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MINISTRY OF TRANSPORT

———— **TECHNICAL REPORT** ————  
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**New hours of bright sunshine normals for Denmark,  
1961-1990.**

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# 1. Introduction

The practice of measurement of hours of bright sunshine has changed at DMI. Former practice used Cambell-Stokes sunshine duration recorders of brand Casella. Present practice computes the number of hours of bright sunshine from the global radiation measured with a pyranometer of brand Star.

Mostly due to the difference in time resolution there is a more or less systematic deviation between sunshine duration hours given by the two methods. The deviation is large enough (up to ~ 20% on average) that the one should not be compared to normals computed of the other.

The present report therefore recalculates the 1961-1990 normals of hours of bright sunshine for Denmark to meet the present Star level of measurement.

‘Star’ signifies in this report the DMI observations of hours of bright sunshine where the number of hours of bright sunshine are computed from the global radiation measured with a pyranometer of brand Star and the computation uses the method of (Oliviéri, 1998) as described by (Nielsen, 2001). Likewise ‘Casella’ in this report signifies the DMI observations of hours of bright sunshine measured by Cambell-Stokes sunshine duration recorders of brand Casella.

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## 2. Stations measuring duration of bright sunshine

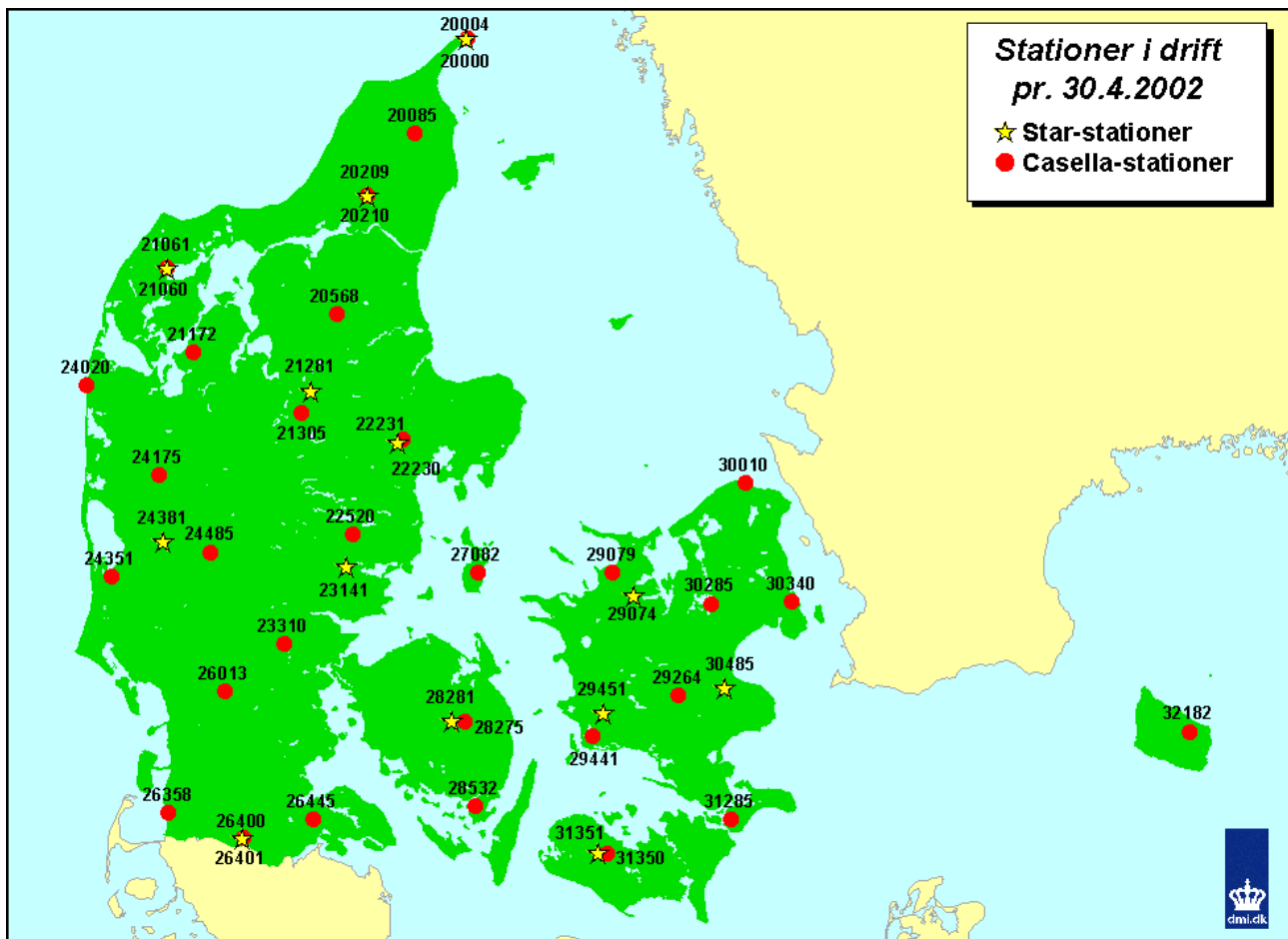


Figure 2-1. These are the stations measuring hours of bright sunshine up until the closing of the Casella stations May 1 2002. The Casella stations are marked by red dots. The Star stations are marked by yellow stars.

The DMI Casella stations were closed 1 May 2002 with two exceptions. The two exceptions are 30340 Københavns Toldbod and 32182 Østermarie that uninterruptedly are measuring duration of bright sunshine using Cambell-Stokes sunshine duration recorders of brand Casella.

The first DMI Star stations were in function 1 October 1999. At present there are 15 Star stations observing hours of bright sunshine. The location of DMI stations measuring hours of bright sunshine at present may be seen in figure 2-2 and information on the stations are listed in table 2-1.

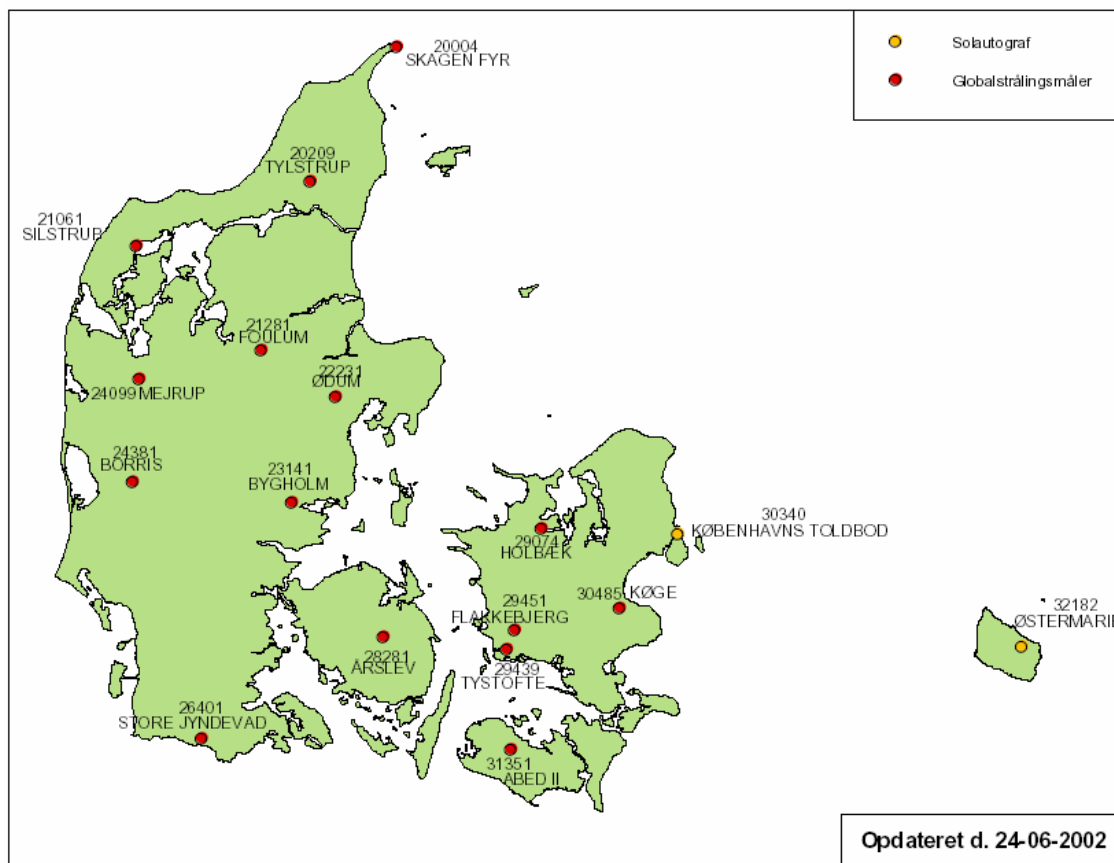


Figure 2-2. These are the stations measuring hours of bright sunshine at present. The Star stations are marked by red dots and the two remaining Casella stations are marked by yellow dots.

St. no. (national)	St. no. (Synop)	Name	data start	UTM zone	Northings	Eastings	Elev. (m.a.s.)
<b>Star:</b>							
20004	06041	Skagen Fyr	15.03.2001	32 V	6400740	597229	3
20209	06031	Tylstrup	25.03.2002	32 V	6338610	557680	13
21061	06019	Silstrup	25.03.2002	32 V	6309770	478230	41
21281	06069	Foulum	01.10.1999	32 V	6261335	535275	54
22231	06072	Ødum II	01.06.2001	32 V	6240560	569835	61
23141	06102	Forskn.center Bygholm	01.06.2001	32 U	6191875	549325	22
24099	06056	Mejrup	20.06.2002	32V	6248956	479727	53
24381	06082	Borris	20.04.2002	32 U	6201565	476750	25
26401	06116	St. Jynde vad II	31.03.2002	32 U	6083725	507940	15
28281	06126	Årslev II	22.06.2001	32 U	6130290	591460	49
29074	06156	Holbæk	01.10.1999	32 U	6179950	663540	12
29439	06136	Tystofte	15.04.2002	32 U	6124.900	648.100	12
29451	06135	Flakkebjerg II	07.06.2001	32 U	6133380	651600	32
30485	06174	Køge/Herfølge	18.03.2002	32 U	6143521	699469	21
31351	06141	Abed II	04.01.2000	32 U	6078280	649690	7
<b>Casella:</b>							
30340	-	København Toldbod	01.05.1968	33 U	6174240	349110	20
32182	-	Østermarie	15.05.1998	33 U	6109220	501695	92

Table 2-1. Danish stations measuring hours of bright sunshine at present (Sep-02). 15 Star and 2 Casella stations.

## 3. Conversion from Casella to Star

### 3.1 Conversion factors

DMI recommends 12 converting factors, one for each month of the calendar, converting monthly sums of Casella hours of bright sunshine to monthly sums of Star hours of bright sunshine. The conversion factors are listed in table 3-1. They have been found from the existing overlapping DMI series of Casella and Star observations of hours of bright sunshine (Laursen & Rosenørn, 2002).

The deviation between the two types of measurements is dependent on the height of the sun and the weather conditions, e.g. cloud cover, during sunshine. A conversion factor for a specific month therefore represents the *average* deviation of Casella to Star for that time of year and should be used with this in mind and only on *monthly* sums of hours of bright sunshine.

### Conversion factors from Casella to Star Monthly sums

The conversion factors are the average Star/Casella fractions from the final overlap series smoothed by a T4253H-filter<sup>1</sup>.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.05	0.98	0.94	0.91	0.87	0.84	0.83	0.83	0.84	0.88	0.96	1.10

**Table 3-1. Conversion factors from Casella to Star monthly sums of hours of bright sunshine. Example: A June monthly sum of hours of bright sunshine of 249 hours (Casella) is converted to  $249 \cdot 0.84 = 209$  hours (Star).**

### 3.2 Conversion factor details

In spring and summer 2002 the longest possible series of overlapping Casella and Star observations of hours of bright sunshine was put together from the various pairs of overlapping stations. The series was scrutinized to make sure only to select Casella and Star overlap-pairs where the differences were due to the methods of measurements and not due to difference in sunshine at the measuring sites. Due to the shortness of the overlap periods it was also investigated how the weather during the overlap period deviated from the normal weather (1961-90 average for Denmark). Where appropriate some values of the overlap series were then adjusted so as better to meet the expected level and behaviour of an climatologically overlap series. A thorough description of the selection and adjustment of the final overlap series is given in (Laursen & Rosenørn, 2002). From the final overlap series the conversion factors were found as the average Star to Casella fraction for every month of the calendar, filtered<sup>1</sup> to make a smooth appearance of the annual variation. Some statistical information on the final overlap series (66 months total) can be found in table 3-2. The annual variation in the conversion factors can be seen in figure 3-1. The highest

<sup>1</sup> 'T4253H-smoothing' is a standard method for smoothing a time series in the data handling software SPSS: The smoother starts with a running median of 4, which is centered by a running median of 2. It then resmooths these values by applying a running median of 5, a running median of 3, and hanning (running weighted averages). Residuals are computed by subtracting the smoothed series from the original series. This whole process is then repeated on the computed residuals. Finally, the smoothed residuals are computed by subtracting the smoothed values obtained the first time through the process. This is sometimes referred to as T4253H smoothing?

Star/Casella fractions are found in the months with the least sunshine: December and January. The lowest Star/Casella fractions are found during June – September.

Star/Casella						
Month	Raw mean	Raw mean Minimum	Raw mean Maximum	Raw mean std. dev.	# Months	Smoothed mean T4253H(Star/Casella)
1	1,0475	1,01	1,09	,03	6	1,0469
2	,9382	,86	1,05	,09	6	,9826
3	,9505	,90	,99	,03	6	,9382
4	,9105	,78	1,05	,09	8	,9051
5	,8752	,81	,93	,05	4	,8701
6	,8342	,81	,87	,02	6	,8407
7	,8284	,74	,92	,06	7	,8291
8	,8207	,74	,90	,05	6	,8305
9	,8498	,81	,89	,05	2	,8424
10	,8803	,82	,96	,06	5	,8789
11	,9150	,86	1,04	,07	5	,9645
12	1,1278	1,01	1,17	,07	5	1,1015

Table 3-2. Information on the Star/Casella fractions from the final overlap series.

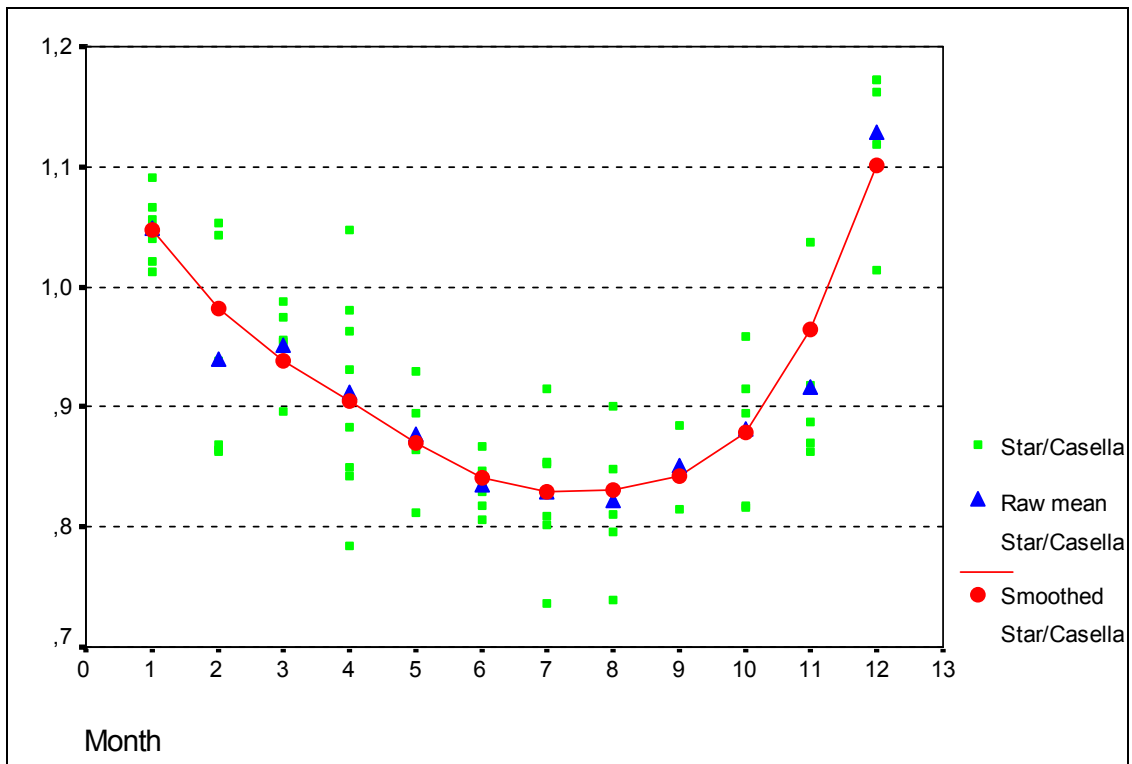


Figure 3-1. Annual variation of Star/Casella. The 12 conversion factors are marked by red dots. Notice the spread in the overlap Star/Casella values (green boxes).

## 4. Recalculated hours of bright sunshine, 1961-1990 normals, Star level.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2000 Skagen Fyr	50	82	129	184	223	234	233	206	144	88	53	48	1674
20056 Nørre Lyngby S	35	69	116	166	210	214	213	185	131	86	55	40	1520
20210 Tylstrup	39	72	117	167	209	218	209	186	130	87	57	42	1534
21060 Silstrup	43	70	114	171	210	219	212	187	129	84	54	44	1539
21120 Erslev	44	71	113	167	205	211	202	185	128	86	56	44	1514
21312 Viborg	35	61	105	155	195	199	182	173	121	81	52	37	1395
22230 Ødum	41	68	112	164	208	212	194	190	130	86	59	44	1506
22595 Spøttrup Strand	41	69	112	166	212	218	201	198	133	90	57	44	1542
23310 Brakker S	45	70	102	154	203	201	184	182	121	84	54	45	1444
24020 Bovbjerg Fyr	48	76	117	164	201	202	186	176	117	80	50	43	1460
24340 Lyngvig Fyr	48	73	116	160	203	196	182	176	117	81	50	45	1447
24485 Døvling	39	68	100	148	196	196	180	173	116	79	49	35	1379
25270 Askov	38	63	98	148	193	187	171	171	116	81	50	40	1356
26370 Højer Hohenwarte	53	77	114	158	209	202	184	182	121	86	54	49	1490
26400 St. Jyndeved	46	71	101	151	202	192	177	174	119	85	50	43	1411
27020 Anholt	45	70	122	182	222	235	220	213	139	90	61	45	1643
27030 Hesselø	44	69	121	179	227	224	211	202	137	95	58	45	1611
28280 Årslev	37	62	102	156	207	205	189	183	127	89	55	37	1448
29120 Refnæs Kysthospital	46	74	120	171	220	219	202	193	136	95	59	48	1581
29340 Drøsselbjerg	44	71	112	168	215	218	201	193	132	95	58	46	1554
29441 Tystofte Huse	42	68	108	164	218	217	204	196	135	93	54	44	1545
30010 Nakkehoved Fyr	45	66	116	167	222	225	194	191	130	87	57	43	1543
30285 Risø	49	72	115	169	214	211	197	189	131	94	59	46	1546
30340 Københavns Toldbod	45	67	110	168	217	218	202	193	133	90	55	42	1539
31075 Stevns	36	62	103	154	214	206	203	192	134	90	56	35	1486
31290 Næsgård	42	63	107	164	217	218	201	194	137	96	56	50	1546
31350 Tjennemarke	42	65	106	162	216	212	202	188	134	95	56	43	1520
32010 Christiansø Fyr	40	68	113	172	240	246	238	224	146	96	53	44	1680
32156 Østerlars SV	36	58	106	168	238	240	222	208	137	88	46	34	1580



The new 1960-1990 normals, Star level, were calculated from the the old 1960-1990 normals, Casella level, (Laursen & Cappelen 1998), (Laursen & Rosenørn 2001) using the conversion factors listed in table 3-1.

**Table 4-1. Recalculated hours of bright sunshine normals, 1961-1990, Star level.**

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
<b>Normal for Denmark</b> (Jylland/Øerne = 'Landstallet')	<b>43</b>	<b>69</b>	<b>110</b>	<b>162</b>	<b>209</b>	<b>209</b>	<b>196</b>	<b>186</b>	<b>128</b>	<b>87</b>	<b>54</b>	<b>43</b>	<b>1495</b>
Jylland	43	71	111	162	206	208	194	184	125	85	54	43	1484
Øerne	42	66	109	163	215	213	199	190	133	92	56	42	1522
Kattegat	46	73	124	182	224	231	221	207	140	91	57	46	1642
Bornholm	38	63	109	170	239	243	230	216	142	92	50	39	1629

## 5. References

Laursen, Ellen Vaarby and John Cappelen. Observed Hours of Bright Sunshine in Denmark –with Climatological Standard Normals, 1961-90. DMI Technical Report No. 98-4. Copenhagen 1998.

Laursen, Ellen Vaarby and Stig Rosenørn. Solskinstimer I Danmark, 1961-1990. Landstalsnormaler og kort. DMI Technical Report No. 01-08. Copenhagen 2001.

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