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Micrometeorological Tower Observations and their Importance in Atmospheric Modelling and Space Technology

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Abstract

Background/Objectives: The assessment of turbulence parameters is important for understanding the heat, momentum exchange and pollutant dispersion at any given site. **Methods/Analysis:** Continuous micrometeorological data were collected at SRM University, Kattankulathur (12° 48' N to 12° 49' N; 80° 02' E to 80° 03' E) a suburban area near Chennai by a 16 m meteorological mast. Data with conventional sensors were obtained for wind, temperature, and humidity from August 2010 to March 2015. **Findings:** The gradient observations were analyzed to explore the atmospheric surface layer parameters and were used in atmospheric dispersion modeling. Wind and temperature data were analyzed to understand their diurnal and seasonal variations. The inter-relationships of temperature and wind patterns were studied and the diurnal variations of temperature and wind profile were plotted for a particular month during study period to assess the climate pattern of this study period. This study may play a vital role in atmospheric modeling and also in space vehicle launching.

Keywords: Micrometeorological Data, Turbulence Parameters, Wind Energy

1. Introduction

Growing urbanization and developmental activities are among the causes of increase in environmental pollution. Industrial growth, population expansion and increase in vehicular traffic lead to increase in air pollution and other adverse environmental impacts. The consequent changes in land cover and topography also lead to alteration in the land–atmosphere energy exchange processes and modification of the local climate[1]. An assessment of these changing local climate parameters requires site specific micro-meteorological data covering the lower atmosphere. The Atmospheric Boundary Layer (ABL) is the region of the atmosphere that is directly influenced by the earth's surface where friction, surface heating and turbulence generation are the dominant atmospheric physical processes[2]. Micrometeorology deals with the atmospheric processes at the microscale level. The predominant influence in the atmospheric boundary layer is the friction. Micro-meteorological towers equipped with conventional wind, temperature and humidity sensors provide the basic data required in the analysis and characterization of the surface boundary layer of the atmosphere[3]. The continuous observations from such towers provide valuable information on the local scale turbulence. Often such towers are widely used in experimental campaigns to characterize the surface friction, exchange of radiation, energy and water vapor quantities in the ABL. A few micrometeorological experiments were conducted in India with a view to understand the low-level monsoon atmospheric processes over land include the Monsoon Trough Boundary Layer Experiment (MONTBLEX)[4] and the Land Surface Processes Experiment (LASPEX)[5]. A 16 m meteorological tower was installed at SRM University campus in collaboration with Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam for studying atmospheric dispersion phenomena across the Kalpakkam coast. A multi-institutional collaborative program called RRE (Round Robin Exercise) with the objectives of validating the atmospheric flow-field and

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dispersion models in the mesoscale region around the tropical coastal site Kalpakkam was conducted in the period 2010–2011[6,7]. As part of this program, a small scale micro-meteorological field experiment was conducted for generating data on wind and turbulence at a number of locations in a 100-km radius around Kalpakkam station by deploying a large number of instruments in the study domain[8-10]. The Kattankulathur station is one of the sites in the observation domain situated about 40-km from Kalpakkam coast. The study location, Kattankulathur, is situated in the semi-arid climate zone of southeast peninsular India. Although many studies are reported from other stations in India, relatively few studies have been conducted in southeastern India to characterize the atmospheric surface layer using micro-meteorological observations[11-13]. In this paper, an attempt has made to characterize the atmospheric surface layer properties at the suburban site Kattankulathur by analyzing the multi-level wind and temperature data collected during monsoon and winter seasons between August 2010 and March 2011. The surface layer parameters were evaluated using surface layer similarity theory and their variability was studied[14,15].

The objectives of the study are: 1. to analyze and characterize the surface layer parameters over the suburban semi-arid station Kattankulathur, and 2. to analyze the temporal variation in the parameters.

1.1 Description of the Site Characteristics

The study area is the SRM University campus which is located at Kattankulathur, about 40 km from Chennai (12° 48' N to 12° 49' N and 80° 02' E to 80° 03' E). It is a semi-urban site with mixed scrubs, grasses, crop-lands and built-up land features. The soils are mixed silt, silt loam, sandy clay type. The average minimum and maximum temperatures are 20 and 37 °C. In the day time during peak summer, the temperature can go as high as 43°C. The normal annual rainfall varies from 1105 mm to 1214 mm. The rainfall is received mainly during the winter northeast monsoon starting in October and from a number of low pressure depressions in November–December. The region surrounding the tower is fast growing in terms of infrastructure as it abuts a major national highway; there are many industrial and residential clusters within a few kilometers radius. This is a potential cause for the presence of air pollutants in the area[16].

1.2 Micrometeorological Observations

A 16-m tall meteorological was installed in the SRM University campus for continuous and automated measurements of micrometeorological parameters. The tower is installed on a plain ground with least obstructions in all directions to obtain unbiased observations. The instruments to measure the parameters consist of three-cup anemometers for wind speed, wind vane for wind direction, and probes for air temperature and relative humidity. Meteorological data collected from August 2010 to March 2015 were used in the analysis. The wind speed and direction were measured using anemometers at 2 m, 4 m, 8 m, and 16 m levels and wind vanes at 2 m and 16 m. Temperature was measured with resistance thermometers at 2 m and 10 m. Air pressure is measured using an aneroid capacitance sensor at 2 m. The data was screened to remove anomalies and hourly averages were calculated. The data was sampled at five minutes interval, averaged over 60 minutes and stored in the data logger[17].

2. Material and Methods

The wind data was analyzed through NRG software and WRPLOT. Temperature and wind profiles for daily and monthly variations were analyzed with the observed wind speed at 16 m and variation in the wind speeds up to 100 m height was analyzed[18-20].

3. Results and Discussion

3.1 Mean Meteorological Parameters

First, the mean meteorological quantities observed at different measurement levels at the site are presented. Wind speeds were measured at 2, 4, 8, and 16 m levels and temperatures measured at 2 and 10 m levels. The average wind speeds and standard deviations for the twelve months are shown in Figure 1-5. The maximum and minimum temperatures values were provided in Figures 6-10. The variation in wind speed is high especially at the higher levels. The wind speeds reduce at the lower levels consistently for all the months. The wind speeds at the 2 m, 4 m, and 8 m levels were 75%, 64%, and 49% less than that at 16 m on average during the study period. The occurrence of relatively stronger winds at higher levels can be attributed to the increase in turbulence at lower levels due to surface friction and the development of resulting shear forces.

The maximum wind speeds at all levels remained more or less constant from August through October. They were the highest in November and again reduced in December, probably due to the transition in the wind patterns from northeast monsoon to easterlies. Average wind speeds were the highest in January and started reducing in February. Along the coast, wind speeds are lower when the wind is from south/southwest direction (over land) and higher when the winds are from east (over water). The same trend was also noted in the standard deviations of wind speed in all the months. The standard deviation is about half the mean wind speed at any given height. Figure 3 shows the maximum winds in different months. The maximum wind at the site is found during October-November months in the northeast monsoon. The minimum winds occurred on March 11. There is a large difference in the observed maximum wind speeds at different heights during August-October period and the winds at different heights converge in the subsequent period. The large differences in winds in the August- October season may be due to larger shear associated with monsoon flow. The observed vertical variation of winds at the experimental site indicates the normal phenomena of downward transport of momentum due to friction and generation of shear turbulence. Figures 6-9 illustrate the vertical variation of average, maximum and minimum temperatures at two levels 2 m and 10 m Above Ground Level (AGL). The temperatures at the two levels also remained almost the same till October, and then saw a gradual decline. The temperatures again started increasing by February, after the end of the monsoon season in January. The average and maximum temperatures at 2 m were higher than those at 10 m by almost a degree, due to the influence of the land surface. The relatively higher temperatures at bottom most layer relative to the upper layers indicates an upward transport of heat. The highest temperatures were in August and lowest temperatures during December in winter as expected. A difference of roughly 2°C is found in the average, maximum as well as minimum temperatures between 2 m and 10 m levels in most months except during winter (December–February) when the temperature gradient reduced to 1°C. The temperature difference is quite large in the 2–10 m layer and denotes the occurrence of steep lapse rates denoting highly unstable conditions during most time of the year and the lesser gradients in winter indicate relatively stable conditions at the site.

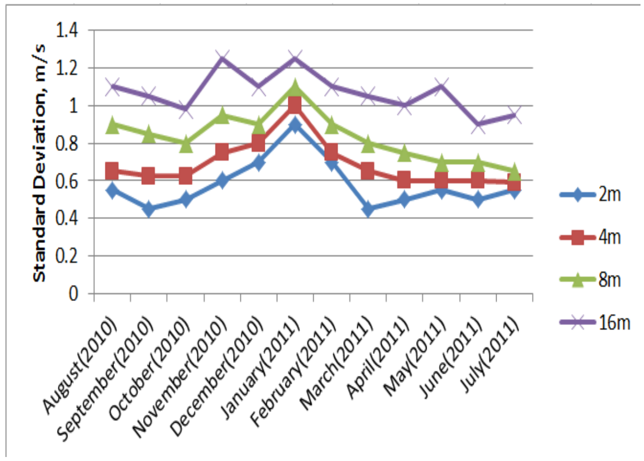

Figure 1. Fluctuations in wind speed for the year 2010, 2011.

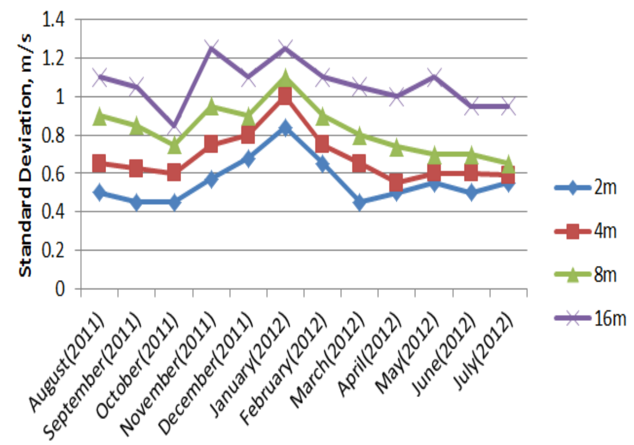

Figure 2. Fluctuations in wind speed for the year 2011, 2012.

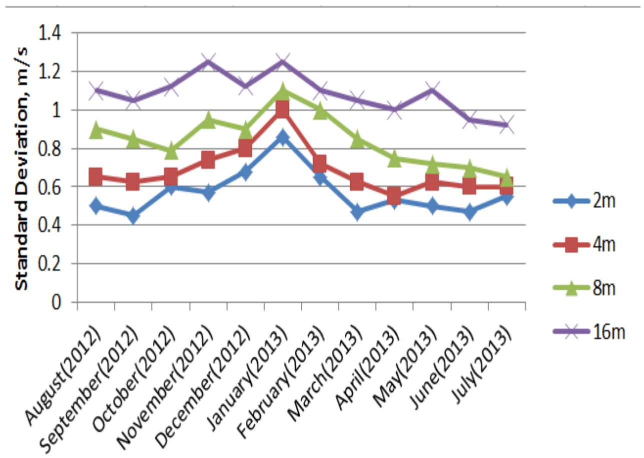

Figure 3. Fluctuations in wind speed for the year 2012, 2013.

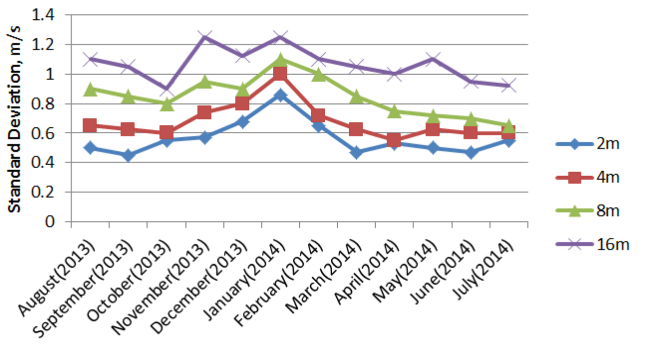

Figure 4. Fluctuations in wind speed for the year 2013, 2014.

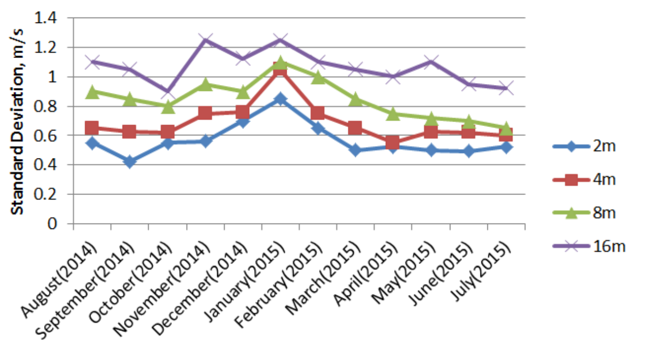

Figure 5. Fluctuation in wind speed for the year 2014-15.

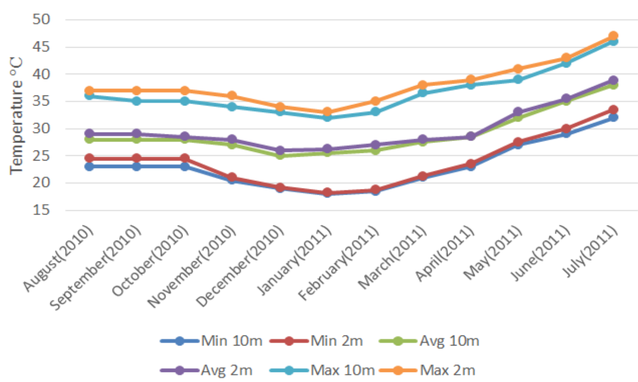

Figure 6. Fluctuations in Temperature for the year 2010-11.

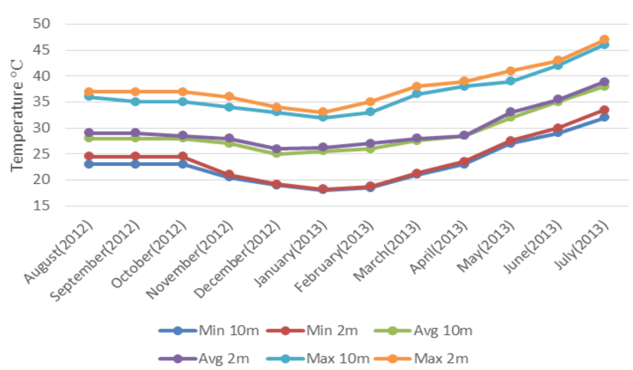

Figure 7. Temperature fluctuations at different seasons for the year 2012, 2013.

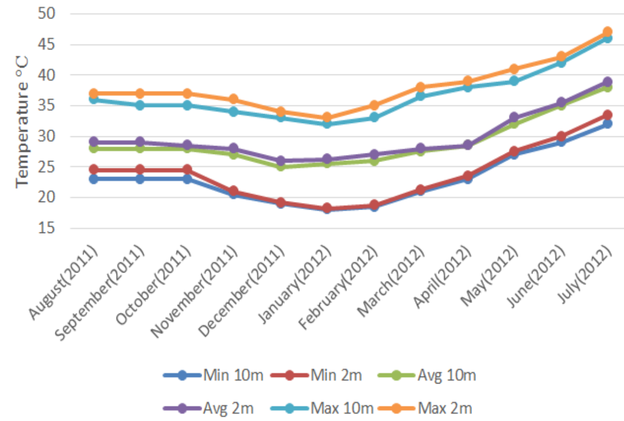

Figure 8. Temperature fluctuations at different seasons for the year 2011, 2012.

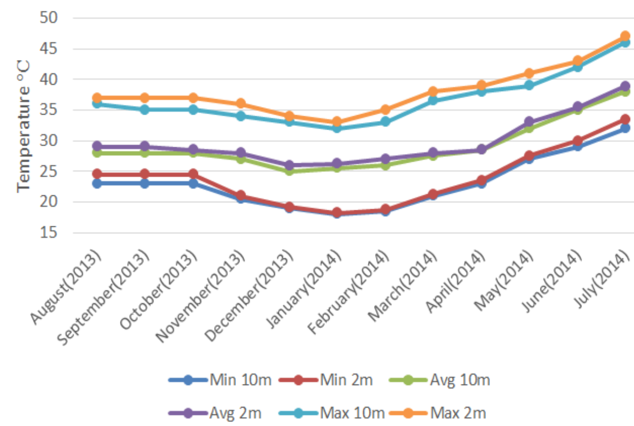

Figure 9. Temperature fluctuations for the year 2013, 2014.

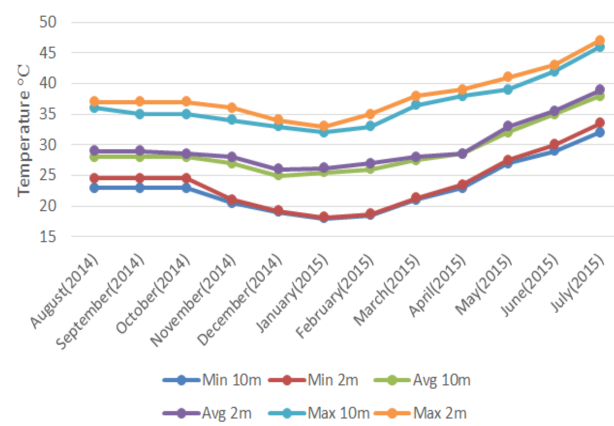

Figure 10. Temperature fluctuations for the year 2013, 2014.

3.2 Diurnal Variations

The diurnal variations of wind and temperature averaged over each month are calculated and presented in Figure 11 for August 2010 data as an example. In August, the maximum speed was less than 3 m/s. High winds occurred between 09:00 IST and15:00 IST with the peak around 10:00 IST. Low speeds at 06:00 IST and 20:00 IST. The temperature peaked between 13:00 IST and 14:00 IST and the lowest temperature was at 06:00 IST –07:00 IST. Figure 11 shows the time periods of peaks and lows of the winds. While the wind peaked in the morning in August, it shifted by September and peaked for a longer duration after noon time till December. Low winds occurred early in the morning around 06:00IST till November and shifted to a longer low wind period after midnight in December. All the months experienced a second low wind at night between 19:00 IST and 22:00 IST. The winds had a more complex pattern in November with more variation through the day. The peaks occurred between noon IST and 18:00 IST, with prolonged high speeds through the entire afternoon. There were three peaks – around noon IST, at 15:00 IST and around 17:00 IST. The peak temperature reduced by almost 2 degrees compared to the previous months. The temperature also showed more variation in the later part of the day. The maximum temperature in December reduced by almost 2.5 degrees compared to November values.

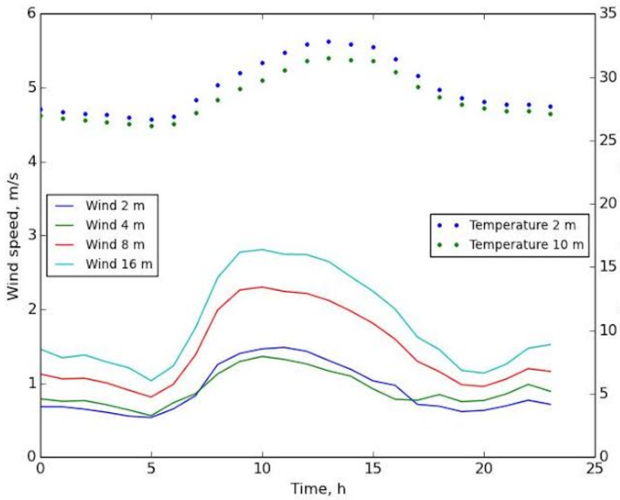

Figure 11. Diurnal variation of wind speed and temperature at different altitude.

4. Conclusion

Meteorological data collected through a 16-m observation tower near Kattankulathur were analyzed and turbulence parameters were calculated. The wind speeds at the 2 m, 4 m, and 8 m levels were 75%, 64%, and 49% were less than that at 16 m on average during the study period. Average wind speeds were the highest in January and started reducing in February. The highest temperatures occurred in August and the lowest temperatures in December. The temperature difference is quite large in the 2–10 m layer and denotes the occurrence of steep lapse rates denoting highly unstable conditions during most time of the year and the lesser gradients in winter indicate relatively stable conditions at the site. Between August and March, the resultant wind shifted clockwise from a westerly to an easterly direction. In January the occurrence of calms increased to a maximum. Winds are highly fluctuating at both the 2 and 16 m levels especially during the convective daytime, with stronger winds at 16 m relative to 2 m.

5. Acknowledgement

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