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Temperature climatology for Schiphol (the Netherlands), for present-day and climate scenarios in 2050

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Part of the Knowledge for Climate research project "Climatology and Climate Scenarios Schiphol" (project HSMS02).

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Contents

1. Introduction

1.1 General

In this report, a climatology of temperature is presented for Schiphol Airport (hereafter denoted as *Schiphol*), derived from observations in the period 1981-2010. This is done for the present-day as well as projected into the future. This future climatology is based on the KNMI'06 Climate Scenarios (KNMI, 2006), a set of four scenarios for the evolution of the Dutch climate throughout the 21^{st} century. The present study is part of a research project carried out by KNMI (Royal Netherlands Meteorological Institute) as part of the Dutch national research program Knowledge for Climate. The project is also funded by Air Traffic Control the Netherlands (LVNL) and Schiphol Airport (AAS). In other reports as output of the same research project, other climatological variables are studied, such as visibility, precipitation, wind and upper-air characateristics. All output of the project and other relevant information are gathered on the website http://www.knmi.nl/samenw/kbs.

1.2 Relevance

Temperature is important for many aspects of Schiphol Airport. Firstly, temperature determines some important limitations and needs for procedures at the airport. For example below freezing point, the probability of wintery problems such as slippery surfaces due to frozen or freezing precipitation strongly increases. Also in these conditions the de-icing of airplanes becomes an important part of the operations. Furthermore the need for cooling or warming of buildings is largely determined by the outside temperature, making it an important factor in determining the capacity of systems, and the energy demand of the airport. For many specific operations there are important, specific temperature thresholds. For example, for asphalting runways temperatures of above 10°C are required. For flight operations information about upper air temperatures is crucial. These however are discussed in two separate reports about Schiphol's upper air climatology (Wolters and Groen (2010) and Groen and Wolters (2010) for the atmosphere above and below 1500 m respectively).

For those working outside, temperature is of physiological importance. The impact of low temperatures is however also strongly linked to the wind speed. With high windspeeds, objects and human bodies lose heat much more quickly than with lower windspeeds. This effect is incorporated in indices for apparent temperature or *wind chill equivalent temperature (WCET).* KNMI uses the JAG/TI method to calculate apparent temperatures in cold weather. Climatological information about apparent temperature at Schiphol according to JAG/TI is published in a separate report (Groen, 2009). This report includes projected future climatology of apparent temperature based on the KNMI'06 climate scenarios.

1.3 Outline

Chapter 2 contains a brief description of the observational methods that are at the basis of this research. Chapter 3 contains information about the present-day temperature climate at Schiphol. This chapter starts with an analysis of the average daily minimum and maximum temperature in different parts of the year (Section 3.1), and the number of days per month and per year on which certain thresholds for minimum and maximum temperature are exceeded (Section 3.2). This is followed by an analysis of the occurrence of extreme monthly and annual minimum and maximum temperatures (Section 3.3), estimating return values with return periods of up to 50 years.

Chapter 4 describes the future climate at Schiphol according to climate scenarios. First an introduction is given of these scenarios, and of the methodology used to derive projected climatological information (Sections 4.1 and 4.2). Then (Section 4.3), projected climatology is presented according to four scenarios. In order to easily compare the present and future climate, the same types of tables and figures are presented as in Chapter 3, for four different climate scenarios for two future time horizons. The first time horizon is 2010, aiming to estimate how much the climate may already have changed since 1995, the center of the used observational period of 1981-2010. The second horizon is 2050.

A summary of results, and concluding remarks are given in Chapter 5.

2. Observational Methods

All presented climatological information is based on observations in the 30-year period 1981-2010, the current period for climatological normals in use by KNMI. We have used observations of daily and monthly minimum and maximum temperature from the KNMI weather station at Schiphol (WMO station code 06240). The weather station is one of currently 35 KNMI automatic surface weather stations in the Netherlands. Temperature is measured by a sensor inside a naturally ventilated multi-plate screen (see Figure 2.1A), and recorded at 0.1°C accuracy. Minimum and maximum temperature are taken from one-minute averages. The temperature observations are according to WMO (World Meteorological Organisation) observational standards. Figure 2.1B shows the current location of the temperature sensor on the airport. Before September 1991 the temperature observations were carried out inside a Stevenson thermometer screen, on a different location on the terrain of Schiphol. This relocation has not significantly affected observed daily maximum temperatures, while daily minimum temperatures most likely have increased about 0.45°C on average (T. Brandsma, personal communication, September 2011). This difference in location can be considered to represent some of the spatial variability present over different parts of the airport. Currently no suitable method exists for the homogenization of time series of daily minimum temperature. The same observational series has been used to derive the official climatological normals displayed in the KNMI Climate Atlas (www.klimaatatlas.nl). For more detailed information about the current observational instruments and methods we refer to the KNMI observational guidelines (KNMI, 2010).

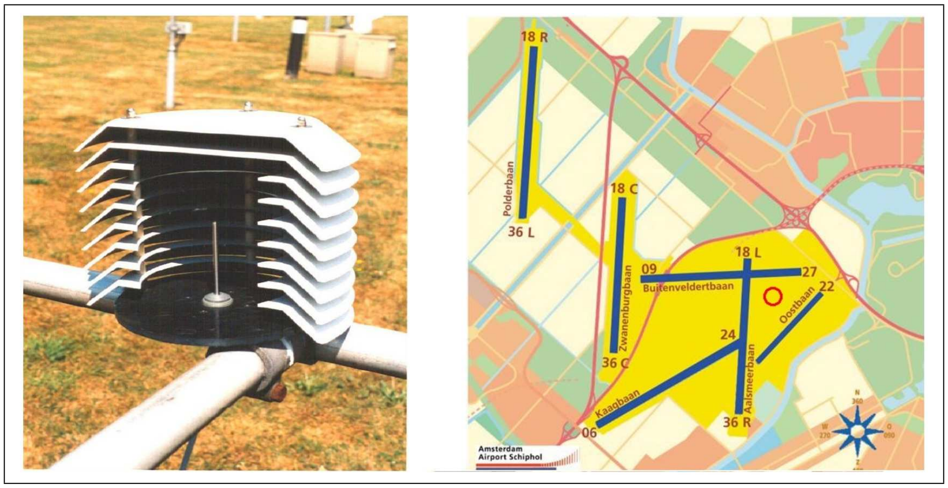

Figure 2.1: Left: thermometer screen (cut open to show the temperature sensor). Right: Layout of Schiphol Airport showing runways. Red circle: present location of temperature sensor. Modified from www.schiphol-nieuws.nl.

3. Present-day climatology based on observations in 1981-2010

3.1 Average minimum and maximum temperatures

Regarding temperature, daily extremes (daily minimum and maximum temperature) are among the most elementary climatological parameters. Figure 3.1 shows the annual cycle of the average daily minimum and maximum temperature, together with their 10% and 90% percentiles, derived from observations in 1981-2010. The percentiles represent the minimum and maximum temperatures that are exceeded on average once every ten years for that day, indicating the statistical spread around the mean. These percentiles can also be interpreted as the values that are exceeded on average once every ten days in that time of the year. In Figure 3.1, the averages and percentiles were first derived for every day in the year from 30 annual observations. Then as a smoothing method, a 15-day moving average (centered) was taken.

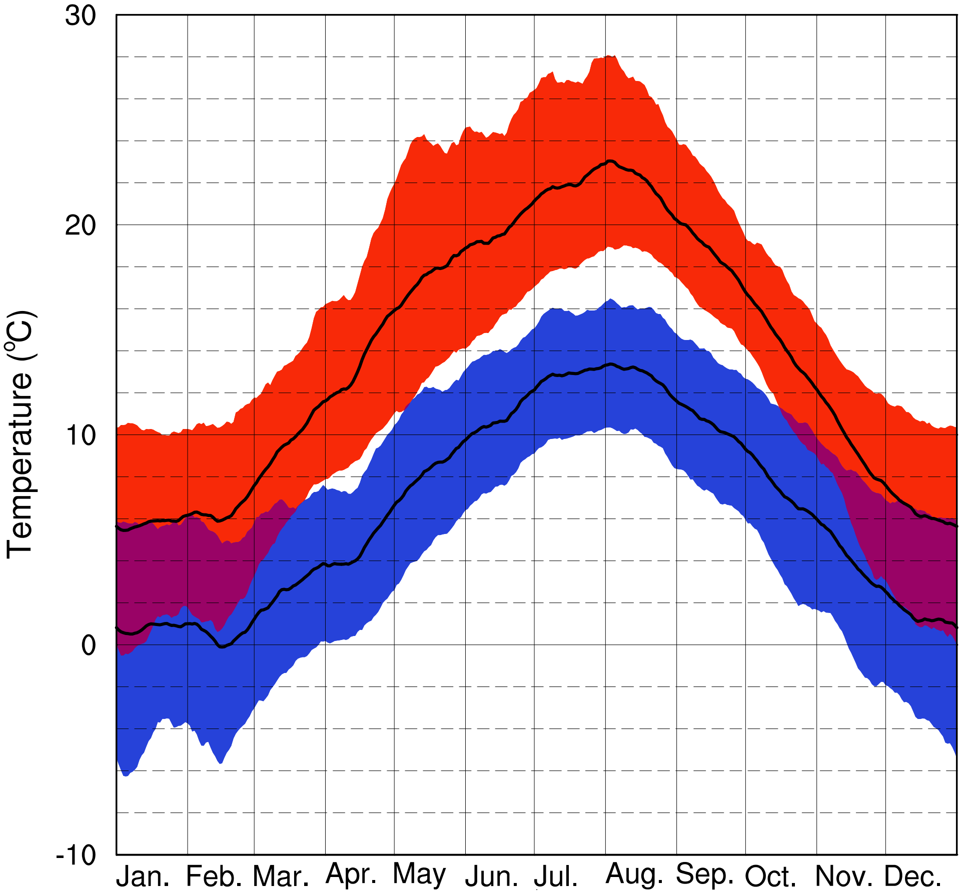

Figure 3.1: Centered moving 15-day mean daily minimum and maximum temperatures (black lines) at Schiphol, with 10% and 90% exceedance quantile bands of minimum and maximum temperature (blue and read areas respectively, with overlapping areas shown as purple), derived from observations in 1981-2010.

Figure 3.1 shows an annual cycle that is typical for the Netherlands, with average minima and maxima in summer of roughly 10°C and 20°C respectively, and average minima and maxima in winter of roughly 0°C and 6°C respectively. In spring and autumn, temperatures lie in between these values. The difference between the average daily minimum and maximum temperature is around twice as large in summer as it is in winter. This is largely caused by the stronger solar radiation and longer sunshine duration in summer, causing temperatures to rise more strongly during the day. Furthermore, the spread in minimum temperatures (characterized by the blue shaded area) is much larger in winter than it is in summer. Nighttime cooling rates strongly vary with varying weather conditions (depending especially on cloud cover and wind speed), allowing for wider ranges in minimum temperature during winter when nights are longer. The spread in maximum temperatures (the red shaded area) is also somewhat larger in winter than in the other seasons.

Table 3.1 summarizes the average daily minimum and maximum temperature at Schiphol for all months and for all decades of days[1], providing similar information as Figure 3.1, but in numbers. In the KNMI Climate Atlas (www.klimaatatlas.nl) the same information is presented for a large number of observational sites in the Netherlands, including Schiphol.

Table 3.1: Average daily minimum and maximum temperatures per decade of days and per month at Schiphol, derived from observations in 1981-2010.

Month	**Decade #**	**Daily min.(°C)**		**Daily max.(°C)**	
Jan.	1	0.4	**0.8**	5.4	**5.8**
	2	1.1		6.0	
	3	0.8		5.8	
Feb.	1	1.0	**0.5**	6.4	**6.3**
	2	-0.2		5.8	
	3	0.7		6.9	
Mar.	1	1.7	**2.6**	8.2	**9.6**
	2	2.7		9.7	
	3	3.4		10.9	
Apr.	1	3.8	**4.6**	11.9	**13.5**
	2	4.2		13.0	
	3	5.9		15.6	
May	1	7.1	**8.2**	16.3	**17.4**
	2	8.4		17.8	
	3	9.0		18.1	
Jun.	1	10.5	**10.8**	19.4	**19.7**
	2	10.5		19.3	
	3	11.4		20.5	
Jul.	1	12.7	**13.0**	21.6	**22.0**
	2	12.9		21.9	
	3	13.3		22.6	
Aug.	1	13.2	**12.8**	22.9	**22.1**
	2	13.0		22.5	
	3	12.2		21.0	
Sep.	1	11.4	**10.6**	19.9	**18.8**
	2	10.4		18.7	
	3	10.0		17.8	
Oct.	1	8.9	**7.5**	16.1	**14.5**
	2	7.2		14.6	
	3	6.5		13.0	
Nov.	1	5.5	**4.2**	11.5	**9.7**
	2	4.1		9.6	
	3	3.0		8.2	
Dec.	1	2.0	**1.5**	7.0	**6.3**
	2	1.1		6.2	
	3	1.3		5.9	

3.2 Exceedance of thresholds of minimum and maximum temperature

Table 3.2 shows the average number of exceedances for a range of thresholds for minimum and maximum temperature, for all months separately and per year. In the KNMI Climate Atlas (www.klimaatatlas.nl) the same information is presented for a large number of observational sites in the Netherlands, including Schiphol. Thresholds have been defined such that common-used indices such as tropical days, frost days and ice days are included in the results.

Table 3.2: Average number of days per month and per year on which the minimum or maximum temperature is below or above certain thresholds, derived from observations in 1981-2010. Ann.: annual. -: did not occur in data. Valid for non-leap years.

Minimum temperature

	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
< **10°C**	30.9	27.9	30.8	28.6	21.8	11.9	3.5	4.3	12.0	23.1	28.5	30.7	254.1
< **5°C**	25.6	23.7	22.6	16.1	5.2	0.4	-	-	0.7	6.9	16.4	24.2	141.8
< **0°C**	11.6	11.4	6.5	2.3	0.1	-	-	-	-	0.7	4.1	11.3	47.9
< **-5°C**	3.6	3.0	0.5	-	-	-	-	-	-	-	0.3	2.2	9.5
< **-10°C**	0.8	0.6	0.1	-	-	-	-	-	-	-	-	0.2	1.7
< **-15°C**	-	-	<0.05	-	-	-	-	-	-	-	-	-	<0.05

Maximum temperature

	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
< **0°C**	3.1	1.9	0.2	-	-	-	-	-	-	-	0.3	2.0	7.6
≥ **10°C**	4.2	4.8	12.9	23.5	30.4	30.0	31.0	31.0	30.0	29.0	15.6	5.8	248.3
≥ **15°C**	-	0.3	2.5	9.5	21.0	27.1	30.9	30.9	27.7	13.8	1.1	-	164.8
≥ **20°C**	-	-	0.1	2.6	8.4	12.6	20.0	21.2	8.6	1.3	-	-	74.9
≥ **25°C**	-	-	-	0.3	2.4	3.5	7.2	5.9	1.0	<0.05	-	-	20.3
≥ **30°C**	-	-	-	-	0.1	0.4	1.0	0.9	-	-	-	-	2.4
≥ **35°C**	-	-	-	-	-	-	-	-	-	-	-	-	-

3.3 Statistics of temperature extremes

The statistics discussed above are obtained from emperical estimation; i.e. counting and averaging observed occurrences. By empirical estimation it is only possible to estimate the probability of events that are observed at least once in the considered observational period. Furthermore, for events that happened only once or a few times in the considered time period (*extreme events*), the sample size is very small and thus their estimated probability has a large relative uncertainty. In order to reduce this uncertainty, and/or in order to estimate the probability of extreme events that did not happen in the observational period, statistical methods can be applied. In these methods often *return periods* are considered, the inverse of probabilities. In this section we use statistical methods to estimate minimum and maximum temperatures at Schiphol corresponding to return periods of up to 50 years.

3.3.1 GEV distributions

In order to analyse the occurrence of temperature extremes at Schiphol, a GEV (*Generalised Extreme Value*) distribution is fitted to the observed extremes. According to the *extremal types theorem*, the limit distribution of the *block maxima* of a variable can be described by a GEV distribution. Block maxima are maxima observed within certain, fixed periods of time ('blocks'). Usually annual maxima are considered, i.e. taking blocks that have a length of one year. The GEV distribution contains three parameters which should be fitted to observed maxima, obtaining a model of the probability distribution

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[1] Decades of days are a subdivision of months, dividing the month in days 1-10 (first decade), days 11-20 (second decade), and days 21 and later (third decade).

of these extremes. From the fitted GEV distribution it is possible to estimate the probability of events that are so rare, that they did not occur in the sampled time period, using information from all observed maxima. The mathematical formula for the GEV (cumulative) probability distribution is given in Equation (3.1). For more elaborate information about the GEV distribution see e.g. Coles (2001).

$$P(X \leq x) = F(x, \mu, \sigma, \xi) = \begin{cases} exp\{-[1+\xi(\frac{x-\mu}{\sigma})]^{-1/\xi}\} & \text{if } \xi \neq 0 \\ exp(-exp(\frac{-(x-\mu)}{\sigma})) & \text{if } \xi = 0 \end{cases} \tag{3.1}$$

In equation (3.1) $P(X \leq x)$ is the probability that the random variable X takes on a value less than or equal to x, and μ, σ and ξ are the parameters to be fitted to the observed data. μ (the *location parameter*) roughly reflects the center of the distribution. σ (the *scale parameter*), reflects the width of the distribution and ξ (the *shape parameter*) reflects the type of upper tail of the distribution. Negative values of ξ imply a distribution with a relatively thin, bounded upper tail, while with positive values the distribution is more heavy-tailed with no upper bound. GEV distributions with ξ=0 are also called *Gumbel* distributions.

Using a fitted GEV distribution, probabilities can be estimated for the occurrence of certain values, and using the inverse approach, it can be estimated which values correspond to certain probabilities or return periods. In the remainder of this section we will discuss the estimation of return values of monthly and annual minimum and maximum temperatures for different return periods, by fitting GEV distributions to observed monthly extremes.

3.3.2 GEV fitting procedure

In order to estimate the GEV parameters μ, σ and ξ from observed extremes we have used *Maximum Likelihood Estimation (MLE)*[1]. The following sections describe the fitting procedure followed for monthly minimum and maximum temperature separately. For minimum as well as for maximum temperature we first discuss fitting GEVs to all calendar months independently, and then examine whether GEV fits can combine data from different calendar months to obtain more robust estimates of the GEV parameter ξ.

Monthly minimum temperatures

The GEV distribution describes block maxima that become more extreme with increasing values, such as maximum temperatures. In order to be able to apply the GEV distribution to minimum temperatures, the minimum temperatures were first subjected to a negative transformation (multiplication by -1). After fitting the distribution and obtaining results, the results are transformed back by multiplication by -1.

First we have fitted GEV distributions to observed (negative transformed) minimum temperatures for all months separately. Figure 3.2 shows the parameters obtained by these GEV fits. The location parameter μ shows a distinct sinusoidal annual course which strongly resembles the annual course of temperature (Figure 3.1). Note that the variation from month to month in this parameter estimate strongly exceeds the standard deviation of the parameter estimation for each month, indicating systematic differences between calendar months.

The estimates of the scale parameter σ also seem to have a systematic annual variation. Two 'regimes' may be distinguished. During meteorological spring and summer (MAMJJA) the average σ is 1.6 with a standard error of 0.2 °C, during autumn and winter the fitted distributions are significantly wider with σ=2.6±0.4°C. Physically this may be connected to the annual course in daytime length. During autumn and winter, nights are much longer than during spring and summer, allowing for stronger nocturnal cooling in calm, clear nights, which may increase the range in possible minimum temperatures. Another cause may be the stronger meridional temperature gradients during autumn and winter, leading to larger ranges of possible temperatures in the Netherlands.

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[1] Fits were performed using the function *fgev*, present in the package *evd* within the statistical program R

Regarding the shape parameter ξ, values are relatively small compared to their standard errors (average ξ=-0.17±0.14). Again, two regimes may be discerned. From April until November (AMJJASON), values of ξ are significantly negative (averaged ξ=-0.29 and average standard error of 0.12), while from December until March (DJFM) they are near zero or positive (averaged ξ=0.05 with average standard error of 0.19, not significantly deviating from zero). Thus, from December until March minimum temperatures have longer-tailed distributions than during the rest of the year. One possible cause may be the occurrence of snow cover in these months (December until March are the only months that have on average more than 1 day per month with morning snow cover in Amsterdam). Due to insulation of the ground, suppressing the soil heat flux, in situations with snow cover nocturnal cooling can be strongly increased. This often leads to extremely low minimum temperatures in clear, calm nights. This effect may be stretching the tail of the distributions of monthly minimum temperatures. Also the occurrence of snow in upwind directions may lead to the advection of very cold air, in which low minimum temperatures are more likely.

Note that in Figure 3.2, March is the only month with a distinctly positive fitted ξ (value 0.3). This is strongly connected to one observed case, a minimum temperature of -16.7 in the morning of March 4, 2005. This case can be consiered an 'outlier' in comparison to other 29 minima in March (all between -7,7 and 0.2). Considering this, and the fact that March is a 'transition month' between winter and spring, with average minima strongly increasing between the beginning and end of the month (see Table 3.1), we think that this value of 0.3 may not well characterize the distribution of minima in March. Therefore, later in this chapter it is tested whether these minima can also be characterized by Gumbel distribution, having ξ=0.

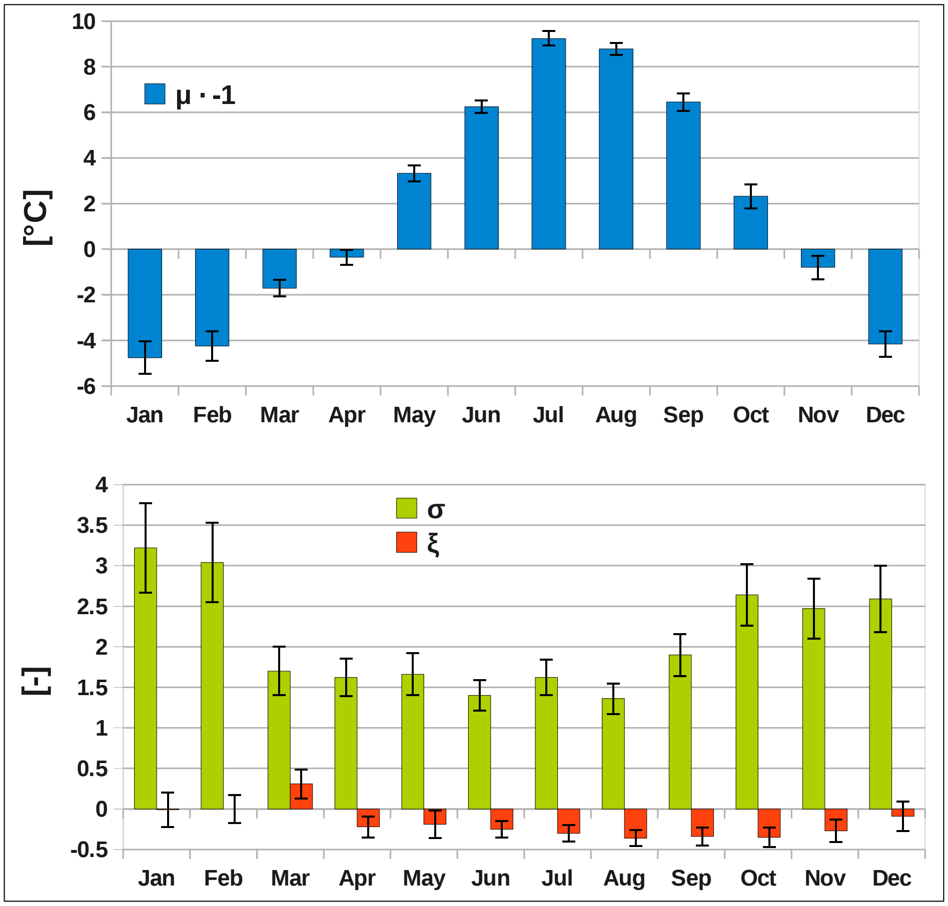


Figure 3.2: μ (above, negative transformed), σ and ξ (below) for GEV distributions fitted to negative transformed monthly minimum temperatures, for all months separately. Error bars show ranges between plus and minus 1 standard error.

Considering that for larger return periods the return values can be quite sensitive to the estimated value of ξ, and given the relatively large standard errors of ξ with respect to their absolute values, it would be desirable to obtain a more precise estimate of ξ. We have therefore investigated whether ξ could be re-estimated using data from different months combined. For this we have looked separately at both parts of the year mentioned above. In this method one value for ξ is used in all monthly GEV models in AMJJASON, and another for the models in DJFM. These values are then estimated using data from all months included in both periods, a technique often denoted as *pooling* of data. Such a procedure may benefit the derived statistics, since ξ will be based on more observations and the influence of noise in the estimated values of ξ will be reduced, making the tails of the distribution in different months more uniform and balanced. In our case this procedure may be particularly recommended since relatively few (30) annual maxima are used in the estimation of the model parameters. In the following, such a reduced model will be denoted as the *null model* m_0, with respect to the 'alternative' model with more parameters m_1 that was described in the beginning of this section.

The two values of ξ used in m_0 have been derived using a *profile likelihood* approach. In this approach, for each month the parameters μ and σ are re-fitted using fixed values for ξ. The ξ value that is finally selected corresponds to the highest combined likelihood in the considered months. This combined likelihood is expressed in LL_{sum}:

$$LL_{sum} = \sum_{n=1}^{N} ln\left[L(m_0; \tilde{\mu}_n, \tilde{\sigma}_n, \xi)\right] \tag{3.2}$$

in which $L(m; \tilde{\mu}_m, \tilde{\sigma}_m, \xi)$ is the likelihood under the GEV model for month n in method m_0, with free μ and σ, and fixed ξ.

Since in our case we distinguish two periods, this procedure must be performed twice; once for DJFM and once for AMJJASON. Figure 3.3 shows $ln(LL_{sum})$ for the two different parts of the year, as a function of ξ, using steps of 0.025. From these likelihood profiles optimal values for ξ have been derived: -0.3 for AMJJASON and 0.1 for DJFM. In the following it will be tested whether GEV models based on these fixed values of ξ will perform significantly worse than GEV models with freely-varying ξ as displayed in Figure 3.2.

Please note that in Figure 3.3, between ξ of 0.0 and 0.1 the slope of LL_{sum} is relatively flat. It was already mentioned that for only one of the months in DJFM (March) ξ distinctly differs from 0, while this deviation can be debated because it is caused by a single case. Therefore, at the end of this paragraph it will be tested whether the minima in DJFM can be described by Gumbel distributions, having ξ = 0.

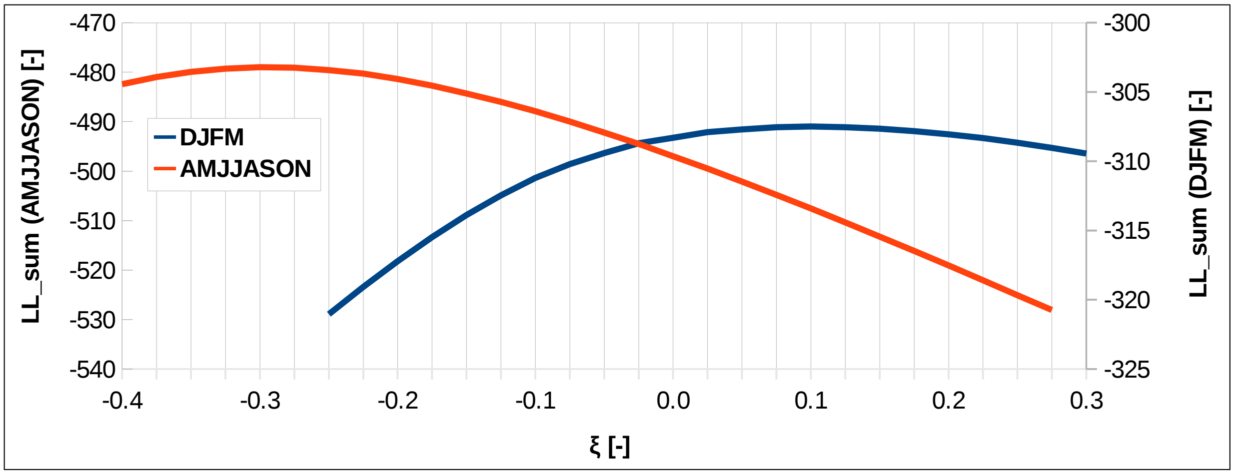


Figure 3.3: Log-likelihood profiles for ξ in two distinct parts of the year (DJFM and AMFFASON), from GEV fits with free μ and σ.

The next step is to investigate whether the reduced model m_0 performs significantly worse than the alternative model m_1 derived with free ξ. This has been been done by means of a *likelihood-ratio test* (Coles, 2001). The likelihood ratio statistic D expresses how much more likely the observed values are under one model than under the other. For a fit of GEV models to one set of data, D is expressed as:

$$D = -2ln\left[\frac{L_0 : L(m_0; \hat{\mu}, \hat{\sigma}, \xi)}{L_1 : L(m_1; \tilde{\mu}, \tilde{\sigma}, \tilde{\xi})}\right] \tag{3.3}$$

In which L_0 is the likelihood under m_0, and L_1 is the likelihood under m_1. If the extra parameters present in m_1 do not provide a better model, then D follows a χ^2-distribution with $df_1 - df_0$ degrees of freedom, in which df_1 is the number of degrees of freedom (parameters) in the model m_1 and df_0 is the number of degrees of freedom in the model m_0. Large values of D lead to rejection of m_0. For a test at the 5% (significance) level D must exceed the 95% percentile of the χ^2 distribution. If the exceedance probability p of D in this χ^2 distribution is less than 0.05, then m_0 is rejected at the 5% level.

In our case we will evaluate the sum of D over all months:

$$D_{sum} = -2\sum_{n=1}^{12} ln\left[\frac{L(m_0; \hat{\mu}_n, \hat{\sigma}_n, \xi_n)}{L(m_1; \tilde{\mu}_n, \tilde{\sigma}_n, \tilde{\xi}_n)}\right] \tag{3.4}$$

which can be expressed as:

$$D_{sum} = 2\sum_{n=1}^{12}\left[ln\ L(m_1; \tilde{\mu}_n, \tilde{\sigma}_n, \xi_n) - ln\ L(m_0; \hat{\mu}_n, \hat{\sigma}_n, \hat{\xi}_n)\right] \tag{3.5}$$

allowing for calculation of D_{sum} from the log-likelihoods of the estimated GEV distributions. D_{sum} will be tested against a χ^2 distribution with:

$$\sum_{n=1}^{12}(df_{1,n} - df_{0,n}) = \sum_{n=1}^{12} df_{1,n} - \sum_{n=1}^{12} df_{0,n} = 3 \cdot 12 - (2 \cdot 12 + 2) = 10 \tag{3.6}$$

degrees of freedom. Equation 3.4 yields D_{sum}=5.2, which is not significant at the 5% level. Thus the model m_0 is not rejected.

Next, as proposed earlier, we have tested a further reduction of the model, taking ξ=0.0 for all months in DJFM. This reduces the model m_0 with 1 additional degree of freedom. Testing for the months DJFM separated from the rest of the year, with respect to the model with ξ=0.1, yields D_{sum}=1.6, which in a ${\chi^2}_1$ distribution is not significant at the 5% level. Testing for all months combined, with ξ=0.0 in DJFM with respect to m_1 above yields D_{sum}=5.2+1.6, which is not significant at the 5% level in a ${\chi^2}_{11}$ distribution. Therefore we have taken ξ=0.0 in DJFM to derive our climatology of return values of extreme minimum temperatures.

A similar procedure was carried out for an even further simplified model, taking the profile-likelihood estimate of one value of ξ for all months together ($\xi = -0.15$) as m_0. Testing with respect to m_1, against ${\chi^2}_{11}$, yields D_{sum}=28.44 which is significant at the 5% level, so that this further reduced model is rejected.

Monthly maximum temperatures

Figure 3.4 shows the parameters of GEV distributions fitted to monthly maximum temperatures. Similar to the minimum temperatures (Figure 3.2), the estimates of μ show a distinct annual course, well correlated to the annual course of temperature (Table 3.1). Standard errors are again much smaller than the amplitude of this variation, indicating significant differences between months. The estimated values for σ reveal an annual course more or less opposite to that for the monthly minimum temperatures, with higher values from February until September, and lower values from October until January. Again, this may be connected to the annual cycle in daytime length. In spring and summer sunshine is much

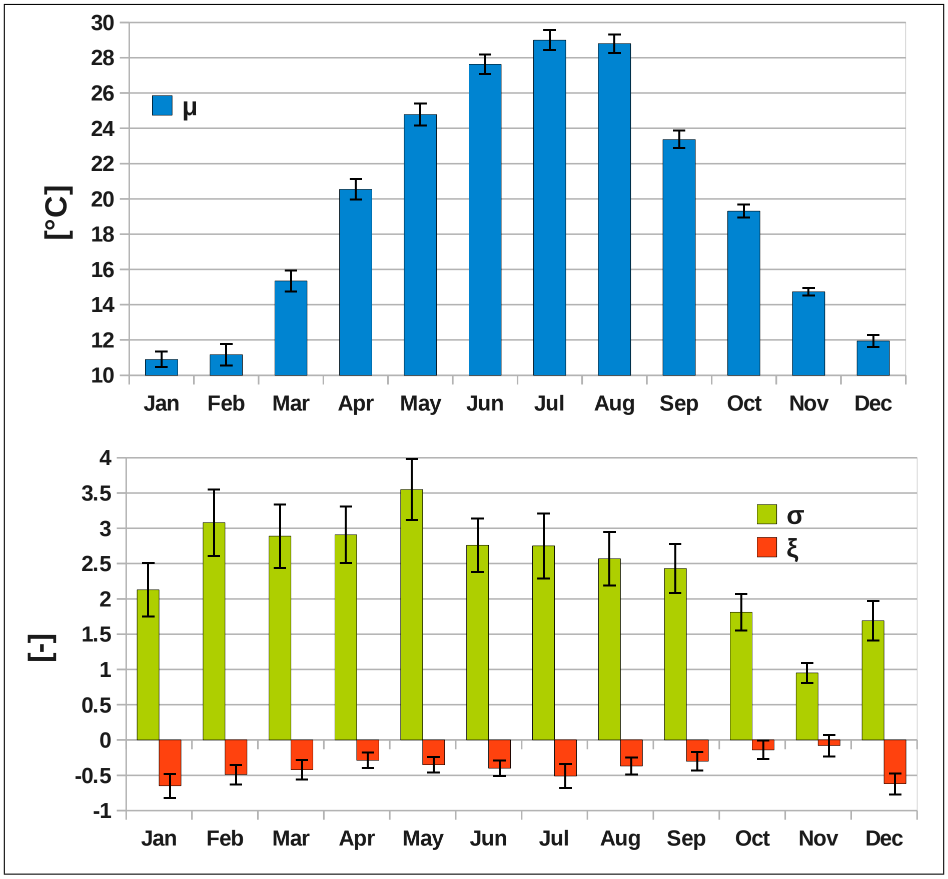


Figure 3.4: μ (above), σ and ξ (below) for GEV distributions fitted to monthly maximum temperatures at Schiphol during 1981-2010, for all months separately. Error bars show standard errors of the estimated parameters.

stronger and days are longer, allowing for stronger heating during the day in clear weather conditions, which may increase the range in possible maximum temperatures. The values of σ well exceed their standard errors.

Regarding ξ, standard errors are only slightly less than magnitude. There are distinct differences between months, however no clear, physically connected annual cycle is distinguished. Therefore it has been tested whether one value for ξ can be taken for all months, using the same approach as above for monthly minimum temperatures. From the profile likelihood method follows an estimated ξ of -0.35, for all months together, with D_{sum} of 15.44, which is not significant at the 5% level and thus can not be rejected. Therefore we have used this reduced model to derive our climatology of extreme maximum temperatures.

Calculation of return levels

In the above we have estimated the probability distributions of monthly minimum and maximum temperature. From these distributions we will derive return levels of extreme temperature values. The return period of exceeding a value x_T is expressed as the inverse of the probability:

$$T = P(X > x_T)^{-1} \tag{3.7}$$

Since $P(X > x_T) = 1 - P(X \leq x_T)$, return periods can be expressed in terms of the cumulative probability distribution function (see equation (3.1)) by:

$$T = (1 - P(X \leq x_T))^{-1} \tag{3.8}$$

Which, solving for x_T in equation 3.1, yields:

$$x_T = \begin{cases} \mu + \sigma \dfrac{\left[(-ln(1-1/T))^{-\xi}\right] - 1}{\xi} & \text{if } \xi \neq 0 \\ \mu + \sigma \cdot \left[ln\left(-ln(1-1/T)\right)\right] & \text{if } \xi = 0 \end{cases} \tag{3.9}$$

allowing for the calculation of the return values of monthly maximum and minimum temperatures that correspond to different probabilities and return periods.

Annual extremes

From the estimated occurrence of monthly minima and maxima we have also estimated the occurrence of *annual* minima and maxima. When independence between consecutive monthly maxima is assumed, probabilities of annual maxima can be derived by multiplication of all monthly probabilities:

$$P(X_y \leq x_T|m) = \prod_{n=1}^{12} P(X_n \leq x_T|m) \tag{3.10}$$

in which x_T is the return value of the annual extreme X_y, and X_n are the extremes for all separate months under method m, containing GEV distributions for each month. Although we have assumed independence of monthly minimum and maximum temperature between consecutive months, this assumption has not been tested. In mid-latitude meteorology, the 'memory' of weather patterns on a monthly timescale is often considered neglegible. However, cold or warm spells that run over the border between two months, may introduce a degree of dependence between consecutive monthly minimum and maximum temperatures in some cases. This dependence may introduce some inaccuracy in our results, however the resulting annual extremes are well in line with those observed (see section 3.3.3).

In order to calculate return values of annual extremes, for each considered return period (2, 5, 10, 25 and 50 years) first the corresponding annual probability was derived by rearranging Equation (3.8) into:

$$P(X_y \leq x_T) = 1 - 1/T \tag{3.11}$$

$P(X_y \leq x_T)$ was calculated for a wide and dense range of possible values of x_T, using Equation (3.10). From these values, for each return period T, x_T was taken that yields $P(X_y \leq x_T)$ most closely corresponding to T, according to Equation (3.11).

3.3.3 Results

In the above, GEV distributions were derived for monthly and annual minimum and maximum temperature. For monthly minima, two distinct values of ξ were taken for all months in two parts of the year. These values were determined using a profile likelihood approach. For monthly maxima one value of ξ was taken for all months, determined using a profile likelihood approach. From these GEV distributions monthly and annual return values of temperature were calculated, shown in Table 3.3 for return periods of 2, 5, 10, 25 and 50 years. Return values for annual extremes are also presented in a graphical form in Figure 4.3 (on page 19), also showing future return values according to different climate scenarios. These climate scenarios are discussed in the following chapter.

In Figure 4.3, next to the annual return values estimated from the monthly GEV distributions, also the observed annual minima and maxima are shown. The empirical return periods for these extremes are given by $R = (N - 0.3)/(m + 0.4)$, in which N is the total number of extremes (30), and m is the rank of the concerned extreme. The GEV-estimated return periods are well in line with those determined empirically from observed annual extremes, indicating that the methods applied to estimate the distributions of annual extremes from observed monthly extremes have worked reasonably well.

Another clear feature in Figure 4.3 is that the increase in return values of maximum temperature with increasing return period has a tendency to level off with respect to the Gumbel-transformed x-axis. This is connected to the underlying GEV distributions having bounded tails, implied by the negative shape parameters set at ξ=-0.35. The return values of annual minima however show nearly straight lines. This is connected to the underlying GEV distributions for the winter months being Gumbel-shaped with $\xi = 0$. The observations do not show a tendency to level off or 'run away' towards lower values with respect to the Gumbel-transformed x-axis, supporting our decision to assume Gumbel distributions (having ξ=0.0) for minima in the months DJFM.

Table 3.3: Return values of monthly and annual minimum and maximum temperatures at Schiphol, for different return periods (RP) at Schiphol, derived from observations in 1981-2010 using methods described in Section 3.3.2. Ann.: annual.

RP (yr)	Minimum temperature (°C)												
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
2	-5.9	-5.4	-2.8	-1.0	2.6	5.7	8.7	8.4	5.9	1.5	-1.7	-5.0	-8.8
5	-9.5	-8.8	-5.0	-2.5	1.0	4.5	7.3	7.2	4.3	-0.7	-3.9	-7.8	-12.1
10	-11.9	-11.1	-6.5	-3.3	0.3	3.8	6.6	6.7	3.5	-1.8	-5.0	-9.7	-14.3
25	-15.0	-14.0	-8.4	-4.0	-0.5	3.2	5.9	6.1	2.8	-2.8	-6.0	-12.1	-17.2
50	-17.2	-16.1	-9.8	-4.4	-0.9	2.9	5.5	5.8	2.3	-3.5	-6.7	-13.8	-19.3

RP (yr)	Maximum temperature (°C)												
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
2	11.2	11.9	16.2	21.7	25.8	28.4	29.6	29.6	24.3	20.3	15.3	12.2	31.4
5	12.7	14.3	18.4	24.3	28.3	30.6	31.7	31.7	26.4	22.1	16.3	13.4	32.8
10	13.5	15.4	19.5	25.5	29.5	31.7	32.7	32.7	27.4	23.0	16.8	14.0	33.5
25	14.1	16.4	20.5	26.6	30.7	32.7	33.6	33.6	28.3	23.8	17.2	14.6	34.2
50	14.5	17.0	21.1	27.2	31.3	33.2	34.1	34.2	28.8	24.2	17.5	14.9	34.6

Note that in Table 3.3 the annual return values for a given return period are always more extreme than those in any of the individual months. This is caused by the fact that for every year there are multiple months which may produce the annual extreme.

4. Future climatology: climate scenarios

4.1 Introduction

Figure 4.1 shows annual mean temperatures for Schiphol with moving thirty year averages. The figure also shows thirty year averages for De Bilt, for the fact that this station has a longer observational record. A warming trend can be observed over the twentieth century. The most important part of this temperature rise has happened since the eighties. The magnitude of the warming is around 1°C since the mid-20th century, at Schiphol as well as in De Bilt. The largest part of the temperature rise can be attributed to anthropogenic global warming, and is expected to continue in the coming decades (KNMI, 2008). Figure 4.1 also shows this projected temperature rise until the mid-21st century, according to the four KNMI'06 scenarios *G*, *G+*, *W* and *W+*, which were introduced by KNMI in 2006. In these scenarios until 2050 annual mean temperature is projected to rise with 0.8-2.2°C compared to the 1981-2010 mean.

In the present chapter we present statistics of the future climate at Schiphol, consistent with the KNMI'06 scenarios. To allow for intercomparison, similar statistics are presented as in the previous chapter for the present-day climate. The projected statistics are given for all 4 scenarios, for 2 different time horizons (2010 and 2050). The time horizon of 2010 may be used to estimate how much, according to the KNMI'06 Climate Scenarios, the climate may have already changed since the 1981-2010 normal period used for the present-day statistics presented earlier. Assuming a linear trend the 1981-2010 period may be most representative of its central year 1995.

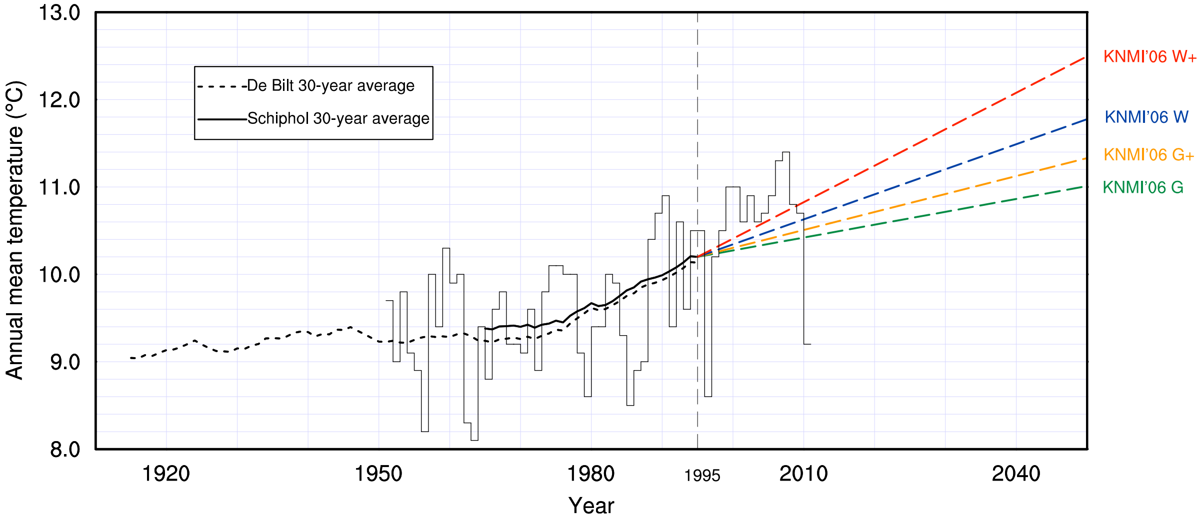
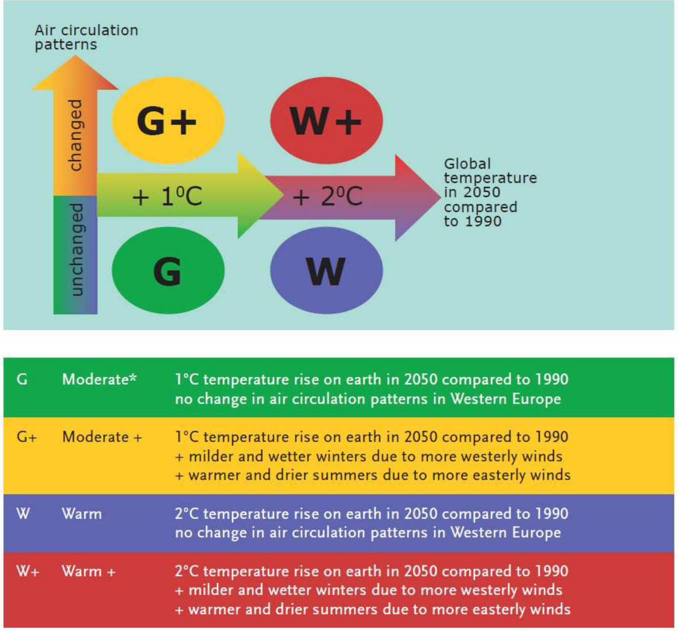


Figure 4.1: Time series of annual mean temperature at Schiphol (rectangular line) with centered ten and thirty year moving averages, thirty year moving averages in De Bilt and projected average annual mean temperatures at Schiphol according to the KNMI'06 climate scenarios until 2050. 1995: center of the 1981-2010 observational period.

4.2 Climate scenarios and time series transformation

4.2.1 General

The KNMI'06 climate scenarios are projections for temperature and precipitation for the Netherlands into the 21^{st} century, mostly based on the output of global and regional climate models. They are designed to cover roughly 80% of the range of possible changes. There are four scenarios, varying in two degrees of freedom which correspond to the two directions of largest uncertainty in the used models. Figure 4.2 provides a schematic overview of this set-up. The first degree of freedom is the magnitude of increase in global mean temperature. The *G* (*gematigd*, Dutch for 'moderate') scenarios assume a moderate global mean warming of 1°C in 2050 compared to 1990; the *W* ('warm') scenarios assume a stronger global mean warming of 2°C. The second degree of freedom is whether or not mean atmospheric circulation patterns around the Netherlands will change in response to the warming, most likely causing more westerly winds in winter and more easterly winds in summer. Such circulation changes would give milder and wetter winters, and drier and warmer summers. Combining both degrees of freedom yields the scenarios *G* and *W* for no circulation changes, and *G+* and *W+*, incorporating circulation changes. See KNMI (2006) for more elaborate information about the KNMI'06 climate scenarios, and Van den Hurk *et al.* (2006) for a more in-depth and technical description.



G	Moderate*	1°C temperature rise on earth in 2050 compared to 1990 no change in air circulation patterns in Western Europe
G+	Moderate +	1°C temperature rise on earth in 2050 compared to 1990 + milder and wetter winters due to more westerly winds + warmer and drier summers due to more easterly winds
W	Warm	2°C temperature rise on earth in 2050 compared to 1990 no change in air circulation patterns in Western Europe
W+	Warm +	2°C temperature rise on earth in 2050 compared to 1990 + milder and wetter winters due to more westerly winds + warmer and drier summers due to more easterly winds

Figure 4.2: Schematic overview of the four KNMI'06 Climate Scenarios. *'G' stands for 'Gematigd', Dutch for 'moderate'. Taken from KNMI (2006).

The scenarios contain quantitative information about changes in the mean as well as the statistical spread of temperature, derived from climate models. Based on this information, a method was developed to transform past observed time series of temperature into the future according to the scenarios (Bakker and Bessembinder, 2011). For temperature, the method accounts for an increase in the mean combined with a changing variance of the distribution. For this it applies a predefined offset combined with a linear scaling of the statistical distribution of the series. The resulting changes in the 10%-, 50%- (median) and 90%-percentiles are predifined for each calender month in each scenario. We have used this method to transform the 1981-2010 observational series from Schiphol (centered around, and thus most representative of, 1995) to 2010 and 2050, according to all four climate scenarios.

The KNMI'06 Climate Scenarios and the transformation of time series applied here yield useful information about the future climate, reflecting current insights in climate science. However, there are some important limitations. The presented results should not be interpreted as ‘the’ climate for the 21^{st} century, but as plausible futures. The climate in 2050 will likely be somewhere ‘in between’ the presented scenarios, but the change could also be less or more than in one of the scenarios, since they are intended to cover around 80% of the possibilities. The presented numbers should not be taken literally, but rather be used to obtain a more general ‘impression’ of the possible future climate.

4.2.2 Application in the present study

The transformation method was initially designed for application to daily mean temperatures. Minimum and maximum temperatures have been derived by first transforming time series of daily mean temperature, and then applying the deviations of the observed daily minima and maxima from the observed daily mean to these transformed daily mean temperatures on all individual days:

$$TX_f = (TX_o - TG_o) + TG_f \tag{4.12}$$

in which TX_f is the transformed (future) maximum (or minimum) temperature, TX_o is the observed maximum (or minimum) temperature, TG_o is the observed daily mean temperature and TG_f is the transformed daily mean temperature. Thus it is assumed that in the scenarios there are no changes in the climatological daily temperature range.

The method for time series transformation assumes linear changes throughout the 21^{st} century and was designed to transform input representative of the period 1976-2005. The present study is based on observations in the period 1981-2010. To compensate for the 5-year difference in base period we have subtracted 5 years from the future horizon given as input to the transformation method (2045 instead of 2050, and similarly 2005 instead of 2010). We have used version 1.0 of the transformation software (Bakker and Bessembinder, 2011).

The following sections contain climatological information based on 4 scenarios, for 2 time horizons (2010 and 2050). The same type of statistics are presented as in the present-day climatology in Chapter 2. First, average daily minimum and maximum temperatures are discussed for all months in the year. Subsequently, the exceedance frequencies for minimum and maximum temperature for different thresholds are considered. statistics of extreme temperatures based on the GEV distribution are derived and discussed. For as much as possible, we have combined information for different horizons and scenarios in single tables or graphs, in whicn the present-day climatological information derived in Chapter 2 is included as well. More elaborate results, for which such a combined view is not possible or logical, are added as appendices to this report.

4.3 Results

4.3.1 Average daily minimum and maximum temperatures around 2010 and 2050.

Table 4.1 shows values for the average daily minimum and maximum temperature at Schiphol for all months, according to the different climate scenarios, for 2010 and 2050. The table includes values for the 1981-2010 period, shown earlier in Table 3.1.

In 2010, changes in temperature with respect to the averages of the 1981-2010 base period, are in the range of of 0.2-0.8°C. In 2050 changes are in the range of 0.8-2.7°C. In the *G* and *W* scenarios the temperature rise is rather equally divided over the year; in the *G+* and *W+* scenarios warming is stronger in summer than in winter.

4.3.2 Exceedance of temperature thresholds in 2010 and 2050.

Table 4.2 shows average numbers of exceedance of thresholds for minimum and maximum temperature per year, for 1981-2010 and for the scenarios in 2010 and 2050. Appendix A contains tables that show this information for all separate months. These can be compared to Table 3.2 for the 1981-2010 period.

Table 4.1: Average daily minimum and maximum temperatures per month at Schiphol around **2010** and **2050**, according to the KNMI'06 climate scenarios **G**,**G+**, **W** and **W+**, and in observations during **1981-2010**.

	Daily min. temp. (°C)					Daily max. temp. (°C)				
	1981-2010	**2010**				**1981-2010**	**2010**			
		G	*G+*	*W*	*W+*		*G*	*G+*	*W*	*W+*
Jan.	0.8	1.0	1.0	1.2	1.3	5.8	6.0	6.0	6.2	6.3
Feb.	0.5	0.7	0.8	1.0	1.1	6.3	6.5	6.6	6.8	6.9
Mar.	2.6	2.8	2.9	3.1	3.2	9.6	9.8	9.9	10.1	10.2
Apr.	4.6	4.8	4.9	5.1	5.3	13.5	13.7	13.8	13.9	14.1
May	8.2	8.4	8.5	8.6	8.8	17.4	17.6	17.8	17.9	18.1
Jun.	10.8	11.0	11.1	11.2	11.5	19.7	19.9	20.1	20.2	20.4
Jul.	13.0	13.2	13.3	13.4	13.7	22.0	22.3	22.4	22.5	22.8
Aug.	12.8	13.0	13.2	13.3	13.6	22.1	22.3	22.4	22.5	22.8
Sep.	10.6	10.8	11.0	11.0	11.3	18.8	19.0	19.2	19.2	19.5
Oct.	7.5	7.7	7.8	7.9	8.1	14.5	14.7	14.8	15.0	15.2
Nov.	4.2	4.4	4.5	4.6	4.8	9.7	9.9	10.0	10.2	10.4
Dec.	1.5	1.7	1.8	1.9	2.1	6.3	6.6	6.6	6.8	6.9

	1981-2010	**2050**				**1981-2010**	**2050**			
		G	*G+*	*W*	*W+*		*G*	*G+*	*W*	*W+*
Jan.	0.8	1.6	1.8	2.4	2.9	5.8	6.6	6.8	7.4	7.9
Feb.	0.5	1.4	1.6	2.2	2.7	6.3	7.2	7.4	8.0	8.5
Mar.	2.6	3.5	3.7	4.3	4.8	9.6	10.4	10.7	11.3	11.8
Apr.	4.6	5.5	5.8	6.3	7.0	13.5	14.3	14.6	15.1	15.8
May	8.2	9.0	9.4	9.9	10.7	17.4	18.3	18.7	19.1	19.9
Jun.	10.8	11.6	12.1	12.4	13.4	19.7	20.6	21.0	21.4	22.3
Jul.	13.0	13.8	14.3	14.6	15.7	22.0	22.9	23.4	23.7	24.7
Aug.	12.8	13.7	14.2	14.5	15.6	22.1	22.9	23.4	23.7	24.8
Sep.	10.6	11.4	11.9	12.3	13.3	18.8	19.6	20.1	20.5	21.5
Oct.	7.5	8.3	8.7	9.1	9.9	14.5	15.3	15.7	16.2	17.0
Nov.	4.2	5.0	5.3	5.9	6.5	9.7	10.6	10.9	11.4	12.0
Dec.	1.5	2.3	2.5	3.1	3.6	6.3	7.2	7.4	8.0	8.5

From Table 4.2 it follows that according to the scenarios in 2050 the number of frost days per year has declined from 48 (1981-2010) until 22-36 (*G* and *W+*). The number of days per year with a maximum temperature of 20°C or above has increased from around 75 until 90-121; the number of days with a maximum temperature of 30°C or above has increased from around 2.5 until 4-11.5. Temperatures of 35°C or more, which were never measured during the observational period, in 2050 according to the *W+* scenario are expected to occur more than once per year.

Table 4.2: Average number of days per year on which the minimum or maximum temperature is below or above certain thresholds, around **2010** and **2050**, according to the KNMI'06 climate scenarios **G**,**G+**, **W** and **W+**, compared to observations in **1981-2010**. -: did not occur in data. Table is valid for non-leap years. See Table 3.2 and A.1-A.4 for information on separate months in 1981-2010 and in the climate scenarios respectively.

Minimum temperature

	1981-2010	**2010**				**2050**			
		G	*G+*	*W*	*W+*	*G*	*G+*	*W*	*W+*
< **10°C**	254.1	249.7	247.5	244.5	240.1	236.0	228.3	218.7	203.8
< **5°C**	141.8	137.3	136.2	133.3	129.8	124.9	118.8	106.7	97.0
< **0°C**	47.9	45.9	44.7	40.7	39.7	35.9	32.8	27.2	21.8
< **-5°C**	9.5	8.8	8.4	8.1	7.4	7.1	6.4	5.0	3.7
< **-10°C**	1.7	1.5	1.5	1.4	1.3	1.2	0.9	0.6	0.4
< **-15°C**	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-

Maximum temperature

	1981-2010	**2010**				**2050**			
		G	*G+*	*W*	*W+*	*G*	*G+*	*W*	*W+*
< **0°C**	7.6	6.9	6.6	6.0	5.6	4.9	4.1	3.1	2.1
≥ **10°C**	248.3	252.7	254.4	257.8	260.6	266.0	270.2	281.9	291.2
≥ **15°C**	164.8	167.4	168.9	171.7	173.8	177.3	182.2	190.2	198.4
≥ **20°C**	74.9	77.9	80.8	82.7	87.2	90.2	98.2	106.5	121.2
≥ **25°C**	20.3	21.5	23.0	23.5	25.6	26.0	30.3	32.2	42.9
≥ **30°C**	2.4	2.9	3.3	3.3	4.1	4.2	6.1	6.8	11.4
≥ **35°C**	-	-	<0.05	<0.05	<0.05	<0.05	0.2	0.3	1.4

4.3.3 Projected statistics of extreme temperatures

Changes to the temperature distribution by time series transformation

GEV analyses were carried out on the transformed time series, as done in Chapter 2 for the 1981-2010 observed time series. The transformation method applied modifications to the median and the 10% and 90% percentiles of the temperature distribution, which can be interpreted as modifications to the mean and the spread of the distribution. It is therefore expected that the location and scale parameters of the GEV distribution will change as a result of the transformation, while the shape parameter does not. Therefore, our GEV distributions for the transformed minimum and maximum temperatures were fit on the location and scale parameters, keeping the shape parameters at their values derived in Chapter 2 for the observed data.

Temperature extremes for different return periods in 2010 and 2050

Figure 4.3 shows the estimated return values of minimum and maximum temperatures for return periods up to 50 years, according to observations in 1981-2010 (as derived in Chapter 2) as well as in the scenarios for 2010 and 2050. Regarding the minimum temperatures, in 2010 and 2050 *G+* is cooler then *W*, implying that the circulation change in the *G+* scenario has a smaller effect than the difference of 1°C warming between the scenarios *G* and *W*. For the maximum temperatures in Figure 4.3 however, *G+* is almost as warm as *W*. This is consistent with the circulation change in the scenario's being set largest during the summer months, the period of the year in which annual maximum temperatures occur.

For more elaborate results, see Appendix B, containing tables with return values of minimum and maximum temperatures for different calendar months, for 2010 and 2050 according to the four scenarios.

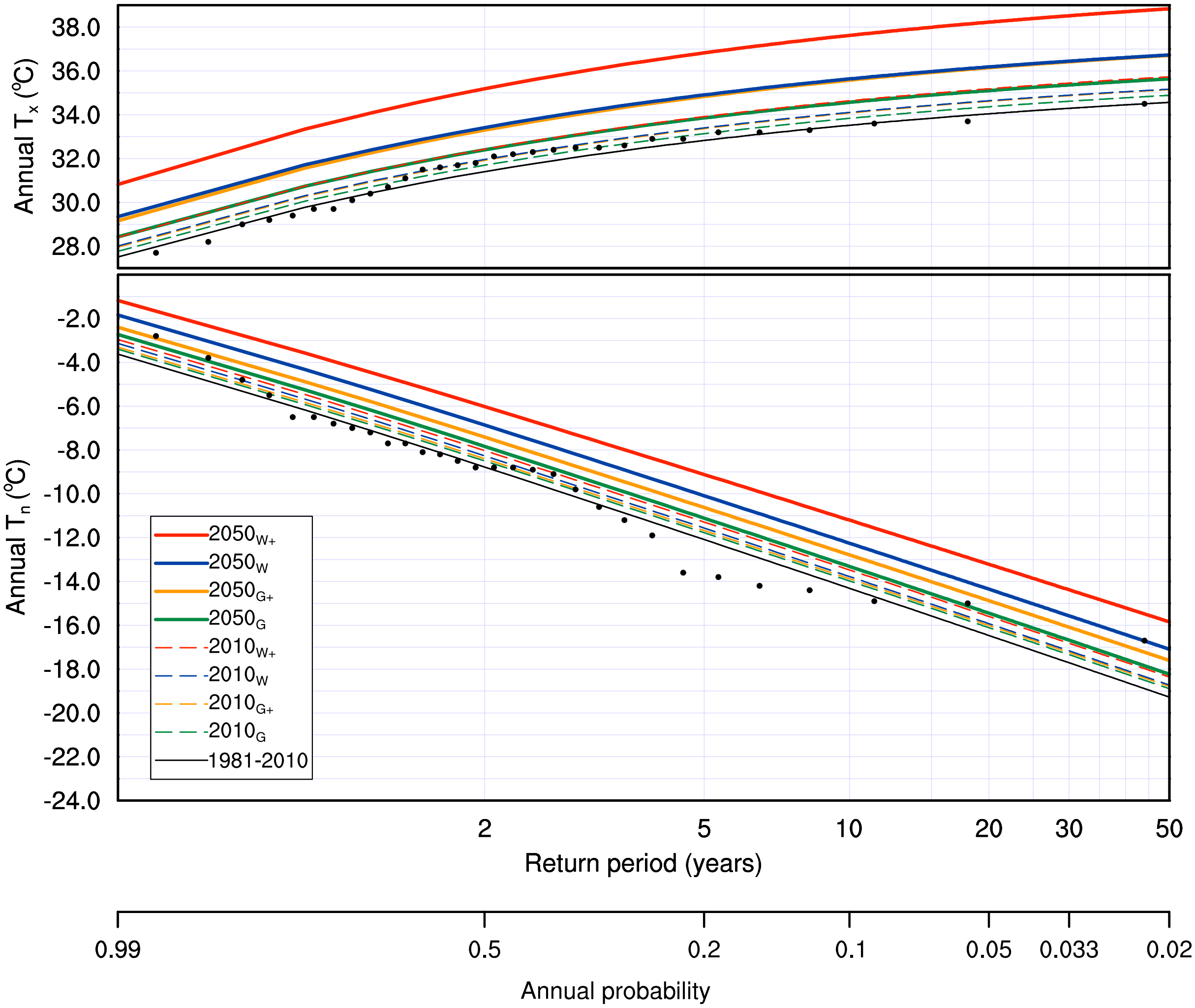


Figure 4.3: Annual return values of minimum and maximum temperatures based on GEV distributions fitted to observations in **1981-2010**, and observations transformed according to the KNMI'06 climate scenarios **G**,**G+**, **W** and **W+**, around **2010** and **2050**. Black dots: annual minima and maxima observed in 1981-2010 against their empirical return periods. The x-axes are transformed such that a Gumbel distribution will be represented by a straight line.

5. Summary and conclusions

Temperature is an important climatological variable at Schiphol Airport (Amsterdam, the Netherlands), for many aspects of daily operations as well as for longer-term planning. Mostly due to anthropogenic global warming, temperature at Schiphol Airport has been rising over the past decades and is projected to continue to rise over the 21^{st} century. In this report, a climatology of daily, monthly and annual minimum and maximum temperature is derived from observations at Schiphol Airport in the period 1981-2010. This was done for the present-day climate as well as projected into the future, according to the KNMI'06 Climate Scenarios for the Netherlands. These scenarios incorporate different estimates of the increase of the mean temperature and the change of its variance, into the 21^{st} century.

For the present-day climate we have considered the average daily minimum and maximum temperature for different parts of the year (months and decades of days). We have also looked at the average number of days per month and per year on which certain thresholds for minimum and maximum temperature are exceeded.

Furthermore, for the present-day climate we have carried out an analysis of the occurrence of extreme monthly and annual minimum and maximum temperatures. In this analysis GEV statistical distributions were fitted on observed extremes. In the derivation of the GEV shape parameter, we have pooled together observations from different months in the year. It was derived that for monthly minimum temperatures one negative value of the GEV shape parameter could be used for April through November, and value 0 (resulting in Gumbel distributions) for December through March. For monthly maximum temperatures one value of the GEV shape parameter could be applied for all calender months. From the fitted distributions, return values of monthly and annual minimum and maximum temperatures were derived for return periods of up to 50 years.

The observed time series of daily minimum and maximum were then transformed, applying changes to their statistical distribution according to four climate scenarios, for time horizons 2010 and 2050. All above-described analyses were repeated for these transformed time series, obtaining projected future climatologies of minimum and maximum temperature. The statistics for the time horizon of 2010 can be used to estimate how much, according to the scenarios, the climate may have already changed since the 1981-2010 normal period, which may be most representative for its central year 1995.

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A. Appendix: exceedance of temperature thresholds in 2010 and 2050

Table A.1: Average number of days per month and per year at Schiphol on which the minimum or maximum temperature is below or above certain thresholds, around **2010**, according to the **G** scenario. Ann.: annual. -: zero occurrences in data.

Minimum temperature

	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
< **10°C**	30.9	27.9	30.7	28.3	21.1	11.2	3.1	3.9	11.1	22.6	28.3	30.7	249.7
< **5°C**	25.1	23.5	22.3	15.2	4.5	0.4	-	-	0.6	6.3	15.7	23.8	137.4
< **0°C**	11.3	10.8	6.1	2.1	0.1	-	-	-	-	0.7	3.9	10.8	45.9
< **-5°C**	3.3	2.8	0.4	-	-	-	-	-	-	-	0.2	2.0	8.8
< **-10°C**	0.7	0.6	0.1	-	-	-	-	-	-	-	-	0.2	1.5
< **-15°C**	-	-	<0.05	-	-	-	-	-	-	-	-	-	<0.05

Maximum temperature

	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
< **0°C**	3.0	1.8	0.1	-	-	-	-	-	-	-	0.3	1.7	6.9
≥ **10°C**	4.7	5.3	14.1	24.0	30.5	30.0	31.0	31.0	30.0	29.4	16.3	6.4	252.7
≥ **15°C**	-	0.3	2.5	10.1	21.5	27.5	30.9	30.9	27.9	14.5	1.3	-	167.4
≥ **20°C**	-	-	0.1	2.7	8.7	12.9	20.6	21.9	9.5	1.4	-	-	77.9
≥ **25°C**	-	-	-	0.3	2.5	3.6	7.4	6.3	1.3	<0.05	-	-	21.5
≥ **30°C**	-	-	-	-	0.1	0.4	1.2	1.1	-	-	-	-	2.9
≥ **35°C**	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A.2: Average number of days per month and per year at Schiphol on which the minimum or maximum temperature is below or above certain thresholds, around **2010**, according to the **G+** scenario. Ann.: annual. -: did not occur in data.

Minimum temperature

	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
< **10°C**	30.9	27.9	30.7	28.1	20.9	10.7	2.7	3.6	10.7	22.3	28.3	30.7	247.5
< **5°C**	25.0	23.5	22.1	15.0	4.2	0.4	-	-	0.5	6.2	15.7	23.7	136.2
< **0°C**	11.1	10.6	5.9	1.9	0.1	-	-	-	-	0.6	3.8	10.6	44.7
< **-5°C**	3.2	2.7	0.4	-	-	-	-	-	-	-	0.2	1.9	8.4
< **-10°C**	0.7	0.6	<0.05	-	-	-	-	-	-	-	-	0.2	1.5
< **-15°C**	-	-	<0.05	-	-	-	-	-	-	-	-	-	<0.05

Maximum temperature

	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
< **0°C**	2.9	1.6	0.1	-	-	-	-	-	-	-	0.3	1.7	6.6
≥ **10°C**	4.8	5.4	14.6	24.3	30.5	30.0	31.0	31.0	30.0	29.5	16.7	6.6	254.4
≥ **15°C**	-	0.3	2.6	10.2	21.7	27.5	30.9	30.9	28.0	15.2	1.4	-	168.9
≥ **20°C**	-	-	0.1	2.8	9.1	13.4	21.1	22.9	10.0	1.4	-	-	80.8
≥ **25°C**	-	-	-	0.4	2.7	4.0	7.6	6.8	1.5	<0.05	-	-	23.0
≥ **30°C**	-	-	-	-	0.2	0.5	1.4	1.2	<0.05	-	-	-	3.3
≥ **35°C**	-	-	-	-	-	-	-	<0.05	-	-	-	-	<0.05

Table A.3: Average number of days per month and per year at Schiphol on which the minimum or maximum temperature is below or above certain thresholds, around **2010**, according to the **W** scenario. Ann.: annual. -: did not occur in data.

Minimum temperature

	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
< **10°C**	30.8	27.8	30.6	28.0	20.5	10.2	2.5	3.3	10.3	21.7	28.2	30.6	244.6
< **5°C**	24.6	23.0	22.0	14.6	3.9	0.3	-	-	0.4	6.0	15.3	23.3	133.3
< **0°C**	10.4	10.0	5.2	1.7	0.1	-	-	-	-	0.5	3.3	9.5	40.7
< **-5°C**	3.1	2.6	0.4	-	-	-	-	-	-	-	0.2	1.8	8.1
< **-10°C**	0.7	0.6	<0.05	-	-	-	-	-	-	-	-	0.1	1.4
< **-15°C**	-	-	<0.05	-	-	-	-	-	-	-	-	-	<0.05

Maximum temperature

	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
< **0°C**	2.6	1.4	0.1	-	-	-	-	-	-	-	0.3	1.5	6.0
≥ **10°C**	5.2	5.7	15.3	25.0	30.7	30.0	31.0	31.0	30.0	29.7	17.3	7.0	257.8
≥ **15°C**	-	0.4	2.7	10.6	22.4	27.9	31.0	30.9	28.3	15.8	1.7	-	171.7
≥ **20°C**	-	-	0.1	3.0	9.2	13.6	21.2	23.5	10.5	1.5	-	-	82.7
≥ **25°C**	-	-	-	0.4	3.0	4.2	7.6	6.8	1.5	<0.05	-	-	23.5
≥ **30°C**	-	-	-	-	0.2	0.5	1.4	1.2	<0.05	-	-	-	3.3
≥ **35°C**	-	-	-	-	-	-	-	<0.05	-	-	-	-	<0.05

Table A.4: Average number of days per month and per year at Schiphol on which the minimum or maximum temperature is below or above certain thresholds, around **2010**, according to the **W+** scenario. Ann.: annual. -: did not occur in data.

Minimum temperature

	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
< **10°C**	30.8	27.8	30.5	28.0	19.5	9.5	2.3	2.9	9.4	20.8	28.0	30.5	240.1
< **5°C**	24.2	22.9	21.2	14.1	3.6	0.3	-	-	0.4	5.8	14.6	22.9	129.9
< **0°C**	10.3	9.8	5.0	1.6	0.1	-	-	-	-	0.5	3.1	9.2	39.7
< **-5°C**	3.0	2.4	0.4	-	-	-	-	-	-	-	0.1	1.5	7.4
< **-10°C**	0.6	0.6	<0.05	-	-	-	-	-	-	-	-	0.1	1.3
< **-15°C**	-	-	<0.05	-	-	-	-	-	-	-	-	-	<0.05

Maximum temperature

	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
< **0°C**	2.6	1.3	0.1	-	-	-	-	-	-	-	0.3	1.4	5.6
≥ **10°C**	5.4	5.8	15.8	25.5	30.8	30.0	31.0	31.0	30.0	29.7	17.9	7.6	260.6
≥ **15°C**	-	0.4	2.8	11.0	22.8	28.2	31.0	30.9	28.6	16.4	1.9	-	173.8
≥ **20°C**	-	-	0.1	3.3	9.6	14.3	22.2	24.4	11.5	1.7	-	-	87.2
≥ **25°C**	-	-	-	0.5	3.1	4.4	8.3	7.4	1.9	<0.05	-	-	25.6
≥ **30°C**	-	-	-	-	0.2	0.6	1.7	1.6	<0.05	-	-	-	4.1
≥ **35°C**	-	-	-	-	-	-	-	<0.05	-	-	-	-	<0.05

Table A.5: Average number of days per month and per year at Schiphol on which the minimum or maximum temperature is below or above certain thresholds, around **2050**, according to the **G** scenario. Ann.: annual. -: did not occur in data.

Minimum temperature

	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
< **10°C**	30.7	27.8	30.4	27.7	19.0	8.6	2.0	2.7	8.8	20.6	27.7	30.3	236.0
< **5°C**	23.5	22.2	20.4	13.4	3.0	0.1	-	-	0.3	5.3	14.3	22.3	125.0
< **0°C**	9.5	9.1	4.4	1.3	<0.05	-	-	-	-	0.4	2.8	8.4	35.9
< **-5°C**	2.9	2.3	0.4	-	-	-	-	-	-	-	0.1	1.4	7.1
< **-10°C**	0.6	0.5	<0.05	-	-	-	-	-	-	-	-	0.1	1.2
< **-15°C**	-	-	<0.05	-	-	-	-	-	-	-	-	-	<0.05

Maximum temperature

	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
< **0°C**	2.3	1.2	0.1	-	-	-	-	-	-	-	0.2	1.1	4.9
≥ **10°C**	6.3	6.6	16.8	26.1	30.8	30.0	31.0	31.0	30.0	30.0	18.8	8.6	266.0
≥ **15°C**	-	0.5	3.0	11.6	23.3	28.5	31.0	30.9	28.8	17.3	2.2	0.1	177.3
≥ **20°C**	-	-	0.2	3.4	10.0	14.5	22.9	25.1	11.9	2.0	-	-	90.2
≥ **25°C**	-	-	-	0.5	3.2	4.6	8.4	7.4	1.9	<0.05	-	-	26.0
≥ **30°C**	-	-	-	-	0.2	0.7	1.7	1.6	<0.05	-	-	-	4.2
≥ **35°C**	-	-	-	-	-	-	-	<0.05	-	-	-	-	<0.05

Table A.6: Average number of days per month and per year at Schiphol on which the minimum or maximum temperature is below or above certain thresholds, around **2050**, according to the **G+** scenario. Ann.: annual. -: did not occur in data.

Minimum temperature

	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
< **10°C**	30.7	27.8	30.3	26.9	17.5	7.1	1.5	2.0	7.7	19.2	27.4	30.2	228.3
< **5°C**	23.0	21.9	19.5	12.3	2.3	0.1	-	-	0.3	4.5	13.0	21.8	118.8
< **0°C**	9.1	8.4	3.8	0.9	-	-	-	-	-	0.3	2.3	8.0	32.8
< **-5°C**	2.6	2.1	0.3	-	-	-	-	-	-	-	0.1	1.3	6.4
< **-10°C**	0.5	0.3	<0.05	-	-	-	-	-	-	-	-	0.1	0.9
< **-15°C**	-	-	<0.05	-	-	-	-	-	-	-	-	-	<0.05

Maximum temperature

	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
< **0°C**	2.1	0.9	0.1	-	-	-	-	-	-	-	0.1	0.9	4.1
≥ **10°C**	6.7	7.0	17.8	26.7	30.8	30.0	31.0	31.0	30.0	30.2	19.9	9.1	270.2
≥ **15°C**	-	0.5	3.4	12.4	24.4	28.9	31.0	31.0	28.9	19.0	2.7	0.1	182.2
≥ **20°C**	-	-	0.2	3.7	10.7	16.1	24.6	26.2	14.4	2.4	-	-	98.2
≥ **25°C**	-	-	-	0.6	3.8	5.3	9.5	8.6	2.4	0.1	-	-	30.3
≥ **30°C**	-	-	-	-	0.3	0.9	2.6	2.2	0.1	-	-	-	6.1
≥ **35°C**	-	-	-	-	-	<0.05	0.1	0.1	-	-	-	-	0.2

Table A.7: Average number of days per month and per year at Schiphol on which the minimum or maximum temperature is below or above certain thresholds, around **2050**, according to the **W** scenario. Ann.: annual. -: did not occur in data.

Minimum temperature

	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
< **10°C**	30.6	27.4	29.9	25.9	16.1	5.7	1.0	1.1	6.7	18.3	26.3	29.8	218.7
< **5°C**	21.0	20.5	17.4	10.4	1.6	<0.05	-	-	0.2	3.6	11.5	20.5	106.7
< **0°C**	7.9	7.3	3.0	0.5	-	-	-	-	-	0.2	1.8	6.5	27.2
< **-5°C**	2.1	1.7	0.3	-	-	-	-	-	-	-	-	0.9	5.0
< **-10°C**	0.4	0.2	<0.05	-	-	-	-	-	-	-	-	0.1	0.6
< **-15°C**	-	-	-	-	-	-	-	-	-	-	-	-	-

Maximum temperature

	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
< **0°C**	1.8	0.5	<0.05	-	-	-	-	-	-	-	<0.05	0.7	3.1
≥ **10°C**	8.7	8.9	20.4	27.7	30.9	30.0	31.0	31.0	30.0	30.5	21.4	11.3	281.9
≥ **15°C**	0.2	0.6	4.2	13.6	25.8	29.4	31.0	31.0	29.5	20.5	3.9	0.5	190.2
≥ **20°C**	-	-	0.5	4.2	11.6	17.3	26.3	28.1	15.5	3.0	-	-	106.5
≥ **25°C**	-	-	-	0.6	4.0	5.7	9.9	9.1	2.7	0.1	-	-	32.2
≥ **30°C**	-	-	-	-	0.5	1.2	2.8	2.2	0.1	-	-	-	6.8
≥ **35°C**	-	-	-	-	-	0.1	0.1	0.1	-	-	-	-	0.3

Table A.8: Average number of days per month and per year at Schiphol on which the minimum or maximum temperature is below or above certain thresholds, around **2050**, according to the **W+** scenario. Ann.: annual. -: did not occur in data.

Minimum temperature

	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
< **10°C**	30.6	27.4	29.5	24.2	12.6	3.9	0.4	0.5	4.5	15.5	25.1	29.5	203.8
< **5°C**	19.9	19.8	15.6	8.5	0.9	<0.05	-	-	0.1	2.8	9.7	19.7	97.0
< **0°C**	6.8	6.0	2.3	0.3	-	-	-	-	-	0.1	1.2	5.1	21.8
< **-5°C**	1.7	1.3	0.1	-	-	-	-	-	-	-	-	0.6	3.7
< **-10°C**	0.3	0.1	<0.05	-	-	-	-	-	-	-	-	-	0.4
< **-15°C**	-	-	-	-	-	-	-	-	-	-	-	-	-

Maximum temperature

	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
< **0°C**	1.4	0.3	-	-	-	-	-	-	-	-	-	0.5	2.1
≥ **10°C**	10.3	10.2	22.6	28.9	30.9	30.0	31.0	31.0	30.0	30.5	23.2	12.6	291.2
≥ **15°C**	0.2	0.6	5.1	15.5	27.1	29.6	31.0	31.0	29.6	23.1	5.0	0.5	198.4
≥ **20°C**	-	-	0.5	5.1	13.3	20.2	28.2	29.3	19.9	4.9	-	-	121.2
≥ **25°C**	-	-	-	0.8	4.7	7.5	12.7	12.4	4.4	0.3	-	-	42.9
≥ **30°C**	-	-	-	<0.05	0.7	1.9	4.5	3.8	0.4	-	-	-	11.4
≥ **35°C**	-	-	-	-	-	0.2	0.5	0.7	-	-	-	-	1.4

B. Appendix: extremes of temperature for different return periods in 2010 and 2050

Table B.1: Return values of monthly and annual minimum and maximum temperatures at Schiphol, according to different return periods (RP). From GEV fits to transformed data. Valid for around **2010**, according to the **G** scenario. Ann.: annual.

RP (yr)	Minimum temperature (°C)												
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
2	-5.7	-5.1	-2.5	-0.8	2.8	5.9	8.9	8.6	6.1	1.7	-1.5	-4.7	-8.5
5	-9.3	-8.5	-4.8	-2.3	1.2	4.7	7.5	7.4	4.5	-0.4	-3.6	-7.5	-11.8
10	-11.6	-10.8	-6.3	-3.0	0.5	4.0	6.8	6.9	3.7	-1.5	-4.7	-9.4	-14.0
25	-14.6	-13.7	-8.1	-3.7	-0.3	3.4	6.1	6.3	3.0	-2.6	-5.8	-11.7	-16.8
50	-16.9	-15.8	-9.5	-4.1	-0.7	3.1	5.7	6.0	2.5	-3.2	-6.4	-13.4	-18.9

RP (yr)	Maximum temperature (°C)												
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
2	11.4	12.1	16.4	21.9	26.0	28.7	29.9	29.9	24.6	20.5	15.5	12.4	31.7
5	12.9	14.5	18.6	24.5	28.6	30.9	32.0	32.0	26.7	22.4	16.5	13.6	33.1
10	13.7	15.6	19.7	25.7	29.8	32.0	33.0	33.0	27.7	23.2	17.0	14.2	33.8
25	14.3	16.6	20.7	26.8	30.9	33.0	33.9	34.0	28.6	24.1	17.4	14.8	34.5
50	14.7	17.2	21.3	27.4	31.5	33.5	34.5	34.5	29.2	24.5	17.7	15.1	34.9

Table B.2: Return values of monthly and annual minimum and maximum temperatures at Schiphol, according to different return periods (RP). From GEV fits to transformed data. Valid for around **2010**, according to the **G+** scenario. Ann.: annual.

RP (yr)	Minimum temperature (°C)												
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
2	-5.6	-5.0	-2.4	-0.7	2.9	6.0	9.0	8.7	6.2	1.8	-1.4	-4.6	-8.4
5	-9.2	-8.4	-4.7	-2.2	1.3	4.8	7.6	7.6	4.6	-0.4	-3.5	-7.4	-11.7
10	-11.5	-10.7	-6.2	-2.9	0.6	4.1	6.9	7.0	3.8	-1.5	-4.6	-9.3	-13.9
25	-14.5	-13.6	-8.0	-3.6	-0.2	3.5	6.2	6.4	3.0	-2.5	-5.7	-11.6	-16.7
50	-16.7	-15.7	-9.4	-4.1	-0.6	3.2	5.8	6.1	2.6	-3.2	-6.3	-13.4	-18.8

RP (yr)	Maximum temperature (°C)												
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
2	11.4	12.1	16.4	22.0	26.2	28.9	30.1	30.2	24.8	20.7	15.6	12.4	31.9
5	12.9	14.5	18.7	24.6	28.7	31.1	32.2	32.3	26.9	22.5	16.6	13.6	33.4
10	13.6	15.6	19.7	25.8	29.9	32.2	33.2	33.3	27.9	23.4	17.1	14.2	34.1
25	14.3	16.6	20.7	26.9	31.1	33.1	34.2	34.2	28.9	24.2	17.5	14.8	34.8
50	14.7	17.2	21.3	27.5	31.7	33.7	34.7	34.8	29.4	24.7	17.8	15.1	35.2

Table B.3: Return values of monthly and annual minimum and maximum temperatures at Schiphol, according to different return periods (RP). From GEV fits to transformed data. Valid for around **2010**, according to the **W** scenario. Ann.: annual.

RP (yr)	Minimum temperature (°C)												
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
2	-5.4	-4.9	-2.3	-0.6	3.1	6.1	9.1	8.8	6.4	2.0	-1.2	-4.5	-8.3
5	-9.0	-8.3	-4.5	-2.0	1.5	4.9	7.7	7.7	4.8	-0.2	-3.4	-7.3	-11.6
10	-11.4	-10.6	-6.0	-2.8	0.8	4.3	7.0	7.1	4.0	-1.3	-4.5	-9.2	-13.8
25	-14.4	-13.4	-7.9	-3.5	0.0	3.7	6.3	6.6	3.3	-2.3	-5.5	-11.5	-16.6
50	-16.7	-15.6	-9.3	-3.9	-0.4	3.4	5.9	6.2	2.8	-2.9	-6.1	-13.3	-18.7

RP (yr)	Maximum temperature (°C)												
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
2	11.6	12.3	16.6	22.2	26.3	29.0	30.1	30.2	24.8	20.8	15.7	12.6	32.0
5	13.1	14.7	18.8	24.8	28.8	31.2	32.3	32.3	27.0	22.6	16.7	13.8	33.4
10	13.9	15.8	19.9	26.0	30.0	32.2	33.3	33.3	28.0	23.5	17.2	14.4	34.1
25	14.5	16.8	20.9	27.1	31.2	33.2	34.2	34.2	28.9	24.3	17.6	15.0	34.8
50	14.9	17.4	21.5	27.7	31.8	33.8	34.7	34.8	29.4	24.7	17.9	15.3	35.2

Table B.4: Return values of monthly and annual minimum and maximum temperatures at Schiphol, according to different return periods (RP). From GEV fits to transformed data. Valid for around **2010**, according to the **W+** scenario. Ann.: annual.

RP (yr)	Minimum temperature (°C)												
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
2	-5.2	-4.7	-2.1	-0.4	3.2	6.3	9.3	9.0	6.5	2.1	-1.0	-4.3	-8.0
5	-8.8	-8.1	-4.3	-1.8	1.6	5.1	7.9	7.8	4.9	-0.1	-3.2	-7.1	-11.3
10	-11.1	-10.3	-5.8	-2.6	0.9	4.4	7.2	7.2	4.1	-1.2	-4.2	-8.9	-13.5
25	-14.1	-13.2	-7.6	-3.3	0.1	3.8	6.5	6.7	3.3	-2.3	-5.3	-11.2	-16.3
50	-16.3	-15.3	-9.0	-3.7	-0.3	3.5	6.1	6.3	2.8	-2.9	-5.9	-13.0	-18.4

RP (yr)	Maximum temperature (°C)												
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
2	11.7	12.4	16.7	22.3	26.6	29.3	30.6	30.7	25.3	21.0	15.9	12.7	32.4
5	13.2	14.7	19.0	24.9	29.1	31.6	32.8	32.8	27.4	22.9	16.9	13.9	33.9
10	13.9	15.8	20.0	26.1	30.3	32.6	33.8	33.8	28.5	23.8	17.3	14.5	34.6
25	14.5	16.8	21.0	27.2	31.5	33.6	34.7	34.8	29.5	24.6	17.8	15.0	35.3
50	14.9	17.4	21.6	27.8	32.1	34.2	35.3	35.3	30.0	25.0	18.0	15.3	35.7

Table B.5: Return values of monthly and annual minimum and maximum temperatures at Schiphol, according to different return periods (RP). From GEV fits to transformed data. Valid for around **2050**, according to the **G** scenario. Ann.: annual.

RP (yr)	Minimum temperature (°C)												
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
2	-5.0	-4.5	-1.8	-0.2	3.4	6.5	9.5	9.2	6.7	2.4	-0.8	-4.0	-7.8
5	-8.6	-7.9	-4.1	-1.6	1.9	5.3	8.1	8.0	5.2	0.2	-2.9	-6.8	-11.1
10	-11.0	-10.1	-5.6	-2.3	1.2	4.7	7.4	7.5	4.4	-0.9	-4.0	-8.7	-13.3
25	-14.0	-13.0	-7.4	-3.0	0.4	4.1	6.7	6.9	3.6	-1.9	-5.0	-11.1	-16.1
50	-16.2	-15.1	-8.8	-3.4	-0.0	3.7	6.4	6.6	3.2	-2.5	-5.6	-12.8	-18.2

RP (yr)	Maximum temperature (°C)												
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
2	12.0	12.7	17.0	22.5	26.7	29.4	30.6	30.6	25.3	21.2	16.1	13.0	32.4
5	13.5	15.0	19.2	25.1	29.2	31.6	32.7	32.7	27.4	23.0	17.1	14.2	33.9
10	14.2	16.1	20.3	26.3	30.4	32.7	33.7	33.8	28.4	23.9	17.6	14.8	34.6
25	14.9	17.2	21.3	27.4	31.6	33.6	34.7	34.7	29.4	24.7	18.0	15.3	35.3
50	15.3	17.8	21.9	28.0	32.2	34.2	35.2	35.2	29.9	25.2	18.3	15.6	35.6

Table B.6: Return values of monthly and annual minimum and maximum temperatures at Schiphol, according to different return periods (RP). From GEV fits to transformed data. Valid for around **2050**, according to the **G+** scenario. Ann.: annual.

RP (yr)	Minimum temperature (°C)												
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
2	-4.6	-4.1	-1.5	0.2	3.8	6.9	9.8	9.5	7.0	2.7	-0.5	-3.7	-7.4
5	-8.2	-7.5	-3.7	-1.3	2.2	5.6	8.4	8.3	5.4	0.5	-2.6	-6.4	-10.6
10	-10.5	-9.7	-5.2	-2.0	1.5	5.0	7.7	7.7	4.5	-0.6	-3.6	-8.3	-12.8
25	-13.4	-12.5	-7.0	-2.7	0.7	4.3	6.9	7.1	3.7	-1.6	-4.7	-10.6	-15.5
50	-15.6	-14.6	-8.4	-3.1	0.3	4.0	6.5	6.8	3.2	-2.3	-5.3	-12.3	-17.6

RP (yr)	Maximum temperature (°C)												
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
2	12.0	12.8	17.1	22.8	27.2	30.1	31.4	31.5	26.0	21.7	16.3	13.1	33.3
5	13.5	15.0	19.4	25.4	29.8	32.4	33.6	33.8	28.3	23.5	17.3	14.3	34.8
10	14.2	16.1	20.4	26.6	31.0	33.5	34.7	34.8	29.3	24.4	17.8	14.8	35.6
25	14.8	17.1	21.4	27.7	32.1	34.5	35.6	35.8	30.3	25.2	18.2	15.4	36.3
50	15.2	17.7	22.0	28.3	32.8	35.1	36.2	36.4	30.9	25.7	18.5	15.7	36.7

Table B.7: Return values of monthly and annual minimum and maximum temperatures at Schiphol, according to different return periods (RP). From GEV fits to transformed data. Valid for around **2050**, according to the **W** scenario. Ann.: annual.

RP (yr)	Minimum temperature (°C)												
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
2	-4.1	-3.6	-1.0	0.7	4.3	7.4	10.3	10.0	7.6	3.3	0.1	-3.1	-6.9
5	-7.6	-6.9	-3.2	-0.7	2.8	6.2	8.9	8.9	6.0	1.1	-2.0	-5.9	-10.1
10	-9.9	-9.1	-4.6	-1.4	2.0	5.6	8.2	8.3	5.2	0.0	-3.1	-7.7	-12.3
25	-12.9	-12.0	-6.5	-2.1	1.3	5.0	7.5	7.8	4.5	-1.0	-4.1	-10.0	-15.0
50	-15.1	-14.0	-7.8	-2.5	0.8	4.6	7.1	7.4	4.0	-1.6	-4.7	-11.7	-17.1

RP (yr)	Maximum temperature (°C)												
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
2	12.7	13.4	17.8	23.4	27.6	30.3	31.5	31.6	26.2	22.1	16.9	13.8	33.4
5	14.2	15.8	20.0	26.0	30.1	32.6	33.7	33.8	28.4	23.9	17.9	15.0	34.9
10	15.0	16.9	21.1	27.2	31.3	33.7	34.7	34.8	29.5	24.8	18.4	15.5	35.6
25	15.6	17.9	22.1	28.3	32.5	34.7	35.7	35.8	30.4	25.6	18.8	16.1	36.3
50	16.0	18.5	22.7	28.9	33.1	35.3	36.2	36.3	31.0	26.1	19.1	16.4	36.7

Table B.8: Return values of monthly and annual minimum and maximum temperatures at Schiphol, according to different return periods (RP). From GEV fits to transformed data. Valid for around **2050**, according to the **W+** scenario. Ann.: annual.

RP (yr)	Minimum temperature (°C)												
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
2	-3.4	-2.9	-0.3	1.4	5.0	8.1	11.0	10.6	8.1	3.9	0.8	-2.4	-6.0
5	-6.7	-6.1	-2.4	0.0	3.4	6.7	9.5	9.4	6.4	1.7	-1.3	-5.0	-9.1
10	-9.0	-8.3	-3.8	-0.7	2.6	6.1	8.7	8.7	5.5	0.6	-2.3	-6.8	-11.2
25	-11.8	-11.0	-5.6	-1.4	1.9	5.4	8.0	8.1	4.7	-0.5	-3.3	-9.0	-13.9
50	-13.9	-13.0	-6.9	-1.8	1.4	5.0	7.6	7.7	4.2	-1.2	-3.9	-10.6	-15.9

RP (yr)	Maximum temperature (°C)												
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Ann.**
2	12.9	13.6	18.1	24.0	28.5	31.7	33.2	33.4	27.7	23.0	17.4	14.0	35.2
5	14.3	15.8	20.3	26.6	31.1	34.1	35.5	35.8	30.2	24.9	18.4	15.1	36.8
10	15.0	16.9	21.3	27.8	32.4	35.3	36.6	36.9	31.3	25.9	18.8	15.7	37.6
25	15.6	17.9	22.3	28.9	33.5	36.3	37.7	37.9	32.4	26.7	19.3	16.2	38.4
50	15.9	18.4	22.8	29.5	34.2	36.9	38.2	38.5	33.0	27.2	19.5	16.5	38.8

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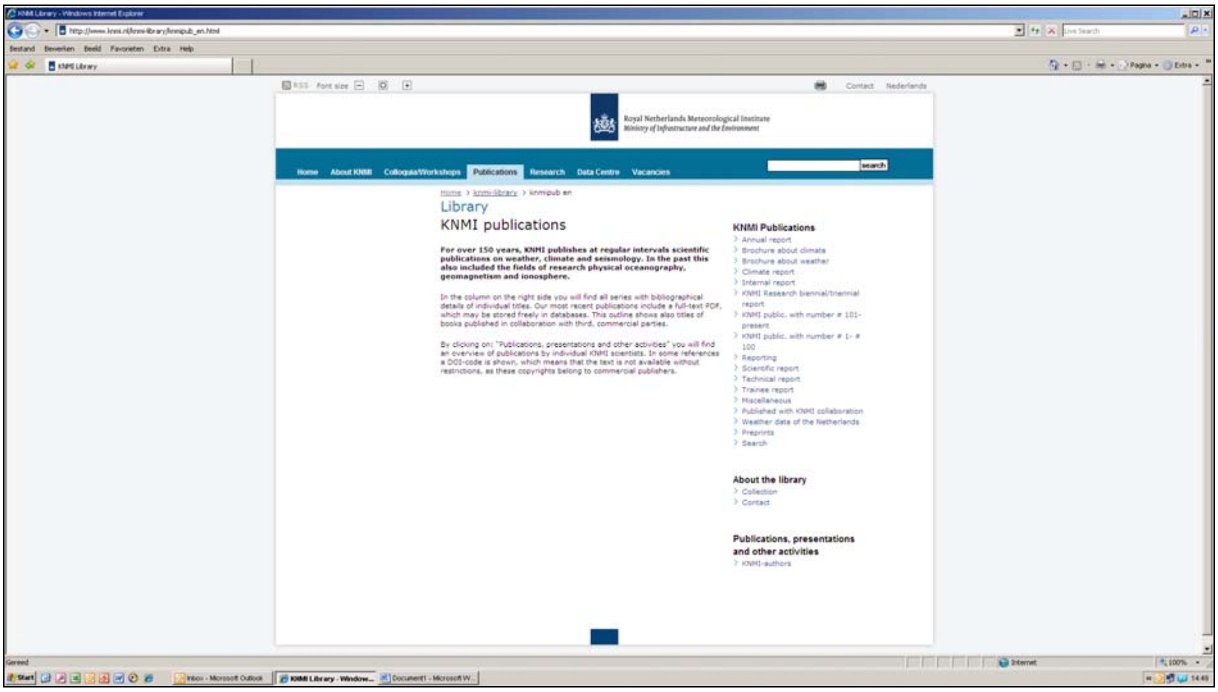

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