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Observed Changes in the Convective Parameters over Chennai

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Abstract

Different events are happening every time in the atmosphere in which much of them are randomly generated. The studies on thermodynamic environments supporting convection is important for understanding potential changes in a climate. Parameters like Convective available potential energy, Level of free convection, Equivalent temperature, pressure is varying time to time. In this work, we have performed comparative day to day, monthly and seasonal variations of convective parameters by using the data from Chennai region, for the year 2022.The variations in CAPE are connected to the changes in atmospheric energy balance and convective activity, making them a possible indication of climate change. The seasonal fluctuations demonstrate that the CAPE is larger during the monsoon than it is during the pre-monsoon or post-monsoon seasons, which shows that large-scale dynamics and thermodynamic conditions conducive to high CAPE are required for organised monsoon convections across this region. The monsoon rainfall over the Indian subcontinent may be maintained by the systematic growing tendency in CAPE, which may be compensating for weakening of the monsoon circulation.

Keywords: Convective available potential energy, level of free convection, Monsoon convections

1. Introduction

India is experiencing drastic climate changes year to year. Unusual and unprecedented spells of hot weather are expected to occur, a decline in monsoon rainfall since the 1950s, triggering more frequent droughts as well as greater flooding in large parts of India [1]. Intense convective activities are a very common climatic feature in various parts of the Indian subcontinent. These types of activities are mainly found to occur during the pre-monsoon (March to May) and monsoon (June to September) seasons [2]. A better understanding of local climatology and their accompanying environments is important for operational forecasters, emergency managers, and risk estimation. Using multiple tropical stations and reanalysis data previous studies observed that convective available potential energy increased very strongly with a growth rate of ~20 % per decade during the period 1958–1997 due to an increase in surface heating and moisture.[3]

1.1 Convective available potential energy (CAPE)

CAPE can be estimated by vertically integrating the parcel buoyancy between the level of free convection (LFC) and level of neutral buoyancy, and thus it measures the maximum kinetic energy per unit air mass achievable by the convection of moist air from the sub cloud layer, assuming undiluted ascent, and gives an upper limit to the cumulus updraft vertical velocity. Previous studies had already explained CAPE as an indicator of sudden climatic changes and thermal instability of the atmosphere [4]. CAPE may be expressed as follows:

$$\mathrm{CAPE} = \int_{p_f}^{p_n} R_d \left(T_{vp} - T_{ve} \right) d\ln p, \quad (1)$$

where T_{vp} is the virtual temperature of a lifted parcel moving upward moist adiabatically from the level of free convection to the level of neutral buoyancy, T_{ve} is the virtual temperature of the environment, R_d is the specific gas

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constant for dry air p_f is the pressure at the level of free convection, and p_n is the pressure at the level of neutral buoyancy.

1.2 Level of free convection (LFC)

The LFC is the height at which an air parcel lifted dry adiabatically until saturated and then moist adiabatically thereafter, would first become warmer (less dense) than the surrounding environmental air. The parcel would then continue to rise freely above this level until it becomes colder (denser) than the surrounding air. It is the altitude in the atmosphere where the temperature of the environment decreases faster than the moist adiabatic lapse rate of a saturated parcel of air at the same level. Increased surface latent heat flux makes it simpler to approach saturation when the lower troposphere is moist and thermally stratified. This favours convective initiation over the wet surface by lowering the lifting condensation level (LCL) and bringing the LFC closer to the top of the planetary boundary layer (PBL). A deeper PBL, however, offers a lifting mechanism by which air parcels can adiabatically reach the LCL and LFC over the same dry surface in a weakly stratified environment, favouring convective start.

The LFC is the altitude in the atmosphere where an air parcel lifted adiabatically until saturation becomes warmer than the environment at the same level, so that positive buoyancy can initiate self-sustained convection [5]. The LFC is found to increase considerably in all Indian subdivisions. Consequently, the coastal regions particularly the western coast experience increases in severe thunderstorms and severe rainfall frequency in the pre-monsoon period, while the inland regions especially Central India experience an increase in ordinary thunderstorms and weak rainfall frequency during the monsoon and post-monsoon periods.[6]

1.3 Equivalent temperature

The equivalent temperature or isobaric equivalent temperature is the temperature that a moist air parcel would have if all water vapour in it were condensed out at constant pressure and adiabatically, i.e., all the latent heat released in the condensation is used to heat the air. Equivalent potential temperature, is a quantity that is conserved during changes to an air parcel's pressure that is, during vertical motions in the atmosphere, even if water vapor condenses during that pressure change. It is therefore more conserved than the ordinary potential temperature, which remains constant only for unsaturated vertical motions (pressure changes)[7]. Equivalent temperature can be used to compare the temperature of air parcels that are at different levels in the troposphere. Temperature tends to decrease with height**.**

$$T_{ie} = T\left(1 + \frac{Lw}{c_p T}\right), \qquad (2)$$

where T_{ie} is the isobaric equivalent temperature, T the temperature, w the mixing ratio, L is the latent heat, and c_p is the specific heat of air at constant pressure. As motivated by previous studies[8,12,13] on the nature of convection around the world we have made an attempt to study the variation of convective thermodynamic parameters.

2.Data Analysis

Earth surface monitoring can give information that may be used in complex analysis of the air conditions, temperature, humidity etc. Data from a vertical profile of the atmosphere is also essential for accurate thunderstorm forecasting. That data is collected by radiosondes–telemetry instruments carried into the atmosphere usually by balloons[9]. Information delivered by radiosonde monitoring is important for providing meteorological warnings and post incidental case studies .Upper air monitoring is also source of data for the numerical weather prediction models, which are based on the concept of the characteristics of the atmosphere as a fluid. That data is also useful in the analysis of a vertical profile of the atmosphere. In this study we have examined the seasonal and daily variation of Convective available potential energy - CAPE, Level of Free Convection – LFC and Equivalent temperature. CAPE is a measure of the amount of energy available for convection in the atmosphere. It is a measure of the convective potential in the atmosphere and it can predict valuable climatic information. Most of the studies on CAPE are based on radiosonde observations. Globally, the radiosondes are launched twice a day, 00:00 and 12:00 UTC. This limits the studies that are available on CAPE at diurnal scales. In this study we have examined the three convective parameters over Chennai station. Chennai, being a tropical region, experiences high moisture content and due to its geographical features moisture convergence is likely to be high, which should lead to similarly increased convective precipitation rates.

The radiosonde database of the University of Wyoming, which is one of the most popular datasets worldwide, was used to obtain radiosonde data over a period of 40 years (1979–2018). Furthermore, because radiosonde-mounted balloons have the tendency to drift up to a maximum of 75 km at a 300-hPa pressure level depending on the surrounding wind velocity [10], continuous vertical sounding from a fixed location cannot be guaranteed. Nevertheless, we assumed that most errors resulting from sensors and spatial displacement were smoothed out via long-term averaging of radiosonde data. The present study analysed the Radiosonde data collected from Wyoming University Archive for 2022 January1,00UTC to 2022December31, 12UTC.[11].Radiosonde sensors measure upper-air conditions like atmospheric pressure, temperature and humidity, wind speed and direction. The data is important for aviation safety, and meteorologists use radiosonde information to prepare weather forecasts.

Data was analysed for each day, each time interval and for the further analysis average of these two-time intervals were taken and is plotted, which shows the variation of each parameter in a day-to-day basis. As a next step the daily data was averaged to get the monthly average. In order to look in to the seasonal variability, the monthly data was averaged in four different seasons such as Winter (December, January and February), Pre-Monsoon (March, April, May), Monsoon (June, July, August), and Post Monsoon (September, October, November).

3. Results and Discussions

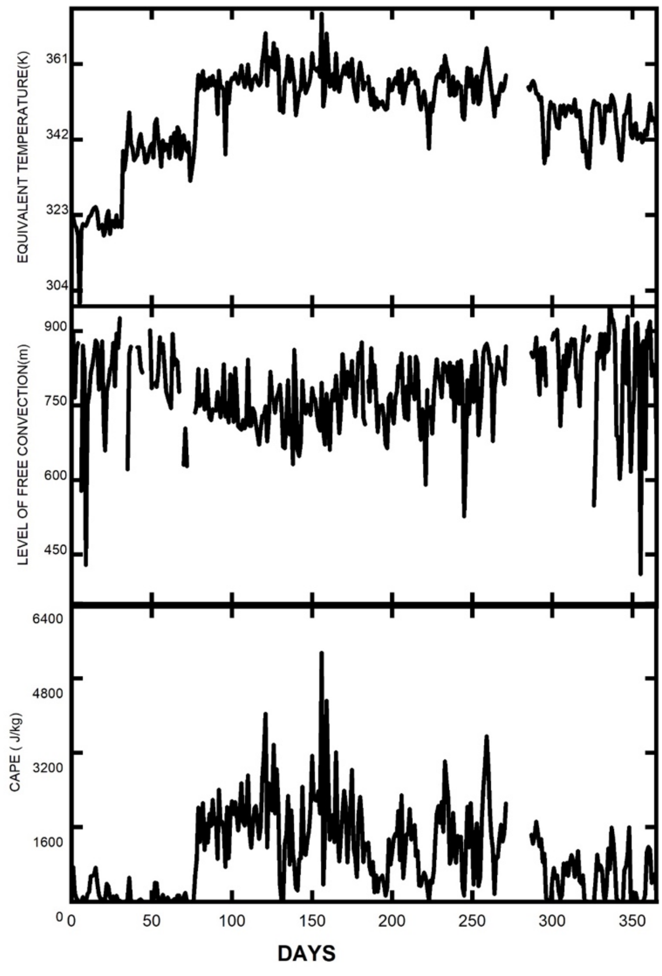

Figure 1: Day to day variation of CAPE,level of free convection and equivalent temperature over Chennai during 2022(January1 to December31).

Figure 1 shows daily variation of CAPE, LFC, Equivalent temperature over Chennai Station, (13.00'N, 80.18'E). The Radiosonde data sets are archived for 00UTC and 12UTC per day from January 1 to December 31 of 2022. The three parameters were calculated two times in a day and the daily value was made of the average of these two values. CAPE attains its highest value, 5346 J/kg in the month of July and goes to minimum in certain months. LFC has its peak value of 928.7 m in December and its values are comparatively high in January and December. Similarly, the Equivalent temperature shoots to maximum value of 368.7 K in May.

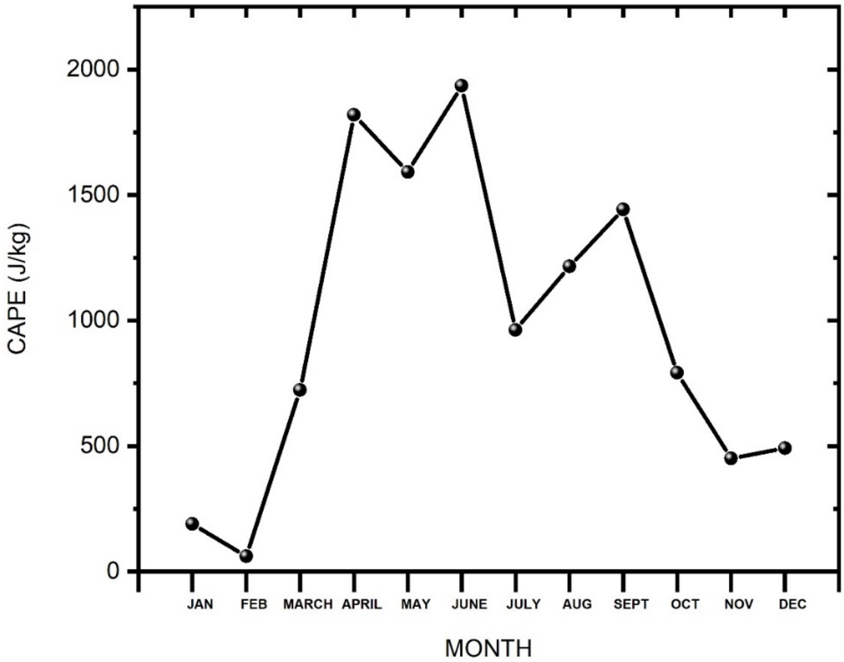

Figure 2(a): Monthly variation of CAPE over Chennai in 2022.

The daily values of CAPE are again averaged for each month in order to have the monthly variation in each parameter. Figure 2(a)shows the monthly average values of CAPE in 2022, for present study location. Daily CAPE is increasing from March, with a peak of 1934.8 J/kg in June, decreasing gradually from September. Monthly CAPE values are found to be high from April to September months, and minimum during the other months.

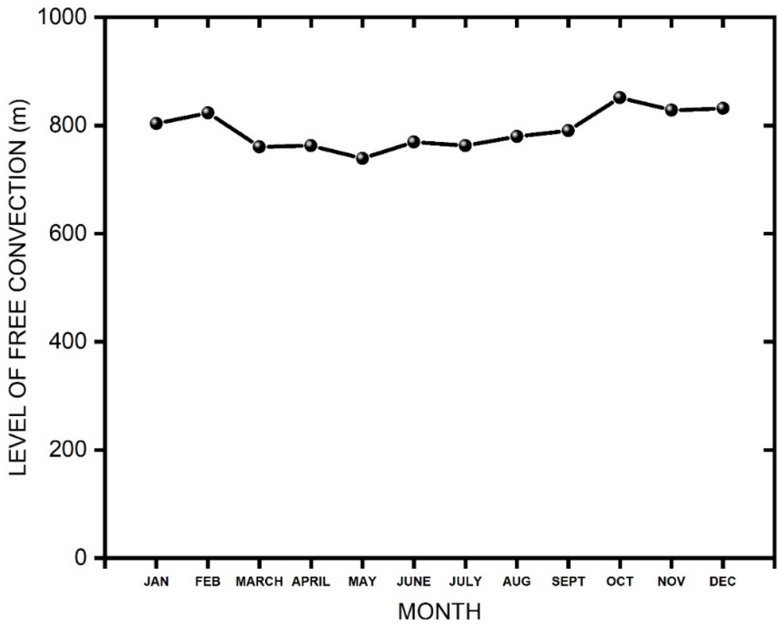

Figure 2(b): Monthly variation of Level of free convection over Chennai in 2022.

Figure 2(b) shows monthly variation of Level of free convection in Chennai during 2022. Level of free convection is found to have a maximum amplitude of 851.7 m in October and minimum of 738.9 in May. The monthly values of LFC are high in January, February, October, November and December,and minimum being from March to September.

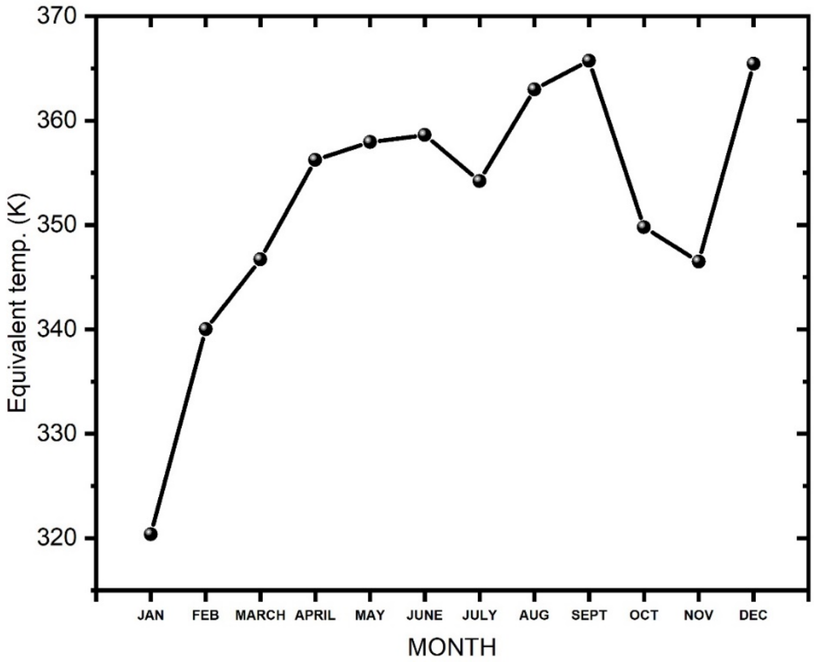

Figure 2c): Monthly variation of Equivalent temperature over Chennai in 2022.

The monthly distribution of equivalent temperature over Chennai is plotted in Figure 2 (c). From the plot it is clear that the equivalent temperature is low in January (320.4 K) and highest in September (365.7 K). Equivalent temperature is relatively high from March to September. Monthly equivalent temperature shows consistency in the months April to July.

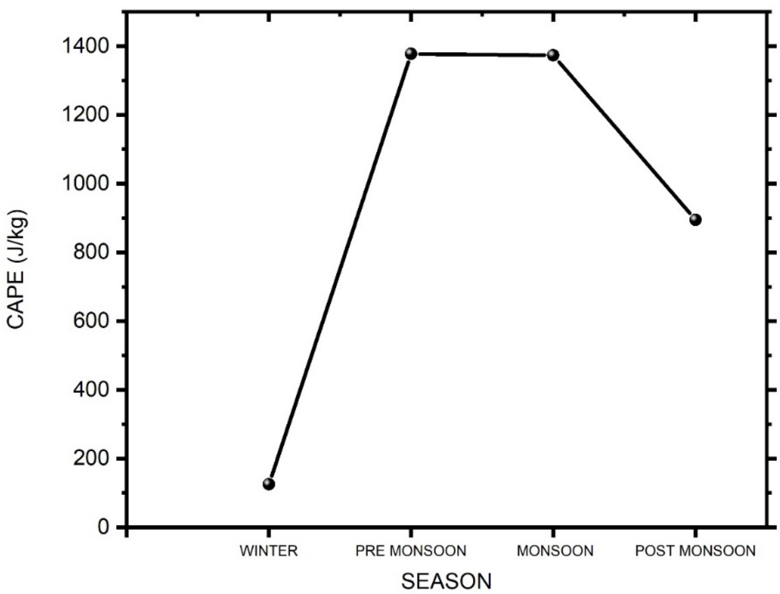

Figure 3(a). Seasonal variation of CAPE over Chennai in 2022..

The seasonal variation of CAPE is shown in Figure 3(a). Monthly values of CAPE are grouped on a seasonal basis to get the seasonal average. Four different seasons were considered as Winter (December, January and February), Pre-Monsoon (March, April, May), Monsoon (June, July, August), and Post Monsoon (September, October, November). CAPE is found to be lowest in winter, peaks in pre-monsoon, following almost the same pattern during monsoon and then decreases. The maximum amplitude of CAPE is observed in the pre-monsoon (1377.6 J/kg) and minimum amplitude is observed in the winter (125.4 J/kg). In the pre-monsoon season, an increasing activity of thunderstorms is observed due to higher instability connected to high CAPE values.

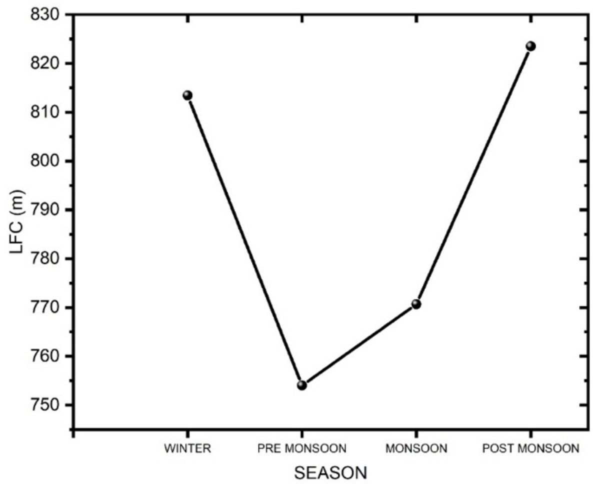

Figure.3(b). Seasonal variation of level of free convection over Chennai in 2022.

The seasonal variation of the Level of free convection in 2022 for Chennai is studied and depicted in figure 3.3(b). The monsoon and post-monsoon season experiences more prominent ascension in LFC height, increasing the tropospheric stability, which leads to increased thunderstorms and occurrences of weak rainfall all over the Indian region. It decreases gradually in the pre monsoon and monsoon season. In the post monsoon season Level of free convection is slightly high with an amplitude of 823.5 m and it is observed to be minimum in the pre-monsoon(754 m).

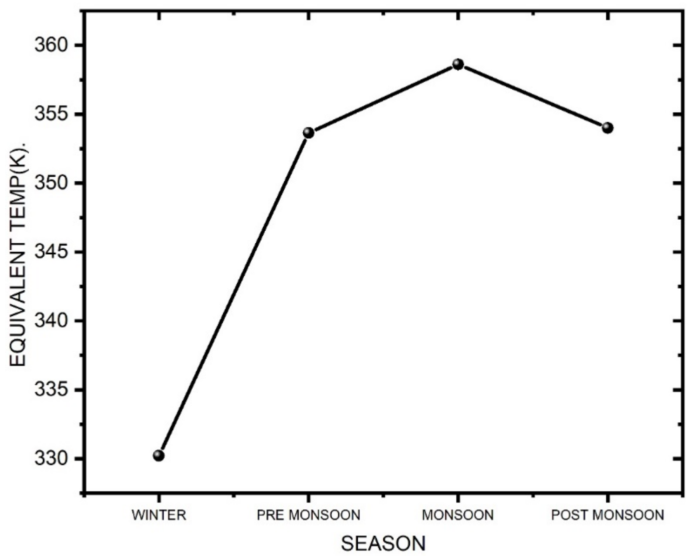

Figure 3(c). Seasonal variation of equivalent temperature over Chennai in 2022.

Analysis of equivalent temperature shows that it is relatively high in pre monsoon, monsoon and post monsoon seasons. It decreases in the winter. The relatively highest value of equivalent temperature is observed in the monsoon(358.6193K) and lowest value is in the winter(330.2009K).Season wise variation of the Equivalent temperature over the study location is shown in Figure 3(c).The study reveals that CAPE is increasing in a monsoon, however a corresponding decrease in LFC acts as a complementary force. The nature of convection provides an environment where CAPE can build to extreme levels that may result in more frequent severe convection. Results from the study suggest that convection and severe weather are expected because of enhanced CAPE.

4. Conclusion

Day to day, monthly and seasonal variation of the three convective parameters, CAPE, LFC and equivalent temperature is examined during 2022 over Chennai using radiosonde data collected from Wyoming university Archive. CAPE is high in July 2022 in the Chennai station with a value of 5346 J/kg. Similarly, the Level of free convection has its maximum value of 925.6 m in January 2022. The relatively high value of the Equivalent temperature is 368.7 K, in May 2022. During pre-monsoon and monsoon CAPE rises and correspondingly equivalent temperature increases., thereby decreasing the altitude of LFC.

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