# Conversion and analysis of historical air pressure data

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## Contents



# 1 Common data format

The common data format is a table with all available information from the original digitised files. Each line represents a unique observation time and the following list of standard names are used whenever applicable:

- `Latitude, Longitude, Elevation` for the location of the station
- `Location.missing, Elevation.missing` to indicate whether location is known or estimated 0 location or elevation is known 1 location or elevation has been estimated
- `Year, Day, Month, Time` for observation date and time from original record
- `Local.time` for observation time converted to HH:MM
- `Time.missing` to indicate whether time has been estimated 0 time is known 1 time has been estimated (e.g. sunrise)
- `Local.date` Datestring collating the above in local time (YYYY-MM-DD HH:MM:SS)
- `UTC.date` Datestring in UTC (YYYY-MM-DD HH:MM:SS)
- `P, P.1, P.2, P.3` pressure reading in original units
- `P.units` pressure units in original file
- `Tcorr` flag for temperature correction in original record
  - 0 no temperature correction
  - 1 corrected
- `mmHg` barometer readings in mm
- `P.orig` barometer readings in hPa corrected for local gravity
- `QFE` station pressure in hPa reduced to 0 deg. C
- `QFE.flag` temperature correction of station pressure
  - 0 missing value
  - 1 corrected in original record (and sometimes rebased, e.g. from 55 F to 0 C)
  - 2 corrected using temperature at the barometer

- 3 corrected using in-situ outside air temperature
    - 4 corrected using 20CR climatology

- `QFF` sea level pressure in hPa
- `QFF.flag` temperature used to reduce to sea level
    - 0 missing value
    - 1 QFF available from original record
    - 2 corrected using in-situ outside air temperature
    - 3 corrected using 20CR climatology

- `TP and TA` for temperature at barometer and temperature of outside air

# 2 Processing of pressure data

## 2.1 Conversion of observation times

Observation times are available in various formats in the original records. All observation times are assumed to refer to local (solar) time.

In case observation times are missing, but observations have been taken at regular intervals, missing observations times are replaced with the most frequent observation time for this interval (e.g. 9PM for evening observations if 9PM is the most frequent known time for evening observations). If the observation schedule is fully unknown, a local observation time of 2PM is assumed. In both cases, the time flag for these observations is set to missing (i.e. `Time.missing = 1`).

Qualitative observation times are converted to quantitative times using the simple lookup table below.

- morning = 8AM
- noon = 12PM
- afternoon = 4PM
- evening = 8PM

In cases for which observation times are noted as *sunrise* and *sunset*, the local sunrise and sunset is computed based on the date and latitude of the station based on the following formula

$$H_{sun} = \arccos\left(-\tan\phi \cdot \tan\delta\right) \cdot \frac{24\ h}{2\pi}$$

where $H_{sun}$ is the half-day length in hours, $\phi$ the latitude of the station and $\delta$ the declination of the sun. The declination of the sun $\delta$ is computed based on the Julian day and the function `declination` from the R-package `insol`.

## 2.2 Conversion of length units

Pressure in original units is converted to mm Hg using the appropriate conversion factors. The conversion factors are detailed below. Generally, only the largest length unit used is indicated, sub-units follow base 12 unless specified.

- English inches: 1 in = 2.54 cm
- French inches: 1 in = 2.707 cm
- Swedish inches: 1 tum = 2.969 cm
- Rijnlands inches: 1 in = 2.62 cm

## 2.3 Correction of barometer readings to standard conditions

We correct all converted barometer readings in mmHg to standard correction. This involves a correction for local gravity and a correction for temperature following WMO 2010. Barometer readings that are available in hPa are only corrected for temperature if metadata does not indicate that such a correction has already been performed.

### 2.3.1 Correction for local gravity

To convert the pressure reading in mmHg to hPa we use the following formula:

$$P_n = \rho \cdot g_{\phi,h} \cdot mmHg \times 10^{-5}$$

where $P_n$ is the absolute pressure in hPa reduced to normal gravity, $\rho = 1.35951 \times 10^4 \ kgm^{-3}$ is the density of mercury at 0 degrees C, $g_{\phi,h}$ is the local gravity (see below), and $mmHg$ is the barometer reading in mm. This is equivalent to correcting pressure in hPa for local gravity by using

$$P_n = g_{\phi,h}/g_n \cdot P_0$$

where $P_0$ is the absolute pressure not reduced to normal gravity and $g_n = 9.80665 \ ms\breve{}^2$.

Local gravity $g_{\phi,h}$ is estimated based on the latitude $\phi$ and elevation $h$ (in m above sea level) assuming flat terrain around the station

$$g_{\phi,h} = 9.80620 \ ms^{-2} \cdot (1 - 0.0026442 \cdot \cos 2\phi - 0.0000058 \cdot \cos^2 2\phi) - 0.000003086 \cdot h$$

### 2.3.2 Reduction to 0º C

Pressure readings are converted to 0º C using the following formula

$$P_T = P \ (1 - \gamma \cdot T)$$

where $\gamma = 1.82 \times 10^{-4} \ K^{-1}$ is the thermal expansion coefficient of mercury at 0º C, $P$ is the pressure reading not corrected for temperature, and $T$ is the temperature at the barometer (`TP.orig`). If `TP.orig` is not available, then *in-situ* outside air temperature measurement `TA.orig` is used instead. If no *in-situ* measurements are available, then the closest (in space and time) 30-year climatology of 3-hourly temperatures from the 20$^{\text{th}}$ century reanalysis is used. These climatologies are computed from the years 1871-1900. To further reduce variability, a 11-day moving mean has been applied per timestep, so that the climatology for temperature on January 6, 12:00 UTC, is the average of temperature on January 1-11, 12:00 UTC, for the years 1871-1900.

Where pressure observations have been reduced to some temperature other than 0º C at the time of reading, the pressure readings are rebased to 0º C using above formula.

## 2.4 Reduction to mean sea level

To further reduce station pressure `QFE` to pressure at sea level `QFF`, we follow the guidelines of WMO 2010, but diverge where necessary. The station pressure $P_S$ (`QFE` in common data format) is reduced to sea level pressure $P_0$ using

$$P_0 = P_S \cdot \exp\left(\frac{\frac{g(\phi,h)}{R} \cdot h}{T_S + a \cdot \frac{h}{2}}\right)$$

where the $g(\phi, h)$ is the local gravity, $R = 287.05\ Jkg^{-1}K^{-1}$ is the gas constant of dry air, $h$ is the elevation in m, $a = 0.0065\ Km^{-1}$ is the standard lapse rate of the fictituous air column below the station, and $T_S$ is the temperature at the station in K. In contrast to WMO 2010, we do not correct for humidity and instead of using the station elevation in geopotential meters and normal gravity, we use station elevation in m and local gravity. Also, we do not further adjust low-level stations based on the mean annual normal value of virtual temperature.

As for the reduction of pressure readings to 0º C, we use *in-situ* air temperature observations (`TA.orig`) where available and resort to using climatological temperatures from the 20$^{\text{th}}$ century reanalysis (1871-1900) instead. We do not use temperature at the barometer (`TP.orig`) to reduce pressure readings to sea level as this is measured indoors in most cases and may be affected by heating in the room or adjacent rooms.