Towards Evidence-Based Climate Change Adaptation Policies for Heatwave

Yeora Chae

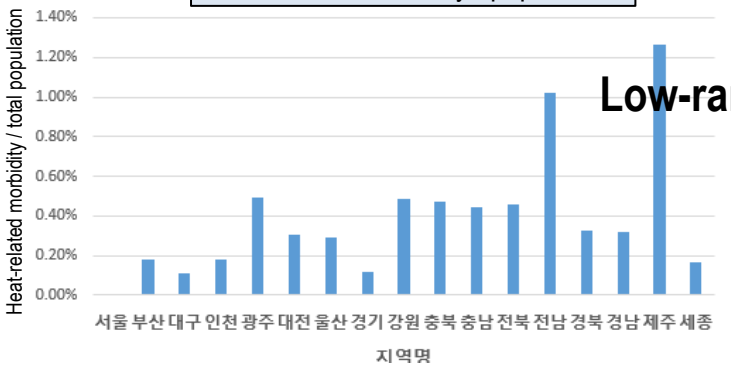
KEI 한국환경정책·평가연구원
Korea Environment Institute

01. Background

☐ Heatwave Damage (2017)

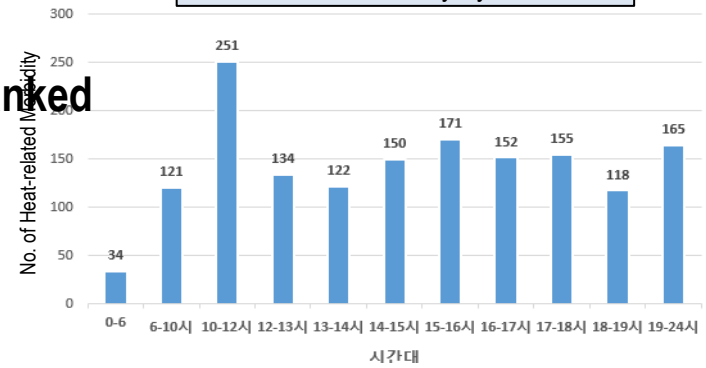
- Heatwave Damage [~07 of September, CDC(2017)]
  - Morbidity: 1,537
  - Mortality: 11
- Characteristics of Heat-Related mortality
  - Time Zone: 10:00-12:00 〉15:00-16:00 〉19:00-24:00 〉17:00-18:00
  - Age Group: 50s(24%) 〉40s(17%) 〉 60s(15%) 〉 70s(11%)
  - Place: Workshop(31%) 〉 Field(17%) 〉Roads(10%) 〉Playground(6%)

Heat-related morbidity / population

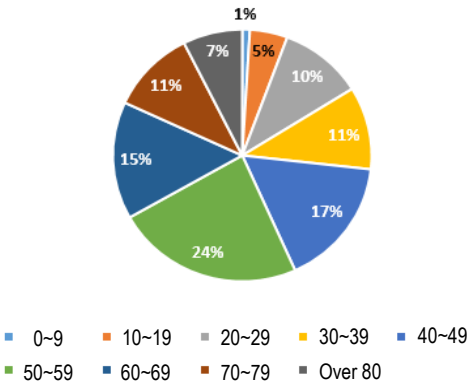


Low-ranked

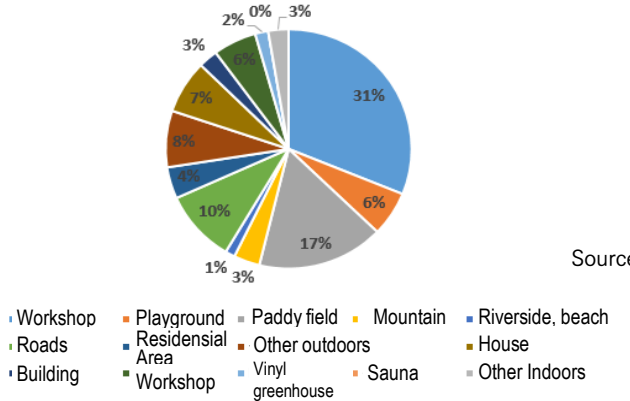
Heat-related morbidity by time zone



Heat-related mortality by age



Heat-related mortality by place



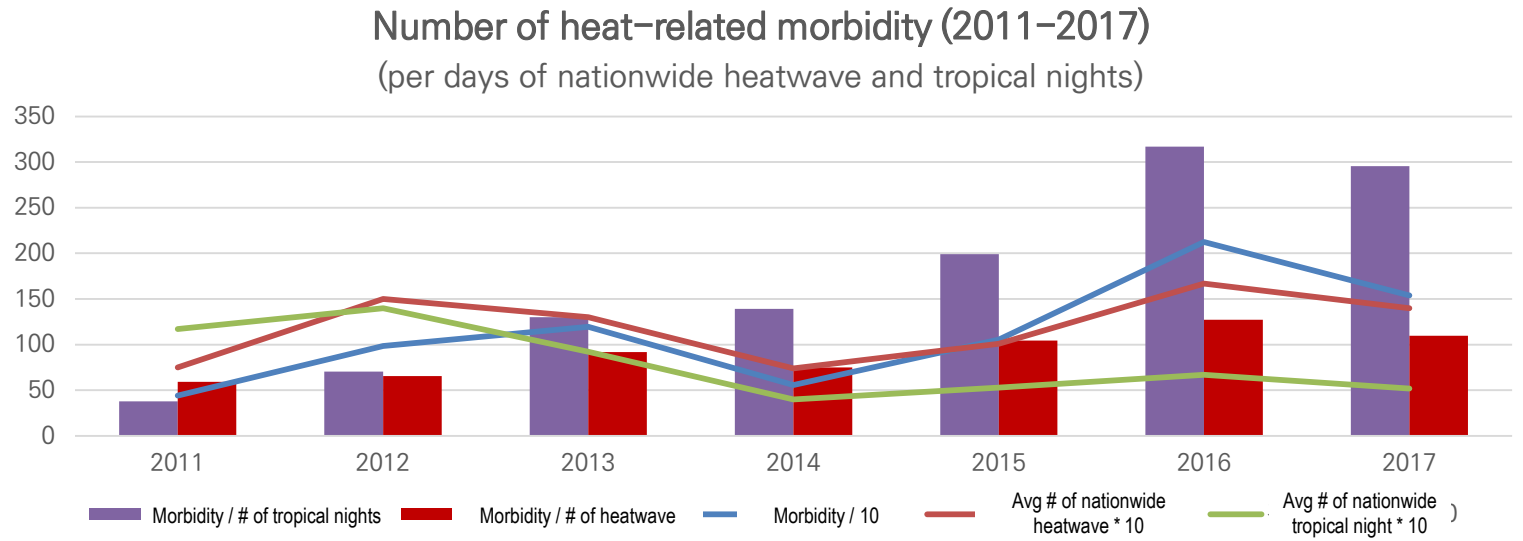
Source: CDC(2017)

01. Background

☐ Need for customized adaptation policies

○ National, metropolitan, local governments have established adaptation plan based on vulnerability assessment in order to reduce climate change damage

- Little evidence on how current adaptation plan reduces actual vulnerability (IPCC, 2014)
- Difficulties in understanding the processes and drivers of vulnerability (Ford et al., 2016)
  - Current vulnerability assessment system includes only some factors of the adaptive capacity indexes, such as the number or existence of the resources(the number of civil servants, facilities, and etc.)
- Limits to establish adaptation plan with the regional characteristics and the needs of residents(Kim, Do-woo, 2014)



01. Background

☐ Customized adaptation plan using big data

○ Climate change

- A cross-cutting issue over economy, society, environment, politics, and etc.
- Need for integrated approaches
- Big data: regarded as an opportunity in climate change adaptation
  - Applying detailed temporal and spatial changes of society, economy, and environment
  - Identifying the processes and drivers of vulnerability formation
  - High-resolution spatial data, such as image from satellite and drone
    → Analyzing spatially vulnerable and hazardous areas by changing climate of sub-regions (Ford et al., 2016)
  - Attracting the interests of the people, identifying issues, and drawing the public reaction, participation, cooperation, and consensus (Kim, Mi-jeong et al., 2013)

01. Need for Big data-based heat-related morbidity analysis

	Factor	Key findings	Author(year)
Social Factors	Sex	Men are less likely to suffer from heatwave than women	Park, et al.(2008)
	Age	Number of deaths of the age of 65 or more is approximately 1.5 times as high as that of the age under 65	Park, et al.(2008)
	Disease	Cerebrovascular disease, Cardiovascular disease, hyperthermia	Park, et al.(2008)
	Income	The lower the income level, the more vulnerable to heatwave	Kim and Joh(2006)
Environmental Factors	Temperature	Daily maximum temperature, Daily minimum temperature, Heat Index, Increase of the days of heatwave duration	Park, et al.(2008) Lee, Sara(2010) Lee, et al.(2010) Kim, et al(2014) Shin, Donghee(2015)
	Temperature Index	Heat Index, perceived temperature index, wind chill temperature index	Lee, et al.(2014) Lim, Soojeong and Lee, Seungho(2016)
	Air mass	very hot and very dry air mass, hot and humid air mass	Lee, et al.(2010)
	Urbanization	The incidence of heat-related morbidity in rural areas is higher than that in cities	Kim, et al.(2014)
	Land cover	Agricultural area and urbanization area	Park, et al.(2016)

Source: re-organized by author based on references

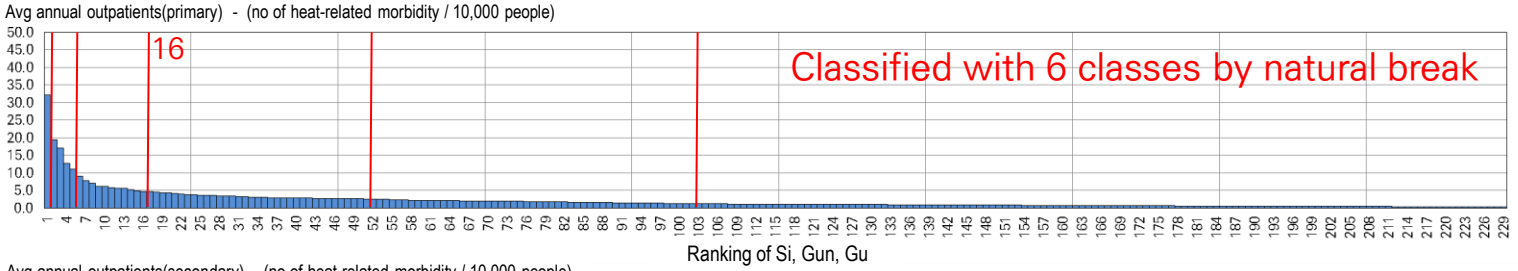
02. Data and Methodology

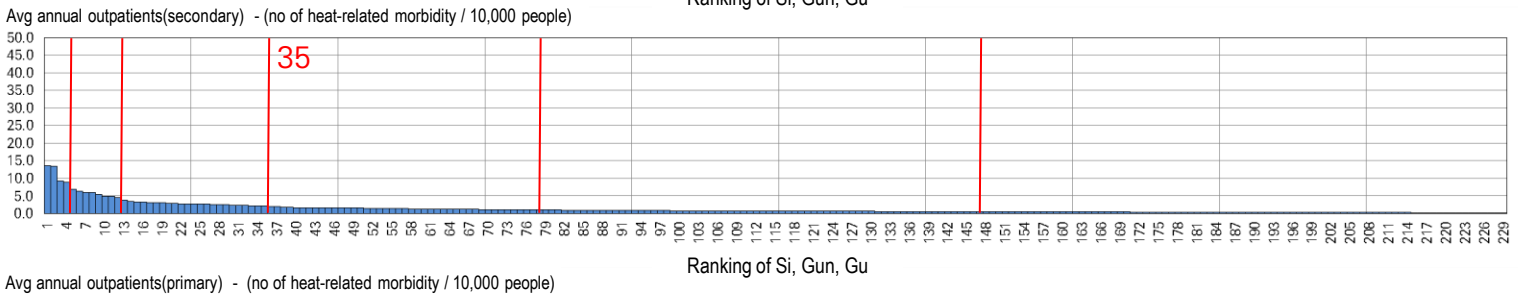
☐ Health and Medical big data

High values appear in some regions

〈Ranking by City / Town〉

NHIS





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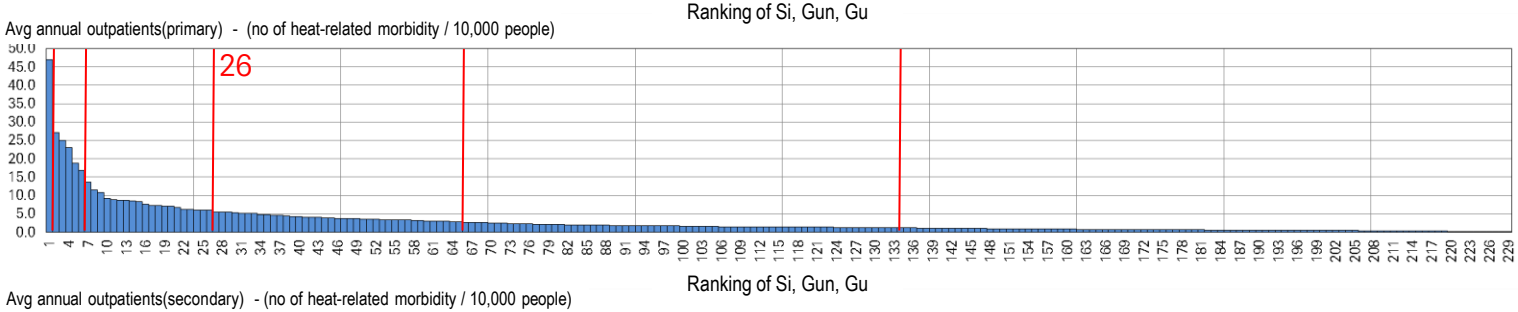
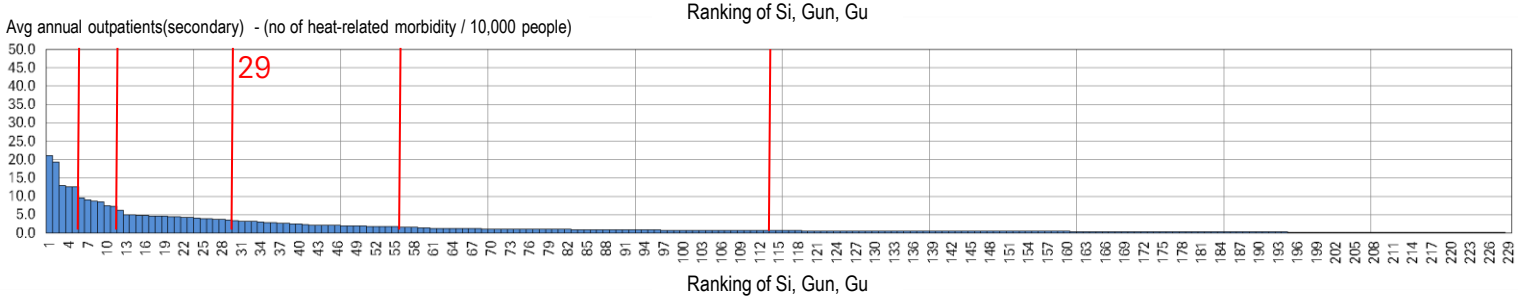
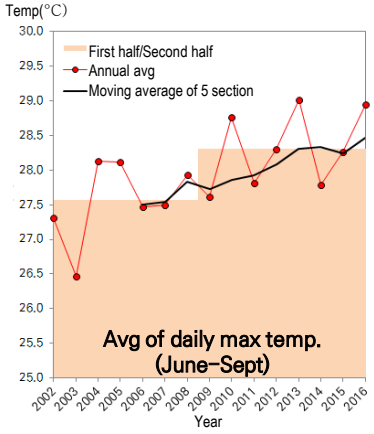


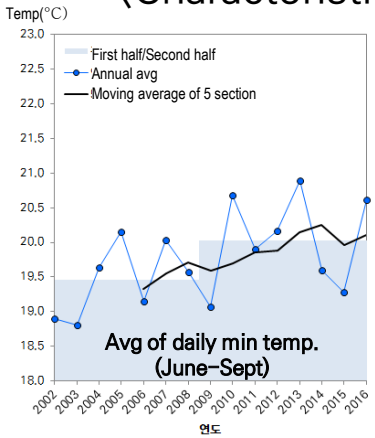


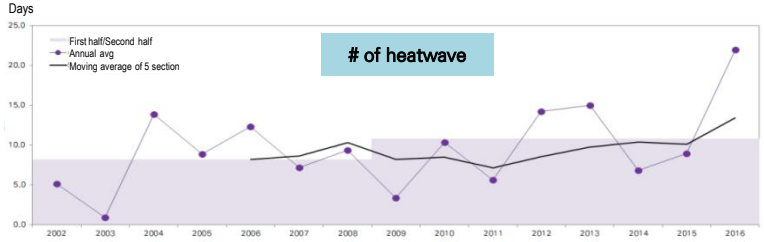
02. Data and Methodology

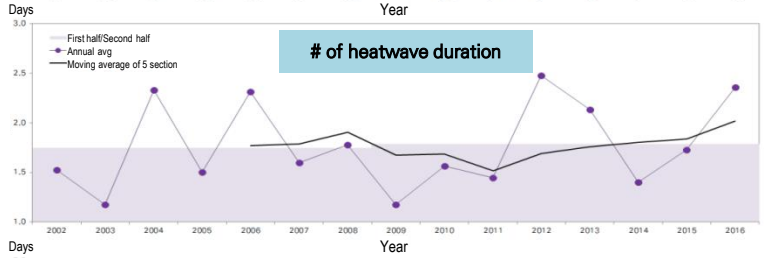
☐ Temperature Data

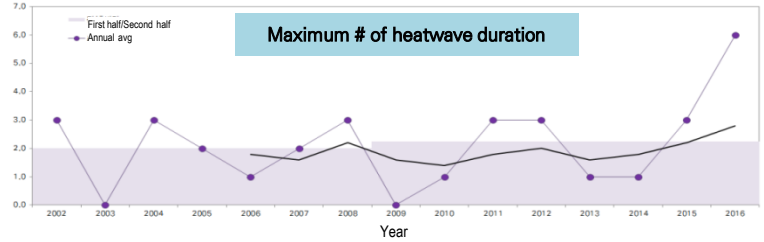
〈Characteristics of Temperature〉

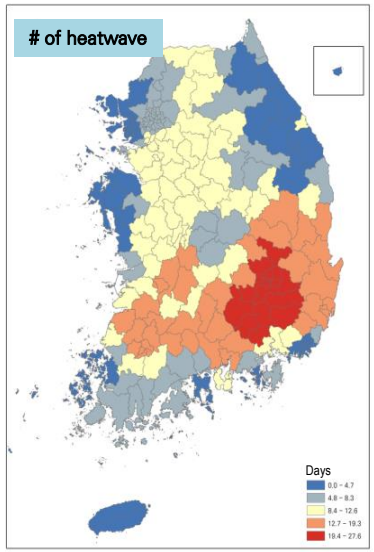


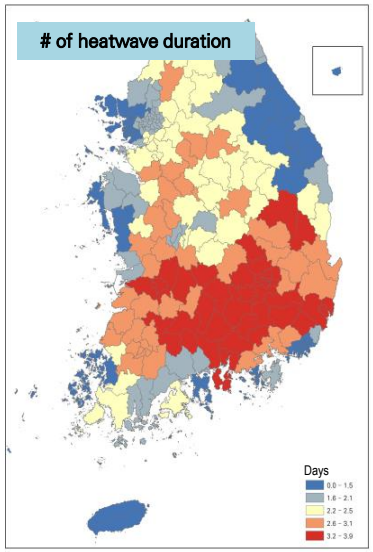


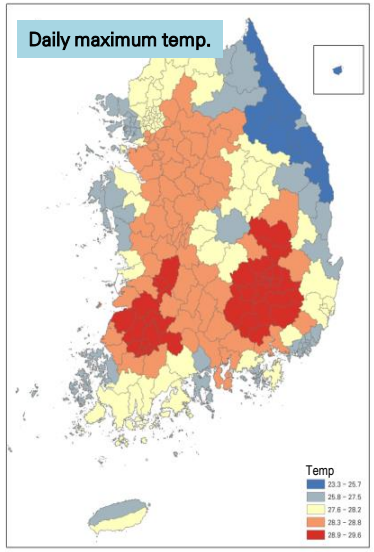


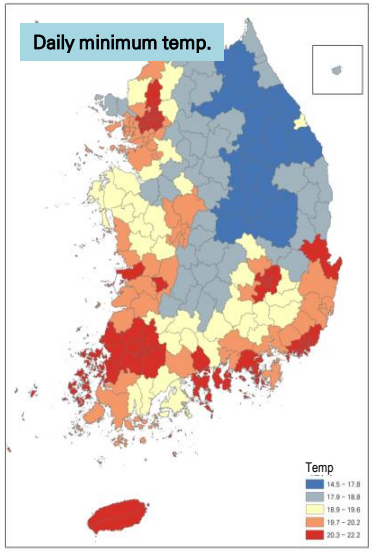










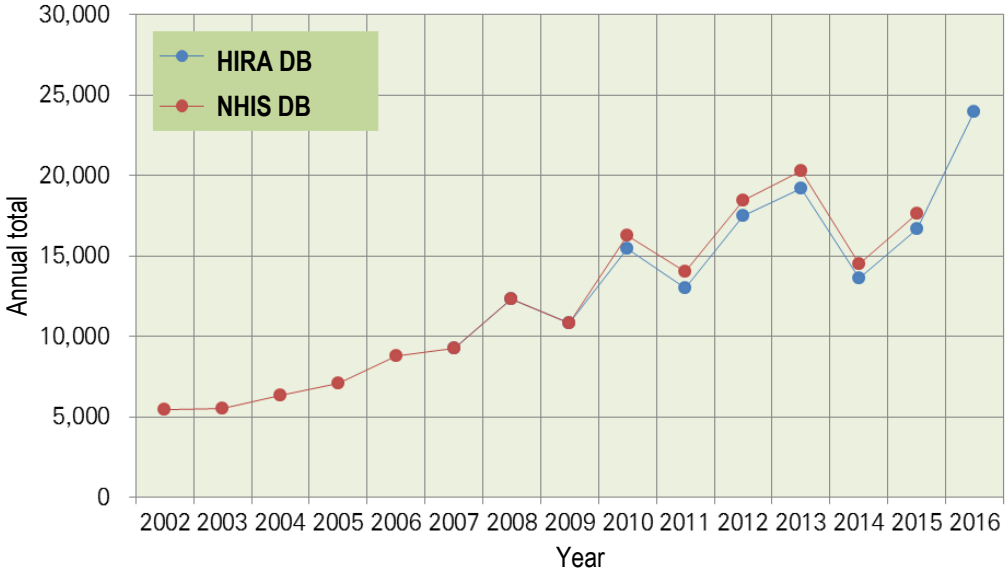


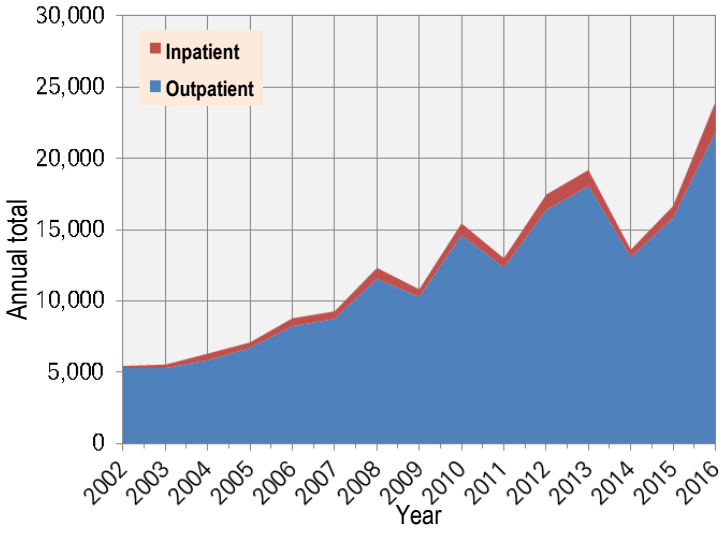
Used average area of 59 stations

03. Characteristics of heat-related morbidity

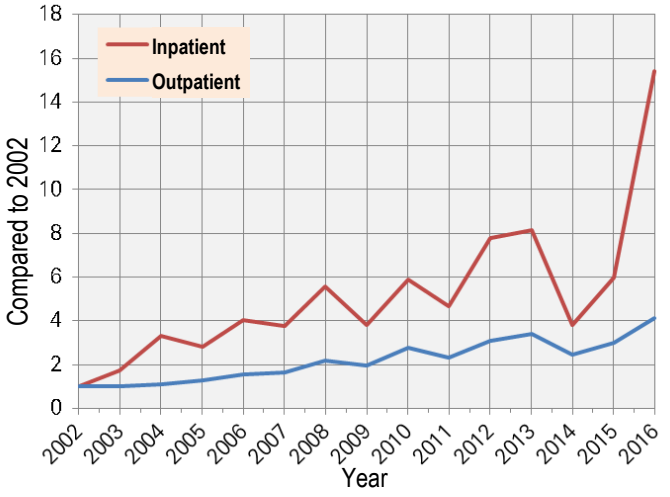
☐ Characteristics of nationwide outbreak

〈Annual total outbreak〉





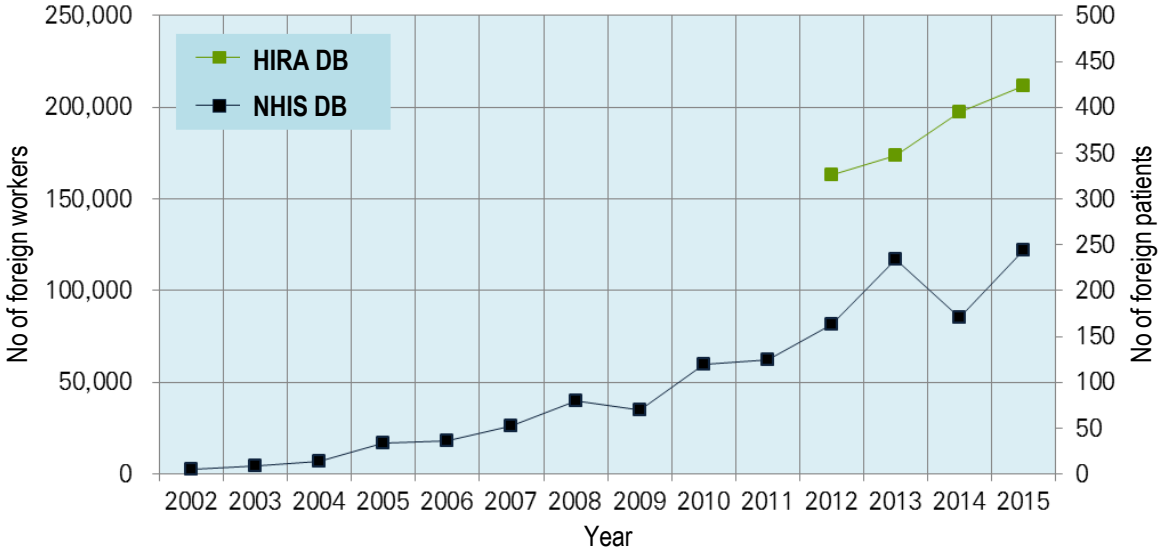
- Heat-related morbidity has steadily increased
- Most of the total outbreaks are outpatients
- Up to 4 times more outpatients compared to 2002
- Up to 16 times more hospitalized patients compared to 2002

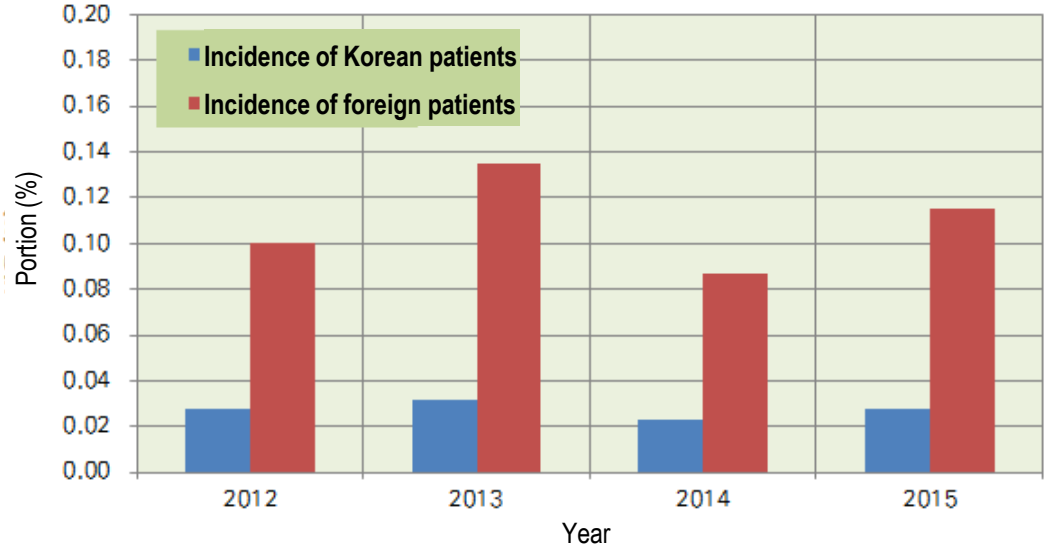


03. Characteristics of heat-related morbidity

☐ Characteristics of nationwide outbreak

〈Incidence of foreigners〉





- Foreigners account for less than 1.5% of the total

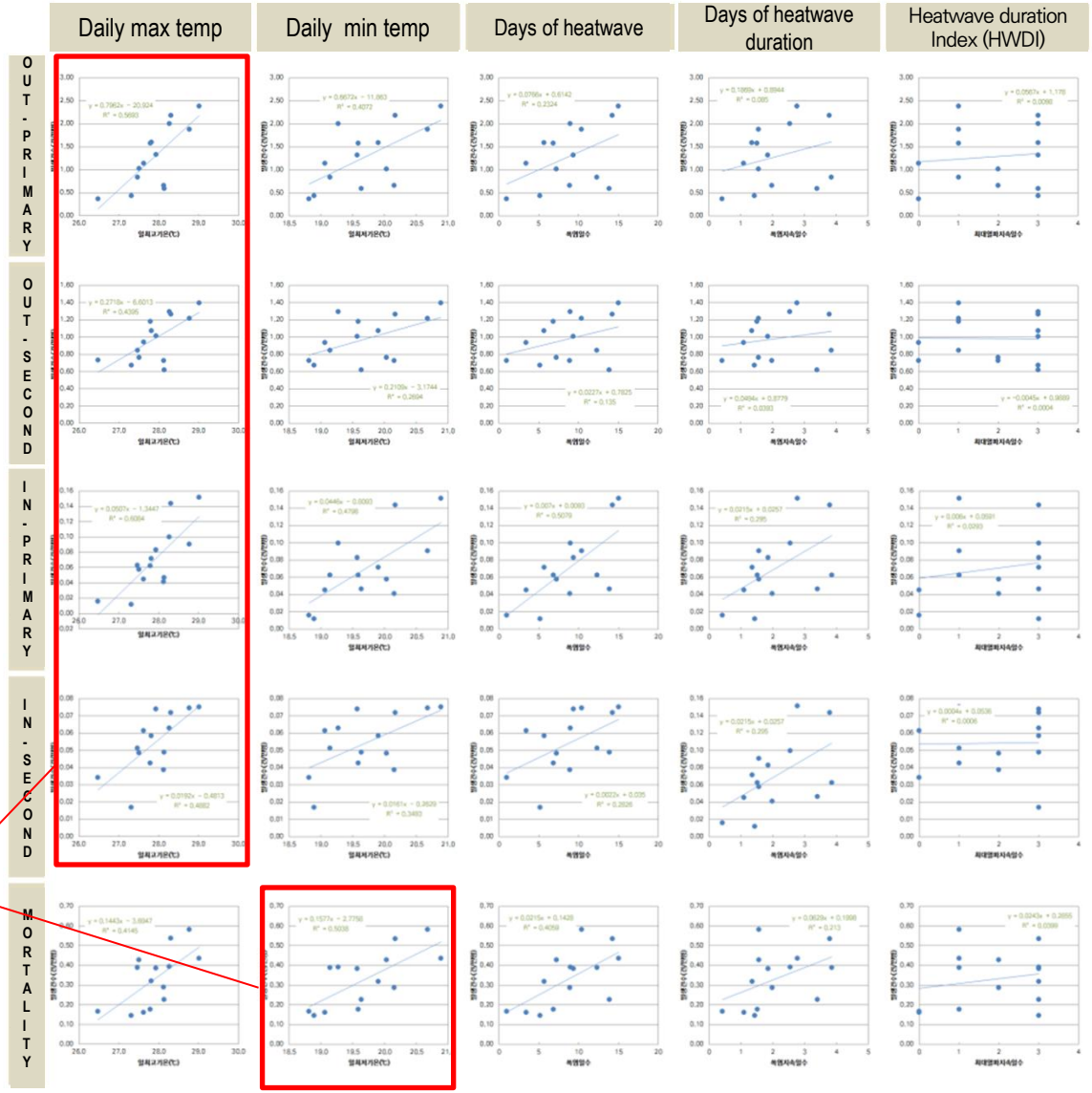
- The incidence of foreigners is four times that of Koreas aged 20-64

- Source:
* Foreigners: Korea Employment Information Service
* Total patients and population: Age of 20 to 64

03. Characteristics of heat-related morbidity

☐ Characteristics of nationwide outbreak

〈Relation between nationwide annual avg of heat-related morbidity/mortality and temperatural environment〉



The highest coefficient of determination

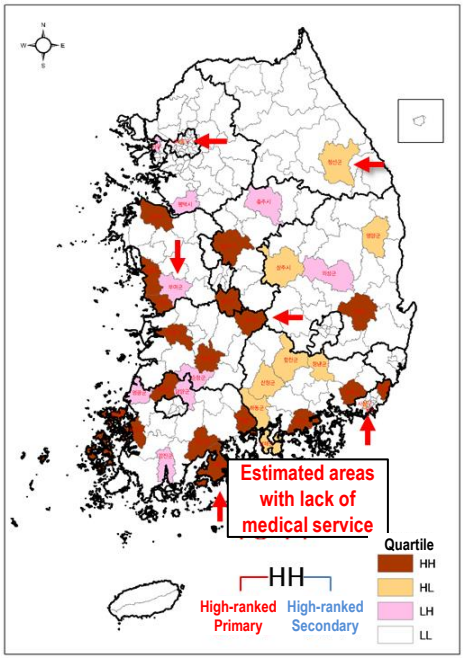
03. Characteristics of heat-related morbidity

☐ Characteristics by region

〈High-ranked regions 2007~2015〉

Outpatient

NHIS



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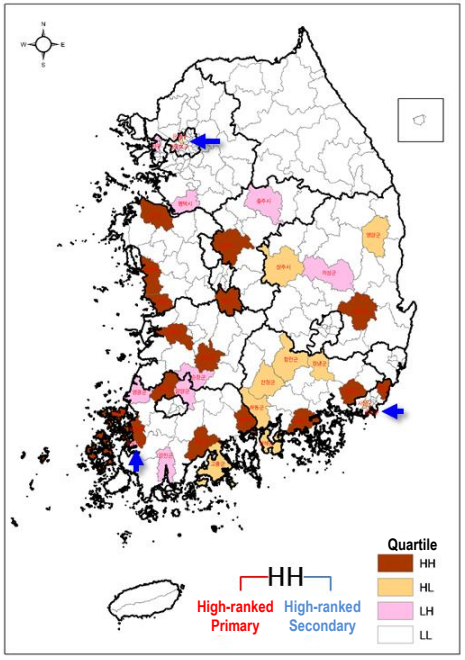
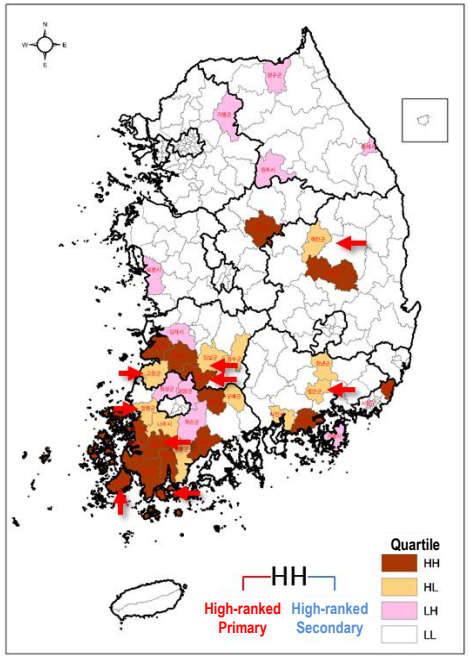


Inpatient

NHIS



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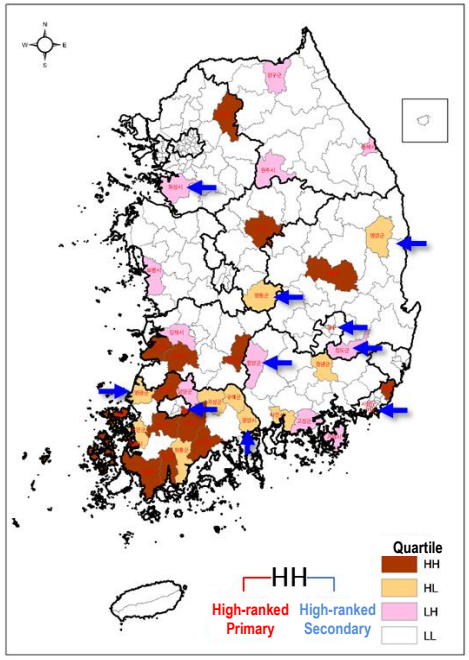
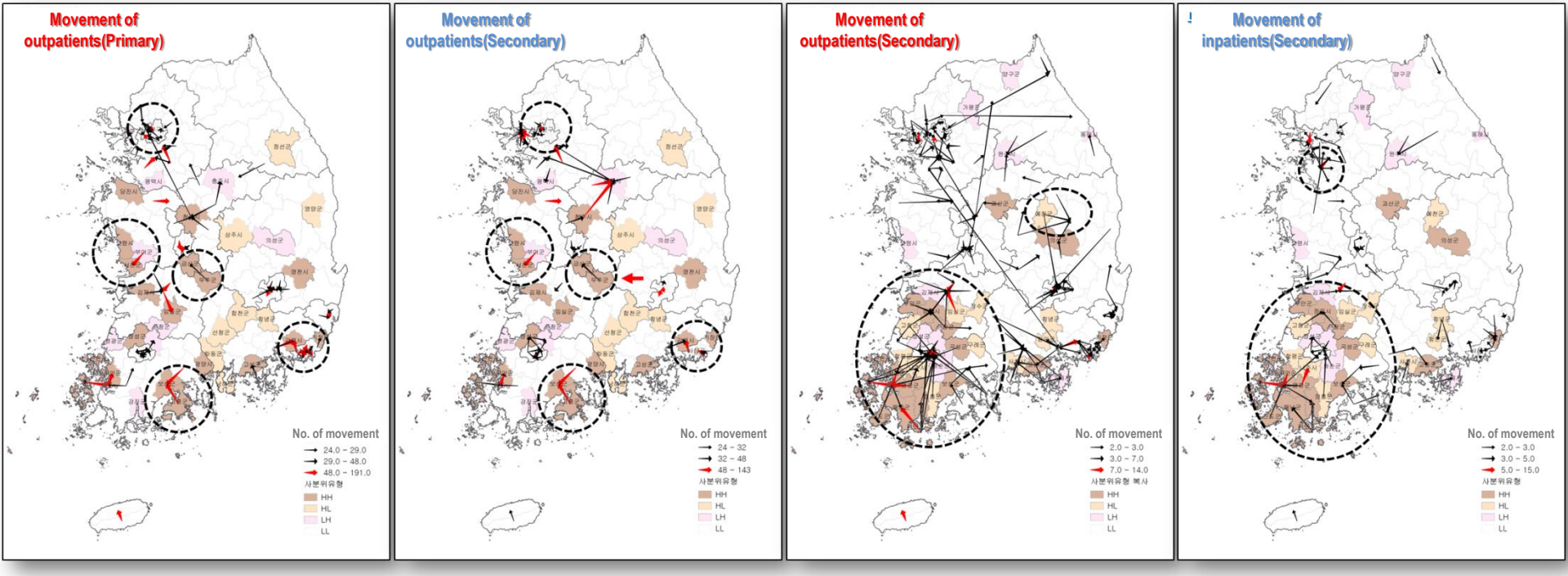


- Estimated areas with lack of medical service
- Estimated areas as Medical service supplied

03. Characteristics of heat-related morbidity

☐ Characteristics by region

〈Analysis of the movement from residence to treatment region (2002~2015)〉



*Movement from regions with lack of medical services to surrounding regions

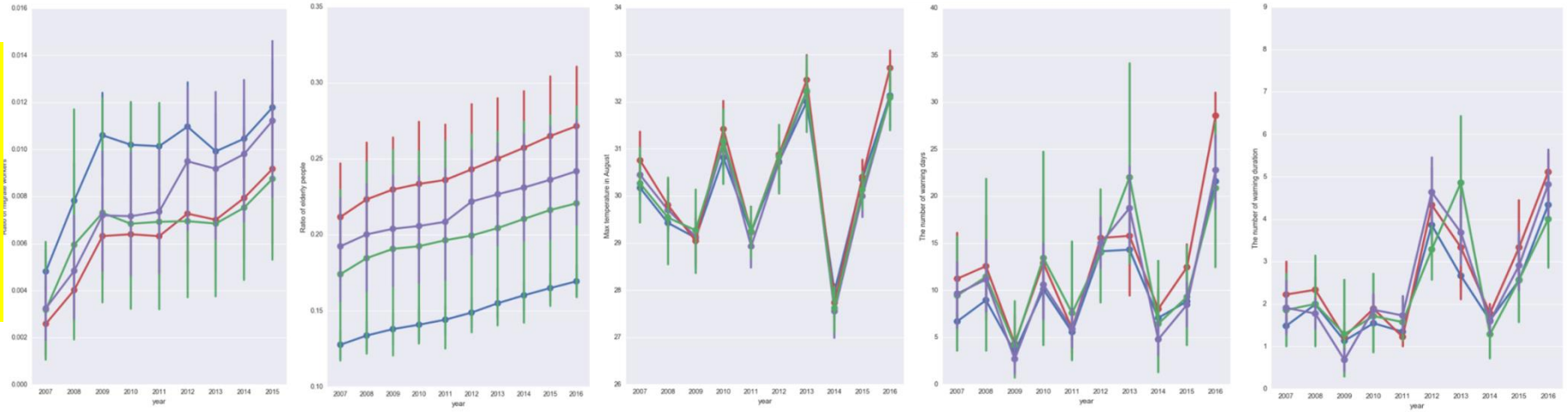
03. Characteristics of heat-related morbidity

☐ Characteristics by region

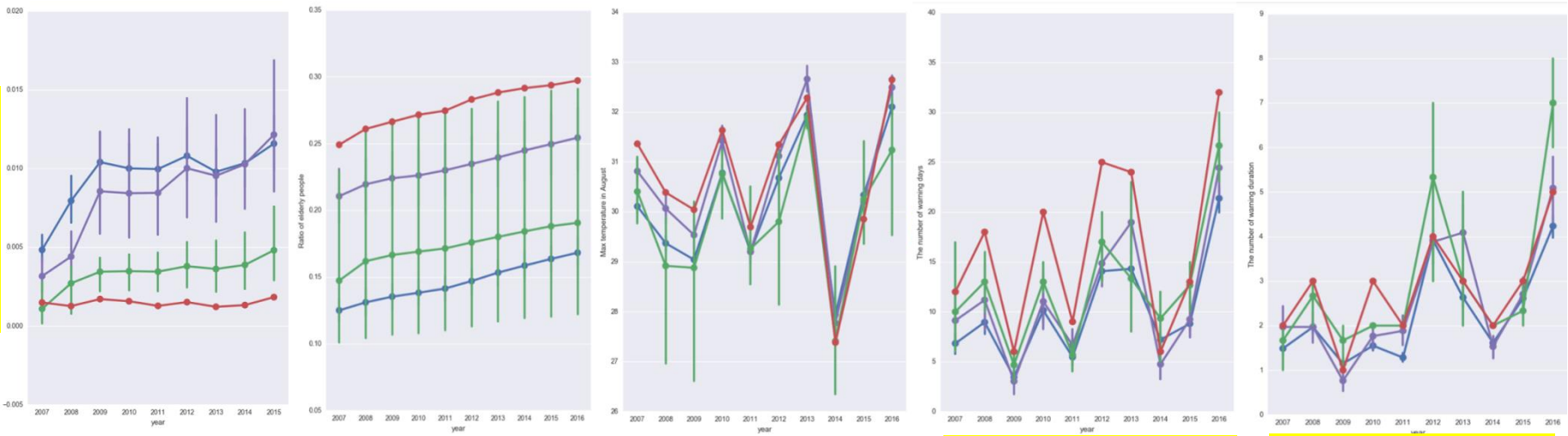
〈Comparison of socioeconomic change by timing of inclusion into High-ranked regions〉

Low rank
High rank (Recent)
High rank (Past)
High rank (Whole)

NHIS OUT



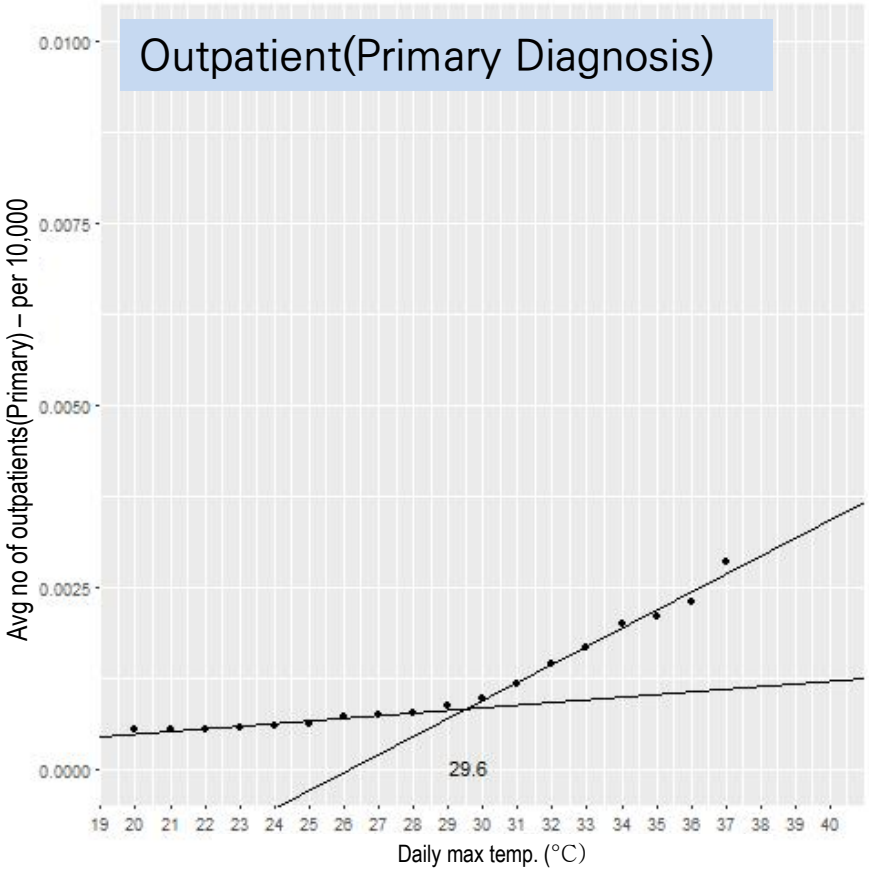
NHIS IN

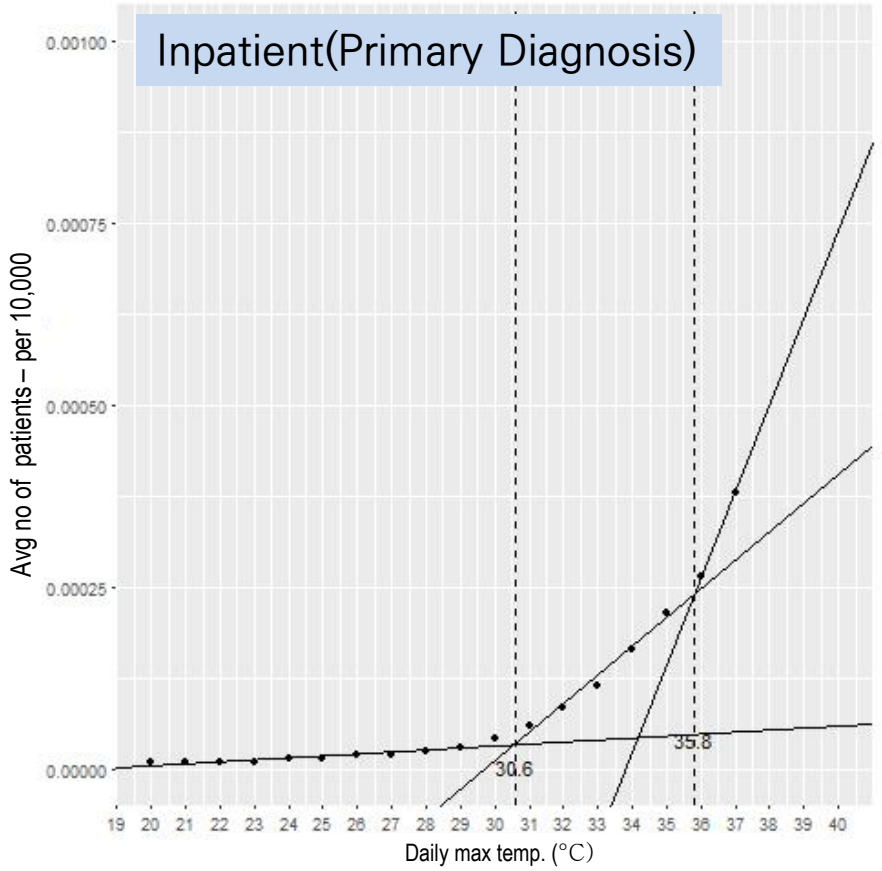


Ratio of foreign worker	Ratio of population aged over 65	Avg of daily max temp. (Aug)	# of heatwave	# of heatwave duration

☐ Threshold temperature of heat-related morbidity

〈Nationwide avg threshold temp. of the outpatient and inpatient〉





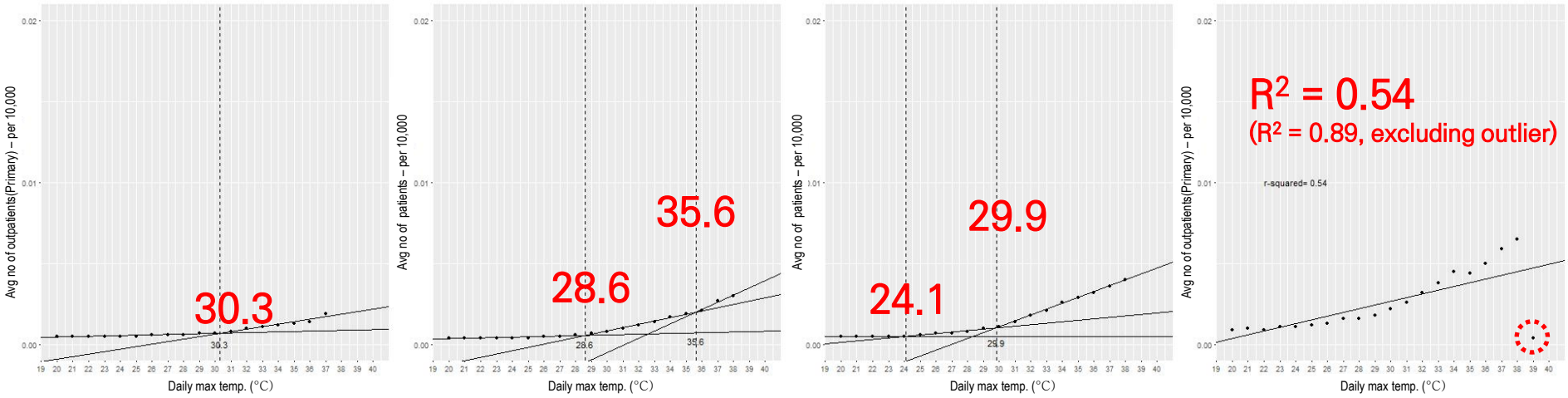
Threshold temp.: Nationwide avg of daily max temperature, approx. 30°C

03. Characteristics of heat-related morbidity

☐ Threshold temperature of heat-related morbidity

〈Threshold temp for outpatients by age(Primary diagnosis)〉

Under 30s	40s	50~64	Over 65

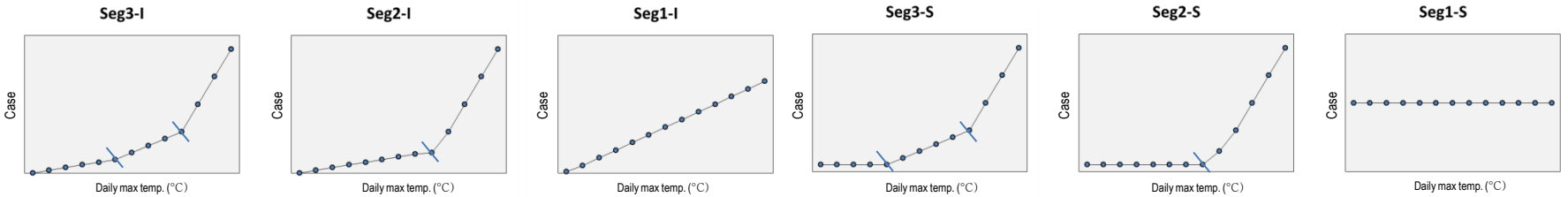


The older the age, the lower the threshold temp → Linear increase

03. Characteristics of heat-related morbidity

☐ Threshold temperature of heat-related morbidity

〈6 main patterns of heat-related morbidity by temperature〉



Outpatient(Primary)

	seg3	seg2	seg1
I	22	50	29
S	47	69	12

Outpatient(Primary)

	seg3	seg2	seg1
I	3	5	3
S	37	131	50

Type of high-ranked region

	seg3	seg2	seg1
I	3	8	10
S	3	3	1

Type of high-ranked region

	seg3	seg2	seg1
I	2	1	3
S	7	12	3

- Seg3-I: Changnyeong, Seocheon, Hadong
- Seg3-S: Sangjoo, Gwangyang, Jangseong
- Seg2-I: Goseong, Boryeong, Mooan, Hapcheon, Damyang Sasang-Gu, Gijang-Gun, Sancheong
- Seg2-S: Namhae, Youngcheon, Gimhae
- Seg1-I: Imsil, Goheung, Shinan, Boseong, Dangjin, Jeongsun, Gimje, Geumsan, Moojoo, Youngyang,
- Seg1-S: Cheongjoo

- Seg3-I: Shinan, Haenam
- Seg3-S: Jeongeup, Wando, Gochang, Imsil, Hampyeong Goryeong, Mokpo
- Seg2-I: Jangheung
- Seg2-S: Mooan, Gurye, Gokseong, Soonchang, Najoo, Boseong, Sacheon, Jindo, Buan, and etc.등
- Seg1-I: Jangsoo, Gangjin, Changnyeong
- Seg1-S: Euiseong, Gijang, Gapyeong

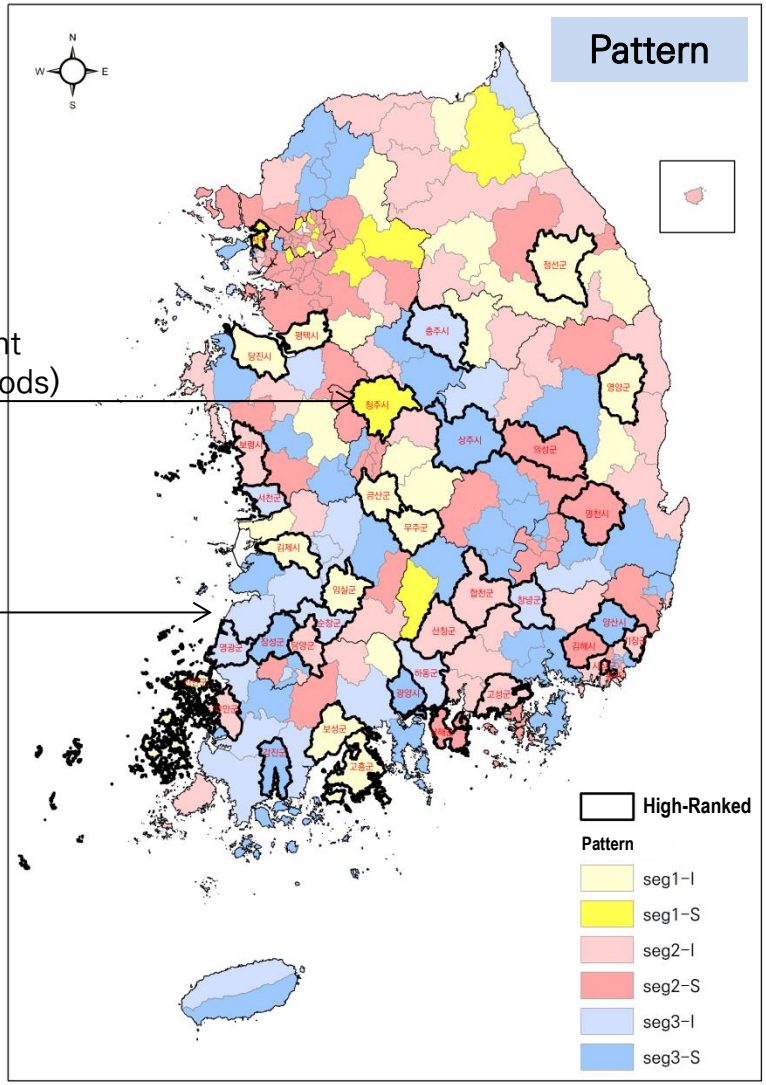
03. Characteristics of heat-related morbidity

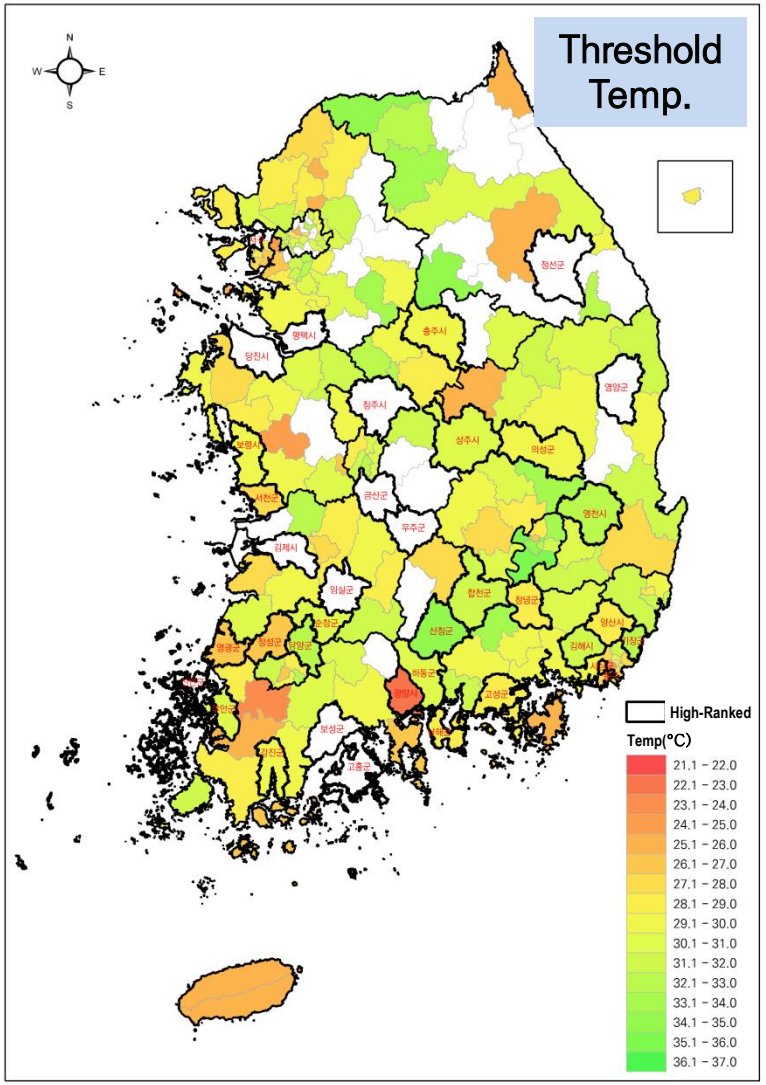
☐ Threshold temperature of heat-related morbidity

〈Pattern and threshold temperature of outpatient(Primary)〉

Many Patient
(Whole periods)

Various
Pattern

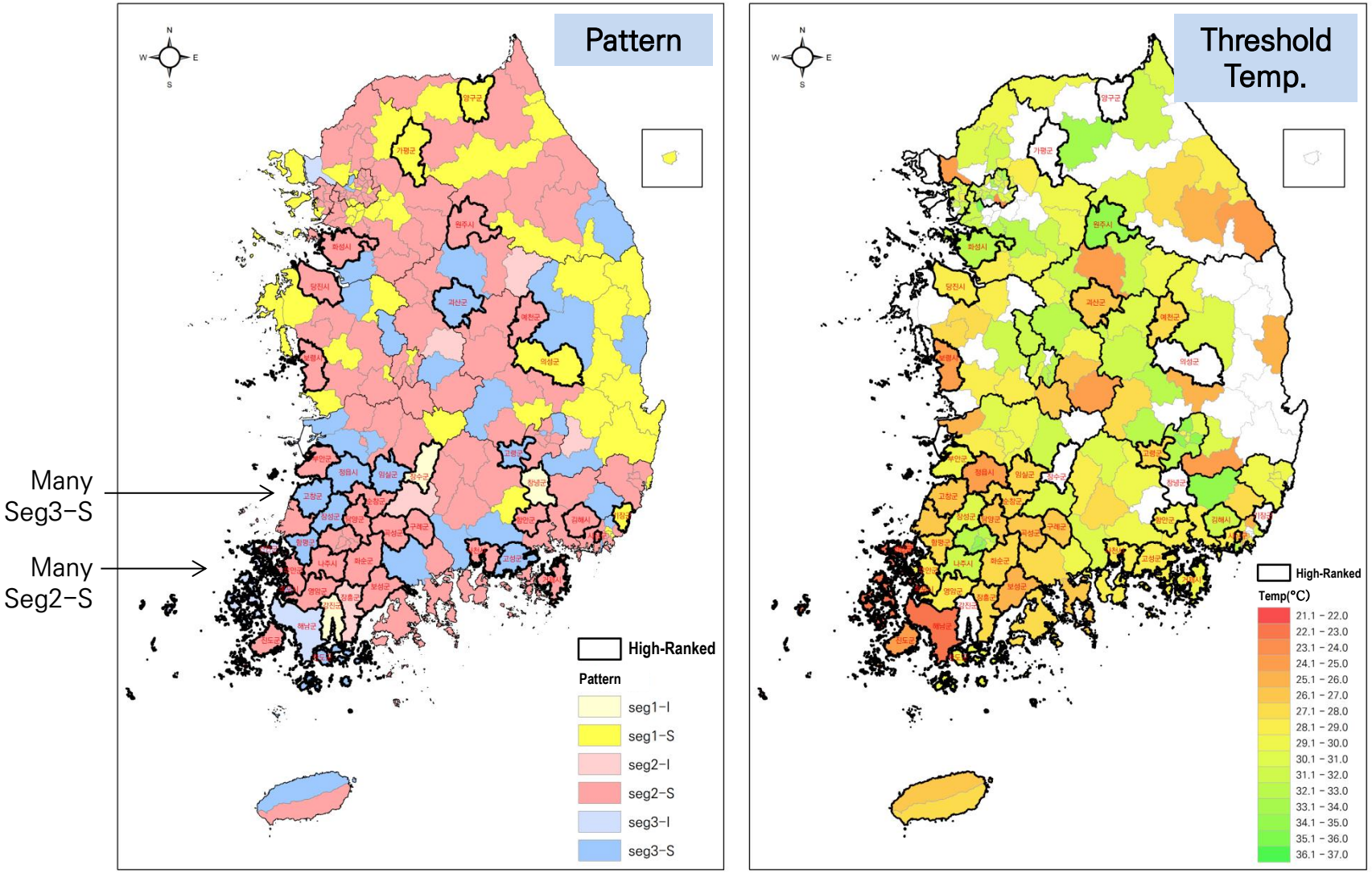




03. Characteristics of heat-related morbidity

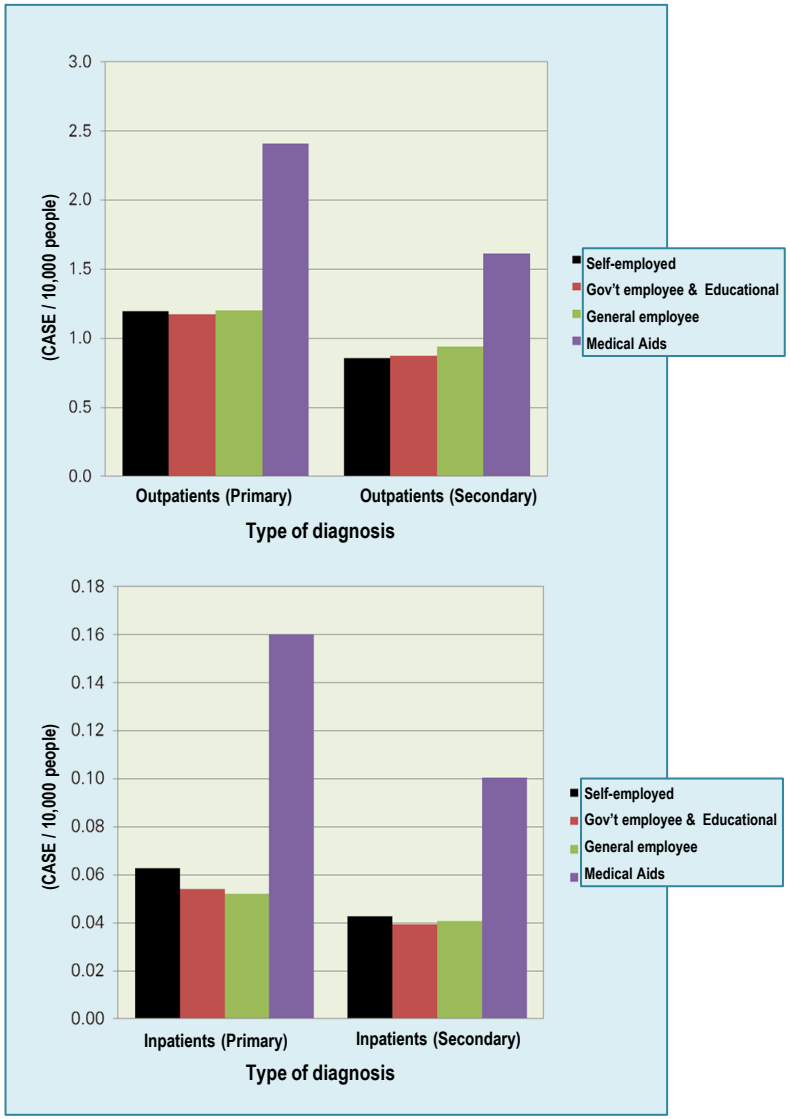
☐ Threshold temperature of heat-related morbidity

〈Pattern and threshold temperature of inpatient(Primary)〉

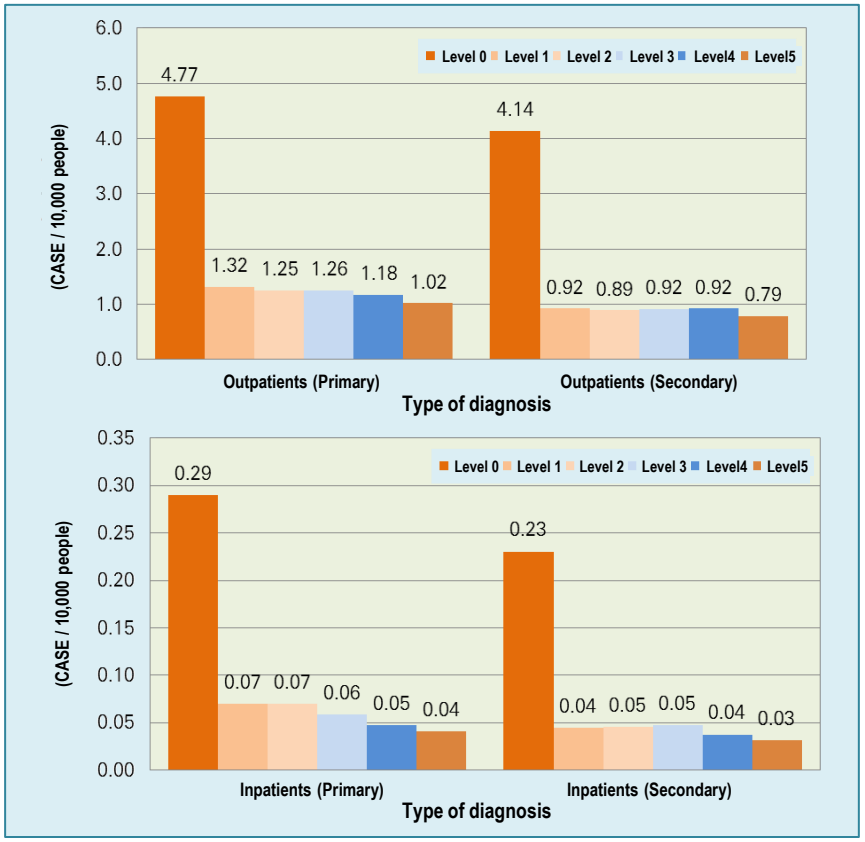


☐ Contributing factor of high-ranked regions by region

〈Heat-related morbidity by occupational classification〉



〈 Heat-related morbidity by the level of medical premium〉

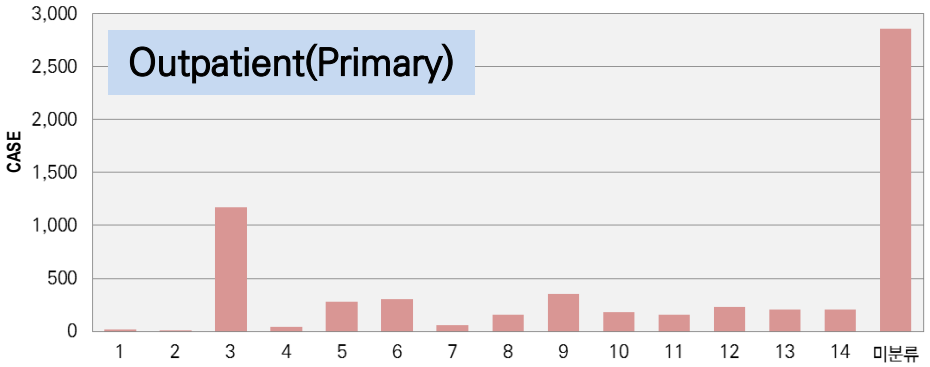


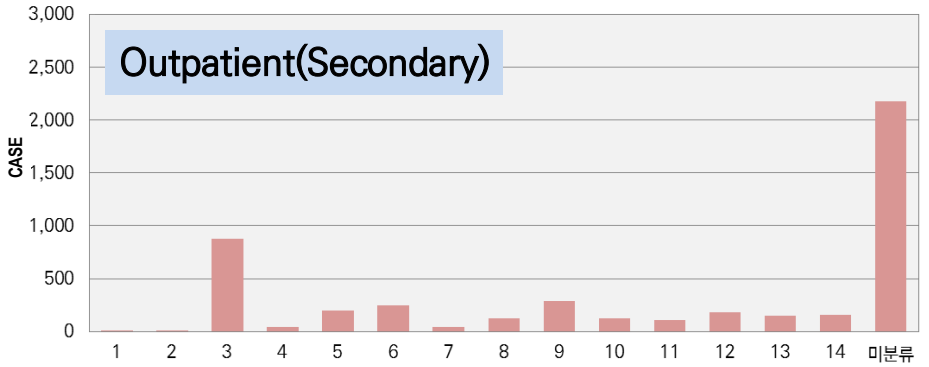
✓ Total population of level 0 is based on the data of medical benefits(basic living recipients, men of national merit, and etc.)

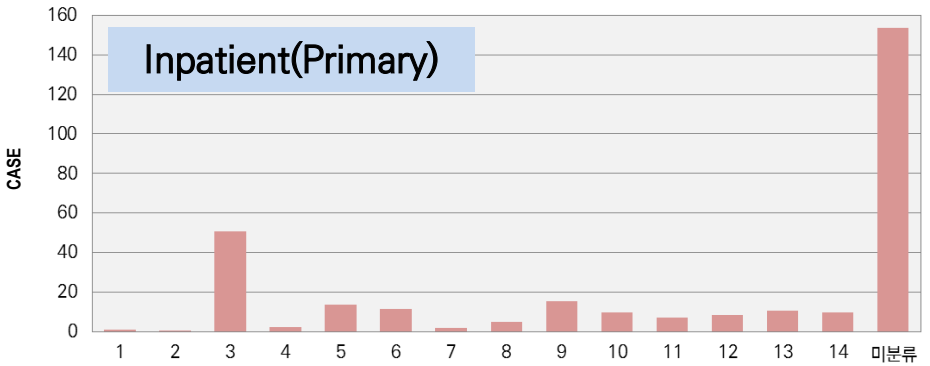
03. Characteristics of heat-related morbidity

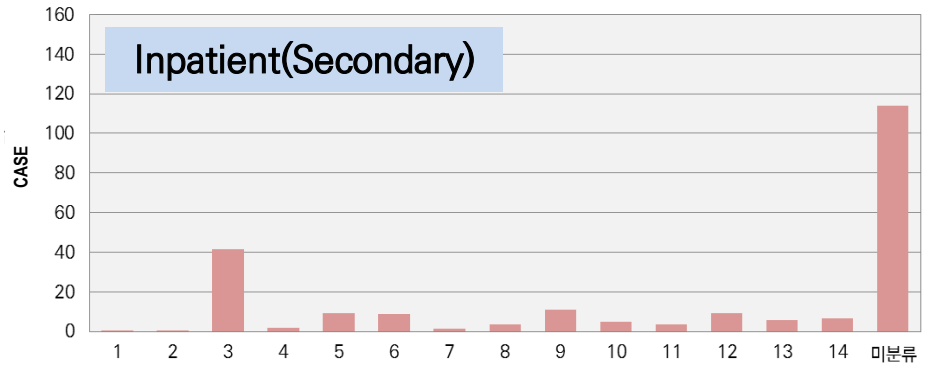
☐ Contributing factor of high-ranked regions by region

〈Heat-related morbidity by occupation – annual avg〉









1) Agriculture, Forest, Fishery
2) Mining
3) Manufacturing
4) Electricity, Housework, Water
5) Construction
6) Retail and wholesale, Repairing
7) Accommodation, Restaurants
8) Finance, Insurance
9) Real estate, Leasing, Business Service
10) Public defense, Social security
11) Education Service
12) Health, Social Welfare
13) Other public societies, Private service
14) Transportation, warehouse, communication

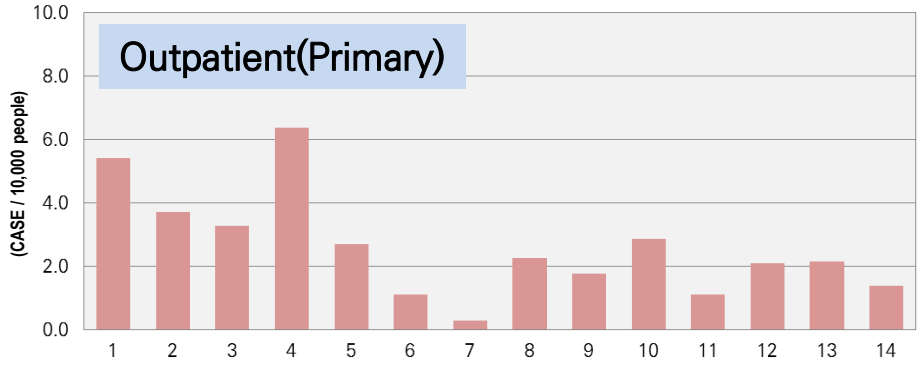
[Outpatient (Primary/Secondary)]
Uncategorized 〉Manufacturing 〉Real estate, Leasing, Business Service 〉Retail and Wholesales
[Inpatient (Primary/Secondary)]
Uncategorized 〉Manufacturing 〉Real estate, Leasing, Business Service 〉Construction

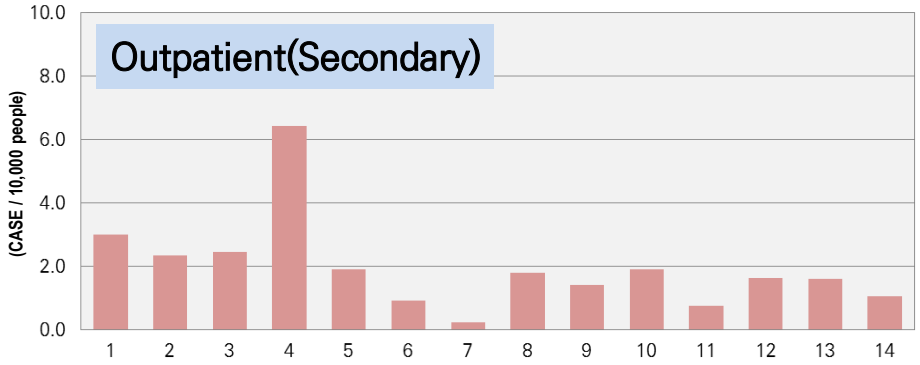
- uncategorized: In case of no information of the occupation, such as the self-employed.

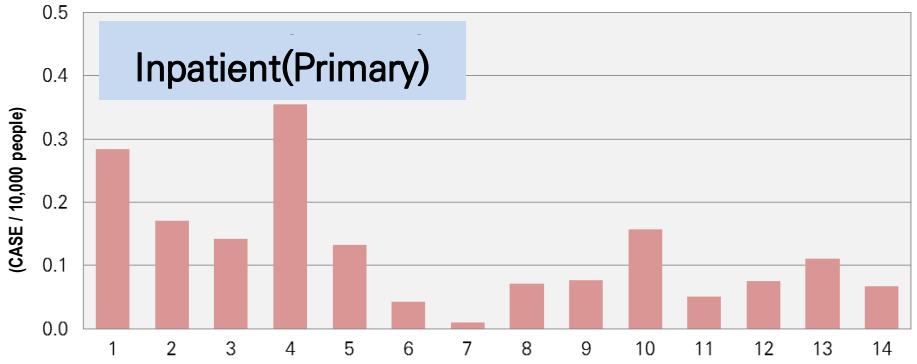
03. Characteristics of heat-related morbidity

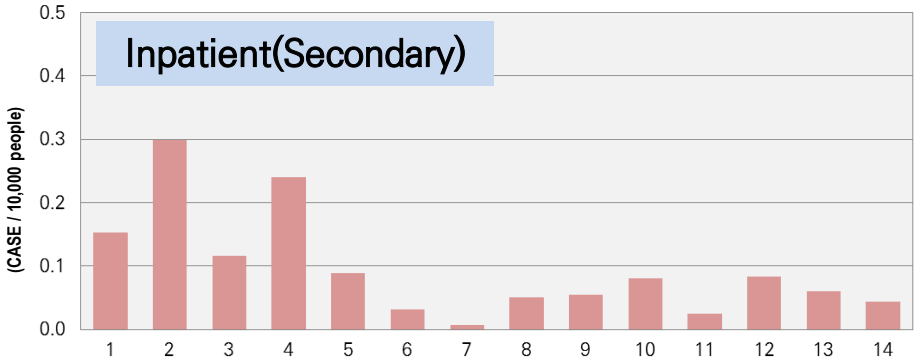
☐ Contributing factor of high-ranked regions by region

〈Heat-related morbidity by occupation – per 10,000 employees〉









1) Agriculture, Forest, Fishery
2) Mining
3) Manufacturing
4) Electricity, Housework, Water
5) Construction
6) Retail and wholesale, Repairing
7) Accommodation, Restaurants
8) Finance, Insurance
9) Real estate, Leasing, Business Service
10) Public defense, Social security
11) Education Service
12) Health, Social Welfare
13) Other public societies, Private service
14) Transportation, warehouse, communication

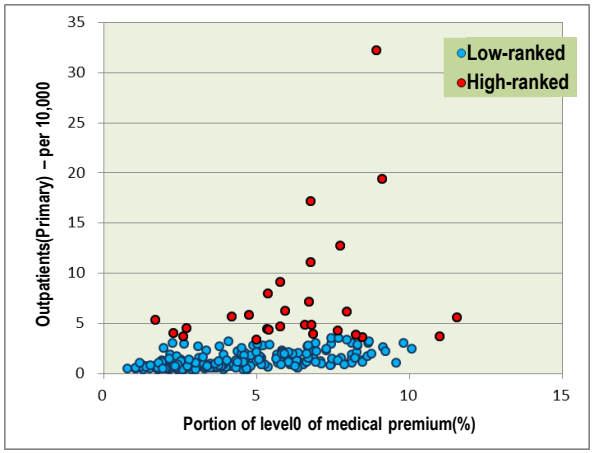
[All types of diagnosis, but inpatient(Secondary)]
Electricity, Housework, Water 〉 Agriculture, Forest, Fishery 〉 Mining 〉 Manufacturing 〉 Public Defense

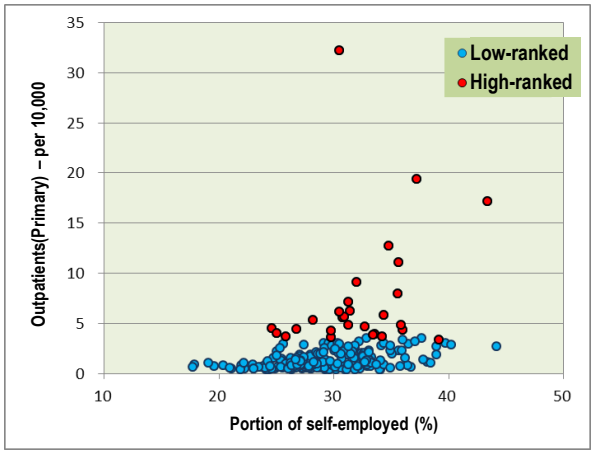
[Inpatient(Secondary)]
Mining 〉 Electricity, Housework, Water 〉 Agriculture, Forest, Fishery 〉 Manufacturing 〉 Construction

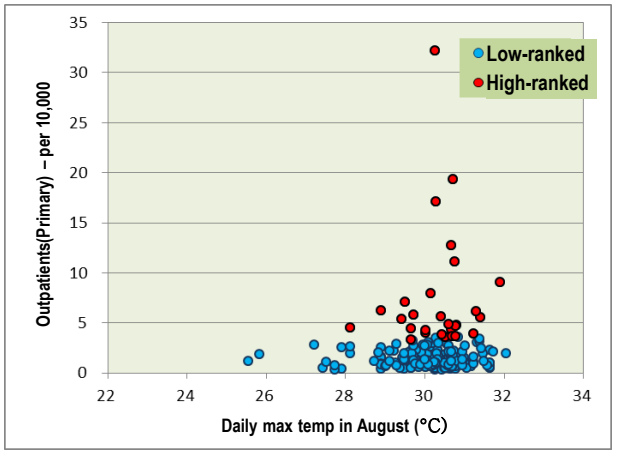
03. Characteristics of heat-related morbidity

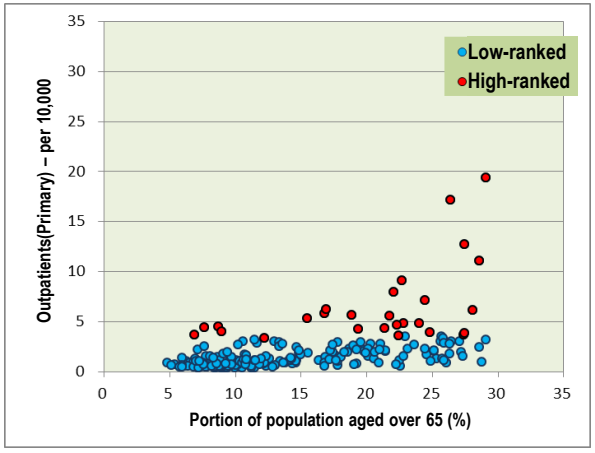
☐ Contributing factor of high-ranked regions by region

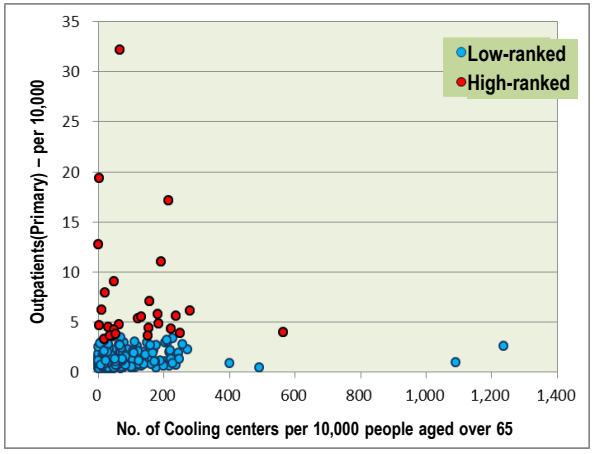
〈Scatter plot of socioeconomic factors of Si, Gun, Gu and the number of outpatient(Primary) (2002~2015)〉

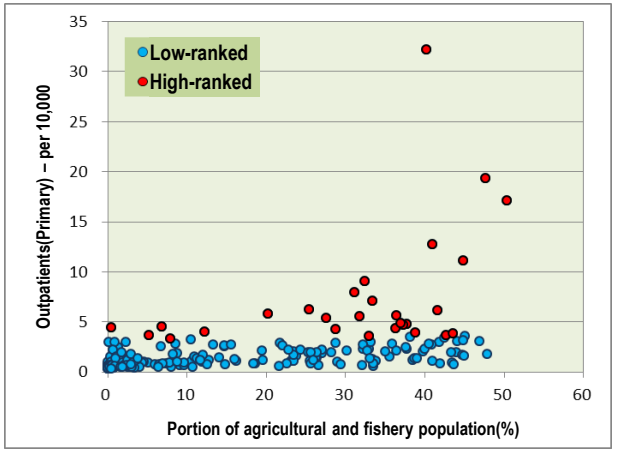












03. Characteristics of heat-related morbidity

☐ Contributing factor of high-ranked regions by region 〈Outpatient(Primary)〉

Rank	Si, Gun, Gu	Morbidity per 10,000	Ratio of Self-employed	Ratio of the age of over 65 yr	Ratio of Level 0 of premium	Ratio of agricultural population	Ratio of fishery population	Avg. of daily max temp. (Aug)	No. of cooling center per 10,000 elders	Pattern	Threshold Temp.
1	Imsil Gun	30.91		○	○	○				seg1-I	
2	Goheung Gun	17.89	○	○	○	○	○		○	seg1-I	
3	Shinan Gun	16.50	○	○		○	○			seg1-I	
4	Boseong Gun	12.00		○		○	○		○	seg1-I	
5	Namhae Gun	10.62	○	○			○			seg2-S	28.7
6	Changnyeong Gun	8.85						○		seg3-I	28.3
7	Goseong Gun	7.77	○				○			seg2-I	28.2
8	Seocheon Gun	6.75					○			seg3-I	27.5
9	BoRyeong Si	6.12					○		○	seg2-I	29.3
10	Mooan Gun	5.96					○			seg2-I	30.3
11	Hapcheon Gun	5.82		○	○	○		○		seg2-I	31.4
12	Dangjin Si	5.79					○			seg1-I	
13	Jeongseon Gun	5.47								seg1-I	
14	Gimje Ji	5.24			○			○		seg1-I	
15	Hadong Gun	4.69	○				○			seg3-I	30.0
16	Damyang Gun	4.65								seg2-I	32.4
17	Cheongjoo Si	4.64								seg1-S	
18	Sangjoo Si	4.47							○	seg3-S	30.4
19	Geumsan Gun	4.18	○							seg1-I	
20	Busan – Sasang Gu	4.17								seg2-I	30.1
21	Gwangyang Si	4.08								seg3-S	22.3
22	Yeongcheon Si	4.08								seg2-S	33.0
23	Gimhae Si	3.93								seg2-S	31.6
24	Busan – Gijang Gun	3.81	○							seg2-I	32.2
25	Moojoo Gun	3.81				○		○		seg1-I	
26	SanCheong Gun	3.72		○	○	○				seg2-I	35.0
27	Youngyang Gun	3.50		○	○	○				seg1-I	
28	Jangseong Gun	3.47			○					seg3-S	26.8

03. Characteristics of heat-related morbidity

☐ Contributing factor of high-ranked regions by region 〈Inpatient(Primary)〉

Rank	Si, Gun, Gu	Morbidity per 10,000	Ratio of Self-employed	Ratio of the age of over 65 yr	Ratio of Level 0 of premium	Ratio of agricultural population	Ratio of fishery population	Avg. of daily max temp. (Aug)	No. of cooling center per 10,000 elders	Pattern	Thresh old Temp.
1	Shinan Gun	2.11	○	○		○	○			seg3-I	23.0
2	Haenam Gun	1.29	○				○			seg3-I	23.0
3	Jangsoo Gun	0.57			○	○				seg1-I	
4	Jeongeup Si	0.56			○					seg3-S	25.0
5	Mooan Gun	0.53					○			seg2-S	28.1
6	Euiseong Gun	0.52		○	○	○		○		seg1-S	
7	Gurye Gun	0.50		○	○			○		seg2-S	27.0
8	Gijang Gun	0.45	○							seg1-S	
9	Wando Gun	0.44	○				○	○		seg3-S	29.7
10	Gapyeong Gun	0.37	○						○	seg1-S	
11	Gokseong Gun	0.37		○	○	○				seg2-S	27.0
12	Soonchang Gun	0.37		○		○				seg2-S	27.5
13	Gochang Gun	0.36	○			○				seg3-S	26.9
14	Najoo Si	0.36								seg2-S	31.6
15	Gangjin Si	0.36		○	○		○	○		seg1-I	
16	Janggeung Gun	0.35		○			○			seg2-I	27.5
17	Boseong Gun	0.35		○		○	○		○	seg2-S	25.5
18	Imsil Gun	0.34		○	○	○				seg3-S	27.6
19	Sacheon Si	0.32					○			seg2-S	28.9
20	Hampyeong Gun	0.32		○	○	○				seg3-S	27.7
21	Goryeong Gun	0.31						○		seg3-S	28.0
22	Jindo Gun	0.30	○	○	○	○	○	○		seg2-S	25.0
23	Booan Gun	0.30	○				○	○		seg2-S	30.0
24	Youngam Gun	0.29								seg2-S	28.0
25	Yecheon Gun	0.29		○	○	○		○		seg2-S	27.5
26	Changnyeong Gun	0.28						○		seg1-I	
27	Haman Gun	0.26						○		seg2-S	30.0
28	Mokpo Si	0.26						○		seg3-S	26.0

04. Implication

- Nationwide heat-related morbidity has kept increasing,
- Incidence of foreigners was 4 times as high as that of Koreans
- Nationwide average threshold temperature was 30˚C, but was different by region.
- The older the age, the lower threshold temperature
- High-ranked Si, Gun, and Gu was Imsil, Goheung, Shinan, Boseong, Changnyeong, Muan and etc.
- Contributing factors to heat-related morbidity were different by region
  - Imsil Gun: Elderly population, low-income, Agriculture
  - Goheung Gun: Elderly population, low-income, Agriculture, Fishery, Lack of cooling center
  - Shinan Gun: Elderly population, Agriculture, Fishery
  - Changnyeong Gun: Max temperature of August.
  - Boseong Gun: Elderly population, Agriculture, Fishery
- Need to establish differentiated preventative measures for heat-related morbidity by region/type of diagnosis/age/business type

Thank you

KEI 한국환경정책·평가연구원
Korea Environment Institute