1961-90 CLIMATIC NORMALS

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Climate is an important factor in agriculture, commerce, industry, and transportation. It is a natural resource that affects many human activities such as farming, fuel consumption, structural design, building site location, trade, analysis of market fluctuations, and the utilization of other natural resources. The influence of climate on our lives is endless. The National Climatic Data Center (NCDC) inherited the U.S. Weather Bureau's responsibility to fulfill the mandate of Congress "... to establish and record the climatic conditions of the United States," an important provision of the Organic Act of October 1, 1890, which established the Weather Bureau as a civilian agency (15 U.S.C. 311).

The mandate to describe the climate was combined with guidelines established through international agreement. The end of a decade has been set by the World Meteorological Organization (WMO) as the desirable term for a 30-year period from which to calculate climatic conditions. The average value of a meteorological element over the 30 years is defined as a climatological normal. The normal climate helps in describing the climate and in determining climatic time trends by comparing the current 30-year period with earlier periods.

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I. PUBLICATIONS OF 1961-90 CLIMATIC NORMALS

A. *Climatography of the United States No. 85*, Divisional Normals and Standard Deviations of Temperature, Precipitation, Heating and Cooling Degree Days, 1931-90 (1931-60, 1941-70, 1951-80, 1961-90).

This publication presents normals and standard deviations for the four 30-year periods and the 60-year period between 1931-90 for each division in a state. A division represents a region within a state that is, as nearly as possible, climatically homogeneous. Some areas, however, may experience rather extreme variations within a division (for example, the Rocky Mountain states). The divisions have been established to satisfy researchers in hydrology, agriculture, energy supply, etc., who require data averaged over an area of a state rather than for a point (station).

The divisional data are displayed by name and number for a state or island. The states and islands include the contiguous United States, Alaska, Puerto Rico, and the Virgin Islands, and are arranged alphabetically. Hawaii is not included because the varied topography and locations of the observing stations do not allow for the establishment of homogeneous divisions. The data include monthly and annual values of mean temperature, precipitation, heating degree days (base 65°F), and cooling degree days (base 65°F). Standard deviations of these values are also provided.

The divisional normals as well as the 60-year sequential monthly and annual data are also available on microfiche and magnetic tape.

B. *Climatography of the United States No. 81 (By State)*, Monthly Station Normals of Temperature, Precipitation, and Heating and Cooling Degree Days, 1961-90.

This publication presents normals of average monthly and annual maximum, minimum, and mean temperature, monthly and annual total precipitation, and heating and cooling degree days (base 65°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.

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."

C. *Climatography of the United States No. 84*, Daily Normals of Temperature, Precipitation, and Heating and Cooling Degree Days, 1961-90.

This publication presents daily 1961-90 normal maximum, minimum, and mean temperature, heating and cooling degree days (base 65°F), and precipitation for 422 National Weather Service offices and principal climatological stations. Monthly, seasonal, and annual normals of these elements are also presented. Monthly and annual precipitation probabilities and quintiles are included in the back of the publication. The data are published in a separate pamphlet for each location.

The daily normals were derived by statistically fitting smooth curves through monthly values; daily data were not used to compute daily normals. As a result, the published values reflect smooth transitions between seasons. The typical daily random patterns usually associated with precipitation are not exhibited; however, the precipitation normals may be used to compute average amounts accumulated over time intervals.

The published data are also available on microfiche and magnetic tape.

II. COMPUTATIONAL PROCEDURES

A. DIVISIONAL NORMALS. Climatic divisions are regions within each state that have been determined to be reasonably climatically homogeneous. The maximum number of divisions in each state is 10. Monthly divisional average temperature and total precipitation data were derived using data from all stations reporting both temperature and precipitation within a climatological division. The number of reporting stations within a division varies from month to month and year to year. This variation was ignored in the computation of the normals.

Monthly temperature normals and 60-year averages for a division were computed by adding the yearly values for a given month and then dividing by the number of years in the period. The annual normal and 60-year average were computed by adding all the monthly normal or long-term average values and then dividing by 12. Consequently, if an annual normal were computed by averaging annual values obtained for each year in the period (by adding the corresponding 12 monthly values and then dividing by 12), it may be slightly different from the average of the 12 monthly normals because of rounding differences. Precipitation normals and 60-year averages were computed in a similar manner, except that the annual values are the totals of the 12 monthly values.

Sequential monthly degree days were derived using procedures developed by Thom (1954, 1966). This technique utilizes the historical monthly average temperature and its corresponding standard deviation (over some "standardizing period") to compute degree days. The procedure for the computation of the divisional degree day normals involved the following three steps: 1) calculate the standard deviations of the temperatures for each of the 12 calendar months over the standardizing period; 2) use the Thom technique to compute the heating and cooling degree days for every month for every year in the period 1931-90; and 3) calculate the 30-year normals and 60-year (1931-90) averages of the degree days using the procedure discussed in the preceding paragraph.

B. <u>MONTHLY NORMALS FOR FIRST ORDER AND COOPERATIVE STATIONS</u>. 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.

As noted earlier, 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. NOTE: This Environmental Information Summary corrects some minor inaccuracies in the narrative of some copies of the <u>Climatography of the United States No. 81</u> publication. The estimation of missing data and inhomogeneity adjustments made to the First Order stations were done as indicated in this Summary.

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 ($r^2 > 0.6$) 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 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 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.

C. DAILY NORMALS. Daily normals of maximum, minimum, and mean temperatures, heating and cooling degree days, and precipitation were prepared for 422 stations by interpolating between the monthly normal values. The interpolation scheme was a cubic spline fit through the monthly values. Each element was interpolated independently from the other elements. The procedure is described by Greville (1967).

The series of daily values of an element resulting from the cubic spline yields a smooth curve throughout the year without requiring the use of daily data. Another property of this technique is that the average of the daily temperatures in a month equals the monthly normal and that the total of the daily precipitation or degree days in a month equals the monthly normal. In order to eliminate discontinuities between December 31 and January 1, the spline interpolation was performed on a series of 24 monthly values. This extended series was created by appending July-December normals before January and January-June normals after December.

Since each element was interpolated independently, the daily series of temperatures and degree days were edited to remove spurious inflection points caused by rounding and to ensure adherence to functional relationships among the elements. Specifically:

1. All inflection points were examined for climatological reasonableness.

2. One-half of the sum of a daily maximum and minimum temperature, after rounding, was checked for equivalence with the daily mean temperature.

3. The relationship between a daily mean temperature T and the heating H and cooling C degree days for the day was checked to ensure that

$$|T-65 + H-C| = 0$$

Daily precipitation normals were published as generated by the cubic spline interpolation. The smooth curve through a month does not represent a climatologically reasonable distribution. The spreading of the monthly precipitation by the spline over all the days in a month is useful for accumulating amounts over specified time intervals. A climatologically reasonable normal precipitation, based on daily data, for any one date would be much different from the published normals.

For some dates at most locations the published degree days are shown by an asterisk. The symbol represents a value of less than one degree day, but more than zero degree days. It is used to smooth through aperiodic oscillations of zeroes and ones that are climatologically unreasonable. For example, if a station has 17, 15, and 18 normal heating degree days in June, July, and August, respectively, it is not possible to distribute the 15 July degree days evenly throughout the month using integer values (zeroes and ones) without creating unrealistic oscillations through the 3-month period. The use of fractional degree days (asterisks) does allow for a smooth transition from June through July to August.

III. REFERENCES

Greville, T.N.E., 1967: "Spline functions, interpolation, and numerical quadrature," Mathematical Methods for Digital Computers, Vol. II, A. Ralston and H.S. Wilf (eds.), pp. 156-168, Wiley, New York.

Guttman, N.B., 1989: "Statistical descriptors of climate," Bulletin of the American Meteorological Society, Vol. 70, pp. 602-607.

Karl, T.R., and C.N. Williams, Jr., 1987: "An approach to adjusting climatological time series for discontinuous inhomogeneities," Journal of Climate and Applied Meteorology, Vol. 26, pp. 1744-1763.

Karl, T.R., C.N. Williams, Jr., P.J. Young, and W.M. Wendland, 1986: "A model to estimate the time of observation bias associated with monthly mean maximum, minimum, and mean temperatures for the United States," Journal of Climate and Applied Meteorology, Vol. 25, pp. 145-160.

Karl, T.R., C.N. Williams, Jr., F.T. Quinlan, and T.A. Boden, 1990: "United States Historical Climatology Network (HCN) Serial Temperature and Precipitation Data," Oak Ridge National Laboratory Environmental Sciences Division Publication No. 3404 (ORNL/CDIAC-30, NDP-019/R1), 377 pages.

Thom, H.C.S., 1954: "The rational relationship between heating degree days and temperature," Monthly Weather Review, Vol. 82, pp. 1-6.

Thom, H.C.S., 1966: "Normal degree days above any base by the universal truncation coefficient," Monthly Weather Review, Vol. 94, pp. 461-465.

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