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Synoptic Oscillations of Arabian Anticyclones in the transition season*

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ABSTRACT. In this paper, an attempt has been made to study the significant circulation features over the Arabian Sea characterising the summer transition and the onset of southwest monsoon rains along the West Coast of India in two contrasting years. It was found that the more important feature was the sudden northward shift of the Arabian Sea sub-tropical anticyclone and its establishment over West Pakistan and the adjoining areas of Iran particularly at the 300-mb level. At the 500-mb level, in addition to similar changes the monsoon trough also forms over the Malabar Coast simultaneously A study of the movements of the sub-tropical anticyclones over the Arabian Sea and Africa during May 1963 at 300-mb level shows that these are displaced meridionally under the influence of troughs in westerlies, the maximum equatorward displacement taking place when troughs move to a more southerly latitude. A more northerly position of the Arabian Sea anticyclone in April or early May appears to be associated with early commencement of the monsoon rains over Kerala.

1. Introduction

It has been shown by several authors (Yeh, Dao and Li 1959, Koteswaram 1958, Ramanathan 1958 and Yin 1949), notably Yeh (1959), that over southern Asia and adjoining areas the circulation pattern changes abruptly from a winter regime to a summer regime, almost in a spectacular manner towards the end of the transition period. The object of the present preliminary study is to ascertain the more important of the significant features which characterise the end of the transition period and the beginning of the monsoon regime over India.

2. Procedure

Probably the most effective way of unravelling the significant features which characterise the circulation pattern associated with the end of the transition period is to examine the conditions obtaining during two contrasting years, one with a short transition period and the other with an unusually prolonged transition period. The year 1956 in which the monsoon rains set in along Kerala coast early, *i.e.*, on 21 May, and 1958 in which the onset of the monsoon rains was delayed until 14 June were chosen for this purpose. A preliminary examination of the daily weather charts for these two years indicated that a consistent feature which markedly differentiates the one from the other is the position and movement of the subtropical anticyclone over the Arabian Sea and adjoining areas, particularly at 300 mb.

In 1956, the subtropical anticyclone moved over to West Pakistan and the adjoining areas by 21 May which marked the end of the transition period. As the charts available for 1956 and 1958 do not extend much beyond the Indian region and as data in respect of extra-Indian stations are meagre, the extended charts of the current years analysed in IMC were examined with a view to tracking the movement of subtropical anticyclones over the Arabian Sea and adjoining areas and to identifying factors which influence their oscillations. Subsequent discussions will, therefore, relate to charts of 1963. Apparently, synoptic oscillations of the subtropical anticyclones east of the Indian region do not affect significantly the oscillations of the Arabian anticyclones. Hence the former were left out in the present study.

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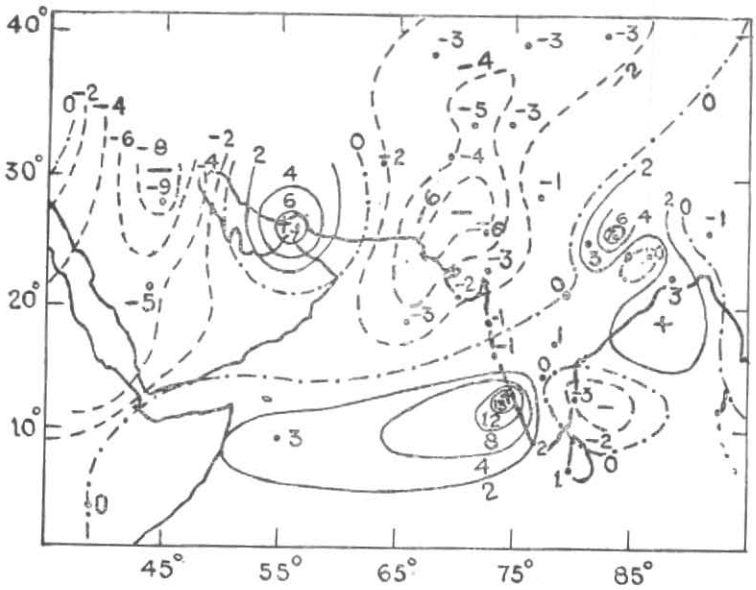

Fig. 1. Vorticity field, 500 mb, 1200 GMT, 31 May 1963

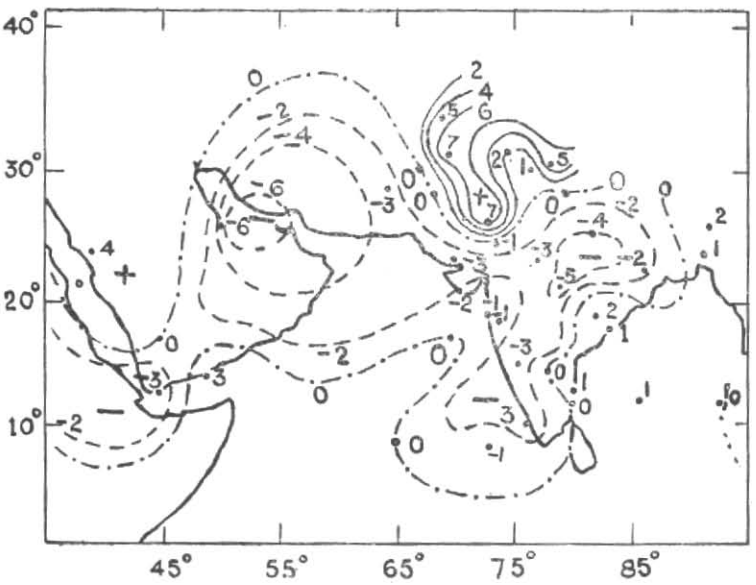

Fig. 2. Vorticity field, 500 mb, 1200 GMT, 31 May 1958

Units are kt/deg. lat. This can be converted by using 1 kt/deg. is approximately equal to $0{\cdot}46\times10^{-5}$ sec^{-1}. Positive values are shown by continuous lines, negative values by dashed lines and the zero isopleth by alternate dotted and dashed lines

In 1963, the Arabian Sea subtropical anticyclone moved over to West Pakistan by 31 May, at 300 mb. This synoptic situation and also the conditions at 500 mb resemble closely the circulation pattern on 21 May 1956. Hence, this is taken as representing the circulation pattern marking the end of the 1963 transition period. To distinguish the salient circulation features characterising this situation, these charts were compared with the conditions on the same date in 1958, the year of prolonged transition period. The marked differences are —

In 1963, at 500 mb there is an extensive anticyclonic cell over West Pakistan. This is much nearer the average seasonal position for July than for April. For the first time in this season the monsoon trough has appeared over the Arabian Sea between 10° to 12°N. In 1958, on the other hand, over the south Peninsula, there is an anticyclone. Over northwest India and West Pakistan where there should have been an anticyclone there is an intense westerly trough. The situations are in marked contrast.

To bring out the features quantitatively, vorticities were computed over India and neighbourhood and their fields were drawn for the above dates (Figs. 1 and 2). In 1963, the monsoon trough is seen as a fairly intense cyclonic vortex near 12°N on the west coast. The maximum vorticity near the centre is $+0{\cdot}6\times10^{-4}$ sec^{-1}. The vorticity near the centre of the anticyclone over northwest India and West Pakistan is $-0{\cdot}3\times10^{-4}$ sec^{-1}. In 1958, in the position where the monsoon trough should have been, the vorticity is negative and about $-0{\cdot}1\times10^{-4}$ sec^{-1}. Along the westerly trough over north India the vorticity is $+0{\cdot}4\times10^{-4}$ sec^{-1}.

Significantly, features shown on the charts for 31 May 1963 resemble average July conditions while those for 31 May 1958 resemble April conditions. Possibly then, close tracking of the position and movement of the Arabian Sea anticyclone may yield useful indications regarding duration of the transition period and commencement of the southwest monsoon season over India. Naturally, a synoptic oscillation of the subtropical anticyclone must be distinguished from the seasonal march; this aspect of the study is being pursued and will be presented later.

Figs. 3 and 4 are smoothed curves showing the daily latitudinal fluctuations of the central position of Arabian anticyclones during May 1963 at 300 mb. In the beginning of this month there were two anticyclones, one over Ethiopia and the other over the southeast Arabian Sea centred near 11°N, 70°E. The former is designated A_1 in Fig. 3 and the latter A_2 in Fig. 4. The smoothed curves were obtained by plotting daily 0000 GMT and 1200 GMT latitudinal positions of centres of each anticyclone on a graph sheet, drawing straight lines connecting each point and then smoothing out suitably after careful checking so as to avoid random errors in fixing centres when data are meagre. It will be seen from Fig. 3 that anticyclone A_1 gradually shifted north and by the middle of the month had reached 19°N. Thereafter, it moved south and after 23 May remained more or less at 13°N for five days. On the 28th it became indistinct due to a severe cyclonic storm moving into that area. There were seven oscillations, generally associated with troughs in the westerlies or cyclonic circulations passing north of the region. The positions of significant troughs are also shown in the graph.

The more important features of Fig. 4 showing the oscillations of the Arabian Sea anticyclone A_2 are—

(1) During the first three weeks of May 1963 there were several troughs in the westerlies which affected the movement of this anticyclone;

(2) A well-marked trough in the westerlies which came down as far south as the equator on the 10th completely effaced the anticyclone;

(3) Another well-marked trough which reached 5°N on the 15th displaced the anticyclone almost down to the equator. With the passage of this

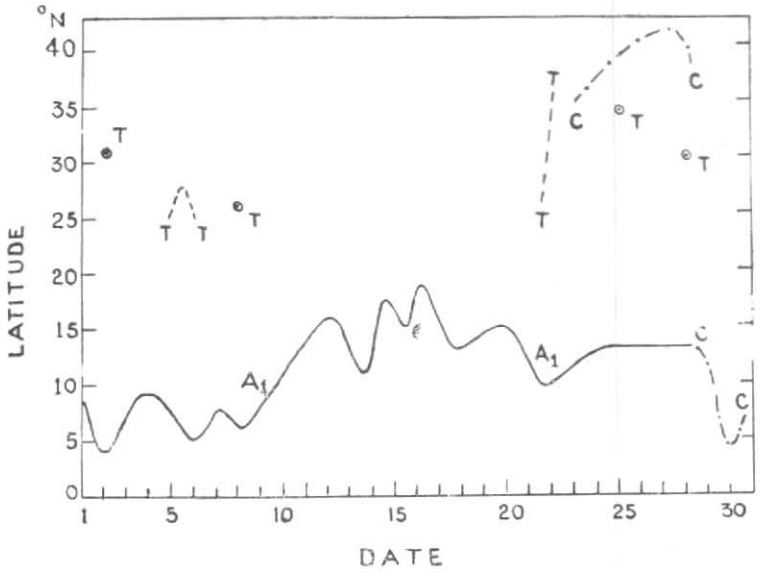

Fig. 3. Latitudinal oscillations of Anticyclone A-1, significant troughs and cyclone circulations at the 300-mb level during May 1963

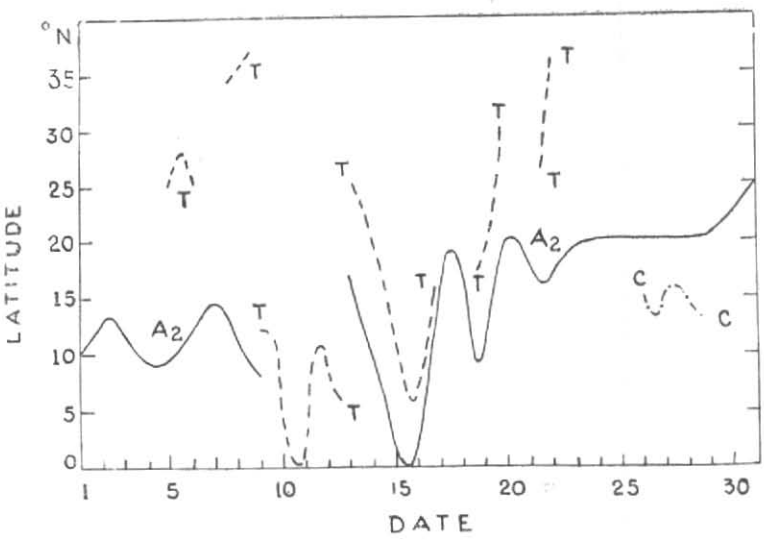

Fig. 4. Latitudinal oscillations of Anticyclone A-2, significant troughs and cyclonic circulations at the 300-mb level during May 1963

Solid line portrays variations of position A-1, A-2 ; dashed line—variation of trough in westerlies; dot-dash line—variations in positions of cyclonic circulations (Fig. 3)/positions of cyclonic storm in the Arabian Sea (Fig. 4); T refers to trough, C to cyclone

trough A_2 moved northwards to 19°N by the 17th;

(4) The anticyclone was again displaced southwards by another trough on the 18th;

(5) Thereafter the anticyclone rapidly shifted northwards and remained steady along 20°N till the 29th.

(6) Subsequently when a cyclonic storm in the Arabian Sea moved west of 50°E, there was a spectacular northwestward movement of the anticyclone into West Pakistan by 31 May.

At 200 mb similar fluctuations were noticed. However, they were not so well-marked as at 300 mb. Also, during the last three days of May, the northwestward movement of the Arabian Sea anticyclone (A_2), its rapid expansion meridionally and zonally and the weakening of the westerly maxima over and around the northern borders of the anticyclone possibly as a result of decrease of temperature and pressure gradients, occurred rapidly, almost in a spectacular manner.

To ascertain whether the shift of the Arabian Sea sub-tropical anticyclone at 300 mb over West Pakistan by the end of the transition period is a special feature of the years examined or generally occurs, significant changes in upper winds over Bombay (Santacruz) and Veraval at 9 km, in May and June were examined for the period 1956—63. Table 1 shows that in most of these years upper winds over these stations changed to a direction between north and east indicating a ridge or anticyclone to the northwest of these stations on dates falling before or coinciding with the commencement of increase in the rainfall over Kerala.

In view of the above it appears that there is a significant relationship between the position and movement of the Arabian Sea subtropical anticyclone and the duration of the transition season. This is also in agreement with the findings of Sutcliffe and Bannon (1954) regarding the appearance of easterly winds over Aden and its association with the monsoon onset over the Malabar coast of India.

Fig. 5 shows curves of daily fluctuations in latitudinal positions of the subtropical ridge (complete data were not available for locating the centre of anticyclone and hence only the latitude of the ridge could be estimated) at 9 km relating to the relevant periods in 1956 and 1958. It will be seen that in 1958, the mean position of the ridge was well to the south and onset of the monsoon rains was considerably delayed, whereas in 1956, the year of early monsoon rains, the mean position of the ridge was at a more northern latitude, even in April. In 1961, which was an exceptional year, the ridge was comparatively in a more northerly position, except on some occasions, when well-marked troughs in the westerlies displaced the ridge southwards.

As troughs in the westerlies affect the northward progression of the Arabian Sea anticyclone and are, therefore, liable to have an indirect bearing on the onset of the monsoon rains over India, it appears worthwhile to examine this aspect in detail. As a rough measure, Table 2 prepared from weekly weather reports issued by the India Meteorological Department indicates that probably some association exists.

It is also noticed that after the onset of the southwest monsoon rains, the oscillations of the anticyclone affect the position of the monsoon trough which in turn affects the rainfall over the country.

3. Conclusion

The present preliminary study indicates that—

(1) During May-June, when an extensive subtropical anticyclone at 300 and 500 mb becomes located over West Pakistan and adjoining areas while a trough extends eastwards from the southeast Arabian Sea, the change-over from the transition period to the southwest monsoon season is taking place over India.

TABLE 1

Changes in upper wind at Bombay and Veraval at 9 km around the date of onset of monsoon rains over Kerala (speeds in kt, observations at 1200 GMT)

Date	VERAVAL					BOMBAY (Santacruz)					Onset of monsoon rains over Kerala
	Dates and upper winds					Dates and upper winds					
1956	May*	5th	6th	7th	8th	May*	2nd	3rd	4th	5th	21 May
		..	050/14	070/19	090/17		..	..	020/03	070/30	
1957	May	26th	27th	28th	29th	May	27th	28th	29th	30th	1 Jun
		130/19	150/11 †	050/09	080/08		110/17	120/14 †	050/10	360/09	
1958	Jun	10th	11th	12th	13th	Jun	13th	14th	15th	16th	14 Jun
		260/16	280/11 †	010/07	050/10		210/15	200/03 †	090/10	130/15	
1959	Jun 19th	20th	21st	22nd	23rd	May	20th	21st	22nd	23rd	31 May
	270/13	190/04	120/13 †	070/07	050/05		150/09	300/15 †	090/21	070/10	
1960	May	8th	9th	10th	11th	May	7th	8th	9th	10th	14 May
		250/16	260/02 †	080/03	190/13		260/12	190/03 †	050/13	130/15	
1961	May	25th	27th	28th	29th	May	6th	7th	8th	9th	18 May
		270/15	300/10 †	030/06	060/07		270/03	340/16 †	010/21	360/09	
1962	May	17th	18th	20th	21st	May	14th	15th	16th	17th	17 May
		200/13	280/22 †	100/06	020/07		290/07	340/12 †	040/12	150/10	
1963	May 26th	27th	28th	29th	30th	May	24th	25th	26th	27th	31 May
	240/04	350/07	350/09 †	020/17	040/23		110/10	120/04 †	060/12	010/07	

† Indicates change in upper wind to a direction between 360 deg. to 090 deg.
*In 1956 changes in upper wind took place earlier than 1 May

TABLE 2

Relation between number of Western Disturbances passing over India in April and May (first half) and the date of onset of monsoon rains over Kerala

Date of onset of monsoon rains	Western Disturbances in April	Western Disturbances in first fortnight of May	Total
1 Jun 1954	5	4	9
29 May 1955	4	3	7
21 May 1956	4	1	5
1 Jun 1957	9	3	12
14 Jun 1958	6	5	11
31 May 1959	4	2	6
14 May 1960	4	2	6
18 May 1961	5	3	8
17 May 1962	4	4	8
31 May 1963	8	4	12

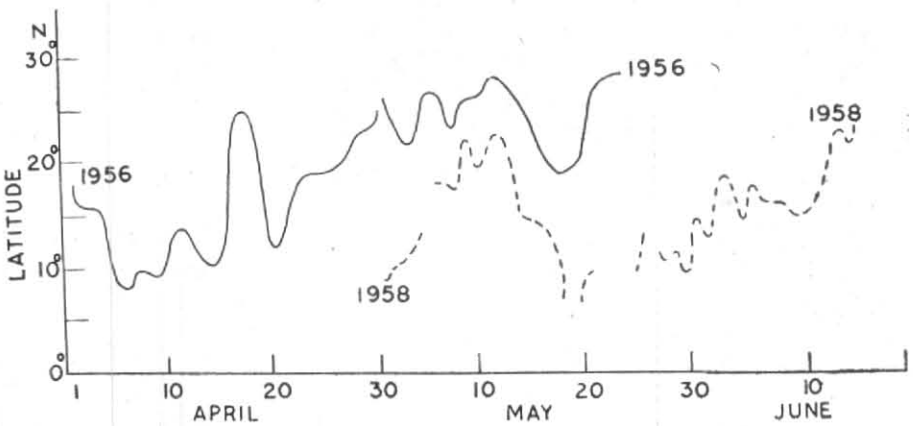

Fig.5. Latitudinal oscillations of the sub-tropical ridge line along 70°E, during relevant periods of transition seasons 1956 and 1958

(Interruptions of lines occur at times when data were not available)

(2) Due to the close association between oscillations of the anticyclone and passage of low latitude troughs in the westerlies, a careful assessment of the intensity and changes of circulation index and tracking the Arabian Sea subtropical anticyclone from April onwards may be helpful for medium range forecasting of the onset of the southwest monsoon rains over India.

4. Acknowledgement

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Discussion

SAHA (K.R.): We have been used to thinking so far that the Tibetan anticyclone is the guiding factor during the onset of the monsoon and afterwards controls the strength of the easterly current at 300 mb and above. I think it is very interesting to see the shift in the centre of action. Nowadays we believe it has shifted on to the Arabian Sea side. I would like to know in what way these two anticyclones are linked—the Tibetan anticyclone and the anticyclone that has been studied by Mr. Ramamurthi. Are these two a part of the big anticyclone that controls the monsoon current?

RAMAMURTHI : What we have seen from the charts of this year is that the Tibetan anticyclone comes over that area much later, after the onset of the monsoon. As my study was confined to the significant features relating to the onset of the monsoon I have not studied the relationship between these two highs. It is to be studied in a subsequent period.

KESHAVAMURTY : One point to be made from the July charts it looks as though the Tibetan anticyclone comes only during strong monsoon conditions and not in the normal monsoon.

RAMAN (C.R.V.) : Recent analyses show that the anticyclones in the upper troposphere appear to be centred somewhat to the south rather than over the Tibetan plateau. So, at 500 mb it ought to be a little more to the south than at 200 mb.

CHELAM (E. V.) : The monsoon activity, even according to the charts produced here may seem to be related to the number of westerly disturbances. With a greater number of westerly troughs, the monsoon is delayed; they act as a destructive agent. Strong activity of the westerly regime inhibits onset of the monsoon. And if you are looking for the stronger monsoon, naturally you have to turn to the upper easterly current. As a matter of fact it is well known that this year the monsoon was not worthwhile until some disturbances developed in the easterlies and moved from east to west. In fact, the motion of easterly disturbances indicates the importance of the easterly current and not the westerlies. I am certain that the strength and intensity of the Tibetan high which regulates the intensity of the easterlies, and the easterly current will increase with height, if the high is very marked. So as far as the Tibetan high rule is concerned I am afraid I almost cross swords with Mr. Raman.

RAMAN : As regards the strength of the upper easterlies and movement westwards of perturbations in the easterlies, I, like you, was one who thought along those lines. Some further re-thinking seems to be necessary.

DESAI (B.N.) : I have to supplement what Dr. Chelam says. I think that these people who spoke have sufficiently demonstrated that the larger the number of westerly disturbances and the further south they move, the later is the date of the onset of the monsoon. My personal feeling is that the 1963 behaviour of, and the statement that there are a larger number of westerly disturbances completely vindicate the view that the Tibetan high was not allowed to become established by the unusual activity of the troughs in the westerlies. The whole trouble is that the easterlies did not develop because either the high was not allowed to exist or because it was annihilated. I think that the older view is supported by these analyses.