Eiko Takaoka

Comparison of the temperatures of a concrete roof and a green area in central Tokyo

Eiko Takaoka
[1] *Sophia University, Chiyoda, Tokyo, Japan, m-g-eiko@sophia.ac.jp*

dated : 13 July 2015

1. Introduction

An urban heat island (UHI) is a metropolitan area that is significantly warmer than surrounding rural areas due to human activity. The temperature difference is usually larger at night than during the day. Such UHI effects are most noticeable during the summer and winter.

The present author is a member of the LiveE! Project[1], which is concerned with independently monitoring weather conditions in various regions using meteorological equipment that gathers weather information and transmits it through an IP network at intervals of several seconds. Of the more than 80 measurement locations around the world, two are in our university campus in central Tokyo. One is on the concrete roof of a building and the other is in an area of greenery [Takaoka and Hioki, 2009].

The purpose of the present study was to determine whether, even within the limited area of a university campus, temperature differences exist that are similar to those produced by the UHI effect. Air-temperature data for the two locations for the period 2010 to 2014 were used, and the values that were compared were the temperature at 4:00, 14:00 and 22:00, the mean temperature, and the maximum and minimum temperatures. The monthly maximum temperature difference and the monthly mean difference in maximum temperature were then calculated.

2. Related Work

[Chandler 1965] was perhaps the first heat island investigator to develop a climate-based classification of the city. Numerous studies have shown that the urban air temperature can be higher than the rural or surrounding air temperature on average. For example, [Georgakis et al. 2010] concluded that the major factor controlling urban–suburban air temperature differences was the geometry of the urban area. Other factors were the orientation of the observation sites, the weather conditions, and inversion of the air mass just above ground level. The difference in air temperature between urban street canyons and a suburban station was found to decrease as the aspect ratio increased. [Christy et al. 2009] determined the monthly average of the daily maximum temperature, daily minimum temperature, and daily mean temperature in Kenya and Tanzania over a one hundred year period using several sources. Although increased urbanization appeared to have little impact on the maximum temperature, it was found to have caused a significant increase in the minimum temperature". [Schatz and Kucharik 2014] shows that clear, calm summer nights still had higher UHI intensities than clear, calm winter nights, indicating that some background factor, such as vegetation, shifted baseline UHI intensities throughout the year. [van Hove et al. 201] shows that the differences are larger for the minimum temperatures than for the maximum temperatures. [Stewart and Oke 2012] suggests meaningful definition and intercity comparison of UHI magnitude (ΔT Local Climate Zone X – Y); guided exploration of heat island causes and controls.

3. Equipment

Using compact digital meteorological equipment installed at specific locations, LiveE! allows for finer-scale meteorological monitoring than the Automated Meteorological Data Acquisition System (AMeDAS) which Japan Meteorological Agency uses. This equipment is easy to set up and allows rapid measurements at short intervals. Its setup and maintenance costs are also low. We installed such devices on the concrete roof of a building and in a green space in our university on July 2009, as shown in Fig. 1. The concrete roof is well ventilated, being on top of a five-story building that rose approximately 25 m above the ground.

[1] Live E! Available from http://www.live-e.org/en/instrument/index.html

Fig. 1 Digital meteorological equipment.

4. Methods

Based on the measured temperatures for the two locations for the period 2010 to 2014, the mean temperature, the monthly mean of the maximum daily temperature, the monthly mean of the minimum daily temperature, the mean temperature difference, the monthly maximum temperature difference, the monthly minimum temperature difference, and the difference between the daily maximum temperature at 4:00, 14:00, and 22:00 were calculated.

5. Results and Discussion

5.1 Mean temperature, monthly mean of maximum daily temperature, and monthly mean of minimum daily temperature

Figure 2 shows the monthly mean daily temperature for the concrete roof and the green area for different months from 2010 to 2014. It is clear that the roof temperature was always higher, regardless of the month or year. Figure 3 shows the monthly mean of the maximum and minimum daily temperatures for the green area during the same period. There is no evidence of a heat-island effect, except that the temperature in 2010 is higher than usual.

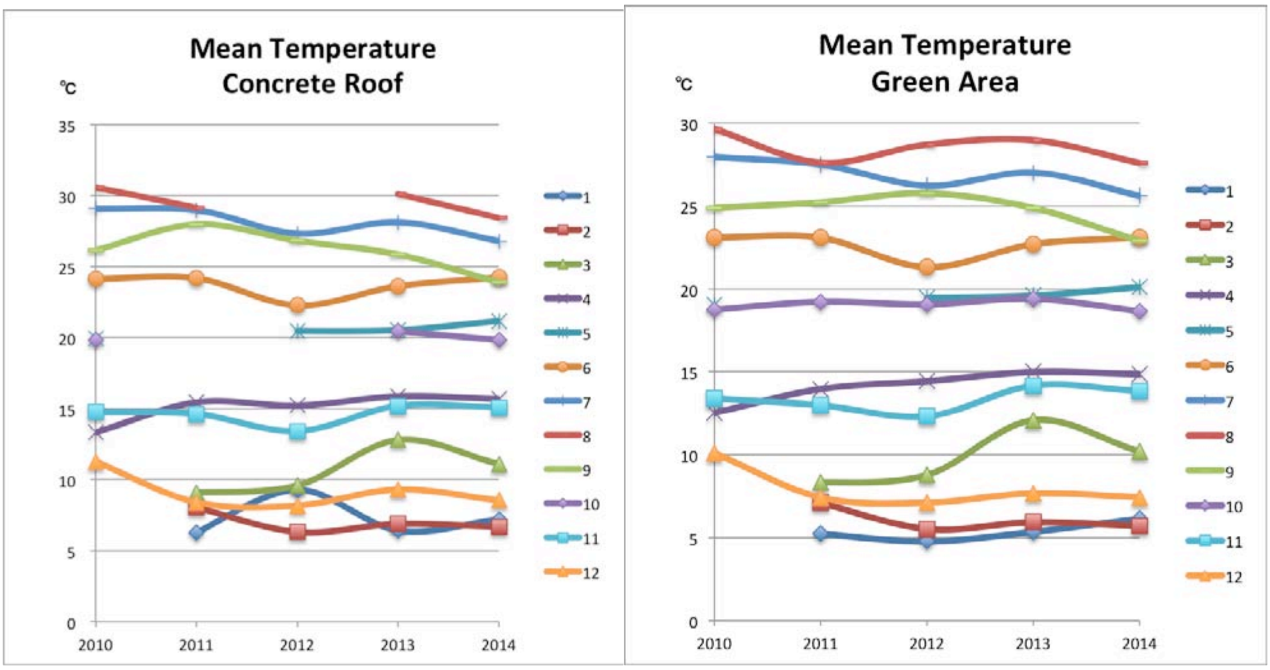


Fig. 2 Mean temperature for concrete roof and green area for different months from 2010 to 2014.

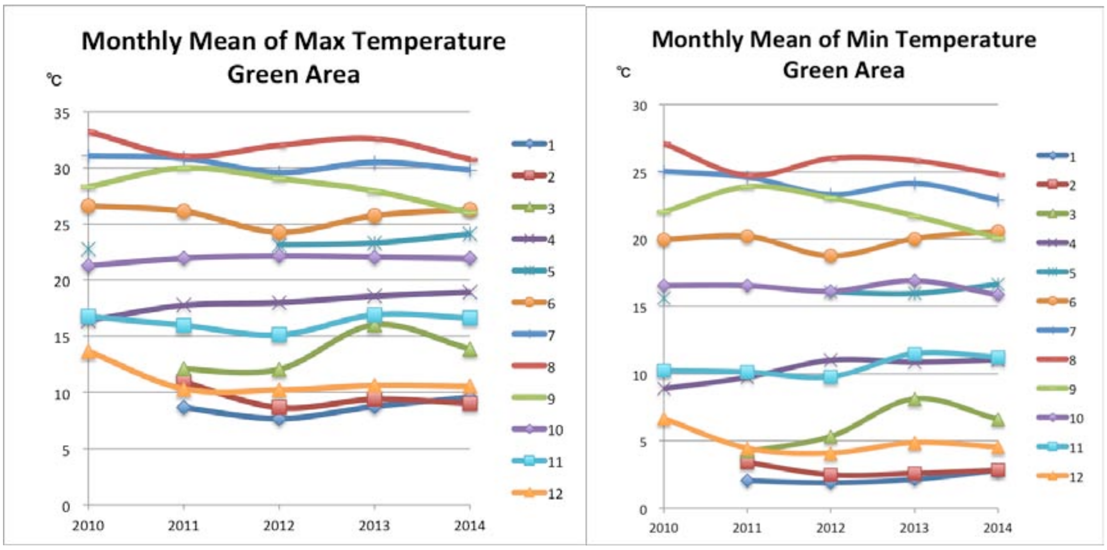


Fig. 3 Monthly mean of daily maximum and minimum temperatures for green area for different months from 2010 to 2014.

5.2 Mean temperature difference, monthly maximum temperature difference and monthly minimum temperature difference

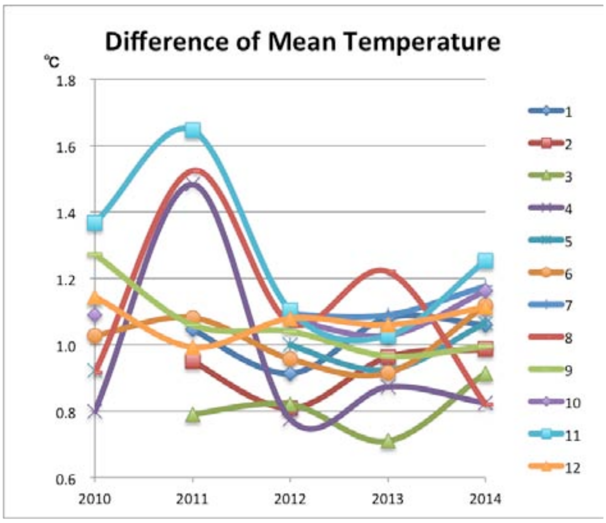


Fig. 4 Mean temperature difference.

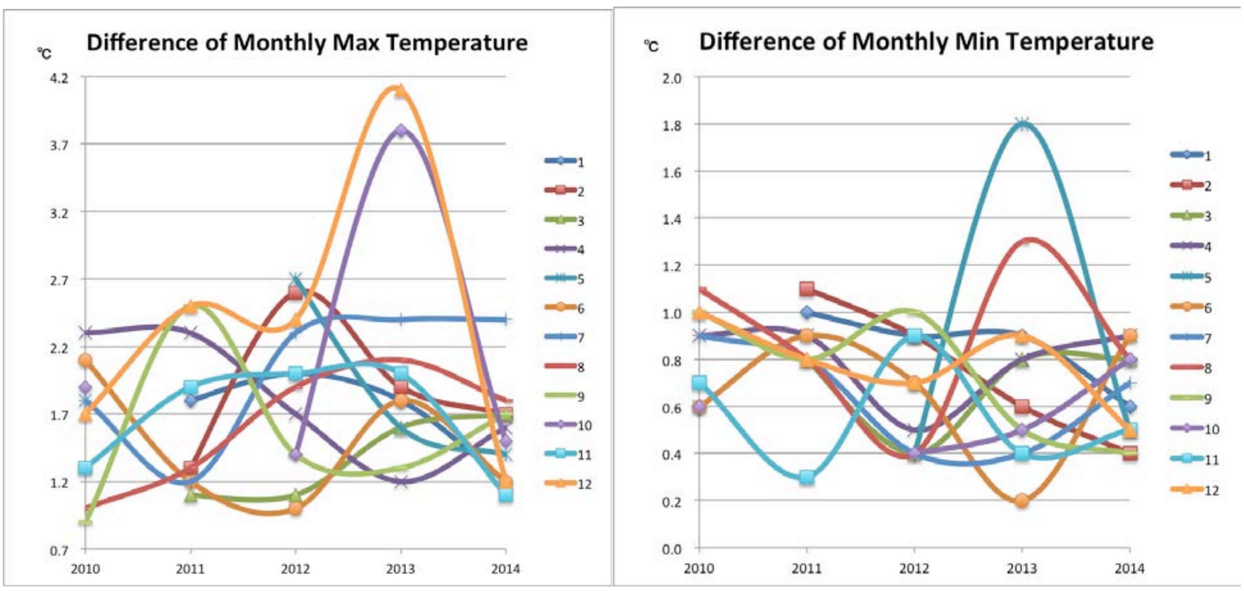


Fig. 5 Monthly maximum and minimum temperature difference.

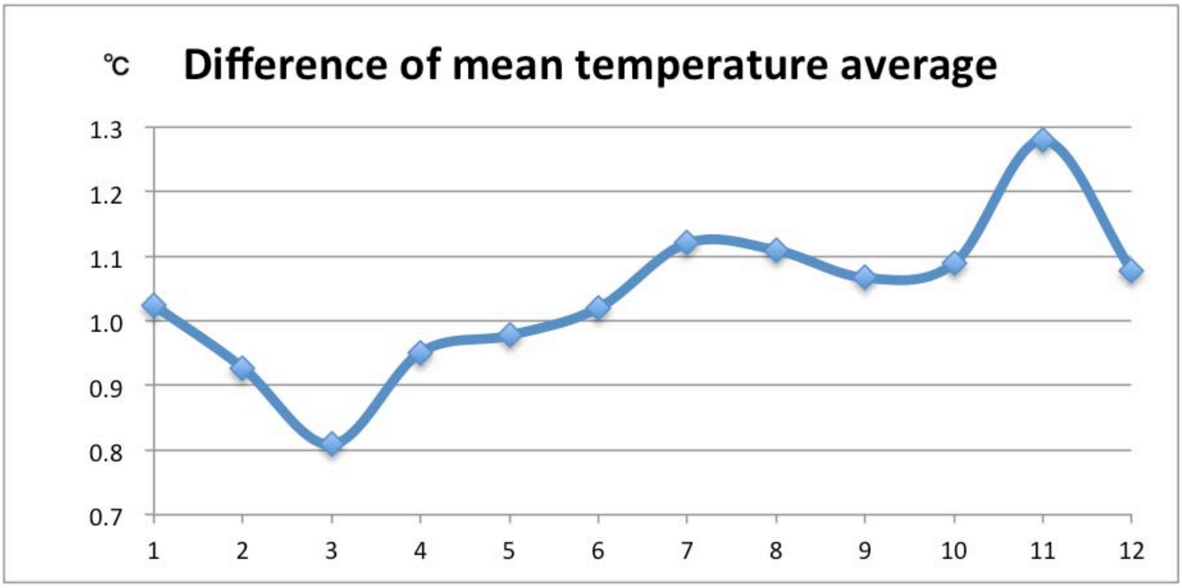


Fig. 6 Difference of mean temperature average from 2010 to 2014.

Figures 4, 5 and 6 show the mean temperature difference, the monthly maximum temperature difference and the monthly minimum temperature difference between the two locations, and difference of mean temperature average from 2010 to 2014respectively. From figure. 5 and 6 there is almost no difference between two location, however, figure 6 indicate that there is large difference in winter than summer. This phenomenon is similar to the UHI.

5.3 Difference between daily maximum temperatures at 4:00, 14:00, and 22:00

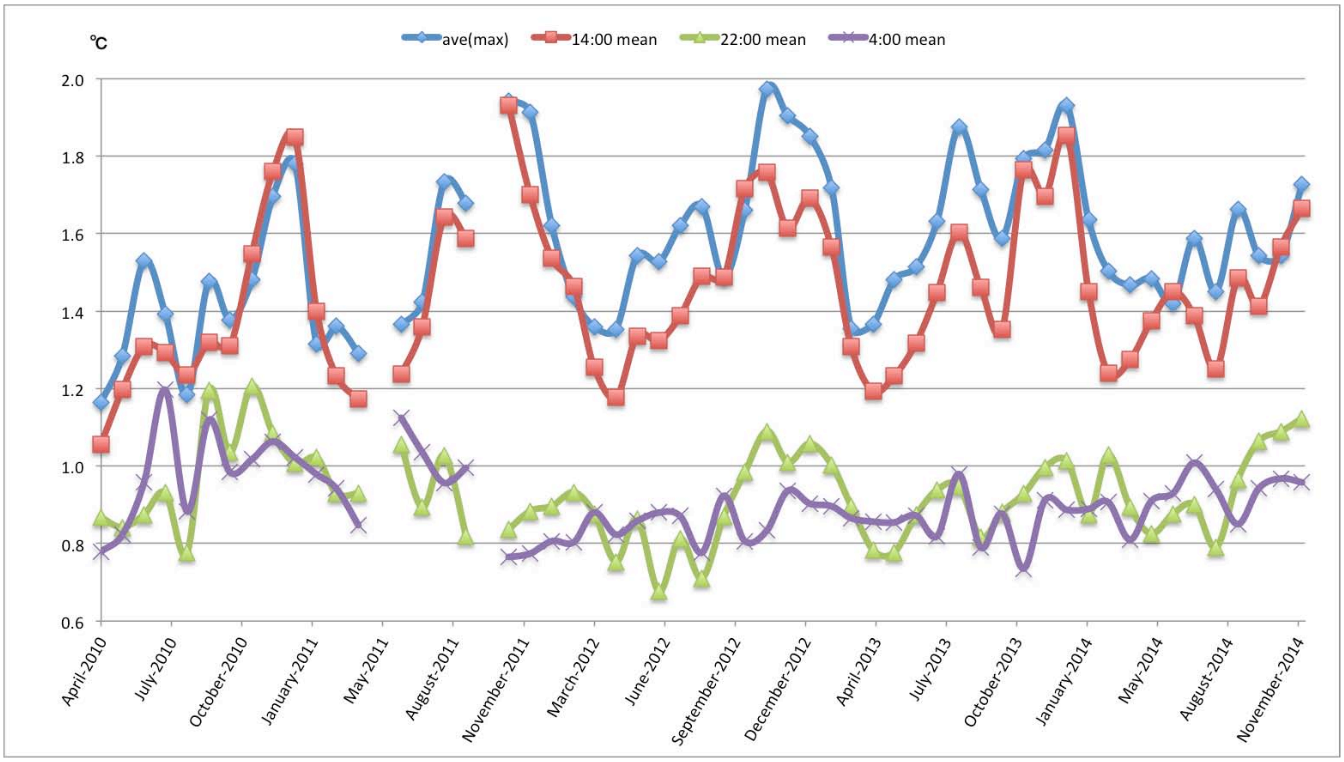


Fig. 7 Monthly average difference between daily maximum temperatures at 4:00, 14:00, and 22:00.

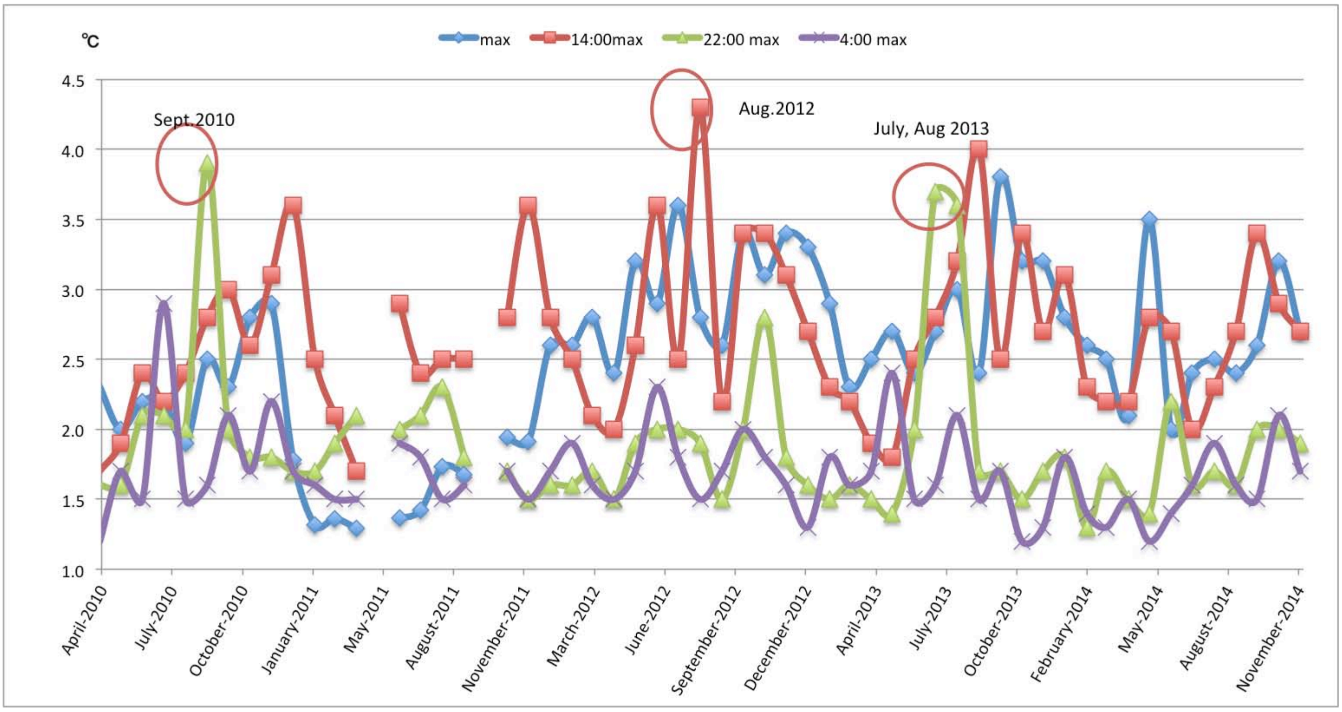


Fig. 8 Largest monthly difference between daily maximum temperatures at 4:00, 14:00, and 22:00.

Figure 7 shows the monthly average difference between the daily maximum temperatures at 4:00, 14:00, and 22:00. It can be seen that the differences are largest from autumn to winter, and during the daytime. Figure 8 shows the largest monthly difference between the daily maximum temperatures at 4:00, 14:00, and 22:00. Many large differences occur during the summertime, even at night (22:00). There are also days when the temperature difference is larger at night than during the day. These days were characterized by the following weather conditions:

- 28th September 2010: it was raining in the morning, there was thunder at noon, rain stopped in the afternoon, and the temperature difference was large throughout the night and into the next morning.
- 18th August 2012: There was gusty rain for a short time in the morning (around 10:00 – 11:00, at most 80 mm/h) this day.
- 30th September-1st October 2012: The typhoon No.17 passed Tokyo.
- 14th July 2013: atmosphere conditions were unstable, there was gusty rain and thunder for a about 1 hour in the evening (At most, 70 mm/h).
- 12th August 2013: there was heavy rain and thunder in the evening (around 18:00 – 19:00, at most 30 mm/h).

Therefore, it can generally be concluded that when large temperature differences occurred, atmosphere conditions were unstable. Following rain, the temperature for the green area did not increase as rapidly as that for the concrete roof.

6. Conclusion

The results indicated that the concrete roof was warmer than the green area; the temperature difference was larger during winter than summer, similar to the UHI case. However, the temperature difference was larger during the day than at night, which is opposite to the UHI case. This is thought to be because the concrete roof was well ventilated, being on top of a five-story building that rose approximately 25 m above the ground. In addition, the weather was investigated for days when there were large temperature differences between the two locations, and for days when the temperature difference was larger at night than during the day. It was found that on such days, inclement weather events such as gusty rain, thunderstorms and typhoons had occurred.

Thus, it can be concluded that an effect similar a UHI may occur even within the limited confines of a university campus, if the influence of ventilation is excluded. Further investigations should be carried out to determine the importance of factors such as the height at which the measurements are performed. In addition, it is important to retrieve and analyze weather data in accordance with the new approach like “local climate zones” that [Stewart and Oke 2012] proposed.

References

Takaoka, E., and Hioki, Y., 2009: Development of a Weather Visualization System and Analysis of Live E! Weather Data. *Technical Report of IEICE*, **IA2009-81**, 91–96 (in Japanese).

Georgakis, C., Santamouris M., and Kaisarlis,G., 2010: The Vertical Stratification of Air Temperature in the Center of Athens, *J.*

Appl. Meteor. Climatol., **49**, 1219–1232.

Chandler, T. J., 1965: The Climate of London. Hutchinson

Christy, J. R., Norris, W.B., and McNider, R. T., 2009: Surface Temperature Variations in East Africa and Possible Causes. *J. Climate*, **22**, 3342–3356.

Schatz, J, Kucharik, C. J.,: Seasonality of the Urban Heat Island Effect in Madison, Wisconsin, J. Appl. Meteor. Climatol., **53**, 2371–2386.

Stewart, I. D., and Oke, T. R. 2012: Local climate zones for urban temperature studies. Bull. Amer. Meteor. Soc., **93**, 1879–1900.

van Hove, L.W.A., Jacobs, C.M.J., Heusinkveld, B.G., Elbers, J.A., van Driel, B.L., Holtslag, A.A.M., Temporal and spatial variability of urban heat island and thermal comfort within the Rotterdam agglomeration, Building and Environment, **83**, 91-103.

Comparison of the temperatures of a concrete roof and a green area in central Tokyo

Eiko Takaoka, Sophia University, Japan

Live E! Project

The conference aims

To construct and develop an "Electronic" information infrastructure that can be used in the free sharing and distribution of "Live" "Environmental" information regarding the wide scope of the "Earth".

What we do

Monitoring weather conditions in various regions using meteorological equipment that gathers weather information and transmits it through an IP network at intervals of several seconds.

Of the more than 80 measurement locations around the world, two are in our university campus in central Tokyo. One is on the concrete roof of a building and the other is in an area of greenery [Takaoka and Hioki, 2009].

Measurement Data

the mean temperature,
the monthly mean of the maximum daily temperature,
the monthly mean of the minimum daily temperature,
the mean temperature difference, the monthly maximum temperature difference,
the monthly minimum temperature difference, and
the difference between the daily maximum temperature at 4:00, 14:00, and 22:00

Overview

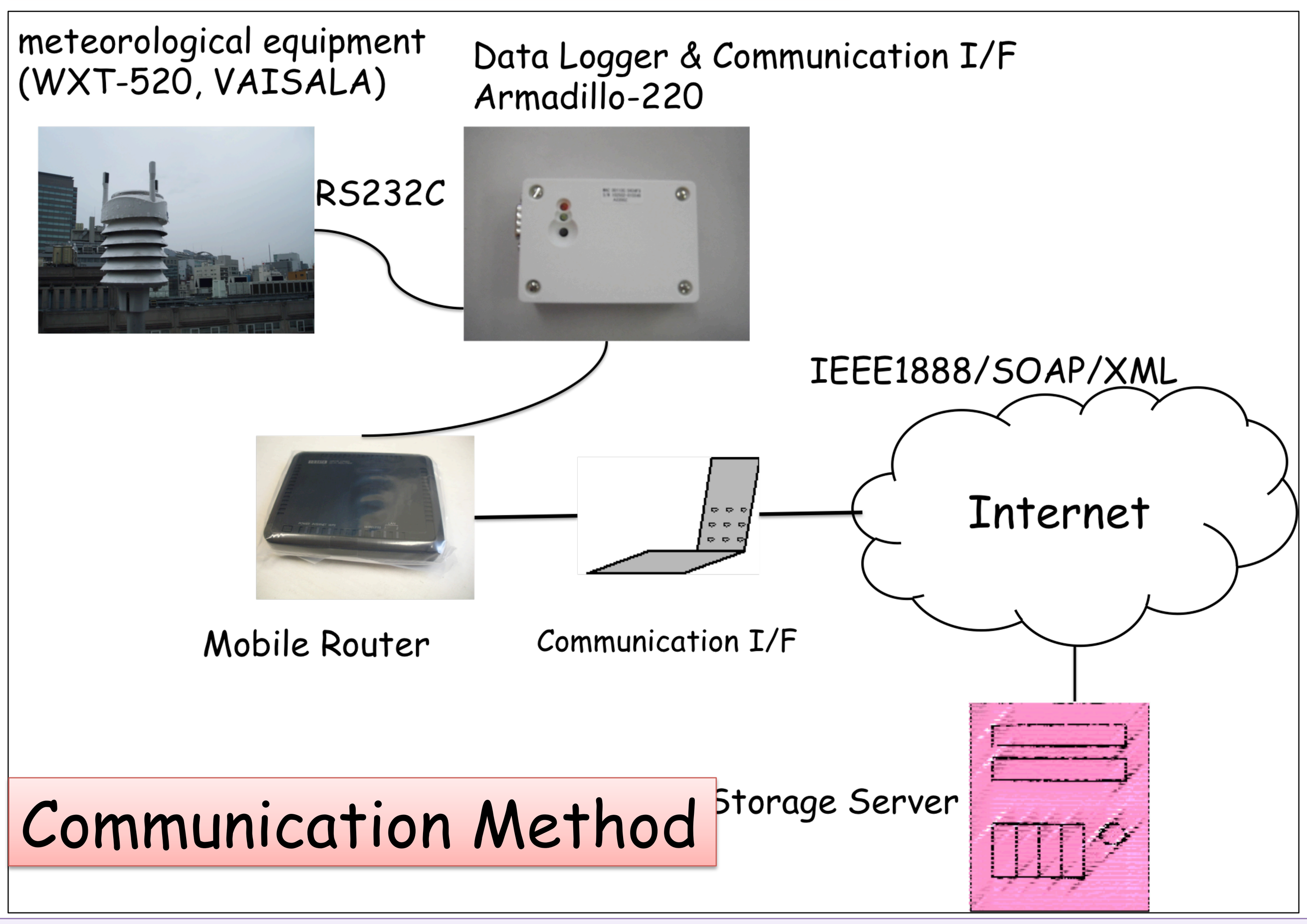
The purpose of this study

To determine whether, even within the limited area of a university campus, temperature differences exist that are similar to those produced by the UHI effect.

Equipment

Finer-scale meteorological monitoring System

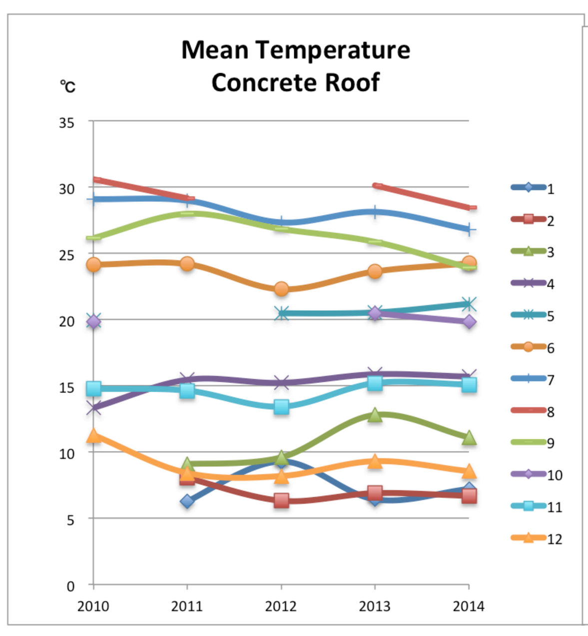
- easy to set up
- allows rapid measurements at short intervals.
- Its setup and maintenance costs are also low

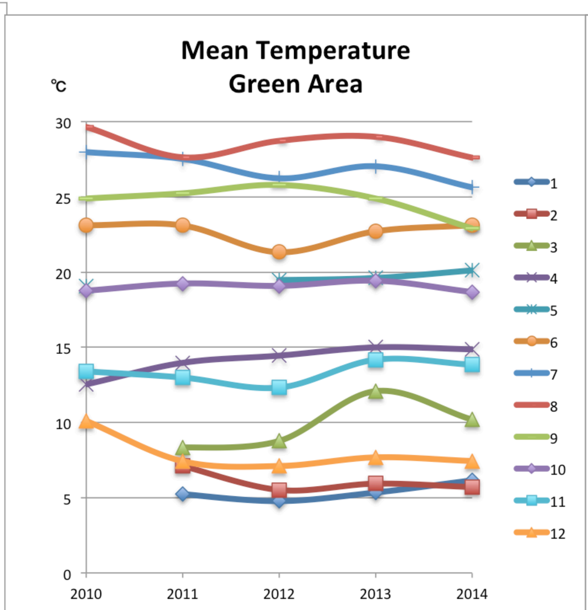


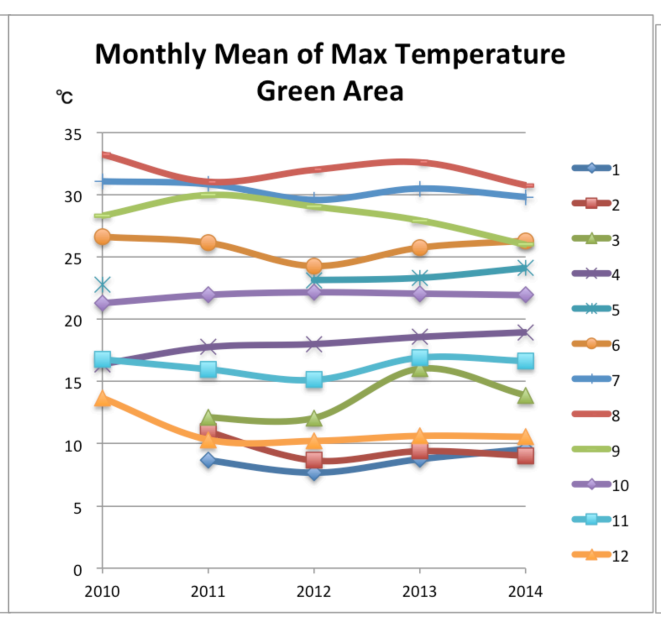
Communication Method

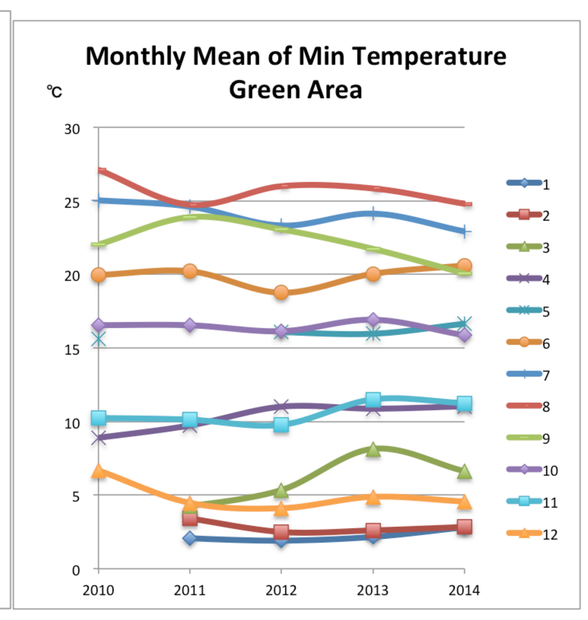
concrete roof is well ventilated, being on top of a five-story building that rose approximately 25 m above the ground.

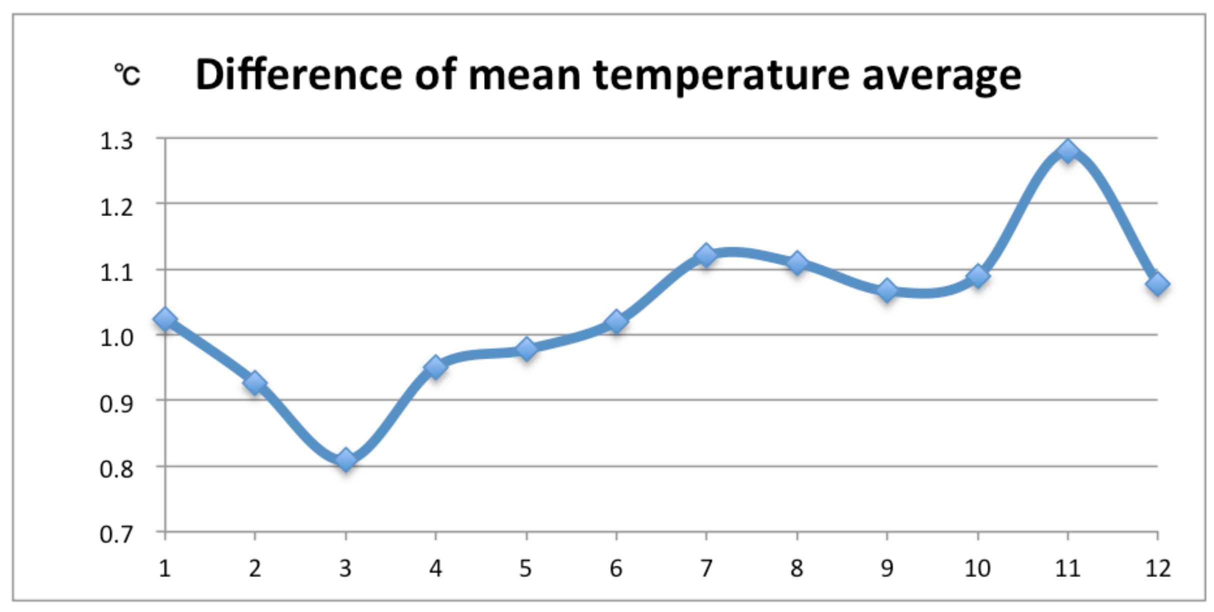
Result and Discussion

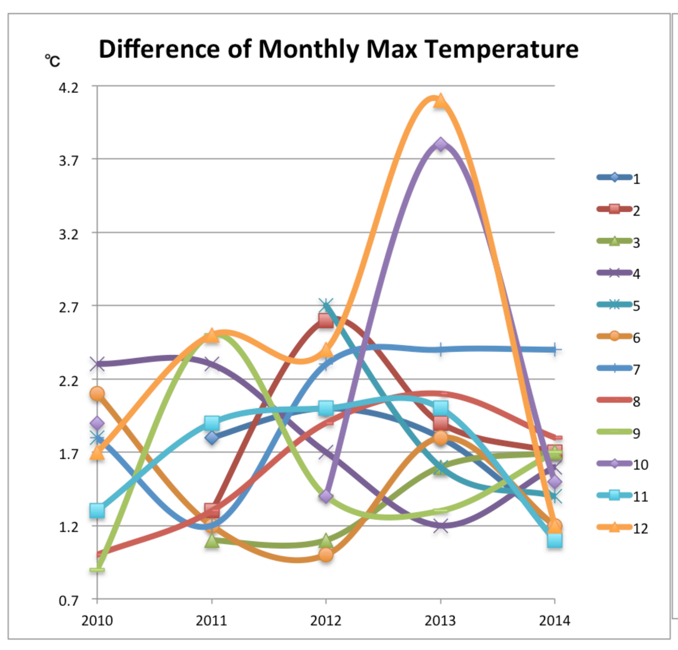


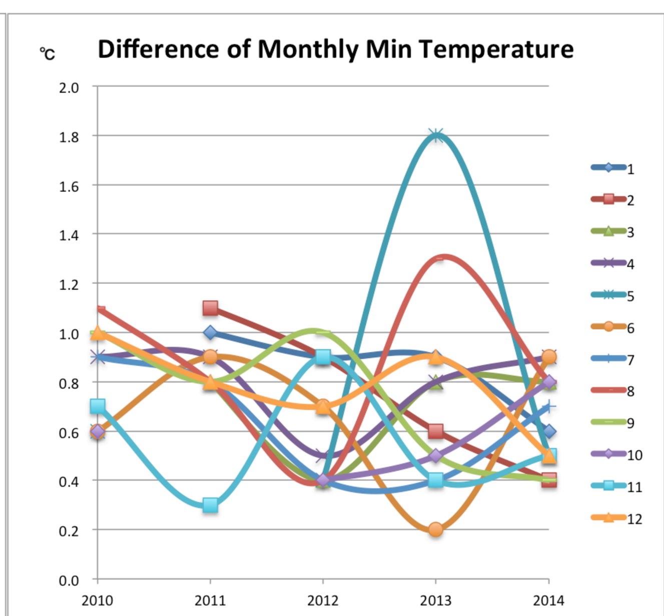


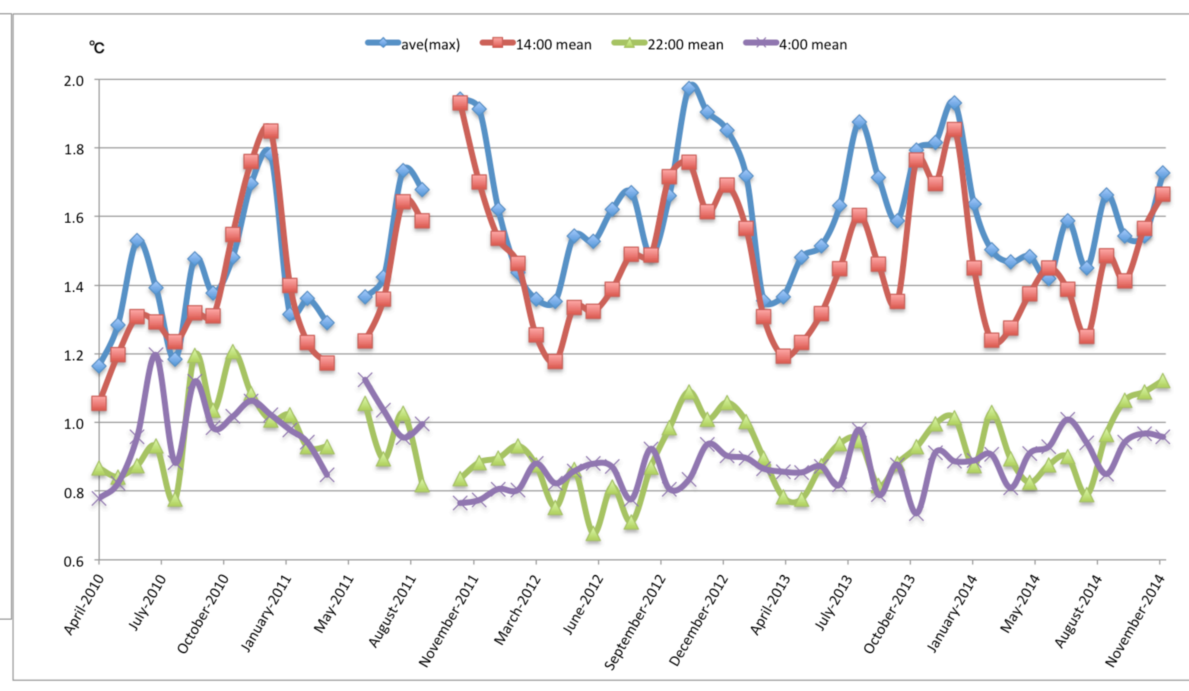


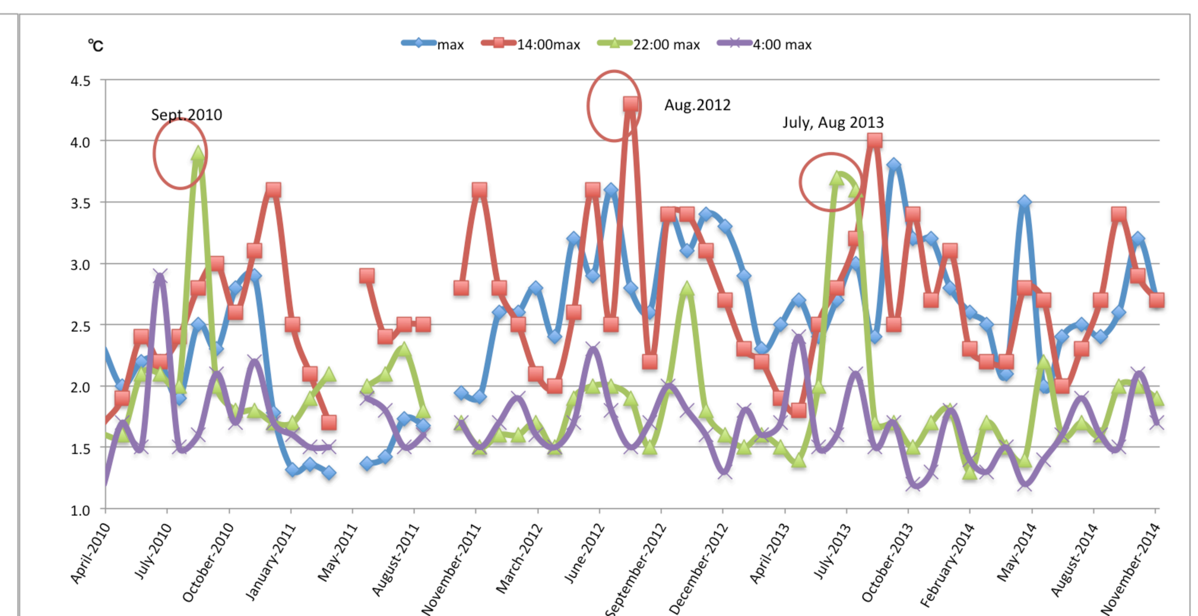












Isolated Example

Many large differences occur during the summertime, even at night (22:00). There are also days when the temperature difference is larger at night than during the day.

These days were characterized by the following weather conditions:

- 28th September 2010: it was raining in the morning, there was thunder at noon, rain stopped in the afternoon, and the temperature difference was large throughout the night and into the next morning.
- 18th August 2012: There was gusty rain for a short time in the morning (around 10:00 – 11:00, at most 80 mm/h) this day.
- 30th September-1st October 2012: The typhoon No.17 passed Tokyo.
- 14th July 2013: atmosphere conditions were unstable, there was gusty rain and thunder for a about 1 hour in the evening (At most, 70 mm/h).
- 12th August 2013: there was heavy rain and thunder in the evening (around 18:00 – 19:00, at most 30 mm/h).

Conclusion

The results indicated that

The concrete roof was warmer than the green area; the temperature difference was larger during winter than summer, similar to the UHI case.
However, the temperature difference was larger during the day than at night, which is opposite to the UHI case.

WHY?

#1 The concrete roof was well ventilated, being on top of a five-story building that rose approximately 25 m above the ground.
#2 The weather condition: inclement weather events such as gusty rain, thunderstorms and typhoons had occurred.

Conclusion

An effect similar a UHI may occur even within the limited confines of a university campus, if the influence of ventilation is excluded.

Future Work

#1 Further investigations should be carried out to determine the importance of factors such as the height at which the measurements are performed.
#2 It is important to retrieve and analyze weather data in accordance with the new approach like "local climate zones" that [Stewart and Oke 2012] proposed.

2015/07/20