

04.07 Climate Functions (Edition 2001)

Overview

The results obtained in the course of the climate investigations for the Berlin Environmental Atlas have permitted the development of a comprehensive inventory of the climatic situation in the urban area and in the nearby surrounding countryside. In addition to a multitude of fundamental data, such as air and surface temperatures, vapor content of the atmosphere and near-ground wind speeds, the Maps 04.02 - 04.06 and 04.09 (SenStadt 2001 a-d and SenSUT 1998) also contain derived information on bioclimatic stress potentials.



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

The purpose of this map is to delimit urban areas according to their **climatic function** and their effect on other areas, and to assess the **sensitivity** of this function with respect to structural change. On this basis, **measures** for the maintenance and/or improvement of the climatic situation can be developed. Updating of the state of information as of 2000 has also permitted the construction projects of the '90s to be taken into consideration.

The local climate is always formed within the context of the overarching **general weather situation**. As a rule, high-exchange weather conditions with wind speeds of over 4 m/s also have an equalizing effect in terms of both climate and of air purity in heavily built-up inner-city areas. By contrast, problem weather conditions appear primarily at low wind speeds (under 4 m/s), high-radiation intensity and cloud cover of less than 4/8. Also, the heat and vapor contents introduced by the large-scale inpouring of atmospheric air masses influence the formation of local climate conditions.

Table 1 shows the proportional shares of particular weather conditions for 1991 through February 1993, differentiated between 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, by Exchange and Sunlight Conditions, from January 1991 through February 1993

Basically, 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 represents weather conditions with slight wind speeds and high radiation intensity, which are a problem both in terms of climate and of air purity. During 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 by

stationary high-pressure areas, in the course of which considerable bioclimatic stress potential can develop locally. In the summers under investigation, these weather conditions appeared in more than 38% of all observed cases.

Especially in view of these spatially caused problem weather conditions, climatically favorable structures and structures which provide relief are of great significance. These include on the one hand **extensive open spaces** near the **periphery** of cities with offshoots extending, in some cases, as far as the city center. Determinant for their degree of efficacy are the terrain-relief situation, vegetational structures and the density of development in the transition areas between the city center and the surrounding countryside. Even slightly sloped valleys or **ventilation paths** leading toward the city can serve a climatic effect and provide clean-air relief, if they are openly structured.

With increasing distance from the outskirts and reduced connections to the climatic equalization areas of the surrounding countryside, small-scale wind systems between **inner-city open spaces** and their immediate environment gain in importance. 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 ventilation is to be expected, depending on the vegetation structure. At low exchange weather conditions, the near-ground cold air formed there causes additional stabilization of the near-ground air layer. Thus the pollution risk to green spaces must be classified as very high. This shows clearly 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 extent of the impact area is determined by the structure of building development around its edges.

Investigations and measurements in the **Great Tiergarten** illustrate the connections described; however, they refer to conditions prior to the extensive construction activity of the '90s. The temperature differences measured between the internal area of the Tiergarten and the heavily built-up adjacent areas to the southwest and to the north amounted to 7°C. The broadly laid out streets within this open space led to a break-up of this island of coolness into several parts (Horbert and Kirchgeorg 1980). The elevated city rapid-rail and main-line rail line hindered the exchange of air between the Tiergarten and the neighboring area to the north and northwest. By contrast, considerable extents could be ascertained at the underpasses in the south and east. To the west, the impact extends along the Strasse des 17. Juni up to Ernst-Reuter Platz, and then southwest to Breitscheidplatz (von Stülpnagel 1987).

The results of the construction in the Potsdamer Platz-Ministerial Gardens-Pariser Platz / Brandenburg Gate area up to the Spree Bend are elucidated in the climate maps mentioned above and also here, under Map Description.

Due to the limited amount of open space, measures for the relief of urban areas, including their built-up and densely-developed areas, are necessary. Of considerable importance in this regard is the greening of city spaces, streets, buildings and courtyards. In this way, overwarming can be decreased, the moisture level of the air can be increased, and dust can be bound.

The warming of roofs depends very greatly on their color and their material (cf. Map 04.06, SenStadt 2001d). Most favorable are greened roofs, with the type of plants playing a major role. However, the positive effects of such roofs, at their high locations, on the greatly burdened street area must be considered as limited. The greening of facades might have a greater overall climatic impact. Extensive investigations into the significance of **facades and roof greening** for the micro-climate were carried out in Berlin by Bartfelder and Köhler (1987).

The landscaping and/or the planting of vegetation for courtyard areas is also part of the climatic and clean-air improvement of residential areas (Horbert, von Stülpnagel, Welsch 1986, Horbert 1992). Narrow closed courtyards are characterized by a decrease in daytime temperatures and a slight cooling in the evening and nighttime hours. Insolation is greatly limited, as is air exchange, which creates a high pollution risk. The climatic condition improves with the greening of these courts, although wall-greening is more favorable for the promotion of air exchange than the planting of trees. Large courtyards achieve clearly more favorable climatic characteristics than narrow courts and street areas, especially, if the degree of sealing is low and the vegetation loosely structured. The cooling rate in the evening and nighttime hours is high. The air exchange is very good. A connection with adjacent smaller courtyards via vacant lots promotes this 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 1994b)
- Temperature and Moisture Conditions in Medium and Low-exchange Nocturnal Radiation Periods (Map 04.04, SenStadtUm 1993f) and (SenStadt 2001b)
- Urban Climate Zones (Map 04.05, SenStadt 2001c)
- Surface Temperatures at Day and Night (Map 04.06, SenStadtUm 2001d)
- Sealing of Soil Surface (Map 01.02, SenStadtUm 1995d)
- Actual Use of Built-up Areas (Map 06.01, SenStadtUm 1995b)
- Inventory of Green and Open Space (Map 06.02, SenStadtUm 1995f)
- 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 und Vogenbeck, A. 2000)
- 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 goals and methods is that no concrete limits and index values for evaluation can be taken from any regulation, i.e., comparable to the Technical Instruction on Air Quality (TA-Luft).

It has therefore been necessary to define particular criteria and goals for the map of climate functions. The guidelines of the German Meteorological Society (DMG, 1989) provide a rough framework, since they set the goal of an ideal situation in which an urban climate would be largely free of pollutants, and would offer city-dwellers the greatest possible diversity of atmospheric conditions, while avoiding the extremes.

Moreover, since the end of 1997, the VDI Guideline 3787, Sheet 1: Climatic and Air Hygiene Maps for Cities and Regions, has existed, in which methods for the preparation of climatic and air hygiene maps are to be introduced and recommended. The main emphasis of the recommendations is the use of so-called synthetic climatic maps, "which no longer show the spatial distribution of climatic elements, but rather mutually delimit spaces in which certain climatic features relevant for planning occur together and can mutually reinforce their effects" (ibid.). The abstraction necessary for that is to be achieved by the certification of climatic zones, i.e., spatial units in which the micro-climatically most important factors are relatively homogeneous and their consequences differ little.

For example, the Synthetic Climatic Functions Map, Ruhr District, Dortmund Section of the KVR defines the following climatic zones for the municipal area: Manor Homes, Outskirts, Urban, Inner-City, Business District, and Industrial/Commercial. They can be ascertained relatively easily for major areas by means of interpretation of heat-images of the surface temperatures, topographical maps and land-use surveys. Climatic functional areas are delimited, and planning indicators developed, on the basis of these climatic zones in other examples as well (e.g. City Manager of the City of Münster 1992, Stuttgart Neighborhood Association 1992).

The present map pursues an approach of abandoning this static philosophy, and also taking into account as far as possible functional connections, the structure of the investigation area and such other criteria as area size, location of the area in the city or the surrounding countryside, and the interactions of areas with one another (cf. also Mosimann, T. et al. 1999). The knowledge (Map 04.04.4, SenStadt 2001b) gained in the preceding investigation projects has served to confirm the statements. As a result, e.g. the same area in an inner-city impact location would thus be judged differently from a location at the outskirts, since the impact factors on the area or the effect which the

area exerts on other areas could be very different. In the case of an assessment related only to structural types (e.g. the "Manor Homes Climate" type), by contrast, a uniform assessment would result in both cases.

The functional areas delimited should be able to provide answers to the question as to where:

- on one hand, a potential for **relief** of other (adjacent or even remote) spaces would be available (Categories 1a and 1b); and
- on the other hand, the greatest **additional burdens** could be expected, beyond the large-scale effects (Categories 4a and 4b).

Between these two poles, spaces were defined:

- in which the climatic conditions are favorable, i.e. no climatic burden exists (**relief** Category 2); and
- in which the structures and functions present are **transitional** between burdened and relief areas (Category 3).

In addition, areas were to be marked which are to be assumed to be preferred **air exchange areas**, i.e. which play an important role in near-ground fresh-air transportation.

For these climatic functional areas, **sensitivity to use intensification** was estimated. This sensitivity was rated as high if a use intensification made reclassification into a less favorable functional area category probable. "Use intensification" means an increase in the built-up as opposed to the undeveloped proportion of an area. "This includes the transformation of the natural ground surface into a three-dimensional modeled space consisting predominantly of artificial materials, the resulting reduction of vegetation-covered surface area, and the effect of technical measures 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 proportion of vegetation-covered area, so that these areas function as cold-air generators. The wind and exchange conditions over open areas during the day can be considered very good. However, in tree-stocked parks and especially in forests, they decrease rapidly. In particular, high pollution risks sometimes occur at night, depending on the proportion of open areas, due to 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 which lie within the burdened areas of Categories 4a/4b, or border directly on them, have been defined in **climatic relief Category 1a**. These areas are spatially direct connected to densely built-up areas, and, due to their function as cold-air generators, provide essential potentials for the relief of these residential areas. The extent to which this potential affects any single area can only be ascertained through detailed investigations. In addition to the area's size and geometry, the area's edge structures and/or the surrounding development are the most important factors. von Stölpnagel (1987) cites an area of approx. 10 ha as a standard of orientation for a major external effect, but also demonstrates that even smaller areas can, given suitable local conditions, assume equalization functions.

The areas in Category 1a demonstrate the most extreme sensitivity toward development and sealing. They must be permanently supported in their function, i.e. especially through avoidance of any pollutant emissions within these areas.

Category 1b areas can be found on the outskirts of the city and in the open spaces of the surrounding countryside. They are not of course directly adjacent to the burdened areas. However, due to their great extent, they also perform an important relief function. They have a high sensitivity to use-intensifying measures. It is especially their size and the fact that they extend well into the outskirts of the city which makes them so decisively important.

These areas are to be distinguished from built-up areas, which of course profit from the relief function of the Category 1b areas, but which, due to their development and their degree of sealing, have higher average temperatures and slighter cooling rates than the relief areas themselves. Due to their still favorable climatic structures, the **relief areas** (Category 2) offer the greatest potential for structural consolidation of all functional spaces. According to current knowledge, a cautious densification of development in these areas would not result in reclassification as a climatically less favorable area. The range within which structural densification might take place cannot be indicated overall; the possibilities would have to be examined in each case on site, and the negative climatic effects be compensated with such measures as roof or facade greening.

The climatic **transitional areas** (Category 3) include areas of very heterogeneous uses, with differing degrees of sealing and vegetational-coverage proportions. Accordingly, the climatic parameters differ between the values of Category 2 and the burdened Category 4a.

In the Map of Urban Climatic Zones (Map 4.05, SenStadt 2001c), the transitional area thus corresponds largely to Climatic Zone 3. That means moderate urban climatic change. In the areas directly adjacent and hence in direct interaction with relieved (Category 2) or burdened areas (Categories 4a/4b), there is a high sensitivity to use-intensifying activities, since structural densification can be expected to have a climatically unfavorable effect on this interactive function. However, the exact delimitation of the sensitivity areas will require further-reaching investigation.

Burdened areas are those with a high degree of sealing (> 60%) and built-up proportion (for the most part > 50%), where high mean temperatures, slight cooling in the evening and nighttime hours, and high humidity risks have been recorded. The often poor wind and exchange conditions can lead to a local high pollution burden (cf. Map 04.03, SenStadtUm 1994a).

The burdened area is subdivided into areas of high sensitivity to use-intensifying activities (Category 4a) and areas of very high sensitivity and the urgent need for implementation of suitable rehabilitation measures (Category 4b), depending on the intensity of climatically negative changes. Here, all open spaces, even the smallest, are to be maintained.

The local and/or regional **wind systems** which produce air exchange between green and built-up areas (corridor-wind effect) and/or the surrounding countryside and the inner city, cannot as a rule be ascertained without costly, targeted measurements in field or model tests. The present map thus on the one hand shows areas which, because of their structure, are preferred areas for near-ground fresh-air transportation, and/or are to be examined for this purpose. Criteria for their appropriateness are particularly slight roughness of the surface, a sufficient width (if possible 10 times the height of the structures around the edge of the area) and a predominantly low pollution burden (Kuttler 1993, Mayer and Matzarakis 1992). Good **air-flow channels** are thus formed e.g. through broad river courses, railway lines and green areas with low vegetation.

On the other hand, the present map shows small-scale air exchange between equalization and burdened areas for open spaces within or directly adjacent to areas of Categories 4a and 4b. Here, **corridor-wind currents** are primarily to be expected during low-exchange radiation weather conditions, because of the large temperature gradient to the overheated neighboring developed areas. The range of the relief effects or the existence of possible exchange obstacles can however only be ascertained through more detailed investigations in the immediate vicinity, or through model experiments, since it will require a major technical effort.

Clear meteorological proof of these valuable wind-circulation corridor processes could be obtained e.g. in the area of the **Weissensee farmland** between Heinersdorf, Malchow, Karow and Blankenburg (German Meteorological Service DWD 1994). In the investigation area, it was shown that at wind speeds of less than 1.5 m/s, an inflow of air from the surrounding countryside in the direction of the city center occurred, regardless of the state of overall air circulation. Under the current regional land-use plan, large parts of this area are part of the projected future open-space loss areas, due to rezoning as mixed or residential areas (Berlin Land-Use Plan, SenStadt 2001e). Model investigations on wind-corridor effects have been presented, e.g. in the context of the project "Effects of Regional Climate Change in Metropolitan Areas, Using the Example of Berlin", by the Federal Ministry for Research and Technology (Wagner 1993). Here, temperature and currents were simulated for a 7x7 km² inner-city area on the basis of various 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 the Tiergarten and the Rehberge Volkspark, the temperatures are clearly lower than in the heated, largely sealed areas. In the green-space areas, an acceleration of the air current is shown, while currents decelerate in the heavily built-up areas because of friction. The associated increase in air exchange is significant for the clean-air situation in Berlin.

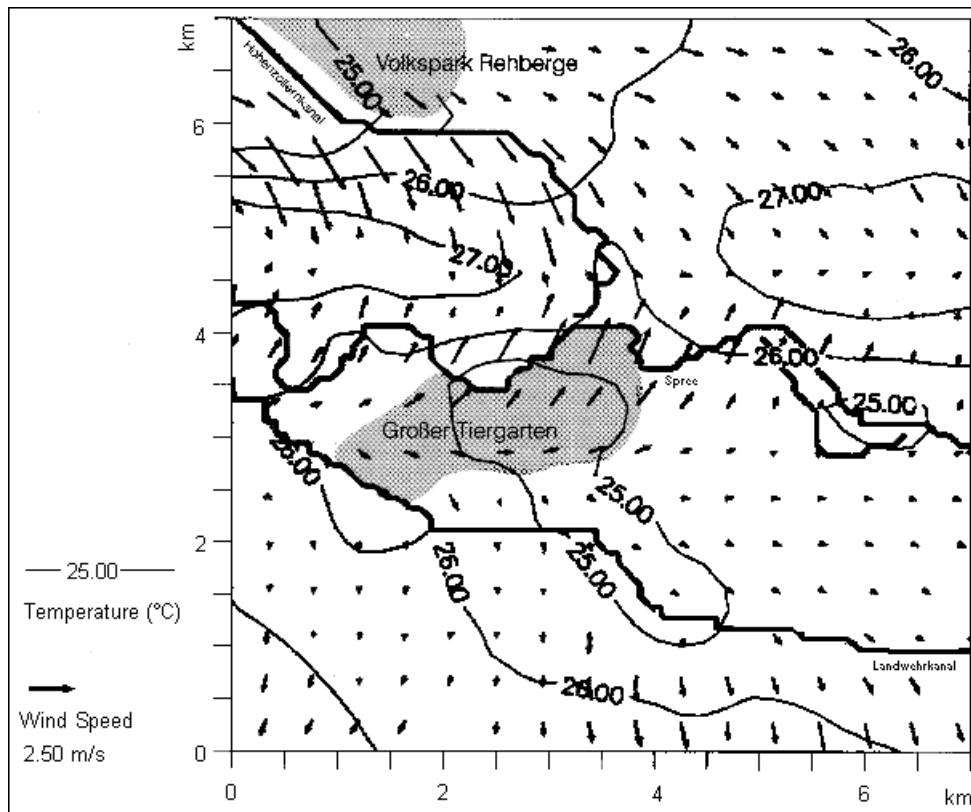


Fig. 1: Simulation of the Temperature and Wind Fields at 10 m Height in the Inner-City Area of Berlin during a Summer Radiation-Weather Period around 2.00 p.m. CET, Considering Land Use. Model Assumes a West Wind of 3m/s (from: Wagner 1993, changed slightly).

On the basis of these functional areas, the climatically necessary measures can be derived which are necessary for the minimization of local burdens, to preserve the available climatically favorable open spaces, and to optimize the air exchange between burdened spaces and those which contribute to equalization.

Map Description

While in the 1993 edition (cf. Map 04.07, SenStadtUm 1993g) still could be spoken of a two-split heat-island; now serious changings have been arisen in result of the urban development.

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 Niederschöneeweide. 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, Friedrichshagen, 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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