1. INTRODUCTION

The U.S. Army forts recorded daily weather observations starting in the early 1800’s. Many of these records continue into the mid-1800’s. In the mid- to late 1800s, other volunteer observer networks were managed by the Smithsonian Institution and the U.S. Department of Agriculture. These station networks eventually evolved into the Weather Bureau’s Cooperative Observer Network. The National Climatic Data Center (NCDC) holds these 1800’s records on microfilm. As part of NCDC’s Climate Database Modernization Program, these records have been scanned and indexed, and are available online to the research community. Researchers can request on-line access to particular data by following the procedures at: http://www.ncdc.noaa.gov/oa/climate/cdmp/wssrd.html.

Many of the daily records from these 1800’s stations are being digitized. Approximately 160 priority stations (about 3 per state) have been selected for digitization, with more stations to be digitized as funding permits. Most of the data types recorded by the observers are being digitized. When completed, this digitized data set will allow for extension of the analysis of daily climate variables back into the 1800s and will provide a link between the more recent instrument records and paleoclimate records. Additional data sources are being located and added to this data periodically.

2. DEVELOPMENT OF STANDARD OBSERVING PRACTICES

Significant changes in instrumentation and observation practices occurred during the period covered by this data set. At the beginning of instrument observations, the temperature and other data types were observed several times a day, typically three, and occasionally up to six times a day at specified times (“at-hour” observations). Temperature was the most common data type observed in the early 1800’s. Figure 1 shows a typical hand-drawn table of temperature, wind, and weather observations recorded by U.S. Army staff at Fort Armstrong (Rock Island), Illinois, in 1820.

Over time, additional instruments were added to weather stations, and more data types were recorded on standardized forms. By the mid-1800’s, weather observations typically included precipitation, temperature, cloud cover and movement, wind direction and movement, barometric pressure, and dry- and wet-bulb temperatures, from which relative humidity was calculated. Figure 2a and 2b shows a typical standard printed form for volunteer observers to report weather observations to the Smithsonian Institution, with observations for Peoria, Illinois, in January, 1861. River gauge heights and surface water temperatures were also included in the standard set of data types observed for some stations in the 1880’s.

With the development of the maximum/minimum thermometer, daily maximum and minimum temperature observations were added to the at-hour observations beginning in the 1870’s. Eventually, the at-hour observations for temperatures were replaced by 24-hour observations, with few Cooperative Observer Network stations continuing at-hour observations after 1900.

The need for a more standard thermometer shelter was recognized in the mid-1800’s. It took many years for a standard shelter to be developed and placed in use at all weather stations. In 1883, the Signal Office conducted a thermometer exposure survey of its weather stations, which is now preserved at the National Archives. The survey requested the observers to answer several questions in detail about the exact location of the thermometers and their surroundings. At this time, wood shelters were in use at some stations, although they were not of uniform construction (Chenoweth, 1993). Figure 3 shows a non-standard...
thermometer exposure typical for the time, with the thermometer attached to the back of a small wood building at the Signal Service station in Wellington, Kansas. Figure 4 shows a detailed sketch of a free-standing thermometer shelter at the Signal Service station in Fort Buford, Dakota Territory. The shelter is of wood construction, with a single-layer roof and blinds on the side, and open on the bottom, which is relatively close to the current standard. The sketch in Figure 5 shows the location of a free-standing thermometer shelter in the shade of a tree at the Signal Service station in Worthington, Indiana. The shelter is a small, shallow box, open in front, facing west, such that the sun may shine on the thermometers in the evening in the winter months. Figure 6 shows a building constructed specifically for the weather station in Peoria, Illinois, in 1906, with the thermometers located in a shelter near the building. By this time, most observing practices and instrumentation for daily weather stations had become standardized.

3. DATA AVAILABLE FOR DIGITIZATION

The approximately 160 priority stations include about three per state, for geographic coverage of the continental U.S. These stations include more than 50 with over 50 years of observations. Over 60 of the priority stations have at least 10 years of observations before 1850. Due to the large volume of data to be digitized for each station, about 20 stations will be completed during the first year of production digitization. As shown in Figure 7, these stations were selected for length and general coverage of the U.S.

Thirty-nine data types have been identified for digitization (Table 1). Many of these data types include observations for both 24-hour periods and periods less than 24 hours. For some stations, for example, the precipitation was recorded at three times per day. In all cases, the final digitized data set will include both 24-hour and less-than-24-hour observations, as recorded, to allow for the greatest research potential.

5. METADATA

A comprehensive set of metadata is being developed to complement the data set. Some of the various standard forms used by the collecting organizations included a large variety of information about how the observations were made and recorded. Almost all forms and journals included the basic, necessary information about the station, including station name, latitude/longitude, elevation, and instruments in use. Some of the documents also included other, more detailed information, such as instrument make and model, barometer correction and other instrument adjustments, instrument exposure, and damage and replacement of instruments. Some standard forms have specific places for the observer to record this information, while in journals, the observers may have noted such information in the remarks.

A set of web-based metadata entry tools were developed specifically for this project, to manage the wide variety of information available while allowing for efficient entry of the metadata based on the manner in which it is presented on the forms. Since pulling up an image and becoming familiar with the information on it is relatively time-consuming, the metadata entry tools allow the keyers to systematically enter all information from the form. While looking at an image, the metadata keyers also enter information about each data element type recorded on the form. Preliminary keying of the daily data demonstrated that, since there are so many different forms used within this dataset, the greatest quality assurance challenge is to properly identify each data element type as it is keyed. In effect, the metadata keyers, who are trained meteorologists, produce a set of keying instructions for each image, which include the data element type list, for the daily data keyers, who are not trained meteorologists. The data element list is also used again in the quality assurance process after digitization of a station is completed.

<table>
<thead>
<tr>
<th>TABLE 1. Thirty-nine data types are to be digitized from the 1800s daily weather observations.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature: at-hour, maximum, minimum, daily mean, daily range, dry bulb, wet bulb, dew point, relative humidity.</td>
</tr>
<tr>
<td>Barometric Pressure: uncorrected, corrected for temperature, adjusted to sea level, temperature from attached thermometer.</td>
</tr>
<tr>
<td>Precipitation: total precipitation, melted snow, snowfall, snow depth, precipitation type (rain or snow), time of beginning, time of ending.</td>
</tr>
<tr>
<td>Wind: direction, velocity, force, maximum wind direction, maximum wind velocity, total wind movement.</td>
</tr>
<tr>
<td>Clouds: clearness of sky, cloud amount, type, direction, velocity.</td>
</tr>
<tr>
<td>State of the Weather.</td>
</tr>
<tr>
<td>Character of the Day.</td>
</tr>
<tr>
<td>River Gauge Height: gauge height, gauge height daily change.</td>
</tr>
<tr>
<td>Surface Water Temperature: surface air temperature, surface water temperature, bottom water temperature, depth to bottom.</td>
</tr>
</tbody>
</table>
4. DIGITIZATION AND QUALITY ASSURANCE

A series of quality control tests and procedures are being applied to the digitized data to assure the digitized data accurately represents the observations recorded on the original documents. The quality assurance includes double keying of the data to minimize keying errors and internal consistency checks and range checks on the monthly totals and means. The checks on the monthly totals and means help ensure that the data types are properly identified, particularly for temperature and precipitation. Internal consistency and extremes checks on individual values are also being applied to the data for each station. Suspect values will be flagged and will be retained in the data set.

Management of the various quality assurance tests is handled with a web-based tool to display values that fail the various tests and to record information about any corrections which are required. The tests must be applied sequentially to the data; for example, the data element types must be checked and any corrections made before internal consistency checks among the element types can be applied. In general, the issues with the quality of the daily data are more related to the observation techniques and general keying process, rather than to the keying of individual values. Double-keying minimizes keying errors in the individual values, while problems due to image quality, identification of observer habits, and non-standard observation practices remain challenges to identify.

6. ANALYSIS

Due to the changes in instrumentation and observation practices over time, as well as changes in the location of stations, it will not be possible to simply add the digitized data to the beginning of the more recent observations at the same stations. The metadata being digitized in this project will be useful for identifying the timing of potential changes in the daily data. The information gathered in a related pilot project funded through the Climate Database Modernization Program will also be helpful for analysis. In this project, detailed station history information for several stations with very long records is being gathered together, covering the beginning of record through the mid-1900’s. The station histories may include records on everything from the precise siting of the instruments, with pictures, to the way of life and motivations of the observers.

Analysis will be necessary to determine the stability of changing observation techniques to a particular application. For example, Andsager and Angel (2000) examined biases between the 2 PM temperature and the daily maximum temperature to extend the analysis of heat wave days from about 1900 back to 1856 for several Illinois stations. The data may also be used in conjunction with proxy climate data; for example, Druckenbrod, et al. (2003) used tree-ring and meteorological diary reconstructions to examine the seasonality of precipitation from James Madison’s era to the mid-1900’s. When completed, the large number of data types included in this 1800’s digitized data set will allow for extension of the analysis of a variety of daily climate variables back into the 1800’s.

7. ACKNOWLEDGEMENTS

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8. REFERENCES


Chenoweth, M., 1993: Nonstandard thermometer exposures at U.S. cooperative weather stations during the late Nineteenth Century. J. Climate, 6, 1787-1797.

FIGURE 1. First month of record for Fort Armstrong (Rock Island), Illinois, in July, 1820. Common data types observed in the early 1800’s included three times daily temperature, wind direction, and state of the weather. Also common were remarks, which for some observers were highly detailed.
FIGURE 2a. Weather observations for Peoria, Illinois, for January, 1861, on the first of two pages of the standard form of the time for the volunteer observers reporting to the Smithsonian Institution. Common data types observed in the mid-1800’s and recorded here include three times daily temperatures, precipitation, clouds, and wind.
FIGURE 2b. Second of two pages for weather observations for Peoria, Illinois, for January, 1861. Common data types recorded here include three-times-a-day information about pressure and relative humidity.
Figure 3. Sketch of thermometers attached to the back of a small wood building at the Signal Service station in Wellington, Kansas, in 1883 thermometer exposure survey. The text with the sketch describes the location and exposure of the thermometers as follows, “The thermometers are exposed to all conditions of the weather except only on occasions of threatening hail or wind storms – instruments are subjected to rain or snow. Surrounding country level open prairie, no timber, or trees. Six buildings small, within 600 feet.” Note thermometers are attached to the north side of the building, over sod.

Figure 4. Sketch of free-standing thermometer shelter at the Signal Service station in Fort Buford, Dakota Territory, in 1883 thermometer exposure survey. The shelter is of wood construction, 2 ft by 3ft by 3 ft, with a single-layer roof and blinds on the side, and open on the bottom. The text with the sketch describes the location and exposure of the shelter as follows, “Eight feet west of Hospital building, exposed to all winds except a due E wind, no other building near, prairie land, ground under shelter is sod.”
Figure 5. Sketch of free-standing thermometer shelter near a tree at the Signal Service station in Worthington, Indiana, in 1883 thermometer exposure survey. The shelter is a small, shallow box, open in front, three inches deep, and two feet long. The open side of the box faces west, and is always in the shade, except in the evening in November, December, and January. The shelter is between a coal house and an ice house in a yard behind the W. B. Squire Drug Store, a brick building. Another brick building and a frame building are also nearby. The barometer is located on the west wall inside the Drug Store.

Figure 6. Photograph of the Weather Bureau observer’s building on the campus of Bradley University in Peoria, Illinois, in 1906. The thermometer shelter is the small white box to the left of the building, in front of the building in the distance. There are stairs in front of the shelter for reaching the thermometers. The anemometer is located on the pole to the left in the picture, toward the center of the building’s roof.
FIGURE 7. First-year priority stations to be digitized. These stations were selected for length and general coverage of the U.S.