International Conference on

Climate Change
The environmental and socio-economic response
in the southern Baltic region

University of Szczecin, Poland
25 - 28 May 2009

Conference Proceedings

Editors: Andrzej Witkowski, Jan Harff
and Hans-Jörg Isemer

International BALTEX Secretariat
ISSN 1681-6471
Publication No. 42
May 2009
Global environmental change and urban climate in Central European cities

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1. Introduction

Cities are the places where about a half of human population lives. It is expected that this proportion will increase in the next future. Urbanization affects on local climate conditions in different ways and in consequence climate of towns differs from the climate of surrounding rural areas. On the other hand, cities belong to the main hot-spots of the emission of atmospheric pollution including greenhouse gasses and therefore play important role in global environmental change (Grimmond, 2007). Svirejeva-Hopkins et al. (2004) suggest that more than 90% of anthropogenic carbon emissions are generated in cities. The main purpose of this work is to characterize main feature of urban climate of Central European cities and put them in the perspective of the global environmental change.

2. Factors changing local climate at urban areas

There are many factors leading to alternation of the urban climate. The most important of them are:
- city metabolism – the most striking effect of it is an air pollution which alters radiation conditions by reduction of incoming solar radiation (especially direct solar beam), and intensifies downward longwave radiation (reduce net radiation losses by longwave emission). The air pollution is also a source for increased number of condensation nucleus in urban atmosphere. Other result of city metabolism is anthropogenic heat emission.
- urban geometry – influences of radiation by increasing urban albedo and decreasing longwave losses. In general it intensifies turbulence and turbulent transport but also reduce ventilation in narrow, wind perpendicular, urban street canyons.
- urban fabric and cover – changes thermal properties of the surface (heat conductivity, heat capacity) and alters albedo and emissivity. Impervious materials cause rapid water runoff.

The role of these factors in modification of weather/climate conditions by cites depends on:
- city location which determines large scale climate condition (climatic zone),
- rural surroundings of the city like degree and type of agricultural land use, type of natural vegetation and soil properties, presence of big river or water reservoirs,
- local topography
- actual weather conditions, especially wind speed, cloud cover and stability of the atmosphere,
- season and time of a day,
- city size and density.

3. Singularities of urban climate in the perspective of climatic changes

The best known (Oke, 1995) singularity of the urban climate is urban heat island (UHI). Under favor weather conditions the temperature in the city is much higher than at surrounding rural areas. It appears at the temperature file as a warm island in a sea of cold air. UHI is a dynamic phenomenon – the highest urban-rural temperature differences (UHI intensity, $\Delta T_{u-r}$) are observed at calm, cloudless night (Fig. 1). During the day or under the windy and/or cloudy weather UHI disappears. In fine weather UHI intensity at night can reach 8–10°C or even more – the highest values of urban-rural temperature differences in Polish cities are: >11°C in Łódź, >10°C in Warsaw, 9°C in in Wroclaw, 8°C in Cracow. In general the highest $\Delta T_{u-r}$ is proportional to the logarithm of city population (Oke, 1973). This allows to expect even higher values of $\Delta T_{u-r}$ when cities population grown. However, climate change can reduce this effect. UHI is observed mainly in the anticyclonic situation. Wind speed and clouds related with atmospheric lows significantly reduce UHI. Some investigations suggest increase of cyclonic activity in Baltic region (see: Bärring and Fortuniak, 2009 for discussion). Thus number of situations with well developed UHI should decrease. On the other hand, even rare UHI episodes could cause significant consequences for a society. Heat waves are one of the potential consequences of global warming which directly affect human health. For example, the heat wave that affected Europe in 2003 claimed more than 35000 lives (Schar et al., 2004). During heat wave episodes the city temperature at night stays a few degrees higher than rural one. As a result temperature in the city can remains above acceptable threshold for a few consecutive days and city population has now nighttime rest form hot temperature. Intensively operating air conditioning produce a large amount of anthropogenic heat and can additionally amplify UHI in such situations. A city influences on the humidity field too. The combined effect of UHI an urban modification of humidity field can cause even stronger total stress for human body during heat wave (Diaz et al., 2002). Moreover, in city the health-damaging effects of high temperatures can be intensified by air pollution.
(notably ozone and total suspended particulates) further stressing the body’s respiratory and circulatory systems (Souch and Grimmond, 2004). On the other hand, there are positive aspects of UHI. Increase of the city temperature in winter can reduce energy used for building heating, but opposite effect, increased energy consumption for air conditioning, can be observed in summer. Net influence of both effects on total energy consumption depends on the climatic zone and degree of economical development. Urban heat island reduces stability of the urban atmosphere at night. This can prevent urban atmosphere form high concentration of air pollution emitted by surface sources. But, increased instability of the urban atmosphere together with large amount of condensation nucleus can intensify growth of convective clouds (Klysik et al., 1990). In the perspective of increased events of heavy precipitations and thunderstorms the city population can be especially affected by these dangerous weather phenomena. It can increase economical losses caused by them and need extra costs for adaptation of urban storm-water drainage. Possible climatic changes which result in increase in convective precipitation and decrease in large scale precipitation alter surface water balance and can lead to water deficit. At urban areas this effect can be more pronounced. Large parts of the cities are covered by impervious materials and majority of rain water is taken off by urban drainage system. During drought periods deficit of soil water content at small lawns can be higher than at rural areas. Deep soil water used by single trees scattered between buildings can be also reduced by urbanization. In result urban green could be even more sensitive for increasing number of dry period than rural one (Fig. 2). An extra water supplied by irrigation system could be needed to mitigate this effect. Possible increased number of days with high wind speed (e.g. Leckebusch et al., 2006) can also make more uncomfortable conditions for city population. In general urbanization reduces mean wind speed, but tunneling of wind between high buildings can generate local wind speed above critical value for human comfort or even for human stability. Moreover, sudden changes in wind speed and wind direction being a result of urban structure have a significant impact on the response of an individual to the strong wind. High gradients of wind urban structure can obviously cause danger situations for urban transport and constructions.

4. Conclusions

While predicting climate change and its impacts is still highly uncertain, its negative effects can be amplified at urban areas. Although high developed cities in Central Europe and Baltic region are less vulnerable to potential climate change than cities in low latitudes some effect could have severe socioeconomical consequences. These possible effects could be reduced by mitigation strategies which adopt urban environment to be less vulnerable to climate change. Some of them like increasing of building and road reflectivity by using high reflection paints for roads, buildings and vehicles; improved roof and walls insulations; application of district heating and cooling systems can be applied to the already existing city districts. Other ones like changes in building spacing and building heights, greenroofs and greenwalls or significant increase of greenspaces must be taken into consideration in planning of new parts of city. In the perspective of global environmental change mitigation of negative consequences for city-dwellers should be one of priority in urban planning.

Figure 2. Increasing Bowen ratio during dry period from a typical value for urban site ($\beta=2$) to extremely high one: $\beta>7$ – values characteristic for semiarid areas (on the base of data from Łódź 2005).

References


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