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1.3C THE SUPPRESSION OF CONVECTIVE WAVEBREAKING BY RADIATIVE TRANSFER PROCESSES

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INTRODUCTION

SCHOEBERL et al. (1983) suggested that convective wavebreaking of monochromatic gravity waves might be suppressed by radiative transfer processes if the vertical wavelength waves were sufficiently short. As the vertical wavelength of the gravity wave decreases, radiative transfer between adjacent vertical layers becomes increasingly important. This exchange can increase the radiative relaxation time scale so that the wave will no longer grow with altitude. Thus, very short vertical wavelength waves may dissipate radiatively rather than become convectively unstable. SCHOEBERL et al. (1983) showed that gravity waves with $(\bar{u}-c) < 22\ ms^{-1}$ (λ_x = 1000 km), and $(\bar{u}-c) < 13\ ms^{-1}$ (λ_x = 100 km) would be radiatively damped.

Since publication of these results, APRUZESE and STROBEL (1984) have revised the exchange coefficients used in SCHOEBERL et al. (1983). Also, CHAO and SCHOEBERL (1984) pointed out that the computation made by LINDZEN (1981) of the convective diffusion rate may be a factor of two too low as the convective adjustment processes tends to minimize the thermal transport by the wave. The purpose of this note is to revise the values given in SCHOEBERL et al. (1983). These results also suggest that the very thin turbulent layers observed by MST radars (e.g. WOODMAN, 1980) cannot be produced by the convective instability of monochromatic gravity waves with large horizontal scales.

METHODOLOGY AND RESULTS

The condition required to prevent convective wavebreaking is

$$\gamma_{diff} = \gamma_{rad} \tag{1}$$

where γ_{diff} is the diffusive damping time scale required to prevent wave growth with altitude and γ_{rad} is the radiative damping time scale. Now,

$$\gamma_{diff} = \alpha^2 D \tag{2}$$

where $$D = \frac{m(\bar{u}-c)^4}{H\ \delta^3\ N^3},\quad \alpha = \frac{N}{\bar{u}-c}$$

D is twice LINDZEN'S (1981) turbulent diffusion (see CHAO and SCHOEBERL, 1984), and α is the vertical wave number of the gravity wave. The other terms in (2) are; H, the atmospheric scale height (7 km), N, the buoyancy frequency (2 x $10^{-2}\ s^{-1}$), m, the zonal wave number ($2\pi/L$) and $\delta = (1 + k^2/m^2)^{1/2}$ where k is the meridional wave number. For simplicity we take $\delta = 1$.

For γ_{rad} we use Equation (20) from FELS (1982) which agrees with the recent results of APRUZESE and STROBEL (1984) and also includes the effect of O_3 in the IR exchange parameterization. The transcendental system (1) can then be solved numerically. Since D varies with m and γ_{rad} varies with altitude, our results for $\bar{u}$ min (c=0) are shown in Figure 1 verses L at 5 km intervals from 20 to 70 km. The values shown in Figure 1 are the magnitudes of zonal mean wind values below which convective wave breaking would not take place for a standing gravity wave. Below 20 km the exchange approximation given by FELS is not valid because of CO_2 line overlap. Above 70 km non-LTE effects dominate. In the intermediate region N and H are assumed constant. The background temperature is given by the 1962 US Standard Atmosphere.

DISCUSSION

A vertically propagating gravity wave will grow in amplitude with height unless the vertical wavelength is small enough that radiative exchange between layers damps the gravity waves. The equivalent minimum phase speed in a resting atmosphere (or equivalent zonal wind speed for a stationary wave) for a gravity wave which will be so strongly damped radiatively that it will not grow with height is shown in Figure 1. These results were obtained from (2) and the FELS (1982) parameterization of IR cooling.

Obviously from Figure 1 the cutoff phase speeds are very slow, thus these wave approach periods where the inertial frequency cannot be neglected. Under such situations, full solution of Laplace's tidal equation is required; however, compared to Laplace tidal results, (2) tends to underestimate the vertical wavelength so the cutoff velocities shown in Figure 1 will be lower limits.

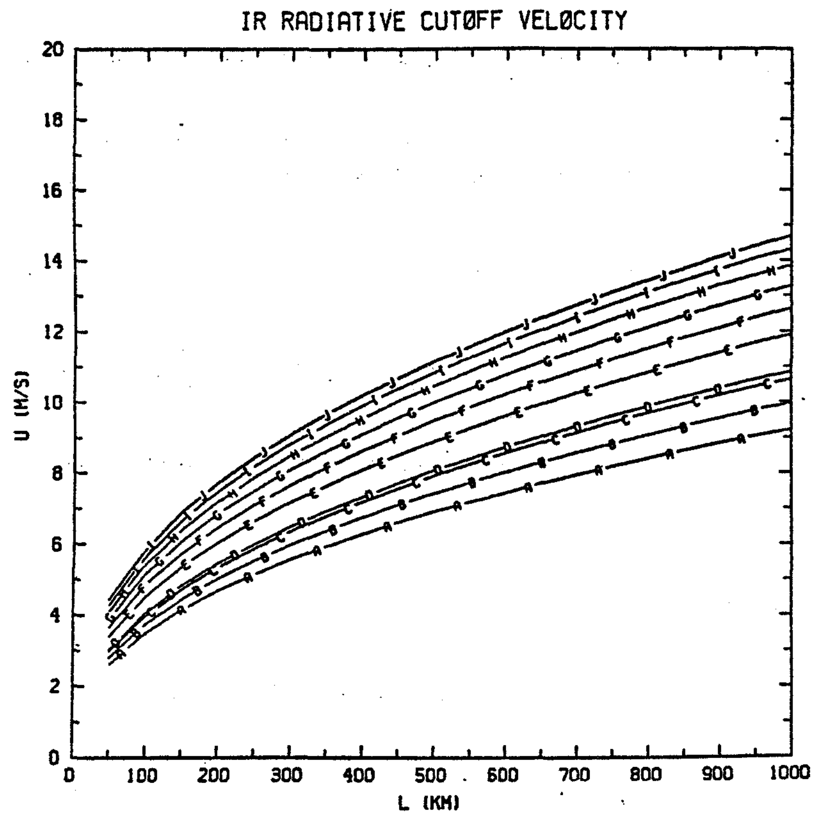

Figure 1. The minimum zonal wind possible for convective wavebreaking by a monochromatic gravity wave with zonal wavelength L and zero phase speed. The letters correspond to computations at different altitudes with 5 km increments starting at 20 km (e.g. A = 20 km, B = 25 km,..., J = 70 km). For wind values below that shown, the wave is radiatively damped so strongly that it cannot grow in amplitude with height.

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