Mausan,(1980), 313, 457-460

551.524.7

Long term variations in equatorial strato-and mesospheric temperatures

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(*Received 28 November 1979*)

ABSTRACT. M-100 Rocketsonde temperature data of Thumba in the 30 to 80 km height range for the period 1971-74 are analysed for studying the long term variations at 5 km altitude intervals. It is observed that the amplitude of the semi-annual oscillation dominates over that of the annual oscillation in the stratosphere and close to mesopause. However, the amplitude of the annual oscillation shows a quasi-peak around 70 Km altitude. The phase of the semi-annual oscillation is observed to propagate downward from mesopause while the phase of the annual component propagates on to either side from the stratopause.

From a vertical time-section prepared after filtering out periods greater than 3 months wave disturbances of a few weeks period with vertical scale sizes greater than 20 Km sides are observed. A power spectral analysis shows a dominant period well above the noise level at 52.5 days above the stratopause. Secondary peaks of lesser significance are observed with periods between 17.5 and 30.0 days.

1. Introduction

The discovery of a semi-annual oscillation of the Zonal wind in the equatorial strato-and mesospheres was made by Reed (1965, 1966). Subsequently, several workers (Quiroz & Miller 1967, Angell & Korshower 1970, Belmont and Dartt 1973, Hopkins 1975 and Hirota 1978) studied the mean zonal wind and observed that the semi-annual variation is global in extent with its maximum amplitude at the stratopause in the equatorial region and that the phase of the wave propagates downwards into the lower stratosphere. Similar findings in temperature data of the Nimbus-5 selective chopper radio-meter observations were reported by Hirota (1976) and Mc Gregor and Arthur Chapman (1978). It was observed that the monthly root mean square wave amplitudes of the temperature at the Stratopause level shows a prominent semi-annual variation in tropics with maxima after equinoxes. Hirota (1976) argued that planetary Rossby waves are responsible for the semi-annual reversal of the wind. The planetary Rossby waves were shown to be penetrating into equatorial upper atmosphere from mid-latitudes during the westerly regime (Barnett 1976). These waves were observed to have vertical scale sizes of about 20 Km in the equatorial stratosphere (Hopkins 1975) and were observed with enhanced activity during the easterlies and showed a marked semi-annual variation (Hirota 1978). From their characteristics, these waves were identified as Kelvin waves with periods of about 10 days and are expected to play an important role in producing the semi-annual reversal of the mean zonal wind by supplying the westerly momentum at the equatorial mesospheric levels. In the present paper, the annual and semi-annual oscillations in the rocketsonde temperature data of Thumba are studied. The relatively shorter wave periods present in the temperature data of strato and mesospheres are also estimated from power spectral analysis.

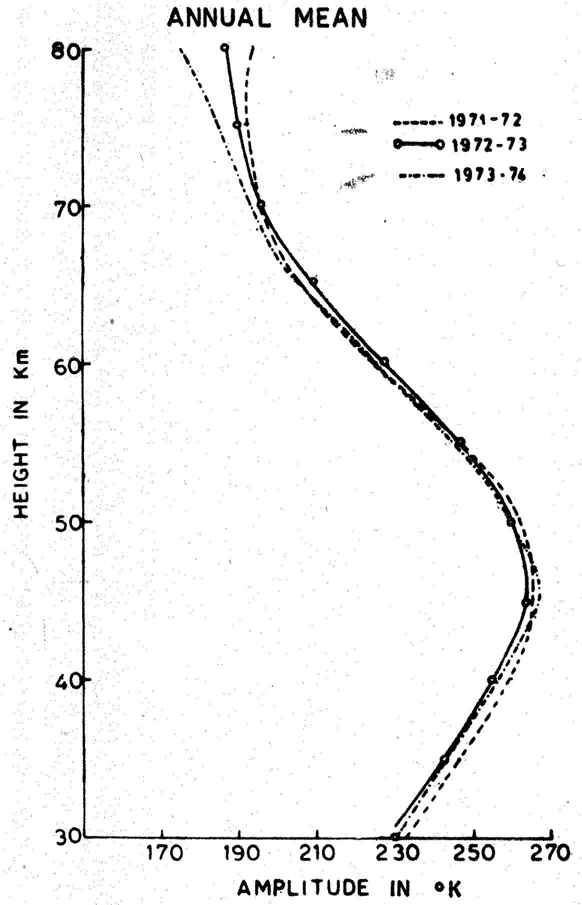

Fig. 1. Annual mean temperature (°K) profiles for the period 1 June 1971 to 31 March 1974

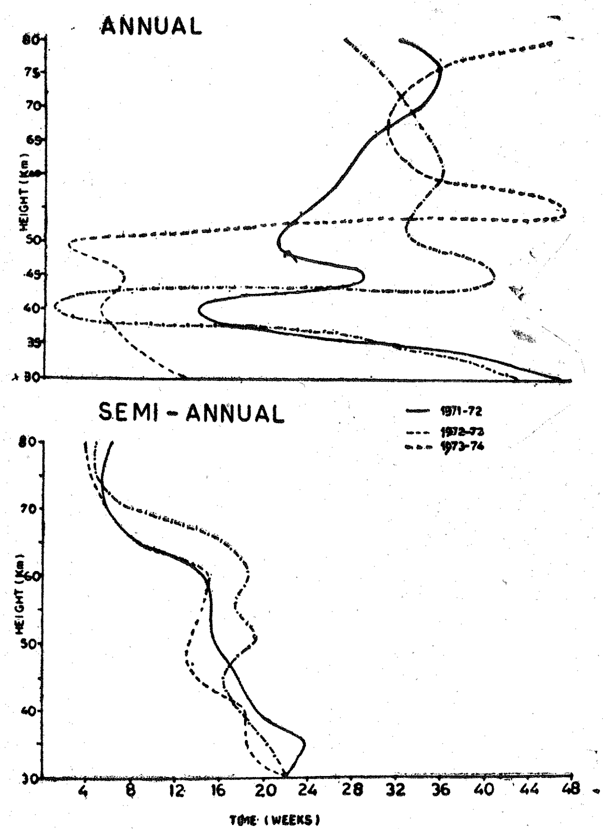

Fig. 2(*b*). The phase of the annual and semi-annual oscillations in temperature

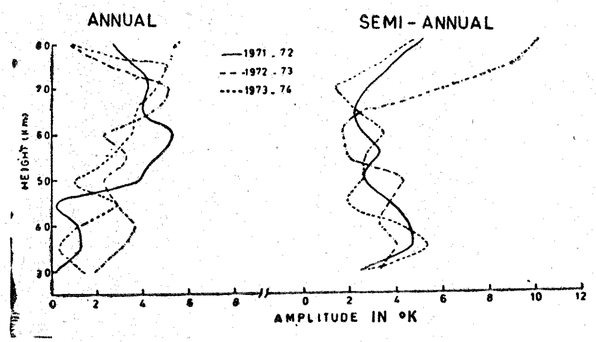

Fig. 2(*a*). Amplitudes of the annual and semi-annual oscillations in temperature (°K)

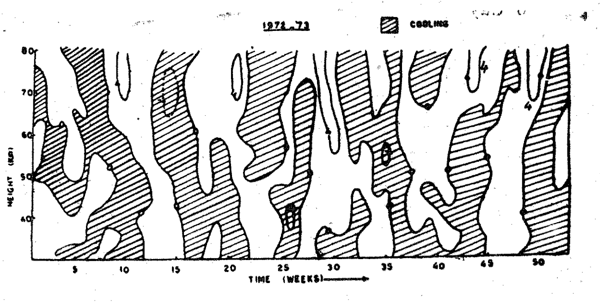

Fig. 3. Vertical time section of the temperature for June 1972, May 1973 after removing the mean annual and its second, third and fourth harmonic amplitudes

2. Data

The rocketsonde temperature data are obtained by *M*-100 rockets at Thumba launched on every Wednesday of the weak. The flights are around 2000 hrs IST. The data includes wind and densities. However, in the present work, only the temperature data are analysed. The error of the estimation in the temperature is more at higher altitudes. The temperature data chosen are spread from June 1971 to May 1974. The data are analysed on an yearwise basis for the altitude range 30 to 80 Km at height intervals of 5 Km.

3. Results

The temperature data are analysed individually for each height level and for each year over the period June to May. A harmonic analysis is carried out and the mean values of the temperature are plotted as a function of altitude in Fig. 1. The mean values for all the three years closely agree with each other with a maximum temperature of 265°K at the stratopause. The

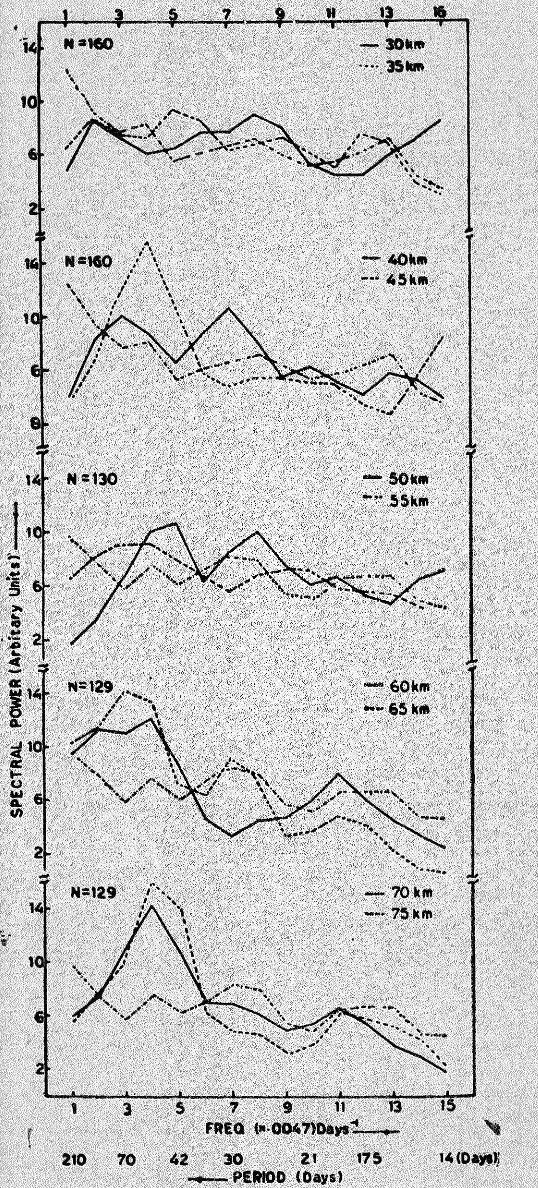

Fig. 4. Power spectra of temperature time series along with the noise power spectrum (—.—.) at various heights

stratopause level (45 Km observed) does not show significant variation from year to year. As the data is characterised by larger errors at higher altitudes, the temperature profile above 70 Km show some variability.

In Fig. 2a, the amplitudes (in degrees Kelvin) of the annual and the semi-annual oscillations for the years 1971-72, 1972-73 and 1973-74 are plotted. It is very clearly seen that the semi-annual component is more dominant than the annual component at the stratospheric and near the mesopause heights. At heights considerably above 60 Km the annual component is significantly increased in magnitude. The variability is more in the semi-annual component at mesospheric height. In the case of the annual component, the maximum amplitudes are seen around 70 Km. These maxima show gradual increase with height from year to year. In 1971-72, the maximum is at 60 Km which shifts to 70 Km in 1972-73 and finally reaches the 75 Km height in 1973-74. Whereas, in the semi-annual component such variation is not seen in the amplitude which continues to increase above 60 Km. The semi-annual amplitude appears to exhibit a quasi-peak at 35 Km in the years 1971-72 and 1973-74 and a minimum in 1972-73. This is probably due to the influence of the quasi-biennial oscillation which is more prominent at lower heights (Hirota 1978).

Fig. 2b shows the time of the maxima for both annual and semi-annual components as a function of height. The plots representing the three-year period show good self-consistency. The maximum is first seen around stratopause in the annual component. This appears to propagate in both downward and upward directions. In the semi-annual component, the maximum first occurs at the mesopause and propagates downwards in course of time.

Fig. 3 shows a vertical time section plotted for the year 1972-73. The data are plotted after removing the mean and the first four harmonic components of the year. Thus the vertical section is free from long period components of period greater than three months. From the time section, it is clear that the vertical scale sizes of the wave-like disturbances are more than 20 Km in altitude. From a perusal of the shaded and unshaded regions, it can be seen that periods of more than 5 weeks duration are existing at various levels. However, comparatively smaller periods are seen at lower heights and the wave periodicity appears to increase with height. A power spectral analysis of the temperature data is also carried out in a manner similar to that adopted by Naidu *et al.* (1977) and the spectral power distribution as a function of the period is shown in Fig. 4 for various levels. A noise power spectrum is also shown in the same figure. Peaks with power greater than the noise power level are noted as prominent periods at various heights and the data of periods are presented in Table I.

In estimating the spectral power, the first assumption made is that only periods between 14-70 days are present. The data chosen at every 5 Km interval are plotted as time series. A mean line is drawn for each time series covering periods of 3 months or more (Naidu *et al.* 1977). The deviations from this mean line are noted and the power spectrum is computed for the deviation series. In evaluating the spectrum, 15 lags are chosen as this corresponds to 15 spectral components covering 14 to 210 day periods. The higher cut-off period of 210 days is intentionally chosen to get better resolution at higher frequencies. In the three-year duration, the data at each height covers nearly 160 weeks and at higher levels the data points are lesser in number. A seasonal study could not be made as the data are insufficient. A little ambiguity in the spectra still remains to a certain extent, as seasonal behaviour is not eliminated.

4. Discussion and conclusion

Fig. 1 clearly brings out the expected vertical temperature profile. It can be seen that the temperature increases upto 45 Km with a rate of increase of 1° K/Km. Subsequently, the temperature decreases at a rate of approximately 3.5° K/Km leaving a small isothermal layer around the stratopause. At altitudes above 70 Km, the data indicates a certain amount of variability. Fig. 2 shows that the semi-annual component is more prominent than the annual in the stratosphere and mesopause for the year 1971-72 and 1973-74 but there is a slight variation in this trend, for 1972-73; particularly, in the lower stratosphere. However, in general, the results are in agreement with those of other workers for tropical latitudes (Reed 1966, Belmont and Dart 1973, Hopkins 1975 and Hirota 1978). The variation in 1972-73 values at stratospheric heights can be attributed to the influence of quasi-biennial oscillation which is also reflected in the annual oscillation. However, in the plots of the annual component there is a good consistency showing a prominent maximum in mesosphere, which shows a gradual increase in height from year to year. From the phase variation, it can be seen that the annual maximum occur first at the stratopause, and propagates to either side with large values of propagating speed. From the amplitude and phase diagram, it can be inferred that the seat of annual component is the stratopause and this disturbance propagates on to either side with large variability in the propagating speed. The features of the semi-annual component as shown by Hirota (1978) for Ascension Island closely agree with the present results. The semi-annual maximum occurs around summer solistice at mesospheric heights and propagates downwards. The seat of the semi-annual disturbance thus originates at mesospheric heights and the disturbance propagates down to stratosphere.

The vertical time section clearly shows that waves of less than 3-month periodicity are existent and that their vertical scale sizes are more than 20 Km. From the power spectral analysis, it is seen that longer periods of 52.5 days appear to be more prominent above the statopause height. Around and below the stratopause, lower periods become prominent as evidenced by data in Table 1 as well. These values are very close to the periods of 20 and 40 days at the stratopause observed by Naidu *et al.* (1978).

TABLE 1

Height (Km)	First prominent		Second prominent	
	Period in days	Power in arbitrary units	Period in days	Power in arbitrary units
30	26.3	9.0	..	..
35	23.3	7.2	17.5	7.5
40	30.0	10.5	..	..
45	52.5	15.4	..	..
50	52.5	10.3	26.3	10.0
55	52.5	9.1	23.3	7.1
60	52.5	12.2	19.1	8.0
65	52.5	13.3	30.6	9.0
70	52.5	14.4	..	..
75	52.5	16.0	..	..

The results of the present investigation as well as those of Naidu *et al.* (1978) and Madden and Julian (1971) indicate that waves with periods of 15 to 55 days exist in the atmosphere through the troposphere to the mesopause.

Acknowledgements

Two of the authors (BNM and RC) acknowledge the financial assistance given by the University Grants Commission, New Delhi.

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