04.05 Urban Climate Zones (Edition 2001)

Overview

Climate parameters such as air temperature, atmospheric moisture, excessive humidity and wind conditions are modified by urban structures and use patterns, such as topological profiles, and vegetation structures. A division of the urban area into various climate zones should contribute to a comprehensive description of the total ecological situation. The inclusion of other local factors, such as soil nutrient and moisture conditions, enables the definition of specific and separate urban areas. Specific plant and animal societies can then be attributed to them (cf. Sukopp 1990).

Numerous studies of flora and fauna in the Berlin urban area have been made. They clarify the sometimes critical influence of local climatic conditions on the variety of resident species. The specific value of the bog habitat type in climatically uninfluenced locations outside the city, for example, lies particularly in its very high number of more rare and endangered subarctic species. These species have survived as "relics of the late ice-age". They are bound directly to the extreme climatic conditions with very low minimum temperatures over the entire year and great variations of temperature (Working Group Species Protection Program 1984 - *Arbeitsgruppe Artenschutzprogramm 1984*).

Urban climate conditions can also facilitate the immigration or dissemination of other species. Certain plants and animals find suitable habitats in the urban heat island; such as ailanthus *(Ailanthus altissima)*, robinia, and summer lilac; and numerous amphibians and invertebrates. The climatic characteristics of the inner city such as excessive warming, excessive humidity, and low cooling rates can have high negative bio-climatic effects on humans in the summer.

The Climate Function Map (Map 04.07, SenStadtUm 2001) has been developed to present the essential data contained here so as to be used for planning purposes.

Statistical Base

The preparation of the Map of Urban Climate Zones required no measurements to be specially performed. The following maps could be used and integrated as bases:

- Mean Annual Air Temperature 1991-'92 at 2 m above ground (SenStadtUm 1993e)
- Long-Term Mean Air Temperatures 1961 - 1990 (Map 04.02, SenStadtUm 2001)
- Equivalent Temperatures under Low-exchange Weather Conditions (Map 04.04.3, SenStadtUm 1993f)
- Near-Ground Wind Speeds (Map 04.03, SenStadtUm 1994b)

Moreover, the following updated maps were used to include the structural developments since 1992:

- Long-Term Temperature Distribution 1961 - 1990 (Map 04.02, SenStadt 2001a) and
- Air Temperatures at Low-Exchange Weather Situations (Map 04.04.1, SenStadt 2001b).

Methodology

Definition of Urban Climate Zones

The following indicators were included for the definition of various urban climatic zones:

- **thermal changes**, which allow the derivation of tendencies for overheating, nocturnal cooling, and the number of frost days; and
- **moisture changes**, which, together with temperature changes, allow the determination of excessive humidity.

In addition, the description of zones included:

- **modification of near-ground wind conditions**; this provides insight into possible interactions between different climatic areas, as well as reference points for potential endangerment from emissions.

The most obvious modifications of climate conditions in metropolitan areas are to be expected from **temperature**. This parameter seemed appropriate as the main criterion for dividing Berlin into urban climatic zones. Table 1 gives air temperatures at 16 climate stations from September through November 1999.

Tab. 1: Characteristic Air Temperature Values, September through November 1999 at Climate Stations in Berlin

Station	Mean maximum	Mean value	Mean minimum	Mean daytime	Q*)
	°C				%
Wilmersdorf, Bamberger Strasse[1)]	14,8	11,7	8,9	6	51
Kreuzberg, Dessauer Strasse[1)]	15,1	11,4	8,2	6,9	61
Mitte, Alexanderplatz[2)]	15,1	11,8	8,9	6,1	52
Tegel, Airport [2)]	15,2	11,2	7,6	7,5	67
Tempelhof, Airport [2)]	15	11	7,3	7,7	70
Great Tiergarten[1)]	15,2	11	7,3	7,9	72
Zehlendorf, Miquelstrasse[1)]	15	10,8	7	7,9	73
Adlershof, Science Park[3)]	14,8	11	7,5	7,3	66
Mahlsdorf, Bergedorfer Strasse[3)]	14,8	10,3	5,8	9	87
Zehlendorf, Podbielskiallee[2)]	15	10,6	6,8	8,1	77
Steglitz, Fichtenberg (Meteor. Institute)[2)]	14,7	10,8	7,7	6,9	64
Steglitz, Colony K.-L.-Brücke-Nord[1)]	15,1	10,3	5,7	8	78
Spandau, Spandauer Strasse[1)]	15,9	10,5	6	9,9	95
Grunewald Forest, Dahlem Field[1)]	15,2	10,2	5,5	9,7	95
Grunewald Forest, Jagen 91[1)]	14,6	10,3	6,5	8,1	78
Karow, Kita Busonistrasse[3)]	14,4	10,5	6,6	7,8	74

[1)] Stations of the Tech. Univ. Measurement Network, [2)] data of the Berlin Weather Map (FU Berlin), [3)] Stations of the Investigation Program

*) Q describes the quotients from the mean daytime amplitude and the mean value of the air temperature multiplied by 100

Tab. 1: Reference Values of Air Temperatures from September through November 1999 at Climate Stations in Berlin

The quotient Q in Table 1 describes the average daily amplitude of average air temperature. This value is dependent upon the location of the climate stations in the urban area. Locations with high nocturnal cooling rates (such as the outer-city areas, or inner-city grassland areas) display a quotient Q of more than 85, while at stations in heavily built-up city center locations, the Q value is generally below 60. Regression analysis gives statistically significant proof for the connection between given quantities of mean annual or mean minimum temperatures and the target quantity Q. Q is thus a value well suited for the description of urban climate change.

Six **climatic zones** have been developed by means of the Q classification, analogous to the procedure chosen in the first edition of the Environmental Atlas (SenStadtUm 1985). A clearer overview was achieved by calculating the classification quanta for the temperature factors Mean Annual Temperature, Average Minimum Temperature and Average Daily Amplitude in the Q values, and including them in the climatic zone descriptions (see Table 2). Zone 0 describes areas unaffected by urban climate; Zones 1 through 4 show an increase in mean and average minimum air temperature and daily amplitude. The high degree of correlation between mean annual temperatures and the number of frost days (von Stülpnagel 1987) permits derivation of statements regarding the number of frost days in each zone.

Tab. 2: Parameters of Air Temperature and Number of Frost Days According to Climate Zone							
Zone	Urban Climate Change	Q 1)	Mean	Average Minimum	Average Daily Amplitude	Long-term Mean	No. of Frostdays
			1999[2)]			1961 - 90	1999 [2)]
		%	°C				
4	high	< 63	> 11,3	> 8,0	< 6,8	> 10,1	< 11
3	moderate	63 - 75	10,8 – 11,3	7,0 – 8,0	6,8 – 7,8	9,2 – 10,1	11 - 16
2	low	75 - 83	10,4 – 10,8	6,0 – 7,0	7,8 – 8,8	8,6 – 9,2	16 - 21
1	very low	83 - 97	9,8 – 10,4	5,0 – 6,0	8,8 – 9,8	7,6 – 8,6	21 – 26
0	none	97 -114	9,0 – 9,8	4,0 – 5,0	9,8 – 10,4	6,9 – 7,6	26 – 31
0*	none, extreme terrain climatic conditions	> 114	< 9.0	< 4,0	> 10,4	< 6,9	> 31

1) Q describes the quotient of average daily amplitude and mean air temperature multiplied by a factor of 100 multipliziert mit 100

[2]) September – November 1999

Tab. 2: Parameters of Air Temperature and Number of Frost Days, by Climatic Zone

Annual mean maximum and minimum temperatures from June 1991 through May 1992 were calculated for all measuring points on the individual monitoring routes (cf. Map 04.04.4). The West Berlin measurements were taken between 1981 and 1983, and were calculated for 1991-'92 on the basis of data from long-term climate stations. Measurements for East Berlin and the surrounding countryside were taken in 1991 or 1992. Supplementary measurements: In 1999, a total of 12 measurement trips were conducted on three routes. This resulted in 1935 test points, which were measured four times each. At the same time, the wind measurement was taken at 80 test points. Three climate stations were established especially for the check-up period. Taking into account all the time periods, **162 measurement trips** with **3735 test points** along **37 measurement routes**, and the data of **42 measurement stations** were evaluated. The measurement points were assigned to climatic zones, and point values on surfaces were interpolated.

Negative Bio-climate Effects

The superimposition of climate zones onto the distribution of equivalent temperatures during low-exchange weather conditions in 1991 (cf. Map 04.04.3) enables a depiction of areas **at risk of excessive humidity**. Equivalent temperature is derived from air temperature and the latent warmth potentially available by condensation of the given water vapor. The risk of excessive humidity was calculated on the basis of low equivalent temperatures because the available measurements of temperature and water vapor content of the air were taken at night. Areas greatly at risk of excessive humidity were defined on the basis of these conditions to be in Zone 4 at equivalent temperatures exceeding 38 °C, and in zone 3 at equivalent temperatures exceeding 39 °C. A classification of minimal risk of excessive humidity was assigned at equivalent temperatures under 36 °C, regardless of the climate zone's location. The matrix presented in Table 3 for **risk of negative bio-climatic effects** was derived by correlating the probability of risks of excessive humidity and the various nocturnal cooling values. The database was updated (2000).
Additional surveys for this parameter can be found in the Map 04.09 Bioclimate -Day and Night.

Tab. 3: Estimation of Negative Bioclimatic Effect Potentials in Relation to Risk of Excessive Humidity and Daily Amplitude					
Zone	Daily Amplitude[1)]	Equivalence Temperature [2)]			
		< 36	36 – 38	> 38	> 39
		° C			
0	9,7 – 10,1	very low	low		
1	9,1 – 9,7	very low	low	low	low
2	8,2 – 9,1	very low	low	low	low
3	7,2 – 8,2	moderate	moderate	moderate	high
4	< 7,2		high	very high	very high

Risk of excessive humidity: low medium high combination not available

[1)] Mean June 1991 - May 1992 - [2)] Mean in low-exchange nocturnal radiation period June 1991 - May 1992

Tab. 3: Estimation of Negative Bioclimatic Effect Potentials in Relation to Risk of Excessive Humidity and Daily Amplitude

Wind conditions proved capable of being described independent of urban climate zones. They may be classified according to use-specific factors (cf. Map 04.03). Only areas around high-rise developments and power plants are presented separately here. These areas can be assumed to have very high wind speeds and very turbulent wind conditions.

Map Description

Zone 0 basically includes meadows and pastures, farmland, forests, sewage farms and, in individual cases, very loosely cultivated areas with large percentages of vegetation, mainly outside the urban area. One focus is the open heathland and the meadows and pastures west of a line from Hennigsdorf to Potsdam. Also in this zone are Berlin forest areas near the city‘s edge, such as lowland glades or bogs (Bars Lake, Pech Lake, and the Teufelsbruch).

Nocturnal cooling is classified as very high; in forest areas as high. The frost day frequency is also high. Risk of excessive humidity is slight, almost without exception. Lowland areas such as the Döberitz Heath and the Teufelsbruch meadows east of Schönwalde present conspicuous terrain-climatic extreme situations **(Zone 0*)**. Nocturnal cooling and frost day frequency is especially high there.

Both daytime and nighttime wind speeds are considerably lower in closed forest areas. This is also true of non-densely built residential areas with large green areas. Wind reduction in grasslands and fields is moderate to slight during the day, and moderate at night. The formation of strong ground inversion layers during the nocturnal radiation period reduces wind speeds, and thus aeration, considerably.

Zone 1 was the zone which the first edition of this map assumed would reflect open-landscape conditions. In fact, however, the inclusion of the surrounding countryside shows the occurrences of clearly lower mean temperatures and minimum temperatures, as well as greater daily temperature amplitudes. It must therefore now be assumed that areas in Zone 1 are only very slightly influenced by the city. These areas are mainly long stretches of forests located near the city‘s outskirts; large green areas, mostly far from the inner city; a large portion of areas in the surrounding countryside used agriculturally; and large, low-density residential areas outside of Berlin. Some specific large open areas at the edge of the inner city have characteristics of Zone 1, such as the Südgelände, the Prenzlauer Berg Volkspark, Jungfernheide Park, and forest and allotment garden areas around the Königsheide.

Nocturnal cooling and incidence of frost days are generally high here, and, in forest areas, more moderate. The risk of excessive humidity is very slight in most areas of this zone.

Both daytime and nighttime wind-speed reduction in areas of denser vegetation are categorized as very high. Parks near inner-city emission areas are extremely endangered by emissions. Agricultural areas experience high daytime and moderate nighttime wind speeds. Cold air formation here causes stabilization of near-ground air layers during low-exchange nocturnal radiation periods.

Zone 2 use-patterns are largely those typical for the city's edge, such as low-density and allotment gardens. This zone also includes large inner-city or near-inner-city open space complexes, or parts of them, such as:

- Tempelhof Airport, the Hasenheide, cemeteries, Bergmannstrasse;
- the Südgelände, allotment gardens on both sides of Priesterweg, the Bergstrasse Cemetery, the Insulaner;
- the Tiergarten.

Also assigned to Zone 2 are all major bodies of water; but for technical reasons, only their banks and shores could be used for direct measurements of climatic parameters. Major horizontal gradients across the expanses of bodies of water are not to be expected, however.

Zone 2 is distinguished by moderate nocturnal cooling and frost day frequency. Some portions are located in areas of very slight risk of excessive humidity; most, however, are in areas of moderate risk of excessive humidity. Wind speeds are reduced greatly to moderately throughout the daytime, depending on the vegetation and development structures. Large-surface bodies of water and knolls are very well aerated, and are thus less endangered by emissions.

Zone 3 includes a large part of the inner city's edge, some areas on the outskirts with high-density development, and also most high-rise residential areas on the outskirts of the city. The inner city area

itself has some small parks and vacant areas, but adjacent open spaces and developed edge areas as described in Zone 2 are categorized here.

Nocturnal cooling and frost-day frequency in this zone are slight. The risk of excessive humidity is only moderate, except for a few areas of very slight risk (Olympic Stadium, the northwestern Wuhlheide) or high risk (the Haselhorst, the Tegel industrial area, the Köpenick old town core).

Reduction of daytime and nighttime wind speeds ranges from moderate to slight, depending on building and vegetation structures. Small green spaces are aerated more poorly. Urban vacant areas have higher daytime and greatly reduced nighttime wind speeds, depending on the degree of stabilization of near-ground air layers. Small business and industrial areas with large portions of undeveloped space, and railway areas, are relatively well-aerated all day. High-rise settlement areas must be assumed to have even stronger winds.

Zone 4 includes almost only the very dense inner city, and the heavily built-up and widely sealed industrial areas outside the inner city (such as the Spree Valley industrial area in the borough of Spandau).

In this map, analogously to the statements of the other updated climate maps, the area **of strongest inner-city change must now be represented as a closed ring**. The previous interruptions related to the connections of the Gleisdreieck area to the Humboldt Port and the area north of the Great Tiergarten can no longer be ascertained, as a result of major construction projects. The limits of Zone 3, which is favorably influenced by the Great Tiergarten, are approximately the Landwehr Canal to the south, Ebertstrasse to the east, and the Moabiter Werder to the north.

Nocturnal cooling and frost day frequency are very slight. There is a high risk of excessive humidity in most of Zone 4.

Reduction of wind speeds during the day can be asseumed to be moderate to slight. The normal wind speed reduction at night is at least delayed because in the street corridors, there is a lesser tendency for the near-ground air layers to stabilize. High winds are generally due to the narrow street corridors. However, this provides no improvement of the air exchange situation, because there is only an insufficient connection to higher air layers, or to the surrounding countryside. Endangerment from emissions is very high because of insufficient aeration, especially within closed development structures.

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