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Interannual variation of northeast monsoon rainfall over southern peninsular India

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Area average rainfall of southern peninsular India is calculated for northeast monsoon season from daily gridded data. Years of strong and weak northeast monsoon were identified. Sea level pressure (SLP), sea surface temperature (SST), and 850 h Pa zonal wind are analyzed for years of strong and weak northeast monsoon rainfall. Difference between years of strong and weak rainfall of northeast monsoon high pressure anomaly over west pacific region near Philippines, low pressure over west Indian Ocean including Arabian sea, high SST anomaly over equatorial Pacific and Bay of Bengal. Among these the Sea level Pressure difference (SPD) between west pacific and west Indian ocean plays the key role in determining the strength of northeast monsoon rainfall over southern peninsular India.

[Keywords: Monsoon, recharge, season, rainfall, zonal wind, anomaly, peninsular]

Introduction

India is bestowed with two distinct phases of monsoon. About eighty percent of our national average rainfall we do receive from southwest monsoon phase and the rest twenty percent showers from the northeast phase of monsoon. Indeed the northeast monsoon phase is a rather less researched area though the studies by Raj, Sing and Sontakke, Kripalani and Pankaj are some of the genuine efforts to understand it.[1,2,3] The regions mainly benefited from northeast monsoon are coastal Andhra Pradesh, Tamil Nadu, Rayaleseema, interior Karnataka, Kerala and Lakshadweep. About fifty percent of rainfall of Tamil Nadu and forty eight percent of rainfall of southeast coast of India is obtained from northeast monsoon [3] which occur during the period of October to December. Farmers depend on monsoon rainfall for irrigation of their fields and follow rainfed agricultural system. Ground water recharging during the northeast monsoon season is helpful to overcome the dry winter and premonsoon summer. So the onset, seasonal and subseasonal variability of northeast monsoon rainfall has distinct social and economical consequences.

Present study consists the role of local and remote meteorological parameters in deciding the occurrence of strong and weak northeast monsoon . Also the extent and nature of walker circulation occurring in Indo-Pacific region during extreme intensities of northeast monsoon was also examined.

Materials and Methods

In order to understand the interannual variability of northeast monsoon, the data utilized is daily gridded rainfall data from India meteorological department[8]. The other meteorological parameters such as SST, SLP, and zonal wind at 850 mb(850 hPa) were taken from NCEP/NCAR (National Centre for Environmental Prediction/National Centre for Atmospheric Research) reanalysis data[6] downloaded from internet. The region enclosed by latitudes 8°N and 13°N and longitudes 70°E and 80°E is taken as southern peninsular India (the study area).

The daily gridded rainfall data for fifty three years from 1951 to 2003 is used for the analysis. The area averaged daily rainfall is calculated for southern peninsular India. The seasonal mean daily rainfall of northeast monsoon (SRNM) for the same region is determined from the area averaged daily rainfall of southern peninsular India by doing time average from October 1 to December 31. The climatological mean daily rainfall of northeast monsoon (CRNM) is calculated from SRNM by averaging it for fifty three years (1951-2003). Those years with SRNM deviation more than one standard deviation from CRNM to the positive side are taken as strong northeast monsoon years and SRNM deviation beyond one standard deviation to the negative side are counted as weak northeast monsoon years. Similar classification was done by different authors to identify strong and weak monsoon[4,5,6,7].

Results and Discussion

The time series diagram of SRNM for a period of fifty three years from 1951 to 2003 is given (figure 1). It reveals strong biennial oscillation during the intervals of 1951-55, 1967-71 and 1980-89. These intervals show very steady oscillations. But the interval of 1955-66 exhibits a different type of oscillation with three consecutive increases and one subsequent decrease. 1974-77 shows a steep increase of SRNM by 6.2 mm per day during a three year period. The peak year of SRNM, 1977 have a value 8.4 mm per day whereas 1988 reported as the year of minimum SRNM of 2.1 mm per day. The period 1988-93 also have a shooting up of 5.5 mm per day during 5 years. 1993 was the year of second peak with SRNM of 7.5 mm per day. Finally 2000-03 displays steady biennial oscillation.

The analysis of meteorological parameters such as SST, SLP and zonal wind at 850 mb are done 39 years from 1960 to 1998. Selected years of strong northeast monsoon rainfall are 1966, 1972, 1977, 1978, 1993 and 1997. Weak northeast monsoon rainfall are observed on 1968, 1974, 1988 and 1995. The spatial distribution of above parameters was closely observed for further analysis of strong and weak monsoon.

Pressure anomaly (figure 2) is the difference between mean SLP of strong northeast monsoon and that of weak northeast monsoon. Strong northeast monsoon is characterized by a high pressure anomaly over the west Pacific centered at the east off Philippines (120°E to 140°E and 5°N to 15°N) and a low pressure anomaly at west Indian Ocean centered at the east off Somalia (55°E to 65°E and 5°N to 15°N). The Head Bay region exhibits considerably strong high pressure anomaly.

Temperature anomaly (figure 3) is the difference between mean SST of strong northeast monsoon and mean SST of weak northeast monsoon years. The composite analysis of SST shows that the strong northeast monsoon years are associated with extreme cooling at Indonesian region and corresponding warming at east Pacific, West Indian Ocean and south China sea.[8,9,10] The high temperature in the south China sea and northern part of Indian Ocean helps out for providing adequate moisture for the northeast monsoon showers. Simultaneously the low temperature at the Indonesian region and west Pacific including northwest Pacific trigger out high pressure anomaly and act as a source for the prevalence of easterly anomaly of zonal wind over the Indian ocean region.

Zonal wind anomaly (figure 4) depicts the difference between mean zonal winds of strong and weak northeast monsoon. The replacement of the westerly zonal wind with easterly soon after the withdrawal of the Asian summer Monsoon is considered as the sign of onset of northeast monsoon season.[1] Strong northeast monsoon years are marked with easterly anomaly of zonal wind all over Indian Ocean. But in the case of week northeast monsoon years, the zonal wind remains westerly throughout the Indian Ocean.

The SST area averaged over the Pacific Ocean box bounded by 160°E and 120°W longitudes and the latitudes of 5°S and 5°N is represented as 'NinoT'. Similarly the local SST in Bay of Bengal averaged over the area of box extend from 80°E to 90°E longitudes and 5°N to 15°N latitudes is represented as BayT. Indian Ocean Dipole Mode Index (DMI) is taken as suggested by Saji et. al.[8] The interannual time series of these parameters are shown in figure 5.

The year 1974 gives only very little rainfall in the northeast monsoon season (SRNM = 2.25 mm per day). Corresponding values of NinoT and BayT are 300°K and 301°K respectively.The heavy rainfall year 1977 has SRNM 8.5 mm per day and very strong SST over NinoT (301.4°K) and BayT (301.35°K).

The year 1988 which gives the weakest northeast monsoon rainfall (SRNM = 2mm per day) may due to extremely cool NinoT (298.8°K) even if BayT is 301.6°T.Better rainfall of 1993 (SRNM = 7.5 mm per day) is associated with NinoT of 301°K and BayT of 301.6°K.

The correlation of SRNM with NinoT is 0.382 and have a 98% statistical significance. There is a correlation of 0.302 between SRNM and BayT which have 95% statistical significance.

The large scale circulation of air in vertical-zonal plain observed in the tropics is known as Walker Circulation. The convection cells are primarily driven by pressure gradients produced by air rising over the warmer areas of the oceans and continents and subsiding over the cooler area. Sea level pressure difference (SPD) between west Pacific Ocean box (110°E to 140°E and 10°S to 20°N) and west Indian Ocean Box (45°E to 75°E and 10°S to 20°N) is taken as an Index for northeast monsoon Walker circulation. The area average zonal wind over the box extend from 45°E to 140°E and 10°S to 20°N also represent the strength of northeast monsoon Walker circulation

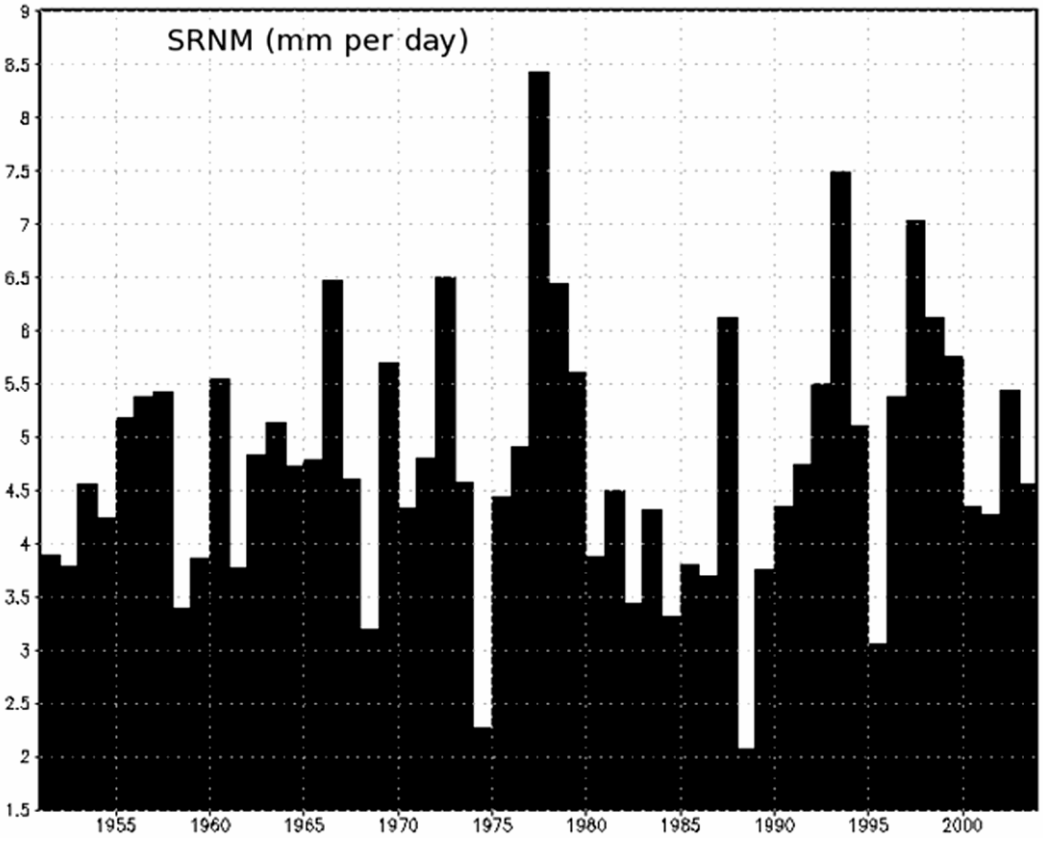

Figure 1—Interannual time series of northeast monsoon rainfall.

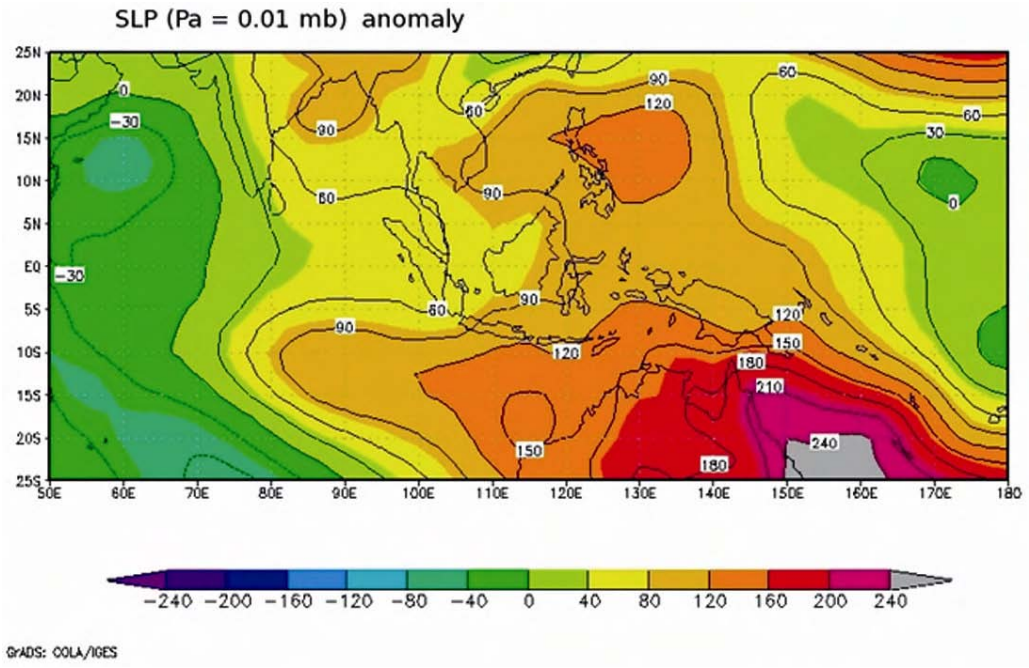

Figure 2—SLP difference between strong and weak northeast monsoon.

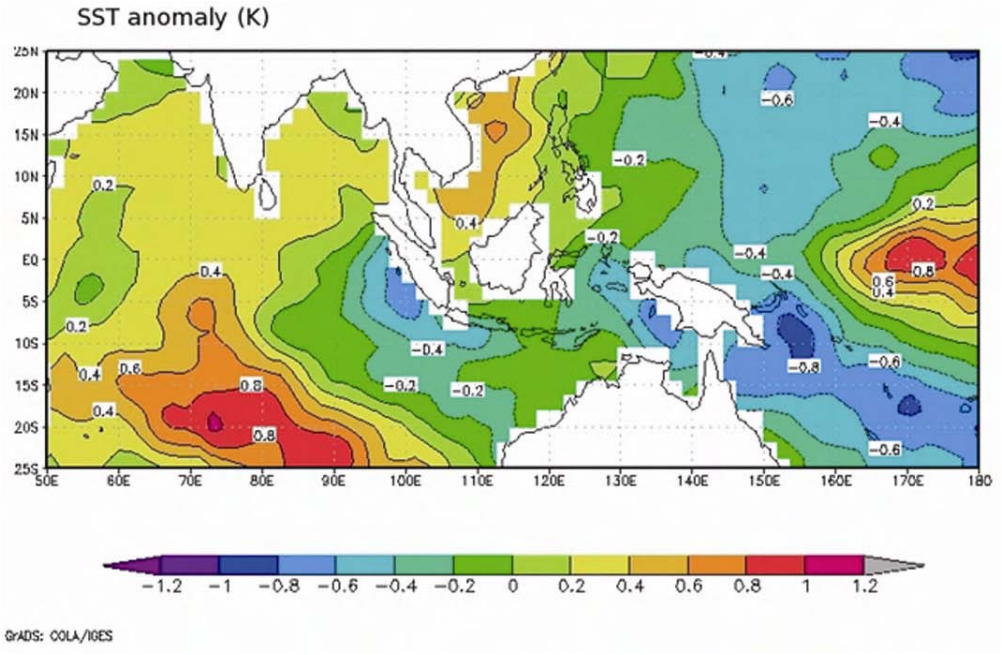

Figure 3—SST difference between strong and weak northeast monsoon.

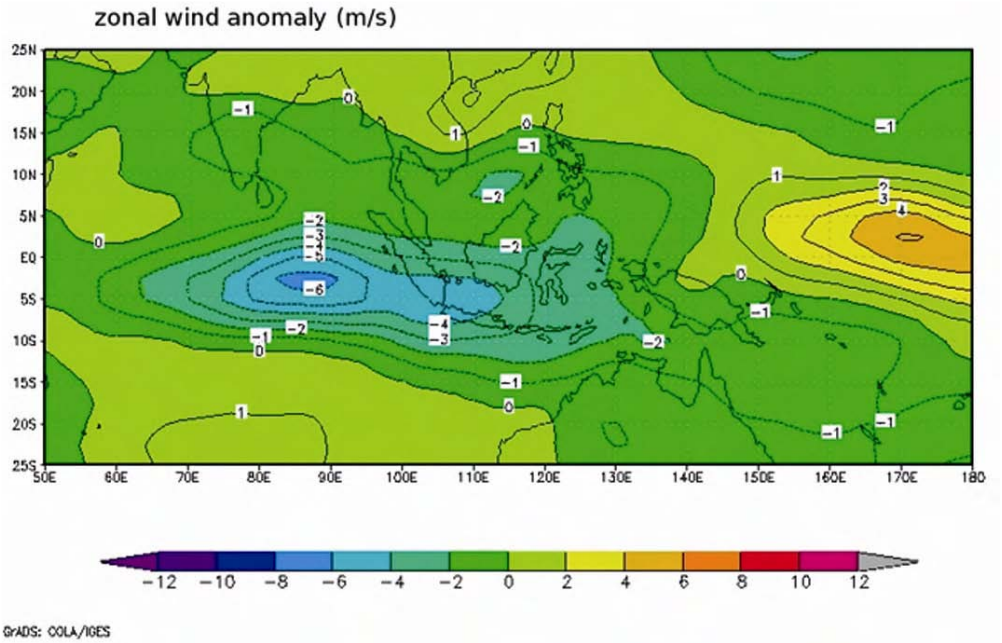

Figure 4—Zonal wind of 850 mb difference between strong and weak northeast monsoon.

of the Indian Ocean. The interannual variation of these parameters and SRNM are shown in figure 6.

A positive anomaly of SPD strengthen the easterly anomaly of zonal wind and hence support northeast monsoon rainfall. Therefore the SPD index plays a key role in determining the strength of northeast monsoon rainfall.[8] Earlier studies have suggested that the anticyclonic formation over western Pacific Ocean increase precipitation along east Asian winter monsoon front during December, January and February.[11,2,10] The present finding shows that the pressure gradient (SPD) and resulting wind pattern strengthen the northeast monsoon of southern peninsular India during October, November and December.

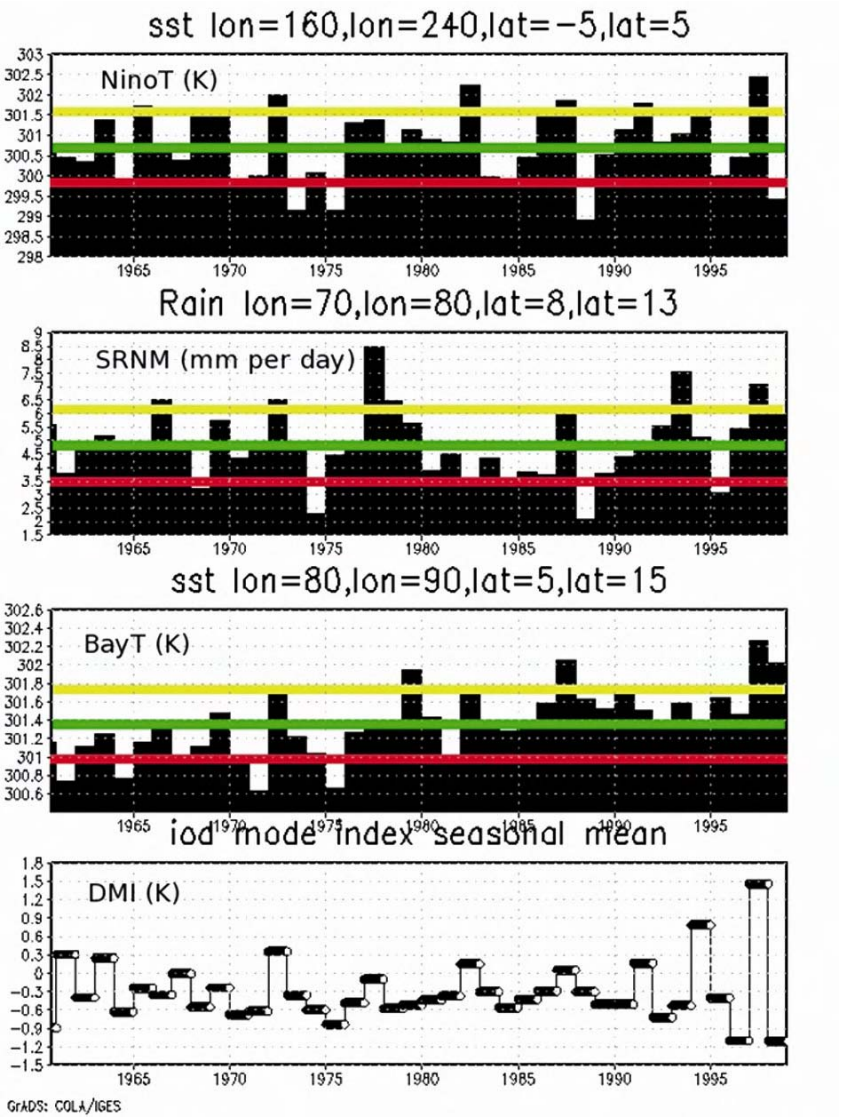

Figure 5—Interannual variation of SRNM with NinoT, BayT, and DMI.

The study reveals that there are six years of high intensity of rainfall (table 1) and four years of weak rainfall (table 2) during northeast monsoon season. Out of these years 1972 and 1997 have very warm NinoT to support rainfall. Very strong positive DMI is also exhibited by these years. The year 1997 also have very warm BayT. The strong northeast monsoon rainfall of 1966, 1972, 1977and 1997 are strongly supported by the strength of SPD. The years 1974, 1988 and 1995 of weak northeast monsoon are having negative anomaly of SPD. This shows the importance of SPD to determine the strength of northeast monsoon rainfall.

All the four years of weak northeast monsoon rainfall are having negative DMI. The weakest rainfall of 1988 is due to the coexistence of cooler NinoT, negative DMI and negative anomaly of SPD.

The strong northeast monsoon rainfall of 1993 may be due to overcoming the effect weak SPD index by the positive anomaly of NinoT and BayT. The strongest northeast monsoon year 1977 is followed by another year heavy rainfall of northeast monsoon in 1978 even if the supporting parameters have weakened. This suggests the existence of another supporting parameter beyond the scope of present study. The weak northeast monsoon rainfall of 1968 is a result of the suppressing effect of the negative anomaly of local parameters which overtake the influence of positive anomaly of NinoT. The SPD index is weak but positive in this year.

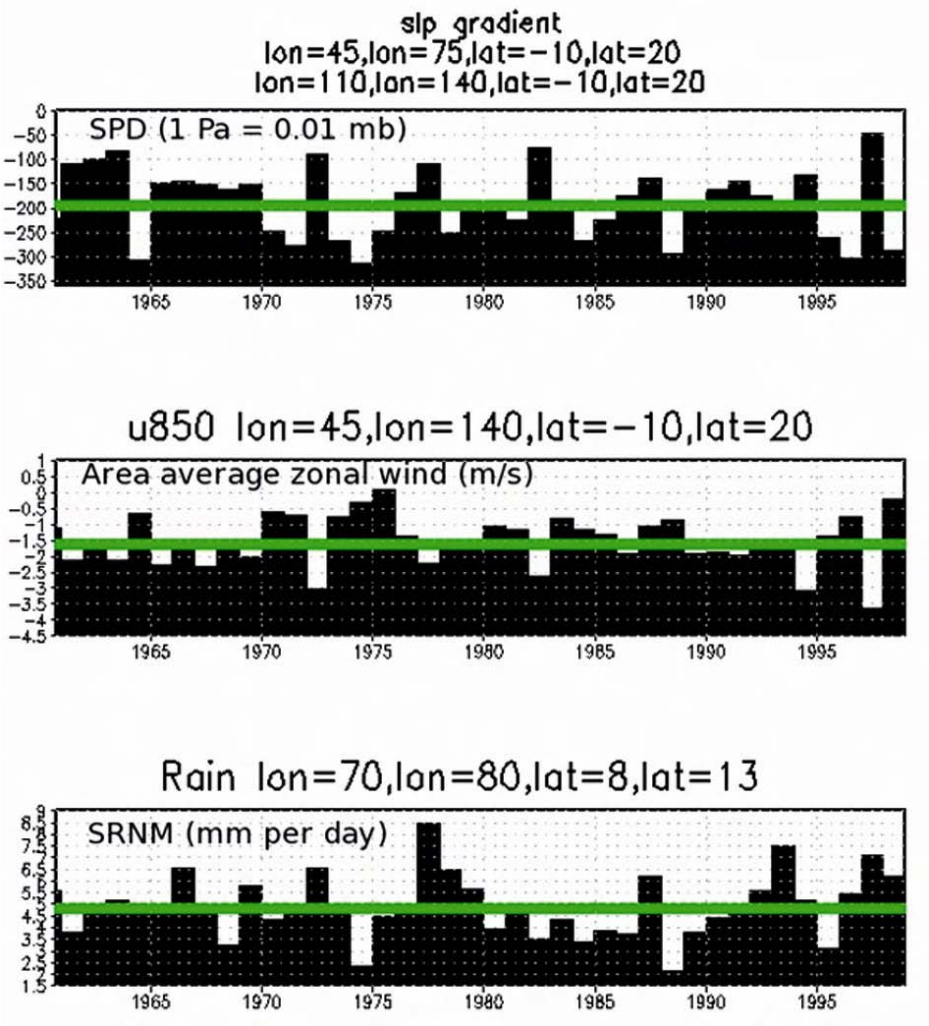

Figure 6—Interannual variation of SRNM with SPD and area average zonal wind

Table 1—Anomaly of meteorological parameters for the years of strong northeast monsoon.

Order of Strength	Year	NinoT anomaly	BayT anomaly	DMI	SPD
1	1977	Positive	Neutral	Neutral	Strong Positive
2	1993	Positive	Positive	Negative	Neutral
3	1997	Strong Positive	Strong Positive	Strong Positive	Strong Positive
4	1966	Neutral	Neutral	Negative	Strong Positive
5	1972	Strong Positive	Positive	Strong Positive	Strong Positive
6	1978	Neutral	Neutral	Negative	Negative

Table 2—Anomaly of meteorological parameters for the years of weak northeast monsoon

Order of Strength	Year	NinoT anomaly	BayT anomaly	DMI	SPD
1	1988	Strong Negative	Positive	Negative	Strong Negative
2	1974	Negative	Negative	Strong Negative	Strong Negative
3	1995	Negative	Positive	Negative	Strong Negative
4	1968	Positive	Negative	Negative	Positive

Conclusion

Most of the strong northeast monsoon years have positive anomaly in NinoT, BayT, DMI and SPD. Most of the weak northeast monsoon years show negative anomaly in the same. SRNM shows very strong correlations with the supporting parameters such as NinoT and BayT. The influence of SPD dominate other parameters in the interannual timescale.

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