

# CLIMATE NORMAL FOR FOULUM 1991-2020

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## Abstract

A climate normal is climatological data assessed as average values of climatic elements in a consecutive period of 30 years. A climate normal may be used for estimating changes and development of the climate. Foulum meteorological station is situated at 56°29'N, 9°34'E, 54 m above sea level, and the measured climatological data from this station are particularly used in relation to agricultural research.

The climate normal for Foulum meteorological station 1991-2020 shows that the yearly average temperature was 8.2°C and precipitation measured 1.5 m above ground level was 678 mm. This is 0.9°C and 51 mm higher, respectively, compared to the corresponding climate normal from the previous 30-year period 1961-1990. The largest increase in temperature was registered in the months from January through April, where the rise was between 1.2 and 1.7°C. The precipitation has increased particularly in January and February with 15 and 13 mm, respectively, but most precipitation is still registered from July through October.

## Background

The climatological data for Denmark and other countries worldwide is assessed as average values in consecutive periods of 30 years, termed climate normals, starting from 1901 (World Meteorological Organization, 2007). The climate normals are utilised in many situations, but especially they are used to estimate the changes and development trends of the climate. The climate normal for a country is based on measurements performed at national meteorological stations positioned around the country.

For the meteorological station in Foulum (Figure 1), a climate normal has previously been calculated for the periods 1931-1960 and 1961-1990 (Olesen, 1991). Data from this station is widely used to interpret and discuss experimental results or for modelling in relation to research performed at this location.

The aim of this study was to calculate and present the 1991-2020 climate normal for the meteorological station in Foulum, and compare to the former period for selected variables.



**Figure 1** *Foulum meteorological station is located in Jutland, Denmark.*



## Materials and methods

Foulum meteorological station is situated at 56°29'N, 9°34'E, 54 m above sea level. The area is levelled and covered with grass continuously cut to a height of 4-7 cm. The grass is grown without water stress as it is well supplied with water from supplemental irrigation.

Data are automatically sampled every minute with Campbell CR10X data loggers (Campbell Sci., United Kingdom) and stored in an Access database as 10-minute values. The data have been quality controlled and if needed error corrected. The quality control is based on graphical inspection of every meteorological element, which is measured with replicate sensors. In case of deviations between replicates, errors are identified and removed. The sensors are following the recalibration scheme recommended for each sensor. Based on these 10-minutes data, daily values are calculated and further used for calculation of the climate normal.

### Instruments

Air temperature was measured at 2 m height in a Stevenson screen with a pt100 resistance thermometer.

Daily precipitation was measured at 1.5 m height. In the period 1 January 1991 to 31 December 2014, it was measured at 8 a.m. with a manual Hellmann type precipitation recorder with an area of 200 cm<sup>2</sup>. Thereafter, a Geonor (Geonor, Norway) was used until April 2016. From that date until 19 March 2019 an Ott Pluvio1 rain gauge (OTT Hydromet, Germany) was used and thereafter a Pluvio2 rain gauge (OTT Hydromet, Germany). From 1 January 2015 the daily precipitation was measured at 0 o'clock midnight.

Global radiation was measured with a CMP11 pyranometer (Kipp & Zonen, the Netherlands) in the spectral range from 285 to 2800 nm.

Ontario Corn Heat Units were calculated using measured air temperature at 2 m height and the following equation (Brown, 1972):

$$y_{\max} = 3.33 * (\text{maxtemp} - 10) - 0.084 * (\text{maxtemp} - 10)^2$$

$$y_{\min} = 1.8 * (\text{mintemp} - 4.4)$$

$$\text{Ontario Corn Heat Units} = (y_{\max} + y_{\min}) / 2$$

Where maxtemp and mintemp are daily maximum and minimum temperature, respectively.

Potential evapotranspiration from well irrigated short grass was estimated based on Makkink's equation, modified by Aslyng and Hansen (1982):

$$E^* = 0.7 \frac{\Delta}{\Delta + \gamma} \frac{S_i}{\lambda}$$

Where  $\Delta$  is the slope of the curve of the saturation vapour pressure versus the temperature,  $\gamma$  is the psychrometric constant,  $S_i$  is the global radiation, and  $\lambda$  is the latent heat of vaporization of water.

The new normal (1991-2020) for the Foulum meteorological station is calculated as simple minimum, maximum, average or sum of the various climatic elements.



## Results and discussion

The climate normal for Foulum meteorological station, 1991-2020, shows that the yearly average temperature was 8.2°C (Table 1). It is 0.9°C higher than the corresponding climate normal of 7.3°C in the previous 30-year period from 1961-1990 (Table 2). The increase in temperature is universal for all months of the year except June. However, the largest increase was registered during the period January, February, March and April, where the temperature was between 1.7, 1.7, 1.2, and 1.4°C higher, respectively, than in the corresponding months in the previous normal from 1961-1990.

**Table 1** *Climate normal for Foulum 1991-2020. The values are calculated as simple minimum, maximum, average or sum of the various climatic elements.*

<b>Foulum Normal 1991-2020</b>	<b>Jan</b>	<b>Feb</b>	<b>Mar</b>	<b>Apr</b>	<b>May</b>	<b>Jun</b>	<b>Jul</b>	<b>Aug</b>	<b>Sep</b>	<b>Oct</b>	<b>Nov</b>	<b>Dec</b>	<b>Year</b>
Absolute min. temperature, °C*	-16.1	-17.7	-15.2	-5.2	-1.4	1.7	5.7	5.7	0.1	-4.6	-6.9	-16.5	-17.7
Average min. temperature, °C	-1.2	-1.2	0.1	3.0	6.6	9.7	11.9	12.1	9.4	5.9	2.6	0.0	4.9
Absolute max. temperature, °C*	11.2	13.5	19.2	25.2	27.2	29.6	31.0	30.4	27.6	23.3	16.1	12.6	31
Average max. temperature, °C	3.2	3.3	6.1	11.0	15.2	17.9	20.5	20.5	16.6	11.6	7.0	4.1	11.5
Average temperature, °C	1.2	1.2	3.0	6.9	10.9	13.9	16.2	16.2	12.9	8.7	4.9	2.2	8.2
Number of frost days, $T_i < 0^\circ\text{C}$ **	16.9	16.3	14.0	5.1	0.2	0.0	0.0	0.0	0.0	2.1	6.9	13.7	75.3
Number of ice days, $T_x < 0^\circ\text{C}$ ***	6.8	5.9	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	4.4	19.7
Number of summer days, $T_x > 25^\circ\text{C}$	0.0	0.0	0.0	0.0	0.3	1.4	4.4	4.1	0.2	0.0	0.0	0.0	10.4
Precipitation at 1.5 m, mm	51	41	42	39	44	60	69	72	68	74	61	57	678
Number of precipitation days	17	15	15	13	13	13	14	16	17	19	20	19	190
Max. precipitation at 1.5 m in a day, mm	20	20	21	23	29	46	81	44	48	30	21	18	81
Global radiation, $\text{MJ m}^{-2}$	52	108	257	411	574	590	575	462	294	158	61	37	3579
Potential evaporation (Makkink), mm	6	12	32	59	93	102	104	84	50	24	8	4	579
Ontario Corn Heat Units	0	0	0	17	181	375	516	614	502	257	22	0	2484
Days with precipitation at 1.5 m $\geq 0.5$ mm	13.2	10.9	10.6	9.3	10.0	10.5	11.2	12.6	13.1	14.2	14.7	13.9	144
Days with precipitation at 1.5 m $\geq 1$ mm	11.0	9.2	8.7	7.5	8.5	9.2	9.6	11.1	11.3	12.2	12.2	11.6	122
Days with precipitation at 1.5 m $\geq 2$ mm	8.1	6.8	6.3	5.7	6.5	7.2	7.6	8.6	8.9	9.6	8.8	8.8	92.9
Days with precipitation at 1.5 m $\geq 5$ mm	3.5	2.9	3.0	2.5	3.2	3.8	4.4	5.1	4.7	5.2	4.3	4.2	46.8
Days with precipitation at 1.5 m $\geq 10$ mm	1.0	0.5	0.7	0.8	1.0	1.5	2.1	1.9	1.6	2.3	1.4	1.2	16.1

\* The Absolute min. and max. temperature is the lowest and highest temperature, respectively, registered during the entire 30-year period.

\*\* Number of frostdays is the number of days where the daily average minimum temperature is below 0°C.

\*\*\* Number of ice days is the number of days where the daily average maximum temperature is below 0°C.

The precipitation climate normal 1991-2020 in Foulum measured 1.5 m above ground level was 678 mm (Table 1). This is 51 mm higher than the precipitation climate normal of 627 mm in the period from 1961-1990 (Table 2).

The monthly precipitation in 1991-2020 was registered to be highest from July to October, which is similar to the observation in 1961-1990. However, the largest increase in precipitation is observed in January and February with 15 and 13 mm more, respectively, than in the corresponding months in the 1961-1990 normal. Furthermore, the number of days with precipitation has increased from 165 in 1961-1990 to 190 in 1991-2020. Also, the maximum amount of precipitation (Max. precipitation) in one day has increased to 81 mm, which is 22 mm more than the registered amount in the previous period.

**Table 2** *Climate normal for Foulum 1961-1990. The values are calculated as simple minimum, maximum, average or sum of the various climatic elements. Data derived from Olesen, 1991.*

<b>Foulum Normal 1961-1990</b>	<b>Jan</b>	<b>Feb</b>	<b>Mar</b>	<b>Apr</b>	<b>May</b>	<b>Jun</b>	<b>Jul</b>	<b>Aug</b>	<b>Sep</b>	<b>Oct</b>	<b>Nov</b>	<b>Dec</b>	<b>Year</b>
Absolute min. temperature, °C*	-28.0	-25.0	-17.9	-10.4	-3.6	0.1	3.8	0.4	-1.9	-5.4	-14.7	-23.0	-28.0
Average min. temperature, °C	-3.1	-3.3	-1.3	1.3	5.6	9.0	10.8	10.3	8.0	5.1	1.5	-1.5	3.6
Absolute max. temperature, °C*	10.6	12.9	19.2	23.5	26.8	30.9	31.5	33.5	27.4	22.6	15.1	11.7	33.5
Average max. temperature, °C	1.8	2.2	5.0	9.9	15.1	18.8	19.9	20.0	16.2	11.9	6.7	3.4	11
Average temperature, °C	-0.5	-0.5	1.8	5.5	10.5	14.2	15.4	15.1	12.1	8.5	4.2	1.1	7.3
Number of frost days, $T_i < 0^\circ\text{C}^{**}$	19.4	19.4	17.1	9.5	1.9	0.0	0.0	0.0	0.3	4.3	9.6	17.6	99
Number of ice days, $T_x < 0^\circ\text{C}^{**}$	8.7	7.6	2.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	1.1	4.8	25
Number of summer days, $T_x > 25^\circ\text{C}$	0.0	0.0	0.0	0.0	0.3	2.7	3.6	3.2	0.1	0.0	0.0	0.0	9.9
Precipitation at 1.5 m, mm	36	28	41	35	45	52	67	66	69	68	68	51	627
Number of precipitation days	16.4	11.4	14.0	11.9	11.6	11.4	13.1	13.0	15.1	15.2	16.4	15.7	165
Max. precipitation at 1.5 m in a day, mm	18.0	24.0	17.0	24.0	44.0	59.0	45.0	50.0	31.0	36.0	22.0	22.0	59
Global radiation, $\text{MJ m}^{-2}$	51	112	235	386	537	590	550	467	292	155	67	39	3480
Potential evaporation (Makkink), mm	5	12	28	54	86	103	98	83	48	23	9	4	553
Ontario Corn Heat Units	1	1	10	74	273	447	541	533	355	162	24	5	2425
Days with precipitation at 1.5 m $\geq 0.5$ mm	12.8	9.1	12.1	10.0	10.2	10.0	11.2	11.6	13.4	13.2	14.9	13.8	142
Days with precipitation at 1.5 m $\geq 1$ mm	9.9	7.3	9.8	8.4	9.0	8.9	9.9	10.5	12.1	11.7	12.7	11.9	122
Days with precipitation at 1.5 m $\geq 2$ mm	6.2	4.7	6.9	5.8	6.4	6.5	8.3	8.2	9.3	9.3	9.7	8.1	89
Days with precipitation at 1.5 m $\geq 5$ mm	1.8	1.6	2.7	2.5	2.9	3.4	4.8	4.7	4.9	4.8	5.0	3.2	42
Days with precipitation at 1.5 m $\geq 10$ mm	0.5	0.3	0.4	0.3	1.0	1.5	1.9	2.2	1.9	1.6	1.6	0.9	14

\* The Absolute min. and max. temperature is the lowest and highest temperature, respectively, registered during the entire 30-year period.

\*\* Minimum and maximum temperature below  $0^\circ\text{C}$ ,  $T_i$  and  $T_x$ , respectively, are calculated according to Olesen (1991).

The global radiation climate normal, 1991-2020, was 3579 MJ m<sup>-2</sup>. This is an increase of 99 MJ m<sup>-2</sup> compared to 1961-1990, where it was 3480 MJ m<sup>-2</sup> (Table 2). The global radiation has in particular increased during the months March, April, May and July.

## Conclusion

Compared to the previous climate normal from 1961-1990, the precipitation measured at 1.5 m above ground, air temperature and global radiation have increased in the new normal from 1991-2020. Especially, the winter and spring months have become warmer, and the spring months and July get more global radiation. January and February have become wetter, though the late summer and autumn months still get the most precipitation.

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## SUMMARY

This report describes a 30-year climate normal calculated from data measured at Foulum meteorological station situated at 56°29'N, 9°34'E, 54 m above sea level. The work was carried out at Department of Agroecology, and the data are widely used to interpret and discuss experimental results or for modelling.

The publication contains results that reveal the climate normal of data measured from 1991-2020 for Foulum meteorological station concerning:

- Yearly and monthly average temperature
- Yearly and monthly average precipitation measured 1.5 m above ground level
- Yearly and monthly global radiation
- Comparison to the normal in the previous 30-year period 1961-1990.

