Reply

D. J. OLBERS AND J. WILLEBRAND[1]

Max-Planck-Institut für Meteorologie, Hamburg

27 September 1983

The difference in opinion between Killworth (1980, 1984) and our paper (Olbers and Willebrand, 1984) is stated most easily in terms of Needler's formula [i.e., (3.1) in OW]

$$(u, v, w) = \alpha(J_{yz}, -J_{xz}, J_{xy}). \quad (1)$$

We claim that the simultaneous vanishing of all three velocity components is normally associated with the vanishing of the three Jacobians in (1) whereas Killworth claims that the alternative possibility $\alpha = 0$ is at least equally likely. We have rejected this possibility because, as shown in OW, the density gradients and hence the Jacobians in (1) are singular at points where $\alpha = 0$ unless the atmospheric forcing has a very specific form.

Here we only want to demonstrate that, although perhaps not immediately apparent, the argument in Killworth's comment again would lead to $\alpha = 0$. From his Eq. (7), or equivalently from Eq. (4.10) in OW, we can derive the representation

$$\alpha = -\frac{g\rho_z J_{xy}}{D} = g\frac{J_{xy}}{r_z J_{xy} - q_z K_{xy} + \rho_z L_{xy}} \quad (2)$$

with $L_{xy} = q_x r_y - q_y r_x$ (notation as in Killworth's comment).

As Killworth correctly points out, at a point where $w = 0$, and hence $J_{xy} = 0$, from his Eqs. (1)–(3) one finds that either

$$u = v = 0$$

or

$$K_{xy} = 0, \quad \text{and also} \quad L_{xy} = 0.$$

In the first case when K_{xy} and L_{xy} do not vanish we have $\alpha = 0$ from (2) and hence singularities in the density gradient that are unacceptable in our opinion. In the latter case the representation (2) becomes indeterminate but α remains finite as seen, e.g., from (4.12) in OW. Hence we have $w = 0$ but $u, v \neq 0$ unless the other two Jacobians in (1) happen to vanish at this point.

[1] Present affiliation: Institut für Meereskunde, Düsternbrooker Weg 20, D-23 Kiel 1, FRG.

REFERENCES

Killworth, P. D., 1980: On the determination of absolute velocities and density gradients in the ocean from a single hydrographic section. *Deep-Sea Res.*, **27A**, 901–929.

——, 1984: Comments on "The level of no motion in an ideal fluid." *J. Phys. Oceanogr.*, **14**, 213.

Olbers, D. J., and J. Willebrand, 1984: The level of no motion in an ideal fluid. *J. Phys. Oceanogr.*, **14**, 203–212.