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Climate Change: A Study of Air Temperature Trend and Variation in the City of Bengkulu

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ABSTRACT: Climate change is noticeable, but the impact and the change are not easily detected. The most pronounced and easily detected climate change is air temperature changes, which affect both the state of natural ecosystems and human social life. Increasing climate and weather variability and extreme climate events affect human life and natural systems more detrimental than the effect of climate change in the form of climate means. This study aims to determine the change in air temperature and extreme air temperature during the last 37 years. Data of average air temperature (AAT), maximum air temperature (MAT), and minimum air temperature (MiAT) from 1985 to 2022 from the P. Baai Station and Fatmawati Station were used. Trendline analysis was performed to find an increasing air temperature trend, while the frequency distribution analysis was performed to find extreme climate even. The study concluded that AAT in the City of Bengkulu increased by about 0.026°C yr^{-1}, the MAT increased by about 0.005°C yr^{-1}, and the MiAT increased 0.025°C yr^{-1} during the last 37 years. However, extreme climate events have detected neither low nor high air temperatures. The AAT, MAT and MiAT are currently 26.4°C, 31.3°C, and 21.3°C, respectively.

Keyword: average air temperature, climate variability, extreme climate event, maximum temperature, minimum temperature.

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INTRODUCTION

Climate change is a serious issue that has caused pressure on various stakeholders since the last few decades, because climate change causes problems for the environment, human health, agriculture, and the global economy. One clear thing that impacts the entire surface of the earth is changes in air temperature. As greenhouse gases (GHGs) continue to increase, the Earth's climate changes at an unpredictable rate, causing very pronounced changes in temperature distribution patterns.

GHGs such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) mostly come from anthropogenic activities. Burning fossil fuels (coal, petroleum, and natural gas) releases CO2 and other gases into the atmosphere (Sulistyono, 2012; Nasution et al., 2013; Pratama & Parinduri, 2019; IPCC, 2018). Methane gas and N_2O, which are no less important than CO_2 in terms of absorbing heat in the atmosphere, are often produced by activities in the agricultural sector such as animal husbandry, lowland rice cultivation, burning of savannas, and burning of agricultural waste (Chandramanik et al., 2016 and Gustiar et al., 2014).

Climate change as an impact of global warming is a long-term change in air temperature, rainfall, and various atmospheric conditions, most of which are caused by anthropogenic activities (Anggraeni, 2015, Susandi et al., 2010). The IPCC (2019) states that human activity has been the leading cause of global warming since the 20th century.

This global warming has a broad and varied impact on ecosystems, climate and weather patterns, and the frequency and intensity of extreme weather such as heat waves, extreme rainfall, and drought. The most pronounced and easily detected climate change is the change in air temperature, which affects both the state of natural ecosystems and human social life. GHGs trapped in the atmosphere increase global air temperatures. Air temperature, which is one of the climate elements, is interrelated with other climate elements such as solar radiation, humidity, air pressure, wind speed, and rainfall. For example, high air temperature will be followed by increased evapotranspiration so that air humidity will increase, which can increase rainfall (Eka, 2017).

Apart from increasing global temperatures, climate change can also cause extreme weather, such as extreme rainfall or extreme temperatures, which can take the form of increasing maximum air temperature (MAT) or decreasing minimum air temperature (MiAT), and the frequency of these extreme temperatures. Griffiths et al., (2005) stated that there has been an increase in maximum temperature and a decrease in minimum temperature as well as an increase in the frequency of extreme weather in the Tropical Asia Pacific region around the coast and in areas far from settlements. Climate change, which is thought to be mainly caused by anthropogenic activities, has attracted research by scientists. In 2003, hot wind storms in France caused the deaths of 14,947 people. Mainly due to dehydration, hyperthermia, and heat stroke (Poumadère et al., 2005). The average global air temperature of the earth's surface over the last 100 years has increased by 0.74℃ (Setyonegoro, 2015). Even though an increase in global temperature has been detected, the impact of the temperature rise that triggers climate change is not felt evenly across the earth's surface. Changes in temperature are not easily felt by or directly impact living creatures, including humans. Based on data from BMKG observations, the MAT in several regions in Indonesia has increased, ranging from 37℃ - 38℃, as occurred in Semarang City, DKI Jakarta, Majalengka and Palembang (BMKG, 2023). According to Akbar & Lubis, (2022) Bengkulu City has experienced an increase in average air temperature (AAT) every year of 0.03℃. The MAT in Bengkulu City ranges between 30℃ – 31℃ and the minimum temperature ranges between 23℃ – 24℃ (Triono et al., 2018). The relatively high average temperature in the City of Bengkulu is influenced by several factors such as the proximity to a body of water (Indian Ocean), and the presence of mountains throughout Bengkulu Province, which makes Bengkulu an area with high humidity and rainfall, as stated by (Soraya et al., 2020).

Climate change, which can take the form of changes in temperature, rainfall, and the intensity and frequency of extreme weather, may directly or indirectly affect agricultural activities and productivity in general, including agriculture, forestry, animal husbandry, and aquaculture. As stated by IPCC (2012), climate change in the form of increasing climate and weather variability and extreme climate events affects human life and natural systems more detrimental than the effect of climate change in the form of climate means. Predicting the effect of climate change by using climate means on human life and the natural systems will most likely be underestimated. Pratiwi (2023) reported that increasing air temperature can increase the laying hens' temperature, ultimately reducing egg production. Warriss et al. (2005) reported that increasing MAT up to 13 – 17°C at the beginning of the summer season increases broiler mortality by up to 30%. In agricultural cultivation of plantation crops, it is reported that increasing rainfall significantly reduces solar radiation, which can reduce the photosynthesis process and ultimately reduce the productivity of rubber plants (Hasibuan et al., 2018). The impact of temperature changes on milkfish cultivation has also been reported, and changes in air temperature result in a change in land suitability for milkfish cultivation in East Java because milkfish species require specific air temperatures. Changes in temperature in one place may cause land that was initially suitable to become unsuitable for milkfish cultivation (Lestari, 2016).

Climate change will surely occur, but recognizing these changes is not easy. Apart from not being easy to identify, climate change can also give rise to different symptoms from one place to another. For this reason, there is a need for studies that can determine what changes in climate elements are occurring in an area. This research

was conducted to detect climate changes related to changes in air temperature in the City of Bengkulu.

This research aims to determine climate change, especially changes in AAT, and extreme air temperatures in the City of Bengkulu from 1985 to 2020.

METHODOLOGY

This research was carried out from August to November 2023 at the Meteorology, Climatology and Geophysics Agency, Bengkulu Class I Climatology Station (P. Baai Station) and Fatmawati Sukarno Bengkulu, Class III Meteorology Station (Fatmawati Station). The data used in this research are maximum, minimum, and AAT data from 2 climatology stations in Bengkulu City from 1985 to 2020.

The collected data were grouped into two periods. The first period was air temperature data from 1985-2002, and the second was from 2002-2022. The data were analyzed using a trendline, time series, and normality test methods (Snedecor and Cohran, 1998). Trendline analysis was used to identify and assess trends or patterns in the City of Bengkulu air temperature data. In contrast, time series analysis was used to find air temperature differences between the 1st and 2nd periods. Data Normality Test was carried out to compare the distribution of AAT for each period and determine whether there is any up normality in the AAT distribution as an indicator of extreme temperature.

RESULTS AND DISCUSSION

Result

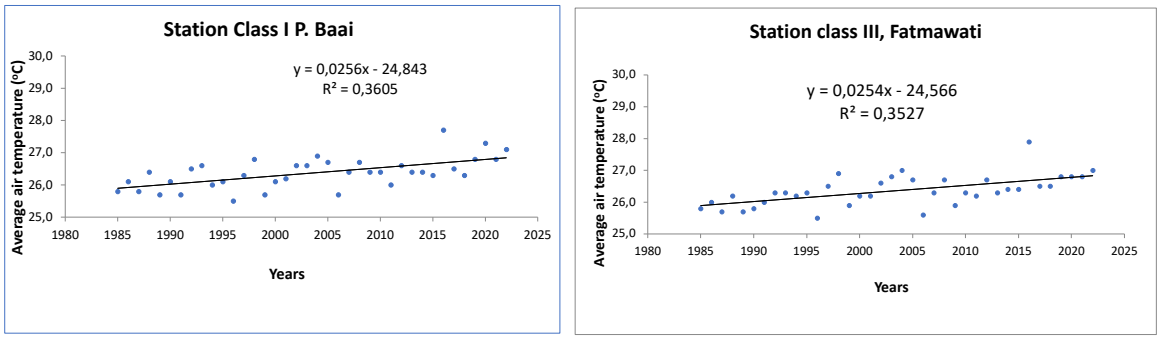
The maximum, minimum, and AAT of the City of Bengkulu in the last 37 years are presented in Table 1. The average monthly maximum and MiAT show no significant difference between the months of the year. The maximum air temperatures in the P. Baai Station were 31.5°C found in May, and the MiAT (21.3°C) was found in August and September. In the Fatmawati Station, the maximum and MiAT were 31.9°C and 20.5°C, respectively, in May and August. The monthly average air temperature among the months during a year of both stations shows relatively less variability than the annual AAT (26.5 and 26.4°C), with 26.2°C, the lowest AAT, and 27.1°C, the highest AAT in that station. The highest monthly air temperature was found in Station P Baai in May, reaching 27.1°C, while the lowest was 26.1°C found in the Fatmawati Station in August and September. In general, both climatological stations show similar maximum, minimum, and AAT.

Table 1. The monthly MAT, MiAT and AAT from 1985 – 2022 at the P. Baai Station and Fatmawati Station in the City of Bengkulu.

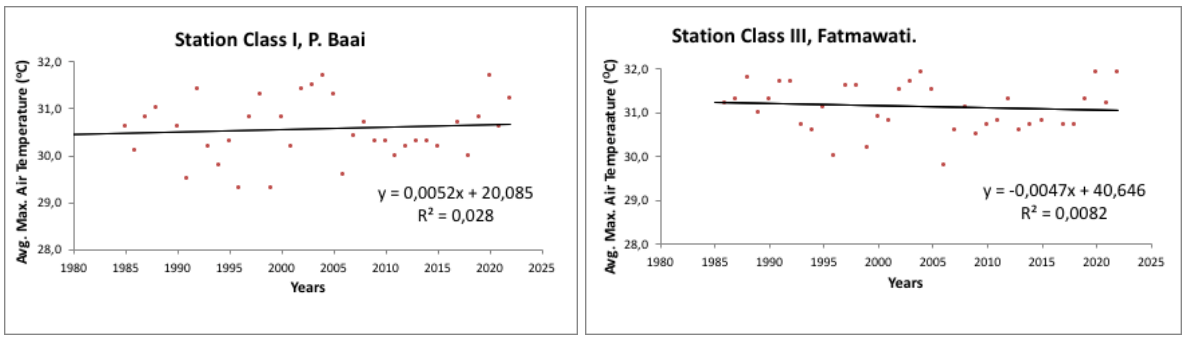
No	Month	P. Baai Station			Fatmawati Station		
		MAT	MiAT	AAT	MAT	MiAT	AAT
		---------- (°C) ----------					
1	January	30.6	21.9	26.3	31.1	21.4	26.4
2	February	30.9	22.0	26.5	31.6	21.4	26.5
3	March	31.1	22.1	26.7	31.6	21.5	26.7
4	April	31.2	22.4	26.9	31.7	22.0	27.0
5	May	31.5	22.4	27.1	31.9	21.7	27.0
6	June	31.2	22.0	26.7	31.7	21.2	26.6
7	July	31.0	22.4	26.3	31.3	20.6	26.2
8	August	30.9	21.3	26.2	31.2	20.5	26.1
9	September	30.7	21.3	26.2	31.0	20.7	26.1
10	October	30.6	21.9	26.3	31.0	21.5	26.2
11	November	30.3	22.1	26.3	30.9	21.5	26.3
12	December	29.9	22.0	26.3	30.5	21.4	26.2
	Total	369.9	263.8	317.8	375.5	255.4	317.3
	Average	30.8	22.0	26.5	31.3	21.3	26.4

Trend of AAT, MAT, and MiAT

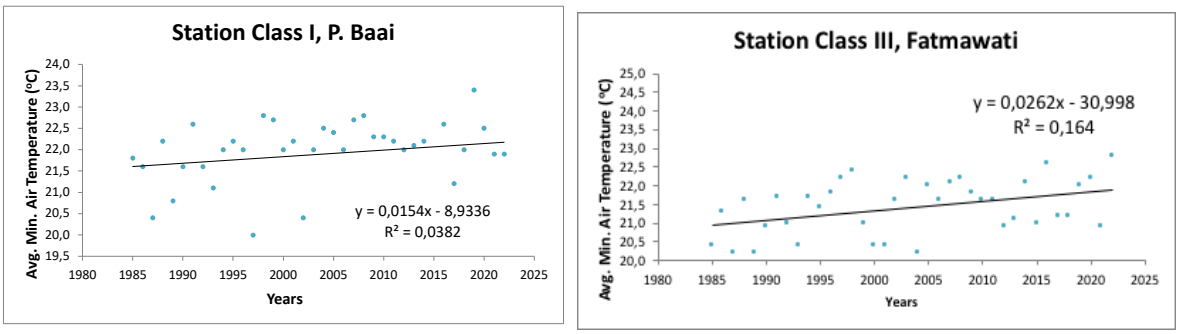
The average air temperature in both stations has increased for the last 37 years (Fig. 1 A). The increasing average temperature rates were 0.0256 and 0.0254°C year-1 for the P. Baai Station and Fatmawati Station, respectively. It means the increasing air temperature in Bengkulu for the last 100 years was about 2.5°C. It is comparable with IPCC conclusions, which stated that in the previous 100 years, the global air temperature has risen by about 3°C. The increasing air temperature in the City of Bengkulu is slightly lower than the global air temperature change. It may be due to the local condition of the City of Bengkulu, which is situated adjacent to the body of water, the Indian Ocean. Besides its closeness to the body of water, the City of Bengkulu is also situated next to the Bukit Barisan Mountain, resulting in very high rainfall (>4,000 mm year-1) and high relative humidity (>85%). Rainfall and high humidity moderate the air temperature fluctuation by increasing the minimum and reducing the MAT. It may locally moderate the effect of global warming.



A (AAT)



B (MAT)



C (MiAT)

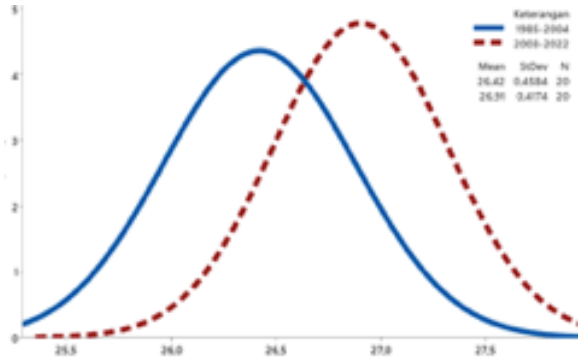
Figure 1. The AAT, MAT, and MiAT trends in P. Baai and Fatmawati Stations in Bengkulu from 1985 to 2022.

The trend of increasing MAT showed in the P. Baai Station with the rate of 0,015°C year-1, with the coefficient of the determinant (R2) was 0.0382, while the Fatmawati Station, the trend line model was y = 0.0047x +40.646, with a coefficient of the determinant (R2) was 0.0082. (Fig. 1 B). The model shows a decreasing trend of MAT, but the coefficient of the determinant was only 0,82 %. This temperature change was slightly lower than the result released by the Meteorological, Climatological and Geophysical Agency of Indonesia (BMKG, 2022), which reported that the MAT increase was 0.6°C from 1981 to 2022 or about 0.03°C yr-1.

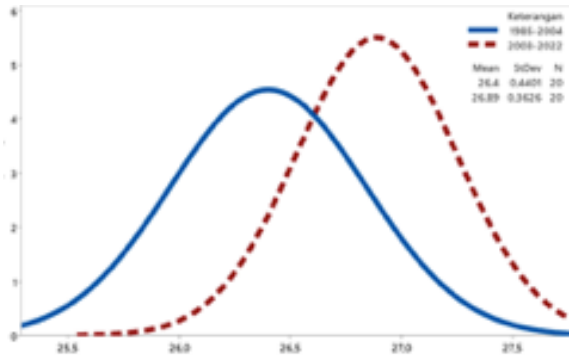
The MiAT of both stations shows an increasing trend, with rates of 0.015°C and 0.026°C year-1 for the P. Baai Station and Fatmawati Station, respectively (Fig. 1 C). This was also slightly higher than the MiAT of Indonesia reported by BMKG (2022), about 0.033°C yr-1. Overall, the data indicated that increasing AAT during the last 37 years was supported by increasing maximum and minimum temperatures during the same period.

Shifting Frequency distribution of AAT, MAT, and MiAT

The normality test of the whole data, between stations and between periods, shows a normal distribution of the monthly AAT, MAT, and MiAT. This indicates that no extreme air temperature (low minimum or high maximum temperature) has been found in the city of Bengkulu during the last 37 years. The representation of the AAT, MAT, and MiAT of both stations is presented in Fig 2. A, B, and C. The air temperature frequency distribution generally confirms the presence of increasing AAT, MAT, and MiAT from the First Period to the Second Period, as indicated by the normal distribution of the temperature data. A test of outlier data was also performed, and no data outlier was found.

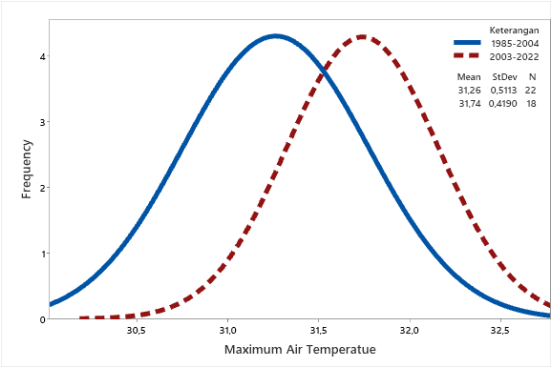


P. Baai Station, November.

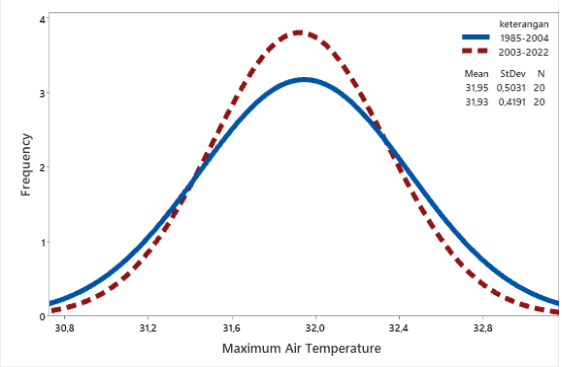


Station Fatmawati, February

A (AAT)

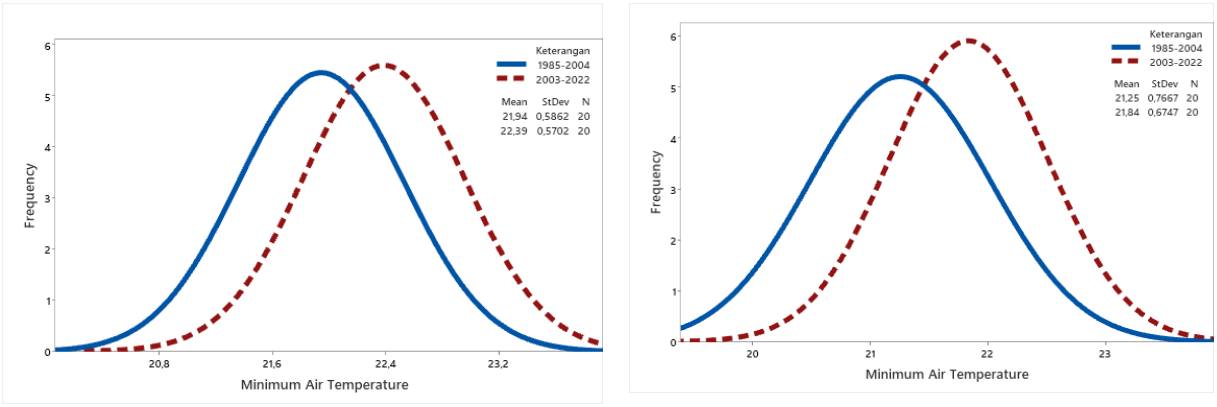


P. Baai Station, May.



Statiom Fatmawati, July

B (MAT)



P. Baai Station, November. Statiom Fatmawati, March

C (MiAT)

Figure 2. Representative of shifting the monthly AAT, MAT, and MiAT frequency distribution between the First Period (1985 – 2005) and the Second Period (2005 – 2022) in the P. Baai and Fatmawati Stations

The frequency distribution of the AAT in both stations generally shows an increase in AAT of about 0.5°C (Fig. 2A). Besides increasing the AAT, an increase in the frequency of higher air temperature is also found in both stations. Fig. 2A represents the increasing average and frequency distribution of AAT from both stations' first and second periods. As an example, the AAT in November in the first period was about 26°C, and in the second period, the AAT was 26.4°C for the P Baai Station. The Fatmawati Station also shows increasing AAT between the first and second periods from 2.63 to 27.0°C. In general, similar shifting to higher air temperature was found in the maximum as well as MiAT of both stations, except the MAT for the Fatmawati Station in July. The MAT frequency distribution of Fatmawati Station did not change from the first and the second periods with the MAT of about 32°C (Fig. 2B). A slight change, however, showed the distribution of MAT in Fatmawati Station in July. It indicates that more MAT was close to the mean value during the second period, while the values were either lower or higher than the mean values were fewer than that of the first period. It means that the MAT in the first period was more homogenous than in the second period. It corresponded to the decreasing trend of MAT, as shown in Fig. 1B.

The MiAT frequency distribution consistently shows an increasing average. For example, the frequency distribution of MiAT in P Baai Station increased from about 21.9 to about 22.4°C in November, and it increased from about 21.2 to 21.9°C in the Fatmawati Station in March (Fig. 2C). No frequency distribution pattern was detected between the first and second periods in both stations.

Discussion

Results of data analyses indicated that air temperature in the City of Bengkulu has increased during the last 37 years by about 0.03°C yr^{-1}. This is much higher than the global average increase in air temperature from 1850 to 2000, as reported by IPCC (2007), which was about 0.007°C yr^{-1}. In the same report, however, the IPCC (2007) also reported that the increase in AAT during the letter period (1950 – 2000) was about 0.014°C yr^{-1}. Among the different parts of the earth's surface, changing AAT varied greatly, ranging from the lowest (-0.03°C yr-1) in the southern hemisphere (South Pole) to the highest (0.10°C yr-1) in the northern hemisphere, North America. Like most of the earth's surface in Indonesia, AAT's rise was around 0.006 to 0.03°C yr^{-1} (IPCC, 2007). Understandably, the impact of global climate change varies with regional places, which was determined by the local condition (Benistal et al. 1994, Hulme and Finer, 1998). Increasing AAT in Bengkulu was in the range of temperature change reported by IPCC (2007). Meteorological, Climatological, and Geophysical Agency of Indonesia (BMKG, 2022) reported that the rise of AAT in Indonesia from 1981 to 2022 was 0.6°C or about 0.015°C yr^{-1}, showing that the change of AAT in Bengkulu was higher.

The relatively higher increase of AAT in the City of Bengkulu could be due to the relatively dense population of the surrounding climatological stations or the population of the city of Bengkulu in general. It agreed with the result of the He et al. (2022) study, which concluded that the area of the dense population usually experiences higher increasing air temperature than that of the sparse population. Another reason may agree with the result of Pepin and Losleben's (2002) study, which concluded that lowlands experience temperature change (increase) due to global climate change higher than highlands. Thornton et al. (2014) reported that in less developed tropical areas where the anthropogenic impact on the environment was severe, the impact of climate change on some climate elements, including air temperature, was higher. This result may apply to the increasing AAT, MAT, and MiAT in the City of Bengkulu.

Typically, the frequency distribution of the AAT, MAT, and MiAT in the City of Bengkulu indicates that no extreme temperature has been experienced for the last 37 years. Figure 2A, the P. Baai Station shows the increasing mean of the AAT from about 26.0 to 26.5°C, but the frequency distribution of the AAT shows no different shape between the first and the second periods. This means no extreme event of lower or higher temperature has happened during the last 37 years. No means of MAT was increased in the Fatmawati Station (Fig. 2A), but it shows a slightly different frequency distribution between the first and the second periods. The second period indicated that higher AAT values were detected in both stations, corresponding with the increase in AAT over the last 37 years. The frequency distribution shows the same pattern between the first and the second periods, which means no extreme temperature happened. Both stations also had similar trends and frequency distributions of MAT and MiAT. It was agreed with the BMKG (2022) study that reported maximum and minimum temperature change during the last 41 years was about 0.012°C yr-1 and 0.024°C yr-1, respectively.

CONCLUSION

Based on the study of AAT, MAT, and MiAT in the City of Bengkulu utilizing data from 1985 to 2022, it can be concluded that AAT in the City of Bengkulu increased about 0.026°C yr-1, the MAT increased about 0.005°C yr-1, and the MiAT increased 0.025°C yr-1 during the last 37 years. Still, neither extremely low nor high air temperature was detected. The AAT, MAT, and MiAT at present are 26.4°C, 31.3°C, and 21.3°C, respectively.

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