

# The Favorable Synoptic Patterns of Heat Waves in Korea

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## 1. Introduction

Hot environment can cause unseen economic loss by slowdown of human activities owing to the accumulation of heat stress. The attack of a strong heat wave to the highly populated urban areas was even evaluated to result in the more fatal damages than any other natural disaster such as flooding or blizzards (Changnon et al, 1996). In reality, the increased mortality by abrupt occurrences of heat wave was very often reported in America and Europe, especially since the 1990s (Craig, 1994; Matzarakis et al, 1997; Smoyer et al, 2000a and 2000b). The Asia is not also an irrelevant area to hazard of heat waves so that the casualties of patients with blood circulation disease (i.e. heat stroke or sun stroke) significantly increased in a ripen summer of 1994 in Japan and Korea (Nakai et al, 1999; Choi et al, 2002a). In addition, efficient alternative of energy usage to prepare for the potential occurrence of heat waves started to be suggested based on the analysis of climate data (Palombo, 2001).

In Korea, climatology of heat stress across South Korea, which shows the general spatial and temporal pattern of the occurrence of heat stress, was examined (Choi et al, 2002b). However, In spite of the importance of prediction of heat waves, the favorable synoptic patterns and mechanisms of the occurrence of strong heat stress in the northeast Asia is little known up to date. Most of domestic researches relevant to hot environments are based only on analysis of the synoptic pattern for occurrence of high temperature and drought (i.e. Byun, 1996).

Thus, this research aimed at defining heat waves that are applicable to the northeast Asia and finding the predominant synoptic patterns to occur this extreme heat wave in Korean peninsular. In the long run, this research tried to offer the basic data that can be used to predict the occurrence of heat waves.

## 2. Data and Methods

Northeast Asia belongs to a monsoon regime so that the summertime shows muggy climate owing to high temperature and humidity. High temperature in the air makes human body stressed through the heat transfer from the air to inner body whose temperature should be constant at 36.7°C. More importantly, low gradient of humidity between the humid air and the surface of sweaty human skin in muggy monsoon regime also interrupts the evaporation of sweat, which is related to the loss of latent heat from the human body. Thus, to define the heat waves for the northeast Asia in this muggy monsoon system, this research used heat index improved by the NWS of the United States, which considered the synergetic effect of high

temperature and humidity of monsoon regime. Based on the guideline of NOAA (1980) and previous research on urban mortality by heat stress in Korea (Choi, 2002), the case when both the daily maximum heat index exceeding 40.6°C and the nocturnal heat index at LST 03h exceeding 26.7°C at least for the consecutive 2 days and in one fourth of weather stations of South Korea (15 among 61 weather stations) was defined as a heat wave episode. This spatial criterion can exclude the case of high heat index that was occurred by local effect. The duration threshold that was used can also fully reflect the characteristics of stagnant heat waves that can significantly influence on human society. Furthermore, the thresholds of heat index used above indicates the magnitude that human possibly gets sunstroke, heat cramps or heat exhaustion and heat stroke by prolonged exposure and physical activities during daytime and, and that human can feel fatigue during the nighttime by prolonged exposure and physical activities (NOAA, 1980)

The synoptic reanalysis data gained from NECP/NCAR (<http://www.cdc.noaa.gov/cdc/data.ncep.reanalysis.html>) was employed to find the favorable synoptic conditions for heat waves. In detail, air temperature, geopotential height, specific humidity, and wind at the level of 1000 hPa, 850hPa, 500hPa, and 200hPa as well as the ocean temperature within 5 meters were analyzed to find the source of the thermal and water vapor advection in the occurrences of heat waves. Additionally, to examine more detailed synoptic pattern of small pressure systems in the northeast Asia that NECP/NCAR data cannot show owing to the sparse spatial resolution, weather charts that were produced by the Japanese Meteorological Administration was also used.

### 3. Synoptic patterns and possible mechanisms of the occurrences of heat waves in Korea

Table 1 summarizes heat wave episodes that occurred in South Korea for the period of record (1973-1998), matching the thresholds suggested above. Except for July 15-16 of 1994, most of heat wave episodes occurred approximately in the period of between summer Changma and another rainy season in the middle of August.

**Table 1 the occurrence record of heat waves in South Korea (1973-1998)**

Year	Month	Date
1978	July	26-27
1983	August	1-3
1984	August	8-9
1990	July	29-30
1994	July	15-16
1994	July	22-23
1994	August	5-6
1996	August	1-2

According to the anomaly of monthly average thickness between 500hPa and 850hPa that each heat wave episode belongs to, a positive signal is predominant over the western part of the Former Soviet Union, Manchuria, and the Korean Peninsular. Interestingly, the anomaly of thickness in the southwest Asia including Iran, Iraq, and Saudi Arabia also shows a strong

positive signal exceeding to 50m, when heat waves emerged in Korean Peninsular. On the other hand, the anomaly of thickness in the northeastern Pacific in 180°E-120°W of longitude and 20°N-50°N shows the strong negative signal by at least 50m in the period of heat waves episodes. The geopotential height at 200 hPa, in all of episodes, shows the strong positive anomalies in Korean Peninsular, while the geopotential height at 500hPa shows the strong negative anomalies in the Okhotsk Sea and the Kamchatka Peninsular.

As an illustration, if we examined the muggy case occurred on the 22nd of July 1994 among 8 heat wave events, in the inner regions of South Korea showed the high air temperature above 36°C. However, high heat index exceeding 44°C appeared rather in regions adjacent to water bodies such as Yangpyeong, Boryeong, and Miryang. The summer in 1994 recorded little precipitation in the beginning of the summer changma. The dry surface could easily become hot by the high temperature. The condition where the Pacific subtropical high was extending along south of the Tibet Plateau to the northern Manchuria also helped the development of heat waves. The core of the Pacific subtropical high was located in the northern Pacific Ocean and The 1470m of geopotential height at 850hPa level extended into the western part of the Pacific that covers the Korean Peninsular.

Interestingly, according to the satellite image, typhoon Walt approached to the southern part of the Korean Peninsular at 06Z on the 22nd of July 1994. The anomaly of specific humidity at 2m above the surface appeared as the positive phase in the regions of 10°N - 35°N of latitude and 110°E-170°E of longitude including most of western part of the Taebaek mountain ridge, the southwestern region of China and the western Pacific near the northeastern Asia. In addition, the low pressure systems developed in the eastern Manchuria and Mongolia respectively. The rest of cases show the similar synoptic pattern like this case.

#### 4. Discussions

The analysis of weather charts for each episode indicates that the predominant synoptic pattern of heat waves in Korean Peninsular initiates with the surge of the subtropical high pressure system. The surged high pressure system contains the humid and hot air mass. Then, the low pressure system starts developing in the eastern part of Manchuria. Another low pressure system follows the former in Mongolia or the Baikal Lake. At the same time, the typhoon, which was originated from the southern region of China or Japan, approaches toward the Korean Peninsular. This structure where those low pressure systems and typhoons surround the high pressure system over the Korean Peninsular can make the hot and humid air stagnant. As a result, stressful heat waves can continue during a couple of days until the typhoon approaches and then gives the rainfall to drop temperature around the Korean Peninsular.

Differently from this pattern, an exceptional heat wave episode among all cases occurred on August 1-3 1983. In this case, a Changma front moved into the northern part of the Korean Peninsular and stagnated in the Manchuria during several days. The stagnant Changma front helped the high pressure to stay longer in its southern part without the influence of any low pressure system and typhoon. Of course, however, the heat wave system in this case was withered by the retreat of the Changma front back to the south.

The source of water vapor to arise the humidity for heat waves system may come from the warm ocean surrounding the Korean Peninsular. The distribution of ocean temperature anomaly within the 5 meter shows that sea surface temperature (SST) in each episode was abnormally

higher by 2-4°C than the normal. This warm ocean may offer the favorable condition that humidity in the air increases. The ENSO is the major mechanism in the Pacific. The distribution of SST is associated with the seesaw system of El Nino-La Nina. Every heat wave episode found in this research commonly occurred in the shifting period between El Nino and La Nina. The large scale of ocean circulation made the SST of the northwestern Pacific abnormally higher. Ultimately, the ocean circulation may also plays an important role in occurring heat waves in the Korean Peninsular.

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