WORLD CLIMATE PROGRAMME

DATA

# CALCULATION OF MONTHLY AND ANNUAL 30-YEAR STANDARD NORMALS

Prepared by a meeting of experts, Washington, D.C., USA,

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This document is the result of an expert meeting held in Washington, D.C., USA, in March 1989. Its intent is to provide general information to Members as they prepare to calculate standard and/or provisional 30 year Normals. The expert participants in the meeting were:

K. Davidson, WMO
N. Guttman, National Climatic Data Center, USA
C. Ropelewski, Climate Analysis Center, USA
N. Canfield, Climate Analysis Center, USA
E. Spackman, Meteorological Office, UK
D. Gullett, Atmospheric Environment Service, Canada

CALCULATION OF MONTHLY AND ANNUAL 30-YEAR STANDARD NORMALS

## I. PURPOSE

The purpose of this document is to establish general procedures to be used for the calculation of the WMO monthly and annual 30 year (1961-1990 and following periods) standard and provisional normals and to suggest other climatic descriptors. These procedures were produced for use by all countries, and will be produced and distributed as a computer application and written document. However, all countries may use this information but certain procedures may be difficult to implement without the use of computers.

## II. BACKGROUND

The International Meteorological Committee in 1872 decided to compile mean values over a uniform period in order to assure comparability between data collected at various stations. The outgrowth of this was the recommendation for calculation of 30 year normals for stations. As stated in WMO Technical Regulation No. 49, Vol. 1, Section B "Each Member should establish and periodically revise normals for stations whose climatological data are distributed on the Global Telecommunications System in accordance with the provisions of Annex II (Manual on Codes, Volume 1) and forward these normals to the Secretariat". The initial period was determined to be 1901-1930. Succeeding periods were decided to be at 30-year intervals (i.e. 1931-1960, 1961-1990). However, many WMO members have been updating their 30-year normals at the completion of each decade. This was recommended in 1956 and noted in Technical Note No. 84. The WMO regulations require the calculations only each 30-year period. The WMO guidelines and regulations provide little guidance on "how to" calculate the 30-year normals; "how to" handle missing data; "how to" handle periods of data that contain obviously erroneous data; or "how much" data is required for a 30-year normal verses provisional normals. This paper is intended to provide a procedure with generalized rules and data completeness or quality indicators to be used in the calculation of the 30-year normals and to provide suggested ancillary data descriptors that will help to better describe the climate in statistical terms. These procedures are presented as practical advice only and are not considered to be the "best or only" methods of calculating normals.

## III. STANDARD NORMALS AND PROVISIONAL NORMALS

Climate data are often more useful when they are compared with standard or normal values. The Technical Regulations define normals as "period averages computed for a uniform and relatively long period comprising at least three consecutive ten-year periods" and climatological standard normals as "averages of climatological data computed for consecutive periods of 30 years as follows: 1 January 1901 to 31 December 1930, 1 January 1931 to 31 December 1960, etc." In the case of stations for which the most recent climatological standard normal is not available (either because the station has not been in operation for the period of 30 years or for some other reason), provisional normals should be calculated. Provisional normals are short-period means based on observations extending over a period of at least ten years. The concept of "normals calculation" is extended in this document to include an analysis of data homogeneity and the calculation of other climate descriptors. This extension is based on WMO Tech Note 84.

## IV. DATA EXAMINATION

It is assumed that routine hourly, daily and monthly quality control has been performed on the data as suggested in the WMO/TD-No. 111, WCP-85, Guidelines on the Quality Control of Surface Climatological Data. Climatological quality control (i.e. homogeneity) investigation and data inspection over a long period should also be performed. The following paragraphs recommend steps to analyze data homogeneity and identify heterogeneities (ref. WMO Guide to Climatological Practices). Suggested procedures to examine data homogeneity are:

1. Examine the data for trends, shifts (step functions), spurious data values, other data problems and evidence of data heterogeneity. Techniques include:

    a. Basic data descriptions e.g. frequency counts, means, medians, standard deviations, variances, extremes, and percentiles.

    b. Graphical analysis e.g. histograms, time series displays and areal comparisons.

    c. Nonparametric tests e.g. runs, sign, trend and serial correlation. The significance level should be .95.

2. Examine the data for heterogeneities by analyzing the results of the techniques listed above for identifying the cause of non-climatic discontinuities and variations. Potential non-climatic heterogeneities are:

    a. Station/sensor relocation e.g. horizontal and/or vertical movement of some or all of the station sensors to a new location.

    b. Instrument effects e.g. drift, calibration, maintenance and new/replacement instruments.

    c. Environmental effects e.g. vegetation changes, building effects on airflow and land use changes.

    d. Systematic observer bias and observing/coding changes.

After the data have been examined, it is necessary to decide if heterogeneity exists and if the cause is climatic or non-climatic. Reasons for the decision should be documented. Data should be classified as:

i Essentially homogeneous;
ii Essentially heterogeneous because of:
- station/sensor relocation
- instrument effects
- observing and coding practices
- local environmental effects.
iii Data not examined.

Adjustments may be made, if heterogeneities are known to be caused by documented non-climatic effects. Spurious data values may be eliminated/corrected. There are three options:

a. Adjust data to make a homogeneous record, e.g. to latest location or proper sensor calibration, if the form and magnitude of the correction is known. Sometimes adjustments can be made for station/sensor relocations, instrument effects and observing/coding practices. Adjustments for environmental effects should not be made (e.g. urban warming).

b. Split the long-term heterogeneous series into one or more separate, homogeneous parts and treat the individual parts separately.

c. Process data as if it were homogeneous, but identify the data as heterogeneous. If changes have been made to the data then at the completion of the above process the data should be re-examined. If desired, interstation comparisons may be made.

Suggested procedures include:

a. Determine statistical distributions and characteristics of the data.

b. Use statistical characteristics to determine the applicability and validity of models such as:

i Double mass analysis
ii Multiple regression
iii Spatial analysis
iv Time series analysis
v Principal component analysis.

c. Apply valid models.

d. If the comparisons indicate potential heterogeneities, the data should be further investigated.

## V. CALCULATION PROCEDURES FOR SURFACE ELEMENTS

### 1. CALCULATION OF MONTHLY VALUES (DAILY TO MONTHLY)

Table 1 identifies the principal climatological elements and units of measure for which monthly values should be calculated.

TABLE 1. PRINCIPAL CLIMATOLOGICAL SURFACE ELEMENTS

| | UNIT | PRECISION |
|---|---|---|
| 1. Precipitation Total | mm | .1 |
| 2. Days with Precipitation Greater than or Equal to 1 mm | count | 1 |
| 3. Temperature Tx, Tn, Tm | deg C | .1 |
| 4. Pressure | kPa | .01 |
| 5. Sunshine | hours | .1 |
| 6. Vapour pressure | kPa | .01 |

NOTE: Precision recommendations are based on consistency of calculations, even though it is meteorologically unreasonable to imply the indicated precision for annual totals.

The method of calculation is described below. When arithmetic means are to be calculated for each month of each year from daily data the following rule (hereafter referred to as the "3/5 rule") applies. If more than 3 consecutive daily values are missing or more than 5 daily values in total in a given month are missing, the monthly mean should not be computed and the year-month mean should be considered as missing. The number of days for which monthly means are calculated is N, where N can vary from 23 to 31. The symbol S in the equations indicates a summation of all N values.

a. Precipitation Total--Totals shall be calculated for each month of each year from daily data. Monthly totals should be based on a full month's data. However, accumulated amounts during the month are acceptable in lieu of individual daily totals provided that each accumulation is for 3 or less days. If accumulated data are used, the monthly total should be identified with an "accumulation" indicator. If any daily totals are missing and the corresponding accumulated totals are also missing, the monthly total should not be computed and the year-month total should be considered as missing.

b. Days With Precipitation Greater Than or Equal to 1mm--Totals should be calculated for each month of each year from daily data. Monthly totals should be based on a full month's data, that is, no missing daily counts are permitted.

c. Temperature--Calculate average monthly maximum ($\overline{Tx}$), minimum ($\overline{Tn}$), and mean ($\overline{Tm}$) temperature from the daily values Tx, Tn, Tm as follows:

$$\bar{T}_x = \frac{ST_X}{N} \quad ; \quad \bar{T}_N = \frac{ST_N}{N}$$

$$T_M = \frac{S([T_X + T_N]/2)}{N}$$

Note that because of rounding errors, $\bar{T}m$ should not be calculated by averaging the monthly means of maximum (Tx) and minimum (Tn) temperatures, but rather by summary and averaging the daily values (Tx,Tn). The "3/5 rule" for missing data applies.

d. Pressure--Calculate average monthly sea level pressure ($\bar{P}sl$) and station level pressure ($\bar{P}st$) from the average daily pressures observed at 00,06,12,18Z.

$$\overline{Psl} = \frac{S((Psl,00 + Psl,06 + Psl,12 + Psl,18)/4)}{N}$$

$$\overline{Pst} = \frac{S((Pst,00 + Pst,06 + Pst,12 + Pst,18)/4)}{N}$$

e. Sunshine--Totals should be calculated for each month of each year from daily data. Monthly totals should be based on a full month's data, that is, no missing daily totals are permitted.

f. Vapour Pressure--Average daily vapour pressure (VP) should be computed by averaging 24 hourly observations per day. If 24 hourly values are not available for each day, the daily average may be alternatively calculated from 8 (00,03,06,09,12,15,18,21Z) observations per day. The number of observations per day should be identified with a 'frequency' indicator. The monthly mean vapour pressure (VP) should be calculated as follows and the "3/5 rule" for missing data applies.

$$\overline{VP} = \frac{SVP}{N}$$

Other climatological elements for which monthly values may be calculated are listed in Table 2.

TABLE 2. OTHER SUGGESTED CLIMATOLOGICAL ELEMENTS (LISTED IN PRIORITY ORDER) AND METHOD OF CALCULATION

| ELEMENT | METHOD | UNIT | PRECISION |
|---|---|---|---|
| Relative Humidity (max, min) | i | % | 1 |
| Dewpoint (mean) | vii | deg C | .1 |

| ELEMENT | METHOD | UNIT | PRECISION |
| --- | --- | --- | --- |
| Wind direction(prevailing) | ii | deg | 10 |
| Wind speed (mean) | vii | m/s | .1 |
| Vector wind direction (mean) | vii | deg | 1 |
| Vector wind magnitude (mean) | vii | m/s | .1 |
| Wind steadiness (mean) | vii | --- | --- |
| Snowfall (total) | iv | cm | .1 |
| Soil temperature (mean per observation time at depth) | iii | deg C | .1 |
| Days with specified phenomenon (e.g. thunder, hail, fog, gale, blowing sand) | ii | count | 1 |
| Cloud amount (total) | vii | okta | .1 |
| Pan evaporation | vii | mm | .1 |
| Solar radiation | vi | $MJ/m^2$ | .01 |

METHOD NOTES

(i) Determine daily maximum and minimum relative humidity $RH_x$ and $RH_N$ from 24 hourly observations per day. If 24 hourly values are not available each day, then 8 (00,03,06,12,15,18,21Z) observations each day should be used. The number of observations each day should be identified with a frequency indicator. The average monthly values $\overline{RH}_x$ and $\overline{RH}_N$ are calculated as follows and the "3/5 rule" for missing data applies.

$$\overline{RH}_X = \frac{SRH_X}{N}$$

$$\overline{RH}_N = \frac{SRH_N}{N}$$

(ii) Prevailing wind direction should be calculated by identifying the most frequent direction that occurred within a month. Frequency counts should be based on 24 hourly observations per day. If 24 hourly observations are not available for each day, then 8 (00,03,06,09,12,15,18,21Z) observations each day should be used. The number of observations per day will be identified with a "frequency" indicator. The number of direction categories (36 is preferred) should be identified by a "direction" indicator.

(iii) See methodology described in Section V.1.c for maximum temperature.

(iv) See methodology described in Section V.1.a. for precipitation total.

(v) See methodology described in Section V.1.b for days with precipitation greater than or equal to 1mm.

(vi) See methodology described in Section V.1.e for sunshine.

(vii) See methodology described in Section V.1.f for vapour pressure.

2. NORMALS CALCULATIONS (Year-Month to Monthly Normal to Annual Normal)

Monthly 30-year standard normals are calculated from year-month values. If for a given month (e.g. January) 3 consecutive year-month values (e.g. January 1970, 1971, 1972) are missing or more than 5 values in total for the given month are missing, the 30-year standard normal should not be calculated.

Monthly Normals Z for an element X are calculated by

$$Z = \frac{S\bar{X}}{M}$$

where M is the number of months for which year-month values are available (M can vary between 25 and 30).

Annual normals for an element are calculated by averaging the 12 monthly normals. For precipitation totals, sunshine, solar radiation, days with specified phenomenon, standard annual normals should be calculated by adding all 12 monthly normals. Normals should exist for all 12 months to calculate an annual normal, that is, no missing monthly normals are permitted if an annual normal is to be calculated.

3. PROVISIONAL NORMALS (Heterogeneous Data and/or Short-Period)

If a data series has not been examined for homogeneity or other data problems, or if a data series has at least 10 year-month values but fewer than that required for the calculation of 30-year standard normals, then provisional normals Z' for an element $\bar{X}'$ may be calculated by:

$$Z' = \frac{S\bar{X}'}{M'}$$

where M' is the number of months for which year-month values are available (M' can vary between 10 and as much as 30 for heterogeneous data). The years for which monthly values are available are identified by a "year" indicator.

Provisional annual normals are computed by averaging 12 provisional monthly normals. For precipitation totals, sunshine, solar radiation, days with specified phenomenon, provisional annual normals should be calculated by adding all 12 provisional monthly normals. Provisional monthly normals should exist for all 12 months to calculate a provisional annual normal, that is, no missing provisional monthly normals are permitted if a provisional annual normal is to be calculated.

All provisional monthly or annual normals should be identified by a "provisional" indicator.

## VI. NORMALS FOR UPPER AIR ELEMENTS

Monthly averages should be calculated for the elements listed in Table 3 at the following levels:

1. Surface
2. 85 kPa
3. 70 kPa
4. 50 kPa
5. 30 kPa
6. 20 kPa
7. 15 kPa
8. 10 kPa
9. 05 kPa
10. 03 kPa

TABLE 3. PRINCIPAL CLIMATOLOGICAL UPPER AIR ELEMENTS

| | UNIT | PRECISION |
|---|---|---|
| 1. Height | gpm | 1 |
| 2. Temperature | deg C | .1 |
| 3. Dewpoint depression/RH | deg C% | .1/1 |
| 4. Wind direction | deg | 1 |
| 5. Wind speed | m/s | 1 |
| 6. Wind steadiness | --- | --- |

Averages should be calculated for each element at each level for the separate hours of 00,06,12,18Z by:

$$\bar{Y} = \frac{SX}{N}$$

where $\bar{Y}$ is the monthly average for element X at a given level for a given time, and N is the number of daily values for which the average is calculated.(N can vary between 1 and 31)

Decadal means should be calculated by:

$$Z_1 = \frac{S\bar{Y}_1}{M_1} \quad Z_2 = \frac{S\bar{Y}_2}{M_2} \quad Z_3 = \frac{S\bar{Y}_3}{M_3}$$

where $Z_1$, $Z_2$, $Z_3$ are the decadal monthly means for the periods 1961-70, 71-80, 81-90; $Y_1$, $Y_2$, $Y_3$ are the year-month averages at a given level, observation time and month for the periods 1961-70, 71-80, 81-90; and $M_1$, $M_2$, $M_3$ are the number of year-month values in the decades 1961-70, 71-80, 81-90 for which means are calculated ($M_1$, $M_2$, $M_3$ can vary between 1 and 10). The decadal means $Z_1$, $Z_2$, $Z_3$ and counts $M_1$, $M_2$, $M_3$ should be considered an integral part of the upper air normals.

The monthly normal Z should be calculated by:

$$Z = \frac{S\overline{Y}}{M}$$ (note $\overline{Y}$ is the monthly average, i.e. year-month value)

where

$$M=M_1+M_2+M_3$$

Note that the monthly normals Z should be calculated from the year-month value Y and not from the decadal means.

The annual normal is calculated by averaging the 12 monthly normals. Normals should exist for all 12 months to calculate an annual normal. All upper-air normals will be considered provisional unless data homogeneity can be demonstrated.

## VII. OTHER CLIMATE DESCRIPTORS

Descriptors other than normals should be provided to allow more complete assessment of the variable nature of climate.

Because of CLIMAT reporting requirements (ref. WMO 306) it is necessary to calculate precipitation quintiles as described in WMO Guide to Climatological Practices, Chapter 8, 1983, pp. 8.5-8.7. Quintiles are required for monthly precipitation totals. A "method" indicator should accompany the calculated quintiles.

Other descriptors that should be considered for individual decades and the whole 1961-90 period are:

1. Standard deviation of daily and monthly maximum, minimum and mean temperatures, and sea level and station level pressure and upper air parameters.

2. Percentiles at the 10, 25, 50, 75, 90 levels for all elements calculated for both daily and monthly data.

3. Frequency of non-occurrence of precipitation, sunshine and cloud amount.

4. Distribution of extremes.

## VIII. SUPPLEMENTAL INFORMATION

To ensure proper use and understanding of the Normals (provisional or standard), the following information should accompany the normals:

1. Country code
2. Country name
3. Station name

4. WMO region
5. Latitude (deg, min, N or S)
6. Longitude (deg, min, E or W)
7. Elevation
8. WMO Block/Index Number
9. Quality and processing indicators

   a. Accumulation (number of accumulation periods)
   b. Frequency (either 24 or 8 observations per day)
   c. Years (individual years with data)
   d. Direction (either 36, 16 or 8 point compass)
   e. Method for computing quintiles

      i. From data
      ii. From gamma distribution model
      iii. From other model

   f. Provisional normal

      i. Yes or no (no indicates standard normal)

   g. Reasons for provisional normal

      i. Insufficient period of record
      ii. Heterogeneity

         1. Station/sensor relocation
         2. Instrument effects
         3. Observing/coding practices
         4. Local environmental effects
         5. Unknown

      iii. Both VIII.9.g.i and VIII.9.g.ii

   h. Data completeness

      i. Standard normal with no monthly values missing
      ii. Standard normal with some monthly values missing
      iii. Number of data values used to compute a provisional normal.

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| WCDP-9 | REPORT OF MEETING OF CLICOM EXPERTS, PARIS, 11-15 SEPTEMBER 1989. |
| WCDP-10 | CALCULATION OF MONTHLY AND ANNUAL 30-YEAR STANDARD NORMALS (Prepared by a meeting of experts, Washington, D.C., USA, March 1989). |