Atmósfera (1993), **6**, *pp. 155-162*

Onset characteristics of land/sea breeze circulation and its effect on meteorological parameters at a coastal site

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(Manuscript received Jan. 29, 1992; accepted in final form Oct. 23, 1992)

RESUMEN

En este estudio se discuten las características climatológicas de los sistemas de brisas océano/tierra y su influencia sobre los parámetros meteorológicos en Kalpakkam en el proyecto de Energía Atómica en Madras situado en la costa este de la India. En el estudio se utilizan los datos obtenidos de manera continua en el laboratorio Meteorológico del lugar. La velocidad, rango de direcciones, temperatura del aire, humedad relativa y específica son parámetros tomados en cuenta para el estudio.

El cambio en las características de los parámetros estuvo gobernado por el tiempo de aparición del flujo océano/tierra. El cambio es más significativo durante el establecimiento de la brisa marina. El análisis de los datos reveló que el cambio se debió a la advección y a la variación diurna de los parámetros. Los cambios estacionales en el tiempo de aparición de las brisas océano/tierra así como su influencia en los parámetros meteorológicos se discuten y explican cualitativamente con base en la variación de los vientos en altura. El papel relativo que la advección y la variación diurna juegan en los cambios observados también se discute.

ABSTRACT

This study discusses the climatological characteristics of sea/land breeze systems and their influence on meteorological parameters at Kalpakkam, Madras Atomic Power Project site on the east coast of India. Continuous data recorded at the meteorological laboratory at the site is used in the study. Wind speed and direction range, air temperature, relative and specific humidity are considered for the study.

The change in the characteristics of the parameters was mainly governed by the onset time of sea/land flow. The change is more significant during the onset of sea breeze. Analysis of the data revealed that the change was due to advection and the regular diurnal variation of the parameters. Based on the variation in upper winds both the seasonal change in onset time for sea/land flows and its influence on meteorological parameters are discussed and explained qualitatively. The relative role of advection and diurnal variation of the parameters on the observed changes are also discussed.

1. Introduction

Meteorological characteristics at a coastal location are quite different than those at an inland site due to sea-land breeze circulation and its influence on local weather. In India, many studies have appeared in connection with sea–land breeze circulation. Dekate (1968) carried out a climatological study of sea and land breeze over Bombay. The mean vertical extent of the sea breeze cycle was found to have higher variation in summer months compared to that in winter months at Bombay. Ramanathan (1931) showed that, inspite of the 100 km distance and a high hill range between the Arabian sea and Pune, sea breeze penetrates onshore and is clearly felt in Pune particularly in the summer months. In a study on sea breeze circulation for Karachi by Ramdas (1932), it is found that the sea breeze which sets in suddenly is usually colder, moister, and has a larger wind speed compared to the preceeding land breeze. A study of sea breeze at Madras (Roy, 1932) showed sea breeze occurrence in the afternoon or evening from June to September, and the depth of the sea breeze is also estimated.

In this note, the influence of land and sea breeze on meteorological parameters is discussed using data for the annual cycle of the year 1975 at Kalpakkam (Madras Atomic Power Project Site) about 60 km south of Madras. Relevant aspect of the data collection and analysis are also briefly outlined in the note.

2. Data collection and analysis

Wind speed and direction data are routinely collected by cup anemometer and potentiometric windvane at 6 and 30 m levels on a meteorological tower located about 500 m from the coast line and recorded on strip chart recorder. Figure 1 shows the mean hourly wind speed and direction at 30 m for different months. Surface (at Stevenson Screen level) data on air temperature, relative humidity, rainfall, etc., are also collected on routine basis. Specific humidity is evaluated based on air temperature and relative humidity using standard psychrometric formulae.

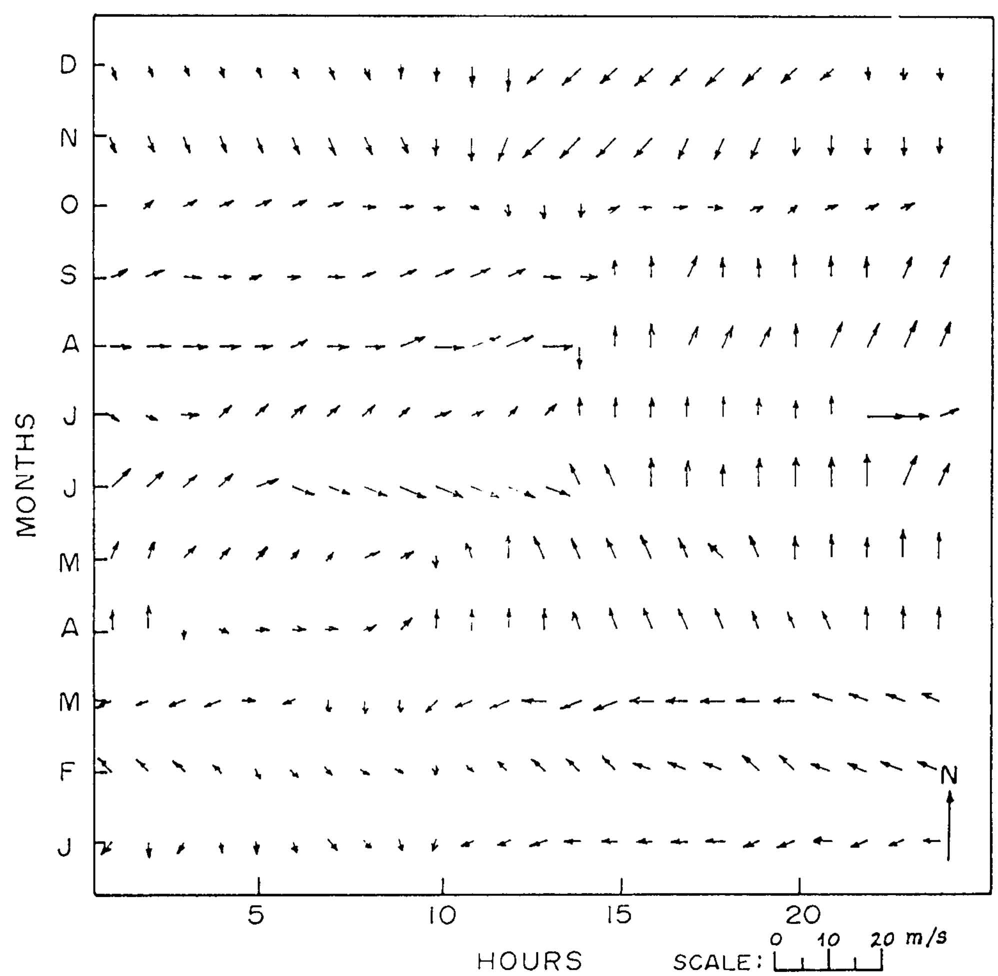

Fig. 1. Mean hourly wind speed and direction for different months at Kalpakkam for the year 1975.

Land and sea breeze are defined on basis of prevailing wind direction. Time at which change over of wind direction from sea to land occurs is taken as time of onset of sea breeze, and similarly for land breeze. Based on the above definition of onset time, values of wind speed, range of wind direction fluctuations, air temperature, relative and specific humidity, observed one hour before and after the onset of sea breeze and land breeze on every day in the complete year, are obtained from recorded data and presented as averages for each month. Monthwise change in the mean values of these parameters with the onset of sea and land breeze are presented in Figures 2(a), 2(b) and 3(a), 3(b).

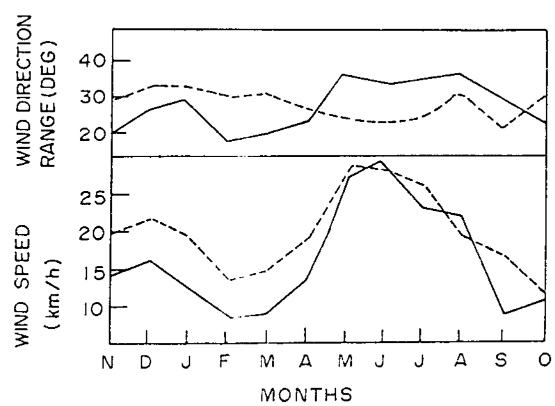

Fig. 2(a). Change in monthly mean values of wind speed, wind direction range with the onset of SEA BREEZE at Kalpakkam. (—— Pre-onset, - - - - Post-onset).

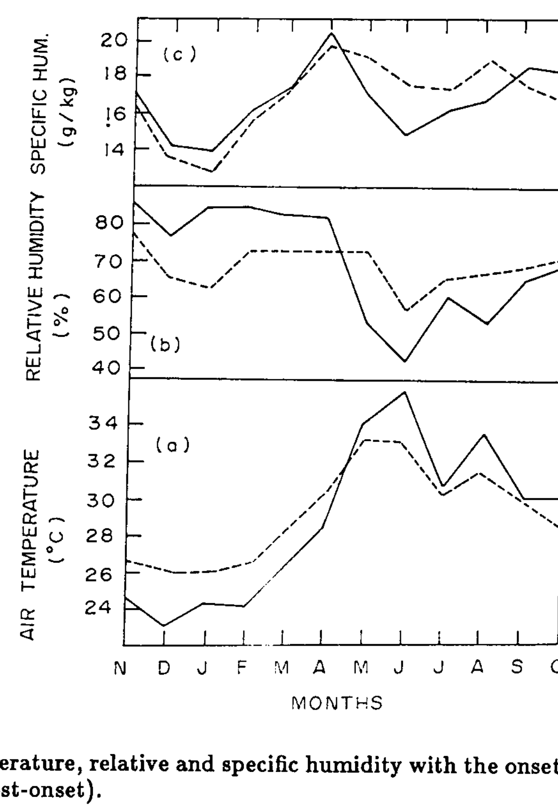

Fig. 2(b). Change in air temperature, relative and specific humidity with the onset of SEA BREEZE at Kalpakkam. (—— Pre-onset, - - - - Post-onset).

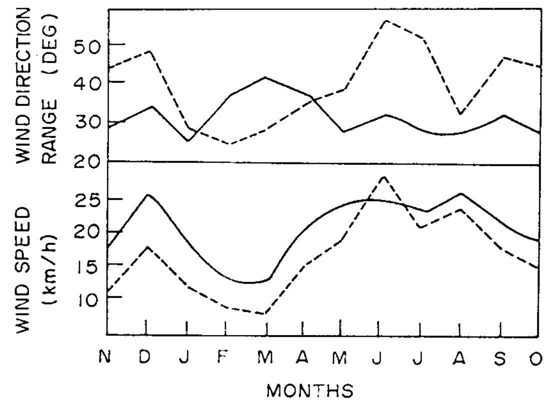

Fig. 3(a). Change in monthly mean values of wind speed, wind direction range with the onset of LAND BREEZE at Kalpakkam. (——— Pre-onset, - - - - Post-onset).

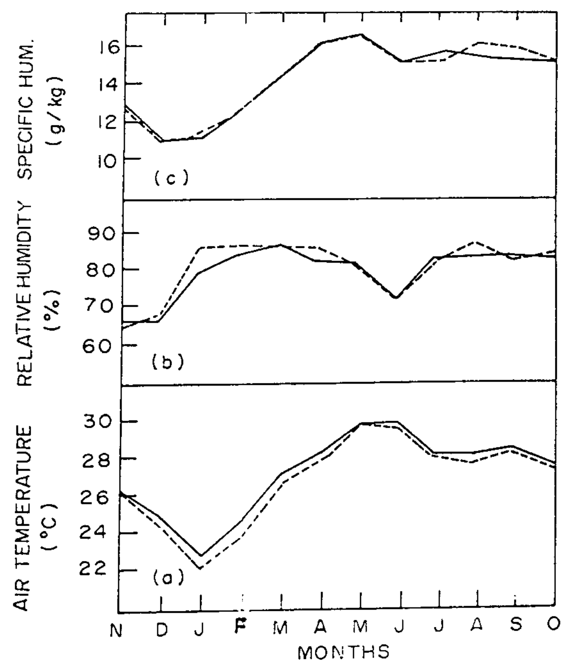

Fig. 3(b). Change in air temperature, relative and specific humidity with the onset of LAND BREEZE at Kalpakkam. (——— Pre-onset, - - - - Post-onset).

Table I. Monthwise Onset Time (hrs IST) for Sea and Land Breeze at Kalpakkam

Month	J	F	M	A	M	J	J	A	S	O	N	D
Sea wind	1000	0800	0800	0800	1100	1600	1200	1400	1200	1300	1100	1000
Land wind	0400	0400	0400	0300	2000	2000	0200	2300	0200	2200	2100	0200

Mean onset time is obtained by considering the hour at which the maximum number of cases of onset occurs during each month. It varies for both sea and land breeze during the winter and summer in the annual cycle. November to April are considered as winter months and May to October are considered as summer–cum–rainy months in this study. Onset hours observed by Roy (1932) in his study of sea breeze at Madras agrees well with mean onset time obtained in the present study. Madras has similar terrain features as Kalpakkam. Table I gives the monthwise mean onset time for sea breeze and land breeze at the site.

3. Results and discussion

The following significant features are noted from the figures:

In Fig. 2(a) and 2(b), with the onset of SEA BREEZE

(a1) Wind speed increases significantly during winter months.

(b1) Wind direction fluctuations (R_θ) increase during winter months and decrease during summer months.

(c1) Air temperature increases during winter months and decreases during summer months.

(d1) Relative humdity (RH) shows a slight decrease and specific humidity (q) does not show any significant change during winter, but both relative and specific humidity increase with the onset during summer months. In Figure 3(a) and 3(b), with the onset of LAND BREEZE.

(a2) Wind speed decreases all year, except during June.

(b2) Wind direction range increases all year, except during the months of February, March and April.

(c2) Air temperature as well as humidity are not significantly influenced.

3.1 Effect of onset of SEA BREEZE on meteorological parameters wind speed

Mean onset time (Table I) for sea breeze during some of the winter months is around 0800 hrs IST. Pre– and post– onset values of wind, show an increase in wind speed of about 6 km/h. The reason for observed change can be due to lower aerodynamic surface roughness (Z_o) of the sea as compared to that of land. At Kalpakkam, average Z_o over sea is 0.01 cm and that over land is 10 cm (Panchal and Chandrasekharan, 1983). Another point to consider can be the thermal gradient between land and sea surface.

The recorded wind can be considered to be the resultant of two components: 1) due to planetary winds and 2) due to land–sea temperature difference (DT), i.e., local thermal wind component. If no change in planetary wind is considered (constant geostrophic wind) the change in wind direction and speed are due to local thermal wind component. During winter, the planetary wind (I. M. D., 1960) is directed onshore and is generally weak (< 3–4 m/s). During early morning hours (0700 hrs IST), when the land surface temperature is lower than at the sea, the land breeze is strong enough to result in net offshore flow. At 0900 hrs IST (post–onset of sea breeze) the sea breeze flow is augmented by planetery wind resulting in a net increase in wind speed between pre– and post–onset conditions. The surface winds studied in this paper is considered to be the resultant of mean synoptic wind and the overall circulation. Strength of overall circulation would be modified in presence of synoptic flow. However, when onshore synoptic winds prevail, observations indicate earlier onset of surface level onshore flow than would be in the case when no geostrophic flow is imposed. Similarly when offshore synoptic winds prevail, earlier onset of surface level offshore flow will occur.

During summer, the planetary winds (I. M. D., 1960) are stronger (> 4 m/s) and directed offshore. Thus occurrence of sea breeze is delayed (1300 LST) and as the change in DT is small during the pre– and post–onset conditions, observed increase in wind speed is much smaller than in winter (Panchal, 1989).

Wind direction range (R_θ)

In general, weak turbulence is expected in the flow from the sea region considering the effect of lower Z_0 over sea. But the average value of R_θ at the site shows an increase in turbulence with the onset of sea breeze during some of the winter months. The turbulence consist of mechanical component due to Z_0 and thermal component arised due to vertical temperature structure. Sea breeze commences at 0800 hrs IST during these months. Prior to the onset, land is cooler compared to the sea. When sea breeze commences, air masses having higher turbulence (though warmer and hence lighter) are convected over land along with planetary flows resulting in an increase in R_θ. In summer, during the late onset of sea breeze (1300 hrs IST), higher thermal turbulence prevails over land compared to that over sea. Hence, air masses over sea having comparatively weak turbulence advect over land resulting in a decrease of R_θ.

Air temperature

In winter months, synoptic flow is onshore and hence transition from offshore to onshore flow occurs even before land becomes warmer than sea due to solar heating. It is concluded that the flow is essentially governed by synoptic flow. Thus this transition should rather be termed as from 'offshore' to 'onshore' flow than 'land breeze' to 'sea breeze'. In winter, during the pre–onset of sea breeze condition (0800 hrs IST), sea is warmer than land. Thus an air mass advecting to land from sea causes an increase in air temperature. However, it should be noted that an increase in insolation with the sunrise may also conbribute in raising the air temperature. During summer, pre–onset of sea breeze, winds are from land which is hotter as compared to sea. Hence, with the onset of sea breeze, colder winds from sea blows over land and air temperature shows a significant fall.

Relative and specific humidity (RH and q)

RH is a function of moisture content and temperature of the air mass under consideration. During morning hours, over sea and adjacent regions, moisture content is at the saturation level even if air temperatures are different over sea and land.

With the onset of sea breeze, warmer air advects over land (warmer and lighter air masses are dragged over land by planetary flows which are directed onshore). Since RH is inversely proportional to the temperature, a decrease in its value can be noticed. However, q nearly remains unchanged. This can be ascribed to the early onset of sea breeze when considerable amount of water droplets exist over adjacent land surface which evaporate with sunrise. Hence, with the commencement of sea breeze, the specific humidity does not show any significant change.

Over homogeneous terrain, even a decrease in specific humidity is reported in the study of Camuffo and Bernardi (1982). The study found that, at initial hours after sunrise, water droplets over vegetation are evaporated, hence the observed increase in specific humidity, but the following erosion of inversion and increase in mixing height give way to an observed decrease. Though there is addition of advected moisture, the decrease due to mixing is predominant. Hence, a net decrease in specific humidity is observed.

During summer, around the onset time (1300 hrs IST), relative humidity over sea can be assumed to be higher compared to that over land. Hence an increase in relative humidity is observed with the onset. Similarly, specific humidity over sea is also higher due to availability of water and evaporation due to insolation. Hence with the onset of sea breeze, an increase in specific humidity is also observed.

3.2 Effect of onset of LAND BREEZE on meteorological parameters wind speed

In general, with the onset, a decrease in wind speed is noticed except during the month of June. With the setting in of wind from land, the air flow encounters higher drag due to larger aerodynamic roughness of land. This causes retardation in speed. It is seen that the average decrease in the parameter is not equal for each of the months. This can be attributed to the direction dependent roughness (Panchal and Chandresekharan, 1983) which are encountered by the air flow during different months. Further, local wind components at pre– and post–onset time, arising due to corresponding DT, are also responsible for the change in speed.

Wind direction range (R_θ)

Wind direction range is the combine effect of mechanical and thermal turbulence. The aerodynamic roughness effect seems to be predominant as compared to that of thermal component causing an increase in wind direction range except during the months of February, March and April. During these months, around the onset time (0400 hrs IST), higher turbulence prevails over sea as compared to that over land. Hence there is decrease in wind direction range with the onset.

Air temperature and humidity

There is insignificant differences in temperature and humidity between sea and land. Hence the onset of land breeze does not show any significant change in these parameters.

4. Summary and conclusion

(i) Changes in wind, air temperature and humidity with the onset of sea/land breeze are due to (a) advecting flows, and (b) gradual diurnal variations in these parameters.

(ii) Surface winds are the resultant of mean synoptic winds and closed sea/land breeze circulations. Onset of sea breeze occurs earlier due to the onshore synoptic winds and onset of land breeze occurs earlier due to the offshore synoptic winds.

(iii) Strength of sea/land breeze circulation depends not only on horizontal temperature gradient between land and sea but also on the strength and direction of synoptic winds at the site.

(iv) Magnitudes of the change in wind speed, turbulence, air temperature and humidity are strongly governed by the time of onset of onshore/offshore winds which is due to the relative magnitude of these parameters over sea and land.

Acknowledgements

Thanks are due to Dr. K. C. Pillai Head, Health Physics Division. Discussions with Dr. T. M. Krishnamurthy Head, Site Evaluation Section, Shri V. Sitaraman, Dr. V. N. Bapat and Dr. V. J. Daoo were useful in the preparation of the paper.

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