P3.1 MAXIMUM URBAN HEAT ISLAND INTENSITY IN SEOUL

Yeon-Hee Kim[1] and Jong-Jin Baik[2]
[1]Meteorological Research Institute/KMA, [2]Seoul National University, Seoul, Korea

1. INTRODUCTION

The maximum Urban Heat Island (UHI) intensity in Seoul, Korea is investigated with two specific objectives. The first objective is to characterize the maximum UHI intensity in Seoul and relate it to meteorological elements using a multiple linear regression method. The second objective is to develop a neural network model for the prediction of the maximum Seoul UHI intensity and demonstrate the potential of a neural network model in predicting UHI intensity by comparing its performance with that of a multiple linear regression model. For this, 24 years (1973-1996) of data collected at two meteorological observatories, representing an urban site (Seoul) and a rural site (Yangpyong), are used.

2. ANALYSIS AND PREDICTION OF THE MAXIMUM UHI INTENSITY IN SEOUL

2.1 Characteristics of the maximum UHI intensity

To investigate the effect of each meteorological parameter on the Seoul UHI intensity, the frequency distribution of the maximum UHI intensity as a function of wind speed, relative humidity, and cloudiness is plotted in Fig. 1. For wind speeds greater than about 0.8 m s^{-1}, the maximum UHI intensity decreases as the wind speed increases (Fig. 1a). For very strong winds, the thermal contrast between the two sites disappears. In the relative humidity plot (Fig. 1b), 72% of the total data exists in the 60-90% relative humidity range. It is difficult from this figure to find a particular relationship between the maximum UHI intensity and relative humidity. In Fig. 1c, the number of days with cloudiness 0 at the time of the maximum UHI intensity in Seoul is 3480 (40% of the total data). The number of days with cloudiness 10 at the time of the maximum UHI intensity is 2100 (24% of the total data). The most prominent occurrence of the maximum UHI intensity has a peak at 4.5°C when the cloudiness is zero. A secondary peak is observed at 1.7°C when the cloudiness is ten. Well-defined UHI phenomena are observed even when the sky is completely covered by clouds or precipitation or fog exists, but the maximum UHI intensities are usually much weaker than those when there are no clouds.

2.2 Regression analysis

Table 1 shows normalized regression coefficients for the four meteorological predictors and the percent of total variance explained by the multiple linear regression model. The case in which data are unstratified (second column of Table 1) is examined first. The most important predictor among the four variables is the maximum UHI intensity for the previous day (PER). The maximum UHI intensity tends to be strong if the maximum UHI intensity for the previous day was strong. PER is largely dependent upon the duration of certain types of weather. The second most important predictor is the wind speed (WS). WS is negatively correlated with the maximum UHI intensity, meaning that the latter is weakened as the wind speed increases. The third most important predictor is the cloudiness (CL). The correlation between CL and the maximum UHI intensity is negative. The least important predictor is the relative humidity (RH). The maximum UHI intensity tends to decrease as the relative humidity increases.

The data are partitioned into daytime and nighttime data sets to examine the day-night dependency of the four predictors in relation to the maximum UHI intensity. The order of the magnitude of the regression coefficients for the four predictors and the signs of the regression coefficients for the daytime and nighttime data sets are the same as those for the total data set. The magnitude of each regression coefficient of PER, CL, and RH is larger in the nighttime than in the daytime. On the other hand, the magnitude of the regression coefficient of WS is smaller in the nighttime than in the daytime. The total variance explained in the nighttime

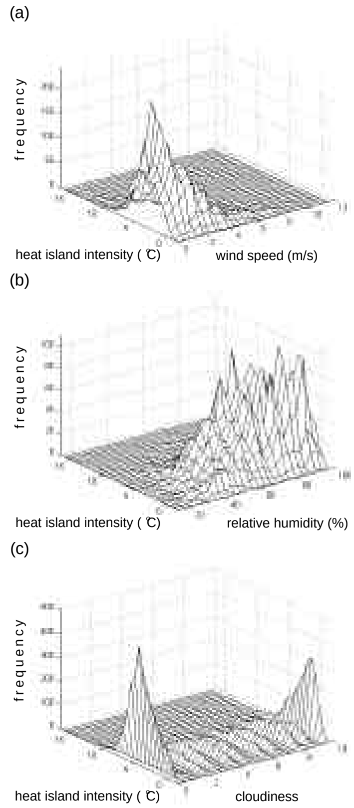

Figure 1. The frequency distribution of the maximum temperature deviation between Seoul and Yangpyong observatories as a function of (a) wind speed, (b) relative humidity, and (c) cloudiness.

Corresponding author address: Yeon-Hee Kim, Meteorological Research Institute/KMA, 460-18, Seoul 156-720, Korea; e-mail: kyh@metri.re.kr

(51.9%) is larger than that in the daytime (32.4%). This result is consistent with previous studies. To examine seasonal dependency, the total data are stratified with season and the regression analysis is again performed. The sign of each regression coefficient for seasonally stratified data sets is the same as that for the total data set, but the order of the magnitude of the regression coefficient is different, depending on season. In spring, the most important predictor is wind speed. In summer with much larger precipitation amounts than other seasons, the relative humidity is the second most important predictor. In fall, the cloudiness is the second most important predictor, with the magnitude of its regression coefficient being slightly larger than that of the regression coefficient of the wind speed. In winter, the persistence predictor is dominant over the other three predictors relative to other seasons. The regression coefficient of the relative humidity in winter is not statistically significant at the 95% confidence level. The total variance is largest in summer (43.1%) and smallest in spring (32.5%).

2.3 Neural network model

Table 2 lists the average prediction errors from the multiple linear regression model and the neural network model, together with the average maximum UHI intensity. For the unstratified test data, the average maximum UHI intensity is 3.41°C and the average prediction errors from the regression model and the neural network model are 1.26°C and 1.18°C, respectively. Therefore, the neural network model improves upon the regression model by 6.3%. When the data are partitioned into the daytime and nighttime data sets, it is revealed, as expected, that the nighttime maximum UHI intensity is stronger than the daytime one. The prediction error from the neural network model is smaller than that from the regression model for both stratified data sets. The improvement of the neural network model upon the regression model is higher in the daytime (6.1%) than in the nighttime (3.3%). When the data are stratified with season, it is revealed that the maximum UHI intensity is highest in fall and weakest in summer. The neural network model improves upon the regression model in all seasons, ranging from 0.8% in spring to 6.5% in winter. The reason for the improvement of the neural network model upon the multiple linear regression model in predicting the maximum UHI intensity in Seoul is that the neural network has an internal ability to take complex nonlinear interactions into account. This ability is achieved by including the nonlinear activation function in the neural network. For further details of this study, see Kim and Baik (2002).

3. ACKNOWLEDGMENTS

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4. RERERENCE

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Table 1. Normalized regression coefficients of the four meteorological predictors (PER: maximum UHI intensity for the previous day, WS: wind speed, CL; cloudiness, RH: relative humidity). All regression coefficients are statistically significant at the 95% confidence level except for that with superscript (*). r^2 is the percent of total variance explained by the multiple linear regression model and n is the sample size.

	all	daytime	nighttime	spring	summer	fall	winter
PER	0.52	0.43	0.52	0.31	0.37	0.42	0.53
WS	-0.24	-0.27	-0.23	-0.34	-0.17	-0.26	-0.27
CL	-0.21	-0.18	-0.21	-0.24	-0.24	-0.28	-0.13
RH	-0.12	-0.04	-0.16	-0.14	-0.28	-0.14	-0.00*
r^2(%)	46.1	32.4	51.9	32.5	43.1	41.6	39.7
n	8765	8765	8765	2208	2207	2184	2166

Table 2. Average UHI intensity in Seoul (upper values: 10% test data, lower values in parentheses: total data) and average prediction errors of the maximum UHI intensity from the multiple linear regression model and the neural network model. N is the number of prediction-experiment cases. The units are in °C.

	all	daytime	nighttime	spring	summer	fall	winter
UHI intensity	3.41	2.26	3.25	3.24	2.00	4.35	4.33
	(3.39)	(2.22)	(3.23)	(3.17)	(2.02)	(4.28)	(4.22)
regression prediction error	1.26	1.32	1.22	1.18	0.88	1.12	1.53
neural prediction error	1.18	1.24	1.18	1.17	0.87	1.07	1.43
N	876	876	876	220	220	218	216