Analyzing Climate Trends for Lansing Michigan

Background and Motivation:

Understanding long-term climate trends is critical for assessing the environmental, economic, and social challenges facing communities today. In recent decades, growing concerns over global climate change have led to an increased focus on localized climate analyses to better inform policy, urban planning, agriculture, and public health. While global temperature increases are well documented, regional trends can vary significantly due to local geography, land use, and atmospheric dynamics. This underscores the importance of studying climate at the local level. This report focuses on the city of Lansing, Michigan—an inland urban center in the American Midwest that experiences a humid continental climate characterized by cold winters, warm summers, and significant seasonal variability. By analyzing historical temperature data over multiple decades, this study aims to identify trends in average temperatures, seasonal patterns, and variability in daily conditions. These insights can help determine whether Lansing is experiencing statistically significant warming, increased temperature extremes, or shifting seasonal behaviors. The motivation for this project stems from a broader effort to understand how climate change manifests at the local scale. Accurate local climate assessments are essential for informing future infrastructure resilience, energy demand planning, agricultural adaptation strategies, and public awareness. Through quantitative analysis and data visualization, this report seeks to provide a clear, data-driven picture of how Lansing's climate has evolved over time and what these changes may imply for the region's future.

Methodology:

Data cleaning:

For this project I analyzed data from the Lansing International Airport Weather Station website. Initially I tried using efficient methods for collecting the data, but the website stored all of it where the curl command in class wouldn't work. I tried more sophisticated methods but I ended up opting to just copy and paste the data into an excel sheet since I calculated only a few day's worth of work.

The data was stored as follows: each month had 3 columns (high, average, and low) for a total of 12 months with each row a day of that month. One sheet contained one year, and I had 65 sheets from 1960- 2024 (1960 was the furthest back the weather station was reporting this data). After all the data was put into an excel sheet I then had to decide the best way to pull data. Storing the data into a Pandas frame, I recognized several issues. First being the data had a NaN's values for the empty spots from each month that had less than 31 days. This seemed easy to solve given the pattern but it had to be addressed. Secondly several months had missing days, or extra days that didn't exist. Lastly for the low temperature data, there became an increasing amount of zeros that did not make physical sense (12 nights in a row with zero degrees in july) the further in the past you looked. The first part of this project consisted of fixing these issues and this actually took up the majority of the time. And this brings me to my main method in which I created to easily fix and navigate this messy data.

I estimated the missing low data by using the high and the average to recover the low. $2T_{avg} - T_{high} = T_{low}$. This is by no means a fool proof way of recovering data, but without this analyzing the lows would be impossible. I am stating my estimation method for the sake of transparency.

I created a class that's main purpose was to streamline the process of collecting data, so when it came time to the analysis I was confident that I was pulling clean, true data in the way I intended to. Firstly I knew pulling all the days in a month was going to be useful so I created a function that did all the tedious indexing, and checks to confidently pull the entire month's worth of data for a specific year. Secondly I knew pulling all the values across the years for a single day would be useful and created a section function that does this. With these functions created, I self-consistently used them to compare to metrics I knew were corrected or needed to be asserted and performed many tests and checks to clean the data for the issues described above.

All of this work is saved in the /tests folder on github, and the class was continually updated to fit my needs.

I'm collecting the temperatures for each month for all the years, and checking to see if the amount of data I have matches what I would expect for that month.

```
years = tp.years
for year in years:
    for month in (np.arange(12)+1):
        temps_high = tp.collect_month(month,year,"high")
        size = temps_high.size
        tp.check_length_of_month(size,month,year)

        temps_avg = tp.collect_month(month,year,"average")
        size = temps_avg.size
        tp.check_length_of_month(size,month,year)

        temps_low = tp.collect_month(month,year,"low")
        size = temps_low.size
        tp.check_length_of_month(size,month,year)

print("Completed.")
```

```
Completed.
```

Above is an example of using my class to check weather, in this case fixed missing data, for the entire data set. The check_length_month function would throw an error if data was missing. All versions of the class are saved in the src/class_history folder. Now after many weeks of cleaning data and refining the class I could confidently pull data in an efficient way.

Trends to look for:

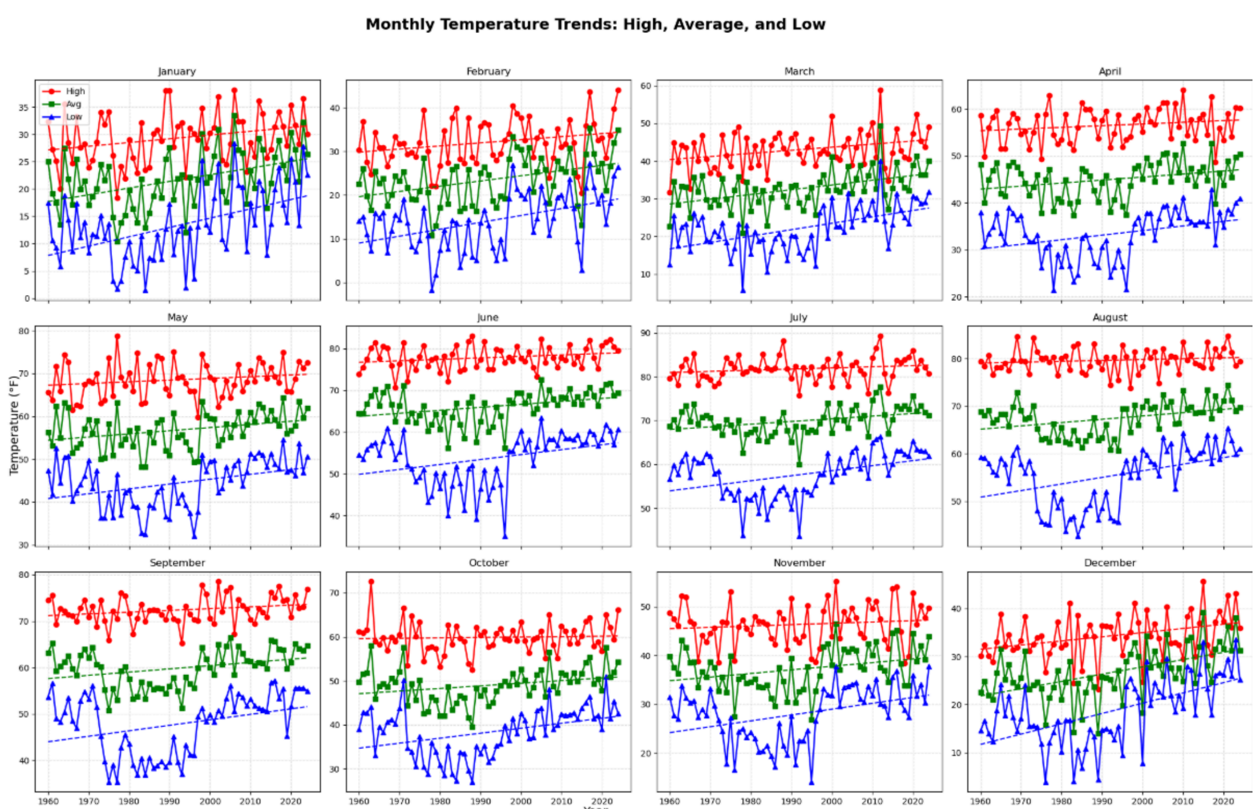
Having all this data for each day of the year from 1960-2024 isn't helpful unless we look at certain trends comparing certain quantities from the past to times closer to modern day. I decided to initially look at the average temperatures for each month from all the years 1960-2024 to see if there are any obvious large-scale warmings in the area. Looking at seasonal variations in Michigan is important, and are highly dependent on the high, average, and lows of the day so I wanted to include these averages when analyzing.

Next I wanted to look at how winters were changing. A good way to measure this is looking at the number of days with highs below freezing. For many Michiganders winters are defined by ice fishing, skiing, and a consistent snowpack on the ground. This metric would clearly show how these winters quantitatively and culturally are changing.

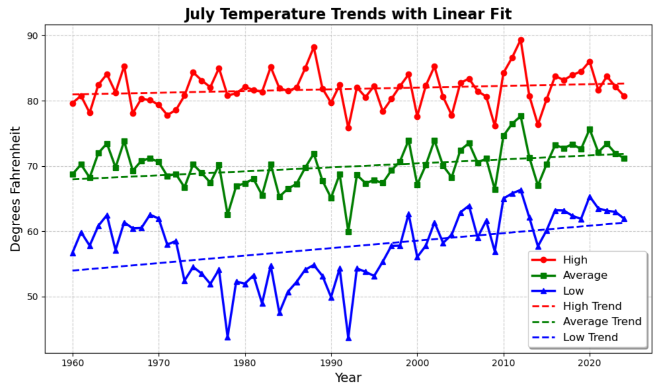
The last metric I wanted to see was more anecdotal. I have had several people that have lived in Lansing their whole lives say back in their day there was a foot of snow on the ground from December to April. To address this statement I look at the averaged temperature (1960-1990 to look at the years they are referring to) for each day between December and April and see if these temperatures are consistently below freezing or not. This was a fun way to see if the particularly harsher winters are sticking out in their minds more, or if they were accurate in their memory.

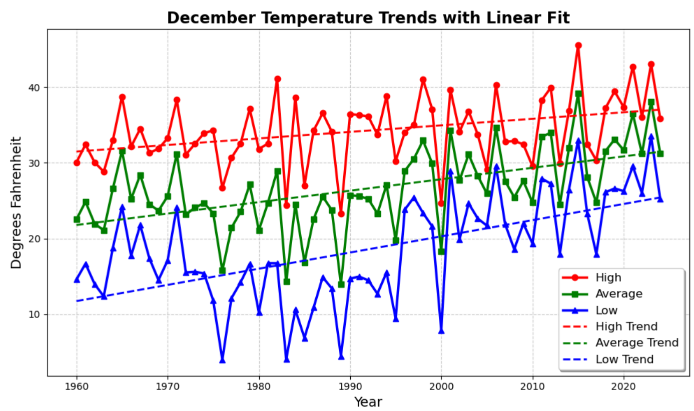
Results:

Looking at the temperature trends for each month we see an interesting result. (All temperatures are reported in Farenheit for the entirety of this project).



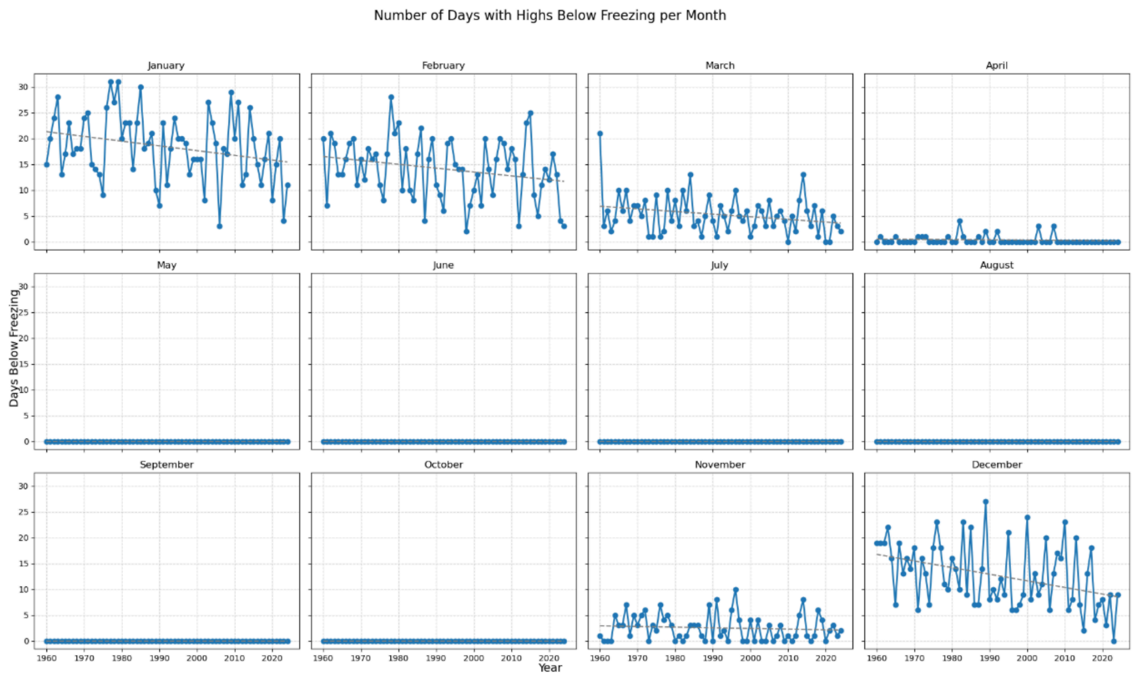
The y axis is temperature in Fahrenheit while the x axis in the year. Red is high, green is average, blue is low. Fitting the data linearly we see clear trends. Night time lows are warming significantly, and specifically winter warming is occurring at a faster rate compared to summer.



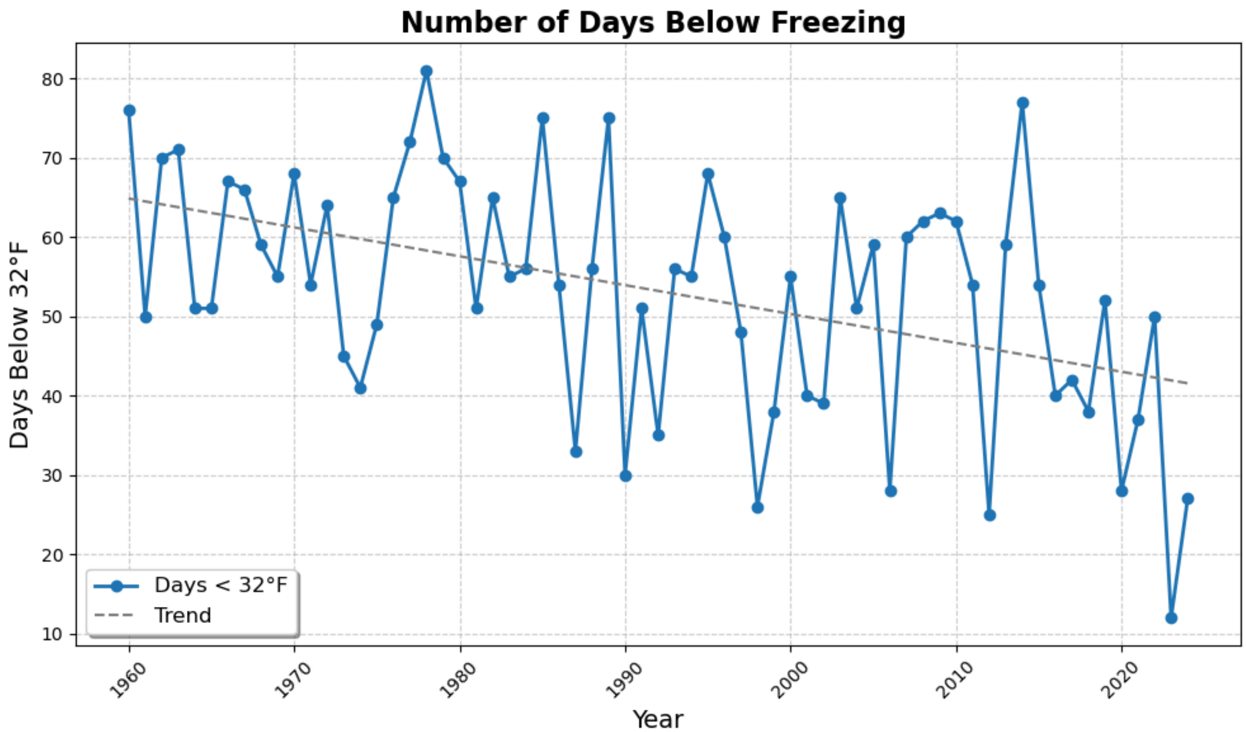


Looking specifically at December and July we see just how sharply this warming difference is. Using the parameters fitted from the line we can quantify this trend. Winters are warming at roughly 0.86 degrees per decade (2 degrees for the lows). Summers are warming at 0.26 degrees per decade (1.14 for lows). This data suggests winters are warming at about twice the rate than summers. The average level of warming is about .5 degrees per decade for michigan. This is consistent with the national average, but far faster than the global average of around .36 degrees fahrenheit [1]. In a sense, climate change for Lansing Michigan isn't making it "hotter" but making the winters less cold. Overall this is making the climate more mild and less variable. This is backed by additional studies showing increased cloud coverage making nightimes warmer by acting as a thermal blanket [2]. Less snow coverage during the day also traps more heat from the sun than reflecting it, thus making the ground radiate more energy away during the nights [3].

Looking at the number of days with highs below freezing for each month of year gives the result

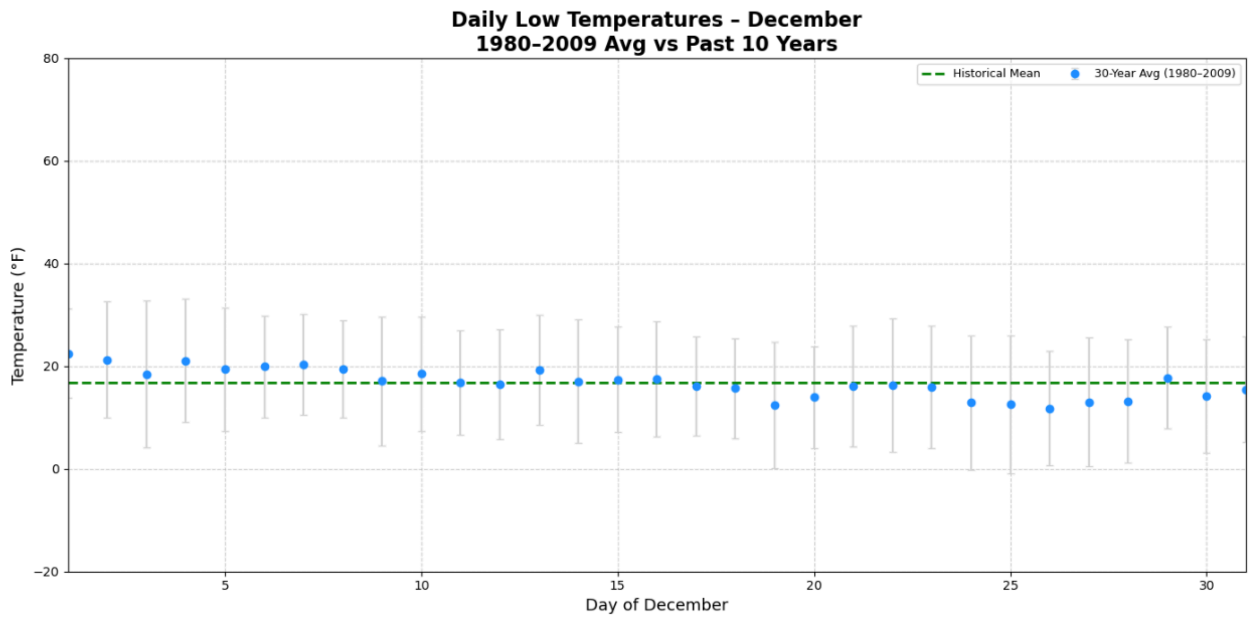


A clear trend showing a decrease in the amount of possible snow and ice growth days. What is interesting already is that April rarely had days below freezing so the snow would be melting rapidly by then, casting doubt on the tale of foot high snow in April. What is interesting is that early spring and late fall show a slower decrease than the winter months. So counting all the days across all months for each year gives the plot

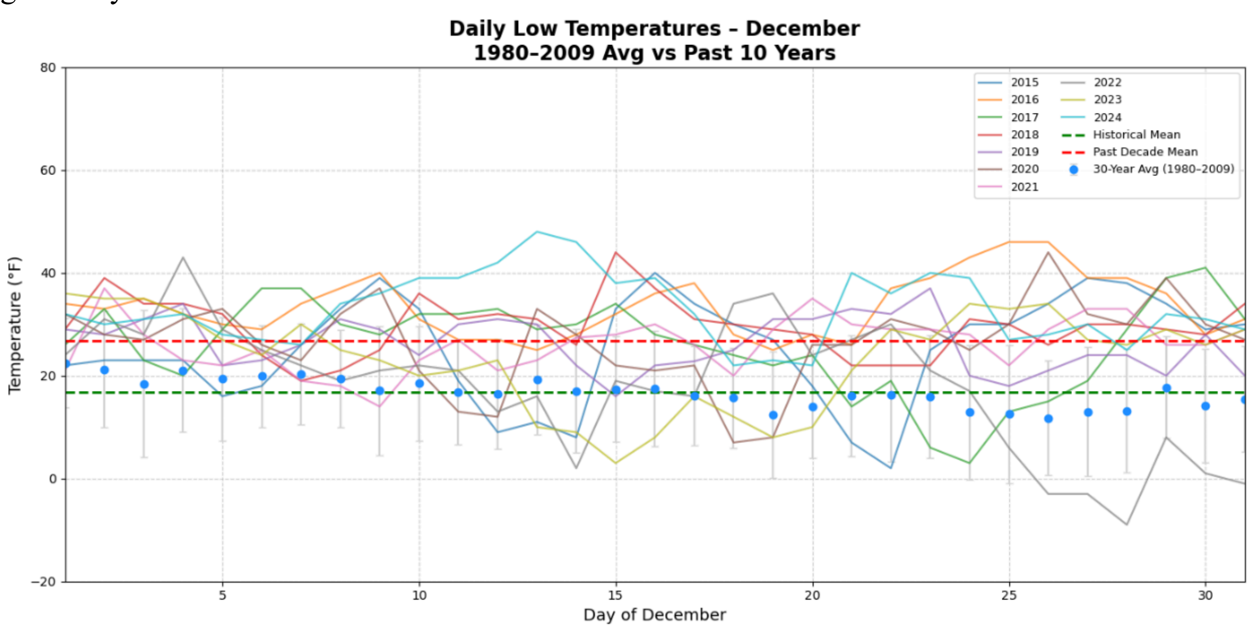


Using the fit parameters we see 3.5 days are lost on average per decade. From 1960 to 2024 gives a total of 24 days of below freezing days lost. This has devastating effects on winter industries and the culture of Michiganders [4][5][6]. These include winter traditions, business, sports and other winter related activities. People are losing their livelihood and this shows clearly that Michiganders whose income depends on winter have lost nearly a month's worth of profits since 1960.

Finally I would like to show that the averages are not skewed by random heat waves throughout winter. Yes this does occur, but genuinely every day of winter you can expect to be warmer than it was in the past.

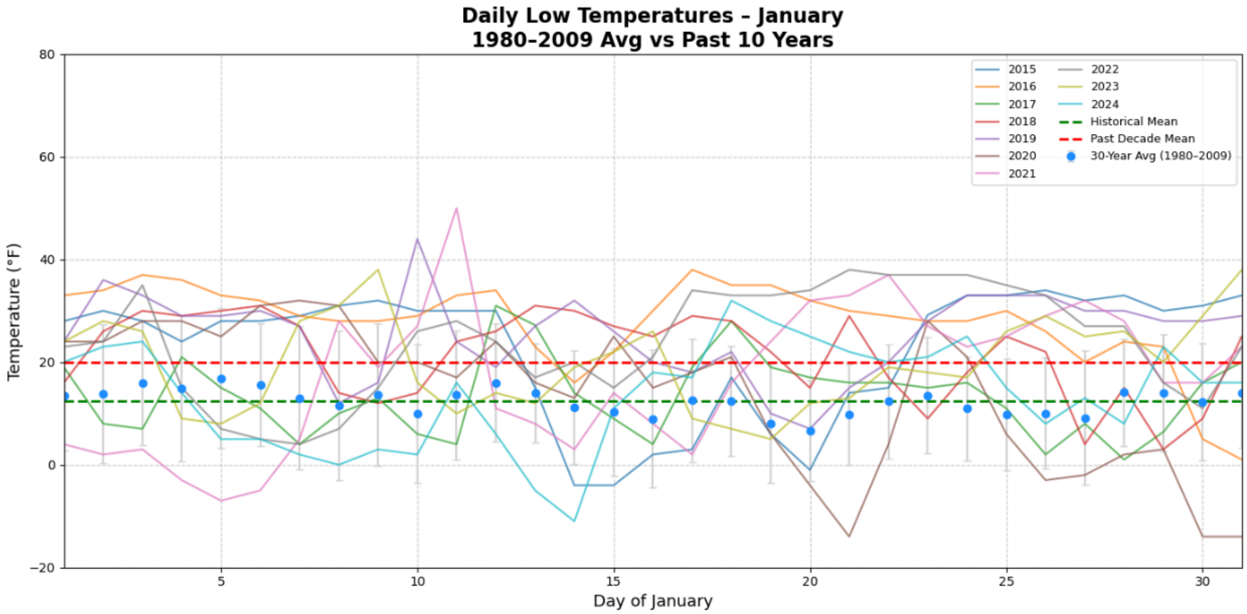


This plot shows a 30 year average from 1980-2009. Typically weather stations or climate trends are established in 30 year intervals. Each blue dot is the average temperature for that day in December, the gray bar is the standard deviation for that day, and the green line is just the average of all the blue dots. If we were to plot a specific year temperatures for each day, you would expect heat waves to be temporary intervals over the green line and not consistently over the green. Now I add the past 10 years on top of this plot. Each color represents a different year. No averaging is done on this new data, each point now presents the actual temperature for that given day.

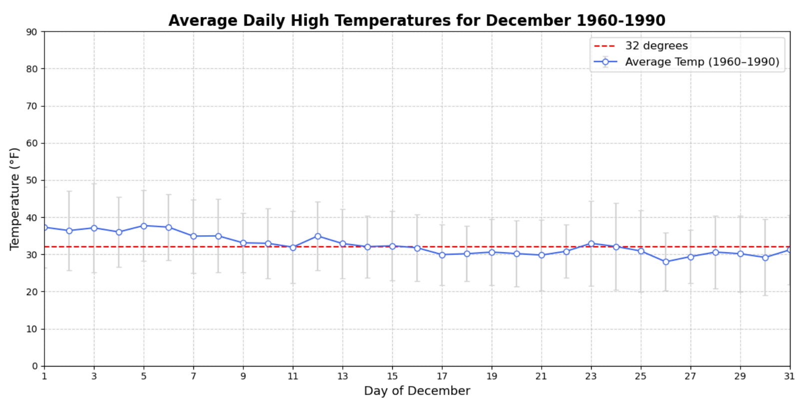


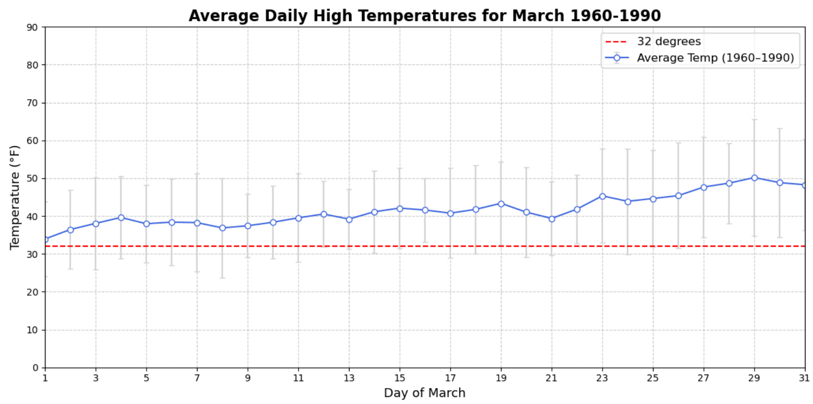
The past decade's average is plotted in the red dashed line. We can see very little cold snaps happening in december. Most of the lowest points are still within the standard deviation, but while most of the temperatures fall in the upper half of the first standard deviation, or above it.

Additionally we see very little variance in the first part of December. This suggests that temperatures are actually becoming more consistently mild and less extreme. My github shows this data for all the winter months highs and lows, but the story is consistent among them all. Sometimes just less visually obvious but the mean is still clearly higher. As shown for January lows.



Finally we try to look at the anecdotal claim of a foot of snow from December to April. Here I plot the average daily high for a day of December and March with the standard deviations over the points. The red dashed line is 32 degrees Fahrenheit.





Now December actually appears to be nice and cold, but still by December 15th it's only below freezing half the time. In my opinion March seals the deal on this old myth. We can see the majority of the time we are above freezing in March. So not only is snow in April not normal, significant melting starts to occur in March.

Conclusion:

This report has presented a comprehensive analysis of climate trends in Lansing, Michigan, from 1960 to 2024, drawing on daily temperature data to explore how seasonal patterns, winter conditions, and overall climate behavior have evolved over time. Through extensive data cleaning, methodical programming, and visual inspection, it became clear that Lansing's climate is undergoing significant and measurable changes—particularly during the winter months.

The most striking finding is the rate at which winters are warming, with average low temperatures rising nearly twice as fast as their summer counterparts. This winter warming is not only contributing to milder seasonal conditions but also leading to a marked decline in the number of days with temperatures below freezing. Such a shift has far-reaching implications for local ecosystems, infrastructure, and especially the winter-based cultural and economic practices that many Michiganders cherish.

By combining statistical rigor with historical context and personal observation, this project affirms that climate change in mid-Michigan is not an abstract phenomenon—it is an ongoing and tangible transformation. These findings underscore the need for local adaptation strategies and reinforce the importance of continuing to monitor and understand regional climate dynamics. While winters may be becoming more manageable from a temperature perspective, the loss of seasonal consistency and the traditions tied to it reflect a deeper challenge: preserving not just the environment, but the identity and rhythm of life it helps shape.

Sources:

[1]
https://dev-04-drupal-climate.woc.noaa.gov/news-features/understanding-climate/climate-change-global-temperature
[2]
https://blog.ucs.org/kristy-dahl/with-climate-change-nights-are-warming-faster-than-days-why/?utm_source=chatgpt.com
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