4.8 NORMALS

Climate normals are used for two principal purposes. They serve as a benchmark against which recent or current observations can be compared, including providing a basis for many anomaly-based climate datasets (for example, global mean temperatures). They are also widely used, implicitly or explicitly, as a prediction of the conditions most likely to be experienced in a given location.

Historical practices regarding climate normals (as described in previous editions of this Guide (WMO-No. 100), the *Technical Regulations* (WMO-No. 49) and the *Handbook on CLIMAT and CLIMAT TEMP Reporting*[1] (WMO/TD-No. 1188)) date from the first half of the twentieth century. The general recommendation was to use 30-year periods of reference. The 30-year period of reference was set as a standard mainly because only 30 years of data were available for summarization when the recommendation was first made. The early intent of normals over a standard period was to allow comparison among observations from around the world. The use of normals as predictors slowly gained momentum over the course of the twentieth century.

Traditionally, climatological normals have focused on the mean value of a climate element over a period of time. As discussed in section 4.4.2, the mean is an incomplete description of the climate, and many applications require information about other aspects of that element's frequency distribution and statistical behaviour, such as the frequency of extended periods when a value is above a threshold. Extreme values of an element over a specified period, and other statistical descriptors of the frequency distribution of an element (such as the standard deviation of daily or monthly values), are useful descriptors of the climate at a location and should be included with datasets of normals.

Many NMHSs calculate daily, pentad (5-day) or decade (10-day) normals along with monthly and annual normals. Although not required by WMO, short duration normals illustrate the non-random variations of an element that cannot be captured with monthly normals. They are calculated by averaging the values of an element for a specified calendar date or dates over a period of time. For some elements such as temperature, the observed values are often smoothed by, for example, 3- to 7-day moving averages or binomial smoothing to reduce the effects of random high-frequency temporal variability of weather systems. Another smoothing approach is to fit the series of daily or short duration averages calculated from the observations with spline, trigonometric or polynomial smoothing functions, and these smoothed series become the daily or short duration normals (see section 5.8).

4.8.1 Periods of calculation

Under the current WMO *Technical Regulations*, recognising the realities of a changing climate, **climatological standard normals** are defined as averages of climatological data computed for successive 30-year periods, updated every ten years, with the first year of the period ending in 1, and the last year, with 0. That is, consecutive 30-year normals include: 1 January 1981 to 31 December 2010, 1 January 1991 to 31 December 2020, and so forth. Countries should calculate climatological standard normals as soon as possible after the end of the decennium. Climatological standard normals periods should be adhered to whenever possible in order to allow for a uniform basis for international comparison.

Also under the WMO *Technical Regulations*, recognising the need for a stable base for long-term climate change and variability assessment, a fixed **reference period** is defined as the 30-year period 1 January 1961 to 31 December 1990. This period should be used to compare climate change and variability across all countries relative to this standard reference period. It will remain fixed in perpetuity, or until there is a sound scientific reason to change it. .

Secular trends reduce the representativeness of historical data as a descriptor of the current, or likely future, climate at a given location. Furthermore, the existence of multidecadal variability in the climate system causes differences in climate normals from one 30-year period to the next such that the representativeness of any given normal for the present climate is reduced. Periods shorter than 30 years allow averages to be calculated for a much wider range of stations than is usually possible for a standard normals period. For elements that show a substantial underlying trend (such as mean temperature), predictive accuracy is improved by updating the averages and period averages frequently.

A number of studies have found that 30 years is not generally the optimal averaging period for a predictive use of normals. The optimal length of record varies with element, geography and secular trend. For example, the optimal period for temperatures is often substantially shorter than 30 years, but the optimal period for precipitation is often substantially greater than 30 years. In that sense the 30 year averaging period represents a compromise for the sake of consistency. *The Role of Climatological Normals in a Changing Climate* (WMO/TD-No. 1377) and

[1] CLIMAT TEMP was discontinued in 2010 (Ref. Resolution 3 (CCl-XV) DISCONTINUATION OF THE MONTHLY UPPER-AIR CLIMAT TEMP REPORTS).

other references at the end of this chapter provide much detail on the predictive use of normals of several elements.

For these reasons, shorter period averages (also known as **provisional normals**) may be calculated at any time, especially for stations not having 30 years of available data (see 4.8.4). Period averages are averages computed for any period of at least ten years starting on 1 January of a year ending with the digit 1 (for example, 1 January 1991 to 31 December 2004). Although not required by WMO, some countries calculate period averages every decade. However, it is strongly recommended not to use provisional normals as the basis for climate change and variability assessment.

In any publication of normals and averages, and also in any publication that uses them for analysis and display of climate variability, it is important to document the period used for the calculation and the calculation methodologies. The CLIMAT and CLIMAT SHIP codes contain a provision for a start year and an end year to be incorporated in normals distributed through such messages.

4.8.2 Stations used in the calculations

Climate normals and averages should be calculated for as wide a range of stations as possible, subject to the requirement that a station meet standards for the amount and completeness of available data. As a minimum, they should be calculated, if possible, for all stations whose data are distributed on the Global Telecommunication System (section B.1.3.1.2 of the *Technical Regulations*).

4.8.3 Homogeneity of data

As far as possible, the data used in the calculation of climate normals and averages should be homogeneous. The issue of homogeneity is addressed more fully in section 5.2. In the context of climate normals and averages, homogeneity issues that require particular attention are changes of site location; changes of observation procedure, including changes of observation time; changes of instrument type; changes of instrument exposure over time; and changes in the processing of data.

In practice, at many locations it will not be possible to construct a suitably homogenous dataset. It may instead be necessary to produce normals from a composite of two or more parts of an inhomogeneous record. An option is to make adjustments to the earlier part of a record to make it as homogeneous as possible with the most recent data.

4.8.4 Missing data

Normals calculated from incomplete datasets can be biased. For example, if one year in a period was particularly cold, a normal calculated without data from that year would be higher than a normal that did include that year. As there is often considerable autocorrelation in climatological data, consecutive missing observations can have more impact on normals than the same number of missing observations scattered randomly through the period in question.

As a guide, normals or period averages should be calculated only when values are available for at least 80 per cent of the years of record, with no more than three consecutive missing years. An alternative option, when there is an extended period of missing data but reasonably complete data after that time, is to calculate a period average using only data from the years following the break in the record.

Annual normals or averages should be calculated as the mean or sum (as appropriate) of the 12 monthly normals or averages, without consideration of the varying lengths of the months (section B.1.4.2.4 of the *Technical Regulations*). No missing monthly normals are permitted in the calculation of annual normals.

It is recommended that a monthly value should not be calculated if more than ten daily values are missing or five or more consecutive daily values are missing. In the case of elements for which the monthly value is a sum of daily values rather than a mean (such as for rainfall or sunshine), a monthly value should be calculated only if either all daily observations are available, or if any missing days are incorporated in an observation aggregated over the period of missing data on the day when observations resume. The *Calculation of Monthly and Annual 30-Year Standard Normals* (WMO/TD-No. 341) recommends stricter criteria for calculating averages, with the limits being more than five missing days in total, or more than three consecutive missing days.

4.8.5 Average daily temperature

There are many methods for calculating an average daily temperature. These include methods that average a daily maximum and daily minimum, 24 hourly observations, synoptic hour observations, and observations at certain specified hours during a day. The best statistical approximation of an average is based on the integration of continuous observations over a period of time; the higher the frequency of observations, the more accurate the average. Practical considerations generally preclude the calculation of a daily average from a large number of observations evenly distributed over a 24-hour period because many observing sites do not measure an element

continuously. For comparative purposes, a standard processing methodology is desirable for all stations worldwide, with the number of stations maximized.

All ordinary climatological stations observe a daily maximum and minimum temperature (see section 2.2.1). Hence, the recommended methodology for calculating average daily temperature is to take the mean of the daily maximum and minimum temperatures. Even though this method is not the best statistical approximation, its consistent use satisfies the comparative purpose of normals. An NMHS should also calculate daily averages using other methods if these calculations improve the understanding of the climate of the country.

4.8.6 Precipitation quintiles

Quintiles of precipitation are used to relate an observed monthly precipitation total to the frequency distribution of values observed over the period for which normals have been calculated. No universally accepted method exists for the calculation of quintile boundaries, and the choice of method can make a substantial difference to the calculated values. The recommended procedure for calculating the boundaries, however, is as follows:

For any month the 30 monthly values of precipitation recorded during the 30-year normal period are listed in ascending order. The list is then divided into five groups of quintiles of six values each. The first quintile contains the six lowest values for the month in question that have been observed during the 30-year period, the second quintile the next six lowest values, and so on to the fifth quintile, which contains the six highest values.

The boundary between two adjacent quintiles is set halfway between the top value of the one quintile and the first value of the next. The quintile index is the number of the lowest quintile containing the monthly precipitation in the month for which the report is being prepared, with the following special rules:

(a) If the precipitation is 0: use index 0 if this has not occurred during the reference period; use 1 if it has occurred but fewer than 6 times; use 2 if it has occurred between 7 and 12 times; use 3 if it has occurred 13 to 18 times, and so on;
(b) If the precipitation is less than any value in the reference period: use index 0 (regardless of whether the precipitation is 0);
(c) If the precipitation is greater than any value in the reference period: use index 6.

4.8.7 Dissemination of normals

A main avenue for international dissemination of climate normals is through CLIMAT (for land-based surface stations) and CLIMAT SHIP (for ship-based surface observations) coded messages sent on the Global Telecommunication System. Coding and reporting procedures are described in the *Handbook on CLIMAT and CLIMAT TEMP Reporting* (WMO/TD-No. 1188).