

Toward Impacts Based Forecasts for Heatwave

Yeora Chae



Need for Heat Wave Plan from Stakeholder Perspective

Ch.1
Heat Wave in
2018

Ch.2
Heat Wave
Impacts based
on Socio-
economic
Conditions

Ch.3
Towards
Impacts Based
Heatwave
Forecasts

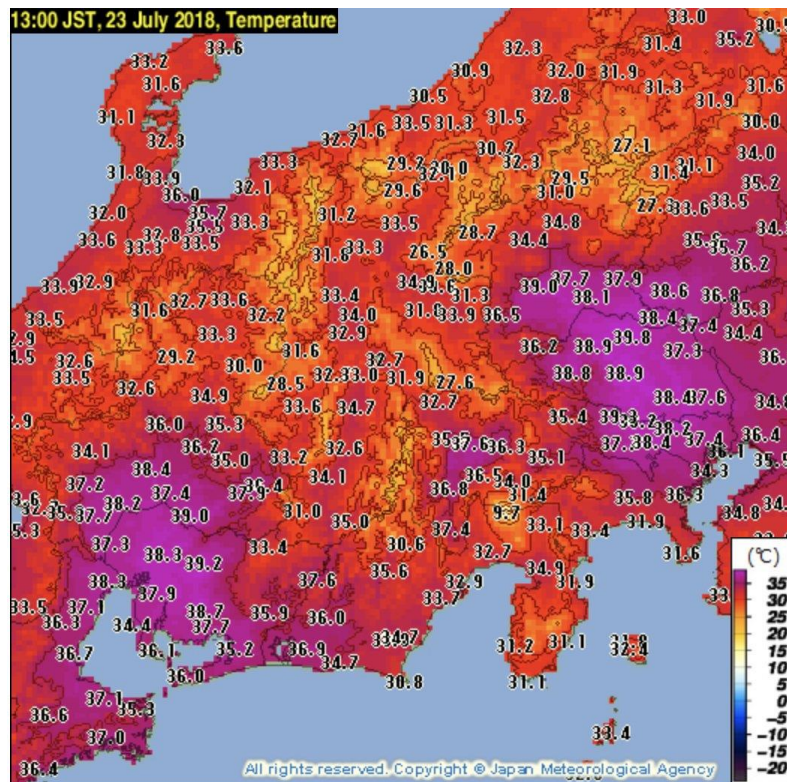
Ch.1 Heat Wave in 2018

Heat Wave in 2018

► People are killed and sick from heat wave in 2018

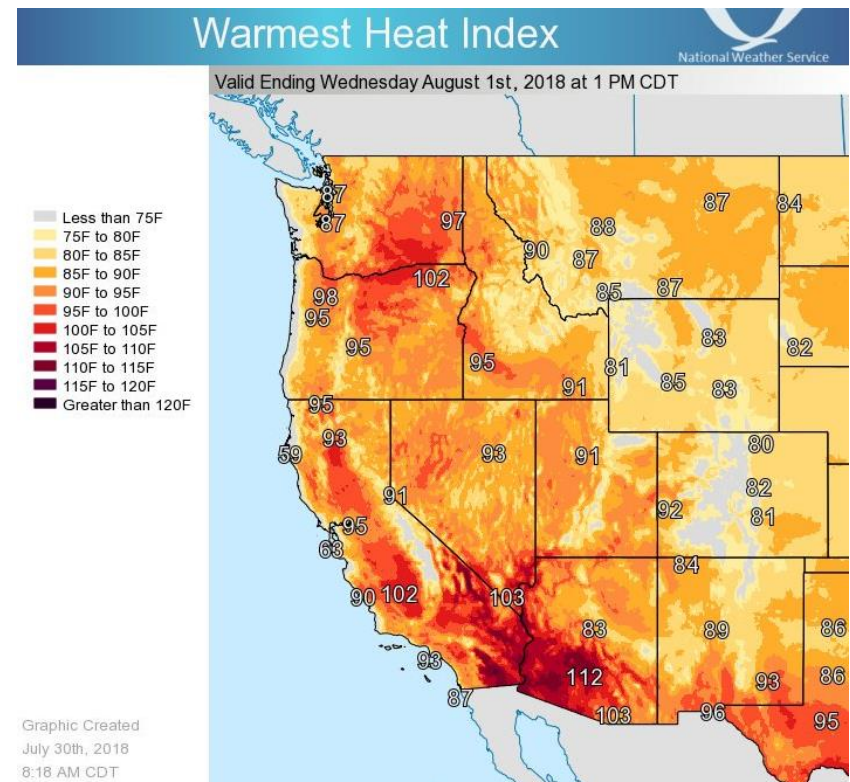
- More than 90 people died and injured more than 57,000 in Japan
- At least 70 people died in Canada
- In May, a heat wave killed 65 people in Karachi, Pakistan

◁July 23rd 2018 Hourly Temperature in Japan



Source: JMO

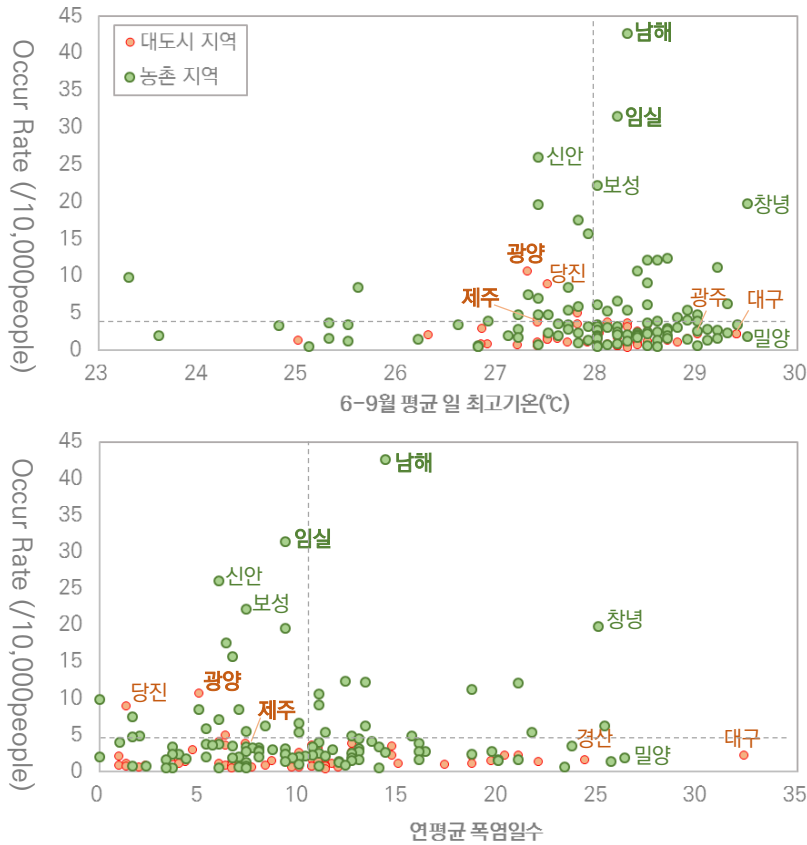
◁August 1st 2018 Hourly Temperature in the U.S.



Graphic Created
July 30th, 2018
8:18 AM CDT

Source: NWS

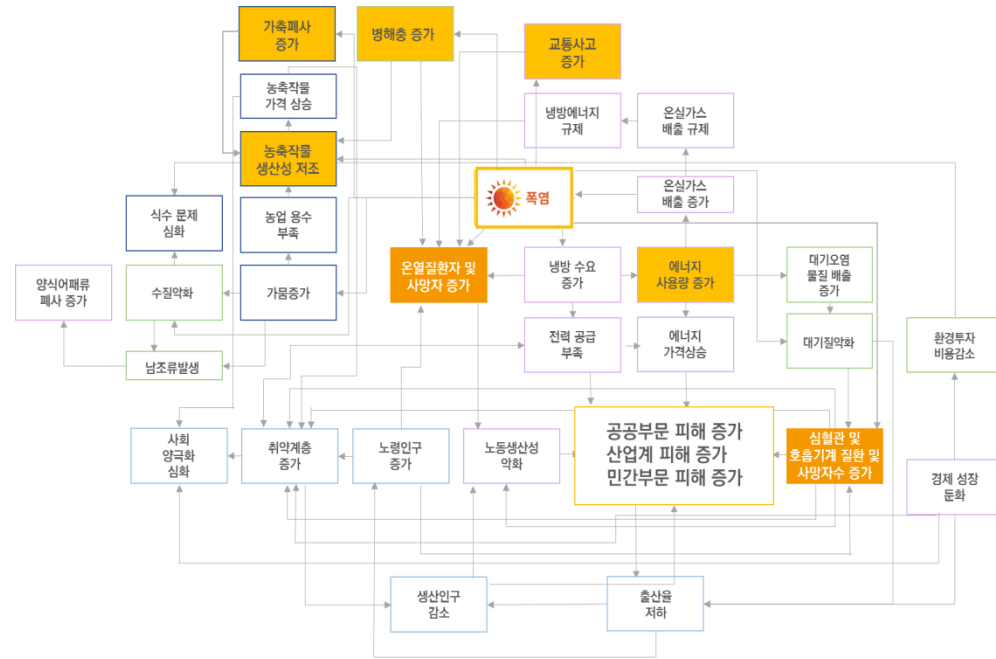
▶ Heat wave effects is not always proportional to temperature



Source: Chae et al.(2017)

<Number of heat wave days and heat related diseases occur rate>

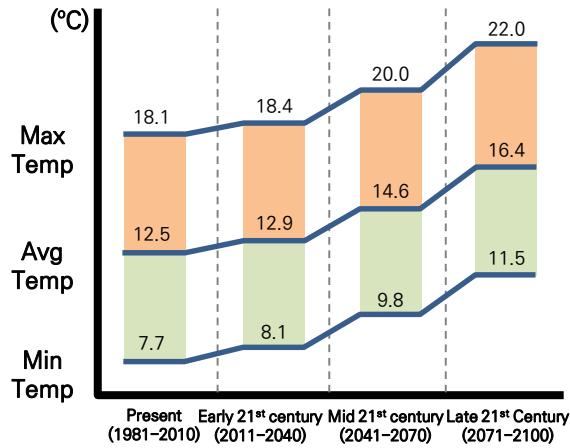
▶ Heat wave affects to other sector 2nd and 3rd effects



<2nd and 3rd effects from Heat Wave>

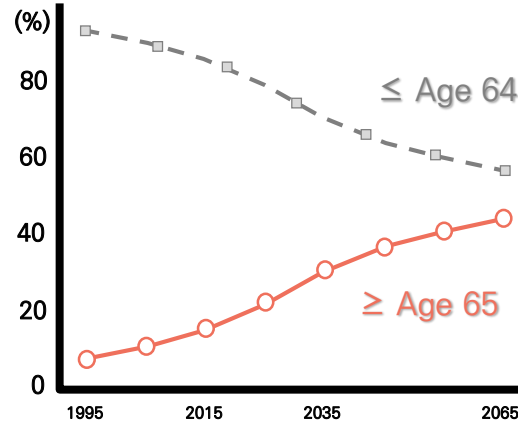
Climate Change, Aging, and Polarization and Heat Wave

▶ Heat wave is predicted to increase for climate change, aging, and polarization



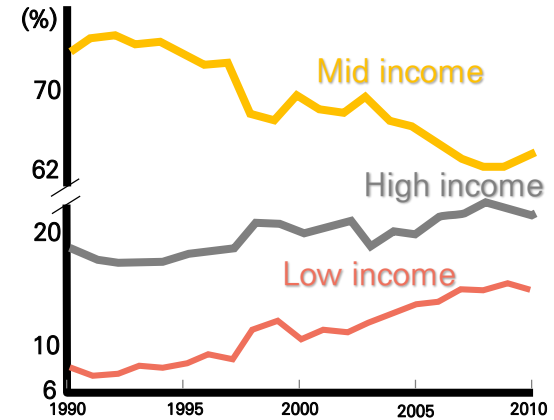
Source: KMA(2017)

〈South Korea RCP8.5 Scenario〉



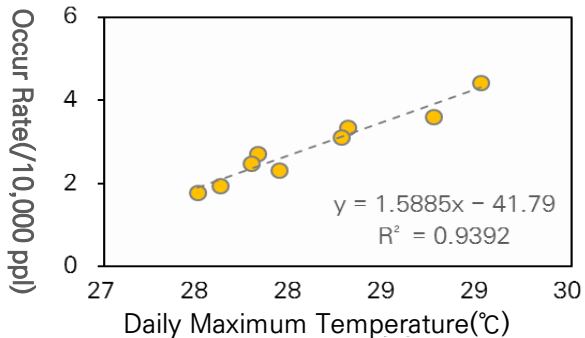
Source: KOSTAT(2016)

〈Future Population Trend 2015-2065〉



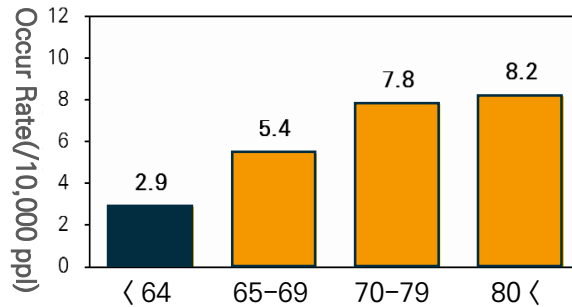
Source: Baek(2012)

〈Market Rate in Different Income Level〉



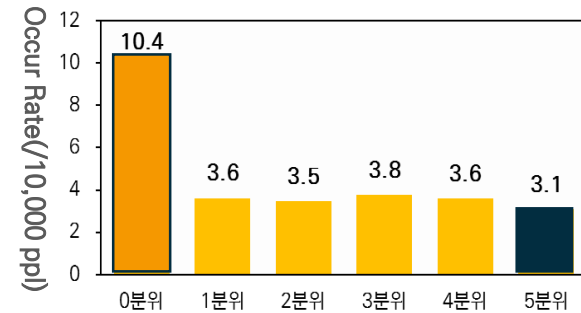
Source: Chae et al.(2017)

〈Daily Max. Temp. and Heat-related Diseases Occur Rate 2007-2015〉



Source: Chae et al.(2017)

〈Age and Heat-related Diseases Occur Rate 2013-2015〉

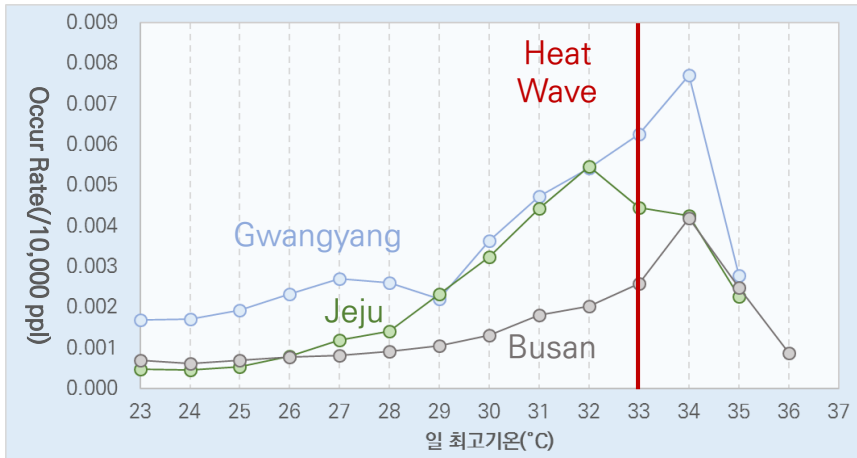


Source: Chae et al.(2017)

〈Heat-related Diseases Occur Rate in Income Quantile 2013-2015〉

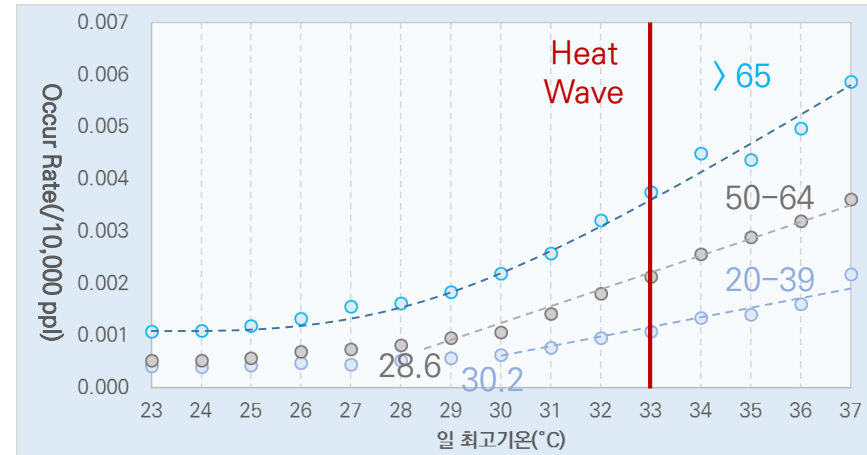
Limitations on temperature based heat-wave forecast

► Need to Consider Temperature and Impacts difference with Location, Age, Income, Occupation, and Spatial Conditions



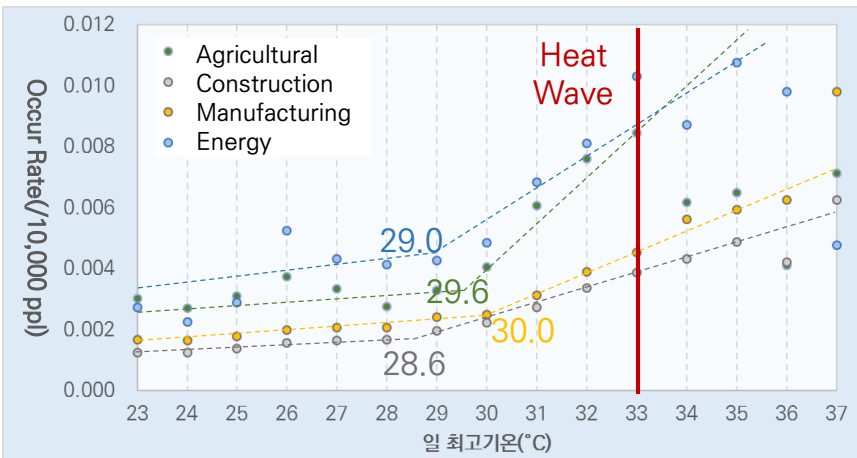
Source: Chae et al.(2017)

〈Difference in Critical Temperature in Different Location〉



Source: Chae et al.(2017)

〈Difference in Critical Temperature in Age Group〉



Source: Chae et al.(2017)

〈Difference in Critical Temperature in Each Occupation〉



Source: WISE

〈Temperature Difference in Location〉

Need for customized information for heat-wave

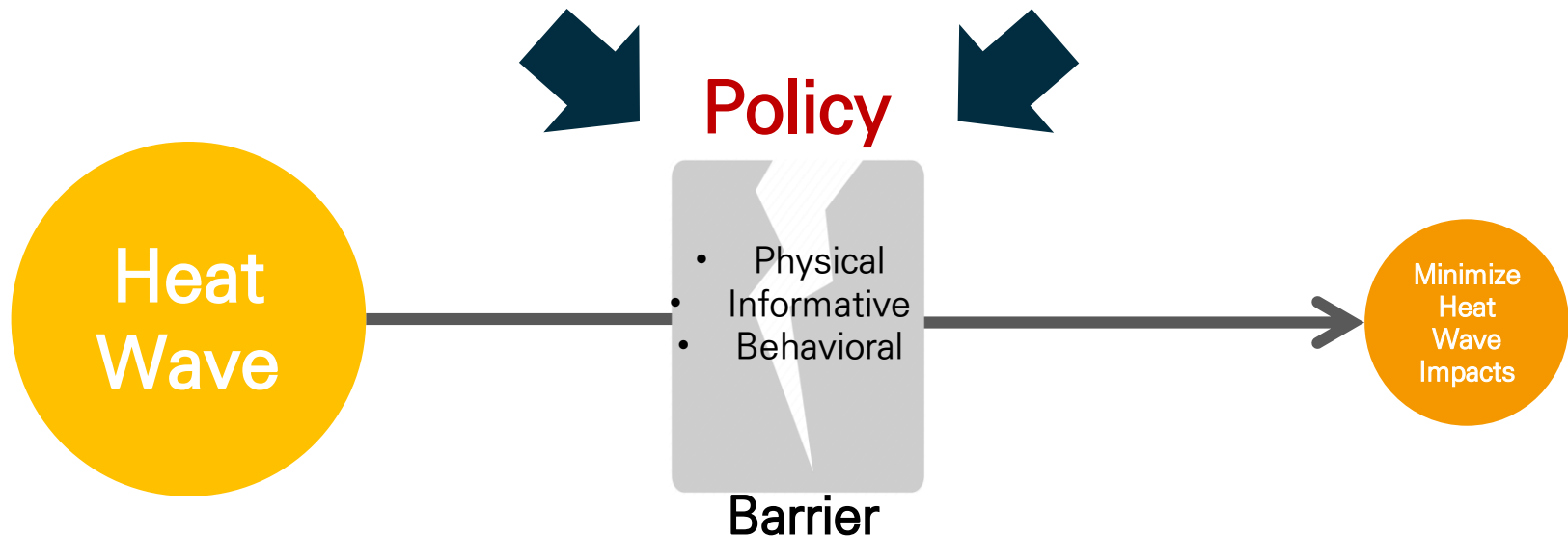
Limitation of current heat wave alert

Limitations to reduce actual damage due to non-reflection of temperature-oriented social, economic and environmental factors

Limitations to measure mid to long-term plan

Consists of mid- to long-term vulnerability and risk analysis-based supplier-centric policies with non-represented consumer characteristics

To improve the quality of life for the demanders need to analyze the effects of heat waves and prepare a prediction system



Ch.2 Heat Wave Impacts based on Socio-economic Conditions

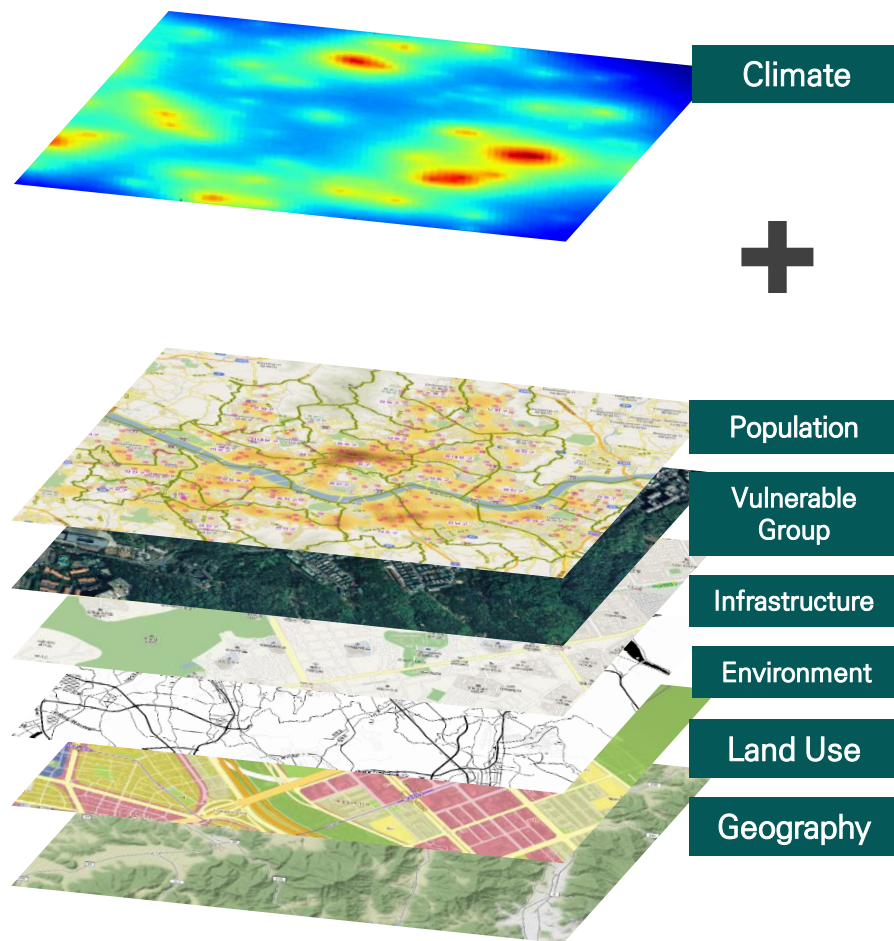
Current Heat Wave Warning

- 2 days and more with maximum temperature exceeds 33 °C (35 °C)
- Temporal/Spatial Scale: daily/Si · gun

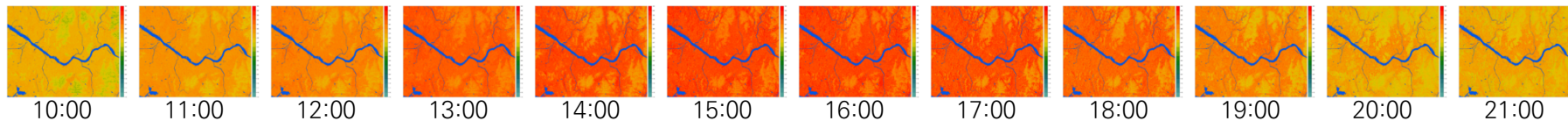


Heat Wave Impacts

- Heat wave impacts considering climate · social · economic conditions
- Temporal/Spatial Scale: hourly/100m x 100m



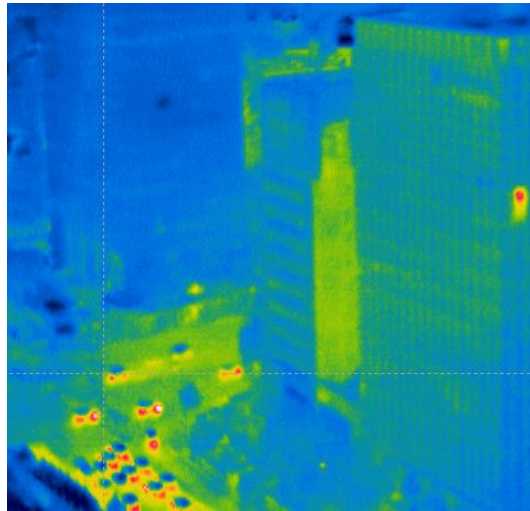
2017. 08. 04.



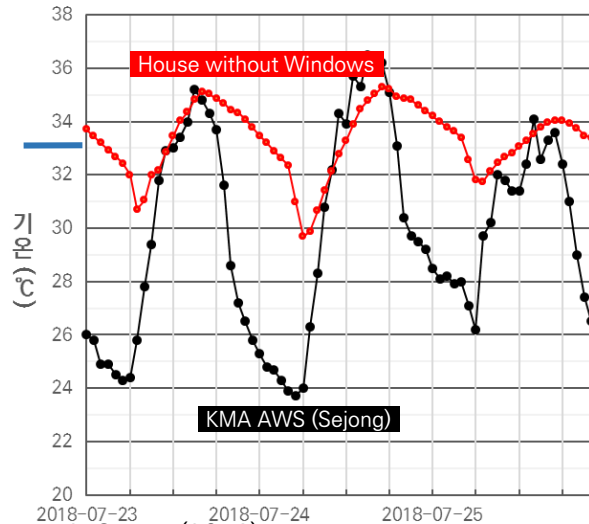
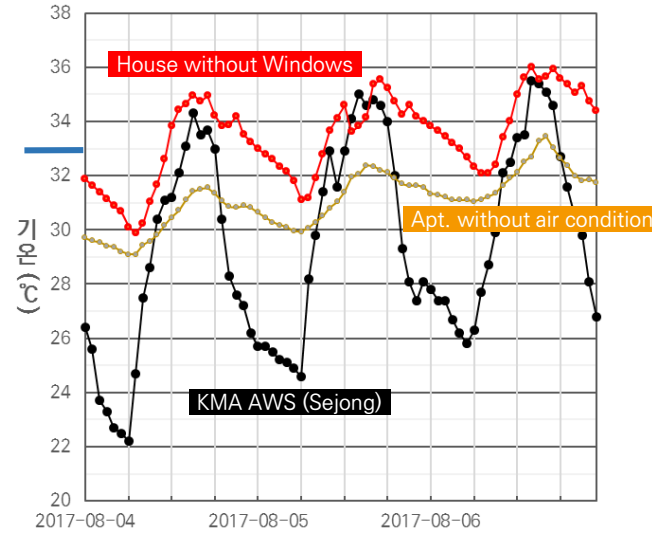
Difference in Exposed Temperature with Land Coverage and Residential Conditions

► Change in temperature in houses without window

〈2016.6.7 Heat Environment Change in Seoul〉



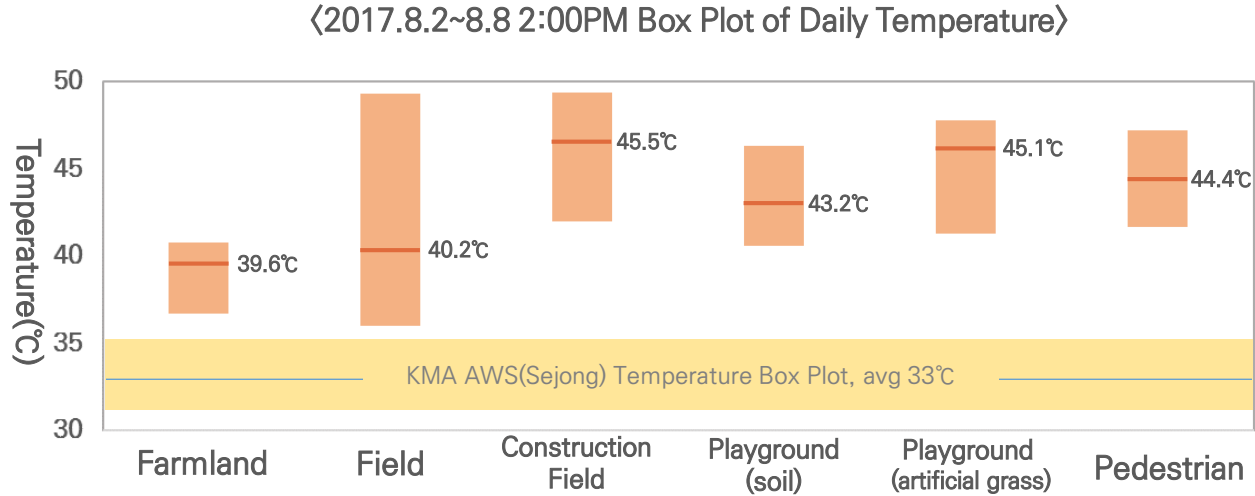
〈Temperature Change with different residential conditions〉



Source: Chae et al.(2017, 2018)

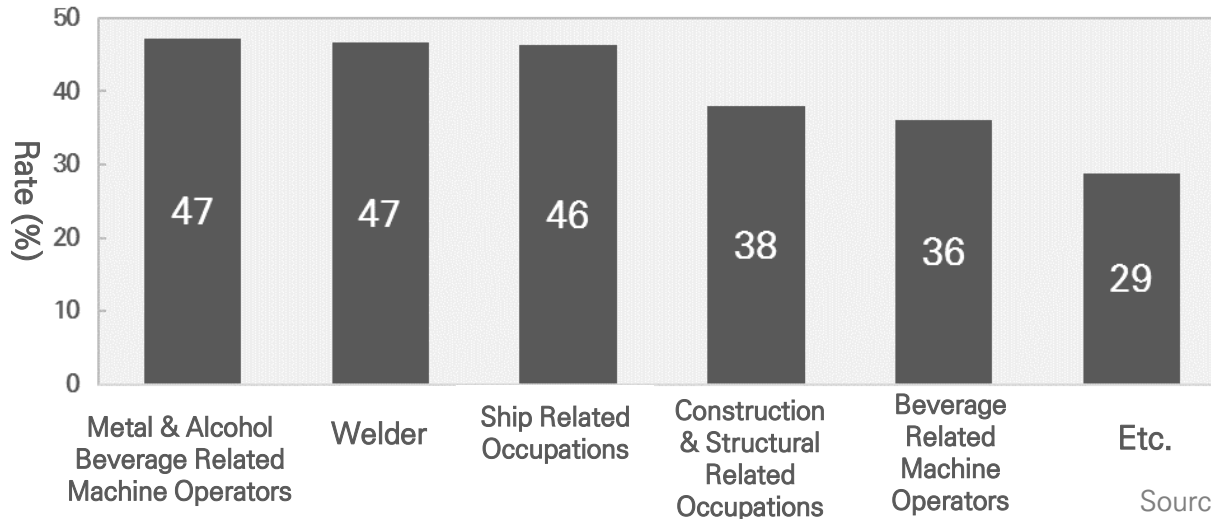
Difference in Temperature with Work Space and Occupation

► Exposed temperature with work space



Source: Chae et al.(2017)

► High temperature exposed rate of vulnerable occupations to heat wave



Source: Kim and Lee(2014) 12

Heat Wave Impacts Varies With Location

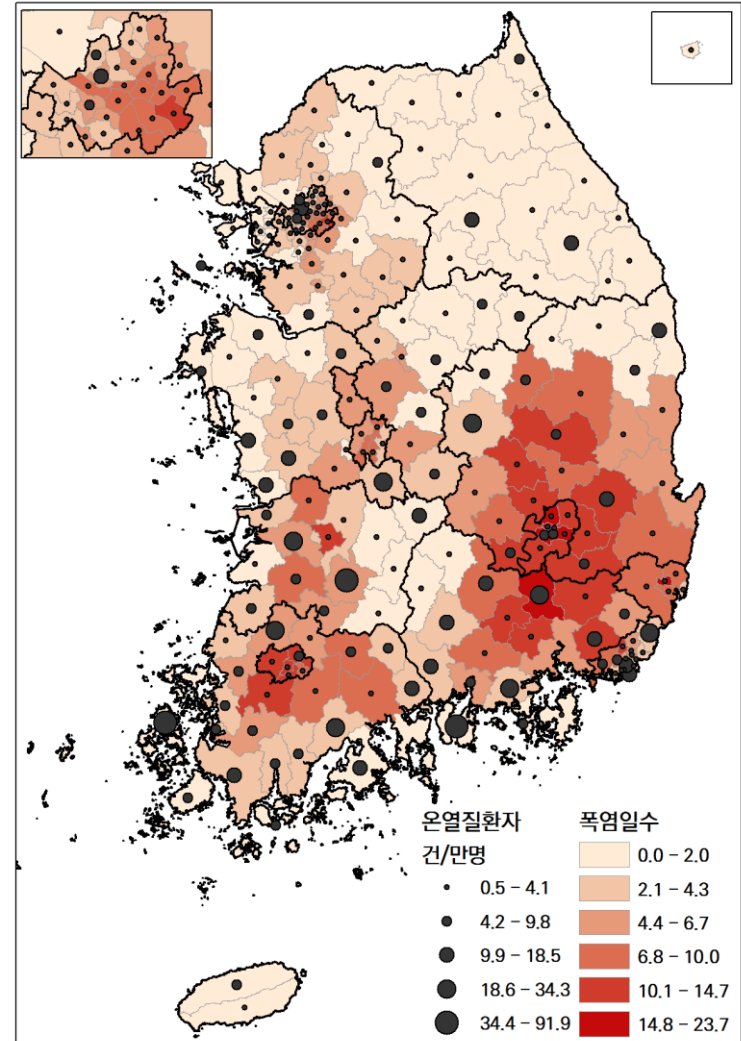
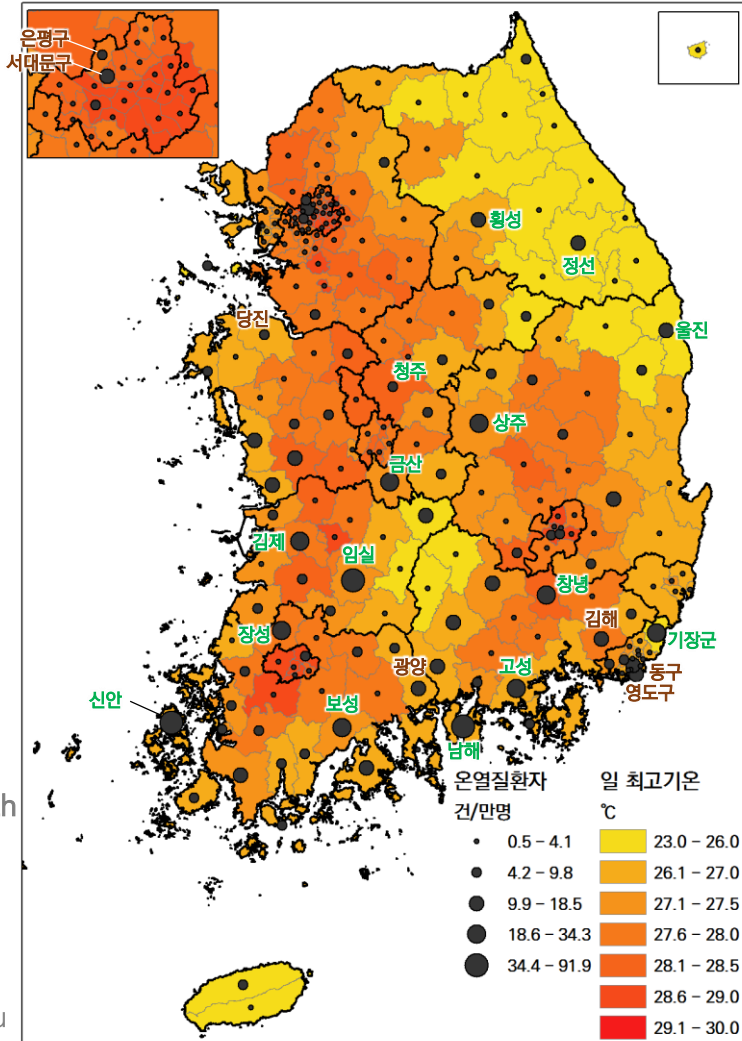
► Heat related diseases incidence rates varies with location

2013~2015년, Jun-Sep

Heat related disease occur rates and daily max. temp

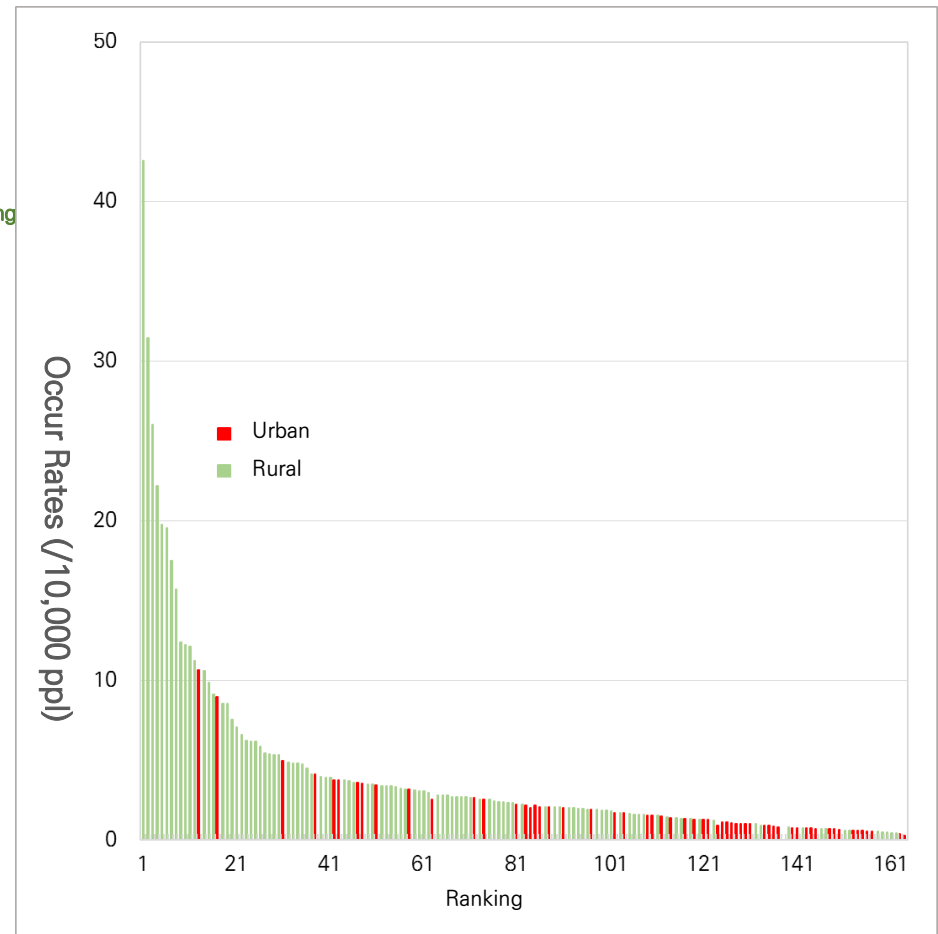
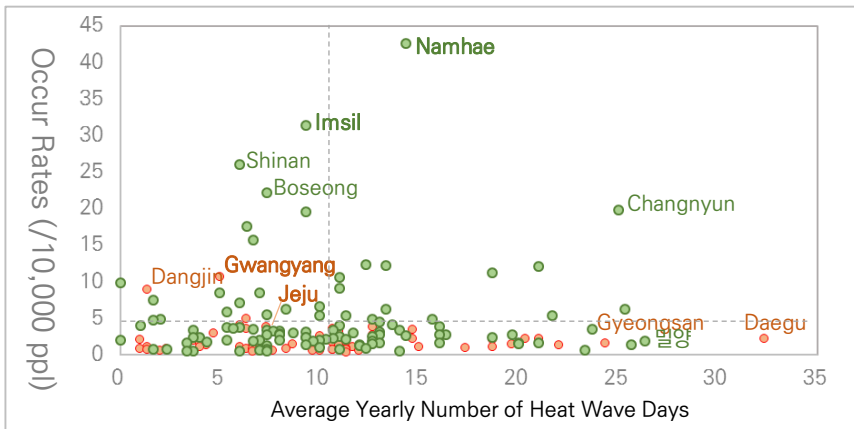
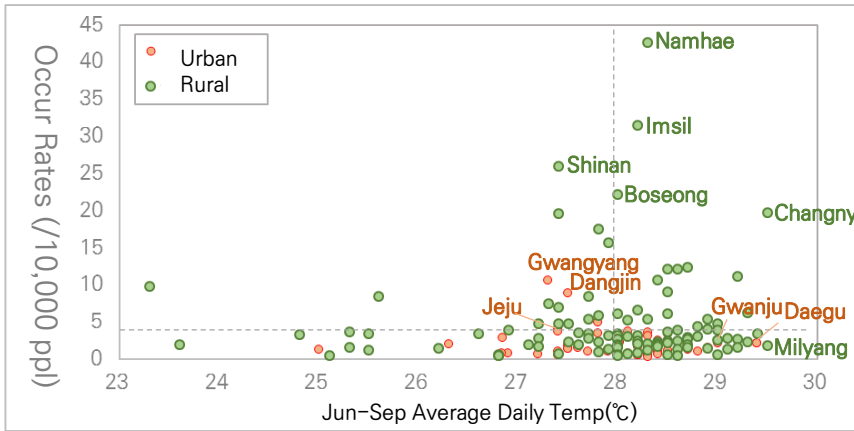
2013~2015년, Jun-Sep

Heat related disease occur rates and number of heat wave days



Heat Wave Impacts Occurs in Specific Location

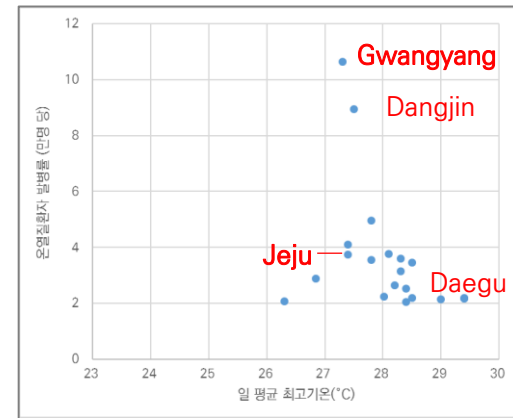
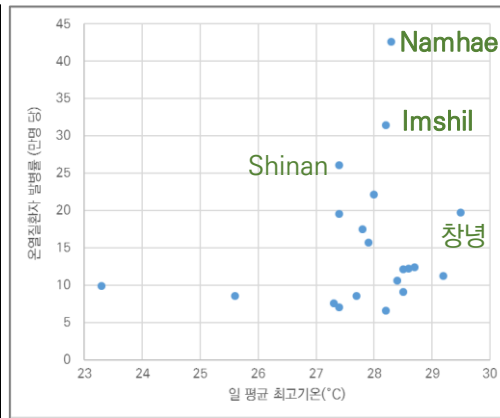
► Heat related disease incidence rates are higher in rural area than urban area



Source: Chae et al.(2017)

〈Daily Max. Temp, # of Heat Wave Days, Heat-Related Disease Occur Rates(2013-2015)〉

Heat Related Diseases incidence Rates Location



〈Relationship of Heat Related Disease Occur Rates and Daily Average Max. Temp〉

〈Location Characteristics〉

Location	Population	Elder people(%)	Low Income(%)	Agricultural/Fiisheris/Liv estock(%)	Manufacturing(%)
Average	309,500	19	4	19	8
Namhae	46,685	33	5	43	2
Imsil	29,753	31	6	35	5
Gwangyang	151,368	10	2	10	11
Jeju	440,503	12	3	14	2

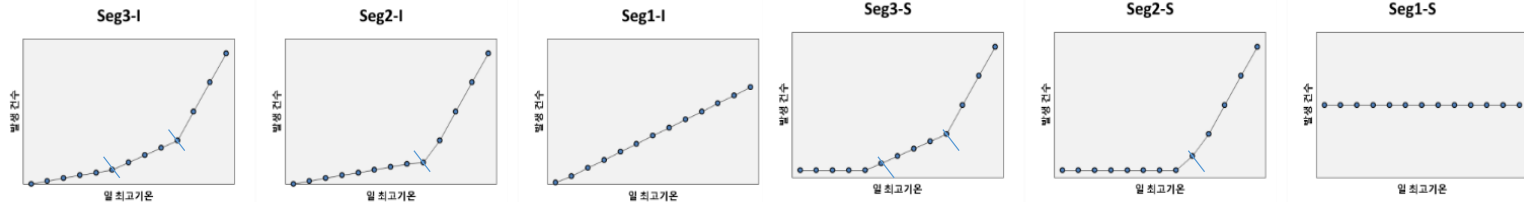
Source: Chae et al.(2017)

〈Top 20 Region of Average Heat Related Diseases Occur Rates(2013-2015)〉

Source: Chae et al.(2017)

Threshold Temperature of Heat Related Patients

〈Six Main Types of Heat Related Disease Patterns by Temperature〉



Outpatient			
	seg3	seg2	seg1
I	22	50	29
S	47	69	12

Types of High Occurrence Areas			
	seg3	seg2	seg1
I	6	9	11
S	5	4	2

Inpatient			
	seg3	seg2	seg1
I	3	5	3
S	37	131	50

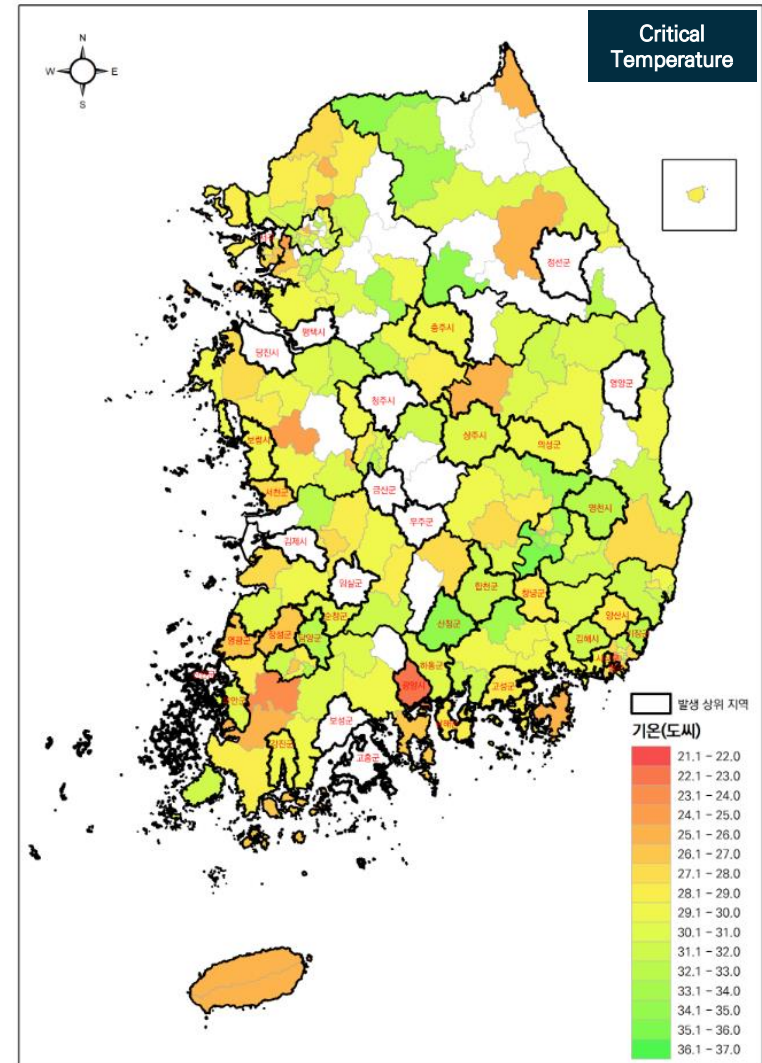
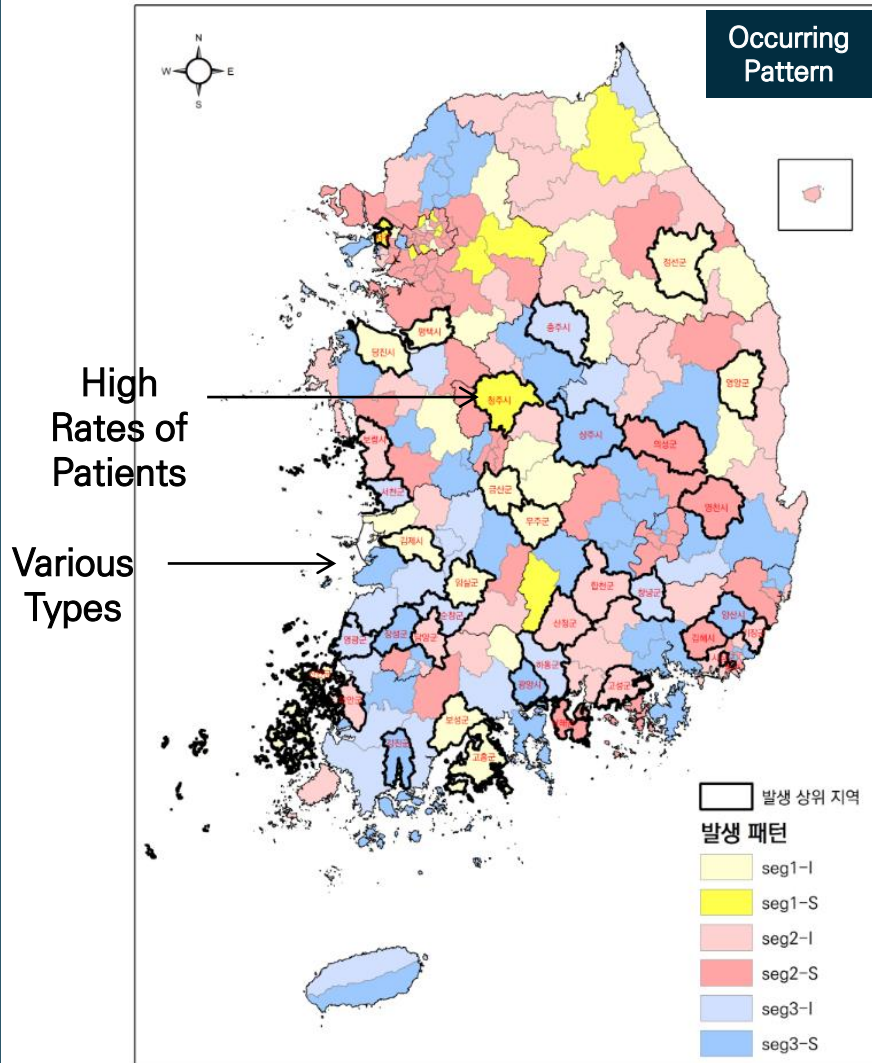
Types of High Occurrence Areas			
	seg3	seg2	seg1
I	2	1	3
S	10	21	4

- Seg3-I: Chungju, Seochoen, Sunchang, Yeongwang, Changnyeong, Hadong
- Seg3-S: Gwangyang, Ganjin, Jangsung, Sangju, Yangsan
- Seg2-I: Busan, Boryeong, Damyang, Muahn, Goseong
- Seg2-S: Yeongchun, Eisung, Gimhae, Namhae
- Seg1-I: Pyeongtak, Jungsun, Dangjin, Geumsan, etc.
- Seg1-S: Chungju, Incheon Seogu

- Seg3-I: Haenam, Shinahn
- Seg3-S: Geosan, Jungeup, Imsil, Gochang, Mokpo, Hampyeong, etc.
- Seg2-I: Jangheung
- Seg2-S: Busan Sasnaggu, Hwasung, Wonju, Damyang, Gokseong, etc.
- Seg1-I: Jangsu, Gangjin, Changnyeong
- Seg1-S: Gijang, Gapyeong, Yanggu, Euisung

Threshold Temperature for the incidence of Heat Related Patients

<Patterns and Critical Temperature of Outpatients>



Analysis of Characteristics of Regional Health Impacts (outpatients)

► Customized Adaptive Plan based on Data

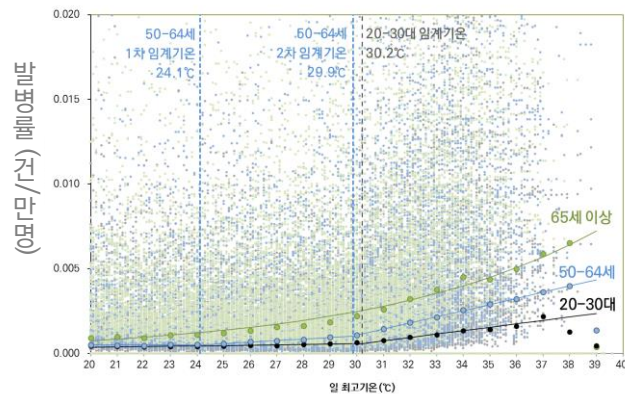
Rank	Region	Patients (/10,000 ppl)	Regional Subscriber Rates	Rate of age > 65	0 th percentile Insurance Rates	Agricultural Rates	Fisheries Rates	Avg. Daily Max. Temp in Aug	# of Shelters per 10,000 elderly people	Pattern	Critical Temp
1	Imsil	30.91		○	○	○				seg1-l	
2	Goheung	17.89	○	○	○	○	○		○	seg1-l	
3	Shinahn	16.50	○	○		○	○			seg1-l	
4	Boseong	12.00		○		○	○		○	seg1-l	
5	Namhae	10.62	○	○			○			seg2-S	28.7
6	Changnyeong	8.85						○		seg3-l	28.3
7	Gosung	7.77	○				○			seg2-l	28.2
8	Seocheon	6.75					○			seg3-l	27.5
9	Boryeong	6.12					○		○	seg2-l	29.3
10	Muahn	5.96					○			seg2-l	30.3
11	Habcheon	5.82		○	○	○		○		seg2-l	31.4
12	Dangjin	5.79					○			seg1-l	
13	Jungsun	5.47								seg1-l	
14	Gimje	5.24			○			○		seg1-l	
15	Hadong	4.69	○				○			seg3-l	30.0
16	Damyang	4.65								seg2-l	32.4
17	Chungju	4.64								seg1-S	
18	Sangju	4.47							○	seg3-S	30.4
19	Geumsan	4.18	○							seg1-l	
20	Sasanggu	4.17								seg2-l	30.1
21	Gwangyang	4.08								seg3-S	22.3
22	Yeongchun	4.08								seg2-S	33.0
23	Gimhae	3.93								seg2-S	31.6
24	Gijanggu	3.81	○							seg2-l	32.2
25	Muju	3.81				○		○		seg1-l	
26	Sancheon	3.72		○	○	○				seg2-l	35.0
27	Yeongyang	3.50		○	○	○				seg1-l	
28	Jangsung	3.47			○					seg3-S	26.8

Analysis of Characteristics of Regional Health impacts (inpatients)

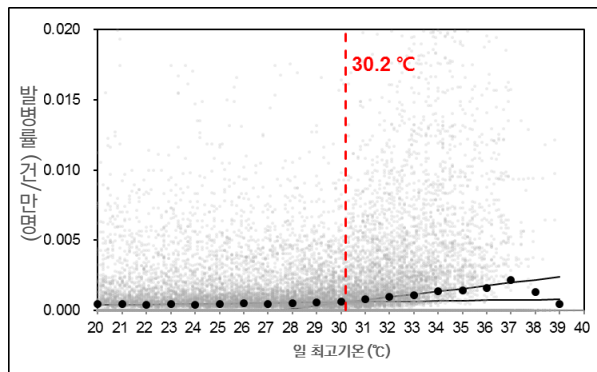
► Customized Adaptive Plan based on Data

Rank	Region	Patients (/10,000 ppl)	Regional Subscriber Rates	Rate of age > 65	0 th percentile Insurance Rates	Agricultural Rates	Fisheries Rates	Avg. Daily Max. Temp in Aug	# of Shelters per 10,000 elderly people	Pattern	Critical Temp
1	Shinahn	2.11	○	○		○	○			seg3-I	23.0
2	Haenam	1.29	○				○			seg3-I	23.0
3	Jangsu	0.57			○	○				seg1-I	
4	Jeungeup	0.56			○					seg3-S	25.0
5	Muahn	0.53					○			seg2-S	28.1
6	Euisung	0.52		○	○	○		○		seg1-S	
7	Gurae	0.50		○	○			○		seg2-S	27.0
8	Gijang	0.45	○							seg1-S	
9	Wando	0.44	○				○	○		seg3-S	29.7
10	Gapyeong	0.37	○						○	seg1-S	
11	Goksung	0.37		○	○	○				seg2-S	27.0
12	Sunchang	0.37		○		○				seg2-S	27.5
13	Gochang	0.36	○			○				seg3-S	26.9
14	Naju	0.36								seg2-S	31.6
15	Gangjin	0.36		○	○		○	○		seg1-I	
16	Jangheung	0.35		○			○			seg2-I	27.5
17	Boseong	0.35		○		○	○		○	seg2-S	25.5
18	Imsil	0.34		○	○	○				seg3-S	27.6
19	Sacheon	0.32					○			seg2-S	28.9
20	Hampyeong	0.32		○	○	○				seg3-S	27.7
21	Goryeong	0.31						○		seg3-S	28.0
22	Jindo	0.30	○	○	○	○	○	○		seg2-S	25.0
23	Buahn	0.30	○				○	○		seg2-S	30.0
24	Yeongam	0.29								seg2-S	28.0
25	Yecheon	0.29		○	○	○		○		seg2-S	27.5
26	Changnyeong	0.28						○		seg1-I	
27	Hamahn	0.26						○		seg2-S	30.0
28	Mokpo	0.26						○		seg3-S	26.0

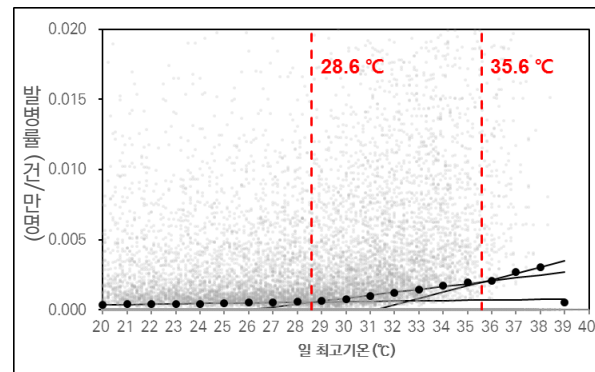
As the age increases, the threshold temperature decreases and the incidence increases



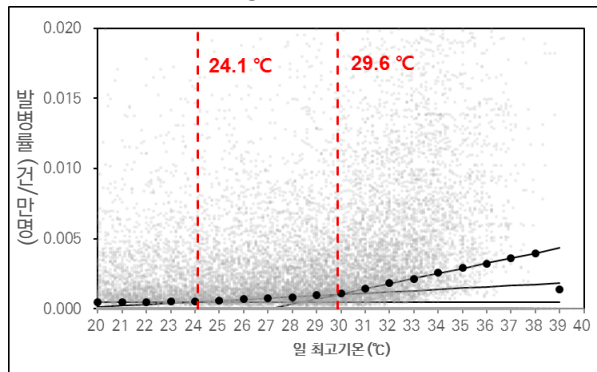
Age 20-30



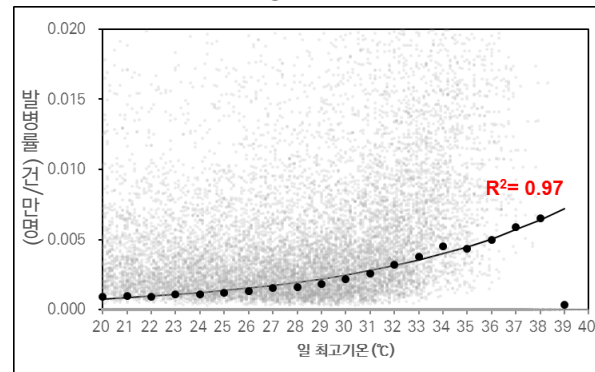
Age 40



Age 50-64

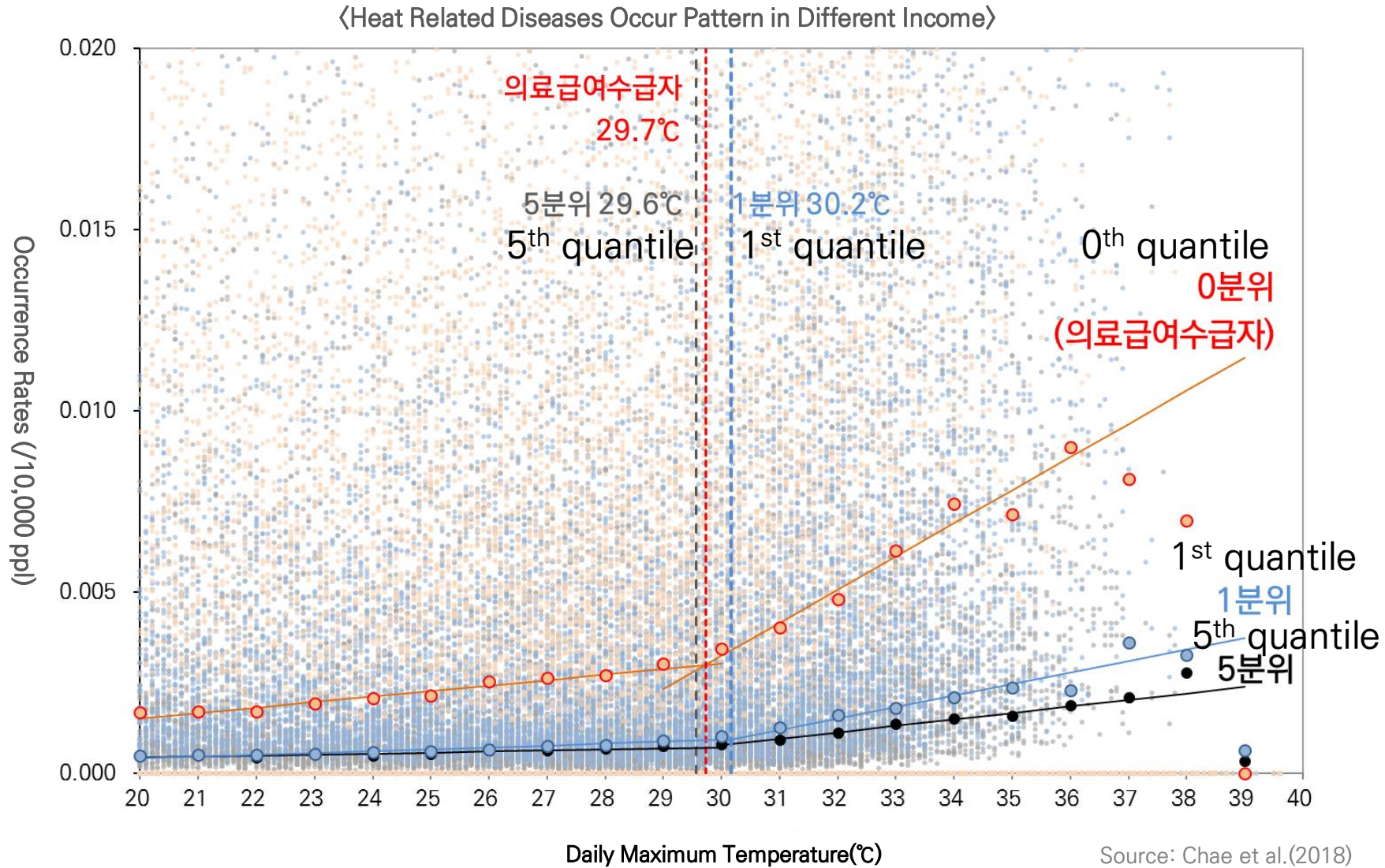


Age > 65



Less Income, Higher in Heat Related Diseases incidence Rates

► Similar in threshold temperature, differences in incidence

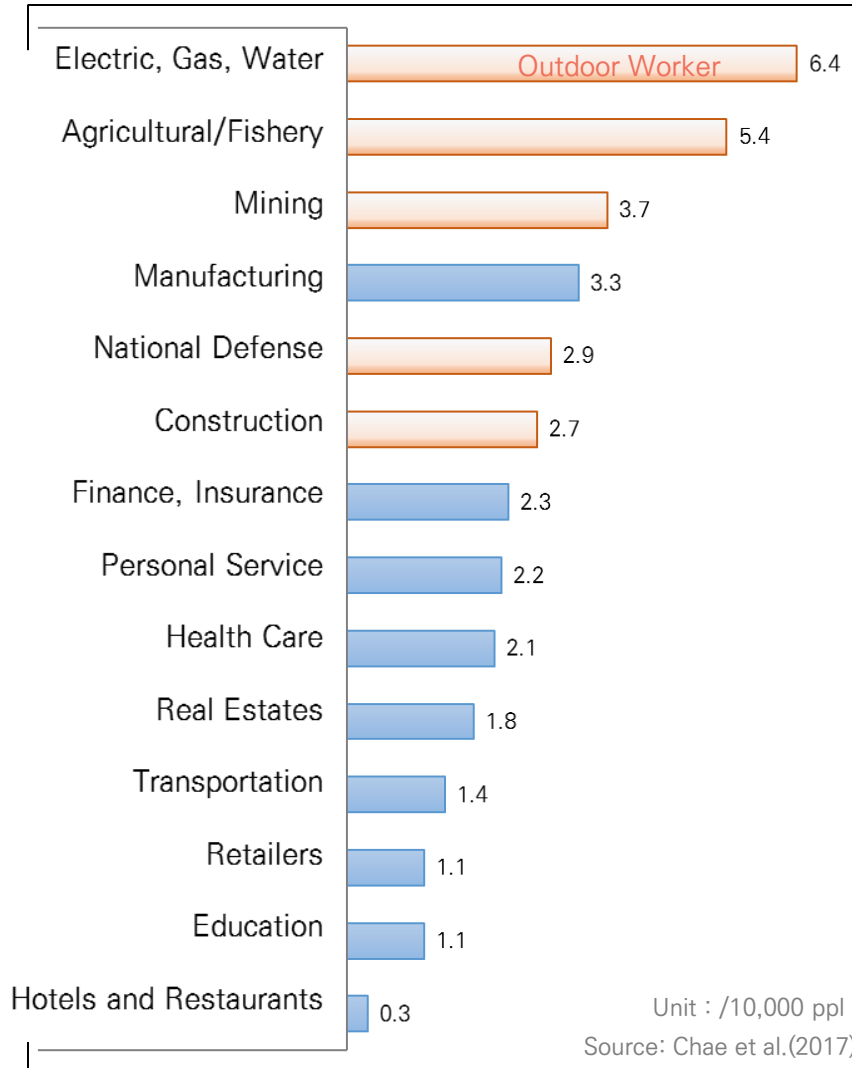


Source: Chae et al.(2018)

Outdoor Workers and Foreigner's Heat Related Diseases incidence Rates Are Higher

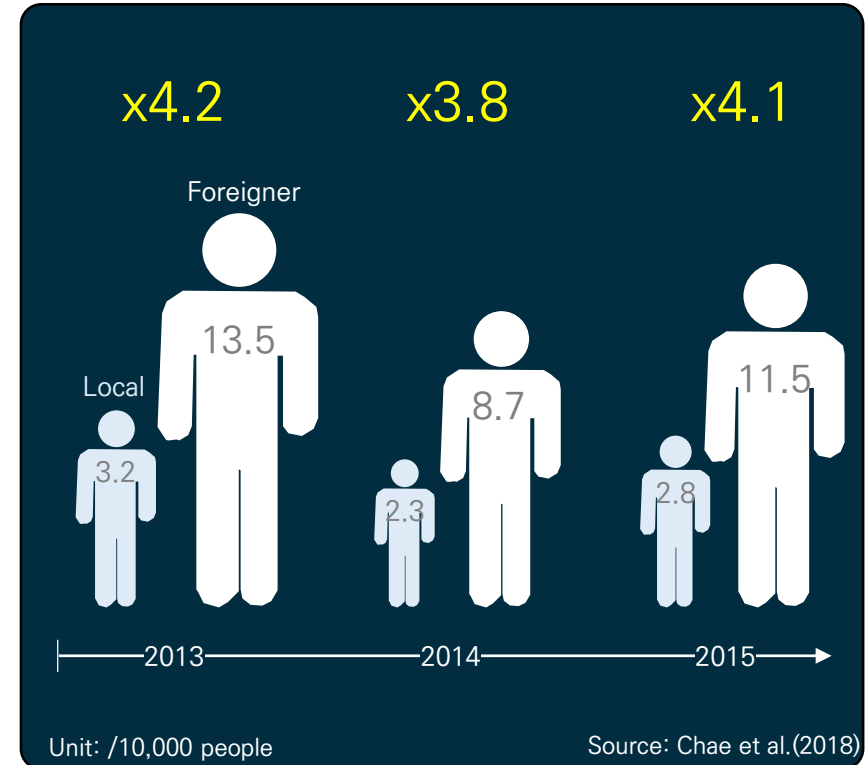
► incidence Rates of Outdoor Workers are higher than others

〈2009–2015 Occurrence Rates in Different Occupation〉



► Foreigner's incidence Rates are Four Times Higher than Local People

〈Comparison of Occurrence Rates with Local and Foreigner〉



* Foreigner : Employed Foreigners' Occurrence Rates

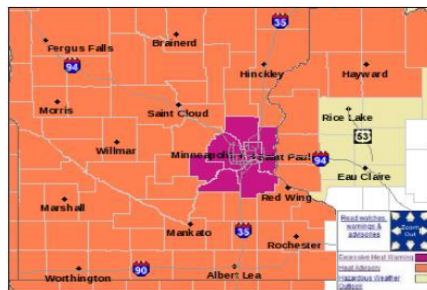
* Local : Occurrence Rates in Age 20~40

Ch.3 Towards Impacts Based Heatwave Forecasts

Heat Wave Warning Systems in Other Countries

► Heat wave alert services in other countries

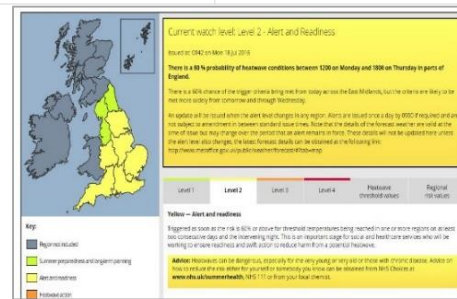
		United States	France	United Kingdom	Australia
Services		National Weather Service	Vigilance météorologique	Heat-Health Watch	Heatwave Service for Australia
Impact Forecasting	Hazard	Heat/cold wave, flood, extreme wind, heavy precipitation, tornado, etc.	Heat/cold wave, flood, extreme wind, heavy precipitation, tornado, etc.	Heat wave	Heat wave
	Exposure	Region, road, vulnerable group	Region, road, vulnerable group	Region, vulnerable group	Region
	Vulnerability	Qualitative	Qualitative	Qualitative (health oriented)	-
	Response	○	○	○	×
Scale	Temporal	When meteorological hazard is predicted	Hourly (twice in a day)	Update regularly	Daily (5 days)
	Spatial	State, County, Zone	Region (99 region)	England (10 region)	National (8 region)
Use		3 stage Heat Wave Index	4 stage Alert Index	4 stage Alert Index + Probability	4 stage Heat Wave Index
Critical Temperature		○	○	○	×



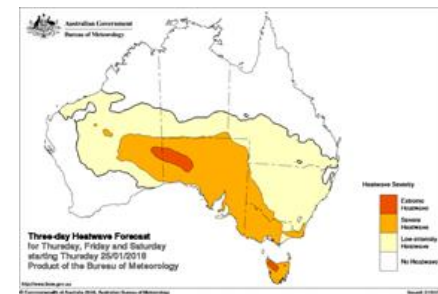
⟨United States⟩



⟨France⟩



⟨United Kingdom⟩



⟨Australia⟩

Toward Impacts Based Forecast for Heat-wave

► Other system has not reached the level of impact forecast by detailed time and space units

[Technology in other countries]

Hazard
<ul style="list-style-type: none"> Heat Wave (Temporal O, Spatial X)
Exposure
<ul style="list-style-type: none"> Broad spatial scale <ul style="list-style-type: none"> – County, State, Region Limited information of each sector <ul style="list-style-type: none"> – health, transportation, wildfire, etc.
Vulnerability
<ul style="list-style-type: none"> Generalized vulnerability of exposed group Not considering regional characteristics
Preparedness Actions
<ul style="list-style-type: none"> Proposing general response plan

[Technology in this research]

Hazard
<ul style="list-style-type: none"> Heat Wave (Temporal O, Spatial O)
Exposure
<ul style="list-style-type: none"> Considering factors of detailed exposed region <ul style="list-style-type: none"> – 100m X 100m spatial scale Considering multiple socio-economic indicators Multiple sectors (health, agricultural, energy, etc.)
Vulnerability
<ul style="list-style-type: none"> Providing vulnerability information of exposed group in detailed spatial scale Considering regional characteristics
Preparedness Actions
<ul style="list-style-type: none"> Suggest customized response plan

Impacts based forecasting and warning

- US, France, Canada, UK
- Provide climate indicators and projected impacts

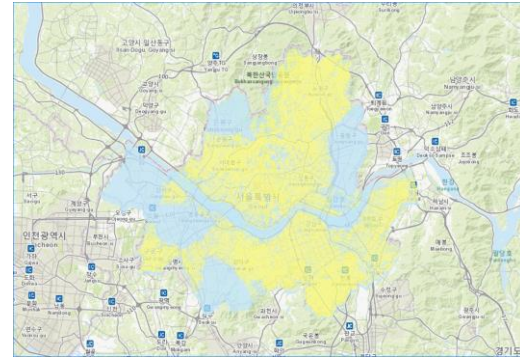
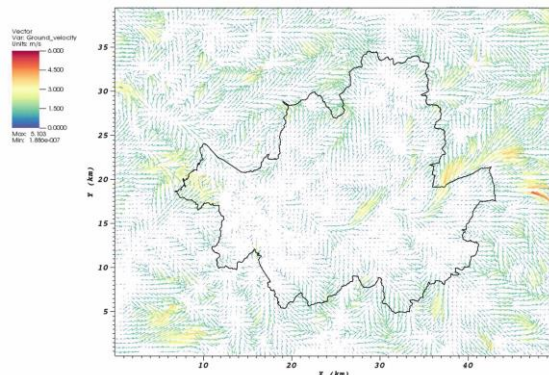
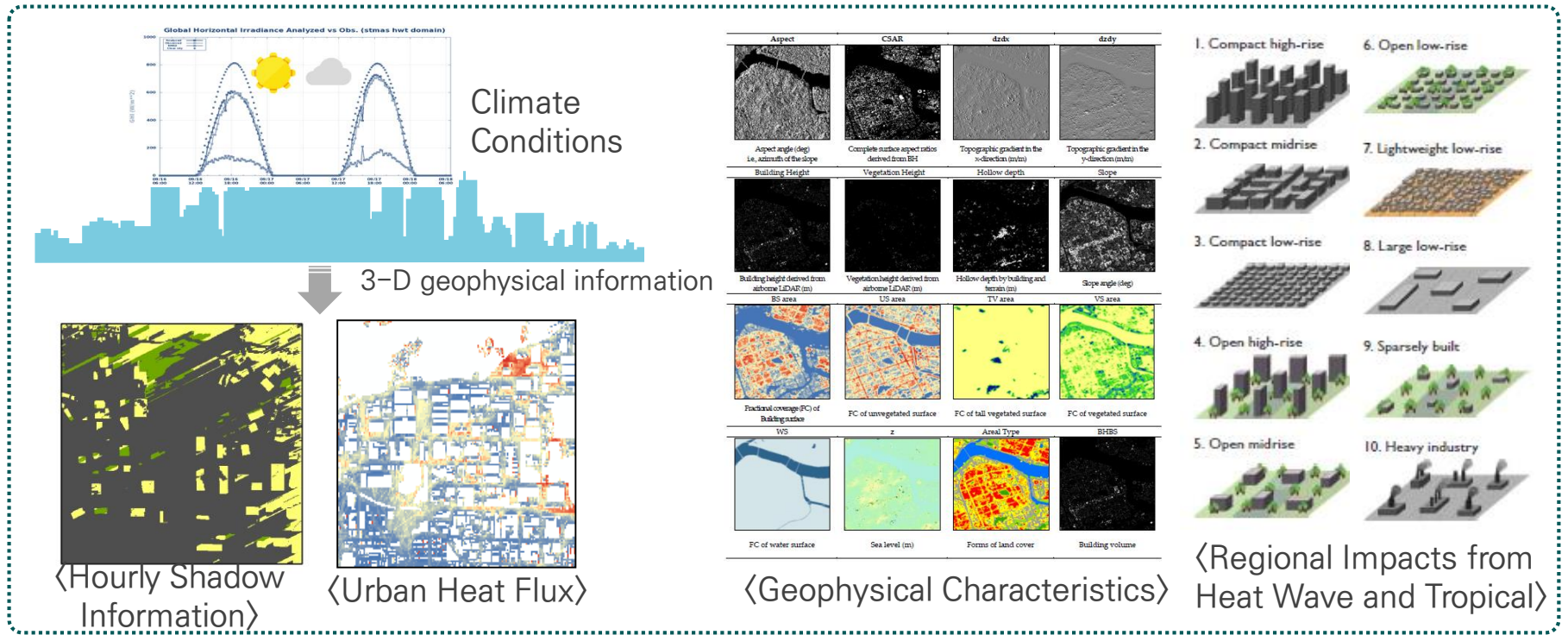
Forecasting and warning

- Development of research technology
- Provide characteristics of exposed group

Climate Forecasting and Warning

South Korea and other countries

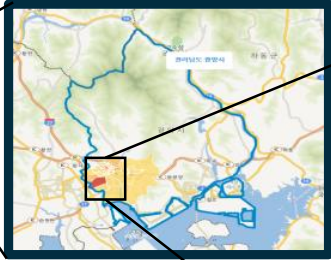
Differences in Detailed Climate Projection



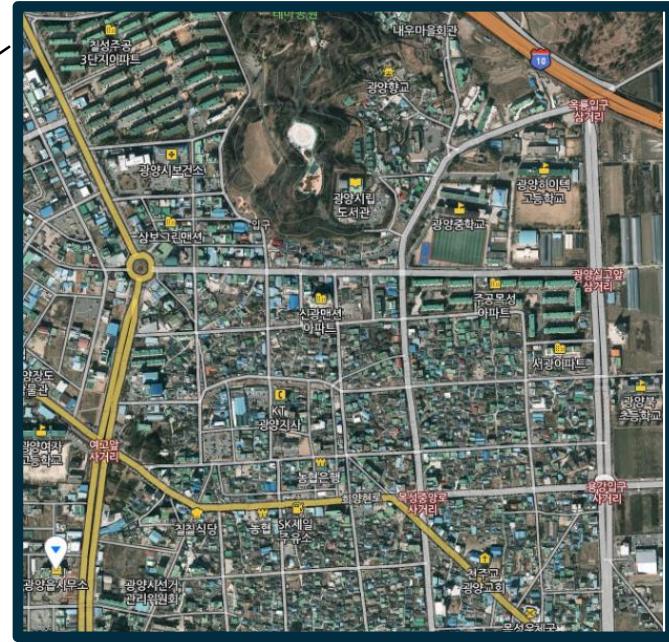
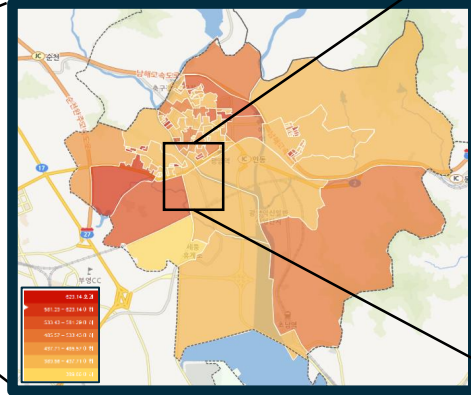
〈Generate Meteorological Information Considering Temporal/Spatial Variability (100m x 100m, 1.5m Altitude)〉

Characteristics of Exposed Region

► Exposed characteristics by analyzing various panel data

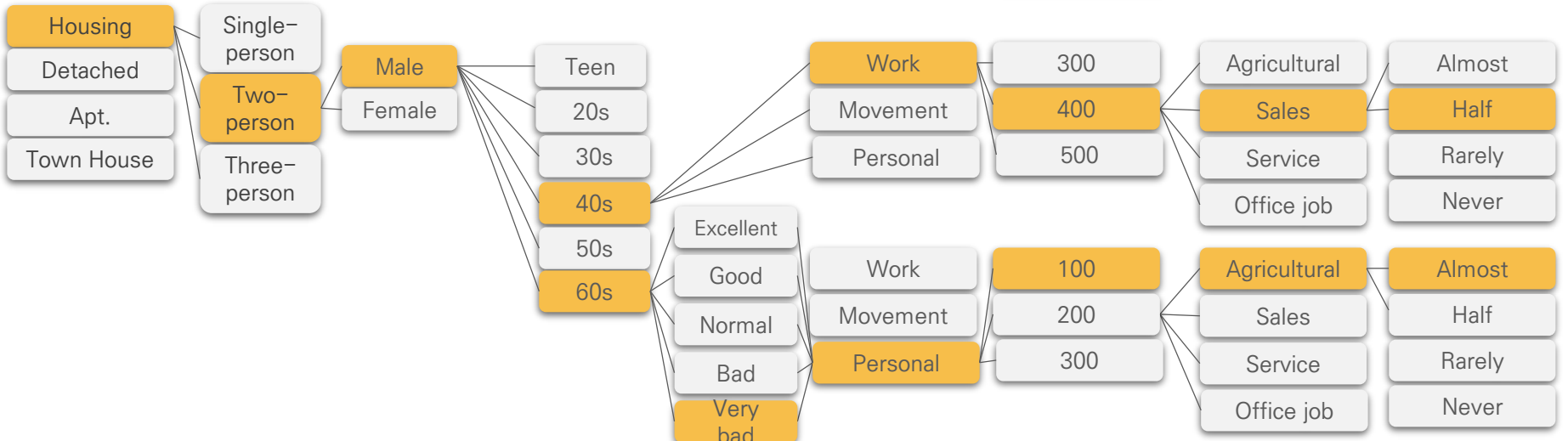


〈Gwangyang Population Distribution〉



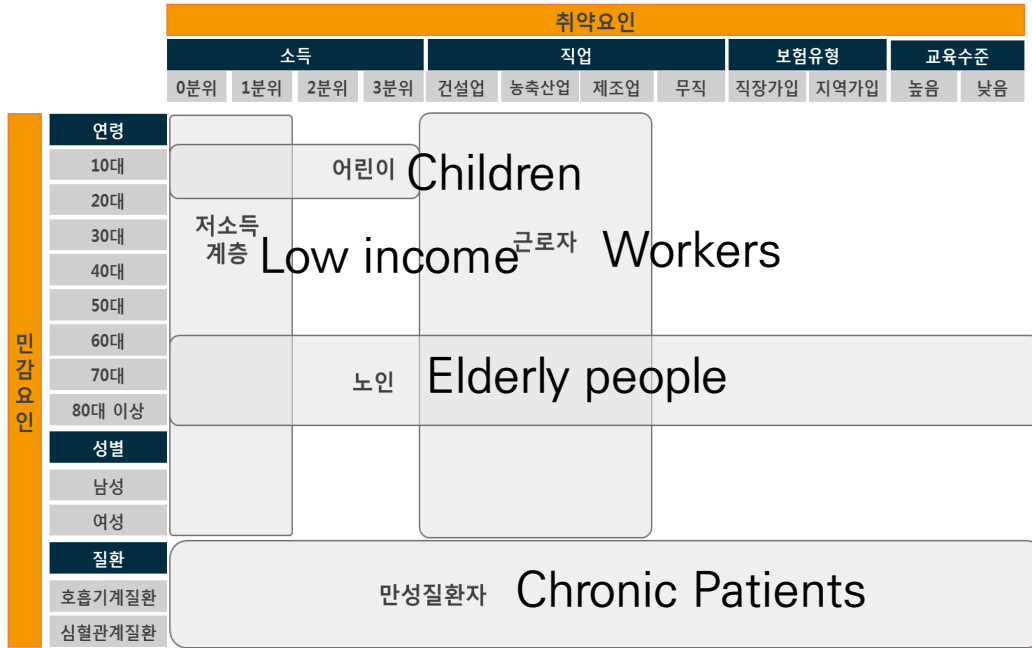
Population		Elderly People	Life Pattern	Work Conditions		
------------	--	----------------	--------------	-----------------	--	--

Housing, # of family, gender, age, etc.		Health	Spare time	Monthly Income	Occupation	Exposed to Heat
---	--	--------	------------	----------------	------------	-----------------

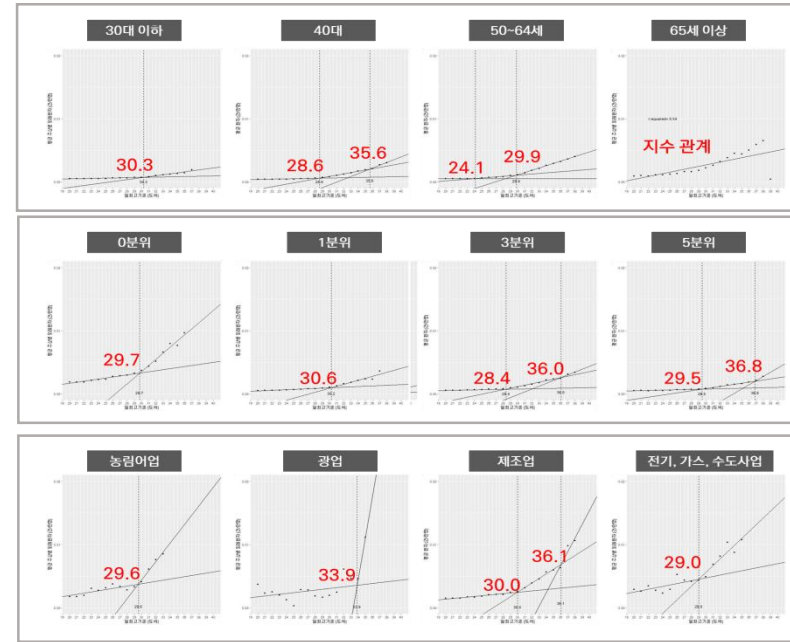


Analyzing Impact Function in each Vulnerable Group

▶ Selecting vulnerable group considering susceptibility and vulnerability to heat wave



〈Selecting Vulnerable Group〉



Source: Chae et al.(2017)

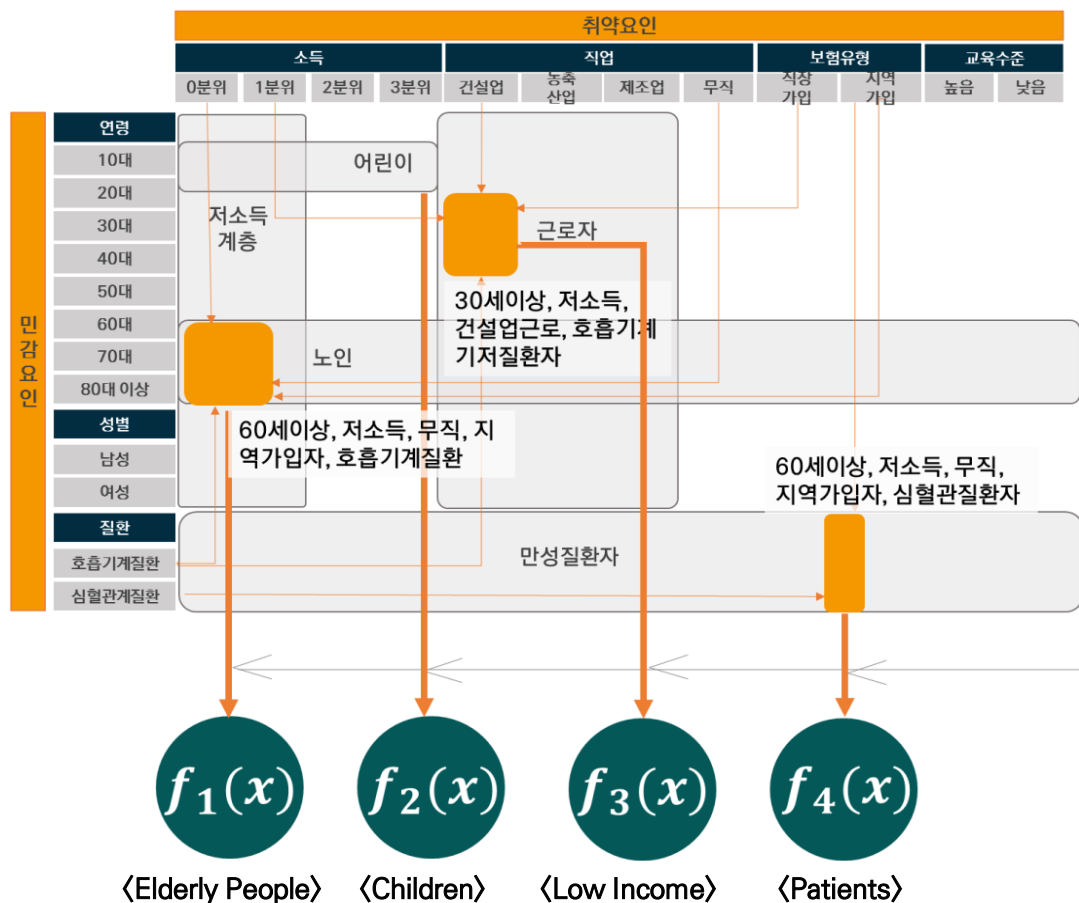
〈Critical Temperature of Age, Income, and Occupation〉

Indicators	Source
Age	채여라 외(2017), Kim et al.(2017), Heo et al.(2016), 이나영 외(2014), Son et al.(2014), 정대호(2013), Li et al.(2012), Kyseř and Kim(2009), Bell et al.(2008)
Gender	Son et al.(2014), 정해관 외(2014), Lim et al.(2013), 정대호(2012), Kyseř and Kim(2009), Anderson et al.(2013), Bell et al.(2008)
Income	채여라 외(2017), Kim and Joh(2006)
Occupation	채여라 외(2017), 김도우 외(2014), Zander et al.(2015)
Education Level	이지수 외(2016), Bell et al.(2008)
Insurance	채여라 외(2017), Schmeltz et al.(2016)
Hospitality	Kim et al.(2017), Heo et al.(2016), 이나영 외(2014)

〈Indicators of Socio, Economic, and Environmental Vulnerability of Heat Wave〉

Analyzing and Projection of Impacts from Heat Wave considering social, economic, environmental characteristics of vulnerable group

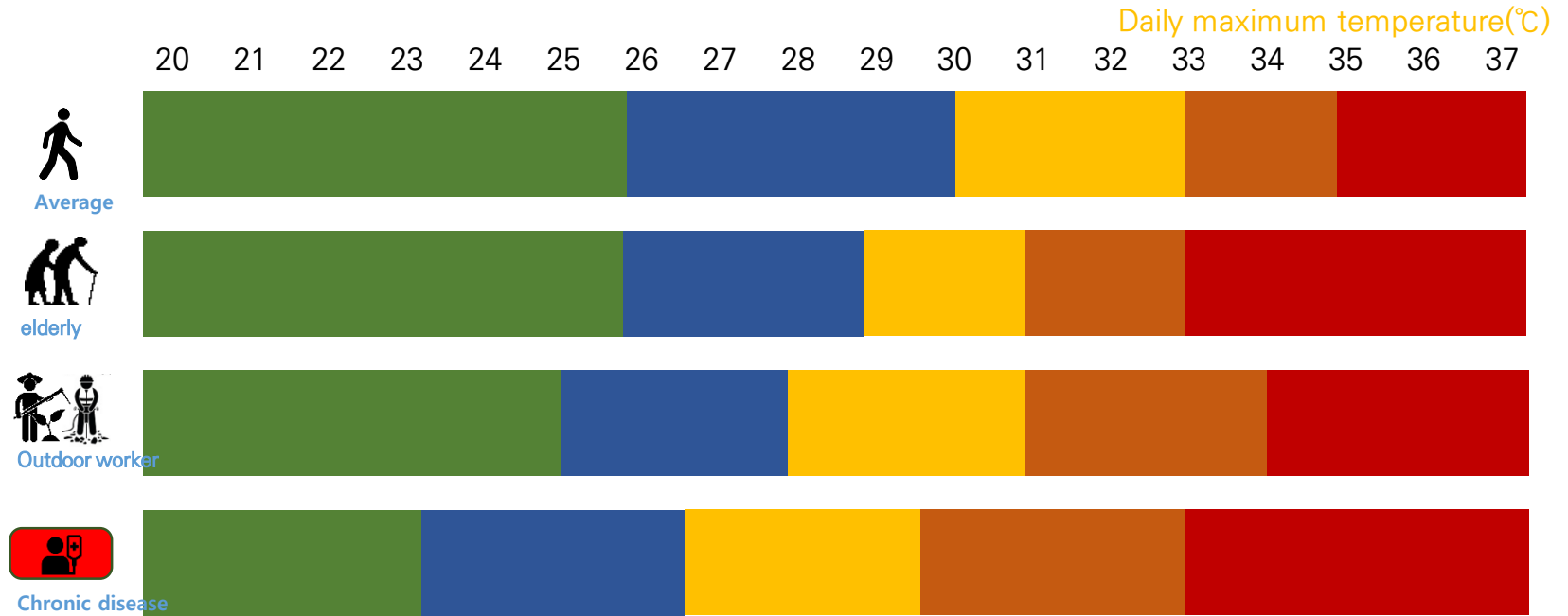
- ▶ Developing heat wave impact function considering age, income, occupation, work environment, etc.
- ▶ Analyzing the second and third indirect effects of heat waves by groups of vulnerable people and mapping systems
 - Reduce in work productivity, increase in vulnerable group



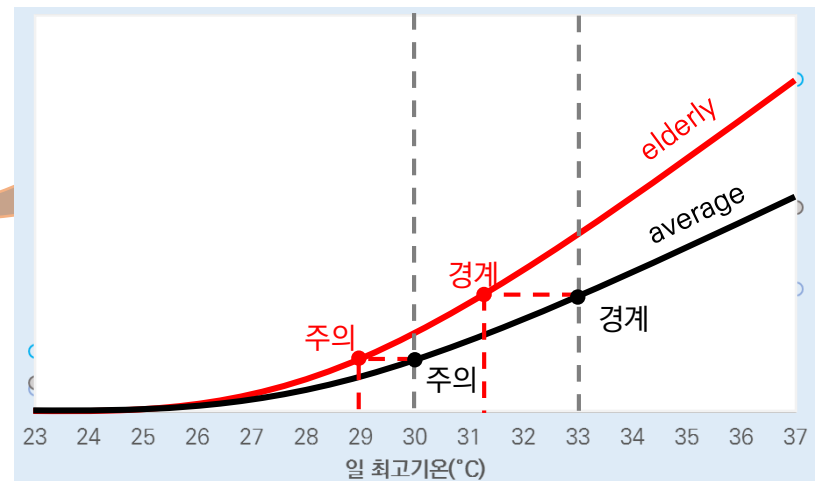
<Climate Variables>
 Maximum temperature, daily maximum temperature, average daily temperature, relative humidity, etc.

Towards Impacts Based Forecast

► Heath

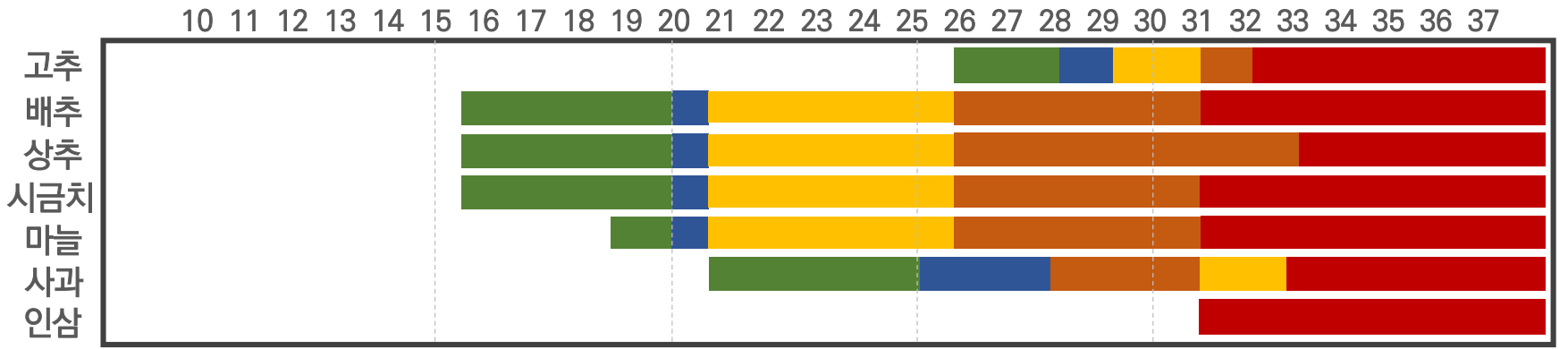
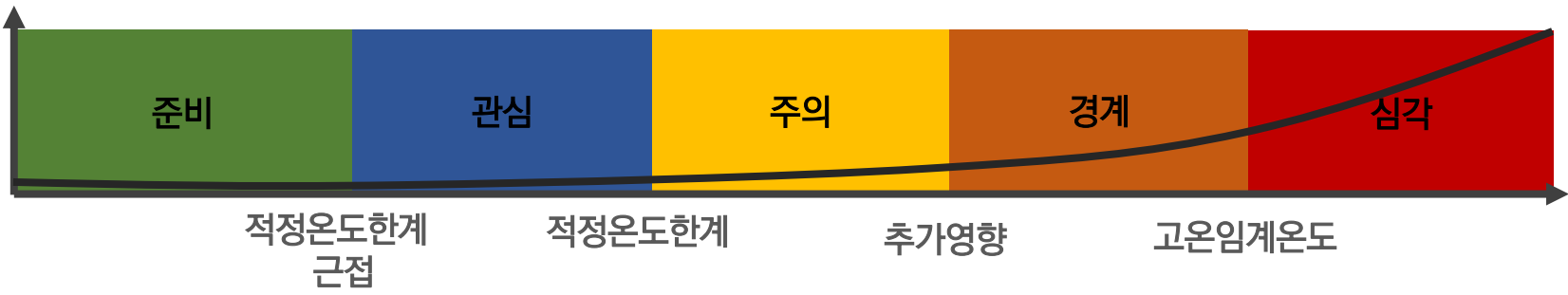
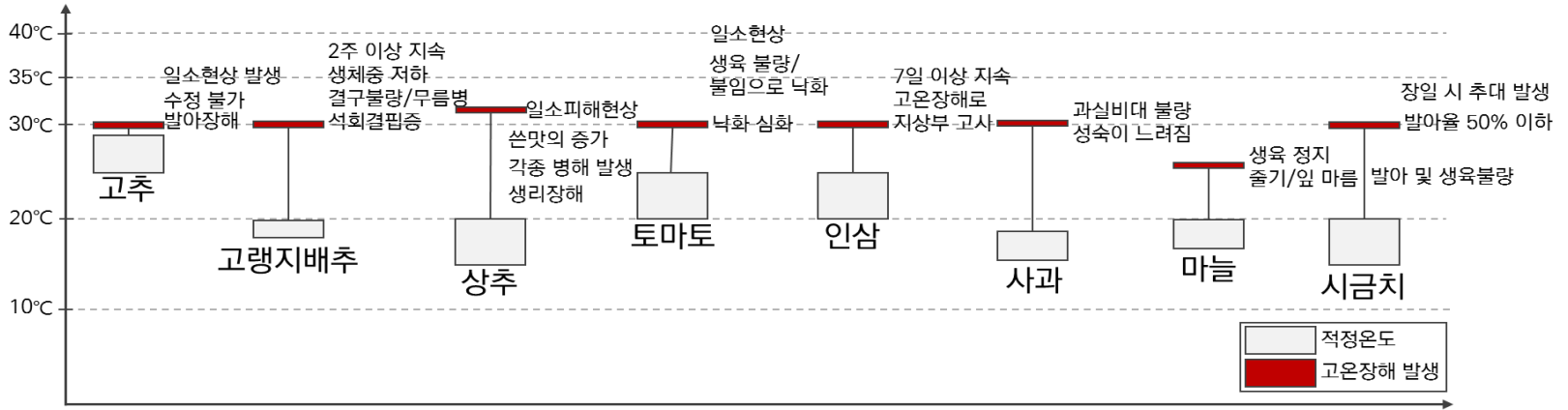


RR



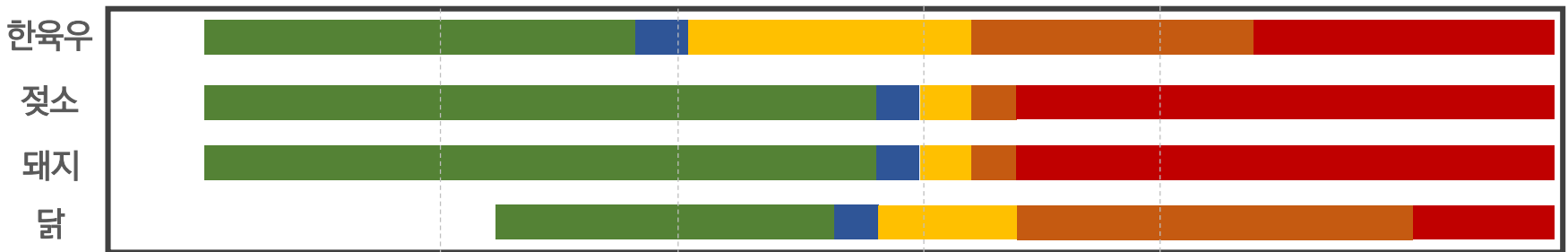
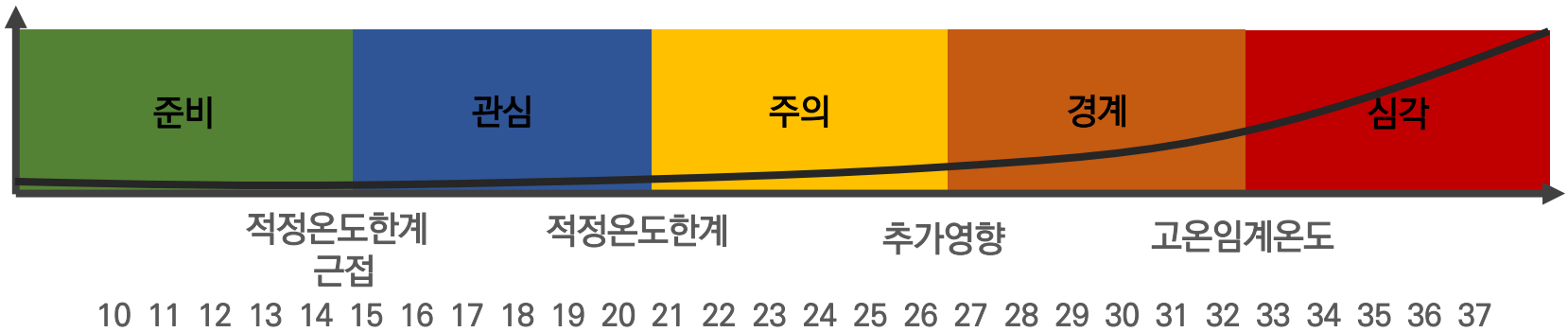
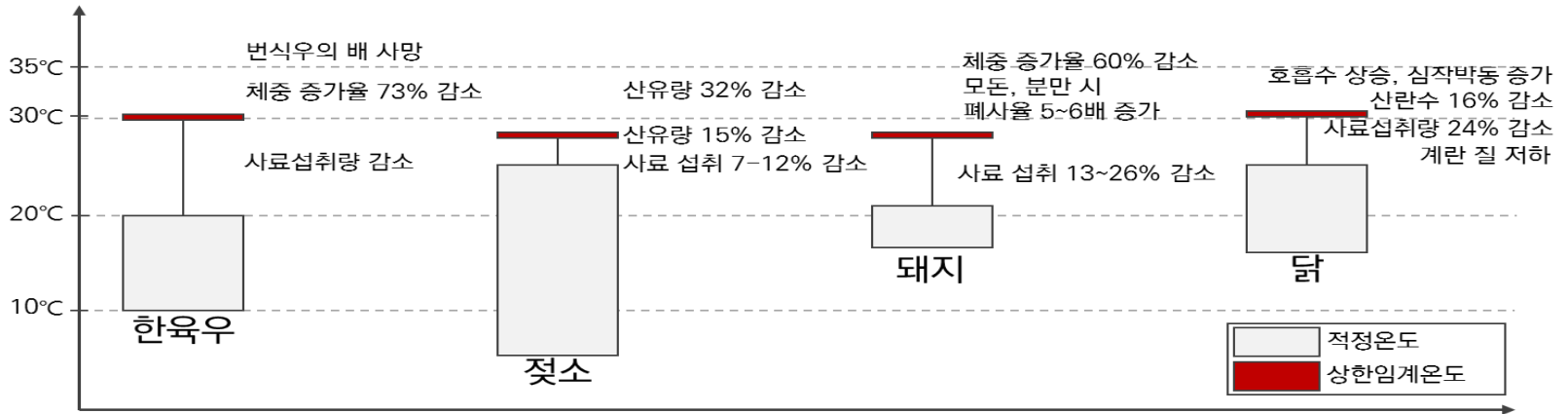
Towards Impacts Based Forecast

► Agriculture



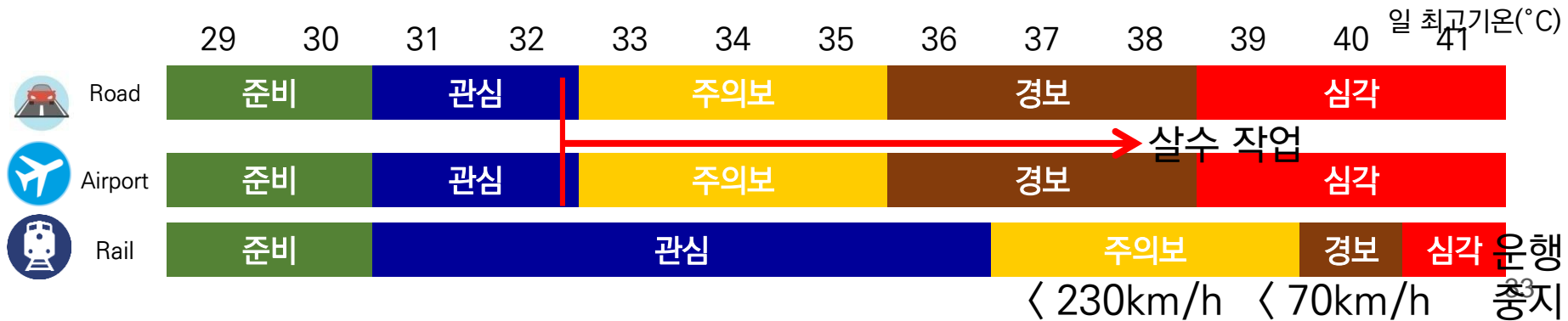
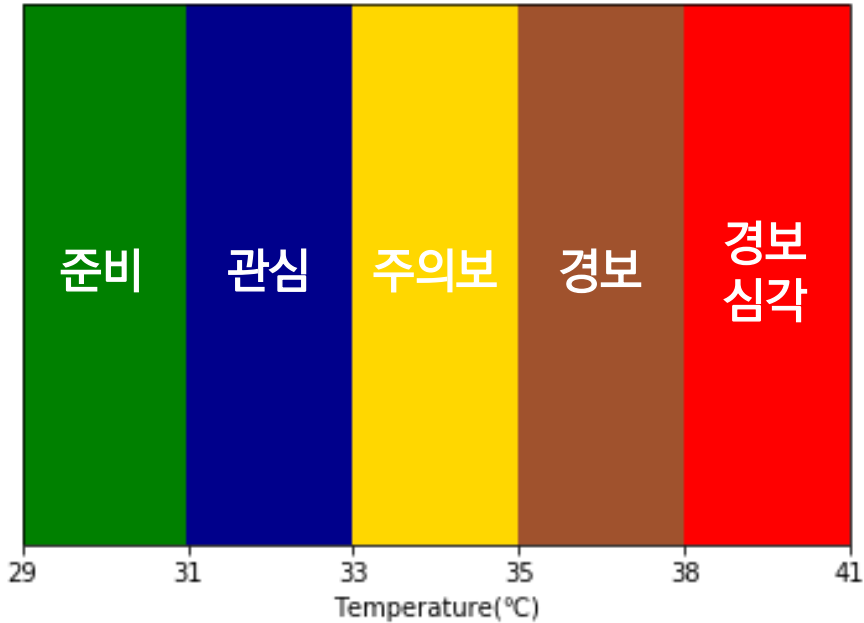
Towards Impacts Based Forecast

▶ Livestock



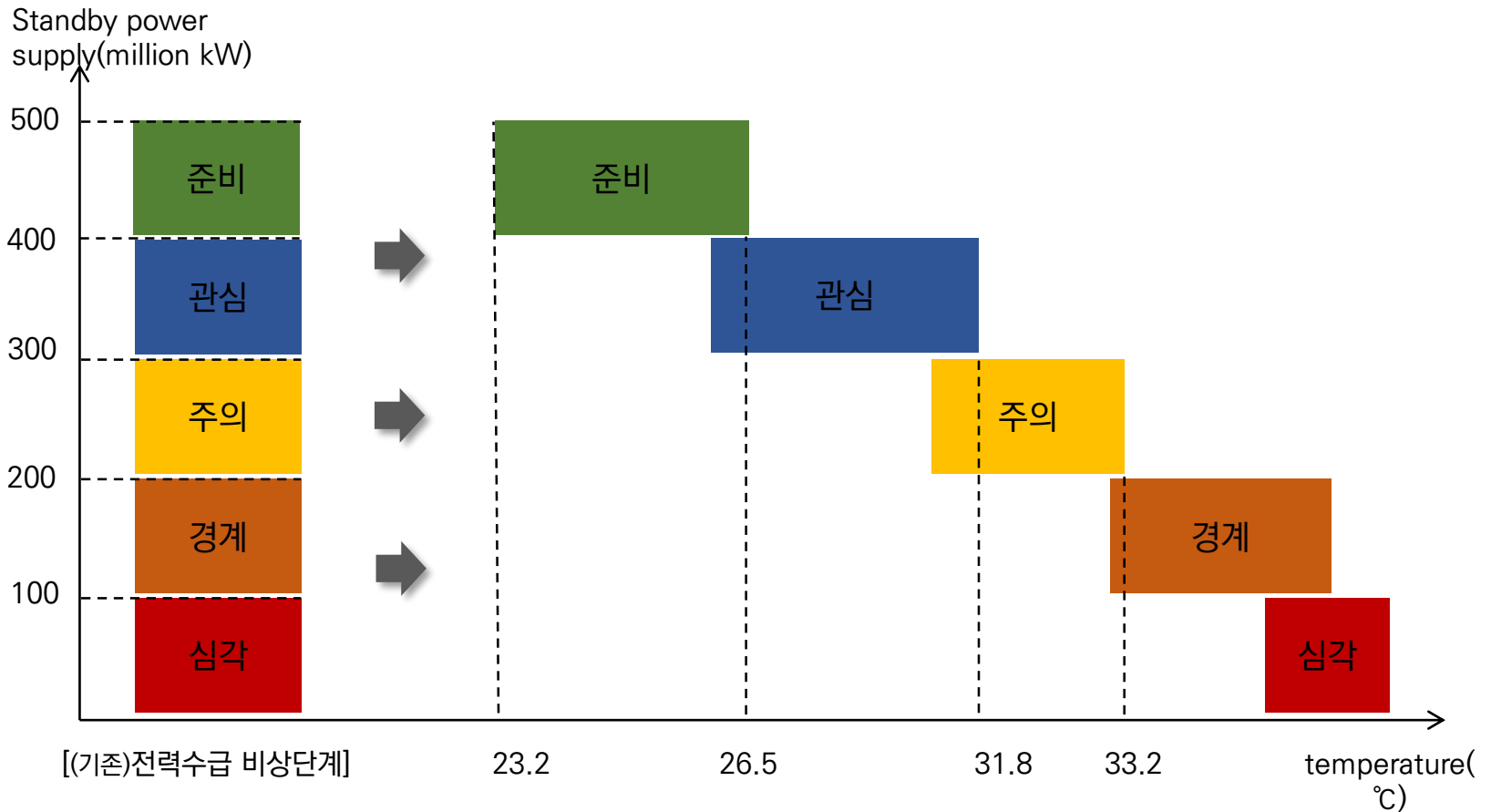
Towards Impacts Based Forecast

▶ Transportation



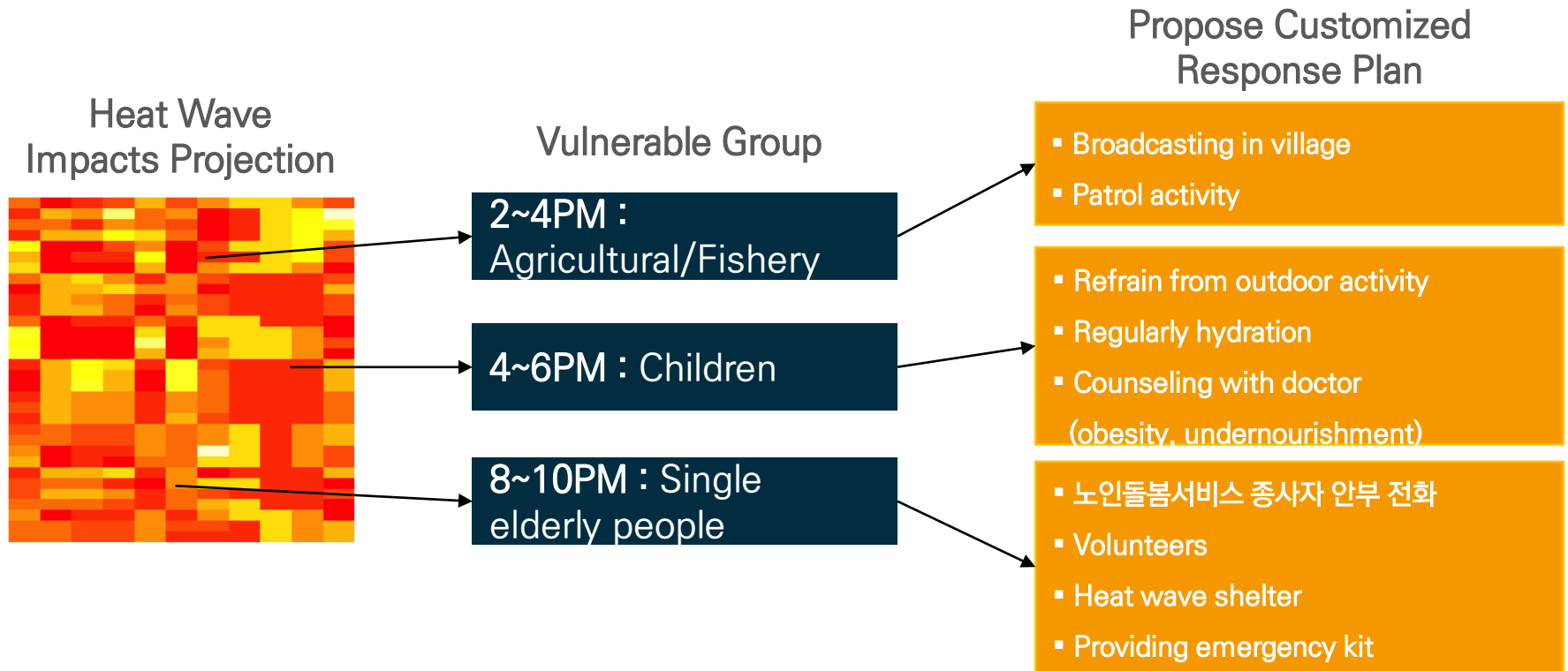
Towards Impacts Based Forecast

▶ Power supply



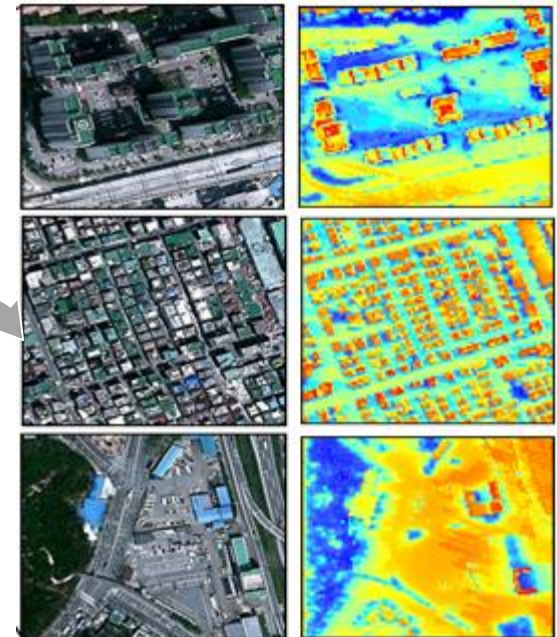
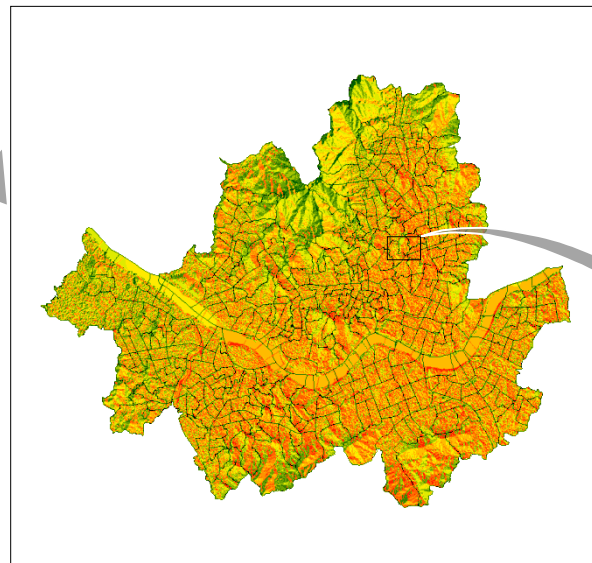
Customized measures for Different Vulnerable Groups Based on IBF

▶ Suggesting customized response plan based on impact function



Application of Real-Time Automation System by Regional Characteristics and Connection with Heat Disaster Impact Forecasting System

- ▶ Real-time generation of weather forecasts by regional characteristics and link to systems for predicting impacts of heat waves
 - Providing real-time climate information(temperature, humidity, wind, flux)
 - 100m x 100m, twice per day, 1-2days projection
- ▶ Extending major urban surface models by regional characteristics
- ▶ Application of surface model variables in time series and parametric
 - Spatialization of surface thermal environment (absorption and release) and air flow related variables



〈Example of Urban Heat Exposure〉

Development of GIS based Heat Wave Impacts Projection Platform

► Present impacts function and results of projection from heat wave

폭염 재해영향 예보 시스템

Case. 시범지역 내 축산시설 선택
→ 축산 부문 함수 결과 정보 표출
→ 폭염 재해영향 결정요인 표출

돼지 28°C 위험

- 25°C ~ 사료섭취량 11% 감소
증체량 약 16% 감소
- 27°C ~ 고온임계온도 대응필요

대응 방안

Case. 시범지역 내 대중이용시설선택
→ 폭염 재해영향 함수 결과 정보 표출
(Box line으로 위험 표시)

야외운동장 31°C 위험

- 야외운동장
오후 1시 - 4시 야외운동 위험 상승

상세정보 **대응 방안**

각 격자를 선택하였을 때
해당격자의 폭염 재해영향 예보 정보 표출

선택 시 폭염 재해영향 결정요인 상세정보 제공

폭염 재해영향 분석 항목 표출

성별: 남(100명), 여(110명) — 연령: 60대(30명), 50대(20명), 40대(20명), 30대(15명), 20대(10명) — 건강상태: 매우 좋음(30%), 좋음(20%), 보통(30%), 나쁨(20%) — 생활시간: 일(7시간), 이동(2시간), 여가(1시간) — 직업: 농림어업(30%), 판매업종(20%), 기타(50%) — 이동수단: 보도(20%), 자동차(30%), 전철(20%), 버스(30%)

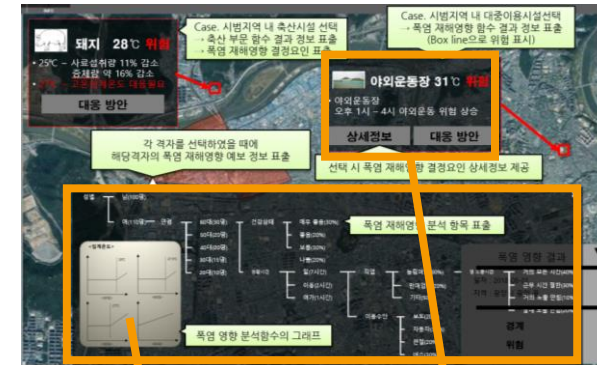
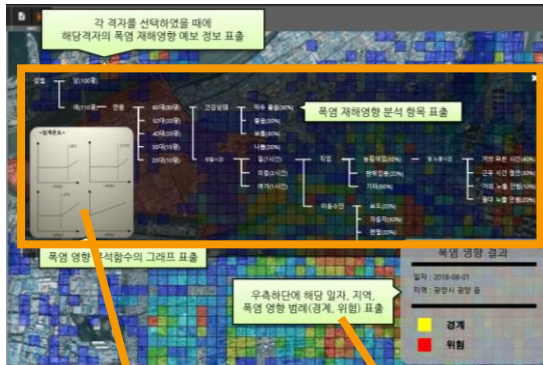
폭염 영향 분석함수의 그래프

폭염 영향 결과

- 일 노출시간: 거의 모든 시간(40%), 근무 시간 절반(30%)
- 지역: 광안리(광안리) 거의 노출 안됨(10%)
- 본래 주출입(20%)

경계 위험

Application



Elderly People

Ministry of Health and Welfare

- Assisting vulnerable group
- Heat wave shelter
- Support air conditioning system

Ministry of the Interior and Safety

- Operating heat wave shelter

Local Government

- Heat wave helper
- Promote heat wave action plan

Pedestrian

National Police Agency

- Traffic guidance for accident-prone area

School

- Operate Green Mother's Association (children's traffic assistance)

Local Government

- Establishment of traffic safety plan

Agricultural/livestock

Ministry of Agriculture, Food and Rural Affairs

- Establishment of supply and demand safety measures

Local Government

- Promote heat wave action plan

Agricultural/Fishery Worker

National Police Agency

- Patrol on agricultural/fishery workplace

Village

- Broadcasting heat wave action plan

Local Government

- Heat wave education

Worker

Ministry of Employment and Labor

- Suggest break time during heat wave for outdoor worker

Local Government

- Heat wave safety education

Children

School

- Assistance of physical education
- Guidance of outdoor activity

National Police Agency

- Traffic guidance for accident-prone area

Local Government

- Establishment of traffic safety plan
- Education

Example of Application

Public

FAX/E-mail

AS
-
IS

Risk Level and Suggested Behavior

- Heat related diseases occur rate is high(age > 65 is at particularly high risk)
- Indoor temperature and humidity is need to be controlled
- Outdoor agricultural work is prohibited from 10:00 to16:00
- Children and elderly people are refrained from physical activity
- 30 minutes break needed after 30 minutes outdoor work, hydrate with salted water or ionized beverage

- No information in detailed temporal/spatial units
- Providing uniform risk information

TO
-
BE

Aug. 16th Heat Wave Impact Projection in Gwangyang

Time	Location	Impacts	Suggested Activity
06-09	Crossroad	Increase in traffic accidents of elderly people	Assistance of elderly people is needed
10~15	Steel Works	Increase in heat related diseases and accidents	Break time for outdoor workers
13-15	Elementary School	Increase in heat related diseases for children	Refrain from outdoor activity
	Crossroad	Extreme temperature occurs in high population area	Sprinkler truck needed to operate
20-06	Madong	Increased in underlying diseases patients due to tropical nights	Night heat wave shelter and volunteers needed

- Suggesting a detailed guideline in specific time and location

Example of Application

National

KMA WEB

AS
-
IS

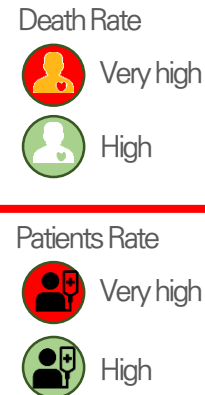
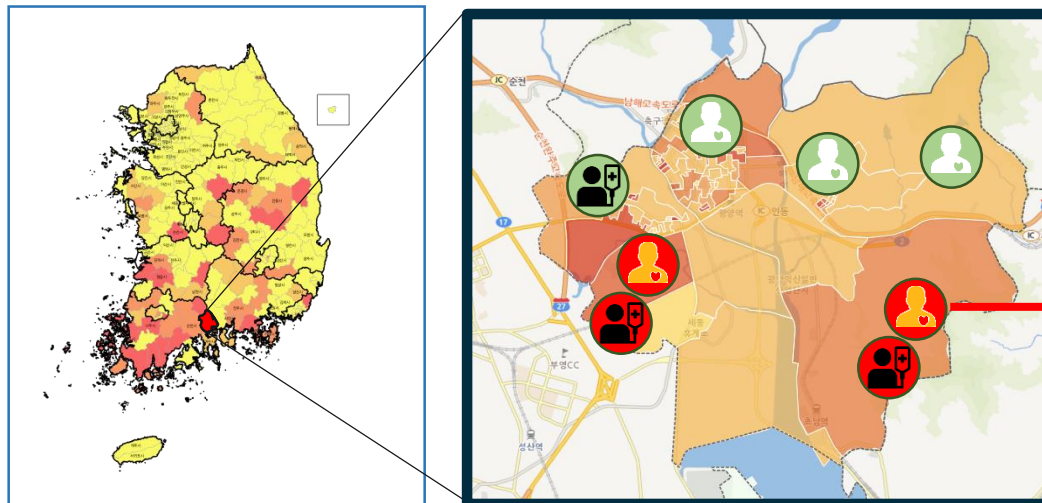


- Life Weather Index
 - e.g. heat index

TO
-
BE

> Heat-related diseases

Gwangyang



- Impacts Projection
 - e.g. heat related diseases

Characteristics

Housing, gender, age, life pattern, income, etc.

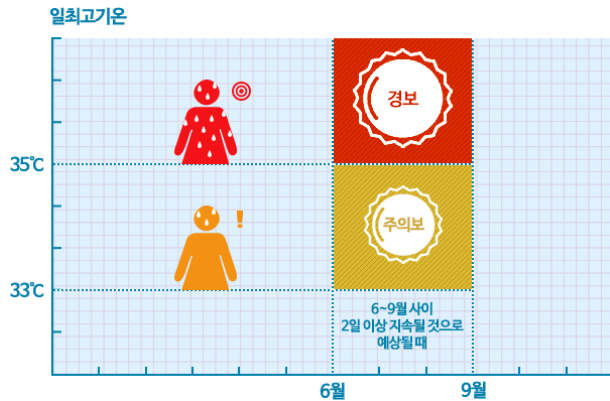
Example of Application

National

KMA WEB

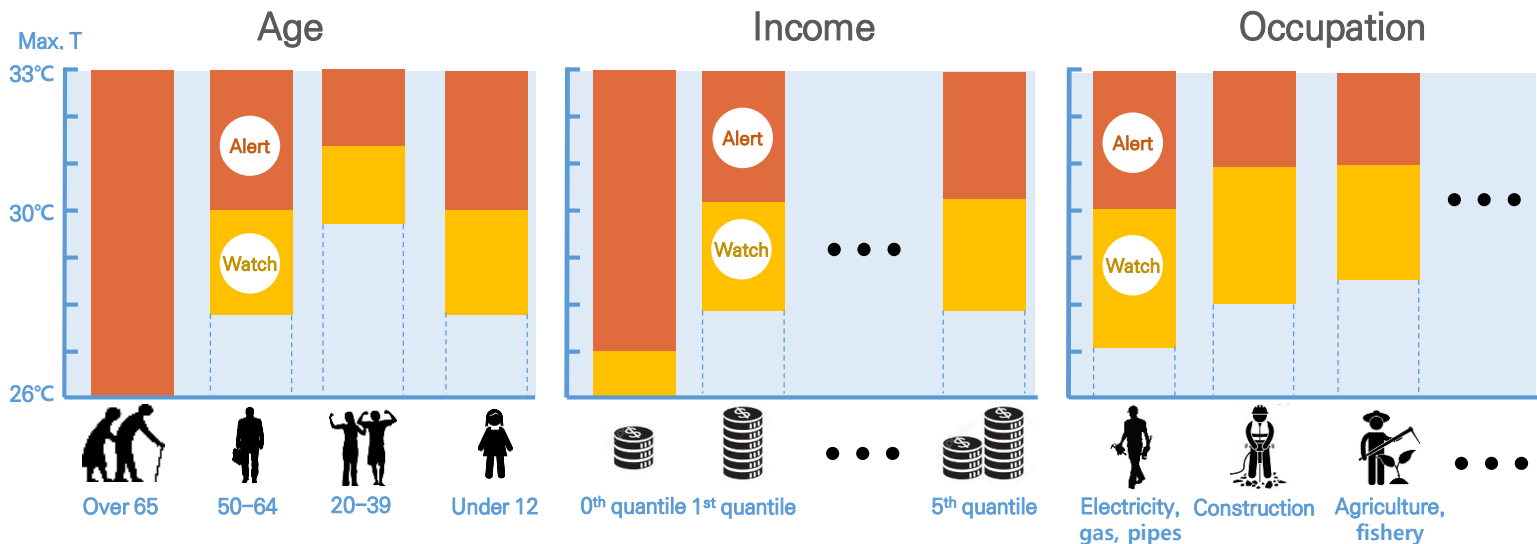
AS
-
IS

- Heat waves alert is based on same temperature nationwide and suggest equal response actions



TO
-
BE

- Heat wave alert varies with regional climate, social, economic, environmental conditions



Example of Application

National

KMA WEB

AS
-
IS






Uniform response action

외출시

 12~17시 실외활동 자제하기	 자외선 차단제 사용
 햇볕 노출 피하기	 응급환자 발생시 119 전화
 물 충분히 마시기	 격렬한 운동 하지 않기

TO
-
BE

Customized response action considering location, temporal information

Location	Subject	Hour	Temperature	Impacts	Response
GwangGeumho- yang Steel Works Jungdong Elementary School	 Worker	10-15	30°C	Heat related diseases increase in outdoor workers	Break time operation
	 Children	10-16	28°C	Increase in heat related disease for children	Refrain from outdoor activity
Gwan- yang Eup Detached House		12-14	31°C	Increase in risk of pedestrian accidents	Traffic assistant
	 Single elderly ppl	20-06	25°C	Increase in death rate from underlying disease	Night heat wave shelter operation
	 Agriculture/ Fishery	12-14	30°C	Increase in poultry collapse	Air circulation
	 Elderly ppl	16-20	26°C	Traffic accidents increase for elderly people	Traffic assistant activity

Thank You

Korea Environment Institute
Yeora Chae

