# Statistical Analysis on Climate Change and How It Is Affected by Global Warming

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***Abstract*—This research is about an analysis of climate and how the global warming is effecting it. This research focuses on the daily changes in climate and CO2 emission. Using linear regression model, we found a co-relation co-efficient among the climate factors and CO2 emission data. Also using the same method we did a prediction on the given dataset. (*Abstract*)**

***Keywords*—climate change, global warming, temperature, co2 emission, rainfall***

## I. Introduction

It is no new phenomenon that the surface temperature has been increasing every year. The climate of today is not the same as it was 10 years ago. However, even though it was possible to predict weather conditions based on previous data, nowadays it has been to predict the weather due to some factors. The factors include human activity which is causing the increase in global warming. Due to global warming the ozone layer is being affected which in return is heating up the Earth. Now how does global warming affect Bangladesh? Bangladesh is one of the most vulnerable countries in the world. Bangladesh is a high climate exposure area due to its geographical location. There are many threats that contribute to these risks. Such as sea-level rise, floods, cyclones and many more. This causes various infrastructural and economic problems in the country. Even though these risks are not avoidable it is possible to minimize the risks by proper policy making. And in order to have a good policy it is necessary to know about the risks of climate change.

As it is mentioned before, global warming is one of the key factors for the uncertainty of climate change. It is necessary to add the factor of global warming while predicting the weather. Bangladesh is a country that is rising in the industrial world. However there are many chemicals which are not tended to as per the sustainable development goals. This is one of the key factors for the rising of $CO_2$ emission in the country. One particular pollutant that is released by such industries is $PM_{2.5}$. $PM_{2.5}$ is a particulate matter. They are fine inhalable particles which cause health problems and contribute to global warming.

The average global temperature and sea level are predicted to continue to rise, and models concur that human activity is changing the climate. It is also agreed that the weather will change. The purpose of this study is to find a relationship between climate change and global warming and how global warming is affecting the climate in Bangladesh. This research is necessary for policy making. And also in order to reach certain sustainable development goals in the future. Global warming is a phenomenon that is affecting the entire world and causing uncertainty in various aspects of the climate.

## Research Questions

1. How has the climate changed overtime?
2. How has global warming changed overtime?
3. Is Bangladesh actually getting warmer?
4. How has global warming affected different aspects of weather?
5. Is there a relationship between global warming and precipitation level?
6. How is global warming going to affect the climate of Bangladesh in the near future?

The data that is collected for the following research are collected from Bangladesh meteorological department. The data spans from 2016 to 2022. Also the data regarding global warming is collected from sources such as World Bank Data. The data that we have collected can be used to give valuable insights in many fields such as changes in temperature, wind, humidity and rainfall. It can also show the prospects in various fields such as renewable energy, agriculture, sea-level rise etc. However this research will focus more on how global warming is affecting the temperature, wind, humidity and rainfall in Bangladesh.

## Analysis

As data is collected of the weather and global warming. This research will focus on these two factors. The variables of weather such as temperature, wind, humidity and rainfall will be used to build a relationship with the data collected for global warming. The goal of this is to observe how these variables are sensitive to the changes in global warming. Then using a simple linear regression model it will be used to see trends and give a prediction regarding it.

## II. Literature Review

The weather conditions in India are unpredictable and may lead to some unprecedented events if they are not taken into account. This research paper prepared by Diksha Khatani and Dr. Udayan Ghose aims to solve this problem by creating a model using the hidden markov rule. Before moving on to the implementation the paper explains the techniques, benefits and limitations of using the Hidden Markov Model. While the Hidden Markov model is used, the algorithm that is used in this is the Viterbi Algorithm. And for the handling of data, transmission matrix and emission matrix is used. External toolkits are also used such as the MATLAB software for accurate weather prediction. The data that is used in this model uses 21 years of data from 1996 to 2017. The data is cleaned using various categorizing conditions and classifications. After cleaning the data the data is put to test.

After testing the data it is seen that to predict the weather data for the next five days the approach works very well. The weather pattern is shown as the output but the exact temperature could not be predicted [1].

It is known that there are various drawbacks when it comes to predicting weather. Inorder to reduce such problems, various algorithms are used. But among them Kalman filter gives the most accurate prediction within meteorological purpose and other applications. Kalman filter algorithms' structure is better suited to describe linear processes. This makes their application to meteorological parameters with discontinuous or nonlinear behavior always suspect. The results on this research is based on temperature and pressure on two different locations within South Europe. This study's foundation is the nonlinear Kalman filter correction of forecast bias. It specifically focuses on the examination of one meteorological parameter over time, based on an estimation of this parameter's bias as a function of the direct result of the forecasting model. The data set that is used here is of one year worth of data. Even though the results were the same as the other methodologies this method offers lowers computational cost and higher accuracy [2].

It is no new phenomenon that the surface temperature is increasing at an alarming rate and along with that the global $CO_2$ emission has also been increasing. Now we know that a relationship exists between these. two. Global $CO_2$ emission has a direct impact on global temperature. The research aims to combine time-series and spectral analysis techniques is developed in this paper. Based on 129 years of data from 1860 to 1988, the method is applied to a numerical study of the relationship between $CO_2$ emissions and global climate change. The earliest continuous instrumental L. Sun and M. Wang 329 records for temperature, including climate temperature anomalies, are available to the authors. These data, along with those for global $CO_2$ emissions, are obtained from the Carbon Dioxide Information Center, a renowned research center with a focus on $CO_2$ research. The algorithm that is used here is the Granger causality test. It is used to test the relationship between these two variables i.e global warming data and global $CO_2$ emission data. At first the Dicker fully unit roots test is done to judge whether the process is stationary. After extracting a regression model that is stationary. To make the results more accurate a pre-whiten filter was used to make the model more stationary statistically and two other tests were done which were the Sim test and the Geweke-Meese-Test.The spectral analysis investigates the characteristics of time series in the frequency domain, which corresponds to causality analysis in the time domain. This paper aims to investigate how $CO_2$ emissions and climate change are related. A cross spectral analysis was used as a result, which estimates the spectra using multichannel spectral estimation. After all these tests it is seen that the change in $CO_2$ is ahead in terms of temperature. As a result, the models' findings imply that carbon dioxide is partially to blame for the temperature changes. The study offers compelling numerical proof that rising $CO_2$ emissions do indeed result in a rise in global temperatures [3].

Although there are many researches that focus on land or ocean, there are researches that rarely focus on streams and lakes. This research proposes to examine the correlation between the stream temperature and air temperature. Temperature records for 43 streams scattered throughout the state of Minnesota were obtained for this study from the U.S. Geological Survey (USGS)stream database. The average span of these records are 3 years but it differs from station to station. Air temperature records were obtained from theMidwest Climate Center of the Illinois State WaterSurvey in Champaign, Illinois. The algorithm that was used to analyze the data is simple linear regression. From the analysis it is seen that the measured water temperatures closely match the cycle of the yearly air temperatures. By using the model it is also predicted that Minnesota's air temperatures are predicted to increase by 4.3°C in the warm season (April–October) if atmospheric $CO_2$ doubles in the future. If stream temperature remained unchanged, this would result in an average increase in stream temperature of 4.1°C [4].

Global warming has increased at an alarming rate in all parts of the world. According to the National Oceanic and Atmospheric Administration it is 0.7 °C. Every observational dataset in the world shows an increase in global temperature. This particular study is conducted in Serbia, which is located on the Balkan Peninsula in southeast Europe. This study aims to investigate the spread of future climate characteristics and their effects in relation to future human behavior in GHG emissions. The dataset that is used is obtained from E-OBS daily temperature data for the period 1961-2015. Ensemble regression algorithm is used to analyze the dataset. This research also helps to predict risks that might occur due to climate change. Last but not least, the results section reveals that the mean temperature will rise by 2.5 °C under the stabilization scenario RCP4.5 and by over 5 °C under the constant increase scenario RCP8.5, along with a decrease in summer precipitation and an increase in precipitation intensity, while total annual values do not demonstrate any discernible changes. Furthermore, it is more crucial to consider precipitation when analyzing precipitation change because model variability indicates greater uncertainty and a border that runs through Serbia, which separates future increases in precipitation at the north and decreases at the south, varies greatly among models [5].

It has been known for decades that climate change has a direct impact on human crises and agricultural production. But no research has been done to examine this arbitrary connection. This research examined how to do just that. The data is collected from both times. One from a time of harmony while the other in a time of crisis. The information gathered includes historical information on the climate, agroecology, economy, society, human ecology, and demography in Europe between the years of 1500 and 1800. The analysis was done following three steps. Firstly a relationship was built between variables and a causal linkage was done to connect climate change and temperature. Second, correlation and regression tests were conducted to confirm the consistency and strength of the causal linkages. Cross correlation and multiple linear regression tests were done for this. Finally, the time sequence of the causal linkages was verified using Granger Causality Analysis. Given that the information used in this study comes from both the golden and dark ages of Europe, the findings show that pre-industrial Europe and the

Northern Hemisphere's major human crises were ultimately caused by climate change, and that the economic downturn that resulted from it was a direct cause [6].

In order to make policies for climate aid, it is required to know the climate outcomes under various policies. Even though there is much research regarding climate prediction. This research focuses on the uncertainty of climate change. These uncertainties include both economic and components of climate. Historical large-scale climate data is used for this process. It is not mentioned what span of data or the location of data that is used for this research. The model that is used to train the model is called Integrated Global System Model prepared by MIT. This model contains the EPPA model, climate model, 2D ocean model, terrestrial ecosystem model and natural emission model. This uncertainty analysis shows that the sea level rise due to thermal expansion will have a significant increase in uncertainty and that the temperature change in 2100 will be somewhat greater. The inability of the climate change diagnostics to limit the uncertainty in the rapid heat uptake by the deep ocean, however, renders many results related to sea level inaccurate [7].

The planning of electricity generators depends on the electricity load forecast. Weather forecasting is now required in order to predict the electricity load. Inefficient electricity generators or a lack of electricity in the grid system may result from overestimated or underestimated forecasting values. In this paper possible weather parameters are studied that affect electricity load. The data for this is collected from an isolated power grid system at Bali Island and the weather data is collected from European Centre for Medium-Range Weather Forecasts. With these two combined a correlation is investigated. Then the generalized algorithm neural network and Support Vector Regression is used to find the trends and predict weather and electricity load data. The findings indicate that the temperature, followed by sun radiation and wind speed, is the weather variable that has the highest correlation value with Bali's electricity load. With correlation coefficient values of 0.95 and 0.965, respectively, the GRNN and SVR provide the best prediction [8].

Convection jumps (CJs), which are characterized climatologically by an abrupt increase in convection over the western North Pacific (WNP) around 20°N and 150°E, occur in mid-July and are linked to a quick decline in the Baiu rainband over central Japan through the excitation of a stationary Rossby wave. The repeatability of seasonal precipitation fluctuations across central Japan is assessed using the CMIP3 multi-model. Based on this assessment, they compute weighted multi-model ensembles and analyze potential future changes to the Baiu withdrawal and related changes to seasonal evolutions over the WNP. According to earlier studies, the departure of the Baiu rainy season over Japan will be delayed by global warming. There is a correlation between the Baiu withdrawal and the start of convective activity over the WNP in mid-July, according to observational studies. Active convections above the WNP move southeastward under conditions of global warming. This adjustment is related to the Baiu retreat being postponed in a warmer climate. According to future projections, the tropical and subtropical North Pacific will experience greater SST warming than the other regions. By imposing these warm SST anomalies, AGCM experiments demonstrate that the shift in CJ's location related to the spatial distribution of warm SST anomalies may have played a significant role in the postponement of the Baiu withdrawal over central Japan [9].

Numerous physical and biological systems have already been impacted by global climate change, and terrestrial ecosystems paint a clear picture of the observed changes. Phenology, the study of naturally occurring recurrent phenomena, is one of the chosen indicators because the dates it records offer a high-temporal resolution of ongoing changes.
Consequently, multiple assessments have shown a longer growing season and earlier commencement of spring events for mid and higher latitudes. It is indisputable that spring phenology responded to temperature. It was discovered that the earlier species were more sensitive and were better at detecting temperature changes. This was presumably due to the higher temperature variability in the spring months. Further research on the observed effects of climate change in fall should clearly distinguish between these phases because the autumn signal was ambiguous (later leaf coloration, but earlier fruit ripening due to heat, with the latter more prominent in agricultural than wild plants). Early spring phases once more showed the highest reactivity, with temperature responses varying between 4.6 days 1C1 in the spring and 1 2.4 days 1C1 in the autumn. It may be possible to parametrize straightforward site-specific phenological models in the future where no data were observed because all spring phases in European countries, with the exception of R. pseudoacacia flowering, showed a stronger response to temperature in warmer countries with earlier mean onset dates [10].

By analyzing the records of temperature anomaly from the 1970s to 2010s, this study has accomplished this by adding to our understanding of climate change. The conclusions are drawn from a larger-scale analysis that covers the post-1977 era. Since then, the years with greater temperatures are documented, and there is a clear link between rising ocean surface temperatures and those years. This study identifies some of the nascent and emerging global warming trends and provides the first examination of global warming patterns. Future research on global warming from both the perspectives of context-specific and global-scale assessments will be aided by the innovative findings of this study. Three crucial conclusions about global warming trends and their severe effects on certain regions are made in this study. It challenges current research that exclusively examines small-scale or adaption metrics and instead advances knowledge with more general—yet primary—discoveries. The study comes to the conclusion that humans can only detect, evaluate, and comprehend global warming patterns on a global scale. The repercussions are more sub-regional in scope, but they have negative effects around the globe, notably with a significant disparity between the northern and southern hemispheres. The findings are concerning, and if the current patterns continue, the effects will worsen more quickly than anticipated and rise in severity [11].

The findings of a study on how global warming might affect river flow patterns in Great Britain are summarized in this research. Using a conceptual rainfall-runoff model with daily inputs of precipitation, potential evaporation, and, for a subset of the catchments, temperature, the study simulated daily river flows in 21 catchments. The UK Climate Change Impacts Review Group (CCIRG, 1991) served as the basis for the climate change scenarios, and the effects of changes relative to a baseline period of 1951–1980 were evaluated. The scenarios of equilibrium and transitory change were both used. The study's findings suggest that climate change may have a significant impact on river flow regimes in the UK, especially over shorter time periods. Under most scenarios, the flow range would increase, with higher winter flows and lower summer flows. However, there is a lot of ambiguity over the size of the change in river flows, partly because of variations in climate change scenarios [12].

Cities will be subject to localized impacts of urbanization, such as the urban heat island, and radiative forcing caused by greenhouse gasses. The HadAM3 Global Climate Model's urban land-surface model demonstrates that areas with rapid population expansion also have substantial urban heat island potential. Urban heat islands' climatic potential can fluctuate due to climate change, with certain sites seeing rises of 30% and a global average decrease of 6%. Climate change widens the gap between rural and urban areas in terms of the frequency of extremely hot nights. Warming and extreme heat events caused by urbanization and rising energy use are simulated to have an impact comparable to doubling CO2 levels in some places. The outcomes of these simulations show how local factors might increase urban people's potential susceptibility to climate change. Understanding and estimating the risks of future climate stress are crucial for research on climate impacts and adaptation, therefore it is crucial to take into account not just climate change but also population dynamics, urbanization, and energy usage. Our understanding of climate change in cities will continue to advance thanks to the continuous development of urban land-surface schemes appropriate for climate models. As a result of both local and global climate forces, GCMs can be an effective tool for estimating the possible cumulative effects of climate change on urban society and infrastructure [13].

The change in the global mean surface temperature following equilibrium in response to a doubling of the atmospheric CO2 concentration is known as equilibrium climate sensitivity (ECS). This paper focuses on studying the increase of ECS under global warming. For this data historical big data is collected from the following sources: preindustrial control simulations (piControl), simulations with instantaneously quadrupled atmospheric CO2 concentration and the extended Representative Concentration Pathway. In the end it was seen that the increase in ECS was the result of an increase in water vapor feedback [14].

Precipitation change is something that needs to be forecasted and it is widely used in various fields and a necessary thing. Now global warming affects the weather in many different ways. Thus, precipitation level is also sensitive to global warming. This paper studies the effects of global warming on precipitation sensitivity. The information gathered is from the gridded terrestrial precipitation dataset first published in Hulme (1992; 1994). The climate prediction model called HadCM2 model was used for the analysis. Now with large amounts of data it has been possible to predict the precipitation level of some areas but again for some areas there is a level of uncertainty due to various factors that were not taken into account [15].

## III. METHODOLOGY

### DATA COLLECTION

The research is about weather prediction and its effects on global warming. So naturally, the weather data was needed for analysis. Since the weather is based on Bangladesh, the weather of this country has to be collected. The weather data from 2016 to 2022 were collected from 'Bangladesh Meteorological Department' using a fetch method. However the dataset that was given was incomplete. There were no data for the year 2021. One of the possibility that the data is missing is because of the intervention of covid-19 for which the data was not collected. Another data that was collected was the daily emission of $PM_{2.5}$. $PM_{2.5}$ are the fine particles that are present in the air which is the result of $CO_2$ emissions. This data was collected from data storage platform. The data that was collected was based on the station situated at the Dhaka US Consulate office.

### METHODS

The main purpose of this method was to find how global warming was being affected by climate change. So for this we wanted to find a co-relation between the climate change factors which are temperature, wind speed and rainfall. We wanted to find a co-relation among these with the $CO_2$ emission dataset.
Now in order to do that first we had to pre-process the data. There are many values which contain NaN values and the analysis does not accept it in any way. For this the null values were identified and then converted to 0. Then each day was classified based on the temperature, wind speed and rainfall. The classification was done on hot/cold, calm/windy and dry/rainy [1]. Using these methods the weather was classified. The next step was to analyze the current weather step by step.

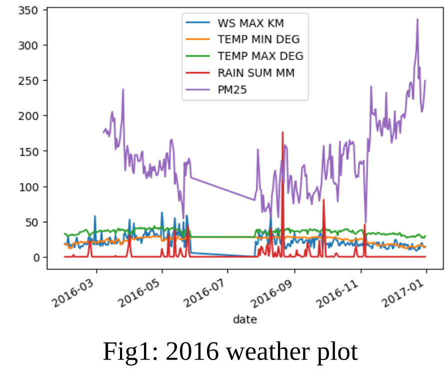


Fig1: 2016 weather plot

The above diagram shows the weather plot for 2016. From the graph we can see that the CP2 emission has been increasing steadily over the months. However no direct relation is seen with the temperature. However it is noticeable that with the decrease of temperature the CO2 emission increases. Also in 2016 we can see consistent rain between the months August to November. Withing these consistent rainy days we can see the CO2 emission decreasing.

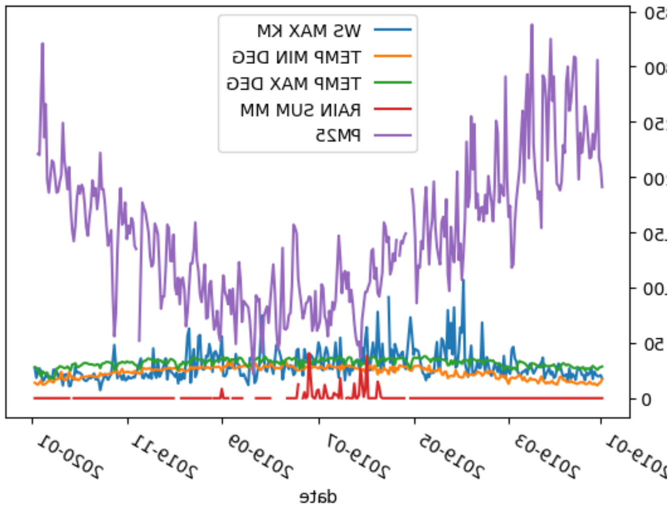

Fig 2: 2019 Weather plot

The above diagram shows the same type of analogy as before. With the increase in temperature the CO2 emission decreases while by the increase in temperature it decreases. Also with consistency of rainy days the CO2 emission decreases. However we have to find a statistical co-relation between these variables. For this we have used linear regression model. Other than finding the co-relation co-eficient, we also research on weather prediction using linear regression. For prediction we had to train and test the data. For training the data we used the data from 2016 to 2019 and for testing, we used the data after that.

## RESULT

In this study we wanted to do a statistical analysis on climate change and how global warming is affecting it. Now from the visual data we have seen that with the increase of temperature the CO2 emission decreases also the same with the increase of rainy days. Examining the co-relation heat map we have found the PM2.5 variable and minimum temperature variable share a strong negative co-relation which is -0.8. It also shares a negatice co-relation with the rainy days. From this we interpreted the interception point of the regression co-efficient which is 27.355 and the regression co-efficient being -0.039. Thus the equation that can be derived from this is $27.35 \ + (-0.039) pm25$

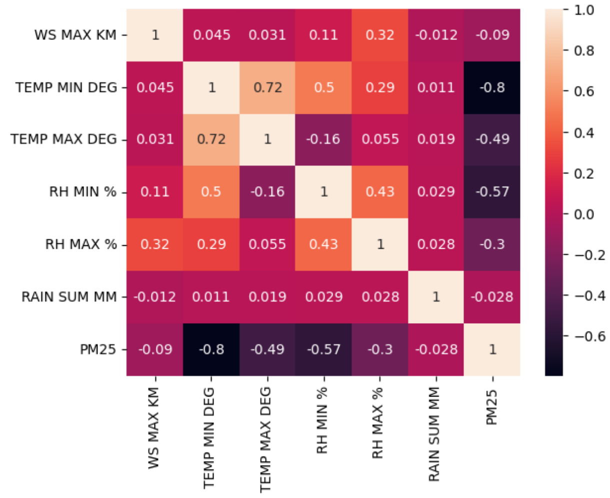


Fig 3: Co-relation Heatmap

Next is the weather prediction that is also done using linear regression model. Below shows the change of temperature from 2016 to 2022.

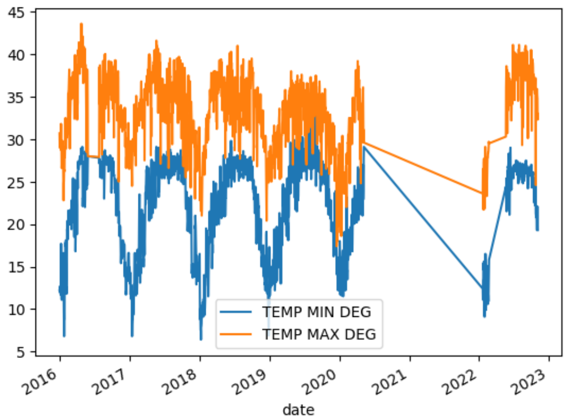


Fig 4: Change in Temperature Over the Years

From the above visual data it can be seen that the minimum temperature and maximum temperature has increased overtime. Also from the visual data we have seen that apart from temperature other temperature factor such as rainfall has decreased. Now for weather prediction we wanted to predict the max temperature of the dataset. For this we chose the predictors as rainfall, maximum temperature and minimum temperature. Using linear regression model we tested the dataset and found a mean absolute error of 1.5883027970168209. We were only of 1.58302℃.

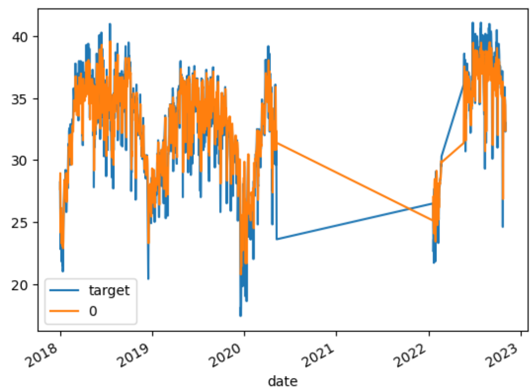

Fig 5: Prediction Model

Figure 5 shows the prediction model of our data. The orange colored data is our test data, while the blue colored data is our predicted data. Since the dataset of 2021 is missing the model was not able to predict the data for that year. In conclusion we have achieved an accuracy of 97.5%.

## IV. CONCLUSION

The main topic of this research was to know about the if the climate of Bangladesh is affected by CO2 emissions. From the data we have seen that the temperature and CO2 emission share a negative co-relational value. So the release of daily CO2 emission inversely affects the temperature. However, from the research paper reviewed it is seen that the global warming does not directly affect a regions temperature. Due to continuous accumulation the temperature of the region is changed. The temperature of the world has definitely changed over the years and it is not possible to determine it with daily CO2 emissions. In order to statistically analyze the data we would have get a historical big data of the temperature and CO2 emissions year by year. With that data we will be able to statistically prove whether the temperature has increase over the years. With the research shown in this study we have shown that the climate factors have a co-relation with the CO2 emission. However in order to analyze the data in a broader concept we would need big historical data of the region.

For data analysis of the climate factors we have seen that the max temperature has definitely has increased over the years. Both maximum temperature and minimum temperature has increased over the years. From the prediction of temperature data we achieved a mean absolute error of 1.58302℃.

With enough historical data we will be able to decrease the mean absolute error by a lot and give future prediction with the data.

## REFERENCES


[1] Khiatani, D., & Ghose, U. (2017, October). Weather forecasting using hidden Markov model. In *2017 International Conference on Computing and Communication Technologies for Smart Nation (IC3TSN)* (pp. 220-225). IEEE.

[2] Galanis, G., Louka, P., Katsafados, P., Pytharoulis, I., & Kallos, G. (2006, October). Applications of Kalman filters based on non-linear functions to numerical weather predictions. In *Annales geophysicae* (Vol. 24, No. 10, pp. 2451-2460). Copernicus GmbH.

[3] Sun, L., & Wang, M. (1996). Global warming and global dioxide emission: an empirical study. *Journal of Environmental Management*, *46*(4), 327-343.

[4] Pilgrim, J. M., Fang, X., & Stefan, H. G. (1998). Stream temperature correlations with air temperatures in Minnesota: implications for climate warming 1. *JAWRA Journal of the American Water Resources Association*, *34*(5), 1109-1121.

[5] Vuković, A. J., Vujadinović, M. P., Rendulić, S. M., Đurđević, V. S., Ruml, M. M., Babić, V. P., & Popović, D. P. (2018). Global warming

[6] impact on climate change in Serbia for the period 1961-2100. *Thermal Science*, *22*(6 Part A), 2267-2280.

[7] Zhang, D. D., Lee, H. F., Wang, C., Li, B., Pei, Q., Zhang, J., & An, Y. (2011). The causality analysis of climate change and large-scale human crisis. *Proceedings of the National Academy of Sciences*, *108*(42), 17296-17301.

[8] Webster, M., Forest, C., Reilly, J., Babiker, M., Kicklighter, D., Mayer, M., ... & Wang, C. (2003). Uncertainty analysis of climate change and policy response. *Climatic change*, *61*(3), 295-320.

[9] Aisyah, S., Simaremare, A. A., Adytia, D., Aditya, I. A., & Alamsyah, A. (2022). Exploratory Weather Data Analysis for Electricity Load Forecasting Using SVM and GRNN, Case Study in Bali, Indonesia. *Energies*, *15*(10), 3566.

[10] Inoue, T., & Ueda, H. (2012). Delay of the Baiu withdrawal in Japan under global warming condition with relevance to warming patterns of SST. *Journal of the Meteorological Society of Japan. Ser. II*, *90*(6), 855-868.

[11] Menzel, A., Sparks, T. H., Estrella, N., Koch, E., Aasa, A., Ahas, R., ... & Zust, A. N. A. (2006). European phenological response to climate change matches the warming pattern. *Global change biology*, *12*(10), 1969-1976.

[12] Cheshmehzangi, A. (2020). The analysis of global warming patterns from 1970s to 2010s. *Atmospheric and Climate Sciences*, *10*(3), 392-404.

[13] Arnell, N. W., & Reynard, N. S. (1996). The effects of climate change due to global warming on river flows in Great Britain. *Journal of hydrology*, *183*(3-4), 397-424.

[14] McCarthy, M. P., Best, M. J., & Betts, R. A. (2010). Climate change in cities due to global warming and urban effects. *Geophysical research letters*, *37*(9).

[15] Meraner, K., Mauritsen, T., & Voigt, A. (2013). Robust increase in equilibrium climate sensitivity under global warming. *Geophysical Research Letters*, *40*(22), 5944-5948.

[16] Hulme, M., Osborn, T. J., & Johns, T. C. (1998). Precipitation sensitivity to global warming: Comparison of observations with HadCM2 simulations. *Geophysical research letters*, *25*(17), 3379-3382.