# THE "REFERENCE YEAR", A SET OF CLIMATIC DATA FOR ENVIRONMENTAL ENGINEERING

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# The "Reference Year", a set of climatic data for Environmental Engineering

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The present paper describes a data collection, the "Reference Year", especially suited for computerized calculation of indoor climate and predictable yearly running cost of heating and air conditioning systems.(1).

The "Reference Year" contains 8760 hourly values of temperature, humidity, radiation, wind, clouds, air pressure and other weather data as well as daily values of precipitation, duration of sunradiation, etc. Totally more than 130.000 values of 34 parameters are given. It is with few limitations considered valid for Denmark, exclusive the Faroe Islands and Greenland.

The principles for selection of such data collections are discussed, as well as the possibilities for expanding the geographical area for which they can be made valid.

Examples of the use of the "Reference Year" are included.

Contribution to

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## Introduction.

A number of computerized calculation methods exist today for determining man's artificial environment. Especially many methods are in use for the calculation of the room (thermal) climate, air conditioning loads, and annual costs of heating and cooling. The existing methods are presenting most different results, depending on the built-in simplifications of the methods, and and of course on the applied weather data which are sometimes also built-ins of the methods (2).

For the comparison and evaluation of the different methods standardized weather data would be desirable. Even for the consulting engineer and others who are constructing buildings and air conditioning systems, such data would be valuable, and they would allow a comparison of projects made by different architects and consultants.

Most calculation methods use only a small number of weather data, i.e. calculations using and giving hourly values under periodic-stationary conditions for a clear or an overcast day. For a specified building, however, it is often rather difficult to determine which type of weather will be most critical or typical (3).

For many methods, therefore, it would be preferable to use a whole year, giving as results statistical information, frequencies, etc. With high speed computers this is very well possible even from an economic point of view.

## Content.

The "Reference Year" is a data collection giving hourly values for 8760 hours of dry bulb temperature, humidity, direct solar radiation and diffuse radiation from the sky, wind, cloud amount and cloud types, air pressure, etc. Further, it gives daily values of precipitation, duration of sun radiation, maximum and minimum temperatures, etc. (Fig. 1). Generally, all available weather data have been included, even when their usefulness for environmental calculations cannot be seen just now.

## Principles for selection data.

The "Reference Year" has been selected after the main meteorological parameters which influence the indoor climate. It should be as near an average or normal year as possible. The parameters used for the selections are:

a. daily mean dry bulb temperature
b. daily maximum dry bulb temperature
c. daily sum of shortwave radiation on horizontal surface.

It was found, that these three parameters were sufficient to describe the weather situation with regard to the proposed use of the data collection.

For cooling load calculations the content of humidity in the air will also be of importance, and so will the wind speed for the heating load calculations. For Danish conditions it will very often be possible to avoid mechanical cooling, and in such cases the humidity will be of minor importance during the summer.

Further, there seems to be some correlation between the night minimum temperature and the dewpoint temperature.

The wind shows such great variations locally, that a selection after wind direction or force seems unsuitable. Both wind and humidity are, however, considered in an other way.

The selection after c) daily sum of radiation, have caused some problems which will be discussed later.

For the compilation of the data collection two possible methods can be considered:

1. From available meteorological measurements over several years one can select days, weeks, months, or a whole year, either by random choice or by formation of criteria for the selection of periods which together constitute a "mean" or "typical" year.

2. From our knowledge of monthly and annual mean values of temperature and other parameters and their standard deviation, a "typical" year can be compiled in a purely artificial way.

For the second method much lesser data input is needed but as the correlation between the single parameters is not known, it is impossible to introduce it in the compilation.

The first method has the advantage, that all the data possess a true correlation. However, a random choice of single days would give risk of establishing non-typical sequences which could not be permitted.

As the length of the period for many room-climate calculations range from one day to a week, it would not be suitable to select a shorter period than two weeks. Choosing for each week in a year a week with correct mean temperature, such periods would be excluded from the whole year, having either high or low temperatures which actually do occur every year. On the other hand, selection of a single year requires more than the available 11 years of observations to obtain the same statistical "quality".

The "Reference Year" has therefore been composed of actual measurements, and in such a way that the periods selected are the months.

From the period 1959-1969 for which data were available on tape, one January, one February, etc., were selected with the following criteria:

A. Exclusion of the months with abnormal weather conditions or circulation pattern for the season. Round 20 different weather parameters have been compared with corresponding values in the period 1931-60. This comparison was performed by an experienced meteorologist.

B. Selection of 12 months with mean values of temperature, daily maximum temperature and global radiation as near as possible to the corresponding average value for the 11-years' period.

C. Selection of months with standard deviation of those three parameters as near as possible to the average standard deviation for the 11-years' period.

Criteria B and C rank 11 months in descending order. If the "best" month is not excluded by criterion A, then this month is chosen for the "Reference Year", else the second or third in rank is chosen.

Original data.

The data originated from three sources:

I Synoptic weather registrations from the meteorological services. Such SYNOP-registrations are available from many countries and locations. Site: 20 km NW of Copenhagen.

II Registrations of global radiation, either every 10 minutes or continuously. Site: 20 km W of Copenhagen, and 15 km from the SYNOP-measuring site.

III Daily registration of hours of clear sun in Copenhagen.

Artificial data.

The humidity is given in three ways: as dewpoint temperature, as relative humidity and as entalphy of the air.

The measured global radiation is divided into two, diffuse radiation on a horizontal surface, and direct solar radiation given as normal radiation. The distribution between diffuse and direct radiation is done with a modification of a method proposed by K. Kimura and D. G. Stephenson (4), taking into account cloud amounts and cloud types, solar altitude and season.

The most important weather parameters have been carefully examined, gaps filled (from other sources, by interpolation or by intelligent guesswork), and patent errors corrected. All such artificial data are indicated. The parameters examined are the temperatures, global radiation, wind and cloud amounts.

## Selection after radiation.

In the "Reference Year" the selection has been done after the daily global radiation on a horizontal surface. It has later become apparent, that this magnitude during winter is not very well suited, because the diffuse radiation shows a greater variation than the direct radiation, as the direct radiation at low solar altitude will be small even by clear sky.

A selection, either after the daily number of sunshine-hours, or using the cloud amount, is likely to give results in better accordance with mean values. Using the cloud amount given in oktas, it must however be noted, that a rather complicated expression seems to connect the cloud amount, cloud types and solar height with hours of clear sun. The average monthly cloud amount alone will not be sufficient.

## Area of validity.

The "Reference Year" is considered valid for Denmark (except the Faroe Islands and Greenland) with only a few limitations: In coastal areas, not exceding a few hundred meters from the coast, the wind pattern and speed and daily temperature variations may differ considerably. In inner city areas further the global radiation could deviate.

No reservation is at present taken for the local differences in monthly mean temperatures which in most months are round $\pm 1^{\circ}C$, related to the originating site for the "Reference Year", neither for average monthly sunshine-hours which may locally differ up to 30 hours per month.

## Working group.

The preparation of the "Reference Year" has been carried out by a working group consisting of Bo Andersen, Stig Eidorff, Hans Lund, Erik Pedersen, Stig Rosenørn, and Ole Valbjørn, thus representing the users of data for environmental calculations, the meteorologists and the Danish Building Research Institute who are to distribute the "Reference Year". We feel, that this cooperation has been absolutely necessary for the usefulness of the result.

## Expansion of geographical area of validity.

The "Reference Year" is constructed for use in a geographically limited area. A feasability study has been initiated to show, whether a similar construction could be made useful for the whole Scandinavian area, extending 1800 km N-S and 1300 km E-W.

A possible way could be to use something like the "Reference Year", and then modify some of the weather parameters to local mean values.

We can, tentatively, use the word "Standard Year" for this data collection which must be composed of actual weather data from a locality in the estimated geographical area of validity. The aim must be to have to change as few as possible of the single weather parameters to use the Standard Year for another location in the area. If possible, then only the average monthly dry bulb temperature. A comparison for each important weather parameter of a) its standard deviation in the estimated geographic area of validity, with b) its standard deviation over several years for one location, could give an indication of the permissibility hereof.

At present it seems possible to separate the whole area in four or five topological homogeneous parts which then get their own Standard Year.

The following gives the variation over the area of some of the important weather parameters:

The average monthly dry bulb temperature varies from 1°C to -17°C in January, and from 9 to 18°C in July. A modification to local values for January and July and an interpolation between these are necessary. (Fig 2).

The average daily temperature variation varies within 3.5 - 10°C in January, 5 - 13°C in March, and 6 - 12.5°C in July, the lowest figures for coastal positions only. A grouping in four or five geographical groups seem sufficient to give homogeneity in each group. (Fig 4 and 5).

In July the mean monthly maximum temperature excedes the mean temperature with 9.5 - 14.8°C. In January the mean monthly minimum temperature lies 7 - 22°C under mean temperature. Here too, a grouping is possible. (Fig 3).

If relative humidity is given, a local correction will most likely not be necessary.

Solar radiation may be given as diffuse radiation and normal radiation. Radiation on a wall or through a window can be calculated with the actual orientation and geographical latitude. Corrections may be necessary in cities (reduced normal radiation) or according to height over sea level.

The cloud amount influences the long wave radiation during the night. It is not clear, whether a grouping is possible.

The wind shows very great local differences, especially in coastal areas. Even in the microclimate in cities and near buildings the wind shows great variations. It seems very difficult to introduce any sort of correction.

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Conclusions concerning a "Standard Year".

All parameters in question need a more thorough statistical treatment, before a final decision concerning the grouping of localities and selection of four or five Standard Years is possible.

A major part of this work will be a matter for meteorologists if the procedure already developed for the "Reference Year" can be accepted.

The basis for selection of a Standard Year should be a period of at least 10 years of SYNOP-registrations on punched cards or tape.

Examples on use of the "Reference Year".

1. In a typical office building the staff complained about too high temperatures during the summer.

   A calculation using the "Reference Year" with a computer programmed method was done. The programme uses heat balances with time step 15 min., and takes into account heat accumulation. The claims were confirmed, as the calculated temperature with the "Reference Year" reached a maximum of 31 °C, and during the working hours 8-16 a total of 122 hours exceeded 25 °C.

   Changing the working hours from 7 to 15 o'clock would reduce the number of hours exceeding 25 °C with 26 hours, or 20%.

2. Solar energy presents a possibility for heating one-family houses. Using the same computer programme as mentioned before, a calculation can be made which with various sizes of the solar collector (flat-plate collector) and the heat storage (watertank) can tell how many days a year an additional heat supply is needed.

   One of the calculations showed, that during the "Reference Year" a well-insulated one-family house with a solar collector of 42 sq.m and a 20 $m^3$ tank (the "Zero-energy house", 144 sq.m) needed no additional heating. (For dimensioning, an additional heat supply has to be installed.)

   During October to April only 22% of the energy for hot water consumption had to be supplied by electric heaters.

3. The necessity of humifiers in ventilation system in schools is discussed. It is therefore interesting to know, how many hours of the normal school-day, 8-16, during the year a lower limit of 30% RH by 22 °C is exceeded. This limit corresponds to 5 g water per kg. dry air.

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With a specified ventilation rate the pupils will increase the water content in the room air with 2g/kg.

The number of hours, during which the limit is exceeded, is then the number of hours, in which the humidity outside is lower than 5 - 2 = 3 g water per kg air.

From a summarizing table over data in the "Reference Year", the total number of hours can be read which in the hours 8 - 16 shows 0- 1 g/kg, 1 - 2 g/kg, 2 - 3 g/kg, etc. Totally 1 + 75 + 204 = 280 hours have less than 3 g/kg, representing less than 10% of the year's number of hours 8 - 16, 2920 hours.

No moisture accumulation is considered in this example.

References:

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3. P.S. Scanes: Climatic design data for use in thermal calculations for buildings - estimated clear sky solar radiation versus measured solar radiation. Paper EH 72 at the international conference "Sun in the service of mankind". Paris 1973.

4. K. Kimura and D.G. Stephenson: Solar Radiation on Cloudy Days. ASHRAE Transactions no.2106.1969/II.

5. K.H. Quenzel: Meteorological Data. Forster Verlag, Zürich, 1969.

| Observation | | Interval or observation time |
|---|---|---|
| Dry bulb temperature | $^oC$ | h |
| Dew point temperature | $^oC$ | h |
| Relative humidity | % | h |
| Entalphi, calc. | kJ/kg | h |
| Minimum temperature<br>Maximum temperature | $^oC$ | 7 and 19 MET |
| Snowcower and-thickness,<br>State of ground surface | | 13 MET |
| Hours with clear sun | h | 24 MET |
| Global radiation (on horizontal) | $W/m^2$ | h |
| Diffuse radiation, calc. | $W/m^2$ | h |
| Normal radiation, calc. | $W/m^2$ | h |
| Precipitation | mm | 1,7,13 and 19 MET |
| Cloud cower | | h |
| Wind direction | | h |
| Wind speed | knots | h |
| Visibility | | h |
| Weather | | h |
| Weather since last major observation | | h |
| Cloud cower in low or medium altitude | | 3h |
| Cloud types, low altitude | | 3h |
| Altitude of lowest clouds | | 3h |
| Cloud types, medium altitude | | 3h |
| Cloud types, high altitude | | 3h |
| Cloud cower, lowest clouds $\geq 5/8$ of sky | | h |
| Cloud type herein | | h |
| Altitude hereof or vertical visibility | | h |
| Cloud cower, lowest clouds $\leq 4/8$ of sky | | h |
| Cloud type herein | | h |
| Altitude | | h |
| Barometrie pressure | mbar | 3h |
| Character of change in pressure | | 3h |
| Weather symbols (not always present) | | h |
| Month, day, hour | | h |

Fig. 1. Weather parameters in the "Reference Year". "h" indicates hourly presence, "3h" every third hour (the "synoptic" hours 1,4,7,1o --- MET). MET means Middle European Time ~ GMT + 1. All temperatures are given with o,1$^oC$, pressure with o,1 mbar, precipitation o,1 mm, and radiation with 1 $W/m^2$ and wind speed with 1 knot as least significant digit.

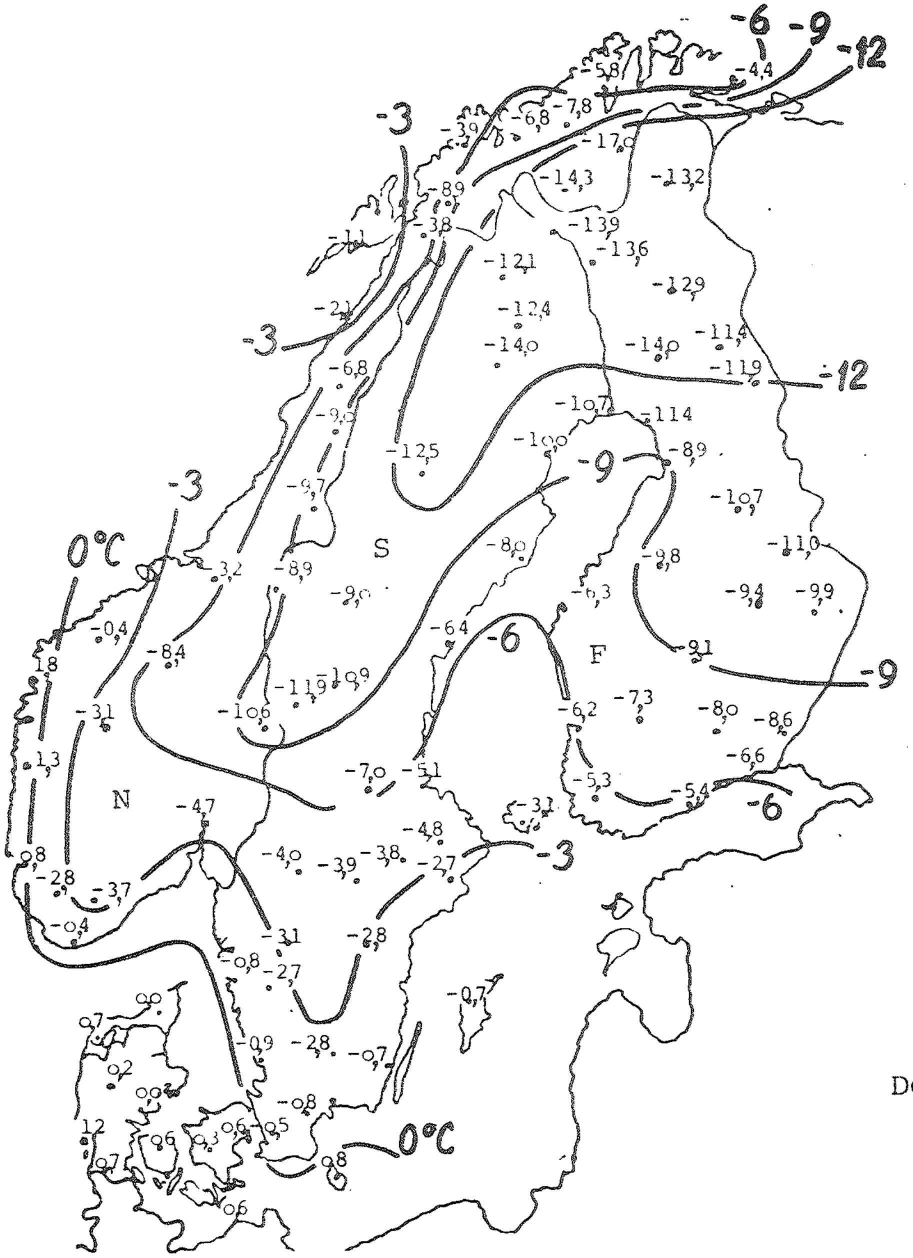


Fig 2. Monthly mean temperature, °C, January. After Quenzel. Isothermes.

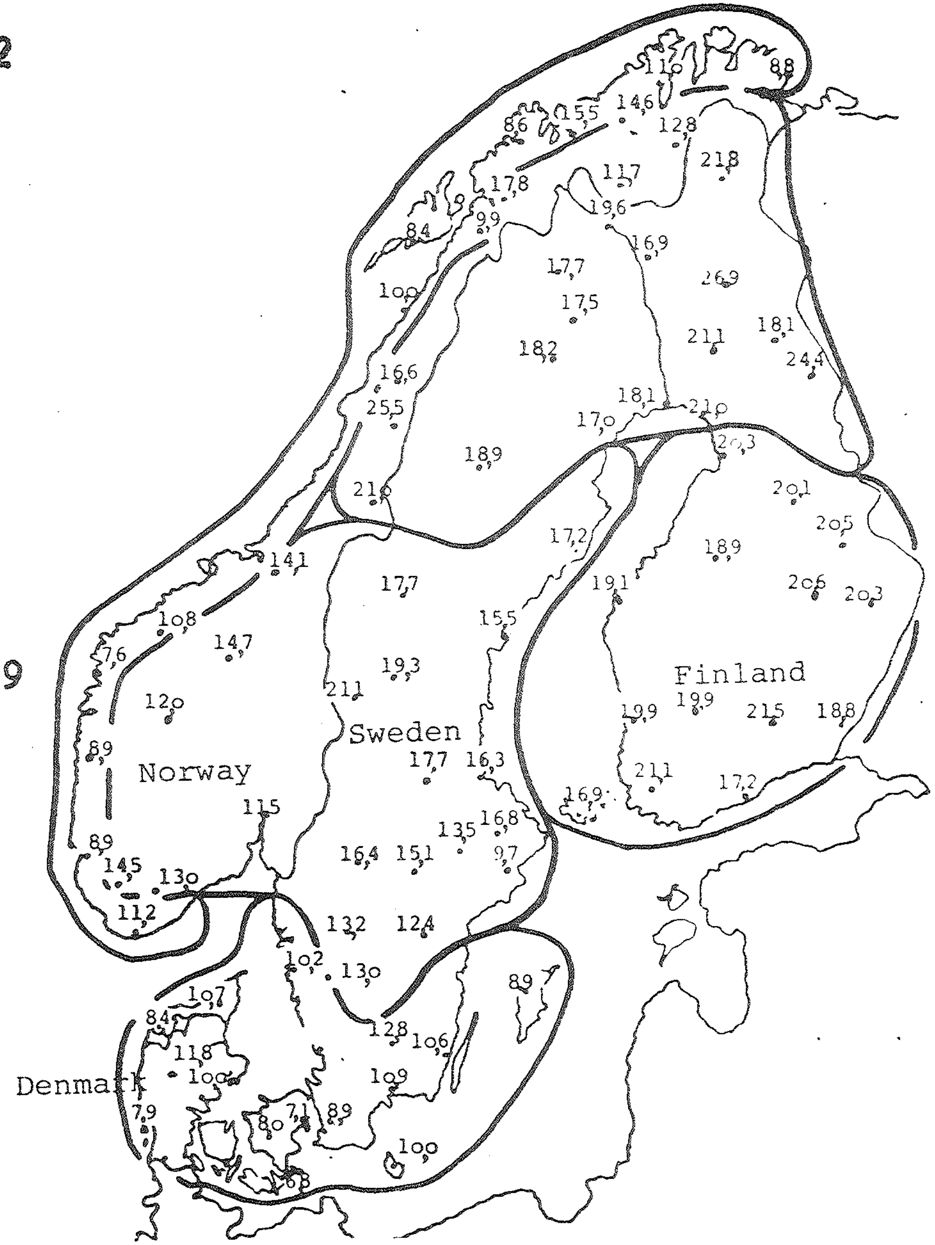


Fig 3. Monthly mean temperature minus mean monthly minimum temperature, °C, January. After Quenzel. Example of possible grouping.

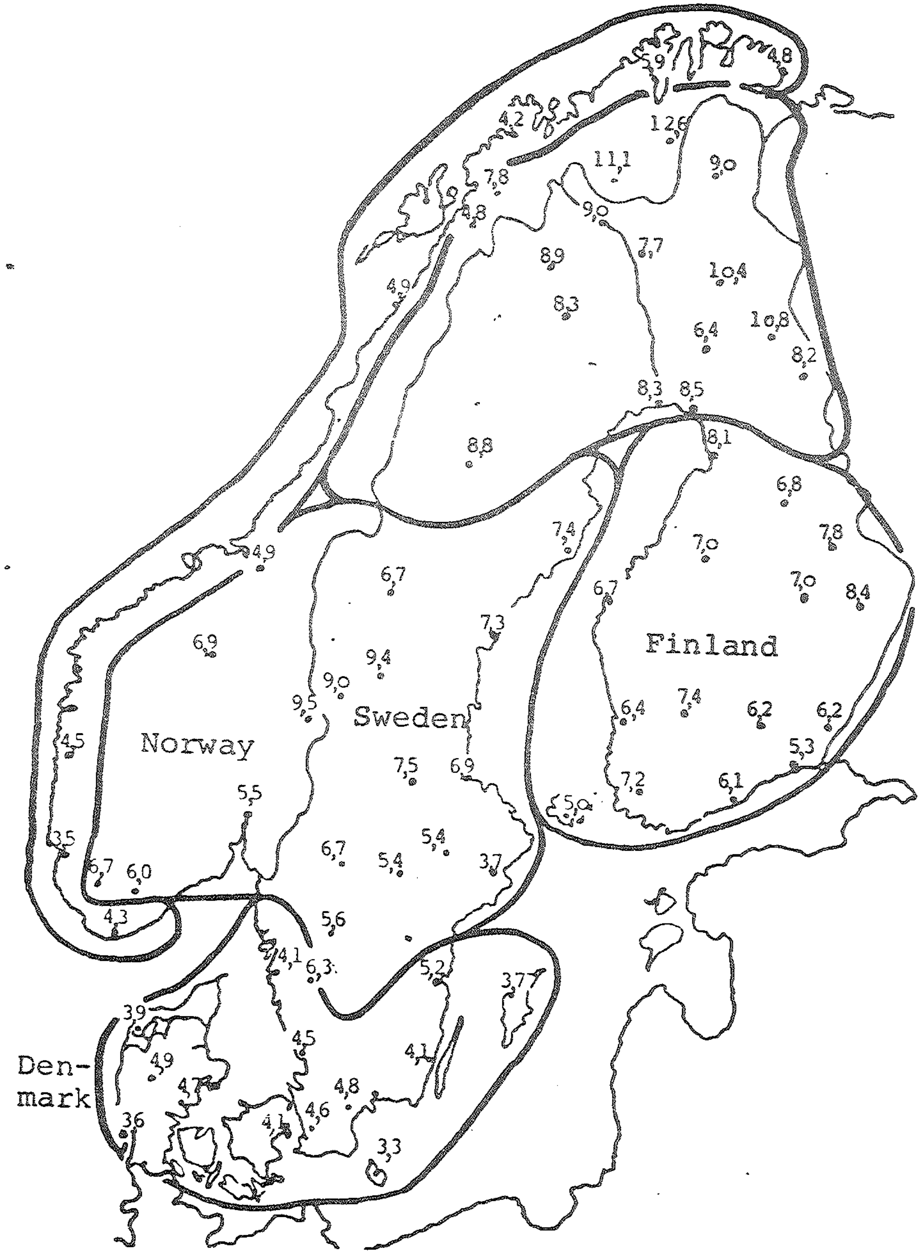


Fig 4. Average daily temperature variation, <u>January</u>, °C. Example of grouping.

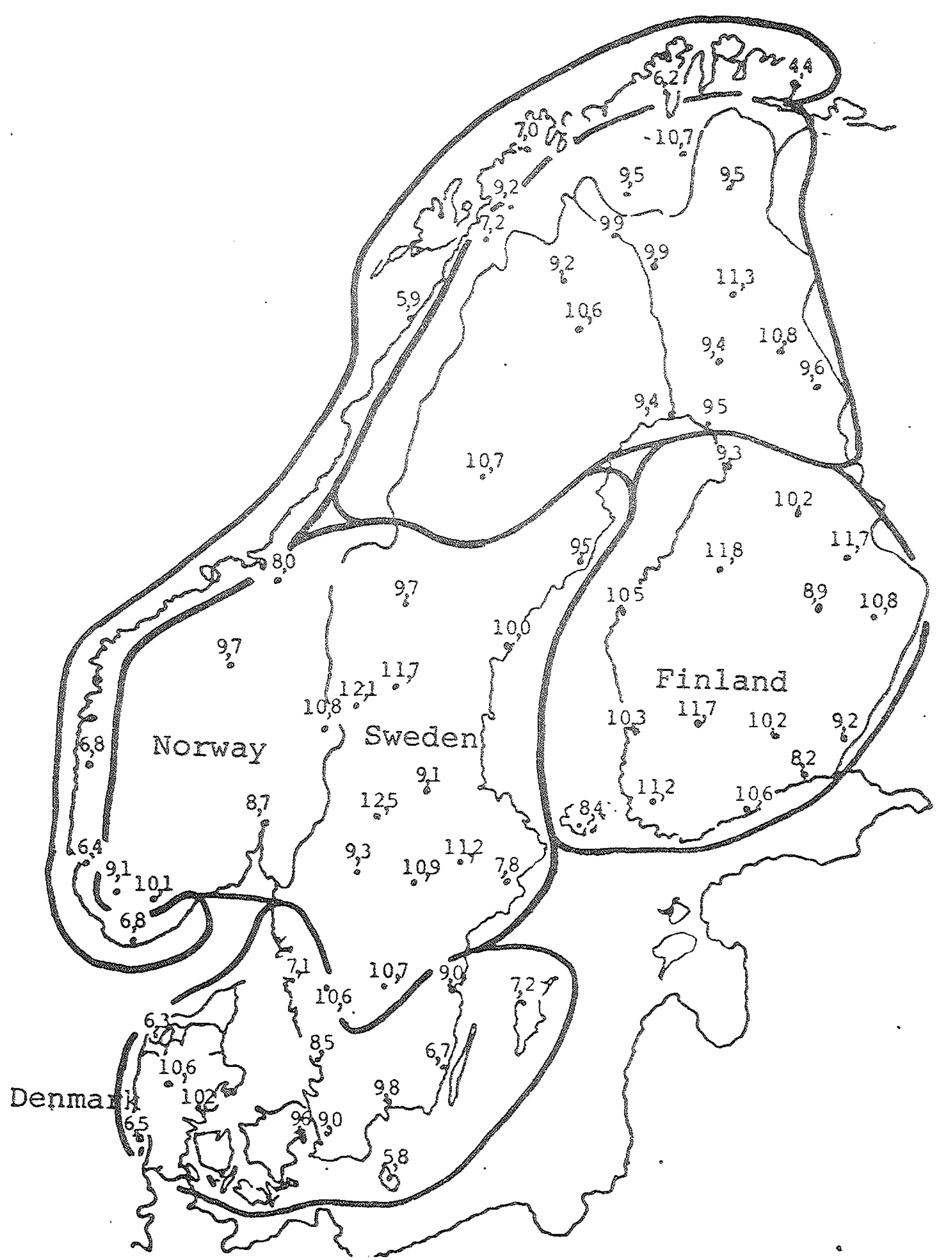


Fig 5. Average daily temperature variation, <u>July</u>, °C. Example of grouping.