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DIVERGENCE AND DIFFLUENCE ARE NOT SYNONYMS

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1. Introduction

One of the main tasks operational meteorologists face in day to day forecasting is determining the sign of the vertical velocity. In situations where the dynamic forcing for vertical motion is weak, forecasters often attempt to determine this parameter through a kinematic approach. This method requires knowledge of the horizontal velocity divergence.

Until the advent of advanced data sets, forecasters have not had the tools necessary to obtain an accurate assessment of the horizontal velocity divergence. The diagnosis of diffluence has, on the other hand, been quite easy. Consequently, diffluence and horizontal velocity divergence are often considered as the same thing, with areas of diffluent flow assumed to be divergent as well. Diffluence does NOT automatically imply divergence and making the assumption that it does can lead to incorrect estimates of the implied vertical motion.

2. Discussion

Although the concepts of divergence and diffluence have existed for a long time (e.g. Petterssen 1956), confusion still remains in the application of these ideas in the operational setting. To see how horizontal velocity divergence and diffluence differ, it is helpful to use the natural coordinate system. In two dimensions, this is an orthogonal coordinate system with the s-axis parallel to the flow at each point (positive downstream) and the n-axis perpendicular to it with positive values to the left of the flow looking downstream. Following Saucier (1955), with V representing the magnitude of the horizontal velocity vector (wind speed) and beta the wind direction of the horizontal velocity, divergence can be written as

$$Divergence = \frac{\partial V}{\partial s} + V\frac{\partial \beta}{\partial n} \quad (1)$$

The first term in (1) is called the stretching term and describes how the wind speed is changing along the s-axis (streamline). If the wind speed is increasing downstream then this term is positive (also known as speed divergence). The second term in (1) is the spreading term and describes how the wind direction is changing along the n-axis (perpendicular to the flow). If the flow spreads out downstream (is diffluent), then this term is positive (V is always greater than zero).

From equation (1) it is obvious that diffluence is only a part of the total horizontal divergence. In evaluating horizontal velocity divergence, one must consider not only the pattern of the streamlines but also the structure of the wind speed along the streamlines. What makes the evaluation difficult is that often times the two terms in (1) oppose each other, that is, in areas where the streamlines spread out downstream the wind speed decreases. Consequently, an accurate quantitative (and often even a qualitative) assessment of the divergence using streamlines and isotachs is next to impossible.

Instead of using streamlines and isotachs, many forecasters use geopotential height charts to infer horizontal velocity divergence. To do this, they look for areas where the geopotential height lines spread out looking downstream. These areas are labeled "diffluent flow," and it is incorrectly assumed that horizontal divergence is automatically occurring there. In these cases little attention is given to the stretching term in equation (1).

What makes this method suspect is that when forecasters use geopotential heights to deduce the wind vectors they are often assuming that the flow is geostrophic. Thus, where geopotential height contours spread out (diffluent geostrophic flow) there must be, by definition, geostrophic speed convergence. Hence the stretching term in (1) is negative and the spreading term is positive. Which has the greater magnitude? It's anybody's guess! Furthermore, assuming a constant Coriolis parameter, the geostrophic wind is nondivergent! So any use of the geostrophic wind to determine horizontal velocity divergence is just not theoretically sound.

A glaring example showing how diffluent flow is not necessarily divergent is shown in Figure 1. Shown are the NGM geopotential heights and divergence at 500 mb created using gridded model output. Note how the geopotential height lines ("geostrophic streamlines") spread out over the area extending from eastern Nebraska to western Tennessee. This is the area of diffluent flow. The dashed lines in this same area are isopleths of the horizontal divergence of the actual wind. Note that the values are negative (denoted by dashed isolines) which means that horizontal convergence is occurring here!

3. Summary

This paper has shown that diffluence and divergence are not synonymous. Diffluence is only a part of the overall divergence and it is not always a good idea to assume that areas of diffluent flow correspond to areas experiencing horizontal divergence. In cases of very strong diffluence indeed horizontal divergence may exist. But applying this rule of thumb to all cases is asking for trouble.

Unfortunately, attempting to determine divergence from standard graphics available to most forecasters is difficult. But there is hope. New gridded data sets currently available on the DARRRE-II work station at the WSFO in Denver allow forecasters to create both analyses and forecasts of horizontal divergence from a variety of sources. Plan views on various isobaric and isentropic surfaces as well as vertical cross sections of divergence are available to forecasters and have proven quite useful in everyday forecasting. These types of data sets will be available in the AWIPS-90 era to all NWS field offices.

4. References

Petterssen, S., 1956: Weather Analysis and Forecasting, Vol. 1. McGraw Hill, New York, NY, 428 pp.

Saucier, W. J., 1955: Principles of Meteorological Analysis. Univ. of Chicago Press, Chicago, IL.

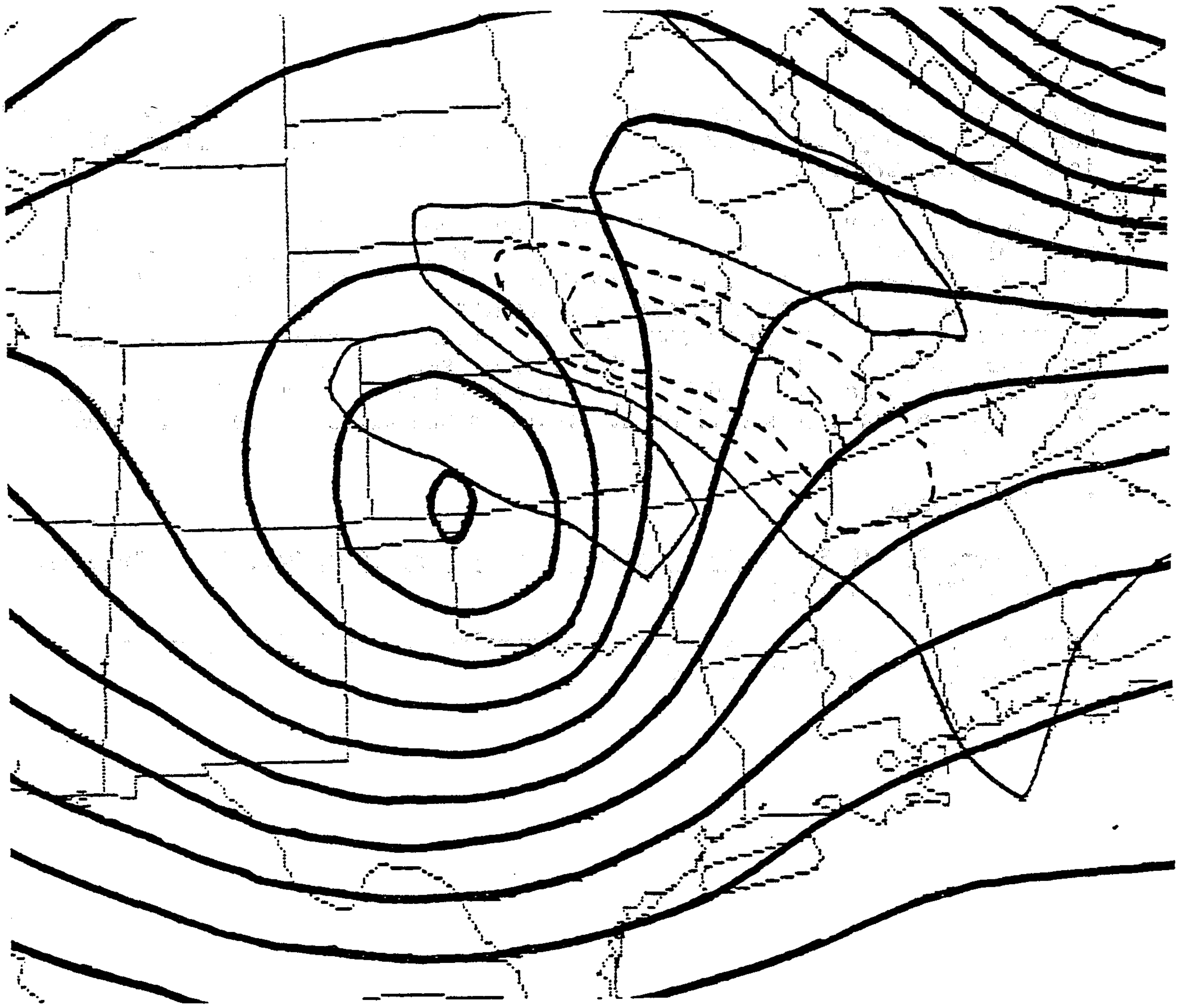

Figure 1. NGM geopotential heights (thick lines, gpm) and isopleths of divergence (thin lines, $*10^{-5}$ sec^{-1}). Dashed thin lines denote negative divergence or convergence.