J17.3 **Impact Assessment on Local Meteorology due to the Land Use Changes During Urban Development in Seoul**

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1. INTRODUCTION

In urban area, land cover and land use changes can affect the surface energy budget, atmospheric boundary layer, and urban circulations representing a type of thermally driven flow. The Seoul city government is now adopting policies to mitigate the urban heat island by means of reducing the anthropogenic heat, reforming the artificial surface covers to diminish the sensible heat flux to latent heat flux ratio, and improving the urban structure to facilitate cooled air passage. Specifically, the impacts of the restoration of inner-city stream called Cheonggye and urban development in the north-west region of Seoul were investigated in relation to the nature-friendly urban planning and development. The mitigation effects on urban heat island were studied by observing the spatiotemporal variations in temperature and humidity at the development sites (Kim et al., 2008). Despite very helpful to quantifying the impacts on local meteorology, it was difficult to maintain the monitoring network for a long period. Numerical models are very useful to the complement of such direct observation.

In this study, the spatial and temporal distribution of temperature and wind flow in street canyons were analyzed to assess the impacts on local meteorology due to the land use changes during the urban development.

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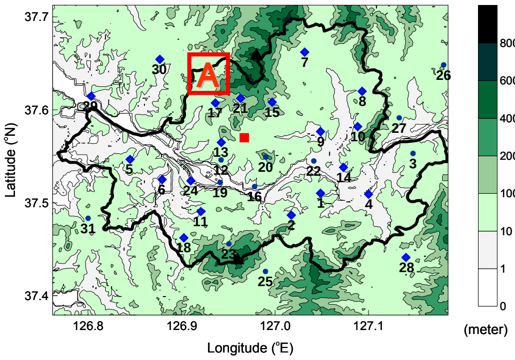
2. ANALYSIS METHOD

Seoul is characterized by moderate annual mean temperature (12.2^{o}C) and precipitation amount (1344 mm year^{-1}), and annual mean wind speed of 2.4 m s^{-1} (Climatological values from 1971 to 2000; Korea Meteorological Administration, 2001). Fig. 1 shows the locations and topography of 31 AWSs (a) and 9 portable T-RH (temperature and relative humidity) loggers (b) in the Seoul metropolitan area. Fig. 1(c) shows the northwest urban development area called Eunpyeong before the construction. It is about 30~90 m above sea level, contains a great portion of green spaces and less urbanized areas. And also, there are 1-3 story low rise residential buildings and agricultural fields.

Five automatic weather stations (AWSs) around Eunpyeong new town area, which is under development, were selected to analyze the spatial and temporal distribution patterns of air temperature depending on the weather conditions from 1998 to 2008. Additionally, the nine portable T-RH loggers were installed inside the development area to investigate more detailed structures of spatiotemporal changes of air temperature from March 2007 to February 2008. Then, a computational fluid dynamics (CFD) model (Kim and Baik, 2004; Baik et al., 2007) was employed to simulate the changes in local wind speed and flow patterns due to the development in the north-west region of Seoul. The urban development, which started in February 2004 and scheduled to finish in October 2011, includes the changes in land use and terrain height over 3.4 square km. Guidance on urban planning in regard to the wind flow has been suggested based on the impacts of the development on air flow in street canyons and surrounding areas.

(a)



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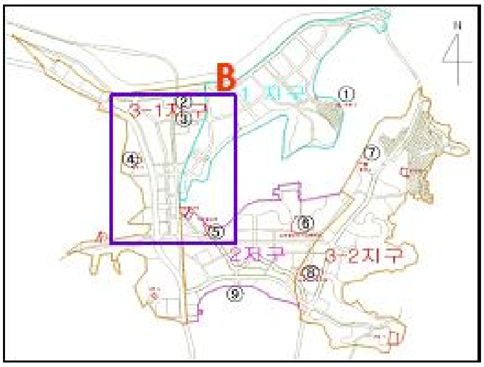

(c)

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Fig. 1 (a) Locations and topography of 31 automatic weather stations (AWSs) and (b) 9 T-RH loggers in the Seoul metropolitan area including the urban development area (represented as A in (a)) in 2002. The numerical experiment domain is marked as blue box (area B) and black dotted box in (b) and (c), respectively.

3. EXPERIMENTAL MODEL SETUP

A CFD (Computational Fluid Dynamic) model for this study is adapted from Kim and Baik (2004) based on the Reynolds-averaged Navier-Stokes equation (RANS) that contains the renormalization group (RNG) k-ε turbulence model (Yakhot et al., 1992).

(a) Model domain: The size is 1180 m in the x-direction, 1400 m in the y-direction, and 750 m in the z-direction (see area B from the Fig. 1b and 1c). The grid intervals are D*x* = 10 m, D*y* = 10 m, and D*z* = 3 m. The integration time was 1 hour with time step of 1 sec.

(b) Estimation of the temperature of building surfaces: The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) satellite images are used to calculate the surface temperatures of street canyon and building wall and roof (Baik et al., 2007). The ASTER surface temperature data (90m resolution data was interpolated to 10m.) measured at 11:22 AM in 17th April 2004 was used according to the data transformation methods by the National Institute of Meteorological Research (2007). The temperature of the building walls was set at the same temperature on the rooftop temperature.

(c) Application of high resolution data: Building height and topography data are extracted from the high resolution digital maps (1:5000) of the National Geographical Information System (NGIS) in Korea. But the underlying surface type and roof materials were not considered in this study.

4. RESULTS AND DISCUSSION

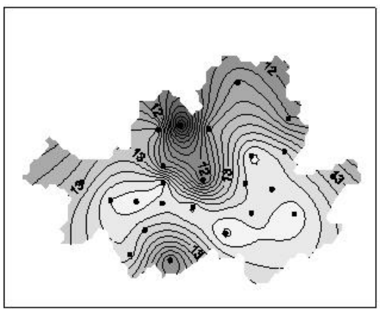
4.1. Spatiotemporal structure of air temperature

10-year mean temperature of 1998 to 2007 at the 5 AWSs (Seodaemun, Eunpyeong, Mt. Bukhan, Nunggok, and Goyang), was 11.9 °C and it is 1.1 °C lower than the mean temperature from the 31 AWSs

(13.0 °C in Fig. 2). The lower mean temperature of this area is mainly due to the Mt. Bukhan (837m ASL) and less urbanized surrounding areas.

Fig. 3 shows the spatial distribution of the difference between the mean temperature of the 5 AWS (11.8 °C) and the individual 9 T-RH loggers mean temperature (the 9 sites mean was 11.4°C) during March 2007 to February 2008. The average temperature difference was -0.4°C. Most T-RH sites had lower temperatures than the surrounding mountain areas. P8 is closer to the streets and residential houses and shows higher mean temperature than the other sites whereas P4, which is located at nearby park, shows the lowest. The temperature distribution was affected by land use type and land cover. And also it would be affected by the changes in the local thermal environment after the urban development. We will have to operate the T-RH loggers throughout the development to evaluate the thermal environmental changes.

(a)



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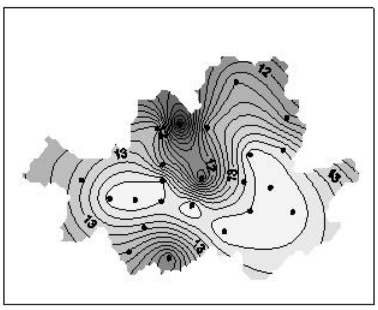


Fig. 2 Distribution of air temperature averaged for two periods in Seoul: (a) 1998~2007 and (b) March 2007 to February 2008. The contour interval is 0.2 °C.

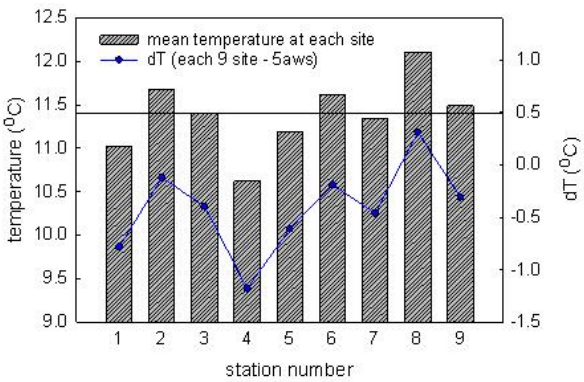


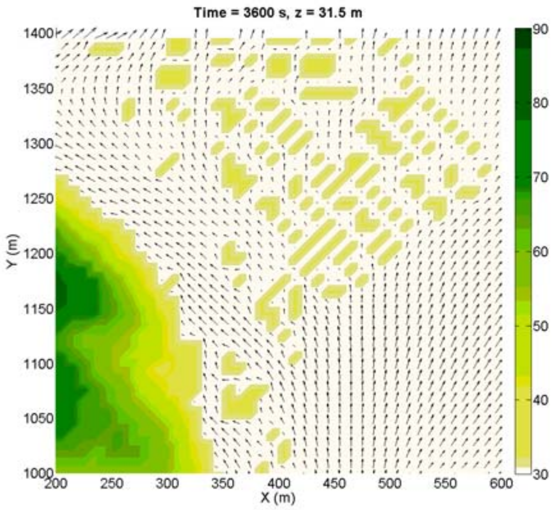
Fig. 3 Difference of air temperature at each T-RH site P1-P9 and mean temperature of the 5 stations (11.8°C) during March 2007 to February 2008. The horizontal line (11.4°C) represents the mean temperature of the 9 sites.

4.2. Numerical experiment results

The changes of land use/land cover due to the urban development can affect the local temperature field and flow structure with wind speed and atmospheric stability. Fig. 4 shows a part of the wind field simulated by the CFD model. To investigate the street and building heating effect, the surface temperature data from ASTER at 11:22 AM in 17th April 2004 was used. The initial wind speed and wind direction from Seoul surface observation data at 11 LST for the same day was also used. The changes of the wind fields were very critical by the complex buildings and topography even if the surface heating was not considered (Fig. 4a). It indicates that the complex buildings and topography can affect ventilation environment. Although the buildings are not high, the flows are more convective. In Fig. 4b, when the surface heating was considered, the wind fields were changed dramatically. When the walls of buildings and the street canyons were heated, it induced the local circulation by the changes of the temperature fields.

Based on the results, the experiment domain can be characterized as an area where the city government should keep the advantages of the ventilation paths considering the human comfort aspects of the urban climate. Direct solar radiation and thermal inertia should be considered as possible driving forces.

a)



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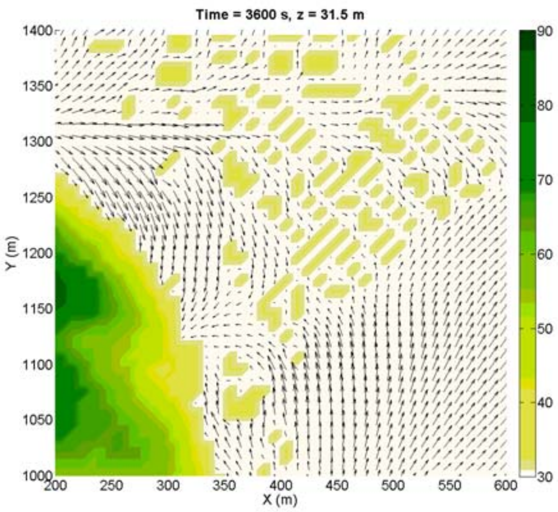

Fig. 4 Wind fields at t = 3600 s at the 31.5 m height in the case of no heating (a) and heating (b).

5. CONCLUSIONS

We estimated the effects of building geometry and surface temperature on local temperature and wind fields. These results will be provided as a guideline on the impacts of atmospheric environment for scientific urban management planning. In order to accurately investigate the urban development effects over the non-homogeneous surface areas, numerical simulation methods as well as long term meteorological monitoring are required.

6. ACKNOWLEDGMENT

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7. REFERENCES

1) Baik, J.-J., Kang, Y.-S., and Kim, J.-J., 2007: Modeling reactive pollutant dispersion in an urban street canyon. *Atmos. Environ.*, 41, 934-949.
2) Kim, J.-J., and Baik, J.-J., 2004: A numerical study of the effects of ambient wind direction on flow and dispersion in urban street canyons using the RNG κ-ε turbulence model. *Atmos. Environ.*, 38, 3039-3048.
3) Kim, Y.-H., Ryu, S.-B., Baik, J.-J., Park, I.-S., Koo, H.-J., and Nam, J.-C., 2008: Does the restoration of an inner-city stream in Seoul affect local thermal environment?. *Theor. Appl. Climatol.*, 92, 239-248.
4) Kim, W.-S., 2007: A Study on Improving Scheme of Environmental Review Aspects in Urban Management Planning in Seoul, *Focus on the Seoul Policy*, Seoul Development Institute, 23.
5) Korea Meteorological Administration, 2001: *Climatological Normals of Korea (in Korean)*, KMA, 632 pp.
6) National Institute of Meteorological Research,

2007: *Diagnosis of Characteristics of Local Meteorology and Development of Techniques for the Meteorological Environmental Impact Assessment (II)*, 153 pp.

7) Yakhot, V., Orszag, S.A., Thangam, S., Gatski, T.B., Speziale, C.G., 1992: Development of turbulence models for shear flows by a double expansion technique. *Physics of Fluids*, A4, 7, 1510-1520.