

The Normals and Extremes of Heat Stress in South Korea

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1. Introduction

Extremely high apparent temperatures continued for several weeks across the South Korea in summer 1994. These remarkably high apparent temperatures mostly above 26°C were recorded and they continued even in the nights. This unusual heat event caused above-normal human mortality (Ho-Jang Kwon, 1998). Many recent articles notify an increase in temperature. This trend results in the increase of physiological stress on humans by increasing heat and/or humidity. However, few studies based on a long period of record (hereafter POR) for the apparent temperature have been done in Korea. Chong-Bum Lee et al (1982) analyzed annual normal pattern of cumulative heat stress in Korea. The geography of apparent temperature in South Korea over a long POR is, however, not well understood yet. In this study we develop a broad-scale climatology of apparent temperature in South Korea based on 61 stations for the period of 1973 to 1998.

2. Data and Method

This study used the latest version of Heat Index (hereafter HI) developed by NWS (National Weather Service) in 1998 (Rothfusz, 1998). Recently KMA (Korean Meteorological Association) considers adopting this HI to alert the public to the dangers of exposure for extended periods of high temperature with the added effects of humidity. Table 1 shows presents the possible symptoms at each threshold suggested by NWSs empirical experiments on Heat index.

Categories	Heat Index Range	Possible Symptoms
Caution	26.7 - 32.2°C	Fatigue with prolonged exposure and physical activity
Extreme Caution	32.2 - 40.6°C	Sunstroke, Heat cramps and heat exhaustion with prolonged exposure and physical activity under these conditions
Danger	40.6 - 54.5°C	Sunstroke, heat cramps or heat exhaustion are likely. Heatstroke with prolonged exposure and physical activity
Extreme Danger	over 54.5°C	Heatstroke or sunstroke are imminent

Table 1. Possible Symptoms in each Heat Index range

The HI is based only on the ambient dry bulb temperature (T) in F and relative humidity (R) in % as shown below and then HI transformed into degree Celsius (°C);

$$\begin{aligned}
 HI = & - 42.379 + 2.04901523T + 10.1433127R - 0.22475541TR \\
 & - 6.83783 \times 10^{-3}T^2 - 5.481717 \times 10^{-2}R^2 + 1.22874 \times 10^{-3}T^2R \\
 & + 8.5282 \times 10^{-4}TR^2 - 1.99 \times 10^{-6}T^2 R^2
 \end{aligned}$$

This equation is valid with the atmospheric condition of 26.7°C or higher and relative humidity of 40% or higher. In actual application, we applied this equation down to 25.5°C of air temperature, since that temperature with relative humidity of 80% can produce a HI above 26.7°C.

In this paper, we calculate HI for every 6-hour (LST 3h, 9h, 15h, 21h) for 61 stations in South Korea for POR of 1973 to 1998. This new HI data set was then analyzed for its broad scale climatological characteristics of normals as well as extreme runs of days and hours with high HI values. This high station density (61) and the long POR used (1973-1998) allow the creation of detailed maps of normals for HI. This study used a linear; Kriging procedure that formatted the data into 0.1° × 0.1° grid across the study area for drawing maps.

3. Results

The map of frequency of HI equal to or above 26.7°C in South Korea splits into three areas with high frequencies; the central inner area including Taejon and Ch'ongju, the southwestern area including Sunch'on, Namwon, Chongup, Kwangju, and Chunju, and the southeastern area including Taegu, Miryang, and Hapch'on. Spatial pattern of frequency of HI equal to or above 32.2°C is similar to that of 26.

7°C except for new high frequency in Jeju Island. However, the spatial patterns of HI equal to or above 40.6°C are different from those of the previous maps. The southwestern core of HI migrates northward to Puyo and Puan. Miryang and Ulsan show highest frequency of such intense HI in the southeastern area. Highest frequency of nighttime HI appeared in large cities such as Seoul, Kangnung, Sokch'ŏ, Kwangju, Daegu, P'ohang, Pusan, and Mokp'ŏ. This pattern indicates that tropical night phenomenon happens by the influences of the urban heat island as well as the large magnitude of sultry airmass.

Two remarkably unusual HI events occurred for POR. Taejon recorded 57.6°C at 3 P.M. on July 28, 1977 with 33.7°C in temperature and 91% in relative humidity. Yongdok recorded 55.3°C at 3 P.M. on August 29, 1973 with 34.3°C in temperature and 83% in relative humidity. Extreme sultry events were occurred in the year of 1978, 1983, 1984, 1986, 1990, 1994, 1995 and 1996 during POR. The longest duration (22days) of daily maximum HI over 40.6°C continued in Miryang from July 3 to July 24 in 1994. Most extreme HI events above 40.6°C roughly started at the end of Summer Changma and finished before Autumn Changma. Most longest runs of daily maximum HI were recorded in summer 1994.

4. References.

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