04.11 Climate Model Berlin - Evaluation Maps (Edition 2004)

Overview

The results obtained in the context of the application of the climate model FITNAH (phase I) led to a comprehensive, actual survey of the climatic situation in the city and closer surrounding countryside (cf. Map 04.10 Climate Model Berlin - Analysis Maps (Edition 2003). The following explanations refer now to the phase II of the Climate Model. Goal of the available maps is to define spaces of the city according to their different climatic functions, i.e. their effects on other areas and to evaluate the sensitivity of these function in relation to structural changes. On this base measures result for preservation and/or improvement of the climatic situation. The actualization of the level of knowledge on the conditions end of 2001 permits also the consideration of the climatic consequences occurring from structural development since beginning of the 90's.
Due to the close relationship of the contants, the explanation texts for the maps 04.11.1 and 04.11.2 show a common presentation in the chapters problem, data basis and methodology. In the chapter description of maps follows a partitioning into the individual evaluations:

- Map 04.11.1 Climate Functions and
- Map 04.11.2 Planning Advices Urban Climate.

The knowledge of the existing local climate in a city, the resulting air quality situation as well as the climatic coherences of function are significant aspects of environmental provision and city development. The protected subject climate/air is, as an important element of spatial planning, part of the deliberation process for urban land use planning, environmental impact assessments and site analyses. Against the background of competing planning objectives, the availability of area-related information is a fundamental resource for the appropriate appraisal of this subject.

The guiding ideas regarding climate and immission-ecological quality goals are the protection, development and regeneration of important climate- and immission-ecological surface structures, and is aimed at the improvement/preservation of beneficial bio-climatic conditions, air quality and special local climates.

The climate ecology analyzes "the impact of climatic elements and climate on the ecological system of the landscape and its balance, including flora, fauna, men and biocoenosis. Further subject of analysis is the management of significant near-ground atmospheric processes through the general landscape structural quantities (relief, development...)" (Mosimann et al. 1999).

Starting point for a climatic analysis is the structuring of the investigation area into burdened settlement areas, in terms of bio-climate and/or air-quality (**affected space**) on the one hand, and cold air-producing, undeveloped space characterized by vegetation on the other hand (**compensation space**). If these spaces are not adjacent to one another and the air exchange process is strong enough, they can be connected by linearly aligned, marginal developed open spaces (**air-stream channels**). The classification of favourable and unfavourable spaces as well as the connecting structures results in a complex picture of the process system of air-exchange flows of the **compensation space-affected space-structure**. After compiling the necessary evaluation maps in phase I by applying the climate model FITNAH Climate Model Berlin - Analysis Maps (Map 04.10, Edition 2003), the purpose of this investigation is the division of urban areas regarding their climatic functions and the provision of a current, complex and high resolution Climate Functions Map. Additionally, the sensitivity of these functions regarding structural changes is evaluated in a further step and presented in the form of a digital Planning Advices map.

The execution into area-specific climate- and immissions ecological quality goals debouches in the requirement for recommendations for action. By having a precise attribution of information relevant to planning to the important, climate-ecological process-controlling structural elements, e.g. cold air generating areas, air-stream channels and comfort areas, these can, on the one hand, be preserved and protected from negative influences (see Planning Advices Map). On the other hand burdened areas with an aeration deficiency and/or polluted air can be identified easily.

This methodical procedure provides funded conclusions for the scale range of 1 : 100.000 to 1 : 20.000. A first evaluation with regard to the impact of planning measures is also present on the level of local development planning.

Statistical Base

The basis for the evaluation and separation of areas based on their climatic functions are the simulation findings for a radiation weather condition with low interexchange, as they were presented and specified by the results of the Climate Model Berlin - Analysis Maps. The insights gained by the regional climate model FITNAH are the foundation for the analysis of the actual climatic state, from which the interrelation of functions can be deduced.

Contrary to the previous widespread - drawing primarily on VDI directive 3787 sheet 1 - static considerations based on climate zones, in which a land use related uniform micro-climate was assumed independent from the position of the climatopes, the model-based approach provides now area-wide quantities of different parameters regarding the cold-air balance in Berlin. Furthermore, the dynamic aspect within the climate balance is considered sufficiently. The detailed calculation of wind and temperature conditions in Berlin was carried out using the FITNAH model (**F**low over **I**rregular **T**errain with **N**atural and **A**nthropogenic **H**eat Sources). A precise mathematical and physical description of the model can be found in the Digital Environmental Atlas and Groß (1993).

During summer high-pressure weather conditions with low wind speeds, local climatic peculiarities can develop particularly well in landscapes. Said weather conditions are characterized by cloudless skies and a very weak synoptic wind of less than 4 m/s. In the numeric simulation carried out here the spacious synoptic basic conditions are determined as follows:

- coverage ratio 0/8,
- geostrophic wind speed 0 m/s
- relative air moisture 50 %.

Beside the highlighting of the interrelation and neighbouring correlation between cold air producing green spaces and urban areas also a quantitative and qualitative evaluation as well as an illustration of the climatic burden and compensation potential of the variously structured spaces in the urban area takes place. Also the effects of the surrounding and undeveloed open spaces on the urban area were assessed. For this purpose the block areas of the Digital Map Berlin 1 : 50.000 (ISU50) were assigned all parameters, e.g. wind speed, air temperature at a height of 2 m and cold air mass flow. If a building block takes up more than one grid cell of a parameter, an average value is generated from the single values of the cells. Consequently, each building block has available a range of climatic parameters. Based on this, the variously structured spaces were awarded evaluation indices, more on which can be found in the chapter Methodology.

To identify areas with slope inclinations of > 1°, on which extensive cold air out-flows occur, a relief analysis was carried out, using the FITNAH Terrain-Height-Model. In addition to the FITNAH results, the potential traffic-based air pollution is figured out by the annual average nitrogen dioxide concentration in the street space calculated for 2001 (a detailed description [in German] is given by the publication "Rating of traffic-relevant atmospheric loads by means of calculation models 2001" for download).

Methodology

The delimited climatic-functional regions shall reveal statements in which areas

- on the one hand a potential for the discharge of other (adjacent and also further) areas is present
- on the other hand due to the spacious influence the strongest auxiliary loads can be expected,
- preferred air interchange ranges can be assumed, i.e. an important role for near-surface fresh air transport is taken over.

The peculiarity of the different climate-ecological parameters were transferred into an appraising classification scheme for a better planning grading. These classifications take place after technical demands and orient themselves in regard to the class width at the value spectrum existing in the investigation area. As below, the qualitative gradation of the determined parameters, subdivided according to the topic tables units, is described. Finally, the grading of structural elements relevant to planning is depicted.

Green- and open space inventory

As cool air-producing ranges vegetation-coined open spaces are considered such as forests, parks and graveyards and, in addition, green-coined settlements with a small sealing degree (usually under 30%). For a better handling the approx. 13.500 relevant single areas of the Urban and Environmental Information System (ISU) have been aggregated to approx. 700 functionally with one another connected green area units, whereas the subsumption took place with priority after the aspect of the spatial proximity. Thus several green areas form a matching unit with a minimum size of 0,5 hectares (cp. Fig. 1).

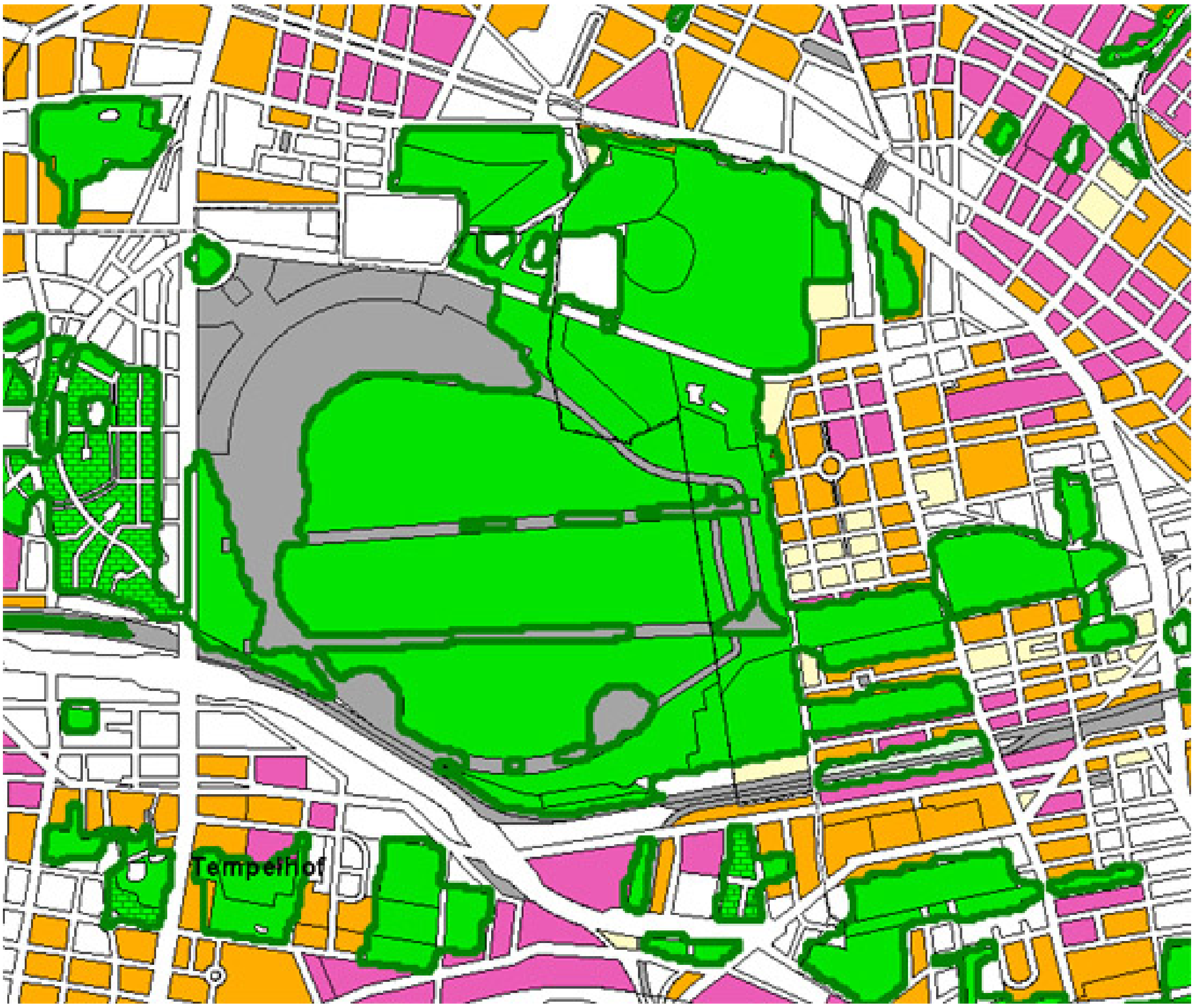

Fig. 1: Green area aggregation considering the example Airport Tempelhof and functionally connected areas. The dark green line marks the outline of the green area unit.

To characterize the balancing performance of green areas within the city as well as the cold air-producing areas of the surrounding countryside the cold air mass flow is adducted in the Climatic Functions Map. It expresses the inflow of cool air from the neighbouring grid cells in 1000 m³/s per 200 m raster cell, as it was determined in the context of the analysis phase of the model application (cf. Map 04.10 Climate Model Berlin (Edition 2003).

Figure 2 illustrates with the example of the Airport Tempelhof the near ground current field, which is used to delimite the affect range of the cold air producing areas.

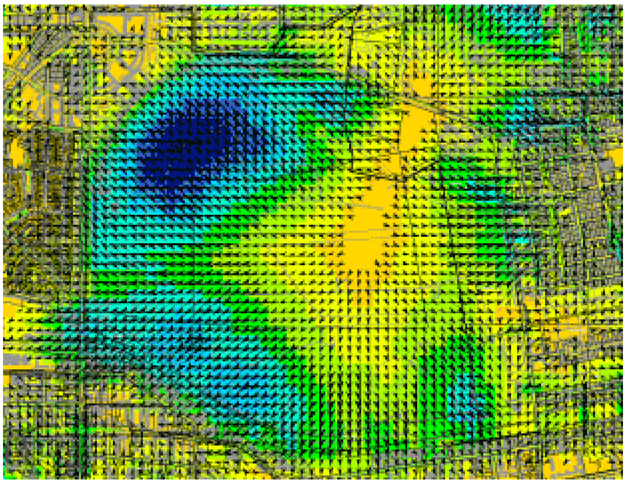

Fig. 2: Near ground current field and affect range of the cold air producing area of the Tempelhof Airport

To ensure that the size of the respective green area remains considered in the evaluation, a ratio has been evaluated for the compensation benefit. It consists of an area ratio from a green area to a 200 m grid cell (=40,000 m²) as well as the determined cold air mass flow within this area. An example computation for an area of 19,5 ha and an average mass flow of 3,49 in the green area clarifies the procedure:

(195.000 m² / 40.000 m²) * 3,49 = 17,01 (corresponds to a quantitatively average mass flow)

The qualitative classification of the values in shown in table 1, whereby for an climate ecologically effective mass flow a value of at least 1 is regarded (cf. table 1).

Tab. 1: Cold Air delivery of the cold-air generating surfaces (Mass Flow)	
Ratio Cold Air Flow	**Rating**
0 - 1	Very low
1 - 5	Low
5 - 100	Medium
> 100	High

Tab.1: cold air delivery of the cold air generating surfaces (Mass Flow)

The ranges of the discharge effects are characterised as "affecting ranges of the cold air generating surfaces" in the Climate Functions Map and are explained under the column of residential areas.

The inner-city cold air producing areas are illustrated by a colour, the cold air quantities of the surrounding countryside is marked by an arrow signature. The capability of cold air delivery is expressed by the arrow size, whereas the direction of the arrow reflects the main stream direction within a cold air catchment area. The spheres of influence, starting from the cold air producing areas of the surrounding countryside, are marked by outlines. They were defined by the cold air flow field at the 6:00 a.m. point of time so that they reflect the minted catchment area at the end of the night. Contrary to the green areas on the urban area of Berlin the cold air producing areas of the surrounding countryside do not receive planning advices.

The **planning classification** of a cold air producing green area in the Planning Advices Urban Climate Map is primarily determined by its location in the city and its proximity to burdened settlement areas. The sensitivity of an intensification of use comes along with the climatic relevance for the assigned residential areas (cp. table 2).

For areas with an urban climate importance of "very high" a maximum of sensitivity against housing, parcelling and sealing is given; they have to be supported in their function lastingly, i.e. particularly by avoidance of pollutant emissions within these surfaces.

Tab. 2: Planning classification of cold-air generating open spaces	
Relevance for urban climate	**Location**
Very high	Assignment to burdened settlement areas
High	Assignment to settlement areas with beneficial microclimate
Low	Minor effect on settlement areas and/or marginal Cold-Air production

Tab. 2: Planning classification of cold air producing areas

Open spaces with a very small cold air production within burdened areas possess only a minor urban climate importance. This concerns usually areas which do not have a connection to existing airstream channels due to their isolated position within the settlements. Furthermore these green spaces have not a compensation flow because of their small size. Nevertheless these areas can fulfil a function as a climate-ecological comfort island.

Settlement areas

The residential areas can be subdivided into sufficient aerated areas respectively climatically favourable settlement structures on the one hand and burdened areas on the other hand. The **affect range** of the cold air producing areas marks the maximum outflow of cold air from open areas into the surrounding settlement during a low-exchange, cloudless summer night between 10:00 p.m. and 06:00 a.m. A cold air current should obtain a flow velocity of at least 0.2 m/s to be classified as climate-ecologically meaningful. From this it follows that the housing within a cold air effect range exhibits a predominantly small to no bioclimatic burden. Sporadically the burden level rises so much that it cannot be lowered by an arising cool air current.

To allocate a **bioclimatic burden** the degree of aeration is the decisive factor (mean wind velocity within a building block) as well as the positive deviation from the average area value of the evaluation indices PMV (Predicted Mean Vote, cp. also Map 04.09 Bioclimate at Day and Night). The PMV is consulted as a dimensionless factor for the nocturnal thermal load. By combination of the two parameters aeration degree and deviation of PMV the situation of bioclimatic burden was determined (cp. Table 3).

Tab. 3: Bioclimatic burden of settlement areas		
Burden degree	**Dev. from PMV area mean value at 22 o´clock (=-1,51)**	**Mean wind velocity (m/s)**
4 Potentially moderate (-high)	> 0,4	/
3 Potentially low (-moderate)	> 0,2 to <= 0,4	<= 0,2
2 Low	> 0,2 to <= 0,4	>= 0,2
1 Not burdened	Miscellaneous	Miscellaneous

Tab. 3: Bioclimatic burden of settlement areas

The rating class 4 "potentially moderate, in particular cases high" is present during an increased thermal load with a positive PMV deviation from more than 0.4. The flow velocity of the cold air is no longer relevant in this class. It modifies however the burden categories with a moderate thermal load from 0.2 to 0.4 in "potentially small, in particular cases moderate" with lack of aeration as well as "small" at cold air velocities > 0.2 m/s. The **sensitivity of a possible intensification of use** in settlement areas is associated with the bioclimatic burden. It can be considered as "very high" within the burden categories 3 and 4 and "high" within the remaining classes. This concerns mainly areas of high sealing (> 60 %) and covering degree (mostly > 50 %).

"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 modelled 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).

Due to the limited amount of open space, measures for the relief of urban areas, including their build-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, overheating can be decreased, moisture level of the air can be increased and dust can be bound.

The heating of roofs depends very greatly on their colour and their material (cf. Map 04.06). Most favourable 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 und 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. 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 facade-greening is more favourable for the promotion of air exchange than the planting of trees. Large courtyards clearly achieve more favourable climatic characteristics than narrow courts and street areas, especially if the degree of sealing is low and the vegetation is 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.

Climatically beneficial residential areas are characterized by an open settlement structure and a high portion of green spaces, of all functional regions they are most likely to the soonest potential for a structural compression. At present knowledge a careful compression of these areas will entail no re-classification into a climatically more unfavourable classification. At which magnitudes the individual limits for a structural compression are located can not be indicated overall; anyway options should be checked on the spot to compensate negative climatic effects by measures such as roof or facade planting or limitation of large building volume.

Within the street space the **potential traffic-related air pollution along major roads** marks road sections, in which the limit value of the 22. BImSchV is exceeded possibly and/or with a large probability. In how far beyond the actual street space also yard ranges respectively back building parts are concerned, could not be determined in the context of this surface covering modelling.

Air exchange

Air stream channels connect cold air generation areas (compensation space) and burdened areas (affected space) and are thus an elementary component of the air exchange. In consideration of the process types, four different air exchange types were worked out in the maps:

- Air-stream channel, predominantly thermally induced,
- Air-stream channel, predominantly orographically induced (e.g. small flood plain tracts),
- cold air outflow on slope areas (at a slope > 1°),
- Spacious air-stream and ventilation channel (valleys of larger watercourses).

The determination of air-stream channels is geared to the autochthonous cold air flow field of the FITNAH-simulation. The determined air-stream channels are, with exception of river valleys, vegetation-coined surfaces with a linear adjustment on affected spaces. The classification of planning is oriented, similarly to the cold air generating green and open spaces, to the burden situation within the assigned residential areas.

The methodology carried out here, notably to derive the Climate Functions Map, differs in its model-based approach elementary from the previous proceeding, also conducted in Berlin. The hitherto Climate Functions Map (cp. Fig. 3).

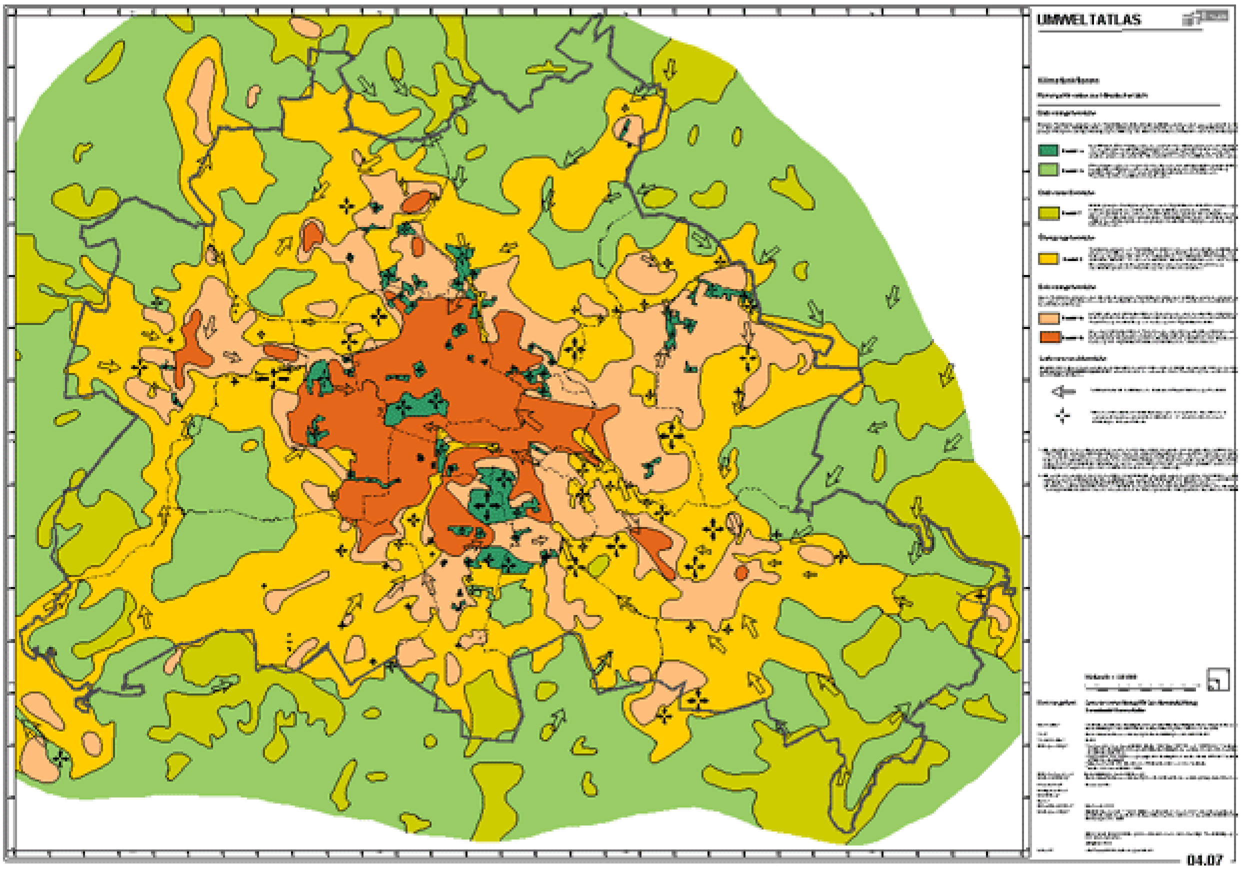

Fig. 3: Previous Climate Functions Map (04.07) of the Berlin Digital Environmental Atlas (Edition 2001)

is based on a large amount of measured parameters, but the ascertainment of plain information and consideration of functional connections as well as interaction between the areas additionally requires the knowledge of the described flow fields. However, this area-wide information with an area size 0f 2.500 km² as covered by the FITNAH model, can only be obtained by numeric models. From this it follows that the previous classification of the burden level in urban areas as well as the compensation effects of green spaces exhibited a relative and not quantitative character.

Furthermore in the past favoured spaces for near-surface fresh air transport have been pictured and proposed for further examination only based on their structure characteristics respectively. Criteria for their suitability were above all a small surface roughness, sufficient width (if possible more than 10 times the height of the surrounding bordering structures) as well as a predominantly weak immission load. Only for few ranges there was a meteorological measurement. Although this procedure offers a descriptive typing of the relevant areas, the process system is, however, due to this rather static and structure-orientated approach, not considered or only considered indirectly. (VDI 1994).

Map Description

Map 04.11.1 Climate Functions

The Climate Functions map illustrates the actual condition of the climatic situation relevant to planning. Thereby bioclimatic burden conditions, equalisation benefits of cold air generating areas as well as spatial relations between compensation spaces and affected spaces are represented. Since both the equalisation effects and burdens are classifiable, planning priorities can be determined to point out which built-up areas are affected by changes in compensating spaces.

Green- and open space inventory

Vegetation-covered, open spaces with a considerable cold air production represent climate- and immission-ecological compensation areas. A high long-wave nocturnal radiant emittance during exchange-poor high pressure weather conditions leads to a strong cooling of the near-surface air layer, whereby particularly city parks near emitters must be considered of being perilled in terms of immissions. The quantity of the produced cold air depends on the prevailing type of vegetation, the soil characteristics and the associated nocturnal cooling rate. All in all 701 Green-space units were demarcated, whose qualitative classification regarding cold air mass flow is shown in Table 4.

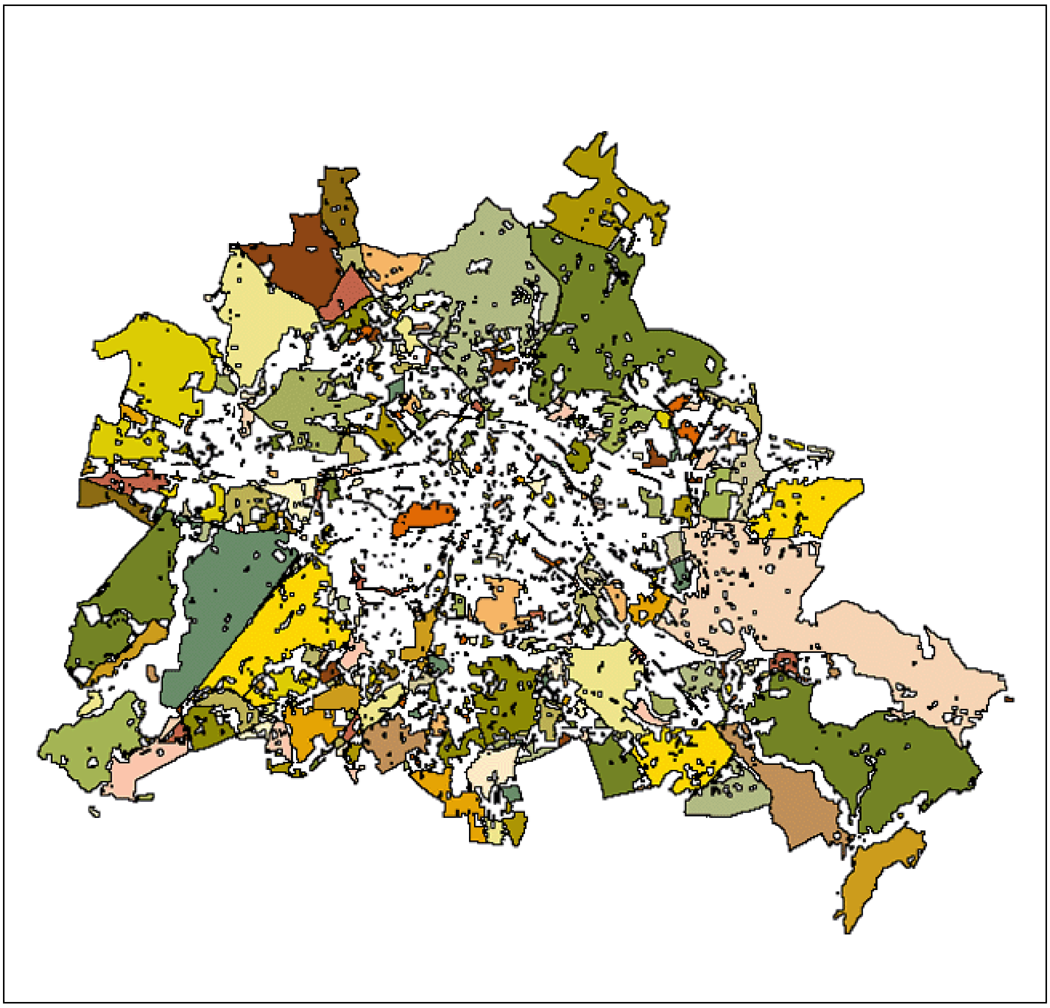

Fig. 4: Aggregation of green and open spaces; altogether 701 aggregation areas

Tab. 4: Overview of the qualitative classification of the aggregated green space areas		
Cold-Air generation	**Number of green space units**	**Total size of category in hectares**
High	58	37 920
Medium	218	5 157
Low to Very Low	425	877

Tab. 4: Overview of the qualitative classification of the aggregated green space areas

The total area of the cold air producing surface amounts to approx. 43.854 ectares, which corresponds to an area percentage of around 49 % of the total urban area and can be regarded as very high.

Green and open spaces with a **high cold air mass flow** are predominately on the outskirts of the city. Usually the larger wooded and ruderal areas, graveyards and allotments are very cold air productive .The most important spatial urban climatic contributions for the city centre are from the **Großer Tiergarten**, the **Airport Tempelhof** and the **allotments Am Priesterweg**. These spaces are characterized by their extensive cold air affect ranges. A large part of the **Grunewald** also counts as a significant open space with a connection to the city centre. Green settlement types, which are aimed towards the city centre as well as occurring slope inclinations > 1°, assist the cold air flow considerably, so that the built-up areas in Schmargendorf and Wilmersdorf have a cold air penetration of up to 2000 m (also see the detailed explanation in the Map 04.10 (Climate Model Berlin). This, together with the allotments north of the Spandauer Damm, at the Heckerdamm as well as the Volkspark Jungfernheide and Rehberge result in a 10 km long cold air affecting area surrounding the western city centre. The green areas around the Volkspark Prenzlauer Berg and the central graveyard in Lichtenberg have a similar relevance for the eastern city centre.

Counting 58 green area units and a total size of approx. 37.820 Hectares, this category is spatially the largest. Its green area quota makes up approx. 86 % of the total green area, which can be traced back to the extensive wooded areas on the city outskirts.

The compensation benefits of areas with an **average cold air mass flow** are also to be regarded as important. In the city centre the Schlosspark Charlottenburg, the Volkspark Friedrichshain and the Volkspark Humboldthain show a significant cold air affect range. In the southern part of the city green settlement types without a connection to park or wooded areas possess an average mass flow. The areal sum of the open spaces classified as average amounts to 5.157 Hectares, which corresponds to about 12% of the total green area.

Green spaces which possess a **low cold air mass flow** make up a portion of 1,7 % of the total with 738 Hectares. This group is mainly composed of small graveyards, allotments and park areas with a size of up to 10 ha. These seldom possess an cold air affect range, as they are usually surrounded by buildings in a generally warmer area. An exception are those areas which are located within the affect range of green spaces with a stronger cold air production.

Green areas with a **very low cold air mass flow** usually cannot generate an affect range. These are small areas of about 2.5 ha, which are typically situated in developed areas. In burdened areas, however, even these small spaces can have a decisive function as climatic ecological comfort islands, as long as they feature a mosaic of different micro-climates, e.g. shadowed and sunny areas or cooling water surfaces (micro-climatic diversity). The percentage of this type of area is only 0.3 % with 139 Hectares.

The **cold air generating areas of the surrounding countryside** are often in direct contact with those of the city and can hence be seen as their extension. Due to the greater distance to the settled areas the flow field is at its maximum at around 6:00 a.m. The largest cold air generating areas can be found to the north-east of Berlin. The relatively conspicuous rise in terrain height here abets a wide-ranging in-flow of cold air into the city. Numerous smaller areas are concentrated at the southern city border, while the western edge of the city can offer only two cold air generating areas. The cold air mass flow is widely characterized as high. On the other hand the smallest cold air generating area west of Frohnau shows an average potential. The relevance of the surrounding areas rises with shrinking distance to residential areas, and is highest in the areas Spandau, Marzahn as well as on the southern city border.

Settlement areas

As was already explained under Methology, the bio-climatic burden situation was calculated on the basis of parameters wind velocity and positive deviation from the PMV-value of the urban area. This composition allows a spatial partition of the settled area into bio-climatically burdened areas on the one hand, and non-burdened or less-burdened areas on the other hand.

The latter are characterized by cold air **affect ranges**, a moderate overheating and an adequate ventilation due to the flows from the cold air producing open spaces. The range of the cold air flowing into the built-up areas depends upon cold air productivity and the impediment properties of the surrounding development. Fig. 4 shows the situation in the periphery of the Großer Tiergarten, whereby the concentric, nocturnal out-flow of cold air as an affected area becomes apparent.

In the area between the John-Foster-Dulles-Allee and the Straße des 17. Juni north of the Großer Tiergarten an area of reduced flow velocities of less than 0.2 m/s is detected. From here the produced cold air is accelerated and, driven by the difference in temperature in consequence of the various land utilisation, infiltrates the surrounding development. Green settlement areas are unburdened, orange and red denote burdened housing blocks.

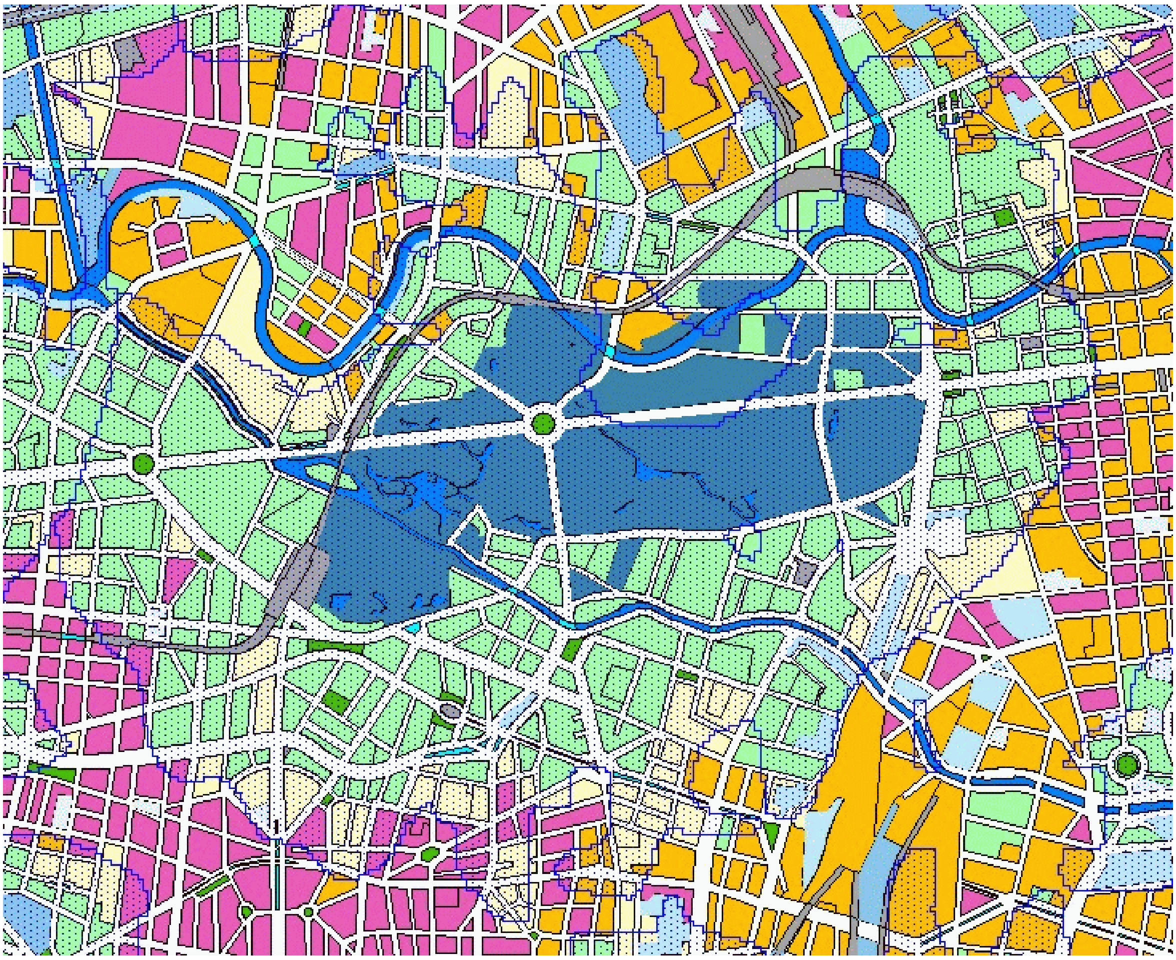

Fig. 5: Simulated affect range of cold air produced in the Großer Tiergarten

The inner city itself profits from the welfare benefits of more sizable open spaces such as the Airport Tempelhof or the Volkspark Friedrichshain. Smaller, preliminary open spaces serve as "green stepping stones" and facilitate the infiltration of cold air into the developed areas.

The favourable areas are juxtaposed to **burdened areas** with an above average heat load and ventilation deficits. This pertains to following boroughs:

- Mitte,
- Pankow,
- Friedrichshain-Kreuzberg,
- Lichtenberg,
- Tempelhof-Schöneberg.

The peripheral, concentrated district-centres, however, also exhibit a raised potential bio-climatic impact, as e.g. in the boroughs or districts

- Spandau,
- Weißensee,
- Hohenschönhausen,
- Marzahn,
- Ober- und Niederschöneweide,
- Mariendorf.

In addition, almost all districts feature insular housing blocks with a potential burden. However, structurally, high-rise settlements tend to have a better ventilation than portrayed in the map. Sporadically, the burden can be so great that even an existent cold air flow cannot compensate it.

The illustration of **potential transport-induced air pollution along main roads** complements the spectrum of occurring burdens. This is a model-based calculation for the reference year 2001, showing for single street sections the boundary values of the 22. BImSchV for NO_2 as an annual mean, which should be adhered to by 01.01.2010, and which will likely and most likely respektively be exceeded. Inner city main roads are especially affected by the elevated burdens; of the total around 10 % of the analyzed road network exceed the later boundary value.

Air exchange

Structures which allow air exchange and introduce cold air are the central link between compensation spaces and bio-climatically burdened affected spaces. Air-stream channels should usually offer a low surface roughness, whereby lesser wooded valley and floodplain areas, larger green spaces and tracks offer the required attributes. Wide roads, because of their immission load, can only aid the climatic balance, but not the transport of fresh air. The air-stream channels are sub-divided according to process in the Climate Functions Map, where a cold air producing (partial) area can also fulfil an air-stream channel function.

The predominant form of air-stream channels are **thermally induced** types in combination with a compensation space, which can be led back to the utilisation-based temperature differences. Exemplary for such inner city channels are the allotments at the Priesterweg which transport the cold air northwards coming from the graveyard on Bergstraße in Steglitz and from Insulaner. Furthermore the allotment am Heckerdamm as well as the Volkspark Rehberge channel a fraction of the cold air produced at the Airport Tegel towards the city centre. A number of further thermally induced air-stream channels can be found north of the axis Tegel - Lichtenberg as well as in the south between Lichterfelde and Bohnsdorf. In the western part of the city the channels are grouped around Spandau and lead cold air directly out of the northern Grunewald and the bordering regions towards the city. If a green space borders directly on a developed area, an air channel becomes obsolete.

Predominantly orographically induced air-stream channels are concentrated in the eastern part of the city. These are about valleys, e.g. Wuhle and Mühlenfließ, which, because of their alignment, width and terrain attributes, can be used as air-stream channels. To that effect, one can class in the western part of the city the depth line from Grunewald trough Hundekehlsee - Dianasee - Koenigssee - Halensee.

The lowlands of the larger rivers like Spree and Havel exceed this function and also possess a characteristic for **superordinated air-stream and ventilation channels**. They benefit the air exchange in the bordering developed areas even under strong, dominating weather conditions.

A **spatial cold air out-flow** is limited to areas with an inclination of > 1°, and is, because of the relatively low height differences, scarce in Berlin.

For that reason this process is interlinked to the few areas with a noteworthy inclination like that of the Grunewald and the Köpenicker Bürgerheide. Furthermore, in the northern part of the Tegeler See, Kaulsdorf and in the Forst Düppel one can assume cold air flow. The cold air delivery is above average on these wooded slopes because the long-wave emission is very high, and with that the primary cooling rate. This occurs not from the ground, but from the upper treetops. Due to the size of the emanating surface the cold air can flow in and over the treetops, instead of first subsiding into the trunk area. (Groß 1989).

Map 04.11.2 Planning Advices Urban Climate

The Planning Advices Urban Climate Map is an integrated evaluation of the facts relevant to planning shown in the Climate Functions Map. Protection and development measures for the improvement of the climate and also – by means of attenuation and removal effects – of the air. The goals of

- Protection,
- Development and
- Reconstruction of

climatic and immissions-ecologically important surface structures (Mosimann et al. 1999) correspond to the main idea of these efforts. The associated planning advices provide information on the sensitivity against usage changes from which climate-founded requirements and measures in the course of areal planning can be deduced. Below, the planning classification of climate-relevant elements in Berlin is considered.

Green- and open space inventory

Urban green spaces and green spaces near settlements have a substantial effect on the urban climate and positively influence the direct surroundings micro-climatically. Larger coherent green spaces constitute the climatic regeneration potential. The produced cold air mass flow as a qualifying parameter, however, takes a back seat in this regard. The spatial position and with it the question which bioclimatic load a respective building development involves, is much more important for a classification in the planning process. Ultimately, a green space with only minor production of cold air can also bring with it a significant benefit in densely settled areas.

Of **very high importance** concerning the urban climate are green and open spaces with an impact on bio-climatically stressed settled areas. These are above all large, inner-city green spaces such as Großer Tiergarten and Volkspark Friedrichshain, and open spaces on the premises of the Airport Tempelhof. Vitally important are furthermore smaller parks, ruderal areas and wasteland, as well as sports grounds that are only sealed up to a moderate extent, as far as they can achieve a relieving effect on the neighbourhood. This results in the **highest sensitivity** of these areas against intensification of utilisation and the following planning advices:

- Avoidance of exchange barriers against built-up border areas,
- Reduction of emissions and
- Cross-linking with open spaces.

This means that edificial works and utilisation contributing to the sealing of these areas can lead to further alarming climatic damage. Alongside the aforementioned and other individual areas of this class the larger distant areas such as open spaces adjoining Blankenfelde or in the Wuhlheide can also be assigned to this category. The largest coherent area in this context extends from the Grunewald over the green coined settlements in the district of Lichtenrade to Rudow.

Green and open spaces with a connection to urban areas with a low level of pollution or even a favourable microclimate possess a **high to medium importance** to the urban climate. They are mostly located in a considerable distance from the city centre and are connected to the urban areas with a minor bio-climatic load that is situated beyond the course of the outer urban railway line (S-Bahn-Ring). Among these are the following areas:

- Green spaces and suburbs pervaded by greenery between Bucher Forest and Malchow,
- Krummendammer- and Köpenicker Bürgerheide,
- Forest Grunewald northwest of the Avus as well as the Airport area Tegel and
- Forest Spandau.

These areas possess a **high sensitivity** regarding utilisation intensification, whereby air exchange with its surroundings should be especially considered.

The third category constitutes green and open spaces of **low urban climatic importance**. These are areas which either possess a minor influence on - burdened - developed settlements, or have an insignificant cold air production. The latter can often only offer a small area size and are usually situated in the inner city. These areas can by all means take on a role as climatically ecological comfort islands, provided that they feature micro-climatic diversity (e.g. bodies of water, shadowed and sunny areas).

The Gatower Heide and the green settlements in Frohnau and Heiligensee are sizable areas which have a **minor relevance**. Constructional intervention in these areas would only carry minor climatic changes, as long as the air exchange is not significantly compromised.

Settlement areas

The settlement areas situated in the **cold air affect range** of a green space are typically sufficiently ventilated and exhibit a **small to no bio-climatic importance**, (see Map 04.11.1 Climate Functions). To preserve this favourable state, the **high sensitivity** regarding utilisation intensification has to be considered. Planning-wise exchange barriers and further aggregation have to be avoided.

Climatically favourable settlement areas are sparsely developed and green settlements, e.g. mansions with a low sealing level, a high vegetation level and a relatively high nocturnal cooling rate. These areas are cold air producers themselves, to a certain extent, and aid the cold air flow of neighbouring open spaces. Green settlements are usually found outside of the S-Bahn-Ring, but some are near the city centre (e.g. Garden City Tempelhof west of the Airport). These areas lead neither to an intensive bio-climatic impact, nor do they impede air exchange. They typically have a **low sensitivity** against utilisation intensification, as long as the building heights are kept low and the parts of the structures are aligned to the cold air flow. Spaces bordering directly on burdened areas will have a **high sensitivity** due to the climatic relevance.

Lesser burdened settlements are also **non-ventilated settlement areas with a low bio-climatic burden**. Crucial for this classification is not so much the non-existent cold air affect range, but rather a low potential heat load. This results in a **high sensitivity** regarding utilisation intensification and the avoidance of further aggregation.

Impacted areas, on the other hand, usually exhibit ventilation deficiencies and an above-average heat load. These are divided into settlement areas with a low, in some cases moderate as well as with an average, in some cases high bio-climatic load. Under consideration of the impact level, **a high or very high sensitivity** regarding utilisation intensification results. Under urban climatic aspects, these areas are in need of rehabilitation, which results in the following planning advice:

- No further aggregation,
- Improvement of ventilation and increase of vegetation,
- Conservation of all open spaces and
- De-sealing and, if necessary, planting of inner courtyards.

Beside the inner city area there are also districts with strongly developed centres, e.g. Spandau, Weißensee or Hohenschönhausen. Furthermore, a low to average local impact may occur in the entire city area and is not limited to the aggregation areas. In isolated cases a bio-climatic impact can occur despite an existing cold air affect range. In such a case the potential impact situation can be so high that even a cold air flow is not able to achieve a significant compensation.

The situation in the peripheral area of Tempelhof is shown in Fig 6. The bio-climatically impacted industrial areas along the S-Bahn tracks are especially visible, in particular in the district of Mariendorf.

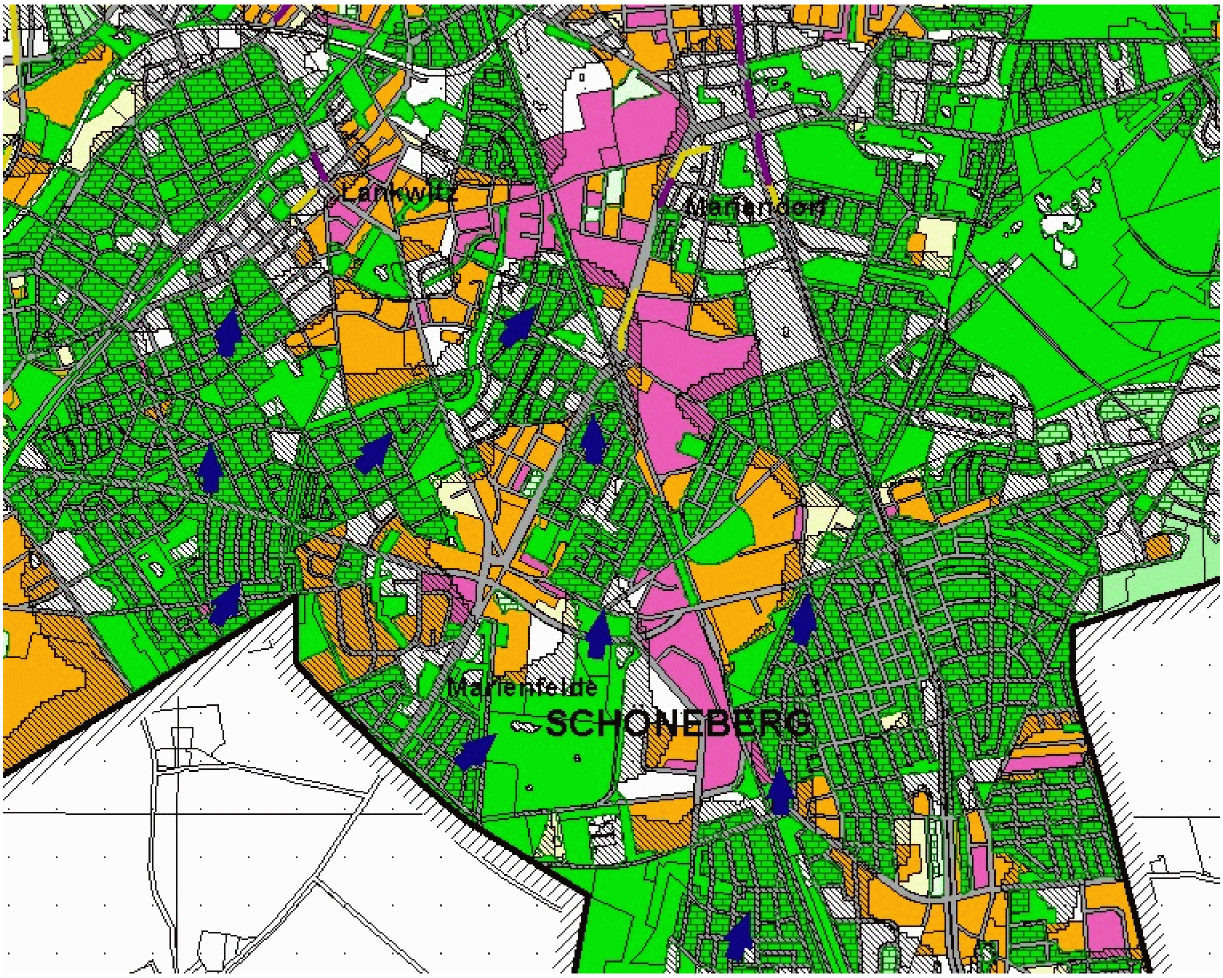

Fig. 6: Examples of local bio-climatic burdened areas outside of the inner city, here in the districts Marienfelde/Mariendorf

Cold air stream channels in the districts of Marienfelde/Mariendorf, which in this case introduce cold air from the surrounding countryside, are denoted by the arrow signature. The Freizeitpark Marienfelde, as well as green settlement types act as stream channels. Due to the attribution to the aforementioned impact areas, a high urban climatic significance can be assigned to the green spaces and their function as a stream channel.

The illustration of **potential traffic-induced air pollution along main roads** complements the spectrum of occurring burdens. This is a model-based calculation for the reference year 2001, showing for single street sections the boundary values of the 22. BImSchV for NO_2 as an annual mean, which should be adhered to by 01.01.2010, and which will most likely be exceeded. Inner city main roads are especially affected by the elevated burdens; of the total around 10 % of the analyzed transport network exceed the later boundary value.

Air Exchange

In the Planning Advices Map **cold air stream channels** and **outflows** are divided into two categories, whereby the significance rises with growing proximity to the impact areas. **Stream channels with a very high significance** promote the penetration of cold air into the inner city area and to burdened district centres. Examples are the allotments at the S-Bahnhof Priesterweg, which carry the cold air from the graveyard on Bergstraße as well as from the Insulaner due north or the Volkspark Rehberge, which allows the transport of the cold air produced at the Airport Tegel towards Mitte. Further stream channels of this category are grouped north and south of the S-Bahn-Ring.

Merely the Grunewald has a **broad extended cold air outflow** with a high significance and at its eastern side a high cold air reach can be assumed. **Stream channels with an average to high significance** are situated mostly on the periphery of Berlin, which is also true of the **spatial cold air outflow** in this category. For these prominent structures or processes the following planning advices can be derived:

- Prevention of constructional barriers, which could induce a cold air congestion,
- Keep building heights as low as possible,
- Align new development to stream channels,
- Prevention of peripheral development and
- Conservation of green and open spaces.

The valley sections of the larger rivers Havel and Spree appear as **spatial air-stream and ventilation channels**, which exceed their local air exchange function. They benefit the air exchange in the bordering development even during strong, superordinated weather conditions. For planning purposes the river banks should be kept free, or at least be lightly developed.

Literature

[1] Bartfelder, F., Köhler, M. 1987:

Experimentelle Untersuchungen zur Funktion von Fassadenbegrünungen, Diss. am Fachbereich 14 der Technischen Universität Berlin, Berlin.

[2] Deutscher Wetterdienst DWD 1996:

Klimakarten für das Land Berlin, Teil 1: Bioklima Berlin, Gutachten im Auftrag der Senatsverwaltung für Stadtentwicklung, Umweltschutz und Technologie, unveröffentlicht.

[3] Groß, G. 1989:

Numerical simulation of the nocturnal flow systems in the Freiburg area for different topographies, in: Beitr. Phys. Atmosph.,H 62, S. 57-72.

[4] Groß, G. 1993:

Numerical simulation of canopy flows, Springer Verlag Berlin.

[5] Groß, G. 2002:

The exploration of boundary layer phenomena using a nonhydrostatic mesoscale model, in: Meteor.Z.schr. Vol. 11 Nr.5, S.701-710.

[6] Kuttler, W. 1993:

Planungsorientierte Stadtklimatologie, Sonderdruck aus: Geographische Rundschau 45. Jg., 2, S. 95-106. KVR (Kommunalverband Ruhrgebiet) (Hrsg.) 1992: Synthetische Klimafunktionskarte Ruhrgebiet, Essen.

]7] Mosimann, T. et al. 1999:

Karten der klima- und immissionsökologischen Funktionen - Instrumente zur prozessorientierten Betrachtung von Klima und Luft in der Umweltplanung, in: Naturschutz und Landschaftsplanung 31,(4),S. 101-108, Stuttgart.

[8] Moriske & Turowski 2002:

Handbuch für Bioklima und Lufthygiene, 8. Ergänzungslieferung, Ecomed-Verlag, Landsberg.

[9] Richter & Röckle (iMA Immissionen, Meteorologie Akustik) o.J.:

Das numerische Simulationsmodell FITNAH, digitale PDF-Datei. Internet: http://www.ima-umwelt.de/downloads/FITNAH-Kurzuebersicht.pdf

[10] VDI (Verein Deutscher Ingenieure) 1994:

Richtlinie VDI 3787, Blatt1, Klima- und Lufthygienekarten für Städte und Regionen, Düsseldorf. Internet: http://www.vdi.de/

[11] Vogt, J. 2002a:

Bericht über orientierende Untersuchungen zur lokalklimatischen Funktion der Flächen des Gleisdreieckes in Berlin, Textteil, Voruntersuchung im Auftrag der Vivico Management GmbH, unveröffentlicht, Berlin.

[12] Vogt, J. 2002b:

Bericht über orientierende Untersuchungen zur lokalklimatischen Funktion der Flächen des Gleisdreieckes in Berlin, Abbildungsteil, Voruntersuchung im Auftrag der Vivico Management GmbH, unveröffentlicht, Berlin.

[13] 22. BImSchV 2002:

22. Verordnung zur Durchführung des Bundesimmissionsschutz- gesetzes (Verordnung über Immissionswerte für Schadstoffe in der Luft-22. BImSchV), 11.09.2002, zuletzt geändert durch Art. 2 V v. 13. 7.2004 I 1612.

Maps

[11] SenStadtUm (Senatsverwaltung für Stadtentwicklung und Umweltschutz Berlin) (Hrsg.) 1993:

Berlin Environmental Atlas, extended and revised edition 1993, Map 01.02 Sealing of Spoil Surface, 1:50 000, Berlin.

[12] SenStadtUm (Senatsverwaltung für Stadtentwicklung und Umweltschutz Berlin) (Hrsg.) 1995a:

Berlin Environmental Atlas, extended and revised edition 1995, Map 06.01 Actual Use of Built-Up Areas, 1:50 000, Berlin.

[13] SenStadtUm (Senatsverwaltung für Stadtentwicklung und Umweltschutz Berlin) (Hrsg.) 1995b:

Berlin Environmental Atlas, extended and revised edition, Map 06.02 Inventory of Green and Open Spaces, 1:50 000, Berlin.

[14] SenSUT (Senatsverwaltung für Stadtentwicklung, Umweltschutz und Technologie Berlin) (Hrsg.) 1998b:

Berlin Digital Environmental Atlas, edition 1998, Map 04.09 Bioclimate - Day and Night, 1:75 000, Berlin.

Digital Maps

[15] SenStadtUm (Senatsverwaltung für Stadtentwicklung und Umweltschutz Berlin) (Hrsg.) 1993:

Berlin Digital Environmental Atlas, extended and revised edition 1993, Map 01.02 Sealing of Spoil Surface, 1:50 000, Berlin.
Internet:
https://www.berlin.de/umweltatlas/en/soil/impervious-soil-coverage/1990/maps/artikel.957353.en.php

[16] SenSUT (Senatsverwaltung für Stadtentwicklung, Umweltschutz und Technologie Berlin) (Hrsg.) 1998a:

Berlin Digital Environmental Atlas, edition 1998, Map 01.08 Terrain Elevations, 1:50 000, Berlin.

[17] SenStadt (Senatsverwaltung für Stadtentwicklun Berlin) (Hrsg.) 2001a:

Berlin Digital Environmental Atlas, extended and revised edition 2001, Map 04.02 Long-Term Mean Air Temperatures 1961-1990, 1:50 000, Berlin.
Internet:
https://www.berlin.de/umweltatlas/en/climate/development-of-climate-parameters/2000/maps/artikel.957384.en.php

[18] SenStadt (Senatsverwaltung für Stadtentwicklung Berlin) (Hrsg.) 2001b:

Berlin Digital Environmental Atlas, extended and revised edition 2001, Map 04.04 Temperature and Moisture Conditions in Medium and Low-Exchange Nocturnal Radiation Periods, 1:125 000, Berlin.
Internet:
https://www.berlin.de/umweltatlas/en/climate/temperature-and-moisture-conditions/2000/maps/

[19] SenStadt (Senatsverwaltung für Stadtentwicklung Berlin) (Hrsg.) 2001c:

Berlin Digital Environmental Atlas, extended and revised edition 2001, Map 04.05 Climate Zones, 1:50 000, Berlin.
Internet:
https://www.berlin.de/umweltatlas/en/climate/urban-climate-zones/2000/maps/

[20] SenStadt (Senatsverwaltung für Stadtentwicklung Berlin) (Hrsg.) 2001d:

Berlin Digital Environmental Atlas, extended and revised edition 2001, Map 04.06 Surface Temperatures Day and Night, 1:85 000, Berlin.
Internet:
https://www.berlin.de/umweltatlas/en/climate/surface-temperature/2000/maps/

[21] SenStadt (Senatsverwaltung für Stadtentwicklung Berlin) (Hrsg.) 2001e:

Berlin Digital Environmental Atlas, extended and revised edition 2001, Map 04.07 Climate Functions, 1:50 000, Berlin.
Internet:
https://www.berlin.de/umweltatlas/en/climate/climate-analysis/2000/maps/artikel.927909.en.php

[22] SenStadtUm (Senatsverwaltung für Stadtentwicklung und Umweltschutz Berlin) (Hrsg.) 2002a:

Berlin Digital Environmental Atlas, extended and revised edition 2002, Map 06.01 Actual Use of Built-Up Areas, 1:50 000, Berlin.
Internet:
https://www.berlin.de/umweltatlas/en/land-use/actual-land-use/2000/maps/artikel.957868.en.php

[23] SenStadtUm (Senatsverwaltung für Stadtentwicklung und Umweltschutz Berlin) (Hrsg.) 2002b:

Berlin Digital Environmental Atlas, extended and revised edition 2002, Map 06.02 Inventory of Green and Open Spaces, 1:50 000, Berlin.
Internet:
https://www.berlin.de/umweltatlas/en/land-use/actual-land-use/2000/maps/artikel.957873.en.php

[24] SenStadtUm (Senatsverwaltung für Stadtentwicklung und Umweltschutz Berlin) (Hrsg.) 2002c:

Berlin Digital Environmental Atlas, extended and revised edition 2002, Map 06.07 Urban Structure, 1:50 000, Berlin.
Internet:
https://www.berlin.de/umweltatlas/en/land-use/urban-structure/2000/maps/artikel.962333.en.php

[25] SenStadtUm (Senatsverwaltung für Stadtentwicklung und Umweltschutz Berlin) (Hrsg.) 2003:

Berlin Digital Environmental Atlas, edition 2003, Map 04.10 Climate Model Berlin - Analysis Maps, 1:50 000, Berlin.
Internet:
https://www.berlin.de/umweltatlas/en/climate/climate-analysis/2001/maps/