# Atmospheric boundary layer observations over Gadanki using lower atmospheric wind profiler: Preliminary results

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**This article describes the atmospheric boundary layer observations over Gadanki using L-band (1357.5 MHz) lower atmospheric wind profiler (LAWP) during clear air conditions. The LAWP at Gadanki is capable of providing continuous high-resolution measurement in the first few kilometers of the atmosphere. The case studies described here revealed the existence of well-defined boundary layer with a height of 1.5–3.2 km during pre-monsoon period. The wind pattern showed the prevalence of north/south easterly flow with maximum wind speed of around ~ 10 m s$^{-1}$. The daytime wind in the boundary layer is uniform with height due to intense turbulent convective mixing during noon hours.**

THE role of atmospheric boundary layer (ABL), the lowest portion of the atmosphere close to the earth's surface, as an active link in the climatic system is already recognized[1]. A better understanding of the structure and dynamics of the atmospheric boundary layer is imperative for understanding and modelling the chemistry and dynamics of the atmosphere at all scales[2]. Recent advances in the radio probing techniques, such as wind profilers[3–6] or boundary-layer radars made it possible to sample large volumes of ABL with good spatial and temporal resolution and without any perturbation of the flow. They offer a unique opportunity to study the boundary layer structure, wind and turbulence field as well as precipitation cloud systems.

An L-band UHF wind profiler, commonly referred to as Lower Atmospheric Wind Profiler (LAWP), was installed at Gadanki (13.5°N, 79.2°E), Andhra Pradesh, India (Figure 1), in collaboration with the Ministry of Posts and Telecommunications/Communication Laboratory, Japan for investigating ABL dynamics and precipitation cloud systems. Here we report diurnal evolution and vertical extent of ABL, during clear, pre-monsoon, dry, summer days over Gadanki using LAWP.

The LAWP is located at the National MST Radar Facility (NMRF), Gadanki (~ 375 m above msl) and is about 120 km from the nearest coastal weather station of India Meteorological Department at Chennai. The terrain around Gadanki is complex, with a number of hills (average height ~ 750 m) within 10 km radius and a mixture of agricultural and population centres. Since Gadanki is situated in a bowl of hills, the topography[7] of this site can also influence the ABL features.

The LAWP is a low power, L-band UHF (1357.5 MHz) pulsed coherent, phased array radar having an effective peak power aperture product of 1.2 × 10$^4$ Wm$^2$ capable of providing continuous high-resolution wind measurements in the first few kilometres of the atmosphere. The system and data processing details are given in Table 1. More details about the fabrication and operating characteristics are given in refs 7,8. The Doppler power spectra were analysed to get the three wind components. Hourly averages of the wind components were subjected to the statistical filtering[9] to discard those points which fall outside 2 or 3 times the standard deviation for each 1 h duration. The measured wind values were found to be in general agreement with those measured by radiosonde and MST radar[7,10]. A typical example of simultaneous measurements of wind speed with LAWP, MST radar and

**Table 1.** System specifications for LAWP

| Parameter | Specification |
|---|---|
| Operating frequency | 1357.5 MHz |
| Peak power | 1 kW |
| Maximum duty ratio | 5% |
| Antenna | 3.8 m × 3.8 m, phased array |
| Antenna gain | 29 dB |
| Beam control | Electrical steering, 3 directions |
| Beam switching | Zenith, 15° north, 15° east |
| Beam width | 4° |
| *Rx* gain | 52–120 dB |
| Pulse width | 0.33,1, 2 μs (variable) |
| IPP | 20–999 μs (variable) |
| Height resolution | 50, 150, 300 m (variable) |
| No. of range gates | 1–64 (variable) |
| Coherent integration | 1–256 (variable) |
| Incoherent integration | 1–128 (variable) |
| No. of FFT points | 64–2048 (variable) |

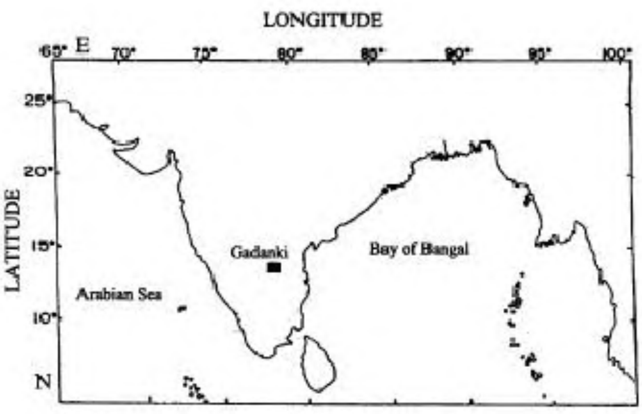


**Figure 1.** Location map showing Gadanki.

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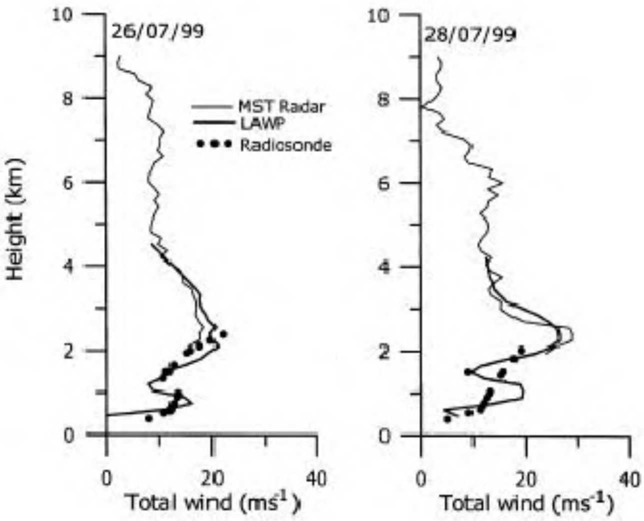


**Figure 2.** Comparison of wind speed measured by LAWP, MST radar and radiosonde on 26 July 1999 (1030 IST) and 28 July 1999 (1615 IST).

radiosonde is given in Figure 2. In the present study data collected during precipitation free periods only are used.

The vertical extent of ABL can be defined in different ways: the height where vertical gradient of the potential temperature or virtual potential temperature has a maximum; the crossover point of buoyancy flux profiles[11]; the region of enhanced radar reflectivity due to strong humidity gradients and turbulence[12]. The enhancement in radar reflectivity is in accordance with numerical experiments[11,13,14] which show maximum refractive index structure constant in the inversion layer or in the regions where temperature and humidity gradients are large[15]. In the present study radar reflectivity is used to identify the top of the boundary layer.

In this section the boundary layer over Gadanki is described during clear days in March, April and May 1999. To examine the diurnal variation of ABL, time height reflectivity plots are given in Figure 3 *a–d*. The top panels in Figure 3 *a–d* shows the contours of the logarithm

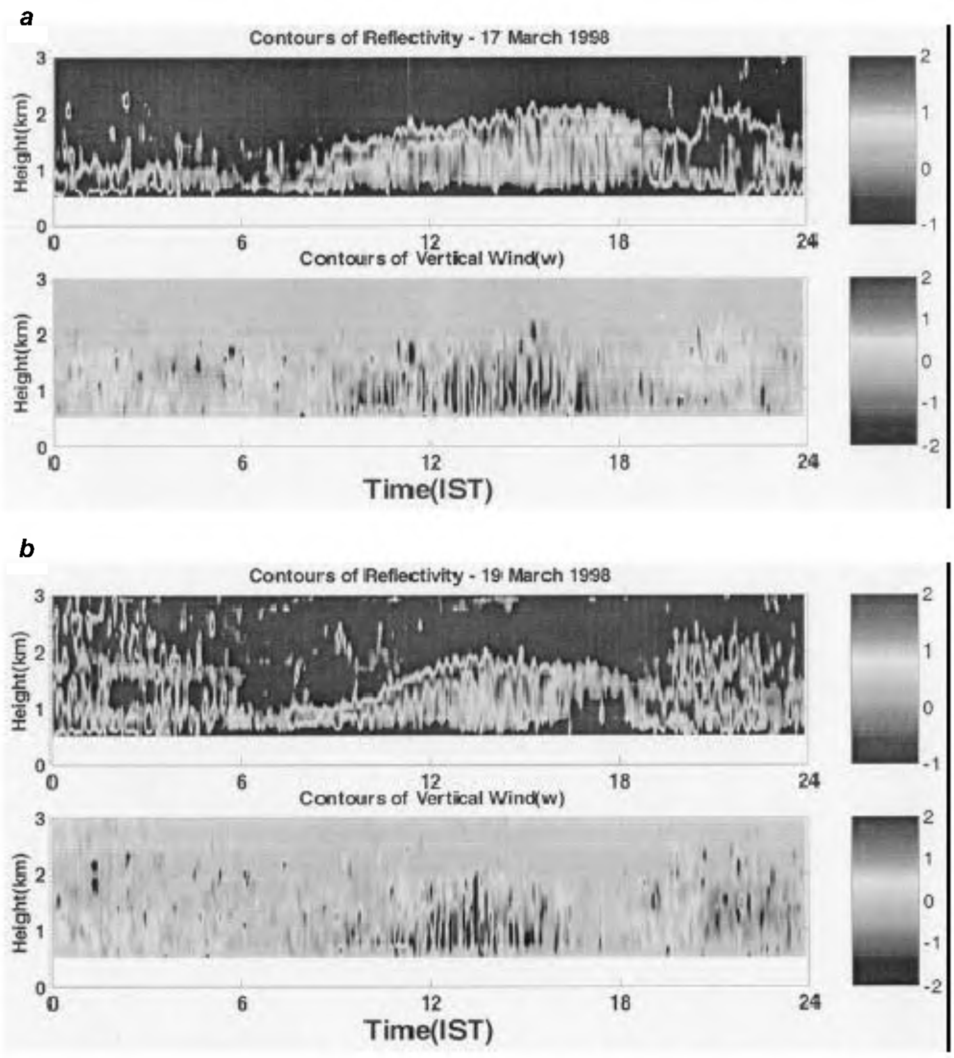


**Figure 3 *a–b*.** (Top) Contours of reflectivity in arbitrary scale and (bottom) contours of vertical wind component in m s$^{-1}$. ***a***, Case 1 (17 March 1998); ***b***, Case 2 (19 March 1998).

of radar reflectivity measured by the vertical beam in arbitrary units. The bottom panels represent the vertical velocity in m $s^{-1}$. It is evident from Figure 3 that the time height plot of the wind profiler reflectivity can be used to distinguish the top of the boundary layer. The striking features that can be observed from the reflectivity contours are the two strong echo regions. The first one is observed in the morning hours associated with the convective activity. The second region is the extremely strongecho region observed during the night hours. The echo region observed during the morning hours corresponds to the morning transition or the morning rise of inversion. This significant echo region appears in the lowest observational heights and ascends gradually, reaching a maximum height in the afternoon hours. This strong echo region marks the height of the daytime boundary layer or convective boundary layer (CBL). So this can be considered as the top of the boundary layer. The observations of this echo associated with morning transition in this study are similar to those observed by other boundary layer radars in clear air days[3,6,14,15]. The vertical velocity ($w$) contours in the bottom panels of Figure 3 *a–d* suggest the growth of thermals up to the base of the inversion layer; intense updrafts and downdrafts are also evident. These motions are generally considered as buoyancy-generated motions that tend to form concentrated regions of high magnitude, positive, vertical velocity fluctuations ($+w$) in 'updrafts' and compensating regions of negative, vertical velocity fluctuations ($-w$) in 'downdrafts'[16]. These regions of dominantly upward and downward moving fluid are primarily responsible for the transport of fluxes of momentum, heat and passive scalars[17] and strongly influence the near-ground horizontal velocity field.

The case studies considered here show that the vertical extent of the boundary layer differs from day to day: 2, 1.6, 2.6 and 2 km for the cases 1 to 4, respectively. The monthly variation of ABL heights estimated from radar

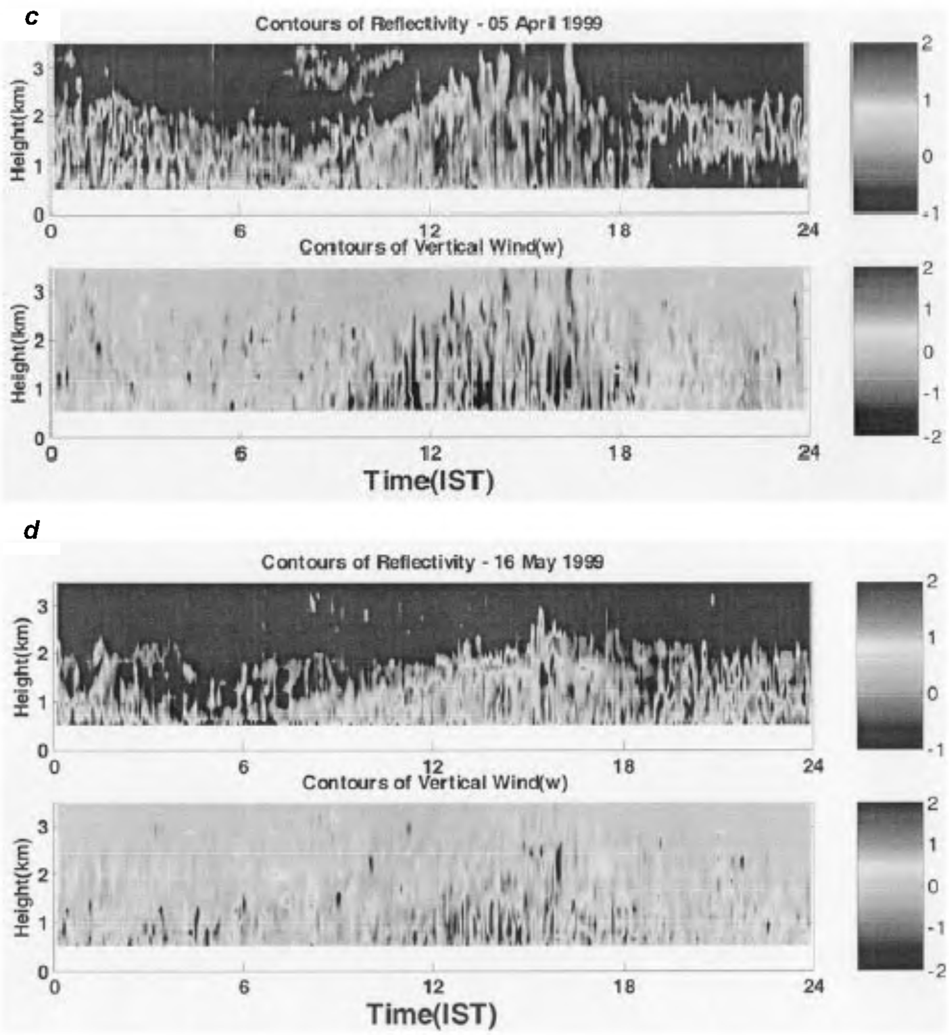


**Figure 3.** (Top) Contours of reflectivity in arbitrary scale and (Bottom) Contours of vertical wind component in m $s^{-1}$. ***c***, Case 3 (5 April 1999); ***d***, Case 4 (16 May 1999).

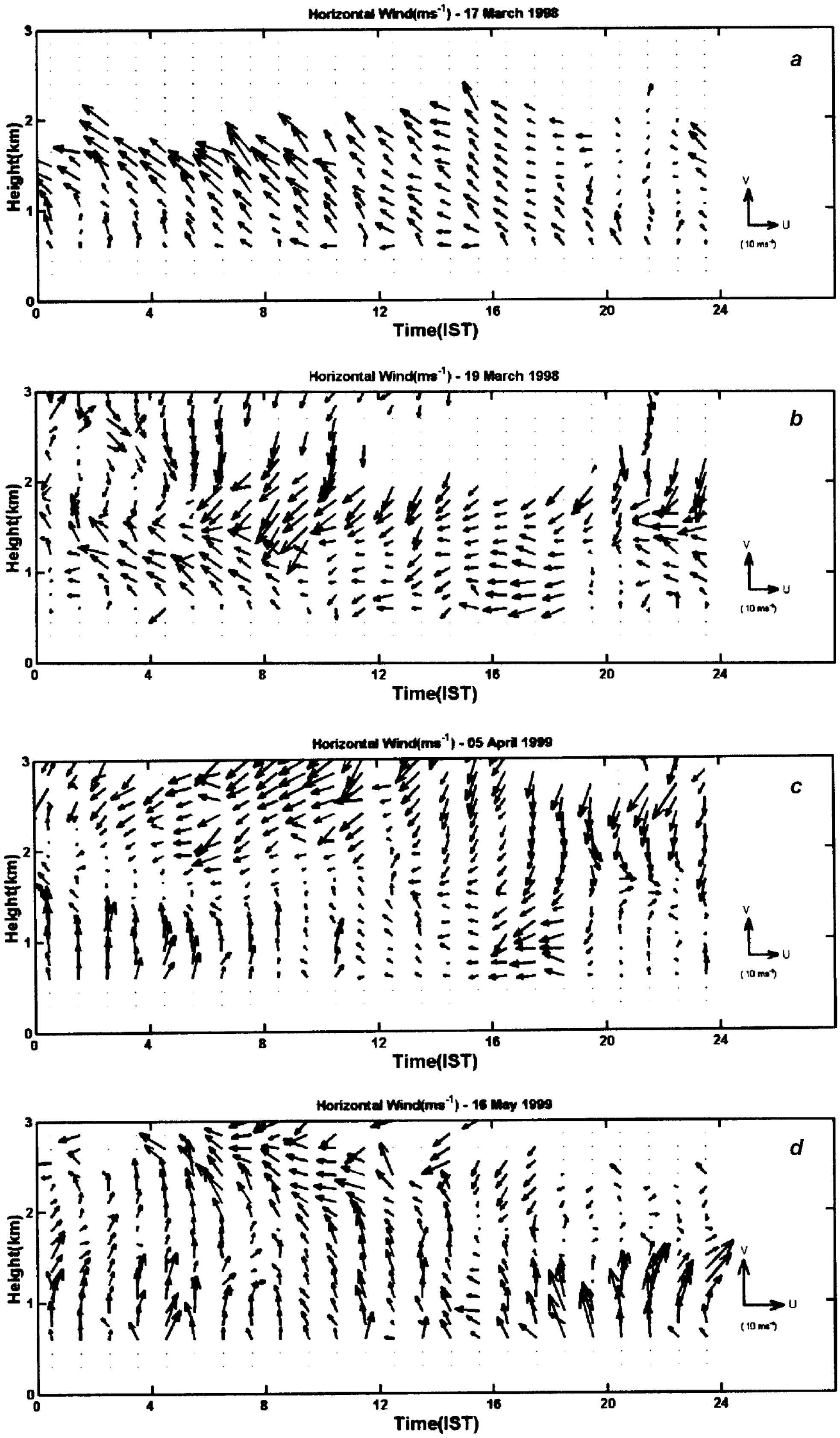


**Figure 4.** One hour averaged horizontal wind on ***a***, 17 March 1998; ***b***, 19 March 1998; ***c***, 05 April 1999; and ***d***, 16 May 1999.

**Table 2.** ABL height during pre-monsoon period

| Month and year | No. of days considered | ABL height (km) |
|---|---|---|
| March 1999 | 9 | 1.94 ± 0.53 |
| April 1999 | 22 | 2.26 ± 0.52 |
| May 1999 | 20 | 2.23 ± 0.22 |

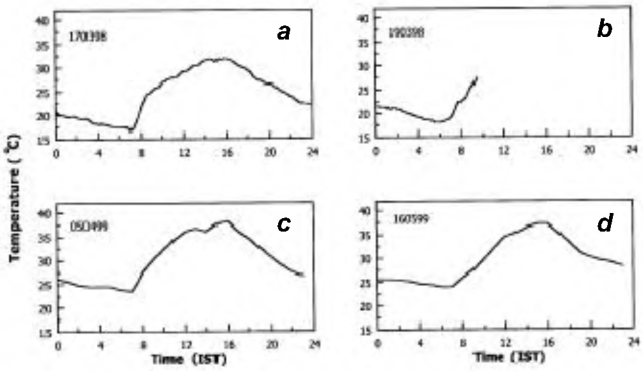

**Figure 5.** Diurnal variation of near-surface temperature on ***a***, 17 March 1998; ***b***, 19 March 1998; ***c***, 5 April 1999 and ***d***, 16 May 1999. Temperature data are available only up to 1000 IST on 19 March 1998.

reflectivity is shown in Table 2. The ABL height reaches an average value of ~ 2 km during the pre-monsoon period with a range of 1.5 to 3.2 km. This value is high compared to mid latitudes, where the boundary layer height maximum is mostly around 1.5 km (refs 2, 18, 19). But the general features of the ABL over this tropical station are comparable to those from the near-equatorial region[6].

Figure 4 *a–b* shows the diurnal variation of the hourly averaged horizontal winds for the case studies considered above. It can be seen that the north/south easterly winds prevailed most of the time, but the day-to-day variability is also evident. During noon hours, the wind structure revealed a uniform wind up to the top of the boundary layer. This can be due to the intense turbulent mixing within the boundary layer because of the increased convective activity (see the vertical velocity contours). The maximum value of wind speed is found to vary around ~ 10 m $s^{-1}$. But one distinct feature that can be noted from Figure 4 is the existence of southerly or southwesterly flow in the early night and morning hours. This is mostly seen up to 1.5 km. This can be the possible signature of the existence of the topographically-induced flow over the site due to the complex terrain effects and it will be addressed in detail in the future studies.

To examine whether the boundary layer evolution has any dependence on surface temperature, the near-surface air temperature obtained from an automatic weather station located near LAWP is shown in Figure 5. The air temperature shows diurnal variation with a maximum around 1500 IST and minimum around 0700 IST. It can be noted that ABL height is also reaching maximum value around 1500 IST.


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