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by Joko Widodo

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Prediction of Extreme Temperature in South Sumatra and Its Applications at The End of The 21st Century

Hamdi Akhsan[1]*, Muhammad Romadoni[1], Melly Ariska[1]

[1] Program Studi Pendidikan Fisika, Fakultas KIP, Universitas Sriwijaya. Inderalaya, OI, Sumatra Selatan, Indonesia.

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Abstract: This study examines trends and variations in extreme temperature indices in Palembang for the period 1980-2020. They are using data from the Indonesian Agency for Meteorological, Climatological and Geophysics, namely the Palembang Climatology Station and the Sultan Mahmud Baharudin II Meteorological Station from the 1981-2020 period, which were analyzed according to the rules of the Expert Team for Climate Change Detection and Indices (ETCCDI). The results obtained based on the analysis showed that the average maximum temperature index (TMAXmean) and the minimum temperature average index (TMINmean) increased significantly with Z values = 5.21 and 7.10. Based on the correlation analysis between time and extreme temperature index, it is possible to predict the occurrence of TMAXmean and TMINmean for the end of the 21st century, namely in 2100 with a value of TMAXmean = 36.1℃ and TMINmean 25.7℃. The TMAXmean event also has a very close correlation with the total area of Forest and Land Fires, as well as the contribution of Greenhouse Gases (CO^2) in this region. So, it can be concluded that reducing the rate of increase in TMAXmean and TMINmean can be done by not burning forests and land so that the contribution of GHG (CO^2) to the atmosphere is reduced.

Keywords: Climate change; Temperature extremes; Forest fires; Greenhouse gases (CO^2).

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Introduction

Coffee is one of the most popular drinks in the worlEarth is experiencing an increase in the average temperature globally due to human activities, which is known as (global warming). The trend of increasing global average temperature warming began in the pre-industrial era, caused by increasing concentrations of greenhouse gases in the atmosphere (Aldrian, 2007; Tavakol et al., 2020). Almost all countries in the world experienced an extreme increase in average temperature, in Libya, it experienced a temperature increase of 0.49 °C/decade (Bhatti et al., 2020; Siswanto et al., 2016), in Nepal, based on data analysis from the period 1976-2015, experienced a maximum temperature increase 0.45°C/decade and a minimum temperature of 0.09°C/decade (Zhou et al., 2016), and in the West, Iraq region using HadCM3 and CanESM2 modelling data obtained temperature increase of 1.2 °C from the period 2020–2099 (Hassan & Hashim, 2020). In general, this extreme temperature increase indicates that there has been a drastic climate change on earth due to global warming.

Global warming has an impact on climate change (IPCC, 2018; Kumar et al., 2019). Climate change in Indonesia is marked by changes in the pattern of the rainy and dry seasons, which are influenced by extreme temperature events and extreme rainfall. The maximum rainfall (R50mm) coupled with the minimum temperature (TN) will cause a flood disaster. On the other hand, the occurrence of minimum precipitation or days without rain accompanied by the event of maximum temperature (TX) will impact the dry season. A very long duration of days without rain will cause drought in agricultural land areas. It will

* Corresponding Author: hamdi_akhsan@fkip.unsri.ac.id

affect decreasing farmer productivity in the wetland areas of South Sumatra. When the dry season arrives long, it causes food supplies to fall, debt increases, assets are sold, and some rice farmers migrate for work (Akinbile et al., 2020; Siswanto et al., 2015)

In addition to impacting agricultural areas, drought with a very long duration can trigger forest and land fires, especially on the islands of Kalimantan and Sumatra, as the area with the largest peatland area in Indonesia. The size of peatland in Indonesia is around 14.91 million ha, of which 43% is in the Sumatra region, which is 6.44 million ha (Luhwahyudin & Citrosiswoyo, 2012; Swenson & Grotjahn, 2019).

The clearing of new agricultural land triggers forest fires. People in the South Sumatra region mainly do the clearing of pristine farmland by burning natural forest areas because the costs used are much cheaper than the land clearing method recommended by the government. Forest damage is affected by land clearing by burning, for planting oil palm and rice farming (Chonghua Yin, 1994; I. Iskandar, 2010). Forest and peatland fires accompanied by a very long dry season will be difficult to extinguish.

Forest fires with a vast area that occurs for a long duration will cause a smog disaster around the site and increase the contribution of greenhouse gases (CO^{2}) to the atmosphere. Extensive forest clearing activities for agriculture and plantations during the 1990s caused catastrophic fires during the 1997-1998 El-Nino season, which contributed massively to carbon emissions (Hermawan, 2010; M. R. Iskandar, 2014; Sipayung et al., 2007). So, there is a very close correlation between forest fires, the level of greenhouse gas contribution (CO^{2}) to the atmosphere, and extreme temperature events in the South Sumatra region.

It considered the impact of extreme temperature events, air pollution (CO^{2}), and forest fires in South Sumatra. Researchers in this study analyzed the incidence of extreme temperatures, which would be correlated with data on forest and land fires and greenhouse gas pollution (CO^{2}), to predict the average extreme temperature events at the end of the 21st century in the South Sumatra region.

Method

This research data is daily rainfall and temperature data for the 1981-2020 period from the Indonesian Agency for Meteorological, Climatological and Geophysics, namely the Palembang Climatology Station and the Sultan Mahmud Baharudin II Meteorological Station located in the South Sumatra region. Vulnerable to forest fires when the dry season arrives. An extreme dry season has occurred, which started from July to October 2019; even in August, there was no rain at all, which triggers peatland fires in the South Sumatra region (Ramage, 1968; Saji & Vinayachandran, 1999).

Temperature and rainfall data are downloaded from the https://dataonline.bmkg.go.id/ site, compiled annually and per station using Microsoft Excel (Misnawati & Perdanawanti, 2019). The data that the station has collected is processed using R Software using an application package from the Expert Team for Climate Change Detection and Indices (ETCCDI). By testing the data quality using RClimdexQC, RHtest for homogeneity test, and RClimdex analysis to determine the extreme temperature index, presented in Table 2 (Kutzbach, 1967; Steven W. Lyons, 1982).

Table 1. Research Areas and Data

No	Location	Latitude	longitude	Time	
96223	Palembang Climatology Station	-2.92732	104.77197	19 81	20 20
96221	Sultan Mahmud Badaruddin II Meteorological Station	-2.89468	104.70129	19 81	20 20

Table 2. Extreme Temperature Index

Indicator Name	Definition of Indicator	Unit
Mean Tmax	Annual mean of maximum temperature	°C
Mean Tmin	Annual mean of minimum temperature	°C
Maximum Tmax	Monthly maximum value of daily max temperature	°C
Maximum Tmin	Monthly maximum value of daily min temperature	°C
Minimum Tmax	Monthly minimum value of daily max temperature	°C
Minimum Tmin	Monthly minimum value of daily min temperature	°C
Cool nights	Percentage of time when daily min temperature <10th precentile	%
Cool days	Percentage of time when daily max temperature < 10th percetile	%
Warm night	Percentage of time when daily min temperature > 90th percetile	%
Warm day	Percentage of time when daily max temperature > 90th percetile	%
Diurnal temperature range	Monthly mean difference between daily max and min temperature	°C

Extreme Temperature Trend Analysis

Trend analysis was calculated using the non-parametric Mann Kendall (MK) test to detect extreme temperature trends. A positive Z value indicates an increase, and a negative Z value indicates a decrease in temperature (Aldrian, 2001; Hafizhurrahman et al., 2015)

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

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

Where and are consecutive data values. The variance can be calculated using the following equation:

$$ar\ (S) = \frac{n(n-1)(2n+5)}{18}, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (3)$$

Statistically, S approaches the normal distribution if > 8. Statistical tests are carried out using the typical distribution approach and the standard Z test.

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

The slope provides information on how much the temperature extremes have changed from year to year. The pitch is calculated by,

$$\beta = med\,\frac{x_j - x_k}{j-k}, j > k \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (5)$$

β is the slope of Sen, if it is positive, it indicates an increasing trend. If its value is negative, it means a decreasing trend in a time series (Ariska et al., 2020).

Correlation Analysis

Extreme temperature predictions are calculated based on the correlation between time and temperature results. Calculation of the value of the correlation coefficient can be calculated with the following equation (Ariska et al., 2018):

$$r_{xy} = \frac{1}{N-1}\sum_{i=1}^{N}\frac{(x_i-\bar{x})(y_i-\bar{y})}{s_x s_y}, \ldots\ldots\ldots\ldots\ldots\ldots\ (6)$$

Where xi and Yi are time-series data for which the correlation coefficient value will be sought, and sx and sy are standard deviations for each of these time series. The equation expresses the standard deviation value:

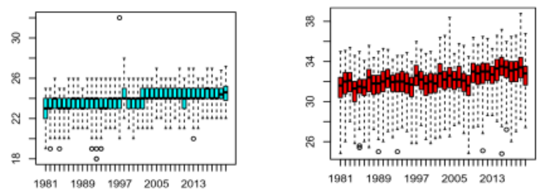
$$s_x = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (7)$$

Correlation analysis was also carried out on forest fire data and (CO^2) pollution data to determine the relationship between these data. The results obtained are used to predict future events.

Results and Discussion

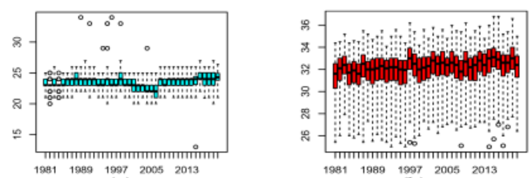
Data Quality Test Results

The results of the Quality control (QC) for the Palembang SK data, there are data deviations, as shown in Figure 1 in October 1997, there was a minimum temperature of TN> 30°C, and for extreme temperatures, there were two consecutive days in February and April in 2004 and 2019 where TX>38°C. The results of QC on SM SMB II show that the minimum temperature is below the normal minimum average temperature where TN<15°C in June in 2015, deviations also occur in a row in the month (Year), January (1995), February (1998), March (1995), May (1996) and December (1989) where TN > TX, which is above 30°C.



(a) (b)

Figure 1. Results of QC analysis for (a) TN and (b) TX in SK Palembang.



(a) (b)

Figure 2. Results of QC analysis for (c) TN and (d) TX in SM SMB II.

Deviant data will be considered missing values according to the rules of ETCCDI before testing the homogeneity of the data (Dewanti et al., 2018; Luhwahyudin & Citrosiswoyo, 2012; Swenson & Grotjahn, 2019).

Data Homogeneity Test Results

After the data has gone through the QC stage and is declared suitable, before being processed using RClimdex to determine the extreme temperature index, the data must be homogenized first according to the Expert Team on Climate Change rules Detection and Indices (ETCCDI). A homogeneity test was carried out to determine two-phase or more linear regression of the data series (Soetrisno & Yoku, 2019). The data homogeneity results are shown in Figure 3 (a) of the Palembang SK TX data, while the TN data is homogeneous without any system adjustments. Homogeneity Test. SM SMB II data obtained results with adjustments for homogenization of the TN data, which can be seen in Figure 4, while the TX data was homogeneous, so it did not require adjustment from the RHtest.

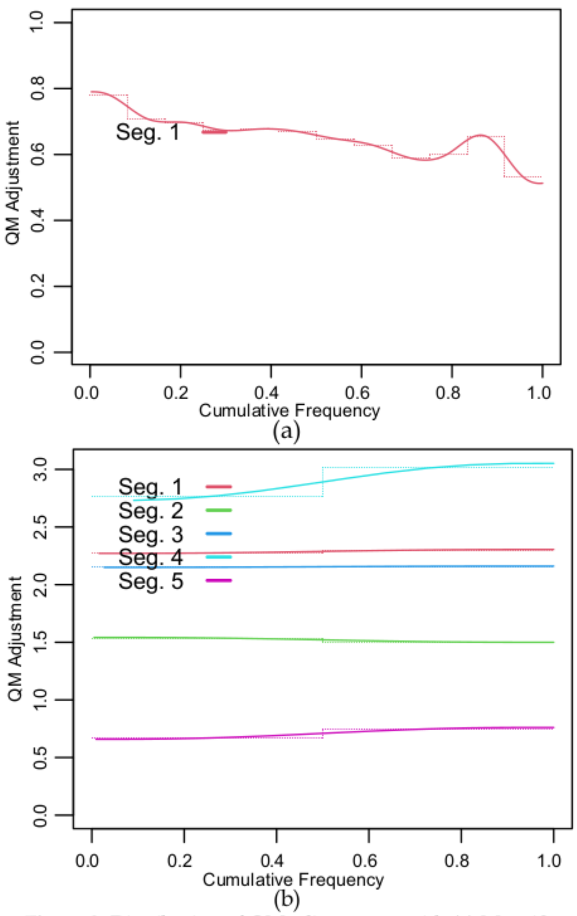


Figure 3. Distribution of QM adjustments with (a) Mq= 12 (TMAX, SK Palembang) (b)Mq= 2 (TMIN SM SMB II).

Mankendal and Sens Test

Sen trend analysis is used because this method does not require data with a normal distribution and can predict temperature and rainfall changes well (YIN & SUN, 2018). The Temperature Index is categorized as extreme if the data distribution experiences a significant trend, either increasing or decreasing. The MK test was conducted to determine the direction of extreme temperatures that occurred in South Sumatra. The results of intense temperature data processing with categories (TMAXmean, TMINmean, TXx, TNx, TNx, TNn, and DTR) generally experience a positive trend, both in SK Palembang and in SM SMB II, which as a whole describes the increase in air temperature in the South Sumatra region.

The TMAXmean in SK Palembang and SM SMB II experienced a very significant trend with values of Z = 5.21 and 7.10; this indicates a very substantial increase in air temperature recorded at the station. The trend in SM SMB II is more significant than that in SK Palembang. The results of the Mankendall and Sens test can be seen in Figure 4 and Figure 5.

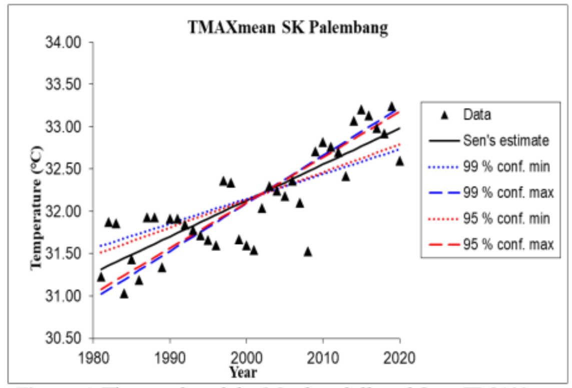


Figure 4. The results of the Mankendall and Sens TMAX test mean in SK Palembang

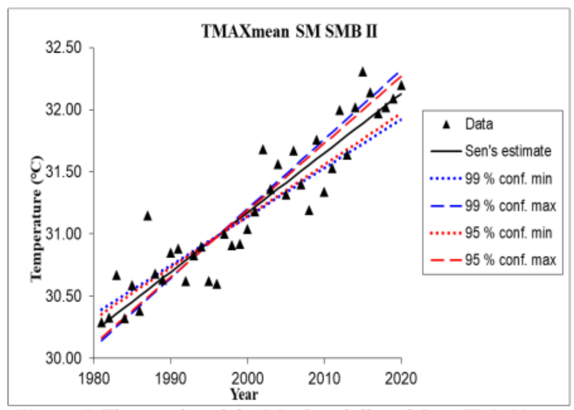
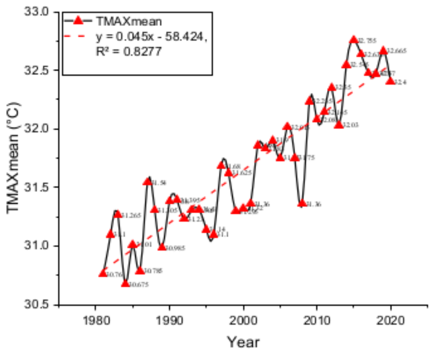


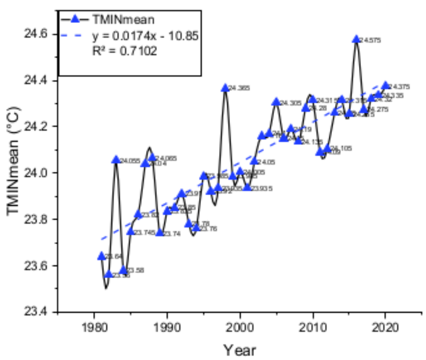
Figure 5. The results of the Mankendall and Sens TMAX test mean in SM SMB II

Extreme Temperature Prediction

The two extreme annual temperature indicators predicted in this study were taken from the average yearly maximum and minimum temperatures recorded in SK Palembang and SM SMB II. Predictions are calculated using the correlation level between the year and the average temperature in the South Sumatra region.



(a)



(b)

Figure 6. trend graphs (a) TMAXmean and (b) TMINmean

Determine the correlation value (r) can be calculated using the value of y and R on the graph (Baeda et al., 2019; IPCC, 2018). Based on Figure 6 (a), the maximum average temperature experienced a very significant trend, the value of y = 0.045x-58.424 and R^2 = 0.8277. Using these results, it can be predicted that the average maximum temperature for the end of the 21st century, namely 2030 = 32.9°C, 2040 = 33.4°C, 2050 = 33.8°C, 2060 = 34.3°C, 2070 = 34.7°C, 2080 = 35.2°C, 2090 = 35.6, 2100 = 36.1°C. There has been a significant increase in the average maximum temperature during the last 40 years starting from 1981-2020, exceeding the agreement from the IPCC, which stated the target of an increase in air temperature of 1.5 since pre-industrial times. The increase also occurred for the average minimum temperature based on graph (b) the value of y = 0.074x-10.85 and R^2 = 0.7102 was obtained. Using these results, it can be predicted that the average minimum temperature that occurs in the South Sumatra region per 10 years, 2030 = 24.5°C, 2040 = 24.6°C, 2050 = 24.8°C, 2060 = 25.1°C, 2070 = 25.2, 2080 = 25.3°C, 2090 = 25.5°C, 2100 = 25.7°C.

Correlation Analysis

Temperature extremes (TMAXmean and TMINmean) in the South Sumatra region experienced a positive trend based on observational data from 1981 to 2020. Rising extreme temperatures in this region are also accompanied by increasing greenhouse gases CO^2. The increase in the human population causes resource consumption to increase. As a result, the contribution of CO^2 exhaust gases from industrial processes increases significantly, which makes the earth's temperature increase (Bhatti et al., 2020; De Beurs et al., 2018; Zhan et al., 2017). In Indonesia, the rise in CO_2 is also due to land burning as the main factor. to see the clear correlation between the increase in extreme temperatures, greenhouse gases CO^2 and fires can be seen in Figure 7.

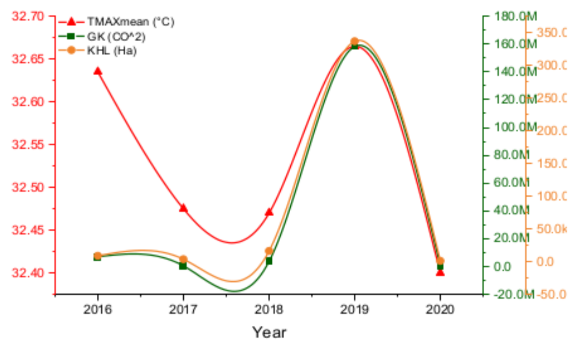


Figure 7. Correlation graph of TMAXmean, GHG (CO^2) and KHL (ha)

Based on observation data from the official website of the Ministry of Environment and Forestry of the Republic of Indonesia through the http://sipongi.menlhk.go.id/ website, there are data on reporting forest and gas fires (CO^2). The data starts from 2016 to 2021. Researchers analyze the correlation of the data with the TMAXmean increase data. Based on Figure 7, it can be seen that there is a very close correlation between TMAXmean, GHG (CO^2), and KHL. Based on the analysis, it can be seen that the increase in the average maximum temperature is influenced by forest and land fires and the contribution of GHG (CO^2) to the atmosphere from the area.

Conclusion

Based on the analysis of extreme temperatures for the 1981-2020 period, it can be concluded that the extreme temperatures that occurred in the South Sumatra region increased significantly both in SK Palembang and SM SMB II with values of Z = 5.21 and

Z = 7.10. Using they-value from the graph of the TMAXmean and TMINmean increases, it can be predicted that the average maximum and minimum temperatures are at 2100, namely, 36.1°C and 25.7°C. Extreme temperature increases are affected by forest and land fires, and emissions from forest fires from Sumatra show this positive trend affecting regional air quality and global concentrations of greenhouse gases. Efforts that can be made to overcome extreme temperature increases are to reduce forest and land burning so that the contribution of GHG (CO^2) to the atmosphere is also reduced.

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