Organization for Landscape and Urban Green Technology Development

Contents

NEWSLETTER ON URBAN HEAT ISLAND COUNTERMEASURES

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Anthropogenic Heat and Urban Heat Islands: A Feedback System

SUBCOMMITTEE ON HEAT ISLAND
COMMITTEE on the Global Environment, Architectural Institute of Japan
http://news-sv.aij.or.jp/tkankyo/s3/

Introduction

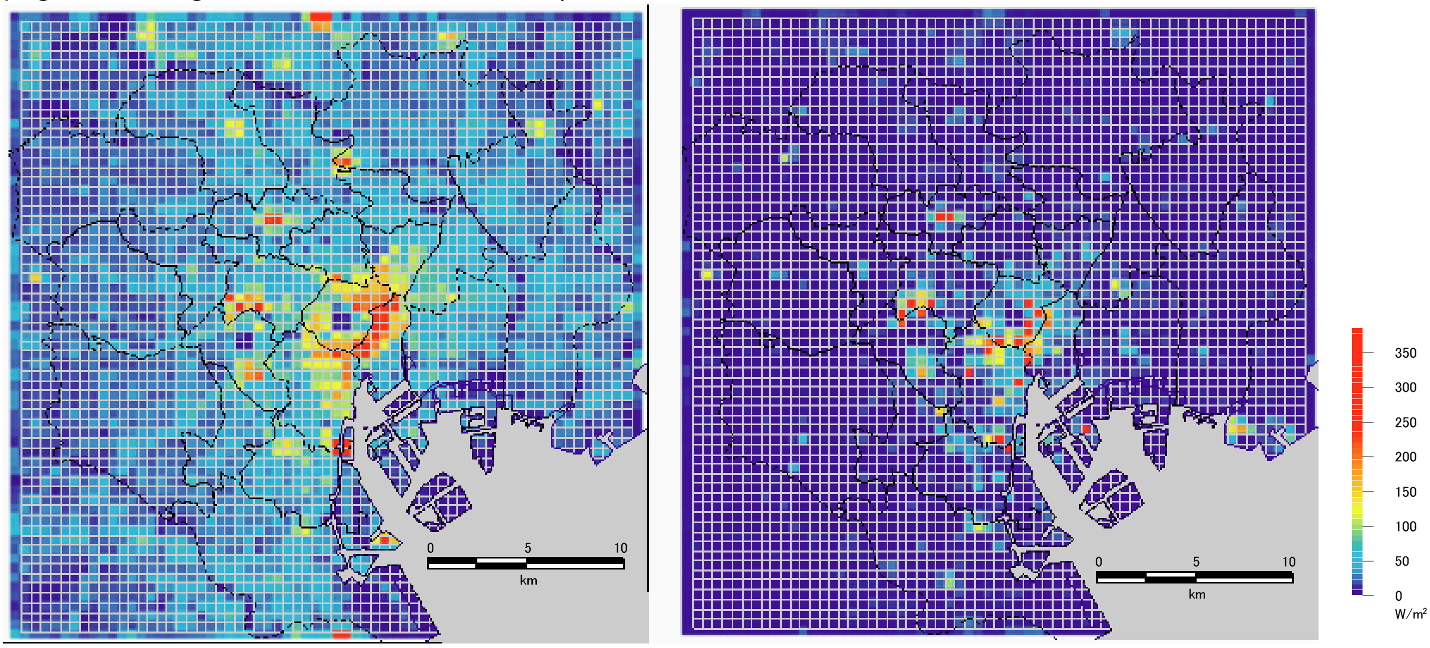
Anthropogenic heat generated by energy consumed in the course of urban activities-especially by buildings, traffic, and industry-plays an important role in urban climates. It is one of the main causes of the urban heat island effect, which is responsible for numerous severe problems in urban areas. To be able to counter the effects of urban heat islands, we need to deepen our understanding of their various causes.

At present, the majority of the worlds' urban climate studies are done in Japan. One of our endeavors is to share this accumulated knowledge with foreign researchers. We hope to help improve climate problems in other cities around world, especially the rapidly growing Asian mega-cities.

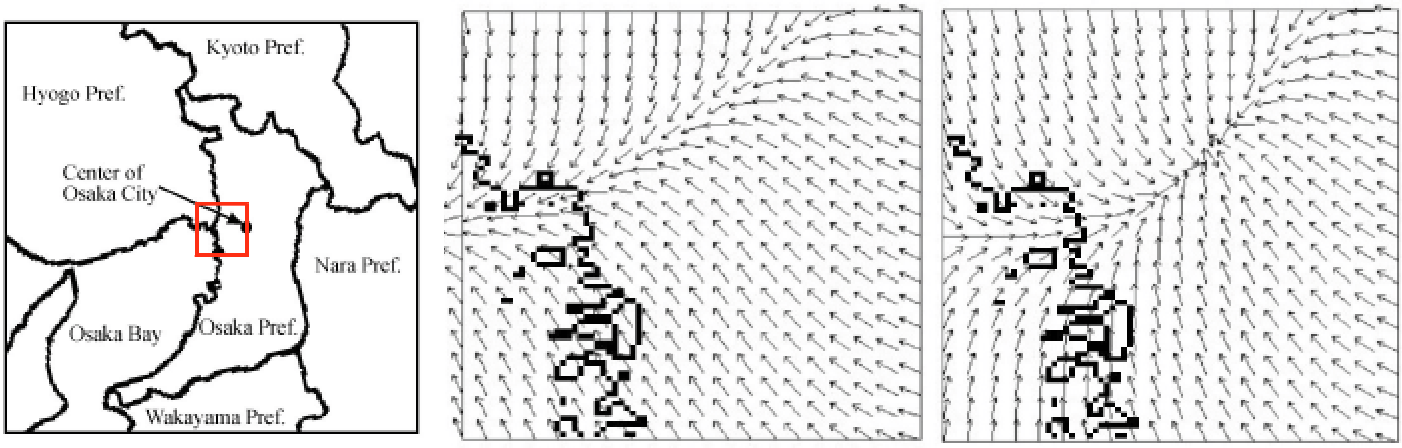
Impacts on urban climate

Many studies have addressed the impact of anthropogenic heating on the urban climate of Tokyo. It has been found that, in summer, the influence of shortwave radiation is strong and the influence of anthropogenic heat is relatively small. In winter, on the contrary, the influence of shortwave radiation is relatively weak and the influence of anthropogenic heat prevails.

In the 23 wards that comprise the inner-city area of Tokyo, the daily average value of anthropogenic heat during summer is 32 W/m^2 (Ashie et al., 2004). That is 18% of the average daily incoming solar radiation. In winter in central Tokyo, the anthropogenic heat flux exceeds 400 W/m^2 during the daytime. The maximum value was found to be 1590 W/m^2 on winter mornings when the area examined was divided into a grid of 250 × 250 m cells (Ichinose et al., 1999). The sea breeze in the Tokyo area is especially weak in wintertime. This together with anthropogenic heating causes the formation of a strong urban heat island.



Sensible (left) and latent (right) anthropogenic heat in Tokyo (Ministry of Environment 2003).



Computed mid-night wind directions around Osaka with (right) and without (left) anthropogenic heat (Narumi et al., 2002). The domain of these figures is depicted by a red square in the left map.

Although there are differences according to the season, the amount of anthropogenic heating at night is lower than during the daytime. Nonetheless, because nighttime shortwave radiation is nearly zero, the impact of anthropogenic heating on temperature is three times as large as during daytime (Narumi et al., 2002). The impact of nighttime waste heat continues into the early morning. In coastal areas such as Tokyo and Osaka, when shortwave radiation weakens in the afternoon, anthropogenic heating delays the reconstitution of the land breeze.

Famous studies on anthropogenic heat conducted outside of Japan, such as those by Oke (1987), Grimmond et al. (1991), and Klysik (1996), have mainly focused on urban energy balances, anthropogenic heat flux to the atmosphere compared with net radiation, and sensible heat flux from the ground surface to the atmosphere. Annual average anthropogenic heat flux is about 20 W/m^2 or less in European and North American cities (e.g., Oke, 1987), but it is greater than 30 W/m^2 for the 23 wards of inner Tokyo (e.g. Ashie et al., 2004).

On the other hand, most studies on anthropogenic heat in Japan have been oriented towards the impacts on urban climate and have aimed to find countermeasures to mitigate urban heating. The background to this emphasis seems to be the fact that coastal mega-cities in Japan show densely concentrated urban activity extending over a very large area. Kimura and Takahashi (1991) used anthropogenic heat data as input to a mesoscale numerical simulation and determined the extent of urban warming caused by anthropogenic heat emissions in Tokyo. Ichinose et al. (1999) gave high-resolution time-series and spatial data for anthropogenic heat in Tokyo and estimated the temporal and spatial distributions of urban warming by anthropogenic heat emissions. In this century, many impact studies followed (e.g., Kikegawa et al., 2003, 2006), and "anthropogenic heat" has become a characteristic keyword for Japanese urban climatology.

One of the few non-Japanese studies with a similar focus is that of Sailor and Lu (2004), which showed a new methodological breakthrough against the limitations of GIS data in urban and surrounding regions.

Causes

Three main causes of anthropogenic heating have been identified: buildings, road traffic, and industrial activities. Cooling in summertime and heating in wintertime are some of the main sources of anthropogenic heat in office and residential buildings. Anthropogenic exhaust heat from buildings is concentrated in the center of Tokyo. A clear relationship has been found between floor space and the ratio of latent heat to total heat (including sensible heat) released from air conditioning systems and related devices (Ashie et al., 2002). This may be due to the effect of cooling towers, which are mainly used in large buildings. Using a GIS database of floor space, Ashie et al. (2002) estimated the total amount of sensible heat released from air conditioning systems and related devices in the 23 wards of Tokyo, and they showed it reached 13 to 14 GW in the daytime and 180 GWh per day. In addition, latent heat released from air conditioning systems and related devices accounted for 25% to 28% of the total daytime heat in the summer.

The impact of anthropogenic heating caused by road traffic extends towards the suburbs, whereas the effects of industrial activity are mainly located around factories. Increased mobilization is expected to intensify the effects of road traffic. The ongoing process of urban agglomeration will boost the effects of anthropogenic heating on urban heat islands.

Technology for countermeasures

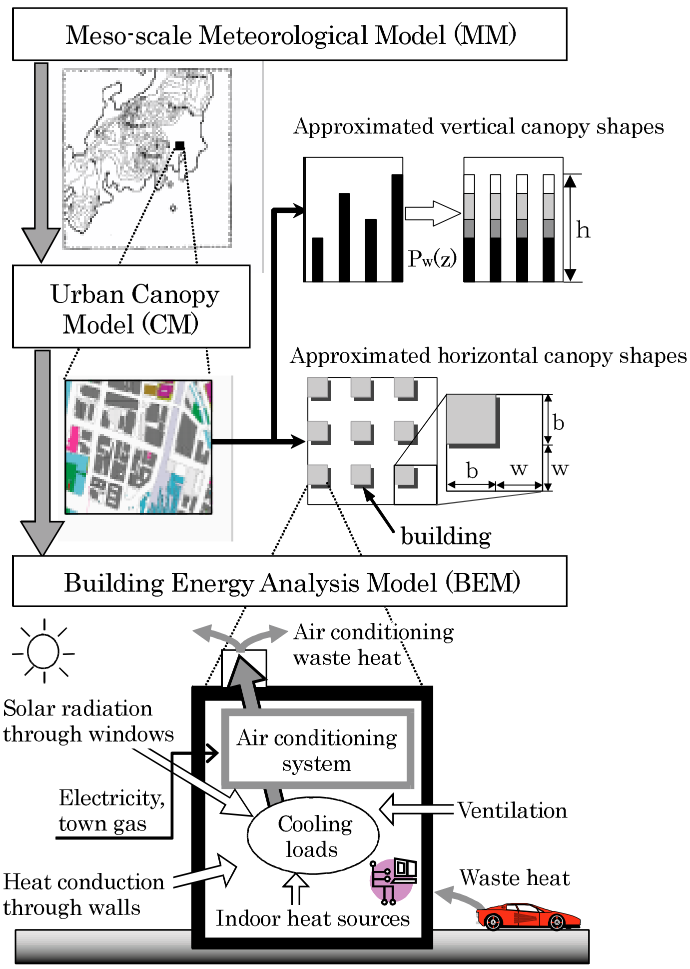
Since the use of energy in cities cannot be reduced to zero, there will always be anthropogenic heating. Nevertheless, energy usage can be reduced to reduce the amount of anthropogenic heating and adaptive measures can be taken to weaken the impact of anthropogenic heating.

Energy usage can be reduced by improving the energy efficiency of air conditioning systems and other cooling equipment. Sewage heat can, in addition to other uses, be utilized for heating in winter (Ichinose et al., 1996; 1998). Passive cooling is an adaptive measure to maintain indoor comfort while reducing the cooling load of air conditioning systems. Passive cooling technologies include reflective surfaces, rooftop planting, and the creation of air corridors for natural ventilation. Adaptation of lifestyles and clothing to higher temperatures can reduce usage of air conditioning systems. Recently, this has come to be known as "CoolBiz" in Japan. "WarmBiz", on the other hand, means the adaptation of lifestyles and clothing to lower temperatures in winter. Together with improved thermal insulation on buildings, these efforts can lead to a reduction in the energy used for heating.

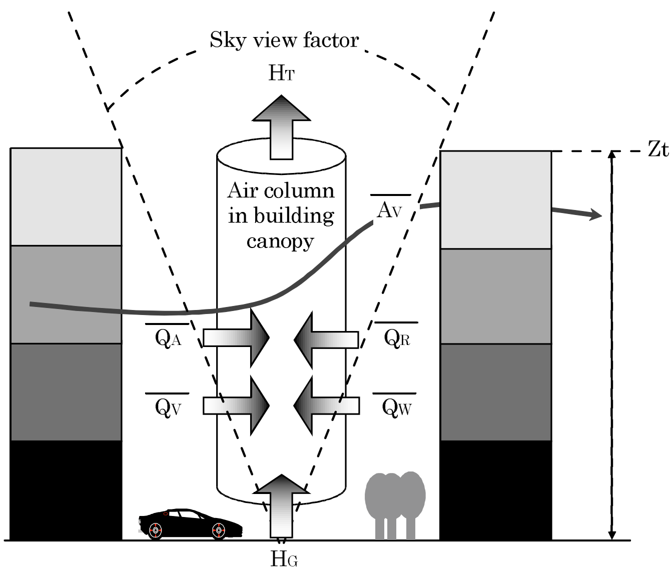
However, we also need to discuss countermeasures from viewpoints other than lifestyles and materials. Kikegawa et al. (2006) focused on urban canopy shape and made some outstanding remarks on urban design. They developed a numerical simulation system (MM-CM-BEM) with the aim of comprehensively assessing urban warming countermeasures, including their impacts upon the energy demands of urban buildings. The model showed that anthropogenic heat emissions became more sensitive to urban air temperature as the sky view factor decreased (Kikegawa et al., 2006). From the results, they divided the 23 wards of Tokyo into several different categories, which can be used to prioritize urban warming countermeasures to reduce anthropogenic heat emissions in different regions.

Future perspectives

Discussions of "low-carbon cities" are currently very popular in Japan. One representative idea to make such cities a reality is the recycling of heat energy. The "Tokyo Half Project" of the University of Tokyo is one such ongoing research project aiming to cut the GHG emissions from Tokyo by half. When we plan such low-carbon cities, we need to understand that there is a feedback system between urban climate and anthropogenic heat emission (energy consumption). Narumi



Composition of the developed simulation system (MM-CM-BEM) (Kikegawa et al., 2003)



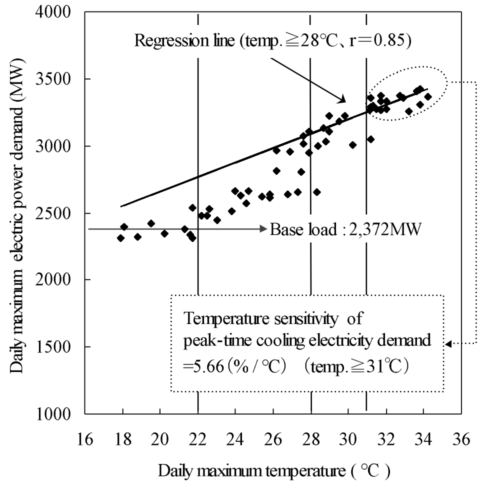
Schematic representation of the atmospheric heat-balance in the urban canopy (Kikegawa et al., 2006).

et al. (2007) showed the effects that temperature increases associated with the heat island phenomena and global warming would have on Osaka's energy consumption in each sector of the economy. Their results showed that, if the year-round temperature increases by 1˚C, the annual energy consumption will decrease in houses but increase in office buildings.

We think that anthropogenic heating needs to be an ongoing topic of research. It is necessary to share case studies from around the world to understand and deal with this phenomenon. Since anthropogenic heating, heat islands, and global warming interact with each other, the research will contribute to broadening urban environmental research throughout the world.

Together with the countermeasures mentioned above, enlightening people can effectively change the situation in the future. With regard to anthropogenic heat, we should instruct citizens on how to improve the thermal environment through changes in lifestyle habits.

This report is a part of the results of the research project, "Study on the Strategic Urban Planning and Assessment of Low-Carbon Cities", The Global Environment Research Fund (Hc-086: FY2008), Ministry of Environment (Head investigator: Prof. Hidefumi Imura, Nagoya University).



Relation between the daily maximum regional electric-power demands and the daily maximum near-ground air temperature in central Tokyo during weekdays from June to August 1998 (Kikegawa et al., 2003) .

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SHASE: Transactions of the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan

JE: in Japanese with English abstract

Information

"5th Japanese-German Meeting on Urban Climatology" was held on October 5 - 11, 2008, at Albert-Ludwings-University Freiburg in Germany. There were 52 oral presentations and 32 poster presentations. The next meeting will be held at Hiroshima Institute of Technology, Japan.

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