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CONTENTS

URBAN CLIMATE AND AIR QUALITY - AN OVERVIEW OF UNIVERSITY RESEARCH IN GERMANY

Wilhelm Kuttler

Introduction

The following overview of urban climate and air quality research in Germany given below builds on the Country Report Urban Climate in Germany (Matzarakis 2005) and is mainly based on the evaluation of publications accessible internationally. In Germany, urban climate and air quality research and teaching are mainly established at university institutes with a meteorological or geographic orientation.

Urban Climate Research

Apart from overall analyses of urban climate (e.g. Endlicher and Lanfer 2003), many studies cover individual aspects. The urban heat island (UHI), one of the best-known features of urban climates, is one of the main focuses of research. Subjects covered by UHI studies include small-scale relationships between surface-specific energy balances (Weber and Kuttler 2005), especially counter-radiation as a function of road geometry and vegetation (Blankenstein and Kuttler 2004), topography (Kuttler et al. 1996) and the effects and dynamics of cold air on UHI intensity and air quality at night (Junk et al. 2003). The demonstration of the penetration depth of rural cold air into urban areas (Weber and Kuttler 2004, Dütemeyer 2000, Kuttler et al. 1998), modelling of cold air dynamics (Sievers 2005) and the occurrence of country breezes (Barlag and Kuttler 1990/91) are relevant for urban planning. The intensity of the UHI is mainly due to the difference of rural and urban land use: although it was possible to establish large-scale relationships, for example with latitude, these were relatively minor, with an explanation of variance of only 6% (Wienert and Kuttler 2005).

In general, the urban boundary layer has lower humidity than the surrounding countryside. However, in low-exchange summer weather situations, these conditions are frequently reversed as the temperature falls below the dew point earlier in the evening and more frequently at night in the surrounding area (Mayer et al. 2003). Studies carried out for a year in the city of Krefeld and the surrounding area show that an urban moisture excess (UME, $\Delta e_{u-r} > 0$ hPa) is established in 36 % of cases (Kuttler et al. 2007).

Knowledge of the complex turbulence structure with the urban boundary layer, especially in urban canyons, and the height of the mixing layer over the course of the day is essential for statements on heat and pollutant transport (Emeis and Turk 2004, Bohnenstengel et al. 2004). This kind of studies are carried out by vertical sounding (Feigenwinter and Vogt 2005, Rotach et al. 2005) and remote sensing (SODAR, RASS, ceilometer, Emeis et al. 2007, Emeis and Schäfer 2006, Emeis 2004, Emeis et al. 2004, Reitebuch et al. 2000). However, numerical model simulations (PALM, Letzel et al. 2008), available to provide also information on the thermal effects of urban canyon circulation (MITRAS, Schlünzen et al. 2003) and wind tunnel studies (Kastner-Klein et al. 2004) are also used. In this context, the validation of the values obtained by numerical model simulation plays an important role (Leitl 2008). It has also been possible to demonstrate large-scale effects of urban settlements on the regional climate. For example, significant changes in total annual precipitation and average air temperatures in connection with the conversion of rural areas into urban areas were quantified using the meso-scale MM5 model (Trusilova et al. 2008).

Urban water bodies and green spaces have a favourable effect on climatic and air quality conditions in urban areas. In this context, green spaces not only include parks at ground level, which can have a positive impact on climatic conditions and air quality even if they only have a very small area (Bongardt 2006, Ropertz 2008), but also planted roofs and façades (Köhler 2008). In addition, lakes can also result in an improvement of the climate in and on the margins of urban areas (Kuttler 1991). In the atmospheric boundary layer of a lake located on the edge of an urban area (surface area 3 ha) lower concentrations of the primary pollutants NO and CO were measured but significantly higher concentrations of ozone, as a secondary pollutant, were observed on clear days (Kuttler et al. 2002).

Air Pollution Research

Particle distribution in the urban atmosphere (PM_{10}) is one of the main focuses of current research related to air constituents. The questions to be answered here include: What kind of mechanisms determine the fine particulate concentrations measured in urban canyons (Holst et al. 2008, Weber et al. 2006), what kind of spatial distribution patterns can be determined as a function of land use (Weber and Weber 2008, Wolf-Benning et al. 2005, Wolf-Benning et al. 2008), what are the effects of the time of day (Vogt et al. 2005), what is the contribution of meteorological (Fig. 1) and traffic conditions (Weber and Litschke 2008)

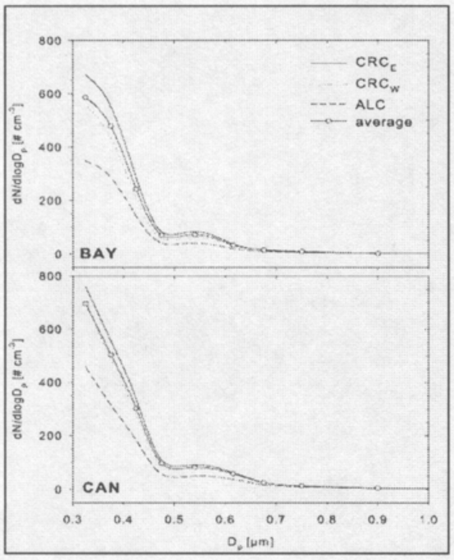

Figure 1: Influence of meteorology on particle number concentrations. The plot shows average number concentration of fine particles measured in a street canyon (CAN) and an adjacent backyard (BAY) during different flow regims within the study area. CRC - flow is perpedicular to street canyon axis either from west (CRCw) or east (CRCe), or is blowing along the canyon axis (ALC). After Weber and Weber (2008).

and how can fine particulate concentrations be predicted with reference to location and time by a high-resolution weather forecast (Klingner and Sähn 2008)?

Comparative studies of fine particulate concentrations in neighbouring cities (Erfurt and Leipzig) show similar patterns in distribution and diurnal course of particle size (Tuch et al. 2003, Tuch et al. 2006). However, as expected, there are significant quality and quantity differences between urban areas and the surrounding countryside (Gietl et al. 2008). There are also relationships between the particle size distribution and vehicle type (Schneider et al. 2008) as well as the source of the air mass concerned (Vester et al. 2007). With respect to air quality improvement, especially near to busy roads, the question arises as to the extent to which planted roadsides and facades can contribute to a reduction in fine particle concentrations (Litschke and Kuttler 2008). To investigate this problem, simulations are conducted with a view to determining the effectiveness of vegetation on the distribution and formation of air pollutant concentration fields (Ries and Eichhorn 2001, Gromke and Ruck 2007) and the basic interaction between plants and the surrounding area with reference to the deposition of dust (Bruse and Fleer 1999). For theoretical modelling, it is important to determine vehicle emission factors as precisely as possible; however, these factors not only vary as a result of fleet differences but are also determined by the season (Ketzel et al. 2007).

A general overview of meteorological factors affecting the propagation of gaseous and particulate pollutants is given by Fisher et al. (2005), who indicate ways to improve air quality. Policy aspects of air pollution are discussed by Schatzmann et al. (2006). As regards the secondary pollutant ozone, it was possible to demonstrate a pronounced north-south gradient in maximum summer concentrations in Germany, as in other European countries. Especially in southern German cities, the EU limits are exceeded, as are the AOT 40 values (Accumulated exposure Over a Threshold of 40 ppb, Klumpp et al. 2006), which have a

sustained detrimental impact on the growth of urban vegetation.
It is still the case that well-founded data for the establishment of carbon dioxide balances for German cities are not yet available. Apart from the calculation of CO_2 emissions from the relevant sources, information which will be needed in this context also includes precise horizontal distributions in the urban canopy layer and a calculation of CO_2 fluxes for different surfaces (Kordowski and Kuttler 2008, Schmidt et al. 2008). Investigations of horizontal CO_2 distribution in urban areas have been made using mobile and stationary measurements in the city of Essen and indicate significant concentration differences as a function of land use during low-wind conditions (Henninger 2008, Henninger and Kuttler 2007). Investigations of the horizontal distribution of CO_2 as a function of relief energy are currently being carried out in the cities of Münster and Lüdenscheid by the Applied Climatology Department of Duisburg-Essen University.

Work on air quality issues also includes epidemiological studies with a view to analysing the effects of air pollutant concentrations as a function of weather conditions on morbidity and mortality rates among the urban population (Junk et al. 2007, Janssen et al. 2008). For the assessment of the air quality component, indices based on various air quality indicators were developed. With the aid of these indices, long and short-term effects on human health can be evaluated. As well, it is possible to give statements on spatial distributions and on the development of air pollutants over the course of time (Mayer et al. 2008b).

Various guidelines of the Association of German Engineers (VDI) on environmental meteorology (such as VDI 3787, Part 1, 2, 5, 9; Baumüller et al. 2008) contain practically oriented notes for the consideration of climate and air quality factors and the presentation of urban climate matters in maps (Scherer et al. 1999). Examples concerning the improvement of air and climate quality in cities are mentioned by Barlag (1997). Mayer et al. (2008a) indicate further possibilities of improving thermal factors by urban planning measures. Widely spread synthetic climate function and planning maps of the type developed in Germany are increasingly being used in other countries, such as China (Katzschner and Mülder 2008) and Japan.

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Correspondence and request for materials should be addressed to:

Wilhelm Kuttler
University of Duisburg-Essen
Campus Essen
Institute for Geographie
Department of Applied Climatology
Universitätsstr. 5
45141 Essen, Germany

e-mail: wiku@uni-due.de
website: www.uni-due.de/klimatologie