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POST-ANALYSIS OF A SEVERE WEATHER EVENT IN NORTHWEST MONTANA USING THE SHARP WORKSTATION AND PCGRIDS

Michael W. Huston - WSO Helena

Introduction

On the afternoon of May 16, 1993, a severe weather event developed near Cut Bank in northwest Montana. Post-analysis of the storm environment using the SHARP Workstation (Hart and Korotky) and PCGRIDS (Meier, 1993) strongly suggested the potential for severe weather that afternoon. Additional information found within the hodograph section of the SHARP Workstation also proved useful in isolating the area of greatest potential for severe weather.

Analysis

The SHARP Workstation was used to analyze the 1200 UTC 16 May sounding (Fig. 1) from Great Falls (GTF). The Lifted Index (LI) of 0 and Convective Available Potential Energy (CAPE) of 51 J/kg indicated that the atmosphere was marginally unstable (Table 1). Adjustments were made to the lowest 2 km of the sounding (Fig. 2) to simulate the destabilizing effect that surface heating would have on the atmosphere that afternoon. The corresponding indices associated with this **modified** sounding (Table 2) clearly indicated a potential for significant convective activity.

Gridded atmospheric model data, generated from the 1200 UTC Eta-X model run, was also examined to determine if the synoptic environment would sustain convective development that afternoon. The initial synoptic data for the 1200 UTC period showed a possibility for severe weather. Low-level ascent (Fig. 3), combined with a moist tongue and an associated equivalent potential temperature (Θ_e) ridge (Figs. 4 and 5, respectively) extended northward along the Continental Divide into western Alberta. This, in combination with low-level ascent, provided the necessary ingredients within the lower levels of the atmosphere for convective activity. Upper-level support for sustained convective activity was initially lacking, however, as the area of ascent associated with divergence aloft (Figs. 6 and 7, respectively) was situated west of the thermal ridge along the Idaho-Montana border.

By 0000 UTC May 17, the synoptic environment appeared to be much more favorable for severe weather. The low-level ascent, moist tongue, and Θ_e ridge (Figs. 8, 9, and 10, respectively) were expected to shift just east of the Continental Divide. Upper-level support associated with a broad area of divergence aloft (Fig. 12) also expanded east of the Divide as ascent (Fig. 11) developed over western and central Montana in response to an exiting jet streak (Fig. 13) diving into the Great Lakes region. The combination of an unstable sounding and synoptic support for sustained convective activity warranted additional analysis of the modified 1200 UTC 16 May 1993 sounding from GTF.

Thermodynamic Analysis

In the past, the Air Weather Service routinely utilized several expedient techniques to forecast peak wind gusts and hail size (Naval Education and Training Support Command, 1974). One method used to forecast peak wind gusts utilized the wet-bulb zero temperature. From the point at which the wet-bulb temperature was zero, a moist adiabat was traced down to the surface and the corresponding temperature was recorded (Fig. 14, see A). The difference between this temperature and the actual dry-bulb temperature (Fig. 14, see B) was used to reference the gust potential (Fig. 15) of storms which developed within this particular atmospheric regime. Using this technique, the maximum wind gust potential was estimated at 43 kts (50 mph).

To estimate the size of hailstones expected to develop within a convective environment, the Air Weather Service used a somewhat cumbersome method utilizing the Convective Condensation Level (CCL), a moist adiabat through the CCL, and a dry adiabat extending from the -5°C dry-bulb temperature level down to the CCL. The first step involved tracing a moist adiabat from the CCL up to the same level at which the dry-bulb temperature equaled -5°C. At this point, the temperature difference between the dry-bulb and the moist adiabat (3.7°C) was referred to as the base of the positive triangle (Fig. 16, see A). The second step involved tracing a dry adiabat down to the CCL from the -5°C dry-bulb temperature level. The temperature difference between these two levels (10.2°C) was referred to as the altitude of the positive triangle (Fig. 16, see B). With these two reference points, Fig. 17 could be utilized to estimate the potential size of hailstones which were expected to develop within the convective environment. Using this technique, the hailstones were generally expected to measure less than 3/4 of an inch in diameter (Fig. 17, see A).

Hodograph Analysis

The initial hodograph analysis provided additional indications that severe weather was possible within the atmospheric regime being investigated. The initial storm relative (SR) helicity associated with a cell moving from the northwest at 12 kts (Fig. 18, see A and B, respectively) was 112 $m^2 s^{-2}$. Johns and Doswell (see Jarboe, 1992; Thunderstorm Type Predictors, p. 9) investigated the relationship between CAPE and helicity in forecasting severe local storms. A scatter diagram (Fig. 19) displaying the relationship between CAPE and helicity values for strong and violent tornadoes was produced. A liberal application of Fig. 19 to the results found on May 16 would indicate that the storm environment was capable of producing tornadoes. Of greater interest here is not the potential for tornadoes, but rather the indication that this atmospheric regime, as a function of CAPE and helicity, was capable of producing severe weather.

Additional information concerning the storm environment was also gathered from the initial hodograph analysis found within the SHARP Workstation. By moving the mouse about the hodograph, one could easily attain information regarding the effect that various storm directions and speeds would have on the helicity values. Furthermore, by graphically adjusting the initial storm motion, corresponding values of SR helicity and mean inflow are automatically tabulated for various atmospheric layers. In general terms, as one moved the mouse from the southwest quadrant of the hodograph (180-270°) to the northwest quadrant (270-360°), a corresponding increase in SR helicity values were noted. With all other factors remaining equal, this information would tend to indicate that cells moving from the northwest were more likely to produce vigorous storms than those moving from the southwest.

Observations

Through the early afternoon hours of May 16, the Missoula radar recorded storm movements for cells stretching from eastern Idaho through western Montana. Cell movements for storms south of Lewiston (LWS), Idaho were reported to be at 230° and 20 kts (Fig. 20, see A). Using this information to adjust the storm motion on the hodograph, the corresponding values of SR helicity and mean inflow (Fig. 21, see A and B, respectively) indicated very little potential for **sustained** thunderstorm development due to the moderate values of mean inflow and negative helicity values. Spotter reports across southwest Montana that afternoon verified this conclusion.

The corresponding cell movements for storms near Cut Bank (CTB), Montana were observed to be at 300° and 20 kts (Fig. 20, see B). Once again, using this information to adjust the storm motion, a greater potential for significant convective activity became evident. The corresponding values of SR helicity and mean inflow (Fig. 22, see A and B, respectively) revealed a greater threat for severe weather that afternoon. Spotter reports across northwest Montana on May 16 (Table 3), verified that severe weather had occurred.

Knowing that cells moving from the northwest held the greatest potential for generating vigorous storms, the SHARP Workstation, in conjunction with the 700 mb steering wind flow and Θ_e ridge, could have been used to forecast the area most conducive to vigorous thunderstorm development. Figure 23 depicts the forecast position of the Θ_e ridge at 0000 UTC 17 May and the wind direction in tens of degrees. The shaded area bounded by the Θ_e ridge and wind directions greater than 300°, could have been used as a first guess for the location of vigorous thunderstorm development on the afternoon of May 16.

Conclusions

The SHARP Workstation proved to be an efficient tool for graphically modifying and analyzing the 1200 UTC May 16 sounding. With little effort, information concerning the stability of the environment and the potential for severe weather was attained. Although calculations concerning the peak wind gusts and hail size were underestimated, they did serve to indicate that the environment was capable of producing atmospheric phenomena which **approached** severe criteria.

The SHARP Workstation, in conjunction with gridded atmospheric data, proved useful in defining an area which was conducive to vigorous thunderstorm development. Utilization of gridded atmospheric data was also helpful in analyzing the synoptic environment in which the storms developed.

Acknowledgements

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References

Hart, John A. and Korotky, Josh: A Skew-T / Hodograph Analysis and Research Program for the IBM and Compatible PC. NOAA/NWS National Weather Service Forecast Office Charleston, WV.

Jarboe, John, 1992: Thunderstorms. Training notes produced for the National Weather Service Training Center.

Meier, Keith W., 1993: PCGRIDS -- A User's Manual. Western Region Scientific Services Division.

Naval Education and Training Support Command, 1974: Aerographer's Mate 1 & C. U.S. Government Printing Office Washington, D.C., pp. 368-377.

Table 1
Single-Station RAOB data for: GTF
Date: 05/16/93 Time: 12 UTC

Convective Indices

Lifted Index @ 500 mb...	0	Cross Totals...........	23
@ 300 mb...	2	Vertical Totals........	27
Showalter Index..............	0	Total Totals............	50
Sweat Index.....................	288	B+............................	51 J/kg
TEI....................................	5.6	B-.............................	22 J/kg
K Index............................	29	Max UVV...............	10 m/s
Precipitable Water..........	0.74 in	BRN.......................	1

Fig. 1
Single-Station RAOB for: GTF
Date: 05/16/93 Time: 12 UTC

Skew-T / log p

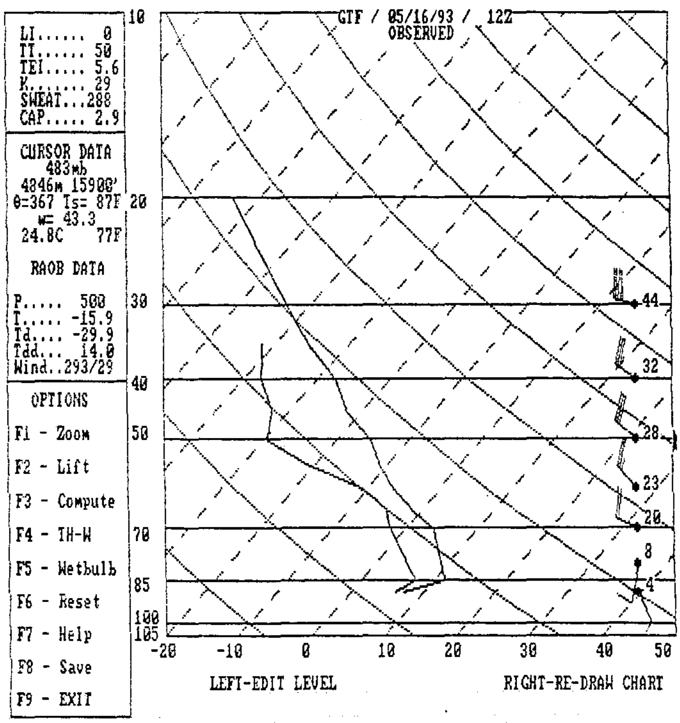


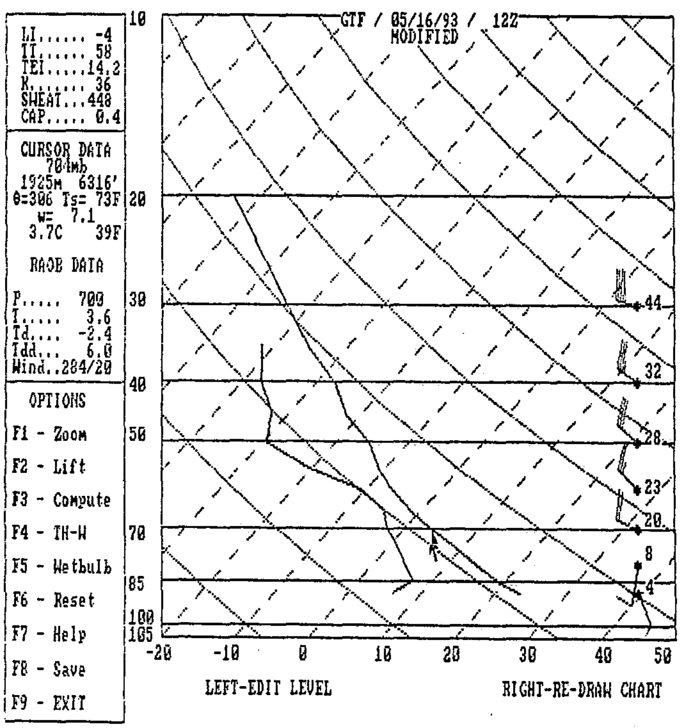
Table 2
Single-Station MODIFIED RAOB data for: GTF
Date: 05/16/93 Time: 12 UTC

Convective Indices

Lifted Index @ 500 mb...	-4	Cross Totals............	23
@ 300 mb...	-3	Vertical Totals........	35
Showalter Index...............	-5	Total Totals.............	58
Sweat Index......................	448	B+............................	1229 J/kg
TEI.....................................	14.2	B-..............................	10 J/kg
K Index.............................	36	Max UVV................	50 m/s
Precipitable Water..........	0.69 in	BRN.........................	26

Fig. 2
Single-Station MODIFIED RAOB for: GTF
Date: 05/16/93 Time: 12 UTC

Skew-T / log p



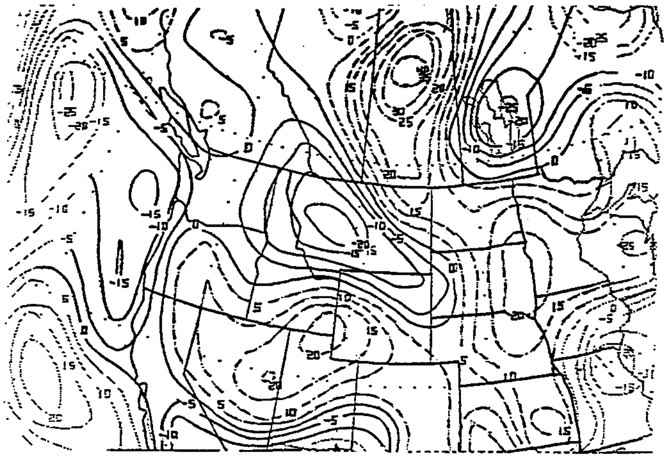


Fig. 3 1200 UTC May 16
700 mb Vertical Velocity ($\mu b\ s^{-1}$)
contoured every 0.5 $\mu b\ s^{-1}$ where 20 is 2.0 $\mu b\ s^{-1}$

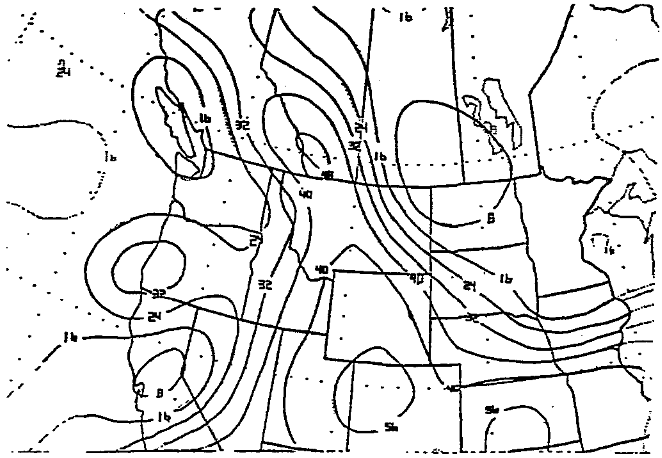


Fig. 4 1200 UTC May 16
700 mb Mixing Ratio ($g\ Kg^{-1}$)
contoured every 0.8 $g\ Kg^{-1}$ where 48 is 4.8 $g\ Kg^{-1}$

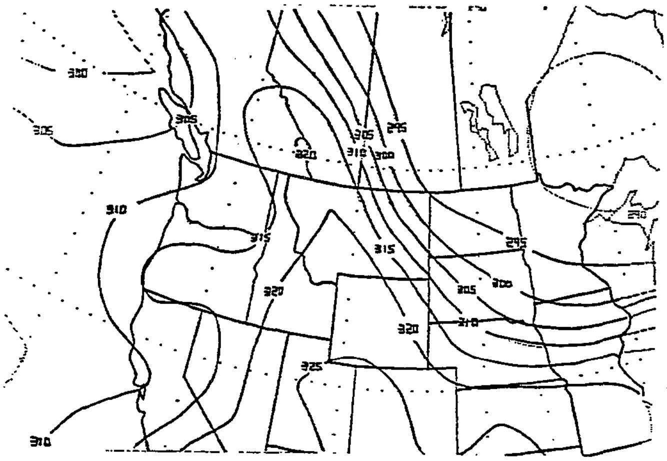


Fig. 5 1200 UTC May 16
700 mb Equivalent Potential Temperature (K)
contoured every 5 K

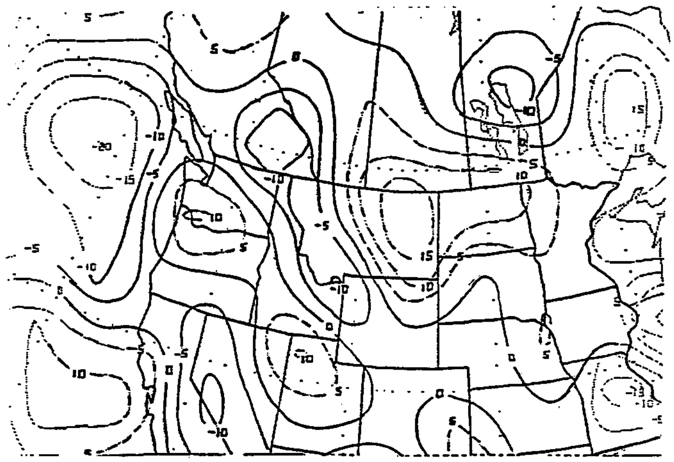


Fig. 6 1200 UTC May 16
250 mb Vertical Velocity ($\mu b\ s^{-1}$)
contoured every 0.5 $\mu b\ s^{-1}$ where 10 is 1.0 $\mu b\ s^{-1}$

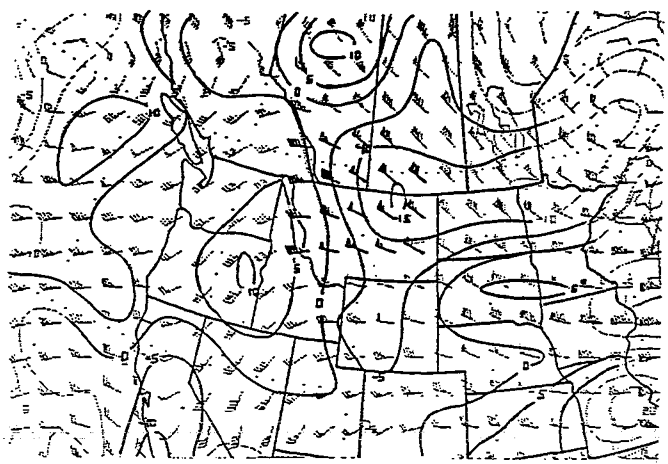


Fig. 7 1200 UTC May 16
250 mb Wind Speed (kts) and Divergence of Total Wind (s^{-1})
Divergence contoured every $0.5 \times 10^{-5}\ s^{-1}$ where 10 is $1.0 \times 10^{-5}\ s^{-1}$

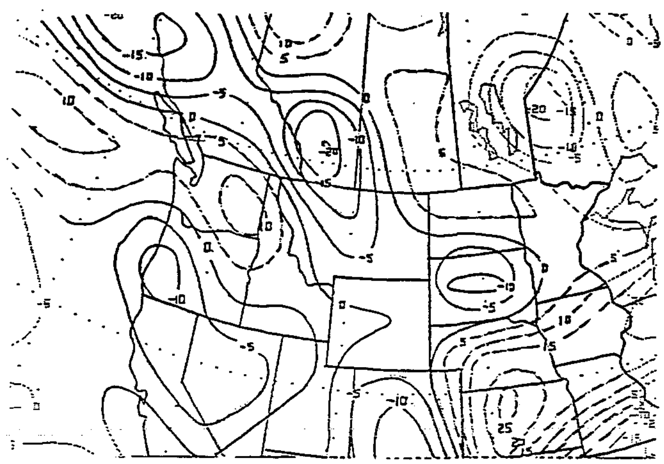


Fig. 8 0000 UTC May 17
700 mb Vertical Velocity ($\mu b\ s^{-1}$)
contoured every 0.5 $\mu b\ s^{-1}$ where 20 is 2.0 $\mu b\ s^{-1}$

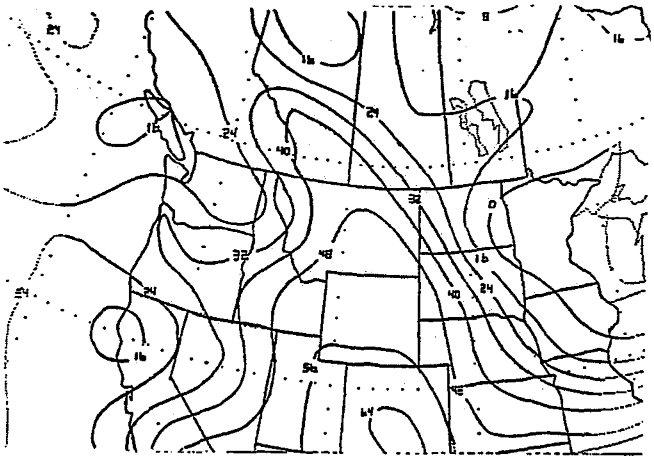


Fig. 9 0000 UTC May 17
700 mb Mixing Ratio (g Kg^{-1})
contoured every 0.8 g Kg^{-1} where 48 is 4.8 g Kg^{-1}

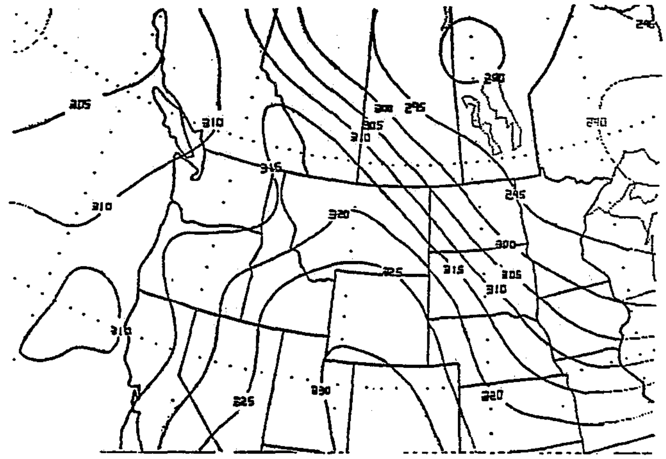


Fig. 10 0000 UTC May 17
700 mb Equivalent Potential Temperature (K)
contoured every 5 K

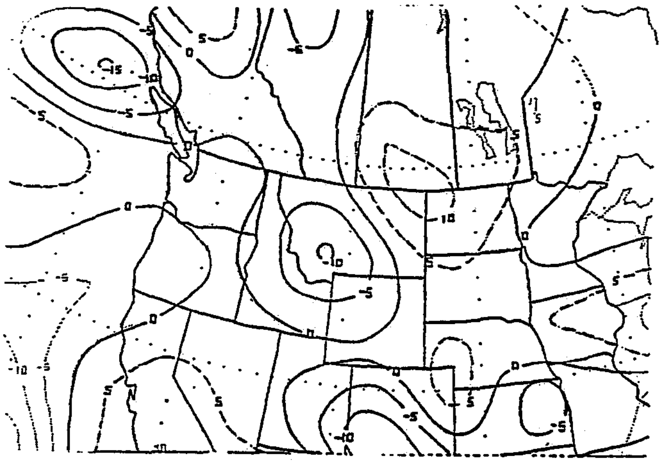


Fig. 11 0000 UTC May 17
250 mb Vertical Velocity ($\mu b\ s^{-1}$)
contoured every 0.5 $\mu b\ s^{-1}$ where 10 is 1.0 $\mu b\ s^{-1}$

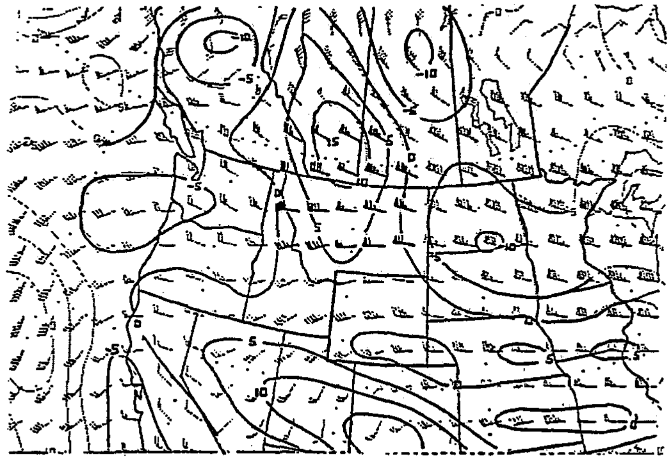


Fig. 12 0000 UTC May 17
250 mb Wind Speed (kts) and Divergence of Total Wind (s^{-1})
Divergence contoured every 0.5 x 10^{-5} s^{-1} where 10 is 1.0 x 10^{-5} s^{-1}

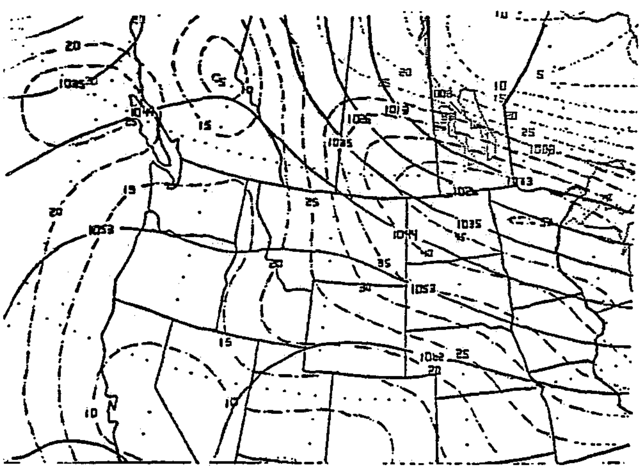
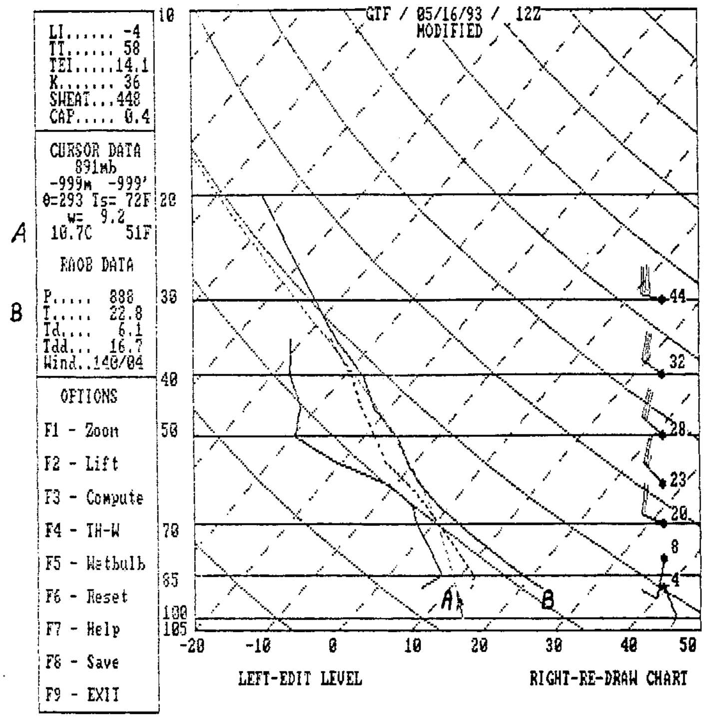


Fig. 13 0000 UTC May 17
250 mb Height (m) solid and Isotach (m s^{-1}) dashed

Fig. 14
Single-Station MODIFIED RAOB for: GTF
Date: 05/16/93 Time: 12 UTC

Skew - T / log p



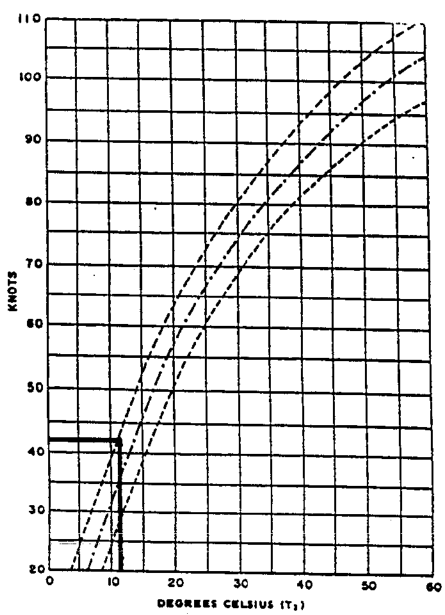
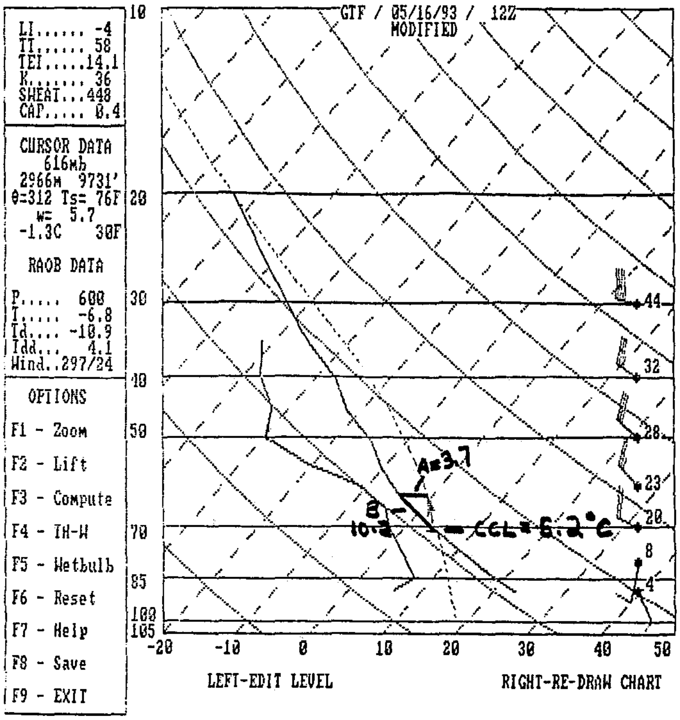


Fig. 15
Probable Maximum Gust
(Naval Education and Training Support Command, 1974. p370)

Fig. 16
Single-Station MODIFIED RAOB for: GTF
Date: 05/16/93 Time: 12 UTC

Skew - T / log p



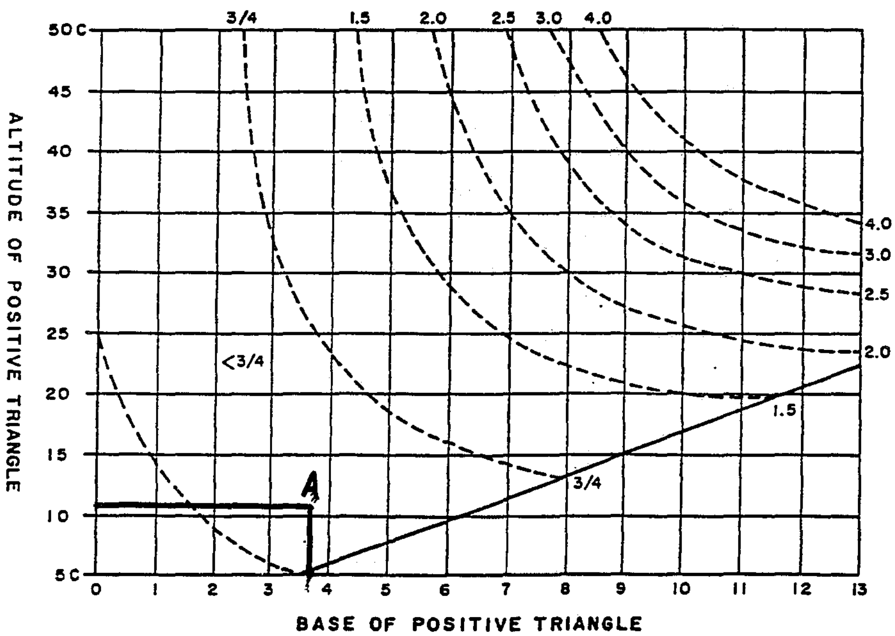
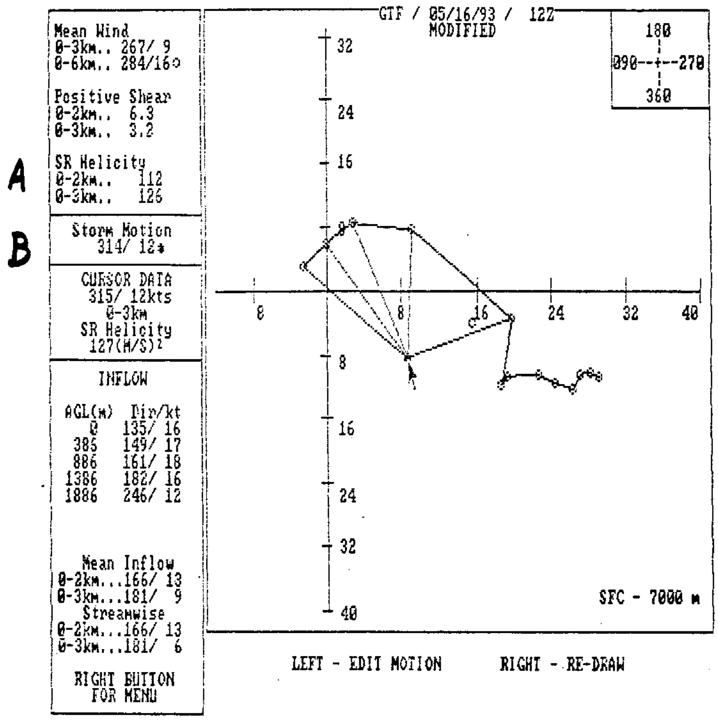


Fig. 17
Hailstone Diameter (inches)
(Naval Education and Training Support Command, 1974, p377)

Fig. 18
Hodograph for: GTF
Date: 05/16/93 Time: 12 UTC



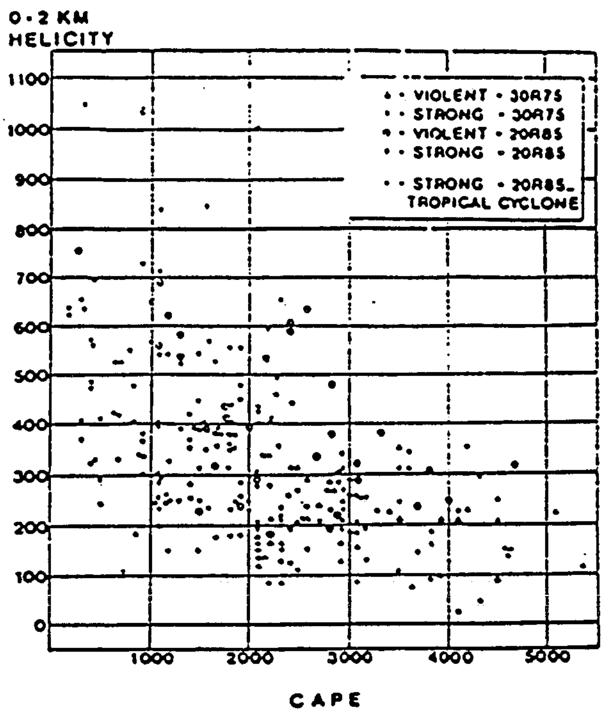


Fig. 19
Strong and Violent Tornadoes
(see Jarboe, 1992; Thunderstorm Type Predictors. p 9)

Fig. 20
Weather Radar Observation WSO Missoula MT
2125 UTC

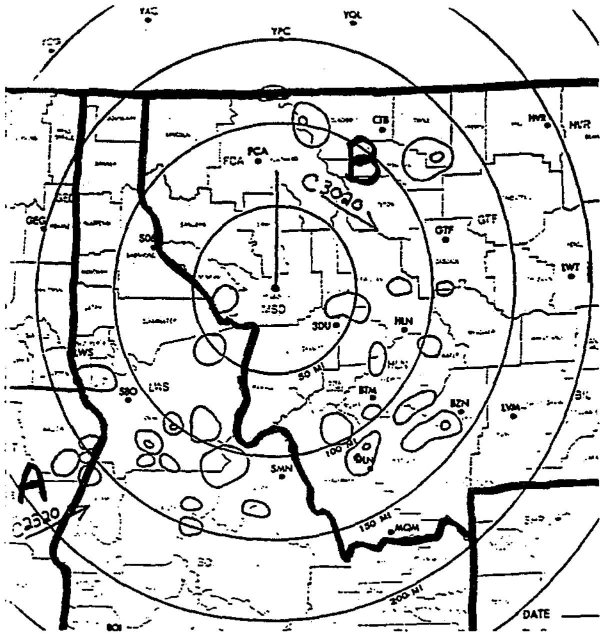


Fig. 21
Modified Hodograph for: GTF
Date: 05/16/93 Time: 12 UTC

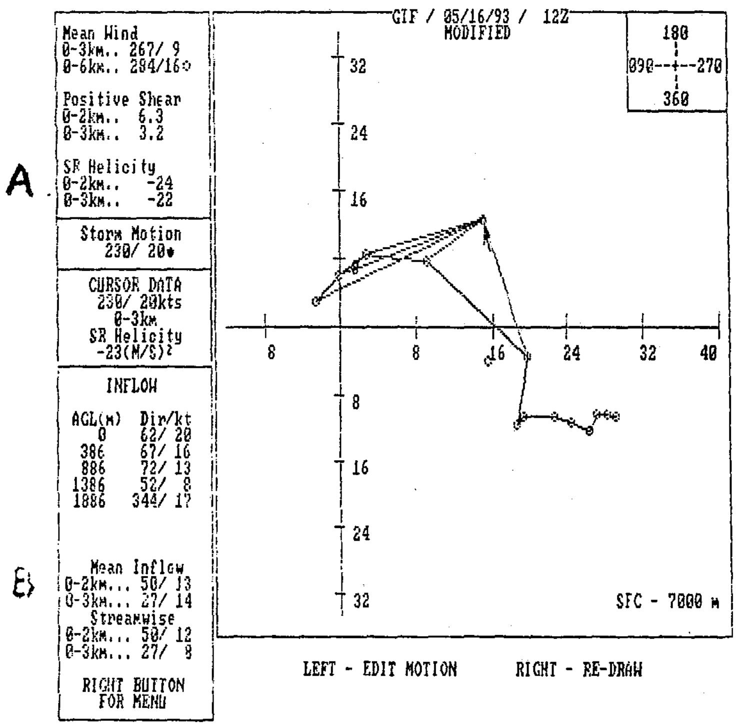
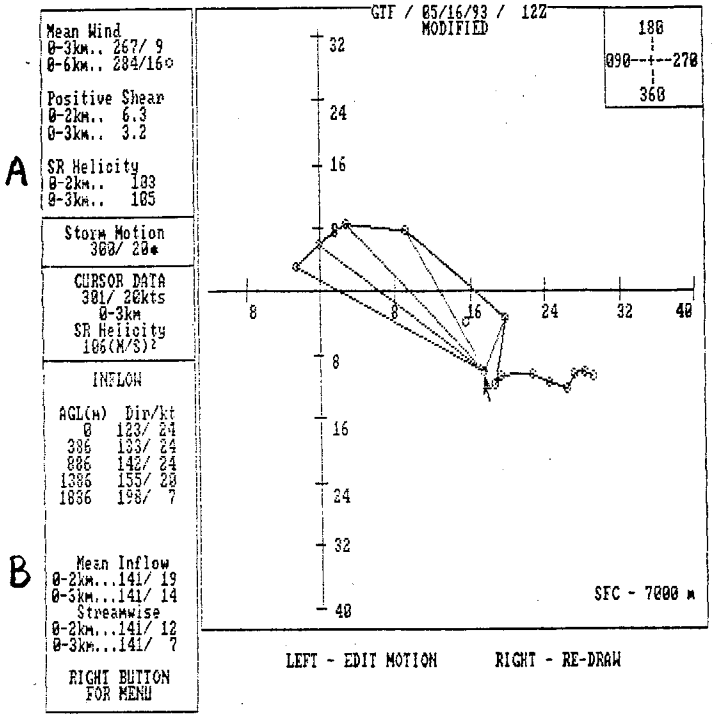


Fig. 22
Modified Hodograph for: GTF
Date: 05/16/93 Time: 12 UTC



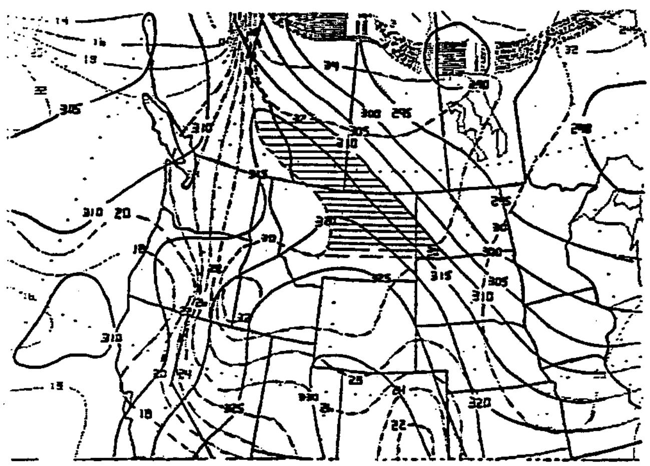


Fig. 23
700 mb 0000 UTC May 17
Equivalent Potential Temperature (solid - contoured every 5 K)
Wind Direction (dashed - contoured every 20°)

Table 3
Storm Reports for May 16 1993

Time	Location	Report
2017 UTC	Cut Bank	Peak gust of 50 kts at airport.
2040 UTC	10S Valier	Air Force reports gust of 65 kts.
2050 UTC	Shelby	Estimated wind gusts over 50 mph.
2105 UTC	20NE Conrad	Air Force reports gust of 86 mph.
2115 UTC	Shelby	0.51 inches of rain in 15 minutes with acorn size hail.
2200 UTC	Chester	Highway Dept. measured wind gust to 75 mph.
2310 UTC	Raynesford	Marble size hail and 40 mph wind gusts.
2322 UTC	30NW Lewistown	Air Force reports gust to 46 kts and 1/4 inch hail.