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The Impact of Climate Change on Air Temperature in the Rainy and Dry Seasons in East Java, Indonesia: A Case Study of Climate Change in the Wlingi Dam Area

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ABSTRACT

Climate change's impact can negatively influence human life, such as increasing temperatures and sea levels. This research aims to analyze the impact of climate change on air temperature during the rainy and dry seasons in East Java, specifically the Wlingi Reservoir area. Daily temperature observation data from 1990-2023 will be analyzed spatially using Inverse Distance Weighting (IDW) interpolation and statistically through analysis of long-term variability, rate of change in annual and seasonal scales and climate anomalies that occur. The results show a positive pattern of increase from 1990-2023, both on an annual and seasonal scale. The average temperature change rate at East Java climate stations increased to more than 1°C/34 years, with the most significant climate anomaly occurring in 2016. The humidity caused by the rain causes the temperature to be warmer than in the dry season. Thinner air pressure in mountainous areas causes cooler temperatures than coastal areas. During the 34 years of observation, the earth's surface has warmed over the years and may continue to rise.

1. INTRODUCTION

Global climate change significantly impacts various aspects of life, including weather patterns and air temperature. It leads to long-term changes in the Earth's climate conditions, including global average temperatures, weather patterns, and sea level rise. Additionally, climate change will affect various aspects of human life, such as human health [1], coastal areas [2], high mountain areas [3, 4], agriculture [5], fisheries [6], water quality [7, 8], and reservoirs [9-11]. Several other researchers have conducted analyses of the impact of climate change on water resources management [12], crop yields [13], water security in dams [14], and water availability [15]. Climate change affects human life in many sectors, such as global losses in the three main crops (wheat, corn, and barley), which have occurred since 1981 and are estimated at 5 billion US dollars annually [16].

In the tropics, climate change impacts significantly affect ecosystem services and coastal areas [17, 18]. Some of the causes are changes in temperature and rainfall patterns also occur in the tropics. Adverse impacts such as seawater intrusion, erosion to cause economic losses such as in Brazil. The impact of climate change can also increase the volume of inundation as happened in the Batanghari River [19]. Understanding these trends is critical for effective climate adaptation and mitigation strategies in the tropics.

Global climate change is one of today's most severe environmental issues [20]. The impacts of climate change have been felt in various regions, including Indonesia. One of the most apparent impacts is changes in weather and climate patterns, including changes in air temperature. East Java is one of the provinces in Indonesia experiencing climate change impacts, such as the coastal environment and land and sea economic activities [21].

East Java has a tropical climate with two rainy and dry seasons [22]. The rainy season generally lasts from October to April, while the dry season lasts from May to September. The impact is felt in the changes in the rainy and dry seasons and increasingly extreme air temperatures, especially in the Wlingi Dam area, which is located in East Java Province. The Wlingi Reservoir Dam is one of the essential dams in East Java. It is a source of irrigation water and electricity generation for the islands of Java and Bali. This dam has the primary functions of irrigation, raw water supply, and flood control. Changes in rainfall patterns and temperature due to a decrease or increase can affect river flow discharge. This climate change has shown its influence on the rainy and dry seasons, with consequences that must be watched out for [23]. Climate change causes an increase in rainfall intensity in a short time [24]. That can result in flooding, landslides, and infrastructure damage [25]. Apart from that, the rainy season in East Java is predicted to experience a shift in time and duration. That can disrupt rice planting and harvest patterns and increase drought risk at the start of the growing season [26]. On the other hand, when the dry season arrives, the air temperature is predicted to get hotter, which can cause dehydration, heatstroke and other heat-related diseases. In addition, an extended dry season can lead to drought, water crises, and crop failure [27-29].

On the other hand, researchers generally believe that air temperature is the main element that influences climate.

Climate change is sometimes equated and associated simply with changes in air temperature. However, it is only possible to identify climate change by considering this element in a comprehensive study. That is reasonable because temperature determines human activities in terms of natural and socio-economic dimensions. Apart from that, little is found in the literature where air temperature is an essential element that influences climate. Researchers at various spatial scales generally use global and regional approaches to present element variability at a local scale. That is different from what Lamb did in 1972 and 1977, which he wrote in his book about climate (past, present and future). In this book, changes in air temperature are one of the most critical studies on climate change in a broader context [30].

In this regard, research on the impact of climate change on temperature has been carried out in the Lake Toba area, Indonesia, using Era5-Land data for the period 1981-2020 [31]. This study was analyzed spatially and temporally in decadal and monthly periods. However, this research has not considered seasonal factors. Therefore, this paper aims to analyze the effect of climate change on temperature on an annual and seasonal scale using climate station observation data in the Wlingi Reservoir Area. The analysis of historical climate data is carried out to determine climate change statistically and spatially. Adaptation and mitigation strategies can be more effective by better understanding climate change in the tropics.

2. MATERIALS AND METHODS

2.1 Methods used

This research uses a case study method with secondary data analysis. Data on average, maximum, and minimum air temperature from the nearest meteorological station will be processed to see climate change trends. A stationary test is used to ensure no bias in the data used. Climate change is statistically analyzed through long-term variability, rate of change, and climate anomalies. The rate of air temperature change will be calculated using the linear regression method. Climate anomalies are analyzed based on the difference between the temperature in a particular year and the expected annual average temperature. Long-term variability is carried out using linear regression using time as a fixed variable (x) and temperature as an independent variable (y). Seasonal analysis is carried out by analyzing the trend of air temperature in the rainy season and dry season.

The study was conducted statistically and spatially. A spatial overview is performed to make it easier to understand the distribution of temperature data. The software used to perform spatial analysis is Arcmap 10.3. The spatial analysis uses the Inverse Distance Weighting (IDW) tool. In the IDW interpolation method, sample points are weighted during interpolation such that the influence of one point relative to another decreases with distance from the unknown point of interest [32].

2.2 Research sites

The case study site is in the Wlingi Dam catchment area, as shown in Figure 1. The area has its source in Batu City, which then passes through Malang City, Malang Regency, and flows into Blitar Regency. Since the climate stations located in the area are minimal, the analysis was also conducted on the surrounding climate stations, see Table 1. These stations were chosen because of the tiny percentage of data loss and the adequacy of the data. The research location has monsoon rain, an annual rainfall pattern with one period of highest and one period of lowest rainfall. The rainy season started from November to April, while the dry season started from May to October.

Figure 1. Location map of climate stations in East Java Province

Table 1. Climate stations in East Java for the period 1990-2023

No.	Name	Elevation (m)	Locations
1	Nganjuk Station	723	Nganjuk Regency
2	Pasuruan Station	832	Pasuruan Regency
3	Java East Station	590	Malang Regency
4	Banyuwangi Station	52	Banyuwangi Regency
5	Juanda Station	3	Sidoarjo Regency
6	Sangkapura Station	3	Gresik Regency
7	Trunojoyo Station	3	Sumenep Regency

2.3 Data source

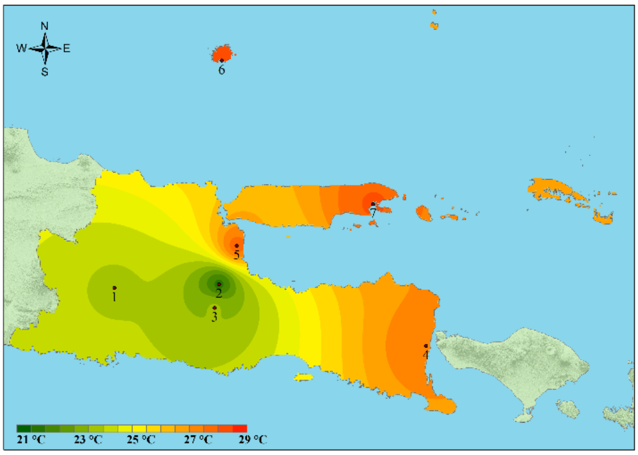
The primary data used in this research was obtained from the Meteorology, Climatology and Geophysics Agency in Indonesia, known as "*Badan Meteorologi Klimatologi, dan Geofisika" (BMKG)* online database centre, accessed at https://dataonline.bmkg.go.id/. Due to the limited data available, the period of years analyzed was from 1990 to 2023. Therefore, to ensure the accuracy of the data, a stationarity test was conducted. The stationarity test aims to minimize bias or errors that may arise due to these limitations. The data used is average, maximum, and minimum air temperatures. Additionally, supporting data, such as station elevation data and spatial mapping coordinates, was obtained.

3. RESULT AND DISCUSSION

3.1 Average air temperature analysis

This paper's analysis commences with a focus on the spatial diversification of temperature conditions, specifically for 1990-2023. The study considers the seasonal variations in Indonesia, namely the rainy and dry seasons. Spatial mapping is performed by utilizing various climate stations' geographical coordinates within the East Java Province. A crucial step in this process is interpolation, carried out using the IDW method, known for its reliability in interpolating temperature data. Figure 2 presents the outcomes of the average air temperature analysis. The average annual air temperature in East Java Province ranges from 21℃ in the highlands to 28℃ in the lowlands. Station 1 (Pasuruan Station), situated at the highest elevation of 832 meters above sea level, registered a temperature of 21.86℃, among the lowest recorded in the province.

On the other hand, stations situated near the coast, such as Station 5 (Juanda Station), 6 (Sangkapura Station), and 7 (Trunojoyo Station), which are at an elevation of 3m above sea level, register warmer temperatures of 27-28℃. Geographical conditions primarily influence the cooler temperatures near stations 1, 2, and 3. Several mountains surround these areas, including Mount Arjuna, Mount Kawi, Mount Bromo, and Mount Semeru. The temperature in mountainous regions is significantly influenced by air pressure. The higher the altitude, the lower the air pressure and, thus, the thinner the air, which causes the temperature to be lower in the mountains than in the lowlands. This phenomenon is commonly referred to as the Lapse Rate Effect, which refers to the rate of change in certain parameters as altitude increases [33]. As the pressure decreases, the distance between the gas molecules increases. More spaced gas molecules mean less heat energy is absorbed and emitted by these molecules, as heat energy is more difficult to transfer between molecules that are further apart. Less intensive interactions between gas molecules also contribute to the decrease in temperature [34].



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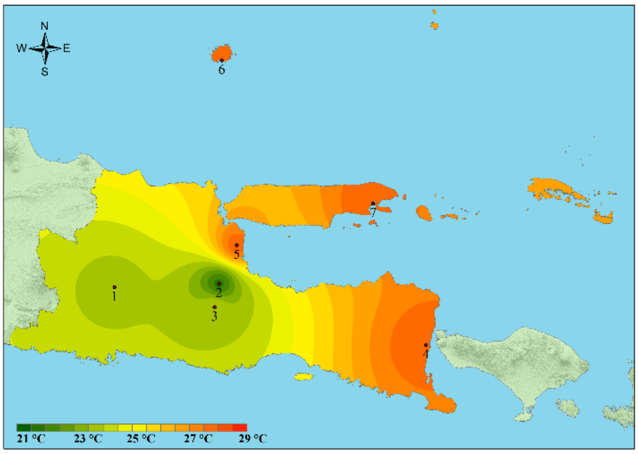

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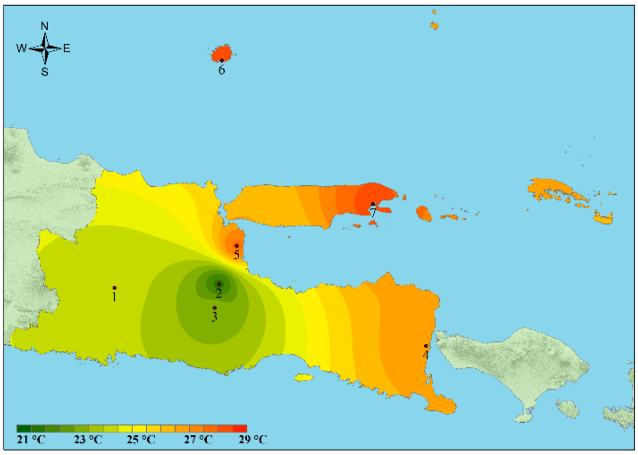

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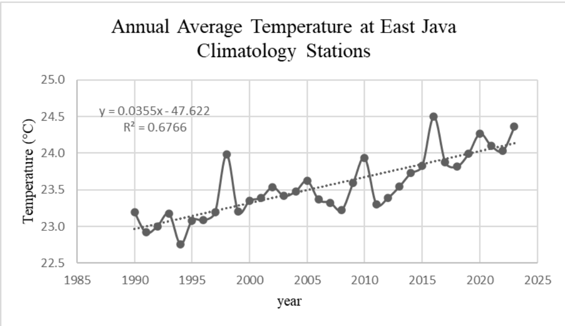
Figure 2. Average air temperature conditions in Java and Bali: (a) annual, (b) wet season, (c) dry season

Station location affects the recorded temperature; coastal areas are relatively hotter. Green on the map indicates lower temperatures, while red indicates warmer temperatures. During the rainy season, stations 3, 4, and 5 are hotter than in the dry season. However, as we enter the dry season, the average air temperature at stations 1, 2, 6 and 7 becomes hotter.

In this paper, a case study of changes in air temperature at the Wlingi Dam is presented. The closest climate station in the rain catchment area is the East Java Climatology Station, which is located in Malang Regency. Figure 3 shows the trend pattern of annual average temperature data (Nov - Mar) and the dry season (Apr-Oct).



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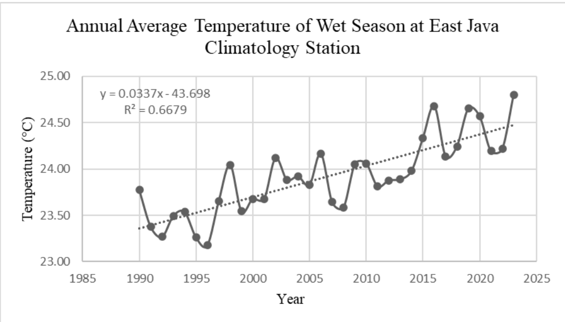

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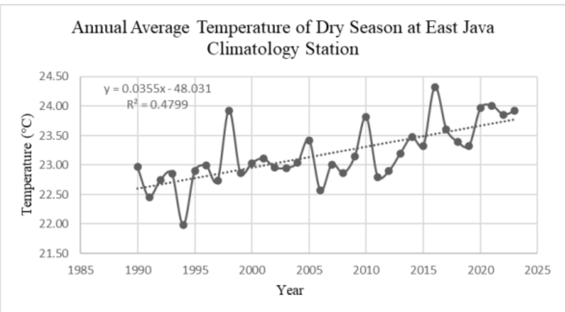

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Figure 3. Long-term variability of average air temperature at East Java stations: (a) annual, (b) wet season, (c) dry season

The trend patterns that occur in annual and seasonal scenarios have similar variability. There were three temperature jumps in 1990-2023, namely 1998, 2010 and 2016. In terms of average yearly temperature, statistically, there is a continuous increase over the long term. The dry season tends to have a similar trend pattern to the annual average temperature in terms of temperature spikes and drops. Meanwhile, the average temperature in the rainy season tends to be higher than the dry season and the average annual temperature. During the rainy season, air humidity increases significantly due to the large amount of water vapour in the atmosphere from rainfall. Water vapour has a high heat capacity, storing and releasing much heat energy. In the presence of high humidity, the heat energy stored in water vapour helps keep the air temperature higher compared to the dry season, when the air humidity is lower.

Tables 2 and 3 rank the highest and lowest temperatures over 34 years. Based on this table, it can be seen that 2016 had the highest temperature, 24.50°C, for the annual average temperature and 24.32°C in the dry season. However, the hottest temperatures will occur in the rainy season in 2023. Temperatures increase in the rainy season, exceeding the annual average and dry season temperatures. The warmest temperatures occurred in 2000, but 1998 the dry season temperature was included among the top 5 hottest years. That was caused by a massive increase in greenhouse gases that year. The growth of CH4 gas in 1998 was due to severe fires in the boreal region [35]. CH4 contributed 22% of all long-lived greenhouse gases 1998 [36]. Climate stress CH_4 contributed 35% of CO_2 in 1998. Also, CO_2 gas was the most significant contributor to greenhouse gases, namely 72% [37]. Then the lowest overall air temperature occurred below 2000.

Table 2. Highest annual and seasonal average air temperature at East Java climate station

No.	Highest Average Air Temperature (°C)					
	Annual	Year	Wet Season	Year	Dry Season	Year
1	24.50	2016	24.80	2023	24.32	2016
2	24.36	2023	24.68	2016	24.01	2021
3	24.27	2020	24.65	2019	23.97	2020
4	24.10	2021	24.57	2020	23.93	1998
5	24.04	2022	24.34	2015	23.92	2023

Table 3. Lowest annual and seasonal average air temperature at East Java climate station in the period (1990-2023)

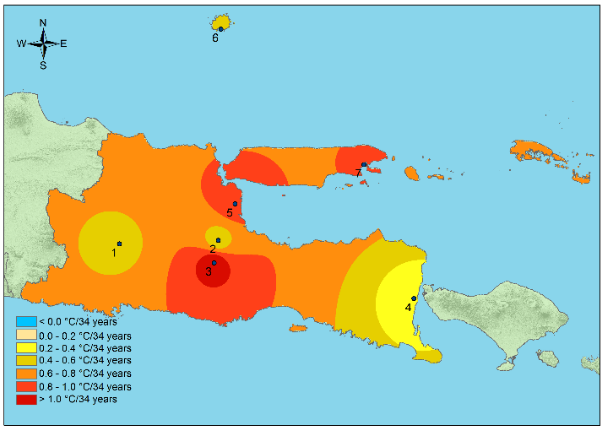
No.	Lowest Average Air Temperature (°C)					
	Annual	Year	Wet Season	Year	Dry Season	Year
1	22.76	1994	23.18	1996	21.98	1994
2	22.92	1991	23.26	1995	22.46	1991
3	23.00	1992	23.27	1992	22.57	2006
4	23.08	1995	23.38	1991	22.73	1997
5	23.08	1996	23.49	1993	22.74	1992

In the annual scenario, East Java Station's average temperature change rate is 1.21°C/34 years. Meanwhile, the average temperature change rate is lower when entering the rainy season, namely 1.15°C /34 years. During the dry season, the average temperature is higher than the annual and rainy season scenarios, namely 1.21°C/34 years. With a high rate of change, in 34 years, the average temperature in the dry season could increase by 1.21°C, hurting human activities.

As a comparison, the average rate of temperature change in East Java Province was also analyzed, as seen in Figure 4. In general, the average rate of change of mean temperature in East Java Province increased positively. The rate of change in annual average temperature in the eastern part is slightly higher than in the western part. In the rainy season, the rate of change in average temperature is lower than during the dry season. Station 3 (Java East Station) has the highest average temperature change rate above 1.0°C/34 years. The negative impact of increasing temperatures in this area must be watched.

3.2 Minimum temperature analysis

Figure 5 shows the minimum temperature conditions in East Java Province. The temperature difference is visible from the blue to the orange colour range. The blue part of the map has a minimum average temperature of around 17-18°C. Meanwhile, the yellow-orange part of the map has a minimum average temperature above 20°C. Only a few areas in East Java have a minimum temperature below 20°C. The distribution of minimum temperatures tends to be the same in each region, while it is more relaxed in the mountains than on the coast. Minimum temperatures in the dry season tend to be higher than in the rainy season except at stations 6 and 7. That could occur due to increased air humidity during the rainy season, which results in warmer temperatures.



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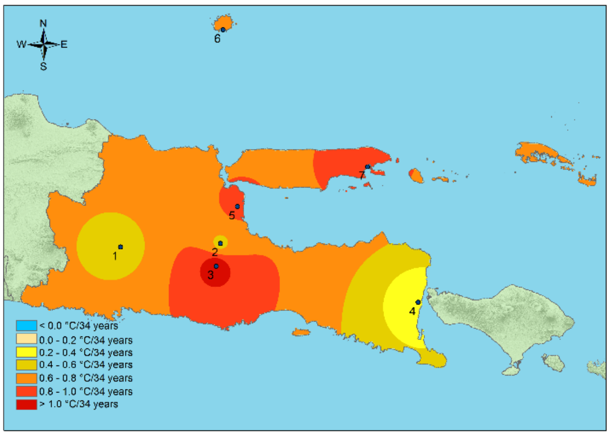

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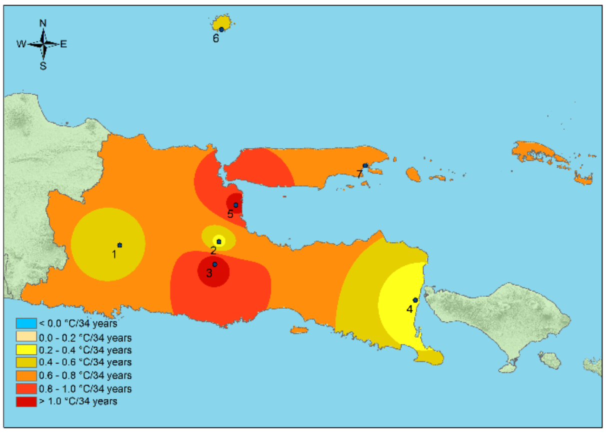

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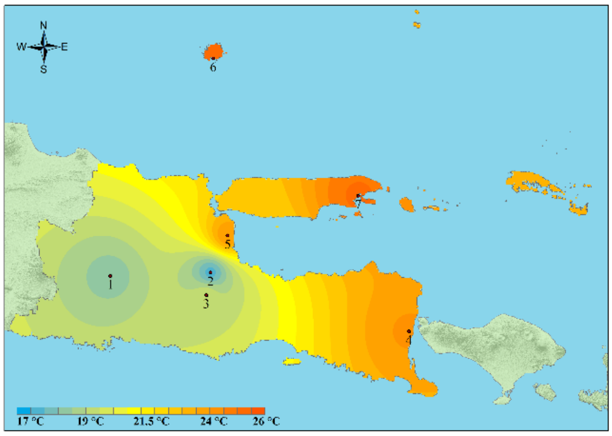
Figure 4. Change rate of average air temperature at East Java Province: a) annual, b) wet season, c) dry season

Figure 6 shows the trend pattern of minimum average air temperature at the East Java Climatology Station. The minimum average temperature in the annual average scenario, the rainy and dry seasons, have the same characteristics; there is a positive change, which means it increases yearly. In general, there was a jump in the growth of the minimum average temperature, namely in 1996, 2010 and 2016. The temperature has reached the highest point recorded at the climate station in recent years. Each scenario's minimum average temperature trend has characteristics, but the minimum temperature recorded in the dry season fluctuates more.



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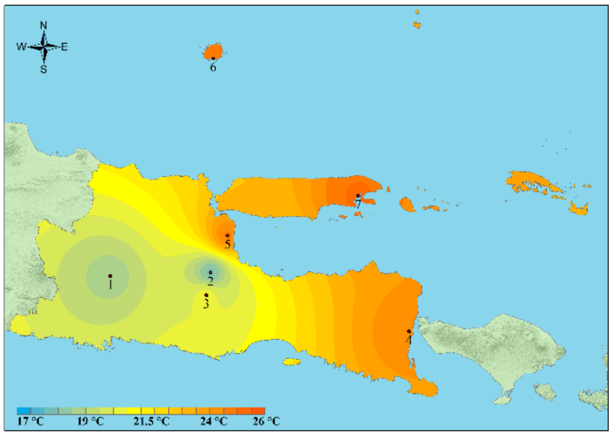

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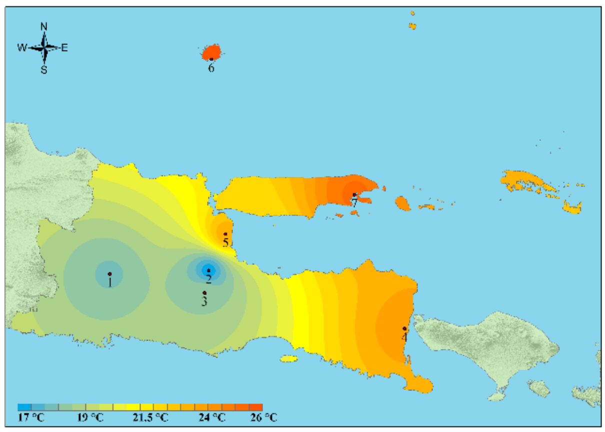

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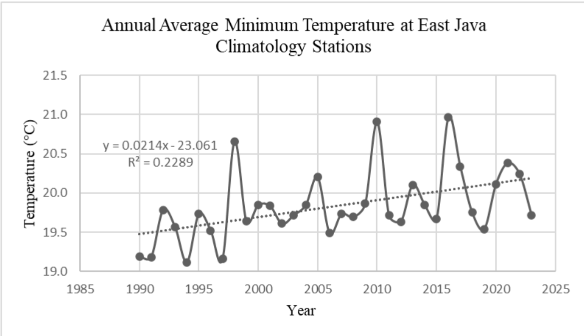
Figure 5. Minimum air temperature conditions in Java and Bali: (a) annual, (b) wet season, (c) dry season

Tables 3 and 4 show the highest and lowest minimum temperatures from 1990-2023 (34 years). Generally, the highest minimum temperature occurred after 2000, but the minimum temperature in 1998 was very high. The high increase in greenhouse gases in 1998 significantly impacted temperature increases. The lowest minimum temperature occurred before 2000 in both annual and seasonal scenarios. In this case, the minimum temperature after 2000 was warmer than the previous year, which was more relaxed. The trend in annual average air temperature is increasing statistically positively.



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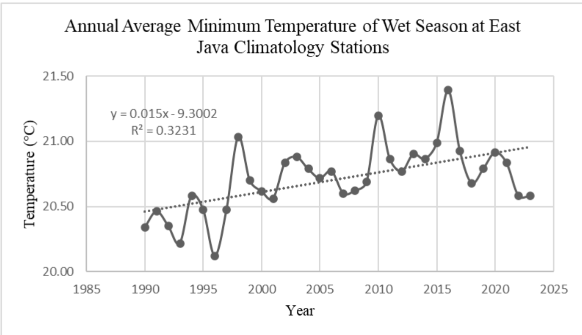

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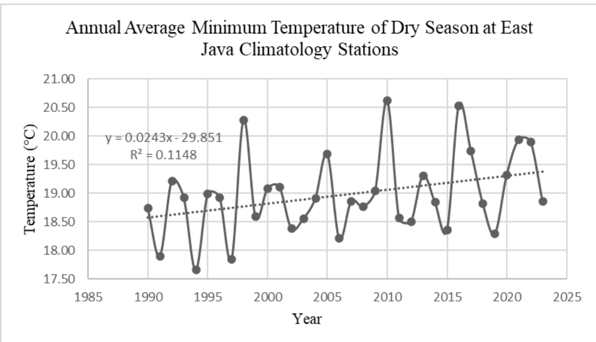

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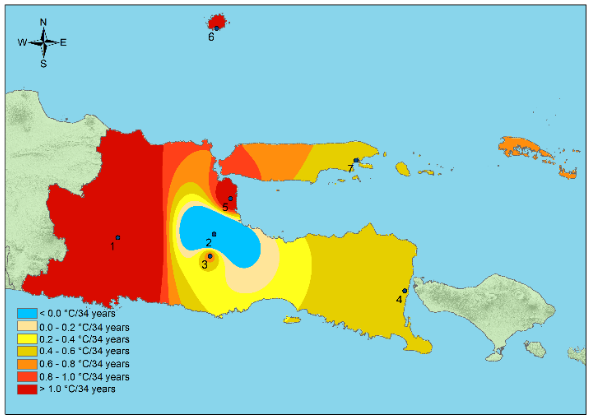
Figure 6. Long-term variability of annual minimum temperature at East Java climatological stations: a) annual, b) wet season, c) dry season

Table 4. Highest annual and seasonal average of minimum air temperature at East Java climate station in the period (1990-2023)

No.	Highest Minimum Air Temperature (°C)					
	Annual	Year	Wet Season	Year	Dry Season	Year
1	20.96	2016	21.39	2016	20.62	2010
2	20.91	2010	21.20	2010	20.53	2016
3	20.66	1998	21.03	1998	20.28	1998
4	20.39	2021	20.99	2015	19.94	2021
5	20.34	2017	20.93	2017	19.89	2022

The rate of change in the annual minimum temperature recorded at the East Java Climatology Station is lower than the average yearly air temperature of 0.73°C/34 years. In the rainy season, the rate of change in minimum temperature is 0.51°C/34 years, lower than in the dry season, which is 0.83°C/34 years. A low rate of change means that, within 34 years (1990-2023), the minimum temperature in the rainy season has not changed significantly.



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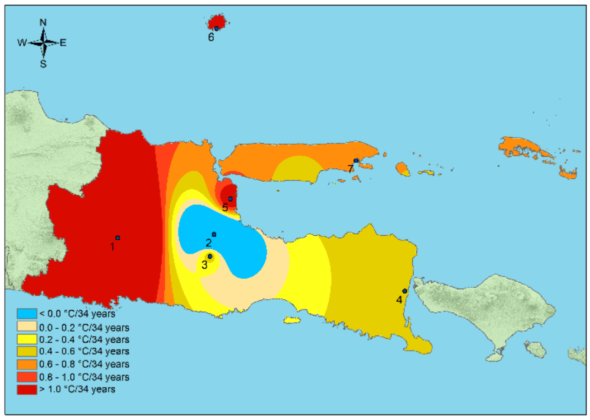

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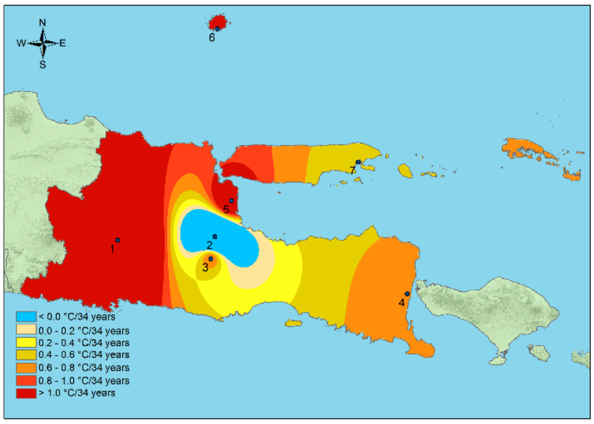

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Figure 7. Change rate of minimum temperature at East Java Province: a) annual, b) wet season, c) dry season

Figure 7 shows the annual and seasonal minimum temperature change rates in East Java Province. The annual minimum temperature change rate can reach values of more than 1.0°C/34 years, as recorded at Stations 1 (Nganjuk Station), 5 (Juanda Station), and 6 (Sangkapura Station). Station 2 (Pasuruan Station) has a negative change rate below -1.0°C/34 years. In general, the rate of change of minimum temperature is still the same as the average temperature, which is higher in the western region than in the eastern part. However, in the seasonal analysis, the minimum temperature change rate is lower than in the dry season.

Tables 4 and 5 show the highest and lowest minimum temperatures at the East Java Climatology Station. The lowest minimum temperature recorded at the East Java Climatology Station in East Java occurred in 1994, namely 19.12°C. In the dry season, the lowest minimum temperature follows the annual average temperature, which also occurred in 1994. In 1994, it was 17.66°C, the coldest temperature at this climate station.

Table 5. Lowest annual and seasonal average of minimum air temperature at East Java climate station in the period (1990-2023)

No.	Lowest Minimum Air Temperature (°C)					
	Annual	Year	Wet Season	Year	Dry Season	Year
1	19.12	1994	20.12	1996	17.66	1994
2	19.16	1997	20.22	1993	17.85	1997
3	19.18	1991	20.34	1990	17.90	1991
4	19.19	1990	20.35	1992	18.21	2006
5	19.49	2006	20.46	1991	18.29	2019

3.3 Maximum air temperature

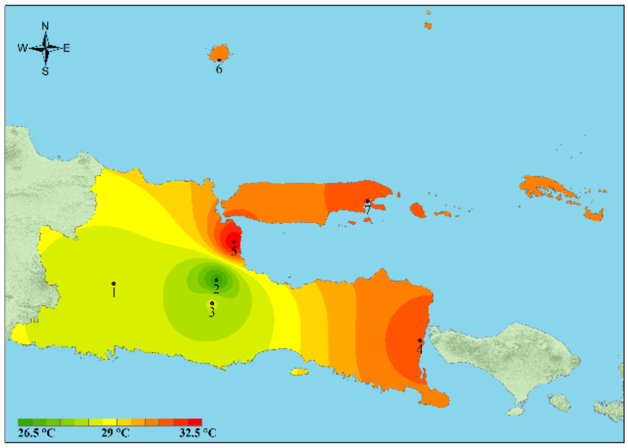
Figure 8 shows that the maximum temperature in East Java Province's islands tends to be above 30°C; only in mountainous areas is it still below 30°C. The distribution of maximum temperatures during the rainy season tends to increase to extremes, as recorded at Station 5 (Juanda Station), namely 32.51°C, the hottest area among all climate stations. That could be due to the impact of the Urban Heat Island (UHI), where Juanda Station is located in Surabaya City, the most populous city in East Java Province. During the dry season, the maximum temperature is lower than the rainy season except at Juanda Station, which is unaffected by seasonal factors. Low humidity levels can cause a lower maximum temperature in the dry season, so the ability of water vapour to store heat is minor. The impact is that the earth's surface feels more incredible during the day than during the rainy season.

The maximum temperature trend pattern recorded at the East Java Climatology Station is shown in Figure 9. There were two jumps in temperature increase, namely in 2023 and 2014. That year, the recorded temperature reached the hottest point in 34 years. Maximum temperature trends in the three scenarios both show an increase from year to year.

The maximum air temperature recorded at the East Java Climatology Station occurred in 2023 at 29.52°C. In the dry season, the maximum temperature can reach 29.81°C, as in 2014. Like the average and minimum temperatures, the maximum temperature recorded in the rainy season is hotter than in the dry season. The ranking of the highest and lowest maximum temperatures can be seen in Tables 6 and 7. Generally, the highest maximum temperatures occurred after 2000 in annual and seasonal scenarios.

Table 6. Highest annual and seasonal average of maximum air temperature at East Java climate station in the period (1990-2023)

No.	Highest Maximum Air Temperature (°C)					
	Annual	Year	Wet Season	Year	Dry Season	Year
1	29.52	2023	29.70	2019	29.81	2014
2	29.49	2014	29.55	2023	29.48	2023
3	29.41	2019	29.37	2016	29.11	2019
4	29.20	2016	29.26	2020	29.10	2015
5	29.13	2015	29.17	2014	29.03	2016



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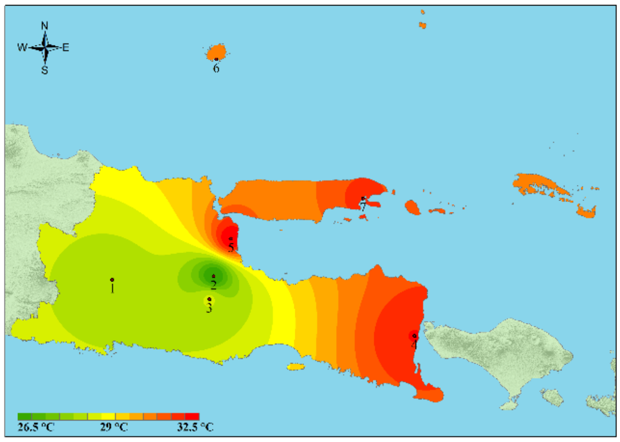

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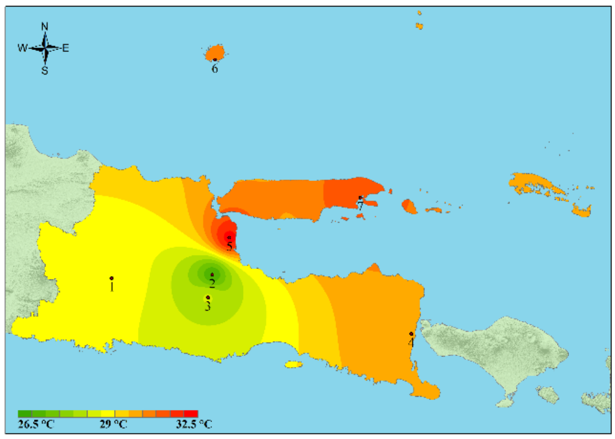

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Figure 8. Maximum *air* temperature conditions in Java and Bali: (a) annual, (b) wet season, (c) dry season

Table 7. Lowest annual and seasonal average of maximum air temperature at East Java climate station in the period (1990-2023)

No.	Lowest Maximum Air Temperature (°C)					
	Annual	Year	Wet Season	Year	Dry Season	Year
1	27.88	1992	27.72	1995	27.77	1992
2	27.93	2000	27.82	1999	27.98	2000
3	27.93	1995	27.87	2000	28.11	2008
4	27.99	1999	27.99	1992	28.13	2006
5	28.11	2008	28.03	2001	28.14	1995

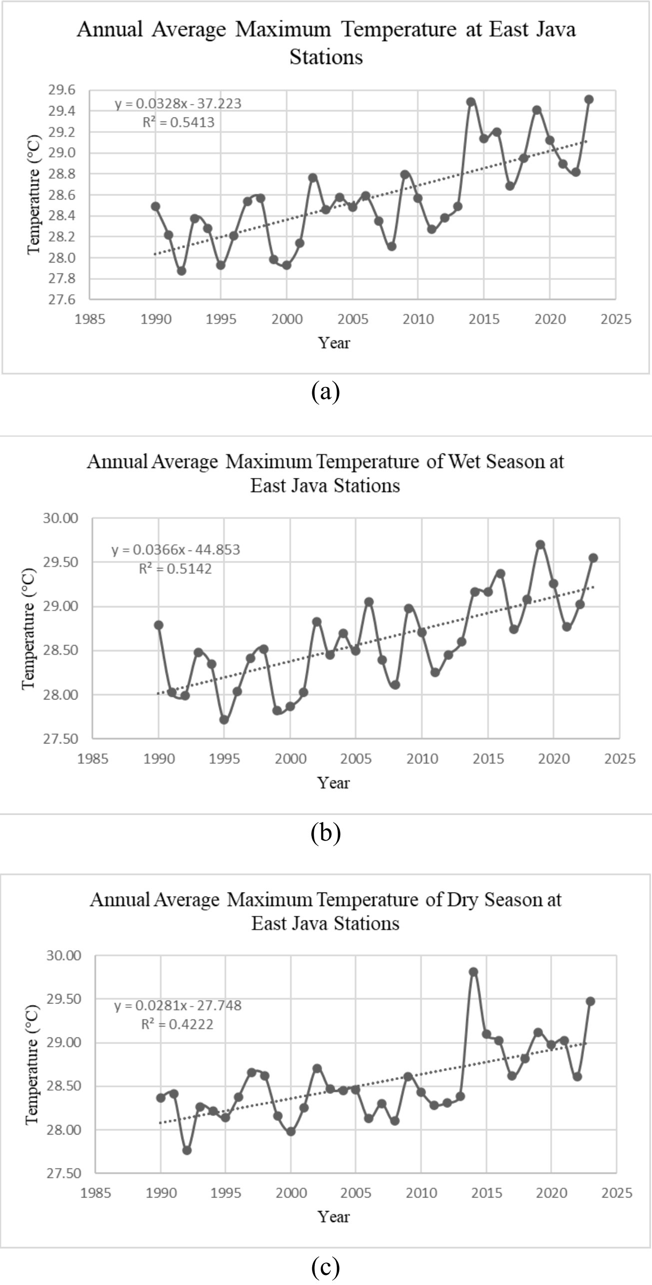

Figure 9. Long-term variability of annual maximum temperature at east Java climatological stations: a) annual, b) wet season, c) dry season

The annual and seasonal average maximum temperature change rate in East Java Province is shown in Figure 10. At the East Java Station, the annual maximum temperature change rate in the dry season is above 1.0°C/34 years; only in the dry season is it in the range of 0.8 - 1.0°C/34 years.

The maximum temperature change rate tends to increase significantly at all stations. Almost all stations experienced an increase of 1.0°C/34 years except Station 5 (Juanda Station) and Station 6 (Sangkapura Station), which were still below 1.0°C/34 years. Station 4 (Banyuwangi Station) experienced a decrease in both the annual and seasonal scenarios. This high rate of change in maximum temperature must be watched out for, especially when doing outdoor activities.

3.4 Air temperature anomaly analysis

Apart from analyzing the rate of change in air temperature, an analysis of air temperature anomalies was also carried out. According to BMKG, the annual air temperature anomaly is the difference between the air temperature in a particular year and the annual average air temperature. The data used as a reference for annual average air temperature in this study uses the period 1990-2023. The data comes from 7 climate stations with good data adequacy and quality data period.

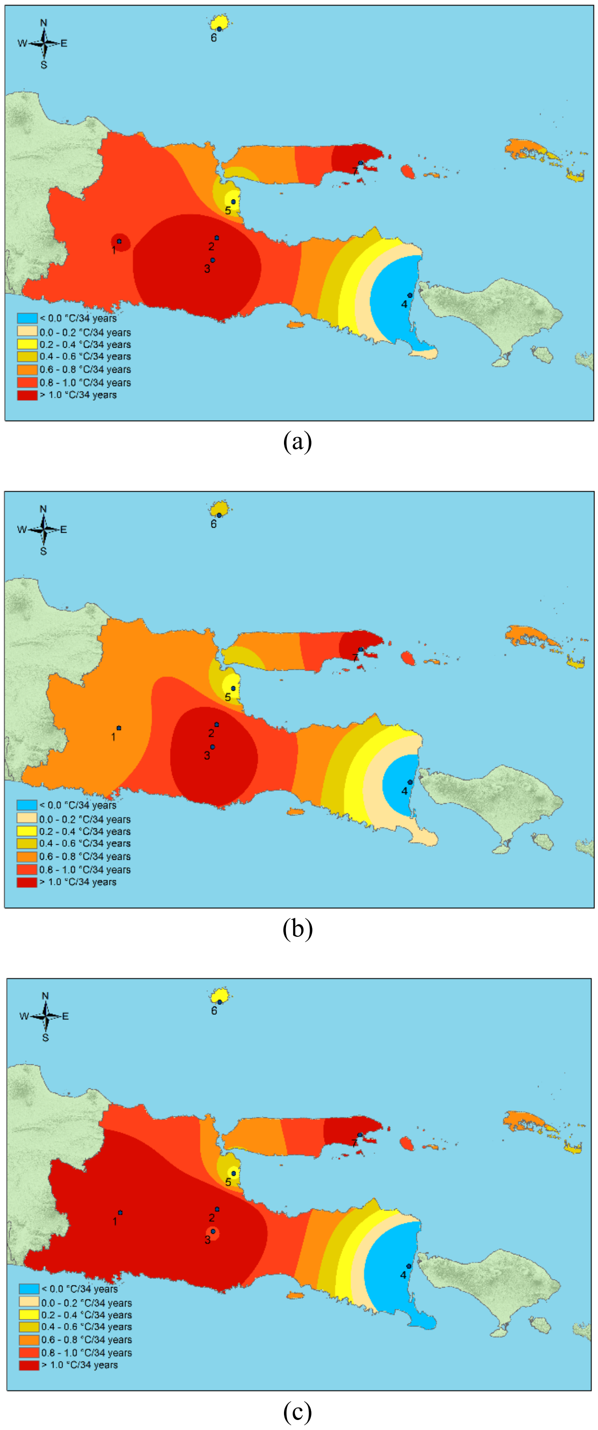

Figure 10. Change rate of maximum temperature at East Java Province: a) annual, b) wet season, c) dry season

Figure 11 shows the blue line shows the average temperature and the orange line shows the large anomaly. Table 8 ranks the most significant positive and negative climate anomalies recorded at the East Java Climatology Station. The highest ranking of the five negative anomalies occurred under 2000, where 1994 was the most significant negative anomaly of -0.789. This contrasts the five most significant positive anomalies that occurred after 2000. This shows that temperatures became warmer after 2000. The most significant air temperature anomaly at East Java Station over the 34 years from 1990 to 2023 occurred in 2016, with an anomaly of 0.955°C. Several factors caused the most significant anomaly to occur in 2016, one of which is that in 2016, the concentration of carbon dioxide (CO_2) in the atmosphere reached a record high, exceeding 400 parts per million (ppm) [38-40]. In addition, methane and nitrous oxide levels also increased, thus contributing to the increase in greenhouse gases [41]. This increase in greenhouse gases is influenced by various factors, including the impact of El Nino conditions and long-term emission trends [42]. The continuous increase in greenhouse gases in 2016 led to increased temperature at the Earth's surface for the third consecutive year, demonstrating the continuing challenge of climate change.

Table 8. Ranking of temperature anomalies at East Java climatology stations

No.	Air Temperature Anomalies (°C)			
	Positive	Year	Negative	Year
1	0.955	2016	-0.789	1994
2	0.814	2023	-0.629	1991
3	0.723	2020	-0.543	1992
4	0.553	2021	-0.466	1995
5	0.489	2022	-0.462	1996

3.5 Discussion

The trend of increasing annual average temperatures in East Java needs serious attention. Efforts to adapt and mitigate climate change must be carried out to minimize its negative impacts. The results of the analysis of the impact of climate change on temperature show positive results, where climate change influences the trend pattern of temperature data in terms of both average temperature data, maximum temperature, and minimum temperature. From 1990 to 2023, the pattern of temperature increase continues to increase statistically. Of course, although it is impossible to completely ignore specific local climate characteristics, based on the data used, it is not easy to show different trends of the characteristics considered in each region of East Java Province. Data distribution that could be better distributed is also an obstacle to comprehensively describing air temperature conditions. Due to data limitations, the research can only be conducted for a limited period of 1990-2023. However, stationary tests were conducted to ensure the data was accurate and avoided bias. The greenhouse gas recording station is also located quite far from the study site, making it challenging to analyze the exact increase in greenhouse gases at the study site.

In general, the increase in temperature at the seven temperature recording stations gave positive results. However, the temperatures recorded at each station provide varied values. For example, Pasuruan Station, located at an elevation of 832 m, recorded a freezing temperature compared to other stations. Juanda, Sangkapura, and Trunojoyo stations, located at an elevation of 3 m, recorded hotter temperatures. This elevation difference may affect the temperature recorded at the climate stations. The higher the geography, the smaller the air pressure, causing the molecules to have more space so that the absorbed heat energy becomes smaller. Interactions between gases also influence reducing temperatures, so temperatures in low places tend to be hotter.

Analysis of the rate of change was outlined at several points recorded from 7 climate stations in East Java Province. It is recorded at the East Java Climatology Station, the closest station to the Wlingi Reservoir. The average temperature change rate at the East Java Climatology Station is above 1.0°C/34 years. This means that within 34 years, the temperature increase can be more significant than 1.0°C.

Seasonal analysis also shows that the rainy season tends to be hotter than the dry season. This can be caused by higher air humidity due to rain. Spatial temperature differences are also influenced by geological factors or the location of climate stations on the earth's surface, where temperatures in mountainous areas tend to be lower than in lowland or coastal areas. The hottest temperature recorded at the nearest climate station to Wlingi Reservoir occurred in 2016, possibly due to the combined impact of long-term temperature increases, primarily caused by greenhouse gases and a temporary boost from the intense 2015/2016 El Nino event [42]. In 1998, an increase in greenhouse gases and the El Nino event caused temperatures to increase significantly [43].

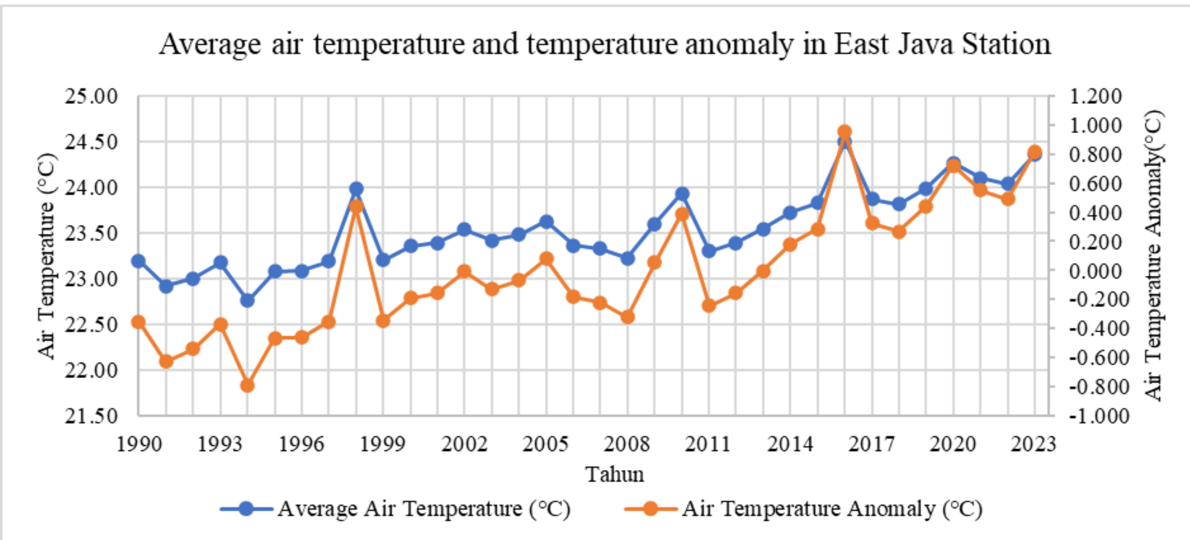

Figure 11. Air temperature and temperature anomaly in East Java station

The increase in greenhouse gases continues to increase yearly [44]. Combined greenhouse gases have increased from the 1992-2019 period by 53% [45]. Greenhouse gases, such as carbon dioxide, can absorb infrared radiation and make the Earth warmer than it should be, causing climate change [37]. The impact of increasing global annual average concentrations of carbon dioxide and methane is the main reason for the rise in global temperature [46].

Finding differences in the trends is highly questionable and indicates heterogeneity in the data used. Spatial analysis of air temperature can provide different values in certain geographic conditions. Such as mountainous areas and coastal areas, which have different temperature characteristics. As in the analysis, the temperature in mountainous areas will be lower than in coastal areas. Research on a smaller scale explains specific air temperature conditions in mountainous or coastal areas.

4. CONCLUSIONS

1. Based on data from the BMKG, there is a positive trend of increasing annual air temperature in East Java Province between 1990 and 2023. This causes the earth's surface to become warmer.
2. The rate of change, assessed at seven climate stations in East Java Province, particularly at the East Java Climatology Station near Wlingi Reservoir, shows an annual average temperature increase of more than 1.0℃ in 34 years. If the increase continues, future temperatures could be even hotter.
3. The most significant air temperature anomaly at East Java Station over the 34 years from 1990 to 2023 occurred in 2016, the hottest year, with an anomaly of 0.955℃.
4. Seasonal patterns show that the rainy season tends to be warmer than the dry season; this is caused by increased humidity due to rainfall.
5. Geological factors influence spatial temperature variations. Mountain areas generally experience cooler temperatures than lowland and coastal areas. The light air pressure in mountain areas causes the gas molecules to get more space and causes less heat energy to be absorbed. Interactions between gases also contribute to the decrease in temperature.
6. Research location suggestions for future researchers should be carried out in locations with greenhouse gas monitoring stations. In Indonesia, there are only 3 Global Atmosphere Watch (GAW), namely Kototabang Hill (North Sumatra), Lindu Bairi ore (Palu-Central Sulawesi), and Puncak Vihara Klademak (Sorong-West Papua).

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NOMENCLATURE

IDW	Inverse Distance Weighting
MCGA	Meteorology, Climatology and Geophysics Agency
UHI	Urban Heat Island