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Bay of Bengal cyclone cluster of November 1992

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सार — नवम्बर 1992 में बंगाल की खाड़ी में बने चक्रवात समूह के बारे में नोआ - ए.वी. एच. आर. आर. द्वारा सुदूर संवेदी आधार पर,1°× 1° ग्रिड औसत से प्राप्त किए गए समुद्र सतह तापमान वितरण के संदर्भ में विचार किया गया है। समुद्र सतह के साप्ताहिक तापमान की जाँच यह दर्शाती है कि चक्रवात समूह के बनने से लगभग एक सप्ताह पूर्व 8° उ. में बंगाल की खाड़ी का समूचा भाग असाधारण रूप से गर्म हो गया था। वास्तव में, उपरोक्त अवधि में 13° से 21° तथा 81° से 90°पू. के बीच के समुद्र क्षेत्र के प्रत्येक 60 ग्रिडों में से प्रत्येक का समुद्र सतह तापमान 30° सेंटीग्रेड तक बढ़ गया था। चक्रवात के उत्पन्न होने के ठीक पहले समुद्र के बड़े पैमाने पर ठंडा होने का भी पता चला है।

ABSTRACT. The cyclone cluster that formed over the Bay of Bengal during November 1992 has been looked into in relation to sea surface temperature (SST) distribution obtained from 1°x1° grid averages remotely sensed by NOAA-AVHRR. Examination of weekly SSTs has revealed that entire Bay of Bengal north of 8°N was unusually warmer about a week before the formation of the cyclone cluster. As a matter of fact, during the above period the SST for each of the 60 grids over the sea area between 13°-21° and 81°- 90°E exceeded 30°C. Widespread cooling of the sea was noticed just before the commencement of cyclogenesis.

Key words — Cyclogenesis, SST, Sea-air interaction.

1. Introduction

The cyclogenesis over the Bay of Bengal during November 1992 was unusual in the sense that within a short span of two weeks three cyclonic storms developed (3-6 Nov, 11-17 Nov and 16-21 Nov). Two of them attained severe intensities, out of which one further intensified into a severe cyclone with a core of hurricane winds. (De *et al.* 1993). In addition to these systems a well marked low pressure area also formed (7-9 Nov.). Therefore, during November 1992, Bay of Bengal was cyclogenetically very active.

Due to the paucity of conventional sea surface temperature (SST) observations often, it becomes difficult to study the cyclogenesis in relation to SST distribution which are required on finer spatial and temporal scales, say, 1°x1° grid values on a weekly scale. National Remote Sensing Agency (NRSA), Hyderabad processes NOAA-AVHRR data and brings out weekly SST averages on a grid mesh of 1°x1°. Under a project sponsored by the DOD the satellite derived SST data have been validated with the help of SST observations collected by the Ocean Research Vessels of NIO, Goa. Therefore, the accuracy of satellite derived SSTs is comparable to that of bucket temperatures. However, the SSTs adjacent to the land and clouds would be less reliable. Further, the satellite derived SSTs would not be available in the event of the wide spread clouding over the sea.

The SST distributions over the Bay of Bengal prior to the cyclogenesis have been examined in the present study. The role of marine parameters like SST and evaporation in the development of tropical disturbances has been studied by many investigators. Some recent studies have been done by Pyke (1965), Warsh (1973), and Singh (1992).

2. Data

Weekly 1°x1° grid averages of NOAA-AVHRR sea surface temperature have been used in the present study. The maps of SST distribution during the period under study have been depicted in Fig.1(a&b). It may be mentioned that the maps have been prepared on the basis of 2.5° x 2.5° grid averages to avoid congestion. The frequency of the cyclones

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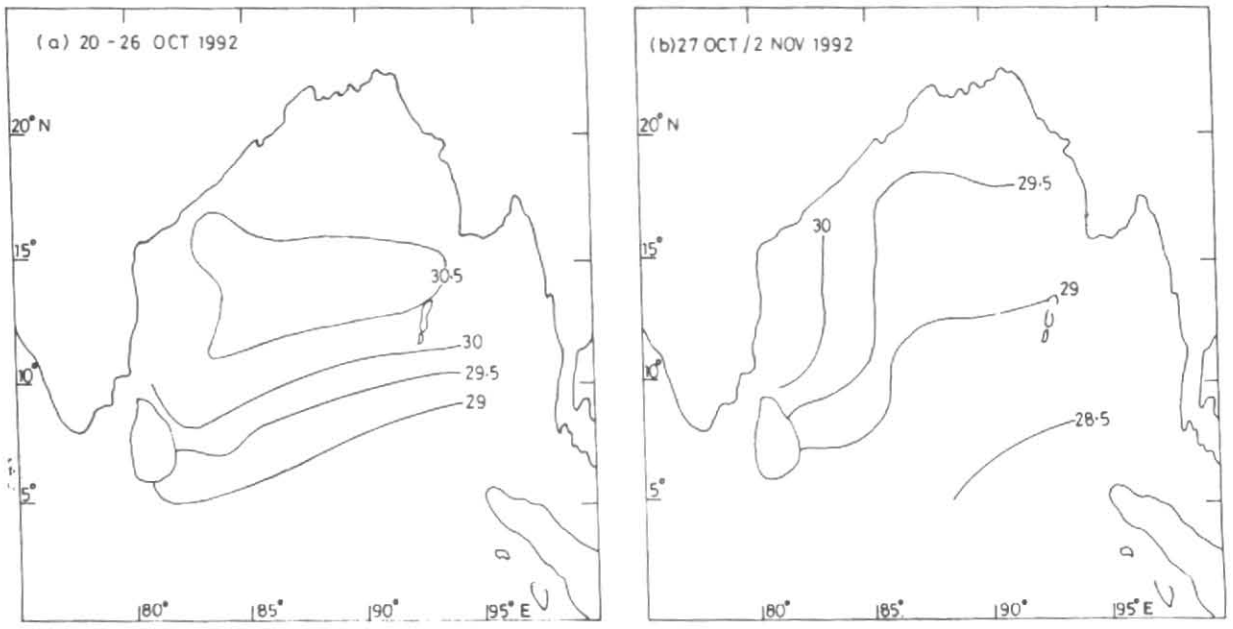

Figs. 1 (a&b). SST distributions over Bay of Bengal

during November 1992 have been obtained from De *et al.* (1993).

3. Results and discussion

De *et al.* (1993) have discussed the tracks of November 1992 cyclones. It may be pointed out that the cyclogenesis commenced with the formation of first cyclone over central Bay of Bengal on 3 November. The remaining two cyclones developed over the southeastern Bay. The quantum of cyclonic activity over the Bay during November 1992 could be assessed from the fact that there was hardly any day during the period 3-21 November when a tropical disturbance (including the well marked low) did not exist over the Bay of Bengal and adjoining land areas. Almost concurrent with the commencement of cyclogenesis was the onset of northeast monsoon over Tamilnadu. Kerala and adjoining areas of Karnataka and Andhra Pradesh on 2 November (De *et al.* 1993). The cyclonic activity was manifested in the northeast (NE) monsoon rains over the south Indian Peninsula during November. The subdivisionwise rainfall departures from normal were: Coastal Andhra Pradesh (AP): +83%; Telangana: +207%; Rayalaseema : +63%; Tamilnadu : + 71%; Coastal Karnataka : +285%; North Interior Karnataka: + 378%; South Interior Karnataka: +201 % and Kerala: + 107%. It was due to good NE monsoon activity during November that 1992 NE monsoon turned out to be excess/normal in spite of deficient rains during October and December over the Peninsula (De *et al.*, 1993). Now we shall examine the SSTs over the Bay of Bengal prior to the commencement of the cyclogenesis. The SSTs reveal some interesting features which are given below.

3.1. *SST over the Bay of Bengal during 20-26 October 1992*

The gridwise SST values are given in Table 1 and the contours for the period 20-26 Oct are shown in Fig.1(a). It is seen from Table 1 that the SST over each of the sixty grids over the Bay of Bengal area between 13°-21° N and 81°-90°E exceeded 30° C. This type of warm SST anomaly prevailing over extensive area of Bay of Bengal is quite unusual because large positive SST anomalies are generally localised in nature over the Bay during November when the normal SSTs themselves are quite high (ranging from 29° to 29.5°C). As a matter of fact during the period of 20-26 Oct, 1992 the entire Bay of Bengal was unusually warmer with SST anomalies ranging from 1° to 1.5°C with higher anomalies over the central Bay as compared to those over the southern Bay. Due to widespread clouding over the Bay of Bengal during 13-19 October, the satellite sensed SST was not available over large portions of the Bay. However, available SST values were compared with the corresponding SSTs of succeeding week (20-26 Oct) and it was noticed that the central Bay of Bengal warmed by about 0.6°C from the week 13-19 to 20-26 Oct.

3.2. *SST over the Bay of Bengal during 27 October-2 November 1992*

An examination of SSTs over the Bay of Bengal during 27 Oct-2 Nov revealed that on an average the sea surface cooled by about 1°C as compared to the previous week Table 1. Fig.1(b) depicts the contours for 27 Oct-2 Nov. Maximum cooling was observed over east central Bay of Bengal which ranged from 1.2° to 1.5°C. The cooling over

TABLE 1

1°x1° grid average of NOAA-AVHRR SST(°C) over the Bay of Bengal. Upper values pertain to the period 20-26 Oct 1992 and the lower ones to 27 Oct-2 Nov 1992(Dashes indicate land/clouds)

Latitude(°N)	Longitude (°E)													
	81	82	83	84	85	86	87	88	89	90	91	92	93	94
5	28.9	29.1	29.1	-	-	-	-	-	-	-	-	-	-	-
	-	28.7	-	-	28.7	28.6	-	-	-	-	-	-	-	-
6	-	29.2	29.1	28.9	28.9	29.0	-	-	-	-	-	-	-	-
	-	28.8	28.8	29.1	28.9	28.7	28.9	-	-	-	-	-	-	-
7	-	29.5	29.3	29	28.8	-	-	-	-	-	-	-	-	-
	-	-	-	29	29.1	28.9	28.8	28.6	-	-	-	-	-	-
8	-	-	29.7	29.4	29.2	29.1	28.9	-	-	-	-	-	-	-
	-	-	-	29.1	29.4	-	28.8	28.7	28.9	-	-	-	-	-
9	-	-	29.9	29.8	29.6	29.2	28.9	29.0	-	-	-	-	-	-
	-	-	-	-	29.5	29.1	28.8	28.8	-	-	-	-	-	-
10	30.0	-	30.1	30.0	29.8	29.4	29.1	29.1	-	-	-	-	-	-
	-	-	-	-	29.6	29.0	28.7	28.9	-	-	-	-	-	-
11	30	30.3	30.3	30.2	30	29.8	29.6	29.5	29.6	-	-	-	-	-
	-	30.8	30.7	-	29.7	29.1	28.9	29.1	-	28.9	-	-	-	-
12	30.2	30.3	30.5	30.5	30.4	30.3	30.3	30.1	29.9	30.1	30.1	-	-	-
	30.9	30.7	30.3	29.9	29.7	29.2	29.0	-	-	-	-	-	-	-
13	30.4	30.4	30.6	30.7	30.7	30.6	30.5	30.5	30.4	30.3	30.3	30.6	-	-
	30.9	30.5	30.2	29.9	29.5	29.2	29.0	29.3	-	-	-	-	-	-
14	30.4	30.3	30.4	30.5	30.6	30.7	30.5	30.5	30.5	30.5	30.6	30.7	30.8	-
	-	30.3	30.2	29.9	29.5	29.2	29.0	29.2	29.4	29.1	29.2	29.3	-	-
15	30.4	30.4	30.4	30.3	30.4	30.5	30.6	30.5	30.6	30.5	30.6	30.6	30.8	31.1
	29.9	30	30.1	29.9	29.6	29.2	29.1	29.2	29.3	29.3	29.2	29.3	-	-
16	-	30.5	30.6	30.5	30.3	30.5	30.5	30.4	30.4	30.4	30.4	30.2	30.4	-
	-	30.0	30.2	29.9	29.7	29.3	29.2	29.2	29.2	29.2	29.2	29.2	-	-
17	-	-	30.7	30.6	30.4	30.4	30.4	30.4	30.4	30.1	29.8	29.9	30.2	-
	-	-	30.3	-	29.5	29.5	29.3	29.3	29.3	20.2	29.2	29.6	-	-
18	-	-	-	-	-	30.4	30.3	30.3	30.3	30.1	29.8	29.9	30.3	30.7
	-	-	-	-	-	29.4	29.4	29.7	29.6	29.3	29.7	29.7	29.3	-
19	-	-	-	-	-	-	30.4	30.5	30.4	30.5	30.0	30.0	-	-
	-	-	-	-	-	-	29.5	29.8	29.5	29.4	29.7	29.5	-	-
20	-	-	-	-	-	-	-	30.6	30.4	30.2	30.2	30.1	-	-
	-	-	-	-	-	-	-	29.8	29.6	29.5	29.8	29.6	-	-
21	-	-	-	-	-	-	-	-	-	30.2	30.3	-	-	-
	-	-	-	-	-	-	-	-	-	30.0	29.9	-	-	-

TABLE 2

Ship SST observations available for comparison

S.No.	Call sign of the Ship	Date	Lat/Long.	SST
		20 Oct - 26 Oct 1992		
1.	9 VBZ	21 Oct	5.9°N/88.6°E	30.0°C
2.	VSBN 3	21 Oct	6.0°N/92.4°E	28.5°C
3.	VSBN 3	23 Oct	5.8°N/81.1°E	28.1°C
		27 Oct - 2 Nov 1992		
4.	GTHZ	31 Oct	5.9°N/88.7°E	27.8°C
5.	LXCH	29 Oct	6.1°N/90.8°E	27.5°C
6.	SHIP	29 Oct	5.8°N/80.5°E	27.0°C
7.	VOCU	31 Oct	11.6°N/82.4°E	28.0°C

western side of central Bay was however, less than 0.5°. The southern Bay of Bengal also cooled considerably. The cooling over the northern Bay of Bengal ranged from 0.5° to 1°C with higher rate of cooling over the northeastern Bay as compared to that over northwestern Bay. The magnitude of cooling is evident from a mere glance at Table 1 or Fig.1 (b) which show that there was not a single grid point between 13°- 20°N and 85°-90°E where SST reached 30°C during the week from 27 Oct-2 Nov in complete contrast to the SST during the previous week from 20 - 26 Oct when the SST over each of the grids exceeded 30°C.

3.3. *Synoptic features*

3.3.1. *SST*

The available ships' observations also suggested cooling of central and south Bay of Bengal between the period 20-26 Oct and 27 Oct-2 Nov (Table 2). The first pair of ship observations are almost from the same location over the southern Bay of Bengal which show the cooling of 2.2°C from 21 Oct to 31 Oct. The second pair show the cooling of 1.0°C from 21 Oct to 29 Oct. The third pair show the cooling of 1.1°C from 23 Oct to 29 Oct 1992. But it was difficult to draw any definite inference, about the magnitude of cooling over different portions of the Bay of Bengal as the observation locations were far separated.

3.3.2. *Synoptic systems*

The first two cyclones (3-6 Nov and 11-17 Nov) were *in situ* formations over the Bay of Bengal, whereas the third (16-21 Nov) was the remnant of the tropical cyclone Forrest which entered the central Andaman sea on 16 Nov as a depression and intensified into a cyclone rapidly on 17th morning.

The western disturbance activity was almost non existent during the period of cyclonic activity. Only one upper air trough in westerlies could be seen during 18-22 Nov at 9.5 km above sea level along about 66°E north of 30°N. Therefore, it appears that upper air troughs did not play any role in the cyclonic activity during 3- 21 Nov 1992.

3.4. *A tentative model for cyclogenesis over the Bay of Bengal during Post monsoon season*

It may be remarked that in short span of one week between 20-26 Oct and 27 Oct-2 Nov almost entire Bay of Bengal cooled by about 1° on an average. Interestingly, the SSTs are normally expected to rise over the Bay of Bengal from mid-October to the first week of November. Thus the extensive cooling of the Bay from the week 20-26 Oct to 27 Oct-2 Nov appeared to be quite anomalous during the year 1992. This happened perhaps, due to abnormally high SSTs which could no longer be sustained by the sea surface. Assuming that the entire heat energy was transferred by the ocean to the overlying atmosphere through evaporation and conduction (*i.e.* in the form of latent heat flux and sensible heat flux), it may be inferred that the total gain of energy by the atmosphere during the one week period must have been enormous. Because it is not feasible to compute the rate of evaporation from the grid SSTs (due to unavailability of corresponding values of wind and dew point), an attempt was made to estimate the rate of evaporation over the central and adjoining south Bay of Bengal using winds and dew point from synoptic charts. The computations using bulk aerodynamic formula showed that the values of latent heat flux ranged from 250-270 Watt m^{-2} during 20-26 Oct. This rate of evaporation over the central and adjoining south Bay of Bengal is very high keeping in view the normal latent heat flux of 160-180 Watt m^{-2} over there during November. It is, therefore, not surprising that this sudden gain of energy was liberated by atmosphere in the form of a cluster of cyclones. It is worth noting that the time lag between the peak SSTs and the commencement of cyclogenesis was one week. Thus SSTs exceeding 30°C over the Bay of Bengal during the Post monsoon season need to be watched carefully. This may provide an additional input to the cyclone forecasting.

4. Conclusion

A week before the formation of November 1992 cyclone cluster, the Bay of Bengal was unusually warmer. Within a short span of one week almost entire of Bay of Bengal cooled by about 1°C, liberating large amount of energy to the atmosphere. The vigorous energy exchange between the ocean and atmosphere was followed by the intense cyclonic activity over the Bay of Bengal and commencement of northeast monsoon rain over the south Indian Peninsula. The SSTs over the Bay of Bengal during the Post monsoon season appear to provide useful indications of cyclogenesis over the Bay and the activity of the NE monsoon over the Indian Peninsula on a time scale of medium range.

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