Simulation of Heat Health Alert System Using Meteorological Data Observed by Automatic Weather Systems in Seoul, Korea

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ABSTRACT:

In this paper the heat health alert system, which is operated this year by way of showing an example, is a simulator linked to the Geographic Information System (GIS), and it uses meteorological data that are observed at Automatic Weather Systems (AWSs) in Seoul, Korea. Simulation results show that it is possible to use meteorological data observed by AWSs when the Korea Meteorological Administration (KMA) has issued alerting the public to the threat of heat waves, and to connect meteorological data to spatial data when the KMA offers local forecasts and weather-related information. However, most AWSs that were installed to manage urban disasters do not measure humidity, so general humidity is used in all districts. Therefore, to issue heat wave warnings about different localities on a small scale, we will study how to complement this problem and to examine the accuracy of data observed at AWS in the future.

KEY WORDS: Heat Health Alert System, AWSs, Heat Wave, GIS, Spatial Data

1. INTRODUCTION

Two reports issued earlier this year by the Intergovernmental Panel on Climate Change (IPCC) warned that the Earth was already warming considerably, and that mankind was almost certainly to blame. They predicted severe consequences including droughts, floods, storms, heat waves, and rising seas. In summer 2003, a heat waves of exceptional strength and duration caused a death toll exceeding 30,000 (Dousset and Gourmelon, 2006). Accounting for the hot weather for 6 days that summer, from July 22 to 29, 1994, the number of deaths is higher than 73% compared to the same period from 1991 to 1993 (Kim *et al.*, 2006).

There have been many research studies that deal with analysis and mitigation of the urban heat island and heat waves. The urban heat island and heat waves were dealt with on a large scale using remote sensing data such as Landsat, SPOT, ASTER, etc (Dousset and Gourmelon, 2006; Rosenzweig *et al.*, 2006; Kato and Yamaguchi, 2007). And Hsieh C. M. Kim *et al.* (2007) and Takebayashi and Moriyama (2007) focused on a small scale such as building in the city center and building roofs etc.

The study of heat waves is an elementary phase in Korea now. Kim *et al.* (2006) studied the relations between the heat waves and weather-related daily mortalities in Korea, Choi (2006) defined heat waves of the actual circumstances and then analysed its properties. Kim *et al.* (2007) researched to analyse foreign cases about extreme heat response plan. There are a few studies into the urban heat waves or the urban heat island using remote sensing but there are even fewer studies into heat waves using remote sensing.

The emissions of greenhouse gases, such as carbon dioxide, are leading to higher temperatures all over the world. In addition, because of urbanization, the urban heat island effect is the temperature increase in urban areas compared to that in surrounding rural areas. In urban areas especially, the fraction of the surface covered by vegetation is particularly low (Rosenzweig *et al.*, 2006). In other words, higher temperature in the city center is affected by anthropogenic heat discharge, increased use of artificial impervious surface materials, and decreased vegetation cover.

Consequently, in this research project focuses on the simulation of heat wave alert system to be based on meteorological data observed by Automatic Weather Systems (AWSs) in Seoul, Korea. We propose that alerting the public to the threat of heat waves is possible for small areas and all districts in Seoul.

2. EXPERIMENTAL DATA AND METHOD

The heat health alert system is issued to use forecasted data. In this paper, to simulate the heat health alert system for Seoul, it does not use forecasted data, but instead, meteorological data observed by AWSs.

2.1 Automatic Weather System Data

Surface meteorological observations are being conducted at 76 manned stations with Automated Synoptic Observing Systems (ASOSs) and 465 unmanned stations with AWSs.

AWSs at mountain areas and isolated islands were deployed and installed to make early monitoring of severe weather conditions such as localized torrential downpour, hail, thunderstorm, gust, and so on. Five elements, including temperature, wind direction and speed, precipitation, and rain sensing are measured automatically every minute. The surface observation data collected from AWSs also play an important role in the preparation of the initial conditions for the numerical prediction models. The distance from site to site by AWSs for watching of severe weather is about 13.5km.

We use maximum temperature data observed by 26 unmanned stations with AWSs in Seoul, Korea (Figure 1). Further, AWSs do not measure humidity so general humidity is used in all districts, Seoul.

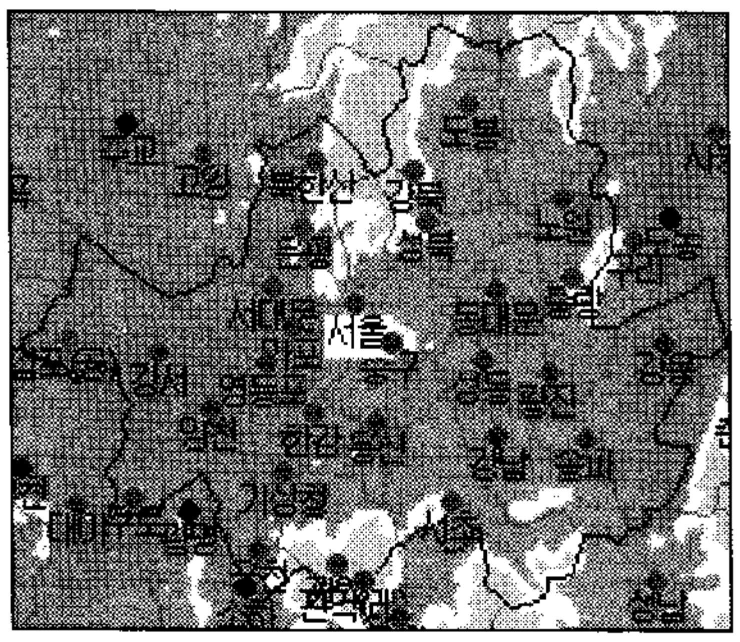


Figure 1. Location of AWSs, Seoul, Korea

2.2 Heat Health Alert System

Since 2003, it has been common to have a national heat waves alert to manage heat waves and protect vulnerable people, including the very young, the elderly, those with chronic illnesses etc. in Europe.

The KMA undertook the initiative of publicly warning those people most at risk of heat-related illness that hot weather conditions presently exist, and suggested they take appropriate precautions as a result of higher temperatures brought about by global warming (Table 1).

Table 1. The national alerting guidelines in Korea

Category	Guideline
Heat Advisory	Issued by KMA when the maximum temperature is expected 33℃ or higher and the heat index is predicted to reach at least 32℃ or higher for at least two consecutive days.
Heat Alert	Issued by KMA when the maximum temperature is expected 35℃ or higher and the heat index is predicted to reach at least 41℃ or higher for at least two consecutive days.

The KMA has issued the heat health alert system several times a day from July 1 to September 30 on the website. A heat advisory was first declared for Naju, Gurye-gun and Suncheon in the province of Jeollanam-do on July 25, 2007. Moreover, the KMA officially plans to trigger the national alerting from 2008 after evaluating the accuracy of the heat health alert system.

2.3 Heat Index

The heat index (sometimes called the apparent temperature) is a measure of the contribution that high temperature and high humidity (expressed either as relative humidity or dew point temperature) make in reducing the body's ability to cool itself.

The computation used for the heat index that was carried out by Lans P. Rothfusz. So, the heat index, to be relative to Korean affairs, must be developed.

Table 2. Possible heat disorders according to heat index

Category	HI	Notes
Extreme Danger	54°C or higher	Heat stroke or sunstroke likely.
Danger	41 - 54°C	Sunstroke, muscle cramps, and/or heat exhaustion likely. Heatstroke possible with prolonged exposure and/or physical activity.
Extreme Caution	32 - 41°C	Sunstroke, muscle cramps, and/or heat exhaustion possible with prolonged exposure and/or physical activity.
Caution	27 - 32°C	Fatigue possible with prolonged exposure and/or physical activity.

The following equation 1 approximates the heat index. The Rothfusz. equation was obtained by multiple regression analysis and there is a ±1.3 degree °F error.

$$\begin{aligned} HI = & -42.379 + 2.04901523\,T + 10.14333127\,R \\ & - 0.22475541\,TR - 6.83783\times10^{-3}\,T^2 \\ & - 5.481717\times10^{-2}\,R^2 + 1.22874\times10^{-3}\,T^2R \\ & + 8.5285\times10^{-4}\,TR^2 - 1.99\times10^{-6}\,T^2R^2 \end{aligned} \quad (1)$$

where HI = heat index(°F)
T = ambient dry bulb temperature(°F)
R = relative humidity(%)

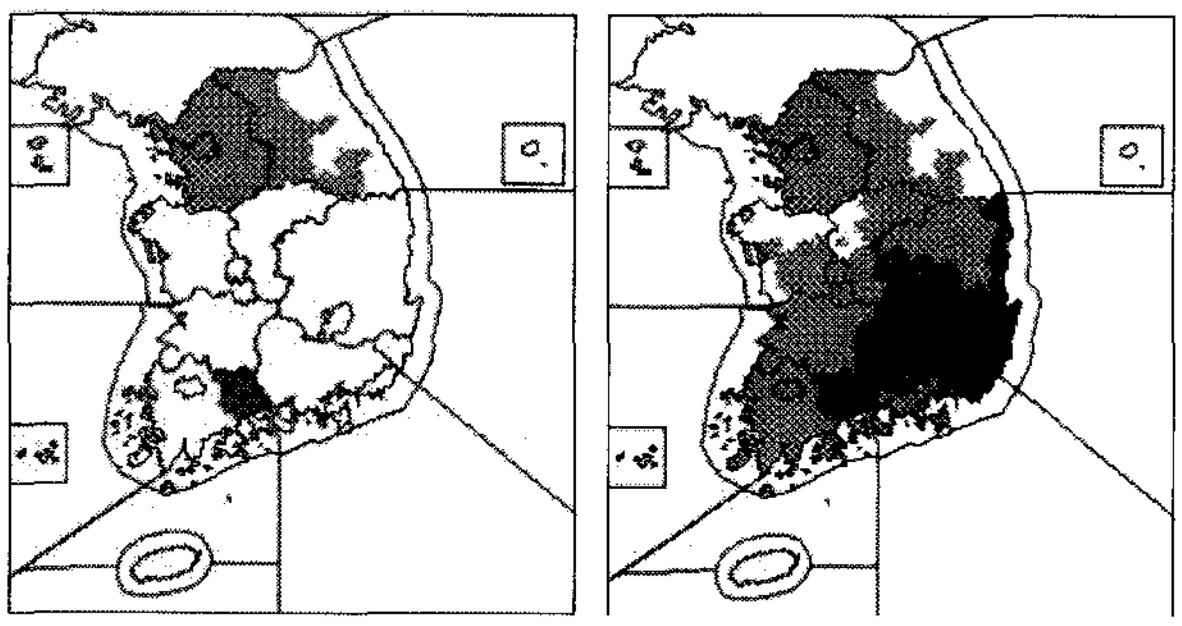
The temperature in Korea is measured in degrees Celsius, so the temperature can be converted to degrees Fahrenheit with equation 2.

$$C = \frac{5}{9}(F - 32) \quad (2)$$

where F = degree Fahrenheit (°F)
C = degree Celsius (℃)

3. EXPERIMENTAL RESULT

During summer 2007, a heat advisory, which targeted Seoul, was declared on August 19 and cancelled on August 21. At that time, the KMA provided information about heat waves on their website, as shown in figure 2.



(a) At 5 p.m. August 19, 2007 (b) After 5 a.m. 21 August, 2007

: Heat Advisory, : Heat Alert

Figure 2. The heat health alert issued by KMA

But, urban air and surface temperatures differ according to various factors such as albedo, surface roughness, elevation, etc. In addition, the stagnant atmospheric conditions of the heat wave trap pollutants in urban areas, so the heat-related deaths in St. Louis during 1966 shows a heavier concentration in the crowded alleys and towers of the inner city, where air quality would also be poor during a heat wave (http://www.nws.noaa.gov assessed by October 4, 2007).

Each district calls a heat advisory on different dates and, especially, the number of heat advisory days called is more than that of the KMA. Simulation results show that the most heat advisories were called between August 24 and 25, 2007 (figure 3).

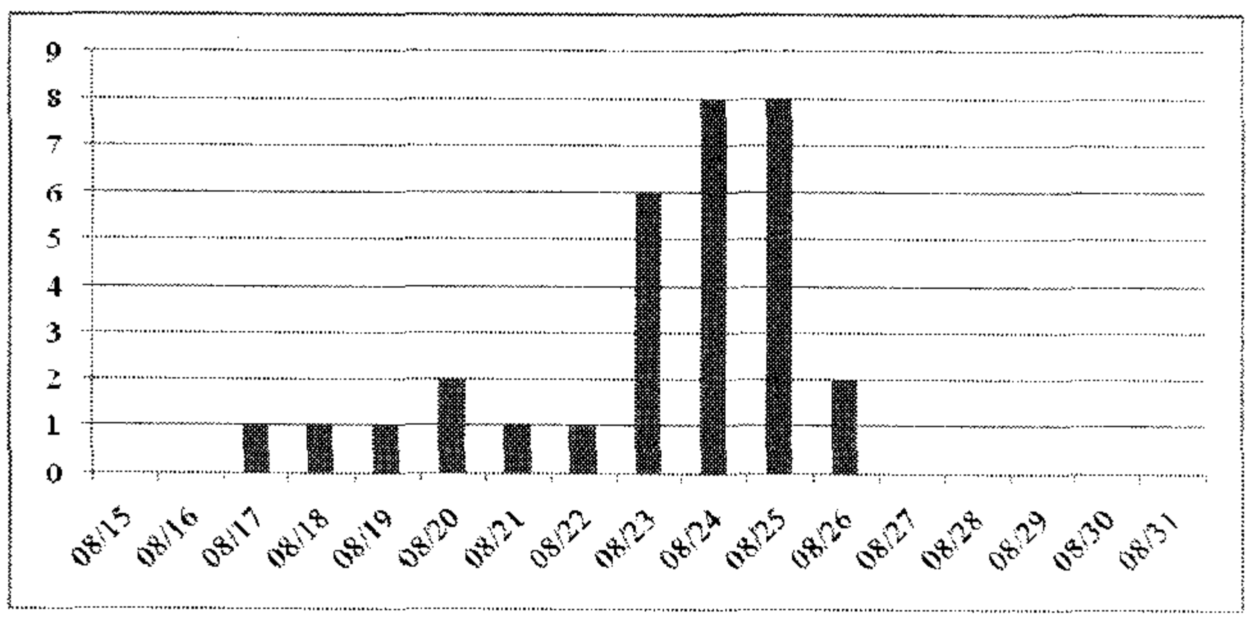


Figure 3. Number of heat advisories, according to date

In detail, both Gangdong-gu and Yangcheon-gu are included on 20 August, 2007, which were issued heat advisories by the KMA, whereas there were 8 districts issued warnings, including Seocho-gu, Songpa-gu, Yangcheon-gu, Dongdaemun-gu, Yongsan-gu, Yeongdeungpo-gu, Gangbuk-gu, Seongbuk-gu, Jongno-gu each on 24 and 25 August, 2007 , as shown in figure 4 and 5.

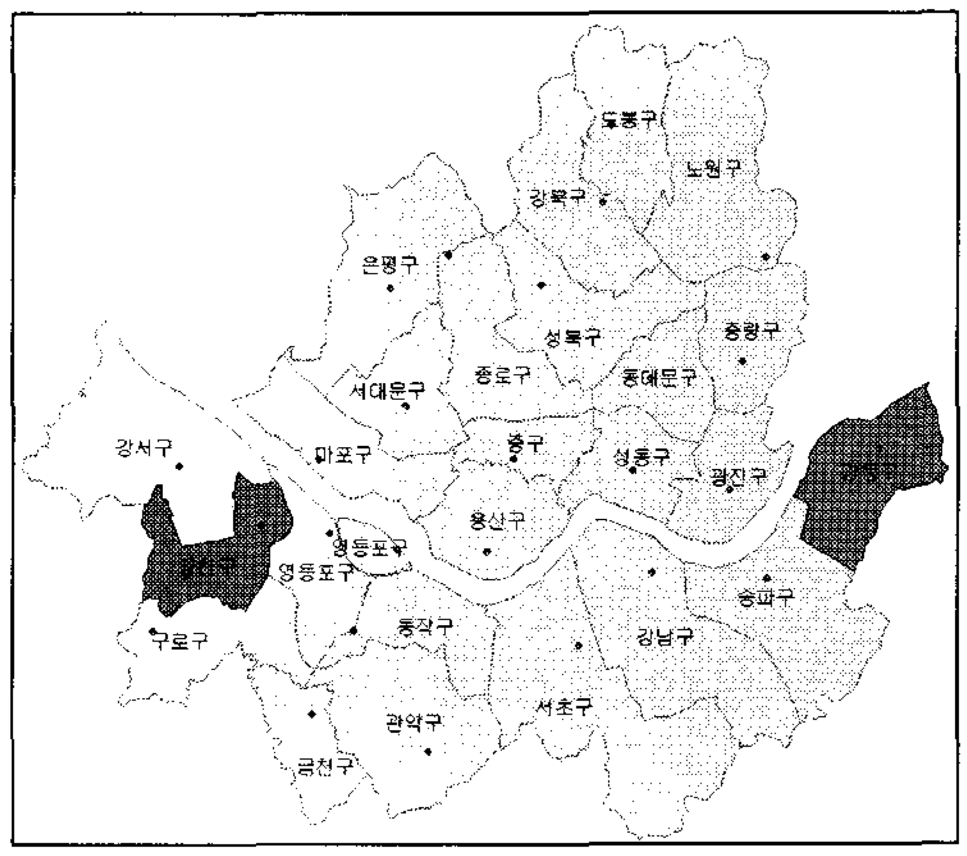
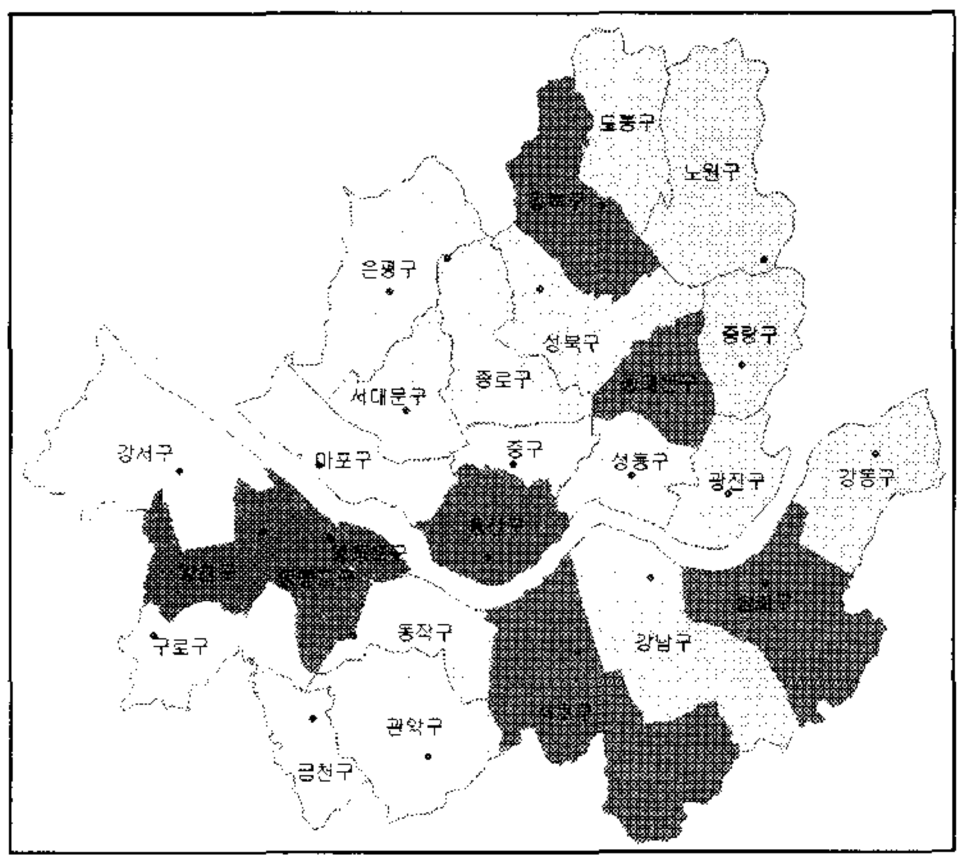
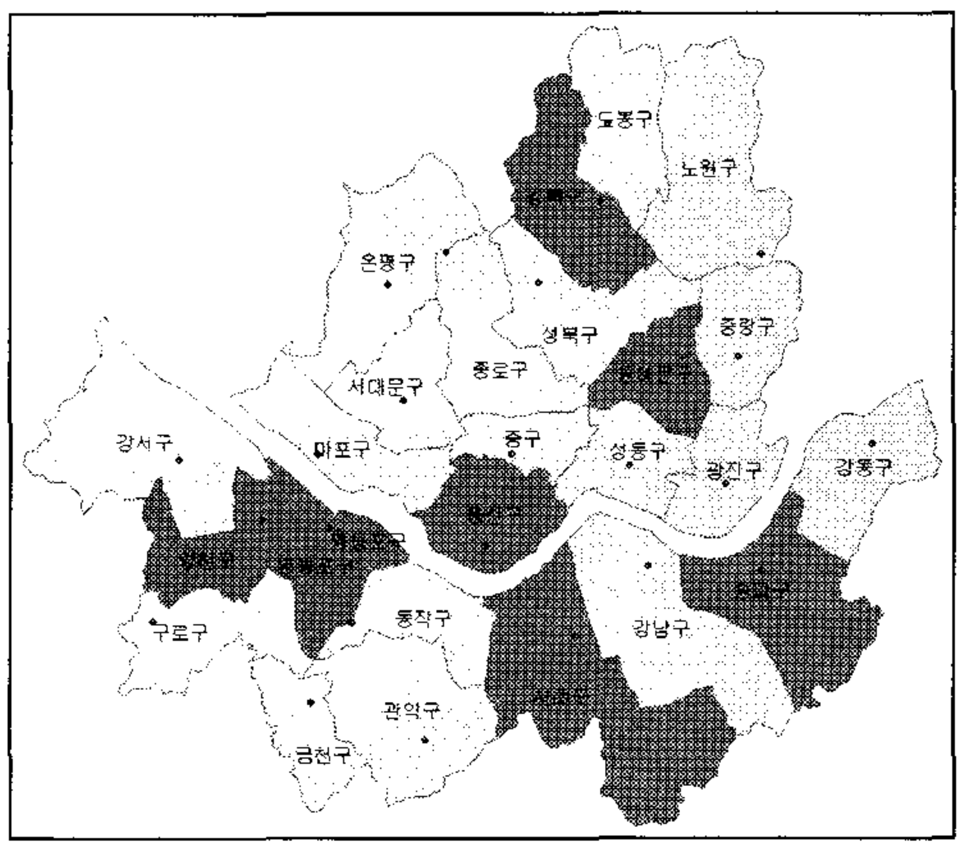


Figure 4. Districts to be issued heat advisory in Seoul on 20 August, 2007



(a) 24 August, 2007



(b) 25 August, 2007

Figure 5. Districts to be issued heat advisories in Seoul

Particularly, it is Seocho-gu that shows the highest number of days alerting heat waves in all districts. Seoul consistently issued health advisories during 6 days, and there were 16 districts which did not issue heat advisories during summer 2007 (figure 6).

We do not analyse the factors that affect temperature and humidity and confirm the cause of regional differences in this study. However, we could find new chance of forecasting heat waves in detail area.

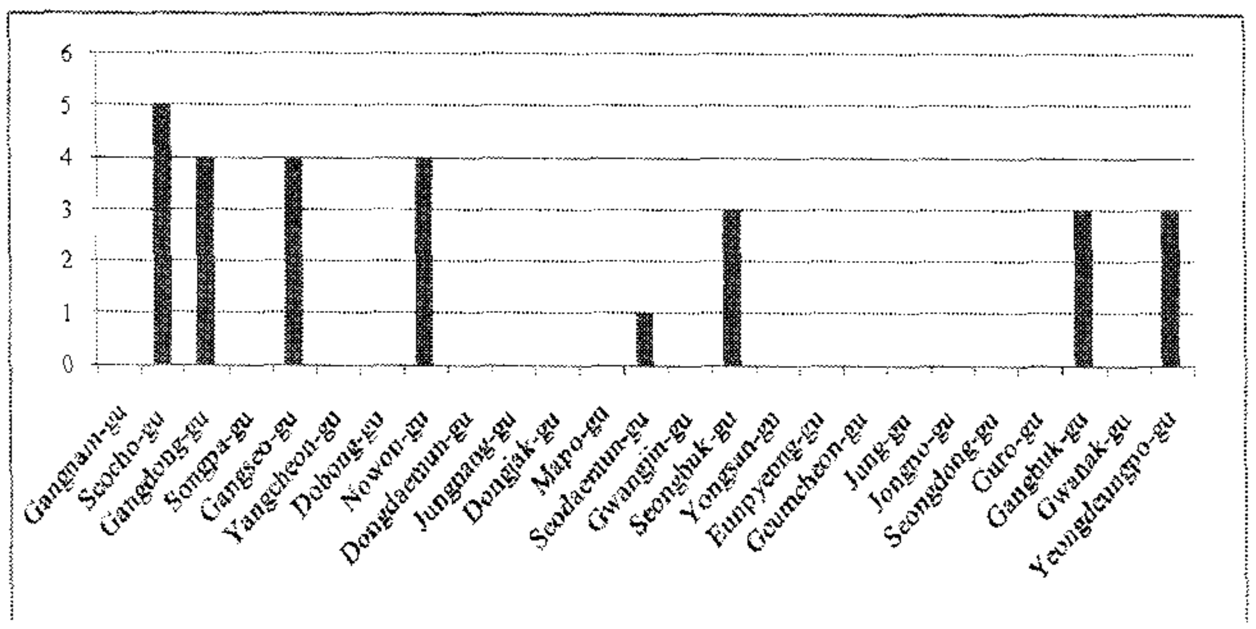


Figure 6. Number of days with heat advisories by district in Seoul

4. CONCLUSION

In this paper, we simulate the heat health alert system in all districts, Seoul. According to our results, first, all districts exhibit different temperatures so that the date on which a heat alert is issued is different. Secondly, if meteorological data observed at AWSs is used, we could provide more detailed, weather-related information on a smaller scale. Finally, most of the meteorological data would be connected to spatial data when the KMA offers local forecasts. Especially, heat waves are relative to land surfaces and spatial data.

In the future, it is necessary that local temperatures in urban areas differ according to various factors such as albedo, surface roughness, elevation, etc., and it must be improved in various ways in order to predict heat waves. Furthermore, we have to advance the accuracy of data to be measure automatically by AWSs and AWSs will have to use devices to observe humidity. Furthermore, we could make full use of devices which measure temperature and humidity, such as the u-pole, as well as RFID and Wet Bulb Globe Temperature (WBGT) etc.

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