THE CHARACTERISTICS OF URBAN EFFECT ON THE CHANGE RELATIVE HUMIDITY IN SEOUL, KOREA

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1. INTRODUCTION

Urbanization is widely recognized as dryness in humidity due to the deforestation (Oke, 1974; Hage, 1975). In observation, the aridity of urban has been obviously measured in relative humidity, compared to adjacent rural area. In relation to water vapor amount, however, it has been already reported that water vapor at urban site is larger relative to rural district on some time band (Ackerman, 1987; Adebayo, 1991).

There are many studies on long-range variation of relative humidity with observation (Chandler, 1967; Lowry, 1977; Brazel and Balling, 1986). But this variation consists of natural variability and artificial variability forced by urbanization, and it should be not easily distinguished on a simple comparison. In this study, to extract quantitatively the effect of urbanization, it is assumed that the urbanization could be divided by the temperature effect and the water vapor effect on the climatic change of relative humidity, which is originated from Adebayo(1991) and Omoto *et al.* (1994). In particular Omoto *et al.* (1994) had reported that the temperature effect has been continuously increased with time but the water vapor effect had a decreasing trend after 1970s in the big city of Japan. Um and Omoto (1994) showed there are differences between cities in Japan.

In this study, we used the evaluation method of composite calculation for urban effect with the data observed in a big urban city and a rural city, using multi-station evaluation (MSE) for natural variation. We also investigated the characteristics of climatic change in urban area based on the variability of annual mean NDVI. To quantify the urban effect, it was assumed that observation in urban area contains the influence of macro-scale, local and urban scale, and observation from rural site doesn't include urban scale.

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2. METHOD AND BASIC IDEA

2.1 *Multi-station evaluation*

With the use of monthly relative humidity for the period of 1908-2003 in Seoul, the temperature and the water vapor effects on relative humidity changes were analyzed as the causes for urban effect. However, the length of data is very important to decide the trend. The data length at the station (C) is relatively short to Incheon (B) station for evaluation of the urbanization. In order to extend the length of C station, we attempted to evaluate the urbanization with Incheon (B) station. This method is called by multi-station evaluation method (MSE). Um et al. (1997) had report the urbanization of Seoul using two-station evaluation (A and C). Figure1 shows Seoul city station and two comparing sites for MSE of this study. The relative humidity of Suwon and Incheon since 1960s near Seoul was used for the evaluation of urbanization.

Basically, it is assumed that the observation of station (A) has macro-scale natural component, local natural component, and urban scale component as [Eq.1], while station C has just natural components.

$$M_o(A) = M_{nm}(A) + M_{nl}(A) + M_u(A) \qquad (1)$$

The basic idea is to separate the components of natural macro (nm) scale, natural local scale (nl), and urban scale (u) in relative humidity variation.

It is assumed that urbanization could be found using comparing adjacent rural citie. Therefore, the urban effect should be computed by the reductions of the difference between city and rural site, and climate difference between two sites, α(A,C). The urban effect is computed as

$$M_u(A)_{ij} = -\overline{\alpha(A,C)_j}^{15} - \overline{M_o(A)_{ij}}^{5} + \overline{M_o(C)_{ij}}^{5} \qquad (2)$$

The i and j mean the numbers of month and year, respectively. The 5 and 15 indicate the mean year number. Similarly, station (A) and station (B) data could be compared as [Eq.3].

$$M_u(A)_{ij} = -\overline{\alpha(A,B_n)_j}^{15} - \overline{M_o(A)_{ij}}^{5} - \overline{M_n(B)_{ij}}^{5} \qquad (3)\text{-}1$$

$$M_n(A)_{ij} = M_o(A)_{ij} + \overline{\alpha(A,B_n)_j}^{15} - \overline{M_o(A)_{ij}}^{5} + \overline{M_n(B)_{ij}}^{5} \qquad (3)\text{-}2$$

where, $\overline{\alpha(A,B_n)_j}^{15} = \frac{1}{15}[\sum_{i=g}^{g+14} M_0(A)_{ij} - \sum_{i=g}^{g+14} M_n(B)_{ij}]$

Now the natural value at station (B) could be computed by the relation between station (B) and station (C) as [Eq. 4].

$$M_n(B)_{ij} = M_o(B)_{ij} + \overline{\alpha(B,C)_j}^{15} - \overline{M_o(B)_{ij}}^{5} + \overline{M_o(C)_{ij}}^{5} \qquad (4)$$

where, $\overline{\alpha(B,C)_j}^{15} = \frac{1}{15}[\sum_{i=f}^{f+14} M_0(B)_{ij} - \sum_{i=f}^{f+14} M_o(C)_{ij}]$

2.2 *Separation of the temperature and the water vapor effects*

To analyze the causes of humidity change in urban area, we attempted to examine the urban effect quantitatively and divide it into the water vapor and temperature effect. Natural variability in urban area was obtained by assumption for simultaneous climate condition for early 15 years. The main idea in this study is to separate the water vapor and temperature effects for urban effect in relative humidity as [Eq.5]. Inversely the sum of temperature and water vapor effect could not be equal the total urban effect as shown in [Eq.6]. So we added the correction term in right and left terms. We assumed that the correction on the urbanization effect would be considered by the vapor effect as [Eq.7]. And then we decided the water vapor effect on natural value as [Eq. 8] finally.

$$H_U(A)_{ij} = H_{TU}(A)_{ij} + H_{VU}(A)_{ij} \qquad (5)$$

$$H_U(A)_{ij}' \neq H_{TU}(A)_{ij}' + H_{VU}(A)_{ij}' \qquad (6)$$

$$H_U(A)_{ij} + \eta_H = H_{TU}(A)_{ij} + H_{VU}(A)_{ij} + \eta_V \qquad (7)$$

$$H_{nV}(A)_{ij}' = H_o(A)_{ij} - (H_U(A)_{ij}' - H_{TU}(A)_{ij}) \qquad (8)$$

3. RESULTS AND DISCUSSION

Figure 2 shows the climatic variation of the relative humidity (%) observed in Seoul with missing data during Korean War. In overall, the climatic change of relative humidity in Seoul has a continuous decreasing trend except a few short periods as the solid line of Fig.2. The most dominant character on urbanization effect is the temperature effect after mid-1970s years. In Fig.2 the dotted line of middle contour shows the water vapor effect calculated by [Eq. 7]. That is, the dotted line was computed to separate the water vapor effect (Fig. 3) and the temperature effect (Fig. 4). As result, the urban effect increased with the temperature effect to 1980s years. This may be due to the change of land-use type as the urban has developed (Henry and Dirks, 1985). After 1980s, however, the temperature effect on urban effect decreased. We assumed that the temperature effect could be reduced by increased urbanization of rural site. So the decreasing temperature effect of Seoul urbanization may be due to the apparent urbanization in Suwon, where the decreasing trend was observed in NDVI. Figure 5 shows the percentile difference between mean during the period of 1991-1993 and mean during the period of 1988-1990 for NDVI over the northwestern of Korea. Ha *et al.* (2001) had reported that the change in NDVI was observed from inter-annual variability of NOAA/NASA PAL AVHRR data. The influence of water vapor tends to be decreased after the dramatic increase in 1970s, which may be related with excess of water vapor owing to change of lifestyle. Even though it is not clear how the water vapor affects the adjustment in the urban effect for decreasing or not increasing trend, the climatic change in the temperature effect and the vapor effect on urbanization of Seoul was investigated with the observation through multi-station evaluation method.

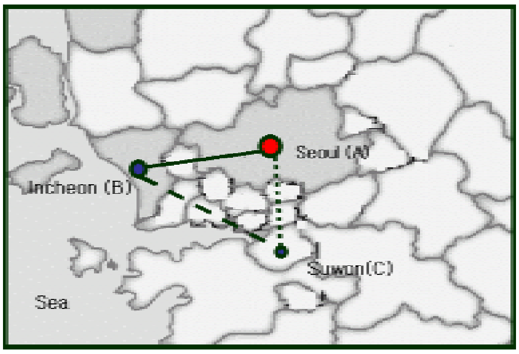

Fig. 1. The location of Seoul and two sites for multi-station evaluation of urbanization.

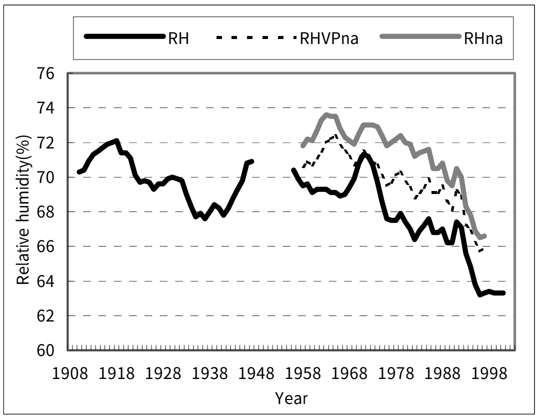

Fig 2. The variation of relative humidity (%) in Seoul. The solid line indicates the observed value, the gray line indicates the natural value, the dotted line indicates $H_{nV}(A)_{ij}$ in eq. (8).

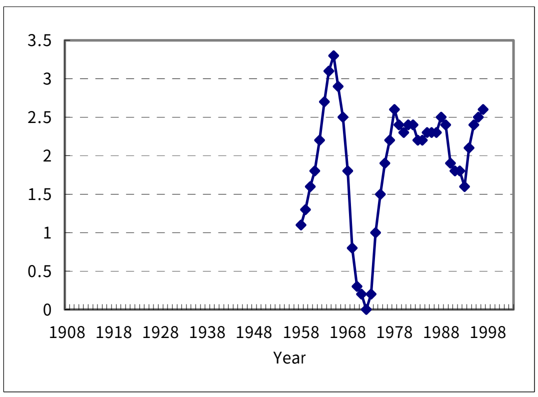

Fig. 3. The water vapor effect on the urban effect.

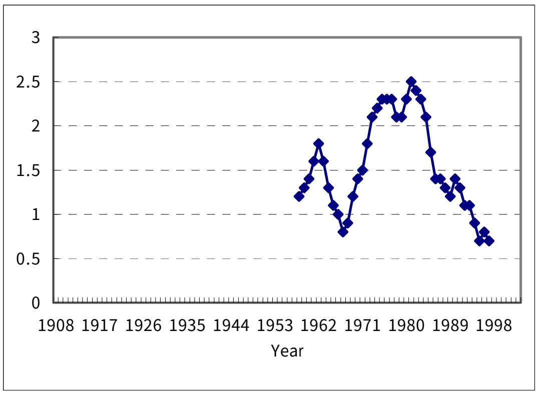

Fig. 4. The temperature effect on the urban effect.

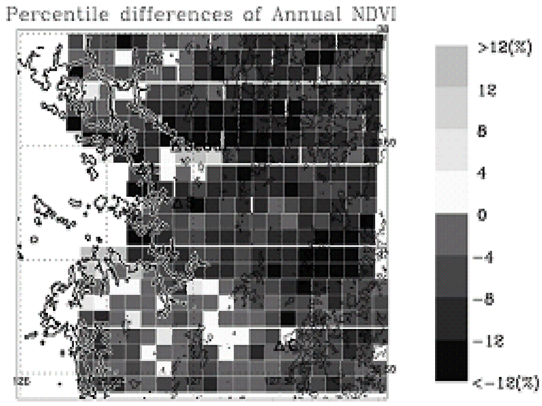

Fig. 5. Percentile differences between the late three years (1991-1993) and the early three years (1988-1990) for NDVI over the northwestern of Korea.

Acknowledgments

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