Sodar Studies of Coastal Boundary Layer Characteristics

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Abstract

Sodar observations of coastal boundary layer of three regions are analyzed to examine evolution characteristics of internal thermal boundary layer, land-sea breeze circulation Besides characterizing turbulent mixing processes such as onset, dissipation , depth of sea/land breeze circulations of interest for environment impact assessment, new observations of thin oscillating elevated layers of low frequency have been observed in lower atmospheric boundary layer in coastal region of Arabian sea, Indian ocean and also at the Antarctica ocean. Wavy periods of about 24 hours and residence time of few days are seen. Observations need further planned investigations through multi probing techniques.

1. Introduction

Sodar is an acoustic remote sensing technique for monitoring dynamics of lower atmospheric boundary layer (ABL) thermal structures in real time [1]. Sodar in its capabilities to provide a direct pictorial view of the prevailing meteorological processes such as onset/dissipation of free convection, inversion, fumigation is considered a useful aid for air quality assessment studies. Use of site specific sodar data on inversion/mixing height is often recommended for environment protection agencies [2] for environment impact assessment (EIA) and planning strategies for disaster management under accidental release of pollutants. In pursuit the same sodar data was collected, at different sites at different times under different programs, as part of inversion/mixing height studies for EIA. As such the data, analyzed in the present work, pertains to different years. First observations were made in seventies (1976) near coastal regions of Arabian sea at Tarapur Atomic Power Station (TAPS), Tarapur for studies of sea breeze circulation. Subsequently, after lapse of nearly two decades, Sodar was operated in nineties (1994) in the coastal region of Arabian sea at Indian petrochemical complex Limited (IPCL) in Baruch and at Sabaro Organics Limited (SOL) at Vapi for mixing height/ inversion studies as part of EIA. In the recent past, during the year 2001 Sodar was operated at the Indian base Matri station over Antarctica, for ABL investigation. Recently, during 2007 and 2008 sodar observations have been made at Paradeep and Keonjhar (Orrisa) in the costal region of Indian Ocean. Though the data base pertains to widely apart different periods, we have availed the opportunity to examine the data with reference to coastal boundary layer phenomenon of interest for R&D. In this context, characteristics of phenomena such as development of sea breeze, growth of the convective thermal internal boundary layer (TIBL) are mainly of concern for studies of the influence of this boundary layer on ventilation processes [3] of coastal pollution from industrial sites.

2. Instrumentation and Data Structure

A mono-static Sodar used in the present studies has been designed developed & fabricated at National Physical Laboratory, New Delhi. The system is capable of monitoring the ABL up to a height of 1 Km. High power. High power acoustic burst, of 100 ms duration, at 2 KHz is repeatedly transmitted vertically, every 6 sec. using acoustic antenna. The antenna comprises of 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 the pictorial appearance of echograms. The typical thermal structures observed at the coastal boundary layer are shown in Fig. 1 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 structures are manifestations of different prevailing meteorological conditions The meteorological processes responsible to generate such structural sodar signatures include phenomena such as free/forced convection, nocturnal cooling of ground, sea breeze, land breeze, advection, subsidence, frontal systems etc. These phenomena generate a turbulence zone boundary in ABL which in turn acts as tracer for sodar interrogation.

3. Results and Discussion

Several studies documenting characteristics of coastal boundary layer phenomena of TIBL sea breeze, land breeze have been reported from time to time. Most of the studies discuss the evolution and development characteristics about the onset decay, intensity and depth of these phenomena and the influence of on-shore/ off-shore synoptic wind flows on the evolution characteristics [4]. At times the results are based on analysis of the multi technique measurements of meteorological parameters coming from tethered balloon, micrometeorological tower, mini sodar etc [5]. Correlation studies of sea breeze detection through meteorological measurements and sodar detection of change in ABL thermal structure dynamics have also been reported [6, 7]. Based such correlation studies sodar capabilities monitoring dynamics of coastal ABL phenomena has been demonstrated [6]. It has been shown that sodar signatures clearly mark the onset, dissipation and depth of TIBL. In view such merits sodar is considered as state-of-art technology to provide detailed information inside the TIBL

Knowledge about characterizing of TIBL is of important consideration in EIA for pollutants released in the coastal regions. In fact pollutants released under sea breeze circulation, the fumigation situation in the presence of TIBL, multiple inversion layers etc get trapped in the land-sea loop circulation and thus emphasis the need to monitor dynamics characterize of such coastal phenomena. Once trapped dispersing characteristics of ABL decide the fate of pollutants. In this context thermal and dynamic characteristics of sea-land breeze and TIBL is influenced due to action of on-shore and off shore synoptic wind flow [8]. Besides high pressure fronts which are known to improve the ventilation factor, it has been seen even in the absence of fronts significant ventilation can occur due to the turbulent mixing and convection processes[3]. Turbulent processes can double the amount of pollution ventilated from the boundary layer. In view such significance of turbulence processes, and sodar being sensitive to detect turbulent regions, it is considered that the sodar potential can be well exploited for online studies of coastal boundary layer phenomena and applications for planning strategies for environmental protection in coastal regions. In pursuit of the same, Fig. 1 shows the sodar signatures turbulent mixing associated with different processes.

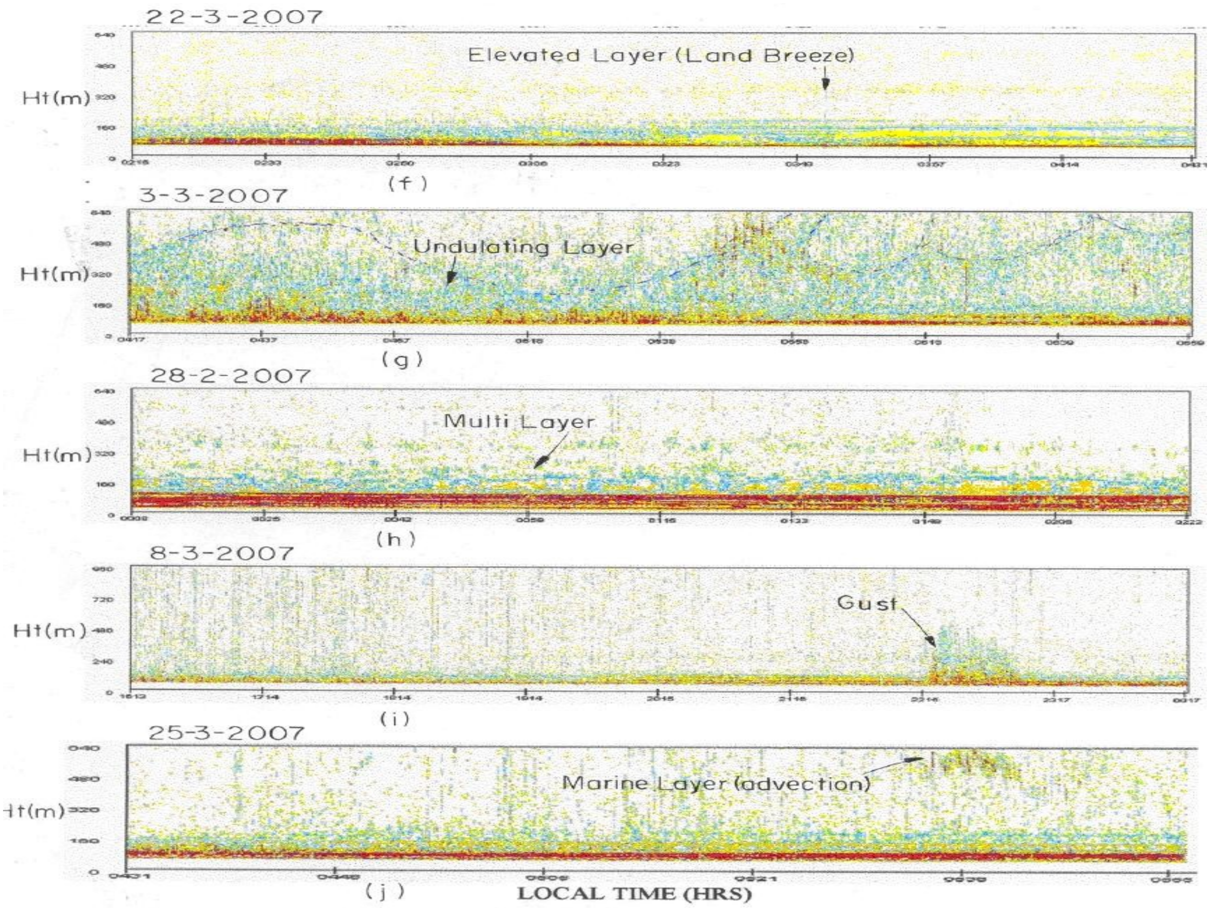

Fig. 1 Sodar Signature of various structures observed at Paradeep near Arabian Sea.

It is seen (Fig.2) that sodar marks well defined elevated layer at the interface of aloft land breeze flow. The TIBL is marked as layer overriding the thermal plumes, and sea breeze causes shallow convective thermal plumes or diffused thermal plumes [6]. Analysis of averaged height of aloft flow of land breeze has revealed the height to be about 300 over the Indian ocean and height of TIBL is less than 100 meters at the observational site which is about 500 m from the coast line. Similar analysis for other sites is yet to be done. However, some interesting new observations have been seen at IPCL. Dahej in the coastal regions of Arabian Sea and over Matri staion over Antarctica. We wish to high light the same, in the present work, for the concerned community.

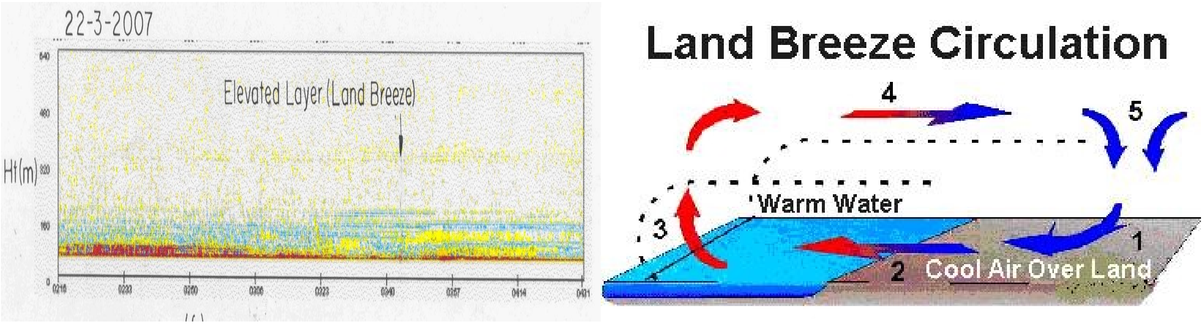

Fig. 2 Sodar Signature of Land Breeze.

3.1 New Observations

Examination of the data base has revealed new observations of thin elevated layers of low frequency oscillations in coastal lower atmospheric boundary layer (Fig. 3).

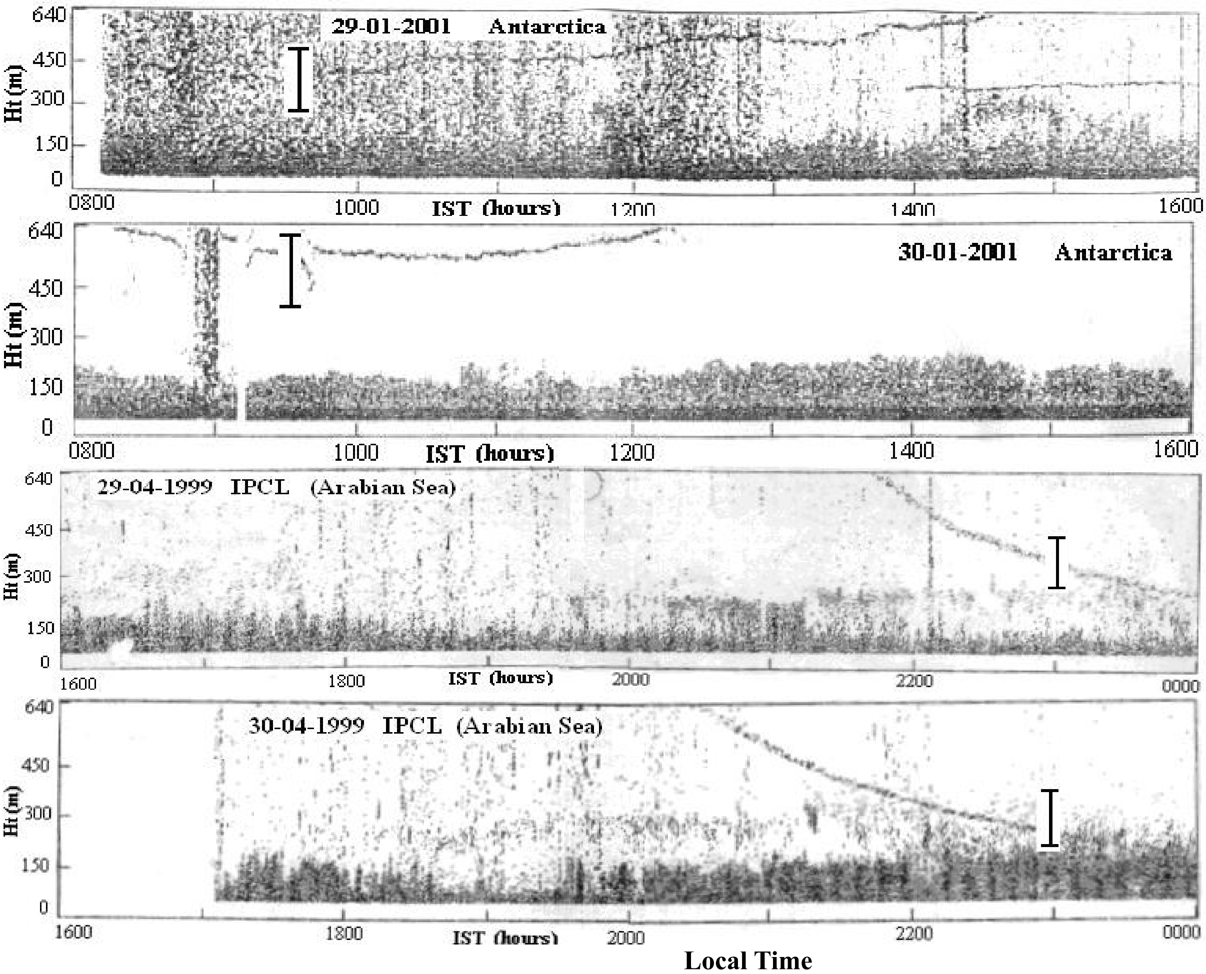

Fig. 3 Thin elevated wavy layers observed IPCL, (Arabian Sea) & Antarctica

These anomalous layers, seen at two different sites are seen to remain in the ABL for more than couple of days. The layers are sharp gradients of discontinuity and seen to emerge from above the probing range of sodar. The same phase (marked as vertical line on the layer) is seen at the same time on consecutive days. This suggest the wave period of about 24 hours. Examinations of meteorological data dose not support any conclusive explanation of the prevailing phenomenon at site. As the layers have been seen in widely spaced different years it is considered that these are typical of coastal boundary layer phenomenon and calls for the need for detailed investigations through multi probing techniques.

4. Conclusions

Anomalous thin elevated layers oscillating at periods of about 24 hours are seen in the coastal region of Arabian Sea and Antarctica. Observations are yet to be understood and call for focused investigations using multi-techniques.

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6. References

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