
Masaru Sasaki

# A study on the temperature distributions in coastal and high-rise urban area

Masaru Sasaki[1], Makoto Yokoyama[2], Kaoru Matsuo[3], Takahiro Tanaka[4], Satoru Sadohara[5]
[1] *Hiroshima University, 1-4-1 Kagamiyama, Higashi-Hiroshima, Japan, m154217@hiroshima-u.ac.jp*
[2] *Hiroshima University, 1-4-1 Kagamiyama, Higashi-Hiroshima, Japan, m145120@hiroshima-u.ac.jp*
[3] *Hiroshima University, 1-4-1 Kagamiyama, Higashi-Hiroshima, Japan, d133596@hiroshima-u.ac.jp*
[4] *Hiroshima University, 1-4-1 Kagamiyama, Higashi-Hiroshima, Japan, ttanaka@hiroshima-u.ac.jp*
[5] *Yokohama National University, 79-7 Tokiwadai, Hodogaya, Yokohama, Japan, sadohara@ynu.ac.jp*

dated : 15 May 2015

## 1. Introduction

In recent years, temperatures in urban area rise because of global warming and urban heat islands (UHI). This urban warming cause uncomfortable outdoor environment, health hazards such as the heat stroke and increase of energy consumption for cooling. Consequently, it is necessary to consider the mitigation of urban warming in the urban design process. Especially, in high-rise urban area comprised of business, commercial and residential area, many people gather and exposed to severe thermal environment in summer, therefore proposing the mitigation measures is needed. Consequently, this study aimed at analyzing the relationship among temperature distributions and urban form, using the temperature data observed in two kinds of coastal urban districts in Yokohama (Minatomirai-21 area and Kannai area).

Generally, measures for mitigating urban warming include improving paved surface, reducing anthropogenic heat release and improving ventilation conditions[1)]. Because many cities are located coastal area in Japan, it is expected that sea breeze has the cooling effect in urban area. One of the previous studies concerned with the cooling effects of sea breeze show that several spatial patterns of sea breeze blowing exist on the river and the patterns influence air temperature around the river, based on field measurements along the Hori River in Nagoya[2)]. Other study also performs the field measurements along the Meguro River in Tokyo and show that high-rise buildings along the river induce upper wind to the river channel[3)]. Other studies using CFD analyze the relationship between urban form and wind distribution around the ground level and reveal that the urban form comprised of uneven height buildings has positive effects for inducing upper wind[4)5)]. As the measures for inducing sea breeze in urban area, the previous studies suggest using two kinds of advection, namely horizontal and vertical direction. This study analyzes the temperature distributions influenced by the variation of urban form with considering these advections.

## 2. Research Outline

### 2-1.Taget Area

Target areas of this study are located in coastal urban area of Yokohama, and two different areas which have different urban forms are selected (Minatomirai-21 area and Kannai area). Fig.1 shows the place of target areas, and Fig.2 shows the bird's-eye view of target areas. Besides, Fig.3 shows the building height ratio in two areas. Minatomirai-21 area has many super high-rise buildings and the building coverage ratio is low (Gross building

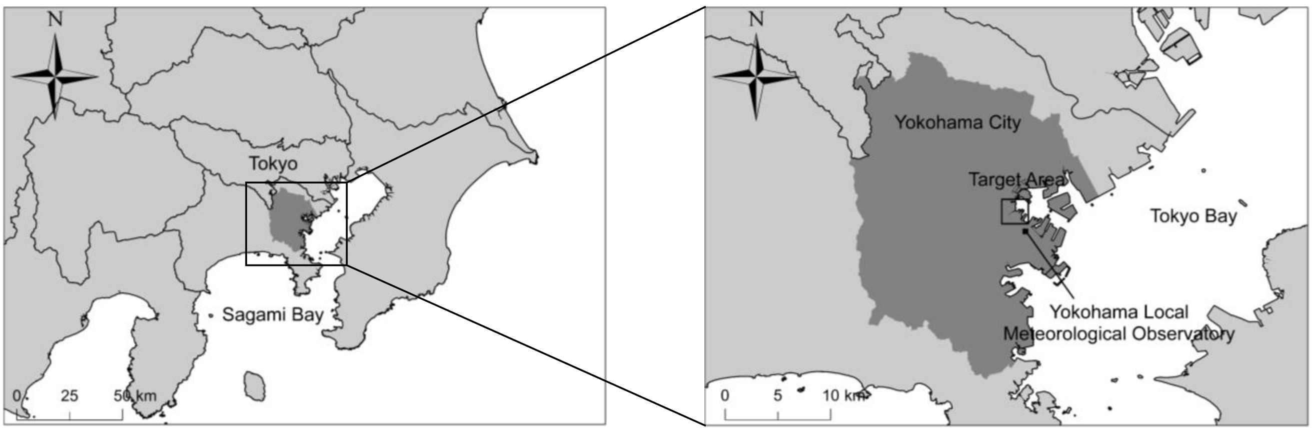



*Fig.1 Place of target areas*

coverage ratio: 37.1 %). To the contrary, Kannai area is occupied by high-rise buildings (Building height is around 30 meters) and the building coverage ratio is relatively high (Gross building coverage ratio: 47.9 %).

### 2-2. Steps of the Study

This study is performed along the following steps.
(1) Analysis on the sea breeze blowing patterns in the target area.
(2) Analysis on the influence of sea breeze on temperature distributions.
(3) Analysis on the effect factors of temperature distribution formations.

Details of the method and the results are described in chapter 3 for (1), chapter 5 for (2), and chapter 6 for (3). In chapter 4, the outline of field measurement data that are used in chapter 5 and 6 are described.

## 3. Sea Breeze Blowing Patterns

### 3-1. Characteristics of Sea Breeze Blowing

Firstly, the wind rose (Fig.4) in summer (July and August from 2010 to 2014) is made using observed data in Yokohama Local Meteorological Observatory that is near from the target area (The place refers to Fig.1). In addition, the height of the wind anemometer is 58.8 meter above sea level (In this paper, “upper wind” means the observed wind data of this meteorological observatory). It can be said that three kinds of winds exist and they are from south-west, the east, and the north. It is thought that the wind from the south-west is the sea breeze blowing from Sagami Bay, and the wind from the east is the sea breeze blowing from Tokyo Bay (In this paper, “SW wind” indicates the wind from the SW, SSW and S, “E wind” indicates the wind from the ENE, E, ESE.). Reference literature 6 and 7 which are focusing on Tokyo also mention about these winds. It is thought that the winds also blow in this area. On the other, the wind from north seems to be land breeze in nighttime.

### 3-2. Classification of Sea Breeze Blowing Patterns

Daily sea breeze blowing patterns are classified using cluster analysis. At first, the typical summer sunny days are selected based on the observed data in the summer (July and August) from 2010 to 2014. The criteria are as follows: (1) precipitation is less than 1 mm, (2) hours of sunlight is more than 5 hours. As a result, 181 days are selected and used for analysis in this chapter. Secondly, the number of SW wind and E wind in the morning (From 0:00 to 12:00) and afternoon (From 12:00 to 24:00) are counted for each day. Finally, the cluster analysis (Ward methods, three classifications) is performed using four variables above.

Fig.5 shows the wind roses of three clusters (patterns). In Pattern A, SW wind blow for all day, therefore, this is named “The day in which sea breeze blow from the south-west for all day”. In Pattern B, north wind blow from the night to the early morning, E wind blow from the early morning to the noon, and SW wind blow from the noon, therefore, this is named “The day in which sea and land breeze circulation occur”. In Pattern C, the tendency is like Pattern B in the morning and E wind blow in the afternoon, therefore, this is named “The day in which sea breeze from the south-west does not blow”. Fig.6 shows the transition of average temperature and average wind speed for each pattern. The average temperature and the average wind speed are larger in the case if SW wind blows than the case if E wind blows in the afternoon. Fig.7 shows the number of observation days for each pattern. The large differences are not seen among the years, and the number of Pattern C is smaller in every years.

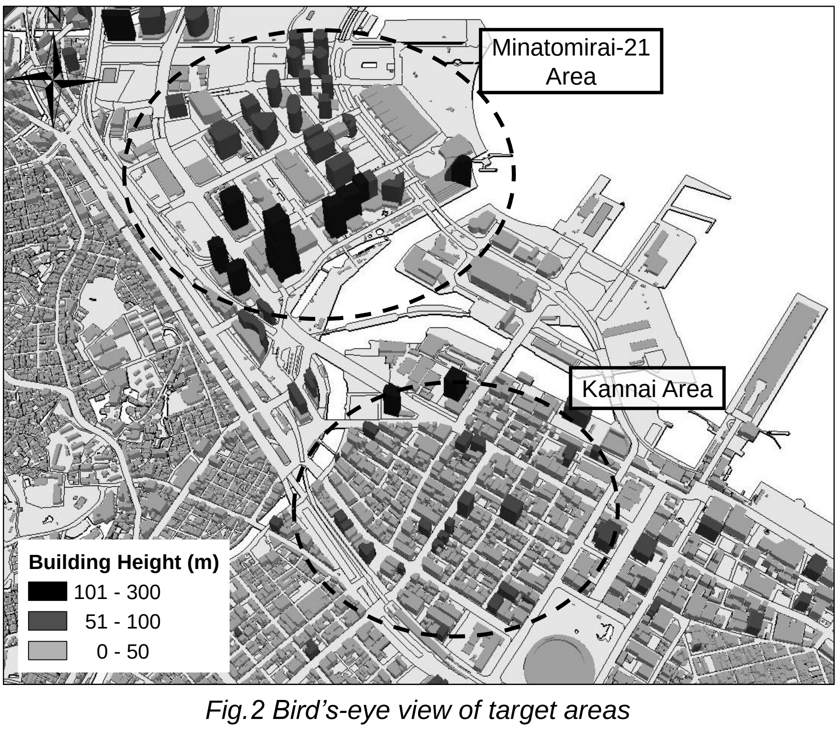



*Fig.2 Bird’s-eye view of target areas*

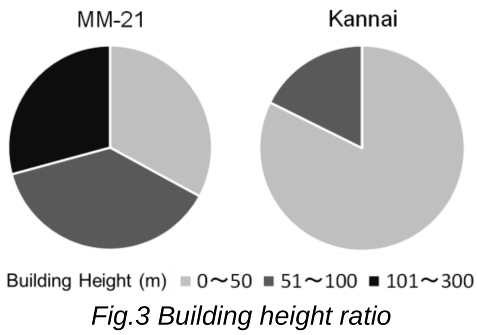



*Fig.3 Building height ratio*

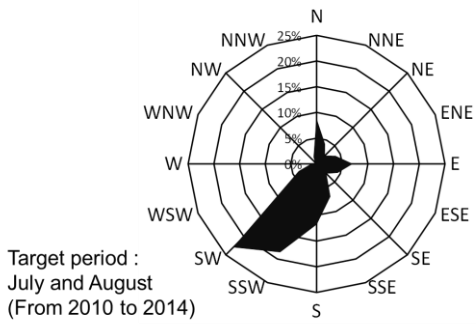



*Fig.4 Wind rose of the upper wind*

## 4. Outline of Field Measurement

### 4-1. Measurement Points and Period

Fig.8 shows measurement points in the target area. The number of the measurement points for air temperature is 21 points in Minatomirai-21 area and 19 points in Kannai area (In this paper, “MM21” means Minatomirai-21 area and “Kannai” means Kannai area). Measurement points are set on street trees that are near from the center between road crossings. Besides, in Rinko Park, wind direction, wind speed, and air temperature are also measured. Measurement period is 25 days from 8/7 to 8/31, 2014, and measurement interval is 10 minutes.

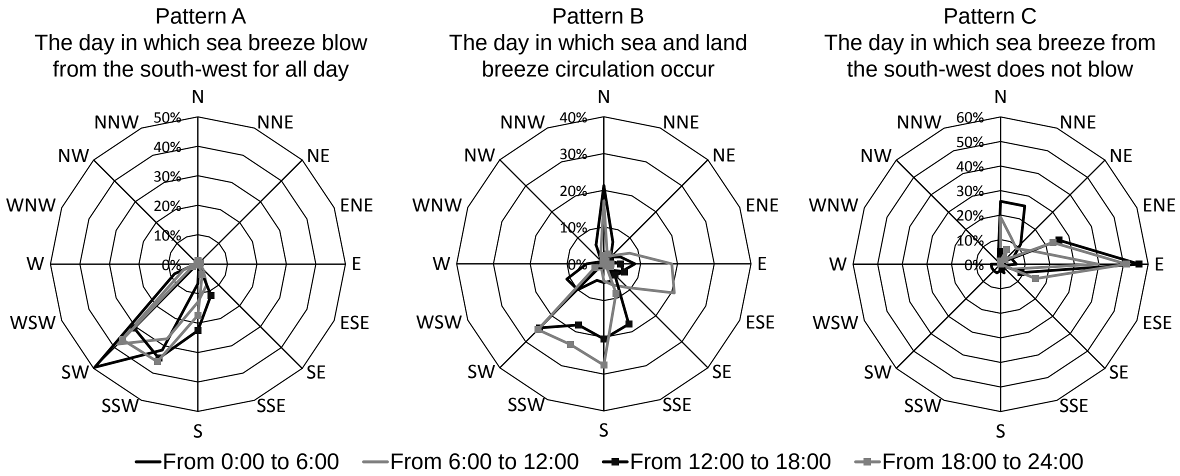



*Fig.5 Wind rose of three clusters (patterns)*

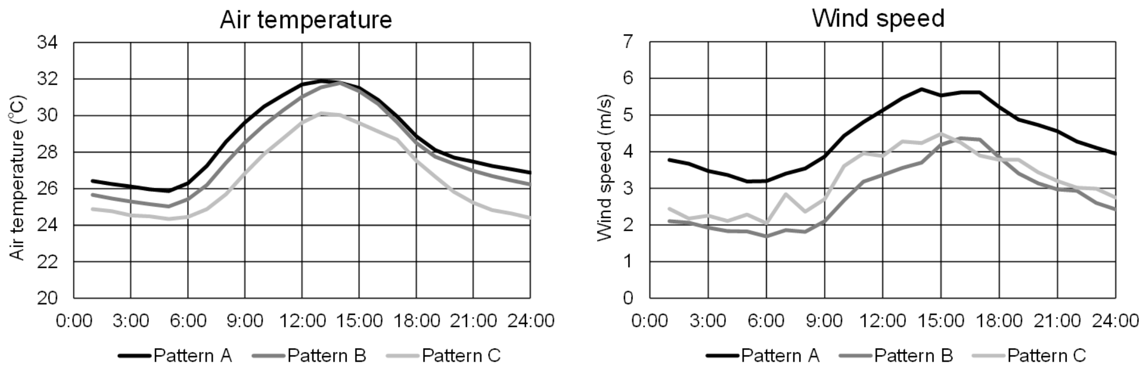
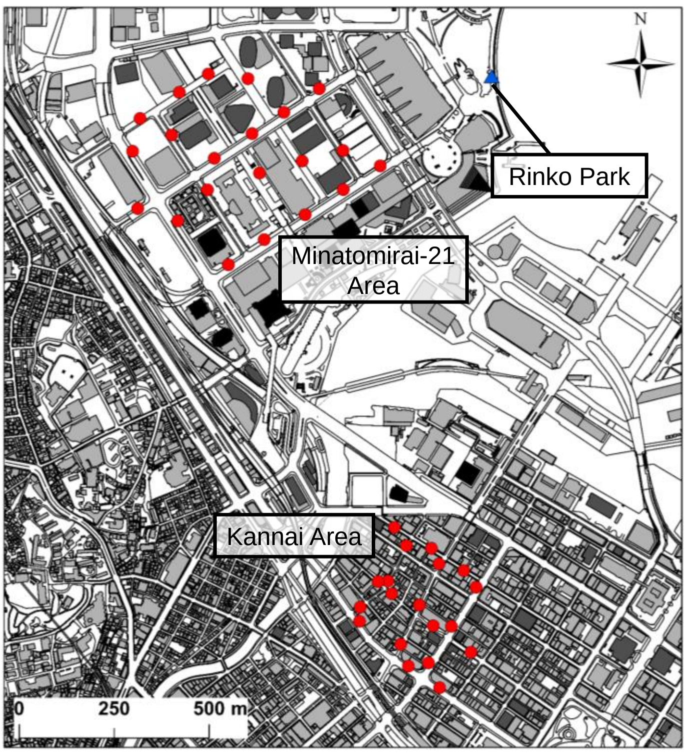



*Fig.6 Transition of average temperature and average wind speed*



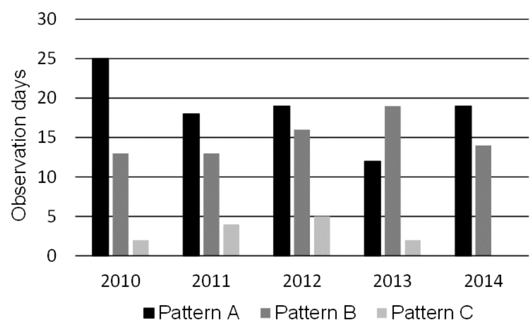




*Fig.7 Number of observation days*

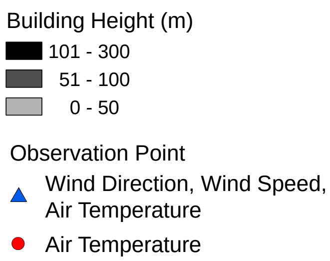



*Fig.8 Measurement points*

### 4-2. Measurement

For temperature mesurement, temperature sensors with the data loggers in solar radiation shields are used, and they are set on street trees in the height 1.8m above the ground. For wind direction and wind speed measurement, anemometer with three cups type and anemoscope with arrow type are set in the height 2.0m above the ground. Mesurement point in Rinko Park seems to be able to measure the wind blowing from sea directly, because the buildings blocking is not around the point (In this paper, “costal wind” means the measured wind data in Rinko Park).

## 5. Analysis on the Influence of Sea Breeze on Temperature Distributions

Fig.9 shows the transitions of upper wind and sea breeze blowing patterns in the period continuing sunny days in the measurement period (from 8/13 to 8/21). 8/13 (Pattern B) and 8/19 (Pattern A) are selected as representative day from the period for the analyses.

Fig.10 shows the transitions of wind direction and wind speed measured at the meteorological observatory and Rinko Park in the representative days, and Fig.11 shows transitions of average temperature in MM21 and Kannai. On 8/13, costal wind speed is larger than upper wind in the time blowing E wind (from 9:30 to 12:30), and average temperature of costal wind is lower than that of upper wind. It seems to be because E wind is not so thick in vertical direction and the air which becomes cool above the sea surface is transported to Rinko Park directly.

The difference of average temperatures among MM21 and Kannai is larger in the daytime on 8/19 in which SW wind speed is large. The difference is significant from 9:30 to 12:30 (the period blowing E wind in 8/13) on 8/19, on the other, that on 8/13 is not significant (significance level is 5%). In MM21 in which building density is lower and building height is uneven, upper wind blow down to the ground level and the temperature become lower when SW wind blow with large thickness in vertical direction.

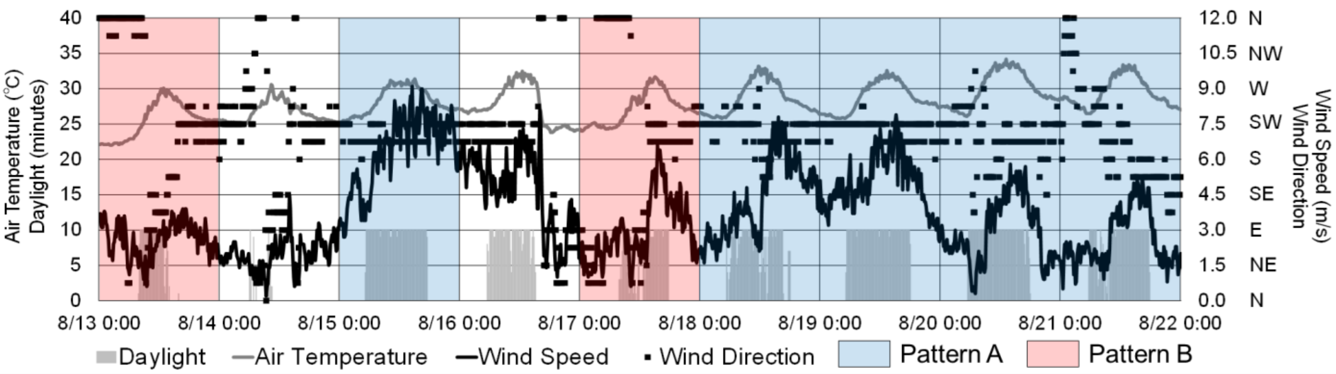



*Fig.9 Transitions of upper wind and sea breeze blowing patterns*

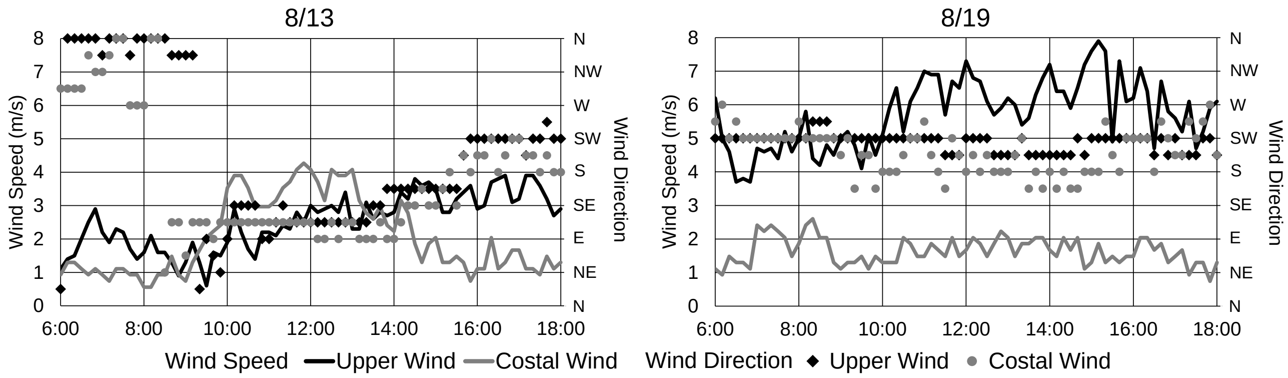



*Fig.10 Transitions of wind direction and wind speed*

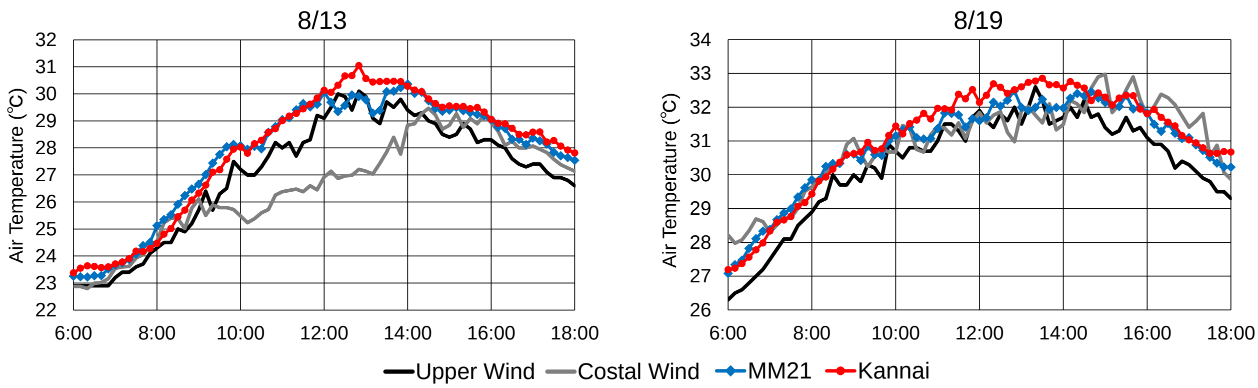



*Fig.11 Transitions of average temperature*

Fig.12 shows spatial distribution of the average temperature from 9:30 to 12:30 for each representative day. In addition, the classification method of symbol colors is equal quantity. On 8/13, temperatures on the street in the right direction with the coastline are lower in MM21 and the temperatures on the street near the coastline are lower in Kannai. On 8/19, the temperatures are lower in MM21 throughout.

Based on the analyses above, the followings are guessed:

・As for the E wind, advection of horizontal direction has large influence on temperature distributions. Therefore, temperatures are different according to the street direction, and temperatures on the street in the right direction with the coastline are lower.

・As for SW wind, advection of vertical direction has large influence on temperature distributions. Therefore, temperatures are different according to urban density and unevenness of building heights, and temperatures in MM21 are lower than Kannai.

## 6. Analysis on the Effect Factors of Temperature Distribution Formations

Multivariate analysis with quantification method class 1 is performed for understanding factors of temperature distribution for each district. Measured temperatures of all points for each time are used as an objective variable, and 7 variables in table 1 are used as explanatory variables. As for building shape and land use, GIS data which are made by the Kanagawa Prefectural Government are used. However, the data were made in 2005. Therefore, some parts are changed based on the field survey in August, 2014. Green coverage ratio is made with referring to land use data and aerial photo.

In the selecting the explanatory variables, correlation analysis among the variables are performed. In MM21, because gross building coverage ratio and sky view factor have high correlation with other variable, they are excluded from the variables. In Kannai, because road width has high correlation with gross building coverage ratio, it is excluded from the variables.

Fig. 13 shows transitions of multiple correlation coefficient and standardized partial regression coefficient. As a whole, multiple correlation coefficients are from 0.5 to 0.8, therefore it can be said that multiple regression equations explain the temperature distributions for each time mostly. In the daytime in MM21, gross floor area ratio is meaningful in the negative direction on the time blowing SW wind, and road width is meaningful in the negative direction on the time blowing E wind. In Kannai, gross building coverage ratio is meaningful in the positive direction throughout the day.

## 7. Summary

In this study, long-term and multi-points field measurements of air temperature are performed in two high-rise districts located in the coastal area of Yokohama, and the factors of spatial temperature distribution patterns are analyzed with focusing on urban form. Major findings are as follows:

・Sea breeze blowing patterns are classified into three patterns: Pattern A “The day in which sea breeze blow from the south-west for all day”, Pattern B “The day in which sea and land breeze circulation occur”, and Pattern C “The day in which sea breeze from the south-west does not blow”.

・As for the E wind, advection of horizontal direction has large influence on temperature distributions. Therefore, temperatures are different according to the street direction, and temperatures on the street in the right direction with the coastline are lower.

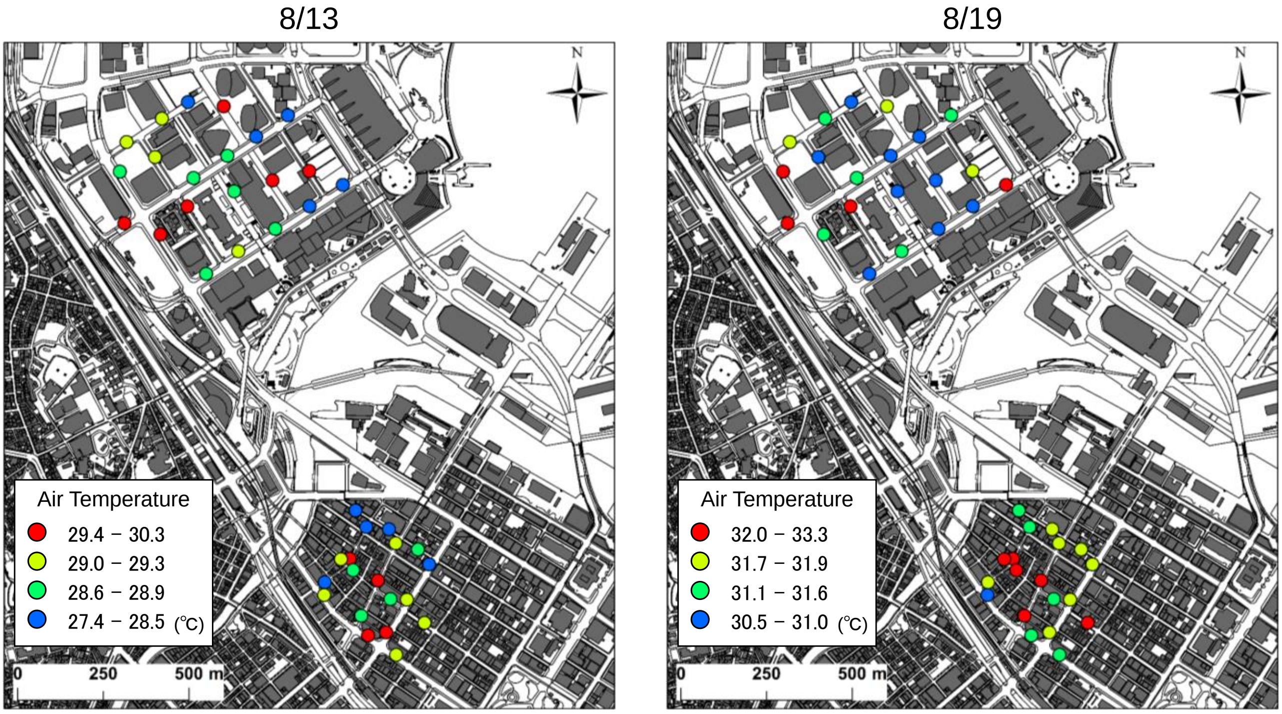



*Fig.12 Spatial distribution of the average temperature from 9:30 to 12:30*

- As for SW wind, advection of vertical direction has large influence on temperature distributions. Therefore, temperatures are different according to urban density and unevenness of building heights, and temperatures in MM21 are lower than Kannai.
- In the daytime in MM21, gross floor area ratio is meaningful in the negative direction on the time blowing SW wind, and road width is meaningful in the negative direction on the time blowing E wind. In Kannai, gross building coverage ratio is meaningful in the positive direction throughout the day.

Proposing the mitigating measures to urban warming based on the results above will be next work. Considering thermal comfort including radiative environment in outdoor space will be also needed.

## References

1) Moriyama, M., 2004: Measures and Technique of the Urban Heat Island, Gakugei Shuppan (in Japan)
2) Hashimoto, T., Horikoshi, T., 2008: Sea breezes blew up along the Horikawa canal in Nagoya based on the field observations at fixed points and its application to wind blow trail design, *Journal of environmental engineering*, 73(634), pp.1443-1449 (in Japan)
3) Narita, K., Kagiya, K., 2010: The effects of a small river as a ventilation path in coastal cities micro-climatological observations in and around the Meguro River in Tokyo, *Journal of environmental engineering*, 75(653), pp.637-644 (in Japan)
4) Yoshie, R., Tanaka, H., Shirasawa, T., Kobayashi, T., 2008: Experimental study on air ventilation in a build-up area with closely-packed high-rise building, *Journal of environmental engineering*, 73(627), pp.661-667 (in Japan)
5) Takebayashi, H., Yamada, T., Moriyama, M., 2011: Effects of characteristics urban block on wind environment in the street canyon - Analysis on the relationship between properties of urban block and wind path in the street canyon for the use of the wind as the climate resources Part 2 -, *Journal of environmental engineering*, 76(670), pp.1087-1092 (in Japan)
6) Fujibe, F., Asai, T., 1979: A study of local winds in Kanto District - Part 1: Structures of wind system with diurnal variation -, *Journal of TENKI*, 26(10), pp.595-604 (in Japan)
7) Ito, M., Sofuku, M., Utagawa, M., 1985: An investigation of air current and pollutant around Tokyo - space structure of the wind -, *Tokyo pollution laboratory annual report*, pp.42-46 (in Japan)

*Table.1 Calculation method of explanation variable*

| Effect Factor | Explanation Variable | Calculation Method |
|---|---|---|
| Urban Form | Gross Building Coverage Ratio | Buffer 30m, 50m, 70m from each point is calculated.<br>Correlative of buffer 70m with the temperature distributions is highest, therefore it is adopted. |
| | Gross Floor Area Ratio | |
| | Road Width | The distance between the building site is calculated of each point. |
| | Road Direction | The road divided right direction and parallel direction with the coastline is set as dummy variable. |
| | Sky View Factor | Sky view factor using the building shape data is calculated. |
| Land Cover | Green Coverage Ratio | Buffer 10m, 30m, 50m from each point is calculated.<br>Correlative of buffer 30m with the temperature distributions is highest, therefore it is adopted. |
| Sea Breeze | Distance from the Coast | The distance between each point and the coastline is calculated. |

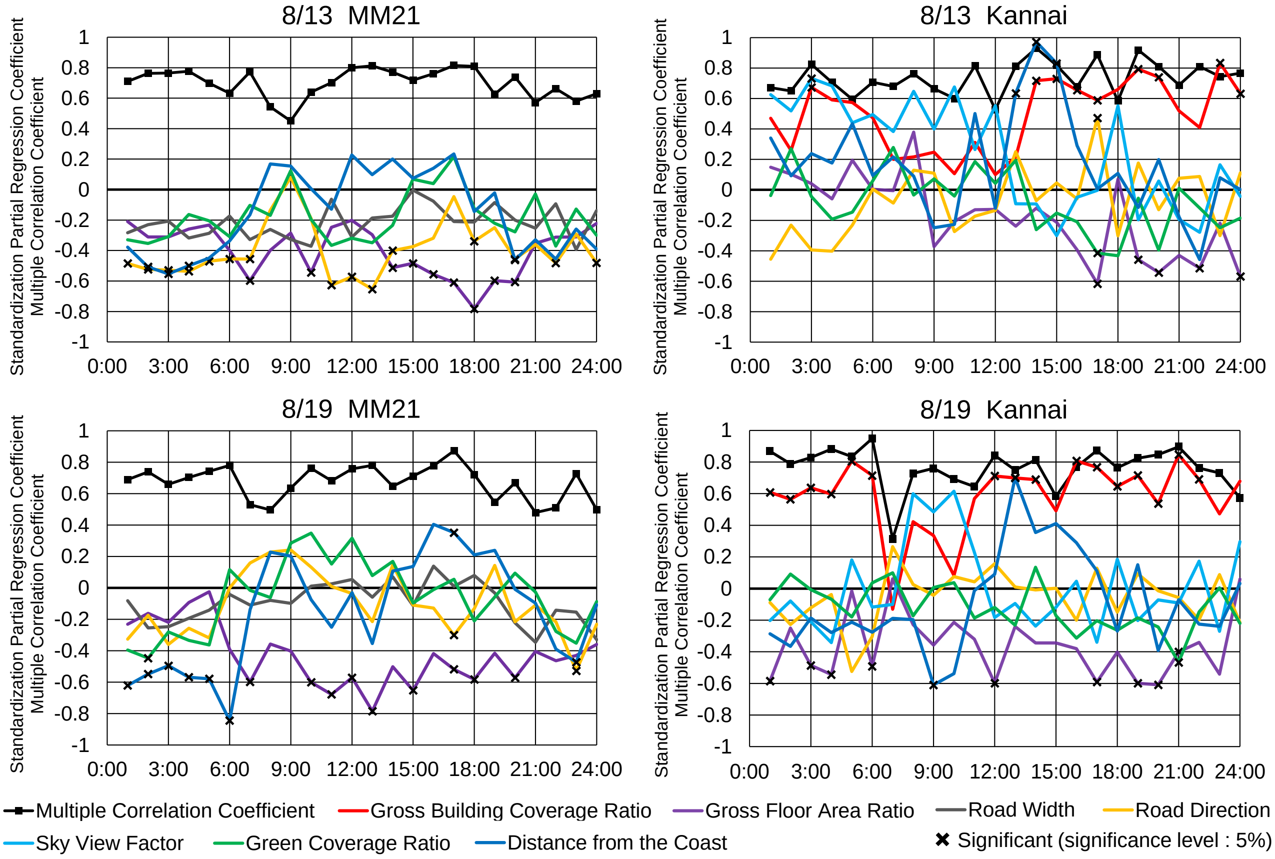



*Fig.13 Transitions of multiple correlation coefficient and standardized partial regression coefficient*