Abstract
This study aims to investigate the change of temperature and wind field by the conversion of urban geometry for the countermeasures of urban heat island. The adopted model in this study is the WRF with Urban Canopy Model (WRF-UCM). First, making comparisons between WRF and WRF-UCM, WRF-UCM estimate nighttime temperature to be higher than WRF, but there is not so much of a difference in calculation accuracy of air temperature. Second, the results from several cases altered building height and building coverage ratio were compared each other. It was found that the effects of building height were more influential to air temperature field than the building cover ratio. The other hand, the effects of building cover ratio were more influential to wind field than the building height.

Key words: heat island, meso-scale, WRF, urban canopy model, sea breeze, validation

1. INTRODUCTION
As one of measures to understand the urban heat island on wider area, there is a numerical simulation using meso-scale model. Especially, because the non-static meteorological model MM5 is suited to the general use and having relatively high accuracy, it was used for many investigations even in the urban climate (Kawamoto et al., 2008). However the development of MM5 already finished, it is going to move to WRF (Weather Research and Forecasting) model now. WRF model is able to combine the Urban Canopy Model (UCM) considering the street form. The option of it was developed by Kusaka et al. (Mukul et al.).
In this study, the urban heat island in Osaka region was simulated under the fine typical weather condition. Using the calculation study, first, the models were compared with observed data, and the solid structure of the urban heat island was analyzed. Second, the simulation study was conducted altering the street form.

2. CALCULATION CONDITIONS AND STUDY OF ACCURACY
2.1 Calculation area
Figure 1 shows the calculation study area. Using nesting method for getting results of higher resolution, Domain1 is set the resolution 3km and 120km × 120km grid scale, and Domain2 is set the resolution 1km and 103km × 103km grid scale. Domain 2 area is analyzed.

2.2 Calculation conditions and calculation cases
Table 1 shows the calculation conditions and input data. For studying the introduction effect of UCM model, two cases, SLAB model (Case0-S) and UCM (Case0-U), were adopted. The calculation period is 9 days on which the typical summer weather was continued. The vertical grid is devided 28 layers from earth surface up to 100hPa. The initial conditions and boundary conditions are used meso-objective analysis value (resolution 10km) issued by the Meteorological Agency. The lacking data such as the sea surface temperature are compensated by the global objective reanalyzed data (resolution 1° (about 111km)) issued by the NCEP. The land use data for UCM model was made anew for getting the higher resolution and accuracy of geographical data set. In this process, 3 categories on urban land use are added to reflect the urban development level using Digital National Land Information data and Normalized Vegetation Index (NVI) data.

2.3 Introduction effects of UCM model by comparison between calculation value and observed value
One of observed data used here are AMEDAS data at 6 points (air temperature: 1.5m aboveground, wind: 10m aboveground). It is provided by the Meteorological Agency. Tower data at 4 points (air temperature: 42.5-57.0 m
aboveground, wind: 42.5-84.0 m aboveground) are also used here. Table 2 and 3 show the accuracy on the air
temperature and wind velocity. According to the result of the comparison between SLAB model and UCM model, air temperature by UCM is higher than SLAB from the midnight to dawn. However, at the midday, air temperature by UCM model and SLAB model are not much difference. The reasons are considered the increase of heat capacity brought from the assumption of buildings, and the low out going radiation caused by the small sky view factor, the shading effect and so on. On the wind, both data are not so much difference on the tower data. However, wind velocity of UCM is lower than SLAB. The reason was thought that it was caused by the hypothesis of buildings. The wind direction is not so much difference.

In the next step, the calculation results were compared with models for checking the accuracy of calculation as shown in Figure 2-3. On the AMEDAS data, though the bios of SLAB in air temperature is relatively large such as from +0.5 to +1.0 deg K, but the values of RMSE (UCM is within 1.2 deg and SLAB is within 1.3) and correlation factor (UCM is more than 0.94 and SLAB is more than 0.96) were almost same level. On the wind velocity, both bios and RMSE of UCM are better than SLAB and the correlation factor is also more the 0.72 except one point. On the whole, the accuracy of UCM was higher than SLAB. On the wind direction, both models are relatively good agreement.

The such same verification was done on the tower data. On the air temperature, bias and RMSE of UCM were better than SLAB, however correlation factor of SLAB was better than UCM. Considering the time variation, observed value of Ishikiri point showed good agreement especially with UCM model. On the wind velocity, bias, RMSE and correlation factor are not much difference between both models. On the wind direction, both two models are better agreement comparing with tower data case, than AMEDAS case.

As mentioned above, the introduction of UCM model was concluded to be effective, because of the good expression on the influence of thermal and wind environment.

3. STRUCTURE OF URBAN HEAT ISLAND IN KINKI REGION

The urban heat island in Osaka region was analyzed horizontally and sectionally. Figure 5 shows the sectional
distribution of air temperature (2m high) and wind (10m high) along the west to east line A-A’ in figure 5.
Even in the midnight 2:00, the sea breeze appears to be blowing at the coast of Kobe and Sakai. On the other
hand, the wind in the south part of Osaka Prefecture is very weak, and the land breeze partly appears. According
to the sectional distribution of the potential temperature, the atmospheric condition is stable. According to the
horizontal distribution of air temperature, the vicinity of coast area was low.
In the morning 8:00, wind is weak and air temperature begin to rise. The stable condition is gradually broken up to
about 600m high and the weak mixing appears.
When the time is around the maximum air temperature, sea breeze is stronger and blows to inland. And the
strong mixing of atmosphere appears near the front part of the sea breeze. In the windward area of the front part,
the sea breeze mitigate urban heat island effect by the cooling effect of the sea breeze, and the atmospheric
condition is stable. On the other hand, in the leeward of the front part, air temperature is very high, and the
atmospheric mixing is to be stronger, and the height of mixing is over 1.5km.
In the evening 20:00, the sea breeze reached to deepest area over Ikoma mountains. The cooling effect of sea
breeze influence to inland and the atmosphere began to be stable.

4. CHANGE OF THERMAL AND WIND ENVIROMENT BY ALTERATION OF STREET FORM

4.1 Hypothesis of street form
To evaluate the influence on thermal and wind environment by the alteration of street form, the simulation study
was conducted altering the high density and tall building area mainly in Osaka City to various street forms.
Table 4 shows the case of present and 6 cases that altered building coverage ratio and building height. The objective day of analysis is August 3, 2006, and the day was a summer typical pressure pattern.

### 4.2 Change of air temperature and wind in the alteration area

The diurnal variation of air temperature and wind near the coast that just the sea breeze begin, was considered because of understanding the influence on the air temperature and wind by the alteration of street form excluding the influence of windward. Figure 6 shows the diurnal variation of air temperature and wind to each case. The alteration of building coverage ratio and tall building seem to influence on the daytime air temperature. Especially, the building coverage ratio has a strong influence. When the ratio is large, air temperature rises and vice versa. The reason seems to be the change of latent heat flux, because the alteration of building coverage ratio causes the change of the value of green area ratio. The building height influences on the wind through a day. When the building height is larger, the wind is weaker and vice versa. It present the tall building to prevent wind flow.

### 4.3 Horizontal distribution of air temperature difference and wind velocity difference

Figure 7 shows the horizontal distribution at 14:00 of the difference between present case and case 4 and case 5 in air temperature (2m) and wind velocity (10m). From this figure, the building ratio affects largely on the air temperature, and the building height affects largely on wind velocity. In case 4, wind velocity increases 0.5m/s, and in case 5, air temperature falls 0.5 to 1.0 deg. On the other hand, it was almost no influence relationship between case 4 and air temperature difference, and case 5 and wind velocity difference.

### 5. CONCLUSIONS

First, urban heat island in Osaka region was analyzed. Air temperature rise in urban area causes stronger sea breeze, and in the windward of front part, air temperature rise is mitigated by the cooling effect of sea breeze. Second, according to the case study that altered street form, the alteration of building coverage ratio affect air temperature, and the alteration of building height affects wind velocity. For the improvement of air temperature rising, the building coverage ratio should be fall, and the lower building height is good for the wind flow.

### Acknowledgment

Authors thank to Prof. T. Osawa, Kobe university and Prof. A. Kondo, Osaka University, et al. for giving us useful suggestions. This study presented herein is supported in part by the grant-in-aid for scientific research (B), sponsored by JSPS.

### References


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![Fig.1 Calculation domains](image)
The seventh International Conference on Urban Climate,  
29 June - 3 July 2009, Yokohama, Japan

Table 2 Calculation accuracy of air temperature (Aug 2-10, 06)

<table>
<thead>
<tr>
<th>Air Temperature</th>
<th>Bias(℃)</th>
<th>RMSE(℃)</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Case0-S</td>
<td>Case0-U</td>
<td>Case0-S</td>
</tr>
<tr>
<td>Osaka</td>
<td>0.42</td>
<td>0.29</td>
<td>1.17</td>
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<td>Kobe</td>
<td>0.08</td>
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<td>Sakai</td>
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<td>1.07</td>
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<td>Hirakata</td>
<td>0.32</td>
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<td>0.87</td>
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<tr>
<td>Toyonaka</td>
<td>0.45</td>
<td>0.96</td>
<td>1.09</td>
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Table 3 Calculation accuracy of wind velocity (Aug 2-10, 06)

<table>
<thead>
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<th>Wind velocity</th>
<th>Bias(m/s)</th>
<th>RMSE(m/s)</th>
<th>Correlation</th>
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<tr>
<td></td>
<td>Case0-S</td>
<td>Case0-U</td>
<td>Case0-S</td>
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<tr>
<td>Osaka</td>
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<td>1.51</td>
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<td>Namba</td>
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<td>Ishikiri</td>
<td>0.28</td>
<td>0.62</td>
<td>1.55</td>
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</table>

Figure 2 Diurnal variation of mean air temperature (Aug 2-10, 06)

Figure 3 Diurnal variation of mean wind velocity (Aug 2-10, 06)

Table 4 Present case and hypothesis cases

<table>
<thead>
<tr>
<th>Case</th>
<th>Building Coverage Ratio</th>
<th>Building Height</th>
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<tr>
<td></td>
<td>Ratio</td>
<td>Actual (%)</td>
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<tr>
<td>0</td>
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<td>44.0</td>
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<tr>
<td>1</td>
<td>1/2</td>
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<td>1</td>
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<td>1</td>
<td>44.0</td>
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<td>1/2</td>
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</tr>
<tr>
<td>6</td>
<td>3/2</td>
<td>66.0</td>
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</table>

Figure 6 Diurnal variation of air temperature and wind at the coast located in the alteration area

Figure 7 Difference with present case in air temperature and wind velocity (14:00)

Figure 5 Horizontal distribution of air temperature and wind (left) and section of potential temperature and wind