NOAA's 1981-2010 Climate Normals: Supplemental Normals

Created: October 24, 2012
Last Modified: October 24, 2012

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Introduction

This report describes the methodology used to compute supplementary products to the 1981-2010 NOAA Climate Normals that were released in July 2011 (Arguez et al. 2012). These new "supplemental normals" consist of four additional normals products: (1) growing degree day normals, (2) frost-freeze date probabilities, (3) probabilities of frost-freeze occurrence, and (4) growing season length normals. Because these products are most commonly utilized by farming interests, they are often referred to collectively as "agricultural normals", although they are utilized in many other industries including, but not limited to, construction, architecture, and pest control. This report offers a preliminary description of all procedures used to compute these products. A journal article on this topic is currently being drafted. If published, the journal article would replace this report as the authoritative reference for the computation of NOAA's 1981-2010 Supplemental Normals.

Source Data

The underlying values used to compute the 1981-2010 Supplemental Normals come from the Global Historical Climatology Network - Daily (GHCN-Daily) dataset (Menne et al., 2012). The data values have undergone extensive quality control (QC) as described by Durre et al. 2010.

Homogenized Monthly Temperature Data

Even though GHCN-Daily goes through rigorous quality control, it is not homogenized like the monthly temperature dataset. As described by Menne and Williams (2009) and Menne et al. (2009), NCDC provides monthly temperature data values that have undergone robust quality control and standardization at the monthly timescale. For the 1981-2010 Normals, the approaches described in these papers were applied to monthly maximum and minimum temperature values that were in turn computed from GHCN-Daily values. The standardization procedures account for both documented and undocumented station moves and other changes in observing practices. The new Supplemental Normals are calculated such that they are consistent with the homogenized monthly temperature data.

Serially-Complete Daily Minimum Temperature Data

Frost-freeze date probabilities and growing season length normals are based on the first and last "killing freeze" of the growing season. A killing freeze is essentially a cold snap that hinders plant growth; the temperature threshold varies from one plant species to another. In order to compute these values, missing daily minimum temperature values must be accounted for. Very few stations (<5%) have complete daily minimum temperature data over any thirty year period,

including 1981-2010. Missing values occur either because no observation exists in our records, or because an observation was flagged as erroneous by the GHCN-Daily QC.
We fill in missing values using a simple anomaly-based approach. For each missing value in a station's daily time series from 1981-2010, the five nearest neighbors whose daily observations are non-missing are identified. Anomalies are computed by taking each of the five minimum temperature observations and subtracting each station's daily temperature normal for that day of the year. Then, the mean of the five anomalies is added to the target station's daily temperature normal for that day of the year.

The serially-complete daily minimum temperature data are adjusted, if necessary, to be consistent with the serially-complete homogenized monthly temperature values used to compute the 1981-2010 Climate Normals released in July 2011. For example, if the 31 daily minimum temperature values from January 2000 average to 45.5F, but the monthly homogenized mean minimum temperature value for January 2000 is 44.5F, the 31 daily minimum temperature values are each reduced by 1.0°F. In relatively few cases, the adjustments result in inter-month discontinuities. These discontinuities are suppressed using an iterative smoothing approach. This helps ensure that frost-freeze date probabilities are not disproportionately concentrated near the beginning or end of a month.

Bootstrapped simulations

Even with serially-complete daily data from 1981-2010, frost-freeze date probabilities and growing season length normals can be quite "noisy" or "jagged" due to the irregularity of first and last freeze events from year to year. To remedy this, a bootstrapping approach is used to generate 10,000 simulations of the 365-point annual cycle of daily minimum temperature. This results in substantially less "jagged" results, for example, in the frost-freeze date probabilities.

To create each simulation of 365 daily values, 12 segments of daily minimum temperature values for each month are pieced together. There are three randomized components: (1) the year from which each 28-31 day sequence is drawn, (2) an offset of ±14 days in the date the sequence begins, and (3) the monthly mean imposed on the sequence. To guard against implausible simulations, an extremes check and a monthly transition check are utilized. If either check fails, a new sequence is generated.

The resulting 10,000 simulations per station compare favorably with the serially-complete data from 1981-2010. Further, the resulting supplemental normals computed using the simulations versus the 30-year dataset also compare favorably. The primary difference is an increase in statistical confidence (and an associated suppression of jaggedness) of the results from the bootstrapping approach.

The bootstrapped simulations are utilized to compute frost-freeze date probabilities, probabilities of frost-freeze occurrence, and growing season length normals. As explained below, neither the bootstrapped simulations nor the serially-complete minimum temperature values are used to compute growing degree day normals.

Frost-Freeze Probabilities of Occurrence

Frost-freeze probabilities are the likelihood that a given minimum temperature will be experienced at least once during a month or year. Probabilities are calculated for the following threshold temperatures: 16°F, 20°F, 24°F, 28°F, 32°F, and 36°F. For example, there is a 15.7% chance that the temperature will drop to 36°F or below at least one day of the year at Miami (FL) International Airport. These probabilities are calculated as the percentage of the 10,000 simulations in which the threshold is reached at least once during a particular month or for the full year.

Frost-Freeze Probability Dates

Frost-freeze probability dates represent the likelihood that a given minimum temperature will be experienced before or after a given date. Probability dates are provided for the beginning of the growing season (i.e., the probability that the last spring freeze will occur on or after the specified date) and the end of the growing season (i.e., the probability that the first autumn freeze will occur on or before the specified date). Probability dates are calculated for the following threshold temperatures: 16°F, 20°F, 24°F, 28°F, 32°F, and 36°F. The probability levels are 10, 20, 30, 40, 50, 60, 70, 80, and 90%. The terms “spring” and “autumn” are used loosely in this sense as not all dates will strictly occur during spring or autumn months for some of the warmer and colder stations across the United States.

The computation of frost-freeze date normals is based on conditional probabilities. This only affects a minority of stations in warmer climates where the probability of occurrence (see example in previous section) is not 100%. The dates represent the probabilities of frost-freeze occurrence before or after the specified date provided the minimum temperature is reached at least once during the cold season. In order to provide frost-freeze date normals, the probability of occurrence must be at least 10%; otherwise the values are shown as the special value -6666, indicating that the minimum temperature is too rare (or never occurs) to compute frost-freeze date normals.

At the other extreme, some stations have some degree of frost-freeze risk year-round. Following NCDC precedent, frost-freeze dates are calculated over the August 1 – July 30 period. Year-round frost-freeze risk occurs for a portion of northern or high elevation stations where reaching the minimum temperature threshold in July or August is not out of the question. Using the 10,000 simulations, a station is given a special value of -4444 if at least one occurrence at or below the minimum temperature threshold is present for each day of the year.

Growing Season Length Normals

Growing season length normals are the likelihood that the growing season (i.e., the number of days between the last spring frost-freeze and the first autumn frost-freeze) will be at least the specified number of days. They are calculated by taking the longest period for each of the 10,000 simulations for which the minimum temperature is above the threshold. Growing season length normals are reported for the same temperature thresholds and probability levels as listed above for the frost-freeze probability dates.

Growing Degree Day Normals

Growing degree days are a measure of agricultural output based primarily on the mean daily temperature (as opposed to the products described above which rely solely on minimum temperature). Computationally, growing degree days are equivalent to cooling degree days, which is a metric of temperature-based cooling demand (primarily in the warm season). For the computation of cooling degree days, see the following documentation:

http://www1.ncdc.noaa.gov/pub/data/normals/1981-2010/documentation/temperature-methodology.pdf

Growing degree days are available for the following base temperatures: 40°, 45°, 50°, 55°, 57°, 60°, 65°, 70°, and 72°F. In addition, growing degree days are provided for a pair of "truncated bases" specifically related to the growth cycle of corn: 48/86 and 50/86. For the 48/86 truncated base computation, minimum temperatures below 48°F are replaced with 48°F, and maximum or minimum temperatures above 86°F are replaced with 86°F. After this adjustment, the growing degree days are computed as they are for the other bases. An analogous computation is done for the 50/86 truncated base.

For more information

To obtain additional information on the 1981-2010 Supplemental Normals or to acquire them, please contact NCDC's User Engagement and Services Branch by sending an email request to NCDC.Orders@noaa.gov or calling 828-271-4800 and selecting option 2.

References

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