LETTER TO THE EDITOR

Comments on "Frictional effects on thermally forced waves"[1]

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In an article in this issue of *Tellus* Shapiro (1977) presents an interesting mathematical analysis of the role of boundary layer friction for idealized neutral "wave-CISK" disturbances. This article criticizes the study of boundary layer frictional effects on mixed Rossby-gravity waves by Holton (1975)—referred to by Shapiro as "the inconsistent solution". The purpose of this note is to help resolve the misleading impression of Holton's solution given in Shapiro's paper.

From observations and scaling arguments we know that for CISK type disturbances the amplitudes of the diabatic heating and vertical motion fields are highly correlated. Thus, for a given heating rate, a given vertical velocity, $W(Z_B)$, is implied (i.e the last two terms in Shapiro's eq. (5) must tend to balance). Because the vertical velocity field for an inviscid Rossby wave mode is quite weak (unless the vertical wavelength is very short), it is obvious that a much larger pressure perturbation is required to obtain a given $W(Z_B)$ in the absence of friction than when friction is included. In fact the pressure and wind fields would have to be of hurricane amplitude to drive a $W(Z_B) = 1$ cm s^{-1} for an *inviscid* easterly wave scale disturbance. However, no one would think of using a pressure field whose amplitude was determined in this manner to drive a frictional boundary layer. It is also clear that although Holton's model may have been oversimplified it was certainly *not* equivalent to the so-called "inconsistent solution". In particular the implication from Table 3 that Holton's model overestimates $W(Z_B)$ by an order of magnitude is clearly incorrect.

The magnitudes of pressure, horizontal velocity, and vertical velocity fields in Holton's figures are all reasonably consistent with observations. What Table 3 really shows is essentially the same point shown in Fig. 1 of Holton (1975); for synoptic scale waves the frictional convergence is an order of magnitude greater than the convergence associated with the inviscid wave dynamics.

Of course neither Shapiro's model, in which the heating rate is specified, nor Holton's model, in which the pressure amplitude is specified, is really completely satisfactory. Further progress in this important area will depend on appropriate observational studies combined with sophisticated numerical simulations which properly incorporate the synoptic-cumulus scale interactions as well as boundary layer friction.

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REFERENCES

Holton, J. R. 1975. On the influence of boundary layer friction on mixed Rossby-gravity waves. *Tellus 27*, 107–115.

Shapiro, L. 1977. Frictional effects on thermally forced waves. *Tellus 29*, 264–271.