A STUDY OF STABLE ATMOSPHERIC BOUNDARY LAYER CHARACTERIZATION OVER HIGHVELD REGION OF SOUTH AFRICA

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1. INTRODUCTION

The stable atmospheric boundary layer (SBL) study over the Highveld South Africa has a special relevance, since it has the majority of the electric power generating plants located in this region. SBL is characterized by a steady wind near the surface, virtual potential temperature increase with height, humidity decrease with height, strong wind shears (directional & speed), turbulence generated mechanically by shear is destroyed by negative buoyancy and viscosity. The non-turbulent periods are frequent and SBL becomes decoupled from the surface. The oscillatory behaviour at the near-surface atmospheric variables is a manifestation of the non-linear character of the turbulent exchange.

The aim of the paper is to study the SBL characteristics over the Highveld region of South Africa using automatic observational network data, theoretical models and recently developed mobile LiDAR system at the Council for Scientific and Industrial Research (CSIR) National Laser Centre (NLC), Pretoria (25.5º S; 28.2º E), South Africa. Here, we present some preliminary results of the time variation of meteorological parameters and turbulent fluxes of momentum and heat and SBL height as detected from LiDAR system.

2. DATA AND METHODS

The data used in this study were sampled continuously for 2 years (2008- 2009), by using Davis automatic weather stations (DAWS) installed at Bethal. The experimental set up for the observation of all relevant meteorological variables and data collection are presented in (Esau e t *al*., 2010). The stations use a combination of fan-aspiration and passive shielding to minimize the effects of solar radiation-induced temperature error. It should be noted that in addition to the Davis station experimental set up, which was mounted at height of 2 m, one more temperature sensor has been installed at 0.5 m to allow for the calculation of turbulent fluxes.

The determination of the turbulent fluxes of momentum and heat is based on the recent advancement of the similarity theory method. First, for the past 60 years, Kolmogorov's (Kolmogorov, 1941) approach for turbulent closure models based on the turbulent kinetic energy (TKE) balance has been a major scientific tool. His hypothesis, however, is theoretically justified for-neutrally stable turbulent flows only. Many attempts to apply Kolmogorov's method for stratified flows have encountered difficulties. The straightforward application of the TKE budget equation leads to the existence of critical Richardson number. The experimental data from laboratory and atmospheric flows have persistently shown that turbulence exists at higher than the critical Richardson number values.

Recently (see Zilitinkevich et al., 2007) it has been shown that the use of the total turbulent energy TTE=TKE +TPE (TPE is the turbulent potential energy), instead of TKE only, is a promising way for development of consistent turbulent closure models. One main result of the new theory is that the critical Richardson number does not separate the turbulent and the laminar flow regimes. Instead turbulence exists at any Richardson number.

The Monin Obukhov (MO) theory, considered for a half a century as an ultimate framework for analyzing surface-layer turbulence, is now generalized (Zilitinkevich & Esau, 2005). In addition to the Monin-Obukhov length L, which characterizes the effect of local buoyancy on turbulence, there are two additional length scales: L_f - describing the effect of the Earth rotation and L_N - characterizing the non-local effect of the static stability of free atmosphere.

$$\frac{1}{L_*} = \left[\left(\frac{1}{L}\right)^2 + \left(\frac{C_N}{L_N}\right)^2 + \left(\frac{C_f}{L_f}\right)^2 \right]^{1/2} \quad (1)$$

Where, $C_N = 0.1$, $C_f = 1$ are empirically determined dimensionless constants. In this paper, the momentum and heat resistance laws are solved using the widely accepted functional form (Businger e t al., 1971) under stable stratified atmosphere condition (eqn 2 and 3).

$$\bar{u}(z) = \frac{u_*}{\kappa}(\ln\frac{z}{z_0} + 4.7\frac{z - z_0}{L}) \qquad (2)$$

$$\bar{T}(z) - \bar{T}(z_0) + \gamma_a(z - z_0) = \vartheta_*(0.74\ln\frac{z}{z_0} + 4.7\frac{z - z_0}{L}) \qquad (3)$$

These equations allows for obtaining analytical solutions for the turbulent fluxes.

Remote sensing data from LiDAR (Light Detection and Ranging) is also used to detect the Boundary Layer Height (BLH). There are three methods for determining the PBL height using LiDAR backscatter measurements: Gradient method, Standard deviation method and Haar wavelet transforms method. In the present paper, gradient and statistical methods are used. The gradient method used to determine the SBL height is based on the analysis of the gradient of the back scattering signal S (z) from the LiDAR:

3. TURBULENCE CHARACTERISTICS AND SBL HEIGHT OVER HIGHVELD

The data in section 2 and the generalized theory discussed in the previous section allow presentation of some preliminary results of the variation of the meteorological variables and turbulent fluxes in stable stratification conditions over the Highveld region. The extreme variability of the stability conditions at micrometeorological scales can be observed in Figure 1, which presents the Monin-Obukhov length variation for a particular night.

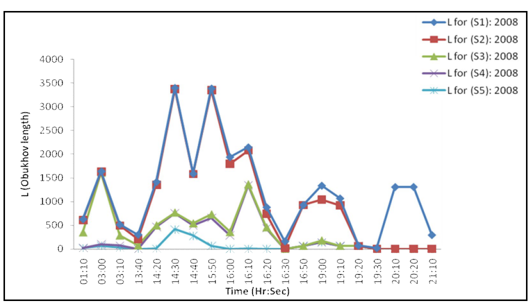

FIG.1. Temporal variation of the Obukhov length over the Highveld region

It is evident from the figure that, stability tend to increase with time at night time SBL, this is indicated by the Obukhov length (L) which is <1500 and decrease with time in the day time SBL where L for station 1(S1) and station 2 (S2) >1000. This is an indication of near neutral stratification of the SBL over these stations.

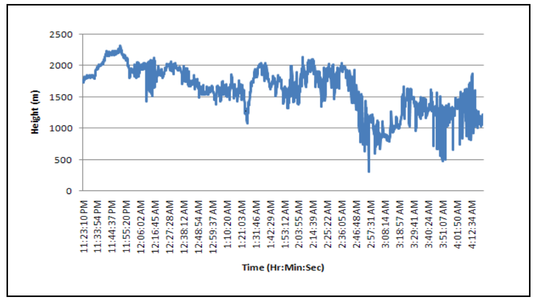

FIG.2. Temporal variation of SBL height over Elandsfontein (part of Highveld).

Figure 2 indicates the temporal variation of the SBL height over Elandsfontein as derived from LiDAR using gradient method. It illustrates the increase of stability with time this is indicated by decreasing trend of the height of the SBL with time at night time, (see from 11:23pm up to 04:09a.m)

4. REFERENCES

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