Vol.13 No.1 **JOURNAL OF TROPICAL METEOROLOGY** June 2007

Article ID: 1006-8775(2006) 02-0073-04

# NUMERICAL EXPERIMENTS OF EFFECT OF SSTA OVER THE INDIAN OCEAN ON ATMOSPHERIC LOW-FREQUENCY OSCILLATION IN THE EXTRATROPICAL LATITUDE

QIU Ming-yu (邱明宇)[1, 2], LU Wei-song (陆维松)[3], CHEN Hui-lin (陈汇林)[1, 2], CAI Qin-bo (蔡亲波)[1]

(1. Hainan Institute of Meteorological Science / Key Laboratory for Meteorological Disaster Prevention and Mitigation in the South China Sea, Haikou 570203 China; 2. Hainan Climate Center, Haikou 570203; 3. Department of Atmospheric Sciences, Nanjing University of Information, Science and Technology, Nanjing 210044 China)

**Abstract:** Numerical experiments on forcing dissipation and heating response of dipole (unipole) are carried out using global spectral models with quasi-geostrophic barotropic vorticity equations. For each experiment model integration is run for 90 days on the condition of three-wave quasi-resonance. The results are given as follows: Under the effects of dipole (unipole) forcing source and basic flow intensity, there exist strong interactions among the three planetary waves and quasi-biweekly and intraseasonal oscillation of the three planetary waves. In the meantime, the changes in the intensity of dipole or unipole forcing source and basic flow have different frequency modulation effects on LFO in the middle and higher latitudes. The results of the stream function field of three quasi-resonant waves evolving with time confirm that the low-frequency oscillation exists in extratropical latitude.

**Key words:** Indian Ocean temperature; dipole (unipole); frequency modulation; waves quasi- resonance; atmospheric low-frequency oscillation

**CLC number:** P461.2 **Document code:** A

## 1 INTRODUCTION

The wave-to-wave interactions in the atmosphere are one of the important research projects in atmospheric dynamics, which have important implication for studies on low-frequency oscillations in the middle and lower latitudes and variation of atmospheric circulation. The patterns of energy variation were first studied for resonant three-wave interactions in the atmosphere by Fjortoft[1]. The phenomenon was then studied in detail by Longguet-Higgins[2] and Wu[3]. In theory, external forcing regulates the periods of low-frequency oscillation in the middle and higher latitudes via the wave-to-wave interactions inside the atmosphere[4].

A large number of numerical experiments have shown that external forcing has significant effect on the atmosphere. The results of numerical simulation by Yamagata et al.[5] stressed the importance of external forcing in intriguing the atmospheric low-frequency oscillation, though without explaining its mechanism. The anomalies of SST near the equator not only affect the atmospheric circulation, weather and climate in the tropics, but is associated with their anomalies in the middle and higher latitudes[6]. The variation of external forcing sources is also found to regulate the atmospheric in the middle and higher latitudes[8]. It is then necessary to study the effect of SST forcing on the low-frequency oscillation.

Under the condition of quasi-resonance, the dipole (unipole) of SST in the Indian Ocean are used as the sources of external forcing and frictional dissipation is taken into account in numerical experiments with quasi-resonance of three planetary waves in an attempt to reveal their patterns of energy variation and regulatory effect on the low-frequency oscillation in the middle and higher latitude atmosphere.

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**Received date:** 2006-03-20; **revised date:** 2007-03-15

**Foundation item:** Natural Science Foundation of China (40275016); Operation “Six Kinds of Talents Summit” Foundation for Jiangsu Province

**Biography:** QIU Ming-yu (1969-), female, native from Inner Mongolia, senior engineer, M.S., mainly undertaking the research atmospheric dynamics.

E-mail: qmywy@163.com

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## 2 MODES OF QUASI-RESONANCE AND EXPERIMENTAL SCHEME

Taken as the controlling equation, a quasi-geostrophic vorticity equation that employs forcing and frictional dissipation is transformed to a dimensionless one. Then, spectral expansion is used together with diamond truncation of 15 waves to determine the predictive equation for the spectral form:

$$\frac{dV(k)}{dt} = F(k) - BF(k) \cdot PS(k)$$

$$-r' \frac{V(k)}{CA^2(k)} + a\,R(k)$$

where $r' = g/2\Omega a^4$, and $a$ is the forcing coefficient.

In the numerical experimental scheme,

(1) the zonal basic flow $A(0,1)$ has three different amplitudes of 1 / 84, 4 / 84 and 8 / 84;

(2) the amplitude of the three quasi-resonant waves and wavenumbers are

$$[A_1(1,2), A_2(2,2), A_3(3,4)] = (0.1, 0.1, 0.1)$$

and

$$[(k_1,l_1),(k_2,l_2),(k_3,l_3)] = [(1,2),(2,2),(3,4)]$$

respectively.

(3) The SSTA data of tropical Indian Ocean (10°S - 10°N, 40°E - 130°E) for October 1997, December 1996, March 1990 and June 1985 are used as the sources of external forcing to study the combined effect of external forcing sources, frictional dissipation and three-wave quasi-resonance within the atmosphere on the low-frequency atmospheric oscillation in the middle and higher latitudes, and

(4) With the coefficient set at $r' = 1.0\times10^{-9}$ for frictional coefficient, the coefficient at $a = 0 \sim 1.0\times10^{-4}$ for thermal forcing, the model uses the frog leap format with integration lasting for 90 d.

When $a \le 1.0\times10^{-5}$, the minimum thermal forcing coefficient is reached for the atmospheric low-frequency oscillation to change. When $a > 1.0\times10^{-4}$, the change of waves with time is basically transformed to those oscillating at high frequency to result in the spill of temporal integration

## 3 RESULTS OF NUMERICAL EXPERIMENTS

### 3.1 Thermal forcing source

It is shown from Fig.1 that waves 1, 2 and 3 show periodic oscillations, with wave 1 and 3 basically in in-phase change, just the opposite to that of wave 2, showing strong interactions among them. Significant anti-cascade transfer of energy exists between waves 1 and 3 and wave 2.

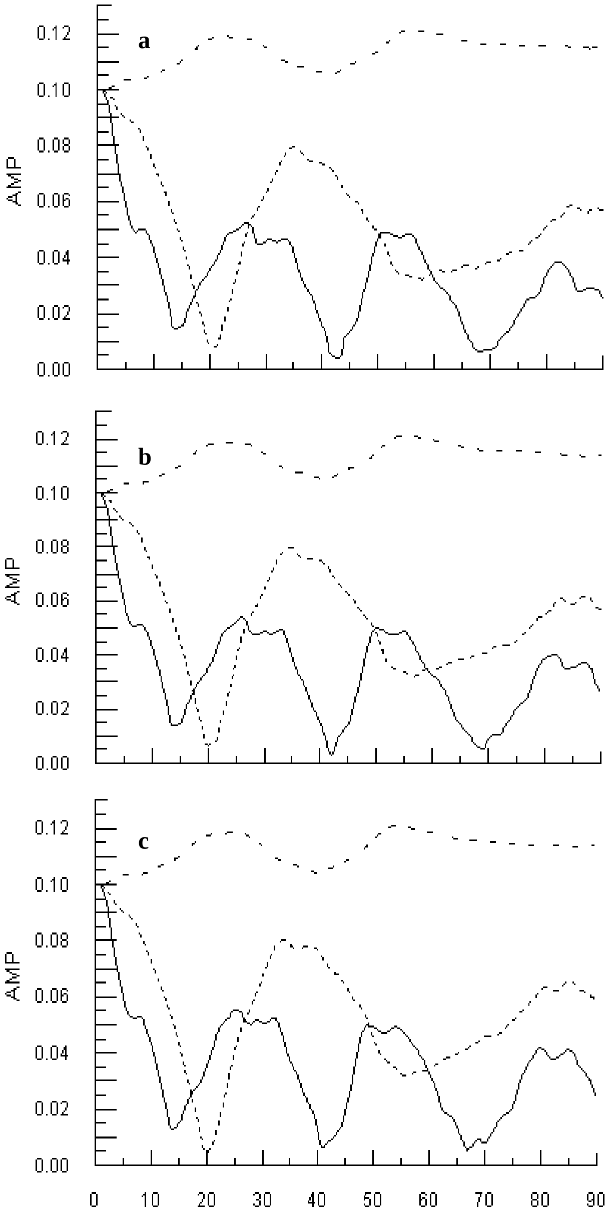

Fig.1 Temporal variation of sources without thermal forcing ($a$ = 0) and quasi-resonant three waves. The abscissa is the number of days. a. The amplitude of basic flow S=1/84; b. S=4/84; c. S=8/84. (broken line: wave 1; dot line: wave 2; real line: wave 3)

With the amplitude of basic flow intensifying to 4 / 84 and 8 / 84, the three waves keep decreasing while their amplitude keep increasing. In other words, the intensity of the basic flow increases, wave oscillation accelerates and periods decrease, illustrating the fact that fluctuations can acquire energy from basic flows.

### 3.2 Forcing fields of positive (negative) dipoles

(1) Monthly mean SSTA field characteristic of positive

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unipole for October 1990 taken as the forcing field (figure omitted)

When the forcing coefficient increases gradually, i.e. $a = 1.0\times10^{-5} \sim 1.0\times10^{-4}$, it is shown from Fig.2 that the three waves have significant variation and high-frequency oscillation further decrease in the period but increases in the speed of oscillation. There is much interaction and transformation of energy between the waves, indicating that the intensification of the dipole-forcing factor regulates the wave action.

With the intensification of basic flow (figure omitted), the threshold time is brought forward in variation of Waves 1, 2 and 3, indicating that the thermal forcing of the dipole tends to accelerate low-frequency oscillation or change it to high-frequency one.

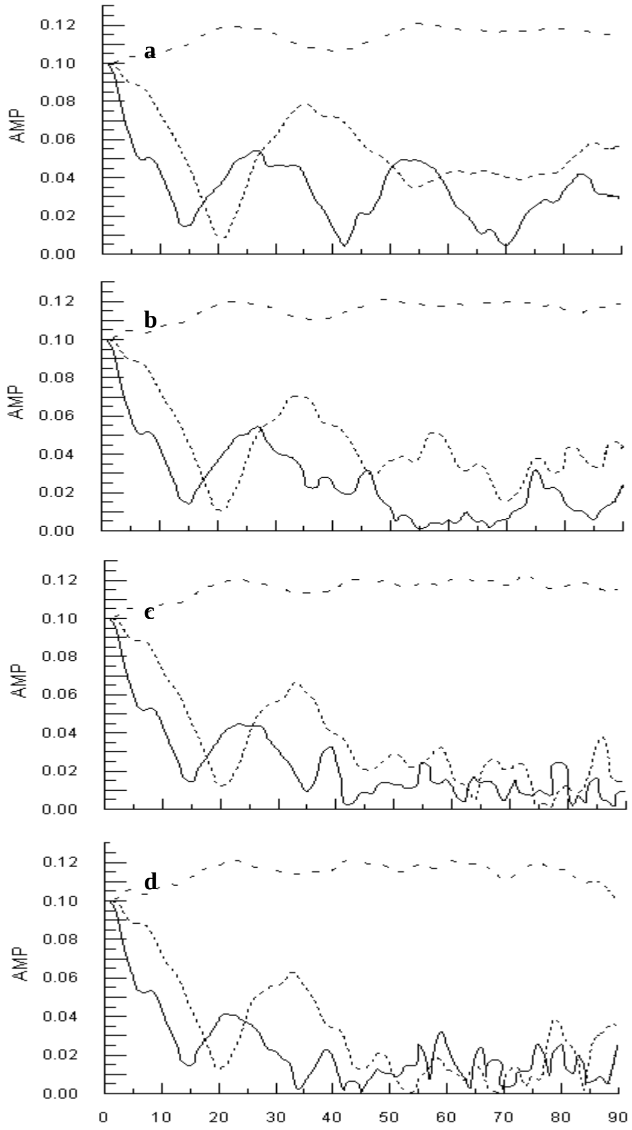

Fig.2 Temporal variation of positive dipole forcing field, basic flow with amplitude ($S$=1/84), different forcing coefficients $a$, and quasi-resonant three-wave amplitude a. $a = 1.0\times10^{-5}$; b. $a = 5.0\times10^{-5}$; c. $a = 8.0\times10^{-5}$; d. $a = 1.0\times10^{-4}$. The abscissa is the number of days.

(2) Monthly mean SSTA field characteristic of negative dipole for December 1996 taken as the forcing field (figure omitted)

The forcing coefficient $a = 1.0\times10^{-5}$. The results of Fig.3 are very similar to those of Fig.1a and Fig.2a.

When the forcing coefficient increases gradually, i.e. $a = 5.0\times10^{-5}$, $8.0\times10^{-5}$ and $1.0\times10^{-4}$, high-frequency oscillation decreases in the period but increase in the speed of oscillation, with the intensification of the negative-dipole forcing factor. Comparing Fig.3 with Fig.2, it is known that the negative dipole has much weaker effect on the low-frequency oscillation than the positive one. With the amplitudes of 4 / 84 and 8 / 84 in the basic flow, the low-frequency component of the three waves still have significant wave-to-wave interaction and the three waves tend to have similar trends of variation except for the fluctuation amplitude. Wave-to-wave interactions are still significant in the low-frequency part of the three waves and significant anti-cascade transfer of energy exists between waves 1 and 3 and wave 2.

It is known from the above analysis that the forcing of positive and negative dipoles and with the intensification of the forcing factor of positive and negative dipoles and basic flow intensity, the time at which low-frequency oscillations superpose or turn into high-frequency oscillations are shortened, the oscillation of waves accelerated and oscillatory period shortened significantly. Significant anti-cascade transfer of energy exists between waves 1 and 3 and wave 2. It is also known that the negative dipole has much smaller effect on the low-frequency than the positive dipole during the regulation of atmospheric low-frequency regulation.

3.3 Positive (negative) unipole forcing field

It is known from analysis (omitted) that the fluctuation of positive and negative unipole forcing factor and the variation of basic flow intensity are also playing an important role in the fluctuation of waves. The intensification of forcing factors and basic flow brings forward the threshold time at which low-frequency oscillations superpose or turn into high-frequency oscillations are brought forward and accelerates the wave oscillation. It is also known that the forcing effect of positive (negative) unipoles are equivalent to the positive (negative) dipoles in regulating the low-frequency atmospheric oscillation and positive (negative) unipoles have the same sensitive zone as positive (negative) dipoles, with the

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positive unipole having a larger regulating effect than the negative one

For analyses of other aspects, refer to the Chinese edition of the journal.

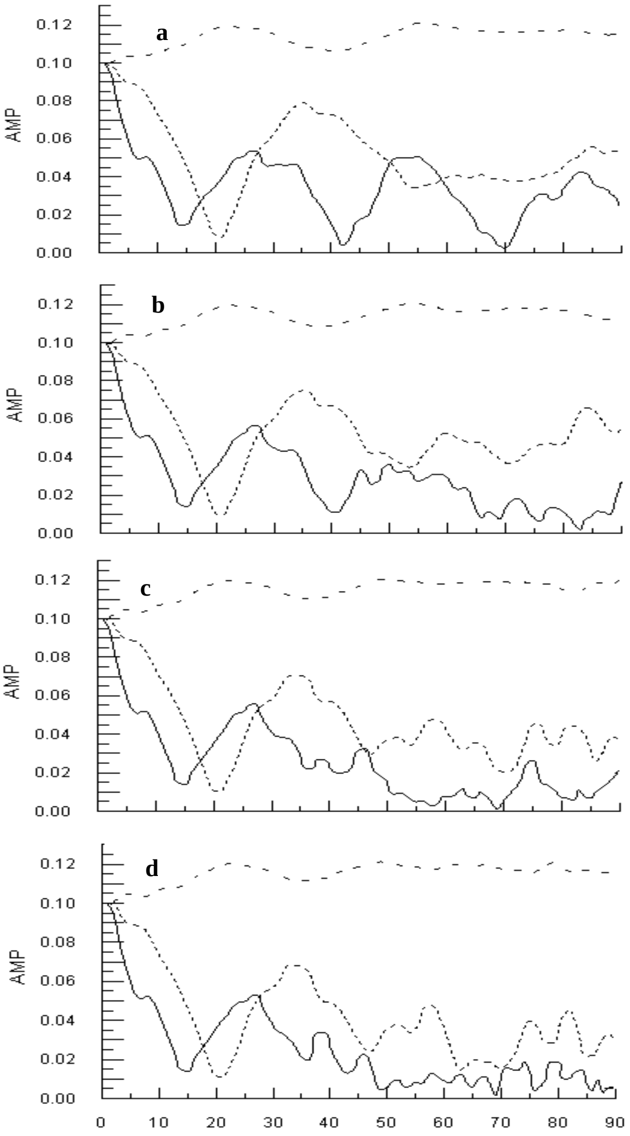

Fig.3 Temporal variation of negative dipole forcing field, basic flow with amplitude ($S$=1/84), different forcing coefficients $a$ , and quasi-resonant three-wave amplitude a. $a=1.0\times10^{-5}$; b. $a=5.0\times10^{-5}$ ; c. $a=8.0\times10^{-5}$ ; d. $a=1.0\times10^{-4}$. The abscissa is the number of days.

## 4 CONCLUSIONS

In the numerical model, with the SST dipole (unipole) of the Indian Ocean treated as the source of external forcing and frictional dissipation taken into account, strong interactions are found among the three planetary waves. Next are the results. (1) Under the combined action of thermal dipole (unipole) forcing sources and the intensity of basic flow, the three planetary waves have strong wave-to-wave interactions, fluctuating quasi-biweekly and intraseasonably. (2) The increase (decrease) of the intensity of thermal forcing and basic flow for the dipole and unipole tend to shorten (prolong) the period of atmospheric low-frequency oscillations. (3) The thermal sources of positive dipole (unipole) regulate the low-frequency oscillation more than the negative dipole (unipole), resulting in much decreased threshold time for it to superpose or become high-frequency oscillation and much speeded up wave fluctuations. (4) The positive (negative) dipole and positive (negative) unipole regulate the atmospheric low-frequency oscillation on the same sensitive zone.

## REFERENCES:

[1] Fjortoft R. On the change in the spectral distribution of kinetic energy for two-dimension non-divergent flow [J]. Tellus, 1953, 5:225-230.

[2] Longuet-Higgins M A, Gill A E. Resonant interactions between planetary waves [J]. Proc Roy Soc, Ser , 1967, 299: 120-140.

[3] WU Rong-sheng. Resonance of barotropic atmospheric waves and variation of energy [J]. Science in China (Series A), 1979, 2: 195-203.

[4] Lu Weisong. Four-wave resonance in a forced-dissipative barotropic atmosphere [J]. Theor Appl Climatol, 1996, 55: 221-228.

[5] Yamagata T , Havahsi Y. A simple liagnostic model for the 30-50 day Oscillation[J].K. Met. Soc. Japan, 1984, 62:709-717.

[6] Horel J D ,Wallace J M. Planetary-scale atmospheric phenomena associated with the Southern Oscillation[J]. Mon Wea Rev, 1981, 109: 813-829.

[7] LU Wei-song, MA Shu-jie, TAO Li. Frequency modulation effect of diabatic heating on atmospheric low-frequency oscillation in the extratropical latitudes [J]. Journal of Nanjing Institute of Meteorology, 1998, 21: 336-345.

[8] QIU Ming-yu, LU Wei-song, TAO Li. Frequency modulation effect of ENSO events on atmospheric low-frequency oscillations in the extra-tropical latitudes [J]. Journal of Nanjing Institute of Meteorology, 2004, 27: 365-373.

[9] Colucci S J, Loesch A Z, Bosart L F. Spectral evolution of a blocking episode and comparison with wave interaction theory [J]. JAS, 1981, 38: 2092-2111.

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