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STORM RELATIVE ISENTROPIC MOTION ASSOCIATED WITH COLD FRONTS IN NORTHERN UTAH

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STORM RELATIVE ISENTROPIC MOTION ASSOCIATED WITH COLD FRONTS IN NORTHERN UTAH

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ABSTRACT

One of the most difficult forecasting problems for Salt Lake City, Utah is the discrimination between wet and dry cold fronts as these weather systems move into the populated regions on the western slope of the Wasatch Mountains. The intent of this paper is to diagnose isentropic vertical motion associated with winter season cold frontal passages at Salt Lake City from a storm relative (Lagrangian) frame of reference in an attempt to discern wet from dry frontal passages. Lagrangian vertical motions associated with cold frontal passages are compared with conventional fixed frame of reference (Eulerian) isentropic motion. All wet frontal passages at Salt Lake City from November 1993 through January 1994 coincided with upward motion using the Lagrangian isentropic analysis scheme. Only 25 percent of the wet frontal systems were identified by upward motion using conventional Eulerian isentropic analysis. Modern computer technology allows forecasters to examine Lagrangian isentropic motion with PCGRIDDS software applications as was performed for this study.

I. INTRODUCTION

The distinction between cool-season dry and wet cold frontal passages is often difficult to forecast over northern Utah. Many cold fronts and their associated upper-level baroclinic zones move into the populated Wasatch Front from the west and northwest during the winter. These weather systems often produce little or no measurable precipitation as they cross the arid lands upstream from Salt Lake City, while precipitation is frequently observed as they approach the high terrain of the Wasatch Mountains. However, a significant percentage of these systems remain dry as they move through northern Utah. The development of a technique that allows for discrimination between precipitating and non-precipitating frontal systems is the focus of this study.

The approach taken here is the application of isentropic analysis to identify the vertical motion field associated with cold fronts as they move into northern Utah. Isentropic analysis is not new. Rossby et al. (1937) emphasized the advantages of isentropic flow patterns as "a fruitful synthesis of thermodynamic and hydrodynamic methods in air mass analysis." Rossby discusses the conservative properties of air parcels on isentropic surfaces. The intention of his argument was the recommendation that the meteorological community, and specifically the then U.S. Weather Bureau, prepare daily weather and forecast maps on isentropic surfaces, rather than pressure or height surfaces. Namias (1938, 1939) and Neamtan (1944) also demonstrated advantages of using isentropic surfaces rather than pressure surfaces. However, the 1950's saw a dramatic decrease in the use of isentropic analysis. The meteorological community focused its attention on forecasting pressure patterns on constant height surfaces (Danielsen 1961; Moore 1988).

More recently isentropic surfaces have been used in the interpretation of cloud and precipitation patterns associated with frontal systems. Relative-wind isentropic trajectories were used to explain the familiar comma cloud pattern of wave cyclones (Carlson 1980), and in the dynamic interpretation of clouds and precipitation patterns in extratropical cyclones (Browning 1990). Shutts (1991) analyzed frontal boundaries in Southern England using a vertical cross-section of isentropic surfaces and normal wind components.

Probably due to the ease in recognizing frontal boundaries, isentropic analysis has gained considerable favor by those studying the movement and development of frontal systems (Anderson 1984; Moore 1988; Sanders 1993). "Southerly busters" in Australia were determined to be orographically initiated by using low-level isentropic coordinates (Coulman et al. 1984). The research program Fronts 87 analyzed mesoscale frontal dynamics on various isentropic surfaces (Thorpe 1991).

The 1990's have seen an explosion of meteorological investigations on isentropic surfaces. The recent access to high speed computers and model gridded data by operational forecasters has allowed for the direct application of isentropic theory to daily weather forecasting (Dunn 1993; Zubrick and Thaler 1993; Shea and Przybylinski 1993).

The computer software known as PCGRIDDS is currently being used by many National Weather Service Forecast Offices to enhance forecasting techniques through the use of model gridded data. The ease of use and the data density provided by model grids has brought application of isentropic analysis back into the realm of operational forecasting. The Washington, D.C. (Sterling) NWS forecast office regularly uses a program that overlays constant mixing ratio lines on isentropic surfaces to forecast precipitation areas (Zubrick and Thaler 1993). The St. Louis NWS Forecast Office has used PCGRIDDS and isentropic surfaces to analyze vertical motions associated with winter storms (Shea and Przybylinski 1993). At the Sterling office, pressure and interpolated winds on isentropic surfaces were used to forecast an early season snowstorm (Gates and Zubrick 1993). The Denver NWS Forecast Office uses an advanced prototype system (MAPS) with a hybrid isentropic/sigma coordinate system (Smith and Benjamin 1993) to derive isentropic potential vorticity fields to forecast developing systems.

Frontal systems and associated synoptic-scale motions produce the majority of precipitation during the winter season at many western U.S. mid-latitude locations, including Salt Lake City. There have been many refinements to the Norwegian cyclone model (Bjerknes 1919; Bjerknes and Solberg 1922) over the years. Anafronts and katafronts, first proposed by Bergeron (1937), expanded on the original Norwegian model. Anafronts have descending cold and ascending warm air currents where the cold air behind the front advances faster than the warm air recedes, while katafronts have descending air on both sides of the front where the warm air ahead of the front recedes faster than the cold air advances. The anafront model best describes the heavier precipitation events, while the katafront model best represents the dry frontal passages.

Browning and Monk (1982) used the visualization of "conveyer-belts" in their refinements to the conceptual model of anafronts and katafronts. In the anafront, the warm southerly conveyor-belt slopes rearward over the advancing cold air behind the surface cold front. In the katafront or "split-front", the conveyor-belt slopes forward away from the surface cold front. The result is an upper-level front out ahead of the surface cold front. Precipitation is often associated with the upper-level front, while the surface front is either completely dry or produces only light showers. Hobbs et al. (1990) suggested a similar model for cold fronts aloft.

Winter precipitation at Salt Lake City is often associated with the passage of an anafront, where the heaviest precipitation falls in the colder air behind the front. Little, if any, precipitation occurs ahead of the boundary. Within the conveyor-belt perspective the wet fronts at Salt Lake City fall into the rearward sloping type. Katafronts are nearly always dry events at Salt Lake City, with subsidence associated with the surface cold front, while the dry low-level conditions in the warm-sector preclude precipitation from the upper-level front. The use of storm-relative isentropic analysis in this study is aimed at discriminating rearward sloping ascent associated with wet anafronts from the descent associated with katafronts. Other frontal types, such as occlusions, have generated major precipitation events, but are often more difficult to diagnose using storm-relative isentropic analysis, and will not be considered in this study.

II. DATA AND METHODS

The concept of "relative wind" isentropic flow (Carlson 1991) has revealed sharply defined boundaries and areas of vertical motion through frontal systems. Isentropic analysis on a fixed (Eulerian) surface depicts upward motion in areas of warm advection, but usually fails to capture upward motion in regions of neutral or cold advection. Thus, isentropic analysis in the vicinity of cold fronts may benefit by using a storm-relative approach. The "relative wind" isentropic analysis technique places the frame of reference with the weather system (Lagrangian), subtracting out the phase speed of the storm. Proper calculation of storm phase speed requires a steady state situation in which the storm exhibits little or no acceleration (Green et al. 1966). To a rough approximation, the relative wind streamlines act as trajectories.

A total of 20 frontal passages were reviewed from November 1993 through early February 1994. The weather observations (SAO's) at Salt Lake City International Airport were used to verify the time of frontal passage at the surface. The PCGRIDDS data from the Eta model were saved from the model run closest and prior to the frontal passage. Isentropic surfaces, θ, were created for the initial condition (0-hour), 6-hour forecast, and 12-hour forecast of the model covering the time of frontal passage. The isentropes were constructed every 5K, covering a pressure range from about 700 mb to 400 mb. Isentropes below 700 mb were avoided because of intersection with the high model terrain located over the eastern Great Basin and Colorado Rockies.

The phase speed and direction of the weather system was calculated by averaging the 500 mb trough speed and direction and the 700 mb frontal speed and direction between the Eta 0h and 12h forecast charts. Locating the 700 mb frontal position was often subjective, but every attempt was made to choose the position along the leading edge of the thermal gradient. Using PCGRIDDS, the mean velocity vector (phase speed) of the system was subtracted from the ambient wind field, and resultant winds (Lagrangian) were plotted on the isentropic surface. Pressure advection was calculated from the Lagrangian winds, and overlaid on the isentropic surface chart.

Vertical motion on an isentropic surface is defined by the following equation (Carlson 1991) in an adiabatic environment:

Equation 1

$$\omega_\theta \cong (\partial z/\partial t)_\theta + (\boldsymbol{V}_\theta \cdot \nabla_\theta p)$$

Terms: 1 2 3

The term on the left-hand side of Eq. 1 (Term 1) is the vertical motion on an isentropic surface with negative values implying ascent. The second term in Eq. 1 accounts for the local height tendency or pressure tendency on an isentropic surface (Moore 1988). This term is assumed to be small for a steady state system, but can be significant in a developmental or decaying weather system. The third term is the pressure advection on an isentropic surface. In a diabatic environment, an additional term must be added to the right-hand side of Eq. 1. This term would account for diabatic heating processes such as latent heat release in a saturated environment and heating from the earth's surface. This additional term is not considered here. However, in a saturated environment the ascent calculated in Eq. 1 would have to considered a lower limit since latent heating would increase the upward motion.

In a Lagrangian frame of reference, the phase speed of the storm (**C**) is subtracted from the actual wind (**V**), and the velocity vector in Eq. 1 becomes (**V-C**). If the system is assumed to undergo little or no change in intensity term 2 may be considered small. The resulting equation for omega on an isentropic surface becomes:

Equation 2

$$\cos\omega_\theta \cong (\boldsymbol{V}-\boldsymbol{C}) \cdot \nabla_\theta \sum p$$

The graphics generated in this study for each case include overlays on an isentropic surface of Lagrangian winds, pressure, and pressure advection. The pressure advection is calculated using the Lagrangian velocity vector (**V-C**). The vertical motion can be calculated directly from the pressure advection field as represented in Eq. 2.

The procedure for this process was simplified by the development of a FORTRAN computer program and several PCGRIDDS macros. The first macro shows the 500 mb height and absolute vorticity charts at 6 hour intervals to allow the forecaster to determine the phase speed of the troughs. A second macro displays the 700 mb height and temperature fields at 6 hour intervals to determine the frontal phase speed. The system phase speed is calculated from the average phase speeds of the 500 mb and 700 mb fields. The third macro displays the 700 mb θ field to determine which isentropic surfaces to diagnose, keeping above model terrain. The FORTRAN program prompts the user for the mean forecast phase speed, as just described. It then converts these variables into the units required by PCGRIDDS and inputs the phase speed data into a PCGRIDDS command file. This command file displays the vertical motion due to storm-relative motions on an isentropic surface. The θ surfaces to be analyzed must be created in PCGRIDDS prior to running the command file produced by FORTRAN. For comparison, another command file is available to display Eulerian isentropic vertical motion. With a little experience, the entire process can be completed in less than two minutes.

III. RESULTS

Of the 20 frontal passages examined in this study, 8 cases verified measurable precipitation at Salt Lake City. Of these 8 wet events, Lagrangian isentropic vertical motion was upward in all 8 cases. Within an Eulerian frame of reference, upward motion was forecast in only 2 of the 8 events. Of the 12 cases where no measurable precipitation (dry front) was recorded, downward or zero vertical motion was forecast nine times using Lagrangian isentropic analysis. From the Eulerian perspective, 10 cases out of 12 showed zero or downward vertical motion. Using Lagrangian winds to calculate vertical motion on isentropic surfaces, no wet events were missed, and only three of the 20 cases (all dry events) were forecast incorrectly.

The heaviest precipitation event occurred on 12 December 1993 and resulted in 0.61 inches. The surface cold front passed Salt Lake City about 1000 UTC on the 12th, with a system phase speed estimated from 290° at 16 m s^{-1}.

The 6-hour forecast charts from the Eta model valid at 0600 UTC 12 December are shown in Figs. 1a through 1c. The storm relative winds, pressure, and pressure advection fields are depicted on the 305K isentropic surface in Fig. 1a. The actual winds (Eulerian), pressure, and pressure advection fields on the 305K isentrope are shown in Fig. 1b. The relative humidity field for the same isentropic surface is presented in Fig. 1c.

The pressure advection, which is equivalent to (-1 * omega), is displayed with solid lines for upward motion (positive) and dashed lines for downward motion (negative). Upward motion is evident over eastern Nevada and western Utah (Fig. 1a), and the relative humidity is greater than 90 percent (Fig. 1c). The strongest upward motion was denoted by the "bulls-eye" over east-central Nevada and over southern Arizona. Dynamic lift and abundant moisture were evident at midlevels in the atmosphere over Salt Lake City. The lower 300K isentropic surface was chosen at the 12-hour forecast time (1200 UTC) as colder air began to move across Utah from the west. Figs. 2a through 2c are similar to Fig. 1a through 1c, but are valid 6 hours later for the 300K isentrope. The Lagrangian vertical motion field predicted upward motion over western Utah (Fig. 2a) with the maximum ascent over northwest Utah. As in Fig. 1b, the Eulerian vertical motion field (Fig. 2b) showed descending motion.

A comparison between Figs. 1a and 1b, as well as 2a and 2b, show a major difference between vertical motion computations. The values in Figs. 1a and 2a were greater than 2 μb s^{-1} with upward motion, while the Eulerian isentropic graphics (Figs. 1b and 2b) indicated descending motion. In this case, the Lagrangian isentropic motion correlated well with the actual weather situation.

Another frontal passage that verified measurable precipitation is displayed in Figs. 3a through 3c. The event occurred 8 February 1994, and was different than the previous case in that the system was splitting as it moved inland from the Pacific Ocean. The cold front passed Salt Lake City around 0800 UTC on the 8th, and dropped 0.35 inches of precipitation. The phase velocity was calculated to be from 320° at 12 m s^{-1}, but this must be considered a rough estimate as the system split and slowed.

The charts (Figs. 3a through 3c) are valid for 1200 UTC on the 8th with a format similar to Figs. 1a through 1c. The upward motion shown on the Lagrangian isentropic chart is near 1 μb s^{-1} (Fig. 3a), but the Eulerian chart indicated weak downward motion (Fig. 3b). The forecast relative humidity was near 90 percent (Fig. 3c).

A case of a dry frontal passage is presented in Figs. 4a through 4c. The case occurred on 11 January 1994, with the cold front passing Salt Lake City around 2100 UTC. The phase velocity was from 340° at 14 m s^{-1}. The Lagrangian isentropic motion was computed as downward at greater than 1 μb s^{-1} (Fig. 4a), and the Eulerian motion was weakly downward with a value near zero (Fig. 4b). The forecast relative humidity was near 90 percent (Fig. 4c), thus a nearly saturated airmass was expected with the frontal passage. The high humidity could have argued for a wet forecast without a thorough investigation of the vertical motion field.

The possibility of error resulting from inaccurate phase speed calculations were explored by varying the FORTRAN program inputs. Little change in results was seen with a slow moving system (15 knots or less) when the direction was varied by ±10 degrees. With a fast moving system the direction of movement is much more important, and more precise approximation of phase speed is required.

IV. DISCUSSION AND CONCLUSION

Pressure is proportional to temperature on an isentropic surface (Moore 1988), and warm advection (positive pressure advection) indicates upward motion. One of the disadvantages of Eulerian isentropic analysis is the poor depiction of upward motion behind anafronts where precipitation frequently occurs. The region behind the anafront is often characterized by cold advection and downward motion from the Eulerian perspective. Lagrangian isentropic analysis has shown better results at identifying post-frontal areas of precipitation and upward motion. Comparing Fig. 2a with 2b (wet frontal system) illustrates the differences. The Lagrangian perspective showed upward motion at Salt Lake City (warm advection) while the Eulerian perspective had weak downward motion (cold advection).

Storm relative (Lagrangian) isentropic analysis has shown promising results, improving over the conventional fixed-frame (Eulerian) isentropic analysis technique. Centers of strongest upward motion were often co-located with areas of maximum precipitation.

The type of front is an important consideration for forecasting precipitation at Salt Lake City. The isentropic analysis technique demonstrated in this paper should provide forecasters with a new tool for examining frontal structure and associated vertical motions. Upon determining the front type, the forecaster can apply the precipitation patterns associated with the conceptual frontal models to the actual meteorological situation.

Although only 20 cases from a four month period have been examined, the results are quite encouraging. Given the difficult problem of discriminating between wet and dry cold fronts in the complex terrain of northern Utah, the calculation of Lagrangian vertical motion on isentropic surfaces correctly identified all 8 wet events, and 9 of the 12 dry events. The FORTRAN program and PCGRIDDS macros developed allow the forecaster to interactively apply this technique in a matter of minutes. Extension of this study is required to determine its utility in the warm season, and to obtain more cases from the next cool season.

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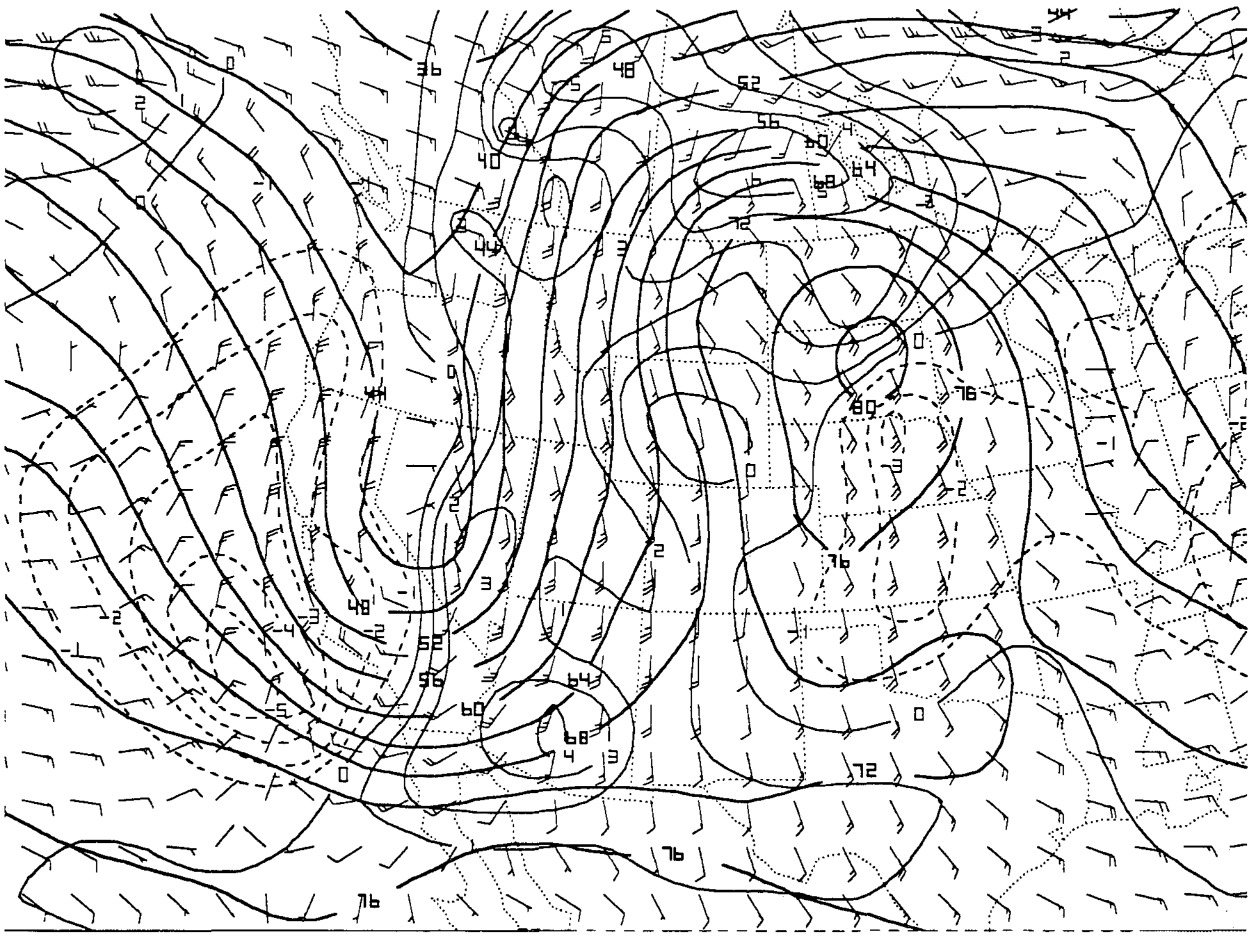

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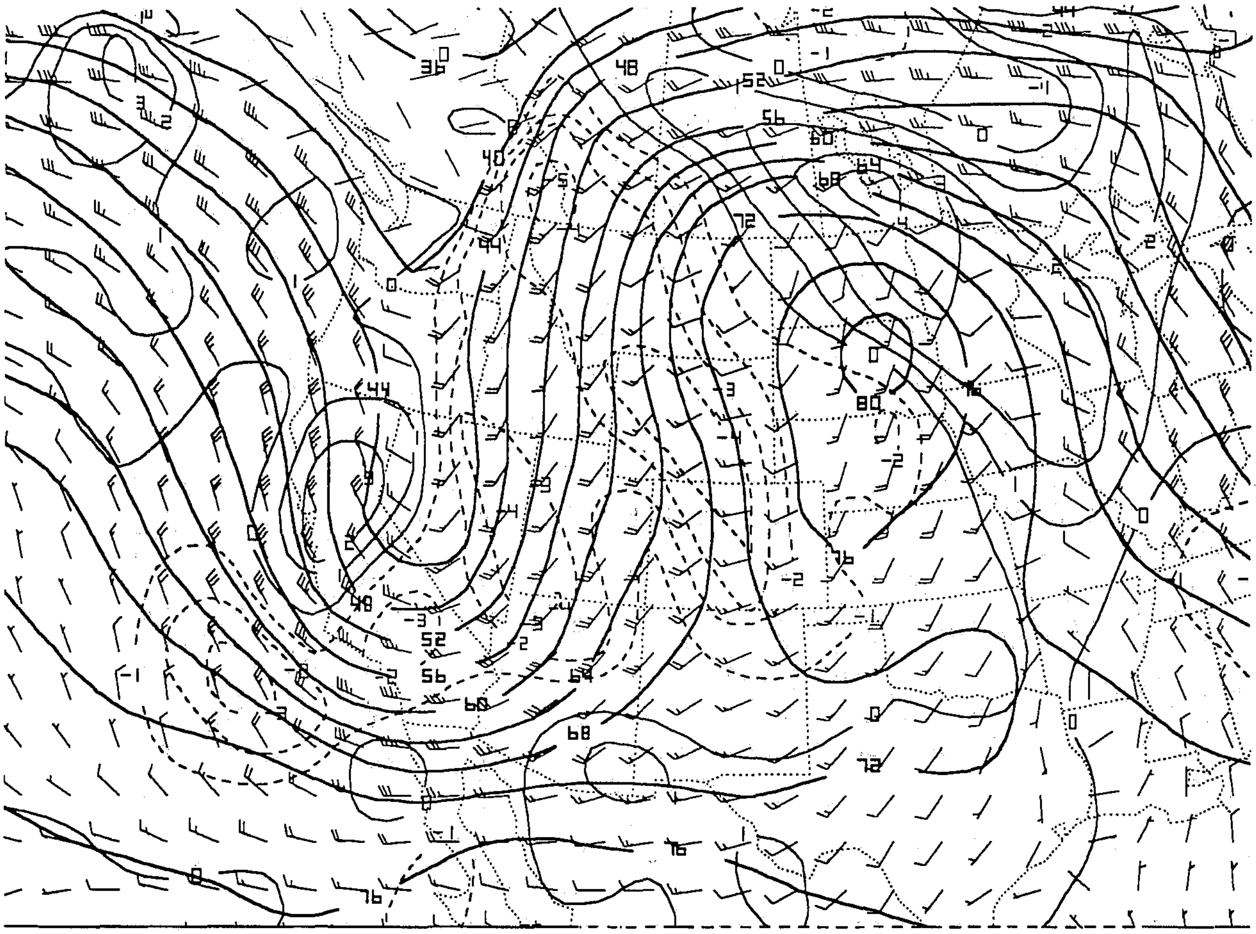
Figure 1a. **Early Eta 6-hour forecast valid at 0600 UTC 12 December 1993, Lagrangian case, wind, pressure, pressure advection, on a 305K isentropic surface.**



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93/12/12/ 0--WIND

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Figure 1b. As in Figure 1a except for Eulerian case.

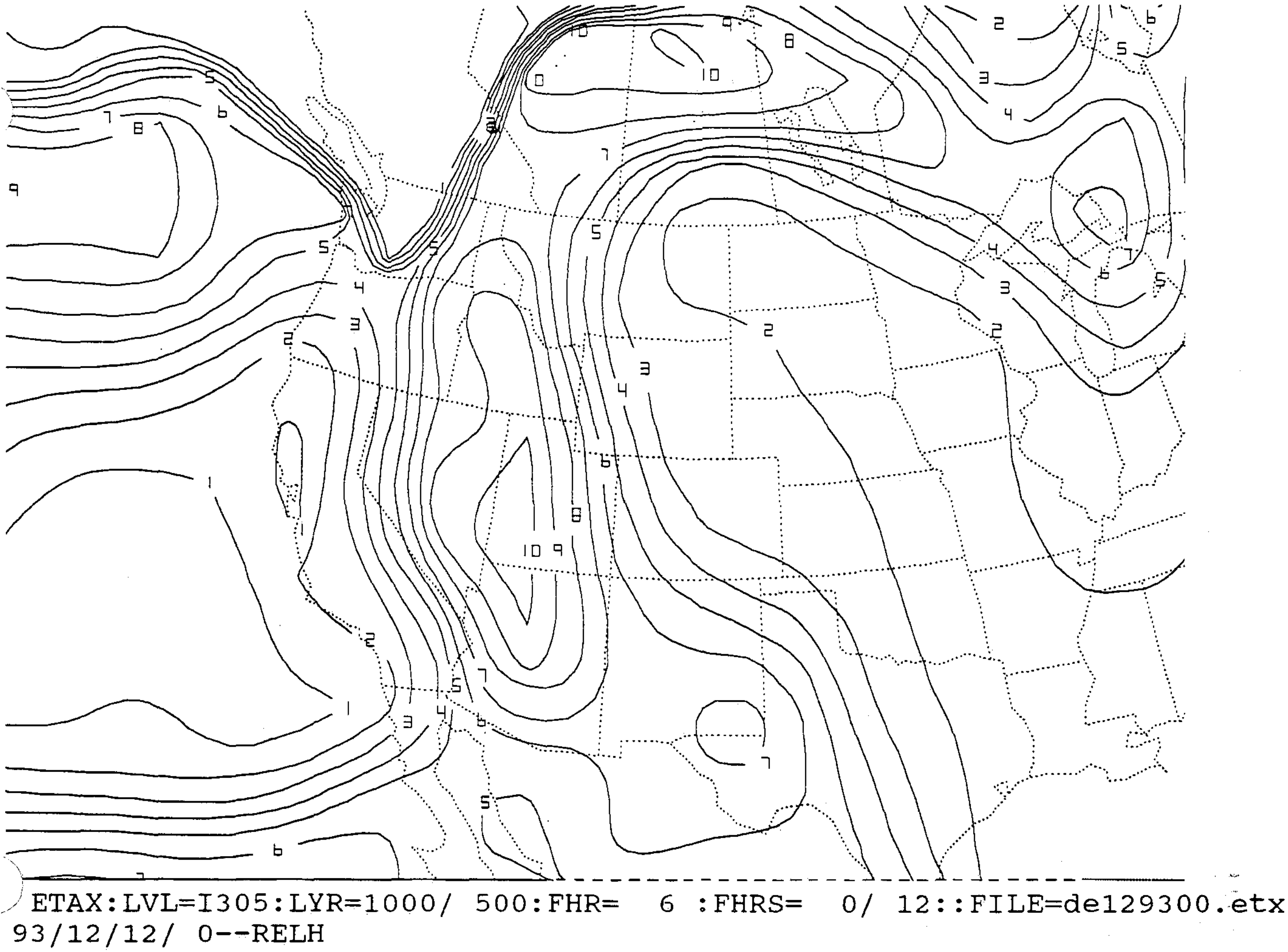
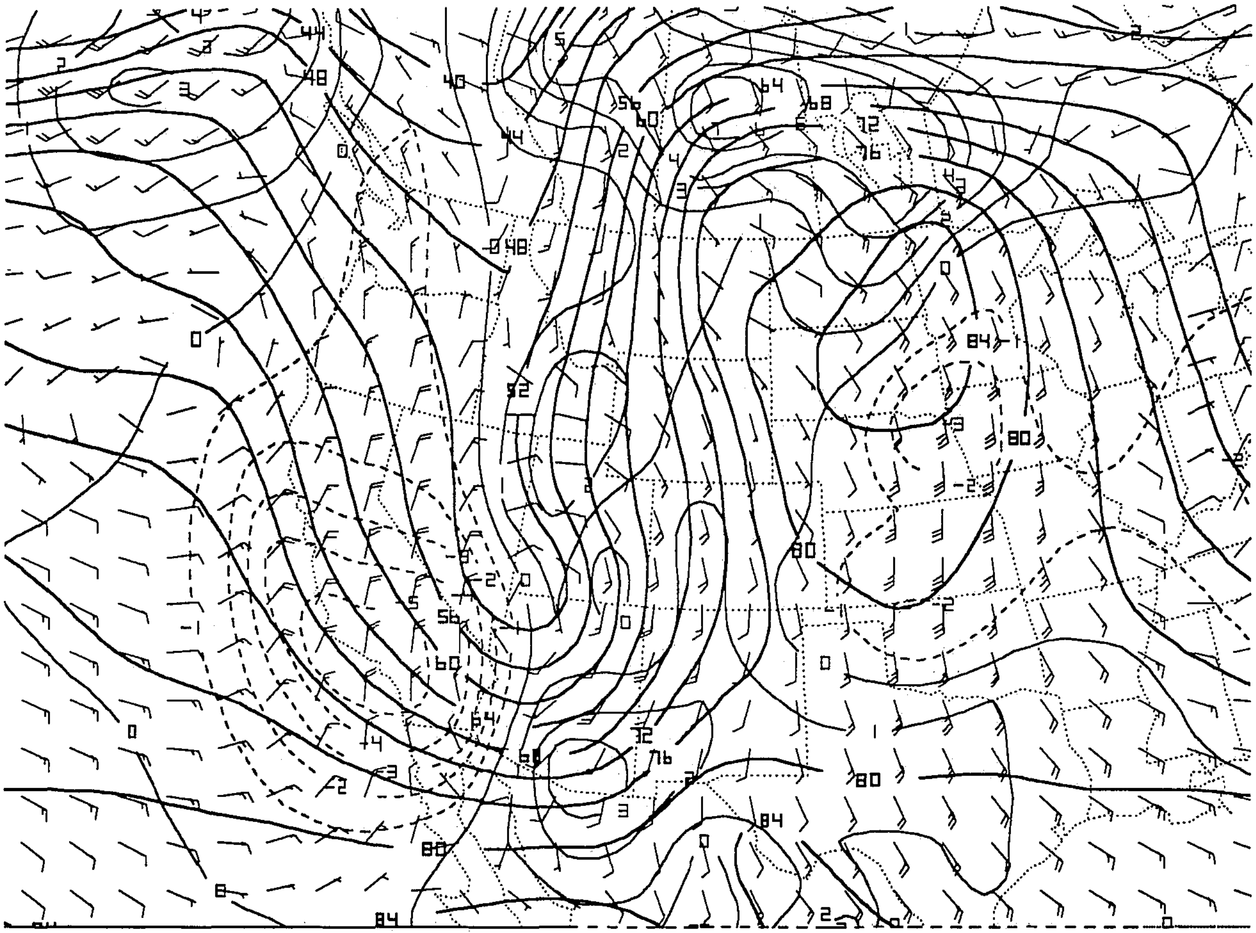


Figure 1c. As in Figure 1a except for relative humidity (tens of %).



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 ETAX:LVL=I300:LYR=1000/ 500:FHR= 12 :FHRS=  0/ 12::FILE=de129300.etx
93/12/12/ 0--ADVT PRES KEPV CI-3 DNEG&

 ETAX:LVL=I300:LYR=1000/ 500:FHR= 12 :FHRS=  0/ 12::FILE=de129300.etx
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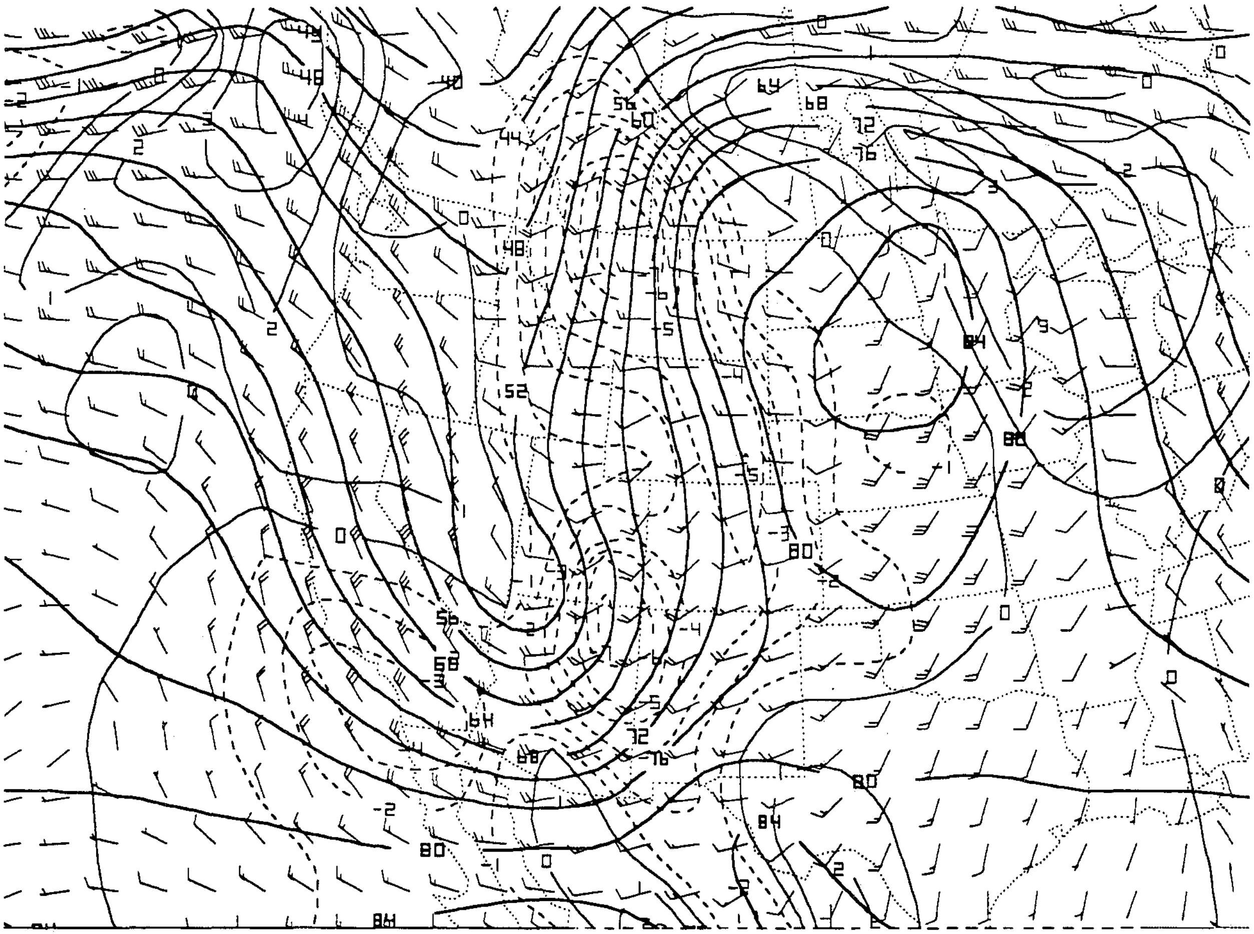
Figure 2a. Early Eta 12-hour forecast valid at 1200 UTC 12 December 1993, Lagrangian case on a 300K isentropic surface, units as in Figure 1a.



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93/12/12/ 0--WIND

 ETAX:LVL=I300:LYR=1000/ 500:FHR= 12 :FHRS=  0/ 12::FILE=de129300.etx
93/12/12/ 0--ADVT PRES WIND C1-3 DNEG&

 ETAX:LVL=I300:LYR=1000/ 500:FHR= 12 :FHRS=  0/ 12::FILE=de129300.etx
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Figure 2b. As in Figure 2a except for Eulerian case.

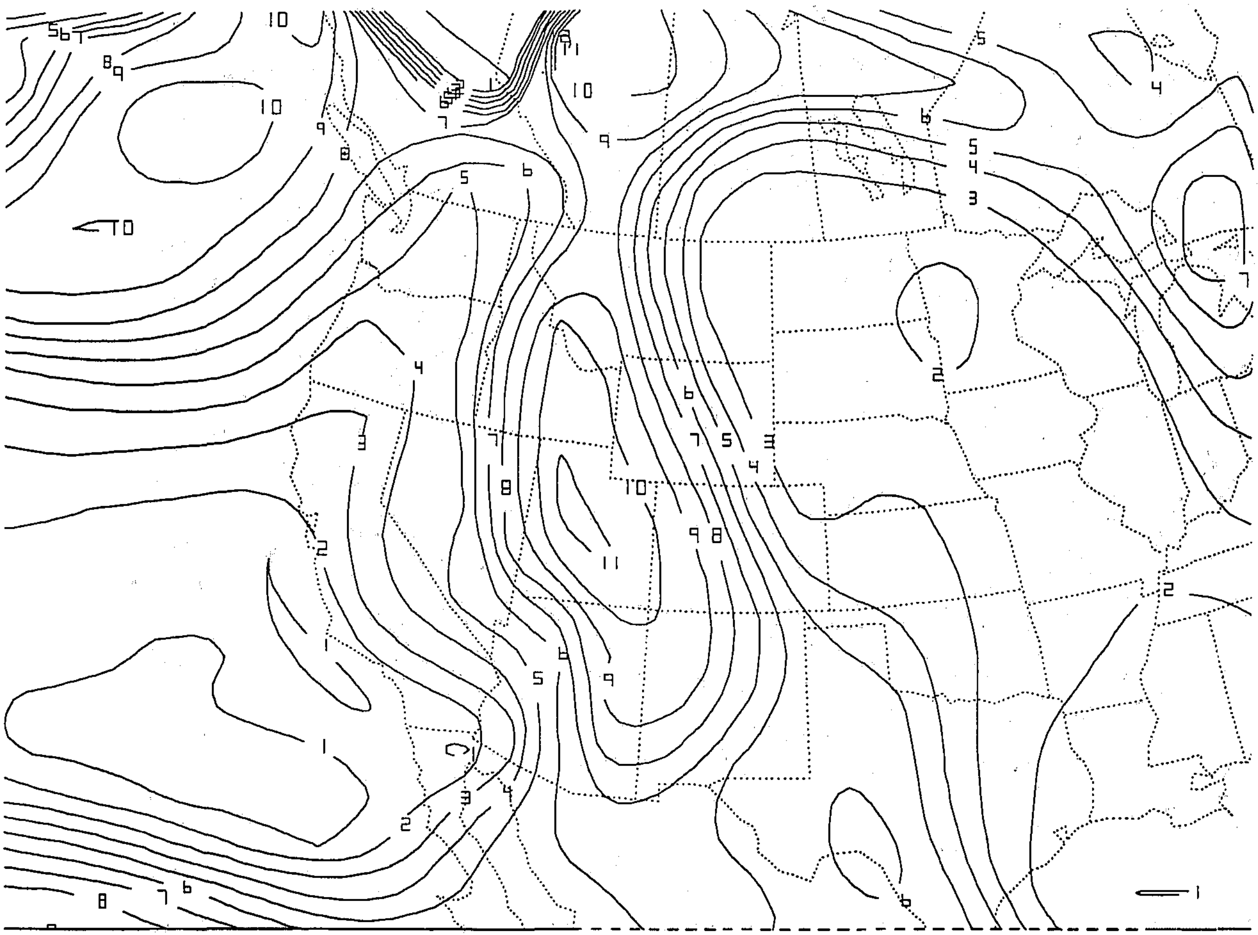

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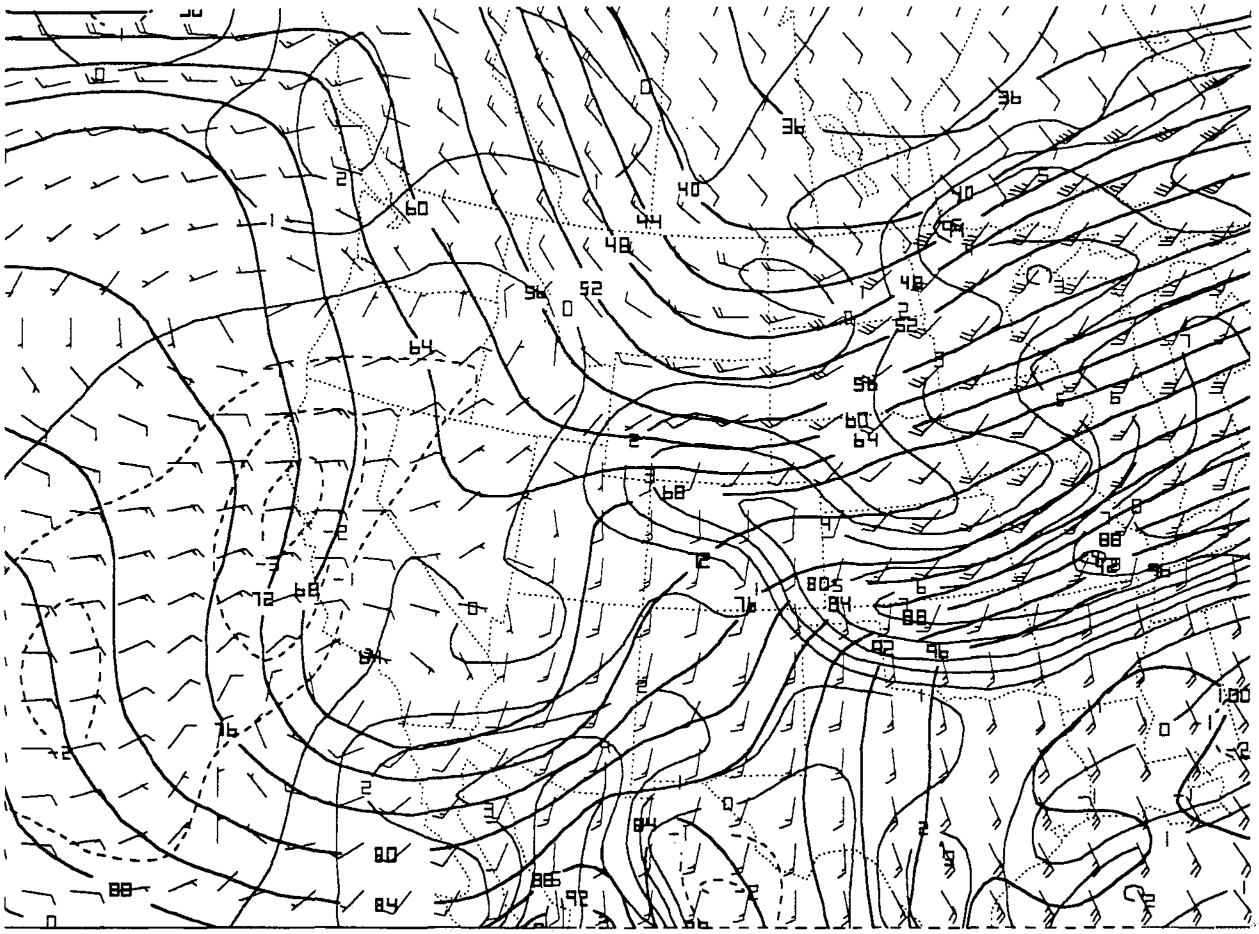
Figure 2c. As in Figure 2a except for relative humidity (tens of %).



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 ETAX:LVL=I295:LYR=1000/ 500:FHR= 12 :FHRS=  0/ 12::FILE=FE089412.ETX
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 ETAX:LVL=I295:LYR=1000/ 500:FHR= 12 :FHRS=  0/ 12::FILE=FE089412.ETX
94/ 2/ 8/12--PRES CI40&
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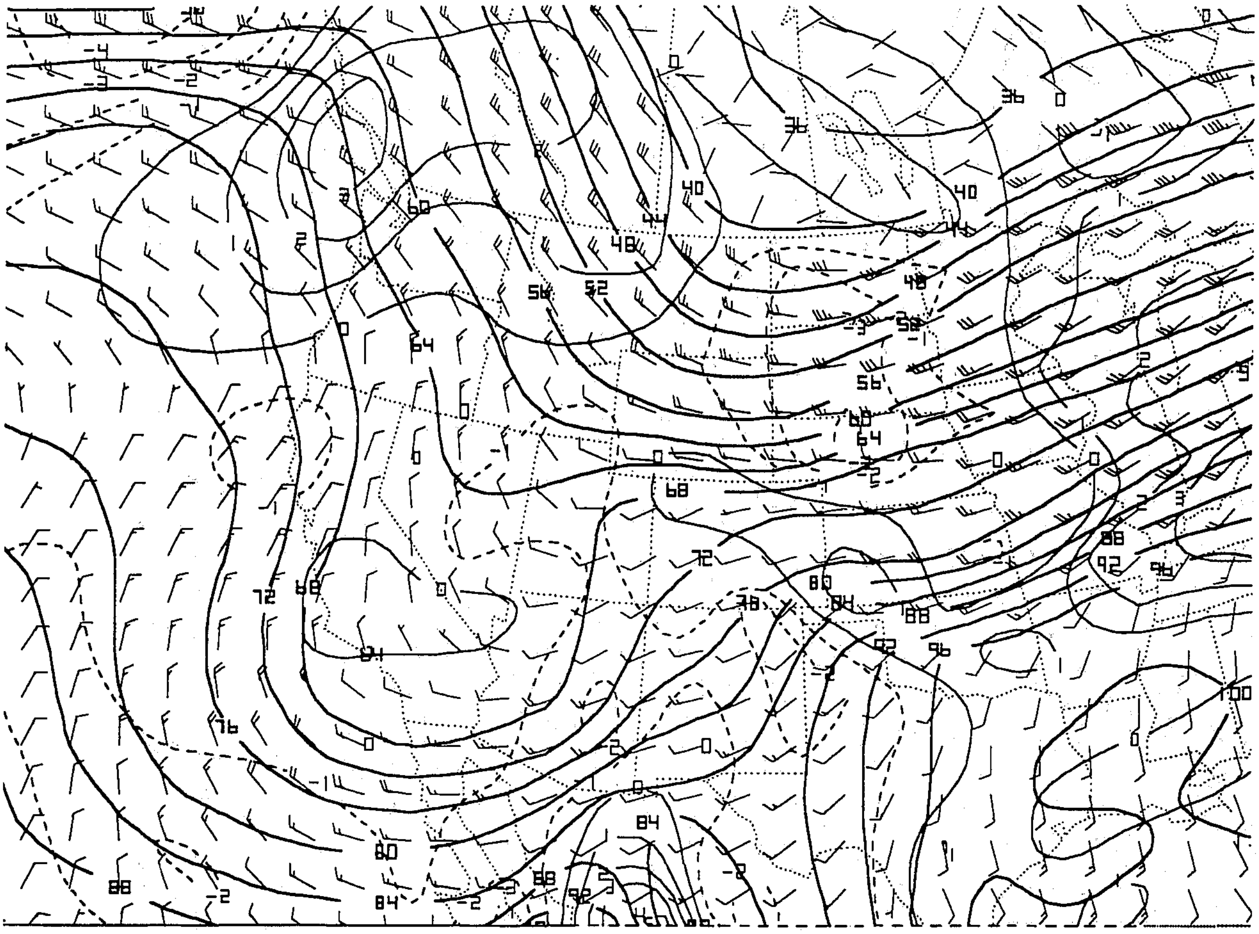
Figure 3a. Early Eta 12-hour forecast valid at 0000 UTC 9 February 1994, Lagrangian case on a 295K isentropic surface, units as in Figure 1a.



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94/ 2/ 8/12--WIND

 ETAX:LVL=I295:LYR=1000/ 500:FHR= 12 :FHRS=  0/ 12::FILE=FE089412.ETX
94/ 2/ 8/12--ADVT PRES WIND C1-3 DNEG&

 ETAX:LVL=I295:LYR=1000/ 500:FHR= 12 :FHRS=  0/ 12::FILE=FE089412.ETX
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Figure 3b. As in Figure 3a except for Eulerian case.

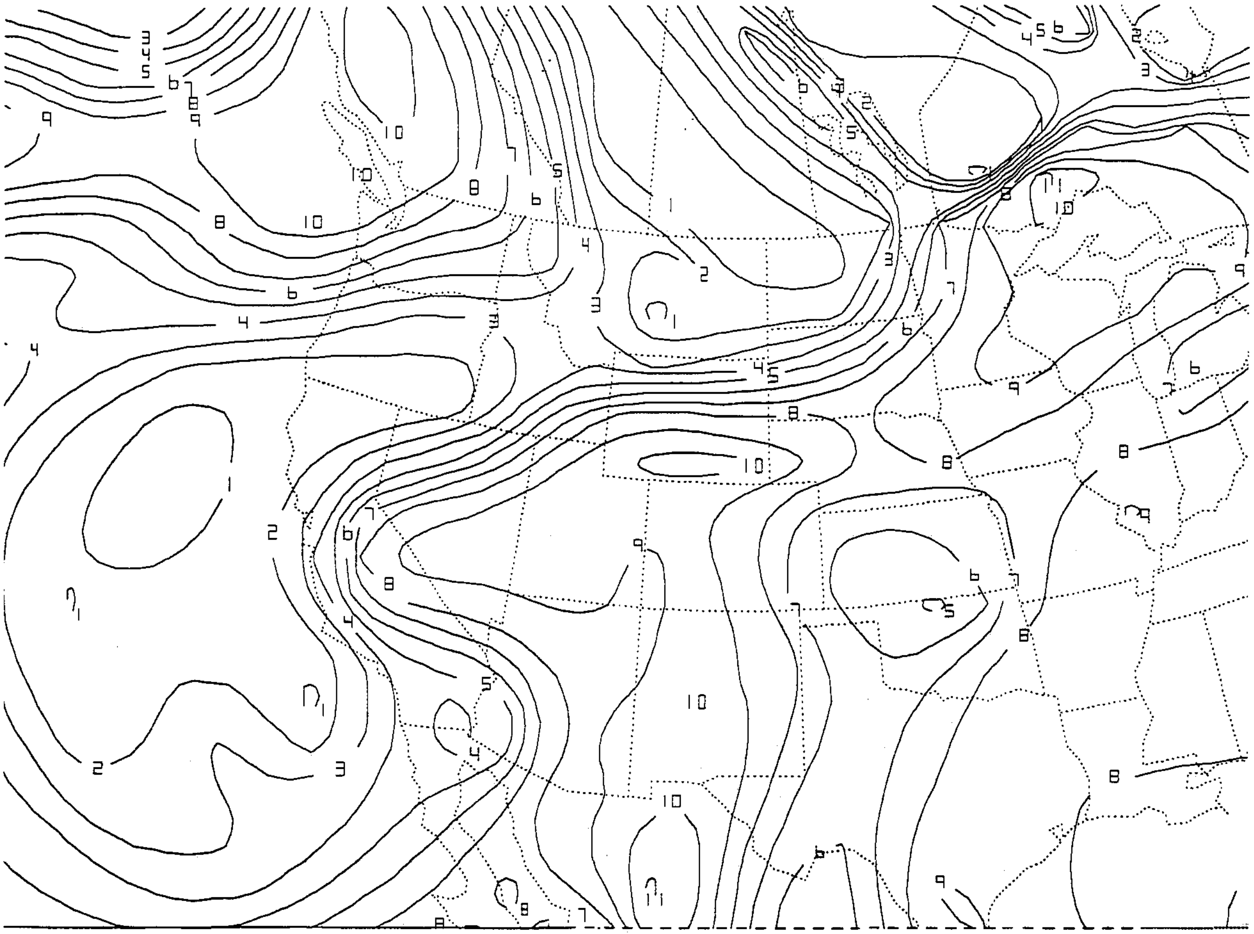
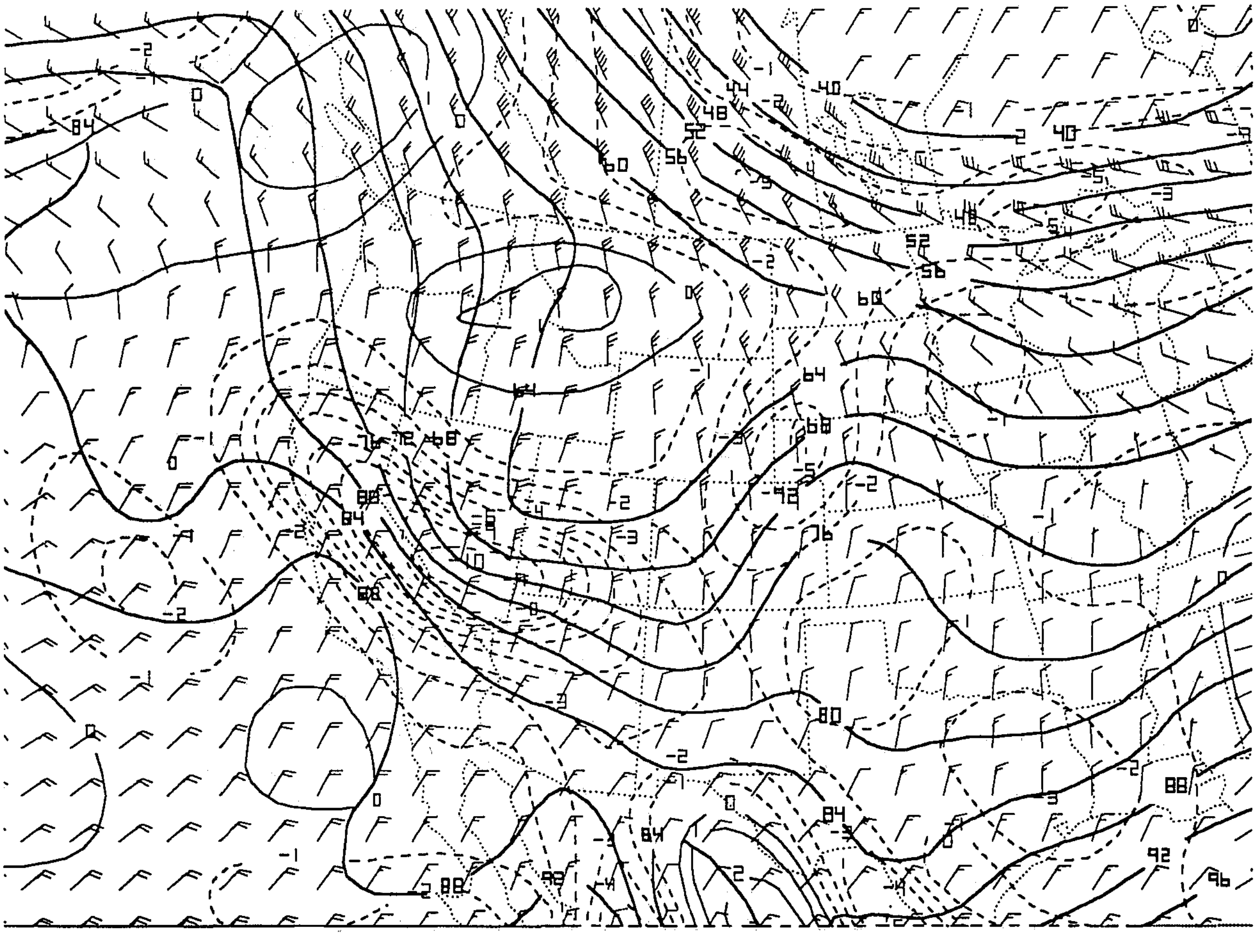


Figure 3c. As in Figure 3a except for relative humidity (tens of %).



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94/ 1/11/12--ADVT PRES KEPV C1-3 DNEG&

 ETAX:LVL=I295:LYR=1000/ 500:FHR= 12 :FHRS=  0/ 12::FILE=JA119412.ETX
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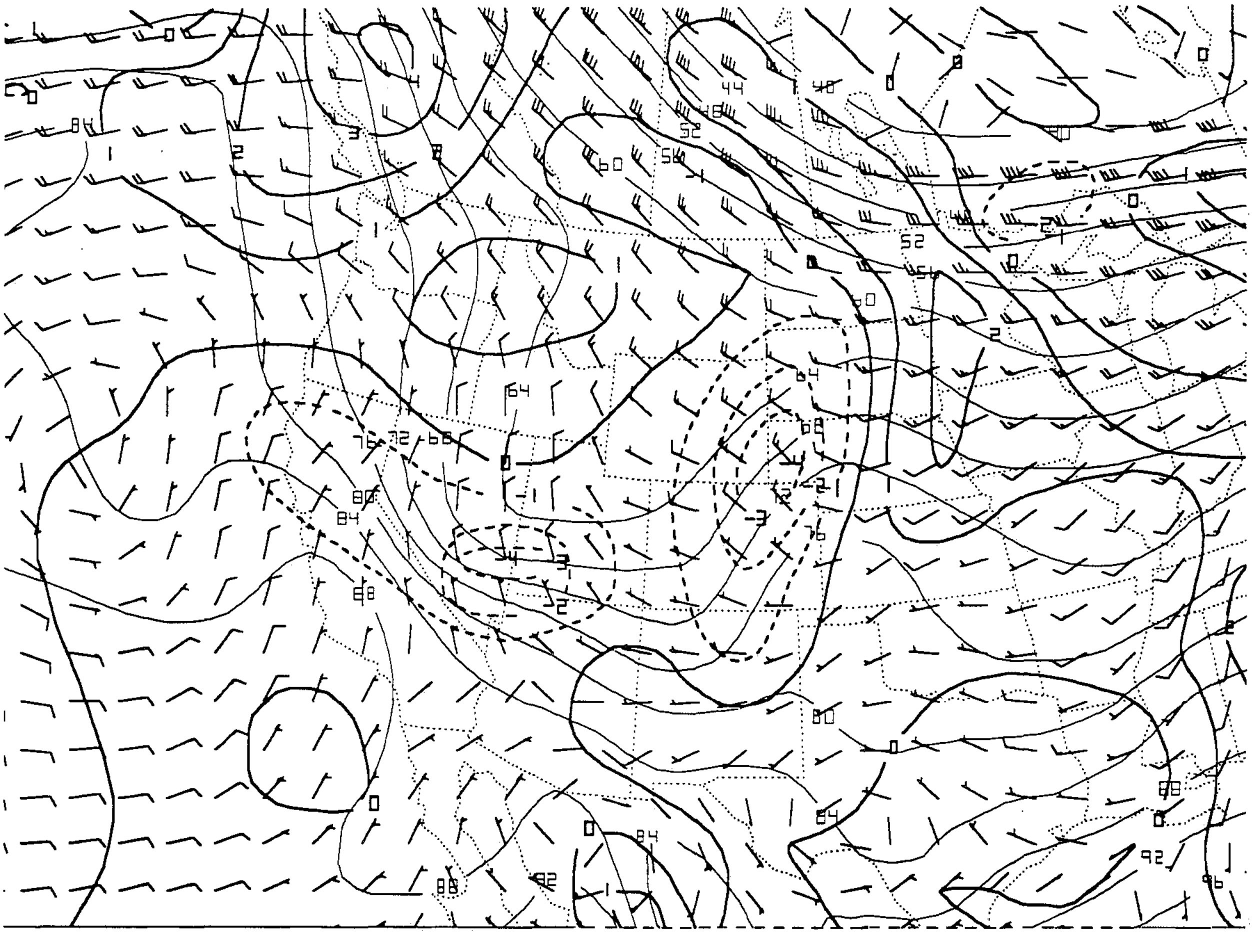
Figure 4a. Early Eta 12-hour forecast valid at 0000 UTC 12 January 1994, Lagrangian case on a 295K isentropic surface, units as in Figure 1a.



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94/ 1/11/12--PRES CI40

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94/ 1/11/12--WIND BARB&

 ETAX:LVL=I295:LYR=1000/ 500:FHR= 12 :FHRS=  0/ 12::FILE=JA119412.ETX
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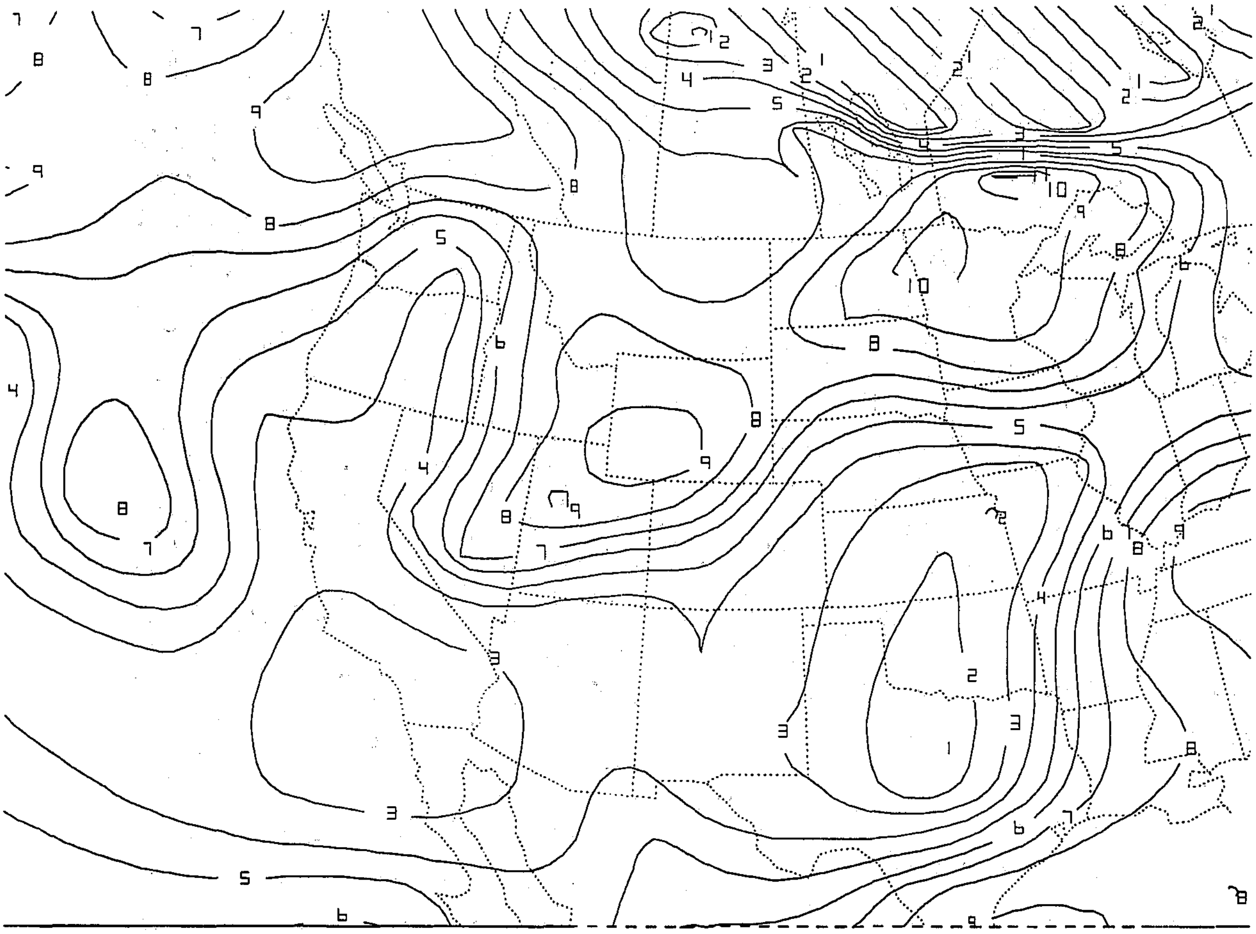
```

Figure 4b. As in Figure 4a except for Eulerian case.



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94/ 1/11/12--RELH CINX

Figure 4c. As in Figure 4a except for relative humidity (tens of %).

APPENDIX

```
C     PROGRAM WRITTEN BY KATHLEEN HADLEY, MARCH 1994
C     METEOROLOGIST/INTERN AT THE NATIONAL WEATHER
C     SERVICE FORECAST OFFICE IN SALT LAKE CITY, UT.
C
C     THIS PROGRAM PROMPTS FOR THE INPUT OF STORM
C     RELATIVE MOTION AND THEN CREATES A COMMAND FILE
C     TO RUN A PCGRIDS APPLICATION THAT WILL ADVECT
C     THE STORM MOTION ONTO AND ISENTROPIC FIELD.
C
C     AT THE TIME THE PROGRAM WAS WRITTEN, LIMITATIONS
C     TO PCGRIDDS REQUIRED THAT THE ISENTROPIC FIELD BE
C     CREATED PRIOR TO RUNNING THIS PROGRAM.
C
C     PROGRAM VARIABLES:  DD = DIRECTION, FF = SPEED
C          DDRAD = THE DIRCTION IN RADIANS
C          FFMETER = THE SPEED IN METERS PER SECOND
C          U & V = COMPONENTS OF THE DDFF
C          INTU & INTV = ROUNDED INTEGERS OF THE U AND V
C                   COMPONENTS USED WHEN THE VALUES
C                   ARE -10 OR LESS TO MAINTAIN AN
C                   OUTPUT FIELD OF ONLY 4 CHARACTERS
C                   OR SPACES (REQUIRED BY PCGRIDDS)
C
C
      INTEGER DD*4, FF*4, INTU*4, INTV*4
      REAL DDRAD*8, FFMETER*8, U*8, V*8
      CHARACTER ANSWER*1
      PARAMETER (PI = 3.14159)
      OPEN (UNIT=20, FILE='ISES.CMD', STATUS='NEW')
C
      WRITE (*,2)
  2   FORMAT ('1')
  1   WRITE (*,11)
 11   FORMAT ('1 ENTER STORM RELATIVE DIRECTION USING COMPASS',/,
      +         '  POINTS (i.e. A STORM MOVING FROM THE WEST',/,
      +         '  WOULD BE ENTERED 270).... '\)
      READ (*,5) DD
  5   FORMAT (I4)
      WRITE (*,2)
      WRITE (*,12)
 12    FORMAT ('1 ENTER STORM RELATIVE SPEED IN KNOTS.... '\)
      READ (*,5) FF
      WRITE (*,2)
 10   FORMAT (////////////////)
      WRITE (*,15) FF, DD
 15   FORMAT ('1 YOU ENTERED A STORM RELATIVE FLOW OF',I4,'
KNOTS',/,
      +         '  FROM A DIRECTION OF',I4,' DEGREES.',///)
      WRITE (*,*) ' IS THIS DATA CORRECT? TYPE N OR n TO
RE-ENTER,'
      WRITE (*,*) ' OR HIT ANY OTHER KEY TO CONTINUE.'
      READ (*,20) ANSWER
 20   FORMAT (A1)
      WRITE (*,10)
```

```
      WRITE (*,10)
      IF (ANSWER.EQ.'N'.OR.ANSWER.EQ.'n') GOTO 1
C
C     CONVERSION TO METERS/SEC AND RADIANS
C
      FFMETER = FF * .515
      DDRAD = (DD * PI)/180.
C
C     DETERMINE THE U AND V COMPONENTS
C
      U = (-FFMETER) * SIN(DDRAD)
      V = (-FFMETER) * COS(DDRAD)
C
C     DETERMINE WHICH WRITE ROUTINE TO USE
C
      IF(U.LE.-10.AND.V.LE.-10) GOTO 133
C
      IF(U.LE.-10) GOTO 143
      IF(V.LE.-10) GOTO 153
C
      WRITE (20,30) U, V
   30 FORMAT ('LOOP',/,'BARB',/,'CONT SSBC',F5.1,' UGRD',/,
     +           'SSBC',F5.1,' VGRD',/,'ADVT PRES KEPV CI-3 DNEG/'
     +           ,/,'PRES CI40/',/,'ENDL')
      CLOSE(UNIT=20)
      GOTO 100
  133 INTU = NINT(U)
      INTV = NINT(V)
      WRITE (20,33) INTU, INTV
   33 FORMAT ('LOOP',/,'BARB',/,'CONT SSBC',I5,' UGRD',/,
     +           'SSBC',I5,' VGRD',/,'ADVT PRES KEPV CI-3 DNEG/'
     +           ,/,'PRES CI40/',/,'ENDL')
      CLOSE(UNIT=20)
      GOTO 100
C
  143 INTU = NINT(U)
      WRITE (20,34) INTU, V
   34 FORMAT ('LOOP',/,'BARB',/,'CONT SSBC',I5,' UGRD',/,
     +           'SSBC',F5.1,' VGRD',/,'ADVT PRES KEPV CI-3 DNEG/'
     +           ,/,'PRES CI40/',/,'ENDL')
      CLOSE(UNIT=20)
      GOTO 100
C
  153 INTV = NINT(V)
      WRITE (20,35) U, INTV
   35 FORMAT ('LOOP',/,'BARB',/,'CONT SSBC',F5.1,' UGRD',/,
     +           'SSBC',I5,' VGRD',/,'ADVT PRES KEPV CI-3 DNEG/'
     +           ,/,'PRES CI40/',/,'ENDL')
      CLOSE(UNIT=20)
      GOTO 100
  100 CONTINUE
      END
```

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