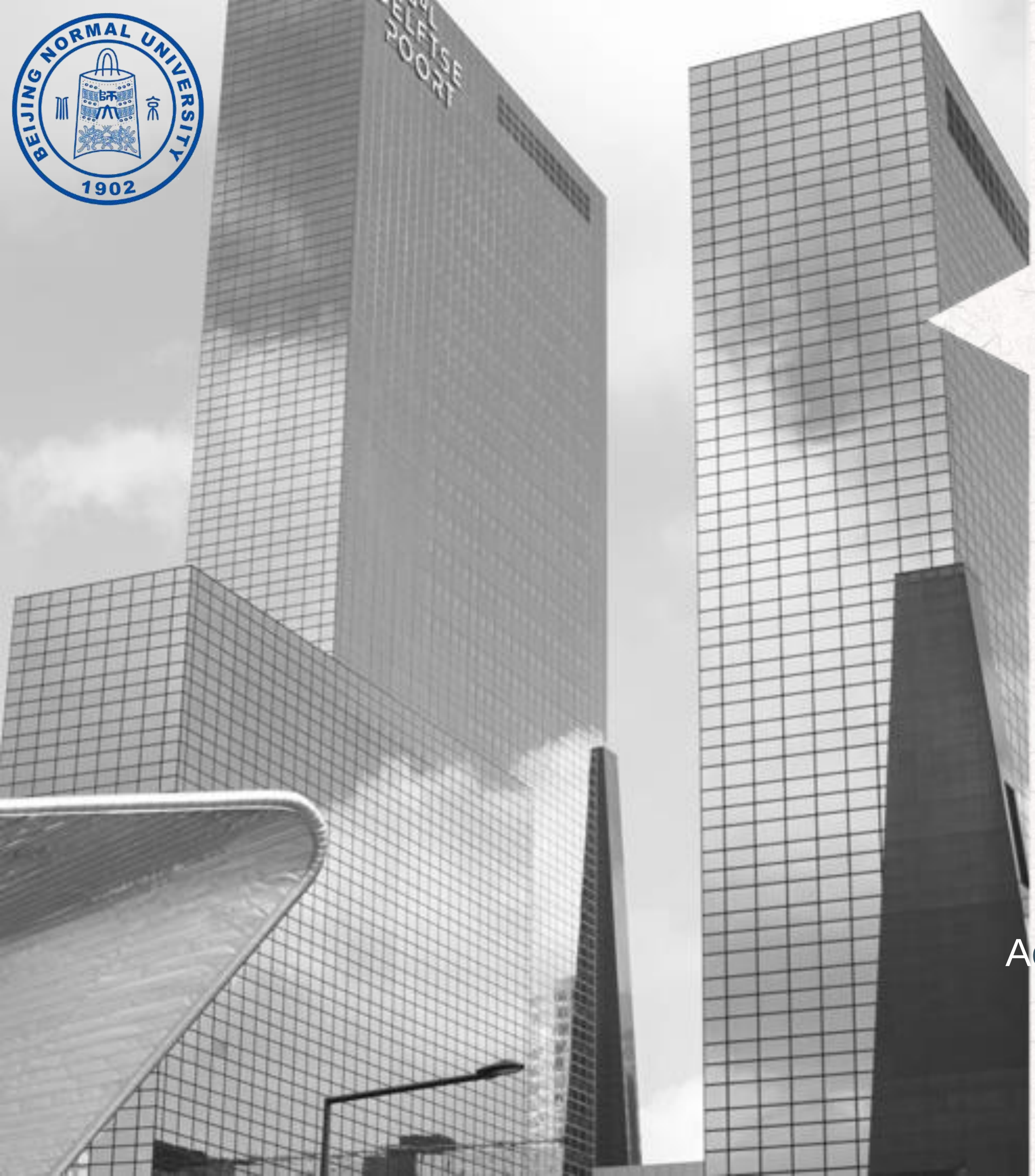

Effectiveness assessment of heatwave early warning system

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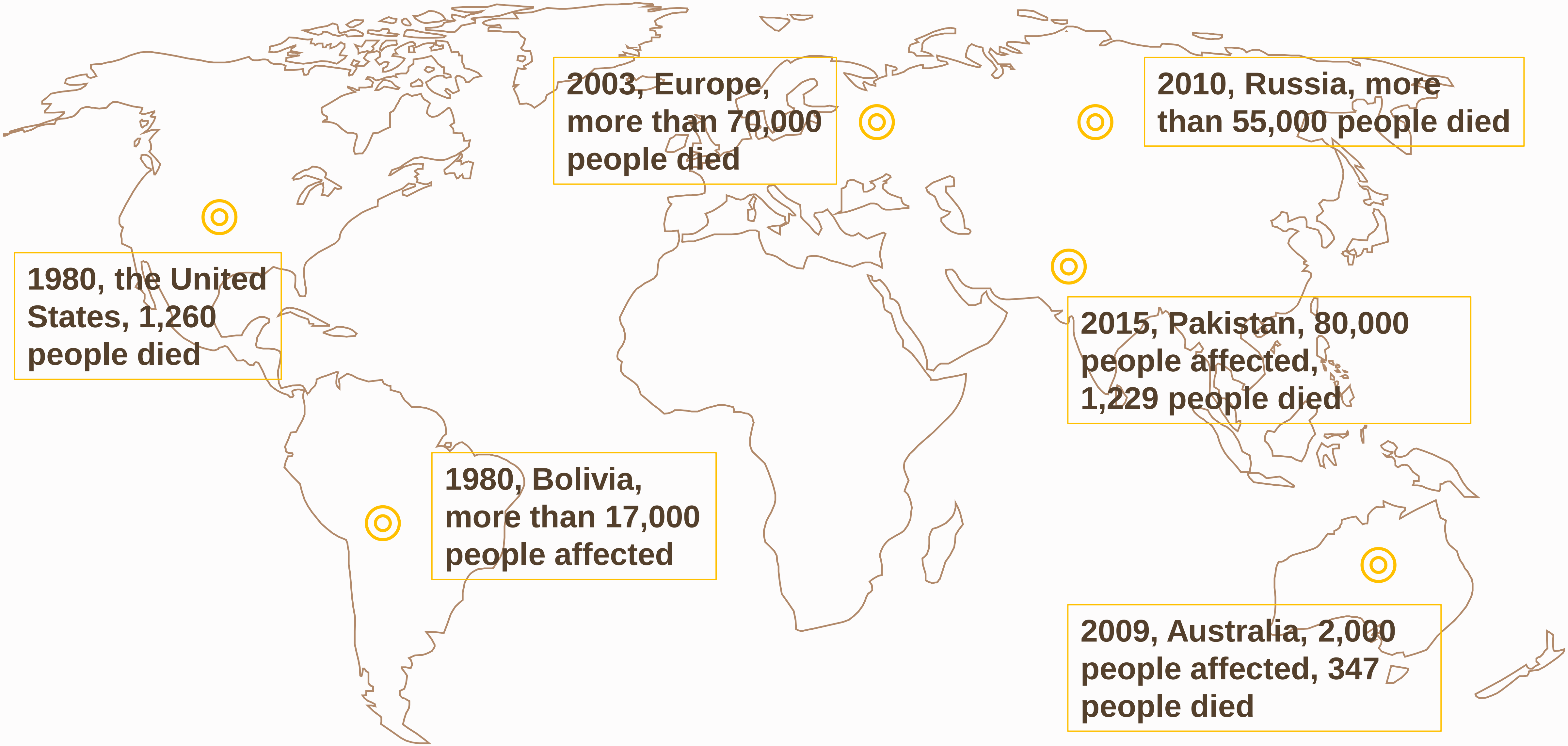
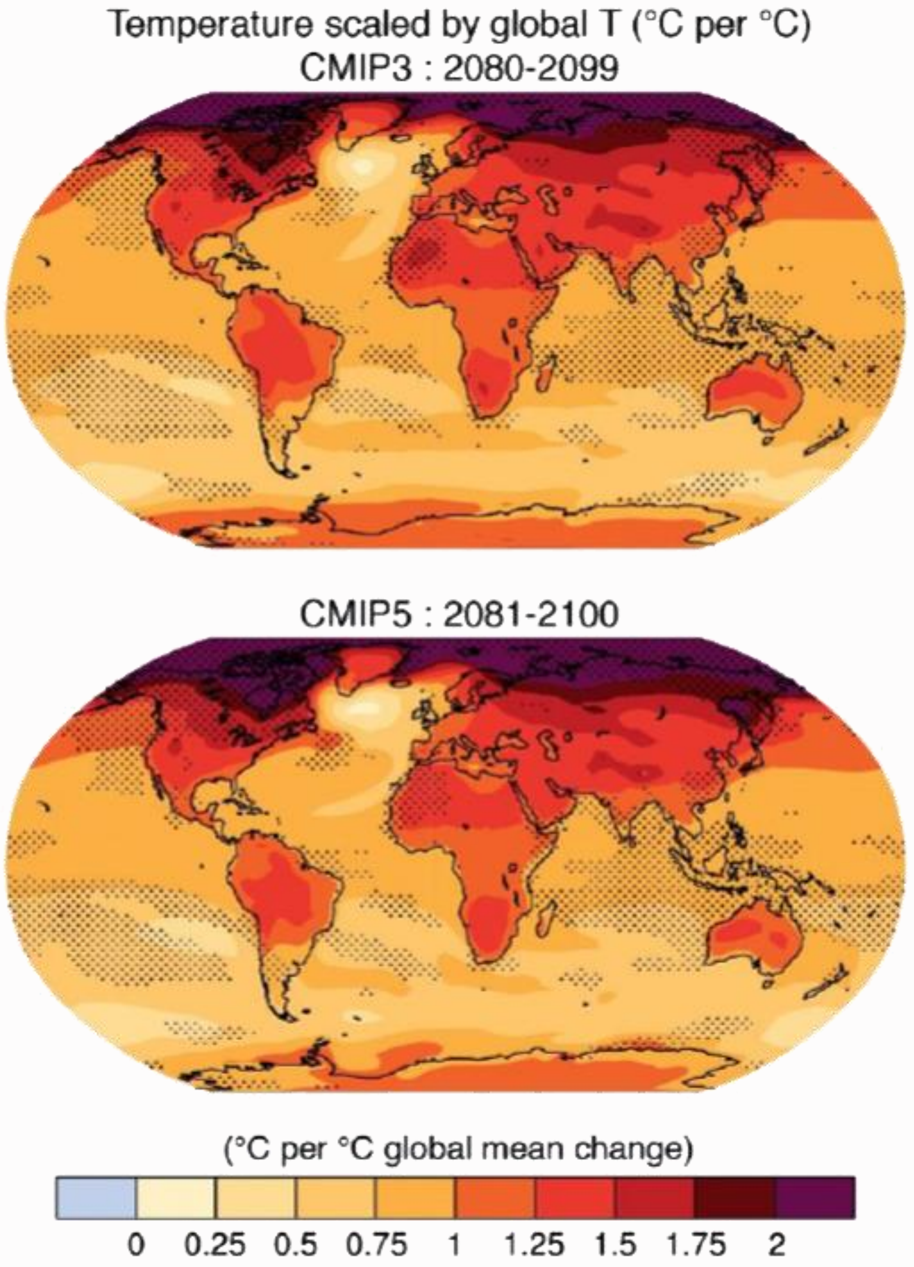
CONTENTS

Heatwave Events



Source： EM-DAT (CRED)



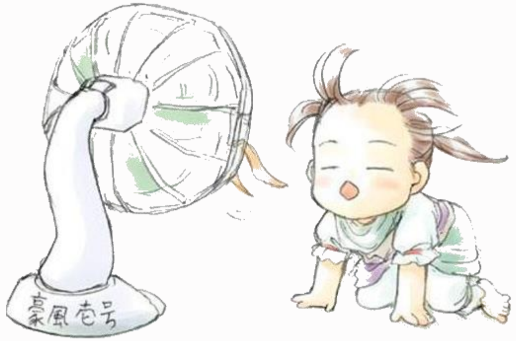
Global warming

More frequent heatwave

Intense extreme high temperature

Increase severity of heatwaves

Increase duration of heatwaves



Heat cramps

Heat rash

Heat exhaustion

Heat oedema

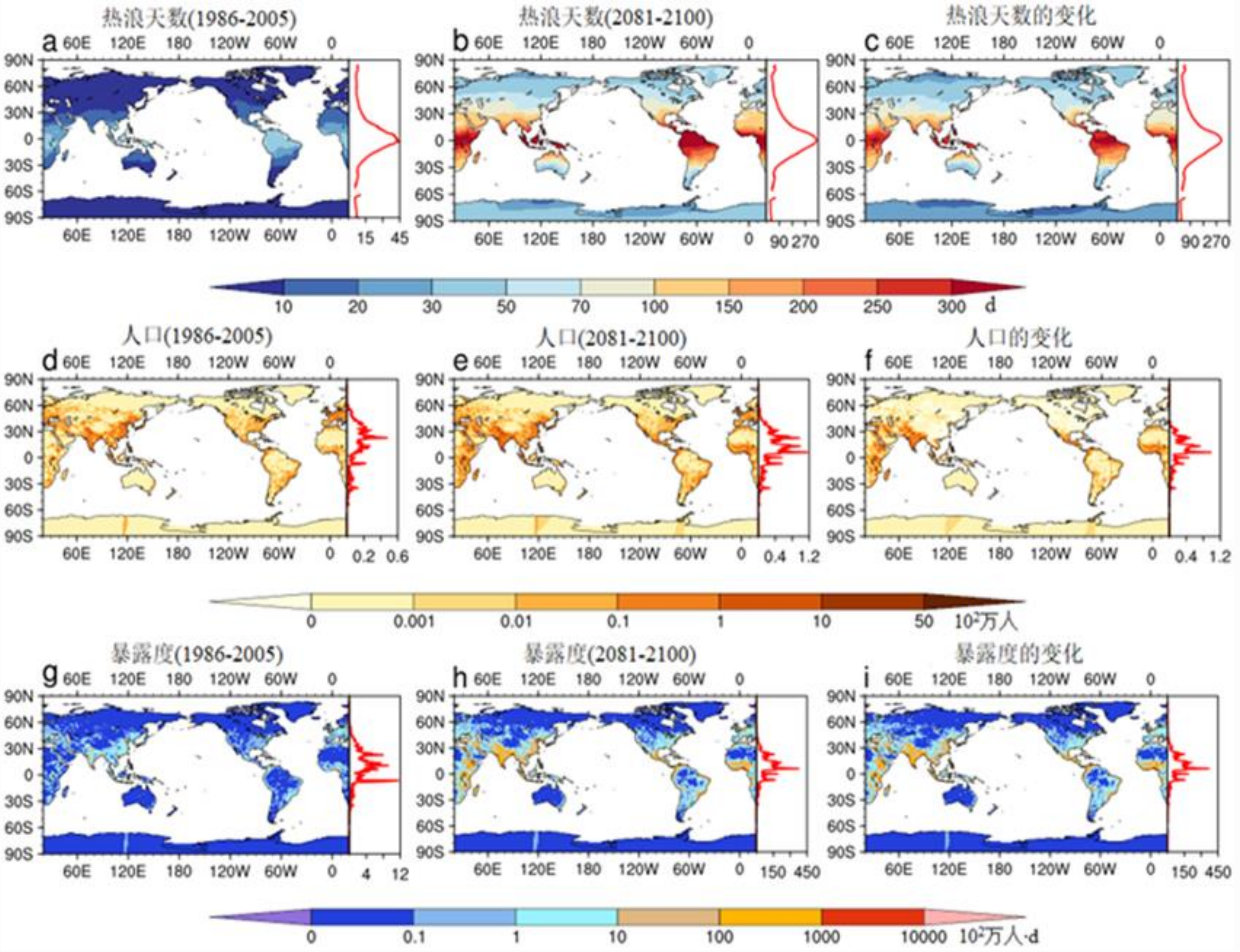
Heat syncope

Life-threatening heatstroke

Source： IPCC AR5 & PreventionWeb

Heatwave, Population and Exposure

Projection Data: CIMP5, 14 models
Historical Data: ECMWF, ERA-Interim
Population: Murakami （2019）
Resolution: 0.5*0.5 (degree)

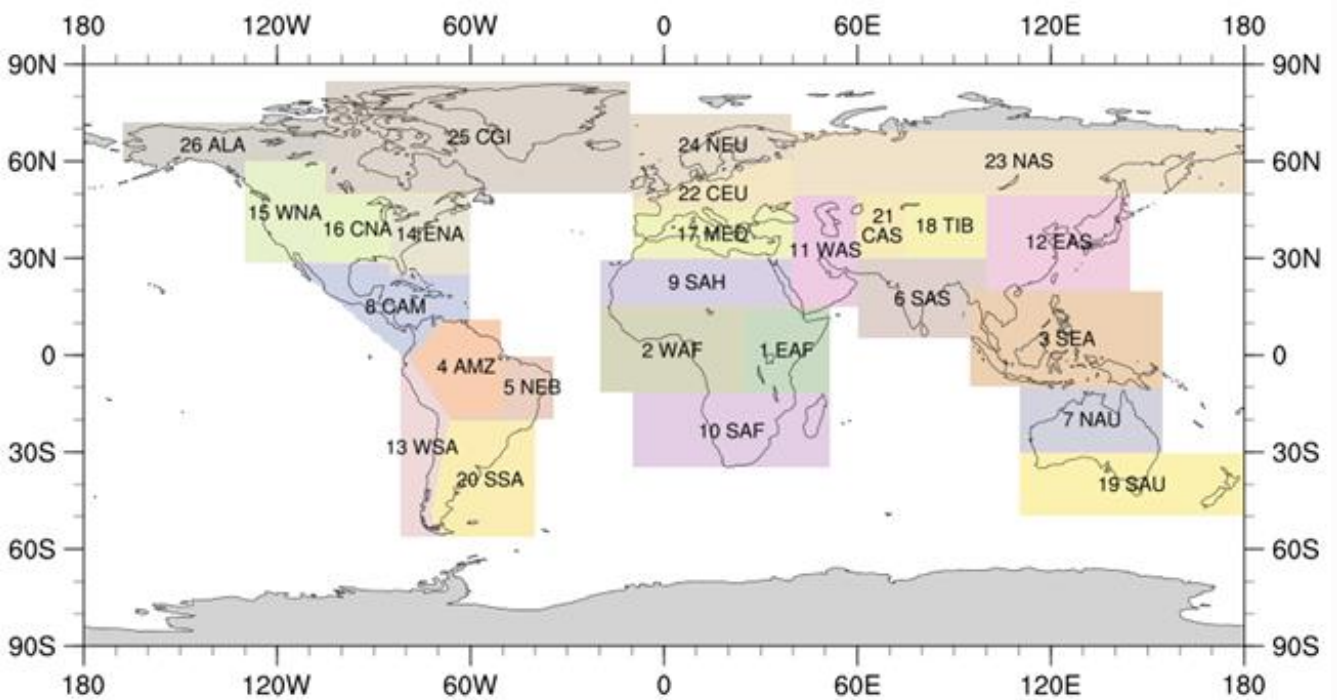


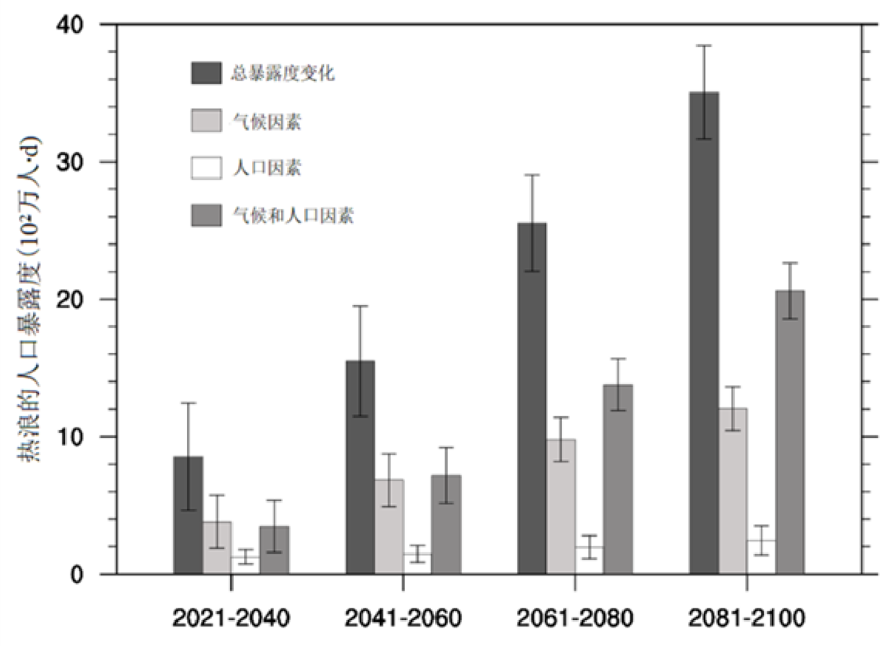
Annual days of heatwave，population and exposure in 1986—2005, 2081—2100

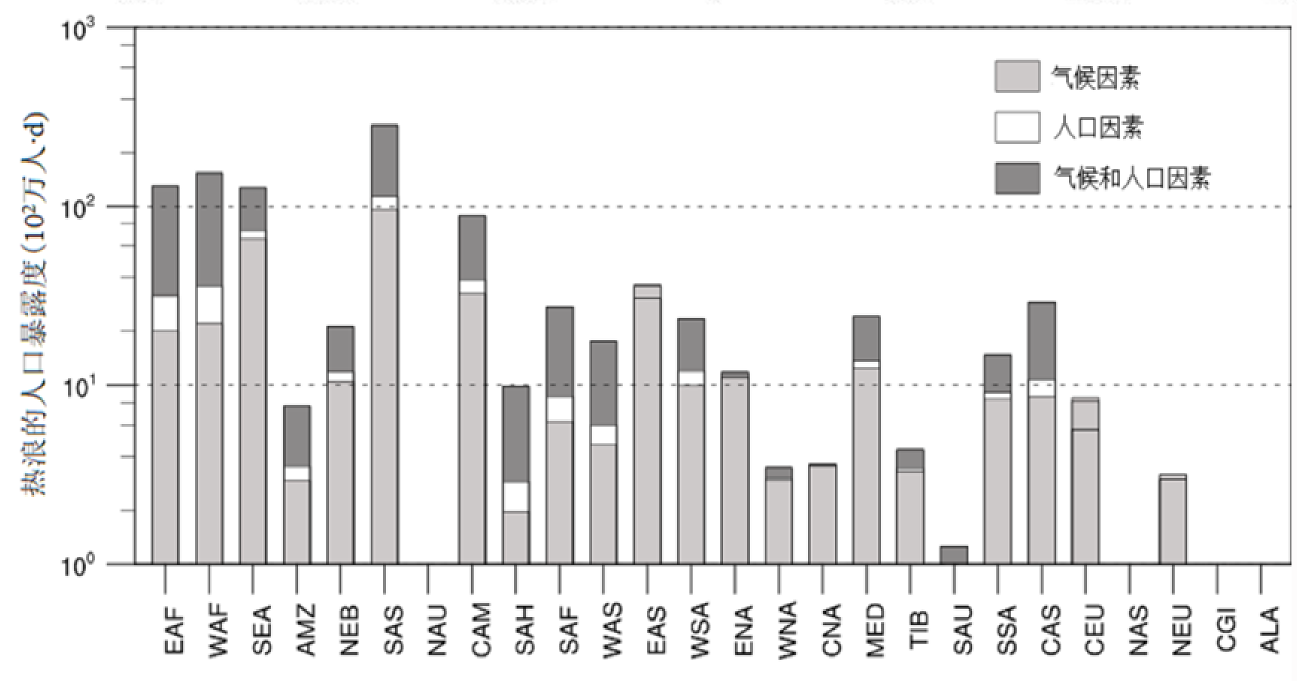
Regional Impact and Contributing factors

$$\Delta E = P_0 \times \Delta C + C_0 \times \Delta P + \Delta C \times \Delta P$$

Climate: $P_0 \times \Delta C / \Delta E$
Population: $C_0 \times \Delta P / \Delta E$
Coupled impact: $\Delta C \times \Delta P / \Delta E$







Contribution composition to Heatwave's population exposure

Heat–Health Systems

No universally accepted indicators

Performances are rarely examined

Country	*Threshold*	*Thresholds based on historical mortality*	*Excess mortality forecast*	*Duration of heat event included*	*Seasonality or adaptation included*	*Regionally variable thresholds*	*Human expertise*
Australia (Queensland)	*AT*			2 days		✓	✓
Belarus	*T*						
Belgium	*Tmax/Tmin*/Ozone			3 days			
Canada (Toronto region)	Airmass	✓	✓	✓	✓	✓	✓
Canada (Montreal)	*Tmax/Tmin*			✓			
Canada (all others)	*Humidex*			✓			
China (Hong Kong)	*NET*						
China (Shanghai)	Airmass	✓	✓	✓	✓		✓
France	*Tmax/Tmin*	✓		3 days		✓	✓
Germany	*PT*			2 days	✓	✓	✓
Greece	*Tmax*			✓			
Hungary (Budapest only)	*Tmean*	✓					
Italy	Airmass/*Tapp*	✓	✓	✓	✓	✓	
Republic of Korea	Airmass	✓	✓	✓	✓	✓	✓
Republic of Korea (Seoul*)	Airmass	✓	✓	✓	✓	✓	✓
Latvia	*Tmax*			✓			
Netherlands	*Tmax*			✓			
Poland	*Tmax/Tmin*						
Portugal	*Tmax*	✓	✓	✓		✓	✓
Romania	*ITU*						
Slovenia	Forecaster						✓
Spain	*Tmax/Tmin*	✓				✓	✓
Switzerland	*HI*						
United Kingdom (England and Wales)	*Tmax/Tmin*			✓		✓	
USA (synoptic**)	Airmass	✓	✓	✓	✓	✓	✓
USA (all others)	*HI*			2 days		✓	✓

Source：WMO&WHO (2015).

EFFECTIVENESS

The effectiveness of HHWSs is measured by the **classification consistency** of HHWSs and actual heat-related illness records.

Shanghai Overview

- Location: 120°52′- 122°12′E, 30°40′- 31°53′N
- Climate: Subtropical monsoon climate, mild and humid, with four distinct seasons, full sunshine and abundant rainfall.
- Total area: 6340.5 km2
- Resident population: 24,237,800 (2018)
- Gross Regional Product (GDP): $493.65 billion
- National technology, trade, information, finance and shipping center.

Tab. 1 Five Heat-health Warning Systems

System	Indicators	Thresholds	Levels
Shanghai Meteorological Service (SMS)	- Maximum temperature	35℃	≥35℃, Yellow warning signal ≥37℃, Orange warning signal ≥40℃, Red warning signal
China Meteorological Administration (CMA)	-Maximum temperature -Duration	35℃ 3 consecutive days	≥35℃ for 3 consecutive days, Yellow warning signal ≥37℃, Orange warning signal ≥40℃, Red warning signal
World Meteorological Organization (WMO)	-Maximum temperature -Duration	32℃ 3 consecutive days	≥32℃ for 3 consecutive days,
Grade of the heatwave-Chinese national standard for heatwave indexes (GB-HI)	-Maximum temperature -Relative humidity -Duration	>33℃ ≥60% 2 consecutive days	$2.8 \leq HI < 6.5$, Level III $6.5 \leq HI < 10.5$, Level II $HI \geq 10.5$, Level I (severe)
U.S. National Oceanic and Atmospheric Administration National Weather Service (NWS)-Heat Index	-Maximum temperature -Relative humidity	26.7℃ 40%	26.7-32.2℃, Caution 32.2-40.6℃, Extreme caution 40.6-54.4℃, Danger >54.4℃, Extreme danger

Six evaluation variables

Variables	Notation
The overlap ratio of heat-related illnesses in area *i*	$Oi = \frac{\text{The number of heat} - \text{related illness records that ocurred on warning days}}{\text{Total number of heat} - \text{related illnesses records}} \times 100\%$
The incidence rate of heat-related illnesses in area *i*	$Qi = \frac{\text{The number of sick days with heatwave warning}}{\text{Total number of warning days}} \times 100\%$
The rejection ratio of sick days in area *i*	$Ri = \frac{\text{The number of sick days without heatwave warning}}{\text{Total number of sick days}} \times 100\%$
The overlap ratio of heat-related mild illnesses in area *i*	$Mi = \frac{\text{The number of heat} - \text{related mild illnesse records ocurring on warning days}}{\text{Total number of heat} - \text{related mild illnesses records}} \times 100\%$
The overlap ratio of heat-related severe illnesses in area *i*	$Si = \frac{\text{The number of heat} - \text{related severe illnesse records ocurring on warning days}}{\text{Total number of heat} - \text{related severe illnesses records}} \times 100\%$
The overlap ratio of heat-related deaths in area *i*	$Di = \frac{\text{The number of heat} - \text{related death records ocurring on warning days}}{\text{Total number of heat} - \text{related death records}} \times 100\%$

Effectiveness of Shanghai warning system

- ✓ Moderate agreement ($K=0.422$, $Po=0.949$, $Pe=0.911$)
- ✓ 50% of heat-related illnesses occurred on heatwave warning days
- ✓ Classification of different warning levels was effective for distinguishing risk levels

  -Qi of yellow alert: 34.1%

  -Qi of orange alert: 60.7%.

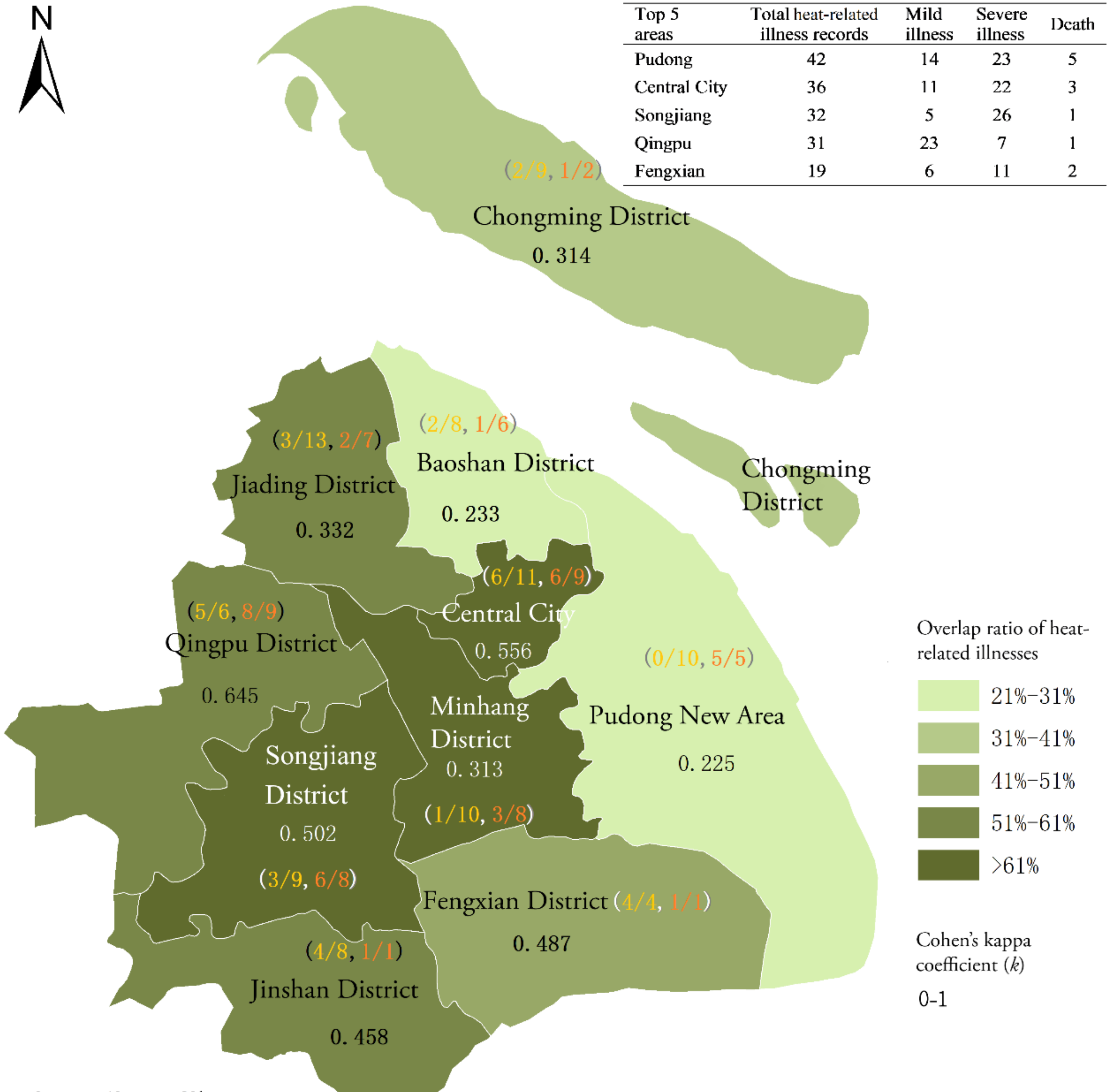
Tab. 2 The performance of the Shanghai HHWS in the form of a Confusion Matrix

		Days with heat-related health dangers ("Heatwave warning days")	
		+	-
Days on which heat-related illness occurred ("Sick days")	+	64	77
	-	80	2,839

Spatial differences

- ✓ K: southwestern > northeastern
  central area > surrounding areas

- ✓ Differences in vulnerability:
  Northeast coastal region-lower temp.



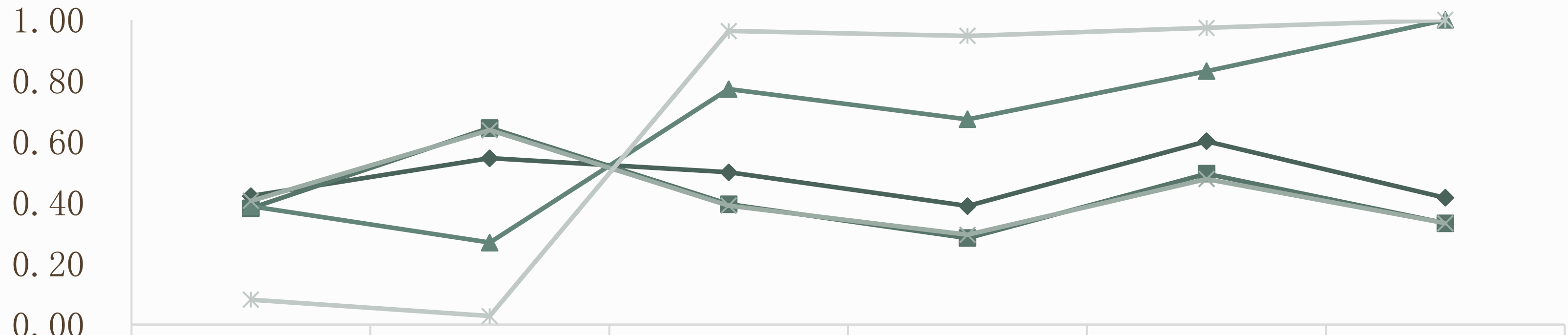
Top 5 areas	Total heat-related illness records	Mild illness	Severe illness	Death
Pudong	42	14	23	5
Central City	36	11	22	3
Songjiang	32	5	26	1
Qingpu	31	23	7	1
Fengxian	19	6	11	2

Note: Numbers in yellow (no. of sick days with yellow warnings/no. of yellow warning days); numbers in orange (no. of sick days with orange warnings/no. of orange warning days)

Comparative analysis

- ✓ For the current threshold (35℃), single metric of temperature outperformed the temperature-duration two-parameter method

- ✓ NOAA-heat index reports the highest percentage of heat-related illnesses. With this threshold, 46.4% more people would be warned.



	Cohen' s kappa coefficient (K)	Reject ratio of sick days (Ri)	Overlap ratio of total heat-related illnesses (Oi)	Overlap ratio of heat-related mild illnesses (Mi)	Overlap ratio of heat-related severe illnesses (Si)	Overlap ratio of heat-related deaths (Di)
SMS	0.422	0.546	0.500	0.389	0.602	0.417
CMA	0.382	0.645	0.395	0.284	0.496	0.333
WMO	0.388	0.270	0.773	0.674	0.832	1.000
GB	0.406	0.638	0.391	0.295	0.478	0.333
NOAA	0.082	0.028	0.964	0.947	0.973	1.000

Fig. 2 Validity check of five heatwave early warning systems in Shanghai during 2014-2015

Temperature is the dominant threshold in morbidity and mortality analysis

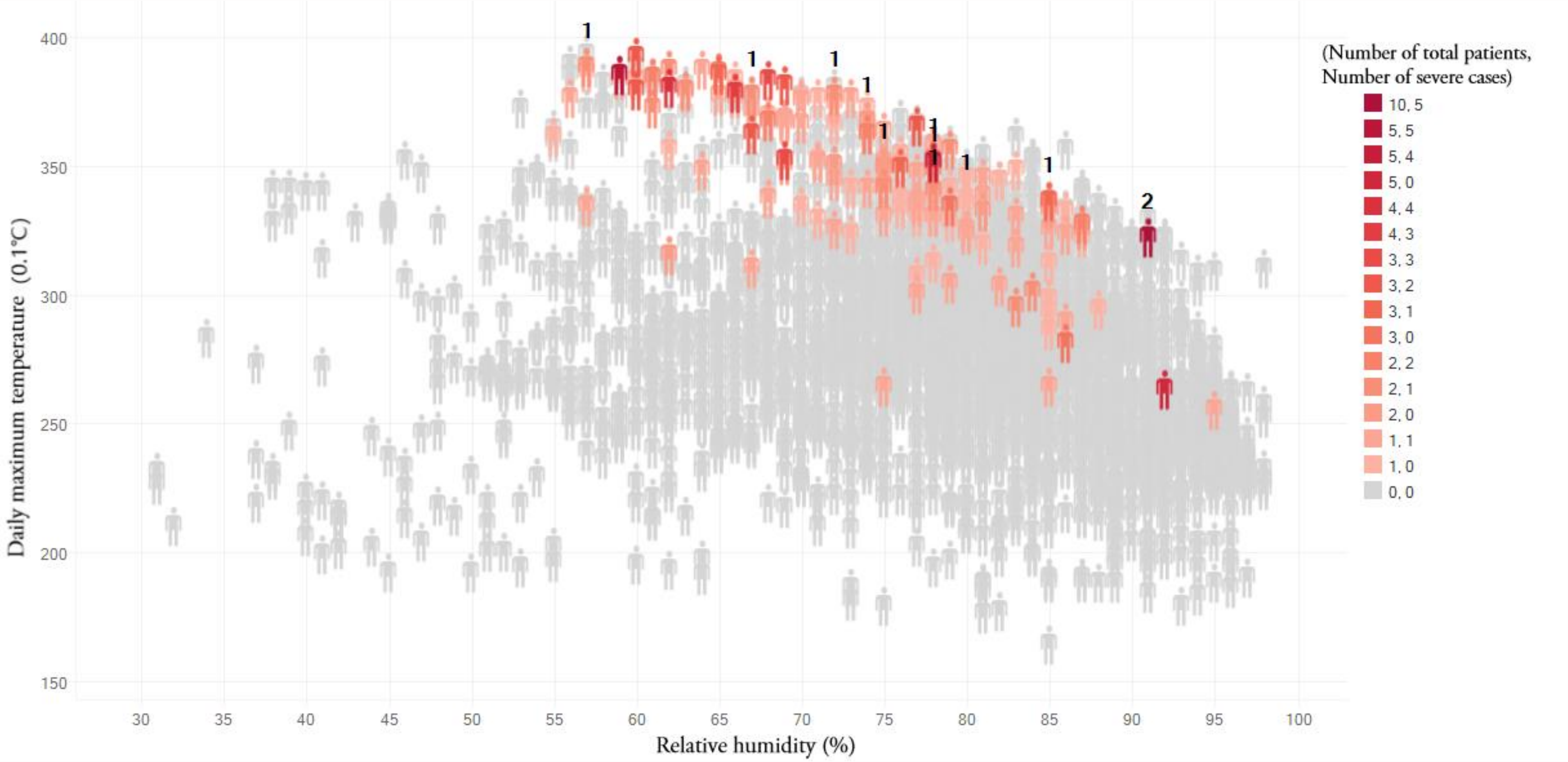
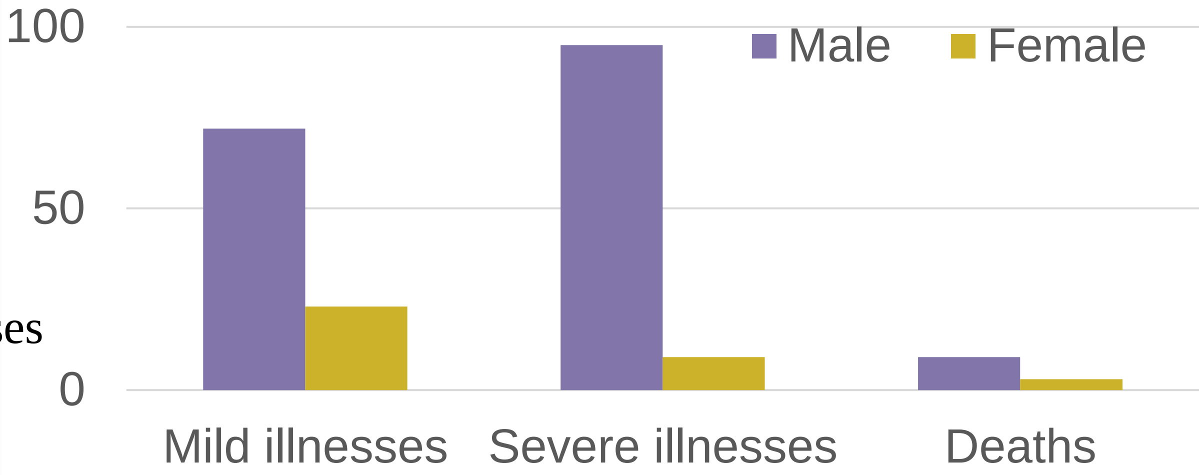
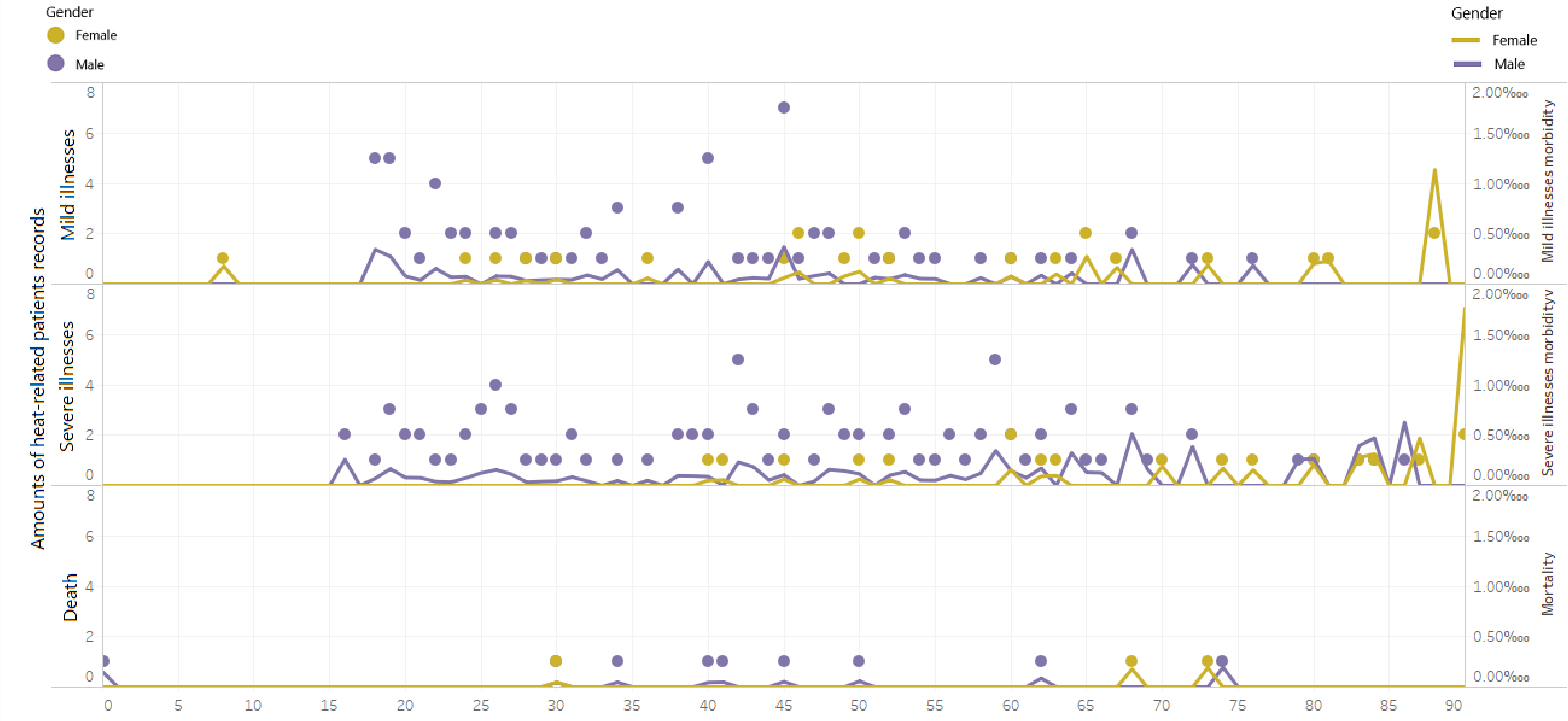


Fig. 3 Distribution of heat-related illnesses in Shanghai in summer 2014-2015 under different combinations of daily maximum temperatures and relative humidities

Different responses of population groups

- Young and middle-aged males suffered more heat-related illnesses
- Males may be more vulnerable to hot weather in Shanghai





Pub

Future work

-Changes in physical adaptation

-Negative impact of extreme weather on human both physically and mentally

-The impact of climate change on excessive mortality of residents

-How to improve the performance of HHWSs with limited data source

THANKS