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# AN EXAMPLE OF THE EFFECT OF LOCAL PRESSURE TENDENCY ON VERTICAL MOTION IN ISENTROPIC COORDINATES

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At 0000 UTC 19 February 1993, anticyclonic westerly 500 mb flow was over Montana with a weak ridge of high pressure over the Pacific Northwest (Fig. 1). At the surface, a high pressure ridge associated with an arctic airmass (Fig. 2) covered the plains of eastern Montana. The sounding for Great Falls at 1200 UTC 19 February showed a nearly saturated airmass up to 400 mb with the depth of the arctic airmass about 8,000 feet (Fig. 3).

The 24 h forecast from the Eta model, valid 0000 UTC 20 February (Fig. 4) suggested backing 500 mb flow over the Pacific Northwest with a shortwave extending from northern Idaho to central Montana. At the surface, the arctic airmass was forecast to continue over the plains of eastern Montana with a strong upslope surface pressure gradient over the northern lee slopes of Montana (Fig. 5).

With the forecast of southwesterly flow aloft over the arctic airmass, the weather situation looked like a good candidate for utilizing forecasts of isentropic surfaces within PCGRIDS. Cross-isobar flow towards lower pressures over northwestern Montana is indicated by the 24 h forecast of the 285K isentropic surface from the Eta model, valid 0000 UTC 20 February (Fig. 6). This implies upward isentropic vertical motion over this area. In fact, in this area, upward vertical motion of 1 to 4 $\mu b\ s^{-1}$ (Fig. 7) may be attributed to advection of pressure on the isentropic surface.

Based on isentropic upglide of the moist airmass, the strong low-level upslope winds, and the approach of the shortwave from the southwest, a Winter Storm Warning for heavy snow was issued for the northern lee slopes of the Rocky Mountains in Montana for the period 1200 UTC 19 February to 0000 UTC 20 February. Although snow did fall during the warning period, snowfall accumulations of an inch or less did not satisfy the heavy snow criteria.

## Why did heavy snow not materialize?

At 0000 UTC 20 February, the airmass was still nearly saturated up to 400 mb, while the depth of the arctic airmass was around 5,000 feet (Fig. 3). From 1200 UTC 19 February to 0000 UTC 20 February, the depth of the arctic airmass lowered from 8,000 feet to 5,000 feet.

Recall that the equation for vertical motion in isentropic coordinates is

$$\omega = \underset{A}{\frac{\partial P}{\partial t}_{\theta}} + \underset{B}{\overline{V}\cdot\nabla_{\theta}P} + \underset{C}{\frac{\partial p}{\partial \theta}\frac{d\theta}{dt}}$$

where term A is the local pressure tendency, term B is the advection of pressure on an isentropic surface, and term C incorporates diabatic processes.

During the period from 1200 UTC 19 February to 0000 UTC 20 February, the height of the 285K isentropic surface lowered from about 680 mb to 750 mb (Fig. 3). PCGRIDS can be used as a rough approximation in evaluating the contribution of local pressure tendency to vertical motion. For the period 1200 UTC 19 February to 0000 UTC 20 February, the contribution to vertical motion of the local pressure tendency of the 285K isentrope (forecast by the Eta model) is shown in Fig. 8. Over the 12 hour period, this computes to a value between 1 and 2 $\mu b\ s^{-1}$ downward vertical motion, while the advection of pressure term contributed to upward vertical motion at Great Falls. Note that these are 12 hour values in comparison to the instantaneous values of Fig. 6. Even though it is difficult to compare terms A and B in an exact quantitative sense, qualitatively term A is partially offsetting term B.

The contribution of term C is also difficult to judge. The soundings from Great Falls showed a nearly saturated airmass from the surface through 400 mb, suggesting the possibility of upward vertical motion due to diabatic heating from latent heat release. However, this effect alone would have induced the lowering of the isentropic surface due to diabatic heating.

Another factor that may have played an important role in the lack of heavy snow was the low liquid water content of the airmass. Even though the airmass was nearly saturated up to 400 mb, precipitable water values for the soundings from Great Falls were only about .25 inch.

Also, observed values of terms A and B may have been more or less than those forecast. In this situation, the observed downward vertical motion of the 285K isentropic surface at Great Falls of 1-2 $\mu b\ s^{-1}$ was greater than the 0-1 $\mu b\ s^{-1}$ downward vertical motion forecast by the Eta model (Fig. 8).

In this case, upward vertical motion along the isentropic surface by the advection of pressure may have been reduced by local pressure tendency increases such that the total vertical motion only supported light snow rather than heavy snow.

Although the advection term is typically the dominant term of the three (Wilson, 1985), forecasters need to keep in mind the effect of local pressure tendencies, which can also be evaluated utilizing PCGRIDS, and diabatic processes. Although this was a case where upward vertical motion was reduced by a local pressure tendency increase, upward vertical motion could be enhanced by a local pressure tendency decrease, such as with a deepening arctic airmass.

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## References


Pike, David, 1993: A Review of Isentropic Analysis with Applications to PCGRIDS, Western Region Technical Attachment No. 93-14.

Wilson, L. J., 1985: Isentropic Analysis - Operational Applications and Interpretation, Third edition. Edited for Training Branch by James Percy. Atmospheric Environment Service, Canada, 35p.


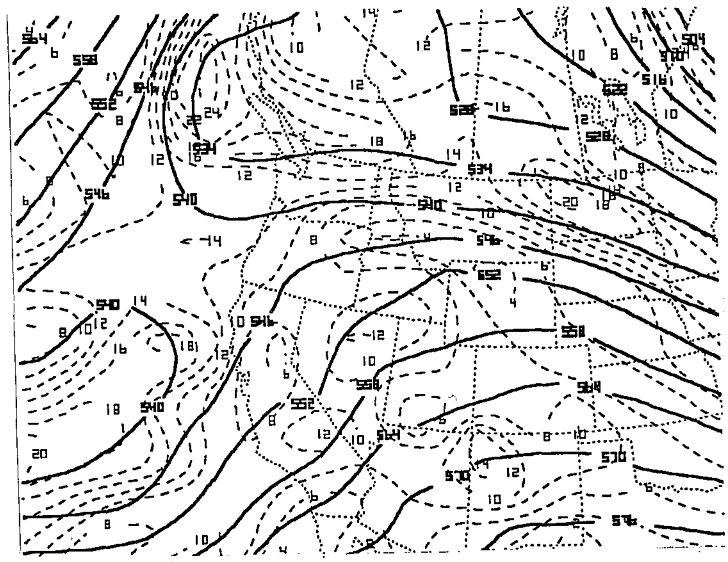

Fig. 1 00 h 0000 UTC 19 February 1993 Eta 500 mb heights (dam) solid and absolute vorticity ($10^{-5}$ $s^{-1}$) dashed.

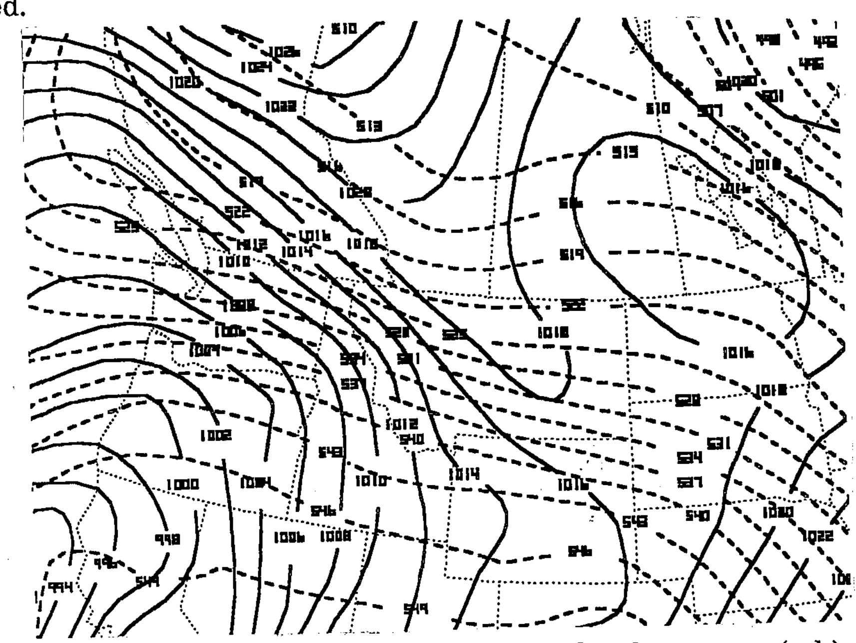

Fig. 2 00 h 0000 UTC 19 February 1993 ETA mean sea level pressure (mb) solid and 1000-500 mb thickness (dam) dashed.

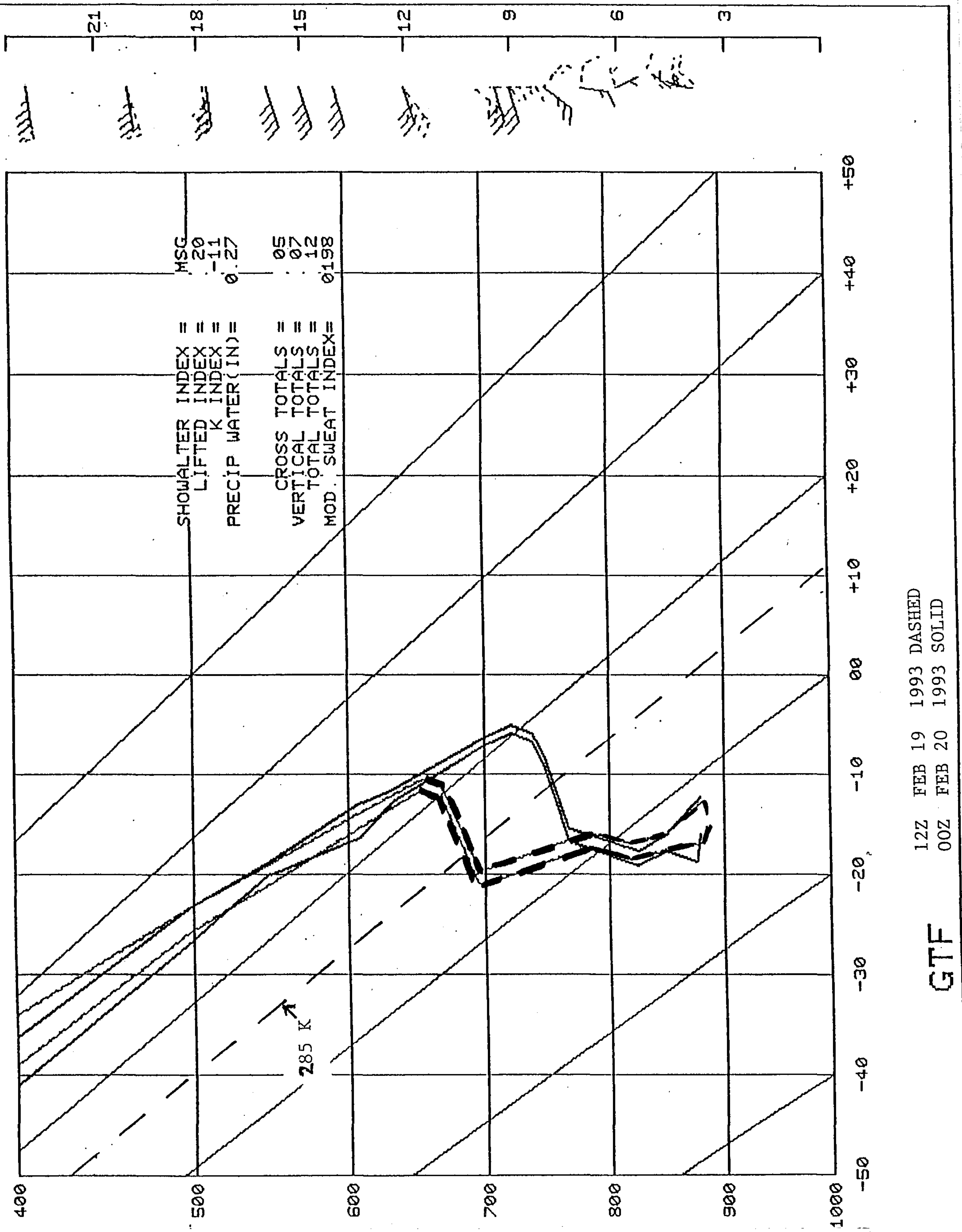


Fig. 3 Great Falls, MT (GTF) sounding at 1200 UTC 19 Feb 1993 (solid) and 0000 UTC 20 February 1993 (dashed).

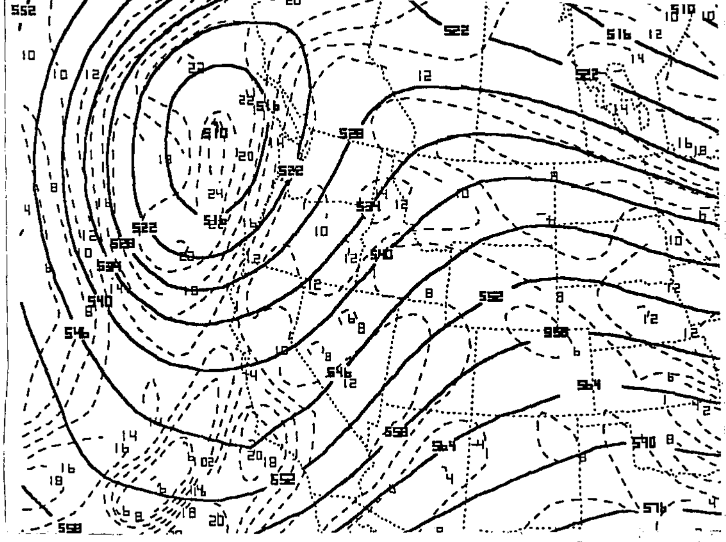

Fig. 4  24 h 0000 UTC 19 February 1993 Eta 500 mb heights (dam) solid and absolute vorticity ($10^{-5}$ $s^{-1}$) dashed.

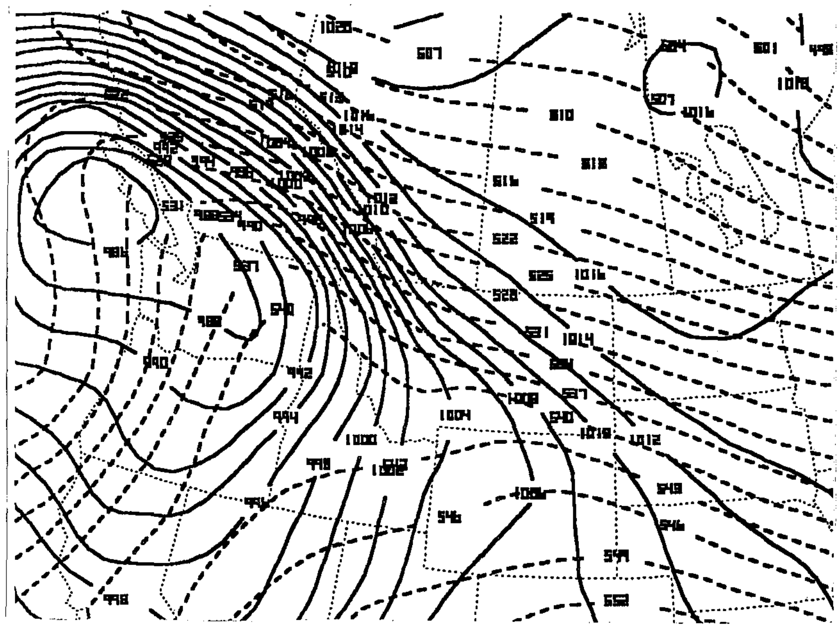

Fig. 5  24 h 0000 UTC 19 February 1993 Eta mean sea level pressure (mb) solid and 1000-500 mb thickness (dam) dashed.

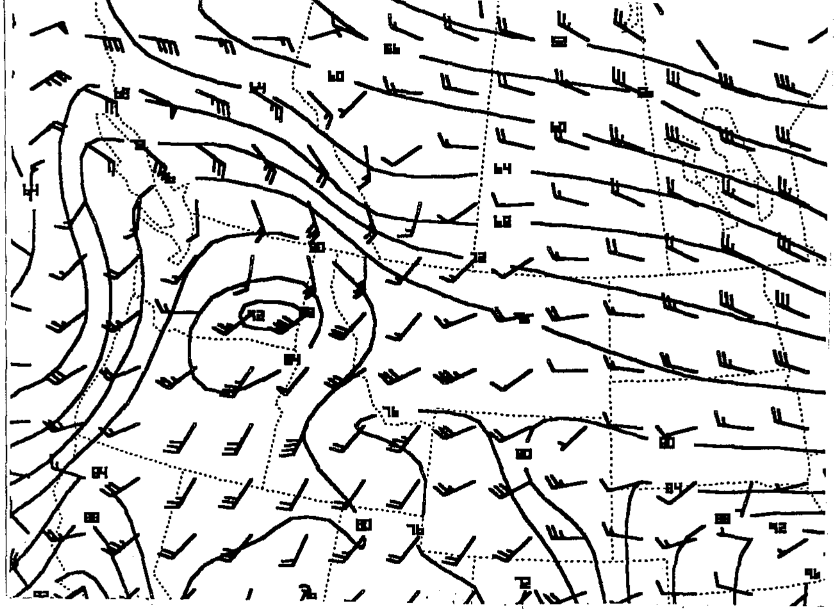

Fig. 6 24 h 0000 UTC 19 February 1993 Eta 285K isentropic surface, pressure ($10^1$ mb) solid and wind (knots).

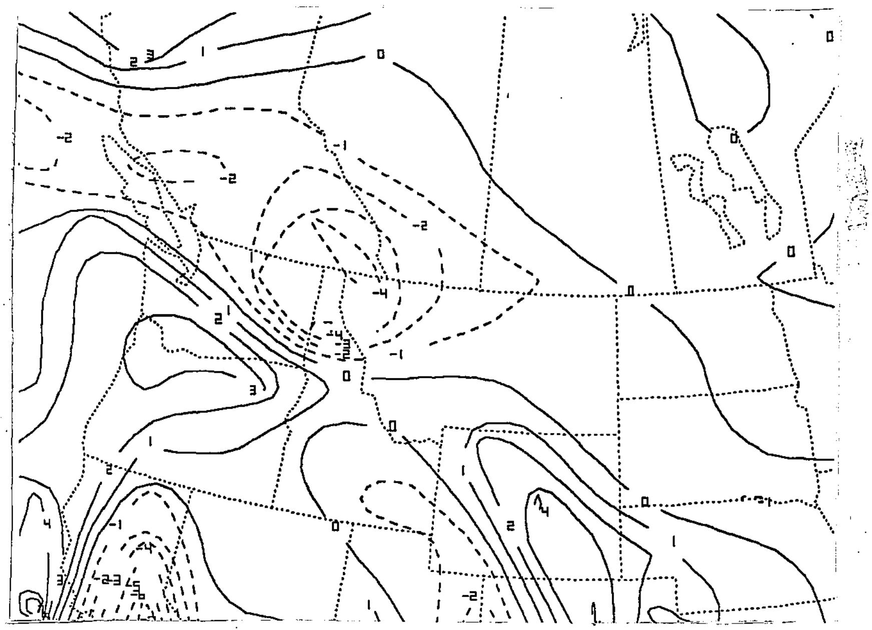

Fig. 7 24 h 0000 UTC 19 February 1993 Eta advection of pressure on the 285K isentropic surface $\mu b\ s^{-1}$

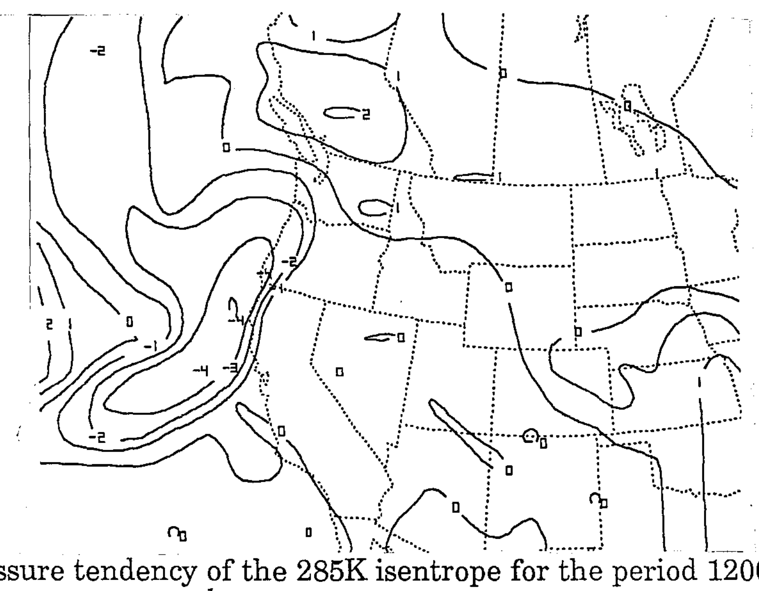

Fig. 8 Local pressure tendency of the 285K isentrope for the period 1200 UTC 19 February to 0000 UTC 20 February ($\mu b\ s^{-1}$), from 0000 UTC 19 February 1993 Eta.