Project 1: Precipitation Downscaling

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# 1. Executive Summary:

The goal of this project was to downscale precipitation data from a coarse resolution to a finer resolution. I aimed to use temperature data from the ERA5 dataset from 2000-2006 and precipitation data from the precip\_tx dataset to predict precipitation over Texas. I planned to use a combination of Principal Component Analysis (PCA) and K-Nearest Neighbors (KNN) to downscale the data. I attempted to compare the results of the PCA/KNN method to a linear regression method, but I was having trouble with the code, so I was not able to output any results. However, I included the code I would use for these steps. Therefore, the later sections of code are not going to run due to the errors, but are what I planned to implement.

# 2. Setup

# 3. Data

precip (24 × 24 × 16365)  
 Datatype: Union{Missing, Float32} (Float32)  
 Dimensions: lon × lat × time  
 Attributes:  
 \_FillValue = NaN  
 var\_desc = Precipitation  
 level\_desc = Surface  
 statistic = Total  
 parent\_stat = Other  
 long\_name = Daily total of precipitation  
 cell\_methods = time: sum  
 avg\_period = 0000-00-01 00:00:00  
 actual\_range = Float32[0.0, 428.02423]  
 units = mm  
 valid\_range = Float32[0.0, 1000.0]  
 dataset = CPC Global Precipitation  
 missing\_value = -9.96921e36

closed Dataset

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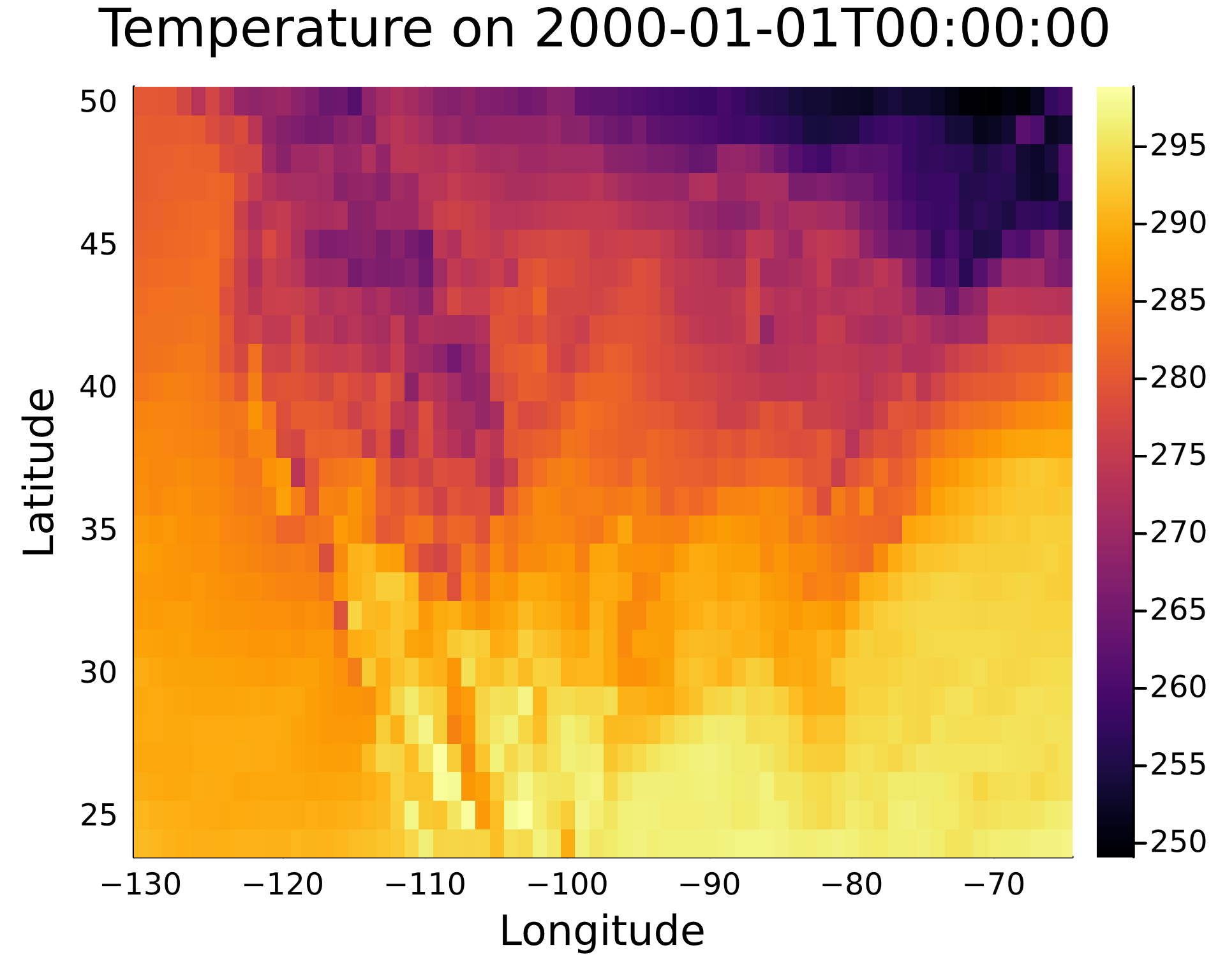
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109357776

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 290.491 289.501 288.937 288.556 271.762 270.315 265.306 266.052  
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 296.626 296.728 296.13 294.482 259.681 258.359 257.509 251.989  
 296.74 296.356 296.145 295.648 … 258.49 257.55 256.781 252.298  
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 295.23 295.949 295.715 295.331 257.964 256.856 254.047 250.458  
 295.587 294.8 294.945 295.269 254.601 256.975 254.432 248.828  
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 296.217 295.214 294.734 295.515 … 256.441 255.593 252.453 248.161  
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 298.872 298.182 297.39 297.223 … 265.872 264.232 263.725 262.298  
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 290.653 290.198 289.306 288.3 270.21 271.228 267.187 267.611  
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 297.923 297.165 296.374 295.423 259.968 259.704 264.917 259.431  
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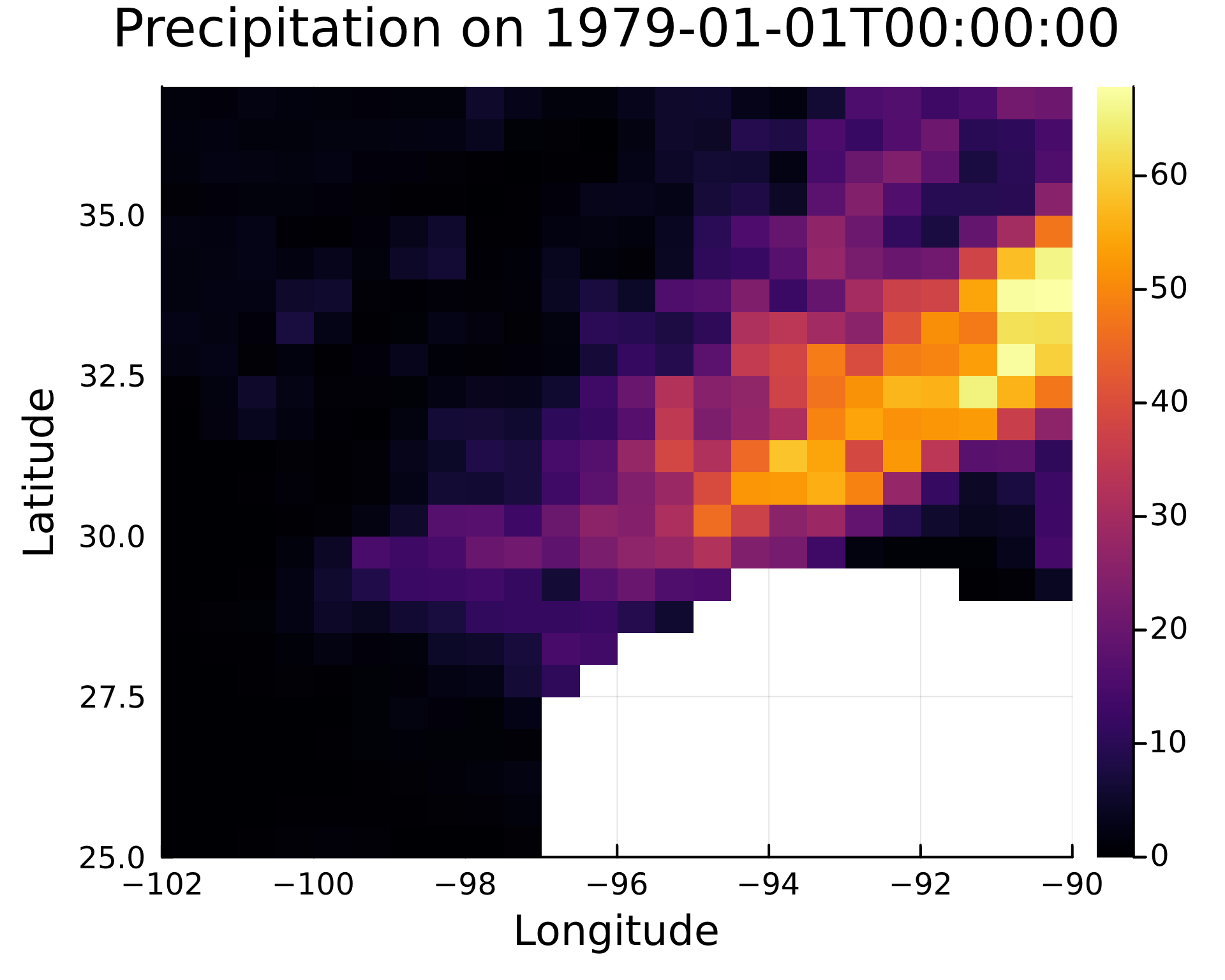
27-element Vector{Any}:  
 5  
 16  
 20  
 12  
 24  
 8  
 17  
 1  
 19  
 22  
 23  
 6  
 11  
 ⋮  
 3  
 7  
 25  
 4  
 13  
 15  
 2  
 10  
 18  
 21  
 26  
 27

24-element Vector{Union{Missing, Float32}}:  
 -101.75f0  
 -101.25f0  
 -100.75f0  
 -100.25f0  
 -99.75f0  
 -99.25f0  
 -98.75f0  
 -98.25f0  
 -97.75f0  
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 -93.75f0  
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 -92.75f0  
 -92.25f0  
 -91.75f0  
 -91.25f0  
 -90.75f0  
 -90.25f0

Minimum Latitude: 25.25, Maximum Latitude: 36.75  
Minimum Longitude: -101.75, Maximum Longitude: -90.25

time (generic function with 2 methods)

24×24×16365 Array{Union{Missing, Float32}, 3}:  
[:, :, 1] =  
 0.0 0.0202463 0.0 … 1.45262 1.57975 1.37582  
 0.114836 0.0602374 0.0308067 2.28766 1.85082 1.20963  
 0.237292 0.121709 0.0490085 2.09293 1.45203 1.97182  
 0.678864 0.389667 0.0664271 1.65327 1.33469 1.5909  
 1.0564 0.24362 0.0964478 2.29071 1.75647 1.43704  
 0.594209 0.192309 0.29584 … 1.24682 1.71966 1.23506  
 0.153464 0.345075 0.50683 1.14913 2.06668 1.34688  
 0.0801041 0.576138 1.06509 0.724487 2.27098 1.45706  
 0.133022 0.706655 1.43136 0.181735 3.71962 5.20069  
 0.53837 1.4474 2.08092 0.163341 0.759342 2.88819  
 missing missing missing … 0.207048 0.461275 1.50673  
 missing missing missing 0.290842 0.139224 1.43436  
 missing missing missing 2.59861 2.13086 3.18961  
 missing missing missing 4.65167 5.16296 5.19326  
 missing missing missing 6.19447 4.47193 5.3778  
 missing missing missing … 5.9169 8.9879 2.81836  
 missing missing missing 2.24706 8.12168 1.80613  
 missing missing missing 14.4421 15.1932 6.17247  
 missing missing missing 20.1535 12.0708 15.3935  
 missing missing missing 23.8688 16.3307 16.41  
 missing missing missing … 18.5016 20.6869 12.77  
 missing missing missing 7.38247 9.67723 14.9623  
 missing missing missing 9.88938 10.5213 21.7209  
 missing missing missing 15.6206 14.5443 20.7196  
  
[:, :, 2] =  
 0.0 0.0 0.0 0.0 … 0.0 0.0 0.0  
 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
 0.0 0.0 0.0 0.0 … 0.0 0.0 0.0  
 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
 0.0 0.0 0.0507107 0.136311 0.0 0.0 0.0  
 0.0 0.0 0.170228 0.353149 0.0 0.0 0.0  
 0.0 0.0 0.0242824 0.079515 0.0 0.0828211 0.0344644  
 missing missing missing missing … 0.0 0.232722 0.116297  
 missing missing missing missing 0.0 0.120667 0.0780643  
 missing missing missing missing 0.0810387 0.209601 0.790819  
 missing missing missing missing 0.202908 0.0694368 0.330909  
 missing missing missing missing 0.193584 0.366478 0.0834752  
 missing missing missing missing … 0.221516 0.392715 0.334877  
 missing missing missing missing 0.0837831 0.847358 0.171142  
 missing missing missing missing 0.12625 2.01706 0.660464  
 missing missing missing missing 0.0 0.0865614 0.309305  
 missing missing missing missing 0.0 0.0 0.206135  
 missing missing missing missing … 0.0 0.355726 0.397575  
 missing missing missing missing 0.064151 0.686435 1.2978  
 missing missing missing missing 0.373319 0.906296 0.998617  
 missing missing missing missing 2.14061 2.16601 0.708568  
  
[:, :, 3] =  
 0.0 0.0 0.0 0.0 … 0.0 0.0 0.0  
 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
 0.0 0.0 0.0 0.0 0.174088 0.0 0.0  
 0.0 0.0 0.0 0.0 0.77125 0.0296272 0.16041  
 0.0 0.0 0.0 0.0 0.0870539 0.0 0.0822869  
 0.0 0.0 0.0 0.0 … 0.0 0.0 0.0  
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 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
 0.0 0.0 0.0 0.0 0.0 0.0879667 0.391579  
 missing missing missing missing … 0.0 0.052071 0.178373  
 missing missing missing missing 0.0 0.0 0.0  
 missing missing missing missing 0.0621035 0.0 0.0  
 missing missing missing missing 0.509918 0.0 0.0  
 missing missing missing missing 0.0975961 0.0 0.0  
 missing missing missing missing … 0.0 0.0 0.0  
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 missing missing missing missing 0.0 0.0 0.0707157  
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;;; …   
  
[:, :, 16363] =  
 0.0 0.0 0.0 0.0 … 0.0 0.0 0.0  
 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
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 missing missing missing missing 0.0296209 0.0 0.0  
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 missing missing missing missing … 0.0207723 0.303631 0.72749  
 missing missing missing missing 0.0399159 0.220527 1.02891  
 missing missing missing missing 0.0 0.127663 0.818845  
 missing missing missing missing 0.0 0.0371985 0.641579  
  
[:, :, 16364] =  
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[:, :, 16365] =  
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## 3.1 From this point on, the code is not going to work becasue of the errors above I am havign a difficult time fixing. Therefore, the follwoing code is what I would do for each step, but I cannot run it.

## 3.2 Split the data

## 3.3 Preprocess

# 4. Principal Component Analysis

## 4.1 Fitting

# 5. K-NN

# 6. Combining

# 7. Linear Regression

# 8. MSE differences between methods

# 9. Written report

## 9.1 Exploratory data analysis

The initial heatmap shows the temperature across the United States during the first hour of January 1, 2000. The temperatures look pretty much as expected. The more southern areas of the US were warmer and the more northern regions were cooler. There are even regions of the US that are cooler than surrounding areas and likely reflect mountain ranges.

The second heatmap shows the precipitation across a Texas-ish area during the first hour of January 1, 1979. The areas near the gulf had higher levels of precipitation. The areas further out from the gulf were generally drier at this time.

The other heatmaps I attempted to create had errors.

## 9.2 Methods

My general method for this project was to use PCA and K-NN to downscale precipitation over Texas. I began by loading in the data for both the ERA5 temperature datasets and the precip\_tx dataset. I reversed latitudes and corresponding tempertures or precipitation values when needed. I used heatmaps to check the data along the way. I attempted to make the latitude, longitude, and time vectors match the temp vector, but had trouble with getting the latitude and longitude to match temp in a way that continued to work during the subsetting step. When I tried to subset the data to only include the Texas region used in the precip\_tx dataset, I ran into issues that I was not able to fix. I continued to try and work through the project without being able to run the code. I separated the data into training and testing sets based on the year. I followed a lot of the techniques used in lab 6 to implement PCA and K-NN. I attempted to use linear regression and compare the results to the PCA/KNN method. I also tried to compare methods using mean squared errors.

## 9.3 Model comparison

While I could not output the models or calculate the MSE, there are still advantages and limitations to the models. One limitation is that I only used temperature to predict precipitation in this project. There are many pieces to accurately predicting precipitation, so neither of these models would be able to predict precipitation extremely well. However, the PCA/KNN method would likely be more accurate than the linear regression method because it takes into account the seasonal and spatial differences in precipitation. Though, more predictors can easily be added to linear regression to make it more accurate in predicting precipitation.

## 9.4 Conclusion

Overall, the task of downscaling precipitation was difficult for me, but is a very helpful technique in environmental engineering. Using PCA/KNN is one way to downscale precipitaton and liner regression is another. These two methods can be compared by comparing MSE. There are limitations and advantages to both methods that need to be taken into account when downscaling precipitation.

## 9.5 Teamwork

I used ChatGPT and GitHub Copilot for some of this code, but I did edit each code to better fit the needs of this project. I discussed general ideas and troubleshooting techniques with classmates.