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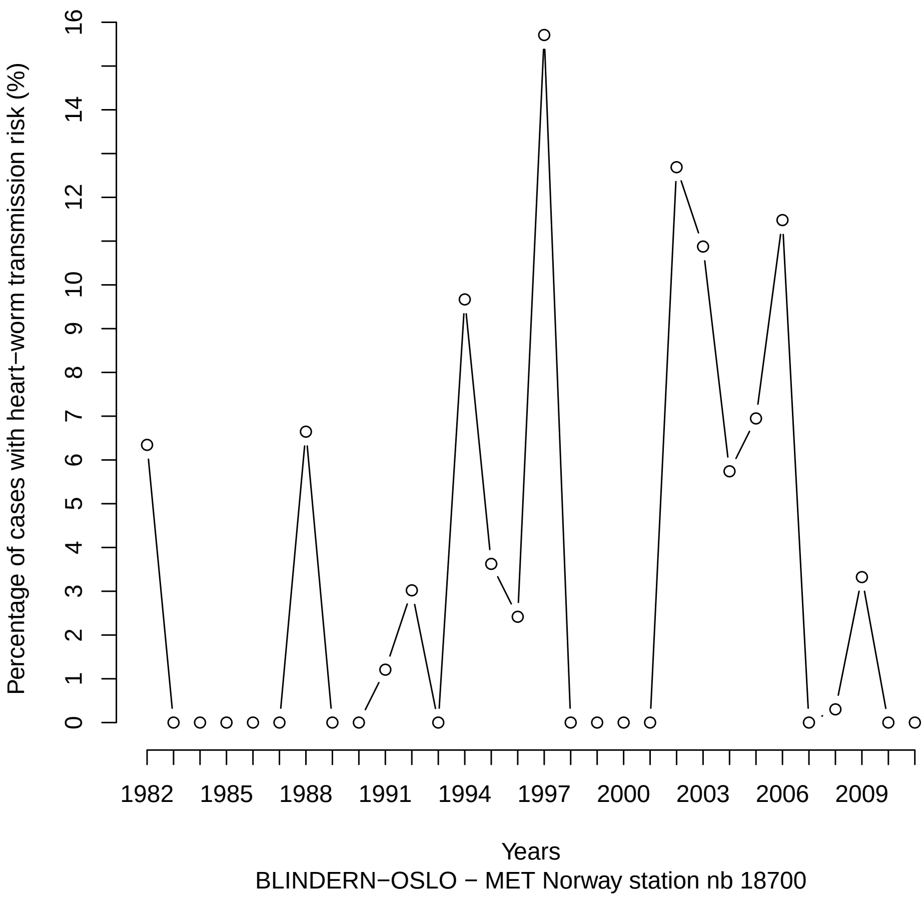
no. 16/2013
Climate

Transmission risk of heartworm disease in Norway.

A preliminary study based on a degree-days model.

Abdelkader Mezghani



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Transmission risk of heartworm Development Units in Norway. A preliminary study based on a degree-days model.	July 25, 2013
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Abstract

A preliminary analysis is addressed to assess heartworm transmission risk in Norway based on 2m air temperature. In the present work, the transmission risk is defined as potential days with suitable temperature values allowing the transmission of the heartworm larvae between hosts (mosquitos) and dogs. A degree-days model based on the definition of Heartworm Development Units (HDUs) derived from minimum and maximum daily temperatures is used. The model assumes 1) that the development of heartworm larvae in the mosquito does not occur below the threshold temperature value of approximately 14°C, 2) 130 cumulative HDUs are needed for the larvae to reach infectivity, and 3) a maximum life expectancy of 30 days. MET Norway daily temperature stations located in south-eastern Norway for the period 1981-2010 are considered to assess the number of potential days for transmission risk. The results show that the highest number of potential days is obtained at Færder-Fyr followed by Oslo-Blindern and Lyngør-Fyr weather stations, with a 30-years average of 12.5 days/year, 11 days/year and 7.5 days/year, respectively. The number of potential days for transmission risk has been found to be high during the period 2002-2006.

Keywords

Daily temperature, Norway, heartworm Development Unit, Dogs

Disciplinary signature

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1 Introduction

Dirofilaria are long, thin parasitic roundworms that infect a variety of mammals. Infection is transmitted by mosquito bites. There are many species of Dirofilaria, but human infection is caused most commonly by three species, *D. immitis*, *D. repens*, and *D. tenuis*. The main natural hosts for these three species are dogs and wild canids, such as foxes and wolves (*D. immitis* and *D. repens*) and raccoons (*D. tenuis*). *D. immitis* is also known as "heartworm" (Defintion extracted from the following web page http://www.cdc.gov/parasites/dirofilariasis/faqs.html).

Analyses on conditions suitable for the spread of the heartworm disease in Norway are carried out by R. K. Davidson (Ph.D. candidate at the Norwegian Veterinary Institute). In the present work, a preliminary study is performed on her request to study temperature conditions that are suitable for heartworm transmission between hosts (mosquitos) and dogs. Heartworm Development Units (HDUs) derived from degree-days above a given threshold temperature is established to reveal the potential transmission risk of the heartworm (hereafter called the transmission risk). The degree-days model was initially developed by *Fortin and Slocombe* (1981) and later modified by *Lok and Knight* (1998). For a heartworm in a mosquito to become infective, it needs 130 HDUs. A threshold value of 130 cumulative HDUs over 30 consecutive days is used to identify potential days with transmission risk.

This report is organized as the following. Section 2 presents the data used, including a general overview of the mean monthly temperature in Norway and the selected daily temperature stations. Section 3 presents the degree-days model used for the calculation of the Heartworm Development Unit (HDU). Results are discussed in Section 4. Section 5 concludes and gives some perspectives.

2 Data

2.1 Mean monthly temperature across Norway

Monthly mean temperature over Norway is characterized by strong east-west, as well as north-south gradients. In winter, mean monthly temperatures are below –15°C in the continental high mountain parts and between 0-2°C in the coastal regions of southern Norway. In summer, mean monthly temperatures range between 6-8°C in high mountain areas in the southern parts, around 10–12°C in lower northern parts and reaches 14-16°C in the coastal south-eastern parts. Moreover, the southern lower level region is known to be the warmest (*Tveito et al.*, 2000; *Hanssen-Bauer et al.*, 2009).

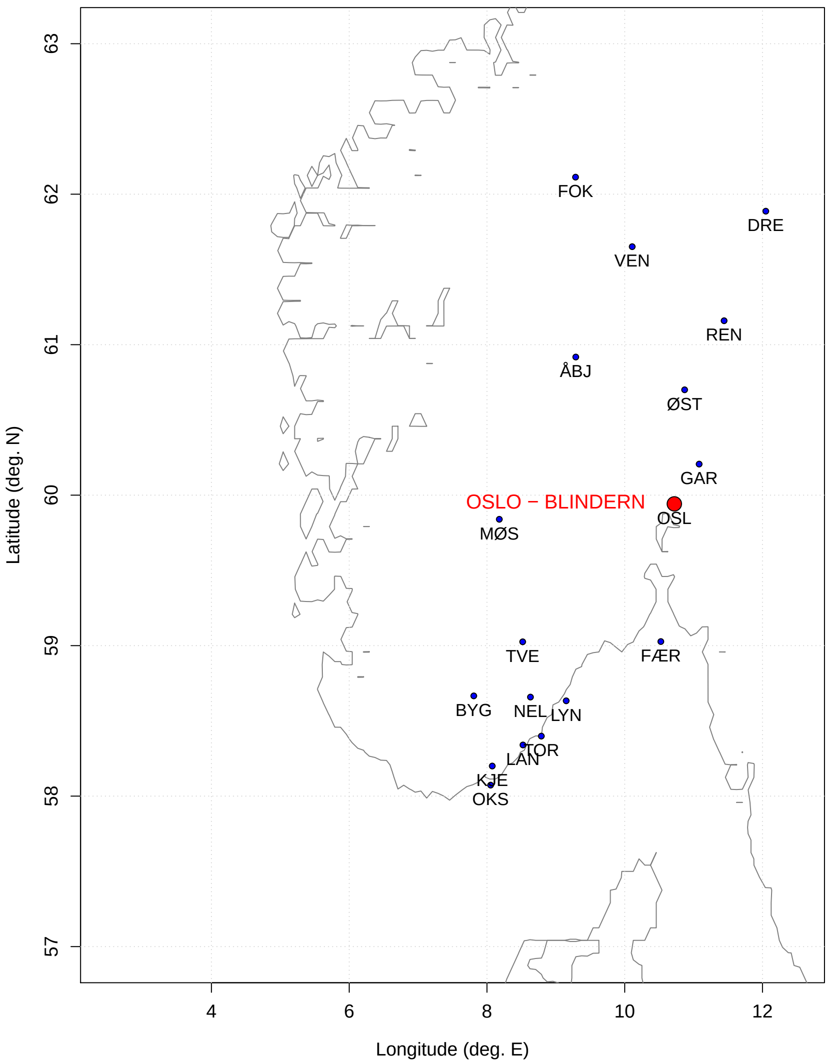

Figure 1: Selected MET Norway daily stations located in south-eastern part and covering the whole period 1981-2010. Abbreviated names of selected temperature stations are shown (black dots). Oslo-Blindern weather station is marked with a red dot.

Table 1: General characteristics of the selected MET Norway daily stations: Number (NUM), Abbreviated name (ABB), Station name (NAME), Station Number (STNR), Latitude (LAT in degree), Longitude (LON in degree), Altitude (ALT in m a.s.l), County, and Municipality.

NUM	ABB	NAME	STNR	LAT	LON	ALT	COUNTY	MUNICIPALITY
1	DRE	DREVSJØ	700	61.8872	12.048	672	Hedmark	Engerdal
2	GAR	GARDERMOEN	4780	60.2065	11.0802	202	Akershus	Ullensaker
3	REN	RENA - HAUGEDALEN	7010	61.1592	11.4425	240	Hedmark	Åmot
4	ØST	ØSTRE TOTEN - APELSVOLL	11500	60.7002	10.8695	264	Oppland	Østre Toten
5	VEN	VENABU	13420	61.6513	10.1087	930	Oppland	Ringebu
6	FOK	FOKSTUGU	16610	62.1133	9.2861	973	Oppland	Dovre
7	OSL	OSLO - BLINDERN	18700	59.9423	10.7201	94	Oslo	Oslo
8	ÅBJ	ÅBJØRSBRÅTEN	23160	60.918	9.2894	639	Oppland	Nord-Aurdal
9	FÆR	FÆRDER FYR	27500	59.0272	10.5242	6	Vestfold	Tjøme
10	MØS	MØSSTRAND II	31620	59.8397	8.1792	977	Telemark	Vinje
11	LYN	LYNGØR FYR	35860	58.6335	9.1503	4	Aust-Agder	Tvedestrand
12	TOR	TORUNGEN FYR	36200	58.3988	8.7893	12	Aust-Agder	Arendal
13	NEL	NELAUG	36560	58.6582	8.6313	142	Aust-Agder	Åmli
14	TVE	TVEITSUND	37230	59.0256	8.5186	252	Telemark	Nissedal
15	LAN	LANDVIK	38140	58.34	8.5225	6	Aust-Agder	Grimstad
16	KJE	KJEVIK	39040	58.2	8.0767	12	Vest-Agder	Kristiansand
17	OKS	OKSØY FYR	39100	58.0731	8.0531	9	Vest-Agder	Kristiansand
18	BYG	BYGLANDSFJORD - SOLBAKKEN	39690	58.6662	7.8085	212	Aust-Agder	Bygland

2.2 Selected daily temperature stations

Stations located in south-eastern Norway and recording daily temperature values covering the period from 1981 to 2010 – 30 years are selected in the present study. South-eastern Norway is here defined by boundaries of Region 1 as in *Hanssen-Bauer* (2005). Counties belonging to this region are : Akershus, Buskerud, Hedmark, Oppland, Oslo, Telemark, Aust-Agder, Vestfold, Vest-Agder, Ostfold. In total, 18 MET Norway stations are selected in the present study. The general characteristics of these stations are given in Table 1 and their geographical location is shown in Figure 1.

3 Method

To identify potential days with transmission risk, a degree-days model is used based on the definition of Heartworm Development Unit (HDU) derived from minimum and maximum daily temperatures. The degree-days model (*Fortin and Slocombe*, 1981) assumes 1) that the development of *D. immitis* larvae in the mosquito does not occur below the threshold temperature value of approximately 14°C, 2) 130 consecutive heartworm development units are needed for the larvae to reach infectivity, and 3) a maximum life expectancy of 30 days (*Lok and Knight*, 1998).

The calculation of the HDU is based on the following steps (*Vezzani and Carbajo*, 2006):

1. Extract daily minimum and maximum temperature time series covering the period 1981-2010 for each station (See Section 2 and Table 1 for a list of the selected stations).

2. Calculate the daily HDU based on the following formula

$$HDU = \begin{cases} ((T_{min} + T_{max})/2) - 14 & \text{if} \quad (T_{min} + T_{max})/2 \geq 14 \\ 0 & \text{if} \quad (T_{min} + T_{max})/2 < 14 \end{cases}$$

   where T_{min} and T_{max} are minimum and maximum daily temperatures. Note that the HDU values are set to zero for negative values.

3. Assume a mosquito vector survival period of 30 days and use a temporal filter based on the sum of consecutive daily HDU values.

4. All possible days for transmission are extracted from the series if the sum of HDU is larger than 130.

5. Compute the annual number of all possible days for transmission,

6. Repeat steps 1 to 5 for all the 18 stations.

4 Results and Discussion

Heartworm development units (HDUs) are estimated for all selected temperature stations following the procedure described in Section 3. The results are presented and discussed hereafter. Oslo-Blindern (red dot in Figure 1) has been studied in more details due to the high population density in this region. Monthly maximum, minimum, and mean temperatures for Oslo-Blindern station are presented in Appendix A, Figures A1 and A2, and mean annual values are presented in Appendix A, Figure A3. Monthly maxima, minima and mean temperature for all other stations are presented in Appendix B, Figures B1 to B17.

Figure 2 shows the percentage of days in the time period 1981–2010 with suitable conditions for possible transmission of a heartworm disease at Oslo-Blindern station.

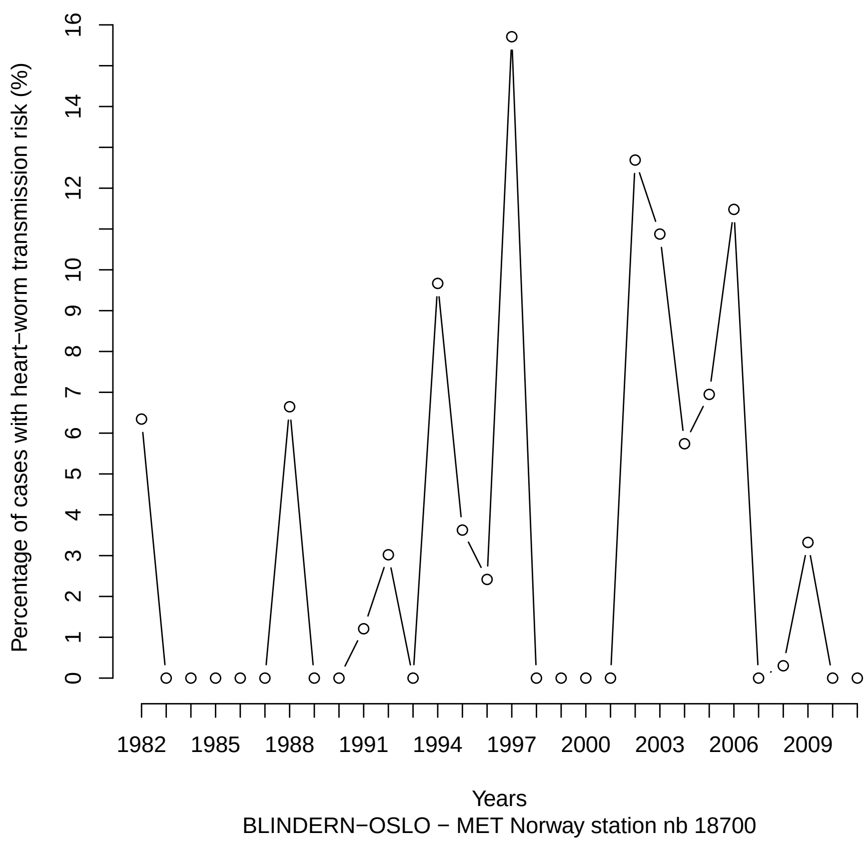

Figure 2: Annual distribution of potential days with transmission risk at Oslo-Blindern station. The x-axis represents the years and the y-axis the percentage of potential days with transmission risk corresponding to a HDU values larger than 130.

The analyses is based on the Daily HDU unit larger than 130 as described in Section 3. The annual number of days with HDU values above 130 within the 30-years period is presented in Figure 3. The annual number of days with HDU values above 130 for all 18 stations is given in Table 2.

For Oslo-Blindern station and overall the whole 30-years period (Table 2), the average number of potential days with a transmission risk is 11 days/year with a total number of 331 days. Note that half of the total number of years have shown possible cases of transmission risk which means that the probability of potential and non-potential days with transmission risk is equal. Therefore, it is difficult to conclude on any tendency between the two sub-periods except the fact that successive years with potential days have occurred more often for the second half of the last 30 years. However, the number of potential days with transmission risk or possible days for transmission is 33% higher considering the last third of the period 1998-2011. For instance, the year 1997 has shown the highest number of potential days with a transmission risk with a value of about 52 days, followed by years 2002 (42), 2006 (38), and 2003 (36). This was expected as those years were registered as warm in the historical data sets. A statistical test would be needed to verify whether the changes between sub-periods are significant or not which is out of the scope of this study.

The same methodology is extended to the 18 stations in order to compute the annual number of possible days for transmission based on the selected stations. The results are summarized in Table 2 and some general features are discussed hereafter:

- The year 1997 shows the highest number of cases i.e. maximum number of possible transmission days across the selected stations, followed by years 2006 and 2002.

- Færder-Fyr (FÆR in Figure 1) station which is located in southern Oslo fjord shows the highest number of possible transmission days of about 375 for the whole 30 year period (Table 2), with a yearly average of 12.5 possible transmission days. Oslo-Blindern station is ranked at the second position with an average number of 11 days/year, followed by Lyngør-Fyr (LYN in Figure 1) station with an average number of 7.5 days/year.

- No detection of possible transmission days is found at Drevsjø, Venabu, Fokstugu, Åbjørsbråten and Møsstrand-II stations. These stations are mainly inland stations and located in mountainous areas with an elevation higher than 500 meters above sea level.

- There is a spatial coherency of the potential number of transmission days across the south-eastern region showing an inland-coastal gradient effect i.e. that stations located in coastal regions show larger number of potential transmission days than the inland stations.

Furthermore, the potential period for heartworm development extends from June to August which is in agreement with the fact that these months are the warmest in the region. For instance, based on the last thirty years (1982-2010), the total number of annual occurrences is about 15 at Oslo-Blindern station. The annual distribution is shown in Figure 3. In addition, only one potential day with transmission risk is detected in June, 3 days in July and 11 days in August (not shown). It is clear that August is a suitable month for the development of a heartworm disease as it corresponds to the warmest month of the year. The same applies for all coastal stations but this does not exclude a possible shift in both time and space of the heartworm transmission risk in the future due to modifications in climatic conditions.

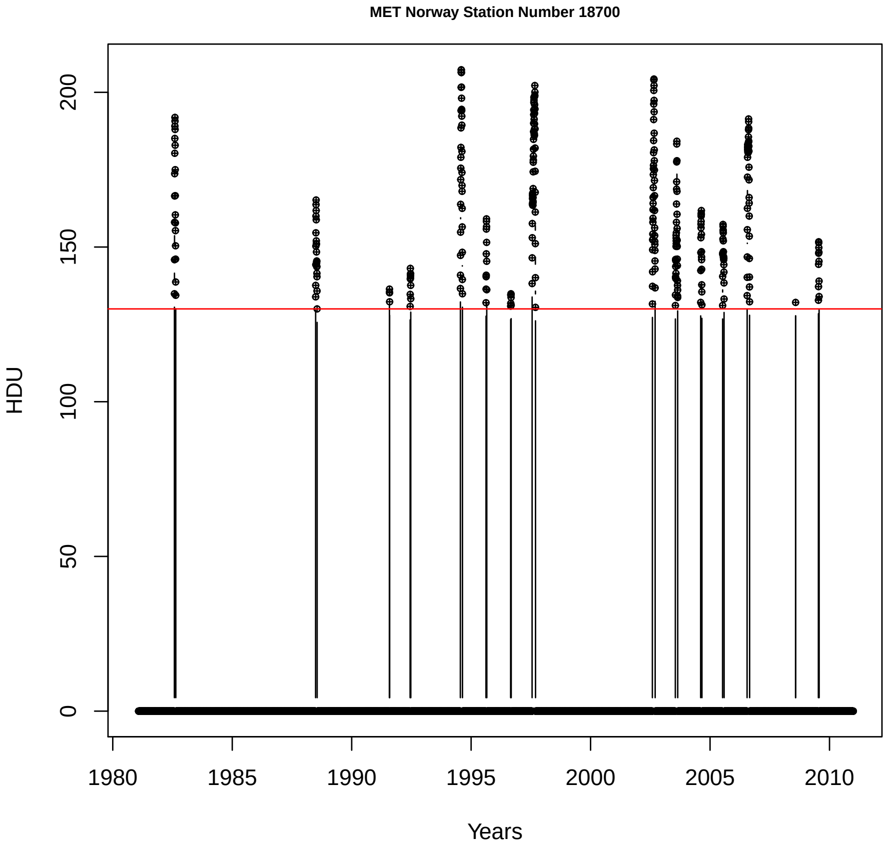

Figure 3: Potential days with transmission risk corresponding to a cumulated HDU values larger than 130 for Oslo-Blindern station. The x-axis represents the years and the y-axis the HDU values in days. The red horizontal line shows the threshold HDU value of 130.

Table 2: Number of potential days with transmission risk cases as a function of the year i.e. number of days showing a potential transmission risk for each year

Years	DRE	GAR	REN	ØST	VEN	FOK	OSL	ÅBJ	FÆ	MØS	LYN	TOR	NEL	TVE	LAN	KJE	OKS	BYG	Total
1981	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	0	15	0	7	0	0	21	0	26	0	16	7	9	5	14	4	7	12	143
1983	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	4
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	5	0	0	0	0	22	0	23	0	3	0	1	0	0	0	0	0	54
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	4
1992	0	0	0	0	0	0	10	0	8	0	0	0	0	0	0	0	0	0	18
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	26	9	18	0	0	32	0	33	0	24	15	24	10	18	21	14	14	258
1995	0	0	0	0	0	0	12	0	27	0	14	8	14	0	9	9	8	10	111
1996	0	0	0	0	0	0	8	0	5	0	0	0	0	0	0	0	0	0	13
1997	0	34	0	4	0	0	52	0	54	0	47	45	26	0	37	34	44	22	399
1998	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	10
2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	18	0	9	0	0	42	0	44	0	38	32	17	2	24	16	32	14	288
2003	0	8	0	0	0	0	36	0	40	0	38	20	9	0	7	12	26	0	196
2004	0	0	0	0	0	0	19	0	20	0	13	0	0	0	0	0	0	0	52
2005	0	0	0	0	0	0	23	0	12	0	0	0	0	0	0	0	0	0	35
2006	0	24	0	3	0	0	38	0	46	0	34	32	27	23	30	26	28	27	338
2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	1	0	14	0	0	0	0	0	0	0	0	0	15
2009	0	0	0	0	0	0	11	0	11	0	0	0	0	0	0	0	0	0	22
2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	130	9	41	0	0	331	0	375	0	227	159	127	40	141	122	159	99	

5 Conclusions & Perspectives

This report summaries some preliminary results for detecting potential transmission days as an ***indication*** of ***possible*** heartworm disease throughout Norway. The heartworm transmission risk is estimated via the Heartworm Development Units based on a degree-days model (*Fortin and Slocombe*, 1981). The condition of a possible transmission of a heartworm risk, is fulfilled based on the formula given in Section 3 and the selected stations given in Section 2. The results show that there are indications that south-eastern Norway would be exposed to such risk. This finding is in agreement with a previous similar study done by *Genchi et al.* (2005) over European regions. The authors predicted a heartworm transmission risk over south-eastern Norway.

It would be interesting to extend the study, for instance, to assess the spatial distribution of the number of possible transmission days across Norway and for the whole Scandinavian regions. Also, it would be interesting to study the effect of a possible warming on the vulnerable period to see whether it might happen earlier in the season and for how long it lasts before returning to a normal situation.

Another interesting extension of this study would be to study the effect of future climate change on the heartworm development across Norway and the Scandinavian regions in terms of occurrences and duration. Moreover, in the current study, a temporal window (w) of 30 days is used and it would be interesting to study the changes in the minimum duration of heartworm larvae life expectancy.

Issues related to climate and the conditions needed for the development of a heartworm larvae are listed hereafter:

- What is the impact of changes in temperature on the heartworm transmission risk characteristics?
- How far in spatial extent and duration is a heartworm development unit possible across Norway and Scandinavia? The answer of this question may or may not confirm the findings of *Morchon et al.* (2012) who considered Norway as a non potential case for heartworm development.

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I would like to thank Rebecca Davidson and Inger Sofie Hamnes for fruitful discussions about the heartworm disease and risk. The climatological data archive is provided by the Norwegian Meteorological Institute. The analysis was carried out using the R language programming tool which is freely available (http://www.r-project.org/). Thanks to Rasmus E. Benestad for supplying some of the R-scripts used in this study. I acknowledge my colleagues Ketil Isaksen and Torill Engen Skaugen for reviewing this report.

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Appendix A

Climatology-based analysis of daily, monthly and annual temperature at Oslo-Blindern station

The Oslo-Blindern station is of particular interest as it

- is close to the city of Oslo which could be affected by this type of disease because there are several tourism activities and dogs traveling,
- has a long and complete record of observations.

In addition, the Oslo-Blindern station is well known by MET Norway (*Nordli* (1997), *Nordli* (2001)). Currently, an homogenization procedure of the Oslo-Blindern time series is being performed by Øyvind Nordli, MET Norway. Also, this station has been extensively used to study, for instance, positive or negative trends in temperature and precipitation.

Statistics computed from Oslo-Blindern time series on a daily, monthly and annual basis are shown in Figures A.1, A.2 and A.3, respectively. Figure A.1 displays the minimum (blue circles) and maximum (red circles) daily temperature values. The mean daily values are shown in black circles. Figure A.2 shows the seasonal cycle showing the warmest period from June to August with daily maximum temperature values reaching 25°C. These months correspond to the summer season. Annual statistics are also drawn in Figure A.3 to check whether a trend exists or not in the time series. The dashed lines show the best linear fit for the mean as well as the minimum and maximum temperature values.

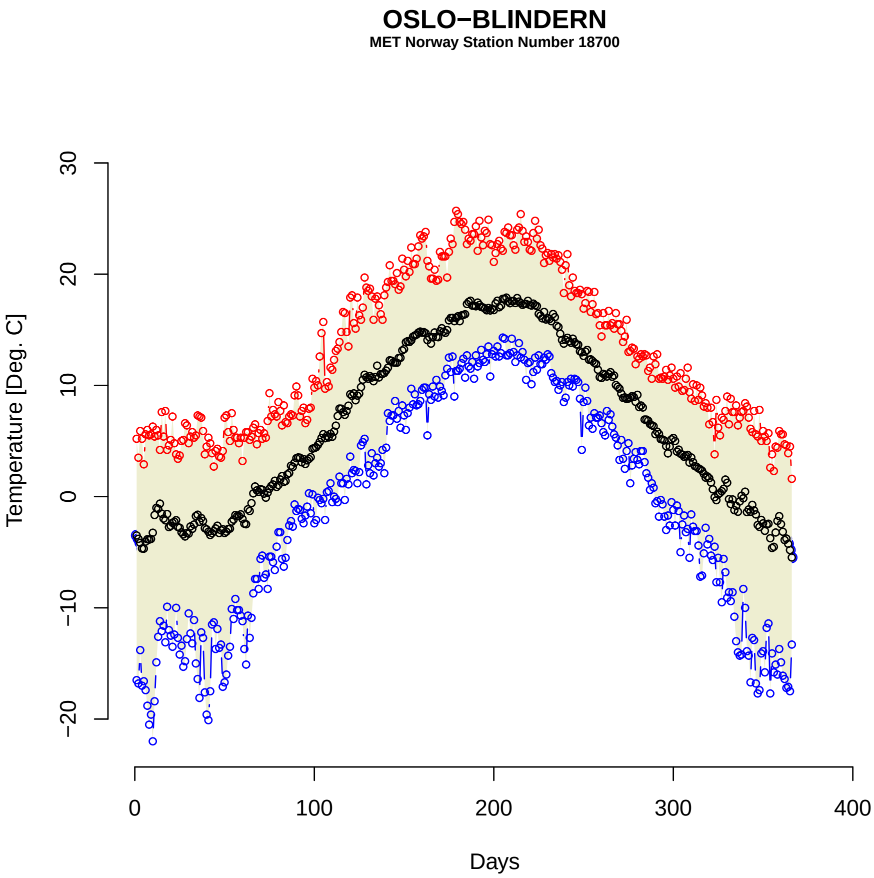

Figure A.1: Calendar statistics of daily mean temperatures (in °C) based on the selected period 1981 - 2010. Monthly minima and maxima are shown with the blue and red lines, respectively, while the black line shows the monthly means. The shaded area represents the envelope of variations across the months.

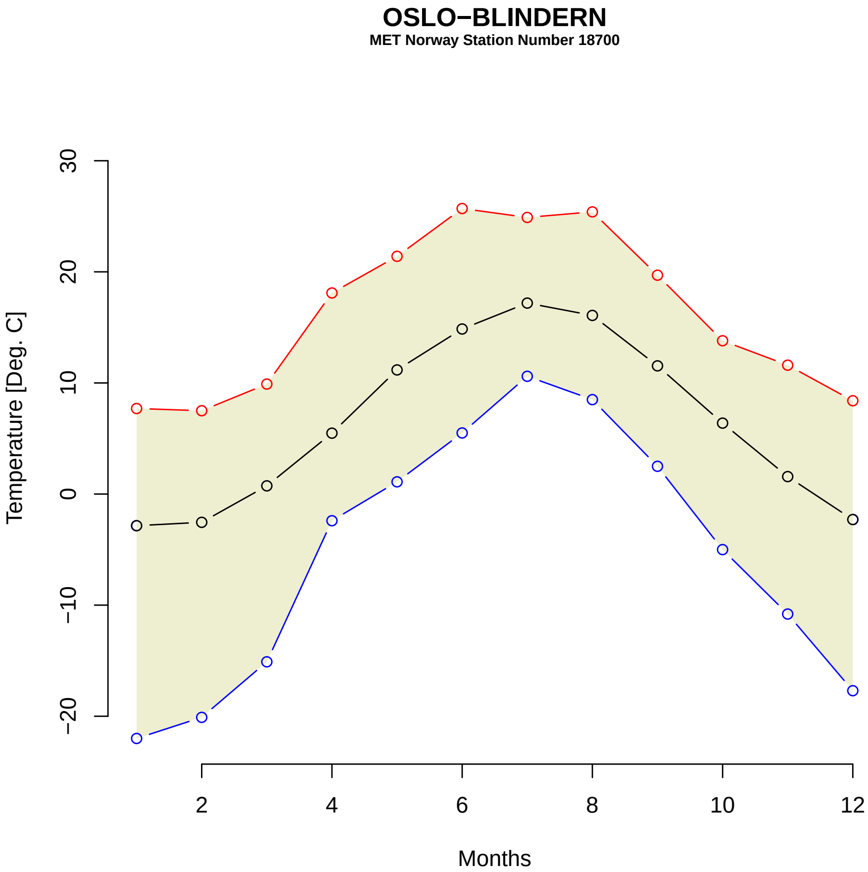

Figure A.2: Monthly statistics of daily mean temperatures (°C) based on the selected period 1981-2010. Monthly minima and maxima are shown with the blue and red lines, respectively, while the black line shows the averaged monthly means. The shaded area represents the envelope of variations across the months.

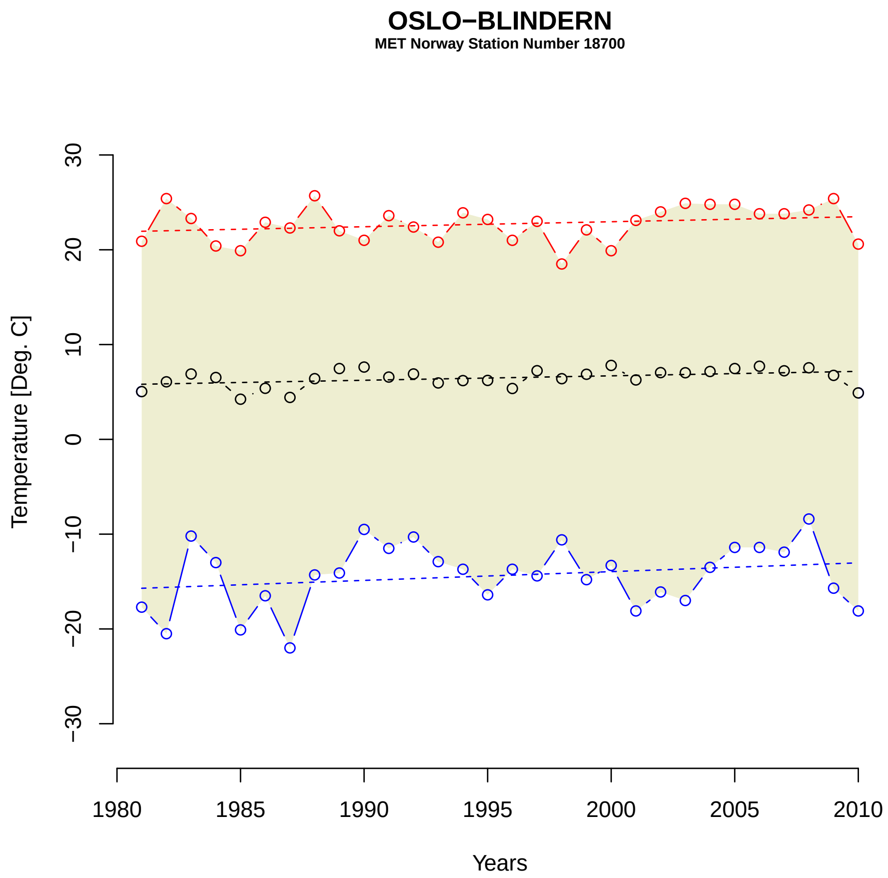

Figure A.3: Annual statistics of daily mean temperatures (°C) based on the selected period 1981-2010. Annual minima and maxima are shown with the blue and red circles, respectively, while the black circles shows the annual means. The shaded area represents the envelope of variations across the years. The dashed lines show the best linear fit for the mean (black) as well as for the max (red) and min (blue) values.

Appendix B

Climatology-based results of daily temperatures for all stations

The climatology of daily temperatures for all selected weather stations listed in Table 1 are shown in the following figures.

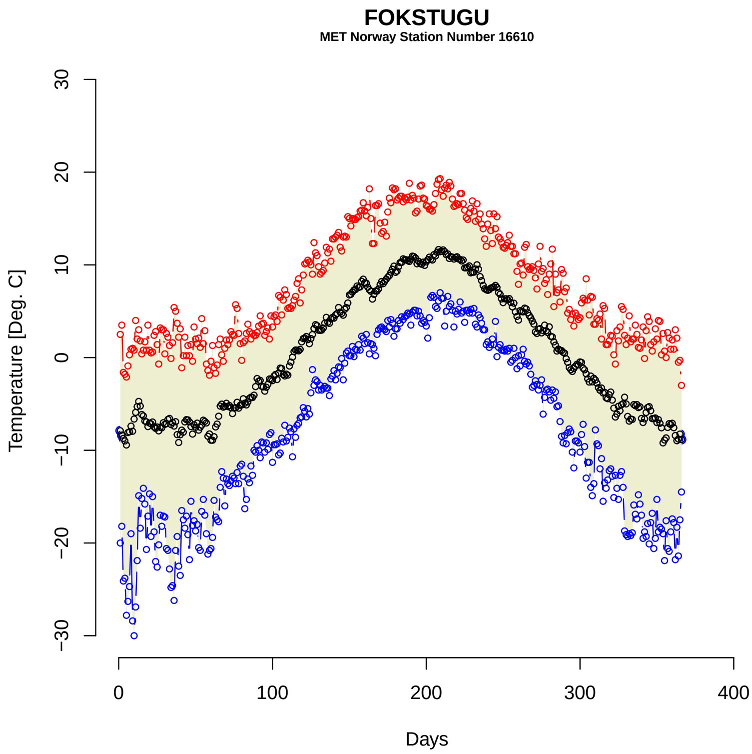

Figure B.1: Daily temperature (°C) for FOKSTUGU station. Monthly statistics of daily mean temperatures (°C) based on the selected period 1981-2010. Monthly minima and maxima are shown with the blue and red lines, respectively, while the black line shows the averaged monthly means. The shaded area represents the envelope of variations across the months.

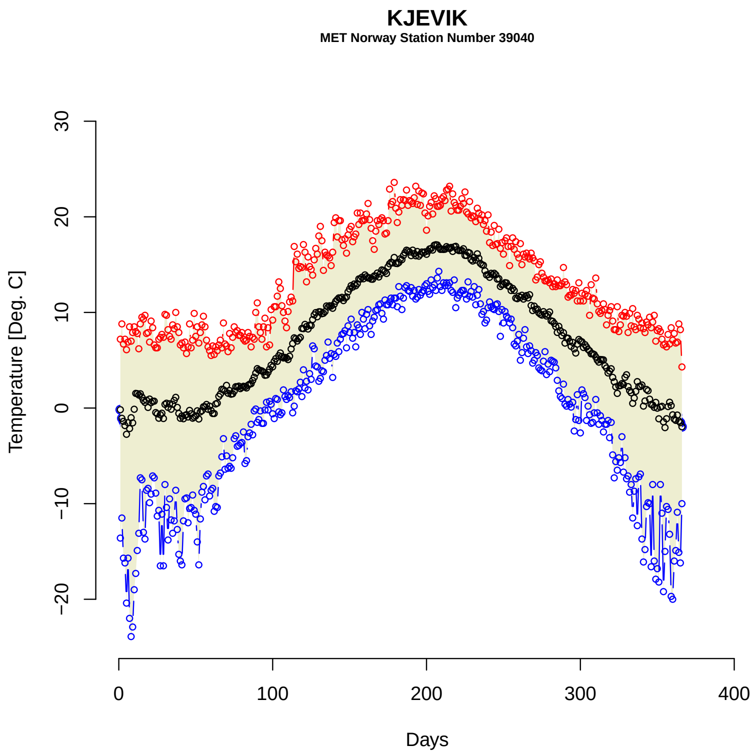

Figure B.2: Daily temperature (°C) for KJEVIK station. Same caption as the previous figure

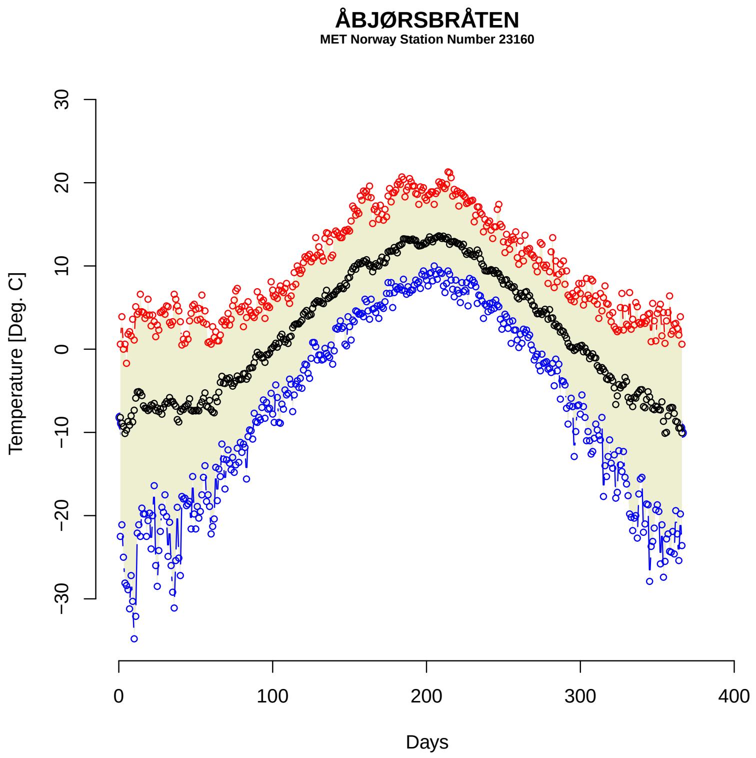

Figure B.3: Daily temperature (°C) for ÅBJØRSBRÅTEN station. Same caption as the previous figure.

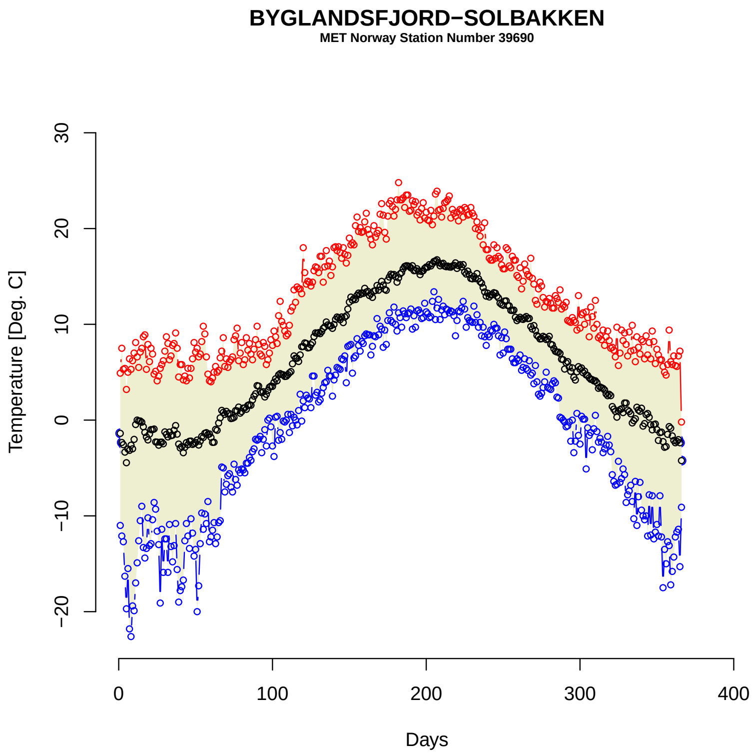

Figure B.4: Daily temperature (°C) for BYGLANDSFJORD-SOLBAKKEN station. Same caption as the previous figure.

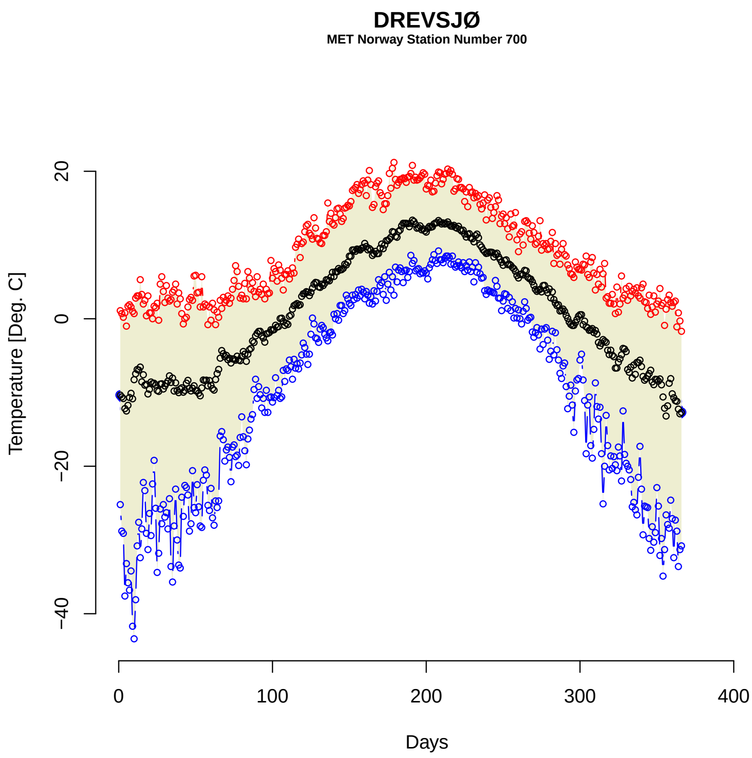

Figure B.5: Daily temperature (°C) for DREVSJØ station. Same caption as the previous figure.

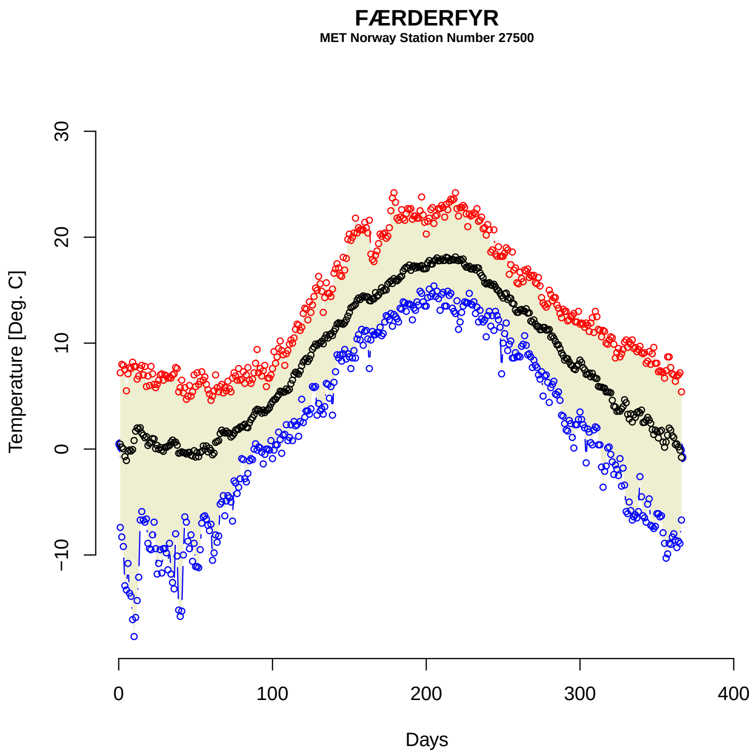

Figure B.6: Daily temperature (°C) for FÆRDER-FYR station. Same caption as the previous figure.

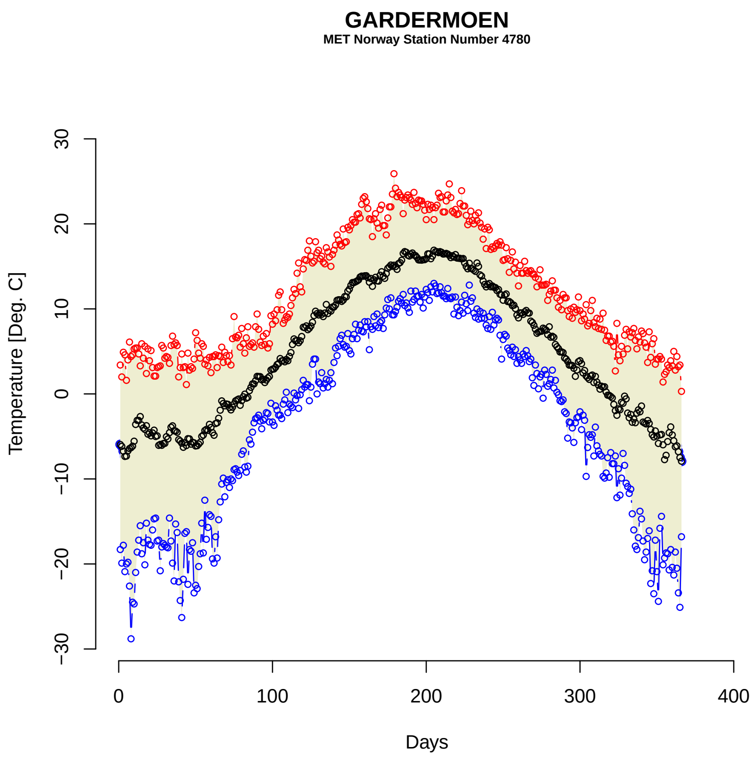

Figure B.7: Daily temperature (°C) for GARDERMOEN station. Same caption as the previous figure.

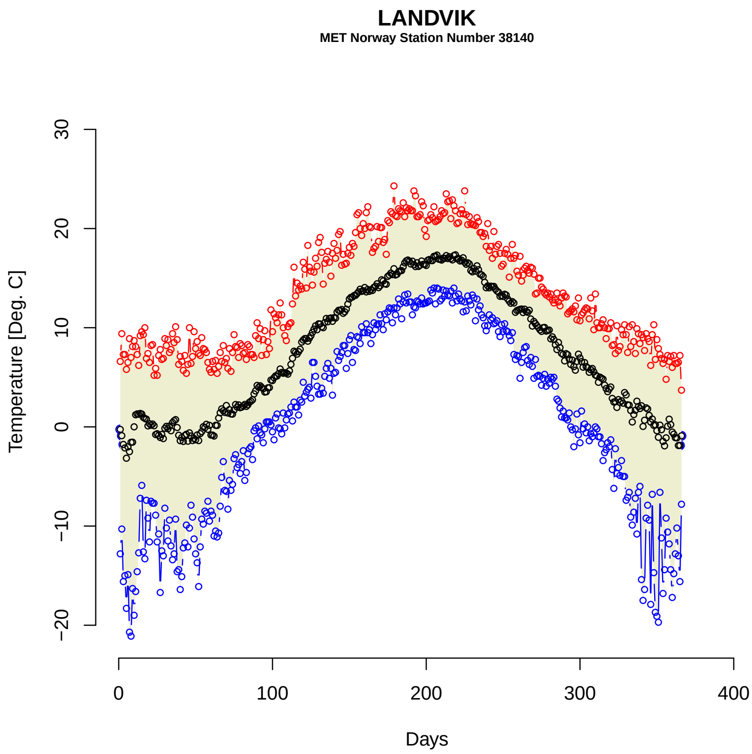

Figure B.8: Daily temperature (°C) for LANDVIK station. Same caption as the previous figure.

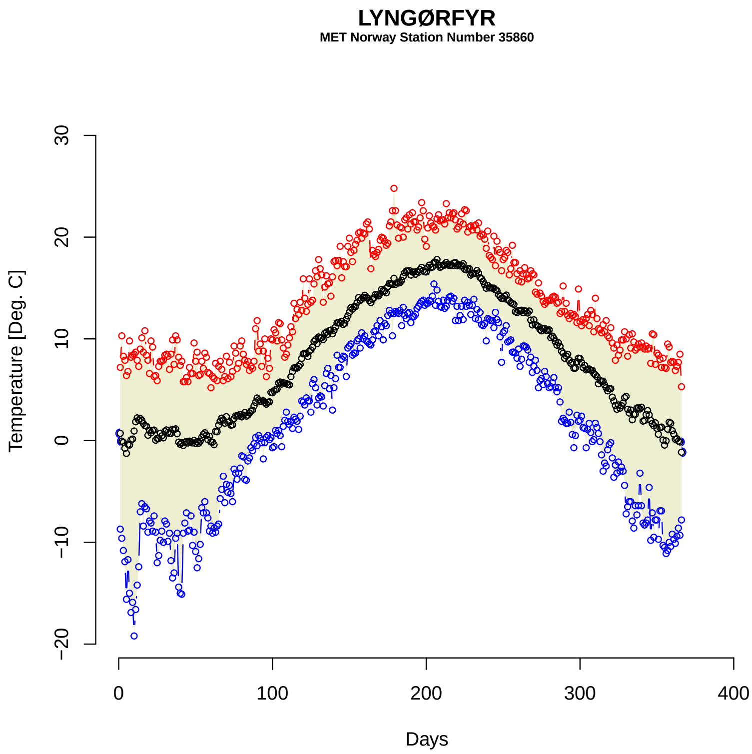

Figure B.9: Daily temperature (°C) for LYNGØR-FYR station. Same caption as the previous figure.

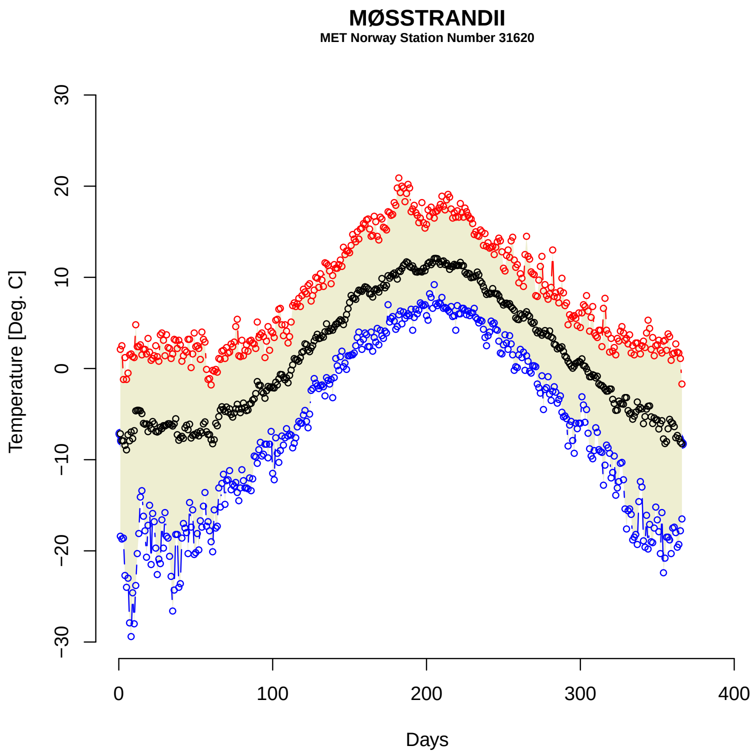

Figure B.10: Daily temperature (°C) for MØSSTRAND-II station. Same caption as the previous figure.

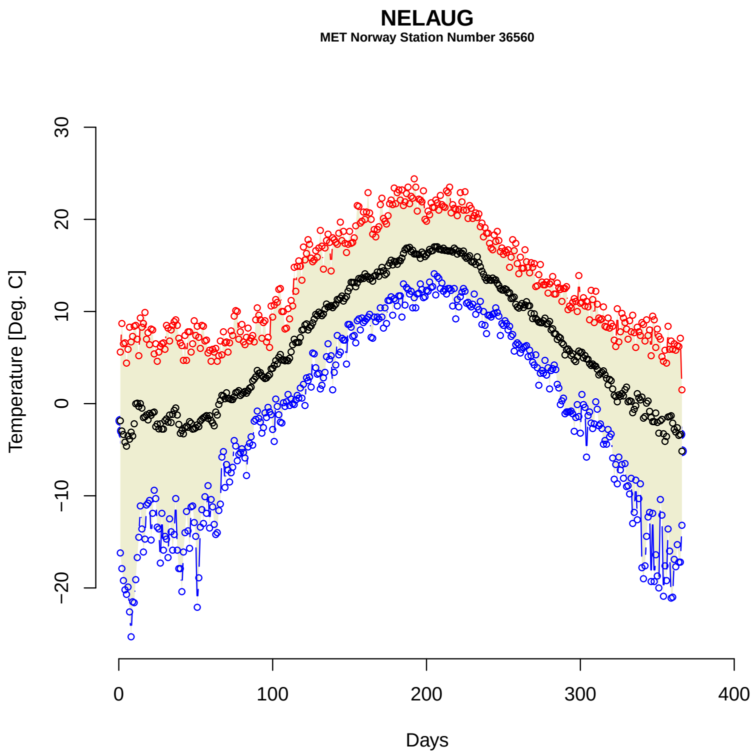

Figure B.11: Daily temperature (°C) for NELAUG station. Same caption as the previous figure.

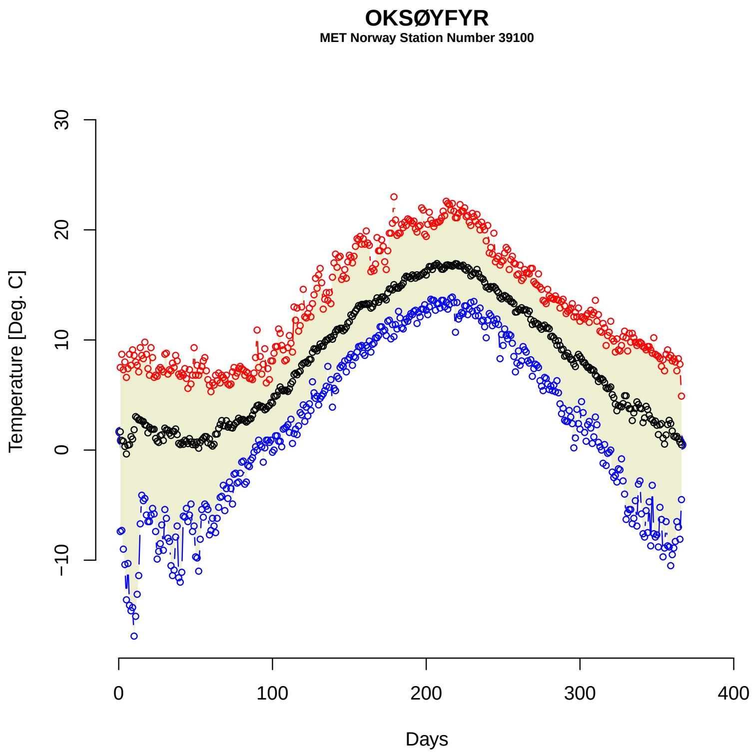

Figure B.12: Daily temperature (°C) for OKSØY-FYR station. Same caption as the previous figure.

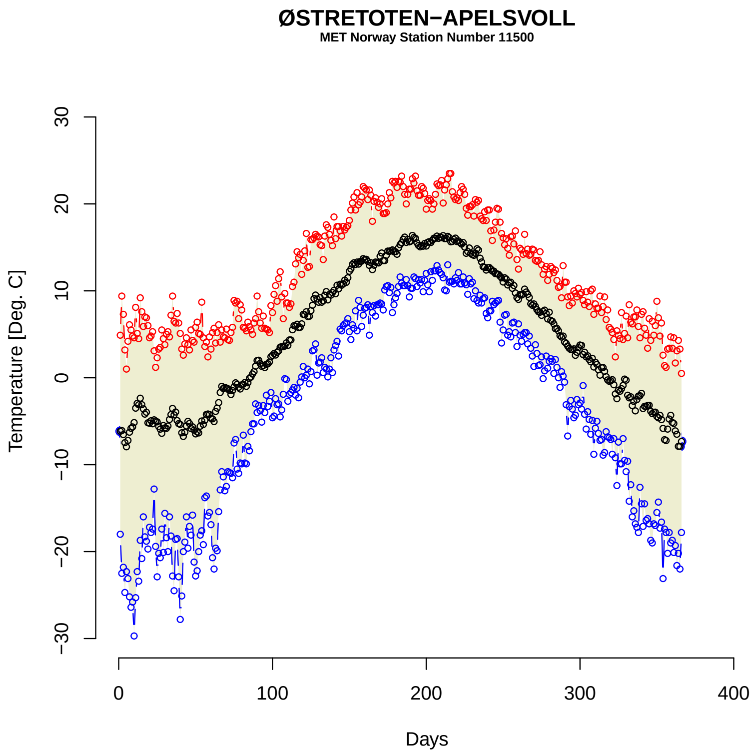

Figure B.13: Daily temperature (°C) for ØSTRE TOTEN - APELSVOLL station. Same caption as the previous figure.

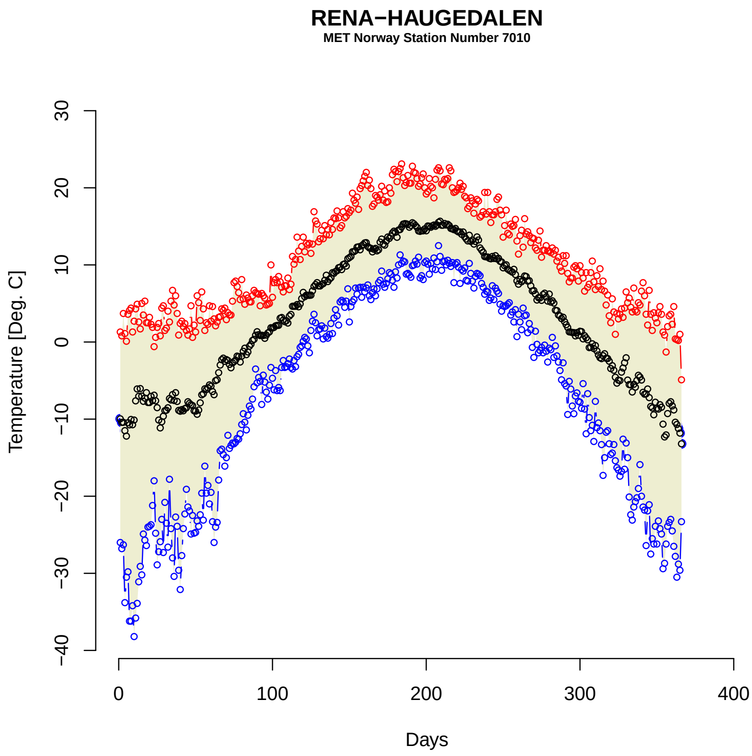

Figure B.14: Daily temperature (°C) for RENA-HAUGEDALEN station. Same caption as the previous figure.

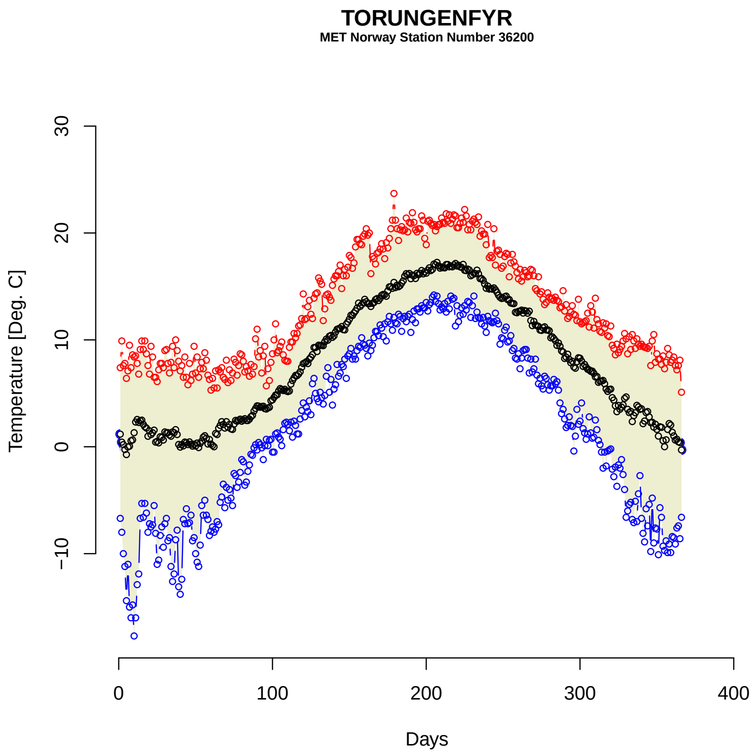

Figure B.15: Daily temperature (°C) for TORUNGEN-FYR station. Same caption as the previous figure.

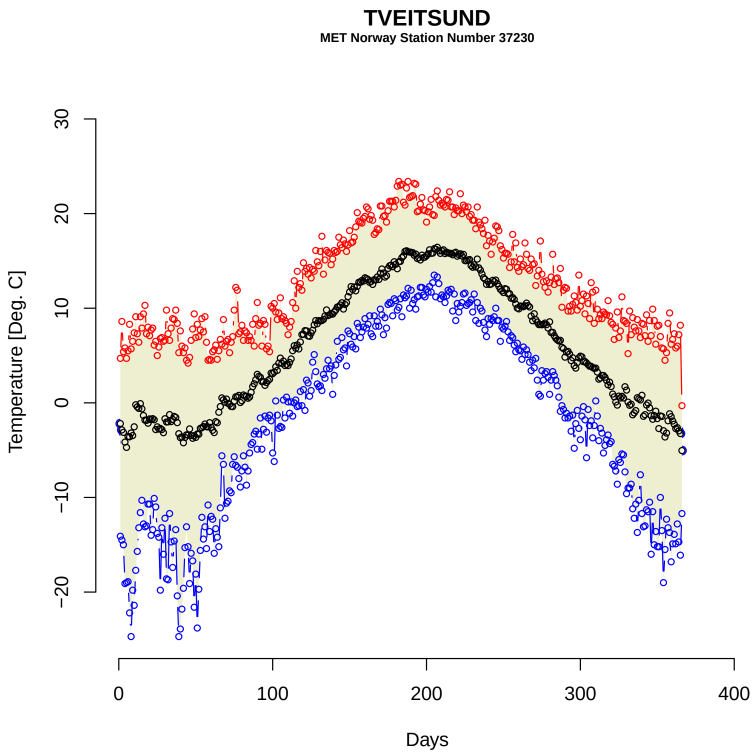

Figure B.16: Daily temperature (°C) for TVEITSUND station. Same caption as the previous figure.

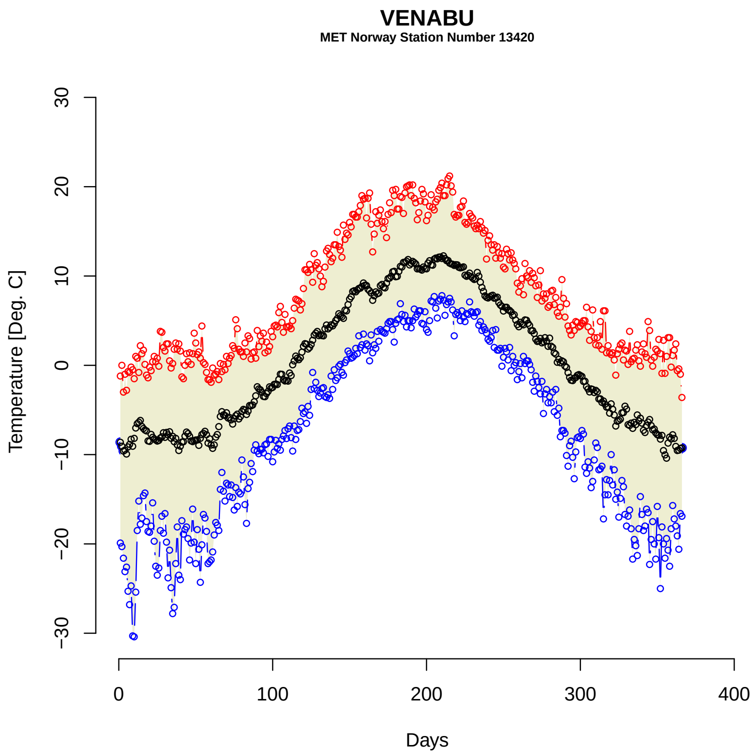

Figure B.17: Daily temperature (°C) for VENABU station. Same caption as the previous figure.