04.02 Long-term Mean Air Temperatures 1961-1990 (Edition 2001)

Overview

Metropolitan areas are subject to fundamental modifications in their thermal balance compared to the surrounding countrysides. Reasons for this are:

- modifications in heat storage capacity and conductivity; and changes in wind and exchange relationships due to masses of built-up structures
- the decrease of evaporating surfaces caused by the high degree of surface sealing and the lack of areas covered with vegetation
- the warming of the atmosphere by the so-called greenhouse effect (especially due to increases of CO_2)
- inflows of energy and water vapor from anthropogenic sources.

Especially problematic aspects of the resulting **urban climate** are considered to be an increase of air temperature, the risk of excessive humidity in summer months, and the year-round worsening of air exchange between higher atmospheric layers and surroundings.

Increase of air temperature in comparison to the climatically unaffected surrounding countryside depends essentially on the density of development and specific vegetation structures. These urban climate influences are confirmed by comparisons of summer temperatures in Berlin between different but typical residential locations, wooded (Grunewald), and open areas near the city boundary (Dahlemer Feld) (see Fig. 1).

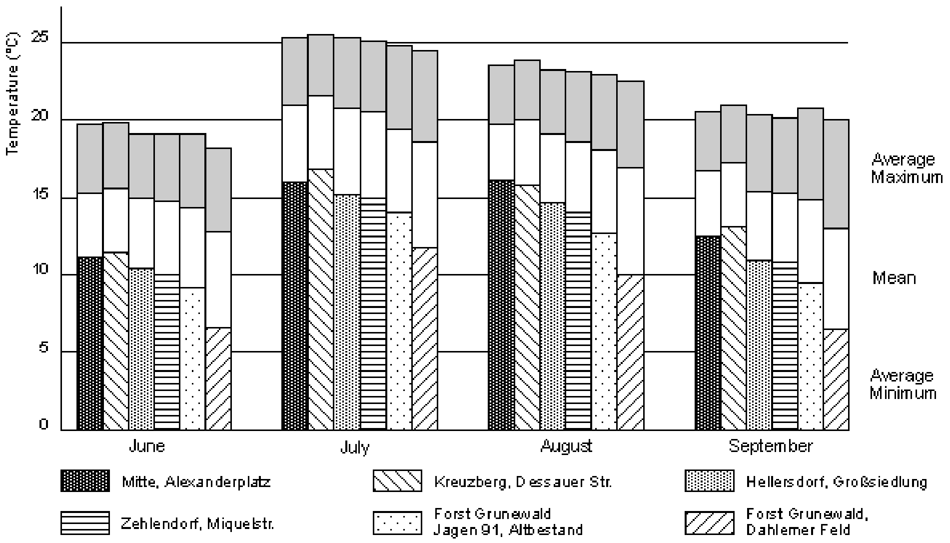

Fig. 1: Mean, Average Maximum and Average Minimum Air Temperature at 2 m, at Various Locations in Berlin from June to September 1991

Differences in average temperatures are due less to average maximum temperatures than to average minimum temperatures. Lack of cooling during summer evenings and nights can lead to impairments of human well-being up to and including sleep and circulatory problems, and heatstroke. The highest temperatures occur in the inner city residential areas of Kreuzberg and at Alexanderplatz. Lower temperatures occur at night in the Hellersdorf large settlement because of its location at the city's edge, but also because of its open building structures. The Zehlendorf borough profits from its high portion of vegetation. Temperatures at the Dahlemer Feld confirm the high nocturnal cooling rates of open field areas at the boundaries of Berlin.

The climate cartography also included areas located outside the city limits (cf. Graphic of Monitoring Routes in Map 04.04.4 SenStadtUm 1993b). Figure 2 shows the course of temperatures along a certain monitoring route. This route runs from Berlin-Mitte over the Spandau borough to Falkensee lake; from there south to the urban area of Potsdam; and subsequently through the Zehlendorf borough back to Berlin-Mitte. Measurements were taken in a low exchange nocturnal radiation period. Temperature differences between the surrounding countryside and the urban area are very clear.

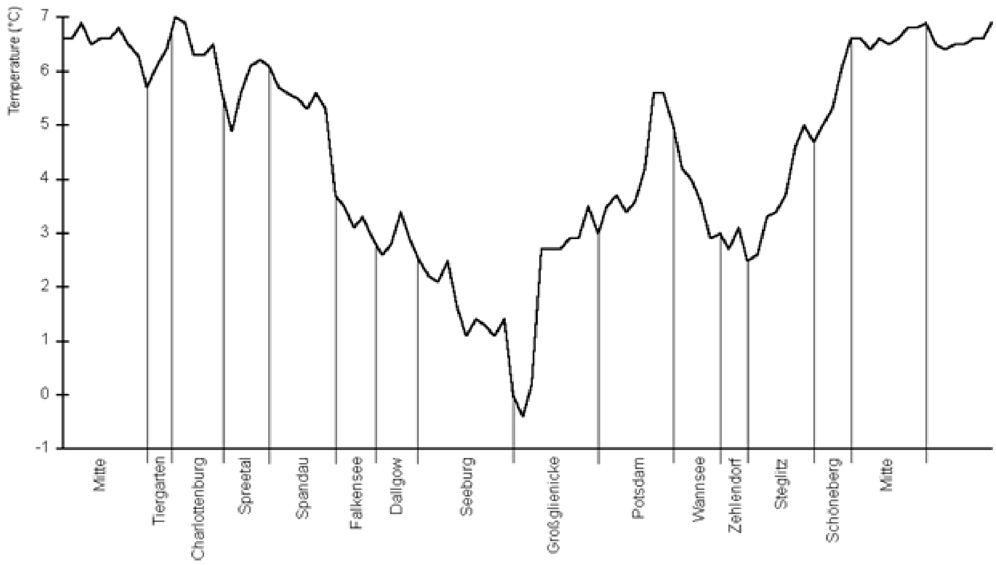

Fig. 2: Air Temperatures at 2 m Plotted through Berlin and Surroundings in a Low-exchange Nocturnal Radiation Period (7 May 1991, 23:15 CET)

The presentation of long-term average temperatures provides a good basis for comparison with other areas, since these climate parameters represent, as a rule, a verified control quantity. They also provide a suitable basis for evaluating current measurements. Long-term mean temperatures are of fundamental ecological significance. The immigration of plant and animal species preferring warm habitats is encouraged by moderate to large increases in long-term mean temperatures and the decrease of the number of frost days compared to the undeveloped surrounding countryside. A rise of temperature from a mean of 7 °C to a mean of 10 °C reduces the number of frost days by one-half (von Stülpnagel 1987).

Statistical Base

West Berlin

Long-term mean air temperatures for **West Berlin** from 1961 through 1980 were available for the first edition of the Environmental Atlas (SenStadtUm 1985). They were used in updating the next edition, in 1993 (SenStadt 1993). Mean values were based on data from 60 daytime and nocturnal measurement trips using a total of 1,000 measurement points, performed from 1981 through 1983 along 24 different routes. The results were integrated into a network of 24 climate stations. Directly measured long-term mean temperature data were available from two of the stations, Dahlem and Tempelhof. Measurements made in 1981 and 1982 were used for other stations.

East Berlin

Data for **East Berlin** and the nearby surrounding countryside were gathered from June 1991 through May 1992. Fourteen climate stations operated during this period in all of Berlin. Forty nocturnal and 20 daytime measurement trips with approximately 500 measurement points were conducted, all in East Berlin, except along one **east-west combined measurement route**, from Rahnsdorf to Grunewald. This program was supplemented by 10 daytime and 20 nocturnal measurement trips, which were undertaken on four routes from the city center into the **surrounding countryside** in order to determine the climatic significance of open areas at the outskirts of town for the affected inner city.

Update of Data Base in 2000

The changes of the use structures in the building stock and also the changed usage of open spaces were expected to cause climatic effects in many places of the city. Another investigation program was therefore processed from September to November 1999 for the classification of the relevant new building and dense-structure areas. The data from 13 climate stations of the TU Measurement Network as well as the Weather Map of the Free University of Berlin were analyzed; three additional stations were built as part of the investigation program. Moreover, during the same time period, 12 nocturnal measurement trips were carried out through representative and structurally changed areas. The air temperature was measured at 2 m of height. For the weighting of the individual measurements for the time periods 1981-'83 and 1991-'92, the prevailing wind directions registered simultaneously with with the temperature measurements at Berlin-Tempelhof were made available as 3-hour values by the German Meteorological Service.

For the situation of land use in Berlin as of 2000, all areas with change potentials of city-wide significance, the construction of which had already been realized in 2000, were taken into account, on the basis of the data from the land-use survey conducted by ID 1 of the Senate Department for Urban Development. In order to also be able to incorporate building projects which had already been initiated, areas were also taken into account on which the projects were slated for completion by 2002.

Methodology

The existence of different data bases made separate calculation of long-term mean temperatures for West Berlin and East Berlin / surrounding countryside necessary. However, the calculation procedures used were largely analogous. The procedure should be briefly outlined, since the entire procedure had to be performed for East Berlin / surrounding countryside.

The **assignment** of individual measurement points to continuously monitoring **climate stations** according to the development and other structure of their surroundings, is of central importance for various stages of calculation. It was assumed that the course of temperatures at the climate stations could be depicted at the measurement points.

As a first step, this assignment enabled the various measurements of a measurement trip to be **synchronized**, i.e., referenced to a point in time (von Stülpnagel 1987). The results of the measurement trips for each measurement point were then **used to calculate a mean value**. The long-term wind statistics for 1950 through 1970 from Berlin-Dahlem (Riemer 1971) were applied for the **weighting** of individual surveys: The relevant air temperature value was weighted for the determination of the mean value by means of the wind direction at the referenced point in time of each survey, and its share of the long-term mean of all wind directions.

The projection of these results onto the **mean annual** values for 1991-'92 again proceeded by means of the measurement points assigned to the climate stations. The climate stations monitored the temperature continuously during 1991-'92. This enabled the determination of mean values for any given point in time. The projection of the mean value for the measurement point required the mean annual values of the climate station and its corresponding time-referenced mean value for the measurement points. Under the assumtion that the locations of the measurement points would behave like their associated climate stations, the difference between these two values measured at the station was carried over to the associated measurement points. Figure 3 shows this procedure schematically.

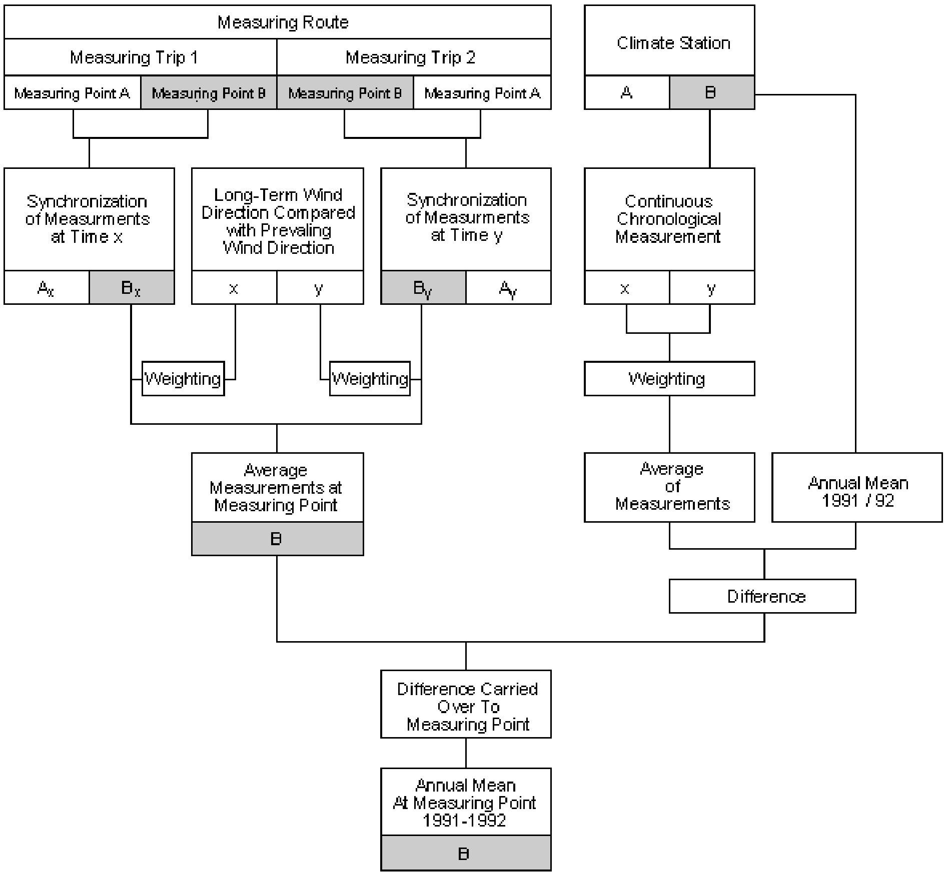

Fig. 3: Schematic Diagram of Annual Mean Calculation for June 1991 - May 1992, Using two Measuring Points from a Measuring Route

The next step was the inclusion of the corresponding measurement trip results for the surrounding countryside. This first step enabled the determination of mean annual temperatures for East Berlin and the surrounding countryside for each measurement point from June 1991 through May 1992 (SenStadtUm 1993e).

Long-term Mean

A transition was now necessary to the **long-term mean** for 1961 through 1990, or, for West Berlin, the conversion of mean annual values for 1961-'80 into mean annual values for 1961-'90. This transition could be only be realized with the help of the two long-term stations at Dahlem and Tempelhof:

West Berlin

The long-term mean at both stations for 1961 through 1980 was around 0.2 °C lower than the newly calculated values for 1961 through 1990 (Institute for Meteorology, FU Berlin 1981-'90 and DWD 1981-'90). The adjustment of the **West Berlin** long-term mean to the new period proceeded on the assumption that this difference of 0.2 °C would apply for all western measurement points of the measurement network, and thus a general increase by this quantity of difference would be justified. Forest locations were the only areas where no changes were undertaken, on the basis of results provided by two stations operated in the Grunewald since 1986.

East Berlin

The calculation of long-term temperature values in **East Berlin** and the nearby **surrounding countryside**, was accomplished on the basis of the mean values calculated for 1991-'92, differentiated according to three different use types. Climate stations were selected which presented a suitable database for the inquiry of the projection factors, because they had been in operation for several years. The **Tiergarten** park station was representative for **parkland/ forest locations**. The **Alexanderplatz** station was assumed to be representative for **dense development**. A 5-year test series between 1975 and 1980 was available for both stations. Under the assumption that these stations would fit between the Dahlem and Tempelhof long-term monitoring stations in the same manner for the period 1975-'80 as for the long-term mean, it was possible to determine long-term mean annual values for Tiergarten and Alexanderplatz. The difference between these means and the mean annual temperatures for 1991-'92 was then used in the projection for the associated measurement points. Figure 4 shows the principles of this procedure, using as examples the Alexanderplatz station and the measurement points for dense development.

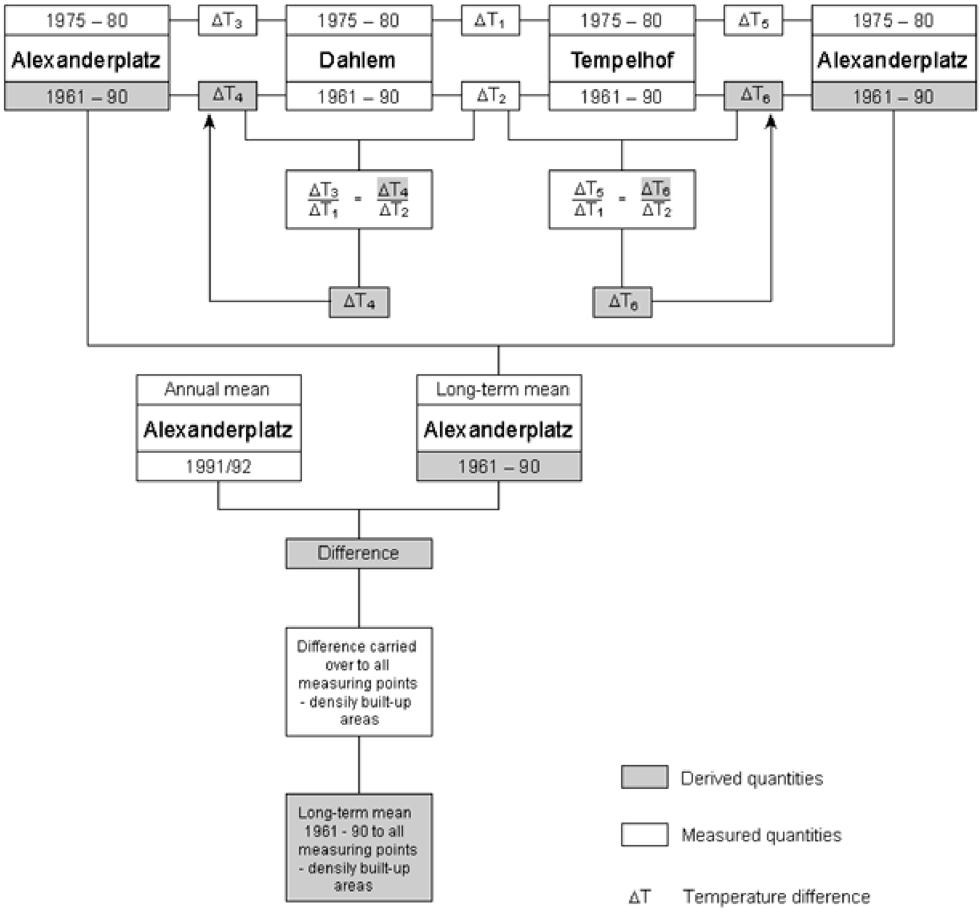

Fig. 4: Schematic Diagram for Calculation of Long-term Mean Using the Example Alexanderplatz Station as Reference for a Location in a Densely Built-up Area

This process provided a long-term mean to use in projections for parkland and forest locations. It is approximately 1.3 °C below the mean annual temperature for 1991-'92. The difference for densely developed locations was about -0.8 °C. The long-term measurement station **Dahlem** represented the third use type of **sparse development**. Its directly measured 30-year average was approximately 1.0 °C below the mean annual temperatures for 1991-'92. Use-referenced values were increasingly included in the projection of 30-year mean temperature values for East Berlin and the surrounding countryside. The interpolation of individual values to areas was performed manually.

Update of the Data Base in 2000

The update of the map to the land use situation of 2000 was carried out in several stages. First, the results from the station and trip measurements were time-corrected. After these raw data were processed, a **scaling of the temperature values** was carried out. The goal was the establishment of a uniform comparative standard to permit the current data of the stations and measurement trips to be entered into the existing 1993 database. The temperature of the investigation period could be compared with the corresponding long-term values by means of the Dahlem reference station.

For areas with use structures which had changed since 1993 and could not be included in the measurement process, an update was carried on the basis of similarity analyses.

Map Description

Unlike (Map 04.06 SenStadtUm 2001b) Daytime and Nighttime Surface Temperatures, the present map calculates a long-term mean situation; it does not depict any individual situation. The temperature spans are thus of course compressed; the minimum and maximum temperatures are less conspicuous.

Long-term mean temperatures in Berlin and the nearby surrounding countryside range from slightly below 7.0 to slightly above 10.5 °C. How high these urban-area-caused values can be more clearly appreciated by a comparison with values at other geographical latitudes. Long-term mean temperatures above 10.5 °C do not appear again until the area of the Upper Rhine Valley, far to the southwest (Walter and Lieth 1964).

A comparison with the 1993 edition of this map shows the climatic effects of construction activity in the city, which as a rule expresses itself in a rise in the temperature level. At some places however, e.g. the areas of the Postal Stadium, and Adlershof (the former Johannisthal Airfield), it was also possible to make corrections in the assignment to temperature classes, due to the now-improved data situation. Here, temperature conditions have to some extent improved, drop toward the level of the surrounding environment.

Within the inner commuter-rail ring (S-Bahn-Ring), three large open areas cause the formation of in some cases very cool zones. These are:

- the Great Tiergarten,
- Tempelhof Airport, and
- the Charlottenburg castle grounds.

They serve to break up the urban “heat island,” which would otherwise be contiguous. This applies particularly to the Great Tiergarten and the Prenzlauer Berg People’s Park near the inner city, the effect of which is amplified by its connection to other green open areas. Former railway switchyards which are presently overgrown with ruderal vegetation, such as the Gleisdreieck South Terrain (*Südgelände*) corridor, also play a similar climatic role.

The South Terrain and such other areas at the edge of the inner city as the Treptow Park/ Plänterwald and the Rehberge People's Park also have a favorable effect.

The structural development of the last 10 years has been characterized by about 30 major and numerous smaller construction projects in the **inner city**. Not all measures were completed by 2001 - the new Lehrte Central Station is a prime example. It is, however already apparent that the climatic conditions have worsened to the south and east of the Great Tiergarten. The area of the highest temperature class (>10.5 °C) has now merged with the "heat island" of Mitte along a line from Potsdamer Strasse through Potsdamer Platz to the east of Friedrichstrasse. Within the Great Tiergarten itself, no remaining major areas of temperature class >9.0 °C could be ascertained (Vogenbeck 2000).

The other residential, commercial and industrial areas bordering these central areas are warmer than 10 °C. These including the Spandau and Potsdam city centers, sections of Siemensstadt, and the industrial and commercial districts of Adlershof and Schöneweide. With the reduction of the density of development and the approximation to the outskirt areas of Berlin, the mean air temperature is decreasing continually.

In the Berlin forests, the mean temperatures are below 8.5 °C, in some cases even below 8 °C. This applies, too, to the woodlands and open fields to the south of Berlin. In the surrounding countryside to the east, north and west of Berlin, there are extensive areas with 8.0 °C or less, which even drops below 7.5 °C in the flat valleys. The Döberitz Heath and the pastureland east of Schönwalde are very cool locations, with mean temperatures below 7.5 °C. This is due primarily to the strong drop in nocturnal temperatures. The moderating influence of bodies of waters is also very apparent. The mean temperatures in the Havel, Spree and Müggel Lake areas are generally between 9.0 and 9.5 °C.

The temperatures of large high-rise residential areas in the east, like Marzahn and Hellersdorf, have conspicuously lower temperatures than those in West Berlin, such as Gropiusstadt and the Märkisches Viertel. This is certainly due in large measure to the fact that the **high-rise residential areas** in East Berlin were built with more extensive open spaces. Their location at the edge of the city also provides them with more exchange with areas less negatively influenced climatically.

The relationship between mean temperatures and the **number of frost days** has been mentioned above. A decline of about 0.5 °C in mean temperature causes an increase of about 10 frost days. The great temperature difference between Berlin and the surrounding countryside, resulting from different use structures, corresponds to extremes of 55 and 120 possible frost days, respectively.

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