Chapter 2

Literature Review
2.1 Wind Measurement and Archival in Automatic Surface Wind Observations

Wind sampling strategy and archival methods are of serious concern among potential wind users' requirements. The concerns mostly relate to wind observations that do not conform to international recommendations for averaging period, short averaging periods representative of small-scale motions rather than large-scale motions that have predictability. The scales of atmospheric motion and its link with wind spectra in the frequency range from 0.0007 to 900 cycles per hour was studied by Van der Hoven (1957). Smedman-Hogstrom and Hogstrom (1975), Panofsky and Dutton (1984) and Champagne-Phillippe (1989) are studied about the position of spectral gap in the wind spectrum. Champagne-Phillippe (1989) computed spectral density from 12 hr of consecutive 3 s average wind data from 10 m masts (14400 points) in a coastal station. They reported that the low frequency peak caused by synoptic and meso-scale weather systems with time scales greater than 1 hr and high frequency peak near 1 min due to micro-scale turbulence, and the spectral gap correspond to time periods of 10-100 min. Pierson (1983) suggested that the spectral gap movement is dependend on wind speed. According to Panofsky and Brier (1965) the wind measurements with averaging periods corresponding to the spectral gap are unaffected by small-scale turbulent fluctuations. There are recommendations of averaging times for surface wind observations, based on the positioning of spectral gap as 4 min averaging by Sparks and Keddie (1971), 20 min averaging by Pierson (1983) and 1 hr by Panofsky and Dutton (1984). The capability of wind measurements, averaged over time periods within the spectral gap to separate scales of motion, will depend upon the frequency of measurement, density of observing site, the compatibility of the media to storage and retrieval, and easy handling of data for different mathematical as well as statistical analyses.
Powel (1993) conducted an informal survey among representatives from several user groups, concerned about Automatic Surface Observing System (ASOS) in wind sampling strategy and archival methods. He summarised that the optimum averaging time for surface wind observations depend upon applications. In ASOS, the sampling strategy is for every second collection of speed and direction data. Five second averages of speed, direction along with peak (gust) in the five seconds are computed, from the collected every second (raw) data. Further, two min averages are derived out of 5 s means (out of 24, five second means). The last 2 min data in an hour archived at the end of an hour, represents surface hourly observation, along with the peak (gust) of that last 2 min derived by using 5 s peaks (24 peaks in 2 min).

The World Meteorological Organisation (WMO) recommends a 10 min wind average for synoptic observations from automatic weather stations and WMO suggests 2 min wind averaging periods for wind indicators in air traffic services (WMO, 1988). Numerical weather prediction suggest hourly or even 10 min frequency surface wind data may suffice (Stauffer et al., 1991). For dispersion and diffusion modelling of a particular site requires 1 hr averages and standard deviations of speed and directions, for a period of at least 1 year (EPA, 1987). In structural engineering applications, International Standard Organisation recommends a peak 2-3 s mean gust. 1 and 10 min mean winds occurring at the time of peak gust also having wide interest in structural analysis.

2.2 Wind Observations in Tower Platforms and Cup Anemometry

Towers offer convenient platforms for observing mean and turbulent properties of flow in the boundary layer. In air quality modelling and meso-scale observing networks small towers are in use and tall towers are necessary for assessing various boundary layer theoretical models. Towers, booms and mounts used for supporting a sensor can interfere with the wind flow (Moses and Daubek,
They noticed that when the air flow on the lee side of the tower may be reduced to nearly one-half of its true value for light winds and nearly 25% for speeds of 10-14 mph. An increase in measured wind speed exceeding 30% occurred when the wind blowing toward the anemometer made an angle of 20 to 40° with respect to the sides of the tower adjacent to the anemometer. The effect on direction was relatively smaller, with greatest mean deviation of 11°. In general, they found out the wind shadow effect, as when the wind blow through the tower before reaching the anemometer, there was a substantial reduction in speeds, the effect being greatest with high winds.

Accuracy of wind measurements on towers and stacks are studied by quarter-scale models in large wind tunnel by Gill et al., (1967). Their analysis showed that in the wake of lattice-type towers disturbances is moderate to severe, and in the wake of solid towers and stacks there is extreme turbulence with reversal of flow. For an open triangular tower with equal sides D, the wake is about 1-1/2D in width for a distance downwind of at least 6D. Sensors mounted 2D out from the corner of such a tower will usually measure speeds within ±10% of that of the undisturbed flow for an arc of about 330°. The disturbance by very dense towers and stacks is much greater. Wind sensors mounted 3 diameters out from the face of a stack will measure wind speeds within ±10%, and directions within ±10° of the undisturbed flow for an arc of about 180°. The study made some recommendations on mounting of wind sensors. In relatively open towers in order to achieve measurements of wind speed that are accurate within ±10% of the true value, the sensor should be placed not less than 1D out from the tower, and extending outward from the corner into the wind of primary concern. Wind sensors should preferably be located at heights of minimum tower member density, and above or below horizontal cross members. For this configuration and location, measurement of speed are true within ±10% for a 310° sector of arc. If the boom is extended to 2D, the wind speed is accurate within ±10% for a 330°
sector of arc. For these two arcs, the measurements of wind direction are accurate within at least ±10°, and probably within ±5°.

The measurement of atmospheric winds using cup anemometer and wind vane are common, and the errors in cup anemometer response to wind speeds are widely discussed (Wyngaard et al., 1974; Busch and Kristensen, 1976 and Kaganov and Yaglom, 1976). Hyson (1972) investigated into cup anemometer response to fluctuating wind speeds and noted that the anemometer overruns under fluctuating wind conditions and the percentage overrun depends on the wind speed, frequency, and amplitude of fluctuations. Surridge (1982) discussed the use of orthogonal propellers for the routine measurement of wind, and compares it with the traditional cups and vane system. In this study, prevailing winds are shown to be approximately the same for the two systems. It is also shown that the integration time of wind will have a marked effect on results.

2.3 Properties on SBL Wind Velocity Profiles

2.3.1 Wind Velocity Profiles

In air pollution and wind energy studies, knowledge of the mean wind profile is important. The logarithmic wind law has been found to satisfy observations in the lower atmosphere up to 100 m or more during adiabatic (neutral) conditions (Lumley and Panofsky, 1964; Tennekes, 1982). In diabatic conditions when the surface heat flux is significantly differ from zero, stability correction should be made to the logarithmic relationship. The stability corrections are important in the correct simulation of diurnal variation of wind speed. Also the frequency distribution of wind is affected by stability variations. Monin and Yaglom (1971) applied Monin-Obukhov similarity theory for the atmospheric surface layer in order to incorporate stability corrections. Dyer (1974) and Yaglom (1977) presented a review of flux-profile relationships for the diabatic surface layer. Logarithmic wind law represents the wind profile over uniform terrain up to
heights of at least 150 m in thick boundary layers with strong winds (Carl et al., 1973). Observed wind profiles up to 150 m over reasonably homogeneous terrain under neutral conditions do not seem to deviate significantly from logarithmic (Thuillier and Lappe, 1964). Hsu (1972) analysed the wind profiles for different timings over a flat coastal environment and reported that the diurnal variations in wind speed profiles are either concave upwards during day or concave downwards during night except during transitional period between land breeze and sea breeze (Hsu 1973).

### 2.3.2 Roughness Length or Parameter ($z_0$) and Frictional Velocity ($U_*$)

Andre et al., (1978) provided a sample of diurnal variation of frictional velocity. Charnok's relation (1955) relates $Z_0$ and $U_*$, which found quite useful for $Z_0$ computations over oceans. Typical values of the roughness length are obtained from Nappo (1977), Smedman-Hogstrom and Hogstrom (1978), Hicks, et al., (1975), Kondo and Yamazawa (1986), Thompson (1978) and Garratt (1977). Directional dependence of wind direction fluctuation ($\sigma_\theta$) is studied at an Indian coastal site of Madras, with significant inhomogeneity in roughness elements distribution around the location of measurement (Panchal and Chandrasekharan, 1983). They suggested incorporation of $Z_0$ in Pansquill stability classification (Pansquill, 1961) in a non-homogeneous terrain. Pansquill (1974) relates $U_*$ with wind direction fluctuation ($\sigma_\theta$) which in turn can relates with surface roughness under neutral conditions. Hicks (1972) suggested relations connecting drag coefficient with frictional velocity and roughness length under neutral atmosphere. Ramachandran et al., (1994) has studied the variability of $Z_0$ for Indian coastal station, Thumba and noted that the $Z_0$ values are low during southwest monsoon season than in other seasons. Variation of $Z_0$ and its dependency on wind directions are also specified in their findings. For the same station, Sen Gupta et al., (1994) have shown that $Z_0$ is maximum when on-shore flow is perpendicular to the coast. When the wind flow is perpendicular to the coastline, the wind
experiences a sudden change in roughness from smooth sea to rough land surface. When the wind is parallel to the sea coast $Z_0$ has an average value of 0.07 m and for on-shore flow it is 0.25 m (Prakash, 1993). Narayanan Nair et al., (1994) showed that the $U_*$ is height dependent for nonuniform terrain and for Thumba, $U_*$ peaks at 1300 hr IST. Panofsky and Petterson (1972) computed $Z_0$ for the immediate surroundings of the tower vary with wind direction.

2.3.3 Power Law Wind Profile in Engineering Applications

For engineering applications *in situ* measurements of the roughness length $Z_0$ are not always available. Many wind profile laws, such as simple logarithmic distribution, cannot be applied. Therefore, many engineers have resorted to the power law wind profile, which, to a large degree, is quite accurate and useful for engineering applications (Panofsky and Dutton, 1984; Arya, 1988). From the recordings of many investigators, such as Davenport (1965), Panofsky and Dutton (1984) and Justus (1985), approximate values of the exponent in the power law can be obtained for practical coastal zone applications. Hsu (1982) obtained $\alpha$ for flat, open coast, towns and cities under different atmospheric stability conditions. The results show for unstable conditions $\alpha = 0.18$, for neutral conditions $\alpha = 0.22$ and $\alpha = 0.50$ for stable conditions. Narayanan Nair et al., (1994) found $\alpha$ for night time stable condition is 0.58±0.02, morning unstable conditions is 0.13±0.04, mid day turbulent internal boundary layer conditions is 0.25±0.02, and for evening neutral conditions 0.28±0.05 for Thumba. Over smooth open terrain a value of $\alpha$ close to 1/7 (or 0.14) is usually found with neutral lapse rate (Blackadar, 1960).

Zhang (1981) made a statistical analysis of the power law and the logarithmic law using wind data from a 164 m tower. In their study, the wind speed distribution with height is analysed by using hourly data for a full year record at 6 levels, and a statistical error analysis shows that power law and logarithmic law are best applicable when the wind is strong. For the height range from 16 to 164 m, the power law represents the actual speed distribution better
than does the logarithmic law. Joffre (1984) stated that the power law profile has the advantage that it permits analytical solutions to be devised for the diffusion equation. This is not possible with the exact logarithmic profile and the exponent is not universal but dependent on roughness, stability and height. Many empirical investigations (e.g., Frost, 1947; De Marris, 1959; Touma, 1977; Sedefian, 1980; Hsu, 1982) have been carried out in order to estimate $\alpha$ as a function of roughness length $Z_0$ and hydrostatic stability, in which most of them are over moderately rough terrain. De Marrais (1959) showed $\alpha$ apparently decreases slowly with increasing instability but with a larger scatter under strongly unstable conditions due to some higher values of $\alpha$.

2.3.4 Wind Shear

Method of shear computation is elaborately discussed by Heald and Mahrt (1981), by specifying two ways as average total shear and average speed shear. According to them the directional changes of wind might be an important factor in shear and largest shears normally occur with strong stratification which most frequently develops on clear nights. In thunderstorm outflows, Fujita and Byers (1977) reported shears of $0.12 \text{s}^{-1}$ extending up to 100 m. Different studies in WMO (1969) show that at most locations, the shear of the 5 or 10 min averaged wind above the surface layer is greater than $0.1 \text{s}^{-1}$ less than 1% of the time. Rijkoort (1969) expressed an increase of maximum shear values as the averaging time and the depth of the layer of computation decreases. Narayanan and Devassy (1972) studied seasonwise structure of shears in the 200 ft lower atmospheric layer over Thumba, India. There exists high wind shears in the afternoon in the layer 2-10 m and 40-50 m in summer and uniform shear in southwest monsoon. Hindu daily (1997) published an article about Madras airport Low Level Wind Shear (LLWS) reports during 1979 to 1988, having importance in landing and take-off from the airport, in which both horizontal as well as vertical shear (30 to 500 m
above ground) are explained, and monthwise and timewise distribution over the port are critically assessed.

2.4 Atmospheric Turbulence, Gusts and Spectral Behaviour

2.4.1 Wind Speed Fluctuations: Atmospheric Turbulence and Gustiness

Properties of turbulence are described by Lumley and Panofsky (1964). Taylor (1938) suggested that for some special cases, turbulence might be considered to be frozen as it advects past a sensor, and derived the Taylor's hypothesis.

Willis and Deardorff (1976) suggests that Taylor's hypothesis should be satisfactory when the turbulent intensity is small relative to mean wind speed, and made a condition to satisfy the requirements that the eddy has negligible change as it advects past a sensor as $\sigma_M < 0.5 M$, where $\sigma_M$ the standard deviation in wind speed and $M$ the mean wind speed. $\sigma_M$ is a measure of intensity of turbulence or turbulent kinetic energy.

Turbulence and gusts of wind are closely interrelated. Sutton (1953) summarised much of the empirical data for the development of turbulence theory through gustiness examinations. Poppendieck (1951) described, the diurnal variation of turbulence is ascribed to a preponderance of mechanical turbulence in the lower layers, whereas effects of thermal turbulence (or buoyancy) dominate at higher elevations and are associated with larger diurnal variations. Observational studies of the instantaneous values of wind speed and direction show that one or other of thermal or mechanical turbulence may predominate.

2.4.2 Wind Velocity Spectra

In turbulent spectrum numerous eddies of different periods are superimposed, apparently randomly, upon the mean state of the lower atmosphere. The difficulty of separating out these eddies accounts, in the main, for the complexity of atmospheric turbulence. Van der Hoven (1957) measured the
horizontal wind power spectrum with the wide range from 0.0007 to 900 cycles per hour at about 100 m height and found that the length of the obvious period is 4 days, 12 hours, and about 1 min. respectively. Quite a remarkable number of studies aimed about atmospheric fluctuations and its spectral characteristics because of its capability to give picture into the wide range of scales over which atmospheric motions occur. (Hwang, 1970; Mori, 1980; Ishida, 1990; Oort and Taylor, 1969). Also it is now clear that kinetic energy of the atmosphere is not spread uniformly over all the wavelengths but has certain preferred scales with gaps between. (Smedman-Hogstrom and Hogstrom, 1975; Fiedler and Panofsky, 1970). The modelling of turbulent velocity spectra dealt by Kaimal et al., (1972), where surface layer velocity spectra in the neutral atmospheric limit and stable conditions are treated. The shape of the unstable spectra is treated by Kaimal et al., (1976), Panofsky (1978) and Peltier et al., (1996)

Studies on the effect of local meso circulations like sea breeze on spectral behaviour are very few for equatorial coastal stations. Prakash et al., (1992) made a spectral behaviour of SBL parameters over the equatorial coastal station, Thumba, India. They detected the characteristics of unstable wind spectrum with a +1 slope in the energy containing region and a spectral fall of -2/3 in the inertial sub range, whereas the stable spectrum gives a -2 slope in the buoyancy sub range as in Lumley (1964) and Weinstock (1981). With the onset of sea breeze, there is a shift in the spectral peak and an increase in longitudinal (u) spectral power is reported. The spectral gap is seen about $8 \times 10^{-4}$ Hz before the onset of sea breeze and widens after onset. Recently Narayanan Nair (1999) analysed wind spectrum during the incidence of Low Level Jet (LLJ) over Thumba, and he detected a spectral enhancement in the lateral (v) component and the spectral fall in the longitudinal (u) component of the wind field at the low frequency side, and during this time it is observed that the LLJ as a thin stream of fast moving meridional flow conserving vorticity. Luo and Zhu (1995) presented the power spectrum at 8
levels for the frequency range from 0.000225 to 0.5 cycles per second. They detected obvious peaks in the period range from several seconds to more than ten minutes in the spectrum, which differ from the former results. In the study, it is found that there is evident relationship in horizontal wind power spectrum at different levels, and the relationship is more clear in low frequencies than in high frequencies.

2.5 Wind Direction Fluctuations: Stability of Atmosphere

As standard deviation of wind speed can be a representation to intensity of turbulence or turbulent kinetic energy. Wind direction fluctuations through standard deviations ($\sigma_\theta$) can be looked as a measure of atmospheric stability. The investigations of atmospheric stability in the lowest part of the atmosphere is very crucial input in air pollution dispersion modelling.

Considerations for the derivation of $\sigma_\theta$ are through various methods. Jones and Pansquill (1959), Brock and Provine (1962) devised sigma computers convert the fluctuating input voltage from the wind direction transducer to a continuous voltage signal proportional to the standard deviation of the input. Harris and Mc Cormick (1963) determined $\sigma_\theta$ form accumulated unidirectional angle and the number of reversals of directions determined from charts records. Sachdev and Rajan (1971) devised an automatic method to output unidirectional angle and number of reversals of directions from a wind vane. Markee (1963) provides a simple and convenient relationship between wind direction standard deviation and the range of wind direction fluctuations, where the range divided by 6 for a sampling periods of the order of 1 hr has taken as $\sigma_\theta$. Theoretical computation procedures to derive $\sigma_\theta$ from the collected speed and direction data are given by Ackermann (1983), Verrall and Williams (1982) and Yamartino (1984). All these theoretical computations are resulted due to the discontinuity of wind direction scale at 360°. Ackermann algorithm assumes that individual point values are
measured as orthogonal components or have been converted from polar speeds and directions to rectangular components. The components would then have been averaged and their variances and covariances computed for a desired time period. These component statistics are then used by the algorithm to compute estimated means and standard deviations of the speed and direction for the time period of interest. Verrall and William (1982) devised the method for estimating $\sigma_0$ from the cosines and sines of direction angles. Yamartino's (1984) method includes the addition of a constant in the $\sigma_0$ derivation. Comparison of above methods are done by Turner (1986) and the eight hours of real atmospheric data applied to each methods show no significant difference between the methods.

Zhong and Takle (1992) measurements of $\sigma_0$ revealed an abrupt increase and decrease in low level turbulence associated with passage of se breeze front over Merritt Island. Pramila Goyal and Nivedika karmakar (1982) made $\sigma_0$ computations in order to know monthwise stability frequencies over Mathura, India and they found out thermal instabilities in the lower atmosphere prior month to winter. Panchal and Chandrasekharan (1983) detected the monotonic decrease of $\sigma_0$ with stability classes from A-F for a land breeze and increase ranging from D to F.

2.6 Probabilistic Properties of Wind Behaviour

The main parameter which measures the variability or dispersion of the individual wind observations are standard deviation and coefficient of variation. They should be specified along with the main measure of central tendency, the mean of wind observations. The process of computing them as basic statistical conceptual tools are elaborately discussed for SBL studies by Stull (1994). The probabilistic nature of wind and its statistical tools for its assessments are thoroughly expressed in Lawson (1980).
Winds are three dimensional but for almost all direct application purposes, especially in engineering needs, they are considered only in their two dimensional form along horizontal surfaces. Crutcher (1962) described the estimation of frequency of winds from any given point, sector or area is only possible with the use of estimates of statistical parameters of a wind distribution. Crutcher (1957) and Scott (1956) provided the general bivariate normal elliptical distribution in order to represent sets of data. Smith et al., (1990) made wind models for aerospace vehicle ascent trajectory biasing for wind load alleviation through bivariate normal probability distribution.

As the bivariate normal distribution theory plays as the best modelling tool for horizontal components of winds, Weibull probability density function, can be as a good model for wind speed distributions. The statistical tool, the Weibull distribution by Swedish physicist Weibull (1951) is one of the major area in Extreme Value Theory (EVT). The Weibull distribution gives a precise quantitative statement of the otherwise vague notion that the more extreme the event, the less likely it is to happen (Smith, 1990). Hennessey (1977) suggested that the Weibull model for the wind power density has many computational advantages, and the wind power studies based solely on the total mean wind power density omit much valuable information about the wind power potential of a site. Justus et al., (1978) reported some of the advantages of Weibull model and described methods of estimating the two Weibull parameters (scale factor, c and shape factor, k) from simple wind statistics. The Weibull distribution is shown to give smaller root-mean-square errors than the square root normal distribution when fitting actual distributions of observed wind speed. Takle and Brown (1978) summarised procedures developed and used for coping with the problems caused by low or zero wind speeds, for computing the Weibull parameters, and for easily ascertaining the qualitative resemblance of a given wind speed distribution to the Weibull. Justus and Mikhail (1976) proposed a set of formulas which allows
The conclusions to be made about the Weibull scale factor, $c$ and shape factor, $k$. Doran et al. (1978) are given a note on vertical extrapolation formulas for Weibull velocity distribution parameters proposed by Justus and Mikhail (1976), and suggested its usefulness in ensemble averages, but the technique can lead to significant errors in individual cases. Stewart and Essenwanger (1978) are found to frequency distributions of wind speed near the surface are skewed to the right of the mean is usually greater than median, and proposed Weibull distribution as a good analytical approximation to the cumulative distribution and is particularly useful for the 90-99% thresholds. Essenhanger (1976) explained a three parameter Weibull model and later Auwera et al. (1980) applied this model and found out the model generally gives more reliable fit to the empirical wind speed frequency. Bardsley (1980) suggested an alternative three parameter Weibull distribution for the description of wind speed data with low frequencies of low wind speeds. Conradsen et al. (1984) made a review of the relevant statistical methods for the estimation of Weibull parameters is given with emphasis on efficiency. In summary, they stated in estimating Weibull statistics from measured wind speed data, one should preferably use the method of maximum likelihood owing to its large sample efficiency.

Wind Variability associated with Meso-scale Systems

Diurnal patterns of wind speed are extensively studied by Matveev (1967), Oke (1978), Reil (1972), Adiga (1981). Haurwitz's (1947) treatment of the sea breeze is generally recognised as an important milestone in sea breeze theory. The mathematical results are expressions for the horizontal wind components at the surface as a function of time, with Coriolis parameter, amplitude of diurnally oscillating pressure-gradient force, and coefficient of linear friction as parameters. The results are presented as wind hodographs depicting the variation of direction and speed over the diurnal period. Defant (1950) proposed linear mathematical
model of the sea breeze circulation similar to Haurwitz theory and Pearce (1955), Estoque (1961) and Fisher (1960) are provided solutions to nonlinear models, relate the physical aspects of the problem in a way that leads to realistic results. Observations by Fisher (1960) and Staley (1957) indicate that local topography not included in the theory, is very crucial to the air motions at individual locations. Frenzei (1962) brought out resultant winds obtained from routine surface and upper air observations in an area which contains both a sea coast and a huge interior valley and to compare these observations with the results of above theories, indicates that oscillations in air interior are in phase with coastal areas with diurnal circulation most well developed below 1000 m.

From the above pioneer investigators, it has been known that the direction of sea and land breezes makes, at any given locality, a complete 360° turn over diurnal cycle, provided that the general wind flow is weak. Neumann (1977) is drawn attention to the observational fact that the rate of turning of the direction of sea and land breezes is far from uniform over the diurnal cycle. Alpert (1983) examined the anticlockwise rotation (in northern hemisphere) or clockwise rotation (in southern hemisphere) of the wind hodograph in the boundary layer, and found out usually the pressure-gradient term is the leading one and the advection term is very small.

Observational studies on the diurnal variation of boundary layer winds are made by investigators for different topographical locations. Reed (1979) analysed anemometer records from five levels on a 151 m meteorological tower over Cape Canaveral and the results show an almost elliptical clockwise diurnal oscillation of the sea breeze component of the wind. The oscillation amplitude increases with height. Hahn (1981) made a study on the diurnal behavior of boundary layer winds, in which rapid clockwise rotation of the wind vector occurred during the period of increased wind speeds. Zhong and Takle (1992) constructed hodographs of the hourly wind vectors at 16.5 m over Kennedy Space Center for three
locations, which reveal the evolution of the low-level wind vector over the diurnal cycle in the areas surrounding these towers. Veering is noticed in all locations with different rate of rotations. A rapid rotation in afternoon and midnight hours occurred in all locations with a quasi-steady state for 3 to 5 hr before sunrise. Their observations of forcing responsible for the rotation was not uniformly distributed neither time or space, which is consistent with Neumann's (1977) theory. Alpert and Eppel (1985) proposed an index for meso-scale activity. The suggested index provides between diurnal to interdiurnal wind variabilities can be used to assess meso-scale or synoptic-scale forcing dominancy for a station.

There are a few studies only on thunderstorm effects on winds in SBL. Fujita, (1955) explained the drastic change in wind speed and direction in association with downdrafts from thunderstorms. Luo and Zhu (1995) in the spectrum analysis of strong winds, they found that all frequency range have almost no obvious difference, but undulation is much more and the amplitude is stronger in high frequency range in thunderstorm strong winds. Narayanan Nair et al., (1994) reported a change in meridional wind shear, amplification of vorticity, vertical wind fluctuations during night time and cyclonic circulation and thunderstorm during early morning hours followed by shallow land-sea breeze circulation over Thumba.