Latitudinal variation of mixing height over Delhi-Hyderabad Corridor

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Abstract

Latitudinal variations of sodar derived mixing heights pertaining to 8 sites over Delhi-Hyderabad corridor are analyzed. Outcome is part of ISRO-GBP land campaign to understand the role of radiative forcing due to aerosols and trace gases over the Indian region Sites exhibiting similar weather conditions and topographical features are considered. Studies reveal increasing trend of mixing height with decreasing latitude. However, forcing due to meteorological factors cause significant departures in the observed trend. Results clearly demonstrate meteorological factors overriding the latitudinal dependence of mixing height and the need to use site specific mixing height for air quality studies.

1. Introduction

Mixing height of the atmospheric boundary layer (ABL) is one of the fundamental quantities for describing the structure and dispersion capabilities of the lower atmosphere [1]. It under goes diurnal and seasonal variation in accordance variation in upward forcing from the ground due changes in prevailing micro-meteorological conditions. As such prevailing meteorological parameters such as temperature, wind humidity profiles, intensity of the incoming solar radiation received the at ground, geographical location or the latitudinal variations and the topographical features of the site play significant role in determining diurnal characteristics of mixing depth at any site.

Use of site specific mixing height is often recommended [2] for meaningful air quality analysis and dispersion modeling in environmental impact assessment (EIA). Sodar in its capability to provide such data in real time is the most suited meritorious and economical choice over the traditional technique of using Holzworth model [3] involving interpolating the radiosode data of nearby meteorological station. In pursuit the same, sodar studies of site specific mixing heights were undertaken by National Physical laboratory (NPL) was a part of the nation wide multi institutional multi technique field experiment over Delhi-Hyderabad corridor. The experiment, named ISRO-GBP land campaign, was organized by the Indian Space Research Organization (ISRO) under Geosphere Biosphere Program.(GBP). Objective was to generate multi disciplinary data base to understand the role of aerosols and trace gases for their radiative forcing over the Indian sub continent the data was collected at 11 sites over 3200 km stretch of Delhi-Hyderabad corridor. Detailed discussion on experimental plan, instrumentation used and the data structure is beyond the scope of present work and can be referred elsewhere [4]. However, as a side product of data base we have, presently, availed the opportunity to examine the latitudinal variations of mixing height as such studies not reported so far.

2. Instrumentation and Data Structure

Sodar is well known acoustic remote sensing technique [5] that maps the dynamics of ABL thermal structures in real time and space up to a height of 1 Km. A transportable battery operated PC based monostatic sodar designed, developed and fabricated at NPL has been used in the present studies. High power acoustic burst, of 100 ms duration, at 2 KHz is repeatedly transmitted vertically, every 6 sec. The sodar antenna used is 4' parabolic dish with a transducer placed at its focus. The backscattered signals from atmospheric turbulent regions occurring along the propagation path are received by the same antenna and processed to produce echogram of prevailing meteorological phenomenon. The echograms are categorized as the thermal echoes and shear echoes and named according to pictorial appearance echograms. The structural nomenclature include names such as thermal plumes, ground based layer with flat /or spiky top, elevated/ wavy, multi layers, rising layer, descending layers etc. The meteorological processes responsible to generate such structural sodar signatures include phenomena such as free/forced convection, nocturnal cooling of ground, wind shear, advection, subsidence, frontal systems etc. These phenomena contribute to the development of turbulence in ABL which in turn generate the mixing depth for the emissions (pollutants) at the ground.

However, sodar signatures (Fig.2) of nocturnal ground inversion, thermal plumes (free convection) and the rising layer (eroding inversion) are repeatable characteristic features of ABL occurring, under clear weather conditions, in accordance with diurnal cycle of solar heating and nocturnal cooling of the ground. Elevated inversions layers /waves are often said to be associated with wind shear, advection, subsidence, frontal passage etc. The echograms structural details can be used to determine atmospheric mixing depth and stability class [5,6] required for air quality dispersion modeling and observational analysis.

Sodar observations were made at 8 different sites (Fig.1) along the Delhi-Hyderabad corridor. Continuous data was collected for about 2 to 3 days at each site during the month long campaign period, 1-29 February, 2004. The Latitudinal and Longitudinal coverage of the sites varied from 17.3^o to 28.6 ^{o} N & 27.2 ^{o} to 78.2 ^{o} E (Fig. 1). Although latitudinal variation of only 10 degrees is available yet the studies assume significance as the preliminary work will attract researchers for more focused studies. The day time (0800-1800 hours) data pertaining to similar weather conditions at all the sites is only analyzed. The sufficient night time data, for a meaningful analysis, was not available at all the sites.

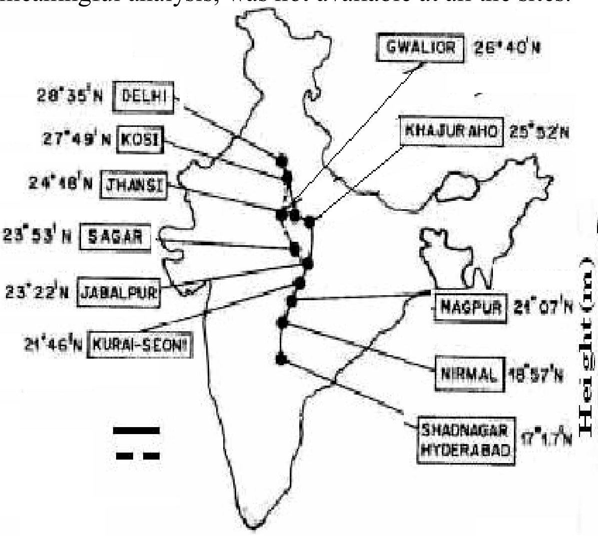

Fig. 1 Observational sites with latitudes (Delhi – Hyderabad Corridor).

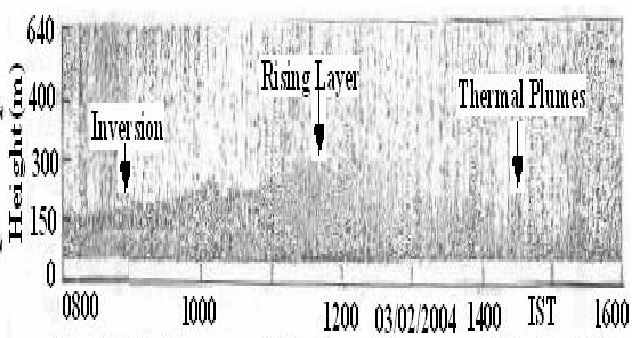

Fig. 2 Sodar signatures of ABL Thermal Structures at NPL, New Delhi

2.1. Mixing Height Evaluation

Mixing height evaluation under different sodar signatures is discussed by Singal et al. [5]. However, in relevance to the present work, it may be mentioned that top of the ground based stable layer gives a fairly good estimate of the inversion height. While for day time convective conditions (thermal plumes on sodar records) the mixing height is estimated using the empirical relationship [5,7] given below:

Mixing height, MH = 4.35 * Ph + 95 : where Ph is the sodar derived height of thermal plumes

The above relation is based on correlation studies of simultaneously measured independent variables of thermal plume height (sodar) and mixing height deduced from temperature profile. As measurements are made at the same site, the topographical impact being embedded in both the measurements gets neutralized in the correlation studies. Thus the empirical relation is considered independent of site characteristics It has been verified for hilly terrains [8] and presently used for all the observational sites

3. Results and Discussions

Diurnal variation of mixing height (Fig.2) integrated over the entire campaign path covering all sites (Fig. 1) shows a trend of maximum mixing height, with large variability, around noon. Further studies for individual sites with latitudinal variations (Fig. 3) also show a general trend of increasing mixing height with decreasing latitude.

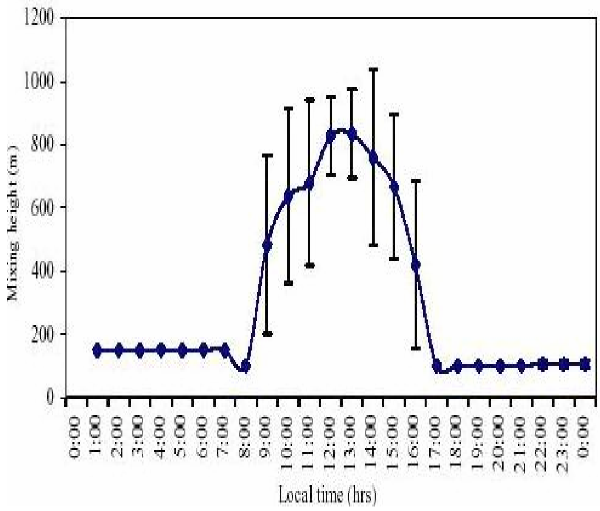

Fig. 3 Diurnal variation of average mixing- height over Delhi-Hyderabad-Delhi corridor.

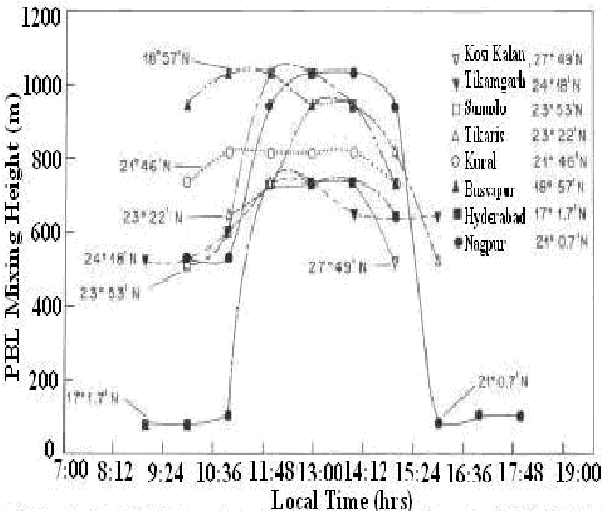

Fig. 4 Latitudinal and diurnal variation of mixing over Delhi-Hyderabad corridor.

The observed trend is expected because the regions at lower latitudes receive more of solar energy due to higher solar zenith angle as compared with higher latitudes. Accordingly in the forenoon hours, mixing height at Kosi (latitude 27^0 49’ N) is seen to be minimum while it is maximum at Bussapur in Nirmal (latitude 18^0 57’ N). Intrestingly Kurai- Seoni lying in between (latitude 21^0 46’ N) shows its mixing height curve also lying to be in between the said curves of minimum and maximum mixing heights.

Further, interesting features is observed around noon hours, when the sun is vertical and ground heating is strong. It is seen that other similar sites lying in between (Sagar with latitudes 23^0 53’ N and Nagpur with latitudes 21^0 07’ N) and also observing mixing heights in between curves of maximum and minimum, in the forenoon, suddenly achieve highest values of mixing height as seen in Fig. 4 and more clearly seen in Fig. 5 showing mixing height around noon (1200-1400 hours). The sudden increase in mixing height around 23^0 N of latitude is contrary to expected trend. This is understood through examination of the monthly averaged synoptic wind flow pattern over the Indian subcontinent. Convergence of winds from the northern and south-eastern sectors is seen taking place around the trans-boundary region located in between latitudes 21^0 and 23^0 N during the observational month of February (Fig. 6). The strong convergence caused additional substantial vertical lift (by way of mechanical lift) to the thermally buoyant air parcels. Thus mixing height sharply reached highest in the convergence zone. The result demonstrates that local meteorological factors play a significant role in determining the mixing depth.

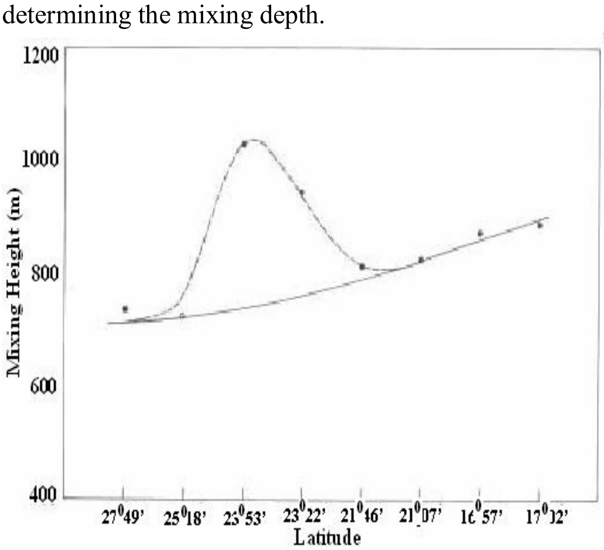

Fig. 5 Latidunal variation of average mixing height (max.)

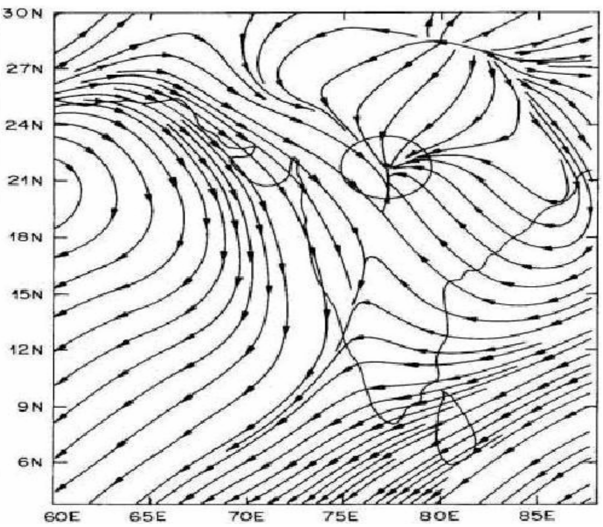

Fig. 6 Synoptic wind over Indian Sub-continent

during 12-14 hours over Delhi- Hyderabad- Delhi corridor. during February.

4. Conclusions

Latitudinal variations of mixing height observed over Delhi-Hyderabad corridor has revealed general trend of decreasing mixing height with the increasing latitude. However, synoptic scale meteorological factors, like convergence of synoptic surface winds flow are seen to override the followed trend of latitudinal variation. of mixing height. Results clearly demonstrate the significant role of meteorological factors in determining mixing height and thus suggest the need for using site specific data of mixing height in dispersion modeling for EIA and air quality observational analysis. These are preliminary studies based on limited set of data base collected on different days at different sites during the campaign period. Further focused studies can lead to development of a mathematical equation fitting the curve of latitudinal variation of mixing height for its use to predict or estimate diurnal variation of mixing height for different latitudes using signal point observations However, extensive studies involving simultaneous observations under similar fair weather conditions and using identical calibrated Sodars at sites having significant latitudinal variations are required for meaningful analysis.

5. Acknowledgements

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