

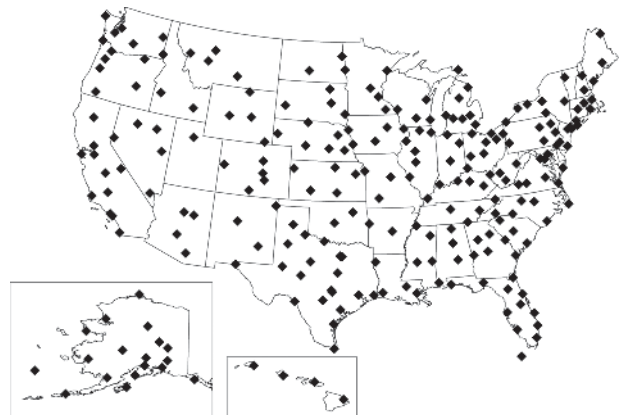
# 1981–2010 U.S. Hourly Normals

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Hourly meteorological data have a wide variety of societal applications. From an engineering perspective, hourly data are critical in estimating heating and cooling requirements, ice loads for power lines, wind loads for buildings, and runoff demands for drainage systems. From an operational perspective, hourly data are crucial to the aviation and shipping industries as well as the management of hazardous materials crises. From a forensic perspective, hourly data support the investigation of insurance claims, criminal cases, and aircraft accidents. In short, hourly records are among the most widely used of all meteorological data.

Given these numerous applications, NOAA's 1981–2010 U.S. Climate Normals include, for the first time, a comprehensive suite of descriptive statistics based on hourly observations. These hourly normals are available for 262 locations distributed in a relatively uniform fashion across the United States and its territories (Fig. 1). Three types of statistics are included for each station: 30-year averages, frequencies of occurrence, and percentiles (10th and 90th) for each hour and day of the year. Table 1 lists the particular variables and statistics computed for each location.

This article provides a brief overview of this new Hourly Climate Normals product from NOAA. In particular, section 2 provides a description of the data and the station selection criteria used. The computational procedures are then explained in section 3. Finally, two applications of hourly normals are provided in section 4.



**FIG. 1. Locations for which hourly normals were computed in the United States. (Eight locations in the West Pacific and San Juan, Puerto Rico, are not shown.)**

**DATA. Source data.** The source data for the 1981–2010 Hourly Normals was the Integrated Surface Dataset-Lite (ISD-Lite). A set of 262 stations (Fig. 1) were selected from ISD-Lite based on their completeness and membership in a list of what were known as “first order stations.” These were typically airport locations with the needed 24 observations per day to make hourly normals possible. All stations had at least 26 of the 30 years represented. Some data conversions were necessary to support the primarily U.S.-centric user community; in particular, temperature and dew point values were converted from tenths of a degree Celsius to Fahrenheit; wind speeds were converted from tenths of  $\text{m s}^{-1}$  to  $\text{mi h}^{-1}$  (pressure and cloud values required no conversion). The original data were also converted from GMT to local standard time (LST).

**Quality control.** ISD undergoes a suite of 54 operational quality assurance reviews on a daily basis. To supplement these operational checks, ISD-Lite values, which are composites of ISD data, were further tested to screen out values meeting the following conditions prior to the computation of normals:

- The value exceeds the established global record for that variable.

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**TABLE 1. Statistics produced for the 1981–2010 hourly normals.**

<b>Temperature, dew point, mean sea level pressure</b>	Average hourly value 10th and 90th percentiles of hourly values
<b>Heating and cooling degree hours</b>	Average hourly value (base 65°F)
<b>Heat index and wind chill temperatures</b>	Average hourly value
<b>Clouds</b>	Hourly percent-frequency of clear, few, scattered, broken, and overcast conditions
<b>Wind</b>	Prevailing and secondary wind direction and percent frequency
	Average wind speed and percentage of calm winds
	Vector-mean wind direction and magnitude

- Streaks of constant values longer than 24, 48, 72, and 24 hours for temperature, dew point, mean sea level pressure, and noncalm wind speed, respectively.
- Mean sea level pressure jumps from a value in excess of 1,059.9 hPa to 960.0 hPa, and vice versa. (This is an effect of the reporting practice that includes only the rightmost three digits in the observation record.)
- The dew point value exceeds the temperature value due to slightly varying times used for the “on the hour” observation (both were considered invalid).
- A value is more than 7 standard deviations from its mean within a 450-observation sample of temperature or dew point.

**COMPUTATIONAL PROCEDURES.** Each hourly normal was computed on the basis of 450 possible values. This was the aggregation of the value for a particular date and time, plus and minus 7 days, over each of 30 years. If fewer than 350 valid values were present, the normal was set to a missing value. Overall, normals were computed for the following eight elements:

*Temperature, dew point, and mean sea level pressure.* These were the most straightforward of the hourly normals. Averages and 10th- and 90th-percentile values were simply computed from the respective samples of these variables.

*Cooling and heating degree hours.* Cooling degree-hour normals were computed by subtracting 65°F from each valid temperature in the sample of 450. Positive differences were summed and divided by the overall number of valid values. Heating degree-hour normals were computed in a similar manner: subtracting valid temperatures from 65°F, summing the positive differences, and dividing by the number of valid values.

*Heat index.* Values of this apparent temperature were computed when the temperature exceeded 80°F and relative humidity was greater than 40%. When these criteria were not met, the temperature replaced the heat index in the sample set. For example, a location with a tempera-

ture normal of 80°F would have roughly half of its temperature values below 80°F. These temperatures, along with heat index values computed when the temperature exceeded 80°F (assuming relative humidity  $\geq 40\%$ ), would form the sample from which the heat index normal was computed. The heat index normal was therefore an average of temperatures as influenced by available heat indices.

*Wind-chill temperature.* Similar to the above heat index computation, the wind-chill temperature was computed when the air temperature was less than 50°F and the wind speed was greater than or equal to 3 mi h<sup>-1</sup>. The wind chill value was set equal to the actual temperature if these conditions were not met.

*Clouds.* Valid cloud observations ranged from 0 to 8, inclusive, representing eighths of sky coverage. An obvious bias was noticed in the reports of values 0, 2, 4, 7, and 8. We computed frequencies of these values as categories of clear, few, scattered, broken, and overcast, respectively. Reports of 1, 3, 5, and 6 were included in the next higher category.

*Wind.* Normals were composed of the following:

- The scalar-mean speed of all wind speed values.
- The frequency of calm winds, less than or equal to 3 mi h<sup>-1</sup>.
- The direction and magnitude of the vector mean

wind, defined as follows: Each wind observation is decomposed into  $u$  and  $v$  components. The average of each component was computed. A resultant vector-mean wind was then assembled from the average components.

For noncalm winds, each was counted in a 45°-wide directional bin centered on 0°, 45°, 90°, . . . , 315°. Counts in these bins were rescaled to account for a bias introduced by wind directions being even multiples of 10°. The identity of the two bins with the highest counts, along with their overall frequencies, was provided.

*Internal consistency checks.* Due to varying sample sizes, the normal values were occasionally inconsistent with logical reality. For example, if there were more valid temperature values than dew points for a given date and time, it was possible for the computed mean of the dew points to be greater than the mean of the temperatures. In such a case, the temperature normal replaced the dew-point normal to address this issue.

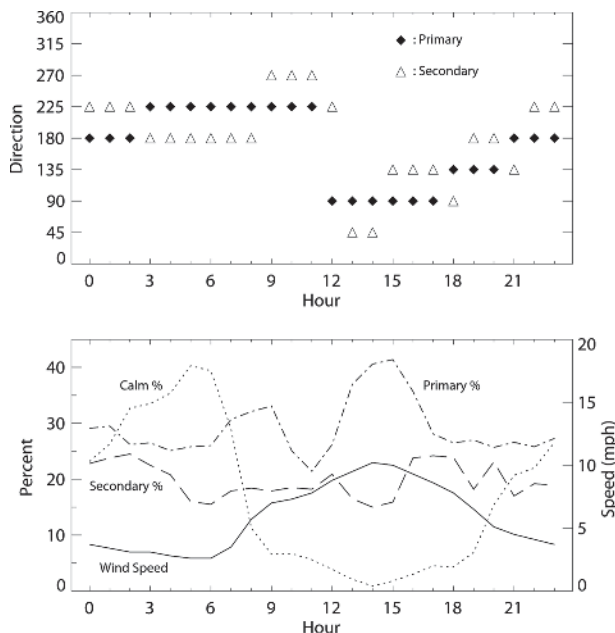
Inconsistencies such as these impacted less than 1.2% of the output for normals in which they could occur, and typically resulted in a change of only one-tenth of unit of measure.

**CAVEATS.** One should not expect any combination of hourly temperature normals to result in the normals for daily and longer time scales described in the companion article by Arguez et al. in this issue of *BAMS*. This is first due to the use of hourly observations rather than daily observations of minimum and maximum temperature. Second, this latter group of observations contains adjustments for historical changes in station location, meteorological instrumentation, observing practice, and siting conditions. We therefore encourage use of the hourly normals for examination of the diurnal changes of a particular variable, or day-to-day changes of values at a particular hour, as illustrated in section 5. For daily, monthly, and seasonal values, the more reliable normals products designed for those time scales should be used.

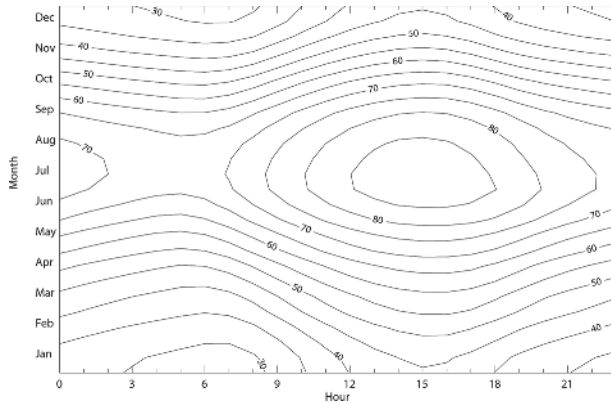
Though the normals described here are intended to be broadly representative of their geographic region, it should be emphasized that most observing locations are at airports. Typically with flat and treeless terrain, the airport might not be representative of a specific location in the surrounding area. Users of these normals must assess the suitability of the observation location for their particular applications.

**SAMPLE APPLICATIONS.** Researchers, policy makers, educators, and others are expected to make extensive use of these new hourly normals. To illustrate their potential application to a more general audience, here we provide two simple examples of the utility of hourly normals: the timing of significant wind shifts at Daytona Beach, Florida, and the diurnal cycle of temperature extremes at Albuquerque, New Mexico.

*Wind at Daytona Beach, Florida.* We first examine the hourly wind normals for Daytona Beach, Florida, on 20 July. The observation location is approximately 6 km from the Atlantic Ocean, with a coastline oriented along compass directions 335°–155°. As seen in Fig. 2, as the day begins, winds are predominantly calm with noncalm modes coming from the south and southwest. At 1200 LST, the shift to the dominant sea breeze begins. Two hours later, the maximum wind speed is reached, calm winds are almost non-



**FIG. 2.** Hourly wind normals for Daytona Beach, Florida, on 20 Jul (1981–2010). In the upper panel, the filled diamonds and open triangles indicate the wind sectors accounting for the highest two percentages of all noncalm wind events. In the lower panel, time series throughout the day are plotted for average wind speed (solid line), percentages associated with primary (dash-dot line) and secondary (long dash line) directions, and calm (dotted line) events.



**FIG. 3. An annual depiction of the diurnal temperature cycle based on hourly temperature normals. For the 14th and 28th of each month in Albuquerque, New Mexico, hourly normals for each date are contoured in 5°F increments. A clear shift in the time of minimum temperature is seen in the left half of the figure. The right portion of the figure shows a nearly constant time of maximum temperature.**

existent, and the sum of the top two modes is more than 55% of all winds recorded. The hourly normals capture a textbook sea-breeze scenario, but also yield

useful information about the timing, intensity, and frequency of the events.

**Temperature at Albuquerque, New Mexico.** Next we look at the hourly temperature normals for the 14th and 28th day of each month for Albuquerque, New Mexico, as seen in Fig. 3. As expected, the minimum temperature during the day is typically found in the morning, with a shift toward earlier hours during warmer months corresponding to an earlier sunrise. In fact, a statistically significant linear relationship exists between the time of the minimum hourly normal temperature and that temperature. More noteworthy, however, is the lack of any such relationship for the time of the maximum normal temperature. For every date plotted here, if 1500 LST is not the singular hour the maximum hourly normal occurs, it is among times tied for the maximum temperature. Thus, hourly normals challenge the typical paradigm of a seasonal shift in the time of day for maximum temperatures for Albuquerque.

**AVAILABILITY.** Hourly normals are available as ASCII text files from NCDC through its website: [www.ncdc.noaa.gov/oa/climate/normal/usnormals.html](http://www.ncdc.noaa.gov/oa/climate/normal/usnormals.html). In addition, dynamic, map-based access is under construction in NOAA's Climate Portal (<http://gis.ncdc.noaa.gov/map/cdo?thm=Normals>). At the same sites, temperature and precipitation normals created for the daily, monthly, seasonal, and annual time scales for thousands of locations are available as separate products.

## FOR FURTHER READING

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