P6.4 A CLIMATOLOGY OF APPARENT TEMPERATURE

Peter A. Browning*
Brian P. Walawender
NOAA/NWS, Kansas City, Missouri

1. INTRODUCTION

The effects of wind and humidity in relation to temperature have been studied to define a means of expressing the relative impact to the comfort (and survival in more extreme cases) of humans. Stedman (1984) defined a universal scale of apparent temperature which uses temperature, wind speed, humidity and solar radiation (including effects of percent clothed and fabric conductivity). Karl and Knight (1997) used a simpler version of Stedman's apparent temperature (minus the wind and solar components) in their assessment of the 1995 Chicago heat wave. Kalkstein and Valmont (1986, 1987) define the weather stress index (WSI) algorithms for both summer and winter seasons based on Stedman's work, using only temperature, humidity and wind. They define the WSI for summer (winter) as "the proportion of days with apparent temperature lower (higher) than the day under review." The WSI is a relative measure which attempts to account for the acclimation and adaption of humans to weather that is typical for their location, while the apparent temperature provides absolute values regardless of location.

The National Weather Service (NWS) has for some time utilized the wind chill index to communicate the potential danger from the combination of wind and cold and a different index (the heat index) to reflect the potential danger of heat and humidity. In March 2006, the NWS included "apparent temperature" as an element in the National Digital Forecast Database (NDFD: Glahn and Ruth, 2003). In the NDFD, apparent temperature is defined as "the perceived temperature in degrees Fahrenheit derived from either a combination of temperature and wind (wind chill) or temperature and humidity (heat index) for the indicated hour. When the temperature at a particular grid point falls to 50°F (10°C) or less, wind chill will be used for that point for the apparent temperature. When the temperature at a grid point rises above 80°F (26.7°C), the heat index will be used for apparent temperature. Between 51°F (10°C) and 80°F (26.7°C), the apparent temperature will be the ambient air temperature". (NWS 2003).

This paper will examine the climatology of apparent temperature as defined in the NDFD. Data from the past 30 years are analyzed to provide a recent climatology of apparent temperature. Frequency of exceedance maps covering the continental United States (CONUS) are presented. Additionally, the distribution of apparent temperature for selected cities will be explored for warm and cold seasons. Finally, a discussion concerning NWS services for extreme temperatures will be provided.

2. DATA

Hourly data from the past 30 years (1978-2007) were retrieved from the NOAA National Climatic Data Center's Integrated Surface Database (Lott et al. 2008) for observation sites in the CONUS. Apparent temperature was calculated for every hour following the NDFD definition. If the temperature exceeded 26.7°C (80°F), then the calculated heat index (Rothfusz, 1990) was substituted for temperature. Similarly, when the temperature was at or below 10°C (50°F), then the wind chill index (NWS 2001) was substituted for temperature.

Stations used for frequency of exceedance maps and site analysis were also checked for completeness. Hours were not counted if a required element (temperature, wind or dewpoint) was not available for use in calculating the apparent temperature. All locations with less than 220,000 apparent temperature hourly observations were removed from the analysis. This removed new observation sites or sites that have closed, retaining 187 locations. These remaining observation locations are shown in Figure 1 to provide a sense of the data density.

* *Corresponding author address:* Peter A. Browning, National Weather Service Central Region Headquarters, Kansas City, MO 64153; e-mail: peter.browning@noaa.gov

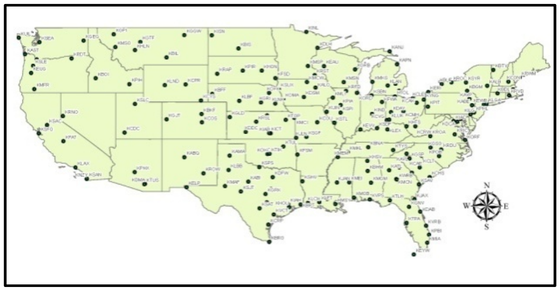

Figure 1: Locations of observation sites with a minimum of 220,000 hourly apparent temperature observations from 1978 through 2007

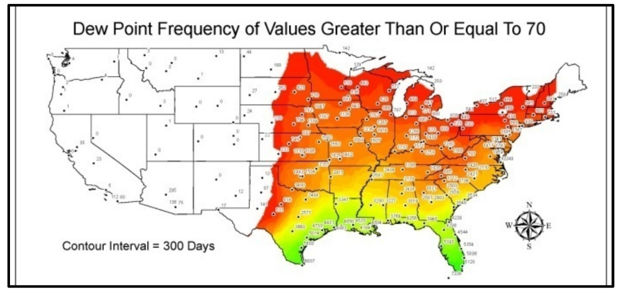

Figure 2: Analysis of the number of days when the dewpoint temperature reached or exceeded 70°F for at least one hour during the 30-year period (1978-2007).

3. FREQUENCY OF EXCEEDANCE

To explore the geographic distribution of extreme hot and cold apparent temperatures, hourly observations were compared to several threshold temperatures. In this paper, the use of the phrase "exceeding the threshold" refers to greater than the threshold value for excessive heat thresholds and less than the threshold value for excessive cold threshold values. On each day, if one or more hours reached or exceeded the threshold, then that day was added to the total number of days reaching or exceeding the threshold. This was done for every available day in the 30-year period for each station, resulting in a total accumulation of days meeting or exceeding each threshold.

3.1 *Excessive Heat*

Frequency charts were generated showing the number of days that temperature thresholds were equaled or exceeded. Thresholds were examined every 5°F from 35°C (95°F), through 48.9°C (120°F). Only the 95°F, 105°F and 115°F charts are shown for temperature (Figs 3a-c) and for apparent temperature (Figs 4a-c).

Examination of the apparent temperature compared to ambient temperature shows the influence of humidity on the apparent temperature (Figure 2). For the 95°F threshold, the ambient temperature chart (Fig. 3a) shows the highest number of days across the southwest with an axis extending north from west and central Texas across the central Plains states. Additionally another maximum can be seen over Georgia with an axis extending northeast into the Washington D.C. area. The corresponding apparent temperature chart (Fig. 4a) shows the highest frequencies have shifted to the east, along the gulf coast states and continue in the desert southwest region. The analysis shows several axes of higher values. These "heat alleys" are located: 1) from peak frequencies over south Texas, north across Oklahoma and east Kansas, into central South Dakota; 2) from peak frequencies from south Texas, across north Louisiana, northeast along the Mississippi River valley into Illinois; 3) from across Florida up the east coast toward New York City, and; 4) the desert southwest and interior valleys of California.

A comparison of the ambient temperature charts for the 95°F and 105°F threshold (Figs. 3a, b) shows a dramatic decrease in the number of days the ambient temperature reached or exceeded 105°F. Higher values are seen in the central Plains and in the desert southwest areas. The 105°F apparent temperature chart continues to show the four heat alleys, but maxima in the southeast U.S. are more focused from southern Alabama and Georgia to maximum values along coastal South Carolina, with an axis extending northeast up the coast to the Washington D.C. area.

The 115°F threshold ambient temperature chart only highlights the desert southwest region (Fig. 3c), while the apparent temperature chart (Fig. 4c) continues to highlight excessive heat occurrences in the central Plains states, along the Mississippi River valley and Gulf Coast region and from Alabama to South Carolina and up the coast to Maryland and New Jersey.

3.2 *Excessive Cold*

Similar to excessive heat, frequency charts were generated showing the number of days thresholds were equaled or exceeded for excessive cold. Apparent temperature thresholds were examined every 5°F from - 20.6°C (-5°F), through -42.8°C (-45°F). Only the -5°F, -15°F, and -35°F charts are shown in Figures 5a-d.

The apparent temperature chart for the -5°F threshold shows a gradient of increasing frequencies oriented northwest to southeast along and east of the

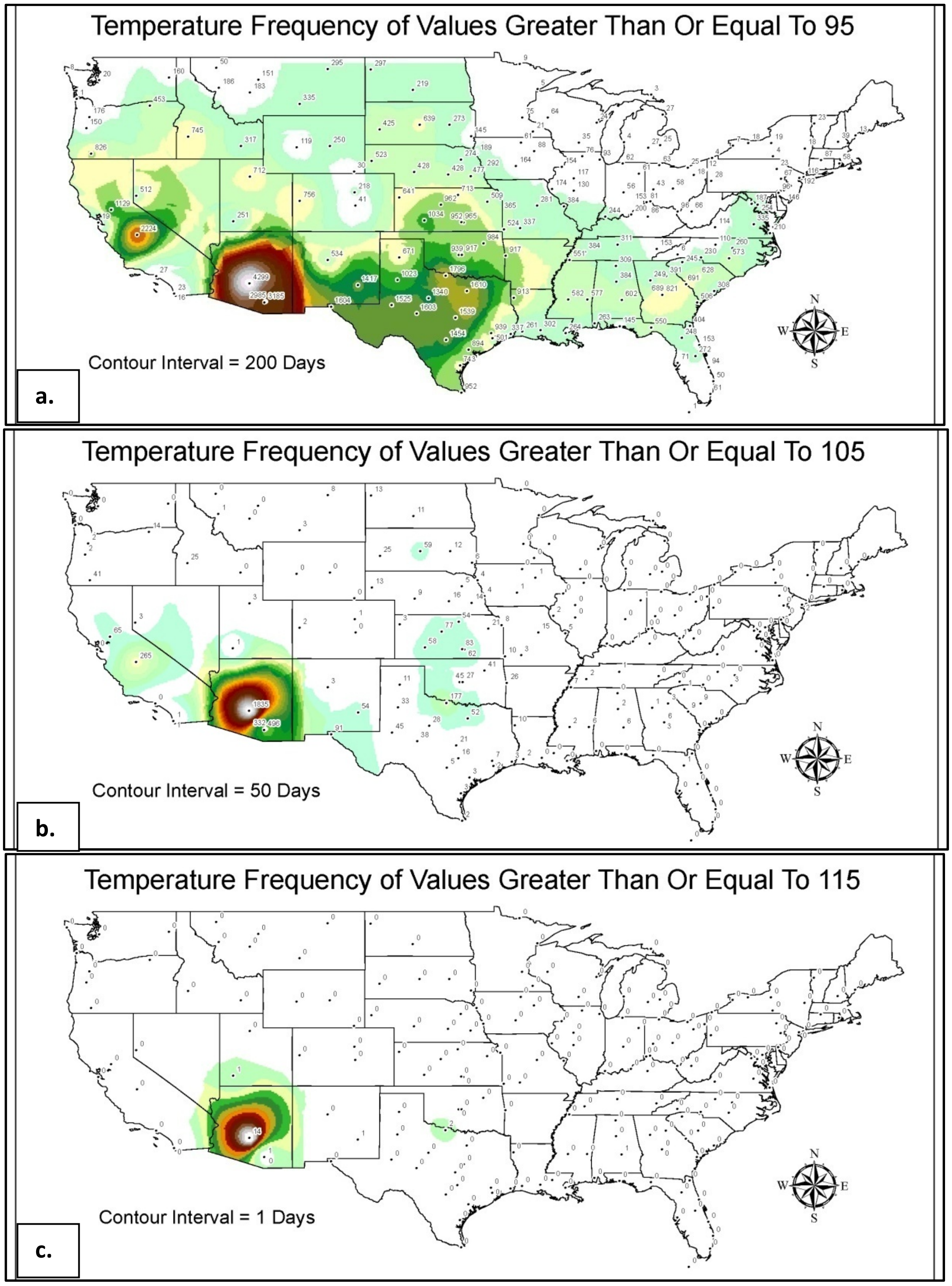

Figure 3: Analysis of the number of days when the ambient temperature reached or exceeded the thresholds of 95°F (a), 105°F (b) and 115°F (c) for at least one hour during the 30-year period (1978-2007).

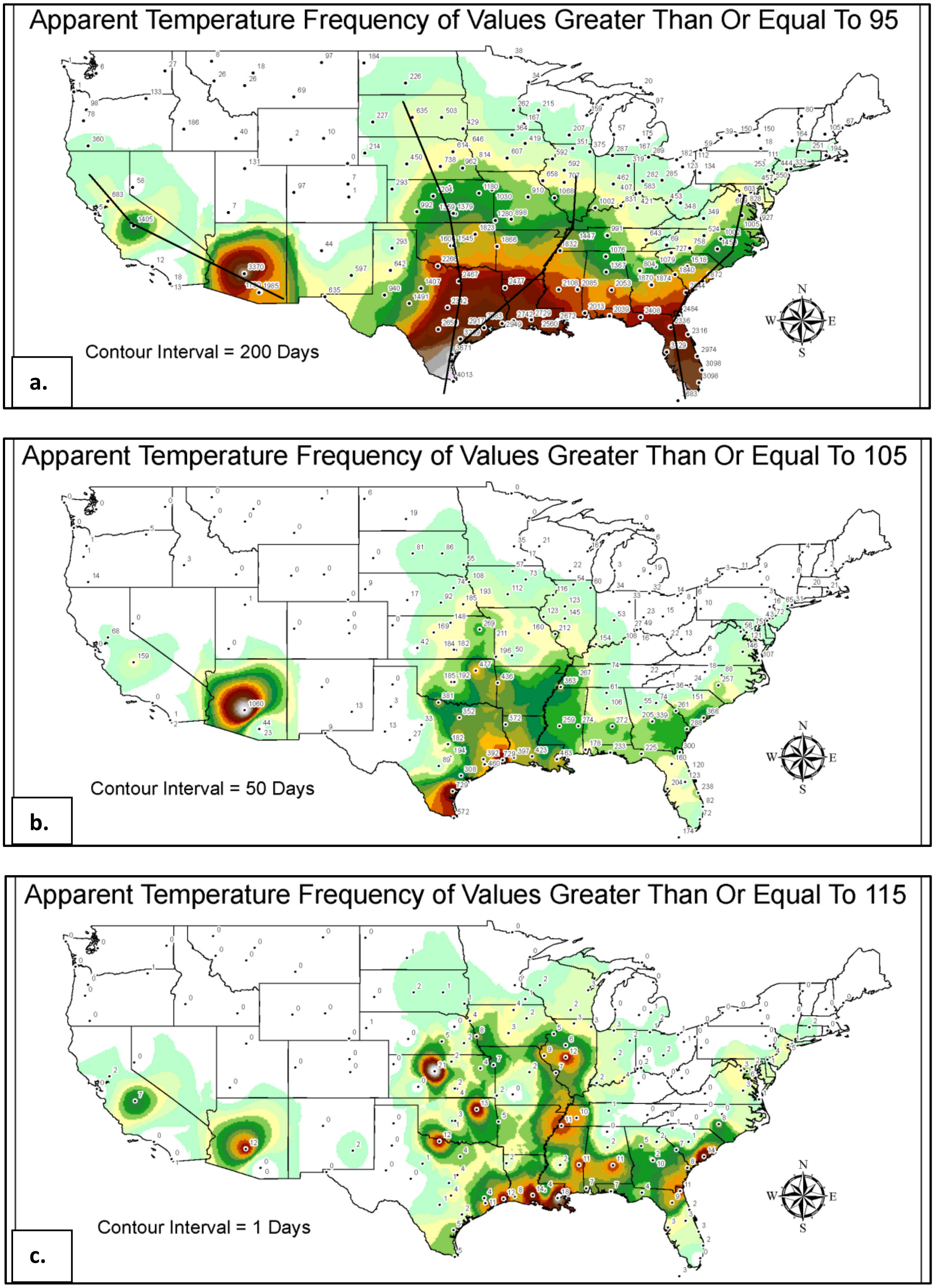

Figure 4: Analysis of the number of days when the apparent temperature reached or exceeded the thresholds of 95°F (a), 105°F (b) and 115°F (c) for at least one hour during the 30-year period (1978-2007). The four "heat alleys" mentioned in the paper are noted on Fig. 4a by solid black lines.

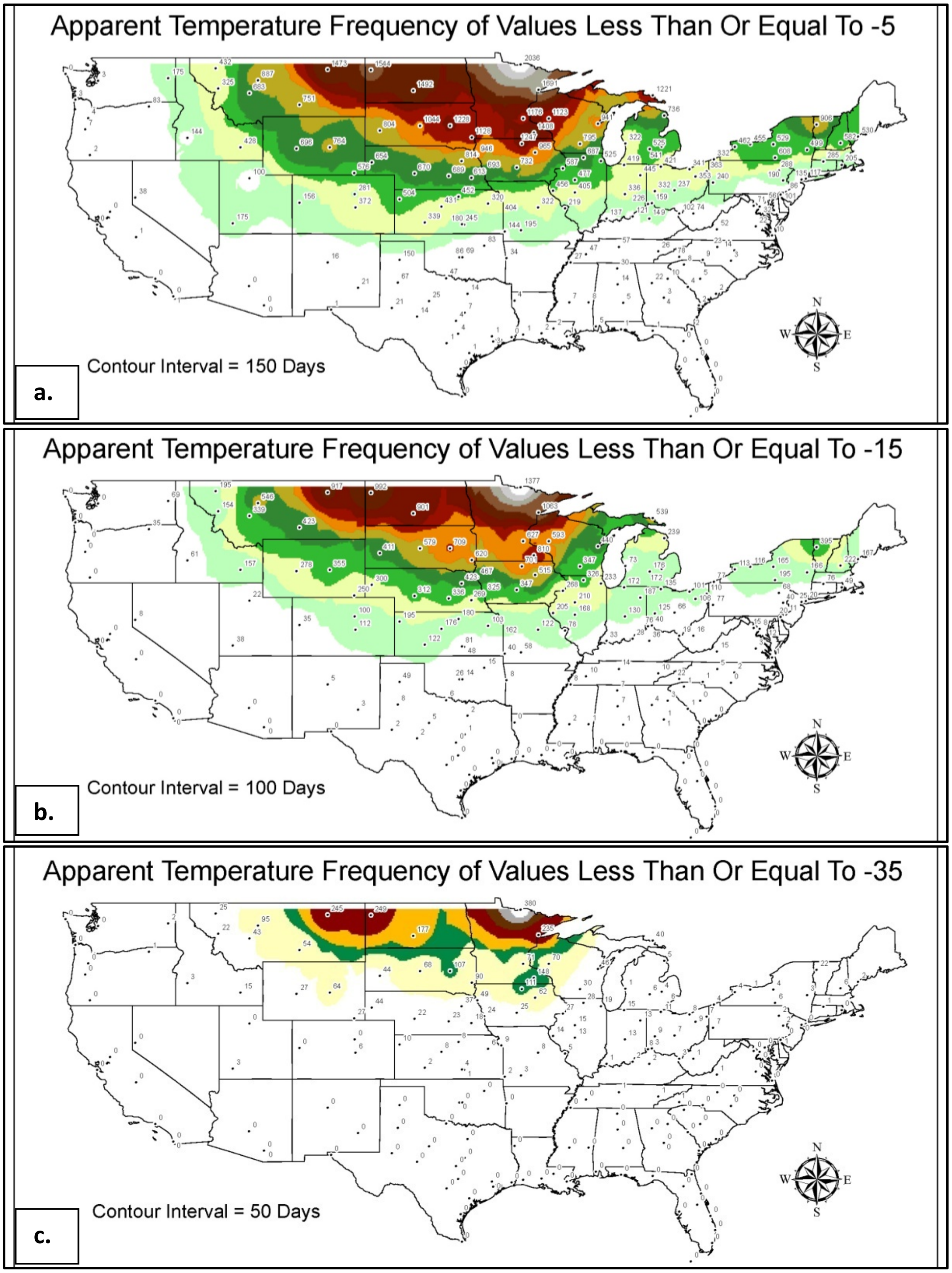

Figure 5: Analysis of the number of days when the apparent temperature reached or exceeded the thresholds of -5°F (a), -15 °F (b), and -35°F (c) for at least one hour during the 30-year period (1978-2007).

Rockies into Colorado, turning more to a west-to-east orientation across Nebraska and Iowa, then to a southwest-to-northeast gradient across Wisconsin. International Falls Minnesota wins the prize for being the coldest location in this database with more than 18 percent of all possible days having at least one hour of -5°F or colder apparent temperature. Although higher frequencies diminish northward as one moves to colder thresholds, along the corridor from northeast Montana to across north Wisconsin, an average of 8 to 10 days a year reach or exceed the -35°F threshold.

4. DAILY DISTRIBUTIONS

Along with hourly apparent temperature data, maximum and minimum apparent temperature for each day were determined from the hourly values. It should be noted that this database does not utilize maximum or minimum ambient temperatures that occur between the hourly observations. Since the corresponding wind and dewpoint temperature at the time of the daily high and low are unavailable, use of the hourly observations will suffice.

For the 30-year period, percentiles were calculated at station locations to observe the range and typical values of apparent temperature for winter and summer seasons. Along with maximum, minimum and median values, the 10th, 25th, 75th, and 90th percentiles were calculated. Figure 6 shows the daily percentiles for the months of June, July and August (JJA) for Chicago Illinois.

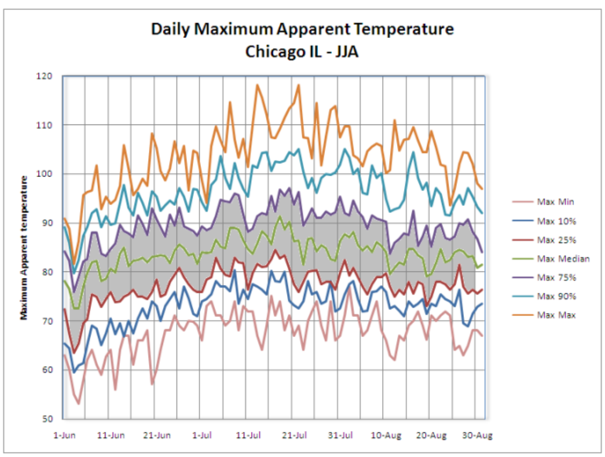

Figure 6: Percentiles of daily maximum apparent temperature for Chicago, IL. The shaded area represents the middle 50% of observations or what could be considered as the "typical" range of maximum apparent temperature.

The shaded area in Fig. 6 is the middle 50 percent of the data. This can be considered as being the typical range of maximum apparent temperature one could expect in Chicago for any given day on the figure. It is interesting to note that the spread of maximum apparent temperature from the 75th percentile to the maximum value in July is nearly as large as the spread between the minimum value and the 75th percentile. There is not an even distribution of values from the minimum to the maximum. In fact, the relatively tight gradient of values on the cool side suggests minimal variability from year to year, but with some extreme heat events.

To contrast this location, Figure 7 shows a similar percentile diagram for Dallas Texas. Typical values for

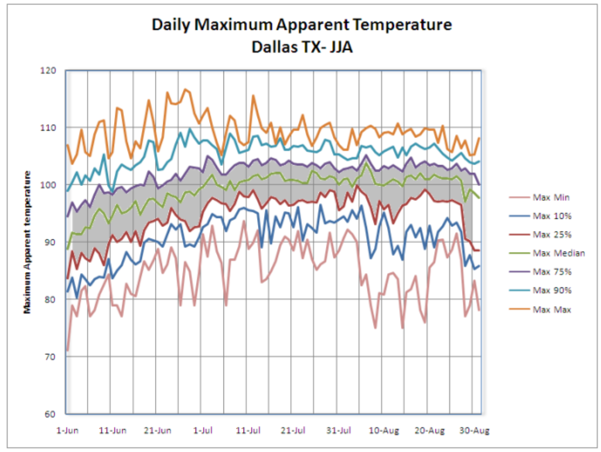

Figure 7: Same as Figure 6 except for Dallas, TX.

Dallas settles into a narrow range in July and August of roughly 97°F to 104°F. In early June, more extreme heat is noted, while in late August, a larger spread in noted on the cool side of 50th percentile.

For extreme cold, Figure 8 shows the winter months of December, January and February (DJF) for Bismarck North Dakota. A large range of minimum apparent temperature is seen in the middle 50% of the.

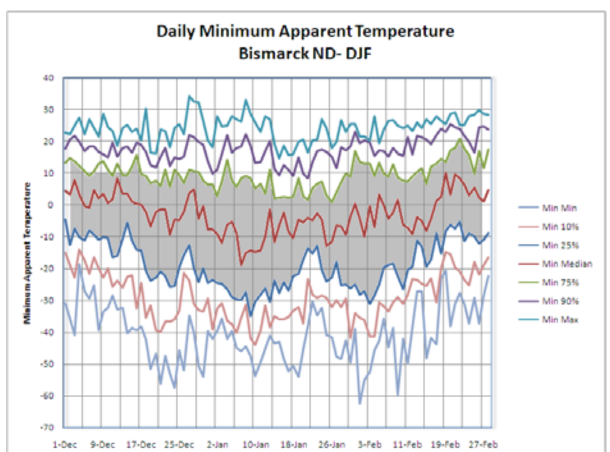

Figure 8: Same as figure 6 except for minimum apparent temperature for Bismarck, ND.

data, as much as 40°F, with the median remaining below 0°F from mid December through mid February.

5. SUMMARY

A database of hourly apparent temperature was developed for the 30-year period 1978-2007 utilizing the definition of apparent temperature used by the NWS in the NDFD. This paper scratches the surface of analyzing these data and developing a climatology of apparent temperature for use by NWS forecasters. Extreme heat and cold can be deadly if people are caught unprepared. The NWS provides advisories and warnings to inform the public to take appropriate actions to protect themselves during these extreme events.

But when should advisories be issued? People acclimate or adapt to typical values. Acclimation tends to occur more with hot weather. Sheridan and Kalkstein (2004) note that mortality records show that the first hot weather period of the season will tend to cause heat-susceptible persons to perish while the population as a whole will acclimatize to warmer conditions over the course of the summer. For cold weather, it is more a matter of adapting to the climatology. Extreme cold will lead to frost bite to exposed skin in minutes. The public adapts to this weather by altering their behavior (e.g., owning and dressing in warm clothing) and avoidance of the threat by staying indoors. A period of extreme cold weather in the south, (i.e., -10°F apparent temperature) will fall into the typical value range in Bismarck. The public may be more at risk in the south if they have not adapted their behavior to the cold weather.

Future work will expand this database beyond 30 years to include the full period of observational records for all stations in the NCDC ISD database. Normalized frequency charts over the CONUS will then be generated to provide better resolution then presented in this paper. Additionally, daily percentile charts will be provided on-line to forecasters for use to compare real-time observations and forecasts with the apparent temperature climatology data so that they can first understand the impact of extreme temperatures throughout the year and then make good advisory and warning decisions. Finally, we will explore the use of advisory and warning criteria which reflects local climatology, perhaps through the use of percentile thresholds or standard deviations.

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