LAGRANGIAN HUMAN BIO-METEOROLOGY

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Abstract

Boundary-Layer meteorology and bio-meteorology are currently on the basis of Eulerian concept, i.e., meteorological factors are evaluated at the fixed observation points. Moving observations are generally for extending Eulerian data to spatial information but not for Lagrangian tracing. Meteorological information at fixed points can be largely different from actual micro-climate in urban canyons where we are living. Also our physiological response to micro-climate can be different by individuals depending on their Lagrangian movement. Here we propose a new Lagrangian concept for urban bio-meteorology named "Lagrangian Human bio-Meteorology". This new concept includes the investigation of continuous changes of micro-climate and the dynamical response of human vital signs along human pathways. We developed a portable Lagrangian measurement system. All meteorological sensors (air temperature, humidity, globe temperature, and wind velicity) were packed into a bag. Blood pressure, pulse rate, and axillary temperature were also measured. The first results of an observation in the Central Tokyo using the Lagrangian measurement system are presented.

Key words: Lagnrangian Observation, Human Biometeorology, Thermal environment in cities

1. INTRODUCTION

Due to the global warming and the heat island phenomenon, increasing heat stroke patients have been becoming serious especially in several Asian mega-cities. Monitoring meteorological information in mega-cities is important for urban amenity and human health. However, official meteorological information at fixed points can be largely different from the actual micro-climate in urban canyons. In addition, our physiological response to micro-climate can be different by individuals depending on their Lagrangian movements and their physical and mental conditions. Thus, Lagrangian observations along human pathways appear to be much suitable for monitoring outdoor human health rather than Eulerian fixed-point observations. Here we propose a new lagrangian concept for urban human bio-meteorology named "Lagrangian Human bio-Meteorology (LHM)". The concept of LHM is to investigate continuous changes of micro-climate and the physiological response along human pathways carrying small bio-meteorological sensors. The current study presents (1) a measurement system for LHM and (2) the first results of the LHM application in the Central Tokyo.

2. LAGRANGIAN MEASUREMENT SYSTEM

Thermal sensitivity is a good index to assess thermal environments. Although the thermal sensations were originally developed for the assessments of indoor thermal environments, some indexes are applicable for the outdoor environments, e.g., new standard effective temperature (SET*[1)]), predicted mean vote (PMV[2)]). All of the sensitivity indexes are computed from ambient temperature (Ta), humidity (RH), globe temperature (GT), and wind velocity (U); these four meteorological items are to be measured by the LHM measurement system. For portability, meteorological sensors for the four variables were aligned on a carry bag, in which a data logger (CR10X) was packed. To deal with the locality of thermal environments in urban canyons, the sensors with small detectors were used (Table 1). For the direct assessment of the thermal impact to human bodies, systolic/diastolic blood pressure (BP), pulse rate (PR), and axillary temperature were also measured (Figure 1).

Table 1 Measurement items

Item	Sensor	Manufacturer	Sampling frequency
Ta	Thermocouple (0.2 mm)	NEWC*2	1 Hz
GT	Globe temperature sensor (40 mm)	Self-produce	1 Hz
RH	Humidity transmitter	Vaisala	1 Hz
U	Hot-wire anemometer	Kanomax	1 Hz
PR BP	Sphygmomanometer (wrist type)	Omron	–
Tb*1	Thermocouple (0.2 mm)	NEWC*2	1 Hz

*1: Axillary body temperature
*2: Ninomiya Electrical Wire CO., Ltd.

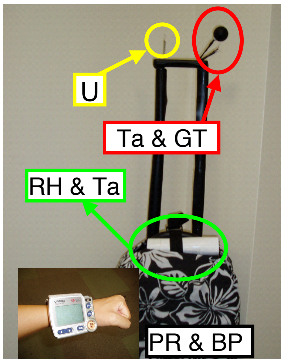

Figure 1 LHM-measurement system

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3. LAGRANGIAN OBSERVATION

To confirm the effectiveness of LHM, a Lagrangian observation was conducted in central Tokyo on a typical fair day in summer, 20th August in 2008. The daily maximum air temperature at Tokyo Meteorological site (the nearest AMeDAS site) was 32.4 C at 13:10 on the day.

3.1. Observational setting

(1) Subject Information
The subject was a 26-year-old man. He was 170 cm tall and weighed 59 kg. PR, systolic BP, and diastolic BP in standing relaxed position in daytime were 70 bpm, 106 mmHg, and 62 mmHg, respectively. The subject conducted the observation in good shape.

(2) Observational fields
Observational fields included commute trains and station platforms in rush hour, urban canyons and vegetated fractions in downtown in central Tokyo, a top of a 54-story skyscraper in a mega complex, and a subway station 42 m below the ground, etc. The summary of the event records are shown in Table 2.

4. RESULT AND DISCUSSION

New standard effective temperature (SET*) and Ta are focused here for micro-climate variables. SET* is a widely-used thermal index based on mathematical models of human thermoregulatory mechanism and energy budget on human body.

Table 2 Summary of event records. Alphabet in ID column corresponds to that in Figure 2.

Time	ID	Location
7:06-8:39	A	Commute trains and station platforms in rush hour
8:40-15:41	B	Urban canyons in downtown (Shibuya)
15:42-16:19	C	Subway trains and station platforms
16:20-18:38	D	Urban canyons in downtown (Roppongi)
18:39-20:04	E	Vegetated fraction in Central Tokyo (Roppongi)
20:05-23:10	F	Urban canyons in downtown (Roppongi)
23:11-23:33	G	Subway trains and station platforms
23:34-23:53	H	Urban canyons in downtown (Shibuya)
23:54-0:28	I	trains and station platforms

4.1. Overview of Result

Figure 2 (a) shows the time series of SET* and Ta from the Lagrangian observation (hereafter Ta_Lag). Ta at Tokyo meteorological observational site (hereafter Ta_AMeDAS) is also plotted in Figure 2 (a) for the comparison of the Lagrangian data and the Eulerian data. Time series of the physiological responses are plotted in Figure 2 (b). Alphabet in Figure 2 corresponds to that in Table 2. Maximum Ta_Lag was 35.2 C (13:55), and was observed in urban canyons in downtown Tokyo. It was higher than Maximum Ta_AMeDAS by 2.8 C; the daytime thermal environment in the urban canyons was generally warmer than Ta_AMeDAS. The subject underwent the abrupt changes of thermal environment (over 10 C of Ta_Lag and SET*). Sudden heat exposure enhances the heat stoke risk (guideline for heat stroke prevention by Japanese Society of Biometeorology), and vital signs may be affected by abrupt shift of micro-climate. Unfortunately, this measurement system could not detect the exact response of BP and PR accompanied by abrupt transition of heat environment. Continuous measuring system of vital signs is necessary for further studies.

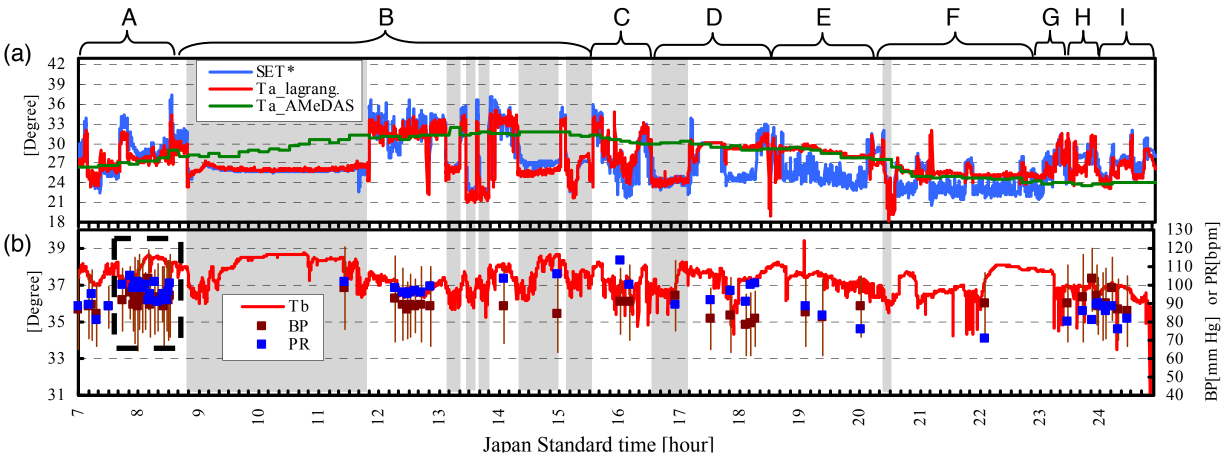

Figure 2 Time series of the lagrangian observation. Except for data in trains and stations, the data in indoor environments air-conditioned are indicated by gray-shaded area.

Figure 3 represents the histograms of SET*. Figure 3 shows that the subject experienced warm environments involved heat stroke risk (red-shaded area in Figure 3). The warm environments were observed in a platform crowded by commuters in morning rush hour and urban canyons in downtown Tokyo in daytime (A, B in Figure 2 (a)). The heat environments and vital signs in the trains and the platforms during the peak hours are discussed in detail below.

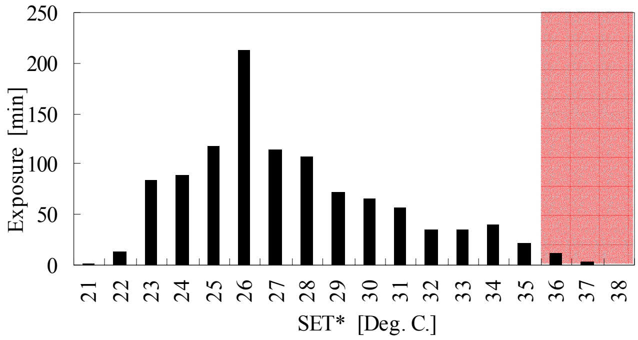

Figure 3 Histogram of SET*. Red-shaded area corresponds to the data where heat stroke risk increases[1].

4.2. Result from specific point of view

(1) Micro-climate in station platform in morning rush hour

Here we focused on micro-climate in the platform of "Shibuya station" in morning rush hour. Shibuya station is the third-busiest rail station in Tokyo metropolitan area. It has multiple platforms and is served by seven train routes, handling over 2.6 million passengers on an average weekday[3), 4), 5), 6)]. Even in the early morning (8:31), Ta_Lag was 34.4 C and SET* was over 37 C in a platform of Shibuya station; the Ta_Lag exceeded the daily maximum Ta_AMeDAS. The warm environment was observed at an underground platform in Shibuya station crowded by commuters (Figure 4). There the ninth-crowded commute trains in Japan run: 198% congestion rate during peak hours[7)]. Anthropogenic heat emissions from a large number of passengers and air-conditioning system of trains possibly resulted in such warm environment in the platforms.

Figure 4 Picture of crowded platform of Shibuya station.

(2) Micro-climate in trains in morning rush hour

The difference of the thermal environment between in the crowded train (Figure 5, hereafter CT) and in the less crowded train (Figure 6, hereafter LCT) during peak hours is discussed here. The ninth-crowded commute train for Shibuya station was termed as CT (7:50-8:30), and trains for the starting station of the commute train were regarded as LCT (7:08-7:21 and 7:22-7:41). Average Ta in CT was 27.8 C (Figure 2(a)) and higher than the preset temperature of the air conditioning system, 25~26 C (the owner company HP). Meanwhile, average Ta in LCT was 25.9 C, and ranged in the preset temperature. The congestion degree in the trains is also likely to affect the thermal environment there, which means that, the anthropogenic heat emission from passengers may be a non-negligible factor for the micro-climate in trains.

Figure 5 Picture of the crowded commute train

Figure 6 Picture in the less crowded train

(3) PR and BP in train and station platform

The values of PR and BP in CT were high compared to those in LCT (region enclosed by broken line in Figure 2 (b)). Average PR and systolic BP in CT were 97 bpm and 111 mmHg, respectively. Meanwhile, those values in LCT were 88 bpm and 104 mmHg, respectively. Figure 7 shows the relation between systolic/diastolic BP and SET* and between PR and SET*. PR and systolic/diastolic BP appeared to be correlated with SET*. Some studies reported that the enhancement of heat stress resulted in an increase of PR but a small decrease of BP[8), 9)]. Our findings were not consistent with them. Meanwhile, it is known that physical and mental stresses increase both PR and BP. Sympathetic nerve is stimulated by the stresses. It causes bodies to tense and blood vessels to shrink, and that leads to increase of both PR and BP. Therefore, the current results may suggest that the influence of physical/mental stresses in CT might lead to the increase of the physiological responses rather than influences of micro-climate in the trains. Thermal environment in trains and station platforms air-conditioned can be influenced by congestion degree, as discussed above. SET* may be an index for the congestion degree in the trains.

Human physiology is affected by various factors, such as, micro-climate, physical/mental conditions, and activities of subjects. Further observations on human physiology in commute trains are necessary.

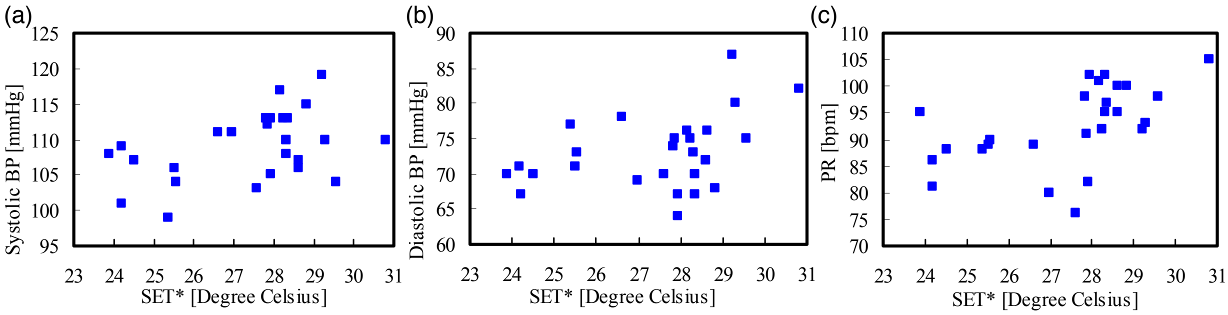

Figure 7 Relation between (a) systolic BP and SET*, (b) diastolic BP and SET*, and (c) PR and SET*.

5. CONCLUSION

In this report;

(1) We proposed the new Lagrangian concept for urban bio-meteorology. The concept is to investigate continuous changes of micro-climate and the physiological response along human pathways carrying a compact measurement system.

(2) Necessary measurement systems for LHM were discussed, and the prototype of the system was developed.

(3) The Lagrangian observation was conducted in central Tokyo. LHM could evaluate the heat-stress record of the subject and could investigate the heat environment in fields difficult to observe micro-climate. The results of the observation suggested that LHM has a potential to contribute to urban biometeorology.

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