Behavior of temperature structure parameter in the lower ABL at a tropical station

Shravan Kumar Muppa and V.K. Anandan
National Atmospheric Research Laboratory, Gadanki, INDIA.

Abstract:

The intensity of acoustic backscatter from a Doppler SODAR at NARL, Gadanki is used to compute the profiles of temperature structure parameter C^2_T. The variations of the temperature structure parameter during the convective and stable conditions were studied for a period of one year from January 2007 to December 2007. The results obtained showed a difference of magnitude of the order of 1-2 in convective conditions than the stable conditions. This is mainly due to two reasons; first it is due to the raise of plume height where high convection takes place so large values of C^2_T are observed. Secondly, it is due to the generation of mechanical turbulence in the mixed layer along with the buoyancy driven turbulence. The drainage winds from the complex terrain also affected the behavior of the temperature structure parameter. Monthly mean values of the C^2_T are presented for the whole year. High values for the C^2_T were in the months of post monsoon October and November and low values for the monsoon starting month i.e. July are reported. The results also agree with the -4/3 similarity law of the C^2_T in the unstable Atmospheric Boundary Layer. Corrections due to the humidity contributions were also made in the measurements of the temperature structure parameter.

1.Introduction:

Sodar is widely used as a remote sensing instrument in the Atmospheric Boundary Layer (ABL). The intensity of the acoustic backscatter signal from a monostatic Doppler sodar due to the temperature fluctuations in the scattering volume is proportional to the temperature structure parameter (C_T^2) in the ABL. Thus the structure function of temperature parameter can be obtained by measurement of the sodar signal. Measurement of the (C_T^2) is very useful for optical tracking and in turbulence studies.it has been extensively studied by Asimakopoulos et al [1], Kaimal et al [2], Haugen and Kaimal [3], Weill et al [4], Coulter and Wesley [5] ,Moulsley et al [6], Dubosclard [6] ,Singhal et al [7], Devara et al [8] , Cuijpers and kohsiek [9] and helmis et al [10] Petenko and Shruygin [11] have developed a two-regime model for the probability density function of the temperature structure parameter in the Convective Boundary Layer (CBL). Haugen and Kaimal [12] have found that measurement of the profile of (C_T^2) using the acoustic sounder can lead to serious in accuracies. Thomson et al [13] showed how to reduce the inaccuracies by using prinicipal sodar calibration techniques and measure the error resulted from it. The combined errors can then be removed from the backscatter signal for the estimation of (C_T^2). Here in this paper we are studying the variations of the temperature structure measured with a Doppler sodar in the CBL through the whole year.

2.Data set and Methodology.

The temperature structure parameter from the sodar equation is calculated by many researchers such as Thomson et al [13] Coulter and Wesley [5], Dubosclard [6], Coulter [14], Helmis et al [10] in the Convective Boundary Layer.

The sodar equation given by Little [15] is

$$P_R = P_e A_e \frac{c\tau}{2} \frac{\sigma\alpha}{Z^2} \qquad (1)$$

Where P_R is acoustic power received , P_e is the acoustic power transmitted, A_e is the effective area of the receiving antenna, α is the attenuation of the acoustic wave along the path , σ is the cross-section of the scattering volume , τ is the transmitted pulse width and c is the speed of sound.

For homogeneous and isotropic turbulence , σ can be written as Little[15]

$$\sigma = 7.2\ 10^{-3}\ \lambda^{-1/3}\ C_T^2\ T^{-2} \qquad (2)$$

where λ is the acoustic wave length, T is the mean temperature and C_T^2 the temperature structure parameter:

From 1 and 2 it follows that

$$C_T^2 = P_{Re}\, Z^2\, C^{-1}\, \alpha^{-1}\, T^2 \qquad (3)$$

Where P_{Re} is the received electrical power and C a factor depending on the sodar parameters. The system parameters for our sodar are tabulated in table 1. The factor C for our sodar is calibrated by using the laboratory standard references. The transducer transmit and receive gain efficiencies are measured using well calibrated instruments(microphones) . the principal sodar calibration errors together with the antenna beam pattern measurements constituted to be about 2 dB for our system.
Data is taken from a Doppler sodar which is continuously operated round the clock located in National Atmospheric Research Laboratory (NARL), Gadanki a tropical low latitude station from Jan 2007 to Dec 2007. Data is taken only in the zenith beam for the present analysis. Received power is taken for the computation of C_T^2 .

3. Results and Discussion:

The temperature structure parameter estimated from the backscatter signal of the Doppler sodar at different height ranges in convective conditions is plotted in figure 1. At an altitude of 390m the C_T^2 shows an increase during the south west monsoon period i.e. in the month of June and starts decreasing during the end of the monsoon in September. There is again an increase during the north east monsoon i.e. month of November and is maintained constant in December. During the month of February due to convection along with the humid air C_T^2 value is increased. During the pre-monsoon period due to the dry air present in the atmosphere C_T^2 behavior shows a gradual decrease. Same trend is maintained by the remaining two range levels with an order of difference in the magnitude of the C_T^2. The temperature structure parameter estimated from the backscatter signal of the Doppler sodar at different height ranges in stable conditions is plotted in figure 2. The C_T^2 shows a typical behavior during the summer season, it is increased during the month of March and the shows a gradual decrease during April. An increase is observed during the months of June and July. This shows high values in the month of august and September for all the range levels. The decreasing behavior is again observed for the months of November and December. . The vertical profiles of monthly mean values for C_T^2 are given in figure 3. These profiles obey the similarity law of the temperature structure parameter (-4/3) law of the surface layer There is a large difference in the magnitude between the lower heights and the higher altitudes. The decrease in C_T^2 is mainly due to decrease of the plume occurrence with height (Petenko and Shurygin 1999). The thermal plumes range from different altitude levels in this station during the different seasons. In summer they range up to500-600m and winter 200-300m.

4. Conclusions:

In this study behavior of the temperature structure parameter in the convective boundary layer was examined for a period of one year using Doppler sodar over Gadanki. The results obtained showed a difference of magnitude of the order of 1-2 high in convective conditions than the stable conditions. This is mainly due to two reasons; first it is due to the raise of plume height where high convection takes place so large values of C^2_T are observed. Secondly, it is due to the generation of mechanical turbulence in the mixed layer along with the buoyancy driven turbulence.

References:

1 Asimakopoulos, D. N., Cole, R. S.,Caughey, S. J. and Crease, B. A. (1976), A quantitative comparison between acoustic sounder returns and the direct measurement of atmospheric fluctuations. *Boundary-Layer Meteorol.,* 10,137-147.

2 Kaimal, J. C., Wyngaard, J. C., Haugen, D. A., Cote, 0. R., Izumi, Y., Caughey, S. J. and Readings, C. J. (1976), Turbulence structure in the convective boundary layer. *J. Atmos.Sci.,* 33,2 1 52-2 169.

3 Haugen D.A., and Kaimal J.C.(1978) Measuring temperature structure parameter profiles with an acoustic sounder, *J. Appl. Meteorol.,*17, 895-899.

4 Weill, A., Klapisz, C., Strauss**,** B.,Baudin, F.**,** Jaupart, C..Van Grundebeeck, P. and Goutorbe, J. P.(1980), Measuring heat flux and structure functions of temperature fluctuations with an acoustic Doppler sodar. *J. Appl. Meteorol.,*19, 199-205.

5 Coulter, R. L. and Wesely, M. L. (1980), Estimates of surface heat flux from sodar and laser scintillation measurements in the unstable boundary layer. *J. Appl.Meteorol.,* 19,1209-1222.

6 Dubosclard. G**.**(1982), A sodar study of the temperature structure parameter in the Convective boundary layer. *Boundary-Layer Meteorol.,* 22,325-334.

7 S.P.Singhal, B.S. gera and S.K. Agarwal (1982) Determination of structure parameters using sodar *Boundary-Layer Meteorol.,* 23,105-114.
8 Devara , P.C.S., K.G. Vernekar and Bh.V. Ramana murthy (1987) on the variation of temperature structure parameter in cloud and clear air during the summer monsoon season .*pageoph* 125, 121-129
9 Cuijpers J.W.M and W. Kohsiek (1989), vertical profiles of the structure parameter of temperature in the stable, nocturnal boundary layer, *Boundary-Layer Meteorol. 47*,111-129.
10 Helmis C.G., J. A. Kalgiros, D. N. Asimakopoulos and A. T. Soilemes (2000), Estimation of potential-temperature gradient in turbulent stable layers using acoustic sounder measurements *Q. J. R. Meteoml. Soc*., 126,31-61.
11 Petenko I.V.,and E.A Shurygin (1999), A two-regime model for the probability Density function of the temperature structure parameter in the convective boundary layer . *Boundary-Layer Meteorol., 93*,381-394.
12 Haugen D.A., and Kaimal J.C.(1978) Measuring temperature structure parameter profiles with an acoustic sounder, *J. Appl. Meteorol.,*17, 895-899.
13 Thomson D. W., R. L.Coulter and Z. Warhaft (1978), simultaneous measurements of turbulence in the lower atmosphere using sodar and aircraft *J. Appl.Meteorol.,* 17,723-734
14 Coulter R.L. (1990), A case study of turbulence in the stable nocturnal boundary layer *Boundary-Layer Meteorol., 52*,75-91.
15 Little, C. G.: 1969, 'Acoustic Methods for the Remote Probing of the Lower Atmosphere', Proc. IEEE 57,571-578.

Figures:

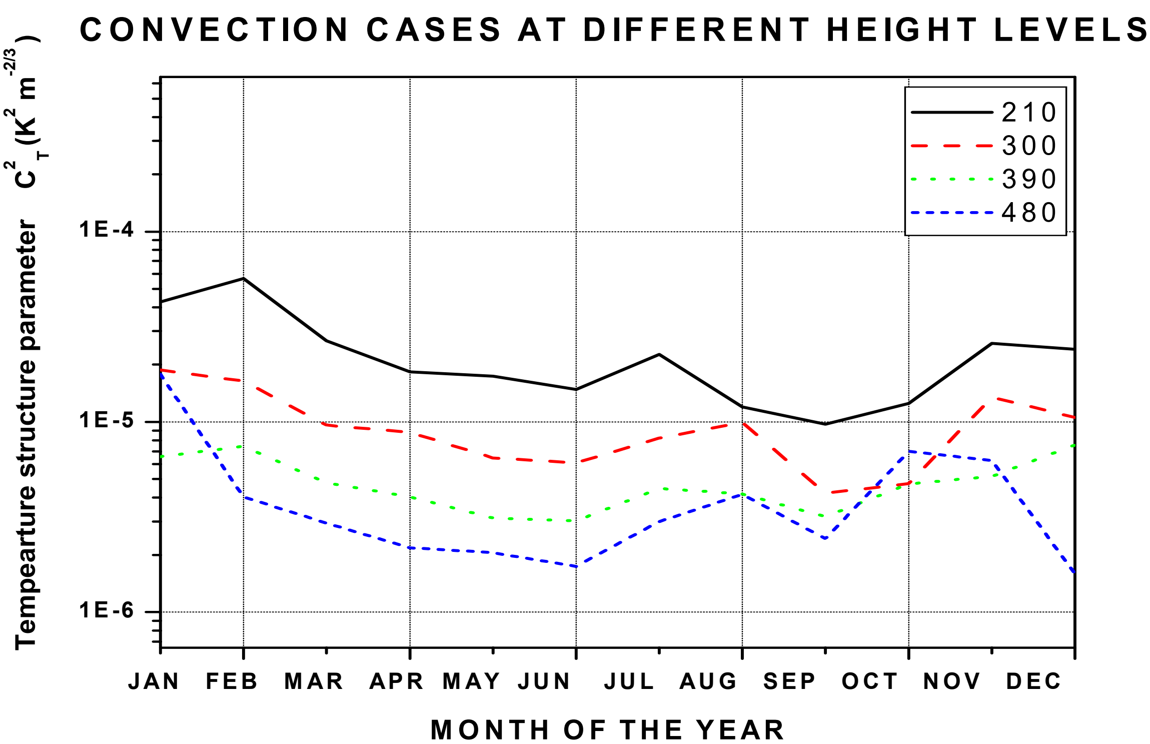

Figure 1 Monthly mean values of C_T^2 during convective conditions.

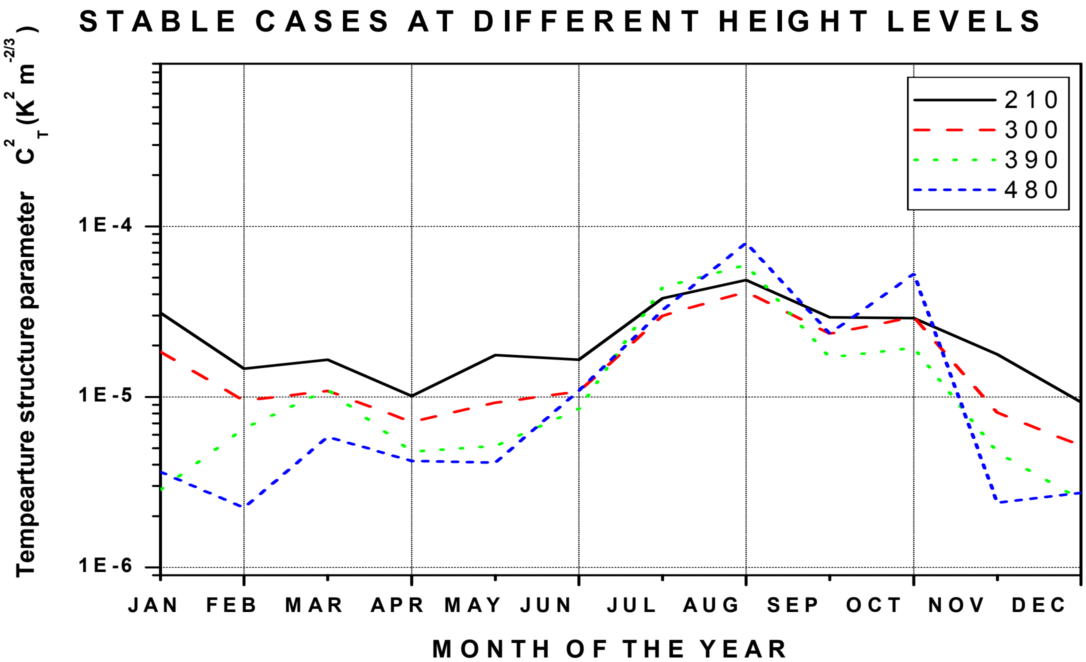

Figure 2 Monthly mean values of C_T^2 during the stable conditions

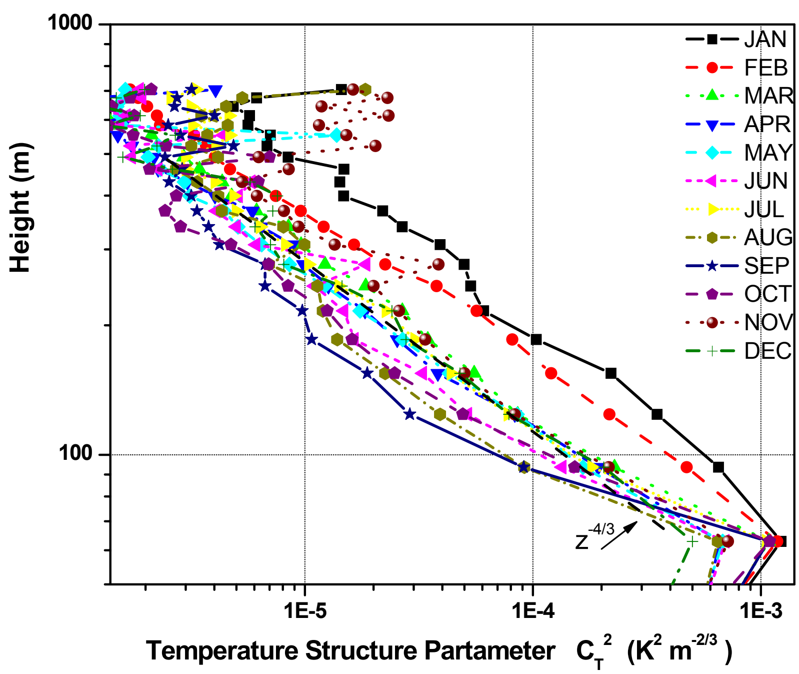

Figure 3 vertical profiles of C_T^2 for a few representative cases for each month.