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Temporal-Spatial Variations Analysis of Surface Temperature in Kalimantan Region in The Period of 2010 - 2020

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ABSTRACT– *Surface temperature information is important to study because it affects other climate parameters and has an impact on various sectors. This study aims to analyze the temporal and spatial variations of maximum surface temperature on Kalimantan Region during the period 2010 to 2020. The data used is Surface Maximum Temperature (SMT) in the form of a 0.5° x 0.5° grid from the Climate Prediction Center (CPC) NOAA PCL. Temporal and spatial analysis were performed for identifying temperature trends and spatial distribution patterns. The results of the temporal analysis showed that the highest monthly SMT values occurred in May (32.00° C) and September (31.75° C). While the lowest monthly SMT values were found in January (30.88° C) and July (31.40° C). The results of the annual SMT trend analysis show that the surface temperature in the Kalimantan Region has increased at an average rate of 0.03°C per year. This value is higher than the increase in global surface temperature (~0.02°C per year). Based on the results of spatial analysis, it was known that the distribution of SMT on Kalimantan Region tends to be stable in the range of 25° C to 35° C throughout the year. Spatial analysis of SMT in 2011 showed that low values (25° - 31° C) dominated South Kalimantan Province, while high values (33°C - 35°C) dominated West Kalimantan Province. The results of the 2019 SMT spatial analysis revealed a similar pattern to 2011. However, there was a significant increase in temperature compared to 2011, especially in the high SMT values observed in West Kalimantan and East Kalimantan Provinces.*

KEYWORDS: *surface temperature; climate change; temporal-spatial variation; Kalimantan*; NOAA PCL.

PENDAHULUAN

Kalimantan Island is one of the largest islands in Indonesia. Administratively, Kalimantan Region is divided into several provinces as shown in Figure 1. East Kalimantan Province has become the focus of government development since the establishment of the plan to move the national capital from DKI Jakarta to East Kalimantan at the Plenary Meeting of the House of Representatives of the Republic of Indonesia in 2022 (Purnama & Chotib, 2023). The relocation project will result in increased development and reduced green space. Changes in land use from green space to buildings will change the surface temperature pattern in an area (Damayanti et al., 2023).

Surface temperature is one of the most important parameters in the context of climate change. Climate change describes the accumulation of weather parameters on a daily or monthly basis over a long period of time, such as 10 years or longer (Lutgens & Tarbuck, 2016). Because the atmosphere is dynamic, climate parameters will influence each other. For example, changes in temperature patterns in a region will have an impact on other climate parameters such as rainfall, humidity, and air pressure (Reynolds et al., 2019). Information on these climate parameters is useful for various sectors, such as energy, agriculture, shipping, and aviation. Therefore, it is important to study the analysis of surface temperature in a region, as it can provide valuable insights in the face of ongoing climate change.

There are several institutions that provide surface temperature data and can be accessed by the public for various purposes, one of

which is the Climate Prediction Center (CPC), part of the National Oceanic and Atmospheric Administration (NOAA). The NOAA is a federal agency responsible for monitoring and forecasting various aspects of the Earth's environment, including weather and climate, and the CPC is one of its specialized centers focused on climate prediction. CPC collects, manages, and provides daily data on various climate parameters, one of which is global surface temperature. The data collected by CPC has been available in a raster-based grid data format since 1979 and covers the regions 89.75N - 89.75SN, 0.25E - 359.75E, as illustrated in Figure 2. The grid data are cells with a certain resolution that represent a geographical area and have numerical values that describe climate parameters. The grid size used varies depending on the type of data and the resolution required for analysis. High grid resolution is produced by small cells. The higher the grid resolution, the more detailed the climate data in an area can be represented. Examples of grid sizes commonly used by NOAA CPC are 0.25° x 0.25°, 0.5° x 0.5°, and 1° x 1°. Each value represents a geographical coverage of area size in both latitude and longitude. The resolution of climate data provided by CPC can be used to analyze climate conditions in the Indonesian region, including Kalimantan.

This study aims to analyze the dynamics of Surface Maximum Temperature (SMT) in the Kalimantan region in the period 2010-2020. The data used in this study comes from the CPC Global Temperature provided by NOAA PCL with a grid size of 0.5° x 0.5°. The data were then analyzed temporally and spatially to identify trends in temperature changes and their spatial distribution patterns.

The results of this study are expected to provide a deeper understanding of the temperature dynamics in the Kalimantan region. In addition, this research also has the potential to become the foundation for further research, such as studies to predict temperature patterns in the Kalimantan region. Thus, the results of this study can contribute to mitigation and adaptation efforts to climate change in the future

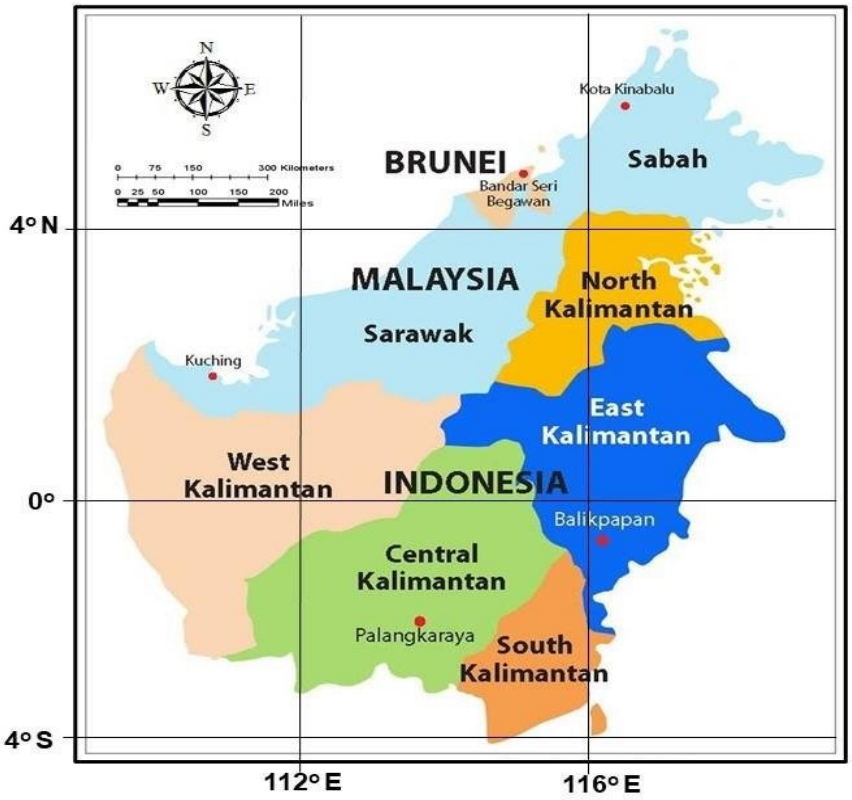


Figure 1. The location and administration map of Kalimantan Island (Sukarman et al., 2021)

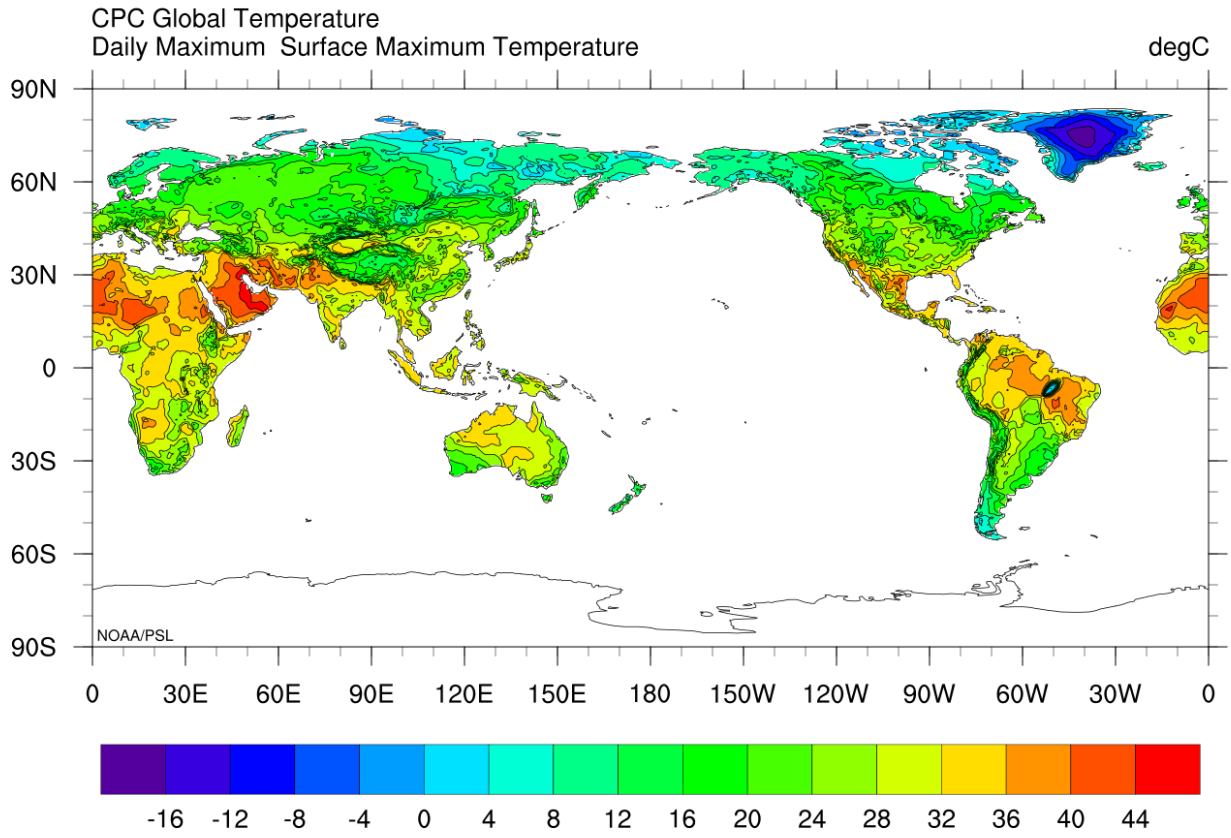


Figure 2. Global availability of Climate Prediction Center (CPC) Surface Maximum Temperature (SMT) data (NOAA PSL, 2023)

METHODOLOGY

This research uses secondary data in the form of CPC Global Temperature provided by NOAA PCL. The data can be downloaded via the following link: https://psl.noaa.gov/thredds/catalog/Datasets/cpc_global_temp/catalog.html. The research domain covers the Kalimantan Island region with coordinates 5N - 9S and 107.5E - 119E during the period 2010 - 2020. Data in the form of Surface Maximum Temperature (SMT) is in the form of a grid with a size of 0.5° x 0.5°.

In this study, data processing was carried out using the Python programming language. Jupyter Notebook is used as an Integrated Development Environment (IDE) in extracting, processing and visualizing data. The downloaded data is an array data consisting of latitude, longitude, time (year-month-day) and maximum surface temperature variables.

The first step after downloading the data is to select data based on the research domain. At this stage, the data was obtained in the form of a matrix measuring 2.587.592 rows and 4 columns. Next, data cleaning was carried out to eliminate temperature parameters that had "NaN" values, resulting in a new matrix of 1.012.536 rows and 4 columns. After the data has been prepared, the analysis is carried out temporally and spatially.

This study used statistical methods to find the average monthly and annual SMT values. The average SMT was calculated based on the following equation:

$$\bar{X} = \sum_{i=1}^{n} \frac{X_i}{n} = \frac{X_1 + X_2 + \cdots + X_n}{n} \qquad (1)$$

where $\bar{X}$ is the monthly or annual SMT average, X_i is the daily SMT data, and n is the number of SMT data (Walpole et al., 2017).

Linear regression analysis was used to estimate the trend of SMT between 2010 to 2020. The *x-axis* is the year, the *y-axis* is the SMT value, and k is the slope gradient of the linear regression equation ($y = kx + b$) representing the rate of trend. Values of $k > 0$ indicate that the SMT is increasing, while values of $k < 0$ indicate the opposite pattern. The equation to calculate the k value is based on the equation:

$$k = \frac{(n\sum_{i=1}^{n} i\,X_i - \sum_{i=1}^{n} i \sum_{i=1}^{n} X_i)}{[n\sum_{i=1}^{n} i^2 - (\sum_{i=1}^{n} i)^2]} \quad (2)$$

where n is the number of years (this study uses 11 years of data), i is the i-th year of data (e.g., 2010), and X_i is the average annual SMT from the i-th year of data (Wang et al., 2022).

RESULT AND DISCUSSION

Temporal Variation

The SMT data for the period January 1, 2010 to December 31, 2020 in the Kalimantan Island region is shown in Figure 3. This data covers the surface maximum temperature recorded daily for 11 years, so there are a total of 4,015 data. The analysis shows that the daily SMT on the Kalimantan Island varies between 31° C - 39° C.

Monthly surface temperature variations on the Kalimantan region from 2010 to 2020 are shown in Figure 4a. During this period, the highest monthly average SMT occurred in April 2016 (32.54°C) and September 2019 (32.60°C). The monthly average trend of SMT in Kalimantan Region from 2010 to 2020 shows 2 peaks and 2 valleys. The highest mean SMT was recorded in May (32.00° C) and September (31.75° C), while the lowest mean SMT occurred in January (30.88° C) and July (31.40° C). This monthly SMT trend pattern shows a correlation with the annual apparent motion of the sun.

The apparent motion of the sun occurs because the earth revolves around the sun on its tilted axis, with a declination of 23.45° (Ray, 2012; Shivalingaswamy & Kagali, 2017). This phenomenon results in the sun periodically dominantly illuminating the north and south sides of the earth throughout the revolutionary year. For example, the sun is on the north side of the equator on December 21, when the declination reaches its maximum of 23.45°. In contrast, the sun is exactly above the equator or without declination (0°) around March 20 and September 22. On June 21, the sun seems to be south of the equator with a minimum declination of -23.45°. This difference in the angle of solar irradiation affects the monthly temperature variations in the region, especially in Kalimantan Island, which is located right on the equator. Therefore, the intensity of sunlight received reaches a peak around March and September, while the minimum intensity occurs around January and June. This phenomenon has implications for surface temperature variations in the Kalimantan region.

The lowest annual mean SMT value was recorded in 2011 at 31.2° C, while the highest value occurred in 2016 which reached 32.84° C. These results correspond with information from NOAA National Centers for Environmental Information, which reported that globally, 2016 was the year with the highest temperature in the range of 1880 to 2022 (NOAA NCEI, 2023; Nurlina et al., 2023).

Trend results of annual SMT based on regression analysis using equation 2 showed a positive slope gradient value ($k > 0$). This result indicates that the tendency of surface temperature to experience an increasing rate from 2010 to 2020. The average annual SMT in the Kalimantan region increased by 0.03°C each year. This value is higher than the global surface temperature rate, which has increased by ~0.02°C annually in the last 40 years (Hansen et al., 2006; Malakouti, 2023).

Spatial Variation

Figure 6a and Figure 6b show maps of the spatial variation of monthly mean SMT in the Kalimantan Region. The average monthly SMT values are represented with purple to red color gradations. Average monthly SMT with low values (25° - 30° C) are represented with purple to blue colors, medium values (30° - 32° C) are represented with green colors, while high values (33° - 35° C) are represented with yellow to red colors.

This study displays the results of spatial variation maps in 2011 and 2019 to compare the spatial variation of SMT in the two time periods. The results of the visualization of the spatial distribution of monthly SMT show that most areas of Kalimantan have surface temperatures that tend to be stable, within the temperature range of 25° C to 35° C. This pattern is influenced by the fact that Kalimantan belongs to a tropical climate,

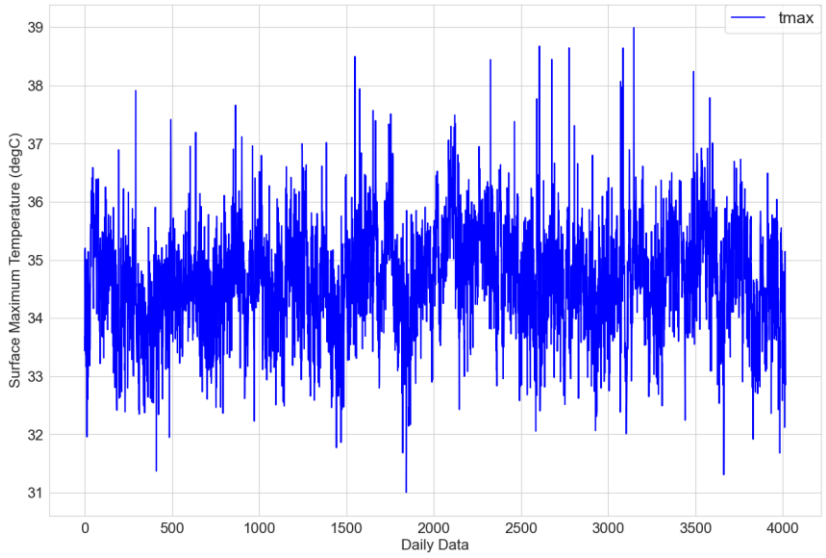


Figure 3. Daily variation of SMT in Kalimantan from 2010 and 2020.

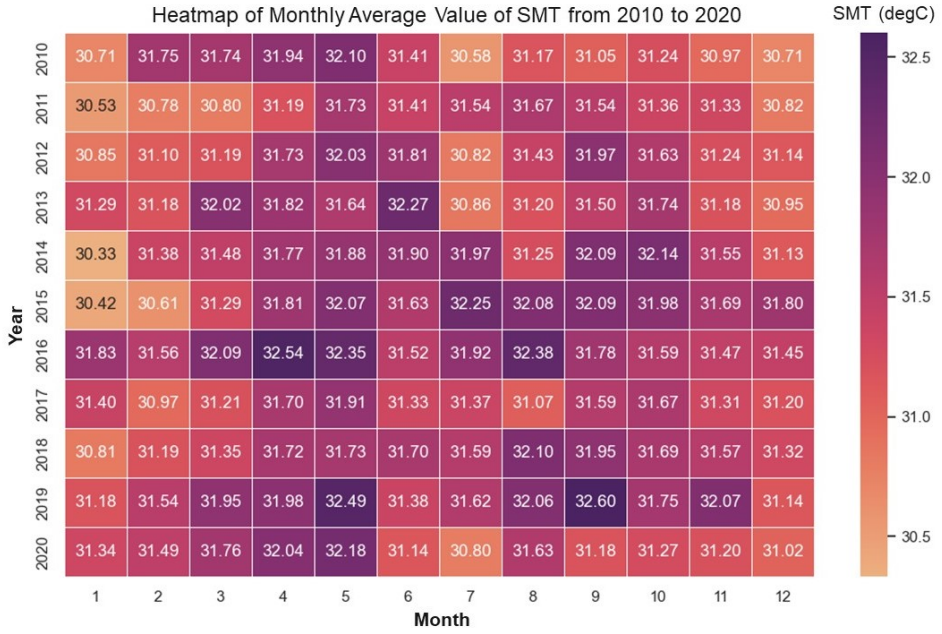


Figure 4a. Monthly average variation of SMT in heatmap form between 2010 and 2020.

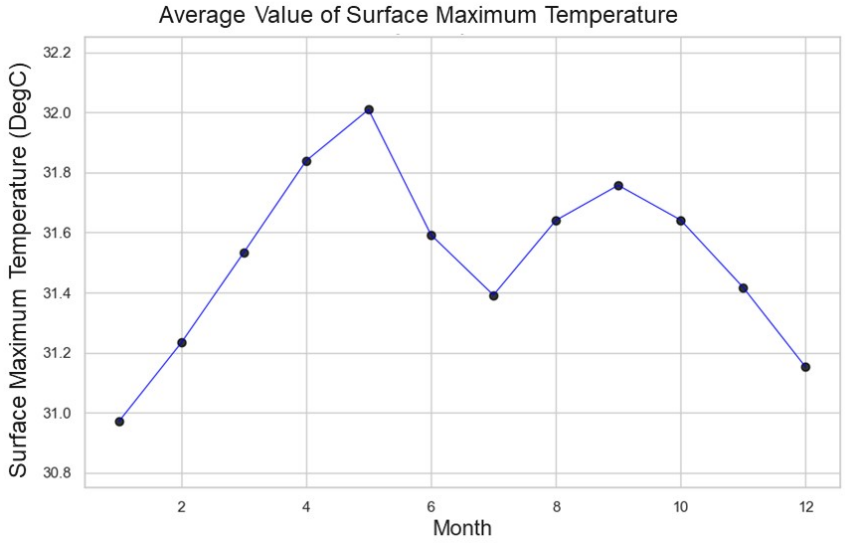


Figure 4b. Monthly average variation trend of SMT on Kalimantan Region from 2010 to 2020.

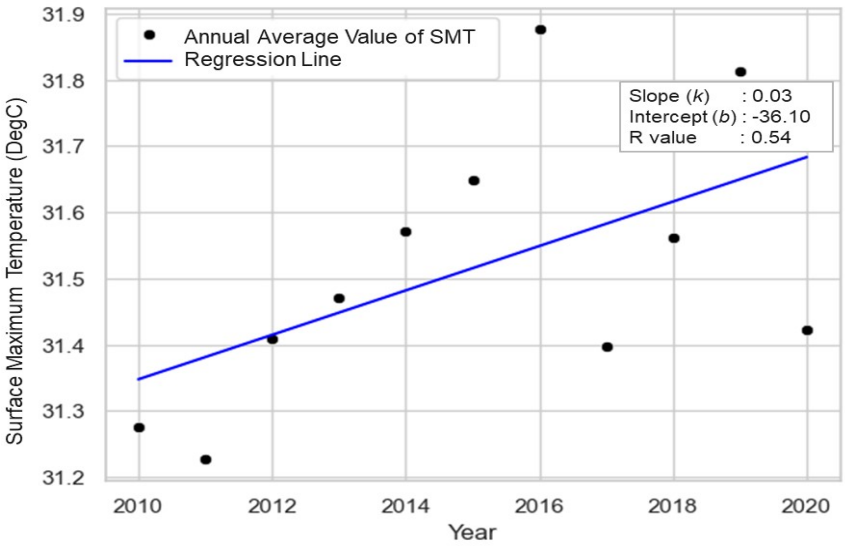
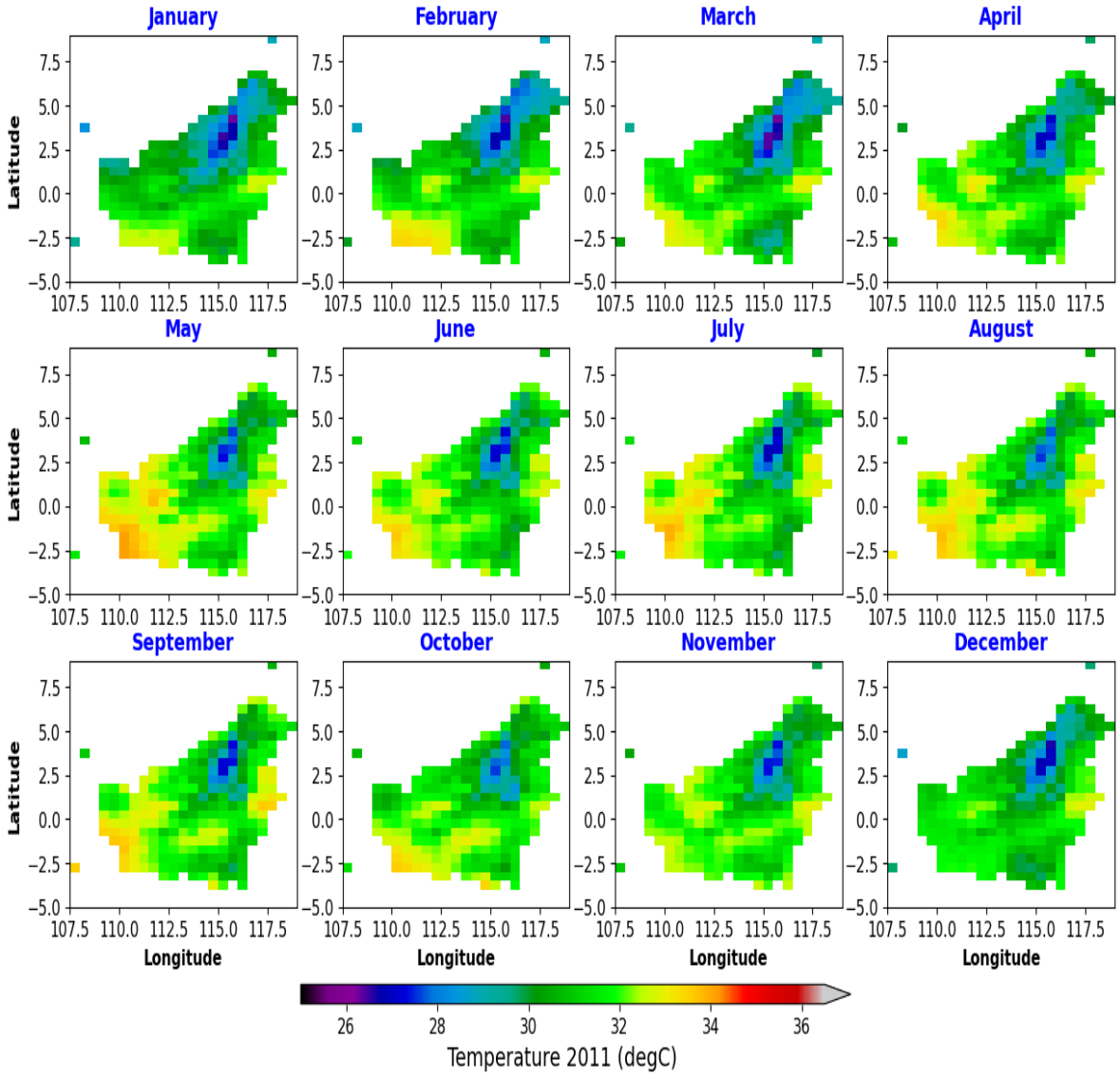
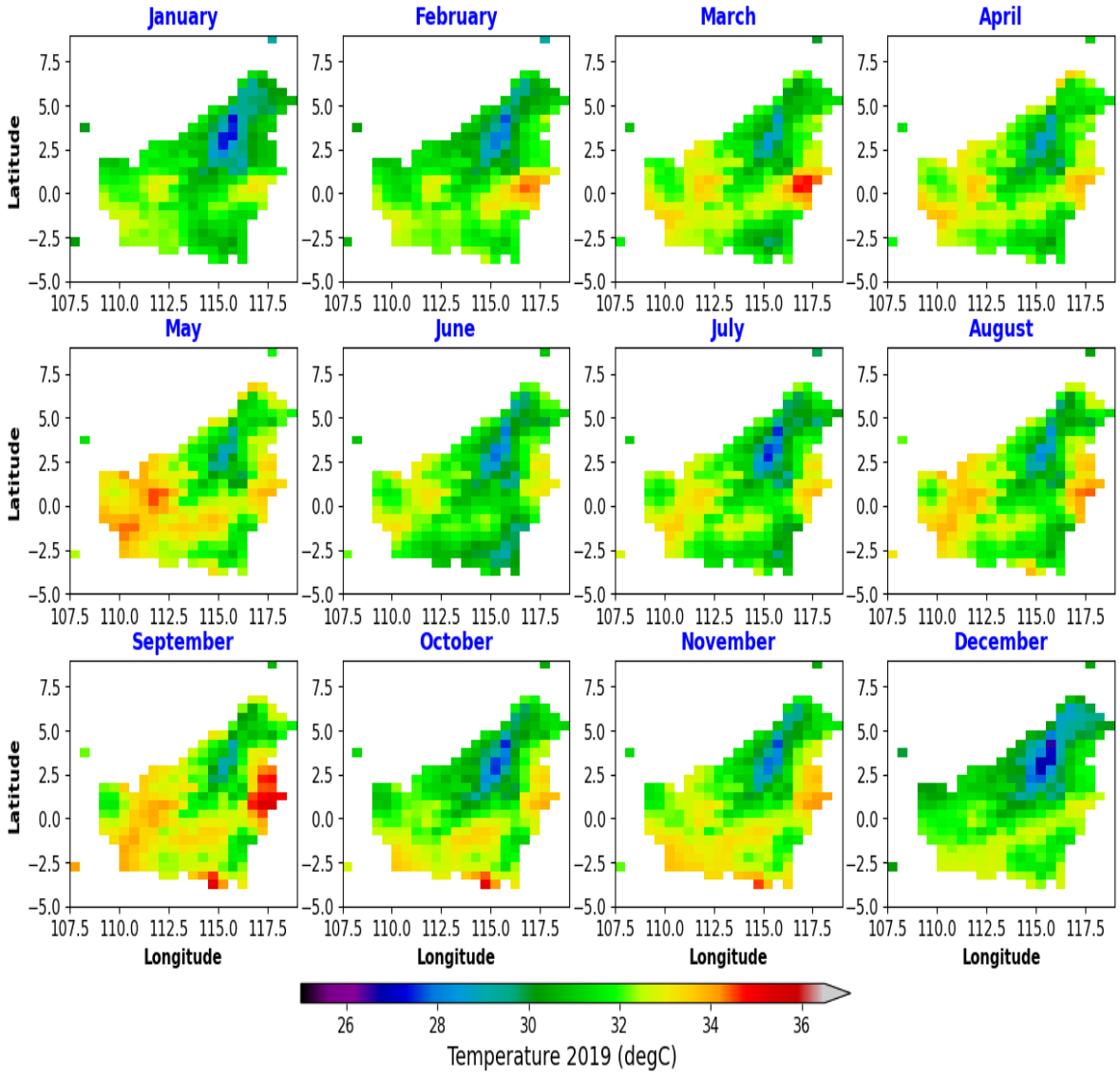


Figure 5. Year-to year variation of SMT on Kalimantan Region from 2010 to 2020.



Gambar 6a. Spatial Variation of SMT on Kalimantan Island in 2011



Gambar 6b. Spatial Variation of SMT on Kalimantan Island in 2019

which generally has stable temperatures throughout the year between 25° C to 35° C, and has little seasonal variation (Lutgens & Tarbuck, 2016). Figure 6a shows that in 2011, the northern part of Kalimantan, especially North Kalimantan Province, was dominated by low temperatures, ranging from 25° C to 30° C. The average SMT with high values was seen in the southwestern side of Kalimantan or in West Kalimantan Province, as shown by purple box in Figure 6a, which reached 34° C in May 2011. This temperature variation has a correlation with land cover in Kalimantan. A report issued by the Ministry of Environment and Forestry in 2016 noted that the provinces with the largest forest cover in Kalimantan are North Kalimantan (84.86%), East Kalimantan (61.26%), Central Kalimantan (51.47%), West Kalimantan (39.65%), and South Kalimantan (25.46%). The presence of forests has a significant impact on leaf area index, transpiration processes, and albedo (Zhang et al., 2021). These factors help reduce the amount of heat energy reaching the Earth's surface.

Figure 6b shows the average monthly SMT in Kalimantan in 2019. In general, the pattern of spatial variation is similar to 2011, which showed the dominance of low temperatures in North Kalimantan. However, there is a significant change in color gradation between Figures 6a and 6b, indicates a rise in temperature in some areas. Temperatures rose significantly in eastern parts of East Kalimantan in September 2019 as shown by purple box in Figure 6b. The finding of this spatial analysis in 2019 are well correlated with the results of the temporal analysis in 2019 in Figure 4a. Previous study indicates that the

increase in surface temperature in East Kalimantan is linked in part to the conversion of forest cover to constructs as part of the New Capital of Indonesia (IKN) Project, which began in 2019 (Denryanto & Virgianto, 2021; Wolff et al., 2021).

CONCLUSION

This study examines the temporal and spatial variations of Surface Maximum Temperature (SMT) on the Kalimantan Island during the period 2010-2020 based on data from NOAA's Climate Prediction Center (CPC). The results of temporal analysis show that the dominant daily SMT is between the range of 33.5° - 35° C. The highest average monthly SMT values occur in May (32.00° C) and September (31.75° C). While the lowest average monthly SMT values were found in January (30.88° C) and July (31.40° C). Based on the average annual trend, the SMT has increased at an average rate of 0.03°C per year, which is higher than the global surface temperature increasing of approximately 0.02°C per year.

Based on the results of spatial analysis, it is known that the distribution of SMT on the island of Kalimantan tends to be stable in the range of 25° C to 35° C throughout the year. SMT analysis in 2011 showed that low values (25° - 31° C) dominated South Kalimantan Province and high values (33° - 35° C) in West Kalimantan Province. The results of the 2019 SMT spatial analysis show a pattern that is almost the same as in 2011, but there is a significant increase in temperature when compared to 2011. High temperature increases were seen to dominate East Kalimantan and West Kalimantan Provinces.

To better understand the factors influencing the increase in high temperatures in both regions, further research is needed. This research could involve factors such as land cover change, human activities, global climate influences, or other local factors. More in-depth analysis will help in identifying the causes and determining concrete steps in reducing the rate of temperature increase in the Kalimantan Region.

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