Senate Department
for Urban Development
and the Environment

be Berlin

04.12 Climate Model Berlin – Development of the Number of Climatological Threshold Days in the Future (Edition 2016)

Overview

Scientific research has long shown that the global climate is changing and will continue to change. The current state of research on the past and likely future global development is published in the framework of the reporting of the IPCC (Intergovernmental Panel on Climate Change, IPCC 2014). In this context, cities, in particular the large metropolises, are not only responsible for reducing greenhouse gas emissions; they are also affected due to increasing loads for different urban infrastructure sectors. According to current calculations of the Potsdam Institute for Climate Impact Research (PIK), in 2100 Berlin will have the climate, with respect to the annual variation of temperature and precipitation, that the southern French city of Toulouse has today (Reusswig, Becker et al. 2016). In particular, the increase in extreme weather events such as prolonged hot and dry periods or heavy precipitation presents enormous challenges to policymakers, the administration and the population.

The Berlin Senate has long recognised the urgency that these forecasts imply for the city, has responded with plans and measures both in the area of mitigation and in the area of adaptation to the impacts of climate change, and is continually developing them further. The legal framework for the field of action of climate protection with its various components was determined with the Berlin Energy Transition Act (EWG Bln 2016) and the strategies and measures for climate neutrality by 2050 in the Berlin Energy and Climate Protection Programme 2030 (Abgeordnetenhaus Berlin 2016).

Climate adaptation is adressed with shared responsibilities in Berlin.

The core elements of Berlin's strategy for adaptation to climate change consist of three components:

- the strategic Concept for Adaptation to the Impacts of Climate Change (*Konzept zur Anpassung an die Folgen des Klimawandels*, AFOK) (Reusswig, Becker et al. 2016), which on the one hand contains climate projections for the future for the entire city and on the other hand points out sectoral vulnerabilities and recommends climate change adaptation measures,
- the Urban Development Plan Climate (*Stadtentwicklungsplan* (StEP) *Klima*) (SenStadtUm 2011), which was already presented in 2011 and contains mostly recommendations for action for spatial planning. In 2016, it was focused on the challenges of the growing city with the StEP *Klima KONKRET* (SenStadtUm 2016a), and
- the new three-part Planning Advices Urban Climate Map of the Environmental Atlas (SenStadtUm 2016b), which points out with high spatial resolution which areas of the city are already suffering from climatic loads and where Berlin has potential for relief.

The planning advices map is the final result of comprehensive urban climate modelling which allowed, besides the comprehensive simulations, also analyses of long-term time series at the Berlin stations Alexanderplatz, Dahlem, Grunewald, Tegel and Tempelhof as well as Potsdam (SenStadtUm 2015). In an excursus in the framework of the ERDF project EFRE "**GIS-based modelling of parameters relevant to urban climate on the basis of high-resolution data on buildings and vegetation**" (SenStadtUm 2015a), a station-specific estimation of possible effects of climate change was already carried out with the regional climate model **WETTREG2010 Scenario A1B** (CEC-Potsdam n.d.), and the results were used also for the maps presented here.

The term "**climatological threshold day**" refers to a day on which a fixed threshold of a meteorological parameter is reached or exceeded. In the context of the subject of urban climate, the following threshold days are particularly relevant, as they are closely linked to the occurrence of bioclimatic loads in settled areas:

- **04.12.01 Summer Days** (maximum temperature ≥ 25 °C),
- **04.12.02 Hot Days** (maximum temperature ≥ 30 °C),
- **04.12.03 Tropical Nights** (minimum temperature ≥ 20 °C).

The long-term measurements of climate parameters exhibit a characteristic distribution of the minimum and maximum temperatures for the different measurement sites in the municipal area in the summer half-year. The distribution reflects the diverse heat behaviour of the city that results from the different use structures but also from the location of a site within the municipal area as a whole. Given otherwise comparable use, the spatial location within the city thus determines to what extent a site can profit from the cooler surroundings or is exposed to the influence of overheated adjacent districts. An open space under the influence of the urban heat island will exhibit a flatter diurnal variation than a comparable area outside the city. As the absolute level of the summer temperature is primarily determined by the predominant weather conditions and the location of the site in the municipal area merely leads to a modification, the characteristic temperature differences allow inferences to be drawn from the measured temperatures of one site about the level at a different site.

The exceedance of fixed values of the daily minima or maxima determines the occurrence of the so-called threshold days. Since especially the daily extrema and likewise the simultaneously measured temperature differences among the stations exhibit a characteristic distribution, knowing the temperature difference with respect to a reference site allows the probability that the threshold values are exceeded there, too, to be determined. Knowing the frequencies of the threshold days per year at a reference site thus allows the frequencies at another site to be estimated.

Statistical Base

The analyses for Map 04.12 (Edition 2016) are closely linked to the work in the framework of the ERDF project 027 **“GIS-based modelling of parameters relevant to urban climate on the basis of high-resolution data on buildings and vegetation”** (SenStadtUm 2015a, 2016, 2016a). The analyses of the long-term measurement series of the Berlin city stations

- Alexanderplatz
- Dahlem
- Grunewald
- Tegel and
- Tempelhof

carried out in this project formed the statistical base for the further statistical considerations of the development of the climatological threshold days and were comprehensively published in a separate map with respect to the individual stations (SenStadtUm 2015). Figure 1 illustrates the location of the stations in the municipal area.

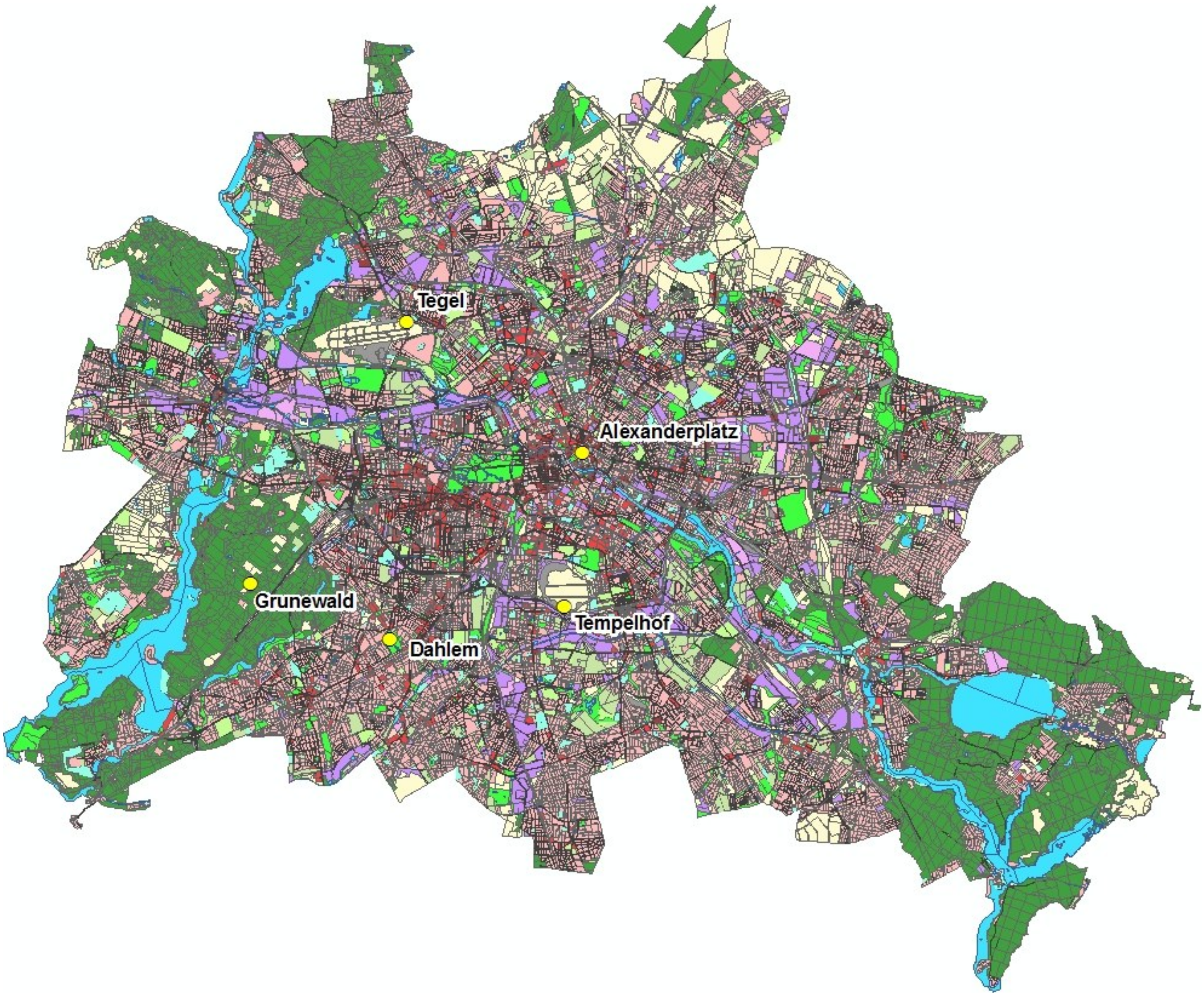

*Fig. 1: **Location of the evaluated Berlin climate stations** in the municipal area of Berlin. The measurement sites are marked by yellow circles. (SenStadtUm 2015)*

The model simulations for the spatial distribution of the temperature during summerly weather conditions used numerous data of the Urban and Environmental Information System (*Informationssystem Stadt und Umwelt*, ISU) as well as other sources. They are described in detail here.

Methodology

In the ERDF project 027 "**GIS-based modelling of parameters relevant to urban climate on the basis of high-resolution data on buildings and vegetation**", the characteristic spatial distribution of the summer minimum and maximum temperatures in Berlin and its surroundings was already simulated based on a model, statistically analysed and published as a separate topic with respect to the summer threshold days of the past decade 2001-2010 (SenStadtUm 2015, 2016).

The work steps and analyses described here in the following build on this. This text contains only a selection of the tables and figures created in the framework of the project. All **analyses for this map** can be downloaded **in a single archive**: Entire analysis of the Berlin climate stations (zip; 49 MB).

As described, the methodological approach (described in detail in GEO-NET 2016) was based on the insight that the urban temperature conditions (always referred to the official measurement height of 2 m above ground in the following) are determined by the predominant weather conditions on the one hand and by the location of an area within the municipal area on the other. The **combination of the available results of the detailed comprehensive modelling at selected points in time with the station results of measuring points in long-term operation** thus allows conclusions to be drawn about the temperature behaviour of arbitrary sites also at points in time other than the ones modelled. The temperature differences of all areas with respect to the reference stations can be determined, which in turn represent different characteristic urban use structures situated in the surroundings of the measuring instruments (cf. Fig. 1). The influence of this location effect particularly on the nocturnal minimum temperatures is illustrated in Figure 2.

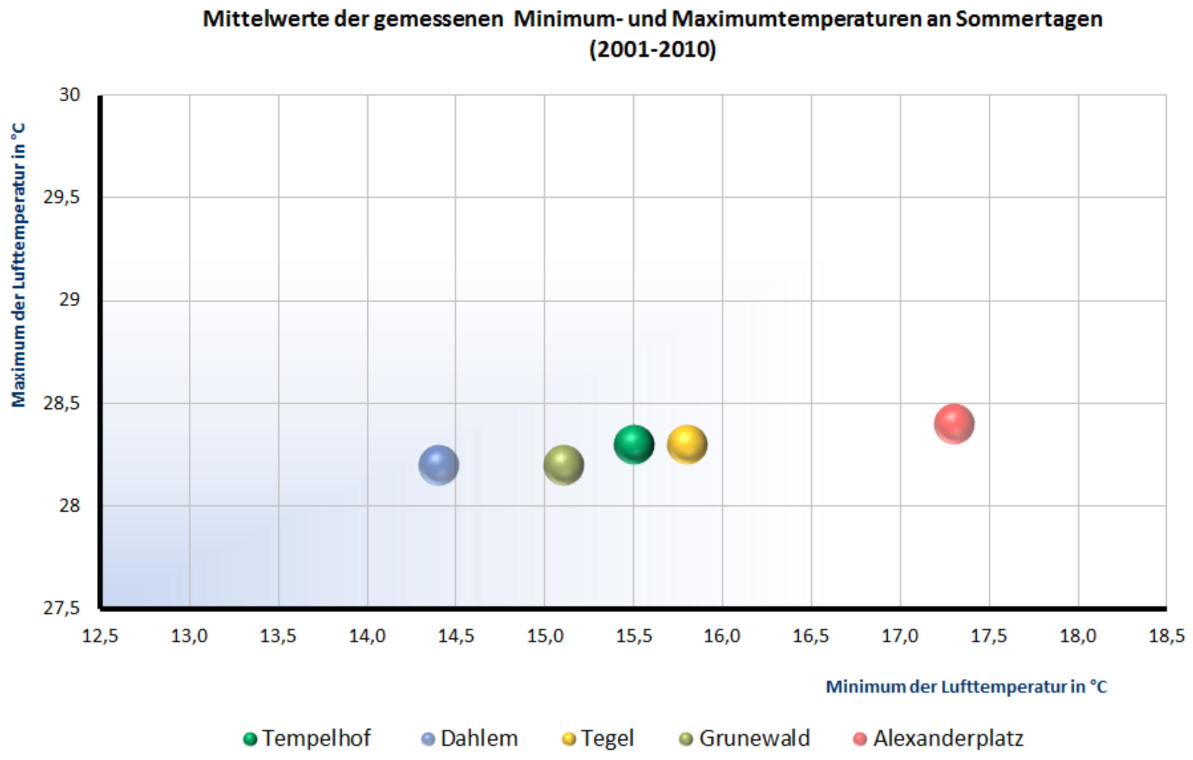

Fig. 2: Measured mean temperature level of the daily minima and maxima on summer days at selected measurement stations within Berlin. (GEO-NET 2016)

Knowing the frequencies of the threshold days at the reference sites thus also allows the frequencies at other sites to be estimated.

Figure 3 shows the principal history of the frequencies of tropical nights, summer days and hot days derived from the 30-year measurement series from 1981 to 2010 as a function of the temperature deviations of the minimum and maximum temperatures from the values at the reference site, the Tempelhof station. While the analyses of the measurements show that the number of tropical nights and hot days as a function of the temperature deviations follow a power law, the frequencies of summer days exhibit a nearly linear relationship with the temperature difference with respect to the reference site in the data range analysed. The knowledge of these relationships was implemented in a first step in that all blocks and block segments of the block map 1 : 5,000 (ISU5) were assigned frequencies of the three threshold days for the “actual state” time period 2001 - 2010. The result is part of the analysis maps for applying the climate model 2015 (SenStadtUm 2016, direct link to the map in the Geoportal).

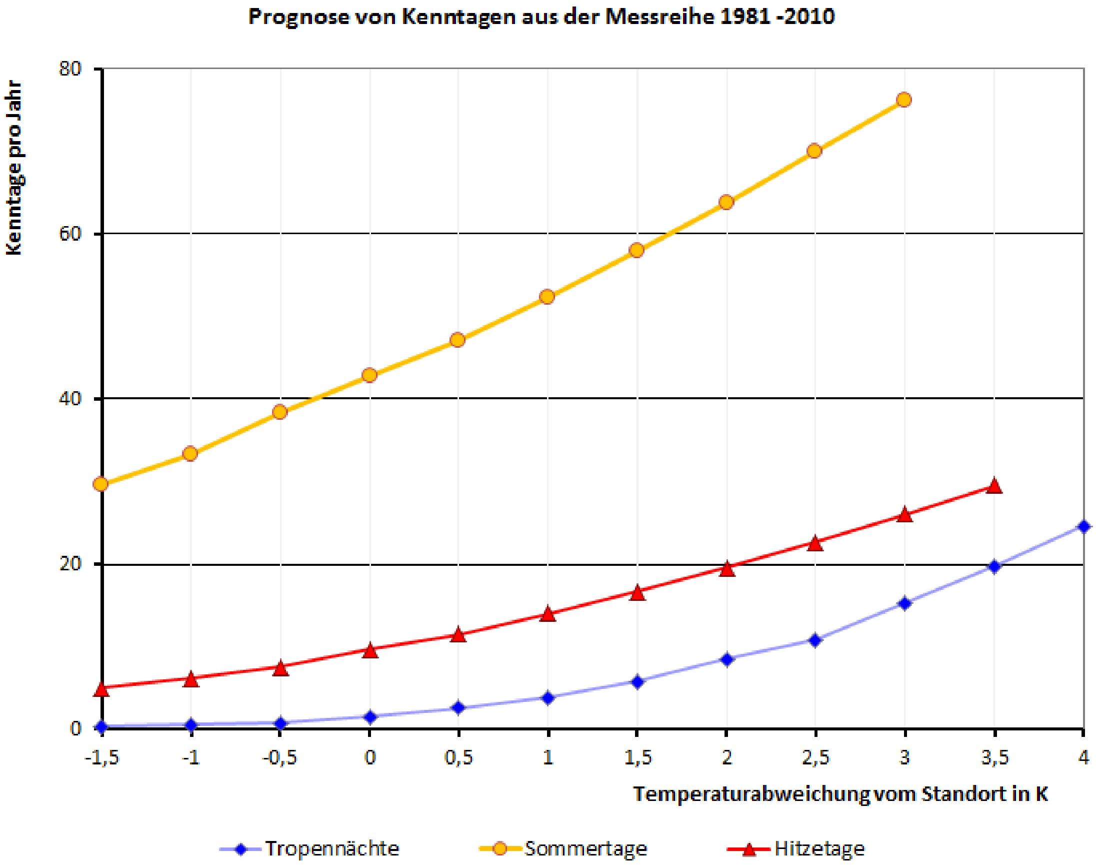

Fig. 3: Estimation of the frequencies of tropical nights, hot and summer days as a function of different temperature deviations from the Tempelhof reference station. (GEO-NET 2016)

To forecast the development of the number of threshold days in the future (time periods 2011-2040 and 2041-2070), the statistical analyses were extended using the available station-specific temperature time series of the **WETTREG-2010 Scenario A1B** (CEC-Potsdam n.d.). This scenario dates back to the 4th Assessment Report of the IPCC (IPCC 2007) and is meanwhile being extended by the slightly more pessimistic, more emission-intensive **Scenario RCP8.5** (IPCC 2014), which was used for the calculations in the framework of Berlin’s Concept for Adaptation to the Impacts of Climate Change (Reusswig, Becker et al. 2016).

The stipulated conditions of any emission scenario necessarily contain imponderables, especially for the more distant future, with respect to the development of the individual underlying parameters, e.g. the economic development or population growth. The Scenario A1B used here, and likewise the Scenario RCP8.5 being used meanwhile, are so-called **business-as-usual scenarios**, which assume a form of economic trade and of energy use for the future that deviates little from the current state. A further influencing factor whose future form is unknown is the **urban development** of Berlin, i.e. the distribution of built-up and greened areas in the future. As no reliable information is available in this regard for the time periods under consideration, an unmodified urban structure was necessarily assumed.

These influencing factors and restrictions are to be taken into account in particular in assessing the differences in the forecast absolute values and in their temporal development. **It is further to be noted that in this study, hot days are simultaneously also counted as summer days**.

Thus it was possible to make the simplifying assumption for the calculations that the relative temperature differences between individual use structures in the city under summerly high-pressure conditions will remain essentially unchanged also in the future.

Three time periods were selected for the forecast of the future development:

- 1981-2010 Reference of the current long-term (30-year) mean
- 2011-2040 Reference of the near future
- 2041-2070 Reference of the intermediate future.

Figure 4 shows the forecast based on the WETTREG 2010 A1B scenario with respect to the development of the frequencies of tropical nights at three Berlin stations with a long-term uninterrupted measurement series. As the climatic influences of the site have a particularly strong effect during the nighttime cooling phases, the depicted development of the number of tropical nights provides a particularly incisive illustration of the climate change-related temperature increase to be expected.

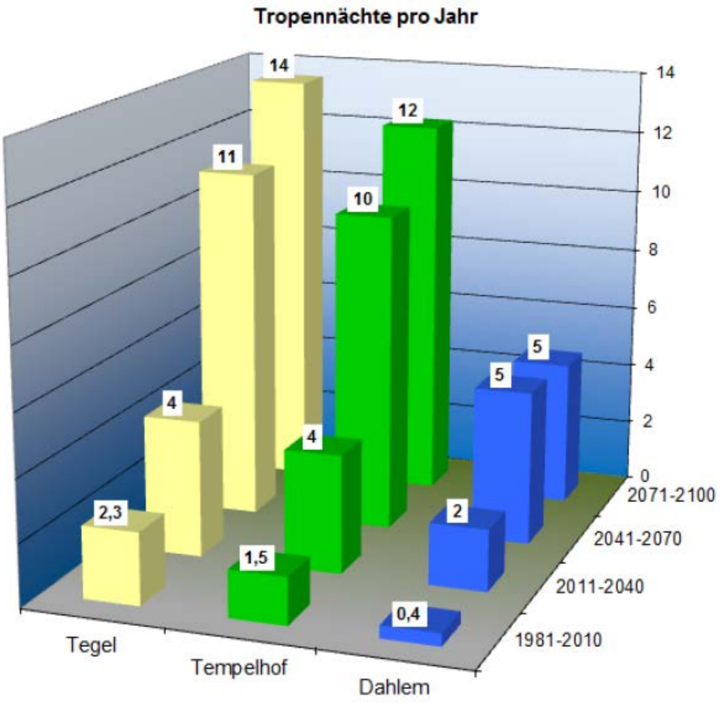

Fig. 4: Future development of the frequencies of tropical nights at selected measurement stations in Berlin (GEO-NET 2016)

The project report (GEO-NET 2016) also contains station-specific statements on the **development of the frost days.** A spatial representation for the municipal area is not possible, as the model simulations can only be used for summerly weather conditions. The corresponding tables and figures are also contained in the zip archive available for download: Entire analysis of the Berlin climate stations (49 MB).

Map Description

As mentioned, the use-related differences in the (summer) temperature behaviour of a city manifest in particular during the night hours with cloudless sky. During the day, the temperature peaks over the individual areas lie much closer together, even when the degrees of development and sealing differ considerably. A figure from the text accompanying Map 04.04 Temperature in Medium Low-exchange Nocturnal Radiation Periods (Edition 2001) is reused here for illustration, as it makes a fundamental point (cf. Fig. 5).

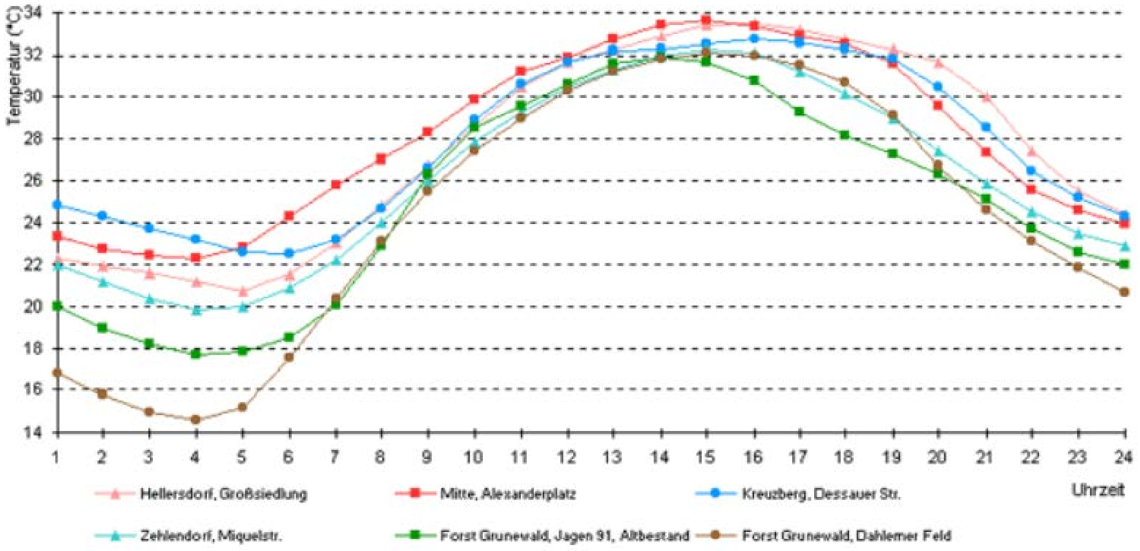

Fig. 5: Diurnal variation of the air temperature at a height of 2 m on a hot low-exchange radiation day (July 8, 1991) at various sites in Berlin (SenStadt 2001)

These fundamental effects also affect the use-related distribution of the number of threshold days.

Table 1 shows the mean number of climatological threshold days per area type (06.08 Urban Structure differentiated, as of 2010, SenStadtUm 2011a) for the calculated time periods 1981-2010, 2011-2040 and 2041-2070 as well as the forecast increases compared to the present. Thus it supplements map statements that spatially locate the tabular statements according to the location of the area types.

In principle, it remains to be noted that the projections represent mean value data of the defined time periods that may vary upwards or downwards due to the natural fluctuations of the climate over the course of the decades under consideration ("interannual fluctuations").

But it also becomes apparent that the model results predict an increase of the frequency per year for all threshold days, the extent of which, however, depends on the threshold day.

So far and also in future, the **tropical nights** (minimum temperature ≥ 20 °C) occur most rarely compared to the summer days and hot days. However, due to the fundamental effects related to the diurnal variation this case exhibits the greatest differentiations between the individual area types. The strongest nighttime cooling effects and thus the lowest expected number of tropical nights (> 2 to 5 in the time period 1981-2010) occur on green and open spaces with open structures. Mainly agricultural areas ("farmland" as well as "grassland"), fallows with meadow-like structure (e.g. the meadows of the airports), but also allotment gardens, and by far the parks stand out in this respect. The latter also comprise forest-like portions, whose radiative power is curbed by the canopies at night. The area types mentioned also exhibit the lowest values and potential loads with respect to the future time periods. In the time period up to 2070, a number of tropical nights of the order of > 12 to 20 days is expected there, which is close to a fivefold increase. Conversely, today and in the future the largest values occur for area types with a high degree of development and sealing, e.g. for the types "core area", "dense block development" and "commercial and industrial area with dense development".

According to Fig. 5, the threshold days that refer to the daily maximum temperature (summer day and heat day) lie much closer together in their absolute values and also in the increases for the future. However, the absolute numbers for the probabilities of occurrence differ considerably.

As described in the chapter "Results of the station evaluations" for Map 04.13 (SenStadtUm 2015), the number of **hot days** in Berlin has been rising for decades. The climate modelling using WETTREG 2010 A1B shows that in future this rise will be much more rapid. While 5 (forest area) to barely 10 (airport, traffic area, but also open vegetation area) hot days are assumed in the analysis period 1981-2010, there will likely already be 19-24 such days in 2041-2070, with the distribution with respect to area types unchanged.

These results lie slightly above the calculations carried out in the framework of the AFOK (main report "Adaptation to the Impacts of Climate Change in Berlin (AFOK)", partial climate protection concept, Chap. 3.1.2 Temperature Extremes, Reusswig, Becker et al. 2016) using the **Scenario RCP8.5** (IPCC 2014). In that case, the majority of the models employed expect an increase in hot day events on the order of up to a doubling for the "near future" (2031-2060).

In the case of the forecast development for the **summer days**, which in this study by definition includes the number of hot days, the individual area types also lie relatively close together. The range lies between 38.1 event days in forest areas and 43.5 at airport sites for the initial time period 1981-2010. By the end of the time period 2041-2070, the number of summer days per year will increase approximately by half and thus lie above 60 days per year throughout.

It is apparent that the manifestation of summer days and hot days is correlated. However, the slope of the values with respect to the initial time period 1981-2010 shows that the increase in summer days is more rapid overall than the increase in hot days. There are no relevant differences among the area types in the absolute manifestation of the event frequency.

Tab. 1: Time series of the mean number of climatological threshold days per area type

Area type code	Area type	Number of blocks / block segments	Summer days					Hot days					Tropical nights				
			1981-2010	2011-2040	2041-2070	Increase 1981-2040	Increase 1981-2070	1981-2010	2011-2040	2041-2070	Increase 1981-2040	Increase 1981-2070	1981-2010	2011-2040	2041-2070	Increase 1981-2040	Increase 1981-2070
1	Dense block development, closed rear courtyard (1870s-1918), 5-6-storey	179	41.4	45.3	64.3	3.9	22.8	8.6	11.6	22.7	3.0	14.1	8.5	15.4	28.8	6.9	20.3
2	Closed block development, rear courtyard (1870s-1918), 5-storey	1,083	41.5	45.4	64.4	3.9	22.9	8.7	11.7	22.7	3.0	14.1	8.1	14.7	27.8	6.6	19.7
3	Closed and semi-open block development, decorative and garden courtyard (1870s-1918), 4-storey	510	41.3	45.1	64.1	3.8	22.8	8.5	11.6	22.6	3.0	14.0	7.5	13.7	26.4	6.1	18.9
6	Mixed development, semi-open and open shed courtyard, 2-4-storey	114	41.8	45.8	64.8	3.9	23.0	8.8	11.8	23.0	3.0	14.1	7.3	13.2	25.8	6.0	18.6
7	De-cored block development, post-war gap closure	431	41.3	45.1	64.1	3.8	22.8	8.6	11.6	22.6	3.0	14.0	7.6	13.8	26.6	6.2	19.0
8	Heterogeneous inner-city mixed development, post-war gap closure	56	41.7	45.6	64.6	3.9	22.9	8.8	11.8	22.9	3.0	14.1	7.6	13.8	26.6	6.2	19.0
9	Large estates and single-tower high-rise buildings (1960s-1980s), 4-11-storey	673	42.0	45.9	65.0	4.0	23.0	8.5	11.6	22.5	3.0	14.0	7.2	13.2	25.8	6.0	18.5
10	Block-edge development with large quadrangles (1920s-1940s), 3-5-storey	595	41.3	45.1	64.1	3.8	22.8	8.5	11.6	22.5	3.0	14.0	7.2	13.2	25.8	6.0	18.5
11	Free row development (1950s-1970s), with landscaped residential greenery, 3-6-storey	850	41.1	44.9	63.8	3.8	22.7	8.4	11.5	22.4	3.1	14.0	6.7	12.4	24.6	5.6	17.8
12	Old school (built before 1945)	186	41.5	45.3	64.3	3.9	22.9	8.6	11.7	22.7	3.0	14.1	7.1	13.0	25.5	5.9	18.4
13	New school (built after 1945)	404	41.8	45.8	64.8	3.9	23.0	8.8	11.8	23.0	3.0	14.1	6.7	12.4	24.6	5.6	17.9
16	Sports facility, uncovered	486	42.4	46.4	65.5	4.0	23.1	9.1	12.1	23.4	3.0	14.2	5.7	10.6	21.9	4.9	16.2
17	Sports facility, covered	52	41.8	45.7	64.8	3.9	23.0	8.8	11.8	22.9	3.0	14.1	5.8	10.8	22.3	5.0	16.5
21	Village-like mixed development	121	41.9	45.9	64.9	4.0	23.0	8.9	11.9	23.0	3.0	14.1	6.1	11.3	23.0	5.2	16.9
22	Row houses and duplexes with yards	844	41.9	45.9	64.9	4.0	23.0	8.9	11.9	23.0	3.0	14.1	5.8	10.8	22.2	5.0	16.4
23	Detached single-family homes with yards	4,658	41.5	45.4	64.4	3.9	22.9	8.6	11.7	22.7	3.0	14.1	5.4	10.2	21.3	4.8	15.9
24	Villas and town villas with park-like gardens (mostly 1870s-1945)	666	40.6	44.3	63.2	3.7	22.6	8.1	11.2	22.1	3.1	13.9	6.0	11.2	22.9	5.2	16.8
25	Densification in single-family home areas, mixed development with yards and semi-private greening (1870s to present)	352	40.9	44.7	63.6	3.8	22.7	8.3	11.4	22.3	3.1	14.0	6.4	11.8	23.8	5.4	17.4
27	Cemetery	187	39.0	42.4	61.1	3.4	22.1	7.3	10.6	20.9	3.2	13.6	5.0	9.5	20.3	4.5	15.3
29	Core area	282	42.9	47.0	66.2	4.1	23.3	9.4	12.3	23.7	3.0	14.3	8.6	15.6	29.0	7.0	20.4
30	Commercial and industrial area, large-scale retail, sparse development	1,052	42.9	47.0	66.2	4.1	23.3	9.4	12.4	23.7	3.0	14.3	6.8	12.5	24.7	5.7	17.9
31	Commercial and industrial area, large-scale retail, dense development	194	42.9	47.1	66.2	4.1	23.3	9.4	12.4	23.7	3.0	14.3	7.8	14.2	27.1	6.4	19.3
32	Utilities area	120	42.1	46.1	65.1	4.0	23.0	9.0	12.0	23.2	3.0	14.2	6.5	12.0	24.0	5.5	17.5
33	Non-residential mixed-use area, sparse development	147	42.1	46.1	65.1	4.0	23.1	9.0	12.0	23.1	3.0	14.2	6.9	12.7	25.0	5.8	18.1
36	Tree nursery / horticulture	91	41.8	45.8	64.8	3.9	23.0	8.8	11.9	23.0	3.0	14.1	4.6	8.8	19.1	4.2	14.5
37	Allotment garden in general	774	42.2	46.2	65.2	4.0	23.1	9.0	12.0	23.2	3.0	14.2	4.0	7.9	17.6	3.9	13.6
38	Non-residential mixed-use area, dense development	22	42.3	46.3	65.4	4.0	23.1	9.1	12.0	23.3	3.0	14.2	7.7	14.0	26.9	6.3	19.2
41	Security and order	93	41.3	45.2	64.1	3.8	22.8	8.6	11.6	22.6	3.1	14.0	6.6	12.1	24.2	5.5	17.6
43	Administrative	186	41.9	45.8	64.9	4.0	23.0	8.9	11.9	23.0	3.0	14.1	7.2	13.2	25.6	6.0	18.4

44	University and research	105	41.8	45.8	64.8	3.9	23.0	8.8	11.9	23.0	3.0	14.1	6.7	12.3	24.4	5.6	17.7
45	Culture	86	41.7	45.6	64.7	3.9	22.9	8.8	11.8	22.9	3.0	14.1	6.9	12.7	25.0	5.8	18.0
46	Hospital	116	40.6	44.4	63.2	3.7	22.6	8.2	11.3	22.1	3.1	13.9	6.7	12.3	24.4	5.6	17.7
47	Children’s day care centre	246	41.2	45.0	63.9	3.8	22.8	8.5	11.5	22.5	3.1	14.0	6.5	11.9	23.9	5.5	17.4
49	Church	115	41.0	44.8	63.8	3.8	22.7	8.4	11.5	22.4	3.1	14.0	6.6	12.1	24.2	5.5	17.6
51	Other youth facilities	68	40.1	43.8	62.6	3.6	22.5	7.9	11.1	21.8	3.2	13.8	5.8	10.9	22.3	5.0	16.5
53	Green space / park	1,190	40.2	43.9	62.7	3.7	22.5	8.0	11.1	21.8	3.1	13.8	5.1	9.8	20.6	4.6	15.5
54	City square / promenade	106	42.4	46.4	65.5	4.0	23.1	9.1	12.1	23.3	3.0	14.2	7.0	12.8	25.2	5.8	18.2
55	Forest	2,795	36.0	38.9	57.2	2.9	21.2	5.7	9.3	18.9	3.5	13.1	5.8	10.8	22.3	5.0	16.5
56	Agriculture	375	43.0	47.2	66.4	4.2	23.3	9.5	12.4	23.8	3.0	14.3	2.2	4.9	12.4	2.8	10.2
57	Fallow area	940	41.8	45.7	64.7	3.9	22.9	8.8	11.8	22.9	3.1	14.1	4.2	8.2	18.0	4.0	13.8
58	Camping ground	19	38.1	41.4	60.0	3.3	21.8	6.9	10.2	20.4	3.3	13.5	5.4	10.1	21.2	4.8	15.9
59	Weekend cottages and allotment-garden-type areas	243	41.1	44.9	63.8	3.8	22.8	8.4	11.5	22.4	3.1	14.0	4.6	8.9	19.3	4.3	14.7
60	Other public facilities and special-use areas	143	41.1	45.0	63.9	3.8	22.8	8.5	11.5	22.5	3.1	14.0	6.4	11.9	23.8	5.4	17.4
72	Parallel row buildings with architectural green strips (1920s to 1930s), 3-5-storey	370	41.1	45.0	63.9	3.8	22.8	8.5	11.5	22.5	3.1	14.0	6.8	12.5	24.7	5.7	17.9
73	Multi-storey residential development since the 1990s (1990s to present)	324	42.6	46.7	65.8	4.1	23.2	9.2	12.2	23.5	3.0	14.3	7.0	12.8	25.1	5.8	18.2
91	Parking area	219	43.1	47.3	66.4	4.2	23.3	9.5	12.5	23.9	3.0	14.4	6.7	12.4	24.5	5.6	17.8
92	Railway station and railway ground, without track area	264	42.8	46.9	66.0	4.1	23.2	9.3	12.3	23.6	3.0	14.3	6.5	12.0	24.0	5.5	17.5
93	Airport	40	43.5	47.7	66.9	4.2	23.5	9.7	12.7	24.1	3.0	14.4	3.4	6.8	15.7	3.5	12.3
94	Other traffic areas (e.g. traffic islands etc.)	558	42.2	46.2	65.3	4.0	23.1	9.0	12.1	23.2	3.0	14.2	6.3	11.6	23.4	5.3	17.1
99	Track area	557	42.5	46.5	65.6	4.1	23.2	9.2	12.2	23.4	3.0	14.2	6.0	11.2	22.7	5.2	16.7

Tab. 1: Time series of the mean number of climatological threshold days for different time periods per area type (data as of December 31, 2010, SenStadtUm 2010)

References

[1] **Abgeordnetenhaus Berlin [House of Representatives of Berlin] 2016:**
Berliner Energie- und Klimaschutzprogramm 2030 [Berlin Energy and Climate Protection Programme 2030] – implementation period 2016 – 2020, draft – for resolution –, printed matter 17/2987, June 7, 2016.
Internet:
http://www.parlament-berlin.de/ados/17/IIIPlen/vorgang/d17-2987.pdf
(accessed on August 28, 2016)

[2] **CEC-Potsdam n.d.:**
WETTREG 2010 – Wetterlagenbasierte Regionalisierungsmethode [regionalisation method based on weather conditions], Online-Informationen und Datenzugriff [online information and data access], Potsdam.
Internet:
http://www.cec-potsdam.de/wettreg.html
(accessed on August 26, 2016)

[3] **EWG Bln (Berliner Energiewendegesetz [Berlin Energy Transition Act]) of March 22, 2016.**
Internet:
http://gesetze.berlin.de/jportal/?quelle=jlink&query=EWendG+BE&psml=bsbeprod.psml&max=true&aiz=true#jlr-EWendGBEpP16
(accessed on August 26, 2016)

[4] **GEO-NET Umweltconsulting GmbH 2016:**
Ergänzung des aktualisierten Grunddatenbestandes Stadtklima um Kennwerte zum Klimawandel [Supplement to the updated basic data set on urban climate with parameters for climate change], Hanover.
Download:
http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/download/Umweltatlas_04_12_2016_Entwicklung_KenntageKlima.pdf
(accessed on August 26, 2016)

[5] **IPCC (Intergovernmental Panel on Climate Change) 2007:**
Fourth Assessment Report (AR4), Climate Change 2007, Geneva.
Internet:
http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm
(accessed on February 19, 2018)

[6] **Reusswig, F.; Becker, C.; Lass, W.; Haag, L.; Hirschfeld, J.; Knorr, A.; Lüdeke, M. K.B.; Neuhaus, A.; Pankoke, C.; Rupp, J., Walther, C.; Walz, S.; Weyer, G.; Wiesemann, E. (2016):**
Anpassung an die Folgen des Klimawandels in Berlin (AFOK) [Adaptation to the Impacts of Climate Change in Berlin]. Partial climate protection concept. Main report. Expert assessment on behalf of the Senate Department for Urban Development and the Environment, Special Division Climate Protection and Energy (*Sonderreferat Klimaschutz und Energie*, SR KE). Potsdam, Berlin.
Internet:
https://www.berlin.de/sen/uvk/klimaschutz/anpassung-an-den-klimawandel/programm-zur-anpassung-an-die-folgen-des-klimawandels/
(accessed on September 17, 2020)

[7] **SenStadt (Senate Department for Urban Development Berlin) (ed.) 2010:**
Flächennutzung und Stadtstruktur - Dokumentation der Kartiereinheiten und Aktualisierung des Datenbestandes [Land use and urban structure - documentation of the mapping units and update of the data base], Berlin.
Internet:
Download (pdf)
(accessed on August 26, 2016)

[8] **SenStadtUm (Senate Department for Urban Development and the Environment Berlin) (ed.) 2011:**
Stadtentwicklungsplan (StEP) Klima [Urban Development Plan Climate], Berlin.
Internet:
https://www.stadtentwicklung.berlin.de/planen/stadtentwicklungsplanung/download/klima/step_klima_broschuere.pdf
(accessed on September 17, 2020)

[9] **SenStadtUm (Senate Department for Urban Development and the Environment Berlin) (ed.) 2013a:**
ERDF Project 027 Urban Climate – Final Report, Berlin.
Internet:

http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/download/Projektbericht_StadtklimaBerlin_SenStadtUm_IIID_2015.pdf
(accessed August 26, 2016)

[10] SenStadtUm (Senate Department for Urban Development and the Environment Berlin) (ed.) 2016a:
Stadtentwicklungsplan Klima KONKRET – Klimaanpassung in der Wachsenden Stadt [Urban Development Plan Climate CONCRETE – Climate Adaptation in the Growing City], Berlin.
Internet:
https://www.stadtentwicklung.berlin.de/planen/stadtentwicklungsplanung/download/klima/step_klima_konkret.pdf
(accessed on September 17, 2020)

Digital Maps

[11] SenStadt (Senate Department for Urban Development Berlin) (ed.) 2001:
Berlin Environmental Atlas, Edition 2001, 04.04 Temperature in Medium Low-exchange Nocturnal Radiation Periods, Berlin.
Internet:
http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/eia404.htm
(accessed on August 26, 2016)

[12] SenStadtUm (Senate Department for Urban Development and the Environment Berlin) (ed.) 2011a:
Berlin Environmental Atlas, Edition 2011, Map 06.08 Urban Structure differentiated, Berlin.
Internet:
http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/eid607.htm
(accessed on August 26, 2016)

[13] SenStadtUm (Senate Department for Urban Development and the Environment Berlin) (ed.) 2015:

Berlin Environmental Atlas, Edition 2015, Map 04.13 Long-term Development of Selected Climate Parameters, Berlin.
Internet:
http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/ei413.htm
(accessed on August 26, 2016)

[14] SenStadtUm (Senate Department for Urban Development and the Environment Berlin) (ed.) 2016:
Berlin Environmental Atlas, Edition 2016, Map 04.10 Climate Model Berlin - Analysis Maps, Berlin.
Internet:
http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/eib410.htm
(accessed on August 26, 2016)

[15] SenStadtUm (Senate Department for Urban Development and the Environment Berlin) (ed.) 2016b:
Berlin Environmental Atlas, Edition 2016, Map 04.11 Climate Model Berlin - Planning Advices Urban Climate, Berlin.
Internet:
http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/eib411.htm
(accessed on August 26, 2016)