Restoration of an inner-city stream and its impacts on air temperature, relative humidity, and perceived temperature

Kyu Rang Kim, Tae Heon Kwon, Hae-Jung Koo, Jae-Young Byon, Byoung-Cheol Choi, Young-Jean Choi, and Chee-Young Choi
Applied Meteorology Research Lab., National Institute of Meteorological Research, Korea Meteorological Administration, Seoul 156-720, Korea
(krk9@kma.go.kr, +82-2-6712-0451)

Introduction

Environmental Impact Assessment (EIA) is being practiced around the world to predict the increase in environmental pollution and thermal stress level due to the large scale development. Assessments of the meteorological changes in EIA are currently minor components. Korea needs systematic and technical supplements in meteorological EIA for more reliable prediction on wind and temperature changes. Thermal EIA can be one of the technical supplements and a case study of thermal EIA during the restoration of an inner-city stream called 'Cheonggye' in Seoul is presented here. The stream, running through the center of Seoul for 5.8km from west to east, had been covered by concrete structures and asphalt pavement roads for 46 years and was restored as a small (ca. 6m width and 40cm depth) stream in 2005.

Previous analysis reported the effects of the restoration as decreases in the air temperature and the ratio of sensible heat flux to net radiation (Kim et al., 2007). However it is difficult for a simple temperature analysis to standardize the weather conditions, which naturally includes changes in surrounding vegetation, traffics, floating populations, and incidents.

Perceived temperature (PT) was introduced as a standard index of thermal balance or comfort of human beings based on observed temperature, RH, solar radiation, and wind speed. The Klima-Michel model (KMM), which is an energy budget model for human, was used to produce PT and to investigate the thermo-physiological environment. It is consisted of Fanger's comfort equations (Fanger, 1970) with a radient model for outdoor conditions and a correction term for humid-warm conditions (Gagge et al., 1986). It links meteorological conditions to human beings in order to assess the atmospheric thermal environment. It is applicable to both warm and cold conditions whereas traditional indices such as discomfort index, apparent temperature, and wind chill are only applicable to summer or winter seasons. The details of the model and PT were described elsewhere (Jendritzky et. al, 2000). In this study, we utilized PT to analyze the thermo-physiological conditions of the Cheonggye stream as a model case of thermal EIA.

Analysis Methods

Perceived temperature is the temperature (C) of a standard environment that induces the same heat and cold stress of the real environment. In the standard environment, air temperature and mean radiant temperature are the same. The Klima-Michel model estimates PT from various weather data including radiation data for the calculation of mean radiant temperature (MRT). They can be obtained from cloud height and amount or observed solar radiation. In order to estimate MRT from solar radiation, the model needs environmental information such as topographical index, land use, albedo, emissivity, and roughness length. The compelled changes in such information due to the restoration was modeled in KMM to reveal the differences in PT.

Air temperature, relative humidity (RH), and wind speed and direction were monitored before, during, and after the restoration around the stream by installing two automatic weather stations (AWS) at 66 (Seongdong) and 173m (Sungshin) from the center of the stream. There were several intensive observation periods (IOPs) before and after the restoration. During the periods, solar radiation, net radiation and 3-dimensional wind speeds were monitored as well as air temperature and RH near the stream area at pre- and over the stream at post-restoration.

For the comparison of thermo-physiological environment near the stream, the data from AWS and IOP sites were compared with reference data from the Seoul weather station. September 23-29, 2005 period during one of the IOPs was chosen and three-hourly PT was calculated. Observed air temperature, RH, and wind speed from each station and air pressure from Seoul weather station were used as input data for KMM. Solar radiation data from the IOP site were used for the three sites near the stream and those from the Seoul weather station were used for the reference PT at Seoul.

Results and Discussion

Fig. 1 (left) shows PT from Cheonggye stream, two AWS sites, and Seoul station during Sept. 23-29, 2005. Seongdong and Cheonggye sites had the same number of data points, whereas Sungshin had missing data during 23-26. Although PT showed a similar trend among the sites, Cheonggye had the lowest PT and distant Sungshin had the highest. It is assumed that the stream effects on lowering maximum PT were strongest at the stream and became weaker with distant.

Fig. 1 (right) is the air temperature at the four sites during the same period as PT. Unlike PT, the temperatures at the stream, Seongdong, and Sungshin are higher than Seoul weather station. The differences of the temperatures among the sites are smaller than that of PT. In conclusion, the thermo-physiological processes in calculating PT make it better at distinguishing temperature changes due to water surface area.

The heat stress levels given by PT in Fig. 1 describe the stream area was more comfortable during the afternoon hours although it was less comfortable in the morning. The highest heat stress level during the observation period was only observed at Seoul station and Sungshin site (Table 1).

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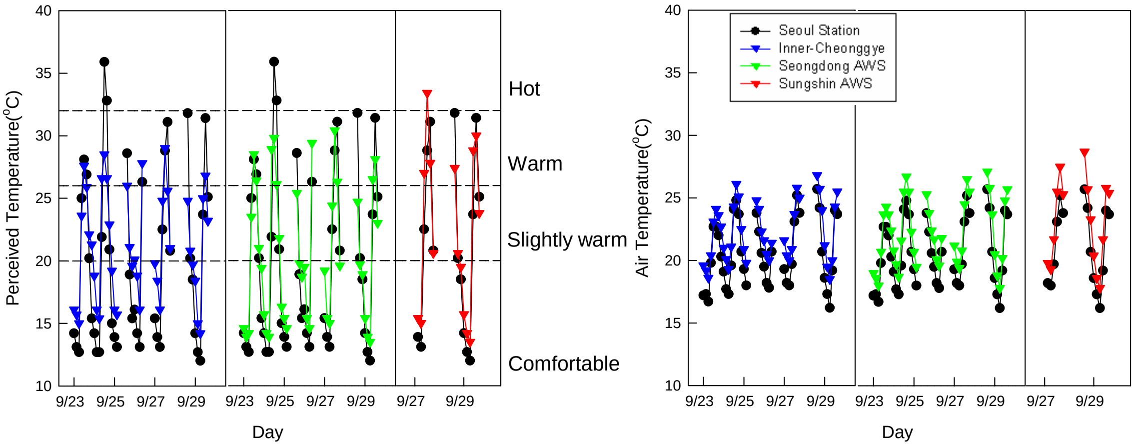

Fig. 1. Perceived temperature and air temperature at Seoul station (black, 1120m from the stream), Cheonggye stream (blue, 0m), Seongdong (green, 66m), and Sungshin (red, 173m). The dashed lines divide the stages of thermal stress (comfort: 0-20C; slightly warm: 20-26C; warm: 26-32C; hot: 32-38C).

Table 1. Percentages of thermal stress levels at each site based on the perceived temperature during the IOP

PT (℃)	0 ≤ PT <20	20 ≤ PT < 26	26 ≤ PT < 32	32 ≤ PT ≤ 38
Thermal Perception	Comfortable	Slightly Warm	Warm	Hot
Cheonggye Stream (%)	46.3	34.1	19.5	0.0
Seongdong AWS (%)	58.5	17.1	24.4	0.0
Sungshin AWS (%)	40.0	20.0	33.3	6.7
Seoul Station (%)	53.7	22.0	19.5	4.9