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NOTE ON ADVECTIVE PRESSURE CHANGES

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MANY of the recent contributions to weather analysis and forecasting have involved a consideration of the pressure-tendency component that is due to horizontal advection in the lower levels. This is particularly true in the case of methods for computing the 3-km. pressure tendency from the surface tendency. The present note deals with a simple scheme for finding this particular component.

Analysis and forecast procedures are often based principally upon the surface chart and one upper-level chart, e.g., the 3-km. chart. Indeed, the use of the surface chart with an upper-level chart superimposed upon it in some not too conspicuous manner is quite convenient. Assuming that we have the data available in some such form, the following procedure should prove to be an easy way to compute the effects of horizontal advection between the surface and the adopted upper level without having to use the temperature pattern.

There is considerable agreement among meteorologists that the horizontal advection effects in the lower layers are much more important than the divergence and vertical motion effects, and therefore contribute the most important part of the total pressure tendency due to processes in the lower layers.

From J. Bjerknes' pressure-tendency equation, we have for the horizontal advective pressure-tendency component at any level h,

$$\left(\frac{\partial p}{\partial t}\right)_h = -\int_h^\infty g\boldsymbol{V}\bullet\nabla_2\rho dz. \qquad (1)$$

The pressure change at the surface due to advection between the surface (s) and an upper level (u) is therefore

$$\left(\frac{\partial p}{\partial t}\right)_s^u = \int_s^u \boldsymbol{V}\bullet\nabla_2(-g\rho)dz$$

which, by using the hydrostatic equation $\partial p/\partial z = -g\rho$, and interchanging the order of the differentiations, may be written

$$\left(\frac{\partial p}{\partial t}\right)_s^u = \int_s^u \boldsymbol{V}\bullet d(\nabla_2 p) = \boldsymbol{V}_m\bullet\nabla_2(p_u - p_s), \qquad (2)$$

in which $\boldsymbol{V}_m$ is the mean velocity between (s) and (u) with respect to the horizontal pressure gradient. Except under unusual conditions, the wind may be considered represented with sufficient accuracy by the geostrophic wind

$$\boldsymbol{V}_G = -\frac{\alpha}{l}\nabla_2 p \times \boldsymbol{k},$$

where $\boldsymbol{k}$ is a unit vertical vector, α the specific volume, and l the Coriolis parameter; and as a preliminary approximation we may take

$$\boldsymbol{V}_m = \frac{1}{2}(\boldsymbol{V}_s + \boldsymbol{V}_u).$$

The result of substituting these expressions into (2) will be the more accurate, the more nearly $\mathbf{V}_G$ varies linearly with height; the expression obtained is

$$\left(\frac{\partial p}{\partial t}\right)_s^u = U_u\left(\frac{\partial p}{\partial x}\right)_s - V_u\left(\frac{\partial p}{\partial y}\right)_s \qquad (3)$$

where

$$U_u = \frac{\alpha_s + \alpha_u}{2l}\left(\frac{\partial p}{\partial y}\right)_u, \quad V_u = \frac{\alpha_s + \alpha_u}{2l}\left(\frac{\partial p}{\partial x}\right)_u.$$

One may interpret equation (3) as follows: The upper-level isobars "steer" the lower-level (surface) isobars with a velocity which equals that of the geostrophic wind computed from the upper-level isobaric pattern on the assumption that the specific volume at that level is the arithmetic mean of the values at the two levels.

Although the geostrophic wind has been used in the above discussion, it may be that the use of the gradient wind would give better results in computing the steering effect; a more accurate expression for $\mathbf{V}_m$ might also be derived. A study along these lines would be of considerable interest and value but is too complex to treat in this paper.

Some extensions of this idea might also be possible; e. g., if a series of charts for various levels were to be used, the effects of horizontal advection could be summed up for the whole column above the surface by allowing each level to steer the next lower level. The greater the number of working levels, the greater the accuracy.

It is well to point out that above about three kilometers the pressure patterns at successive levels vary comparatively little from one another, yet good pressure tendencies are observed at these upper levels. The author interprets this to mean that at these higher levels the other terms in the tendency equation are of greater importance.