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A Note on the Diurnal Wind Variation

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In recent correspondence HARRIS (1960) suggested that the discrepancy between observed winds and those computed from a theoretical model for the diurnal wind variation (HALTINER 1959) may be due, at least in part, to the diurnal pressure variation which had been omitted in the theoretical model. In a reply (1960) the author provided an analytical solution for the diurnal wind variation resulting from a diurnal pressure variation with frictionless flow. The solution indicated that the diurnal wind variations due to corresponding pressure variations were similar to inertial oscillations, though a different period. With respect to the latter, it is found that where the friction force is large, inertial oscillations initiated by geostrophic deviations, other than those caused by friction, usually are quickly damped. Hence it might be expected that wind oscillations due to pressure variations would be suppressed in a similar manner. Nevertheless actual solutions were desirable to verify this inference and the purpose of this note is to report such results.

In addition it was desired to test a form for the coefficient of eddy viscosity suggested by some results of BLACKADAR (1959) who used the geostrophic departure method to determine the vertical and diurnal distribution of the eddy viscosity from a set of averaged wind observations for a 24 day-period. A harmonic analysis of the data (MCBRIDE 1960) showed that about six harmonics were required to fit the data accurately.

However, the general form of the distribution of eddy viscosity can be represented by the mean value as a function of height plus the first harmonic in which the amplitude and phase are also functions of height as follows:

$$K(z,t) = K_0\left\{10|z-5|^2 + 200 + [8(z-5)^2 + 175]\cos\left[\frac{2\pi}{24}t + \frac{(21-1.2z)\pi}{180}\right]\right\} \qquad (1)$$

Here the height z is in hundreds of meters, the time t in hrs, and K_0 is a constant governing the over all magnitude of the eddy viscosity. For a value of K_0 of 400 cm^2/sec, the following table indicates the general range of the eddy viscosity as represented by expression (1).

Height	2400 meters	500 meters	Surface
Maximum K(cm^2/sec)	2.75×10^6	1.5×10^5	3.3×10^5
Minimum K	3×10^5	10^4	3×10^4

In addition, values of K_0 of 800, 200, and 100 cm^2/sec were also used in the numerical integrations in order to determine if such differences in the mean magnitude of eddy viscosity made a significant change in the wind pattern.

The equations of motion which were integrated may be expressed as

Table 1

CASE	u_{min}(m/s)	t_{min}(C)	Alt(m)	u_{max}(m/s)	t_{max}(C)	Alt(m)	v_{max}(m/s)	t_{max}(C)	Alt(m)
A	— 2.2	0100C	200	2.5	0300C	800	9	0300C	425
B		similar to Case A							
C	— 2	0200C	240	1	0400C	50	8.2	0300C	600
D	— 1.35	1700C	240	3.5	2100C	800	9.2	2000C	600
E	— 1.6	0200C	240	2.8	0500C	800	10.7	0400C	600
F	— 1.4	1700C	240	5.0	2300C	800	10.5	2200C	600
Observed	— 3.5	0200C	300	5.5	0600C	700	15	0100C	500

* Only in Cases A and B was the integration performed for a period exceeding 24 hrs; in the other cases integration was stopped efter the maximum value of v had been reached.

$$\frac{\partial u}{\partial t} = f(v - \bar{v}_g) - \frac{1}{\varrho}\frac{\partial p'}{\partial x} + \frac{\partial}{\partial z}\left(K\frac{\partial u}{\partial z}\right)$$
$$\frac{\partial v}{\partial t} = -f(u - \bar{u}_g) + \frac{\partial}{\partial z}\left(K\frac{\partial v}{\partial z}\right) \quad (2)$$

Here p' represents the periodic part of the pressure; and $f\bar{u}_g$ & $f\bar{v}_g$, which are functions of height, give the mean pressure force with respect to time. The numerical integration method was the same as used earlier. The upper boundary of the layer was taken to be 2400 meters and the vertical height increment was 60 meters. A time increment of about two minutes was required to maintain computational stability.

The equations were integrated with (Case A) and without (Case B) the periodic pressure term, as well as with the other values of K_0, namely, 800 cm²/sec (Case C), 100 cm²/sec (Case D). Two additional cases were tried with $K_0 = 800$ cm²/sec (Case E) and $K_0 = 200$ cm²/sec (Case F), in which some indirectly determined values of the geostrophic wind were used instead of the measured values. The former were determined in such a way so as to minimize differences between the computed values of the two coefficients of eddy viscosity individually calculated from the x and y-equations of motion. Table 1 indicates the main results by giving the maximum and minimum values of computed and observed wind components, together with their times of occurrence.

It may be concluded from these experiments that the term representing the diurnal pressure variations made no significant difference in the diurnal wind variation in the friction layer. Secondly, the function (1) for the coefficient of eddy viscosity gives a fair representation of the diurnal wind variation for the period investigated. The largest source of error appears to be in the maximum magnitudes of the velocity components which are only from about $^1/_2$ to $^2/_3$ the observed values. Doubling the basic magnitude of the eddy viscosity did not appear to make a pronounced difference in the results, but reducing it by a factor of two or more gave rather marked differences, particularly in the time of occurrence of maxima and minima.

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