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RESEARCH REPORT

Trend Analysis of Rainfall, Maximum Temperature, and Minimum Temperature over Thailand using CRU TS 4.07 monthly data

Navin Chandra, Mohana S. Thota, Raghavendra Ashrit

May 2024

National Centre for Medium Range Weather Forecasting
Ministry of Earth Sciences, Government of India
A-50, Sector-62, NOIDA-201 309, INDIA

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10	References	18
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Abbreviations

1	Tmax	Maximum Temperature
2	Tmin	Minimum temperature
3	CRU TS	Climate Research Unit and gridded Time Series
4	ITCZ	Intertropical Convergence Zone
5	UHI	Urban Heat Island
6	CRI	Climate Risk Index
7	BIMSTEC	Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation
8	MK test	Mann-Kendal test
9	DJF	December-January-February
10	MAM	March-April-May
11	JJA	June-July-August
12	SON	September-October-November

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Abstract

This study presents a comprehensive analysis of the patterns of meteorological factors, specifically rainfall, maximum temperature (Tmax), and minimum temperature (Tmin) in Thailand. The data utilized for this analysis is sourced from CRU TS (Climate Research Unit and gridded Time Series) v4.07 datasets and covers the period from 1951 to 2020. Thailand is situated in the tropical region and experiences a biannual reversal of the monsoon system. Additionally, its terrain exhibits major variations from the southern to the northern parts of the country. Primarily, it experiences rainfall during the southwest monsoon. Thailand, similar to other tropical nations, is similarly impacted by the climate. Examining the alterations in meteorological characteristics resulting from climate change is crucial. We have conducted an analysis on the rate of change of Tmin, Tmax, and rainfall, and determined if these rates are statistically significant. The changes in rainfall are negative, although they are not statistically significant. If Tmin and Tmax slopes exhibit predominantly positive values and are statistically significant.

सारांश

यह अध्ययन थाईलैंड में मौसम संबंधी कारकों, विशेष रूप से वर्षा, अधिकतम तापमान (टीमैक्स), और न्यूनतम तापमान (टीमिन) के पैटर्न का एक व्यापक विश्लेषण प्रस्तुत करता है। इस विश्लेषण के लिए उपयोग किया गया डेटा सीआरयू टीएस (क्लाइमेट रिसर्च यूनिट और ग्रिडेड टाइम सीरीज़) v4.07 डेटासेट से लिया गया है और 1951 से 2020 तक की अवधि को कवर करता है। थाईलैंड उष्णकटिबंधीय क्षेत्र में स्थित है और यहां मानसून प्रणाली में हर साल दो बार उलटफेर होता है। इसके अतिरिक्त, इसका भूभाग देश के दक्षिणी से उत्तरी भागों तक प्रमुख विविधताओं को प्रदर्शित करता है। मुख्य रूप से, यहां दक्षिण-पश्चिम मानसून के दौरान वर्षा होती है। थाईलैंड, अन्य उष्णकटिबंधीय देशों की तरह, जलवायु से समान रूप से प्रभावित है। थाईलैंड, अन्य उष्णकटिबंधीय देशों की तरह, जलवायु से समान रूप से प्रभावित है। जलवायु परिवर्तन के परिणामस्वरूप मौसम संबंधी विशेषताओं में परिवर्तन की जांच करना महत्वपूर्ण है। हमने टीमिन, टीमैक्स और वर्षा के परिवर्तन की दर पर एक विश्लेषण किया है और निर्धारित किया है कि क्या ये दरें सांख्यिकीय रूप से महत्वपूर्ण हैं। वर्षा में परिवर्तन नकारात्मक हैं, हालाँकि वे सांख्यिकीय रूप से महत्वपूर्ण नहीं हैं। यदि टीमिन और टीमैक्स ढलान मुख्य रूप से सकारात्मक मान प्रदर्शित करते हैं और सांख्यिकीय रूप से महत्वपूर्ण हैं।

1. Introduction

Thailand is a Southeast Asian tropical country situated between 5.6°N to 20.5°N and 97.36°E to 105.61°E, surrounded by Cambodia, Malaysia, Myanmar, Laos, the Gulf of Thailand, and the Andaman Sea. It has hilly regions covered with forests in the north, fertile fields in the centre, and a rugged coast on the narrow southern peninsula. It faces both the Southwest Monsoon (SWM) from May to October and the Northwest Monsoon (NWM) from November to January (Limsakul et al., 2010; Seigo Nasu, 2017; Takahashi & Yasunari, 2006). The primary factors contributing to rainfall in the country are the SWM, the displacement of the Intertropical Convergence Zone (ITCZ), and tropical cyclones (Takahashi et al., 2015). The agricultural industry in Thailand has historically been considered the foundation of the country's economy, with over 30% of the total land area dedicated to agricultural operations. Additionally, agricultural products account for 25% of the country's total exports. Thailand has increasingly seen the effects of climate variability, including changes in agricultural production, prolonged periods of drought, and severe flooding, as a result of climate change (Marks, 2011).

In recent years, there has been a substantial rise in the occurrence of extreme weather events, such as heatwaves, droughts, and heavy rains, which have had a global impact on individuals (Clarke et al., 2022). Gaining comprehension of the impact of climate change on these occurrences can assist in making more precise forecasts and enhancing readiness, while also offering understanding into the whole expense of carbon emissions. It is a well-known fact that climate change at different spatial and temporal scales have a significant impact on weather events and their onset (Calvin et al., 2023; Limsakul et al., 2023).Thailand is highly impacted by the Asian monsoon and is located in close proximity to locations where atmospheric circulation or rainfall experiences significant annual cycles and reaches its peak intensity. Thailand experiences pronounced monsoon patterns, which are defined by the shift in wind direction and the stark difference between the rainy summer and the dry winter (Khedari et al., 2002; Limsakul et al., 2010).

The urban heat island (UHI) phenomenon can lead to substantial variations in temperature, ranging from 2 to 10°C (Singh et al., 2023). These variations are influenced by factors such as geographical location, land use, and changes in land cover (Buyantuyev & Wu, 2010; Thanvisitthpon et al., 2023). Tropical land areas, particularly Central Africa, the Maritime Continent, and the Indian Ocean rim, are projected to undergo the most pronounced and substantial rise in peak seasonal temperatures, according to climate models. According to

Thirumalai et al. (2017), it is estimated that a minimum of 60% of the land areas in these regions will exceed the highest temperatures observed in the late twentieth century by the middle of the twenty-first century. Thailand is currently experiencing the repercussions of temperature changes. The average annual temperature in Thailand has risen by around one degree Celsius between 1981 and 2007, according to the Department of Meteorology (Marks, 2011). Thailand is classified as one of the most vulnerable nations to the impacts of climate change, as indicated by the Climate Risk Index (CRI) (David Eckstein, 2021). Thailand's heavy dependence on climate-sensitive sectors such as natural resources, water resources, agriculture, and fisheries is due to their significant contribution to socio-economic growth and local livelihoods (Marks, 2011; Weiss, 2009).

The alteration of global climates has had a substantial effect on weather patterns, precipitation, and temperature. The impacts of global climate change have manifested in distinct ways across various locations, leading to diverse alterations in local weather occurrences. The examination of the influence of global climate on certain local regions is significant. As a member of the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC), it is crucial to analyze the regional variations in rainfall and other meteorological patterns and their long-term developments in recent decades. The primary aim of the present study is to examine the trends and fluctuations in precipitation, maximum temperature, and minimum temperatures using CRU TS data from 1951 to 2020.

2. Data and Methodology

The present analysis utilized CRU TS (Climatic Research Unit gridded Time Series) data (Harris et al., 2020) with a spatial resolution of 0.5° from 1951 to 2020 on a monthly frequency. CRU TS is a dataset that provides detailed monthly information about land areas (except Antarctica) in a gridded format with high resolution. CRU TS has been extensively utilized by a wide range of users since its initial launch in 2000. It is commonly employed in local weather and climate-dependent models, as well as in bias correction for global and regional climate models and reanalysis products. The ADW (angular-distance weighting) approach was implemented to generate data with a grid resolution of 0.5°. Regularly updated monthly land station observations are available for seven variables: mean, minimum, and maximum temperatures, precipitation, vapor pressure, wet days, and cloud cover.

To obtain the seasonal and yearly rainfall values, the monthly data for each season and year were summed, for the Tmax and Tmin average value was calculated. To assess whether the changes in physical variables rainfall Tmax and Tmin are significant or not, we have used the Mann-Kendall (MK) trend test (Bevan & Kendall, 1971; Mann, 1945). The MK test evaluates the presence of a statistically significant trend, either increasing or decreasing, in the variable across the specified time interval. We have analyzed the trend for rainfall, Tmax, and Tmin for monthly, seasonal, and annual timescales, spatially and area-averaged.

3. Results:

3.1 Rainfall

Figure 1 displays the regional distribution of the decadal slope of rainfall. The monthly rainfall exhibits both negative and positive slopes at different times. The slope ranges from -15mm/decade to +15mm/decade. Only certain areas of Thailand exhibit a notable decline. Starting in October, the slope in the northern portion of Thailand begins to shift in a positive direction, eventually becoming positive for the entire country.

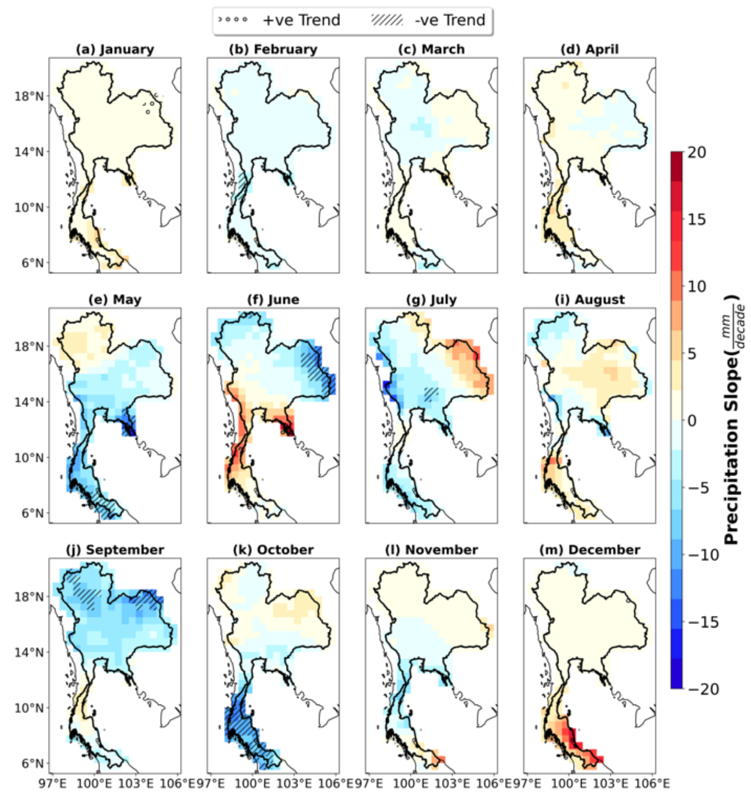

Figure 1 Monthly rainfall slope in mm/decade over Thailand. The area with 95% positive significant trends is marked with 'o ' while 95% negative significant trends are marked with '//'.

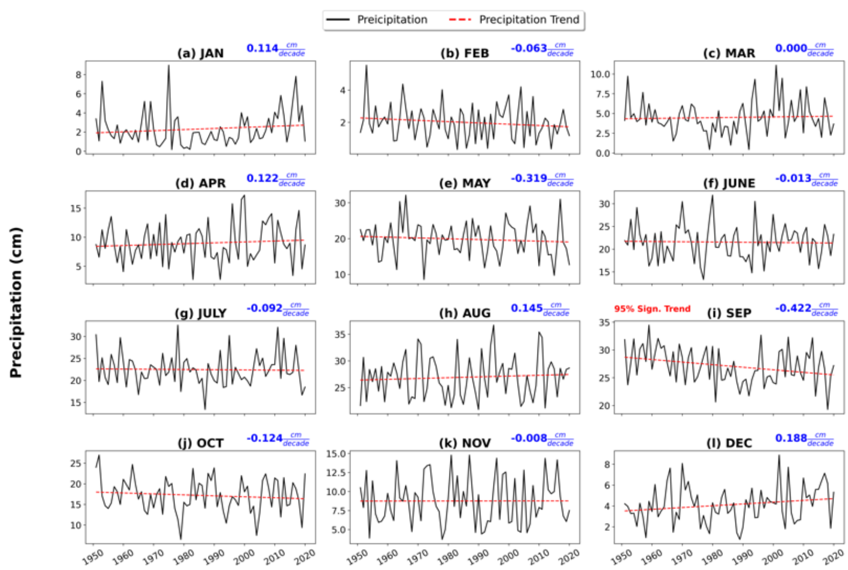

Figure 2 Monthly linear trend of spatially summed rainfall (cm) over Thailand

The highest positive gradient occurs in the southern region around December, whereas it is observed in the central coastal area during June. The geographically averaged trendline in Figure 2 exhibits a negative slope of 0.422 cm/decade specifically for the month of September. The months of January, April, August, and December exhibit a positive tendency, with slopes of 0.114, 0.122, 0.145, and 0.188 cm per decade, respectively. On the other hand, February, May, June, July, September, October, and November display a negative trend, with the steepest slope of -0.422 cm per decade occurring in September.

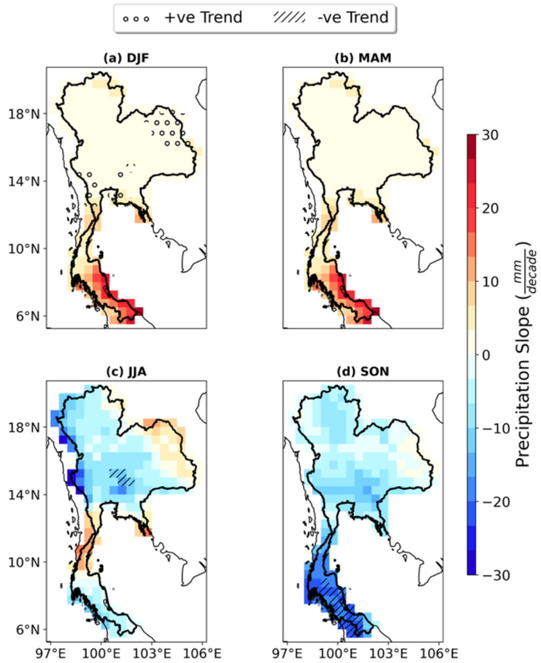

Figure 3 Seasonal rainfall slope in mm/decade over Thailand. The area with 95% positive significant trends is marked with 'o ' while 95% negative significant trends are marked with '//'.

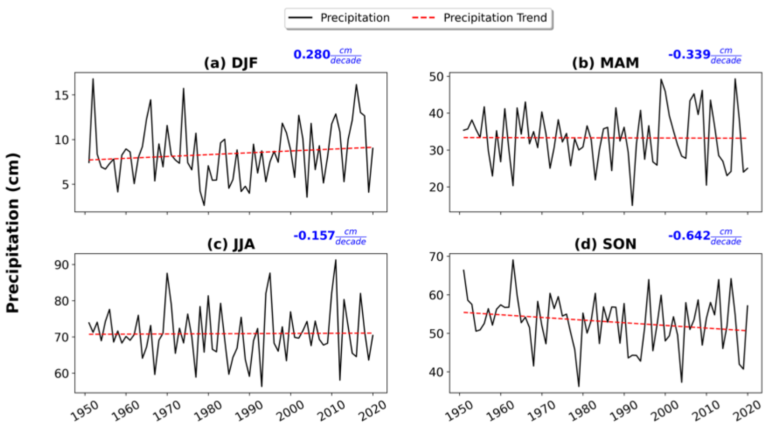

Figure 4Seasonal linear trend of spatially summed rainfall (cm) over Thailand

Figure 3 displays the spatial slope of rainfall throughout the months of December-January-February (DJF), March-April-May (MAM), June-July-August (JJA), and September-October-November (SON). On the other hand, Figure 4 illustrates the cumulative linear trend across different locations. According to the Figure 3, the months of December, January, and February (DJF) and March, April, and May (MAM) exhibit an increasing pattern in rainfall, whereas June, July, and August (JJA) and September, October, and November (SON) display a decreasing tendency. During the months of December, January, and February

(DJF), there is a noticeable tendency in the northeastern and central regions of Thailand. Within the JJA period, a tiny area located in central Thailand exhibited a notable and consistent decline.

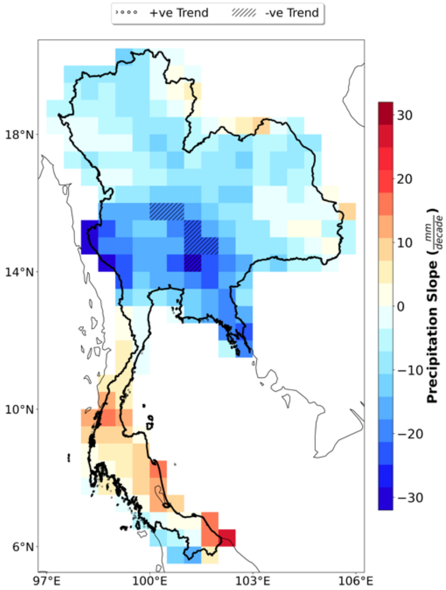

Figure 5 Annual rainfall slope in mm/decade over Thailand. The area with 95% positive significant trends is marked with 'o ' while 95% negative significant trends are marked with '//'.

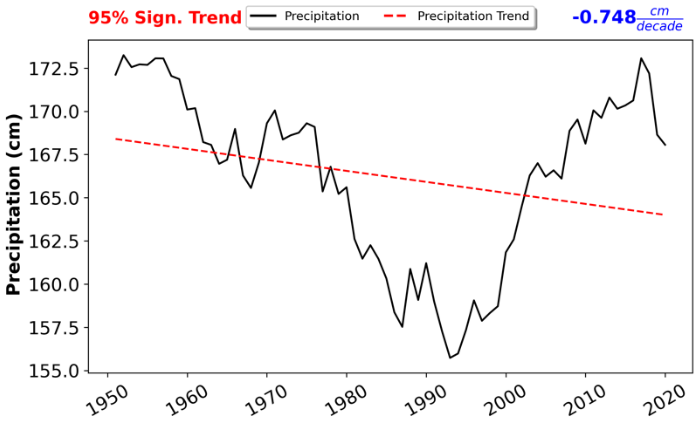

Figure 6 Annual linear trend of spatially summed rainfall (cm) over Thailand

The spatial annual trend shown in figure 5 shows a negative slope over all of Thailand except in the southern region, where it is positive and the value is -30mm/decade, the southern most part shows a positive trend with 15 mm/decade. In central Thailand, some part shows statistically significant negative trend. The linear yearly trend in figure 6 shows a overall negative trend of 0.748 cm/decade.

3.2 Maximum Temperature:

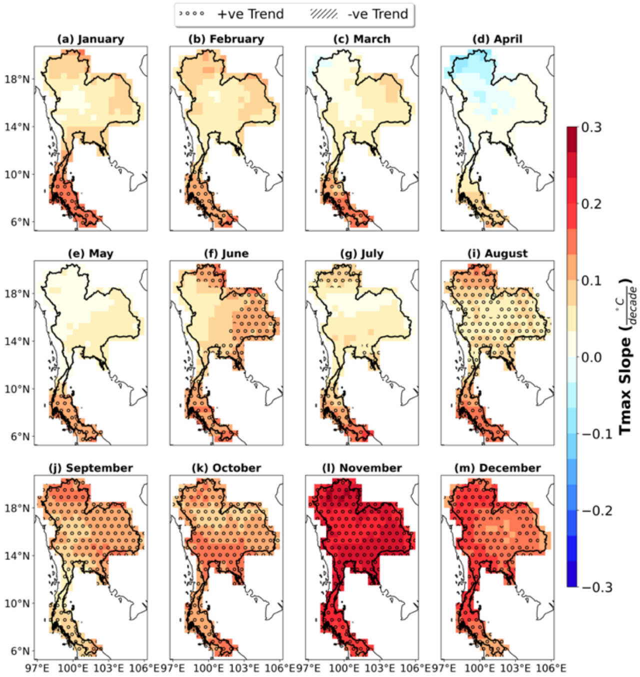

Figure 7 Monthly Maximum temperature slope in over Thailand(°C/decade). The area with 95% positive significant trends is marked with 'o ' while 95% negative significant trends are marked with '//'.

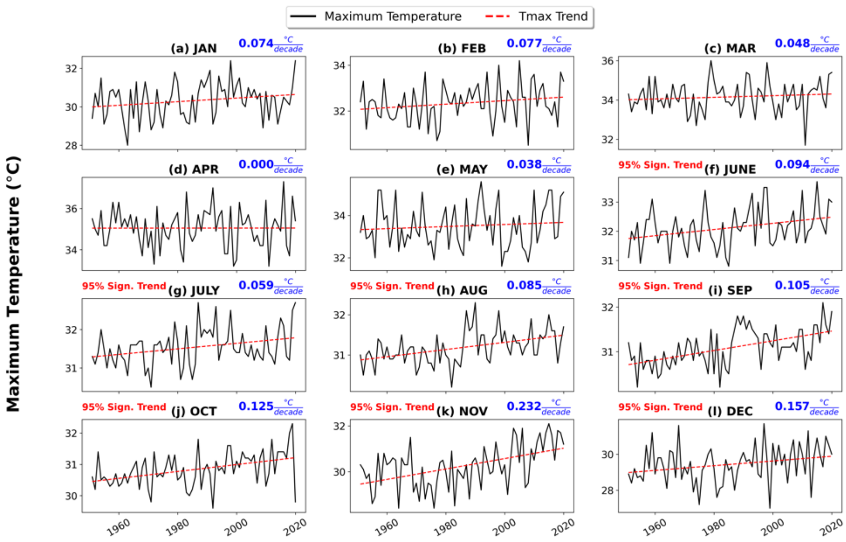

Figure 8 Monthly linear trend of spatially averaged Maximum Temperature (°C/decade) over Thailand

Figure 7 and Figure 8 show the spatial and linear trends for Tmax over Thailand month-wise. The Tmax is showing a positive slope for the entire Thailand for all month except for the April where it is positive in the northern part. The highest slope is in November where it is going upto 0.3°C/decade. The northern and central part of Thailand from January to May. The latter half of the year shows temperature trends are statistically significant. Figure 8 shows the linear trend of Tmax. Trend in Tmax is positive for the entire year and statistically significant from June to December.

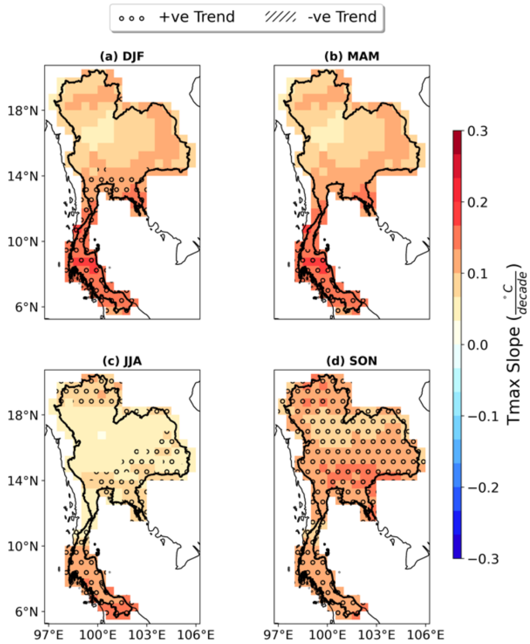

Figure 9 Seasonal Maximum Temperature slope in °C/decade over Thailand. The area with 95% positive significant trends is marked with 'o ' while 95% negative significant trends are marked with '//'.

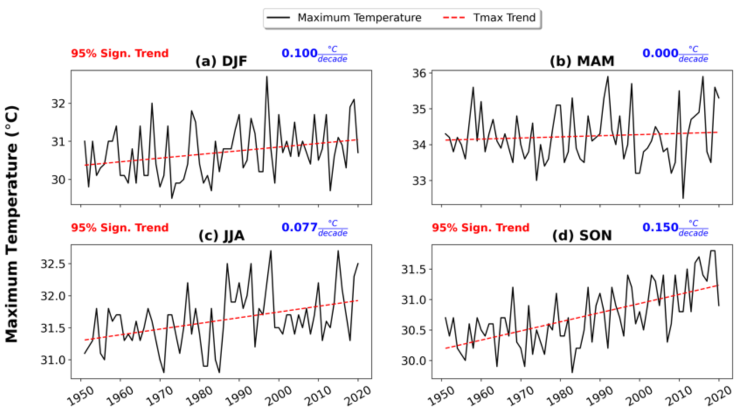

Figure 10Seasonal linear trend of spatially averaged Maximum Temperature (°C/decade) over Thailand.

Seasonal slope for spatial and linear trends are shown in Figure 9 and Figure 10. The seasonal trend shows positive slope for all season and maximum slope is during the SON season which is 0.15 °C. From Figure 9 southern Thailand have significant positive trend during all seasons. During JJA period except in northern Thailand all have area have significant positive trend. For overall Thailand except MAM all seasons are showing significant positive trend.

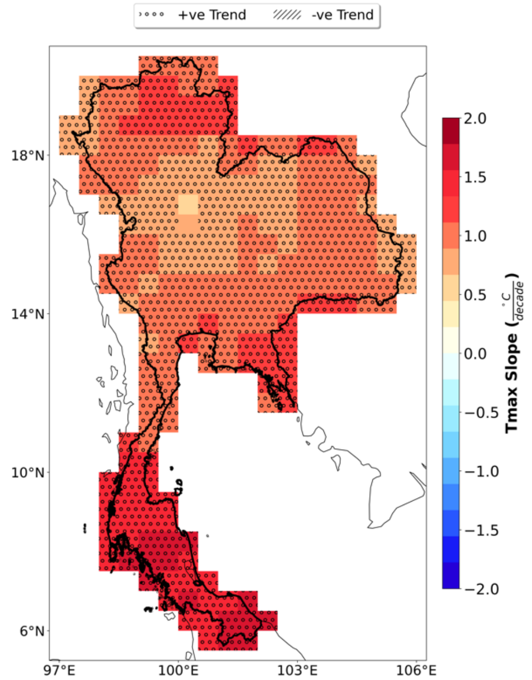

Figure 11 Annual Tmax slope in (°C/decade) over Thailand. The area with 95% positive significant trends is marked with 'o ' while 95% negative significant trends are marked with '//'.

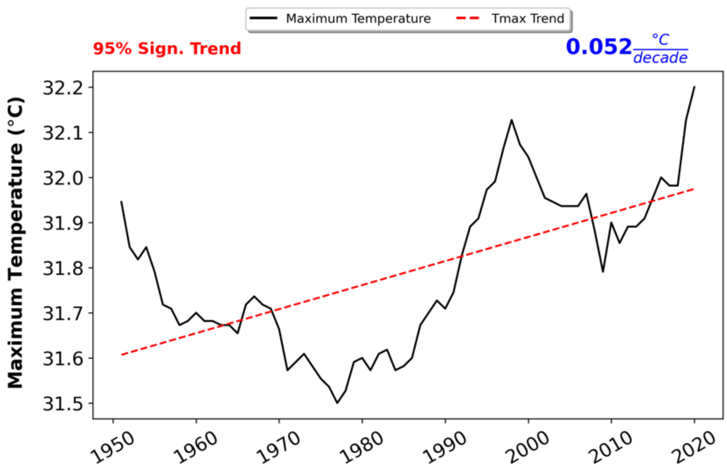

Figure 12Annual linear trend of spatially averaged Maximum Temperature (°C/decade) over Thailand.

The yearly patterns for spatial and linear Tmax can be observed in Figures 11 and 12, correspondingly. Thailand experiences a positive yearly slope, with the highest values observed in the southern region. The entirety of Thailand has a notable and positive trend in Tmax, with the most pronounced incline observed in the southern region of the country.

3.3 Minimum Temperature:

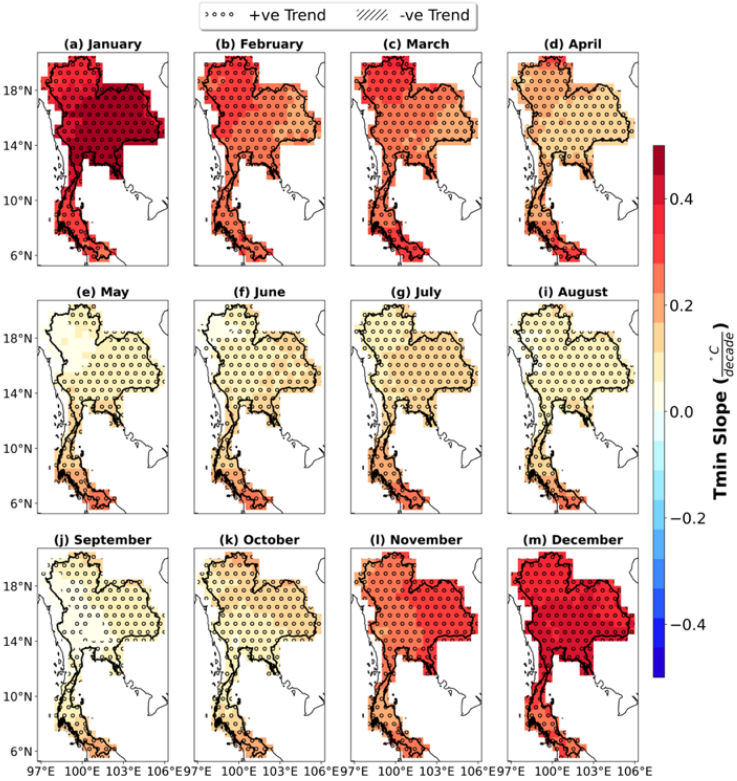

Figure 13 Monthly Minimum temperature slope in over Thailand (°C/decade). The area with 95% positive significant trends is marked with 'o ' while 95% negative significant trends are marked with '//'.

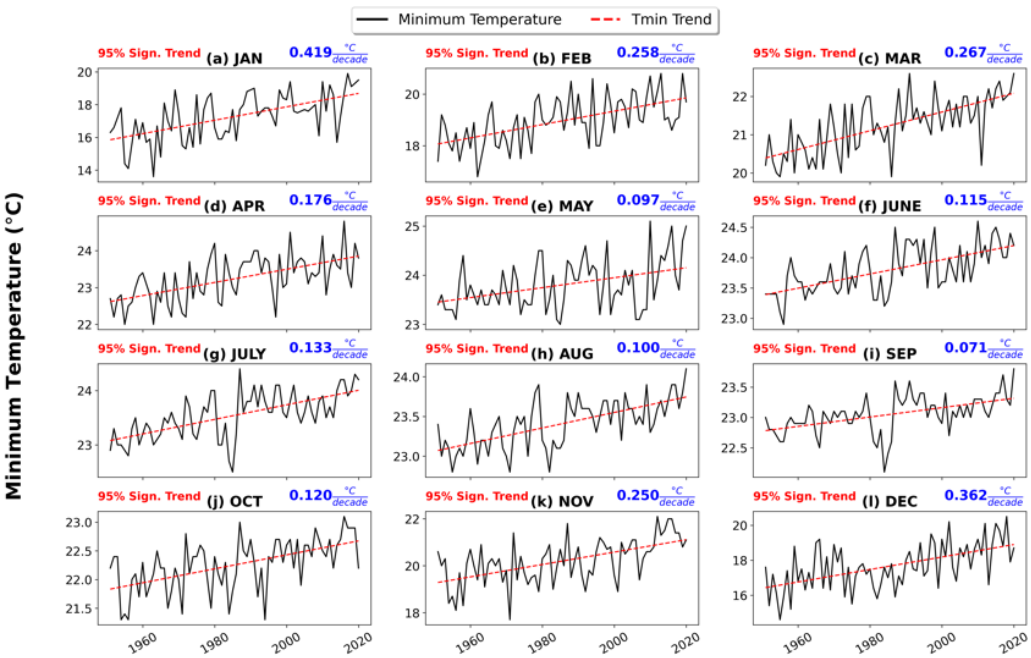

Figure 14 Monthly linear trend of spatially averaged Minimum Temperature (°C/decade) over Thailand

Figure 13 displays the slope of the Tmin, while Figure 14 illustrates the slope for both spatial and linear. Throughout the whole year and across all regions of Thailand, the spatial slope consistently exhibits a positive value. The slope is substantial across the whole area and time period, with the exception of certain isolated sections during the months of May, June, and September. The highest gradient occurs in the month of January, while the lowest gradient occurs in the month of May. The maximum slope during January, as indicated by Figure 14, is 0.419 °C per decade, whereas the minimum slope during May is 0.097 °C per decade.

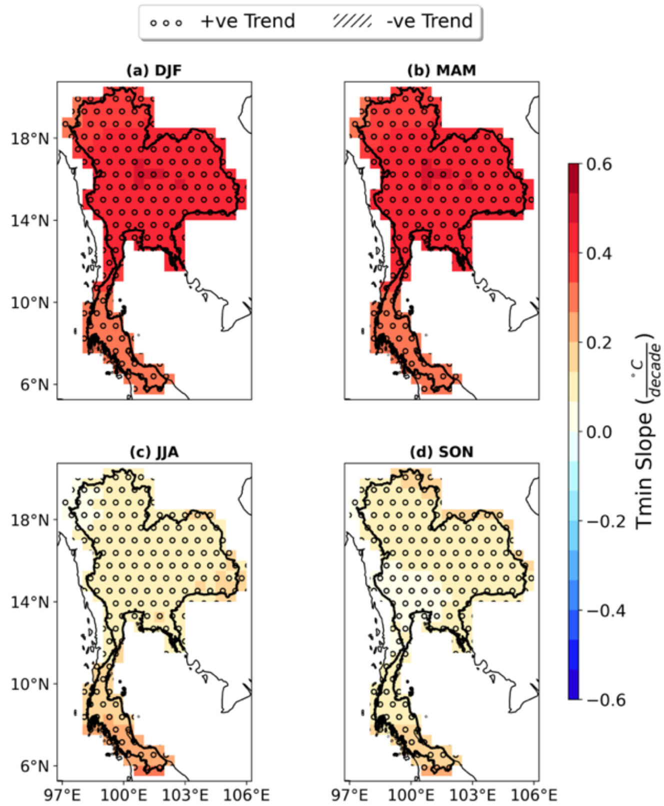

Figure 15 Seasonal Minimum Temperature slope in °C/decade over Thailand. The area with 95% positive significant trends is marked with 'o ' while 95% negative significant trends are marked with '//'.

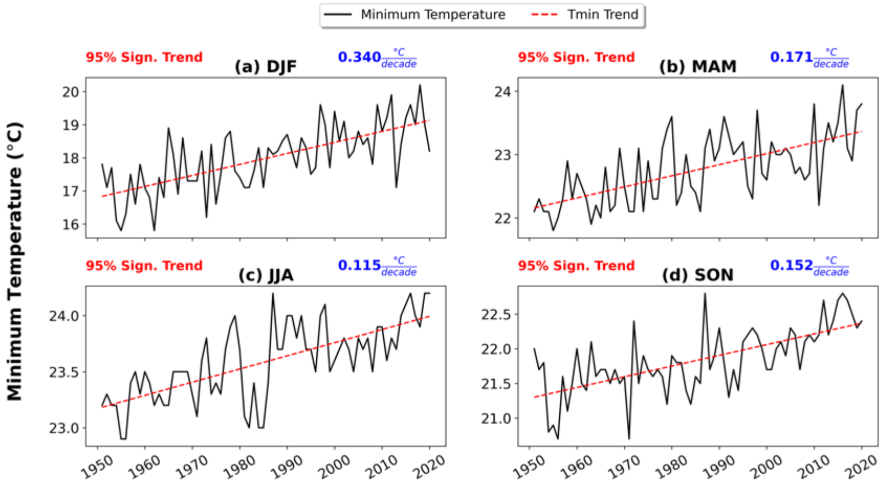

Figure 16 Seasonal linear trend of spatially averaged Minimum Temperature (°C/decade) over Thailand.

The seasonal trend of Tmin is consistently positive across all seasons, with the highest increase observed during the DJF season, reaching up to 0.4 °C each decade. The Tmin slope in northern Thailand is significantly higher compared to southern Thailand. The minimum value for the slope of Tmin occurs during the JJA season. The increase in Tmin seen throughout all seasons and across the whole country of Thailand is statistically significant.

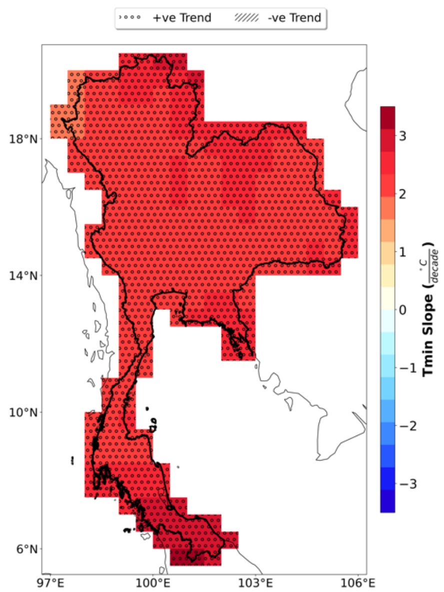

Figure 17 Annual Tmin slope in (°C/decade) over Thailand. The area with 95% positive significant trends is marked with 'o ' while 95% negative significant trends are marked with '//'.

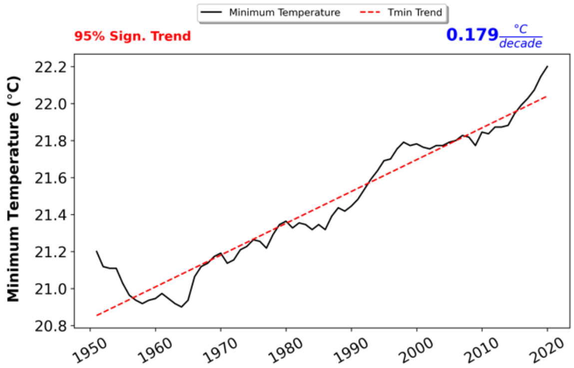

Figure 18 Annual linear trend of spatially averaged Minimum Temperature (°C/decade) over Thailand.

There is a notable increase in the annual Tmin across the entire country of Thailand. In the southernmost region of Thailand, there has been a significant increase in the Tmin by up to 3°C every decade. The average increase is 0.17°C every decade.

4. Conclusion and Future Work:

This paper aims to provide a comprehensive description of the climatic data for key atmospheric variables, namely rainfall, Tmax, and Tmin in Thailand. The data used for this analysis is sourced from CRU TS and covers the period from 1951 to 2020. There is a predominantly negative trend in rainfall throughout most of the year, with a particularly strong negative trend observed solely in the month of September. Both the Tmax and Tmin exhibit notable warming trends throughout all seasons, as seen by the slightly varying positive slope values observed during the months. The increasing slope of Tmin is higher than the increasing slope of Tmax, e.g. for Tmin the yearly slope is 0.179°C per decade and for Tmax it is 0.052°C per decade, which clearly shows the decrease in the gap of Tmax in Tmin with time.

The findings reported in section 3 demonstrate a notable impact of climate change on Thailand, namely in relation to temperature. These sudden alterations may play a direct or indirect influence in extreme events such as droughts, floods, heatwaves, and cyclones. We must assess the frequency and severity of these exceptional occurrences over several decades by utilizing numerous data sources. Additionally, it is not feasible to examine the fluctuations in the frequency of wet and dry days using the data provided in this study.

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Authors Contribution:

Dr. Raghavendra Ashrit developed and oversaw the work. Mr. Navin Chandra conducted the technical work outlined in the study and produced the initial draft of the report. Dr. Mohan S. Thota and Dr. Raghavendra Ashrit guided in the preparation of the final version of the report.

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