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Annual pressure oscillation from sea level to 100 mb in the northern hemisphere

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ABSTRACT. From climatological normals of about 250 upper air observatories in the northern hemisphere, the annual mean, the annual oscillation and the semi-annual oscillation in the geopotential height of 850, 700, 500, 300, 200 and 100 mb pressure levels have been worked out; while the features of semi-annual oscillation are discussed elsewhere (Asnani and Verma 1975). The characteristics of annual mean, and annual oscillation are presented here. At and above 700 mb level the maximum occurs first at the polar latitudes and then at sub-tropical latitudes with a lag of about 3 to 4 weeks. At and south of 40°N the amplitude is maximum at 200-mb level; at higher latitudes, the amplitude increases upto 100-mb level, the last level of our analysis.

The annual mean picture as well as the annual oscillation exhibit some special features over the Asian region.

1. Introduction

Monsoon can be looked upon as an annual oscillation superimposed on the annual mean state of the atmosphere. The annual oscillation is felt over the entire globe with varying degrees of intensity. The economy of some countries, particularly those in southeast Asia is highly dependent on the annual cycle of rain. As atmospheric pressure distribution primarily controlled the distribution of wind and rainfall, it is worthwhile to examine the extent to which the pressure over the region of southeast Asia are similar and dissimilar to those over the rest of the northern hemisphere. The purpose of the present paper is to present the analysis of pressure observations over the northern hemisphere in the atmosphere below 100-mb level.

Although a number of authors have recently analysed the annual and semi-annual wave in the stratosphere and mesosphere (Reed 1962, 1966; Angell and Korshover 1970; Van Loon 1970), a comprehensive analysis of the annual wave in pressure/geopotential field in the troposphere over the whole hemisphere could not be located in literature.

2. Data and analysis

The same data obtained for the study of semi-annual pressure oscillation (Asnani and Verma 1975) have been used for the present study also.

The upper air data used for this analysis are for relatively short periods. However, the authors believe that the broad conclusions drawn from this analysis would not be substantially altered even when the mean upper air data based on longer periods like 30 years become available for study.

The mean monthly data were subjected to harmonic analysis to get annual mean, the amplitude, and phases of 12-monthly, 6-monthly and 4-monthly oscillations at individual stations. Fig. 1 shows the annual normal sea level pressure on the northern hemisphere from equator to 80°N. Figs. 2 to 7 show the annual normal height values of standard isobaric surfaces (850, 700, 500, 300, 200 and 100 mb).

It will be seen from Fig. 1 that there are some special features in sea level pressure pattern over the Asian region distinct from the rest of the northern hemisphere. Thus, there is a permanent ridge of high pressure over the Bay of Bengal and a permanent trough of low pressure over north India. Further, there is a steep pressure gradient of 12 mb within a distance of about 12 degrees of latitude along the meridian 80°E, across the Himalayas.

At 850 mb, the sub-tropical ridge is distorted near the Himalayan region. At 700 and 500 mb, the sub-tropical ridge steadily slopes southwards with height. At 200 and 100 mb, the ridge shifts again northwards and gives considerable pressure gradient in the near-equatorial regions corresponding to relatively strong zonal easterly flow. Thus the easterly jet stream observed over south India, during the summer season is partly due to this contour gradient present in the annual normal picture itself.

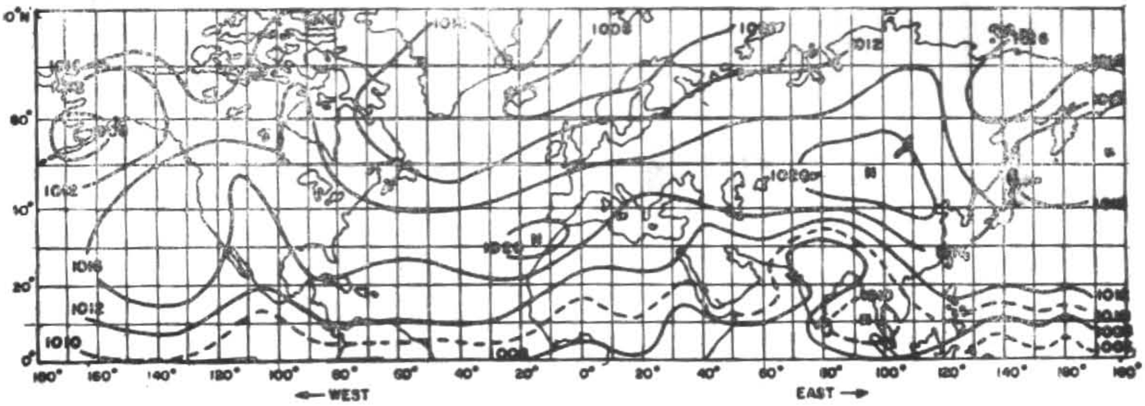

Fig. 1. Annual normal sea level pressure (mb)

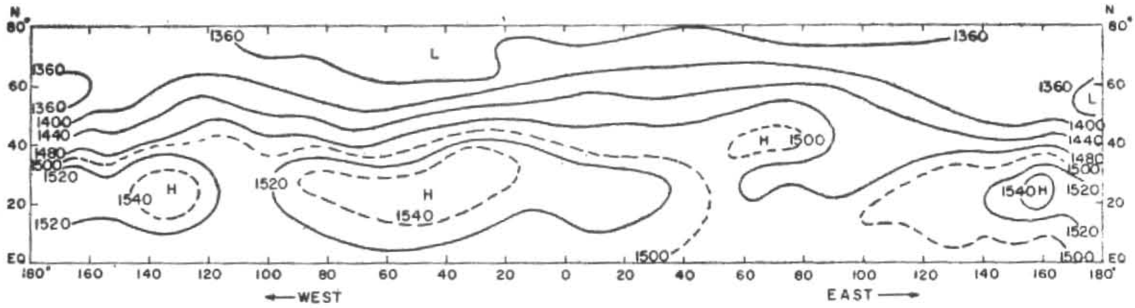

Fig. 2. Annual normal 850-mb height (gpm)

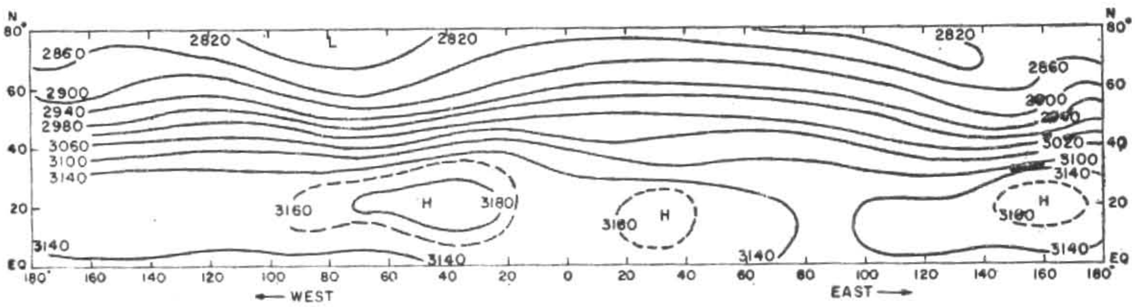

Fig 3. Annual normal 700-mb height (gpm)

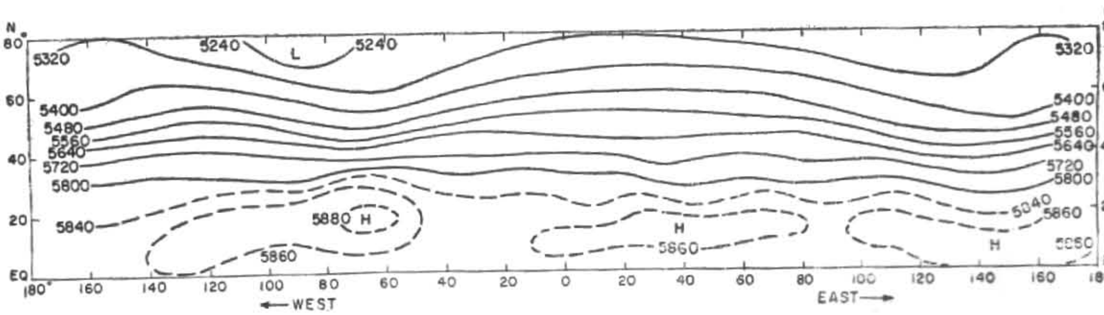

Fig. 4. Annual normal 500-mb height (gpm)

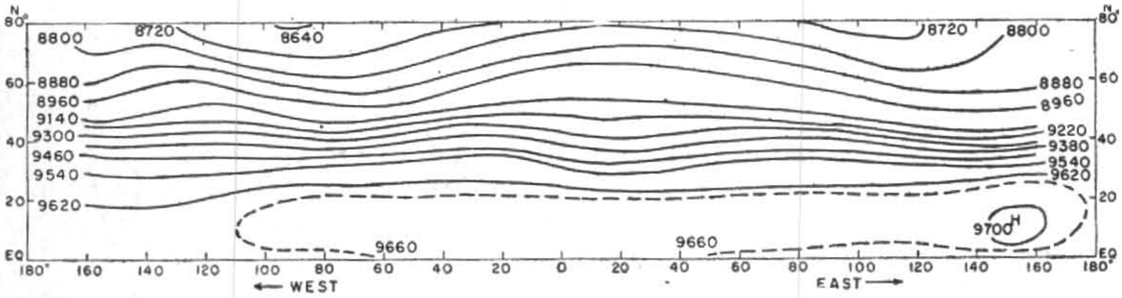

Fig. 5. Annual normal 300-mb height (gpm)

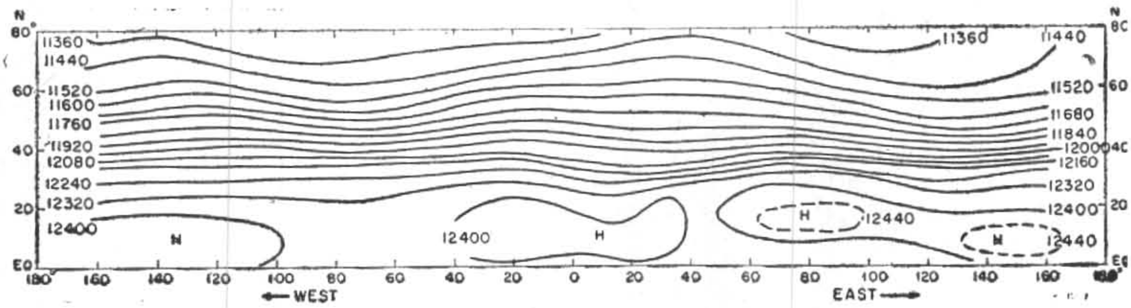

Fig. 6. Annual normal 200-mb height (gpm)

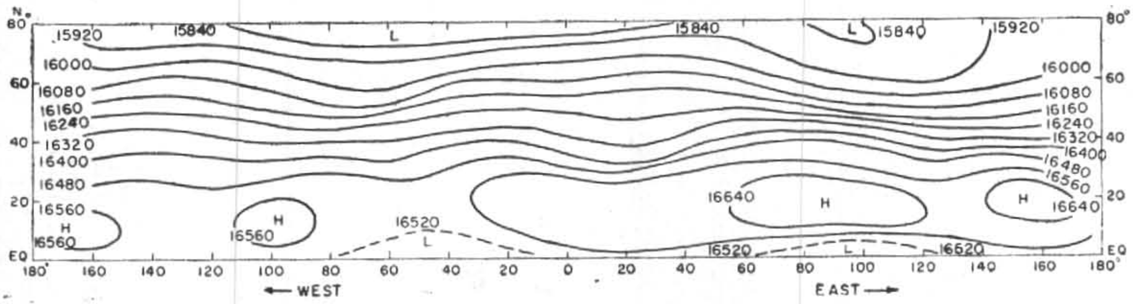

Fig. 7. Annual normal 100-mb height (gpm)

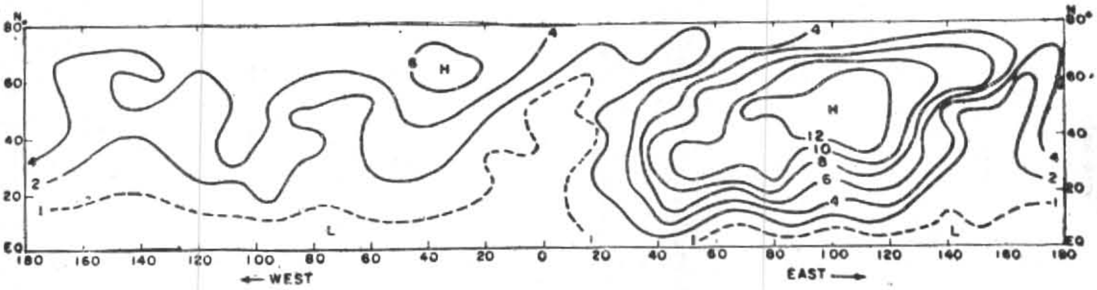

Fig. 8. Amplitude (mb) of 12-month oscillation at mean sea level

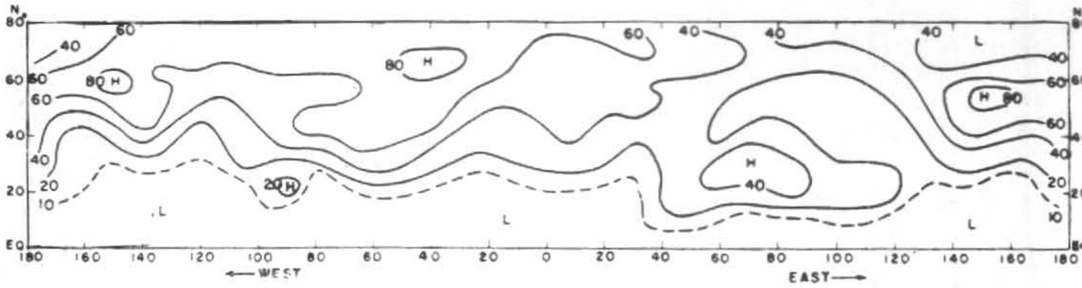

Fig. 9. Amplitude (gpm) of 12-month oscillation at 850-mb level

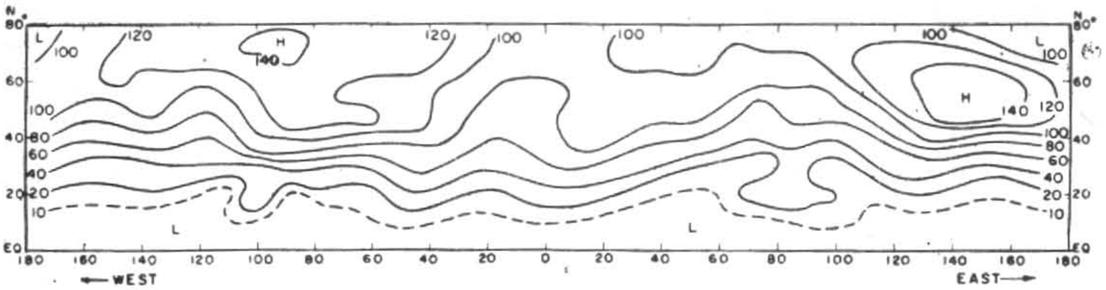

Fig. 10. Amplitude (gpm) of 12-month oscillation at 700-mb level

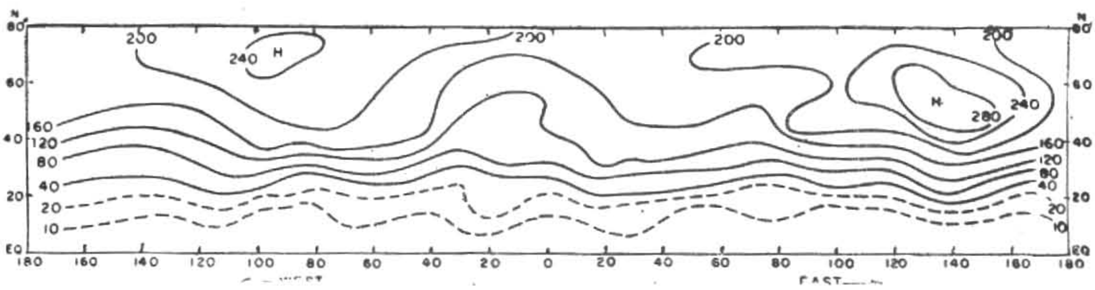

Fig. 11. Amplitude (gpm) of 12-month oscillation at 500-mb level

Figs. 8 to 14 show the amplitude of 12-monthly oscillation of pressure at sea level and of heights of standard isobaric surfaces. From Fig. 8 it is seen that the amplitude of pressure oscillation at sea level is less than 1 mb near the equator throughout the northern hemisphere and becomes maximum in the northern latitudes. It is very interesting to observe that the amplitude is as high as 12 mb over Mongolian region. The orientation of the isolines of amplitude leave no doubt that the Asian land mass is exerting considerable influence on the amplitude of 12-month oscillation over the Asian region.

The contrast seen over the Asian land mass at sea level (Fig. 8) becomes less spectacular as we go to higher levels upto 500 mb. At 300 and 200-mb levels again, we see the contrast showing itself up more markedly over the Asian region, with area of large amplitudes, displaced towards the east of the Mongolian region.

We, thus, see that Asian land mass shows well-marked features in the 12-month oscillation in the lower troposphere as well as higher troposphere.

Fig. 15 shows, in vectorial form, the amplitude and phase of the annual oscillation at different isobaric levels, at different latitudes, in the northern hemisphere. From the analysed chart of each level, values of amplitude and phase were obtained at grid points at the intervals of 20° longitude and 10° latitude. Zonal mean vector was then calculated for each latitude at each isobaric level. The direction of a vector in Fig. 15 indicates the time of occurrence of the maximum

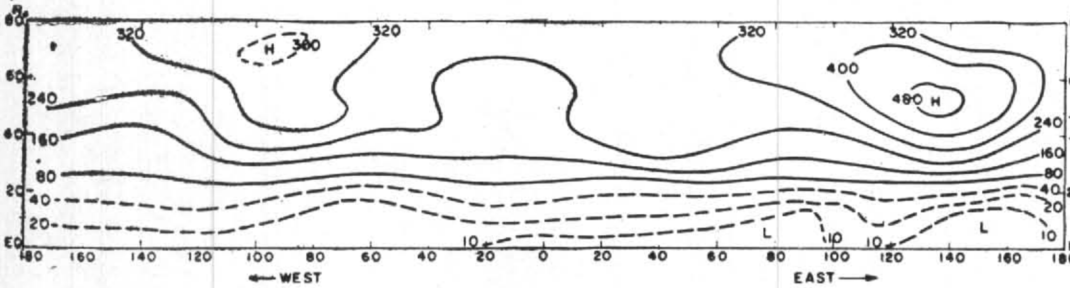

Fig. 12. Amplitude (gpm) of 12-month oscillation at 300-mb level

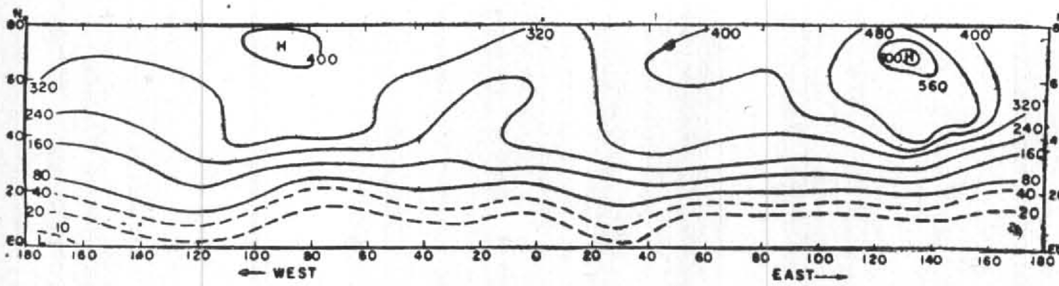

Fig. 13. Amplitude (gpm) of 12-month oscillation at 200-mb level

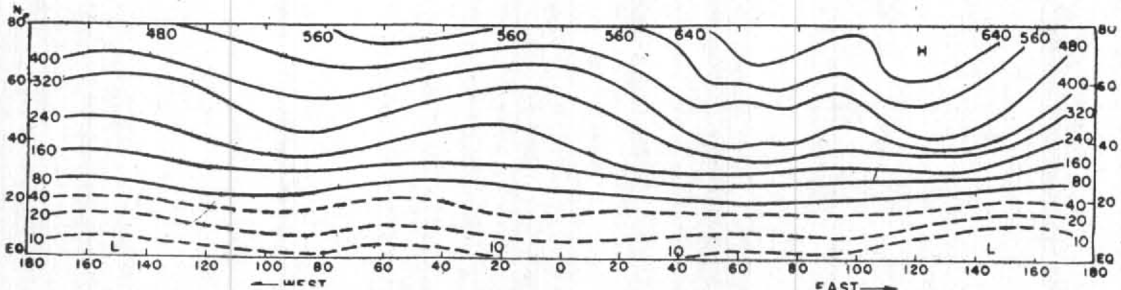

Fig. 14. Amplitude (gpm) of 12-month oscillation at 100-mb level

TABLE 1

Amplitude A (gpm) and phase P (month & date) of geopotential maximum of the annual oscillation at different latitudes and isobaric surfaces

I. S. (mb)	EQ		10°N		20°		30°		40°		50°		60°		70°		80°N	
	A	P	A	P	A	P	A	P	A	P	A	P	A	P	A	P	A	P
100	7	Apr 16	18	Jun 10	61	Aug 3	178	Aug 6	292	Aug 2	369	Jul 27	442	Jul 19	523	Jul 15	579	Jul 12
200	12	Apr 17	20	May 20	79	Aug 5	197	Aug 9	298	Aug 5	348	Jul 30	364	Jul 23	393	Jul 18	390	Jul 16
300	9	Apr 23	14	Jun 1	51	Aug 7	159	Aug 7	246	Aug 6	295	Aug 1	312	Jul 23	316	Jul 22	308	Jul 19
500	4	May 11	8	Apr 20	23	Aug 7	82	Aug 8	151	Aug 4	185	Jul 29	199	Jul 21	208	Jul 19	201	Jul 15
700	4	Jun 29	4	Jun 28	11	Aug 14	38	Aug 17	75	Aug 6	98	Jul 27	109	Jul 17	112	Jul 14	109	Jul 13
850	4	Jul 427	1	Jul 28	6	Nov 26	14	Sep 18	32	Aug 24	44	Jul 31	48	Jul 7	55	Jul 2	54	Jun 27
1000	4	Aug 25	6	Dec 12	18	Jan 15	31	Jan 2	34	Dec 21	25	Jan 14	29	Feb 19	33	Mar 11	34	Mar 15

I. S.—Isobaric surfaces (mb)

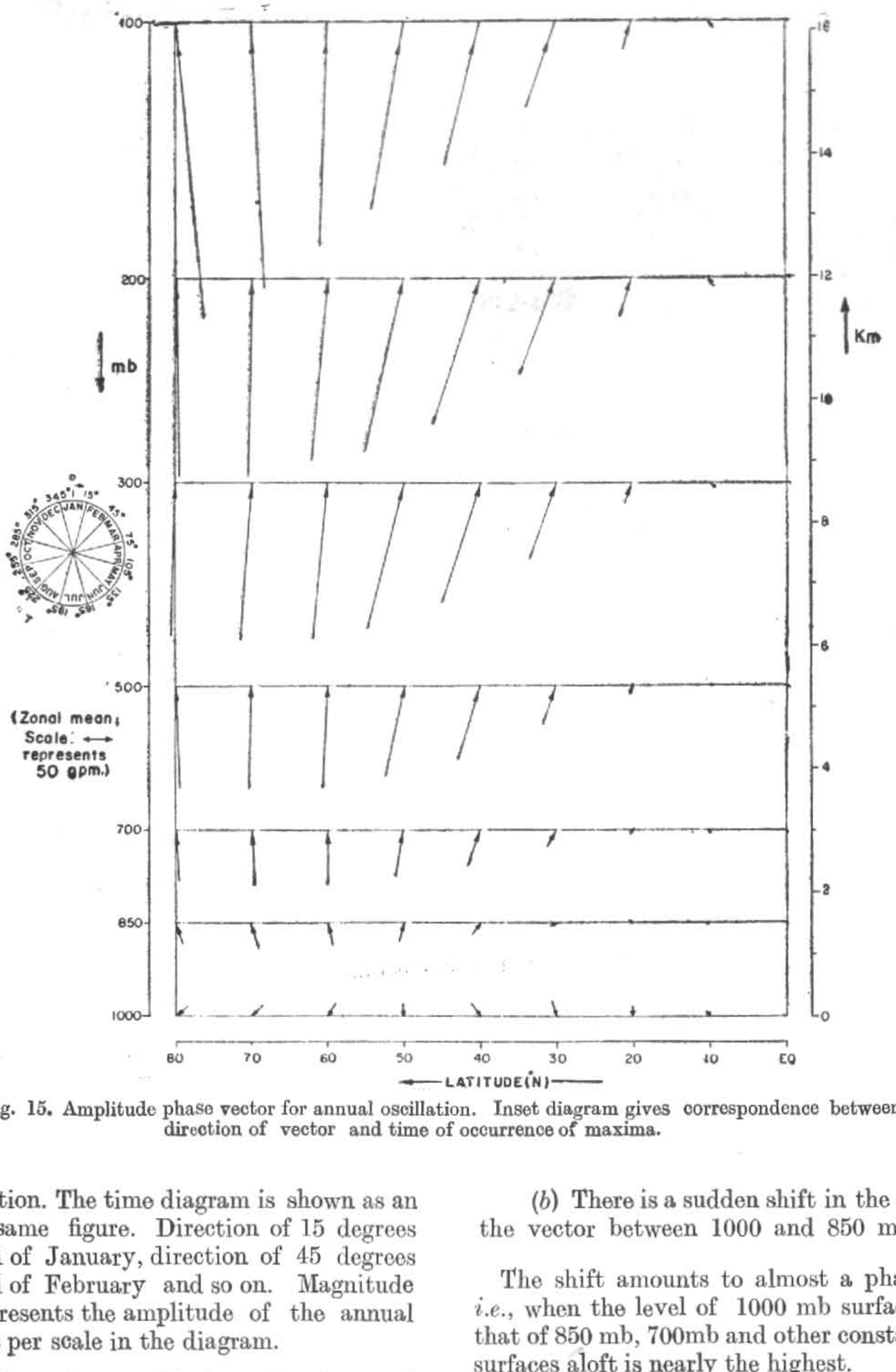

Fig. 15. Amplitude phase vector for annual oscillation. Inset diagram gives correspondence between direction of vector and time of occurrence of maxima.

of the oscillation. The time diagram is shown as an inset in the same figure. Direction of 15 degrees indicates end of January, direction of 45 degrees indicates end of February and so on. Magnitude of vector represents the amplitude of the annual oscillation as per scale in the diagram.

Table 1 gives the amplitude and phase of geopotential maximum of the annual oscillation at different latitudes and different isobaric surfaces.

3. Summary

The following points are noteworthy :

(*a*) Amplitude of the oscillation is very small at all levels in the near equatorial region.

(*b*) There is a sudden shift in the direction of the vector between 1000 and 850 mb.

The shift amounts to almost a phase reversal, *i.e.*, when the level of 1000 mb surface is lowest that of 850 mb, 700mb and other constant pressure surfaces aloft is nearly the highest.

(*c*) At and south of Lat. 40°N, amplitude is generally minimum at 850-mb level and maximum at 200-mb level. The minimum amplitude occurs at 850 mb, because this is close to the level of phase reversal. At and north of Lat. 50°N, amplitude increases with height; the largest value is seen at 100-mb level which is the last level of the analysis.

(*d*) If we disregard those levels where amplitude is equal to or less than 20 gpm, then the following points emerge very clearly :

(*i*) At and above 700-mb level the maxima at various levels at a latitude occur all within a period of 7 to 10 days. At 20° latitude, the maximum occurs between 3rd and 7th August; at 30° between 6th and 17th August; at 40° between 2nd and 6th August; at 50° between 27th July and 5th August; at 60° between 17th and 23rd July; at 70° between 14th and 22nd July and at 80° between 12th and 16th July.

(*ii*) At and above 700-mb level, north of 20°N, maximum at a given isobaric level occurs first at the northern-most latitude and then at the lower latitudes. Thus, at 700-mb level, there is a lag of about one month between the occurrence of maximum at 80°N and at 30°N. This lag is about 3 weeks at 500, 300, 200 and 100 mb.

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