Big Data–Driven Smart Climate Change Prediction Using a Machine Learning Framework

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***Abstract*—This study examines global temperature trends from 1961 to 2019, focusing on the effects of climate change across different countries and regions. Using the FAOSTAT Temperature Change dataset, we analyze the ten most and least affected countries, explore seasonal and yearly trends, and investigate temperature uncertainties. Through regression analysis and clustering techniques, we identify regions that have experienced the most significant temperature rises, particularly industrialized nations like Russia and parts of Europe. Additionally, the analysis highlights vulnerable regions at risk of ecosystem loss due to rising temperatures, such as Nicaragua and Morocco. The results emphasize the urgent need for international climate action to mitigate the effects of global warming and protect ecosystems.**

***Index Terms*—Climate Change, Temperature Trends, Machine Learning, Regression Analysis, Ecosystem Vulnerability**

I. INTRODUCTION

Climate change (CC) is a significant global issue affecting ecological, environmental, socio-political, and socio-economic systems. Over the past 65 years, rising global temperatures have been a major concern, exacerbated by the industrial revolution. This change is not just about warmer weather it is about complex, interconnected changes, including irregular rainfall, rising sea levels, and extreme weather events that are becoming less predictable.

Many scientists believe that both natural processes and human activities are behind these changes. Cutting down many trees and burning fuels like coal and oil have caused more harmful gases in the air, which make the problem worse. To fight this big problem, countries around the world joined together in 2015 and signed the Paris Agreement. This important deal tries to stop the Earth's temperature from rising more than 2°C to less than 1.5°C Climate [1]. The agreement said it is important to be open and honest, take responsibility, and help poorer countries with money and technology. In light of these concerns, this study takes a closer look at how climate change is affecting critical sectors such as agriculture, health, biodiversity, and the economy. It also explores what’s being done in terms of mitigation, adaptation, and global cooperation to tackle the crisis effectively.

II. TEMPERATURE CHANGES OVER THE LAST DECADE

In the last ten years, global warming has picked up speed as the study focuses on identifying the countries that have seen the largest increases in their average annual temperatures during this period (Figure 1). We thoroughly analyzed temperature records year by year and grouped them by country. The results were then sorted to highlight the ten countries with the most dramatic temperature shifts. Surprisingly, most of these countries are either in Europe or close to it, suggesting that this region is facing particularly intense climate impacts [2-4]. Russia also appears on the list, underscoring the trend in northern and eastern parts of the continent.

At the very top is the Svalbard and Jan Mayen Islands—a remote Arctic region near Europe and Russia. Its fragile environment makes it especially sensitive to warming temperatures. What stands out in the analysis is that, apart from Svalbard, all the countries in the top ten are highly industrialized. This pattern supports the widely accepted idea that industrial activity, which contributes heavily to greenhouse gas emissions, is closely linked to rising temperatures.

These findings highlight the urgency for climate-focused policy interventions in these regions, especially in industrialized nations. Without stronger action, the warming trend could continue to accelerate, putting both people and ecosystems at even greater risk.

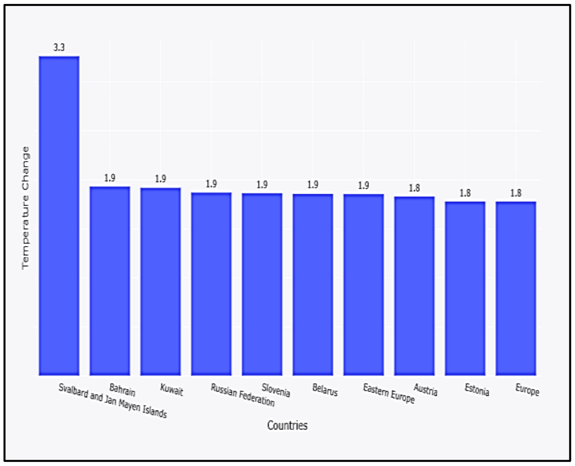

Figure 1 Top 10 Countries that have highest temperature change in last decade

III. COUNTRIES WITH THE LEAST TEMPERATURE CHANGE OVER THE LAST DECADE

While much of the global climate conversation centers on rising temperatures, some countries have seen relatively minor changes over the past ten years. This part of our study looks at those nations where average temperatures have remained more stable, offering a different perspective on climate trends.

To uncover this, we reviewed temperature data for each of the last ten years, calculated the average temperature change for every country, and then ranked them from lowest to highest [5]. Countries with incomplete or missing data were excluded to ensure the accuracy of the findings. The final list includes the ten countries with the smallest temperature shifts during the decade (Figure 2).

One of the most unexpected results is India's placement on this list. Despite its large population and growing industrial sector, India's average temperature change has been relatively modest. This contradicts the common belief that rapidly developing nations automatically face greater climate impacts [6]. It also raises questions about how factors like geography, local climate patterns, and policy decisions influence regional outcomes.

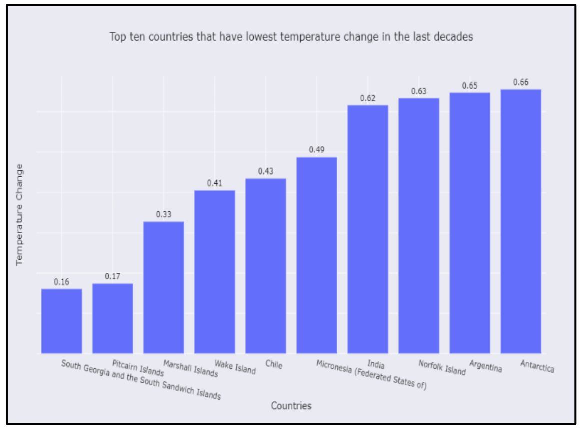

Figure 2 Top 10 Countries that have lowest temperature change in last decade

Interestingly, no highly industrialized or developed countries appear in this group. That observation supports the broader view that nations with a long history of industrial activity tend to show more significant warming due to higher greenhouse gas emissions. Instead, the countries with smaller changes are generally less industrialized or still developing.

These findings highlight the uneven nature of climate change. Studying both extremes—the countries with the highest and lowest temperature shifts—can provide more balanced insights for creating effective climate strategies [7]. A one-size-fits-all approach won't work; climate solutions must be tailored to each country's unique situation.

IV. COMPARATIVE ANALYSIS OF ANNEX I, NON-ANNEX I COUNTRIES, AND GLOBAL AVERAGES OVER TIME

To better understand how climate change is affecting different parts of the world, this section compares temperature trends in two major country groups: Annex I and Non-Annex I nations.

Annex I countries have more industries and they are mostly rich, developed nations that have added the most pollution to the air in the past. But Non-Annex I countries are mostly developing nations, and many of them face bigger dangers from climate problems.

With the help of yearly temperature data, we studied how these two groups were affected by climate change and compared them to the global average [8-9]. This comparison shows that warming is not the same everywhere. It helps us see how rich countries are more responsible, while poorer countries are more at risk. By looking at changes each year, we can find times when warming got faster or slower. This helps us understand how rules or world events may have affected these changes.

4.1 Methodology

To do this comparison, we put the data into three groups—one for Annex I countries, one for Non-Annex I countries, and one for the world average. Each group data showing the average temperature change each year and was named: 'Annex I countries,' 'Non-Annex I countries,' and 'World'.

After setting the groups, we put the data into one file to easily compare them year by year. This step was important to see patterns and differences in temperature changes between rich countries, developing countries, and the whole world. Putting all the data together helped to see how each group has faced climate change over the years.

4.2 Analysis of the Trends

When we looked at the full dataset and its graphs, we saw some clear patterns. For Annex I countries, the rise in temperature over time appears steady and consistent, showing a long-term warming trend.

But the data for Non-Annex I countries is different. The temperature changes are much more unpredictable, with sharp ups and downs (Figure 3). These sudden changes suggest that these regions are facing more intense and frequent climate-related events. The world's trend line is in the middle, not as steady as Annex I countries, but not as jumpy as Non-Annex I ones [10]. This overall pattern reflects mix of what's happening in both rich and developing countries.

4.2.1 Annex I Countries (Industrialized Nations)

For rich countries in Annex I, the data shows that average temperatures have slowly increase over the years. Even though there are small changes each year, the general direction is clear: the climate is gradually warming. This trend shows the historical impact of these nations, which have added greenhouse gases for a long time through factories and industries. Their actions still affect the climate today.

4.2.2 Non-Annex I Countries (Developing Nations)

Unlike their industrialized counterparts, many developing nations show more erratic temperature trends over time. The data reveals sharp rises and falls, which could be linked to factors like geographic diversity, higher vulnerability to climate events, and natural climate variability. In some cases, these countries seem to be hit harder by extreme weather or environmental shocks, making it more difficult for them to adapt or build resilience.

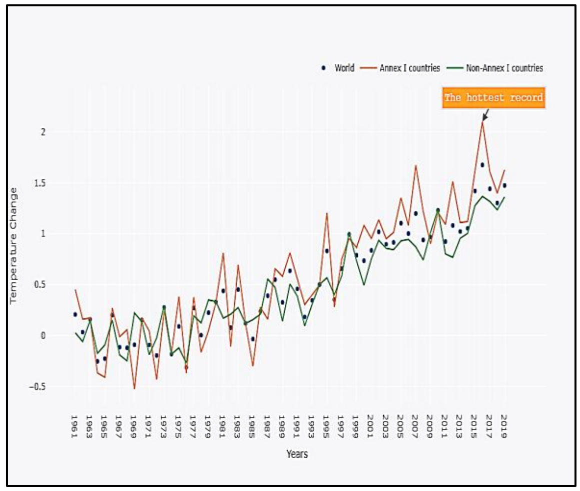

Figure 3–Trends in temperature change over time across World, Annex I, and non-annex I countries

4.2.3 Global Trend

The global temperature trend, as one might expect, falls between the patterns seen in industrialized and developing nations.[11] It blends the steady rise observed in Annex I countries with the more unpredictable changes seen in non-annex I regions. This global average offers a useful way to measure the overall pace and impact of climate change worldwide.

4.2.4 Periodization of Trends

When we look closely at the temperature data for Annex I countries, clear patterns appear in each decade. Every 10 years, the average temperature slowly increase, showing that global warming is growing over time. This rising trend is easy to see in very industrialized countries, where the effects of climate change seem to grow stronger every decade**.**

V. SEASONAL VARIATIONS: ANALYZING THE IMPACT OF GLOBAL WARMING ACROSS DIFFERENT SEASONS

Instead of only looking at yearly temperatures, this part show that global warming is affecting each season—winter, spring, summer, and autumn—one by one. By looking at the data season by season, we can understand how climate change happens during the year and whether certain seasons are being affected more than others.

5.1 Methodology

To see how climate change affects each season, we made separate data sets for winter, spring, summer, and autumn. Each dataset showed the average temperature change for that season and clearly labeled. First, winter grouped with spring, and summer with autumn [12-14]. Then, these two groups were joined into one full dataset to make it easier to compare seasonal changes over time.

5.2 Seasonal Trend Analysis

When we look at the seasonal temperature graphs (Figure 4), we see clear patterns for each season. Some seasons are heating up faster than others, showing that global warming is changing the balance of seasons in a clear way.

5.2.1 Summer

In the last 10 years, summer temperatures have slowly and steadily gone up. Unlike other seasons, summer shows some changes. This steady rise means global warming in summer is happening in a more regular and predictable way.

5.2.2 Winter

Winter temperatures are different. The data shows big changes from year to year, with sudden rises and drops. This means the climate reacts in a more complicated way during winter. It might be caused by things like changes in the polar vortex, jet stream, or surprise cold waves, events now linked to bigger climate changes. These unusual patterns show that global warming doesn't always mean steady heating [15]. Sometimes, it makes winter weather more unstable and harder to predict.

5.2.3 Spring and Fall

Spring temperatures also show a lot of ups and downs, similar to winter. This means spring is affected by sudden weather changes, likely because it's a time when the weather is shifting. On the other hand, fall is more stable. Like summer, fall shows a slow and steady rise in temperature with fewer big changes each year. Overall, this tells us that spring and winter—seasons of change—are more likely to have sudden weather shifts, while summer and fall warm up more steadily.

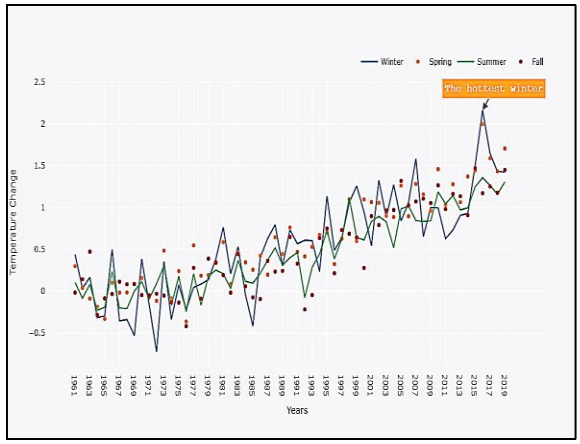

Figure 4 – Seasonal temperature variation trends

5.2.4 Hottest Winter on Record

The winter of 2016 was very unusual, with the highest global temperatures ever seen in winter. This shows how global warming is changing what we expect, even in normally cold seasons. When we compare the seasons, it's clear that climate change doesn't affect all parts of the year the same way [16]. Winter and spring are becoming more unpredictable, with big changes in temperature showing they react more strongly to climate shifts. In contrast, summer and fall show steadier, more gradual warming patterns.

Recognizing these seasonal differences is crucial. As extreme temperature events become more frequent, especially during vulnerable periods like winter, climate response strategies must be season-specific. This ensures that adaptation efforts are better aligned with the unique risks each part of the year brings.

VI. ANALYZING TEMPERATURE TRENDS OVER THE LAST DECADE

Between 2010 and 2019, global temperatures continued to rise—but just how much did this decade accelerate the pace of climate change? To answer this, the analysis focuses on monthly temperature records across those ten years, aiming to pinpoint trends, patterns, and possible turning points.

This period offers a critical lens: not only does it fall within the warmest years on record, but it also reflects growing concerns about the speed of warming [17]. By zooming in on these recent years, we can better understand whether global warming has reached a new intensity and how much these years have pushed the global climate further into uncharted territory.

6.1 Methodology

To focus on global temperature shifts over the past decade, the dataset was filtered to include only rows labeled with 'World' under the 'Country Name' column. From this global dataset, monthly temperature change values were extracted, allowing for a closer, more detailed look at how temperatures varied not just year by year but month by month. This method offered better insight into seasonal fluctuations and helped identify patterns that might be missed in annual averages.

6.2 Analysis of significant acceleration

The results point to a clear and worrying trend: global temperatures have accelerated sharply in recent years. As illustrated in (Figures 5 through 11 covering data from 2000 to 2018), each blue line represents the temperature change for a given month across the years. While earlier years show a slow and steady rise, a noticeable spike appears between October and January. For instance, in October, the average temperature change stayed below 0.5°C for much of the early 2000s. But by 2019, it had climbed above 1.5°C—a threefold increase [18-20]. Such sharp rises, especially during cooler months, are a red flag for the intensifying pace of global warming.

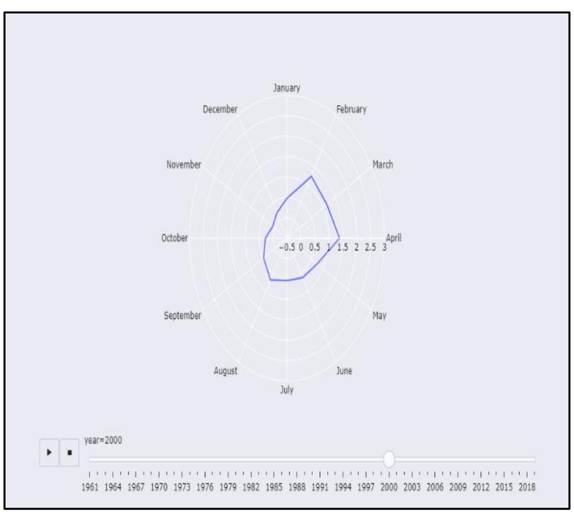

Figure 5 Temperature Change in 2000

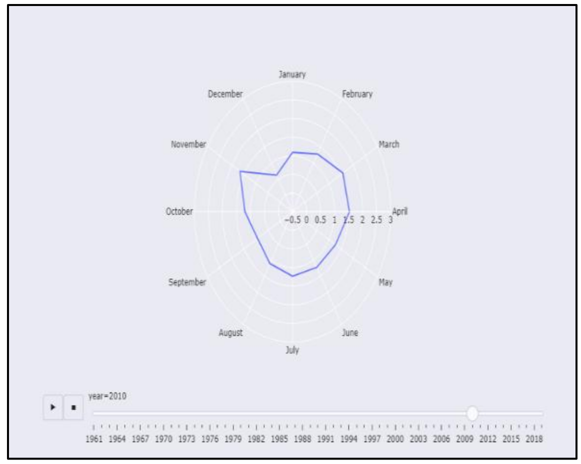

Figure 6 Temperature Change in 2010

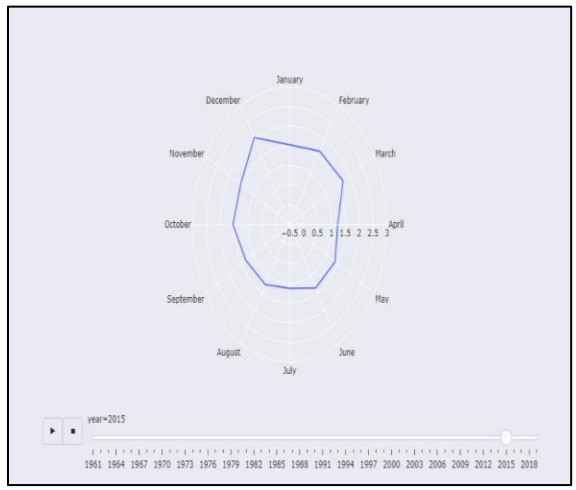

Figure 7 Temperature Change in 2015

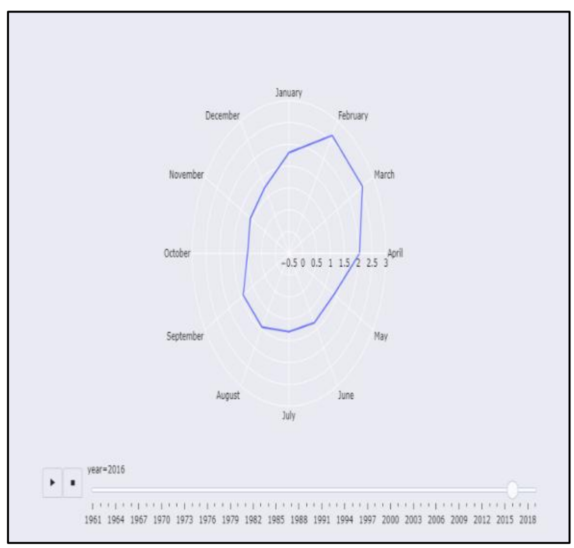

Figure 8 Temperature Change in 2016

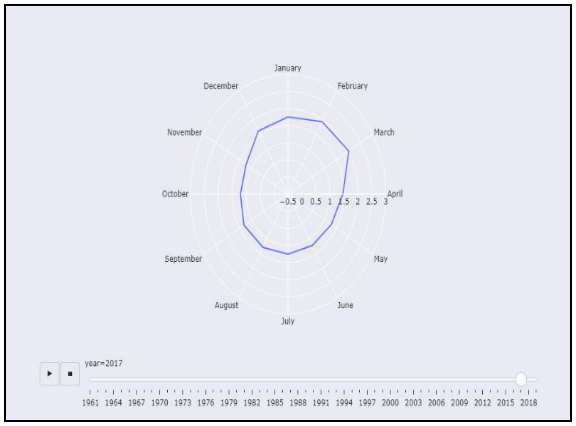

Figure 9 Temperature Change in 2017

Figure 10 Temperature Change in 2018

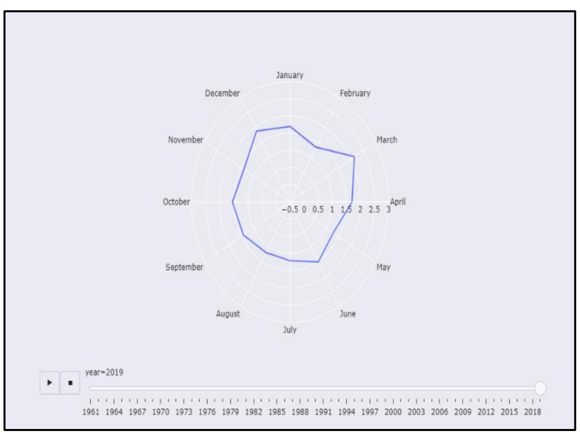

Figure 11 Temperature Change in 2019

6.2.1 Record-Breaking Temperatures

When we look closely at the data, we can see a clear pattern, from 2010 to 2019, eight out of those ten years were the hottest ever recorded in the world. This is not just a rare event, it shows that the Earth's climate is changing quickly and still going on. These record hot years happening again and again show that global warming is speeding up fast. Human actions, especially releasing greenhouse gases are a big reason for this change.

6.2.2 Day-by-Day Temperature Changes

The radar chart representing monthly temperature changes vividly illustrates how global temperatures have steadily increased day by day. Rather than just a few very hot months, the data shows almost every month is getting warmer showing a steady, ongoing trend.

This shows more proof that global warming is not only continuing but gaining momentum. It is fact that most of the hottest years happened between 2010 and 2019 makes this worry even stronger [21]. When we look at the temperature changes it helps us understand how climate change is happening day by day in real time and also tracking temperature changes this closely can show patterns that affect farming, health, and city planning, making it useful for predicting and preparing for climate changes.

VII. REGRESSION PLOT FOR AVERAGE GLOBAL TEMPERATURE

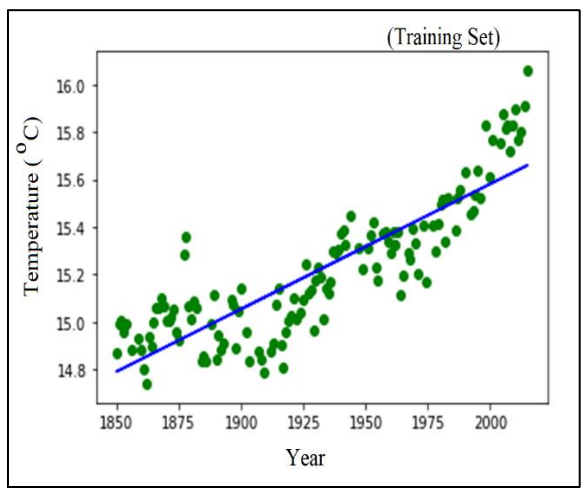

Figure 12 Average Global Temperature Regression Plot for Training Data Set

To understand how global temperatures have changed over time, we used regression analysis. This method helps us to uncover the long-term warming trend by removing short-term fluctuations and showing the overall trend.

We divided the data into two parts, one for training the model and the other for testing its accuracy. The blue line (Figure 12) shows that how global temperatures is rising over time, even if some years are different. The green dots show the real temperatures used to train the model. These slight ups and downs are often influenced by natural events like volcanic eruptions or El Niño cycles, but the overall direction is clearly upward.

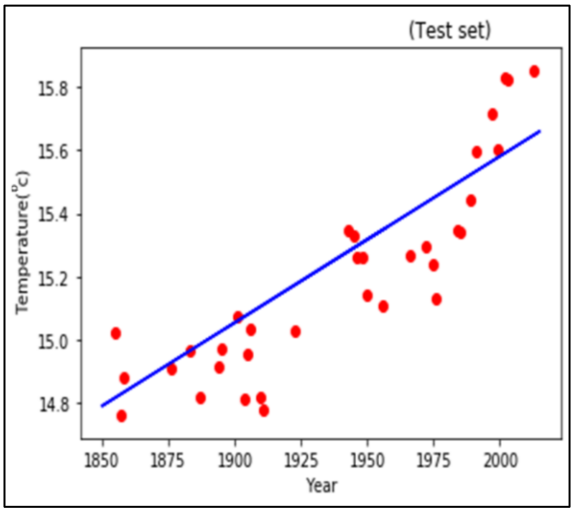

Figure 13 Average Global Temperature Regression Plot for Test Data Set

The model was also tested on a separate dataset. The red dots (Figure 13) show how actual recorded temperatures compare with the predictions [22]. Again, there's some natural variation, but the general rise in temperatures holds steady pointing to a continuing and long-term global warming trend.

VIII. KEY PHASES OF CLIMATE CHANGE FROM 1875 TO PRESENT

Looking back over nearly 150 years of climate data, several clear phases emerge in how Earth's temperature has changed. This section highlights the periods of relative calm as well as those of rapid warming.

Starting in the late 19th century, global temperatures were relatively stable. Industrial activity had just begun to scale, and its impact on the climate was not yet dramatic. However, as the 20th century progressed, especially after the 1950s, the data shows a steady climb in global temperatures.

From the 1980s onward, global warming accelerated. This matches a time when the world used more fossil fuels, built more cities, and cut down more forests [23-25]. The last few decades especially the 2010s have been the hottest ever, with more frequent and stronger temperature rises.

Understanding these time periods is not just about graphs, it shows us where today's climate problems started and how fast human actions can change the Earth's climate

8.1 Gradual but Persistent Rise in Global Temperatures

The Earth's temperature has been gradually rising for more than 150 years. At first, the changes were small, but over time, the warming trend became high. This change is mainly caused by human activities like burning fossil fuels, cutting down forests, and running large industries. Some warming happened before 1900, but after 1950, temperatures started rising much faster, breaking away from the steady patterns of earlier times.

8.2 Acceleration of Warming After 2000

Since 2000, global warming has been rising much faster. Nearly every year now feels like a record-breaker and many are. This rise in heat matches with fast-growing industries, bigger cities, and more carbon pollution [26]. The climate is changing faster than before, and the data shows we are now facing record-high temperatures we have never seen before.

8.3 Phases of Relative Stability: 1875–1900 and 1950–2000

Not every period saw dramatic change. From 1875 to 1900, the climate stayed mostly the same, it was a quiet time in Earth's temperature history. The same goes for 1950 to 2000 when temperatures kept rising but more slowly and steadily. Scientists think these quiet periods were caused by natural things like ocean currents, volcanoes, or short-term cooling in the air. But beneath that calm, the effects of industrialization were quietly building up.

8.4 Cooling Phase: 1900–1950

Interestingly, from 1900 to 1950, the world actually cooled a bit. This wasn't a sign that global warming wasn't happening — instead, pollution played a surprising role. Industrial activities pumped aerosols and other particles into the air that reflected sunlight, leading to cooler surface temperatures for a few decades. Natural cycles like changes in the sun's energy and ocean behavior also contributed. But this dip didn't last and once those aerosols declined, the heat came roaring back.

These changes from calm periods to cooling, then fast warming show us that how complex Earth’s climate system is. But one thing is clear, in the last 20 years, temperatures have been rising quickly and non-stop [27]. Knowing that our past helps us get ready for the future especially now, as time to take action is running out.

IX. TEMPERATURE TRENDS OVER THE LAST FOUR DECADES IN KEY COUNTRIES

Looking at the last 40 years of climate data, we can see that not all countries are warming equally. Global warming affects everyone, but where and how it depends on location, development, and local weather patterns (Figure 14).

Let’s look more closely, in countries like the U.S. and China, temperatures rise has gone up quickly and steadily, especially after 2012. Cities are getting hotter, summers are longer, and heatwaves happen more often. This is linked to growing industries, big cities, and more carbon pollution.

India shows a similar trend [28]. As the economy has grown, energy use has increased mostly from fossil fuels. This has made temperatures rise each year, which leading to more extreme weather and putting pressure on roads, buildings, and farming.

But not all countries follow the same pattern. Australia and Brazil have had some ups and downs. In the last 10 years, their temperatures sometimes dropped, not always rising like the global trend. Why? Scientists say things like La Niña, changes in ocean currents, and local weather patterns can cool temperatures for a short time. But these are not signs that global warming is slowing down they are just short breaks in a bigger warming trend. These differences aren’t just academic they matter for climate planning. A one-size-fits-all solution won’t work. Countries facing fast-rising temperatures may need heat-resilient infrastructure, while others might focus more on droughts, floods, or shifting ecosystems [29-31]. Understanding each region’s unique experience is the first step toward smarter, more effective climate action.

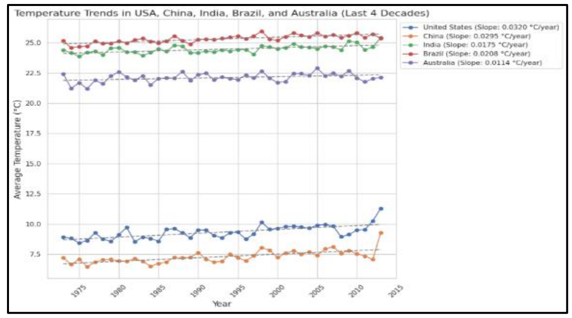

Figure 14 Temperature Trends in Various Countries

X. TEMPERATURE UNCERTAINTY OVER THE YEARS IN THE USA, INDIA, CHINA, BRAZIL, AND AUSTRALIA

Looking back at old climate records, one thing stands out — the farther back we go, the fuzzier the picture gets (Figure 15). Before the 1960s, measuring global temperatures was a real challenge. Tools were less advanced, weather stations were fewer and farther between, and the Earth's natural ups and downs made it tough to draw clear conclusions.

Back then, wild swings in temperature weren’t uncommon. Some of this was driven by nature — volcanic eruptions, changes in ocean currents, and fluctuations in the sun’s energy all played their part. But with limited data, scientists had to work with wide margins of error.

Things began to change in the 1960s. Technology improved. Satellite data became available. Global weather networks expanded. Since then, our confidence in temperature data has steadily grown. The trend lines smoothed out, and the long-term patterns became easier to see.

That said, uncertainty hasn’t vanished completely especially in countries like the United States and China. In recent decades, these nations have experienced some unusual temperature jumps [32]. Factors like heavy industrial activity, city heat islands, and local weather quirks still create bumps in the data, making it harder to predict exactly what’s next.

In short, while our tools have improved, climate is a complex system, and surprises still happen particularly in fast-changing regions. Understanding those uncertainties helps us improve climate models and plan smarter for the future.

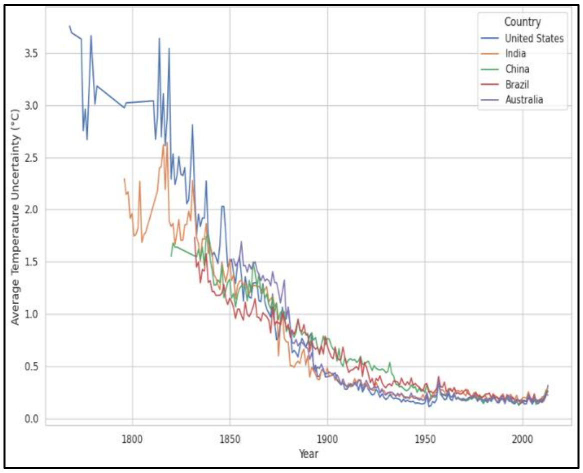

Figure 15 Temperature Trends over Last 4 decades in Various Important Countries

In the United States, weather has always been a wild card from scorching droughts in the West to freezing winters in the Midwest. Over the years, this variability has made it difficult for scientists and policymakers to get a clear handle on long-term temperature trends [33]. As extreme weather events become more common, forecasting and planning for climate risks has only grown more complex.

This unpredictability doesn't just impact science, it makes it harder for cities and states to prepare for what's ahead.

China tells a similar but complex story. In just a few decades, the country has gone through one of the fastest industrial expansions in history. That growth, combined with diverse geography from high plateaus to coastal megacities has created a climate data puzzle. Sudden temperature shifts and unusual weather patterns are becoming more frequent.

XI. REGIONAL CLUSTERING: K-MEANS CLUSTERING OF COUNTRIES BASED ON TEMPERATURE TRENDS

How climate change is affecting various parts of the world, we used K-means clustering (Figure 16) to get a clear picturization K-means is a method that groups all countries based on how their temperatures have changed over time. The goal was to find the proper patterns, which countries are heating up fastest, and which ones are gradually changing. With the help of this we have got a clear view that concludes, countries like Nicaragua and Morocco ended up in clusters showing the sharpest warming — with temperatures rising over 2°C since the 1850s. These regions are among the most climate-vulnerable, not just because of geography, but because they often lack the infrastructure or resources to adapt quickly. The heat is rising fast, but the tools to cope aren't keeping up.

On the other end of the spectrum, countries like Denmark and Austria fell into clusters with more moderate temperature increases. What sets them apart? They've been ahead of the curve — investing early in clean energy, enforcing strong environmental regulations, and weaving sustainability into their development plans [34-35]. As a result, their warming trends have been less severe.

This kind of clustering helps us understand that climate change isn't hitting everyone the same way. Some nations are facing a steeper uphill battle. And while technology and policy can make a huge difference, global cooperation will be key to bridging the gap, especially for countries that are most at risk but least equipped to respond.

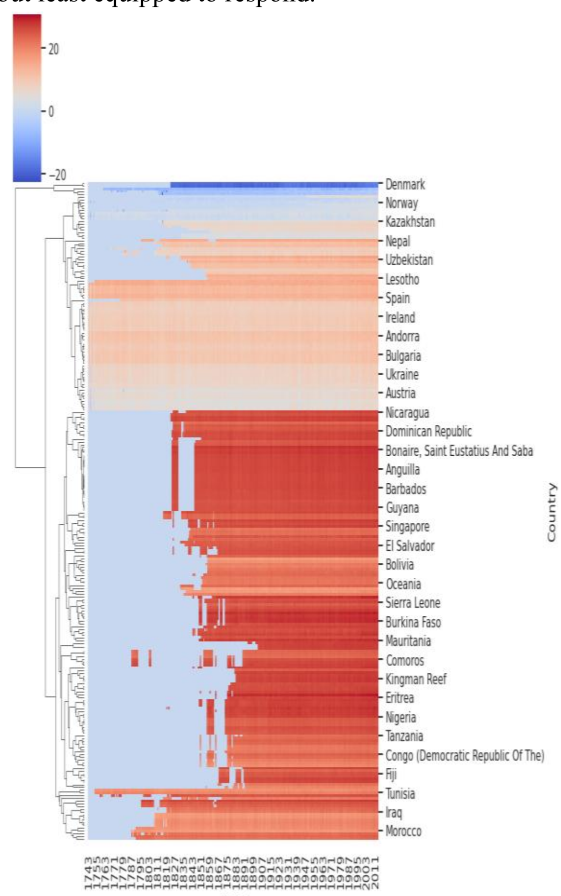

Figure 16 Clustering on Countries Based on Temperature Trends

XII. DISCUSSION

The results of this study paint a clear picture: climate change is real, it's accelerating, and its effects aren't felt equally around the world.

Industrialized nations—especially those in Europe and North America—have seen some of the fastest increases in average temperatures, particularly over the last decade [36]. Regions like Svalbard, Russia, and parts of Northern and Western Europe have warmed significantly, especially during the winter months (Figure 17 through Figure 19). These sharp seasonal changes are more than just numbers on a chart they point to serious shifts in ecosystems, like melting permafrost and shrinking snow cover, which can speed up global warming even more.

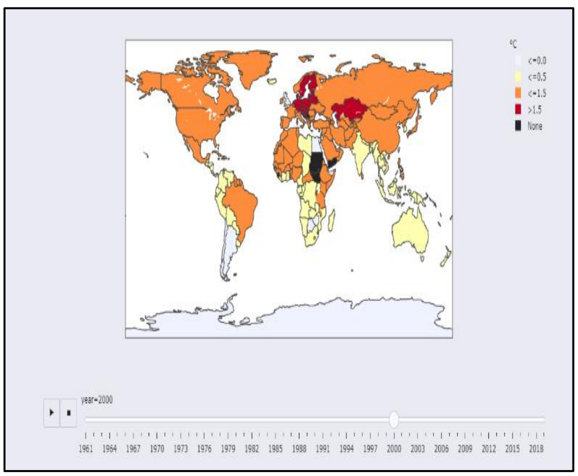

Figure 17 Temperature Map 2000

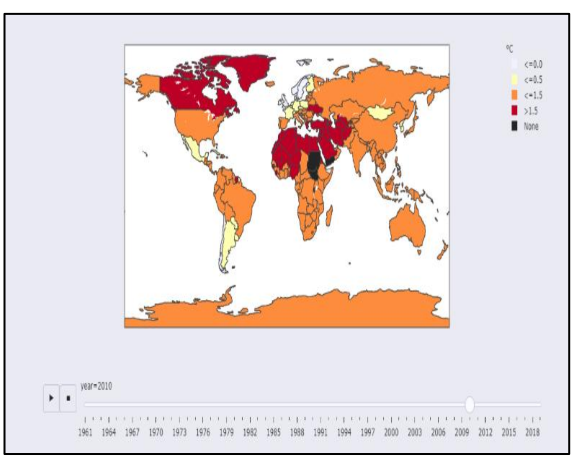

Figure 18 Temperature Map 2010

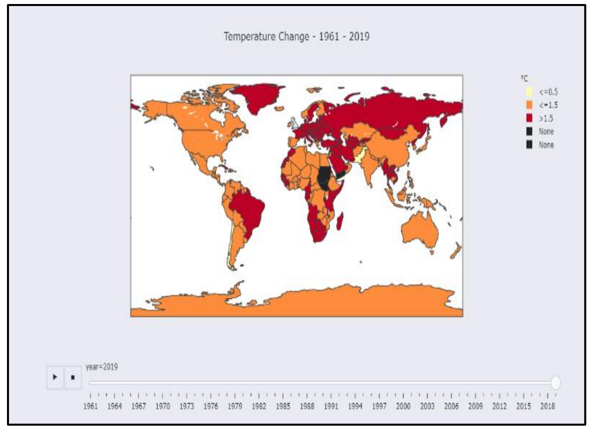

Figure 19 Temperature Map 2019

Meanwhile, countries like India have shown more moderate warming. But that doesn't mean they're in the clear. The areas with large populations and limited resources, even smaller temperature change causes major problems from heatwaves and crop failures to water shortages and health problems.

Some of the largest uncertainties in temperature data come from countries like the USA and China. Their rapid industrial growth and urban sprawl make it harder to predict how temperatures will behave year-to-year [37]. And although Brazil and Australia have recorded short-term cooling trends recently, those are likely due to natural shifts like La Niña — the overall trend is still upward.

The K-means clustering analysis adds another layer to the story. It shows that countries like Nicaragua and Morocco are among the most at risk, with some of the steepest long-term temperature increases. These rising temperatures put stress on crops, ecosystems, and public health. On the other hand, European nations like Denmark and Austria have managed to limit temperature rise more effectively, thanks to stronger environmental policies and investments in clean energy.

What this all tells us is that climate change isn't a one-size-fits-all problem. Some regions are heating faster, some are less prepared, and some are already feeling the impacts in daily life [38]. Tackling this global crisis will require:

- Cutting emissions quickly and significantly
- Investing in sustainable technologies
- Improving how we collect and share climate data
- Helping vulnerable countries with funding, tools, and knowledge

Finally, the path forward must reflect the different roles and responsibilities of each country. Richer nations, with longer histories of emissions, need to lead the way, not just by reducing their own footprint but also by supporting those who are most exposed to climate risks. Only then can we hope to build a future that's both sustainable and fair.

XIII. FORECASTING & PREDICTION

It can be seen Global Average Temperature is constantly increasing It can reach near 30 degrees Celsius in 2050 if it increases in this pace (Figure 20). In Figure 21 Green line considers as Average Global temperature and blue line is the forecasting line till 2050. Grey area is considered as Prediction data range with 95 % confidence interval means there are 95% chance that predicted temperature can lie between this range [39]. In worst Case Global Average Temperature can reach 50-degree Celsius (Figure 20 & 21). Figure 21 shows us that there have 95% probability (95% Confidence Interval) that we can see major temperature rise in near future.

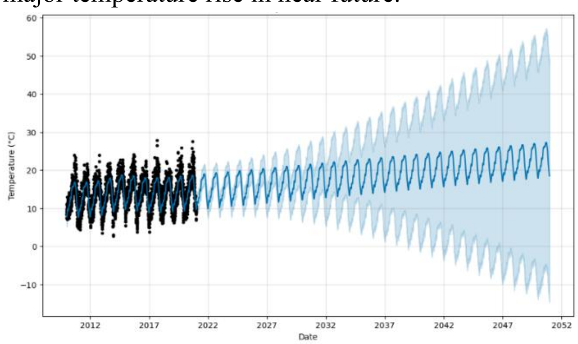

Figure20 Global average temperature forecast till 2050

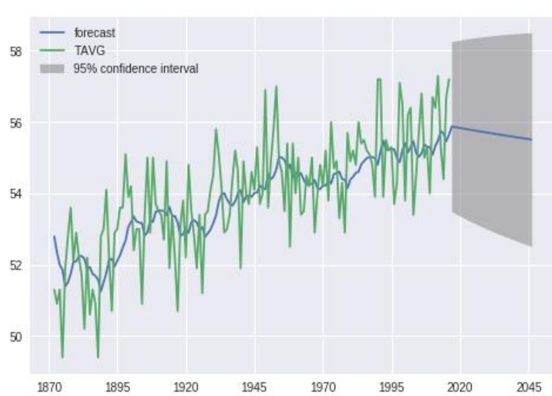

Figure 21 Global Average Temperature Prediction till 2050 with Confidence Interval

XIV. CONCLUSION

The analysis of global temperature trends from 1961 to 2019 reveals significant disparities in how regions are affected by climate change. Industrialized nations, particularly in Europe and North America, have seen the most substantial temperature increases over the last six decades. Areas like the Svalbard and Jan Mayen Islands and Russia have been particularly affected in recent years, highlighting the Arctic's vulnerability to rising temperatures. The data shows a strong link between industrial activities and temperature rise, with most impacted areas being highly industrialized. In contrast, countries such as India, despite their extensive industrial activities, have experienced relatively minimal temperature increases, suggesting that local factors like geography and specific policies may mitigate some global warming impacts [40]. Comparing Annex I (industrialized) and non-Annex I (developing) countries shows that the former group exhibits a steady temperature rise, while the latter shows a more erratic warming trend with frequent peaks. Seasonal analysis indicates that winters have experienced more fluctuations than summers, with 2016 recording the hottest winter globally. The regression analysis reveals a dramatic increase in global temperatures since 2000, emphasizing an urgent need for climate action. Historically, the best climate periods were between 1875-1900 and 1950-2000, with notable declines from 1900-1950. Temperature uncertainty was high before the 1960s, especially in countries like the USA and China, where unpredictable rises complicate mitigation efforts. Clustering analysis shows that countries like Nicaragua and Morocco have seen dramatic temperature increases since the 1850s, while developed European nations like Denmark have managed to stabilize their climate. These findings underscore the urgent need for global cooperation to reduce greenhouse gas emissions, implement sustainable policies, and protect vulnerable regions from the accelerating impacts of climate change. Moreover, global average temperatures are rising steadily and could reach nearly 30°C by 2050 if current trends continue (Figure 20). Figure 21 shows that the green line represents the historical global average temperature, while the blue line forecasts future trends until 2050, with a 95% confidence interval represented by the grey area, indicating a high probability of significant temperature increases in the near future. In a worst-case scenario, global temperatures could rise as high as 50°C, further emphasizing the critical need for global cooperation to reduce greenhouse gas emissions, implement sustainable policies, and protect vulnerable regions from the accelerating impacts of climate change.

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