Analysis of Historical Weather of Karnataka, India for Insights in Climate Trends

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***Abstract*—Climate change in simpler words means the change in the long-term average weather parameters. Climate change is an important issue because its causing imbalance in the environment and affects the lives of all flora and fauna. The climate change is due to many factors, but the major factor is the human activities which are leading to global warming over the past decades. Numerous studies consider analysis of continental or global data, providing the overall insights in climatic changes continentally or globally respectively. The approach in this paper considers regional analysis to provide better insights to the local people needs so they get adapted to the changes that are taking place. This provides a warning to the people to take preventive and precautionary measures. The dataset of Karnataka region from 1951 to 2020 is used to study the regional climate change pattern. The main objective of the paper is to analyze the climate change and extending in the future. The results show that there is a gradual increase of average mean surface air temperature and gradual decrease of the precipitation over each decade between the years 1951 to 2020. The trend line extending to 2040 by analyzing the historical data gives insights about the climate change in the near future. Understanding the historical data and the future predictions are very important to the policy makers, people and researchers so that effective planning can be done for adapting and decreasing the climate change patterns.**

***Index Terms*—Regional Climate trends, Environment impact, Agriculture**

I. Introduction

Climate change refers to the long-term changes in climatic factors. These changes can be due to natural phenomena, such as the sun's activity, volcanic eruptions or changes in atmospheric composition. But it is observed that from recent decades, the human activities have been the main reason for climate change. Climate plays an important role in our lives from deciding what clothes to wear, transportation, food production to our health and wildlife. From the industrial revolution era, the world has warmed by 1°C and this will be increasing. It is crucial to study and understand how the climate is changing for preventive measures and adaptation.

The annual global climate report May 2023 by National Centers for Environmental Information studies the anomalies during period 1850 to 2023. Based on 174 year dataset it observes that the month of May 2023 was ranked third warmest month across the globe [1]. The graph compares the temperature of the month of May with the average global surface temperature value 14.8°C shown in Fig. 1. It can be seen that till 1930 values are negative or below the reference value of 14.8°C. But the recent decades since 1980 it is observed that May month average temperature is gradually increasing above the average global surface temperature value. Table I summarises the warmest years globally.

Climate analysis helps to identify which region will be having harsh weather events. This will allow the government and people to be prepared and minimize the effects of it. By analyzing the current and future trends of the climate, we can learn how much rain we can expect in coming years or above the temperature raising , this will allow us to take to get adapted to the environmental changes. Understanding the climate change allows policy makers to make efficient policies to reduce the factors that are contributing to climate change and for facing the changes [2].

Section II discusses the prior work. Section III elaborates the proposed approach based on study of owning urban garden, the watering frequency, the types of plants and their water needs. A machine learning model and a smart system is developed to manage the watering. Section IV evaluates the system to distinguish plant categories based on water needs. Section V concludes by summarizing the advantages of the approach.

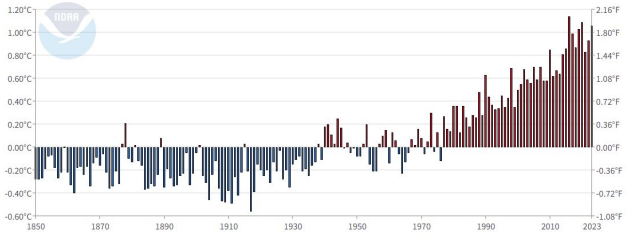

Fig. 1: Land and Ocean Global Climate comparision with the 20th-century average of 14.8C [1].

II. LITERATURE REVIEW

NarasimhaRao et al. implemented an IOT weather forecasting system that measures various parameters such as temperature, humidity, and rainfall and air pollution comparing with

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TABLE I: Summary of warmest years globally [1].

May	Anomaly		Rank		Records		
	°C	°F	(out of 174 years)		Year(s)	°C	°F
Land	+1.25	+2.25	Warmest	8th	2020	+1.51	+2.72
			Coolest	167th	1917	-0.92	-1.66
Ocean	+0.85	+1.53	Warmest	1st	2023	+0.85	+1.53
			Coolest	174th	1911	-0.51	-0.92
Land and Ocean	+0.97	+1.75	Warmest	3rd	2016, 2020	+0.99	+1.78
			Coolest	172nd	1917	-0.52	-0.94

the traditional weather forecasting system. The Iot weather forecasting gives continuous and real time data. The information from the sensors is sent to the cloud server. To make sure that there is no external harm for the data, the data security in cloud provides with encryption and decryption of data while retrieving the information from cloud. This reduces corruption of data, minimizes communication overhead, enhances the security and also helps to give wise predictions. The work uses the traditional database system management is replaced by cloud, cloud has comparatively less maintenance cost, data storage cost and it increases the scalability. It provide enhanced security a homomorphic encryption technique is used, this provides a safer communication between the cloud and user. The homomorphic technique has many advantages compared to the present security systems [2].

Raju and Laxmi examine the use of supervised machine learning algorithm and short-term load forecasting for iot based online load forecasting. The data obtained from a research lab is used for training ML algorithms to short term load forecasting. Online forecasting is considered more effective as it uses recent data for forecasting and training. Different regression algorithms are implemented on cloud for forecasting power consumption. The effectiveness of ML algorithms is known by calculating the performance parameters such as RMSE, MSE and so on. The methodology presented in this paper offers real time prediction of the power consumption due to this its very much preferred in IOT based online home energy management system [3].

Jakaria et al. gives a new method over traditional weather forecasting system. The traditional weather forecasting uses complex models, in spite of this complex model even the smallest disturbance in the atmosphere can result in significant changes in weather pattern over the time, due to this the weather forecasting model can give inaccurate forecasts. To overcome these challenges this paper presents a model that uses past data to train a machine learning model that predicts the weather parameters for the near future. Unlike the traditional weather forecasting system, the proposed model uses lesser energy and reduces the computational cost. The evolution describes that the proposed models do give accurate results and compete with the traditional weather forecasting model. This model utilizes historical data from multiple sources to predict the weather parameters of the specified region which turns out to be advantage compared to the traditional weather forecasting model that uses single data source [4].

Rahman et al. studies about the weather parameters have always been crucial to the human beings. Including machine learning for prediction of weather parameters have increased I recent years. This paper explores about the progress made in weather forecasting including machine learning with respect to weather forecasting. A study has made that describes about the effectives of different machine learning algorithms used in prediction of precipitation and temperature pattern. The machine learning model uses a 20 year span dataset from a single weather station. The algorithms used are Gradient Boosting, AdaBoosting, Artificial Neural Network, Stacking Random Forest, Stacking Neural Network, and Stacking KNN which are evaluated and compared with each other. The results shown by these machine learning algorithms prove that they are perform outstanding compared to the traditional weather forecasting models. Further investigation has explored influential aspects of weather events, revealing critical factors such as wind speed at specific altitudes and directions, absolute and relative humidity, precipitation, and surface pressure [5].

Gebrechorkos et al studies long term trends are analyzed using seasonal and annual time scales of parameters such as rainfall and maximum and minimum temperature of East Africa . The data is collected from international databases like climate hazards group from the year 1981-2016 for rainfall and 1979-2010 for temperature, this provides valuable information about the climatic changes region wise. The changes are shown both Tmax and Tmin of temperature, the Tmax change is higher in eastern parts of Ethiopia compared to Tanzania , the Tmax change is lowest in this region. Tmin are more varied across the regions, in large parts of Kenya and Tanzania it is observed that there is a significant increase in Tmin and n eastern and western Ethiopia there is significant decrease in Tmin. The observed annual rainfall is not significant, near the regions of Nile basin such as western Ethiopia, Kenya and parts of northern Tanzania shows increase in rainfall on the other hand there is significant decrease in rainfall in the regions as central-eastern Ethiopia and south eastern Tanzania [6].

Murphy uses the dynamical downscaling and statistical methods for studying the changes in the predicted values of surface air temperature and precipitation over the period 2080 to 2100 to pre industrial period. The changes are determined by comparing to the pre industrial parameters. The data is observed for two months that is January and July across 976 sites in Europe. There are two dynamic downscaling methods used namely general circulation model and regional climate model. The predicted values of surface air temperature and precipitation is taken from the nearest point in the grid of the general circulation model. The statistical method is obtained by the linear regression relationship between surface air tem-

perature or precipitation and other atmospheric predictor variables. When the predictions for temperature is being compared between general circulation model and regional climate model there is only a small difference which suggests both give a similar projections of temperature values but when comparing the temperature prediction between the statistical model and dynamic downscaling model there is a high difference which suggests that both these model have different temperature projections. For precipitation predictions there is a difference in all the three methods which shows the uncertainty in the predicted values [7].

Tatli et al propose a method to downscale the monthly temperature series by upper air circulation for Turkey. The proposed method has three stages, in first stage the dataset is separated into different components by singular spectrum analysis, in second stage the deterministic components are retained where as the random components of the dataset is eliminated by spatial principal component analysis and later on the statistical and deterministic components are combined together. For downscaling or climate modeling its important to understand the relationship between the large scale climate predictors and local scale climate predictands to do this Sampson correlation ratio is used to know the nature of relation between these two predictors and predictands. The Sampson correlation ration helps to figure out which large scale predictors is closest to predict the local scale variable. The third stage includes redundancy analysis and canonical correlation analysis. The result shows that interpretation of local scale variables using noise reduced data is more efficient than the raw data [8].

Dore conveys the fact that the climate change is just not a talk but reality by studying a large set of data and observing the changes in the pattern of precipitation. It is also observed that the changes in the precipitation patters are due to various reasons such as increase in global surface temperatures and changes in the atmospheric pressure. The synthesis aims to provide the changing patterns in regional and continental levels, in that way the patterns that cant be seen in regional level will be observed in the broader level. The results of the study shows that, the wetter region are having higher precipitation and the drier regions are becoming more drier that is they are having lesser precipitation. The changing patterns that are observed are increase in the precipitation over the northern hemisphere, decrease in the precipitation in china, Australia and other islands in pacific and increased variance in equatorial regions [9].

Stephens et al. developed an Event based hydrologic models are used by engineers and hydrologists for flood design and assessments, to use this model its necessary to calibrate the loss values. The loss values are calculated by the models output and the historical data. These loss values wont be used for calculating the future flood design due to the climate change as it changes the hydrologic cycle. In this paper bottom-up climate change assessment is used to know the future performance changes that occur due to the climate change in the event based model. The assessment is done by comparing the functioning of event based model against the continuous hydrologic model. It is observed that event based model diverges from the continuous hydrologic model which suggests that when compared to continuous hydrologic model, event based model performs poorly. This study concludes that the engineers and hydrologists need to keep in mind the uncertainties when predicting the future flood design [10].

Singh et al. studies the Weather forecasts are really important in the agriculture field as it will help the farmers to produce more crop yield and reduce the losses. With regular and reliable weather forecasts the farmers can change their cropping pattern accordingly and take safety measures. The value -added medium range weather forecasts is obtained for the region Bathinda and Faridkot, which shows the predicted weather forecast for five days and two days outlook. The economic impact of medium range weather forecast was observed during the Rabi season of wheat from 2016 to 2017 and for cotton in Kharif season in 2017. The results that were obtained suggest that the highest accuracy was shown by the rainfall forecast and the least accuracy was shown by the wind speed forecast. With respect to the season, all the parameters except temperature exhibited highest accuracy in pre-monsoon season. The adopted agro-meteorological advisory services was relatively valuable in the interests of crop yield compared to the non- The adopted agro-meteorological advisory services [11].

Do et al. study is based on observing trends in the annual maximum streamflow data that is obtained by the Global Runoff Data Centre databases. The obtained records are broken down to three datasets. The trends are calculated based on two tests namely Kendall non-parametric trend test and field significance test. The results that are observed are, there is a noticeable difference in few of the stations that shows significant increasing or decreasing in the trend compared to the other stations, these changes needs to be taken into considerations while constructing a statistical model for better accuracy [12].

Ahmed et al examine the trend and periodicity of temperature is examined over 1941-2005 by the data collected by fifteen weather stations across Ontario. Statistical analysis such as Fourier series analysis, T-test and Mann Kendall test are used for analyzing the data. The weather stations are decomposed into three regions for analyzing the spatially variability in the temperature. The results show various noticeable trends in the temperature across various regions. The annual maximum mean temperature shows increasing trend in Northwest and mixed trends in the other two regions. The range of trend is between -0.8degree to 15degree over the span of 100 years. For the seasonal analysis, 90% of the stations in northwest exhibits increasing trend, 80% of stations in south-west region exhibits increasing trend and 95% of stations in south-east exhibits increasing trend with respect to the extreme minimum temperature in winter. The variance for the temperature is determined by breaking it into three components: trend, random component and significant periodicities. During the analysis it was observed that the

variance pattern is similar across all the three components and the random component play a vital role in contributing to the variance of the temperature variables [13].

Sharma and Prakash developed a real time IOT weather forecasting model is built to overcome the problems of measuring the weather parameters in the real time and giving accurate results. This system works on client server architecture model using IOT. The system is organized into a two tier architecture. The results of this proposed system is near to the accurate measurements of the real-time data. The observed data is compared to the real-time data of each sensors to know its accuracy [15].

Summarizing the earlier work are studies or approaches that focus on implementing methods of weather forcasting and examine various methods. However, the proposed approach emphasis is analysing historical data to determine regional weather patterns.

III. THE PROPOSED APPROACH

The proposed approach espouses analyzing the local weather of Karnataka region to serve an aspect of Goal 13 - Climate action of the United Nations Sustainable Development Goals (SDG) [16]. The approach analyzes average mean surface air temperature and Precipitation for a period of 1951-2020 to arrive at a conclusion of the regional trend in weather and predicting the future trends.

A. Dataset and tools

The dataset is taken from Climate Change Knowledge Portal (CCKP). The portal provides dataset for different states in India. There are three types of databases variability, trends, and trends with variability for different weather parameters. The tools used for analysis are Google collab and Excel. Google collab is used for analyzing and visualizing the dataset with the help of different plot and by using various libraries such as Pandas, Numpy, Matplotlib, Seaborn and LinearRegression. Excel is used for calculating the absolute difference between each decade of the years from 1950 to 2020 for the average mean surface air temperature which shows by what value are average mean surface air temperature values are increasing in each decade.

B. Analysis

The dataset is analyzed in three methods. Variability and trends for period 1951- 2020 across seasonal cycle are analyzed using the scatter plot. The distribution plot is used to analyze shift in peak over ranges of period. Finally, the trend line is used to analyze the slopes over ranges of periods to determine the increase or decrease of weather parameters and predict the future trend.

IV. EVALUATION AND RESULTS

A. Variability and trends of Average mean surface air temperature across seasonal cycle of Karnataka region

Fig. 2 shows Variability and trends of average mean surface air temperature across seasonal cycle of Karnataka region for the period 1951-2020 to observe the change in surface air temperature of each month over the years. Surface air temperature is usually high in the summer month of April and low in the winter month of December, being highest during period 2011-2020 and lowest in the period 1961-1970. Comparing the average trend values of the latest decade of 1991-2020 with earlier decades a noticeable increase in surface air temperature can be seen mostly during the hotter months March to May. The climatology trend in the recent decade 2011-2020 show much higher temperature values across most of the month.

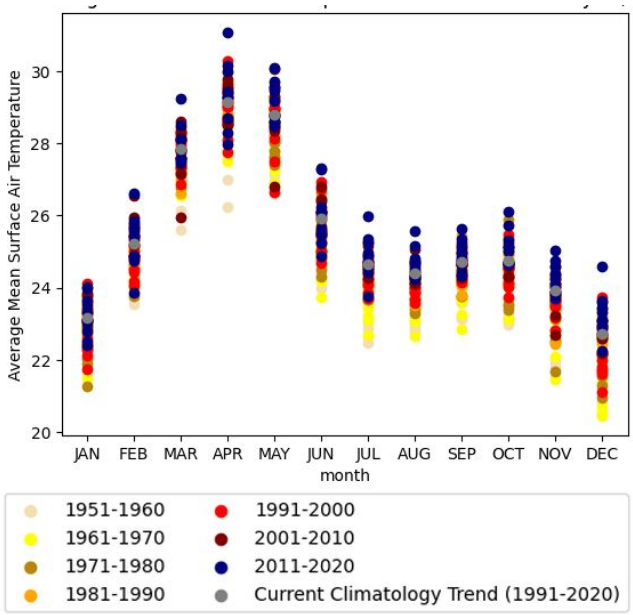

Fig. 2: Variability and trends of average mean surface air temperature across seasonal cycle of Karnataka region.

B. Variability and trends of Precipitation across seasonal cycle of Karnataka region

Fig. 3 shows the variability and trends of precipitation across seasonal cycle of Karnataka region for the period 1951-2020 to observe the change in precipitation of each month over the years. Precipitation is usually high in the monsoon month of July and low in the non-monsoon month of December, being highest during period 1951-1960 and lowest in the period 2001-2010. Comparing the average trend values of the latest decade 1991-2020 with earlier decades, the precipitation values are lower in recent decades compared to earlier years indicating climatology trend of precipitation decrease over the years.

C. Change in distribution of Average mean surface air temperature of Karnataka region

Fig. 4 shows change in distribution of average mean surface air temperature of Karnataka region for three periods 1951-

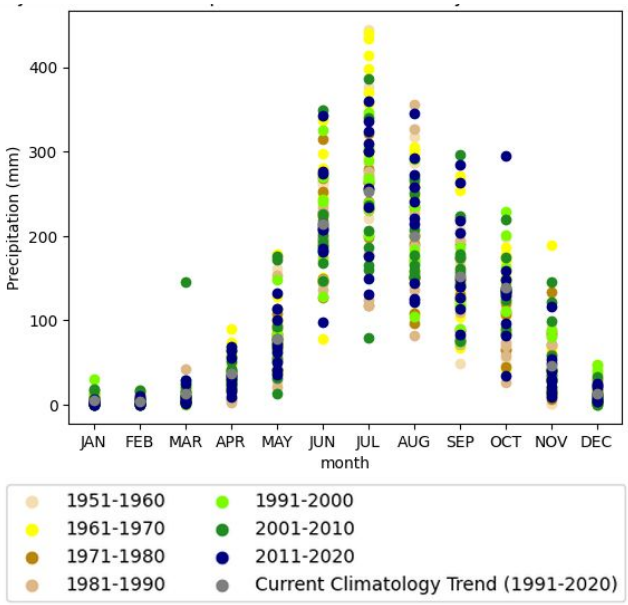

Fig. 3: Variability and trends of precipitation across seasonal cycle of Karnataka region.

1980, 1971-2000 and 1991-2020. It is observed the peaks have shifted 24.50C, 25.150C and 25.60C respectively indicating increase 1.10C in temperature value compared to the previous period. Moreover, the shift does not only signify increase in the peak but also the range of temperatures in later periods. The distribution suggests that the higher temperature event is more often than before.

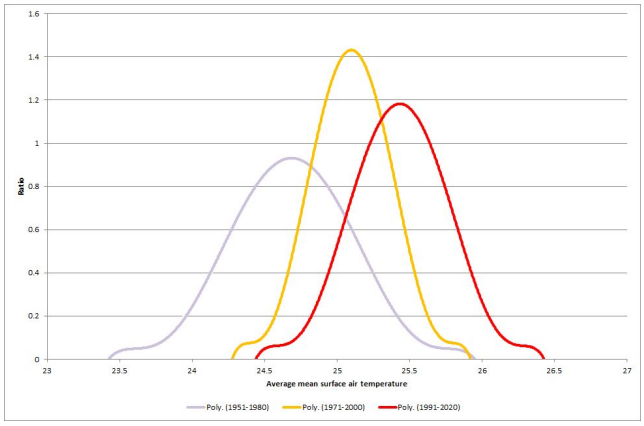

Fig. 4: Change in distribution of Average mean surface air temperature of Karnataka region.

D. Change in distribution of Precipitation of Karnataka region

Fig. 5 shows change in distribution of precipitation of Karnataka region for three periods 1951-1980, 1971-2000 and 1991-2020. The peak value of period 1951-1980 is 1209.42mm is the highest of all the periods indicating decreasing amount of precipitation. The peak value for the period 1971-2000 is 1055.75mm, a shift in the distribution to the left indicating the annual precipitation value have decreased significantly. The peak value in the period 1991-2020 is 1153.79mm shows shift towards right compared to 1971-2020 indicating an increase in precipitation, however, the distribution compared to 1951-1980 is a shifted left indicating lower peak precipitation. It may be concluded that although there is fluctuation in the precipitation, it has decreased through the years.

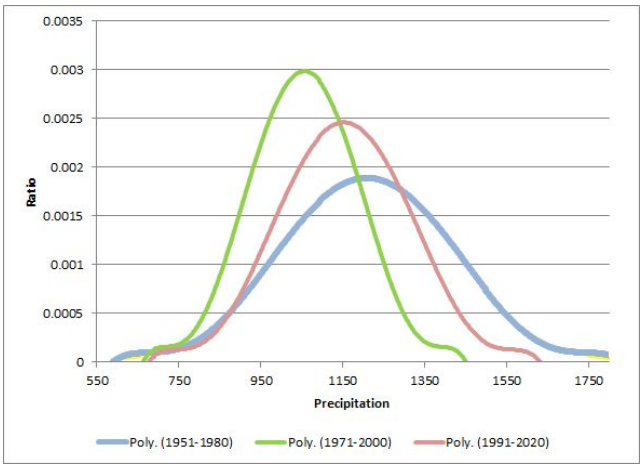

Fig. 5: Change in distribution of Precipitation of Karnataka region.

E. Trend line of the Average mean surface air temperature per decade of Karnataka region

Fig. 6 shows the Trend line of the Average mean surface air temperature per decade of Karnataka region. The annual average mean temperature values have gradually increased from the year 1951 to 2020. The trend line in years 1991-2020 shows the highest increase compared to previous decades indicating that the temperature values are gradually increasing. The increasing rate of the temperature has become more evident from the positive slope and is consistent in the recent decades. The trend line 2001 to 2040 is directed upward suggests further increase in temperature and predicts a more intense warming.

F. Trend line of Precipitation per decade of Karnataka region

Fig. 7 shows the Trend line of the Precipitation per decade of Karnataka region. The annual average mean precipitation values have gradually fluctuated over the period of 1951-2020. Although the recent years 1971-2020, 1981-2020 and 1991-2020 shows an increasing precipitation, there is a decreasing trend compared to the previous period of 1951-2020 and 1961-2020. The trend line 2001 to 2040, is directed downward predicting a decrease in the precipitation.

Observing the plots it may be deduced that the average mean surface air temperature is gradually increasing and the

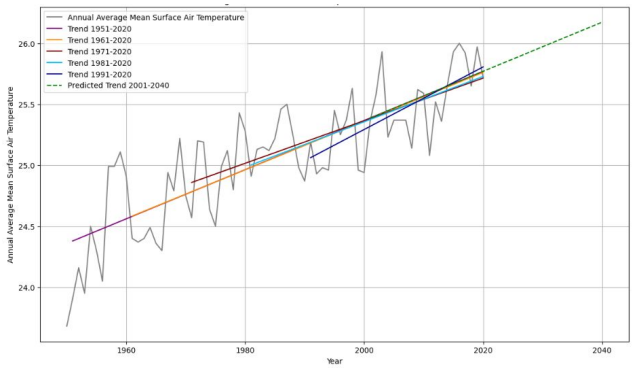

Fig. 6: Trend line of the Average mean surface air temperature per decade of Karnataka region.

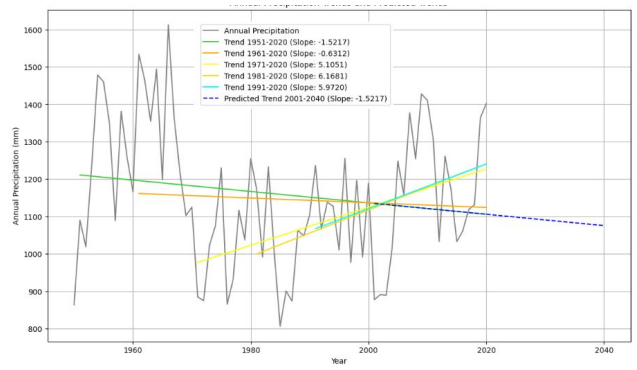

Fig. 7: Trend line of Precipitation per decade of Karnataka region.

precipitation is decreasing implying the weather condions are changing over decades and impacting the regional livelihood.

V. CONCLUSION

The proposed approach analyzes the historical data points from Climate Change Knowledge Portal (CCKP) of the Climate in Karnataka during the period from 1950 to 2020 and predict the changes for next two decades. The approach includes visualization of the monthly variation of surface air temperature and precipitation across decades using scatter plot to compare and observe monthly changes. The visualization of peak values over different periods using density plot that displays the shift of surface air temperature and precipitation peaks over decades. The visualization of the overall trend and also the peak and bottom values using the line plot that estimates the trend and change in climate over decades. The analysis was done using Google collab and Microsoft Excel which provided the platform for handling large datasets. With the use of historical data the future values of precipitation and surface air temperature are predicted for the years 2001 to 2040. By analyzing the average absolute values between each decade of precipitation and surface air temperature it is observed that there is a gradual increase in the surface air temperature and decrease in the precipitation values. Incorporating local dataset and models using city based data that predicts the regional extreme weather events in the state can be helpful for the local people, so necessary steps can be taken at regional level.

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