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Academic Article

Relationship between wind direction and air temperature in the Osaka center city determined using fixed point observation

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ABSTRACT

In 2009, we have carried out traverse observation in the central area of Osaka. These results suggested that the wind direction was the dominant factor in controlling air temperature in this built-up area. Thus, we now investigate the thermal and meteorological environment using several fixed-point observation systems in the same area. The aim of this research is to clearly show the relationship between air temperature and wind direction. The subject area was the same area in the central part of Osaka, where we conducted our previous observations in 2009. We installed observation devices at 34 locations in this area over 23 days in 2011 summer. We found that the air temperature differences on the river side area were lower when the wind blew from the west and the air temperature differences were higher when the wind blew from the north to the east. The air temperature differences in the business districts were higher than the air temperature difference in other areas and the influence of wind direction was not clear in these areas. The traverse observation in the park showed that the temperatures were lower than the temperatures in other areas with any wind direction. However, the fixed-point observations showed that even in the park, wind directions influenced the temperature, similar to the river area.

Key Words : Urban heat island, Wind direction, Fixed-point observation, Traverse observation

1. Introduction

The urban air temperature is rising, which results from the urban heat island effect (UHI). Today, several events such as an increasing number of hot nights, danger of heat stroke and air pollution are serious social problems. UHI is a local climatic effect, which depends on local conditions. Even though UHI is a local effect, it is important to measure and understand this phenomenon to determine an effective countermeasure.

Before this investigation, we performed a traverse observation, where we used a bicycle as an observation platform in the central area of Osaka in 2009. The results of this investigation illustrated that wind direction was the dominant factor that controlled the air temperature in this area. Although the traverse observation by bike has the advantage of allowing detailed observation, this method can only take a snapshot. This means that the traverse method needs further research and other methods to confirm its repeatability.

A commonly-used method is fixed-point observation. When fixed-point observation is performed, air temperature data from meteorological agencies and the local government are often used.

However, detailed observation in a small area is not often performed, because observation methods are not standardized at every management organization and there are few observation points.

In this study, we performed fixed-point observation in the central area of Osaka, the same area that we used for our previous observations in 2009. We installed observation devices at 34 locations in this area over 23 days in the summer of 2011.

2. Traverse observation

In our former investigation in 2009, we performed traverse observations 6 times using 10 bicycles over 2 days (3 and 7 August). Table 1 shows the time schedule of this research. It was a clear day on 3 August 2009, and on 7 August 2009, it was cloudy until noon and then became clear in the afternoon. Table 2 shows the average, maximum, and minimum air temperatures that we found in the traverse research. The days were hot and had no precipitation.

Of the six observations, RUN2 and RUN5 are shown.

RUN2: Observations on 3 August included no sea breeze, and a land breeze blew during the observation. Critical air temperature distribution information was obtained on the day that a land breeze dominated. A WNW wind began to blow in Osaka at 15:30 (this is an estimated sea breeze). Along the Midousuji and ChuoOdori rivers, it has become a severely hot environment (Fig.2).

RUN5: On 7 August, the situation was dominated by a sea breeze. The sea breeze developed more over time and the air temperature near the river was low. The air temperature on the west side of the Honmachi area was low and on the east side, there was a higher temperature trend (Fig.3).

Table 1 Observation dates and times

	Observation day	Observation time
RUN1	3 August 2009	13:15-13:45
RUN2	3 August 2009	15:15-15:45
RUN3	7 August 2009	14:30-15:00
RUN4	7 August 2009	16:00-16:30
RUN5	7 August 2009	18:00-18:30
RUN6	7 August 2009	20:00-20:30

Table 2 Air temperature on the observation day in JMA Osaka

Day	Avg. air temp. (°C)	Max air temp. (°C)	Min air temp. (°C)
3 Aug. 2009	28.7	33.9	24.2
7 Aug. 2009	29.6	33.9	27.2

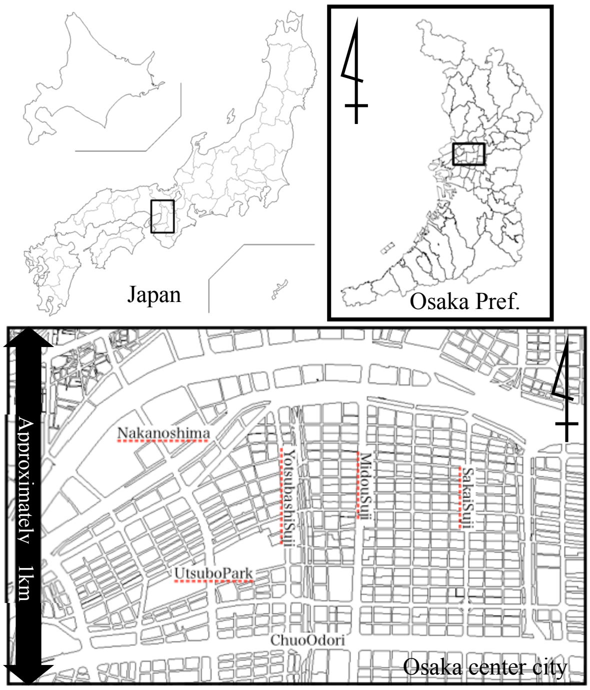


Fig.1 Observation area

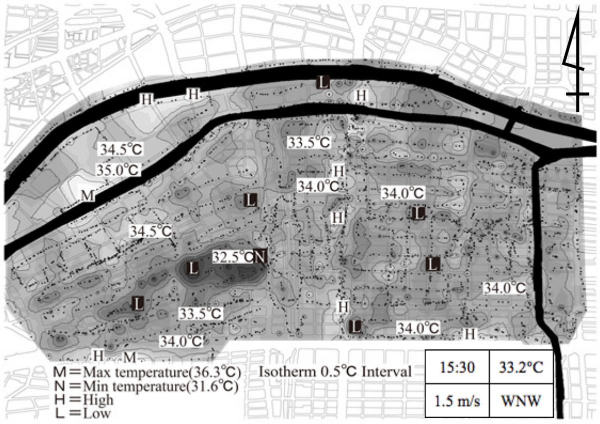


Fig.2 RUN2 From 15:15 to 15:45 3 August 2009

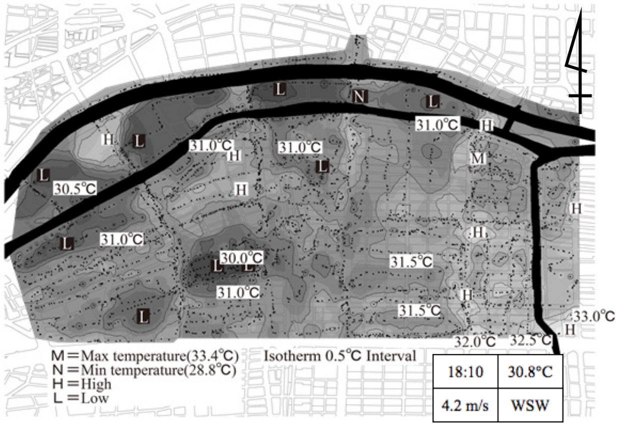


Fig.3 RUN5 From 18:00 to 18:30 7 August 2009

2.1 Traverse observation considerations

In Utsubo Park, the temperature was lower the entire time regardless of the presence or absence of a sea breeze, which seemed to play a role in cool spots in the city.

On 7 August, there was a blowing sea breeze all day, and the air temperature was low along the river, but on 3 August, was no owing sea breeze,and the air temperature was high along the river.

From 15:15 to 15:45 on 3 August, the highest temperature was observed along the rivers. The river's cool spot effect was strongly influenced by the sea breeze.

The RUN5 wind speed doubled compared with RUN4, significantly decreaing the Nakanoshima area temperature. Because the wind speed dropped below the 2 m/s, the wind direction during RUN2 changed from the northeast to the west-northwest, but it is possible that this did not lead to the temperature reduction in Nakanoshima.

3. Fixed-point observation

The subject area was the central part of Osaka, which was the same area as for the traverse observation in 2009. We installed observation devices at 34 locations in this area. Each observation

device was installed at a height of 2,500 mm on street telephone poles that were 250-300 meters apart. Fig.4 shows the observation area and location of the observation points.
The observation interval time was 10 minutes. The observation period was from 19 August to 10 September 2011. Conditions during the observation included cloudy weather for 7 days, clear weather for 10 days, and cloudy and partly rainy weather for 6 days. A radiation shelter made of stainless steel, and with a natural ventilation system, was placed on each thermometer (Fig.5)

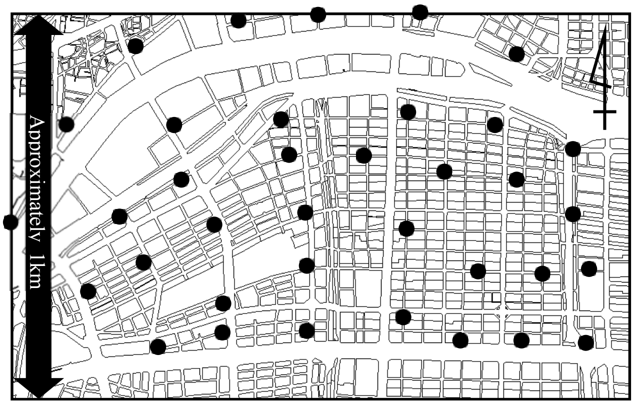


Fig.4 Observation area and points

Radiation shelter with natural ventilation

Thermistor sensor and Data logger T&D Co. RTR-52

Fig.5 Observation device

3.1 Result of fixed-point observation

We excluded 2 of 36 points from the analysis because of theft. In addition, an air conditioner that was close to the observation device caused outlier values, which were also excluded.
We classified the observation area into 7 areas for the analysis. Fig.6 shows the differences between the observed average air temperature at each point and the JMA's (Japan Meteorological Agency) AMeDAS (Automated Meteorological Data Acquisition System) Osaka air temperature. A positive value means that the observed temperature was higher than AMeDAS. The graph shows how air temperature changed in each wind direction. Fig.7 shows the zone map, and Table 3 shows the urban categories.
The air temperature differences were higher in areas A, B, C and E when the wind blew from the north to the southeast (1.2°C) compared with when the wind blew from the south to the northwest (0.5°C).
The air temperature differences were higher in areas D and F when the wind blew from the north to the southeast (1.5°C) compared with when the wind blew from the south to the northwest (0.8°C).
The air temperature difference was higher in area G when wind blew from even most directions (1.5°C). In addition, areas A, B, C and E were approximately 0.3°C lower when wind blew from even most directions, compared with areas D, F and G.

Table 3 Area classifications

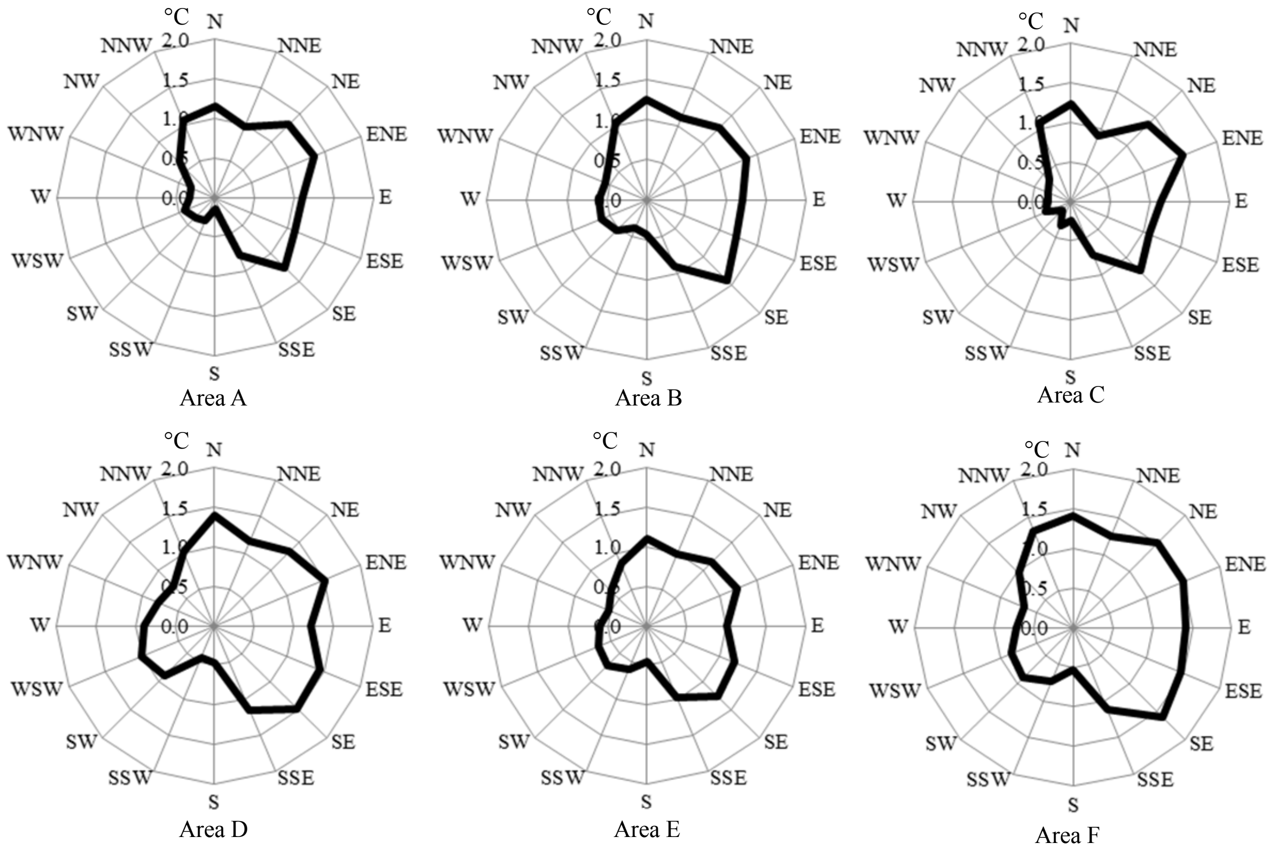
Area	Area classifications	Obs. points
A	West of the river coast	8
B	Western business district	4
C	Around park	3
D	West of avenue	3
E	East of the river coast	5
F	Eastern business district	8
G	East of avenue	3

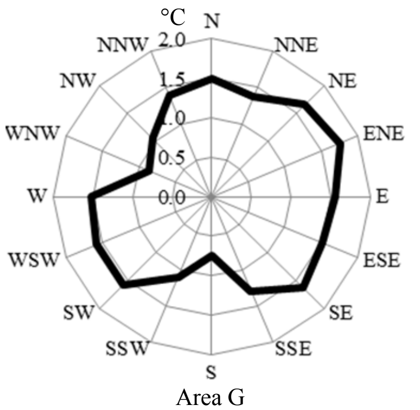
3.2 Fixed-point observation considerations

In area A, a difference of approximately 1.0°C was observed when the wind blew from the north and west.
Fixed-point observations in area C showed different results compared with the former bicycle traverse observation. This may be a result of our ability to observe inside of the park with traverse observation but not with fixed-point observation, which was near, but not in, the park.
In area G, the temperature difference is large. This may be caused by the heavy traffic in the area between the Streets.
In all areas, the temperature difference tended to be smaller when wind blew from the south. However, a local characteristic may have been missed because the south wind was infrequent during the observation period.

4. Comparison between traverse observation and fixed-point observation

For areas A and E, both the traverse and the fixed-point observation methods confirmed the same tendencies that the air temperature was lower when the wind blew from the west, but the air temperature tendancies were higher when the wind blew from the north to the east.
For area C, traverse observation in 2009 showed that the air temperature difference was smaller when the wind blew from the north and the west.
However, fixed-point observation showed that the air





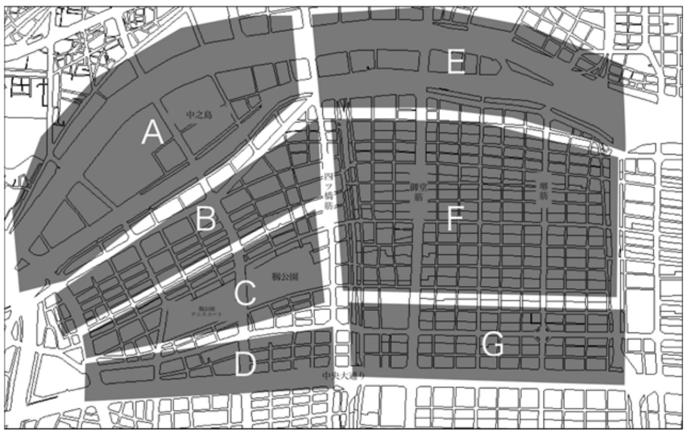


Fig.6 Relationship wind direction and air temperature difference area A-G

Fig.7 Zone map

temperature difference was smaller when the wind blew from the west, but it was larger when wind blew from the north and the east. In addition, we could not confirm differences in areas A and D because the air temperature difference was larger by approximately 1.2°C when wind blew from the north.

There was no clear influence of the wind direction in area D, as assessed using either traverse or fixed-point observation.

5. Conclusion

In this study, we performed fixed-point observation to follow up our former traverse observations that were performed using a bicycle in the central area of Osaka. Both the traverse and the fixed-point observations have advantages and disadvantages that should be determined.

In the test area, the air temperature decreased when the wind blew from the west. This wind direction corresponds to the direction of a large local river. The air temperature increased when wind blew from the north to the east.

Compared with other areas, the air temperature differences in the business districts were higher and the influence of wind direction was not clear in these areas.

Our traverse observation in the park showed that temperatures were lower with any wind direction. However, the fixed-point observation showed that, even in the park, wind directions had an influence on temperature, similar to that along the river area.

References

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