Convective Boundary Layer in the Region of the Monsoon Trough–A Case Study

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ABSTRACT

A case study of the convectively driven monsoon boundary layer has been carried out using the aerological observations at four stations in the region of monsoon trough during Monsoon Trough Boundary Layer Experiment (MONTBLEX) 1988. The Convective Boundary Layer (CBL) in the region of monsoon trough did not show double mixing line structure. A single mixing line representing the CBL with different stabilities with respect to the convective activities was observed.

I. INTRODUCTION

The Convective Boundary Layer (CBL) may be defined as the daytime boundary layer in which convection either dry or moist is present. CBL plays an important role in regulating the transport of heat and moisture upward into the atmosphere from surface. The conserved variable method was used to study the thermodynamic structure of the CBL over the equatorial Pacific (Betts and Albrecht, 1987). In this study, characteristic mixing lines were observed on $\theta_e - q$ diagrams. For shallow CBLs (tops>800 hPa), a single mixing line through cloud and inversion layer was observed whereas in case of deeper CBLs (tops<780 hPa) a double mixing line structure was noticed. In a more general study (Kloesel and Albrecht, 1989) of the thermodynamic structure of the boundary layer over the tropical Pacific also the conserved variable analysis was used. Recently, the CBL structure over the Deccan Plateau region, India during the summer monsoon was studied by Parasnis and Morwal (1991) with the use of conserved variable analysis. In this study it was shown how the CBL structure is progressively modified due to increase in moist convective activity.

Monsoon winds during June to September approach the west coast of India as southwesterly current and are deflected by the Burmeese mountains towards Himalayan foothills so that the flow over the plains of north India is from east to west. This system of winds is closely associated with a quasi–stationary low pressure area over the plains of north India which is usually called the Monsoon Trough. This is a semi–permanent feature of Northern summer in Indian region. Mean trough line runs at surface approximately parallel to the southern edge of Himalayan Mountain and exhibits periodic movement to the north and south of its normal position. Monsoon Trough Boundary Layer Experiment (MONTBLEX) has been taken up by the Department of Science and Technology, Government of India, as a multi–Institutional all–India coordinated programme to study the thermodynamic effects of the processes in the Atmospheric Boundary Layer (ABL) in the monsoon trough region. Aerological observations carried out in the region of monsoon trough during 1988 were used to study the CBL. The purpose of the study is to examine the possible modification of mixing line structure in the boundary layer in the region of monsoon trough.

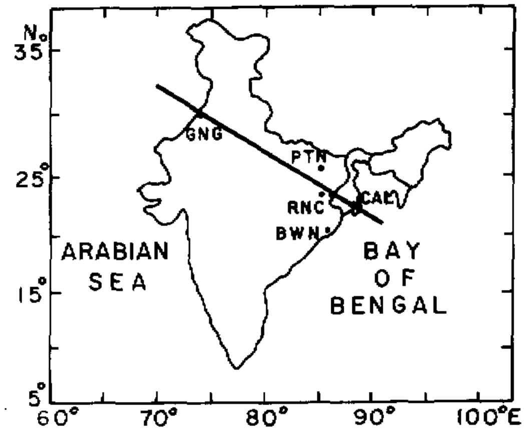

Fig.1. The normal Position of the Monsoon Trough extending from Ganganagar (GNG) to Calcutta and location of the four stations namely Calcutta (CAL), Ranchi (RNC), Bhubaneswar (BWN) and Patna (PTN).

II. LOCATION OF OBSERVATIONS AND METEOROLOGICAL CONDITIONS

Aerological observations were carried out at four stations, namely, Calcutta (22°39′N, 88°28′E, 6 m ASL), Bhubaneswar (20°15′N, 85°50′E, 45 m ASL), Ranchi (23°19′N, 85°19′E, 606 m ASL) and Patna (25°36′N, 86°06′E, 53 m ASL), situated in the region of the monsoon trough during summer monsoon season of 1988, as a part of MONTBLEX. The normal position of the monsoon trough and the location of the four stations are shown in Figure 1. The stations Calcutta, Bhubaneswar and Ranchi are on the monsoon trough line (or on the southern side of the trough line). Under the normal monsoon conditions, the axis of the monsoon trough extends from Ganganagar to Calcutta with its eastward end over the Head Bay. The normal position of monsoon trough is usually associated with enhanced monsoon activity over India. Day time observations during 24–31 July 1988 were used in this study. The surface pressure charts for 24–31 July (0300 UTC) are shown in Fig.2. It is seen that the monsoon trough during this period was almost in the normal position and there was a low pressure area located northwest of Calcutta on 26th. The low pressure area was not seen on 27th but it appeared from 29th onwards. The aerological data were collected using high resolution minisonde from India Meteorological Department. From the comparison of low level minisonde observations with the routine radiosonde, it was observed that for the two stations viz. Calcutta and Ranchi the temperature values were spurious in the lower levels, hence for these two stations routine radiosonde observations (0530 IST) were used. For other stations viz. Bhubaneswar and Patna the minisonde observations compared well with those of radiosondes. The details of the minisonde are given in Table 1.

III. METHOD OF ANALYSIS

The aerological observations at Calcutta, Bhubaneswar, Ranchi and Patna for the period 24–31 July 1988 were used to compute the thermodynamic parameters such as potential temperature (θ,k), equivalent potential

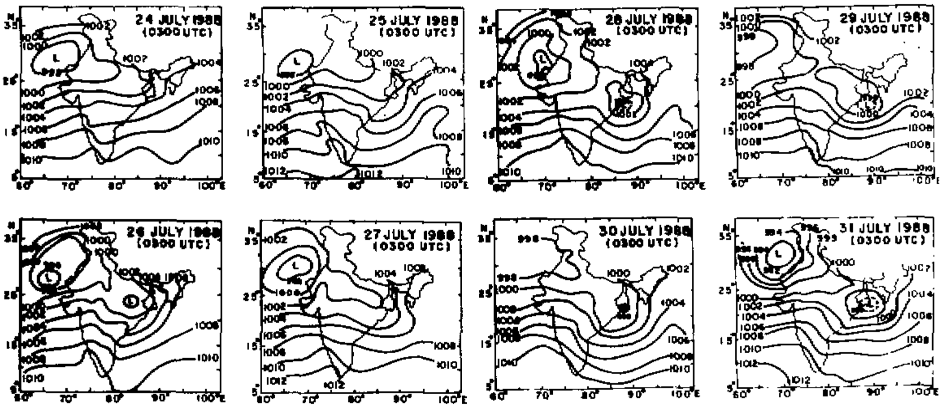

Fig.2. Surface pressure charts for the period 24–31 July 1988 at 0300 UTC.

Table 1. *Details of the Minisonde Measurements*

Parameter	Sensor	Accuracy	Range
Pressure	Aneroid	0.5 hPa	1050—700 hPa
Temperature	Microbead thermistor (Time constant: 1 second)	–0.1℃	0—50℃
Humidity	Microbead thermistor with a wet bulb (Time constant: 1 second)	–0.1℃	0—50℃

temperature (θ_e, k), saturation equivalent potential temperature (θ_{es}, k), and mixing ratio (q, gm kg^{-1}) at an interval of 10 hPa.

1. *Classification of the Soundings*

To characterize the differences in the thermodynamic structure of the boundary layer associated with deep convection, shallow convection and suppressed convection, the classification of the soundings has been made on the basis of low–level stability. Following Kloesel and Albrecht (1989), we considered the ascent of a non–entraining air parcel from the mean sub–cloud layer level. The constant θ_e line through this point representing the ascent of air parcel, usually cuts the θ_{es} at the Lifting Condensation Level (LCL). The difference between constant θ_e path of the parcel and the θ_{es} of the sounding above the LCL is proportional to the temperature difference between the parcel and the environment. If the constant θ_e is warmer than θ_{es} above LCL and cuts the θ_{es} curve below 600 hPa; the soundings are usually associated with inversions. In case the constant θ_e is warmer above LCL and remains warmer at least up to 600 hPa then the soundings are associated with deep convection. In case of suppressed convection, the constant θ_e path is cooler than θ_{es} curve. The θ_e and θ_{es} plots for Calcutta, Bhubaneswar, Ranchi and Patna are shown in Figure 3. It is seen that the soundings at Culcutta, Ranchi and Bhubaneswar can be classified as associated with deep convection whereas soundings at Patna are associated with suppressed convection.

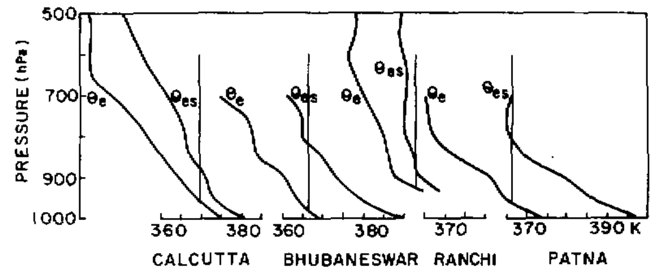

Fig.3. Average diagram for θ_e and θ_{es} for Calcutta, Ranchi, Bhubaneswar and Patna.

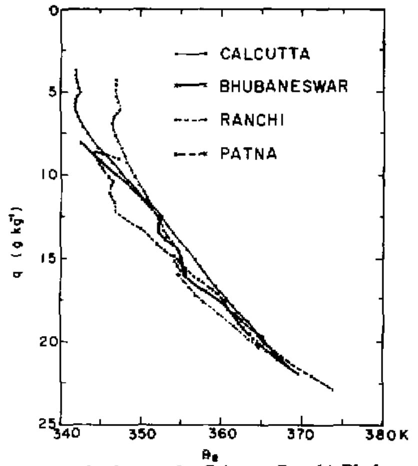

Fig.4. Average diagram for $\theta_e - q$ for Calcutta, Ranchi, Bhubaneswar and Patna.

IV. CONSERVED VARIABLE ANALYSIS

Conserved variable analysis is a useful tool to study the structure of the tropical atmosphere. The use of conserved variables simplifies the consideration of phase changes and allows for representation that can be related to physical processes in the atmosphere (Betts, 1985). $(\theta_e - q)$ plots were used graphically to illustrate how the radiation, precipitation and mixing processes maintain the characteristic structure of the CBL (Betts and Albrecht, 1987).

The conserved variable diagrams $(\theta_e - q)$ for the four stations are shown in Figure 4. No inversion was observed over any of these stations during 24–31 July 1988. It is seen from the Fig.4 that the stations Calcutta, Bhubaneswar and Ranchi have similar thermodynamic structure. There was no q reversal observed in the soundings. The main reason for this may be that the region is situated in convergent zone. There is a single mixing line represented by $\theta_e - q$ profile. When vertical convection mixing dominates over the processes like radiative cooling / warming or the processes of precipitation and evaporation of falling rain a single mixing line structure is observed. For deeper CBLs (top$<$780 hPa) Betts and Albrecht (1987) observed double mixing line structure within the CBL. They attributed this to differential horizontal advection of boundary layers of different depths near the equator. In the present case the monsoon trough is in the normal position therefore monsoon is active over the region hence double mixing line structure was not noticed. It is likely that the double mixing line structure may be observed in case of advection of different boundary layers during the formation and movement of transient disturbances like low pressure, depression etc. in the Bay of Bengal.

The $\theta_e - q$ diagrams at three stations (Calcutta, Bhubaneswar and Ranchi) show different slopes as compared to that for Patna. In the earlier work (Parasnis and Morwal, 1990) it was shown that with progressive increase in moist convective activity the $\theta_e - q$ diagrams indicated change in stability i.e., $\theta_e - q$ diagrams showed increase in stability with increasing monsoon activity. The $\theta_e - q$ profiles in Figure 4 are comparable with those obtained for moderate monsoon activity (Parasnis and Morwal, 1990). Also these profiles can be compared with that of "high θ_e–soundings" over the Pacific region (Kloesel and Albrecht, 1989). The low–level convective activity discussed in Section 3.1 is suppressed at Patna, whereas the low–level stability at the other three stations indicates the association of deep convection. The locations of the stations and differences in the low–level stabilities may be responsible for the changes in the stability of $\theta_e - q$ profiles.

In Figs.3 and 4 the average conditions are seen. However, it is likely that the short term variations such as depression, low pressure noticed in Fig.2 exert some effect on the daily structure of convectively driven monsoon boundary layer. In the case of the low pressure / depression the deep moist convection and hence the CBL may extend to higher levels than the normal value. Also, the intensity of the convection may show increase (i.e., more buoyancy) in the region above LCL in Fig.3.

V. CONCLUSIONS

This case study of CBL structure in the region of the monsoon trough using conserved variable analysis showed that there was no double mixing line structure in the CBL. The mixing lines for the stations located south of the monsoon trough, showed more stability as compared to those observed for the station north of the monsoon trough. Classification based on the low–level stability suggested that soundings at the stations (south of monsoon trough) are associated with deep convection whereas for one station (north of trough) they are associated with suppressed convection.

The above results are based on limited observations. Further investigations are needed to confirm the results which will be carried out using MONTBLEX 1990 data.

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