Analysis of extreme temperatures in the Rio Grande Valley, TX

Paola Granados

School of Earth, Environmental and Marine Sciences, University of Texas Rio Grande Valley

Abstract

Global climate change is set to bring an increase in extreme temperatures. Although models are able to estimate global changes in temperatures, there is much spatial variability in how these changes will happen. It is of particular interest to determine what changes in temperature and extreme events will occur on a local scale. In this study, temperature trends are analyzed for the Rio Grande Valley region of Texas. Annual average temperature, maximum temperature, and minimum temperatures are plotted against time reflecting similar rates of increase in temperature over time. Daily records for maximum and minimum temperatures over the years were compared, revealing there are more maximum temperature records than minimum temperature records over time. A temperature forecast was completed. This study revealed that the Rio Grande Valley region is subject to increasing temperatures due to climate change, and will see rising temperatures and hotter days over time.

Introduction

Global mean surface temperature is the most frequently cited indicator of climate change (Rahmstorf et al., 2017). However, there is spatial variability in how global climate change will impact temperature trends across the globe, and in how these changes will be developed in local regions. In addition, it is of special interest to understand how extreme temperature events will change with climate change. Extreme temperatures pose a greater ecological risk to many species than mean warming, and can impact human systems through impacts on health as well as energy consumption (Sheridan & Lee, 2018). Understanding local changes in temperature will benefit can inform local and regional policymakers on local climate change and can help develop strategies to mitigate effects of extreme weather. In this study 50 years of local temperature data are analyzed to find trends in average annual temperature and extreme temperatures. Extreme temperatures are represented by monthly maximum and minimum temperatures as well as daily temperature records. Using information on current temperature trends, future temperatures will be projected.

Methods

Data for this project was obtained from NOAA's NOWData portal from the National Weather Service's Brownsville, TX site. The data obtained pertained to the McAllen – Miller International Airport, TX and were collected for the years 1970 to 2020. Monthly summarized data and calendar day summaries data sets were downloaded. The calendar day summaries dataset includes the maximum and minimum temperatures recorded for each calendar day within the 1970 to 2020 period. The monthly summarized data include the highest (TMAX) or lowest (TMIN) temperature values, and average temperature recorded within each month.

Data analysis was conducted using Python. Data was manipulated using pandas to include a time series index. This allowed for temperature data to be plotted against time. An investigation of the changes in average annual temperatures, maximum annual temperature, and minimum annual temperature over time was performed by using Scipy's stats functions to perform a linear regression. To investigate extreme temperatures, the number of daily maximum and minimum temperature records for each year were plotted. This involved using pandas's .count() feature to obtain the number of daily records in each year. To forecast future temperature trends in the Rio Grande Valley, an Autoregressive Integrated Moving Average (ARIMA) model was used. A 12-month moving average using monthly average temperatures was used as the input data to forecast future temperature trends. For the ARIMA model, a code from towardsdatascience.com was used (*An End-to-End Project on Time Series Analysis and Forecasting with Python | by Susan Li | Towards Data Science*, n.d.).

Results

Plotting average annual temperature over time showed a positive, linear trend (y = .082-87.719, R-value = 0.759, p-value = $1.087 \cdot 10^{-10}$) (**Figure 1**). Plotting average annual maximum and minimum temperatures also showed positive linear trends (TMAX: y = 0.089x-72.568, R-value = 0.467, p-value = $5.55 \cdot 10^{-4}$, TMIN: y = 0.137x-242.13, R-value = 0.412, p-value = $2.69 \cdot 10^{-3}$)(**Figure 2**). Average annual temperature and annual TMAX linear trends exhibited very similar slopes, indicating they shared similar rate of increase. Annual TMIN's rate of increase was slightly higher than average annual and annual TMAX trends.

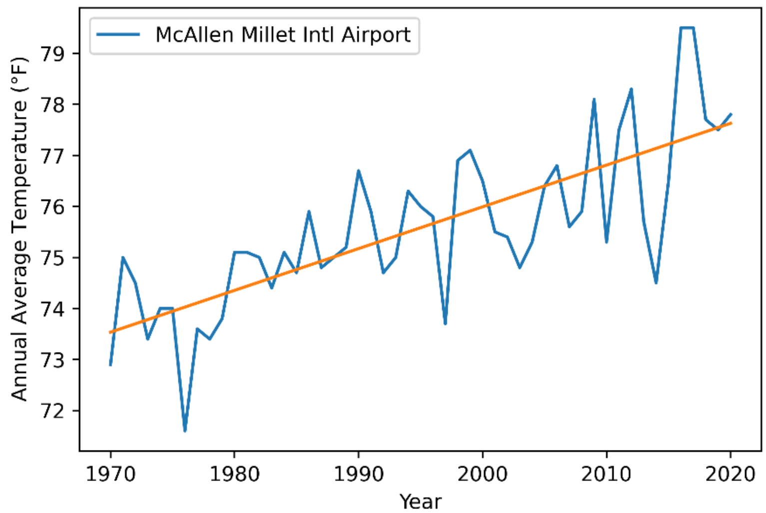


Figure 1. Annual Average Temperatures over time

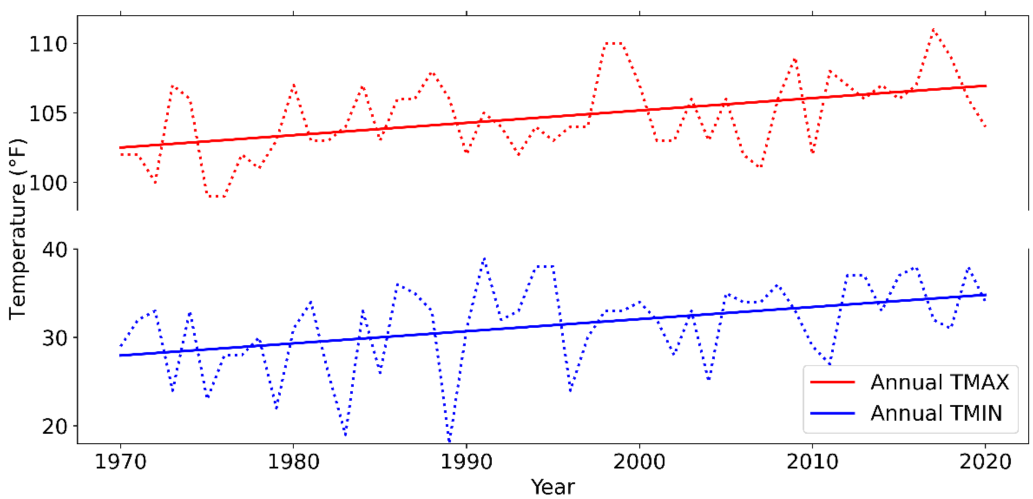


Figure 2. Annual Maximum and Minimum Temperatures over time

Further investigation on extreme temperatures involved plotting the number of record maximum and record minimum temperatures in each year. Maximum daily records appear to increase over time in a nonlinear manner, while minimum temperature daily records decrease over time in a linear manner **(Figure 3)**.

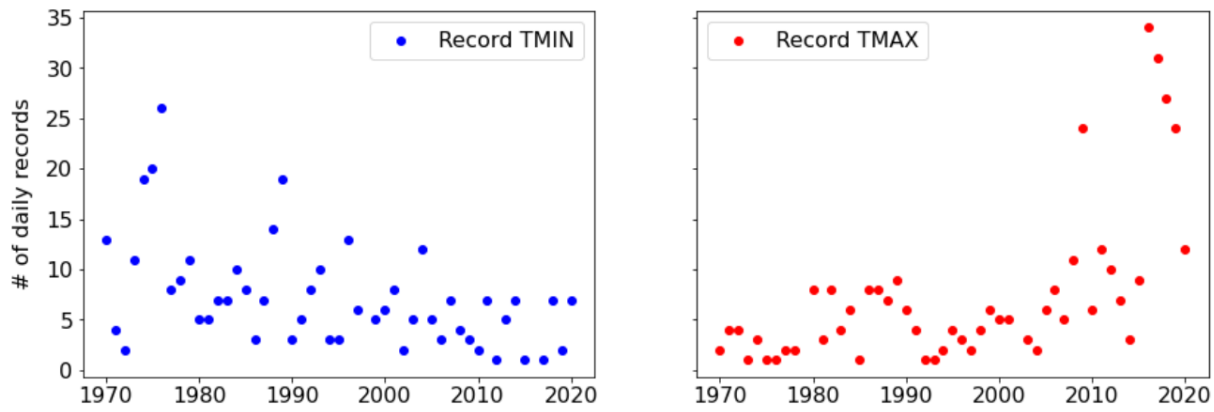


Figure 3. Number of daily minimum and maximum temperature records per year.

The ARIMA model was able to forecast the increasing trend in temperatures over time (**Figure 4**). However, it was not able to capture changes in seasonality. The ARIMA model roughly agrees with linear regression trends. It predicts that by June 2030 there will be a temperature of 78.338°F. Compared to the last data point from the 12 month moving average which was for June 2020 with a temperature of 77.766°F, the ARIMA model predicts a slightly smaller rate of increase of ~.057 degrees per year (for linear regression rate of increase was ~.082 degrees per year). In addition, there was a large variability in the predictions as the time increased represented by the gray cone.

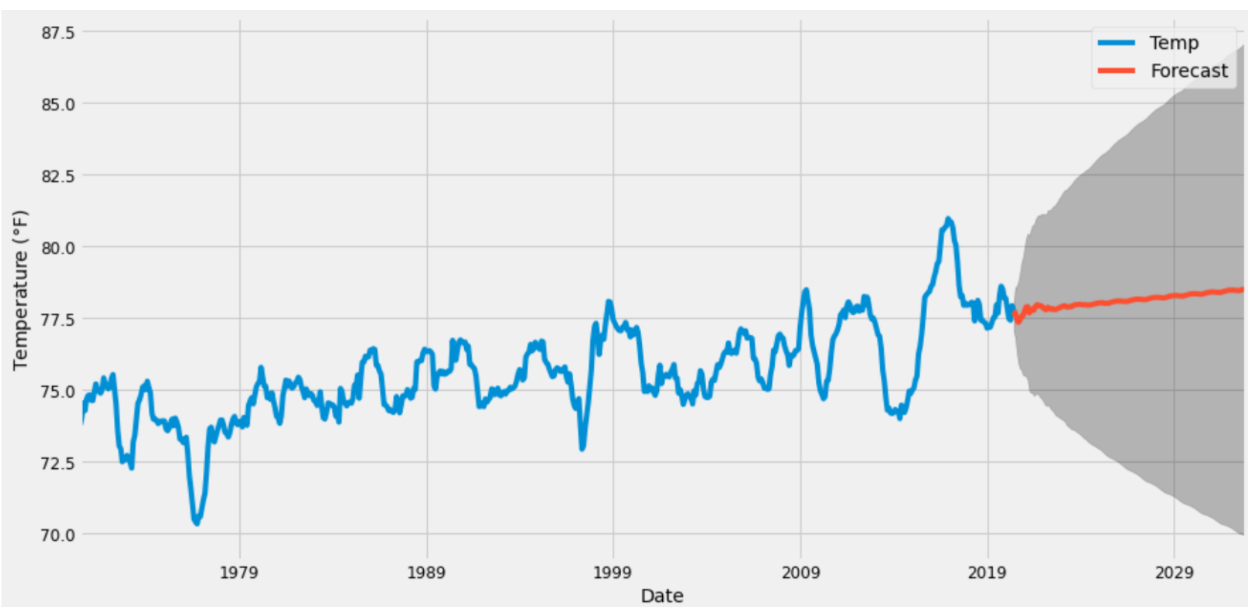


Figure 4. ARIMA model forecast of average monthly temperatures

Discussion

Overall, this study sought to investigate current trends in extreme temperatures in the Rio Grande Valley. All of the data examined in this study agrees with increasing temperatures overall over the years. Trends in average annual temperature suggest ~0.08 increase in temperature per year, which roughly amounts to a 1 degree Fahrenheit increase in average annual temperature every 10 years. This rate of increase is also present in the annual TMIN and annual TMAX temperatures over the years. Examining the number of daily records over time suggests that there are more hot temperature records than cold records occurring over the years. This suggests that in the Rio Grande Valley we can keep on expecting more extreme hot days than extreme cold days. Other studies suggest that the ratio between daily record high maximum temperatures to record low minimum temperatures across the United States is 2 to 1 (Meehl et al., 2009). While this study does not evaluate the ratio of maximum to minimum temperatures, it is consistent with the greater number of high maximum temperature records over low minimum records.

The ARIMA forecasting model ultimately was not able to forecast much of the seasonality patterns. This might be due to the irregular seasons captured by the 12 month moving average. A forecast was also produced using a 9 month moving average which was able to capture seasonality trends, however, it predicted a decrease in temperatures over time, which is not accurate. Minimizing the differences in seasonality while maintaining the overall increasing temperatures trends in the input data might increase the model’s accuracy.

Appendix 1: Sample Code

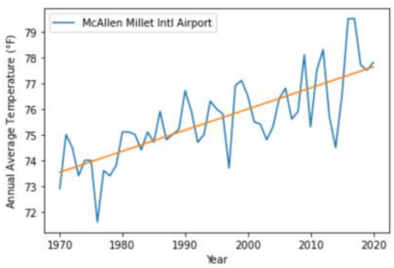
Performing Linear Regression

```
#linear fit for annual temperatures
from scipy import stats
annualtemptrend = stats.linregress(mcmill_month["Year"],mcmill_month["Annual"])
```

```
annualtemptrend
```

```
LinregressResult(slope=0.0818552036199095, intercept=-87.71877828054299, rvalue=0.759017890842581
6, pvalue=1.0865768543536 6e-10, stderr=0.01003052741555894)
```

```
plt.plot(mcmill_month["Year"],mcmill_month["Annual"], label = "McAllen Millet Intl Airport")
plt.plot(mcmill_month["Year"],annualtemptrend.slope*mcmill_month["Year"]+annualtemptrend.intercept)
plt.xlabel("Year")
plt.ylabel("Annual Average Temperature ($\\degree$F)")
plt.legend()
```



Counting the number of daily records per year

```
#Dataset containing the year which holds the MAX temp record
Caldata_TMAX.head()
```

	Day	Month	Year_of_TMAX
1	1	Jan	2006
2	1	Feb	2016
3	1	Mar	1997
4	1	Apr	1970
5	1	May	1980

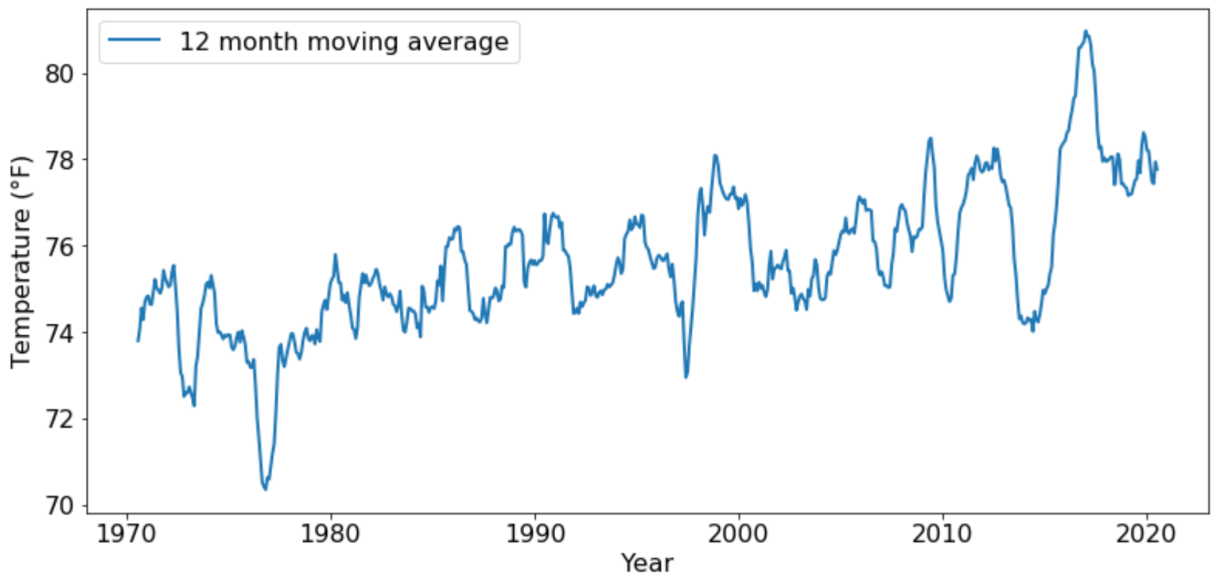
```
#Need to find the number of TMAX values each yeas has
tmax_per_yr = Caldata_TMAX.groupby("Year_of_TMAX").count()
tmax_per_yr = tmax_per_yr.drop(0)
tmax_per_yr.head()
```

	Day	Month
Year_of_TMAX		
1970	2	2
1971	4	4
1972	4	4
1973	1	1
1974	3	3

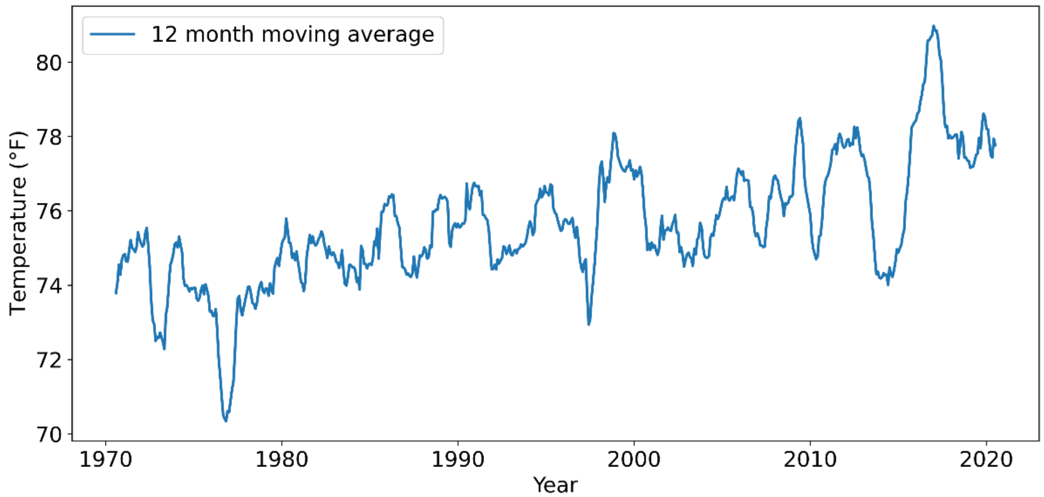
Obtaining a moving average

```
#setting a moving average - 12 months

avg12mon = np.zeros(611)

for i in range(599):
    avg12mon[i+6]=(McMill["Temp"][i+1]+McMill["Temp"][i+2]+McMill["Temp"][i+3]+McMill["Temp"][i+4]+
```

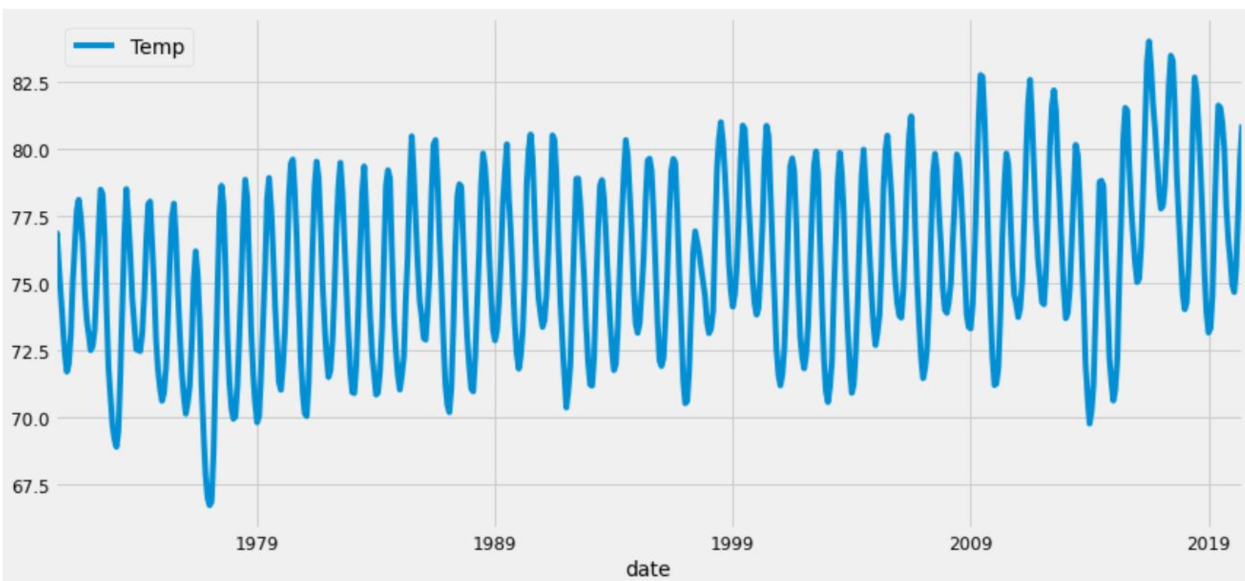
```
plt.plot(McMill["date"][6:-6],avg12mon[6:-6], label = "12 month moving average")
plt.xlabel("Year")
plt.ylabel("Temperature ($\\degree$F)")
plt.legend()
```



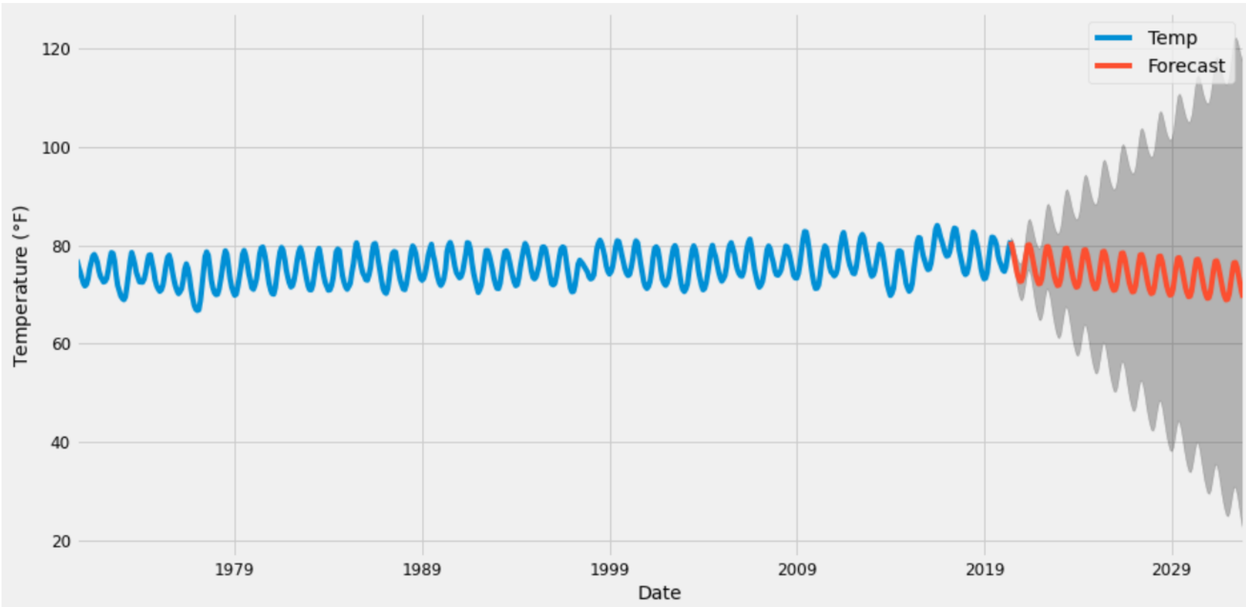
Appendix 2: ARIMA Modeling Components



A2.1: 12 month moving average of monthly temperatures inputted to ARIMA model in Figure 4



A2.2: 9 month moving average of monthly temperature



A2.3: ARIMA model temperatures forecast using 9 month moving average as input data

References

An End-to-End Project on Time Series Analysis and Forecasting with Python | by Susan Li | Towards Data Science. (n.d.). Retrieved May 5, 2021, from https://towardsdatascience.com/an-end-to-end-project-on-time-series-analysis-and-forecasting-with-python-4835e6bf050b

Meehl, G. A., Tebaldi, C., Walton, G., Easterling, D., & McDaniel, L. (2009). Relative increase of record high maximum temperatures compared to record low minimum temperatures in the U.S. *Geophysical Research Letters*, *36*(23). https://doi.org/10.1029/2009GL040736

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