CHAPTER 4

CLIMATE AND COMFORT TRENDS IN CMA

4.1 INTRODUCTION

This chapter analyzes the climate and comfort trends in the CMA through air temperature, thermal comfort indices and their trends using the time series data based on urbanization.

The air temperature and comfort trends of the CMA were studied, using historic climate records from the two meteorological stations, Nungambakkam and Meenambakkam, located with in the study area for 20 years from 1988 to 2008. The air temperature and comfort trend analysis helps in identifying the urban climate trends of the CMA. Being close to the CBD, the climatic data from the Nungambakkam meteorological station is assumed as urban. The data from the Meenambakkam meteorological station is assumed as rural as it is an airport station located outside the city limits. (Refer figure 3.2 in chapter 3 for the location of the meteorological stations in the CMA).

4.2 AIR TEMPERATURE TRENDS

The UHI in the CMA was studied using the daytime and night time climatic records obtained from both the meteorological stations.
4.2.1 **Daytime temperature trends**

Figure 4.1 shows the daytime air temperature trends of the city and rural stations. The rate of increase in the daytime temperature is lesser in the rural station (0.02°C/year) than in the city station (0.06°C/year). The figure also reveals a significant increasing trend in the daytime temperature of the city station ($R^2 = 0.66$) when compared to that of the rural station ($R^2 = 0.21$). Both the stations show a similar trend till 2000 beyond which there is a steep decline at the Meenambakkam station. The trend after 2000 is attributed to the urbanization at the airport station, tending it to shift from the rural to the suburban / city station character.

4.2.2 **Night time temperature trends**

The night time temperature trends are shown in Figure 4.2. The existence of the UHI in the CMA is clearly evident through higher night time temperature at the city station when compared to that of the rural station. There is a significant increasing trend at the rural station ($R^2 = 0.22$) as against the trend at the city station ($R^2 = 0.06$) which is lesser. This is due to the fact that in the CMA, the scope for growth in the suburban limits is greater compared to that within the city limits. This conforms to the earlier findings of Emmanuel (2005a), which indicated the increase in air temperatures in the suburban stations.

4.2.3 **Diurnal Variations**

The diurnal variations reveal a peculiar characteristic as shown in Figure 4.3. In the past 20 years, the diurnal temperature (the difference between the annual average maximum and minimum temperatures) shows a significant increase in the city station (0.05°C/year, $R^2 = 0.61$).
Figure 4.1 Daytime air temperature trends

Figure 4.2 Night time air temperature trends
Figure 4.3 Diurnal temperature variations

This is contrary to the general concept of the UHI, usually indicated by reduced diurnal temperatures (Oke 1987, Emmanuel 2005a). Although, the city station experiences lesser diurnal temperatures compared to the airport station as observed by Oke (1987), Swaid and Hoffman (1990), Eliasson (1996) and Emmanuel (1999, 2005a) confirming the existence of the UHI in the CMA.

Further analysis reveals a significant decreasing trend at both these stations in the recent years (2002 – 2008). While the city station shows only a marginal decrease of $R^2 = 0.05$, the airport station shows a significant decrease of $R^2 = 0.52$. The decrease at the airport station is attributed to urbanization.

4.3 THERMAL COMFORT INDICES

The thermal comfort analysis is done using the Temperature Humidity Index (THI) and Relative Strain Index (RSI). The presence of the
UHI is confirmed by the air temperature trends, but they are not alarming. When the thermal comfort indices of urban and rural stations are compared, the trends are different and the UHI effect increases in the rural station.

### 4.3.1 Temperature Humidity Index

Figures 4.4 and 4.5 show the thermal comfort trend (Temperature Humidity Index) in the last 20 years. The daytime THI trend (Figure 4.4) indicates that both the city and the airport station are well above the upper limits of thermal comfort of 26°C (refer chapter 3 section 3.1.1.1). The daytime thermal comfort at the city station is better than that of the airport station. This is similar to the findings of Plumley (1977) and Emmanuel (1999, 2005a), that the thermal comfort conditions in the city station are better than that of the rural station due to the internal shading of buildings. But from 2003 onwards, the conditions are reversed indicating the behaviour of the airport station to be similar to that of the city station. This is attributed to the rapid urbanization around the airport station in the last decade that has altered the thermal comfort conditions significantly.

The daytime THI of the city station shows a significant increasing trend of $R^2 = 0.55$ exhibiting the thermal discomfort experienced in the city. The night time comfort level of the airport station is better than that of the urban station at present (Figure 4.5), but the trend indicates that it would reverse in the next few years. The significant increasing trend at the airport station reveals the increasing UHI effect. The anthropogenic heat released from the airport during the early hours of the day also contributes to this trend. Although, the night time comfort limit at these stations are well within 24°C indicating that 100% of the people are comfortable.
Figure 4.4 Daytime THI trend

Figure 4.5 Night time THI trend
Figure 4.6 Daytime RSI trend

Figure 4.7 Night time RSI trend
4.3.2 Relative Strain Index

The daytime and night time RSI trends are shown in Figures 4.6 and 4.7 respectively. The upper limit of comfort of the RSI is 0.3 (refer Chapter 3 section 3.1.1.2); whereas the RSI at both the city and the airport stations are around 0.4 indicating that 75% of the people would be distressed. Similar to the THI, the daytime RSI trends are highly above the upper limit of comfort. The RSI trends of the two stations reveal similar patterns till 2003, beyond which a distinct increase in the discomfort level of the city station is evident ($R^2 = 0.06$) when compared to the airport station. The night time RSI trends (Figure 4.7) at both the stations are generally at 0.10 indicating that the nights are 100% comfortable (refer Chapter 3 section 3.1.1.2).

4.4 IMPACT OF URBANIZATION ON THE THERMAL COMFORT TREND IN THE CMA

The impact of urbanization on the thermal comfort conditions of the CMA is analyzed by comparing the THI trends of the typical climate (before urbanization) and the recent climate (during rapid urbanization). The data from 1951-1980 is assumed as the typical climate (IMD, 1951-1980). A significant transition occurred in the air temperature and the thermal comfort trends from 2003 as seen in sections 4.2 and 4.3 and the data from 2003 to 2008 is considered as the recent climate. The transition is attributed to the effect of rapid urbanization observed during recent years in the CMA.

Figure 4.8 shows the comparison of the daytime thermal comfort of the typical and recent climate of CMA. The typical climate of the CMA during daytime has a high degree of thermal discomfort during most part of the year except the winter months of January and December, during which the THI is hovering around 26°C (the lower limit of 100% discomfort). But the recent climate of the CMA has turned out to be uncomfortable all through the
year due to the effect of rapid urbanization. The recent climate has shown an average increase of 1.1°C against the typical climate. Even the lowest THI recorded in the recent climate during the winter months of January is 1.5°C higher than the typical climate and 2°C above the lower limit of 100% discomfort (26°C).

The night time THI comparison of the typical and recent climates is shown in Figure 4.9. The increase in the night time (0.7°C) comfort limits of the recent climate with respect to the typical climate is not as significant as that of the daytime (1.1°C). Even though, the changes in the night time thermal comfort due to urbanization is a matter of concern. During night time, typical climate is uncomfortable for four months (April – July) in a year, while the recent climate is uncomfortable for six months (April – September) due to urbanization.

Figure 4.8 Daytime THI trend of the typical vs recent climate
Figure 4.9 Night time THI trend of the typical vs recent climate

4.5 FINDINGS

- The existence of the UHI is evident through the higher night time temperatures at the city station when compared to the rural station.

- Even though the city station shows increasing diurnal temperature contrary to the general concept of the UHI, the lesser diurnal temperature at the city station when compared to the airport station confirms the existence of the UHI.

- During daytime, the thermal comforts at both the stations are above the upper comfort limit indicating the increasing discomfort. The percentage of people feeling uncomfortably hot during the day is 100% as per the THI and 75% would feel distressed as per the RSI.
• During night time, the thermal comfort in the CMA is around 24°C (the upper limit of 100% comfort) according to the THI and 0.10 (100% comfortable) according to the RSI.

• The recent climate shows an increase in the THI values by 1.1°C during daytime and 0.7°C during night time with respect to the typical climate, attributed to the impact of urbanization.