

## Study of Atmospheric Boundary Layer Characteristics Over Mumbai -A West Coastal Mega City In India



### PHYSICS

**KEYWORDS :** Atmospheric boundary layer, troposphere, geostrophic, surface inversion, aeronautic meteorology, evapotranspiration etc.

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### ABSTRACT

*Atmosphere as varied and vast as the universe itself is a natural phenomenon all pervasive. The process of atmospheric studies has been there ever since the existence of human race. From ancient times when men were living in caves looked up at the skies in anticipation till the modern times of prediction, atmosphere continues to be an area of serious studies and boundary layer knowledge is important in atmospheric related studies. With the same spirit, the present paper attempts a "Study of Atmospheric Boundary layer characteristics over West Coastal Mega City in India."*

*This paper is concerned with the study of atmospheric boundary layer characteristics during South-West Monsoon in the selected mega city. The study is done by taking the surface data and upper air data collected from Indian Meteorological Department. In surface data analysis, meteorological parameters such as temperature, relative humidity, wind speed and wind direction are taken to study the said characteristics and the same meteorological parameters profiles are used for upper air data analysis.*

*Also the study of specific characteristics of atmospheric boundary layer during North-East Monsoon. The surface and upper air data of the selected mega city obtained from Indian Meteorological Department is used for the purpose of study. Though similar meteorological parameter profiles are employed, the conclusive results arrived at vary as the study is carried out during different periods of time.*

### INTRODUCTION:

The lowest layer of the atmosphere is called the troposphere. Stull<sup>(1)</sup> defines the atmospheric boundary layer as "the part of the troposphere that is directly influenced by the presence of the earth's surface, and responds to surface forcings with a time scale of about an hour or less." In this layer physical quantity such as flow velocity, temperature, moisture etc display rapid fluctuations and vertical mixing is strong. Above the atmospheric boundary layer is the free atmosphere where the wind is approximately geostrophic while within the boundary layer the wind is affected by surface drag and turns across the isobars.

According to Jacobson<sup>(2)</sup> during the day, the boundary layer is characterized by a surface layer, a convective mixed layer and an entrainment zone. The surface layer is a region of strong wind shear that comprises the bottom 10% of the boundary layer. Since the boundary layer depth ranges from 500-3000m, the surface layer is about 50-300m thick. Other features of the day time boundary layer are the cloud layer and sub cloud layer. A region in which clouds appear in the boundary layer is the cloud layer and a region underneath is the sub cloud layer<sup>(3,4)</sup>. A cloud forms if rising air in a thermal cools sufficiently. An inversion may prevent the thermal from rising past the mixed layer. During the night, the surface cools radiatively, causing temperatures to increase with height from the ground and creating a surface inversion<sup>(5,6)</sup>.

### GEOGRAPHICAL FEATURES OF MUMBAI

Mumbai is situated on west coast of India with latitude 18° 15' N longitude 72° 52' E has been a major centre of industrial and economic activities. The city of Mumbai has witnessed rapid urbanization, increased industrial activity and massive growth in population during last twenty two years. As a result, city has grown into a mahanagar of 430 sq. km. It is now an urban octopus whose tentacles encompass towns outside the municipal limits, like Thane, Kalyan etc.,

### THEORY AND METHODOLOGY OR NEED AND OBJECTIVE OF THE PRESENT WORK:

The atmospheric boundary layer plays an important role in many fields, including air pollution and the dispersal of pollutants, agricultural meteorology, hydrology, aeronautic meteorology, mesoscale meteorology, weather forecasting and climate.

Air pollution problems in the mega city are due to increase in local atmospheric and surface temperatures inside the city compared to the surrounding rural areas, this is also called as urban-heat island effect<sup>(7,8)</sup>. This effect is primarily due to the concentration of human activities and land surface changes. Specifically, surface and atmospheric temperatures are increased by anthropogenic heat discharge due to energy consumption, increased land surface coverage by artificial materials having high heat capacities and conductivities, and the associated decreases in vegetation and water surfaces, which reduce surface temperature through evapotranspiration<sup>(9)</sup>. The individual contributions to the resultant temperature rise must be clarified in order to mitigate the urban heat-island effect. Simply comparing the temperature in an urban area to that surrounding rural area is not an adequate means of analysis because the temperature rise associated with the heat island effect is the result of a complicated interaction between the above mentioned causes. The heat balance for both rural and urban surfaces must be analyzed in order to quantitatively investigate the individual contributions to this temperature increase. Hence most important mega cities in India which are severely affected by air pollution are considered in the present study.

The meteorological parameters like temperature, relative humidity, mixing ratio, wind speed and wind direction play an important role in understanding the atmospheric boundary layer and its impact on urban climate and pollution concentration in mega cities. The behavior of atmospheric boundary layer is different during South-West and North- East monsoon. During South-West monsoon due to high temperatures in summer the convective processes are responsible for the transport of heat and moisture from surface to the atmosphere above<sup>(3,4)</sup>. They are among the major factors, which bring variability in the weather. During North-East monsoon in winter season high concentrations of pollutants are observed in mega cities of India, since less solar radiation is received by the sun and due to this situation the pollutants are trapped in the boundary layer and hence affect the weather and climate in the atmospheric boundary layer. Hence in the present work the characteristics of atmospheric boundary layer are studied by analyzing the diurnal variation and vertical structure of temperature, relative humidity, mixing ratio, wind speed and wind direction during South-West and North-east monsoon seasons. The pollution levels in the cities of India have exceeded the WHO air quality guidelines<sup>(5,10)</sup>. Hence these mega cities have been considered for the study.

**DATA BASE:**

Surface and upper air data over Mumbai, a west coastal mega city is collected from Indian Meteorological Department (IMD), Pune. The data is taken for a period of 10 days starting from July 1<sup>st</sup> to July 10<sup>th</sup>, 2006 during South-West monsoon and December 1<sup>st</sup> to December 10<sup>th</sup>, 2006 during North-East monsoon at 5:30 hrs and 17:30 hrs respectively.

**ANALYSIS AND RESULTS:**

Results of the analyzed study show the differences in the behaviour of meteorological parameters during South-West and North-East monsoon as shown in figure 1 and figure 2. Following are the discussion and comparison between two monsoons in the selected city.

During South-West monsoon the maximum temperature is 30°C on 6<sup>th</sup> July and minimum temperature is 22°C on 4<sup>th</sup> July whereas during North-East monsoon the maximum temperature is 33°C and minimum is 22°C. Not much difference is observed between both the monsoons. Similarly with relative humidity the maximum during both the monsoons is 95% and 85% and minimum relative humidity is 65% and 26%. During North-East monsoon the relative humidity is observed as 26% between 13:10hrs and 17:10hrs when the temperature is observed high i.e., 33°C. The temperatures are less in Mumbai during South-West monsoon i.e., a difference of 10°C is observed in temperature, which further reduces the wind speed i.e., 7.8m/sec and during North-East monsoon the wind speed is observed maximum on December 1<sup>st</sup>, 2<sup>nd</sup>, and 3<sup>rd</sup> i.e., 5m/sec. On all days wind direction is observed as southwesterly and northwesterly during South-West monsoon and again on all days winds are northeasterly, easterly and southeasterly except on December 1<sup>st</sup> and 7<sup>th</sup> northwesterly during North-East monsoon. The vertical profile of temperature during the South-West monsoon shows that the inversion layer is less than 1km on July 1<sup>st</sup> to 3<sup>rd</sup> at early morning 5:30hrs and 17:30hrs on July 7<sup>th</sup> to 10<sup>th</sup> in the evening at 17:30 hrs the mixed layer height is less than 3km. During North-East monsoon the height of the mixed layer is less than 500m in the early morning on all days and in the evening it is around 2km. Here also the mixing ratio profile shows that increase in temperature also increases the mixing ratio and vice versa. The relative humidity is observed maximum i.e., 90% to 100% sometimes in the lower levels of the atmosphere on all the days during South-West monsoon. During North-East monsoon the relative humidity decreases with respect to height up to a few meters in the early morning and increases in the evening hours.

**CONCLUSIONS:**

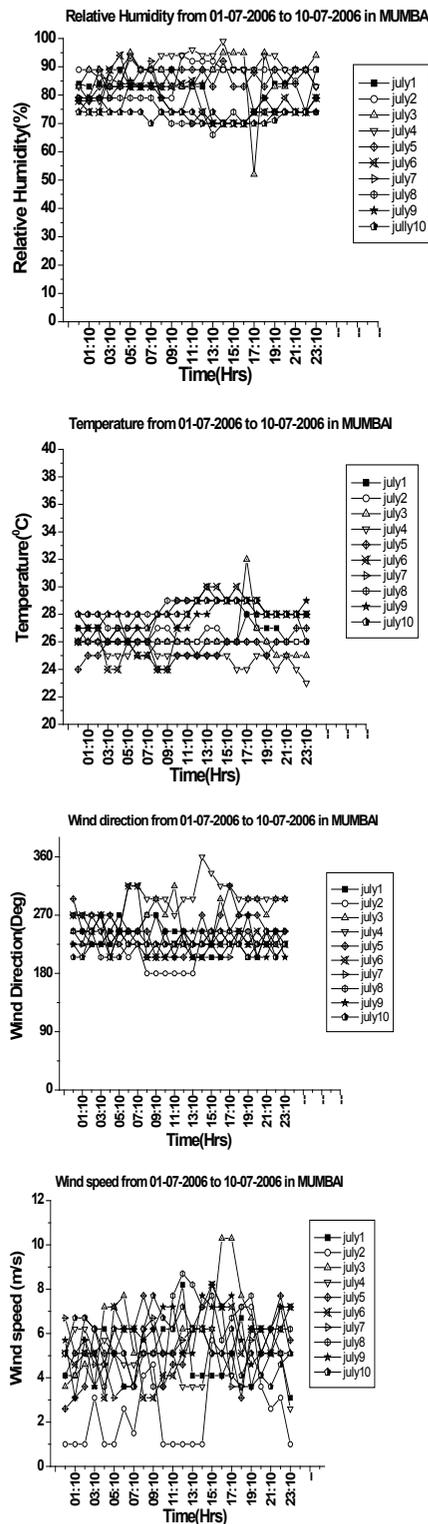
The behavior of atmospheric boundary layer is different during South-West and North-East monsoon since during South-West monsoon due to high temperatures in summer the convective processes are responsible for the transport of heat and moisture from surface to the atmosphere above. They are among the major factors, which bring variability in the weather. During North-East monsoon in winter season high concentrations of pollutants are observed, since less solar radiation is received by the earth and due to this situation the pollutants are trapped in the boundary layer and hence affect the weather and climate in the atmospheric boundary layer.

**In the present work it is concluded that**

- The trends shown by the various meteorological parameters in the atmospheric boundary layer are not uniform in the selected Mumbai mega city.
- In general as solar radiation increases the temperature of the land increases and due to different surface homogeneities in the mega cities like industries, tall buildings parks and more vehicle usage the differential temperature is observed inside the city where as surrounding the mega cities i.e., at suburban areas the temperature is minimum compared to that inside the city. It is known from many scientific studies that there is a difference of 6°C between the temperatures inside and outside the city. Due to this temperature difference, there will be difference in pressure and further due to difference in pressure i.e., high and low pressure winds started varying through out the day, which

is evident from our studies. This resulted in the change of wind direction.

- Orography, the density of population, the distance between the tall buildings, vehicular pollution and the industrial development played an important role in controlling the climate of mega city.



**Figure.1 Diurnal Variation of Temperature, Relative Humidity, Wind speed and Wind direction at the surface in MUMBAI during South-West monsoon**

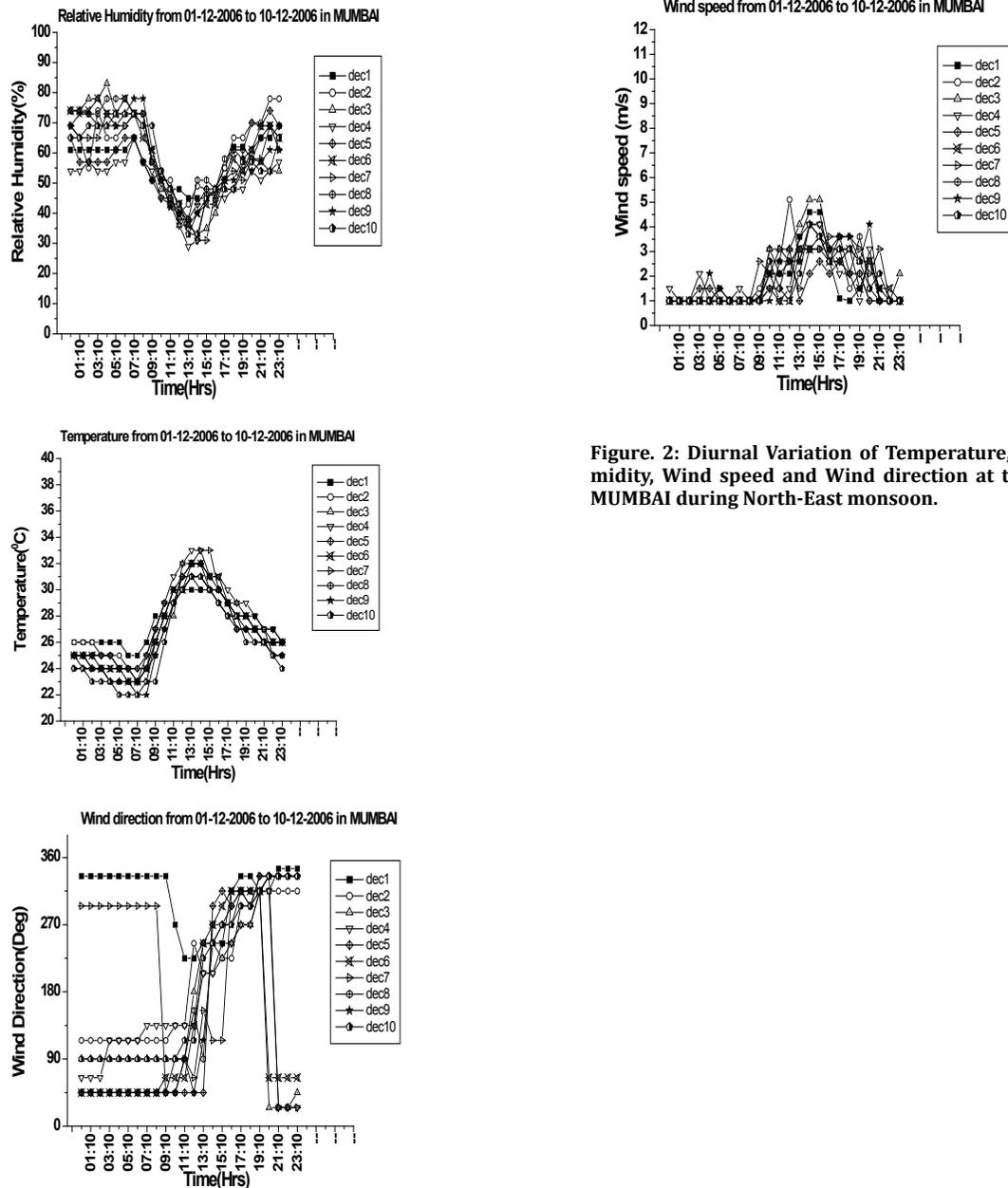


Figure. 2: Diurnal Variation of Temperature, Relative Humidity, Wind speed and Wind direction at the surface in MUMBAI during North-East monsoon.

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