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LAND BREEZE OVER SRIHARIKOTA

1. Meso-scale circulations and their effect on air quality is vital for proper application of meteorology to the solution of energy problems in coastal zones. Sea breeze and land breeze are the direct manifestation of these circulations. Though these are only local phenomena, but are important events and these circulations are more important if it occurs over an airport for landing and take off operations. For the launch of unguided sounding rockets, low level wind changes due to land/sea breeze circulations is an important information. The diffusion of propellant exhausts is also influenced by these circulations. Many studies have been made about the sea breeze occurrence (Arakawa and Utsugi 1937, Roy 1941, Narayanan 1967, Sivaramakrishnan and Prakash Rao 1989) and its characteristics, but only limited studies are available for land breeze (Keen and Lyons 1978, Agarwal *et al.* 1980, Mukherjee *et al.* 1985). Sriharikota (13.7° N, 80.2°E) is the main rocket range of the Indian Space Research Organisation and a study of land breeze will be of practical use for launch operations especially for sounding rockets during night for specific ionospheric/upper atmospheric studies and also for the environmental monitoring.

2. *Data and analysis* — 24 hourly wind records for Sriharikota for the years 1985 to 1989 were considered for the study. Since Sriharikota is along the east coast of India, establishment of dominant westerly wind component during night signifies the land breeze. An inspection of the record showed that during the months October to March easterly component winds are persistent over whole part of the day and night. In April also, on considerable number of days the zonal component of wind is insignificant and southerly winds are strong. Hence the land breeze could be detected mostly during the months May to September and on a few occasions in April. On occasions when land breeze has been detected, the wind speed change and the humidity changes with the establishment of land breeze were examined from the autographic charts. The scrutiny of thermograph charts showed no significant temperature change with the setting in of land breeze. Perhaps the change could have merged in the diurnal cycle of temperature change itself. A sample occurrence of land breeze is shown by presenting the wind plots at different hours in Fig. 1. Land breeze effect is seen from 2200 IST onwards.

3. *Results and discussion*

3.1. *Time of setting* — In all 105 occasions of land breeze occurrence were analysed. When the distribution of land breeze occasions was made on the basis of time of occurrence, peak frequency was found around midnight. The time of setting in of land breeze goes to late night on considerable occasions. Fig. 2(a) depicts the frequency at different times. Table 1 gives the monthly distribution of land breeze occasions based on the time of establishment. It can be seen that June is the month where the land breeze occurrence spreads through all parts of night whereas in July and August it sets in by midnight on most of the occasions. In May and September the tendency appears to be for the occurrence of land breeze either around midnight or later. The reason may be as follows:

May is the month when the day temperatures are maximum and it may take longer time for the land to cool and facilitate the thermal contrast necessary for the generation of land breeze. September is the month when southwest monsoon current is likely to weaken giving way to post monsoon months. Hence it may take longer time to get the steady state wind conditions in night. The normal (mean) time of establishment of land breeze over this island from April through September is shown in Fig. 2(b). The comparison of this with the sea breeze setting time during day is interesting. The sea breeez sets in by 1300 IST during April and May and it could set only after 1400 IST during June, July, and August (Sivaramakrishnan and Prakash Rao 1989). The land breeze sets in by midnight or later during April and May whereas the same could set in earlier during June, July and August. Thus the tendencies of the sea and land breeze are reverse as far as the setting in time is concerned.

3.2. *Wind and humidity changes* — The average wind changes associated with the land breeze for each month is given in Table 2. The average change is not much. Land breeze advances against the headwind in stably stratified surroundings and thus land breeze head has flattened shape and penetrates underneath the surrounding fluid, the updraft at the leading edge being not as strong as in the sea breeze according to Ohra *et al.* (1989) and this may be the reason for it. However, there were occasions though one or two, when the windspeed change can go up to 6 mps is considerable.

Since the land breeze is from land to sea it has a tendency to reduce the moisture content in the planetary boundary layer. The average reduction in relative humidity (%) with the land breeze occurrence is given monthwise in Table 2. About 10% reduction in moisture takes place as a whole.

3.3. *Land breeze setting* — Sea breeze during the day is found to establish itself suddenly. However, when the process of land breeze setting was scrutinised, similar sort of sudden setting in between two full hours could be observed in about 50 to 60% of occasions in July/August and about 30 to 40% occasions in June and September. However, in April and May the sea breeze setting is steady over a period 3 to 4 hours. The wind normally veers from southerly to more westerly component in these two months, *i. e.*, the change over of easterly component into a westerly component is relatively faster during June to September and slow in April and May.

3.4. *Correlation/Forecast criterion* — An attempt was made to see whether any relationship exists between the day's maximum temperature and the time of setting of land breeze in the night. Land breeze occurred on days when maximum temperature is 40°C as well as on days when the maximum temperature is as low as 33° C. However, the night minimum temperature on days of land breeze occurrence was either close to the mean monthly minimum temperature or lower than that. Next the correlation between the two times of occurrence of sea breeze and land breeze of the day, if any, was examined. Unfortunately no clear cut correlation was found to exist between the two times.

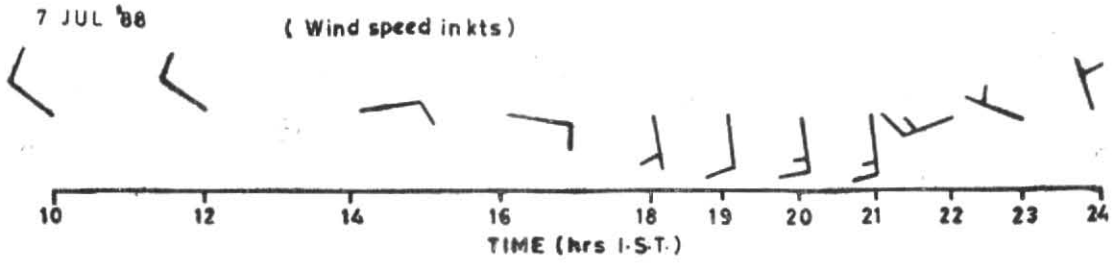
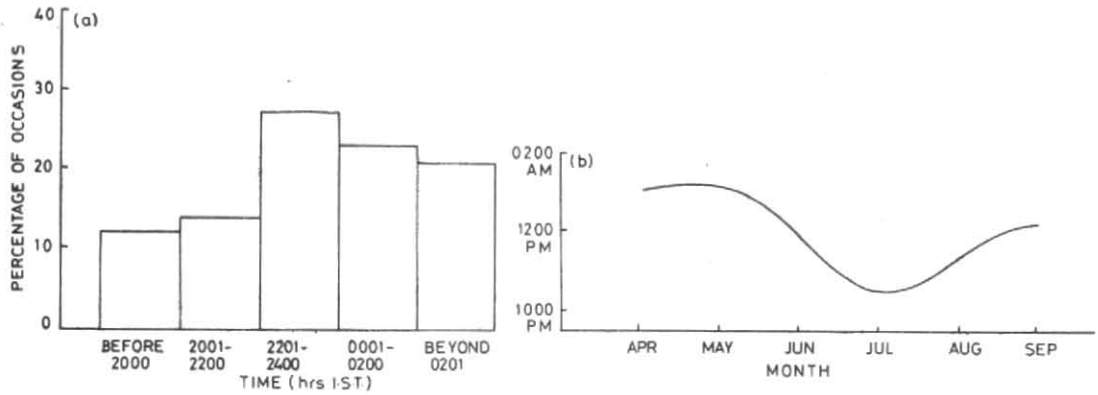


Fig. 1. Wind plot on 7 July 1988 (wind speed in kts)



Figs. 2(a&b). Percentage frequency distribution of land breeze occurrence and (b) average time of occurrence of land breeze

TABLE 1

Percentage distribution of land breeze occurrence

Month	2000 or before (IST)	2001 to 2200 (IST)	2201 to 2400 (IST)	2401 to 0200 (IST)	After 0200 (IST)
April	—	—	36	36	28
May	6	6	13	44	31
June	14	21	17	21	27
July	14	23	45	14	4
August	27	20	20	6	27
September	8	0	42	33	17

3.5. *Land breeze and synoptic events* — Mukherjee *et al.* (1985) have tried to establish the influence of synoptic events over the sea and land breeze circulations over Bombay. Similar influence over Sriharikota, if any, was searched. During the months June to September formation of low pressure systems and depressions in the head Bay or north Bay is the main synoptic event. While land breeze occurrence could be detected on days when there were low pressure area/depression in head Bay, there were occasions of land breeze occurrence over this place during these months even on days when the head Bay/north Bay was clear. No relation between the time of occurrence of land breeze and presence of systems in north Bay or head Bay could be established. Upper air cyclonic circulations over the Peninsula or off the Andhra coast and surface level trough off the east coast or over the coast are some of the other prominent features of the months which are relevant to this area. While presence of these features sometimes facilitated the land breeze occurrence during July and August, it is found to be difficult to clearly establish the sequence of

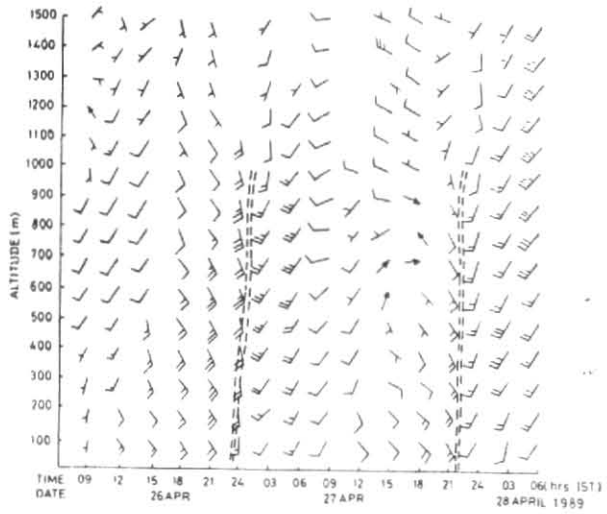


Fig. 3. Vertical time section of low level winds & land breeze occurrence

TABLE 2

Wind speed and relative humidity change with land breeze for each month

Month	Wind speed change (m/s)		Relative humidity change (%)
	Mean	Maximum	
April	1.0	4.0	—
May	1.0	3.6	9
June	1.6	6.0	8
July	1.3	4.5	7
August	0.6	5.0	13
September	0.8	5.0	6

events between these synoptic features and the land breeze behaviour. Perhaps a rigorous study with more data in the years to come may throw more light on this aspect.

3.6. *Vertical extent* — Sivaramakrishnan and Prakash Rao (1989) have studied the sea breeze penetration in vertical direction over this place. It will be interesting to estimate the vertical extent of land breeze front. During 26 to 28 April 1989 three hourly pilot balloon ascents were taken and the time section of winds is shown in Fig. 3. A clear discontinuity in wind direction could be seen between the winds up to about 900 m between 2030 and 2330 IST of 27 April. Similar tendency is clear between 2030 IST of 26 April and 0230 IST of 27 April. As per the surface wind observation land breeze established after about 2200 IST on 27th and around 2400 IST on 26th. A similar experiment conducted on 11 July 1988 showed the penetration of land breeze up to about 900 metres. However some more pibal ascents on dates of clear land breeze occurrence may be required to determine the vertical extent of the land breeze clearly. In this context it may be mentioned that the sea breeze is found to have a vertical extent of about 750 metres (1989). The vertical time section also indicates not much change in the wind speed in the planetary boundary layer with the establishment of land breeze.

4. *Conclusions*—Land breeze over Sriharikota establishes mostly by midnight or later. The mean wind speed change associated with land breeze is about 1 to 2 mps only. The average fall of humidity is about 10% and no significant change in temperature is observed. Land breeze affect is discernible up to about 900 metres above ground level.

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