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CHARACTERISTICS OF THE PLANETARY WAVES ON THE MEAN JANUARY AND JULY CHARTS OF THE STRATOSPHERE

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V. Brahamananda Rao and T. V. Ramana Rao

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PRESIDÊNCIA DA REPÚBLICA
CONSELHO NACIONAL DE PESQUISAS
INSTITUTO DE PESQUISAS ESPACIAIS
São José dos Campos - Estado de S. Paulo - Brasil

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Fernando de Mendonça
General Director

ABSTRACT

January and July mean geopotential field at 100, 50, 30 and 10 mb levels is subjected to harmonic analysis. At these levels the lower wave numbers dominated the flow both in winter and summer, the amplitude in winter being more. The horizontal and vertical structure of the planetary wave number 1 is inferred using the phase information and its applications regarding momentum and heat transport are discussed.

1. INTRODUCTION

Following the discovery of the suddenwarming phenomena by Scherhag (1952), considerable attention has been focused on the dynamics of winter time stratospheric circulation. In spite of many theoretical and synoptic investigations the nature of this complex phenomena is still not completely understood. However, the ultra long waves seem to play an important role in the dynamics of the stratosphere.

Although a number of studies on the warming phenomena have been made deviding the flow into harmonics, the characteristics of the mean field appears to be not very well studied. The characteristics of the mean waves in the stratosphere would help in the clearer understanding of the steady state situation in the stratosphere.

In the present note the mean geopotential field at 100, 50, 30 and 10 mb levels has been subjected to harmonic analysis and the characteristics of the mean waves are discussed. Both January and July months are studied to compare the summer and winter situations.

2. DATA AND ANALYSIS

Mean monthly 100, 50, 30 and 10 mb charts given in ESSA, TWRB-10 and 11 are utilized to obtain the geopotential height field.

Geopotential height is picked up at 10 degree longitude interval on each latitude circle starting with the Greenwich Meridian. These are subjected to harmonic analysis.

ϕ, the geopotential specified along a given latitude ψ and isobaric surface may be expressed in terms of the Fourier expansion of the form,

$$\phi(\lambda,\psi) = \left(\phi(\psi)\right) + \sum_{1}^{15} (a_n \cos n\lambda + b_n \sin n\lambda) \qquad (1)$$

where

$$a_n(\psi) = \frac{1}{18} \sum_{i=1}^{36} \phi(\lambda_i) \cos (2\pi ni/36)$$

$$b_n(\psi) = \frac{1}{18} \sum_{i=1}^{36} \phi(\lambda_i) \sin (2\pi ni/36)$$

and where λ is the longitude, (ψ) is the zonal mean value of the geopotential height and n the zonal wave number. Equation (1) can also be written as

$$\phi(\lambda,\psi) = \left(\phi(\psi)\right) + \sum_{n=1}^{15} A_n \cos (n\lambda - \delta n) \qquad (2)$$

where $A_n(\psi) = \left(a_n^2 + b_n^2\right)^{1/2}$ is the amplitude of the n th zonal harmonic and $\delta_n(\psi) = \text{arc} \tan(\frac{b_n}{a_n})$ is the phase of the n th zonal harmonic.

Thus on any isobaric surface if δ_n increases with latitude then the n th harmonic has a north east to south west tilt. If δ_n decreases with latitude it has a north west to south east tilt. Similarly if at any latitude δ_n decreases with height then the n th harmonic has a westerly tilt with height. If δ_n increases with height it has an easterly tilt with height.

Harmonic analysis is done for January and July 1964 and 1966 from 20^{o}N to 70^{o}N at 10 degree interval. Alternate years are chosen to avoid any possible biennial periodicity in the flow characteritics. Some times data could not be picked up at low latitude because the analysis did not extend to these latitudes.

3. RESULTS

Both in January and July the lower wave numbers dominated the flow field. Muench (1965) also found a similar result at 50^{o}N in January 1958. Amplitudes and phases of the first three harmonics are given in Tables I and II. Table I is for January and Table II is for July. The wave having the maximum amplitude is also given in Tables I and II.

It is seen both in summer and winter in 1964 and 1966 wave number 1 dominated in high latitudes and the higher levels where significant activity takes place in winter. The amplitude of wave number 1 is considerably less in July compared to its amplitude in January.

Kennedy and Nordberg (1967) found a similar dominance of wave number 1 in the radiometric temperatures in the winter of 1964 in the lower stratosphere.

In January at 100 and 50 mb levels in higher latitudes the amplitudes of wave numbers 1 and 2 are comparable and sometimes wave number 2 has more amplitude. At 30 and 10 mb levels, however wave number 1 dominated. In Fig. 1(a) the amplitude and phase of wave number 1 is shown for January 1964 as a function of latitude at the four levels considered. Fig. 1(b) is for January 1966. At any level the amplitude of wave number 1 increased with latitude upto 60^{O}N and then decreased. 10 mb level in 1964 appears to be different, where the amplitude increased slightly from 60^{O}N to 70^{O}N. Further, in 1964 the amplitude of wave number 1 is higher compared to 1966, the difference in higher latitudes being more.

The phase at 100, 50 and 30 mb levels both in 1964 and 1966 increases with latitude upto 50^{O}N and then decreases. The phase at 10 mb level, however increased even to the north of 50^{O}N both in 1964 and 1966. As pointed out earlier, an increase of phase upto 50^{O}N makes the trough (and ridge) axis of the wave to tilt in a NE to SW direction to the south of 50^{O}N. It is well known that the wave with this type of structure will transport momentum to the north in the region south of 50^{O}N and to the south in the region north of 50^{O}N. Thus there is a convergence of momentum around $50^{O}N$ where we usually encounter the polar night jet. At 10mb level the momentum is transported towards the pole beyond $50^{O}N$ both in 1964 and 1966. It is interesting to note that the zonal wind maximum has a northward tilt with height as shown for a typical winter situation by Muench (1965).

From figures 1(a) and 1(b) it can be seen that the phase generally decrease with height. A decrease of phase with height, as pointed on earlier, means a westerly tilt of the trough (or ridge) axis of the wave with height. It is well known that this type of tilt of the wave disturbance indicates a northward transport of sensible heat by the wave. Further, the phase differences between the successive levels in 1964 is generally higher than in 1966.

Figures 2(a) and 2(b) show the variation of zonal mean temperature (in ^{O}C) in 1964 and 1966 January. It is seen that the mean temperature at 100 and 50 mb levels increases from $20^{O}N$ upto $50^{O}N$ and then decreases.At higher levels it decreases with increase of latitude. Thus in the polar stratosphere the sensible heat transport by W.N 1 is down the gradient.

An examination of Table 1(a) and 1(b) showed that the wave number 2 and 3 generally show the same characteristics as wave number 1.

In July 1964 and 1966 wave number 1 has got higher amplitude at almost all levels and latitudes. Figures 3(a) and 3(b) show the amplitude and phase variations with latitude and height for 1964 and 1966 July. It is seen that the amplitude of wave number 1 is much less compared to what it is in January. The amplitude maximum at 30^{o}N at 100 mb lvel is apparently connected to the Tibetan high during the summer monsoon month July. The phase variations are small both with latitude and height and as such confidence cannot be put on the accuracy of the relative differences.

CONCLUSIONS

Harmonic analysis of the January and July mean geopotential field at 100, 50, 30 and 10 mb levels showed that the lower wave numbers dominated the flow field. These waves transport sensible heat towards the pole and transport zonal momentum to the north in the region south of the polar jet and to the south in the region north of the jet.

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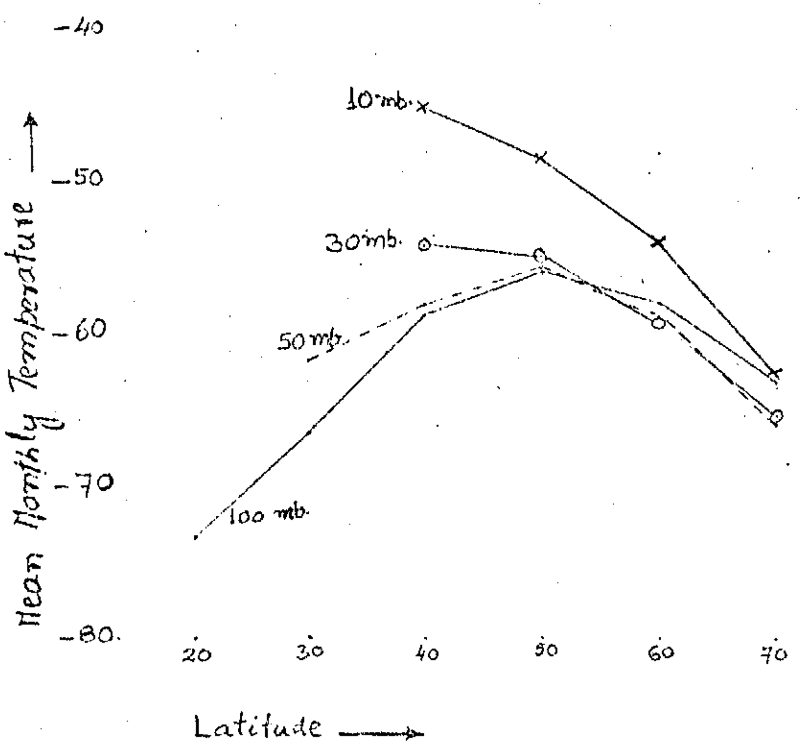
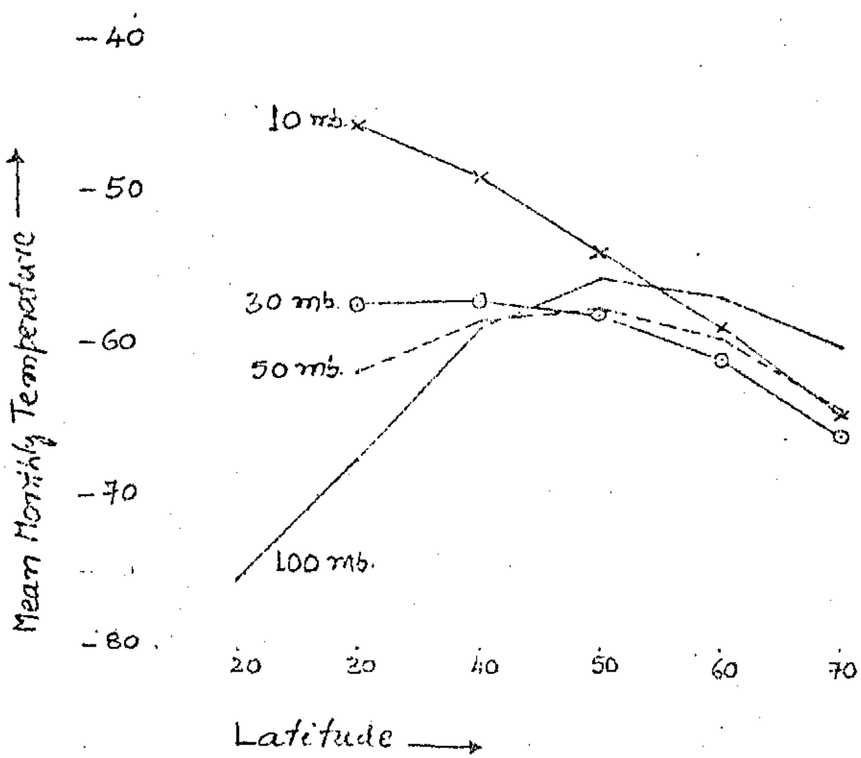


-40
-50
-60
-70
-80.
Mean Monthly Temperature
10 mb.
30 mb.
50 mb.
100 mb.
20
30
40
50
60
70
Latitude



-40
-50
-60
-70
-80
Mean Monthly Temperature
10 mb.
30 mb.
50 mb.
100 mb.
20
20
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60
70
Latitude

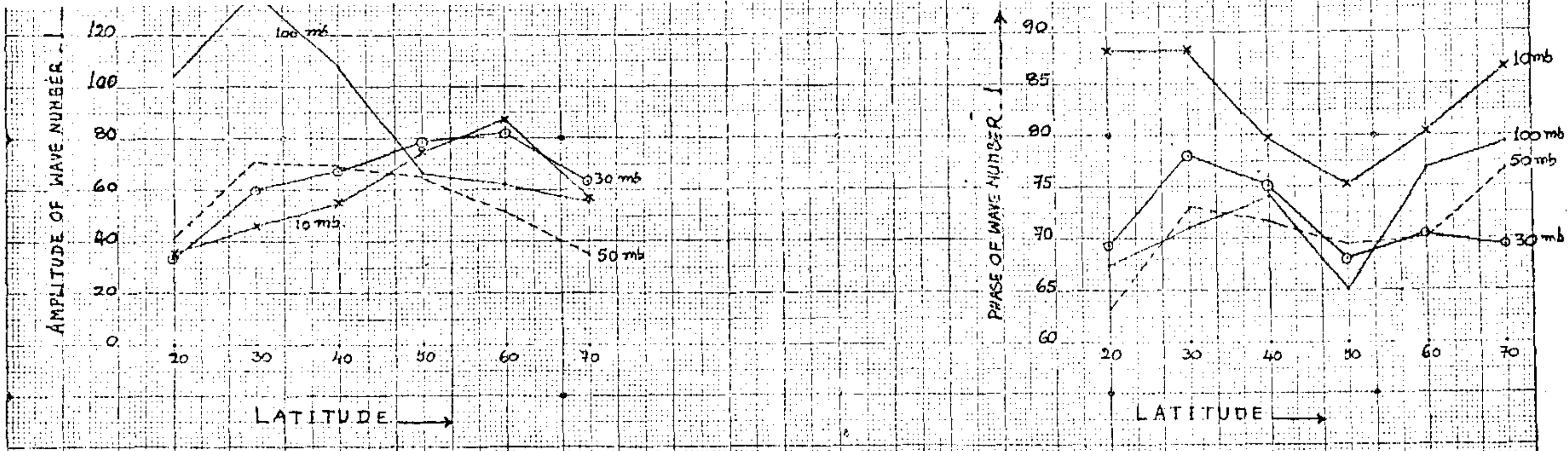

FIGURE. 3 (b)

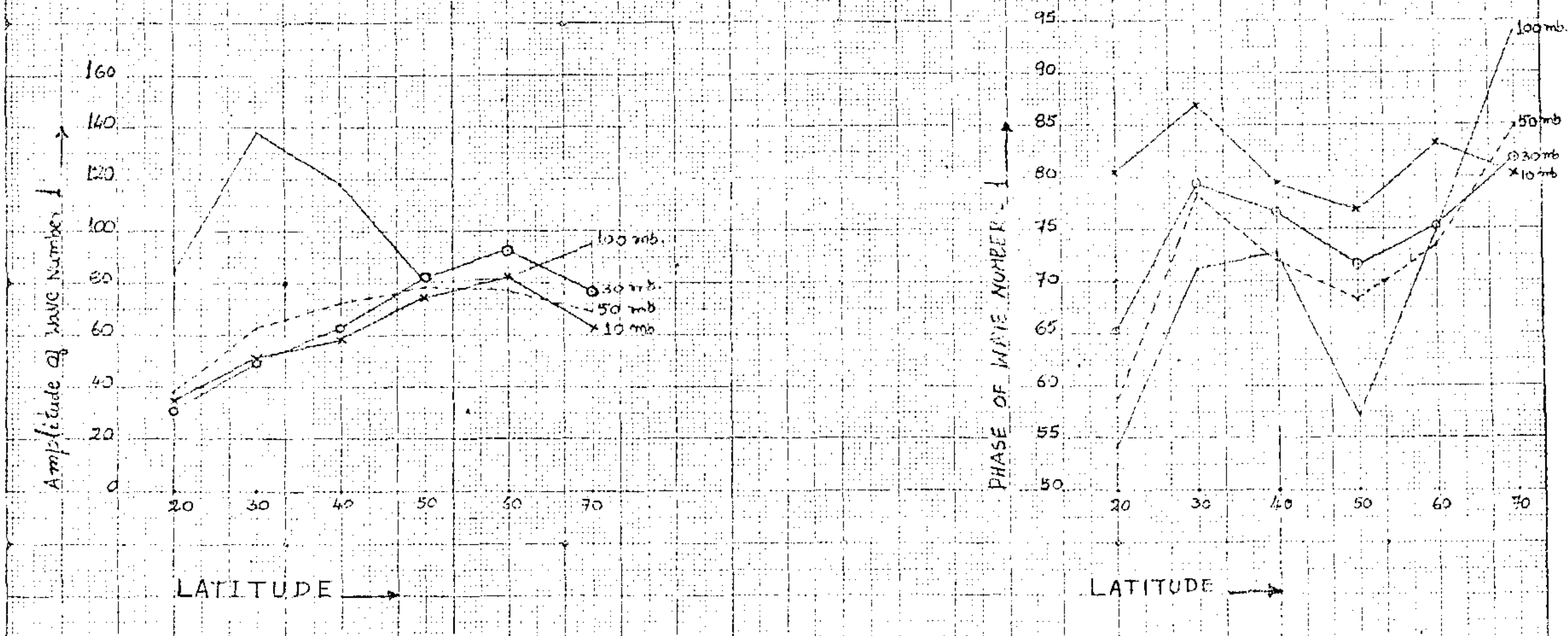

FIGURE. 3 (a)