

CLIMATE ANALYSIS WITH MANN-KENDALL TEST FOR TEMPERATURE TRENDS IN PADANG CITY

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ABSTRAK

Kota Padang merupakan salah satu kota di provinsi Sumatera Barat, kota ini mengalami temperatur rata-rata mulai dari 22 °C sampai 32 °C sepanjang bulan dengan perubahan temperatur minimal diatas 32 °C atau dibawah 22 °C. Analisis dalam paper ini dibuat dengan data yang disediakan oleh Badan Metereologi, Klimatologi dan Geofisika (BMKG) dari tahun 2010-2023 dan perhitungan di paper ini akan dilakukan dengan algoritma yang ditulis dalam bahasa pemrograman Python di Google Colab yang akan menghitung varians dari parameter Temperatur Maks, Temperatur Min, dan Temperatur Rata-Rata tiap bulan di tiap tahun dan menggunakan tes tren Mann-Kendall, algoritma akan mendeteksi tren-tren tiap varians setiap bulan sepanjang tahun-tahun dan setiap tahun dan menyimpulkan apakah ada tren atau tidak dan jika ada, apakah tren tersebut tren menaik atau tren menurun. Dengan membandingkan hasil-hasil perhitungan selama tahun 2010 sampai 2023, analisis ini akan menunjukkan bahwa Kota Padang mengalami perubahan iklim yang minimal dari tahun 2010-2023.

Kata kunci: Temperatur, Varians, Padang, Perubahan Iklim, Tren Temperatur.

ABSTRACT

The city of Padang located in West Sumatra experiences an average temperature ranging from 22°C to 32°C throughout the months with minimal fluctuations above 32°C or below 22°C. This paper's analysis is done with the data supplied by Badan Metereologi, Klimatologi dan Geofisika (BMKG) from the year 2010-2023 and the calculations in this paper will be done using an algorithm written in the Python coding language on Google Colab that calculates the variance of the parameters Maximum Temperature, Minimum Temperature and Average Temperature of each month throughout the year and yearly, using the Mann-Kendall trend test, it will detect the trends of each variance of each month throughout the years and deduce whether there is a trend or not or if there is, whether the trend is ascending or descending. By comparing these values throughout the years, the analysis will show the minimal climate change Padang City has experienced through the years 2010-2023.

Keywords: Temperature, Variance, Padang, Climate Change, Temperature Trends.

1. INTRODUCTION

Temperature can be defined as a measure of hotness or coldness that are expressed in several arbitrary scales and indicates the direction in which heat energy will flow. Different regions may use different temperature scales, Indonesia uses Celsius (°C) which is the standard temperature scale that is adopted by all countries that use the metric system. Temperature trends are the average increase or decrease of temperature throughout the time of interest, in this paper the time of interest is between 2010–2023. The trend detected in temperature trend analysis is the rate at which temperature changes over a certain time period [1]. Temperature trend analysis is important for climate research and the results of which can determine the average rate increase of a certain month, the average rate decrease or if there is no trend.

Climate change refers to long term shifts in weather or temperature patterns. Natural climate change can happen slowly throughout the years due to natural causes such as a volcanic eruption or tsunami. However, since the 1800s, due to human interference such as burning of fossil fuels climate change can occur unnaturally, this kind of climate change is called anthropogenic climate change.

Climate change that occurs in a short time period can be a concerning sign of anthropogenic climate change as natural climate change typically occurs within long spans of time. Climate change has impacted a lot of sectors of human development due to its impacts on the earth such as rise of sea levels, melting of polar ice, bush fires, and much more [2].

Indonesia is a country that has a tropical climate, this is because Indonesia is located in the equator between 6° LU- 11° LS dan 95° BT- 141° BT. Indonesia's tropical climate means that the country only has two seasons, dry season and rainy season with each season lasting for 6 months each. Dry season starts in April and lasts until September whereas rainy season starts in September and lasts until March. Tropical climate regions typically don't have large shifts in temperature as one day can be very similar to the next, but the change between day and night can be higher than average.

Padang is the provincial capital of West Sumatra, Indonesia. It is located on the western coast of Sumatra with an area of 1.414,96 km². More than 60% of that area or around 434,63 km² are hills covered with protected forests and the rest are urban areas for city infrastructure. The average temperature of Padang city for the year is 26.7°C. The average temperature of its warmest month on average which is January is 27.2°C and the average temperature of its coldest month on average which is September is 26.1°C. The temperature in Padang rarely fluctuates above 32°C or below 22°C making Padang a city with an average of hot temperatures year-round thus the climate variance of Padang city should not be drastic from month to month.

Previous studies have been conducted in Padang city's climate such as the study on the influence of the effects of greenhouse gasses on the temperature of Padang [4], the study of thermal comfort in Padang's coastal tour area, and an analysis on the changes of climate elements in Padang City [6]. However, there has not been any studies that involve searching the variability trends of Padang city's temperature. Analysis of temperature variability is a fundamental aspect of climate science that is done to gain insight into climate change and to identify trends.

This paper will focus on the analysis of monthly temperature variability in Padang, West Sumatra from the years 2010 to 2023 and aims to analyze and draw a conclusion to the climate change of Padang city over the years and identify its trends by using the variance of temperature. Variance is the measurement of the spread between numbers in a certain dataset. Previous studies have shown that the trends in temperature variance can be attributed to predicting changes in temperature extremes [7]. The Mann-Kendall test will be used to test the temperature trends in the variance values. The Mann-Kendall test is a test used to detect increasing trends or decreasing trends in a series of data. The Mann-Kendall test can also detect no trend in which the data is stable and is not experiencing much change [8].

2. RESEARCH METHOD

The analysis method used in this paper is Descriptive Analytics. Descriptive Analytics is an analysis conducted to answer questions about events that have happened. This paper's analysis aims to answer the question of "How is the climate change in Padang city from 2010 to 2023?" by looking and comparing the variances of each month and detecting the trends in the variances.

2.1 Data

The data used in this paper is the daily climate data sourced from *Badan Metereologi, Klimatologi dan Geofisika* (BMKG) from Padang, West Sumatra with parameters of Maximum Temperature (Tx), Minimum Temperature (Tn), Average Temperature (Tavg), Average Humidity (RH_avg), Rainfall (RR), Duration of sunshine (ff_x), Wind Speed during maximum speed (ddd_x), The average Wind Speed (ff_avg) and The most wind direction (ddd_car). For this study, the only parameters that will be used are the Maximum, Minimum and Average Temperatures (Tx, Tn, Tavg).

The station that this data is sourced from is the *Unit Pelaksana Teknis* (UPT) station, Meteorology Station Maritim Teluk Banyur nomor 96161. The data is collected by BMKG using various machines that are put in a place called *Taman Alat*. Some of these machines include the Meteorology Cage (*Sangkar Meteorologi*), Hellman Rain Gauge (*Panakar Hujan Hellman*), OBS Rain Gauge (*Panakar Hujan OBS*), Tipping Bucket, Campbell Stokes, and many more [9].

2.2 Research Workflow

Below is a diagram of the workflow analysis of this paper. It details the steps taken to create this paper, starting from data collection and ending at data visualization. The data will be processed using the Python coding language and on Google Colab. The libraries needed to process the data are Numpy (np), Pandas (pd), Matplotlib (plt), Calendar, and Pymannkendall (pk).

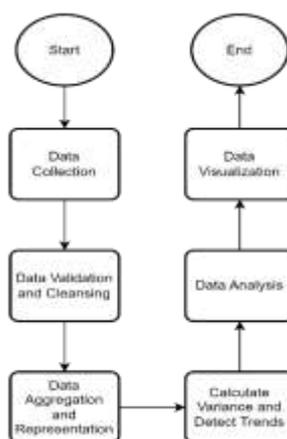


Figure 1. Research Flowchart

2.3 Pre-processing Data

The first step is Data Collection. Data Collection is one of the first steps that must be done in the Big Data cycle. As previously mentioned, the data is collected from BMKG. All data collected are complete on the exception of the year 2023 which at the time of the data collection only had up to April. Climate data is downloaded from the BMKG database for every month in the years 2010 – 2023 and compiled together into a single excel file. This excel file will then be uploaded to Google Drive and read into a Pandas dataframe using the function `pd.read_excel` from the Pandas library.

In the next step, Data Validation and Cleansing plays a crucial role in the Big Data cycle. Data Validation and Cleansing is done to prevent redundancy in the dataset. The data will be loaded into the Google Collab Python algorithm as a dataframe using the function `pd.read_excel()` from Pandas library then the parameters will be checked for any unreadable data values such as the value 8888 which means unmeasured data or the value 9999 which means no data. The values that are unreadable will be replaced with a missing value or NaN.

The data will then be further validated by the criteria set for it. The criteria set for the dataset will determine what value is kept and what value will be replaced with a NaN value. The criterias are:

- For Temperature parameters (Tx, Tn and Tavg), any value that is lower than 17°C or higher than 40°C will pass the criteria and will be replaced with a NaN value
- for Humidity (RH_avg), any value that is lower than 40% will be replaced with a NaN value
- For Wind Speed parameters (ff_x, and ff_avg), any value that is 0 will be replaced with a NaN value
- For the entire dataset, all values from all parameters will be tested according to this comparison:

$$MeanP + 3 * StdP < Value \text{ OR } Value < MeanP - 3 * St \quad (1)$$

In which MeanP means the Mean of the parameter and StdP means the standard deviation of that parameter. Data that fulfills the criteria will be replaced into a NaN value.

The missing values in the dataset will then be counted using the `df.isna().sum()` function in the Pandas library that returns the number of missing values in the dataset. If the function returns a value higher or the same as 30 then the parameter will be dropped. The dataset of Padang city's climate did not have any parameters with NaN values higher than 30 therefore no parameters are dropped.

All NaN values will be filled using the `bfill()` method from the Pandas library in Python which replaces NaN values with the next non NaN value in the parameter. The cleansed and validated data will be saved into the second sheet of the excel file using the Pandas library function `pd.ExcelWriter` and the engine `openpyxl`.

Data Aggregation and Representation is done to group certain parameters in the dataset for the purpose of the analysis. The Date parameter in the dataset will be split into 3 parameters. Year, Month and Date. The split is done using the `dt` function in Pandas to access the date like properties of a series, `dt.month` is used to separate the Date parameter into a Month parameter with numbers to represent which month, `dt.year` is used to separate the Date parameter into a Year parameter and `dt.day_name()` is used to turn the Date parameter to only have the day names.

The calculation of variance is done using the `np.var()` function from the Numpy library. This function calculates the variance of the given parameter this process is repeated for the monthly and yearly datasets and is compiled into a list using a for loop. The equation for variance is:

$$S^2 = \frac{\sum (x_i - \underline{x})^2}{n - 1} \quad (2)$$

Further explanation of the equation:

- a. S^2 = The sample variance.
- b. x_i = One of the values in the parameter.
- c. \underline{x} = The mean of the parameter.
- d. n = The number of values in a certain parameter.

2.4 The Mann-Kendall Test

The result of variance will then be tested for a trend using the Mann-Kendall test. This is done using the `Pymannkendall` library function, `pk.original_test()` where the previous list is converted to a numpy array to execute the function. The Mann-Kendall test is counted with this formula [10]:

$$S = \sum_{s=1}^{n-1} \sum_{t=s+1}^n \text{sign}(x_t - x_s) \quad (3)$$

Further explanation of the equation:

- a. t dan s = The Intervals of the dataset.
- b. x_s = The value of each interval of - s .
- c. x_t = The value of each interval of - t .
- d. n = The number of values in a certain parameter.
- e. With the criteria = $\text{sign}(x_t - x_s) = \{1, (x_t - x_s) > 0, (x_t - x_s) = 0 - 1, (x_t - x_s) < 0\}$

The results of the Mann-Kendall test will be printed out to show whether there is a temperature trend or not and whether that trend is increasing or decreasing. A no trend result means there is no correlation or the result is 0, an increasing trend means that there is an increase in the values throughout time or the result is 1, and a decreasing trend means that there is a decrease in the values throughout time or the result is 0. This process will be repeated for the monthly and yearly datasets

Data Analysis is one of the most important steps in the Big Data cycle, it is done to draw a conclusion to the research so far. As mentioned above, the paper will do a Descriptive Analysis on the dataset thus far, this analysis is done to answer the question of “How is the climate change in Padang city from 2010 to 2023?”. The analysis will draw a conclusion from the available dataset and the calculations done such as the temperature variances and the temperature trends

Data Visualization is the last step in the Big Data cycle. In this step, the data obtained thus far and the calculations done will be visualized in the form of a line graph. The parameter Maximum Temperature (Tx) will be highlighted with a green colored line graph, the parameter Minimum Temperature (Tn) will be highlighted with a red colored line graph and the parameter Average Temperature (Tavg) will be highlighted with a blue colored line graph. This paper will show the graphs of the variances of each month throughout the years.

3. RESULTS AND DISCUSSIONS

In the years from 2010 to 2023, there are little temperature trends. The table below will show the list of months and the temperature trend in each month throughout the years of the parameter Average Temperature (Tavg) using the Mann-Kendall test.

Table 1 Temperature Trend of Variances for Average Temperature (Tavg) from January to December 2010-2023

Month	Trend
January	No Trend
February	No Trend
March	No Trend
April	Decreasing
May	No Trend
June	No Trend
July	No Trend
August	No Trend
September	No Trend
October	No Trend
November	No Trend
December	No Trend

In the table above, all months except April have no trend, this means that the variance values for all months except April don't exhibit any consistent increasing or decreasing values over time. On the other hand, the month of April has a decreasing trend, this can further be seen with the graph below.

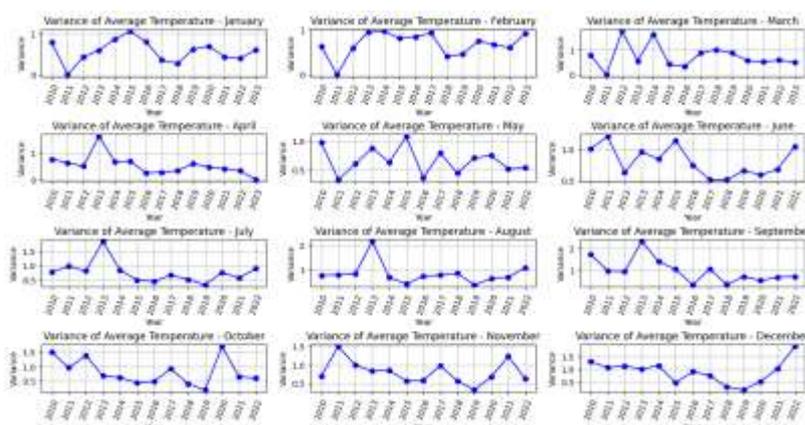


Figure 2. Graph of Average Temperature Variance from January to December 2010-2023

In the graphs above, the month of April is the only month with a steady decrease in variance proving that the temperature trend of April is a descending trend. The descending trend starts at the year 2019 and slowly descends with the year 2023. Variance spikes that can be seen in this graph are the month of February's decrease in temperature variance in the year 2011 and the increase of temperature variance in the year 2013 for the months April, July, August, and September. The month with the most variance fluctuations is May, with high spikes on the year 2010, 2013, and 2015 and low spikes in the year 2011.

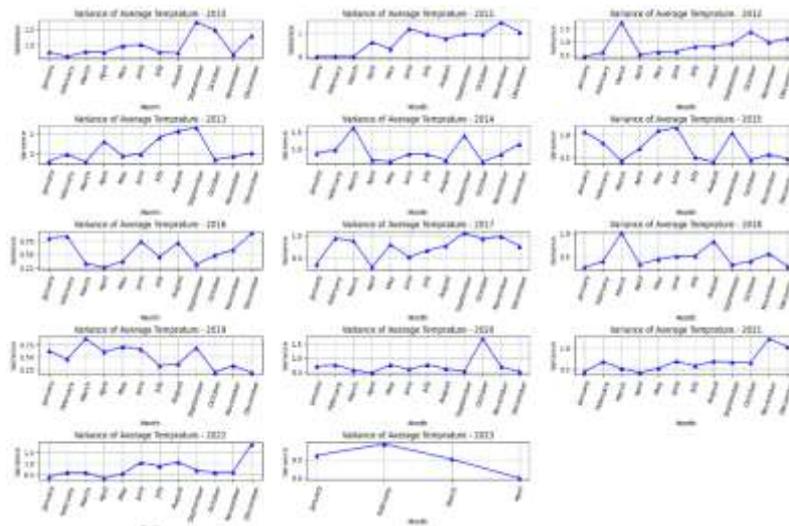


Figure 3. Graph of Average Temperature Variance from 2010-2023

The graph above shows that the spikes of the months from earlier correlate with the overall variance of that year. With the abnormality being the year 2010 and its sudden rise in September, 2012 and its sudden rise in March, 2020 and its sudden rise in October and the year 2022 with its sudden rise in December. Below is the table for the Mann-Kendall test of the yearly variance of Average Temperature

Table 2 Temperature Trend of Variances for Average Temperature (Tx) from 2010-2023

Year	Trend
2010	No Trend
2011	Increasing
2012	Increasing
2013	No Trend
2014	No Trend
2015	No Trend
2016	No Trend
2017	No Trend
2018	No Trend
2019	Decreasing
2020	No Trend
2021	Increasing
2022	No Trend
2023	No Trend

The table shows that the year 2011, 2012, 2019 and 2021 have temperature trends. The other years do not have temperature trends and can be taken as not exhibiting any consistent increase or decrease in value over time.

Refer to Figure 3 to see the graphs. The year 2011 has an increasing temperature trend where it has an increase from March and April, fell in May, increased again in June, fell in July and August and has had a steady ascent to December. The year 2012 has an increasing temperature trend where there is a high spike from February to March, a steep decline in April and a steady increase from April to October, falling in November and increasing again in December. The year 2019 has a decreasing temperature trend where March is the peak height of the variance and it falls in April, increasing at May and falls in June and July, increasing slightly in August and then increasing by much more in September, falls in October, rises slightly in November and falls again in December. The year 2021 has an increasing temperature trend that can be seen with the Image 3. The increase primarily starts in July to November with its peak in November and falls in December.

Below is a list of all the highest variances of each month and the lowest variances of each month:

- a. The highest variance for January is in 2015 (1.060) and the lowest variance is in 2011 (0.050)
- b. The highest variance for February is in 2014 (0.968) and the lowest variance is in 2011 (0.012)
- c. The highest variance for March is in 2012 (1.745) and the lowest variance is in 2011 (0.050)
- d. The highest variance for April is in 2013 (1.630) and the lowest variance is in 2023 (0.0)
- e. The highest variance for May is in 2015 (1.081) and the lowest variance is in 2011 (0.334)
- f. The highest variance for June is in 2011 (1.214) and the lowest variance is in 2018 (0.513)
- g. The highest variance for July is in 2013 (1.835) and the lowest variance is in 2019 (0.330)
- h. The highest variance for August is in 2013 (2.162) and the lowest variance is in 2019 (0.360)
- i. The highest variance for September is in 2013 (2.332) and the lowest variance is in 2016 (0.311)
- j. The highest variance for October is in 2020 (1.690) and the lowest variance is in 2019 (0.198)
- k. The highest variance for November is in 2011 (1.489) and the lowest variance is in 2019 (0.332)
- l. The highest variance for December is in 2022 (1.911) and the lowest variance is in 2019 (0.186).

Table 3 Temperature Trend of Variances for Minimum Temperature (Tn) from January-December 2010-2023

Month	Trend
January	No Trend
February	No Trend
March	Decreasing
April	No Trend
May	No Trend
June	No Trend
July	No Trend
August	No Trend
September	No Trend
October	No Trend
November	No Trend
December	No Trend

In the table above, the only month with a temperature trend is March and it is a decreasing temperature trend, all other months do not have a trend. This means all months except March do not exhibit a consistent pattern of increasing or decreasing values over time. The graph below will clarify the temperature trend decrease as well as show other variances.

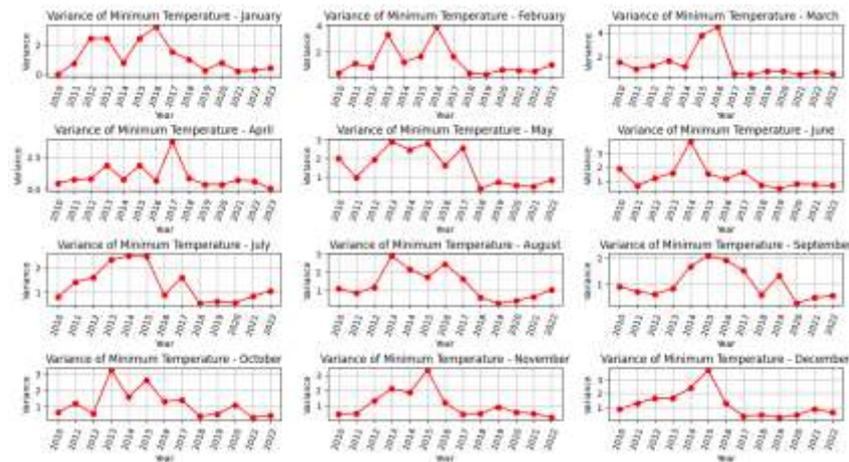


Figure 4. Graph of Minimum Temperature Variance from January to December 2010-2023

In the graphs above, the month of March shows a significant declining temperature trend starting from the temperature variance of 2016, only rising a small amount on the years 2019, 2020 and 2022. Variance spikes that can be seen in this graph are the month of April's increase in variance in 2017, the month of March's increase in the years 2015 and 2016 and February's increase in variance in the year 2013 and 2016. The month with the most variance fluctuations is February with high spikes in the year 2013 and 2016 and low spikes in the year 2010 and 2012.

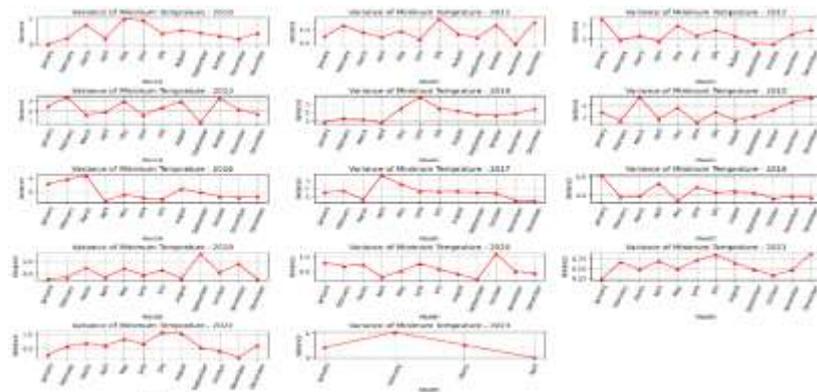


Figure 5. Graph of Minimum Temperature Variance from 2010-2023

The graph above shows the correlation of the earlier spikes with the overall variance of that year. There are no abnormalities in this graph as the variances fluctuate similarly. Below is the result of the Mann-Kendall test for the yearly variance of Minimum Temperature.

Table 4 Temperature Trend of Variances for Minimum Temperature (Tx) from 2010-2023

Year	Trend
2010	No Trend
2011	No Trend
2012	No Trend
2013	No Trend
2014	No Trend
2015	No Trend
2016	No Trend
2017	Decreasing
2018	No Trend
2019	No Trend
2020	No Trend
2021	No Trend
2022	No Trend
2023	No Trend

The table shows that the only year with a temperature trend is 2017. The other years have no trends and thus can be taken as not exhibiting any consistent increase or decrease over time. The year 2017 has a decreasing trend which can be seen with Image 5 where the peak of the year is in April and the variance declines until December.

Below is a list of all the highest variances of each month and the lowest variances of each month:

- a. The highest variance for January is in 2016 (3.188) and the lowest variance is in 2010 (0.0)
- b. The highest variance for February is in 2016 (3.857) and the lowest variance is in 2019 (0.343)
- c. The highest variance for March is in 2016 (4.432) and the lowest variance is in 2021 (0.473)
- d. The highest variance for April is in 2017 (3.728) and the lowest variance is in 2023 (0.0)
- e. The highest variance for May is in 2013 (2.894) and the lowest variance is in 2018 (0.347)
- f. The highest variance for June is in 2014 (3.823) and the lowest variance is in 2019 (0.432)
- g. The highest variance for July is in 2014 (2.457) and the lowest variance is in 2018 (0.576)
- h. The highest variance for August is in 2013 (2.884) and the lowest variance is in 2019 (0.293)
- i. The highest variance for September is in 2015 (2.066) and the lowest variance is in 2020 (0.261)
- j. The highest variance for October is in 2013 (3.209) and the lowest variance is in 2021 (0.318)
- k. The highest variance for November is in 2015 (3.315) and the lowest variance is in 2022 (0.189)
- l. The highest variance for December is in 2015 (3.658) and the lowest variance is in 2019 (0.264).

Table 5 Temperature Trend of Variances for Maximum Temperature (Tx) from January to December 2010-2023

Month	Trend
January	Increasing
February	No Trend
March	No Trend
April	No Trend
May	No Trend
June	No Trend
July	No Trend
August	No Trend
September	No Trend
October	No Trend
November	No Trend
December	No Trend

In the table above, the only month with an identified temperature trend is January. The other months besides January have no discernable trend and doesn't have a consistent increase or decrease of values over time, the temperature trend on January is an increasing trend. The graph below will clarify the temperature trend increase as well as other variances.

In the Figure 6, January can be seen experiencing an increasing trend starting from 2012 and increasing at 2013, the temperature variance decreased in 2014 but increased again from 2015 to 2016, the value decreased in 2017 and slowly increased until 2021, in 2022 it decreased and increased again in 2023. Variance spikes that can be seen with this is the month of August's sudden spike in the year 2018 and 2022. For most of the years August has kept a variance of around or lower than 1. The month with the most variance fluctuations is May with high spikes in the year 2011 and 2018 and low spikes in the year 2012, 2015 and 2017.

In the Figure 7, shows the correlation of the previous spikes with the overall variance of the year. The abnormalities in this graph are the sudden rise in variance in July of 2014 and the sudden rise in variance in December of 2022. The Table 6 for the Mann-Kendall test of the yearly variance of Maximum Temperature can be seen below

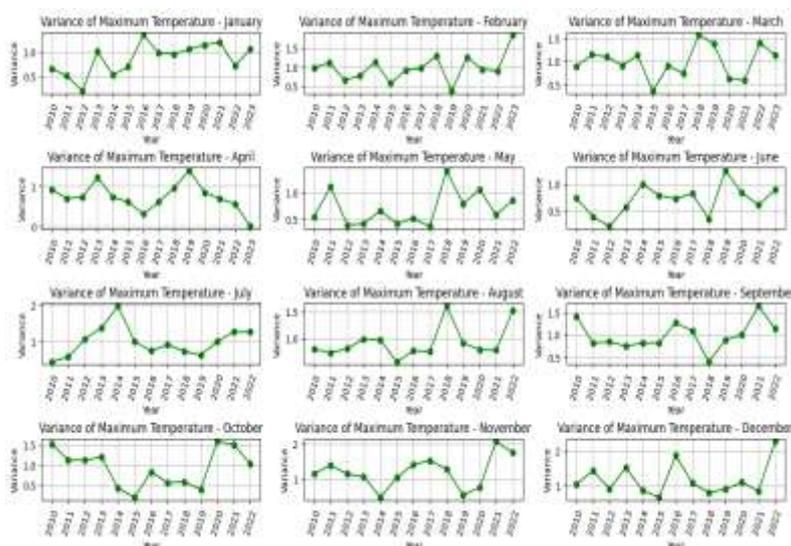


Figure 6. Graph of Maximum Temperature Variance from January to December 2010-2023

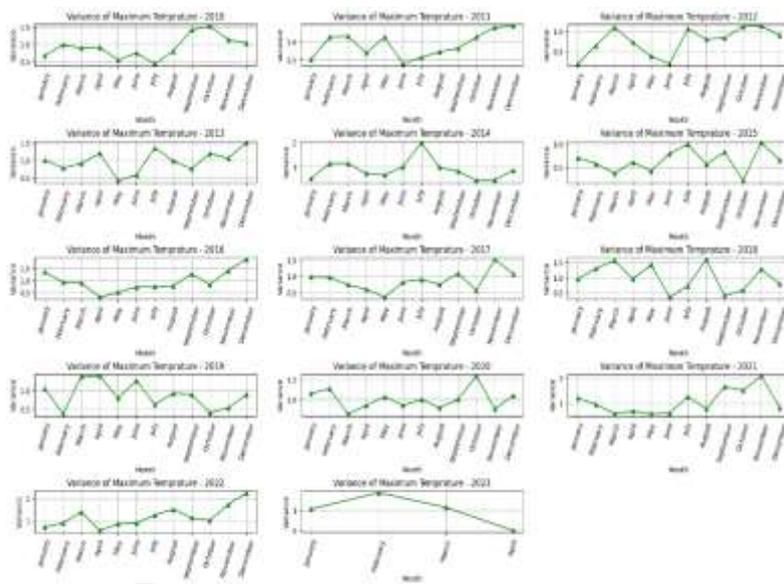


Figure 7. Graph of Maximum Temperature Variance from January to December 2010-2023

Similar to the Mann-Kendall test performed in the months. The majority of the years show no trend with only 2012 and 2022 having trends. On Image 7 the year 2012 has an increase from the month June to July, dropping in August and continuing the ascent till December where it dropped again. On the other hand the year 2022 has a steady increase from June to August, dropped in September and October and increased again till December.

Below is a list of all the highest variances of each month and the lowest variances of each month:

- a. The highest variance for January is in 2016 (1.350) and the lowest variance is in 2012 (0.210)
- b. The highest variance for February is in 2023 (1.856) and the lowest variance is in 2019 (0.371)

- c. The highest variance for March is in 2018 (1.572) and the lowest variance is in 2015 (0.363)
- d. The highest variance for April is in 2019 (1.389) and the lowest variance is in 2023 (0.0)
- e. The highest variance for May is in 2018 (1.425) and the lowest variance is in 2017 (0.362)
- f. The highest variance for June is in 2019 (1.268) and the lowest variance is in 2012 (0.205)
- g. The highest variance for July is in 2014 (2.457) and the lowest variance is in 2018 (0.576)
- h. The highest variance for August is in 2018 (1.608) and the lowest variance is in 2015 (0.558)
- i. The highest variance for September is in 2021 (1.647) and the lowest variance is in 2018 (0.399)
- j. The highest variance for October is in 2020 (1.588) and the lowest variance is in 2015 (0.205)
- k. The highest variance for November is in 2021 (2.066) and the lowest variance is in 2014 (0.469)
- l. The highest variance for December is in 2022 (2.284) and the lowest variance is in 2015 (0.657).

Table 6 Temperature Trend of Variances for Maximum Temperature (Tx) from 2010-2023

Year	Trend
2010	No Trend
2011	No Trend
2012	Increasing
2013	No Trend
2014	No Trend
2015	No Trend
2016	No Trend
2017	No Trend
2018	No Trend
2019	No Trend
2020	No Trend
2021	No Trend
2022	Increasing
2023	No Trend

From the variances and temperature trends observed above, it can be deduced that the climate change in Padang city from 2010 to 2023 is quite minimal. There are signs that the temperature is getting warmer though it isn't by much and happens relatively rare in the timespan of 2010-2023. The variance of the parameter Minimum Temperature experienced the most fluctuations whereas the variance of the parameter Maximum Temperature experienced the least fluctuations in its variance. The parameter with the most abnormalities is Average Temperature.

4. CONCLUSION

The analysis this paper conducted is done with data from BMKG and the data is then processed using an algorithm written in Python. The algorithm is capable of clearing redundancy in the data and calculating the variance and conducting the Mann-Kendall test. The analysis done in this paper is a Diagnostic Analysis done in the purpose to know what is the climate change in Padang, West Sumatra from the year 2010 to 2023. Based on the research and analysis done, this paper can conclude that the climate change happening in Padang city are quite minimal. The Mann-Kendall test shows that there are no trends in most of the months meaning that there is no significant and persistent increase or decrease of value throughout the years

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