Low–Frequency Waves Forced by Large–scale Topography in the Barotropic Model①

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ABSTRACT

A barotropic model containing large–scale topography and zonal mean flow is established to discuss the effects of large–scale topography on the low–frequency waves. The results show that what affects low–frequency waves mostly is maximal height of topography and topographic slope. The former makes frequency of topographic Rossby waves decrease, the latter makes Rossby waves instable. Moreover, when topographic slope is appropriate, it can also make Rossby waves turn into low–frequency waves.

Key words: Large–scale topography, Low–frequency waves, Maximal height of topography, Topographic slope

I. INTRODUCTION

More investigations about atmospheric low–frequency oscillations have been done since Madden and Julian (1971) discovered through spectrum analysis that there are 40–50 day low–frequency oscillations in the variation of atmospheric wind and surface pressure fields in tropics. But the stresses of all researches have been focused on tropics. 30–60 day atmospheric low–frequency oscillations at middle and high latitudes might firstly be found in the research that Anderson et al. (1983) carried on about transport of atmospheric momentum. Based on analyses of FGGE data, Krishnamurti et al. (1985) pointed out that 30–60 day oscillations are a global phenomenon of atmospheric variations. Subsequent studies have shown that there are many differences in vertical structure, zonal scale, zonal propagating direction and time or space evolution of intraseasonal oscillations between middle–high latitudes and low latitudes. Details are something as follows: there is a characteristic of barotropic structure, wavenumber is mainly 2–4 in potential fields, oscillations propagate westward mainly and they have a two–dimensional characteristic of Rossby wavetrains, etc. More detailed difference can be found from Li Chongyin's narration (1991, 1995).

With the discoveries of atmospheric low–frequency oscillation and its characteristics, more investigations have been carried on to discuss the causes of atmospheric low–frequency oscillations. Wallace et al. (1983) attributed the causes of atmospheric low–frequency oscillations to six facts, in fact, they can be concluded as two mechanisms, i.e., the response of atmosphere to outer forces and nonlinear interactions of atmospheric motions. Similarly, more studies have been focused on dynamic mechanism of atmospheric low–frequency oscillations in tropics or low latitudes, some good results also have been obtained in

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explaining causes and characteristics of low–frequency oscillations. But fewer studies have been carried on to research mechanism of atmospheric low–frequency oscillations over middle–high latitudes. Zhang et al. (1991) studied 30–60 day atmospheric oscillations over the Tibetan Plateau (summer half year) and pointed out that the Tibetan Plateau is the active areas and an important source of atmospheric low–frequency oscillations. They also thought that the dynamic and thermal effects of topography might bring low–frequency oscillations to come into being. Zhang (1987) and Yang et al. (1995) took barotropic instabilities of mean flow as an important mechanism to excite atmospheric low–frequency oscillations over middle–high latitudes. Li et al. (1995) have also shown the importance of dynamic instabilities of mean flow in exciting atmospheric low–frequency oscillations over middle–high latitudes. Luo et al. (1992) studied 30–60 day oscillations forced by topography and constant zonal mean flow recently, they found that topography plays an important role in exciting low–frequency oscillations.

Based on the above studies, a barotropic model containing large–scale topography and constant mean flow is established to discuss the dynamic effects of topography with or without Zonal mean flow on Rossby waves over middle latitudes. We mention basic equations in Section 2. Two cases, $\bar{u}=0$ or $\bar{u}\neq 0$, are discussed respectively in Sections 3 and 4 and some analyses are given, too. Section 5 is devoted to some conclusions.

II. BASIC EQUATIONS

The equations of barotropic model with topographical height–$h_s(x,y)$–can be written as:

$$\begin{cases} \dfrac{\partial u}{\partial t}+u\dfrac{\partial u}{\partial x}+v\dfrac{\partial u}{\partial y}-fv=-\dfrac{\partial \varphi}{\partial x} \\ \dfrac{\partial v}{\partial t}+u\dfrac{\partial v}{\partial x}+v\dfrac{\partial v}{\partial y}+fu=-\dfrac{\partial \varphi}{\partial y} \\ \dfrac{\partial \varphi}{\partial t}+\dfrac{\partial(\varphi-\varphi_s)u}{\partial x}+\dfrac{\partial(\varphi-\varphi_s)v}{\partial y}=0 \end{cases} \tag{2.1}$$

where $\varphi=gh$(h–the height of free surface), $\varphi_s=gh_s$(h_s–the topographic height), u, v–the velocity of zonal and meridional direction respectively, f–the Coriolis parameter. We suppose:

$$u=\bar{u}+u',\quad v=v',\quad \varphi=\bar{\varphi}+\varphi', \tag{2.2}$$

where symbols with '—' are the basic quantities, with ' ′ ' are the disturbing quantities, and we suppose that:

$$f\bar{u}=-\frac{\partial\bar{\varphi}}{\partial y},\quad \bar{u}=\text{const},\quad h_s=h_s(y)\ ,\quad \alpha_0=\frac{d\varphi_s}{dy}=\text{const}\ , \tag{2.3}$$

when $y>0$, $\alpha_0<0$ (we call it the north slope); when $y<0$, $\alpha_0>0$ (we call it the south slope). Thus, we may have:

$$\begin{cases} \bar{\varphi}=\bar{\varphi}_0-\gamma_0 y \\ \varphi_s=\varphi_{sm}+\alpha_0 y \end{cases} \tag{2.4}$$

where $\gamma_0=f_0\bar{u}$, $\bar{\varphi}_0=gH$(H–the height of free surface at $y=0$ and when the fluid is static), $\varphi_{sm}=gh_{sm}$(h_{sm}–the maximal height of topography at $y=0$). We can get the linearized form of formula (2.1), if we substitute formulas (2.2), (2.3) and (2.4) into formula (2.1):

$$\begin{cases} \dfrac{\partial u'}{\partial t} + \bar{u}\dfrac{\partial u'}{\partial x} - fv' = -\dfrac{\partial \varphi'}{\partial x} \\ \dfrac{\partial v'}{\partial t} + \bar{u}\dfrac{\partial v'}{\partial x} + fu' = -\dfrac{\partial \varphi'}{\partial y} \\ \dfrac{\partial \varphi'}{\partial t} + \bar{u}\dfrac{\partial \varphi'}{\partial x} + c^2\left(\dfrac{\partial u'}{\partial x} + \dfrac{\partial v'}{\partial y}\right) - \varepsilon v' = 0 \end{cases} \tag{2.5}$$

where $c^2 = c_0^2 - \varepsilon y$, $c_0^2 = \overline{\varphi}_0 - \varphi_{sm}$, $\varepsilon = \alpha_0 + \gamma_0$.

The systems of equations (2.5) are the basic equations used to discuss questions we are interested in this paper. We will explain them according to two cases: $\bar{u} = 0$ and $\bar{u} \neq 0$. So it goes as follows:

III. THE CASE OF $\bar{u} = 0$:

Thus, equations (2.5) may be converted into:

$$\frac{\partial u'}{\partial t} - fv' = -\frac{\partial \varphi'}{\partial x} , \tag{3.1}$$

$$\frac{\partial v'}{\partial t} + fu' = -\frac{\partial \varphi'}{\partial y} , \tag{3.2}$$

$$\frac{\partial \varphi'}{\partial t} + (c_0^2 - \alpha_0 y)\left(\frac{\partial u'}{\partial x} + \frac{\partial v'}{\partial y}\right) - \alpha_0 v' = 0 . \tag{3.3}$$

Eliminating φ' through formulas (3.1) and (3.2), then we can get:

$$\left(\frac{\partial^2}{\partial t \partial y} - f\frac{\partial}{\partial x}\right)u' = \left(\frac{\partial^2}{\partial t \partial x} + f\frac{\partial}{\partial y} + \beta_0\right)v' . \tag{3.4}$$

Eliminating φ' through formulas (3.1) and (3.3), then we have:

$$\left(\frac{\partial^2}{\partial t^2} - (c_0^2 - \alpha_0 y)\frac{\partial^2}{\partial x^2}\right)u' = \left(f\frac{\partial}{\partial t} + (c_0^2 - \alpha_0 y)\frac{\partial^2}{\partial x \partial y} - \alpha_0\frac{\partial}{\partial x}\right)v' . \tag{3.5}$$

Eliminating u' through formulas (3.4) and (3.5), then we obtian:

$$\pounds_1 v' = 0 , \tag{3.6}$$

$$\begin{aligned} \pounds_1 \equiv & \frac{\partial}{\partial t}\left[\frac{\partial^2}{\partial t^2} - (c_0^2 - \alpha_0 y)\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right) + f_0^2 + 2\alpha_0\frac{\partial}{\partial y}\right] \\ & - [\beta_0(c_0^2 - \alpha_0 y) + f_0\alpha_0]\frac{\partial}{\partial x} . \end{aligned} \tag{3.7}$$

Formula (3.6) is the basic equation, which is used to discuss questions in this section. (Notes: In order to guarantee that there isn't any unnecessary solutions to formula (3.6), we don't consider that order variations of left side of formula (3.4) or (3.5) may make any differences, when we eliminate u' through formulas (3.4) and (3.5)). First, we analyze the simplest case of formula (3.6), that is, we don't consider the components containing $\alpha_0 y$, then it can be written as:

$$\frac{\partial}{\partial t}\left[\frac{\partial^2}{\partial t^2} - c_0^2\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right) + f_0^2 + 2\alpha_0\frac{\partial}{\partial y}\right]v' - [\beta_0 c_0^2 + f_0\alpha_0]\frac{\partial v'}{\partial x} = 0 \ . \tag{3.8}$$

We may know that formula (3.8) has solution with the form as follows:

$$v' = V\exp(ikx + ily - i\omega t) \ , \tag{3.9}$$

where V–amplitude of waves, k, l–wave number in x,y direction, respectively, and ω–angular frequency of waves. Substituting formula (3.9) into (3.8), then we have:

$$-\omega^3 + [c_0^2(k^2 + l^2) + f_0^2 + i2\alpha_0 l]\omega + k(\beta_0 c_0^2 + f_0\alpha_0) = 0 \ . \tag{3.10}$$

We can find that the solution to formula (3.10) in low–frequency domains (i.e, we do not consider the components containing–ω^3) is given by:

$$\omega = -\frac{k\beta_0 + kf_0\alpha_0 / c_0^2}{k^2 + l^2 + f_0^2 / c_0^2 + i2\alpha_0 l / c_0^2} \ . \tag{3.11}$$

We may obtain some results from formula (3.11) as follows:

(i) If $\alpha_0 = 0$ and $\varphi_{sm} = 0$, then $c_0^2 = c_{00}^2 = \overline{\varphi}_0$, that is, no topography, then:

$$\omega_{00} = -\frac{k\beta_0}{k^2 + l^2 + f_0^2 / c_{00}^2} \ , \tag{3.12}$$

formula (3.12) is the dispersion relation of Rossby waves at middle latitudes.

(ii) If $\alpha_0 = 0$ and $\varphi_{sm} \neq 0$, then $c_0^2 = \overline{\varphi}_0 - \varphi_{sm} < c_{00}^2$, i.e., only topographic height can take into actions, then:

$$\omega_{01} = -\frac{k\beta_0}{k^2 + l^2 + f_0^2 / c_0^2} \ . \tag{3.13}$$

Compare formulas (3.12) and (3.13), we know $|\omega_{01}| < |\omega_{00}|$, so the elevation of topography is benefit to the development of Rossby waves toward low–frequency waves.

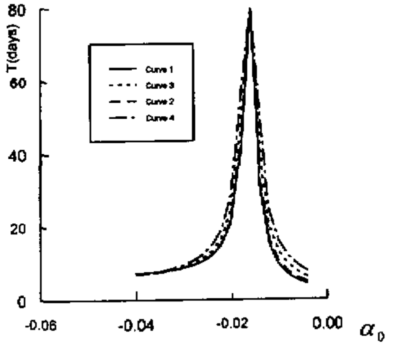

Fig. 1. Variation of T with α_0.

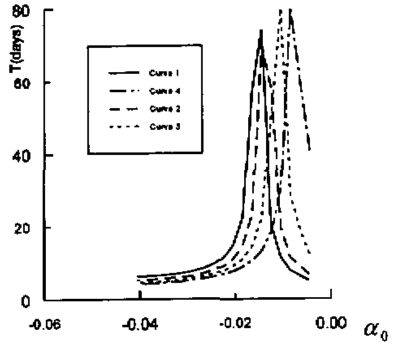

Fig. 2. Variation of T with α_0.

(Notes: Curves 1, 2, 3 or 4 in Fig. 1 and Fig. 2 represent zonal wavenumbers 1, 2, 3 or 4, respectively, we take Northern latitude 30 degree as zero point of y axis, $c_0^2 = 6 \times 10^4 \mathrm{m}^2 / \mathrm{s}^2$. There is mean flow or no mean flow in Fig. 1 or Fig. 2, respectively).

(iii) If $\alpha_0 \neq 0$, that is, the topographic slope takes into actions, the dispersion relation is formula (3.11). letting:

$$\omega = \omega_r + i\omega_i \ , \tag{3.14}$$

where ω_r –disturbance frequency of waves, ω_i –the growth rate of waves.

Substituting formula (3.14) into (3.11), then it yields:

$$\omega_r = -\frac{(k\beta_0 c_0^2 + \alpha_0 f_0 k)(c_0^2 k^2 + c_0^2 l^2 + f_0^2)}{(c_0^2 k^2 + c_0^2 l^2 + f_0^2)^2 + 4\alpha_0^2 l^2} \ . \tag{3.15}$$

$$\omega_i = \frac{2\alpha_0 l(k\beta_0 c_0^2 + \alpha_0 f_0 k)}{(c_0^2 k^2 + c_0^2 l^2 + f_0^2)^2 + 4\alpha_0^2 l^2} \ . \tag{3.16}$$

The analysis from formulas (3.15) and (3.16) is that: On the south slope: $\alpha_0 > 0$, then $\omega_i > 0$, $\omega_r < 0$, so Rossby waves are growing and propagating westward. On the north slope: $\alpha_0 < 0$. When $\alpha_0 > -\beta_0 c_0^2 / f_0$, then $\omega_i < 0, \omega_r < 0$, so Rossby waves are growing and propagating eastward. Therefore, when the topographic slope takes into action, the instability and propagating attributes of Rossby waves may change. Moreover, we can know from formula (3.15) that the north slope plays a more important role in making Rossby waves develop tward low–frequency waves.

The period of waves, T, may be written as:

$$T = 2\pi / |\omega_r| \ , \tag{3.17}$$

thus, we can make out the graphs of the variations of waves period with zonal wavenumber and topographic slope by using formulas (3.15), (3.16) and (3.17), see Fig. 1.

If we do not simplify formula (3.6), then the solution to equation (3.6) may take the form as follows:

$$v' = V(y)\exp(ikx - i\omega t) \ . \tag{3.18}$$

Substituting formula (3.18) into (3.6), it is given:

$$\begin{aligned} &-\omega(c_0^2 - \alpha_0 y)\frac{d^2 V}{dy^2} + 2\alpha_0 \omega \frac{dV}{dy} \\ &+ [\omega(f_0^2 + k^2 c_0^2 - \omega^2 - k^2 \alpha_0 y) + k(\beta_0 c_0^2 + f_0 \alpha_0) - k\beta_0 \alpha_0 y]V = 0 \ . \end{aligned} \tag{3.19}$$

We can find the solution to formula (3.19) in low–frequency areas (i.e., do not consider the components containting ω^3 in equation (3.19), then formula (3.19) can be rewritten as:

$$\begin{aligned} &(c_0^2 - \alpha_0 y)\frac{d^2 V}{dy^2} - 2\alpha_0 \frac{dV}{dy} \\ &- \left[f_0^2 + k^2 c_0^2 + \frac{k(\beta_0 c_0^2 + f_0 \alpha_0)}{\omega} - (k^2 + \frac{k\beta_0}{\omega})\alpha_0 y\right] V = 0 \ . \end{aligned} \tag{3.20}$$

Formula (3.20) is the laplace equation with form as follows:

$$(A_0y+B_0)\frac{d^2V}{dy^2}+(A_1y+B_1)\frac{dV}{dy}+(A_2y+B_2)V=0\ , \tag{3.21}$$

where:

$$\begin{cases} A_0=-\alpha_0 \quad B_0=c_0^2 \quad A_1=0 \quad B_1=-2\alpha_0 \\ A_2=(k^2+k\beta_0/\omega)\alpha_0 \quad B_2=-[k^2c_0^2+f_0^2+k(\beta_0c_0^2+f_0\alpha_0)/\omega] \end{cases} \tag{3.22}$$

letting:

$$V=\tilde{V}\exp(py)\ , \qquad y=\lambda\eta+\mu \tag{3.23}$$

and taking:

$$\begin{cases} \lambda=-A_0/(2A_0p+A_1)=-1/(2p)\ , \qquad \mu=-B_0/A_0 \\ p=-(A_1+\sqrt{A_1^2-4A_0A_2})/(2A_0)=-\sqrt{-A_0A_2}/A_0 \end{cases} \tag{3.24}$$

Substituting formulas (3.23) and (3.24) into (3.20), then formula (3.20) can be written as the following confluent hypergeometric equation:

$$\eta\frac{d^2\tilde{V}}{d\eta^2}+(\gamma-\eta)\frac{d\tilde{V}}{d\eta}-\alpha\tilde{V}=0\ , \tag{3.25}$$

where:

$$\begin{cases} \gamma=(A_0B_1-A_1B_0)/A_0^2=2 \\ \alpha=(B_0p^2+B_1p+B_2)/(2A_0p+A_1)=1+(\omega f_0^2+kf_0\alpha_0)/(2\omega\sqrt{\alpha_0^2(k^2+k\beta_0/\omega)})\ , \end{cases} \tag{3.26}$$

its eigenvalues satisfying: $\tilde{V}|_{\eta=0}<\infty$ and $\tilde{V}|_{\eta\to\infty}\sim\eta^n$ are:

$$\alpha=-n \qquad (n=0,1,2\ \cdots\cdots) \tag{3.27}$$

i.e.,

$$(\omega f_0^2+kf_0\alpha_0)/(2\omega\sqrt{\alpha_0^2(k^2+k\beta_0/\omega)})=-1-n \qquad (n=0,1,2,\cdots\cdots) \tag{3.28}$$

it is given from formula (3.28):

$$(f_0^4-4(n+1)^2\alpha_0^2k^2)\omega^2+(2kf_0^3\alpha_0-4(n+1)^2\alpha_0^2k\beta_0)\omega+k^2f_0^2\alpha_0^2=0\ , \tag{3.29}$$

so:

$$\omega=[(4(n+1)^2\alpha_0^2k\beta_0-2kf_0^3\alpha_0)\pm\sqrt{\Delta}]/[2(f_0^4-4(n+1)^2\alpha_0^2k^2)]\ , \tag{3.30}$$

$$\begin{aligned}\Delta&=(2kf_0^3\alpha_0-4(n+1)^2\alpha_0^2k\beta_0)^2-4k^2f_0^2\alpha_0^2(f_0^4-4(n+1)^2\alpha_0^2k^2)\\&=16(n+1)^2k^2\alpha_0^3((n+1)^2\beta_0^2\alpha_0+k^2\alpha_0f_0^2-\beta_0f_0^3)\ .\end{aligned} \tag{3.31}$$

We can obtain the graph of variations of waves period and the waves growth rate with zonal wavenumber and topographic slope by using formulas (3.30), (3.31) and (3.17), and use it to make out some results (Figures not presented here). The results are: there are 30–60 day low-frequency waves only when the zonal wavenumber is 1 and the topographic slope is small, and they can propagate either eastward or westward and develop unstablely on the south slope, with the increase of wavenumber and topographic slope, the wave periods turn shorter and the waves are instable.

All conclusions above are made on the condition of $\bar{u}=0$, but the condition of $\bar{u}=0$ is a great limitation over middle latitudes, so we will analyze the case of $\bar{u}\neq 0$.

IV. THE CASE OF $\bar{u}=\text{const}\neq 0$

Then the controlling equation is formulas (2.5), similarly, they can be rewritten as:

$$\pounds_2 v'=0\ , \tag{4.1}$$

$$\pounds_2=\left(\frac{\partial}{\partial t}+\bar{u}\frac{\partial}{\partial x}\right)\left[\left(\frac{\partial}{\partial t}+\bar{u}\frac{\partial}{\partial x}\right)^2-(c_0^2-\varepsilon y)\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)+f_0^2+2\varepsilon\frac{\partial}{\partial y}\right]$$

$$-[(c_0^2-\varepsilon y)\beta_0+\varepsilon f_0]\frac{\partial}{\partial x}\ . \tag{4.2}$$

The low-frequency solutions to the simplest case (i.e., the components containing εy in equation (4.1) are not considered) are:

$$\omega=k\bar{u}-\frac{k\beta_0+kf_0\varepsilon/c_0^2}{k^2+l^2+f_0^2/c_0^2+i2\varepsilon l/c_0^2}\ . \tag{4.3}$$

Substituting formula (3.14) into (4.3) and we have:

$$\omega_r=k\bar{u}-\frac{(k\beta_0c_0^2+\varepsilon f_0k)(c_0^2k^2+c_0^2l^2+f_0^2)}{(c_0^2k^2+c_0^2l^2+f_0^2)^2+4\varepsilon^2l^2}\ , \tag{4.4}$$

$$\omega_i=\frac{2\varepsilon l(k\beta_0c_0^2+\varepsilon f_0k)}{(c_0^2k^2+c_0^2l^2+f_0^2)^2+4\varepsilon^2l^2}\ . \tag{4.5}$$

We can get conclusion from formulas (4.4) and (4.5) that the mean flow makes the disturbance frequency and growth rate of Rossby waves change greatly, the detailed analyses are as follows:

(i) When there is mean westerly, then $\bar{u}>0$, $\gamma_0>0$. On the south slope: $\alpha_0>0$, $\varepsilon>0$, $\omega_i>0$, Rossby waves are growing; On the north slope: $\alpha_0<0$, when $0<-\alpha_0<\gamma_0$, then $\varepsilon>0$, $\omega_i>0$, so Rossby waves are growing, when $-\alpha_0>\gamma_0$, then $\varepsilon<0$, if $-\gamma_0>\gamma_0+c_0^2\beta_0/f_0$, then $\omega_i>0$, so Rossby waves are growing; if $\gamma_0<-\alpha_0<\gamma_0+c_0^2\beta_0/f_0$, then $\omega_i<0$, so Rossby waves are decaying.

(ii) When there is mean easterly, then $\bar{u}<0$, $\gamma_0<0$. On the south slope: $\alpha_0>0$, when $-\alpha_0>\gamma_0$, then $\varepsilon>0$, $\omega_i>0$, so Rossby waves are growing, when $0<\alpha_0<-\gamma_0$, then $\varepsilon<0$, if $\alpha_0>-\gamma_0-c_0^2\beta_0/f_0$, then $\omega_i<0$, so Rossby waves are decaying; if $\alpha_0<-\gamma_0-c_0^2\beta_0/f_0$, then $\omega_i>0$, so Rossby waves are growing. On the north slope: $\alpha_0<0$, $\varepsilon<0$, when $-\alpha_0>\gamma_0+c_0^2\beta_0/f_0$, then $\omega_i>0$, so Rossby waves are growing, when $-\alpha_0<\gamma_0+c_0^2\beta_0/f_0$, then $\omega_i<0$, so Rossby waves are decaying.

At the same time, it can be obtained from formula (4.4) that mean flow also makes the propagating direction of low-frequency waves change greatly. Based on formulas (4.4), (4.5) and (3.17), we can draw Fig. 2, from which we can find out some differences between the Figure with and without mean flow.

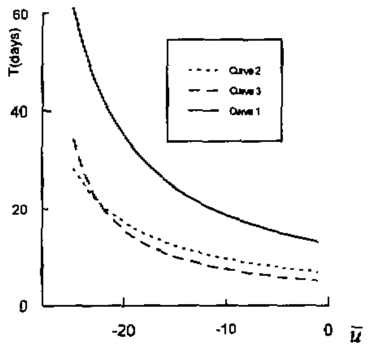

Fig. 3. Variation of T with $\bar{u}$.

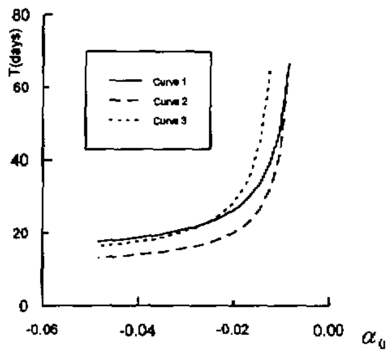

Fig. 4. Variation of T with α_0.

(Notes: Curves 1,2 or 3 in Fig. 3 or Fig. 4 present zonal wavenumbers 1,2 or 3 respectively. We take the Northern latitude 30 degree as zero point of y axis, $n = 0$. $\alpha_0 = -8 \times 10^{-3}$ in Fig. 3 and $\bar{u} = -30$ m / s in Fig. 4).

The low-frequency solution to formula (4.2) can be directly written as:

$$\omega = k\bar{u} + \frac{(4(n+1)^2 \varepsilon^2 k \beta_0 - 2k f_0^2 \varepsilon) \pm \sqrt{\Delta}}{2(f_0^4 - 4(n+1)^2 \varepsilon^2 k^2)} \, , \tag{4.6}$$

$$\Delta = 16(n+1)^2 k^2 \varepsilon^3 ((n+1)^2 \beta_0^2 \varepsilon + k^2 \varepsilon f_0^2 - \beta_0 f_0^3) \, . \tag{4.7}$$

We can obtain graphs about formulas (4.6), (4.7) and (3.17), from which we can find out the variation of wave period and growth rate with zonal wavenumber, mean flow and topographic slope (see Fig. 3 and Fig. 4). From the calculating results, we also find that the north topographic slope is more benefit to low-frequency waves, but they are all stable and propagate eastward or westward. On the contrary, only small wavenumber on the south slope can bring low-frequency waves to birth, and they are instable; when there is mean westerly, they propagate westward; when there is mean easterly, they propagate eastward. At the same time, we can find that the possibility of low-frequency waves coming into being decreases with the increase of wavenumber, though it may be correct sometime, low-frequency waves of intraseasonal scale can come into being with interacting with large-scale topography. Zhang et al. (1991) pointed out that low-frequency waves of 30–50 days scale focus on 30–35°N, 85–90°E areas and come into being during summer more than during winter. At the same time, they thought that instable Rossby perturbances mainly develop in the areas of the Tibetan Plateau southern slope. Luo et al. (1992) pointed out that westerly is stronger in winter and weaker in summer in real atmosphere. The results in our studies show some similar characters. But as we know, topography forces cannot be responsible for the incitement of low-frequency waves solely. The results in our studies can only give part explanations about the incitement of low-frequency waves.

V. CONCLUSION AND CONCLUDING REMARKS

From the simple analyses above, we know that the large–scale topography changes the attributes of Rossby waves greatly. The effects of topographic height are mainly on the alteration of Rossby waves phase velocity. The effects of topographic slope are on the alterations of wave stability and propagating attributes. The topographic height and slope together can indeed make intraseasonal oscillation come into being. Parts of our conclusions are same as that Zhang et al. (1991) made about the Tibetan Plateau observing and statistic investigations. The conclusion made from the simplest case of our model coincides with what Lu (1987, 1986) had concluded. But the role of topographic slope is partly different from traditional conclusions.

Directly speaking, the differences between our conclusions and that Zhang et al. (1991) have made are their reasonableness, for we only consider the dynamic effects of large–scale topography in our work and do not take its thermal effects into consideration, this will make some differences undoubtedly. Furthermore, we also do not consider effects of friction, all these should be studied afterward.

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