MONTHLY TRENDS IN MAXIMA OF LOW TEMPERATURES IN GEORGIA, USA

by

WALEED DE JESUS NAVARRO

(Under the Direction of Lynne Seymour)

ABSTRACT

The monthly maxima of daily low temperatures in the state Georgia are investigated using data from 43 stations taken from the Georgia Automated Environmental Network (GAEMN). Bootstrap methods for time series data are used to model the distribution of the maximum of the low temperatures for each month at each station. The mean and standard deviation of each distribution are then used to standardize each station’s data to determine trends. Rates of increase and/or decrease along the distributions are presented along with significance levels. To display the results, contour plots of Georgia are created for each month with the use of a weighted head-banging spatial-smoothing analysis to account for the significance of the trends.

INDEX WORDS: moving block sub-sampling, bootstrap, correlation, time series, standardize, weighted-headbanging, climate change
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Temperature trends are always controversial issues. One may hear about it with respect to global warming, global cooling, changing weather patterns, etc. Whether these changes in trends are significant or minimal, they affect the lives of individuals daily. Temperature changes affect the state of Georgia greatly since agriculture is a major industry. Some of Georgia’s major products include peanuts, pecans, cotton, tobacco, soybeans, corn, hay, oats, sweet potatoes, and of course peaches. Any change in temperature has the potential to hinder production of these products, which could also have a significant impact on economic trends. For these reasons, USDA plant hardiness maps are readily available to determine what type of plants can be grown in each area of the United States. The maps (Figure 1.1) are organized by zones to distinguish between the possible choices of plants (Masters, 2012).

A comparison of the 2012 USDA Plant Hardiness Zone Map with the 1990 version (Figure 1.1) shows all hardiness zones creeping northward suggesting a warming climate trend since plants growing in warmer climates are now able to grow in areas that used to have colder climates. While these maps depict warming in the overall climate, the rate of warming is not examined.
The objective of this research is to determine whether there are significant changes in the maxima of the low temperatures in the state of Georgia, and to identify where those changes are occurring. Much of the analysis done here is inspired by temperature trend articles by Lund, Seymour, and Kafadar (2001) and Lu, Lund, and Seymour (2005). The maxima of the low temperatures are investigated because cooler temperatures are warming much faster than warmer temperatures so any trends might be much easier to detect. Also, extreme temperatures can tell a more comprehensive and compelling story when examined more closely. Furthermore, the results are divided into seasons since each season has displayed varying results in the aforementioned articles.

The data and its source are discussed in further detail below. The smaller size of the data available for this study and its complex dependence leads to the use of a moving-block sub-sampling bootstrap method for time series data. More on the bootstrap method is discussed in Chapter 2 along with standardization methods to determine any changes in the temperature trends and their significance. Results, discussion, and conclusions are discussed in Chapter 3 along with very illuminating geographic maps displaying the findings of this research.
research. Finally, Appendix A contains the monthly trends and their significance along with rate translations to celcius. Appendix B contains plots of the monthly trends organized by season within each station.

1.1 The Data

The data used in this study are taken from The Georgia Automated Environmental Monitoring Network (GAEMN). The GAEMN is an extensive network of automated weather stations in the state of Georgia developed beginning in 1991 by the College of Agricultural and Environmental Sciences at the University of Georgia. It currently consists of 81 weather stations collecting up to 66 weather variables at each station roughly every 15 minutes (GAEMN, 2012). The amount of available data vary by station due to new stations being installed as more funding becomes available. More information about the GAEMN can be found at www.griffin.uga.edu/aemn/AEMN.htm.

![Figure 1.2: Low Temperatures for Tifton, GA](image)

The variable of interest in this study is the monthly maximum of the daily low air temperatures. An example of available data for the Tifton station is presented in Figure 1.2. Daily minima are taken from a midnight to midnight time frame on the celcius measurement scale. The quality of the data is excellent. However, to avoid extremely small sample sizes,
only stations containing at least 10 full consecutive years are included in the analysis. Fur-
thermore, partial months (usually occurring when stations are first installed) are discarded
to avoid any discrepancies when taking the maximum of each month.

After imposing the restrictions on the dataset, a total of 43 stations are used in this
analysis. Figure 1.3 shows the locations of these stations - one can see a nice distribution
of the stations throughout Georgia. The earliest recorded data are from the fall of 1991
and the latest is from March 2012 (totaling a duration of 10 years to a little over 20 years).
Seasonality in both mean and variance is obvious in Figure 1.2. These are accounted for
in the statistical analysis. Although a minimum of 10 years of data is arbitrarily chosen,
a minimum of 9 years only increases the number of stations by 7 to 50, a minimum of 8
increases the total number of stations to 56, and a minimum of 7 increases the total number
to 61. Although one would like to have as much data as possible, the spatial distribution of
the 43 stations is very good and bootstrapping from much smaller sample sizes may reduce
the quality of the results.

Figure 1.3: Station Locations
Chapter 2

Methods

2.1 A Seasonal Moving-Block Bootstrap

With time series data, there is a complex dependence between observations over time. Figure 2.1 shows the autocorrelation and partial autocorrelation plots of the data from the Tifton station. There is a heavy time series dependence because of the trend, at least in the ACF. Simple bootstrap methods assuming independent and identically distributed observations are not appropriate in this case. Instead, a moving block sub-sampling bootstrap (MBB) method is used because of its ability to preserve the original autocorrelation structure of the series, including any seasonal component that may be present in the data (Politis, 1999).

The idea behind any bootstrap method is to investigate the true underlying distribution through resampling - in our case, the monthly maximum of the low temperatures. Bootstrap methods allow one to easily investigate a problem while avoiding oversimplification (Davison, 1997). The bootstrap replaces the cumulative distribution function (CDF) with the empirical distribution which puts equal probabilities $n^{-1}$, where $n$ is the total number of observations, at each sample value $y_j$. The empirical distribution function (EDF) $\hat{F}$ is
defined as the sample proportion

\[ \hat{F}(y) = \frac{\# \{ y_j \leq y \}}{n} \]

where \( \# \{ A \} \) is the number of times event \( A \) occurs (Davison, 1997).

![ACF and PACF for data from Tifton, GA](image)

Figure 2.1: ACF and PACF for data from Tifton, GA

To employ the MBB, the data for each station is first seasonally standardized before it is sampled. This is accomplished in layers. First, a least squares line is fitted and subtracted from the series, leaving a set of residuals. Then a sine function of the form

\[ \hat{z} = a \sin(b \times t + c) \]
is fitted and subtracted from the residuals, leaving a second set of residuals. In this case, 
\[ a = 9.1284, b = 0.0172, c = -2.7794, \hat{z} \text{ is the predicted residual, and } t \text{ is the day number.} \]
The illustrations in Figure 2.2 show the least squares line that is fitted and subtracted from 
the original data, followed by the sinusoidal function that is fitted and and subtracted from 
the first set of residuals.

The last step in seasonally standardizing the data is to divide each observation by the 
standard deviation of the month the observation belongs to. The result is a detrended series 
of correlated residuals from which one can take samples. Figure 2.3 shows the result of 
the standardization process for the Tifton station along with its autocorrelation and partial 
autocorrelation plots. One can see a reduction in the spikes in the ACF and PACF plots 
once the series is detrended. It should be noted that further reduction in the spikes are 
possible by increasing the number of parameters in the sine function, but this has no ready 
interpretation for the data.

To illustrate the procedure, consider June, which has 30 days. The MBB can commence 
by randomly sampling a block of 30 consecutive observations from the standardized data. 
Each block of 30 days from within the first year is sampled with equal probability to simulate 
a month of correlated noise. For example, suppose the block \( e_{241}, ..., e_{270} \) is randomly chosen 
to simulate a June month for the Tifton station. The block is reseasonalized by multiplying 
the standard deviation of June, adding back the fitted sine function, and finally adding back 
the line. Once the bootstrapped June has been constructed, a maximum is taken: this is the 
boostrapped maximum low temperature for June. To preserve seasonal correlation in the 
series, the next block sampled is one corresponding to the same date the following year, i.e. 
\( e_{606}, ..., e_{636}, e_{1002}, ..., e_{1032}, ..., e_j, ..., e_{j+30} \). Tifton has 20 June observations, so that many 
are sampled with this consecutive seasonal MBB construction.

A maximum monthly low temperature is boostrapped 20,000 times per month for each 
station. Figure 2.4 presents boxplots of the 20 actual maximums (left) and the 20,000
Figure 2.2: Detrending of data from Tifton, GA. Plot 1 shows the grand mean that is subtracted and plot 2 shows the sinusoid that is subtracted in order to detrend the data as much as possible.
Figure 2.3: Correlated Residuals and Autocorrelation Structure for Tifton, GA. Plot 1 shows the detrended data from Tifton and Plot 2 and 3 show the ACF and PACF of the detrended series which show a great reduction of the time series dependence, thus preparing the data for the Moving Block Sub-sampling Bootstrap.
Figure 2.4: Actual Maximum vs. Bootstrap Maximum for June at Tifton, GA station. The boxplot of the actual data contains the data points available for June from 1992 until 2011. The bootstrap boxplot contains the 20,000 bootstrapped values.

One can see the bootstrap distribution of the June maximum low temperatures and a few outliers in red. This process is repeated for all months at all stations. Once this is done, investigation of the bootstrap distribution can begin.
2.2 Exploring the Bootstrap Distribution of the Maximum of Low Temperatures

Since the bootstrap distribution of the maximum low temperatures is an estimate for the true population distribution, the bootstrap distribution is used to determine the rate at which the actual maximum low temperatures are changing. Figure 2.5 shows the distribution of the bootstrap values more closely for June in Tifton.

![Figure 2.5: June Bootstrap Distribution for Tifton, GA](image)

The bootstrap mean and standard deviation can be used to standardize the actual temperatures in preparation for analysis. Standardization allows one to "normalize" the values, transforming them to similar smaller scales. After this, a trend line is fitted and the slope is tested for significance using t-statistics, mainly because of its robustness. The values are standardized using the formula

\[ Z = \frac{x - \mu}{\sigma} \]

where \( x \) is the actual recorded maximum low in a given year, \( \mu \) is the mean of the bootstrap distribution, and \( \sigma \) is the standard deviation of the bootstrap distribution. For June in Tifton,
GA, $\mu = 24.8782$ and $\sigma = 1.2563$. The resulting calculations are summarized in Table 2.1.

<table>
<thead>
<tr>
<th>Year</th>
<th>Actual June Maximum Lows</th>
<th>Standardized June Maximum Lows</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>22.50</td>
<td>-1.8931</td>
</tr>
<tr>
<td>1993</td>
<td>23.00</td>
<td>-1.4951</td>
</tr>
<tr>
<td>1994</td>
<td>24.44</td>
<td>-0.3488</td>
</tr>
<tr>
<td>1995</td>
<td>22.89</td>
<td>-1.5826</td>
</tr>
<tr>
<td>1996</td>
<td>23.00</td>
<td>-1.4951</td>
</tr>
<tr>
<td>1997</td>
<td>21.50</td>
<td>-2.6890</td>
</tr>
<tr>
<td>1998</td>
<td>25.38</td>
<td>0.3994</td>
</tr>
<tr>
<td>1999</td>
<td>22.30</td>
<td>-2.0523</td>
</tr>
<tr>
<td>2000</td>
<td>23.04</td>
<td>-1.4632</td>
</tr>
<tr>
<td>2001</td>
<td>23.39</td>
<td>-1.1846</td>
</tr>
<tr>
<td>2002</td>
<td>23.55</td>
<td>-1.0573</td>
</tr>
<tr>
<td>2003</td>
<td>22.74</td>
<td>-1.7020</td>
</tr>
<tr>
<td>2004</td>
<td>24.48</td>
<td>-0.3170</td>
</tr>
<tr>
<td>2005</td>
<td>23.94</td>
<td>-0.7468</td>
</tr>
<tr>
<td>2006</td>
<td>23.55</td>
<td>-1.0573</td>
</tr>
<tr>
<td>2007</td>
<td>23.08</td>
<td>-1.4314</td>
</tr>
<tr>
<td>2008</td>
<td>23.07</td>
<td>-1.4393</td>
</tr>
<tr>
<td>2009</td>
<td>25.03</td>
<td>0.1208</td>
</tr>
<tr>
<td>2010</td>
<td>24.97</td>
<td>0.0730</td>
</tr>
<tr>
<td>2011</td>
<td>24.71</td>
<td>-0.1339</td>
</tr>
</tbody>
</table>

Table 2.1: June Standardized Values for Tifton, GA

Once the bootstrapped $Z$-scores of the actual maxima are derived, one can estimate a trend for the $Z$-scores over time. A line of the form

$$Z = \beta_0 + \beta_1 t + \epsilon$$

where $\beta_1$ (the slope and value of interest to this study) determines the rate at which the $Z$-score changes over time. Figure 2.6 displays a plot of the Tifton $Z$-scores for June along with its trend line. Fitting a regression line also produces a corresponding significance for its slope. The slope of the trend line, the corresponding standard error, and its p-value are 0.0617, 0.0281, and 0.0413, respectively. The slope of 0.0617 indicates that the $Z$-scores of
the maximum of the low temperatures at the Tifton station are advancing farther into the
tail of their distribution over time.

<table>
<thead>
<tr>
<th>Year</th>
<th>Z-Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td></td>
</tr>
<tr>
<td>1994</td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
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<tr>
<td>2002</td>
<td></td>
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<tr>
<td>2004</td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td></td>
</tr>
</tbody>
</table>

![Figure 2.6: June Standardized Trend for Tifton, GA](image)

To translate the slope of the Z-scores back to °C (Celsius), the respective bootstrap
standard deviation that was used to standardize the values previously are multiplied with
the slope. For easy understanding, the rates will be translated into the rate of change per
decade. For instance, a slope of 0.0617 for June in Tifton translates to a change of 0.7976°C
per decade for June at the Tifton station. For a complete list of translations to °C/decade,
see Appendix A.

### 2.3 Weighted Head-Banging

Analysis for each month and each station using the methods in the previous sections produced
a trend estimate and its standard error. These trends are summarized and spatially smoothed
using the weighted head-banging algorithm, which is a form of median smoothing. The goal
is to create maps that smooth out the results by accounting for location and reliability of the neighboring stations (Mungiole, Pickle, Simonson, 1999).

A weighted median smoothing algorithm is carried out by first selecting a station such as Tifton then selecting the desired level of smoothing. In this case, 7 nearly collinear triples of stations, with Tifton being in the center, are selected for smoothing. Seven triples provide a nice level of smoothing in this case. Angles greater than or equal to 135 degrees works best according to Hansen (Mungiole, et al., 1999). Next, the two endpoint values for each triple are examined. The low values are placed in a "low screen" and the high values are placed in a "high screen."

After separating the low values and high values, sort the observations in each screen so that \( x_{(1)} \leq x_{(2)} \leq ... \leq x_{(m)} \), where \( m \) in this case is 7, and the weights \( w_{(j)} \) (standard errors) remain paired with the corresponding observations. A cumulative sum of the reordered weights is then calculated:

\[
S_k = \sum_{j=1}^{k} w_{(j)}, \quad k = 1, ..., 3
\]

The index location, \( b \), of the weighted median is the smallest value of \( k \) such that \( S_k \) is at least half of the total sum of the weights:

\[
b = \min\{k | S_k \geq S_m/2\}
\]

If \( S_b \) is greater than \( S_m/2 \), the weighted median value is given by \( x_{(b)} \) (Mungiole, et al., 1999). Once the weighted median is selected for each screen, an iteration of the weighted median algorithm described above is undertaken between the final values of the "low screen", "high screen", and the value for Tifton.

For example, the 7 nearest points surrounding the Tifton station are selected and any set of triples that form an angle of 135 degrees or greater is included in the smoothing process.
Since there is only one collection of triples in this example, the weighted median selection process is only carried out between the values at the Cordele, Tifton, and Valdosta stations. The °C per decade and corresponding weight for the Tifton station are 0.7976 and 0.0281, respectively. The "low screen" contains the values for Valdosta station which are 0.7657 and 0.0462. The "high screen" are the values for Cordele station which are 0.9007 and 0.0543. The weighted median selection algorithm requires that the values are first sorted: 0.7657 (0.0462), 0.7976 (0.0281), 0.9007 (0.0543). The cumulative sum of the weights are: 0.0462, 0.0743, 0.1286. Since 0.0743 ≥ 0.1286/2, the weighted median is 0.7976°C/decade. The value remains unchanged, which suggests that this area of the map requires no smoothing.

If there had been more than one set of triples, the low values of the endpoints in each triple are placed in the "low screen" and the high values are placed in the "high screen."
the weighted median algorithm described above is applied to each screen before a weighted median is selected between the values of the station, "high screen," and "low screen".

For stations on corners or edges, triples are linearly extrapolated (Mungiole, et al. 1991). Figure 2.8 shows a comparison between the contour map of the raw trends of the change in °C/decade versus a smoothed map on the right of the figure. One can see differences depicting the effects of the smoothing process, especially in the northern and southernmost areas of the maps. Head-banging methods effectively preserve general features such as edges and ridges while downweighing any outliers (Lu, et al., 2005).

Figure 2.8: Raw Map vs. Spatially Smoothed Map
Chapter 3

Results

This section discusses and summarizes the findings after implementing the methods given in Chapter 2. For organizational purposes, the results are summarized by seasons. Winter months are defined as December, January, and February; spring as March, April, and May; summer as June, July, and August; and fall as September, October, and November. Levels of significance are presented in this section followed by a presentation of the rates of warming or cooling. Similar scales for presentations are maintained in order to distinguish results more easily. Tables containing the actual significance of the warming and the rate at which the temperatures changes are in Appendix A. Graphs of these trends are in Appendix B.

3.1 Significance

Figure 3.1 presents boxplots of the raw significance (p-values) of rate changes for each month. The end of the spring season all the way through the beginning of the fall season shows the most significant changes. On a monthly basis, the most significant are June and August, which suggests more significant changes in the maxima.
Rate increases are especially significant in August with a median p-value of 0.0148. The months surrounding winter have p-values that are not very significant, with mean values being greater than 0.5.

![Box-plot of P-Values for Trends](image)

Figure 3.1: Box-plot of P-Values for Trends

To see where warming and cooling are significant, the p-values are plotted and used to construct contour maps. Figure 3.2 shows the contour plots of the raw p-values. Data are interpolated linearly using a 'nearest neighbor' method and the color scale used is uniform across all months. Warming areas are colored in shades of red while cooling areas are shaded in blue. To show areas that are cooling on the map, p-values are multiplied by -1 for stations that detected a decreasing trend. The smoothed contour maps of the significance level are shown in Figures 3.3 through Figure 3.6.

Winter significances are shown in Figure 3.3. In December, there is a warming trend just as depicted in the boxplots presented previously, especially in the southeastern section.
Figure 3.2: Raw P-Values of Trends in Z-Scores
(around Statesboro and Savannah station) of Georgia. There is also mild cooling in January and February and smaller areas - compared to December - with evidence of warming.

Figure 3.3: Smoothed P-Values of Warming and Cooling, Winter.

The significance of warming increases begin in the month of April and is more prevalent in May (Figure 3.4). The deeper colors of red depict strongly significant warming, especially in the surrounding areas of Atlanta. These more significant changes demonstrated by the results in the spring months were also found in average monthly temperatures in Lund, Seymour, and Kafadar (2001), and Lu, Lund, and Seymour (2005).

Figure 3.4: Smoothed P-Values of Warming and Cooling, Spring.
The smoothed maps in Figure 3.5 show very significant warming in the summer months. June and August especially show the most areas in the State of Georgia with higher significance of the change in temperatures. The month of July shows slightly less significance of warming than June and August with some stations registering cooling trends.

The high values of significance diminish in the fall months. The fall months display slightly less significant values especially in the month of September. The warming significance begins to diminish even more so in October and values show a cooling trend in November (Figure 3.6).

Figure 3.5: Smoothed P-Values of Warming and Cooling, Summer.

Figure 3.6: Smoothed P-Values of Warming and Cooling, Fall.
3.2 Rates

Figure 3.7 presents the rates of change in °C/decade converted from the Z-scores. Once again, the months are organized according to seasons, beginning with the winter months. The rates are mostly warming, especially in the spring and summer months. Cooling trends are evident in January, February, and November.

The contour plots in Figure 3.8 depict the raw rates of change °C/decade, organized by month. Once again, shades of red indicate a warming trend while shades of blue indicate cooling trends. The darker the shade, the higher the rate of change. The spatially smoothed contour plots are shown in Figure 3.9 through Figure 3.12; the plots are smoothed using the standard errors of the rates of change.

The southeastern area (around Statesboro) of the smoothed contour plot for December (Figure 3.9) shows a considerably high warming rate in comparison to other months. According to the significance contour plot, this rate change is also significant. The other winter
Figure 3.8: Rates of Cooling and Warming, Raw Trends.
months show slight decreases (mean of -0.2540°C/decade and -0.3795°C/decade for January and February, respectively) in cooling. However, these trends are not deemed to be very significant.

![Figure 3.9: Smoothed Warming and Cooling Rates, Winter.](image)

Overall warming trends are more pronounced beginning in May and continues through the summer and most of the fall months (Figures 3.10, 3.11, and 3.12). These changes in temperatures, although rising only at average rates of 0.4202°C/decade for May, 1.0055° for June, 0.3537° for July, 1.1261° for August, 0.5053° for September, and 0.3329° for October, are more significant with p-values which register almost at zero (0) for many stations in June and August.
The month of November (Figure 3.12) shows cooling at an average rate of -0.3188°C/decade in areas of the state. However, these rates are not quite as significant as other months. The greatest significance registers at 0.1044 and the average significance for the month of November is 0.6412 - not very significant at all.
3.3 Discussion

Many avenues were taken to determine the best possible way to analyze the data. Examining monthly trends while assuming each observation was identically and independently distributed (i.i.d.) and creating bootstrap distributions with that assumption produced large cooling and warming trends which were unrealistic.

A model-based time series bootstrapping method was attempted. Although creating models for each individual station would give more accurate predictions, an overall analysis would have proven to be extremely time consuming and difficult to employ. Simple AR(1) and MA(1) models were attempted and used in the model-based bootstrap, however, it was clear that there are more complex models needed for each station.

Although the results of the initial analysis of the model-based bootstrap were better than the initial i.i.d bootstrap, the moving block bootstrap method produced the best results. No time series modelling was necessary although it still allows one to preserve the natural autocorrelation structure of the data at each station. It also produced a much better bootstrap distribution since the simulation was sampled only from the original series, unlike model-
based sampling which essentially creates new models. At first, no seasonality was preserved in the sub-sampling procedure to determine if there is a difference. Once the seasonal component was included, slight differences between 0.0001 and 0.1 were detected in the results and could not be ignored.

Overall, the results produced by the moving block sub-sampling method produced smaller slopes which are more realistic and more indicative of actual trends in temperatures that are comparable to previous studies such as Lund, Seymour, and Kafadar (2001) and Lu, Lund, and Seymour (2005).

3.4 Overall Conclusions

There is evidence of overall warming throughout the state of Georgia. The average rates of change in the monthly maximum low temperatures are -0.3346°C/decade in the winter, 0.4792°C/decade in the spring, 0.6175°C/decade in the summer, and 0.3049°C/decade in the fall. The increases at the end of the spring, during the summer, and the beginning of the fall months are found to be more significantly increasing than others. These increases could indicate that the spring and fall months are disappearing and summer seasons are getting longer in the state of Georgia. It should be noted that rates of change detected at some stations may be increasing/decreasing too quickly which may be attributed to small sample sizes. When more data is available at the newer stations, it would be interesting to reexamine the geographic maps and see what new information may be revealed when more stations and larger sample sizes are considered.
Bibliography


Appendix A

Appendix A contains output from the analysis of each station organized by month. The slope of the standardized values from each station are shown in the second column. Standard errors, t-statistics, and p-values are in the following columns. Finally, a translation of each rate of change in the Z-scores to °C/decade along with sample size is available in the last two columns. For ease, stations with significant findings are printed in bold.
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Table A-7: July Trends

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Table A-12: December Trends
Appendix B

Appendix B contains graphical representations of the standardized values at each station, organized by season, along with their trend lines. The $x$ and $y$ axes list the years vs the $Z$ score values.

Figure B-1: Alma Station
Figure B-2: Arlington Station
Figure B-3: Atlanta Station

(B-3)
Figure B-5: Blairsville Station
Figure B-6: Williamson Station
Figure B-7: Brunswick Station

December

January

February

March

April

May

June

July

August

September

October

November

December
Figure B-8: Byron Station
Figure B-9: Cairo Station
Figure B-10: Calhoun Station
Figure B-11: Callaway Station
Figure B-12: Camilla Station

[Graph showing monthly data from December 2000 to November 2010, with x-axis indicating years and y-axis indicating some measured value, with data points for each month displayed.]
Figure B-13: Cordele Station
Figure B-14: Dallas Station

[Graphs of data for December, January, February, March, April, May, June, July, August, September, October, November, December from 2000 to 2010]
Figure B-15: Dawson Station
Figure B-17: Dempsey Station

[Diagram showing time series plots for December to November, with data points from 1995 to 2010 and a y-axis range from -2 to 2.]
Figure B-19: Dublin Station
Figure B-20: Duluth Station
Figure B-22: Eatonton Station

December

January

February

March

April

May

June

July

August

September

October

November

December
Figure B-23: Ellijay Station

December

January

February

March

April

May

June

July

August

September

October

November

December
Figure B-24: Floyd Station

B-24
Figure B-25: Fort Valley Station

[Graphs showing monthly data from December 1995 to November 2010 with y-axis range from -2 to 2 and x-axis range from 500 to 2000 for each month.]

B-25
Figure B-26: Gainesville Station

[Graphs showing temperature variations by month from December 1995 to November 2010.]
Figure B-27: Griffin Station

December

January

February

March

April

May

June

July

August

September

October

November

December

B-27
Figure B-28: Jonesboro Station

![Graphs showing data for each month from December 2000 to November 2010 with a y-axis ranging from -2 to 2 and an x-axis ranging from 2000 to 2010. Each graph represents a different month, with changes in data points indicated.]

B-28
Figure B-29: Lafayette Station
Figure B-30: Midville Station
Figure B-31: Nahunta Station
Figure B-32: Newton Station
Figure B-33: Plains Station
Figure B-34: Savannah Station

January

February

March

April

May

June

July

August

September

October

November

December

B-34
Figure B-35: Sneads Station
Figure B-37: Tifton Station
Figure B-38: Valdosta Station
Figure B-39: Vidalia Station
Figure B-40: Roopville Station
Figure B-41: Watkinsville-Hort Station

December

January

February

March

April

May

June

July

August

September

October

November

December
Figure B-42: Watkinsville-UGA Station

December

January

February

March

April

May

June

July

August

September

October

November

December
Figure B-43: Watkinsville-USDA Station