EFFECT OF MERIDIONAL VARIATION OF MOIST STATIC ENERGY ON MIXED ROSSBY-GRAVITY WAVES

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1. Introduction

Wang and Rui [1990] used numerical solutions for the coupled moist Kelvin-Rossby wave on an equatorial beta plane to show that when there is a meridional gradient in SST, there is a substantial modification of the nature of the equatorially trapped waves. Gadgil and Srinivasan [1990] and Srinivasan et al. [1993] have shown that meridional variation in moist static energy will result in a meridional variation in the moist gravity wave speed. In this paper we study the effect of meridional variation in moist gravity wave speed on the equatorially trapped waves using a simple linear model of the tropical atmosphere.

2. Governing Equations

The 2-layer model for equatorially trapped waves (Wang and Rui, 1990) is

$$u_t+Uu_x-fv = -\phi_x$$
$$v_t+Uv_x+fu = -\phi_y$$
$$\phi_t+U\phi_x+c^2(y)[u_x+v_y] = 0$$

Following Wang (1988), the specific humidity is assumed to vary with the sea surface temperature (SST), which we assume to be linear with latitude. The moist gravity wave speed c then is written as

$$c^2 = c_0^2[1+\Gamma y]$$

here c_0 is the moist gravity wave speed at the Equator. The form for zonal and time dependence is $\exp[I(Kx-Ut-\omega t)]$. The latitudinal velocity is then governed by the Hermite differential equation, with the maximum value displaced in latitude toward the cooler side by an amount proportional to Γ. The eigenvalue equation is

$$\left[\tilde{\omega}^3-\left(\tilde{K}^2+2n+1\right)\tilde{\omega}-\tilde{K}\right]\left[\tilde{\omega}^2-\tilde{K}^2\right]^2 = -\tilde{\Gamma}^2\tilde{\omega}^3\left[\tilde{\omega}^2-3\tilde{K}^2\right]$$

where n is the order of the Hermite polynomial of the V(y) solution.

For gamma equal to zero, the problem reverts to the adiabatic case for mixed Rossby-gravity waves, which was treated by Lindzen (1967). The effect of SST variation with latitude is to increase the order of the eigenvalue equation from three to seven. With a gradient of moist static energy, four additional roots appear. Two of these roots are real, corresponding to stable oscillations, and the other two are a pair of complex roots, indicating a mode which grows in time.

Figure 1 shows root 1 for wavenumber K from 0 to 10 for modes n = 1 through 10. The adiabatic case (Γ = 0) is indicated by the solid lines and is included for n = 0. The moist cases Γ = 0.5 and 1.0 are indicated by the dashed and dotted lines. For n equal to one or greater, the moist static energy gradient Γ makes little difference for this root.

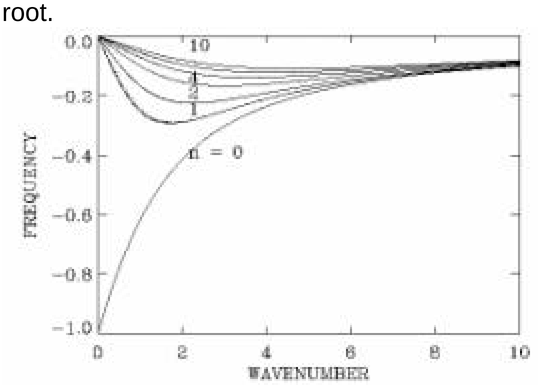

Figure 1: Eigenvalue 1 as fuction of wavenumber for various n. Solid line indicates $\Gamma = 0$, dashed line 0.5 and dotted line 1.0.

Figure 2 shows root 2 in like manner. For this root there is little effect of Γ for n not equal to 0 also. Figure 3 shows root 3. The effect of Γ is small except for the n = 0 case and small wavenumber K.

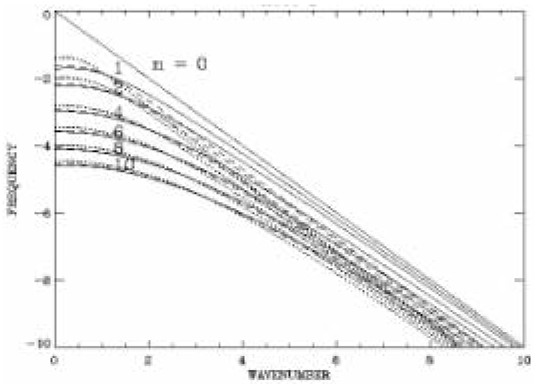

Figure 2: Eigenvalue 2 as fuction of wavenumber for various n. Line code same as for fig. 1.

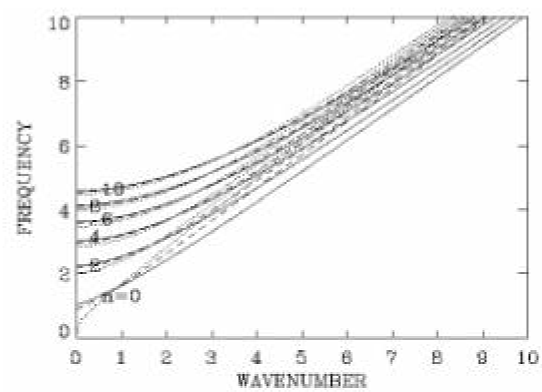

Figure 3: Eigenvalue 3 as fuction of wavenumber for various n. Line code same as for fig. 1.

The case of n = 0 for roots 1 and 2 is shown by fig. 4. The effects of gradient of moist static energy for this case are quite interesting.

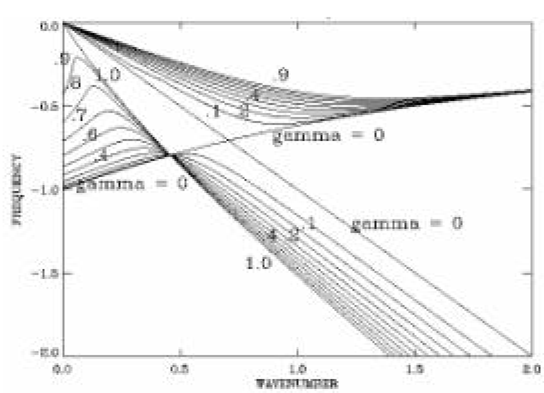

Figure 4. Frequencies of modes 1 and 2 a functions of wavenumber and moist static energy gradient Γ.

The four new roots which appear have imaginary parts, thus describe modes which grow with time for Γ not zero. Figure 5 shows the

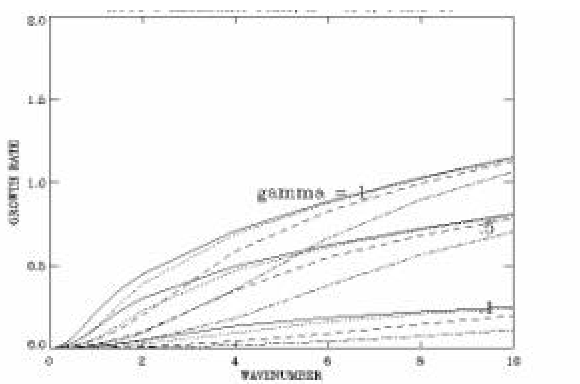

Figure 5. Growth rate of mode due to moist static energy gradient in latitude for G = 0.1, 0.5 and 1.0. Line code: n = 0, solid; n = 1, dotted; n = 4, dashed; n = 10, dash-dot.

The presence of a meridional gradient in moist energy causes the amplification of westward migrating mixed Rossby-gravity waves with wavelength in the range of 8000 to 9000 km and a period on the order of 4 days (10 days) when the mean zonal wind is easterly (westerly) with a speed of 10 m/sec. The predictions of this model are consistent with observed mixed Rossby-gravity waves.

6. References

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