学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Evaluation of the effect of snow cover on the winter urban heat island in Sapporo city, Japan.
（積雪被覆が札幌市の冬季ヒートアイランドに与える影響の評価）

Urbanization alters the land cover from natural vegetation to artificial material, leading to the change of surface energy budget. As a result, urban environments form urban heat island in which urban areas are hotter than rural areas. Urban heat islands have been investigated around the world including tropical and snowy regions. However, the relationship between urban heat island and snow cover has not been clear. Therefore, the purpose of this study is to clarify the snow cover effect on urban heat island in Sapporo city, Japan. This study includes three analyses with a regional climate model coupled with urban canopy model as follow; 1) evaluating the role of snow cover in urban street canyon on the urban heat island, 2) the assessment of snow clearance effect on winter urban heat island, 3) evaluating the sensitivity of urban heat island intensity, defined as the temperature difference between urban and rural areas (hereafter UHI), to the snow cover.

The Weather Research and Forecasting model with 1 km grid spacing was used for numerical experiment during continuous snow cover period in January. To represent snow cover in urban street canyon, this study developed an urban canyon model that is able to consider time-dependent physical properties in urban areas, such as surface albedo, surface emissivity, and thermal conductivity for roof and road as a function of snow depth and snow water equivalent. The effect of latent heat was also simply expressed by defining maximum skin temperature and minimum moisture availability.

To evaluate the role of snow cover in urban street canyon on the urban heat island, two experiments were conducted, with and without snow cover effects in urban canyon. These experiments revealed that snow cover in urban street canyon decrease surface air temperature in urban areas, which is more strongly for daily maximum temperature (0.4−0.6 ˚C) than for daily minimum temperature (0.1−0.3 ˚C). This result is mainly caused by decreased sensible heat flux due to decreased net radiation at building roof because of high snow albedo. This analysis also indicates the decrease in surface air temperature in urban street canyon by the treatment of snow cover is comparable magnitude to the increase in surface air temperature due to anthropogenic heat release in Sapporo.

To discuss the possible influence of local human activities, the effect of road snow clearance was examined by sensitivity experiments with artificially control of the maximum snow depth in road. The nocturnal surface air temperature in urban areas tended to increase with intensive snow clearance, especially in suburban areas. This

result is caused by increase of ground heat transfer as a result of snow clearance.

Finally, to investigate a role of snow cover in modifying UHI, sensitivity experiments with snow cover (i.e., realistic condition) and without snow cover in entire numerical domain were conducted for January. The experiment without snow cover is based on assumptions that snow immediately disappears when it touches at the land surface; hence, snow neither accumulate nor melt. The role of snow cover was to decrease surface air temperature more in rural areas than in urban areas, which was commonly seen throughout a day. The air temperature over snow cover decreases significantly during nighttime, resulting in increasing UHI by 4.0 °C for daily minimum temperature. Snow cover tends to decrease net radiation, sensible heat flux, and ground heat flux that were more obvious in rural areas than urban areas, consistently with a fact that UHI becomes large in snowy period or in snowy regions. Additionally, the difference of snow depth between urban and rural areas is a potential factor to determine the magnitude of nocturnal UHI because deeper snow in rural areas weakens ground heat flux more efficiently than in urban areas.

According to the numerical experiments, the effect of snow cover on urban heat island is summarized as follows; 1) snow cover in urban street canyon reduces urban surface air temperature, resulting in weakening urban heat island, and 2) snow cover tends to decrease surface air temperature in both in urban and rural areas, but more temperature decrease occurs in rural areas than in urban areas, leading to intensifying UHI.