THE STABILITY OF THE SURFACE LAYER AS INDICATED BY MONIN-OBUKHOV LENGTH SCALE

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RESUMO

A escala de comprimento de Monin-Obukhov (L) é um importante parâmetro para a determinação das condições de instabilidade/estabilidade da camada limite superficial. Assim, neste trabalho avaliou-se L para a região do Pantanal Sul Matogrossense durante o período de setembro-outubro de 1996, correspondente à estação seca. Os resultados mostraram valores consistentes de L em duas alturas (19,4 e 25 m), isto é, instabilidade durante a tarde e estabilidade durante a noite e nas primeiras horas da manhã.

INTRODUCTION

It is important to provide a dependable scaling factor in the surface layer of the atmosphere which is dominated by turbulent forces and is characterized by large gradients in meteorological parameters. The stability index provided by Reynolds is essentially a ratio between viscous and kinetic forces and is not taking into consideration thermal forces. Richardson's number is the ratio of thermal and kinematic forces (Garratt, 1992) which over comes the defect of Reynold's number, but is not still a know function with height and not dependable with weak gradients also when either thermal or kinematic forces are dominant (pure thermal turbulence or pure mechanical turbulence). As such Monin and Obukhov developed the similarity theory and developed the stability parameter (Monin and Yaglom, 1971) now recognized by boundary layer meteorologists as appropriate for the surface layer which is the Monin-Obukhov length-scale.

THEORY OF DEVELOPMENT OF MONIN-OBUKHOV LENGTH SCALE (L)

The equation of momentum, heat and the vertical equation for perturbation of ω' taking the buoyancy can be written (Vital Murthy, 1970) as

$$K \frac{du}{dz} = {U_*}^2 \qquad (1)$$

$$K_T \frac{d\theta}{dz} = -\frac{Q_o}{\rho C_p} \qquad (2)$$

$$\omega' \frac{\partial \omega'}{\partial z} = -\frac{1}{\rho}\frac{\partial P}{\partial z} - g = \frac{g(\bar{\rho}-1)}{\rho} = \frac{gT'}{T} = \frac{g\theta'}{\theta} \qquad (3)$$

Here ω' is the vertical velocity fluctuation (m s^{-1}), u is wind speed (m s^{-1}), U_* is the friction velocity (m s^{-1}), θ is potential temperature which is nearly equal to actual temperature in the surface layer as the pressure near the ground is equal to the standard pressure and it is expressed in degrees Kelvin, Q_o is the surface heat input (Wm^{-2}), ρ is the air density (kg m^{-3}), C_p is specific heat at constant pressure (J kg^{-1} K^{-1}), θ' is the fluctuation in potential temperature (K), K is the coefficient of turbulent kinematic viscosity, expressed in m^2 s^{-1}, K_T is the same as K but is a coefficient of thermal turbulence. The above equations contains u, θ, K, K_T and ω' and four dimensional parameters U_*, $-Q_o/\rho C_p$, g/T and z.

Using the Π theorem of dimension, Monin and Obukhov has shown that only one non dimensional combination can be obtained as the parameters (n) are 4 and dimensions (k) are 3 and n – k = 1 and got the following combination

$$U_*; \quad L = \frac{-U_*^3}{\chi \frac{g}{T}\left(\frac{Q_o}{\rho C_p}\right)}; \quad T_* = \frac{1}{\chi U_*}\frac{Q_o}{\rho C_p}; \quad z$$

where χ is von Karman's constant and L is having the dimensions of length and T_* the dimensions of temperature (Arya, 1988).

IMPORTANCE OF MONIN OBUKHOV LENGHT SCALE

The Monin Obukhov length scale is a very important comprehensive scaling factor and z/L is an important non dimensional complex and number of universal function can be constructed against z/L a non dimensional parameter. The importance of "L" is it can determine the condition of instability and stability in the surface layer (Matveen, 1965). If L is negative (it is possible when $Q_o/\rho C_p$ is positive and hence) the layer is unstable. Similarly if L is positive the layer is stable and in neutral stability $Q_o/\rho C_p = 0$ and so L is large tending to infinity.

The aim and objective of this paper is to estimate stability and instability in the Pantanal region as revealed by "L".

TOWER DESCRIPTION AND INSTRUMENTATION

The place selected for the experiment was in the Pantanal wetland of South Mato Grosso State. Measurements were made using a 21 m iron tower at the Base Site of Pantanal Studies (19°58'S; 57°02'W), near Miranda's river, located in Passo da Lontra, Miranda town. The altitude of the tower site is approximately 80 m above the mean sea level. The base belongs to the Federal University of Mato Grosso do Sul. The region vegetation is characterized by savanna, with grass and some sparse trees namely "paratudais" (Magalhães, 1992; Por, 1995).

Near the tower, in the predominant prevailing wind direction, which was between north and west, the fetch was vast, open and flat over a long distance of about 1Km. On the eastern and southern sides there is a closed vegetation or gallery forest (“mata ciliar”) and a building, respectively.

The experiment was conducted in September – October 1996, during dry season. Data selected comprises of measurements made by cup and sonic anemometers and slow response temperature/humidity sensors mounted on the tower. The sonic anemometers (Solent, model 1012 R 2A) were placed at 25 and 19.4m above the surface, and the data from both instruments were obtained at 21Hz approximately. A microcomputer was used to acquire the data. The cup anemometers (Campbell, model 014A) and temperature/humidity sensors (Campbell, model HMP35C) were placed at six heights on the tower, namely 8, 10, 13, 18 and 21.6m above the surface. Data from all of these instruments were recorded at the frequency of 10 minutes in a data logger.

RESULTS AND DISCUSSION

For the Pantanal gradient observation data “L” values were obtained in meters as $(TU_*^2/gk\theta_*)$ using the fast response data obtained from sonic anemometers. Figures 1 and 2 show the diurnal variation of “L” calculated at two heights 19.4 and 25 m for the Julian days 276 and 277. Both the data is similar on both the heights. The data at 25 m on 276 contains only afternoon and late night values and 277 contains morning afternoon values. On day 276 the surface layer is unstable during the afternoon as L is negative and it is stable during the night as L is positive. On 277 the surface layer is stable in the early hours and unstable in the afternoon, similar consistent trend was also found with the estimated “L” values at the height 19.4 m.

Figure 3 indicates how Monin-Obhukov length scale vary comparatively between 19.4 and 25 m. The L values of 19.4 m and 25 m are shown in the ordinate and on the abscissa, respectively. In the graphs the lines are drawn through zero values of L for both 19.4 and 25 m dividing the graphs into four parts. There is also an inclined line passing through origin at 45° which shows the one to one correspondence. So, the values in the upper left corner and lower right corner indicate complete disagreement in L values between 19.4 and 25 m. In the case of former the L value at 19.4 is positive and the same is negative at 25 m. This means that there is stability at the lower level (19.4 m) and instability at the upper level. In the later case the lower right corner, L value at 25 m is positive and L value at 19.4 m is negative, whereby indicating that there is stability at 25 m and at the lower level (19.4 m) there is instability. Such disagreement is much conspicuous on day 276, whereas it is practically absent an Julian day 277 excepts for one point.

The values in the lower left corner corresponds to L negative at both 19.4 – 25 m indicating instability whereas the top right corner L is positive indicating stability. Here, there is a signification of inclined line of one to one correspondence. Talking about instability, if the values are above this line means that L values are more negative at 19.4 m. This means that instability is more at 25 m. If the values are below this line the L values at 25 m, which means that though there is instability at both the levels, the instability is more at 19.4 m and less at 25 m. The top right corner indicates stability (L is always positive at both levels). Here again the degree of stability at 19.4 m and 25 m is determined by the position corresponding to inclined line. If the point is above the inclined line, it indicates that L value is more at 19.4 m, which also indicates that it is less stable corresponding to 25 m even through there is stability at both levels. The values below this line indicate in a similar way that L is more at 25 m thereby indicating that the degree of stability decreases in vertical.

A close observation of graph 3 indicates that the over all stability is less on day 276 comparing to day 277, and on the day 277 de degree of instability is more at 19.4 comparing to 25 m. The meeting point of '0' lines of L is also having significance, even though L is discontinuous at L = 0, its proximity indicates strong stability or instability depending on whether L is positive or negative. Such strong stability was present on the Julian day 276 and this is absent on day 277 as the cluster near the origin on the L negative side is absent.

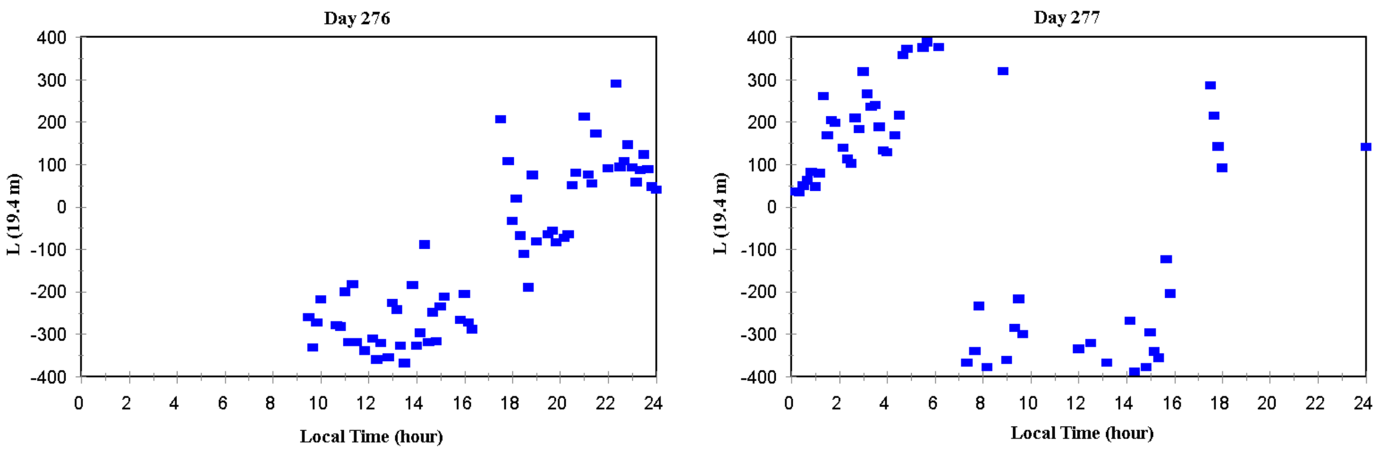

Fig. 1 – Diurnal variation of Monin-Obukhov length (L) in meters at 19.4 m.

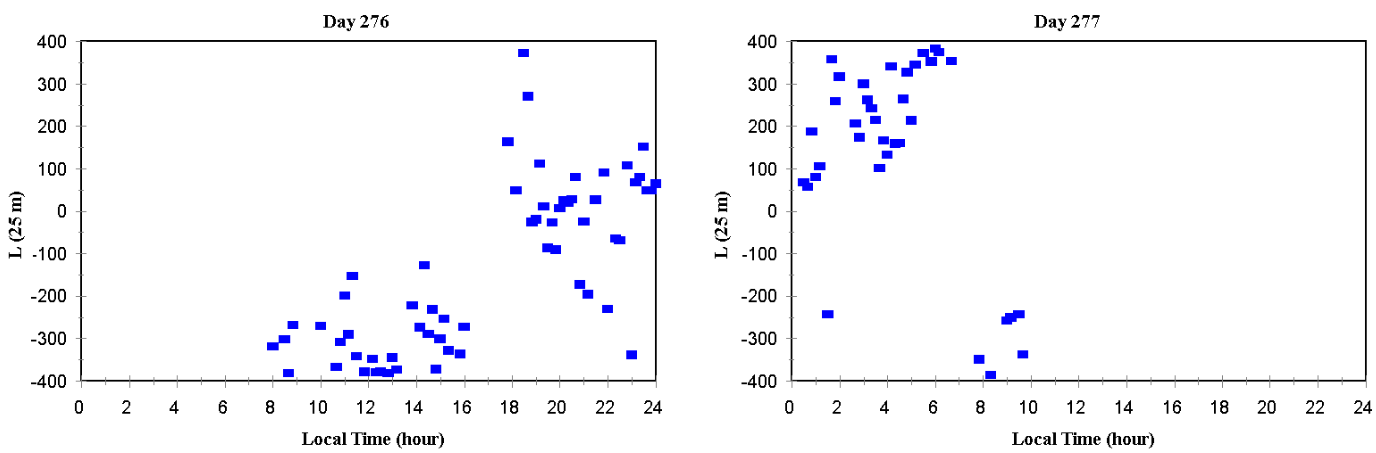

Fig. 2 – Diurnal variation of Monin-Obukhov length (L) in meters at 25 m.

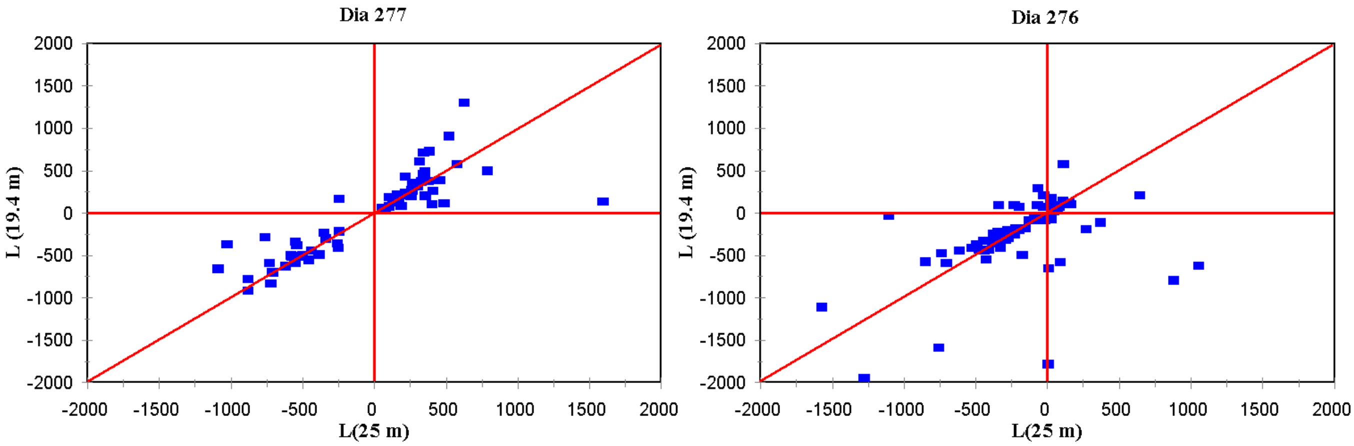

Fig. 3 – Relation of Monin-Obukhov length (L) between 19.4 and 25 m.

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