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Temperature Variation in Kerala: Present and Future

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Temperature is changing worldwide and a warming trend is expected in most parts. This study investigates the long-term (1983-2020) trend analysis of the maximum temperature in Kerala and the future trend in maximum temperature. The future temperature has been downloaded from GFDL-CM3, which is most suited for Kerala conditions was used to assess the future climate change under different representative concentration pathways (RCP) 4.5 and 8.5 scenarios. The Mann-Kendall test was also used for trends analysis for the downloaded data for each RCPs. The baseline (1980 – 2020) temperature was compared with future (2021-2050 and 2051-2080) simulations for the 14 districts of Kerala under different RCPs. An increasing trend of maximum temperature was observed in all districts of Kerala during the period of 1980 -2020. The increasing temperature trend was confirmed by Mann- Kendall test at a 0.01 significant level. The warming is expected to increase in future simulations under RCP 4.5 and 8.5. In the high-range zone, a decrease in temperature is expected during the beginning of the mid-century, but it continues to show an increasing trend in the projected climate. Under RCP 4.5 in most districts, an increase in temperature by 0.03ºC per year is expected in the future. While under RCP 8.5 the temperature is expected to increase by 0.05ºC per year and 0.06ºC per year by mid and end century respectively.

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Keywords: Temperature; GFDL-CM3; warming; mann-kendall; representative concentration pathways (RCP).

1. INTRODUCTION

Temperature is a vital climate quantity that directly influences human and natural systems. The annual mean temperature over India is showing a warming trend [1]. According to AR5, IPCC, [2] the global mean surface temperature is a significant indicator of climate change because it increases quasi-linearly with increasing greenhouse gas emissions. Recent IPCC reported last decade *i.e.* 2011-2020 as the warmest one. The temperature of earth has increased by 1.1^0C from late 1800. The last decade between 2011-2020 was the warmest one on record [3]. Mondal et al. [4] conducted a study on the long-term trend in temperature from 1901 to 2007 over India. He observed an increase in the mean temperature of 0.003 °C/year. Nayak et al. [5] reported a possible warming of 3–5 °C over the entire Indian region in the period 2051–2110 with reference to the period 1951–2010. Raj et al. [6] studied the long-term (1950-2018) temperature variation over Pattambi of Palakkad district in Kerala and observed an increasing trend in maximum temperature. The future climate has been downloaded using Global climate models. Global climate models aid in obtaining information on climate change based on different greenhouse gas emission scenarios. Impacts of climate change on the area of interest are obtained from regional climate models used for downscaling global climate simulations to smaller areas [7]. Different paths are taken by the models to reach four different radiative forcings that correspond to different concentration paths of the greenhouse gases, the so-called Representative concentration pathway (RCPs) [8]. The pathways describe different climate futures, all of which are considered possible depending on the volume of greenhouse gases (GHG) emitted in the years to come. Under RCP 4.5 a peak emission of greenhouse gas is expected around 2040 and then it declines; under RCP 8.5 the emission is expected to increase continuously throughout the 21st century [9]. Kaur and Kaur [10] also observed that the rise temperature was expected to higher under RCP 8.5 than under RCP 4.5. This paper aims to study the present and future variation in the temperature of Kerala

2. MATERIAL AND METHODS

2.1 Study Area

Kerala is the southwestern state of India. Located between $8^0$18' and $12^0$48' N latitude and $74^0$52' and $77^0$22' E longitude. The state has a total geographical area of 38863 sq. km [11] Kerala has 14 districts and the study has been done by analyzing the weather data in 14 districts of Kerala. The whole area has been divided into five agro-climatic zones i.e. Northern zone, central zone, high range zone, problematic zone, and southern zone (Fig. 1).

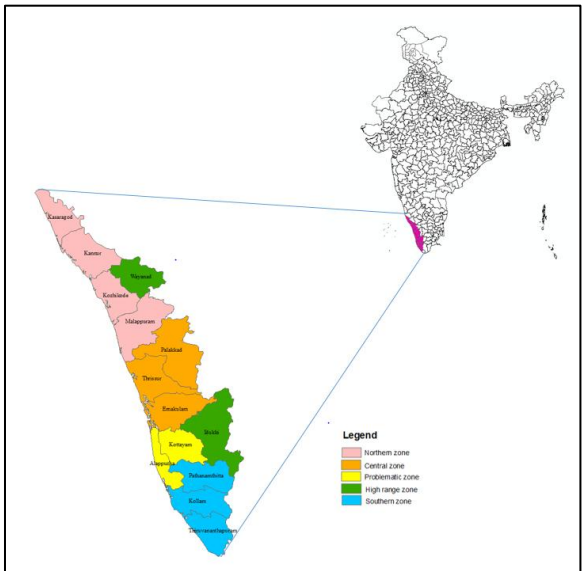


Fig. 1. Study area: Kerala

2.2 Data and Methodology

The maximum temperature from 1983 to 2021 has been collected from India Meteorological Department (IMD) and the future temperature has been estimated using the climate model, GFDL-CM3 developed at the Geophysical Fluid Dynamics Laboratory. The GFDL Climate Model version 3 (CM3) is a coupled general circulation model that has been developed for the atmosphere, ocean, land, and sea ice. The main aim of CM3 was to concentrate on the novel problem of climate change which includes interaction between aerosol and cloud, chemistry and climate, and coupling between the stratosphere and troposphere [12]. The GFDL-CM3 model showed a good ability to simulate the present climate over the central zone of Kerala [13]. To assess the future change in the temperature of Kerala the present temperature (1980 to 2020) is compared with the future scenarios i.e. mid-century (2021 -50) and end of the century (2051-80) under RCP 4.5 and 8.5 and trend analysis has been also carried out.

3. RESULTS AND DISCUSSION

The warming was not found to be uniform in Kerala. Long-term trend analysis of past weather has been compared with the projected temperature under RCP 4.5 and 8.5.

Trend analysis: Long-term analysis of maximum temperature (1983 to 2020) had been done. Results of Mann- Kendall test showed a significant increasing trend in Kerala at a 0.01 significant level. The maximum temperature increased at a rate of 0.03℃ per year in most parts of Kerala (Table 1). The study conducted by Arulbalaji, [14], reported a significant decrease in vegetation cover during the period of 1988–2019 in Akkulam-Veli lake basin of Thiruvananthapuram. This enchanced the warming and an average increase of temperature by 1.6°C was observed. Hence the changes in the land use or land cover may lead to climate change and increase in temperature.

Table 1. Long term analysis of maximum temperature

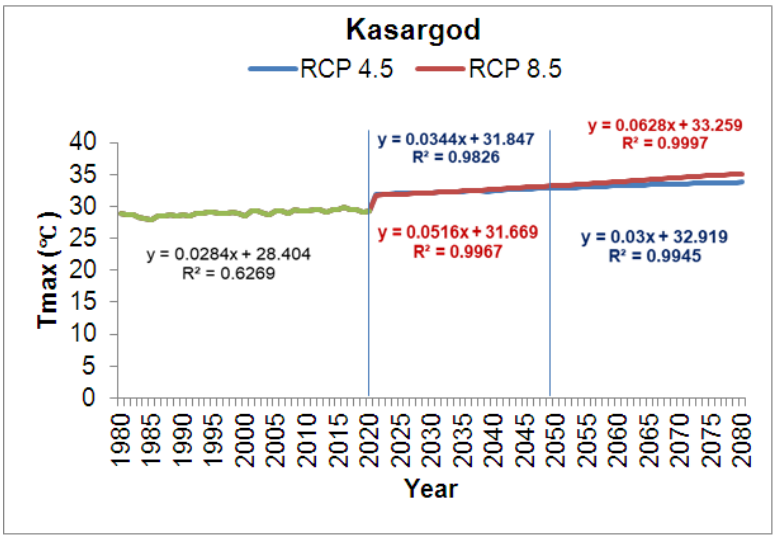
District	Mann-Kendall test	Equation
Kasargod	5.594	y = 0.0284x + 28.404 R^2 = 0.6269
Kannur	5.819	y = 0.0301x + 28.096 R^2 = 0.66
Kozhikode	5.818	y = 0.0316x + 27.647 R^2 = 0.6523
Malappuram	5.897	y = 0.0316x + 27.858 R^2 = 0.6705
Wayanad	6.088	y = 0.0327x + 27.632 R^2 = 0.7036
Palakkad	5.841	y = 0.0317x + 28.365 R^2 = 0.6588
Thrissur	5.886	y = 0.0314x + 28.417 R^2 = 0.6488
Ernakulam	5.762	y = 0.0308x + 29.103 R^2 = 0.6423
Idukki	5.987	y = 0.0314x + 29.665 R^2 = 0.6644
Alappuzha	6.133	y = 0.0308x + 29.768 R^2 = 0.6524
Kottayam	5.975	y = 0.0308x + 29.768 R^2 = 0.6524
Pathanamthitta	6.009	y = 0.0312x + 30.293 R^2 = 0.6726
Kollam	6.076	y = 0.0313x + 30.571 R^2 = 0.6759
Thiruvananthapuram	6.065	y = 0.0317x + 30.967 R^2 = 0.6779

3.1 Analysis of Future Climate

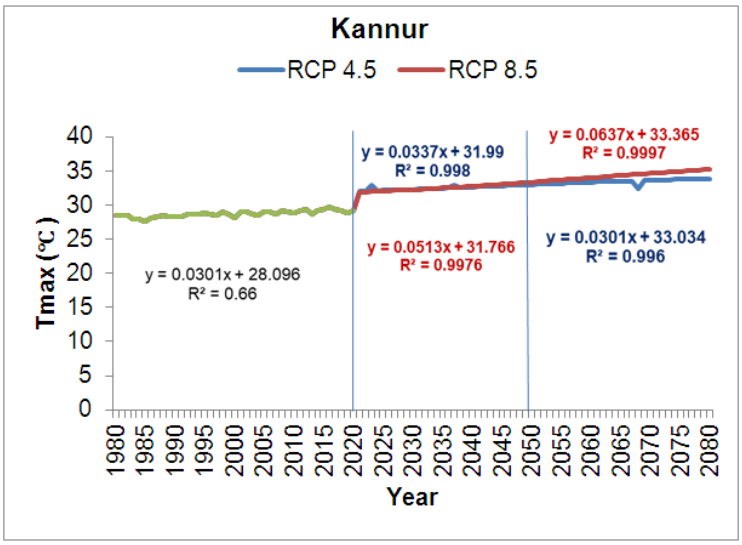
3.1.1 Northern zone of Kerala

Trend analysis: The northern zone of Kerala includes districts like Kasargod, Kannur, Kozhikode and Malappuram. From analyzing the projected climate during mid-century and end century the temperature is expected to increase at the rate of 0.03℃ per year. Under RCP 8.5 the temperature is expected to increase at the rate of 0.05℃ per year during the mid-century and by the end of the century, warming is expected to increase at the rate of 0.06℃ per year.

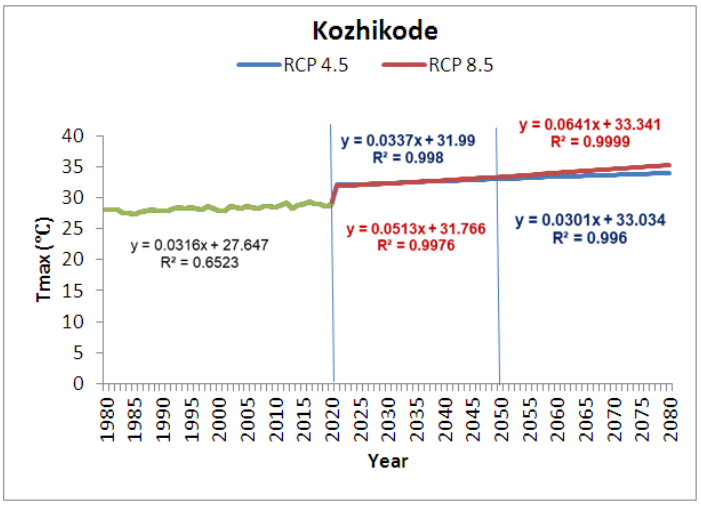
Variation from normal: Under RCP 4.5 during the period 2021-2050 (mid-century) an appreciably above normal (3.1 to 5℃) increase in temperature is expected from normal while during 2051-80 (end of the century) warming is expected to increase in Kozhikode and Malappuram by greater than 5℃ from normal. Under RCP 8.5 during mid-century an appreciably above normal (3.1 to 5℃) increase in temperature is expected from normal while during 2051-80 (end of the century) markedly above normal increase i.e. greater than 5℃ from normal in maximum temperature is expected (Fig 2a-2d).



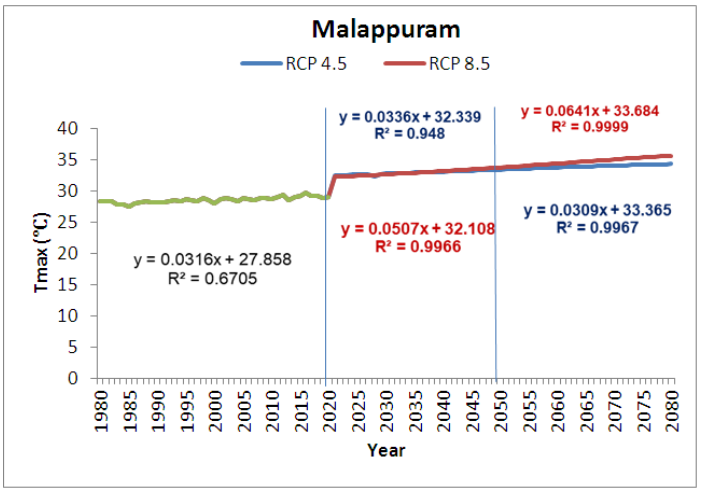
2.a



2.b



2.c



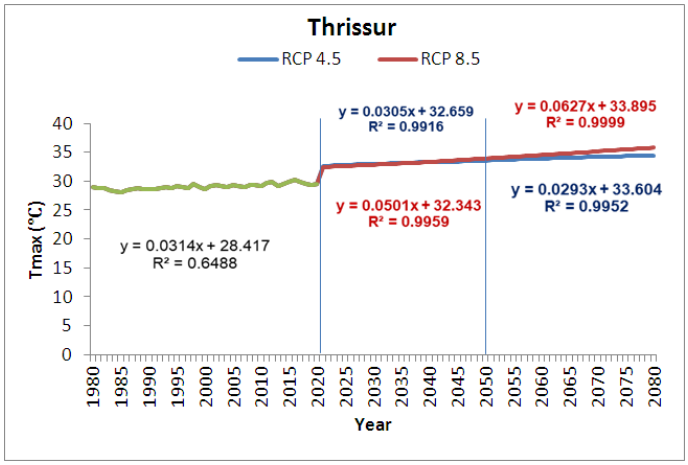
2.d

Fig. 2.a-d. Temperature variation in the northern zone of Kerala

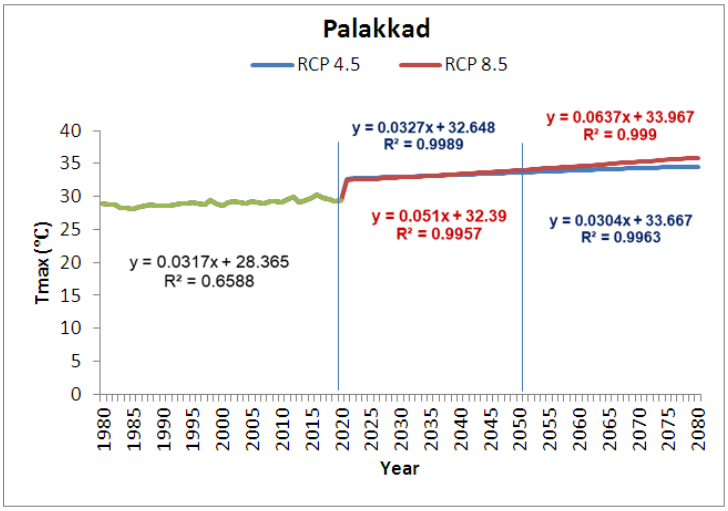
3.1.2 The central zone of Kerala

Trend analysis: The central zone of Kerala includes districts like Palakkad, Thrissur and Ernakulam. From analyzing the projected climate during mid-century, the increasing trend is expected to continue at the rate of 0.03℃ per year. By the end of the century, the increasing rate is expected to decrease. The temperature is expected to increase at the rate of 0.029℃ per year, 0.027℃ per year and 0.03℃ per year in Thrissur, Ernakulam and Palakkad respectively. Under RCP 8.5 the temperature is expected to increase at the rate of 0.05℃ per year during the mid-century and by the end of the century, warming is expected to increase at the rate of 0.06℃ per year.

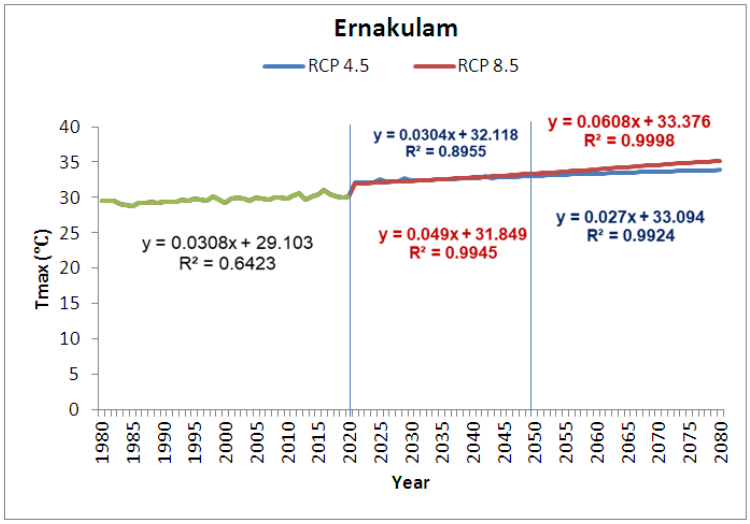
Variation from normal: Under both RCPs during the period 2021-2050 (mid-century) an appreciably above normal (3.1 to 5℃) increase in temperature is expected from normal in Thrissur and Palakkad while in Ernakulam an above normal deviation *i.e.* (1.6 to 3.0℃) is expected. By the end of the century markedly above normal increase in maximum temperature is expected in Thrissur and Palakkad while in Ernakulam an appreciably above normal increase in maximum temperature is expected (Fig 3.a- 3 c).



3.a



3.b



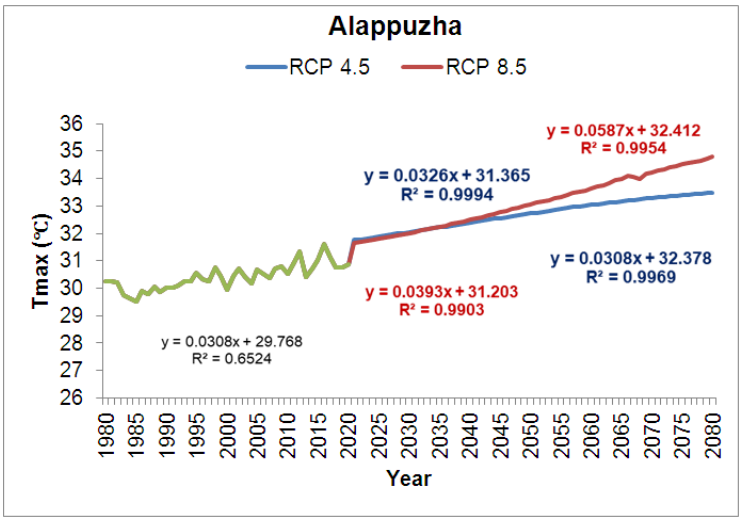
3.c

Fig. 3.a-c. Temperature variation in the central zone of Kerala

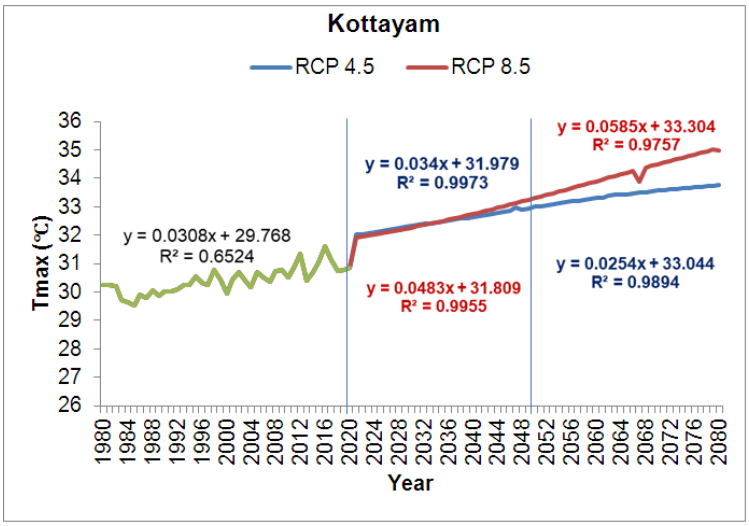
3.1.3 Problem area zone Kerala

Trend analysis: The problem area zone includes Alappuzha and Kottayam districts of Kerala. An increasing trend in maximum temperature was observed from the long-term analysis of maximum temperature (1983 to 2020). The increasing rate per year was found to be 0.03℃ per year. Under projected climate also an increasing trend in maximum temperature was observed. Under RCP 4.5 during the mid-century and end of the century, the increasing trend is expected to continue at the rate of 0.03℃ per year in Alappuzha. While in Kottayam the increasing rate is expected to decrease and the increase per year is expected to be 0.02℃. Under RCP 8.5 the temperature is expected to increase by 0.04℃ per year during the mid-century. By the end of the century, the temperature is again expected to increase by 0.058℃ per year.

Variation from normal: Under RCP 4.5 during the period 2021-2050 (mid-century) an above normal (1.6 to 3℃) increase in temperature is expected from normal while during 2051-80 (end of the century) warming is expected to increase in Kottayam by 3.1 to 5℃ from normal. Under RCP 8.5 during mid-century an above normal increase in temperature is expected from normal while during 2051-80 (end of the century) appreciably above normal increase from normal in maximum temperature is expected (Fig 4.a- 4 b).



4.a



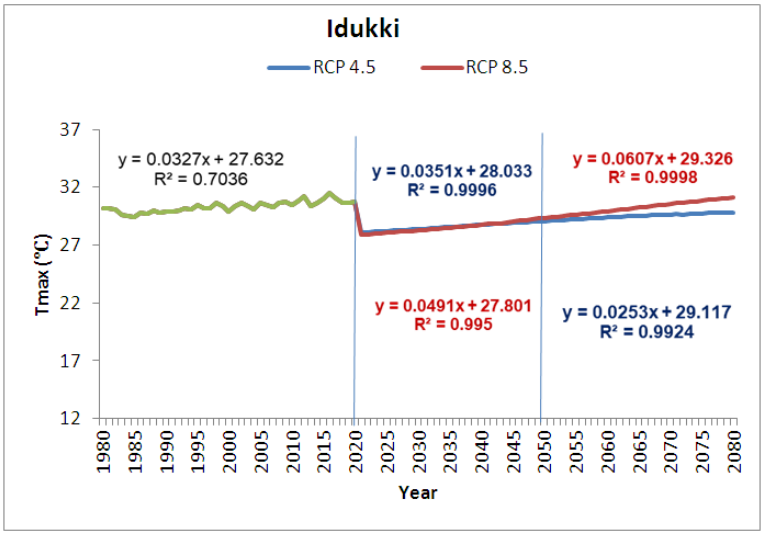
4.b

Fig. 4.a-b. Temperature variation in the problem area zone of Kerala

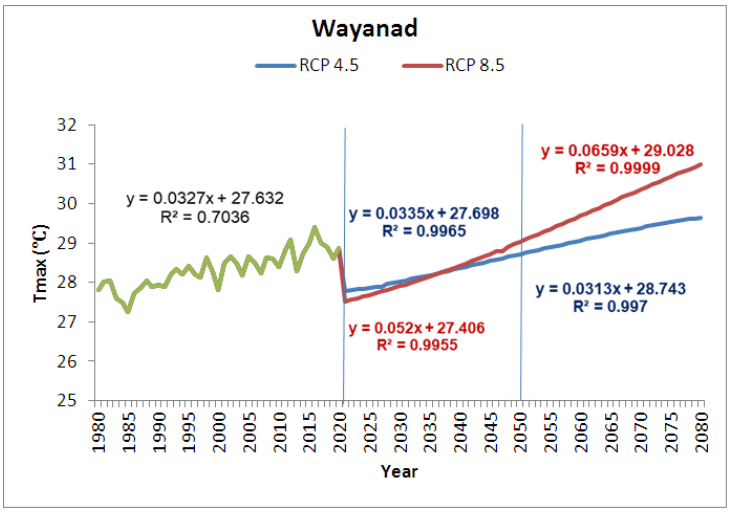
3.1.4 High range zone

Trend analysis: Two districts, Wayanad and Idukki come under the high range zone. During the past 40 years, maximum temperature showed an increase of 0.03℃ per year in the high rage zones of Kerala. Even though a decrease in temperature is expected at the beginning of the mid-century. Under RCP 4.5 the temperature is expected to increase by 0.03℃ during future scenarios in Idukki and Wayanad. While under RCP 8.5 maximum temperature is expected to increase at the rate of 0.05 ℃ per year in mid-century and 0.06℃ per year by the end of the century.

Variation from normal: Under RCP 4.5, the maximum temperature showed below normal departure in Idukki in mid future and by end of the century, a normal departure has been expected. The departure is expected to be normal in Wayanad. In Wayanad, the temperature decreased by 0.1℃ in the mid-century while by end of the century there was a small increase in maximum temperature by 0.9℃. In Idukki, the maximum temperature decreased by 1.74℃ and 0.81℃ during the mid and end of the century respectively. Under RCP 8.5 in Idukki, the temperature decreased by 1.76℃ and 0.05℃ during mid-century and end of the century respectively. While in Wayanad temperature decreased in mid-century by 0.11℃ and then by the end of the century an increase in temperature by 1.73℃ was found (Fig 5.a- 5 b).

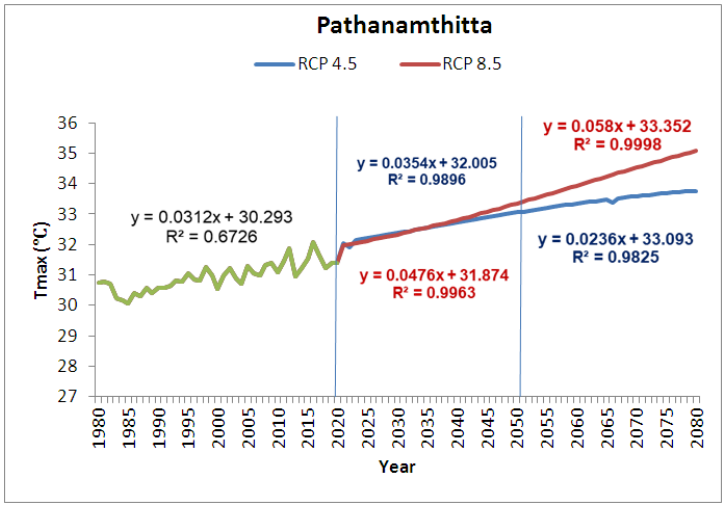


5.a

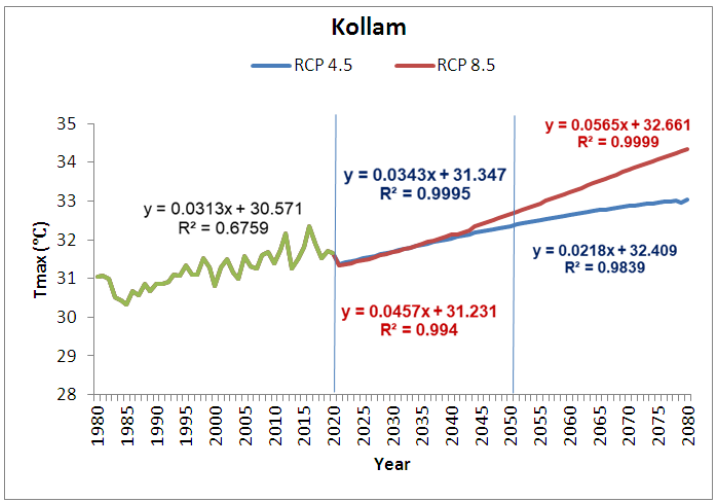


5.b

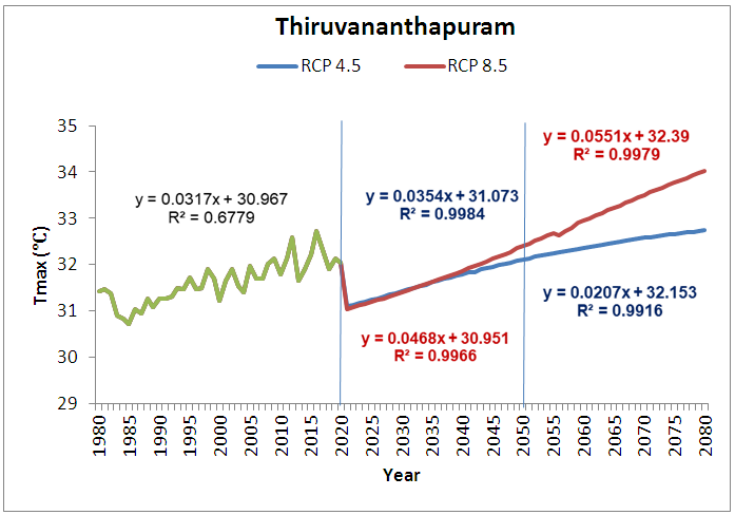
Fig. 5.a-b. Temperature variation in the high range zone of Kerala



6.a



6.b



6.c

Fig. 6.a-c. Temperature variation in the southern zone of Kerala

3.1.5 The southern zone of Kerala

Trend analysis: The southern zone of Kerala includes districts like Thiruvananthapuram, Kollam and Pathanamthitta. In the southern zone of Kerala from 1980 to 2020, an increasing trend in maximum temperature was observed similar to other zones. In the future under RCP 4.5 maximum temperature is expected to increase at the rate of 0.03℃ per year in mid-century while moving towards the end of the century, the increasing rate of maximum temperature decreases to 0.02℃ per year. While under RCP 8.5 maximum temperature is expected to increase at the rate of 0.05℃ per year in mid-century. By the end of the century the warming is expected to increase at the rate of 0.06℃ per year (Fig 6.a- 6 b).

Variation from normal: Under RCP 4.5 in the southern zone of Kerala temperature was expected to increase in Pathanamthitta and Kollam. In Thiruvananthapuram, a slight decrease in maximum temperature was found during mid-century by 0.01℃ and by end of the century, the temperature was found to be increased by 0.8℃. Under RCP 8.5, an increase in temperature was observed In Kollam and Pathanamthitta the temperature increased by 2.3℃ and 3.3℃ by end of the century respectively.

4. CONCLUSION

The maximum temperature has increased at the rate of 0.03ºC per year in Kerala from 1980 to 2020. The warming is expected to increase in future simulations under RCP 4.5 and 8.5. In the high-range zone, a decrease in temperature is expected during the beginning of the mid-century, but it continues to show an increasing trend in the projected climate. Under RCP 4.5 in most districts, an increase in temperature by 0.03ºC per year is expected in the future. While under RCP 8.5 an increase in temperature the temperature is expected to increase by 0.05ºC per year and 0.06ºC per year by mid and end century respectively. The increasing temperature trend was confirmed by Mann- Kendall at a 0.01 significant level. Increase temperature has a major effect on the agriculture. Increase in temperature had a detrimental effect on crop production even though due to the higher concentration of CO_2 photosynthesis rate has increased leading to higher growth and plant productivity. But higher temperatures counteract this effect by increasing crop respiration rates and evapotranspiration, changing the flora of weeds, increasing pest infestation and shortening the duration of crops [15].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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