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Middle atmospheric oscillation over India and its possible association with Indian summer monsoon

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सार – इस शोध -पत्र में थुम्बा और बालासौर के रॉकिटसौन्दे पवन आंकड़ों का प्रयोग करके ऊपरी समताप मंडल और निम्न मध्यमंडल में जोनीय पवनों के मध्य वायुमंडलीय दोलनों का विश्लेषण और अध्ययन किया गया है।

यह देखा गया कि माध्य चित्र में, विषुवतीय भारतीय क्षेत्र (जैसे थुम्बा के ऊपर) पर अर्द्धवार्षिक दोलन मुख्य रूप में प्रमुख था जबकि उष्णकटिबन्धीय भारतीय क्षेत्र (जैसे बालासौर के ऊपर) पर वार्षिक तरंग प्रमुख थी। अच्छे मानसून वर्ष के दौरान, उष्णकटिबन्धीय भारतीय क्षेत्र के ऊपर एक प्रबल अर्द्धवार्षिक तरंग देखी गई थी। अच्छे मानसून वर्ष के दौरान विषुवतीय भारतीय क्षेत्र पर इस अर्धवार्षिक तरंग का आयाम काफी ऊंचा पाया गया। यह अध्ययन ग्रीष्म मानसून के साथ भारत पर मध्य वायुमंडलीय दोलनों का निकट संबंध दर्शाता प्रतीत होता है।

ABSTRACT. In this paper the middle atmospheric oscillations of the zonal wind in upper stratosphere and lower mesosphere have been analysed and studied using the rocketsonde wind data of Thumba and Balasore.

It was observed that in the mean picture, the semi-annual oscillation was predominant in the equatorial Indian region (*i.e.*, over Thumba) while the annual wave was predominant over tropical Indian region (*i.e.*, over Balasore). During good monsoon year, a strong semi-annual wave over tropical Indian region was observed. The amplitude of this semi-annual wave was also found to be significantly higher over the equatorial Indian region during good monsoon year. The study seems to reveal a close association of the middle atmospheric oscillations over India with the summer monsoon.

1. Introduction

A significant feature of the zonal flow of tropical stratosphere and mesosphere is the existence of seasonal oscillations, *viz.*, annual, semi-annual and a non-seasonal Quasi-Biennial Oscillations (QBO) with a period of about 26 months.

Since the discovery of semi-annual oscillation of the zonal wind in the equatorial stratosphere and mesosphere by Reed (1965), it has been one of the most interesting problems associated with the upper atmospheric dynamics yet to be fully understood and solved. After pioneering work by Reed (1965, 1966), using rocket data of Ascension Island (8°S, 14°W) and Barking Sand (22°N, 160°W), Quiroz and Miller (1967), Angell and Korshover (1970), Belmont and Dartt (1973) and Hopkins (1975) studied the structure and behaviour of the semi-annual oscillation of the mean zonal wind. The studies have now well established that this semi-annual oscillation is global in extent. Its maximum amplitude (25-30 mps) occurs near the stratopause level (45-50 km) in the equatorial region. It is, however, interesting to note that the maximum amplitude appears not over the equator but in the southern hemisphere around 10°S, showing an equatorial asymmetry (Belmont and Dartt 1973 and Hopkins 1975). Regarding the phase of the oscillation, the maximum in westerlies first appears in the lower mesosphere just after the equinox and propagates downwards. The transition from westerlies to easterlies occurs rather suddenly throughout a deep layer between 35 and 60 km, in contrast to the transition from easterlies which precedes downwards with a speed of about 10 km per month (Quiroz and Miller 1967).

The amplitude of the annual oscillation is larger in extra-tropical latitudes and decreases towards the equator.

Using rocketsonde data over Thumba (8° 30′ N, 76° 54′ E) George and Narayanan (1975) observed QBO in the middle stratosphere (25 - 35 km) over Indian equatorial region, where westerlies replace the prevailing easterlies in alternate years. The period of one cycle of westerlies and easterlies decreases gradually towards higher as well as lower level becoming semi-annual in the lower mesosphere (45-60 km) and annual in the upper troposphere. Raja Rao (1977) and Raja Rao and Lakhole (1978) tried to relate the phase of QBO with southwest monsoon while Thapliyal (1984) tried to

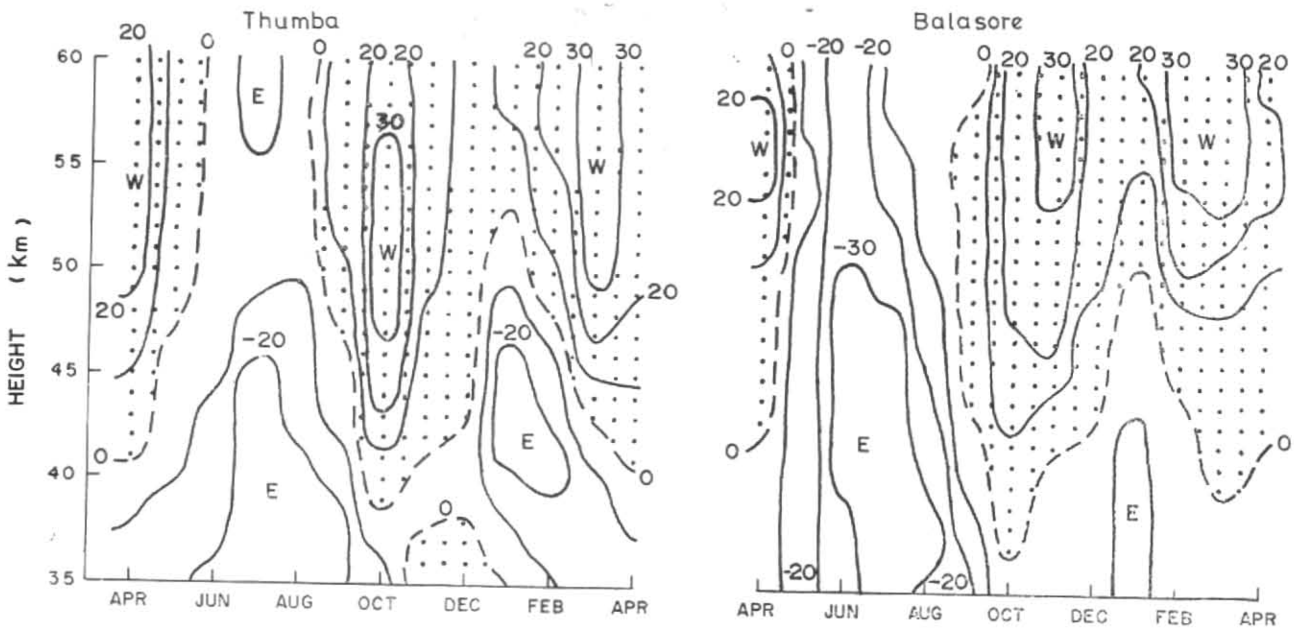

Fig. 1. Mean vertical time-section of zonal wind in m.p.s.

TABLE 1

Mean variance (%) accounted by annual and semi-annual oscillations

Height (km)	Balasore		Thumba	
	Annual	Semi-annual	Annual	Semi-annual
60	61.8	13.1	35.5	60.8
55	59.0	32.4	17.2	75.3
50	60.9	34.7	6.2	74.2
45	52.6	47.0	2.7	77.5
40	46.5	50.9	3.8	78.2
35	80.6	9.3	79.3	13.1

TABLE 2

Variance (%) accounted by annual and semi-annual oscillations during contrasting monsoon years over Balasore

Height (km)	1979		1983	
	Annual	Semi-annual	Annual	Semi-annual
60	—	—	52.4	23.4
55	27.6	12.6	37.5	57.7
50	25.4	4.5	24.2	69.5
45	76.7	19.3	25.8	56.9
40	41.4	45.4	32.5	51.8
35	11.2	32.1	79.8	7.0

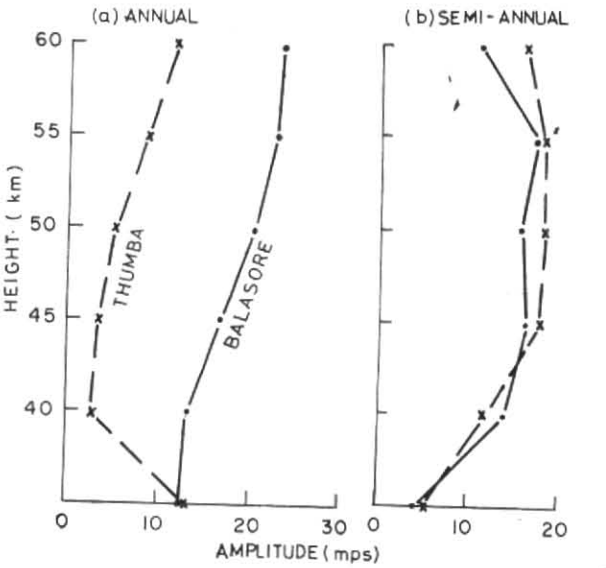

Fig. 2. Altitudinal variation of annual and semi-annual amplitudes of zonal wind oscillations over Balasore and Thumba

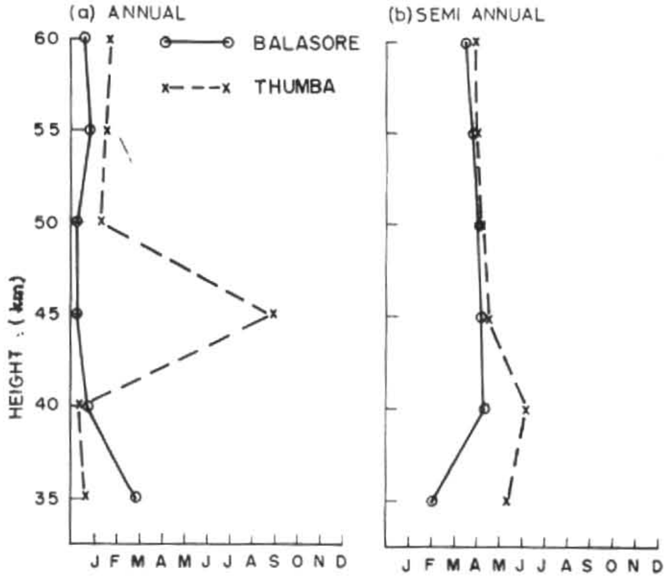

Fig. 3. Mean phase (Time of Max.)

predict Indian droughts with stratospheric winds. Though Sasi and Sengupta (1980) and Appu *et al.* (1980) studied the variation of amplitudes and phases of annual and semi-annual oscillation of the zonal wind and temperature with height over Thumba no attempt has been made so far to investigate the existence, if any, of the relationship between middle atmospheric oscillations (annual and semi-annual) and the southwest monsoon over India.

Earlier studies on the circulation pattern in the equatorial stratosphere and lower mesosphere over India were based only on the available Thumba rocketsonde wind and temperature data. However, since 1979 the year of monsoon experiments (Monex), rocketsonde data over Balasore, a station located in the tropical region of India are also available.

In the present study an attempt has been made to relate year to year variation of amplitudes and phases of annual and semi-annual oscillations of the zonal wind over tropical (Balasore : 21°31′ N, 86° 56′ E) and equatorial (Thumba) regions of India with the behaviour of Indian summer monsoon.

2. Data and analysis

Weekly rocketsonde data of zonal wind over Thumba (using M-100 rocket and Balasore with RH-200 rocket) for the period January 1977 to May 1985 and January 1979 to May 1985 respectively, have been utilised to calculate, for each year, the monthly mean of zonal wind of the level 25 to 60 km at 1 km interval. The monthly means in turn have been averaged for the entire period to get mean monthly wind for each of the levels. This will minimise not only the random errors present in the data but also the effect of QBO to some extent (Sasi and Sengupta 1980).

The monthly mean as well as mean monthly zonal winds, thus obtained, were subjected to harmonic analysis for the total length of record as well as for each year separately to determine the annual and semi-annual amplitudes and phases in relation to different monsoon years.

The monsoon years have been categorised using the area weighted (June to September rainfall) of the plains of the country obtained from the India Meteorological Department, Pune.

In the present sudy, the annual oscillation corresponds to the first harmonic component while the semi-annual oscillation corresponds to the second harmonic component.

As the middle stratosphere (25-35 km) is more susceptible for QBO, the altitude variations of the amplitude and phase of annual and semi-annual oscillation of the zonal wind have been analysed only for upper stratosphere (35-50 km) and lower mesosphere (50-60 km) and at an interval of 5 km.

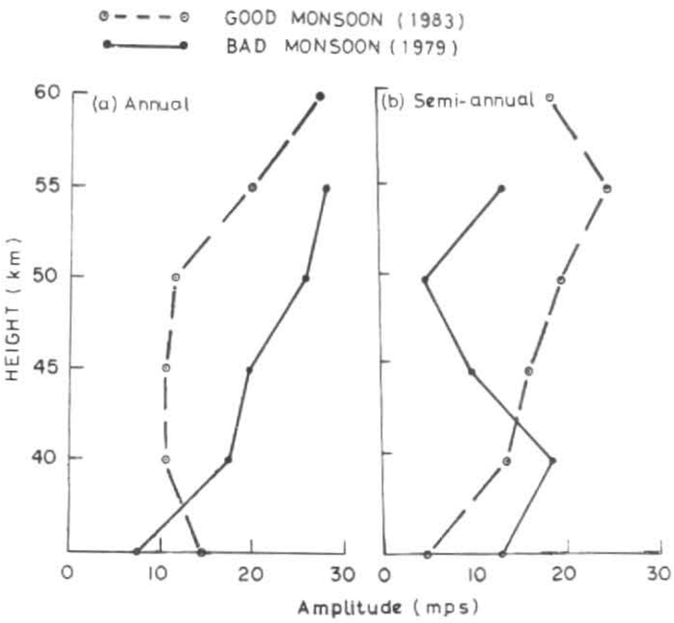

Fig. 4. Variation of annual and semi-annual amplitudes of zonal wind oscillations with altitude over Balasore for two contrasting monsoon years

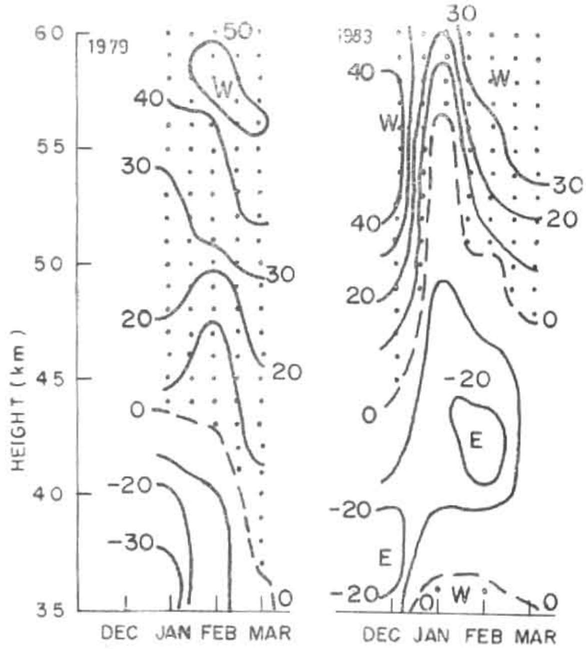

Fig. 5. Vertical time section (December to March) of zonal wind (mps) for two contrasting monsoon years over Balasore

3. Mean annual and semi-annual oscillations in Indian region

Fig. 1 shows the seasonal variation of the zonal wind with height over Thumba and Balasore. It can be seen that circulation above 50 km is generally characterised by easterlies during the summer months and westerlies in the winter months both over Thumba and Balasore. It is interesting to note that below 50 km there is a regular pattern of descent and ascent of lower mesospheric westerlies during the period September to April though there is a year to year variation of the depth of these westerlies.

It may be mentioned here that by analysing the meridional cross-section of the normal zonal wind over the the globe for the month of January, Hopkins (1975) inferred that there is an incursion of the summer easterlies into the winter hemisphere. This incursion extends up to 20°-25° N latitudes and is maximum at stratopause level. Hence, it is likely that the ascent and descent of lower mesospheric westerlies are due to the incursion of easterlies from the winter hemisphere.

Fig. 2 shows the mean height variation of annual and semi-annual amplitudes of the zonal wind oscillations over Balasore and Thumba. The same is discussed ahead.

3.1. Variance accounted by annual and semi-annual oscillations

An examination of the variance accounted by annual and semi-annual oscillations (Table 1) shows that over Balasore at no level, the contribution explained by the semi-annual oscillations dominates over the annual wave. In other words, the annual wave is the most dominant wave over Balasore. The reverse is the case over Thumba, *i.e.*, the semi-annual wave dominates over annual wave except at 35 km where the annual wave explains 79% of the total variance.

3.2. Amplitudes of annual and semi-annual oscillations

Both over Balasore and Thumba, the amplitude of the annual oscillation increases with height even up to 60 km from 40 km upwards (Fig. 2). The amplitude over Balasore is significantly greater than that over Thumba. This agrees well with the usual latitudinal variation of the annual amplitude (Angell and Korshover 1970).

The amplitude of semi-annual oscillation over Balasore and Thumba decreases both at higher and lower levels, with a value less than 25% of the maximum occurring at 45 km in both cases. It is interesting that the amplitudes of semi-annual oscillation over Thumba and Balasore are comparable at all levels in upper stratosphere and lower mesosphere, though these two stations are separated by about 15° latitude. This is not in much conformity with the usual decrease of semi-annual amplitude with increasing latitudes.

3.3. *Phases of annual and semi-annual oscillations*

The annual oscillation appears over Balasore and Thumba almost at all levels between December and January except over Thumba at 45 km where it occurs in September, while semi-annual oscillation appears first at higher levels almost simultaneously around March/April over Balasore and Thumba (Fig. 3).

4. Annual and semi-annual oscillation and Indian summer monsoon

It has already been mentioned that there is ascent and descent of lower mesospheric westerlies from October to March both over Thumba and Balasore. The height of ascents and descents of these westerlies varies year to year so does the depth of semi-annual oscillation of the zonal wind. To examine whether any relationship exists between this depth of the semi-annual wave and monsoon, the amplitude of semi-annual wave of zonal winds is examined for two contrasting monsoon years (1979 and 1983) using wind data for Balasore only, as the wind data for 1982 over Balasore and that of 1983 over Thumba are not available.

In the mean picture (Fig. 2), the amplitudes of annual oscillation of zonal wind over Balasore are quite higher than that of semi-annual oscillation at all levels above 40 km. But, from Fig. 4 and Table 2, it can be seen that amplitudes of semi-annual oscillation were higher than that of annual oscillations between 40 & 55 km in 1983 (good year) while in 1979 (bad year), semi-annual oscillation was predominant only between 35 & 40 km, that is, it was not only confined to lesser vertical extent but also came down to lower levels. The minimum amplitude ($\sim$ 4 mps) could be found in 1979 at 50 km while the maximum amplitude ($\sim$ 24 mps) occurred in 1983 at 55 km. This indicates that semi-annual oscillation of zonal wind has some bearing in influencing the monsoon activities over India and it dominates the upper stratosphere and lower mesosphere during good monsoon year.

Furthermore, it is interesting to note that the height of descent of winter lower mesospheric westerly over Balasore was different in these two contrasting years (Fig. 5). The levels of westerly descent during January to March are quite high in good monsoon year. While in bad monsoon year, these westerlies came down to much lower levels. In other words, there was a deep penetration of summer easterlies into winter upper stratosphere/lower mesosphere prior to good monsoon year.

So, it is likely that there may be some association between strong semi-annual oscillation of zonal wind and deeper penetration of summer easterlies into winter strato-mesosphere during good monsoon year.

The above facts may indicate that the cause of semi-annual oscillation over Balasore may not be Kelvin waves whose amplitudes get dumpted rapidly with increasing latitudes but incursion of summer hemispheric easterlies into winter hemisphere which restrict the descent of lower mesospheric westerlies to higher levels, and have some influence in causing strong semi-annual oscillation over Balasore during good monsoon year.

It may be mentioned that above inferences are based on data for only two years and are very tentative. More data of future years are necessary to establish definite association of monsoon activity and middle atmospheric processes.

5. Conclusions

The following conclusions can be drawn from the study :

(*i*) In the mean picture, the annual wave is predominant over the tropical Indian region, while the semi-annual wave dominates over the equatorial Indian region.

(*ii*) Though, the amplitude of the semi-annual wave over tropical Indian region (Balasore) is not significant, there is a strong semi-annual wave over Balasore during one good monsoon year.

(*iii*) The strong semi-annual wave over Balasore during one good monsoon year appears to be due to the incursion of summer hemispheric easterlies into the winter hemisphere.

(*iv*) The descent of the lower mesospheric westerlies over Balasore in March seems to have some association with the performance of the subsequent monsoon over India. This conclusion is very tentative and is based on only a couple of years data.

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