CHARACTERISTICS OF QUASI-STATIONARY WAVES IN THE SOUTHERN HEMISPHERE

Julio Pablo Reyes Fernandez, Vadlamudi Brahmananda Rao, and Sergio Henrique Franchito

Instituto Nacional de Pesquisas Espaciais, INPE
CP 515, 12201-970, São José dos Campos, SP
e-mails: pablo@met.inpe.br , vbrao@met.inpe.br , fran@met.inpe.br

ABSTRACT

Characteristics of quasi-stationary (QS) waves in the Southern Hemisphere are discussed using 51 years of NCEP/NCAR reanalysis data. The amplitude of QS wave 1 has two maxima in the upper atmosphere, one at 30°S and the other at 60°S. QS waves 2 and 3 have much less amplitude. Monthly variation of the amplitude of QS wave 1 shows that it is highest in October particularly in the upper troposphere and stratosphere.

RESUMO

Características das ondas quase-estacionárias (QE) no Hemisfério Sul são discutidas usando 51 anos de dados da reanálise do NCEP/NCAR. A amplitude da onda QE 1 tem dois máximos na alta atmosfera, um em 30°S e o outro em 60°S. As ondas QE 2 e 3 têm muito menor amplitudes. Variação mensal da amplitude da onda QE 1 mostra que ela é maior em outubro, particularmente na alta troposfera e estratosfera.

INTRODUCTION

Quasi-stationary (QS) waves are forced by inhomogenities of earth's surface: orography (Charney and Elliassen, 1949), land-sea contrast (Smagorinsky, 1953), etc and are observed throughout the globe over a wide range of length scales. Most of the research on QS waves emphasized the Northern Hemisphere (NH). A few studies have been made discussing QS waves in the Southern Hemisphere (SH). van Loon and Jenne (1972), Hartman (1977), Trenberth (1980) and Karoly (1989) discussed QS waves during the winter and summer. Randel (1988) studied QS waves in the SH in the other seasons also. He noted that the QS waves variance has maxima at 30°-40°S and 50°-60°S, in the upper troposphere during the late winter or early spring. He also noted that the maxima in the stratosphere occurred in the latitude band 50°-60°S. Quintanar and Mechoso (1995) used the NMC (National Meteorological Center) analysis for the period January 1979 through December1990 to discuss the QS waves in the SH. They found that the QW wave in the winter is by far the dominant part of the geopotential height field in both the troposphere and stratosphere. QS wave 1 is largest in the latitudes 50°-60°S. The amplitude of the QS wave 1 is maximum in the austral spring (october) both in the upper troposphere and stratosphere.

The above mentioned studies on the QS waves in the SH used limited data series and discussed mostly the winter and summer characteristics. Quintanar and Mechoso (1995) used a relatively longer series (12 years) and discussed the seasonal variation also. The purpose of the present work is to study the characteristics of QS waves in the SH using a long series of data (51 years, 1948-1998) obtained from the NCEP (National Centers for Environmental Prediction)/NCAR (National Center for Atmospheric Research) reanalysis datasets. Unlike the previous NMC analysis, which underwent changes in the model physics (Trenberth and Olson, 1988), NCEP/NCAR reanalysis were prepared using a state-of-the-art model (Kalnay et al., 1996) which makes these data ideally suitable to study interannual variations. To our knowledge this is the first study where 51 years of data have been used to study stationary waves in the SH.

DATA SOURCE AND METHODOLOGY

Any meteorological variable, ϕ (say geopotential height) can be divided into a time mean and a time deviation: $\phi(\lambda, \varphi, z, t) = \phi_o(\lambda, \varphi, z) + \phi'(\lambda, \varphi, z, t)$, where λ, φ, z and t are respectively longitude, latitude, height and time. The time mean ϕ_o can be taken over a month, a year, a decade or longer time depending on the interest. ϕ' is termed as the transient circulation (eddies) and is responsible for weather. ϕ_o can be divided further into a zonal mean and a zonal deviation: ϕ_o (λ, φ, z) = ϕ_{oo} (λ, φ) + ϕ^*(λ, φ, z). ϕ_{oo} represents the stationary symmetric circulation and is known popularly Hadley type circulation. ϕ^* is the asymmetric stationary circulation and is known popularly as stationary waves. Since the stationary waves can change a little (in time) in position and in intensity these are called as QS waves.

As mentioned above, the ime mean ϕ_o is divided into a zonal mean (ϕ_{oo}) and a zonal deviation (ϕ^*). In our case time mean is taken over a period of a month. We can write the zonal wave components for ϕ^* as:

$$\phi^*(\lambda, \varphi, p) = A_k(\lambda, p) \cos [(k\lambda + \alpha_k(\varphi, p)] \qquad (1)$$

where k is the wave number, A_k, the amplitude and α_k is the phase. In our case, k = 1, 20.

In the present study we use monthly mean values of the geopotential height ϕ for the period 1948-1998. These data were obtained from NCEP reanalysis and are available at 1000, 925, 850, 700, 600, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20 and 10 hPa levels, at 2.5° x 2.5° (latitude x longitude) intervals. For a detailed description of NCEP data assimilation method see Kalnay et al. (1996).

RESULTS AND DISCUSSION

In this section we discuss the seasonal and monthy variations of QS waves. Figure 1 shows the QS wave 1 amplitudes for the months of January (summer), April (autumn), July (winter) and October (spring). This figure shows several interesting characteristics. In January in the upper troposphere there are two maxima, one at 30°S and another at 50°S. The value in the higher latitudes is more than double that in the subtropics. A comparison with the values in other months shows that the QS wave is trapped in the lower atmosphere in January, while in other months it propagates into the stratosphere. In October the amplitude values in the lower sratosphere are highest. This October maximum in amplitude of QS wave 1 is noted by Quintanar and Mechoso (1995) also. The subtropical maximum in the upper troposphere is highest in July.

Figures 2 and 3 show the amplitudes of QS waves 2 and 3. Compared to QS wave 1 the amplitude of wave 2 and 3 are much less. It is known that these waves (wave 2 and 3) are primarily eastward moving (Mechoso and Hartman, 1982). QS wave 2 is confined to the lower atmosphere in January whereas in other months it propagates into the lower stratosphere. QS wave 3 is essentially confined to the lower atmosphere in all the seasons.

Figure 4 shows the monthly variation of amplitude of QS waves 1, 2 and 3 at 60°S. At this latitude, the maximum amplitude (100 m) of QS wave 1 in the troposphere is in November and the maximum amplitude in the stratosphere is in October (550 m). In the stratosphere there is a secondary maximum in July (300 m). The lowest values of amplitudes of QS wave 1 is found in the summer (50 m). The monthly variation of the amplitude of QS wave 2 is similar to that of QS wave 1 except that the amplitudes are less and in the stratosphere in October they are about ¼ of those of QS wave 1. The monthly variation of QS wave 3 is very different. A clear winter (July) maximum is found both in troposphere and stratosphere. Compared to QS waves 1 and 2 the amplitudes of QS wave 3 are much less. As we have seen earlier (Figure 3), QS wave 3 is essentially trapped in the troposphere. Thus from the above discussion we can infer the contribution of QS wave 1 for the zonal variance of ϕ^* is by far the most dominant

CONCLUSIONS

In this paper we studied the characteristics of QS waves in the SH using 51 years of NCEP/NCAR reanalysis data. Earlier studies (eg Quintanar and Mechoso, 1995) used data of much less periods. The amplitude of QS wave 1 has two maxima, one at 30°S and the other at 60°S. The maximum at 60°S is noted in all the four seasons and this maximum is more than double that in the subtropics. The maximum in the subtropics is strongest in the austral winter (July) while the maximum at 60°S is strongest in October. Except in the summer (January), the QS wave 1 amplitude increases from the troposphere into the stratosphere. QS waves 2 and 3 have much less amplitudes. Monthly variation of the amplitude of QS wave 1 clearly shows that it is highest in October particularly in the upper troposphere and the stratosphere.

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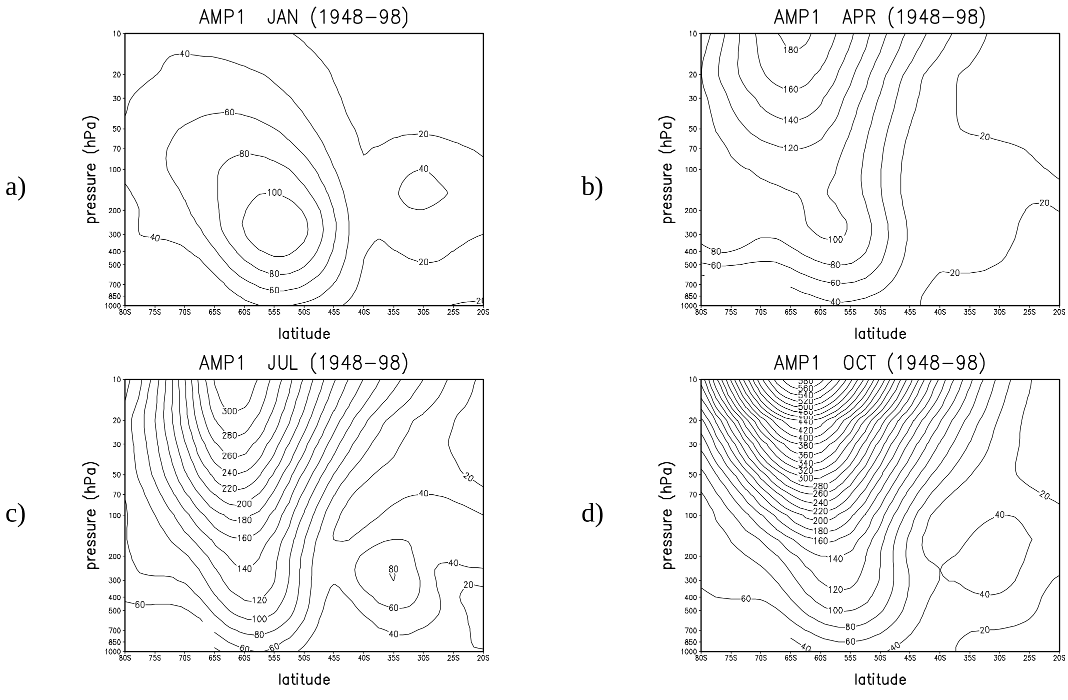


Figure 1: Amplitudes of QS wave 1 (m) for: a) Januray, b) April, c) July and d) October.

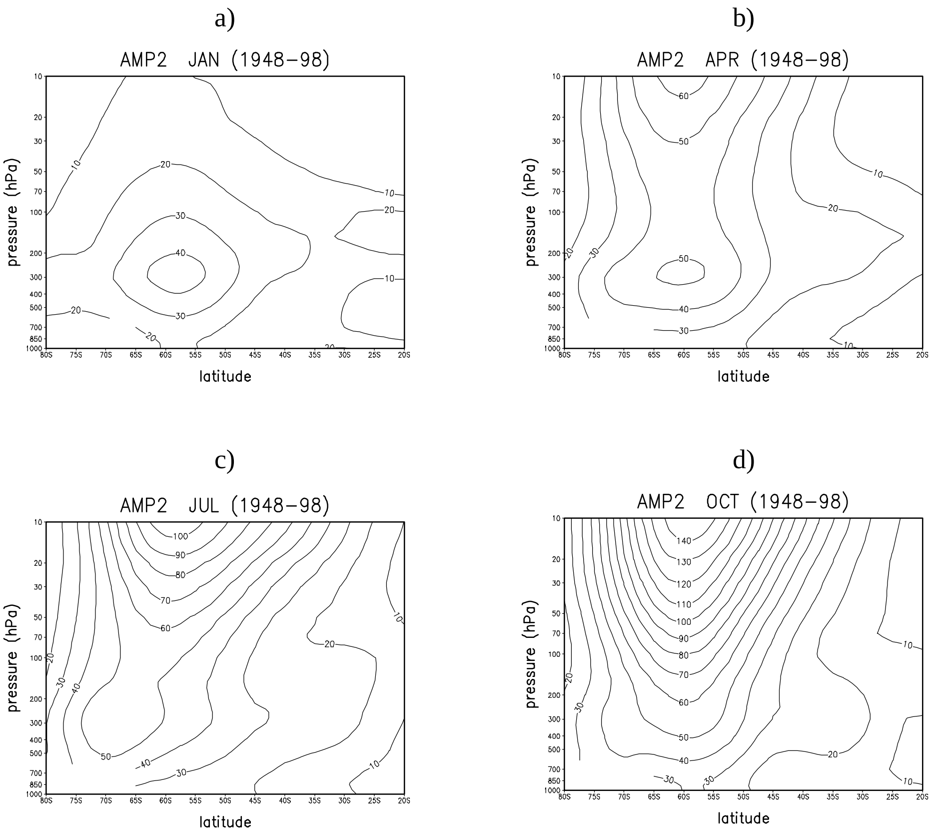


Figure 2: Same as Figure 1, but for QS wave 2.

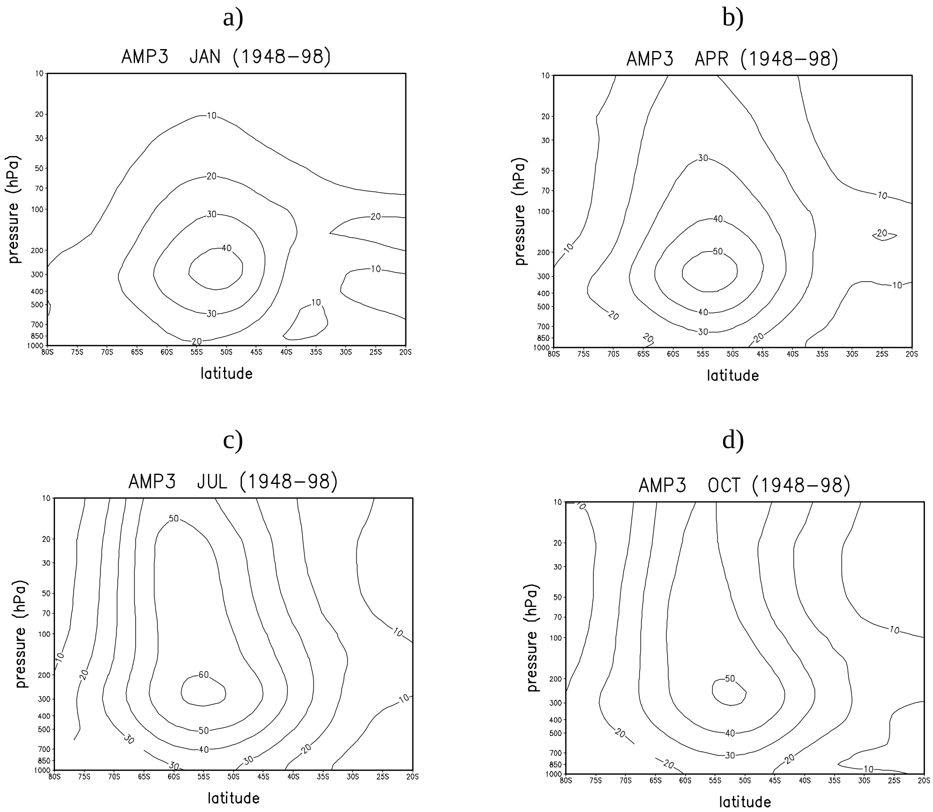
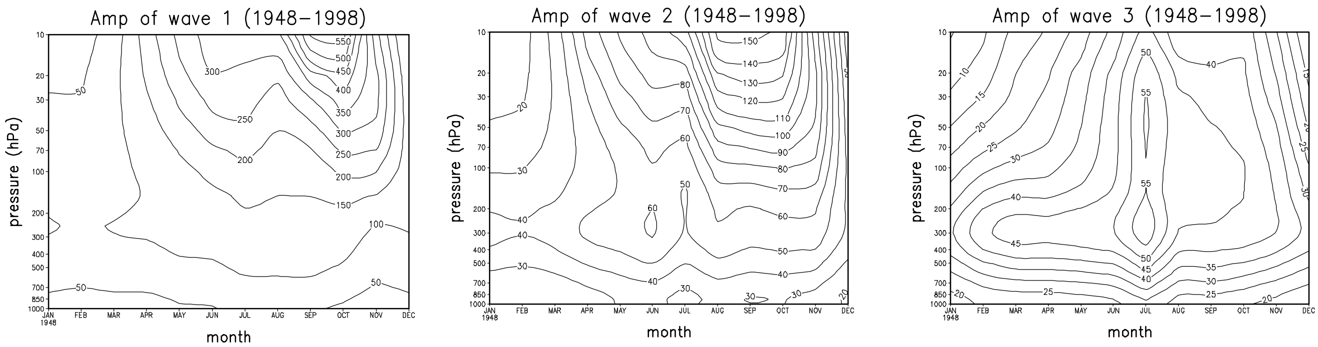


Figure 3: Same as Figure 1, but for QS wave 3.



a) b) c)

Figure 4: Monthly variation of the amplitudes (m) of QS waves 1 (a), 2 (b) and 3 (c) at 60°S.