II -19

SIMULATION OF HEAT AND MASS TRANSFER BETWEEN SOIL AND ATMOSPHERE APPLYING TO URBANISATION

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1. Introduction

This study concerns with an integrated simulation of coupled heat and mass transfer between bare soil and atmosphere. Following SALSA (Soil Atmosphere Linking Simulation Algorithm) (Berge 1990), the heat and mass transfer between bare soil and atmosphere in Hanno test site of Housing Urban Development Co. was simulated. The results provide useful information for estimating water balance in this area where a large scale land development is under way.

2. Model Description

The model is constructed in one dimension from ground water table up to upper atmospheric boundary layer with three main parts: surface, atmosphere and soil. Using measured meteorological data and surface conditions, the model estimates the heat and mass fluxes between soil and atmosphere. After that, the physical processes occurring in atmospheric boundary layer and porous media are simulated.

The processes in the atmosphere are governed by a set of momentum, potential temperature and moisture equations. Transport fluxes of momentum, heat and vapour are estimated from eddy diffusivities which are functions of the corresponding length scales. These scales are obtained by similarity functions, Monin-Obukhov length scale and solution of the turbulent kinematic energy (TKE) equation.

The atmospheric algorithm links with soil one by the surface condition where the conservation of heat and water mass is specified. It is assumed that there is no storage of heat and water mass on the surface. The input net radiation is partitioned into sensible, latent and ground fluxes which are the condition for solving equations in both porous body and atmospheric boundary layer. The water mass transfer through the surface composes of evaporation from soil and the precipitation.

The soil algorithm solved a set of equations used for describing the heat and the water mass transfer in capillary porous bodies. In the heat transfer equation, the soil capacity and soil conductivity are estimated from volumetric participants of porous body. The water in the soil is treated here as a two-phase mixture of liquid water and water vapour. The coupling method of the heat and water mass is given in Berge 1990.

3. Observation Field Site

The field site where the measurement system is working locates in the Hanno new resident town, Saitama prefecture (35°53'N, 138°36'E). The meteorological properties: air temperatures at two height positions, humidity (wet- and dry-bulb), solar radiation, ground heat flux, albedo, precipitation, atmospheric pressure, wind speed and its direction, are measured for every minute. The data in August 1997 are taken into the consideration. The soil water content and temperature at each 10cm from surface down to 1m deep on Aug. 12 1997 also have been measured.

4. Simulation Results

The simulation is carried out for a domain from ground water table up to 3069 m in atmospheric boundary layer. The ground water table is supposed to be at 1.5m below the ground surface. At this boundary, the soil temperature and water content are keeping constant during total simulation period. The porous body is divided into 25 layers by nonuniform mesh. The grid size is smallest (0.2cm) at layer nearest to the surface and gradually increases to 30cm in ground water table layer.

For the atmospheric computational domain, a total 20 grid points are used with smallest size 1.5m at the surface and increases to 700 m for the top layer. At the top layer, the constant potential temperature and mixing ratio are enforced.

The simulation is performed with the same conditions

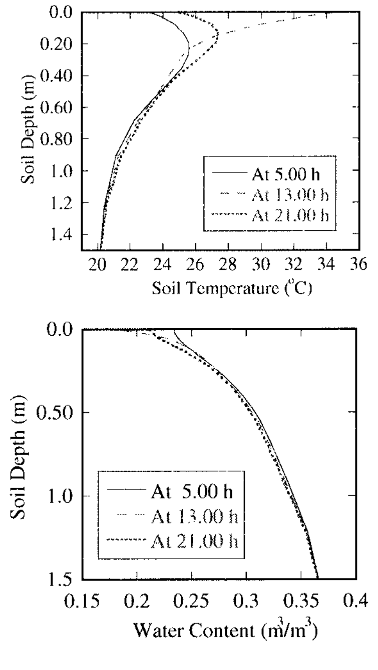

Fig.1 Simulated Vertical Profiles of Soil Temperature and Water Content below Bare Soil on Aug. 12, 1997.

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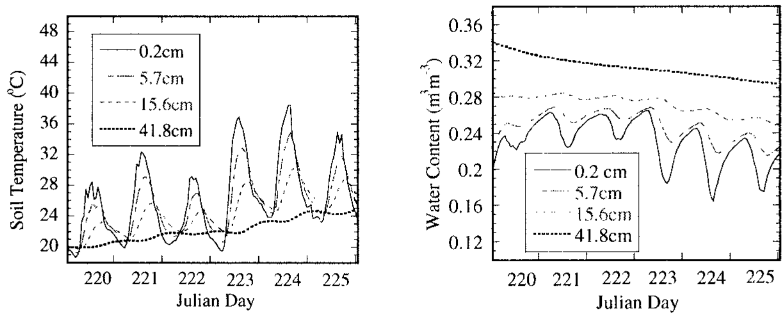

Fig. 2 Time Dependence of Simulated Soil Temperature and Water Content at Different Depths

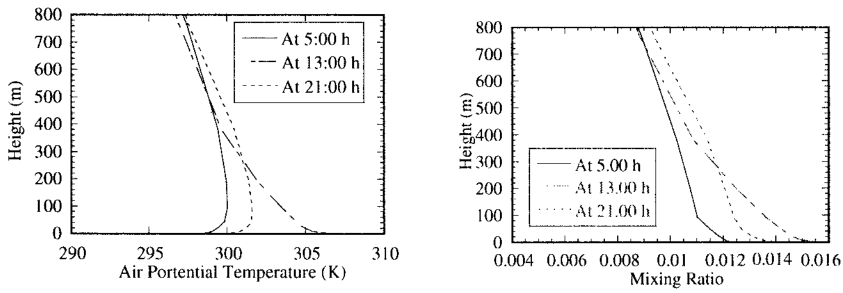

Fig. 3 Simulated Profile of Air Potential Temperature and Mixing Ratio on Aug. 12. 1997

on the field during the period Aug. 6-12, 1997 starting at 0.00 hour on Aug. 6. Time step is 1s during computational period and an implicit Crank-Nicholson differencing scheme is used in time. Figure 1 showed the simulated profiles of temperature and water mass flux from ground water table up to the surface on Aug. 12 (Julian day 225) at 5:00, 13:00 and 21:00 hour. On this day, the net radiation at noon was very strong. As a result, the variation of heat and water mass can be clearly observed on upper part of porous domain (0-0.5m deep). They are weakly being effected on lowered layer. This effect can be seen in the figure 2, the plots of soil temperature and water content at 0.2, 5.7, 15.6, 41.8 cm deep with regard to time. The absent of precipitation in the concerned period causes the surface to be drying, especially for the last two days when the input of net radiation is very strong.

The profiles of simulated air potential temperature and mixing ratio on Aug. 12 at 5:00, 13:00 and 21:00 hour are showed in the figure 3. The variation of potential temperature at 1.5 m, 21 m, 189m and 381m during the simulated period are plotted in figure 4.

5. Conclusion

The reasonable results indicate that the model successfully describes the physical heat and mass transfer in the computational domain from ground water table up to the upper boundary layer. The model therefore can be used as a predicting tool for estimation of evaporation from bare soil. The simulation process has shown that an accuracy of the model depends on a set of location characteristics: soil structure, its conductivity, surface roughness.

Coupling between the dependent variables in porous bodies is strong and is non-linear that requires appropriate numerical method for solving the set of differential equations. Particular attention should be given to capillary force

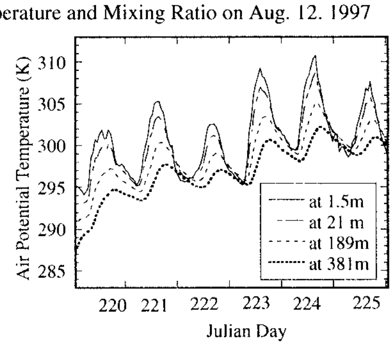

Fig. 4 Simulated Air Potential Temperature

resulting in saturation and thermal induced effects, molecular diffusion due to local vapour pressure and gravity.

Acknowledgement

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