Precipitation Downscaling Project

Lily Metsker (lm88)

2023-11-02

Executive Summary:

The goal of this project is to predict precipitation in Texas at time point "t+1" given temperature at time "t". This analysis uses CPC gauge-based gridded daily precipitation and daily temperature data over roughly the area of Texas from the years 2000 to 2009 to train two different predictive models. Both models applied a principal component analysis (PCA) to downscale the high dimensional temperature data, and then fit models on the selected principal components. In the first approach, K-nearest neighbors (KNN) was applied to the principal components to predict precipitation based on a subsetted testing set of temperature data to allow for comparison to actual values. In the second approach, a linear regression model was applied to the first principal component only to predict precipitation corresponding to the same testing temperature dataset.

In order to validate the fit of the models, mean squared error, mean absolute error, and residuals were calculated. These metrics were also used to compare the performance between the two models. Though upon visual inspection PCA-KNN appears to predict precipitation trends closer to observed values, the PCA-KNN approach exhibited a higher mean squared error and mean absolute error than the PCA-linear regression model despite a lower average residual value. Higher mean absolute error and mean squared error indicates that the PCA-KNN model actually performs worse than the PCA-linear regression model, likely due to large variations and inaccuracies in extreme values. The PCA-linear regression model, on the other hand, exhibits a conservative, "dreary" prediction across all time points, which leads to lower error overall when dealing with extremes.

Methods

Data Management/Preprocessing The original precipitation data was subsetted to only include the years 2000 to 2009 to correspond to the selected temperature data timeframe. Temperature data was subsetted to match the space occupied by the precipitation data and cover roughly the area of Texas. Latitude and longitude were adjusted to ensure consistent formatting across the datasets. To predict on precipitation at time t+1, the precipitation time points used in the analysis were shifted one day from the temperature data time points. Precipitation and temperature data were then split to create training and testing sets, with years 2000 to 2007 included in training and the rest allocated to testing. Temperature data was preprocessed by calculating the mean climatology and obtaining the anomalies rather than working with raw temperatures to better account for seasonal variation.

1. Setup

1.1 Load Packages

2. Data

2.1 Precipitation 2.1.1 Load data

```
24×24×16365 Array{Union{Missing, Float32}, 3}:
[:, :, 1] =
  1.37582   1.57975    1.45262   …  0.0        0.0202463  0.0
  1.20963   1.85082    2.28766      0.0308067  0.0602374  0.114836
  1.97182   1.45203    2.09293      0.0490085  0.121709   0.237292
  1.5909    1.33469    1.65327      0.0664271  0.389667   0.678864
  1.43704   1.75647    2.29071      0.0964478  0.24362    1.0564
  1.23506   1.71966    1.24682   …  0.29584    0.192309   0.594209
  1.34688   2.06668    1.14913      0.50683    0.345075   0.153464
  1.45706   2.27098    0.724487     1.06509    0.576138   0.0801041
  5.20069   3.71962    0.181735     1.43136    0.706655   0.133022
  2.88819   0.759342   0.163341     2.08092    1.4474     0.53837
  1.50673   0.461275   0.207048  …   missing    missing    missing
  1.43436   0.139224   0.290842      missing    missing    missing
  3.18961   2.13086    2.59861       missing    missing    missing
  5.19326   5.16296    4.65167       missing    missing    missing
  5.3778    4.47193    6.19447       missing    missing    missing
  2.81836   8.9879     5.9169    …   missing    missing    missing
  1.80613   8.12168    2.24706       missing    missing    missing
  6.17247  15.1932    14.4421        missing    missing    missing
 15.3935   12.0708    20.1535        missing    missing    missing
 16.41     16.3307    23.8688        missing    missing    missing
 12.77     20.6869    18.5016    …   missing    missing    missing
 14.9623    9.67723    7.38247       missing    missing    missing
 21.7209   10.5213     9.88938       missing    missing    missing
 20.7196   14.5443    15.6206        missing    missing    missing

[:, :, 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        0.0        0.0           0.0507107  0.0       0.0
 0.0        0.0        0.0        0.0           0.170228   0.0       0.0
 0.0344644  0.0828211  0.0        0.0           0.0242824  0.0       0.0
 0.116297   0.232722   0.0        0.0        …   missing    missing   missing
 0.0780643  0.120667   0.0        0.0            missing    missing   missing
```

```
 0.790819   0.209601   0.0810387  0.0836833      missing    missing   missing
 0.330909   0.0694368  0.202908   0.172532       missing    missing   missing
 0.0834752  0.366478   0.193584   0.041639       missing    missing   missing
 0.334877   0.392715   0.221516   0.0368422  …   missing    missing   missing
 0.171142   0.847358   0.0837831  0.0            missing    missing   missing
 0.660464   2.01706    0.12625    0.0            missing    missing   missing
 0.309305   0.0865614  0.0        0.0546165      missing    missing   missing
 0.206135   0.0        0.0        0.0464391      missing    missing   missing
 0.397575   0.355726   0.0        0.0436917  …   missing    missing   missing
 1.2978     0.686435   0.064151   0.364207       missing    missing   missing
 0.998617   0.906296   0.373319   2.32323        missing    missing   missing
 0.708568   2.16601    2.14061    2.34233        missing    missing   missing

[:, :, 3] =
 0.0        0.0        0.0        0.245373   …  0.0       0.0       0.0
 0.0        0.0        0.0        0.218143      0.0       0.0       0.0
 0.0        0.0        0.174088   0.175847      0.0       0.0       0.0
 0.16041    0.0296272  0.77125    0.584347      0.0       0.0       0.0
 0.0822869  0.0        0.0870539  0.0920338     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        0.153964      0.0       0.0       0.0
 0.0        0.0        0.0        0.377731      0.0       0.0       0.0
 0.0        0.0        0.0        0.0           0.0       0.0       0.0
 0.391579   0.0879667  0.0        0.0           0.0       0.0       0.0
 0.178373   0.052071   0.0        0.0        …   missing   missing   missing
 0.0        0.0        0.0        0.0            missing   missing   missing
 0.0        0.0        0.0621035  0.0487938      missing   missing   missing
 0.0        0.0        0.509918   0.990183       missing   missing   missing
 0.0        0.0        0.0975961  0.627761       missing   missing   missing
 0.0        0.0        0.0        0.0        …   missing   missing   missing
 0.0        0.0        0.0        0.0            missing   missing   missing
 0.0        0.0        0.0        0.0            missing   missing   missing
 0.0        0.0        0.0        0.0            missing   missing   missing
 0.0        0.0        0.0        0.0            missing   missing   missing
 0.0        0.0        0.0        0.0        …   missing   missing   missing
 0.0707157  0.0        0.0        0.0            missing   missing   missing
 0.0        0.0        0.0        0.0            missing   missing   missing
 0.0        0.0        0.0        0.0            missing   missing   missing

;;; …

[:, :, 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
 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        0.0        0.0            0.0       0.0       0.0
 0.0        0.0        0.0        0.0         …   missing   missing   missing
 0.0        0.0        0.0        0.0             missing   missing   missing
 0.0        0.0        0.0        0.0             missing   missing   missing
 0.0        0.0        0.0        0.0             missing   missing   missing
 0.0        0.0259045  0.0        0.0             missing   missing   missing
 0.0        0.0        0.207233   0.0         …   missing   missing   missing
 0.0        0.0        0.0300441  0.0             missing   missing   missing
 0.0        0.0        0.0296209  0.0             missing   missing   missing
 0.0761566  0.228387   0.441014   0.237419        missing   missing   missing
 0.275329   0.189209   0.147844   0.189911        missing   missing   missing
 0.72749    0.303631   0.0207723  0.150705    …   missing   missing   missing
 1.02891    0.220527   0.0399159  0.0950709       missing   missing   missing
 0.818845   0.127663   0.0        0.0299711       missing   missing   missing
 0.641579   0.0371985  0.0        0.0             missing   missing   missing

[:, :, 16364] =
 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  0.0     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  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  …   missing   missing   missing
 0.0  2.37197   0.0  0.0  0.0  0.0  0.0  0.0      missing   missing   missing
 0.0  0.683025  0.0  0.0  0.0  0.0  0.0  0.0      missing   missing   missing
 0.0  0.0       0.0  0.0  0.0  0.0  0.0  0.0      missing   missing   missing
 0.0  0.0       0.0  0.0  0.0  0.0  0.0  0.0      missing   missing   missing
 0.0  0.0       0.0  0.0  0.0  0.0  0.0  0.0  …   missing   missing   missing
 0.0  0.0       0.0  0.0  0.0  0.0  0.0  0.0      missing   missing   missing
 0.0  0.0       0.0  0.0  0.0  0.0  0.0  0.0      missing   missing   missing
 0.0  0.0       0.0  0.0  0.0  0.0  0.0  0.0      missing   missing   missing
 0.0  0.0       0.0  0.0  0.0  0.0  0.0  0.0      missing   missing   missing
 0.0  0.0       0.0  0.0  0.0  0.0  0.0  0.0  …   missing   missing   missing
 0.0  0.0       0.0  0.0  0.0  0.0  0.0  0.0      missing   missing   missing
 0.0  0.0       0.0  0.0  0.0  0.0  0.0  0.0      missing   missing   missing
 0.0  0.0       0.0  0.0  0.0  0.0  0.0  0.0      missing   missing   missing

[:, :, 16365] =
 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  0.0     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       0.0326195  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  …   missing   missing    missing
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0      missing   missing    missing
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0      missing   missing    missing
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0      missing   missing    missing
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0      missing   missing    missing
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  …   missing   missing    missing
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0      missing   missing    missing
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0      missing   missing    missing
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0      missing   missing    missing
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0      missing   missing    missing
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  …   missing   missing    missing
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0      missing   missing    missing
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0      missing   missing    missing
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0      missing   missing    missing
```

2.1.2 Close precip dataset

```
closed Dataset
```

2.1.3 Filter data

```
3653-element Vector{DateTime}:
 2000-01-01T00:00:00
 2000-01-02T00:00:00
 2000-01-03T00:00:00
 2000-01-04T00:00:00
 2000-01-05T00:00:00
 2000-01-06T00:00:00
 2000-01-07T00:00:00
 2000-01-08T00:00:00
 2000-01-09T00:00:00
 2000-01-10T00:00:00
 2000-01-11T00:00:00
 2000-01-12T00:00:00
 2000-01-13T00:00:00
 ⋮
 2009-12-20T00:00:00
 2009-12-21T00:00:00
 2009-12-22T00:00:00
 2009-12-23T00:00:00
 2009-12-24T00:00:00
 2009-12-25T00:00:00
 2009-12-26T00:00:00
 2009-12-27T00:00:00
 2009-12-28T00:00:00
 2009-12-29T00:00:00
```

```
 2009-12-30T00:00:00
 2009-12-31T00:00:00
```

2.1.4 Subset data

```
3652-element Vector{DateTime}:
 2000-01-02T00:00:00
 2000-01-03T00:00:00
 2000-01-04T00:00:00
 2000-01-05T00:00:00
 2000-01-06T00:00:00
 2000-01-07T00:00:00
 2000-01-08T00:00:00
 2000-01-09T00:00:00
 2000-01-10T00:00:00
 2000-01-11T00:00:00
 2000-01-12T00:00:00
 2000-01-13T00:00:00
 2000-01-14T00:00:00
 ⋮
 2009-12-20T00:00:00
 2009-12-21T00:00:00
 2009-12-22T00:00:00
 2009-12-23T00:00:00
 2009-12-24T00:00:00
 2009-12-25T00:00:00
 2009-12-26T00:00:00
 2009-12-27T00:00:00
 2009-12-28T00:00:00
 2009-12-29T00:00:00
 2009-12-30T00:00:00
 2009-12-31T00:00:00
```

2.1.5 Reverse latitude

```
24×24×3652 Array{Union{Missing, Float32}, 3}:
[:, :, 1] =
 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       0.0       0.0323414        0.0        0.0        0.0
 0.0       0.0       0.0       0.135582         0.0        0.0        0.0
 0.0       0.0       0.0       0.151623         0.0        0.0        0.031432
  missing   missing   missing   missing      …  0.436169   0.167826   0.0222956
  missing   missing   missing   missing         0.113203   0.219052   0.0204078
  missing   missing   missing   missing         0.0        0.0        0.0
  missing   missing   missing   missing         0.0        0.0        0.0
```

```
  missing   missing   missing   missing      0.0         0.0696384  0.0207805
  missing   missing   missing   missing   …  0.0450895   0.0828177  0.0338578
  missing   missing   missing   missing      0.0         0.0        0.0513665
  missing   missing   missing   missing      0.0764082   0.0628494  0.156683
  missing   missing   missing   missing      0.616311    0.172386   0.0214627
  missing   missing   missing   missing      3.26764     2.32975    3.03718
  missing   missing   missing   missing   …  3.97116     1.08259    3.51391
  missing   missing   missing   missing      1.08442     0.152592   0.607323
  missing   missing   missing   missing      7.1412      1.6474     0.0
  missing   missing   missing   missing      1.00298     0.780391   0.602726

[:, :, 2] =
 0.0       0.0       0.0       …   0.0         0.861222    1.58391
 0.0       0.0       0.0           0.0         0.142009    0.620014
 0.0       0.0       0.0           0.0         0.0         0.0304579
 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         0.0279951   0.10282
 0.0       0.0       0.0           0.0         0.203494    0.390608
 0.0       0.0       0.0           0.299697    1.65651     2.56886
 0.0       0.0       0.0           2.07031     0.885224    1.6951
 0.0       0.0       0.0           2.42535     2.01437     0.887439
  missing   missing   missing  …   4.94332     2.89262     1.55625
  missing   missing   missing     11.1041      5.20581     2.63938
  missing   missing   missing     21.9379      7.78901     4.3323
  missing   missing   missing     28.1783     15.3255     10.0802
  missing   missing   missing     34.7224     28.1705     13.5422
  missing   missing   missing  …  25.7909     27.0969     15.6146
  missing   missing   missing     23.9934     25.7158     22.9741
  missing   missing   missing     22.3714     23.8421     28.7882
  missing   missing   missing     21.7186     23.8547     24.5314
  missing   missing   missing     33.3132     19.215      14.6306
  missing   missing   missing  …  55.1564     27.6612      8.24005
  missing   missing   missing     37.3152     56.9326     26.5516
  missing   missing   missing     24.6176     73.771      51.9611
  missing   missing   missing      8.29554    48.9767     73.7095

[:, :, 3] =
 0.0       0.0       0.0       …   0.0          0.0          0.119807
 0.0       0.0       0.0           0.0640346    0.081867     0.165219
 0.0       0.0       0.0           0.039643     0.118587     0.431731
 0.0       0.0       0.0           0.0          0.0213695    0.271837
 0.0       0.0       0.0           0.0226516    0.0476442    0.131516
 0.0       0.0       0.0       …   0.0273123    0.0882924    0.112214
 0.0       0.0       0.0           0.0          0.243156     0.652184
 0.0       0.0       0.0           0.0254786    0.409578     1.41301
 0.0       0.0       0.0           0.141537     1.47574      2.68291
 0.0       0.0       0.0           0.590031     0.550419     2.79478
  missing   missing   missing  …   1.84155      0.927045     2.13219
  missing   missing   missing      1.7651       0.957743     2.1216
```

```
  missing   missing   missing      1.64877     0.612912    2.59903
  missing   missing   missing      0.780635    0.469386    1.95597
  missing   missing   missing      1.67376     1.71056     1.23499
  missing   missing   missing   …  0.883307    1.35247     1.12839
  missing   missing   missing      1.0367      1.32528     3.07755
  missing   missing   missing      4.9913      2.11696     0.937954
  missing   missing   missing     10.4429      7.33287     2.03677
  missing   missing   missing      8.51849     7.07041     4.33941
  missing   missing   missing   … 10.3645     10.9053      8.96606
  missing   missing   missing     16.6359     18.2572     10.5232
  missing   missing   missing      7.94858    18.4997     17.5984
  missing   missing   missing      8.29728    18.0127     25.2627

;;; …

[:, :, 3650] =
 1.91927   2.18294    4.04477   5.20947   …  0.0       0.0        0.0
 0.203245  0.580783   2.77413   4.15098      0.0       0.0        0.0
 0.237774  1.28198    1.22886   0.721624     0.0       0.0        0.0
 1.80391   2.13242    1.09698   0.152618     0.0       0.0        0.0
 2.32314   1.18486    0.259382  0.0          0.0       0.0        0.0
 1.09869   0.124012   0.0       0.0       …  0.0       0.0        0.0
 0.493284  0.0336855  0.0       0.0          0.0       0.0        0.0
 0.0       0.0        0.0       0.0          0.210678  0.0        0.0
 0.0       0.0        0.0       0.0          0.244225  0.0478664  0.0
 0.0       0.0        0.0       0.0          0.883143  1.56837    0.156057
  missing   missing    missing   missing  …  1.22156   1.51986    1.36312
  missing   missing    missing   missing     2.79113   3.31666    2.07084
  missing   missing    missing   missing     2.48622   2.86405    1.8507
  missing   missing    missing   missing     0.999645  7.01725    4.73033
  missing   missing    missing   missing     1.48617   2.80321    4.4185
  missing   missing    missing   missing  …  0.311555  0.0501361  0.0426737
  missing   missing    missing   missing     0.123578  0.0        0.0
  missing   missing    missing   missing     0.0       0.0        0.0
  missing   missing    missing   missing     0.0       0.0        0.0
  missing   missing    missing   missing     0.0       0.0        0.0
  missing   missing    missing   missing  …  0.0       0.0        0.0
  missing   missing    missing   missing     0.0       0.0        0.0
  missing   missing    missing   missing     0.0       0.0        0.0
  missing   missing    missing   missing     0.0       0.0        0.0

[:, :, 3651] =
 1.25381   1.38226   6.78581   9.23103   …   0.209643  0.06951    0.0322176
 1.77286   1.17652   5.44695   8.42261       0.674334  0.0        0.038588
 5.26336   2.10804   3.33561   5.37528       0.916897  0.0899668  0.0
 4.11361   1.87916   1.61745   5.03068       0.337145  0.891777   0.0281657
 1.10992   0.986878  1.11829   6.67025       3.08982   0.966748   0.270218
 2.73123   2.4278    3.59609   5.59022   …  10.1729    1.6837     0.420492
 3.33995   4.18317   3.80484   3.17682       0.469495  1.02329    0.587488
 5.67861   5.78922   4.2321    1.34415       0.723784  1.02258    1.35627
```

```
 5.94113   5.36736   3.45825   5.4516        1.6775    1.66165    2.03233
 5.672     4.33358   3.37151   5.49953       2.08825   1.21806    2.91972
  missing   missing   missing   missing  …   2.48373   1.6086     1.16387
  missing   missing   missing   missing      2.07946   1.88346    0.863437
  missing   missing   missing   missing      2.36113   1.62808    0.568243
  missing   missing   missing   missing      1.84581   1.57609    1.48535
  missing   missing   missing   missing      1.86876   1.23442    0.884178
  missing   missing   missing   missing  …   1.79652   0.287498   1.20721
  missing   missing   missing   missing      2.98471   0.613985   1.21469
  missing   missing   missing   missing      2.01611   0.473238   0.555291
  missing   missing   missing   missing      1.43036   0.545582   0.477171
  missing   missing   missing   missing      0.386973  0.315955   0.0261992
  missing   missing   missing   missing  …   0.0       0.0310814  0.0
  missing   missing   missing   missing      0.0       0.0293388  0.0
  missing   missing   missing   missing      0.0       0.0        0.0
  missing   missing   missing   missing      0.0       0.0        0.0

[:, :, 3652] =
 0.0       0.0        0.0         …  0.0        0.194001   0.229313
 0.0       0.0        0.0            0.201      0.0        1.05024
 0.0       0.0        0.0            0.794761   0.0        0.239922
 0.0       0.0        0.0            0.487525   0.0712316  0.0
 0.0       0.0        0.0            0.871535   0.725623   0.0546665
 0.0       0.0        0.0         …  0.63043    0.834709   0.935677
 0.0       0.0        0.0            0.737369   0.396731   1.7525
 0.0       0.0        0.0342669      0.810175   0.914279   2.05469
 0.0       0.0        0.418512       0.482352   0.6477     0.834548
 0.0       0.0364437  0.121333       1.36826    1.77949    1.08005
  missing   missing    missing    …  1.58758    4.78649    4.96679
  missing   missing    missing       3.17118    5.32441    3.90305
  missing   missing    missing       3.59475    4.90733    4.06902
  missing   missing    missing       1.31501    5.03513    4.85771
  missing   missing    missing       1.21495    2.24849    4.07878
  missing   missing    missing    …  1.81574    0.2997     1.09506
  missing   missing    missing       1.08286    0.0417713  0.649026
  missing   missing    missing       0.0439509  0.0        0.253759
  missing   missing    missing       0.0449181  0.0        1.20432
  missing   missing    missing       0.264041   0.0        1.47429
  missing   missing    missing    …  0.779127   0.235859   0.301635
  missing   missing    missing       1.42092    0.159816   0.394416
  missing   missing    missing       3.98366    0.940115   1.16965
  missing   missing    missing       0.545287   0.645726   1.59136
```

2.1.6 Convert lon to lon1 format

```
24-element Vector{Float32}:
 -101.75
 -101.25
 -100.75
 -100.25
```

```
  -99.75
  -99.25
  -98.75
  -98.25
  -97.75
  -97.25
  -96.75
  -96.25
  -95.75
  -95.25
  -94.75
  -94.25
  -93.75
  -93.25
  -92.75
  -92.25
  -91.75
  -91.25
  -90.75
  -90.25
```

2.2 Temperature

2.2.1 Load data

```
Dict{Int64, Array{Union{Missing, Float64}, 3}} with 10 entries:
  2003 => [282.275 282.693 … 291.855 291.843; 282.332 282.663 … 291.725
291.825…
  2004 => [277.587 277.948 … 292.118 292.505; 277.904 277.883 … 292.192
292.599…
  2001 => [282.277 282.732 … 291.394 291.7; 282.241 282.585 … 291.294
291.704; …
  2005 => [275.953 277.028 … 291.309 291.787; 276.401 277.778 … 291.375
291.761…
  2008 => [280.872 281.42 … 290.851 291.7; 280.859 281.331 … 290.545 291.318;
……
  2000 => [279.491 280.057 … 290.199 290.589; 279.531 280.12 … 290.026
290.425;…
  2002 => [281.375 281.722 … 292.495 292.614; 281.622 281.596 … 291.817
292.024…
  2009 => [276.942 277.0 … 290.54 290.873; 276.963 277.073 … 290.276 290.623;
……
  2006 => [281.257 281.87 … 291.109 291.009; 281.398 281.981 … 290.75
291.098; …
  2007 => [282.586 283.225 … 290.564 290.928; 282.62 283.199 … 290.448
290.725;…
```

2.2.2 Combine

```
66×27×3653 Array{Union{Missing, Float64}, 3}:
[:, :, 1] =
```

```
 279.491  280.057  280.607  280.917  …  289.866  290.023  290.199  290.589
 279.531  280.12   280.553  281.077     289.713  289.881  290.026  290.425
 279.28   280.175  280.651  281.016     289.702  289.758  289.926  290.237
 276.178  279.946  280.693  280.98      289.692  289.883  290.018  290.189
 273.58   279.514  280.61   280.935     289.735  290.065  290.055  290.214
 277.067  276.623  280.496  281.015  …  289.657  289.969  289.991  290.13
 273.442  275.95   276.05   279.896     289.52   289.897  289.96   290.041
 269.142  278.684  276.2    278.425     289.458  289.821  289.979  290.127
 268.997  273.748  277.069  274.384     289.484  289.773  289.944  290.203
 268.419  268.099  269.77   271.571     289.59   289.863  289.963  290.202
 268.58   265.679  268.572  271.113  …  289.57   289.863  289.99   290.169
 266.085  266.211  269.975  272.546     289.445  289.784  289.933  290.244
 264.757  265.626  270.774  273.479     289.245  289.528  289.771  290.1
   ⋮                                 ⋱                               ⋮
 254.899  260.748  262.287  264.109     294.643  296.035  296.605  296.791
 255.745  260.112  261.232  262.814  …  295.342  296.097  296.557  296.485
 255.495  260.011  261.017  262.453     295.462  295.966  296.195  296.044
 254.944  258.618  259.911  260.492     295.328  295.66   295.582  295.705
 253.234  258.312  259.692  258.167     295.162  295.313  294.967  295.856
 252.139  256.79   259.484  258.771     295.033  294.944  294.888  296.067
 251.687  256.465  258.677  260.193  …  295.004  294.775  295.226  296.419
 251.198  253.888  259.967  259.31      294.953  294.755  295.744  296.741
 250.48   264.074  255.333  255.737     295.092  295.23   295.971  296.872
 251.777  261.876  254.365  256.103     295.154  295.015  295.976  297.019
 260.38   254.461  255.862  257.353     294.93   294.985  296.056  297.025
 261.702  255.281  261.385  260.49   …  294.927  295.222  296.28   296.949

[:, :, 2] =
 277.785  278.38   279.159  280.1    …  289.92   290.165  290.567  290.996
 277.716  278.507  279.004  280.103     289.754  290.153  290.443  290.939
 277.222  278.548  279.249  279.895     289.765  290.133  290.447  290.816
 273.583  278.09   279.134  279.774     289.607  290.211  290.484  290.76
 270.987  277.941  278.876  279.638     289.527  290.125  290.331  290.682
 275.653  273.91   279.103  279.61   …  289.446  289.938  290.117  290.521
 271.838  272.446  273.632  277.845     289.418  289.856  290.03   290.381
 267.648  276.67   274.12   276.756     289.386  289.792  289.96   290.179
 267.639  272.867  275.305  272.49      289.276  289.648  289.91   290.173
 267.453  266.356  268.245  270.097     289.245  289.578  289.889  290.131
 266.813  263.233  269.017  273.323  …  289.218  289.583  289.882  290.17
 265.723  264.585  269.935  274.421     289.139  289.587  289.797  290.14
 264.8    265.987  270.392  273.674     289.145  289.484  289.656  290.002
   ⋮                                 ⋱                               ⋮
 252.019  257.008  262.167  267.321     295.426  296.038  296.136  296.542
 252.789  256.945  262.659  267.498  …  295.654  296.031  296.384  296.576
 252.661  257.45   262.604  267.244     295.556  295.94   296.381  296.708
 252.84   257.821  262.894  267.353     295.407  295.767  296.323  296.741
 253.045  258.766  262.798  267.269     295.214  295.655  296.287  296.516
 253.765  258.141  263.144  267.657     295.108  295.629  296.099  296.47
 254.068  259.351  264.516  268.582  …  294.967  295.444  295.739  296.327
 254.841  260.144  266.131  268.704     294.756  295.213  295.681  296.433
```

```
 254.337  265.358  264.149  267.794     294.815  295.29   295.731  296.415
 255.676  264.265  264.281  267.633     295.117  295.411  295.79   296.309
 262.506  259.107  264.341  267.95      295.309  295.681  295.984  296.424
 264.02   260.764  267.133  269.137  …  295.281  295.695  296.087  296.276

[:, :, 3] =
 280.828  281.828  282.706  282.996  …  289.165  289.84   290.385  290.991
 280.566  281.458  282.289  282.929     288.986  289.586  290.269  290.903
 279.681  281.088  281.875  282.584     288.987  289.367  290.123  290.615
 275.337  280.444  281.437  282.134     288.897  289.346  290.005  290.397
 271.402  278.565  280.973  281.78      288.852  289.269  289.858  290.285
 275.433  274.647  280.394  281.478  …  288.788  289.247  289.601  290.126
 271.669  272.666  274.223  278.408     288.709  289.104  289.461  290.028
 267.078  275.862  273.902  276.648     288.533  288.929  289.433  289.914
 266.979  270.142  274.794  273.056     288.451  288.853  289.353  289.877
 266.514  265.201  267.255  269.509     288.502  288.914  289.375  289.875
 265.282  261.934  267.185  273.036  …  288.627  289.053  289.379  289.887
 264.581  261.941  267.859  273.294     288.549  288.959  289.247  289.778
 264.328  264.095  269.003  272.317     288.527  288.925  289.253  289.673
   ⋮                                 ⋱                       ⋮
 253.715  256.142  259.555  264.432     296.103  296.319  296.661  297.081
 254.471  256.343  259.741  265.014  …  296.04   296.285  296.455  297.006
 254.527  257.199  259.464  265.527     295.941  296.159  296.246  296.607
 255.055  258.063  260.314  266.014     295.842  295.988  296.177  296.391
 255.322  259.694  261.859  266.884     295.564  295.896  296.202  296.499
 255.733  258.6    261.346  267.86      295.304  295.887  296.299  296.556
 255.324  258.223  263.353  267.943  …  295.314  295.824  296.36   296.645
 255.92   261.045  265.461  269.195     295.348  295.96   296.451  296.689
 255.555  266.834  263.836  269.951     295.533  296.057  296.495  296.772
 258.12   265.24   265.328  269.328     295.661  296.118  296.474  296.605
 264.055  260.288  267.399  270.726     295.79   296.078  296.431  296.375
 263.982  262.179  269.563  272.556  …  295.731  295.869  296.299  296.307

;;; …

[:, :, 3651] =
 281.317  281.631  282.055  282.475  …  290.048  290.55   291.19   291.712
 281.224  281.523  281.881  282.373     289.75   290.295  290.943  291.675
 280.949  281.472  281.794  282.254     289.503  290.161  290.857  291.609
 277.409  280.979  281.704  282.156     289.555  290.214  290.808  291.403
 272.98   280.201  281.459  281.905     289.799  290.338  290.839  291.307
 276.845  275.065  280.384  281.192  …  289.797  290.269  290.817  291.452
 270.635  273.917  274.727  276.575     289.674  290.24   290.813  291.307
 261.242  275.57   275.241  274.124     289.558  290.273  290.784  291.108
 260.93   273.561  274.782  273.303     289.557  290.208  290.711  290.94
 264.997  266.236  264.513  266.479     289.322  289.894  290.56   290.772
 266.316  263.749  267.508  268.063  …  289.229  289.762  290.265  290.666
 265.258  266.517  269.136  269.25      289.265  289.864  290.177  290.521
 265.879  266.18   270.629  269.587     289.216  289.707  290.056  290.52
   ⋮                                 ⋱                       ⋮
```

```
 253.361  252.705  252.822  255.428     293.386  294.378  295.293  296.202
 254.197  253.381  254.299  256.346  …  293.853  294.744  295.7    296.497
 254.319  255.045  255.828  257.537     294.197  295.051  295.971  296.718
 254.705  257.057  258.031  259.485     294.546  295.325  296.153  296.919
 255.491  259.084  258.295  260.563     294.833  295.686  296.518  297.227
 257.814  258.49   257.719  263.299     295.112  295.83   296.529  296.991
 259.65   260.214  262.346  264.149  …  295.214  295.795  296.449  297.058
 262.037  264.046  265.519  264.893     295.595  296.247  296.771  297.537
 261.705  269.298  264.476  266.474     295.95   296.84   297.451  298.056
 265.553  268.9    265.503  265.871     296.193  297.139  297.758  298.104
 271.039  264.844  269.122  268.14      296.43   297.167  297.752  298.103
 272.069  266.797  271.938  271.56   …  296.539  297.341  297.835  298.206

[:, :, 3652] =
 280.924  281.381  281.465  281.648  …  290.272  290.567  290.694  290.878
 280.926  281.114  281.336  281.738     290.04   290.36   290.518  290.89
 280.686  280.924  281.356  281.76      289.859  290.191  290.436  290.894
 276.745  280.729  281.195  281.712     289.776  290.063  290.448  290.886
 273.125  279.941  281.124  281.767     289.607  289.957  290.539  290.992
 276.986  275.677  280.511  281.58   …  289.408  289.944  290.686  291.071
 271.443  274.938  275.913  277.995     289.437  290.092  290.683  290.935
 264.532  276.826  275.71   275.997     289.46   290.124  290.51   290.797
 264.48   273.902  275.87   273.69      289.297  289.85   290.338  290.639
 266.745  266.052  266.847  268.699     289.037  289.586  290.106  290.673
 266.968  264.586  269.273  269.912  …  288.935  289.517  289.817  290.912
 266.727  268.063  269.462  270.111     288.909  289.293  290.075  291.102
 267.132  267.341  269.07   270.322     288.931  289.572  290.579  291.034
   ⋮                                 ⋱                       ⋮
 253.825  255.068  255.108  255.468     293.021  293.94   294.713  295.478
 253.326  254.084  254.525  254.247  …  292.976  293.987  294.779  295.577
 253.139  254.191  254.617  255.016     292.884  294.046  294.863  295.511
 252.847  255.042  254.682  255.502     293.003  294.099  294.838  295.45
 252.355  254.32   253.945  254.113     292.948  294.095  294.828  295.47
 252.708  252.801  253.487  256.163     292.884  293.911  294.709  295.344
 252.323  253.393  256.56   255.072  …  292.923  293.938  294.682  295.339
 253.422  255.511  258.346  256.633     293.218  294.192  294.811  295.435
 252.721  259.623  255.915  257.58      293.322  294.28   295.013  295.636
 255.707  259.314  256.864  256.163     293.302  294.318  295.097  295.78
 260.568  255.255  259.262  258.668     293.4    294.283  295.076  295.804
 262.111  257.977  262.539  261.679  …  293.509  294.351  295.143  295.865

[:, :, 3653] =
 280.888  281.313  282.14   283.177  …  290.665  290.918  291.42   291.863
 280.888  281.057  281.772  282.987     290.509  290.748  291.252  291.796
 280.65   281.023  281.667  282.724     290.354  290.692  291.184  291.715
 277.474  280.886  281.462  282.516     290.291  290.545  291.052  291.491
 274.398  280.377  281.522  282.359     290.31   290.447  290.85   291.264
 277.832  276.912  280.86   281.848  …  290.254  290.381  290.608  291.033
 273.217  276.21   276.427  278.753     290.199  290.348  290.416  290.835
 268.404  277.919  276.007  277.287     290.14   290.3    290.243  290.683
```

```
 267.641  273.508  277.048  273.979     289.978  290.042  290.167  290.519
 268.688  267.861  269.159  269.92      289.6    289.749  290.09   290.394
 268.349  264.932  269.081  268.821  …  289.425  289.668  289.92   290.361
 267.662  267.312  269.093  269.592     289.326  289.697  290.011  290.348
 267.469  267.457  269.342  271.291     289.411  289.792  290.118  290.491
   ⋮                                 ⋱                     ⋮
 265.747  265.947  264.79   264.938     295.352  296.136  296.881  297.443
 264.333  264.415  264.751  265.249  …  295.32   295.854  296.607  297.26
 263.013  264.202  263.996  263.92      294.821  295.742  296.315  296.937
 260.457  262.073  262.738  261.584     294.357  295.263  296.039  296.637
 258.505  261.497  263.556  261.326     293.995  294.959  295.777  296.469
 256.852  260.006  261.386  261.116     293.811  294.556  295.434  296.124
 254.831  257.297  260.099  260.703  …  293.698  294.391  295.111  295.891
 254.33   256.677  259.421  258.532     293.688  294.428  294.999  295.743
 252.638  262.568  256.035  256.655     293.43   294.324  294.987  295.735
 254.496  261.304  255.382  256.532     293.127  294.067  294.87   295.672
 260.685  254.638  258.74   259.026     292.917  293.757  294.664  295.52
 261.243  257.23   261.903  261.136  …  292.844  293.684  294.548  295.45
```

2.2.3 Save lon, lat, time, and temp variables

```
open_mfdataset (generic function with 1 method)

3653-element Vector{DateTime}:
 2000-01-01T00:00:00
 2000-01-02T00:00:00
 2000-01-03T00:00:00
 2000-01-04T00:00:00
 2000-01-05T00:00:00
 2000-01-06T00:00:00
 2000-01-07T00:00:00
 2000-01-08T00:00:00
 2000-01-09T00:00:00
 2000-01-10T00:00:00
 2000-01-11T00:00:00
 2000-01-12T00:00:00
 2000-01-13T00:00:00
 ⋮
 2009-12-20T00:00:00
 2009-12-21T00:00:00
 2009-12-22T00:00:00
 2009-12-23T00:00:00
 2009-12-24T00:00:00
 2009-12-25T00:00:00
 2009-12-26T00:00:00
 2009-12-27T00:00:00
 2009-12-28T00:00:00
 2009-12-29T00:00:00
 2009-12-30T00:00:00
 2009-12-31T00:00:00
```

2.2.4 Flip the temperature latitude

```
66×27×3653 Array{Union{Missing, Float64}, 3}:
[:, :, 1] =
 290.589  290.199  290.023  289.866  …  280.917  280.607  280.057  279.491
 290.425  290.026  289.881  289.713     281.077  280.553  280.12   279.531
 290.237  289.926  289.758  289.702     281.016  280.651  280.175  279.28
 290.189  290.018  289.883  289.692     280.98   280.693  279.946  276.178
 290.214  290.055  290.065  289.735     280.935  280.61   279.514  273.58
 290.13   289.991  289.969  289.657  …  281.015  280.496  276.623  277.067
 290.041  289.96   289.897  289.52      279.896  276.05   275.95   273.442
 290.127  289.979  289.821  289.458     278.425  276.2    278.684  269.142
 290.203  289.944  289.773  289.484     274.384  277.069  273.748  268.997
 290.202  289.963  289.863  289.59      271.571  269.77   268.099  268.419
 290.169  289.99   289.863  289.57   …  271.113  268.572  265.679  268.58
 290.244  289.933  289.784  289.445     272.546  269.975  266.211  266.085
 290.1    289.771  289.528  289.245     273.479  270.774  265.626  264.757
   ⋮                                 ⋱                       ⋮
 296.791  296.605  296.035  294.643     264.109  262.287  260.748  254.899
 296.485  296.557  296.097  295.342  …  262.814  261.232  260.112  255.745
 296.044  296.195  295.966  295.462     262.453  261.017  260.011  255.495
 295.705  295.582  295.66   295.328     260.492  259.911  258.618  254.944
 295.856  294.967  295.313  295.162     258.167  259.692  258.312  253.234
 296.067  294.888  294.944  295.033     258.771  259.484  256.79   252.139
 296.419  295.226  294.775  295.004  …  260.193  258.677  256.465  251.687
 296.741  295.744  294.755  294.953     259.31   259.967  253.888  251.198
 296.872  295.971  295.23   295.092     255.737  255.333  264.074  250.48
 297.019  295.976  295.015  295.154     256.103  254.365  261.876  251.777
 297.025  296.056  294.985  294.93      257.353  255.862  254.461  260.38
 296.949  296.28   295.222  294.927  …  260.49   261.385  255.281  261.702

[:, :, 2] =
 290.996  290.567  290.165  289.92   …  280.1    279.159  278.38   277.785
 290.939  290.443  290.153  289.754     280.103  279.004  278.507  277.716
 290.816  290.447  290.133  289.765     279.895  279.249  278.548  277.222
 290.76   290.484  290.211  289.607     279.774  279.134  278.09   273.583
 290.682  290.331  290.125  289.527     279.638  278.876  277.941  270.987
 290.521  290.117  289.938  289.446  …  279.61   279.103  273.91   275.653
 290.381  290.03   289.856  289.418     277.845  273.632  272.446  271.838
 290.179  289.96   289.792  289.386     276.756  274.12   276.67   267.648
 290.173  289.91   289.648  289.276     272.49   275.305  272.867  267.639
 290.131  289.889  289.578  289.245     270.097  268.245  266.356  267.453
 290.17   289.882  289.583  289.218  …  273.323  269.017  263.233  266.813
 290.14   289.797  289.587  289.139     274.421  269.935  264.585  265.723
 290.002  289.656  289.484  289.145     273.674  270.392  265.987  264.8
   ⋮                                 ⋱                       ⋮
 296.542  296.136  296.038  295.426     267.321  262.167  257.008  252.019
 296.576  296.384  296.031  295.654  …  267.498  262.659  256.945  252.789
 296.708  296.381  295.94   295.556     267.244  262.604  257.45   252.661
 296.741  296.323  295.767  295.407     267.353  262.894  257.821  252.84
```

```
 296.516  296.287  295.655  295.214     267.269  262.798  258.766  253.045
 296.47   296.099  295.629  295.108     267.657  263.144  258.141  253.765
 296.327  295.739  295.444  294.967  …  268.582  264.516  259.351  254.068
 296.433  295.681  295.213  294.756     268.704  266.131  260.144  254.841
 296.415  295.731  295.29   294.815     267.794  264.149  265.358  254.337
 296.309  295.79   295.411  295.117     267.633  264.281  264.265  255.676
 296.424  295.984  295.681  295.309     267.95   264.341  259.107  262.506
 296.276  296.087  295.695  295.281  …  269.137  267.133  260.764  264.02

[:, :, 3] =
 290.991  290.385  289.84   289.165  …  282.996  282.706  281.828  280.828
 290.903  290.269  289.586  288.986     282.929  282.289  281.458  280.566
 290.615  290.123  289.367  288.987     282.584  281.875  281.088  279.681
 290.397  290.005  289.346  288.897     282.134  281.437  280.444  275.337
 290.285  289.858  289.269  288.852     281.78   280.973  278.565  271.402
 290.126  289.601  289.247  288.788  …  281.478  280.394  274.647  275.433
 290.028  289.461  289.104  288.709     278.408  274.223  272.666  271.669
 289.914  289.433  288.929  288.533     276.648  273.902  275.862  267.078
 289.877  289.353  288.853  288.451     273.056  274.794  270.142  266.979
 289.875  289.375  288.914  288.502     269.509  267.255  265.201  266.514
 289.887  289.379  289.053  288.627  …  273.036  267.185  261.934  265.282
 289.778  289.247  288.959  288.549     273.294  267.859  261.941  264.581
 289.673  289.253  288.925  288.527     272.317  269.003  264.095  264.328
   ⋮                                 ⋱                       ⋮
 297.081  296.661  296.319  296.103     264.432  259.555  256.142  253.715
 297.006  296.455  296.285  296.04   …  265.014  259.741  256.343  254.471
 296.607  296.246  296.159  295.941     265.527  259.464  257.199  254.527
 296.391  296.177  295.988  295.842     266.014  260.314  258.063  255.055
 296.499  296.202  295.896  295.564     266.884  261.859  259.694  255.322
 296.556  296.299  295.887  295.304     267.86   261.346  258.6    255.733
 296.645  296.36   295.824  295.314  …  267.943  263.353  258.223  255.324
 296.689  296.451  295.96   295.348     269.195  265.461  261.045  255.92
 296.772  296.495  296.057  295.533     269.951  263.836  266.834  255.555
 296.605  296.474  296.118  295.661     269.328  265.328  265.24   258.12
 296.375  296.431  296.078  295.79      270.726  267.399  260.288  264.055
 296.307  296.299  295.869  295.731  …  272.556  269.563  262.179  263.982

;;; …

[:, :, 3651] =
 291.712  291.19   290.55   290.048  …  282.475  282.055  281.631  281.317
 291.675  290.943  290.295  289.75      282.373  281.881  281.523  281.224
 291.609  290.857  290.161  289.503     282.254  281.794  281.472  280.949
 291.403  290.808  290.214  289.555     282.156  281.704  280.979  277.409
 291.307  290.839  290.338  289.799     281.905  281.459  280.201  272.98
 291.452  290.817  290.269  289.797  …  281.192  280.384  275.065  276.845
 291.307  290.813  290.24   289.674     276.575  274.727  273.917  270.635
 291.108  290.784  290.273  289.558     274.124  275.241  275.57   261.242
 290.94   290.711  290.208  289.557     273.303  274.782  273.561  260.93
 290.772  290.56   289.894  289.322     266.479  264.513  266.236  264.997
```

```
 290.666  290.265  289.762  289.229  …  268.063  267.508  263.749  266.316
 290.521  290.177  289.864  289.265     269.25   269.136  266.517  265.258
 290.52   290.056  289.707  289.216     269.587  270.629  266.18   265.879
   ⋮                                 ⋱                      ⋮
 296.202  295.293  294.378  293.386     255.428  252.822  252.705  253.361
 296.497  295.7    294.744  293.853  …  256.346  254.299  253.381  254.197
 296.718  295.971  295.051  294.197     257.537  255.828  255.045  254.319
 296.919  296.153  295.325  294.546     259.485  258.031  257.057  254.705
 297.227  296.518  295.686  294.833     260.563  258.295  259.084  255.491
 296.991  296.529  295.83   295.112     263.299  257.719  258.49   257.814
 297.058  296.449  295.795  295.214  …  264.149  262.346  260.214  259.65
 297.537  296.771  296.247  295.595     264.893  265.519  264.046  262.037
 298.056  297.451  296.84   295.95      266.474  264.476  269.298  261.705
 298.104  297.758  297.139  296.193     265.871  265.503  268.9    265.553
 298.103  297.752  297.167  296.43      268.14   269.122  264.844  271.039
 298.206  297.835  297.341  296.539  …  271.56   271.938  266.797  272.069

[:, :, 3652] =
 290.878  290.694  290.567  290.272  …  281.648  281.465  281.381  280.924
 290.89   290.518  290.36   290.04      281.738  281.336  281.114  280.926
 290.894  290.436  290.191  289.859     281.76   281.356  280.924  280.686
 290.886  290.448  290.063  289.776     281.712  281.195  280.729  276.745
 290.992  290.539  289.957  289.607     281.767  281.124  279.941  273.125
 291.071  290.686  289.944  289.408  …  281.58   280.511  275.677  276.986
 290.935  290.683  290.092  289.437     277.995  275.913  274.938  271.443
 290.797  290.51   290.124  289.46      275.997  275.71   276.826  264.532
 290.639  290.338  289.85   289.297     273.69   275.87   273.902  264.48
 290.673  290.106  289.586  289.037     268.699  266.847  266.052  266.745
 290.912  289.817  289.517  288.935  …  269.912  269.273  264.586  266.968
 291.102  290.075  289.293  288.909     270.111  269.462  268.063  266.727
 291.034  290.579  289.572  288.931     270.322  269.07   267.341  267.132
   ⋮                                 ⋱                      ⋮
 295.478  294.713  293.94   293.021     255.468  255.108  255.068  253.825
 295.577  294.779  293.987  292.976  …  254.247  254.525  254.084  253.326
 295.511  294.863  294.046  292.884     255.016  254.617  254.191  253.139
 295.45   294.838  294.099  293.003     255.502  254.682  255.042  252.847
 295.47   294.828  294.095  292.948     254.113  253.945  254.32   252.355
 295.344  294.709  293.911  292.884     256.163  253.487  252.801  252.708
 295.339  294.682  293.938  292.923  …  255.072  256.56   253.393  252.323
 295.435  294.811  294.192  293.218     256.633  258.346  255.511  253.422
 295.636  295.013  294.28   293.322     257.58   255.915  259.623  252.721
 295.78   295.097  294.318  293.302     256.163  256.864  259.314  255.707
 295.804  295.076  294.283  293.4       258.668  259.262  255.255  260.568
 295.865  295.143  294.351  293.509  …  261.679  262.539  257.977  262.111

[:, :, 3653] =
 291.863  291.42   290.918  290.665  …  283.177  282.14   281.313  280.888
 291.796  291.252  290.748  290.509     282.987  281.772  281.057  280.888
 291.715  291.184  290.692  290.354     282.724  281.667  281.023  280.65
 291.491  291.052  290.545  290.291     282.516  281.462  280.886  277.474
```

```
 291.264  290.85   290.447  290.31      282.359  281.522  280.377  274.398
 291.033  290.608  290.381  290.254  …  281.848  280.86   276.912  277.832
 290.835  290.416  290.348  290.199     278.753  276.427  276.21   273.217
 290.683  290.243  290.3    290.14      277.287  276.007  277.919  268.404
 290.519  290.167  290.042  289.978     273.979  277.048  273.508  267.641
 290.394  290.09   289.749  289.6       269.92   269.159  267.861  268.688
 290.361  289.92   289.668  289.425  …  268.821  269.081  264.932  268.349
 290.348  290.011  289.697  289.326     269.592  269.093  267.312  267.662
 290.491  290.118  289.792  289.411     271.291  269.342  267.457  267.469
   ⋮                                 ⋱                      ⋮
 297.443  296.881  296.136  295.352     264.938  264.79   265.947  265.747
 297.26   296.607  295.854  295.32   …  265.249  264.751  264.415  264.333
 296.937  296.315  295.742  294.821     263.92   263.996  264.202  263.013
 296.637  296.039  295.263  294.357     261.584  262.738  262.073  260.457
 296.469  295.777  294.959  293.995     261.326  263.556  261.497  258.505
 296.124  295.434  294.556  293.811     261.116  261.386  260.006  256.852
 295.891  295.111  294.391  293.698  …  260.703  260.099  257.297  254.831
 295.743  294.999  294.428  293.688     258.532  259.421  256.677  254.33
 295.735  294.987  294.324  293.43      256.655  256.035  262.568  252.638
 295.672  294.87   294.067  293.127     256.532  255.382  261.304  254.496
 295.52   294.664  293.757  292.917     259.026  258.74   254.638  260.685
 295.45   294.548  293.684  292.844  …  261.136  261.903  257.23   261.243
```

2.2.5 Subset temperature to area of Texas instead of US

```
11×11×3653 Array{Union{Missing, Float64}, 3}:
[:, :, 1] =
 291.31   290.912  290.253  289.702  …  287.914  286.397  284.341  283.857
 291.359  292.577  291.752  290.155     288.822  287.284  284.14   283.579
 294.291  293.043  292.334  289.887     287.999  285.853  283.505  282.566
 293.938  292.984  290.842  289.412     285.757  285.144  283.36   283.169
 294.653  293.992  291.703  288.774     284.997  284.048  283.946  283.252
 296.33   295.475  293.28   287.959  …  284.874  284.03   283.941  283.375
 296.416  295.53   293.52   290.233     284.907  283.735  282.815  283.406
 296.158  295.471  293.695  290.598     283.788  283.558  282.356  282.317
 296.254  295.835  294.149  291.078     285.554  283.737  282.379  280.963
 296.419  296.219  294.747  290.463     285.086  285.36   283.302  281.299
 296.699  296.629  295.455  291.055  …  285.868  286.188  285.094  281.852

[:, :, 2] =
 293.682  294.663  293.619  292.196  …  287.538  285.536  283.818  281.873
 294.237  296.073  295.585  293.843     289.812  288.154  285.528  283.329
 296.598  295.877  296.526  294.523     291.016  288.691  286.095  284.717
 295.727  296.559  295.922  294.954     291.273  289.738  287.398  286.099
 295.003  294.79   294.608  295.179     292.05   290.401  288.871  287.385
 296.606  296.265  294.972  295.118  …  292.334  290.859  289.587  288.703
 296.577  296.147  295.147  292.247     292.261  290.22   289.503  288.252
 296.431  295.958  295.31   292.818     291.934  290.013  289.351  286.932
 296.602  296.168  295.596  293.396     291.917  290.509  289.26   287.116
 296.901  296.689  295.971  292.78      291.516  290.681  289.67   287.883
```

```
 297.139  297.121  296.391  292.873  …  290.944  290.096  289.802  288.823

[:, :, 3] =
 292.085  292.854  291.909  290.942  …  282.91   281.018  278.14   274.995
 292.797  294.604  294.149  292.369     285.145  283.904  280.893  277.093
 295.131  294.607  294.906  293.185     286.17   284.659  282.005  278.211
 295.704  295.811  295.002  294.017     286.947  285.41   282.396  279.592
 294.688  294.379  294.588  294.73      288.94   286.131  283.493  280.8
 296.732  296.152  294.6    295.283  …  290.251  287.954  285.039  281.771
 296.851  296.422  295.191  292.597     291.292  289.293  285.617  282.495
 296.851  296.337  295.571  292.925     292.529  290.314  287.826  282.528
 296.955  296.507  295.852  293.724     293.374  291.678  289.932  283.792
 297.132  296.845  296.222  293.522     293.705  292.632  291.251  287.52
 297.489  297.374  296.658  293.777  …  294.035  292.909  291.896  290.317

;;; …

[:, :, 3651] =
 277.637  279.352  280.108  281.083  …  273.931  273.617  275.306  274.236
 279.415  281.736  281.757  281.47      273.664  273.975  275.22   274.934
 281.824  281.551  281.937  280.699     273.825  271.055  273.781  275.18
 283.619  282.434  281.41   279.992     274.713  274.063  272.582  272.55
 290.401  288.971  283.602  279.458     275.537  274.975  273.296  271.246
 291.291  289.646  286.947  279.293  …  275.802  275.287  274.882  271.582
 291.106  289.657  287.574  283.707     275.556  275.47   274.682  273.165
 290.998  289.551  287.295  284.176     276.106  275.714  273.903  271.966
 290.664  289.202  287.009  283.783     276.523  275.666  273.65   272.001
 290.345  288.809  286.681  283.336     276.449  275.371  273.636  272.243
 290.107  288.66   286.521  282.775  …  275.964  275.335  273.596  271.933

[:, :, 3652] =
 282.926  283.67   283.073  282.293  …  278.147  277.116  276.803  275.597
 283.743  284.613  283.219  282.454     278.879  278.547  276.846  274.946
 283.814  283.506  282.525  281.945     278.359  276.623  276.224  274.951
 284.123  283.35   282.25   281.368     278.279  277.436  275.468  275.422
 289.271  288.837  284.726  281.413     278.38   277.147  275.375  274.571
 293.833  292.335  289.518  282.214  …  277.842  277.168  276.265  274.742
 294.774  293.582  291.862  287.782     278.187  277.193  276.447  274.786
 294.876  294.443  292.837  289.089     278.675  277.503  275.921  273.769
 295.069  294.504  292.929  289.629     278.731  277.876  275.461  273.733
 294.882  293.951  292.589  288.941     279.335  278.16   275.93   273.846
 294.284  293.195  291.91   288.445  …  279.817  278.683  276.713  274.464

[:, :, 3653] =
 287.912  288.563  288.156  285.831  …  278.462  275.737  275.032  273.965
 289.026  288.426  287.168  285.252     279.342  277.259  275.216  273.717
 287.971  287.57   286.571  284.772     278.773  276.701  274.801  272.97
 287.954  285.956  285.194  284.001     279.628  277.56   273.967  273.266
 291.792  290.58   287.419  283.298     279.328  278.125  275.064  273.112
```

```
 293.837  292.142  289.986  282.892  …  279.816  278.361  276.646  273.587
 294.218  293.081  290.791  287.237     279.674  279.13   277.867  274.631
 294.547  293.709  290.968  287.526     280.181  280.313  278.919  274.998
 295.046  293.815  291.302  287.042     280.62   280.52   279.354  275.451
 295.541  293.893  291.453  286.918     281.327  280.75   279.292  276.5
 295.487  294.167  291.61   287.925  …  282.428  281.333  279.876  278.086
```

2.2.6 Subset temperature time

```
3652-element Vector{DateTime}:
 2000-01-01T00:00:00
 2000-01-02T00:00:00
 2000-01-03T00:00:00
 2000-01-04T00:00:00
 2000-01-05T00:00:00
 2000-01-06T00:00:00
 2000-01-07T00:00:00
 2000-01-08T00:00:00
 2000-01-09T00:00:00
 2000-01-10T00:00:00
 2000-01-11T00:00:00
 2000-01-12T00:00:00
 2000-01-13T00:00:00
 ⋮
 2009-12-19T00:00:00
 2009-12-20T00:00:00
 2009-12-21T00:00:00
 2009-12-22T00:00:00
 2009-12-23T00:00:00
 2009-12-24T00:00:00
 2009-12-25T00:00:00
 2009-12-26T00:00:00
 2009-12-27T00:00:00
 2009-12-28T00:00:00
 2009-12-29T00:00:00
 2009-12-30T00:00:00
```

2.3 Split data into training and testing sets

```
24×24×731 Array{Union{Missing, Float32}, 3}:
[:, :, 1] =
 0.230964  0.211317   0.0417734  …  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.239267  0.203205   0.0957546     0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.228309  0.229123   0.159002      0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.212892  0.23749    0.212364      0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.179382  0.213751   0.242253      0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.083235  0.157233   0.225679   …  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0       0.0227302  0.12858       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
```

```
  missing   missing    missing   …  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing    missing      0.0  0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing    missing      0.0  0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing    missing      0.0  0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing    missing      0.0  0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing    missing   …  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing    missing      0.0  0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing    missing      0.0  0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing    missing      0.0  0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing    missing      0.0  0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing    missing   …  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing    missing      0.0  0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing    missing      0.0  0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing    missing      0.0  0.0  0.0  0.0  0.0  0.0  0.0

[:, :, 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  0.0  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
  missing   missing   missing  …  0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing     0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing     0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing     0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing     0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing  …  0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing     0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing     0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing     0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing     0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing  …  0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing     0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing     0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing     0.0  0.0  0.0  0.0  0.0  0.0203687

[:, :, 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
 0.0       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  0.0  0.0459444
```

```
 0.0       0.356025  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
  missing   missing   missing  …  0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing     0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing     0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing     0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing     0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing  …  0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing     0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing     0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing     0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing     0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing  …  0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing     0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing     0.0  0.0  0.0  0.0  0.0  0.0
  missing   missing   missing     0.0  0.0  0.0  0.0  0.0  0.0

;;; …

[:, :, 729] =
 1.91927   2.18294    4.04477   5.20947   …  0.0       0.0        0.0
 0.203245  0.580783   2.77413   4.15098      0.0       0.0        0.0
 0.237774  1.28198    1.22886   0.721624     0.0       0.0        0.0
 1.80391   2.13242    1.09698   0.152618     0.0       0.0        0.0
 2.32314   1.18486    0.259382  0.0          0.0       0.0        0.0
 1.09869   0.124012   0.0       0.0       …  0.0       0.0        0.0
 0.493284  0.0336855  0.0       0.0          0.0       0.0        0.0
 0.0       0.0        0.0       0.0          0.210678  0.0        0.0
 0.0       0.0        0.0       0.0          0.244225  0.0478664  0.0
 0.0       0.0        0.0       0.0          0.883143  1.56837    0.156057
  missing   missing    missing   missing  …  1.22156   1.51986    1.36312
  missing   missing    missing   missing     2.79113   3.31666    2.07084
  missing   missing    missing   missing     2.48622   2.86405    1.8507
  missing   missing    missing   missing     0.999645  7.01725    4.73033
  missing   missing    missing   missing     1.48617   2.80321    4.4185
  missing   missing    missing   missing  …  0.311555  0.0501361  0.0426737
  missing   missing    missing   missing     0.123578  0.0        0.0
  missing   missing    missing   missing     0.0       0.0        0.0
  missing   missing    missing   missing     0.0       0.0        0.0
  missing   missing    missing   missing     0.0       0.0        0.0
  missing   missing    missing   missing  …  0.0       0.0        0.0
  missing   missing    missing   missing     0.0       0.0        0.0
  missing   missing    missing   missing     0.0       0.0        0.0
  missing   missing    missing   missing     0.0       0.0        0.0

[:, :, 730] =
 1.25381   1.38226   6.78581   9.23103   …  0.209643  0.06951    0.0322176
 1.77286   1.17652   5.44695   8.42261      0.674334  0.0        0.038588
 5.26336   2.10804   3.33561   5.37528      0.916897  0.0899668  0.0
 4.11361   1.87916   1.61745   5.03068      0.337145  0.891777   0.0281657
```

```
 1.10992   0.986878  1.11829   6.67025       3.08982   0.966748   0.270218
 2.73123   2.4278    3.59609   5.59022   …  10.1729    1.6837     0.420492
 3.33995   4.18317   3.80484   3.17682       0.469495  1.02329    0.587488
 5.67861   5.78922   4.2321    1.34415       0.723784  1.02258    1.35627
 5.94113   5.36736   3.45825   5.4516        1.6775    1.66165    2.03233
 5.672     4.33358   3.37151   5.49953       2.08825   1.21806    2.91972
  missing   missing   missing   missing  …   2.48373   1.6086     1.16387
  missing   missing   missing   missing      2.07946   1.88346    0.863437
  missing   missing   missing   missing      2.36113   1.62808    0.568243
  missing   missing   missing   missing      1.84581   1.57609    1.48535
  missing   missing   missing   missing      1.86876   1.23442    0.884178
  missing   missing   missing   missing  …   1.79652   0.287498   1.20721
  missing   missing   missing   missing      2.98471   0.613985   1.21469
  missing   missing   missing   missing      2.01611   0.473238   0.555291
  missing   missing   missing   missing      1.43036   0.545582   0.477171
  missing   missing   missing   missing      0.386973  0.315955   0.0261992
  missing   missing   missing   missing  …   0.0       0.0310814  0.0
  missing   missing   missing   missing      0.0       0.0293388  0.0
  missing   missing   missing   missing      0.0       0.0        0.0
  missing   missing   missing   missing      0.0       0.0        0.0

[:, :, 731] =
 0.0       0.0        0.0          …  0.0        0.194001   0.229313
 0.0       0.0        0.0             0.201      0.0        1.05024
 0.0       0.0        0.0             0.794761   0.0        0.239922
 0.0       0.0        0.0             0.487525   0.0712316  0.0
 0.0       0.0        0.0             0.871535   0.725623   0.0546665
 0.0       0.0        0.0          …  0.63043    0.834709   0.935677
 0.0       0.0        0.0             0.737369   0.396731   1.7525
 0.0       0.0        0.0342669       0.810175   0.914279   2.05469
 0.0       0.0        0.418512        0.482352   0.6477     0.834548
 0.0       0.0364437  0.121333        1.36826    1.77949    1.08005
  missing   missing    missing     …  1.58758    4.78649    4.96679
  missing   missing    missing        3.17118    5.32441    3.90305
  missing   missing    missing        3.59475    4.90733    4.06902
  missing   missing    missing        1.31501    5.03513    4.85771
  missing   missing    missing        1.21495    2.24849    4.07878
  missing   missing    missing     …  1.81574    0.2997     1.09506
  missing   missing    missing        1.08286    0.0417713  0.649026
  missing   missing    missing        0.0439509  0.0        0.253759
  missing   missing    missing        0.0449181  0.0        1.20432
  missing   missing    missing        0.264041   0.0        1.47429
  missing   missing    missing     …  0.779127   0.235859   0.301635
  missing   missing    missing        1.42092    0.159816   0.394416
  missing   missing    missing        3.98366    0.940115   1.16965
  missing   missing    missing        0.545287   0.645726   1.59136
```

2.4 Preprocessing

2.4.1 Preprocess function

```
preprocess (generic function with 1 method)
```

2.4.2 Preprocess temperature

```
121×731 Matrix{Float64}:
  -5.29162   -9.1721   -15.5382   …  -12.5594   -16.6589   -11.3703
  -6.70991   -9.24213  -14.7215      -11.7596   -15.5633   -11.2349
  -7.4606    -8.66663  -13.3073      -12.1199   -16.0275   -14.037
  -6.92191   -7.86488  -12.4948      -10.7737   -13.6388   -13.1353
  -3.20601   -4.50872   -9.2725       -6.62104   -6.23282   -7.36258
  -3.4356    -4.63927   -9.81719  …   -6.78153   -6.1819    -3.63953
  -3.22345   -4.44058   -9.73227      -6.78883   -6.39981   -2.73266
  -2.99846   -4.25502   -9.58033      -6.43223   -6.53416   -2.6556
  -2.86815   -4.19236   -9.76109      -6.29229   -6.88516   -2.47985
  -2.13038   -3.76691   -9.79706      -6.33689   -7.23386   -2.69678
  -1.22141   -3.01323   -9.46011  …   -6.3053    -7.52295   -3.3459
  -6.42715   -9.37341  -15.0048      -12.5938   -16.2631   -11.9445
  -7.70089   -9.0709   -14.0989      -12.2314   -15.7781   -12.9018
   ⋮                              ⋱                          ⋮
 -10.2321   -12.4993   -19.5512      -17.3013   -16.7106   -13.594
 -13.3914   -17.6619   -18.4287   …  -14.2943   -13.5519   -12.1915
 -13.0153   -17.016    -19.3798      -14.0214   -13.0043   -12.993
 -12.6853   -16.3206   -19.573       -13.7198   -13.2715   -13.5
 -12.877    -16.4353   -20.6092      -17.123    -16.7478   -13.8757
 -12.8246   -15.6923   -19.4179      -18.9243   -18.1075   -14.7821
 -12.6756   -15.5844   -20.1762   …  -19.3405   -17.9994   -14.8398
 -11.9979   -15.4558   -20.235       -16.4364   -15.8031   -14.1816
 -11.0614   -15.3627   -20.6582      -16.4999   -15.7922   -13.9889
 -10.5836   -14.6008   -20.3137      -15.9558   -15.87     -14.1375
 -10.4757   -13.8554   -19.9689      -16.3106   -16.5766   -14.9735
 -10.7302   -13.3602   -20.1791   …  -16.9336   -17.4919   -14.9605
```

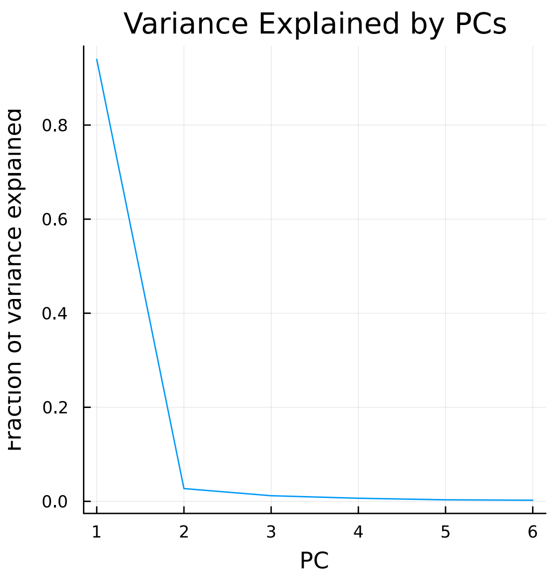
2.4.3 Reshape precip

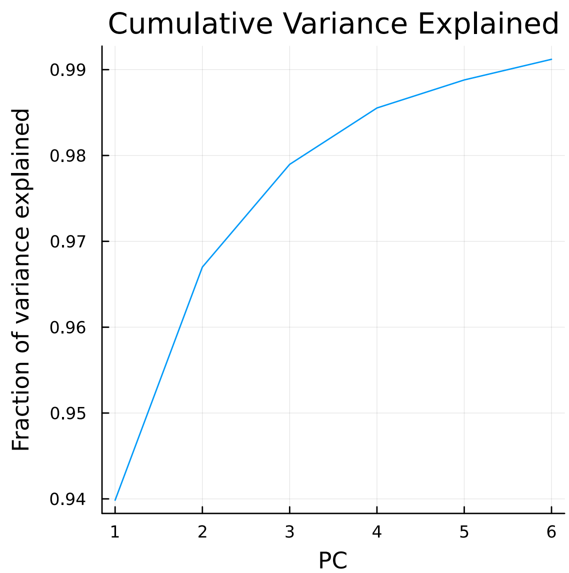
```
576×731 reshape(::Array{Union{Missing, Float32}, 3}, 576, 731) with eltype
Union{Missing, Float32}:
 0.230964  0.0        0.0       0.0        …  1.91927    1.25381    0.0
 0.239267  0.0        0.0       0.0           0.203245   1.77286    0.0
 0.228309  0.0        0.0       0.0           0.237774   5.26336    0.0
 0.212892  0.0        0.0       0.0           1.80391    4.11361    0.0
 0.179382  0.0        0.0       0.0           2.32314    1.10992    0.0
 0.083235  0.0        0.0       0.0        …  1.09869    2.73123    0.0
 0.0       0.0        0.0       0.0           0.493284   3.33995    0.0
 0.0       0.0        0.0       0.0           0.0        5.67861    0.0
 0.0       0.0        0.0       0.0           0.0        5.94113    0.0
 0.0       0.0        0.0       0.0           0.0        5.672      0.0
  missing   missing    missing   missing   …   missing    missing    missing
  missing   missing    missing   missing       missing    missing    missing
  missing   missing    missing   missing       missing    missing    missing
 ⋮                                         ⋱                       ⋮
 0.0       0.0        0.0       0.0           1.8507     0.568243   4.06902
```

```
0.0         0.0         0.0         0.0          …  4.73033     1.48535     4.85771
0.0         0.0         0.0         0.0             4.4185      0.884178    4.07878
0.0         0.0         0.0         0.153876        0.0426737   1.20721     1.09506
0.0         0.0         0.0         0.0202588       0.0         1.21469     0.649026
0.0         0.0         0.0         0.0             0.0         0.555291    0.253759
0.0         0.0         0.0         0.0          …  0.0         0.477171    1.20432
0.0         0.0         0.0         0.0             0.0         0.0261992   1.47429
0.0         0.0         0.0         0.0             0.0         0.0         0.301635
0.0         0.0         0.0         0.0             0.0         0.0         0.394416
0.0         0.0         0.0         0.0             0.0         0.0         1.16965
0.0         0.0203687   0.0         0.0          …  0.0         0.0         1.59136
```

3. Principal Component Analysis 3.1 Fit PCA model

3.2 Plot variance to determine number of PCs to keep





3.3 Transform PCs

```
6×731 Matrix{Float64}:
 100.247       130.942     179.171     …  159.314      159.572       128.187
   3.03334       9.58764   -11.2996        -8.46464    -14.8938       -5.77997
   2.22337      -3.58652     0.21244       -1.39438     -8.892        -7.86022
   2.6004       -3.18065   -10.1462        -3.68285     -0.234302     10.0624
   0.0852445    -1.64579     0.984028      -4.64237     -0.923782      0.668111
   4.67906       2.65186    -1.97371   …    0.396902     0.305045     -4.68379
```

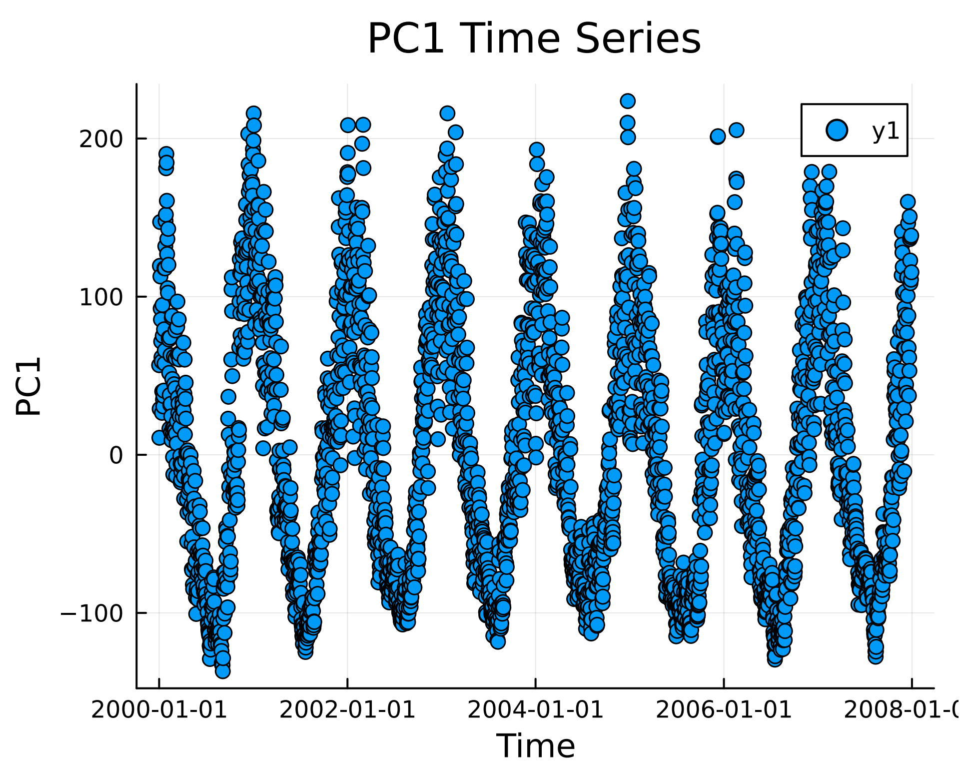
3.4 Save first three PCs

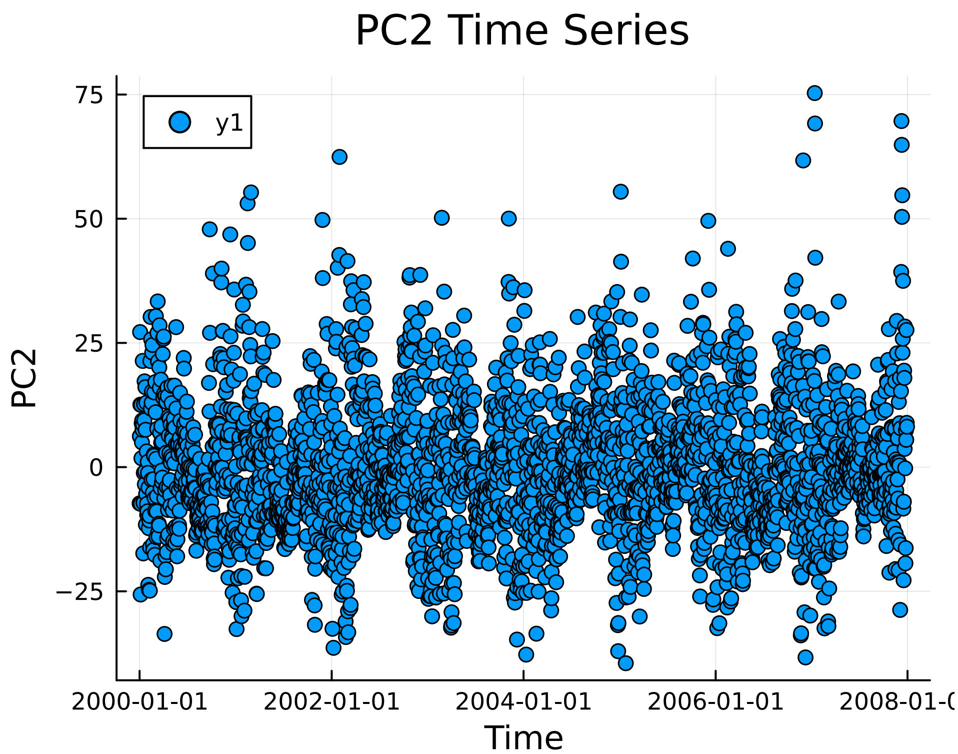
```
2921-element Vector{Float64}:
   3.9052599528110425
  -2.2538113042128542
 -12.537201539433823
 -11.024843758228124
  -0.5726203694196917
```

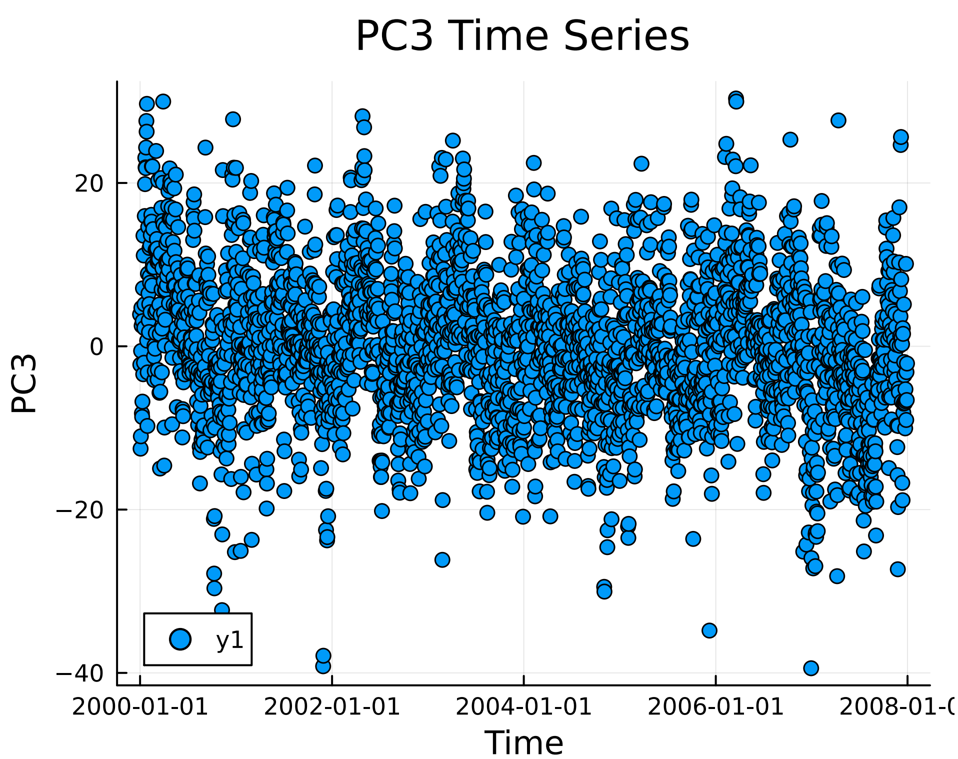
```
  4.701612681874441
  2.5183907610932286
 -8.215061876405912
 -8.658143941931053
 -6.778889657459626
  3.078553367661374
  7.098802390680696
 -3.423404610358853
  ⋮
 -1.9310563142374508
 -3.550451553216818
 -6.775211071460527
 -6.952704268141444
-10.052420445554452
 -5.265265614927885
 -6.733298155961106
 10.088840782427953
 -9.024376763999939
 -3.1651858900584364
 -6.582681154712115
 -2.110570791578569
```

3.5 Plot PCA

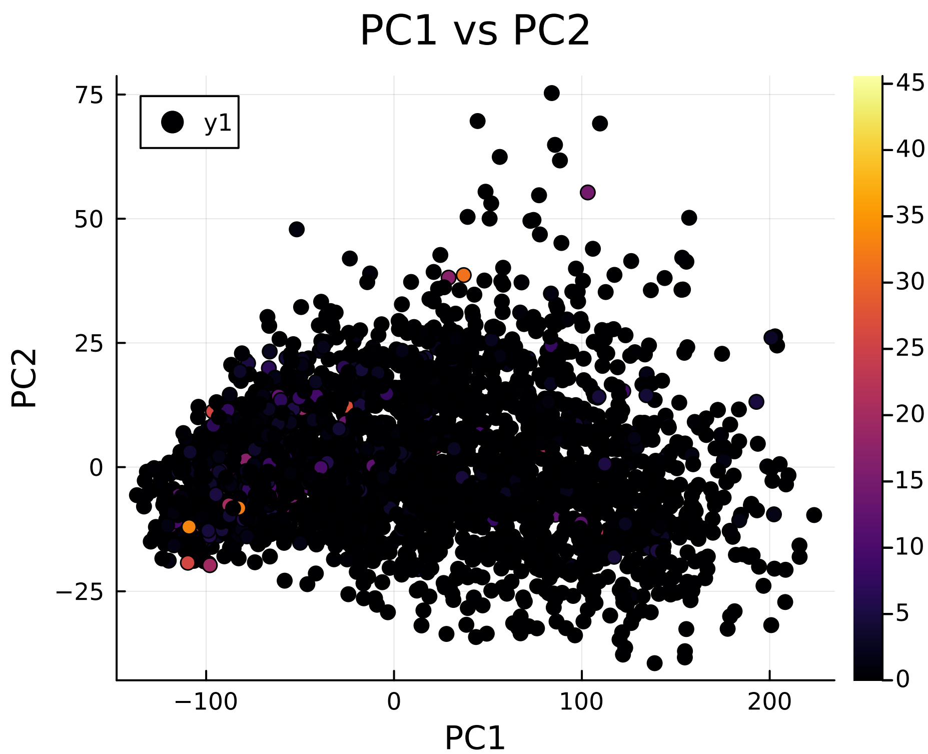
3.5.1 Plot time series of first three PCs



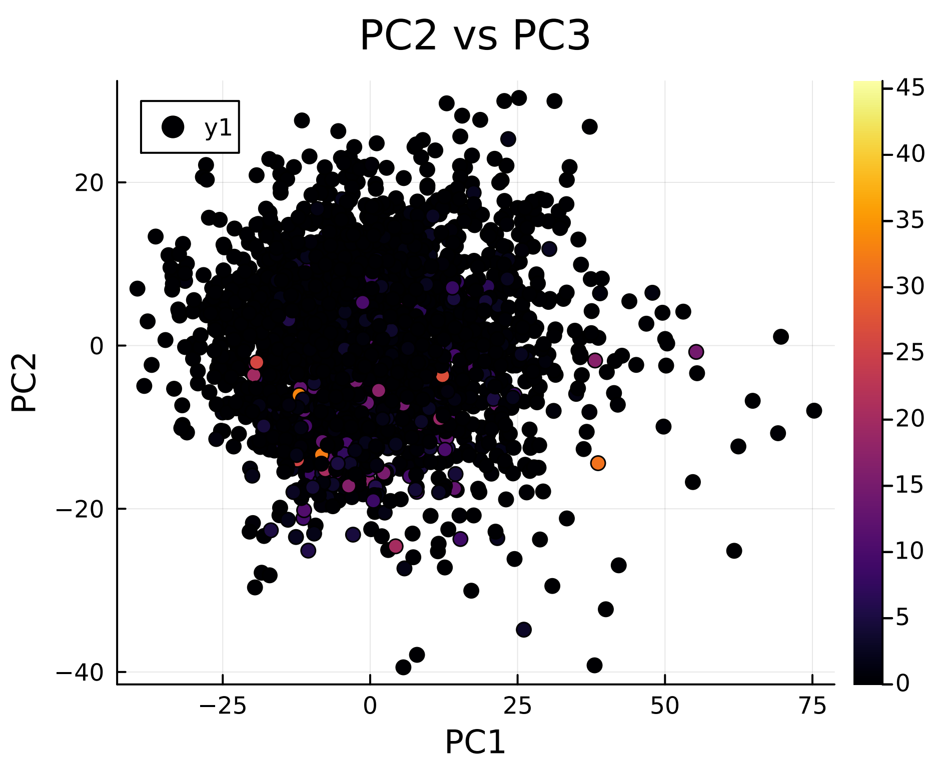




3.5.2 Plot first 2 PCs and mean precipitation



3.5.3 Plot the second and third PCs with mean precipitation



4. Approach 1: KNN

Given the high dimensional structure of the gridded temperature data, a principal components analysis was performed to downscale the features while preserving variation to allow for modeling across space and time. PCA effectively reduces the number of columns (in this case, locations) by projecting the data onto new PC axes. The number of principal components to retain was determined by plotting the variance explained by the principal components and the cumulative variance. After analyzing these figures, a break in variance is observed after principal component number two. The cumulative variance explained plot reveals that approximately 97.8% of the variance is explained by the first three principal components, so three principal components were retained for further analysis. The PCA model was fit to the training temperature data and then the temperature training and testing data were transformed onto the PCA space.

KNN was then used to predict the precipitation data for the testing temperature data given temperature and precipitation over the training period.The KNN function calculates the Euclidean distance between the new datapoint and the existing K data points and assigns weights based on these distances. Weighted sampling is then conducted to obtain the predicted value based on the indexed position sampled. Three was chosen as the hyperparameter for the number of neighbors because this number of neighbors is standard in KNN analysis and serves as an appropriate baseline. The resultant predicted precipitation values were compared to the actual precipitation training data to evaluate the fit of the model using residuals, MAE, and MSE.

4.1 Define KNN function

```
knn (generic function with 1 method)
```

4.2 Combining PCA and KNN

```
predict_knn (generic function with 1 method)
```

4.3 Test the model

```
24×24×731 Array{AbstractFloat, 3}:
[:, :, 1] =
 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  0.0  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  0.0649847     0.0        0.0        0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0218424     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           0.0533735  0.0        0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0           0.0        0.0209779  0.0901863
 0.0  0.0  0.0  0.0  0.0  0.0  0.0           0.0302493  0.0        0.0415976
 0.0  0.0  0.0  0.0  0.0  0.0  0.0           0.19425    0.0473435  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0        …  0.0884871  0.0421871  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           0.0780542  0.0        0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0        …  0.0211939  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        0.176734
 0.0  0.0  0.0  0.0  0.0  0.0  0.0           0.0        0.0        0.152089

[:, :, 2] =
 1.75447   1.41588  1.19977   0.848477   …  0.0        0.0        0.0
 3.56247   1.01861  1.52315   1.49084       0.0        0.0        0.0
 9.91041   1.38696  1.36932   2.96705       0.0        0.0        0.0
 8.48843   2.42787  1.51287   2.51147       0.0        0.0        0.0
 1.6389    1.39423  1.54824   0.957531      0.0        0.0        0.0
 4.94228   2.9396   0.673247  0.0492278  …  0.0        0.0        0.0
 6.01258   5.55706  4.37366   0.18723       0.0        0.0        0.0
 7.2367   11.1376   5.32148   0.156859      0.0        0.0        0.0
 6.91768   7.26536  1.85251   0.0910493     0.0        0.0        0.0
 4.00505   2.66892  1.61451   0.683203      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        …  0.0334075  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        0.0777392
 0.0       0.0      0.0       0.0           0.0723409  0.0859267  0.147741
 0.0       0.0      0.0       0.0           0.0262213  0.0489934  0.195904

[:, :, 3] =
 1.49692   1.99355    2.05643    …  0.0        0.0  0.0  0.0  0.0  0.0
 0.833292  0.72057    1.09722       0.0        0.0  0.0  0.0  0.0  0.0
 3.12063   1.12997    0.357355      0.0        0.0  0.0  0.0  0.0  0.0
 2.17121   1.34081    0.0870448     0.0        0.0  0.0  0.0  0.0  0.0
 0.146885  0.0664999  0.178861      0.0        0.0  0.0  0.0  0.0  0.0
 0.464428  0.344984   0.791974   …  0.0        0.0  0.0  0.0  0.0  0.0
 1.5742    2.66726    1.56431       0.0        0.0  0.0  0.0  0.0  0.0
 1.55001   4.35322    2.61319       0.0        0.0  0.0  0.0  0.0  0.0
 0.500756  2.29461    2.9136        0.0        0.0  0.0  0.0  0.0  0.0
 0.479857  1.89894    2.37473       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           0.035775   0.0  0.0  0.0  0.0  0.0
```

```
 0.0       0.0        0.0           0.0511538  0.0  0.0  0.0  0.0  0.0
 0.0       0.0        0.0        …  0.0340634  0.0  0.0  0.0  0.0  0.0
 0.0       0.0        0.0           0.0237441  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       0.0        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

;;; …

[:, :, 729] =
 0.0  0.0  0.0        0.0  0.0  0.0  …  0.140855   0.0414727  0.436889
 0.0  0.0  0.0        0.0  0.0  0.0     0.598811   0.0493965  0.314328
 0.0  0.0  0.0        0.0  0.0  0.0     0.240909   0.100539   0.407857
 0.0  0.0  0.0        0.0  0.0  0.0     0.0943053  0.266252   0.592172
 0.0  0.0  0.0        0.0  0.0  0.0     0.082403   0.117491   0.129018
 0.0  0.0  0.0        0.0  0.0  0.0  …  0.292574   0.660883   0.528695
 0.0  0.0  0.0        0.0  0.0  0.0     0.236851   0.314418   0.267703
 0.0  0.0  0.0        0.0  0.0  0.0     0.430934   0.222956   0.587176
 0.0  0.0  0.0513685  0.0  0.0  0.0     0.180304   0.129312   0.219643
 0.0  0.0  0.0623262  0.0  0.0  0.0     0.345806   0.176304   0.689809
 0.0  0.0  0.0        0.0  0.0  0.0  …  0.470213   0.479811   0.99668
 0.0  0.0  0.0        0.0  0.0  0.0     0.903811   0.805968   0.633223
 0.0  0.0  0.0        0.0  0.0  0.0     1.55173    1.94446    1.05149
 0.0  0.0  0.0        0.0  0.0  0.0     0.751358   2.42407    0.892646
 0.0  0.0  0.0        0.0  0.0  0.0     0.84299    1.61934    1.53261
 0.0  0.0  0.0        0.0  0.0  0.0  …  0.411869   1.02282    0.344983
 0.0  0.0  0.0        0.0  0.0  0.0     0.954351   1.51298    0.313492
 0.0  0.0  0.0        0.0  0.0  0.0     2.95927    3.57947    1.06551
 0.0  0.0  0.0        0.0  0.0  0.0     1.85423    1.76604    1.70267
 0.0  0.0  0.0        0.0  0.0  0.0     0.606824   0.320045   1.13114
 0.0  0.0  0.0        0.0  0.0  0.0  …  1.41541    0.305823   0.435956
 0.0  0.0  0.0        0.0  0.0  0.0     0.600175   0.637315   0.814799
 0.0  0.0  0.0        0.0  0.0  0.0     0.798034   0.480626   0.410468
 0.0  0.0  0.0        0.0  0.0  0.0     1.01349    1.12795    0.425947

[:, :, 730] =
  0.0       0.0        0.0250906  …  0.0  0.0       0.0        0.0
  0.0       0.0        0.05093       0.0  0.0       0.0        0.0
  0.0       0.0434867  0.163335      0.0  0.0       0.0        0.0
  0.084721  0.455731   0.452126      0.0  0.0       0.0        0.0
  0.376434  0.272408   0.550661      0.0  0.0       0.0        0.0
  1.80568   0.370495   1.58513    …  0.0  0.0       0.0        0.0
  4.14398   2.07312    4.16797       0.0  0.0       0.0        0.0
 10.2574    9.56134    5.12458       0.0  0.0       0.0        0.0
  9.65954   6.17192    4.32784       0.0  0.0       0.0        0.0
  7.42415   5.88919    6.10839       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  0.301538  0.0756907  0.0
  0.0       0.0        0.0           0.0  0.87682   0.408131   0.0
  0.0       0.0        0.0        …  0.0  0.025333  0.36935    0.0624869
  0.0       0.0        0.0           0.0  0.0       0.0766167  0.0
  0.0       0.0        0.0           0.0  0.0       0.032296   0.100898
  0.0       0.0        0.0           0.0  0.0       0.0        0.0469467
  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        0.0532102
  0.0       0.0        0.0           0.0  0.0       0.0        0.0

[:, :, 731] =
 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  0.0  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  0.0  0.0  0.0251531  …  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           0.0208791  0.0       0.0       0.0
 0.0  0.0  0.0  0.0  0.0  0.0        …  3.16174    0.382311  0.0       0.0
 0.0  0.0  0.0  0.0  0.0  0.0           6.56101    1.23528   0.0       0.0
 0.0  0.0  0.0  0.0  0.0  0.0           0.167616   0.41249   0.159337  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
 0.0  0.0  0.0  0.0  0.0  0.0           0.0        0.0       0.0       0.0
```

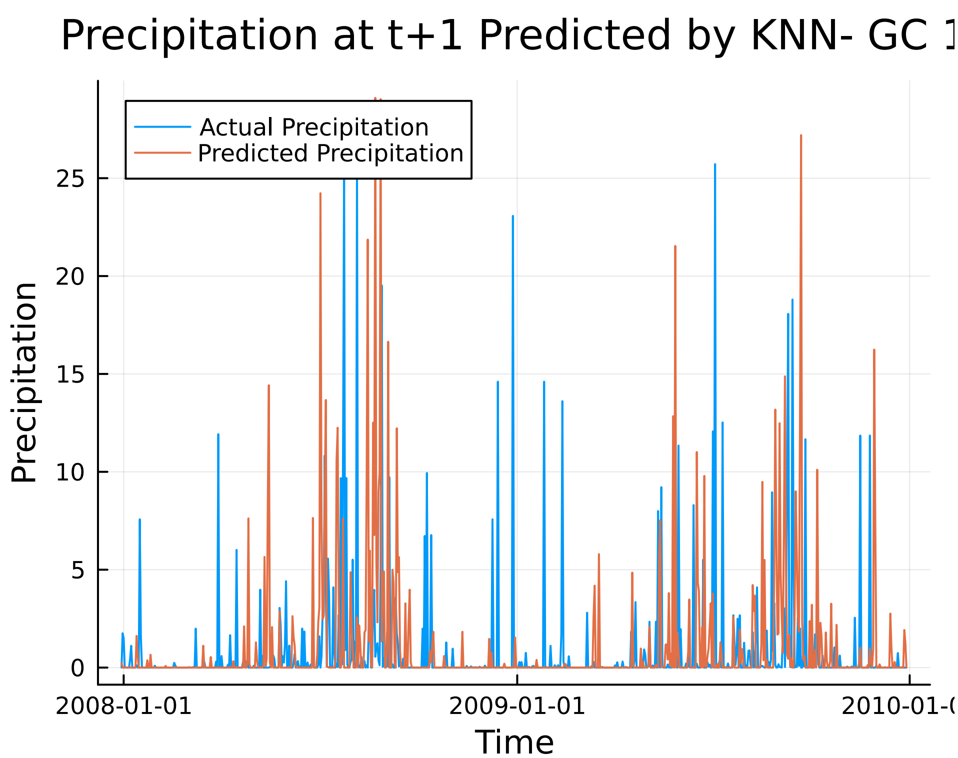
4.4 Analyze Fit

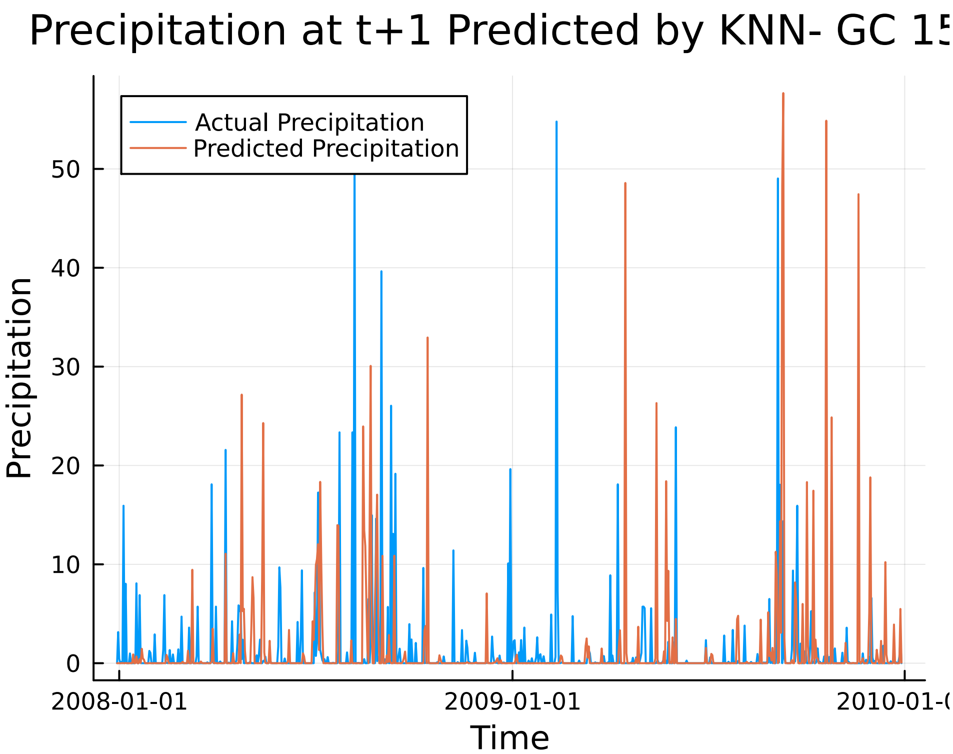
4.4.1 Reshape data for plotting

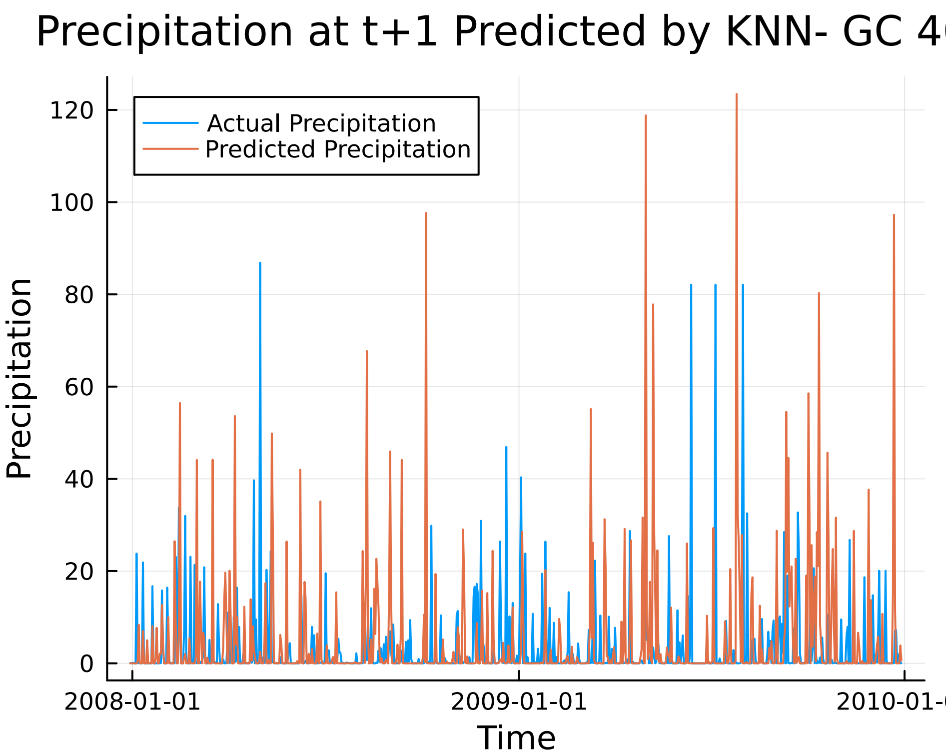
```
576×731 Matrix{AbstractFloat}:
 0.0        1.75447    1.49692   0.0        …  0.0        0.0        0.0
 0.0        3.56247    0.833292  0.0           0.0        0.0        0.0
 0.0        9.91041    3.12063   0.0           0.0        0.0        0.0
 0.0        8.48843    2.17121   0.0           0.0        0.084721   0.0
```

```
0.0        1.6389     0.146885  0.0           0.0        0.376434   0.0
0.0        4.94228    0.464428  0.0        …  0.0        1.80568    0.0
0.0        6.01258    1.5742    0.0           0.0        4.14398    0.0
0.0        7.2367     1.55001   0.0           0.0       10.2574     0.0
0.0        6.91768    0.500756  0.0           0.0        9.65954    0.0
0.0        4.00505    0.479857  0.0           0.0        7.42415    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
⋮                                          ⋱                        ⋮
0.0901863  0.0        0.0       1.0249        1.05149    0.0        0.0
0.0415976  0.0        0.0       0.360796   …  0.892646   0.0        0.0
0.0        0.0        0.0       0.414263      1.53261    0.0        0.0
0.0        0.0        0.0       0.108951      0.344983   0.0624869  0.0
0.0        0.0        0.0       0.212448      0.313492   0.0        0.0
0.0        0.0        0.0       0.0           1.06551    0.100898   0.0
0.0        0.0        0.0       0.0        …  1.70267    0.0469467  0.0
0.0        0.0        0.0       0.0796868     1.13114    0.0        0.0
0.0        0.0        0.0       0.118671      0.435956   0.0        0.0
0.0        0.0777392  0.0       0.0           0.814799   0.0        0.0
0.176734   0.147741   0.0       0.0           0.410468   0.0532102  0.0
0.152089   0.195904   0.0       0.0        …  0.425947   0.0        0.0
```

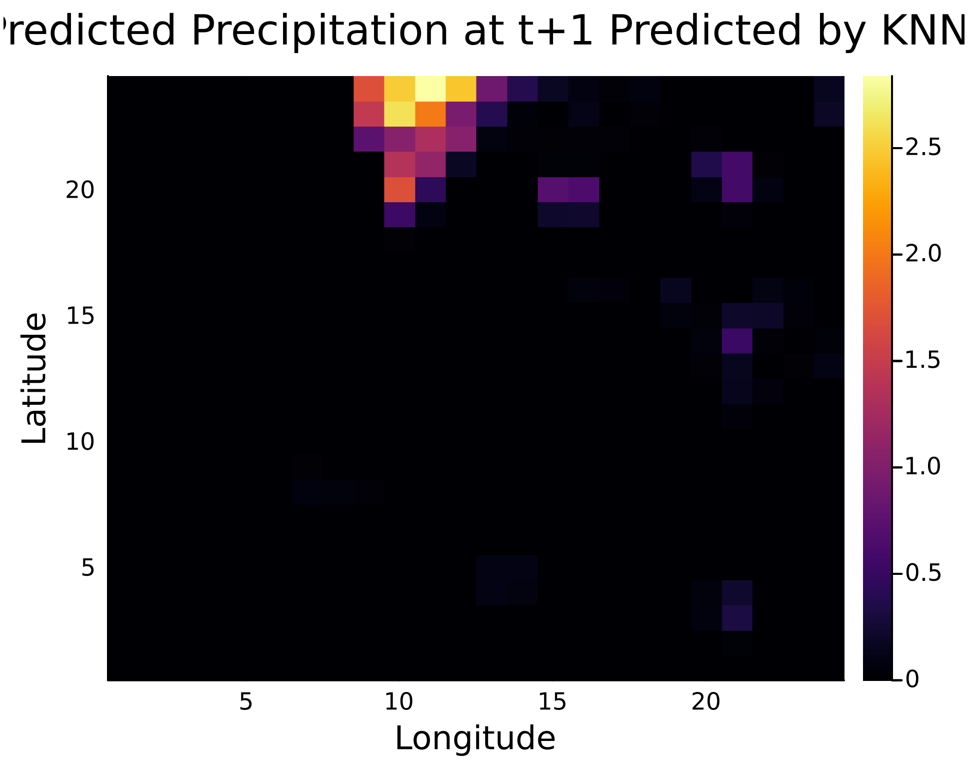
4.4.2 Time series actual vs predicted test precipitation



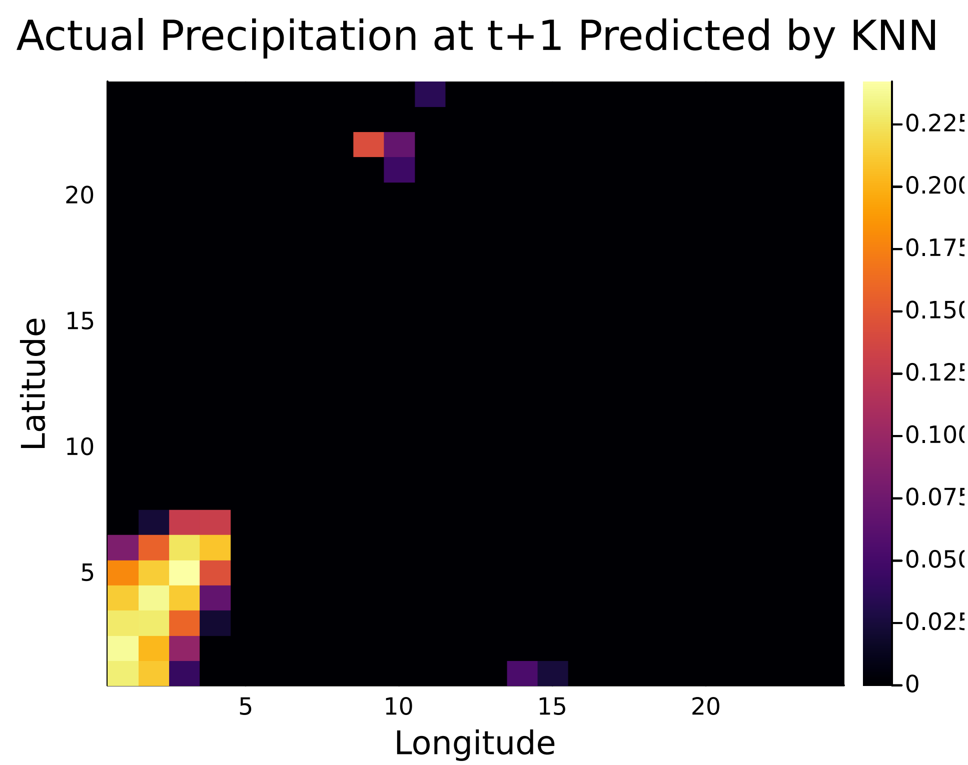




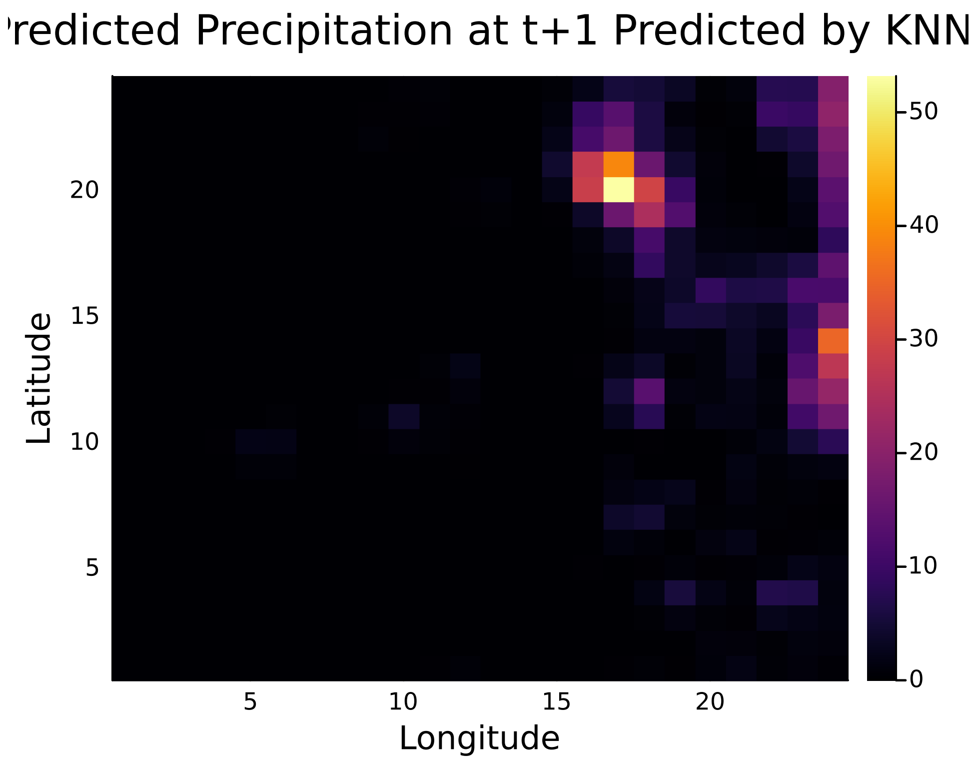
4.4.3 Heatmaps

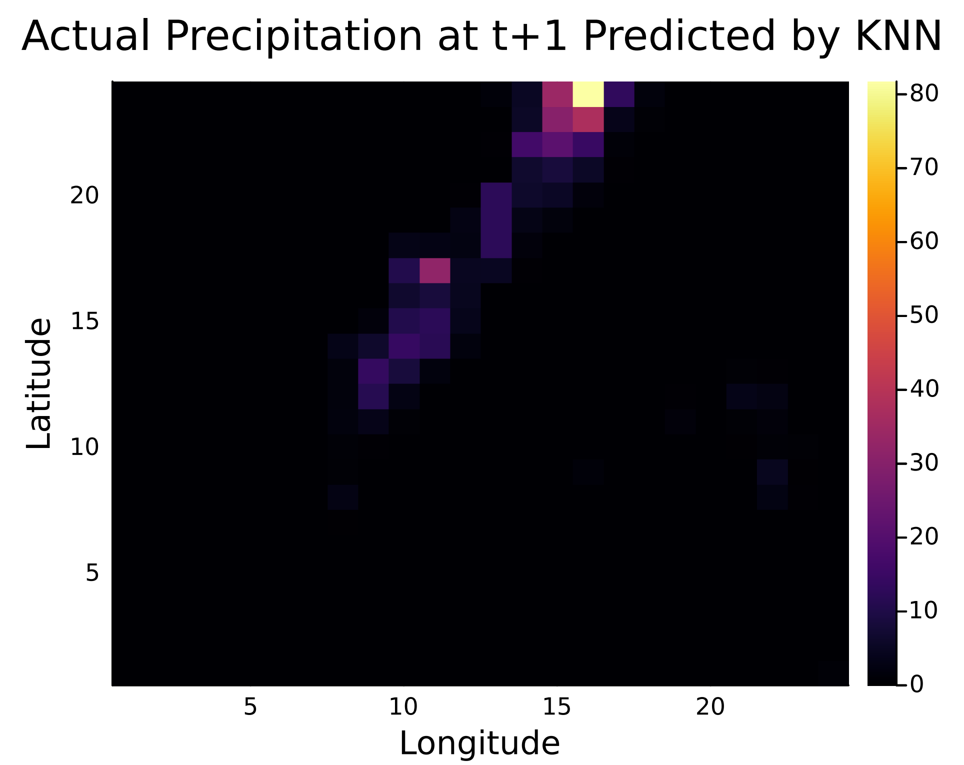


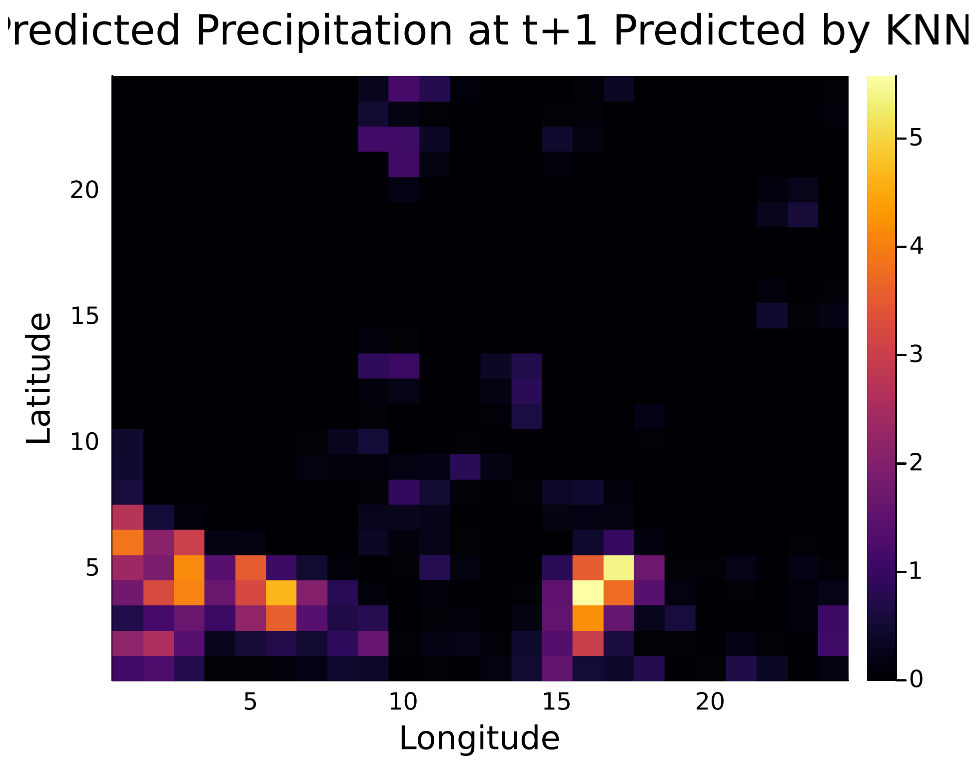
redicted Precipitation at t+1 Predicted by KNN
Latitude
Longitude
5
10
15
20
2.5
2.0
1.5
1.0
0.5
0

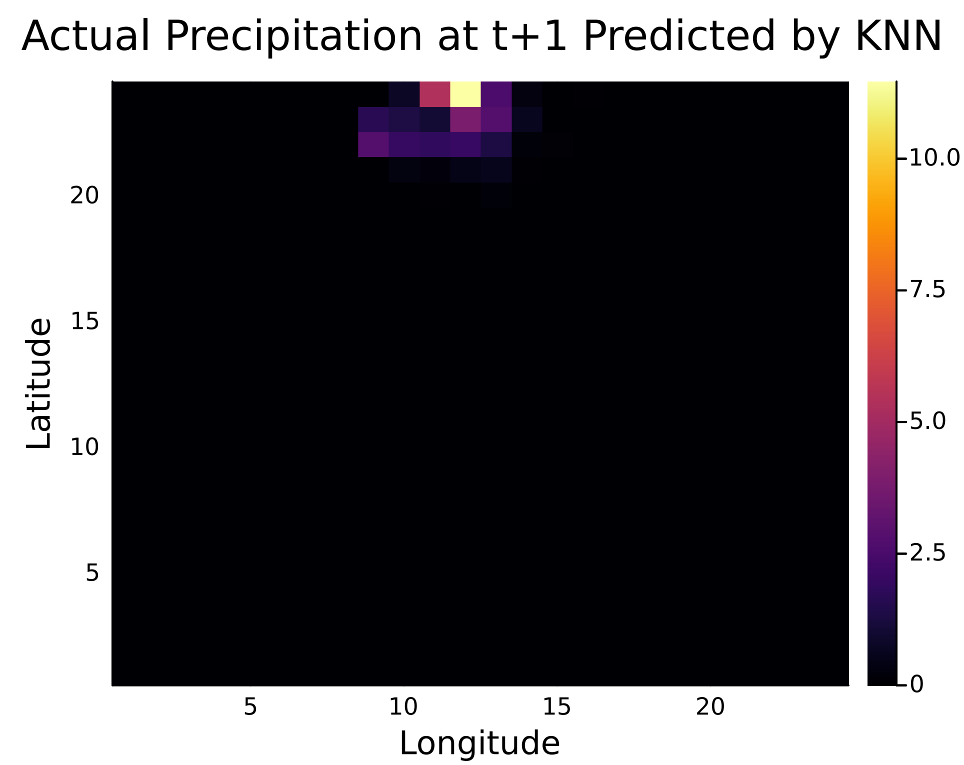


Actual Precipitation at t+1 Predicted by KNN
Latitude
Longitude
5
10
15
20
0


redicted Precipitation at t+1 Predicted by KNN
Latitude
Longitude
5
10
15
20
0
10
20
30
40
50


Actual Precipitation at t+1 Predicted by KNN
Latitude
Longitude
5
10
15
20
0
10
20
30
40
50
60
70
80





4.4.4 Evaluate fit using MSE

```
mean_se (generic function with 1 method)
```

4.4.5 Evaluate fit using MAE

```
mean_abs_error (generic function with 1 method)
```

4.4.6 Evaluate fit using residuals

```
residuals (generic function with 1 method)
```

5. Approach 2: PCA/Linear Regression

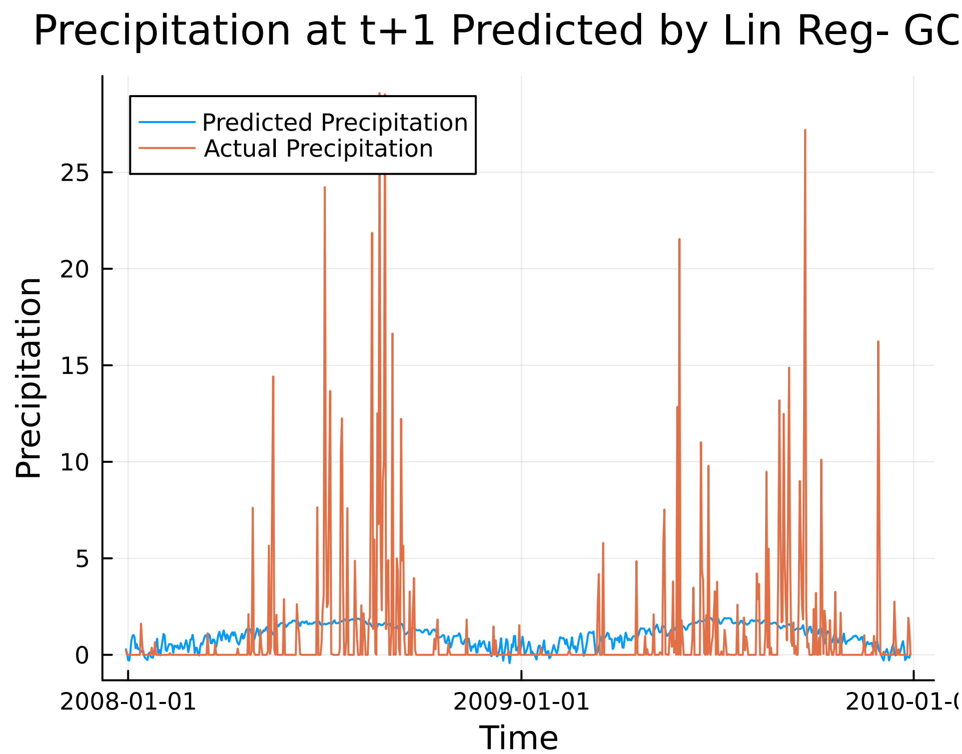
Similarly to Approach 1, Approach 2 employed PCA to reduce the dimensions of the temperature data. Only the first principal component was retained for further linear regression to allow for the creation of simple vectors that are compatible with linear regression syntax. Linear regression was performed on precipitation at each grid cell location following the first principal component of the temperature data. The temperature test data was then applied to this linear model to predict precipitation and was similarly compared to actual observed precipitation to evaluate the model using residuals, MAE, and MSE.

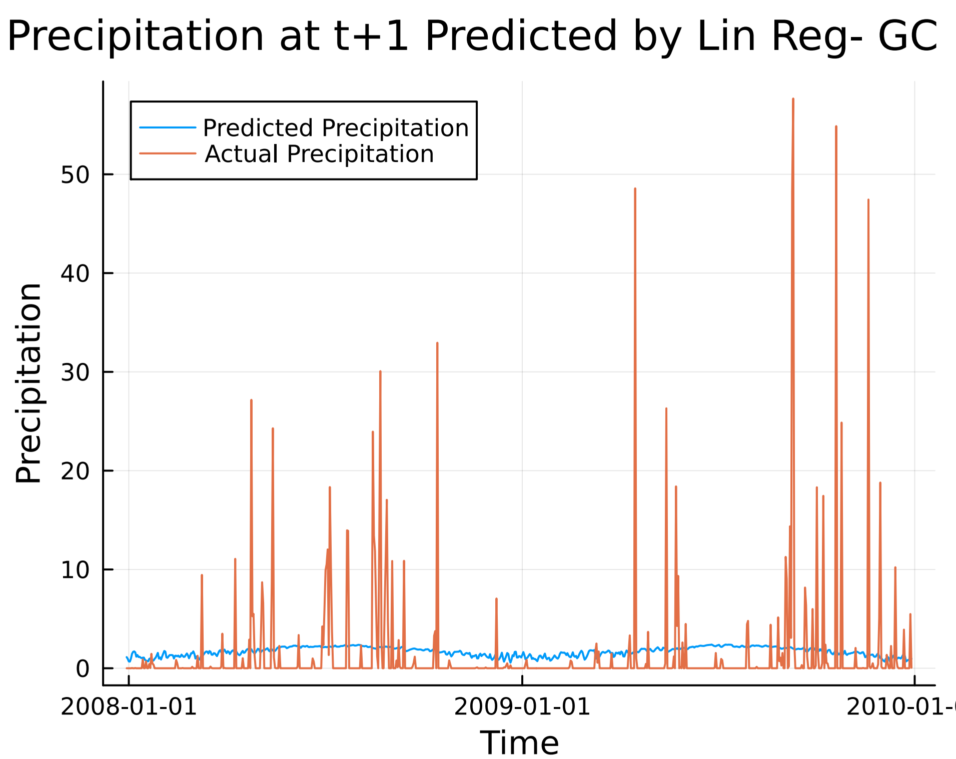
5.1 Linear Regression

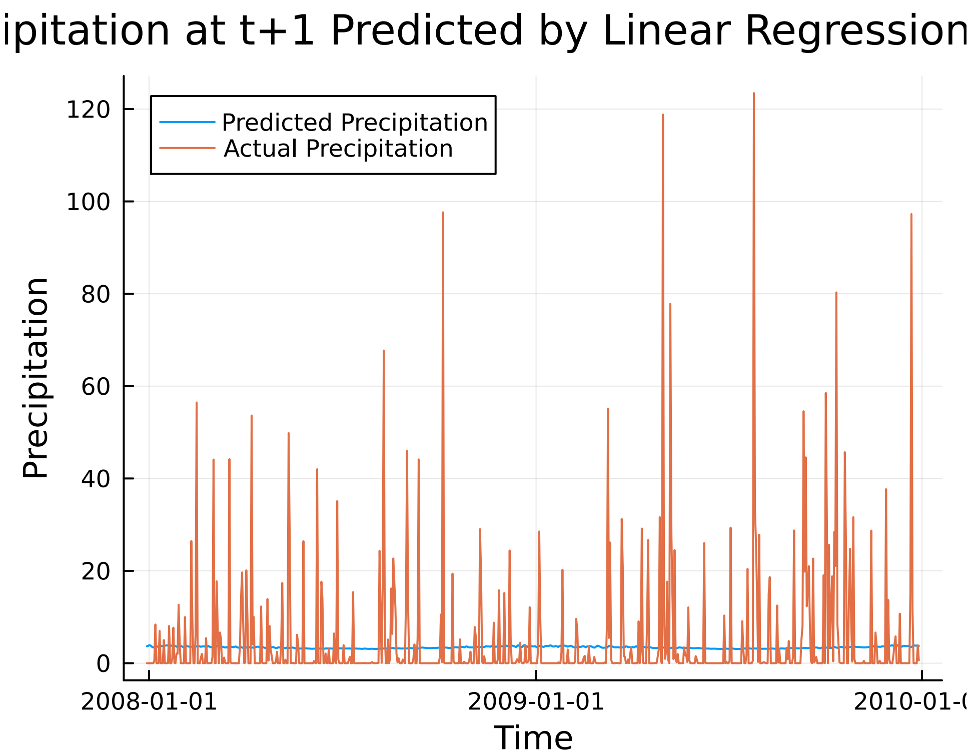
```
576×2921 Matrix{AbstractFloat}:
 0.0         0.0       0.0       0.0        …  0.0      0.0        0.0  0.0
 0.0         0.0       0.0       0.0           0.0      0.0        0.0  0.0
 0.0         0.0       0.0       0.0           0.0      0.0        0.0  0.0
 0.0         0.0       0.0       0.0           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       0.0           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  0.0
 ⋮                                          ⋱                           ⋮
 0.0         4.3323    2.59903   0.0857328     4.40795  0.0384247  0.0  0.0
 0.0        10.0802    1.95597   0.103022   …  2.42879  0.0        0.0  0.0
 0.0207805  13.5422    1.23499   0.0           2.51666  0.0        0.0  0.0
 0.0338578  15.6146    1.12839   0.0           2.64994  0.0472129  0.0  0.0
 0.0513665  22.9741    3.07755   0.0           2.00045  0.0460711  0.0  0.0
 0.156683   28.7882    0.937954  0.0           1.97276  0.0751787  0.0  0.0
 0.0214627  24.5314    2.03677   0.0        …  2.50186  0.0        0.0  0.0
 3.03718    14.6306    4.33941   0.0           2.24995  0.0        0.0  0.0
 3.51391     8.24005   8.96606   0.0           2.30591  0.0429012  0.0  0.0
 0.607323   26.5516   10.5232    0.0           4.07364  0.0        0.0  0.0
 0.0        51.9611   17.5984    0.206645      2.48726  0.659939   0.0  0.0
 0.602726   73.7095   25.2627    1.76726    …  3.56594  2.77694    0.0  0.0

731×576 Matrix{Float64}:
  0.288686    0.326512    0.585564   …  2.21833  2.42359  2.47836  2.48521
```

```
  0.0693047   0.0866469   0.344425        1.94787  2.19186  2.22505  2.27144
 -0.275387   -0.29023    -0.0344529       1.52294  1.82776  1.82705  1.93557
 -0.293983   -0.310562   -0.0548933       1.50001  1.80811  1.80557  1.91745
  0.0960588   0.115899    0.373833        1.98085  2.22012  2.25594  2.29751
  0.714566    0.792159    1.05368     …   2.74335  2.87345  2.9701   2.9002
  0.967155    1.06833     1.33132         3.05475  3.14026  3.26176  3.14632
  1.02983     1.13686     1.40022         3.13202  3.20647  3.33413  3.2074
  0.901364    0.996399    1.25901         2.97364  3.07077  3.18579  3.08221
  0.343025    0.385925    0.645293        2.28532  2.48099  2.5411   2.53816
  0.558737    0.62178     0.8824      …   2.55125  2.70885  2.79017  2.74835
  0.2988      0.337571    0.596682        2.2308   2.43427  2.49004  2.49506
  0.332966    0.374927    0.634237        2.27292  2.47036  2.52949  2.52836
  ⋮                                   ⋱                              ⋮
  0.176906    0.204296    0.462699        2.08052  2.30552  2.34929  2.37629
  0.0974754   0.117448    0.37539     …   1.9826   2.22161  2.25757  2.29889
  0.269593    0.305637    0.564579        2.19479  2.40342  2.45631  2.46661
  0.526515    0.586549    0.846982        2.51152  2.67481  2.75297  2.71696
  0.707819    0.784782    1.04627         2.73504  2.86632  2.96231  2.89362
  0.356321    0.400463    0.659908        2.30171  2.49503  2.55645  2.55111
 -0.272868   -0.287476   -0.0316845   …   1.52604  1.83042  1.82995  1.93802
 -0.178059   -0.183814    0.0725277       1.64292  1.93056  1.93943  2.0304
 -0.066708   -0.0620658   0.194923        1.7802   2.04818  2.068    2.13891
 -0.13347    -0.135062    0.121539        1.69789  1.97766  1.99091  2.07385
 -0.135314   -0.137078    0.119512        1.69562  1.97572  1.98878  2.07206
  0.0889984   0.10818     0.366072    …   1.97215  2.21266  2.24779  2.29063
```

5.2 Analyze Fit 5.2.1 Plot time series of actual vs predicted precipitation at different grid cells


Precipitation at t+1 Predicted by Lin Reg- GC
Predicted Precipitation
Actual Precipitation
Precipitation
0
5
10
15
20
25
2008-01-01
2009-01-01
Time


Precipitation at t+1 Predicted by Lin Reg- GC
Predicted Precipitation
Actual Precipitation
Precipitation
0
10
20
30
40
50
2008-01-01
2009-01-01
Time



5.2.2 Evaluate Fit using MSE

5.2.3 Evaluate fit using MAE

5.2.4 Evaluate fit using residuals

6. Compare

When plotting the predicted precipitation and the actual precipitation for the test data, upon visual inspection it seems that the PCA-KNN model more closely resembles the trends of the actual precipitation. The PCA-KNN predicted precipitation of varying levels while the PCA-linear regression model predicted nearly constant, low-level precipitation year-round, with some reflection of the seasonal trends as the maximum periods of the curves occur over the same range of time. However, upon closer analysis, the PCA-KNN model predictions differed significantly from the actual precipitation values. When considering only the residuals of actual precipitation minus predicted precipitation, the PCA-KNN model appears to perform better because the average of the residuals is lower than the PCA-linear regression model. However, when considering the mean absolute error and the mean squared error, the PCA-linear regression model outperformed the PCA-KNN model with significantly lower MAE and MSE, indicating overall that predictions are closer to actual values than the PCA-KNN model. Residuals might be lower than MSE or MAE for a model if there are both undershoots and overshoots when considering the entire dataset of predictions. For example, if the PCA-KNN model predicted 0 mm on a day that should be 40 mm and 40 mm on a day that should be 0 mm, the averaged residuals would be zero since they cancel out. MSE and MAE, however, are a more robust measure of model performance because they account for differences in sign via squaring and absolute value respectively.

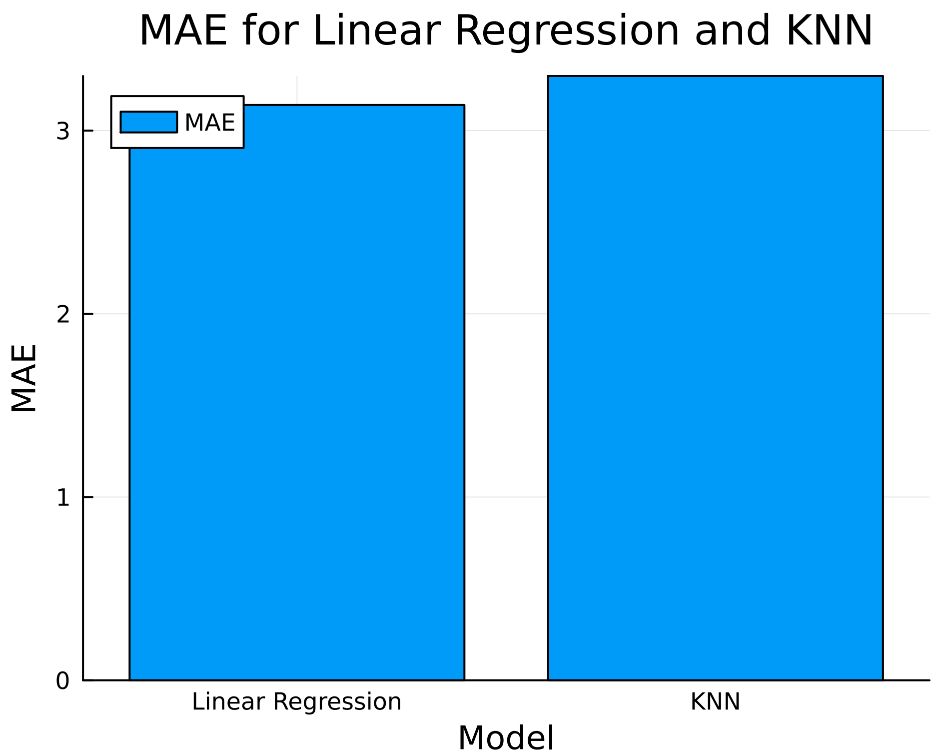
MSE places a greater emphasis on large errors but is sensitive to outliers, which explains why the difference in MSE is greater between the two models than MAE.

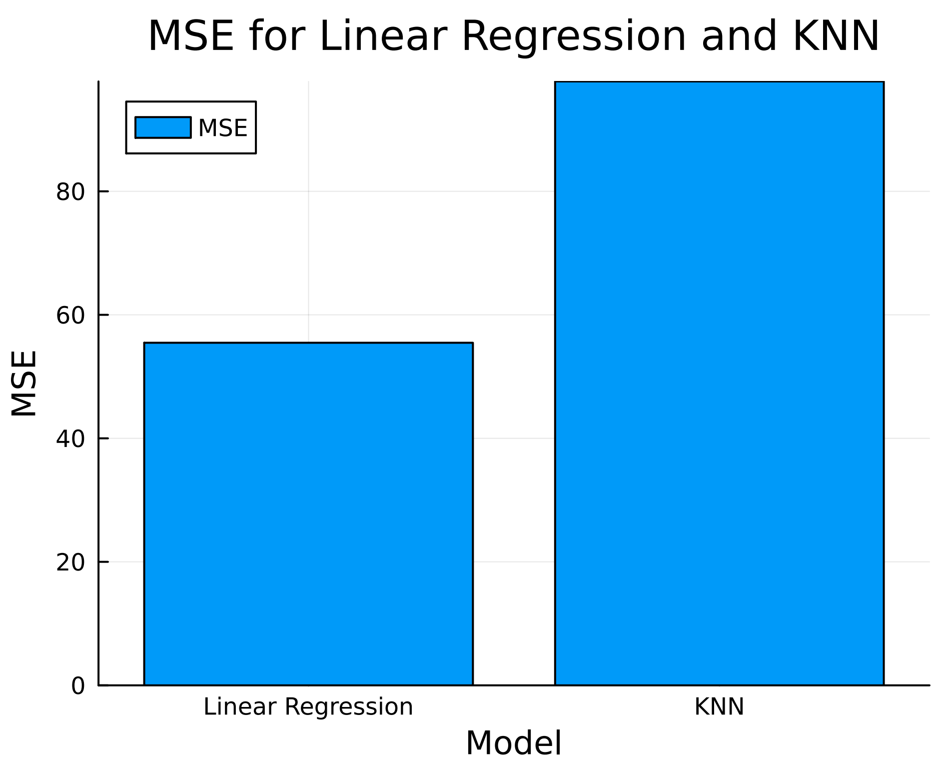
The PCA-KNN model appears to be capturing the general shape of the data better, but local predictions are not very reliable based on the MAE and MSE calculations. This model could be further optimized by optimizing the hyperparameters n_pca and K. N_pca is the number of principal components retained in the model. Three was selected as the n_pca value in this analysis based on fraction of variance explained, but a systematic approach could be taken to test all values of PCs and retain the number with the lowest MSE/MAE. A similar systematic approach could be used to optimize the K parameter as well.

The PCA-linear regression model is demonstrating a “dreary” effect by predicting low level precipitation across the time series. While there are periods of slight increase and decrease over the year corresponding to seasonal variation, this model generally does not capture the shape of the data or minimum/maximum values well. Only the first principal component was retained for simplicity of the model, but to improve the predictions more principal components should be considered. Additional principal components may more accurately capture heavy precipitation patterns and predict values closer to actual precipitation on heavy rainfall days.

A limitation of both models is the handling of missing precipitation values. This analysis elected to replace missing values with 0.0, but this is likely altering predictive accuracy by introducing bias. An improvement would be to remove missing values altogether before conducting data analysis. Another major limitation of both models is only using temperature data to predict precipitation. Based on prior knowledge, pressure data is also important in predicting precipitation and model performance likely would have significantly included if more variables beyond temperature were included.

```
-0.23472928f0
```





7. Conclusion

This report provides preliminary models to predict precipitation at time t+1 based on temperature at time t over Texas. Both approaches employ a principal component analysis to downscale high dimensional spatial data while retaining variance explained within the data. Approach 1 then applies K-nearest neighbors to predict precipitation using weighted sampling indexes of the three closest neighbors. After PCA, Approach 2 applies a linear regression to the first principal component at each grid cell of precipitation following temperature. When comparing predicted and actual precipitation across the two models, Approach 1 appears to capture the range of precipitation values more accurately but exhibits a higher mean squared error and mean absolute error, indicating poorer overall model performance. Approach 2 predicts low level precipitation across the entire time series and thus has lower mean squared error and mean absolute error values due to a lack of appropriate extremes.

If the goal of the model prediction was to minimize MSE and MAE, then Approach 2 would be a better model. Both models would be significantly improved by the optimization of chosen model parameters and the inclusion of additional climate variables, including pressure, to predict precipitation.