Project 1

Precipitation Downscaling

Riley Becker (rb111)

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# 1. Executive Summary

Global climate models are extremely valuable tools as they provide large scale estimates of climate data for wide-scale use. For this project, we were asked to use the ERA5 reanalysis temperature data to downscale precipitation data from the CPC local precipitation data. While global climate models offer climate data estimates for almost the entire world, they do have their drawbacks. One of these being the fact that it can be hard to use global climate models to model local-scale climate data. To help solve this issue that global climate models have, we can do what’s called downscaling to it to help offer higher resolution data at smaller scales.

For this project, I developed a downscaling model that would build a model to downscale precipitation data from the temperature data through performing a principal component analysis and k-nearest neighbors model on the data. I also tried to run a random forest model on my data, but just could not get my code to work for it. I used principal component analysis to summarize the data in the large aggregated ERA5 Dataset to allow the data to be more easily analyzed. This data from the PCA was then inputted into a k-nearest neighbors model, which uses proximity to make predictions.

# 2. Exploratory Data Analysis

## 2.1 1. Packages

Resolving package versions...  
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 No Changes to `C:\Users\Riley Becker\OneDrive\Documents\GitHub\project-01-precipitation-downscaling-rileybecker42\Manifest.toml`  
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## 2.2 2. Loading in Datasets

### 2.2.1 2.1. Precipitation Data

I first loaded in my precipitation dataset using NCDataset, and then made variables precip\_time, precip\_lon, precip\_lat, and precip that represent the time, coordinates, and precipitation at a given coordinate at a given time between January 1, 2010 and December 31 of 2020.

Dataset: data/raw/precip\_tx.nc  
Group: /  
  
Dimensions  
 lat = 24  
 lon = 24  
 time = 16365  
  
Variables  
 lat (24)  
 Datatype: Union{Missing, Float32} (Float32)  
 Dimensions: lat  
 Attributes:  
 \_FillValue = NaN  
 actual\_range = Float32[89.75, -89.75]  
 long\_name = Latitude  
 units = degrees\_north  
 axis = Y  
 standard\_name = latitude  
 coordinate\_defines = center  
  
 lon (24)  
 Datatype: Union{Missing, Float32} (Float32)  
 Dimensions: lon  
 Attributes:  
 \_FillValue = NaN  
 long\_name = Longitude  
 units = degrees\_east  
 axis = X  
 standard\_name = longitude  
 actual\_range = Float32[0.25, 359.75]  
 coordinate\_defines = center  
  
 time (16365)  
 Datatype: DateTime (Int64)  
 Dimensions: time  
 Attributes:  
 long\_name = Time  
 axis = T  
 standard\_name = time  
 coordinate\_defines = start  
 delta\_t = 0000-00-01 00:00:00  
 avg\_period = 0000-00-01 00:00:00  
 units = days since 1979-01-01 00:00:00  
 calendar = proleptic\_gregorian  
  
 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

24×24×4018 Array{Union{Missing, Quantity{Float64, 𝐋, Unitful.FreeUnits{(mm,), 𝐋, nothing}}}, 3}:  
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 0.0 mm 0.0 mm 0.0683543 mm 0.134457 mm  
 0.0 mm 0.0 mm 0.0357297 mm 0.0548465 mm  
 0.0 mm 0.0 mm 0.00484054 mm 0.0398182 mm  
 0.0 mm 0.0 mm 0.0 mm 0.00450338 mm  
 0.0 mm 0.0 mm … 0.0 mm 0.0 mm  
 0.0 mm 0.0 mm 0.0 mm 0.0 mm  
 0.0 mm 0.0 mm 0.0 mm 0.0 mm  
 0.0 mm 0.0 mm 0.0 mm 0.0 mm  
 0.0 mm 0.0 mm 0.0 mm 0.0 mm  
 missing missing … 0.0 mm 0.0 mm  
 missing missing 0.0 mm 0.0 mm  
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 missing missing 0.0 mm 0.0 mm  
 missing missing 0.0 mm 0.0 mm  
 missing missing … 0.0 mm 0.0 mm  
 missing missing 0.0 mm 0.0 mm  
 missing missing 0.0 mm 0.0 mm  
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 missing missing 0.0 mm 0.0230749 mm  
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 missing missing 0.0 mm 0.0 mm  
  
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 0.0 mm 0.0 mm 0.0 mm 0.0 mm 0.0 mm 0.0 mm  
 0.0 mm 0.0 mm 0.0 mm 0.0 mm 0.0 mm 0.0 mm  
 0.0 mm 0.0 mm 0.0 mm 0.0 mm 0.0 mm 0.0 mm  
 0.0 mm 0.0 mm 0.0 mm … 0.0 mm 0.0 mm 0.0 mm  
 0.0 mm 0.0 mm 0.0 mm 0.0 mm 0.0 mm 0.0 mm  
 0.0 mm 0.0 mm 0.0 mm 0.0 mm 0.0 mm 0.0 mm  
 0.0 mm 0.0 mm 0.0 mm 0.0 mm 0.0 mm 0.0 mm  
 0.0 mm 0.0 mm 0.0 mm 0.0 mm 0.0 mm 0.0 mm  
 missing missing missing … 0.0 mm 0.0 mm 0.0 mm  
 missing missing missing 0.0 mm 0.0 mm 0.0 mm  
 missing missing missing 0.0 mm 0.0 mm 0.0 mm  
 missing missing missing 0.0 mm 0.0 mm 0.0 mm  
 missing missing missing 0.0 mm 0.0 mm 0.0 mm  
 missing missing missing … 0.0 mm 0.0 mm 0.0 mm  
 missing missing missing 0.0 mm 0.0 mm 0.0 mm  
 missing missing missing 0.0 mm 0.0 mm 0.0 mm  
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 missing missing missing … 0.0 mm 0.0 mm 0.0 mm  
 missing missing missing 0.0 mm 0.0 mm 0.0 mm  
 missing missing missing 0.0 mm 0.0 mm 0.0 mm  
 missing missing missing 0.0 mm 0.0 mm 0.0 mm  
  
[:, :, 3] =  
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 0.00398183 mm 0.0 mm 0.0 mm 0.0 mm  
 0.0 mm 0.0 mm 0.0 mm 0.0 mm  
 0.0 mm 0.0 mm 0.0 mm 0.0 mm  
 0.0 mm 0.0 mm 0.0 mm 0.0 mm  
 0.00392539 mm 0.0 mm … 0.0 mm 0.0 mm  
 0.00372318 mm 0.0 mm 0.0 mm 0.0 mm  
 0.0 mm 0.0 mm 0.0 mm 0.0103347 mm  
 0.0 mm 0.0 mm 0.0 mm 0.0312466 mm  
 0.0 mm 0.0 mm 0.0 mm 0.0468261 mm  
 missing missing … 0.0 mm 0.0145941 mm  
 missing missing 0.0 mm 0.0171049 mm  
 missing missing 0.00323264 mm 0.00564729 mm  
 missing missing 0.0597011 mm 0.23467 mm  
 missing missing 0.0245914 mm 0.0389802 mm  
 missing missing … 0.14663 mm 0.138762 mm  
 missing missing 0.179308 mm 0.113261 mm  
 missing missing 0.142096 mm 0.0377946 mm  
 missing missing 0.289917 mm 0.221083 mm  
 missing missing 0.213806 mm 0.0890985 mm  
 missing missing … 0.165857 mm 0.0495807 mm  
 missing missing 0.0131071 mm 0.00577657 mm  
 missing missing 0.0 mm 0.0 mm  
 missing missing 0.0 mm 0.0 mm  
  
;;; …   
  
[:, :, 4016] =  
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 0.0 mm 0.0 mm 0.0 mm 0.0 mm  
 0.0 mm 0.0 mm 0.0 mm 0.00477955 mm  
 0.0 mm 0.0 mm 0.0119863 mm 0.00455003 mm  
 0.0 mm 0.0 mm 0.0401172 mm 0.0796996 mm  
 0.0 mm 0.0 mm … 0.152083 mm 0.225361 mm  
 0.0 mm 0.0 mm 0.345653 mm 0.294061 mm  
 0.0 mm 0.0 mm 0.400622 mm 0.556214 mm  
 0.0 mm 0.00741697 mm 0.336176 mm 0.476516 mm  
 0.030115 mm 0.0616208 mm 0.793134 mm 0.337715 mm  
 missing missing … 0.165429 mm 0.356267 mm  
 missing missing 0.127439 mm 0.227779 mm  
 missing missing 0.144041 mm 0.119195 mm  
 missing missing 0.145074 mm 0.211218 mm  
 missing missing 0.206649 mm 0.25608 mm  
 missing missing … 0.219545 mm 0.245329 mm  
 missing missing 1.49819 mm 0.912608 mm  
 missing missing 0.569264 mm 0.877505 mm  
 missing missing 0.0319118 mm 0.0791221 mm  
 missing missing 0.0 mm 0.00593512 mm  
 missing missing … 0.98264 mm 0.0533203 mm  
 missing missing 3.36242 mm 0.0821212 mm  
 missing missing 1.83737 mm 0.272226 mm  
 missing missing 1.1281 mm 0.221517 mm  
  
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 0.0 mm 0.0 mm 0.0396195 mm 0.124755 mm  
 0.0 mm 0.0 mm 0.314623 mm 0.201133 mm  
 0.0 mm 0.0 mm 0.543779 mm 0.41886 mm  
 0.0 mm 0.0 mm … 1.44429 mm 0.845235 mm  
 0.0 mm 0.0 mm 2.36285 mm 1.1666 mm  
 0.010504 mm 0.0273542 mm 2.34767 mm 1.92731 mm  
 0.0099015 mm 0.077644 mm 2.48665 mm 2.02429 mm  
 0.0237783 mm 0.0361714 mm 2.96727 mm 2.43044 mm  
 missing missing … 2.99843 mm 2.26502 mm  
 missing missing 2.33782 mm 1.98635 mm  
 missing missing 1.69999 mm 1.9211 mm  
 missing missing 1.37751 mm 1.53863 mm  
 missing missing 1.40525 mm 1.63776 mm  
 missing missing … 1.26517 mm 1.53066 mm  
 missing missing 1.18776 mm 2.05023 mm  
 missing missing 1.15352 mm 2.16087 mm  
 missing missing 2.02197 mm 1.34096 mm  
 missing missing 1.13124 mm 0.968808 mm  
 missing missing … 1.74192 mm 0.872952 mm  
 missing missing 4.5769 mm 0.71502 mm  
 missing missing 2.84755 mm 0.626385 mm  
 missing missing 1.71595 mm 0.442172 mm  
  
[:, :, 4018] =  
 0.28943 mm 0.428216 mm … 0.0 mm 0.0 mm  
 0.617869 mm 1.05928 mm 0.0 mm 0.0 mm  
 0.419719 mm 0.933642 mm 0.0 mm 0.0 mm  
 0.29599 mm 0.368912 mm 0.0 mm 0.0 mm  
 0.167837 mm 0.260111 mm 0.0 mm 0.0 mm  
 0.0 mm 0.0577809 mm … 0.0 mm 0.0 mm  
 0.0173758 mm 0.286261 mm 0.0 mm 0.0 mm  
 0.0165058 mm 0.267939 mm 0.0 mm 0.0 mm  
 0.128164 mm 0.346535 mm 0.0359488 mm 0.0057642 mm  
 0.590772 mm 0.722955 mm 0.0 mm 0.0 mm  
 missing missing … 0.0556832 mm 0.0 mm  
 missing missing 0.415889 mm 0.0302957 mm  
 missing missing 0.84346 mm 0.25942 mm  
 missing missing 0.88601 mm 0.617807 mm  
 missing missing 0.542405 mm 0.728522 mm  
 missing missing … 0.364344 mm 0.669638 mm  
 missing missing 0.439767 mm 1.09094 mm  
 missing missing 0.766618 mm 0.803027 mm  
 missing missing 1.10269 mm 0.445515 mm  
 missing missing 1.62241 mm 0.678132 mm  
 missing missing … 2.11198 mm 1.05038 mm  
 missing missing 2.44384 mm 1.66078 mm  
 missing missing 2.59856 mm 1.89122 mm  
 missing missing 3.5302 mm 2.36042 mm

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

### 2.2.2 2.2 Temperature Data

#### 2.2.2.1 Loading in Temperature Data Year by Year

Next, I loaded in each temperature dataset from 2010 through 2020 individually, giving each dataset it’s own time, lon, lat, and temp data.

Dataset: data/raw/2m\_temperature\_2010.nc  
Group: /  
  
Dimensions  
 longitude = 66  
 latitude = 27  
 time = 8760  
  
Variables  
 longitude (66)  
 Datatype: Float32 (Float32)  
 Dimensions: longitude  
 Attributes:  
 units = degrees\_east  
 long\_name = longitude  
  
 latitude (27)  
 Datatype: Float32 (Float32)  
 Dimensions: latitude  
 Attributes:  
 units = degrees\_north  
 long\_name = latitude  
  
 time (8760)  
 Datatype: DateTime (Int32)  
 Dimensions: time  
 Attributes:  
 units = hours since 1900-01-01 00:00:00.0  
 long\_name = time  
 calendar = gregorian  
  
 t2m (66 × 27 × 8760)  
 Datatype: Union{Missing, Float64} (Int16)  
 Dimensions: longitude × latitude × time  
 Attributes:  
 scale\_factor = 0.0012804203994790792  
 add\_offset = 277.34915227026903  
 \_FillValue = -32767  
 missing\_value = -32767  
 units = K  
 long\_name = 2 metre temperature  
  
Global attributes  
 Conventions = CF-1.6  
 history = 2023-11-08 14:41:22 GMT by grib\_to\_netcdf-2.25.1: /opt/ecmwf/mars-client/bin/grib\_to\_netcdf.bin -S param -o /cache/data2/adaptor.mars.internal-1699454453.4834075-9403-11-0d41d13c-eb31-4a63-9978-4212d4a47c89.nc /cache/tmp/0d41d13c-eb31-4a63-9978-4212d4a47c89-adaptor.mars.internal-1699454012.1019258-9403-20-tmp.grib

66×27×8760 Array{Quantity{Float64, 𝚯, Unitful.FreeUnits{(K,), 𝚯, nothing}}, 3}:  
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 29.6788 K 29.6119 K 29.5686 K … 26.4457 K 26.1676 K 25.9788 K  
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closed Dataset

#### 2.2.2.2 Repeating each step for temp datasets from 2011 to 2020

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 latitude (27)  
 Datatype: Float32 (Float32)  
 Dimensions: latitude  
 Attributes:  
 units = degrees\_north  
 long\_name = latitude  
  
 time (8760)  
 Datatype: DateTime (Int32)  
 Dimensions: time  
 Attributes:  
 units = hours since 1900-01-01 00:00:00.0  
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 calendar = gregorian  
  
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 Datatype: Union{Missing, Float64} (Int16)  
 Dimensions: longitude × latitude × time  
 Attributes:  
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 add\_offset = 276.6463982022968  
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 missing\_value = -32767  
 units = K  
 long\_name = 2 metre temperature  
  
Global attributes  
 Conventions = CF-1.6  
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closed Dataset

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closed Dataset

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closed Dataset

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closed Dataset

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closed Dataset

### 2.2.3 2.3 Creating One Large Dataset That Combines all Temp Dat & Converting Times to Daily Instead of Hourly

After loading in the temperature data from each year from 2010 through 2020, I then aggregated all of the time and temperature data into 2 large variables called temp and temp\_time.

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 29.4936 K 29.5639 K 29.5961 K 28.2966 K 28.0395 K 27.8027 K  
 29.6612 K 29.595 K 29.4984 K 28.2573 K 28.0056 K 27.7894 K  
 29.5949 K 29.5999 K 29.576 K … 28.3109 K 28.004 K 27.8169 K  
 29.5589 K 29.5885 K 29.5534 K 28.2647 K 27.9457 K 27.8231 K  
 29.5921 K 29.6012 K 29.5339 K 28.0063 K 27.7315 K 27.5935 K  
 29.6317 K 29.57 K 29.4855 K 27.8642 K 27.5763 K 27.396 K  
 29.6295 K 29.5593 K 29.4781 K 27.8157 K 27.5537 K 27.3278 K  
 29.6036 K 29.5622 K 29.4931 K … 27.8069 K 27.5877 K 27.3334 K  
 29.5939 K 29.5852 K 29.52 K 27.8691 K 27.6547 K 27.3948 K  
  
[:, :, 4017] =  
 28.6981 K 28.5201 K 29.0538 K … 27.7043 K 27.4916 K 27.4037 K  
 28.621 K 28.7954 K 29.1976 K 27.8564 K 27.6156 K 27.4864 K  
 29.6386 K 29.6748 K 29.6603 K 27.923 K 27.6877 K 27.5423 K  
 29.569 K 29.6251 K 29.6516 K 27.9762 K 27.8273 K 27.6565 K  
 29.6932 K 29.6516 K 29.5436 K 28.028 K 27.8787 K 27.7239 K  
 29.6908 K 29.6613 K 29.6181 K … 28.1591 K 27.9549 K 27.8122 K  
 29.6782 K 29.679 K 29.6425 K 28.2189 K 27.9411 K 27.8445 K  
 29.6984 K 29.6933 K 29.6492 K 28.2816 K 27.876 K 27.779 K  
 29.7014 K 29.6454 K 29.5628 K 28.392 K 27.962 K 27.7362 K  
 29.6955 K 29.6078 K 29.5248 K 28.4933 K 28.1204 K 27.775 K  
 29.6469 K 29.5954 K 29.5503 K … 28.6046 K 28.3285 K 27.8758 K  
 29.6383 K 29.6215 K 29.603 K 28.6736 K 28.494 K 28.1986 K  
  
[:, :, 4018] =  
 28.2754 K 28.0213 K 28.3419 K … 27.2111 K 27.0889 K 27.1348 K  
 28.2323 K 28.3698 K 28.5211 K 27.3319 K 27.1185 K 27.0711 K  
 29.2174 K 28.9151 K 28.6769 K 27.3622 K 27.1347 K 27.0835 K  
 29.1987 K 29.0054 K 28.8448 K 27.3978 K 27.2749 K 27.0854 K  
 29.4429 K 29.2925 K 29.1535 K 27.4154 K 27.3486 K 27.184 K  
 29.5982 K 29.4931 K 29.3975 K … 27.4858 K 27.3777 K 27.236 K  
 29.6719 K 29.6292 K 29.5461 K 27.5252 K 27.3812 K 27.2745 K  
 29.7172 K 29.6832 K 29.6296 K 27.5015 K 27.284 K 27.2137 K  
 29.7432 K 29.6959 K 29.6225 K 27.5379 K 27.3006 K 27.2362 K  
 29.7567 K 29.6999 K 29.6455 K 27.6072 K 27.4391 K 27.2549 K  
 29.7587 K 29.7097 K 29.6407 K … 27.6835 K 27.5261 K 27.3249 K  
 29.7557 K 29.7064 K 29.6534 K 27.7813 K 27.5922 K 27.4233 K

|  |
| --- |
| Note |
| I’m also matching the latitude and longitude ranges of the temperature data to match with the precipitation data here. |

## 2.3 3. Splitting Data into Testing & Training data

I then split my data into test and training data, with 70% being training data, and 30% being test data.

2813

1206-element Vector{Date}:  
 2017-09-13  
 2017-09-14  
 2017-09-15  
 2017-09-16  
 2017-09-17  
 2017-09-18  
 2017-09-19  
 2017-09-20  
 2017-09-21  
 2017-09-22  
 2017-09-23  
 2017-09-24  
 2017-09-25  
 ⋮  
 2020-12-20  
 2020-12-21  
 2020-12-22  
 2020-12-23  
 2020-12-24  
 2020-12-25  
 2020-12-26  
 2020-12-27  
 2020-12-28  
 2020-12-29  
 2020-12-30  
 2020-12-31

## 2.4 4. Preprocessing

I then preprocessed my temperature data to get information about the variance and reshape it for use in PCA analysis.

preprocess (generic function with 1 method)

168×1206 Matrix{Float64}:  
 0.246649 0.365087 0.502247 0.449165 … -0.523293 -0.42771 -0.850493  
 0.0978807 0.199035 0.277836 0.248383 -0.426422 -0.306767 -0.695505  
 0.160478 0.306792 0.334185 0.448163 -0.251417 -0.190158 -0.611359  
 0.305294 0.302043 0.32267 0.421586 -0.207463 -0.132002 -0.502331  
 0.242629 0.245264 0.327391 0.28253 -0.142384 -0.110384 -0.360704  
 0.195197 0.217417 0.289826 0.291644 … -0.237578 -0.141728 -0.234289  
 0.19127 0.231528 0.292407 0.283805 -0.279084 -0.159811 -0.166113  
 0.207816 0.27446 0.279097 0.219916 -0.248014 -0.141682 -0.122875  
 0.221062 0.266366 0.267747 0.196011 -0.209658 -0.140007 -0.0981435  
 0.16504 0.224049 0.212795 0.192612 -0.211774 -0.1458 -0.0845297  
 0.189048 0.207454 0.165562 0.159504 … -0.240097 -0.196782 -0.0849457  
 0.233839 0.18216 0.192108 0.190923 -0.255091 -0.210652 -0.0932726  
 0.156991 0.310341 0.42363 0.402152 -0.491532 -0.48361 -0.982389  
 ⋮ ⋱ ⋮  
 0.915546 1.15034 1.21922 1.01441 -1.34534 -1.38154 -1.65048  
 0.786099 1.08292 1.21893 1.14061 -1.42811 -1.3354 -1.75072  
 0.726359 0.987319 1.21387 1.17464 -1.23013 -1.29093 -1.74975  
 0.576907 0.827989 1.12947 1.15148 -1.07282 -1.21901 -1.79012  
 0.560874 0.778867 1.01637 1.10981 … -1.08421 -1.14972 -1.68963  
 0.519511 0.744908 0.988602 1.13121 -1.08091 -1.08561 -1.66183  
 0.473776 0.622001 0.882622 1.03144 -1.055 -1.03357 -1.60365  
 0.509375 0.627548 0.923082 1.02861 -1.18877 -1.00323 -1.56861  
 0.617905 0.676281 0.911351 1.03146 -1.34449 -1.00434 -1.50431  
 0.503972 0.702408 0.910545 1.03565 … -1.41765 -0.970427 -1.49046  
 0.431541 0.728346 0.937455 1.02773 -1.45915 -0.916696 -1.4676  
 0.359524 0.64378 0.80094 0.905782 -1.45539 -0.651535 -1.42683

# 3. Methods

## 3.1 1. Principal Components

I then ran principal components analysis on the temperature training data through fitting the training data to PCA and plotting the variance and cumulative variance. ### 1.1 Fitting

PCA(indim = 168, outdim = 7, principalratio = 0.9908618960503978)  
  
Pattern matrix (unstandardized loadings):  
──────────────────────────────────────────────────────────────────────────────────────────────  
 PC1 PC2 PC3 PC4 PC5 PC6 PC7  
──────────────────────────────────────────────────────────────────────────────────────────────  
1 0.359824 0.102052 0.0569219 -0.0238972 0.116397 -0.0475434 0.069335  
2 0.328088 0.0999239 0.0439694 -0.0184282 0.099185 -0.0370868 0.0545694  
3 0.518697 0.142741 0.100736 -0.0275112 0.123081 -0.00865406 0.00291154  
4 0.462696 0.132545 0.0707853 0.010748 0.0871039 0.00835954 -0.0242104  
5 0.297927 0.0883433 0.0262207 0.0726587 0.0238707 0.0366466 -0.0135404  
6 0.264602 0.0878258 0.0011449 0.089663 0.0108801 0.0287011 0.00965347  
7 0.25373 0.0886718 -0.0113668 0.0984156 0.00693906 0.023602 0.0220129  
8 0.246691 0.089919 -0.0199848 0.102209 0.00497387 0.018667 0.0299165  
9 0.240288 0.0892854 -0.028016 0.104792 0.00304428 0.0149815 0.0359709  
10 0.236882 0.0868645 -0.03367 0.105716 0.00291934 0.010155 0.0414377  
11 0.233227 0.0841932 -0.0372191 0.104126 0.00353177 0.00559269 0.0458609  
12 0.2257 0.0816954 -0.0398317 0.100417 0.00478681 0.000570434 0.0486931  
13 0.373384 0.0886807 0.0621963 -0.0115434 0.0892077 -0.0332414 0.0652966  
14 0.450569 0.111979 0.0845589 -0.0204729 0.0885476 -0.016082 0.0246171  
15 0.57902 0.145936 0.137044 -0.0521862 0.110878 0.012579 -0.0172985  
16 0.512294 0.14169 0.0870968 0.00554104 0.0822382 0.0227041 -0.03683  
17 0.333048 0.0884692 0.0321474 0.0837077 0.0159412 0.0473289 -0.0216178  
18 0.294601 0.0933121 0.00556631 0.0972709 0.00478626 0.0356153 0.00377513  
19 0.283224 0.0963498 -0.00826032 0.10537 0.00128241 0.0279726 0.0168204  
20 0.277265 0.0984504 -0.019595 0.10926 -0.000285027 0.022981 0.0253971  
21 0.273126 0.0989997 -0.0285434 0.111277 -0.000952526 0.0172952 0.031945  
22 0.268974 0.0968446 -0.0356412 0.11204 6.76934e-5 0.0103839 0.0387261  
23 0.264392 0.0947054 -0.0406605 0.110314 0.00202673 0.00368136 0.0447419  
24 0.254909 0.0927845 -0.0445725 0.106317 0.00390988 -0.00251326 0.0487005  
25 0.586131 0.133274 0.144399 -0.0751579 0.114312 -0.0116515 0.0263713  
26 0.587351 0.132348 0.131287 -0.0642462 0.10431 -0.0084541 0.00478155  
27 0.6144 0.136399 0.134693 -0.0380854 0.0941974 0.0174759 -0.0276071  
28 0.565421 0.14469 0.101776 -0.00339891 0.0713854 0.0325772 -0.0479494  
29 0.378955 0.0815049 0.0303408 0.0978885 0.00912478 0.0537987 -0.0286683  
30 0.334227 0.0964334 0.0115074 0.100894 -0.00269716 0.0408164 -0.00638682  
31 0.321208 0.102506 -0.00344984 0.109362 -0.00618352 0.0314914 0.00752884  
32 0.31515 0.105598 -0.0153947 0.114566 -0.00622103 0.025194 0.017881  
33 0.311145 0.107732 -0.0261362 0.115311 -0.00508259 0.0170415 0.0260899  
34 0.306965 0.107808 -0.0356838 0.116075 -0.00245133 0.00828985 0.0345835  
35 0.299427 0.106468 -0.0428503 0.115418 7.23312e-5 0.00166303 0.0420493  
36 0.288882 0.105908 -0.0488302 0.109829 0.00330133 -0.0072449 0.0487589  
37 0.659188 0.096296 0.166254 -0.0861769 0.0959712 -0.0142158 0.0298994  
38 0.679702 0.108683 0.146672 -0.0514222 0.091071 0.00329076 -0.000198299  
39 0.645418 0.12843 0.135005 -0.0330741 0.0714496 0.0186127 -0.0338502  
40 0.61428 0.14406 0.114188 -0.0194447 0.0537046 0.0284237 -0.0522384  
41 0.422318 0.078563 0.0365303 0.0970943 0.000819817 0.0580596 -0.0392137  
42 0.383666 0.0977425 0.0204452 0.0981846 -0.0114808 0.0464886 -0.0240743  
43 0.369226 0.10561 0.00356914 0.107474 -0.0140362 0.0358718 -0.00857839  
44 0.3612 0.112275 -0.0102297 0.111366 -0.0130603 0.0255555 0.00420136  
45 0.355484 0.116906 -0.0231472 0.11456 -0.0107864 0.0155572 0.0149922  
46 0.350192 0.119532 -0.0350478 0.117438 -0.00852517 0.00765017 0.0255642  
47 0.341842 0.120805 -0.0445451 0.116823 -0.00419594 -0.00102257 0.0362983  
48 0.330188 0.120778 -0.0509798 0.112377 0.000957629 -0.0107028 0.0449219  
49 0.702224 0.0711821 0.159945 -0.0601439 0.0694807 -0.0127212 0.0271489  
50 0.721447 0.0859782 0.149475 -0.0383614 0.0583864 0.00915642 0.004023  
51 0.700267 0.107296 0.141988 -0.0332532 0.0408898 0.0235133 -0.0272942  
52 0.656532 0.125426 0.113654 -0.0126832 0.0261242 0.032044 -0.0529019  
53 0.560462 0.100493 0.0686181 0.0452049 0.00976171 0.0474514 -0.0633384  
54 0.470183 0.0929985 0.0363704 0.091058 -0.0178784 0.0553201 -0.0477924  
55 0.437916 0.105787 0.0149179 0.101032 -0.0238338 0.0429474 -0.0304926  
56 0.423814 0.116535 -0.00404971 0.106623 -0.0227852 0.0309366 -0.0158656  
57 0.418633 0.125906 -0.0193215 0.109546 -0.020159 0.0180982 -0.00342275  
58 0.412884 0.132739 -0.0325791 0.112094 -0.0158806 0.00760098 0.00949644  
59 0.405999 0.137123 -0.043746 0.113741 -0.00917004 -0.00285461 0.0233141  
60 0.388348 0.135791 -0.0519855 0.112539 -0.00312303 -0.0123443 0.0350639  
61 0.754121 0.0368882 0.151677 -0.0341425 0.0452793 -0.0161691 0.040038  
62 0.75502 0.0646226 0.141555 -0.0203845 0.0292647 0.00416956 0.0157585  
63 0.737383 0.0801475 0.132353 -0.0189831 0.00984466 0.0200837 -0.0120476  
64 0.719253 0.0993215 0.114674 -0.015964 -0.00635351 0.0337612 -0.0404253  
65 0.697446 0.12179 0.0915633 -0.00344635 -0.0160277 0.0317964 -0.0572929  
66 0.661456 0.14257 0.0739101 -0.00357433 -0.0156634 0.0162561 -0.0598235  
67 0.564447 0.0945772 0.0256124 0.0888124 -0.0108131 0.0350854 -0.0443713  
68 0.535315 0.107806 0.00288558 0.0996818 -0.0183052 0.0248851 -0.0317543  
69 0.526343 0.123466 -0.0140019 0.0998921 -0.0176615 0.0107856 -0.0217225  
70 0.53331 0.132387 -0.0274512 0.097414 -0.00737336 -0.0068162 -0.00734034  
71 0.533117 0.142545 -0.0395401 0.0951211 0.00256766 -0.0200292 0.00751774  
72 0.499521 0.140665 -0.0523124 0.105812 0.00362878 -0.0199291 0.0226672  
73 0.782518 0.00988757 0.149321 -0.0214309 0.0154056 -0.00980125 0.041142  
74 0.764019 0.0216163 0.140521 -0.0219535 -0.00689919 0.00404909 0.023689  
75 0.758712 0.0370001 0.125437 -0.0262117 -0.0244814 0.0160435 0.00409011  
76 0.757085 0.0613072 0.107137 -0.0268272 -0.0390046 0.0259275 -0.0177824  
77 0.765581 0.0887822 0.0940093 -0.0211537 -0.0499743 0.0308306 -0.0385051  
78 0.738142 0.120054 0.0746928 -0.0193159 -0.0484165 0.0105167 -0.0471262  
79 0.68965 0.144466 0.0406339 -0.0155627 -0.0409401 -0.0186653 -0.0496867  
80 0.669582 0.158205 0.00773117 -0.00312579 -0.0290431 -0.0342262 -0.046173  
81 0.677447 0.176088 -0.0189929 3.97168e-5 -0.0210289 -0.0594668 -0.0358944  
82 0.669075 0.194699 -0.0389658 0.00486639 -0.0122592 -0.0813846 -0.019415  
83 0.646649 0.20214 -0.0555137 0.011326 0.00422349 -0.0986609 -0.000602276  
84 0.618156 0.175743 -0.0646364 0.0452481 0.0122622 -0.0800275 0.0143557  
85 0.820508 -0.0533197 0.150926 -0.0201685 -0.00572025 -0.0111858 0.0578932  
86 0.82306 -0.0496032 0.147165 -0.028696 -0.0306134 0.00487141 0.0472602  
87 0.831839 -0.0234309 0.12814 -0.0313041 -0.0527898 0.0183296 0.0300188  
88 0.824032 0.00674366 0.104675 -0.0332712 -0.0663353 0.0280171 0.00537481  
89 0.821678 0.0493234 0.085247 -0.0322032 -0.0741315 0.0361227 -0.0152702  
90 0.806264 0.0823264 0.0647455 -0.0314443 -0.0785796 0.0167313 -0.0308995  
91 0.762319 0.107311 0.0330695 -0.0340763 -0.0657251 -0.0166677 -0.0397863  
92 0.736802 0.130103 0.00211649 -0.0328431 -0.0543395 -0.0445342 -0.0391514  
93 0.737699 0.167722 -0.0280885 -0.0356737 -0.0436762 -0.0742731 -0.034508  
94 0.738018 0.18469 -0.056101 -0.024334 -0.0312052 -0.0929022 -0.0227866  
95 0.707966 0.191966 -0.0716542 -0.0164632 -0.0133167 -0.10757 -0.00660047  
96 0.697849 0.202883 -0.0878153 -0.00292258 0.00177251 -0.120571 0.010047  
97 0.870554 -0.121859 0.148831 -0.0150979 -0.0120174 -0.0199207 0.0704305  
98 0.880695 -0.105231 0.133218 -0.0156349 -0.0353083 -0.00400394 0.0600041  
99 0.886238 -0.0825749 0.117879 -0.02005 -0.0598635 0.0138792 0.04513  
100 0.877704 -0.0479573 0.0915776 -0.0265145 -0.0813528 0.0287923 0.0243098  
101 0.866262 -0.0036655 0.0676481 -0.0282413 -0.0888019 0.0375849 0.00461467  
102 0.853457 0.0344162 0.0483322 -0.0345156 -0.088335 0.0249389 -0.0085765  
103 0.834118 0.0741184 0.0208285 -0.0507209 -0.0829276 -0.00140504 -0.0194302  
104 0.809103 0.100347 -0.0127188 -0.0571124 -0.0719947 -0.0267553 -0.0239102  
105 0.804652 0.133379 -0.044328 -0.058801 -0.0568241 -0.0559418 -0.0221875  
106 0.799335 0.15273 -0.0747872 -0.05846 -0.0404202 -0.0753173 -0.016452  
107 0.777881 0.167766 -0.0909076 -0.0462828 -0.0230365 -0.0904005 -0.00617572  
108 0.76452 0.182759 -0.106057 -0.031929 -0.00621215 -0.106299 0.00813483  
109 0.912069 -0.178091 0.120913 0.00898509 -0.0103991 -0.0333628 0.0643887  
110 0.935282 -0.176093 0.113763 0.00248634 -0.0308359 -0.0137938 0.0621252  
111 0.937093 -0.146928 0.099876 -0.00542169 -0.0577545 0.00969357 0.0516585  
112 0.912904 -0.0972128 0.0711029 -0.0145639 -0.0759981 0.0277179 0.0339241  
113 0.896566 -0.0533518 0.0411257 -0.0180961 -0.0789807 0.0374122 0.0183492  
114 0.874606 -0.0123794 0.018488 -0.0305453 -0.0830185 0.0378037 0.00468213  
115 0.875674 0.0255394 -0.00727149 -0.0511963 -0.0778381 0.0205033 0.000329473  
116 0.858314 0.0634346 -0.0386667 -0.0678222 -0.0656353 -0.00362273 -0.00429841  
117 0.8474 0.0852359 -0.0678679 -0.079895 -0.0541043 -0.0262789 -0.00547298  
118 0.843209 0.111284 -0.0933243 -0.0819224 -0.0355026 -0.0453222 -0.00416175  
119 0.833837 0.136318 -0.112295 -0.0692383 -0.0175011 -0.057588 0.00189242  
120 0.811812 0.165035 -0.130145 -0.0533172 -0.00526177 -0.0779395 0.0117415  
121 0.913382 -0.233527 0.0926594 0.036381 -0.00706114 -0.059055 0.0386577  
122 0.958938 -0.222393 0.0749068 0.029414 -0.0134718 -0.0368117 0.0365336  
123 0.972861 -0.190912 0.0641121 0.0175602 -0.0346791 -0.00818437 0.0339349  
124 0.964651 -0.148845 0.0442478 0.00480974 -0.0534085 0.0186393 0.0312702  
125 0.916659 -0.0959089 0.0104873 -0.00726438 -0.0562276 0.0334903 0.0178861  
126 0.911509 -0.0568542 -0.016196 -0.0300825 -0.0633152 0.0407584 0.0115495  
127 0.894994 -0.0133839 -0.0449162 -0.0418465 -0.0531492 0.0318602 0.00651107  
128 0.881902 0.0177249 -0.0731975 -0.0548544 -0.0442711 0.020094 0.00608965  
129 0.883369 0.0414217 -0.0976331 -0.0790105 -0.0286944 0.0085273 0.00673086  
130 0.884583 0.0666892 -0.11857 -0.0909581 -0.0140035 -0.00292229 0.00735057  
131 0.875448 0.0954799 -0.133817 -0.0815514 0.000448007 -0.0196228 0.0101066  
132 0.857798 0.120163 -0.145492 -0.0668833 0.00706572 -0.0371238 0.0133208  
133 0.936452 -0.254022 0.0575337 0.0677354 0.00988459 -0.076954 0.00534104  
134 0.972503 -0.242187 0.0364622 0.0614839 0.00842793 -0.0601056 0.00639702  
135 0.986626 -0.224868 0.0289828 0.0484337 -0.00706919 -0.0287809 0.00800931  
136 0.989216 -0.196015 0.00883643 0.0263779 -0.0180361 -0.000167343 0.00789741  
137 0.958201 -0.157744 -0.0161532 0.00965498 -0.0267594 0.0240538 0.00390517  
138 0.948928 -0.117714 -0.0389656 -0.00934251 -0.0275528 0.0421939 0.00194773  
139 0.938223 -0.0785181 -0.0632669 -0.0341633 -0.0232374 0.0482487 0.00548953  
140 0.920445 -0.0391499 -0.0930542 -0.0585853 -0.0138945 0.046849 0.00772537  
141 0.91692 -0.0110016 -0.122192 -0.0680663 0.00318981 0.0415394 0.0138808  
142 0.919528 0.0218885 -0.139963 -0.0793983 0.0174113 0.0331955 0.0161164  
143 0.92109 0.0569891 -0.154583 -0.0841157 0.0255305 0.0234203 0.0205318  
144 0.905582 0.0842437 -0.16305 -0.0758169 0.0333276 0.00246597 0.0245007  
145 0.960741 -0.287222 0.0354069 0.104146 0.0261552 -0.0966961 -0.0302118  
146 0.982463 -0.275842 0.0123059 0.0922341 0.0277421 -0.0736762 -0.0320453  
147 0.99822 -0.264113 -0.00731649 0.077235 0.0256851 -0.0482621 -0.0288871  
148 1.0155 -0.240185 -0.0231638 0.0541584 0.024299 -0.0185676 -0.0256087  
149 0.998974 -0.200496 -0.0441761 0.031956 0.0180002 0.013009 -0.019575  
150 0.994513 -0.164085 -0.0657383 0.0119213 0.0170633 0.0398325 -0.0180771  
151 0.960674 -0.117698 -0.0835972 -0.0106632 0.0119316 0.0537565 -0.00985029  
152 0.933487 -0.0862463 -0.103016 -0.0352837 0.0161855 0.0618991 -0.00395265  
153 0.925526 -0.0622506 -0.132731 -0.0561123 0.0340433 0.0657768 0.00648455  
154 0.939832 -0.0277204 -0.155481 -0.0683883 0.0473142 0.0608277 0.0143321  
155 0.955573 0.0196206 -0.174246 -0.0811208 0.0589153 0.0525993 0.0249761  
156 0.95108 0.0465893 -0.181103 -0.0772871 0.0615951 0.0392527 0.030632  
157 0.986825 -0.302229 0.00322146 0.12697 0.045339 -0.10268 -0.0662045  
158 1.01034 -0.29269 -0.020718 0.121474 0.0574331 -0.0836555 -0.0670274  
159 1.01923 -0.279633 -0.0385591 0.0997379 0.0610227 -0.0562618 -0.0616598  
160 1.03717 -0.253582 -0.0470023 0.0794154 0.060658 -0.0309714 -0.0518727  
161 1.02659 -0.226658 -0.0628942 0.0567632 0.0549502 0.00072201 -0.0463488  
162 1.03012 -0.189525 -0.0858769 0.0383734 0.0576759 0.0300612 -0.039395  
163 0.999031 -0.158981 -0.102535 0.0120245 0.0537932 0.0481489 -0.0284354  
164 0.980578 -0.136609 -0.119671 -0.0112582 0.0557228 0.0654136 -0.0182028  
165 0.968419 -0.0957673 -0.144667 -0.0343069 0.0648639 0.0684999 -0.0066999  
166 0.961175 -0.0649518 -0.165327 -0.050509 0.0753224 0.0692737 0.00525596  
167 0.954629 -0.0313924 -0.181139 -0.064572 0.0848488 0.0629508 0.0164226  
168 0.968863 0.00927471 -0.19173 -0.0763888 0.0906135 0.0519104 0.0292774  
──────────────────────────────────────────────────────────────────────────────────────────────  
  
Importance of components:  
──────────────────────────────────────────────────────────────────────────────────────────────────────────  
 PC1 PC2 PC3 PC4 PC5 PC6 PC7  
──────────────────────────────────────────────────────────────────────────────────────────────────────────  
SS Loadings (Eigenvalues) 90.8871 2.91201 1.28667 0.788865 0.37422 0.289145 0.168843  
Variance explained 0.931233 0.0298365 0.0131832 0.00808274 0.00383427 0.00296259 0.00172997  
Cumulative variance 0.931233 0.961069 0.974252 0.982335 0.986169 0.989132 0.990862  
Proportion explained 0.939821 0.0301117 0.0133048 0.00815728 0.00386963 0.00298992 0.00174592  
Cumulative proportion 0.939821 0.969932 0.983237 0.991395 0.995264 0.998254 1.0  
──────────────────────────────────────────────────────────────────────────────────────────────────────────

After looking at the cumulative variance explained plot, I decided to use 3 principal components because those three account for almost 0.95 of the cumulative variance, but reduces alot of the noise.

From this plot, we see that principal components 1 & 2 appear to have some sort of relation to the difference in temperatures on land and in the ocean, while the third prinicipal component appears to have some sort of relation to longitude.

From this plot, we can see that principal component 1 is definitely driving the seasonal cycle of the data, principal components 2 and 3 appear more closesly related with daily variances in temperature.

2812-element Vector{Float64}:  
 0.12159371457232913  
 7.616495573392479e-5  
 0.006247931381547322  
 0.015381219605364467  
 0.00843978966235794  
 0.0011483214018485877  
 0.10045980903930878  
 0.08399755394306557  
 0.0005747905597891859  
 9.631115742909012e-5  
 1.1757308597205787e-5  
 0.005711613533798087  
 0.11083589170648846  
 ⋮  
 0.3601354747037253  
 0.04452485449852482  
 0.06564906066944522  
 0.03841942488386106  
 0.08617370971188108  
 0.21874357987796098  
 0.016303344787529078  
 0.0041962744624063535  
 0.056454266280096074  
 0.04952982989850865  
 0.000686609951719161  
 0.017647124457183066

## 3.2 6. K-NN Model

knn (generic function with 1 method)

predict\_knn (generic function with 1 method)

3-element Vector{Matrix{Union{Missing, Quantity{Float64, 𝐋, Unitful.FreeUnits{(mm,), 𝐋, nothing}}}}}:  
 [0.0 mm 0.0 mm … 0.0783728301525116 mm 0.20057315826416017 mm; 0.0 mm 0.0 mm … 0.0818052113056183 mm 0.23614437580108644 mm; … ; missing missing … 0.6310684680938721 mm 0.3703082323074341 mm; missing missing … 1.0033145904541017 mm 0.4386766910552979 mm]  
 [0.4737372398376465 mm 0.16090223789215088 mm … 2.7167837142944338 mm 2.1500776290893557 mm; 0.3739526748657227 mm 0.1150146484375 mm … 2.3486860275268557 mm 1.8218547821044924 mm; … ; missing missing … 0.0 mm 0.0 mm; missing missing … 0.0 mm 0.0 mm]  
 [0.054488527774810794 mm 0.03381277024745941 mm … 0.10773171186447145 mm 0.3044742584228516 mm; 0.15192916393280032 mm 0.05924720168113709 mm … 0.06254687309265138 mm 0.36397480964660645 mm; … ; missing missing … 0.060378712415695195 mm 0.019118070602416992 mm; missing missing … 0.13480685949325563 mm 0.08229385614395142 mm]

## 3.3 7. Random Forest Model

train\_random\_forest (generic function with 1 method)

{julia} rf\_model = train\_random\_forest(temp\_train, temp\_test, precip\_train; n\_pca=3, n\_trees=100)

# 4. Model Comparison

I tried to create a random forest model in order to make a comparison about which model worked best for my data, but couldn’t get my code for the random forest model to work. However, I do believe that my random forest model, if using the original data and not the PCA data, could have been better for my large dataset. I think a big reason my KNN model didn’t do great was because there was still some noise from outliers even after choosing my principal components. Because KNN models are sensitive to noise, that noise may have caused my model to struggle.

# 5. Conclusion

I think that overall, while my KNN model didn’t work great and I couldn’t get a second model to run, this project wasn’t a complete failure. I think that even though I didn’t get the results I wanted, I ended up deepening my understanding of PCA, KNN models, and random forest models hrough the process of trying to put this project together.