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Influence of Bay of Bengal on winter monsoon rainfall

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सार — दो भिन्न/विपरीत प्रवृत्ति के शीत कालीन मानसून वर्ष अर्थात् 1987 और 1988 के सितम्बर माह के दौरान बंगाल की खाड़ी में 5° ग्रिड जाल पर समुद्र मौसम विज्ञान आंकड़ों के उपयोग से गुप्त ऊष्मा अभिवाह, समुद्र सतह तापमान (एस० एस० टी०) और समुद्री तापमान के अन्तर तथा वायु तापमान के अन्तर का अभिकलन किया गया। यह ज्ञात हुआ कि 1987 के अच्छे शीतकालीन मानसून के तत्काल पहले निम्नलिखित घटनाएं हुई : (*i*) पश्चिमी बंगाल की खाड़ी के समुद्र सतह तापमान में उच्च वृद्दि, (*ii*) 10°-20° उत्तर व 80°-91° पूर्व की परिधि के समुद्री क्षेत्र में वाष्पीकरण में अत्यधिक वृद्दि और (*iii*) मध्य बंगाल की खाड़ी के उत्तर में और समीपवर्ती भागों की सतह परत में अस्थिरता। 1988 के खराब शीतकालीन मानसून के तत्काल पहले ये घटनाएं हुई : (*i*) पश्चिमी बंगाल की खाड़ी के समुद्र सतह तापमान में कमी, (*ii*) 10°-20° उत्तर व 80°-90° पूर्व की परिधि के क्षेत्र में अत्यधिक कम वाष्पीकरण और (*iii*) मध्य बंगाल की खाड़ी के उत्तर में और समीपवर्ती भागों की सतह में स्थिरता।

ABSTRACT. Utilizing marine meteorological data, the values of latent heat flux, sea surface temperature (SST) and sea minus air temperature have been computed on a grid mesh of 5° over the Bay of Bengal during September month of the contrasting winter monsoon years 1987 and 1988. It has been found that the good winter monsoon of 1987 followed (*i*) higher SSTs over western Bay of Bengal; (*ii*) very high evaporation rate over the sea area bounded by 10°-20°N, 80°-90°E and (*iii*) instability in the surface layer over north and adjoining central Bay of Bengal, whereas, the bad winter monsoon of 1988 followed (*i*) lower SSTs over western Bay of Bengal; (*ii*) very low evaporation rate over the area 10°-20°N, 80°-90°E and (*iii*) stability in the surface layer over north and adjoining central Bay of Bengal.

Key words — Winter monsoon, Latent heat flux, Instability, Surface layer.

1. Introduction

The contrasting nature of the summer monsoons of 1987 and 1988 has been a rare occurrence. If we consider the summer monsoons of any two consecutive years of 20th century (1900-1993) then all India rainfall contrast for summer monsoons of 1987 and 1988 has been second highest (−19% and +19%) during the entire period. The highest summer monsoon rainfall contrast was, however, for the consecutive years 1917 and 1918 (+23% and −25%). But the contrast of summer monsoons of 1987 and 1988 becomes unique in the sense that in case of the pair 1987 and 1988 the good summer monsoon year (1988) followed the bad summer monsoon year (1987), whereas, in case of the pair 1917 and 1918 the good summer monsoon year (1917) preceded the bad summer monsoon year (1918). The contrasting nature of the summer monsoons of 1987 and 1988 has been discussed in detail by Singh (1993) and Singh and Joshi (1993). Their studies focus on the summer monsoon rainfall variability in relation to the variations of different meteorological/oceanographical parameters over the north Indian Ocean. They have found that the initial state of the north Indian Ocean before the commencement of summer monsoon plays a key role in the performance of subsequent monsoon.

The winter monsoons or north-east (NE) monsoons of 1987 and 1988 were equally contrasting. During the winter monsoon season (October to December) of 1987 the entire Indian peninsula received excess/normal rainfall, whereas, during the same season of 1988 there were large/moderate defects of rainfall over the peninsula. Thus the contrasting summer monsoon years 1987 and 1988 were contrasting winter monsoon years also, but the contrast was in a reverse sense. During 1987 a good winter monsoon followed a bad summer monsoon, whereas, during 1988 a bad winter monsoon followed a good summer monsoon.

The studies pertaining to the winter monsoon season are very few in literature although this season's rainfall is quite important for southern peninsula and contributes substantial percentage of annual rainfall over the meteorological subdivisions of coastal Andhra Pradesh (CAP), Rayalaseema, Tamil Nadu and Kerala (India Met. Dept. 1962, 1973). Raj (1989) has attempted to develop simple regression equations for the prediction of winter monsoon rainfall over the above mentioned four meteorological subdivisions. He has chosen some land-based predictors pertaining to the preceding summer monsoon period.

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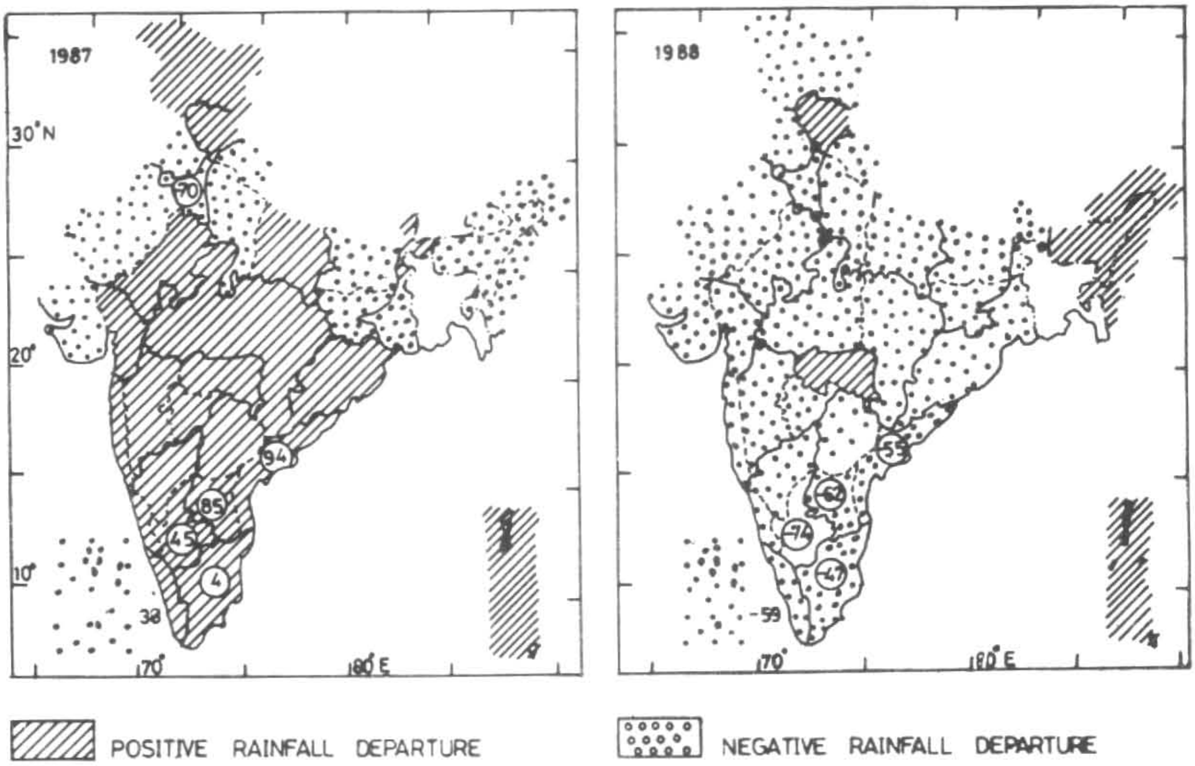

Fig. 1. Winter monsoon (1 October to 31 December) percentage rainfall departures from normal during 1987 and 1988

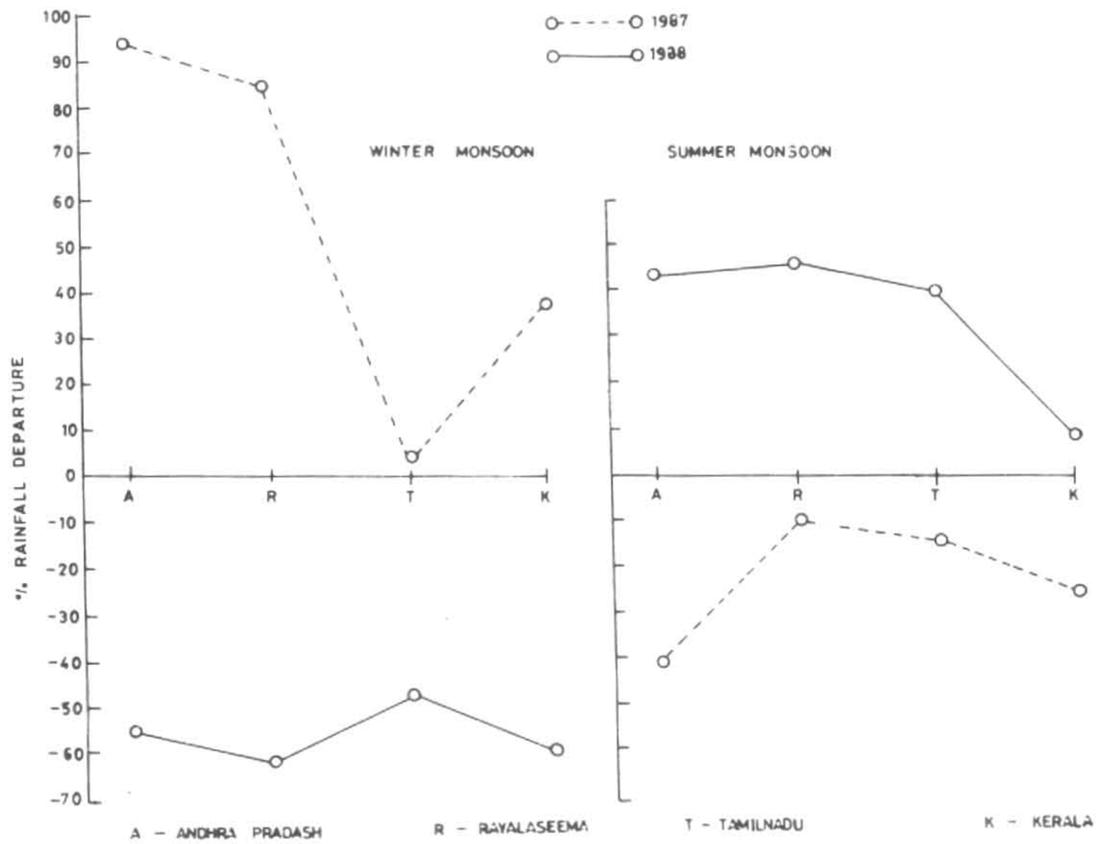

Fig. 2. Rainfall departures during summer and winter monsoons of 1987 and 1988 for the meteorological sub-divisions of coastal Andhra Pradesh, Rayalaseema, Tamil Nadu and Kerala

It is felt that while attempting to predict the quantum of seasonal rainfall over India, be it summer monsoon rainfall or winter monsoon rainfall, the role of probable predictors from the Indian seas can no more be ignored. Primarily, the monsoons are sea-dependent. The summer monsoon air travels through the Indian Ocean and Arabian Sea before reaching the Indian sub-continent. Therefore, the evaporation over the Arabian Sea is bound to influence the summer monsoon rainfall over India. This is established quantitatively by Pisharoty (1965), Ghosh *et al.* (1978), Singh and Joshi (1993), Singh (1994) and others. Similarly, there exists a logical relation between the evaporation over Bay of Bengal and the subsequent winter monsoon rainfall over Indian peninsula. Rajeevan and Butala (1990) have found that warm sea surface temperature (SST) anomalies over the north Indian Ocean preceded the winter monsoon season having more number of cyclones.

The aim of the present study was to examine the variability of SST, the rate of evaporation and the instability in surface layer over Bay of Bengal before the contrasting winter monsoons of 1987 and 1988. The results show that certain functions of these parameters may turn out to be potential predictors for the winter monsoon rainfall over south Indian peninsula.

2. Data and methodology

Marine meteorological observations recorded over Bay of Bengal during summer monsoon seasons of 1987 and 1988 have been used. The data have been arranged on a 5° grid mesh over Bay of Bengal. Monthly averages of relevant parameters like atmospheric pressure, air temperature, dew point temperature, zonal and meridional components of the wind and sea surface temperature were worked out for each grid point.

The latent heat flux, Q_E (Wm^{-2}) has been computed using the following relation :

$$Q_E = \rho_a L C_D (q_s - q_a) V$$

where,

ρ_a = air density (=1.18 kg m^{-3}),

L = latent heat of evaporation (J kg^{-1}),

C_D = drag coefficient, computed using the relation given by Bunker (1976),

q_s = specific humidity at water surface ($kg kg^{-1}$), (corrected for salinity of water),

q_a = specific humidity in the air at deck level ($kg kg^{-1}$).

V = wind speed (ms^{-1}).

Although the computations have been made for all months of summer monsoon (June to September) seasons of 1987 and 1988, the results for September only have been presented here which give predictive signals.

Winter and summer monsoon rainfall data published in *MAUSAM* have been utilized.

3. Results and discussion

3.1. *The winter monsoons of 1987 and 1988*

The percentage rainfall departures from normal for winter monsoon seasons of 1987 and 1988 for different meteorological sub-divisions have been depicted in Fig. 1. During 1987 the entire peninsula received excess or normal winter monsoon rainfall. The departures for the meteorological sub-divisions of CAP, Rayalaseema, Tamil Nadu and Kerala were 94, 85, 4 and 38% respectively. During 1988 the entire peninsula received deficient winter monsoon rainfall. The departure for above four meteorological sub divisions were −55, −62, −47 and −59% respectively.

The rainfall departures for summer and winter monsoons of 1987 and 1988 for these four meteorological sub-divisions have been shown in Fig. 2. The summer monsoon departure pairs for 1987 and 1988 for four sub-divisions are : (−41%, 43%), (−10%, 46%), (−14%, 40%) and (−25%, 9%) respectively. The winter monsoon departure pairs in the same order are (94%, −55%), (85%, −62%), (4%, −47%) and (38%, −59%). It is evident that the winter monsoon rainfall contrast is much more significant than the summer monsoon rainfall contrast for CAP, Rayalaseema and Kerala. The contrast of Tamil Nadu, however, is slightly less for the winter monsoon than that of summer monsoon.

Fig. 3 depicts the tracks of storms/depressions during winter monsoon seasons of 1987 and 1988. There is a striking difference between the directions of movement of these systems during the two years. During 1987 all four systems have moved towards AP/Tamil Nadu coast, whereas, during 1988 only one moved westward and crossed AP coast. In 1987, all systems developed over the area 9.5°-15°N, 85°-90°E, whereas, 1988 systems showed large inconsistency as far as place of formation is concerned.

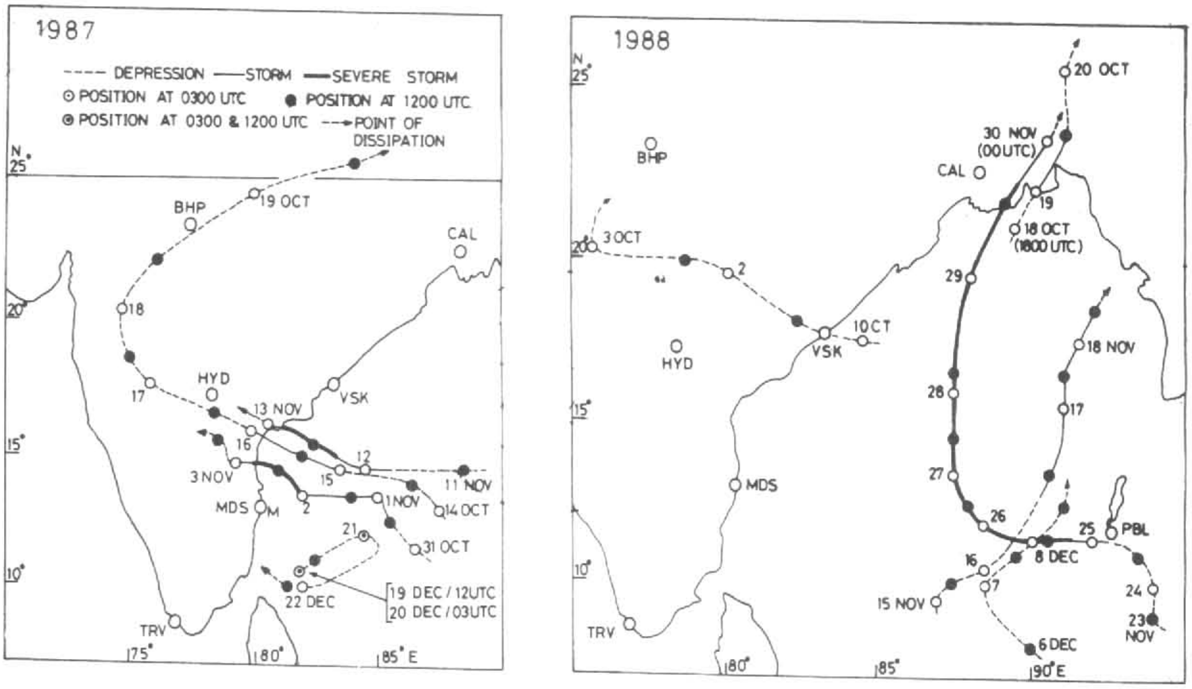

Fig. 3. Tracks of storms/depressions during 1 October to 31 December of the years 1987 and 1988

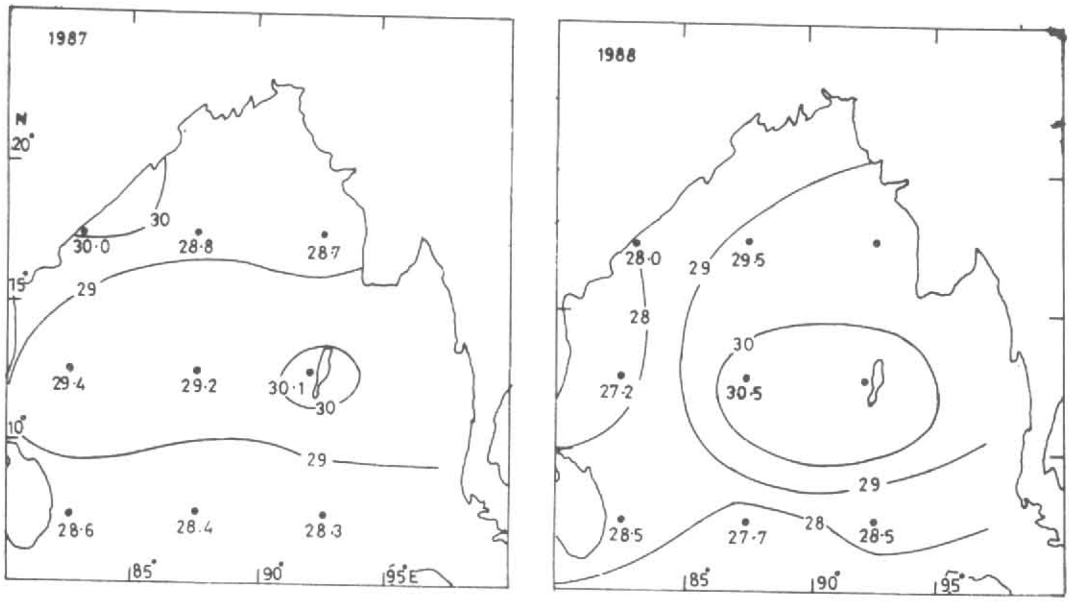

Fig. 4. SST distribution over Bay of Bengal during September month of 1987 and 1988

Most of 1988 systems took northeast course (4 out of 5) and did not affect AP/Tamil Nadu coast.

3.2. *Variability of sea surface temperature over Bay of Bengal*

The gridwise SST distributions over Bay of Bengal during September month of the years 1987 and 1988 have been given in Fig. 4. The following discussions pertain to only September month during 1987 and 1988. The salient feature of SST distribution is that western Bay of Bengal was substantially warmer during 1987 as compared to 1988. The SST over the area between 15°-20°N, west of 85°E was 2°C higher during 1987. Similarly, the area 10°-20°N, west of 85°E was warmer by 2.2°C during 1987 as compared to 1988. The area over central Bay of Bengal bounded by 10°-20°N, 85°-90°E was, however, warmer during 1988. The sea area over southern Bay of Bengal, 5°-10°N, 85°-90°E was

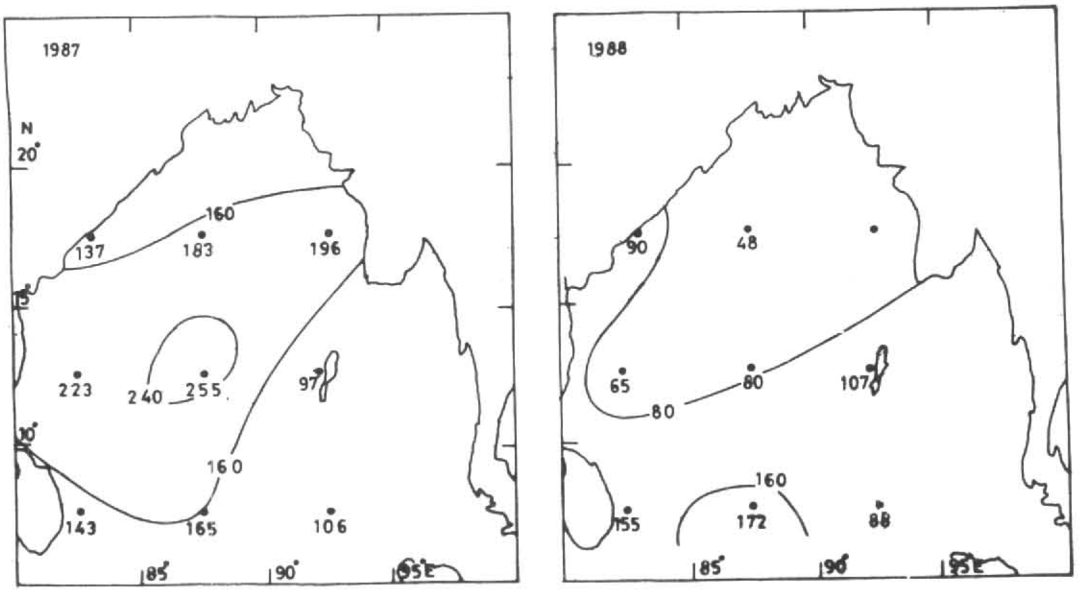

Fig. 5. Latent heat flux over Bay of Bengal during September month of 1987 and 1988

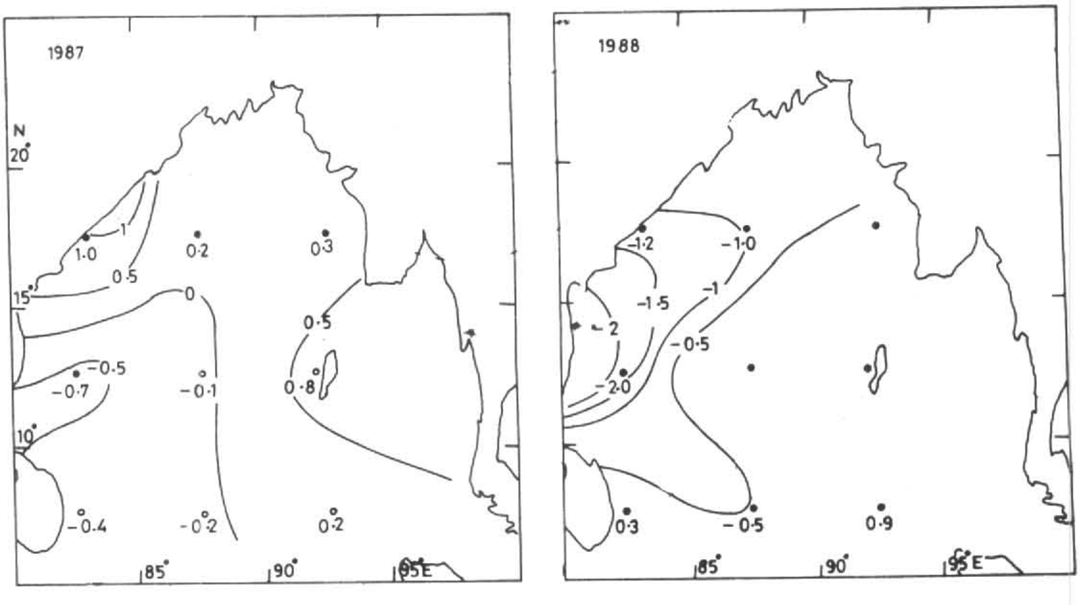

Fig. 6. SST-air temperature over Bay of Bengal during September month of 1987 and 1988

warmer during 1987 by 0.7°C. The SSTs over 5°-10°N, 80°-85°E and 5°-10°N, 90°-95°E were slightly higher (by 0.1-0.2°C) during 1988.

The SST values over western Bay of Bengal during 1987 and 1988 have also been compared with the normals given by Hastenrath and Lamb (1979). It was found that mean SST over western Bay of Bengal during 1987 was about 1.5°C higher than normal whereas mean SST over the same area during 1988 was about 0.5°C lower than normal. Thus it appears that warmer SST anomalies over western Bay of Bengal during September seem to be favourable for subsequent NE monsoon rainfall over Indian peninsula.

3.3. *Variability of evaporation rate over Bay of Bengal*

The computed values of latent heat flux over Bay of Bengal during September of 1987 and 1988 have been given in Fig. 5. The evaporation rate during 1987 was very high over the area bounded by 10°-20°N, west of 90°E. If we consider the mean latent flux over this area, then the values for 1987 and 1988 turn out to be :

September 1987 — 199.5 Wm^{-2}

September 1988 — 70.8 Wm^{-2}

It is evident from these values that the evaporation rate over the above mentioned area of Bay of Bengal during 1987 was more than two-and-half times the value during 1988. The contrast between two evaporation rates is striking. One is tempted to believe that the evaporation rate over north and adjoining central Bay of Bengal before the commencement of NE monsoon season appears to have significant influence on the subsequent winter monsoon rainfall over Indian Peninsula. The mean evaporation rates over the southern Bay of Bengal between 5°-10°N for 1987 and 1988 do not show any contrast (the values are 138 Wm^{-2} and 138.3 Wm^{-2} respectively).

If we compare the computed evaporation rates over the area 10°-20°N, west of 90°E with the normal, it is found that during 1987 the latent heat flux anomaly was about +100 Wm^{-2}, whereas, during 1988 the anomaly was about −30 Wm^{-2}.

3.4. *Variability of instability in the surface layer over Bay of Bengal*

The gridwise values of SST minus air temperature have been given in Fig. 6. The distribution over north and adjoining central Bay of Bengal (15°-20°N) reveals significant difference between September of 1987 and 1988. During 1987 the magnitudes of SST minus air temperature over the latitudinal belt 15°-20°N ranged from +0.2°C to +1.0°C whereas during 1988 the values over the same area ranged from −1.0°C to −1.2°C. Over the area 15°-20°N, west of 85°E the sea was warmer than air temperature by 1.0°C during 1987 and it was cooler than air temperature by 1.2°C during 1988. This shows that in 1987 instability prevailed in the surfacer layer over north and adjoining central Bay of Bengal whereas in 1988 stability dominated the surface layer over the same area.

Thus, it appears that the instability in the surface layer over north and adjoining central Bay of Bengal (between 15°-20°N), before the commencement of NE monsoon, is favourable for ensuing monsoon rainfall over Indian peninsula.

4. Conclusions

Good winter monsoon of 1987 was preceded by very high evaporation rate over Bay of Bengal area bounded by 10°-20°N, 80°-90°E, higher sea surface temperature over western Bay of Bengal and the instability in the surface layer over north and adjoining central Bay of Bengal (between 15°-20°N).

Bad winter monsoon of 1988 was preceded by very low evaporation rate over 10°-20°N, 80°-90°E, lower SST over western Bay of Bengal and the stability in the surface layer over Bay of Bengal between 15°-20°N.

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