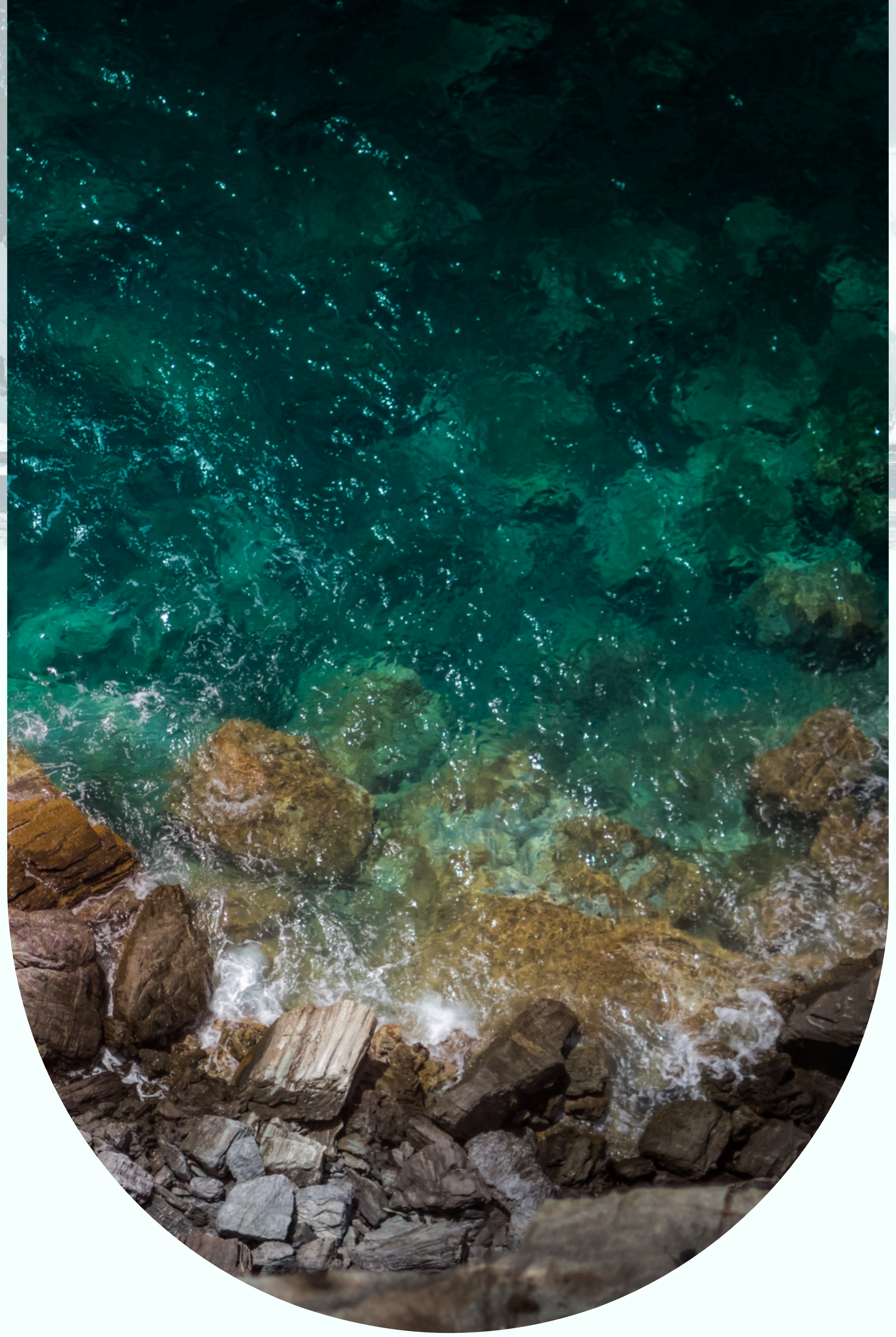

CLIMATE CHANGE DATA ANALYSIS IN THE US (1936 - 2024)

Group 3: Muhammad Ahmed Ehtisham, Ian Appleby, Safae Jdid, Gita Patigana, Mehek Kumar

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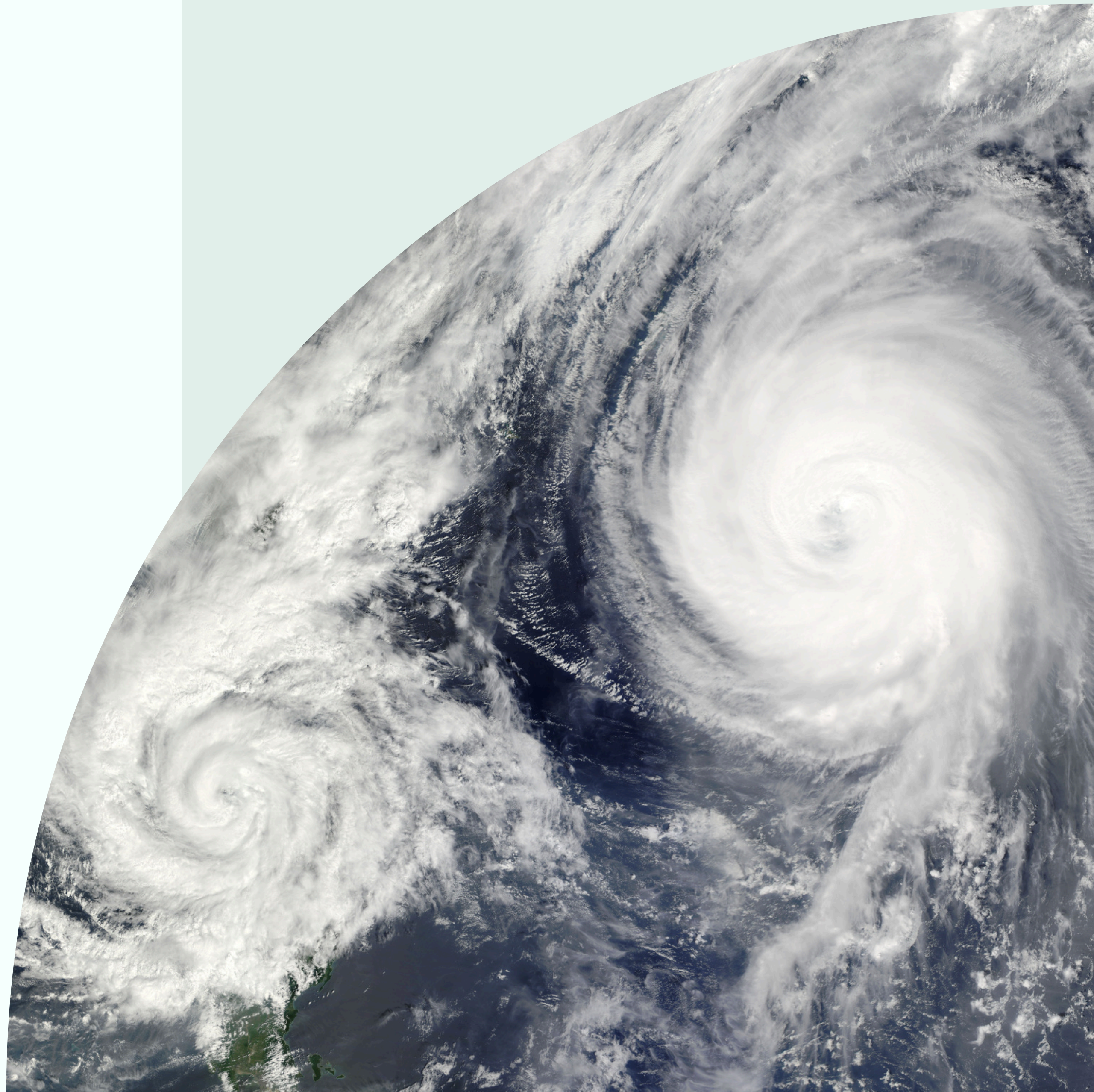
Weather Trends, Anomalies, and Extreme Events

Introduction

Climate change is one of the most pressing issues of our time. Analyzing historical weather data helps us understand long-term trends, temperature anomalies, and extreme weather events.

This project aims to:

✅ Investigate historical weather patterns (1936-2024)
✅ Identify long-term temperature trends
✅ Analyze extreme weather events and anomalies
✅ Understand seasonal and annual variations



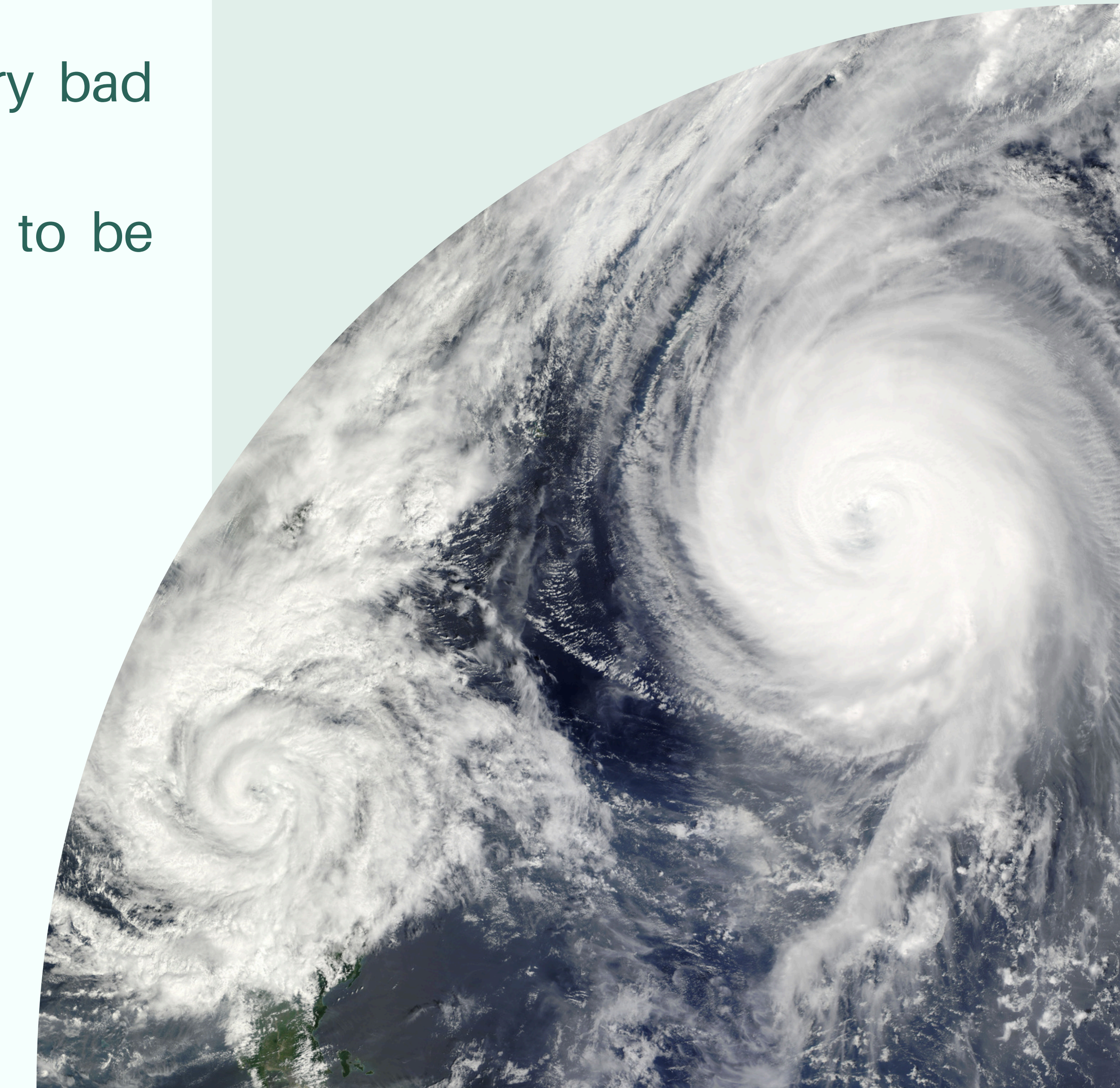
Data Source: https://www.ncdc.noaa.gov/cdo-web/datasets

Issues Faced and Libraries Used

- Data extraction very difficult, took up a lot of time
- NOAA website downtime.
- Gen AI models not using proper analysis tools until specified and reiterated
- Gen AI models using wrong column names again and again causing error in codes
- Visualization code provided by Gen AI tools producing very bad visuals, required a lot of iterations and prompting
- Gen AI having difficulty reading variable types, which had to be corrected manually.

Libraries

- pandas
- matplotlib
- seaborn
- numpy
- sklearn
- statsmodels.tsa.arima.model
- sklearn.linear_model



Data Overview

📌 **Dataset:** Weather records from 1936 to 2024
📌 **Location:** Apalachicola Airport, FL; Barrow Airport, AK; Logan Airport (BOS), MA; Downtown Station (LA), CA
📌 **Key Variables Analyzed:**

- Temperature (TMAX, TMIN, TAVG)
- Wind Speed (AWND, WSFG)
- Precipitation (DP01, DP10, ENSM)
- Seasonal and Yearly Trends

📌 **Data Cleaning:**

- Handling missing values
- Ensuring data consistency
- Checking for outliers and anomalies

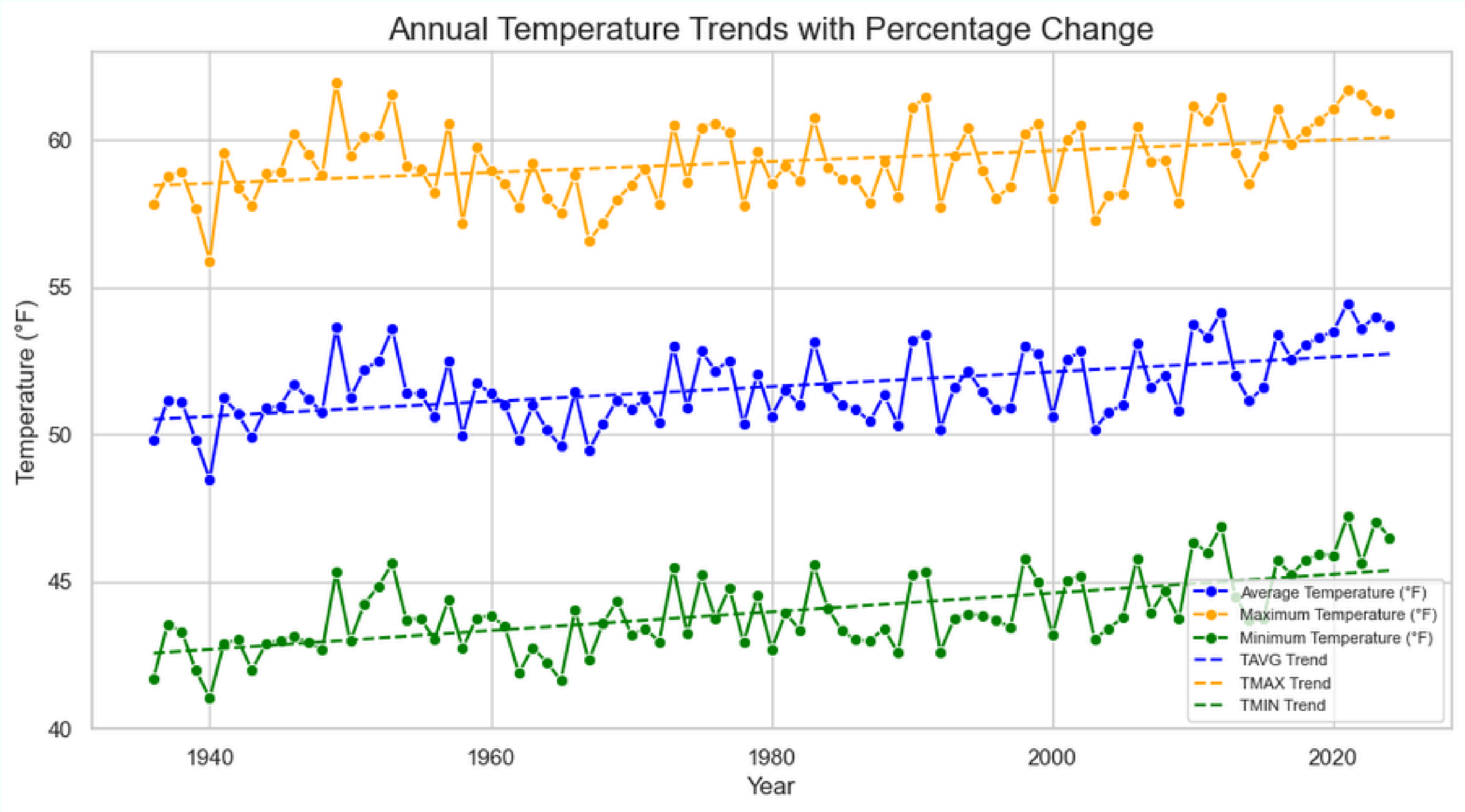
Data Scope (1936 - 2024)

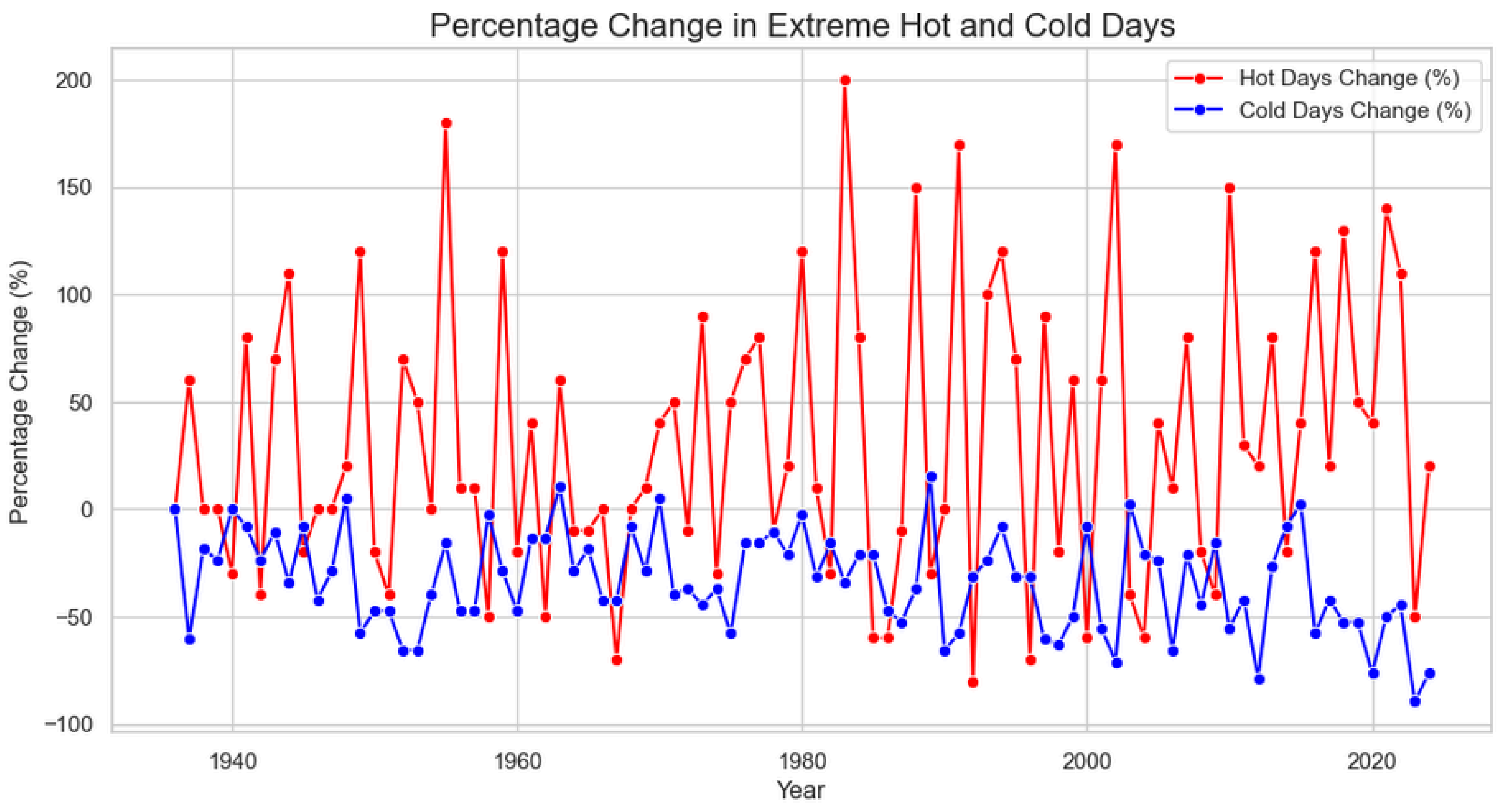
Our Climate Change Data Analysis focuses on historical weather trends from 1936 to 2024 within key regions of the United States. The study specifically examines weather patterns in:

- Boston
- California
- Alaska
- Florida

This analysis provides valuable insights into how climate change manifests differently in each region, helping us assess risks, predict future trends, and support data-driven climate policy recommendations. 🌍📊

Boston





Temperatures

The average, maximum, and minimum temperatures show a consistent upward trend over the years

This confirms a warming trend in Boston. A steady increase suggests higher annual heat retention, with the minimum temperature rising slightly more than the maximum, indicating milder winters

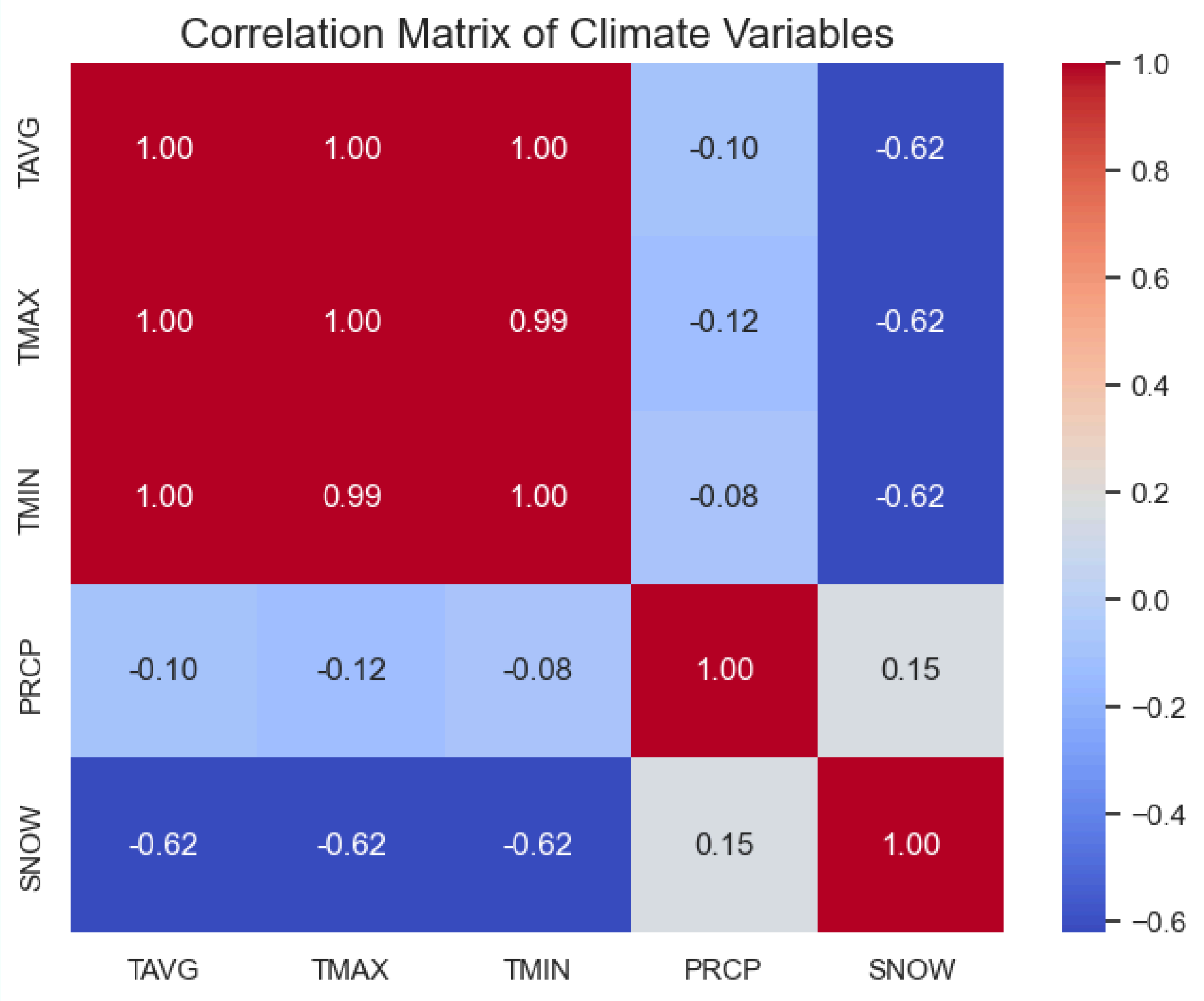
Extreme Hot and Cold Days

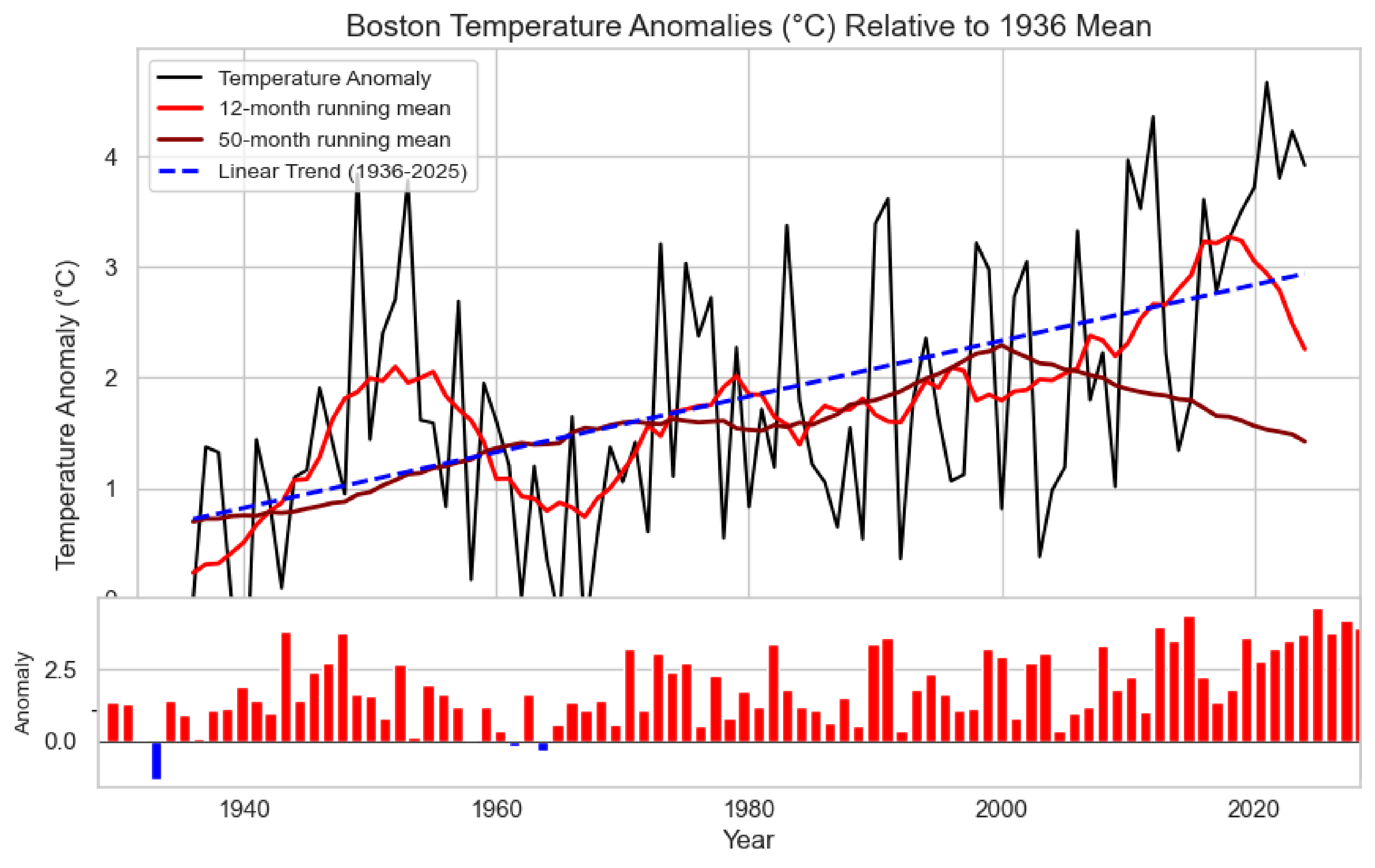
A clear increase in the number of extreme hot days over the decades.

Increased frequency of heatwaves

A decline in the number of extreme cold days, indicative of milder winters.

Boston





Climate Variables Correlation

Temperature and Snowfall: Strong negative correlation (-0.62), indicating that rising temperatures are associated with reduced snowfall.

Precipitation and Snowfall: Weak positive correlation (0.15), suggesting snowfall is less dependent on total precipitation and more on temperature.

Temperature Metrics (TAVG, TMAX, TMIN): High correlation (≈1.00), confirming that changes in one temperature metric (e.g., average) reflect across all.

Relative Temperature anomalies

From 1936 to 2025, the average temperature anomaly has risen significantly, exceeding 4°C in recent years.

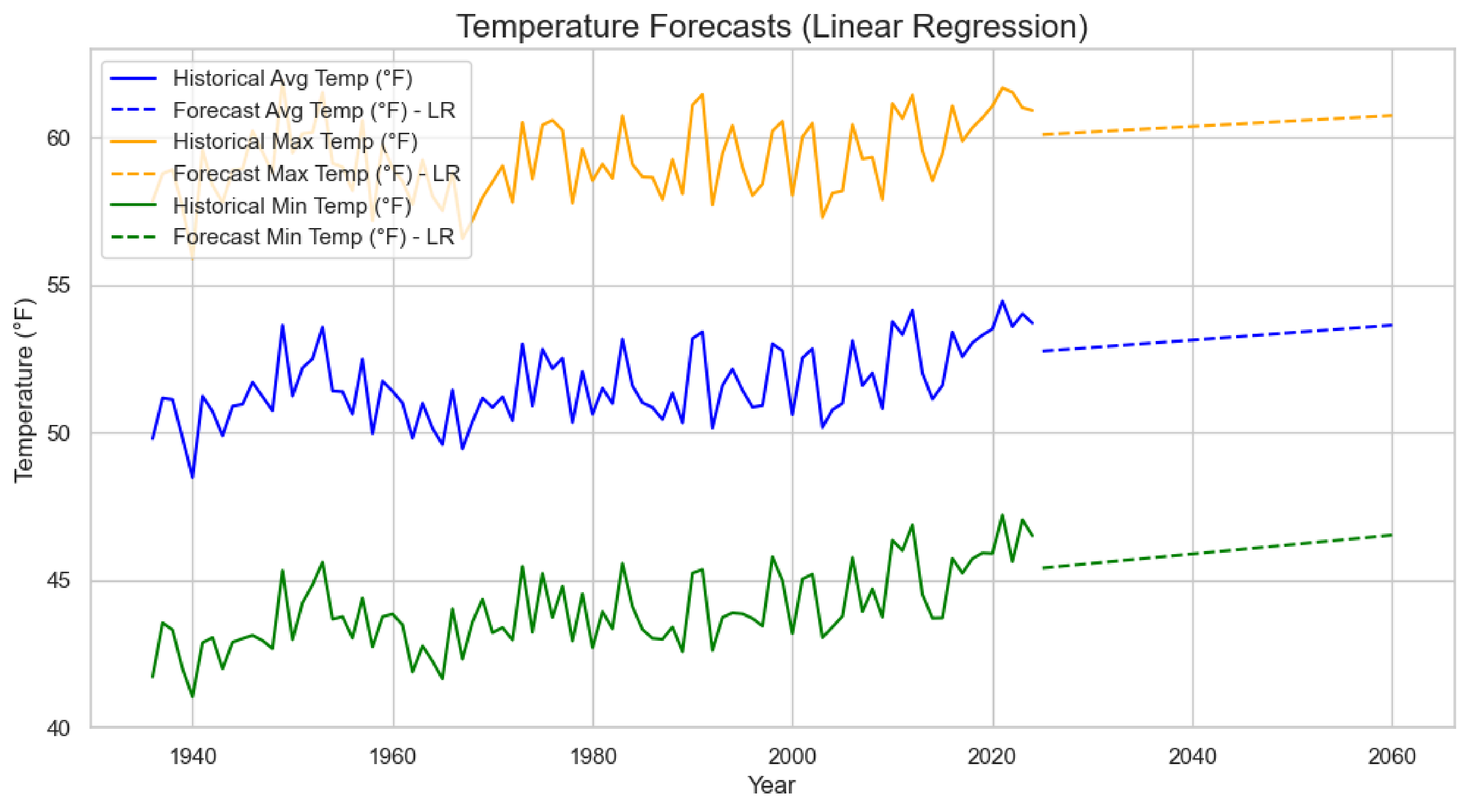
The 12-month running mean (red line) smooths seasonal variations, while the 50-month running mean (dark red line) highlights long-term trends.

The late 20th century and early 21st century show a steeper incline in temperature anomalies.

Recent years exhibit a higher frequency of extreme temperature anomalies, suggesting stronger warming trends.

The rate of warming appears faster in the last few decades, aligning with global climate change patterns.

Boston



Forecast Summary for 2025-2060:

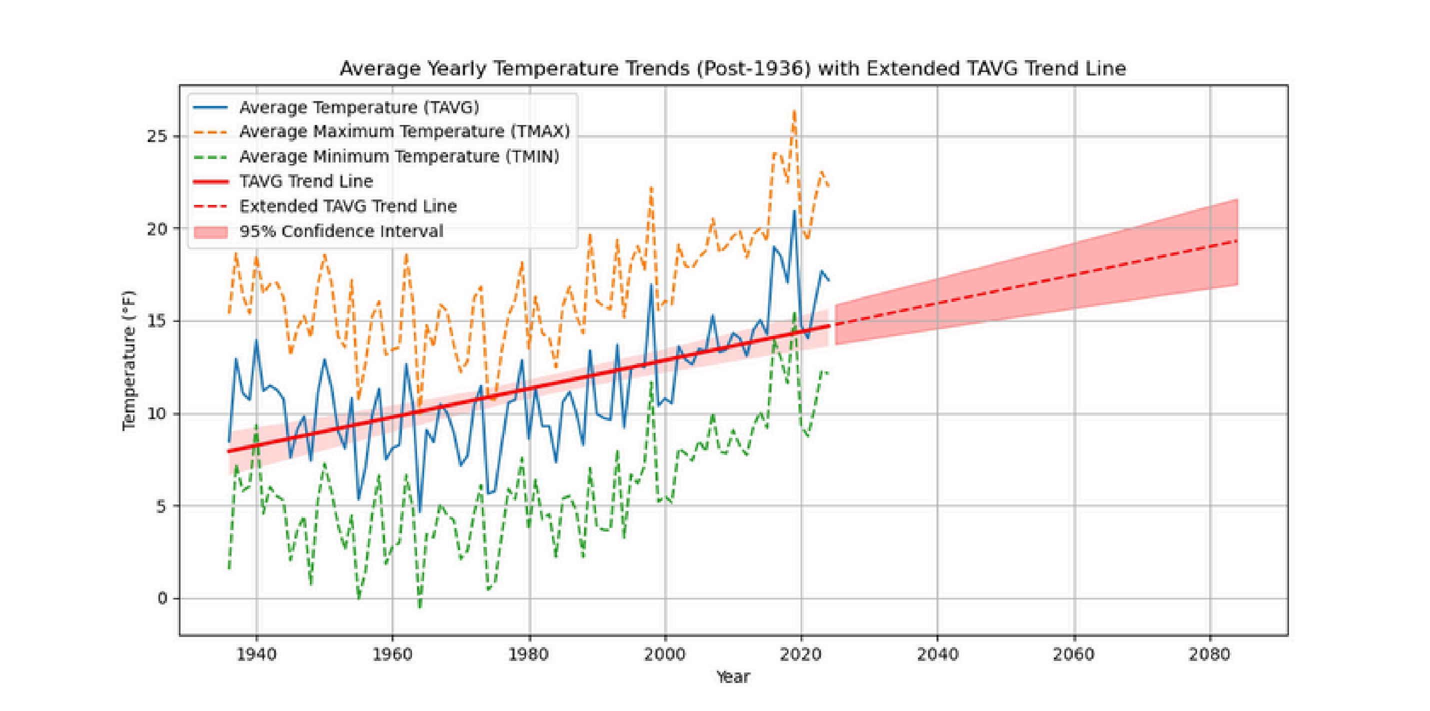
	Year	TAVG_LR	TMAX_LR	TMIN_LR	PRCP_ARIMA	SNOW_EXP	DX90_ES
0	2025	52.755871	60.099653	45.407744	43.070192	45.588497	14.563528
1	2026	52.781050	60.118114	45.439626	42.849957	45.648044	14.589791
2	2027	52.806228	60.136575	45.471509	42.829138	45.707591	14.615922
3	2028	52.831406	60.155036	45.503391	42.827170	45.767138	14.641922
4	2029	52.856585	60.173497	45.535274	42.826984	45.826685	14.667792
5	2030	52.881763	60.191957	45.567156	42.826967	45.886232	14.693533
6	2031	52.906941	60.210418	45.599039	42.826965	45.945779	14.719146
7	2032	52.932120	60.228879	45.630921	42.826965	46.005327	14.744630
8	2033	52.957298	60.247340	45.662803	42.826965	46.064874	14.769987
9	2034	52.982476	60.265801	45.694686	42.826965	46.124421	14.795217
10	2035	53.007654	60.284262	45.726568	42.826965	46.183968	14.820321
11	2036	53.032833	60.302723	45.758451	42.826965	46.243515	14.845299
12	2037	53.058011	60.321184	45.790333	42.826965	46.303062	14.870153
13	2038	53.083189	60.339644	45.822216	42.826965	46.362609	14.894882
14	2039	53.108368	60.358105	45.854098	42.826965	46.422156	14.919487
15	2040	53.133546	60.376566	45.885981	42.826965	46.481703	14.943970
16	2041	53.158724	60.395027	45.917863	42.826965	46.541250	14.968330
17	2042	53.183903	60.413488	45.949745	42.826965	46.600797	14.992568
18	2043	53.209081	60.431949	45.981628	42.826965	46.660344	15.016686
19	2044	53.234259	60.450410	46.013510	42.826965	46.719891	15.040682
20	2045	53.259438	60.468871	46.045393	42.826965	46.779438	15.064559
21	2046	53.284616	60.487331	46.077275	42.826965	46.838985	15.088316
22	2047	53.309794	60.505792	46.109158	42.826965	46.898532	15.111954
23	2048	53.334973	60.524253	46.141040	42.826965	46.958079	15.135475
24	2049	53.360151	60.542714	46.172923	42.826965	47.017626	15.158877
25	2050	53.385329	60.561175	46.204805	42.826965	47.077173	15.182163
26	2051	53.410508	60.579636	46.236688	42.826965	47.136720	15.205332
27	2052	53.435686	60.598097	46.268570	42.826965	47.196268	15.228385
28	2053	53.460864	60.616558	46.300452	42.826965	47.255815	15.251323
29	2054	53.486043	60.635018	46.332335	42.826965	47.315362	15.274147
30	2055	53.511221	60.653479	46.364217	42.826965	47.374909	15.296856
31	2056	53.536399	60.671940	46.396100	42.826965	47.434456	15.319452
32	2057	53.561578	60.690401	46.427982	42.826965	47.494003	15.341934
33	2058	53.586756	60.708862	46.459865	42.826965	47.553550	15.364305
34	2059	53.611934	60.727323	46.491747	42.826965	47.613097	15.386563
35	2060	53.637113	60.745784	46.523630	42.826965	47.672644	15.408710

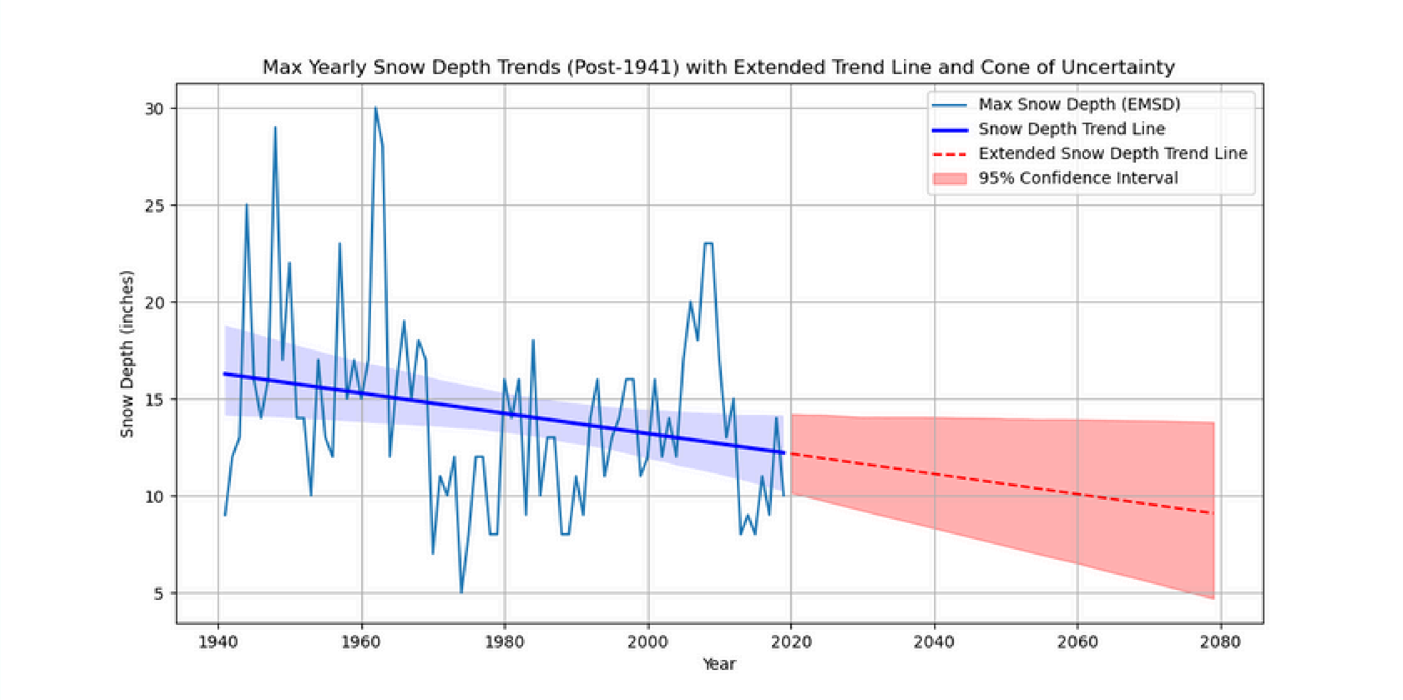
Forecasts

The average temperature is forecasted to increase from approximately 52.76°F in 2025 to 53.64°F in 2060.
The maximum temperature is expected to rise from 60.10°F in 2025 to 60.75°F in 2060
Minimum temperatures are forecasted to increase from 45.41°F in 2025 to 46.52°F in 2060
Heatwave days are predicted to continue increasing from ~14.6 days in 2025 to ~15.4 days by 2060.
Cold days (DX32) show a gradual decline over the historical period.
This indicates a gradual warming trend over the next three decades, peak heat events and milder winters

Total annual precipitation and snowfall is forecasted to stabilize

Alaska





Average Temperature Chart

- There is a clear and substantial rise in temperatures at Barrow Airport in Alaska.
  - Average yearly temperatures began around 10 degrees Fahrenheit in the 1930s and 1940s but there is a clear upward trend from 1980 on.
  - As we approach the 2020s, we begin seeing average temperatures for most years above 15 degrees Fahrenheit. 2019 saw an average temperature above 20 degrees.
- This trend seems to be accelerating
  - Future predictions with a linear regression seem to indicate a continued rise in. average temperature.
  - The upper interval of the confidence interval seems to indicate that there is a strong possibility that 20 degree average temperatures will be the new normal 60 years from now.

Max Snow Depth Chart

- There is much more variance than we see in temperatures, but there is still a clear decrease in the snowfall totals over time (note: data only available from 1941 on).
  - Since 1960, there has been a clear drop off in maximum snow depth, and in the last 10 years there hasn't been a depth of greater than 15 inches.
- The predicted trend from this data is a little less concerning
  - The upper band of the confidence interval stays constant, highlighting that levels have a possibility of staying constant.
  - There is still a clear downward trend from the predicted data.

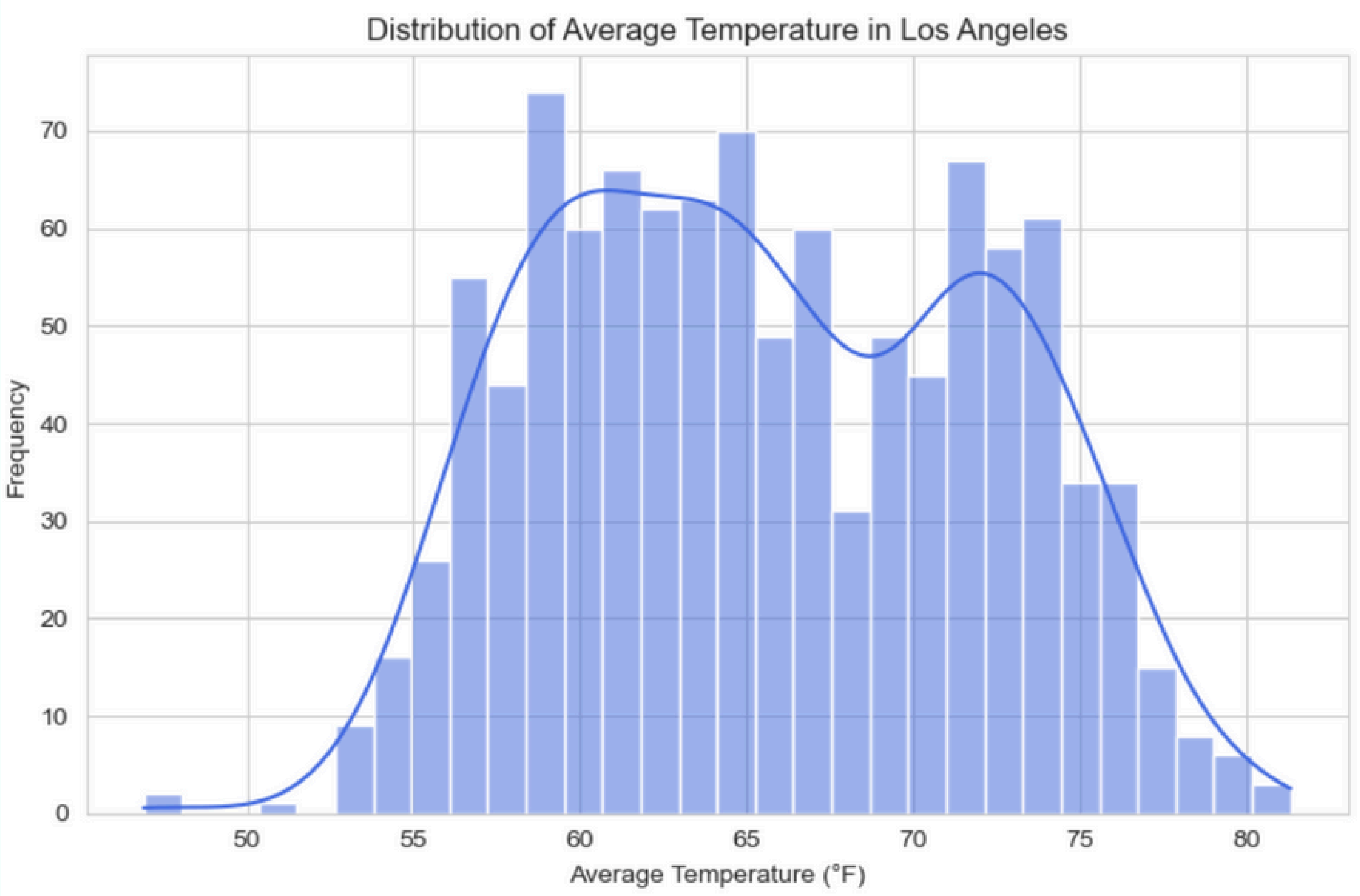
CALIFORNIA

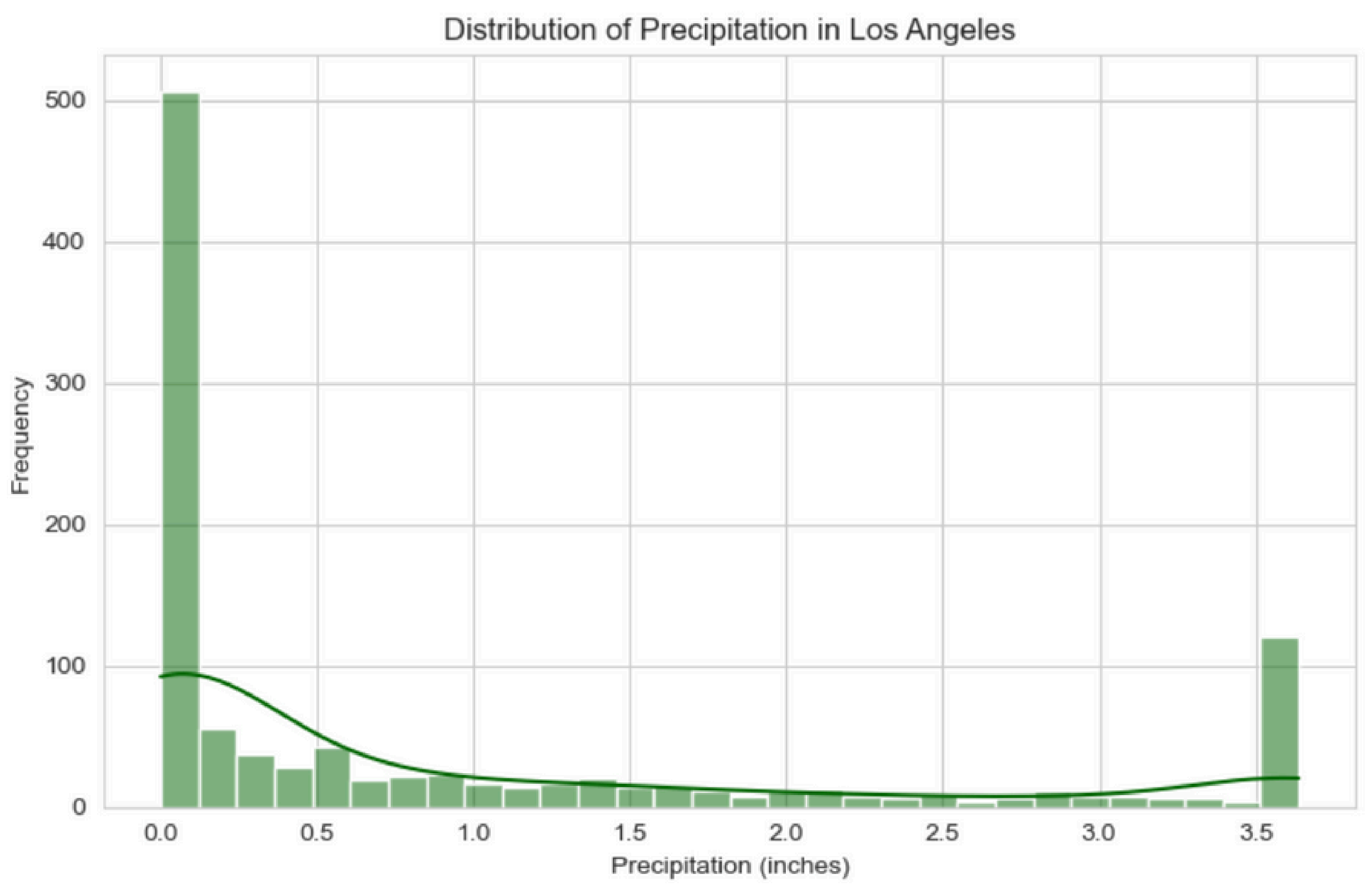
LOS ANGELES Downtown station

The Los Angeles Downtown weather station was selected to represent the Southwest region, as it captures critical urban climate data from one of the largest metropolitan areas in the U.S. This station is particularly relevant due to its unique climate characteristics, including rising temperatures and drought variability.

California

LOS ANGELES Downtown station



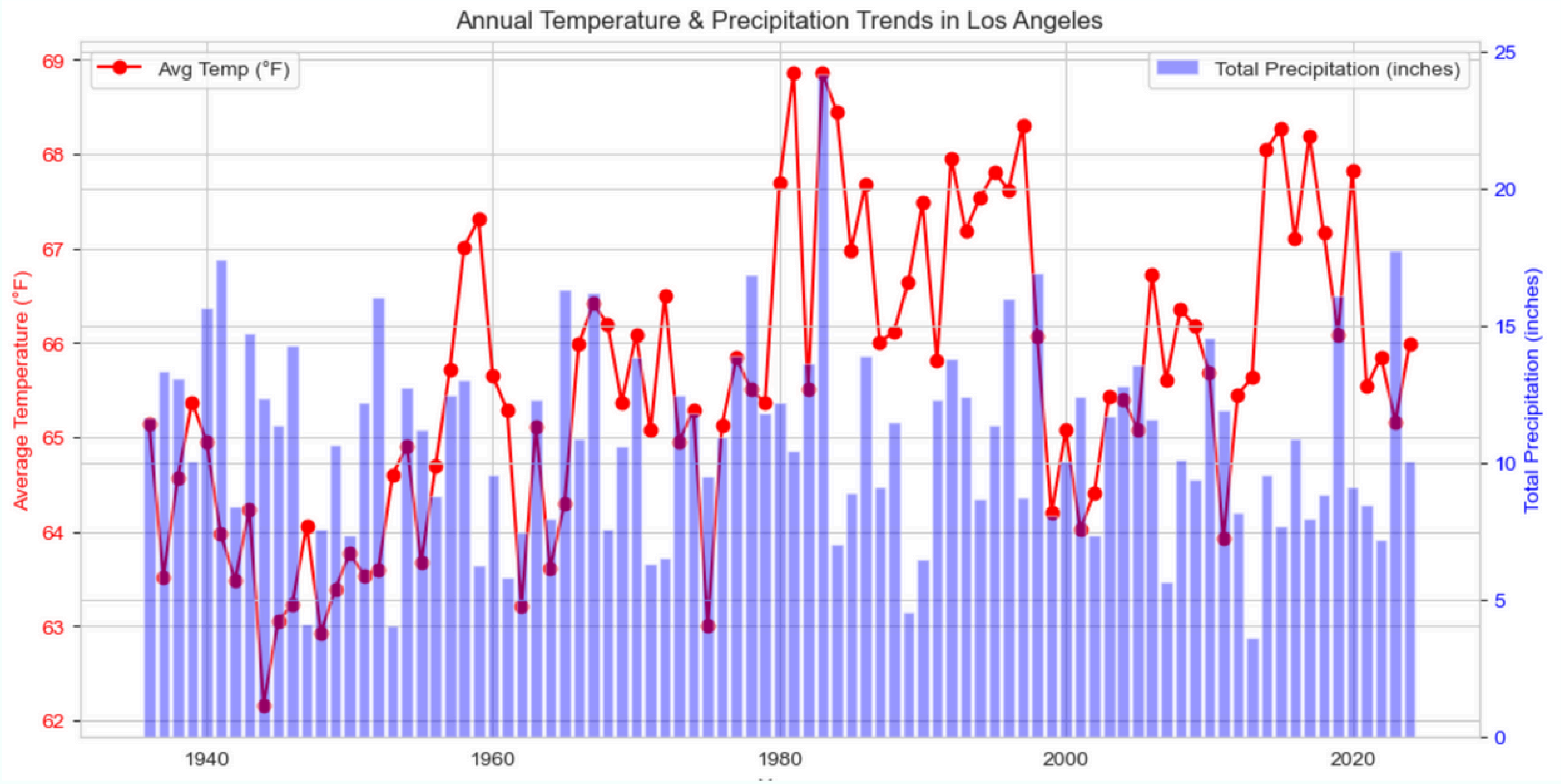


Temperature Distribution Reflecting Urban Warming Trends

With most temperature values clustered between 55°F and 75°F, peaking around 65°F. This aligns with Los Angeles' mild Mediterranean climate, characterized by warm, dry summers and cooler, wetter winters. The slight skew toward higher temperatures corresponds to the gradual warming trend observed in the dataset from 2000 to 2024, consistent with real-life evidence of urban heat effects and climate change impacts in the Southwest region.

Temperature Distribution Reflecting Urban Warming Trends

The right graph, showing the distribution of precipitation, underscores the predominantly dry nature of Los Angeles, with the majority of days recording little to no rainfall. This is reflected in the dataset, where dry years dominate, punctuated by occasional extreme precipitation events. Such patterns align with real-world phenomena, such as the prolonged droughts experienced in California during the early 2010s, followed by sporadic heavy rainfall events like those seen during El Niño years. These findings highlight the region's susceptibility to water scarcity and the growing unpredictability of rainfall patterns due to climate change.



California

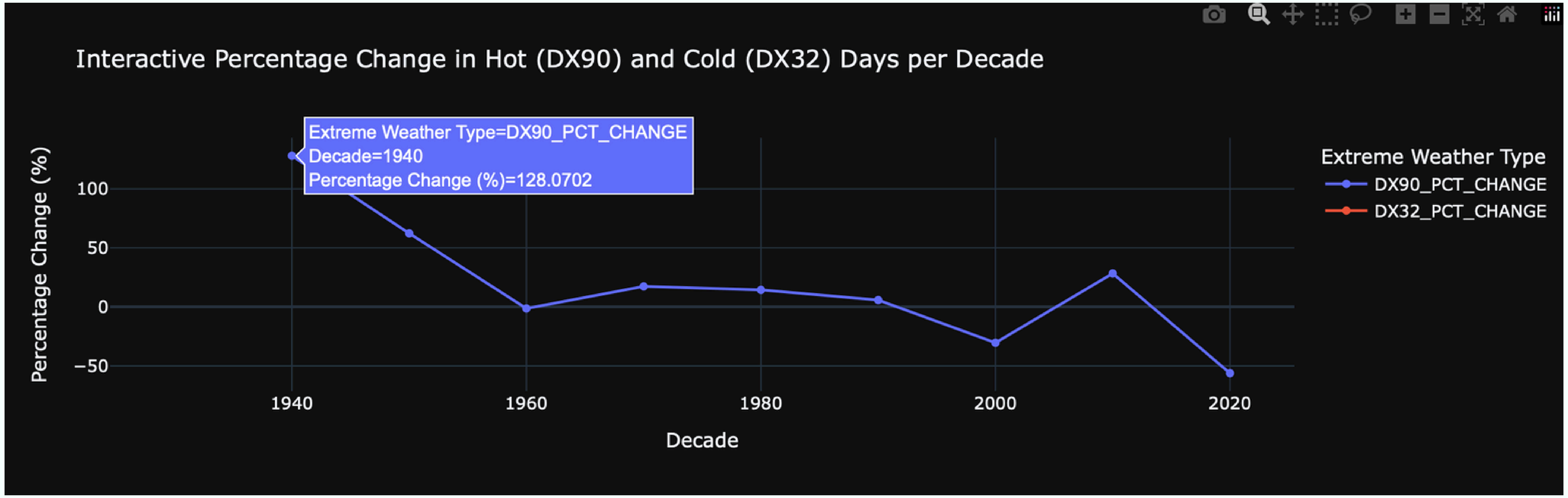
LOS ANGELES Downtown station

Water scarcity

The natural climatic pattern already predisposes the region to periodic water scarcity. However, the observed increase in temperature intensifies evapotranspiration rates, leading to a significant reduction in surface and groundwater availability.

Higher temperatures also impact the hydrological cycle by reducing snowpack in the Sierra Nevada—a critical water source for Southern California—and increasing the reliance on imported water from external basins.

Elevated temperatures exacerbate soil desiccation, decrease agricultural yields, and contribute to the depletion of ecosystems that depend on intermittent precipitation. The data underscores the urgency of adaptive strategies, such as improved water conservation technologies, enhanced storage capacity, and a transition to drought-resilient infrastructure, to mitigate the long-term impacts of rising temperatures on this inherently arid region.



California

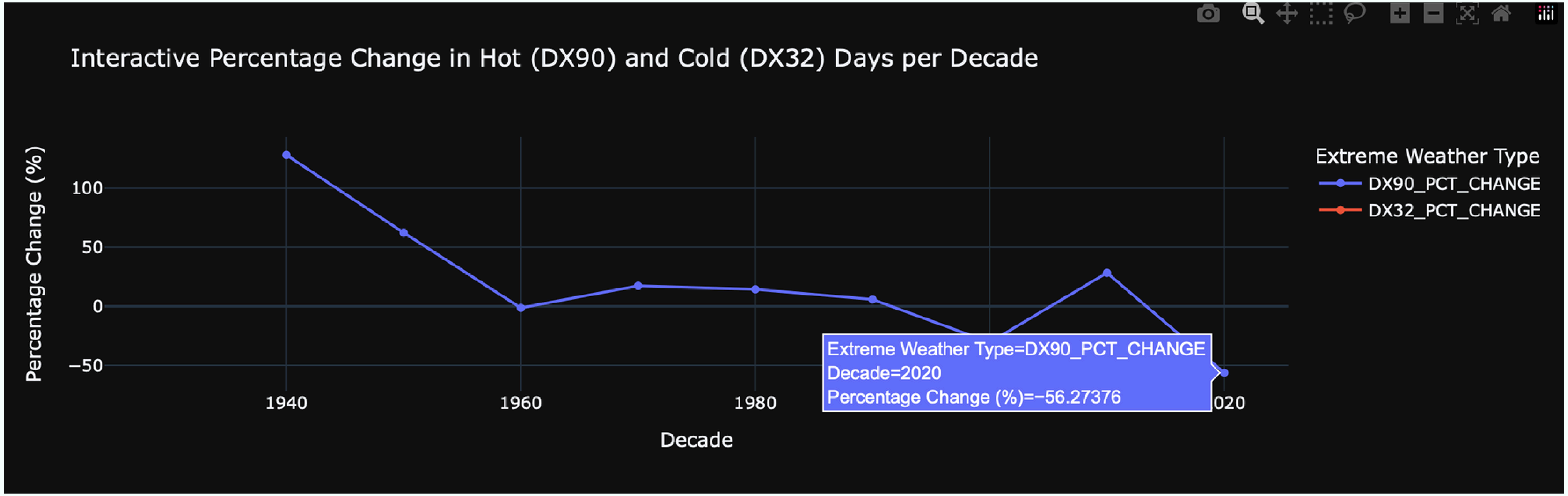
LOS ANGELES Downtown station

Climate change glimpses

- **Extreme Heat Variability**: The sharp rise in extreme heat events by +128% during the mid-20th century reflects a significant climatic shift, potentially driven by changing atmospheric conditions. However, the -56% decline in recent decades indicates a more complex trend requiring further study.
- **Consistent Mild Winters:** The absence of any cold days highlights the stability of Los Angeles' mild winters, with no significant temperature drops recorded across the dataset.
- **Regional Implications:** These findings emphasize the need for localized climate adaptation measures, particularly for managing the risks of heat waves while considering the long-term stability of mild winter temperatures.

California

LOS ANGELES Downtown station



Climate change glimpses

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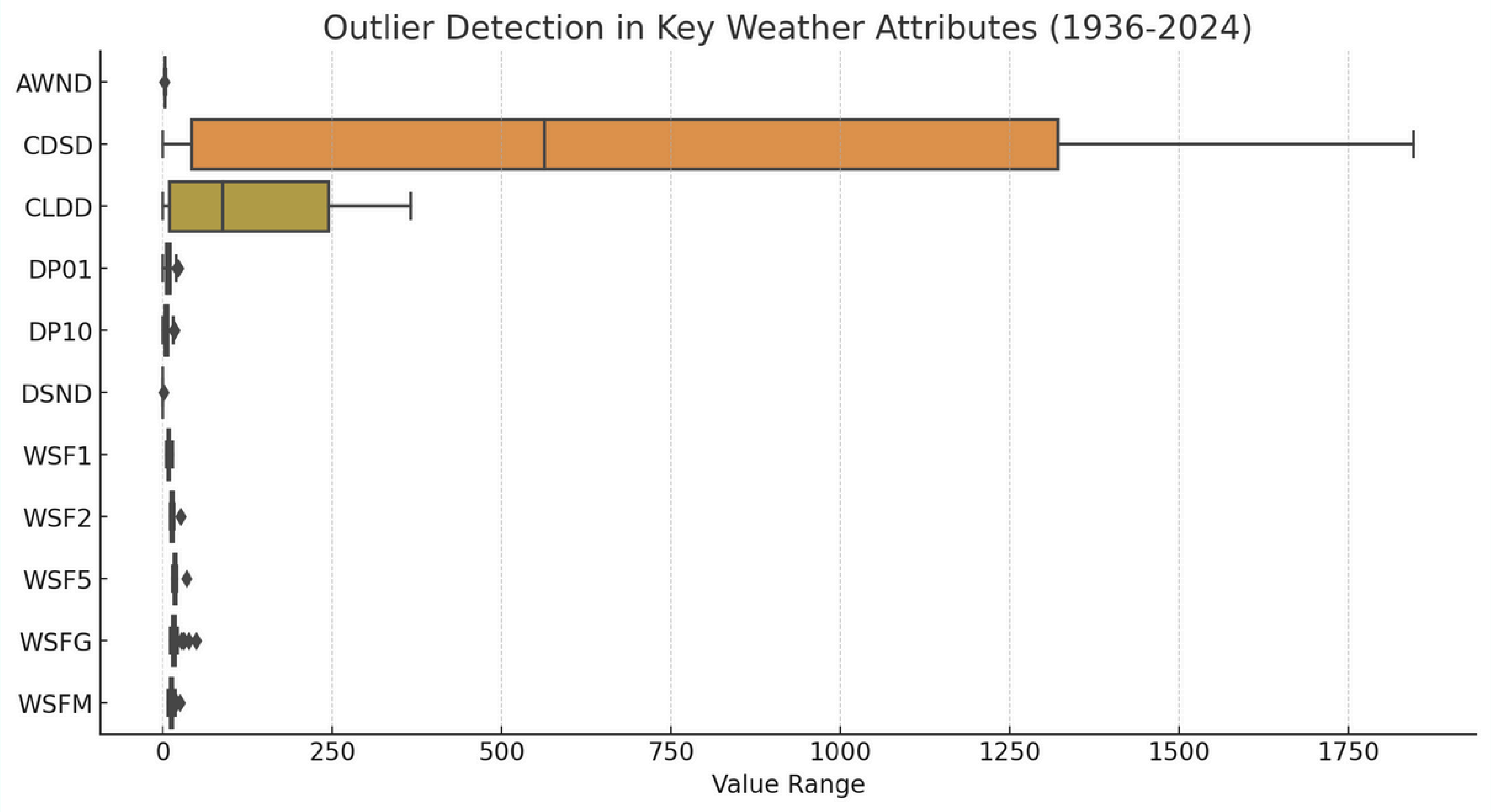
Florida

This analysis provides insights into weather patterns in Apalachicola Airport, FL, focusing on temperature anomalies, seasonal variations, extreme weather events, and long-term trends. Below is a breakdown of the findings based on the uploaded visualizations.



Outlier Detection in Key Weather Attributes

CDSD

Cooling Degree Days (CDSD) and CLDD (Cooling Load Degree Days) exhibit significant outliers, indicating extreme variations.

Precipitation

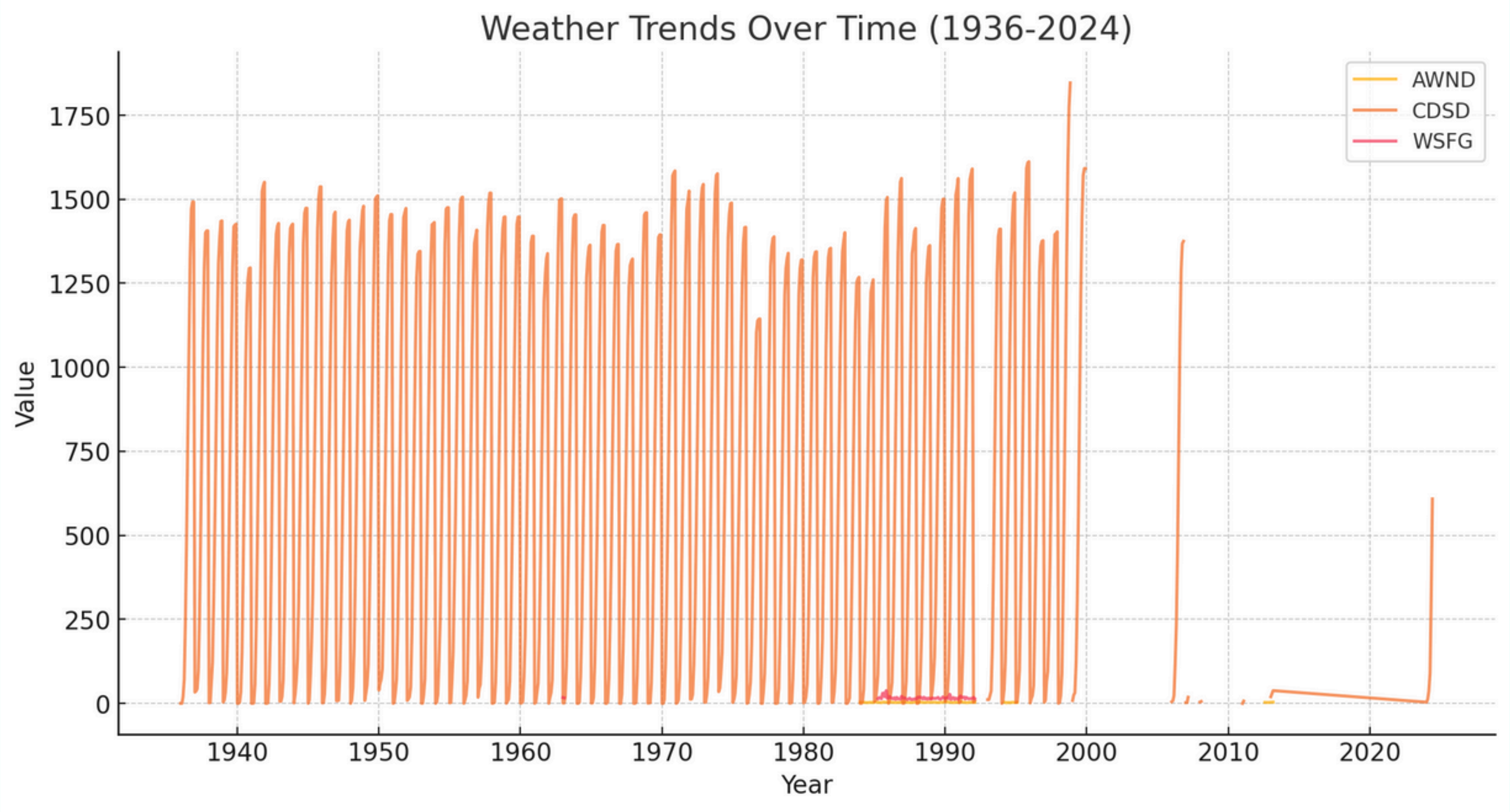
Precipitation-related variables (DP01, DP10) also show multiple outliers, hinting at unusual rainfall patterns.

Wind Speeds

Wind speeds (WSF1, WSF2, WSF5, WSFG, WSFM) have extreme values, which may correspond to hurricanes or storm events.

These extreme values indicate possible climate shifts, such as more frequent and intense heatwaves or storms. Outliers in wind speed could signify major weather events like hurricanes or tropical storms affecting the region.

Wheater Trends Over Time



CDSD

CDSD (Cooling Degree Days) shows an increasing trend, reflecting rising temperatures and increased energy consumption for cooling.

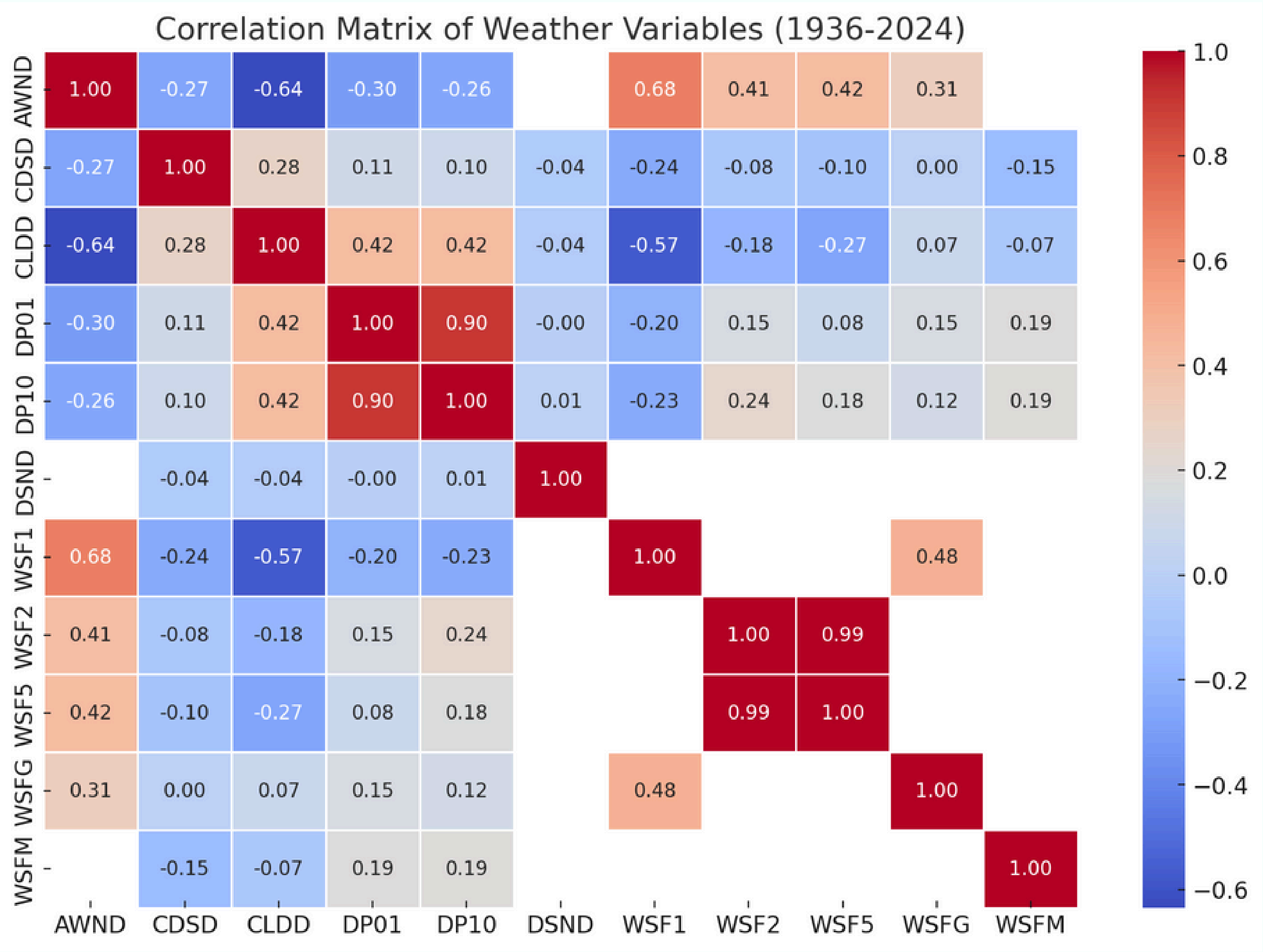
Precipitation

AWND (Average Wind Speed) remains relatively stable, suggesting no drastic long-term changes in background wind conditions.

Wind Speeds

Wind gust speeds (WSFG) fluctuate significantly, with peaks corresponding to extreme weather events.

- **The increasing CDSD trend suggests a warming climate, with more demand for cooling systems.**
- **Periodic spikes in wind speeds might be linked to storm seasons or specific extreme events.**
- **The relatively stable AWND suggests that while extreme weather events occur, the general wind pattern has not changed drastically.**



Correlation Matrix of Weather Variables

CDSD

Strong positive correlation between precipitation-related variables (DP01 & DP10) indicates that when it rains, it tends to be heavy.

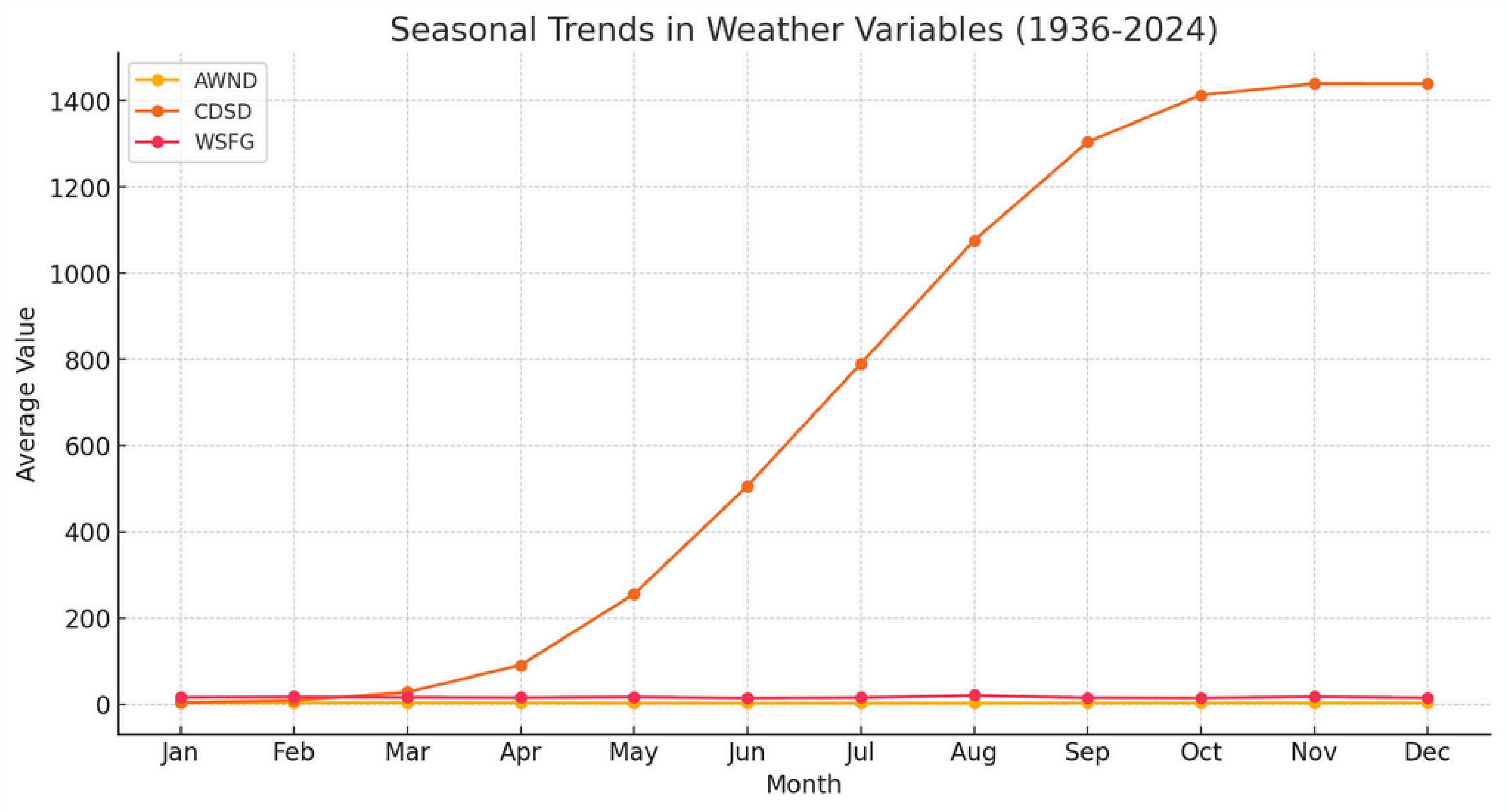
Precipitation

High correlation between wind speed measurements (WSF1, WSF2, WSFG, WSFM), indicating that they capture similar weather conditions.

Wind Speeds

Negative correlation between wind speeds and temperature-related variables (CDSD, CLDD) suggests that higher temperatures do not necessarily correlate with stronger winds.

- **The high correlation between precipitation variables suggests that heavy rainfall events tend to occur together rather than being evenly distributed.**
- **The negative correlation between wind and temperature indicates that storms do not necessarily bring hotter or cooler conditions.**
- **The strong correlation among wind speed variables confirms data consistency and reliability.**



Seasonal Trends in Weather Variables

CDSD

CDSD (Cooling Degree Days) peaks in summer (June-August), indicating higher temperatures during these months.

Precipitation

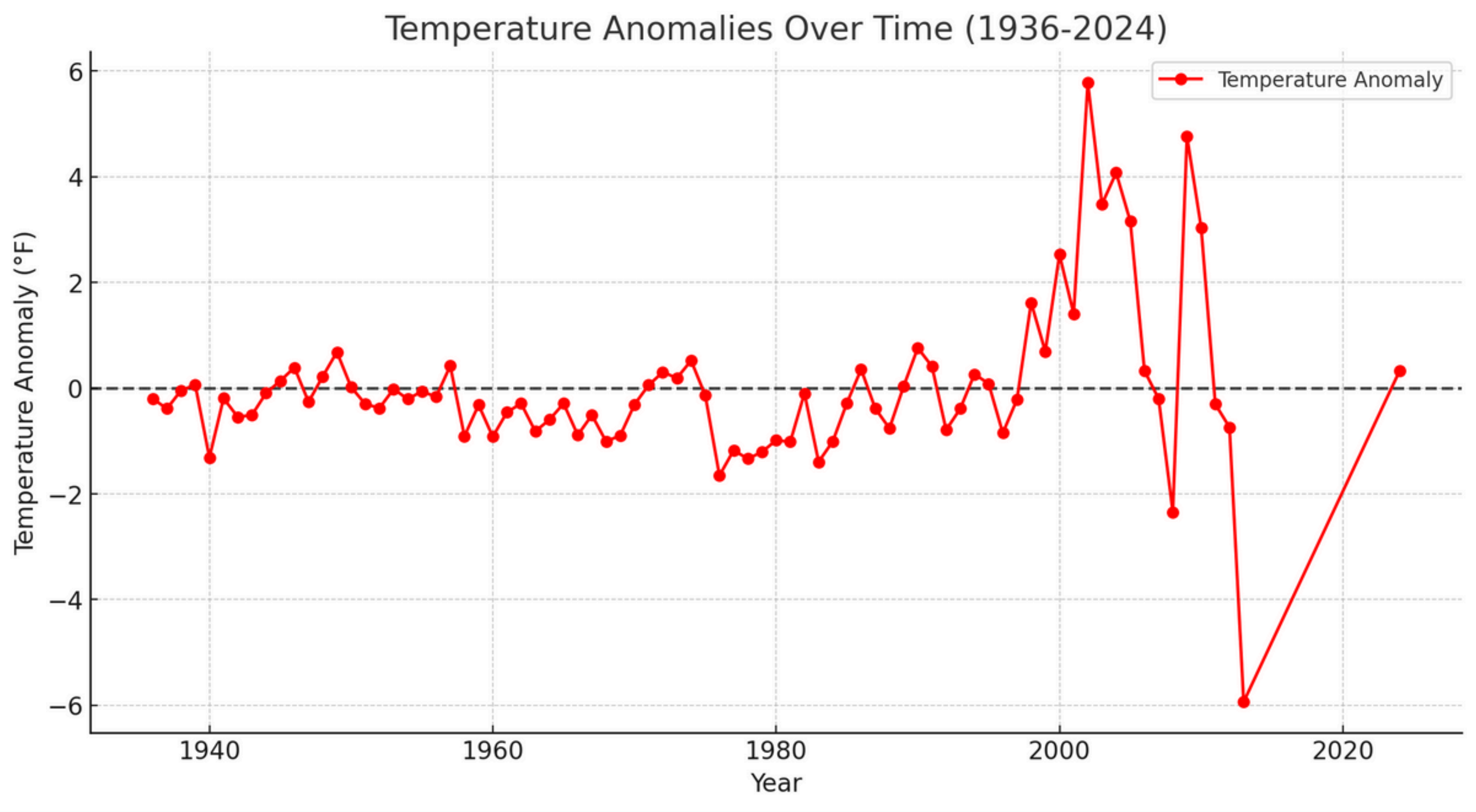
WSFG (Wind Gust Speed) appears slightly elevated in some months, possibly during storm seasons.

Wind Speeds

Wind speeds show minor seasonal variations, with no drastic seasonal spikes.

- **High summer CDSD values confirm increased temperatures, requiring more cooling energy.**
- **Wind speeds are relatively stable throughout the year, suggesting that extreme wind events are more storm-driven than seasonal.**
- **Minor variations in WSFG could be linked to hurricane seasons or occasional high-wind weather systems.**

Temperature Anomalies Over Time (1936-2024)

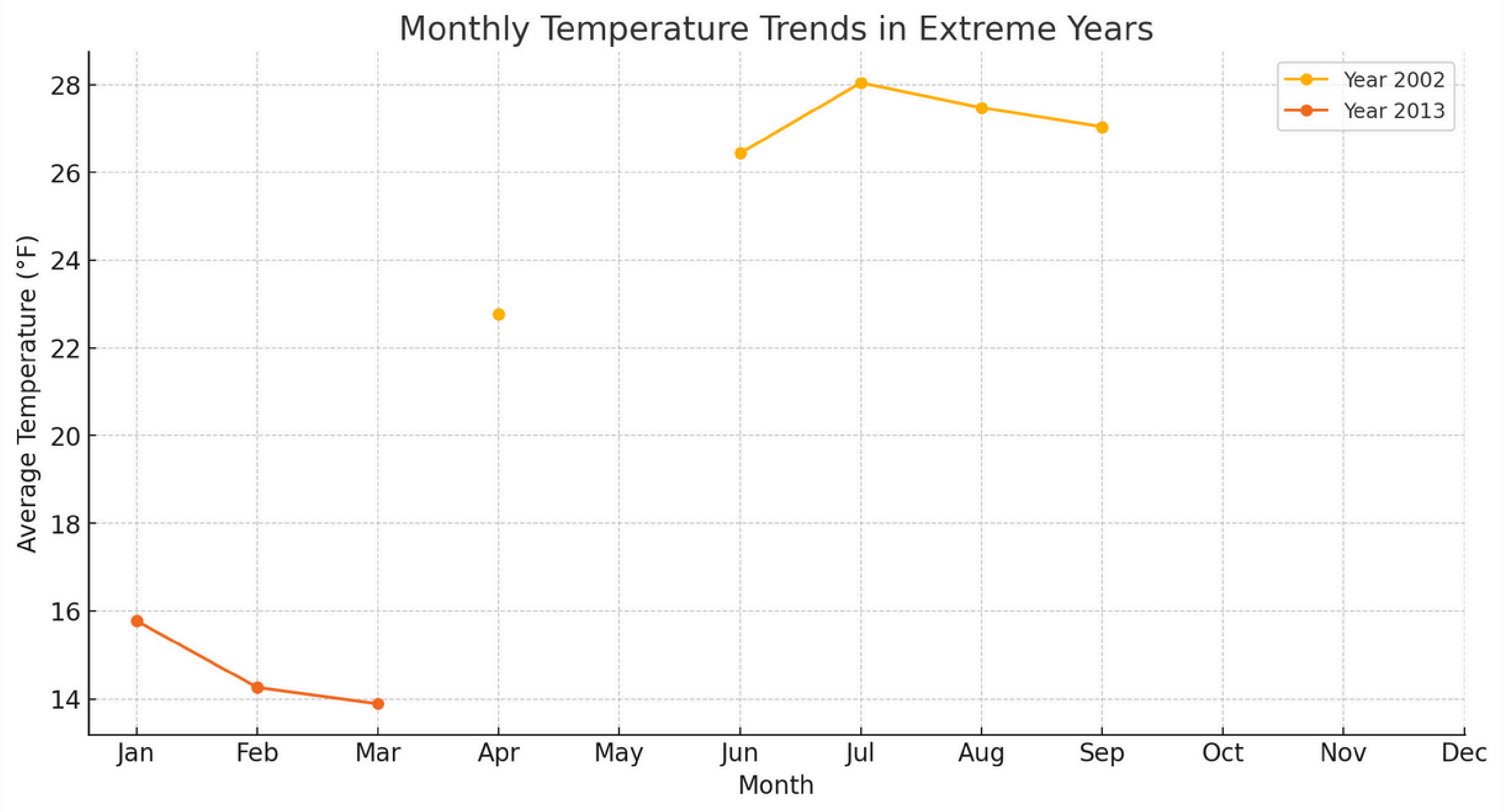


Temperature anomalies have increased significantly over the past few decades, indicating a warming trend.

Some years experienced negative anomalies, but the general trend remains upward

Several extreme peaks in recent years show significant deviations from the baseline average temperature.

- This is strong evidence of climate change, with a general warming trend over time.
- Extreme positive anomalies may indicate heatwaves or warmer-than-usual years.
- Occasional negative anomalies show cooling years, but these are becoming less frequent.



Monthly Temperature Trends in Extreme Years

Hottest years exhibit a significantly higher temperature trend across all months.

Seasonal variations remain, but extreme years deviate further from typical trends.

Coldest years show a deviation from the norm, particularly in winter months.

- Extreme years confirm the increasing intensity of climate fluctuations.
- The hottest years demonstrate persistent warming across all months.
- Coldest years are becoming rarer, with most deviations favoring warmer trends.

Conclusion

Florida

🌍 Climate change is evident in the dataset, with clear signs of warming trends and extreme weather events.

- Rising temperature anomalies suggest a long-term warming trend.
- Increased Cooling Degree Days (CDSD) indicate higher summer temperatures, leading to greater energy consumption.
- Wind speed outliers point to extreme weather events like hurricanes or strong storms.
- Precipitation trends show variability, with heavy rainfall events becoming more clustered.
- Extreme temperature years highlight the growing frequency of heatwaves and seasonal disruptions.

Alaska

- Both in the temperature and snowfall totals, we see a consistent trend in the wrong direction.
- Climate change has made clear impacts in both temperature and snow totals at the northernmost point in the US, highlighting the warming trend.
- Further research could explore more aspects related to temperature and snowfall, including looking at days with extreme values.

California

- Average annual temperatures show a gradual increase over the years, with a range typically between 55°F and 75°F.
- The data highlights the arid nature of Los Angeles, with most years experiencing little to no significant rainfall.
- The number of days exceeding 90°F has increased, indicating more frequent and intense heatwaves in recent years.
- Winters are characterized by moderate rainfall, while summers remain predominantly dry, consistent with the region’s Mediterranean climate.

Challenges in Unlocking Insights from the NOAA Dataset

Missing Data

Several columns, such as RHAV (Relative Humidity Average) and PSUN (Percent Sunshine), contained significant amounts of missing values, making them unusable for detailed analysis.

Sparse Precipitation Data

The majority of precipitation records indicated zero rainfall, reflecting the arid nature of Los Angeles, but this created challenges in analyzing trends or variability.

Data Formatting

The dataset required substantial preprocessing, such as date formatting and unit consistency (e.g., ensuring all temperature values were in °F).

Inconsistent Temporal Coverage

Occasional unrealistic values in temperature and precipitation needed to be detected and cleaned to ensure the reliability of trend analysis.

Extreme Outliers

Occasional unrealistic values in temperature and precipitation needed to be detected and cleaned to ensure the reliability of trend analysis.

Conclusion and Final Thoughts

The simultaneous increase in heatwaves and decline in cold events highlights the significant shift in seasonal and annual weather patterns due to climate change.
The changes may disproportionately affect vulnerable populations, especially in areas unprepared for such climatic shifts.

The forecasted trends align with global climate projections, showing robust consistency with observed historical patterns.
Tools like Exponential Smoothing and Linear Regression provide reliable short-term predictions, but long-term accuracy may depend on mitigating factors such as greenhouse gas emissions and adaptation measures.

How accurate are these Forecasts?

Temperature Projections: Forecasts a gradual increase in average temperatures from approximately 52.76°F in 2025 to 53.64°F in 2060, while Published Projections, like the "Climate Ready Boston" report indicates that, under high-emission scenarios, average temperatures could rise by 5.1°F to 10.3°F by the end of the century.

Precipitation Projections: Analysis suggests stabilization of annual precipitation around 42.83 inches from 2028 onwards, however, the Massachusetts Climate Projections anticipate a 2-13% increase in total annual precipitation by mid-century, with winter precipitation potentially increasing by up to 21%.

Extreme Weather Events: Forecasts suggest an Increase in more than average heat wave days by 5.5% and extremely cold days decline by 12% .
These trends align with Published Projections that projects an increase in the frequency and intensity of extreme events, such as heatwaves and heavy rainfall.

Key Takeaways:
Both our analysis and published projections agree on increasing average temperatures, more frequent heatwaves, and declining cold days.
These findings reinforce the urgent need for mitigation strategies to address the impacts of rising temperatures and extreme weather events.

Differences in precipitation and snowfall projections highlight the limitations of statistical tools compared to climate models that incorporate global dynamics.
Published projections emphasize a greater increase in precipitation and a reduction in snowfall, which are not fully reflected in our dataset-driven analysis.

THANK YOU!

Group 3

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