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Some structural characteristics of pre-monsoon depression in the Bay of Bengal

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सार — 6 से 16 मई 1995 की अवधि के दौरान बंगाल की खाड़ी के पश्चिम में एक के बाद एक तीन गहन अवदाब बनकर दक्षिण से उत्तर की ओर बढ़े इस अवधि के दौरान रेडियो सौन्दें/रेडियो विंड और उपलब्ध अन्य तटीय प्रेक्षणों का उपयोग करते हुए अवदाब के केन्द्र के आस-पास प्रेक्षित तापीय और ताप-गतिकीय फील्ड के वितरण से इन सिस्टमों की संरचनात्मक विशिष्टताओं के संबंध में इस शोध-पत्र में अन्वेषण किया गया है। इस अध्ययन से जो मुख्य उपलब्धियां सामने आईं वे इस प्रकार हैं :- (*i*) इन अवदाबों में निम्नस्तर पर शीतक्रोड़ और मध्य एवं ऊपरी क्षोभमंडलीय क्रोड़ उष्ण हैं। (*ii*) तापीय और आर्द्र फील्ड ऊंचाई के साथ उत्तर की ओर झुकते हैं किन्तु सम्मोच ऊँचाई का उर्ध्वाधर झुकाव सभी स्तरों पर एक समान नहीं है। (*iii*) इस सिस्टम के तीव्रीकरण के समय तापमान और आर्द्रता में उल्लेखनीय वृद्धि 700 hPa से अधिक हो जाती है और सम्मोच ऊंचाई में उल्लेखनीय गिरावट 300 hPa से कम हो जाती है।

ABSTRACT. During the period 6 to 16 May, 1995, three deep depressions formed one after another over west Bay of Bengal and moved from south to north. In this paper, structural characteristics of these systems are investigated from the distribution of thermal and thermodynamical field observed around the depression center utilising daily Rs/Rw and other available coastal observations during the period. Major findings of the study are: (*i*) The depressions have low level cold core and middle and upper tropospheric warm core. (*ii*) Thermal and moisture fields tilt north ward with height but vertical tilt of contour height is not uniform at all levels. (*iii*) During intensification of the system significant increase in temperature and moisutre occurs above 700 hPa and significant fall of contour height occurs below 300 hPa.

Key words — Depression, Thermodynamical structure, Structural changes.

1. Introduction

There have been numerous studies on large scale thermal and dynamical structure of monsoon depression (Sarkar and Choudhury, 1998, Rajamani and Kulkarni, 1986 etc). Sarkar and Choudhury (1988) presented a three dimensional composite structure of depression utilising Rs/Rw data of 14 stations for 27 depression cases in July and August months during 1961-74. They showed that monsoon depression belongs to the class of tropical systems comparable to hurricanes.

Because of absence of observational data while system lies over the oceanic areas, a clear understanding of three dimensional structure of tropical depression is yet to emerge. Interestingly, during the period 6 to 16 May, 1995 three deep depressions formed one after another over west Bay of Bengal and moved from south to north. These systems produced widespread rain over the coastal areas during the passages. These systems were lying very close to the coast and provide an opportunity to study their structural characteristics during their life span utilising coastal Rs/Rw and other observations. In the present study, thermal and thermodynamical structure of these systems are investigated using daily Rs/Rw and other available coastal observations during the period 6 to 16 May, 1995.

2. Computation and results

2.1. *Structure*

Track positions of these depressions as indicated in weekly weather report published from India Meteorological Department, New Delhi is given in Fig. 1. It is observed that on 6 May at 1200 UTC the first depression (system I) of this series was centered near Karaikal, on 9 May at 1200 UTC the second depression (system II) was centered near Visakhapatnam and last depression of the series (system III) was lying centered near Bhubaneswar on 14 May at 1200 UTC. Utilising available 1200 UTC coastal observations of 6 May, 9 May and 14 May vertical cross- section of temperature anomaly in degree celsius, geopotential height anomaly

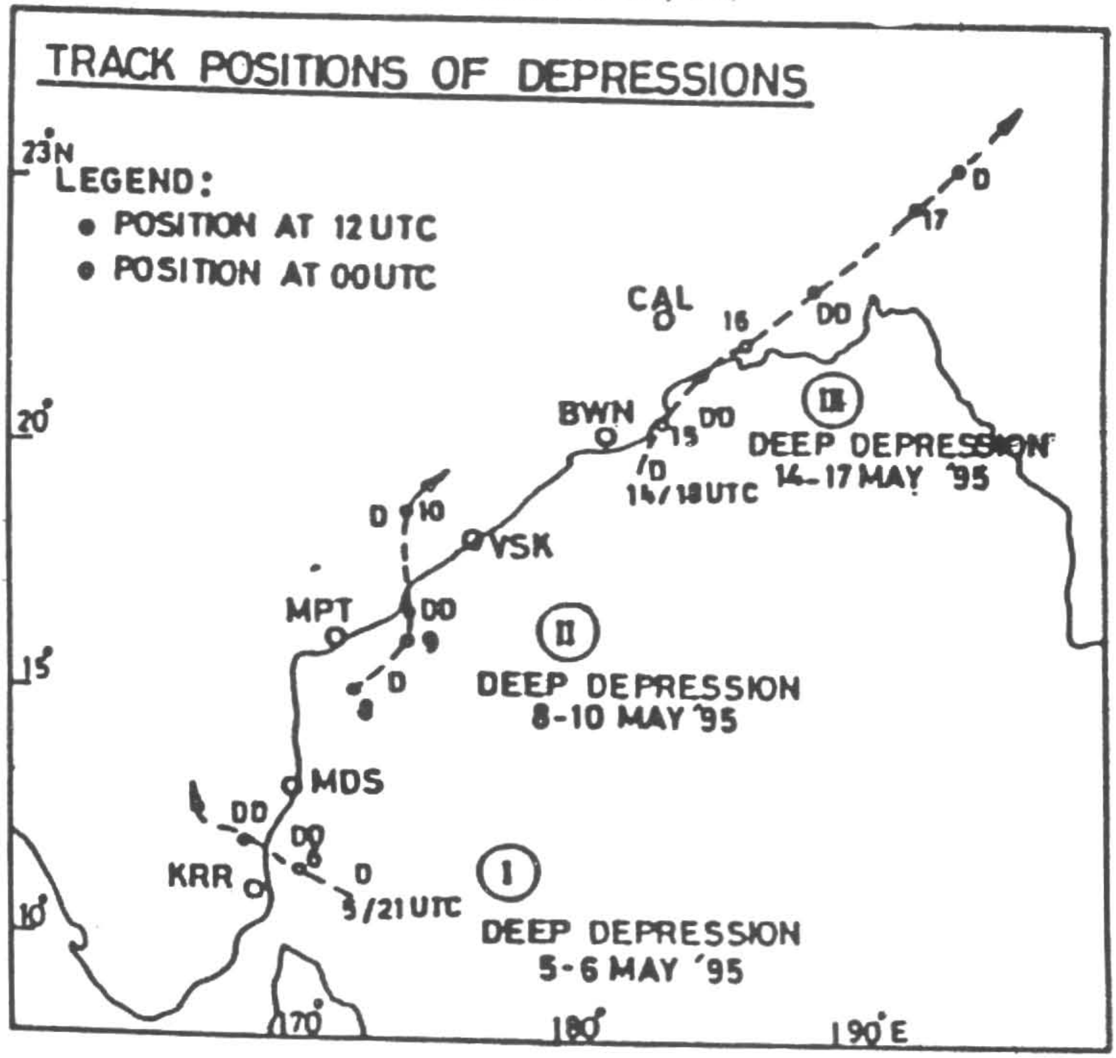


Fig.1. Depression track and upper air coastal stations

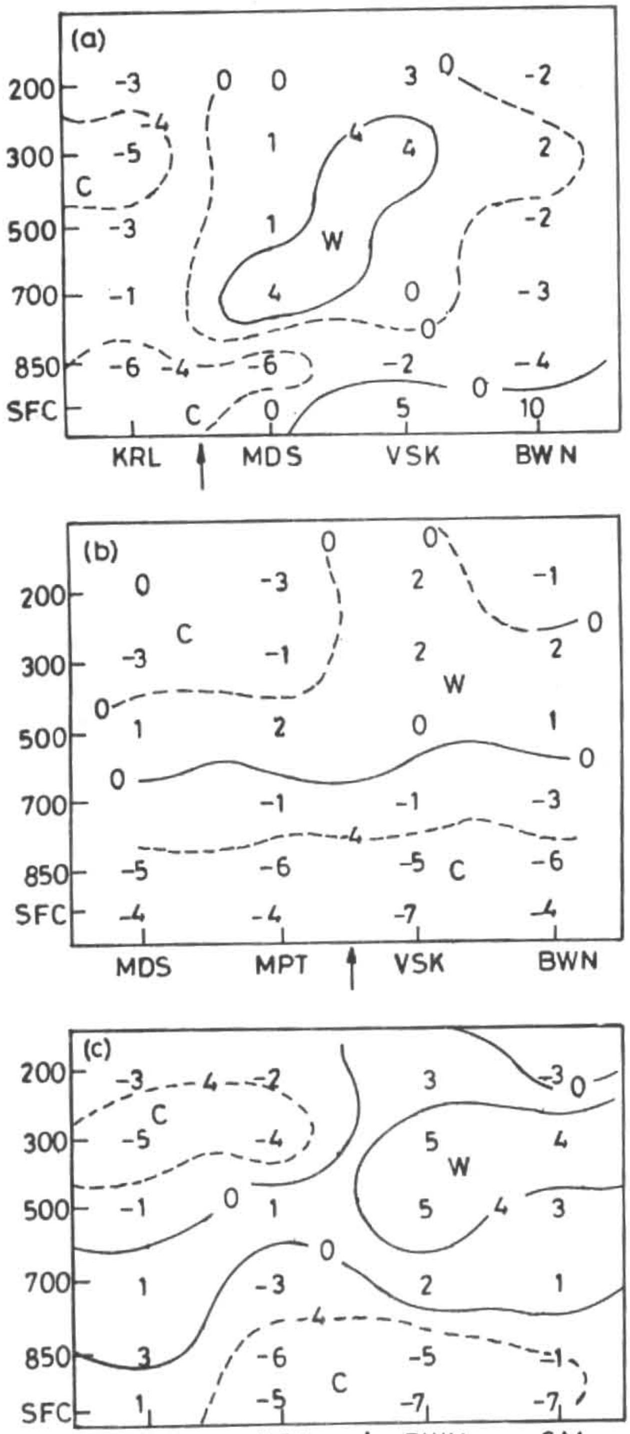
in gpm and relative humidity in percentage are prepared separately for each of these systems.

(i) Thermal structure

In Figs. 2 (a-c) vertical structures of temperature anomaly fields of system I,II and III respectively are presented. These structures exhibit a cold core in the lower tropospheric levels and warm core in the middle and upper tropospheric levels. The reversal of temperature anomaly occurs between 850 and 700 hPa for system I and III and between 700 and 500 hPa for system II. The depression vortex has warm core characteristic at around 700 hPa for system I, at 500 hPa for system II and between 500 and 300 hPa for system III. This warm core above the low level cold core may be attributed to the effect of latent heat release due to cumulus convection. In all the three cases warm core tilt northwards with height. Strongest temperature gradient occurs between 850 and 700 hPa indicating the level of maximum thermal winds.

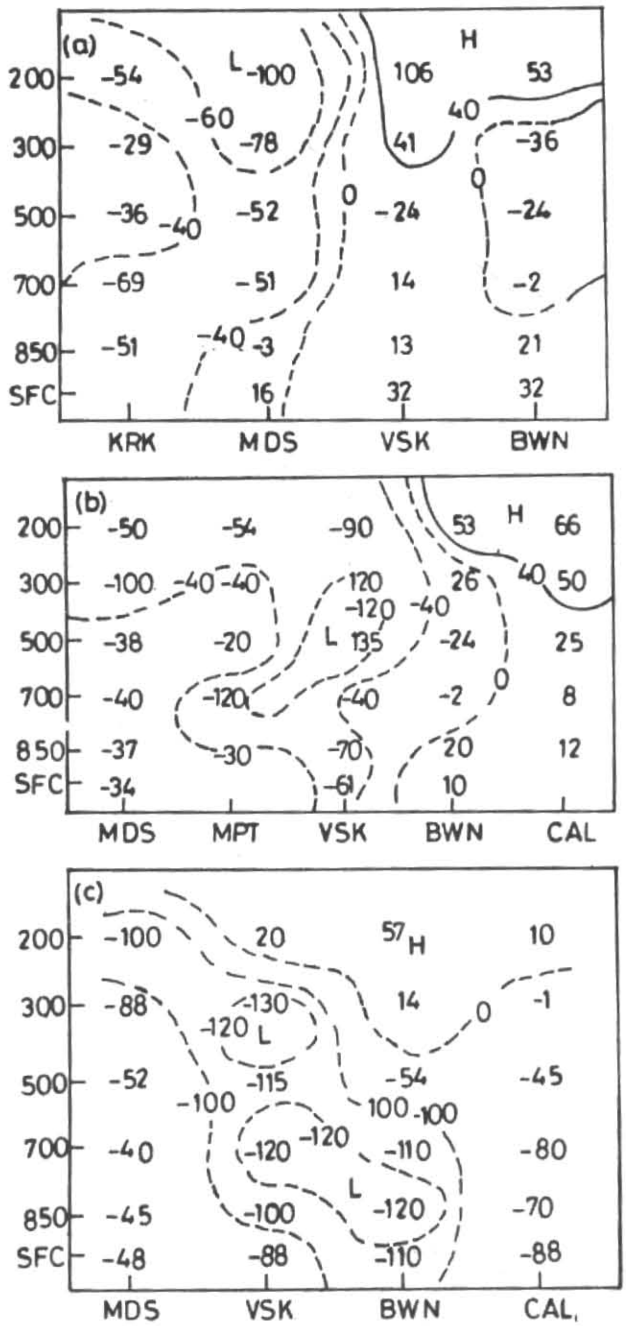
(ii) Height contour

Contour height anomaly of particular pressure level is a reflection of integrated temperature anomalies above that pressure surface. Vertical structure of contour height anomaly for system I, II and III are illustrated in Figs. 3 (a-c) respectively. Here surface pressure departure from normal in hPa multiplied by 10 is used to represent height anomaly at the surface. It is found that vertical tilting of contour field is not uniform at all levels. Lowest height contour below 700 hPa is around centre for system I and II, thereafter it slightly tilts northwards with height. For the system III, lowest contour height below 850 hPa is around centre and then tilts south wards with height. In the cases II and III, an area of high over-lies above 300 hPa to the north of the system.



Figs.2(a-c). Vertical profile of temperature anomaly in degree celsius W indicates warm and C indicates cold

(a) at 1200 UTC of 6 May for system I
(b) at 1200 UTC of 9 May for system II
(c) at 1200 UTC of 14 May for system III

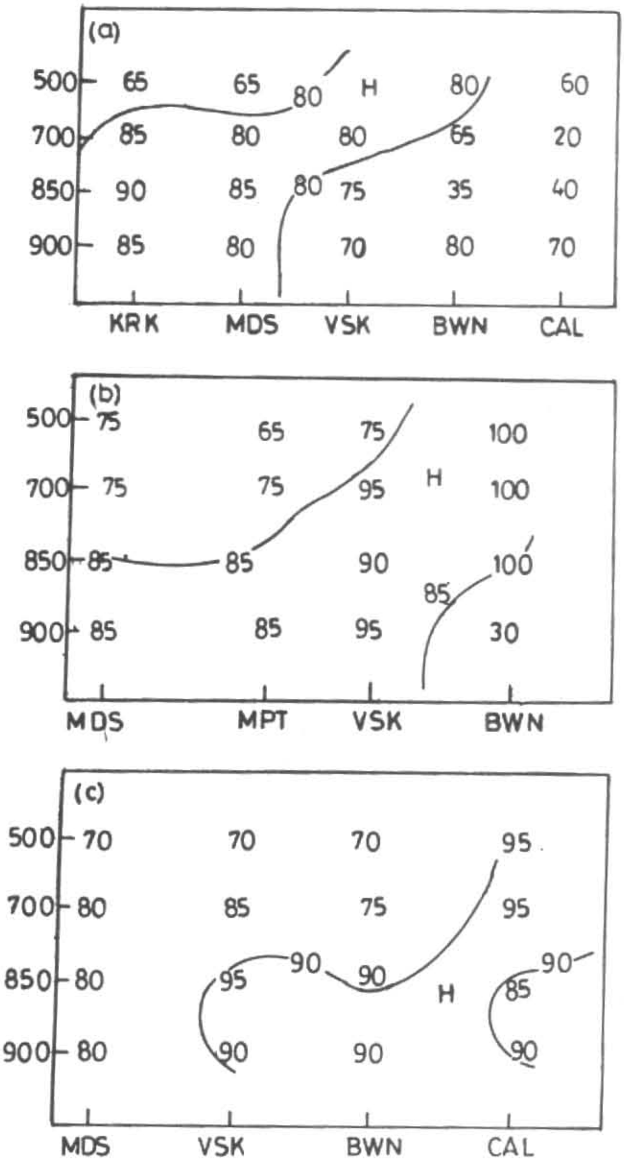


Figs.3 (a-c). Vertical profile of height anomaly in gpm. L indicates low and H indicates high

(a) at 1200 UTC of 6 May for system I
(b) at 1200 UTC of 9 May for system II
(c) at 1200 UTC of 14 May for system III

(iii) Moisture profile

The moisture distribution has been examined in terms of relative humidity as presented in Figs. 4 (a-c) for the three cases respectively. There is a pronounced north ward slope with height below 500 hPa and a very moist region between



Figs.4(a-c). Vertical profile of relative humidity in percentage. H indicates high.
(a) at 1200 UTC of 6 May for system I
(b) at 1200 UTC of 9 May for system II
(c) at 1200 UTC of 14 May for system III

700 and 500 hPa ahead of the depression. This may be because of easterly moist air from sea and presence of enough mixing and turbulence exchange between the depression center and its surroundings. The presence of saturated air mass around the depression field may be due to continuous precipitation.

The vertical distribution of wind, thermal, pressure and moisture fields of monsoon depression are asymmetric with south ward tilt with height as documented by Sarkar and Choudhury (1988). In contrast to asymmetric wind field, thermal and pressure anomalies around core region of an intense low pressure system generally tend to by symmetric (Holland, 1984). In this study, main thermal and moisture asymmetric (northerly slopes with height) as observed seems to arise due to interaction with dry continental westerlies and moist oceanic easterlies. This kind of continental effect was also noted by McBride and Keenon (1982) over Australian region.

2.2. *Structural changes*

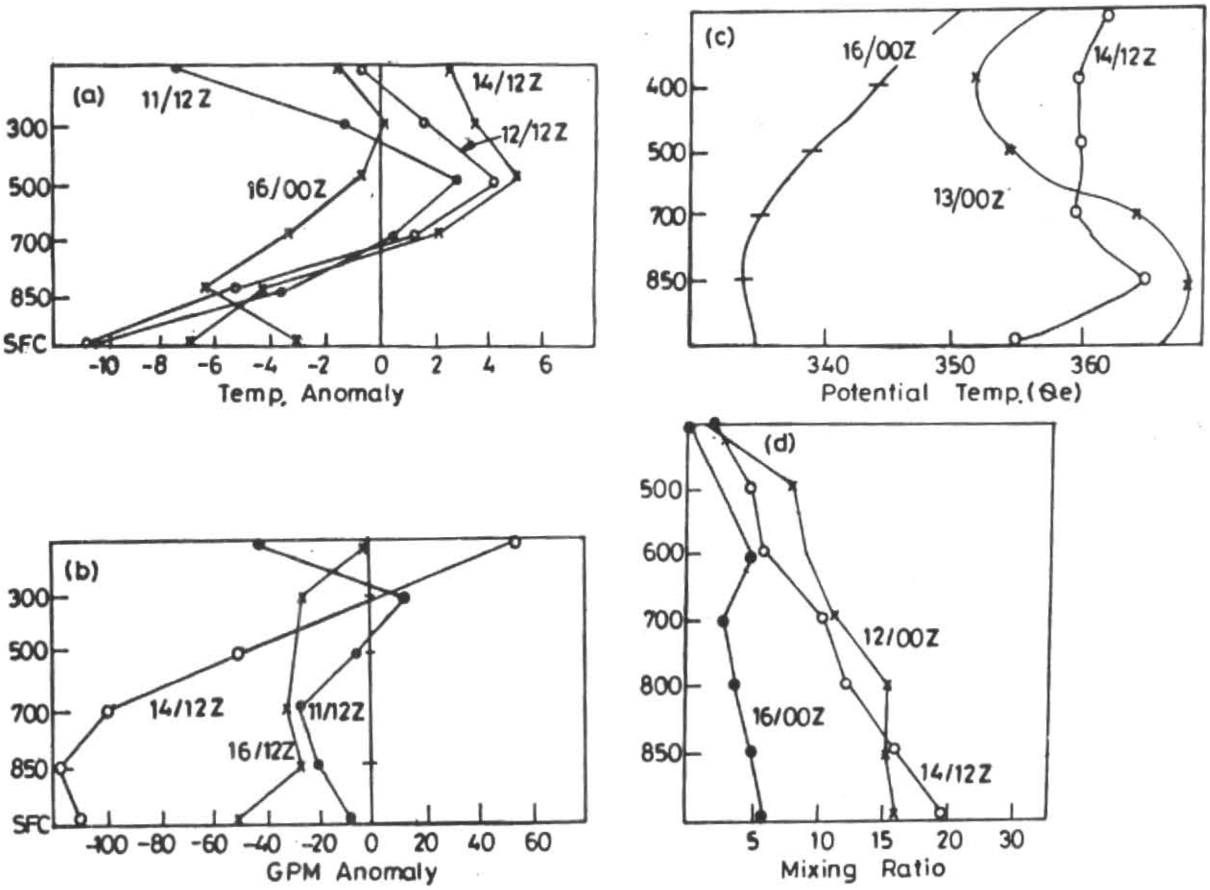
Generally, intensity change of low pressure system is accomplished by a co-operative interaction between conventive and large scale processes that is influenced by thermodynamical and dynamical interactions with the underlying surface and with surrounding environment. In this study system I and II were short lived and weakened rapidly after crossing coast, presumably due to entrainment of relatively dry continental air into the system and moisture supply being cut off. On the other hand, system III was having long sea travel, moved north-north-east wards almost parallel to coast for about 4-5 days and thus could acquire a distinct structure as revealed from previous section. Here structural changes of the system III are examined during its life span.

(*i*) *Changes in temperature anomaly profile*

Temperature anomaly profiles of Bhubaneswar for 1200 UTC of 11, 12 and 14 May and 0000 UTC of 16 May are presented in Fig. 5(a). It can be seen that during the intensification of the system there is a remarkable increase in temperature above 700 hPa and rapid decrease when system moved further north north-east wards. Highest rise in temperature anomaly of order 11 degree celsius occurs at 200 hPa from 1200 UTC of 11 May to 1200 UTC of 14 May. The increase of temperature may be due to increase in latent heat release during intensification of the system. This corroborates the inference of Reed and Recker (1971) that release of latent heat, heats the atmosphere above 500 hPa. The enhanced latent heat could provide required energy to drive the circulation and for intensifying the system (Emanuel, 1986).

(*ii*) *Change in geo-potential height*

Geo-potential height anomaly profiles of Bhubaneswar for 1200 UTC of 11,14 and 16 May are presented in Fig. 5 (b). Surface anomaly indicates surface pressure departure from normal in hPa multiplied by 10. It is seen that during intensification period, that is during 11 to 14 May there is significant fall of height anomaly below 300 hPa and after the system moved away north north-east wards there is a marked rise. During intensification fall of geopotential height anomaly below 700 hPa is more remarkable. Highest



Figs.5 (a-d). Structural changes for system III

(a) Temperature anomaly profile in degree celsius of Bhubaneswar during 1200 UTC of 11 May to 0000 UTC of 16 May
(b) Geopotential anomaly profile in gpm of Bhubaneswar during 1200 UTC of 11 May to 1200 UTC of 16 May
(c) *Qe* (degree K) profile of Bhubaneswar during 0000 UTC of 13 May to 0000 UTC of 16 May
(d) Mixing ratio (gm/kg) profile of Bhubaneswar during 0000 UTC of 12 May to 0000 UTC of 16 May

fall of order 100 gpm occurs at 850 hPa from 1200 UTC of 11 May to 1200 UTC of 14 May.

(*iii*) *Changes in equivalent potential temperature (Qe)*

Vertical profiles of *Qe* of Bhubaneswar for 0000 UTC of 13 May and 16 May and 1200 UTC of 14 May are shown in Fig. 5(c).It is interesting to note that at 0000 UTC of 13 May,*Qe* is larger and near constant below 850 hPa. At 1200 of 14 May *Qe* falls below 700 hPa and becomes larger and near constant above 700 hPa. This indicates the increase of moist air at middle and upper tropospherеic levels when system was intensifying and approaching closer to the station Bhubaneswar. The profile reverses on 16 May while system moved north-north-east of the station and dry contenental north-westerly wind entered over the station. Highest rise of*Qe* of order 10 degree K occurs at 450 hPa between 0000 UTC of 13 May and 1200 UTC of 14 May.

(*iv*) *Changes in the moisture profile*

Vertical profile of moisture distribution has been prepared in terms of mixing ratio and shown in Fig. 5(d) for 0000 UTC of 12 and 16 May and 1200 UTC of 14 May. On 12 May at 0000 UTC maximum amount of mixing ratio 16 gm/kg extended all the way upto 800 hPa and there after reduces gradually. On 14 May at 1200 UTC mixing ratio at 900 hPa increased to 20 gm/kg but reduced from 850 hPa onwards. On 16 May while the system was lying north of the station there has been a significant decrease in the vertical profile of mixing ratio.

3. Conclusions

Following conclusions can be drawn from this study :

(*i*) Like monsoon depression, pre-monsoon depression exhibits a cold core in the lower troposphere and warm core in the middle and upper troposphere. Strongest vertical temperature gradient occurs between 850 hPa and 700 hPa.

(*ii*) The vertical distribution of thermal and moisture field around depression centre shows a pronounced northward tilt with height in contrast to that of south-west ward tilt of monsoon depression.

(*iii*) Vertical tilting of contour height is not uniform at all levels. An area of high over-lies above 300 hPa to the north of the system.

(*iv*) During intensification from low pressure to depression significant increase in temperature anomaly occurs above 700 hPa and fall of geopotential height occurs below 300 hPa with highest fall at 850 hPa.

(*v*) During intensification into depression *Qe* above 700 hPa becomes larger and near constant indicating increase in moisture at middle and upper tropospheric levels.

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