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TECHNICAL REPORT 98-4

Observed Hours of Bright Sunshine in Denmark - with Climatological Standard Normals, 1961-90

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Front cover picture

Campbell-Stokes sunshine recorder (CASELLA type) installed at Jægersborg north of Copenhagen.

This particular sunshine recorder is used in the testing of new kinds of automatic sunshine duration instruments.

The photo was taken 14 November 1996.

Photographer: Helge Faurby

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1. Introduction

The amount of sunshine received in a given area is one of the factors determining the climate of that locality. For more than the past hundred years the duration of sunshine has been measured in Denmark to a resolution of within one hour using sunshine recorders, these measurements being aggregated to hours of bright sunshine on a daily, monthly and yearly basis.

The main point of this report is to publish the hours of bright sunshine observed in Denmark since 1961, including the climatological standard normals from the period 1961-90, which is the latest standard normal period defined by the World Meteorological Organisation (WMO). WMO Technical Regulations define climatological standard normals as "averages of climatological data computed for the following consecutive periods of 30 years: 1 January 1901 to 31 December 1930, 1 January 1931 to 31 December 1960, etc.". Climatological normals are defined from the same regulations as "period averages computed for a uniform and relatively long period comprising at least three consecutive ten-year periods". Shorter series and series not satisfactorily homogeneous must be referred to as provisory "normal" average values.

This report presents:

Climatological standard normals for 1961-90 based on complete and homogeneous series of hours of bright sunshine from 14 sites in Denmark.

29 series of monthly hours of bright sunshine in Denmark covering various periods between 1961 and 1997 (including the 14 series mentioned above) .

The longest ever published series of hours of bright sunshine from Denmark - Copenhagen, 1876-1997.

The problems of studying long series of data and calculating long-term averages when changing instruments, observation sites etc. are treated in this report. A change in the type of sunshine recorder for all stations has necessitated the correction of all series facing that problem. The rationale and methodology involved are explained in detail.

Besides tables and graphics the climatological standard normals, monthly values and information concerning the different measuring sites can be found on the floppy disk included.

2. Sunshine recorders in Denmark

Campbell-Stokes type sunshine recorders have been used in a few places in Denmark since the end of the last century. Before that, visual observations were used in Copenhagen, starting in 1876 (see chapter 8 for details). After 1920, hours of bright sunshine were measured in so many places that it was possible to calculate an average value for the country as a whole.

The instrument was developed by Campbell as early as 1853. In its initial version it consisted of a spherical glass bulb filled with water, supported in the centre of a wooden-bowl segment. The solar radiation, focused on the inner surface of the bowl, burned a trace on a record card, giving an indication of sunshine duration. Measurements in Copenhagen from 1887 until 1901 were performed with such an instrument. Stokes (1879) improved the instrument to its present-day design. The front page of this report shows a Campbell-Stokes sunshine recorder.

A glass sphere, made of high-quality, uniform, transparent glass is supported in the middle of a metal bowl, designed to carry the record charts. The instrument can be adjusted depending on the latitude, because the altitude of the sun varies with the latitude. The record charts in the bowl lie in an east-west direction so that as the sun moves round the sky from east to west, its image moves round the bowl from west to east. The sun's image is brought to a focus on the surface of the recording charts and causes the card to burn, thus marking it. The result is a line of burn which is continuous throughout the time the sun is shining and is interrupted by portions of untouched card while the sun is obscured. The card is printed with hour lines so that the duration as well as the exact time of sunshine can be measured.
The whole instrument is fixed on a stand so as to provide a free horizon and no obstruction to the sun's rays while rising and setting. In many instances sunshine recorders are installed on the roofs of buildings or at the top of lighthouses.

In Denmark the Danish Meteorological Institute (DMI) used Campbell-Stokes sunshine recorders from a firm called FUESS until the 60s and the 70s, when most of the instruments were replaced with sunshine recorders from a firm called CASELLA. In the Faeroes and Greenland DMI is still using the FUESS instrument. The main difference between the two instruments is the glass bowl. The FUESS glass bowl was not guaranteed in the same way as the CASELLA glass bowl in respect of the characteristics of the glass sphere, e.g. the minimum threshold value of the solar radiation capable of initiating a record. Every FUESS glass bowl was different, and this is actually a problem when changing instruments at a certain site or comparing hours of bright sunshine at different sites.

Fortunately, in many places, the two types of instruments have been operating during overlapping periods, making it possible to calculate corrections to the FUESS measurements in order to change them to the CASELLA level (see chapter 4).

3. Observations

In 1961 the Danish sunshine recording network consisted of 25 Campbell-Stokes sunshine recorders of the FUESS type. A general change of instrument from FUESS to CASELLA took place in Denmark during the mid-sixties and early seventies, as mentioned in the preceding chapter. Since 1961 many sunshine recording stations have been closed down and many new ones established. At present (October 1997) the Danish network of sunshine recorders consists of 33 Campbell-Stokes recorders, all of the CASELLA type.

With regard to the climatological standard normals, 1961-90, it is possible to construct these at 14 different sites. The 14 sites are marked on the map, figure 3-1. The 14 station records meet the following three criteria: The station has been operating for the major part of the period 1961-1990; it is possible to replace all missing observations during the period 1961-1990 with values constructed on the basis of observations from nearby stations; and finally it is possible to correct all values of FUESS origin to match the calibration of a CASELLA sunshine recorder.

In addition to the 14 1961-1990 series, 15 other sun recording sites are selected as interesting. These latter 15 series can not satisfy the criteria to make 1961-1990 climatic normals, but they recorded at CASELLA level (or easily converted to CASELLA level) at interesting locations and are of some length. The sites of these 15 series can be seen on the map, figure 3-2. This map shows the position of all stations considered in this report. Listed for each station is the period for which monthly sums of observed hours of bright sunshine are available on the floppy disk included.

All monthly values presented here are taken from the 29 series mentioned above after the series have been made continuous and all values made compatible at CASELLA level. In addition it was possible to construct one long series of recorded sunshine at one location: The 1876-1997 Copenhagen series described in detail in chapter 8.

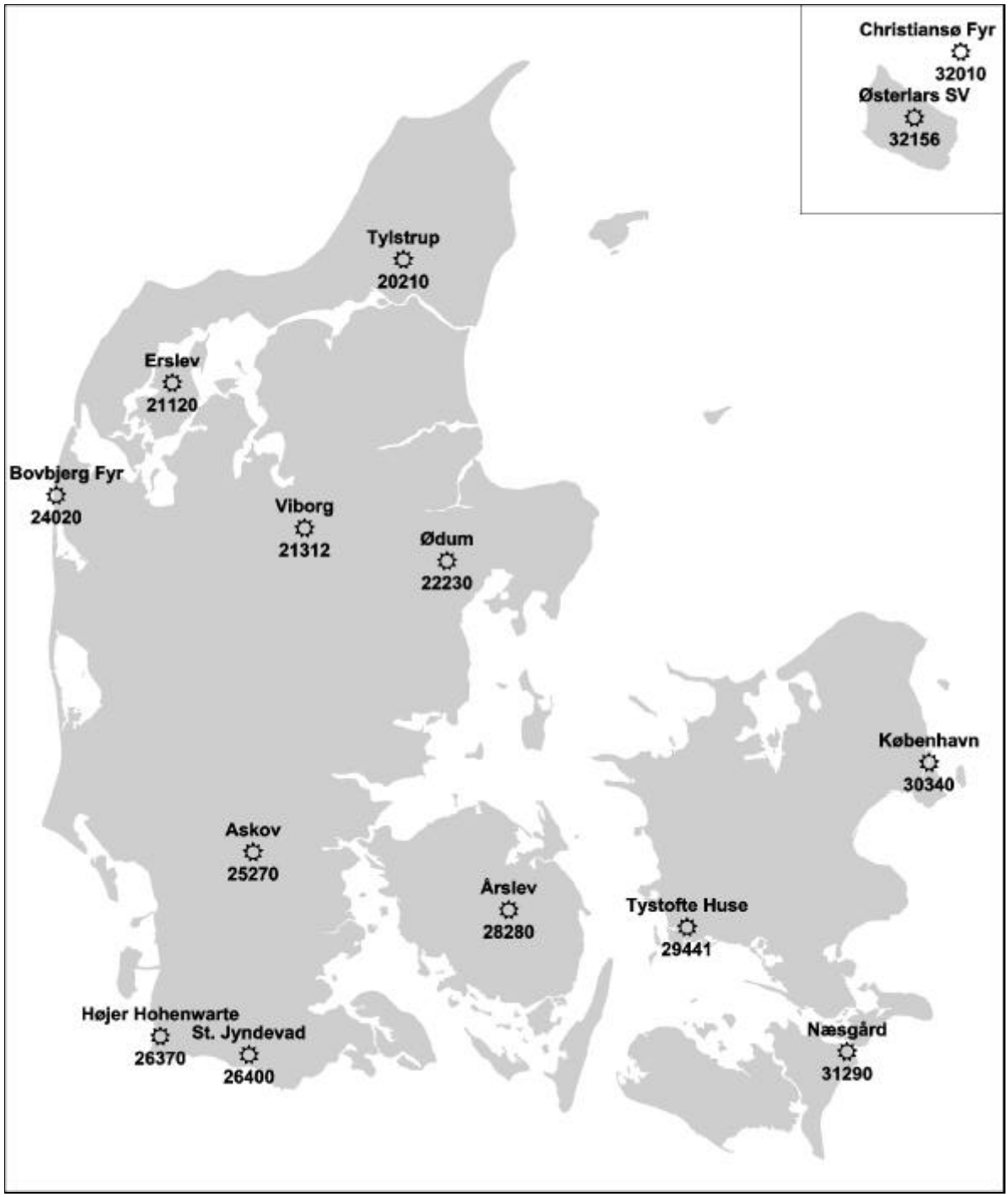


Figure 3-1: Position of the 14 sites, where measurements of hours of bright sunshine have been performed in a way, so as to enable monthly climatological standard normals to be constructed for the period 1961-90. The climatological normals are available on the floppy disk included together with the station position in geographical coordinates.

Figure 3-2: Position of the 29 sites, with a description of the station name and -number, and the period for which, hours of bright sunshine on a monthly basis are available on the floppy disk included. The floppy disk also include the station position in geographical coordinates.

4. Station history and metadata

At DMI a station history file is kept for each station. The file contains photographs of the station sites and comments on instrument replacement or correction. In many instances the older station history is incomplete. Metadata, i.e. descriptions of changes in instrumentation or station siting, are essential for interpreting the data. In the case of sunshine recording during the period 1961-1990 the crucial metadata are the knowledge of whether the Campbell-Stokes sunshine recorders were FUESS or CASELLA type. Appendix 2 shows a list of the instrumentation used in the original observations behind the 29 series presented in this report.

Appendix 1 gives a station catalogue with the position (at the time of the end of the record presented in the report) of each of the 29 record sites together with a letter describing the quality of the record. The quality mark follows the guidelines of the NACD project (see Frich et al., 1996).The basis for the quality mark is outlined in chapter 5.

4.1 Replacement for missing observations

The series of monthly sums of hours of bright sunshine presented are all continuous, either originally or by filling in gaps.

Observation missing

Any monthly sum missing has been replaced, either by a monthly sum from a neighbouring station or by a mean of the monthly sum from neighbouring stations.

Missing days in monthly sum

The number of daily sums constituting each monthly sum has been checked through. In the event of any daily sum missing, the cloud cover that day has been looked up at the nearest synoptical weather station and the missing daily sum replaced with a daily sum from the same station at the same time of year on a date with a similar cloud cover pattern. Where overcast or nearly overcast, the monthly sum has not been corrected.

4.2 Correction of FUESS values

The first CASELLA instrument was set up in 1965 (July 26th 1965 at station 25270 Askov). This means that all the 1961-1990 series have had to be corrected for periods of at least 4.5 years so as to make the earliest observations compatible with observations made later with the calibrated CASELLA instrument. A correction factor is found for each month of the calendar for each FUESS sphere. Where there is an overlap between FUESS and CASELLA measurements at the same station, the correction factors are found as the mean ratio for each month of the calendar of the CASELLA sum of sunshine hours to the FUESS sum of sunshine hours. Taking the mean for each month of the ratios between FUESS and CASELLA gave the most unambiguous results: No clear connection was found between the actual values of the FUESS recorder and the correction factor for each month. Nor was any trend in the correction factor for any particular month found during the overlap period. In the four instances of no overlap at the same station site (the Viborg, Tystofte Huse, Østerlars SV and

Christiansø series) observations from surrounding stations were used in a Standard Normal Homogeneity Test (SNHT) to estimate the proper FUESS correction factors.

An example of correction of FUESS observations

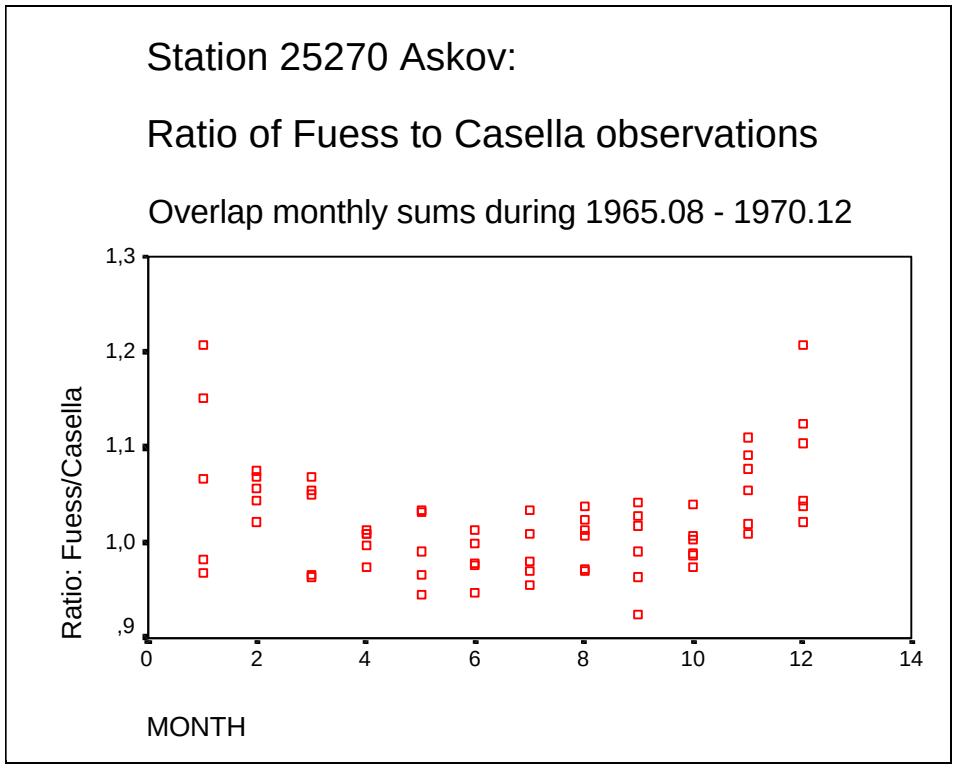


Figure 4-1. The ratio between FUESS and CASELLA monthly sums of hours of bright sunshine is plotted against the month for the station 25270 Askov during the overlap period August 1965 to December 1970.

In the 1961-1990 series from station 25270 Askov, FUESS values from January 1961 to July 1965 had to be corrected. At Askov a CASELLA sunrecorder was installed in late July 1965. But the FUESS instrument was not closed until July 31st 1972 and the FUESS recordings until December 31st 1970 are stored electronically at DMI. This makes an accessible overlap of observations from August 1965 to December 1970. From the ratios plotted in Figure 4-1 the following means of correction factors ('corr.') were found and employed:

Month:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Corr.	1.07	1.05	1.02	1.00	0.99	0.98	0.99	1.00	0.99	1.00	1.06	1.09

Following adjustment, the series underwent the standard normal homogeneity test described below with satisfactory results.

5. Standard Normal Homogeneity Test

5.1 Background

Temporal and spatial homogeneity of observations is critical to any kind of analysis. The homogeneity of a series requires the local measurement to have been carried out with the same type of instrument and according to instructions unchanged over time. For spatial homogeneity individual sunshine recorders are also required to follow the same calibration as their neighbours.

Inhomogeneity occurs when one or several factors change during the observation period. The relocation of a station will not necessarily lead to abrupt inhomogeneity when the sunshine recorder is installed correctly, which means that the horizon should be clear down to 3°. But the change of instrument from FUESS to CASELLA certainly will.
The erection of new buildings that shade out the sun without the sunshine recorder being relocated (as it should) will also have an effect, as will the rectification of incorrectly setting-up angles to the instruments or cardboard.

When one or several factors change slowly, the series will show a non-natural trend in observed sunshine. One example could be the growth of trees over the allowed horizon. Another example (when instructions concerning maintenance and regular cleaning of the recorder are not observed!) could be gradual smearing of the sphere by dust, mud or bird droppings. Both cases would normally lead to a linear or non-linear decrease in measured sunshine level.

Since 1961 both abrupt and gradual changes have occurred at the Danish sunshine recording stations, but not all of these changes have had a significant influence on the homogeneity of the series.

A method is therefore needed to separate significant changes from insignificant ones. The method must also be able to detect both abrupt and gradual inhomogeneities. Furthermore, the existence of multiple breaks must be considered.

The problem of homogeneity: testing existing series has been solved by using software developed at DMI (Steffensen, 1996), ensuring the same treatment of the Danish 1961-1990 series, including e.g. the Danish precipitation 1961-1990 (Frich et al. 1997).

5.2 Testing for homogeneity

The above-mentioned software (SNHT) performs a standard normal homogeneity test (Steffensen, 1996). This is a statistical test to compare the ratio between a test series and several reference series. In this way *actual* changes in sun climate over time do not emerge as inhomogeneities. The test is performed on both annual and seasonal sums of hours of bright sunshine.

The test output will give the year(s) of possible break(s) or trend, and the size and significance of the break(s) or trend. In the case of the series that had had FUESS values corrected it was important to do the SNHT in order to check the credibility of the adjustment.

In the case of FUESS values that could not be corrected due to a lack of FUESS-CASELLA overlap, the SNHT was used to find the correction factors. This was done on the assumption that the change from FUESS to CASELLA was the cause of the breaks distinctly detected on instrument changeover.

All of the final series in this report have been labelled according to the test results (see station catalogue, Appendix 1). Series comprising less than 10 years (Skagen and Stevns) could not be tested. Also, only the 1961-1990 part of the 1876-1997 Copenhagen series has been tested.

The test result may be homogeneous (label H), in which case the series can be used for all kinds of spatial and temporal analysis. Inhomogeneous series are labelled I, and care should be taken when using these series for further analysis. A third group of series is labelled T, meaning they have been tested but are not perfectly homogeneous. This can be caused by either breaks or trends near the end of the series or by multiple breaks, which cancel out over the 30-year period. T may also indicate that one season shows an inhomogeneity but this cannot be explained by any known physical changes at the station. The quality marking is listed in table 5-1.

Quality mark	**Description**
H	Homogeneous, rigorously tested and possibly adjusted
T	Tested, possibly adjusted but not perfectly homogeneous
N	Not tested, but not necessarily inhomogeneous
E	Environmental changes prevent climatic change studies
I	Inhomogeneous series that is presently unadjustable

Table 5-1: The quality mark is the same as in the NACD project (see Frich et al., 1996). For the purpose of this report it should therefore be remembered that, whether 'H' or 'T', all series with FUESS observations have been adjusted prior to the final SNHT.

6. Climatological normals, 1961-1990

6.1 Monthly and yearly means for 14 stations

Table 6-1 below shows hours of bright sunshine - monthly and yearly means - from the 14 sites shown on the map in figure 3-1, where calculation of climatological normals, 1961-90, could be performed. The monthly data and the calculated normals are available on the floppy disk included, see Appendix 4 for a record-layout.

Mean, 1961-1990
Hours of bright sunshine. CASELLA level.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
20210 Tylstrup	38	74	124	184	240	259	252	224	155	99	59	38	**1746**
21120 Erslev	42	72	120	184	236	252	244	223	153	98	59	40	**1722**
21312 Viborg	33	62	111	170	224	237	219	208	144	92	54	34	**1589**
22230 Ødum	39	69	119	180	239	252	233	228	154	97	61	40	**1713**
24020 Bovbjerg Fyr	46	77	124	180	231	240	224	212	140	91	52	39	**1657**
25270 Askov	37	64	104	162	221	223	206	206	138	92	52	36	**1542**
26370 Højer Hohenwarte	51	79	121	174	240	241	222	219	145	98	56	45	**1689**
26400 St. Jyndevad	44	72	108	166	233	229	214	209	141	97	52	39	**1603**
28280 Årslev	35	63	108	171	238	244	228	220	151	101	57	34	**1650**
29441 Tystofte Huse	40	69	115	180	251	259	246	237	161	106	57	40	**1761**
30340 København	43	68	117	185	249	259	244	233	158	103	57	38	**1753**
31290 Næsgård	40	65	114	180	250	259	242	234	163	109	59	45	**1761**
32010 Christiansø Fyr	38	70	120	189	275	293	286	270	174	109	56	40	**1920**
32156 Østerlars SV	34	59	112	184	274	285	268	251	163	99	48	31	**1810**
Maximum 1961-1990:	**51**	**79**	**124**	**189**	**275**	**293**	**286**	**270**	**174**	**109**	**61**	**45**	**1920**
Minimum 1961-1990:	**33**	**59**	**104**	**162**	**221**	**223**	**206**	**206**	**138**	**91**	**48**	**31**	**1542**

Table 6-1: Climatological normals, 1961-1990 - hours of bright sunshine per month - at 14 sites shown on the map in figure 3-1. Maximum and minimum values are shown in bold in the last two rows of the table.

6.2 Monthly extremes for 14 stations

Table 6-2 shows hours of bright sunshine - maximum and minimum monthly values - together with the year and location of the extremes.

Extremes, 1961-1990, 14 stations
Hours of bright sunshine. CASELLA level.

	Maximum sum	Recorded at	**Minimum sum**	Recorded at
Jan	**113**	26400 St. Jyndevad in 1963	**3**	20210 Tylstrup in 1969
Feb	**140**	26370 Højer H. in 1986	**9**	20210 Tylstrup in 1972
Mar	**195**	31290 Næsgård in 1974	**19**	32010 Chr.ø Fyr in 1985
Apr	**320**	22230 Ødum in 1974	**68**	32010 Chr.ø Fyr in 1966
May	**374**	32010 Chr.ø Fyr in 1989	**83**	21312 Viborg in 1983
Jun	**385**	32010 Chr.ø Fyr in 1968	**109**	25270 Askov in 1987
Jul	**381**	32010 Chr.ø Fyr in 1982	**131**	26370 Højer H. in 1984
Aug	**330**	21120 Erslev in 1976	**112**	25270 Askov in 1980
Sep	**241**	30340 København in 1969	**96**	25270 Askov in 1968
Oct	**183**	31290 Næsgård in 1979	**16**	31290 Næsgård in 1976
Nov	**111**	31290 Næsgård in 1973	**16**	21312 Viborg in 1963
Dec	**87**	26370 Højer H. in 1970	**5**	30340 København in 1965
Year	**2208**	32010 Chr.ø Fyr in 1968	**1318**	25270 Askov in 1987

Table 6-2: Extreme monthly sums, location and year for 14 stations, 1961-1990.

7. Other series, various periods

Also stored on the floppy disk included are monthly sums of hours of bright sunshine recorded at 15 other stations listed below. These stations are available for various periods (See also Station Catalogue, Appendix 1, and map in figure 3-2 for the position of the stations.). The record-layout is described in detail in Appendix 4.

St. no.	**Station name:**	**Period available on floppy disk**:
20000	Skagen	1988.06-1997.12
20056	Nørre Lyngby S	1976.10-1996.03
21060	Silstrup	1971.01-1997.12
22595	Spøttrup Strand	1974.05-1997.08
23310	Brakker S	1970.01-1997.12
24340	Lyngvig Fyr	1973.10-1988.11
24485	Døvling	1974.12-1997.12
27020	Anholt	1970.01-1980.02
27030	Hesselø	1961.01-1982.02
29120	Refnæs Kysthospital	1961.01-1984.10
29340	Drøsselbjerg	1971.07-1997.12
30010	Nakkehoved Fyr	1986.07-1997.12
30285	Risø	1970.01-1997.12
31075	Stevns	1967.03-1974.07
31350	Tjennemarke	1970.01-1997.12

The 15 series include all available monthly sums recorded at the stations at CASELLA level. In two instances (Hesselø and Refnæs Kysthospital) the series were deemed long enough to make it worthwhile also including monthly sums of FUESS origin, even though these had first to be made available electronically, then be adjusted to match the CASELLA level.

Warning

As the 15 series are not of equal length and none of them covers the whole of the 1961-1990 period, great care should be taken when comparing means. This is stressed when considering the 1876-1997 Copenhagen series, which shows a larger mean annual amount of sunshine in the period 1991-1997 compared to the mean for the 1961-1990 period. This clearly indicates, for instance, that the mean annual sum of the Skagen series (1988-1997) is not readily comparable with the mean annual sum of other known ‘high-level’ series such as Christiansø (1961-1990) and Anholt (1970-1980). The means of monthly and annual sums for the 15 series will be found in Appendix 3.

8. Copenhagen, 1876-1997

Observations of sunshine duration have been made since 1876 in Copenhagen using different instruments. The 122-year-long-series of hours of bright sunshine presented in this report is the longest ever published in Denmark.

8.1 Adjustment of original observations

The duration of sunshine was recorded by visual observations at the Copenhagen Botanical Garden from January 1876 through December 1890. From May 1887 through September 1901 recordings were also made with a water-filled glass bowl installed as a Campbell-Stoke recorder at Copenhagen harbour. From August 1901 until June 1997 measurements were made by a FUESS type Campbell-Stoke recorder. Since May 1968 sunshine has been recorded on a CASELLA type recorder installed on a roof at Toldboden (the old customs house) by Copenhagen harbour.
Due to the overlap between these four different series it has been possible to construct one long continuous series of recorded sunshine in Copenhagen, 1876-1997, adjusted to CASELLA level.
The monthly sums of sunshine hours from the original visual observations for January 1876 - April 1887 were corrected to water-bowl level. The mean monthly corrections during the overlap period of May 1887 - December 1890 were used for this. Then the corrected visual observations plus the water-bowl observations for May 1887 - July 1901 were corrected to FUESS level. This correction was based on the two-month overlap between the water bowl

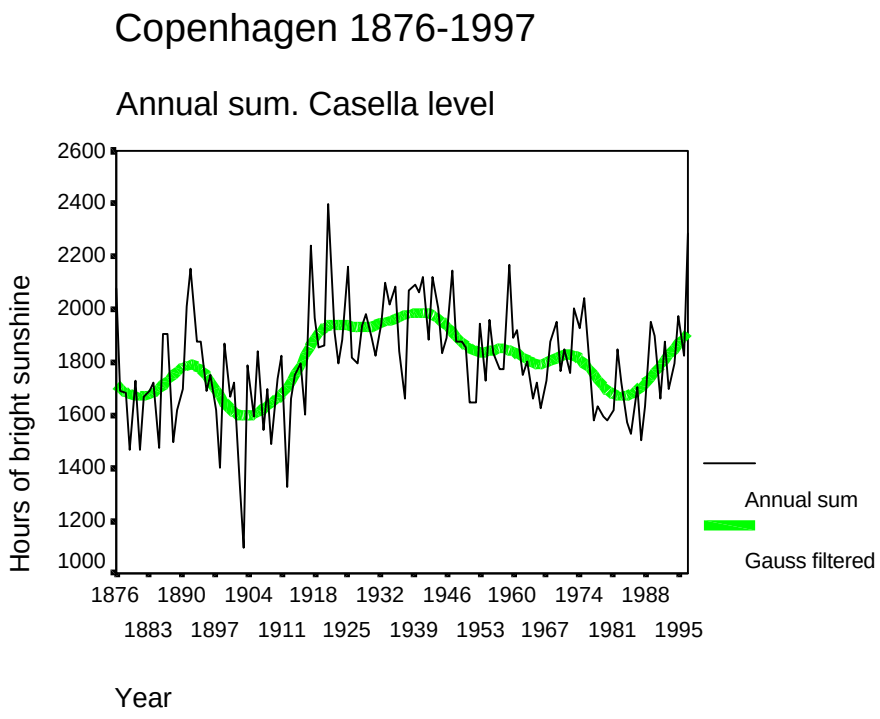


Figure 8-1: Hours of bright sunshine - annual sums - Copenhagen, 1876-1997. The heavy line represents filtered values using a 4 - year gauss filter.

and the FUESS measurements, August 1901 - September 1901, and the same adjustment was consequently used for all months. Finally all these corrected observations plus the FUESS observations for August 1901 - April 1968 were corrected to CASELLA level. This correction was based on the May 1968 - December 1990 overlap between FUESS and CASELLA measurements.

The history of sunshine duration observation in Copenhagen has been investigated earlier, and comparisons of adjusted sunshine and cloud cover series covering the period 1876-1993 have been made (see Frich, 1994). In this earlier investigation adjustments were made per season instead of per month, and adjustments of visual observations were not made directly to the original observations. Quantitatively, however, this produced only insignificant differences between the two adjusted series in the overlapping period 1876-1993.

8.2 Trends 1876-1997

Trends in the Copenhagen series for 1876-1997 can be seen on the five seasonal plots figures 8-1 and 8-2, and in table 8-1, showing seasonal sums during five periods.

A common picture is that hours of bright sunshine in Copenhagen had the lowest level at the end of the last century, rising to the highest level in the middle of this century, followed by a slight decrease in the 60s and 70s and an overall increase in the 80s and 90s. All seasons show the same tendencies, but notice the relatively “flat” curve for autumn and the virtually overall increase for winter sunshine duration.

The low level of the 60s and the 70s followed by the increase during the last twenty years could be explained by a shift in the general atmospheric circulation pattern affecting Denmark in the late 70s.

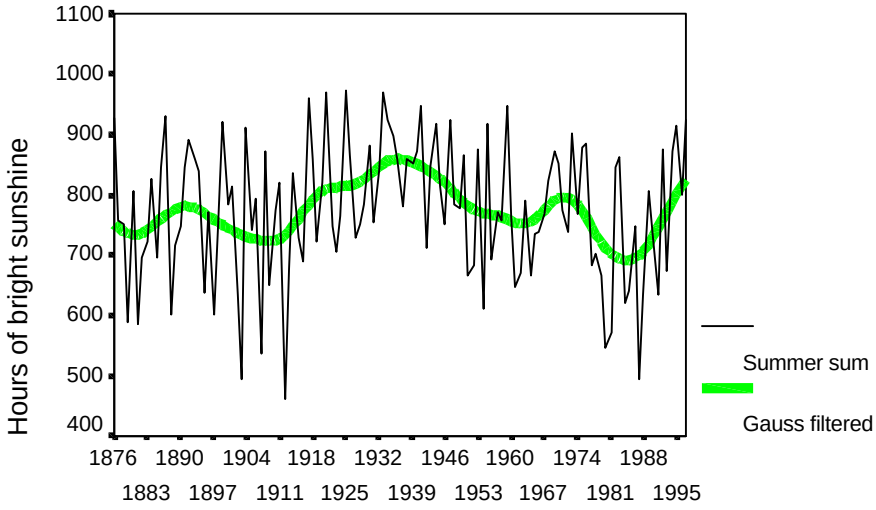
Copenhagen 1876-1997. Seasonal sums .
Hours of bright sunshine. CASELLA level.

Period	Winter	Spring	Summer	Autumn	Year
1876-1900	112	541	764	304	**1718**
1901-1930	124	568	766	319	**1777**
1931-1960	153	620	821	328	**1923**
1961-1990	147	551	735	318	**1753**
1991-1997	169	562	813	312	**1852**

Table 8-1: Mean seasonally sums of hours of bright sunshine - at five successive time intervals - Copenhagen 1876-1997.

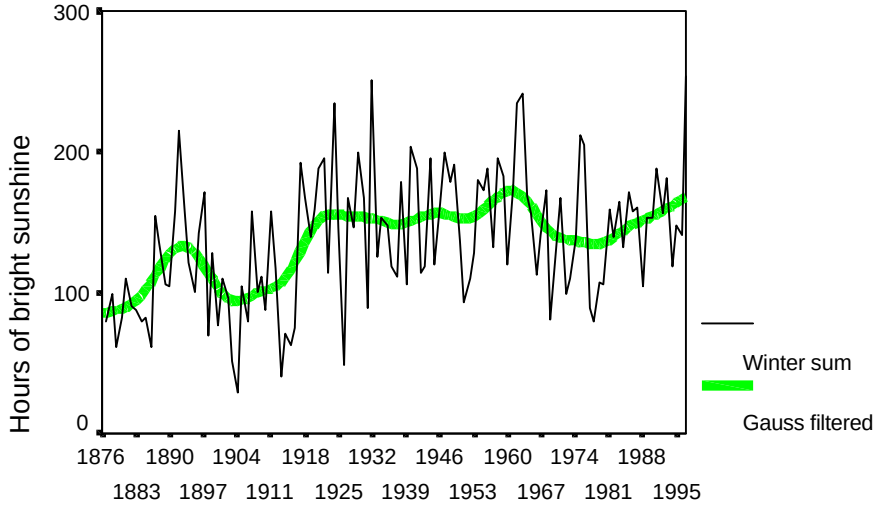
Copenhagen 1876-1997

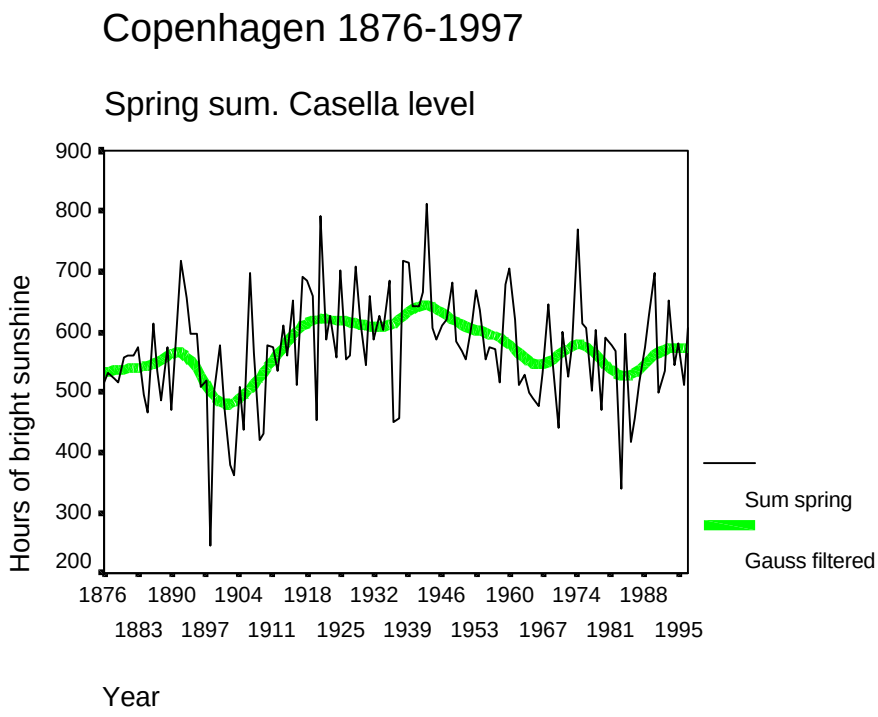
Summer sum. Casella level



Copenhagen 1876-1997

Winter sum. Casella level





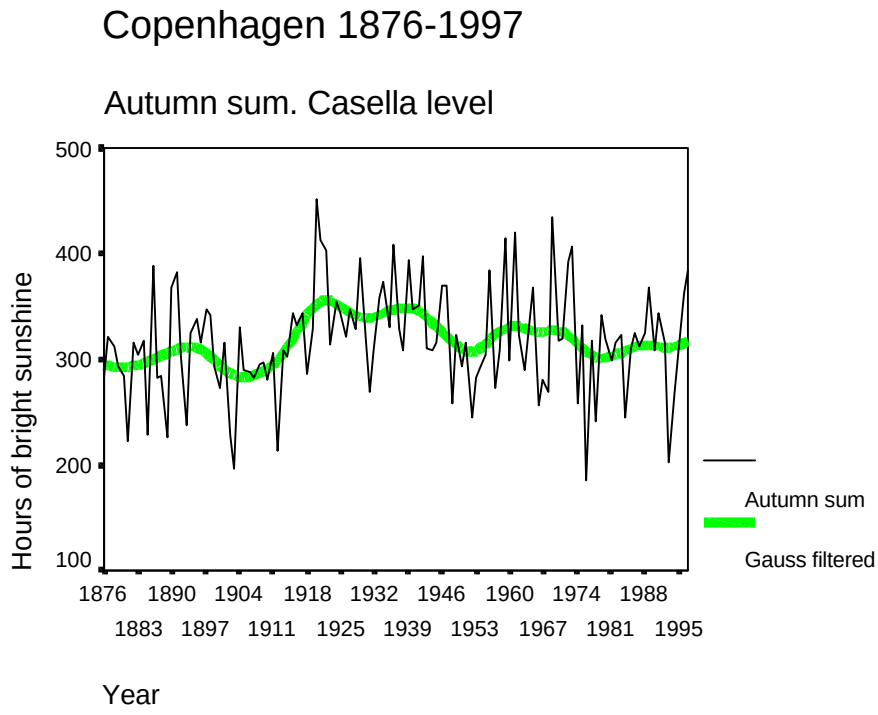


Figure 8-2: Hours of bright sunshine - split into the four seasons: summer, winter, spring and autumn - Copenhagen 1876-1997. The heavy line represents filtered values using a 4-year gauss filter.

9. Discussion: the sun climate of Denmark

The sunshine duration in Denmark varies from place to place. As a general picture the highest yearly sums occur in the northern part of Jutland, the Kattegat regions and Bornholm. The lowest values are found in central Jutland.

In-land stations versus island stations

The reasons for the high values have something to do with the fact that island stations in Denmark, affected by the sea, receive more sunshine than in-land stations. Figure 9-1 below shows the inter annual variation for two sites: the spot in Denmark that received the most sunshine during the period 1961-90 (Christiansø) versus the spot that received least during that same period (Askov). The island station of Christiansø in Østersøen receives more sunshine than the in-land station of Askov in central Jutland throughout the year - an average of 378 hours more. The figure also shows that during the summertime the in-land station is more affected by thermal activities causing more clouds than the island station. In spring time, on the other hand, the weather is more unstable on the islands because of the relatively cold sea water. This is difficult to see in figure 9-1, but the extremes shown in table 6-1 tell us that record minimum values in March and April are found precisely at Christiansø.

The relatively high amounts of sunshine in the northern part of Jutland could also be explained by the sheltering effect of the Norwegian mountains, in cases where the weather come from a northwesterly direction.

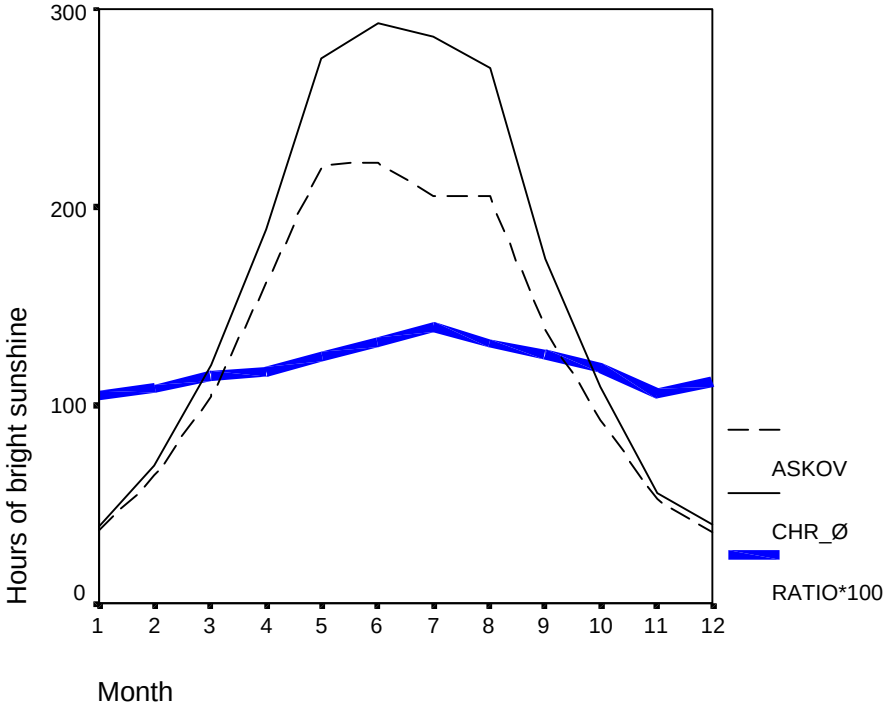


Figure 9-1: Mean 1961-1990 monthly sums of hours of bright sunshine: The Askov ('in-land') and Christiansø ('island') series. The heavy line displays the ratio between the Christiansø and the Askov values (the vertical scale pertains to the ratio times 100).

10. References

Frich, P., 1994: North Atlantic Climatological Dataset (NACD), - objectives, methodology and present status. Preprints Nordisk Meteorologi Møde, Kristianssand.

Frich, P. (Co-ordinator), H. Alexandersson, J. Ashcroft, B. Dahlström, G. Demarée, A. Drebs, A. van Engelen, E.J. Førland, I. Hanssen-Bauer, R. Heino, T. Jónsson, K. Jonasson, L. Keegan, P.Ø. Nordli, T. Schmith, P. Steffensen, H. Tuomenvirta, O.E. Tveito, 1996: North Atlantic Climatological Dataset (NACD Version 1) - Final Report. DMI Scientific Report 96-1, 47 pp.

Frich, P., S. Rosenørn, H. Madsen, and J.J. Jensen, 1997: Observed Precipitation in Denmark, 1961-90. DMI Technical Report 97-8, 38 pp.

Steffensen, P., 1996: Standard Normal Homogeneity Test for Windows®, User Guide. DMI Technical Report 96-13. 35 pp.

WMO, 1986: Compendium of lecture notes on meteorological instruments for training class III and class IV meteorological personnel. WMO No. 633, Vol. 1.

Appendix

Appendix 1. Station Catalogue

Station No.	Station Name	Latitude (degrees, min. N)	Longitude (degrees, min. E)	Elevation (m.a.s.)	Quality
20000	Skagen Fyr	57° 44’	10° 38’	6	N
20056	Nørre Lyngby S	57° 25’	9° 45’	17	T
20210	Tylstrup	57° 11’	9° 57’	13	H
21060	Silstrup	56° 56’	8° 39’	41	H
21120	Erslev	56° 50’	8° 44’	26	T
21312	Viborg	56° 25’	9° 25’	44	H
22230	Ødum	56° 19’	10° 10’	77	H
22595	Spøttrup Strand	55° 56’	10° 16’	1	H
23310	Brakker S	55° 35’	9° 24’	58	H
24020	Bovbjerg Fyr	56° 30’	8° 08’	35	H
24340	Lyngvig Fyr	56° 03’	8° 06’	18	H
24485	Døvling	55° 55’	8° 56’	30	T
25270	Askov	55° 29’	9° 09’	36	H
26370	Højer Hohenwarte	54° 57’	8° 41’	1	H
26400	St. Jyndevad	54° 54’	9° 08’	15	H
27020	Anholt	56° 42’	11° 33’	8	H
27030	Hesselø	56° 12’	11° 43’	7	H
28280	Årslev	55° 19’	10° 26’	49	T
29120	Refnæs Kysthospi-tal	55° 42’	11° 02’	20	T
29340	Drøsselbjerg	55° 28’	11° 13’	18	T
29441	Tystofte Huse	55° 15’	11° 20’	12	H
30010	Nakkehoved Fyr	56° 07’	12° 21’	37	T
30285	Risø	55° 42’	12° 05’	8	H
30340	København	55° 41’	12° 36’	20	T
31075	Stevns	55° 20’	12° 14’	13	N
31290	Næsgård	54° 52’	12° 07’	15	T
31350	Tjennemarke	54° 49’	11° 21’	11	T
32010	Christiansø Fyr	55° 19’	15° 11’	29	T
32156	Østerlars SV	55° 09’	14° 56’	113	T

For each series of recorded sunshine in this report, the number of the station is given, together with the station position in geographical coordinates and a quality mark: H (homogeneous, possibly adjusted), T (almost homogeneous, possibly adjusted), N (not tested, not necessarily inhomogeneous).

Appendix 2. Instrumentation of original observations

Any missing values during or in-between the periods listed below have been replaced according to the procedure outlined in chapter 3. Details are described in files kept at DMI.

Series: 20210 Tylstrup 1961.01-1990.12
Instrument type in original observations:

Station no.	Station name	Period	Type
20210	Tylstrup	1961.01-1965.07	FUESS
20210	Tylstrup	1965.08-1990.12	CASELLA

Series: 21120 Erslev 1961.01-1990.12
Instrument type in original observations:

Station no.	Station name	Period	Type
21120	Erslev	1961.01-1970.12	FUESS
21120	Erslev	1971.01-1990.12	CASELLA

Series: 21312 Viborg 1961.01-1990.12
Instrument type in original observations:

Station no.	Station name	Period	Type
21310	Folkekuren (Hald Ege)	1961.01-1970.06	FUESS
21310	Stanghede	1970.07-1975.04	CASELLA
21311	Skelhøje	1976.04-1982.07	CASELLA
21312	Viborg Flyveplads	1982.08-1990.12	CASELLA

Series: 22230 Ødum 1961.01-1990.12
Instrument type in original observations:

Station no.	Station name	Period	Type
22350	Højbjerg (by Århus)	1961.01-1961.04	FUESS
22230	Ødum	1961.05-1971-03	FUESS
22230	Ødum	1971.04-1990.12	CASELLA

Series: 24020 Bovbjerg Fyr 1961.01-1990.12
Instrument type in original observations:

Station no.	Station name	Period	Type
24020	Bovbjerg Fyr	1961.01-1968.05	FUESS
24020	Bovbjerg Fyr	1968.06-1987.06	CASELLA
24020	Bovbjerg Fyr	1989.03-1990.12	CASELLA

Series: 25270 Askov 1961.01-1990.12
Instrument type in original observations:

Station no.	Station name	Period	Type
25270	Askov	1961.01-1965.07	FUESS
25270	Askov	1965.08-1990.06	CASELLA
23310	Brakker S	1990.07-1990.12	CASELLA

Series: 26400 St. Jyndevad 1961.01-1990.12

Instrument type in original observations:

Station no.	Station name	Period	Type
26400	St. Jyndevad	1961.01-1971.06	FUESS
26400	St. Jyndevad	1971.07-1990.12	CASELLA

Series: 28280 Årslev 1961.01-1990.12
Instrument type in original observations:

Station no.	Station name	Period	Type
28280	Årslev	1961.01-1965.07	FUESS
28280	Årslev	1965.08-1990.12	CASELLA

Series: 29441 Tystofte Huse 1961.01-1990.12
Instrument type in original observations:

Station no.	Station name	Period	Type
29440	Tystofte	1961.01-1974.03	FUESS
29441	Tystofte Huse	1974.04-1990.12	CASELLA

Series: 30340 København 1961.01-1990.12
Instrument type in original observations:

Station no.	Station name	Period	Type
30340	Københavns Toldbod	1961.01-1968.04	FUESS
30340	Københavns Toldbod	1968.05-1990.12	CASELLA

Series: Copenhagen, 1876.01-1997.12
Instrument type in original observations:

Station no.	Station name	Period	Type
30380	Copenhagen	1876.01-1887.04	Visual
30380	Copenhagen	1887.05-1901.07	Water-bowl
30340	Københavns Toldbod	1901.08-1968.04	FUESS
30340	Københavns Toldbod	1968.05-1997.12	CASELLA

Series: 31290 Næsgård 1961.01-1990.12
Instrument type in original observations:

Station no.	Station name	Period	Type
31290	Næsgård	1961.01-1977.03	FUESS
31290	Næsgård	1977.04-1990.12	CASELLA

Series: 32010 Christiansø Fyr 1961.01-1990.12
Instrument type in original observations:

Station no.	Station name	Period	Type
32010	Christiansø Fyr	1961.01-1973.06	FUESS
32010	Christiansø Fyr	1973.07-1990.12	CASELLA

Series: 20000 Skagen 1988.06-1997.12
Instrument type in original observations:

Station no.	Station name	Period	Type

20000	Skagen Fyr	1988.06-1997.12	CASELLA

Series: 20056 Nørre Lyngby S 1976.10-1996.03
Instrument type in original observations:

Station no.	Station name	Period	Type
20056	Nørre Lyngby S	1976.10-1996.03	CASELLA

Series: 21060 Silstrup 1971.01-1997.12
Instrument type in original observations:

Station no.	Station name	Period	Type
21060	Silstrup	1971.01-1997.12	CASELLA

Series: 22595 Spøttrup Strand 1974.05-1997.08
Instrument type in original observations:

Station no.	Station name	Period	Type
22595	Spøttrup Strand	1974.05-1997.08	CASELLA

Series: 23310 Brakker S 1970.01-1997.12
Instrument type in original observations:

Station no.	Station name	Period	Type
23310	Brakker	1970.01-1997.12	CASELLA

Series: 24340 Lyngvig Fyr 1973.10-1988.11
Instrument type in original observations:

Station no.	Station name	Period	Type
24340	Lyngvig Fyr	1973.10-1988.11	CASELLA

Series: 24485 Døvling 1974.12-1997.12
Instrument type in original observations:

Station no.	Station name	Period	Type
24485	Døvling	1974.12-1997.12	CASELLA

Series: 26370 Højer Hohenwarte 1961.01-1990.12
Instrument type in original observations:

Station no.	Station name	Period	Type
26370	Højer Hohenwarte	1961.01-1971.06	FUESS
26370	Højer Hohenwarte	1971.07-1987.10	CASELLA
26358	Emmerlev Klev	1988.06-1990.12	CASELLA

Series: 27020 Anholt 1970.01-1980.02
Instrument type in original observations:

Station no.	Station name	Period	Type
27020	Anholt By	1970.01-1980.02	CASELLA

Series: 27030 Hesselø 1961.01-1982.02
Instrument type in original observations:

Station no.	Station name	Period	Type
27030	Hesselø/Hesselø Fyr	1961.01-1969.08	FUESS

27030	Hesselø	1969.09-1982.02	CASELLA

Series: 29120 Refnæs Kysthospital 1961.01-1984.10
Instrument type in original observations:

Station no.	Station name	Period	Type
29120	Refnæs Kysthospital	1961.01-1971.03	FUESS
29120	Refnæs Kysthospital	1971.04-1984.10	CASELLA

Series: 29340 Drøsselbjerg 1971.07-1997.12
Instrument type in original observations:

Station no.	Station name	Period	Type
29340	Drøsselbjerg	1971.07-1997.12	CASELLA

Series: 30010 Nakkehoved Fyr 1986.07-1997.12
Instrument type in original observations:

Station no.	Station name	Period	Type
30010	Nakkehoved Fyr	1986.07-1997.12	CASELLA

Series: 30285 Risø 1970.01-1997.12
Instrument type in original observations:

Station no.	Station name	Period	Type
30285	Risø	1970.01-1997.12	CASELLA

Series: 31075 Stevns 1967.03-1974.07
Instrument type in original observations:

Station no.	Station name	Period	Type
31060	Thinghøj	1967.03-1972.09	CASELLA
31075	Tryggevælde	1972.10-1974.07	CASELLA

Series: 31350 Tjennemarke 1970-1997
Instrument type in original observations:

Station no.	Station name	Period	Type
31350	Abed	1970.01-1993.08	CASELLA
31350	Tjennemarke	1994.03-1997.12	CASELLA

Series: 32156 Østerlars SV 1961.01-1990.12
Instrument type in original observations:

Station no.	Station name	Period	Type
32145	Bornholms Højskole	1961.01-1966.06	FUESS
32140	Almindingen	1969.12-1975.03	CASELLA
32155	Østerlars SV	1975.12-1990.12	CASELLA

Appendix 3. Means, 15 other series

Mean over various periods
Hours of bright sunshine. CASELLA level.

Station & mean period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
20000 Skagen Fyr **1988.06-1997.12**	58	75	135	206	286	283	310	257	169	102	58	47	**1996**
20056 N. Lyngby S **1976.10-1996.03**	37	69	102	178	257	241	257	210	144	93	59	34	**1686**
21060 Silstrup **1971.01-1997.12**	42	70	115	188	255	254	270	228	147	95	56	35	**1756**
22595 Spøttrup Str. **1974.05-1997.08**	47	72	109	179	253	249	260	234	147	98	59	40	**1732**
23310 Brakker S **1970.01-1997.12**	44	69	107	169	241	236	233	221	140	99	57	40	**1656**
24340 Lyngvig Fyr **1973.10-1988.11**	44	79	119	177	234	225	217	207	133	86	51	35	**1615**
24485 Døvling **1974.12-1997.12**	43	71	100	161	233	220	225	205	134	89	52	31	**1564**
27020 Anholt **1970.01-1980.02**	38	64	141	204	270	306	275	278	166	105	59	42	**1950**
27030 Hesselø **1961.01-1982.02**	42	68	133	200	261	279	248	248	166	107	59	41	**1853**
29120 RefnæsKysth. **1961.01-1984.10**	43	72	129	191	246	268	246	239	163	106	62	44	**1815**
29340 Drøsselbjerg **1971.07-1997.12**	45	69	117	185	251	243	254	236	148	105	60	39	**1752**
30010 Nakkeh. Fyr **1986.07-1997.12**	48	66	129	193	269	248	265	239	149	106	59	44	**1822**
30285 Risø **1970.01-1997.12**	48	69	119	187	254	242	251	237	150	106	63	41	**1766**
31075 Stevns **1967.03-1974.07**	28	54	133	190	230	287	257	262	167	111	67	38	**1813**
31350 Tjennemarke **1970.01-1997.12**	42	64	112	179	252	242	256	233	153	105	59	36	**1734**

Appendix 4. Contents of 3.5” floppy disk

This 3.5” HD disk contains 3 files (**station.dat, normal.dat, monthly.dat**) in fixed ASCII format, one in Microsoft Word format (**readme.doc**) and one in ASCII text format (**readme.txt**). Data from this 3.5” HD disk may only be used with proper reference to the accompanying report (Laursen, E.V. & J. Cappelen, 1998: Observed Hours of Bright Sunshine in Denmark - with Climatological Standard Normals, 1961-90. DMI Technical Report 98-4).

Station file: station.dat

The station catalogue contained in the file **station.dat** describes the number, name, position, elevation and quality of 29 Danish sunshine recording stations representing the 29 series of this report. Each record of the file contains information about one station. The file is sorted by station number and has the following layout:

Position	Format	Description
1-8	F8.0	Station number
9-28	A20	Station name
29-36	F8.2	Latitude (Degrees N , Minutes N)
37-44	F8.2	Longitude (Degrees E, Minutes E)
45-48	F4.0	Elevation (metres above sea level)
49-50	A2	Quality of time series (cf. below)

Quality mark	**Description**
H	Homogeneous, rigorously tested and possibly adjusted
T	Tested, possibly adjusted but not perfectly homogeneous
N	Not tested, but not necessarily inhomogeneous
E	Environmental changes prevent climatic change studies
I	Inhomogeneous series that is presently unadjustable

Normal File: normal.dat

Normal values for the standard normal period 1961-1990 are contained in the file **normal.dat**. The file contains normal values from 14 stations, all described in the Station Catalogue. The file is sorted by station number. Each record of the file contains the mean monthly and annual values from one station in the following format:

Position	Format	Description
1-6	F6.0	Station number
7-14	F8.2	First (year, month) in normal period (always 1961,01)
15-22	F8.2	Last (year, month) in normal period (always 1990,12)
23-28	F6.0	January normal value (hours of bright sunshine)
29-34	F6.0	February normal value (hours of bright sunshine)
35-40	F6.0	March normal value (hours of bright sunshine)
41-46	F6.0	April normal value (hours of bright sunshine)
47-52	F6.0	May normal value (hours of bright sunshine)
53-58	F6.0	June normal value (hours of bright sunshine)
59-64	F6.0	July normal value (hours of bright sunshine)
65-70	F6.0	August normal value (hours of bright sunshine)
71-76	F6.0	September normal value (hours of bright sunshine)
77-82	F6.0	October normal value (hours of bright sunshine)
83-88	F6.0	November normal value (hours of bright sunshine)
89-94	F6.0	December normal value (hours of bright sunshine)
95-100	F6.0	Annual normal value (hours of bright sunshine)

Monthly File: monthly.dat

Time series for the 29 stations presented in this report (13 1961-1990 series (the 14 minus the one from København, this being included in the long Copenhagen series), the 1876-1997 Copenhagen series and the 15 other series from various periods) are contained in the file **monthly.dat**. The file is sorted by station number, year and month (month 13 gives the annual sum). Each record of the file contains one monthly value (or annual sum) for one station in the following format:

Position	Format	Description
1-6	F6.0	Station number
7-12	F6.0	Year
13-18	F6.0	Month (1-12 and 13 for annual)
19-24	F6.0	Monthly sum of hours of bright sunshine (hours adjusted to CASELLA level). The annual sum is only calculated when 12 months are available.