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Seasonal Variation of Coastal Meteorological Phenomena as Revealed by Acoustic Sounder

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A climatology of the boundary layer of the atmosphere at Visakhapatnam is compiled using the acoustic sounder data collected for a period of 3 yr from May 1980 to April 1983. The meteorological phenomena as inferred from the facsimile records are classified into 13 categories and then analyzed for percentage period of occurrence of each category in each month. It is found that the complex meteorological processes in coastal zones have a significant seasonal dependence.

1 Introduction

In a pioneering effort, Clark and Bendun[1] made some climatological studies of the boundary layer at Jervis Bay (Australia) using a numerical classification scheme that divides the sounder echoes into various types depending on their structures. Fukushima *et al.*[2] also reported some diurnal and seasonal variation in the structure of planetary boundary layer at Tokyo (Japan). Schubert[3] classified the sounder record patterns obtained at two sites in the eastern United States and identified the diurnal cycle of the boundary layer which was mostly repetitive. Other studies of this type led to some important conclusions[4-7]. However, the studies so far conducted do not provide any quantitative information regarding the unique meteorological phenomena of coastal zones. As Visakhapatnam is a coastal city with mushroom growth of various industries, a statistical study has been conducted with a view to understanding the coastal boundary layer climatology and for knowing the stability stratification of the first layers of atmosphere.

2 Experimental Technique and Site

An acoustic sounder[8-10] has been in continuous operation since May 1980 at Andhra University campus, Visakhapatnam. The sounder operates with 1600 Hz sugnal of 100 ms duration, repeating every 18 sec, with a peak power of 100 W and maximum range of 1 km. The antenna site is located roughly 1 km away from the coastline and is oriented in the northeast-southwest direction with Bay of Bengal in the east. Meteorological data on temperature, relative humidity, winds and weather conditions are from the meteorological observatory of the India Meteorological Department situated a few tens of metres away from the experimental site.

3 Data Analysis

The acoustic sounder data collected for a period of approximately 19,000 hr from May 1980 to April 1983 have been analyzed in the present study. As all the classification schemes reported so far represent the atmospheric phenomena of inland stations, a classification scheme has been suggested for coastal boundary layer. The descriptors of the scheme are as follows.

Thermal plume structures

TP	Thermal plume activity
TPEL	Thermal plumes superposed with a rising and weakening elevated layer observed in early morning hours

Sea breeze structures

SBP	Sea breeze with intensified low level plume-like activity alone
SBPEL	Sea breeze with low level plume-like activity capped by an elevated layer
SBEL	Sea breeze with elevated layer only (This structure occurs when sea breeze continues till late hours in the night even after low level convection dies out by evening.)
SBSBL	Sea breeze with surface based layer alone

Inversion layer structures

SBL	Surface based layer associated with development of surface temperature inversion
EL	Elevated layer not being related to sea breeze phenomenon

Other structures

N	No echo
L	Line echoes
W	Wavy layers
ME	Multiple echoes with a combination of stratified layers and above said structures
R	Rain

The sounder records were not always perfectly distinct and hence there were chances of miscategorization. However, efforts were made to minimize such possibilities using all the available meteorological data. The monthly mean percentage time of occurrence of various atmospheric structures has been estimated with respect to the total time of observation.

4 Results and Discussion

Fig. 1 compiles the distribution of the 3 years' data over the classified categories. The monthly variation of percentage occurrence of the three distinct states of atmosphere has been produced in Fig. 2. The occurrence of stable stratification has been observed to increase steadily from January to May with a maximum of 82.1% in May and to be almost constant during both the monsoons, around 68% for southwest monsoon and nearly 51% for northeast monsoon. In contrast to the above trend, the occurrence of convective stratification has been observed to decrease from January to May with a minimum of 9.6% in May and maintained some degree of constancy during both the monsoons, around 20% for southwest monsoon and nearly 35% for northeast monsoon. It is evident that the hottest month of year (May) experiences maximum percentage of stably stratified structures and minimum percentage of unstable weather conditions. The observed increase in the percentage time of occurrence of atmospheric stability in dry and hot season (January-May) is attributed to sea breeze activity which increases as the two seasons progress. The daily occurrence of sea breeze in May considerably enhances the atmospheric stability. The moderate occurrence percentage of stable atmospheric stratification in southwest monsoon is inferred to be the strong monsoonal circulation that governs the local atmospheric stability. The development of sea breeze is rare during northeast monsoon and so the diurnal trend is the same as observed at inland stations.

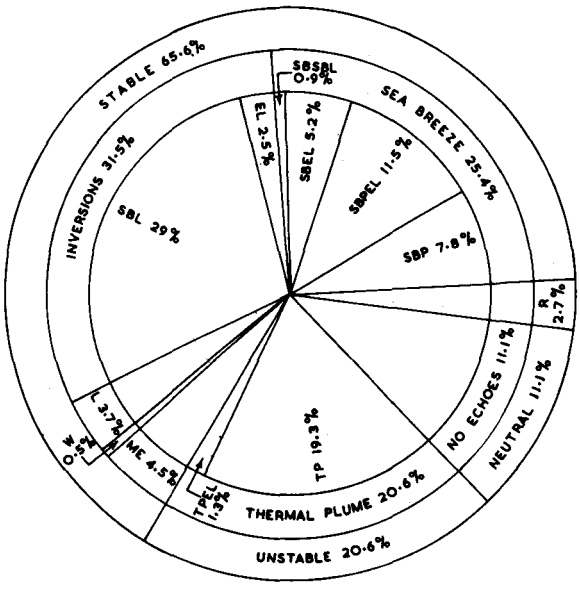

Fig. 1—Occurrence percentage of classified sounder echoes

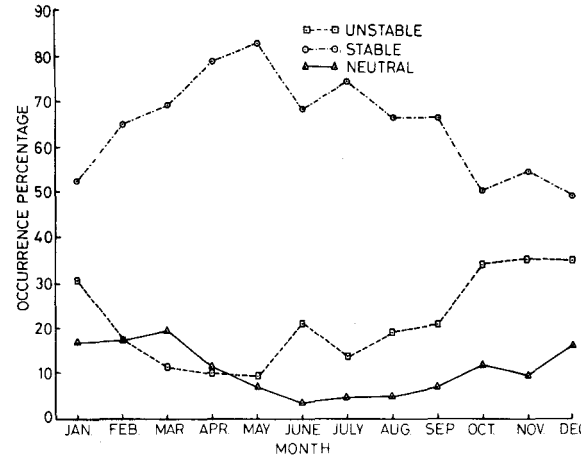

Fig. 2—Monthly variation of occurrence percentage of atmospheric stability stratification

The occurrence percentage of "no echo" regions also showed some seasonal dependence. The percentage time is minimum in southwest monsoon (5.1%), moderate for both hot season (9.1%) and northeast monsoon (12.5%) and maximum for dry season (17.9%). The observed long periods of "no echoes" during dry season and northeast monsoon suggest that the absence of echoes is favoured by weather conditions associated with light winds and clear skies during evenings. On the other hand, during southwest monsoon, weather conditions are characterized by moderate wind speeds and increased cloud activity helps in acoustic returns. Continuation of sea breeze till late into the night explains the moderate occurrence percentage of "no echo" region during the hot season.

The monthly variation of occurrence percentage of sea breeze and its four sub-sects is graphically

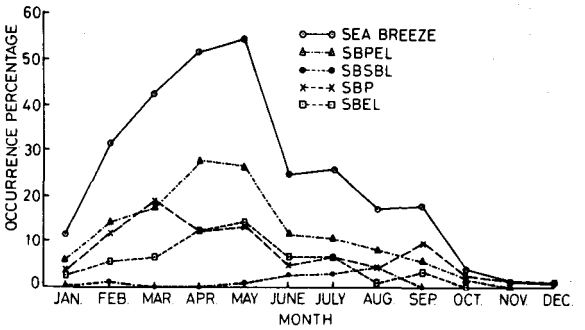

Fig. 3—Monthly variation of occurrence percentage of sea breeze and its sub-sects

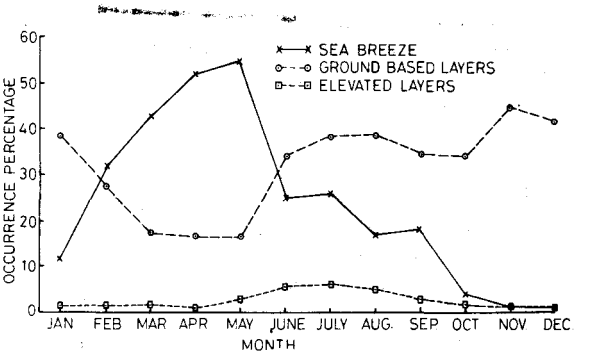

Fig. 4—Monthly variation of occurrence percentage of sea breeze and inversion layers

represented in Fig. 3. The observed increase in the sea breeze activity from 11.5% in January to 54.5% in May is due to increasing solar radiation and surface temperatures over land and coastal upwelling of Visakhapatnam. The sudden fall in the sea breeze activity from May to June is due to the onset of southwest monsoon. Occurrence of sea breeze is rare in northeast monsoon as land and sea temperature contrasts are least on account of the fact that the prevailing winds have a component from the sea.

Out of the four sub-sects of sea breeze, SBPEL is the most frequent one. The sea breeze, after its land-fall, gets modified and an internal boundary layer is formed at the base of the circulation, in addition to an elevated inversion, frequently in the height range 200-800 m. The SBP category is present in all the seasons and the weak sea breeze activity in November and December is depicted by this category alone. The predominance of SBEL category of sea breeze in hot season indicates that the land-sea temperature difference continues to be positive till late hours in the night during this season. The observed higher occupancy of SBSBL category of sea breeze in southwest monsoon is due to the increased amount of cloud that reduces the solar heating of the ground which, in turn, may not be substantial at times to modify the advected stable stratification[11].

Several studies have showed that acoustic sounder is a simple and easy method for detection of nocturnal radiation inversions[12]. Single unambiguous ground-based layer observed in night hours has been considered to be associated with the formation of nocturnal radiation inversion. These inversions have been observed ~30% of the total time and about 60% of the total nights covered. Fig. 4 represents the monthly variation of occurrence percentage of inversion layers along with that of sea breeze. The occurrence of radiation inversions has been observed to decrease from January to March and maintained a minimum constant value in April and May. The occurrence time is almost constant in the entire southwest monsoon and October. The maximum occurrence percentage is found in November. It is inferred from Fig. 4 that the variation of radiation inversions is mostly in opposition to that of sea breeze activity. On sea breeze days nocturnal cooling is reduced due to higher water vapour content in the atmosphere. The lesser the sea breeze activity, the greater will be the persistence of inversion.

Single elevated layer, not being related to sea breeze, is considered to be associated with subsidence inversions which are formed by adiabatic processes[9]. The occurrence of elevated inversion layers is maximum during southwest monsoon. The disturbed weather conditions associated with considerable periods of rains introduce a stable stratification in the lower atmosphere[13]. The occurrence percentage is less during northeast monsoon and dry season.

5 Conclusion

The complex meteorological phenomena in coastal zones have a significant seasonal dependence. A more complete picture of mesoscale climatology of this coastal city requires studies with more acoustic sounders located at different distances land-inwards. A modest beginning in this has been made with the installation of two more acoustic sounders.

Acknowledgement

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