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Development of Intelligent Computer Software (AUSSSM TOOL) to Estimate the Urban Heat Island Effects

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The computer software AUSSSM TOOL, originating from the methodology of the revised-Architectural-Urban-Soil-Simultaneous Simulation Model (*revised-AUSSSM*), was developed by adopting the Graphical User Interface (GUI) features to support users, who can use the interactive computer display for parameter settings, simulating, visualizing, and reporting the numerical calculation results instead of complicated programming. The purpose of the AUSSSM TOOL is to determine quantitative parameters such as air temperature, exhaustive heat from air conditioning systems, and etc. within the Urban Canopy structure, which data enables the evaluation of effects of Urban Heat Island (UHI) useful to urban planners, architects, engineers, and so forth in the field of urban climatology involving building scale. In addition to conducting a full numerical simulation, in order to simplify a comparison among complex factors influencing UHI, numerical experiments based on Taguchi Design of Experiment theory (DOE) were carried out. The results of the numerical experiments were stored in a database and ready to be instantly grasped by any inexperienced user corresponding to their specified conditions. This paper describes the fundamental method of the revised-AUSSSM, the structures of the AUSSSM TOOL, and the techniques comprising its algorithm to present the numerical simulation results in particular.

Key words: *AUSSSM TOOL, revised-AUSSSM, Graphical User Interface, Urban Heat Island, Urban Canopy structure, Taguchi Design of Experiment*

1. Introduction

Recently, using a computer to handle a numerical simulation has become a significant solution to solve complex calculating schemes in the field of Urban Thermal Environments studies. We found that many researchers have adopted programming features that allow the computer to perform their numerical calculations. For example, regarding research of an urban canopy-layer climate model, G. Mills¹⁾, equipped a computer simulation model to design the assessing of thermal characteristics of the Urban Canopy Layer (UCL). The simulated layer includes both closed volumes (buildings) and open volumes (canyons). J.F Sini et al.²⁾ built a numerical model to simulate the small-scale atmospheric flows within the urban canopy, based on the lower atmosphere classical assumptions and the standard $k-\epsilon$ two-equation turbulence

model, which used to study the flows and exchanges of pollutants within the street, above the roof, and long street canyon. Also, E. Guilloteau³⁾ developed and optimized the computing method to study the surface transfer coefficients in surface layer based on state-of-art empirical flux-profile relationships.

Increasingly, computer simulation has become quite useful for urban planning specialists and urban climate researchers. Generally, most researchers self-generate the computer programs to simulate a selected subject and subsequently present the simulated results in many papers. Consequently, from a viewpoint of practical business such as urban planners and architects, it is very difficult to comprehend at once the algorithm and the concept of the programs and the research content itself, so it is really hard to adopt them as their application. However, this *gap* between research and practical application might be closed if the development process of the computer programming is expanded to support various levels of users of simplified computer simulation.

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Therefore, to resolve the above difficulties, we used techniques of computer programming to develop various types of intelligent computer software, including *ET_AEE*⁴⁾ and *Angle Factor*, which were designed for educational use. These programs can be downloaded from our web-site. Additionally, *MCDM-23*⁵⁾, developed as a computer tool and embedded within IEA SH&C Task 23 Activity, was designed to aid urban planners in decision-making during the primarily design process of sustainability buildings. These programs have been devised to provide a simpler and more intuitive interface between the user and the computer by providing GUI ability.

To this end, we recently developed computer software called the *AUSSSM TOOL*, which was based on the revised-AUSSSM method^{6), 7)}. This software quantitatively estimates and evaluates the main causes of UHI. This paper describes the original method of the revised-AUSSSM, the applications of AUSSSM TOOL, and its developing environment in detail.

2. Methodology of the revised-AUSSSM

AUSSSM, proposed as an original methodology for predicting and estimating the UHI effects, was defined not as a sub-model for the *meso-scale* model but as a stand-alone and comprehensive frame for a real simultaneous solution connected to the building thermal system, the urban atmosphere, and the ground covering. In developing AUSSSM, it was necessary to consider both accuracy and the appropriate calculating load for a large number of numerical experiments. Regarding the atmospheric sub-model, AUSSSM was classified as a single-layer model based on the *Monin-Obukhov* Similarity. Consequently, the revised-AUSSSM, based on the basic concept of the AUSSSM, was developed as a multi-layer model to offer more accurate and precise calculation results. The methodology of the revised-AUSSSM was adopted later as the principal methodology of AUSSSM TOOL development.

2.1 Outline of revised-AUSSSM

In order to make precision of estimating UHI effects in the urban canopy structure, that has the complexity and diversity, without omission, we composed the relevant sub-models related to the urban atmosphere, the land surface, and the buildings, which interact each other, as the

main components of the revised-AUSSSM. These sub-models are adopted based on one-dimensional transportation equations, which are involved in the several simplified models we developed for estimating source terms. The sub-models have relatively the same level of accuracy, which allows us to obtain a practically correct and significant solution. In a practical calculation process, all sub-models are coupled dynamically, which means the revised-AUSSSM is treated as a whole; that is, as a complete simultaneous non-linear system.

The schematic diagram of the revised-AUSSSM is illustrated in Fig.1. Similar buildings are assumed to be in a rectangular lattice space, arranged homogeneously and infinitely in a supposed urban area. This premise means that only the vertical atmospheric diffusion is considered.

2.1.1 Urban Atmospheric sub-model

The sub-model involves the one-dimensional equations of momentum, heat, and vapor contained in the Urban Canopy Model (UCM) to clarify the diffusing potentials of air temperature, wind velocity, and specific humidity, respectively⁸⁾, read:

$$G \frac{\partial u}{\partial t} = \frac{\partial(K_m \cdot G \frac{\partial u}{\partial z})}{\partial z} - F_{ri} \quad (1)$$

$$G \frac{\partial \theta}{\partial t} = \frac{\partial(K_h \cdot G \frac{\partial \theta}{\partial z})}{\partial z} + H \quad (2)$$

$$G \frac{\partial q}{\partial t} = \frac{\partial(K_v \cdot G \frac{\partial q}{\partial z})}{\partial z} + W \quad (3)$$

where u is the wind velocity [ms^{-1}], θ is the air temperature [K], q is the specific humidity [kgkg^{-1}], and G is the ratio of volume density of fluid [-]. Here, $G = 1$; $z > H_{canopy}$ and $G = 1 - \{ B / (B + W_r) \}^2$; $z \leq H_{canopy}$ where B is the building width [m], W_r is the road width [m], and H_{canopy} is the building height [m]. F_{ri} [ms^{-2}], H [Ks^{-1}] and W [$(\text{kgkg}^{-1})\text{s}^{-1}$] are source terms. The eddy coefficient of momentum, heat, and vapor are parameterized as K_m , K_h , and K_v [m^2s^{-1}], respectively⁹⁾.

2.1.2 Soil sub-model

In this sub-model, three types of land surfaces, including bared soil, lawn (on both ground and rooftop), and pavement, are assumed and estimated by using the one-dimensional heat conductive equation. In addition, to clarify the relation between UHI and alternation in land usage, it is crucially important to estimate water balance, which affects heat balance, at the urban surface. Hence, the investigation of evaporation from

those respective surfaces is also considered¹⁰⁾. The water balance and evaporation equations for *Soil* surface are given as:

$$\rho_s \cdot \Delta x \frac{d\phi}{dt} = P - EVS - GD(\phi) + C \quad (4)$$

$$EVS = re(\phi/\phi_{sat}) \frac{\alpha}{C_p L_w} (x_{sat} - x_{air}) \quad (5)$$

where C is the diffusional water/moisture flux supplied from a bottom of the surface soil layer [$\text{kg}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$], GD is the hydraulic transmittable flux by gravity [$\text{kg}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$], EVS is the evaporation rate [$\text{kg}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$], P is the precipitation rate [$\text{kg}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$], and Δx is the depth of the surface soil [m] ($=0.1$). The water content of the soil ϕ [$\text{kg}\cdot\text{kg}^{-1}$] is defined as $\phi \leq \phi_{sat}$, where ϕ_{sat} is the saturated water content of the soil [$\text{kg}\cdot\text{kg}^{-1}$]. ρ_s is the density of the soil [$\text{kg}\cdot\text{m}^{-3}$] that computed as $\rho_s = (1-\phi)^{-1} \rho_{dry}$, where ρ_{dry} is the density of completely dried soil [$\text{kg}\cdot\text{m}^{-3}$]. C_p is the specific heat of humid air [$\text{J}\cdot\text{kg}^{-1}\cdot\text{K}^{-1}$], L_w is the Lewis number [-] ($L_w=0.83$), re is the evaporation ratio [-], x_{air} is the absolute humidity of air [$\text{kg}\cdot\text{kg}^{-1}$], x_{sat} is the saturated absolute humidity at the soil surface temperature [$\text{kg}\cdot\text{kg}^{-1}$], and α is the convective heat transfer coefficient [$\text{W}\cdot\text{m}^{-2}\cdot\text{K}^{-1}$].

The heat balance equation of *Lawn* surface is given as:

$$SR + LR + CD + CV + l \cdot EVL = 0 \quad (6)$$

where SR is the incident solar radiation [$\text{W}\cdot\text{m}^{-2}$], CV is the convective heat flux [$\text{W}\cdot\text{m}^{-2}$], l is the latent heat of water [$\text{J}\cdot\text{kg}^{-1}$], and LR is the incident infrared radiation [$\text{W}\cdot\text{m}^{-2}$]. The evapotranspiration rate EVL [$\text{kg}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$] is determined as $EVL = \kappa \cdot EVS$, where EVS is the bare soil's evaporation rate [$\text{kg}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$]. CD is the conductive heat flux [$\text{W}\cdot\text{m}^{-2}$], which is derived as $CD = (T_{SB} - T_{SU}) / ETR$, where ETR is the equivalent thermal resistance of lawn [$\text{m}^2\cdot\text{K}\cdot\text{W}^{-1}$], T_{SB} is the lawn surface temperature of leaf-top [K], T_{SU} is the lawn

surface temperature of leaf-bottom [K]. ETR and κ are designated as lawn's thermal features.

The water balance equation of *Artificial Surface* (pavement) is given as:

$$\frac{\partial \phi}{\partial t} = -EV + P \quad (7)$$

$$EV = re(\phi/\phi_{max}) \frac{\alpha}{C_{pm} \cdot L_w} (x_{sat}(T_s) - x_{air}) \quad (8)$$

where EV is the evaporation rate [$\text{kg}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$] and P is the precipitation [$\text{kg}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$]. C_{pm} is the specific heat of humid air [$\text{J}\cdot\text{m}^{-3}\cdot\text{K}^{-1}$], t is the elapsed time after precipitation stopping [s], and $x_{sat}(T_s)$ is the saturated absolute humidity at the soil surface temperature [$\text{kg}\cdot\text{kg}^{-1}$]. ϕ is the water content near surface [$\text{kg}\cdot\text{m}^{-2}$] which $\phi \leq \phi_{max}$, where ϕ_{max} is the maximum water content near the surface [$\text{kg}\cdot\text{m}^{-2}$] (asphalt $\phi_{max}=0.3$, roofing water-proofed with asphalt sheet $\phi_{max}=0.45$, concrete slab $\phi_{max}=0.3$).

2.1.3 Building sub-model

This sub-model is used to clarify the building heat load and the exhaustive heat corresponding to HVAC systems. As the hypothetical building shown in Fig. 1, the building sensitive heat load (H_s) and latent heat load (H_l) are given as:

$$H_s = \sum_{4\text{directions}} S_j \cdot \alpha_j \cdot (T_{set} - T_{s,j}) + S_f V_{oa} C_{air} \gamma_{air} (T_{set} - T_o) \quad (9)$$

$$H_l = l \cdot S_f V_{oa} \gamma_{air} (X_{SET} - X_o) + S_f W_l \quad (10)$$

where C_{air} is the specific heat of the air [$\text{J}\cdot\text{kg}^{-1}\cdot\text{K}^{-1}$], l is the latent heat of water [$\text{J}\cdot\text{kg}^{-1}$], S is the floor area [m^2], V_{oa} is

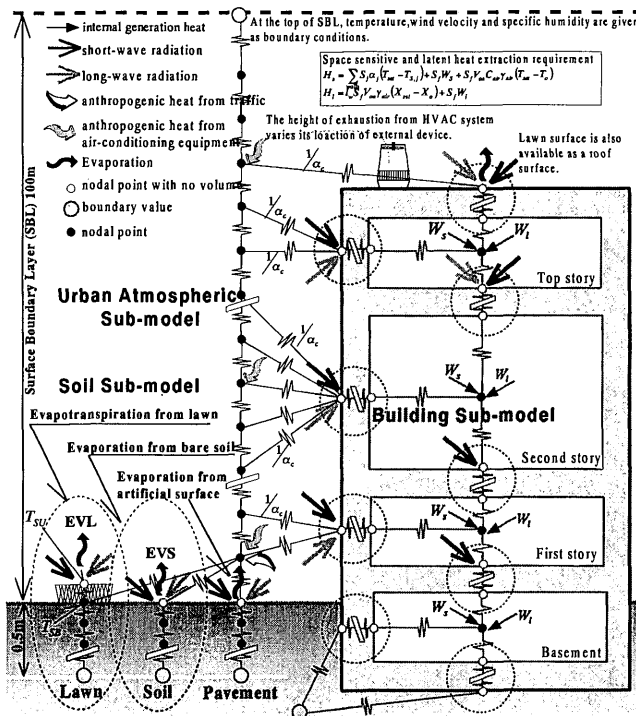


Fig.1 The schematic diagram of the revised AUSSSM

Table 1 Basic assumptions for the Standard Solution

Street Configuration	Building width=32 m, Road width=16.88 m, Building height=23.8 m, Building volume proportion =700%, Gross building volume proportion =300%
Street grid pattern	Staggered array
Reflectance of Solar Radiation	Building wall=0.4, Asphalt (pavement) =0.1, Soil=0.3, Lawn=0.25
Wall materials	Indoor side insulation (25mm) + outdoor side concrete (180mm)
Glazing	Transparent glass thickness = 6mm, Ratio of glazing = 35%
Rooftop finishing	Soil (10cm) + lawn (default is 0%)
Ground covering ratio	Asphalt (pavement) : soil : lawn= 1 : 1 : 1
Anthropogenic heat from vehicles (at the peak)	9.7 W per square meter of the area of the block
Indoor heat generation of building (at the peak)	Sensitive heat=56 W per square meter of the area of the room, latent heat=13W per square meter of the area of the room
HVAC Systems	Air Source Heat Pump (HPair) = 30%, Turbo Refrigerator (TR) = 31%, Gas Fueled Absorption Refrigerator (AR) = 39%
Setting of air conditioning	26°C, RH=50% constant (8:00 - 21:00), ventilation 2.7m ³ /hr

the amount of ventilation [$m^3m^{-2}s^{-1}$], W_i is the internal latent heat generation [Wm^{-2}], W_s is the internal sensitive heat generation [Wm^{-2}], α_j is the indoor heat transfer coefficient ($\alpha=8$) [$Wm^{-2}K^{-1}$], and γ_{air} is the specific weight of humid air [kgm^{-3}]. The subscript $-j$ designates the wall, $-f$ is the floor, $-SET$ is the set point of air-conditioning systems, and $-o$ is the outdoor air. In this case, the heat and vapor losses due to ventilation are also considered.

Anthropogenic heat from building (Q_s) that varies with the building thermal load and strongly influenced by the mechanical performance of heating ventilating and air conditioning systems, and HVAC systems, is determined as:

$$Q_s = rat \cdot \left(1 + \frac{1}{COP}\right) \sum_i^{all} (H_{s,i} + H_{l,i}) \quad (11)$$

where COP is the total mechanical performance of HVAC systems[-] and rat is the ratio of sensible heat disposal to total at an exterior air-conditioning equipment[-] ¹⁰.

2.2 Standard Solution

The basic assumptions for the Standard Solution are illustrated in Table 1. Geometric figures of the street are determined by statistical data obtained in Tokyo. Anthropogenic heat from traffic and building internal heat gain are given in the pattern of the time series data, based on the previous investigation. The boundary conditions of air temperature and solar radiation at a height of 100 meters, the top of the Surface Boundary Layer (SBL) as shown in Fig. 2, were obtained through the statistical process for a hot day

during the summer season in Tokyo based on the public observation data, which are usually used in pragmatic calculations to estimate building thermal load. Wind velocity and absolute humidity at the SBL were $5 ms^{-1}$ and constant $19.3 g.kg^{-1}$, respectively. The assumed amount of precipitation was 20 mm. per a day at once a week in early morning before sunrise. In addition, rainfall took place on the 7th, 14th, and 21st day. One simulation was carried out continuously for 21 days to obtain the so-called periodic steady-state solution. The calculation results of the 20th day (the day before precipitation) and the 21st day (the day after precipitation) were mainly considered.

2.3 The Design of Experiment

The causes of UHI are so complicated and so widely ranging that numerical experiments should be considered relative to a certain strategic scheme, in order to consider

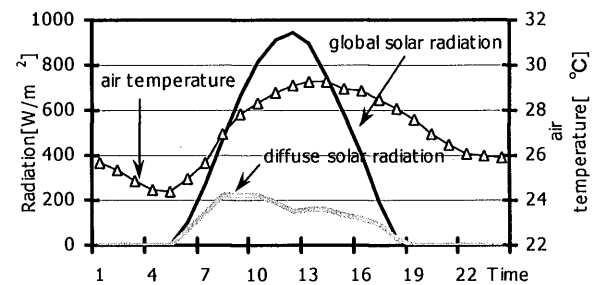


Fig. 2 The boundary conditions

Table 2 Factors and Levels in the numerical experiment based on the Taguchi Design of Experiment Theory

Factor	Level	L1	L2	L3
A	Building Volume Proportion	700%	1000%	1300%
B	Gross Building Volume Proportion	150%	250%	350%
C	Ground Surface Covering	Asphalt 1 : Soil 0	Asphalt 1 : Soil 1	Asphalt 0 : Soil 1
D	Glazing Area Proportion on Building Walls	35%	60%	85%
E	Reflectance of Solar Radiation for Building Walls	0.8 (high-albedo painting finish)	0.5	0.2
F	Heat Generation in Building Space	General Present Status	1.5 times	2 times
G	Set Room Air Temperature for HVAC Control	24°C	26°C	28°C
H	HVAC Systems	Private System HPair : 30% TR : 31% AR : 39%	Private System + Heat Storage HST+HPair : 30% HST+TR : 31% AR : 39%	DHC + Heat Storage DHC+HST+HPair : 27% DHC+HST+HPwater : 41% DHC+HST+TR : 9% DHC+AR : 23%
I	Rooftop finishing	None	50% Vegetation	100% Vegetation
J	HVAC Systems Operating Time	8:00am-21:00pm	20:00pm-8:00am	12:00pm-1:00am
K	Reflectance of Solar Radiation for Rooftop	0.8	0.5	0.3
L	Reflectance of Solar Radiation for Asphalt	0.8	0.5	0.1

Considered Interactions : A×B, A×C, A×D, A×E, B×C, B×E, B×F, B×H, B×I, B×K, B×L, C×L, D×E, D×F, E×F, E×I, F×G, F×H, F×J, G×H, G×I, H×I, H×J, H×K, I×K

DHC: District Heating and Cooling System, HST: Heat Storage System, HPair: Air Source Heat Pump, TR: Turbo Refrigerator, AR: Gas Fueled Absorption Refrigerator

particular factors or levels that should be taken into account in the experiments. Therefore, based on the limitation assumed in the revised-AUSSSM, the significant factors of UHI are regarded from the overview of building architectural design, building mechanical design, or urban planning. The factors are screened and the numerical experiments subsequently conducted based on the Taguchi Design of Experiment Theory (DOE) ¹²⁾⁻¹⁵⁾.

The DOE method incorporates fractional factorial matrixes or orthogonal arrays to minimize the number of experiments required to achieve a given set of performance characteristics. The Taguchi experimental approach allows a statistically sound experiment to be completed, while investigating a minimum number of possible combinations of parameters or factors.

The factors and levels selected for the DOE analysis are shown in Table 2. The 12 factors identified as main affecting the UHI effects are given, and for any initial interactions that may take place among the factors, an $L_{243}(3)^{121}$ array, with three levels for each factor, was chosen for the DOE. The $L_{243}(3)^{121}$ designation refers to the number of experiments (243), the number of levels for each factor (3), and the maximum number of factors or interactions (121). A full factorial experiment would consist

of 3 ^(number of factors) experiments as compared to the Taguchi experiment, which required only 243 experiments. In this experiment, 25 interactions are assumed.

According to the DOE theory, the main factorial effect and the indicated interaction effect allow the prediction of *characteristic values* within the range of a 5% statistical error. This characteristic values represent the significant parameters we applied to estimate the UHI effect. The principal characteristic value focused in this principle is the increase of air temperature in the entire canopy and near the ground surface (street level) where people walk. In addition, exhaustive heat from buildings, thermal requirements for HVAC systems, heat flux at the top of surface boundary layer, and energy balance flux were given particular consideration.

3. The Implementation of the AUSSSM TOOL

3.1 AUSSSM TOOL Structure

The AUSSSM TOOL has three offshoot programs: *Simulator*, *PostGraph*, and *Viewer*, as shown in Fig. 3. *Simulator* works as a preprocessor for data input, and as a solver based on the revised-AUSSSM. *PostGraph* provides a wide variety of schematic expressions for the simulation results. Those two programs work together to run the simulation solver, whereas *Viewer* functions alone, providing stages to see a set of results of characteristic values coming from a compact database to confirm various factorial effects on UHI. The results are solved previously based on the Taguchi DOE theory, which is depicted in section 2.3.

3.2 Applications of Simulator

Simulator carries out the numerical simulation process based on the revised-AUSSSM executed file to calculate the groups of data used to estimate UHI effect depending on the input conditions such as urban & building design data, meteorological data, and HVAC systems data. Fig. 4 illustrates the dialog for input data related to urban and building design.

3.3 Viewing the calculated results by PostGraph

PostGraph allows the user to display, export (data-handling), or print the output data given by performing the numerical simulation process on the Simulator with an interactive

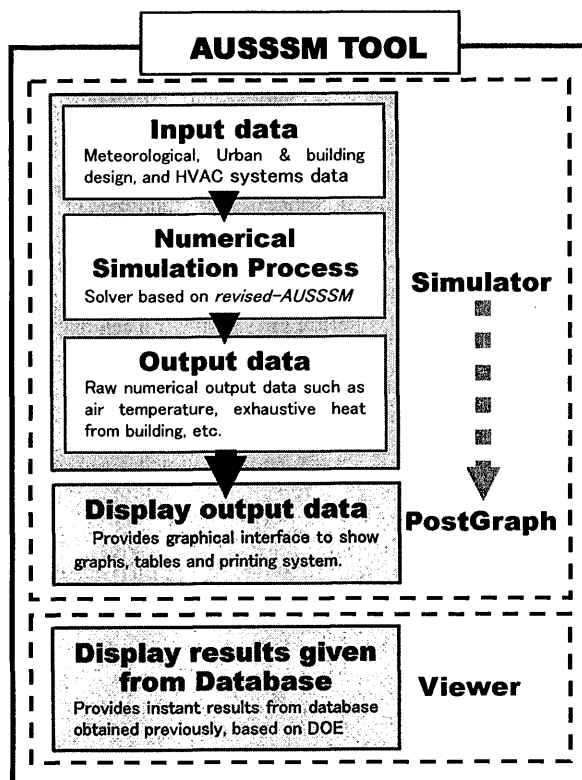


Fig. 3 The holistic structure of the AUSSSM TOOL

environment. Fig. 5-6 illustrate the variety of results provided in PostGraph. Note that the results shown in this section reflect input conditions that were defined with the default values as mentioned above in section 3.2.

3.4 Viewer

Viewer was developed to support the user's investigation of the primary results (called

characteristic values) derived from the numerical experiments (243) previously done. The main concept is that the numerical experiments are based on the DOE theory, as explained earlier. Secondly, the entire results obtained from each experiment were saved in one database (DB). Hence, from the DB, the user can instantly catch the results of characteristic values related to the defined initial conditions (the factors and levels

The screenshot shows the 'AUSSSM General Condition' dialog box with the following sections and values:

- Building Related:** Building Width (m) 32.000, Gross Building Volume Proportion (%) 300.000, Floor Height (m) 3.400, Number of Floors (7-15 F) 7.
- Radiation Related:** Solar Absorptance of Building Roof 0.700, Solar Absorptance of Building Wall 0.600, Solar Absorptance of Asphalt Surface 0.900, Solar Absorptance of Soil Surface 0.700, Proportion of Building Windows Area 0.350.
- Ground Covering Proportion:** Asphalt 0.333, Soil 0.333, Lawn/Grass 0.334.
- Heat Generation or HVAC:** Anthropogenic Heat from Vehicles (W/m²) [AHV] 9.700, Indoor Sensible Heat Gain (W/m²) [ISHG] 55.000, Indoor Latent Heat Gain (W/m²) [ILHG] 13.000, Indoor Set Temperature (°C) 26.000, Indoor Set Humidity (%) 50.000, Indoor Heat Transfer Coefficient (W/m².K) 8.000.
- Others:** Building Allocation System Staggered Lattice, Proportion of Roof Vegetation Area 0.000, Irrigation to Roof (Enable), Irrigation Rate to Roof (mm/hr) 0.000, Evaporation from Asphalt(Road) and Concrete(Floor) (Enable), Indoor Ventilation (m³/(s.floor area)) 0.00075.
- Wall Materials:** Indoor side is Insulation, and Outdoor side is Concrete (selected); Concrete Insulation: Thickness (m) 0.18 (Concrete), 0.025 (Insulation); Heat Conductivity (W/m.K) 1.1 (Concrete), 0.037 (Insulation); Specific Heat (J/m³.K) 880 (Concrete), 1200 (Insulation); Specific Weight (kg/m³) 2200 (Concrete), 28 (Insulation).
- Soil Condition:** Do you want to define the new condition of soil? (No selected); Ground/Roof properties: Specific Weight (kg/m³) 1237/1237, Saturated Water Content (kg/kg) 0.2301/0.2301, Specific Heat Capacity (J/m³.K) 2130000/2130000, Heat Conductivity (W/m.K) 0.574/0.574.

Fig. 4 The input data related to urban and building design (default values)

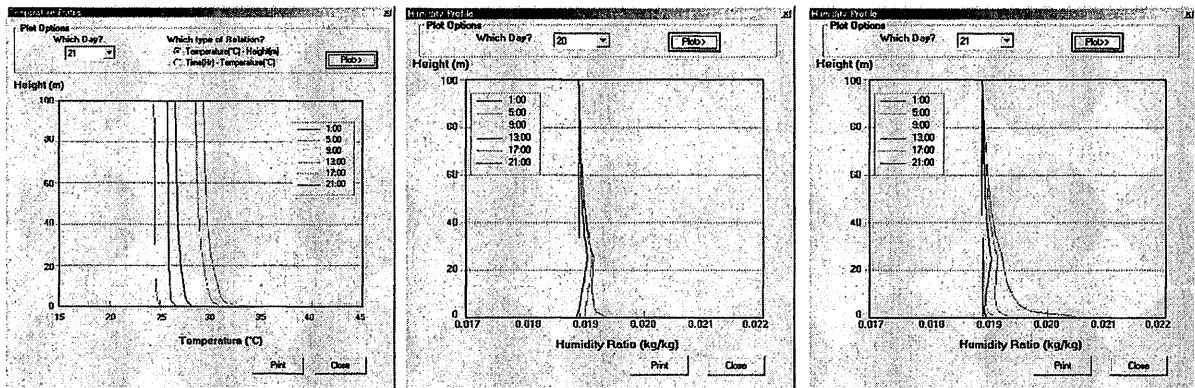


Fig. 5 Plots of vertical distributions of air temperature and the humidity ratio given from PostGraph

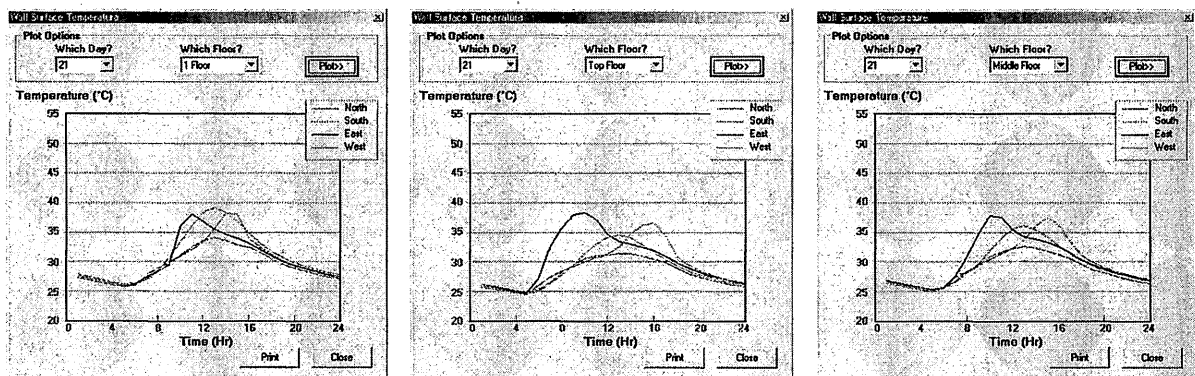


Fig. 6 Building walls surface temperature

indicated in Table 2). In order to illustrate how to work Viewer, we created three hypothetical case studies and the respective conditions for discussion, as shown in Table 3. It can be noted that Case A is assumed to be the relaxation case (i.e., it exhibits a severe UHI effect), whereas Case B is supposed to be an extremely severe case. Case C is defined as having a severity halfway between that of Case A and that of Case B.

In this example, the characteristic values mentioned above are as follows: air temperature at 1.2 m height and in whole canopy, sensitive-latent thermal requirement for building air conditioning, sensitive-latent exhaustive heat from HVAC systems,

sensitive-latent heat flux at the SBL, and energy balance fluxes (net radiation, convection, and evaporation) at the top of the building canopy. These results are available only for the daily maximum, daily average, and/or daily minimum value on the 20th and 21st days, respectively. Viewer can also display the results for various case studies simultaneously. In fact, the results for up to 7 cases can be shown. An example of comparison graphs is shown in Fig. 7. From these graphs, it was found that both the atmospheric temperature and exhaustive heat in Case B have attracted growing. These results agree with the supposed conditions, which, in this Case, involved a severe effect on the UHI.

Table 3 The supposed conditions for Case A, B and C

Factor	Level	Case A	Case B	Case C
Building Volume proportion		1300%	700%	1000%
Gross building volume proportion		150%	350%	250%
Ground covering proportion (Asphalt : Lawn)		0:1	1:0	1:1
Proportion of Glazing area		85%	35%	60%
Reflectance of Solar Radiation for building wall		0.8	0.2	0.5
Indoor sensitive and latent heat generation		Default	x2 times	x1.5 times
Indoor set temperature		28°C	24°C	26°C
HVAC system		DHC	Standalone	Stand-alone +HST
Proportion of roof top vegetation area		100%	0%	50%
HVAC system operating time interval		8am-21pm	20pm-8am	12pm-1am
Reflectance of Solar radiation for roof top		0.8	0.3	0.5
Reflectance of Solar radiation for asphalt		0.8	0.1	0.5

4. Developing Environment

The AUSSSM TOOL was developed as an advanced Windows application by using the powerful features of Visual Basic (VB) programming to offer the user a graphical interface¹⁶⁾⁻²⁰⁾. On the other hand, the revised AUSSSM executed a file called Solver, the core of performing the numerical simulation process, which was written in and complied with FORTRAN^{21), 22)}. Although the program seemed clear and simple, a number of help features were included to allow the user to implement and understand it more easily. This comprehensive help function was documented on RoboHELP Office²³⁾, and is provided in the Simulator, PostGraph, and Viewer, respectively, to provide the user with a

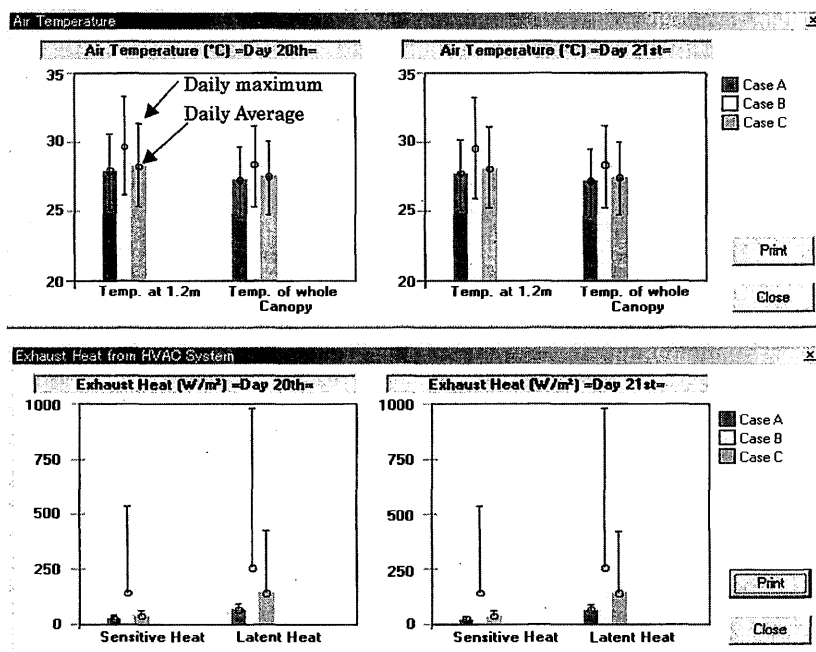


Fig. 7 The example of comparison graphs for Case A, Case B, and Case C

variety of information, including an introduction to the revised-AUSSSM and details of its methodology, how to get started using the program, many useful techniques to facilitate effective using, and so on.

Finally, the program install package is prepared with InstallShield Express²⁴. This package includes many files devoted to the software itself and the entire source codes in both VB and Fortran.

5. Conclusions

The revised-AUSSSM, relevant methodologies, and development of the AUSSSM TOOL for coupling simulation with a building thermal system and urban climatology to estimate UHI effects in quantitative terms are described in detail. We have outlined the three parts of the AUSSSM TOOL, which offer the user different respective features. *Simulator* provides a wide range of condition settings and full numerical simulation results corresponding to the defined initial conditions, which will no doubt make it useful for climatological researchers or experts in urban thermal study who require detailed results for particular situations. *Viewer* works independently to provide the user with results of characteristic values without waiting for the simulation to be completed because the set of results derived from numerical experiment was compacted into the DB. This database provides results that are adequate for the user who requires only characteristic values indicated for the day before and after precipitation, and in the case of result related to many conditions have to be compared each other. *Viewer* is probably most useful for the inexperienced user who have a general interest in studying UHI, because the input conditions are already fixed. That is, the user simply makes the required choices and proceeds to obtain results.

The AUSSSM TOOL is accessible on our web site (<http://ktlabo.cm.kyushu-u.ac.jp/>). It can be downloaded not only as an executable package but also with the source codes for the revised-AUSSSM written in Fortran and the interface portion in Visual Basic.

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