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Wind Direction Dependent Vertical Wind Shear and Surface Roughness Parameterization in Two different Coastal Environments

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Abstract: ***Analysis Surface Boundary Layer parameters (SBL) of wind direction dependent vertical wind shear, surface roughness lengths and surface layer wind conditions has been carried out at a coastal and an urban coastal site for the different wind flow regime. The analysis is carried out from the profile of meteorological data collected from 50m towers at Satayabhma University and Ediyur, Kalpakkam sites during the year 2013. Vertical exchange of heat, moisture, and momentum at the earth's surface strongly depends on the turbulence generated by surface roughness and topography. The differential response of the near coastal and inland urban site SBL parameters (wind shear, roughness length, etc.) was examined as a function of wind direction. Site specific surface roughness parameter can be estimated; derived experimentally or calculated using measured data for roughness parameterization studies.***

Keywords: Coastal site, Roughness, Wind Shear, SBL, Parameterization.

1. Introduction

The lower part of the atmosphere where we live is directly influenced by locally generated turbulence exchange processes which can develop an individual local climate, different to the expected average conditions. Analyzing the interactions between the environment and the atmosphere on a local scale is much more complicated than looking at the same system on a meso-scale. The sea-land breeze is a meso-scale phenomenon (Oke2005) specific to coastal environments. Especially in coastal urban areas the great variety of different surfaces and sheltering obstacles produces a pattern of distinct microclimate systems. The local vegetation and aerodynamic characteristics on land surface directly affect the transport of energy and substances between land surface and atmospheric boundary layer. Thus the subject of every kind of process on land surface becomes important (Stull, 1988; Weingara 1993; Masao, 1997). Atmospheric boundary layer parameters and surface layer parameterizations are important in air pollution dispersion analysis. Many pollution sources and their dispersion occur within the roughness surface layer in the lower atmosphere. A better understanding of the flow within the roughness sub layer will help in the interpretation of the data obtained from all levels within the urban, coastal complex environments. Aero dynamic roughness parameter is used to describe the degree of roughness of the earth's surface. The roughness length is important in determining wind shears over a surface, and influences mechanical turbulence development in the PBL. A high roughness length increases surface friction and this increases vertical turbulent mixing and wind shear. Roughness length is strongly dependent on wind direction as upstream topographic features are more relevant to local turbulence and horizontal winds. In complex terrains, however the topography and the non-uniform land use around the measurement point affect the winds and turbulent characteristics. To examine these local systems and site specific surface atmospheric parameter estimates, micro scale observational network is needed. In this study surface layer wind shear profile and roughness parameters are examined as function of wind direction in urban coastal site of Sathyabhama University and near coastal site at Ediyur, Kalpakkam using data from 50m meteorological tower measurements. The choice of a representative value of the roughness length (z0) is a key aspect to estimate the momentum flux in the lower atmosphere layer by means of traditional micrometeorological methods. Two types of wind profile laws are frequently used in the atmospheric surface-layer: the theoretically derived logarithmic profile with corrections for non-neutral thermal stratification and the empirically derived power law (J.F.Manevell,2010). The need for the establishment of the variable power law indices α which are site specific and are critical in wind speed calculations is often emphasized (Ray, et.al, 2006). This study undertakes an analysis of data from multilevel meteorological instrumentation within the roughness sub layer using ten minutes averaged observational data collected at the Kalpakkam Ediyur site (near coastline) and Satyabhama university campus site (urban, coastal site) during summer, south west monsoon (SW) and North East monsoon synoptic period for the year 2013.

2. Background

2.1 The vertical wind speed profile and winds shear

The atmospheric surface layer closest to the earth, whose height typically ranges from 2-2000 m above the ground is influenced by contact with the earth's surface. The lowest 10% of the ABL, called the surface layer is where turbulence and friction drag from the ground are the most significant effects (Huschke, 1989). The surface layer of the ABL has been studied extensively due to its accessibility and importance, as all human life resides in this layer. Observed characteristics of these studies were often consistent and were used to form the basis of the similarity theory principles that are used today in defining the behaviours of vertical wind profiles within in ABL (Stull, 1988). Specific scaling relationships (such as the Monin-Obukhov similarity theory) were developed for the surface layer and subsequently proven to be accurate when the winds are not calm, and in heights between 10-200 m above ground (Panofsky et al., 1977). These similarity relationships began to function as the foundation for the scientific study of the most significant feature of the surface layer for wind energy developers and air quality managers. Two kinds of models are most widely used in practice: the logarithmic and the power law models. They have been applied in studying the transport and dispersion of air pollutants (Strom 1976; Touma 1977; Irwin 1979; King 1982; Panofsky and Dutton 1984; Stern et al. 1984; Carney and Dodd 1989; Juda-Rezler 1989). Determination of values for the exponent in the power law model has also been the topic of much research (Sutton 1953; Strom 1976; Irwin 1979; Touma 1977; Simiu and Scanlan 1978).

Empirical studies using Monin-Obukhov similarity relationships revealed that wind speed variation with elevation in the surface stratum of the ABL can often be accurately identified by a logarithmic decay curve in neutral atmospheric conditions (Oke,1987). When wind speeds are plotted against the natural logarithm of height, In (z), the profile approximates a straight line. This provides the theoretical basis of the logarithmic wind profile, or Prandtl-von Karman equation. The logarithmic law is expressed as based on a logarithmic wind profile governed by the terrain surface roughness length z_0: The equations used by the model to calculate mean wind are those of similarity (Panofsky and Dutton, 1988):

$$\bar{u} = \frac{u_*}{k_a}\left[\ln\frac{z}{z_0} - \psi_m\left(\frac{z}{L}\right)\right] \qquad (1)$$

where, U_* is the scale velocity related to mechanical turbulence, Ka the von Karman constant and Zo is the ground roughness. Ψm is the stability function (Ψm =1 for neutral stability).

The similarity expression is utilized within the surfer layer. Alternatively, the wind speed profile can be described by a power law expressed as follows (Panofsky and Dutton, 1988):

$$\frac{\bar{u}_z}{\bar{u}_1} = \left(\frac{z}{z_1}\right)^n \qquad (2)$$

where uz and u1 are the mean horizontal wind speeds at heights Z and Z1 respectively and ‘n’ is an exponent that is related to the intensity of turbulence(Irwin,1979).
The power law function has the following form

$$u = b1Z^{b2} \qquad (3)$$

where *u* is the wind speed at any reference height Z and *b1* and *b2* are fitting coefficients. The term *b2* is the power-law exponent, which depends on surface roughness and atmospheric stability.

The wind shear exponent is used in connection with the assumption of a power-law wind profile:

$$U(z) = U_r\,(z/z_r)^{\alpha} \qquad (4)$$

Where Ur and Zr is the reference wind speeds and measurement height and n is the power law or wind shear exponent. The power law fits well the diabatic vertical wind speed profile, particularly when Eq. (4) is used locally. In order to compute a mean shear profile the function a sequence of speed series and a sequence of measurement heights is used. Then it computes the mean speed of each series over the common time steps and fits a power function using the equation (3) gives exponent b1, the coefficient b2. The number of common time steps and the computed means at each height and compare the fitted power function with observed means (Hogstrom (1988) method is used to approximate the wind profile using a second-order polynomial and fitted parameters determined by a least-squares method). As the wind shear and mean speed varies across directions, the wind shear estimated for each direction sector using the mean shear profile function. In order to extrapolate your data from measured height to another height you can apply the corresponding power law exponent to each speed value. The observed and calculated reference shears are compared by linear fitting and R is can be estimated at the best coefficient of determination. Finally the shear extrapolation takes speed, direction, measurement height, destination height and the exponents for each direction sector and gives the extrapolated speed.

2.2 Roughness Length

Over most natural terrain, the surface cover is not uniform and changes significantly from location to location. While atmospheric pressure gradient forces are the major control of wind speed and direction in the ABL, winds near the ground are heavily influenced through frictional drag imposed by surface roughness (Oke,1987). This frictional drag cause’s turbulence, giving rise to a sharp decrease in wind speed as the underlying surface is approached. The height at which this frictional drag influence is felt is related to the size and distribution of the underlying surface elements. Theoretically, z0is defined as the height in meters above the ground at which the mean wind speed becomes zero when extrapolating the logarithmic wind speed profile downwards through the surface layer (Huschke,1989). As z0 is observed to increase with the average height and spacing of individual elements of the ground cover, such as trees or houses, it is often defined in this fashion (Jackson, 1980). An alternative but related definition suggests that z0 is the size of turbulent eddies on the ground surface created when winds are disrupted by items on the surface; where larger z0 values indicate larger eddy mixing, and likely larger surface objects (Panofsky and Dutton, 1984). There are numerous ways for the z0 calculation. There are two classes of these methods: (i) micrometeorological (or anemometric) and morphometric (or geometric) methods.

Roughness length has commonly been estimated for local sites from vertical wind profiles and micrometeorological theory. Average wind speed increases as the height increases.

Frictional forces play an important role when dealing with wind speed profile. In fact the frictional forces are caused by the surface layer of earth which is called roughness length. The common profile to represent wind speed in atmospheric boundary layer profiles is logarithmic profile. The influence of z0 on the logarithmic wind profile is significant. When z0 is small, the wind profile increases rapidly with height over a short length, and then is relatively stable above that height. When z0 is large, the profile has a slow and smooth increase with height (World Meteorological Organization, 1981).

Two methods are considered here: the first requires observations of mean wind speed at multiple levels; the second wind speed (*U*) and the standard deviation of wind speed at one level (S. B. Grimmond.et.al, 1998). Given the logarithmic wind profile equation, and using the D and slope (*u/k)* value with the wind speed at one level, *z*0 and *zd* can be determined. Since the turbulent fluxes are proportional to the square of ln(z0),values of the natural logarithm of the aerodynamic roughness length, ln(z0), are used for Zo analysis. Power law derived wind shear power law component is related to z0 by the Equation (9), An alternative method introduced by Beljaars (1987) can be used to calculate z0 from the standard deviation of the wind speed, as σu/u is directly proportional to the degree of surface roughness in neutral atmospheric stability. This technique is often used with hot-wire quick response anemometers (Liu et al., 2003) or sonic anemometers (Martano, 2000). Counihan, 1975 presents several roughness characteristic parameters and their correlation with the roughness length. Also, the roughness length is an adequate parameter to characterize the intensity of turbulence profile. In particular, the longitudinal turbulence intensity vertical distribution could be guess in the form with σ the root mean square of the velocity fluctuations. If one knows or have estimated α or zo, but still wants to use other relationship the formula (10) can be used ,giving deviations of only few percentage for standard deviations. A relationship between surface roughness and exponent α (Freris, L.L, 1990) is given by the following equation:

$$Zo = 15.25 \exp(-1/\alpha) \qquad (5)$$

This prediction is accurate within a few percentages over the range of roughness lengths of interest. It is important to note that the power law has no theoretical foundations; however, it is often used by engineers. Using one or the other form, to find the mean wind speed distribution, one has to solve the task of estimating roughness parameters or wind shear coefficient. As the hourly mean wind speeds are themselves strongly dependent on the wind direction and the season of the year. Roughness length and wind shear profile for different wind directions as being analyzed for different season over the site.

A number of models were subsequently developed to predict the influence of a change in roughness lengths in the wind profile over fetch distances, which were then incorporated into larger meso-scale wind flow models (Jensen, 1978; Taylor, 1970; Walmsley et al., 1986; Yu et al., 2006).

3. Sites and Measurements

Two types of sites are considered in this analysis –near coastline, and inland coastal urban site are depicted in Figure.1. The near coastal site Ediyur -Kalpakkam is on the coastline (12.23N, 81.102E) and is surrounded by fields and marshland in the west and forest field in a NE direction and industrial building in far south directions. Inland urban coastal site located in Satyabhama University (12.23N, 81.102E). The tower location categorized as a costal urban site. There were few vegetation cover near the tower site and surrounded by industrial and academic buildings in East and South side. To the west and southwest is a residential area.

Figure 1: An aerial photograph of near-coastline site (Ediyur site, Kalpakkam) and Inland urban-coastal site (Sathyabama University site.

Analysis of data from multilevel meteorological instrumentation (50m Meteorological tower) within the roughness sub layer by looking to estimate Ten minutes averaged observational data collected at the Kalpakkam-Ediyur site (near-coastline) and Sathyabama university campus site (Inland urban-coastal site) during Summer and SW and NE monsoon synoptic period for the year 2013 have been utilized for direction dependent roughness parameter (Zo) and shear analysis. The statistics on the mean wind speed, direction and shear profile (and their variants) are decomposed into 22.5° sectors of the compass. The data are divided into 16 equal, directional sections, too, those with their wind direction classified as sector 0, 1 and 15. Roughness length by 16 wind direction sector for the 2, 8,50m layers were determined using a least squares fit to the neutral logarithmic wind profile (e.g. Hiyama, et al., 1996, and Beljaars, 1982) and Shear parameters (α) between the layers for the 2,8,50m were also determined from the power law (Irwin, 1979) wind profile method. Roughness length and wind shear analyzed for different wind directions.

3.1 Synoptic wind regimes – Wind rose summary

Wind rose's summaries the occurrence of winds at a location, showing their strength, direction and frequency. The joint frequency distribution for wind speed and direction in the form of wind roses are presented in Figure 2-4 for various seasons. Wind roses in Figure 2 shows that the winds at Ediyur (near coastal) and Sathyabama University during NE monsoon period (Sep-Dec) blow from the northeast and north and easterly much of the time.

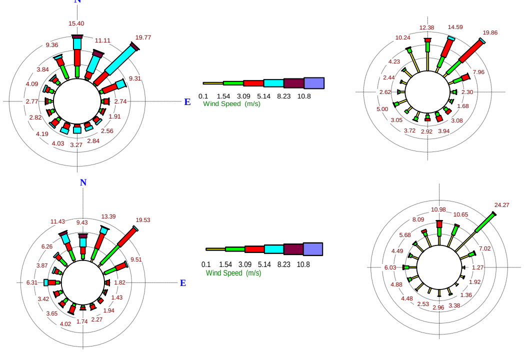


Figure 2: NE monsoon- Wind roses for different observational heights (50m, 2m) at Ediyur (Top panel) and Sathyabama (Bottom panel) sites.

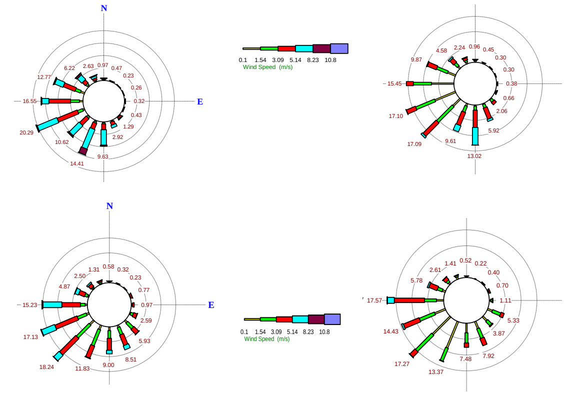


Figure 3: SW monsoon- Wind roses for different observational heights (50m, 2m) at Ediyur (Top panel) and Sathyabama (Bottom panel) sites.

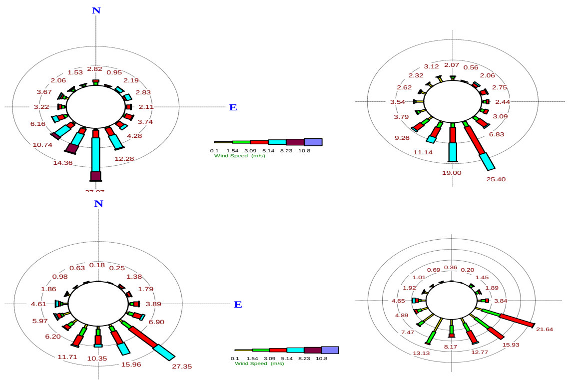


Figure4:Summer season-Wind roses for different observational heights (50m, 2m) at Ediyur (Top panel) and Sathyabama (Bottom panel) sites.

During SW monsoon period strong synoptic winds are primarily observed from south west and westerly directional sector (Fig.3). Sea breezes are most frequently observed on the both site during the summer period. Figure 4 shows that the wind is blows from the south east and southerly direction. Generally winds at 50m and 2m height slightly differ from upper air flow (upper height measurements) due to terrain roughness and represent significant shear at the surface.

4. Results and Discussion

It is important to consider seasonal effects on the value of wind shear parameters. It is an indication of how much the surrounding surface roughness elements change seasonally.

4.1 NE Monsoon Season

North east monsoon associated with the formation of northeasterly wind regime over the study region. During day time NE synoptic flow merges with sea breeze flow in the eastern directional sector.

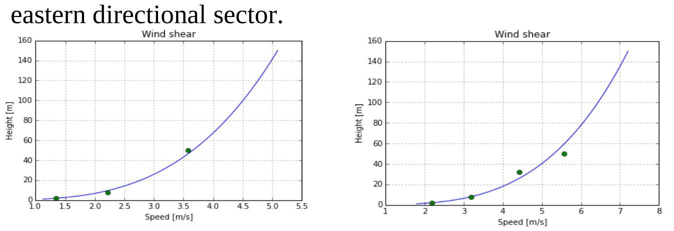


Figure 5: Mean wind shear profile (global shear profile) for a) Sathyabama university (left panel) b) Ediyur site during NE monsoon season period (right panel**).**

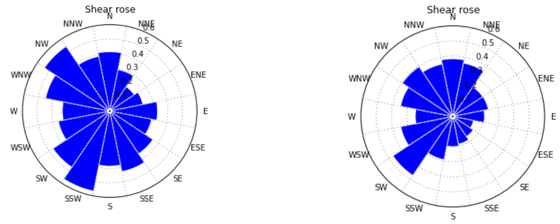


Figure 6: Shear rose a) Sathyabama university (left panel) b) Ediyur site during NE monsoon season period (right panel).

Figure 5, and 6 (right panel) shows the NE monsoon seasonal pattern of mean wind shear profile and shear rose from sataybhama site. Figure 7 shows the direction dependent wind shear profile.

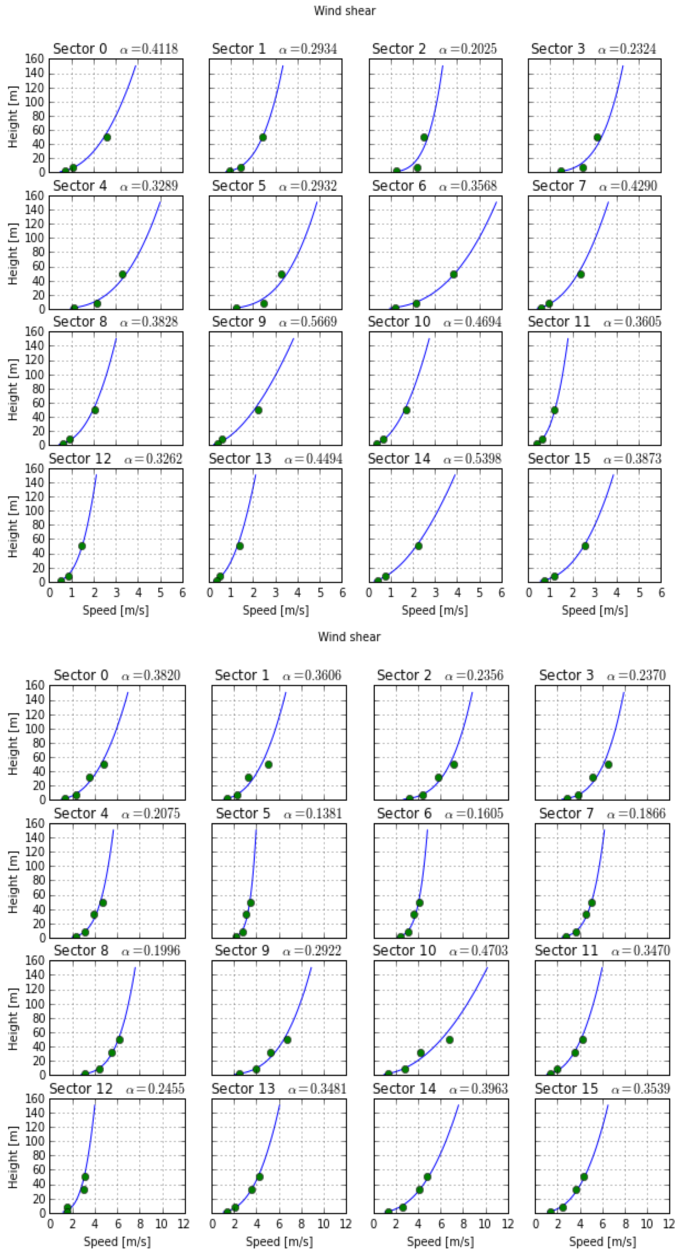


Figure 7: Direction dependent shear profile (Top panel-Sathyabama University; Bottom panel-Ediyur site) -Mean wind

speeds produced by power law fit. Average meteorological tower observations are shown with circles and power law fit is shown with lines.

Traditionally neutral atmosphere associated with 0.14 (1/7 power law), the value higher than 0.14 indicating the stable and value lower than 0.14 indicating unstable conditions. High values of the shear value indicate that the wind speed changes rapidly with height, which is common in stable regimes when the surface layer decoupled from the rest of the boundary layer and vertical momentum transport is limited. In contrast, low values of the shear component indicate that the wind speeds are fairly uniform with height, which is common during unstable regimes with substantial vertical mixing. In locations with a large degree of surface heating shear component drastically changes. The Shear rose depicted in Figure.6 shows that the shear at urban coastal site–Sathyabama University is high compared to the Ediyur site. Direction dependent shear profile at Sathyabama University (Figure7 Top panel) shows the power law exponent lie in the range of 0.202-0.539. The values range from the largest shear value for sector15 (300-330 Deg) to the smallest sector 3 (30-60 Deg). Overall estimated mean values for Sathyabama were found to be 0.309.

Direction dependent mean wind speed profile for Ediyur site is depicted in Figure 7(Bottom Panel). Directionally-dependent profiles exhibit a strong logarithmic relationship with the sector 3, 4 (30-80 Deg) and 8,9 (140-195 Deg). The wind shear profiles shape in the sector 6, 7 and 13 (100-150 Deg, 130,250-285 Deg) seems to be influenced by directionally-dependent speed reductions in the 50 m wind speed. However, in the northerly sector (300-260 Deg), the 50m m sensor measurement seems to be fast. The profile exhibits Logarithmic, have comparatively large roughness lengths, which could be caused by displacement height effects. Across all directional sectors the values of power law exponent α lie in the range of 0.138-0.470 are noticed. The values range from the largest shear value for sector 15 (210-245 Deg) to the smallest sector 6 (100-125 Dg). Overall estimated mean values of Ediyur site were found to be 0.278.

4.2 SW Monsoon Season

The SW monsoon is the most significant characteristic of Indian climate. Large scale winds are become stronger and oppose the sea breeze formation during this season (June-September).Diurnal changes in wind is lower in this season compared to others season.

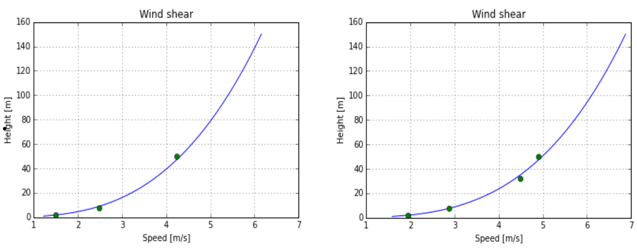


Figure 8: Mean wind shear profile for a)Sathyabama university (left panel) b) Ediyur site during NE monsoon season period (right panel).

Figure 8, and 9 (right panel) shows the SW monsoon seasonal pattern of mean wind shear profile and shear rose from sataybhama site. The same depicted for Ediyur site in Figure 8 and 9 (Right Panel)

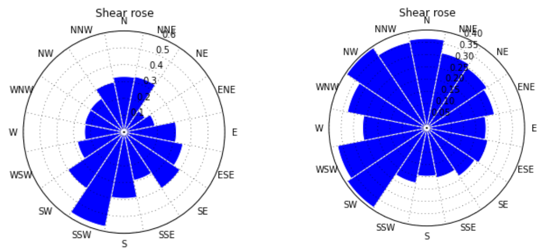


Figure 9: Shear rose a) Sathyabama university (left panel b) Ediyur site during NE monsoon season period (right panel)

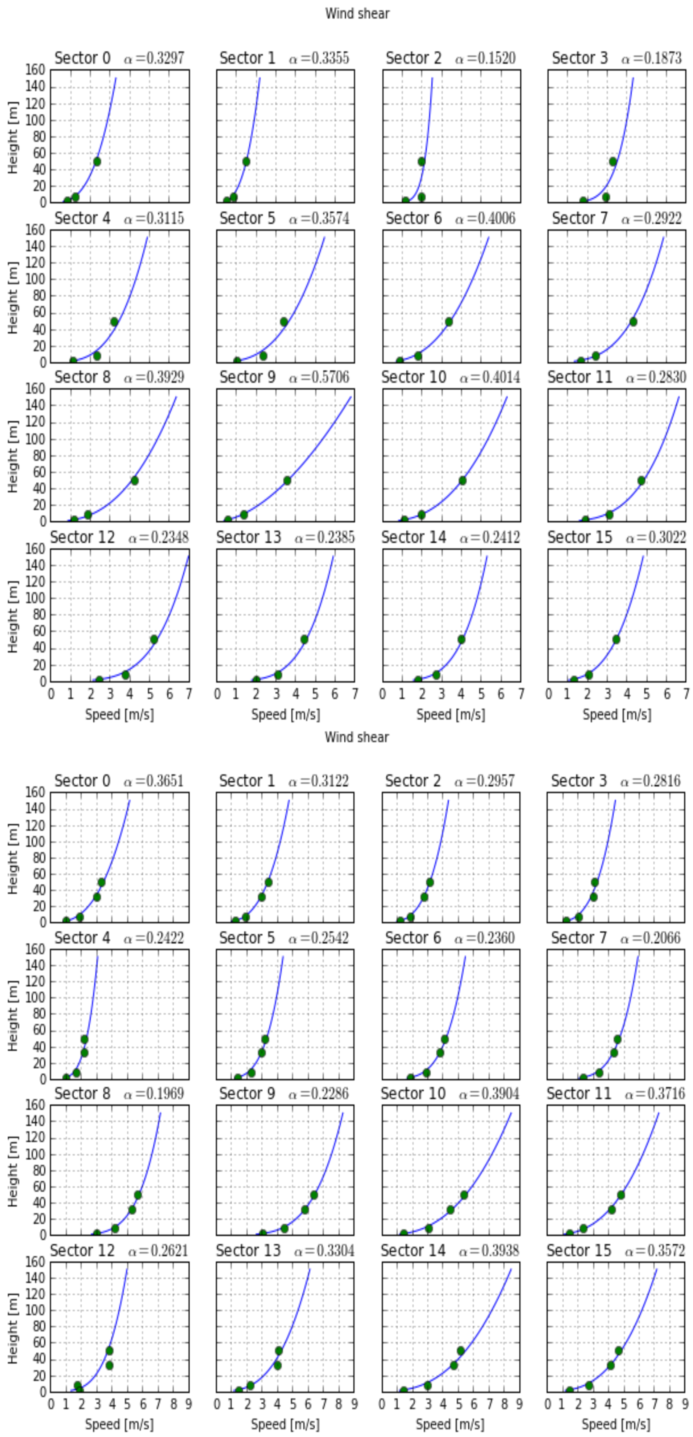


Figure 10: Direction dependent shear profile (Top panel-

Sathyabama University, Bottom panel-Ediyur site) -Mean wind speeds produced by power law fit. Average meteorological tower observations are shown with circles and power law fit is shown with lines.

During SW monsoon season the both sites show higher wind shear in the directional sector SSW-WSW (190-260 Deg) direction (Figur.9). Overall estimated mean values of sathyabama site were found to be 0.322.The mean shear profile is shown in the Figure.8 (Left panel). Direction dependent profile at Sathyabama University exhibits a strong logarithmic relationship in majority of the sector (Figure 10 Top panel). The clear exception seen in sector 2, 3 (10-60 Deg) which has a marked departure from a logarithmic trend. Across all directional sectors the values of power law exponent lie in the range of 0.152-0.570 are noticed. The values range from the largest shear value for sector 10 (190-220 Deg) to the smallest sector 3 (30-60 Deg).The mean shear profile is shown in the Figure.8 (Right panel). Direction dependent wind shear profile for the near coastal site (Ediyur) depicted in Figure.10 (Bottom panel). Across all directional sectors the values of power law exponent lie in the range of 0.19-0.393 are noticed. The values range from the largest shear value for sectors 11, 15 (200-240, 300-330 Deg) to the smallest sector 9 (160-195 Deg). Overall estimated mean values for Ediyur during the SW monsoon season were found to be 0.294. The directionally-dependent profiles at Ediyur site follow a generally logarithmic trend in most of the sectors.

4.3 Summer Season

The study regions predominately influenced by meso-scale sea -land breeze circulation in summer season. The diurnal variations of wind speed are higher than that of other seasons. Figure 11 and 12 (Left panel) shows the summer period seasonal pattern of mean wind shear profile and shear rose for Sathyabama and Ediyur sites.

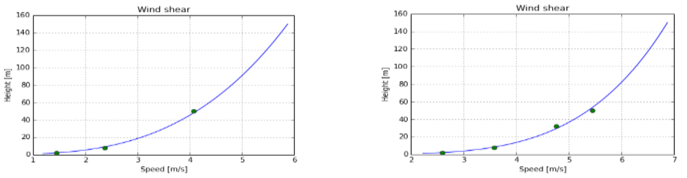


Figure 11: Mean wind shear profile for a) Sathyabama University (left panel) b) Ediyur site during summer monsoon season period (right panel).

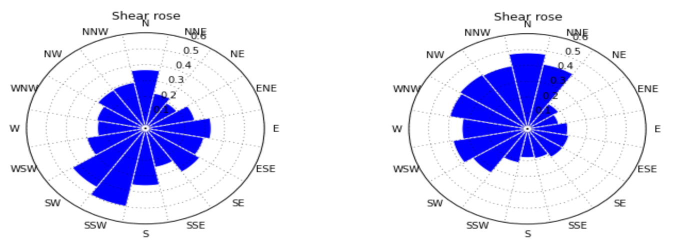
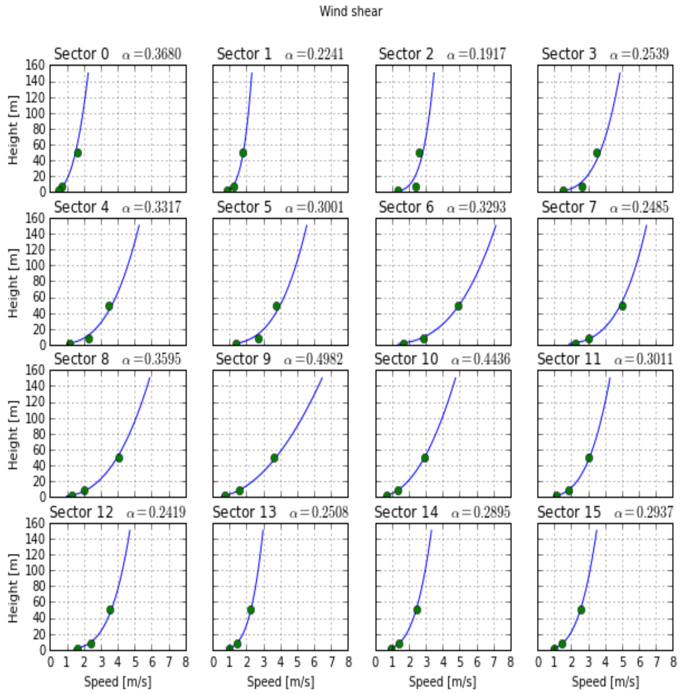


Figure 12: Shear rose a) Sathyabama university (left panel b) Ediyur site during summer monsoon season period (right panel).

Figure 11 and 12 (right panel) shows the summer period seasonal pattern of mean wind shear profile and shear rose from Ediyur site. The shear rose depicted in Figure.12 (right panel) shows that the shear at the near coastal site (Ediyur) quite different from inland site (Sathyabama University.) The low shear winds in the seaside direction sectors are likely related to the overall sea breeze pattern along the kalpakkam (Ediyur) coast. Overall estimated mean values of stayabhma site were found to be 0.307.The mean shear profile is shown in the Figure.11 (Left panel). Figure 13 (Top panel) shows the direction dependent wind shear profile for stayabhma university site. Wind shear profile in the sector 3-11 (65-220 degrees) exhibits a strong logarithmic relationship. The clear exception seen in north and north westerly sectors (0-45 deg, 290-315 deg), which has a marked departure from a logarithmic trend. Across all directional sectors the values of power law exponent lie in the range of 0.19-0.498 are noticed. Direction dependent wind shear profile for the near coastal site (Ediyur) depicted in Figure.13 (Bottom panel).



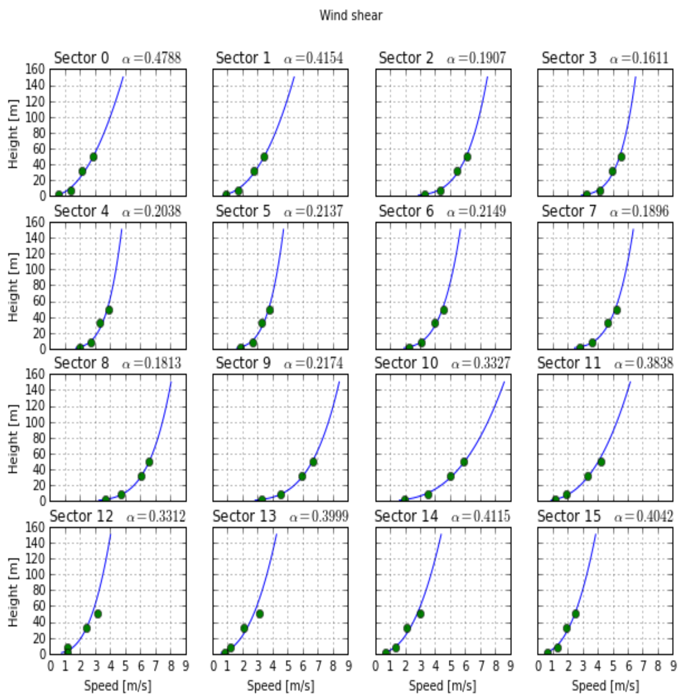


Figure 13: Direction dependent shear profile (Top panel-Sathyabama University, Bottom panel-Ediyur site) -Mean wind speeds produced by power law fit. Average meteorological tower observations are shown with circles and power law fit is shown with lines.

The values range from the largest shear value for sector10 (190-220 Deg) to the smallest sector 4 (50-80 Deg). Overall estimated mean values for Ediyur during the summer monsoon season were found to be 0.225.The directionally-dependent profiles at Ediyur site follow a strong logarithmic trend in the sectors 2-12 (20-190 Deg), which shows distinct unstable well mixed layer (TIBL) near the coastal site. The variation of mean wind shear coefficient strongly related to the thermal conditions of the region and can be explain on the basis of Thermal Stratification. NE and SW monsoon seasons show higher values of the wind shear component, whereas summer season it shows lower values. This behaviour can be justified, since during summer the ground temperatures are higher, it can cause active expansion of air in the vicinity of the surface and hence, better merger of the air takes place over the ground, which results in low values of the Wind shear components , while, during the SW and NE monsoon synoptic wind regimes and winter seasons the ground becomes much cooler than higher air, and hence, higher values of wind shear coefficients are obtained. During summer period Low and high wind shear values are clearly observed during onshore and offshore flows, respectively. At Ediyur sea-coastline orientation lies between 60°–200° sector shows lowest value (during sea breeze) and highest value (land breeze) shown in the sector the sector 220°-45deg. Mean structure of ranges from 0.19 to 0.47 with respect to wind direction

4.4 Roughness distribution

An estimate of roughness length is required by some atmospheric models and is also used to determine surface layer wind profile under neutral conditions. The choice of technique for determining roughness lengths is generally constrained by the available input data. Here, we compare sets of roughness lengths derived by different methods. The simplest method using logarithmic profile formula from this ln (zo) values generated from the profile measurements, Alternatively Beljaars (1987) give empirical formulae for determining roughness lengths from wind shear or power law coefficient. Aerodynamic roughness length changes with wind direction and topography.

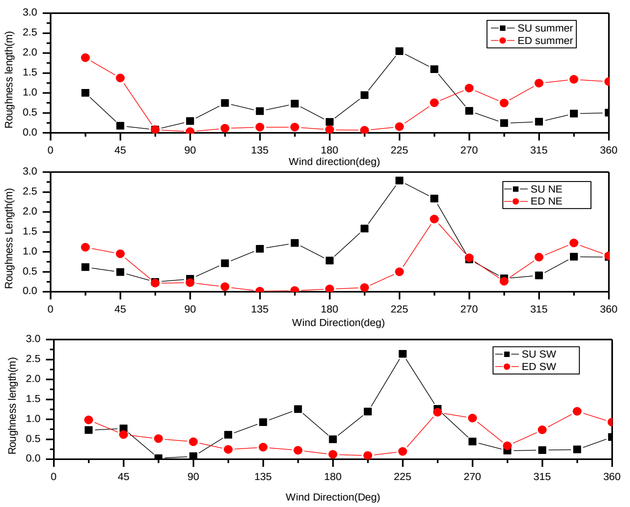


Figure 14: Direction dependent surface roughness parameter for different Season (SU-Sathyabama University site, ED-Ediyur site).

Figure 14 shows direction dependent mean value's roughness length derived for the 10 minute period in the summer, South West and NE monsoon case at Sathyabama and kalpakkam (Ediyur) site. Roughness length has obvious seasonal patterns. Low and high values are clearly observed during onshore and offshore flows, respectively, with sharp decrease around 450° - 190°and build-up in starts as nearing to the coast at 220° orientation due to land frictional effect. The aerodynamic roughness length is higher on the Sathyabama university site than on Ediyur site. At Ediyur site for all the season the low zo estimated in the direction sector (90-200 Deg) corresponds to the area covered by coastal ocean. The large value observed in the direction sector (220-250 Deg) during NE and SW monsoon season, whereas in the summer period the high value lies in the northerly and north-westerly sector. As demonstrated in the figure 14 large zo values for sectors (180-240 deg) observed for the sathyabama site. A high value of zo levels related to the roughness elements around urban area (coastal urban -Sathyabama University). While the low zo value for north and north westerly site correspond to the open fetches and some space building.

5. Summary

In this work, considering a near coastal and urban coastal wind site such as Ediyur and stayabhma university site where wind shear coefficient has been determined and the effect of wind shear on velocity profile has been analyzed. For near coastal smooth terrain the power law is a good approximation to the real surface layer wind profile. At Kalpakkam coastal site (Ediyur), a significant influence of land-sea interface shows lower wind shear coefficient during sea breeze conditions than in land breeze circulation period.

The variation of mean wind shear coefficient strongly related to the thermal conditions of the region and can be explain on the basis of thermal Stratification. NE and SW monsoon seasons show higher values of the wind shear component, whereas summer season it shows lower values. The mean shear coefficient at inland coastal site -Sathyabama University is more than the near coastal site .The variation of wind shear with different directional sector emphasized the major role played by the topography and land use.

Roughness length is strongly dependent on wind direction, as upstream topographic features are more relevant to local turbulence in horizontal winds, rather than local topographic features. Low and high values are clearly observed during onshore and offshore flows at a near coastal site Kalpakkam. The characteristics of roughness length and its variation strongly affected by land-sea interface sectors.

Site specific direction dependent roughness and shear coefficient estimation studies confirmed that the default power law coefficient should be used with caution for wind energy and pollutant dispersion analysis in various underlying surface and structure in the atmospheric surface layer. In addition, more work still needs to be done to fully investigate the variation of α, u and z 0 as for the different thermal stability conditions and seasons as well as during rainy, cloudy and clear sky conditions.

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