Chapter-3

Mean Rainfall Distribution

In this chapter, various features of mean rainfall during the NE monsoon are discussed.

3.1. **Mean Rainfall over Met Sub-divisions**

The mean monthly rainfall in the various meteorological sub-divisions in the south peninsula during the period October to December is given in Table 3.1. These mean values are calculated using the rainfall data of 1971-2020.

TABLE 3.1

Mean monthly, seasonal and annual rainfall (cm)

Based on the IMD sub-divisional data for the period 1971-2020

Subdivision name	OCT	NOV	DEC	Season's total	ANNUAL
COASTAL ANDHRA PRADESH & YANAM					
Rainfall(cm)	18	11	3	32	104
Rainfall as % of seasonal total	56	34	9		
Season's total as % of annual total				31	
RAYALSEEMA					
Rainfall(cm)	13	8	3	24	73
Rainfall as % of seasonal total	54	33	13		
Season's total as % of annual total				33	
TAMIL NADU, PUDUCHERRY & KARIAKAL					
Rainfall(cm)	17	18	9	44	92
Rainfall as % of seasonal total	39	41	20		
Season's total as % of annual total				48	

SOUTH INTERIOR KARNATAKA					
Rainfall(cm)	14	5	1	20	103
Rainfall as % of seasonal total	70	25	5		
Season's total as % of annual total				19	
KERALA & MAHE					
Rainfall(cm)	31	15	3	49	289
Rainfall as % of seasonal total	63	31	6		
Season's total as % of annual total				17	

Table 3.1 shows that for the South Peninsula as a whole, October is the rainiest month. However, in Tamil Nadu, November gets as much as rains in October. By December, the rainy season is practically confined over extreme south Peninsula including Tamil Nadu. The south peninsula receives rainfall, when the seasonal east-west convergence zone (ITCZ) and associated weather systems are present over the region. During December when the ITCZ moves further south, rainfall over the south peninsula sharply reduces. When the east-west trough is present, synoptic systems like lows and depressions form over this trough zone and move towards the south peninsula contributing to widespread rainfall activity.

Coastal Andhra Pradesh (CAP) gets rainfall during both the southwest and northeast monsoon seasons. During the NE Monsoon season, CAP receives about 32 cm of seasonal rainfall, with October contributing 56% of seasonal rainfall. About 34% of seasonal rainfall occurs during November. The NE monsoon season contributes about 31% of annual rainfall. Over Rayalaseema, the NE monsoon season contributes about 24 cm, which is 33% of the annual total. October is the rainiest month during the season and rainfall activity sharply reduces in November and December.

Tamil Nadu receives more rainfall during the NE monsoon season (October-December) compared to that during the Southwest monsoon season. There is a

considerable increase in rainfall activity from September to October and November. In December, rainfall activity is confined only to the coastal districts. The seasonal rainfall during the NE monsoon season is around 44 cm contributing to 48% of its annual rainfall. Over South-interior Karnataka (SIK) seasonal rainfall is around 20 cm, which is about 19% of the annual total. Over SIK, October contributes maximum rainfall during the season, while December hardly contributes to the seasonal total.

Over Kerala, the NE monsoon season contributes about 49 cm, which is about 17% of the annual total. During the NE monsoon season, Kerala receives maximum rainfall, even slightly more than Tamil Nadu. October contributes maximum rainfall over Kerala, which reduces in November and December.

3.2. **Mean Spatial Distribution of Rainfall**

Fig. 3.1 a, b and c show the monthly rainfall climatology during the months of October, November and December. The mean values are calculated using the IMD gridded data (0.25 X 0.25 degree) from 1972-2021. During October, maximum rainfall exceeding 200 mm is observed over the coastal Andhra Pradesh, coastal Tamil Nadu and Kerala. Over central parts of Kerala, monthly rainfall exceeds 300 mm. However, rainfall reduces sharply towards the interior parts of south peninsula, where monthly rainfall is less than 150 mm. During November, monthly rainfall sharply increases over the northern parts of coastal Tamil Nadu and southern parts of coastal Andhra Pradesh, where monthly rainfall is more than 300 mm. Over Tamil Nadu, monthly rainfall sharply reduces towards the interior parts. Southern parts of Kerala experiences monthly rainfall exceeding 200 mm. Over the rest of Tamil Nadu and Kerala, rainfall is between 100 and 150 mm. Over the South interior Karnataka and Rayalaseema, monthly rainfall is less than 100 mm. During December, rainfall sharply reduces everywhere in the south peninsula. Maximum rainfall exceeding 200 mm is observed over coastal Tamil Nadu and reduces sharply towards interior parts. Over the rest of the south peninsula, monthly rainfall is less than 75 mm.

The spatial distribution of mean seasonal rainfall (October to December) is shown in Fig. 3.1 d. The spatial distribution suggests a rainfall maximum along the east coast of north Tamil Nadu and south coastal Andhra Pradesh with seasonal average exceeding 800 mm. Seasonal rainfall reduces sharply towards interior parts of South Peninsula. Another rainfall maximum is observed over Kerala. Over south peninsula, isohyets (lines of equal rainfall) run parallel to the east coast with maximum over the east coast and reducing towards the interior parts. During the NE monsoon season, the Kariakal-Vedarnyam belt receives the highest rainfall in the range 900-1000 mm with Vedarnyam receiving 103 cm. The decrease of rainfall south of Vedarnyam is probably due to sheltered nature of the coast (due to Sri Lanka land mass on the east). Tuticorin registers only 40-45 cm of normal rainfall.

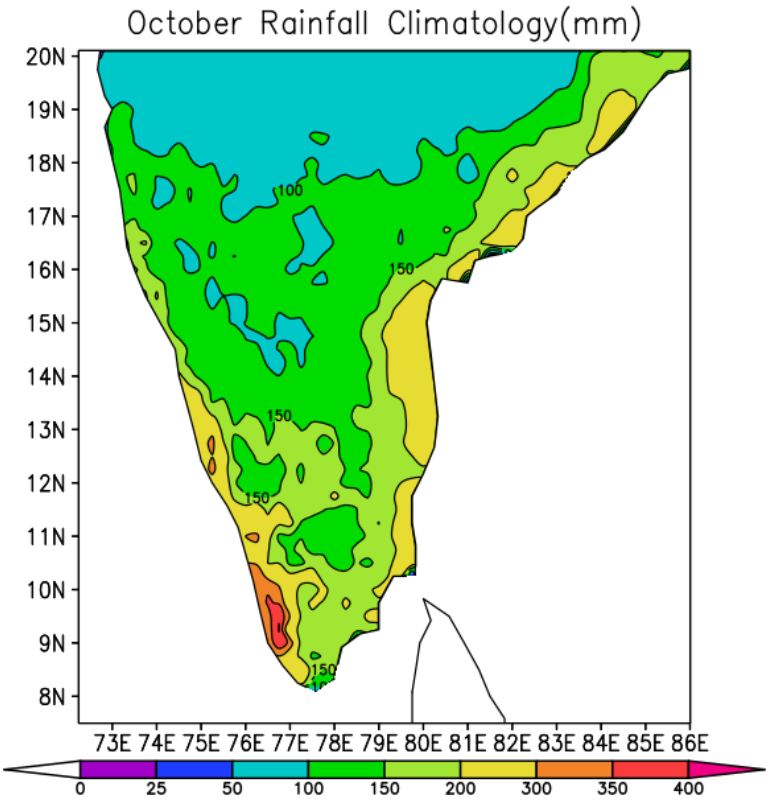

Fig. 3.1 a. IMD Observed Rainfall Climatology in mm during October (1972-2021). Source: IMD gridded data.

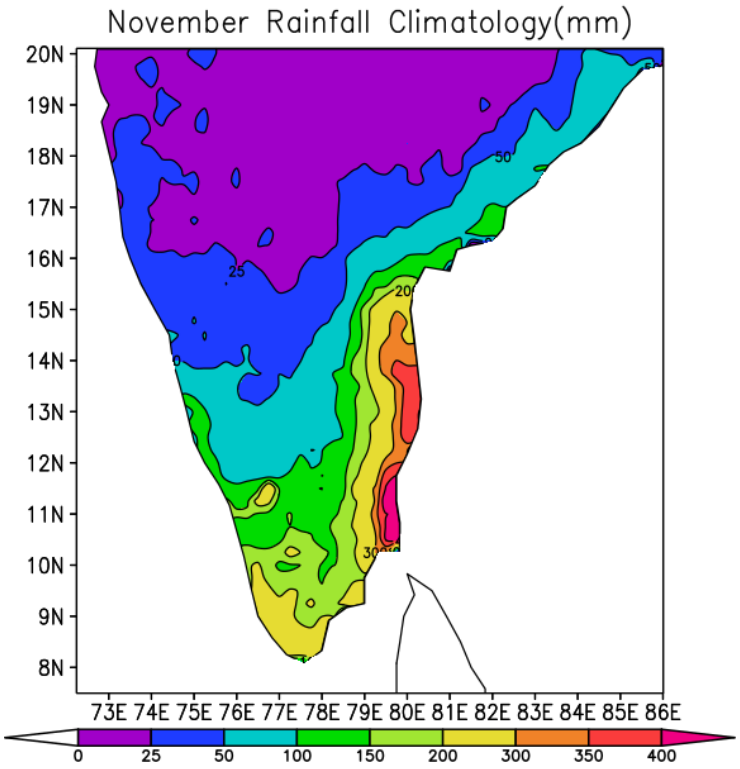

Fig. 3.1 b. Same as 3.1 a, but for November.

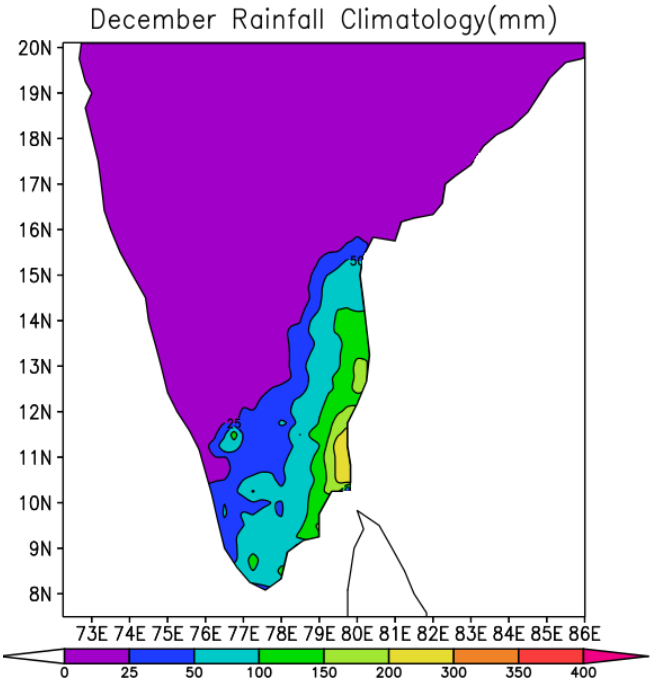

Fig. 3.1 c. Same as Fig 3.1 a, but for December.

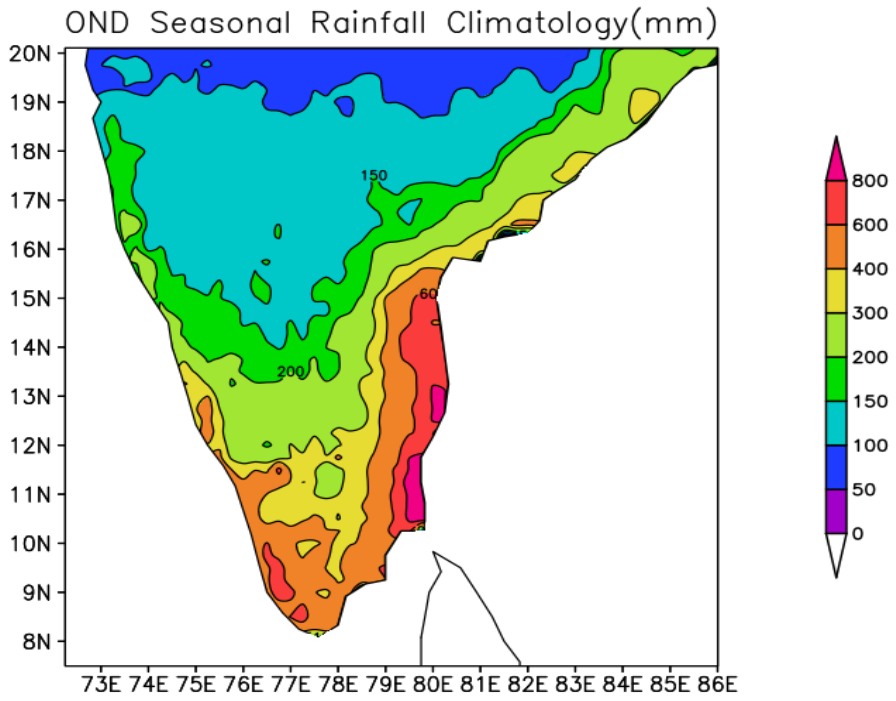

Fig. 3.1 d. Seasonal Rainfall Climatology (in mm) during the northeast monsoon season (October- December), 1972-2021. Source: IMD gridded rainfall data.

Fig. 3.2 shows the time variation of mean rainfall averaged over the south peninsula from 01 Sept to 31 Dec. The mean rainfall is calculated using the data of 1979-2021. The plot shows that October and December months contribute maximum rainfall over the region. From the first week of December, rainfall activity over the region is sharply reduced. This is due to the fact that by first week of December, the ITCZ shifts towards much south and rainfall activity is mostly confined south of 10^0N.

The Coefficient of Variation (CV) of seasonal (October to December) monsoon rainfall over the southern peninsula is given in Fig. 3.3. The CV of NE monsoon seasonal rainfall is generally higher compared to southwest monsoon season. CV varies from 30 to 50% over the south peninsula with the east coast experiencing smaller CVs compared to interior.

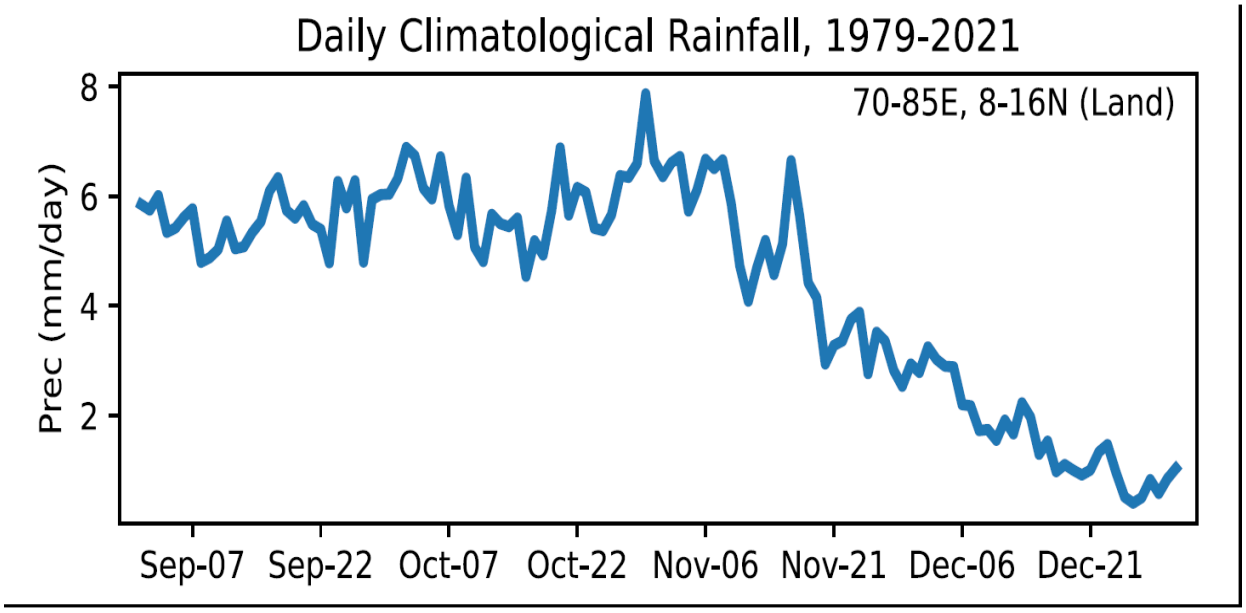

Fig. 3.2. Daily climatological rainfall (in mm/day) over NE India from 1 Sep to 31 Dec averaged over the period 1979-2021. The averaging was done over the area 70-85^0 E, 8-16^0 N.

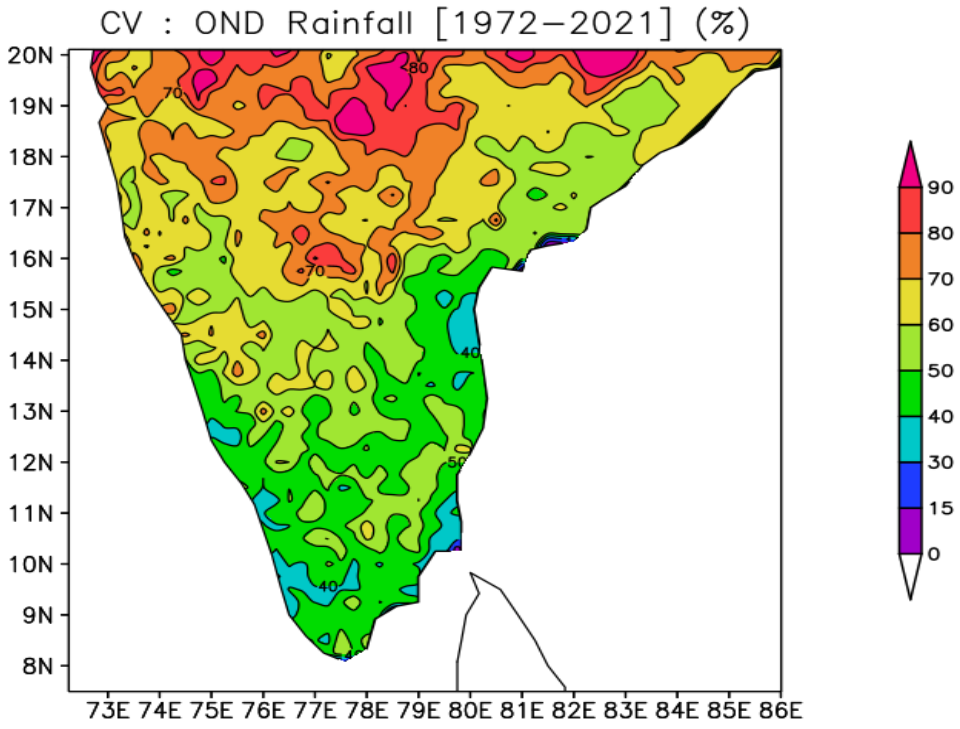

Fig. 3.3. Coefficient of variation of seasonal Rainfall (in %) during the northeast monsoon season (October- December), 1972-2021. Source: IMD gridded rainfall data.

During the NE monsoon season, a rainy day is assumed to be a day with rainfall of 2.5 mm or more. Fig. 3.4 shows the spatial distribution of the mean number of rainy days during the NE monsoon season. Over the north Tamil Nadu coast and parts of Kerala and south Karnataka, mean rainy days are more than 30 during the season. Over the remaining parts of Tamil Nadu, coastal Andhra Pradesh and remaining parts of Kerala, number of rainy days varies between 20 and 30 days. Statistical trend analysis suggests (Fig. 3.5), the mean number of rainy days over the interior parts of south Peninsula is increasing. It is important to note that this pertains to long term climatology. In a particular year, there could be an increase or decrease in the number of rainy days over a particular station.

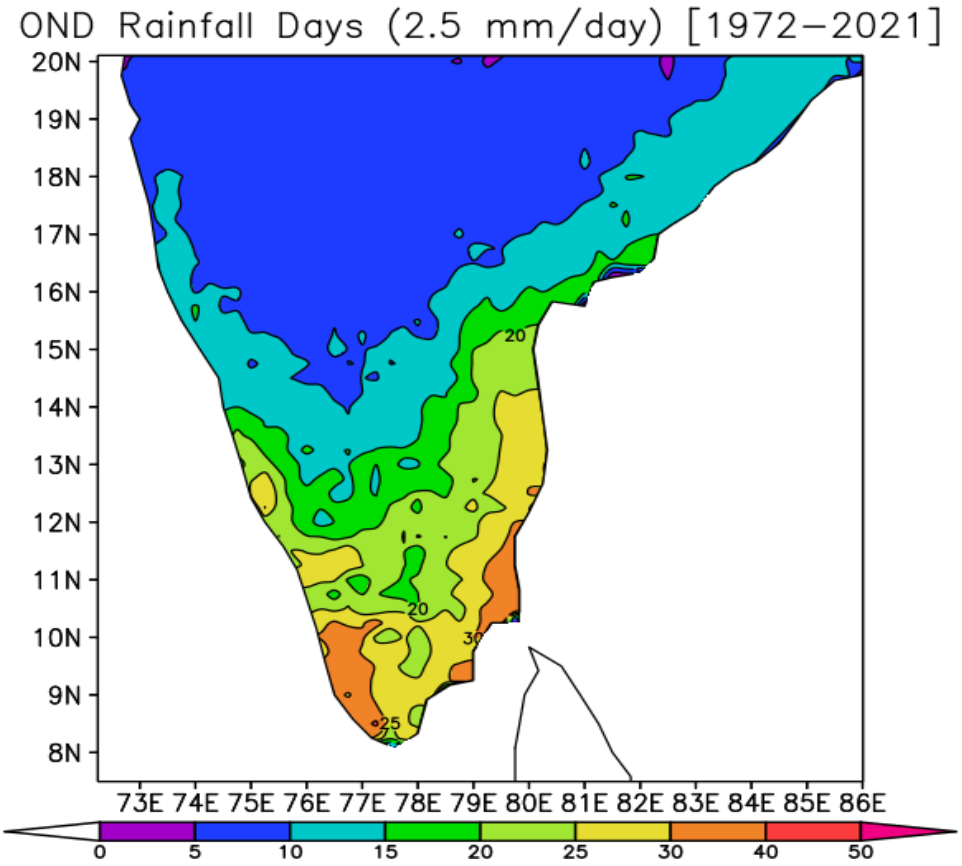

Fig. 3.4. Number of rainy days (> 2.5mm) during October to December (1972-2021). Source: IMD gridded Data

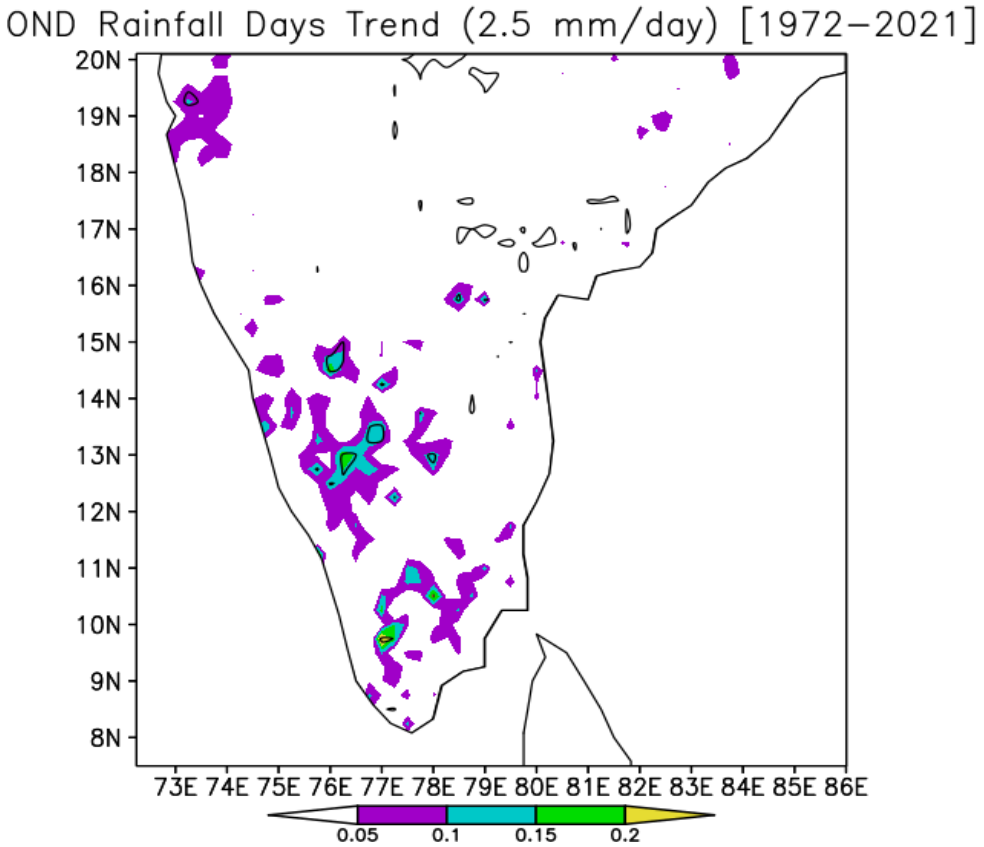

Fig. 3.5. Trend in rainfall days during October to December (1972-2021).

3.3. **Heavy Rainfall events during the NE monsoon season**

It is important to know the spatial pattern of climatology of heavy rainfall over the region. This will provide information on the climatological probability of heavy rainfall occurrence over the region during the season. The spatial pattern of heavy rainfall events was prepared using the IMD 0.25 × 0.25 degree daily rainfall data (Pai et al. (1972-2020). It may be noted that the IMD's definition of heavy, very heavy and extreme heavy rainfall is based on rainfall station data. Since the analysis given below is based on the IMD's gridded data and somewhat smoothed data, IMD's definition cannot be strictly used for defining heavy, very heavy and extreme rainfall. However, even with the gridded data, we could get a reliable understanding of the spatial distribution of such heavy rainfall events.

Fig. 3.6 shows the spatial pattern of the number of days with heavy rainfall between 65 mm-124 mm. It suggests the maximum number of days with heavy rainfall is confined to the east coast of Tamil Nadu and the south coastal Andhra Pradesh, where on average we can expect more than 2 days of heavy rainfall. Another area of maximum heavy rainfall days is observed over south Kerala. Number of days with heavy rainfall sharply reduces towards the interior parts of the south Peninsula.

Fig. 3.7 shows the spatial distribution of frequency (number of days) of rainfall with 125 mm or more during the NE monsoon season. It suggests maximum frequency is found over the coastal parts of north Tamil Nadu and Andhra Pradesh. It suggests that these very heavy rainfall spells are associated with the landfall of tropical cyclones/depressions and lows along the east coast. On an average, we can expect about one day of such an event over this region during the NE monsoon season.

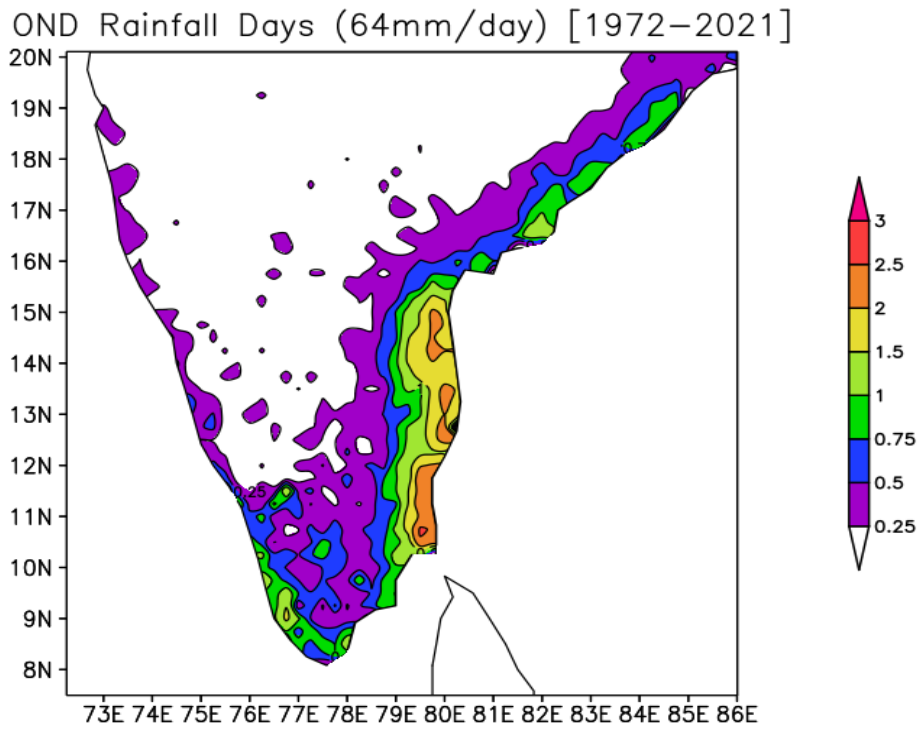

Fig. 3.6. Mean number of days during October-December with 65 mm-124mm. Period of the data 1972-2021.

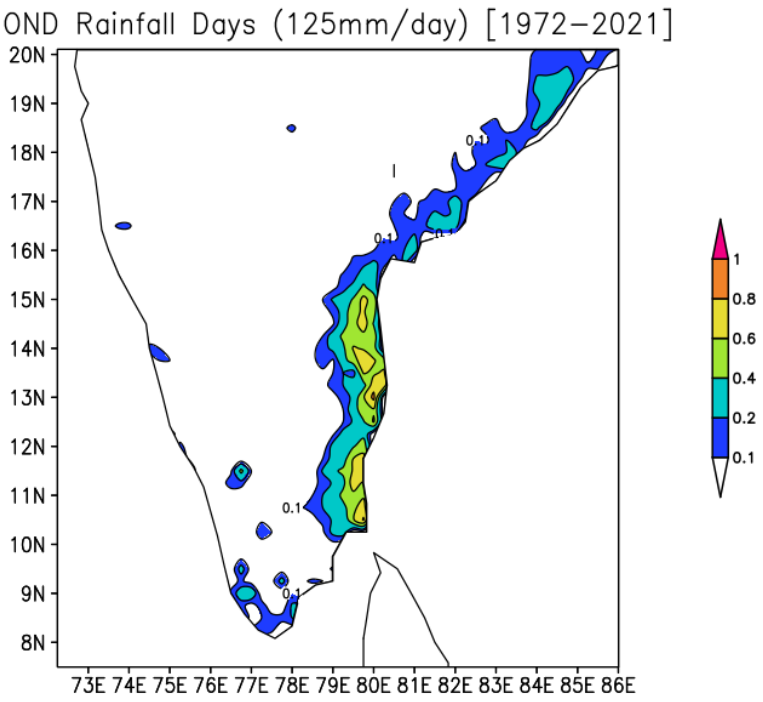

Fig. 3.7. Mean in rainfall days with more than 125 mm/day (Period: 1972-2021).

3.5. **Maximum Probable frequency of heavy rainfall**

Fig. 3.8 shows the maximum probable frequency of heavy rainfall (between 65 and 124 mm) during October to December calculated using data from 1951-2019. This map was taken from the IMD Climate Hazards and Vulnerability Atlas of India, 2022. A maximum probability of more than 7 days can be expected over the east-coast of Tamil Nadu and Southern parts of Kerala and Tamil Nadu. Over the interior parts of the south Peninsula, the maximum probability lies between 3-4 days.

Fig. 3.9 shows the maximum probable frequency of heavy, very heavy and extreme heavy rainfall (number of days) during the NE monsoon season (Oct-Dec). Over the east coast of north Tamil Nadu, South Coastal Andhra Pradesh and southern most districts of Tamil Nadu and Kerala, the maximum probable frequency is more than 15 days. Over other parts of coastal Pradesh, Tamil Nadu and south Kerala, the maximum probable frequency is between 10-14. Over interior parts of the south Peninsula, this number varies between 5-10 days.

Fig. 3.10. shows the maximum probable frequency of very heavy and extreme heavy rainfall (number of days) during the season. Over the eastern coast of north Tamil Nadu, south coastal Andhra Pradesh and southern most parts of Tamil Nadu and Kerala, the maximum probable frequency of very heavy and extreme rainfall is between 5 and 11 days. Over the interior parts of the south Peninsula, this number varies between 1 and 4.

Thus, the eastern coast of north Tamil Nadu and south coastal Andhra Pradesh is the region, with maximum probable frequency of heavy rainfall days during the NE monsoon season. Southern parts of Tamil Nadu and Kerala also have similar maximum probable frequency.

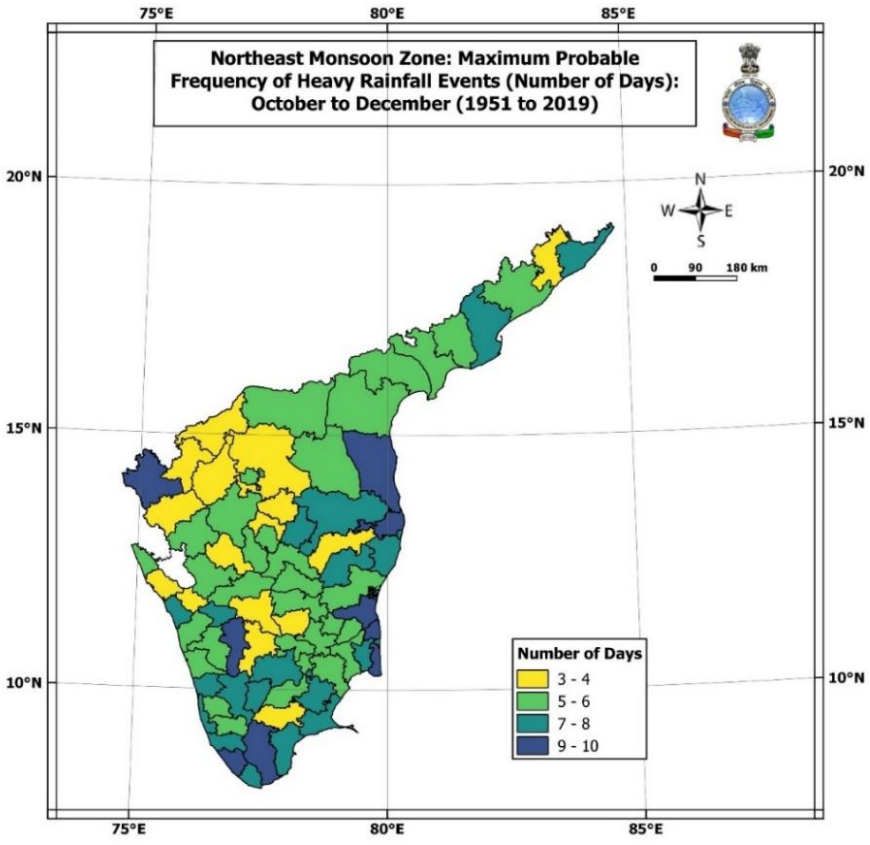

Fig. 3.8. Maximum Probable frequency of heavy rainfall events (Number of days): October-December, 1951-2019. (Source: IMD Climate Hazards and Vulnerability Atlas of India, 2022).

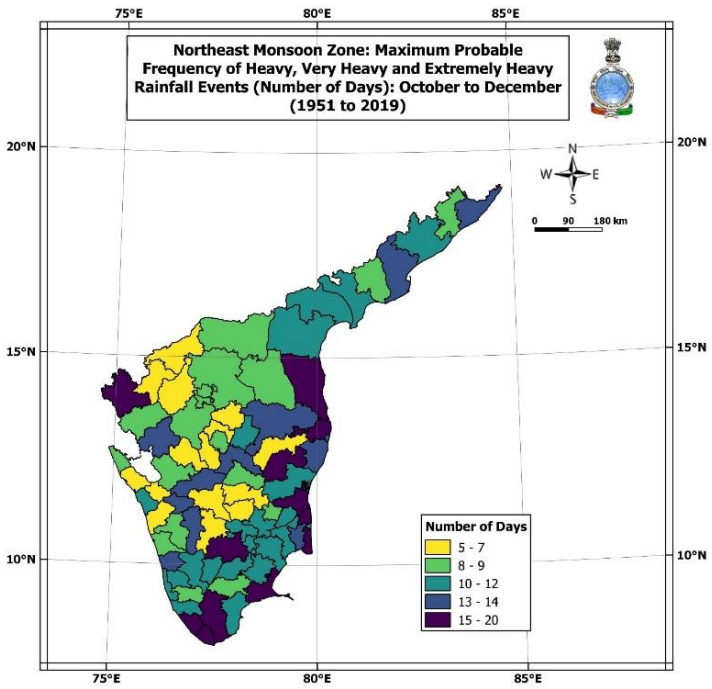

Fig. 3.9. Maximum Probable frequency of heavy, very heavy and extremely heavy rainfall events (Number of days): October-December, 1951-2019. (Source: IMD Climate Hazards and Vulnerability Atlas of India, 2022).

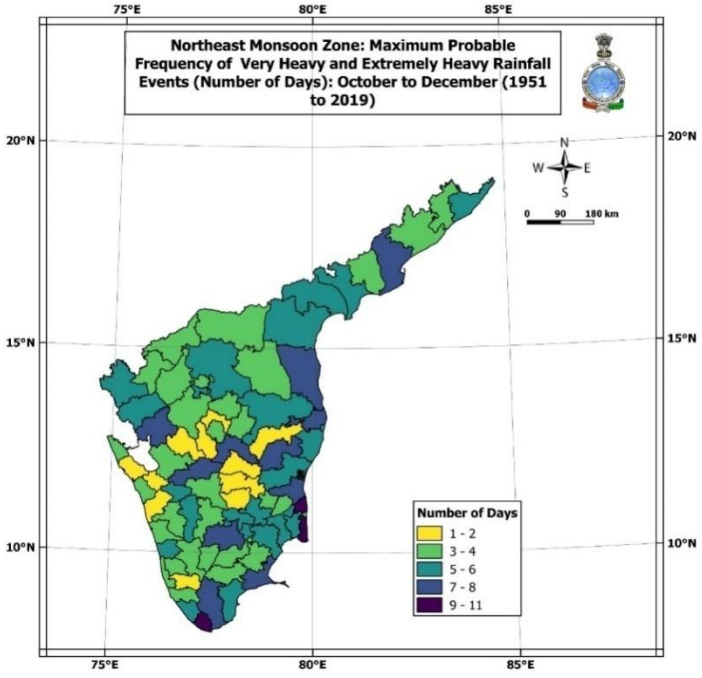

Fig. 3.10. Maximum Probable frequency of very heavy and extremely heavy rainfall events (Number of days): October-December, 1951-2019. (Source: IMD Climate Hazards and Vulnerability Atlas of India, 2022).

The city of Chennai experienced three phases of heavy rainfall that resulted in devastating floods during November and early December, 2015. Chakraborty (2015) examined synoptic aspects of this flood event in detail. The study revealed that propagating convective systems from the west Pacific Ocean intensified further over the warm Indian Ocean before moving north towards the Indian land region. This northward propagation was guided by two highs of mid-troposphere to the east and west of the Indian region. While the high to the east was typical of an El Nino year, that the west was associated with global phase shift of upper tropospheric Rossby wave. The study revealed that similar highs to the west were present during other years of heavy rainfall along the east coast of Peninsular India.

Fig. 3.11 shows Spatial variation of correlation coefficient between monthly mean rainfall over the Indian landmass and area averaged 500 hPa geopotential height over 30-60^{0}E, 20-45^{0}N (Middle-east) in November for the period 1948-2014. It suggests that a high GPH over the Middle East is positively correlated with high amount of rainfall over central and south India land regions. The highest positive correlation is found along the east coast of the Indian peninsula over Tamil Nadu and Andhra Pradesh. The study concluded that an anomalous mid-tropospheric high to the west of the Indian region can induce anomalous northerly to the north that does not allows propagating systems to mover further north and west. This results in dry conditions in the northwest Indian region and wet conditions to the southeast Indian peninsula. It suggests that an anomalous high over Middle east in November can help increase the northeast monsoon rainfall over the south peninsula.

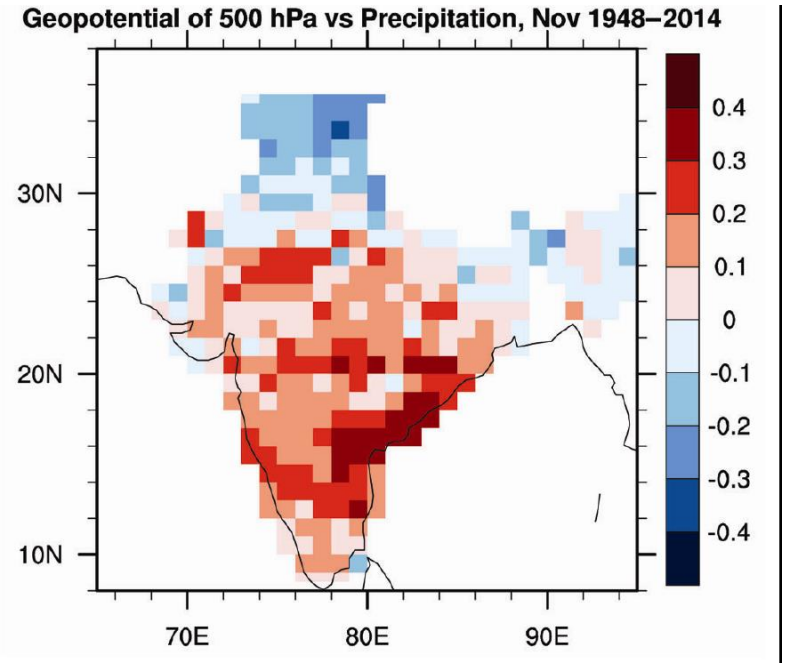

Fig. 3.11. Spatial variation of correlation coefficient between monthly mean rainfall over the Indian landmass and area averaged 500 hPa geopotential height over 30-60^{0}E, 20-45^{0}N in November for the period 1948-2014 (After Chakraborty, 2016).

Nageswara Rao et al., (2019) made an extensive analysis of NE monsoon rainfall using IMD gridded data set. Their analysis revealed that the seasonal rainfall has increased over Tamil Nadu, Rayalaseema, as well as South Peninsula because of an increase in the number of high-intensity rainfall events in the recent period with respect to the earlier period (1901–1958), while it has decreased over the other sub-divisions. The percentage contribution of moderate rainfall events to the seasonal rainfall is more compared to the other events.

The study by Koteswara Rao et al., (2020) revealed there will be an increase in precipitation in near future (about 5%). The future climate projections also indicate that both the intensity and frequency of precipitation extremes in most parts of the South peninsular India may increase under the warming scenarios during the northeast monsoon season.