

A pre-monsoon precursor for foreshadowing of northeast monsoon rainfall over Tamilnadu

R. ASOKAN and S. BALACHANDRAN

Regional Meteorological Centre, Chennai, India

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e mail : asokan.ramasamy@gmail.com

सार – इस शोध-पत्र में 1901–2004 की अवधि के सतही तापमान विसंगतियों (एस. टी. ए.) और एन. ई. एम. आर. टी. के मध्य पाए गए संबंध का विश्लेषण करने पर तमिलनाडु (एन. ई. एम. आर. टी.) में उत्तरपूर्वी मानसून वर्षा के पूर्व लक्षणों के लिए एक संभाव्य पूर्वसूचक का पता लगाया गया है। क्षेत्रों (80° पू. – 90° पू. 20° उ. – 25° उ.) और (80° पू. – 100° पू. 5° द. – 5° उ.) और इस पी. एम. टी. ए. सूचकांक में क्षेत्रीय औसतन तापमान विसंगतियों के मध्य परिभाषित किए गए पूर्व मानसून याम्योत्तरी तापमान विसंगति (पी. एम. टी. ए.) सूचकांक का एन. ई. एम. आर. टी. के साथ उल्लेखनीय रूप से प्रतिकूल संबंध पाया गया है। 1901–2004 की अवधि में पी. एम. टी. ए. सूचकांक और एन. ई. एम. आर. टी. के मध्य सहसंबंध गुणांक (सी. सी.) –0.37 पाया गया है (95% के स्तर पर उल्लेखनीय)। पी. एम. टी. ए. सूचकांक और एन. ई. एम. आर. टी. के मध्य 30 वर्षों के परिकलन सहसंबंध से गत दो दशकों के दौरान 0.6 की अपेक्षा उल्लेखनीय अधिकतम सी. सी. सहित परिमाण का पता चला है। एन. ई. एम. आर. टी. के संबंध में पी. एम. टी. ए. सूचकांक के पूर्वलक्षणों की क्षमताओं का समाश्रयण विश्लेषण और संभाव्य पूर्वानुमान पद्धतियों के उपायों द्वारा विचार-विमर्श किया गया है।

ABSTRACT. A potential predictor for foreshadowing the Northeast Monsoon Rainfall over Tamilnadu (NEMRT) has been identified from the analysis of relationship between Surface Temperature Anomalies (STA) and NEMRT for the period 1901-2004. A Pre-monsoon Meridional Temperature Anomaly (PMTA) index is defined as the difference between the area averaged temperature anomalies over the regions (80° E - 90° E; 20° N - 25° N) and (80° E - 100° E; 5° S - 5° N) and this PMTA index is found to have significant inverse relationship with NEMRT. The Correlation Coefficient (CC) between PMTA index and NEMRT for the period 1901-2004 is -0.37 (significant at 95% level). The 30 year sliding correlation between PMTA index and NEMRT show significant CC with magnitude greater than 0.6 during the last two decades. The foreshadowing skill of PMTA index with reference to NEMRT is discussed by means of regression analysis and probability forecast methods.

Key words – Northeast monsoon, Pre-monsoon meridional temperature anomaly index, Sliding correlation, Probability forecast, Regression

1. Introduction

After the end of southwest monsoon season (June to September), the rainfall belt shifts progressively towards southern peninsular India. The period comprising of October to December months is known as northeast monsoon (NEM) season or post-monsoon season. The sub-divisions of southern peninsular region that receive substantial rainfall during this season and the contribution of NEM to the annual rainfall (percentage values in bracket) are, *viz.*, Kerala (17%), Tamilnadu (49%), South Interior Karnataka (24%), Rayalaseema (29%) and Coastal Andhra Pradesh (38%) [Zubair and Ropelewski, 2006]. For coastal parts of Tamilnadu, NEM accounts for about 60% of annual rainfall. NEM is important in other sub-divisions also. As contribution of NEM to Tamilnadu

sub-division is large among these sub-divisions, we focus our study for this sub-division. Earlier attempts on NEM related studies could be found in Krishna Rao and Jagnathan (1953), Rao (1963), IMD (1973) and references therein. Latter, Raj (1992 & 1998) and Raj *et al.* (1993) have documented a good number of studies covering the aspects of onset, withdrawal, intraseasonal and interannual variability of Northeast monsoon rainfall over Tamilnadu (NEMRT) and southern Peninsular India. Rao (1963) noted the absence (presence) of blocking high in the European region favouring (not favouring) good NEMRT. Raj *et al.* (1993) and Raj (1998) have identified a few upper air parameters that have predictive potential for NEMRT and southern peninsular region of India. Recently Balachandran *et al.* (2006) discussed the local and teleconnective associations between NEMRT and

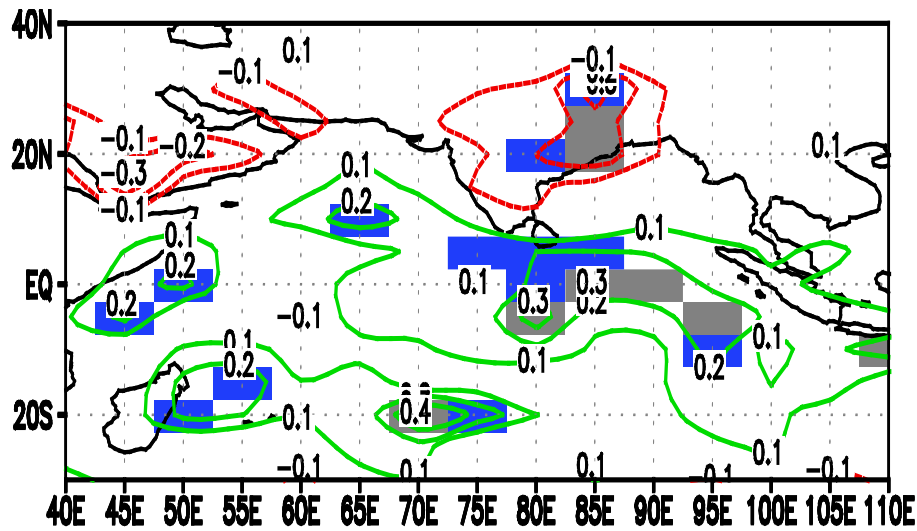


Fig. 1. Spatial distribution of Correlation Coefficient (CC) between STA during month of April over Asian region and adjoining Indian seas and the subsequent NEMRT

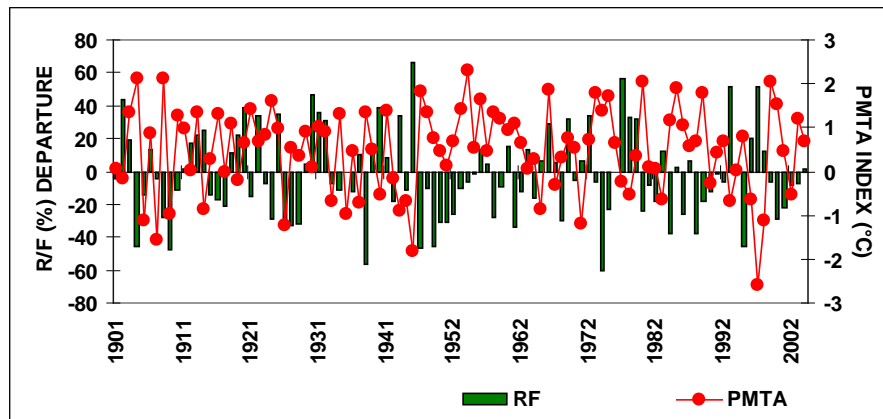


Fig. 2. Time series of PMTA index and the subsequent NEM over Tamilnadu

global Surface Temperature Anomalies (STA). In the present study, the relationship between STA over the Asian region during month of April and the subsequent NEMRT is examined. The details of the data and methodology are described in section 2. The results are discussed in the section 3 and conclusions are given in the section 4.

2. Data & methodology

The main data sets used are the grid point monthly global temperature anomalies for the period 1901-2004.

This data set are a combination of land surface air temperature anomalies and SST anomalies on $5^{\circ} \times 5^{\circ}$ Latitude \times Longitude, grid box (Jones *et al.* 1997). The base period for both land and SST anomalies is from 1961 to 1990. The SST anomalies were constructed from the updated version of Meteorological Office Historical Sea Surface Temperature (MOHSST 6). The land surface air temperature and the SST anomalies were combined using the algorithm developed by Parker *et al.* (1994). These data are downloaded from <http://dss.ucar.edu/data>. Nicholls *et al.* (1996) showed that there is a trend in global surface temperature that is most prominent during

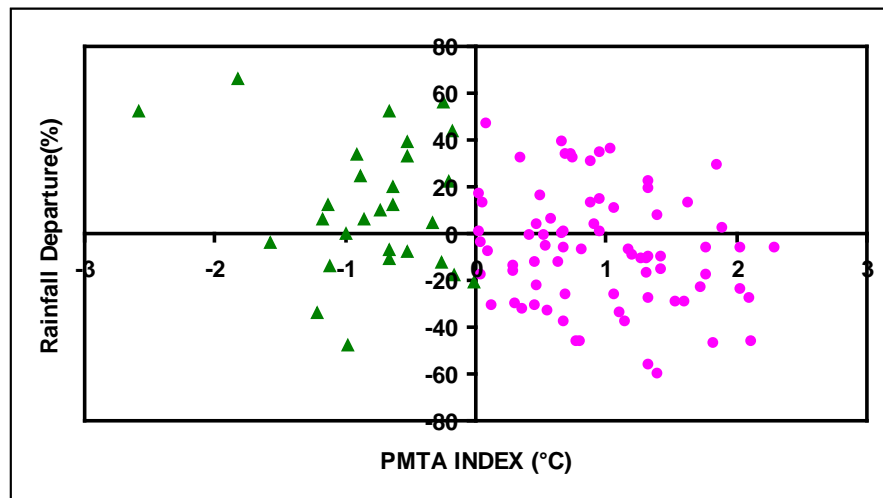


Fig. 3. Scatter diagram between NEMRT and PMTA index. Circle (triangle) points refer to positive (negative) values of PMTA index

recent decades. Hence the monthly grid point surface temperature anomalies for the period 1901-2004 were detrended by means of simple linear regression method and these detrended anomalies are used in the further analysis.

The NEMRT series during 1901–2004 was prepared as follows: The daily rainfall data of 173 stations in Tamil nadu for the period 1901-1996 were obtained from India Meteorological Department (IMD). Using this daily data, the seasonal rainfall series of Tamilnadu sub-division for the period 1901–1996 was constructed. The data for the remaining part of the series was collected from the weekly weather report of Regional Meteorological Centre, Chennai of IMD. For the present study, excess (deficient) NEM monsoon years are identified as defined by IMD. Based on these criteria, there are 32 excess, 32 normal and 40 deficient NEM years during the period 1901-2004.

We first analyse the spatial distribution of correlation between STA and NEMRT to identify regions showing significant relationship between them. Then an index having predictive potential for NEMRT is defined, as described in the following section, which is subjected to the further analysis using regression and probability analysis methods.

3. Results and discussion

As mentioned earlier, Balachandran *et al.* (2006) discussed the CC between NEMRT and global scale STA for all months. We analysed those figures around the Asian monsoon region to seek predictive signals on regional scale. It was seen except April and October, no

significant predictive signal related to STA could be noticed over the Asian monsoon region. Since we are interested for outlook of NEMRT in antecedent mode, April month analysis is considered here for further analysis.

3.1. Spatial pattern of correlation between STA during April with subsequent NEMRT

The spatial distribution of Correlation Coefficient (CC) between STA during the month of April over Asian region and adjoining Indian seas and the subsequent NEMRT is shown in Fig. 1. In this figure, the grid boxes with CC's significant at 1% (5%) are shaded dark (light). In the CC patterns, the positive CC regions indicate that whenever the surface air temperatures over these areas are warmer (cooler) than normal, the NEMRT is above (below) normal; the negative CC regions indicate that whenever the surface air temperatures over these areas are cooler (warmer) than normal, the NEMRT is above (below) normal.

In Fig. 1, most of the equatorial Indian ocean region depict positive CCs while the northern tropical land region above 20° N depict negative CCs with NEMRT. Of course, these CC's are not significant over all the grid boxes. In general, a north to south directed gradient is seen in the spatial pattern of CC. In particular, the STA anomalies over the Eastern India (EI) region (80° E - 90° E; 20° N - 25° N) and the equatorial Indian ocean region (80° E - 100° E; 5° S - 5° N) are considered for further analysis.

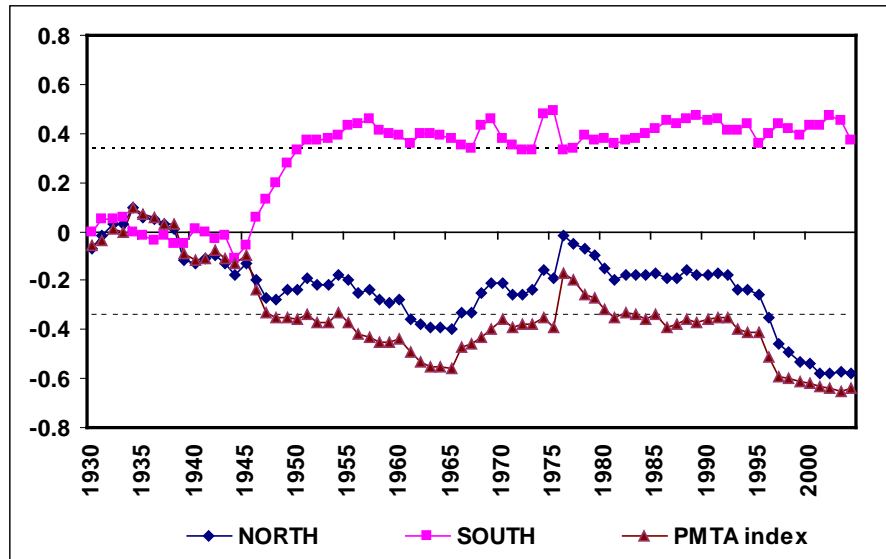


Fig. 4. 30 years moving correlation between NEMRT and PMTA index as well as area averaged STA over the Eastern India (EI) region (North) as well as that over equatorial Indian ocean regions (South) used for defining PMTA index

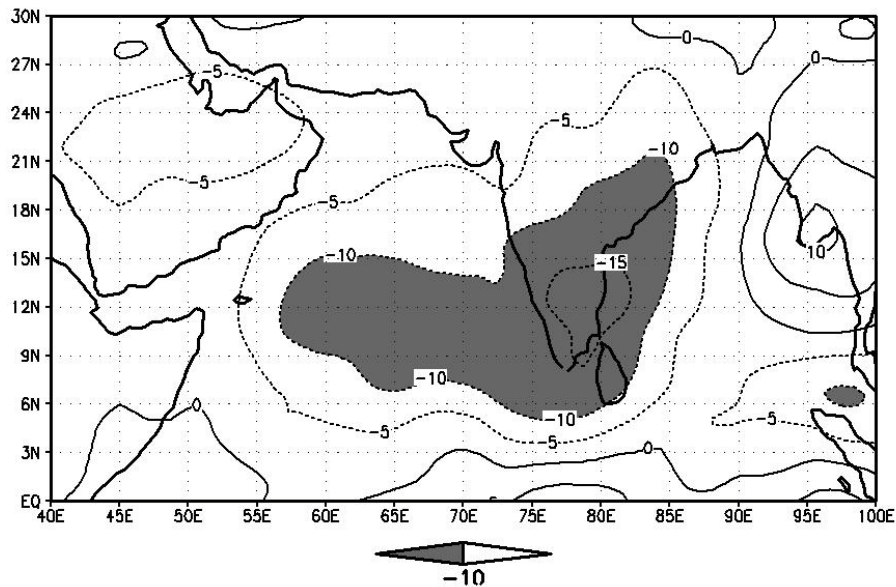
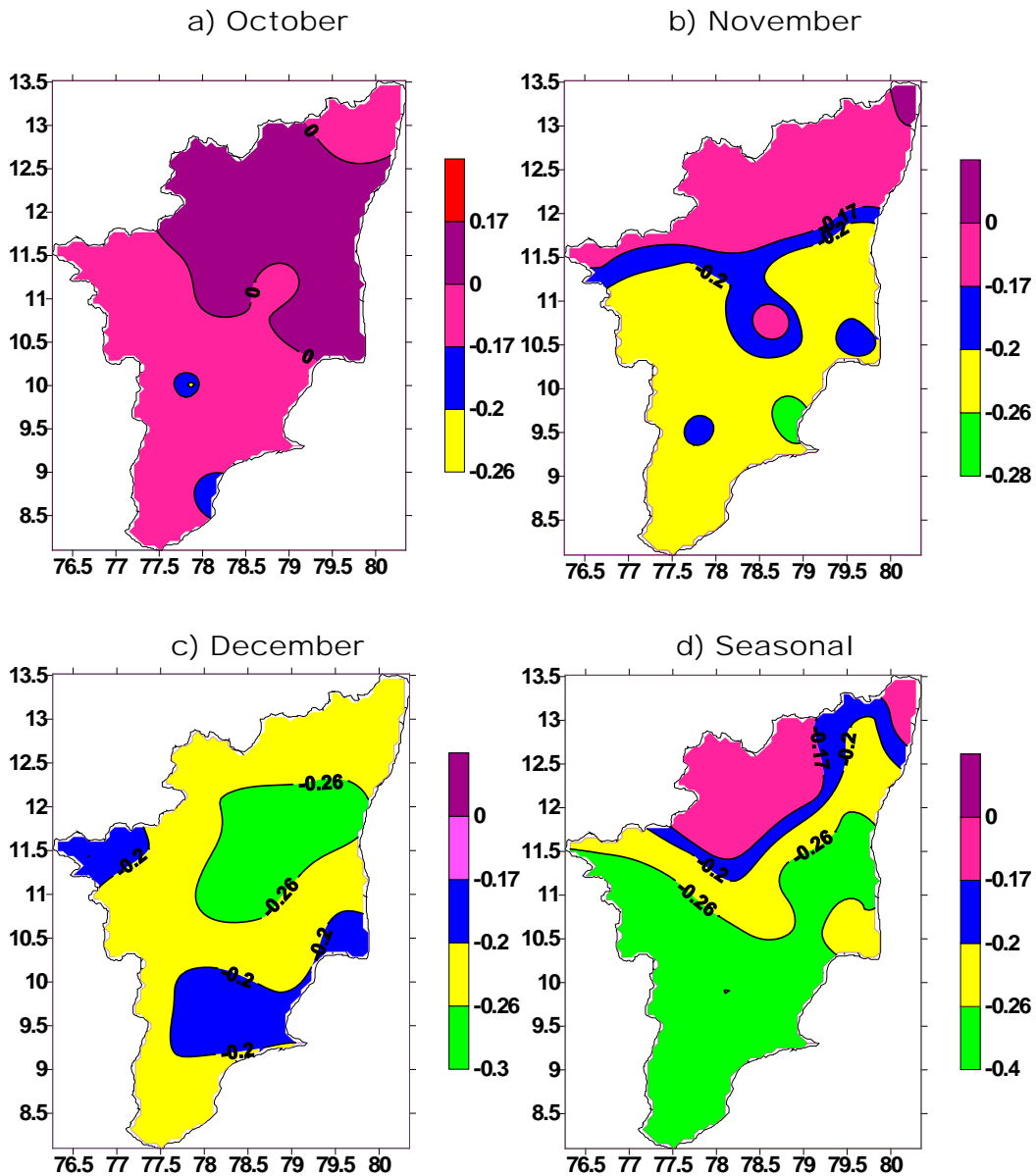


Fig. 5. The spatial distribution of OLR for the difference between negative PMTA years and positive PMTA years

The STA anomalies over the Eastern India (EI) region ($80^{\circ}\text{E} - 90^{\circ}\text{E}$; $20^{\circ}\text{N} - 25^{\circ}\text{N}$) and the equatorial Indian ocean region ($80^{\circ}\text{E} - 100^{\circ}\text{E}$; $5^{\circ}\text{S} - 5^{\circ}\text{N}$) are averaged. A pre-monsoon meridional temperature anomaly (PMTA) index is defined as the difference

between the area averaged STA over EI region and that over the equatorial Indian ocean region during the month of April. The plot of PMTA index and the subsequent NEMRT is shown in Fig. 2. This figure shows that, in general, whenever the PMTA index is positive (negative),



Figs. 6(a-d). Spatial distribution of Correlation Coefficient (CC) between (a) October, (b) November, (c) December and (d) October to December rainfall over districts of Tamilnadu sub-division and PMTA index

the departure from normal of the NEMRT is negative (positive). Fig. 3 shows the scatter diagram between NEMRT and PMTA index. Most of the deficient NEM years are in the lower right quadrant and most of the excess NEM years are in the upper left quadrant indicating the potential of PMTA index for foreshadowing the NEMRT. It may be mentioned here that the CC between NEMRT and the meridional temperature anomaly index based on STA of EI and the equatorial eastern Indian

ocean region are computed for other months also. However, most of them except for the months of April and October are not significant.

3.2. Relationship between PMTA index and NEM over Tamilnadu

The CC between NEMRT and PMTA index for the period 1901-2004 is -0.37 (significant at 1%). The

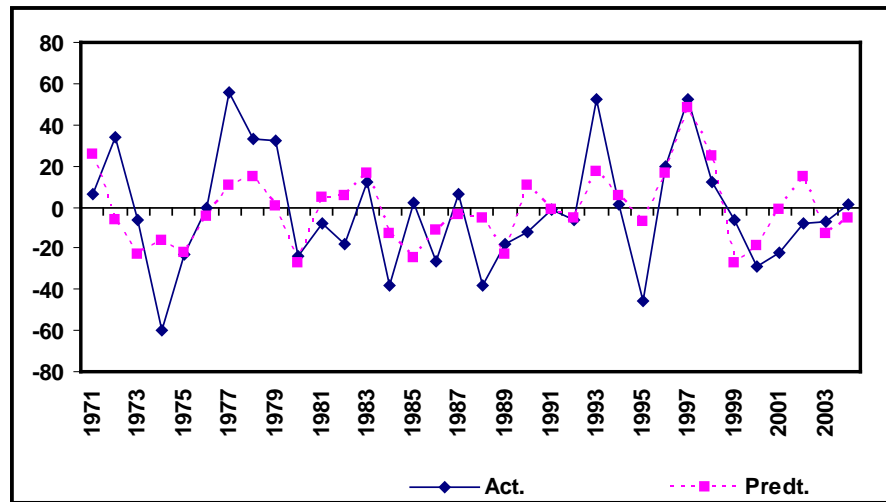


Fig. 7. Performance of linear regression between NEMRT and PMTA index for 1979-2000 with verification for 2001 to 2004

stability of PMTA-NEMRT relationship is examined by means of 30 years moving correlation between NEMRT and PMTA index (Fig. 4). The magnitude of CC between PMTA index and NEMRT is greater than -0.6 during the last two decades. The 30 years moving correlations between NEMRT over Tamilnadu and area averaged STA over the Eastern India region as well as that over equatorial Indian ocean regions used for defining PMTA index are also shown in Fig. 4. It is noted that the CC between area averaged STA over the equatorial Indian ocean region and NEMRT is more stable. On the other hand, the CC between area averaged STA over the Eastern India region and NEMRT is not much consistent and the nature of variation of 30 years sliding CC for PMTA index follows that of the Eastern India region. The correlation coefficients between PMTA index and October, November and December rainfall of Tamilnadu sub-division for the period 1901 – 2004 are -0.03, -0.28, and -0.33 respectively. Thus, the PMTA index has significant inverse relationship with November and December rainfall over the Tamilnadu while it is not significant for October month rainfall. This may be due to the onset of northeast monsoon taking place during the latter part of the October month and the normal date for the same is around October 20. The spatial pattern of difference in the outgoing long wave radiation (downloaded from www.cdc.noaa.gov) between negative PMTA years and positive PMTA years during the period 1980 – 2004 show (Fig. 5) negative anomaly over southern peninsula and neighbourhood indicating more convection and cloudiness and hence good NEMRT during negative PMTA years.

Similar to Fig. 1, the spatial distribution of the CC between PMTA index and NEMRT over the 29 districts of the Tamilnadu has been calculated for the period 1901 to 1996 for October, November, December and for the season October to December. These are shown in Figs. 6(a-d). In this figure, contours are drawn for CC's significant at 10% (CC = -0.17), 5% (CC = -0.20) and 1% (CC = -0.26) levels. During the month of October, only very small area show significant CC. During the month of November, the southern districts display more significant correlations than the northern districts. In the month of December, significant correlations are displayed more over central parts of Tamilnadu. In case of seasonal rainfall, most of the districts display significant CC with PMTA index. It may be not noted here that the number of rainfall observations are not uniform over all the districts.

Next, a single parameter linear regression equation is developed using PMTA index and NEMRT for recent 30 years data from 1971 to 2000. This equation is verified for an independent test period 2001 to 2004. The results are shown in Fig. 7. The regression equation during independent data period show good matching for change of sign but not for the magnitude. This implies that PMTA index is able to give a qualitative picture rather than giving a quantitative information on subsequent NEMRT and hence considerations, apart from PMTA, have to be paid for other factors also. This is quite natural as monsoon like system is determined by combination of many factors. A contingency table of the frequency of occurrence of deficient, normal and excess NEMRT in relation to PMT index during April month was made

TABLE 1

Contingency table of frequency of excess, normal and deficient rainfall over Tamilnadu during the northeast monsoon for various class intervals of PMTA index

Value of PMTA index	Excess NEM	Normal	Deficient	Total
Less than -1	3	2	2	7
Between -1 to 0	10	6	5	21
Between 0 to +1	13	15	15	43
Greater than +1	6	9	18	33
Total	32	32	40	104

(Table 1). The probabilities for the occurrence of excess and deficient NEM rainfall were estimated from the contingency table and same are given below:

- (i) For years with PMT index less than -1
P (E) = 0.43 , P(D) = 0.23
- (ii) For years with PMT index between -1 to 0
P (E) = 0.48 , P(D) = 0.24
- (iii) For years with PMT index between 0 to +1
P (E) = 0.31 , P(D) = 0.36
- (iv) For years with PMT index greater than +1
P (E) = 0.18 , P(D) = 0.55

Thus, the probability for excess (deficient) NEMRT is more than that for deficient (excess) NEMRT for the negative (positive) value of PMTA index.

Finally we consider the physical linkage between PMTA index and NEM rainfall over the Tamilnadu which is not clearly known at this stage. Yet a plausible reasoning could be given in the light of earlier studies on NEM variability. It is well known that surface temperature is an important factor controlling the energy exchange processes between the earth's surface and atmosphere. Basically PMTA index refers to a land (on the northern land regions) – Sea (on the southern oceanic region) contrast, which act as a boundary condition affecting the monsoon circulation. Raj *et al.* (2004) pointed out that westerly zonal wind anomalies, negative temperature anomalies and southern position of ridge at 75° E at 200 hPa during the preceding pre-monsoon and monsoon season, by and large, favours good NEMRT. In the present study, we note negative temperature anomalies (Fig. 8) over the northern land regions of the Asian region during excess NEMRT years. This resembles the reflection of cold temperature conditions at upper

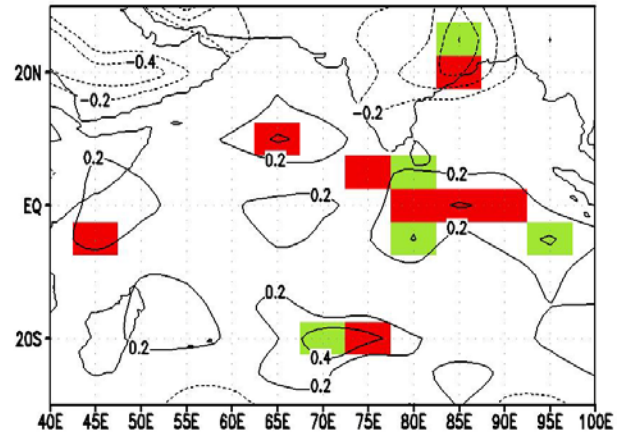


Fig. 8. Spatial distribution of composite of STA for (excess-deficient) NEMRT years

troposphere [as observed by Raj *et al.* (2004)] at surface which may be the effect of southward extension of mid-latitude cold westerly anomalies. Moreover, a number of studies reported the occurrence of above normal NEM rainfall during El-Nino events (Sridharan & Muthuswamy, 1990 and Ropelewski & Halpert, 1987). We have computed the CC between the well known Nino indices and PMTA index during the period 1950 to 2004 and it has been observed that the PMTA index has some inverse relationship with El-Nino events. This implies that PMTA index may have some connection with the El-Nino – NEM relationship. We admit that the physical linkage between PMTA-NEM is not well developed. Basically PMTA index represents land-sea contrast, which can act as a boundary forcing. The CC between PMTA and NEM over Tamilnadu was calculated for all months. Except April and October, no significant predictive signal related to STA could be noticed over the Asian monsoon region. However, exact linkage connecting all these components requires further study.

4. Conclusion

From the analysis of relationship of the spatial distribution of surface temperature anomalies over the Asian and neighbourhood region during the pre-monsoon month of April with subsequent NEM rainfall over Tamilnadu, a pre-monsoon meridional temperature anomaly (PMTA) index, defined as the difference between the area averaged temperature anomalies over the regions (80° E - 90° E; 20° N - 25° N) and (80° E - 100° E; 5° S - 5° N), is found to have significant inverse relationship with NEM over Tamilnadu. The Correlation Coefficient (CC) between PMTA index and NEMRT for the period is -0.37 (significant level at 1%) for the period

1901-2004 and the 30 year sliding correlation between them show significant CC with magnitude greater than 0.6 during recent two decades. The PMTA index is observed to be useful in qualitative sense rather than in quantitative way to obtain information on the subsequent NEMRT. The probability for excess (deficient) NEMRT is more than that for deficient (excess) NEMRT for the negative (positive) value of PMTA index.

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