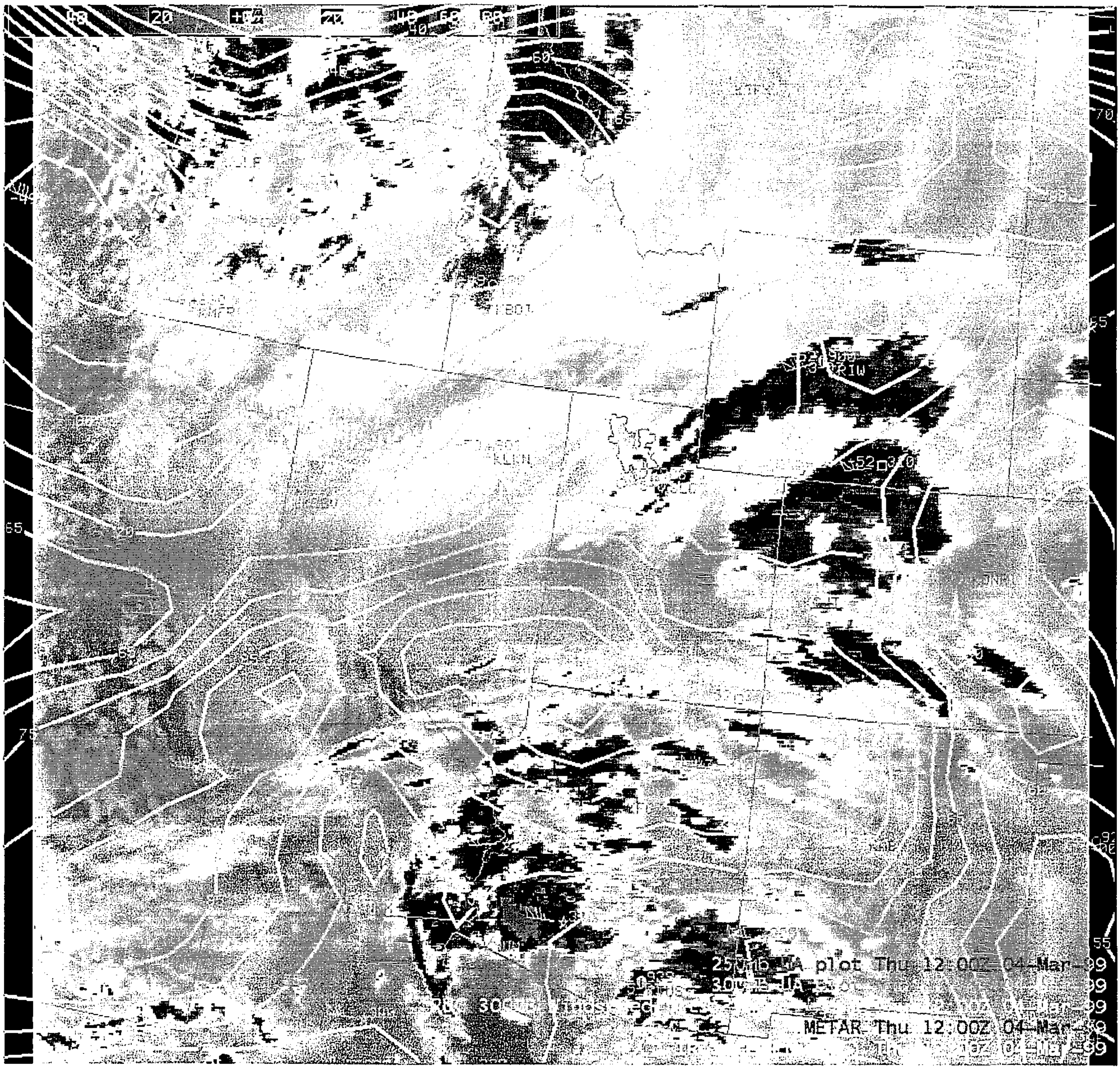

Fig. 7 - The RUC isotach analysis jet across southern Utah and another across Idaho and Wyoming.

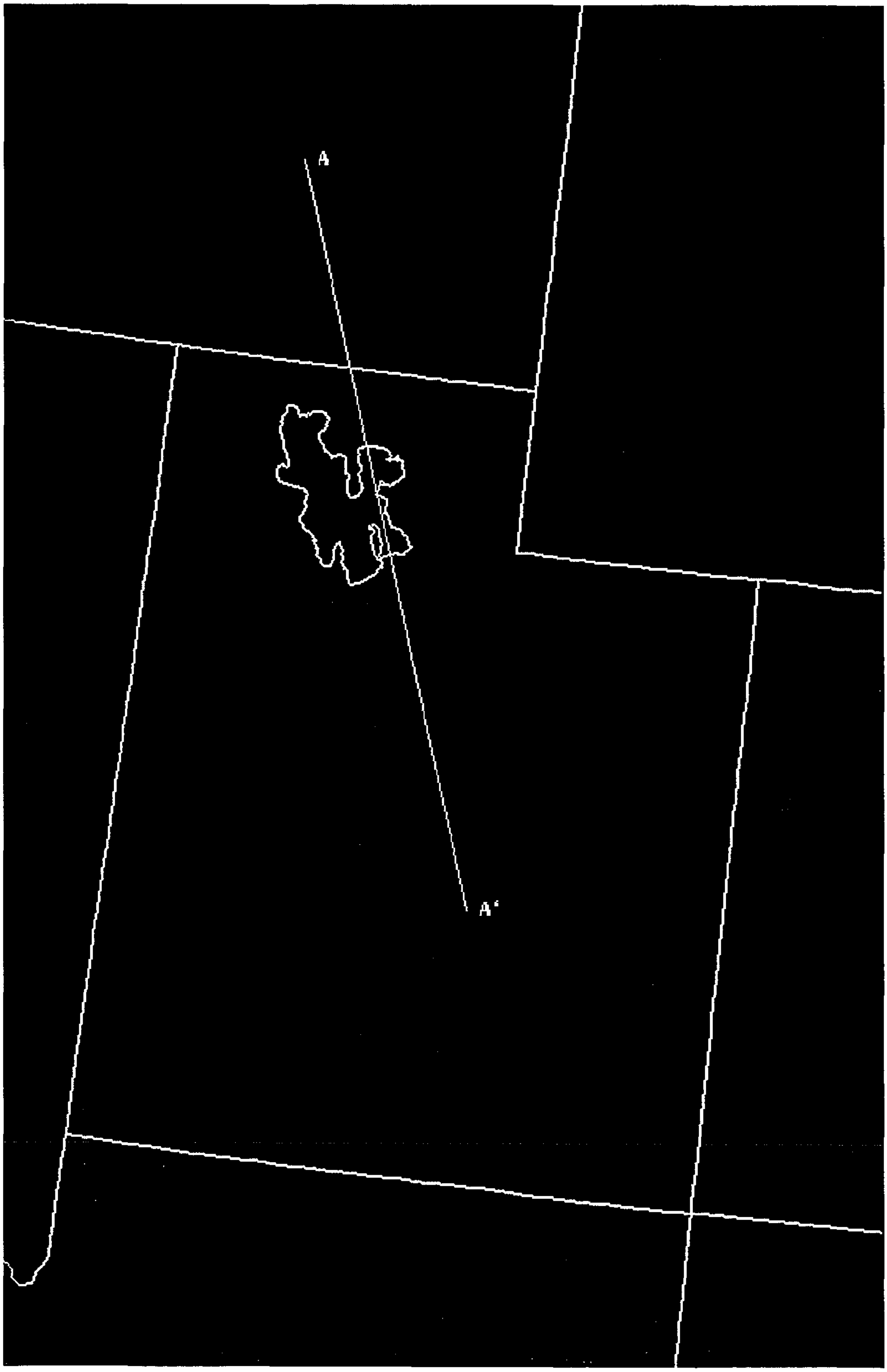

Fig.8 - The baseline used in this case.

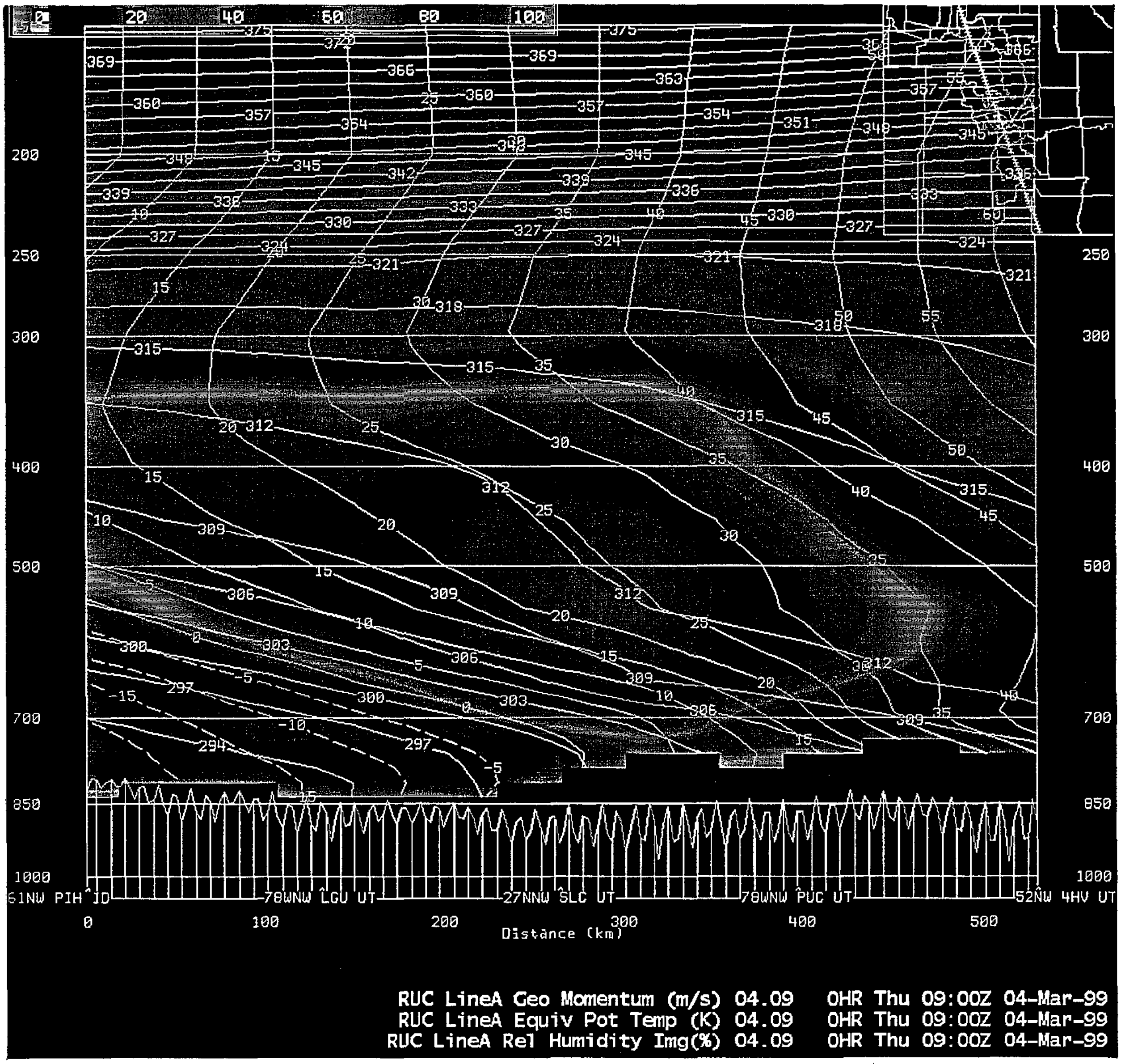

Fig. 9 - A X-section at 0900Z

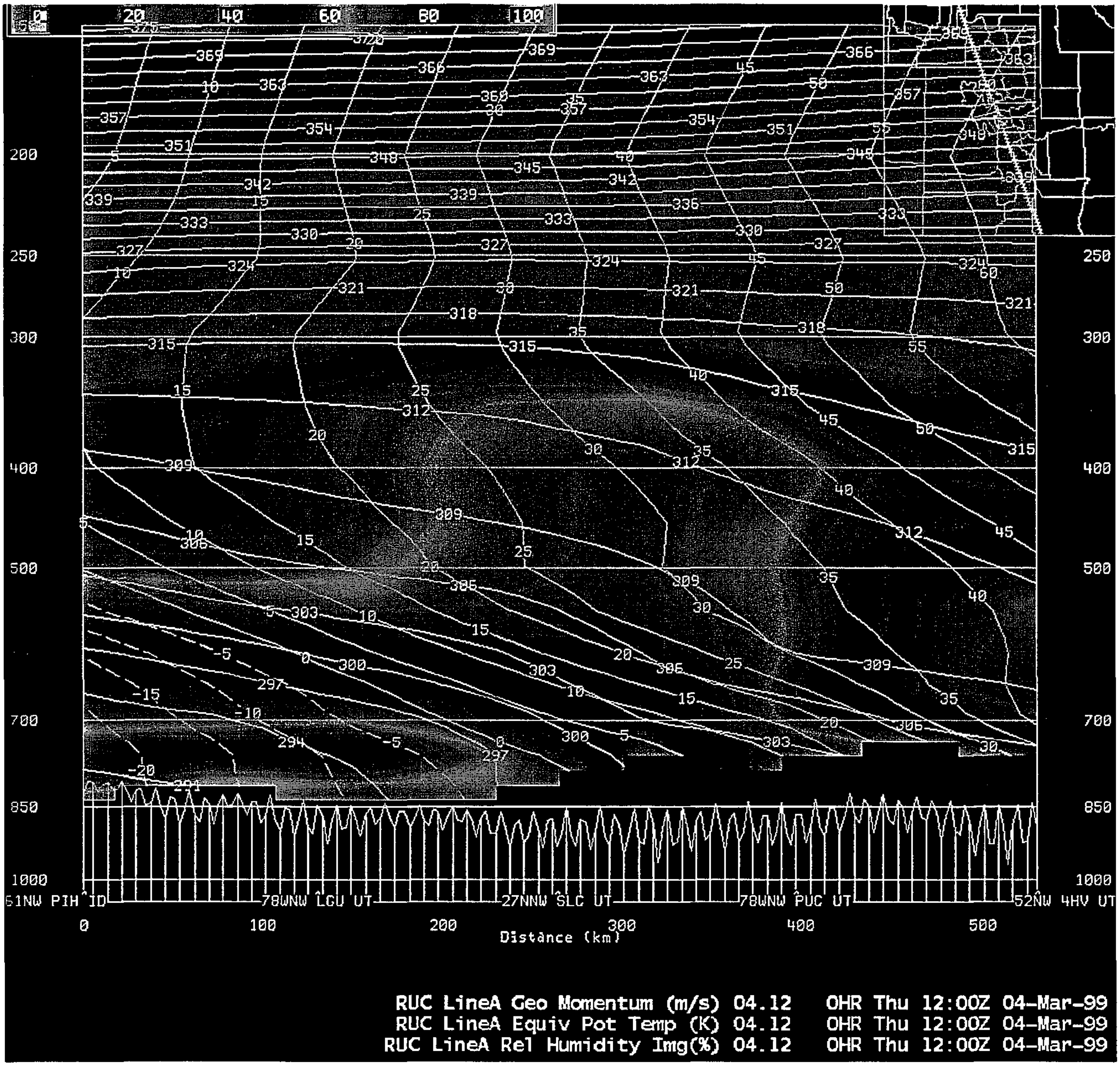

Fig. 10 - A X-section at 1200Z