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Variability of Temperature Extreme Observes in Kalimantan

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Abstract: This study aims to analyze the trend of extreme temperatures in Kalimantan over the past few decades. The data used are daily temperatures from meteorological stations in West Kalimantan, Central Kalimantan, and South Kalimantan, with an observation period of January 1985 to December 2022. The research methodology involves four main stages: data collection, extreme temperature index calculation, trend detection, and correlation analysis with ENSO and IOD. The results showed an increasing trend in extreme temperatures (warming). The increase in mean annual maximum temperature (TXmean) ranged from 0.03°C to 2°C per century, while the mean annual minimum temperature increased from 0.2°C to 0.5°C per century. Monthly maximum value of daily max temperature (TXx) the increasing trend ranged from 0.19°C to 1.7°C, monthly maximum value of daily min temperature (TNx) increased from 0.1°C to 0.5°C. The monthly mean difference between daily max and min temperature (DTR) also shows an increase of 0.5°C to 1.7°C. This trend indicates that daytime (TXmean, TXx) and nighttime (TNmean, TNx) conditions in Kalimantan, especially in West, Central, and South Kalimantan, are getting hotter, with the daytime experiencing a more significant increase in temperature. The correlation between the extreme temperature index and ENSO and IOD is negative and positive, indicating that ENSO and IOD do not fully influence the increase in extreme temperatures. These findings have important implications for disaster mitigation planning and adaptation to climate change in the Kalimantan region.

Keywords: Climate change; Extreme temperatures; ENSO and IOD; Kalimantan; Mann Kendal test

Introduction

An increase in the Earth's surface temperature indicates that climate change has occurred due to global warming. According to the latest Intergovernmental Panel on Climate Change (IPCC) report in 2023, there is a 50% chance that global temperatures will increase by about 1.5°C between 2021 and 2040 (World Research Institute, 2023). Rising temperatures result in a variety of impacts that can damage the environment. High temperatures cause polar ice caps to melt, resulting in rising sea levels that can increase the potential for flooding in coastal areas (Qu et al., 2020). In addition to the potential for flooding, especially in coastal areas, another impact of extreme temperatures is exposure to intense heat waves that can cause disease and death (Ebi et al., 2021). The diseases include cardiovascular and respiratory diseases. In addition, increased extreme temperatures are often associated with forest and land fires, reduced availability of clean water, reduced agricultural yields, settlements, and public facilities, and disrupted economic activities (Ahima, 2020).

Kalimantan is one of the regions that frequently experiences forest and land fires, which are a serious

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environmental problem with long-term impacts on biodiversity and global climate (Manaswini et al., 2015). In 2019, Indonesia experienced another 328,722 hectares of forest and land fires. Although the amount of land burned was smaller than in 1997 and 2015, it was significant. These fires mainly occurred in Kalimantan and Sumatra (Sarmiasih & Pratama, 2019). One of the main impacts of the fires was the release of carbon emissions and haze, which affected the local environment and spread to neighboring countries such as Malaysia and Singapore (Nurdiati et al., 2022). The resulting carbon emissions increase global emissions and trigger global warming (Hooijer et al., 2006; Prinz, 2009).

In recent decades, much research has focused on climate variability and its implications for regions of the world (IPCC, 2023), and Kalimantan is no exception. Kalimantan is prone to floods, droughts, and forest and land fires that are feared to spread to residential areas (Sukmara et al., 2022; Sarmiasih & Pratama, 2019). Therefore, a thorough and continuous analysis of the observed trends in extreme temperature events is necessary. Such analysis provides a meaningfull understanding of changing climatic conditions and their potential impacts on populations and ecosystems in the region.

Several studies on climate extremes, especially temperature extremes, have been conducted in several regions. During 1983-2012 (30 years) 88 weather stations throughout Indonesia showed a significant warming trend. Shown through the frequency of daytime (TX10p) and cold nights (TN10p) has decreased while warm days and nights (TX90p and TN90p) have increased. In addition, the average daily maximum (TXmean) and minimum (TNmean) temperatures have increased by 0.8 °C and 0.3 °C per decade significantly (Supari et al., 2017). The same results were shown in the Kalimantan region. With a significant increase in TXmean and TNmean of 0.36 °C (Supari et al., 2016b). In different areas, the same results were also obtained (Siswanto et al., 2016). The analysis of daily temperature data at the Jakarta Observatory for 134 years showed that the average annual temperature of Jakarta increased by 1.6 °C per century. This increase exceeds the global average temperature increase. The increase in daily maximum temperature is more significant than the increase in average minimum temperature. Recent research was conducted in South Sumatra and Bengkulu. Both regions experienced temperature increases of 0.26-0.29 °C and 1.07 °C, respectively (Akbar & Lubis, 2022; Akhsan et al., 2023). Although there are many studies related to extreme temperatures, limited studies examine this topic for the Kalimantan region. In addition, the studies that have been conducted often do not involve comprehensive long-term trend analysis, focusing more on short-term analysis or specific events.

The climate in Indonesia is influenced by the Asia-Australia monsoon system and is divided into three distinct sub-regions (Robertson et al., 2011; Aldrian et al., 2003). The northwest and southeast monsoons drive rainfall variations in Indonesia, causing the country to have wet and dry seasons. Much of its interannual variability is influenced by the El Niño-Southern Oscillation (ENSO) and Indian Ocean dipole events (Supari, et al., 2016). When El Niño and/or IOD occur, the positive impacts in Indonesia are increased temperatures and decreased rainfall. This can prolong dry conditions that can trigger fires. Fires have far-reaching impacts that endanger human health and safety but also cause damage to ecosystems, biodiversity, and economies (Lohberger et al., 2017). The impacts range from habitat loss for endangered species to impacts on the agriculture and tourism sectors.

Meanwhile, there are still gaps in the literature regarding the temperature extremes observed in Kalimantan over the long term. Addressing this gap requires a better understanding of climate dynamics in the region and improves the accuracy of future climate projections and risk assessments. Therefore, this study aims to bridge the gap by providing a structured analysis of Borneo's observed extreme temperature trends. By utilizing meteorological data that has been observed over several decades (1985-2022). This study uses statistical data analysis to evaluate changes in extreme temperature events over time. The trends and patterns of extreme temperatures identified explain the causes and mechanisms underlying these changes and their relation to the ENSO and IOD phenomena. In addition, based on the impacts previously described, this research is expected to develop mitigation, adaptation, early warning system improvement, risk reduction, and policy-making measures to reduce the impact of climate change (increase in extreme temperatures).

Method

Kalimantan is the third largest island in the world, with an area of 743,330 km^2 (Wooster et al., 2012). Administratively, 73% of Kalimantan is the territory of Indonesia, 26% is Malaysia, and 1% is Brunei Darussalam. Astronomically, Kalimantan is located between 4° 24′ N - 4° 10′ N and 108° 30′ E - 119° 00′ East. Islands and seas surround Kalimantan. The Sulu Sea borders the northern part of Kalimantan, the South China Sea borders the western part, the Sulawesi Sea borders the eastern part, and the Java Sea borders the southern part. Kalimantan is located in the equator region. They are causing this island to have a tropical climate with high rainfall and temperature (Yulianti & Hayasaka, 2013). Based on annual rainfall patterns, the climate type in this region is semi-monsoonal in the western and northeastern parts and monsoon rainfall type in the eastern and southern parts of Kalimantan. The semi-monsoonal rainfall type has two monthly rainfall peaks per year, namely in March-April-May and October-November. In contrast, the monsoonal rainfall type only has one monthly rainfall peak yearly, namely in December-January (Supari et al., 2016). The Kalimantan region is divided into five provinces, namely West, East, Central, South and North Kalimantan. West Kalimantan is the largest province, with an area of 153,564.50 Km^2. At the same time, the smallest is South Kalimantan, which has an area of around 38,744.23 Km^2 (Government of East Kalimantan Province, 2019). Kalimantan is also known as the heart of Borneo because it has pretty extensive forests with diverse flora and fauna. However, the forests in Kalimantan have experienced a lot of deforestation and rapid forest degradation. These two things are one of the causes of global warming and climate change. Figure 1. shows the research area.

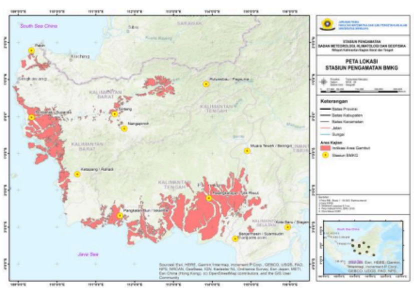

Figure 1. Research location

Table 1. Location of BMKG Stations Used in the Study

Meteorological Station	Province	Coordinates	
		Latitude	Longitude
SM. Rahadi Oesman	West Kalimantan	-1.80000	109.97000
SM. Nangapinoh	West Kalimantan	-0.42000	111.47000
SM. Supadio	West Kalimantan	-0.14206	109.45000
SM. Tebelian	West Kalimantan	0.06000	111.47000
SM. Tjilik Riwut	Central Kalimantan	-2.22000	113.95000
SM. Iskandar	Central Kalimantan	-2.73000	111.66000
SM. Syamsudin Noor	South Kalimantan	-3.44200	114.75400
SM. Gusti Syamsir Alam	South Kalimantan	-3.30000	116.17000

This study uses data from BMKG from eight observation stations. The stations are located in three provinces: West, Central, and South Kalimantan. The data period is from 1985-2022 (38 years). The list and information of the stations used can be seen in Table 1.

Data and Procedures

Data processing in this study was carried out through several stages, namely: 1) quality control and homogeneity test; 2) calculation of the value of each extreme temperature index; 3) determining the trend of extreme temperature index using Mann-Kendall and Sen's slope; 4) analyze the correlation between extreme temperature index with ENSO and IOD. The research flow is explained in Figure 2.

The extreme temperature index based on ETCCDI is adjusted to the climate in Indonesia. This study uses five extreme temperature indices based on ETCCDI (Zhang et al., 2011). The description of the extreme temperature index can be seen in Table 2.

Table 2. Extreme Temperature Index

Index name	Definition of index	Unit
TXmean	Annual mean of maximum temperature	°C
TNmean	Annual mean of minimum temperature	°C
TXx	Monthly maximum value of daily max temperature	°C
TNx	Monthly maximum value of daily min temperature	°C
DTR	Monthly mean difference between daily max and min temperature	°C

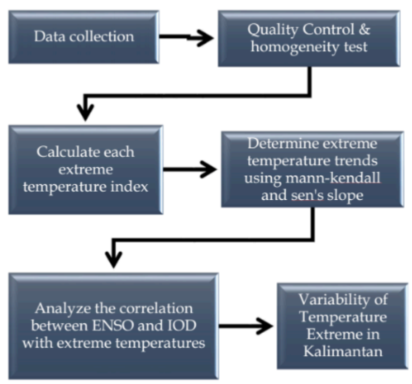

Figure 2. The research flow

Man-Kendall Test

The Mann-Kendall test is a non-parametric test used to determine the data trend based on the relative ranking of a certain period (Peterson et al., 2001). This test does not have to fulfill the assumption of normality. The Mann-Kendall test can be calculated using the following equation:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k) \quad (1)$$

$$sgn\,(x_j - x_k) = \begin{cases} +1, if\ (x_j - x_k) > 0 \\ 0, if\ (x_j - x_k) = 0 \\ -1, if\ (x_j - x_k) < 0 \end{cases} \quad (2)$$

If the S value is positive, it indicates an increasing trend, but if the S value is negative, it indicates a decreasing trend. The variance of the S value can be calculated using the following equation:

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i-1)(2t_i+5)}{18} \quad (3)$$

If n is greater than eight, S is statistically close to a normal distribution. Statistical tests are performed using the typical distribution approach, and the standard Z test statistic is calculated using the following equation:

$$Z = \begin{cases} \frac{S-1}{\sqrt{var\,(S)}}, if\ S > 0 \\ 0, if\ S = 0 \\ \frac{S+1}{\sqrt{var\,(S)}}, if\ S < 0 \end{cases} \quad (4)$$

If the Z value is positive, it indicates an increasing trend; if the Z value is negative, it indicates a decreasing trend.

Sen's Slope Estimator

The slope of Sen provides information on how much the average extreme rainfall changes from year to year. This trend test is assumed to be linear and quantifies time-varying data. Sen's slope test is better than the linear regression test because the test is not affected by outliers and data errors. The equation used is as follows (Sen, 2013):

$$Q_i = \frac{(x_j - x_i)}{j - i}, i = 1,2,3, \ldots N \quad (5)$$

xj and xi are the data at time j and i, respectively, Where j>i. If there are n values of xj in the time series, then the slope estimate N=(n(n-1))/2. The N Qi values are sorted from smallest to largest. Then, the slope of Sen is calculated using the median Qi. A two-sided test estimating the Qmed values at 90% and 95% confidence intervals are calculated using the following equation:

$$Q_{med} = \begin{cases} Q_{\left[\frac{N+1}{2}\right]}, \ if\ N = odd \\ \frac{Q_{\left[\frac{N}{2}\right]} + Q_{\left[\frac{N+2}{2}\right]}}{2}, if\ N = even \end{cases} \quad (6)$$

Result and Discussion

Average Extreme Temperature Trend

The results of the extreme temperature trend analysis are summarized in Table 3. Table 3 shows a warming trend in the West, Central, and South Kalimantan regions during the 38 years of observation.

Table 3. Average trend of Extreme Temperature Index from Eight Stations

Index	Average Trend
TXmean	0.005
TNmean	0.002
DTR	0.004
TXx	0.006
TNx	0.0003

Based on the average trend of the extreme temperature index in Table 3, it can be seen that the overall average trend value has increased. TXx is seen to have the highest trend increase, and the lowest is TNx. Almost all observation stations for the maximum temperature experienced an increase in trend. Eight stations experienced increased trends in the TXmean and TXx indices. Meanwhile, six and four stations had increasing trends for the annual mean minimum temperature (TNmean) and Monthly maximum value of daily min temperature (TNx).

Moreover, the least number of stations experiencing an increasing trend is in the DTR index (4 out of eight stations). The calculation results show that monthly maximum value of daily max temperature (TXx) experienced the most warming trend, followed by the Annual mean of maximum temperature (TXmean), the monthly mean difference between daily max and min temperature (DTR), annual mean of minimum temperature (TNmean), and monthly maximum value of daily min temperature (TNx). This warming trend is also experienced by South Sumatra and Bengkulu (Akbar & Lubis, 2022; Akhsan et al., 2023). The average results of the increase in TXmean and TNmean obtained are slightly different from those obtained by Supari et al. (2016) with the observation period 1986-2010, even though in the same region.

Extreme Temperature Trends

All observation stations experienced an increase in TXmean and TXx trends, and 87.5% experienced a significant increase at the 95% level. This is in line with the results of research (Tan et al., 2021), which shows an increasing trend in the TXmean and TXx indices in the Malaysian region in the 1985-2018 observation years.The largest TXmean and TXx increasing trends both occurred at SM. Iskandar, with values of 0.02°C and 0.017 °C per year, respectively. The trend of TXmean and

TXx for each station can be seen in Figure 3 and Figure 5. While TXmean and TXx index data every year can be seen in the Figure 4 dan 6.

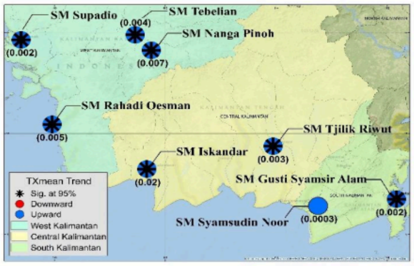

Figure 3. Trend TXmean

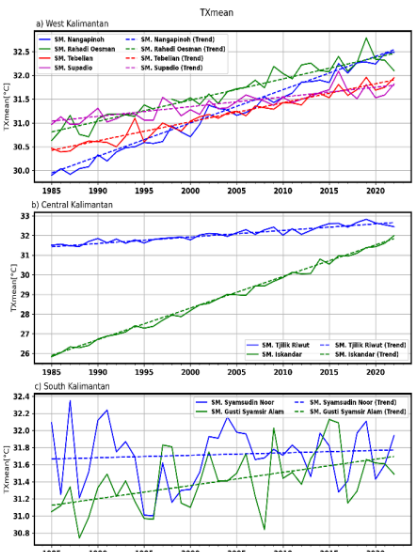

Figure 4. Time series of TXmean from January 1985 to December 2022 observed at a) West Kalimanta, b) Central Kalimantan, c) South Kalimantan

Furthermore, TNmean and TNx experienced an increasing trend at almost 75% and 50% of the observation stations significantly at the 95% level. Tan et al. (2021) also shows the increasing trend of TNmean and TNx for the Malaysian region during 1985-2018. The largest increasing trend of TNmean and TNx was found in SM. Tebelian (West Kalimantan) has a value of 0.005 °C per year. The trend of each station from TNmean and TNx can be seen in Figures 7 and 8, respectively. The TNmean and TNx values for each year can also be seen in the Figure 9 and 10.

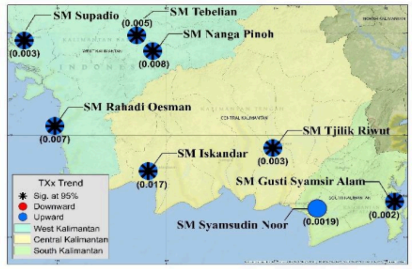

Figure 5. Trend TXx

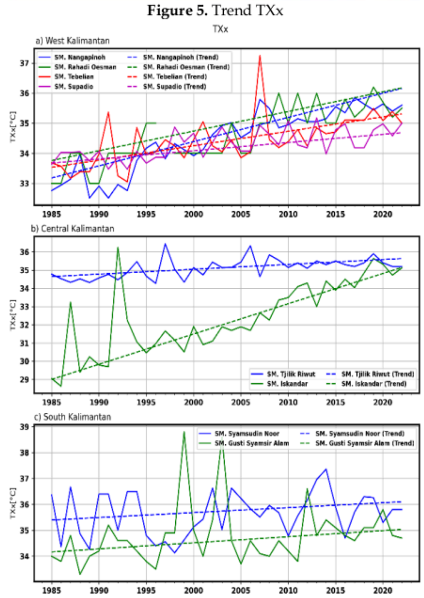

Figure 6. Time series of TXx from January 1985 to December 2022 observed at a) West Kalimanta, b) Central Kalimantan, c) South Kalimantan

The increase in DTR trend was only 50% of all observation stations and was significant at the 95% significance level. In this study, 50% of the observation stations obtained a decreasing trend, in line with the results of study Tan et al. (2021), which showed that the DTR index obtained a significantly decreasing trend for the Malaysian region from 1985 to 2018. The largest DTR was found in SM. Iskandar (Central Kalimantan) with an increased value of 0.017 ^{o}C per year. The DTR trend for each station can be seen in Figure 11. Figure 12 shows the DTR value every year for 38 years of observation.

Previous research conducted by Supari et al. (2017) in 1983-2012 in the Indonesian region obtained a more minor increase in TXmean trends compared to the results of this study. Meanwhile, the TNmean trend is greater than that in this study. Siswanto et al. (2016) also showed a larger TNmean trend for the Jakarta area in 1961-2010.

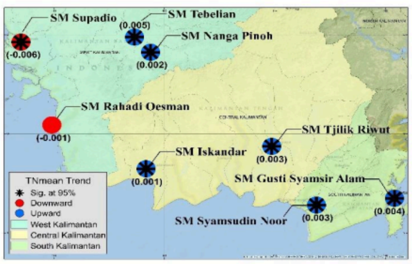

Figure 7. Trend TNmean

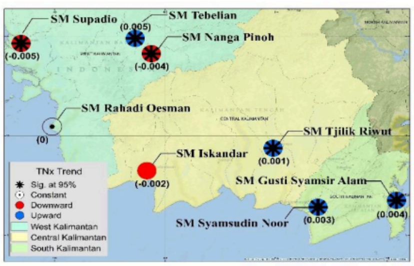

Figure 8. Trend TNx

Some study areas, such as Sarawak, India, Thailand and Pakistan, showed significant increases in some extreme temperature indices. In Sarawak, the TN index increased more than TX, causing the DTR trend to decrease (Sa'adia et al., 2023). The same thing happened in Northern Thailand, where the decrease in DTR trends was due to higher TN and TNx trends compared to TX and TXx (Masud et al., 2016). Meanwhile, in Punjab (Pakistan), significant increases were seen in the TN and Tmean indices, with the DTR trend also decreasing (Nawaz et al., 2019). In India, both TX and TN showed an increasing trend (Agnihotri et al., 2018). Analysis of extreme temperature variations in these regions indicates that the extreme temperature indices continue to increase, leading to hotter conditions in the future.

The results show an increasing trend of hotter extreme temperatures. TXmean and TXx have increased at all observation stations, most of which are significant. In contrast, TNmean and TNx did not show an increasing trend at all stations, although more stations recorded an increasing trend in minimum temperatures (TNmean, TNx) higher than maximum temperatures (TXmean, TXx). This caused the DTR trend to decrease at some observation stations.

Research by Safitri et al. (2022) in East Kalimantan (Capital City of Indonesia) showed that the increase in surface temperature was caused by a decrease in vegetation, expansion of development areas, and an increase in agricultural land. Meanwhile, Akhsan et al. (2022) suggested reducing forest and land burning to suppress the increase in average maximum and minimum temperatures and reduce greenhouse gas (GHG) contributions to the atmosphere.

IOD and ENSO Correlation with Extreme Temperatures

In addition to trends, the extreme temperature index also correlates with interannual variability (e.g., ENSO and IOD). The results of the extreme temperature index correlation with IOD and ENSO can be seen in Figures 13 and 14.

All observed extreme temperature indices correlate negatively and positively with ENSO and the IOD. The positive correlation with the IOD indicates an increase in sea surface temperature in the western TIO, which increases the extreme temperature index. The opposite condition is for negative correlation. The highest TXmean correlation with the IOD phenomenon occurs in SM. Tebelian (West Kalimantan), which is 0.285.

This means that increasing sea surface temperature is influenced by the average annual maximum temperature in the region. Two observation stations have a negative correlation between TXmean and IOD, namely SM. Rahadi Oesman (West Kalimantan) and SM. Gusti Syamsir Alam (South Kalimantan) has a large correlation of -0.156 and -0.101, respectively.

This means the Indonesian region is dry when the positive IOD phenomenon occurs, and the maximum average temperature decreases (TXmean). This condition does not occur naturally; we assume this is due to local phenomena. 75% of observation stations have a TXmean index positively correlated with IOD. In line with previous research conducted by Lestari et al. (2018), there was a positive IOD in July 2015 in the Kalimantan region.

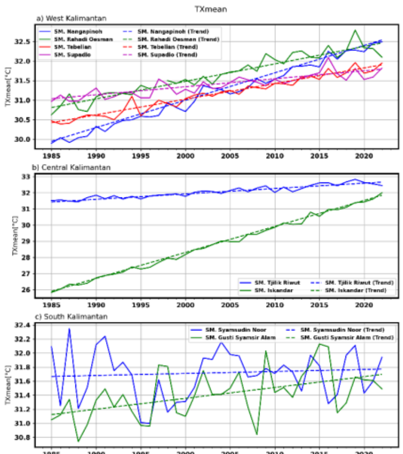

Figure 9. Time series of TNmean from January 1985 to December 2022 observed at a) West Kalimanta, b) Central Kalimantan, c) South Kalimantan

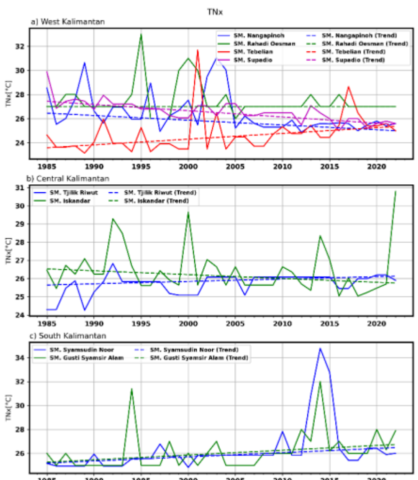

Figure 10. Time series of TNx from January 1985 to December 2022 observed at a) West Kalimanta, b) Central Kalimantan, c) South Kalimantan

Furthermore, the ENSO phenomenon is a sea surface temperature anomaly in the Pacific Ocean. The correlations obtained are also positive and negative. A positive correlation means that when the El Niño phenomenon occurs, the impact received by Indonesia is a decrease in rainfall (dry), and the extreme temperature index will increase. For negative correlations, when the El Niño phenomenon occurs, the extreme temperature index in the Indonesian region will decrease. The most considerable ENSO correlation to TXmean is found in SM. Syamdusin Noor (South Kalimantan) of 0.343.

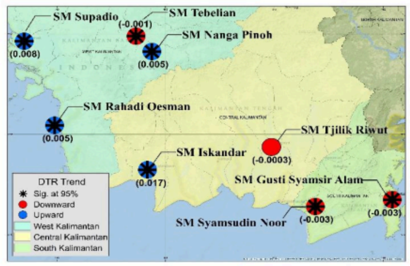

Figure 11. Tren DTR

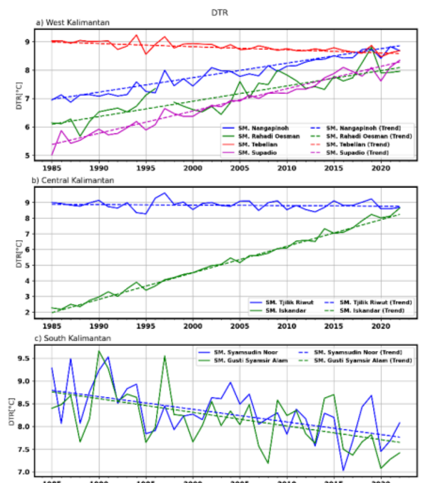

Figure 12. Time series of DTR from January 1985 to December 2022 observed at a) West Kalimanta, b) Central Kalimantan, c) South Kalimantan

There are only two observation stations whose TXmean is positively correlated with ENSO, both in the

South Kalimantan region. This means that when there is a prolonged dry season (El Niño), the Kalimantan region tends to get hotter, increasing TXmean. Meanwhile, the TXmean index is negatively correlated with ENSO for the West and Central Kalimantan regions. Only 25% of observation stations have a TXmean index that is positively correlated with ENSO. It can be assumed that the increase in the extreme temperature index of Central Kalimantan and West Kalimantan is influenced by other factors. Akbar et al. (2022) have previously found for different regions that the increase in land temperature in the Bengkulu region is influenced by local factors such as land use change and population growth. Research that has been conducted in several countries also states that one of the factors driving the increase in extreme temperatures is anthropogenic factors and GDP (Gross Domestic Product) (Estrada et al., 2023).

The following extreme maximum temperature index is TXx (the largest daily maximum temperature in one month). The largest IOD correlation with TXx is found in SM. Tebelian (West Kalimantan) at 0.434. 75% of observation stations have a positive correlation with IOD. Previous research by Akhsan et al. (2023) also shows that daily maximum temperature correlates with IOD. While the TXx correlation with ENSO is only 37.5%, the largest correlation is found in SM. Syamsudin Noor (South Kalimantan) is 0.254. This means that an increase in sea surface temperature in the Indian and Pacific Oceans influences the increase in the largest daily maximum temperature in the region.

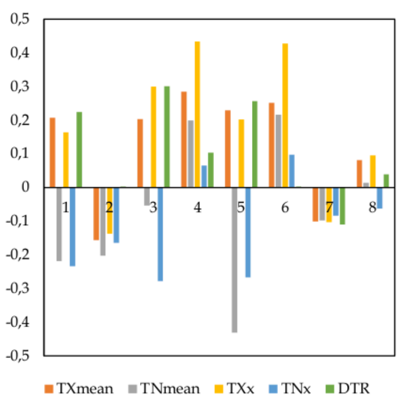

Figure 13. Partial Correlation of IOD to Extreme Temperature Index at eight Stations. (1: SM. Supadio; 2: SM. Rahadi Oesman; 3: SM. Nangapinoh; 4: SM. Tebelian; 5: SM. Iskandar; 6: SM. Tjilik Riwut; 7: SM. Gusti Syamsir Alam; 8: SM. Syamsudin Noor)

The annual mean minimum temperature (TNmean) correlates negatively and positively with the IOD. The largest correlation is found in SM. Tjilik Riwut (Central Kalimantan) with a value of 0.216. 37.5% of TNmean observation stations are positively correlated with the IOD. This aligns with research conducted by Akhsan et al. (2023), which shows that the minimum daily temperature correlates with the IOD. A positive correlation means that an increase in sea surface temperature in the Indian Ocean affects the annual average minimum temperature in the region. In addition to the Indian Ocean, sea surface temperatures in the Pacific Ocean also affect the annual average minimum temperature increase in some observation areas. Less compared to the IOD. TNmean with ENSO is only positively correlated at SM. Supadio, SM. Iskandar, and SM. Gusti Syamsir Alam have values of 0.148, 0.047, and 0.006 respectively. The rest have a negative correlation.

The following minimum temperature index is TNx. TNx is the largest minimum daily temperature in a month. The largest correlation between TNx and IOD was found in SM. Tjilik Riwut (Central Kalimantan) with the value of 0.098. As many as 25% of TNx observation stations correlate positively with IOD. Meanwhile, the largest correlation between TNx and ENSO is found at SM. Syamsudin Noor (South Kalimantan) with a value of 0.241. As many as 62.5% of observation stations correlate positively with TNx and ENSO. This is in line with the results of research conducted by Kemarau et al. (2023) in the Kuching City, which states that El nino affects temperatures in the region.

Furthermore, the largest correlation between DTR and IOD is found in SM. Nangapinoh (West Kalimantan) with a value of 0.301. 87.5% of observation stations whose DTR index is positively correlated with IOD. This means that the phenomenon of positive IOD and/or negative IOD impacts changes in maximum and minimum temperature values at almost all observation stations. At the same time, the DTR correlation with ENSO is less than with IOD. As many as 50% of the DTR index observation stations correlate positively with ENSO. Akhsan et al. (2023) also showed the same research results, with the largest correlation found in SM. Tjilik Riwut (Central Kalimantan) with a value of 0.362. This means that the increase in sea surface temperature in the Pacific Ocean only affects some areas, while other areas are influenced by sea surface temperatures in the Indian Ocean. Besides Kalimantan, Malaysia's weather and climate are also influenced by ENSO and IOD (Eboy & Kemarau, 2023).

The correlation between ENSO and IOD on the extreme temperature index shows that IOD is more influential than ENSO. The same results were also obtained by Akhsan et al. (2023) for the eastern Sumatra region during 1981-2020. However, both climate phenomena are equally influential on changes in the extreme temperature index. For a more comprehensive area coverage, several previous studies have also stated that ENSO affects increasing extreme temperatures (Yang et al., 2018; Thirumalai et al., 2017; Moura et al., 2019).

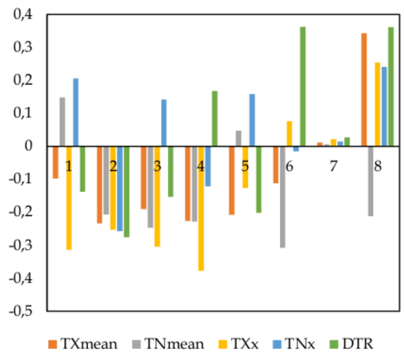

Figure 14. Partial Correlation of ENSO to Extreme Temperature Index at eight Stations. (1: SM. Supadio; 2: SM. Rahadi Oesman; 3: SM. Nangapinoh; 4: SM. Tebelian; 5: SM. Iskandar; 6: SM. Tjilik Riwut; 7: SM. Gusti Syamsir Alam; 8: SM. Syamsudin Noor)

Most extreme temperature index trends have increased in all observation areas, so Kalimantan has experienced climate change. This increase in extreme temperatures also increases the fire risk (Cordero et al., 2024). Central and West Kalimantan showed the highest number of hotspots from 2008 to 2018 (Kirana et al., 2020). The impact felt is not only in the form of hydrometeorological disasters but can be in the form of disease. Central Kalimantan had an increase in dengue fever from 2016-2017, and in the previous year, 2011, the highest malaria disease had occurred (Kamaliah & Marlina, 2021).

Conclusion

Over 38 years of observation (1985-2022), Kalimantan shows an increasing trend of extreme temperatures indicative of climate change. Extreme temperature indicators such as TXmean and TXx show an increasing trend in all observation stations, with seven out of eight stations recording significant increases. The increase in TXmean trends ranged from 0.03°C to 2°C per century, while TXx increased between 0.19°C to 1.7°C per century. For TNmean, only six stations recorded significant trend increases with a range of 0.1°C to 0.5°C per century. TNx recorded increases at four stations with similar ranges, while DTR showed significant increases at four stations with a range of 0.5°C to 1.7°C per century. These trends suggest that daytime and nighttime temperatures will likely get hotter, with Central Kalimantan recording the highest increase in all four extreme temperature indices. Globally, extreme temperature increases were also detected in several regions, such as Sumatra, Bengkulu, Jakarta, Sarawak (Malaysia), India, Pakistan, and Northern Thailand. However, the ENSO or IOD phenomena do not entirely influence this trend. Other contributing factors include local phenomena, landform changes, increased building construction, population growth, anthropogenic, reduction of agricultural land, and increased greenhouse gases. Increased temperature extremes significantly negatively impact local ecosystems, including biodiversity and water quality. In addition, extreme temperatures also affect human health, reduce agricultural productivity, and increase the risk of forest fires.

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Conflicts of Interest
The authors declare no conflict of interest.

References

Agnihotri, I., Punia, M. P., & Sharma, J. R. (2018). Assessment of spatial variations in temperature and precipitation extremes in west-flowing river basin of Kutch, Saurashtra and Marwar, India. *Current Science*, *114* (2), 322-328. https://doi.org/10.18520/cs/v114/i02/322-328.

Ahima, R. S. (2020). Global warming threatens human thermoregulation and survival. *Journal of Clinical Investigation*, *130*(2), 559–561. https://doi.org/10.1172/JCI135006

Akbar, A. J., & Lubis, A. M. (2022). Analysis of Land and

Sea Temperatures Trend During 1985-2021 Period to Understand Local or Global Warming Effect in Bengkulu City. *Indonesian Review of Physics*, *5*(1), 16–24. https://doi.org/10.12928/irip.v5i1.6073

Akhsan, H., Irfan, M., & Iskandar, I. (2023). El Niño Southern Oscillation (ENSO), Indian Ocean Dipole (IOD), and the Rise of Extreme Temperatures in Eastern Sumatra: Exploring Climate Change Dynamics. *Jurnal Penelitian Pendidikan IPA*, *9*(2), 600–608. https://doi.org/10.29303/jppipa.v9i2.3084

Akhsan, H., Romadoni, M., & Ariska, M. (2022). Prediction of Extreme Temperature in South Sumatra and Its Applications at The End of The 21st Century. *Jurnal Penelitian Pendidikan IPA*, *8*(2), 925–931. https://doi.org/10.29303/jppipa.v8i2.1363

Aldrian, E., & Susanto, R. D. (2003). Identification of three dominant rainfall regions within Indonesia and their relationship to sea surface temperature. *International Journal of Climatology*, *23*(12), 1435–1452. https://doi.org/10.1002/joc.950.

Cordero, R. R., Feron, S., Damiani, A., Carrasco, J., Karas, C., Wang, C., Kraamwinkel, C. T., & Beaulieu, A. (2024). Extreme fire weather in Chile driven by climate change and El Niño–Southern Oscillation (ENSO). *Scientific Reports, 14*, 1974. https://doi.org/10.1038/s41598-024-52481-x 2.

Ebi, K. L., Capon, A., Berry, P., Broderick, C., de Dear, R., Havenith, G., Honda, Y., Kovats, R. S., Ma, W., Malik, A., Morris, N. B., Nybo, L., Seneviratne, S. I., Vanos, J., & Jay, O. (2021). Hot weather and heat extremes: health risks. *The Lancet*, *398*(10301), 698–708. https://doi.org/10.1016/S0140-6736(21)01208-3

Eboy, O. V., & Kemarau, R. A. (2023). Analysis of Extreme Heat Land Surface Temperature at a Tropical City (1988-2022): A Study on the Variability of Hot Spot during El Niño Southern Oscillation (ENSO). *Science and Technology Indonesia*, *8*(3), 388–396. https://doi.org/10.26554/sti.2023.8.3.388-396.

Hooijer, A., Silvius, M., Wösten, H., & Page, S. (2006). *PEAT-CO2. Assessment of CO2 emissions from drained peatlands in SE Asia.* Retrieved from https://inis.iaea.org/Search/search.aspx?orig_q=RN:42022627

Kemarau, R., A., Eboy, O., V. (2023). Exploring the Impact of El Niño–Southern Oscillation (ENSO) on Temperature Distribution Using Remote Sensing: A Case Study in Kuching City. *Applied Sciences*, 13, 8861. https://doi.org/10.3390/app13158861.

Kirana, A. P., Sitanggang, I. S., Syaufina, L., & Bhawiyuga, A. (2020). Spatial and Temporal Clustering Analysis of Hotspot Pattern Distribution of Critical Land in Kalimantan, Indonesia. *IOP Conference of Series: Earth and Enviromental Science, 528*, 012042. https://doi.org/10.1088/1755-1315/528/1/012042.

Kamaliah, K., & Marlina, S. (2021). Kajian Dampak dan Adaptasi Perubahan Iklim di Kalimantan Tengah. *Media Ilmiah Teknik Lingkungan*, *6*(1), 34–42. https://doi.org/10.33084/mitl.v6i1.2105hing.

IPCC. (2023). *Climate change 2023: synthesis report. Contribution of working groups I, II and III to the sixth assessment report of the intergovernmental panel on climate change.* The Australian National University.

Lohberger, S., Atwood, E. C., & Siegert, F. (2017). Spatial evaluation of Indonesia's 2015 fire-affected area and estimated carbon emissions using Sentinel-1. *Wiley Global Change Biology,* 1–11. https://doi.org/10.1111/gcb.13841.

Manaswini, G., & Sudhakar Reddy, C. (2015). Geospatial monitoring and prioritization of forest fire incidences in Andhra Pradesh, India. E*nvironmental Monitoring and Assessment*, 187(10). https://doi.org/10.1007/s10661-015-4821-y.

Masud, M. B., Soni, P., Shrestha, S., & Tripathi, N. K. (2016). Changes in Climate Extremes over North Thailand, 1960–2099. *Journal of Climatology*, 1-18. http://dx.doi.org/10.1155/2016/4289454.

Moura, M. M., dos Santos, A. R., Pezzopane, J. E. M., Alexandre, R. S., da Silva, S. F., Pimentel, S. M., de Andrade, M. S. S., Silva, F. G. R., Branco, E. R. F., Moreira, T. R., da Silva, R. G., & de Carvalho, J. R. (2019). Relation of El Niño and La Niña phenomena to precipitation, evapotranspiration and temperature in the Amazon basin. *Science of the Total Environment*, 651, 1639–1651. https://doi.org/10.1016/j.scitotenv.2018.09.242.

Nawaz, Z., Li, X., Chen, Y., Guo, Y., Wang, X., & Nawaz, N. (2019). Temporal and Spatial Characteristics of Precipitation and Temperature in Punjab, Pakistan. *Water*, *11*, 1916. https://doi.org/10.3390/w11091916.

Nurdiati, S., Sopaheluwakan, A., Septiawan, P., Ardhana, M. R. (2022). Joint Spatio-Temporal Analysis of Various Wildfire and Drought Indicators in Indonesia. *Atmosphere, 13,* 1591. https://doi.org/10.3390/ atmos13101591.

Peterson, T., Folland, C., Gruza, G., Hogg, W., Mokssit, A., & Plummer, N. (2001). *Report on the activities of the working group on climate change detection and related rapporteurs* (p. 143). Geneva: World Meteorological Organization. Retrieved from http://etccdi.pacificclimate.org/docs/wgccd.2001.pdf.

Prinz, D. (2009). Contributor and Victim - Indonesia's Role in Global Climate Change with Special

Reference to Kalimantan. *Jurnal Sains &Teknologi Lingkungan*, *1*(2), 138–153. https://doi.org/10.20885/jstl.vol1.iss2.art5.

Qu, Y., Liu, Y., Jevrejeva, S., & Jackson, L. P. (2020). Future sea level rise along the coast of China and adjacent region under 1.5 °C and 2.0 °C global warming. *Advances in Climate Change Research*, *11* (3), 227–238. https://doi.org/10.1016/j.accre.2020.09.001

Robertson, A. W., Moron, V., Qian, J. H., Chang, C. P., Tangang, F., Aldrian, E., Koh, T. Y., & Juneng, L. (2011). *The Maritime Continent Monsoon*. World Scientific Publishing. https://doi.org/10.1142/9789814343411_0006

Sarmiasih, M., & Pratama, P. Y. (2019). The Problematics Mitigation of Forest and Land Fire District Kerhutla) in Policy Perspective (A Case Study : Kalimantan and Sumatra in Period 2015-2019). *Journal of Governance and Public Policy*, *6*(3). https://doi.org/10.18196/jgpp.63113.

Sa'adi, Z., Yaseen, Z. M., Farooque, A. A., Mohamad, N. A., Muhammad, M. K. I., & Iqbal, Z. (2023). Long-term trend analysis of extreme climate in Sarawak tropical peatland under the influence of climate change. *Weather and Climate Extremes*, *40*, 100554. https://doi.org/10.1016/j.wace.2023.100554.

Safitri, R., Marzuki, Shafii, M. A., Yusnaini, H., & Ramadhan. (2022). Effects of Land Cover Change and Deforestation on Rainfall and Surface Temperature in New Capital City of Indonesia. *Jurnal Penelitian Pendidikan IPA*, *8*(6), 2849–2858. https://doi.org/10.29303/jppipa.v8i6.2182.

Sen, P. K. (2013). Estimates of the Regression Coefficient Based on Kendal's Tau. *Journal of Chemical Information and Modeling*, *53*(9), 1689–1699. Retrieved from http://www.jstor.org/stable/2285891

Siswanto, S., van Oldenborgh, G. J., van der Schrier, G., Jilderda, R., & van den Hurk, B. (2016). Temperature, extreme precipitation, and diurnal rainfall changes in the urbanized Jakarta city during the past 130 years. *International Journal of Climatology*, *36*(9), 3207–3225. https://doi.org/10.1002/joc.4548

Supari, Tangang, F., Juneng, L., & Aldrian, E. (2016a). Observed changes in extreme temperature and precipitation over Indonesia. *International Journal of Climatology*, *37*(4), 1979–1997. https://doi.org/10.1002/joc.4829

Supari, Tangang, F., Juneng, L., & Aldrian, E. (2016b). Spatio-temporal Characteristics of Temperature and Precipitation Extremes in Indonesian Borneo. *AIP Conference Proceedings, 1784*, 060050. https://doi.org/10.1063/1.4966888

Supari, Tangang, F., Salimun, E., Aldrian, E., Sopaheluwakan, A., & Juneng, L. (2017). ENSO modulation of seasonal rainfall and extremes in Indonesia. *Climate Dynamics*. https://doi.org/10.1007/s00382-017-4028-8

Tan, M. L., Juneng, L., Tangang, F. T., Chung, J. X., & Radin Firdaus, R. B. (2021). Changes in temperature extremes and their relationship with ENSO in Malaysia from 1985 to 2018. *International Journal of Climatology*, *41*(S1), E2564–E2580. https://doi.org/10.1002/joc.6864

Thirumalai, K., DInezio, P. N., Okumura, Y., & Deser, C. (2017). Extreme temperatures in Southeast Asia caused by El Ninõ and worsened by global warming. *Nature Communications*, *8*, 1–8. https://doi.org/10.1038/ncomms15531

Wooster, M. J., Perry, G. L. W., & Zoumas, A. (2012). Fire, drought and El Niño relationships on Borneo (Southeast Asia) in the pre-MODIS era (1980-2000). *Biogeosciences*, *9*(1), 317–340. https://doi.org/10.5194/bg-9-317-2012

World Research Institute. *10 Big Findings from the 2023 IPCC Report on Climate Change*. Retrieved from https://www.wri.org/insights/2023-ipcc-ar6-synthesis-report-climate-change-findings.

Yang, S., Li, Z., Yu, J. Y., Hu, X., Dong, W., & He, S. (2018). El Niño-Southern Oscillation and its impact in the changing climate. *National Science Review*, *5*(6), 840–857. https://doi.org/10.1093/nsr/nwy046

Yulianti, N., & Hayasaka, H. (2013). Recent Active Fires under El Nino Conditions in Kalimantan, Indonesia. *American Journal of Plant Sciences*, *04*(03), 685–696. https://doi.org/10.4236/ajps.2013.43a087

Zhang, X., Alexander, L., Hegerl, G. C., Jones, P., Tank, A. K., Peterson, T. C., Trewin, B., & Zwiers, F. W. (2011). Indices for monitoring changes in extremes based on daily temperature and precipitation data. *Wiley Interdisciplinary Reviews: Climate Change*, *2*(6), 851–870. https://doi.org/10.1002/wcc.147

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