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THERMODYNAMICS OF THE MIXING PROCESSES IN THE ATMOSPHERIC BOUNDARY LAYER OVER PUNE DURING SUMMER MONSOON SEASON

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ABSTRACT

Knowledge of mixing processes in Atmospheric Boundary Layer (ABL) is important for the understanding of the dynamical aspects of ABL. Mixing processes depend on stability and stratification of the ABL. In this report mixing processes in monsoon ABL over Pune have been examined with the help of the aerological observations on some days during the summer monsoon season of 1980. The saturation point analysis technique (Betts, 1982) has been used in this study. It was observed that during break monsoon conditions, the mixing of cloud and environmental air was unable to produce downdraft or updraft below the base of the inversion but could produce cooler downdraft above the inversion layer. During active monsoon conditions, however, mixing of the cloudy parcel with environmental air produced warmer updraft up to 600 mb level.

1. Introduction

Mixing processes in the Atmospheric Boundary Layer (ABL) play a vital role for development of subcloud layer and formation of clouds in the atmosphere. Knowledge of mixing processes in ABL is useful for the understanding of coupling between subcloud layer and cloud layer. Mixing processes involve the atmospheric stratification, updraft and downdraft structure and also the micro-physical processes such as condensation, evaporation and precipitation. Betts (1982) has put forward the saturation point concept and has shown that the saturation point analysis helps to understand the mixing processes between cloudy air and environmental air. Variations in thermodynamic parameter in the ABL during active and weak monsoon conditions have been brought out (Parasnis et al., 1985; Parasnis and Goyal, 1988). In this report aerological observations on a few days during the summer monsoon season of 1980 at Pune have been used to study the mixing processes in the ABL. The purpose of this research report is to bring out the differences in the mixing processes in ABL during different weather conditions during the observational period.

2. Meteorological Conditions and Observations

Pune (18°32', 73°51', 559 m ASL) is situated on the lee side of the Western Ghats. The surface rises from west to east to an average of 0.8 km in a distance of 65 km and then ends in a plateau of average height of 0.6 km. Winds are mostly westerly to southwesterly in the lower troposphere. Westerly airflow in the lower troposphere during the summer monsoon (June-September) brings a large influx of moisture inland from the Arabian Sea. Synoptic and mesoscale disturbances leading to low-level convergence and vertical motions of the humid air give rise to continuous to intermittent rain from stratiform/cumulus clouds.

Special aerological observations were carried out at Pune during the summer monsoon season of 1980 in connection with the Cloud Seeding Experiments conducted by Indian Institute of Tropical Meteorology, Pune. These observations were taken between 1130-1200 IST daily. The two periods considered in this research report are

12-17 July 1980 and 1-6 August 1980. The first period represents the break monsoon conditions and during the later period the monsoon was active. During the break monsoon conditions (12-17 July 1980) the axis of the monsoon trough was located at the foothills of Himalayas. The period of active monsoon condition (1-6 August 1980) was associated with the southward shift of the monsoon trough to its normal position. There was a cyclonic circulation over the central part of Madhya Pradesh in the lower troposphere in the first half of this period. In the later half it moved west in south Madhya Pradesh and adjoining north Maharashtra. Mid-tropospheric circulation was present over the region (73^{o}E, north of 17^{o}N) The trough off the west coast also persisted. The representative synoptic situations during the two periods are shown in Figs 1a and 1b. The rainfall recorded at Indian Meteorological Department, Pune during both the periods are given in Table 1. The mean values of temperature (T) and dew point temperature (T_d) (starting from surface up to 500 mb at an interval of 50 mb) during both the periods were used to compute the saturation points at different levels.

3. Method of Analysis

3.1 Saturation Point Analysis

When a parcel of unsaturated air is lifted adiabatically to a level where it gets saturated with the available moisture then that level is called as the Lifting Condensation Level (LCL). Betts (1982) has called this level as saturation level and a point on this level representing LCL a Saturation Point (SP). The SP can be computed using the T and T_d observations at any particular level. Since the SP remains unchanged during adiabatic ascent or decent, it can be used as thermodynamic tracer of an air parcel. The SP can be specified uniquely by θ, θ_e and q at saturation level. The difference between the data pressure level p and pressure at saturation level (P_{SL}), which plays an important role in the mixing processes defined by

$$P = P_{SL} - P$$

Thus P is the saturation pressure deficit (Betts, 1985).

3.2 Mixing Line Construction

The SP of the mixture of two air parcels at different levels can be obtained easily by taking the average of the thermodynamic parameters such as potential temperature (θ) mixing ratio (q) associated with the saturation points of two air parcels at different levels. The line joining the saturation points of all mixtures (in any ratios) is the mixing line. The slope of the mixing line is also important in the downdraft, updraft structure. The position of the mixing line with respect to dry and moist adiabats gives the idea of the prevailing characteristic weather conditions (Betts, 1982). The saturation points along with temperature and dew point temperature are usually plotted on thermodynamic diagram (T - ϕgram).

In this study SPs have been obtained at different levels from surface up to 500 mb at an interval of 50 mb using T and T_d profiles. As far as the mixing line is concerned the SP of the cloud base level and SP of the inversion base, in the case of break monsoon period, have been used for the construction of mixing line. In case of active monsoon conditions the SPs at cloud base level and 600 mb level have been considered for mixing line construction. The mixing line thus obtained are shown in Figures. The conventional method uses gradients of θ (dry adiabatic lapse rate) and θ_e for the consideration of the stability. In this method the slope of the mixing line alone decides the stability of the atmosphere.

4. Results and Discussion

The synoptic situation during the two periods i.e. break & active are shown in Figure 1a and 1b respectively. The vertical profiles of T and T_d from surface to 500 mb, during both the periods are shown in Figure 2. Mean thermodynamic diagrams for the two periods are shown in Figure 3a and 3b. The dry and moist adiabats, T and T_d profiles, mixing line and environmental saturation points are shown in this figure.

On the days of active monsoon conditions the temperature profiles showed adiabatic stratification up to 850 mb and then stable lapse rates aloft, whereas on the days of break monsoon adiabatic stratification was observed up to 780 mb (Figure 2).

An inversion layer in temperature (2°C km^{-1}) was observed between 750-700 mb layer during break monsoon days. This stable (Inversion) layer was observed on all 6 days of observations. On active monsoon days the moisture from lower levels is pumped upwards by synoptic disturbances. The midtropospheric cyclonic circulation causes pumping of the moisture to higher levels (Srinivasan and Sadasivan, 1975). Thus the transport of moisture content to higher levels is attributed to the synoptic conditions prevailed on active monsoon days. On the days of break monsoon conditions, due to absence of favourable synoptic system the moisture has not reached beyond 750 mb.

The mixing line structure during break monsoon conditions (Figure 3a) is nearly parallel to the atmospheric stratification up to the base of the inversion (750 mb). Thus there is no possibility of downdraft or updraft in the layer between the cloud base and base of the inversion. Mixing line from the base of the inversion to 700 mb has shifted away from the environmental stratification. Since this shift is to the left of the environmental stratification there seems to be possibility of cooler downdrafts in this region. The break monsoon period is associated with the synoptic scale subsidence which inhibits the cloud growth. The mixing line structure during break monsoon conditions also provides support to the subsidence. The above results are in agreement with those obtained from the observations collected during undisturbed weather conditions during BOMEX (Betts, 1982).

During active monsoon period the environmental stratification is nearly moist adiabatic between 850-500 mb (Figure 3b). The mixing line is to the right of the environmental stratification up to 600 mb (warmer). This shows that mixing of cloudy air and environmental air will produce warmer updraft up to 600 mb. The mixing line above 600 mb is to the left of environmental curve indicating that there is a possibility of cooler downdraft in the region between 600 to 500 mb. The active monsoon period is associated with the synoptic scale convergence which promotes the cloud growth. The mixing line structure during active monsoon conditions provides support to the prevailing weather conditions.

CONCLUDING REMARKS

The study of the mixing processes in the ABL has suggested the following:

During break monsoon conditions, the mixing line structure being closer to atmospheric stratification, there is no possibility of updraft or downdraft below the base of the inversion. During active monsoon condition the mixing line suggests that mixing of the cloudy parcel with environmental air will produce warmer updraft up to 600 mb level. These results could be attributed to the weather conditions prevailed during break and active monsoon days. These results are obtained with limited data and confirmation needs further studies.

Acknowledgment

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Legend

Figure 1a : Representative synoptic charts for break monsoon period (12-17 July, 1980).

Figure 1b : Representative synoptic chart for active monsoon period (1-6 August, 1980).

Figure 2 : Vertical profiles of temperature(T, solid line), dew point temperature (T_d, dashed line) during the two periods of observations. The slanted straight line indicates dry adiabatic lapse rate.

Figure 3a : Mean thermodynamic diagram showing saturation points (open circles) and mixing line (dashed line) during break monsoon conditions.

Figure 3b : Same as Figure 3a for active monsoon conditions.

Table 1 : Daily Rainfall at Pune during break and active monsoon periods.

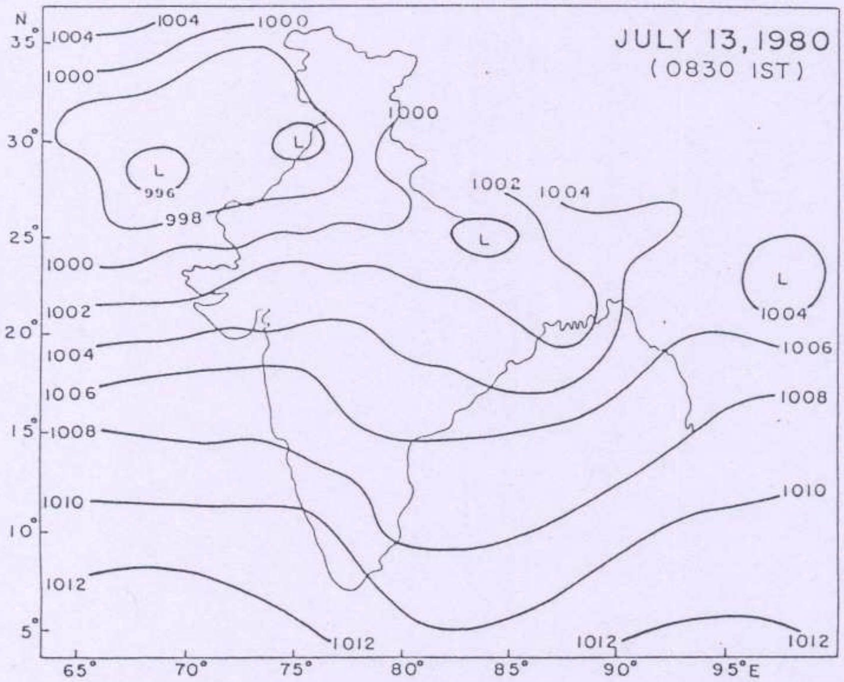

Figure 1a : Representative synoptic charts for break monsoon period (12-17 July, 1980).

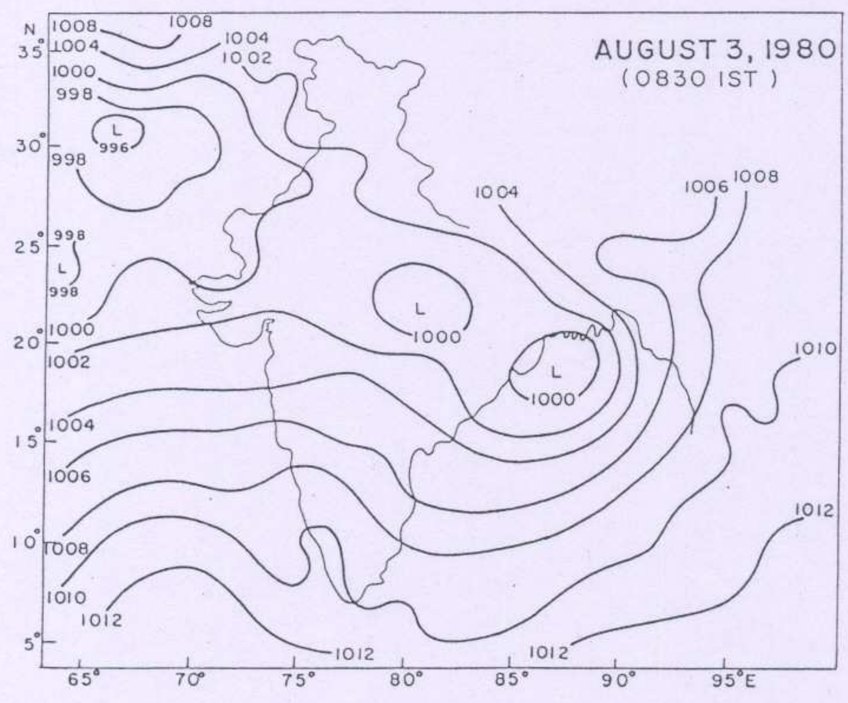

Figure 1b : Representative synoptic chart for active monsoon period (1-6 August, 1980).

Table 1 : Daily Rainfall at Pune during break and active monsoon periods.

Monsoon Conditions			
Break		Active	
Day	Rainfall (in mm)	Day	Rainfall (in mm)
12 July	1	1 August	03
13 July	0	2 August	12
14 July	0	3 August	42
15 July	0	4 August	20
16 July	0	5 August	08
17 July	0	6 August	06

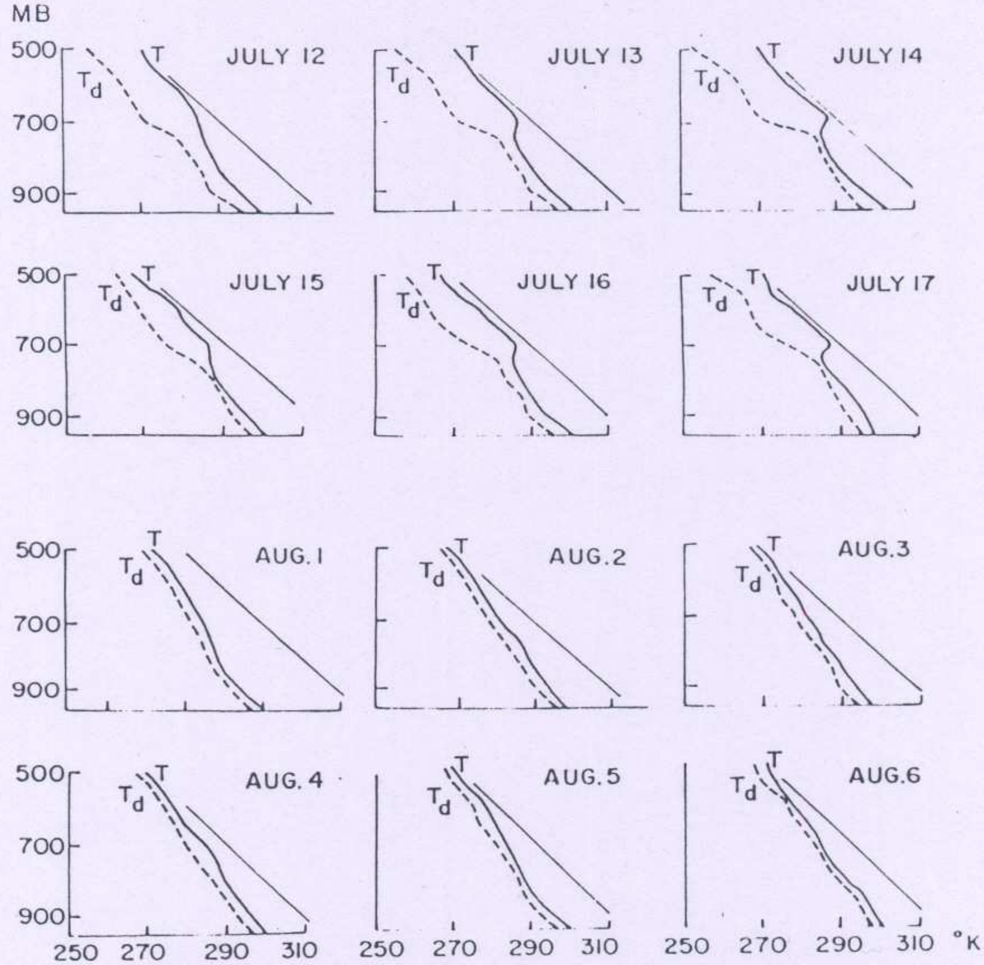

Figure 2 : Vertical profiles of temperature(T, solid line), dew point temperature (T_d, dashed line) during the two periods of observations. The slanted straight line indicates dry adiabatic lapse rate.

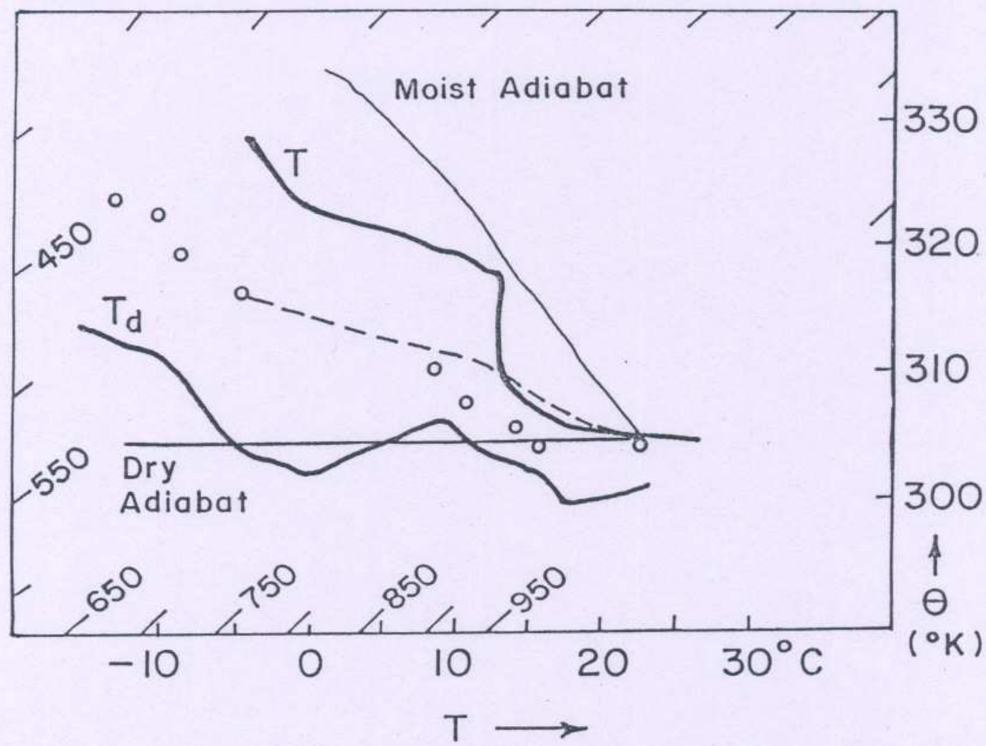

Figure 3a : Mean thermodynamic diagram showing saturation points (open circles) and mixing line (dashed line) during break monsoon conditions.

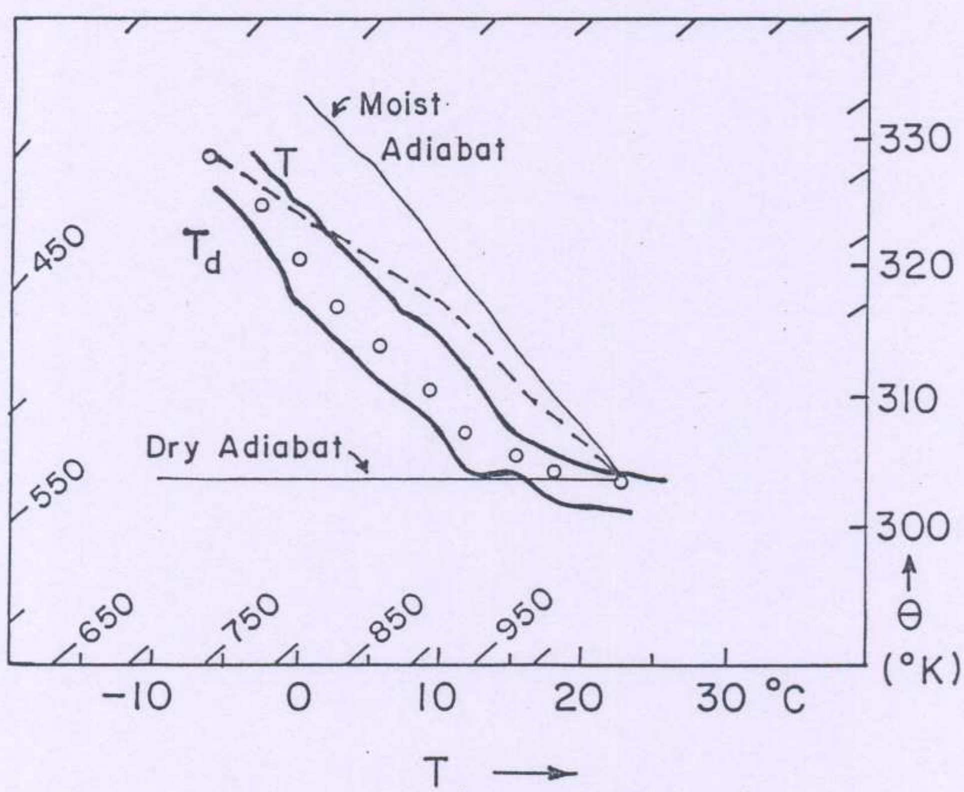

Figure 3b : Same as Figure 3a for active monsoon conditions.