2.1 INTRODUCTION

In this chapter the synoptic situation along with the circulation parameters for the period and area under consideration over the Arabian Sea are presented.

Earlier studies [Rao (1976), WMO (1975)] have reported the importance of both cross equatorial flow and evaporation from Arabian Sea, as sources of moisture for the Indian monsoon. Both these moisture sources are undoubtedly related to the strength of the low level southwesterly flow but the available water vapour has to be lifted upward for further development of weather. Here comes the importance of low level convergence and upper level divergence. The purpose of the study included in this chapter is to find out the characteristics of circulation, amount of water vapour and kinetic energy which prevailed during the four Phases.

The circulation parameters studied in detail are wind, vorticity, divergence and vertical velocity. The methods used for the computations of these parameters are given in the previous chapter, Section 1.5.

2.2 SYNOPTIC SITUATIONS

In this Section, the synoptic conditions prevailing
over the Arabian Sea and the West coast of India, during the period of study as revealed by the India Daily Weather Reports are broadly presented for each of the phases.

PHASE-1

The general synoptic features for the period 7 to 20 June 1977 can be summarised as follows: A well marked trough of low, off the West coast seen on the 7th developed into a marked low pressure area over East Central Arabian sea and by the 9th, it concentrated into a depression, with the upper air cyclonic circulation extending upto 7.6 Km above sea level. By tenth, it became a cyclonic storm centered at 18.5°N and 64.5°E. It then rapidly moved westwards and intensified into a severe cyclonic storm, and on the 11th reached 19.5°N and 64.5°E [Fig.2.1(a)]. The seasonal trough of low pressure lay over South East Bay and adjoining Andaman Sea. By 13th June the severe cyclonic storm moved westwards and the trough of low over East Central Arabian Sea off Goa coast persisted upto the 17th. On the 14th and 15th, the main feature was a depression in the West Central Bay, off Andhra coast. The trough of low moved north and ran through Dehra Dun to Aijal. By 16th June the monsoon advanced into North interior Karnataka and adjoining Maharashtra. From 18th to 19th June a well marked low pressure area over Gangetic West Bengal and a feeble trough of
FIG. 2.1(a) WEATHER MAP FOR 11TH JUNE 1977.
low on sea level chart off West coast were the main features. This trough off West coast persisted upto 20th June.

PHASE-II

A well marked low pressure area seen over North Arabian sea and adjoining Mekran coast on 1st July moved westwards by the 2nd. A mid tropospheric circulation (MTC) over South Rajasthan and a trough off West coast were the other features. By 5th July a low pressure area over North West Bay seen on the 3rd intensified into a deep depression and crossed the coast [Fig.2.1(b)]. The MTC persisted and the trough off West coast extending from South Gujarat to Lakshadweep persisted upto 7th July and was marked off Kerala-Karnataka coast. On the 9th, a well marked low was seen over West Rajasthan and South Pakistan and the trough off west coast weakened. By 11th July, the low pressure area over North West Rajasthan became an upper air cyclonic circulation extending upto 4.5 Kms above sea level. The trough off West coast still persisted from South Gujarath coast to Lakshadweep and on the 12th it was well marked off Goa-Maharashtra coast. The upper air cyclonic circulation over North West Rajasthan persisted upto the 13th and moved away by 14th July. The axis of seasonal trough during this period was almost always through Bikaner to North East Bay. Monsoon was weak in Konkan, Goa, Coastal Karnataka and Kerala. The
FIG. 2.1(b) WEATHER MAP FOR 05TH JULY 1977.
trough off West coast extending from South Gujarat coast into North Lakshadweep persisted up to the 15th and by then a well marked off-shore vortex was seen embedded in it off Goa-Karnataka coast.

PHASE-III

The general synoptic features over the Arabian Sea near to this polygon area, during the period were as follows. A feeble trough persisted over East Central Arabian sea off Goa-Maharashtra coasts between 2.1 and 3.6 Kms above sea level from 17th to 19th May. On the 20th, a low pressure area extending up to mid troposphere entered Arabian sea and by 21st May, it became an upper air cyclonic circulation over North Rajasthan and neighbourhood. The lower tropospheric westerlies strengthened to about 35 knots and as a result of these, there was rain in the coastal areas of Kerala and Karnataka. During the next two days, the conditions were favourable for onset of monsoon over South Andaman Sea. On 25th May, the south west monsoon advanced into the Andaman Sea [Fig.2.1.(c)]. A trough line at 3.1 Kms above sea level passed through 8°N, 55°E, 3°N, 85°E and thence to Port Blair and Rangoon from the 25th to the end of the phase with very small fluctuations in its position on the different days. On the 26th and 27th May, a cyclonic circulation was seen embedded in this trough. Another upper
FIG. 2.1(c) WEATHER MAP FOR 25TH MAY 1979.
air cyclonic circulation present over Comorin and Maldives area between 2.1 and 5.8 Kms above sea level on the 27th, moved to Kerala and adjoining Lakshadweep on the 28th and stayed there till 29th May. On the 30th, these systems moved eastwards and thereafter weakened.

PHASE-IV

The synoptic conditions that prevailed on 2nd and 3rd June were favourable for the onset of South West Monsoon over Lakshadweep and Kerala. But a trough of low pressure over Lakshadweep and adjoining Arabian Sea which persisted from 2nd to 4th June, moved westwards and hence by 4th, conditions became unfavourable for the onset. By the 5th a trough line present 3.1 kms above 6°N, 55°E and 4°N, 85°E on 2nd and 3rd moved northward and dry weather prevailed over Kerala. But on the 6th it came further down to 4°N, 55°E, Trivandrum and Port Blair and thereafter the lower tropospheric westerlies over Sri Lanka strengthened and another trough of low appeared over Lakshadweep. This trough which extended upto middle troposphere persisted upto the 14th. On 7th June a cyclonic circulation developed over South Tamil Nadu and by next day it had shifted to extreme South Peninsula. The trough of low pressure over Lakshadweep moved east by the 7th to the Kerala, South Karnataka coast, strengthened and under its influence, conditions became favou-
rable for the monsoon onset. On 10th and 11th the trough line at 3.1 Kms above sea level, ran roughly along 10°N over Arabian sea and 9°N, 85°E and onset of monsoon took place over Kerala [Fig.2.1(d)]. On 12th June a mid-tropospheric cyclonic circulation moved westwards across extreme South peninsula and by 13th reached Lakshadweep and remained there while monsoon strengthened over South Arabian Sea. By 14th, the trough at 3.1 Kms above sea level ran through Mangalore, (11°N, 78°E), and Trivandrum.

2.3 SPECIFIC HUMIDITY, WIND, PRECIPITABLE WATER VAPOUR, KINETIC ENERGY, VORTICITY, DIVERGENCE AND VERTICAL VELOCITY.

In this Section, the diurnal, the day-to-day and vertical variation of the above parameters are discussed one by one.

2.3.1 Specific Humidity

The vertical profiles of specific humidity at 00 and 12 GMTs are shown in Figs 2.2(a) to 2.2(h) respectively for Phases-I, II, III and IV.

PHASE-I

The specific humidity decreased with height consistently on all the days and at both the timings and, values
FIG. 2.1(d) WEATHER MAP FOR 11TH JUNE 1979.
FIG. 2.2(a) VERTICAL VARIATION OF SPECIFIC HUMIDITY AT 00 GMT DURING PHASE-I
FIG. 2.2(b) VERTICAL VARIATION OF SPECIFIC HUMIDITY AT 12 GMT DURING PHASE-I
reached zero by about 200 mb. The decrease was rather sharp up to middle troposphere and gradual thereafter. However, the variation beyond the mid-troposphere becomes less important in view of the very low humidities at these levels. Generally, the values varied between 20 gms/Kg at the surface to 3 gm/Kg at 500 mb.

PHASE-II

The specific humidity variations were almost similar to that of the previous phase with a consistent decrease with height. There were rare occasions of reversals at about 550 mb level. The values were generally lower at 00 GMT, than that at 12 GMT and also than that during Phase-I.

PHASE-III

No significant differences were noticed in the values when compared to the previous phase.

PHASE-IV

Although specific humidity showed similar vertical variations to that of the other phases, the surface values were slightly higher especially so during the latter part of this phase.
FIG. 2.2(c) VERTICAL VARIATION OF SPECIFIC HUMIDITY AT 00 GMT DURING PHASE-II
FIG. 2.2(d) VERTICAL VARIATION OF SPECIFIC HUMIDITY AT 12 GMT DURING PHASE-II
FIG. 2.2(e) VERTICAL VARIATION OF SPECIFIC HUMIDITY AT 00 GMT DURING PHASE-III
FIG. 2.2(f) VERTICAL VARIATION OF SPECIFIC HUMIDITY AT 12 GMT DURING PHASE-III
FIG. 2.2(g) VERTICAL VARIATION OF SPECIFIC HUMIDITY AT 00 GMT DURING PHASE-IV
FIG. 2.2(h) VERTICAL VARIATION OF SPECIFIC HUMIDITY AT 12 GMT DURING PHASE-IV
2.3.2 Wind

Here (Fig.2.3(a) to Fig.2.3(h)) the variation of zonal and meridional components of wind at 00 and 12 GMTs, in the vertical for the four Phases-I, II, III and IV respectively are discussed.

PHASE-I

On all the days at 00 GMT, westerlies persisted almost upto 500 mbs and on some days penetrated upto 400 mbs. The westerly intensity maximum was found around 900 mb level, except on 17th June.

The meridional component did not vary much in the vertical, upto 400 mb. In fact many a time, the maximum was found at the surface itself. The change of direction from southerly to northerly took place mostly around 700 mb. There were rare occasions of changing directions twice.

At 12 GMT, the winds were slightly stronger. But the pattern of variation was almost similar. The change from westerly to easterly took place between 400 and 500 mb region and the meridional winds very rarely changed sign twice in the vertical. The westerly maximum was noticed around 800 mb region. It was also seen that, as in the case of 00 GMT, the meridional winds were weak.
FIG. 2.3(a) VERTICAL VARIATION OF ZONAL AND MERIDIONAL WIND AT 00 GMT DURING PHASE-I
FIG. 2.3(b) VERTICAL VARIATION OF ZONAL AND MERIDIONAL WIND AT 12 GMT DURING PHASE-I
Since the westerlies persisted up to middle levels, it could be inferred that the southwest monsoon was quite strong during this period. It should also be noted that the zonal wind maximum was around 200 mb level where the Easterly jet is normally located, during the monsoon period.

PHASE-II

In this phase too, westerlies existed well above 500 mb level and the changing over to easterlies took place at comparatively higher levels from 1st up to 8th July than rest of the period. The zonal wind maximum was at 200 mb while the westerly maximum was around 800 mb.

In this phase also, the meridional wind velocity as well as variations were much less. On many days, they changed direction more than once in the vertical. The domination of zonal to meridional winds could be easily seen. The variations were similar at both the synoptic hours.

PHASE-III

During this phase, the zonal winds were comparatively of lower velocities and the westerlies prevailed in a much shallow lower layer. In other words, surface westerlies changed to easterlies at around or below 650 mb level. The change of direction took place more than once and hence one finds strong westerlies in the higher levels too. From 17th
FIG. 2.3(c) VERTICAL VARIATION OF ZONAL AND MERIDIONAL WIND AT 00 GMT DURING PHASE-II
FIG. 2.3(d) VERTICAL VARIATION OF ZONAL AND MERIDIONAL WIND AT 12 GMT DURING PHASE-II
FIG. 2.3(e) VERTICAL VARIATION OF ZONAL AND MERIDIONAL WIND AT 00 GMT DURING PHASE-III
FIG. 2.3(f) VERTICAL VARIATION OF ZONAL AND MERIDIONAL WIND AT 12 GMT DURING PHASE-III
to 24th May, there was a clear steep decrease in velocity of the easterlies in the upper levels and on some days it became westerlies by 300 mb level. After 24th this decrease was very gentle. On almost all the days the easterly maximum was noticed around 400 mb. Although the patterns were similar at 00 and 12 GMTs, the zonal wind velocity was higher at 12 GMT.

The meridional component was clearly insignificant and southerlies were observed in the lowest layers but the direction changed more than twice in the vertical.

**PHASE-IV**

From 2nd to 7th June, the zonal wind velocities and their vertical variations were insignificant and from 8th onwards, the pattern was similar to that during Phase-I. The westerly maximum was around 850 mb and the winds decreased in intensity and almost vanished at about 500 mb level. The easterlies were strongest around 200 mb and the zonal winds changed direction only once in the vertical.

An interesting feature is the dominance of northerlies in the lower layers from 7th to 11th June at both the synoptic hours and on many days these northerlies became southerlies only in the upper levels. During the rest of the period southerlies were present in the near surface layer.
FIG. 2.3(g) VERTICAL VARIATION OF ZONAL AND MERIDIONAL WIND AT 00 GMT DURING PHASE-IV
FIG. 2.3(h) VERTICAL VARIATION OF ZONAL AND MERIDIONAL WIND AT 12 GMT DURING PHASE-IV
The above discussions have brought to light the following observations: There were no significant change in the specific humidity values, and the meridional components of wind also exhibited little variation. During the active phase of the monsoon, zonal winds changed direction only once in the vertical, and westerlies persisted to relatively higher levels and also there was an easterly wind maximum around 200 mb level. The diurnal variation of these parameters were insignificant.

2.3.3 Precipitable Water Vapour

Fig.2.4(a) to 2.4(d) give the day to day variations of precipitable water during the four phases. [One unit is \(1 \times 10^2\) Kg, which is equal to 4.92 kg/m\(^2\) in phase I and II and 5.3 Kg/m\(^2\) in Phase-III and IV]. The daily and diurnal variations of moisture in terms of amount of precipitable water vapour integrated from surface to 200 mb for the entire polygon area is discussed in this section.

PHASE-I

The diurnal variations were much less for this parameter and there was no regular pattern for the diurnal variation. From the 7th to 10th and on 19th and 20th of June the values were comparatively higher and above \(10 \times 10^2\) kg. The highest values were found to be on the 7th and lowest on 14th June.
FIG. 2.4(a) VARIATION OF PRECIPITABLE WATER VAPOUR DURING PHASE-I
PHASE-II

This phase was comparatively drier with the values being almost always less than 10 units. Higher values were observed between 10th and 15th July with a gradual increase in the water vapour content from the 9th to 11th. There were conspicuous or sudden variations on many days.

PHASE-III

During this period the values were almost always above ten units and there were significant day-to-day as well as diurnal variations too. For example, on 24th May between 00 and 06 GMT, the value decreased by 9 units. (From 26th to 29th there is lack of data). The exceptionally high values on 24th and 25th is a noteworthy feature. The maximum during this phase was observed at 00 GMT on 24th. There was a gradual increase in value from 9th to 22nd and from 28th to 30th and a decrease from 24th to 27th May.

PHASE-IV

During this period, the amount of precipitable water vapour is high almost always being above \(11 \times 10^{12}\) Kg. The value showed an increasing trend from the 2nd evening to the 5th and on some days such as 7th and 11th June. A prominent jump of about \(3 \times 10^{12}\) Kg. was noticed at 00 GMT on 12th.
FIG. 2.4(b) VARIATION OF PRECIPITABLE WATER VAPOUR DURING PHASE-II
FIG. 2.4(c) VARIATION OF PRECIPITABLE WATER VAPOUR DURING PHASE-III
FIG. 2.4(d) VARIATION OF PRECIPITABLE WATER VAPOUR DURING PHASE-IV
2.3.4 Kinetic Energy

Time section of kinetic energy at four levels, for the four phases are now discussed below. Fig.2.5(a) to 2.5(d) show the values for the Phases-I to IV respectively.

PHASE-I

It can be seen that kinetic energy showed a steady increase at all the levels from 7th to 10th June. This was followed by a slight decrease up to the 12th and thereafter remained almost unchanged till the end of the phase. Kinetic energy maximum was at 700 mb on a few days (7th, 8th and 9th) in the earlier part of the phase and at 200 mb level afterwards. The value was minimum at 500 mb level where the low level westerlies changed over to easterlies. The highest value was around $2.5 \times 10^2$ m sec$^{-2}$.

PHASE-II

In general, the kinetic energy values were much higher than that in the previous phase, with the maximum values around $4 \times 10^2$ units. The day to day variations were significant at the 200 mb level with alternate high and low values. The values were highest at 200 mb level and it was the lowest at 500 mb. At the surface, the values were that between 700 mb and 500 mb levels.
FIG. 2.5(a) VARIATION OF KINETIC ENERGY DURING PHASE-I
FIG. 2.5(b) VARIATION OF KINETIC ENERGY DURING PHASE-II
PHASE-III

The values were much lower, almost one order lesser than that in the previous two phases. The maximum and minimum values differed considerably. Except during the period from 23rd-26th May, the lowest energy was observed at the 700 mb level. Kinetic energy was maximum at the 200 mb level from the 19th to 26th while on other days maximum was at 500 mb level. The variations at 200 mb and 500 mb levels were characterised by good fluctuations while it was less at the surface and 700 mb levels except on 25th May.

PHASE-IV

Except during the period from 4th to 7th June, the daily variations of kinetic energy at the levels other than 200 mb, were very low. There was generally an increasing trend from the 2nd to 7th and the 9th to 11th and decreasing on other days. In the latter part of the phase, the values were rather very high at the 200 mb level. The level of minimum energy was 700 mb upto 7th June and thereupon 500 mb.

The variation pattern of kinetic energy did not show a consistent decrease or increase with height. It followed the prevailing wind pattern.
FIG. 2.5(c) VARIATION OF KINETIC ENERGY DURING PHASE-III
FIG. 2.5(d) VARIATION OF KINETIC ENERGY DURING PHASE-IV
2.3.5 Vorticity, Divergence and Vertical Velocity

This section deals with the vorticity, divergence and vertical velocity during the four phases. The gaps in the figures are due to lack of data and the shaded areas represent anticyclonic vorticity, divergence and downward motion.

PHASE-I

Fig.2.6(a) shows the vorticity, divergence and vertical velocity respectively during this phase.

Vorticity

On 7th and 8th June (except at 18 GMT) the atmosphere had generally anticyclonic vorticity in the near surface layer and cyclonic vorticity from about 950 to 250 mb. From 18 GMT on the 8th, to 00 GMT on the 10th, it was very high cyclonic vorticity although. The period from 12th June onwards was characterised by anticyclonic vorticity from surface to about 850 mb and in the higher levels from 400 to 200 mbs. Anticyclonic vorticity was very strong at the higher levels throughout the period and in the lower layers from 12 GMT of 13th to 12 GMT of 16th June. The middle layer had intermittent days of cyclonic and anticyclonic vorticity.
Anticyclone Vorticity, Divergence, Downward motion.

FIG. 2.6(a) Vertical time section of (a) vorticity (b) divergence and (c) vertical velocity during phase-I
Divergence

The period was characterised by divergence on almost all the days in the lower layers up to about 900 mb level except on 9th and 19th of June. The values were exceptionally high in lower levels at 00 GMT on 7th and 06 GMT on 9th. Above 900 mb it was mostly high convergence up to 500 mb on the 7th and 8th and only up to about 700 mb on the other days. Except on certain days like 8th, 17th and 18th June, where convergence prevailed even up to 250 mb, it was mostly upper level divergence on all the days with very high values like that on 7th, 16th and 19th June. From the 18th to the 20th, low level convergence and upper level divergence were noticed with the latter being of higher magnitudes.

Vertical Velocity

Downward motion prevailed in the lower atmosphere up to about 750 mb on almost all the days except from the 9th to 13th and 19th June. One could notice strong upward motion from surface to 200 mb, from the 9th to 13th with the core on 9th. This could be mainly because of the cyclonic storm that was formed in the Arabian Sea during this period. In general, positive vorticity coupled with convergence was the dominant feature during this period. However from the 13th to 18th, it was downward motion throughout the atmosphere, except on the 16th and the reverse was true from 18th to
Anticyclone Vorticity, Divergence, Downward motion.

FIG. 2.6(b) VERTICAL TIME SECTION OF (a) VORTICITY, (b) DIVERGENCE and (c) VERTICAL VELOCITY DURING PHASE-II
20th. If one recalls the divergence pattern during the 18th to 20th, it was low level convergence and upper level divergence which could also lead to upward motion.

During this phase, the variation of the above three parameters was in conformity to the synoptic situations which prevailed during that period, specially the vorticity pattern.

PHASE-II

Fig.2.6(b) shows the variation of above three parameters during the second phase.

Vorticity

Anticyclonic vorticity was predominant from surface to 450 mb from 1st to 8th July, while from the 8th to 15th, anticyclonic vorticity was confined to the layers from surface to 850 mb and that above 500 mb. The intermediate layer experienced cyclonic vorticity except during the latter half of this Phase (12th to 13th), where the middle layer cyclonic vorticity extended up to about 350 mb.

Divergence

It was mostly divergence in the lower levels almost up to 700 mb with exceptions on 1st, 9th and 13th July. Divergence dominated the whole atmosphere during this phase,
except in the middle levels from the 1st to 4th, 7th and 8th and in the upper levels on 4th, 7th, 13th and 14th July.

**Vertical Velocity**

Except for the downward motion in the lower layers from surface to 700 mb, from 1st to 3rd July at 12 GMT, it was upward motion elsewhere, on these three days. Very high values of downward motions were noticed throughout the whole atmosphere at 12 GMT on the 3rd and this suddenly changed to strong updrafts by 18 GMT. From the 3rd to 5th it was mostly upward motion and vice versa after that up to 9th. In general, from the 9th to 12th updrafts dominated the whole atmosphere and on the 10th it was updrafts all through with exceptionally high velocities at 12 GMT. A noteworthy feature is the sudden transition from high downward velocities at 12 GMT to very strong upward velocity at 18 GMT on 3rd and vice versa on 12th from 12 to 18 GMT, and again a reversal at 06 GMT on 13th. On 14th and 15th July, upward motion dominated the lower layers while it was the downward motion in the upper levels.

The circulation parameters especially vertical velocity pattern, clearly revealed the period to be an inactive phase of monsoon. It should be recalled that the synoptic charts also gave the same idea.
PHASE-III

Vertical time section of Vorticity, Divergence and Vertical Velocity for this phase are shown in Fig.2.6(c).

Vorticity

On 17th and 18th May it was almost all through cyclonic vorticity except from surface to 900 mb on 17th. From 19th to 21st May, cyclonic vorticity was observed from 900 to 600 mb and anticyclonic vorticity in the surface layers as well as upper levels. The situation was almost reversed from 21st to 23rd and anticyclonic vorticity dominated the whole atmosphere. From the 23rd to 28th, it was lower level (upto 800 mb) anticyclonic vorticity with cyclonic vorticity above that. Very strong cyclonic vorticity was found on 24th, above 300 mb and on the 25th and 26th around 400 mb level.

Divergence

Although there was an overall dominance of divergence during this period, convergence was seen in the lowest layers from 1000 to 900 mb on almost all the days with exceptionally high values on 25th May where it was convergence all through. In the middle layers also, convergence was seen on a few days while, it was divergence on all the days in the upper levels except on the 21st, 23rd and 24th.
Anticyclone Vorticity, Divergence, Downward motion.

FIG.2.6(c) VERTICAL TIME SECTION OF (a) VORTICITY, (b) DIVERGENCE and (c) VERTICAL VELOCITY DURING PHASE-III
Upper level divergence were very high (more than $2 \times 10^{-5}$ sec) on all the days from 17th to 22nd and also on 24th May. The change from convergence to divergence took place within a span of 6 hours on many days like that on the 24th, at 18 GMT. In general, divergence values were higher than convergence.

Vertical Velocity

The figure 2.6(c) reveals alternate upward and downward motions with both being very strong on many days. For example, from 900 to 250 mb at 00 GMT on 18th, the atmosphere was characterised by strong upward motions of the order of $+2.5 \times 10^{-3}$ mb/sec. and at 18 GMT on 25th it was even higher $3 \times 10^{-3}$ mb/sec downward motions. Sudden transitions from downward to upward motions were also noticed as can be seen on 25th May. There were synoptic hours on which only upward or downward motions were noticed. From the 17th to 25th in the lower layers and from the 25th to 29th 06 GMT, it was mostly upward motions, in the whole atmosphere.

The presence of strong cyclonic vorticity, low level convergence and strong upward motions on 17th and 18th May, may be due to the presence of a low in the vicinity of the polygon area, during that period. An examination of the synoptic charts on these days clearly reveal the presence of high pressure vortex over the Arabian Sea, near to the
polygon area, under study. Although the vertical velocity picture does not fully reveal the characteristics of the persistent anticyclone, the pattern of vorticity and divergence does suggest the presence of anticyclonic circulation during the latter part of the period.

**PHASE-IV**

Fig.2.6(d) gives the vertical and time to time variation of the three parameters for Phase-IV.

**Vorticity**

In general it was strong cyclonic vorticity in almost the whole layer of atmosphere on all the days except 5th June. The values were very high on the 3rd, 4th, 7th, 9th and 12th June. Anticyclonic vorticity prevailed in the higher levels from the 4th to 7th and early hours of the 11th with highest values on the 4th, while on the 5th, it extended down to 650 mb level.

**Divergence**

On 2nd and 3rd June, it was convergence from 1000 mb to 900 mb and divergence from 900 to 200 mbs. From the 4th to 9th, although convergence dominated the whole atmosphere, divergence were also seen in the middle levels. During the period from 9th to 12th June, mostly strong convergence were
Anticyclone Vorticity, Divergence, Downward motion.

(a) VERTICAL TIME SECTION OF (a) VORTICITY, (b) DIVERGENCE and (c) VERTICAL VELOCITY DURING PHASE-IV
noticed in the lower layers while it was divergence in the middle layer. It should be noted that, it was upper level convergence on all days except 2nd, 3rd and 4th June. Very high values of convergence were noticed at 00 GMT on the 9th from 650 to 300 mb level. In general one could not delineate the dominance of convergence or divergence during this phase.

Vertical Velocity

The whole phase was dominated by downward motion, except on 2nd, 3rd and 7th June and on these days upward motion was present almost all through the atmosphere. On certain days, like the 6th, 9th, 10th and 11th although not at all the synoptic hours, updrafts were present in the lower levels. On 3rd June at 18 GMT and on 4th at 00 and 06 GMTs, it was very high upward motions, from about 850 mb to 300 mb and within 12 hours, it suddenly changed to very high downward motions.

The synoptic situations reveal that this period was still a pre-onset phase. Although the vorticity pattern revealed good cyclonic conditions, this was not seen in the divergence and vertical velocity patterns.

A general comparison of the two years shows that 1977 was a better monsoon year than 1979. In June, when the
polygon positions were almost same, the synoptic situations were different. In 1977 June, the conditions were that of cyclonic situations, while in June 1979, there was predominance of downward motion, divergence, and low humidity. It should be remembered that, the period of study, during 1977, was monsoon onset time and that of 1979 was the pre-onset period. These conditions were more or less corroborated by the parameters discussed above.