04.03 Near Ground Wind Speeds (Edition 1995)

Overview

Wind Conditions in Conurbations

Near ground air exchange processes have an essential significance for the air hygiene conditions and the climate of a region. The wind speed is used as a measure of air exchange. It describes the speed of the wind stream; at the same time showing that the atmosphere pulls or pushes away air masses. Within built-up areas, as opposed to the open countryside, an average of 20 - 30 % decrease in the wind speed at near ground can be expected. A simultaneous increase in the level of bio-climatic and air hygienic pollution frequently prevents the introduction of unpolluted air masses on the one hand as well as the turbulence, thinning and the evacuation of this polluted air on the other hand. In the immediate vicinity of individual building structures and in the street area, it can come however to very heavy increases in the wind speed caused by squalls and wind channelization with its accompanying unpleasant effects to persons (wind load, dust squalls, eye irritation etc.).

The wind is defined in terms of a vector of its **direction** and **speed**. The continuous wind measurements are taken, as per international agreement (World Meteorological Organization 1983), at fixed, least disturbed stations at a height of 10 m above the ground.

The decisive determinant of the vertical profile of the wind speed is the respective terrain roughness (cf. Fig. 1).

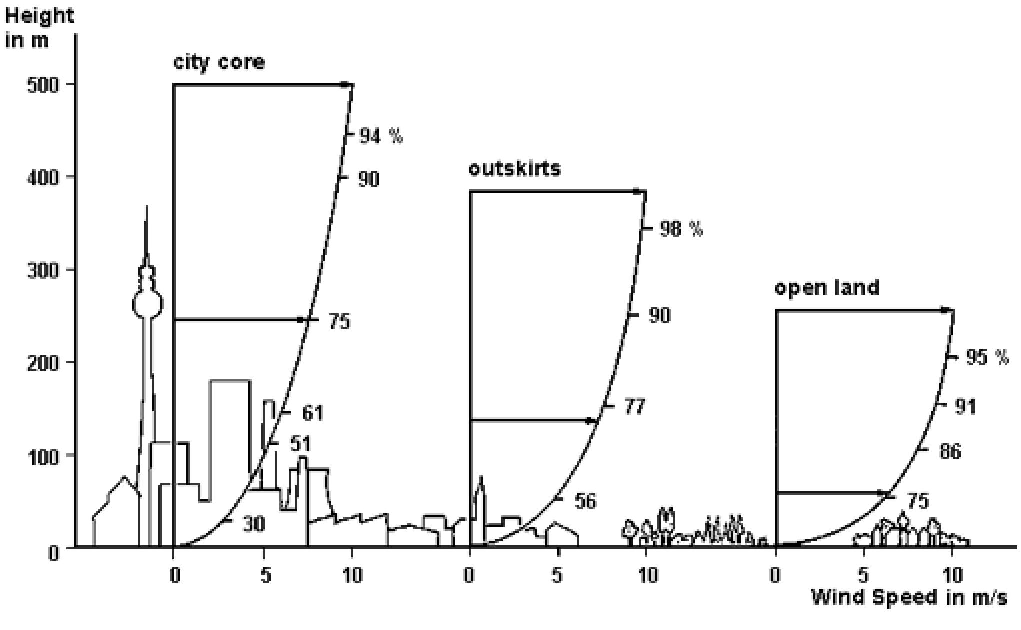

Fig. 1: Decrease in Wind Speed as Influenced by Varieties of Terrain Roughness (according to Baumbach 1991)

Further influence can be exerted either by relief-conditioned cold air drainage especially during low exchange nocturnal radiation periods with slight degree of cloudiness or in urban areas by particular wind systems created through plain wind effects.

The air masses ascending as a result of the strong warming of the city cause after-streams of cooler air from the surrounding countryside. Plain wind effects can only work in the inner city if from the center of town outgoing air channels are available or at least permeable building structures leading to the urban periphery. For very big conurbations like Berlin the plain wind effect plays a role in the above all near cold air generating areas on the city periphery, but also in green spaces in the inner city. The proof for such plain winds requires enormous effort and therefore has up to now only been simulated in a model for Berlin (cf. Wagner 1993 and Map 04.07, SenStadtUm 1993).

Wind Direction and Wind Speed

In Berlin different long-term measurement series for the horizontal wind conditions can be found for different wind measurement stations. The meteorological station at the airfield Tempelhof gives, in comparison to all other stations, the least disturbed and for regional standards the most representative wind speed measurements (cf. SenStadtUm 1994).

In the regional standard, the wind conditions in Berlin are determined through the situation in the transition between continental and more oceanic climate. Certainly the west - to northwest winds correspond to the oceanic component with mainly less polluted sea air. The east - to southeast winds correspond to the continental component with lower wind speeds and above all the higher pollutant concentration in the winter (cf. Fig. 2 and 3). Within the city boundaries however, small scale elements, like temperature - and pressure differences between different city structures also influence the wind currents.

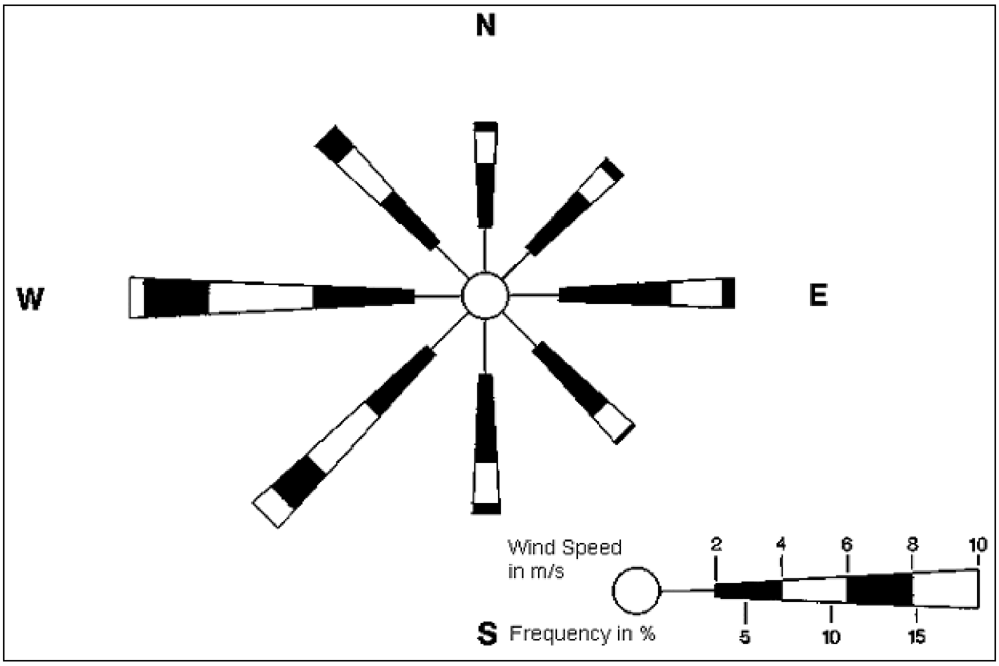

Fig. 2: Relative Frequency of Hourly Averages for Wind Direction and Speed at the Station Tempelhof Airport 1975-1990, Measurement Height 10 m (Institut für Industrieaerodynamik 1993)

The distribution of the wind directions for the Berlin region is representative for both day - as well as night hours (cf. Fig. 2). The most frequent wind direction is west with 21 % of all hours, followed by southwest with 16 %. At both wind directions wind speeds > 4 m/ s appear with the most frequency. North and north east are represented as wind directions of least frequency.

The mean wind speed (averaged over the year) is greatest (cf. Fig. 3) at the most frequent wind directions (west and southwest). Winds from the southeast display, on average, the lowest wind speeds. The annual course of the wind speed has its maximum in the winter and its minimum in the summer months.

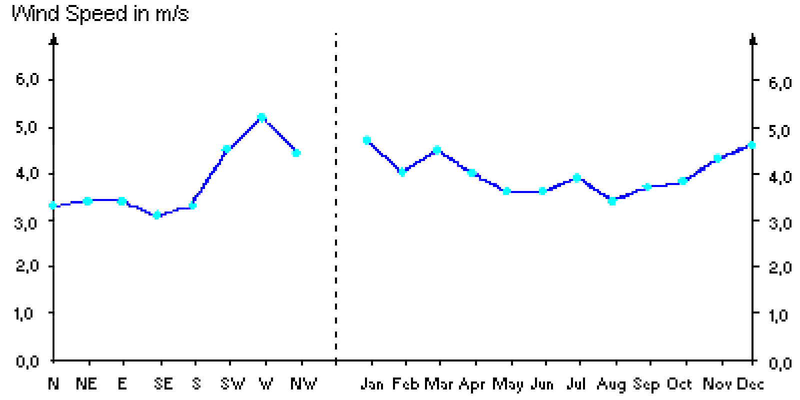

Fig. 3: Mean Wind Speeds in the Course of the Year and in Relation to the Wind Direction at the Station Tempelhof Airport 1975 - 1990, Measurement Height 10 m (Deutscher Wetterdienst 1993)

Emission-climatologically unfavorable weather conditions with wind speeds < 2 m/ s and/or lulls have been registered at 18 %. As mentioned, in the winter the frequency distribution shifts in favor of higher wind speeds.

From this standpoint, the open monitoring site Tempelhof airport is neither altogether nor during the winter months to be ranked as an emission-climatologically unfavorable location.

Wind directional distribution

A comparison of long-term measurement series from four stations in Berlin (Ostkreuz, Buch), Potsdam and Schönefeld for the **wind directional distribution** shows for all measurement sites a similar predominance of west - to southwest winds (cf. Fig. 4). Wind roses are presented for the long-term Berlin reference station Dahlem additionally for the half-year periods summer (May-October) and winter (November-April) (cf. Fig. 5).

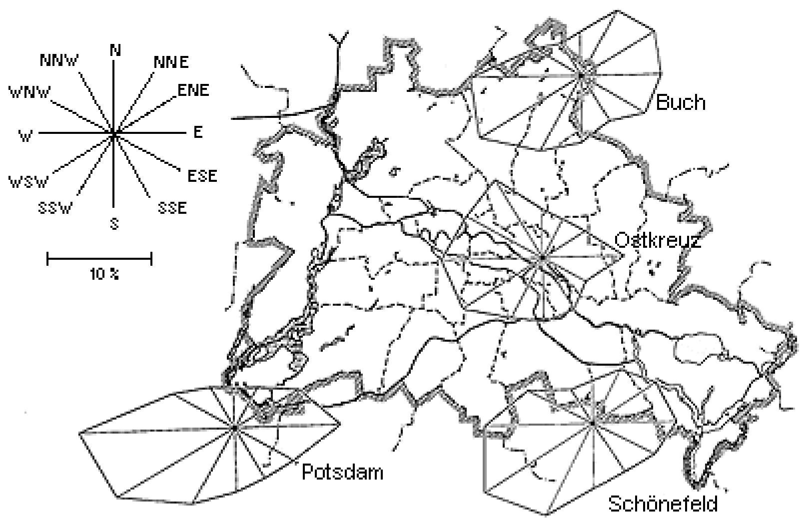

Fig. 4: Relative Incidence of the Wind Direction at the Stations Berlin - Buch, Berlin - Ostkreuz, Schönefeld and Potsdam 1962 - 1976 (according to Hupfer et al. 1990)

The wind roses in Fig. 5 also show the above-mentioned distributions, nonetheless with great seasonal variations. Thereby it should be noted that especially the distribution of the remaining wind directions at all stations differ greatly. The cause for these deviations lies in the respectively specific environment the measuring stations. Similar heterogeneity in the measuring results can also be seen in the maps of near ground wind direction (Maps 04.03.3 and 04.03.4, SenStadtUm 1985). Here the wind directions are presented only for the respective measuring site. Unlike with the wind speeds the statements cannot be applied directly to comparable city structures.

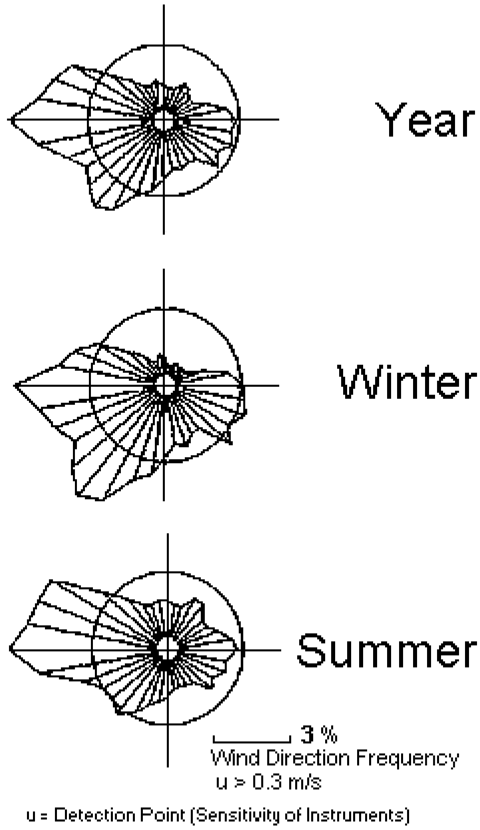

Fig. 5: Relative Frequency of the Wind Directions at the Station Berlin - Dahlem for the Whole Year, Summer (May- October) and Winter (November - April) 1971 - 1990 (SenStadtUm 1994)

Statistical Base

The mobile climate monitoring vehicle of the Department of Bioclimatology of the Technische Universität Berlin was used for the data collection. The data bases for the existing maps were 29 day - and 70 nighttime measurement trips over the years 1980 to 1984 in the area of the western boroughs of Berlin as well as 21 day - and 42 nighttime measurement trips in the year 1991 with the emphasis on the eastern part of the city (cf. Map 04.04.4, SenStadtUm 1994)., The wind speed was measured with an anemometer at a height of 2.70 m at altogether 770 measuring points. Statements as to the wind comfort for pedestrians along with the near ground wind field can thereby be derived. Data on the wind speed at the least disturbed station, Tempelhof airport, at the time of the measuring trips were provided by the German Weather Service (cf. Deutscher Wetterdienst 1992). In addition, research on block courtyard and forest locations were evaluated (cf. Horbert et. al. 1992 and Horbert et. al. 1993).

Methodology

Wind climatic questions have long played a role on the plane of object-related investigations for the impact of planned developments. They can be solved satisfactorily with the aid of corresponding technical resources (wind tunnel studies), also without on site measurements. However this approach is hardly feasible for a metropolitan area. For this reason wind measurements were bound in the climatic investigations to the existing environment atlas. In addition, wind speeds were determined for selected building structures. These were set in relationship to the corresponding values for the reference station Tempelhof airport which is classified as undisturbed.

Since fundamentally in the course of the day the wind speed lies between the maximum at noon and/or in the early afternoon and the minimum in the night, day - and night measurements were evaluated separately. The two median values existing thus at the individual measuring points were collated with city structural types contained in the Environment Information System (UIS) of the Berlin

Department of Urban Development and Environmental Protection (cf. Map 06.07, SenStadtUm, in preparation).

The city structural types consist of 14 groups, in which the wind speed conditions themselves are approximately comparable. A median value for the measuring trip results was calculated separately for each of these groups again by the times of day. As a result **average values of the wind speed** could be calculated **for day and night periods** in 2.70 m height and in reference to 14 structural types -groups.

As comparable values for relatively uninfluenced wind conditions - in reference to the points in time of the day- and nocturnal measuring trips - the medium wind speeds at the station Tempelhof Airport were collected (cf. *Deutsche Wetterdienst* 1992). As the values in Tempelhof are measured at 10 m above ground, a conversion was used, under consideration of the terrain roughness, to adjust the remaining measurements for those taken at a measurement height of 2.70 m resulted. As calculation result the mean lay for the periods of all ascent for the station Tempelhof in 2.70 m height with 3.6 m/s and/or that of the night excursions with 2.3 m/s.

In a further work step the medium values of the wind speeds of the individual structure types - groups were set proportionally to the values of the airport Tempelhof in relationship, whereby the day - and night values of Tempelhof were set respectively 100 %. The wind speeds in block courtyards and in forest areas could be determined from the above named research together with the monitoring trips (cf. Fig. 6). For the area the bodies of water was established because of general knowledge normatively the respectively least deviation compared to that of the reference station.

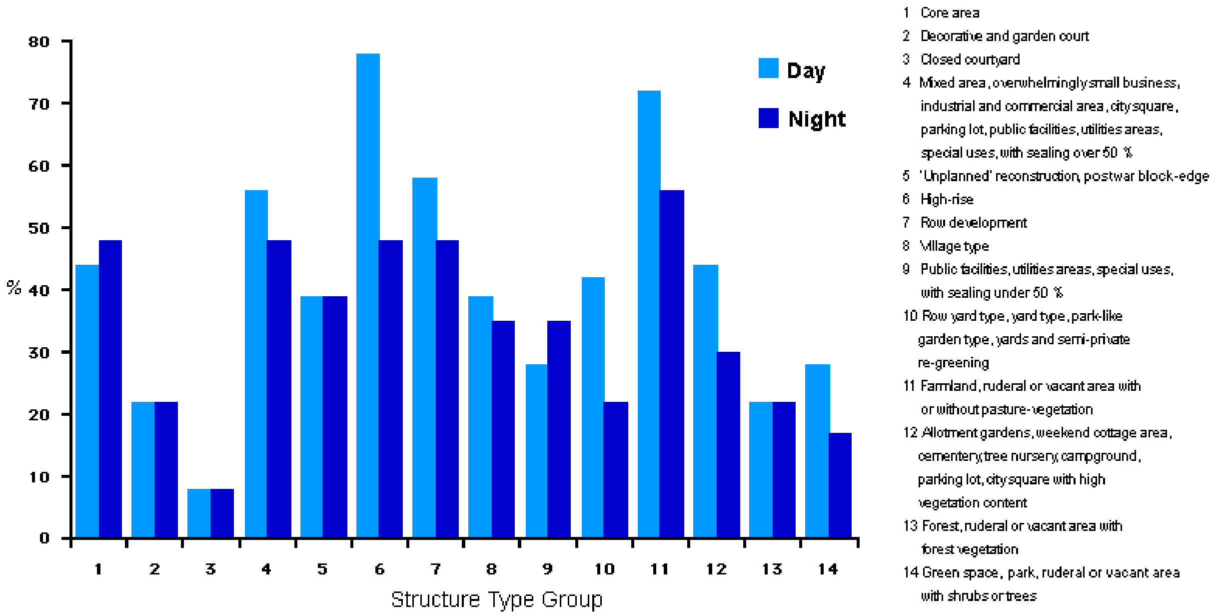

Fig. 6: Average Wind Speed of the Structural Types - Groups in 2.70 m Height Above Ground in Correlation with the Reference Station Tempelhof Airport in % (Tempelhof = 100 % daytime and at night)

The methodological approach chosen presents average wind speeds for each group of urban structure types for selected, representative day - and night situations. Due to the respective surface contours, the particular vegetation structures, the situations in the urban area etc. individual surfaces within each group local peculiarities could only be taken partially into consideration. Here specifically targeted investigations for each individual case are necessary. So the wind speeds can be very different within the structure group farmland, vacant and barren areas without or with meadow-like vegetation. The great farmlands on the outskirts of town display as a rule very high daytime values. During the same time of day reduced speeds are typical for inner city, chiefly smaller areas of similar structure. Likewise at night these differences in area and situation play an essential role. The outskirts and wide-open areas promote the formation of stable near ground air layers and cause with it a considerable wind speed reduction. Inner city smaller surfaces are far less subject to this effect. The largely unstable air stratification here contributes mostly higher wind values, also at night. A similar situation is to be observed also at bodies of water. The large, lake-like bulges in the Havel and Spree admit higher speeds in comparison to the city Spree and to the canals. In order to take into consideration these fluctuations within a structure group, the wind speeds were classified for the depiction.

Map Description

In most cases, the greater aerodynamically-effective roughness of the environment structures have been ascertained reductions of the wind speed for all urban structure types-groups both at daytime as well as in the night in comparison to the reference station Tempelhof airport.

Map 04.03.1 Near Ground Wind Speeds by Day

The lowest wind speeds are displayed in the small **closed courts** of the inner city boroughs Kreuzberg, Schöneberg and Prenzlauer Berg. **Garden court structures** and **forests** reach of course a better, if only very slight ventilation level with reductions of about 80 % compared to the reference value. In forests the structure of the tree stock prevents the wind's intrusion in the stem area, rather it is diverted chiefly above the crowns. Thus the emission risk in these areas is high. **Inner city green spaces** and **vacant spaces with sparse bush - and tree vegetation** are better ventilated, with a wind speed of up to 30 % of that measured at Tempelhof. However increased emission risk exists here also. This is especially true of street intersections because of the shielding effect of the vegetation. The **outer areas** with lower development density and height as well as sparser vegetation structures and **small business areas** display favorable ventilation conditions. **Farmland, open vacant areas and green spaces** are with up to 80 % of the wind speed measured in Tempelhof very well ventilated.

The highest wind speeds for the built-up areas were measured in **high-rise settlements**. Turbulences, jet effects and wind canalization are produced through the unfavorable position of very high building masses. Occasionally such effects can make presence in these open spaces nearly intolerable. Under some circumstances additional air hygienic burdens from dust whirls are also to be expected.

Map 04.03.2 Near Ground Wind Speeds at Night

In contrast to the day situation, the differences at night among the individual urban structures are in comparison to the reference station less noticable. The reason for this adjustment is the general decrease in the wind speed at night. So the wind speed itself for the reference station Tempelhof, calculated at a height of 2.70 m, has been reduced around 35 % and thus corresponds to the reduction in the long-term mean daily course for 1974 - 1990 (cf. Deutscher Wetterdienst 1993). Currently, opposite tendencies within the development structures can be observed. Above all **areas with closed courtyards** show no changes in the daily course of the wind speed. They are the worst ventilated in the night as well as the daytime. The wind speeds in **areas with garden courtyards** and in the **forests** are very slight both at night and during the day. The predominantly unsealed open spaces like **farmland, green land, allotment gardens**, but also the **parks** and similarly structured **vacant areas** exhibit the greatest reduction comparing day and night wind speeds. Here near ground cold air formation in built-up areas results in an additional stabilization of the upper air layer. Given the bad ventilation conditions with here, these areas are ranked as greatly at risk from emissions.

Moreover, it is striking that the **high rise settlements** are ranked two classes further down compared to the reference values. Here the large building masses mean that no stabilization of the near ground air layer can be expected. It can therefore be assumed that the night winds are too weak to produce the squalls which are noticable during the day. So the wind speed in the high-rise areas decreases compared to the day by around more than 60 %. High reductions compared to those at the freely exposed station Tempelhof as well as in the direct comparison with their day values are also displayed in the **greened development areas**. Beside the cooling down of vegetation areas, the daytime protective effect of tree structures contribute to this phenomenon.

The densely built-up, sealed areas of **public facilities , utilities and special use** exhibit minimal changes in either their relative values or their day values. Even the **core areas** exhibit similar qualities, the heat dissipation from the building mass prevents an effective stabilization the near ground air layer.

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