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THE 6 JULY AND 9 JULY 1995 SEVERE WEATHER EVENTS IN THE NORTHWESTERN UNITED STATES: RECENT EXAMPLES OF SSWEs

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Abstract

During early July of 1995, two significant weather episodes affected parts of the northwestern United States. Severe weather, over a relatively large area, was reported with each event across portions of Washington, Oregon, Idaho, and the western portions of Montana and Wyoming. Although the occurrence of severe weather in the northwestern United States is typically isolated in nature, a recent study by Evenson and Johns (1995-hereafter EJ) indicated that these significant severe weather episodes (SSWEs) occur at an average frequency of about two per year. In the work by EJ, common synoptic and thermodynamic patterns were found to produce these SSWEs. Characteristic composite charts were developed to assist forecasters in recognizing the parameters associated with these rather destructive severe weather events.

This study will examine two recent SSWEs, the events of July 6 and 9, 1995. On July 6, severe weather was reported (33 reports) across portions of Washington, Oregon, Idaho, and the western portions of Montana and Wyoming. Wind damage was the primary severe weather phenomena during this event. On July 9, the presence of unusually large instability lead to the development of severe weather (42 reports) across portions of Washington, Oregon, Idaho, and the western parts of Montana. Of importance to note is that very large hail, between baseball and grapefruit size, was common over parts of Washington and Oregon. This lead to extensive crop and property damage totaling over eighty million dollars. Common synoptic and thermodynamic conditions associated with these events are discussed and compared with the findings by EJ. It will be noted that these conditions producing the SSWEs were similar to those found by EJ. This suggests that a greater understanding of the synoptic environment associated with these significant and destructive events exists which should help forecasters in better forecasting and early detection of such phenomena.

I. Introduction

Recent work by Evenson and Johns (1995-hereafter EJ) noted that significant severe weather episodes (SSWEs) in the northwestern United States occur at an average frequency of about two per year. These episodes, which are generally atypical of the type of severe weather commonly found in the western United States (e.g., isolated high based thunderstorms producing damaging winds), have been found to produce severe weather over a relatively large area and can be quite destructive. Because of factors such as population density (McNulty, 1981), the average may actually be higher than two per year. The addition of radars, public awareness, and spotters will likely lead to an increased detection (documentation) of SSWEs, such that the climatology will be more representative of actual events.

In early July 1995, two SSWEs occurred across portions of Oregon, Washington, Idaho, and the western portions of Montana and Wyoming. On the 6th, 33 severe weather events were reported (Fig. 1), and 42 severe weather events were recorded on the 9th (Fig. 2). Very large hail, between baseball and grapefruit size, fell on the 9th contributing to over eighty million dollars in damage to crops and property across portions of north-central and northeast Oregon as well as southeast Washington. In addition, wind gusts between 60 and 80 mph and a tornado were reported.

This study will examine the synoptic and thermodynamic conditions associated with the SSWEs on the 6th and 9th. Data from these two events will be compared with each other as well as with the characteristic composite synoptic patterns developed by EJ. In addition, forecast implications of the findings will also be discussed.

II. SSWEs

As defined by EJ, an SSWE is any of the following:

1) A severe weather episode where 10 or more severe weather events occur in the study area[1] during a 24-hour period beginning at 1200 UTC.

2) A severe weather episode with 5 or more severe weather events in the study area during a 24-hour period beginning at 1200 UTC, including at least one tornado of F3 or greater intensity.

3) A severe weather episode in which the *Storm Data* description suggests a widespread severe weather event has occurred in the study area even though the specific severe weather report criteria in either 1) or 2) are not met (e.g., a generalized entry indicating that numerous trees were blown down and/or large hail has occurred over a large portion of a state or over portions of several states).

During the March-September time periods from 1955-1993, 27 SSWEs were found using the guidelines noted above. For this 39 year period, the average

[1]For this project, the study area is defined as the following states: Washington, Oregon, Idaho, and the western portions of Montana and Wyoming.

frequency is less than one per year. However, in the last 13 years of that period (1981-1993), over 50 percent of all severe weather events were reported in every state of the study area, and 21 of the 27 SSWEs were identified during this time period as well. Given this trend in the reporting of severe weather, the data suggest that SSWEs may occur as often as twice per year.

The monthly distribution of SSWEs is noted in Fig. 3. All SSWEs have occurred during the months of April through September. One third (9) of all SSWEs have occurred in the month of June followed by July and August each having reported five SSWEs. This indicates that SSWEs are primarily a summer season phenomenon.

Two common synoptic patterns based on mid- and upper-level trough orientation were common with SSWEs:

1) Pattern A - the negative tilt pattern

2) Pattern B - the trough axis pattern

The study area was divided into two regions when analyzing the meteorological features associated with SSWE development. Region 1 consists of Idaho and the western sections of Montana and Wyoming, with Oregon and Washington in region 2. Pattern A is the most common synoptic pattern associated with SSWEs occurring in both regions (21 cases). The 6 July 1995 and 9 July 1995 cases closely resemble the characteristic composite charts for Pattern A cases affecting Oregon and Washington (Fig. 4).

In the study by EJ, several common features appear to be associated with Pattern A SSWEs. All of these cases are associated with a trough to the west of the study area, and a south to southwesterly flow, at mid and upper levels, prevails over the area of severe weather occurrence. In addition, all cases are associated with a shortwave trough moving into the region and in most situations, the shortwave trough is negatively tilted[2].

The mid- and upper-level flows are relatively strong with a 40 to 60 knot 500 mb jet max and a 50 to 100 knot jet max at 300 mb. Severe weather development is typically associated with a diffluent region at 500 and 300 mb and usually takes place along and ahead of the boundary layer cold front. Because of terrain effects and general higher elevation over the western United States, the boundary layer cold front is most easily identified by examining the 700 mb thermal field (Williams, 1972) and its 12 and 24 hour changes. The front is typically located near the tightest thermal gradient at 700 mb.

Instability typically reaches moderate values in the Pattern A cases with surface based lifted index (SBLI) of -3 to -6 and surface based Convective Available Potential Energy (CAPE) of 1000 to 2000 Jkg^{-1}. In some cases SBLI values may be as low as -8 with CAPE values to 2500 Jkg^{-1}. Destabilization as the result of cooling aloft is typically not a major factor

[2] A negatively tilted trough is one whose axis is not meridionally oriented, but leans toward the west with increasing latitude (Bluestein 1992).

with Pattern A cases, but is brought about by the strong diurnal heating in advance of the frontal boundary where surface dew points are at least 45 degrees Fahrenheit (F). In most cases, late night or early morning precipitation can contribute to an increase in low-level moisture, enhancing potential instability. This late night or early morning precipitation contributes to the vertical distribution of moisture in the low and mid levels of the atmosphere. In addition, a backing upper-level flow ahead of a negatively tilted trough in Pattern A cases can contribute to the horizontal transport of moist air from the southwestern United States, especially during the monsoon season (Hales, 1974).

III. The Case of 6 July 1995

The 1200 UTC upper-air data on 6 July 1995 are shown in Fig. 5. At 850 mb, a thermal ridge extended from the Alberta-British Columbia border southward across western Montana, central Idaho, and the eastern portions of Nevada. The frontal boundary, although somewhat difficult to detect, was defined by examining the 24 hour temperature changes at 700 mb. This placed the location of the front from southern British Columbia southwestward into the Pacific Ocean along the Washington and Oregon coasts. Southwesterly flow aloft (500 and 250 mb) existed across Washington, Oregon, and Idaho while ridge axes extended from west-central Montana southward into central Arizona. A band of 40-50 knot 500 mb winds prevailed from northwest California northeastward into central Idaho while 50-80 knot winds at 250 mb existed across the same area. Height falls at both 500 and 250 mb (between 40 and 70 meters at 500 mb and 60 to 100 meters at 250 mb) were noted across southwest Oregon and northern California which indicated the approach of a relatively strong shortwave trough. It is not uncommon in SSWEs to see the existence of stronger height falls at 250 or 300 mb than at 500 mb. Thus, the 250 or 300 mb level may be more useful in evaluating the presence of a shortwave trough. Satellite photos (not shown) confirmed the presence of a well-defined shortwave trough moving into northwest California at 1200 UTC. Precipitation occurred during the overnight hours across portions of eastern Oregon and parts of Idaho and surface dew points across this area were greater than 45°F. A region of surface dew points in the low to mid- 50s existed across northeast Oregon and the central sections of Idaho.

Environmental soundings for Spokane, Washington (GEG) and Boise, Idaho (BOI) taken at 1200 UTC are shown in Fig. 6. Both soundings showed the airmass was slightly stable with SBLIs of +1 at BOI and +4 at GEG. However, moisture had increased substantially in the past 12 hours on both soundings. An increase in mid-level moisture on the BOI sounding helped create an inverted-V structure, a common thermodynamic profile for the development of dry microburst which produce damaging winds. While the moisture in the lower layers of the atmosphere had increased on the GEG sounding, the profile also exhibited inverted-V characteristics. This increase in moisture would enhance the potential instability that would be realized later in the afternoon as surface heating occurred.

Upper-air data at 0000 UTC on 7 July 1995 are displayed in Fig. 7 and the resulting composite chart is shown in Fig. 8. Note that the composite chart for 0000 UTC on 7 July 1995 (Fig. 8) is somewhat similar to the composite chart developed by EJ for Pattern A cases affecting Washington and Oregon (Fig. 4). The 850 mb thermal ridge extended from southeast British Columbia southeastward across central Idaho and into western Utah. The frontal boundary (at 700 mb) had now moved eastward into the central sections of Washington and Oregon as well as northern California. Southwesterly flow aloft (at 500 and 250 mb) continued to exist across the region as the ridge axes extended from the Alberta-Saskatchewan borders southward across the central portions of Montana and Wyoming. Wind speeds greater than 40 knots at 500 mb extended from northern California northeastward into southwest Montana. In addition, greater than 60 knot 250 mb winds prevailed across the western portions of Oregon. Late afternoon surface temperatures in advance of the 700 mb front reached into the 80s and lower 90s across much of eastern Washington, eastern Oregon, and Idaho. Meanwhile, surface dew points greater than 45 °F existed over this area with readings as high as 60°F in north central Idaho. This resulted in SBLIs as low as -6 with CAPE values between 1000 and 2000 Jkg^{-1} across the extreme eastern portions of Washington and Oregon as well as parts of Idaho. Sounding analysis at 0000 UTC for GEG and BOI on 7 July 1995 (Fig. 9) showed the existence of an inverted-V environment, especially on the BOI sounding. This enhanced the potential for damaging downburst winds.

Severe thunderstorms, mainly producing wind gusts between 50 and 60 knots (although several reports of hail greater than 3/4 inch in diameter were reported over parts of Idaho), developed during the afternoon hours over northeast Oregon, southeast Washington, and western Idaho ahead of the 700 mb front (Fig. 1). The severe thunderstorms then spread northeastward into portions of western Montana, southeast Idaho, and northwest Wyoming during the late afternoon and early evening hours.

IV. The Case of 9 July 1995

The morning upper-air data at 1200 UTC is depicted in Fig. 10. The main thermal ridge at 850 mb was oriented farther east than is typically observed with Pattern A SSWEs as the axis extended from northern Utah northeastward into eastern Montana. However, a secondary thermal axis was noted across the east-central sections of Idaho extending northward into northwest Montana. In addition, a rather large area of extensive moisture (dew points between 8 and 10 degrees Celsius) covered a large part of Washington, Oregon, Idaho, and the western sections of Montana. Twelve hour changes in the thermal pattern at 700 mb revealed the main frontal boundary over the western portions of Washington and Oregon. Southwesterly flow aloft prevailed at both 500 and 250 mb while ridge axes at these levels extended from the Alberta-Saskatchewan borders southward across central Montana, western Wyoming, and eastern Utah. The main jet axis at 500 mb (60 knots) extended along the Pacific Coast while a secondary jet was noted across northwest Nevada, southeast Oregon, and southwestern Idaho. This resulted in a diffluent flow pattern over portions of Washington and Oregon and the northern portions of Idaho.

A band of 90+ knot winds at 250 mb extended from southwest Oregon into west-central Washington. In addition, strong height falls of 80-100 meters were noted at 250 mb (50-60 m at 500 mb) over western Oregon in response to a shortwave trough moving onshore. The 1200 UTC soundings from GEG and BOI (Fig. 11) showed that the moisture in the lower levels had increased in the past 12 hours in response to thunderstorm activity that moved across the area during the nighttime and early morning hours.

The 0000 UTC 10 July 1995 upper-air analyses are shown in Fig. 12 and the resultant composite chart is displayed in Fig. 13. The resultant composite chart from 0000 UTC on 10 July 1995 closely resembles the characteristic composite chart found by EJ to produce Pattern A SSWEs in Washington and Oregon. The 850 mb thermal ridge axis at 0000 UTC continued to exist across the east-central portions of Idaho into northwest Montana. Dew points of 8 to 10 degrees Celsius also persisted over the eastern portions of Washington and Oregon, Idaho, and the western portions of Montana. The sharpest thermal gradient at 700 mb existed across the central sections of Washington and Oregon indicating the presence of the main frontal boundary. Southwesterly flow aloft at 500 mb and 250 mb continued to persist over the region and ridge axes remained across central Montana, western Wyoming, and eastern Utah. The 500 mb wind fields continued to show a double structure to the jet maxima with one axes extending along the Washington and Oregon coasts and another from central California into northwest Nevada and southwest Idaho. This structure indicated the presence of diffluence aloft over portions of Washington, Oregon, and Idaho.

Meanwhile, a diffluent pattern was also noted at 250 mb as a double jet structure also existed. One jet axis was situated across the coastal sections of Washington, Oregon, and northwest California while another jet axis extended from central California into northwest Montana. The 0000 UTC soundings at GEG and BOI from 10 July 1995 showed the presence of moderate to strong instability (Fig. 14). Surface temperatures well into the 80s and lower-90s and surface dew points in the mid-50s to mid-60s greatly contributed to significant airmass destabilization ahead of the approaching 700 mb front. Based on the 0000 UTC 10 July 1995 soundings from GEG and BOI, SBLIs between -6 and -10 existed with CAPE values as high as 3355 Jkg^{-1}. Given the close proximity of the GEG sounding to the most significant severe weather producing storm, the surface conditions were modified on the GEG sounding using SHARP (Hart and Korotky, 1991) to sample the thermodynamic environment over southeast Washington where the thunderstorm, responsible for producing a tornado and hail up to four inches in diameter, was moving. Inputting the surface data (note wind data was not changed) from Walla Walla (ALW; surface temperature of 90°F and surface dew point of 65°F) lead to the extremely large amount of CAPE (3355 Jkg^{-1} on the

GEG sounding, and helps to explain why hail as large as the size of grapefruits fell over the region.

The significant severe thunderstorms, producing numerous reports of golfball to grapefruit size hail, developed over north-central Oregon by early afternoon on the 9th and moved northeastward during the afternoon and evening hours across portions of northeast Oregon, eastern Washington, western and central Idaho, and western Montana (Fig. 2).

V. Forecast Implications

From the severe weather events on the 6th and the 9th, it appears that recognition of a Pattern A SSWE event was very useful in determining the severe weather potential on these two days. In addition, examination of the thermodynamic environment was crucial in recognizing the type of severe weather expected. In the cases of the 6th and the 9th, surface dew points were in the mid-40s to mid-50s, and mid-50s to mid-60s, respectively. Late night and early morning precipitation occurred over the area on both days which helped increase the depth of moisture. The vertical advection of moisture in higher based thunderstorm activity helped transfer the amount of moisture from the mid levels downward into the lower levels. This resulted in evolving from an airmass primarily conducive for high based thunderstorms producing damaging winds (on the 6th) to an environment where storms would have lower bases and have much greater potential instability to produce large hail as well (on the 9th). This was the most obvious difference between the 6th and the 9th, as soundings on the 6th reflected more of an inverted-V environment over the entire region resulting in more of a threat for damaging microburst winds. It is noted that the soundings on the 6th were not characteristic of those found by EJ during SSWEs as the depth of moisture in the sounding is usually greater than what was indicated on the 6th. However, thunderstorm activity on the 7th and especially the 8th helped increase the vertical extent of moisture on the 9th, especially in the eastern portions of Washington and Oregon. SBLIs/CAPE values on the 6th were as low as -6/1000-2000 Jkg^{-1}, respectively, while SBLIs/CAPE values on the 9th were -6 to -10/as high as 3355 Jkg^{-1}, respectively.

Although the dataset of EJ for Pattern A SSWEs in Washington and Oregon contained only four cases, the event of 9 July 1995 supports the characteristic composite charts of synoptic and thermodynamic conditions associated with Pattern A SSWEs in this part of the country (Fig. 4). The SSWE event of 6 July 1995 was not as well defined in terms of the characteristic composite chart for Pattern A cases in Washington and Oregon. This may be a function of the limited number of cases that comprise the composite chart. However, the most significant meteorological parameters necessary for SSWE development was observed over the area. In addition, the environmental soundings from GEG and BOI on the 6th exhibited a drier environment than is typically found in Pattern A cases. Sufficient moisture did exist however to result in an "inverted-V" environmental sounding which was conducive to the numerous occurrence of damaging winds reported on that day. As noted earlier, increased spotter groups, heightened meteorological awareness, and the addition of the WSR 88-D should contribute to greater detailed recognition of more widespread severe weather events in this part of the country. Given that fact, a greater understanding of the conditions that produce SSWEs will be important to the operational forecaster when dealing with episodes of such magnitude.

From a national center perspective, initial Day One convective outlook forecasts (from the National Severe Storms Forecast Center; NSSFC) at 0700 UTC on both the 6th and the 9th indicated a "slight" risk of severe thunderstorms over portions of the northwestern United States. In both situations, the characteristic composite charts were used to help identify the potential for severe thunderstorms. Given the recognition of favorable synoptic patterns, the degree of moisture, and the resultant instability on the 9th, the forecast was upgraded to indicate a "moderate" risk of severe thunderstorms by early afternoon across the eastern portions of Washington and Oregon, parts of Idaho, and northwest Montana. Severe thunderstorm watches were issued in both situations as well.

Recognition of these SSWEs can help differentiate between days when severe thunderstorms are generally isolated in nature and occur from high based thunderstorms to days when longer lived, deeper convection producing widespread large hail, damaging winds, and possibly tornadoes over a larger area occurs. This differentiation can also aid in the decision to issue watches since SSWEs have been found to produce numerous amounts of severe weather.

Acknowledgements

Special thanks to Mr. Steve Weiss (NSSFC) for his specific interest in this project and valuable review of the manuscript.

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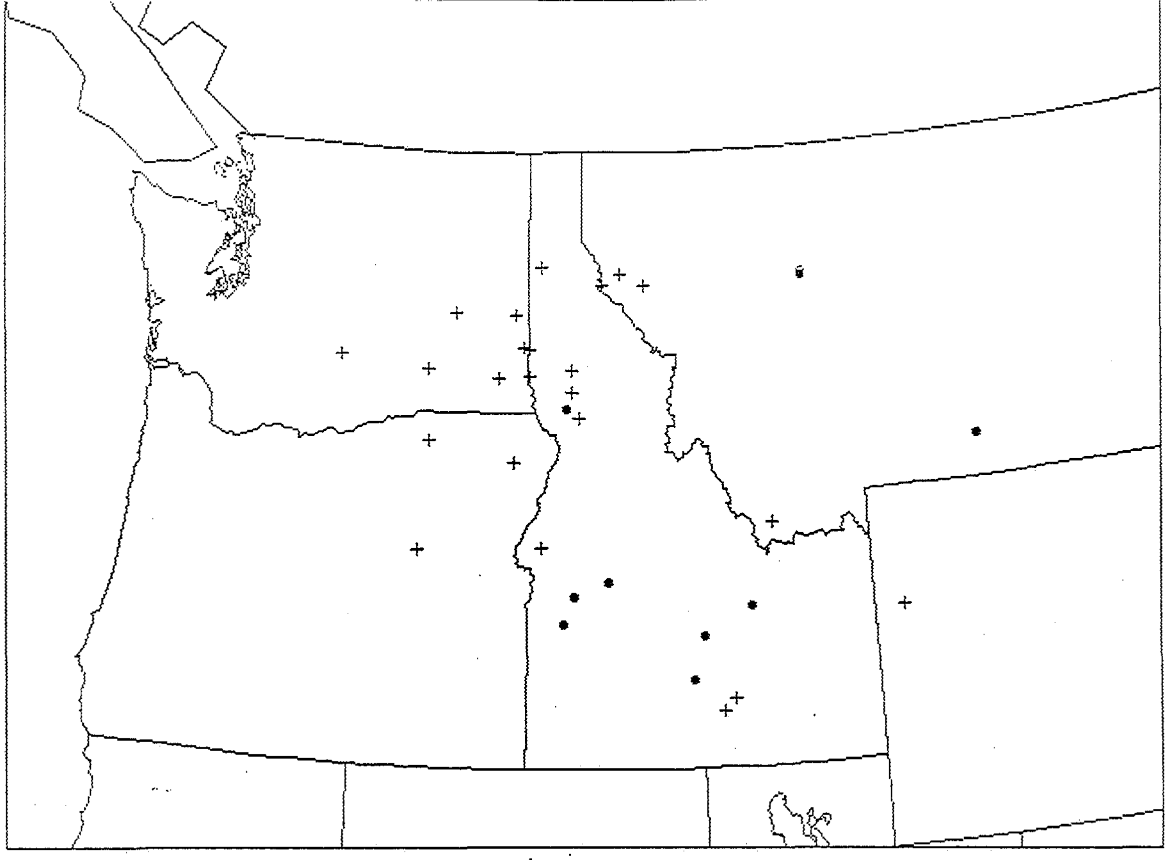


Fig. 1. Plot of all severe weather reports for the 24-hour period beginning at 1200 UTC 6 July 1995. Dark circles indicate hail reports while the cross symbol represents wind gusts or damage. Triangle represent tornadoes and diamond shapes indicate hail and wind damage reported at the same location.

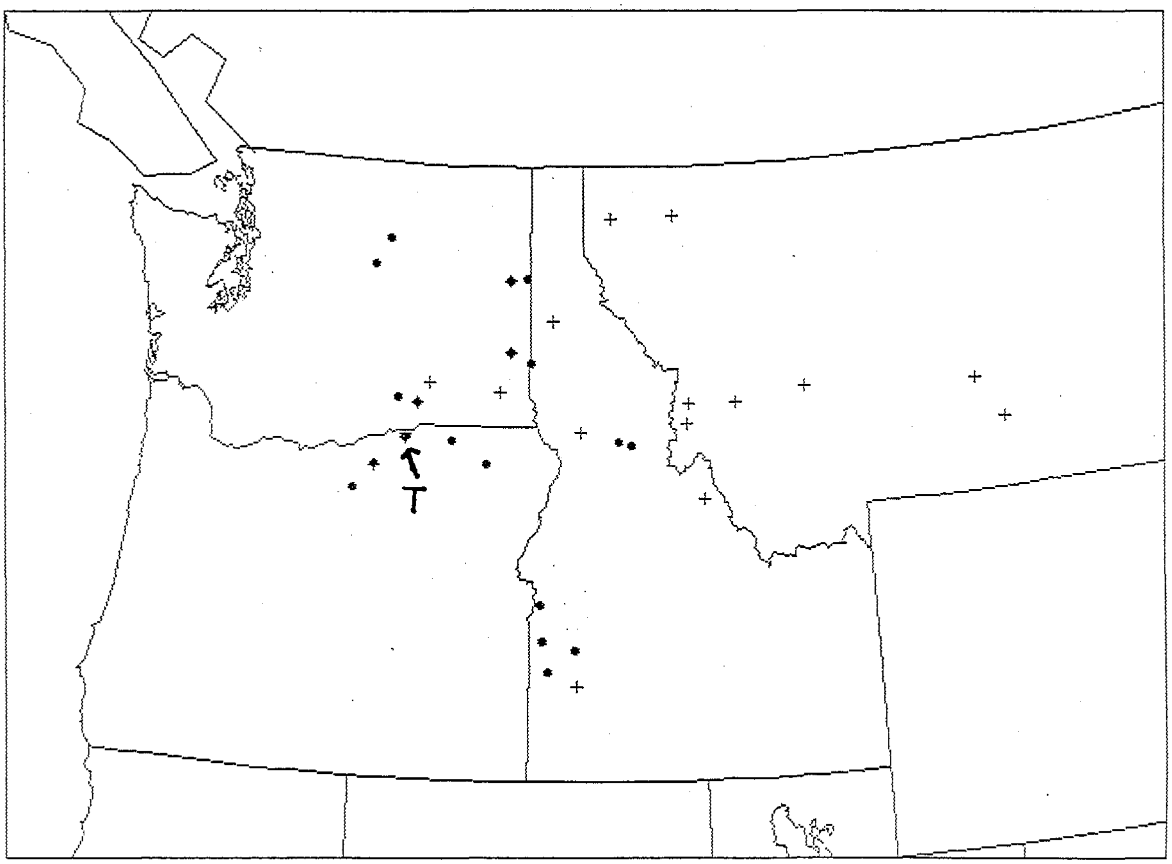


Fig. 2. Same as Fig. 1 but for the 24-hour period beginning at 1200 UTC 9 July 1995. Note the letter "T" indicates the location of a tornado.

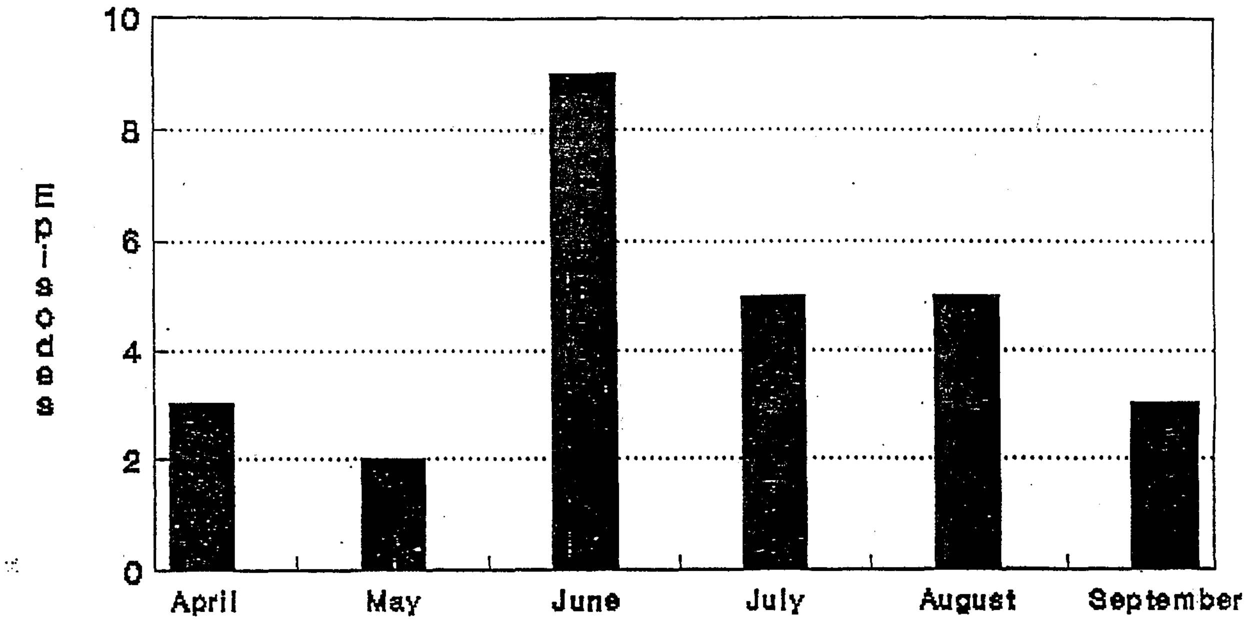


Fig. 3. Monthly distribution of SSWEs during the period from 1955 through 1993.

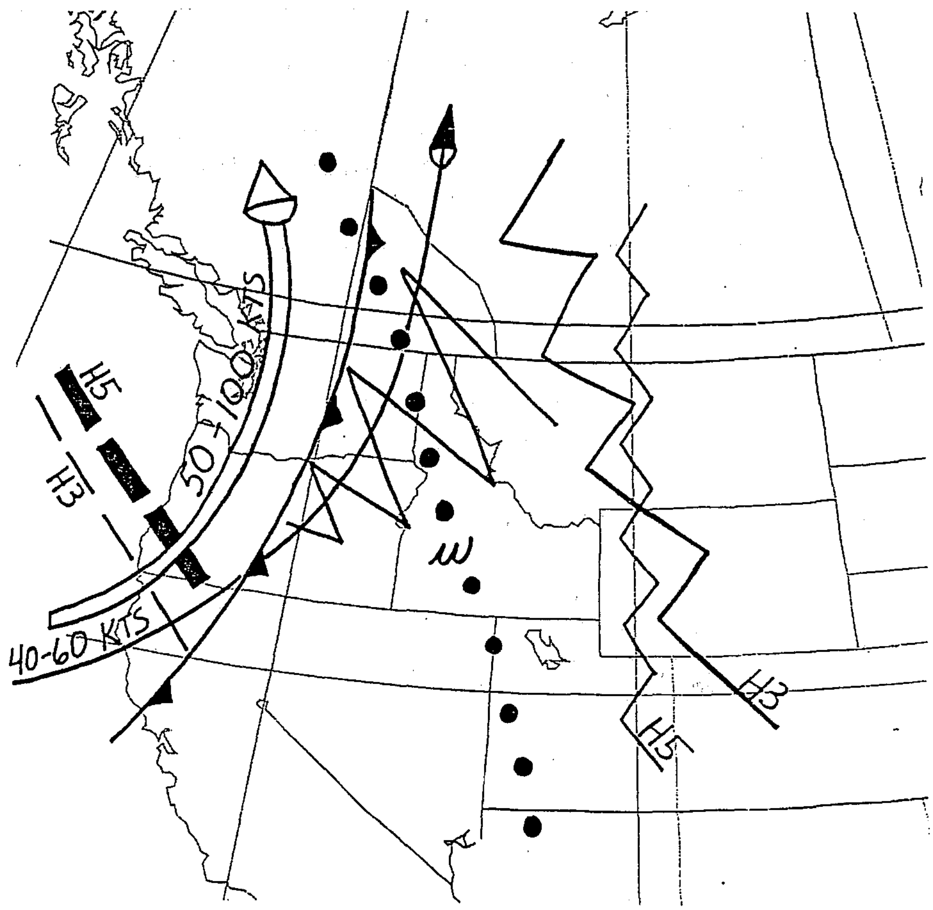
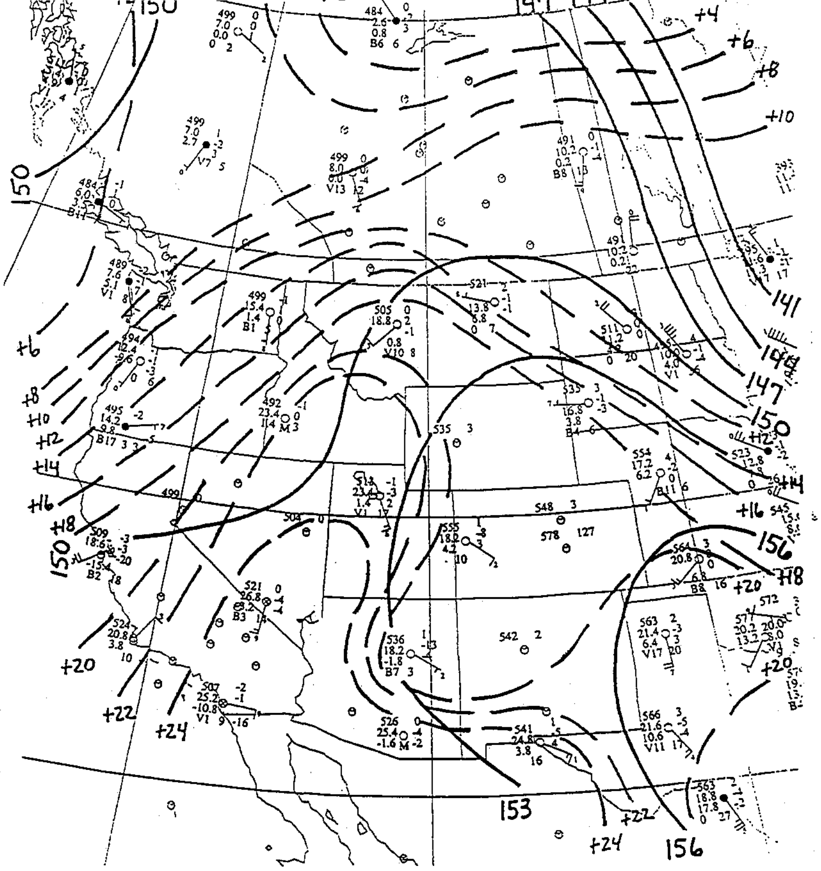
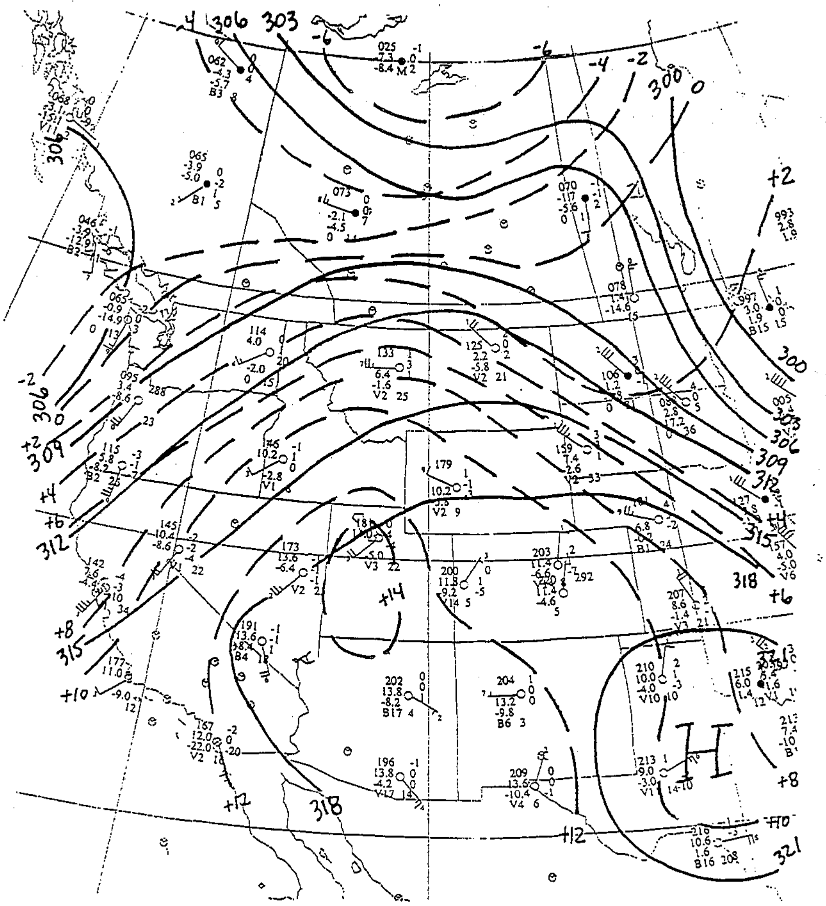


Fig. 4. Mean composite chart at 0000 UTC for Pattern A SSWEs affecting Washington and Oregon. Dotted line denotes 850 mb thermal ridge. Frontal boundary is position of 700 mb front. Long dashed lines labeled H5 and H3 indicate trough axis positions at 500 and 300 mb. Thin line with arrow indicates the jet axis at 500 mb while thick line with arrow represents the jet axis at 300 mb. Broad zigzag line shows an area of 500 and 300 mb diffluence while 500 and 300 mb ridge axes are denoted by long, north-south oriented narrow zigzag line.

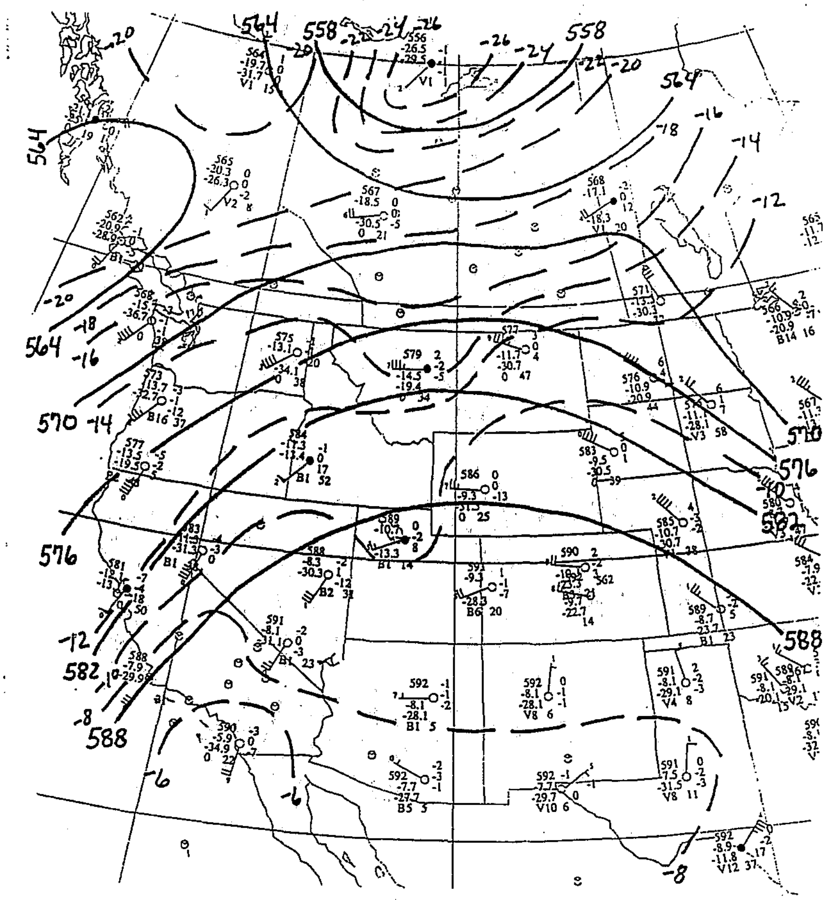


(A)
850 mb

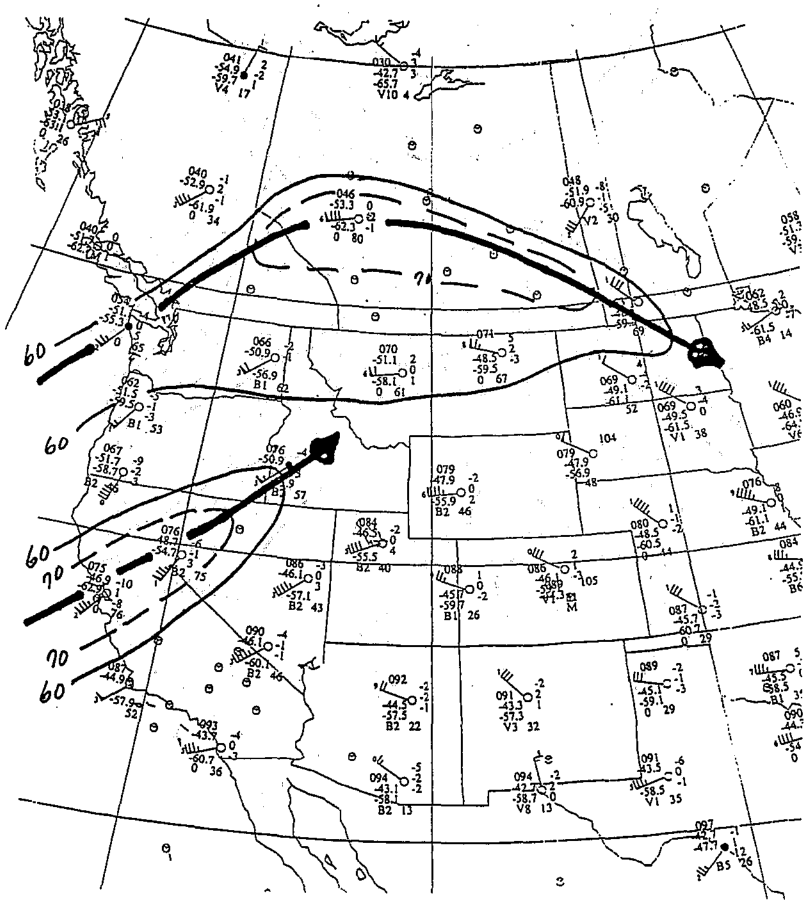


(B)
700 mb

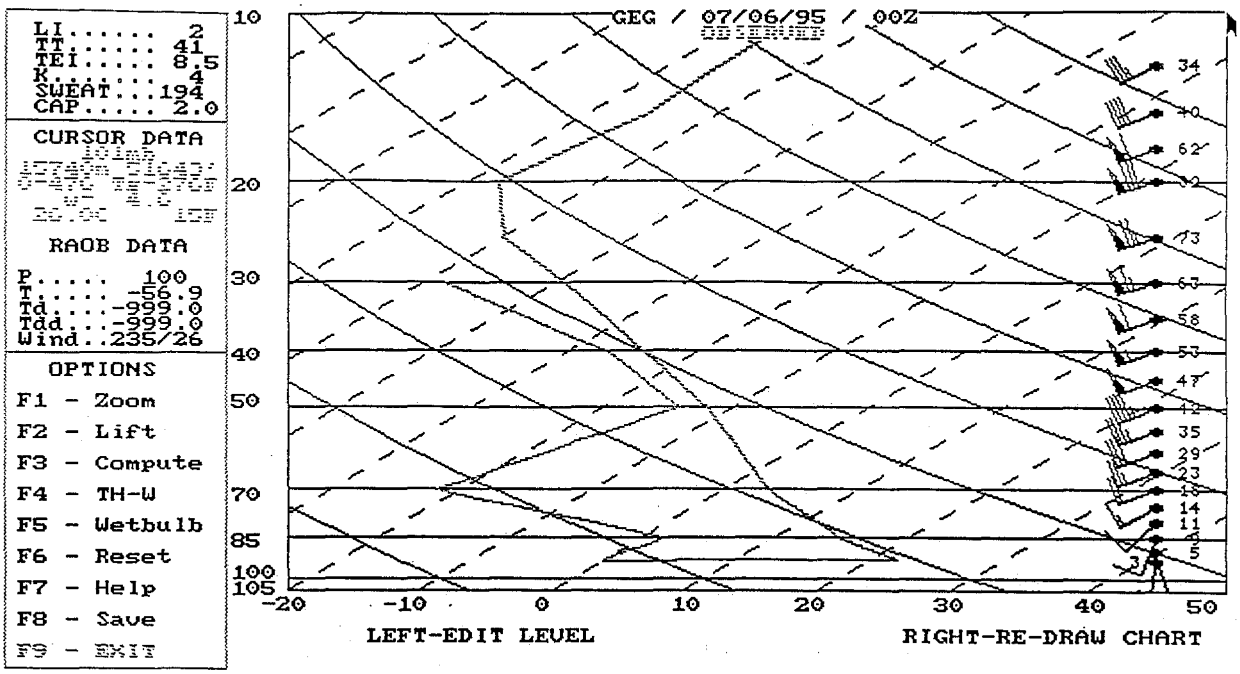
Fig. 5. Upper air analyses at (a) 850 mb, (b) 700 mb, (c) 500 mb, and (d) 250 mb levels for 1200 UTC 6 July 1995.



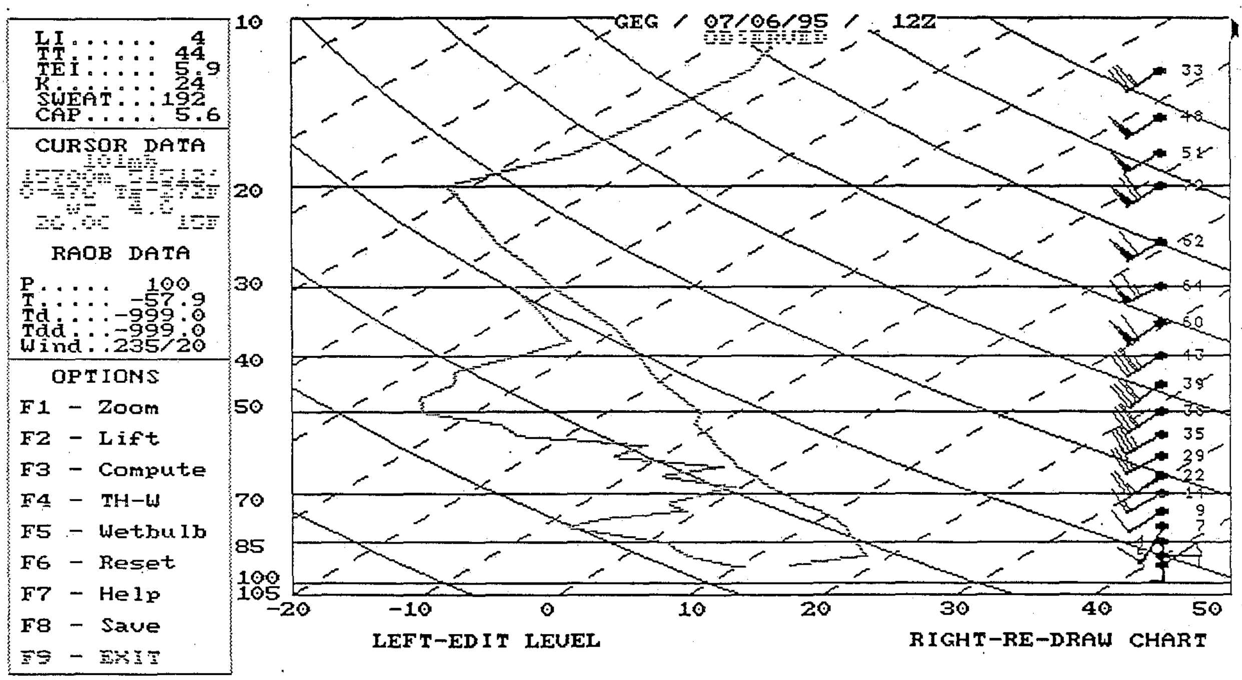
(C)
500 mb



(D)
250 mb

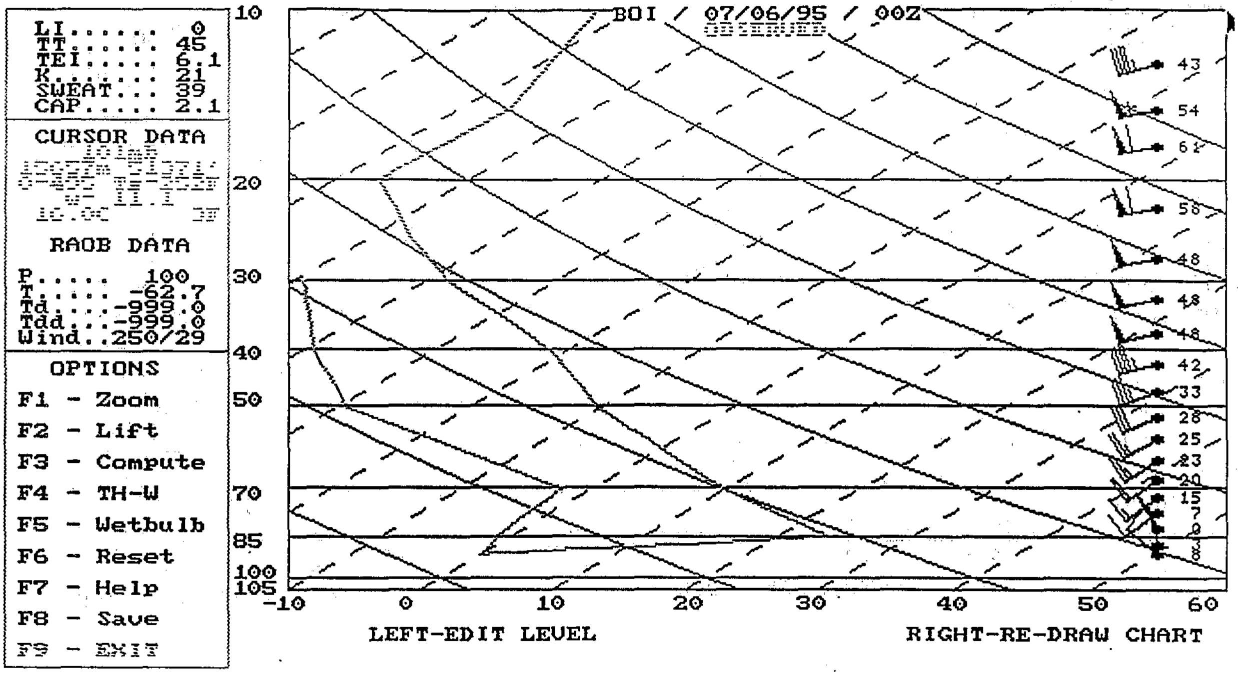


(A)



(B)

Fig. 6. Skew-T log p upper air sounding analyses for Spokane, Washington (GEG) for July 1995 at (a) 0000 UTC 6th, (b) 1200 UTC 6th, and for Boise, Idaho (BOI) for July 1995 at (c) 0000 UTC 6th and (d) 1200 UTC 6th.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TEI..... 6.1
K....... 21
SWEAT... 39
CAP..... 2.1
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RAOB DATA
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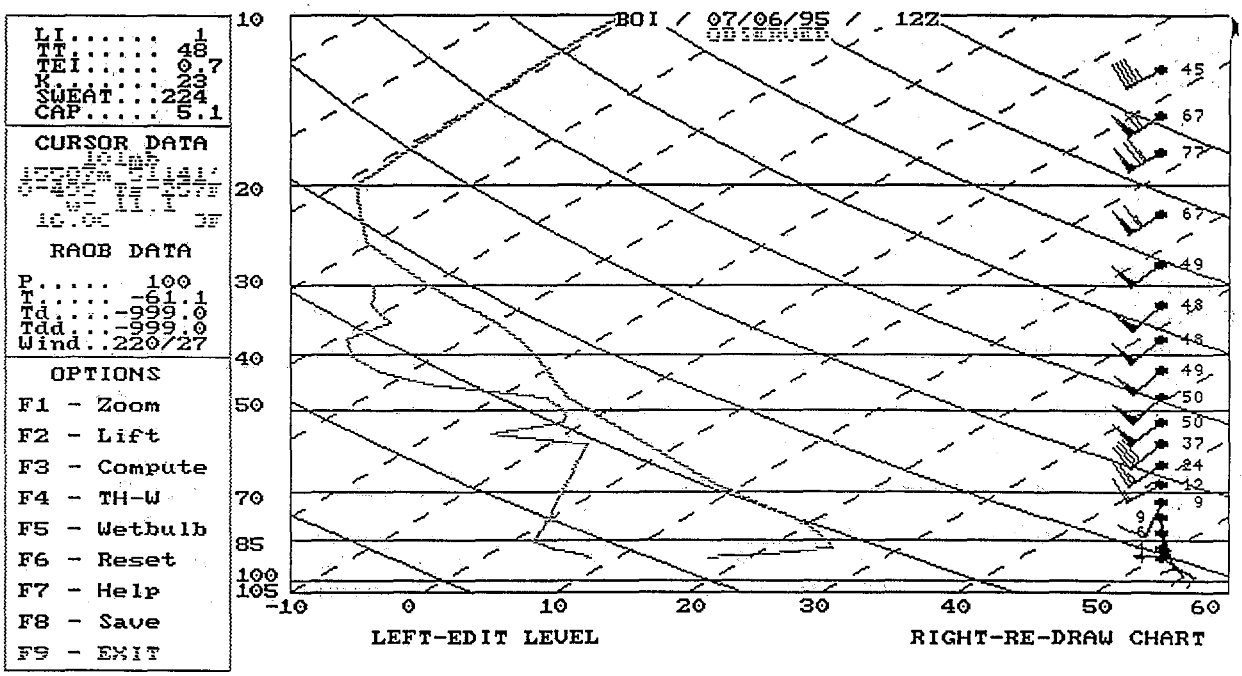
T..... -62.7
Td....-999.0
Tdd...-999.0
Wind..250/29
OPTIONS
F1 - Zoom
F2 - Lift
F3 - Compute
F4 - TH-W
F5 - Wetbulb
F6 - Reset
F7 - Help
F8 - Save
F9 - EXIT
BOI / 07/06/95 / 00Z
OBSERVED
LEFT-EDIT LEVEL
RIGHT-RE-DRAW CHART

(C)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TEI..... 0.7
K....... 23
SWEAT...224
CAP..... 5.1
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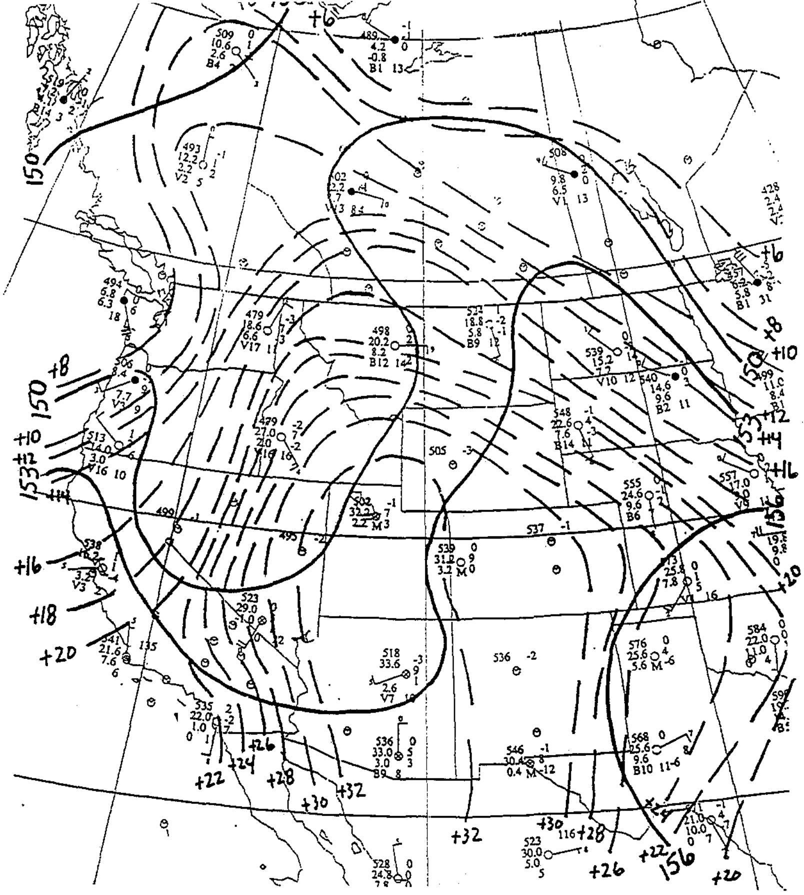
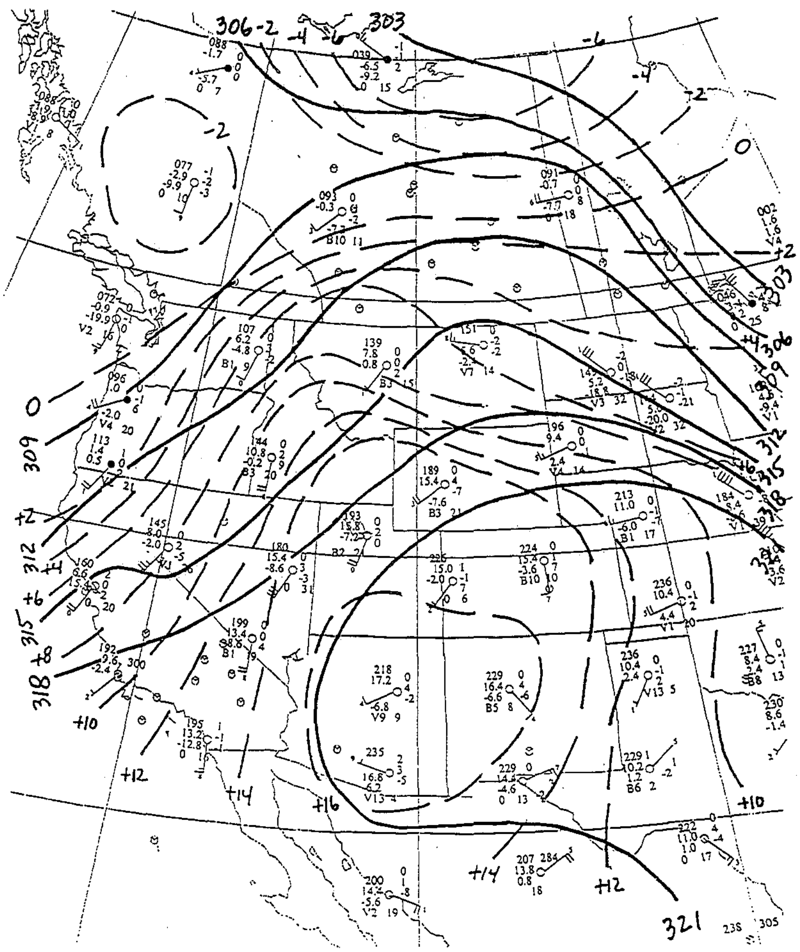
RAOB DATA
P..... 100
T..... -61.1
Td....-999.0
Tdd...-999.0
Wind..220/27
OPTIONS
F1 - Zoom
F2 - Lift
F3 - Compute
F4 - TH-W
F5 - Wetbulb
F6 - Reset
F7 - Help
F8 - Save
F9 - EXIT
BOI / 07/06/95 / 12Z
OBSERVED
LEFT-EDIT LEVEL
RIGHT-RE-DRAW CHART

(D)

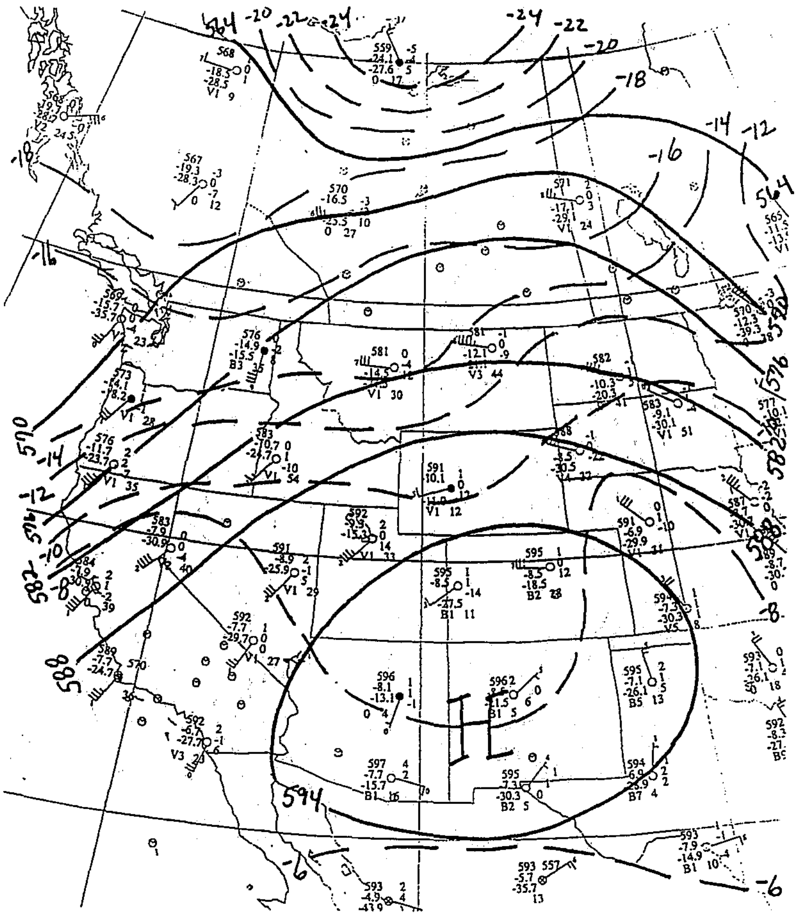


(A)
850 mb

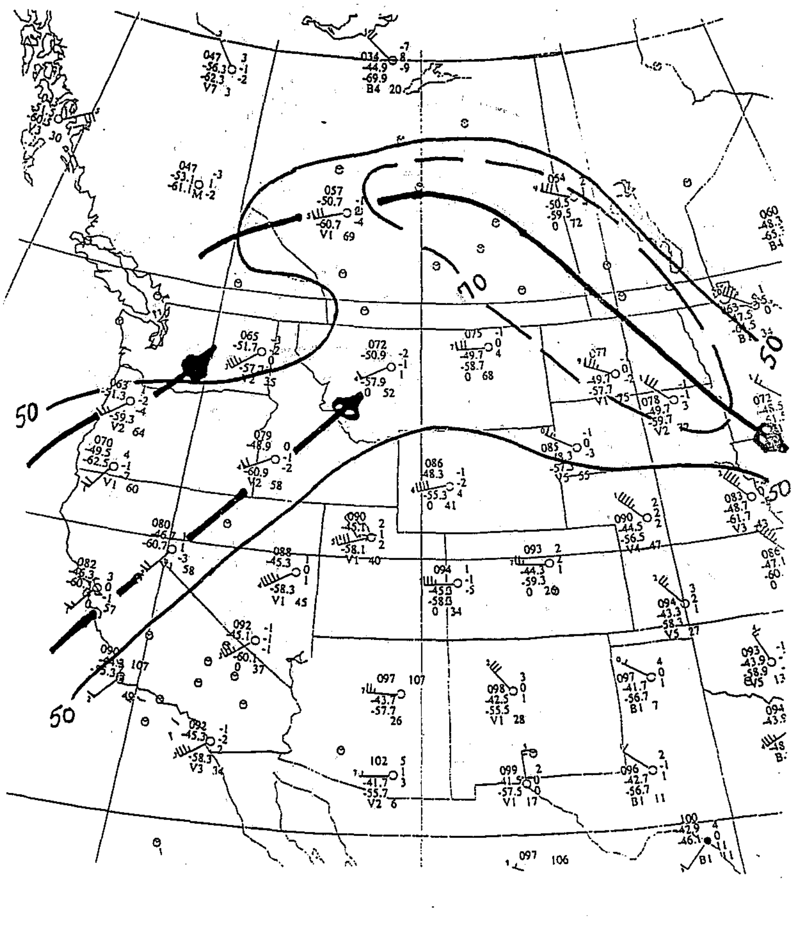


(B)
700 mb

Fig. 7. Same as Fig. 5 but for 0000 UTC 7 July 1995.



(C)
500 mb



(D)
250 mb

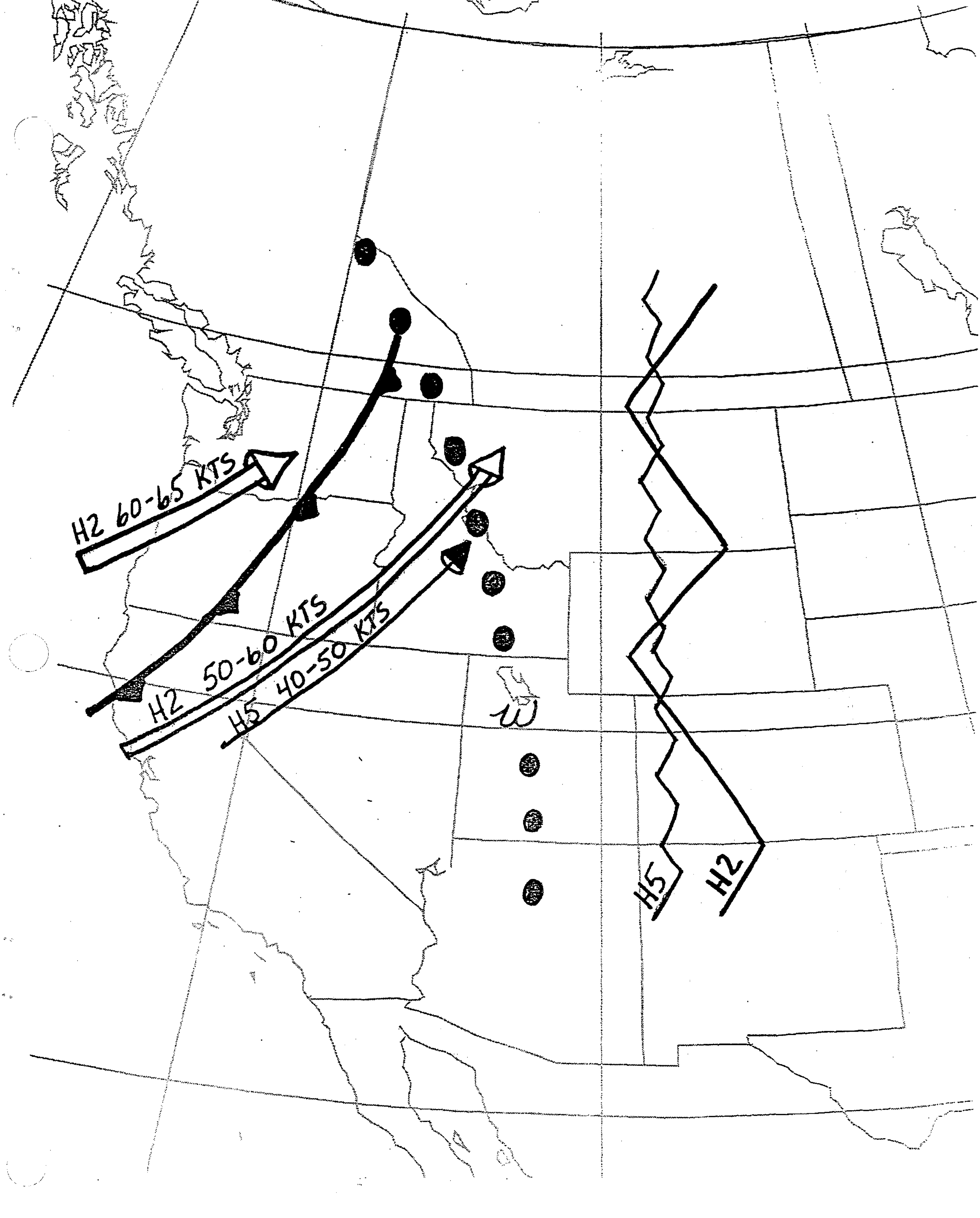
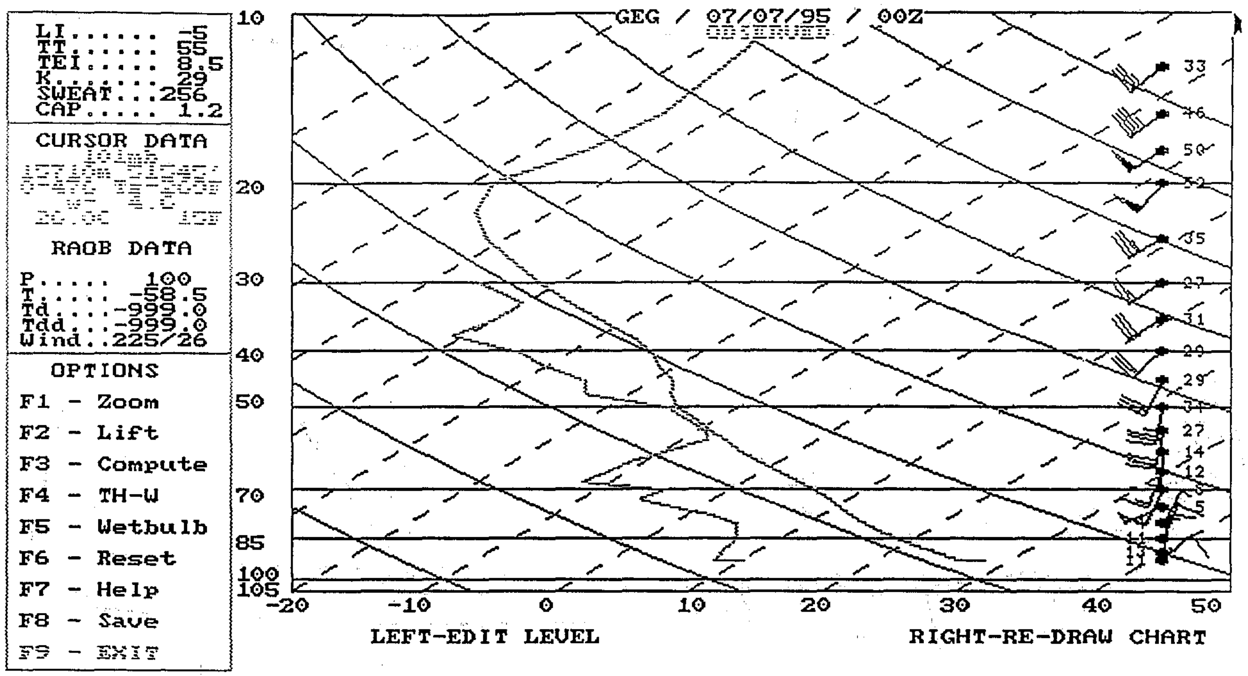
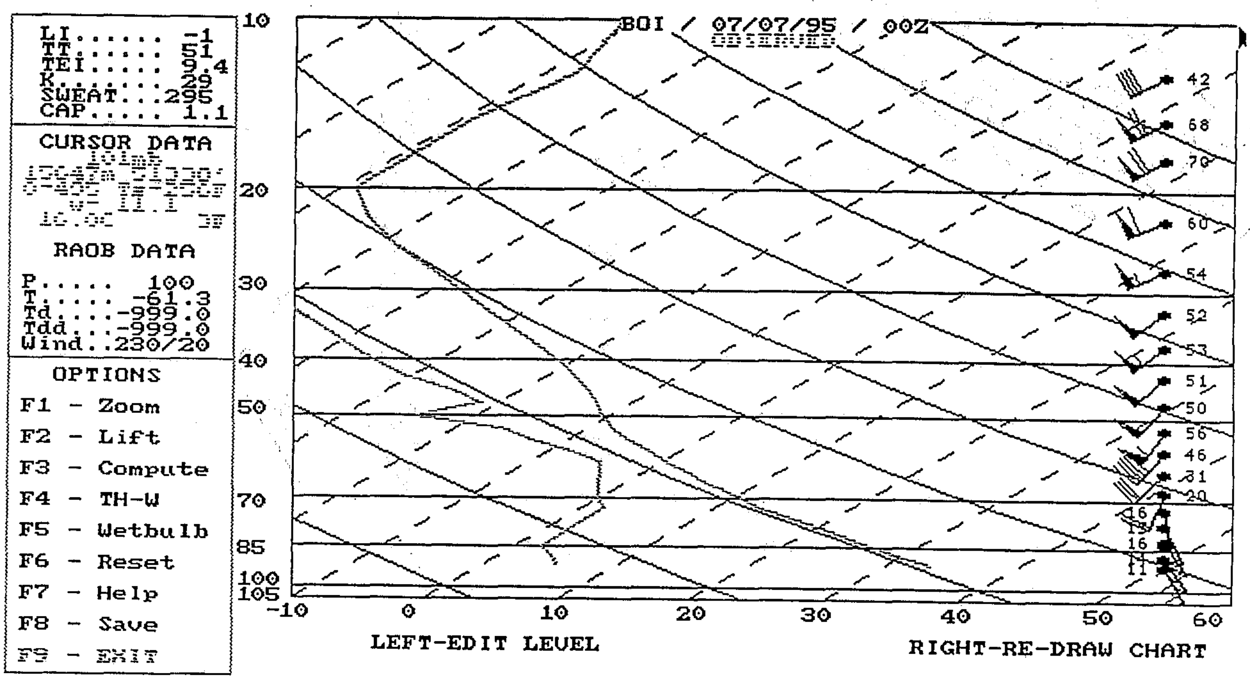


Fig. 8. Same as Fig. 4 but for 0000 UTC 7 July 1995.

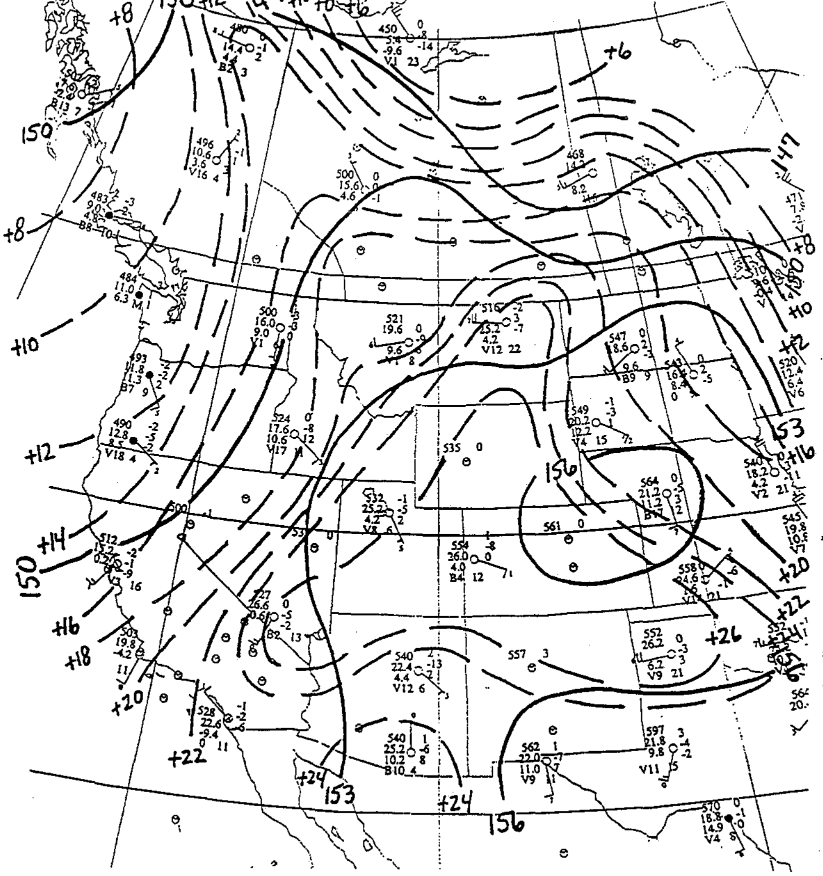


(A)

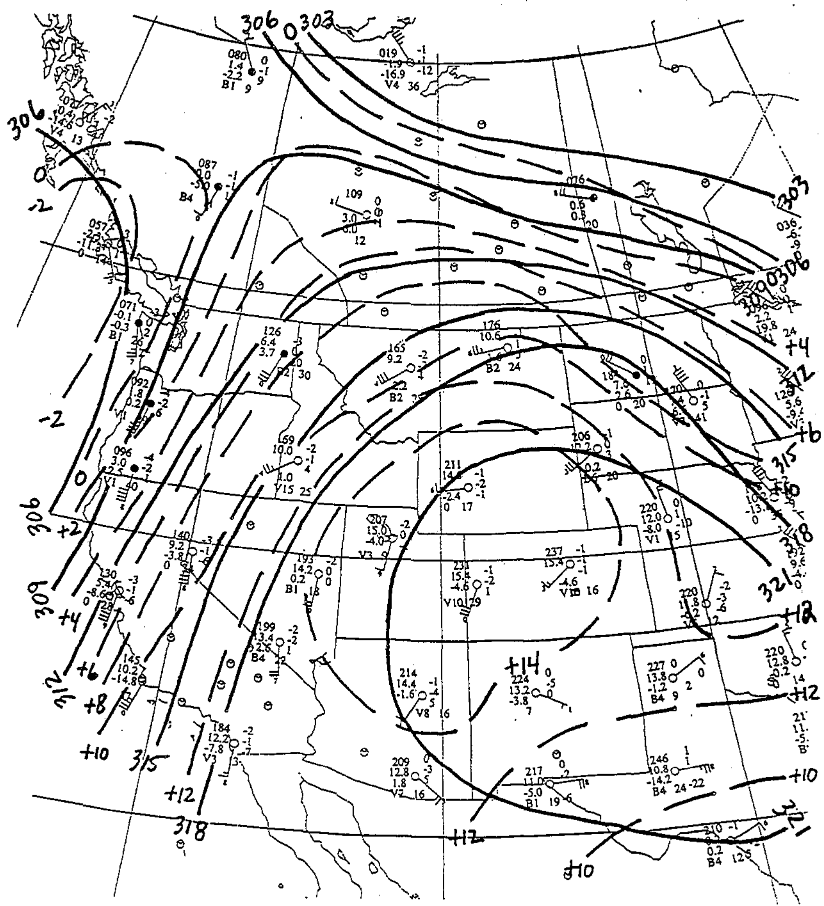


(B)

Fig. 9. Skew-T log p upper air sounding analyses for Spokane, Washington (GEG) for July 1995 at (a) 0000 UTC 7th and for Boise, Idaho (BOI) for July 1995 at (b) 0000 UTC 7th.

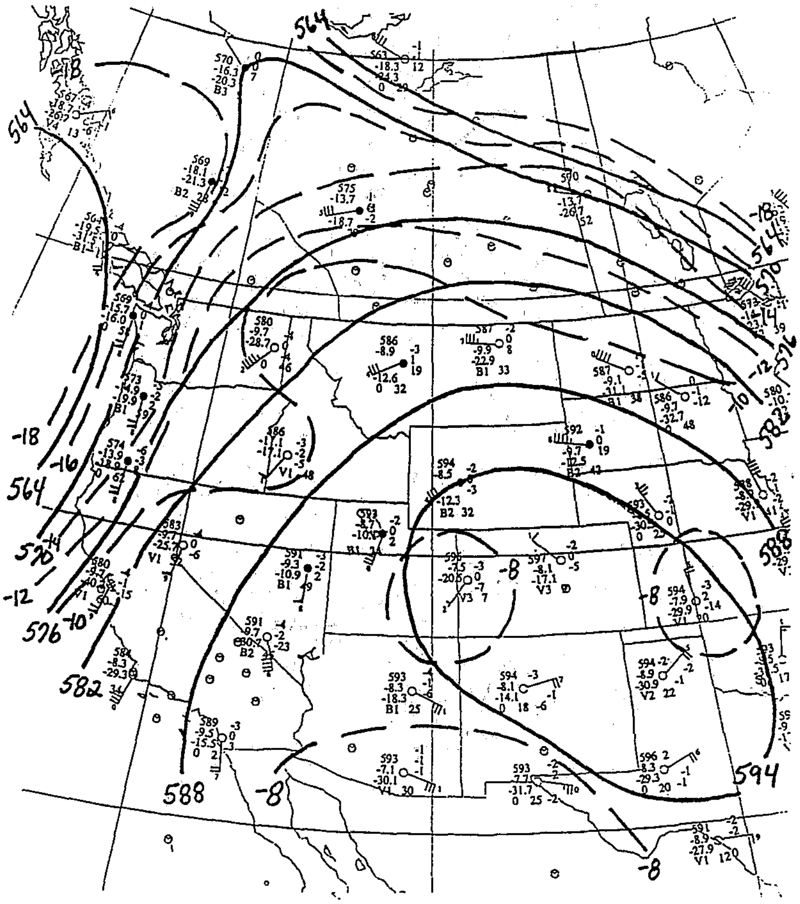


(A)
850 mb

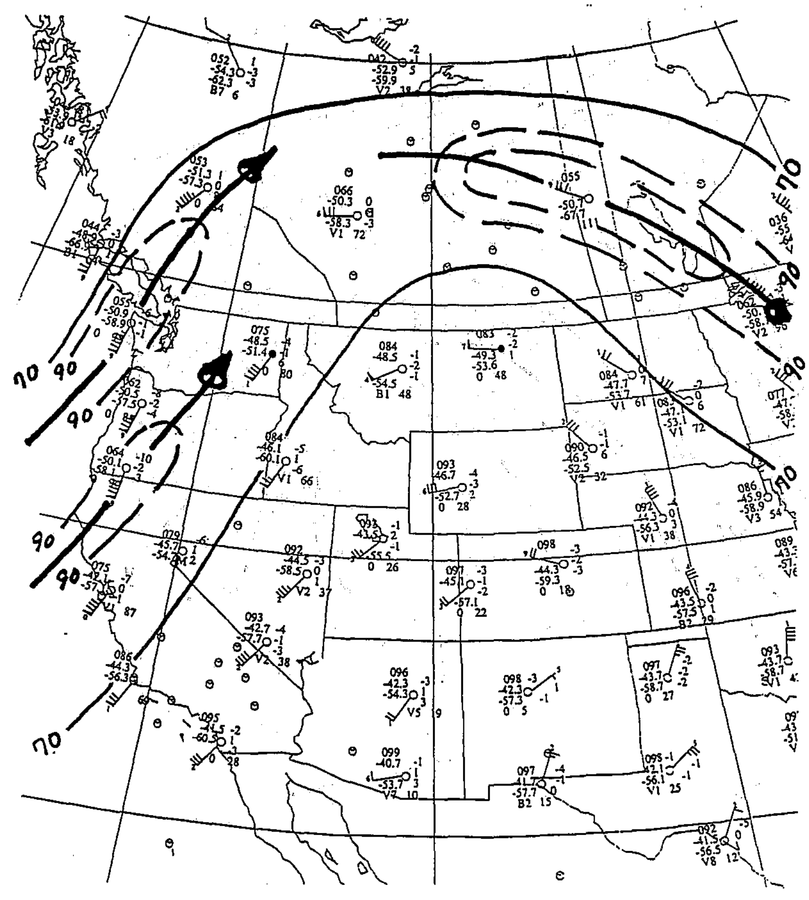


(B)
700 mb

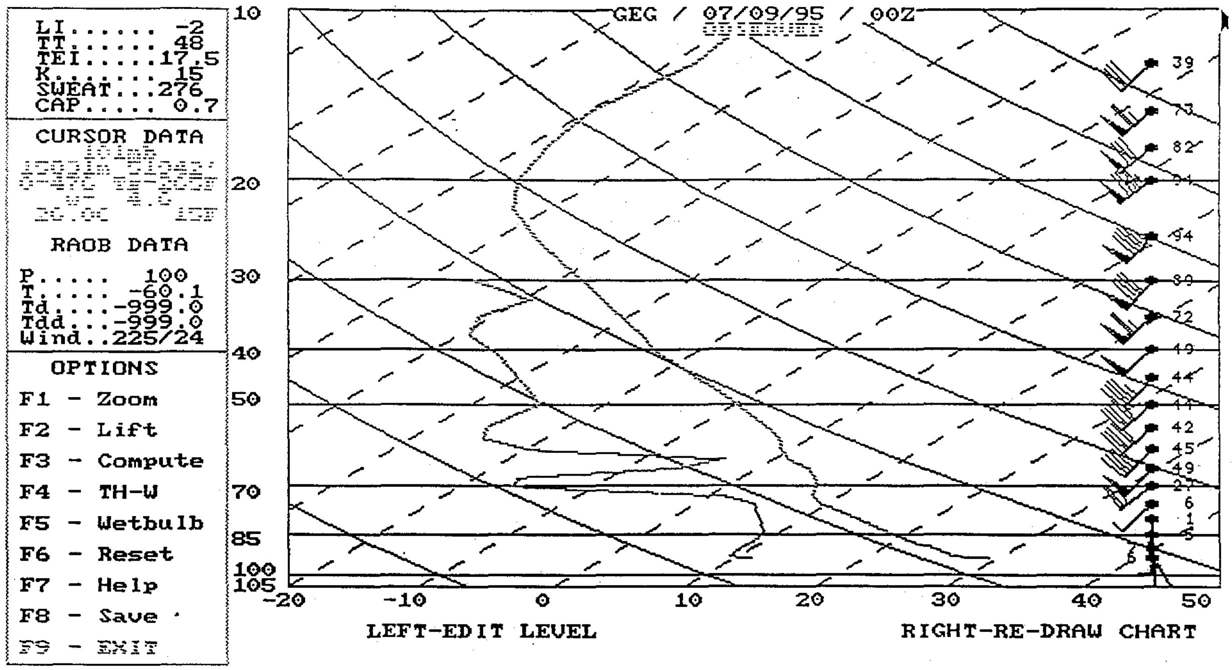
Fig. 10. Same as Fig. 5 but for 1200 UTC 9 July 1995.



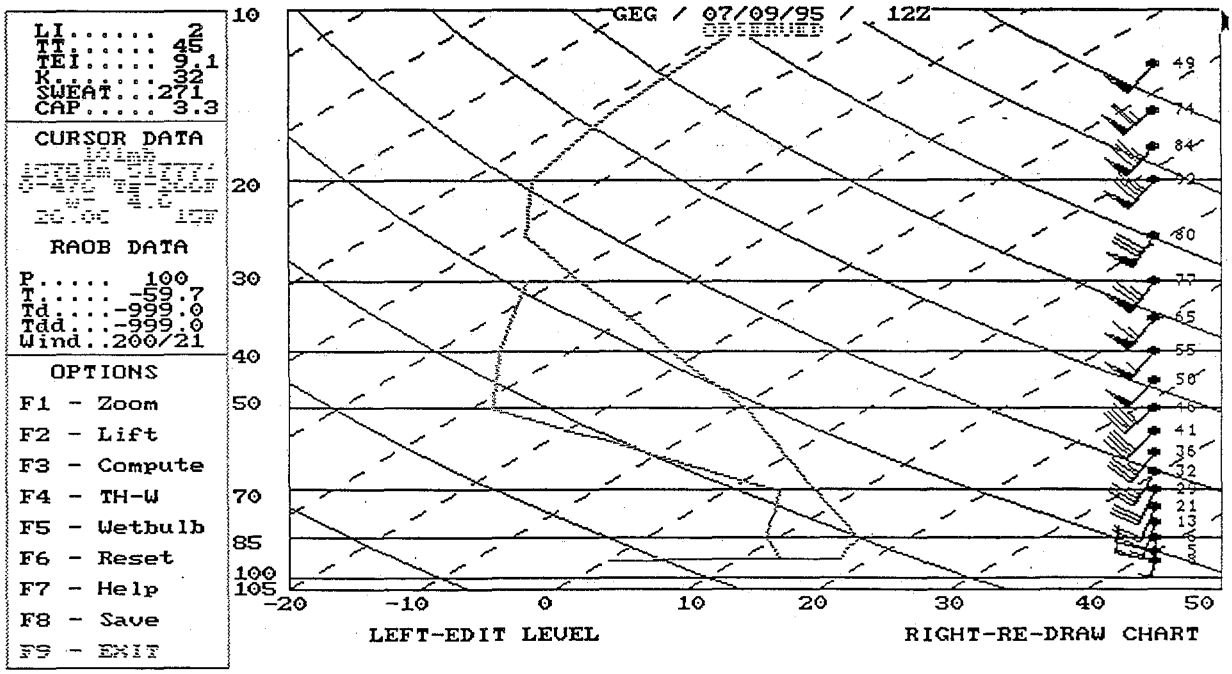
(C)
500 mb



(D)
250 mb

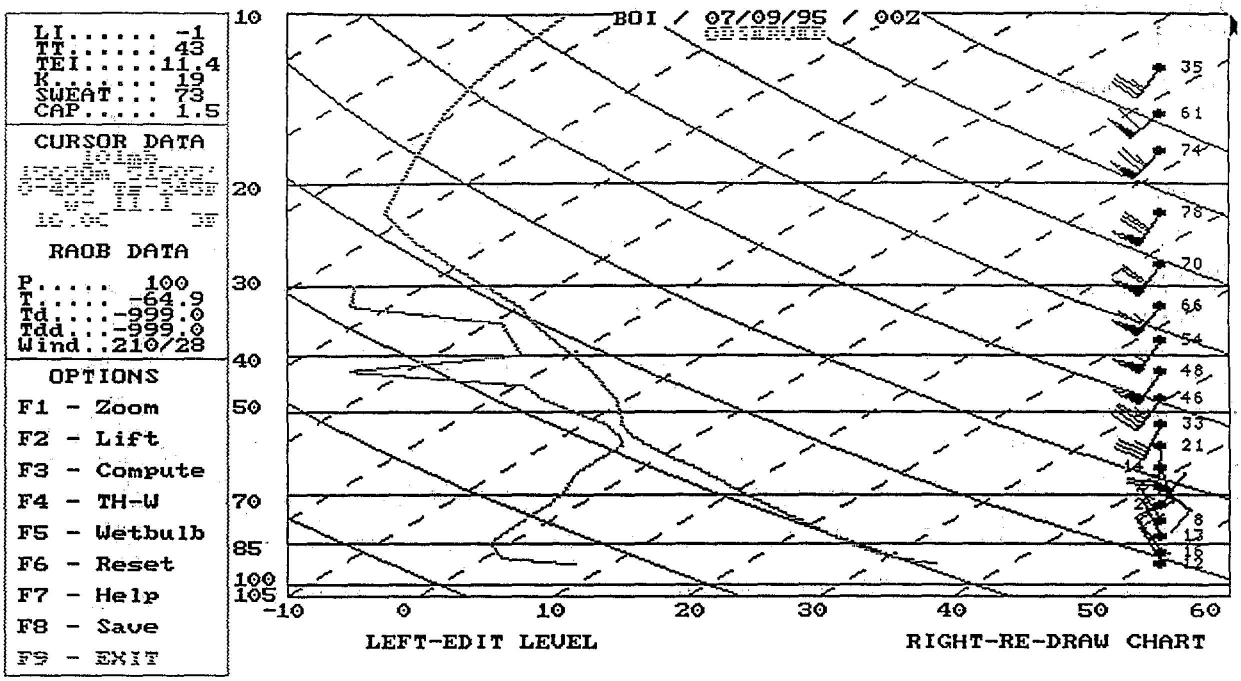


(A)



(B)

Fig. 11. Same as Fig. 6 but for 0000 UTC 9th and 1200 UTC 9th.



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TEI.....11.4
K....... 19
SWEAT... 73
CAP..... 1.5
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RAOB DATA
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T..... -64.9
Td.... -999.0
Tdd... -999.0
Wind..210/28
OPTIONS
F1 - Zoom
F2 - Lift
F3 - Compute
F4 - TH-W
F5 - Wetbulb
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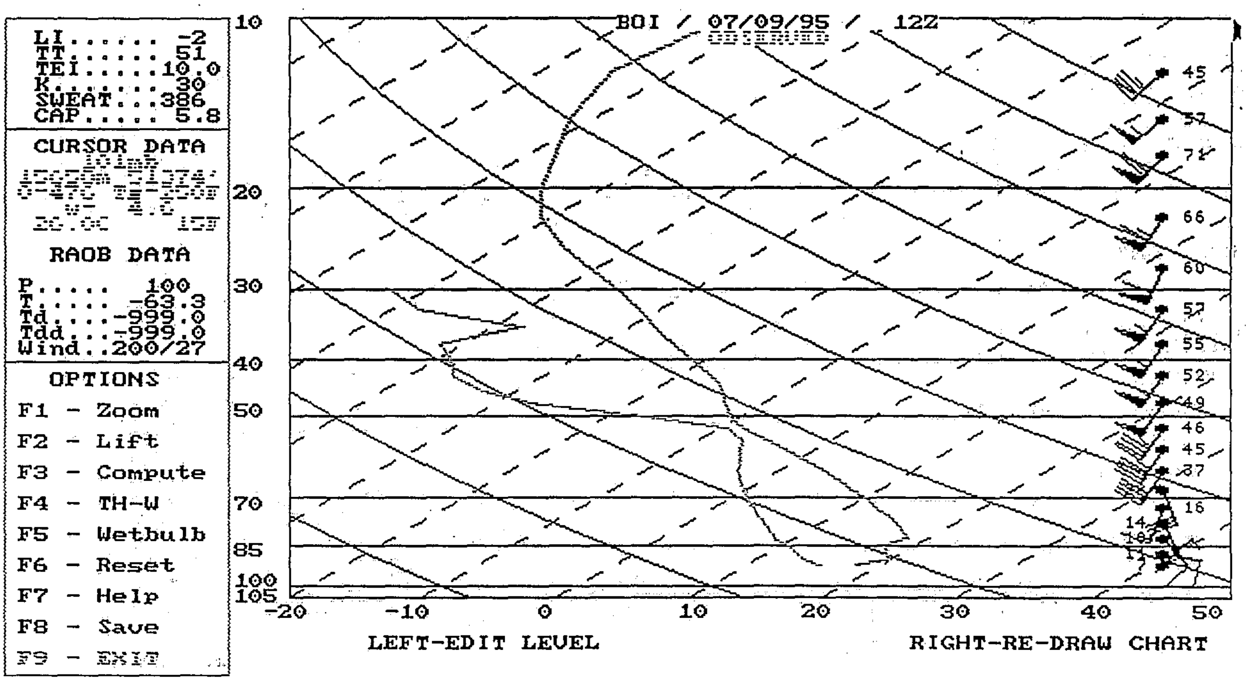
F8 - Save
F9 - EXIT
BOI / 07/09/95 / 00Z
LEFT-EDIT LEVEL
RIGHT-RE-DRAW CHART

(C)



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TEI.....10.0
K....... 30
SWEAT...386
CAP..... 5.8
CURSOR DATA
RAOB DATA
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T..... -63.3
Td.... -999.0
Tdd... -999.0
Wind..200/27
OPTIONS
F1 - Zoom
F2 - Lift
F3 - Compute
F4 - TH-W
F5 - Wetbulb
F6 - Reset
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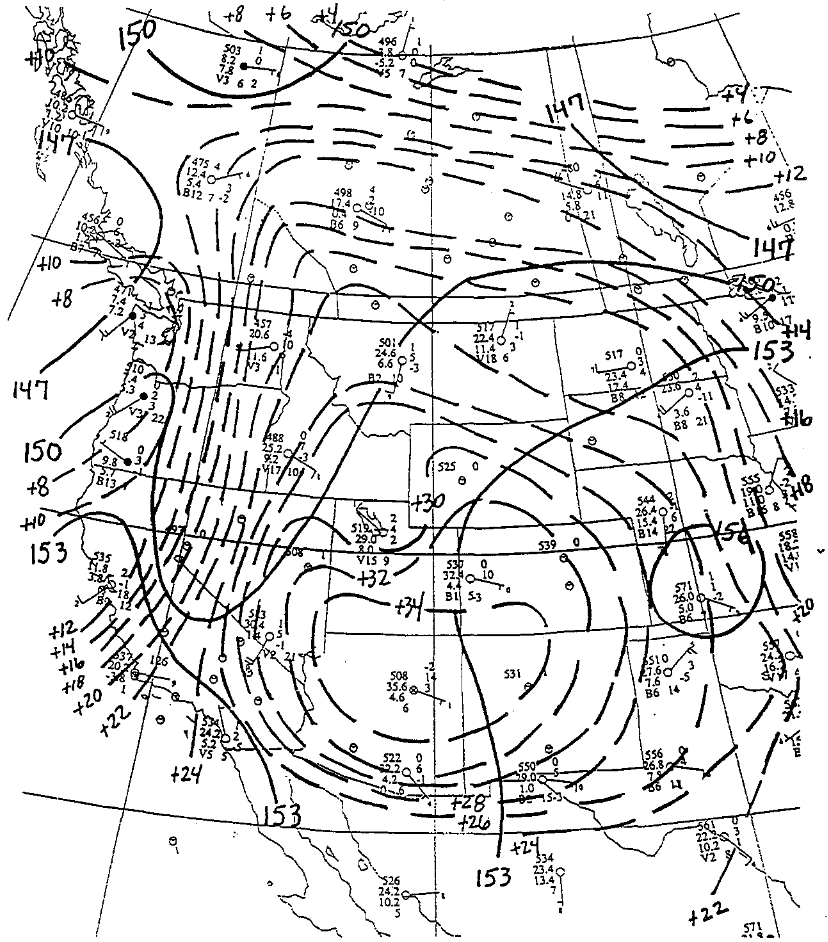
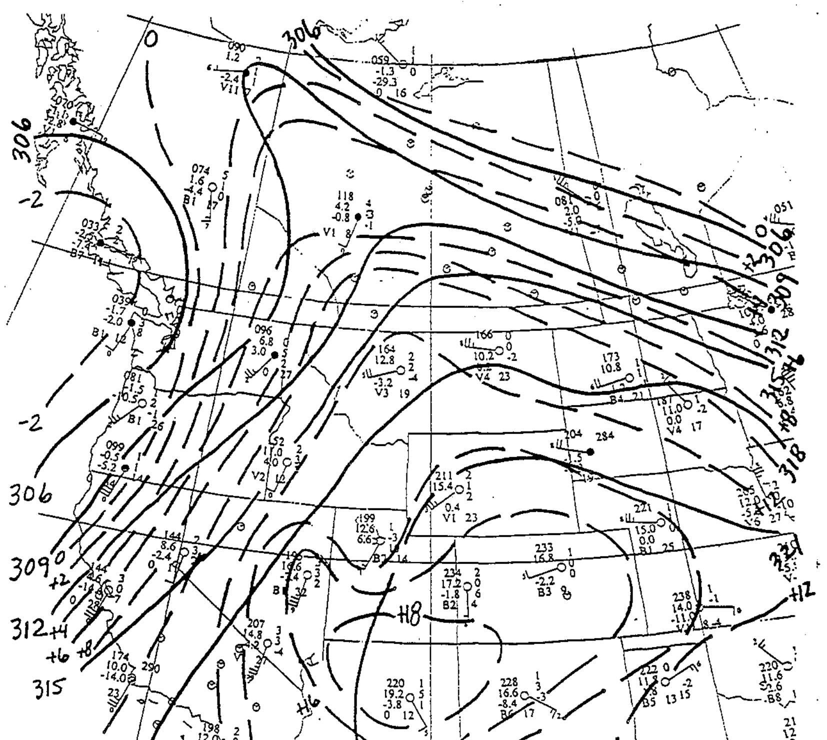
F8 - Save
F9 - EXIT
BOI / 07/09/95 / 12Z
LEFT-EDIT LEVEL
RIGHT-RE-DRAW CHART

(D)



(A)
850 mb



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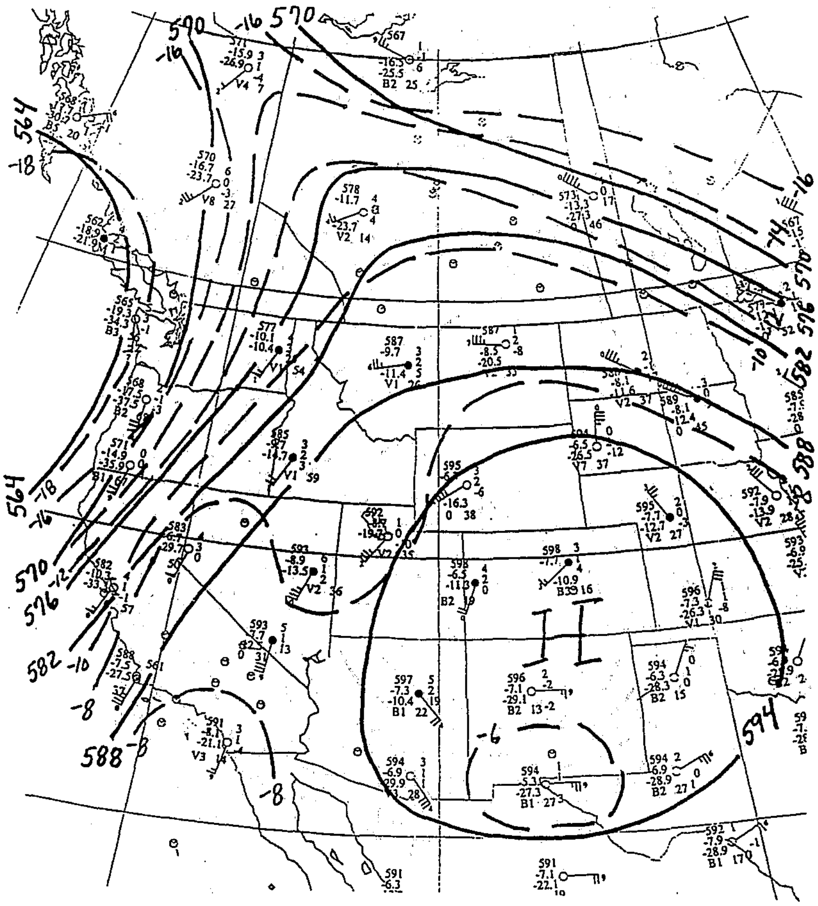
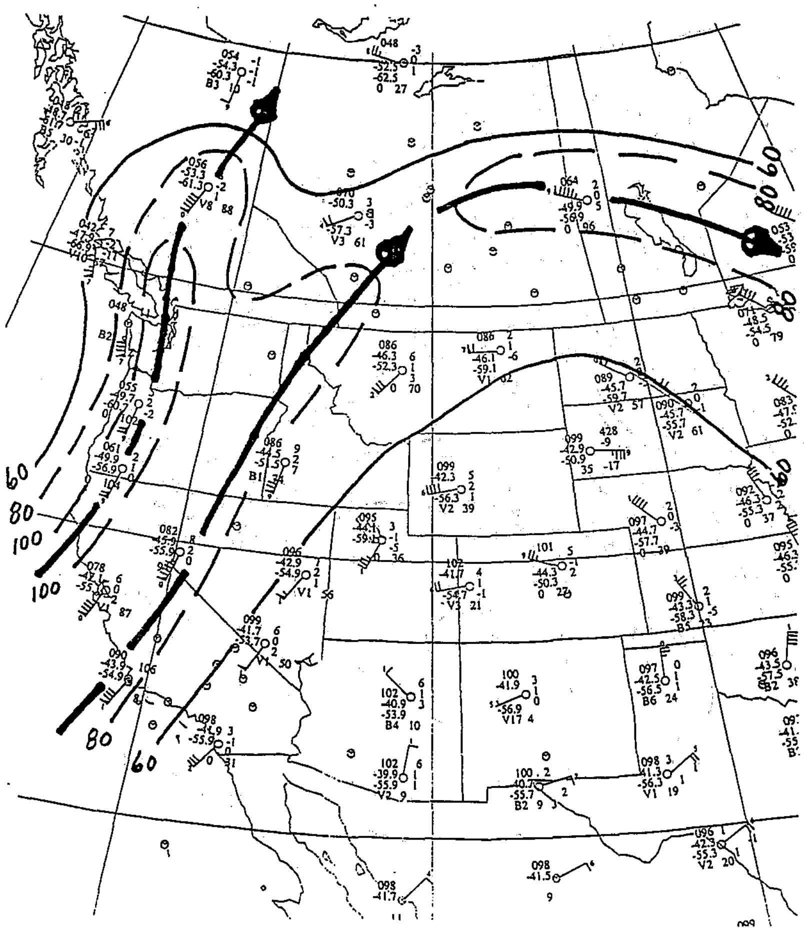
700 mb

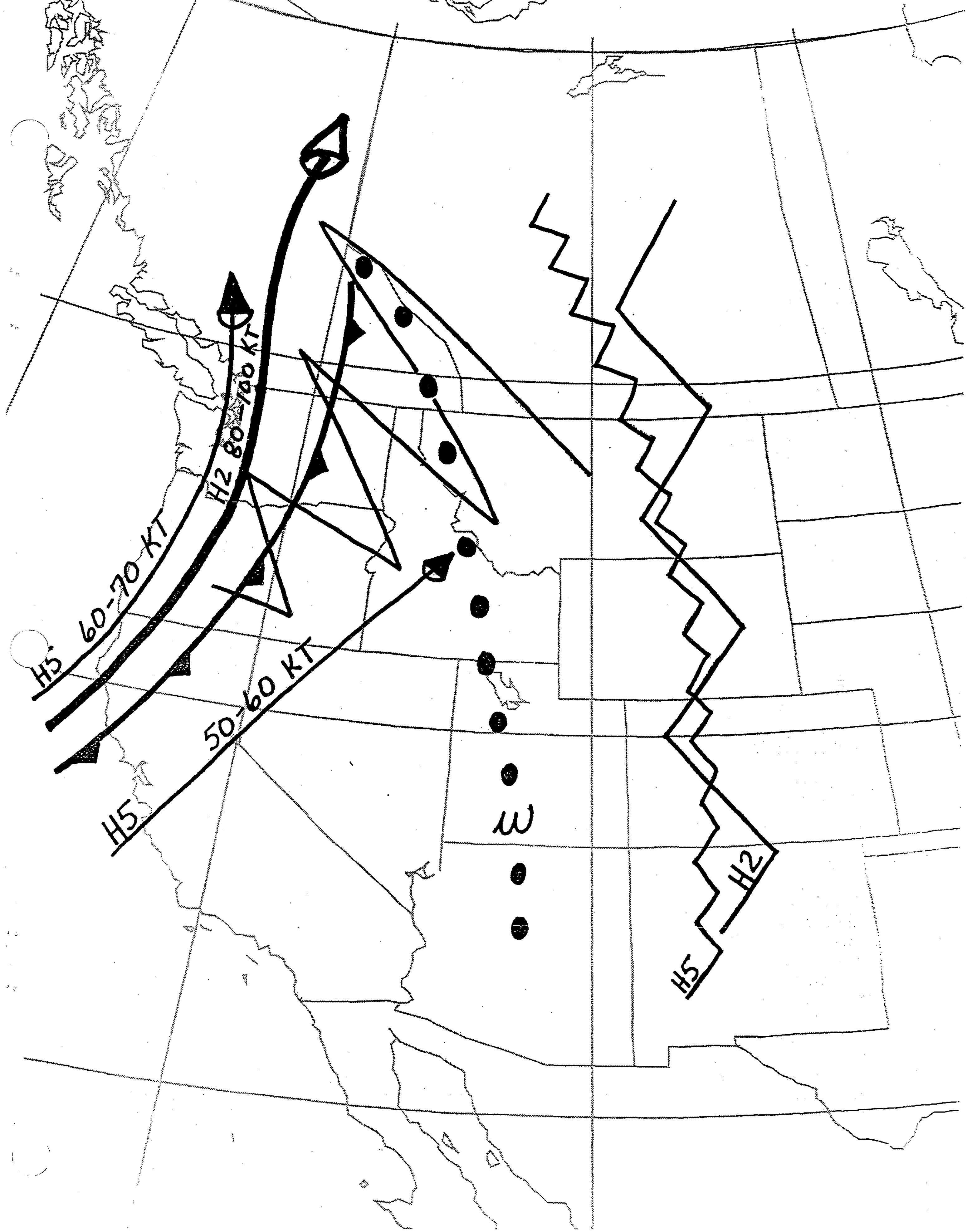
Fig. 12. Same as Fig. 5 but for 0000 UTC 10 July 1995.



(C)
500 mb



(D)
250 mb



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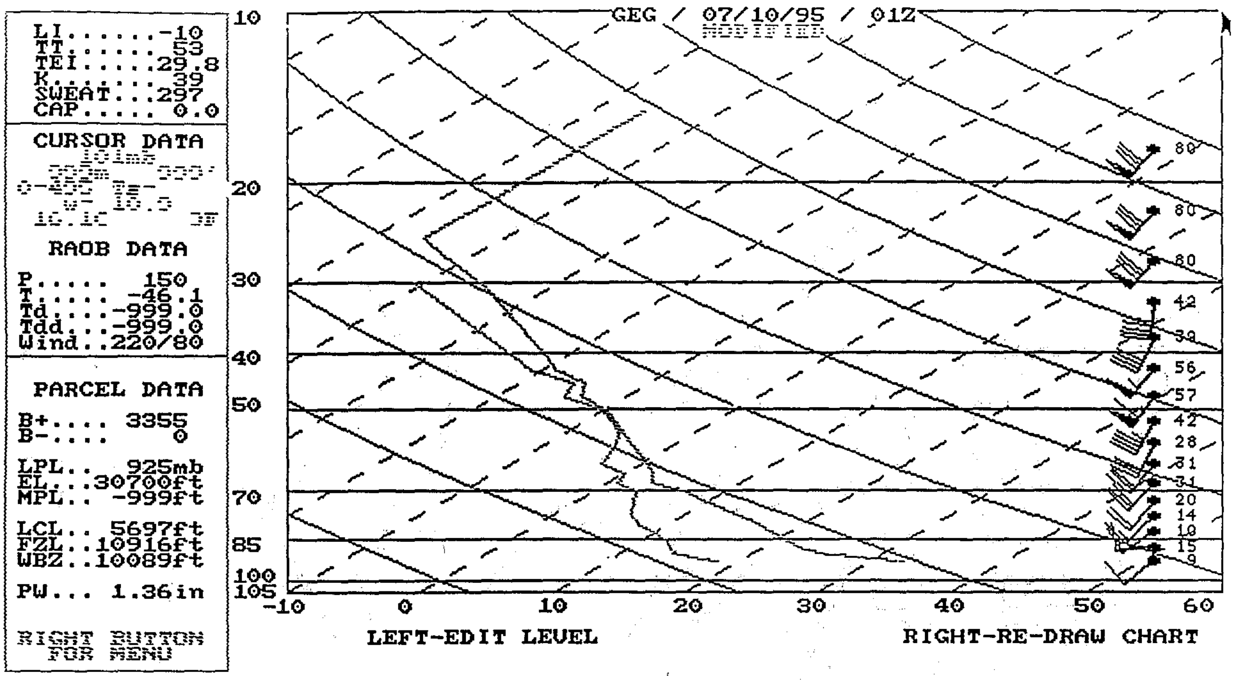
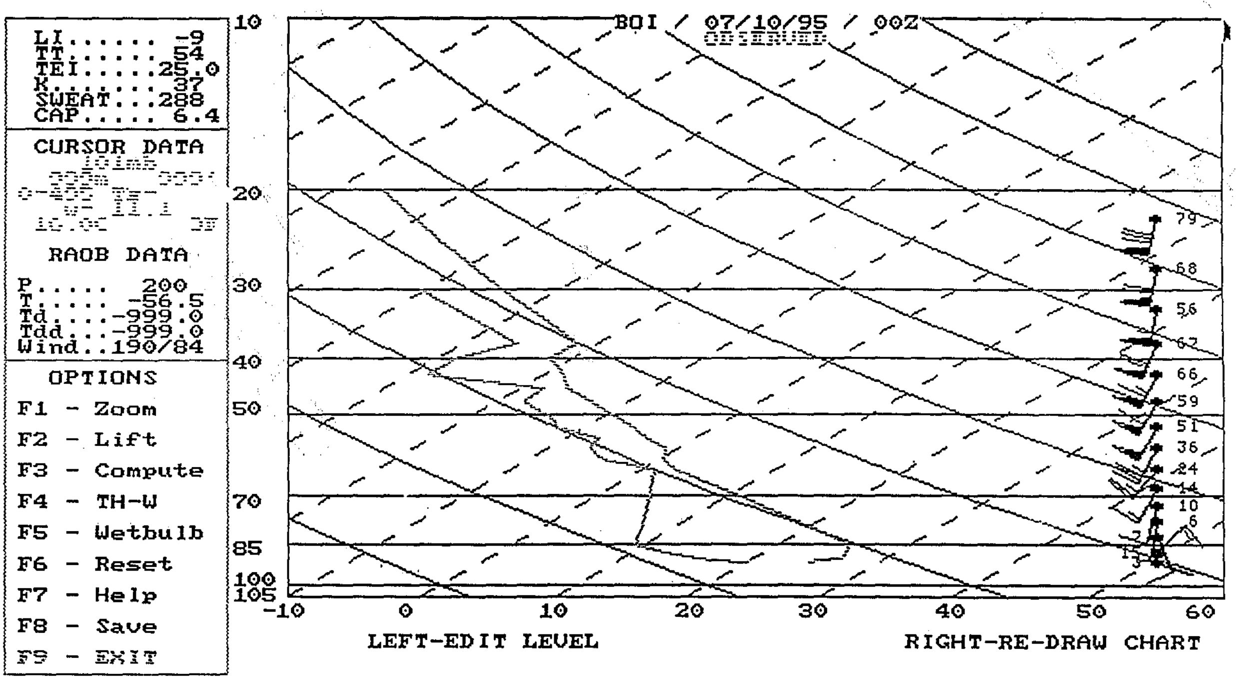


(A)



(B)

Fig. 14. Same as Fig. 9 but for 0000 UTC 10 July 1995.

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