

A Study on the Influence of Heat Wave and Cold Wave Characteristics and Vulnerable Areas in Busan, Ulsan and Gyeongsangnam-do

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Introduction

According to the IPCC report, greenhouse gas emissions continue to increase, resulting in frequent extreme weather phenomena worldwide. In particular, heat waves are often strong during extreme weather events. In Korea, the heat wave has been included in natural disasters since 2018 as not only social damage but also human casualties have occurred. In this study, weather observation data related to the summer (June to August) heat wave in Busan, Ulsan and Gyeongsangnam-do were analyzed to identify the weather conditions for the heat wave. In addition, the effects of heat wave by sector were analyzed in relation to the heat wave impact forecast currently being implemented by the Korea Meteorological Administration. Meanwhile, from 2018, cold waves will also be included in natural disasters, and research will be needed to match local characteristics. Weather conditions of cold wave occurrence were identified by dividing cold file water in Busan, Ulsan, and Gyeongsangnam-do into three temperature ranges depending on the time of increase of cold-related patient. In preparation for the cold wave impact forecast service that will take effect in December, the government plans to investigate cases of damage from cold wave in different areas and analyze the impact from each vulnerable area to set the critical values for cold wave impact forecast in Busan, Ulsan and Gyeongsangnam-do.

Data and Method

- Analysis of heat wave and cold wave characteristics
 - Analysis of the Temperature Correlation between High-Rise Observation Data and Ground Meteorological Observation Data in the Last 4 Years(2015-2018)
 - [High-rise] Temperature data from Changwon point 925hPa, 850hPa(09, 15, 21KST)
 - [ground] maximum temperature at Changnyeong point, lowest temperature at Geochang point, wind direction and wind speed(excluding measured value)
- Analysis of the impact of Heat Wave Vulnerabilities
 - Analysis of impact by sector(health, livestock, fisheries, agriculture and industry) in the last 7 years(2012-2018)
 - risk level of heat wave impact forecast
 - [No Severe Weather] 31°C, [Be Aware] 33°C, [Be Prepared] 35°C [Take Action] 38°C
 - the Number of heat-related patient, the number of livestock died, heat damage to fish-farming, heat damage by crops

Weather Conditions in areas with frequent heat and cold waves in Busan, Ulsan and Gyeongsangnam-do

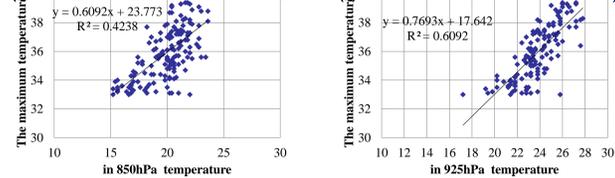


Fig. 1 The maximum temperature correlation. (a) in 850hPa, 21KST, (b) in 925hPa, 15KST

Correlation Analysis between High-Rise Temperature and Ground Maximum Temperature

- 850hPa Tem. – Ground Max. Tem.
 - 21KST > 15KST > 09KST
- 925hPa Tem. – Ground Max. Tem.
 - 15KST > 21KST > 09KST

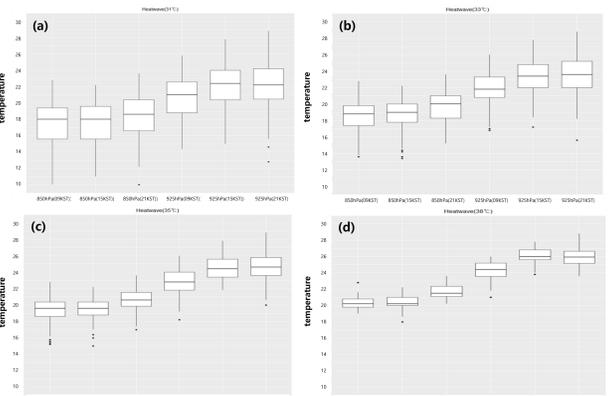


Fig. 2 The case Analysis of the upper temperature in 850hPa and 925hPa in Changwon about the maximum temperature ((a) 31°C, (b) 33°C, (c) 35°C, (d) 38°C) in Changnyeong

Table. 1 Risk table of heat wave levels

The Maximum Temperature (Risk Level)	Critical Value (%ile)	Impact	850hPa Tem. (°C)	925hPa Tem. (°C)
38°C (Take Action)	50	High probability	22	26
	25	Possible occurrence	21	25
35°C (Be Prepared)	50	High probability	21	24
	25	Possible occurrence	20	23
33°C (Be Aware)	50	High probability	20	23
	25	Possible occurrence	18	22
31°C (No Severe Weather)	50	High probability	18	22
	25	Possible occurrence	16	20

Correlation Analysis between High-Rise Temperature and Ground Maximum Temperature

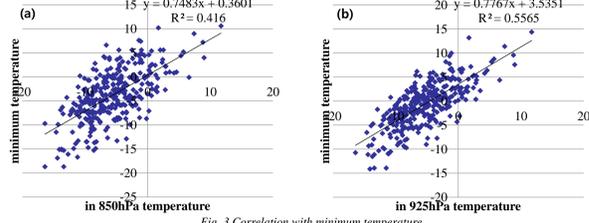


Fig. 3 Correlation with minimum temperature (a) in 850hPa and the previous day 21KST, (b) in 925hPa and the previous day 21KST

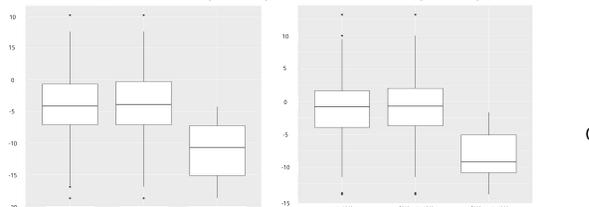


Fig. 4 Geochang Correlation with minimum temperature (a) in 850hPa and the previous day 21KST, (b) in 925hPa and the previous day 21KST

The Lowest Temperature	Critical Value (%ile)	Impact	Day before 850hPa Tem.(°C)	Day before 925hPa Tem.(°C)
6°C	50%ile	High probability	-4	-0.7
	25%ile	Possible occurrence	-0.4	1.6
0°C	50%ile	High probability	-4.2	0.8
	25%ile	Possible occurrence	-0.7	1.6
-12°C	50%ile	High probability	-10.9	-9.1
	25%ile	Possible occurrence	-7.1	-5.1

Table. 2 Risk table of cold wave levels

Correlation Analysis between High-Rise Temperature and Ground Maximum Temperature

- 850hPa Tem. – Ground Max. Tem.
 - Day before 21KST > 09KST > 21KST
- 925hPa Tem. – Ground Max. Tem.
 - Day before 21KST > 09KST > 21KST

Analysis of wind direction and wind speed characteristics by minimum temperature range

- Less than 6°C, Less than 0°C (fig 12 reference)
 - NNW > W > NW
- Less than -12°C (special weather report)
 - N > NNW > NNE
- The stronger the cold wave, the weaker the wind speed

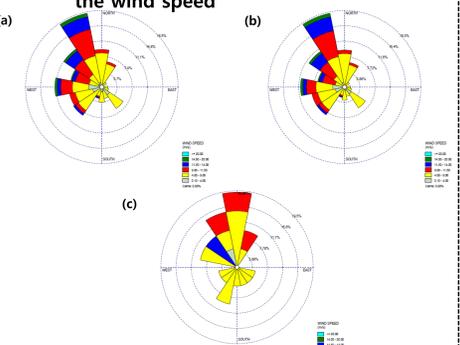


Fig. 5 Geochang windrose of temperature (a)below 6°C, (b) below 0°C and, (c) below -12 °C

Analysis of the Heat Wave Impact in Busan, Ulsan and Gyeongsangnam-do

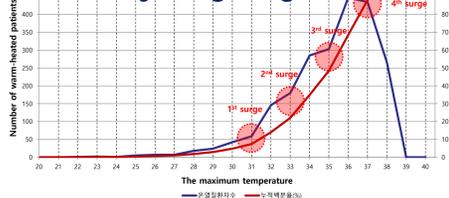


Fig. 6 The number of patients with the maximum temperature of each day for 7 years(2012-2018year) in Busan, Ulsan and Gyeongnam

[The field of health] Cumulative Percentage of Heat-related Patients by Maximum Temperature

- A tendency to increase rapidly in four sections
 - 31°C(cumulative 10%), 33°C(cumulative 20%), 35°C(cumulative 50%), 37°C(cumulative 90%)
- Same as the risk level for heat wave impact forecast except for the 'Take Action'

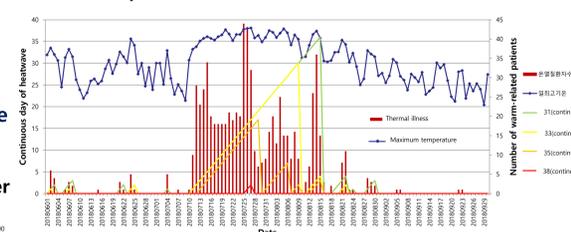


Fig. 7 The number of heat-related patients during continuous days of heatwave in 2018 In Busan, Ulsan and Gyeongnam

[The field of livestock] Cumulative Percentage of number of livestock deaths by Maximum Temperature

- Similar trend to the field of health
 - 30°C(cumulative 5%), 33°C(cumulative 20%), 35°C(cumulative 50%), 36°C(cumulative 80%)
- Compared to Forecast of heat wave impact Standard temperature by risk level, 'No Severe Weather' is 1 degree lower and 'Take Action' is 2 degree lower

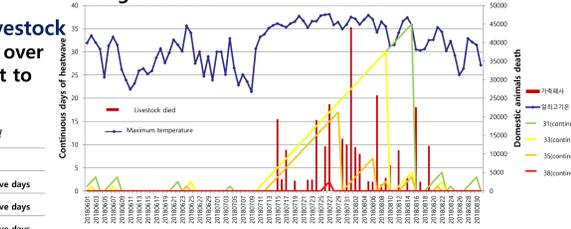


Fig. 9 The number of domestic animals death during continuous days of heatwave in 2018 in Busan, Ulsan and Gyeongnam

The relationship between the number of consecutive heat waves and the occurrence of heat-related diseases

- Highly correlated with the incidence of thermal illness when consecutive days over 35 degrees are continuous

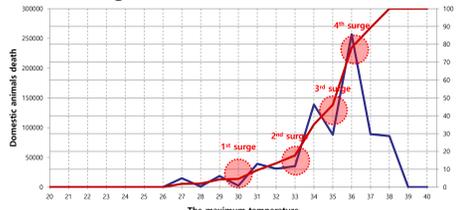


Fig. 8 The number of domestic animals death with the maximum temperature of each day in the last 7 years(2012-2018) year

The relationship between the number of consecutive heat waves and the death of livestock

- It tends to increase when consecutive days over 35 degrees are continuous, but it is difficult to find distinct features.

Table. 3 Criteria for determination of heat wave impact prediction by risk level

Risk Level	기준
관심	Daily maximum temperature 31 or more for 3 consecutive days
주의	Daily maximum temperature 33 or more for 2 consecutive days
경고	Daily maximum temperature 35 or more for 2 consecutive days
위험	Daily maximum temperature 38 or more for 2 consecutive days

Analysis of the Cold Wave Impact in Busan, Ulsan and Gyeongsangnam-do

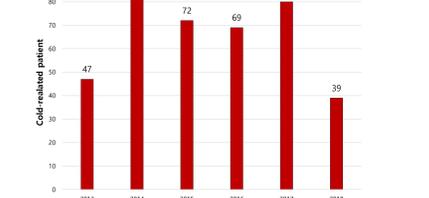


Fig. 10 The annual number of cold-related patients for the last 6 years (2013-2018) year In Busan, Ulsan and Gyeongnam

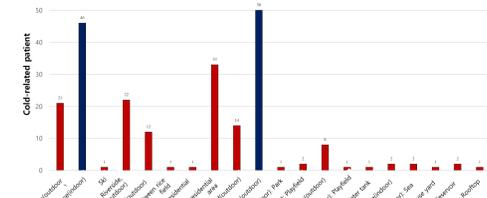


Fig. 11 The station distribution of cold-related patients in the last 6 years(2013-2018) year In Busan, Ulsan and Gyeongnam

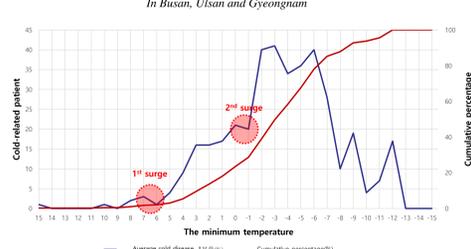


Fig. 12 The number of cold-related patients by temperature for the last 6 years(2013-2018) year In Busan, Ulsan and Gyeongnam

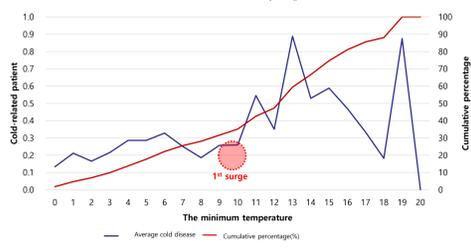


Fig. 13 The number of cold-related patients and number of files(below 0°C) in the past 6 years(2013-2018) year In Busan, Ulsan and Gyeongnam

- The number of cold disease patients according to the duration of the cold wave
 - When the number of cold files continued for 10 days in a row, the number of cold disease increased rapidly

- It shows twice the tendency of the outbreak of cold patients.
 - 1st soaring section: 5~7°C
 - 2nd soaring section: 0°C

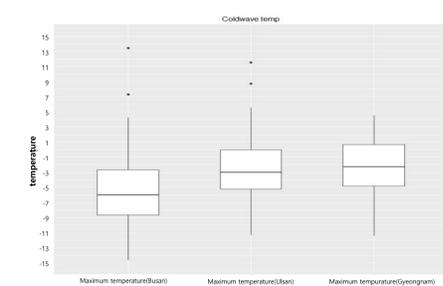


Fig. 14 critical temperature for cold-related patients in Busan, Ulsan and Gyeongnam

- Minimum temperature threshold of cold disease outbreak(25%ile)
 - Gyeongnam, Ulsan: 0°C
 - Busan: -2°C

Result

This study analyzed the weather conditions of heat and cold weather in Busan, Ulsan and Gyeongsangnam-do using high-rise temperature, ground temperature, wind direction, and wind speed. The heat wave appeared to be related to the temperature of 21 KST at 850 hPa and the correlation between the temperature of 15 KST at 925 hPa and the maximum temperature(Changnyeong) at R²=0.42 and R²=0.61, respectively. The risk levels of the heat wave impact forecast for each sector were about the same based on the health sector, but they differed by 1 to 2°C. Cold waves appeared to be linked a day earlier with the correlation between 21 KST temperatures of 850 hPa and 925 hPa and the lowest temperature(Geochang) of R²=0.42 and R²=0.56, respectively. The possibility of cold wave was high when wind direction was close to north wind and wind speed was weak. Cold-related patient numbers surged when the cold spell lasted 10 days in a row. Cold-related patients tended to develop in Ulsan and Gyeongsangnam-do from 0°C and in Busan from -2°C.