1980-2014 Write-Up for Temperature Data

Ann Marie Matheny

July 15, 2019

Contents

The following write-up is part of the exploratory analysis for my research project proposal. Much of this data comes from various weather stations with the Lake Champlain watershed region which includes parts of Vermont, New York and Canada. One objective is to compare this data to the predicted weather data produced by a Weather Research and Forecasting model.

I am interested in the extreme distribution of WRF model temperature predictions in comparison to station data. In this case, extreme will be defined as the top 90th percentile for temperature. In particular, I want to see how temperature varies over both time and space between the years 1980-2014

within the Lake Champlain basin region. I will also be examining what (if any), changes occur during this time.

1 Time Series Plots for WRF Data

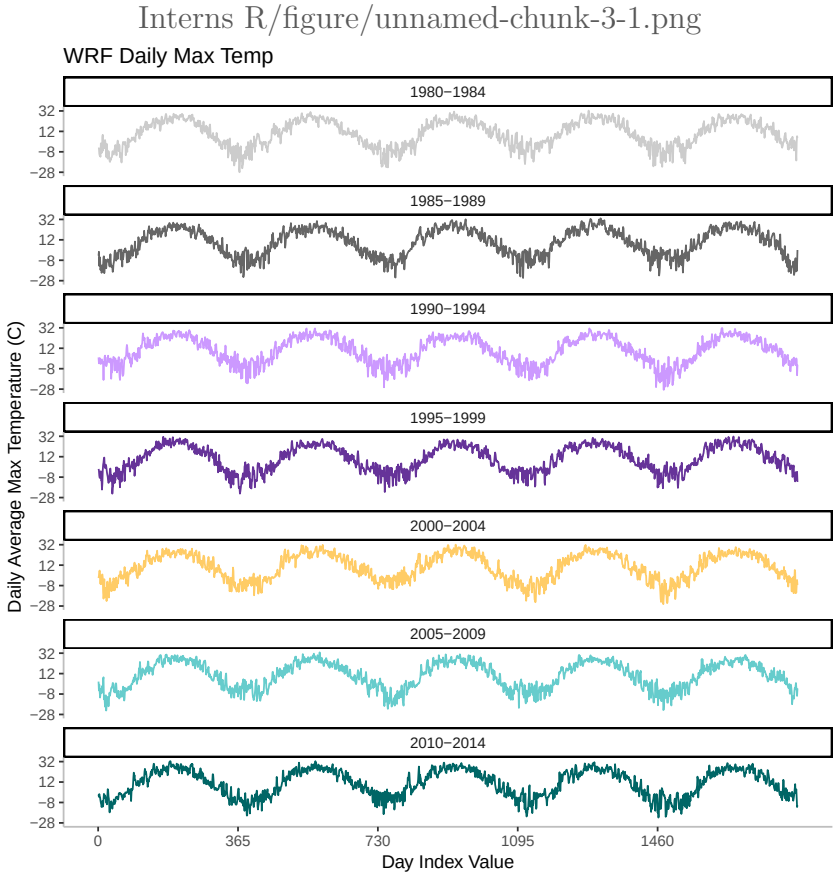

Figure 1: Time Series for daily WRF Max Temperature data from 1980 to 2014 over 5 year periods

The figure one displays a time series for WRF model daily temperature data from 1980-2014 divided into 7 individual 5-year graphs, each period indicated by a different color. This is an average over all WRF data. The cyclical trends are expected; colder summer transitiioning to warmer summers and back down to cool end-of-year temperatures. Winter of 2002 (light yellow) was predicted warmer in comparison to other years. There also appears to be more variation in the middle to late winter months (January-Febuary) each year.

2 Time Series Plots for Station Data

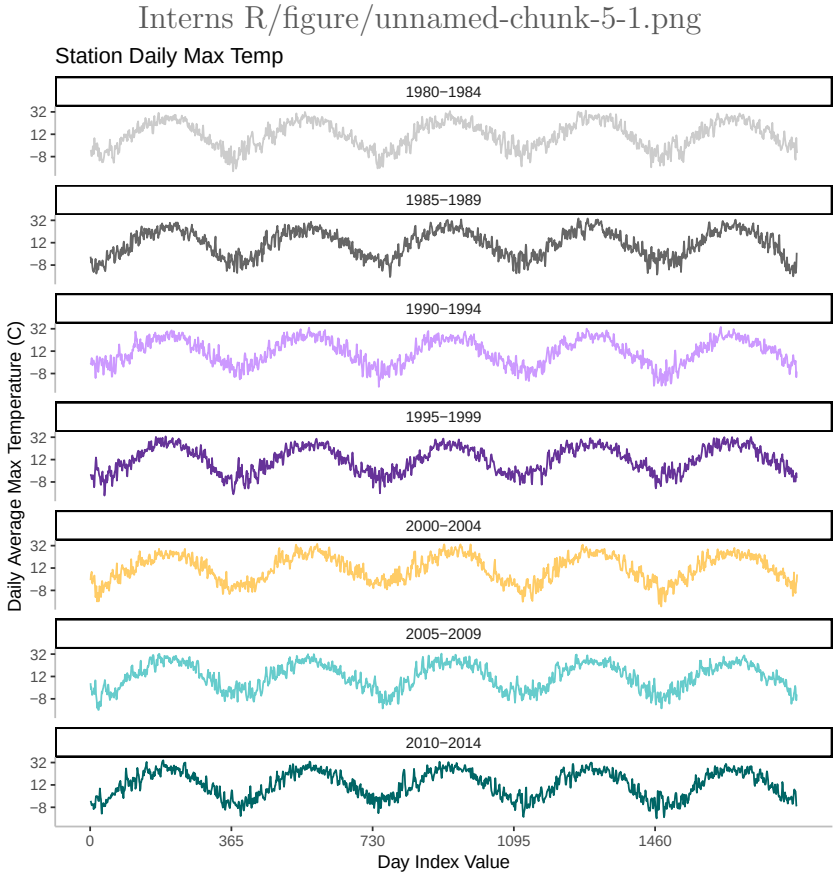

Figure 2: Time Series for daily Station Max Temperature data from 1980 to 2014 over 5 year periods

The figure above shows the daily maximum temperature from station data for all stations from 1980-2014 indicated by different colors. Winter of 2002 is slightly warmer as also observed in the WRF model time series previously. Again, winter month tend to have slightly more variation in maximum temperature in comparison to the rest of the year for each year.

3 Time Series Comparison for WRF and Station Data

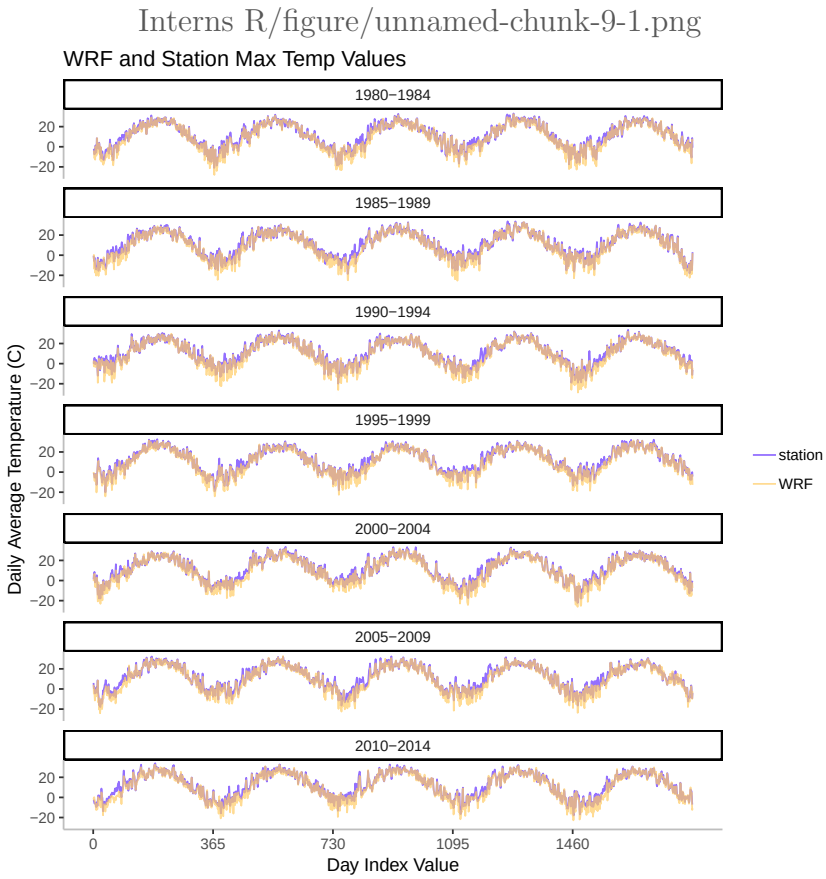

Figure 3: Time Series for daily Station and WRF Max Temperature data from 1980 to 2014 over 5 year periods

Now, we have a comparison time series of both Station and WRF data from the same time period as the previous two plots, this time WRF indicated by the yellow time series and the station time series indicated by purple. One can see that WRF overestimates winter maximum temperatures. As temperatures rise in the spring months, WRF tends to then underestimate daily maximum temperautres. This occurs specifically for spring of 1980, '82-'85, '87, '93, '94, '96-'99, 2004, '07-'09, and 2010.

4 Daily Differences for Station and WRF data for TMAX

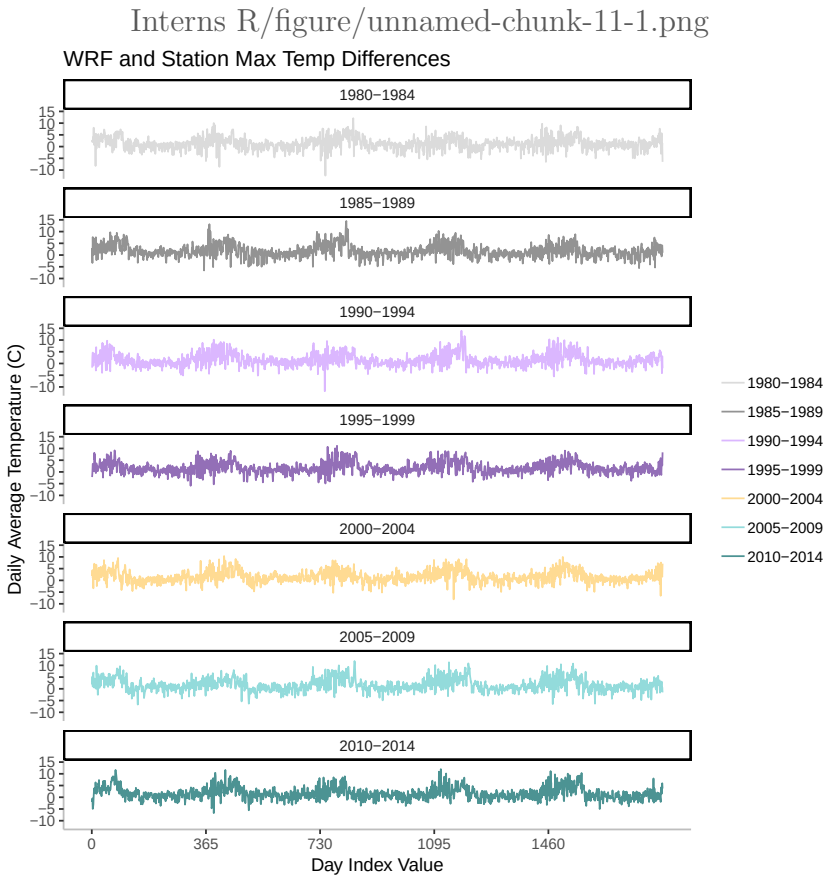

Figure 4: Difference in daily maximum temperature between observed station data and WRF model predictions

Unlike before, we have no taken the difference between each daily temperature observed by station data and predicted by the WRF model. The dense clusters of each graph indicate a greater difference between the observed versus estimated maximum temperature. This occurs during the winter months, which affirms the preious observations in Figures 1-3.

5 Temperature Differences

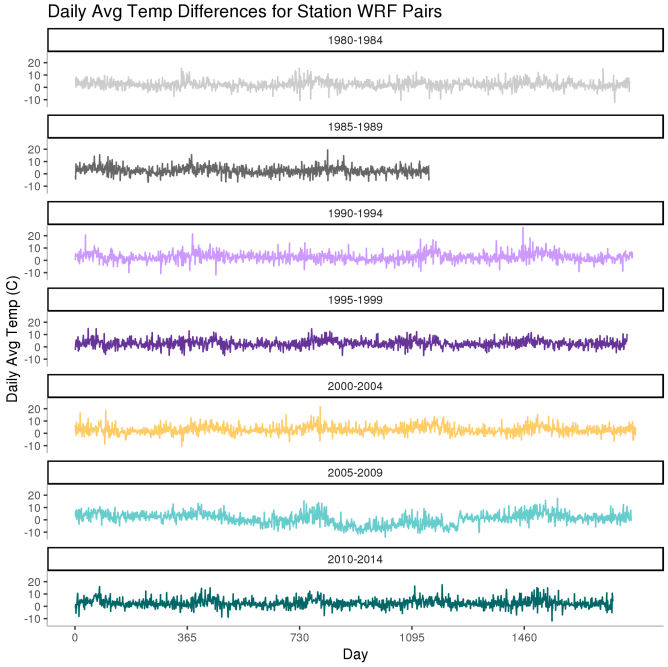

Figure 5: Station WRF Pair Differences for individual station

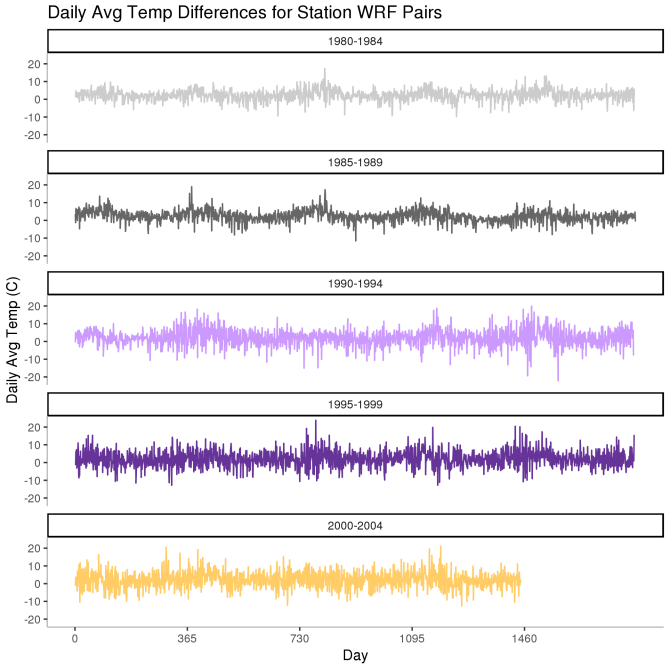

Figure 6: Station WRF Pair Differences for individual station

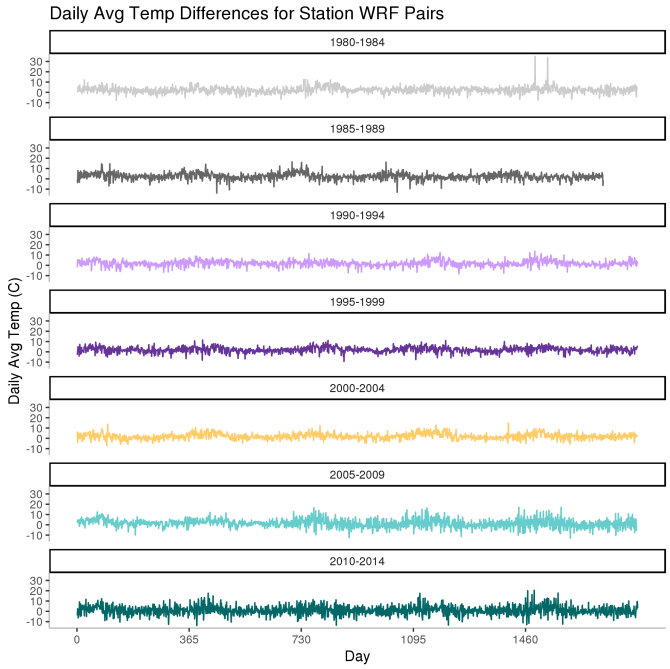

Figure 7: Station WRF Pair Differences for individual station

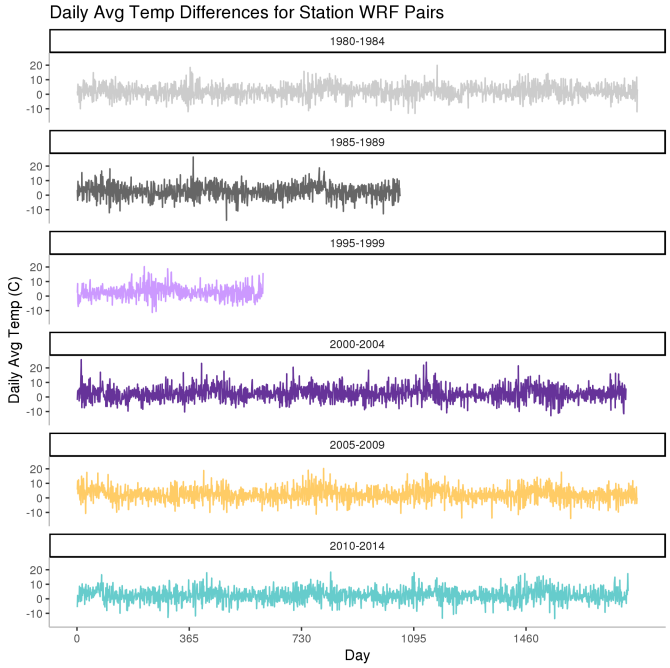

Figure 8: Station WRF Pair Differences for individual station

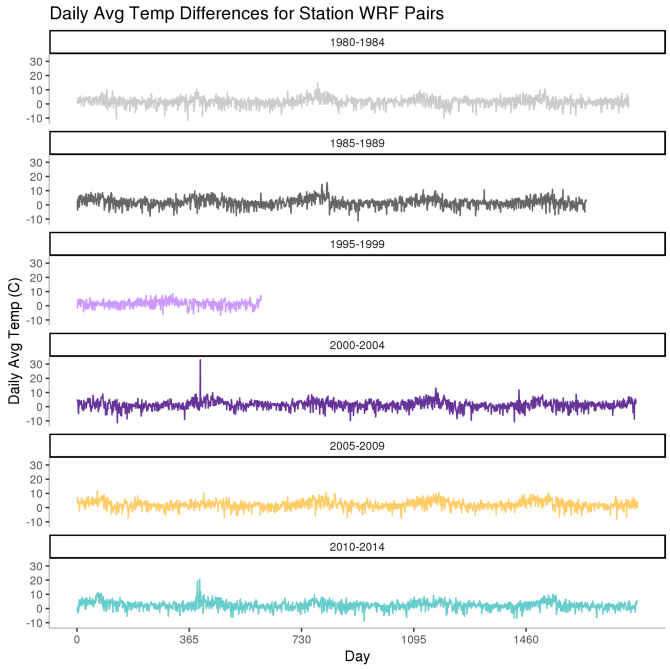

Figure 9: Station WRF Pair Differences for individual station

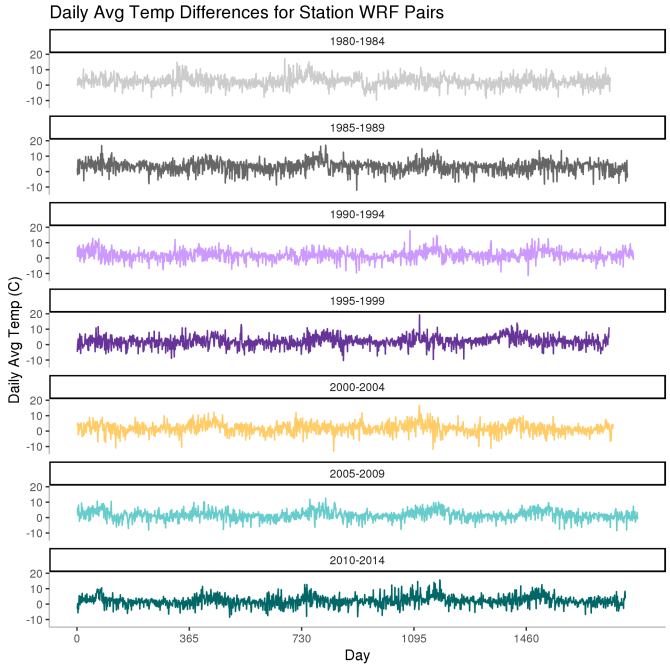

Figure 10: Station WRF Pair Differences for individual station

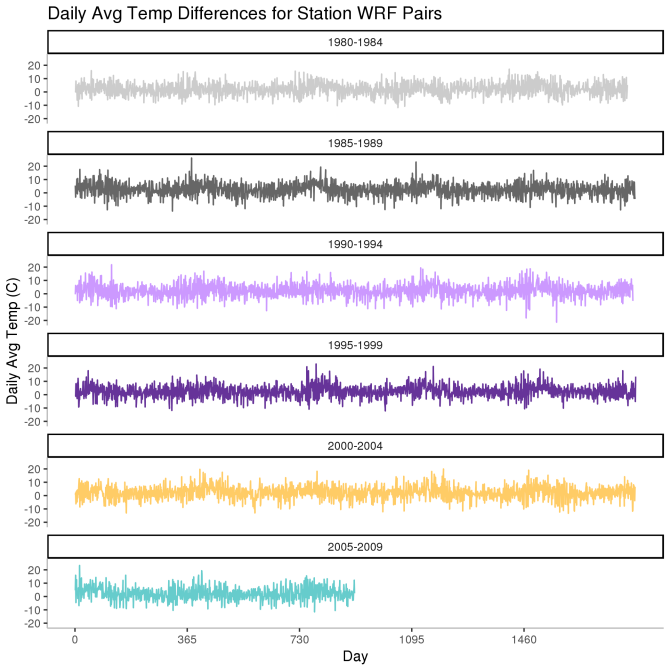

Figure 11: Station WRF Pair Differences for individual station

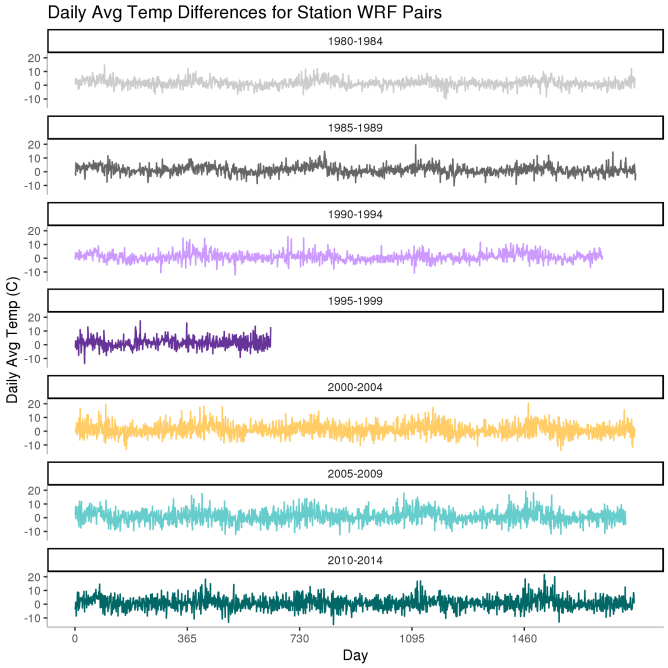

Figure 12: Station WRF Pair Differences for individual station

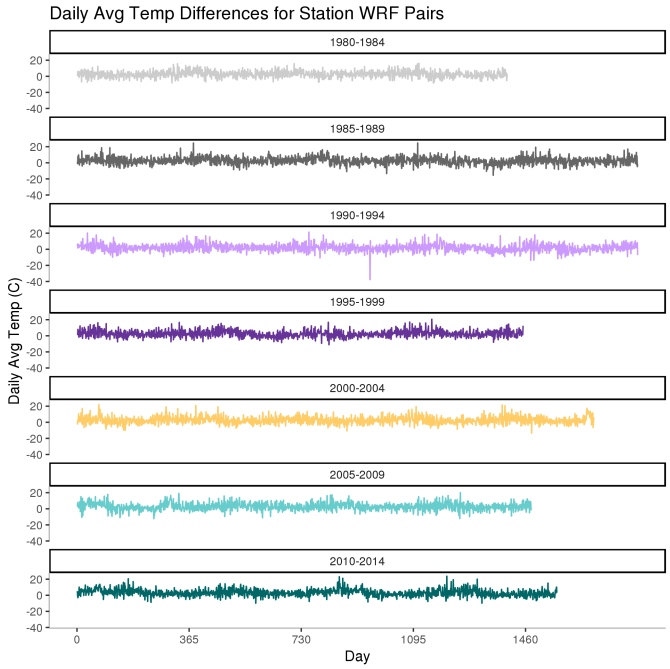

Figure 13: Station WRF Pair Differences for individual station

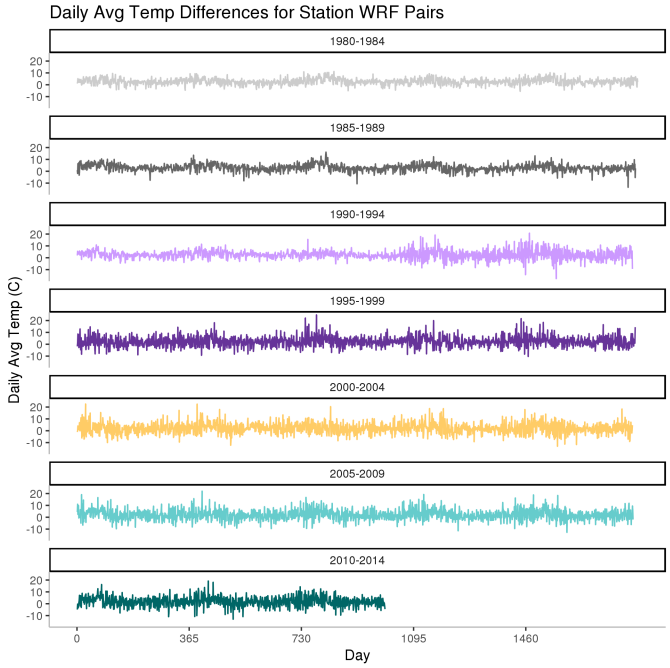

Figure 14: Station WRF Pair Differences for individual station

The 10 plots above display the daily maximum temperatures between 10 randomly selected individual stations and WRF predictions, as opposed to Figure 4 which is a comparision between all stations. Some data is missing or unavailable for certain years and/or months. There are no notable trends.

6 90th Percentile Station and WRF Data by Season

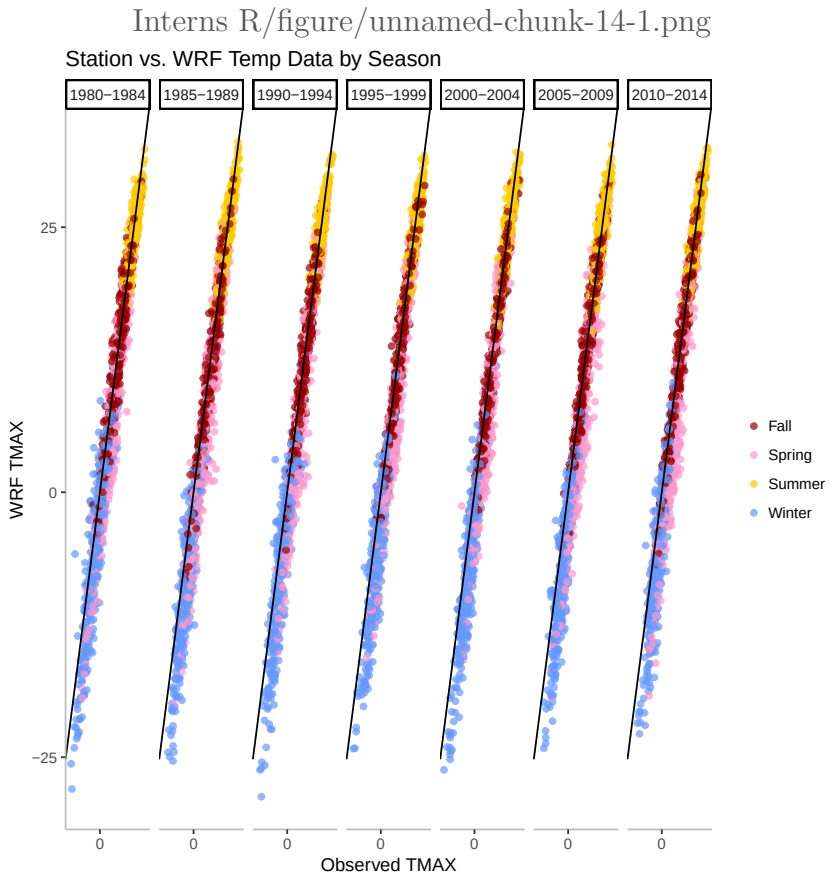

Figure 15: Scatter plots of observed station data versus WRF data in consideration of season

Each season is indicated by color. Again, winter is the most variable season across the years for daily maximum temperature. This is in accords with previous observations.

7 Perkins Skill Score and Maps for TMAX Across Space and Time

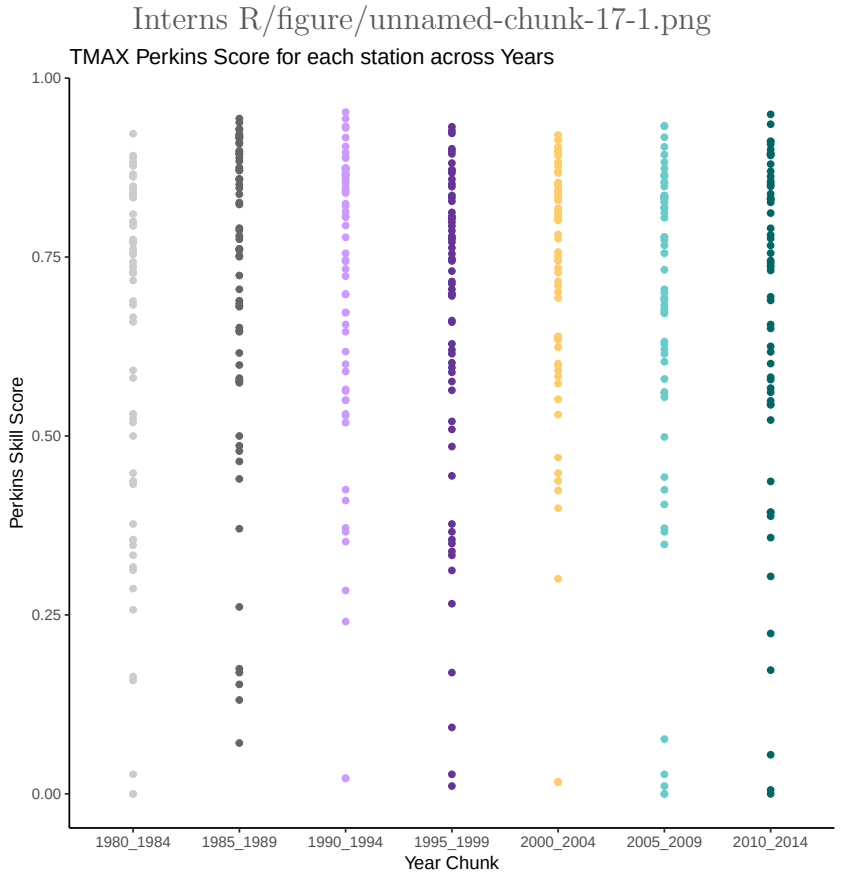

Figure 16: Perkins Skill Score for every station across 35 years

A Perkins Skill Score is a measure of a probability density function's performance [S.E. Perkins, 2007] In this case we compare the PDF of the distribution of station data and WRF model data. If the model gives precisely opposite results to the observations, i.e. high temperatures when they should be low, and vice versa, but gives the same distribution, it will have a score of 1., and 0 otherwise. The closer the Perkin's score is to 1, the more ideal.

Each 5-year period consists of 73 stations. There is a heavy score concentration between .70-.90. However there is plenty of variability, with considerable low skill scores in each year chunk.

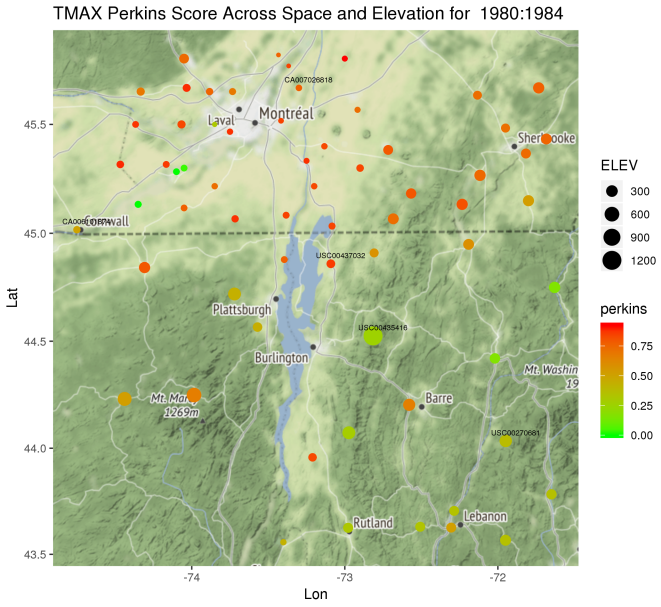

Figure 17: TMAX Perkins Score across space and time

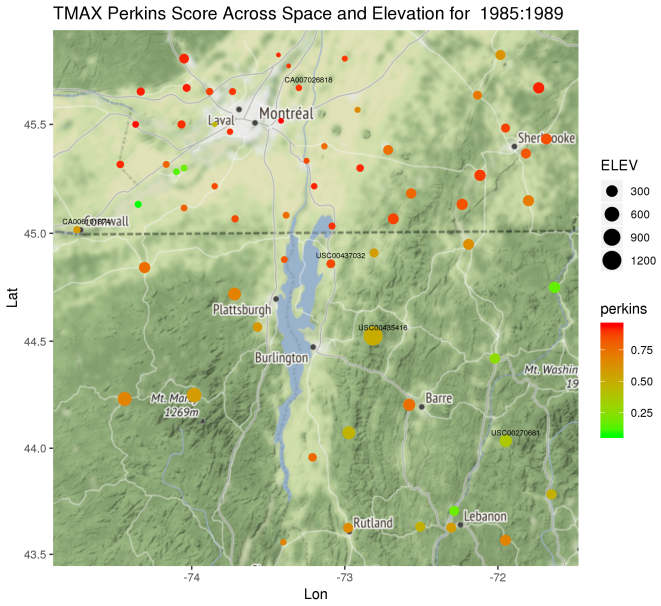

Figure 18: TMAX Perkins Score across space and time

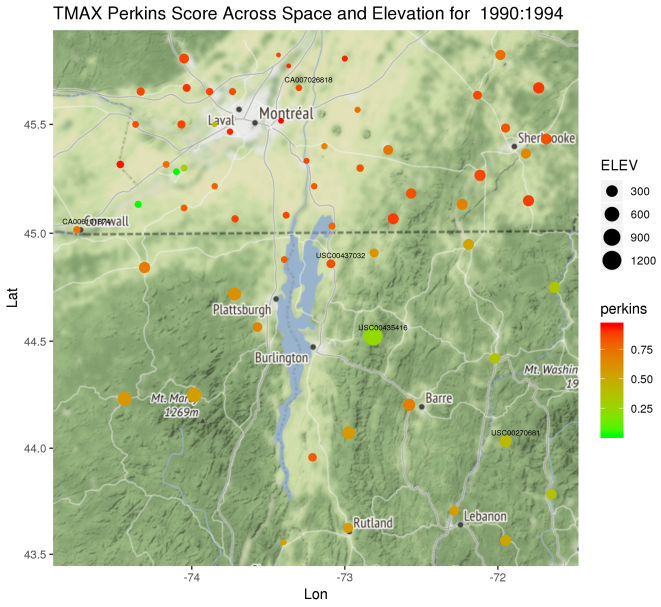

Figure 19: TMAX Perkins Score across space and time

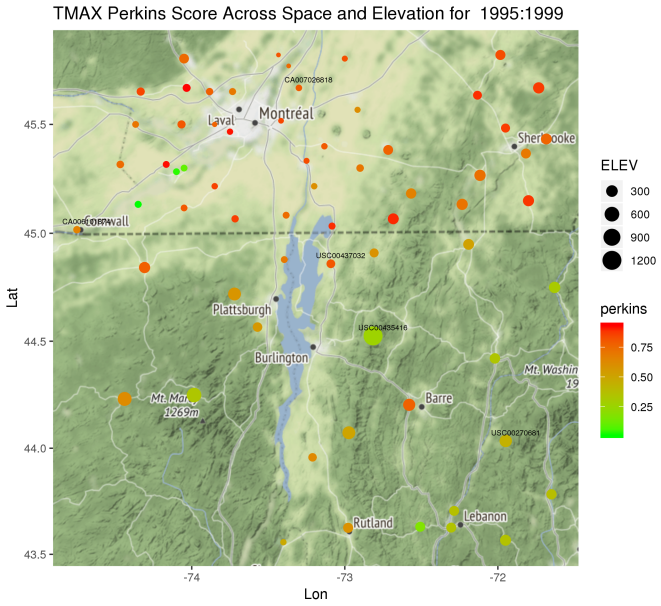

Figure 20: TMAX Perkins Score across space and time

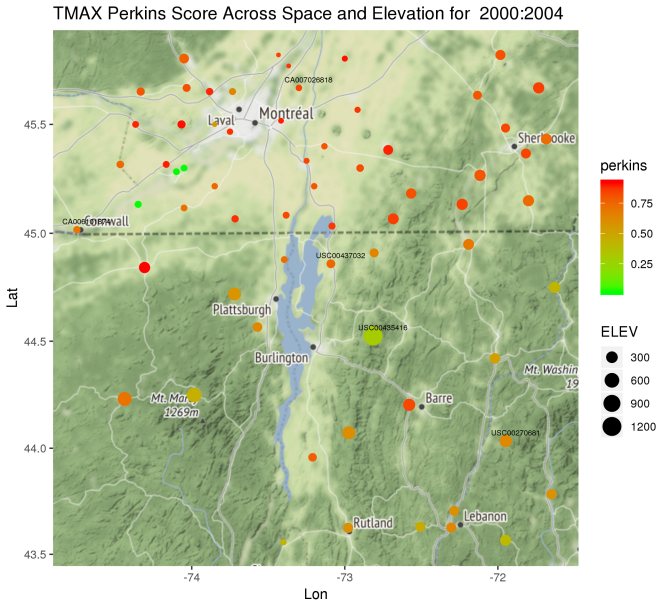

Figure 21: TMAX Perkins Score across space and time

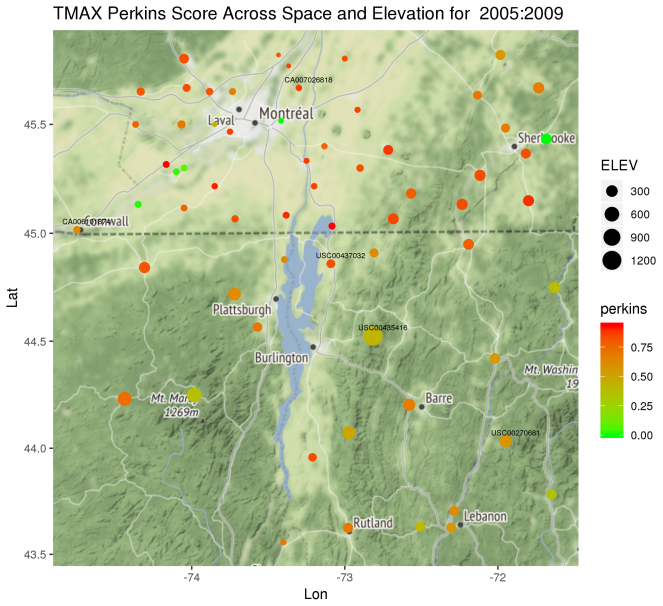

Figure 22: TMAX Perkins Score across space and time

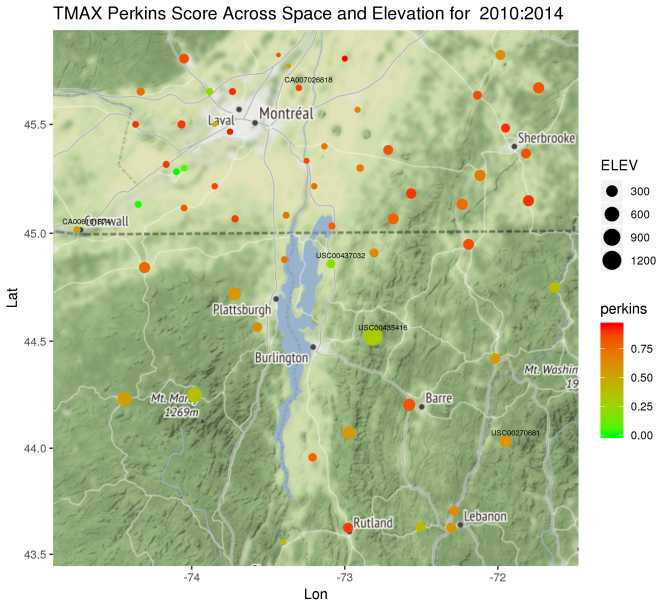

Figure 23: TMAX Perkins Score across space and time

The 7 plots above each correspond to the seven 5-year time chunks from 1980-2014. The maps of the Lake Champlain watershed region pinpoint station locations indicated by different size and colors. Red points imply higher Perkins score in contrast to green points. Bigger points imply the station is located at a higher elevation in contrast to smaller points.

The cluster of stations in the southeast quadrant of the map fade from green to a darker orange as the years progress suggesting their Perkins score improved with time.

The largest point on the map at the highest elevation occurs at Mt. Mansfield, the highest point in Vermont. Specifically this point is station ID USC00435418. Overall, this station has a low, variable Perkins score. This could be due to the climate flucuation on the mountain at this altitude.

The three station points northeast of Cornwall, CAN have a score of 0 on every map. There could suggest a malfunction in these stations.

Lastly, station USC00437032 located just east of St. Alban's Bay on Lake Champlain has a very high Perkins score up until the most recent time period 2010-2014, it abruptly drops significantly.

8 Perkins vs. Elevation

Year Chunk	Avg Perkins Score
1980-1984	0.6353250
1985-1989	0.7086584
1990-1994	0.7010379
1995-1999	0.6664096
2000-2004	0.7079513
2005-2009	0.6803376
2010-2014	0.6866988

Interns R/figure/unnamed-chunk-21-1.png

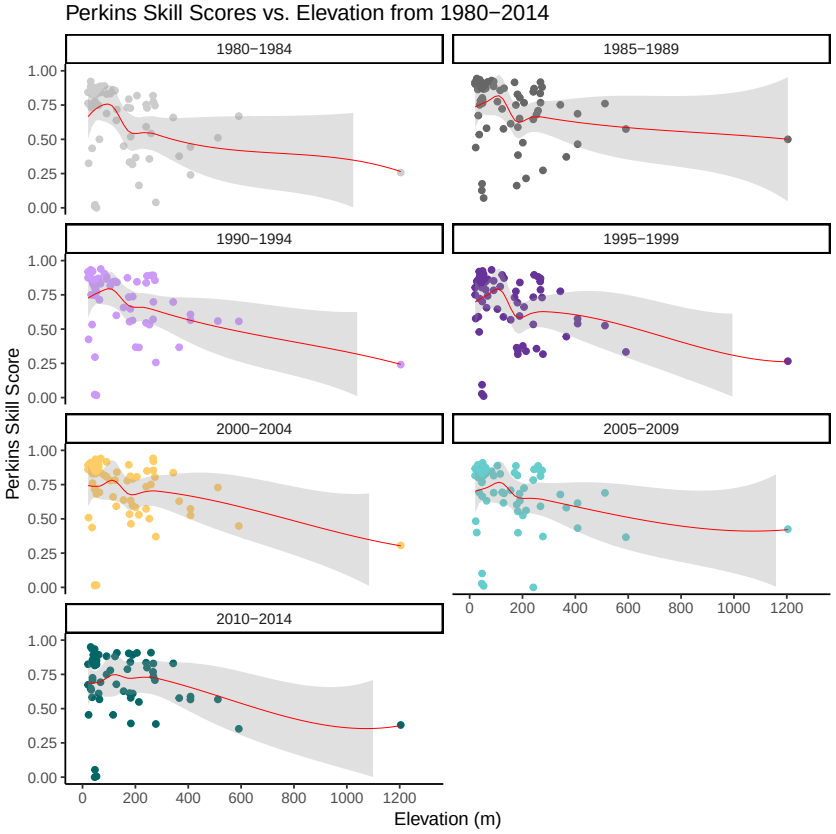

Figure 24: Scatterplot of Perkins Score vs. station elevation

Figure 24 depicts a scatter plots comparing Perkins scores to station elevation from 1980 to 2014. This setup allows us to see if there exists any association or reltionship between these two variables. For each graph, the perkins score seems to cluster around values greater than 0.50 and slightly around higher elevations. 1980-1984 has the most variation. Each graph has a couple outliers in the bottom-right quandrant probably due to limited observations for these stations at such a high elevation. This agrees with the plots in fig. 17-23.

9 WRF Station 90th Percentile Histogram Density Plots

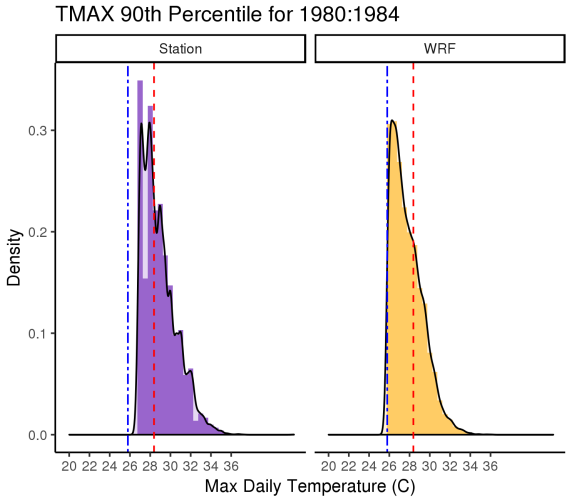

Figure 25: Station and WRF temperature density plot

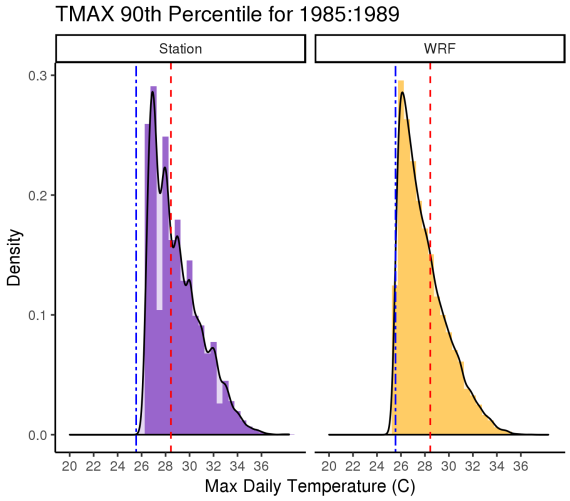

Figure 26: Station and WRF temperature density plot

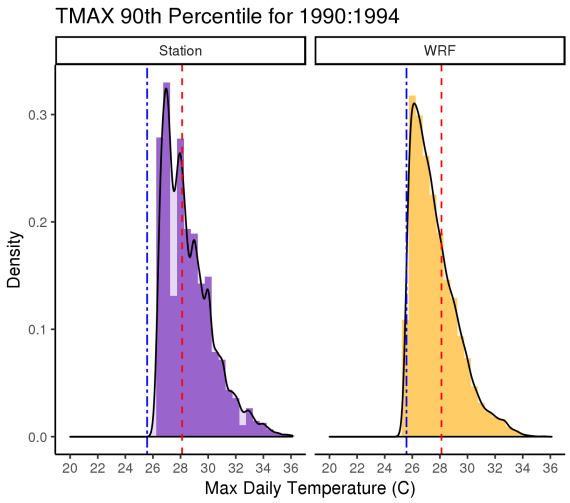

Figure 27: Station and WRF temperature density plot

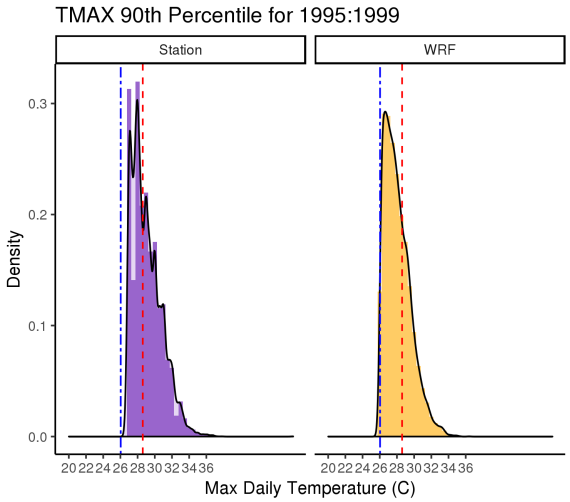

Figure 28: Station and WRF temperature density plot

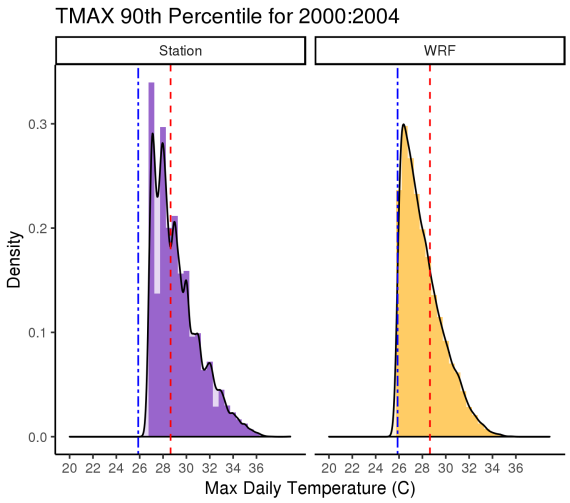

Figure 29: Station and WRF temperature density plot

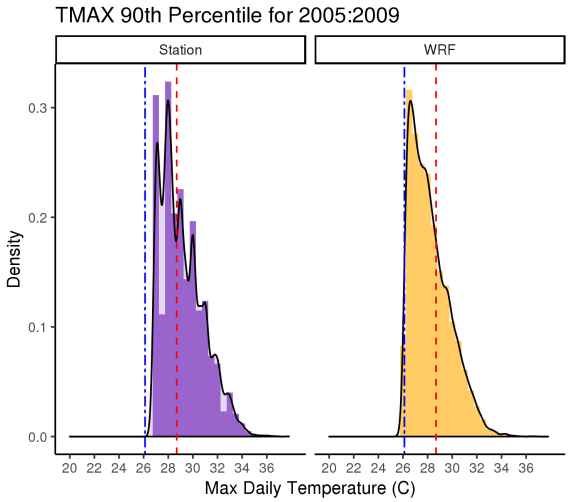

Figure 30: Station and WRF temperature density plot

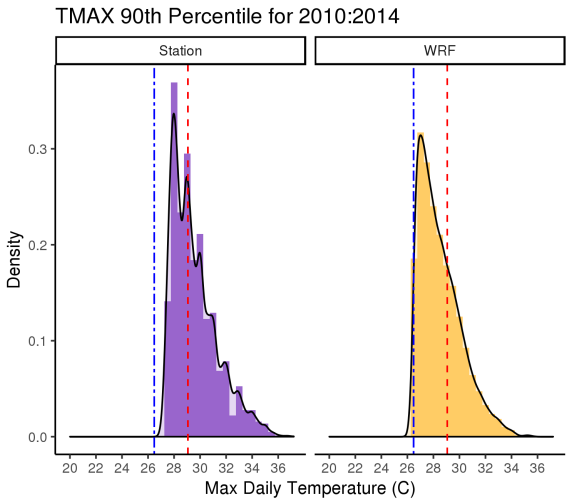

Figure 31: Station and WRF temperature density plot

Each of the following density plots correspond to each of the seven 5-year chunks for daily maximum temperature data. A density plot visualizes the distribution of data over a continuous interval or time period, in this case the 5-year chunks we have been observing. The blue dotted line indicates the minimum of the plot, and the red line indicates the mean. The peaks of each density plot help display where values are concentrated over the interval.

In each graph, it it shown that the distribution of station data, indicated by purple, is skewed right (positively skewed) and has a jagged appearance compared to the WRF distributions. This could be due to the natural flucuation and variation in temperature patterns within a given climate system. From the plots, we can see WRF's distrubution is skewed farther right that the observed data.

10 Biased Corrected Perkins Scores

Year Chunk	Avg Perkins Score
1980-1984	0.8202719
1985-1989	0.8191793
1990-1994	0.7982077
1995-1999	0.8118544
2000-2004	0.8471386
2005-2009	0.7886212
2010-2014	0.7918916

Interns R/figure/unnamed-chunk-26-1.png

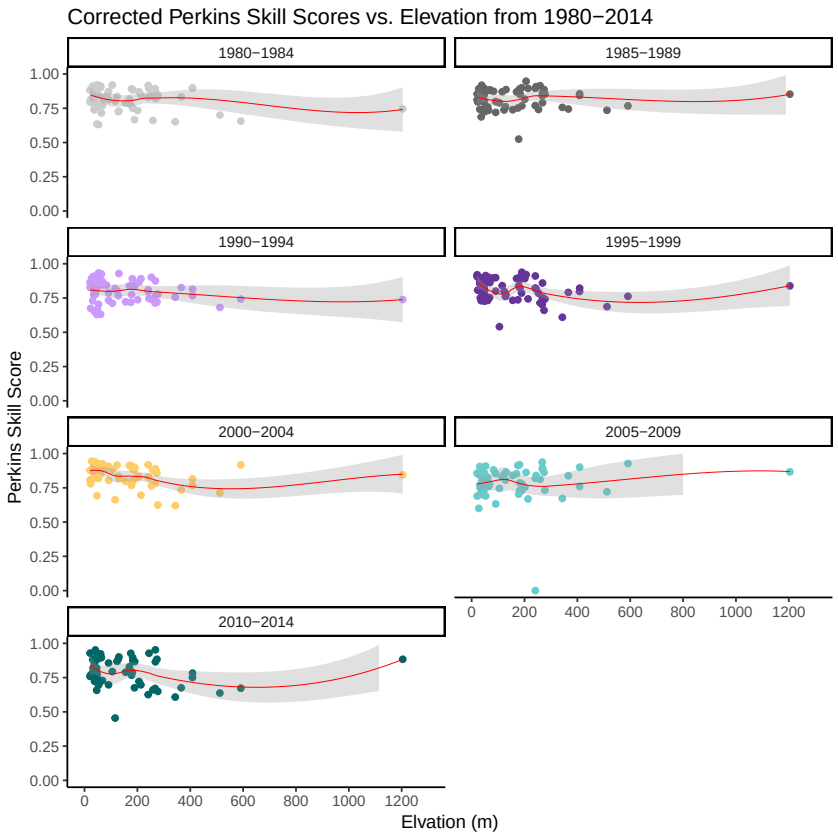

Figure 32: Biased Corrected Perkins Skills Score vs. Elevation for TMAX 1980-2014 by Year

Figure 32 displays the bias corrected Perkins Skills Score across time and elevation. In this situation we corrected by year. In particular, 2010-2014 and 1995-1999 are more heroskedastic in comparison to the other years. We see overall lower score produced by stations.

11 Biased Corrected Perkins Skill Scores Across Elevations by Month

Year Chunk	Avg Perkins Score by Month
1980-1984	0.8325487
1985-1989	0.8151219
1990-1994	0.8130233
1995-1999	0.8281359
2000-2004	0.8508491
2005-2009	0.8205128
2010-2014	0.8135327

Interns R/figure/unnamed-chunk-30-1.png

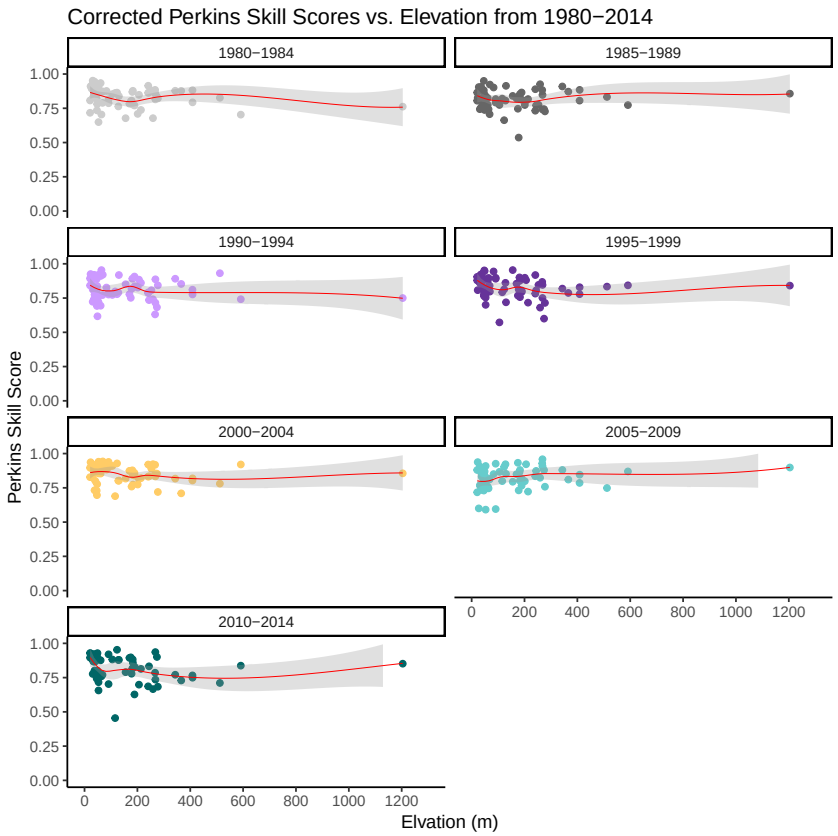

Figure 33: Biased Corrected by Month Perkins Skills Score vs. Elevation for TMAX 1980-2014

The biased corrected points show are more consistent and homoskedastic in shape and form in contrast to Figure 32 on the previous page. This is what we expect to see after corrected the data by month. Overall we see higher Perkins Skill Scores in each year chunk but especially in 2010-2014. The majority of stations still have scores around .75 which is lower than what would be considered ideal. This plot is more suitable to show perkins scores.

12 Bias Corrected Perkins Score Distributions Across Year Chunks

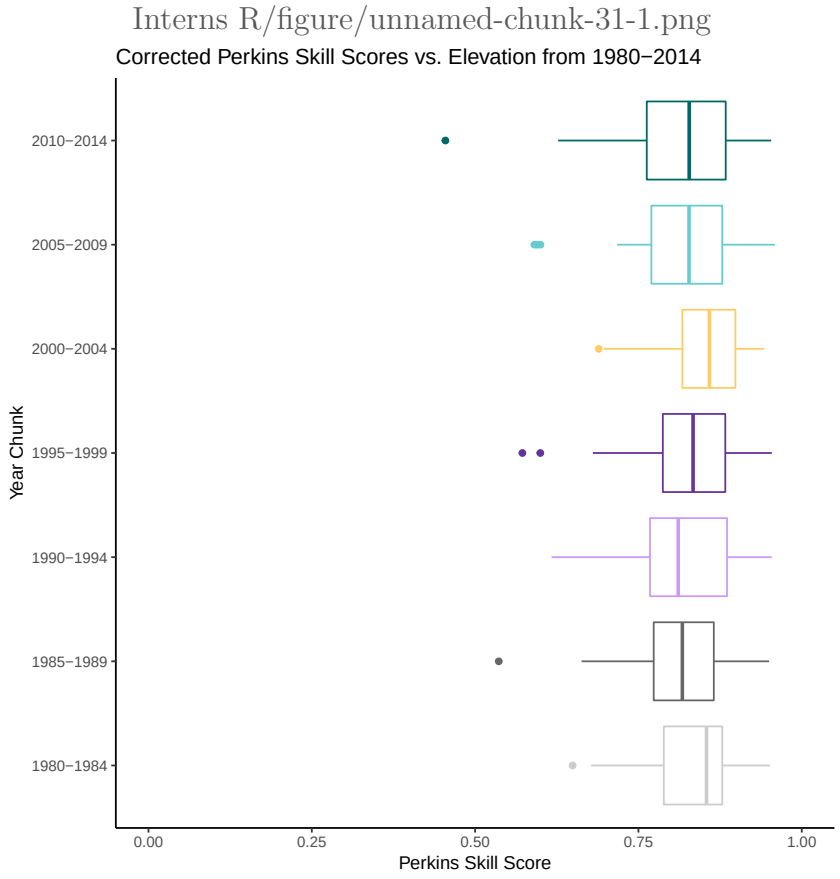

Figure 34: Biased Corrected Perkins Scores vs. Elevation corrected by month

The boxplots displayed in Fig. 34 show the distribution of perkins scores for each year chunk. We see the widest distribution in 2010-2014, where as earlier in 2000-2004, the perkins scores where more highly concentrated in the top 70 percent.

13 Density Plots Comparing Corrected WRF Data

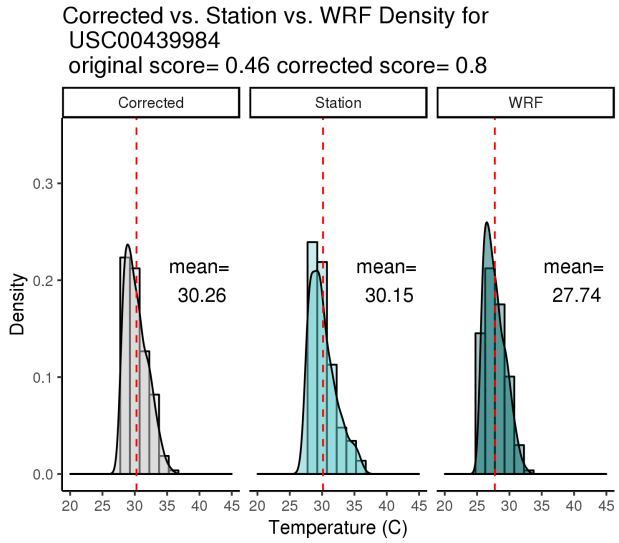

Figure 35: Corrected Data vs. Station vs. WRF 90th Percentile Density Plot for USC00439984, 2000-2004

The graphs above are a comparison of the density distributions between the maximum daily temperature for station data, raw WRF data and the bias corrected WRF data as indicated in the different colored plots. The peaks of a density plot help display where values are concentrated over the interval. An advantage these plots have over Histograms is that they're better at determining the distribution shape because they're not affected by the number of bins used. The average (mean) Perkins Skills Score is printed on the right of each distribution and indicated by the red, dashed lines. Each graph appears to be concentrated around cooler temperatures, particularly 30 degrees Celcius. In general we see a positively skewed distribution for the Corrected panel, and the mean for the raw WRF panel fairs more to the right of the distribution. Overall the WRF mean is lower and the Corrected data matches more accurately with the station data. From the 31 plots created over different time periods, theere is a .276 increased on avergae of Perkins Skills Score between the Bias Corrected Perkins Score and Original, the maximum differenece being .56 and the minimum being .02.

This station in Figure 35 is displays the general trend we see in the overall data.

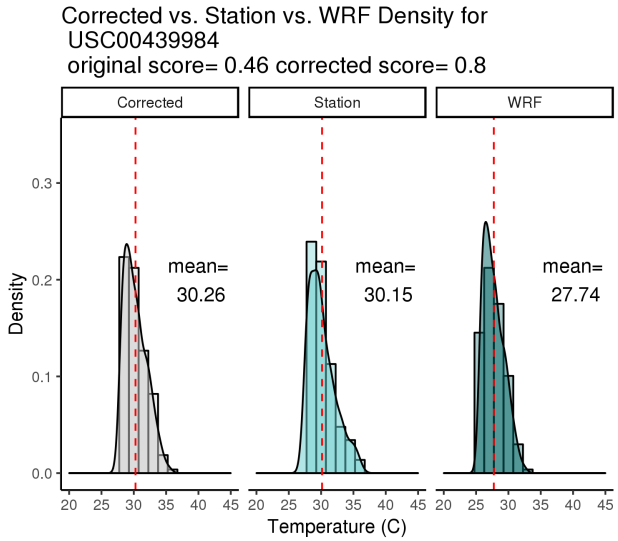

Figure 36: Corrected Data vs. Station vs. WRF 90th Percentile Density Plot for USC00437032, 2000-2004

Figure 36 displays the overall trend of data as described in Figure 35.

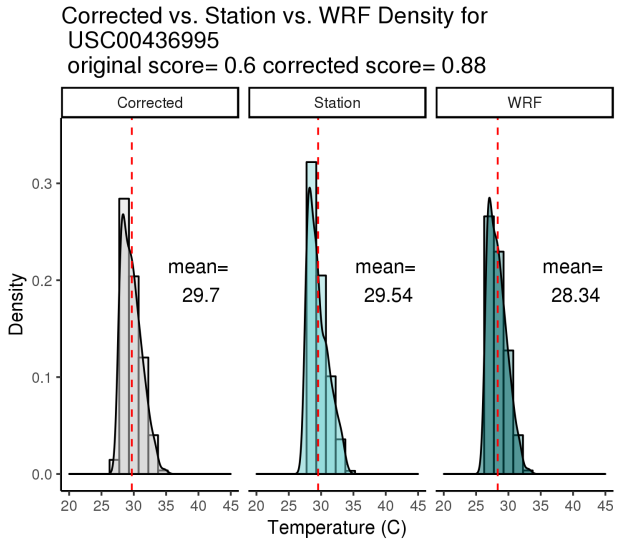

Figure 37: Corrected Data vs. Station vs. WRF 90th Percentile Density Plot for USC00436995, 2000-2004

Figure 37 displays the overall trend of data as described in Figure 35.

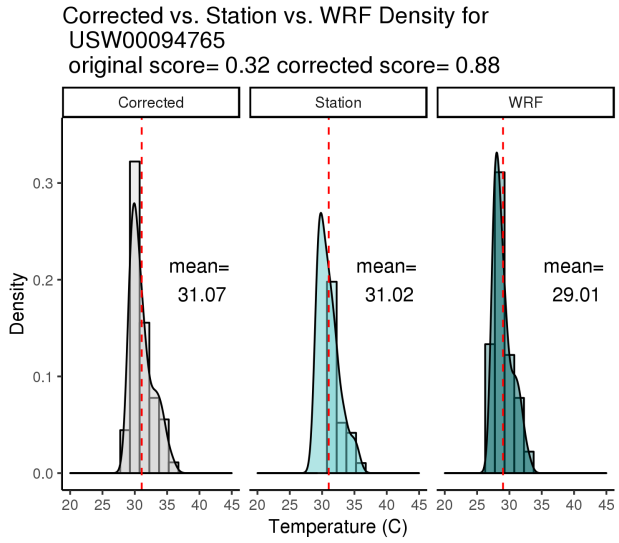

Figure 38: Corrected Data vs. Station vs. WRF 90th Percentile Density Plot for USW00094765, 1995-1999

Fig. 38 displays the plot that produced the greatest difference in Perkins scores between the original data and bias corrected data (.56). This same plot all is one of three that produced a maximum corrected Perkins score of .9.

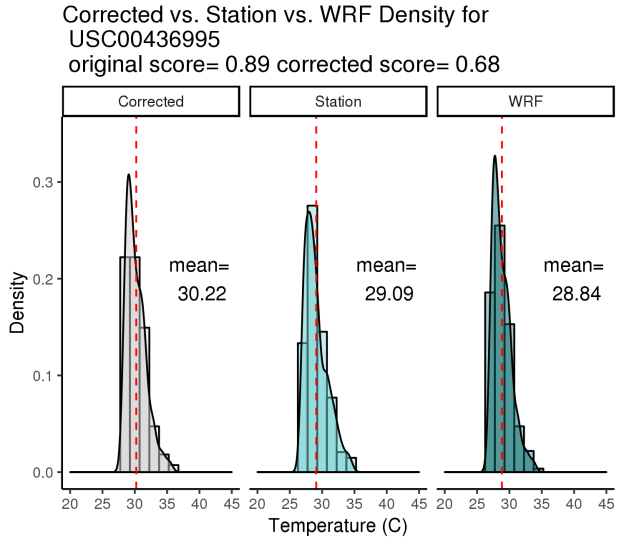

Figure 39: Corrected Data vs. Station vs. WRF 90th Percentile Density Plot for USC00436995, 2010-2014

The above figure displays, unlike the other constructed plots. the Perkins score actually decreased by .21, going against the common trend.

14 Density Plots Comparing Corrected WRF Data on Training Data

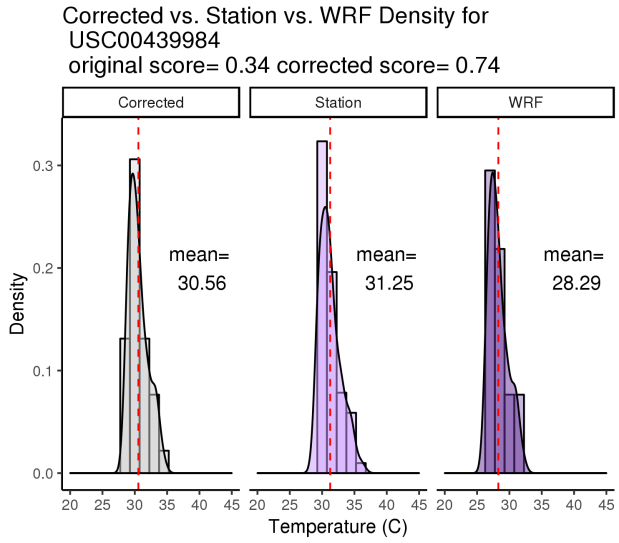

Figure 40: Corrected Data vs. Station vs. WRF 90th Percentile Density Plot for USC00439984, 1995-1999

The methods follow the similar process. This time, data was ONLY corrected from 1996-2014 based solely on data from 1980-1995, whereas before we were corrected all data based on all the data. This would be an unrealistic approach if we wanted to correct future WRF data for which we didn't have station observations. That is why it is important to look at how well bias correction performs based on only a subset of the data.

The patterns emerge in this data as in the section before. The raw WRF data is lower in comparison to the Station data and the Correted panel produces a higher mean, reflecting that of the station data. In general, as shown in Fig. 40, the distibutions are positively skewed, with the mean WRF temperature to the right and mean Corrected temperature to the left. There is muchsonsistency throughout the 15 plots created.

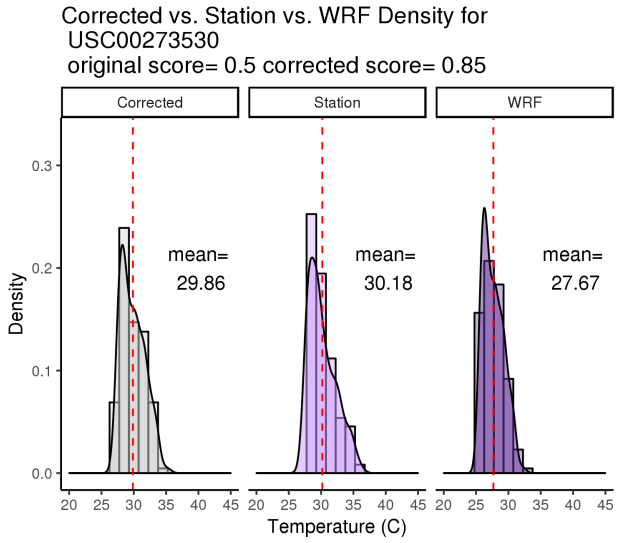

Figure 41: Corrected Data vs. Station vs. WRF 90th Percentile Density Plot for USC00273530, 2000-2004

Figure 41 displays the overall trend of data as described in Figure 40.

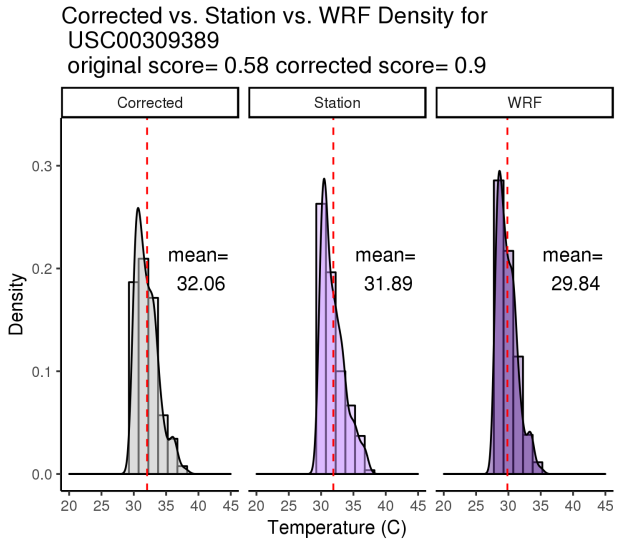

Figure 42: Corrected Data vs. Station vs. WRF 90th Percentile Density Plot for USC00309389, 2010-2014

Figure 42 displays the overall trend of data as described in Figure 40.

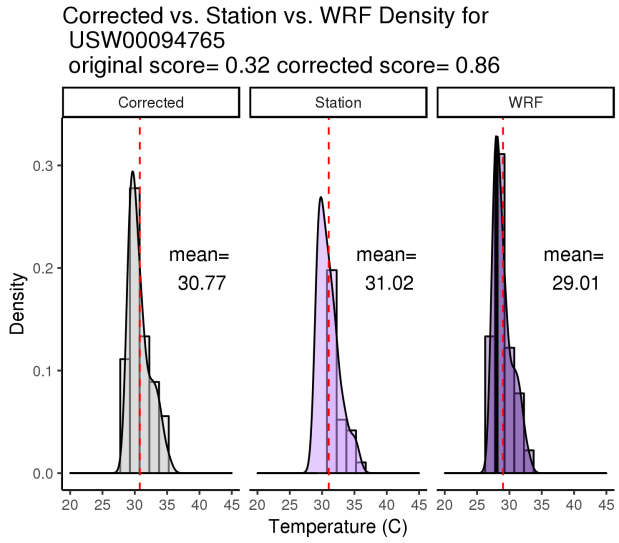

Figure 43: Corrected Data vs. Station vs. WRF 90th Percentile Density Plot for USW00094765, 1995-1999

Fig. 43 displays the plot that produced the greatest difference in Perkins scores between the original data and bias corrected data (.54). 2 sets of plots produced a maximum corrected Perkins score of 0.9 and they were station IDs USC00309389 in 2010-2014 and USC00273530 in 1995-1999.

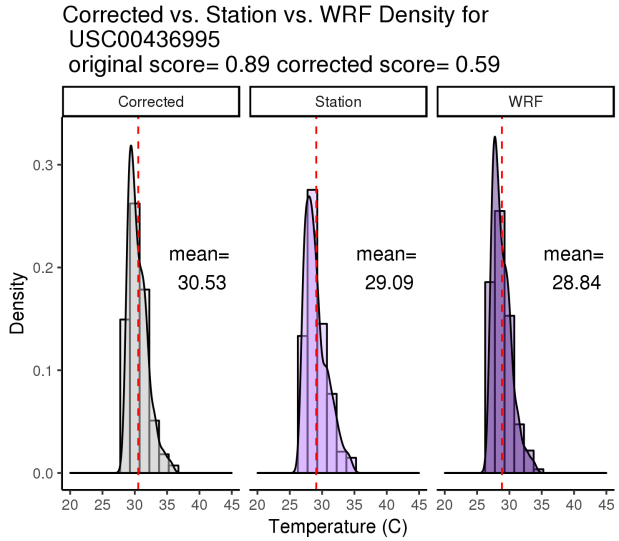

Figure 44: Corrected Data vs. Station vs. WRF 90th Percentile Density Plot for USC0043995, 2010-2014

Figure 44 displays, unlike the other constructed plots. the Perkins score actually decreased by .30, going against the common trend. This same phenomenon occured in the process and comparing raw WRF data to station and corrected data with out training on certain years.