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Distribution of mean monthly surface/upper air parameters during July-August months of 1982-83 and 1987- 88

K. SEETHARAM

India Meteorological Department, Kolkata – 700 027, India

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सार – भारतीय ग्रीष्मकालीन मानसून को समुद्र और धरातल की मिली–जुली वायुमंडलीय परिघटना मानते हुए इसका अध्ययन भूमंडलीय प्रकृति के परिदृश्य में किया गया है। इस अध्ययन में दो विषम परिस्थितियों में मानसून के व्यवहार को समझने के लिए क्रमशः कम और अधिक दोनों तरह की वर्षा वाले दो वर्षों (1982, 1987), दो वर्षों (1983, 1988) में ग्रीष्मकालीन मानसून के दो प्रमुख महीनों जुलाई और अगस्त के दौरान शून्य अंश उ. से 40 अंश उ./40 अंश पू. से 100 अंश पू. के क्षेत्र में माध्य मासिक धरातलीय प्राचलों के वितरण को लिया गया है। इसके अतिरिक्त ग्रीष्मकालीन मानसून पर क्षोभमंडलीय पश्चिमी हवाओं के प्रभाव और पश्चिमी विक्षोभों की गतिविधि का मूल्यांकन करने के लिए निम्न क्षोभमंडल की कटिबंधीय पवनों के वितरण अर्थात्, जुलाई, अगस्त के महीनों में 850 हैक्टापास्कल और 700 हैक्टापास्कल के स्तरों जनवरी, मई, जुलाई और अगस्त के महीनों के लिए 500 हैक्टापास्कल पर भूस्थितिज ऊँचाइयों का अध्ययन किया गया है। इस अध्ययन से प्राप्त हुए परिणामों पर विचार–विमर्श किया गया है।

ABSTRACT. Indian summer monsoon is considered as an ocean-land-atmosphere coupled phenomenon and also of global nature. In present study, the distribution of mean monthly surface parameters within 0° N – 40° N / 40° E – 100° E region during the two representative months of summer monsoon, July and August, in both deficient years (1982, 1987) and excess years (1983, 1988) was taken up to understand the behaviour of monsoon during two contrasting situations. Apart from this, the distribution of lower tropospheric zonal winds *viz.*, 850 hPa and 700 hPa levels during July, August months, 500 hPa geopotential heights for the months of January, May, July and August months studied to assess the influence of tropospheric westerlies and activity of Western Disturbances on the summer monsoon. The results discussed.

Keywords – Precipitable Water, *U*-wind, *V*-wind, Westerlies, Western disturbances**.**

1. Introduction

The monsoon rainfall is variable both in space and time which influences the agriculture, water resources of the country. Many human economic and cultural activities of the country depend on the performance of the monsoon. An excess summer monsoon rainfall may lead to floods and a deficient monsoon rainfall may lead to drought. The study of the past two decades indicated that the summer monsoon was normal in the years 1980, 1981, 1984, 1985, 1989 to 2001, 2003 and 2004, deficient in the years 1982, 1986, 1987 and 2002 and excess only in the years 1983 and 1988. The dynamics behind these excess and deficient rainfalls of Indian summer monsoon is still not fully understood. However, some of the summer monsoon deficient years were believed to be due to occurrence of ENSO phenomenon. Many scientists have studied the summer monsoon variability by way of teleconnections with remote parameters and also by understanding the internal dynamics of monsoon. The studies showed that the summer monsoon is a global phenomenon and is a land-ocean coupled system and have a global influence. In India, the years 1982 and 1987 were drought years and incidentally the ENSO event 1982-1983 was very strong with MEI touching +3.0 in months of March / April, 1983 and 1987-1988 ENSO-event was moderate with MEI touching +1.9 in months of March/April, 1988. During these 1982 and 1987 years the all India summer monsoon rainfall was 735.6 mm and 697.4 mm respectively. These are two of such events which were followed by cold events and subsequently India had excess rainfalls in the years 1983 and 1988 with 955.9 mm and 961.7 mm respectively. The summer monsoon rainfall of the year 1982 was deficient with 85% of the normal rainfall and 1987 summer monsoon rainfall was deficient with 81% of the normal rainfall. In the other two years 1983 and 1988, the summer monsoon rainfall was excess with 113% and 119% of the normal summer monsoon rainfall respectively. Earlier the relationship between Arabian Sea features and Indian summer monsoon was explored to understand the observed variability in the Indian Summer Monsoon Rainfall (Shukla and Misra, 1977). In this paper, an attempt has been made to understand surface/upper air circulation

TABLE 1

Showing comparison of surface/upper air features in excess/deficient years of summer monsoon

(a) Relative humidity

Years/ sectors	July: 25° N - 30° N / 90° E - 95° E	July: North of 15° N / West of 55° E	July: 10° N - 18° N / 75° E along West coast of India	July: 10° N - 12° N / 80° E along East coast of India	July: 20° N - 25° N / 70° E - 85° E	August: 25° N - 30° N / 90° E - 95° E	August: North of 15° N / West of 55° E	August: 10° N - 18° N / 75° E along West coast of India	August: 10° N - 12° N / 80° E along East coast of India	August: 20° N - 25° N / 70° E - 85° E
1982	High	Low	Maximum with 95%	Minimum with 66%	Low	High	Low	Maximum with 96%	Minimum with 79%	Low
1983	High	Low	Maximum with 95%	Minimum with 72%	High	High	Low	Maximum with 96%	Minimum with 79%	High
1987	High	Low	Maximum with 95%	Minimum with 66%	Low	High	Low	Maximum with 96%	Minimum with 73%	Low
1988	High	Low	Maximum with 95%	Minimum with 73%	High	High	Low	Maximum with 96%	Minimum with 81%	High

(b) Precipitable water

Years/ sectors	July: 14° N - 20° N / 72° E	July: North of 12° N - 16° N / 82° E	July: 12° N - 14° N / 78° E	July: 20° N - 25° N / 70° E - 85° E	August: 14° N - 20° N / 72° E	August: North of 12° N - 16° N / 82° E	August: 12° N - 14° N / 78° E	August: 20° N - 25° N / 70° E - 85° E
1982	Maximum with 51 kg/m^2	Maximum with 52 kg/m^2	Minimum with 45 kg/m^2	Low	Maximum with 55 kg/m^2	Maximum with 54 kg/m^2	Minimum with 48 kg/m^2	Low
1983	Maximum with 54 kg/m^2	Maximum with 53 kg/m^2	Minimum with 49 kg/m^2	High	Maximum with 57 kg/m^2	Maximum with 55 kg/m^2	Minimum with 48 kg/m^2	High
1987	Maximum with 49 kg/m^2	Maximum with 49 kg/m^2	Minimum with 41 kg/m^2	Low	Maximum with 55 kg/m^2	Maximum with 52 kg/m^2	Minimum with 46 kg/m^2	Low
1988	Maximum with 56 kg/m^2	Maximum with 53 kg/m^2	Minimum with 53 kg/m^2	High	Maximum with 56 kg/m^2	Maximum with 52 kg/m^2	Minimum with 48 kg/m^2	High

(c) Surface zonal wind and meridional wind

Years/ sectors	Zonal July: Indian Mainland	Zonal July: Bay of Bengal	Zonal August: Indian Mainland	Zonal August: Bay of Bengal	Meridional July: Bay of Bengal	Meridional July: Southern tip of West coast of India	Meridional August: Bay of Bengal	Meridional August: Southern tip of West coast of India
1982	Westerlies 4 m/s – 2 m/s	Westerlies 8 m/s – 6 m/s	Westerlies 4 m/s – 2 m/s	Westerlies 8 m/s – 6 m/s	Southerly flow 8 m/s – 4 m/s	No meridional component	Southerly flow 8 m/s – 4 m/s	No meridional component
1983	Westerlies 6 m/s – 4 m/s	Westerlies 6 m/s – 4 m/s	Westerlies 6 m/s – 4 m/s	Westerlies 6 m/s – 4 m/s	Southerly flow 8 m/s – 4 m/s	Southeastward flow	Southerly flow 8 m/s – 4 m/s	Southeastward flow
1987	Westerlies 4m/s – 2 m/s	Westerlies 8 m/s – 6 m/s	Westerlies 4 m/s – 2 m/s	Westerlies 8 m/s – 6 m/s	Southerly flow 8 m/s – 4 m/s	No meridional component	Southerly flow 8 m/s – 4 m/s	No meridional component
1988	Westerlies 6 m/s – 4 m/s	Westerlies 6 m/s – 4 m/s	Westerlies 6 m/s – 4 m/s	Westerlies 6 m/s – 4 m/s	Southerly flow 8 m/s – 4 m/s	Southeastward flow	Southerly flow 8 m/s – 4 m/s	Southeastward flow

(d) 850 hPa and 700 hPa zonal wind

Years/sectors	850 July: 10° N - 15° N / 55° E - 70° E	850 August: 10° N - 15° N / 55° E - 70° E	700 July: 10° N - 15° N / 55° E - 70° E	700 August: 10° N - 15° N / 55° E - 70° E
1982	Westerlies 16 m/s	Westerlies 18 m/s	Westerlies < = 8 m/s, weaker than 850 hPa	Westerlies < = 8 m/s, weaker than 850 hPa
1983	Westerlies 18 m /s	Westerlies 18 m/s	Westerlies < = 8 m/s, weaker than 850 hPa with 12 m/s at 5° N / 60° E in July	Westerlies < = 8 m/s, weaker than 850 hPa
1987	Westerlies 14 m/s	Westerlies 14 m/s	Westerlies < = 6 m/s, weaker than 850 hPa	Westerlies <= 6 m/s, weaker than 850 hPa
1988	Westerlies 20 m/s	Westerlies 16 m/s	Westerlies < = 10 m/s, weaker than 850 hPa with 14 m/s at 5° N / 60° E in July	Westerlies < = 8 m/s, weaker than 850 hPa

TABLE 1(*Contd.*)

(e) 500 hPa geopotential height

	Zonal				Meridional			
	July		August		July		August	
Years/ sectors	25° N - 30° N / East of 80° E in January	25° N - 35° N / East of 80° E in May	25° N – 35° N / East of 80° E in July	25° N - 35° N / East of 80° E in August	25° N - 30° N / West of 80° E in January	25° N - 35° N / West of 80° E in May	25° N - 35° N / West of 80° E in July	25° N - 35° N / West of 80° E in August
1982	Higher than 1983 (Warm)	Higher than 1983 (Warm)	Lower than 1983 (Cold)	Lower than 1983 (Cold)	Higher than 1983 (Warm)	Higher than 1983 (Warm)	Lower than 1983 (Cold)	Lower than 1983 (Cold)
1983	Lower than 1982 (Cold)	Lower than 1982 (Cold)	Higher than 1982 (Warm)	Higher than 1982 (Warm)	Lower than 1982 (Cold)	Lower than 1982 (Cold)	Higher than 1982 (Warm)	Higher than 1982 (Warm)
1987	Higher than 1988 (Warm)	Higher than 1988 (Warm)	Lower than 1988 (Cold)	Higher than 1988 (Warm)	Higher than 1988 (Warm)	Higher than 1988 (Warm)	Higher than 1988 (Warm)	Higher than 1988 (Warm)
1988	Lower than 1987 (Cold)	Lower than 1987 (Cold)	Higher than 1987 (Warm)	Lower than 1987 (Cold)	Lower than 1987 (Cold)	Lower than 1987 (Cold)	Lower than 1987 (Cold)	Lower than 1987 (Cold)

features in order to study the excess/deficient rainfall situation over India during Indian summer monsoon.

2. Data and methodology

The surface data *viz*., Mean sea level Pressure, Air temperature, Relative Humidity, Precipitable Water, *U*-component and *V*-component of Wind and Upper air parameters like 850 hPa and 700 hPa zonal winds for the months of July and August, 500 hPa geopotential height for the months of January, May, July and August months in the two ENSO years 1982 and 1987 and subsequent La Nina years 1983 and 1988 from the NCEP/NCAR reanalysis – I data from Climate Diagnostic Centre, NOAA-CIRES, USA and plot of the surface data generated from the selected data obtained and analyzed to explain the observed time variability in terms of these surface/upper air features. Kalnay *et al*. 1996 discussed the reanalysis data and in the reanalyzed data sets the observed phase relationship between sea surface temperature anomalies and low level circulation features were captured as in the real ocean-atmosphere coupled system. The precipitable water was included in the surface data because it is measured in the unit column of air extending from surface to the top of the atmosphere.

3. Results and discussion

The success and failure of the monsoon depends on the performance of monsoon during peak season, that is, July and August months since by this time, monsoon establishes itself over Indian sub-continent. Failure of monsoon during these representative months may lead to deficient rainfall and initial failure and later recovery of the monsoon during these two months may lead to normal rainfall or sometimes excess rainfall. There in this paper an attempt has been made to understand the distribution of surface parameters in these two months with reference to Indian sub-continent. Earlier, a study indicated that the convective activity over Bay of Bengal induces stronger winds over Arabian Sea and enhances moisture advection into the Indian land mass that in turn lead to increase in precipitable water and strength of the monsoon indicating increase in precipitable water in the month of July leads to increased rainfall (Srinivasan and Ravi, 2002).

The present study, mostly, involves the distribution of mean monthly surface feature like, Mean Sea level pressure, air temperature, relative humidity, precipitable water, *U*-wind, *V*-wind and upper air data like, 850 hPa and 700 hPa zonal winds during July and August months, 500 hPa geo-potential height for January, May, July and August months in the region 0° N – 40° N latitude and 40° E – 100° E longitude over Indian sub-continent in deficient years of 1982/1987 and excess years 1983/1988. The differences in distribution of these selected surface/upper air features in contrasting years of Indian summer monsoon are brought out and discussed. The summary of the results presented in Table 1.

(*i*) *Mean Air temperature (°C)*

In July 1982, the mean monthly air temperature showed a pattern with mean air temperatures decreasing towards inland from 29° C to 25° C within region 10° N - 20° N / 70° E - 85° E and then increased northwestwards within region 20° N - 30° N / 75° E - 60° E (up to 33° C) and decreased further northwestwards. The mean air temperatures east of 65° E were lower in comparison with west of the same longitude above 30° N. High mean air

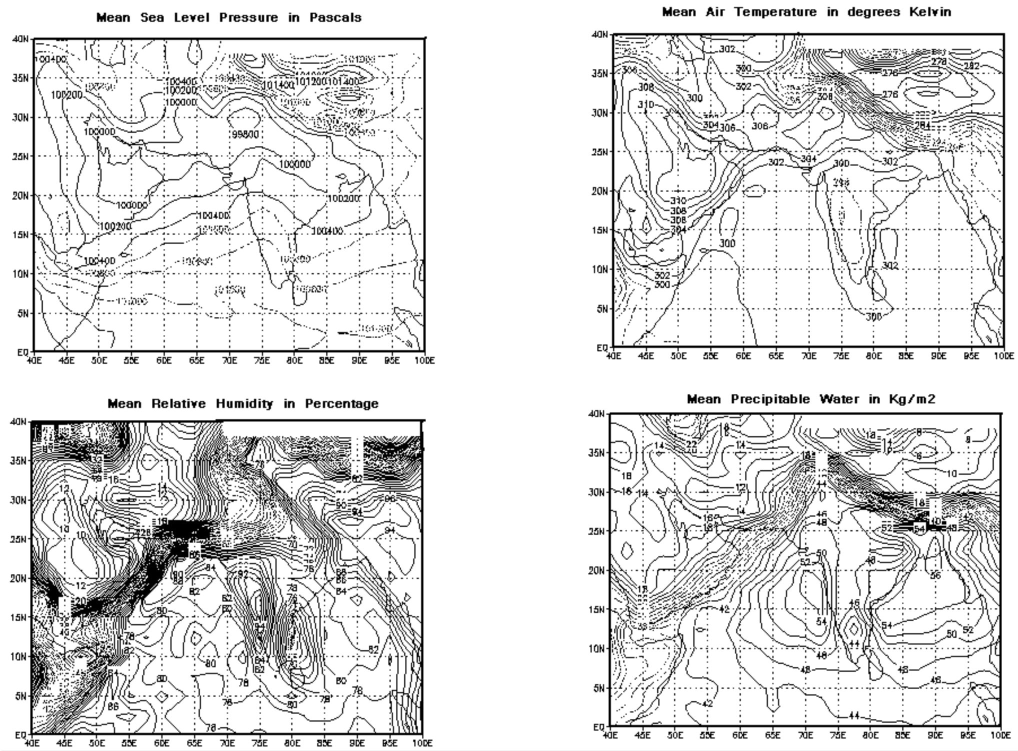

Fig. 1(a). Showing distribution of mean monthly surface parameters for the month of July, 1982 within region 0° N – 40° N / 40° E – 100° E

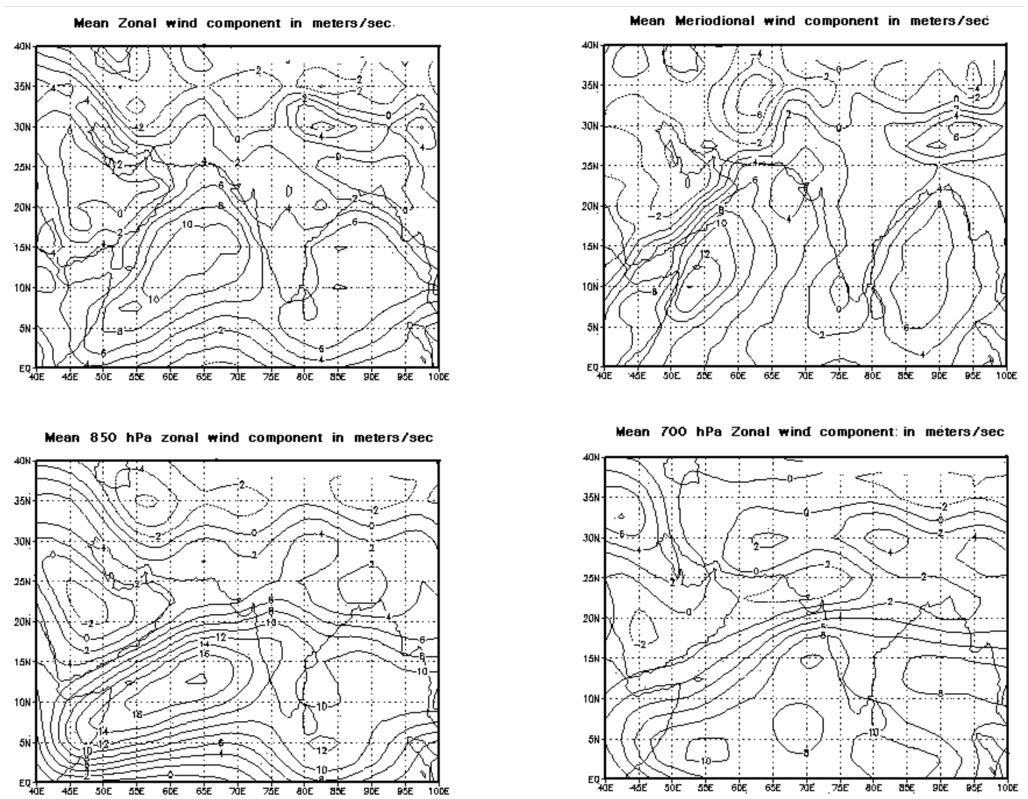

Fig. 1(b). Showing distribution of surface / Upper air parameters for the month of July, 1982 within region 0° N – 40° N / 40° E – 100° E

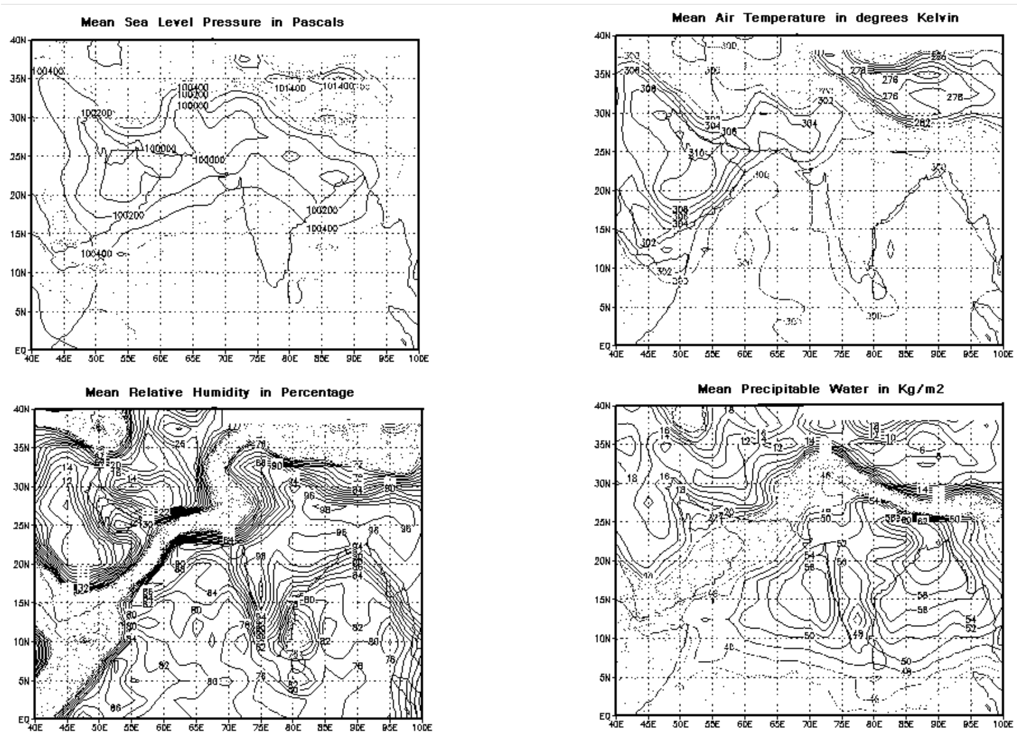

Fig. 2(a). Showing distribution of mean monthly surface parameters for the month of August, 1982 within region 0° N – 40° N / 40° E – 100° E

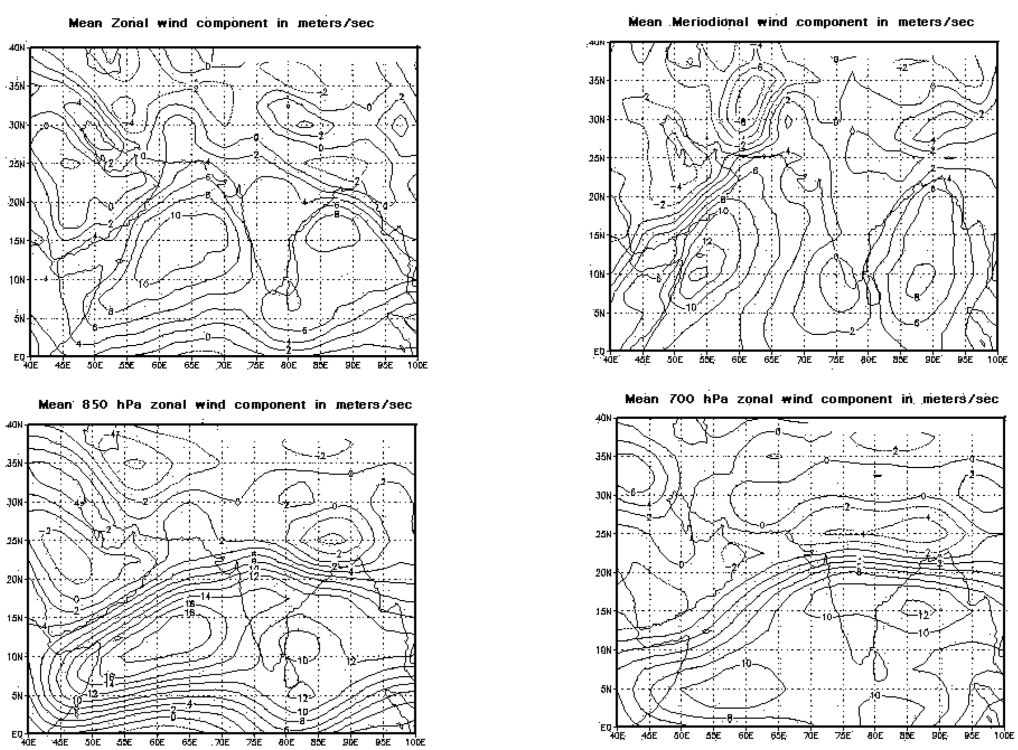

Fig. 2(b). Showing distribution of mean monthly surface / upper air parameters for the month of August, 1982 within region 0° N – 40° N / 40° E – 100° E

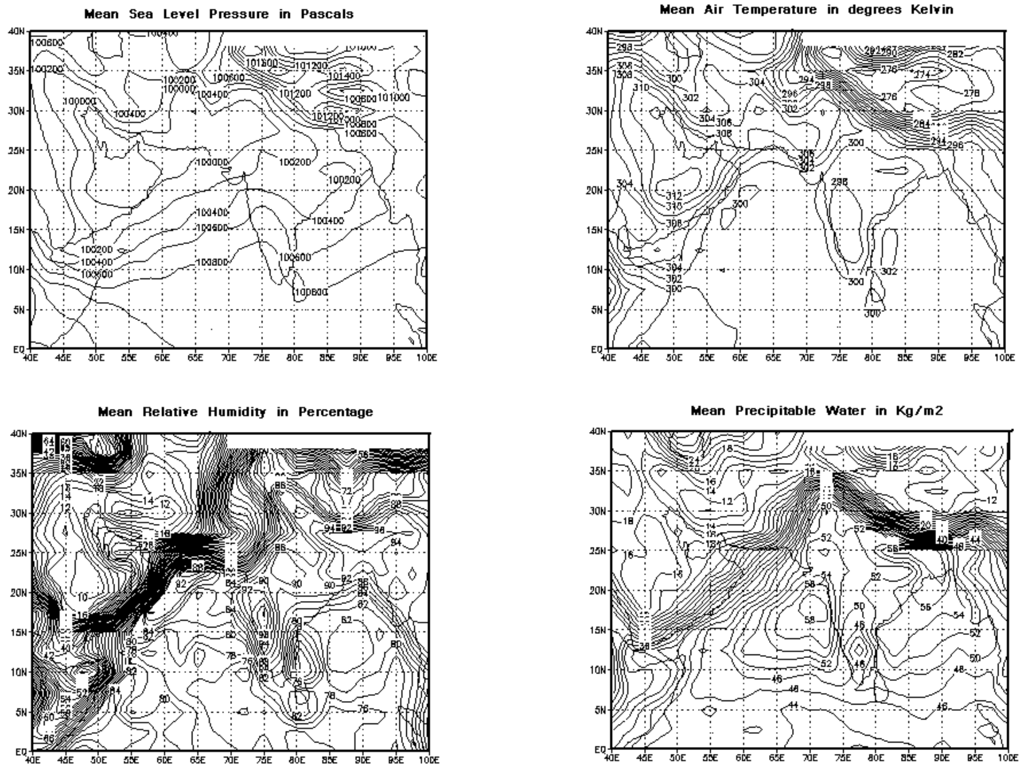

Fig. 3(a). Showing distribution of surface parameters for the month of July, 1983 within region 0° N – 40° N / 40° E – 100° E

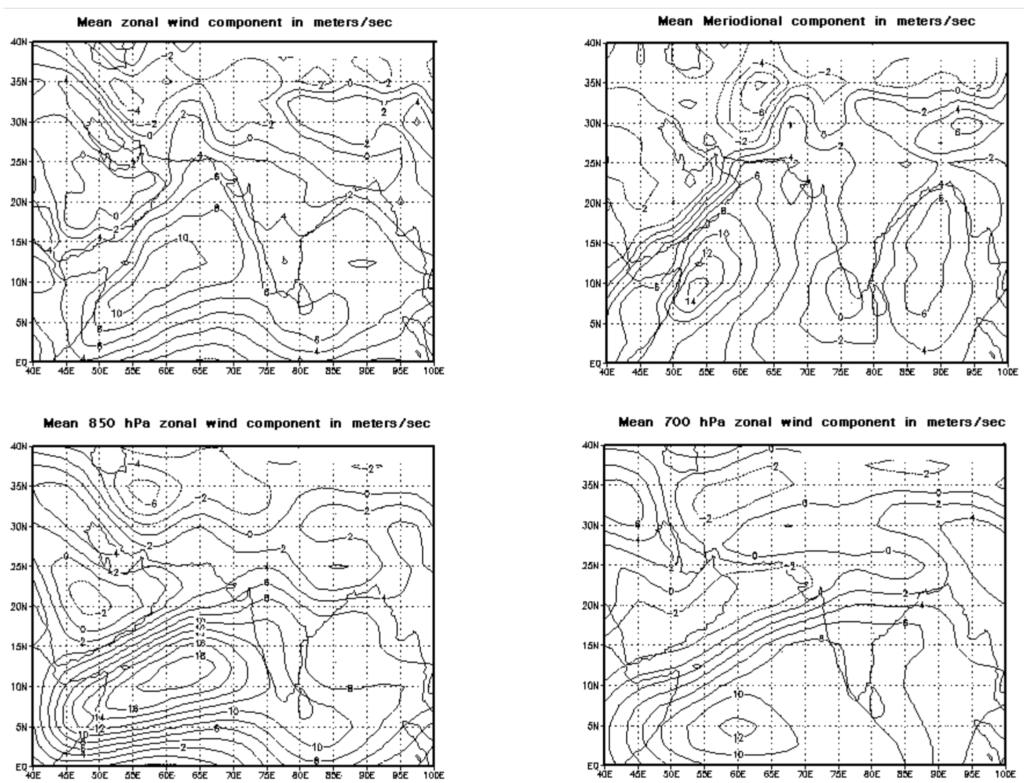

Fig. 3(b). Showing mean monthly surface / upper air parameters for the month of July, 1983 within region 0° N – 40° N / 40° E – 100° E

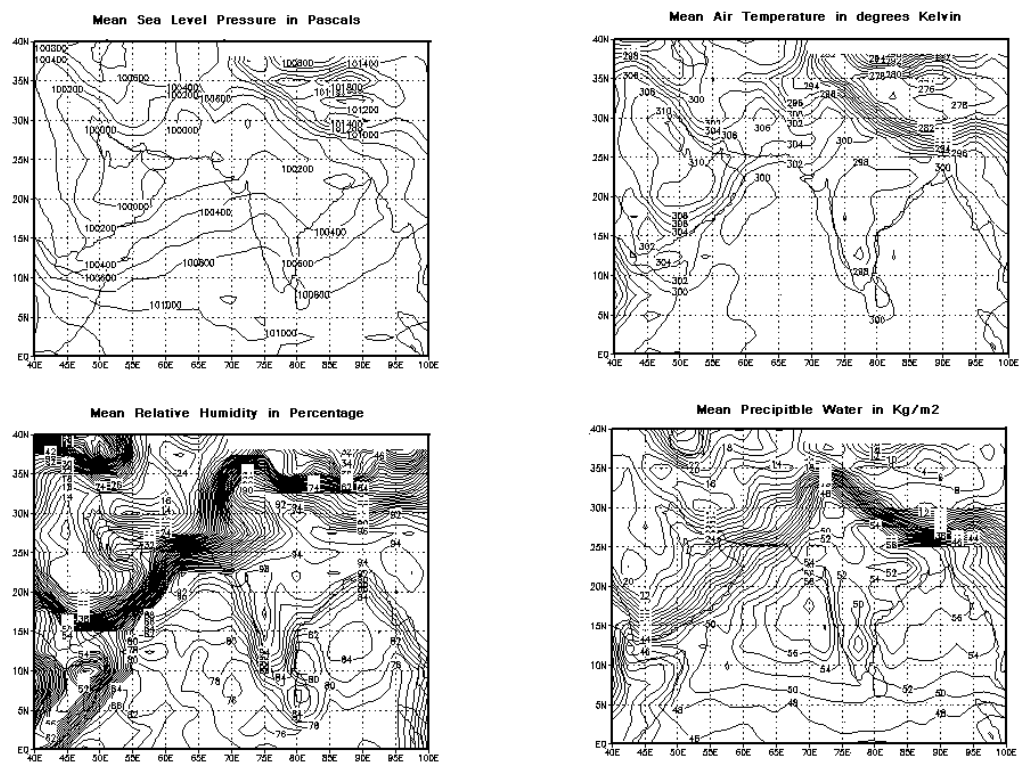

Fig. 4(a). Showing distribution of mean monthly surface parameters in the month of August, 1983 within region 0° N – 40° N / 40° E – 100° E

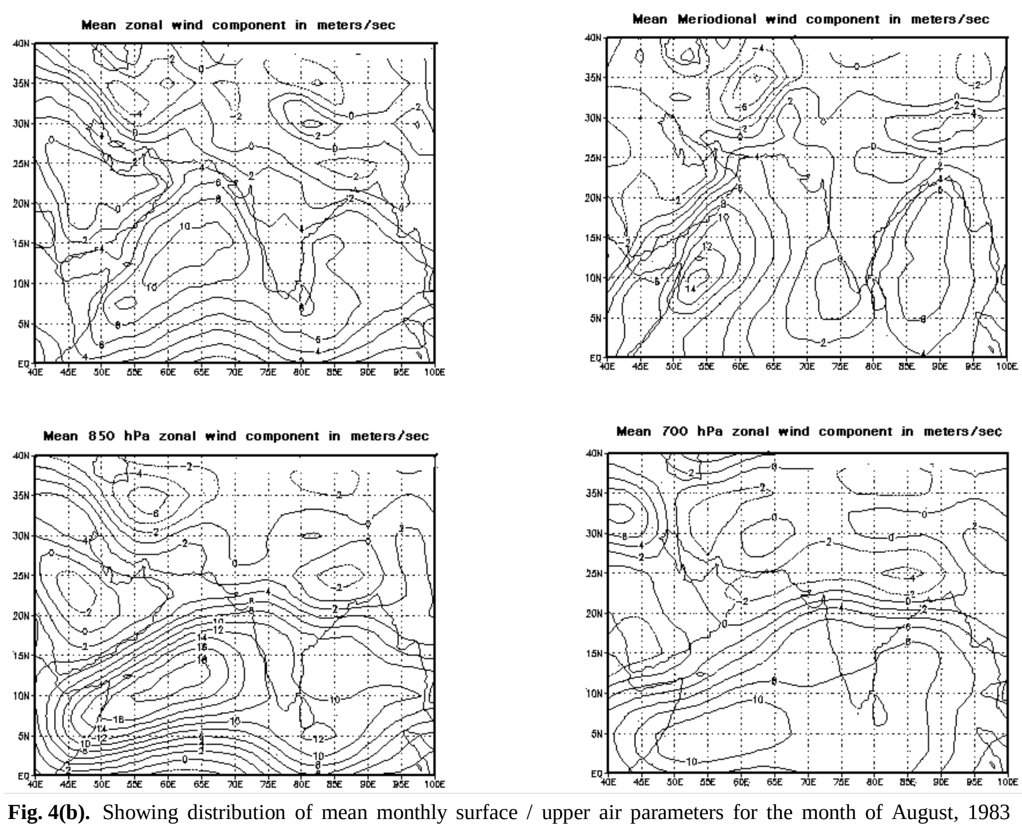

Fig. 4(b). Showing distribution of mean monthly surface / upper air parameters for the month of August, 1983 within region 0° N – 40° N / 40° E – 100° E

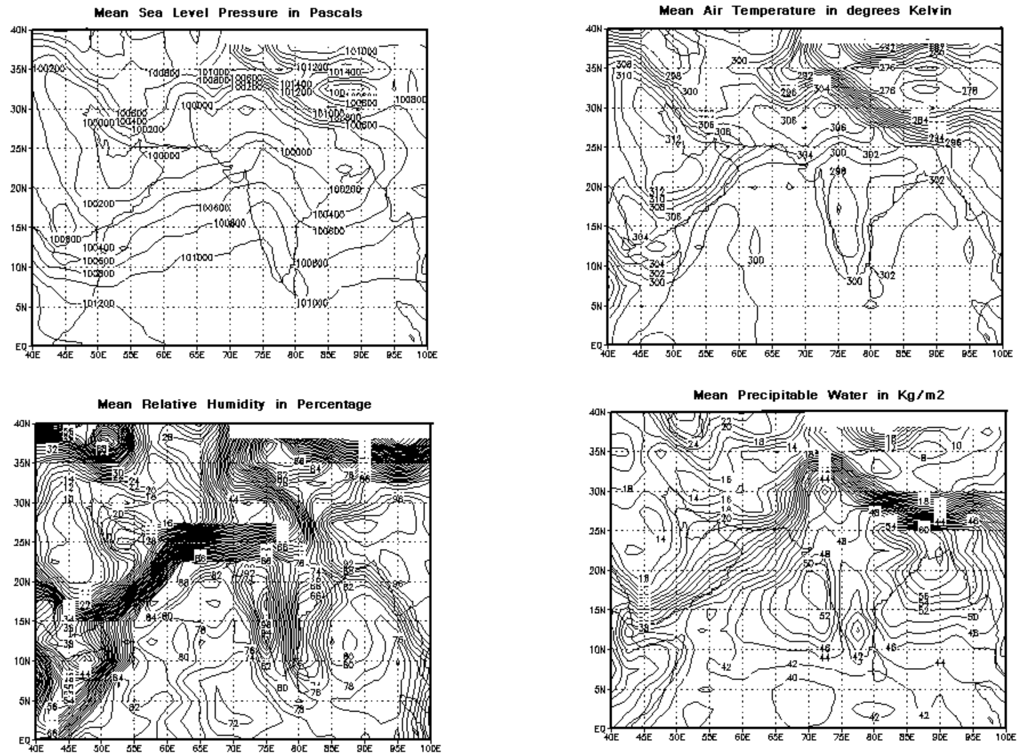

Fig. 5(a). Showing distribution of mean monthly surface parameters for the month of July, 1987 within region 0° N – 40° N / 40° E – 100° E

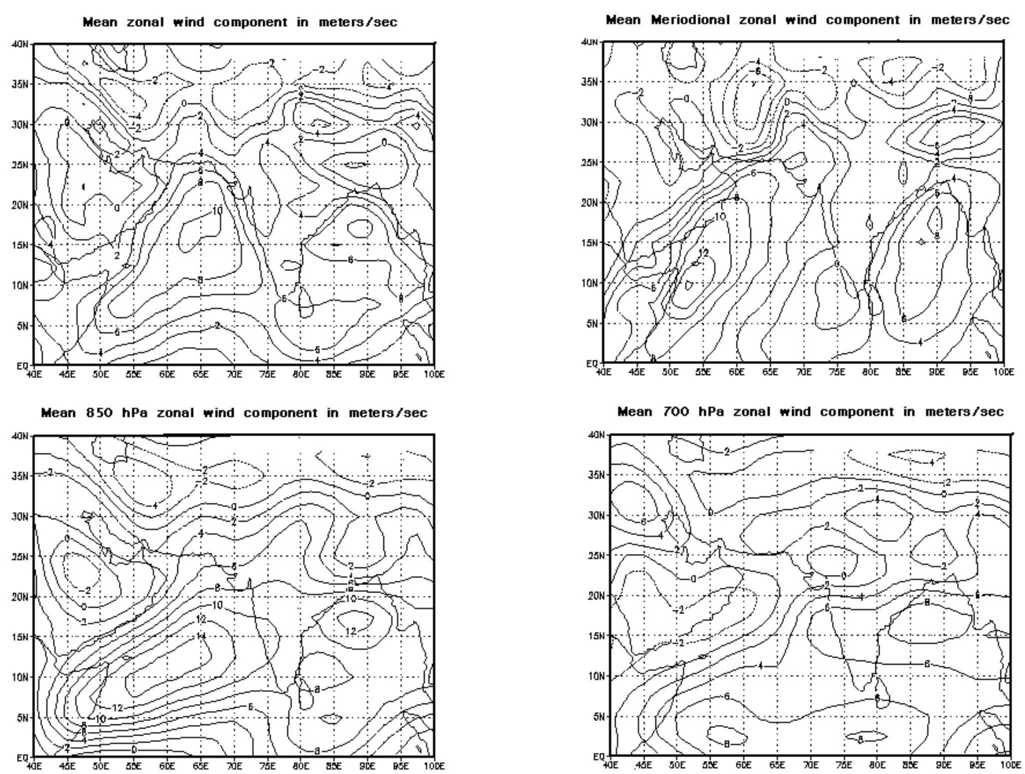

Fig. 5(b). Showing distribution of mean monthly surface / upper air parameters for the month of July, 1987 within region 0° N – 40° N / 40° E – 100° E

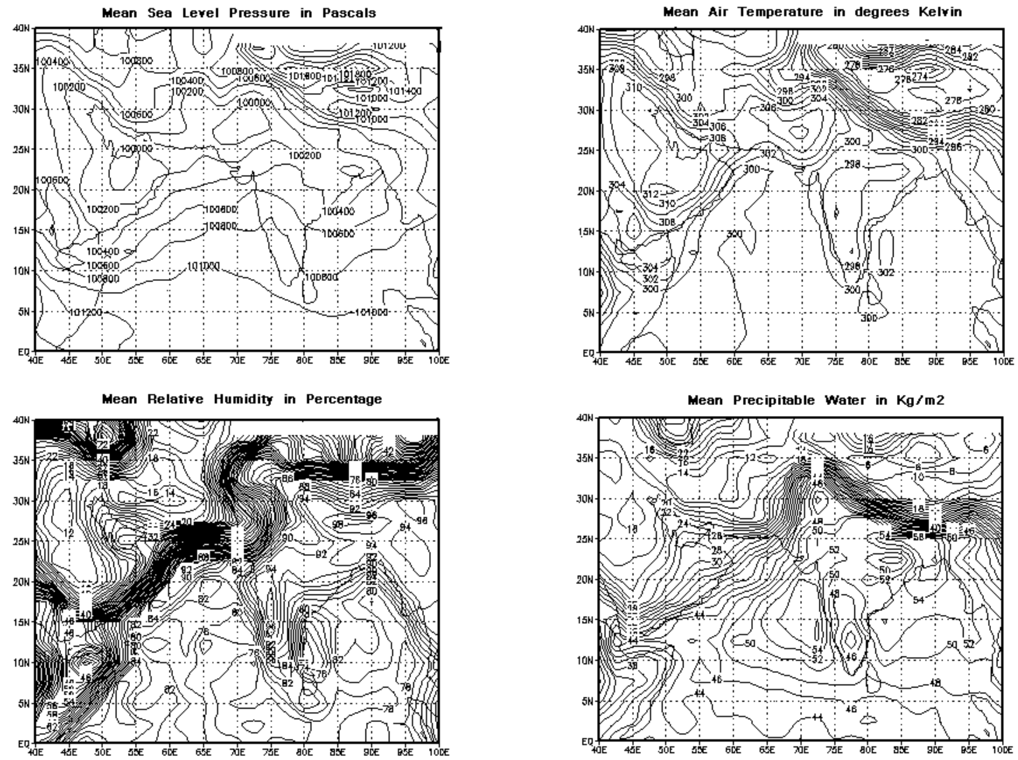

Fig. 6(a). Showing distribution of mean monthly surface parameters for the month of August, 1987 within region 0° N – 40° N / 40° E – 100° E

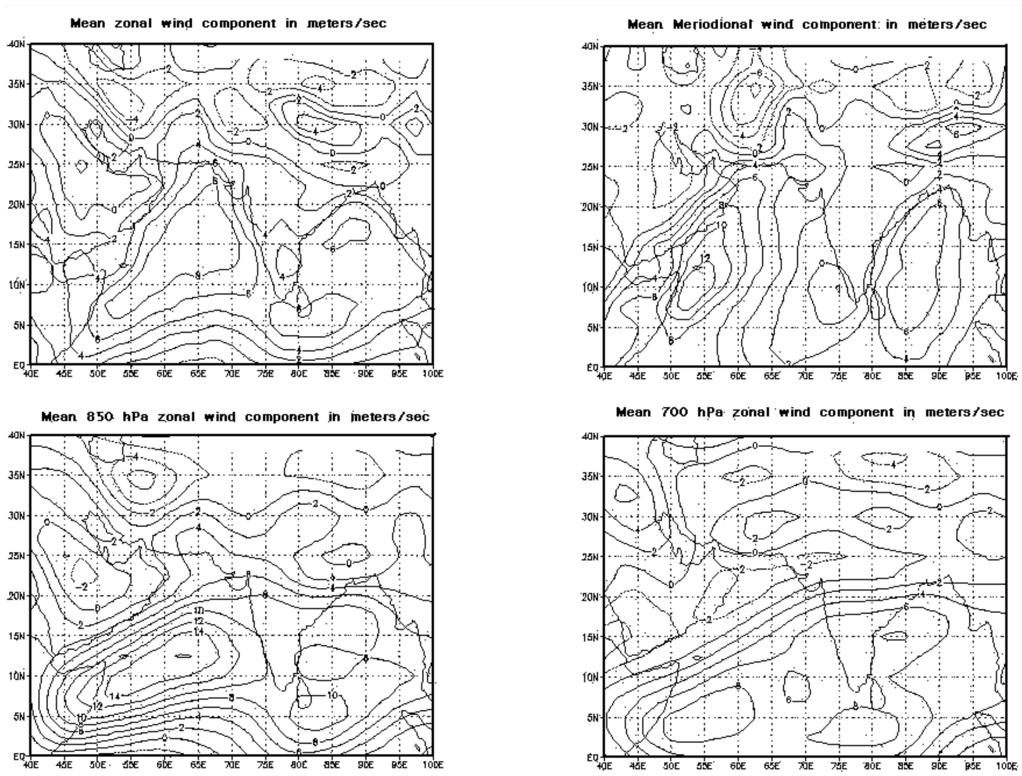

Fig. 6(b). Showing distribution of mean monthly surface / upper air parameters for the month of August, 1987 within region 0° N – 40° N / 40° E – 100° E

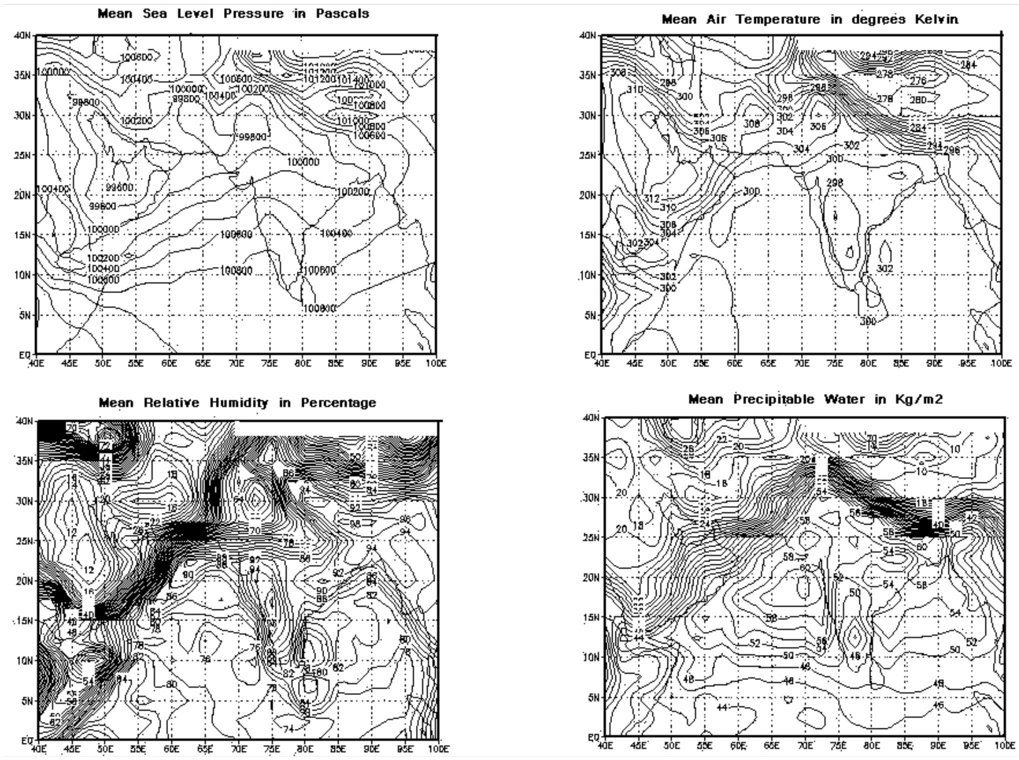

Fig. 7(a). Showing distribution of mean monthly surface parameters for the month of July, 1988 within region 0° N – 40° N / 40° E – 100° E

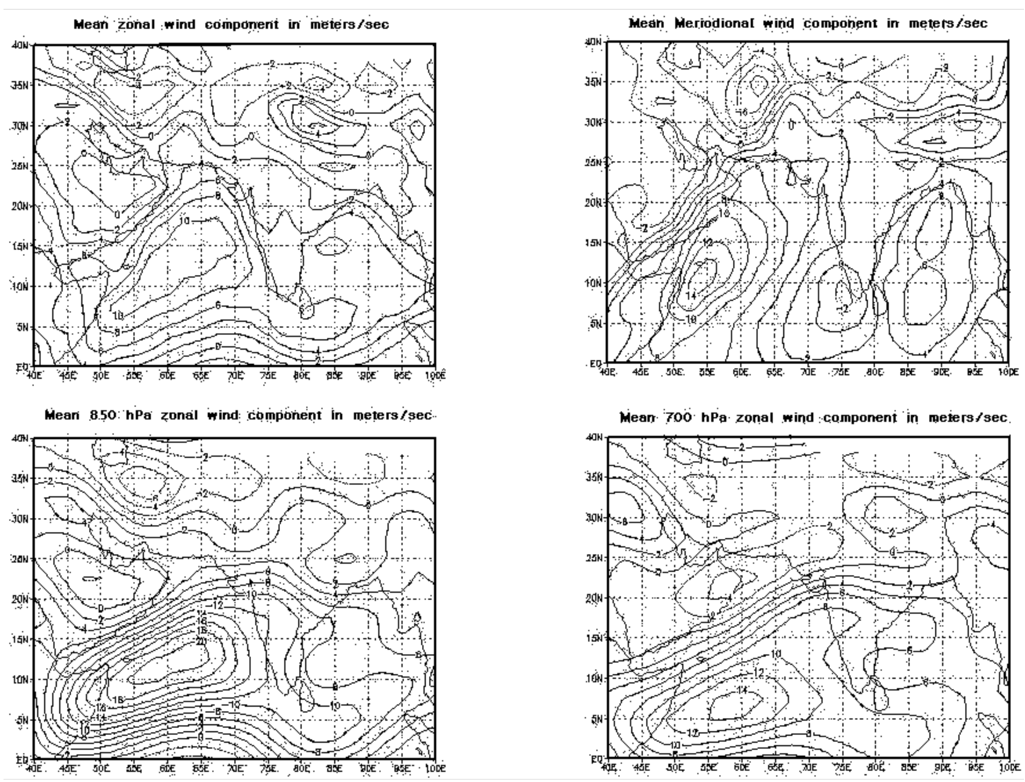

Fig. 7(b). Showing distribution of mean monthly surface / upper air parameters for the month of July, 1988 within region 0° N – 40° N / 40° E – 100° E

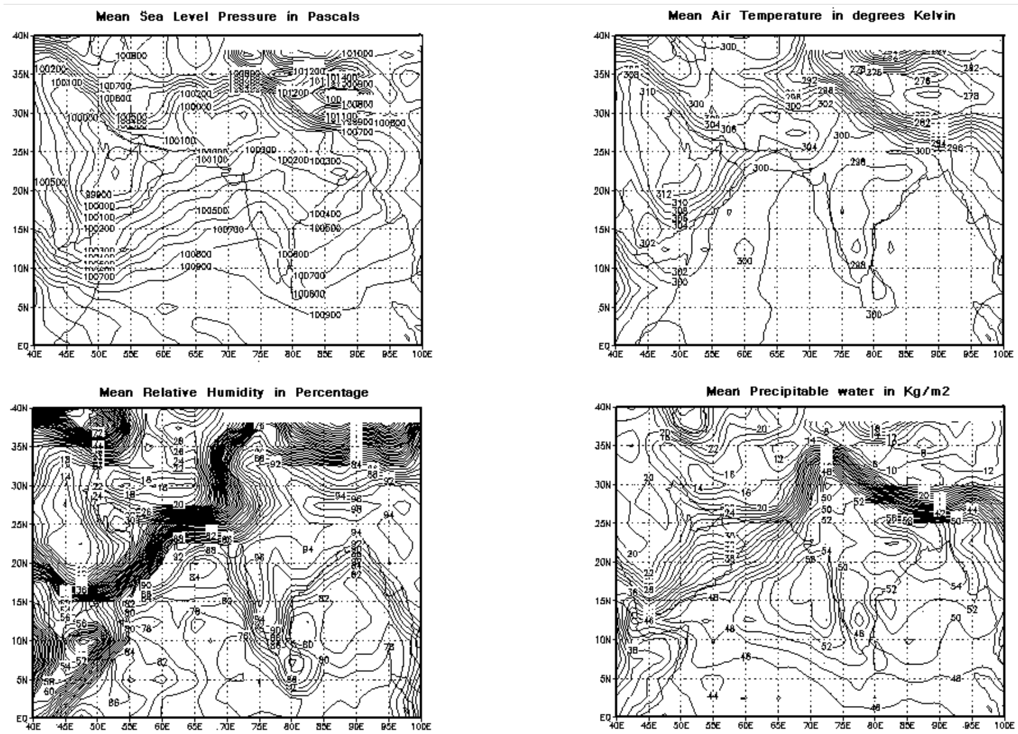

Fig. 8(a). Showing distribution of surface parameters for the month of August, 1988 within region 0° N – 40° N / 40° E – 100° E

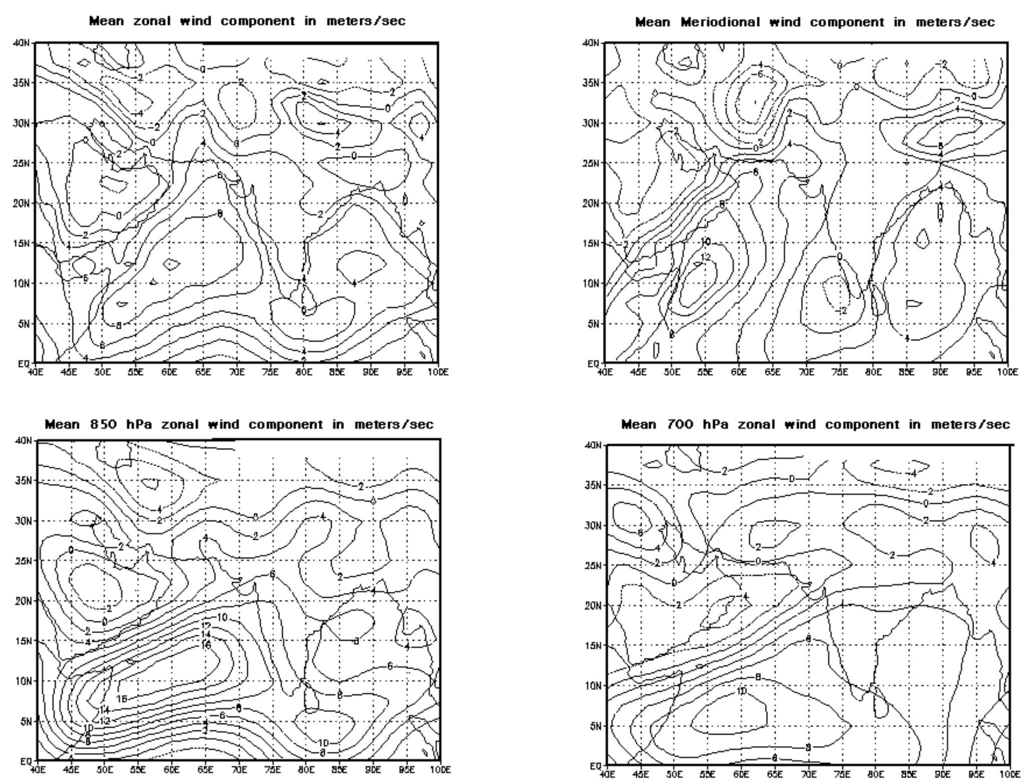

Fig. 8(b). Showing distribution of mean monthly surface / upper air parameters for the month of August, 1988 within region 0° N – 40° N / 40° E – 100° E

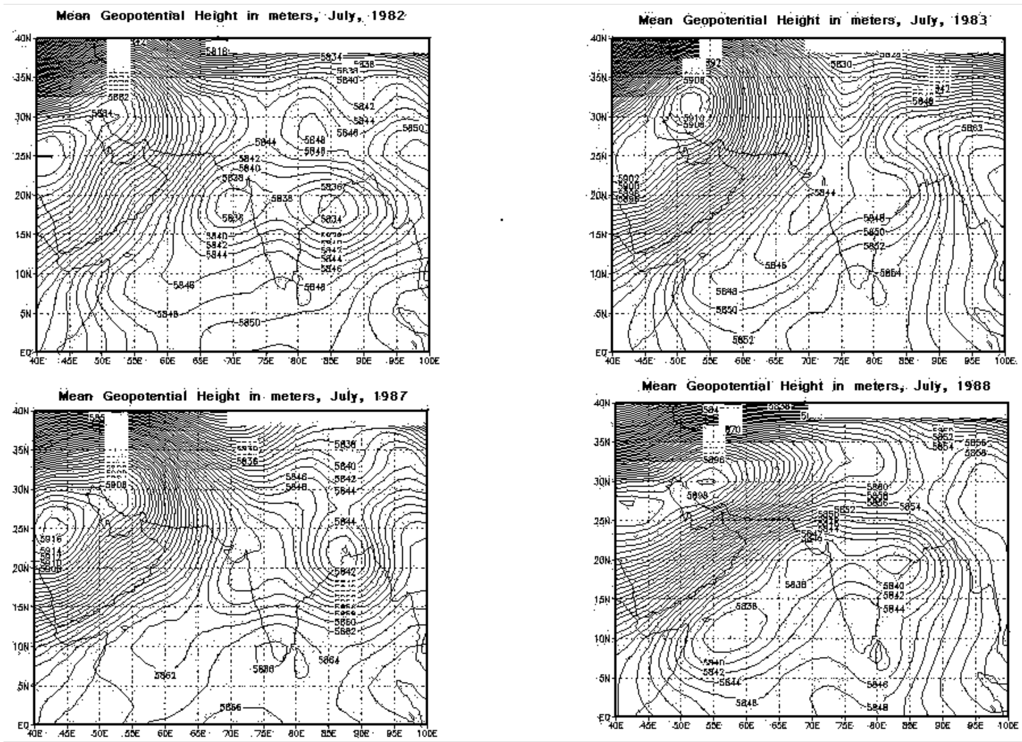

Fig. 9. Showing distribution mean monthly 500 hPa Geopotential height for the month of July within region 0° N – 40° N / 40° E – 100° E

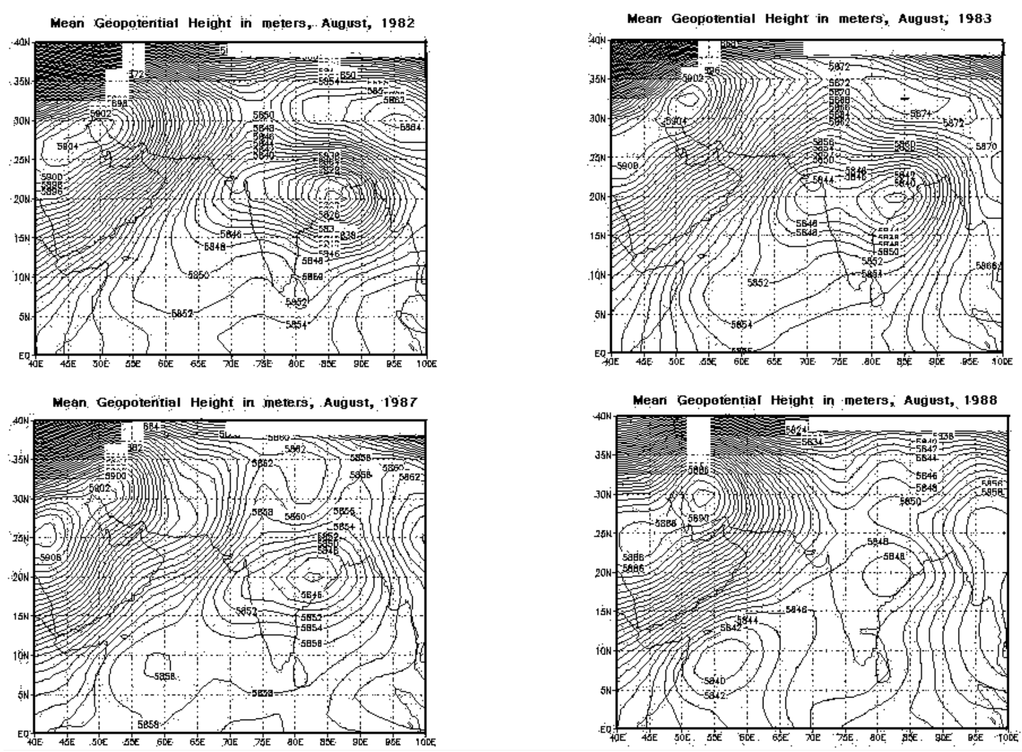

Fig. 10. Showing distribution mean monthly 500 hPa Geopotential height for the month of August within region 0° N – 40° N / 40° E – 100° E

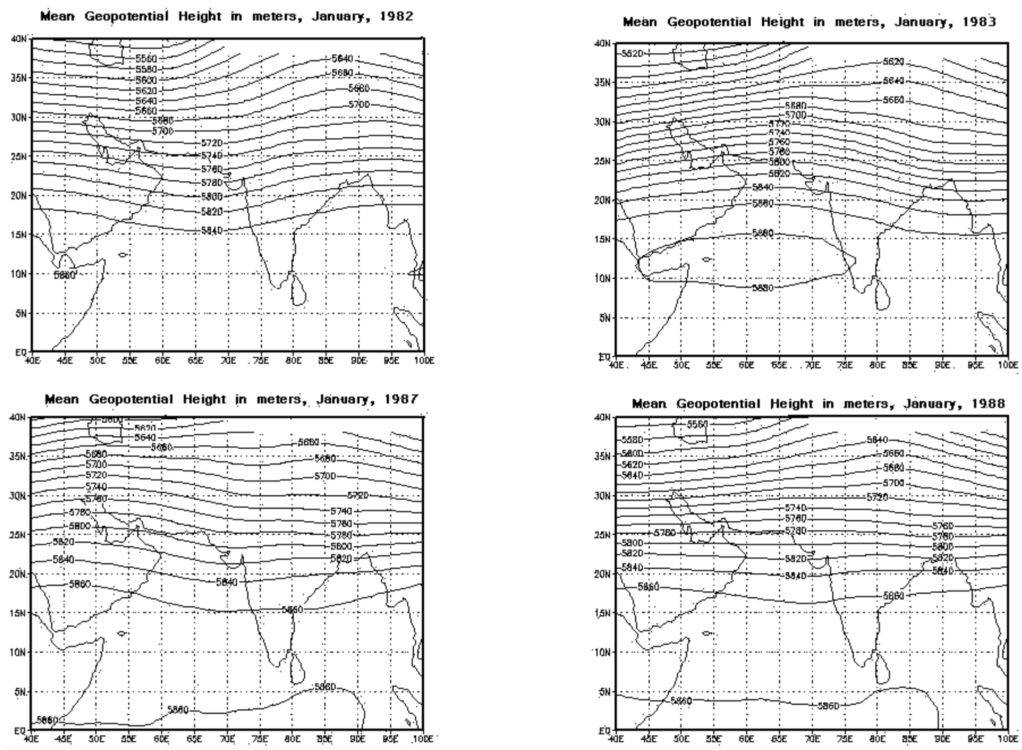

Fig. 11. Showing distribution of mean monthly 500 hPa Geopotential height for the month of January within region 0° N – 40° N / 40° E – 100° E

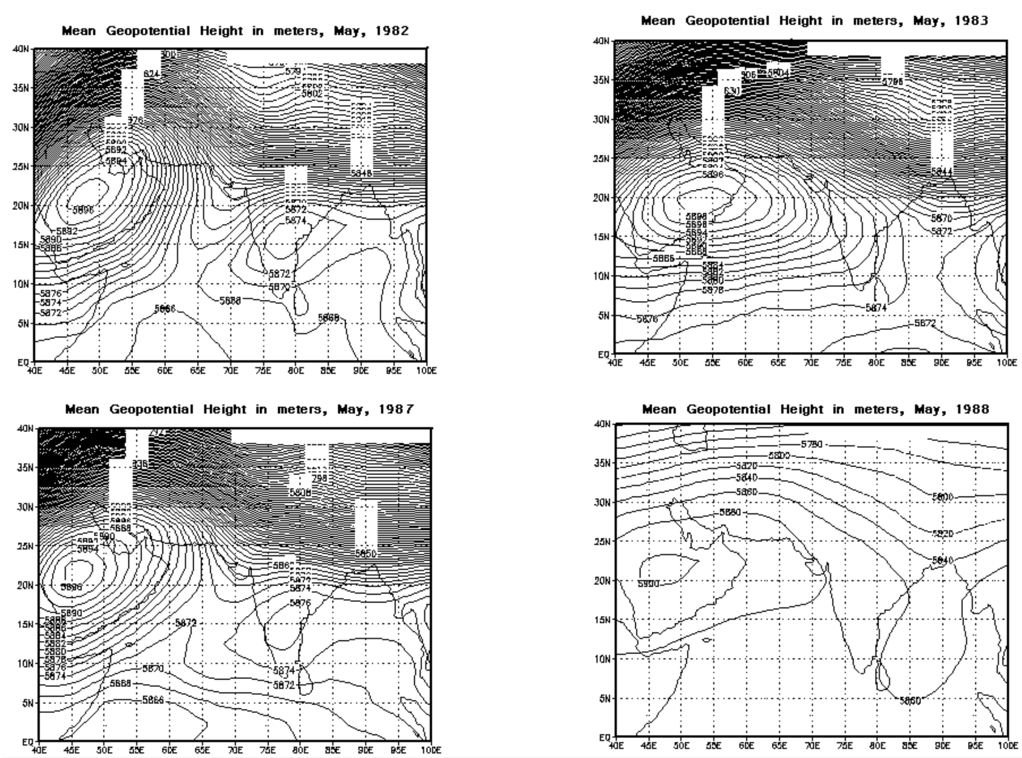

Fig. 12. Showing distribution of mean monthly 500 hPa Geopotential height for the month of May within region 0° N – 40° N / 40° E – 100° E

temperatures (37° C) were observed over Arabian region within latitude 15° N - 25° N and longitude 45° E - 55° E. Similar pattern was observed in July of years 1983, 1987 and 1988. However, the air temperatures were warmer in the region 8° N - 4° N / 75° E - 83° E and cooler in the region 12° N - 10° N / 82° E - 83° E in the year 1982 in comparison with the year 1983. In the year 1987 the mean air temperature over Bay of Bengal was warmer by 2° C than the year 1988 in the regions of North Bay and East Central Bay. In August, the mean air temperature showed similar pattern in all four years except in the year 1983 the 29°C mean air temperature contour extended slightly into the Arabian Sea along the west coast and also over central and southern parts of India (Figs. 1 to 8).

(*ii*) *Mean sea level pressure (Pascal)*

The mean monthly isobars showed similar type of pattern in both July and August months of years 1982, 1983, 1987 and 1988 with mean sea level pressures decreasing northward from equator to 30° N from 1010 hPa to 998 hPa. And mean sea level pressures increasing above 30° N. The monsoon components like heat low, monsoon trough, offshore troughs over Bay of Bengal and Arabian Sea were seen in both the months of four years considered (Figs. 1 to 8).

(*iii*) *Relative humidity (Percentage)*

The relative humidity field studied in this paper, suggested high values of relative humidity values within the region 25° N - 30° N / 90° E - 95° E and low values above 15° N and west of 55° E. The mean monthly distribution of relative humidity in July and August months in all the four years showed maxima along West Coast (10° N - 18° N / 75° E) and minima along East Coast (10° N - 12° N / 80° E). The average relative humidity within region 10° N - 20° N / 75° E along west coast was observed as 95% in July and 96% in August months in all four years considered in this study. Along east coast within region 10° N - 14° N / 82° E, the average relative humidity was observed as 66%, 72%, 66%, 76% in the month of July and as 73%, 79%, 73% and 81% in August during the years 1982, 1983, 1987 and 1988 respectively indicating that in excess years the minima values were on the higher side compared with the deficient years and higher relative humidity values in August than July in years studied. It is also seen that higher relative humidity values within region 20° N - 25° N / 70° E - 85° E during excess years than deficient years. (Figs. 1 to 8).

(*iv*) *Precipitable water (kg/m^2)*

The precipitable water pattern showed that the precipitable water decreasing with increasing latitude within the region of study. The mean monthly distribution of precipitable water in July and August months showed in all the four years a pattern indicating maxima along west coast (14° N - 20° N / 72° E), second maxima along east coast (12° N - 16° N / 82° E) and minima over south peninsular India (12° N - 14° N / 78° E). The average precipitable water within region 10° N - 20° N / 72° E was observed as 51 kg/m^2, 54 kg/m^2, 49 kg/m^2, 56 kg/m^2 and within region 10° N - 14° N / 78° E as 45 kg/m^2, 49 kg/m^2, 41 kg/m^2, 53 kg/m^2 and within region 10° N - 14° N / 82.5° E as 52 kg/m^2, 53 kg/m^2, 49 kg/m^2, 53 kg/m^2 in years 1982, 1983, 1987 and 1988 respectively for the month of July. Further, the average precipitable water within region 10° N - 20° N / 72° E was observed as 55 kg/m^2, 57 kg/m^2, 55 kg/m^2, 56 kg/m^2 and within region 10° N - 14° N / 78° E as 48 kg/m^2, 48 kg/m^2, 46 kg/m^2, 48 kg/m^2 and within region 10° N - 14° N / 82.5° E as 54 kg/m^2, 55 kg/m^2, 52 kg/m^2, 52 kg/m^2 in years 1982, 1983, 1987 and 1988 respectively for the month of August. The comparison of these values suggests the maxima values along west coast and also along east coast were higher during excess years 1983, 1988 than the deficient years 1982, 1987 in the month of July and higher in the month of August than July. Similarly, in July month, the minima values were on the higher side during excess years (1983, 1988) with 49 kg/m^2 and 47 kg/m^2 respectively in comparison with deficient years (1982, 1987) with 45 kg/m^2 and 41 kg/m^2 respectively and also higher values of precipitable water were observed in the month of August than July month. The precipitable water was 48 kg/m^2, 50 kg/m^2, 46 kg/m^2, 48 kg/m^2 in years 1982, 1983, 1987 and 1988 respectively in the month of August. It is also seen that within region 20° N - 25° N / 70° E - 85° E higher precipitable water in excess years than deficient years (Figs. 1 to 8).

(*v*) *U-Wind (m/s)*

The mean monthly *U*-wind distribution suggested that the *U*-component of wind was strong in the months of July and August during deficient years over Bay of Bengal in which *U*-wind was about 6 m/s to 8 m/s in comparison with excess year in which the *U*-wind was about 4 m/s to 6 m/s (Figs. 1 to 8) with 6 – 4 m/s over mainland during excess years of 1983 & 1988 and 4 – 2 m/s over mainland during deficient years of 1982 & 1987 respectively.

(*vi*) *V-Wind (m/s)*

The mean monthly distribution suggested similar pattern with southerly flow over Bay of Bengal with 8 - 4 m/s in all the four years considered for the study in both July and August months except a negative *V*-component over southern tip of the west coast in the excess years of 1983, 1988 indicating a southeastwards flow (Figs. 1 to 8) with almost no meridional component over mainland.

(*vii*) *Lower tropospheric winds (m/s)*

To study the distribution of lower tropospheric winds, zonal winds at 850 hPa, 700 hPa were considered for the months of July, August in the years 1982 and 1983, 1987 and 1988 within the region 0° N – 40° N / 40° E -100° E. Firstly, at 850 hPa zonal wind distribution approximately showed easterlies above 30° N and westerlies below 30° N until equator in both the months of all the four years studied with westerly wind strength decreasing with increasing latitude. It is also seen that within region 10° N - 15° N / 55° E - 70° E stronger westerlies prevailed with varying speeds in July (August) with 16 m/s (18 m/s), 18 m/s (18 m/s), 14 m/s (14 m/s) and 20 m/s (16 m/s) in 1982, 1983, 1987 and 1988 respectively indicating higher strength of lower level jet in excess years in comparison with deficient years. Further, stronger westerlies were noticed over Bay of Bengal during deficient years than excess years in both the months studied.

At 700 hPa, westerly winds were seen below 35° N and easterlies above 35° N in both the months of the four years *viz*., 1982, 1983, 1987 and 1988 with decreased strength with increased latitude. Moreover, within the region 10° N - 15° N / 55° E - 70° E, the strength of westerlies decreased in comparison with 850 hPa zonal winds. However, westerlies with 12 m/s and 14 m/s noticed at 5° N / 60° E in the month of July in both the excess years *viz*., 1983 and 1988 respectively (Figs. 1 to 8).

From the present study, the distribution of precipitable water indicates advection of moisture and trapping moisture in southern peninsular India due to orographic influence. The strong *U*-wind over Bay of Bengal during deficient years of 1982, 1987 suggests an eastward flow at surface level which might be a cause for decrease in Indian summer monsoon rainfall in the months of July and August. Furthermore, weakening of findlarjet and somalijet was observed during the ENSO year 1987 (Krishnamurti, *et al*., 1989).

(*viii*) *Western disturbances*

In order to study western disturbances mean monthly 500 hPa Geo-potential heights within region 0° N - 40° N / 40° E - 100° E for the months of January, May, July and August months of the four years *viz*., 1982, 1983, 1987 and 1988 were considered. The anomalies computed from the long term mean (1968-1996) were positive in all the years in the months of January, May, July and August. However, inter-comparison of the monthly mean geo-potential heights within region 25° N - 35° N / East of 80° E indicated for the month of January that the environment was warmer within 25° N - 30° N and colder within 30° N - 35° N in the year 1983 than in the year 1982. Similarly, in the year 1988 within 25° N - 30° N the environment was same and colder within 30° N - 35° N than 1987. It is also observed that in the May, the environment was colder in excess years than deficient years. In July, the environment was warmer in excess years than deficient years. However, in case of August month, it is seen that the environment was warmer in the year 1983 than 1982 and colder in the year 1988 than 1987. For sector 25° N - 35° N / West of 80° E, the environment was warmer in deficient years than excess years for the months of January and May. However, the environment was warmer in 1983 than the year 1982 and colder in 1988 than 1987 in both July and August months (Figs. 9 to 12).

4. Conclusions

The present study is helpful in understanding the Indian summer monsoon rainfall and reiterates the moisture advection into the Indian landmass following cross equatorial flow and the influence of orography in trapping the moisture. Further, strong eastward wind over Bay of Bengal may reduce the monsoon rainfall during months of July and August. In August month higher values of relative humidity and precipitable water were observed than the month of July and both these parameters being on higher side during excess years (1983, 1988) than deficient years (1982, 1987). The study of lower tropospheric winds indicated that the stronger Low Level Jet at 850 hPa is favourable for good monsoon as stronger Low Level Jet noticed in excess years than deficient years. The passage of less number of upper air westerly troughs during winter and pre-monsoon influences adversely the performance of monsoon as warmer environment within 25° N - 35° N was seen in deficient years than excess years. Further, warmer environment was seen within 25° N - 35° N in the year 1983 than 1982 in both months of July and August and colder environment in the year 1988 than 1987 in July and August months except within region 25° N - 35° N / East of 80° E for July in 1988 which was warmer than 1987.

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