

The Urban Heat Island Phenomenon and its Effect on Cheon-An City in Korea.

Kim, Ho-Young¹ KIM, Byung-Ryl¹ Yoon, Jae-Ock²

¹ Graduate course, HOSEO University, Asan, Korea

² Professor, HOSEO University, Asan, Korea

ABSTRACT: Recently, several phenomena associated with abnormal climate changes on the earth have been receiving attention. The increasing use of fossil fuels and other energy sources and the intensification of energy use in urban environments have given rise to the so called heat island effect that occurs in cities. In this research, we measured and analyzed this heat island effect in Cheon-An city, a medium sized city whose population and urbanization has increased rapidly in the past ten years. Temperature and humidity were measured by the continuous measurement method. The locations of the field measurements were the main commercial area and two residential areas within Cheon-an City. Instantaneous measurement was measured 4 times (before sunrise, during the morning commute hours, during the warmest time of the day, and during the evening commute hours) during one day in fall (October 16, 2007) and during one day in winter (February 12, 2008). Temperature, humidity and air velocity were measured. Also, surface temperature was measured in order to analyze the different effects caused by surface materials.

Keywords: Heat Island, Continuous Field Measurement, Instantaneous Measurement

NOMENCLATURE

1. INTRODUCTION

Recently news of unusual weather phenomena has increased and concern over global warming has grown. It is believed that global warming is the result of the increasing use of fossil fuels and CO₂ emissions which have been concomitant with rapid industrialization around the world.

The rise in temperature could have a dramatic and negative effect on the quality of life on earth. The so called heat island effect which arises in cities through a mixture of air pollution, the increasing use of electrical appliances, the concentration of large buildings and factories, and the use of concrete and asphalt over the city landscape

is believed to be contributing to global warming significantly.

This phenomenon – heat island effect – used to be confined to the largest cities in Korea, especially Seoul. However, recently this phenomenon is starting to occur in even small and medium-sized cities which are also developing rapidly. This research investigated the phenomenon of the heat island effect in a medium sized city – Cheon-an. It is hoped that this research will contribute to our understanding of this problem and how it might be resolved in the future.

Cheon-an has developed very rapidly compared to other cities or areas. In this present study we measured the temperature, humidity and air velocity in and around Cheon-an and then gathered field measure-

ment data and compared and analyzed it with the data measured by Cheon-an Meteorological Observation Station.

In order to evaluate the heat island effects with regard to the ground covering materials and seasonal factors, data from field measurements recorded in the winter-season and the mid-season was gathered. The field measurement data was analyzed and a heat island effect was discovered.

In order to examine the possibility of the heat island phenomenon in Cheon-an city, measurements were recorded from 2007 October 10th until October 22nd for 13 days (mid-season), and from 2008 January 15th until February 7th for 24 days (winter-season), and temperature and humidity were measured continuously. We divided the areas to be measured into the Commercial Area and the Residential Areas.

Continuous measurements were carried out in Commercial Area No. 1 and Residential Areas Nos. 1 and 2. The commercial area in the city center was selected because there is a large concentration of buildings there and the volume of traffic is great. The residential areas selected have large concentrations of apartment complexes and the population is dense. Measurements were recorded continuously at these sites.

Instantaneous measurements were measured in the C1 area. We selected 4 points in the C1. And then measurement was recorded air temperature, humidity and air velocity during 4 time zones. Surface temperature was together recorded in instantaneous measurement points.

The aim of this paper was to discover the extent of the heat island effect in a middle sized city.

2. Heat island phenomenon

From collected data over the last 150 years it is believed that the concentration of carbon dioxide has increased by about 30% to 270~360ppm, and the average temperature of the earth rose in the same period by

about 0.6°C. From 1919 Korea's meteorological observations began. During the time since then the average temperature has risen by about 1.5°C. These kinds of statistics are causing growing concern around the world

Cheon-an city is located in Chungcheongnam-Do in the northeast of South Korea and it is a hub city in terms of transportation. It is a medium-sized town and is representative of the kind of rapid economic and industrial development that has occurred in South Korea in recent times. It was therefore deemed as an appropriate choice to investigate the phenomenon of the heat island effect.

3. Analysis of Cheon-an Climate

Currently, 530,000 people are living on a 636.25 km² site in Cheon-an city. Cheon-an city's population has increased by 37.4% during the last 10 years.

Because of its rapid growth and to observe any changes in temperature or in the local climate, Cheon-an meteorological observation station was established in 1998 and has been analyzing temperature data for the last ten years.

4. Area of field Measurement

4.1 Selected Measurement Point

In order to measure the heat island phenomenon of a medium-sized town, a continuous measurement point in the Commercial Area (C1) was selected and in two Residential areas (R1, R2). These measurement points were 1 and a half meters above the ground. The residential areas were selected to compare the heat island effect with the commercial area. Also, in order to examine the effect the material covering on the ground might have on temperature surface temperature measurement points were also selected.

(1) Continuous Measurement

The continuous measurement points were placed in the commercial area and the

residential areas and measurements were taken. The commercial area is in the city center near the bus terminal (C1) and the volume of traffic there is great and many housing facilities and large buildings have also sprung up there recently. The population density in the residential areas has increased rapidly over recent years- (R1, R2).

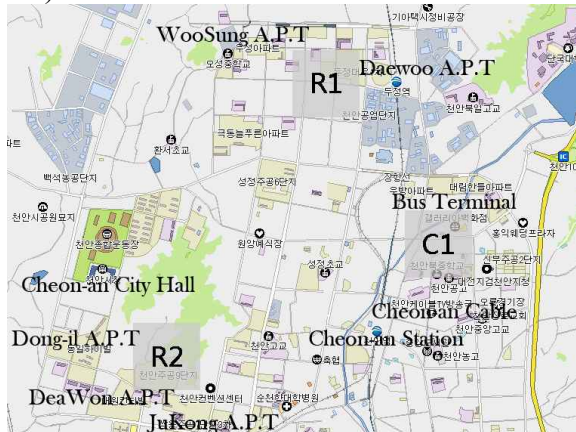


Fig. 1 Continuous Measurement Point

When selecting the measurement point in the commercial area we had to consider that the traffic flow and subsequent air currents could affect the temperature as well as the natural east-west wind direction in Cheon-an. So a place was chosen to minimize these factors. With regard to the residential areas, sites were chosen in the center of the residential areas where there are pedestrian spaces and the sites are not influenced by the heat generated by automobiles.

In the commercial area (C1) the ground covering material was cement and the measuring point was placed in an area dense with buildings. The ground covering material of residential area 1(R1) was soil. The ground covering material of residential area 2(R2) was a kind of cement block used for sidewalks. See figure 1.

(2) Instantaneous Measurement

To take the instantaneous measurements, the commercial area was divided into four separate areas: (1) a crossroads, (2) the terminal, (3) a water space area and (4) a park.

The instantaneous measurement points are shown in figure 2.

The ground covering material of the crossroads (1) was concrete and there are many buildings there. The ground covering material of the terminal (2) was the blocks used for sidewalks and many vehicles park or stop temporarily there. The ground covering material of the water space area (3) were trees. The water space area was not affected by buildings or vehicles. The ground covering material of the park (4) was soil and green spaces inside the commercial area of the city center.



Fig. 2 Instantaneous Measurement Point

(Commercial Area)

(3) Surface Temperature Measurement

Surface temperature measurements were also recorded at the same locations as the instantaneous measurement points but the latter were measured at a distance of 1.5 meter from the ground. The kind of material covering the ground is representative of an environmental circumstance. Ground covering material is shown in table 1.

Table 1 Ground Cover Material

Point	Cover Material
Cross Road	cement, asphalt, barrier pave
Terminal	block for sidewalk, asphalt
Water Space	surface on the bridge, block for sidewalk, soil(with lawn)
Park	soil(without lawn), block for sidewalk, painted cement footway

4.2 Field Measurement

In order to measure the city heat island phenomenon of a medium-sized town, the

continuous measurement and instantaneous measurement of temperature, humidity and velocity were undertaken. And in order to examine what effect ground covering material has, surface temperature was also measured.

(1) Continuous Field Measurement

We divided the city into the commercial area and the residential areas and the measurement period was set for 2007.10.10 ~ 2007.10.22 (13days) and for the winter period 2008.1.17 ~ 2008.2.7 (22days). Our data was compared with the data of Cheon-an meteorological observation station and both sets of data were then analyzed.

The continuous measurement measured the temperature and humidity and the same instrument was used. The instrument used for measuring temperature and humidity was the TR-72U and measurements were taken every 10 minutes throughout the day. Three measurements points were used. To increase the accuracy of the measurements, a place where there is no direct solar radiation was selected. The measurements were taken at a distance of 1.5m from the ground. This is the same height used by Meteorological Office.

Table 2 Time Zone (Mid & winter)

NO	Time Zone	Background Determining time
(a)	06:00	Lowest temperature for day(sunrise right before)
	~ 07:00	
	* 06:30	
	~ 07:30	
(b)	09:30	right after rush hour(effect traffic) (Mid & winter season is same.)
	~ 10:30	
(c)	13:30	Highest temperature (include Solar radiation)
	~ 14:30	
	* 14:00	
	~ 15:00	
(d)	19:30	after the close hour (effect traffic and urban latent heat) (Mid & winter season is same.)
	~ 20:30	

* Shadow sell is winter-season.

(2) Instantaneous Measurement

The commercial area was divided into four locations: a crossroads, the bus terminal, a water space area and a park. The measurement period was mid-season (2007.10.16) and winter-season (2008.2.12). The measurement data was compared with the data of Cheon-an meteorological observation station and both sets were then analyzed.

The instantaneous measurement measured temperature, humidity and the air velocity. Measurement of temperature and humidity were taken by using the TR-72U. Measurement of the air velocity was taken by using a hot wire anemometer (A-542) and the measurements were taken at a height of 1.5m from the ground. The measurement instrument recorded data for 5 minutes at 1 second intervals during a one hour period and 300 bits of data were gathered. Maximum value, minimum value and average value were obtained. Mid-season measurements were taken from 6: 00, the winter-season measurements were taken from 6: 30. Measurement time zones are shown in table2.

(3) Surface Measurement

Surface temperature was recorded on 2008 February 12th. The TR-71U surface temperature sensor was used. It was measured during the winter instantaneous measurement time zone.

Table 3 Measurement Instrument

Measurement Type	content	instru ment	*
continuous measurement	temperature/ humidity	TR-72U	3
	temperature/ humidity	TR-72U	4
instantaneous measurement	velocity	A-542	4
	surface temperature	TR-71U	11

*the Number of Measurement Point

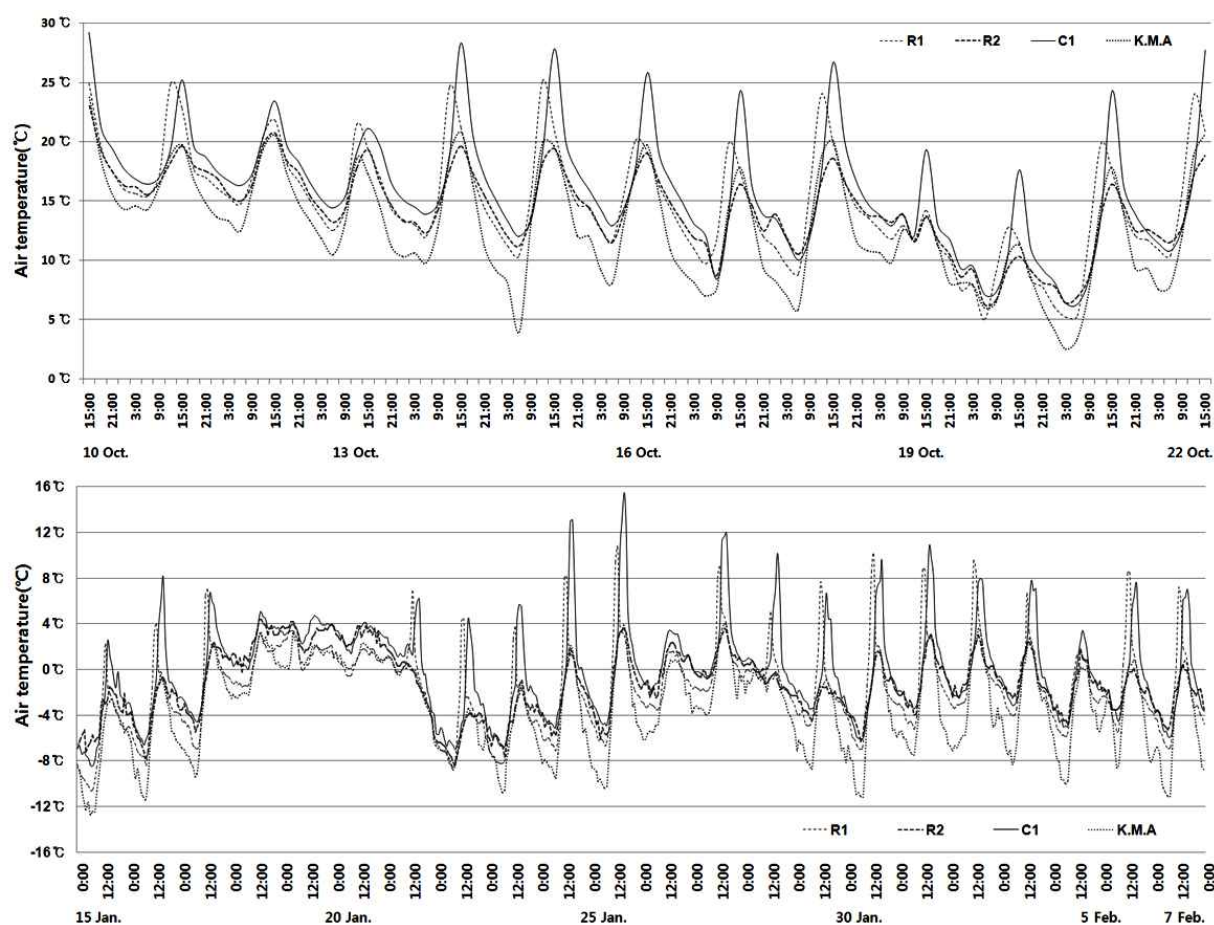


Fig. 3 Mid-Season(upper), Winter-season(lower) Air Temperature [Continuous Measurement]

Four kinds of ground covering material were selected. When measurements were taken, the effect of direct solar radiation was avoided. In order to secure the reliability of the data, an infrared ray surface temperature measurement instrument was used. The measurement instruments used are shown in table3.

5. Result and analysis

The weather period during which measurements were taken was the factor that influenced temperature and humidity the most. Accordingly, we conferred with the weather data of the weather station taken for these periods to compare and evaluate.

5.1 continuous measurements

The data from the 3 points measured in the mid-season and winter season were

compared with the AWS data of the weather station.

(1) Mid-Season

Temperature and humidity for the middle season is shown figure 3.

Temperatures of mid-season were analyzed in the following order: $C1 > R1 > R2 \geq K.M.A$. The difference between day and night temperatures in the commercial area was between $12^{\circ}\text{C} \sim 17^{\circ}\text{C}$ during the measurement period.

The highest temperature difference recorded between residential area 1 and residential area 2 was between $3^{\circ}\text{C} \sim 6^{\circ}\text{C}$.

Because of residential area 2's higher altitude and the presence of green areas in the surrounding vicinity, the temperature was therefore lower. The weather station is in a rural area and is not influenced by artificial heat, so it recorded the lowest temperature.

The highest temperature during daytime occurred on October 10th. The highest temperature was C1 (29.2 °C) and the lowest temperature was R2 (23 °C) on October 10th.

Humidity distribution at mid-season was in the following order: K.M.A > R2 > R1 > C1. The change in humidity because of temperature was clear.

(2) Winter-Season

On January 17th, during the winter season, the lowest temperature occurred immediately before sunrise. The order for the lowest temperatures recorded was as follows: K.M.A (- 12.7°C) > R1 (- 10. 6°C) > C1 (- 8.4°C) > R2 (- 7.2°C) before sunrise.

On the same day the order for the maximum temperature in the middle of the day was as follows: C1 (2.5°C) > R1 (2.3°C) > R2 (-1.5°C) > K.M.A (-2.6°C) order. The highest daytime temperature recorded in the commercial area was 5.1°C and the lowest was 0.2°C.

5.2 Instantaneous Measurements

Fig4 shows the instantaneous measurement graph. Instantaneous measurements were taken in the commercial area of the city. Instantaneous measurement was measured in order to analyze different effects produced by ground covering materials. The locations were: an intersection at a cross roads, a bus-terminal, a water-space and a park in the city center.

(1) Mid-Season

The cross road and bus-terminal recorded the highest temperatures in (b) and (c). The temperature recorded at (c) at the cross roads was higher by 3.9°C than the (b) time zone and at the terminal there was an increase of 4.8°C at time zone c compared to (b) time zone. (Fig. 4)

At the park, the highest temperature measured was in time zone (a) and the velocity measured was slow during all time zones.

The maximum velocity at the water-space area was 1.78 m/s and the minimum was 0.70 m/s. The velocity at the water-space area was greater than any of the other three points. The temperature recorded at the water-space area was the lowest during all time zones.

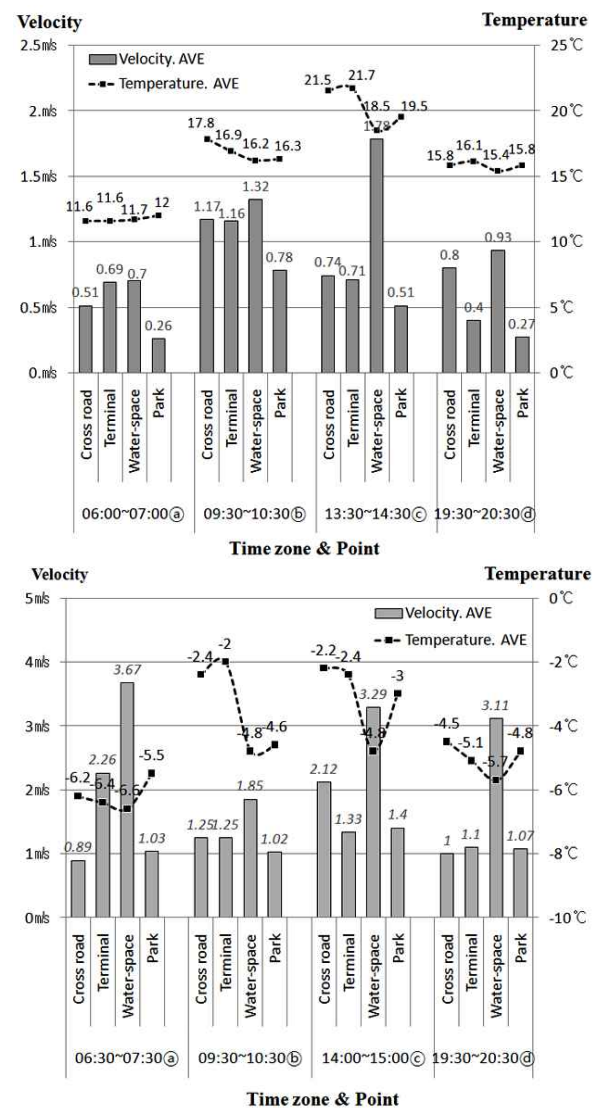


Fig. 4 Mid-Season(upper), Winter-season(lower) [Instantaneous Measurement]

(2) Winter-Season

The cross roads and bus-terminal recorded their highest measurements during time zones (b) and (c). These points recorded temperatures 2~2.8°C higher than the other 2 points (water-space and park) during time zones (b)(the cross roads temperature was 3.8°C and the terminal temperature was

4.4°C). Time zone ③ showed a similar tendency.

At the park during ①, the temperature was highest and the maximum velocity was recorded at 1.4m/s; the minimum was 1.02m/s. That was the lowest velocity recorded. At the water-space area during ①, the maximum velocity was 3.67 m/s and the minimum was 1.85 m/s. The fastest velocity was recorded at that point. Therefore environmental circumstances have a great impact on velocity.

(3) Surface temperature measurements

For the measurement of the surface temperature, 11 different kinds of ground covering materials were selected. These materials were selected from amongst the instantaneous measurement sites.

During time zone ①, the surface on the water-space area recorded the lowest temperature at -6.6°C and the soil covering of the park recorded the highest temperature at -3.6°C.

In time zone ②, we could discern that the surface temperatures of all ground covering materials rose as the quantity of solar radiation increased.

The surface temperature at the cross roads and the bus-terminal recorded a large increase in temperature. The volume of traffic at these sites is great during the rush hour.

During time zone ③, the highest temperatures were recorded at the asphalt and the cement covered sites and the lowest temperatures were recorded at the water-space area. At the cement surface of the cross roads the highest temperature was 0.3°C ~ 1.0°C higher than at the other ground covering material sites.

Time zone ④ and ⑤ had a similar temperature. At the asphalt and the cement surfaces higher temperatures higher temperatures were recorded than at the water-space area during time zones ④ and ⑤.

6. Conclusion

In this study, we measured and analyzed the heat island effect in Cheon-an city.

1) In the C1 (commercial area) there is a high concentration of buildings and they are arranged in an unnatural and artificial manner. The temperature recorded there is higher than any other area.

2) According to environmental circumstances differences in temperature, humidity and air velocity occur in each time zone according to the data gathered by the instantaneous measurement method. Velocity was measured at its fastest at the water-space area and at its lowest at the park.

3) Solar radiation quantity, which affected surface temperature, traffic volume, artificial production of heat and the kind of ground covering material, all combined to cause the phenomenon of the city heat island.

The measurement data concerning seasonal factors must be researched more thoroughly and the city council must actively engage in research about changes in climate. The beneficial results that follow from the restoration of rivers and establishment of greens spaces must also be examined more closely.

REFERENCE

- [1] Hideki Takebayashi, Masakazu Moriyama. 2007. Surface heat budget on green roof and high reflection roof for mitigation of urban heat island. Building and environment 42 pp. 2971-2979
- [2] Goldreich Y. 1995. Urban climate studies in Israel-a review. Atmospheric Environment 29: pp. 467-78
- [3] 2007 Climate Data of Cheon-an Weather Station
- [4] 2007 IPCC 4th REPORT