Reply

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The first comparison shown in the comments differs from the tests used by Pandolfo (1966) in two respects.

First, Kapoor and Sundararajan make use of Swinbank's (1964) wind measurements at the 0.5-m level. These are used in the computation of vertical wind differences, and in the deduction of a basic non-measured quantity u^* .

Use of the 0.5-m level wind measurements was avoided in the analysis by Pandolfo on the basis of Swinbank's (1964, 1966) observations that light winds, which are obviously more prevalent at 0.5-m level, especially under conditions of small L (precisely the region where the theoretical and calculated K_H/K_M values differ largely in Fig. 1 of Kapoor and Sundararajan), introduce two kinds of error effects.

The first effect would lead to overestimates of the shear, while the second would lead to underestimates. The fact that the errors tend to compensate is of no consolation to the careful analyst. Without quantitative estimates of each effect, he is incapable of even estimating the quality (sign) of the resulting error in computed vertical wind differences. No attempt is made to estimate the effects of these errors on their computed H_E by Kapoor and Sundararajan. Nor is any attempt

made to correct u_M^* , u_M^{*2} or L_M for these errors. They do apply, however, a correction for yet another source of error in u_M^{*2} and L_M .

For these reasons, omission of the 0.5-m anemometer data from these analyses seems desirable. The appropriateness of Kapoor and Sundararajan's analytical procedure in tests of the consistency of a theory with observations or with other theories can also be questioned. This method of analysis is limited in validity to tests of the *internal* consistency of a given theory, unless *independent* eddy flux and profile measurements are available. It has, in addition, the disadvantage that the significance of observational scatter is obscured. Both these points were made in Pandolfo (1966), but they apparently need restatement and amplification.

Thus, a second difference between the comparison tests is that the quantity u^* , which can only be deduced from profile observations by use of a profile theory, appears in the first Kapoor and Sundararajan figure in both coordinates. This deduced quantity does not appear in the coordinates of the Pandolfo test graphs, except in Figs. 7 and 8, in the coordinate L_M . The conclusion drawn from these figures, namely, that the quantities represented as the other coordinate are

essentially constant with L , is not invalidated by undeterminable errors of estimate in u_M^{*2} and therefore L_M .

There are no simultaneous independent measurements of u^* in Swinbank's (1964) observations; such measurements are in Swinbank's (1955) observations. Therefore, these earlier observations were cited in Pandolfo (1966). Kapoor and Sundararajan, following Swinbank (1964), use an adiabatic wind profile law, plus an assumption that the drag coefficient is constant with stability, to deduce u_M^* . Pandolfo used a diabatic wind profile law, with simultaneous temperature difference observations, to deduce u^* . The two sets of deduced u^* are inconsistent with each other, and this was clearly stated in the original paper.

Kapoor and Sundararajan's estimates of the relative magnitude of the stratification effect on u_M^* when compared to a similar effect of K_H/K_M are irrelevant. Independent estimates of this effect on $u_{0.5}$ and hence u_M^* would be pertinent if available. Unfortunately, no such estimate, independent of a diabatic wind profile theory, can be made (Swinbank, 1964), although Swinbank made such an estimate based on the exponential wind profile law.

Fig. 7 (Pandolfo, 1966) shows the exponential wind profile to be inconsistent both with Pandolfo's theory and the observations. One might conclude that both sets of deduced u^* have equal claim to being designated "observations." Kapoor and Sundararajan refer to actual drag coefficient measurements but give no specific citations. There are none in the Swinbank (1964) paper. However, from the results of the Great Plains Observational Program (Lettau and Davidson, 1957) and the discussion of Lettau and Vehrencamp in the same reference, one could easily conclude that the dependence of the drag coefficient on stratification was obscured by observational error.

The second comparison figure which Kapoor and Sundararajan show demonstrates that the wind profile (Pandolfo, 1966) is inconsistent with the KEYPS profile, when an empirical constant given by Panofsky in the discussion (1966) of Swinbank's paper is used. The KEYPS profile is described by Kapoor and Sundararajan as giving good fit to Swinbank's observations. This claim is disputed by Swinbank (1966). Moreover, the graph from which goodness of fit is judged so differently results from an analysis in which a third set of deduced u^* is used. The value of the constant, $\gamma=7$, is indeed given by Panofsky as providing the best fit to the Swinbank (1964) observations, in the report cited in Pandolfo (1966).¹ The value $\gamma'=18$, used by Kapoor and Sundararajan, was obtained as a best fit to earlier observations, as stated by Panofsky (Swinbank, 1966).

A final point requires clarification. The consistency of the constant values, $(z/L)_T$ and c , as derived both

from theory and empirical evaluation, is offered in Pandolfo (1966) as supporting the validity of the entire set of hypotheses on which the newly derived laws are based. This consistency is important in the confirmation of two important assumptions other than that of the equivalence of Ri and z/L . These are that the Monin-Obukhov wind profile, and the Priestley temperature profile are each valid at the transition value $(z/L)_T$. Thus, the consistency of the constant values leads Pandolfo to conclude that the K_H/K_M formulas are valid over the entire range for which the two basic profile laws from which they are derived are valid. This range has generally been considered to include at least conditions away from $(z/L)_T$. The fact that the theoretical values are derived from continuity conditions at $(z/L)_T$ is not relevant. The degree of agreement of these values with experimental values obtained over a wide range of stability conditions is the crucial point.

The practical equivalence of Ri and z/L , once L is assumed constant with height, has been shown in Swinbank's observations to hold up to values about 50 times the transition value [see Fig. 1, Pandolfo (1966)]. It should be noted that the extreme conditions included in this data sample coincide with wind shears so small (Ri so large) that even Swinbank's excellent instruments are not capable of allowing determination of Ri with relative accuracy greater than about 20%. Kapoor and Sundararajan ignore these data. Priestley's (1960) data extended to Ri values 5–10 times the transition value, without showing systematic departures from equivalence in this range of stability. They cannot be used to dispute the equivalence at greater values.

Kapoor and Sundararajan have not critically reviewed Pandolfo's analysis procedure, nor pointed out specific deficiencies in the interpretation of the interpolation test results, and have further chosen to ignore the observational evidence in Fig. 1 of the original paper. Therefore, a major conclusion of that paper has not yet been invalidated. This is, that over the range of unstable Ri for which observations are available, and within the accuracy of these observations, Ri and z/L are practically equivalent.

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¹ Blackadar *et al.*, 1965: Final Rept., Contract No. AF (640)-6641, prepared for AFCRC, Air Force Cambridge Research Center.