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 (Holton 1979). This method requires knowledge of the horizontal velocity divergence.

Until the advent of advanced datasets, forecasters have not had the tools necessary to quickly 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 to be the same thing, with areas of diffluent flow assumed to be divergent as well. Diffluence does NOT automatically imply divergence and making that assumption 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 right of the flow looking downstream. Following Saucier (1955), with V representing the magnitude of the velocity vector (wind speed) and α the wind direction in radians (degrees $\times$ $\pi/180$), the horizontal velocity divergence can be written as

$$\text{Divergence} = \frac{\partial V}{\partial s} + V\frac{\partial \alpha}{\partial n} \qquad (1)$$

The first term in (1) is called the stretching (or speed divergence) 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 (or the directional divergence) term and describes how the wind direction is changing along the n-axis (perpendicular to the flow). If the flow spreads out downstream (diffluence), then this term is positive (V is always greater than zero).

From (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 oftentimes 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 (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 not theoretically sound.

A glaring example showing how diffluent flow is not necessarily divergent is depicted 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 region 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 which means that horizontal convergence is occurring here!

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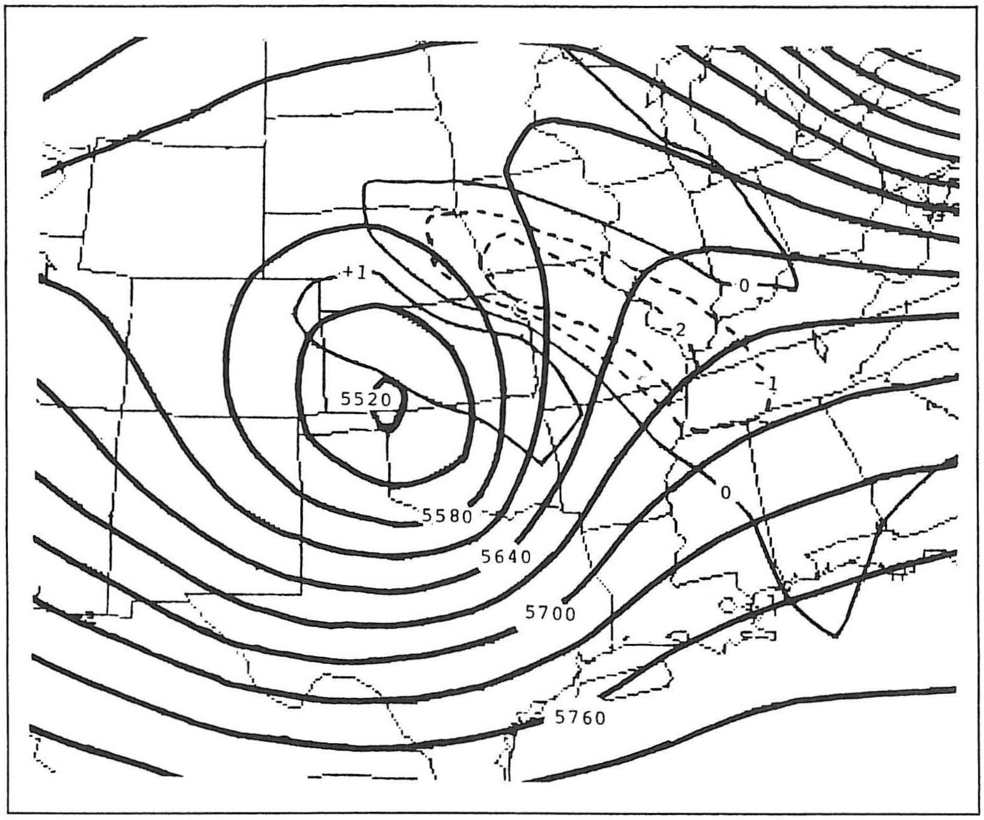

Fig. 1. NGM geopotential height (thick lines, gpm) and isopleths of divergence (thin lines, $*10^{-5}$ sec $^{-1}$). Dashed thin lines denote negative divergence or convergence.

References

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