A HIGH RESOLUTION PROFILE OF NORTHEASTERN UNITED STATES TEMPERATURE

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1. INTRODUCTION

Surface air temperature data of a high spatial and temporal resolution provide valuable information for planning and decision making for nearly all economic and societal concerns. These include, but are not limited to, agricultural use, transportation, recreation, energy, and industrial use. The northeastern United States with its high population density and diverse needs for temperature information is an excellent candidate for such detailed information.

Although daily and weekly normals are available in published form for first-order meteorological stations, their utility is severely limited because of a number of deficiencies. First-order stations are relatively few and are generally located within urban areas. Therefore, they are not representative of large portions of the Northeast, due to heat island effects. Another problem associated with the published daily normals is that they are interpolated from mean monthly data. Because of the use of temporally coarse monthly data in the interpolation procedure, important meteorological singularities or step changes, that have been shown to exist in the average annual cycle of daily data (Gutmann and Plantico 1987; 1989; Robinson et al. 1994), are not represented in the published material.

Therefore, in cooperation with the Northeast Regional Climate Center (NRCC), we have created a unique dataset of pentad (5-day) temperature normals for the 12 state northeastern region. This set includes pentad normals for the period 1961-90 for 14 temperature and temperature-derived variables. Observations from 361 stations were interpolated to a 0.25° latitude x 0.25° longitude grid and grid values were subsequently adjusted for the effects of elevation. The availability of the temperature information in a gridded format facilitates its incorporation into studies employing geographic information system methodologies.

2. DATA

Daily maximum and minimum temperature observations were collected from 361 stations in the 12 state northeastern region as well as adjacent stations in Virginia, Ohio and Canada (Fig. 1). This includes first-order and cooperative stations from the U.S. National Weather Service and Canadian Atmospheric Environment Service networks. Only stations with few or no moves and observation time changes were selected for analysis. Station records also were required to be at least 95% complete for the 1961-90 interval and the temperature data had to pass a quality control check without any observations flagged as suspicious (Robinson 1993). As the temperature files generated in this project are intended for a variety of applied uses, we have kept the data in degrees Fahrenheit and express elevation in feet above sea level throughout this study.

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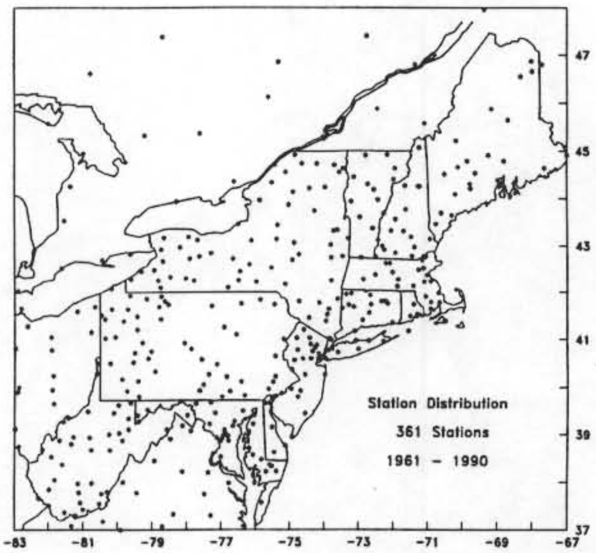

Fig. 1. Location of stations used in this study within the 12 state northeastern region as well as adjacent portions of Virginia, Ohio and Canada.

3. METHODOLOGY

a. Variables

Thirty-year normals for 12 temperature and temperature-derived variables were generated from the daily maximum and minimum observations for each station on a daily basis. They include:

* mean temperature and standard deviation
* mean maximum temperature and standard deviation
* mean minimum temperature and standard deviation
* mean temperature range and standard deviation
* mean heating degree days (base 65°) and standard deviation
* mean cooling degree days (base 65°) and standard deviation

These values were subsequently averaged for the 73 pentads of the year beginning with 1-5 January (February 29 was ignored). In addition, the extreme high maximum and extreme low minimum observations during the 30 year period on any day in the given pentad were extracted from the base dataset.

b. Gridding

An inverse distance squared, nearest neighbor routine was used to interpolate the 361 station values, for each variable, to a 0.25° latitude by 0.25° longitude grid (Fig. 2) (Surfer 1992). This procedure was carried out for each pentad period. Thus, 14 variables were gridded for each of 73 pentad periods, yielding 1022 data grids. Each of these grids was smoothed using a matrix smoothing routine including the eight grid boxes surrounding the center box.

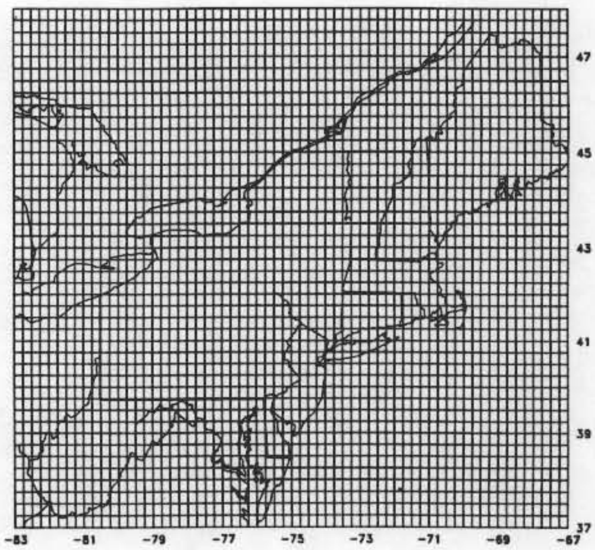

Fig. 2. Grid density (0.25° x 0.25°) used in this study.

c. Elevation adjustment

The topography of the Northeast is quite variable and the locations of observation sites are not necessarily representative of the mean elevation of the grid cells they represent. Therefore, an adjustment of station-derived grid values for many of the 14 temperature variables was required. This was a five-step process.

1) An elevation grid of the Northeast derived from the elevations of the 361 stations was constructed. The data were interpolated to

the same grid as the temperature data and smoothed in the same manner.

2) National Geophysical Data Center (NGDC) digital elevation model data with a grid cell resolution of 0.08° x 0.08° were aggregated to a 0.25° x 0.25° grid box mean. To maintain consistency, these values were subsequently interpolated and smoothed in the same manner as the station grid.

3) The station-derived elevation grid was subtracted from the NGDC-derived grid to obtain an elevation difference grid. Differences in elevation between the two products are below 500 feet over most of the Northeast. Exceptions, with differences ranging from 500 feet to 1500 feet, include western Maine, the White Mountains of New Hampshire, the Green Mountains of Vermont, the Catskill Mountains of New York, and the eastern mountains of West Virginia.

4) For each region, mean lapse rates were calculated from the station network by regressing temperature variables at each station against the station elevation. From sensitivity analyses it was determined that the latitude and longitude of the stations did not affect the value of the lapse rates. Only the timing within the annual cycle causes appreciable variations in lapse rate calculations. Thus for each pentad and for each variable a regional lapse rate was calculated. Pentad lapse rates for mean temperature exemplify the annual variability (Fig. 3). Values range from approximately -2.2°F/1000 ft in spring to about -3.2°F/1000 ft in mid summer. A similar shape and magnitude to the annual cycle is observed for the other variables. The mean daily temperature range and the standard deviations of the variables exhibit no pronounced elevation dependence and were therefore not adjusted for elevation for the final dataset.

5) The elevation difference grid and the mean regional lapse rate for a pentad were multiplied to obtain a temperature adjustment grid value. This value was subsequently added to the initial (station) temperature grid value to obtain an elevation-adjusted temperature for a grid box. Again taking mean temperature as an example, for most of the Northeast (elevation adjustment less than 500 ft), the elevation-adjusted temperatures are no more than about 1.0° (spring) to 1.75° (summer) lower than station-derived temperatures. These values are

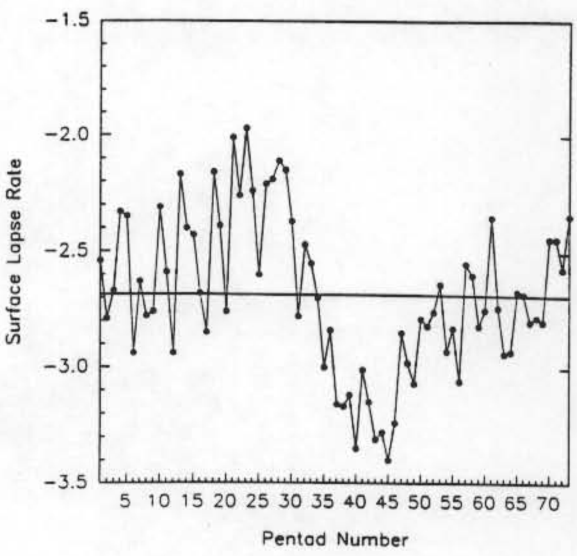

Fig. 3. Pentad lapse rates for mean temperature calculated from the 361 study stations.

close to those observed for other variables (reverse sign for heating degree days).

4. RESULTS

The data and methodology discussed above were used to produce 1022 mean pentad maps for the diverse temperature variables. A small sample of maps generated from the gridded data files is presented in Figs. 4-8.

All temperature variables across the Northeast vary with latitude and elevation. In winter, latitude is the most apparent control on temperature. This is particularly so inland, away from the maritime influence of the Atlantic, and outside the influence of Lakes Erie and Ontario. The influence of elevation is apparent at all times of the year, and plays a greater role in summer, when latitudinal control is less pronounced. Specifically, four major areas show the effect of increased elevation. The eastern mountains of West Virginia stand out clearly as an area of decreased temperature in the southern portion of the Northeast. The temperature gradient is quite large along the eastern side of the mountains, where temperatures rise from the piedmont to the coastal plain. In addition, the Allegheny Plateau in northwest Pennsylvania and southwest New York is very distinct, as are the Catskill

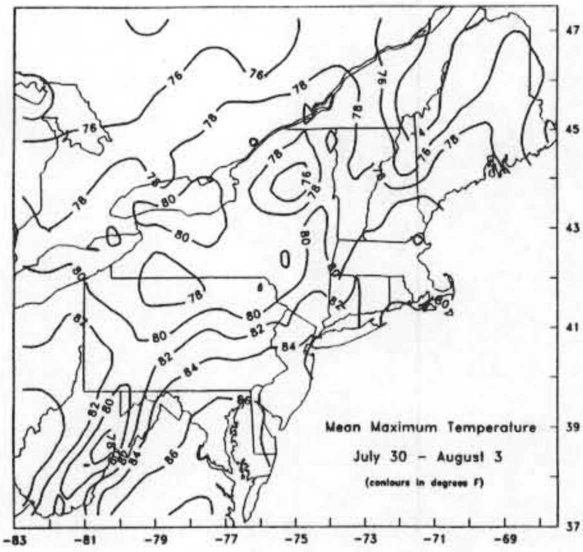

Fig. 4. Mean daily maximum temperature across the Northeast during pentad 43.

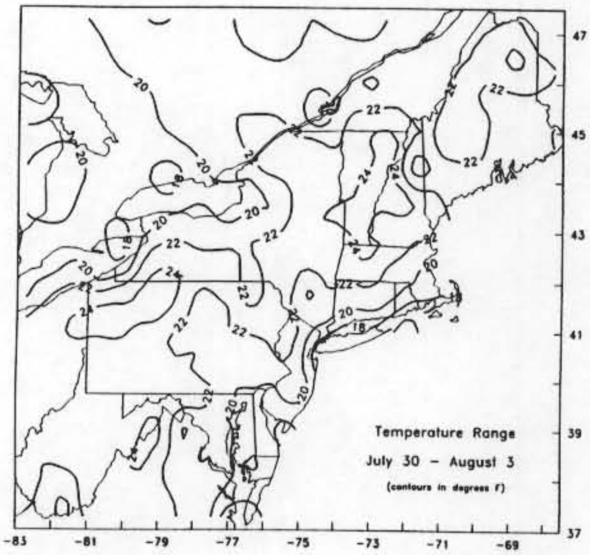

Fig. 6. Mean daily temperature range (mean pentad maximum minus mean pentad minimum) across the Northeast during pentad 43.

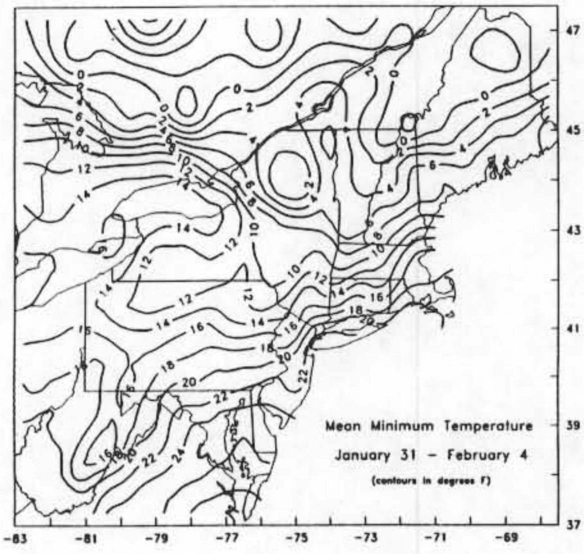

Fig. 5. Mean daily minimum temperature across the Northeast during pentad 7.

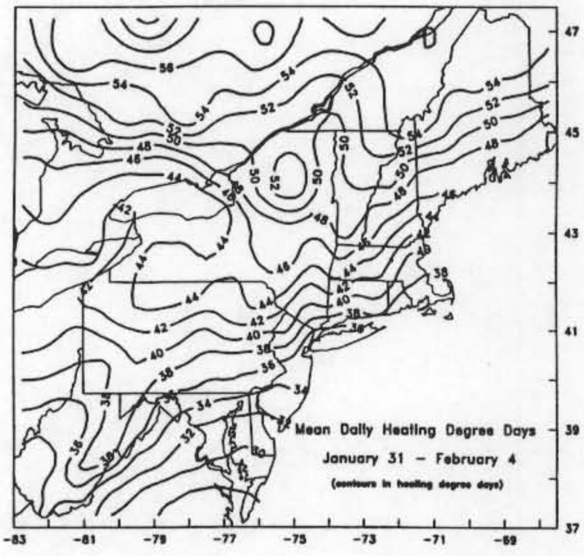

Fig. 7. Mean daily heating degree days across the Northeast during pentad 7.

Mountains. Finally, the Adirondack Mountains in New York and the White and Green Mountain are recognized in all temperature files.

Major river valleys of the Northeast also stand out in several of the temperature products. The Hudson River valley in eastern New York and southern portions of the Connecticut River valley can be identified in Figs. 4 and 5. Urban heat islands, while not visible in the contoured figures, with the possible exception of the New York City metropolitan area in the summer maximum figure (Fig. 4), are identified in several 0.25° x 0.25° grids. As the majority of stations employed in this analysis, as well as the

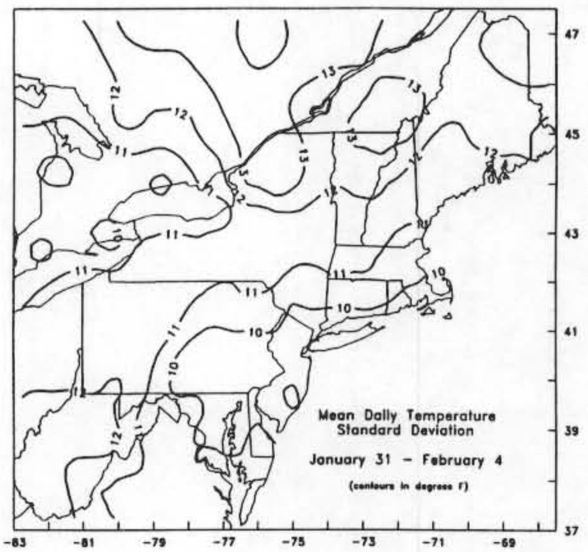

Fig. 8. Mean standard deviation of daily mean temperature across the Northeast during pentad 7.

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bulk of the Northeast, lie outside the sphere of direct urban influence, heat island affects are considered minor in this dataset.

Temperature-derived variables exhibit the same geographic controls as seen for the observed temperatures. Heating degree day values are much larger in areas with higher elevations and to the north, while cooling degree day values show the opposite tendencies. The standard deviation of temperature is generally larger across the northern portion of the region, at higher elevations, and away from the Atlantic and the Great Lakes.

5. DISCUSSION AND CONCLUSIONS

We anticipate that the temperature dataset generated in this project will be of use to many who require regional temperature information produced in a consistent manner at high spatial and temporal resolutions. Users should include those in the applied climate community, as well as those interested in climate change issues. Of some relevance to both groups should be work we are currently completing, where the 1961-90 interval is being placed in historic perspective. We are comparing this period to observations extending back 60 to 100 years. This is being done on a pentad level using a subset of 50 stations. Due to the limited availability of digital daily data prior to the late 1940s, this study uses fewer stations that are analyzed individually and are not corrected for elevation. Preliminary results indicate that the most recent 30 year interval was not the warmest, nor the coldest of the past century across the Northeast. Differences within the region have been recognized, as have variations within different seasons. Results of the historical analysis will be published at a later date and filed with the Northeast Regional Climate Center.

In the meantime, the pentad data files generated for the study discussed in this paper have been delivered in hardcopy (map) and digital (grid) formats to the Northeast Regional Climate Center. They are available to all interested users.

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