ISSN 0252-1075
Contribution from IITM
Research Report No. RR-117

OLR and Rainfall Variations across India in Relation to Changing Global Atmospheric Thermal Conditions

H.N. Singh, Nityanand Singh
and
N.A. Sontakke

APRIL 2007

Indian Institute of Tropical Meteorology
Dr. Homi Bhabha Road, Pashan Pune - 411 008
Maharashtra, India

E-mail : lip@tropmet.res.in
Web : http://www.tropmet.res.in
Fax : 91-020-25893825
Telephone : 91-020-25893600

CONTENTS

OLR and Rainfall Variations across India in Relation to Changing Global Atmospheric Thermal Conditions

H. N. Singh, Nityanand Singh and N.A. Sontakke
Indian Institute of Tropical Meteorology, Pune – 8.

ABSTRACT

Declining trend has been noticed in outgoing longwave radiation (OLR) as well as in rainfall fluctuations during 1974-2005 over most parts of India during major parts of the year. This is contrary to physical understanding. To know possible reasons fluctuation features of important circulations e.g. mean sea level pressure (MSLP), geopotential height, global thermal conditions as well as mean temperature of the layer between isobaric levels 925 hPa and 400 hPa over the country have been examined. The parameters did not show significant changes over the period. It may be noted that the area averaged series of these parameters for the global tropics showed rising trend. Trends of opposite sign or of same sign but much larger magnitude are observed in these parameters over both the Polar Regions. Declining rain-producing systems around Indian region appears to be associated with these contrasting climatic fluctuations over the tropical and polar region via changes in geographical location and intensity of 'centres of actions' but it require investigations. The tropospheric temperature gradient during winter and spring can be used as reliable predictor for the combined convection-rainfall activities during the monsoon season for major parts of the country.

Keywords: OLR; Global Atmospheric Temperature, summer monsoon rainfall; northeast monsoon rainfall

1. INTRODUCTION

Though in situ observations are very valuable for its actual long-record available for the studies of the global climate change and its natural variations from the climate trend, it has its own limitations of being inhomogeneous and sparse spatial sampling especially over the oceanic region and dense forest where the installation of the instruments are practically impossible or very difficult. The satellite measurements and their products have much better spatio-temporal sampling characteristics and hence researchers widely used the remotely sensed satellite-derived data for studies of large scale to global scale climate variations on intraseasonal as well as interannual timescale. Variation in rainfall is very large compared to any other parameters such as pressure, temperature, geopotential height etc. But the variation of the OLR, which is generally treated as the proxy of rainfall, is more coherent spatially and its temporal variation is compatible with the parameters of the atmospheric circulations. Keeping this in mind, it was curious whether the variation in the satellite-derived OLR data can be explained and predicted. Preliminary investigation indicated declining trend in OLR temporal variation over and across India during 1974-2005. Many researchers used most frequently the long term satellite derived datasets of OLR (Gruber et al. 1978; 1984) and Highly Reflective Cloud (HRC) for many aspects of the climatological studies of tropical convection such as in monitoring and understanding the tropical circulation as well as regional climate change studies (Murakami 1980; Liebmann and Hartmann 1982; Horel et al. 1989; Waliser et al. 1993), the El Nino-Southern Oscillation phenomena (Gill and Rasmusson 1983; Rasmusson and Wallace 1983; Lau and Chan 1988), the intraseasonal (30-60–day) oscillation (Weickmann 1983; Weickmann et al.1985; Lau and Chan 1985) and to make estimates of tropical precipitation (Arkin 1984; Morrissey 1986; Yoo and Carton 1988). The satellite-derived OLR data have been used extensively by the atmospheric scientists as one component of the radiation balance of the atmosphere (Ohring and Gruber, 1982) as well as to infer the changes in the amount, height and vertical extent of the clouds. It is an indicator of both how warm the earth's surface is and how clear the atmosphere is overhead. Warm surfaces radiate more in the longwave range and the values of OLR are typically due to clouds in the atmosphere. The radiation from below the clouds gets trapped by them and it is the temperature of the cloud top heights which determine the amount of longwave radiation measured at the Top of the Atmosphere (TOA). The OLR at the top of the earth's atmosphere is modulated mainly by two factors viz. the cloud characteristics and the surface temperatures both of which are correlated to precipitation to some varying degrees. The surface temperature varies modestly through the annual cycle over the tropics and hence the strongest variation in the OLR is modulated by the changes in the amount, vertical distribution, depth of the cloud and the temperature at the top of the clouds (Xie and Arkin, 1998). Clouds in the tropical atmosphere occur in a wide range of sizes starting from isolated cumulus to a large cloud clusters that exhibit meso-scale organization and it plays a major role in the vertical transport of the energy from the planetary boundary layer to the upper troposphere (Wlllium and Houze 1987). Most of the precipitation over the tropical region is associated with the deep convection. This direct physical connection with the clouds led to the use of OLR in quantitative precipitation estimation for the tropical areas where the total OLR flux is strongly modulated by deep convective clouds (Lau and Chan, 1983; Xie and Arkin, 1998; Arkin 1984; Arkin et al.1989; Motell and Weare 1987; Janowiak and Arkin 1991). Since water vapor is one of the prime emitters of longwave radiation, knowledge of its concentration in the atmospheric vertical profile is necessary in solving the radiative transfer equation accurately. A moist atmosphere containing a high water concentration will have a larger component of longwave radiation than a dry atmosphere. The temperature structure of the atmosphere also plays a role as the temperature at the various layers is directly used in the Stephan's Boltzmans equation in calculating the OLR. By using the temperature and moisture profiles of the given atmosphere we can improve upon the algorithm by taking these factors into account. In case of higher latitudes where effects of surface temperatures largely modulate the OLR, the relationship between OLR and precipitation could not be established well, rather very complex with interannual variations in both clouds and snow cover. Arkin (1984) analyzed the monthly and seasonal relationship between the OLR and rainfall over the tropical Pacific for the period 1974-1980 and found that 57% of the variance in the gauged-observed rainfall for 2.5° lat-lon could be explained by a linear function (Slope = - 0.186; intercept = 54.1) of the mean OLR. This good explanation of linear function is mainly due to the most sensitiveness of the satellite-derived OLR to the cloud top temperature and in the tropics, cold high clouds are associated with deep tropical convection and thus, in turn, with rainfall (Lau and Chan 1985). Similar linear relationship between OLR and the rainfall has been derived by Motell and Weare (1987) which has a slope of – 0.189 with an intercept of 53.1. Morrissey (1986) analyzed the relationships among the OLR, precipitation and moisture budget over the tropical Pacific to isolate cirrus overlying non-convective conditions in this region and found that the daily OLR correlates negatively and significantly with precipitation over the tropical areas where deep convection dominates. The spatial distribution patterns of the OLR as derived from the Indian national Satellite Systems are also in good agreement with those of the precipitation as estimated by the Geostationary Operational Environmental Satellites (GOES) Precipitation Index (GPI; Arkin 1979; Arkin et al.1989; Arkin and Meisner 1987). To fill in the gaps of the GPI estimates over areas where geostationary satellites do not provide coverage, a linear function was developed using a regression analysis to estimate the precipitation from OLR over the global tropics (Janowiak and Arkin 1991; Huffman et al. 1995; 1997; Xie and Arkin 1996). There are significant spatial changes in the relationship between OLR and rainfall across the global tropics. In short the OLR-Rainfall relationship is region specific and period specific and hence new approaches for establishing new relationship incorporating spatio-temporal dependence are attempted (Yoo and Carton 1988; Singh, H.N. 2004). Significant spatial changes in the relationship can be seen over the tropical Atlantic Ocean where the precipitation is mainly contributed to by low or middle clouds such as altocumulus and stratocumulus over the western Atlantic, whereas low altitude stratus and high altitude cirrus clouds prevail along with the convective clouds over the eastern Atlantic. The precipitation is mainly associated with the easterly waves under low-layer moist-conditions over the western Atlantic. On the other hand, it is associated with large-scale subsidence prevailing along with the convective clouds over the eastern Atlantic. To overcome the overestimate rainfall in the eastern Atlantic and the underestimate rainfall in the western Atlantic by any ordinary zonally independent OLR-Rainfall relationship, Yoo and Carton (1988) developed a new technique, incorporating the spatial dependence due to differing cloud types, heights of the cloud top as well as the height of the base of the trade-wind inversion, to estimate the total precipitation over and across the tropical Atlantic Ocean from the OLR. The OLR is widely used as reliable proxy for convection and rainfall activities, and declining trend in the OLR is suggestive of increased convection and rainfall over India. But trend analysis of contemporary rainfall data (1974-2005) showed declining trend in rainfall over major parts of the country during southwest (June through September) and northeast monsoons (October through December), the period of most rainfall activities. The primary objectives of this study are to investigate (i) the large-scale monsoon circulation as well as associated cloudiness and the heavy rainfall over and across India, (ii) possible causes of this changing relationship between OLR and rainfall, and (iii) the influence of global atmospheric thermal changes on the OLR/convection and rainfall variation over India.

2. DATA USED

2.1 OLR

The satellite-derived monthly 2.5° x 2.5° lat-lon gridded emitted terrestrial radiation with wavelength greater than 5μm from its operational sun-synchronous polar orbiting satellites of NOAA/NESDIS, referred to as OLR, are used in this study. The total OLR flux for a month is obtained by averaging all nighttime and daytime estimates within the period. The primary advantage of the NOAA OLR dataset is that it is a long term data [since Jun1974; Data Missing: March 1978 – Dec. 1978) and is updated on near-real-time basis (http://www.cdc.noaa.gov/). Satellite measures the radiances & the measured radiances are to convert to Brightness Temperature (T_{BB}). The Brightness Temperature (T_{BB}) thus converted is again to be converted to Flux Temperature T_F. This flux equivalent blackbody temperature (T_F) is translated to the outgoing longwave emittance, known as the OLR, with the Stefan-Boltzmann law, $F = \sigma * T_F^{\ 4}$, Where, σ=5.67051 x 10^{-8} W/m^2/K^4, using the Radiative Transfer model for 99 different atmospheres covering a broad range of temperatures, humidities, and cloudiness, and for different zenith angles (secθ = 1.0, 1.25, 1.5, 1.66, 1.75. 2.0, 2.25 and 2.5). There have been several changes in satellite, their orbits, equatorial crossing time (ECT) and instrumentation as well as in the procedures for treating the observations (Gadgil et al., 1992; Waliser and Zhou, 1997). The ECTs in local solar time (LST), period of data record, instruments onboard & window channel radiometers for those satellites used in deriving the dataset is presented in **Table 1**. The data set has been derived using data from several satellites and two different instruments viz. (i) the Very High Resolution Radiometer (VHRR), which flew on NOAA satellites prior to NOAA 6 with the window channel 10.5-12.5μm; and (ii) the Advanced Very High Resolution Radiometer (AVHRR), since the launch of TIROS N with the window channel 10.5-11.5 μm for TIROS N and NOAA 6 but 11.5-12.5 μm for NOAA 7 onwards.

2.2 RAINFALL

Instrumental monthly rainfall records from a well spread network of 316 raingauges (**Figure 1**) across India for the period 1974-2005 is used in this study (Singh et al. 1996, Sontakke et al. 1996, Singh et al. 2005). The seasonal and annual rainfall series for all India are obtained by averaging the corresponding data over the period specified for each season. As rainfall is the most variable meteorological phenomenon over space and time, it is very difficult to represent the summer monsoon rainfall (SMR) series for the country as a whole. Singh et al. (1991) have pointed out limited spatial representation of the all-India SMR by computing Index of Areal Representativeness (IAR) which is defined as

$$IAR = \frac{S_R^2}{(1/M)\sum_{i=1}^{M} S_i^2} \times 100$$

where S_R^2 is the variance of the area averaged series and S_i^2 that of the individual rainfall series and M the number of stations averaged. The authors have prepared the all-India SMR series by nine different methods and found IAR to vary between 7% and 14%. The examination of fluctuation in areally averaged OLR and rainfall and the association between the two parameters for the whole country (India) provides only broad information. Keeping this idea as well as for developing an effective system for monsoon rainfall studies including the large-scale, long period intense rain events across India, the above analysis was repeated for 11 rainfall zones of the country that were identified based on the subjective considerations such as spatial and temporal variation in rainfall;

orographic effects; drainage pattern; physiography; continentality; oceanic influence; rain-shadow effect; rainfall regime; rain inducing disturbances (type, frequency and annual cycle); tropical-extra-tropical interaction; large-scale subsidence motion associated with remote, organized rising motion. The 11 rainfall zones are as follows (**Figure 2**): (i) Extreme North India (ENI), (ii) North West India (NWI), (iii) Ganga Plains (GPs), (iv) Central India (CI), (v) North East India (NEI), (vi) West Coast (WC), (vii) West Coast (South) {WC(S)}, (viii) Central Peninsular India (CPI), (ix) East Coast (North) {EC(N)}, (x) East Coast (South) {EC(S)}, and (xi) South Peninsular India (SPI). The area-averaged monsoon and monsoon monthly rainfall series for the period 1974-2005 has been prepared from simple arithmetic mean of the number of raingauges available in the particular zone – 41 in ENI, 81 in NWI, 87 in GPs, 26 in NEI, 78 in CI, 20 in EC(S), 23 in EC (N), 33 in WC, 25 in WC(S), 32 in SPI and 34 in CPI.

2.3 GLOBAL ATMOSPHERIC TEMPERATURE

The structure of the vertical profile of atmospheric temperature also plays a role in the formation of clouds and clouds condensation nuclei which are assumed to have direct relationship with rainfall. The temperature at the various atmospheric layers is directly used in the Stephan's Boltzmans equation in calculating the OLR and hence the knowledge of atmospheric vertical temperature profile is an important parameter to know the possible causes of the changing relationship between OLR (convection) and rainfall. In this study, the departures series of the seasonal (winter, spring, summer and autumn) and annual temperatures (Angell, 1990) derived from radiosonde data for surface air (upto 850 hPa), troposphere (850-300 hPa), tropopause (300-100 hPa) and the surface – 100 hPa over the two hemispheres, the whole globe and seven latitudinal zones (north Polar: 60°-90°N; north temperate:30°-60°N; north subtropic: 10°-30°; equator: 10°S – 10°N; south subtropic:10°-30°S; south temperate:30°-60°; and south polar: 60°-90°S) are used. The reference period of this dataset is 1958-1977 and is updated (http://cdiac.ornl.gov/). The standard isobaric level temperature and geopotential height datasets derived from the NCEP/NCAR reanalysis (Kalnay, E., et al., 1996) were also used in this study.

3. LIMITATIONS OF THE DATASETS USED

Though the OLR dataset is regarded as vital information for the large-scale monsoon circulation as well as associated cloudiness and the heavy rainfall over India and climate change studies it has its own limitations regarding the data reduction procedures, radiometric characteristics, and orbital parameters of the satellite systems. The longwave band extends from 5–100 μm but satellite measures the radiant exitant flux (OLR) only through the window channel (10.5-12.5μm/11.5-12.5μm) at the satellite height not at the top of atmosphere (known as inverse problem) and only of two observations daily. To measure the radiant exitance from a point, one must observe the point from all possible directions but satellites, however, observe a single point from a single direction (known as the angular dependence problem). Not only this problem but also the change in equator crossing times of the satellite as well as several changes involved in both instrumentation and in the algorithm used for deriving the total longwave emittance from window channel measurements (Lucas, 2001). The accuracy of Radiation Budget estimates from the satellite instruments is very difficult to assess the degree of its reliability because of the lack of independent observations. But the shortwave parameters such as albedo, absorbed solar radiation, and thus the net radiation are considered to be less accurate than the OLR estimates as these estimates include angular and spectral corrections while the algorithm for estimating the shortwave parameters do not include for the angular dependence problem as well as the spectral correction. On the other hand the in situ rainfall data has also its own limitations of being inhomogeneous and sparse spatial sampling especially over the oceanic region and dense forest where the installation of the instruments is practically impossible or very difficult. The global atmospheric temperature dataset used in this study are based on the fixed and well spread 63 radio-sonde stations across the globe which needs to increase the network for better spatial coverage.

4. RESULTS AND DISCUSSIONS

4.1 RELATIONSHIP BETWEEN OLR AND RAINFALL ACROSS INDIA

Sixty eight (68) 2.5° x 2.5° lat-lon grids provides complete coverage of the geographical spread of the country. Linear trends in OLR and rainfall sequences have been approximated by the method of least-squares. Negative trend is seen in OLR; 19% area of the country during winter, 65% during summer, 100% during monsoon and 50% during post-monsoon. Further, negative trend is seen over the entire country during each of the four monsoon months, June (100%), July (98%), August (98%) and September (85%). Declining trend in OLR fluctuation over India seems a modest conclusion which is an indicative of increased convection and clouding. Increasing trend in the cloud amount has been confirmed from 20-year (1985-2004) sequence of the International Satellite Cloud Climatology Project (ISCCP) dataset. Detailed investigation revealed that the rising trend is essentially in high-lying clouds, and there is slight downward trend in low-lying clouds. During the period 1985-1999, the percentage difference between high-lying and low-lying clouds remained steady at 7- 8%, but during 2000-2004 the difference has almost doubled to 13%. Decrease in rainfall over major parts of India during most parts of the year appears to be due to thinning of the low-lying clouds caused by stretching of the cloud layer (700-300 hPa thickness) associated with atmospheric warming.

Negative trend in rainfall fluctuation is seen over 26% area of the country during winter and 33%, 67% and 47% during summer, summer monsoon and post-monsoon respectively. During monsoon months, June, July, August and September, the percentage area with negative trend is as 22%, 67%, 61% and 51% respectively. For rainfall also negative trend seems fair conclusion than positive or no trend. Negative trend in OLR as well as rainfall variation over area is paradoxical according to physical understanding. But irrespective of trend in OLR and rainfall negative correlation is found between the two parameters for the different grids during each of the four seasons and each of the four monsoon months, though with large spatial variation, which is consistent with physical understanding. The trend analyses for both the parameters and their relationship were examined for all the 11 zones of the country during monsoon monthly, monsoon season and post monsoon season for the period 1974-2005. The OLR and rainfall series for the period 1974-2005 as well as the scatter diagram between the two parameters are presented in **Figure 3(a-f)** for all the 11 zones. Features of grid-wise and regional OLR as well as rainfall variations across India are also analyzed. The seasonal and annual OLR and rainfall series along with their scatter diagram is also presented in **Figure 4**. The scatter plot of OLR and observed rainfall shows a large scatter throughout the range of both the variables though correlated negatively on monthly and seasonal scale over and across India. This could be due to cirrus contamination of OLR as well as the increase in the non-rainy clouds. The large amount of spatial variability in the observed rainfall data as well as the diurnal biases in the twice daily OLR measurements may also be a factor responsible for this large magnitude of scatter. The OLR shows decreasing trend over the whole country as well as the different zones of the country for the monsoon season, the post-monsoon season and each of the four monsoon months whereas rainfall shows variety of fluctuations (increasing, decreasing or stationary) though correlated negatively on grid scale with large spatial variation (**Table 2**). The correlation between these two parameters is always negative and highly significant in most of the cases but, in general, it is region specific and period specific. The relation is stronger for smaller regions with monthly data. The fluctuation in monsoon OLR over the whole country shows decreasing trend at the rate of -0.33 $W/m^2/yr$. The monthly distribution of the OLR trend is as June -0.44, July -0.28, August -0.30 and September -0.31 $W/m^2/yr$. The correlation between tropopause temperature gradient between north subtropic and equator during summer and the monsoon OLR is -0.66 (significant at 1%). Monsoon rainfall shows decreasing trend at the rate of -1.60mm/yr. Monthly distribution of the trend is as June 0.51, July -1.18, August -1.10 and September 0.17 mm/yr. The

CC between monsoon OLR and rainfall is -0.28. For June the CC is -0.74 (significant at 0.1%), for July -0.25, for August -0.18 and for September -0.61 (significant at 0.1%). The insignificant CC value for the peak monsoon months July and August could be due to the fact that the convective clouds, generally, produce greater rainfall during the initial developing stages compared to the mature and decaying stages. However this result is inconclusive and needs further investigation which is underway.

4.2 INFLUENCE OF ATMOSPHERIC THERMAL CONDITION ON CONVECTIVE ACTIVITIES/CLOUDINESS DURING SUMMER MONSOON SEASON

The influences of global atmospheric thermal changes on the OLR/convection and rainfall variation over India have also been analyzed. The linear trend in the seasonal and annual temperature departures of the surface air, the troposphere and the tropopause over different climatic zones, the two hemispheres and the whole globe for the period 1958-2005 is also given in **Table 3**. The time series plot of the same is also presented in **figure 5**. The correlation between all-India as well as the 11 zonal OLR with each of the regional differences, seasonal differences and level differences in the temperature departures were calculated to understand the effect of horizontal and vertical gradient in seasonal temperature departures on the convection and in turn rainfall over India. The direct correlation between the all-India as well as the 11 zonal monsoon rainfall with each of the regional differences, seasonal differences and level differences in the temperature departures was also calculated. The good agreement between the CCs is noted for both the parameters with the atmospheric thermal conditions. The correlation between the area-averaged all India monsoon OLR with the tropopause temperature gradient between north temperate and equator during summer is found to be -0.63 whereas it is 0.61 with the tropopause temperature gradient between equator and south subtropic. The correlation between tropopause temperature gradient between north temperate and south temperate during summer and the monsoon rainfall is 0.40 (significant at 5%). Singh and Patwardhan (2002) have shown the effect of atmospheric thermal conditions on the monsoon of the Indian region. Effective degrees of freedom are worked out for testing the significance of the correlation co-efficient (CC). The tropospheric/tropopause temperature gradient between north subtropic/north temperate and equator/south subtropic/south temperate during summer influences significantly the monsoon season convection. The tropospheric temperature gradients during winter and spring seasons have shown significant correlation with the monsoon season convection and rainfall. The product moment correlation coefficient between different atmospheric temperature departure series and the area-averaged summer monsoon (JJAS) OLR series of different 11 zones as well as all-India have been calculated to examine the (degree of) influence of the atmospheric thermal conditions in the development of convective activities/cloudiness. Besides the direct correlation of the seasonal temperature departures, the correlation of the regional difference, seasonal differences and the level differences in the atmospheric temperature departures with the OLR series have also been computed to know the influence of differential of spatial and temporal warming/cooling of the atmospheric thermal conditions over different parts of the country. The statistical significance test of all the CC's calculated are done against an effective sample size as the different temperatures series show significant trends. The effective number of degrees of freedom has been calculated as

$$N' = N\frac{1-\rho}{1+\rho}$$

where N is the number of observations and ρ is the product of the 1^{st} serial correlation coefficient of the two series (WMO Tech Note 79, 1966).

4.2.1 STATIC CONDITION

The CC of the concurrent year seasonal temperature departures series of the surface air, the troposphere, the tropopause and the surface – 100 hPa layer over different climatic zones, the two hemispheres and the whole globe with the area-averaged monsoon (JJAS) OLR series over each of 11 zones as well as the whole India during 1974-2005 are calculated and the same are presented in the **Table 4 (a-l)**. The CC values superscripted with * is significant at 5% level and that with ** at 1% level and above. The thermal conditions which may help in developing the convective activities/cloudiness in turn assumed to be associated with rainfall activities over the respective zones are as under-

Extreme North India (Table 4-a):

Troposphere: Warming north subtropic during winter; cooler over south temperate during summer; cooler over equator during autumn.

Tropopause: Cooler over globe during winter and autumn.

Surface-100 hPa: Cooler over south temperate during winter; cooler over equator during autumn.

North West India (Table 4-b):

Surface: Warmer over north temperate during autumn.

Troposphere: Warmer over north temperate during summer; cooler over equator during the autumn.

Surface-100 hPa: Cooler over equator during the autumn.

Ganga Plains (Table 4-c):

Surface: Warmer over northern hemisphere, southern hemisphere, tropic, globe, equator, south subtropic, south temperate during winter; warmer over northern hemisphere during spring; warmer over northern hemisphere, globe, north polar, south subtropic during summer; warmer over south subtropic during autumn.

Troposphere: Warmer over north subtropic during winter and spring; warmer over north temperate during summer; cooler over equator during autumn.

Tropopause: Cooler over globe, equator, south temperate, southern hemisphere during winter and autumn; cooler over equator during spring and summer; cooler over tropic during autumn.

Surface-100 hPa: Warmer over north subtropic during winter and spring; cooler over equator during summer and autumn; warmer over north temperate during summer.

Central India (Table 4-d):

Surface: Warmer over northern hemisphere, southern hemisphere, tropic, globe, equator, south subtropic, south temperate during the winter; warmer over northern hemisphere during bth the spring and summer.

Troposphere: Warmer over north subtropic during winter and spring; warmer over north temperate during summer; warmer over south polar during autumn.

Tropopause: Cooler over southern hemisphere and equator during winter and autumn; cooler south temperate during winter; cooler over globe during autumn.

Surface-100 hPa: Warmer over north subtropic during winter and spring; warmer over north temperate during spring; warmer over equator during the autumn.

North East India (Table 4-e):

Surface: Warmer over northern hemisphere, southern hemisphere, globe, tropic, north temperate, equator, south temperate during winter; warmer over northern hemisphere, globe, tropic, south temperate during spring; warmer over northern hemisphere, globe, tropic, north polar, equator, south subtropic during summer; warmer over globe, tropic, southern hemisphere, south subtropic during autumn.

Troposphere: Warmer over northern hemisphere, north temperate, north subtropic during winter; warmer over subtropic during spring; warmer over globe, southern hemisphere, south subtropic, south polar during autumn.

Tropopause: Cooler over southern hemisphere, equator, south temperate, south polar during winter; cooler over equator during spring and summer; cooler over globe, tropic, southern hemisphere, equator during autumn.

Surface-100 hPa: Warmer over northern hemisphere, north temperate, north subtropic, south polar during winter; warmer over north subtropic during spring; cooler over equator during autumn.

West Coast (Table 4-f):

Troposphere: Warmer over northern hemisphere, north subtropic during winter; warmer over north subtropic during spring.

Surface-100 hPa: Warmer over north subtropic during spring.

West Coast South (Table 4-g):

Troposphere: Warmer over northern hemisphere during winter; warmer over north subtropic during spring.

Central Peninsular India (Table 4-h):

Surface: warmer over globe, equator during winter.

Troposphere: Warmer over northern hemisphere, north subtropic during winter; warmer over tropic, north subtropic during spring; warmer over northern hemisphere, north temperate during summer.

Surface-100 hPa: Warmer over north subtropic during winter and spring; warmer over northern hemisphere, north temperate during summer.

East Coast North (Table 4-i):

Surface: warmer over northern hemisphere, globe, tropic, southern hemisphere, north temperate, equator, south subtropic, south temperate during winter; warmer over northern hemisphere, globe, tropic, north subtropic during spring; warmer over northern hemisphere, globe, tropic, southern hemisphere, north polar, north subtropic, south subtropic during summer; warmer over northern hemisphere, globe, tropic, southern hemisphere, south subtropic during autumn.

Troposphere: Warmer over northern hemisphere, north temperate, north subtropic, south subtropic during winter; warmer over north subtropic, south subtropic during spring; warmer over northern hemisphere, globe, north temperate, north subtropic, south subtropic during summer; warmer over globe, north temperate, south subtropic, south polar during autumn.

Tropopause: Cooler over globe, southern hemisphere equator, south temperate, south polar during winter; cooler over equator during spring and summer; cooler over northern hemisphere, globe, tropic, southern hemisphere, equator during autumn.

Surface-100 hPa: Warmer over northern hemisphere, north subtropic, south subtropic, south polar during winterwarmer over north subtropic during spring; warmer over north temperate, south subtropic during summer; warmer over north temperate and equator during autumn.

East Coast South (Table 4-j):

Surface: Warmer over equator during winter; warmer over southern hemisphere, south subtropic during summer.

Troposphere: Warmer over northern hemisphere, tropic, north subtropic, south subtropic during winter; warmer over tropic, north subtropic during spring; warmer over south polar during summer; warmer over south temperate during autumn.

Tropopause: Cooler over southern hemisphere, south polar during autumn.

Surface-100 hPa: Warmer over northern hemisphere, north subtropic during winter; warmer over north subtropic during spring; warmer over south polar during autumn.

South Peninsular India (Table 4-k):

Troposphere: Warmer over north subtropic during winter and spring.

Whole India (Table 4-l):

Surface: Warmer over northern hemisphere during winter, spring and summer; warmer over globe, tropic throughout the year (during winter, spring, summer, autumn); warmer over southern hemisphere, south subtropic during winter and autumn; warmer over north temperate during winter and spring; warmer over north subtropic during spring and summer; warmer over equator and south temperate during winter; warmer over north polar and south subtropic during summer.

Troposphere: Warmer over northern hemisphere, north temperate during winter and summer; warmer over north subtropic during winter and spring; warmer over south subtropic during spring; warmer over north temperate, equator, south polar during autumn.

Tropopause: Cooler over globe, southern hemisphere, equator, south temperate during winter and autumn; cooler south polar during winter; cooler equator during spring and summer; cooler over tropic during autumn.

Surface-100 hPa: During winter warmer over south polar but cooler over northern hemisphere and north subtropic; warmer over north subtropic during spring; warmer over north temperate during summer and autumn; cooler over equator during autumn.

4.2.2 REGION DIFFERENCE

The CC of regional difference in the concurrent year seasonal temperature departures with the area averaged summer monsoon OLR over different 11 zones as well as the whole India during 1974-2005 presented in the **table 5 (a-l)**. The CC values presented in these tables are significant at 5% level and those superscripted with * indicates significant at 1% level and above. The thermal conditions which may help in developing the convective activities/cloudiness in turn assumed to be associated with rainfall activities over the respective zones are as under-

Extreme North India (Table 5-a):

Surface: During summer warmer over north subtropic compared to south temperate

Troposphere: During winter warmer over north subtropic compared to south temperate. During spring cooler over north polar compared to north subtropic; warmer over tropics compared to equator. During summer cooler over equator compared to north temperate, north subtropic, south subtropic, south polar and whole tropics; cooler over south temperate compared to north temperate, north subtropic, south subtropic and south polar. During autumn cooler equator compared to north subtropic, south polar and tropics; warmer over south polar compared to south subtropic and tropics; warmer over north subtropic compared to tropics.

Tropopause: During summer warmer over north subtropic compared to equator and whole tropics; cooler over equator compared to tropics. During autumn warmer over north subtropic compared to equator and whole tropics; cooler over equator compared to tropics.

Surface-100 hPa: During winter warmer over north subtropic compared to south temperate. During spring cooler over equator compared to north subtropic and whole tropics; warmer over north subtropic compared to north polar. During summer cooler over equator compared to north temperate, north subtropic, south subtropic, south polar, tropics; warmer over north temperate compared to south temperate; cooler over south temperate compared to south polar. During autumn cooler over equator compared to north temperate, north subtropic, south subtropic, whole tropics; warmer over north subtropic compared to whole tropics.

North West India (Table 5-b):

Surface: During summer cooler over equator compared to north polar, north temperate, north subtropic; cooler over south temperate compared to north temperate and north subtropic. During autumn warmer over north temperate compared to south temperate.

Troposphere: During summer warmer over north temperate compared to equator, south temperate and whole tropics; cooler over equator compared to north subtropic, south subtropic, whole tropics. During autumn cooler over equator compared to north temperate, north subtropic, south polar, whole tropics; warmer over south polar compared to whole tropics.

Tropopause: During summer warmer over north subtropic compared to equator and whole tropics.

Surface-100 hPa: During winter warmer over north subtropic compared to south temperate. During summer warmer over north temperate compared to equator, south temperate and whole tropics; cooler over equator compared to north subtropic, south subtropic and whole tropics. During autumn cooler over equator compared to north temperate, north subtropic, south subtropic and whole tropics; warmer over tropics compared to north subtropic.

Ganga Plains (Table 5-c):

Surface: During summer warmer over the north polar compared to equator, south temperate and the whole tropics.

Troposphere: During spring warmer over the south subtropic compared to south polar; during summer cooler over equator compared to north polar, north temperate, north subtropic, south subtropic, south polar and the whole tropics; warmer over north temperate compared to south temperate and the whole tropics. During autumn cooler over equator compared to north subtropic, south subtropic, south polar and whole tropics; warmer over south polar compared to whole tropics but cooler with respect to south subtropic.

Tropopause: During winter cooler over south polar compared to north temperate, north subtropic, south subtropic and whole tropics; cooler over equator compared to north subtropic, south subtropic, whole tropics; cooler over south temperate compared to north subtropic, south subtropic, whole tropics; warmer over south subtropic compared to whole tropics. During spring cooler over equator compared to north temperate, north subtropic, south subtropic, whole tropics; warmer over north subtropic compared to south subtropic, whole tropics. During summer cooler over equator compared to north temperate, north subtropic, south subtropic, whole tropics; warmer over north subtropic compared to south temperate and whole tropics; warmer north temperate compared to south temperate. During autumn cooler over equator compared to north temperate, north subtropic, south subtropic and whole tropics but warmer north subtropic than tropics.

Surface-100 hPa: During winter cooler over south polar compared to north polar, north temperate, north subtropic, south subtropic and whole tropics; cooler over equator compared to north subtropic, south subtropic and whole tropics. During spring cooler over equator compared to north subtropic, south subtropic and whole tropics. During summer cooler over equator compared to north polar, north temperate, north subtropic, south subtropic, south polar, whole tropics; warmer over north temperate compared to south temperate and whole tropics; warmer north subtropic than whole tropics; warmer over south subtropic compared to south polar. During autumn cooler over equator compared to north temperate, north subtropic, south subtropic, whole tropics; cooler over north subtropic than tropics.

Central India (Table 5-d):

Surface: During summer warmer over north polar compared to equator, south temperate, tropics.

Troposphere: During spring warmer over south subtropic compared to south polar. During summer warmer over north temperate compared to equator, south temperate, whole tropics; cooler over equator compared to north polar, north subtropic, south subtropic, south polar and whole tropics. During autumn warmer over south polar compared to tropics; cooler over equator compared to north subtropic, south subtropic, south polar and tropics.

Tropopause: During winter cooler over equator compared to south subtropic, tropics; warmer over south subtropic compared to south temperate and tropics. During spring warmer over south subtropic compared to equator and tropics; cooler over equator compared to tropics. During summer warmer over north subtropic compared to equator, south temperate, whole tropics; cooler over equator compared to north temperate, south subtropic and whole tropics. During autumn cooler over equator compared to north temperate, south subtropic and tropics; warmer over north subtropic compared to equator and tropics.

Surface-100 hPa: During spring warmer over north subtropic compared to south temperate; cooler over equator compared to tropics. During summer warmer over north temperate compared to equator, south temperate, tropics; cooler over equator compared to north polar, north subtropic, south subtropic, tropics; warmer over south subtropic compared to south temperate and tropics. During autumn cooler over equator compared to north temperate, north subtropic, south subtropic and tropics; warmer over north subtropic compared to tropics.

North East India (Table 5-e):

Surface: During winter cooler over south polar compared to north temperate, equator, south polar, south temperate and tropics. During summer warmer over north polar compared to north temperate. During autumn warmer over south subtropic compared to south temperate.

Troposphere: During winter warmer over north temperate compared to south polar. During summer cooler over equator compared to north subtropic, south subtropic and whole tropics. During autumn cooler over equator compared to north subtropic, south subtropic, south polar and the whole tropics.

Tropopause: During winter cooler over south polar compared to north polar, north temperate, north subtropic, equator, south subtropic, south temperate, whole tropics; cooler over equator compared to north subtropic, south subtropic, tropics; warmer over north subtropic compared to tropics. During spring warmer over north subtropic compared to tropics; cooler over equator compared to north temperate, north subtropic, south subtropic, tropics. During summer cooler over equator compared to north polar, north temperate, north subtropic, south subtropic, tropics; warmer over south subtropic compared to south temperate, tropics; warmer over north temperate compared to south temperate, tropics; warmer over south subtropic compared to tropics. During autumn cooler over equator compared to north polar, north temperate, south subtropic, tropics; warmer over north subtropic compared to equator and whole tropics.

Surface-100 hPa: During winter cooler over south polar compared to north polar, north temperate, north subtropic, equator, south subtropic, south temperate, whole tropics; cooler over equator compared to south subtropic, tropics. During spring cooler over equator compared to north temperate, north subtropic, south subtropic, whole tropics. During summer cooler over equator compared to north temperate, north subtropic, south subtropic, tropics; warmer over south subtropic compared to the whole tropics. During autumn cooler over equator compared to north temperate, north subtropic, south subtropic, whole tropics; warmer over south subtropic compared to whole tropics.

West Coast (Table 5-f):

Surface: During summer warmer over north subtropic compared to south temperate.

Troposphere: During winter warmer over north subtropic compared to south temperate. During summer warmer over north temperate compared to north polar, south temperate; warmer over north subtropic compared to south temperate. During autumn cooler over equator compared to north subtropic, south temperate, whole tropics; warmer over north subtropic compared to whole tropic.

Surface-100 hPa: During winter cooler over south temperate compared to north subtropic and tropic. During summer warmer over north temperate compared to north polar. During autumn warmer over north subtropic compared to equator and tropics; cooler over equator compared to south temperate.

West Coast South (Table 5-g):

Surface: During summer warmer over north subtropic compared to south temperate.

Troposphere: During winter warmer over north subtropic compared to south temperate. During summer warmer over north temperate compared to north polar, south temperate; warmer over north subtropic compared to south temperate. During autumn warmer over north subtropic compared to equator and tropics; cooler over equator compared to south temperate and tropics.

Surface-100 hPa: During winter cooler over south temperate compared to north subtropic, south subtropic and tropics. During summer cooler over north polar compared to north temperate. During autumn warmer over north subtropic compared to equator and tropics; cooler over equator compared to south temperate and whole tropics.

Central Peninsular India (Table 5-h):

Troposphere: During summer warmer over north temperate compared to south subtropic, south temperate, equator and whole tropics. During autumn warmer over north subtropic compared to whole tropics; cooler over equator compared to north subtropic, south temperate, south polar and whole tropics.

Surface-100 hPa: During summer warmer over north temperate compared to north polar, south temperate, equator and the whole tropics. During autumn cooler over equator compared to north subtropic, south temperate and whole tropics.

East Coast North (Table 5-i):

Surface: During winter cooler over south polar compared to north temperate, equator, south subtropic and whole tropics. During autumn cooler over south temperate compared to south subtropic and whole tropics.

Troposphere: During winter cooler over south polar compared to north temperate, north subtropic, south subtropic, whole tropics. During spring warmer over south subtropic compared to south temperate. During summer cooler over equator compared to north temperate, north subtropic, south subtropic, whole tropics; warmer over north temperate compared to south temperate; warmer over south subtropic compared to tropics. During autumn cooler over equator compared to north temperate, north subtropic, south subtropic, south polar, whole tropics; warmer over south subtropic and south polar compared to whole tropics.

Tropopause: During winter warmer over north subtropic compared to equator, south temperate, south polar; warmer over south subtropic compared to equator, south temperate, south polar, tropics; warmer over whole tropics compared to south temperate and equator. During spring warmer north subtropic compared to equator and whole tropics; cooler over equator compared to south subtropic and whole tropics. During summer cooler over equator compared to north temperate, north subtropic, south subtropic, south polar and whole tropics; warmer over north subtropic and south subtropic compared to whole tropics. During autumn cooler over equator compared to north polar, north temperate north subtropic, south subtropic, south temperate, whole tropics; cooler over tropics compared to north temperate, north subtropic, whole tropics.

Surface-100 hPa: During winter cooler over south polar compared to north polar, north temperate, north subtrpic, south subtropic, tropics; cooler over equator compared to south subtropic, tropics; warmer over south subtropic compared to south temperate and tropics. During spring cooler over south temperate compared to north subtropic, south subtropic; cooler over equator compared to south subtropic, tropics. During summer cooler over equator compared to north polar, north subtropic, south subtropic, tropics; warmer over north temperate compared to equator, south temperate, whole tropics; warmer south subtropic compared to south temperate, whole tropics. During autumn warmer over north temperate compared to equator, south temperate, tropics; cooler over equator compared to north subtropic, south subtropic, south temperate, whole tropics; warmer over south subtropic compared to whole tropics.

East Coast South (Table 5-j):

Surface: During autumn warmer over south subtropic compared to south temperate.

Troposphere: During winter cooler over south temperate compared to north temperate, north subtropic, south subtropic. During summer cooler over north polar compared to north temperate and south polar. During autumn cooler over equator compared to north subtropic, south subtropic, south temperate, whole tropics.

Tropopause: During summer cooler over equator compared to north polar, north temperate, north subtropic, south subtropic, whole tropics. During autumn cooler over equator compared to north temperate, north subtropic, south subtropic, whole tropics; cooler over south polar compared to north temperate, north subtropic, south subtropic, south temperate.

Surface-100 hPa: During winter cooler over south temperate compared to north subtropic and whole tropics. During summer cooler over north polar compared to north temperate; warmer over south polar compared to equator. During autumn cooler over equator compared to north subtropic, south subtropic, south temperate, whole tropics.

South Peninsular India (Table 5-k):

Surface: During summer warmer over south polar compared to south temperate.

Troposphere: During winter cooler over south temperate compared to both north subtropic and south subtropic. During summer cooler over north polar compared to north temperate and south polar. During autumn cooler over equator compared to north subtropic, south temperate, whole tropics.

Tropopause: During summer warmer over north polar compared to equator.

Surface-100 hPa: During winter cooler over south temperate compared to north subtropic and whole tropic. During summer cooler over north polar compared to north temperate and south polar. During autumn cooler over equator compared to north subtropic, south temperate and whole tropics.

Whole India (Table 5-l):

Surface: During both the summer and autumn, cooler over south temperate compared to north polar and south subtropic respectively.

Troposphere: During winter cooler over south polar compared to north temperate, north subtropic and south subtropic. During spring cooler over equator compared to tropics, south subtropic; and warmer over south subtropic compared to south temperate. During summer cooler over equator compared to north polar, north temperate, north subtropic, south polar, south subtropic and whole tropics; warmer over north temperate compared to south temperate and tropics; warmer over south temperate compared to the whole tropics. During autumn cooler over equator compared to north temperate, north subtropic, south subtropic, south polar and the whole tropics; warmer over south polar compared to the whole tropics.

Tropopause: During winter cooler over south polar compared to north polar, north subtropic, equator, south subtropic, south temperate and the whole tropics; cooler over equator compared to north subtropic, south subtropic, whole tropics; cooler over south temperate compared to north subtropic, south subtropic, whole tropics; warmer over south subtropic compared to whole tropics. During spring cooler over equator compared to north subtropic, south subtropic, north temperate and whole tropics; warmer north subtropic compared to whole tropics. During summer cooler over equator compared to north polar, north temperate, north subtropic, south subtropic, whole tropics; cooler over tropics compared to north subtropic and south subtropic. During autumn cooler over equator compared to north polar, north temperate, north subtropic, south subtropic, whole tropics; cooler over whole tropics compared to north temperate, north subtropic and south subtropic.

Surface-100 hPa: During winter cooler over south polar compared to north polar, north temperate, north subtropic, south subtropic, whole tropics and equator; cooler over equator compared to south tropic and whole tropics; warmer over north subtropic compared to south temperate. During spring cooler over equator compared to north temperate, north subtropic, south subtropic and whole tropics; cooler over south temperate compared to north temperate, north subtropic and south subtropic. During summer cooler over equator compared to north polar, north temperate, north subtropic, south subtropic, south polar and the whole tropics; warmer over north temperate compared to south temperate and the whole tropics; cooler over the whole tropics compared to north subtropic and south subtropic. During autumn warmer over north temperate compared to equator, south temperate and whole tropics; cooler over equator compared to north subtropic, south subtropic, south temperate and the whole tropics; cooler over the whole tropics compared to north subtropic and south subtropic.

4.2.3.1 SEASON DIFFERENCE

The CC of difference in the seasonal temperature departures from one season to the following seasons(s) of the concurrent year with the area averaged summer monsoon OLR over different 11 zones as well as the whole India during 1974-2005 presented in the **table 6 (a-l)**. The CC values presented in these tables are significant at 5% level and those superscripted with * indicates significant at 1% level and above. The thermal conditions which may help in developing the convective activities/cloudiness in turn assumed to be associated with rainfall activities over the respective zones are as under-

Extreme North India (Table 6-a):

Surface: Warmer over northern hemisphere during winter compared to spring; warmer over north polar during winter compared to autumn.

Tropopause: Warmer over globe during summer compared to autumn.

North West India (Table 6-b):

Surface: warmer over northern hemisphere and north polar during winter compared to spring and autumn respectively.

Tropopause: Warmer over globe during summer compared to autumn.

Ganga Plains (Table 6-c):

Surface: Cooler over south temperate, south polar and southern hemisphere during winter compared to spring; warmer over north subtropic during summer and autumn compared to winter.

Troposphere: Warmer over south polar during both summer and autumn compared to spring.

Tropopause: Warmer over north subtropic during winter compared to autumn; warmer over globe, southern hemisphere during summer compared to autumn.

Surface-100 hPa: Cooler over south temperate and southern hemisphere during winter compared to spring; warmer over northern hemisphere during winter compared to autumn.

Central India (Table 6-d):

Surface: Cooler over southern hemisphere during winter compared to spring; cooler over north subtropic during winter compared to autumn.

Troposphere: Cooler over south polar during spring compared to autumn.

Tropopause: Warmer over north subtropic during winter compared to autumn; warmer over globe, north subtropic, northern hemisphere, southern hemisphere during summer compared to autumn.

Surface-100 hPa: Cooler over southern hemisphere during winter compared to spring; warmer over northern hemisphere during winter compared to autumn.

North East India (Table 6-e):

Surface: Cooler over south temperate and southern hemisphere during winter compared to spring.

Troposphere: Warmer over south subtropic and tropic during winter compared to autumn.

Tropopause: cooler over south subtropic during spring compared to summer; warmer over globe and south subtropic during summer compared to autumn.

West Coast (Table 6-f):

Surface: Warmer north polar during winter compared to autumn.

Troposphere: Warmer over equator and tropic during spring compared to autumn; warmer over equator, tropic and cooler over south temperate during summer compared to autumn.

Tropopause: Warmer over equator during spring compared to summer; warmer over equator and tropic during spring compared to autumn.

Surface-100 hPa: Warmer over equator and tropic during spring compared to autumn.

West Coast South (Table 6-g):

Surface: Warmer over north polar during winter compared to autumn.

Troposphere: Warmer over equator, south subtropic, tropic during spring compared to autumn; warmer over equator, south temperate and tropic during summer compared to autumn.

Tropopause: Warmer over south polar during winter compared to spring; warmer over equator during spring compared to summer; warmer over equator and tropic during spring compared to autumn.

Surface-100 hPa: Warmer over equator and tropic during spring compared to autumn.

Central Peninsular India (Table 6-h):

Troposphere: Warmer over equator and tropic during spring compared to autumn; cooler over south temperate during summer compared to autumn.

Tropopause: Warmer over south temperate during summer compared to autumn.

Surface-100 hPa: Warmer over equator and tropic during spring compared to autumn.

East Coast North (Table 6-i):

Surface: Cooler over southern hemisphere during winter compared to spring.

Tropopause: Warmer over globe, south subtropic, tropic, southern hemisphere during summer compared to autumn.

Surface-100 hPa: Warmer over globe, southern hemisphere during summer compared to autumn.

East Coast South (Table 6-j):

Troposphere: warmer over equator and tropic during spring compared to autumn.

Tropopause: Warmer over equator during spring compared to summer; warmer over south polar, southern hemisphere during spring compared to autumn; warmer over globe, south polar, southern hemisphere during summer compared to autumn.

Surface-100 hPa: Warmer over equator and tropic during spring compared to autumn; warmer over south polar and southern hemisphere during summer compared to autumn.

South Peninsular India (Table 6-k):

Surface: Warmer over north polar during winter compared to autumn.

Tropopause: Warmer over south polar during winter compared to spring; cooler over equator during both summer and autumn compared to spring.

Surface-100 hPa: Warmer over equator during spring compared to autumn; warmer over south polar during summer compared to autumn.

Whole India (Table 6-l):

Surface: Cooler over south temperate and southern hemisphere during winter compared to spring

Troposphere: Warmer over tropics during winter and cooler over south polar during spring compared to autumn.

Tropopause: Warmer over globe, south subtropic and southern hemisphere during summer compared to autumn.

4.2.4 LEEVL DIFFERENCE

The CC of the regional/hemispheric/globe seasonal temperature departures between surface air and upper air with the area averaged summer monsoon OLR over different 11 zones as well as the whole India during 1974-2005 presented in the **table 7 (a-l)**. The CC values presented in these tables are significant at 5% level and those superscripted with * indicates significant at 1% level and above. The thermal conditions which may help in developing the convective activities/cloudiness in turn assumed to be associated with rainfall activities over the respective zones are as under-

Extreme North India (Table 7-a):

Winter: Warmer surface air over southern hemisphere compared to troposphere; cooler tropopause over globe compared to surface air as well as troposphere; warmer troposphere over equator and northern hemisphere compared to tropopause.

Spring: Warmer surface air over north polar compared to troposphere.

Autumn: warmer surface air over equator compared to troposphere; warmer surface air over globe, equator compared to tropopause.

North West India (Table 7-b):

Winter: Cooler troposphere over southern hemisphere and cooler tropopause over globe compared to surface air.

Autumn: Warmer surface air over equator, north subtropic and tropic compared to troposphere; warmer surface air over globe, north temperate, northern hemisphere compared to tropopause.

Ganga Plains (Table 7-c):

Winter: Cooler troposphere and tropopause over globe, equator, south temperate, south hemisphere compared to surface air; warmer surface air over south subtropic, south polar, tropic, northern hemisphere compared to troposphere; cooler troposphere over globe, equator, south temperate, south polar, tropic, southern hemisphere compared to tropopause.

Spring: warmer surface air over north temperate and northern hemisphere compared to troposphere; cooler tropopause over globe, equator, tropic compared to surface air; warmer troposphere over equator, south subtropic, tropic, southern hemisphere compared to tropopause.

Summer: Warmer surface air over globe, north polar, equator, southern hemisphere compared to tropopause; warmer troposphere over globe, equator, southern hemisphere compared to tropopause.

Autumn: Warmer surface air over equator compared to troposphere; warmer surface air over globe, equator, south subtropic, south temperate, tropic, southern hemisphere compared to tropopause; warmer troposphere over globe, equator, south polar, south temperate, tropic, southern hemisphere compared to tropopause.

Central India (Table 7-d):

Winter: warmer surface air over globe, south temperate, southern hemisphere compared to troposphere; warmer surface air over globe, equator, south temperate, tropic, southern hemisphere compared to tropopause, warmer troposphere over globe, equator, south temperate, tropic, southern hemisphere compared to tropopause.

Spring: Warmer surface air over north temperate, northern hemisphere compared to troposphere; warmer surface air over equator compared to tropopause; warmer troposphere over equator, south subtropic, tropic compared to tropopause.

Summer: Warmer troposphere over southern hemisphere and globe compared to tropopause.

Autumn: Warmer surface air over equator compared to troposphere; warmer surface air over globe, equator, tropic, southern hemisphere compared to troposphere; warmer troposphere over globe, equator, south polar, southern hemisphere compared to troposphere.

North East India (Table 7-e):

Winter: Warmer surface air over equator and south temperate compared to troposphere; cooler tropopause over globe, equator, south temperate, south polar, tropics, southern hemisphere compared to surface air as well as troposphere; warmer surface air over north temperate compared to tropopause.

Spring: Warmer surface air over south temperate compared to troposphere; cooler tropopause over globe, equator, south subtropic, tropic, northern hemisphere, southern hemisphere compared to surface air as well as troposphere; warmer surface air over south temperate compared to tropopause.

Summer: warmer surface air over equator compared to troposphere; warmer surface air and troposphere over globe, equator, tropic, southern hemisphere compared to tropopause.

Autumn: Warmer surface air over equator compared to troposphere; cooler tropopause over globe, equator, south subtropic, tropic, south hemisphere compared to surface air as well as troposphere; warmer troposphere over south temperate compared to tropopause.

West Coast (Table 7-f):

Winter: Warmer troposphere over northern hemisphere compared to tropopause.

West Coast South (Table 7-g):

Winter: Warmer troposphere over northern hemisphere compared to tropopause.

Central Peninsular India (Table 7-h):

Winter: Warmer troposphere over north temperate, equator, northern hemisphere compared to tropopause.

Summer: Cooler surface air over north temperate compared to troposphere

Autumn: Warmer troposphere over globe, south polar, southern hemisphere compared to tropopause.

East Coast North (Table 7-i):

Winter: Warmer surface air over globe, equator, south temperate, southern hemisphere compared to troposphere and tropopause; warmer surface air over north temperate, south subtropic, tropic, northern hemisphere compared to tropopause; warmer troposphere over globe, north temperate, equator,, south temperate, tropics, southern hemisphere compared to tropopause.

Spring: Cooler surface air over northern hemisphere compared to troposphere; warmer surface air over globe, equator, south subtropic, tropic, northern hemisphere, southern hemisphere compared to tropopause; warmer troposphere over globe, equator, south subtropic, tropic, northern hemisphere, southern hemisphere compared to tropopause.

Summer: Cooler surface air over north temperate compared to troposphere; warmer surface air over globe, equator, tropic, south hemisphere compared to tropopause; warmer troposphere over globe, equator, tropic, northern hemisphere, southern hemisphere compared to tropopause

Autumn: Warmer surface air over north polar and equator compared to troposphere; warmer surface air over globe, equator, south subtropic, tropic, northern hemisphere, southern hemisphere compared to tropopause; warmer troposphere over globe, equator, south subtropic, tropic, northern hemisphere, southern hemisphere compared to tropopause.

East Coast South (Table 7-j):

Winter: Warmer troposphere over equator and tropics compared to tropopause.

Summer: Cooler surface air over north temperate compared to troposphere; warmer troposphere over equator compared to tropopause.

Autumn: Cooler surface air over south temperate compared to troposphere but warmer over south polar compared to tropopause; warmer troposphere over globe, south polar, southern hemisphere compared to tropopause.

South Peninsular India (Table 7-k):

Winter: Warmer troposphere over equator compared to tropopause.

Autumn: Cooler surface air over south temperate compared to troposphere.

Whole India (Table 7-l):

Winter: Surface air warmer over globe, south temperate, southern hemisphere, equator compared to troposphere and tropopause; warmer surface air over north temperate, south subtropic, south polar, tropic, northern hemisphere compared to tropopause; warmer troposphere temperature over globe, north temperate, equator, south temperate, south polar, tropic, northern hemisphere and southern hemisphere compared to tropopause

Spring: Warmer surface air over northern hemisphere compared to troposphere and tropopause; warmer surface air over globe, equator, tropic compared to tropopause. Warmer troposphere over globe, equator, south subtropic, tropic and southern hemisphere compared to tropopause.

Summer: Cooler surface air over north temperate warmer equator compared to troposphere; cooler tropopause over globe, equator, tropic, southern hemisphere compared to surface air and troposphere.

Autumn: Warmer surface air over equator and tropic compared to troposphere and tropopause; cooler tropopause over globe, equator, tropic, south subtropic, south temperate, northern hemisphere, southern hemisphere compared to surface air and troposphere; warmer troposphere over north temperate compared to tropopause.

5. SUMMARY AND CONCLUSION

(i) Broadly speaking OLR over and across India shows decreasing trend whereas rainfall shows variety of fluctuations (increasing, decreasing or stationary) over the whole country as well as different regions but on grid scale the correlation between the two parameters is negative, though with large spatial variation, consistent with physical understanding;

(ii) The correlation between OLR and rainfall is always negative and highly significant in most of the cases but, in general, it is region specific and period specific. The relation is stronger for smaller regions with monthly data.

(iii) Rising trend in standard isobaric levels and spreading of the cloud layer (700-300 hPa) associated with global warming appear to be the main cause of the changing relationship between OLR and rainfall over India;

(iv) The tropopause temperature gradient from north subtropic to equator during summer season (June-August) significantly influences the convection over and across the country during monsoon season. But the correlation is weak with rainfall; and

(v) The tropospheric temperature gradient during winter and spring can be used as reliable predictor for the combined convection-rainfall activities during the monsoon season for major parts of the country.

In conclusion, we would like to state that perhaps the efficiency of cloud to rainfall processes over the country has declined due to decrease in the frequency of rain-producing disturbances over and around the region; and the low OLR values over the country is due to accumulation of the clouds that did not rain. This was the main reason of subdued rainfall activities over India in the past few decades. Fluctuations of equatorial, tropical and subtropical circulations around the Indian region are being examined in order to understand the possible causes of decline in the frequency of the rain-producing disturbances.

Acknowledgements:

The authors are grateful to Prof. B.N. Goswami, Director, Indian Institute of Tropical Meteorology, Pune for the necessary facilities to carry out this research work. The authors also thank Mr. S.D. Patil who go through the whole manuscript. The rainfall data used in this study was obtained from India Meteorological Department, Pune. The authors also would like to take the privilege to acknowledge the NOAA-CIRES Climate Diagnostics Center, Boulder, Colorado, USA, from where the interpolated OLR data for this study (Web site at http://www.cdc.noaa.gov/) were obtained.

REFERENCES

Arkin P.A., 1979: The relationship between fractional coverage of high-cloud and rainfall accumulations during GATE over the B-scale array. *Monthly Weather Review*, 107, pp. 1382-1387.

Arkin P.A., 1984: An examination of the southern oscillation in the upper tropospheric tropical and subtropical wind field. *Ph. D. Dissertation, University of Maryland,* 240 pp.

Arkin P.A., and B.N. Meisner, 1987: The relationship between large-scale convective rainfall and cold cloud over the Western Hemisphere during 1982-84. *Monthly Weather Review*. 115, pp. 51-74.

Arkin P, Rao A.V.R.K., Kelkar R.R., 1989: Large-scale precipitation and longwave radiation from INSAT-1B during the 1986 Southwest monsoon season, *J. Climate*, **2**, Pp. 619-628.

Angell, J.K., 1990: Temperature anomalies, In: Trends "90, A Compendium of Data on Global Change, (Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee, U.S.A., 37831-6335), 198-209.

Arvind V. Gambheer, and G.S. Bhat, 2000: Life cycle characteristics of deep cloud systems over the Indian Region using INSAT-1B pixel data. *Monthly Weather Review*, 128, 4071-4083.

Gadgil, S., A. Guruprasad & J Srinivasan, 1992: Systematic bias in the NOAA outgoing longwave radiation dataset. *J. Climate*, **5**, Pp. 867-875.

Gill, A.E., and E.M. Rasmusson, 1983: The 1982-83 climate anomaly in the equatorial pacific, *Nature*, 305, pp. 229-234.

Gruber, A., and A.F. Krueger, 1984: The status of the NOAA outgoing longwave radiation data set, *Bull. Amer. Meteo. Soc.*, **65**, **9**, Pp. 958-962.

Gruber, A. and J. S. Winston, 1978: Earth Atmosphere Radiative heating based on NOAA Scanning Radiometer measurements, *Bull. Amer. Meteo. Soc.*, **59**, **12**, pp. 1570-1573.

Horel, J., A.N. Hahmann, and J.E. Geisler, 1989: An investigation of the annual cycle of convective activity over the tropical Americas. *J. Climate,* 2, pp. 1388-1403.

Huffman, G. J., R.F. Adler, R.B. Rudlof, U. Schneider, and P.R. Keehn, 1995: Global precipitation estimates based on a technique for combining satellite-based estimates, rain gauge analysis, and NWP model precipitation information. *J. Climate*, 8, pp. 1284-1295.

Huffman G. J. and coauthors, 1997: The Global Precipitation Climatology Project (GPCP) combined precipitation dataset, *Bull. Amer. Meteor. Soc.*, **78**, pp. 5-20.

Janowiak, J.E., and P.A. Arkin 1991: Rainfall variation in the tropics during 1986-1989, as estimated from observations of cloud-top temperature. *J. Geophys. Res.*, 96, pp. 3359-3373.

Kalnay, E., et al., 1996: The NCEP/NCAR 40-year reanalysis project, *Bulletin of the American Meteorological Society*, 77, 3, pp. 437-471.

Kidder, S.Q., and T. H. Vonder Haar, 1995: Satellite Meteorology, an introduction. *Academic Press*, pp. 466.

Lau, K.M., and P.H. Chan, 1983: Short term climate variability and atmospheric teleconnections from satellite-observed outgoing longwave radiation. I: Simulteneous relationships. *J. Atmos. Sci.* 40, pp. 2735-2750.

Lau, K.M., and P.H. Chan, 1985: Aspects of the 40-50 day oscillation during the northern winter as infrared from outgoing longwave radiation. *Monthly Weather Review*, 113, pp. 1889-1909.

Lau, K.M., and P.H. Chan, 1988: Intraseasonal and interannual variations of tropical convection: A possible link between the 40-50 day oscillation and ENSO? *J. Atmos. Sci.* 45, pp. 506-521.

Liebmann B, and D.L. Hartmann, 1982: Interannual variations of outgoing IR associated with tropical circulation changes during 1974-1978. *J. Atmos. Sci.* 39, pp. 1153-1162.

Liebmann B., and C.A. Smith, 1996: Description of a complete (interpolated) Outgoing Longwave Radiation dataset, *Bull. Amer. Meteor. Soc.*, **77**, pp. 1275-1277.

Lucas, L.E., D.E. Waliser, P.Xie, J.E. Janowiak; B. Liebmann, 2001: Estimating the Satellite Equator Crossing Time biases in the daily, global outgoing longwave radiation dataset, *J. Climate*, **14**, pp. 2583-2605.

Morrissey, M.L., 1986: A statistical analysis of the relationships among rainfall, outgoing longwave radiation and the moisture budget during January-March 1979. *Monthly Weather Review*, 114, pp. 931-942.

Motell, C.E., and B.C. Weare 1987: Estimating tropical Pacific rainfall using digital satellite data. *J. Applied Meteor.*, 26, pp. 1436-1446.

Murakami T., 1980: Empirical orthogonal function analysis of satellite-observed outgoing longwave radiation during summer. *Monthly Weather Review*, 108, 205-222.

Ohring, G., and A. Gruber, 1982: Satellite radiation observations and climate theory. *Advances in Geophysics*, Vol. 25, Academic Press, 237-304.

Rasmusson, E.M., and J.M. Wallace, 1983: Meteorological aspects of the El Nino/ Southern Oscillation. *Science*, 222, pp. 1195-1202.

Singh, H.N, 2004: Investigations into relationship between extreme wet/dry conditions over India and space-based OLR observation over global tropics, *M. Tech. Thesis, Andhra University*, 106 pp

Singh, N. and N.A. Sontakke, 1996: The instrumental period rainfall series of the Indian region: a documentation, *Research Report* No. RR. **067**, *Indian Institute of Tropical Meteorology, Pune,* 79 pp.

Singh, N., N.A. Sontakke, and H.N. Singh, 2005: Indian Atlas of Rainfall Spatio Temporal variations, Volumes I–IV (under publication). *Indian Institute of Tropical Meteorology, Pune,* Volumes I (322 pp), II (173 pp), III (165 pp), IV (210 pp).

Singh, N. and Patwardhan, S.K., 2002: Effect of global atmospheric thermal conditions on the monsoons of the Indian region, *Korean J. Atmos. Sci,* vol. 5, S, 39-54.

Singh,N., Pant, G.B., and Mulye, S.S., 1991:A statistical package for constructing representative area-averaged rainfall series and its updating using selected stations data, Proc. National Seminar on the Use of Computers in Hydrology and water resources,, 16-18 December 1991, Vol. II pp. 122-134, IIT, Delhi.

Sontakke, N. A., & Nityanand Singh, 1996: Longest instrumental regional and all India summer monsoon rainfall series using optimum observations: reconstruction and update, *The Holocene*, **6**, 3, Pp. 315-331.

Waliser, D.E., and W. Zhou, 1997: Removing satellite equatorial crossing time biases from the OLR & HRC dataset, *J. Climate*, **10**, Pp. 2125-2146.

Waliser, D. E., N.E. Graham, and C. Gautier, 1993: Comparison of the Highly Reflected Cloud and Outgoing Longwave Radiation Datasets for use in estimating Tropical Deep Convection. *J. Climate*, 6, pp. 331-353.

Weickmann, K.M., 1983: Intraseasonal circulation and outgoing longwave radiation modes during northern hemisphere winter. *Monthly Weather Review*, 111, pp. 1838-1858.

Weickmann, K.M., G.R. Lussky, and J.E. Kutzbach, 1985: A global-scale analysis of intraseasonal fluctuations of outgoing longwave radiation and 250 mb stream function during northern winter. *Monthly Weather Review*, 112, 941-961.

Willium, M., and R.A. Houze Jr., 1987: Satellite-observed characteristics of winter monsoon cloud clusters. *Monthly Weather Review*, 115, 505-519.

World Meteorological Organisation(WMO), 1966: Climatic Change, *WMO Technical Note* No. 79, WMO No. 195-TP-100.

Xie, P. and P. A. Arkin, 1996: Analyses of global monthly precipitation using gauge observations, satellite estimates, and numerical model predictions, *J. Climate*, 9, pp. 840-858.

Xie, P. and A. Arkin 1997: Global precipitation: A 17-year monthly analysis based upon gauge observations, satellite estimates and model outputs, *Bull. Amer. Meteor. Soc.*, **78**, Pp. 2539-2558.

Xie, P. and A. Arkin, 1998: Global monthly precipitation estimates from satellite observed outgoing longwave radiation. *J. Climate*, **11**, Pp. 137-164.

Yoo, J.-M. and J.A. Carton, 1988: Spatial dependence of the relationship between rainfall and Outgoing Longwave Radiation in the Tropical Atlantic, *J. Climate*, **1**, Pp. 1047-1054.

Table 1: Table showing the ECTs in local solar time (LST), period of data record, instruments onboard & window channel radiometers for those satellites used.

Satellite	ECT (LST)	Period of record	No. of days	Instruments onboard	Window channel & sensor used
NOAA-SR series NOAA 3 NOAA 2 NOAA 3 NOAA 4 NOAA 5	0850 0830 0850 0840 0840	01Jun74 – 30Jun74 01Jul74 – 15Oct74 16Oct74 – 16Dec74 17Dec74 – 14Sep76 15Sep76 – 28Feb78		2VHRR, 2VTPR, 2SR, SPM	10.5-12.5 μm SR Series (VHRR)
No Satellite	****	**01Mar78-31Dec78**	****	****	****
TIROS N	0330	01Jan79 - 31Jan80	396	AVHRR/1,HIRS/2, SSU, MSU, SEM, DCS	10.5-11.5 μm AVHRR
NOAA 6	0730	01Feb80 – 06Sep81	584	AVHRR/1,HIRS/2,SSU, MSU, SEM, DCS	10.5-11.5 μm AVHRR
NOAA 7	0230	07Sep81 – 04Feb85	1247	AVHRR/1,HIRS/2, SSU,MSU, SEM, DCS	11.5-12.5 μm AVHRR/2
NOAA 9 *	0220	05Feb85 – 07Nov88	1372	AVHRR/2,HIRS/2,SSU,MSU, DCS, ERBE, SBUV/2, SAR	11.5-12.5 μm AVHRR/2
NOAA 10 *	0730	08Nov88 - 30Nov88 01Jul90 – 04Jul90 05Mar91 13Mar91 14Aug91	23 4 1 1 1	AVHRR/1,HIRS/2,SEM,MSU, DCS, ERBE, SAR	11.5-12.5 μm AVHRR
NOAA 11 *	0130	01Dec88 –30Jun90 05Jul90 – 04Mar91 06Mar91– 12Mar91 14Mar91– 13Aug91 15Aug91– 14Oct92 16Oct92 – 01Feb94 03Feb94 – 13Sep94	577 243 7 153 427 474 223	AVHRR/2,HIRS/2,SSU,MSU, SBUV/2, SEM, DCS, S&R	11.5-12.5 μm AVHRR/2
NOAA 12	0600	15Oct92 02Feb94 14Sep94 – 31Jan95 29Jun95 17May96–18May96	1 1 140 1 2	AVHRR/1,HIRS/2, MSU, DCS	11.5-12.5 μm AVHRR/2
NOAA 14	0230	01Feb95 – 28Jun95 30Jun95 – 16May96 19May96–28Feb '01	148 322 1741	AVHRR/3, HIRS/3, AMSU-A, AMSU-B, SBUV/2, SEM/2, DCS/2, S&R/2	11.5-12.5 μm AVHRR/2
NOAA 16	0150	01Mar'01 07Aug'05	1621	AVHRR/3, HIRS/3, AMSU-A, AMSU-B, SBUV/2, SEM/2, DCS/2, S&R/2, MHS, EPS	11.5-12.5 μm AVHRR/2
NOAA 18	0155	08Aug05–31Dec'05	146	AVHRR/3, HIRS/3, AMSU-A, AMSU-B, SBUV/2, SEM/2, DCS/2, S&R/2, MHS, EPS	11.5-12.5 μm AVHRR/2

Table 2: Least square linear trend in OLR ($W/m^2/yr$), rainfall (mm/yr) and their CC over the period 1974 - 2005 for the 11 zones and the whole country (* is significant at 5% and ** at 1% and above).

Period	Parameters		Extreme North India	North West India	Ganga Plains	Central India	North East India	West Coast	West Coast (South)	Central Peninsular India	East Coast (North)	East Coast (South)	South Peninsular India	All India
June	OLR trend	**b**	-0.32	-0.51	-0.71	-0.63	-0.33	-0.24	-0.24	-0.33	-0.52	-0.19	-0.14	-0.44
		r	-0.42	-0.45	-0.49	-0.41	-0.44	-0.21	-0.20	-0.27	-0.42	-0.14	-0.11	-0.56
	Rain trend	**b**	0.32	0.71	0.54	0.58	0.99	0.36	-0.16	-0.35	0.54	0.43	-0.06	0.51
		r	0.09	0.19	0.11	0.11	0.16	0.03	-0.01	-0.10	0.09	0.11	-0.01	0.16
	CC (OLR Vs Rain)	**R**	**-.070****	**-0.81****	**-0.78****	**-0.80****	**-0.57****	**-0.69****	**-0.74****	**-0.45****	**-0.47****	**-0.06**	**-0.67****	**-0.74****
July	OLR trend	**b**	-0.14	-0.25	-0.21	-0.24	-0.32	-0.05	-0.04	-0.13	-0.31	-0.13	-0.08	-0.28
		r	-0.11	-0.17	-0.22	-0.28	-0.41	-0.05	-0.03	-0.13	-0.34	-0.13	-0.09	-0.47
	Rain trend	**b**	-2.38	-0.99	-1.93	0.41	-1.74	-2.43	-1.79	-0.10	0.33	-0.79	-1.91	-1.18
		r	-0.27	-0.14	-0.27	0.06	-0.22	-0.20	-0.16	-0.02	0.06	-0.19	-0.24	-0.25
	CC (OLR Vs Rain)	**R**	**-0.72****	**-0.75****	**-0.68****	**-0.72****	**-0.26**	**-0.77****	**-0.72****	**-0.59****	**-0.28**	**-0.19**	**-0.67****	**-0.25**
August	OLR trend	**b**	-0.22	-0.11	-0.37	-0.18	-0.40	-0.08	-0.12	-0.15	-0.42	-0.22	-0.10	-0.30
		r	-0.23	-0.11	-0.38	-0.20	-0.46	-0.07	-0.09	-0.15	-0.54	-0.23	-0.10	-0.51
	Rain trend	**b**	-0.56	-2.17	-1.16	-2.50	1.47	-2.04	-2.10	-0.21	-1.25	0.08	-1.64	-1.10
		r	-0.07	-0.32	-0.18	-0.40	0.19	-0.24	-0.28	-0.04	-0.22	0.02	-0.32	-0.30
	CC (OLR Vs Rain)	**R**	**-0.69****	**-0.51****	**-0.63****	**-0.41***	**-0.66****	**-0.38***	**-0.48****	**-0.67****	**-0.28**	**-0.57****	**-0.56****	**-0.18**
Sept	OLR trend	**b**	-0.24	-0.29	-0.46	-0.41	-0.36	0.02	0.01	-0.14	-0.40	-0.13	-0.002	-0.31
		r	-0.27	-0.24	-0.35	-0.29	-0.38	0.01	0.01	-0.10	-0.39	-0.11	-0.001	-0.43
	Rain trend	**b**	0.67	0.81	0.70	1.11	0.37	-1.91	-2.23	-1.68	-0.71	-0.51	-1.53	0.17
		r	0.09	0.13	0.10	0.16	0.05	-0.20	-0.25	-0.25	-0.11	-0.10	-0.22	0.04
	CC (OLR Vs Rain)	**R**	**-0.72****	**-0.83****	**-0.81****	**-0.86****	**-0.69****	**-0.75****	**-0.75****	**-0.81****	**-0.73****	**-0.83****	**-0.81****	**-0.61****
Monsoon	OLR trend	**b**	-0.23	-0.29	-0.22	-0.37	-0.35	-0.09	-0.10	-0.19	-0.41	-0.17	-0.08	-0.33
		r	-0.35	-0.36	-0.28	-0.47	-0.60	-0.12	-0.12	-0.27	-0.62	-0.26	-0.12	-0.67
	Rain trend	**b**	-1.95	-1.65	-1.84	-0.41	1.09	-6.03	-6.28	-2.35	0.33	-0.78	-5.13	-1.60
		r	-0.12	-0.12	-0.15	-0.03	0.07	-0.28	-0.28	-0.18	0.02	-0.09	-0.30	-0.17
	CC (OLR Vs Rain)	**R**	**-0.67****	**-0.66****	**-0.60****	**-0.62****	**-0.47****	**-0.68****	**-0.68****	**-0.52****	**-0.41***	**-0.42***	**-0.61****	**-0.28**
Post-Monsoon	OLR trend	**b**	0.27	0.21	0.09	0.01	0.03	-0.30	-0.37	-0.20	-0.24	-0.33	-0.36	0.001
		r	0.42	0.37	0.18	0.01	0.08	-0.38	-0.43	-0.27	-0.33	-0.40	-0.42	0.001
	Rain trend	**b**	-0.09	-0.79	-0.04	0.45	2.68	0.96	1.92	0.39	3.66	1.43	1.79	0.41
		r	-0.02	-0.26	-0.01	0.10	0.35	0.11	0.17	0.07	0.36	0.10	0.13	0.12
	CC (OLR Vs Rain)	**R**	**-0.53****	**-0.44***	**-0.41***	**-0.34**	**-0.05**	**-0.78****	**-0.81****	**-0.71****	**-0.44***	**-0.75****	**-0.82****	**-0.42***

Table 3: Linear Trend (ºC/10-year) in the seasonal and annual temperature departures of the surface air, the troposphere and the tropopause over different climatic zones, the two hemispheres and the whole globe: 1958-2005

Zones	Surface					Troposphere					Tropopause				
	Win	Spr	Sum	Aut	Ann	Win	Spr	Sum	Aut	Ann	Win	Spr	Sum	Aut	Ann
North Polar	0.336	0.298	0.164	0.251	0.262	-.007	0.033	0.114	0.017	0.039	-.373	-.453	-.228	-.198	-.313
N Temp	0.325	0.212	0.109	0.148	0.199	0.129	0.091	0.192	0.113	0.131	-.134	-.191	-.163	-.107	-.149
N Subtr	0.249	0.225	0.180	0.236	0.223	0.002	0.027	0.067	0.049	0.037	-.156	-.139	-.153	-.208	-.164
Equat	0.206	0.234	0.215	0.173	0.207	0.060	0.011	0.030	0.029	0.033	-.416	-.366	-.388	-.457	-.406
S Subtr	0.168	0.256	0.215	0.235	0.218	0.170	0.184	0.133	0.113	0.150	-.062	-.058	-.0001	-.030	-.038
S Temp	-.084	-.031	-.030	-.063	-.052	0.007	0.095	0.074	0.014	0.047	-.409	-.258	-.262	-.299	-.307
South Polar	0.188	-.032	0.149	0.272	0.144	0.179	0.075	0.225	0.241	0.180	-.892	-.270	0.017	-.537	-.421
Trop	0.208	0.238	0.200	0.215	0.215	0.100	0.078	0.077	0.064	0.080	-.211	-.187	-.180	-.228	-.202
N. Hemi	0.282	0.234	0.158	0.198	0.218	0.053	0.051	0.110	0.062	0.069	-.228	-.246	-.208	-.210	-.223
S. Hemi	0.094	0.071	0.121	0.131	0.104	0.111	0.108	0.111	0.087	0.104	-.375	-.212	-.150	-.275	-.253
Whole Globe	0.188	0.174	0.140	0.166	0.167	0.082	0.080	0.111	0.075	0.087	-.301	-.206	-.169	-.243	-.230

Table 4-a: CC of the concurrent year seasonal temperature departures of the surface air, the troposphere, the tropopause and the surface–100 hPa layer over different climatic zones, the two hemispheres and the whole globe with the area-averaged JJAS OLR over ENI during 1974-2005. (* is significant at 5%; ** at 1% level)

Surface		Region		Troposphere	Tropopause		Region		Surface – 100 hPa
WINTER									
-0.26 (NH)	-0.22	N Pol	-0.07	-0.26 (NH)	0.32 (NH)	0.12	N Pol	0.01	-0.10 (NH)
	-0.16	N Tmp	-0.13			0.31	N Tmp	-0.06	
-0.29 (Glob)	-0.17	N Sbtrp	-0.40*	-0.03 (Glob)	0.42* (Glob)	0.18	N Sbtrp	-0.27	0.14 (Glob)
	-0.26	Equat	-0.01			0.33	Equat	0.12	
-0.29 (Trop)	-0.29	S Sbtrp	-0.15	-0.09 (Trop)	0.27 (Trop)	0.07	S Sbtrp	-0.16	-0.07 (Trop)
	-0.13	S Tmp	0.25			0.37	S Tmp	0.43*	
-0.26 (SH)	-0.001	S Pol	0.22	0.23 (SH)	0.40* (SH)	0.37	S Pol	0.34	0.32 (SH)
SPRING									
-0.26 (NH)	-0.23	N Pol	0.29	-0.06 (NH)	0.16 (NH)	0.26	N Pol	0.28	-0.05 (NH)
	-0.21	N Tmp	-0.12			0.03	N Tmp	-0.13	
-0.13 (Glob)	-0.18	N Sbtrp	-0.37	-0.08 (Glob)	0.21 (Glob)	-0.22	N Sbtrp	-0.39	0.00 (Glob)
	-0.08	Equat	0.12			0.21	Equat	0.18	
-0.10 (Trop)	0.002	S Sbtrp	-0.24	-0.16 (Trop)	0.04 (Trop)	-0.01	S Sbtrp	-0.17	-0.09 (Trop)
	0.22	S Tmp	0.07			0.18	S Tmp	0.15	
0.18 (SH)	0.07	S Pol	-0.07	-0.07 (SH)	0.19 (SH)	0.14	S Pol	0.04	0.04 (SH)
SUMMER									
-0.16 (NH)	-0.18	N Pol	-0.04	-0.20 (NH)	0.13 (NH)	0.19	N Pol	0.01	-0.09 (NH)
	-0.17	N Tmp	-0.32			0.04	N Tmp	-0.26	
-0.14 (Glob)	-0.25	N Sbtrp	-0.20	-0.12 (Glob)	0.19 (Glob)	-0.16	N Sbtrp	-0.13	-0.03 (Glob)
	0.16	Equat	0.24			0.38	Equat	0.33	
-0.08 (Trop)	-0.22	S Sbtrp	-0.22	-0.07 (Trop)	0.22 (Trop)	0.12	S Sbtrp	-0.12	0.08 (Trop)
	0.28	S Tmp	0.40*			-0.04	S Tmp	0.34	
-0.06 (SH)	-0.15	S Pol	-0.37	0.003 (SH)	0.19 (SH)	0.08	S Pol	-0.31	0.05 (SH)
AUTUMN									
-0.24 (NH)	-0.13	N Pol	0.001	-0.13 (NH)	0.34 (NH)	0.31	N Pol	0.04	-0.04 (NH)
	-0.25	N Tmp	-0.20			0.17	N Tmp	-0.19	
-0.24 (Glob)	-0.15	N Sbtrp	-0.18	-0.08 (Glob)	0.42* (Glob)	0.06	N Sbtrp	-0.12	0.09 (Glob)
	-0.18	Equat	0.51*			0.45*	Equat	0.52*	
-0.26 (Trop)	-0.32	S Sbtrp	0.03	0.12 (Trop)	0.36 (Trop)	0.25	S Sbtrp	0.01	0.22 (Trop)
	-0.11	S Tmp	0.05			0.25	S Tmp	0.15	
-0.21 (SH)	0.01	S Pol	-0.37	-0.001 (SH)	0.36 (SH)	0.17	S Pol	-0.04	0.20 (SH)

Table 4-b: CC of the concurrent year seasonal temperature departures of the surface air, the troposphere, the tropopause and the surface–100 hPa layer over different climatic zones, the two hemispheres and the whole globe with the area-averaged JJAS OLR over NWI during 1974-2005. (* is significant at 5% ; ** at 1% level)

Surface		Region		Troposphere	Tropopause		Region		Surface – 100 hPa
WINTER									
-0.29 (NH)	-0.29	N Pol	-0.08	-0.26 (NH)	0.30 (NH)	0.09	N Pol	-0.04	-0.11 (NH)
	-0.18	N Tmp	-0.15			0.39	N Tmp	-0.07	
-0.36 (Glob)	-0.18	N Sbtrp	-0.31	-0.09 (Glob)	0.35 (Glob)	0.17	N Sbtrp	-0.22	0.06 (Glob)
	-0.21	Equat	-0.04			0.27	Equat	0.09	
-0.30 (Trop)	-0.34	S Sbtrp	-0.11	-0.13 (Trop)	0.19 (Trop)	-0.06	S Sbtrp	-0.18	-0.08 (Trop)
	-0.17	S Tmp	0.22			0.35	S Tmp	0.34	
-0.35 (SH)	-0.14	S Pol	0.08	0.10 (SH)	0.30 (SH)	0.27	S Pol	0.19	0.19 (SH)
SPRING									
-0.30 (NH)	-0.20	N Pol	0.20	-0.10 (NH)	0.10 (NH)	0.19	N Pol	0.19	-0.11 (NH)
	-0.28	N Tmp	-0.16			0.04	N Tmp	-0.17	
-0.14 (Glob)	-0.22	N Sbtrp	-0.33	-0.09 (Glob)	0.08 (Glob)	-0.26	N Sbtrp	-0.39	-0.04 (Glob)
	-0.15	Equat	0.10			0.16	Equat	0.15	
-0.13 (Trop)	0.03	S Sbtrp	-0.20	-0.14 (Trop)	-0.02 (Trop)	-0.08	S Sbtrp	-0.17	-0.11 (Trop)
	0.26	S Tmp	0.05			0.17	S Tmp	0.15	
0.26 (SH)	0.13	S Pol	-0.01	-0.05 (SH)	0.11 (SH)	0.04	S Pol	0.05	0.04 (SH)
SUMMER									
-0.26 (NH)	-0.23	N Pol	-0.18	-0.24 (NH)	0.10 (NH)	0.19	N Pol	-0.11	-0.14 (NH)
	-0.34	N Tmp	-0.41*			0.05	N Tmp	-0.36	
-0.13 (Glob)	-0.26	N Sbtrp	-0.12	-0.13 (Glob)	0.14 (Glob)	-0.19	N Sbtrp	-0.08	-0.03 (Glob)
	0.19	Equat	0.28			0.31	Equat	0.34	
-0.04 (Trop)	-0.12	S Sbtrp	-0.19	-0.01 (Trop)	0.16 (Trop)	0.09	S Sbtrp	-0.10	0.10 (Trop)
	0.22	S Tmp	0.32			0.03	S Tmp	0.32	
0.06 (SH)	-0.04	S Pol	-0.25	0.05 (SH)	0.19 (SH)	0.06	S Pol	-0.19	0.10 (SH)
AUTUMN									
-0.33 (NH)	-0.14	N Pol	0.003	-0.18 (NH)	0.33 (NH)	0.30	N Pol	0.03	-0.10 (NH)
	-0.41*	N Tmp	-0.31			0.21	N Tmp	-0.30	
-0.31 (Glob)	-0.17	N Sbtrp	-0.12	-0.09 (Glob)	0.39 (Glob)	0.07	N Sbtrp	-0.09	0.05 (Glob)
	-0.17	Equat	0.52*			0.37	Equat	0.50*	
-0.26 (Trop)	-0.31	S Sbtrp	0.10	0.18 (Trop)	0.30 (Trop)	0.20	S Sbtrp	0.05	0.24 (Trop)
	-0.19	S Tmp	0.03			0.28	S Tmp	0.13	
-0.22 (SH)	0.01	S Pol	-0.32	0.03 (SH)	0.33 (SH)	0.15	S Pol	-0.04	0.20 (SH)

Table 4-c: CC of the concurrent year seasonal temperature departures of the surface air, the troposphere, the tropopause and the surface–100 hPa layer over different climatic zones, the two hemispheres and the whole globe with the area-averaged JJAS OLR over Ganga Plains during 1974-2005. (* is significant at 5%; ** at 1% level)

Surface		Region		Troposphere	Tropopause		Region		Surface – 100 hPa
WINTER									
-0.45* (NH)	-0.22	N Pol	-0.02	-0.36 (NH)	0.22 (NH)	-0.03	N Pol	-0.09	-0.27 (NH)
	-0.30	N Tmp	-0.27			0.33	N Tmp	-0.20	
-0.57* (Glob)	-0.36	N Sbtrp	-0.49*	-0.22 (Glob)	0.45* (Glob)	0.07	N Sbtrp	-0.46*	-0.02(Glob)
	-0.52*	Equat	0.06			0.50*	Equat	0.22	
-0.53* (Trop)	-0.47*	S Sbtrp	-0.22	-0.17 (Trop)	0.31 (Trop)	0.04	S Sbtrp	-0.27	-0.12 (Trop)
	-0.53*	S Tmp	-0.02			0.52*	S Tmp	0.14	
-0.58** (SH)	-0.04	S Pol	0.17	-0.03 (SH)	0.53* (SH)	0.47*	S Pol	0.42*	0.20 (SH)
SPRING									
-0.40* (NH)	-0.28	N Pol	0.10	-0.11 (NH)	0.13 (NH)	0.17	N Pol	0.09	-0.13 (NH)
	-0.30	N Tmp	-0.08			-0.09	N Tmp	-0.16	
-0.37 (Glob)	-0.35	N Sbtrp	-0.41*	-0.09 (Glob)	0.26 (Glob)	-0.18	N Sbtrp	-0.43*	-0.02 (Glob)
	-0.27	Equat	0.07			0.47*	Equat	0.24	
-0.34 (Trop)	-0.23	S Sbtrp	-0.30	-0.21 (Trop)	0.28 (Trop)	0.26	S Sbtrp	-0.22	-0.09 (Trop)
	-0.18	S Tmp	0.09			0.26	S Tmp	0.16	
0.01 (SH)	0.18	S Pol	0.14	-0.04 (SH)	0.35 (SH)	0.05	S Pol	0.18	0.08 (SH)
SUMMER									
-0.43* (NH)	-0.50*	N Pol	-0.23	-0.32 (NH)	-0.01 (NH)	0.11	N Pol	-0.25	-0.25 (NH)
	-0.34	N Tmp	-0.48*			-0.17	N Tmp	-0.47*	
-0.41* (Glob)	-0.35	N Sbtrp	-0.22	-0.27 (Glob)	0.23 (Glob)	-0.28	N Sbtrp	-0.18	-0.15 (Glob)
	-0.12	Equat	0.29			0.46*	Equat	0.43*	
-0.34 (Trop)	-0.41*	S Sbtrp	-0.23	-0.07 (Trop)	0.19 (Trop)	0.02	S Sbtrp	-0.26	0.06 (Trop)
	-0.05	S Tmp	-0.11			0.36	S Tmp	0.19	
-0.21 (SH)	-0.02	S Pol	-0.36	-0.15 (SH)	0.40 (SH)	-0.01	S Pol	-0.24	-0.02 (SH)
AUTUMN									
-0.32 (NH)	-0.25	N Pol	-0.08	-0.29(NH)	0.30 (NH)	0.12	N Pol	-0.11	-0.14 (NH)
	-0.26	N Tmp	-0.24			0.16	N Tmp	-0.22	
-0.36 (Glob)	-0.16	N Sbtrp	-0.24	-0.26 (Glob)	0.54* (Glob)	0.01	N Sbtrp	-0.15	0.01 (Glob)
	-0.35	Equat	0.40*			0.53*	Equat	0.50*	
-0.38 (Trop)	-0.45*	S Sbtrp	-0.24	-0.07 (Trop)	0.40* (Trop)	0.27	S Sbtrp	-0.15	0.14 (Trop)
	-0.18	S Tmp	-0.06			0.44*	S Tmp	0.14	
-0.36 (SH)	-0.19	S Pol	-0.48*	-0.24 (SH)	0.54* (SH)	0.30	S Pol	0.01	0.16 (SH)

Table 4-d: CC of the concurrent year seasonal temperature departures of the surface air, the troposphere, the tropopause and the surface–100 hPa layer over different climatic zones, the two hemispheres and the whole globe with the area-averaged JJAS OLR over CI during 1974-2005. (* is significant at 5%; ** at 1% level)

Surface		Region	Troposphere		Tropopause		Region	Surface – 100 hPa	
WINTER									
-0.42* (NH)	-0.27	N Pol	-0.04	-0.36 (NH)	0.22 (NH)	-0.02	N Pol	-0.10	-0.26 (NH)
	-0.28	N Tmp	-0.23			0.35	N Tmp	-0.17	
-0.54* (Glob)	-0.29	N Sbtrp	-0.48*	-0.25 (Glob)	0.38 (Glob)	0.01	N Sbtrp	-0.41*	-0.08 (Glob)
	-0.49*	Equat	-0.03			0.42*	Equat	0.13	
-0.48* (Trop)	-0.45*	S Sbtrp	-0.25	-0.20 (Trop)	0.25 (Trop)	-0.04	S Sbtrp	-0.30	-0.08 (Trop)
	-0.49*	S Tmp	-0.03			0.47*	S Tmp	0.13	
-0.56* (SH)	-0.01	S Pol	0.12	-0.08 (SH)	0.40* (SH)	0.34	S Pol	0.29	0.09 (SH)
SPRING									
-0.40* (NH)	-0.27	N Pol	0.13	-0.13 (NH)	0.08 (NH)	0.14	N Pol	0.09	-0.17 (NH)
	-0.32	N Tmp	-0.10			-0.09	N Tmp	-0.18	
-0.35 (Glob)	-0.31	N Sbtrp	-0.41*	-0.11 (Glob)	0.17 (Glob)	-0.19	N Sbtrp	-0.43*	-0.07 (Glob)
	-0.30	Equat	-0.01			0.37	Equat	0.14	
-0.32 (Trop)	-0.19	S Sbtrp	-0.30	-0.26 (Trop)	0.19 (Trop)	0.16	S Sbtrp	-0.25	-0.16 (Trop)
	-0.08	S Tmp	0.10			0.20	S Tmp	0.17	
0.03 (SH)	0.17	S Pol	0.14	-0.05 (SH)	0.24 (SH)	-0.02	S Pol	0.14	0.03 (SH)
SUMMER									
-0.41* (NH)	-0.46*	N Pol	-0.28	-0.38 (NH)	-0.05 (NH)	0.11	N Pol	-0.28	-0.31 (NH)
	-0.37	N Tmp	-0.52*			-0.16	N Tmp	-0.50*	
-0.39 (Glob)	-0.32	N Sbtrp	-0.26	-0.32 (Glob)	0.14 (Glob)	-0.33	N Sbtrp	-0.23	-0.21 (Glob)
	-0.06	Equat	0.20			0.35	Equat	0.33	
-0.28 (Trop)	-0.34	S Sbtrp	-0.29	-0.14 (Trop)	0.09 (Trop)	-0.06	S Sbtrp	-0.31	-0.04 (Trop)
	-0.003	S Tmp	0.12			0.32	S Tmp	0.19	
-0.20 (SH)	-0.07	S Pol	-0.32	-0.18 (SH)	0.031 (SH)	-0.02	S Pol	-0.24	-0.07 (SH)
AUTUMN									
-0.30 (NH)	-0.18	N Pol	-0.01	-0.24 (NH)	0.28 (NH)	0.19	N Pol	-0.03	-0.15 (NH)
	-0.32	N Tmp	-0.27			0.15	N Tmp	-0.26	
-0.32 (Glob)	-0.12	N Sbtrp	-0.26	-0.25 (Glob)	0.49* (Glob)	-0.01	N Sbtrp	-0.18	-0.01 (Glob)
	-0.27	Equat	0.35			0.47*	Equat	0.45*	
-0.32 (Trop)	-0.39	S Sbtrp	-0.19	-0.08 (Trop)	0.33 (Trop)	0.17	S Sbtrp	-0.14	0.10 (Trop)
	-0.12	S Tmp	-0.06			0.34	S Tmp	0.10	
-0.28 (SH)	-0.04	S Pol	-0.44*	-0.21 (SH)	0.48* (SH)	0.31	S Pol	0.03	0.15 (SH)

Table 4-e: CC of the concurrent year seasonal temperature departures of the surface air, the troposphere, the tropopause and the surface–100 hPa layer over different climatic zones, the two hemispheres and the whole globe with the area-averaged JJAS OLR over NEI during 1974-2005. (* is significant at 5%; ** at 1% level)

Surface		Region		Troposphere	Tropopause		Region		Surface – 100 hPa
WINTER									
-.45* (NH)	0.03	N Pol	0.09	-0.44* (NH)	0.03 (NH)	-0.12	N Pol	-0.05	-0.43* (NH)
	-0.41*	N Tmp	-0.43*			0.16	N Tmp	-0.41*	
-0.53* (Glob)	-0.33	N Sbtrp	-0.41*	-0.34 (Glob)	0.39 (Glob)	-0.10	N Sbtrp	-0.47*	-0.13 (Glob)
	-0.72**	Equat	0.00			0.46*	Equat	0.13	
-0.54* (Trop)	-0.38	S Sbtrp	-0.38	-0.30 (Trop)	0.23 (Trop)	0.05	S Sbtrp	-0.33	-0.21 (Trop)
	-0.51*	S Tmp	-0.02			0.53*	S Tmp	0.02	
-0.49* (SH)	0.21	S Pol	0.20	-0.16 (SH)	0.58** (SH)	0.59**	S Pol	0.55*	0.16(SH)
SPRING									
-0.44* (NH)	-0.30	N Pol	-0.10	-0.35 (NH)	0.26 (NH)	0.22	N Pol	0.03	-0.25 (NH)
	-0.36	N Tmp	-0.34			0.05	N Tmp	-0.34	
-0.52* (Glob)	-0.33	N Sbtrp	-0.48*	-0.28 (Glob)	0.38 (Glob)	-0.03	N Sbtrp	-0.40*	-0.12 (Glob)
	-0.32	Equat	-0.01			0.49*	Equat	0.19	
-0.41* (Trop)	-0.35	S Sbtrp	-0.35	-0.29 (Trop)	0.34 (Trop)	0.24	S Sbtrp	-0.23	-0.11 (Trop)
	-0.46*	S Tmp	0.09			0.22	S Tmp	0.08	
-0.36 (SH)	0.11	S Pol	-0.03	-0.12 (SH)	0.37 (SH)	0.16	S Pol	0.12	0.02 (SH)
SUMMER									
-0.42* (NH)	-0.42*	N Pol	-0.18	-0.31 (NH)	0.03 (NH)	0.01	N Pol	-0.23	-0.30 (NH)
	-0.17	N Tmp	-0.35			-0.25	N Tmp	-0.37	
-0.49* (Glob)	-0.38	N Sbtrp	-0.31	-0.36 (Glob)	0.25 (Glob)	-0.06	N Sbtrp	-0.29	-0.26 (Glob)
	-0.49*	Equat	0.12			0.48*	Equat	0.25	
-0.60** (Trop)	-0.59**	S Sbtrp	-0.29	-0.19 (Trop)	0.24 (Trop)	-0.12	S Sbtrp	-0.37	-0.11 (Trop)
	-0.24	S Tmp	-0.19			0.36	S Tmp	-0.16	
-0.36 (SH)	0.07	S Pol	-0.29	-0.36 (SH)	0.37 (SH)	0.01	S Pol	-0.14	-0.22 (SH)
AUTUMN									
-0.28 (NH)	-0.33	N Pol	-0.07	-0.31 (NH)	0.26 (NH)	-0.01	N Pol	-0.15	-0.21 (NH)
	-0.11	N Tmp	-0.31			0.06	N Tmp	-0.28	
-0.40* (Glob)	-0.17	N Sbtrp	-0.25	-0.41* (Glob)	0.46* (Glob)	0.04	N Sbtrp	-0.16	-0.17 (Glob)
	-0.37	Equat	0.20			0.59**	Equat	0.40*	
-0.44* (Trop)	-0.55*	S Sbtrp	-0.47*	-0.25 (Trop)	0.45* (Trop)	0.27	S Sbtrp	-0.36	0.01 (Trop)
	-0.19	S Tmp	-0.20			0.35	S Tmp	-0.04	
-0.50* (SH)	-0.29	S Pol	-0.48*	-0.45* (SH)	0.45* (SH)	0.20	S Pol	-0.06	-0.09 (SH)

Table 4-f: CC of the concurrent year seasonal temperature departures of the surface air, the troposphere, the tropopause and the surface–100 hPa layer over different climatic zones, the two hemispheres and the whole globe with the area-averaged JJAS OLR over West Coast during 1974-2005. (* is significant at 5% ; ** at 1% level)

Surface		Region		Troposphere	Tropopause		Region		Surface – 100 hPa
WINTER									
-0.25 (NH)	-0.15	N Pol	0.12	-0.42* (NH)	0.24 (NH)	0.12	N Pol	0.11	-0.26 (NH)
	-0.21	N Tmp	-0.27			0.33	N Tmp	-0.19	
-0.22 (Glob)	-0.12	N Sbtrp	-0.43*	-0.27 (Glob)	0.17 (Glob)	0.09	N Sbtrp	-0.32	-0.16 (Glob)
	-0.30	Equat	-0.31			0.09	Equat	-0.22	
-0.20 (Trop)	-0.14	S Sbtrp	-0.32	-0.34 (Trop)	0.02 (Trop)	-0.20	S Sbtrp	-0.29	-0.34 (Trop)
	0.08	S Tmp	0.24			0.20	S Tmp	0.29	
-0.11 (SH)	-0.05	S Pol	0.12	-0.06 (SH)	0.08 (SH)	0.07	S Pol	0.09	-0.04 (SH)
SPRING									
-0.19 (NH)	-0.13	N Pol	0.10	-0.29 (NH)	-0.04 (NH)	-0.01	N Pol	-0.02	-0.31 (NH)
	-0.20	N Tmp	-0.27			0.17	N Tmp	-0.21	
-0.13 (Glob)	-0.12	N Sbtrp	-0.44*	-0.32 (Glob)	-0.04 (Glob)	-0.27	N Sbtrp	-0.42*	-0.28 (Glob)
	-0.05	Equat	-0.21			-0.08	Equat	-0.16	
-0.08 (Trop)	0.04	S Sbtrp	-0.26	-0.35 (Trop)	-0.24 (Trop)	-0.35	S Sbtrp	-0.28	-0.32 (Trop)
	0.23	S Tmp	-0.12			0.12	S Tmp	-0.04	
0.001 (SH)	-0.03	S Pol	-0.07	-0.25 (SH)	-0.07 (SH)	0.003	S Pol	-0.04	-0.19 (SH)
SUMMER									
-0.08 (NH)	0.07	N Pol	0.02	-0.30 (NH)	-0.11 (NH)	-0.24	N Pol	-0.01	-0.28 (NH)
	-0.15	N Tmp	-0.34			-0.14	N Tmp	-0.33	
-0.17 (Glob)	-0.22	N Sbtrp	-0.33	-0.24 (Glob)	-0.09 (Glob)	-0.14	N Sbtrp	-0.28	-0.24 (Glob)
	0.10	Equat	-0.09			0.19	Equat	0.01	
-0.09 (Trop)	-0.17	S Sbtrp	-0.16	-0.23 (Trop)	0.02 (Trop)	-0.17	S Sbtrp	-0.15	-0.15 (Trop)
	0.28	S Tmp	0.25			-0.15	S Tmp	0.06	
-0.20 (SH)	-0.34	S Pol	-0.35	-0.12 (SH)	-0.06 (SH)	0.07	S Pol	-0.34	-0.20 (SH)
AUTUMN									
-0.07 (NH)	-0.05	N Pol	0.06	-0.14 (NH)	0.01 (NH)	0.08	N Pol	0.05	-0.11 (NH)
	-0.16	N Tmp	-0.20			-0.10	N Tmp	-0.21	
-0.05 (Glob)	0.05	N Sbtrp	-0.22	-0.15 (Glob)	0.15 (Glob)	-0.14	N Sbtrp	-0.17	-0.07 (Glob)
	0.06	Equat	0.39			0.22	Equat	0.32	
-0.02 (Trop)	-0.17	S Sbtrp	0.13	0.10 (Trop)	0.08 (Trop)	-0.01	S Sbtrp	-0.003	0.09 (Trop)
	0.12	S Tmp	-0.28			-0.09	S Tmp	-0.27	
0.01 (SH)	0.06	S Pol	-0.22	-0.13 (SH)	0.19 (SH)	0.26	S Pol	0.10	0.01 (SH)

Table 4-g: CC of the concurrent year seasonal temperature departures of the surface air, the troposphere, the tropopause and the surface–100 hPa layer over different climatic zones, the two hemispheres and the whole globe with the area-averaged JJAS OLR over WC_S during 1974-2005. (* significant at 5% ; ** at 1% level)

Surface		Region	Troposphere		Tropopause		Region	Surface – 100 hPa	
WINTER									
-0.27 (NH)	-0.15	N Pol	0.10	-0.43* (NH)	0.23 (NH)	0.13	N Pol	0.11	-0.29 (NH)
	-.023	N Tmp	-0.29			0.30	N Tmp	-0.22	
-0.23 (Glob)	-0.13	N Sbtrp	-0.39	-0.28 (Glob)	0.15 (Glob)	0.06	N Sbtrp	-0.31	-0.18 (Glob)
	-0.30	Equat	-0.33			0.08	Equat	-0.23	
-0.22 (Trop)	-0.16	S Sbtrp	-0.34	-0.34 (Trop)	-0.002 (Trop)	-0.20	S Sbtrp	-0.31	-0.35 (Trop)
	0.11	S Tmp	0.26			0.17	S Tmp	0.31	
-0.10 (SH)	-0.05	S Pol	0.12	-0.06 (SH)	0.06 (SH)	0.06	S Pol	0.08	-0.05 (SH)
SPRING									
-0.17 (NH)	-0.12	N Pol	0.11	-0.27 (NH)	-0.01 (NH)	0.01	N Pol	0.002	-0.27 (NH)
	-0.16	N Tmp	-0.25			0.22	N Tmp	-0.17	
-0.12 (Glob)	-0.10	N Sbtrp	-0.40*	-0.32 (Glob)	-0.04 (Glob)	-0.25	N Sbtrp	-0.39	-0.27 (Glob)
	-0.06	Equat	-0.23			-0.08	Equat	-0.17	
-0.10 (Trop)	-0.08	S Sbtrp	-0.27	-0.35 (Trop)	-0.24 (Trop)	-0.38	S Sbtrp	-0.30	-0.33 (Trop)
	0.24	S Tmp	-0.14			0.11	S Tmp	-0.05	
0.01 (SH)	-0.04	S Pol	-0.08	-0.27 (SH)	-0.09 (SH)	-0.02	S Pol	-0.07	-0.21 (SH)
SUMMER									
-0.09 (NH)	0.09	N Pol	0.03	-0.29 (NH)	-0.09 (NH)	-0.23	N Pol	-0.002	-0.27 (NH)
	-0.15	N Tmp	-0.33			-0.11	N Tmp	-0.31	
-0.17 (Glob)	-0.22	N Sbtrp	-0.32	-0.23 (Glob)	-0.09 (Glob)	-0.13	N Sbtrp	-0.28	-0.24 (Glob)
	0.08	Equat	-0.12			0.19	Equat	-0.002	
-0.12 (Trop)	-0.20	S Sbtrp	-0.16	-0.23 (Trop)	0.02 (Trop)	-0.18	S Sbtrp	-0.16	-0.16 (Trop)
	0.31	S Tmp	0.28			-0.18	S Tmp	0.08	
-0.20 (SH)	-0.33	S Pol	-0.32	-0.10 (SH)	-0.08 (SH)	0.07	S Pol	-0.32	-0.19 (SH)
AUTUMN									
-0.10 (NH)	-0.07	N Pol	0.04	-0.15 (NH)	0.01 (NH)	0.08	N Pol	0.03	-0.13 (NH)
	-0.18	N Tmp	-0.22			-0.11	N Tmp	-0.23	
-0.07 (Glob)	0.004	N Sbtrp	-0.21	-0.15 (Glob)	0.15 (Glob)	-0.13	N Sbtrp	-0.17	-0.07 (Glob)
	0.07	Equat	0.41			0.23	Equat	0.33	
-0.04 (Trop)	-0.18	S Sbtrp	0.14	0.12 (Trop)	0.09 (Trop)	-0.01	S Sbtrp	-0.07	0.10 (Trop)
	0.12	S Tmp	-0.29			-0.10	S Tmp	-0.28	
-0.01 (SH)	0.04	S Pol	-0.19	-0.12 (SH)	0.20 (SH)	0.26	S Pol	0.12	0.02 (SH)

Table 4-h: CC of the concurrent year seasonal temperature departures of the surface air, the troposphere, the tropopause and the surface–100 hPa layer over different climatic zones, the two hemispheres and the whole globe with the area-averaged JJAS OLR over CPI during 1974-2005. (* -- significant at 5%; ** -- at 1% level)

Surface		Region		Troposphere	Tropopause		Region		Surface – 100 hPa
WINTER									
-0.37 (NH)	-0.29	N Pol	0.04	-0.50* (NH)	0.24 (NH)	0.12	N Pol	0.04	-0.35 (NH)
	-0.26	N Tmp	-0.31			0.34	N Tmp	-0.23	
-0.41* (Glob)	-0.20	N Sbtrp	-0.53*	-0.38 (Glob)	0.21 (Glob)	0.02	N Sbtrp	-0.45*	-0.25 (Glob)
	-0.42*	Equat	-0.30			0.21	Equat	-0.15	
-0.35 (Trop)	-0.29	S Sbtrp	-0.36	-0.34 (Trop)	0.06 (Trop)	-0.19	S Sbtrp	-0.36	-0.37 (Trop)
	-0.25	S Tmp	0.05			0.25	S Tmp	0.13	
-0.35 (SH)	-0.02	S Pol	0.12	-0.16 (SH)	0.14 (SH)	0.10	S Pol	0.12	-0.11(SH)
SPRING									
-0.35 (NH)	-0.25	N Pol	0.08	-0.29 (NH)	-0.04 (NH)	0.01	N Pol	-0.04	-0.34 (NH)
	-0.30	N Tmp	-0.21			0.04	N Tmp	-0.22	
-0.28 (Glob)	-0.21	N Sbtrp	-0.52*	-0.34 (Glob)	-0.04 (Glob)	-0.28	N Sbtrp	-0.51*	-0.30 (Glob)
	-0.25	Equat	-0.26			0.09	Equat	-0.14	
-0.25 (Trop)	-0.16	S Sbtrp	-0.37	-0.44* (Trop)	-0.11 (Trop)	-0.21	S Sbtrp	-0.37	-0.38 (Trop)
	0.10	S Tmp	-0.11			0.13	S Tmp	-0.03	
0.02 (SH)	0.10	S Pol	0.01	-0.28 (SH)	0.001 (SH)	-0.05	S Pol	0.04	-0.20 (SH)
SUMMER									
-0.29 (NH)	-0.18	N Pol	-0.17	-0.44* (NH)	-0.14 (NH)	-0.12	N Pol	-0.19	-0.40* (NH)
	-0.35	N Tmp	-0.54*			-0.20	N Tmp	-0.53*	
-0.37 (Glob)	-0.28	N Sbtrp	-0.37	-0.38 (Glob)	-0.05 (Glob)	-0.24	N Sbtrp	-0.32	-0.34 (Glob)
	0.02	Equat	-0.04			0.21	Equat	0.09	
-0.19 (Trop)	-0.27	S Sbtrp	-0.27	-0.26 (Trop)	-0.01 (Trop)	-0.17	S Sbtrp	-0.30	-0.18 (Trop)
	0.14	S Tmp	0.16			0.06	S Tmp	0.09	
-0.31 (SH)	-0.35	S Pol	-0.39	-0.34 (SH)	0.08 (SH)	0.06	S Pol	-0.36	-0.24 (SH)
AUTUMN									
-0.19 (NH)	-0.10	N Pol	-0.07	-0.29 (NH)	0.12 (NH)	0.18	N Pol	-0.05	-0.22 (NH)
	-0.28	N Tmp	-0.26			-0.02	N Tmp	-0.27	
-0.19 (Glob)	-0.001	N Sbtrp	-0.32	-0.35 (Glob)	0.29 (Glob)	-0.06	N Sbtrp	-0.22	-0.16 (Glob)
	-0.14	Equat	0.29			0.28	Equat	0.29	
-0.17 (Trop)	-0.30	S Sbtrp	-0.08	-0.08 (Trop)	0.15 (Trop)	0.02	S Sbtrp	-0.15	-0.003 (Trop)
	-0.01	S Tmp	-0.36			0.07	S Tmp	-0.27	
-0.14 (SH)	0.05	S Pol	-0.38	-0.34 (SH)	0.32 (SH)	0.32	S Pol	0.08	-0.05 (SH)

Table 4-i: CC of the concurrent year seasonal temperature departures of the surface air, the troposphere, the tropopause and the surface – 100 hPa layer over different climatic zones, the two hemispheres and the whole globe with the area-averaged JJAS OLR over EC_N during 1974-2005. (* -- significant at 5% ; ** -- at 1% level)

Surface		Region		Troposphere	Tropopause		Region		Surface – 100 hPa
WINTER									
-0.55* (NH)	-0.25	N Pol	-0.04	-0.51* (NH)	0.14 (NH)	-0.12	N Pol	-0.17	-0.47* (NH)
	-0.42*	N Tmp	-0.42*			0.29	N Tmp	-0.38	
-0.65** (Glob)	-0.35	N Sbtrp	-0.43*	-0.37 (Glob)	0.40* (Glob)	0.06	N Sbtrp	-0.40*	-0.19 (Glob)
	-0.71**	Equat	-0.09			0.53*	Equat	0.09	
-0.63** (Trop)	-0.57*	S Sbtrp	-0.50*	-0.33 (Trop)	0.31 (Trop)	0.01	S Sbtrp	-0.47*	-0.27 (Trop)
	-0.48*	S Tmp	-0.05			0.54*	S Tmp	0.16	
-0.60** (SH)	-0.15	S Pol	-0.24	-0.15 (SH)	0.51* (SH)	0.43*	S Pol	0.43*	0.08 (SH)
SPRING									
-0.50* (NH)	-0.35	N Pol	0.04	-0.29 (NH)	0.29 (NH)	0.25	N Pol	0.12	-0.23 (NH)
	-0.38	N Tmp	-0.28			0.06	N Tmp	-0.29	
-0.53* (Glob)	-0.41*	N Sbtrp	-0.47*	-0.25 (Glob)	0.33 (Glob)	0.01	N Sbtrp	-0.41*	-0.13 (Glob)
	-0.38	Equat	-0.05			0.49*	Equat	0.13	
-0.43* (Trop)	-0.39	S Sbtrp	-0.44*	-0.36 (Trop)	0.33 (Trop)	0.17	S Sbtrp	-0.34	-0.20 (Trop)
	-0.22	S Tmp	0.18			0.22	S Tmp	0.21	
-0.24 (SH)	0.11	S Pol	-0.02	-0.13 (SH)	0.29 (SH)	0.01	S Pol	0.05	-0.02 (SH)
SUMMER									
-0.48* (NH)	-0.45*	N Pol	-0.23	-0.45* (NH)	0.09 (NH)	0.10	N Pol	-0.24	-0.38 (NH)
	-0.31	N Tmp	-0.52*			-0.15	N Tmp	-0.49*	
-0.54* (Glob)	-0.43*	N Sbtrp	-0.42*	-0.44* (Glob)	0.21 (Glob)	-0.10	N Sbtrp	-0.34	-0.33 (Glob)
	-0.32	Equat	0.07			0.49*	Equat	0.24	
-0.55* (Trop)	-0.58**	S Sbtrp	-0.52*	-0.34 (Trop)	0.24 (Trop)	-0.13	S Sbtrp	-0.51*	-0.19 (Trop)
	-0.11	S Tmp	0.03			0.31	S Tmp	0.02	
-0.40* (SH)	-0.08	S Pol	-0.31	-0.36 (SH)	0.28 (SH)	-0.15	S Pol	-0.26	-0.26 (SH)
AUTUMN									
-0.41* (NH)	-0.32	N Pol	-0.02	-0.36 (NH)	0.40* (NH)	0.18	N Pol	-0.07	-0.25 (NH)
	-0.37	N Tmp	-0.43*			0.06	N Tmp	-0.42*	
-0.46* (Glob)	-0.25	N Sbtrp	-0.27	-0.40* (Glob)	0.56* (Glob)	0.14	N Sbtrp	-0.16	-0.13 (Glob)
	-0.30	Equat	0.33			0.72**	Equat	0.55*	
-0.46* (Trop)	-0.59**	S Sbtrp	-0.44*	-0.20 (Trop)	0.55* (Trop)	0.25	S Sbtrp	-0.39	0.07 (Trop)
	-0.13	S Tmp	-0.11			0.33	S Tmp	0.05	
-0.42* (SH)	-0.15	S Pol	-0.48*	-0.36 (SH)	0.51* (SH)	0.27	S Pol	-0.01	0.03 (SH)

Table 4-j: CC of the concurrent year seasonal temperature departures of the surface air, the troposphere, the tropopause and the surface – 100 hPa layer over different climatic zones, the two hemispheres and the whole globe with the area-averaged JJAS OLR over EC_S during 1974-2005. (* is significant at 5% and ** at 1% level)

Surface		Region	Troposphere		Tropopause		Region	Surface – 100 hPa	
WINTER									
-0.31 (NH)	-0.15	N Pol	0.01	-0.53* (NH)	0.13 (NH)	0.03	N Pol	-0.01	-0.42* (NH)
	-0.26	N Tmp	-0.37			0.18	N Tmp	-0.31	
-0.32 (Glob)	-0.15	N Sbtrp	-0.46*	-0.36 (Glob)	0.22 (Glob)	-0.03	N Sbtrp	-0.41*	-0.23 (Glob)
	-0.40*	Equat	-0.29			0.27	Equat	-0.15	
0.30 (Trop)	-0.23	S Sbtrp	-0.41*	-0.40* (Trop)	0.13 (Trop)	-0.03	S Sbtrp	-0.33	-0.34 (Trop)
	-0.10	S Tmp	0.25			0.32	S Tmp	0.24	
-0.23 (SH)	-0.01	S Pol	0.13	-0.10 (SH)	0.24 (SH)	0.17	S Pol	0.17	-0.02 (SH)
SPRING									
-0.25 (NH)	-0.17	N Pol	0.11	-0.33 (NH)	0.03 (NH)	0.04	N Pol	0.01	-0.32 (NH)
	-0.23	N Tmp	-0.30			0.12	N Tmp	-0.25	
-0.27 (Glob)	-0.16	N Sbtrp	-0.50*	-0.37 (Glob)	0.05 (Glob)	-0.21	N Sbtrp	-0.44*	-0.31 (Glob)
	-0.14	Equat	-0.25			0.10	Equat	-0.13	
-0.24 (Trop)	-0.27	S Sbtrp	-0.35	-0.43* (Trop)	-0.07 (Trop)	-0.20	S Sbtrp	-0.35	-0.35 (Trop)
	0.01	S Tmp	-0.10			0.04	S Tmp	-0.10	
-0.15 (SH)	0.03	S Pol	-0.10	-0.30 (SH)	-0.01 (SH)	0.01	S Pol	-0.01	-0.23 (SH)
SUMMER									
-0.15 (NH)	0.02	N Pol	0.10	-0.27 (NH)	-0.06 (NH)	-0.19	N Pol	0.05	-0.26 (NH)
	-0.08	N Tmp	-0.30			-0.24	N Tmp	-0.31	
-0.34 (Glob)	-0.37	N Sbtrp	-0.38	-0.31 (Glob)	0.04 (Glob)	-0.07	N Sbtrp	-0.30	-0.28 (Glob)
	-0.07	Equat	-0.06			0.35	Equat	0.10	
-0.32 (Trop)	-0.40*	S Sbtrp	-0.23	-0.26 (Trop)	0.16 (Trop)	-0.13	S Sbtrp	-0.24	-0.14 (Trop)
	0.07	S Tmp	0.04			-0.001	S Tmp	-0.11	
-0.42* (SH)	-0.35	S Pol	-0.42*	-0.30 (SH)	0.09 (SH)	0.002	S Pol	-0.41*	-0.32 (SH)
AUTUMN									
-0.11 (NH)	-0.06	N Pol	0.06	-0.16 (NH)	0.07 (NH)	0.04	N Pol	0.03	-0.13 (NH)
	-0.10	N Tmp	-0.20			-0.14	N Tmp	-0.21	
-0.11 (Glob)	-0.09	N Sbtrp	-0.24	-0.28 (Glob)	0.35 (Glob)	-0.08	N Sbtrp	-0.19	-0.08 (Glob)
	-0.07	Equat	0.30			0.37	Equat	0.33	
-0.20 (Trop)	-0.32	S Sbtrp	-0.19	-0.08 (Trop)	0.22 (Trop)	0.07	S Sbtrp	-0.27	-0.01 (Trop)
	0.09	S Tmp	-0.41*			0.06	S Tmp	-0.31	
-0.09 (SH)	0.09	S Pol	-0.23	-0.36 (SH)	0.42* (SH)	0.43*	S Pol	0.24	-0.01 (SH)

Table 4-k: CC of the concurrent year seasonal temperature departures of the surface air, the troposphere, the tropopause and the surface–100 hPa layer over different climatic zones, the two hemispheres and the whole globe with the area-averaged JJAS OLR over SPI during 1974-2005. (* is significant at 5% ; ** at 1% level)

Surface		Region	Troposphere		Tropopause		Region	Surface – 100 hPa	
WINTER									
-0.19 (NH)	-0.09	N Pol	0.07	-0.39 (NH)	0.20 (NH)	0.06	N Pol	0.05	-0.25 (NH)
	-0.16	N Tmp	-0.24			0.24	N Tmp	-0.17	
-0.15 (Glob)	-0.08	N Sbtrp	-0.42*	-0.22 (Glob)	0.21 (Glob)	0.12	N Sbtrp	-0.29	-0.11 (Glob)
	-0.26	Equat	-0.24			0.17	Equat	-0.15	
-0.15 (Trop)	-0.09	S Sbtrp	-0.32	-0.33 (Trop)	0.12 (Trop)	-0.04	S Sbtrp	-0.23	-0.27 (Trop)
	0.09	S Tmp	0.29			0.25	S Tmp	0.31	
-0.06 (SH)	-0.02	S Pol	0.15	-0.01(SH)	0.17 (SH)	0.11	S Pol	0.13	0.04 (SH)
SPRING									
-0.14 (NH)	-0.08	N Pol	0.13	-0.27 (NH)	-0.01 (NH)	0.002	N Pol	0.02	-0.27 (NH)
	-0.16	N Tmp	-0.27			0.16	N Tmp	-0.20	
-0.11 (Glob)	-0.10	N Sbtrp	-0.41*	-0.28 (Glob)	0.04 (Glob)	-0.21	N Sbtrp	-0.37	-0.23 (Glob)
	0.02	Equat	-0.16			-0.03	Equat	-0.10	
-0.06 (Trop)	-0.07	S Sbtrp	-0.22	-0.30 (Trop)	-0.16 (Trop)	-0.27	S Sbtrp	-0.22	-0.26 (Trop)
	0.15	S Tmp	-0.09			0.08	S Tmp	-0.05	
-0.06 (SH)	-0.05	S Pol	-0.08	-0.21 (SH)	-0.03 (SH)	0.05	S Pol	-0.03	-0.16 (SH)
SUMMER									
-0.01 (NH)	0.16	N Pol	0.18	-0.18 (NH)	-0.04 (NH)	-0.27	N Pol	0.12	-0.18 (NH)
	0.01	N Tmp	-0.20			-0.16	N Tmp	-0.20	
-0.17 (Glob)	-0.26	N Sbtrp	-0.32	-0.18 (Glob)	0.01 (Glob)	-0.03	N Sbtrp	-0.25	-0.19 (Glob)
	0.08	Equat	-0.05			0.29	Equat	0.07	
-0.14 (Trop)	-0.23	S Sbtrp	-0.13	-0.20 (Trop)	0.15 (Trop)	-0.10	S Sbtrp	-0.11	-0.09 (Trop)
	0.20	S Tmp	0.17			-0.14	S Tmp	-0.04	
-0.29 (SH)	-0.37	S Pol	-0.36	-0.15 (SH)	-0.01 (SH)	0.03	S Pol	-0.38	-0.23 (SH)
AUTUMN									
-0.01 (NH)	-0.01	N Pol	0.12	-0.06 (NH)	0.01 (NH)	-0.01	N Pol	0.09	-0.04 (NH)
	-0.05	N Tmp	-0.14			-0.13	N Tmp	-0.14	
-0.003 (Glob)	0.01	N Sbtrp	-0.17	-0.11 (Glob)	0.22 (Glob)	-0.13	N Sbtrp	-0.14	0.003 (Glob)
	0.07	Equat	0.36			0.28	Equat	0.33	
-0.04 (Trop)	-0.17	S Sbtrp	0.03	0.07 (Trop)	0.15 (Trop)	0.04	S Sbtrp	-0.07	0.08 (Trop)
	0.20	S Tmp	-0.27			-0.08	S Tmp	-0.24	
0.03 (SH)	0.07	S Pol	-0.15	-0.14 (SH)	0.28 (SH)	0.33	S Pol	0.19	0.05 (SH)

Table 4-I: CC of the concurrent year seasonal temperature departures of the surface air, the troposphere, the tropopause and the surface – 100 hPa layer over different climatic zones, the two hemispheres and the whole globe with the area-averaged JJAS OLR over India during 1974-2005. (* is significant at 5%: ** at 1% level)

Surface		Region	Troposphere		Tropopause		Region	Surface – 100 hPa	
WINTER									
-0.54* (NH)	-0.19	N Pol	0.04	-0.50* (NH)	0.22 (NH)	-0.05	N Pol	-0.07	-0.41* (NH)
	-0.43*	N Tmp	-0.43*			0.37	N Tmp	-0.36	
-0.65** (Glob)	-0.36	N Sbtrp	-0.52*	-0.34 (Glob)	0.50* (Glob)	0.07	N Sbtrp	-0.48*	-0.11 (Glob)
	-0.71**	Equat	-0.04			0.54*	Equat	0.15	
-0.61** (Trop)	-0.52*	S Sbtrp	-0.40	-0.33 (Trop)	0.32 (Trop)	0.01	S Sbtrp	-0.39	-0.23 (Trop)
	-0.52*	S Tmp	0.08			0.60**	S Tmp	0.18	
-0.61** (SH)	-0.09	S Pol	0.21	-0.10 (SH)	0.60** (SH)	0.55*	S Pol	0.49*	0.17 (SH)
SPRING									
-0.53* (NH)	-0.35	N Pol	0.02	-0.33 (NH)	0.22 (NH)	0.22	N Pol	0.08	-0.29 (NH)
	-0.44*	N Tmp	-0.34			0.04	N Tmp	-0.36	
-0.50* (Glob)	-0.41*	N Sbtrp	-0.58**	-0.28 (Glob)	0.32 (Glob)	-0.15	N Sbtrp	-0.54*	-0.14 (Glob)
	-0.34	Equat	0.02			0.48*	Equat	0.21	
-0.41* (trop)	-0.28	S Sbtrp	-0.41*	-0.34 (Trop)	0.27 (Trop)	0.16	S Sbtrp	-0.30	-0.18 (Trop)
	-0.21	S Tmp	0.11			0.27	S Tmp	0.17	
-0.15 (SH)	0.16	S Pol	-0.01	-0.13 (SH)	0.35 (SH)	0.11	S Pol	0.11	0.02 (SH)
SUMMER									
-0.49* (NH)	-0.47*	N Pol	-0.25	-0.42* (NH)	0.06 (NH)	0.07	N Pol	-0.26	-0.36 (NH)
	-0.37	N Tmp	-0.56*			-0.19	N Tmp	-0.54*	
-0.48* (Glob)	-0.44*	N Sbtrp	-0.34	-0.39 (Glob)	0.25 (Glob)	-0.14	N Sbtrp	-0.29	-0.26 (Glob)
	-0.24	Equat	0.24			0.54*	Equat	0.38	
-0.48* (Trop)	-0.53*	S Sbtrp	-0.38	-0.19 (Trop)	0.27 (Trop)	-0.06	S Sbtrp	-0.39	-0.06 (Trop)
	-0.08	S Tmp	0.02			0.31	S Tmp	0.03	
-0.27 (SH)	0.01	S Pol	-0.34	-0.28 (SH)	0.38 (SH)	0.001	S Pol	-0.21	-0.15 (SH)
AUTUMN									
-0.40 (NH)	-0.33	N Pol	-0.04	-0.35 (NH)	0.39 (NH)	0.17	N Pol	-0.09	-0.23 (NH)
	-0.35	N Tmp	-0.43*			0.13	N Tmp	-0.41*	
-0.48* (Glob)	-0.19	N Sbtrp	-0.27	-0.39 (Glob)	0.58** (Glob)	0.10	N Sbtrp	-0.16	-0.12 (Glob)
	-0.38	Equat	0.45*			0.68**	Equat	0.59**	
-0.48* (Trop)	-0.61**	S Sbtrp	-0.33	-0.10 (Trop)	0.53* (Trop)	0.31	S Sbtrp	-0.27	0.14 (Trop)
	-0.23	S Tmp	-0.17			0.41*	S Tmp	0.02	
-0.50* (SH)	-0.20	S Pol	-0.56*	-0.36 (SH)	0.54* (SH)	0.26	S Pol	-0.06	0.03 (SH)

Table 5-a: Correlation of regional difference in the concurrent year seasonal temperature departures with the area averaged summer monsoon OLR over Extreme North India (ENI) during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Level	Season	Difference between regions (CC)
Surface	Summer	N.Sub-S.Temp(-0.45)
Troposphere	Winter	N.Sub-S.Temp(-0.42)
	Spring	N.Polr-N.Sub(0.48); Equa-Trop(0.40)
	Summer	N.Temp-Equa(-0.43); N.Temp-S.Temp(-0.51); N.Sub-Equa(-0.45); N.Sub-S.Temp(-0.44); Equa-S.Sub(0.46); Equa-S.Polr(0.48); Equa-Trop(0.49); S.Sub-S.Temp(-0.46); S.Temp-S.polr(0.46)
	Autumn	N.Sub-Equa(-0.58*); N.Sub-Trop(-0.42); Equa-S.Polr(0.54); Equa-Trop(0.59*), S.Sub-S.Polr(0.40); S.Polr-Trop(-0.46)
Tropopause	Summer	N.Sub-Equa(-0.50); N.Sub-Trop(-0.53); Equa-Trop(0.44);
	Autumn	N.Sub-Equa(-0.44); N.Sub-Trop(-0.40); Equa-Trop(0.42)
Surf-100hPa	Winter	N.Sub-S.Temp(-0.50)
	Spring	N.Polr-N.Sub(0.44); N.Sub-Equa(-0.40); Equa-Trop(0.42)
	Summer	N.Temp-Equa(-0.43); N.Temp-S.Temp(-0.48); N.Sub-Equa(-0.43); Equa-S.Sub(0.41); Equa-S.Polr(0.46); Equa-Trop(0.43); S.Temp-S.Polr(0.40)
	Autumn	N.Temp-Equa(-0.40); N.Sub-Equa(-0.58*); N.Sub-Trop(-0.47); Equa-S.Sub(0.46); Equa-Trop(0.56)

Table 5-b: Correlation of regional difference in the concurrent year seasonal temperature departures with the area averaged summer monsoon OLR over North West India (NWI) during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Level	Season	Difference between regions (CC)
Surface	Summer	N.Polr-Equa(-0.41); N.Temp-Equa(-0.47); N.Temp-S.Temp(-0.41); N.Sub-Equa(-0.43); N.Sub-S.Temp(-0.41)
	Autumn	N.Temp-S.Temp(-0.40)
Troposphere	Summer	N.Temp-Equa(-0.54); N.Temp-S.Temp(-0.53); N.Temp-Trop(-0.46); N.Sub-Equa(-0.42); Equa-S.Sub(0.47); Equa-Trop(0.48)
	Autumn	N.Temp-Equa(-0.46); N.Sub-Equa(-0.53); Equa-S.Polr(0.50); Equa-Trop(0.53); S.Polr-Trop(-0.43)
Tropopause	Summer	N.Sub-Equa(-0.44); N.Sub-Trop(-0.48)
Surf-100hPa	Winter	N.Sub-S.Temp(-0.40)
	Summer	N.Temp-Equa(-0.51); N.Temp-S.Temp(-0.56); N.Temp-Trop(-0.47); N.Sub-Equa(-0.40); Equa-S.Sub(0.41); Equa-Trop(0.42)
	Autumn	N.Temp-Equa(-0.48); N.Sub-Equa(-0.54); N.Sub-Trop(-0.44); Equa-S.Sub(0.42); Equa-Trop(0.52)

Table 5-c: Correlation of regional difference in the concurrent year seasonal temperature departures with the area averaged summer monsoon OLR over Ganga Plains (GP) during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Level	Season	Difference between regions (CC)
Surface	Summer	N.Polr-Equa(-0.50); N.Polr-S.Temp(-0.43); NPolr-Trop(-0.43)
Troposphere	Spring	S.Sub-S.Polr(-0.44)
	Summer	N.Polr-Equa(-0.41); N.Temp-Equa(-0.60*); N.Temp-S.Temp(-0.43); N.Temp-Trop(-0.50); N.Sub-Equa(-0.53); Equa-S.Sub(0.52); Equa-S.Polr(0.49); Equa-Trop(0.57)
	Autumn	N.Sub-Equa(-0.55); S.Sub-S.Polr(-0.40); Equa-S.Sub(0.54); Equa-S.Polr(0.59*); Equa-Trop(0.66*); S.Polr-Trop(-0.49)
Tropopause	Winter	N.Temp-S.Polr(-0.42); N.Sub-Equa(-0.49);N.Sub-S.Temp(-0.45); N.Sub-S.Polr(-0.46); Equa-S.Sub(0.54); Equa-Trop(0.55); S.Sub-S.Temp(-0.47); S.Sub-S.Polr(-0.46); S.Sub-Trop(-0.41); S.Temp-Trop(0.40); S.Polr-Trop(0.43)
	Spring	N.Temp-Equa(-0.48); N.Sub-Equa(-0.61*); N.Sub-S.Sub(-0.46); N.Sub-Trop(-0.62*); Equa-S.Sub(0.44); Equa-Trop(0.55)
	Summer	N.Temp-Equa(-0.53); N.Temp-S.Temp(-0.41); N.Sub-Equa(-0.65*); N.Sub-S.Temp(-0.47); N.Sub-Trop(-0.66*); Equa-S.Sub(0.48); Equa-Trop(0.59*)
	Autumn	N.Temp-Equa(-0.46); N.Sub-Equa(-0.55); N.Sub-Trop(-0.50); Equa-S.Sub(0.46); Equa-Trop(0.53)
Surf-100hPa	Winter	N.Polr-S.Polr(-0.44); N.Temp-S.Polr(-0.43); N.Sub-Equa(-0.45); N.Sub-S.Polr(-0.51); Equa-S.Sub(0.45); Equa-Trop(0.48); S.Sub-S.Polr(-0.48); S.Polr-Trop(0.45)
	Spring	N.Sub-Equa(-0.48); Equa-S.Sub(0.48); Equa-Trop(0.52)
	Summer	N.Polr-Equa(-0.56); N.Temp-Equa(-0.66*); N.Temp-S.Temp(-0.56); N.Temp-Trop(-0.56); N.Sub-Equa(-0.57); N.Sub-Trop(-0.41); Equa-S.Sub(0.61*); Equa-S.Polr(0.46); Equa-Trop(0.61*); S.Sub-S.Polr(-0.55)
	Autumn	N.Temp-Equa(-0.42); N.Sub-Equa(-0.59*); N.Sub-Trop(-0.43); Equa-S.Sub(0.53); Equa-Trop(0.61*).

Table 5-d: Correlation of regional difference in the concurrent year seasonal temperature departures with the area averaged summer monsoon OLR over Central India (CI) during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Level	Season	Difference between regions (CC)
Surface	**Summer**	N.Polr-Equa(-0.49); N.Polr-S.Temp(-0.42); N.Polr-Trop(-0.42)
Troposphere	**Spring**	S.Sub-S.Polr(-0.44)
	Summer	N.Polr-Equa(-0.40); N.Temp-Equa(-0.57); N.Temp-S.Temp(-0.47); N.Temp-Trop(-0.49); N.Sub-Equa(-0.48); Equa-S.Sub(0.48); Equa-S.Polr(0.41); Equa-Trop(0.52)
	Autumn	N.Sub-Equa(-0.54); Equa-S.Sub(0.46); Equa-S.Polr(0.54); Equa-Trop(0.60*); S.Polr-Trop(-0.45)
Tropopause	**Winter**	Equa-S.Sub(0.51); Equa-Trop(0.48); S.Sub-S.Temp(-0.47); S.Sub-Trop(-0.44)
	Spring	N.Sub-Equa(-0.51); N.Sub-Trop(-0.51); Equa-Trop(0.47)
	Summer	N.Temp-Equa(-0.42); N.Sub-Equa(-0.57); N.Sub-S.Temp(-0.46); N.Sub-Trop(-0.59*); Equa-S.Sub(0.40); Equa-Trop(0.50)
	Autumn	N.Temp-Equa(-0.41); N.Sub-Equa(-0.50); N.Sub-Trop(-0.44); Equa-S.Sub(0.46); Equa-Trop(0.50)
Surf-100hPa	**Spring**	N.Sub-S.Temp(-0.40); Equa-Trop(0.41)
	Summer	N.Polr-Equa(-0.50); N.Temp-Equa(-0.60*); N.Temp-S.Temp (-0.59*); N.Temp-Trop(-0.53); N.Sub-Equa(-0.50); Equa-S.Sub(0.55); Equa-Trop(0.54); S.Sub-S.Temp(-0.42); S.Sub-Trop (-0.49)
	Autumn	N.Temp-Equa(-0.42); N.Sub-Equa(-0.56); N.Sub-Trop(-0.42); Equa-S.Sub(0.48); Equa-Trop(0.57)

Table 5-e: Correlation of regional difference in the concurrent year seasonal temperature departures with the area averaged summer monsoon OLR over North east India (NEI) during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Level	Season	Difference between regions (CC)
Surface	Winter	N.Temp-S.Polr(-0.43); Equa-S.Polr(-0.48); S.Sub-S.Polr(-0.41); S.Temp-S.Polr(-0.42): S.Polr-Trop(0.43)
	Summer	N.Polr-N.Temp(-0.40)
	Autumn	S.Sub-S.Temp(-0.46)
Troposphere	Winter	N.Temp-S.Polr(-0.46)
	Summer	N.Sub-Equa(-0.45); Equa-S.Sub(0.40); Equa-Trop(0.46)
	Autumn	N.Sub-Equa(-0.41); Equa-S.Sub(0.58*); Equa-S.Polr(0.50); Equa-Trop(0.59*)
Tropopause	Winter	N.Polr-S.Polr(-0.47); N.Temp-S.Temp(-0.44); N.Temp-S.Polr(-0.59*); N.Sub-Equa(-0.57); N.Sub-S.Temp(-0.57); N.Sub-S.Polr(-0.62*); N.Sub-Trop(-0.47); Equa-S.Sub(0.49); Equa-S.Polr(-0.50); Equa-Trop(0.57); S.Sub-S.Temp(-0.47); S.Sub-S.Polr(-0.57); S.Temp-S.Polr(-0.50); S.Temp-Trop(0.47); S.Polr-Trop(0.58*)
	Spring	N.Temp-Equa(-0.40); N.Sub-Equa(-0.53); N.Sub-Trop(-0.49); Equa-S.Sub(0.47); Equa-Trop(0.52)
	Summer	N.Polr-Equa(-0.41); N.Temp-Equa(-0.59*); N.Temp-S.Temp(-0.46); N.Temp-Trop(-0.41); N.Sub-Equa(-0.54); N.Sub-Trop(-0.41); Equa-S.Sub(0.56); Equa-Trop(0.57); S.Sub-S.Temp(-0.40); S.Sub-Trop(-0.47)
	Autumn	N.Polr-Equa(-0.49); N.Temp-Equa(-0.59*); N.Sub-Equa(-0.60*); N.Sub-Trop(-0.53); Equa-S.Sub(0.54); Equa-Trop(0.59*)
Surf-100hPa	Winter	N.Polr-S.Polr(-0.53); N.Temp-S.Polr(-0.63*); N.Sub-S.Polr(-0.64*); Equa-S.Sub(0.40); Equa-S.Polr(-0.48); Equa-Trop(0.41); S.Sub-S.Polr(-0.62*); S.Temp-S.Polr(-0.52); S.Polr-Trop(0.61*)
	Spring	N.Temp-Equa(-0.42); N.Sub-Equa(-0.41); Equa-S.Sub(0.42); Equa-Trop(0.44)
	Summer	N.Temp-Equa(-0.45); N.Sub-Equa(-0.46); Equa-S.Sub(0.51); Equa-Trop(0.50); S.Sub-Trop(-0.47)
	Autumn	N.Temp-Equa(-0.41); N.Sub-Equa(-0.50); Equa-S.Sub(0.57); Equa-Trop(0.58*); S.Sub-Trop(-0.45)

Table 5-f: Correlation of regional difference in the concurrent year seasonal temperature departures with the area averaged summer monsoon OLR over West Coast (WC) during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Level	Season	Difference between regions (CC)
Surface	Summer	N.Sub-S.Temp(-0.44)
Troposphere	Winter	N.Sub-S.Temp(-0.44)
	Summer	N.Polr-N.Temp(0.42); N.Temp-S.Temp(-0.43); N.Sub-S.Temp(-0.41)
	Autumn	N.Sub-Equa(-0.53); N.Sub-Trop(-0.46); Equa-S.Temp(0.45); Equa-Trop(0.45)
Surf-100hPa	Winter	N.Sub-S.Temp(-0.41); S.Temp-Trop(0.43)
	Summer	N.Polr-N.Temp(0.44)
	Autumn	N.Sub-Equa(-0.44); N.Sub-Trop(-0.40); Equa-S.Temp(0.51)

Table 5-g: Correlation of regional difference in the concurrent year seasonal temperature departures with the area averaged summer monsoon OLR over West Coast South (WC_S) during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Level	Season	Difference between regions (CC)
Surface	Summer	N.Sub-S.Temp(-0.46)
Troposphere	Winter	N.Sub-S.Temp(-0.44)
	Summer	N.Polr-N.Temp(0.41); N.Temp-S.Temp(-0.44); N.Sub-S.Temp(-0.43)
	Autumn	N.Sub-Equa(-0.53); N.Sub-Trop(-0.46); Equa-S.Temp(0.46); Equa-Trop(0.45)
Surf-100hPa	Winter	N.Sub-S.Temp(-0.42); S.Sub-S.Temp(-0.41); S.Temp-Trop(0.46)
	Summer	N.Polr-N.Temp(0.44)
	Autumn	N.Sub-Equa(-0.45); N.Sub-Trop(-0.40); Equa-S.Temp(0.54); Equa-Trop(0.40)

Table 5-h: Correlation of regional difference in the concurrent year seasonal temperature departures with the area averaged summer monsoon OLR over Central Peninsular India (CPI) during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Level	Season	Difference between regions (CC)
Troposphere	Summer	N.Temp-Equa(-0.44); N.Temp-S.Sub(-0.41); N.Temp-S.Temp(-0.51); N.temp-Trop(-0.42);
	Autumn	N.Sub-Equa(-0.54); N.Sub-Trop(-0.42); Equa-S.Temp(0.46); Equa-S.Polr(0.46); Equa-Trop(0.52)
Surf-100hPa	Summer	N.Polr-N.Temp(0.47); N.Temp-Equa(-0.44); N.Temp-S.Temp(-0.54); N.Temp-Trop(-0.44)
	Autumn	N.Sub-Equa(-0.46); Equa-S.Temp(0.49); Equa-Trop(0.44)

Table 5-i: Correlation of regional difference in the concurrent year seasonal temperature departures with the area averaged summer monsoon OLR over East Coast north (EC_N) during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Level	Season	Difference between regions (CC)
Surface	**Winter**	N.Temp-S.Polr(-0.41); Equa-S.Polr(-0.42); S.Sub-S.Polr(-0.48); S.Polr-Trop(0.42)
	Autumn	S.Sub-S.Temp(-0.56); S.Temp-Trop(0.41)
Troposphere	**Winter**	N.Temp-S.Polr(-0.48); N.Sub-S.Polr(-0.40), S.Sub-S.Polr(-0.48); S.Polr-Trop(0.42)
	Spring	S.Sub-S.Temp(-0.48)
	Summer	N.Temp-Equa(-0.50); N.Temp-S.Temp(-0.41); N.Sub-Equa(-0.51); Equa-S.Sub(0.59*); Equa-Trop(0.59*); S.Sub-Trop(-0.46)
	Autumn	N.Temp-Equa(-0.49); N.Sub-Equa(-0.53); Equa-S.Sub(0.66*); Equa-S.Polr(0.56); Equa-Trop(0.71*); S.Sub-Trop(-0.40); S.Pol-Trop(-0.43)
Tropopause	**Winter**	N.Sub-Equa(-0.53); N.Sub-S.Temp(-0.47); N.Sub-S.Polr(-0.42); Equa-S.Sub(0.60*); Equa-Trop(0.60*); S.Sub-S.Temp(-0.51); S.Sub-S.Polr(-0.43); S.Sub-Trop(-0.46); S.Temp-Trop(0.42)
	Spring	N.Sub-Equa(-0.51); N.Sub-Trop(-0.43); Equa-S.Sub(0.52); Equa-Trop(0.53)
	Summer	N.Temp-Equa(-0.54); N.Sub-Equa(-0.58*); N.Sub-Trop(-0.46); Equa-S.Sub(0.58*); Equa-S.Polr(0.42); Equa-Trop(0.60*); S.Sub-Trop(-0.47)
	Autumn	N.Polr-Equa(-0.48); N.Temp-Equa(-0.73*); N.Temp-Trop(-0.49); N.Sub-Equa(-0.67*); N.Sub-Trop(-0.53); Equa-S.Sub(0.71*); Equa-S.Temp(0.42); Equa-Trop(0.72*); S.Sub-Trop(-0.56)
Surf-100hPa	**Winter**	N.Polr-S.Polr(-0.53); N.Temp-S.Polr(-0.53); N.Sub-S.Polr(-0.51); Equa-S.Sub(0.47); Equa-Trop(0.40); S.Sub-S.Temp(-0.42); S.Sub-S.Polr(-0.58*); S.Sub-Trop(-0.47); S.Polr-Trop(0.52)
	Spring	N.Sub-S.Temp(-0.42); Equa-S.Sub(0.45); Equa-Trop(0.44); S.Sub-S.Temp(-0.46)
	Summer	N.Polr-Equa(-0.40); N.Temp-Equa(-0.53); N.Temp-S.Temp(-0.46); N.Temp-Trop(-0.40); N.Sub-Equa(-0.49); Equa-S.Sub(0.61*); Equa-Trop(0.57); S.Sub-S.Temp(-0.45); S.Sub- Trop(-0.60*)
	Autumn	N.Temp-Equa(-0.59*); N.Temp-S.Temp(-0.44); N.Temp-Trop(-0.43); N.Sub-Equa(-0.65*); Equa-S.Sub(0.72*); Equa-S.Temp(0.45); Equa-Trop(0.74*); S.Sub-Trop(-0.56)

Table 5-j: Correlation of regional difference in the concurrent year seasonal temperature departures with the area averaged summer monsoon OLR over East Coast South (EC_S) during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Level	Season	Difference between regions (CC)
Surface	**Autumn**	S.Sub-S.Temp(-0.44)
Troposphere	**Winter**	N.Temp-S.Temp(-0.40); N.Sub-S.Temp(-0.45); S.Sub-S.Temp(-0.42)
	Summer	N.Polr-N.Temp(0.46); N.Polr-S.Polr(0.43)
	Autumn	N.Sub-Equa(-0.47); Equa-S.Sub(0.41); Equa-S.Temp(0.51); Equa-Trop(0.54)
Tropopause	**Summer**	N.Polr-Equa(-0.41); N.Temp-Equa(-0.47); N.Sub-Equa(-0.42); Equa-S.Sub(0.43); Equa-Trop(0.44)
	Autumn	N.Temp-Equa(-0.47); N.Temp-S.Polr(-0.44); N.Sub-Equa(-0.43); N.Sub-S.Polr(-0.42); Equa-S.Sub(0.40); Equa-Trop(0.42); S.Sub-S.Polr(-0.40); S.Temp-S.Polr(-0.41)
Surf-100hPa	**Winter**	N.Sub-S.Temp(-0.43); S.Temp-Trop(0.40)
	Summer	N.Polr-N.Temp(0.50); Equa-S.Polr(0.42)
	Autumn	N.Sub-Equa(-0.46); Equa-S.Sub(0.46); Equa-S.Temp(0.56); Equa-Trop(0.49)

Table 5-k: Correlation of regional difference in the concurrent year seasonal temperature departures with the area averaged summer monsoon OLR over South Peninsular India (SPI) during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Level	Season	Difference between regions (CC)
Surface	**Summer**	S.Temp-S.Polr(0.40)
Troposphere	**Winter**	N.Sub-S.Temp(-0.48); S.Sub-S.Temp(-0.40)
	Summer	N.Polr-N.Temp(0.44); N.Polr-S.Polr(0.43)
	Autumn	N.Sub-Equa(-0.45); Equa-S.Temp(0.42); Equa-Trop(0.44)
Tropopause	**Summer**	N.Polr-Equa(-0.41)
Surf-100hPa	**Winter**	N.Sub-S.Temp(-0.41); S.Temp-Trop(0.40)
	Summer	N.Polr-N.Temp(0.46); N.Polr-S.Polr(0.40)
	Autumn	N.Sub-Equa(-0.42); Equa-S.Temp(0.50); Equa-Trop(0.40)

Table 5-l: Correlation of regional difference in the concurrent year seasonal temperature departures with the area averaged summer monsoon OLR over whole India during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Level	Season	Difference between regions (CC)
Surface	**Summer**	N. Polr – S. Temp(-0.40).
	Autumn	S. Subt – S. Temp(-0.49).
Troposphere	**Winter**	N.Temp-S. Polr(-0.46); N. Subt – S.Polr(-0.41); S.Subt-S.Polr(-0.40).
	Spring	Equa – S. Subt(0.42); Equa – Trop(0.43); S. Subt – S. Temp(-0.41).
	Summer	N.Polr-Equa(-0.40); N.Temp-Equa(-0.63*); N.Temp-S.Temp(-0.43); N. Temp – Trop(-0.50); N. Subt – Equa(-0.60*); Equa – S. Subt(0.61*); Equa – S. Polr(0.44); Equa – Trop(0.65*); S. Subt – Trop(-0.43).
	Autumn	N. Temp – Equa(-0.54); N. Subt – Equa(-0.62*); Equa – S. Subt(0.66*); Equa – S. Polr(0.68*); Equa – Trop(0.77*); S. Polr – Trop(-0.56).
Tropopause	**Winter**	N.Temp-S.Polr(-0.50); N.Subt-Equa(-0.53); N.Subt-S.Temp(-0.53); N. Subt – S. Polr(-0.54); Equa – S. Subt(0.61*); Equa – Trop(0.61*); Equa-S.Polr(-0.42); S.Subt-S.Temp(-0.57*); S.Subt-S.Polr(-0.55); S. Subt – Trop(-0.47); S. Temp – S. Polr(-0.42); S. Temp – Trop(0.49); S. Polr – Trop(0.52).
	Spring	N.Subt – Equa (-0.60*); N. Subt – Trop (-0.56); Equa – S.Subt (0.51); Equa – Trop (0.58*); N. Temp – Equa (-0.40).
	Summer	N.Temp–Equa(-0.61*); N.Subt–Equa(-0.66*); N. Subt – Trop(-0.57*); Equa – S. Subt(0.60*); Equa – Trop(0.65*); N. Polr – Equa(-0.42); S. Subt – Trop(-0.43).
	Autumn	N.Temp–Equa(-0.64*); N.Temp–Trop(-0.40); N.Subt – Equa(-0.66*); N. Subtr – Trop(-0.56); Equa – S. Subt(0.62*); Equa – Trop(0.67*); S. Subt – Trop(-0.43); N. Polr – Equa(-0.46).
Surf-100hPa	**Winter**	N.Polr–S.Polr(-0.50); N.Temp–S.Polr(-0.56); N.Subt–S.Polr(-0.59*); N.Subt – S.Temp(-0.41); S.Subt – S.Polr(-0.60*); S.Polr – Trop(0.56); Equa – S. Subt(0.47); Equa – S. Polr(-0.41); Equa – Trop(0.46).
	Spring	N.Temp–Equa(-0.46); N.Temp–S.Temp(-0.41); N.Subt–Equa(-0.51); N. Subt – S. Temp(-0.47); Equa – S. Subt(0.52); Equa – Trop(0.56); S. Subt – S. Temp(-0.40).
	Summer	N.Polr–Equa(-0.53); N.Temp–Equa(-0.67*); N.Temp–S.Temp(-0.51); N.Temp–Trop(-0.55); N. Subt – Equa(-0.59*); N. Subt – Trop(-0.41); Equa – S. Subt(0.65*); Equa – Trop(0.64*); Equa – S. Polr(0.40); S. Subt – Trop(-0.59*).
	Autumn	N.Temp–Equa(-0.60*); N.Temp–S.Temp(-0.40); N.Temp–Trop(-0.44); N. Subt – Equa(-0.68*); N. Subt – Trop(-0.44); Equa – S. Subt(0.69*); Equa – S. Temp(0.51); Equa – Trop(0.75*); S. Sub – Trop(-0.49).

Table 6-a: Correlation of difference in the seasonal temperature departures from one season to the following seasons(s) of the concurrent year with the area averaged summer monsoon OLR over Extreme North India (ENI) during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Level	Difference between Season	Region (CC)
Surface	Winter - Spring	N.Hem(-0.42)
	Winter – Autumn	N.Polr(-0.40)
Tropopause	Summer – Autumn	Glob(-0.42)

Table 6-b: Correlation of difference in the seasonal temperature departures from one season to the following seasons(s) of the concurrent year with the area averaged summer monsoon OLR over North West India (NWI) during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Level	Difference between Season	Region (CC)
Surface	Winter - Spring	N.Hem(-0.47)
	Winter – Autumn	N.Polr(-0.41)
Tropopause	Summer – Autumn	Glob(-0.44)

Table 6-c: Correlation of difference in the seasonal temperature departures from one season to the following seasons(s) of the concurrent year with the area averaged summer monsoon OLR over Ganga Plains (GP) during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Level	Difference between Season	Region (CC)
Surface	Winter - Spring	S.Temp(0.44); S.Polr(0.42); S.Hem(0.54)
	Winter – Summer	N.Sub(0.41)
	Winter – Autumn	N.Sub(0.43)
Troposphere	Spring - Summer	S.Polr(0.40)
	Spring – Autumn	S.Polr(0.50)
Tropopause	Winter – Autumn	N.Sub(-0.43)
	Summer – Autumn	Glob(-0.57); S.Hem(-0.41)
Surf – 100hPa	Winter - Spring	S.Temp(0.40); S.Hem(0.44)
	Winter – Autumn	N.Hem(-0.42)

Table 6-d: Correlation of difference in the seasonal temperature departures from one season to the following seasons(s) of the concurrent year with the area averaged summer monsoon OLR over Central India (CI) during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Level	Difference between Season	Region (CC)
Surface	Winter - Spring	S.Hem(0.44)
	Winter – Autumn	N.Sub(0.42)
Troposphere	Spring – Autumn	S.Polr(0.47)
Tropopause	Winter – Autumn	N.Sub(-0.47)
	Summer–Autumn	Glob(-0.60*); N.Sub(-0.41); N.Hem(-0.40); S.Hem(-0.40)
Surf – 100hPa	Winter - Spring	S.Hem(0.41)
	Winter – Autumn	N.Hem(-0.40)

Table 6-e: Correlation of difference in the seasonal temperature departures from one season to the following seasons(s) of the concurrent year with the area averaged summer monsoon OLR over North East India (NEI) during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Level	Difference between Season	Region (CC)
Surface	Winter - Spring	S.Temp(0.40); S.Hem(0.46)
Troposphere	Winter – Autumn	S.Sub(-0.43); Trop(-0.41)
Tropopause	Spring - Summer	S.Sub(0.40)
	Summer – Autumn	Glob(-0.41); S.Sub(-0.54)

Table 6-f: Correlation of difference in the seasonal temperature departures from one season to the following seasons(s) of the concurrent year with the area averaged summer monsoon OLR over West Coast (WC) during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Level	Difference between Season	Region (CC)
Surface	Winter – Autumn	N.Polr(-0.43)
Troposphere	Spring – Autumn	Equa(-0.44); Trop(-0.45)
	Summer – Autumn	Equa(-0.45); S.Temp(0.42); Trop(-0.43)
Tropopause	Spring - Summer	Equa(-0.41)
	Spring – Autumn	Equa(-0.41); Trop(-0.41)
Surf – 100hPa	Spring – Autumn	Equa(-0.46); Trop(-0.48)

Table 6-g: Correlation of difference in the seasonal temperature departures from one season to the following seasons(s) of the concurrent year with the area averaged summer monsoon OLR over West Coast South (WC_S) during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Level	Difference between Season	Region (CC)
Surface	Winter – Autumn	N.Polr(-0.41)
Troposphere	Spring – Autumn	Equa(-0.46); S.Sub(-0.40); Trop(-0.47)
	Summer – Autumn	Equa(-0.50); S.Temp(0.45); Trop(-0.46)
Tropopause	Winter - Spring	S.Polr(-0.42)
	Spring - Summer	Equa(-0.41)
	Spring – Autumn	Equa(-0.42); Trop(-0.42)
Surf – 100hPa	Spring – Autumn	Equa(-0.49); Trop(-0.49)

Table 6-h: Correlation of difference in the seasonal temperature departures from one season to the following seasons(s) of the concurrent year with the area averaged summer monsoon OLR over Central Peninsular India (CPI) during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Level	Difference between Season	Region (CC)
Troposphere	Spring – Autumn	Equa(-0.42); Trop(-0.42)
	Summer – Autumn	S.Temp(0.40)
Tropopause	Summer – Autumn	S.Temp(-0.53)
Surf – 100hPa	Spring – Autumn	Equa(-0.42); Trop(-0.47)

Table 6-i: Correlation of difference in the seasonal temperature departures from one season to the following seasons(s) of the concurrent year with the area averaged summer monsoon OLR over East Coast North (EC_N) during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Level	Difference between Season	Region (CC)
Surface	Winter - Spring	S.Hem(0.44)
Tropopause	Summer – Autumn	Glob(-0.63*); S.Sub(-0.53); Trop(-0.46); S.Hem(-0.47)
Surf – 100hPa	Summer – Autumn	Glob(-0.41); S.Hem(-0.40)

Table 6-j: Correlation of difference in the seasonal temperature departures from one season to the following seasons(s) of the concurrent year with the area averaged summer monsoon OLR over East Coast South (EC_S) during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Level	Difference between Season	Region (CC)
Troposphere	Spring – Autumn	Equa(-0.42); Trop(-0.40)
Tropopause	Spring - Summer	Equa(-0.40)
	Spring – Autumn	S.Polr(-0.40); S.Hem(-0.47)
	Summer – Autumn	Glob(-0.52); S.Polr(-0.44); S.Hem(-0.50)
Surf – 100hPa	Spring – Autumn	Equa(-0.44); Trop(-0.43)
	Summer – Autumn	S.Polr(-0.48); S.Hem(-0.42)

Table 6-k: Correlation of difference in the seasonal temperature departures from one season to the following seasons(s) of the concurrent year with the area averaged summer monsoon OLR over South Peninsular India (SPI) during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Level	Difference between Season	Region (CC)
Surface	Winter – Autumn	N.Polr(-0.42)
Tropopause	Winter - Spring	S.Polr(-0.45)
	Spring - Summer	Equa(-0.49)
	Spring – Autumn	Equa(-0.41)
Surf – 100hPa	Spring – Autumn	Equa(-0.40)
	Summer – Autumn	S.Polr(-0.42)

Table 6-l: Correlation of difference in the seasonal temperature departures from one season to the following seasons(s) of the concurrent year with the area averaged summer monsoon OLR over whole India during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Level	Difference between Season	Region (CC)
Surface	Winter - Spring	S. Temperate (0.40); S. Hemisphere (0.49).
Troposphere	Winter – Autumn	Tropics (-0.40).
	Spring - Autumn	S. Polar (0.44).
Tropopause	Summer - Autumn	Globe (-0.60*); S. Subtropic (-0.52); S. Hem. (-0.43).

Table 7-a: Correlation of the regional/hemispheric/globe seasonal temperature departures between surface air and upper air with the area averaged summer monsoon OLR over Extreme North India (ENI) during 1974-2005. CC values significant at 5% level are given; * significant at 1% level.

Season	Difference between levels	Region (CC)
Winter	Surf – T'sphere	S.Hem(-0.42)
	Surf – T'pause	Glob(-0.42)
	T'sphere – T'pause	Glob(-0.41); Equa(-0.42); N.Hem(-0.41)
Spring	Surf – T'sphere	N.Polr(-0.42)
Autumn	Surf – T'sphere	Equa(-0.46)
	Surf – T'pause	Glob(-0.41); Equa(-0.44)

Table 7-b: Correlation of the regional/hemispheric/globe seasonal temperature departures between surface air and upper air with the area averaged summer monsoon OLR over North West India (NWI) during 1974-2005. CC values significant at 5% level are given; * significant at 1% level.

Season	Difference between levels	Region (CC)
Winter	Surf – T'sphere	S.Hem (-0.41)
	Surf – T'pause	Glob(-0.40)
Autumn	Surf – T'sphere	Equa(-0.46); N.Sub(-0.41); Trop(-0.40)
	Surf – T'pause	Glob(-0.43); N.Temp(-0.43); N.Hem(-0.41)

Table 7-c: Correlation of the regional/hemispheric/globe seasonal temperature departures between surface air and upper air with the area averaged summer monsoon OLR over Ganga Plains (GP) during 1974-2005. CC values significant at 5% level are given; * significant at 1% level.

Season	Difference between levels	Region (CC)
Winter	Surf – T'sphere	Glob(-0.50); Equa(-0.44); S.Temp(-0.47); S.Hem(-0.58*)
	Surf – T'pause	Glob(-0.58*); Equa(-0.63*); S.Sub(-0.41); S.Temp(-0.63*); S. Polr (-0.43); Trop(-0.55); N.Hem(-0.40); S.Hem(-0.63*)
	T'sphere – T'pause	Glob(-0.53); Equa(-0.58*); S.Tem(-0.48); S.Polr(-0.43); Trop(-0.43); S.Hem(-0.53)
Spring	Surf – T'sphere	N.Temp (-0.42); N.Hem(-0.48)
	Surf – T'pause	Glob(-0.41); Equa(-0.53); Trop(-0.42)
	T'sphere – T'pause	Equa(-0.56); S.Sub(-0.52); Trop(-0.54); S.Hem(-0.43)
Summer	Surf – T'pause	Glob(-0.42); N.Polr(-0.42); Equa(-0.43); S.Hem(-0.45)
	T'sphere – T'pause	Glob(-0.45); Equa(-0.40); S.Hem(-0.48)
Autumn	Surf – T'sphere	Equa(-0.53)
	Surf – T'pause	Glob(-0.56); Equa(-0.57); S.Sub(-0.45); S.Temp(-0.45); Trop(-0.48); S.Hem(-0.59*)
	T'sphere – T'pause	Glob(-0.58*); Equa(-0.45); S.Temp(-0.40); S.Polr(-0.41); Trop(-0.44); S.Hem(-0.58*)

Table 7-d: Correlation of the regional/hemispheric/globe seasonal temperature departures between surface air and upper air with the area averaged summer monsoon OLR over Central India (CI) during 1974-2005. CC values significant at 5% level are given; * significant at 1% level.

Season	Difference between levels	Region (CC)
Winter	Surf – T'sphere	Glob(-0.44); S.Temp(-0.40); S.Hem(-0.50)
	Surf – T'pause	Glob(-0.51); Equa(-0.55); S.Temp(-0.56); Trop(-0.47); S.Hem(-0.52)
	T'sphere – T'pause	Glob(-0.47); Equa(-0.55); S.Temp(-0.44); Trop(-0.40); S.Hem(-0.43)
Spring	Surf – T'sphere	N.Temp(-0.44); N.Hem(-0.46)
	Surf – T'pause	Equa(-0.45)
	T'sphere – T'pause	Equa(-0.48); S.Sub(-0.43); Trop(-0.46)
Summer	T'sphere – T'pause	Glob(-0.40); S.Hem(-0.40)
Autumn	Surf – T'sphere	Equa(-0.45)
	Surf – T'pause	Glob(-0.50); Equa(-0.50); Trop(-0.40); S.Hem(-0.51)
	T'sphere – T'pause	Glob(-0.53); Equa(-0.40); S.Polr(-0.41); S.Hem(-0.52)

Table 7-e: Correlation of the regional/hemispheric/globe seasonal temperature departures between surface air and upper air with the area averaged summer monsoon OLR over North east India (NEI) during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Season	Difference between levels	Region (CC)
Winter	**Surf – T'sphere**	Equa(-0.53); S.Temp(-0.46)
	Surf – T'pause	Glob(-0.53); N.Temp(-0.41); Equa(-0.67*); S.Temp(-0.63*); S.Polr(-0.49); Trop(-0.49); S.Hem(-0.64*)
	T'sphere – T'pause	Glob(-0.52); Equa(-0.57); S.Temp(-0.49); S.Polr(-0.54); Trop(-0.45); S.Hem(-0.64*)
Spring	**Surf – T'sphere**	S.Temp(-0.40)
	Surf – T'pause	Glob(-0.59*); Equa(-0.57); S.Sub(-0.46); S.Temp(-0.40); Trop(-0.50); N.Hem(-0.42); S.Hem(-0.54)
	T'sphere – T'pause	Glob(-0.62*); Equa(-0.64*); S.Sub(-0.55); Trop(-0.68*); N.Hem(-0.43); S.Hem(-0.52)
Summer	**Surf – T'sphere**	Equa(-0.53)
	Surf – T'pause	Glob(-0.48); Equa(-0.60*); Trop(-0.48); S.Hem(-0.52)
	T'sphere – T'pause	Glob(-0.54); Equa(-0.51); Trop(-0.41); S.Hem(-0.59*)
Autumn	**Surf – T'sphere**	Equa(-0.44)
	Surf – T'pause	Glob(-0.53); Equa(-0.64*); S.Sub(-0.51); Trop(-0.55); S.Hem(-0.58*)
	T'sphere – T'pause	Glob(-0.58*); Equa(-0.60*); S.Sub(-0.48); S.Temp(-0.40); Trop(-0.58*); S.Hem(-0.57)

Table 7-f: Correlation of the regional/hemispheric/globe seasonal temperature departures between surface air and upper air with the area averaged summer monsoon OLR over West Coast (WC) during 1974-2005. CC values significant at 5% level are given; * significant at 1% level.

Season	Difference between levels	Region (CC)
Winter	**T'sphere – T'pause**	N.Hem(-0.40)

Table 7-g: Correlation of the regional/hemispheric/globe seasonal temperature departures between surface air and upper air with the area averaged summer monsoon OLR over West Coast south (WC_S) during 1974-2005. CC values significant at 5% level are given; * significant at 1% level.

Season	Difference between levels	Region (CC)
Winter	**T'sphere – T'pause**	N.Hem(-0.40)

Table 7-h: Correlation of the regional/hemispheric/globe seasonal temperature departures between surface air and upper air with the area averaged summer monsoon OLR over Central Peninsular India (CPI) during 1974-2005. CC values significant at 5% level are given; * significant at 1% level.

Season	Difference between levels	Region (CC)
Winter	**T'sphere – T'pause**	N.Temp(-0.40); Equa(-0.50); N.Hem(-0.45)
Summer	**Surf – T'sphere**	N.Temp(0.41)
Autumn	**T'sphere – T'pause**	Glob(-0.42); S.Polr(-0.40); S.Hem(-0.41)

Table 7-i: Correlation of the regional/hemispheric/globe seasonal temperature departures between surface air and upper air with the area averaged summer monsoon OLR over East Coast North (EC_N) during 1974-2005. CC values significant at 5% level are given; * significant at 1% level.

Season	Difference between levels	Region (CC)
Winter	Surf – T'sphere	Glob(-0.48); equa(-0.42); S.Temp(-0.45); S.Hem(-0.47)
	Surf – T'pause	Glob(-0.58*); N.Temp(-0.47); Equa(-0.72*); S.Sub(-0.46); S.Temp(-0.61*); Trop(-0.60*); N.Hem(-0.41); S.Hem(-0.61*)
	T'sphere – T'pause	Glob(-0.54); N.Temp(-0.44); Equa(-0.73*); S.Temp(-0.46); Trop(-0.55); S.Hem(-0.56)
Spring	Surf – T'sphere	N.Hem(0.46)
	Surf – T'pause	Glob(-0.55); Equa(-0.59*); S.Sub(-0.44); Trop(-0.54); N.Hem(-0.48); S.Hem(-0.44)
	T'sphere – T'pause	Glob(-0.54); Equa(-0.68*); S.Sub(-0.56); Trop(-0.72*); N.Hem(-0.43); S. Hem(-0.44)
Summer	Surf – T'sphere	N.Temp(0.46)
	Surf – T'pause	Glob(-0.48); Equa(-0.55); Trop(-0.45); S.Hem(-0.47)
	T'sphere – T'pause	Glob(-0.57); Equa(-0.56); Trop(-0.52); N.hem(-0.43); S.Hem(-0.50)
Autumn	Surf – T'sphere	N.Polr(-0.40); Equa(-0.46)
	Surf – T'pause	Glob(-0.63*); Equa(-0.71*); S.Sub(-0.52); Trop(-0.63*); N.Hem(-0.51); S.Hem(-0.60*)
	T'sphere – T'pause	Glob(-0.67*); Equa(-0.70*); S.Sub(-0.45); Trop(-0.65*); N.Hem(-0.52); S.Hem(-0.60*)

Table 7-j: Correlation of the regional/hemispheric/globe seasonal temperature departures between surface air and upper air with the area averaged summer monsoon OLR over East Coast South (EC_S) during 1974-2005. CC values significant at 5% level are given; * significant at 1% level.

Season	Difference between levels	Region (CC)
Winter	T'sphere – T'pause	Equa(-0.57); Trop(-0.42)
Summer	Surf – T'sphere	N.Temp(0.40)
	T'sphere – T'pause	Equa(-0.46)
Autumn	Surf – T'sphere	S.Temp(0.48)
	Surf – T'pause	S.Polr(-0.40)
	T'sphere – T'pause	Glob(-0.43); S.Polr(-0.48); S.Hem(-0.51)

Table 7-k: Correlation of the regional/hemispheric/globe seasonal temperature departures between surface air and upper air with the area averaged summer monsoon OLR over South Peninsular India (SPI) during 1974-2005. CC values significant at 5% level are given; * significant at 1% level.

Season	Difference between levels	Region (CC)
Winter	**T'sphere – T'pause**	Equa(-0.40)
Autumn	**Surf – T'sphere**	S.Temp(0.41)

Table 7-l: Correlation of the regional/hemispheric/globe seasonal temperature departures between surface air and upper air with the area averaged summer monsoon OLR over whole India during 1974-2005. CC values significant at 5% level are given; * indicates significant at 1% level.

Season	Difference between levels	Region (CC)
Winter	**Surf – T'sphere**	Glob(-0.50); Equa(-0.47); S. Temp(-0.54); S. Hem(-0.53).
	Surf – T'pause	Glob(-0.65*); N. Temp(-0.52); Equa(-0.73*); S. Subt(-0.42); S. Temp(-0.68*); S.Polr(-0.49); Trop(-0.60*); N.Hem(-0.46); S. Hem(-0.69*).
	T'sphere – T'pause	Glob(-0.62*); N. Temp(-0.49); Equa(-0.71*); S.Temp(-0.49); S. Polr(-0.50); Trop(-0.56); N. Hem(-0.43); S. Hem(-0.63*).
Spring	**Surf – T'sphere**	N. Hem(-0.41).
	Surf – T'pause	Glob(-0.52); Equa(-0.57); Trop(-0.45); N. Hem(-0.44).
	T'sphere – T'pause	Glob(-0.55); Equa(-0.60*); S. Subt(-0.54); Trop(-0.63*); S. Hem(-0.50).
Summer	**Surf – T'sphere**	N. Temp(0.43); Equa(-0.41).
	Surf – T'pause	Glob(-0.48); Equa(-0.55); Trop(-0.45); S. Hem(-0.47).
	T'sphere – T'pause	Glob(-0.57); Equa(-0.53); Trop(-0.45); S. Hem(-0.54).
Autumn	**Surf – T'sphere**	Equa(-0.60*); Trop(-0.41).
	Surf – T'pause	Glob(-0.65*); Equa(-0.72*); S. Subt(-0.57); S. Temp(-0.43); Trop(-0.62*); N. Hem(-0.49); S. Hem(-0.65*).
	T'sphere – T'pause	Glob(-0.68*); N. Temp(-0.40); Equa(-0.61*); S. Subt(-0.43); S. Temp(-0.42); Trop(-0.59*); N.Hem(-0.51); S.Hem(-0.63*)

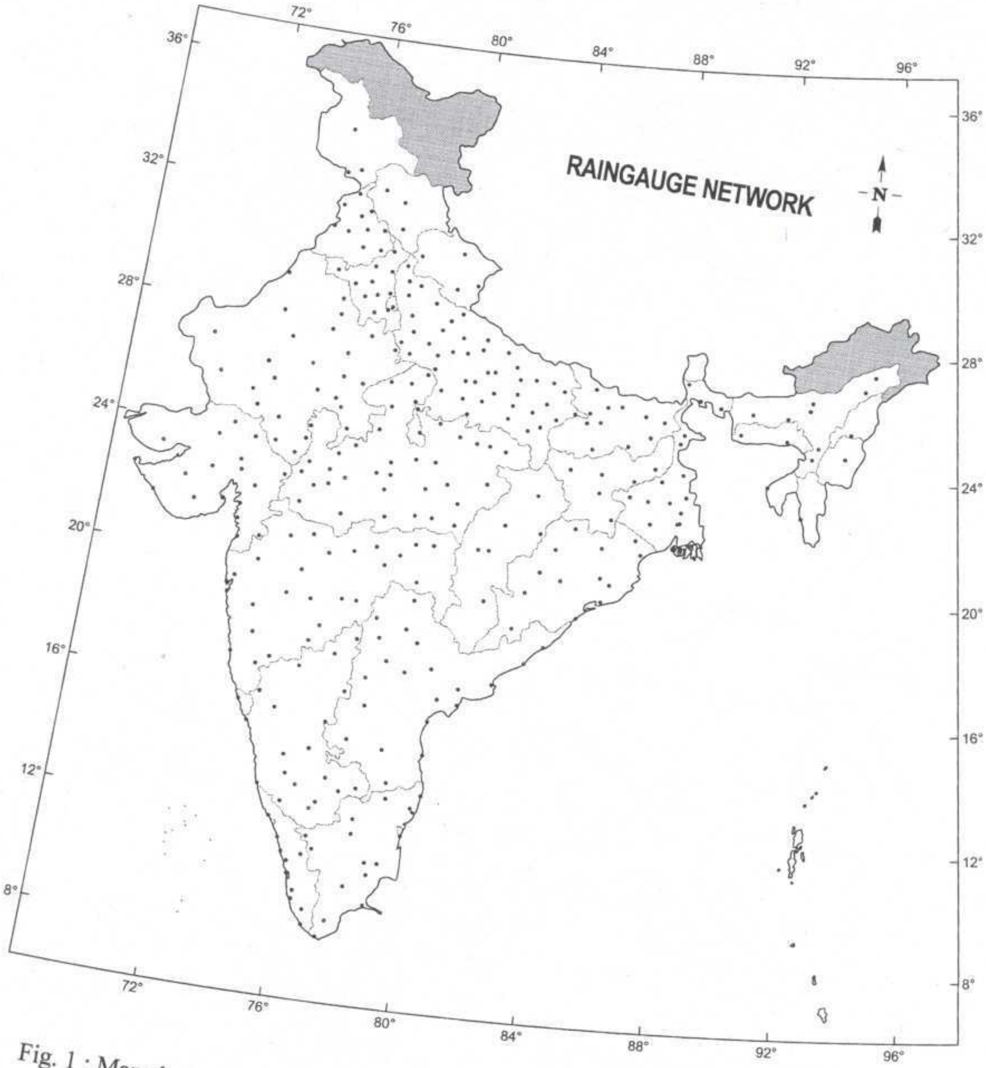


Fig. 1 : Map showing the well spread network of 316 raingauges across India

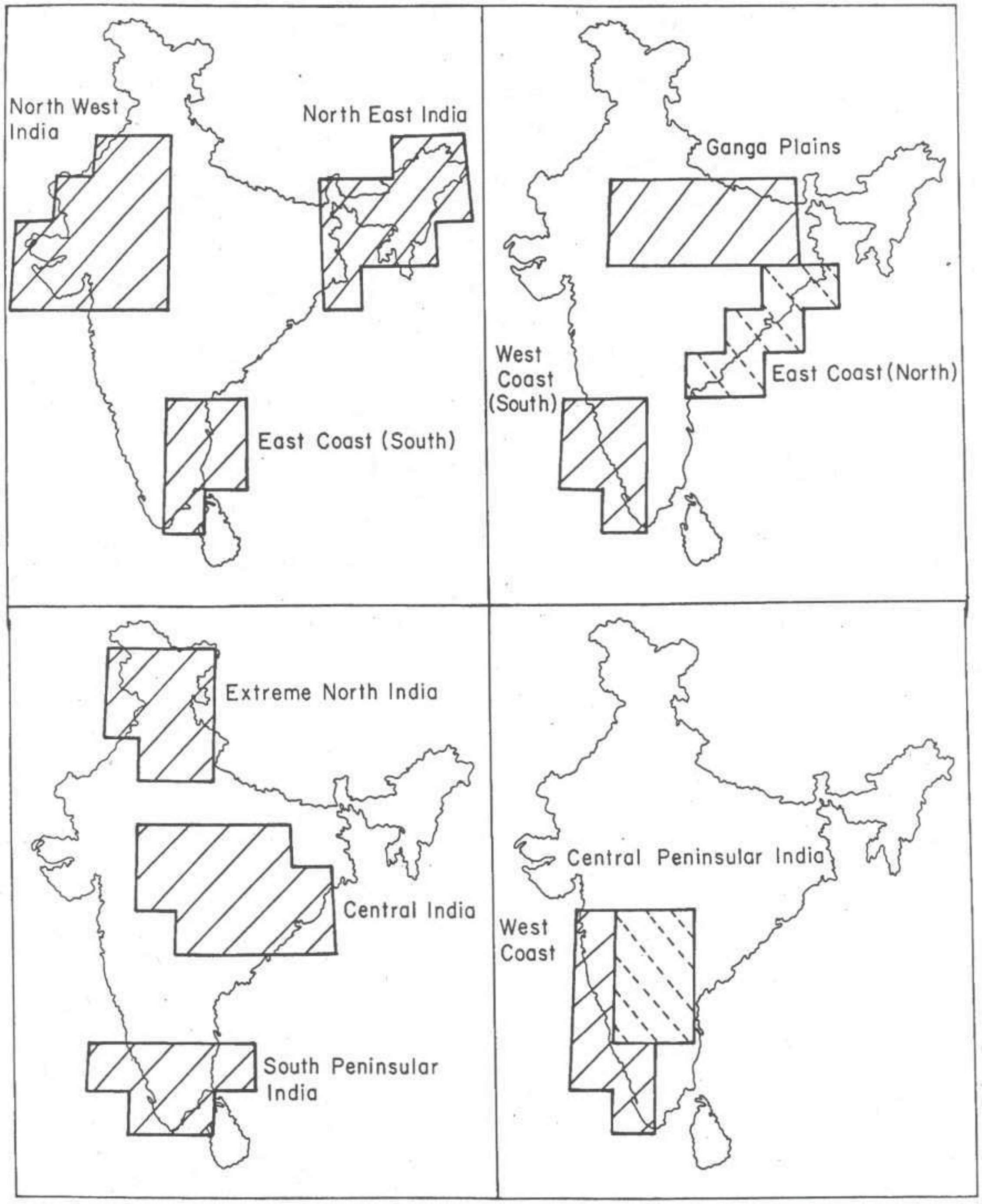
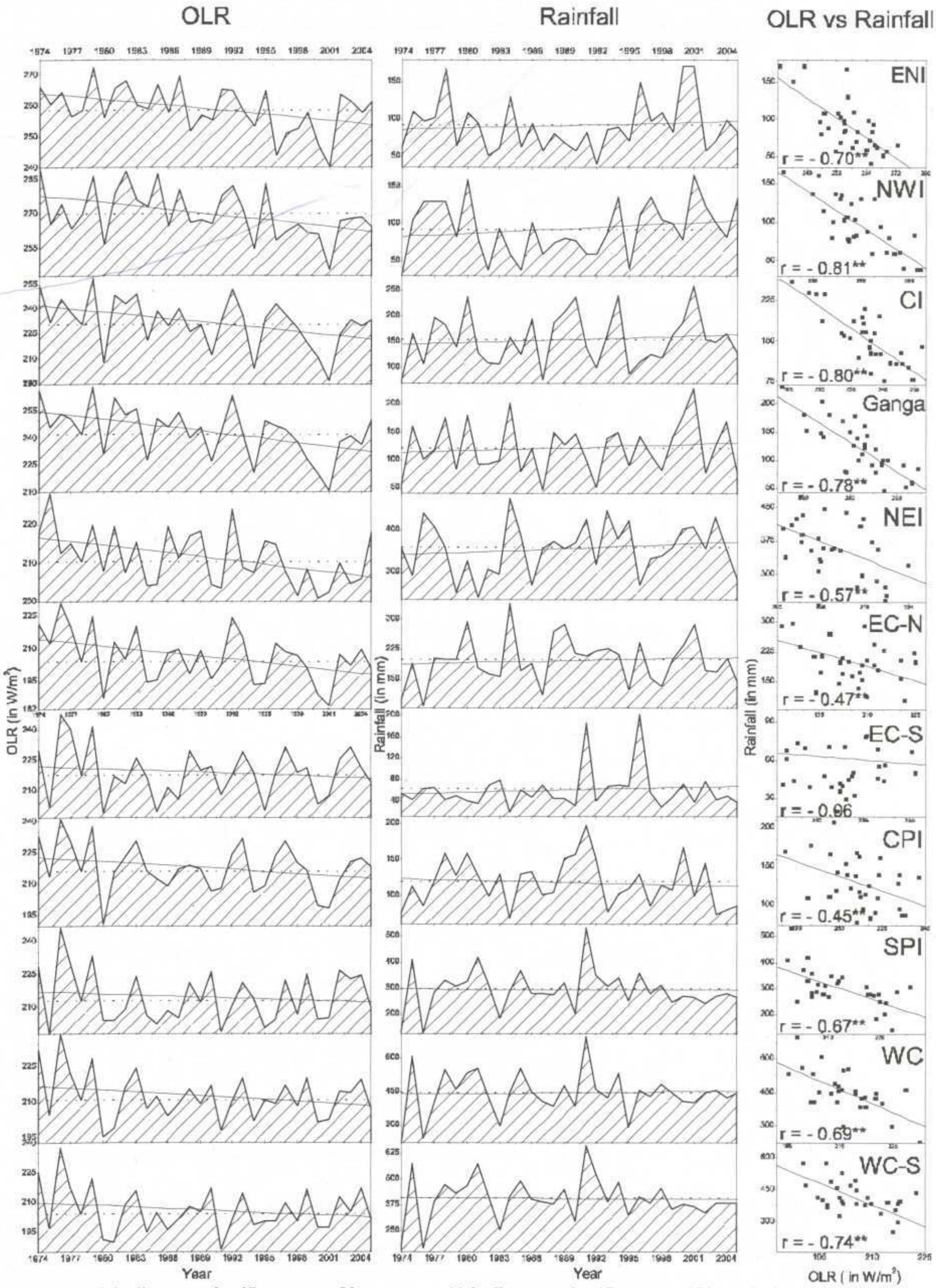
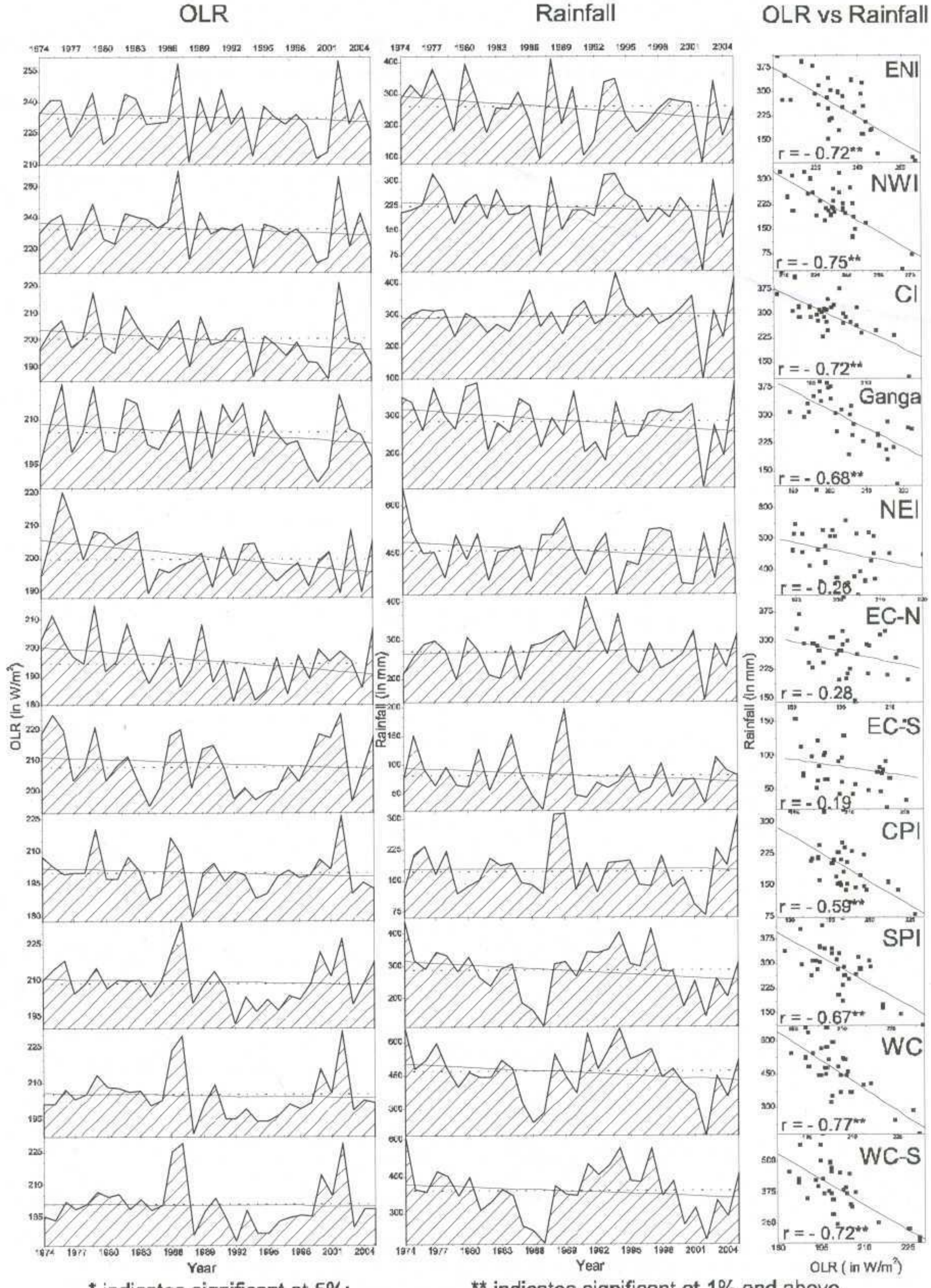


Fig. 2 : Map showing the 11 zones of India



* indicates significant at 5%; ** indicates significant at 1% and above.

Fig. 3-a: Trends in OLR and rainfall variation during June over 11 zones of India



* indicates significant at 5%; ** indicates significant at 1% and above.

Fig. 3-b: Trends in OLR and rainfall variation during July over 11 zones of India

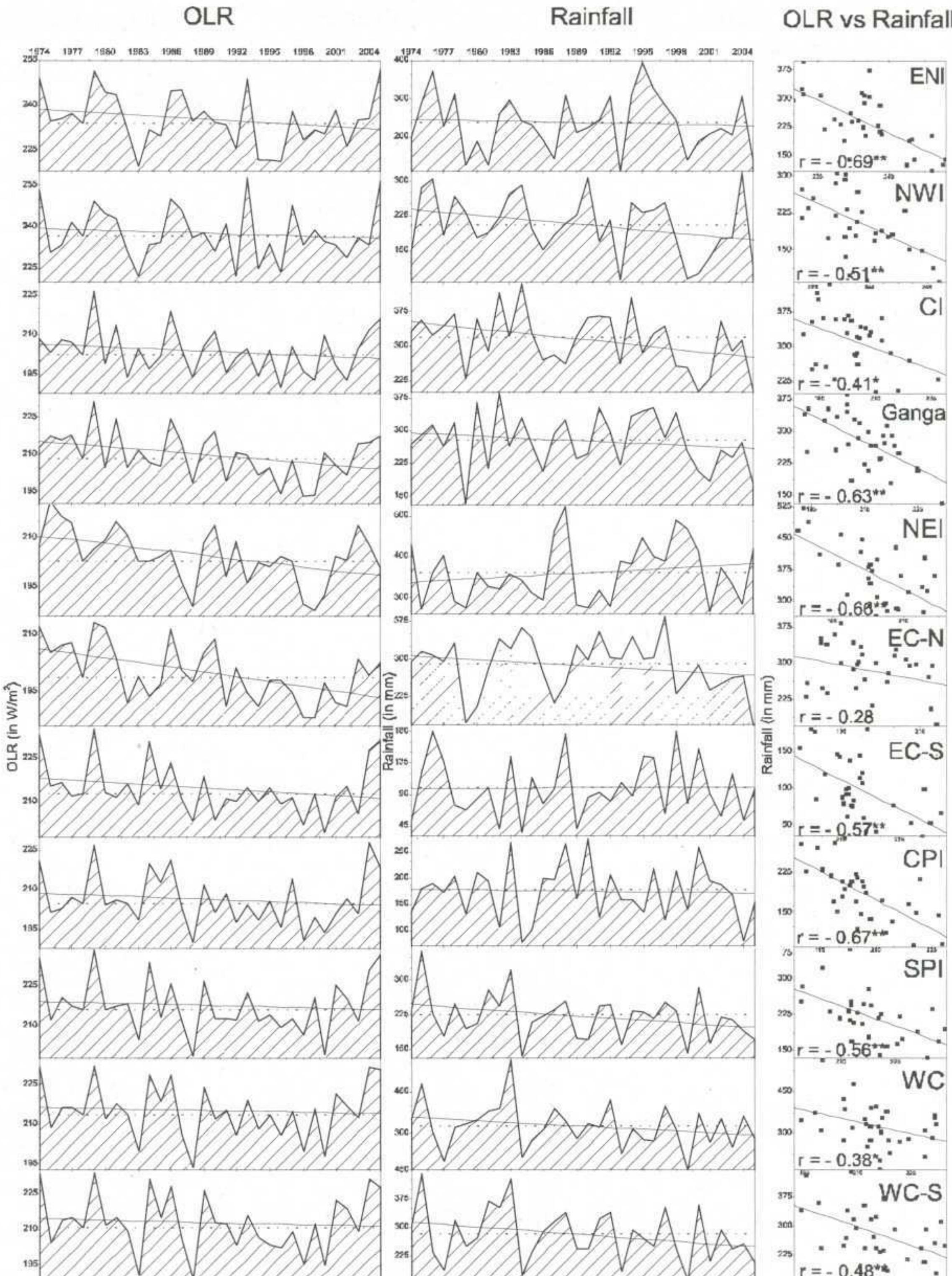


Fig. 3-c: Trends in OLR and rainfall variation during August over 11 zones of India

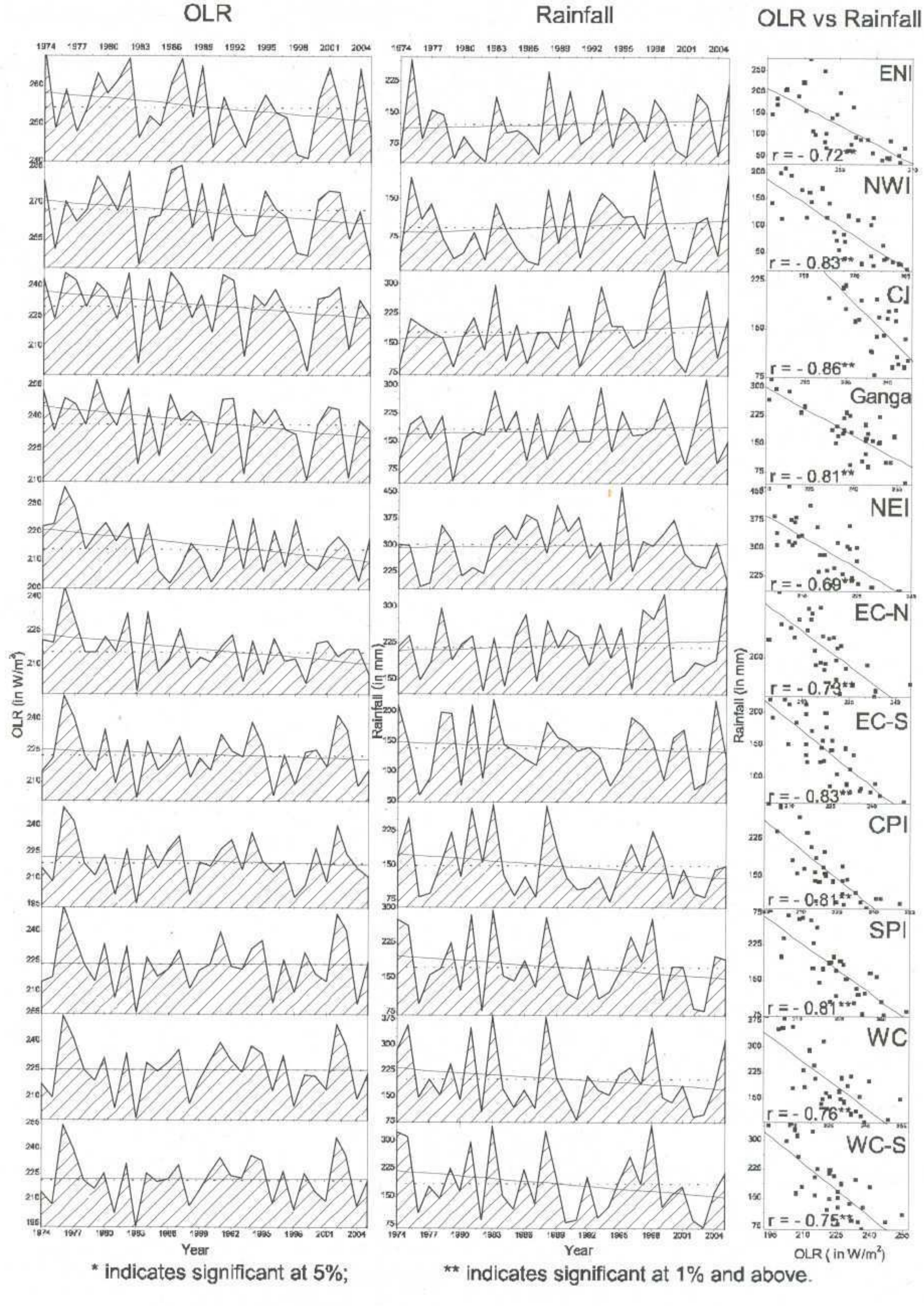
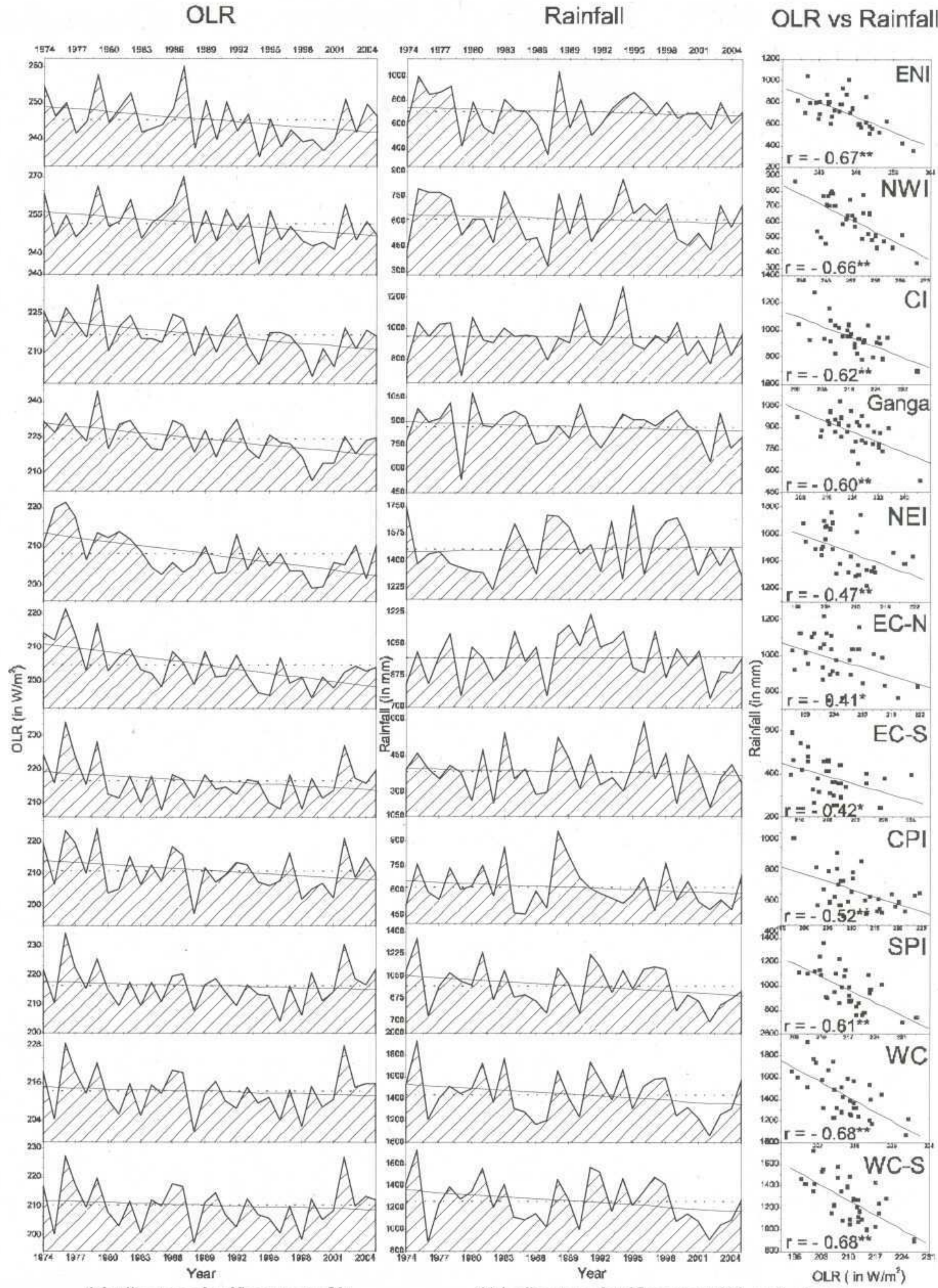


Fig. 3-d: Trends in OLR and rainfall variation during September over 11 zones of India



* indicates significant at 5%; ** indicates significant at 1% and above.

Fig. 3-e: Trends in OLR and summer monsoon rainfall variation over 11 zones of India

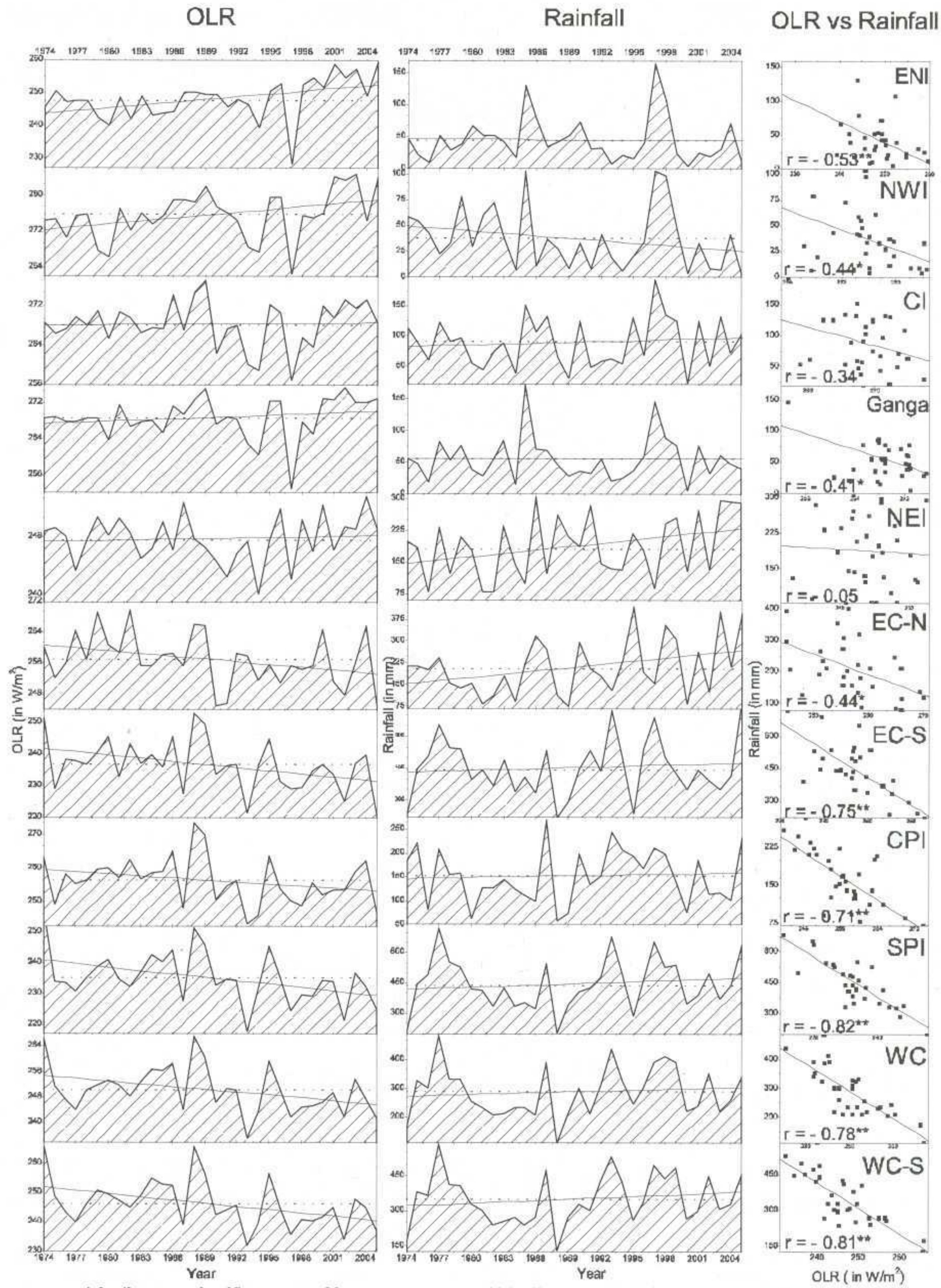


Fig. 3-f: Trends in OLR and post-monsoon rainfall variation over 11 zones of India

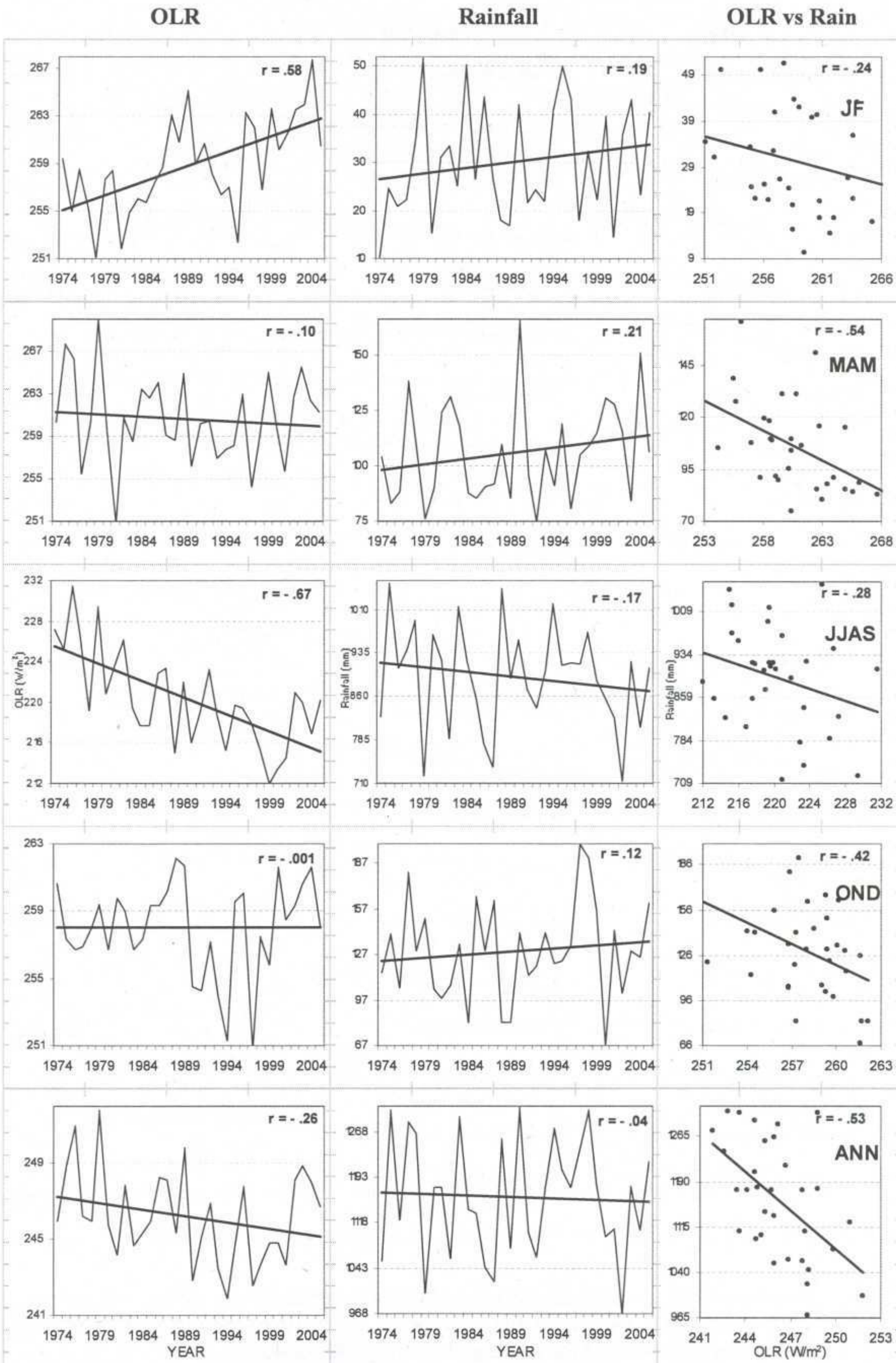


Fig. 4: Trends in seasonal and annual OLR and Rainfall variation over India

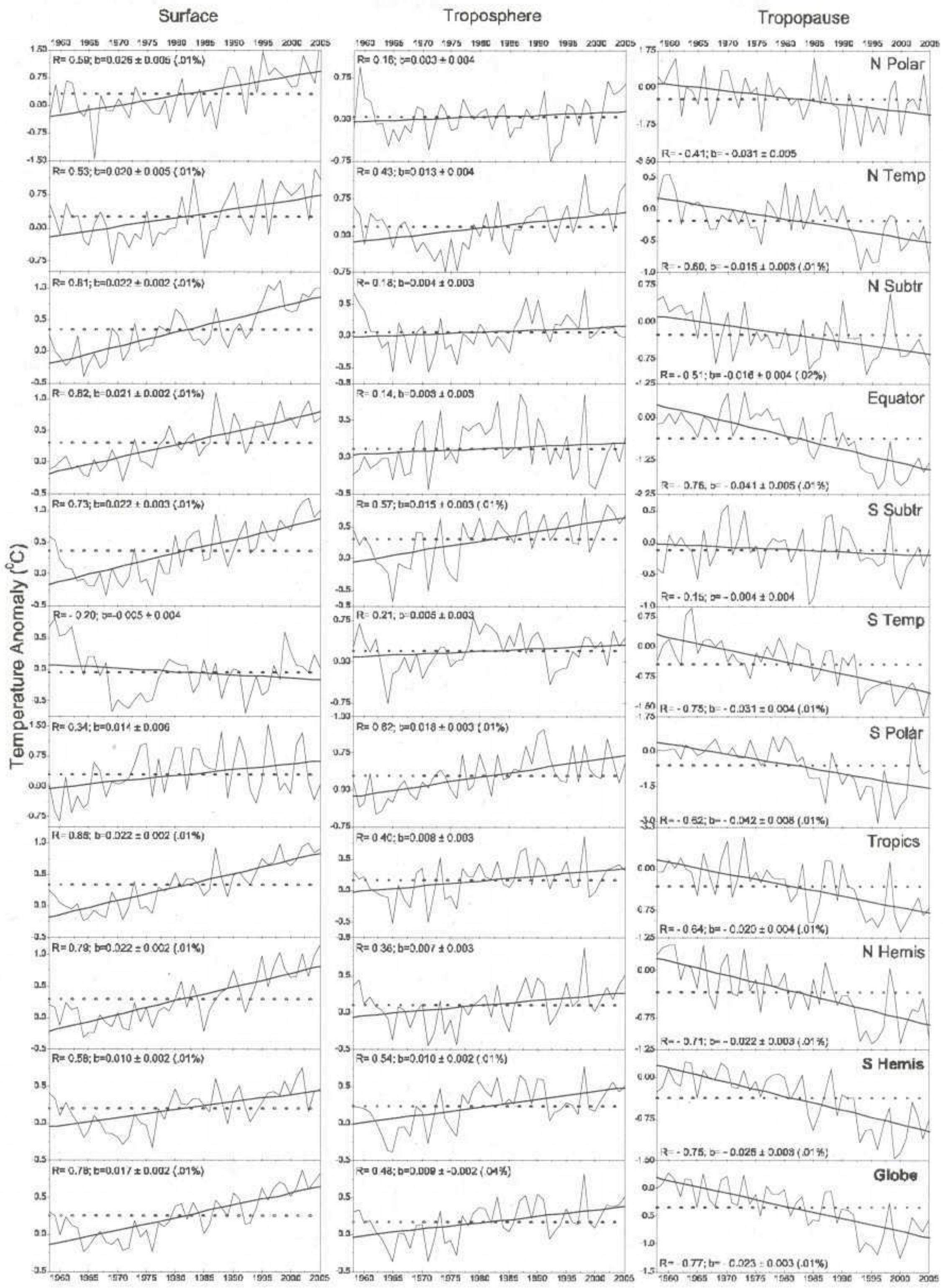


Fig. 5: Liner trend in the interannual variation of annual temperature departures (reference period: 1958-1977) of the surface air, the troposphere and the tropopause over different regions, the two hemispheres and the whole globe during 1958-2005