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THE GENERATION OF INTERNAL WAVES

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INTRODUCTION

The generation of internal waves in the radiatively stable stellar region by the turbulent motion at the boundary of the overlaying convective zone is similar to the same case in the deep ocean or in the earth atmosphere (Townsend, 1965), and can be described in a simple way as following: When an turbulent fluid element arrives at the boundary of the convective region with a non-zero momentum, it beats and it deforms the interface between both regions. This disturbance of the equilibrium state excites a train of internal waves propagating below the convective zone in the horizontal and vertical directions for the frequencies lower than the characteristic one for the stable stratification (Brunt-Väisälä frequency).

MATHEMATICAL MODEL (FOURIER TRANSFORM)

We use the model proposed by Townsend (1965) to described the internal waves in the earth atmosphere. He considered that the disturbance at the boundary can be written by a gaussian function of space and time and describes the effect of this perturbation through a Fourier Transform:

$$\xi(z,t) = \iint_{-\infty}^{\infty} u(z \mid l, \omega) \exp\left(\frac{1}{2}\cdot(\alpha^2 l^2 + \tau^2\omega^2)\right) \exp(\imath\,(lx - \omega t))\, dl\, d\omega$$

where α and τ are the characteristic size and period for an turbulent element of fluid; u is the vertical perturbation propagating in z-direction. We take u as the vertical velocity of the internal waves given by Press (1981) with the following assumptions:

- Plane-parallel geometry : $r_\circ - r \equiv z$, and Brunt-Väisälä frequency (N) constant below convective zone.
- ω^2 much smaller than N^2.
- The radiative damping term can be written :

$$\frac{1}{2}\int_{r_\circ}^{r} \frac{\sigma N^3}{\omega^4}\, k_H^3\, dr \simeq \frac{1}{2}\, F(z)\cdot\left(\frac{\omega_\circ}{\omega}\right)^4$$

where σ is the thermometric diffusivity, k_H the wave number, and $\omega_\circ$ the circular frequency attached to the largest wave length of the turbulent

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motion; involving that we consider for the different l-components the same damping, that one corresponding about to the pression scale hight.

COMPUTATIONAL METHOD

Fourier Transform given out by the application of Townsend' model has ben resolved using the method of steepest descent. This supposes first, that function behaves like a gaussian near its maximum, second, that the oscillation frequency is low enough compared to the gaussian decrease. In our case, this method is valid for values obeying the ω condition

$$\omega^4 \ll 2 \cdot 6^3 \omega_o^4 F$$

SUPERIMPOSITION OF GAUSSIAN PULSES

The motion below an turbulent region is the result of the superimposition of the effects of many fluids elements beating the boundary. As the arrival of the turbulent elements at the interface between the convective and stable regions is a random function of time and horizontal coordinates, the mean-square vertical velocity at any depth will arise from the product of the number of disturbances per unit of time and area and the mean-square vertical velocity due to a single pulse. Then

$$<u^2>= \frac{3}{4}\frac{\pi}{\sqrt{6}} \left(\frac{\rho_o}{\rho}\right) \left(\frac{r_o}{r}\right)^3 \frac{u_{H_o}^2}{N^2} \cdot (2 \cdot F(z))^{\frac{1}{3}} \exp\left(-3 \cdot \left(\frac{F(z)}{4}\right)^{\frac{1}{3}} (\omega_o^4 \tau^4)^{\frac{1}{3}}\right)$$

where the index o refers to the boundary of the convective zone, ρ is the density and u_{H_o} is the imposed horizontal velocity at the boundary.

DIFFUSION COEFFICIENT

If we introduce the above vertical velocity in the expression of the diffusion coefficient given by Press for monochromatic internal waves, and assume that the turbulent flow in the convective zone can be described by the Kolmogorov spectrum, the diffusion coefficient that arise out is $F^{-\frac{3}{4}}$ times smaller than the one obtained by Schatzman (1991) using the Press' formalism and the same turbulence spectrum.

The validity of the results presented here are limited by the approximations employed in order to overcame the mathematical difficulties of the analytical method.

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