Indian J. Met. Hydrol. Geophys. (1975), 26, 4, 501-505

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On deep inland penetration of sea breeze

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(*Received 22 December 1972*)

ABSTRACT. Based on surface autographic charts of Jagdalpur for the period 1962-1972, a study of sea breeze has been attempted. The paper also attempts to explain the structure of the breeze. The fluctuations in temperature and humidity have also been discussed. A plausible explanation for the deep inland penetration of the sea breeze is advanced.

1. Introduction

The study of sea breeze in India began in early thirties when Ramanathan (1931) and Ramdas (1932) investigated the structure of the breeze at Poona and Karachi respectively. In recent years, Dekate (1968) made a study of sea breeze at Bombay. For the east coast the study was made in respect of Madras, first by Roy (1941) and later by Rao (1955)

The prevailing wind over the Peninsula during March to May have a predominant westerly component. On account of the favourable wind, the onset of sea breeze on the west coast is regular, steady and smooth and the gustiness strong. Thus the prevailing wind aids the sea breeze to reach as far inland as Poona situated about 130 km from the west coast. In contrast, the growth of sea breeze on the east coast is retarded by prevailing westerlies and unless the strength of the breeze is such as to overcome prevailing wind, the onset cannot materialise. The frequency of the sea breeze over the east coast should, therefore, be less than that over the west coast. The present study deals with some salient features of deep landward penetration of sea breeze on the east coast at Jagdalpur.

Jagdalpur (19°5′ N, 82°02′ E) is the headquarters of Bastar district in Madhya Pradesh. It is situated 150 km from the east coast, 552 metres above mean sea level on *Indravati* river, a tributary of river *Godavari* (Fig. 1). The terrain around Jagdalpur is not flat but has hills and mountains with peaks seldom higher than 1200 m. A range of the Eastern Ghats with general elevation of about 1000 m asl runs parallel to the east coast and lies approximately 70 km southeast of Jagdalpur.

The charts at Jagdalpur for pre-monsoon months reveal, during evenings between 1500 and 2100 IST, a reversal of wind direction from a general westerly to easterly or southerly, accompanied by an onset of fresh gustiness on many days. The fresh wind is cooler and more moist than that originally blowing. This is apparently due to the effect of sea breeze which penetrated inland. The general characteristics of this breeze are given in this note.

2. Data and analysis

Since the sea breeze develops better with clear skies of the dry season, pre-monsoon months were selected for the present study. Autographic charts of Jagdalpur from March to May for the period 1962 to 1972 were utilised. All those dates which showed reversal of surface wind direction during evenings from prevailing westerlies/northwesterlies to easterlies or southerlies, associated with fresh gustiness, lowering of temperature and rise in relative humidity, were selected.

The percentage number of occasions of occurrence has been depicted by histograms in Fig. 2. It can be seen that maximum number of cases of onset takes place in May.

3. General characteristics

Some of the general characteristics of the sea breeze at Jagdalpur are described below.

3.1. *Time of onset of sea breeze*

The time of onset depends on the speed with which the sea breeze front moves inland and vary from day to day. These variations, in turn, depend upon synoptic pattern, depth of marine layer etc. The sea breeze at Jagdalpur arrives between 1500 and 2100 IST (Fig. 3). However in about 83 per cent of the cases, the onset occurs between 1600 and 1900 IST. The most probabl

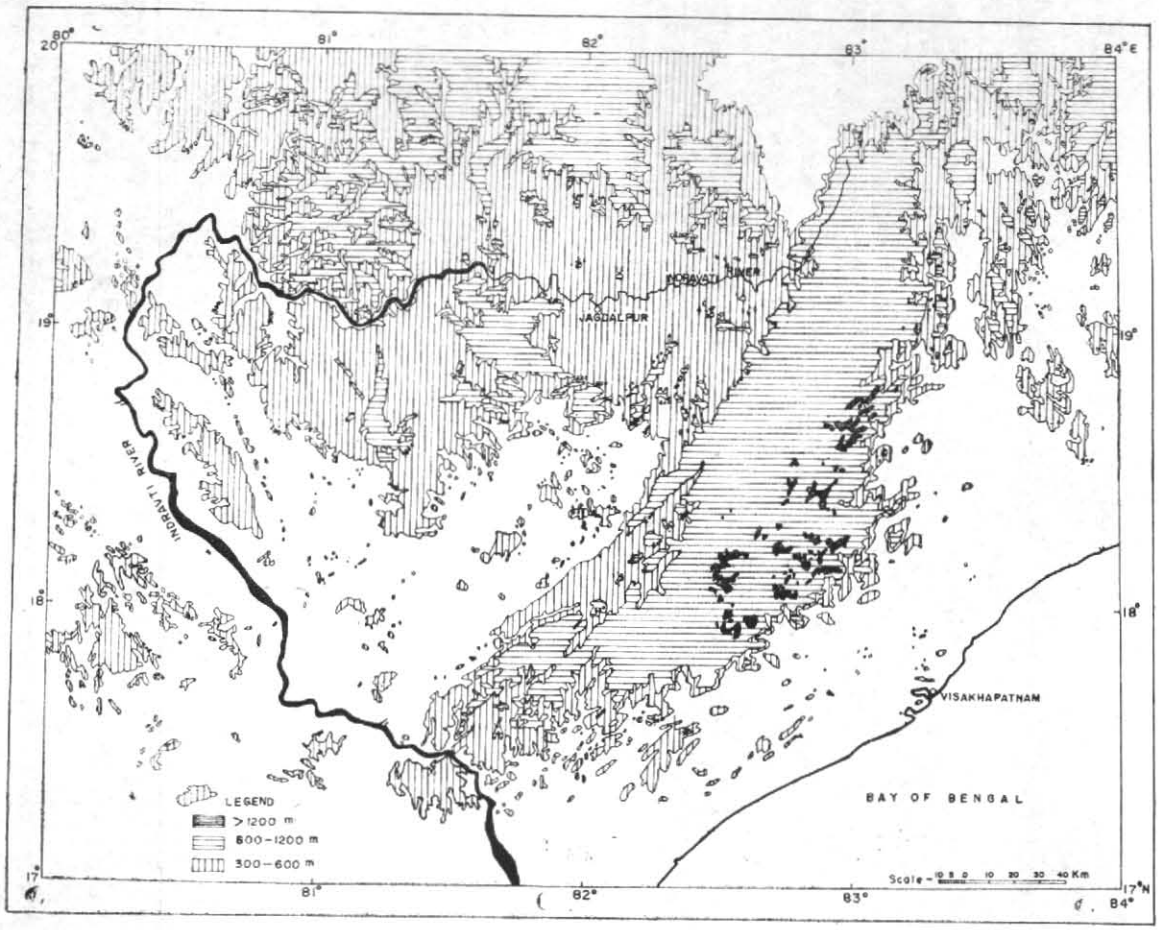


Fig. 1. Orographical features around Jagdalpur

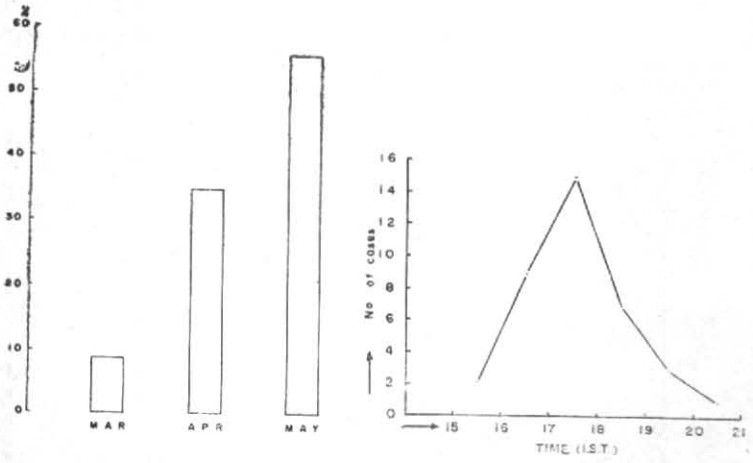


Fig. 2. Percentage distribution of occurrence of sea breeze during pre-monsoon months (1962-1972)

Fig. 3. Frequency polygon of onset of sea breeze at Jagdalpur

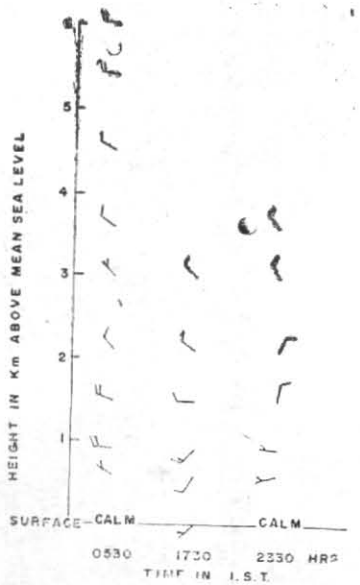


Fig. 4. Structure of sea breeze over Jagdalpur on 22 April 1970

TABLE 1

Contingency table showing fall in temperature and rise in relative humidity

Fall in temp. (°C)	Rise in R.H. (%)			
	10-20	20-30	30-40	Total
0–2	2	3	—	5
2–4	13	10	–	23
4–6	2	3	2	7
6–8	1	1	1	3
Total	18	17	3	38

time of arrival appears to be around 1700-1800 IST. This is in conformity with the distance of the station from coast and the average speed of the breeze.

3.2. *Temperature fall*

The onset of sea breeze is accompanied by sudden fall in temperature. In general, the fall in temperature varies between 2° to 4°C Table 1) but in three cases fall in temperature between 6° to 8°C was noticed.

3.3. *Rise in relative humidity*

With the advent of sea breeze, relative humidity registers a sudden jump. It may be seen from Table 1 that the rise in relative humidity is generally between 20 to 40 per cent.

4. Vertical extent of sea breeze

The depth and structure of sea breeze have been the subject of many studies in the past. In the present study, on many occasions, 12 GMT pilot ascent was very close to the time of advent of the sea-air at Jagdalpur. With a view to bring out the difference in the vertical wind structure at Jagdalpur, brought about by the marine air invasion, a day was selected when the sea breeze had set in nearly at the time of the 12 GMT pilot ascent. One such instance is shown in Fig. 4, when sea breeze arrived at 1615 IST. The change of wind from a westerly direction to a southwesterly direction from morning to evening can be noticed particularly upto 1·5 km.

Fig. 5 shows the horizontal projection of trajectory of pilot balloon ascent which was taken when the sea breeze arrived at Jagdalpur at 1715 IST. It clearly shows that the cold sea current extended upto 1·7 km above which the return current prevailed. The wind shift associated with the onset of the sea breeze is not so well marked at lower levels apparently due to the effect of local topographical features.

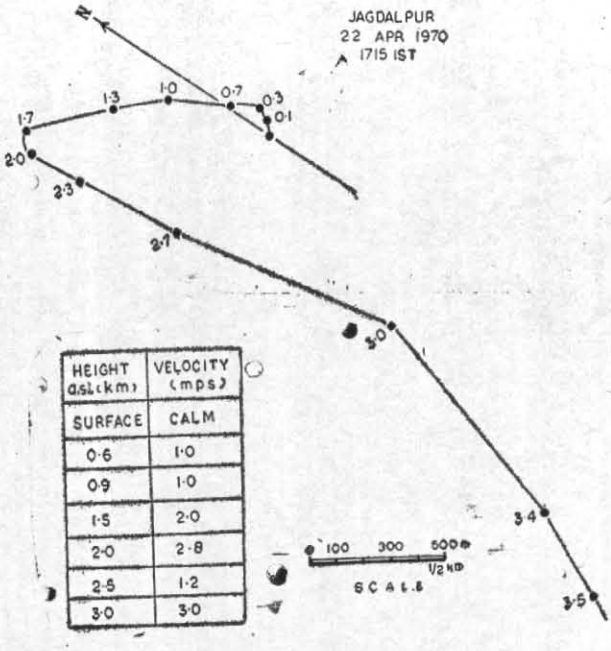


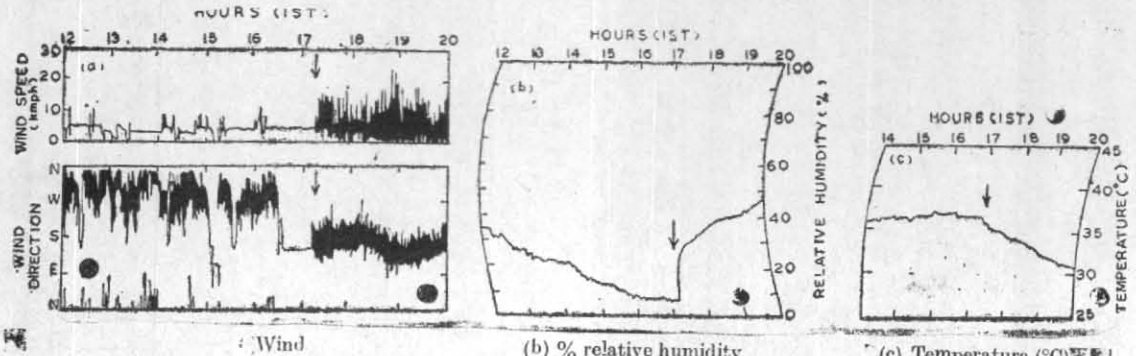
Fig. 5

5. Favourable conditions for onset of sea breeze at Jagdalpur

5.1. *Synoptic situations*

The importance of synoptic situations in the development of local winds like land or sea breeze cannot be ignored. In fact, synoptic scale weather pattern exerts controlling force on the sea breeze. They determine the depth of the marine air and therefore the distance upto which it can penetrate. Ramdas (1932) suggested that a favourable situation may help in early onset of sea breeze, increase the life period and sometimes even strengthen it. Estoque (1962) studied sea breeze as a function of prevailing synoptic situations with the aid of theoretical models. He determined the effects of the geostrophic wind on the intensity, extent and shape of circulation induced by differential heating and concluded that the landward penetration of the sea breeze is dependent on the prevailing wind.

With a view to determine the extent of influence of the synoptic situations on advent of breeze at Jagdalpur, all types of synoptic situations which generally occur in the pre-monsoon months were studied so as to delineate the situations which are favourable, unfavourable or indifferent towards the phenomenon. It was found that in about 75 per cent of the cases, a high pressure areas on the surface was located in the morning over west central Bay. This high was associated with weak anticyclone extending generally upto 0·9 km a. s. l. Thus, this low level high appears to be a favourable factor for the deep penetration of the breeze.



(a) Wind (b) % relative humidity (c) Temperature (°C)

Fig. 6. Autographic record of Jagdalpur on 22 April 1970

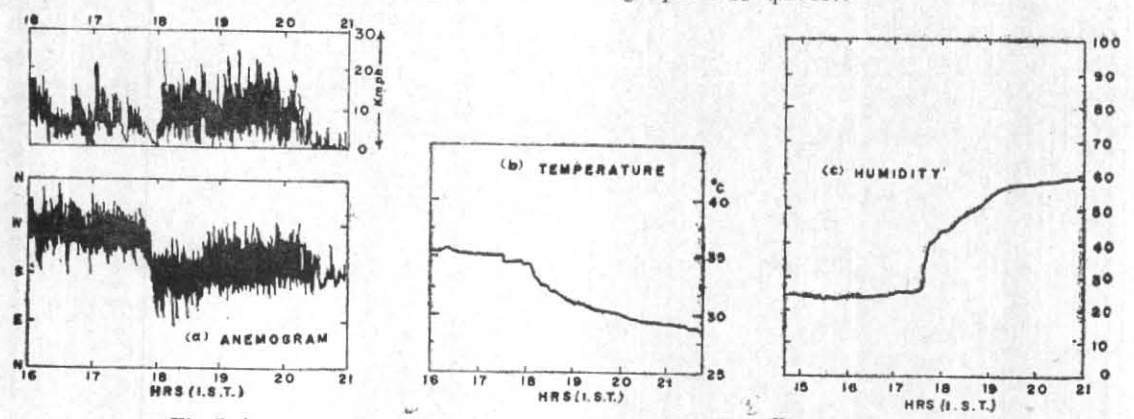


Fig. 7. Anemogram, temperature and humidity trace at Jagdalpur on 2 May 1969

TABLE 2

Percentage frequency of pressure gradient between Jadgaipur and Visakhapatnam for days of occurrence and non-occurrence of sea breeze at Jagdalpur

Time GMT	<1·0 mb	1·1-2·0	2·1-3·0	3·1-4·0	4·1-5.0	5·1-6·0 mb
	For days of non-occurrence of sea breeze					
06	40·2	35·0	15·3	5·8	4·3	
09	11·6	22·8	33·0	28·1	4·5	
	For days of occurrence of sea breeze					
06	12·1	33·3	27·3	15·2	12·1	
09	3·3	0	26·7	33·3	16·7	20·0

5.2. *Pressure gradient*

It is well known that during the afternoon, an increasingly sea-land temperature gradient develops which is the cause for the formation and landward progress of the sea breeze front. In the present study the pressure difference between Visakhapatnam and Jagdalpur was taken as an indicating factor for the arrival of sea breeze at Jagdalpur. Obviously this difference should be greater at 09 GMT than at 06 GMT. For the sake of comparison, the pressure difference was worked out for the days of occurrence and the days of non-occurrence of the breeze. The results are presented in Table 2. It is evident from the table that on the day when sea breeze was observed over Jagdalpur, the pressure gradient in its vicinity started building up from 06 GMT and reached its peak by 09 GMT. It was found that on 97 per cent of the occasions the pressure difference between the two locations exceeded 2 mb and was more than 3 mb in 73 per cent of the cases at the 09 GMT observations.

6. Typical instances

6.1. *Sea breeze on 22 April 1970*

On this day, the 00 GMT chart showed presence of a weak anticyclone extending upto 0·9 km a.s.l. near Visakhapatnam in west central Bay. Under its influence the low level winds over Jagdalpur had a predominant southerly component. At 06 GMT, the surface high over west central Bay started taking shape and in the east coast, building up of a pressure gradient was also observed. The surface high persisted at 09 GMT when the pressure gradient between Jagdalpur and Visakhapatnam became marked and the pressure difference between them increased from 2·7 mb at 06 GMT to 3·8 mb at 09 GMT. The skies over the area, till 09 GMT were generally clear. The sea breeze arrived at Jagdalpur at 1715 IST and was remarkable for the abrupt changes in the wind

direction and strength, temperature and humidity (Fig. 6 a to c).

6·2. *Sea breeze on 2 May 1969*

A high pressure area was seen over west central Bay at 06 GMT when a low pressure area also developed over east Vidarbha and adjoining parts of Madhya Pradesh. By 09 GMT the low shifted southwards and lay over Telangana and neighbourhood, the high pressure area persisted over the Bay. The off-shore high pressure area and the low in the interior during the afternoon period provided strong pressure gradient as would be inferred from the mean sea level pressure difference between Jagdalpur and Visakhapatnam. This difference increased to 5·4 mb from 2·8 mb between 06 and 09 GMT. The onset of sea breeze occurred at 1800 I.S.T. There was a conspicuous wind shift from westerlies to southerlies with an increase in gustiness. The commencement and decay of the breeze and the relevant traces of surface temperature and humidity are depicted from Fig. 7(a to c).

7. Conclusions

The sea breeze arrives at Jagdalpur in shallow layer extending approximately to 1·1·5 km.'

The sea breeze is not a regular feature over Jagdalpur during the pre-monsoon months. However, under favourable situations the sea-air on the east coast does penetrate deep inland upto Jagdalpur in the afternoon. Apart from steep pressure gradient, presence of a high pressure area over west central Bay associated with a weak anticyclone, which in turn gives a more southerly component to wind at Jagdalpur, accelerates the growth and imparts momentum to the sea breeze.

Acknowledgement

The authors are thankful to Shri K.S. Venkataraman, Regional Director for guidance and useful suggestions. They are also thankful to Shri S. M. Pardhi, Draftsman for drawing the diagrams.

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