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Numerical Experiments for Vegetation Mitigation Effects on Thermal Environment

Kimio Inoue*, Kou Nakazono* and Toshikazu Kawakata*

Summary

We evaluated changes in land-use patterns on surrounding thermal environments. Our numerical model was a modified version of the coupled atmosphere-plant-soil model（CAPSM）developed by Inoue（1995）. Numerical experiments focus on a rural-suburban area including Tsukuba Science City.

This paper details field experiments on the temperature variations in the transition boundary in which wind passes from one surface to another with different roughesses. Simulation and observation were conducted in clear summer weather in 1996. The prevailing wind was from NE to SW for July 1996 simulations. In CAPSM, individual land plots corresponding to paddy fields, grassland, industrial zones,were parameterized by model canopies with different aerodynamic properties, radiation profiles, stomatal resistance, and turbulence.

(1) Simulation showed that monthly mean air temperature and canopy temperature within model canopies are lower for relatively wet plots such as paddy fields and forests than for relatively dry plots such as upland crops and industrial zones, mainly because much short-wave radiation at wet sites is used as latent heat to evaporate water into the atmosphere. We found that midday temperatures at wet sites were 3-6℃ lower than at dry sites, indicating that wet sites modify surrounding thermal environments to a greater extent than dry sites. Simulation for intentionally modified terrain showed that monthly mean of daily mean and daily maximum air temperatures at z=1.5m are related to the Bowen ratio characterizing the energy balance as a land-use pattern. This means that latent heat flux due to evapotranspiration plays an important role in vegetation mitigation in thermal environments.

(2) To evaluate the sensible temperature on thermal conditions experienced by human beings, we used Linke's equation. Sensible temperature is expressed as a function of simulated wind velocity, global solar radiation, and air temperature distributions at z=1.5 m above ground. The sensible temperature thus calculated was apparently lower over paddy fields and forests with larger latent heat flux than over grassland and houses with larger sensible heat flux. These results agree well with spatial distribution patterns of the canopy temperature obtained from our CAPSM simulation results.

(3) Our field experiments indicated that horizontal variations in air temperature affected by thermal environments of nonuniform terrain in the transition boundary layer are controlled strongly by mean wind velocity, roughness length, and short-wave radiation and suggested that the roughness effect is indispensable to moderating thermal environments. Our results agree qualitatively with our CAPSM simulation results.

Keywords: land-use pattern, vegetation mitigation, transition boundary layer, local climate model, sensible temperature

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*National Agricultural Research Center