U.S. National 1961-1990 Climate Normals
CLIMATOGRAPHY OF THE UNITED STATES NO. 81
Monthly Station Normals

September 29, 1995

Description

This publication presents normals of average monthly and annual maximum, minimum, and mean temperature (degrees F), monthly and annual total precipitation (inches), and heating and cooling degree days (base 65 degrees F) for individual locations for the 1961-90 period. There are temperature and degree day data for 4,775 stations and precipitation data for 6,662 stations. The locations represent cooperative weather observer sites, National Weather Service offices, and principal climatological stations in the 50 states, Puerto Rico, Virgin Islands, and Pacific Islands (station map).

The monthly normals are published by state. The data are arranged in four tables representing temperature, precipitation, heating degree days, and cooling degree days. The locations are listed alphabetically within each table. A station locator map and cross reference index providing station name, number, type, location, and elevation are included in the publication for each state.

The monthly normals as well as the 30-year sequential temperature and precipitation data are available on microfiche and magnetic tape. The cross reference index is also available on magnetic tape and is designated as the "monthly 1961-90 normals name tape."

Computational Procedures

Monthly normals were computed for as many stations as practical. In order to be included, the station had to have at least 10 years of monthly temperature data and 10 years of monthly precipitation data from the period 1961-90.

A normal is the arithmetic mean of a climatological element computed over three consecutive decades (Guttman, 1989). The data record should be consistent (have no changes in location, instruments, observation practices, etc.; these are identified here as *"exposure changes"*) and have no missing values so a normal will reflect the actual average climatic conditions. If any significant exposure changes have occurred, the data record is said to be *"inhomogeneous"* and the normal may not reflect a true climatic average. Such data need to be adjusted to remove the nonclimatic inhomogeneities. The resulting (adjusted) record is then said to be *"homogeneous"*. If no exposure changes have occurred at a station, the normal was calculated

simply by averaging the appropriate 30 values from the 1961-90 record.

To address the inhomogeneity problem, the normals methodology involved the following four steps:

1. estimating missing data;
2. adjusting First Order stations with inhomogeneous records;
3. calculating the average monthly values; then
4. converting the temperature averages to the station's official normal, which is valid for the current (as of 1990) observation time.

Neighboring stations were used to estimate missing data. For precipitation, missing values were estimated by averaging the precipitation values from the four nearest neighbors having data for the month in question. The neighboring stations included First Order and Cooperative stations that were within a 30-mile radius of the station being estimated.

For temperature, the nearest 40 neighboring stations were examined and their temperature variations were compared to the temperature variations at the station for which the normals were being calculated (the candidate station). Of these, a pool of 20 neighbors that had the highest correlation with the candidate station were used to estimate the candidate station's missing temperature value. The estimate was calculated using a weighted average of the values from these neighboring stations. The neighboring stations included stations that were part of the Historical Climatology Network (HCN; see Karl, *et al.*, 1990).

The method used to adjust for inhomogeneities is based on the HCN methodology outlined by Karl and Williams (1987). This technique involves comparing the record of the candidate station to the records of neighboring stations. A neighboring station was not used if its record did not cover the same time period as the candidate station. The underlying assumption behind such a methodology is that variations in average weather have similar tendencies over a region. For example, cold winters at a candidate station usually occur simultaneously at its neighboring stations. If this assumption is violated, then there will be a systematic difference between the stations which will show up as temperature differences (or precipitation ratios) that do not follow the expected statistical pattern. Acceptance of this methodology allows the use of certain well-defined statistical techniques to make the adjustments.

Inhomogeneities in the candidate station's record were determined by examining the location, instrument, and observation history of the station.

After the periods of inhomogeneity were determined, adjustments were applied to remove the biases. The adjustments were determined using the following criteria. Neighboring stations were found which had homogeneous data records that covered the time period of the candidate station's inhomogeneous period. If the candidate station and a neighbor had a reasonably high correlation (r squared > 0.6) of monthly anomalies for the period in question, then the established homogeneous neighboring station was used to assess the impact of the candidate station's discontinuity. The part of the data record before the discontinuity was statistically compared to the part after the discontinuity. The Student's t-test was used for the temperature differences, while the nonparametric Wilcoxon rank-sum test was used for the precipitation ratios. If the statistical test indicated that the two parts of the candidate station's record were significantly different, then the earlier part of the record was adjusted (further details, with examples, can be found in Karl and Williams, 1987). After all exposure changes at the candidate station were corrected, the normal was estimated by averaging the appropriate 30 values from the 1961-90 adjusted record. If none of the neighboring stations had a sufficiently high correlation, then no adjustment was made. The climatological

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elements (maximum temperature, minimum temperature, and precipitation) were adjusted separately.

Exposure change adjustments were made to First Order stations in the Lower 48 States, but not to the stations in Alaska, Hawaii, or U.S. possessions because of the lack of a sufficient number of neighboring stations. The neighboring stations used in the adjusting procedure included stations from the Cooperation Station Network. No exposure change adjustments were made to the Cooperative Stations due partly to a lack of adequate computerized station history information, but also because a Cooperative Station's identity changes (according to National Weather Service standards) when significant moves occur (generally at least 5 miles horizontally or 100 feet in elevation, subject to the judgement of the National Weather Service Cooperative Program Manager).

Due to the adjustment techniques employed, the normals published in the Climatography of the United States No. 81 publication will not necessarily agree with values calculated by simply averaging the monthly observed values from 1961-90.

Comparison of temperature data between stations works best if all of the stations involved have the same observational schedule. This is generally true for First Order Stations which use the calendar day (midnight) observation time. Unfortunately, some Cooperative Stations have an observation time in the morning, some in the afternoon, some in the evening, and some at midnight, and this introduces a nonclimatic bias into the record. For an explanation of this bias, see Karl *et al.* (1986). To make the data reflect a consistent observational schedule, the adjustment technique developed by Karl *et al.* (1986) was used to determine midnight observation time adjustment factors to convert the maximum and minimum temperature data for all appropriate stations to a midnight-to-midnight schedule, thus removing the time of observation bias. No adjustments were made to stations in Alaska, Hawaii, or U.S. possessions because of the lack of a sufficient number of neighboring stations.

It should be emphasized that the official normal temperature values printed in the Series No. 81 publication are for the current (as of December 1990) observation time. The station's observation time and the adjustment necessary to convert the temperature values to a midnight-to-midnight observation time are also shown in the tables. The adjustment factors should be added to the official normals to approximate a "midnight observation time average." This helps a user determine if temperature differences between nearby stations are true climate differences or if they may be caused by different observing schedules. The precipitation data were not adjusted for observation time.

The monthly normals for maximum and minimum temperature were computed as described above. The monthly average temperature normals were computed by averaging the corresponding maximum and minimum normals. The annual temperature normals were calculated by taking the average of the 12 monthly normals. The annual precipitation normals were calculated by adding the 12 monthly normals.

Simple arithmetic procedures were ***not*** applied to obtain the heating and cooling degree day normals. Instead, the rational conversion formulae developed by Thom (1954, 1966) were used. These formulae allow the adjusted mean temperature normals and their standard deviations to be converted to degree day normals with uniform consistency. In some cases this procedure will yield a small number of degree days for months when degree days may not otherwise be expected. This results from statistical considerations of the formulae. The annual degree day normals were calculated by adding the corresponding monthly degree day normals.

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Normals Included In Other Publications

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Climate normals for U.S. stations are frequently included as part of other National Climatic Data Center publications. This section briefly describes some of these publications and the normals that are included in them.

Local Climatological Data (LCD).

The 1961-1990 monthly station normals appear in the *Normals, Means, and Extremes* table in the **Local Climatological Data, Annual Summary** issue. The climatic statistics include maximum, minimum, and mean temperature; heating and cooling degree days; and precipitation. Some stations also have monthly normals for relative humidity; snowfall; and days with snowfall, precipitation, and temperature beyond specified thresholds.

The LCD *Normals, Means, and Extremes* tables for the National Weather Service principal climatological stations are reprinted together in the publication **Historical Climatology Series 6-3: Climatic Averages and Extremes for U.S. Cities**.

Comparative Climatic Data (CCD).

This publication contains data extracted from the **LCD** *Normals, Means, and Extremes* table. The data are repackaged in tables arranged by climatic element so that values of the same element can be compared for different locations by use of a single table. The elements include monthly and annual means or extremes of temperature; snowfall; wind speed; sunshine; relative humidity; and number of days with minimum temperature equal to or below 32 degrees F, with precipitation at least 0.01 inches, and with skies clear, partly cloudy, or cloudy. Also included are the 1961-1990 monthly normals of maximum, minimum, and mean temperature; heating and cooling degree days; and precipitation.

Climatography of the United States No. 81 (CLIM81) - Supplement No. 1: Monthly Precipitation Probabilities.

A probability value is the frequency of occurrence of a quantity (say, a certain precipitation amount) over a given time period. For example, if the quantity has an annual probability of 0.1, then it would be expected to occur on average once out of every ten years, or 3 times out of every 30 years, etc. It can also be thought of in a predictive sense to mean that, in any given year, there is a ten percent chance (0.1 probability) that the quantity will occur. In this product, probabilities are applied to monthly and annual precipitation amounts. The sequential year-month values of monthly (and annual) precipitation, which were used to compute the monthly normals in the Climatography of the United States No. 81 product, were used in the preparation of this **Supplement**.

The **Supplement No. 1** publication presents the monthly and annual precipitation values (in inches) corresponding to three probability levels: 0.10, 0.50, and 0.90. The stations are listed alphabetically. There is a separate volume of this publication for each state.

Monthly and annual precipitation probabilities are also available on microfiche and magnetic tape. The values are summarized in two tables. The first table shows the amount of precipitation expected at 15 probability levels (0.005, 0.01, 0.05, 0.10, 0.20, 0.30, 0.40, 0.50, 0.60, 0.70, 0.80, 0.90, 0.95, 0.99, and 0.995) for each month of the year and for the annual total. The second table shows the expected precipitation values at the five quintile levels:

- First Quintile: 0-20%
- Second Quintile: 20-40%
- Third Quintile: 40-60%
- Fourth Quintile: 60-80%
- Fifth Quintile: 80-100%

for each of the twelve months and for the year.

Climatography of the United States No. 81 (CLIM81) - Supplement No. 2: Annual Degree Days to Selected Bases.

This publication presents annual heating degree day normals to the following bases (in degrees F): 65, 60, 57, 55, 50, 45, and 40, and annual cooling degree day normals to the following bases (also in degrees F): 70, 65, 60, 57, 55, 50, and 45. The values were computed for all Climatography of the United States No. 81 temperature stations and are summarized alphabetically by state within each state or territory.

Monthly and annual degree day normals are available on microfiche and magnetic tape. The heating degree day normals are to the following bases: 70, 65, 60, 57, 55, 50, 45, 43, 40, 35, 32, and 30. The cooling degree day normals are to the following bases: 80, 75, 70, 65, 60, 57, 55, 50, 45, 43, 40, and 32.

Climatography of the United States No. 81 (CLIM81) - Supplement No. 3: Maps of Annual 1961-90 Normal Temperature, Precipitation, and Degree Days.

This publication contains four maps showing isopleths based on a manual analysis of the 1961-1990 monthly station normals published in the Climatography of the United States No. 81. The elements depicted are the

annual normals for mean temperature, total precipitation, heating degree days, and cooling degree days. The analyzed isopleths are somewhat generalized and may depart to some extent from actual local conditions, because of the station density and the scale of the topography.

Climatic Atlas of the United States.

This publication is an 80-page, large format (16-inch by 22-inch) collection of 231 maps, 21 graphs, and 13 tabulations depicting the climate of the United States in terms of the distribution and variation of temperature, precipitation, wind, barometric pressure, relative humidity, dew point temperature, sunshine, sky cover, heating degree days, solar radiation, and evaporation. It is based on data mainly from the 1931-1960 period.

Climatography of the United States No. 20 (CLIM20) - Supplement No. 1: Freeze/Frost Data.

This publication contains freeze/frost-related information for 3106 observation sites within the United States (the 1879 stations for which 1951-1980 monthly temperature normals were computed and published in the 1951-1980 edition of the Climatography of the United States No. 20 publication, plus 1227 additional locations) for which a serially-complete daily maximum/minimum temperature observation data set had been edited and validated at the National Climatic Data Center.

The main contents of this publication are freeze/frost probability tables for each station, listed by state. The tables contain the dates of probable first and last occurrence, during the year beginning August 1 and ending July 31, of freeze-related temperatures; probable durations (in days) where the temperature exceeds certain freeze-related values; and the probability of experiencing a given temperature, or less, during the year period August 1 through July 31. For the fall and spring dates of occurrence, and freeze-free period, probabilities are given for three temperatures (36, 32, and 28 degrees F) at three probability levels (10, 50, and 90 percent). Six maps present calendar data related to the probability of occurrence of freeze at two temperature thresholds.

Extended tables of freeze/frost data, which contain the dates for probabilities of 0.1 through 0.9 in increments of 0.1 versus temperature thresholds of 36, 32, 28, 24, 20, and 16 degrees F, are available on magnetic tape or on microfiche (by state) for all of the sites given in the publication.

Climatography of the United States No. 60 (CLIM60): Climates of the States.

This publication was issued for each of the 50 states and for Puerto Rico and the Virgin Islands combined. Each publication contains a narrative climatic summary of the state; the means and extremes table for each station in the state that was included in the latest CLIM20 series; and the *Normals, Means, and Extremes* table from the latest LCD Annual Summary for National Weather Service stations that were available for the area at the time of publication. The most recent edition of the **CLIM60** publication was published in the 1970's and includes CLIM20 summaries from 1951 to the mid-1970's and 1941-70 normals in the *Normals, Means, and Extremes* tables.

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