STATEMENT ON CLIMATE FOR THE STATE OF KERALA: 2024

INSTITUTE FOR CLIMATE CHANGE STUDIES, KOTTAYAM

A Research Organization under the Kerala State Council for Science Technology and Environment (KSCSTE), Govt. of Kerala

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HIGHLIGHTS

The state-averaged annual mean land surface air temperature in Kerala during 2024 was +0.99°C above the Long Period Average (LPA, 1991–2020). **This makes 2024 the warmest year on record for the state since 1901.** The second and third warmest years on record was 2016 (+0.77°C anomaly) and 2023 (+0.76°C anomaly) respectively.

All the seasons witnessed record warming in mean temperatures: winter (1.17°C anomaly, warmest winter since 1901), summer (1.13°C anomaly, second warmest since 1901), monsoon (0.95°C anomaly, second warmest since 1901), and post-monsoon (0.81°C anomaly, second warmest since 1901). Nine of the ten warmest years on record occurred in the recent decade (2015–2024).

The State averaged annual maximum as well as minimum temperatures during the 2024 were warmer than average (1991-2020) with anomalies of +0.85°C (2nd warmest) and 1.14°C (warmest since 1901) respectively. The following months of 2024 recorded the warmest mean temperatures since 1901: February (+1.27°C anomaly), April (+1.79°C anomaly), and September (+1.13°C anomaly). Similarly, the following months of 2024 recorded the warmest minimum temperatures since 1901: January (+1.71°C anomaly), February (+1.32°C anomaly), April (+1.74°C anomaly), and September (+0.86°C anomaly). Similarly, the following months of 2024 recorded the warmest maximum temperatures since 1901: February (+1.21°C anomaly), April (+1.85°C anomaly), and September (1.39°C anomaly).

During 2024, Kerala experienced a rainfall deficit of 13% (1%) below its Long Period Average (LPA, 1991–2020) during the southwest (northeast) monsoon season. However, it recorded an excess of 183% (39%) above its LPA during the winter (summer) season.

Introduction

The Institute for Climate Change Studies (ICCS), Kottayam is an autonomous Research and Development institution under the Kerala State Council for Science Technology and Environment (KSCSTE), Government of Kerala. The Centre is envisioned for integrated research, technical support, and capacity building in all aspects of Climate change issues and integrate development policies, plans and programs at State level. Last year, as part of its state level climate monitoring activities, ICCS had issued statement of annual climate for the State of Kerala for the year

2023 in line with national level annual statement being issued regularly by India Meteorological Department (IMD) for the country. Now, ICCS has prepared annual climate statement for the year 2024 and presented here. The present statement contains, important information about the monthly, seasonal, and annual state averaged temperature and rainfall for the year 2024 vis a vis the same during the last 124 years. The rainfall and temperature data and extreme weather events information used for the preparation of this report was provided by IMD.

Temperatures

The monthly and seasonal maximum, minimum and mean temperature anomalies averaged over the State of Kerala is given in the **Fig.1**. The anomalies were computed based on the Long Period Average (LPA) for the period 1991-2020. The State averaged monthly maximum temperatures were warmer than average during all the months of 2024. The following months of 2024 recorded the warmest mean temperatures since 1901: February (+1.27°C anomaly), April (+1.79°C anomaly), and September (+1.13°C anomaly). Similarly, the following months of 2024 recorded the warmest minimum temperatures since 1901: January (+1.71°C anomaly), February (+1.32°C anomaly), April (+1.74°C anomaly), and September (+0.86°C anomaly). Similarly, the following months of 2024 recorded the warmest maximum temperatures since 1901: February (+1.21°C anomaly), April (+1.85°C anomaly), and September (1.39°C anomaly). All the seasons witnessed record warming in mean temperatures: winter (1.17°C anomaly, warmest winter since 1901), summer (1.13°C anomaly, second warmest since 1901), monsoon (0.95°C anomaly, second warmest since 1901), and post-monsoon (0.81°C anomaly, second warmest since 1901). These findings indicate a persistent warming trend throughout 2024, with multiple monthly and seasonal temperature records either being broken or ranking among the highest since 1901.

During the year 2024, the state-averaged annual mean land surface air temperature in Kerala during 2024 was +0.99°C above the Long Period Average (LPA, 1991–2020). This makes 2024 the warmest year on record for the state since 1901. The nine warmest years on record prior to 2024 on ascending order are: 2021 (0.29°C), 2022 (0.30°C), 1987 (0.38°C), 2015 (0.42°C), 2017(0.56°C), 2020 (0.67°C), 2019 (0.75°C), 2023 (0.76°C), and 2016 (0.77°C). It is also important to note that 9 of the ten warmest years on record occurred in the recent decade (2015–2024). Consequently, the annual mean temperature of Kerala during the past decade (2011–2020/2015–2024) was the highest on record, with a decadal average annual mean temperature anomaly of 0.35°C / 0.58°C. A significant increasing trend of 1.15°C/100 years is observed in the state averaged annual mean temperature during 1901-2024 (**Fig.2**).

During 2024, State averaged annual maximum as well as minimum temperatures during the 2024 were warmer than average (1991-2020) with anomalies of +0.85°C (2nd warmest) and 1.14°C (warmest since 1901) respectively (**Fig.2**). During the period 1901-2024, the State averaged maximum temperature showed a significant increasing trend (1.78°C/100 years) and the State averaged minimum temperature showed a relatively lower increasing trend (0.52°C/100 years). As seen in the **Fig.2,** the anomalies of annual maximum temperature were more negative than that of annual minimum temperatures till late 1980's. Thereafter, the role was reversed. This is mainly because of the observed faster increasing trend in the maximum temperatures compared to that in the minimum temperatures. This has also resulted in the increased annual State averaged diurnal variation (not shown here) in recent decades.

The trends in the district averaged maximum, minimum and mean temperatures for the period 1901-2024 is shown in the **Figures 3a**, **3b** and **3c** respectively. There are significant increasing trends

in the district averaged maximum and mean temperatures for all the 14 districts of the State. However, in the case of minimum temperature, significant increasing trends were observed in 10 out of the 14 districts. Among the remaining four districts, Kannur showed increasing but non-significant trend. Kasaragod, the northern most district, showed significant decreasing trend, and Kollam and Thiruvananthapuram, the two southern most districts showed decreasing but insignificant trends.

Rainfall

The monthly and seasonal rainfall averaged over the State of Kerala and expressed as the percentage of departure from the Long Period Average (LPA) for the period 1991-2020 is given in the **Fig.1** along with temperature anomalies. Kerala receives most of its annual rainfall during the two monsoon seasons; southwest monsoon season (June to September) and northeast monsoon season (October to December). Kerala experienced a rainfall deficit of 13% (1%) below its Long Period Average (LPA, 1991–2020) during the southwest (northeast) monsoon season. However, it recorded an excess of 183% (39%) above its LPA during the winter (summer) season. It is observed that the State averaged seasonal rainfall for the southwest monsoon as well as northeast monsoon seasons during the past 124 years (**Figures 4 & 5**) show decreasing trends (-12.4% and -5.4% of LPA/100 years respectively).

During the 2024 Southwest Monsoon season, four out of Kerala's 14 districts experienced deficient rainfall, with actual precipitation falling at least 20% below the LPA. The most affected districts were Idukki (-33%), Wayanad (-30%), Ernakulam (-27%), and Alappuzha (-21%). All other ten districts received normal rainfall (percentage departure from normal lies between -19 & +19%). On the other hand, northeast monsoon season had spatially contrasting characters. Two districts that received deficient rainfall were Ernakulam (-24%) and Kollam (-21%). Remaining 12 districts received normal rainfall with Kozhikode (+31%) recording the highest.

The trend map of the district averaged southwest monsoon season rainfall during the period 1901-2024 (**Fig.6a**) shows decreasing trends in all the districts except in Idukki, where increasing but insignificant trend is seen. The decreasing trends in the seasonal rainfall over 4 districts in the south (Kottayam, Alappuzha, Kollam and Pathanamthitta) and 5 districts in the north (Kannur, Wayanad, Kozhikode, Malappuram, and Palakkad) are significant. In case of northeast monsoon season (**Fig.6b**), decreasing trends in the seasonal rainfall was seen in all the districts except in Kasaragod, with significant decreasing trends in Palakkad and Kottayam. Kasaragod showed increasing but non-significant trend.

Extreme Weather Events:

Table 1 shows the highest maximum and minimum temperatures and highest rainfall recorded in the 13 IMD met observatories across Kerala along with the dates during 2024. It is seen that, among these stations, Palakkad station reported the highest maximum temperature of 41.8^{o}C (on 28th April) followed by Vellanikara (40.3^{o}C on 11th April). The lowest minimum temperature was recorded at Punalur in Kollam district (15.5^{o}C on 2nd March) followed by Trivandrum City (19.7^{o}C on 6th November). The highest one-day rainfall was recorded by Kannur Airport (248.6 mm) on 30th July followed by Karipur AP (241.6 mm) recorded on 30th July. Among these observatories, the highest number of daily heavy rainfall events (>64.5mm) were recorded by Kannur Airport (14 days) followed by Kannur and Vellanikara (10 days). **Fig.7** shows the locations of extreme rainfall of various intensities that occurred during 2024 based on rainfall data available from all the stations including the 13 IMD stations given in Table 1.

Table 1: Highest/lowest maximum and minimum temperatures and highest rainfall recorded by the 13 IMD meteorological observatories across Kerala along with the dates during 2024.

IMD Stations	Highest Max. Temperature ^{0}C (Date)	Lowest Max. Temperature ^{0}C (Date)	Highest Min. Temperature ^{0}C (Date)	Lowest Min Temperature ^{0}C (Date)	Highest Rainfall mm (Date)	Frequency of Heavy Rainfall Events (>64.5 mm)
Kannur	37.50 (10-04-2024)	25.80 (19-07-2024)	30.30 (03-05-2024)	21.60 (17-12-2024)	175.80 (30-07-2024)	10
Kannur Airport	39.80 (15-04-2024)	25.40 (19-07-2024)	29.00 (03-05-2024)	19.90 (17-12-2024)	248.60 (30-07-2024)	14
Kozhikode city	39.00 (03-05-2024)	26.00 (31-07-2024)	31.30 (03-05-2024)	22.30 (06-07-2024)	155.80 (03-12-2024)	9
Karipur A. P.	37.40 (30-04-2024)	25.00 (31-07-2024)	29.10 (03-05-2024, 04-05-2024)	21.70 (06-07-2024)	241.60 (30-07-2024)	6
Palakkad	41.80 (28-04-2024)	25.00 (19-07-2024)	29.00 (03-05-2024)	20.30 (18-01-2024)	162.80 (30-07-2024)	2
Vellanikkara	40.30 (11-04-2024)	25.90 (31-07-2024)	28.50 (03-05-2024)	20.70 (17-12-2024)	185.20 (30-07-2024)	10
Kochi (NAS)	35.40 (27-02-2024)	25.80 (31-07-2024)	30.60 (03-05-2024)	19.90 (18-12-2024)	136.60 (23-05-2024)	7
Kochi (CIAL)	38.00 (09-05-2024)	25.30 (31-07-2024)	29.20 (03-05-2024)	21.00 (27-01-2024)	146.40 (02-12-2024)	8
Alappuzha	38.30 (30-04-2024)	26.70 (17-07-2024)	30.30 (03-05-2024, 05-05-2024)	21.70 (10-10-2024)	155.70 (12-10-2024)	3
Kottayam	39.00 (13-03-2024)	26.50 (02-07-2024, 31-07-2024)	28.60 (03-05-2024)	20.80 (10-10-2024)	183.80 (02-12-2024)	9
Punalur	40.00 (09-05-2024)	25.60 (26-10-2024, 03-12-2024)	28.20 (03-05-2024)	15.50 (02-03-2024)	83.40 (13-08-2024)	3
Trivandrum AP	36.70 (09-05-2024)	26.30 (26-10-2024)	30.20 (03-05-2024)	20.90 (06-11-2024)	132.20 (19-05-2024)	3
Trivandrum city	37.80 (09-05-2024)	25.80 (26-10-2024)	29.20 (03-05-2024)	19.70 (06-11-2024)	121.50 (19-05-2024)	4

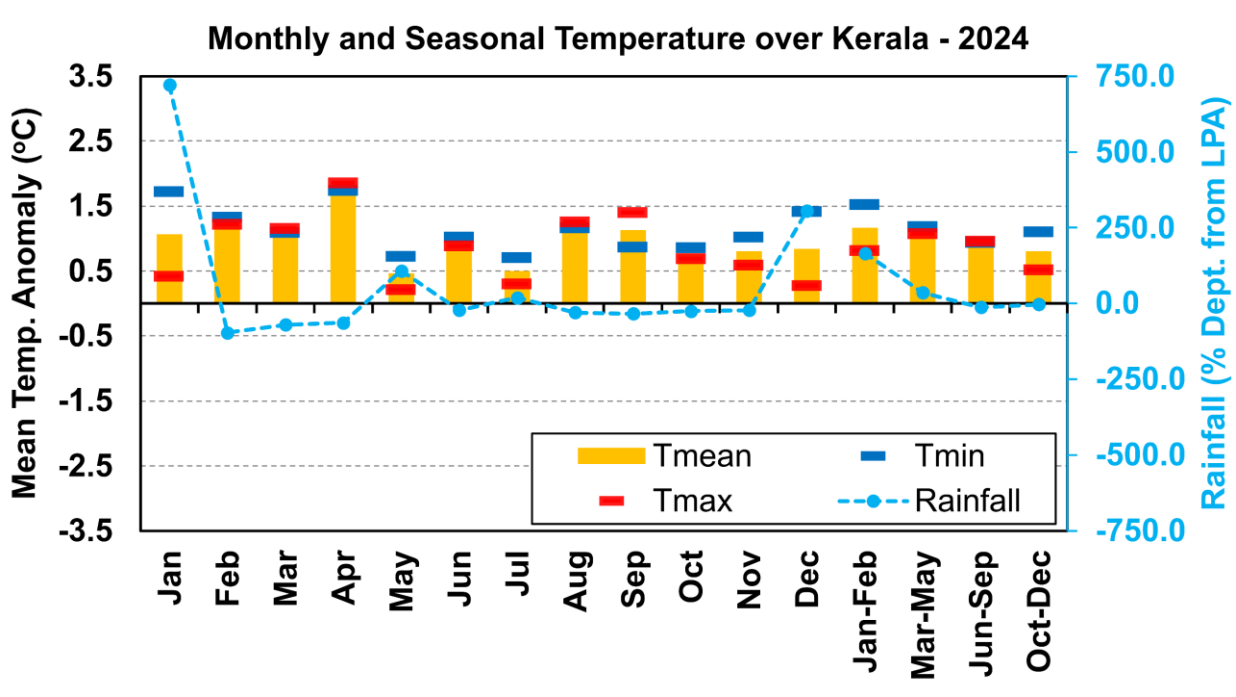

Fig.1. Monthly and Seasonal Maximum, Minimum and Mean Temperature anomalies (°C) averaged over Kerala during 2024. Monthly and seasonal Rainfall anomalies (% departure) averaged over Kerala during 2024 is also depicted. The anomalies were computed from Long Period Average (LPA) for the base period of 1991-2020.

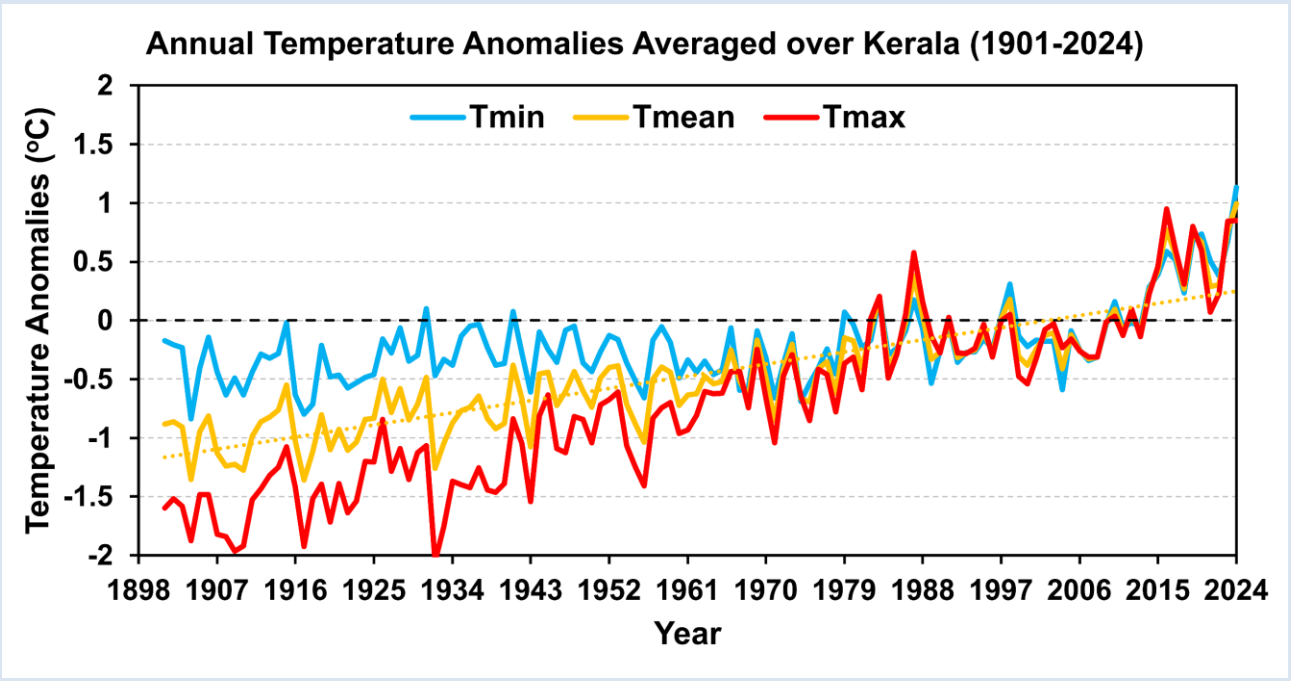

Fig.2: Annual maximum, minimum and mean land surface air temperature anomalies averaged over the State of Kerala for the period 1901-2024.The anomalies were computed with respect to the base period of 1991-2020. The dotted yellow line indicates the linear trend in the annual mean temperature time series.

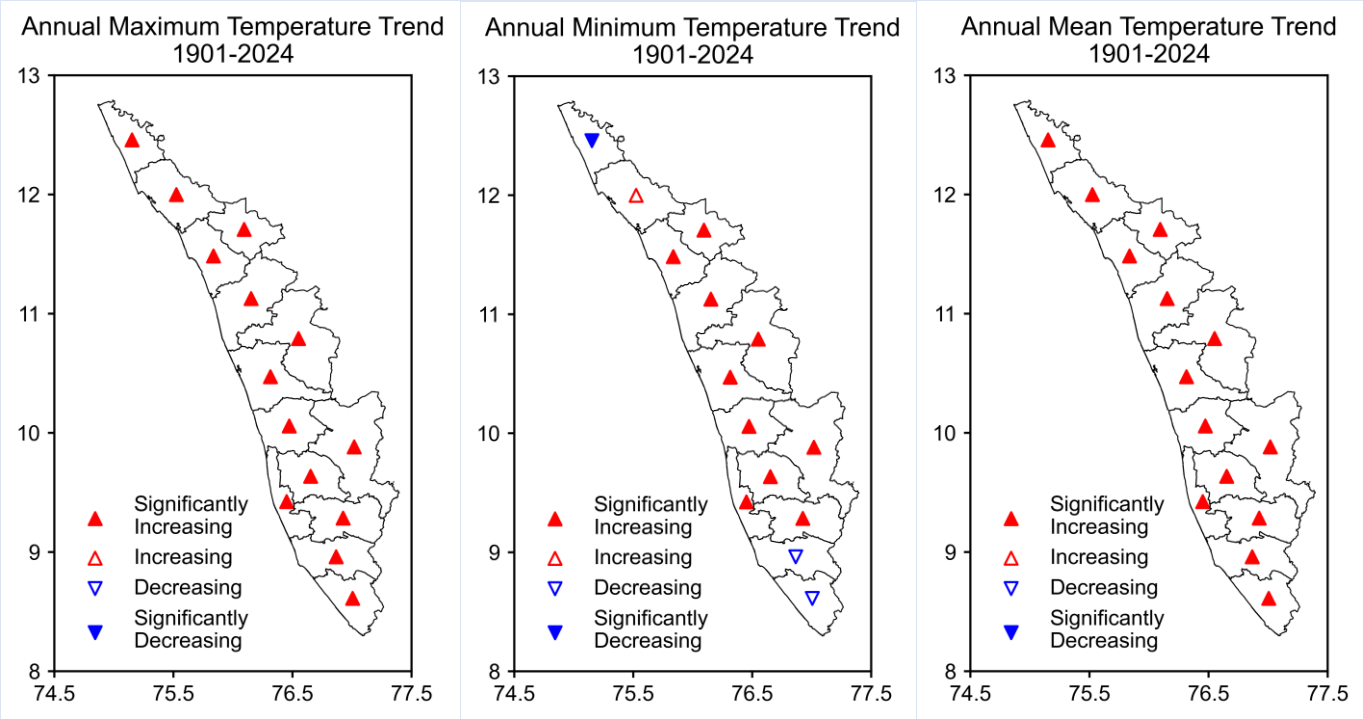

Fig.3: Trends in district averaged **a)** maximum, **b)** minimum, and **c)** mean land surface air temperatures for the period 1901-2024.

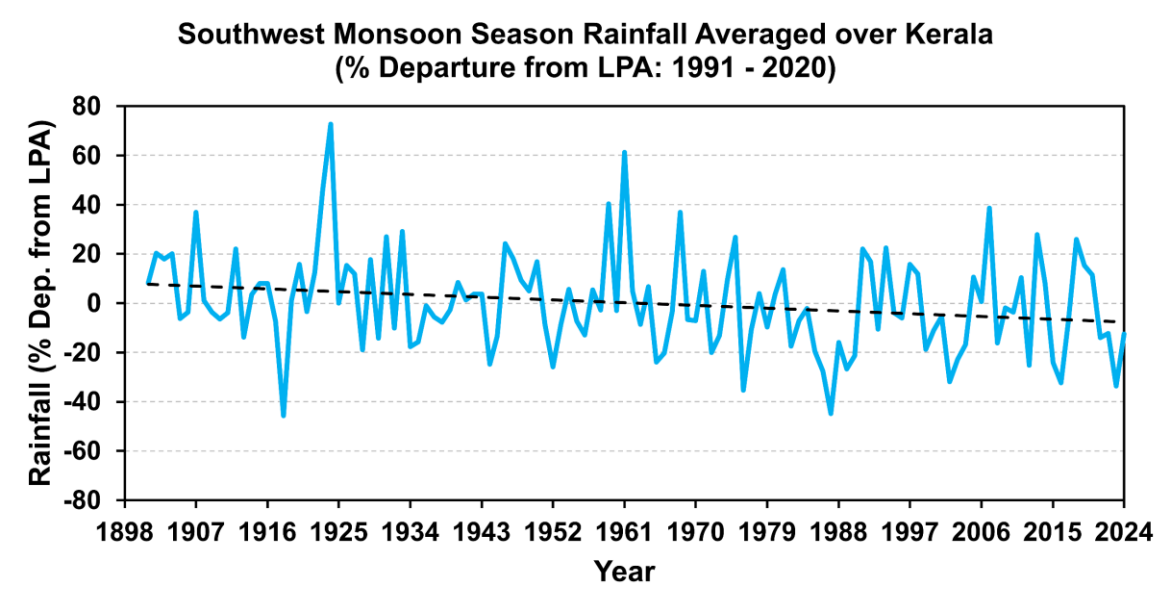

Fig.4: Seasonal departure of southwest monsoon rainfall averaged over Kerala expressed as the percentage from Long Period Average (LPA) computed for the base period of 1991-2020.

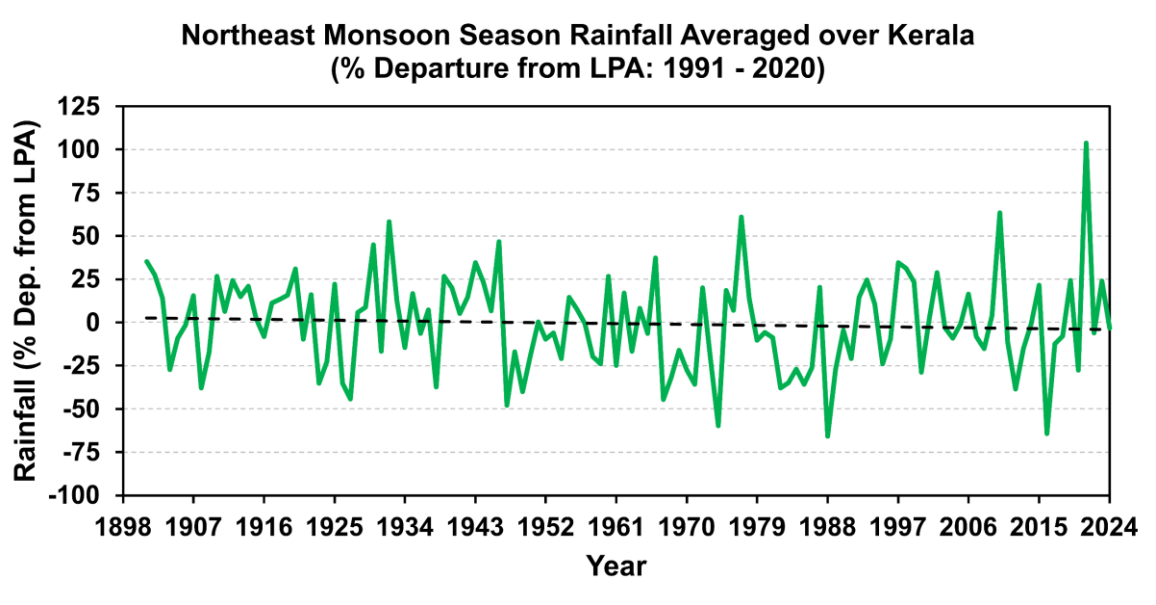

Fig.5: Seasonal departure of northeast monsoon rainfall averaged over Kerala expressed as the percentage from Long Period Average (LPA) computed for the base period of 1991-2020.

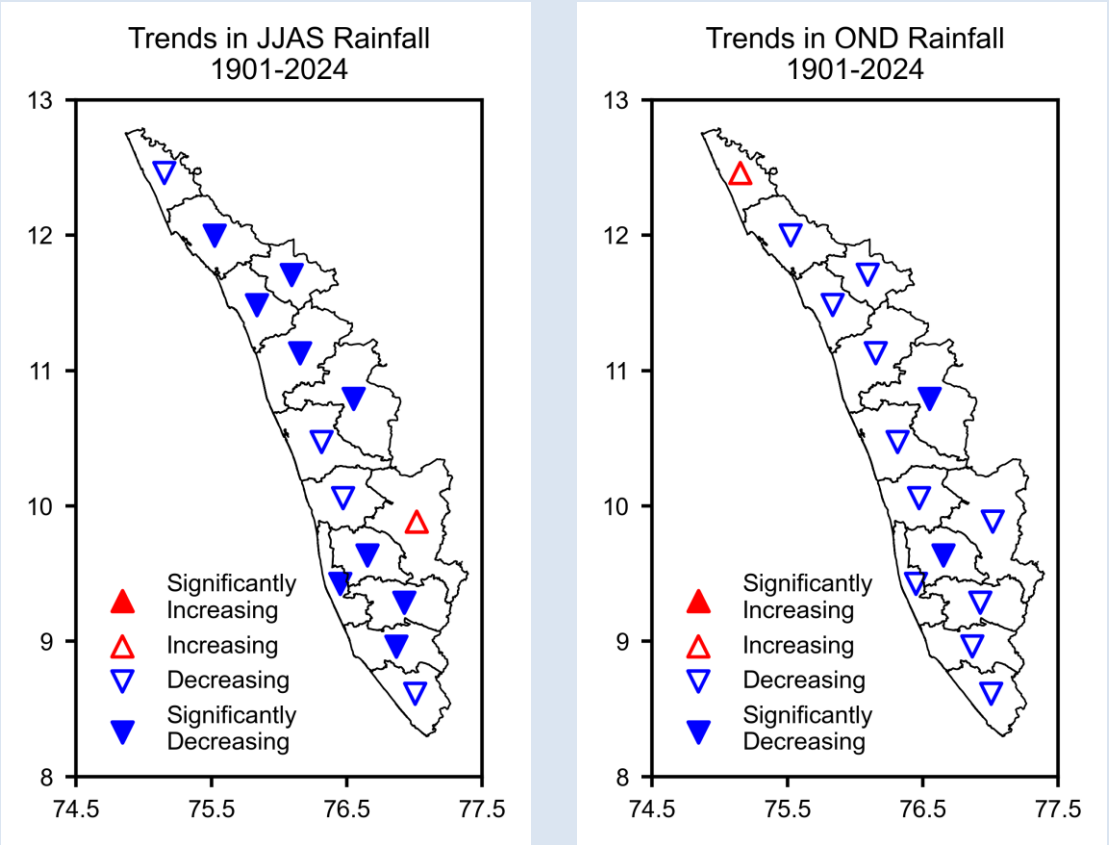

Fig.6: Trends in district averaged **a)** southwest monsoon (JJAS), and **b)** northeast monsoon (OND) season rainfalls for the period 1901-2024.

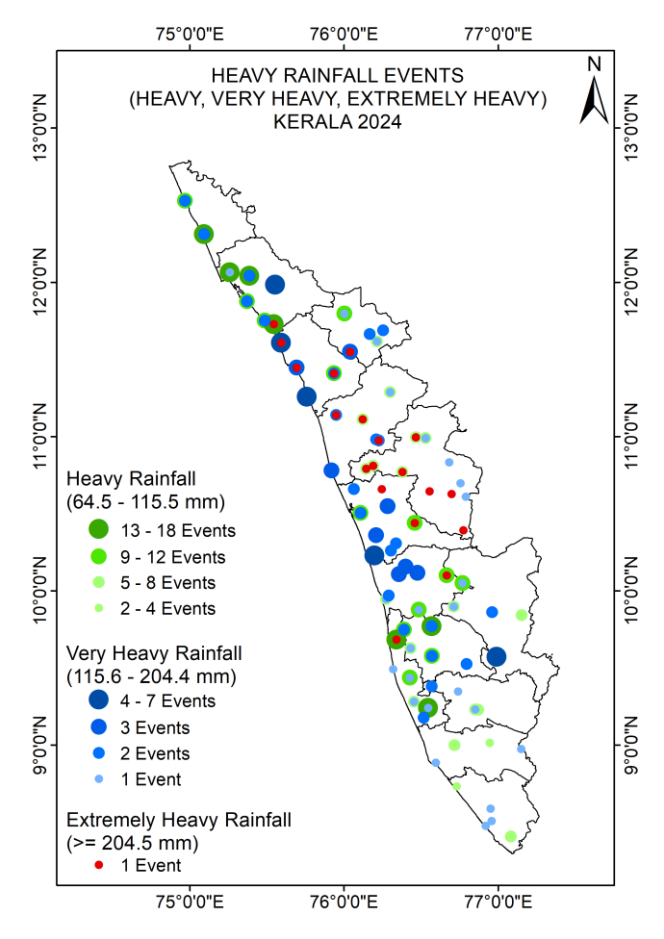

Fig.7: Location of Heavy Rainfall (64.5-115.5mm), Very Heavy Rainfall (115.6-204.4 mm) and Extremely Heavy Rainfall (more than 204.5 mm) reported stations over Kerala during 2024.