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Mean structure of inland monsoon low

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सार — मेघ,वर्षा, पवन, क्षेत्र, भ्रमिलता क्षेत्र,अपसरण, अभिसरण/क्षेत्र, तापमान क्षेत्र और ओसांक अवदाब क्षेत्र का संदर्भ देकर भूमिक्षेत्र पर मानसून अवदाब के माध्य प्रतिदर्श पर पहुंचने का प्रयास किया गया है । ये सभी प्राचल दनिक विचरण दर्शाते हैं । मेघाच्छन्नता का अधिकतम क्षेत्र द० प० खंड में स्थित रहा । शाम और रात्रि के दौरान द० प० खण्ड में विचलित हो जाती है । उ० प० खण्ड कपासी वर्षा मेघों के विकास के लिए वरीय क्षेत्र है । पवन क्षेत्र 700 मि० बार पर सबसे प्रबल होता है । भ्रमिल 700 मि० बार तक ऊर्ध्वाधर होता है और वह इस स्तर के ऊपर से ऊंचाई के साथ साथ दक्षिण की ओर विचलित हो जाती है । 900 मि० बार पर धनात्मक भ्रमिलता और अपसरण क्षेत्र अधिक सुदृढ़ होता है । निम्नतम क्षोभमंडल में भ्रमिल की प्रवृत्ति शीतक्रोड वाली और मध्य और उपरितन क्षोभमंडल में गर्म क्रोड वाली होती है । द० प० दिशा में ऊंचाई के साथ भ्रमिल के साथ नम क्षेत्र संबद्ध होता है और उच्च नमी की राशि 600 मि० बार तक लगातार बनी रहती है ।

ABSTRACT. An attempt is made to arrive at a mean model of a monsoon low over land area with respect to clouds, rainfall, wind field, vorticity field, conv/div fields, temperature field and dew point depression fields. All these parameters show a diurnal variation. Area of maximum cloudiness is located in the SW sector. Rainfall is more in SW sector during evening and night and it shows a shift in NW sector during day time. NE sector is the preferred area for *Cb* development. Wind field is strongest at 700 mb. The vortex is vertical upto 700 mb and it shifts southward with respect to height above this level. Positive vorticity and convergence fields are more pronounced at 900 mb. The vortex is of cold core nature in the lower troposphere and warmer in the middle and upper troposphere. The moist region associated with vortex in the SW direction with height and high moisture content continues upto 600 mb.

1. Introduction

The vertical structure of monsoon lows over the inland area of northern India was investigated by the method of spectral analysis by Murakami (1977). He brought out a periodicity of around five days over monsoon trough region, corresponding to the passage of monsoon lows during the monsoon season of 1962. The author also brought out changes in the temperature and moisture field when a monsoon low from north Bay emerges inland. However, he had not attempted to make a composite model of mean structure of inland monsoon lows. In this paper an attempt is made to arrive at the mean structure of an inland monsoon low based on ten cases.

2. Data used

Data for the following ten cases of monsoon lows which had crossed coast as low, were studied for evolving a composite structure :

Date	*Time (GMT)*
16 Jul 1962	03 & 12 GMT
21-22 Jul 1962	12 & 03 GMT
24-25 Jul 1963	12 & 03 GMT
17-18 Jul 1968	12 & 03 GMT
16-17 Aug 1963	12 & 03 GMT
23 Aug 1967	03 & 12 GMT
29-30 Aug 1967	12 & 03 GMT
08 Sep 1964	03 & 12 GMT
05-06 Sep 1965	12 & 03 GMT
11-12 Sep 1967	12 & 03 GMT

West Longitude East

Latitude \ Longitude	7–6 W	6–5 W	5–4 W	4–3 W	3–2 W	2–1 W	1–0 W	0–1 E	1–2 E	2–3 E	3–4 E	4–5 E	5–6 E	6–7 E
7–6 N	6	7	8	8	8	6	6	6	6	6	6	6	6	7
6–5 N	8	7	8	7	6	6	6	8	6	6	6	7	8	6
5–4 N	6	7	8	7	7	6	7	8	6	6	7	6	6	7
4–3 N	7	7	7	7	6	7	6	6	6	6	8	7	7	7
3–2 N	7	6	6	7	6	8	7	8	8	8	6	8	6	6
2–1 N	7	8	8	8	8	8	8	7	6	6	7	6	6	6
1–0 N	8	7	7	8	8	8	8	6	6	7	7	6	7	6
0–1 S	8	8	6	8	8	8	6	6	7	7	7	7	8	7
1–2 S	7	8	8	8	8	8	6	8	8	7	6	6	7	—
2–3 S	7	8	7	8	8	8	6	7	8	8	7	7	7	—
3–4 S	8	7	8	8	8	8	7	7	7	7	—	—	—	—
4–5 S	8	8	7	8	8	8	6	7	8	7	—	—	—	—
5–6 S	8	8	8	7	8	8	8	8	8	8	—	—	—	—
6–7 S	8	8	8	8	6	6	8		6	6				

Fig. 1. Mean cloudiness —1200 GMT (okta)

Latitude \ Longitude	7–6 W	6–5 W	5–4 W	4–3 W	3–2 W	2–1 W	1–0 W	0–1 E	1–2 E	2–3 E	3–4 E	4–5 E	5–6 E	6–7 E
7–6 N			8		8					6				6
6–5 N	6	6			6	6		8	6	6	6	6	7	
5–4 N	6	6	6		6	6	6	6			6		6	6
4–3 N	6	8	6	6	6	6	6	6		6	6	6	6	6
3–2 N		8	6	6	6	8	6	6	6	6	6	6	6	6
2–1 N	6	6	6	6	8	6	7	6	7	6	6		6	6
1–0 N	6	6	6	6	6	6	3	6	6	6	6		6	6
0–1 S	6	6		6	6	6	3	6	6	6	6	6	7	6
1–2 S	6	6	6	7	6	6	6	6	6	6	6	6	6	—
2–3 S	6	6	6	6	6	6	6	6		6	6	6	6	—
3–4 S	6	6		6	6	6	6			7	—	—	—	—
4–5 S	6	6	7	7	6	6	6	6	6	7	—	—	—	—
5–6 S	6	6	6	6	8	6	6	6	6		—	—	—	—
6–7 S	6	7	6	6	6	6	8	6			—	—	—	—

West Longitude East

Fig. 2. Mean low cloudiness — 1200 GMT (okta)

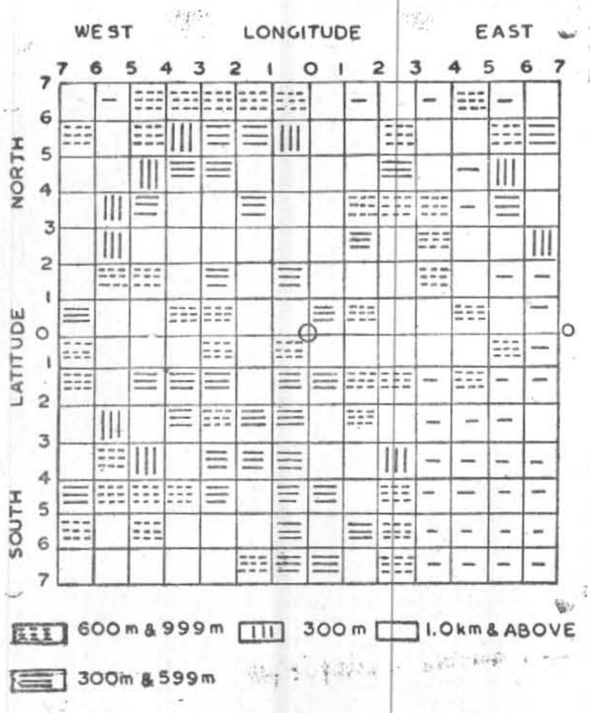

Fig. 3. Low cloud-mean height 1200 GMT

3. Methodology

3.1. Cloudiness, rainfall, upper winds and temperatures were extracted from *Indian Daily Weather Reports* for 12 GMT and 03/00 GMT. The rainfall amount during 03 to 12 GMT was plotted on 12 GMT chart and the amount of rainfall from 12 GMT to 03 GMT next day was plotted on 03 GMT. A grid of 14 deg. Lat. and 14 deg. Long. at 1 deg. interval was used to study the mean cloudiness and rainfall amounts. For upper air studies the same grid at 2 deg. interval was used.

3.2. For each set of observations, the centre of low 900 mb is assigned both X and Y coordinates as zero. All stations are then re-identified in terms of distance (in degrees of Lat. and Long.) with respect to the centre of low as origin. The revised Lat. and Long. of stations falling within one degree have been rounded off to a whole degree. In other words, a one degree mesh with respect to low centre as origin is generated and data for stations lying in the same one degree Lat. - Long. box are averaged over as representative of the box. The X axis represented the movement of the lows. The moving grid concept was used.

3.3. Upper winds were studied with the same 14 deg. Lat. and 14 deg. Long. grid but at intervals of 2 deg. by moving centre method. In this, grid was placed on upper wind charts with the centre of the grid at the centre of the low. The X axis represented the direction of movement of the system. The winds were noted within 49 grid squares as plotted on the chart and a constant angle by which the grid is rotated with respect to Lat., was uniformly subtracted from the wind direction. This gave the winds with respect to the direction of movement. The mean winds were computed by resolving each wind observation in to u and v components along east and north respectively, averaging and finding the resultant from the mean u and v components. The winds at 900 mb, 850 mb, 700 mb, 500 mb, 400 mb and 300 mb were averaged for 00 GMT and 12 GMT and streamline-isotach analysis was done.

3.4. From the averaged values of u and v, the conv/div and vorticity field was calculated by finite difference method at 900 mb, 850 mb, 700 mb and 500 mb. The temperature fields were averaged for surface, 900 mb, 850 mb, 700 mb, 600 mb, 500 mb, 400 mb and 300 mb. Dew point depression field was averaged at surface, 900 mb, 850 mb, 700 mb and 600 mb respectively. All parameters were studied for 12 GMT and 03/00 GMT synoptic periods.

4. Discussion of results

4.1. *Cloudiness*

Mean cloud cover — The mean dstribution of total amount of clouds expressed in terms of oktas is shown in Fig. 1. Maximum clouding (*i.e.,* overcast sky) is found to be in SW sector. The patterns of 12 GMT and 03 GMT are similar. Minimum cloudiness (4-6/$\bar{8}$) is observed in NE Sector.

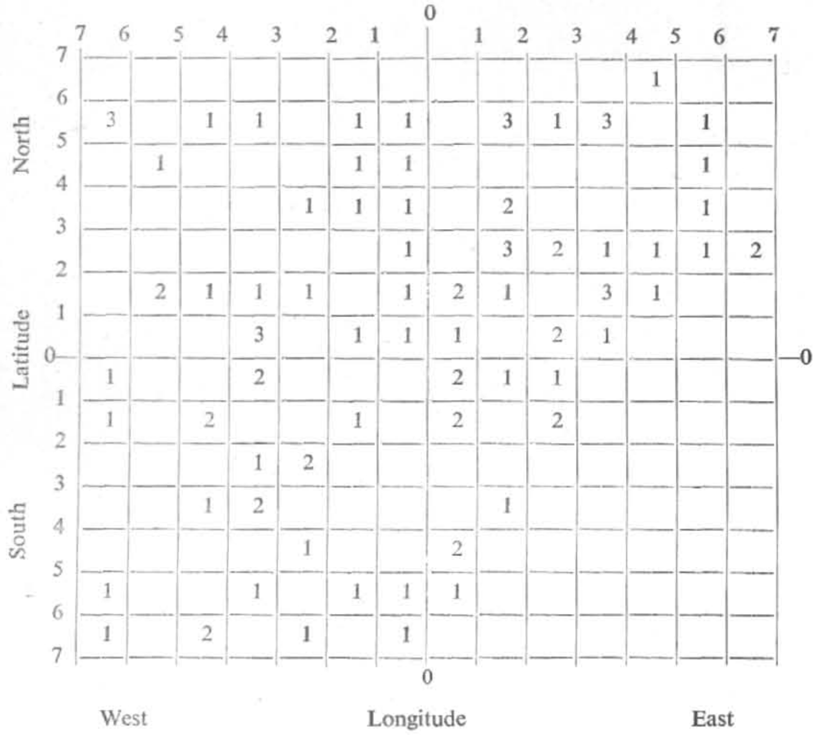

Fig. 4. '*Cb*'-Frequency — 1200 GMT (okta)

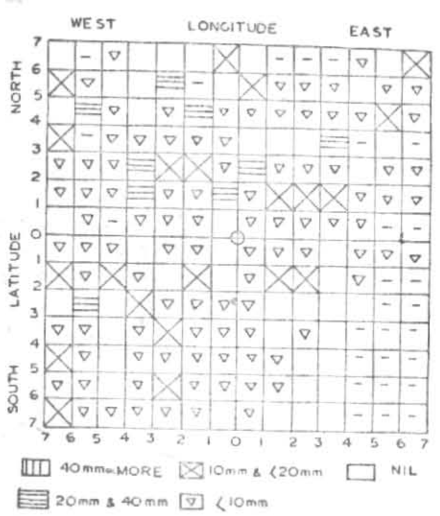

Fig 5. Rainfall 1200 GMT (0300 GMT to 1200 GMT)

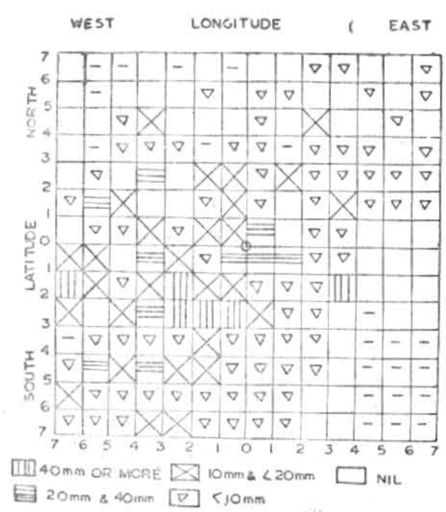

Fig. 6. Rainfall 0300 GMT (1200 GMT to 0300 GMT)

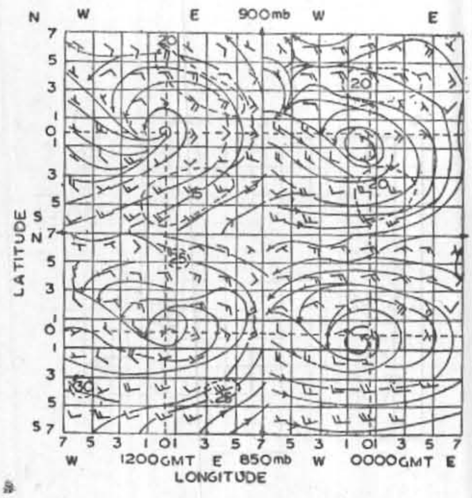

Fig. 7 (a). Wind field

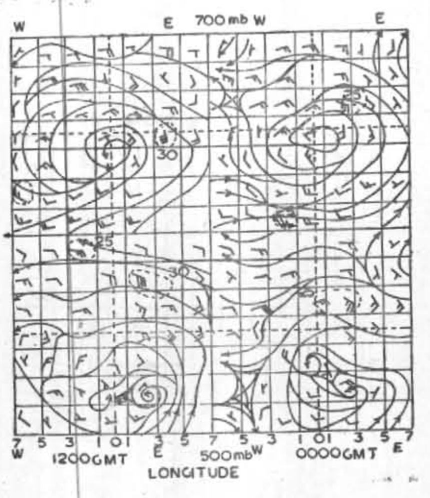

Fig. 7 (b). Wind field

4.2. *Mean low cloud cover*

12 *GMT* — 6 to 8 octas of low clouds occur 2 deg. to 3 deg. away in NW sector. A secondary maxima is observed ahead of the system. Clouding is comparatively lesser in SE sector. Over the centre of low only 3 to 4 octas of clouds are seen (Fig. 2). The pattern of mean low cloud cover for 03 GMT is almost similar to that of 12 GMT.

4.3. *Height of base of low clouds*

Mean height of base of low clouds for 12 GMT is shown in Fig. 3. Base of low clouds are much higher as compared to that of 03 GMT.

4.4. '*Cb*' *cloud distribution*

The field of monsoon low is surprisingly free from intense *Cb* cloud activities. The *Cb* frequency is more at 12 GMT than that at 03 GMT. The frequency of occurrence is higher in NE sector (Fig. 4).

5. Rain pattern

5.1. *Rainfall*

(*a*) 03 *GMT* — During the 15 hour period from 12 GMT to 03 GMT, rainfall occurs in all the sectors with comparatively lesser amounts in SE and NE sectors. The heaviest pptn (more than 40 mm) is observed in SW sector (Fig. 5).

(*b*) 12 *GMT* — During 9 hour period from 03 GMT to 12 GMT, the fall is comparatiely lesser than the above period. However, more than 30 mm rainfall occurs in WSW sector. The second maxima is seen in NW sector. NE and SE sectors are the regions of comparatively lesser rainfall (Fig. 6).

5.2. The spatial coverage of rainfall is more in SW sector during 12 GMT to 03 GMT period. During 03 to 12 GMT period, the spatial coverage of rainfall is more in the NW sector.

6. Wind field (Fig. 7)

6.1. *900 mb*

(*a*) 12 *GMT* — The wind field in southern sector is weaker as compared to north sector. A 15 kt isotach is observed in southern sector while a 20 kt isotach is observed in the NE sector.

(*b*) *00 GMT* — However, the wind field is similar in both the sectors at 00 GMT. The 20 kt isotachs are seen in southern and northern sectors.

6.2. *850 mb*

The wind field is stronger at 850 mb as compared to 900 mb.

(*a*) 12 *GMT* — The 30 kt isotach is seen in SW sector while 25 kt isotach lies in SE and northern sectors.

(*b*) 00 *GMT* — The wind field is similar in both the sectors (north and south). 25 kt isotach maxima is seen in southern and NE sectors.

6.3. *700 mb*

The wind field is strongest at this level.

(*a*) 12 *GMT* — A 30 kt isotachs maxima in seen in NE sector and a 25 kt isotach in SW sector.

(*b*) 00 *GMT* — The 25 kt isotach maxima are seen in southern and northern sectors. The wind field is similar in both the sectors.

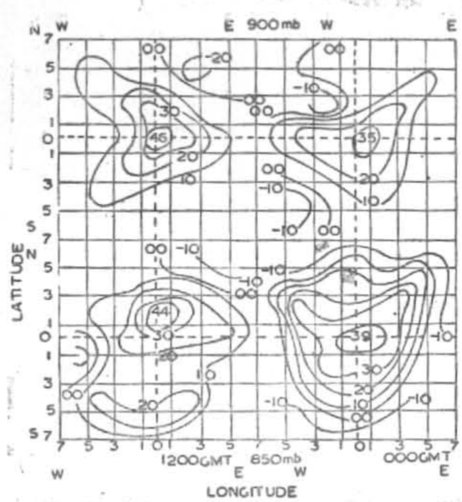

Fig. 8 (a). Vorticity field ($\times 10^{-6}$ sec^{-1})

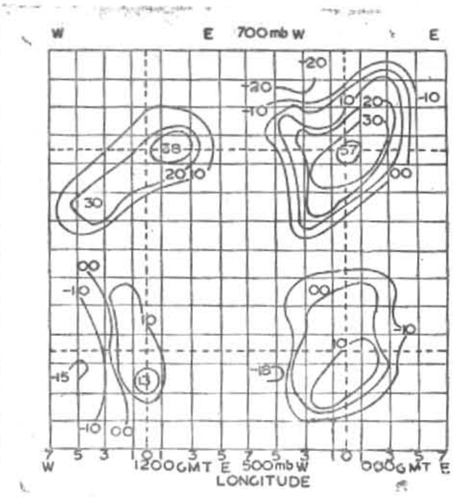

Fig. 8 (b). Vorticity field ($\times 10^{-6}$ sec^{-1})

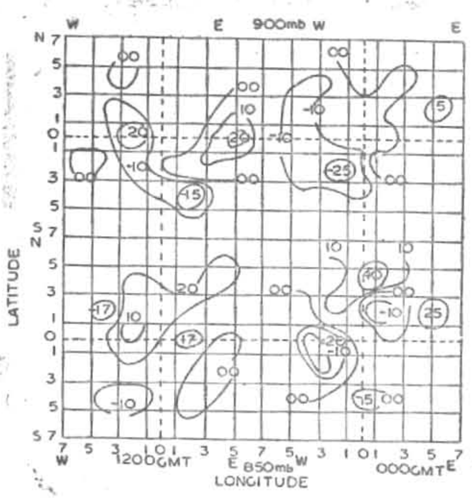

Fig. 9 (a). Vergence field ($\times 10^{-6}$ sec^{-1})

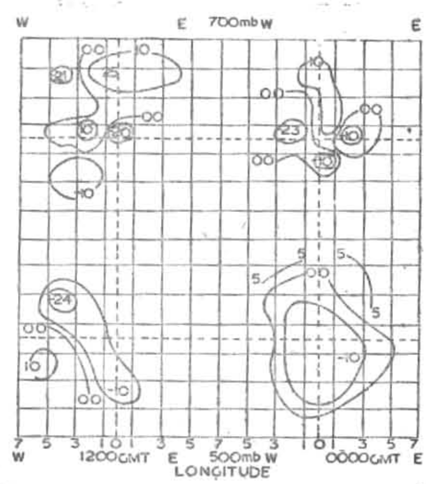

Fig. 9 (b). Vergence field ($\times 10^{-6}$ sec^{-1})

6.4. *500 mb*

The system is weak at this level and degenerates into two vortices.

(*a*) 12 *GMT* — The 30 kt and 25 kts isotachs in northern sector are located at 6 deg. to 8 deg. from the centre of the circulation.

(*b*) 00 *GMT* — The system is weaker comparatively. The 25 kt isotach is located at 4 deg. in northern sector. However, the vortices are having a weak wind field.

6.5. The circulation associated with the vortex is almost vertical up to 700 mb. However, a southward shift is seen beyond this level. The system degenerats into two vortices, one tilting SSE and another SSW. The circulation extends upto 400 mb. On the contrary, Murakami (1977) found that the cyclonic circulation of monsoon lows prevails in the lower troposphere and their axis tilts slightly westward with height.

7. Vorticity field (Fig. 8)

The vorticity field was calculated at 900 mb, 850 mb, 700 mb and 500 mb.

7.1. *900 mb* — The positive vorticity dominates over most of the domain.

(*a*) 12 *GMT* — The maximum value of positive vorticity is over the centre (46 units). The anticyclonic vorticity is seen in NE sector about 400 km away from the centre.

(*b*) The field of positive vorticity is relatively weaker (Max. 35 units) at 00 GMT.

7.2. *850 mb* — The positive vorticity field is stronger at 12 GMT than that at 00 GMT.

(*a*) 12 *GMT* — The positive maxima (44 units) is shifted northward. A secondary maxima of 20 units is seen in southern sector.

(*b*) 00 *GMT* — Positive vorticity field of 39 units is seen over the cyclonic centre. It is surrounded by a weak anticyclonic field.

7.3. *700 mb* — At 700 mb, the value of positive vorticity at 00 GMT is higher than that at 12 GMT.

(*a*) 12 *GMT* — The maxima of positive vorticity shifts in NE sector (37 units). A second maxima is seen in SW sector (30 units)

(*b*) 00 *GMT* — A maxima of positive vorticity of the order of 57 units is observed very close to the centre. It continues to be surrounded by a weak negative vorticity field.

7.4. *500 mb* — Both at 12 GMT and 00 GMT. the vorticity fields are very weak.

7.5. Positive vorticity is maximum at 900 mb. It decreases with height with the southward shift of the vortex. The 12 GMT values are higher than that at 00 GMT. However, at 700 mb, value at 00 GMT appears to be stronger than that at 12 GMT;

8. Vergence field (Fig. 9)

The vergence field was calculated for 900 mb, 850 mb, 700 mb and 500 mb.

8.1. *900 mb*

(*a*) 12 *GMT* — The central zone is predominantly of convergence field. The field is stronger in western sector (20 units). The max divergence of 20 units is seen in eastern sector at about 400 km from the centre.

(*b*) The field is stronger than that at 12 GMT.

8.2. *850 mb* — Convergence field is comparatively smaller in area as compared to the 900 mb field.

(*a*) 12 *GMT* — The convergence field of 17 units lies to the east of centre of circulation. Divergence field is seen in northern sector.

(*b*) 00 *GMT* — The convergence field is more organised at 00 GMT as compred to 12 GMT. A maxima of 20 unit lies in SW sector. Divergence is well marked. A zone of divergence (max value 40 units) is seen in N-Sector Vergence gradient is strongest at this level at 00 GMT.

8.3. *700 mb*

(*a*) 12 *GMT* — The divergence field has increased over NW sector. A 20 units of convergence field is seen near centre and 21 units at 400 km away from the centre in NW.

(*b*) 00 *GMT* — The convergence field is more organised in forward sector with a maximum value of 23 units. Divergence field is comparatively weaker than that at 12 GMT.

8.4. *500 mb* — A week convergence is seen over the area of vortices.

8.5. The convergence field is stronger at 00 GMT as compared to 12 GMT. It is more pronounced at 900 mb. However, the gradient is more at 850 mb. There is a slight decrease in

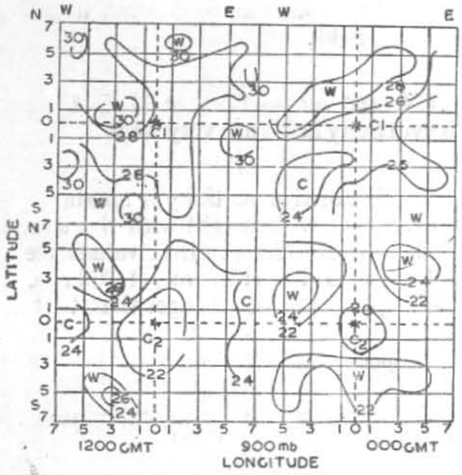

Fig. 10 (a). Temperature field

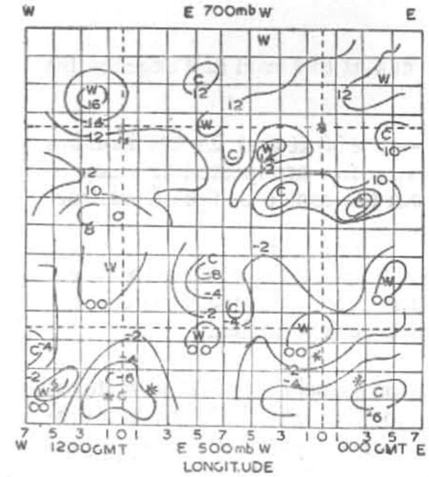

Fig. 10 (b). Temperature field

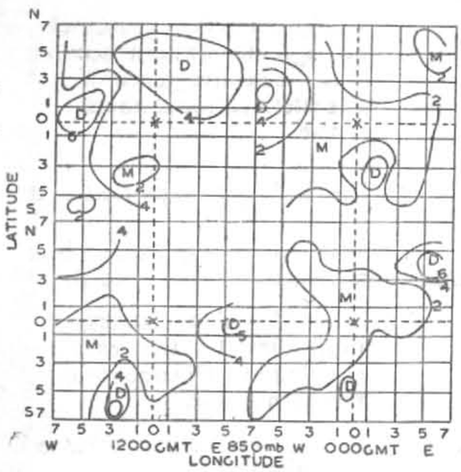

Fig. 11 (a). Moisture field

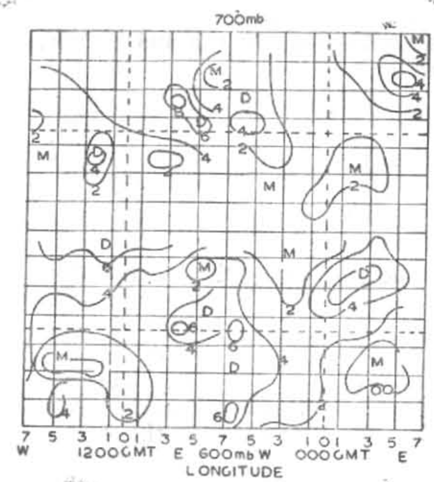

Fig. 11 (b). Moisture field

vergence field with height up to 700 mb in the region of circulation.

9. Temperature field (Fig. 10)

9.1. The temperature field was studied for surface, 900 mb, 700 mb, 500 mb, 400 mb and 300 mb.

9.2. *Surface and 900 mb* — Over the area of vortex, the temperatures are colder. It is surrounded by warmer zones. The gradient of temperature between surroundings and vortex area is of 2 deg. to 4 deg. C.

9.3. *700 mb* — At 700 mb, the southern sector is colder by 2deg. to 3 deg. C. However, the northern sector is significantly warmer (4 deg. to 5 deg.) as compared to the vortex area.

9.4. *500 mb* — At 500 mb, on 12 GMT field, the area of vortices continues to be colder than the surroundings (5 to 6 deg. C). However, at 00 GMT the temperature field is indefinite.

9.5. The vortex upto 900 mb is of cold core nature. At 700 mb the vortex is still towards colder region. At 500 mb, the two vortices are towards colder region at 12 GMT. At 400 mb the air over the two vortices is warmer. Murakami (1977) also found warm cold structure of such lows in the upper levels. However, he found that in lower levels, the amplitude of the temperature is small and the disturbance is neither warm nor cold cored. It may be mentioned that Murakami studied monsoon lows based on only Calcutta data.

10. Moisture field (Fig. 11)

The temperature depression (TT-TdTd) was calculated and studied for surface, 850, 700 and 600 mb levels.

10.1. *Surface* — At 12 GMT, the southern sector is more moist as compared to other regions. However at 00 GMT, the areal extent of moist air is much larger. At 12 GMT and 00 GMT, relatively drier area is seen about 400 km away from the centre in the western sector. A secondary moist area is seen in extreme NE sector (at 00 GMT) which could be associated with orographic features of NE India.

10.2. *850 mb* — At 12 GMT, the moist are extends westwards from the centre of the low. A comparatively drier area is seen in southern and eastern sector. The moist area is situated in the northern sector.

10.3. *700 mb* — Comparatively drier areas are situated in southern and NE sectors. The areal coverage of moist region is more at 00 GMT than 12 GMT.

10.4. *600 mb* — At 12 GMT, moist area is associated with the vortex, extending in a east-west orientation. However, at 00 GMT, the moist region shifts eastwards.

10.5. The moist region associated with vortex has got a vertical slope in the SW direction with height. The high moisture content continues upto 600 mb. Murakami also found in his study of land lows that more moist are as are situated ahead of the system.

11. Conclusions

This study has revealed that there is a significant diurnal change in cloud/rainfall patterns during day and evening/night. The main results are as follows :

(*a*) The area of maximum cloudiness is located in SW sector and comparatively an area of less cloudiness lies in the NE sector.

(*b*) The amount of low cloud cover is more in the forward sector than the rear sector The low cloud coverage is more at 03 GMT than that at 12 GMT.

(*c*) The frequency of '*Cb*' cloud is more at 12 GMT. NE sector is more favourable for '*Cb*' development at both the synoptic hours.

(*d*) The rainfall is more in SW sector during 12 GMT to 03 GMT. It shows a shift in NW sector during 03 to 12 GMT and it decreases in quantity from the first period to the second period.

(*e*) The wind field of the vortex is more pronounced at 700 mb with isotaches maxima of 30 kt in NE sector and 25 kt in SW sector (12 GMT). The circulation associated with vortex is also almost vertical upto 700 mb. However, a southward shift is seen beyond this level. At 500 mb, the system degenerates into two vortices, one tilting SSE and another SSW. The circulation extends up to 400 mb.

(*f*) Positive vorticity is maximum at 900 mb. It decreases with height with the southward shift of the vortex. At 12 GMT, the values are higher than that at 00 GMT.

(*g*) Convergent field is stronger at 00 GMT than that at 12 GMT. It is more-pronounced at 900 mb. There is a slight decrease in the vergence field with height upto 700 mb in the region of circulation.

(*h*) The vortex up to 900 mb is of cold core nature. At 700 mb the vortex is still towards colder region. At 500 mb, the two vortices are towards colder region at 12 GMT. At 400 mb the air over the two vortices is warmer. The moist region associated with vortex has got a vertical slope in the SW direction with height.

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