NUMERICAL STUDY ON TEMPERATURE VARIATION IN THE JAKARTA AREA DUE TO URBANIZATION

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Abstract

Effect of urbanization around the Jakarta area on temperature rise was investigated using a meso scale meteorological model. After the validation of the model performance, calculation of the local meteorology in dry season was carried out based on the land use data for 1970s and 2000s obtained from the population density data. Calculated results showed that 1) in the present case (2000s), a sea breeze was developed relatively earlier than that in 1970s, 2) the averaged daytime and maximum temperatures at the old city area in 2000 were 0.6 [°C] and 0.9 [°C] higher than those in 1970s due to urbanization.

Key words: Jakarta, meso-scale model, urbanization, temperature rise, land use

1. INTRODUCTION

The extensive change of land use, for example, by rapid urbanization often causes the modification of local climate. Since the modified local climate directly affects human activities through the change of natural environment, many observation or numerical studies are conducted to clarify the relationship between land use change and local climate. In particular, the effect of urbanization on local climate were often studied (e.g., Kitada et al., 1998, Kusaka et al., 2000 and many others). This study mainly focuses on urbanization in a develop country and evaluates the impact on temperature rise. The city we focused is Jakarta which is one of the mega cities in Asia. The population in 2000 is about 12 millions, while 5 millions in 1970s. With rapid population increase, urban area is also expanded rapidly within several decades. In the present study, the effect of land use change (urbanization) in Jakarta on temperature was evaluated using a meso-scale meteorological model.

2. OBSERVED TEMPERATURE FROM 1970s TO 2000s

Figure 1 shows variation of daily maximum, mean and minimum temperatures from 1979 to 2007. The observation site is located at the old city area of Jakarta (S6° 10' 59", E106° 49' 59"). As shown in the figure, the daily mean and minimum temperatures begin to increase from 1980s. In addition, daily maximum temperature also started to increase from 1990. Until 2000s, all temperatures increased about 1 [K] for past 30 years. Population in Jakarta has also increased from 1950s and is predicted that it will exceed 15 millions within a decade. The rate of population increase is 370 thousand per year in 1990s and 2000s, while 175 thousand per year in 1970s and 1980s. Since the rate of temperature increase from 1990s to 2000s is also larger than that it before, rapid urbanization may result in temperature rise in the old city of Jakarta.

![Fig. 1 Averaged temperatures in the old town of Jakarta.](image-url)

3. MODEL SETTINGS

3.1. Meso scale meteorological model

MM5 (Dudhia and Gill, 2005) is adopted for the calculation of meteorological field. Table 1 shows sub-modules selected in the present study. Boundary condition was given from ECMWF data at every 6 hours.
### 3.2. Calculation domains

Figure 2 shows calculation domains set in this study. Since wind and temperature fields in a synoptic scale strongly influence on local meteorology (Sofyan et al., 2007), Domain 1 (DO1 in the figure) covers a large area of the eastern part of Indonesia. The number of horizontal grid for DO1 is 61 * 61 with 27 km intervals. Domain 2 (DO2) is 49 * 58 with 9km intervals and Domain 3 (DO3) is 79 * 85 with 3 km, which covers the west side of the Java Island. Each domain has been connected as 2 way nesting. For vertical direction, sigma coordinate is adopted. In this study, 23 layers was set from the ground to the plane of 100 hPa.

![Fig. 2 Calculation domains](image)

### 3.3. Land use

U.S. Geological Survey (USGS) data (25 categories) was used. Figure 3 and Table 2 denote the distribution of land use and classification around Jakarta. Note that only No. 1, 3 and 6 are described in Table 2 since land use around Jakarta mainly occupied by No. 1, 3 and 6. In Fig. 3, no number describes a sea surface and number in a square is an area that already urbanized in 1970s. Present urban area (i.e., No. 1) is obtained manually from a population density data (BPS-Statistics Indonesia and JICA, 2000). In this study, ‘urban’ was assumed that population density is more than 5000 people/ km². No land use is changed other than urban.

![Fig. 3 Land use around Jakarta](image)
Table-2 Land use type and physical parameters for the ground surface

<table>
<thead>
<tr>
<th>No.</th>
<th>class</th>
<th>Albedo [%]</th>
<th>Moisture Avail. [%]</th>
<th>Emissivity [% at 9 μm]</th>
<th>Roughness Length [cm]</th>
<th>Thermal Inertia [cal cm⁻² K⁻¹ s⁻¹/²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Urban</td>
<td>15</td>
<td>10</td>
<td>88</td>
<td>80</td>
<td>0.03</td>
</tr>
<tr>
<td>3</td>
<td>Irrg. Crop. Past.</td>
<td>18</td>
<td>50</td>
<td>98.5</td>
<td>15</td>
<td>0.04</td>
</tr>
<tr>
<td>6</td>
<td>Crop./Wood Mosc</td>
<td>16</td>
<td>35</td>
<td>98.5</td>
<td>20</td>
<td>0.04</td>
</tr>
</tbody>
</table>

4. SIMULATION

4.1 Model validation

The validation was carried out using temperature and wind speed measured at two sites in Jakarta, and calculated results are good agreement with observed data (Figures are not shown). Calculation period is from 7:00 on Aug. 6, 2004 to 0:00 on Aug. 10, 2004 (LST).

4.2 Simulation cases

Three simulation cases (Table 3) were assumed: 1) present case (Case 0), Simulation was done under the land use shown in Fig. 3, 2) 70s case (Case 1), Urban area (No. 1) is specified only in a square, and 3) no urban case (Case 3) which urban area in the present case is replaced by No. 3.

Table-3 Simulation cases

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Land Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 0</td>
<td>present (control run)</td>
</tr>
<tr>
<td>Case 1</td>
<td>70s</td>
</tr>
<tr>
<td>Case 2</td>
<td>no urban</td>
</tr>
</tbody>
</table>

5. RESULTS

5.1 Influence of urbanization on a sea breeze

Figure 4 a,b illustrate temperature and wind fields around Jakarta at 12:00 (LST) on Aug. 9, 2004. The height of wind vectors is 10m above the ground. As shown in the figure, sea breeze in Case 0 reaches to relatively inland area, while still no sea breeze is developed since a thermal low is not formed in Case 1.

![Fig. 4 Wind and temperature fields at 12:00 in (a) Case 0 and (b) Case 1](image)

5.1 Temperature variation in the old city

Figure 5 shows calculated temperatures at the old city for all cases. As shown in the figure, temperature in the present situation (Case 0) is higher than those in the other cases. Difference of daily mean and maximum temperatures between Case 0 and 1 is about 0.6 [K] and 0.9 [K], while the difference between Case 0 and 2 is 2.3 [K]. As shown in Fig. 1, the difference between Case 0 and 1 is close to that of observed data. This suggests that temperature rise in the old city can be induced by an extended urban area around the old city.
6. CONCLUSIONS

Jakarta which one of the mega cities in Asia has been rapidly urbanized past a few decades. In addition, a population is predicted that it will be more than 15 millions. This expects that land use also has been largely modified due to urbanization. On the other hand, a long term observation shows the increase of mean temperature in the old city of Jakarta is about 1 [K] for the past 30 years. This strongly suggests that urbanization in the Jakarta area may cause temperature rise.

This study clarified the effect of extended urban area on local meteorology, especially temperature variation. The results showed that 1) in the present case (Case 0), a sea breeze was developed relatively earlier than the other cases and 2) the averaged daytime and maximum temperatures at the old city area in 2000 were 0.6 [°C] and 0.9 [°C] higher than those in 1970s.

References

BPS-Statistics Indonesia and JICA. 2000. Population Census


National Climatic Data Center, NOAA. http://www.ncdc.noaa.gov/oa/ncdc.html
