Western Region Technical Attachment
No. 93-29
September 28, 1993

COMMENTS ON WESTERN REGION TECHNICAL ATTACHMENT 93-27

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Introduction

Two weeks ago, an excellent Western Region Technical Attachment (93-27) was published by Michael W. Huston (WSO-Helena). In summary, the study investigated a convective event over north-central Montana on May 16-17, 1993. An excellent presentation was included on the useful interaction between PCGRIDS and the SHARP Workstation in assessing the convective potential. Specifically, the author found that the Eta model 700 mb vertical velocity, equivalent potential temperature (θe) ridge, and 250 mb divergence helped to isolate the "area of concern" for forecasted convection. Also, cell motion and the use of modified hodographs provided northwest Montana with the greatest kinematic thunderstorm support. Upon reading the paper, I felt some interesting additional methods, which utilize the data available to the operational meteorologist, could have been used to assess the threat as well. This attachment will present these data. Also, some discussion is provided on the use of the mean wind and its role in storm motion and structure. I believe the conclusions drawn in the study (Huston, 1993) are valid and well supported. This paper provides additional methods to the forecasting "funnel" when considering deep convection.

Vertical Velocity

When the operational meteorologist evaluates NMC model output (i.e., Eta, NGM, AVN, etc.), it is necessary to dissect the origin of a given solution to determine the subjective confidence level. In this same context, it is important to find the cause and origin of vertical motion generated by a given model. The numerical models contain terrain-induced motion, classic QG-motions, ageostrophic motions, isentropic motions, and many forcing mechanisms which collectively compose the vertical motion fields. The models integrate the equations of motion directly, with a few parameterizations (i.e., convective). Although the author discussed the 700 mb vertical velocity, possible causes into the origins of the motion were not presented. This, I believe, is a necessary evaluation when conducting case studies.

A vertical cross-section was constructed near west-east through Montana (see Fig. 5) for 0000 UTC 17 May 1993 using the 12-h Eta model forecast, the time nearest to when the convection occurred (Huston, 1993). An exiting jet streak was centered near 250 mb over the eastern portions of Montana (refer to Fig. 5). Evaluating divergence of the wind field can help diagnose the origins of model vertical velocity. Notice the couplets of divergence/convergence at upper/lower levels (Fig. 1). This is strongly correlated with the divergence of the ageostrophic wind. Also, the eastern portion of the cross-section penetrates into the entrance region of the upper-level jet (Fig. 2). Since the jet streak is almost straight-line, the corresponding secondary circulation is not surprising; however, it is shifted slightly toward the warm air. This shift is partially due to the orientation of the cross-section not being exactly perpendicular to the jet streak. Other possible reasons for the shift would include temperature advections (cold air into jet entrance region, Keyser, 1986) or the interaction of the confluent southwesterly air stream. This, however, provides some insight into the model forcing for the generated vertical velocity fields.

Vertical Cross Sections of θe

The importance of the low-level equivalent potential temperature ridging in relation to convection is fairly well known. The general idea is that convective potential is highest along the warm edge of θe gradients while general, more random convection occurs within the ridge itself. This is true and well-supported. However, convective instability is defined as:

$$d\theta e/dz < 0$$

which describes a layer in the vertical where the equivalent potential temperature decreases with height. The characteristics of this layer usually consists of a warm, moist bottom and a markedly drier, cooler top. If such a condition exists, and the layer is lifted, rapid destabilization occurs. This is accomplished because the top of the layer cools more rapidly than the bottom of the layer. Specifically using pseudo-adiabatic theory, the bottom (top) is cooling at the moist (dry) adiabatic lapse rate until both become saturated which induces destabilization. Therefore, a low-level θe ridge may exist (i.e. 700 mb), while in the vertical, the atmosphere exhibits a θe profile such that $d\theta e/dz > 0$ (convective <u>stability</u>). The forecaster can be misled in such cases by only evaluating the horizontal θe distribution.

Vertical cross-sections of θe, both spatial (Fig. 3) and temporal (Fig. 4), allow easy interpretation of the model's convective instability. It is easy to see the regions where θe decreases with height (convectively unstable) and which areas had the most significant change over the 12-hour period. Overlaying divergence of the total wind illustrates a favorable forcing mechanism which may release the instability. From the figures, the greatest convective instability is found west of 111° W and increases through the afternoon (due to low-level radiational heating). Also at the 12 hour forecast period, the upper-level divergence is vertically coupled with low-level convergence over the convectively unstable area (again near 111° W). This is the area which experienced the convection.

Mean Wind Forecasts

Although PCGRIDS is currently designed to evaluate meteorological phenomena on the meso-alpha scale (200-2,000 km) or larger, the use of the SHARP Workstation in concert with individual gridpoint data can be useful into the meso-gamma scale (2-20 km). For example, Huston (1993) explained two regimes of radar-estimated storm motion: 230° at 20 knots over southern Idaho, and 300° at 20 knots over northwestern Montana. These motions, when compared to the low-level inflow, can dictate storm-type (i.e., pulse-type, multicell, etc.) and produce varied hodographs which the author alluded to. For example, if the mean low-level flow below the lifted condensation level were 200° at 15 knots, the storm-relative inflow would vary accordingly for the two storm motion regimes described above. Using the mean wind as the storm motion, which neglects propagation or new cell development flanking the mean wind, the storm relative inflow would be approximately 90° at 10 knots and 150° at 28 knots over extreme southwestern and northwestern Montana, respectively. These varying inflow environments alter the storm structure drastically and longer-lived storms, with preferable low-level helicity values, are achieved within the environment over northwestern Montana. In addition, the 150° storm-relative inflow would have been advecting along the θe ridge into the storm, providing maximum latent instability.

PCGRIDS, in concert with the SHARP Workstation, can help in forecasting the changes to the mean flow over a given period and aid the meteorologist in determining a storm motion for modifying a hodograph. The 850-400 mb mean wind ($\approx$ 0-5.5 km AGL) compares well with the two storm motion vectors over southern Idaho and northwestern Montana, especially the initial analysis (Figs. 5 and 6). Through the 12-hour period, note the change to a more westerly component over southern Idaho and the intensification of the 290-300° wind in northwestern Montana. However, this provides a good first guess on mean storm motion (neglecting cell development) over a given region and can also be used as input into the SHARP Workstation. Therefore, although PCGRIDS is intended for larger scales than thunderstorms, data for these spacial scales can be "roughly" extracted to provide some insight into changing environments.

Discussion

Using the SHARP Workstation and PCGRIDS to analyze not only planar views of the atmosphere (i.e., x-y), but three-dimensional profiles, can no doubt improve forecast process and quality. It is this new ability to quickly assess the vertical and horizontal structures of various meteorological parameters, both spatially and temporally, in a matter of minutes that is very useful when utilized. In concert with theory, the forecast funnel has been made easier and more efficient than in years past, as new tools allow a more detailed assessment of the atmospheric environment. It is these tools, now being brought forth through the modernization, which we must use and integrate to gain a better understanding of the three-dimensional structure (and processes) of the atmosphere on a daily basis. Through this understanding comes improved public products.

Man masters nature not by force but by understanding.

-Jacob Bronowski

References

Keyser, D., and M. A. Shapiro, 1986: A review of the structure and dynamics of upper-level frontal zones. *Mon. Wea. Rev.*, **114**, 452-499.

Huston, M. W., 1993: Post-analysis of a severe weather event in northwest Montana using the SHARP workstation and PCGRIDS. *NOAA/NWS Western Region Technical Attachment, 93-27.*

Hart, J. A., and J. Korotky, 1992: A Skew-T/Hodograph Analysis and Research Program for the IBM and Compatible PC. NOAA/NWS/ERCP-13MC.

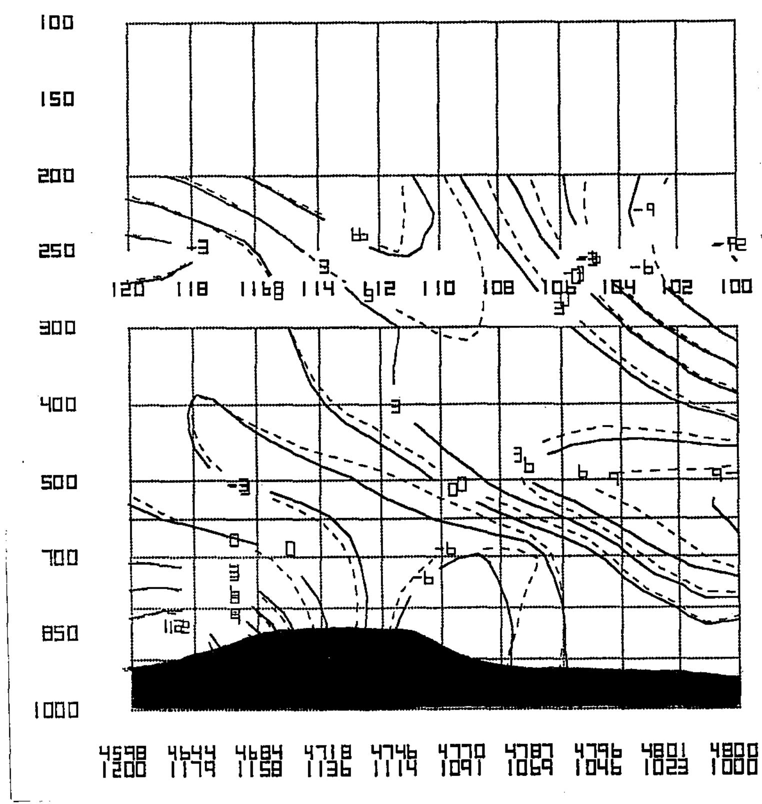


Figure 1. Vertical cross section from 46°N 120°W - 48°N 100°W (near west-east, shown in Fig. 5) from the Eta model 12h forecast valid at 0000 UTC 17 May 1993. Solid lines represent total divergence (every $3x10^{-6}s^{-1}$), dashed lines represent ageostrophic divergence (every $3x10^{-6}s^{-1}$).

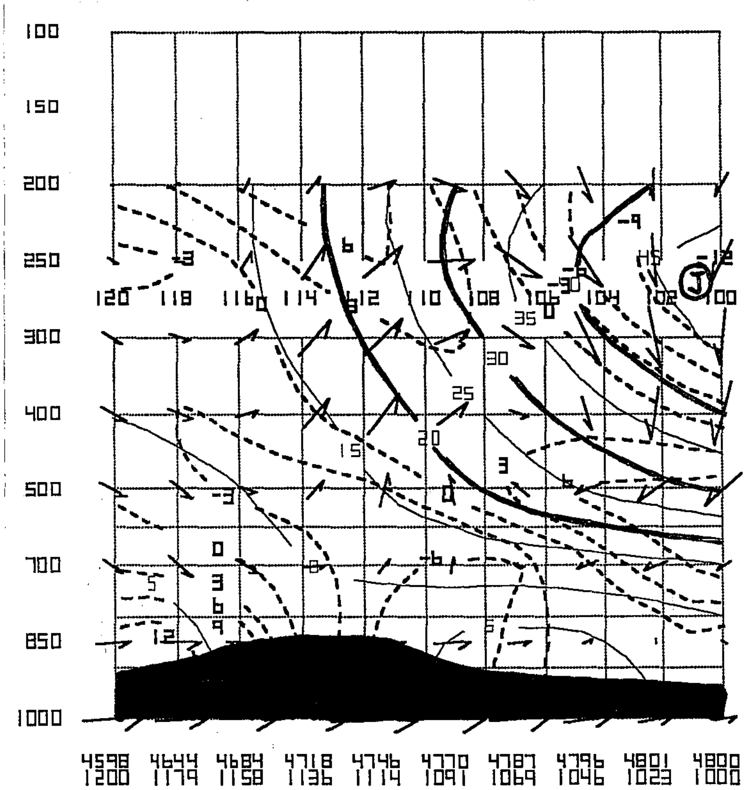


Figure 2. Same as Fig. 1, except solid lines represent total wind (m/s), dashed lines total divergence (every $3x10^{-6}s^{-1}$), and arrows are secondary circulation vectors using AGEO and VVEL from PCGRIDS.

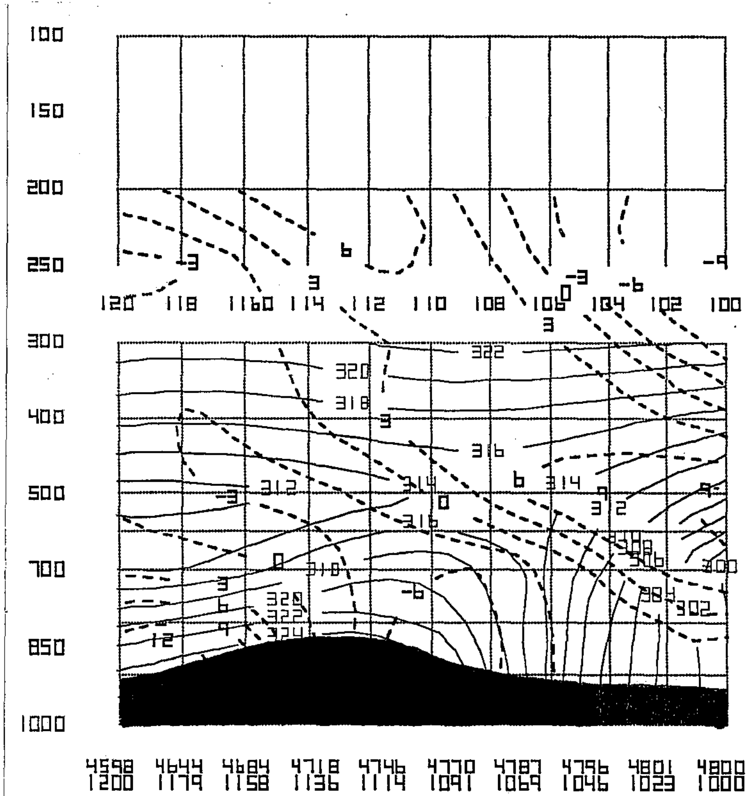


Figure 3. Same as Fig. 1, except solid lines are equivalent isentropes (every 2K) and dashed lines are total divergence (every $3x10^{-6}s^{-1}$).

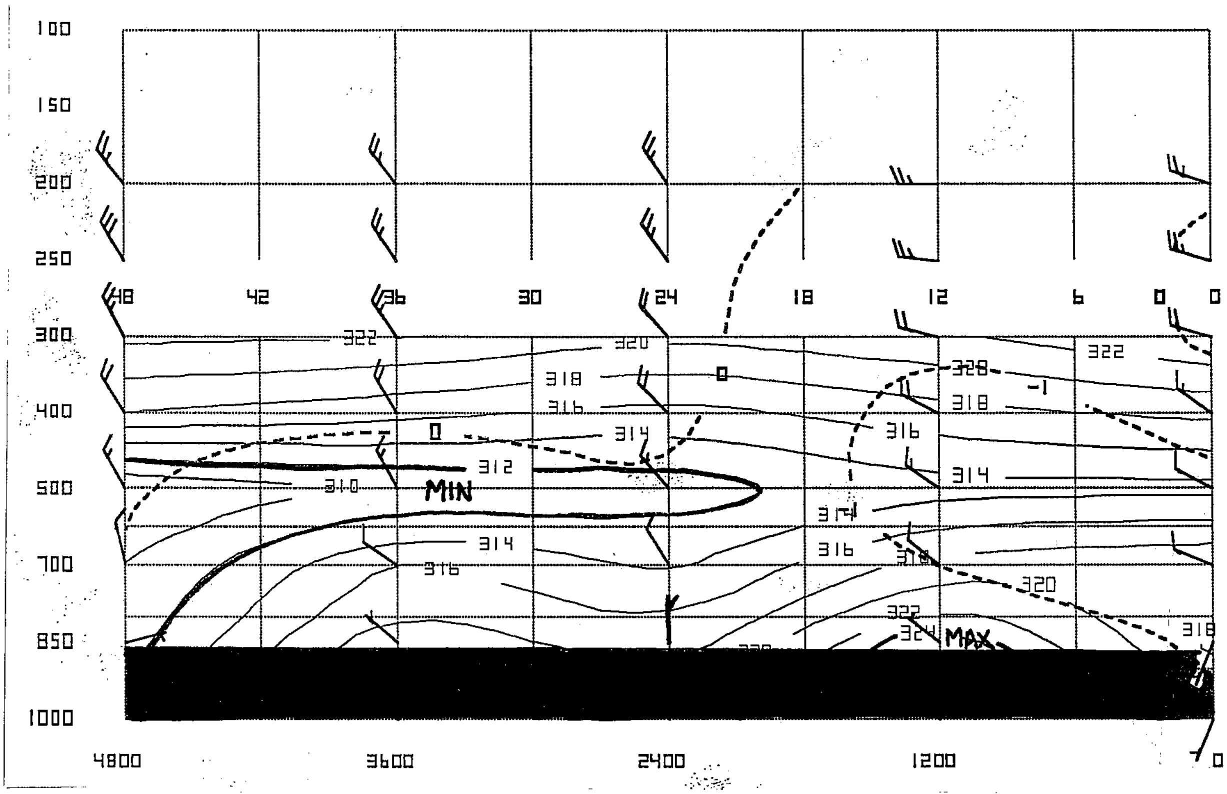
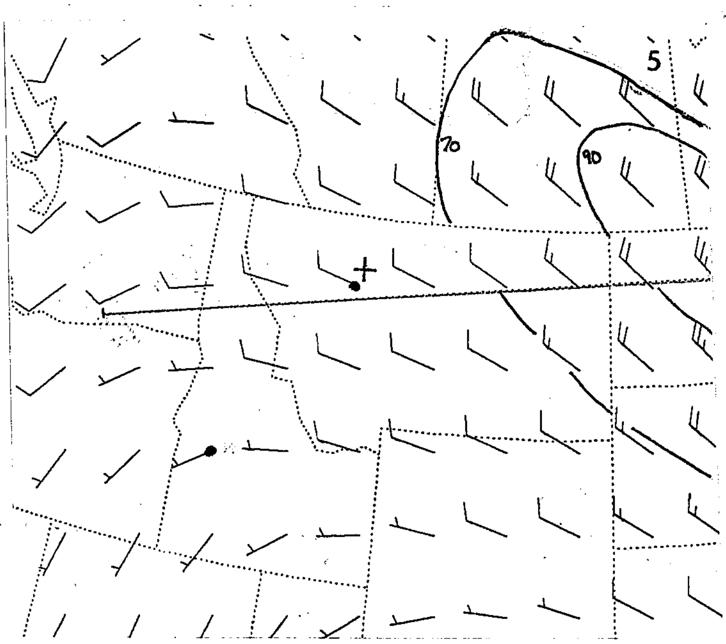
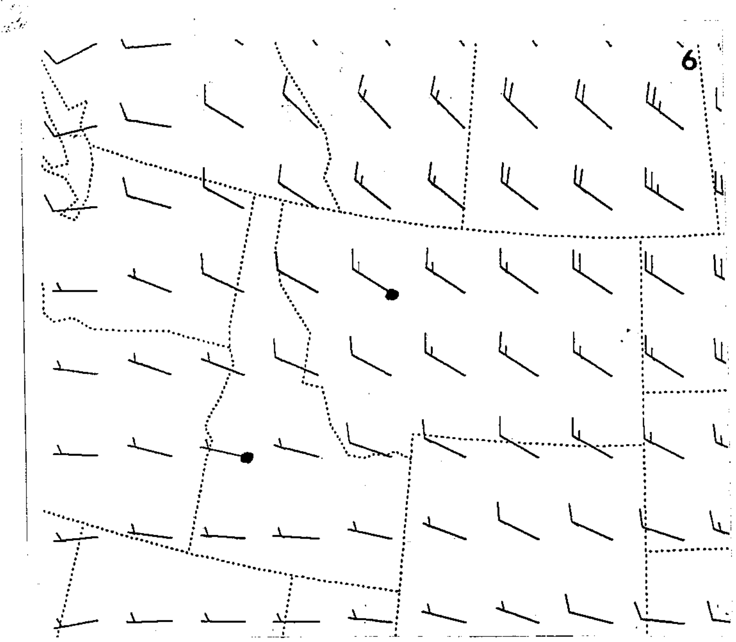


Figure 4. Time vs. height cross section at 48°N 112°W (shown in Fig. 5) for 0-48 hours from the Eta model initialized 1200 UTC 16 May 1993. Solid lines represent equivalent isentropes (every 2K), winds plotted in knots in standard X-Y convention, and dashed lines represent vertical velocity (every 1 ub/s). MIN (MAX) indicates mid-level (low-level) θe minimum (maximum).





Figures 5 and 6. 850-400 mb mean wind (m/s) from the Eta model for the initial analysis at 1200 UTC 16 May 1993 (Fig. 5) and the 12-h forecast valid 0000 UTC 17 May 1993 (Fig. 6). Mean wind is standard weighted mean using 850, 700, 500, and 400 mb winds. Cross indicates time section position (Fig. 4) and solid-dot line indicates orientation of cross section in Figs. 1-3. Solid contours indicate 250 mb jet core in knots.