Senate Department for Urban Development and Environment

04.07 Climate Functions (Edition 1993)

Overview

The results obtained as part of the climate investigations for the Environmental Atlas Berlin have led to an inclusive inventory of the climatic situation in the urban area and in the nearer surrounding countryside. The Maps 04.02 - 04.06 (SenStadtUm 1993 and 1993d-f) contain besides a multitude of fundamentals, like air and surface temperature, vapor content of the atmosphere and near ground wind speeds also derived statements to the bioclimatic stress potential.

The inventory documents the connection also confirmed in many other investigations between the climate of different urban areas and their building, open space and vegetation structures. The typical local climate emerges however not only through the **structure** of an urban area but also through the **situation** within the city itself. So different spaces within a city can be affected by mutual interaction or that with the surrounding countryside. The temperature differences of adjacent areas are thereby of decisive significance for the climatic exchange. A reduction of these differences, e.g. through increase in the density of construction or assimilation of the structures worsens the city climate.

The purpose of this map is to delimit urban areas according to their **climatic function** and their effect on other spaces and to assess the **sensitivity** of this function with respect to structural changes. On this basis **measures** emerge for the maintenance and/or the improvement of the climatic situation.

Local climate is always formed within the context of the overarching **general weather situation**. As a rule, high exchange weather conditions with wind speeds over 4 m/s also have a climatically and air hygienic equalizing effect in the heavily built-up inner city area. In contrast, problematic weather conditions appear primarily at low wind speeds (under 4 m/s), high radiation intensity and at cloud degrees under 4/8. Also the warmth and vapor content brought in with the wide-area inpouring air masses of the atmosphere influence the formation of local climate conditions

Table 1 contains the proportional share of particular weather conditions for the years 1991 to February 1993, differentiated for the summer and the remaining seasons.

Tab. 1: Incidence of Particular Weather States According to Exchange and Sunlight Conditions from January 1991 to February 1993

Wind Speed (m/s)	Degree of Cloudiness (1/8)									
	0–1		2–3		4–5		6–7		≥ 8	
< 2	8,0	6,7	5,9	2,0	2,6	1,4	7,9	5,4	3,2	6,3
2 – < 4	15,4	14,8	8,8	4,5	6,5	3,2	18,3	13,0	5,3	14,2
4 – < 6	3,0	3,5	2,5	2,1	2,6	2,0	7,1	7,9	1,6	7,9
≥6	–	0,3	0,3	0,4	0,2	0,5	0,5	2,0	0,3	1,8

Summer | other seasons — potential for formation of local climatic effects

Entries in percentage of incidence rate for weather state, as to 3 hour values at measuring point Dahlem
Wind speeds (10-Minute Average) measured at ca. 16 m above buildings
(Source: Evaluations of the Institutes für Meteorologie der Freien Universität Berlin)

Tab. 1: Incidence of Particular Weather States according to Exchange and Sunlight Conditions from January 1991 to February 1993

Fundamentally a two-peak distribution can be found for each season. One peak represents weather conditions with slight wind speeds and relatively heavy cloudiness. The other peak represents the both climatically as well as air hygienic problematic weather conditions with slight wind speeds and high radiation intensity. In the winter months these weather conditions tend toward low exchange situations with high pollutant content in the atmosphere. In the summer they are caused chiefly through stationary high-pressure areas, in whose course a considerable bioclimatic stress potential can develop locally. In the summers under investigation, these weather conditions appeared in more than 38 % of all observed cases.

Above all against the background of these spatially conditioned problematic weather conditions, climatically favorable and structures with a relief impact are significant. These are on one hand the **extensive open spaces** near the **periphery** of the cities with their offshoots reaching in part as far as the city center. Determining for their efficacy are relief relationships, vegetation structures and the density of development in the transition areas between city center and surrounding countryside. Even slightly inclined valleys or **ventilation paths**, which proceed in the direction of the city, can function climatically and provide air hygienic relief, if these areas are openly structured.

With increasing distance from the outskirts and reduced connection to the climatic equalization areas of the surrounding countryside, small-scale wind systems between **inner city open spaces** and their direct environment become important. The air masses ascending over the built-up warmed area are replaced by cool air from the adjacent open spaces (plain wind effect). Within the green spaces themselves, a strong decrease in the ventilation is to be expected according to vegetation structure. At low exchange weather conditions the near ground cold air formed there causes an additional stabilization the near ground air layer. Thus the pollution risk to green spaces must be classified as very high. This makes clear that the positive effects of open spaces on the environment can only be fully unfolded if climatic equalization spaces are not burdened by near ground emitters. The spatial expansion of the impact area is determined by the edge development structure.

Investigations and measurements in the **Tiergarten** illustrate the connections described. The measured temperature differences between the internal area of the Tiergarten and the heavily built-up areas southwesterly and adjacent to the north amount to 7 °C. The broadly laid out streets within this open space lead to a division of the cold island in several parts (Horbert and Kirchgeorg 1980). The elevated city rail (S) and long-distance rail line hinders the exchange of air between the Tiergarten and the environment to the north and northwest. In contrast, at the underpasses in the south and east considerable ranges could be ascertained. To the west, the impact extends along the Straße des 17en Juni to Ernst-Reuter-Platz; then southwest up to the Breitscheidplatz (v. Stülpnagel 1987).

On account of the limited extent of open spaces, measures for the relief of conurbations also in the built-up and condensed areas are necessary. Of considerable importance in this connection is the greening of city places, streets, buildings and courtyards. Overwarming can be decreased so, the moisture level of the air increased and dust bound.

The warming of roofs depends very greatly on their color and their material (cf. Map 04.06, SenStadtUm 1993f). The most favorable conditions are to be found on greened roofs, whereby the kind of the plants plays a large role. However it must be acknowledged that the positive consequence of highly placed roofs on the more greatly burdened street space is limited. Altogether the greening of facades might have a greater climatic impact. Extensive investigations as to the significance of **facades and roof greening** for the micro-climate were conducted by Bartfelder and Köhler (1987) in Berlin.

The layout and/or the planting of vegetation for courtyard areas is also part of the climatic-air hygiene improvement of the residential area (Horbert, v. Stülpnagel, Welsch 1986, Horbert 1992). Narrow closed courts distinguish themselves through a decrease in the daytime temperatures and a slight cooling in the evening and night hours. The solar illumination is greatly limited. This applies also for the air exchange, from which a high pollution risk emerges. The climatic conditions improves with the greening of these courts, whereby for the advancement of the air exchange a wall greening is more favorable than the planting of trees. Larger court yards reach, in contrast to narrow courts and street space, clearly more favorable climatic characteristics especially, if the degree of sealing is low and the greening loosely structured. The cooling rate in the evening and night hours is high. The air exchange counts as very good. A connection with adjacent smaller courts via empty sites furthers their ventilation.

Statistical Base

The derivation and delimitation of spaces according to their climatic function required the collation of various basic information. Beside climate parameters data on use and surface structures as well as sealing were evaluated:

- Annual Mean Air Temperature 1991/92 at 2 m Elevation (SenStadtUm 1993c)
- Near Ground Wind Speeds (Map 04.03, SenStadtUm 1994)
- Temperature and Moisture Conditions in Medium and Low-exchange Nocturnal Radiation Periods

(Map 04.04, SenStadtUm 1993d)

- Urban Climate Zones (Map 04.05, SenStadtUm 1993e)
- Surface Temperatures at Day and Night (Map 04.06, SenStadtUm 1993f)
- Sealing of Soil Surface (Map 01.02, SenStadtUm 1995a)
- Actual Use of Built-up Areas (Map 06.01, SenStadtUm 1995b)
- Inventory of Green and Open Space (Map 06.02, SenStadtUm 1995c)
- Climate-effective Urban Structure Types (SenStadtUm 1993b)
- Density of Construction (SenStadtUm 1993a)
- Relief Map of the German Planning Atlases (Akademie für Raumordnung und Landesplanung 1949)

For some areas of Berlin expert opinions on climate could be consulted over and above this, so for:

- the Tiergarten (Sukopp et. al. 1979)
- the former “central district” area of West Berlin (borough Tiergarten and Gleisdreieck) (Sukopp et al. 1982)
- the Volkspark Rehberge (Sukopp et al. 1984)
- the Südgelände (Gleisdreieck/ allotment garden Priesterweg) (Horbert et al. 1982) and the Lehrter city station (Horbert 1991).

Methodology

An essential problem in the definition of climatically based aims and methods exists therein, that concrete limits and index values for the appraisal cannot be drawn from one of the regulations comparable to the Technical Instruction Air (i.e. TA-Luft). The commission “Reinhaltung der Luft” (Air Purity) of the Union of German Engineers (VDI) and the German Institute for Standardization (DIN) is working of course on a guideline for establishing of climate and air hygiene maps also for urban spaces. However, their release is to be expected in 1994 at the earliest.

It was thus necessary to define particular criteria and goals for the map of climate functions. The guidelines of the German Meteorological Society (DMG, 1989) prescribe a crude framework in that they strive for as ideal state of affairs a city climate which is largely free from pollutants and offers city-dwellers the largest possible diversity of atmosphere conditions under avoidance of extremes.

Basis for the available climate function maps (e.g. City manager of the City of Münster 1992, Neighborhood Association Stuttgart 1992, Local Government Association Ruhrgebiet (KVR) 1992) is the determination of the so-called **climatope**, spatial units, which are defined essentially through the elements relief and use and assumed to be relatively homogeneous in their microclimate. The synthetic climate function map for the Ruhr area, Dortmund part of the KVR defines for the urban area the following climate types: villa, outskirts, city, inner city, city center, industry and small business. The way they are recorded for large spaces makes it relatively easy to generate interpretations of heat pictures of the surface temperatures, topographical maps and land use inventory. On the basis of these climatopes climatic function areas are delimited and planning references compiled.

In the present map an attempt is made, which relies more essentially on the measurements of climate parameters and also further criteria, such as the area, location in the city and/or surrounding countryside as well as considers the mutual interactions among the sections. Thus the same terrain in the inner city load area would be judged differently than if it were situated on the outskirts of town. That is because the influential factors to which the area is subject and/or the influence, which the area exercises on others can be very different. In case of an appraisal based only upon structure types, it would only be concerned an uniform appraisal in both cases (e.g. Type "villa climate").

The delimited function spaces should be able to deliver statements as to which areas where

- on one hand a potential for the relief of other (adjacent and also further remote) spaces is available (areas of 1a and 1b) and
- on the other hand beyond the wide-area effects, the strongest addition loads are to be expected (areas of 4a and 4b).

Between these two poles, spaces were defined,

- in which the climatic conditions are favorable, i.e. no climatic load exists (relieved area 2)
- those in which their structures and functions present transitions between burdened and relieved areas (area 3).

Besides areas were to be marked, which to be assumed as preferred **air exchange areas**, i.e. which play an important role for the near ground fresh air transport.

For these climatic function areas the **sensitivity** was estimated **against use intensifications**. This sensitivity was rated as high, if an use intensification made probable a new classification as a more unfavorable function area. By use intensification is understood an increase in the built-up share as opposed to the undeveloped area. "This includes the transformation of the natural ground surface into a three-dimensional modeled space consisting predominantly of artificial materials, the reduction with it of vegetation covered surface as well as the influence through technical arrangements that cause waste heat and pollutant emissions" (Kuttler 1993).

The most important equalization effects issue from the **relief areas**. A low mean temperature as well as high cooling rates in the evening and night hours are made possible by their slight degree of sealing (< 20 %) and high vegetation share, so that these areas function as cold air generators. The wind and exchange relationships over open areas during the day can be considered as very good. However in tree stocked parks and especially in forests, they worsen rapidly. Above all, high pollution risks emerge occasionally at night, dependent on the proportion of open areas, through the stabilization of the near ground air layer, causing a significant decrease in the climatic equalization potential of these areas. This is especially true in the vicinity of emitters.

All open spaces were defined as climatic **relief areas 1a**, which lie within the load areas 4a/4b or border directly on these. The areas stand spatially in direct cover overbuilt areas and present in their function as cold air origin areas an essential potential for the relief of these equalization spaces. The extent to which this potential affects any single area can only be clarified through detailed investigations. Beside the area size and -geometry, the area's edge structures and/or the surrounding development are most important. According to v. Stülpnagel (1987) an area of approx. 10 ha can be taken as orientation measure for a larger outside effect. This assumes however, that also smaller areas at suitable local conditions can perceive equalization functions.

The extreme sensitivity toward development and sealing applies to the surfaces in area 1a. They are on the contrary in need of continuous maintenance, i.e. above all through avoidance of any pollutant emissions within these areas.

Area 1b can be found on the outskirts of town and in the open spaces of the surrounding countryside. They do not of course lie in direct proximity to the load areas. However due to their extensive area they exercise likewise an important relief function. Here a high sensitivity exists toward use-intensifying measures. It is especially their extensive area and the fact that these areas reach well into the outskirts of the city which gives them their decisive importance.

These areas are to be distinguished from built-up areas, which profit of course from the relief function the 1b areas, however through their development and degree of sealing which leads to average higher temperatures and slighter cooling rates than the relief areas themselves. Due to the still favorable climatic structure, the **relieved area** (area 2) offers the greatest potential for structural consolidation of all function spaces. According to current knowledge a cautious consolidation of these areas would result in no new classification as a climatically more unfavorable area. In which orders individually the boundaries for a structural condensation lie, can not be indicated all-inclusive; in each trap the possibilities are to be examined at the place itself, to compensate with measures like roof or facade greening negative climatic effects.

The climatic **transition area** (area 3) includes areas of very heterogeneous uses with different degrees of sealing and vegetation shares; accordingly the climate parameters differ between the values of the area 2 and the load area of 4a.

In the Map of Urban Climate Zones (Map 4.05, SenStadtUm 1993e) corresponds to the transition area in wide parts of the climate zone 3. That means moderate urban climatic change. In the areas direct nearby and with it direct interaction with relieved (area 2) or loaded (areas of 4a/4b) city spaces exists a high sensitivity facing use-intensifying actions, since at a structural condensation a climatically unfavorable consequence on this interaction function is to be expected. The exact delimitation of the sensitivity areas presupposes however broader investigations.

Load areas are those with a high degree of sealing (> 60 %) and over-construction (chiefly > 50 %), in which high mean temperatures, a slight cooling in the evening and night hours as well as a high humidity risk have been recorded. The in part, bad wind and exchange relationships lead locally to high pollution loads (cf. Map 04.03, SenStadtUm 1994).

The load area in areas are divided according to the intensity of climatically negative changes into high sensitivity toward use-intensifying actions (area 4a) and areas with very high sensitivity and urgent necessity for the implementation of suitable rehabilitation measures (area 4b). Here all open spaces are, even the smallest, are to be maintained.

The local and/or regional **wind systems** which produce air exchange between green and built-up areas (plain wind effect) and/or the surrounding countryside and the inner city cannot as a rule be registered without costly, targeted measurements in the terrain or model tests. In this map areas are shown on one hand, as preferred because of their structure for the near ground fresh air transport depicted and/or are to be examined for this purpose. Criteria for their appropriateness are above all a slight roughness of the surface, a sufficient width (as more as possible as the 10-fold amount of the surrounding edge structures) as well as predominantly low pollution load (Kuttler 1993, Mayer and Matzarakis 1992). Good **airstream channels** thus become formed e.g. through broad courses of the river, path lines and green areas with lower vegetation. On the other hand a small scale air exchange between equalization and load spaces for open spaces within or in direct proximity to the areas of 4a and 4b is presented. Here **plain wind currents** are primarily to be expected because of the large temperature gradient to the overheated neighboring developments during low exchange radiation weather conditions. The range of the relief effects or the existence of possible exchange obstacles can be ascertained however only through more exact investigations in the vicinity or experiments.

The first investigations into plain wind effects for Berlin were produced by the model study meanwhile supported by the BMFT "Project Effect of Regional Climate Changes in Urban Conurbations Using the Example of Berlin" (Wagner 1993). Here temperature and currents were simulated for a 7 x 7 km^2 inner city area on the basis of different land use parameters. Figure 1 shows a summer simulation, which was run using the marginal values typical for this season: In the green spaces of Tiergarten and Volkspark Rehberge the temperatures lie clearly lower than in the heated greatly sealed areas. In the area of the green spaces an acceleration in the current is indicated, while currents decelerate in the heavily built-up areas because of the friction. The increased air exchange proceeding with it is significant for the air hygiene situation in Berlin.

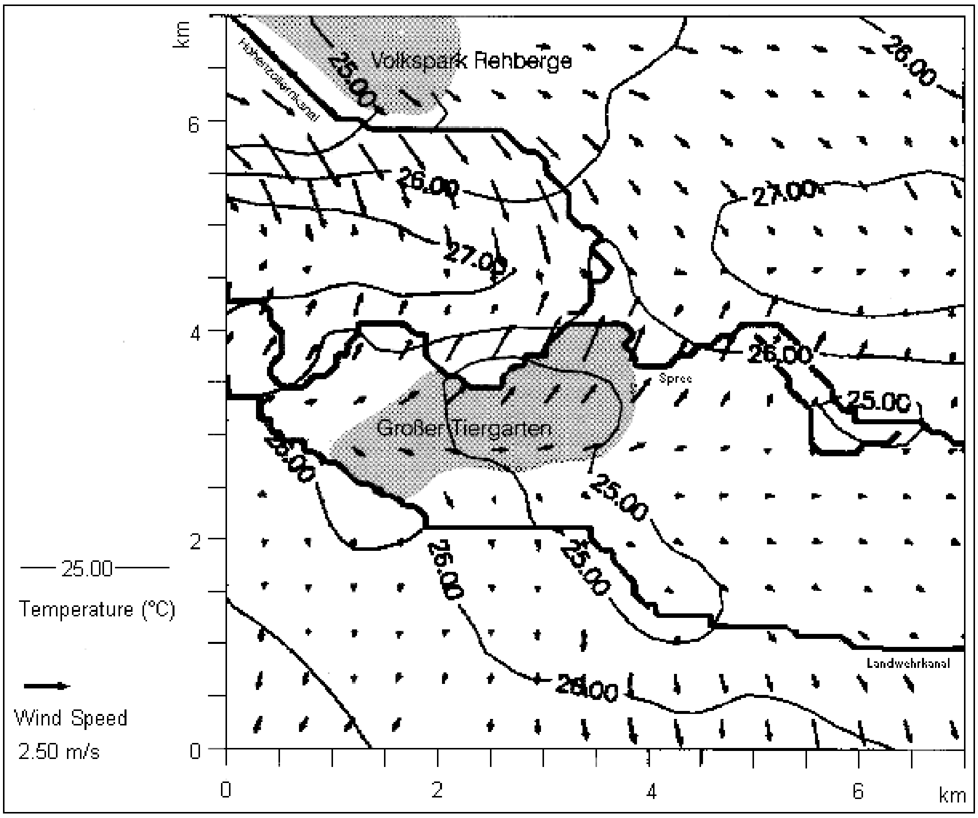

Fig. 1: Simulation of the Temperature and Wind Fields at 10 m Height in the Inner City Area of Berlin During a Summer Radiation Period around 14.00 o'clock CET, Considering Land Use. Model Assumes a West Wind of 3m/s (from: Wagner, changed slightly).

On the basis of the function spaces the measures emerge which are necessary for climatic reasons to minimize the local loads, to maintain available climatically favorable space and the air exchange between loaded and to optimize equalizing working spaces.

Map Description

A climatic relief function comes from two different open space types:

Area 1a includes islands within the climatic load area, through which up to now have prevented the formation of a closed inner city heat island in Berlin. These spaces are of particular importance in this regard

- Tiergarten/ Zoological Garden,
- Tempelhof Airport / Hasenheide/ cemeteries Bergmannstraße and
- Gleisdreieck to the north and south of the Yorckstrasse.

Examples for further important open spaces are the palace gardens Charlottenburg and the vacant and barren areas in Marzahn and in the industrial area Hohenschönhausen. Beside a multitude of smaller areas which are to be included, such as Kleistpark in Schöneberg or the Volkspark in Mitte, there also individual minute areas, which cannot be depicted at this scale, for which the described functions and characteristics nonetheless also fundamentally apply.

The **area 1b** includes largely undeveloped green areas on the outskirts of town and in the surrounding countryside. Above all in Weißensee and Pankow they reach from the former sewage farms and agricultural areas far into the urban area. A further important equalizing space is in the urban area formed by the up to now only sparsely built-up single-family settlements in Mahlsdorf-South and Kaulsdorf-South together with the adjacent Krummendammer Heide. Also the remaining inner city forests can be so classified. Wide-scale relief areas lie outside the urban area. On account of the former wall strip, here they border partly directly on the settlement areas of the city (e.g. large-scale settlement Gropiusstadt or high-rise development at the Tirschenreuther Ring in Marienfelde).

Climatically **relieved areas (area 2)** are subject either to the influence of the relief area 1b or are presently hardly climatically burdened because of their low degree of sealing and high amount of vegetation. In the urban area itself are only relatively few areas, such as Kladow, Lichterade, Rahnsdorf and Schmöckwitz are so classified. By far greater part of the relieved areas lies in the surrounding countryside near Zepernick, Neuenhagen, Schöneiche, Eichwalde/ Zeuthen, Blankenfelde, Teltow, Falkensee, Stolpe and Schildow.

In terms of area, the largest share of the inner city take the form of climatic **transition areas (area 3).** Beside all larger bodies of water, they include above all areas on the outskirts of town, in so far as they are subject to more intensive development, but still no congestion. (e.g. Staaken, Heiligensee, Buchholz, Karow, Mahlsdorf, Rudow, Buckow, Marienfelde, Zehlendorf). In the northeast and east of the city, the transition area extends to quite near the center of town (Prenzlauer Berg, Rummelsburger Bucht).

A mostly very dense development, joined with a high degree of sealing and an only slight vegetation share mark the climatic **load area**. This includes core areas of the city, whereby the east part with the exception of the borough Mitte is burdened only slightly. In this central section there are still extensive areas which are not excessively built-up. Areas outside the inner city which can be classified as stressed are distinct concentrations, for example the Spandau old town or the area Niederschöneweide. Two areas can be distinguished according to the degree of the climatic load.

Area 4a includes built-up areas of varying density, in part also climatically overloaded smaller open spaces, industry and small business areas, which display moderate to highly urban climatic characteristics. As a rule these areas border on the most heavily burdened area of 4b. In certain spaces, however, they are themselves the most heavily burdened areas. This is above all in the very congested parts of town lying on the outskirts (Zehlendorf, Friedrichshagen, Hellersdorf, Buch) and in the surrounding countryside (Potsdam suburban housing development, parts of Babelsberg, Schönefeld and Hennigsdorf). In this area not only is the sensitivity toward use intensifications high, rather climatic improvements must be made as part of building and rehabilitation measures. This affects the improvement of ventilation and likewise an increase in the presently meager amount of vegetation.

Area 4b delimits the urban areas, in which the highest negative changes in the radiation and heat balance as well as in the air exchange conditions is to be expected. Large parts of the inner city boroughs Tiergarten, Wedding, Prenzlauer Berg, Mitte, Friedrichshain, Kreuzberg, Tempelhof, Schöneberg and Charlottenburg form an urban heat island, which is ameliorated solely by the large green and open spaces of the relief area 1a. The sensitivity with respect to use intensifications is very high throughout. The improvement of the climatic situation must be given highest priority in building and rehabilitation measures.

Only an isolated incidence of relief-influenced **airstream channels** is to be expected because of the slight relief differences in Berlin. More decisive than the relief are e.g. the roughness of the terrain and the relationship between height and width. Thus the broad courses of the river Havel and the Spree flats can be said to function as effective airstream channels. However, this also applies to less distinctive streams like the Wuhletal, Teltow and Landwehr canal. Similar channel functions are also to be expected from the lines of the city rail (S) and long-distance railways as well as by individual green areas. The broad road network typical for Berlin is unfit for these purposes because of the high pollution load. Suitable and if necessary locally monitored airstream channels should be kept free of congestion, obstructive development and emissions. Also the green spaces lying in sphere of influence of the channels should be structured as openly as possible.

Extensive cold air movements (plain winds) can occur fundamentally in the impact area of all larger green spaces. In this map such air movement is presented however only for green spaces within and/or in direct vicinity of the exposure areas. As already shown, it does not deal with individually detected incidents, but with assumed movements.

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