AN INVESTIGATION OF OZONE AND PLANETARY BOUNDARY LAYER DYNAMICS OVER GADANKI, INDIA

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1. Introduction

It is now widely recognized that the dynamics of convective boundary layer (CBL) in tropics are very important to understand the global climate, and meteorological now–casting, including the prediction of boundary layer evolution and pollution dispersion. The daily cycle of CBL growth and collapse can be seen clearly in time-height displays of the reflectivity profiles of lower atmospheric wind profilers (LAWP). There are usually sharp gradients in aerosol concentration and specific humidity through the entrainment zone at the CBL top as cleaner and dryer air from the free atmosphere is entrained and mixed into the aerosol-laden, moisture boundary layer (Cohn and Angevine, 2000). Although ozone in the CBL exists only in the parts per billion (ppb) range, it is an important gas due to its key role in influencing the oxidation capacity of the lower atmosphere. Several studies have examined the impact of the Asian pollutants on other parts of the world (e.g., Jacob et al., 1999). In spite of the importance of the tropical troposphere, there are no systematic simultaneous measurements of surface ozone and its precursor gases over the Indian region (except those at Ahmedabad, an urban site) until recent years (Naja and Lal, 1996; Lal et al., 2000). The tropospheric ozone problem was once thought to be restricted to urban areas, but now it is recognized that ozone concentrations in rural areas can rival those measured in urban areas. Study of ozone chemistry is important at rural sites because ozone precursors get transported to there from the near–by urban or industrial areas (Angevine et al. 2003). This paper concerns an evaluation about the ozone (O_3) and CBL dynamics over the tropical rural site at Gadanki using UV absorption based analyzer and LAWP for 30 days, during April 1999.

2. Observational Site

The National MST (Mesosphere-Stratosphere Troposphere) Radar Facility (NMRF) at Gadanki (13.5^{o}N, 79.2^{o}E, 375 m above sea level) is situated in a rural area of Chittoor district (Andhra Pradesh state) in the southern part of India [Figure 1 (a)]. The terrain surrounding the radar site is illustrated by the three-dimensional contour map in Figure 1(b). The local and general topography is rather complex with a number of hills and a very irregular mix of agricultural, small-scale industrial and rural population centers. There are hills in the northern and southern sides of the observation site within 1 to 10 km distance. The average height of the hills is about 550 m, with a maximum height of about 1000 m. A major road passes through near the observation site, with the usage of a few thousands of heavy vehicles every day. There is no major industry in the Chittoor district except for few small-scale units at major towns. Tirupati (population about 0.6 million) and Chittoor (population about 0.3 million) are the nearest urban regions about 30 km in Northeast and south/southwest to the experimental site. The observation site is about 120 and 200 km from the two nearby major cities, Chennai (Madras) to the southeast and Banglore to the Southwest, respectively.

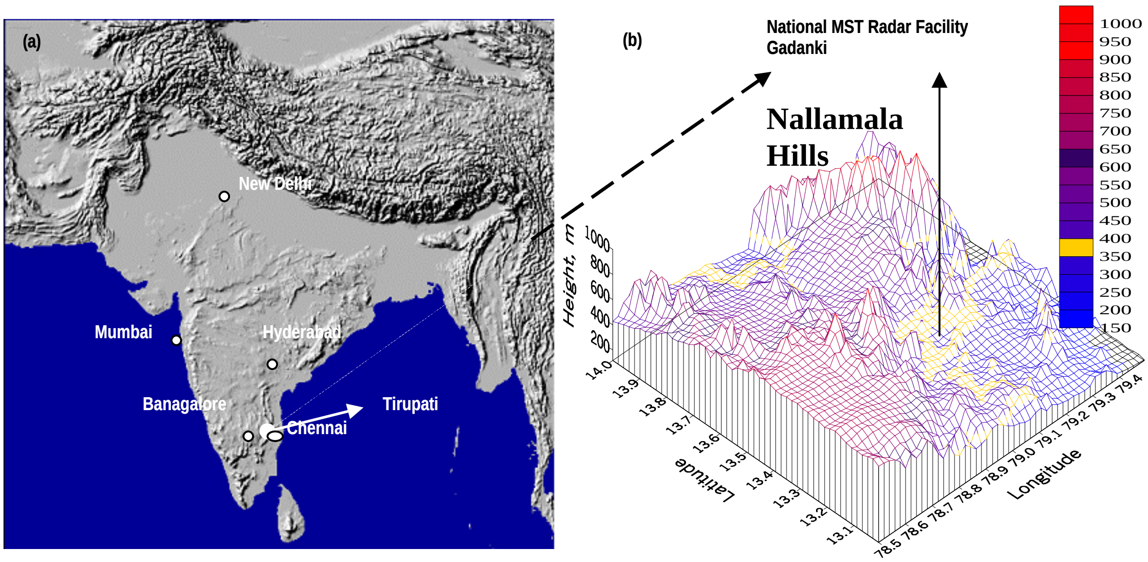

Figure 1.(a) Map showing several cities and major towns near by National MST Radar Facility (NMRF) and (b) Three dimensional view of the main topography around Gadanki (after Reddy et al. 2002).

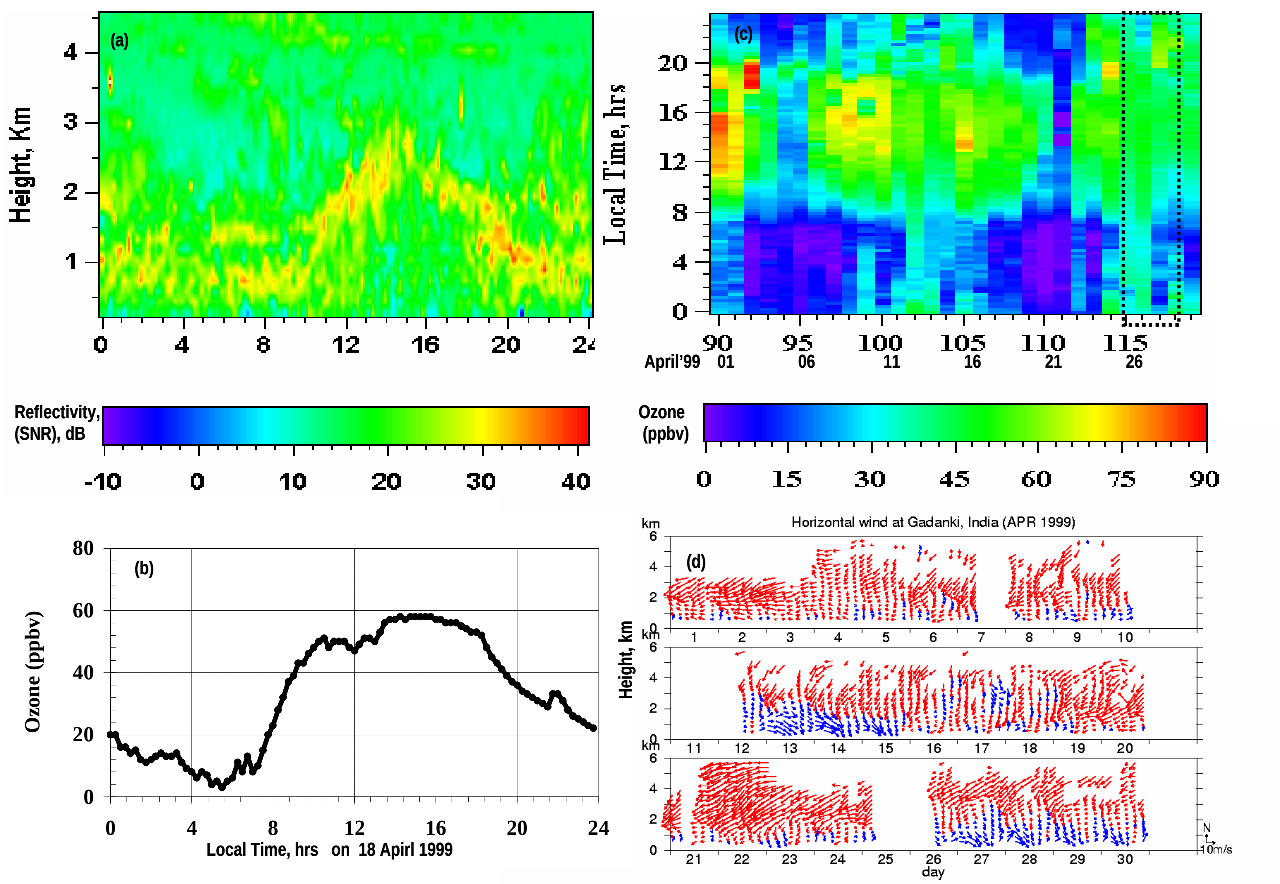

Figure 2. Time-height cross–section of the Gadanki–LAWP Reflectivity (SNR) averaged over 10 min for the vertical beam on clear, sunny day (18 April 1999). Diurnal variation of Ozone distributions at Gadanki on (b) 18 April 1999 and (c) for entire month of April 1999. (d) Zonal-meridional winds averaged every 4-h observed with the Gadanki-LAWP from 01 to 30 April 1999 during dry period.

3. Results and discussion

The LAWP observations [Figure 2(a)] show the top of CBL as a distinctive signature in a time-height plot of reflectivity. Figure 2(b) shows diurnal variations of ozone observed at Gadanki on 18 April 1999. The distribution of ozone in the CBL is irregular due to localized production zones and the dynamic processes of the region. The summer afternoon periods that are most conducive to ozone production and also periods of intense convective mixing in the CBL. Precursor gases are drawn into turbulent eddies from localized sources and from horizontally advected sources located near the top of the boundary layer or folded into the boundary layer by meteorological processes. The irregular nature of the summer afternoon ozone distribution could observed in vertical profiles and time sequences of ozone measurements. At other times of the day, the stable nocturnal boundary layer may exhibit almost constant ozone values. Ozone can be produced during the day by photo oxidation of precursor gases (Crutzen et al., 1999, and references therein). Mixing ratios of ozone start increasing gradually after sunrise, attaining maximum values during near local noontime. Figure 2(c) shows the diurnal variations of ozone observed at Gadanki from 01-30 April 1999 (DOY 90-120). Boundary layer processes and meteorology influences the ozone variability at rural site, Gadanki. Daytime production of ozone is observed throughout the month except during cloudy and rain days. At Gadanki, near to the UV analyzer, LAWP is used to obtain three dimensional wind speed measurements up to about 4000 m with a vertical resolution of 150 m, with a precision of 1 m/s for the wind speed and 10 degree for the wind direction (Reddy et al. 2002). The wind patterns are clearly dominated by the diurnal thermal regime. The daytime winds in the valley were typically from 7 to 10 m/s northeasterly wind regime which developed up to 1800 m between 08:00–09:00 LT (local time) and 19:00–20:00 LT, while the night time winds are rather weak, 1–2 m/s, blowing from the south. A Northeasterly stable wind regime could be noticed [Figure 2(d)] above 1500 m msl during one-month observations. Our results indicate that the diurnal cycle of ozone production is controlled by local thermal winds. In the nighttime, for several days (13-15 & 27-30 April 1999) high Ozone concentrations are noticed when the boundary layer winds are Westerly/northwesterly. Figure 2(c) and (d) show that important aspects of high Ozone concentration patterns are due to the local circulations and sensitive to the interaction of synoptic, regional, and local influences.

The month of April is dry period/pre-monsoon and also the beginning of summer-hot and very humid in southern India. During this period, maturation of the crops and consequent cessation of evapo-transpiration occur. No measurable rain fell during dry season; so soil moisture was probably quite low. It is an ideal situation to form the convective boundary layer at Gadanki region. The depth of the boundary layer is one of the fundamental properties that influences on fluctuating trace gases mixing ratios. The evolution of surface ozone, dynamics and the estimation of the CBL height are shown in Fig.3(a). From the figure it can be inferred that the surface averaged Ozone and CBL height are reasonably in good agreement. Fig.3 (c) and (d) one can notice that the boundary layer winds during 27-29 April 1999 were strong, a shift in wind direction in the middle of the boundary layer, discernable despite in mixing height at Gadanki after 1830 LT. The shift to westerly/southwest winds simply results in the ozone transport from nearby city (Bangalore) that is being advected towards Gadanki region.

The data collected during one-month experiment should prove useful for a wide range of modeling and analytical studies. The data are now being analyzed to obtain a detailed description and understanding of the nighttime ozone transportation from the urban region.

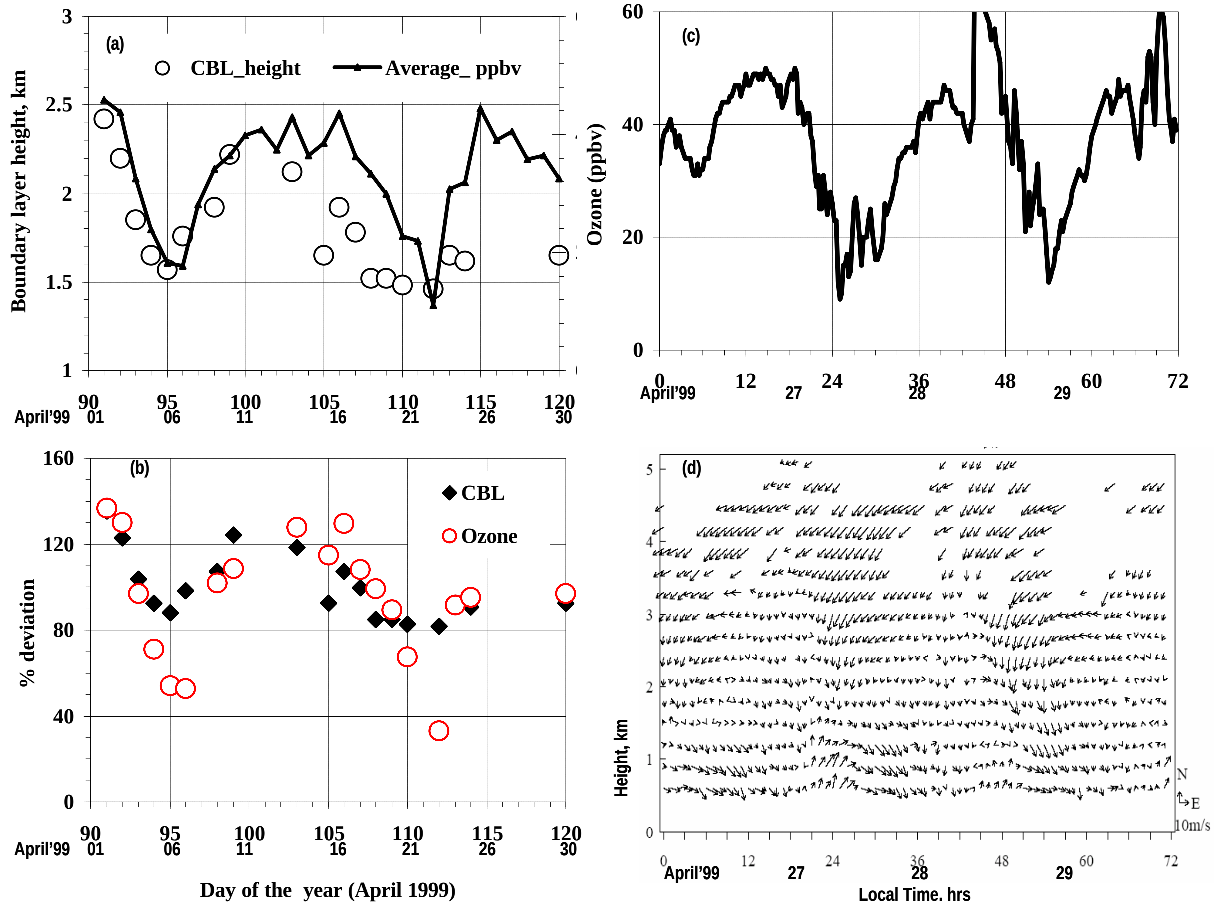

Figure 3. (a) Average convective boundary layer heights and (b) averaged surface Ozone (average over 1200-1500 hrs LT for each day) from 01-30 April 1999. (c) Diurnal variation of suface Ozone and (d) horizonal winds observed from 27-29 April 1999.

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