



STATEMENT ON CLIMATE FOR THE STATE OF KERALA: 2023



INSTITUTE FOR CLIMATE CHANGE STUDIES

A Research Organization under Kerala State Council for Science
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HIGHLIGHTS

The Kerala State averaged annual mean land surface air temperature during 2023 was $+0.66^{\circ}\text{C}$ warmer than the average (1971-2020). Thus 2023 was the 5th warmest year for Kerala along with 2015 on record since 1901. The warmest year for Kerala on record was 2016 (anomaly $+0.97^{\circ}\text{C}$) followed by 2019 (anomaly $+0.88^{\circ}\text{C}$).

The warmer than normal annual mean temperature over the State during 2023 was mainly contributed by the above average mean temperatures during the monsoon (anomaly $+1.14^{\circ}\text{C}$) and post monsoon (anomaly $+0.99^{\circ}\text{C}$) seasons. The monsoon and post monsoon seasons of 2023 were also the warmest ever recorded since 1901. The 9 of the 10 warmest years in record were pertaining to the recent decade (2014-2023) and therefore the annual mean temperature of Kerala during the past decade (2011-2020/ 2014-2023) was also the warmest decade on record with the decadal averaged annual mean temperature anomaly of $0.51^{\circ}\text{C} / 0.64^{\circ}\text{C}$.

The State averaged annual maximum as well as minimum temperatures during the 2023 were warmer than average (1971-2020) with anomalies of 0.94°C (3rd warmest) and 0.39°C (10th warmest) respectively.

The observed warming trend in the average annual mean temperature of Kerala is in line with the observed warming trends in the Global mean surface temperature and in the all India averaged annual mean temperature.

Month wise, both the State averaged August monthly minimum (anomaly $+0.98^{\circ}\text{C}$) and monthly maximum (anomaly $+3.03^{\circ}\text{C}$) temperatures were warmest ever recorded since 1901.

Kerala experienced a rainfall of 30.9% below its Long Period Average (LPA, 1971-2020) during the southwest monsoon season but received 30.7% above its LPA during the northeast monsoon season, which are the main rainy seasons of the State.

Introduction

The Institute for Climate Change Studies (ICCS) is an autonomous Research and Development institution under 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 2022 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 2023 and presented here. The present statement contains, important information about the monthly, seasonal, and annual state averaged temperature and rainfall for the year 2023 vis a vis the same during the last 123 years. This statement also includes state specific information related to various extreme weather and climate events experienced during 2023. 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 1971-2020. The State averaged monthly maximum temperatures were warmer than average during all the months of 2023. Among the months, August recorded highest monthly maximum temperature (anomaly of +3.03°C; the warmest since 1901) and highest monthly minimum temperature (anomaly of +0.98°C; the warmest since 1901). December reported highest monthly minimum anomaly of 1.83°C, the warmest since 1901. Season wise, the monsoon (June to September) season recorded the highest State averaged maximum temperature (anomaly of 1.66°C; the warmest since 1901), and post monsoon season (October to December) recorded the highest State averaged minimum (anomaly of 1.14°C; the warmest since 1901) and mean temperatures (anomaly of 0.99°C; the warmest since 1901).

During the year 2023, the annual mean land surface air temperature was +0.66°C warmer than the average (1971-2020). Thus 2023 was the 5th warmest year for Kerala on record since 1901. The nine warmest years on record prior to 2023 on ascending order are: 2014 (0.42°C), 2021 (0.44°C), 2022 (0.45°C), 1987(0.45°C), 2015 (0.66°C), 2017 (0.71°C), 2020 (+0.81°C), 2019 (+0.88°C), 2016 (+0.97°C). It is also important to note that 9 of the 10 warmest years in record were pertaining to the recent decade (2014-2023). As a result, the annual mean temperature of Kerala during the past decade (2011-2020/ 2014-2023) was also the warmest decade on record with the decadal averaged annual mean temperature anomaly of 0.51°C /0.64°C. A significant increasing trend of 1.07°C/100 years is observed in the state averaged annual mean temperature during 1901-2023 (**Fig.2**).

During 2023, both the State averaged annual maximum and minimum temperatures were warmer than average (1971-2020) with anomalies of 0.94°C (3rd warmest) and 0.39°C (10th warmest) respectively (**Fig.2**). During the period 1901-2023, the State averaged maximum temperature showed a significant increasing trend (1.68°C/100 years) and the State averaged minimum temperature showed a relatively lower increasing trend (0.45°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 1901-2023 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 1971-2020 is given in the **Fig.1** along with temperature anomalies. It can be seen that there is a general inverse relationship between the monthly rainfall and 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). The State experienced a rainfall of 30.9% below its LPA (1971-2020) during the southwest monsoon season but received 30.7% above its LPA during the northeast monsoon season. This can be attributed to the El Nino conditions that evolved during the first half of the south west monsoon season and positive Indian Ocean Dipole conditions that formed in the latter half of the season. The favorable phases of the Madden Julian Oscillation (MJO) during November-December also helped stronger than normal northeast monsoon season rainfall over Kerala. It is observed that the State averaged seasonal rainfall for the southwest monsoon as well as northeast monsoon seasons during the past 123 years (**Figures 4 & 5**) show decreasing trends (-12% and -6% of LPA/100 years respectively). Since 1901, Kerala has received southwest season rainfall less than that received during 2023 only in three years with lowest in 1918 (43.4% below LPA) followed by 1987 (42.6% below LPA), and 1976 (32.6% below LPA). In case of the northeast monsoon, the State received an above average rainfall (30.7% above LPA). The highest ever State averaged northeast monsoon season rainfall since 1901 was recorded in 2021 with rainfall of 114.8% above LPA followed by 2010 (72.4% above LPA) and 1977 (69.9% above LPA)

During 2023 southwest monsoon season, all the 14 districts received less than LPA rainfall with Idukki (46.1% below LPA), Wayanad (42.4% below LPA), and Palakkad (42.2% below LPA) recorded the lowest among the districts. On the other hand, during northeast monsoon season, 13 out of 14 districts received more than LPA rainfall with Pathanamthitta (97.1% above LPA) recording the highest and Wayanad (0.03% below LPA) recording the lowest rainfall among all the districts.

The trend map of the district averaged southwest monsoon season rainfall during the period 1901-2023 (**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) were significant. In case of northeast monsoon season (**Fig.6b**) also decreasing trends in the seasonal rainfall was seen in all the districts except in Kasaragod and Ernakulam, with significant decreasing trends in Palakkad and Kottayam. Kasaragod and Ernakulam showed increasing but non-significant trend.

Extreme Weather Events:

Table 1 shows the highest maximum and minimum temperatures and highest rainfall recorded in the 12 IMD met observatories across Kerala along with the dates during 2023. It is seen that, among these stations, Palakkad station reported the highest maximum temperature of 40.1°C (on 14th, 15th, and 19thApril) followed by Vellanikara (40.0°C on 14thApril). The lowest minimum temperature was recorded at Punalur in Kollam district (14.0°C on 13thJanuary) followed by Palakkad (18.2°C on 15thJanuary). The highest one-day rainfall was recorded by Trivandrum AP (211.4 mm) on 15thOctober followed by Kannur (193.7 mm) recorded on 6thJuly. Among these observatories, the highest number of daily heavy rainfall events (>64.5mm) were recorded by Kannur (13 days) followed by Kozhikode city (10 days). Fig.7 shows the locations of extreme rainfall of various intensities that occurred during 2023 based on rainfall data available from all the stations including the 12 IMD stations given in Table 1.

The year 2023 witnessed many extreme weather events like heavy rainfall, floods, landslide, lightning, thunderstorms, etc over many parts of Kerala. Districts that experienced major Extreme Weather Events during 2023 are shown in the **Fig.8**. A few of such events and its impact that caused loss of life are listed in table 2. The casualties mentioned here are based on the media reports.

Table 1: Highest/lowest maximum and minimum temperatures and highest rainfall recorded in the 12 IMD meteorological observatories across Kerala along with the dates during 2023.

IMD Stations	Highest Max. Temperature °C (Date)	Lowest Max. Temperature °C (Date)	Highest Min. Temperature °C (Date)	Lowest Min. Temperature °C (Date)	Highest Rainfall mm (Date)	Frequency of Heavy Rainfall Events (>64.5 mm)
Kannur	38.60 (03-03-2023)	25.40 (05-07-2023) (26-07-2023)	28.50 (18-05-2023)	20.30 (11-01-2023)	193.70 (06-07-2023)	13
Kozhikode city	37.40 (14-04-2023) (18-04-2023) (21-04-2023) (22-04-2023) (16-04-2023)	26.60 (05-07-2023)	29.40 (17-05-2023)	21.60 (12-01-2023)	148.50 (05-07-2023)	10
Karipur A. P	36.40 (14-02-2023)	25.40 (07-07-2023)	28.00 (17-05-2023) (20-05-2023)	20.70 (11-01-2023)	112.50 (05-07-2023)	5
Palakkad	40.10 (14-04-2023) (15-04-2023) (19-04-2023)	25.10 (05-07-2023)	28.00 (13-05-2023)	18.20 (15-01-2023)	123.80 (15-10-2023)	4
Vellanikkara	40.00 (14-04-2023)	25.00 (04-07-2023)	27.10 (18-05-2023) (21-05-2023)	18.40 (29-01-2023)	113.90 (05-07-2023)	6
Kochi (NAS)	35.20 (23-04-2023)	25.40 (04-07-2023)	29.00 (19-04-2023)	21.40 (12-01-2023)	123.20 (05-07-2023)	7
Kochi (CIAL)	37.30 (03-03-2023) (04-03-2023)	26.10 (05-07-2023)	27.60 (19-04-2023)	18.70 (20-01-2023)	187.40 (05-11-2023)	7
Alappuzha	37.20 (18-04-2023) (23-04-2023)	26.80 (04-07-2023)	27.80 (23-04-2023)	21.10 (21-01-2023)	131.20 (15-10-2023)	8
Kottayam	38.00 (03-03-2023) (10-03-2023) (13-03-2023) (19-04-2023) (23-04-2023)	25.50 (04-07-2023)	27.50 (17-05-2023)	19.40 (21-01-2023)	137.60 (04-07-2023)	8
Punalur	38.50 (19-04-2023) (25-04-2023)	25.20 (18-12-2023)	29.00 (02-06-2023)	14.00 (13-01-2023)	139.00 (07-11-2023)	5
Trivandrum AP	35.20 (30-12-2023)	25.20 (18-12-2023)	28.80 (15-05-2023)	19.60 (13-01-2023)	211.40 (15-10-2023)	3
Trivandrum city	36.60 (01-04-2023)	24.70 (18-12-2023)	27.90 (15-05-2023)	19.60 (13-01-2023)	149.30 (23-11-2023)	4

Table 2: Extreme Weather Events occurred during 2023 that caused loss of human Lives.

Impacted weather Events, 2023 Kerala			
Event	Number of casualties	Season (casualty [*])	Affected districts
Heavy Rain and Floods	14	Southwest Monsoon (14)	Kannur, Kozhikode, Alappuzha, Palakkad, Malappuram, Kasaragod, Wayanad, Thrissur, Thiruvananthapuram
Landslides/mud slips	1	Post Monsoon (1)	Idukki
Lightning and Thunderstorm	9	Pre-monsoon (5) Southwest Monsoon (3) Post Monsoon (1)	Alappuzha, Malappuram, Kannur, Kozhikode, Kottayam, Wayanad

(*Based on the media reports and government sources)

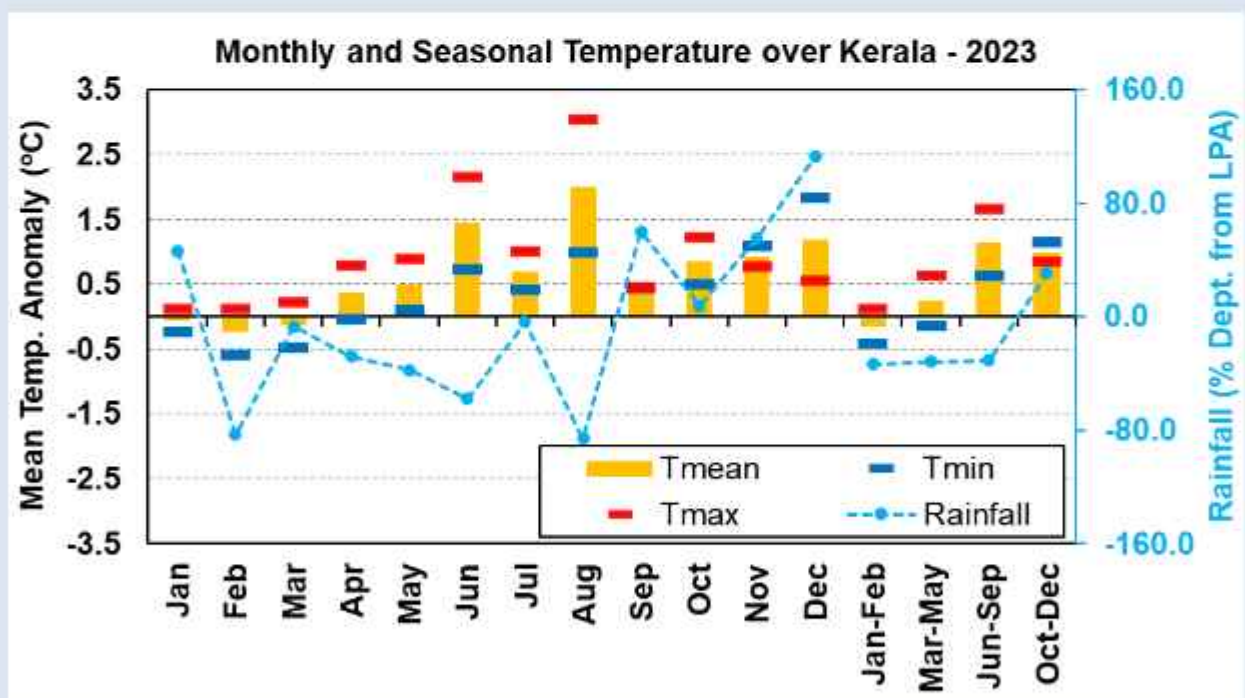


Fig.1. Monthly and Seasonal Maximum, Minimum and Mean Temperature anomalies averaged over Kerala ($^{\circ}\text{C}$) during 2023. Monthly and seasonal Rainfall anomalies averaged over Kerala (percentage departure) during 2023 is also depicted. The anomalies were computed from Long Period Average (LPA) for the base period of 1971-2020.

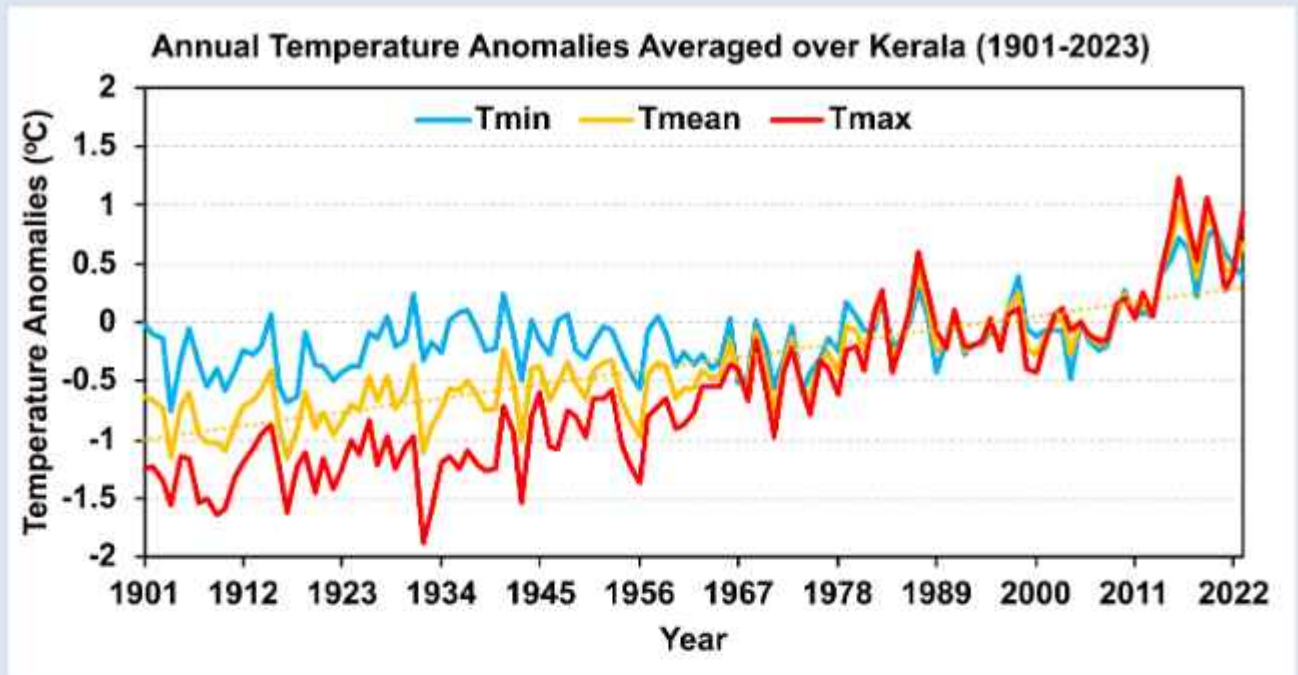


Fig.2: Annual maximum, minimum and mean land surface air temperature anomalies averaged over the State of Kerala for the period 1901-2023. The anomalies were computed with respect to the base period of 1971-2020. The dotted line indicates the linear trend in the annual mean temperature time series.

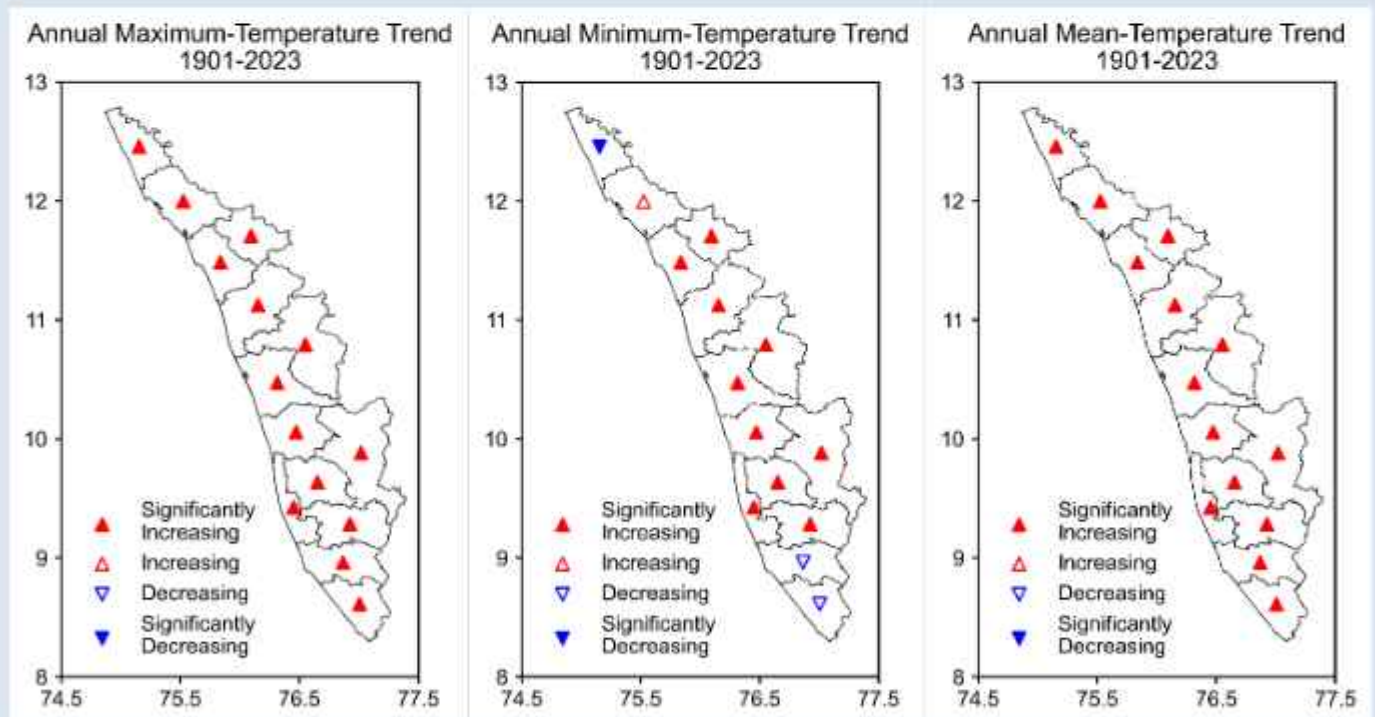


Fig.3: Trends in district averaged a) maximum, b) minimum, and c) mean land surface air temperatures for the period 1901-2023.

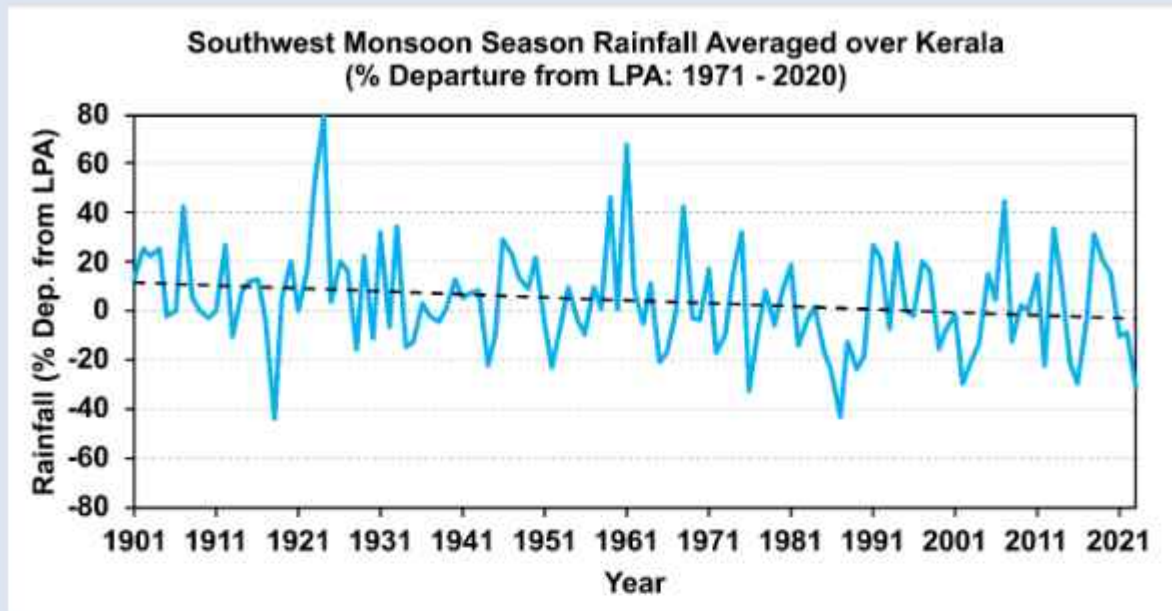


Fig.4: Seasonal departure of southwest monsoon rainfall averaged over Kerala expressed as the percentage from Long Period Average (LPA) computed for the base period of 1971-2020.

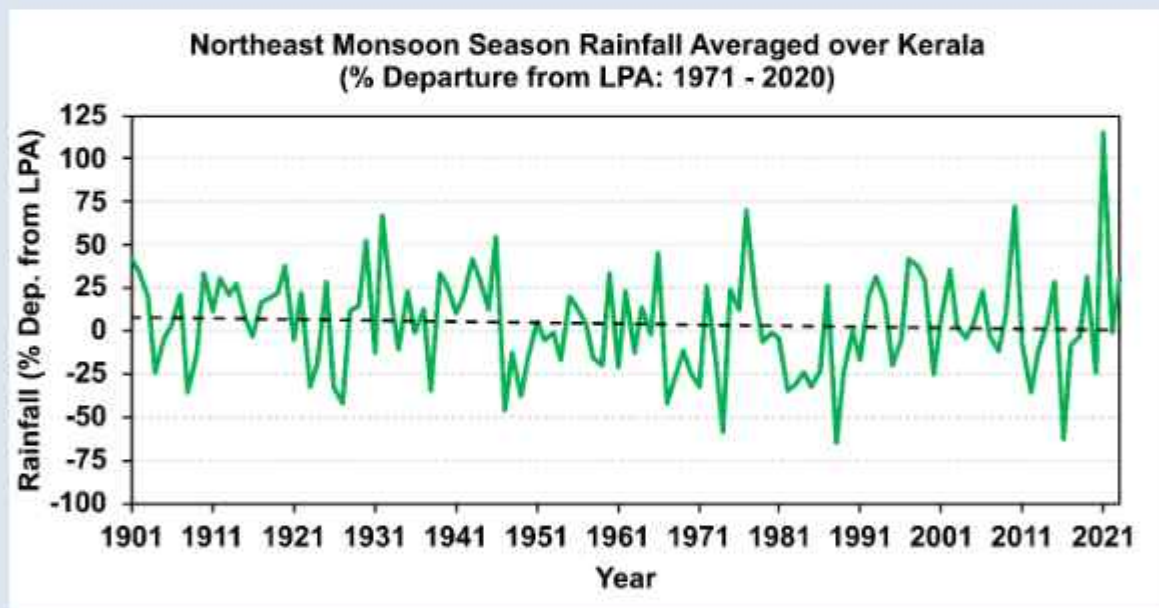


Fig.5: Seasonal departure of northeast monsoon rainfall averaged over Kerala expressed as the percentage from Long Period Average (LPA) computed for the base period of 1971-2020.

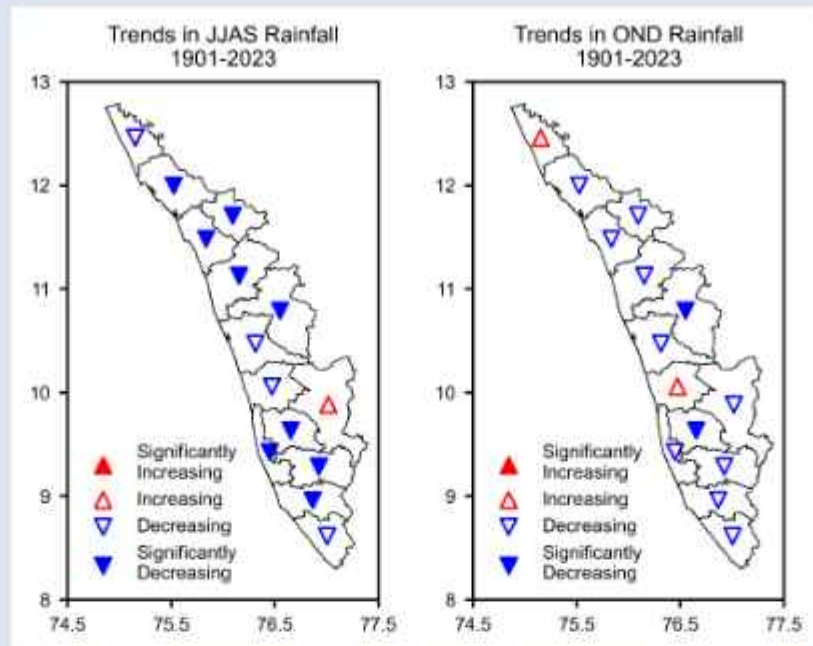


Fig.6: Trends in district averaged **a)** southwest monsoon (JJAS), and **b)** northeast monsoon (OND) season rainfalls for the period 1901-2023.

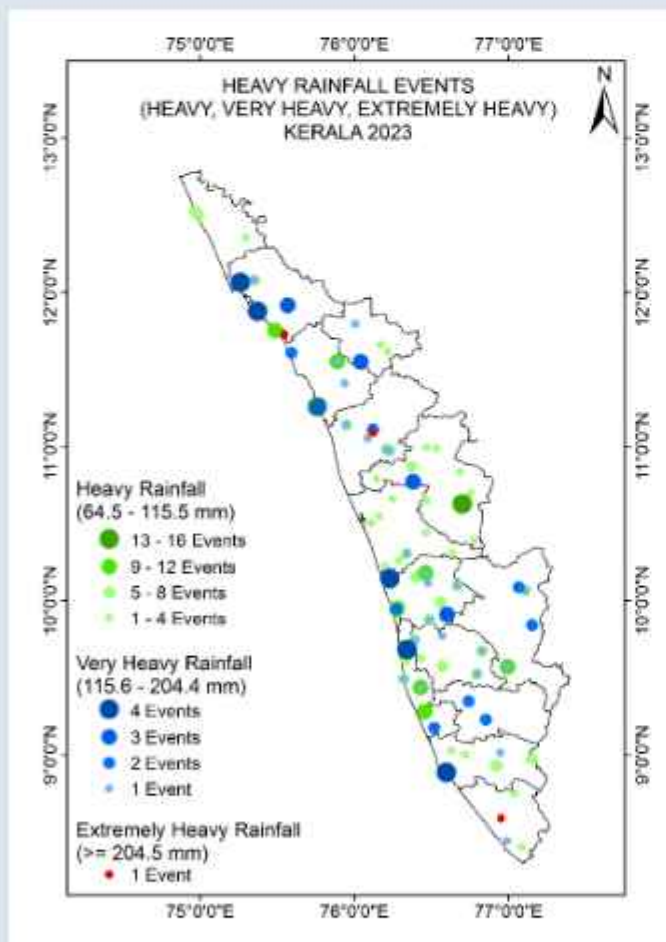


Fig.7: Location of Heavy Rainfall (64.5-115.5mm), Very Heavy Rainfall (115.6-204.4 mm) and Extremely Heavy Rainfall (more than 204.5 mm) reported stations over Kerala during 2023.

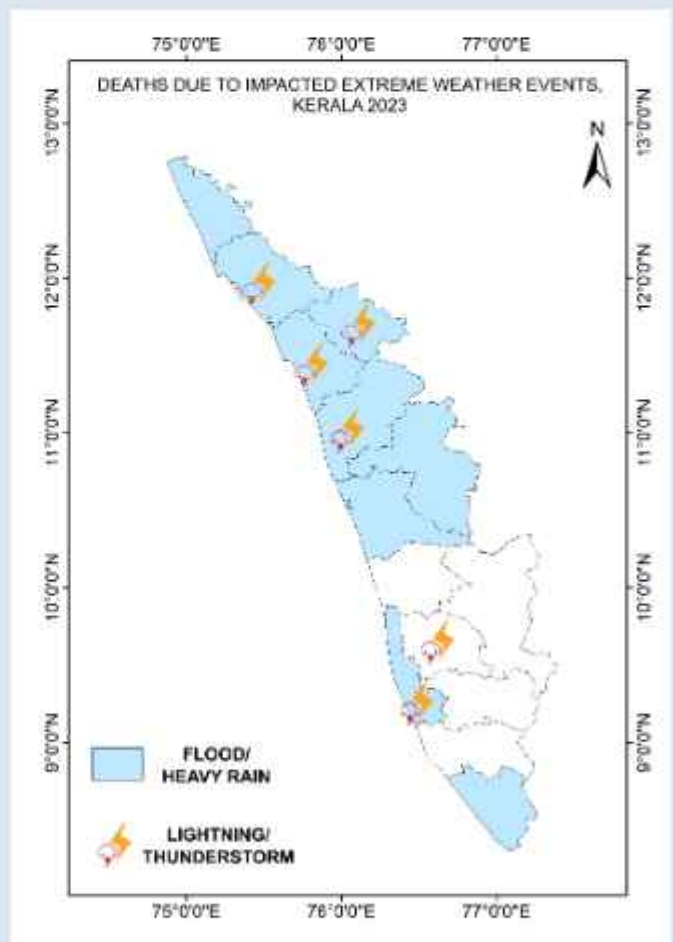


Fig.8: Locations of Major Extreme Weather Events occurred during 2023 that caused loss of life (details provided in Table 2).