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Semi-annual oscillation of constant pressure surfaces (1000-100 mb) in the northern hemisphere

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ABSTRACT. Monthly mean values at about 250 stations in the northern hemisphere were analysed for the study of semi-annual pressure oscillation at sea level and at 850, 700, 500, 300, 200 and 100 mb levels. It is found that at all levels and at all longitudes, the amplitudes are smallest in the equatorial latitudes and largest in sub-tropical or higher latitudes. In the vertical, the amplitudes generally increase upwards upto about 200 mb level. There is a surface of phase reversal or sharp phase shift which slopes equatorwards with increase of height. Below this surface maximum occurs towards the end of April and October. Above this surface, the maximum occurs towards the end of January and July. The oscillation is studied in some detail for the Indian region.

1. Introduction

The present paper is purely an observational study of geopotentials of constant pressure surfaces in the northern hemisphere. Van Loon and Jenne (1969) have done study of semi-annual oscillation in the southern hemisphere in respect of zonal wind and temperature and also of geopotentials of 200 mb level for southern hemisphere. They also extended (Van Loon and Jenne 1970) their study of zonal wind and temperature to the northern hemisphere between longitudes 60° and 120°E. Our study differs from theirs in so far as it relates to the whole northern hemisphere and is in respect of geopotentials of all standard constant pressure surfaces.

The study of semi-annual oscillation has gained importance during recent years. Significant semi-annual wave in the temperature of the tropical stratosphere was discovered by Reed (1962, 1964). He showed that the amplitudes increased upward. Presence of a semi-annual oscillation in zonal wind of the tropical stratosphere and lower mesosphere was also reported by Reed (1965, 1966). Wallace (1966) also showed semi-annual oscillation in mean zonal wind from 20°N and 20°S between 50 and 10 mb levels indicating smaller magnitudes over equatorial region. Rocket wind analysis by Quiroz and Miller (1967) and Angell and Korshover (1970) have further confirmed the semi-annual wave in both temperature and wind. Van Loon, Labitzke and Jenne (1972) studied the half yearly wave in stratospheric temperature above the 50 mb level.

Chiusano (1970) developed a tentative theory for semi-annual zonal wind and temperature oscillations in the tropics. Dickenson (1971) has attempted an analytical model for zonal winds in the tropics.

Searching through published material we found that a detailed analysis of northern hemispheric tropospheric observations in respect of semi-annual oscillation of constant pressure geopotentials was not available in literature. Hence, we decided to undertake and present the analysis of observations so that we know better the observed features which are to be explained by any theory.

2. Data and analysis

About 250 stations between equator and 80°N were selected. Mean sea level pressure and the geopotential heights of 850, 700, 500, 300, 200 and 100-mb pressure levels at these stations were obtained from the following data sources.

(*i*) *Climatological Normals (CLINO) for climat and climat ship stations for the period 1931-1960*, WMO/OMM-No. 117. TP. 52, 1971 for m. s. l. pressure.

(*ii*) *Short period averages for 1951-1960 and provisional average values for climat temp and climat temp ship stations*, WMO/OMM No. 170-TP. 82, 1965-for geopotential heights of standard constant pressure levels.

(*iii*) Five-year (1967-71) averages were prepared in Theoretical Studies Division of the Institute for 18 additional near equatorial stations from the monthly values given in "*Monthly Climatic Data for the World*, Vols. 20-24, published by WMO in cooperation with U. S. Weather Bureau.

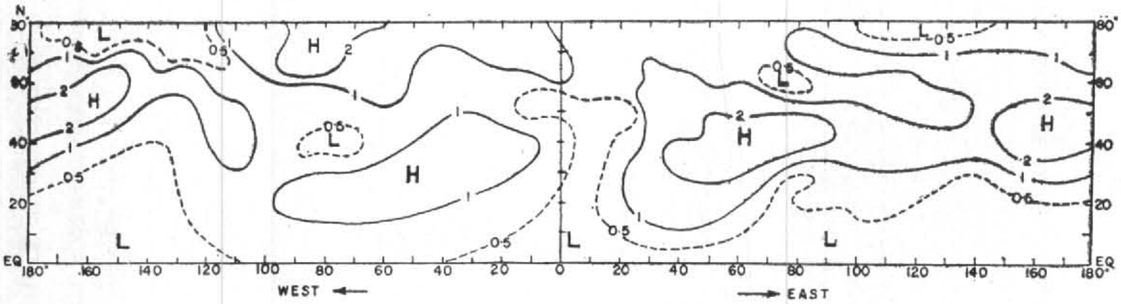

Fig. 1. Amplitude (mb) of six-month oscillation at mean sea level

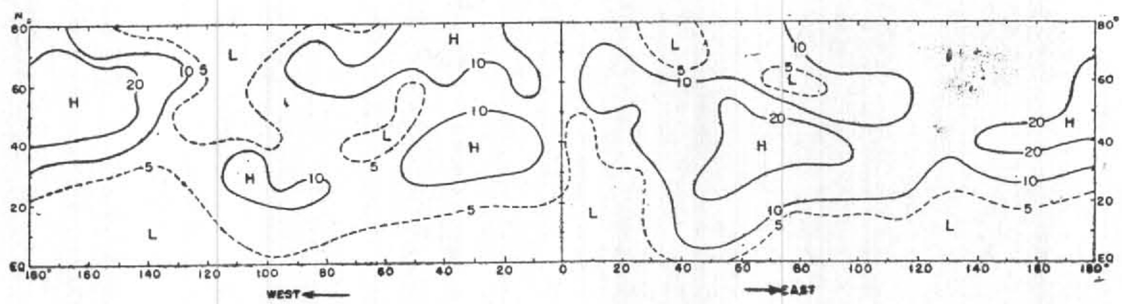

Fig. 2. Amplitude (gpm) of six-month oscillation at 850 mb

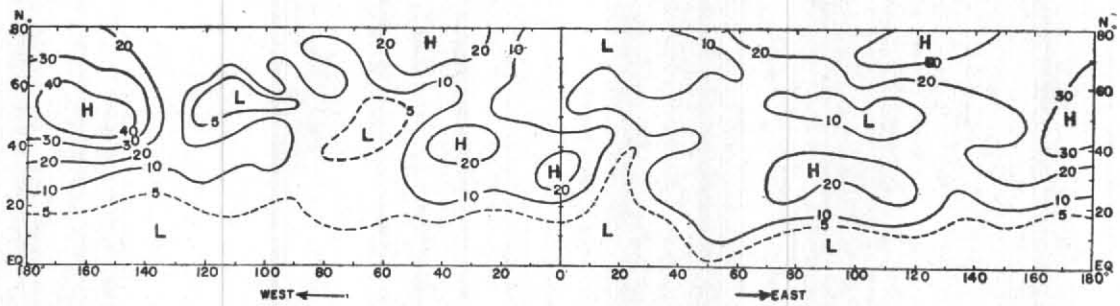

Fig. 3. Amplitude (gpm) of six-month oscillation at 700 mb

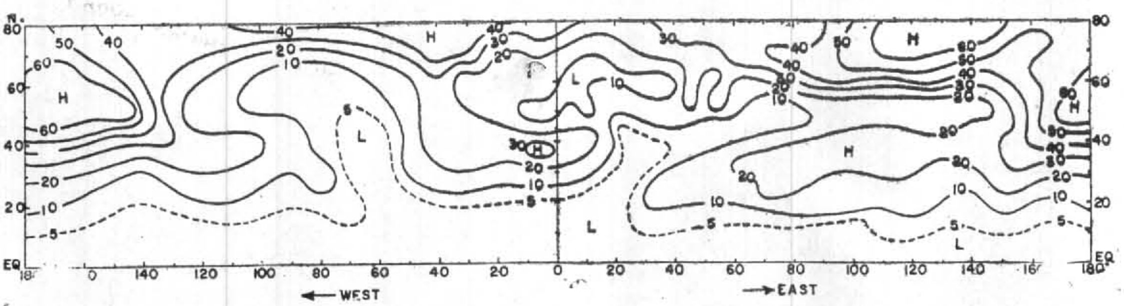

Fig. 4. Amplitude (gpm) of six-month oscillation at 500 mb

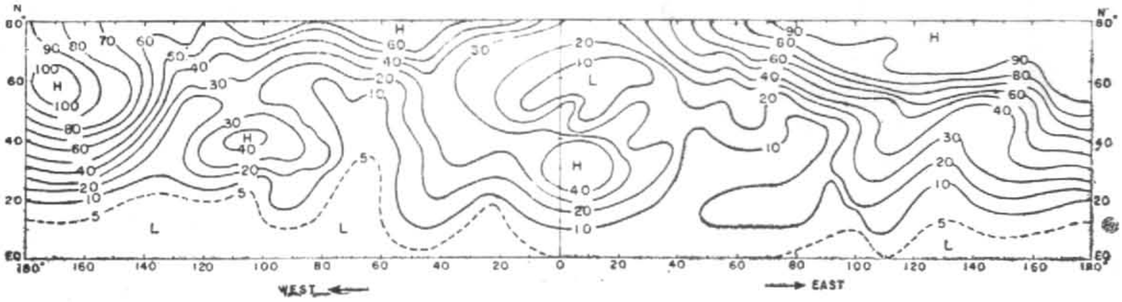

Fig. 5. Amplitude (gpm) of six-month oscillation at 300 mb

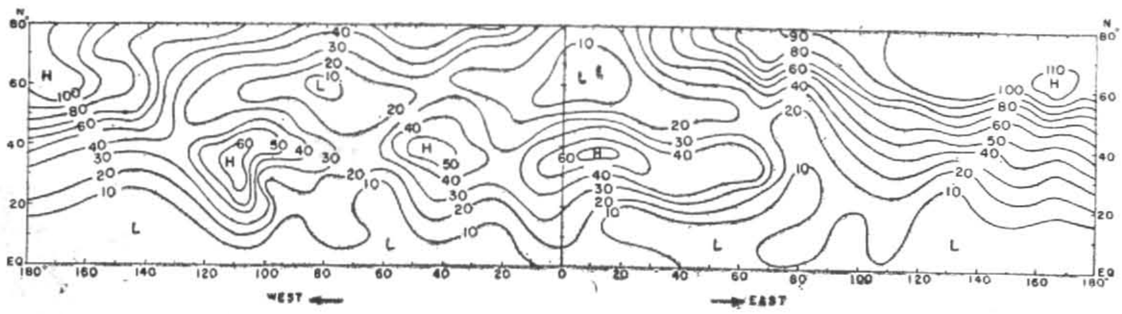

Fig. 6. Amplitude (gpm) of six-month oscillation at 200 mb

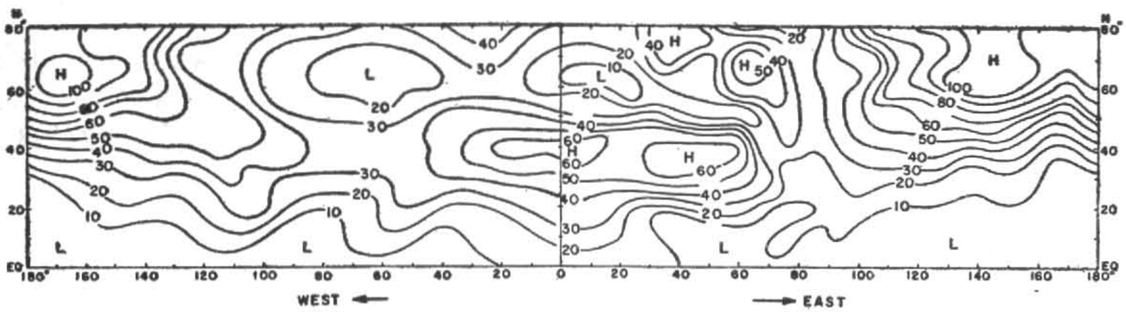

Fig. 7. Amplitude (gpm) of six-month oscillation at 100 mb

The mean monthly data were subjected to harmonic analysis to get annual mean as also the amplitudes and phases of 12-monthly, 6-monthly and 4-monthly oscillations at individual stations. The analysis of annual mean and 12-monthly oscillation in geopotential height is being presented elsewhere (Asnani and Mishra p. 355) in this issue. Here, we shall present the analysis of 6-monthly oscillation. Since the data consist of normals commencing from January and ending in December, the zero of the phase angle was counted from mid-January.

3. Results and discussions

3.1. Fig. 1 shows the amplitude of six-monthly oscillation in pressure at m. s. l. Figs. 2 to 7 correspond to 850, 700, 500, 300, 200 and 100 mb levels respectively, giving amplitudes in gpm. The following points are noteworthy :

(*i*) At all levels under consideration, amplitudes are smallest in the equatorial latitudes and largest in sub-tropical or higher latitudes. This is somewhat different from the features of southern hemisphere at 200-mb level, as reported by Loon and Jenne (1969). These authors analysed the amplitudes of 6-monthly oscillation over southern hemisphere at 200-mb level and found that the amplitude minimum was situated over the equator in most of Pacific Ocean but lay close to 15°S in the eastern-half of the hemisphere. Over this eastern-half, they found a maximum at the equator and also in middle or higher latitudes.

(*ii*) If north of equatorial latitudes, we draw one line joining highs and another line joining lows, it is seen that there is something like a sub-tropical ridge line running nearly along 30°N and a trough line running roughly along 50°N.

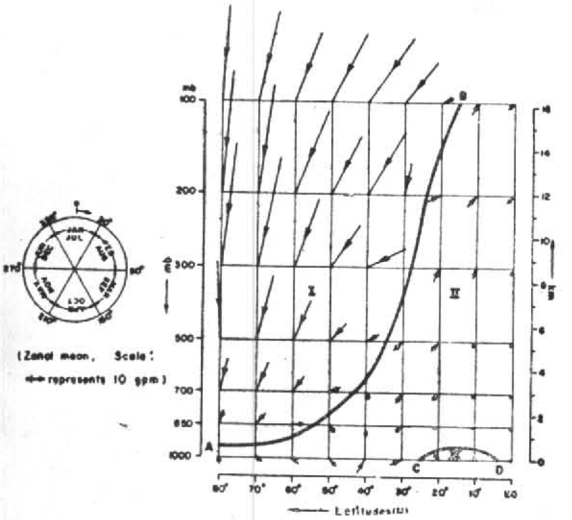

Fig. 8. Amplitude-phase vector for semi-annual oscillation Inset diagram gives correspondence between direction of vector and time of occurrence of maxima.

Of course, there are local northward and southward shifts. Relationship between these lines and the sub-tropical ridge of high pressure and middle latitude trough of low pressure is being studied separately.

(*iii*) When we look into the highest values of the amplitude of successive levels, it is found that these are of the order of 20 gpm at 850-mb level and below but increase to about 100 gpm at 200 mb and 100-mb levels. Thus, the amplitudes increase as we go from lower troposphere to upper troposphere. This general hemispheric picture is, however, not true in respect of smaller regions or individual stations, the latter showing their peculiar local features in respect of vertical variation of the amplitude. For example, over central Indian region, the amplitudes become largest in the middle troposphere rather than in the upper troposphere.

(*iv*) A relatively high amplitude zone exists over northern Pacific in the neighbourhood of Aleutian Islands.

3.2. From the analysed chart of each level, values of magnitude and phase were obtained at grid points at the intervals of 20° longitude and 10° latitude. Zonal mean vector was calculated for each latitude. Fig. 8 shows the amplitude-phase variations with height and latitude. The presentation is in the form of vectors, the magnitude of which represents the amplitude of the semi-annual oscillation, the scale is shown in the diagram. The direction of the vector indicates the time of occurrence of maxima of oscillation. The time diagram is shown as an inset in the same figure. The cycle of 360° is completed in six months. Considering all months to be of equal duration, we can represent each month by 60° as shown in the inset diagram. The zero of the phase angle is counted from mid-January. Hence, January is represented by 30° on either side of zero. February is represented by the angle 30° to 90°, and so on. There are two maxima and two minima during the whole year, the successive maxima (minima) occurring at six-monthly interval. Hence, January and July are represented identically in the diagram.

The following points are noteworthy—

(*a*) There is a surface of phase reversal or sharp phase shift which slopes equatorwards with increase of height (indicated by the thick line AB). The slope is rather steep from 15° to 35°N and quite gradual therefrom.

Above this surface of phase shift, the maxima occur towards the end of January and July (let us call this region I). Below this surface, the maxima occur towards the end of April and October (region II). There seems to be another small region III, below line CD which shows January and July maxima. This is near the equatorial region between surface and 850-mb level.

(*b*) The magnitudes are comparatively large in the region I.

3.3. The semi-annual oscillation over the Indian region was analysed in some detail. As stated in 3·1(*iii*), the Indian region showed some peculiar features.

(*i*) Fig. 9 shows the standard pressure level at which the amplitude of the semi-annual oscillation was largest along the vertical over India and neighbourhood. In the same diagram, the actual amplitude and phase at that level are also plotted. It will be seen that in the shaded region, the maximum amplitude occurs in the middle troposphere (700 or 500 mb); outside this region, either the largest amplitude occurs at 200 mb or the amplitude goes on increasing upwards upto the last level of our analysis (100 mb).

(*ii*) Further, it was considered to be of some interest to know whether, during mid-monsoon period, the north-south gradient of semi-annual geopotential perturbation was re-inforcing or counteracting the prevailing zonal westerlies and easterlies over the Indian region. From the harmonic analysis already made, the values of semi-annual geopotential perturbation of 15th July were calculated for Delhi, Nagpur, Bombay, Madras, Bangalore, Trivandrum and Colombo. A smooth curve was then drawn for each level to represent perturbation geopotential roughly along

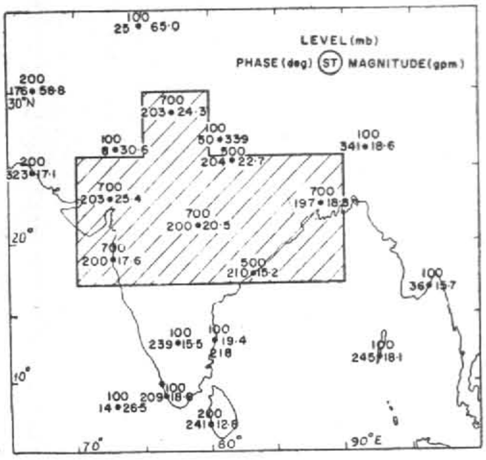

Fig. 9. Level, magnitude and phase of maximum amplitude

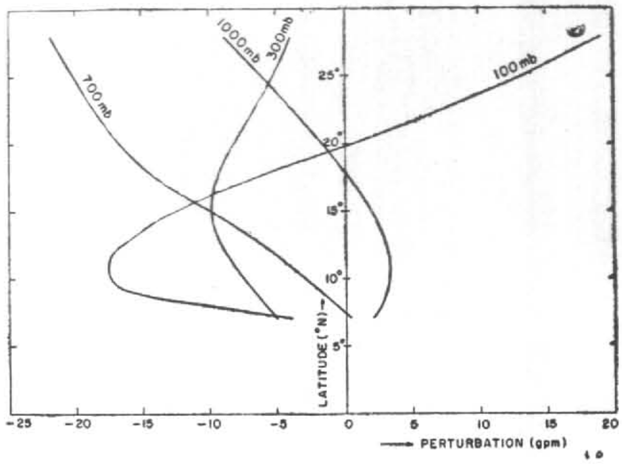

Fig. 10. Normal contour height perturbation (gpm) along $77\frac{1}{2}$ °E due to semi-annual oscillation at 1000, 700, 300 and 100 mb levels, in mid-July

longitude $77\frac{1}{2}$°E over the Indian region. These curves are shown in Fig. 10 for four levels. It will be seen that at 1000-mb level, the perturbation value increases from 7°N to about 11°N and decreases northwards. In other words, the semi-annual oscillation contributes easterly component which slightly counteracts the sea level westerlies south of 11°N as well as a westerly component of wind at that level between 11° N and 28°N. At 700 mb, at all latitudes, this oscillation gives rise to a westerly component; at 300 mb, a westerly component south of 15°N and an easterly component northwards. At 100-mb, it contributes westerly component south of 11°N and easterly component northwards and a geopotential difference of about 25 gpm between Lat. 15° N and 25°N. At a mean latitude of 20°N, this will cause a geostrophic easterly wind of abour 4.5 m/sec.

4. Summary

(*i*) Analysis of semi-annual oscillation in constant pressure geopotentials over the northern hemisphere is presented for the first time. This observational study would form a base for future theoretical studies.

(*ii*) A surface of phase reversal sloping equatorwards with increase of height is clearly brought out by this analysis.

(*iii*) The oscillation is studied in some detail for the Indian area. These details show some regional characteristics different from the hemispheric features.

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