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Role of CAPE and CINE in modulating the convective activities during April over India

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सार — उत्तरी पश्चिमी भारत को छोड़कर देश के शेष भागों में अप्रैल के महीने में वर्षा संवहनी गतिविधियों में वृद्धि के फलस्वरूप मेघ गर्जन के साथ होती है जबकि उत्तरी पश्चिमी भारत में वर्षा प्रायः मध्य अक्षांशीय पश्चिमी तंत्रों के कारण पश्चिमी विक्षोभों के रूप में होती है। अन्य वर्षों की अपेक्षा, अप्रैल 1997 के महीने में संवहनी गतिविधियाँ अधिक घटने के कारणों का पता लगाने के लिए उपलब्ध संवहनी स्थितिज ऊर्जा (सी. ए. पी. ई.) और संवहनी संदमन ऊर्जा (सी. आई. एन. ई.) की भूमिका का अध्ययन किया गया है। इन परिणामों से यह पता चलता है कि भारत के विभिन्न भागों में पाए गए उपलब्ध संवहनी स्थितिज ऊर्जा के दीर्घतर मानों और संवहनी संदमन ऊर्जा के लघुतर मानों के फलस्वरूप अन्य वर्षों की तुलना में अप्रैल 1997 में संवहनी गतिविधियाँ अधिक घटी हैं और इन्हीं के कारण तापमान में अप्रैल 1997 में पर्याप्त गिरावट आई है।

ABSTRACT. During the month of April, except over northwest India, where rain is normally associated with the intrusion of midlatitudinal westerly systems in the form of western disturbances, other parts of the country receive rain due to enhancement of convective activities in the form of thundershowers, occuring over many parts of the country. The role of Convective Available Potential Energy (CAPE) and Convective Inhibition Energy (CINE) were studied for the occurrence of more convective activities in the month of April 1997 compared to other years. The results reveal that larger values of CAPE and smaller values of CINE in April 1997 over various parts of India compared to other years were responsible for more convective activities and consequently appreciable fall in temperature in April 1997.

Key words - Convective available potential energy, Convective inhibition energy.

1. Introduction

April 1997 was the coolest April during last ten years. The month was characterised by very good convective activities all over the country except over northeast India and Kerala. Consequently as many as 28 out of 35 meteorological sub-divisions of the country received excess or normal rainfall.

Development of convective storms depend on the presence of environmental conditions favourable for occurrence of deep convection. A particular useful measure is the convective available potential energy (CAPE), a quantity first conceptualized by Margules (1905) but named by Moncrieff and Miller (1976). CAPE provides a measure of maximum possible kinetic energy that a statistically unstable parcel can acquire assuming that parcel ascends without mixing with the environment and instantaneously adjusts to the local environmental pressure.

CAPE has been shown to play an important role in system ranging in scale from thunderstorms (Williams *et al.*, 1992) through mesoscale systems (Moncrieff and Miller, 1976).

Values of CAPE and CINE for different stations over the country have been calculated and an effort has been made to determine its role for the occurrence of above convective activities, besides plausible diagnostic synoptic causes. Similar studies for the year 1995, 1996 for same month (April) have been done for comparison.

2. Data used

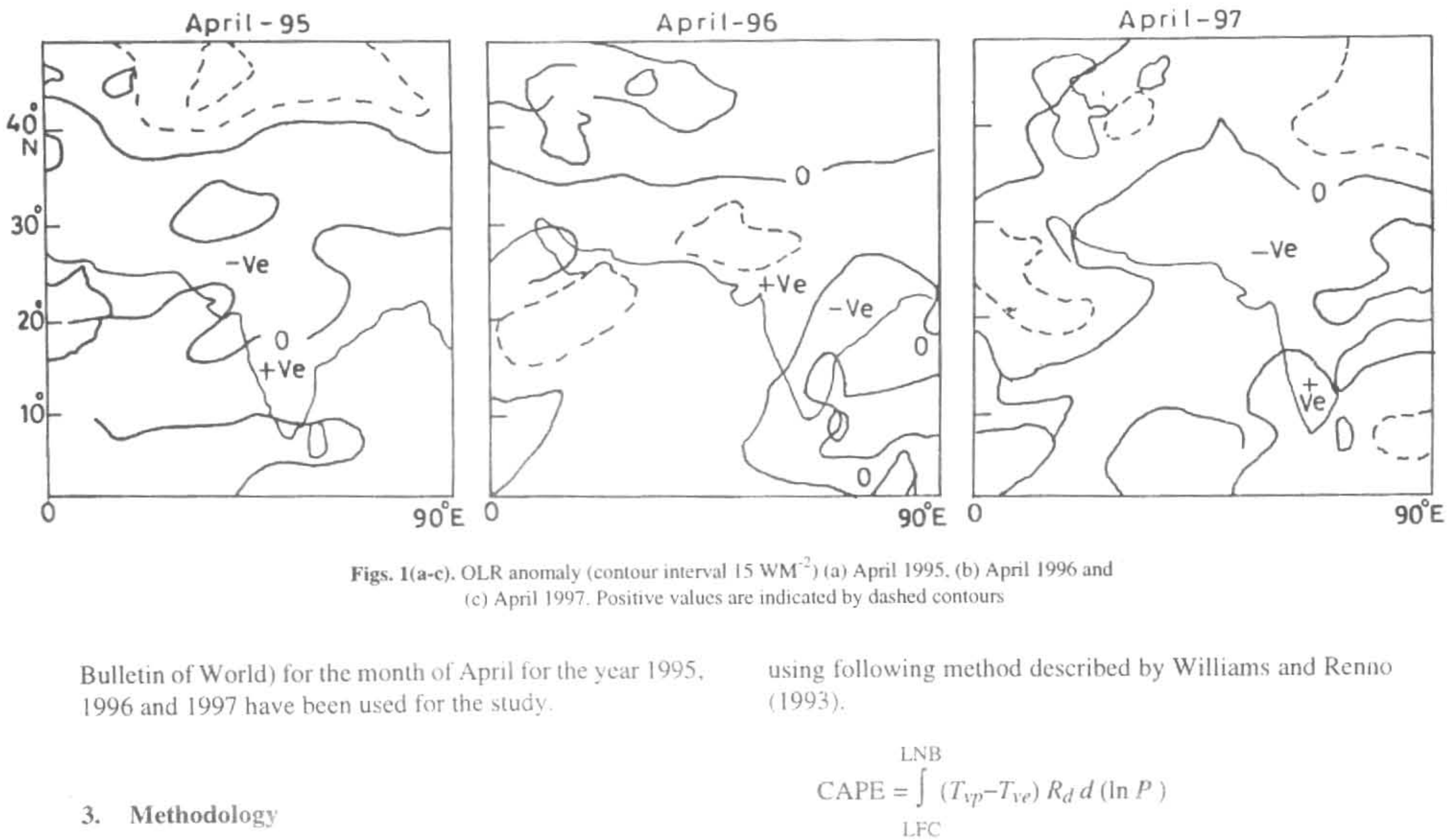
Upper air radiosonde data (taken from the monthly climate data for the world), OLR anomaly values, divergence anomaly at 200 hPa (taken from Climate Diagnostics

TABLE 1

CAPE (Joule/kg)

S. No.	Station Name	1995	1996	1997
1.	Srinagar	27.80	125.12	205.34
2.	Delhi	335.44	47.64	513.44
3.	Lucknow	98.44	278.52	984.26
4.	Guwahati	503.69	656.94	1114.19
5.	Patna	*	350.28	750.11
6.	Ahmedabad	152.39	523.83	841.62
7.	Calcutta	3052.24	2324.70	2377.36
8.	Bhubaneshwar	1969.74	*	3129.37
9.	Visakhapatnam	2910.18	*	3186.70
10.	Nagpur	52.03	53.15	80.75
11.	Hyderabad	487.9	1678.95	1177.84
12.	Bombay	1196.35	1571.32	1032.62
13.	Goa	1431.55	1568.88	1389.08
14.	Madras	3260.32	3155.21	2086.20
15.	Mangalore	2577.40	1797.62	2527.56
16.	Port Blair	3202.58	1821.3	2336.48
17.	Cochin	3485.04	3172.06	2939.95
18.	Minicoy	3378.33	3166.14	3356.60
19.	Trivandrum	3206.35	3016.22	2525.19

*Data Not Available



Figs. 1(a-c). OLR anomaly (contour interval 15 WM^{-2}) (a) April 1995, (b) April 1996 and (c) April 1997. Positive values are indicated by dashed contours

Bulletin of World) for the month of April for the year 1995, 1996 and 1997 have been used for the study.

3. Methodology

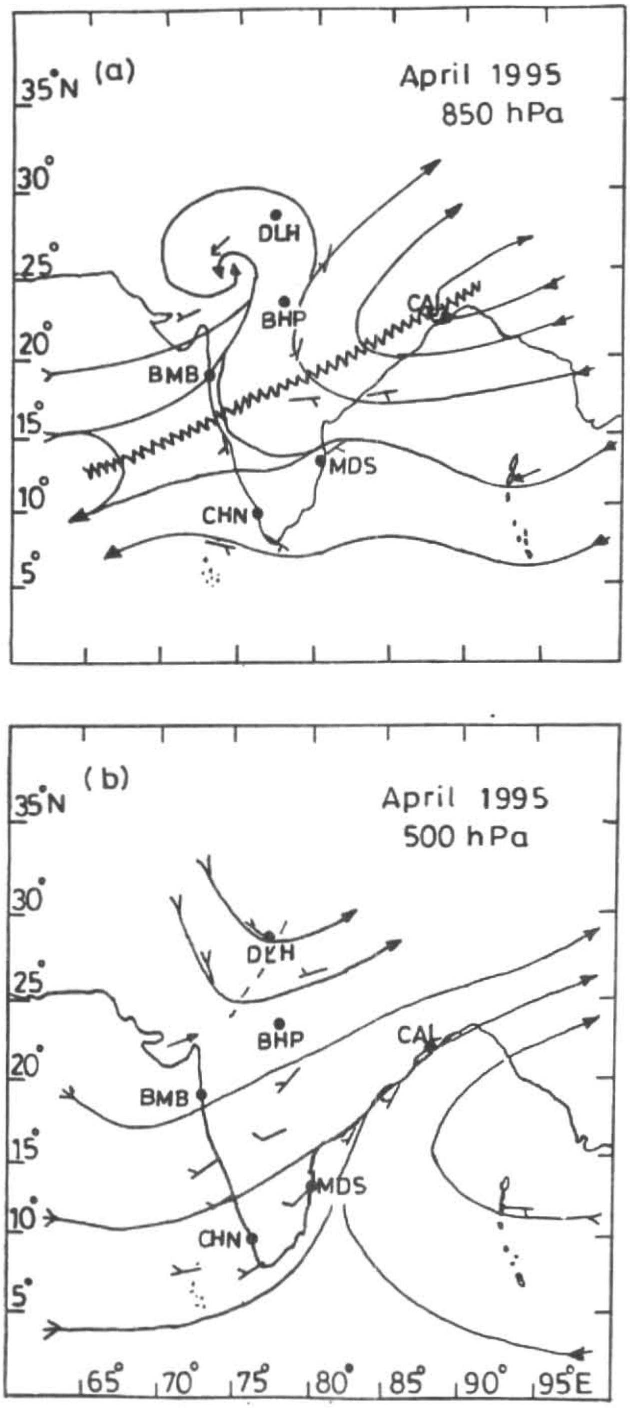
3.1. *Computation of CAPE*

CAPE is the work done by the buoyancy force on a parcel on ascent under moist convection and was calculated using following method described by Williams and Renno (1993).

$$CAPE = \int_{LFC}^{LNB} (T_{vp} - T_{ve})\, R_d\, d\,(\ln P)$$

where, T_{vp} and T_{ve} are the virtual temperature of the parcel and environment respectively.

R_d = Gas constant of dry air



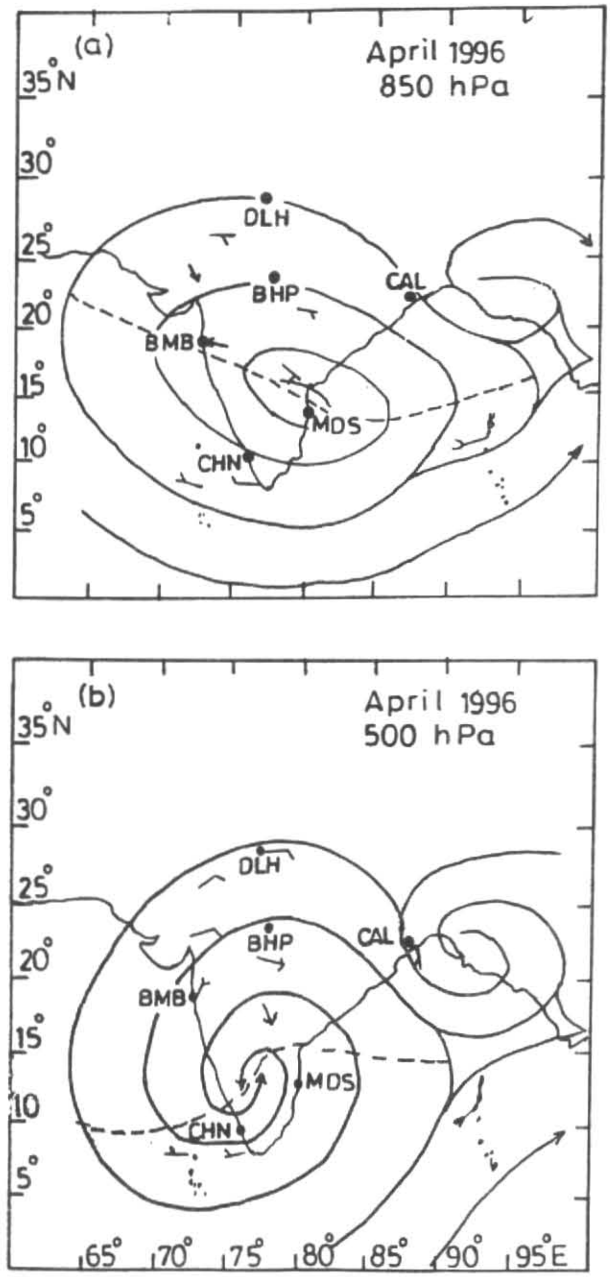
Figs. 2(a&b). Monthly wind anomalies for April 1995(a) 850 hPa and (b) 500 hPa

$$T_v = T(1+0.61\, q_v)$$

where, q_v is water vapour mixing ratio.

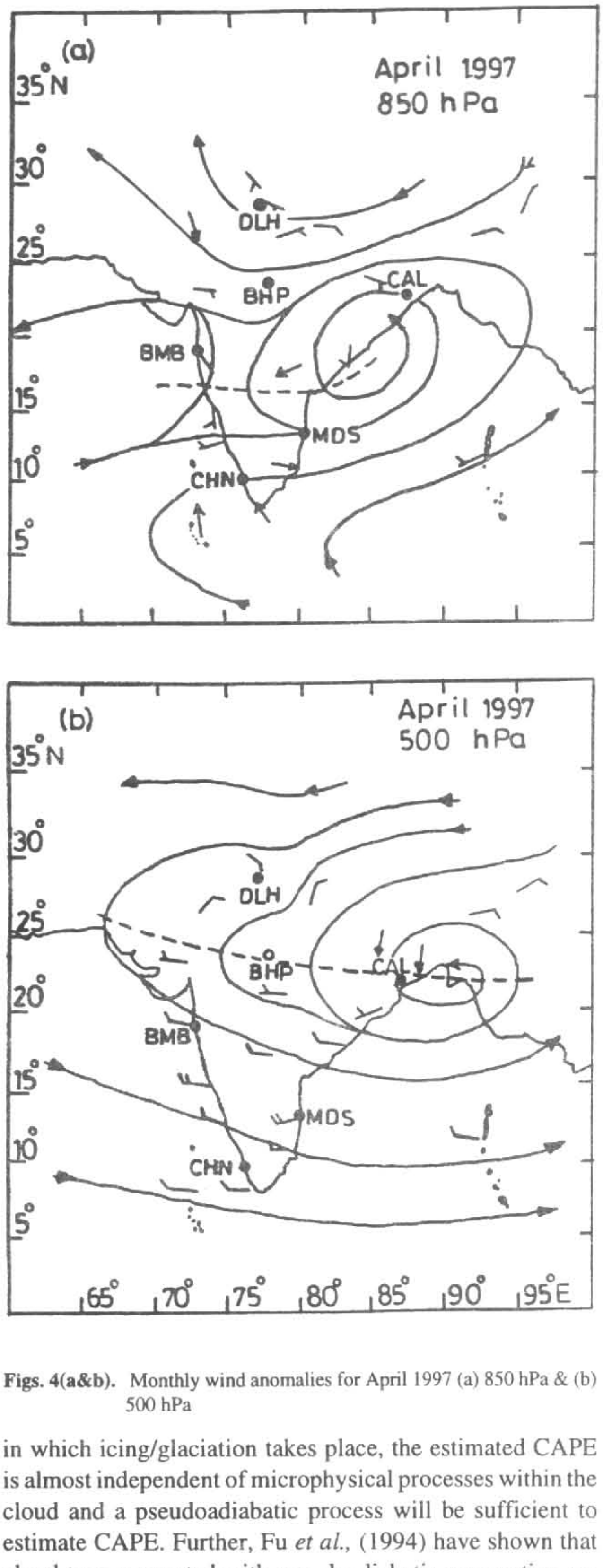
LFC= Level of free convection.

LNB = Level of neutral buoyancy, also known as level of vanishing buoyancy (LVB).



Figs.3 (a&b). Monthly wind anomalies for April 1996 (a) 850 hPa & (b) 500 hPa

Condensation, precipitation, freezing of liquid water, and level of parcel origin, all influence the virtual temperature of the air parcel and hence CAPE, as the parcel undergoes undiluted ascent in the atmosphere (*e.g.*, Saunders 1957, Emanuel 1994, Fu *et al.*, 1994). Xu and Emanuel (1989) pointed out the estimated buoyancy even for undiluted ascent, to be within the uncertainties in measurements when all condensed water is retained in the cloud (*i.e.*, for reversible moist adiabatic process). However, it has been shown by Williams and Renno (1993) that for a deep cloud



Figs. 4(a&b). Monthly wind anomalies for April 1997 (a) 850 hPa & (b) 500 hPa

in which icing/glaciation takes place, the estimated CAPE is almost independent of microphysical processes within the cloud and a pseudoadiabatic process will be sufficient to estimate CAPE. Further, Fu *et al.,* (1994) have shown that cloud tops computed with pseudoadiabatic assumption are closer to the observation and for such processes, uncertainties in evaluating CAPE values due to measurement errors are negligible compared to CAPE values. Hence in the present study CAPE is calculated assuming the pseudoadiabatic process.

3.2. *Role of CINE in convective activity*

It has been found that a substantial amount of CAPE is always present over large areas of tropics, throughout the day. However, observations show that deep convection breaks out over a relatively small area despite this widespread availability of energy for instability. While searching for other causes which may prohibit the occurrence of convective activities, Williams and Renno (1993) studied the role of 'Convective Inhibition Energy' (CINE) for initiation of convective instability. Actually this is the energy which is required to be given to the air parcel for its initial movement from surface to the level of condensation at dry adiabatic lapse rate and thereafter upto level of free convection at pseudoadiabatic lapse rate. CINE is represented by the negative area on tephigram at low levels and is defined by

$$\mathrm{CINE} = \int_{\mathrm{Sfc}}^{\mathrm{LFC}} (T_{vp} - T_{ve})\, R_d \, d\,(\ln P)$$

where LFC = level of free convection,

Sfc = surface level.

It was found that CINE acts as a significant barrier to the release of convective instability and CINE of order 20 Joule/kg (normally present also) can prevent convective activities. Therefore, in addition to large value of CAPE, convective activities can occur when either value of CINE is small or presence of some synoptic systems which may act as a trigger to release the energy or both.

It is worthy to mention that, in mid-latitudes no consideration is given to CINE as synoptic systems are available there in plenty to minimise the effect of CINE and only consideration of CAPE is sufficient. But for tropics, CINE plays an important role for the release of conditional instability.

3.3. *Climatological features and associated weather of April*

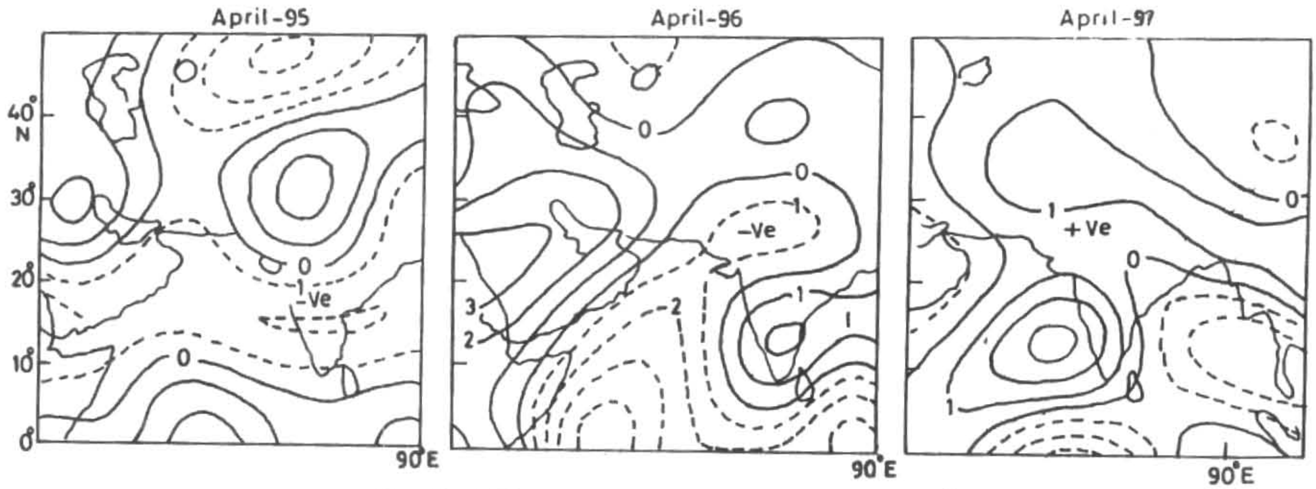
During the month, a heat low develops over central parts of India, often seen on surface level chart and a north-south trough line in lower levels extending upto 1.5 km a.s.l. is marked over the peninsular India in the field of wind discontinuity due to anticyclones in Bay of Bengal and Arabian Sea. The northwest region of the country still being invaded by mid latitudinal baroclinic westerly systems in the form of western disturbances which move from west to east. These western disturbances often cause induced systems, *viz.,* induced cycirs/lows slightly southward to their

TABLE 2

CINE (Joule/kg)

S. No.	Station name	1995	1996	1997
1.	Srinagar	157.55	262.66	123.87
2.	Delhi	425.67	619.98	289.59
3.	Lucknow	700.30	850.66	324.79
4.	Guwahati	373.62	205.5	110.26
5.	Patna	*	359.47	310.25
6.	Ahmedabad	559.65	464.94	249.68
7.	Calcutta	206.20	288.22	120.49
8.	Bhubaneshwar	382.11	*	85.57
9.	Visakhapatnam	189.87	*	112.54
10.	Nagpur	693.36	543.49	482.01
11.	Hyderabad	438.11	194.29	179.23
12.	Bombay	457.98	360.82	305.59
13.	Goa	275.95	226.73	166.49
14.	Madras	92.46	52.66	133.00
15.	Mangalaore	143.49	132.01	67.02
16.	Port Blair	71.176	14.51	45.61
17.	Cochin	37.46	13.98	16.70
18.	Minicoy	25.77	22.56	19.31
19.	Trivandrum	30.75	15.06	33.34

*Data Not Available



Figs. 5 (a-c). Divergence anomaly (200 hPa) contour interval 1×10^{-6} S^{-1}. Positive values are indicated by solid contours

normal position and even reaching upto south Rajasthan and northern parts of Gujarat and move from west to east like their parent systems. Many a times with the passage of western disturbances or induced cycirs from northwest region to northeast area an east-west trough line could also be seen in lower levels from Bihar plains to northeast region.

During the month convective activities occur mainly in Andaman and Nicobar Islands, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, West Bengal, Sikkim, Kerala and parts of northwest India.

For the month of April, normal convective activities over northwest India could be attributed to the induced baroclinity by the invasion of mid latitudinal westerlies, enhanced insolation and north-south trough in lower levels over peninsular and southern Indian minimise the effect of CINE for realisation of thunder showers over same area while abundant moisture supply from the anticyclone in the Bay of Bengal, topography of region and passage of western dusturbances, induced cycirs/troughs overcome the effect of CINE for the release of CAPE over northeast India.

The present study is concerned with convective activities on monthly scale and hence uses monthly mean sounding for estimating CAPE and CINE. For the purpose upper air radiosonde data for the country for the month of April for 1995, 1996, 1997 have been taken and CAPE and CINE have been calculated and possible synoptic causes for the minimising the effect of CINE particularly for plains and central India for the year 1997 are looked into by analysing anomaly flow patterns and studying divergence anomalies at 200 hPa taken from Climate Diagnostics Bulletin.

It is worth mentioning that Bhat, G.S. *et al.* (1996) have shown that CAPE calculation based on monthly mean sounding is comparable to the monthly averages of daily CAPE.

4. Results and discussion

OLR anomalies for the April month for the years 1995, 1996 and 1997 are shown in Fig. 1. It is clear that for the April 1997 OLR anomalies are negative over more parts of the country in comparision to the last two years for the same month suggesting that convective developments took place over largers parts of the country in April 1997.

The value of CAPE and CINE for different stations are given in Tables 1 and 2. It is found that values of CAPE for the year 1997 are more over Visakhapatnam, Bhubaneshwar and over stations north of Nagpur except over Calcutta. Similarly values of CINE for April 1997 are considerably less over most of stations. This suggests that northern and central part of the country was more conductive for convective activities in April 1997.

The anomaly flow patterns for April month for different years are given in Figs. 2,3 and 4 while divergence anomalies for the same are shown in Fig. 5. It is apparent from the anomalous flow pattern of April 1997 that anomalous circulation at 850 hPa over west central Bay and adjoining areas and east-west trough from it persisted even at 500 hPa with little northward movement. Similarly divergence anomaly at 200 hPa for the year 1997 was more positive for the whole country in comparison to the other years for the April month. This anomalous convergence/trough extending upto 500 hPa and more positive anomalous divergence at 200 hPa for the year 1997 might have accounted for minimising effect of CINE for the release of CAPE for April 1997.

5. Conclusions

(*i*) Values of CAPE over most of stations over northern and central India were comparatively more for the April 1997.

(*ii*) Values of CINE over most of stations were considerably less for the April 1997.

(*iii*) For April 1997, the anomalous circulation at 850 hPa over central Bay and adjoining areas and east-west trough from it, persists even at 500 hPa with little northward movement.

(*iv*) The anomaly of divergence at 200 hPa for the April 1997 were more positive for the whole country in comparison to the years 1995, 1996 for the same month.

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