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Influence of nearby plants and artificial structures on the surface air temperature statistics: Continuous in-situ measurement at central Tokyo

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Dated: 01 July 2015

ABSTRACT

In order to clarify the influence of obstacles on temperature measurement, two years' continuous observation was made in the meteorological enclosure of the Japan Meteorological Agency (JMA) in central Tokyo (Otemachi) by installing an extra thermometer at a spot that was surrounded by trees and was 20m distant from the thermometer for operational observation. In the early afternoon of the warm season, the temperature at the spot surrounded by trees was found to be higher than the operational temperature. The temperature difference was about 0.5 degrees Celsius on the average, and was correlated with daily solar radiation with a correlation coefficient of over 0.7 at 15JST from March to September. On the other hand, difference of nighttime temperature was generally small, so that the monthly mean difference of daily mean temperatures was less than 0.1 degree Celsius for all the months of the year. It was also found from observation using supersonic anemometers that the wind speed at the spot surrounded by trees was only one third of that at the center of enclosure. It is speculated that the reduced ventilation under strong insolation is a cause of anomalous temperature in the spot surrounded by trees in the daytime of the warm season.

1. Introduction

Surface air-temperatures are affected by their observation environment. From data sets of surface observation, many researches were conducted to detect the temperature difference, or to develop revision methods (Mahmood *et al.*, 2006; Runnalls and Oke, 2006; Peterson 2006; Pielke *et al.*, 2007). From the several decades dataset of Japan meteorological agency, trends of temperature was associated with trends of wind speed (Fujibe, 2009). In a meteorological enclosure, temperature difference or distribution were observed within a month (Hawkins et al. 2004; Kondo 2004ab, 2012; Kumamoto et al., 2013). But, continuous observations over a year were limited (Shido et al., 2015). Japan Meteorological Agency continuously conducts surface air-temperature measurements in about 900 sites. So, we tried to continue to measure temperature using additional thermometer for years in a meteorological enclosure to clarify the influence of obstacles.

2. Data

In this study, we installed an extra sensors in the “Otemachi meteorological closure” (Fig. 1a), where is located about 1km north-west of JR Tokyo Station. From 1964 to 2014, Japan meteorological Agency have measured air-temperature by “the main thermometer” (Fig. 1b) as the temperature of central Tokyo. So we called this sensor “JMA”. From April 2011, an additional thermometer “Field” was located at east edge of the enclosure (Fig. 1c). From June 2014, two supersonic anemometers were located at near the center of the enclosure (Fig 1b), and at the top of the pole of the “Field” thermometer (Fig. 1c). From hemispherical photographs, the sky factor at near “JMA” was 77%, and at near “Field” was 65% (Fig. 2). For analysis, we used solar radiation and wind speed data measured at the roof of “the science museum” (700m west of the Otemachi enclosure). These data are measured by Japan Meteorological Agency.

3. Result

The temperature difference between Field and JMA reached about 0.5 degrees Celsius on the average at 15:00(JST) in May and August (Fig. 3). During night time, the temperature difference was generally small compared with daytime. Therefore, maximum temperature differences were large, and minimum temperature differences were less than 0.1 degree Celsius for all the months of the year (Fig.4). Temperature differences were strongly correlated with daily solar radiation, and the correlation coefficient was over 0.7 at 15JST from March to September (Fig.5). This relationship indicated influence of building shadow. From the relationship of solar orbits and building, if only one sensor was in building shadow, then temperature difference was large (Fig. 6, 7). The wind speed at the spot surrounded by trees was only one third of that at the center of the enclosure (Fig. 8). It is speculated that the reduced ventilation under strong insolation is a cause of anomalous temperature in the spot surrounded by trees in the daytime of the warm season. From observation using supersonic anemometers, it is found that averaged wind speed was 1-3m/s (averaged 9:00-15:00) when temperature difference (at 15:00) was

over 1 degree Celsius (Fig. 9). It implied that the wind speed was related to the temperature difference between Field and JMA.

Fig.1. (a) The Otemachi meteorological enclosure at the Tokyo Regional Headquarters, Japan Meteorological Agency. The upper side is almost the north. (b) The main thermometer (at the start and end points of the indigo arrow), called "JMA", and the central anemometer (the aqua arrow) in the enclosure. (c) The extra thermometer (the pink arrow), called "Field", with the other anemometer (the green arrow).

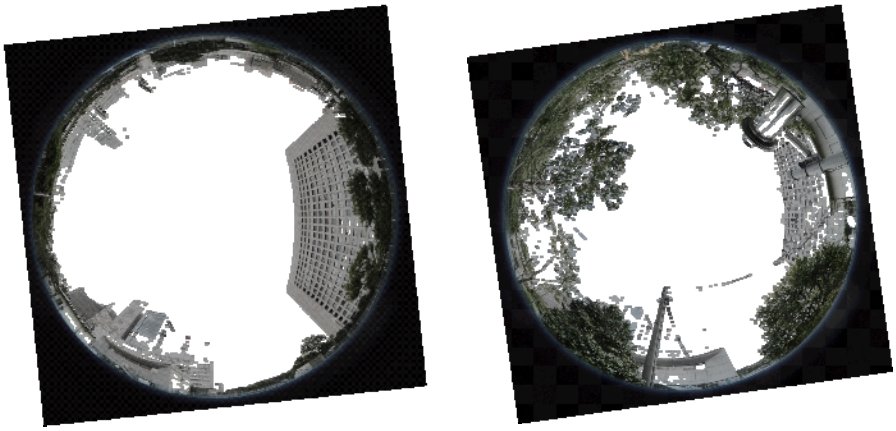

Fig. 2. Hemispherical photographs. (a) From the center of the enclosure (near the start point of the aqua arrow in Fig.1a). (b) From near the "Field" (thermometer) (the start point of the pink arrow in Fig. 1a). The upper side is north, the left side is east, the down side is south, and the right side is west.

JST / Month	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	24:00	max.	min.	mean
JAN	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.2	−0.1	0.0	0.0	0.0	0.1	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	0.0	0.0	−0.1
FEB	−0.1	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.2	0.0	0.0	0.1	0.2	0.2	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	0.1	0.0	0.0
MAR	−0.1	0.0	0.0	0.0	−0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	−0.1	−0.1	0.2	0.0	0.0
APR	0.0	0.0	0.0	−0.1	−0.1	−0.1	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.4	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.1
MAY	0.0	0.0	0.0	0.0	0.0	−0.1	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.5	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.1
JUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.1
JUL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.3	0.3	0.4	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.1
AUG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.6	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.5	0.0	0.1
SEP	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	0.0	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.1	0.0	0.0	0.0	0.0	−0.1	−0.1	−0.1	−0.1	0.3	0.0	0.0
OCT	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.3	0.1	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	0.2	0.0	0.0
NOV	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.2	0.0	0.0	0.0	0.1	0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	0.0	0.0	−0.1
DEC	0.0	−0.1	0.0	0.0	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.2	−0.1	−0.1	−0.1	0.0	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	0.0	0.0
daily max.	0.2	0.3	0.2	0.3	0.2	0.2	0.3	0.4	0.4	0.6	0.6	0.9	0.9	0.9	1.3	0.6	0.6	0.5	0.3	0.5	0.4	0.3	0.2	0.2	1.6	0.4	0.3
daily min.	−0.5	−0.5	−0.4	−0.4	−0.4	−0.5	−0.3	−0.4	−0.5	−0.4	−0.6	−0.4	−0.4	−0.3	−0.3	−0.4	−0.4	−0.5	−0.6	−0.4	−0.4	−0.4	−0.4	−0.4	−0.6	−0.4	−0.2

Fig. 3. Monthly mean temperature difference between Field and JMA from 01Oct2011 to 30Sep2013. Each values under a time are calculated from 60 minutes averaged temperature.

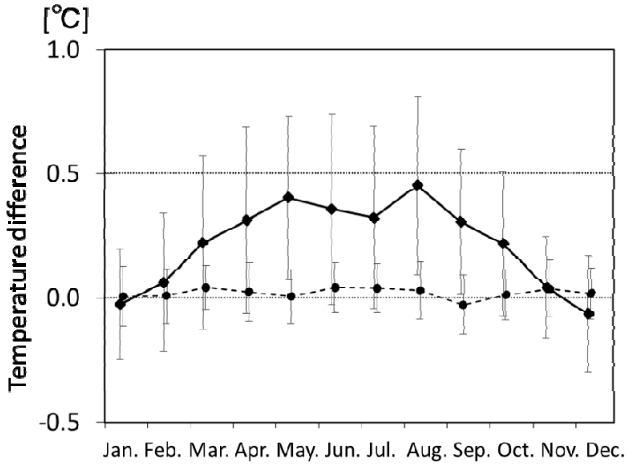

Fig. 4. Monthly averaged maximum & minimum temperature difference (δT_{max}, δT_{min}) between Field and JMA. Solid line shows δT_{max}, and dash line shows δT_{min}. Standard deviations were indicated with error bars

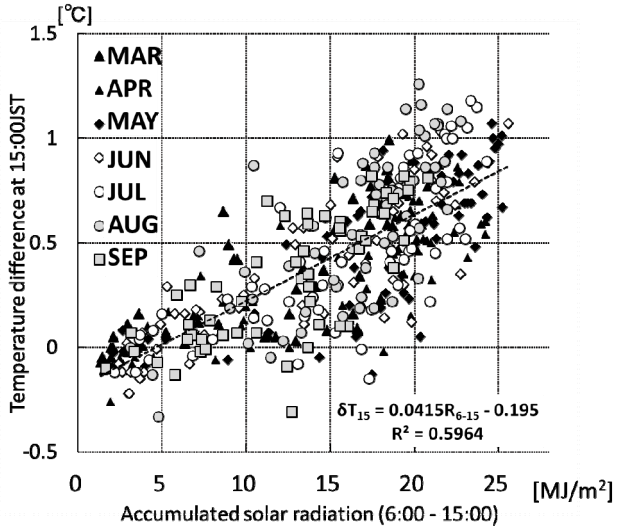

Fig. 5. A scatter diagram with daily solar radiations on x-axis and surface air-temperatures differences at 15:00 JST between Field and JMA on y-axis. The analysis period was limited from Apr. to Sep. in 2012-13.

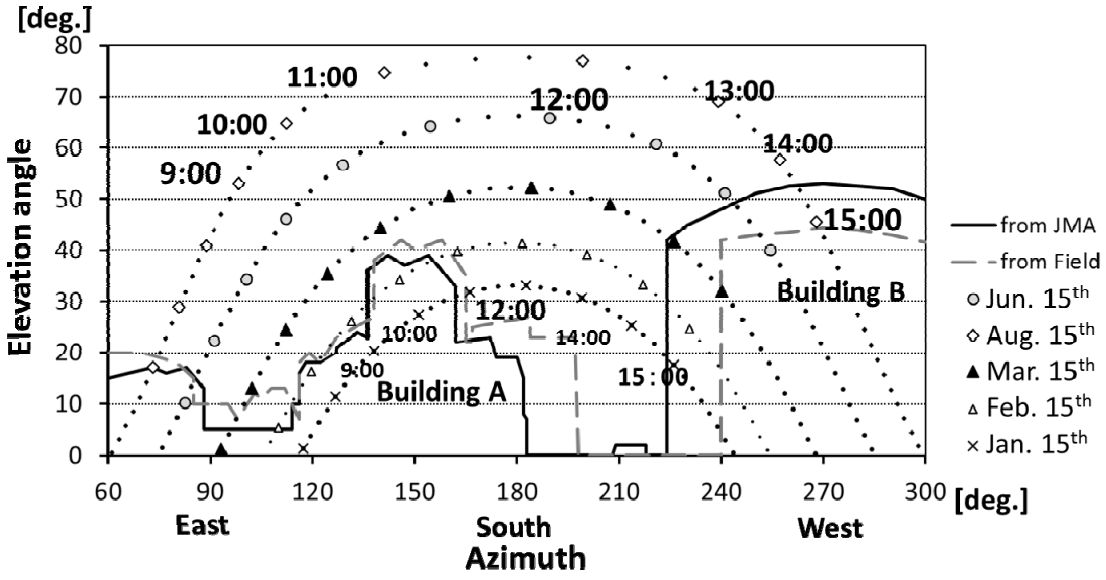

Fig. 6. Solar orbits (dots and symbols) and building covers (the solid line and the dash line) in the sky at the Otemachi enclosure. The x-axis expresses azimuth angles, and y-axis expresses elevation angle. From top to bottom, Dotted lines and symbols express solar orbits at Jun.15th, at Aug. 15th, at Mar. 15th, at Feb. 15th, and at Jan. 15th.

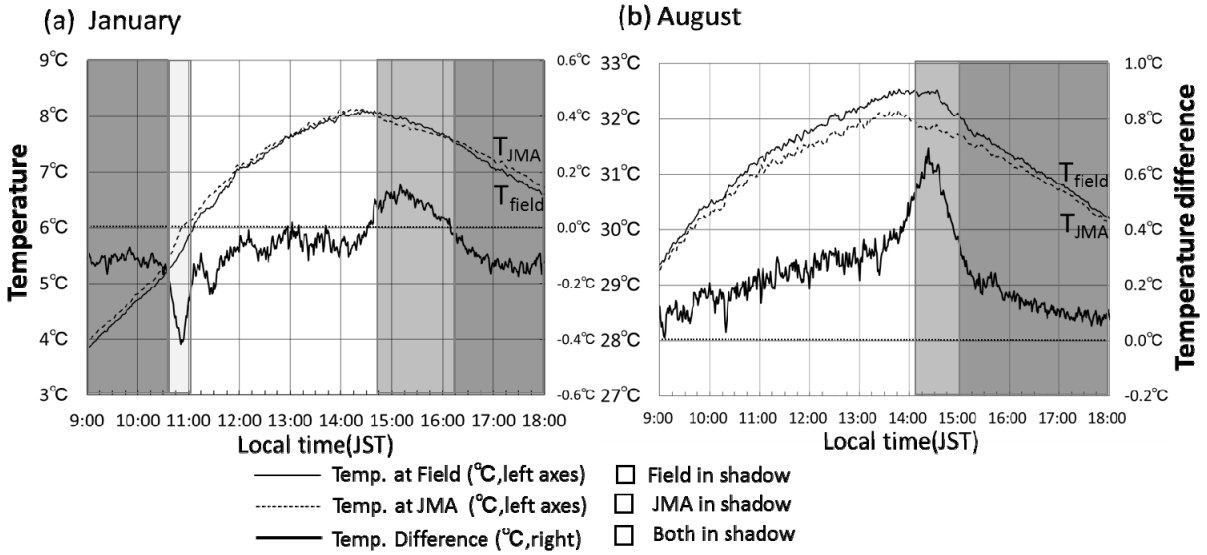

Fig. 7. Time series of the monthly mean temperature measured at the Otemachi enclosure (a) in January, and (b) in August during 2012-2013.

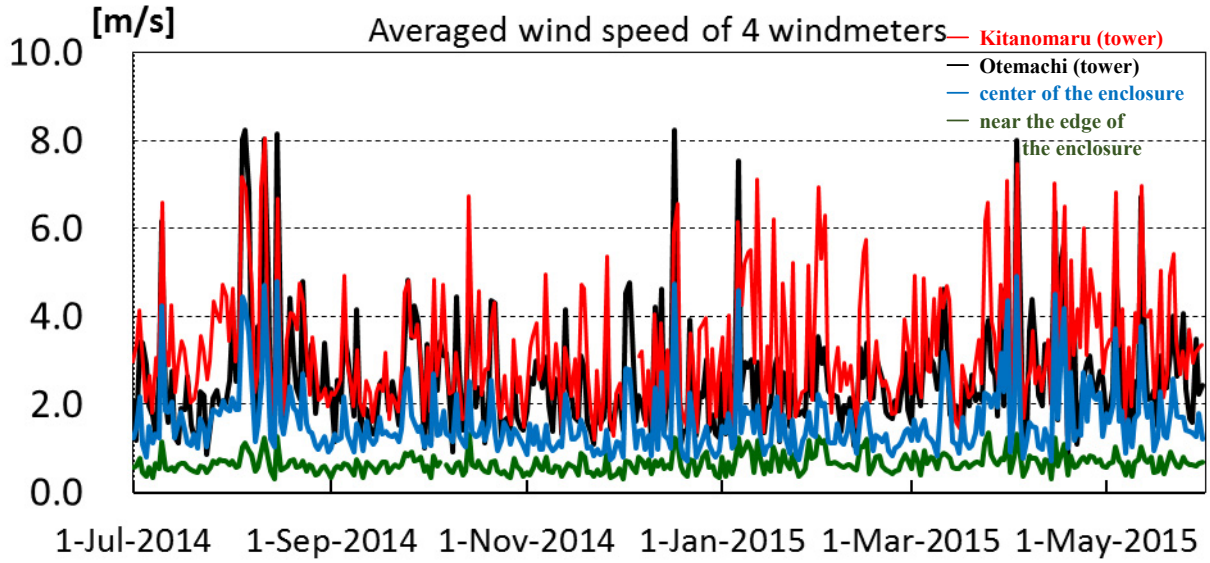

Fig. 8. Daily values of 6 hours averaged wind speeds during 9:00 and 15:00JST (daytime).

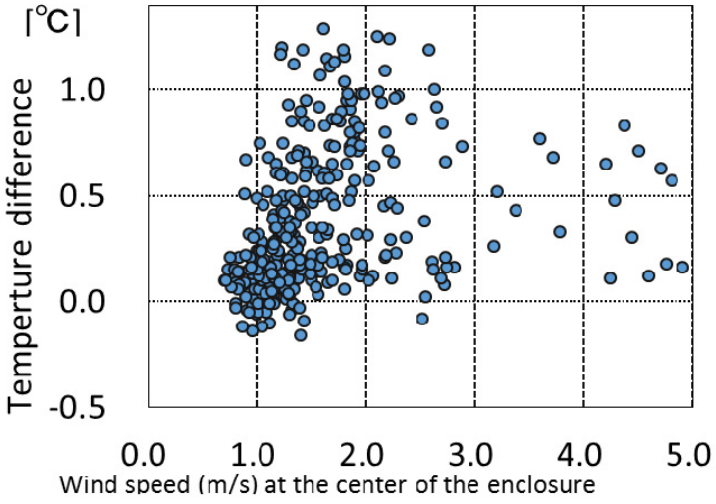

Fig. 9. A scatter diagram with wind speed at the center of the enclosure (on x-axis) and surface air-temperatures difference between Field and JMA at 15:00 JST (on y-axis).

Acknowledgment

This work was supported by JSPS KAKENHI Grant Number 26400473.

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