APPLICATION OF SOLAR RADIATION ESTIMATION MODEL BY USE OF
SHADING EFFECT TO URBAN AREA

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Abstract

Heat island phenomenon is noted as getting worse thermal environment in urban area. Therefore, there are a number of studies about atmospheric environment in this area. However, it is difficult observation in urban area because of these areas have complex geometry properties. In this work estimated horizontal distribution of solar radiation that it is main factor of thermal environment at surface of urban area. This study use estimation solar radiation model (Kurose, 1991). But this model not take into account structure, so using terrain data change from 250m DEM (Digital Elevation Model) to 2m DSM (Digital Surface Model). This dataset is enough to reproduce urban structure.

As a result, when compared with observation to model output, both sides of time-lag are from low of -12 min to 21 min in clear sky.

Keywords: solar radiation flux, urban canyon, shading effect, estimation model

1. Introduction

Solar radiation, in urban area, is one of the most critical elements to describe the environment. Although the horizontal distribution of the radiation flux is highly diversified not only with height and direction but also with shading effect of the surrounding buildings in urban area, it provides environmental conditions of living space, vegetation lining a street and so on. In the previous works, Nunez and Oke (1977) showed the effects of energy flux with width of street, wall height and its direction, and surface reflectance. Kondo (2001) calculated the urban albedo, using a modeling approach with simplified three-dimensional building of equal size, arranged in a regular lattice.

We developed an estimation model for spatial distribution of solar radiation flux, which varies by solar altitude and weather condition, with taking into account of shading effects in surrounding buildings. In order to utilize this model as a practical assessment technique of urban environment, a fine and effective grid size was selected for digitizing of the urban canyon. To understand solar radiation distribution over actual surface including significant buildings, we provide DSM of Hachobori, Tokyo. We used 2m mesh data (including building height) to reproduce the shading effect and quantify estimate accuracy of surrounding buildings.

2. Data and Method

Generally, global solar radiation flux was modified by fractions of direct solar radiation or diffused solar radiation varying with weather condition. In this research, we assumed clear sky condition for background weather condition, because principal subject of the present research was focused on discussions of a potential role of the shading effect. Interval time of the sun trajectory calculation is 3 minutes. Digital database of the canyon structure was quoted from the Digital Surface Model (DSM) with a grid size of 2 meters around Hachobori, Tokyo metropolitan area (Fig. 1). Japan. Heterogeneity of the building height in this area is represented by from 5 meters for smallest one to 30 meters one for tallest one having an average height of 30 meters (Fig. 2a).

To estimate statistical backgrounds of seasonal change of the global solar radiation flux around the referenced area of Hachobori, prior to the main calculation, climatic data were provided by Tateno Aerological Observatory (140.01° E, 36.06° N) and Ootemachi meteorological observatory (139.76° E, 35.67° N) from 1964 to 2007. Additionally, to verify the projected solar radiation fluxes by the present model, special observations of surface fluxes (1.5 meters high) were carried out at the Point1 from 21 October to 11November 2008 and at the Point2 from 29 October to 11 November. Recording interval was 30 seconds. Locations of these observation points were shown in Fig. 2b.
3. Result and Discussion

Spatial distribution of the projected global solar radiation flux (MJ/m$^2$/day) is shown by Fig. 3 in annual average. Reddish color indicates much insolation area, which appears over water surface, wide streets, intersections and roof tops of buildings. On the other hand, blackish color corresponds with highly shaded area just behind in the north side of in the individual building. Yellowish color is the area affected partially by obstacles protecting the direct solar radiation flux. We showed that the estimated radiation flux over the street facing to the north side of the buildings is about 20% lower than that on the other sides. These properties agree well with the results proposed by Swaid (1993).

In order to verify the projected values, actual global solar radiation flux was measured at Point 1 and Point 2. As shown in Fig. 2a, these two points were established along an open area lying in E-W direction among buildings with 20-30 meters height. Fig. 4 shows time changes of the observed (solid line) and estimated (broken line) global solar radiation fluxes. The time zones represented by orange shades shows durations with direct solar radiation. The present model cannot reproduce the shading effect around 8 o'clock. However around 12:30 (Fig.4a), it is projected that the interception of the direct solar radiation by the surround obstacles can be described and the differences between estimated and observed solar radiation come out by 21 and 18 minutes for Point1 and Point2, respectively.

Estimated solar radiation flux by the present model fitted observed value temporally, but the magnitude of estimated solar radiation was under estimate about 10%. This difference was caused by the present model which did not take into account reflecting solar radiation from surrounded structure walls. The average in differences of solar radiation is about 10% (maximum 50Wm$^{-2}$) in this day. As compared with the magnitude of differences at moon between estimated and observed value, it express larger value at Point1 than that at point2. The difference describes the amount of reflected solar radiation from buildings and it is caused mainly by heterogeneity in the spatial distribution of the building density. This is caused partly by sizing of 2m DSM.
4. Conclusive Remarks

The present study addresses that potential solar radiation on urban area is essential meteorological element to understand the thermal phenomena in urban area. The assessment of urban environment application to this model has enough resolution ever for the real building canopy such as Hachobori, in Tokyo. As a result at temporal reproduction, difference of shading effect that falls over the canopy structure was appeared within -12 ~ +21 minutes in timing. So, when estimating of solar radiation using 2m DSM, we can get temporal daily variability within -12 ~ +21 minutes. We can reproduce daily variability of solar radiation flux in urban canopy. At spatial reproduction, we can estimate solar radiation distribution on the each direction of streets, water surface and roof tops in urban area.

References

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