A Value-Added Approach in Degree Day Calculation

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Introduction

The National Weather Service (NWS) uses the mean of the daily maximum and minimum 24-hour temperature ($T_{nws}$) to determine daily heating or cooling degree days (where $T_{nws} = \frac{(T_{max} + T_{min})}{2}$). This method has been shown to be relatively accurate when the hourly temperatures within a given day are distributed normally. However, under certain weather regimes this is not the case. To determine the percentage of this non-normality, the Skew of daily temperatures at Burlington, VT (BTV) for the period 2001-2010 is calculated. From this it is shown that approximately 20 to 40 percent of days each month exhibit a non-normal distribution in hourly temperatures, with higher percentages favoring the cooler months of fall and winter.

Prior research has shown that more accurate methods of determining daily mean temperature exist than those currently used by the NWS (Dubin and Gamponia, 2007). Among these include the use of the daily average temperature ($T_{avg}$, where $T_{avg} = \frac{(T_1 + T_2 + ... T_{24})}{24}$). The value in using $T_{avg}$ over $T_{nws}$ lies in the fact that it is not affected by extreme high or low temperature values to the extent $T_{nws}$ is. Given the potential for a more accurate calculation of daily mean temperature, differences in heating and cooling degree days using the $T_{nws}$ and $T_{avg}$ methods are calculated. Results show that while the differences on most days are less than 2 °F, days exhibiting a high degree of non-normality in hourly temperatures show differences often in excess of 4 °F. These findings demonstrate the value in using $T_{avg}$ as opposed to $T_{nws}$ on a daily, monthly and annual basis. To illustrate these differences graphically, a dedicated NWS real-time web page displays results with a customized retrievable daily search function. Finally, practical applications to utility revenue adjustments and the agricultural industry are discussed.

Data and Methodology

Hourly temperature data from BTV was tabulated from January 2001 through December 2010. To determine the degree of normality in hourly temperatures by day, Skew ($\gamma$) was calculated. Non-normal days were defined when $|\gamma| > 0.50$. Daily average temperatures were then determined using the both the daily average formula ($T_{avg} = \frac{(T_1 + T_2 + ... T_{24})}{24}$) and the $T_{nws}$ formula ($T_{nws} = \frac{(T_{max} + T_{min})}{2}$). Differences in $T_{avg}$ and $T_{nws}$, defined as $T_{dif}$ (where $T_{dif} = |T_{nws} - T_{avg}|$) were calculated, with high $T_{dif}$ values defined as those $\geq 4°F$. Subsequent degree days were then calculated (where $HDD = 65 - T_{avg} (T_{nws})$ and $CDD = T_{avg} (T_{nws}) - 65$). To display the
differences noted among the two methodologies, graphical plots were displayed via a web page interface.

**Results**

Plots of the Skew of daily temperatures at BTV showed that moderate to high values occurred on approximately 20 to 40 percent of days each month (Figure 1). Higher percentages favored the cool season months, which is not surprising given the more variable and occasional sharp thermal gradients that exist in the region during this time. These findings suggest a significant number of days each month exhibit a non-normal distribution in hourly temperatures, suggesting a more accurate method than $T_{nws}$ be examined.

Comparisons of $T_{avg}$ and $T_{nws}$ over the ten year period at BTV showed that while most days exhibited only minor $T_{dif}$ values of less than 2°F, occasional values greater than 2 to 3°F were not uncommon in a positively-skewed distribution (Figure 2). During a sample month, these differences are significant, with monthly $T_{dif}$ summed values ranging from 21-56°F over the study period (Figure 3). The variable $T_{dif}$ does not explicitly represent actual heating or cooling degree days however. Resultant heating degree plots for a sample day, month and year using both methods show the largest differences of up to 20 percent occur on the daily time frame, with smaller differences of 1-2 percent observed during the longer monthly and yearly periods (Figure 4). Yearly sample plots of heating and cooling degree data show similar results (Figure 5).

Therefore, it seems plausible that the use of $T_{avg}$ to determine degree days has the most immediate value on the daily time frame. In this way, significant value could be added during days in which high $T_{dif}$ values are observed. However, in longer time scales the cumulative value of small gains in accuracy each day could potentially lead to significant real-world value. This is not an unrealistic assumption. As an example, Dubin and Gamponia studied long term revenue adjustments for a standard utility company serving one million customers. Their results showed that for each additional heating degree day (HDD) per annum, revenues rose by $50,000, or $0.05 per customer per degree day. For a test year, potential revenue adjustments could run in the millions ($1,500,000 dollars in their cited example with an annum difference of 25 HDD).

To illustrate the observable differences in daily degree day values between the $T_{nws}$ and $T_{avg}$ methods, a dedicated web page has been established. Graphical plots are created via an hourly observational database available from the National Weather Service’s AWIPS platform and Graphical Forecast Editor interface. The data is archived and available through a customized daily search function from January 21, 2012 onward.
Conclusion

Hourly temperature data for Burlington, VT from 2001-2010 was tabulated to determine the value in using alternate methods of calculating degree days on a daily, monthly and annual time frame. It was shown that use of the average temperature of the day ($T_{avg}$) provided a more accurate method than the existing daily mean temperature used by the NWS. Daily temperature differences between the schemes averaged less than 2°F, though a significant number of days exhibited values in excess of 2-3°F. Immediate value was seen on the daily time scale where these differences ranged from 10 to 20 percent on high $T_{dif}$ days. While percentage differences were only 1 to 2 percent on monthly and yearly time scales, real-world value in using the alternate $T_{avg}$ methodology was shown to occur in potential utility annum revenue adjustments. To illustrate this potential value, and the differences that arise on a daily basis by using these different schemes, a dedicated web page was established.

Figures

Figure 1. Percentage of moderate to high Skew in daily temperatures by month (2001-2010).
Figure 2. Total Decadal Tdif Count by Magnitude at BTV

Figure 3. Monthly Tdif Sums 2001-2010 at BTV
Data Comparison

- December 8, 2002: \( T_{\text{dif}} = 8 \) (\( T_{\text{avg}} = 27 \), \( T_{\text{nws}} = 19 \))
  \[ - T_{\text{avg}} \text{ HDD} = 38 \\
  - T_{\text{nws}} \text{ HDD} = 46 \]
  17.4\% decrease in HDD with \( T_{\text{avg}} \)

- Month of December 2002:
  \[ - T_{\text{avg}} \text{ HDD} = 1208 \\
  - T_{\text{nws}} \text{ HDD} = 1221 \]
  1.1\% decrease in HDD with \( T_{\text{avg}} \)

- Heating Year July 2002 – June 2003:
  \[ - T_{\text{avg}} \text{ HDD} = 7860 \\
  - T_{\text{nws}} \text{ HDD} = 7946 \]
  1.1\% decrease in HDD with \( T_{\text{avg}} \)

Figure 4. Comparison of resultant HDD differences between \( T_{\text{avg}} \) and \( T_{\text{nws}} \) methods during a sample day, month and year.

Figure 5. Comparison of differences in HDD and CDD among \( T_{\text{nws}} \) and \( T_{\text{avg}} \) methods during three sample years.
References


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