2014 TCCIP – IWCC
TCCIP International Workshop on Climate Change

Climate variability and change and their potential health effects in Taiwan

--Case studies of Vector-borne diseases and temperature extreme associated deaths

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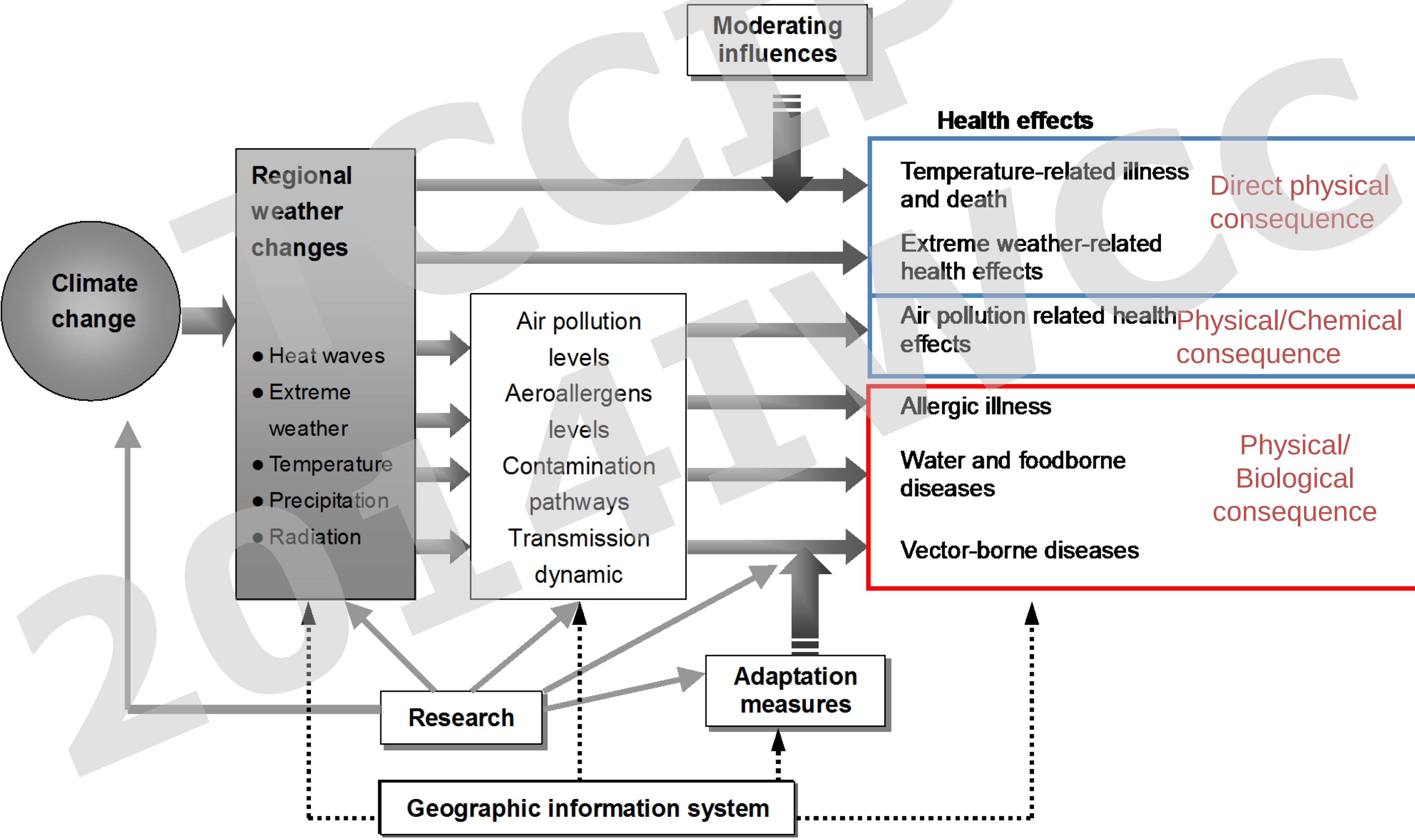
Potential health outcomes associated with climate variability and changes



[Modified from Patz, 2002]

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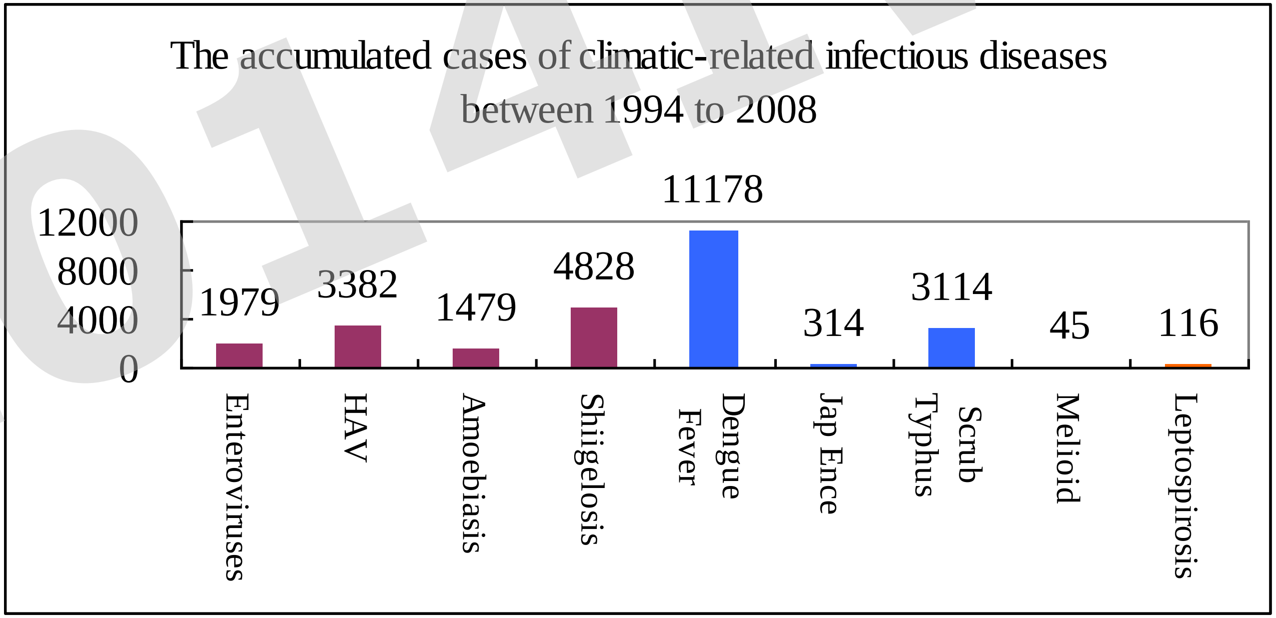
Climate and Infectious Diseases

Diseases	ICD-9	The category of Disease	Incubation
HAV	701	Food/ Water-borne Diseases	15-50 days
Amoebiasis	006		2- 4 weeks
Enteroviruses	749		2-10 days
Shigellosis	004		1 week
Scrub Typhus	812	Vector-borne Diseases	6-21 days
Dengue Fever	061		3-14 days
Japanese Encephalitis	620		5-15 days
Leptospirosis(2006-08)	100	Flood-Related Diseases	2-30 days
Melioidosis(2007-08)	025		2 days+



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Research scheme for infectious diseases

	Long-term pattern	Effects of extreme weather
Size of epidemic in endemic areas	✓ Time-series analysis (ARIMA) or Poisson regression	✓ Relative risk during event period (Relative Risk; RR)
The geographic distribution of infectious diseases	✓ spatial regression model	✓ spatial regression model
Outbreak and the region have potential for disease outbreak		✓ temporal-spatial cluster analysis
Socioeconomic factors and regional vulnerability	✓ PCA spatial regression model	✓ PCA spatial regression model

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Climate variability and dengue fever transmission in Taiwan

Hypothesis

-weather variability v.s. epidemic

-climate patterns and other factors v.s. regional vulnerability

Application

- ✓ Establish the early warning system by integrating weather parameters to predict the occurrence of diseases in epidemic area
- ✓ Identifying the "determinants" for regional vulnerability for policy or action plan

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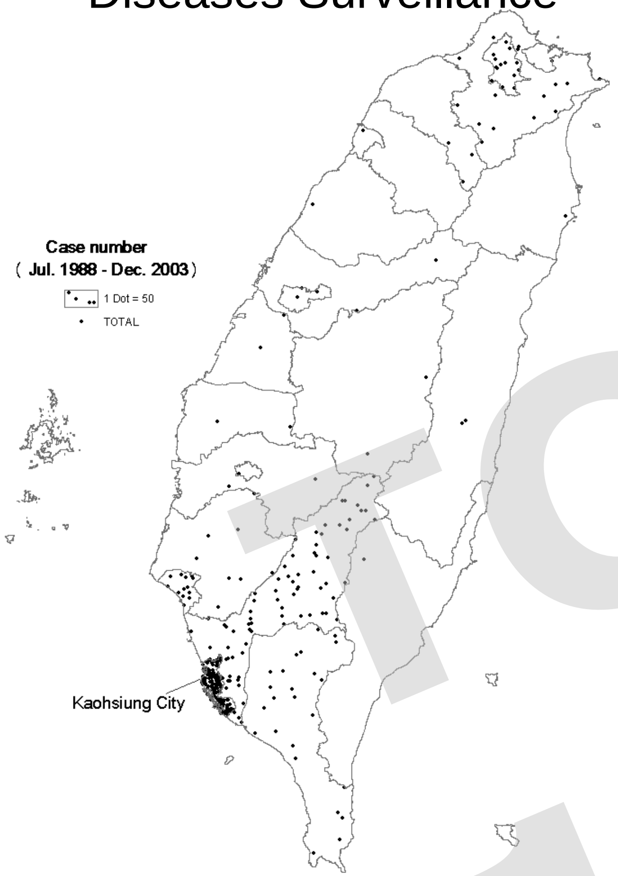
Diseases Surveillance

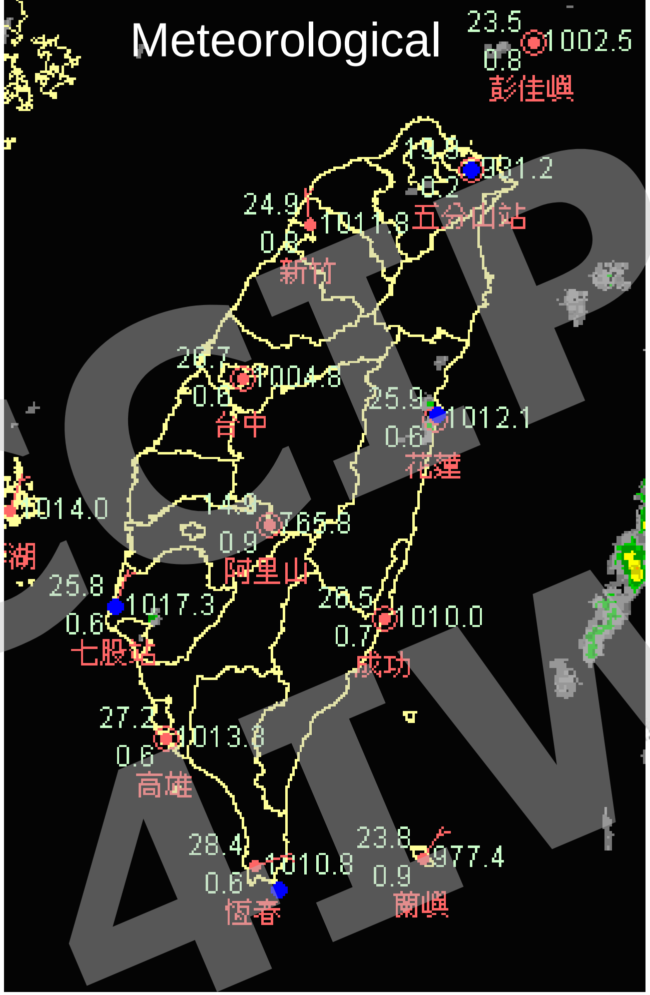


1988-1998: paper records, monthly and county level

1998-2002: electrical data, daily, township level

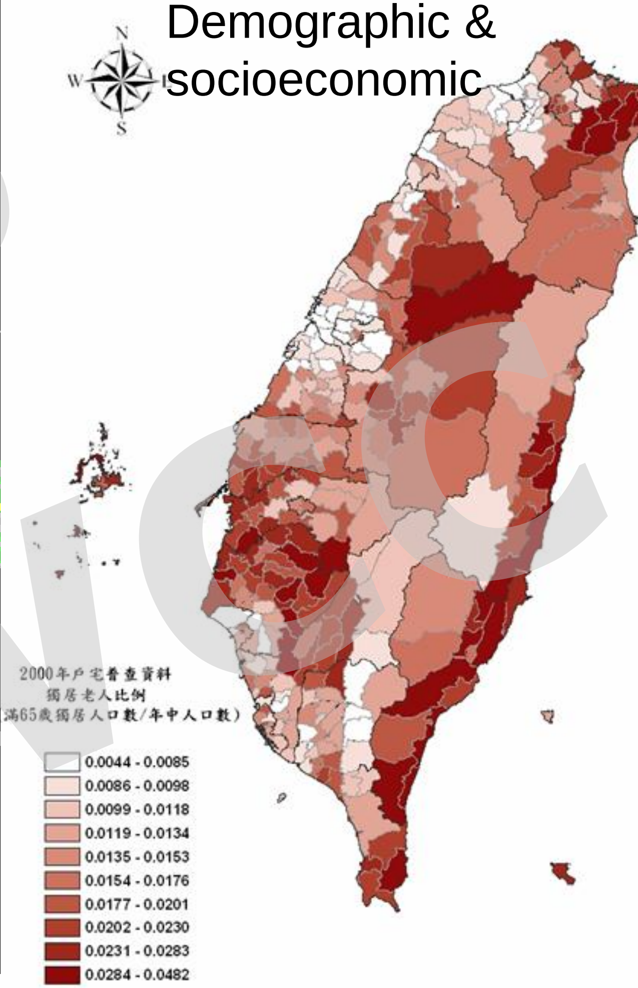
2003-current: electrical data, daily, **x,y location**

Meteorological



25 monitoring station mainly located in city, islands, and the top of mountain

Demographic & socioeconomic



Demographic census in 1980, 1990, and 2000
Township levels

Dengue fever

- Dengue fever is regarded one of world's most widespread vector-borne disease, and about 2,500 million people live in regions with the potential risk of dengue transmission *(Gubler 2004).*

- **Infectious agents** -The virus of dengue fever are flavivirues and include serotype 1, 2, 3, and 4. The same virus are responsible for dengue hemorrhagic fever.

- **Transmission**-By the bite of infective mosquitoes, principally *Aedes aegypti* and *Aedes albopictus* in Taiwan.

- **Incubation period-** from 3 to 14 days, commonly 4-7 days

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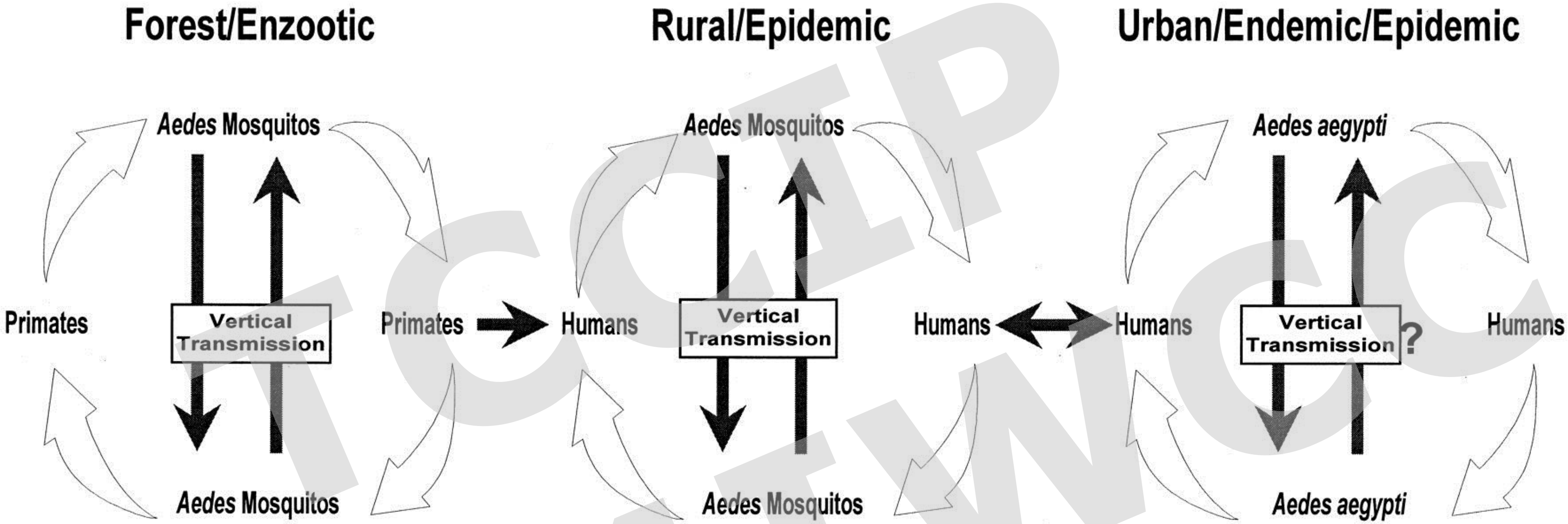
Transmission cycle



Africa = *Aedes* (*Diceromyia*)

Aedes (*Stegomyia*)

Asia = *Aedes* (*Finlaya*)

Aedes (*Stegomyia*)

? Americas = *Aedes* Sp. ?

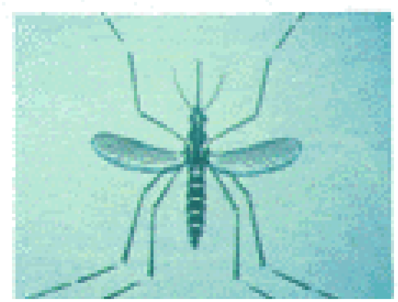
A. aegypti

A. albopictus

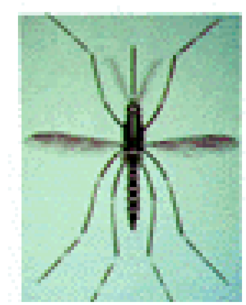
A. polynesiensis

A. mediovittatus ?

A. aegypti



Aedes aegypti



Aedes albopictus

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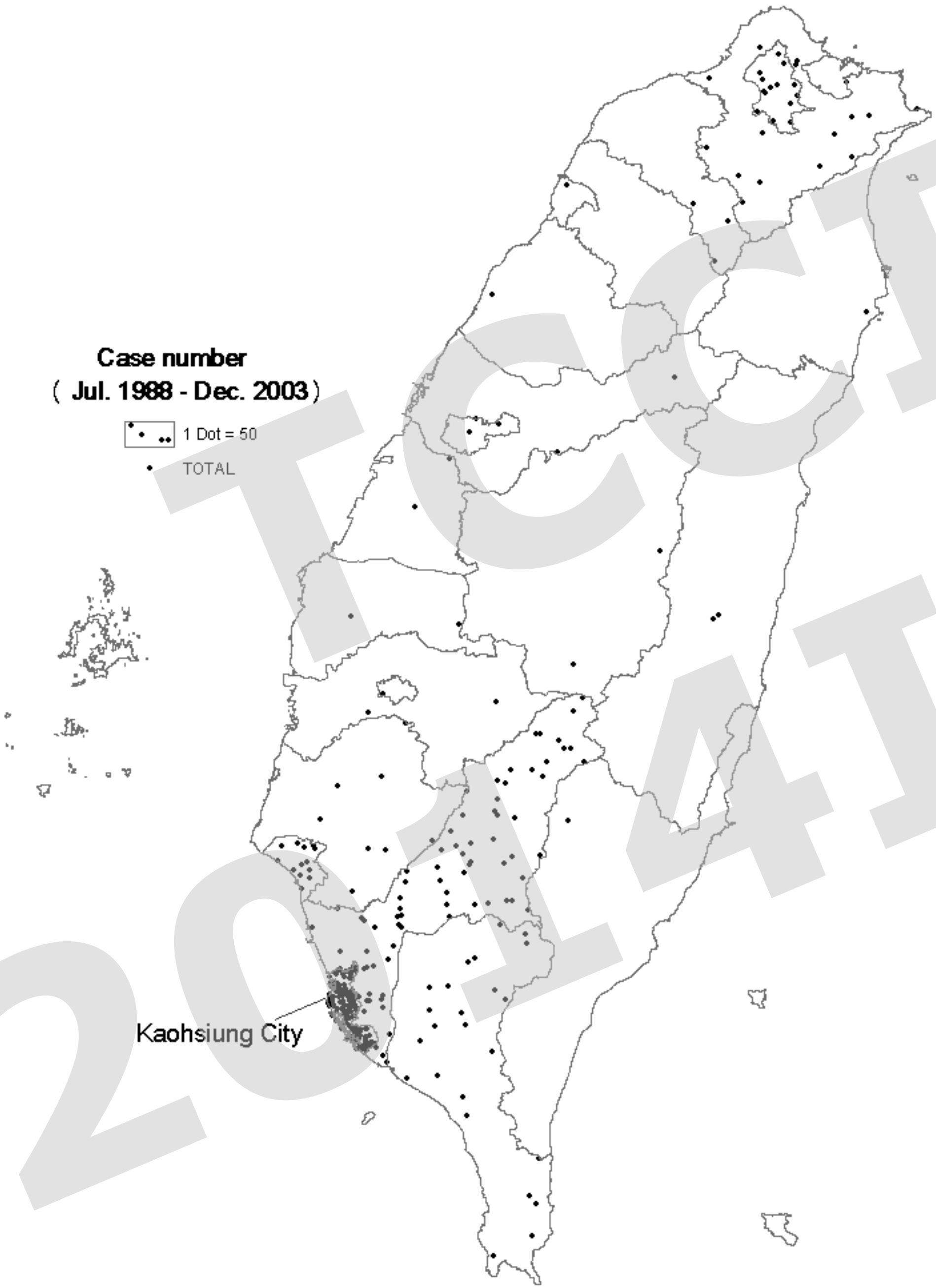

Endemic area of dengue fever

- According to the surveillance system of the Center for Disease Control Taiwan (Taiwan CDC), Kaohsuing City had **7,500** confirmed dengue fever cases from July 1988 to December 2003, accounting for about **46.3%** of the total cases in Taiwan (16,193)

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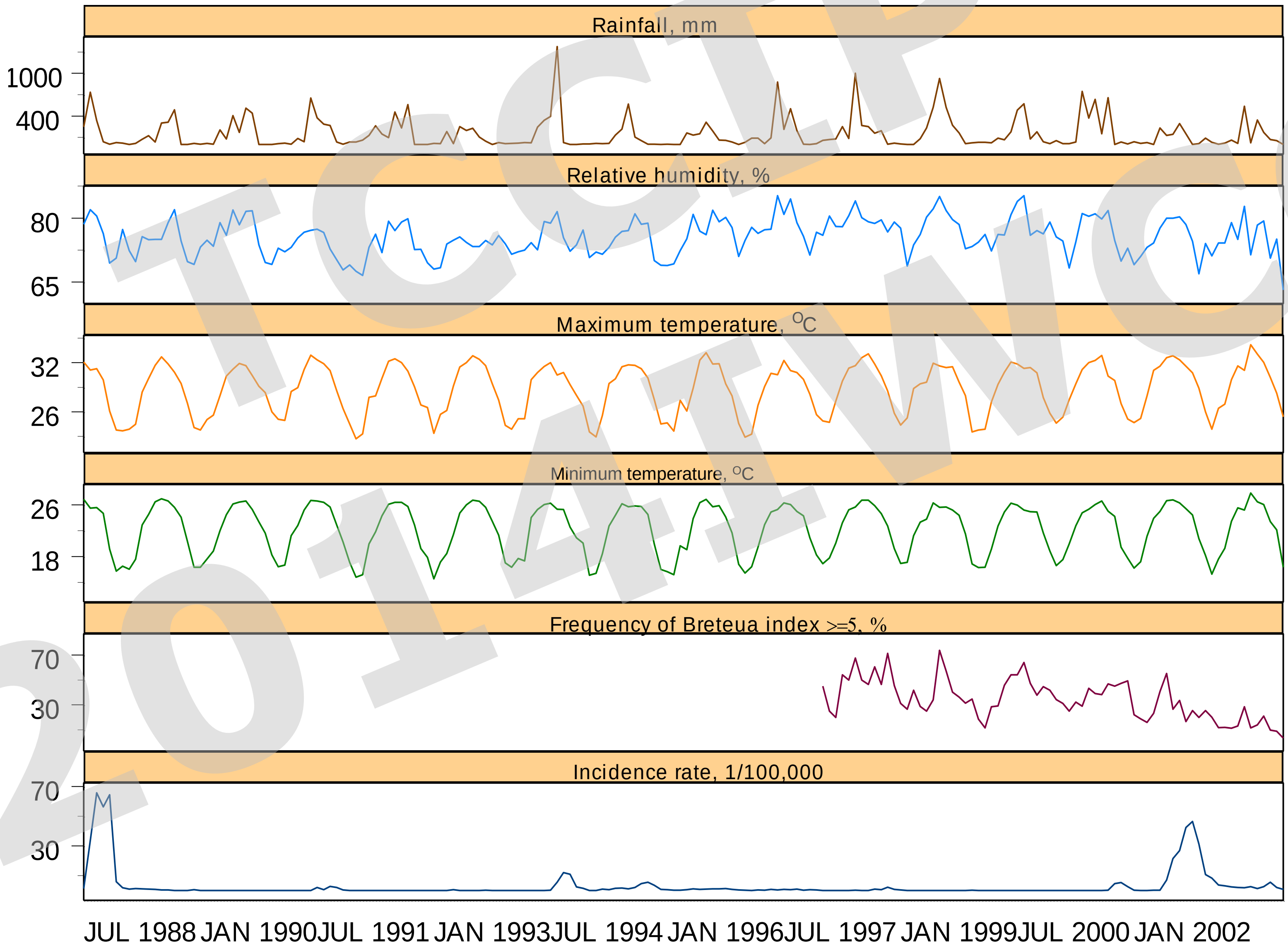
Reported dengue fever incidence by temperature, relative humidity, rainfall, and frequency of Breteua Index ≧ 5 from July 1988 to December 2003



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Cross-correlation coefficients between climate variables, recovery of vector and incidence of Dengue fever in Kaohsiung, Taiwan (Jul. 1988-Dec. 2003)

Time-lag (months)	Maximum temperature	Minimum temperature	Relative humidity	Rainfall	[a]Frequency of BI≧5
-5	0.072	0.051	-0.001	-0.018	-0.118
-4	0.161*	0.149	0.078	0.032	-0.050
-3	0.211*	0.200*	0.159*	0.142	-0.052
-2	0.239*	0.233*	0.202*	0.180*	-0.095
-1	0.205*	0.210*	0.169*	0.142	-0.140
0	0.099	0.099	0.010	0.006	-0.211

[a] Available monthly vector surveillance data (Jan. 1998 to Dec. 2003)

* Statistical significance

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Time span of transmission

- The predominant vector transmitting dengue fever in Kaohsiung City was *Aedes aegypti*, which hatched from eggs and went through several stages in their life cycle between 7.2 to 39.7 days in a range of temperature between 15-35℃ before becoming adults, and higher temperature would reduce the time needed for development. [Tun-Lin et al., 2000]

- The life span of an adult *A. aegypti* is about 30 days. [Lansdowne et al., 1975]

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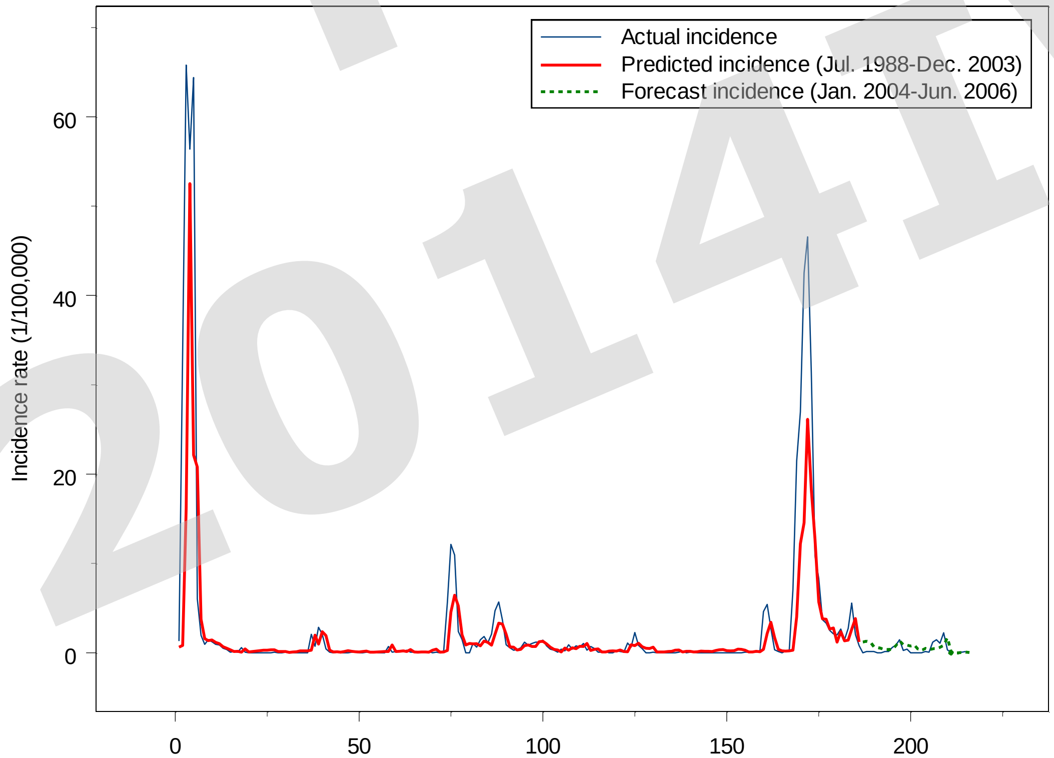
Weather as an Effective Predictor for Occurrence of Dengue Fever in Taiwan

Final model	β	SE	P-value
Td	-0.126	0.062	0.044
Relative humidity	-0.025	0.013	0.048
Intercept	2.380	1.253	0.060



The actual incidence, predicted incidence and forecast incidence from Jan. 2004 to May 2006 by auto-regressive integrated moving average (ARIMA) model of weather variation in Kaohsiung City, Taiwan

[Acta Tropica 103 (2007) 50–57]

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Discussion- Temperature

- The major breeding sites of *A. aegypti* are mostly artificial water containers commonly found in and around the house such as tires, flower vases, cans and bottles in urban area.
- Temperature gets too high, and effectively evaporates the water from these man-made, stagnant water site, it might, in turn, affect the vector population density through decreasing the survival of immature vector by drying the breeding site, as we have observed in Kaoshuing City.

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Discussion- Humidity

- Relative humidity is another crucial factor affecting the life pattern of mosquitos, such as mating ,oviposition, and seeking host pattern.
- Experimental condition of higher temperature and lower humidity, 28℃/50-55% R.H., appeared to be a more favorable state for mosquitoes to be faster in seeking their hosts, compared to the environment of lower temperature and higher humidity, 25℃/85-90% R.H.
- In this study, relative humidity is generally high (ranging from 63.16 to 85.29%) to maintain the basic survival rate of mosquitoes. However, relative humidity was shown to have a significant reverse effect on incidence of dengue fever with a very small coefficient (β=-0.028). Such a finding might imply that feeding pattern of *A. aegypti* varied with the change of relative humidity.

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Practical applications

- Minimum temperature, maximum temperature and relative humidity have been found to be meaningful determinants of incidence of dengue fever, with the most dominant effect at a lag of 2 months.
- Such a finding could be applied to assist in establishing a early warning system based on weather forecasts and in making decision on public health prevention program such as timing for executing programs on vector control, other environmental intervention, and personal protection promotion.

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Higher temperature and urbanization affect the spatial patterns of dengue fever transmission in subtropical Taiwan

- This study therefore examined the linkage between weather profiles and other environmental factors, from a spatial standpoint, with geographical distribution of dengue fever epidemic.

- It also attempted to identify the size of population at risk in Taiwan by integrating all variables with existing database using geographic information system (GIS).

[Science of the total Environment, 2009]

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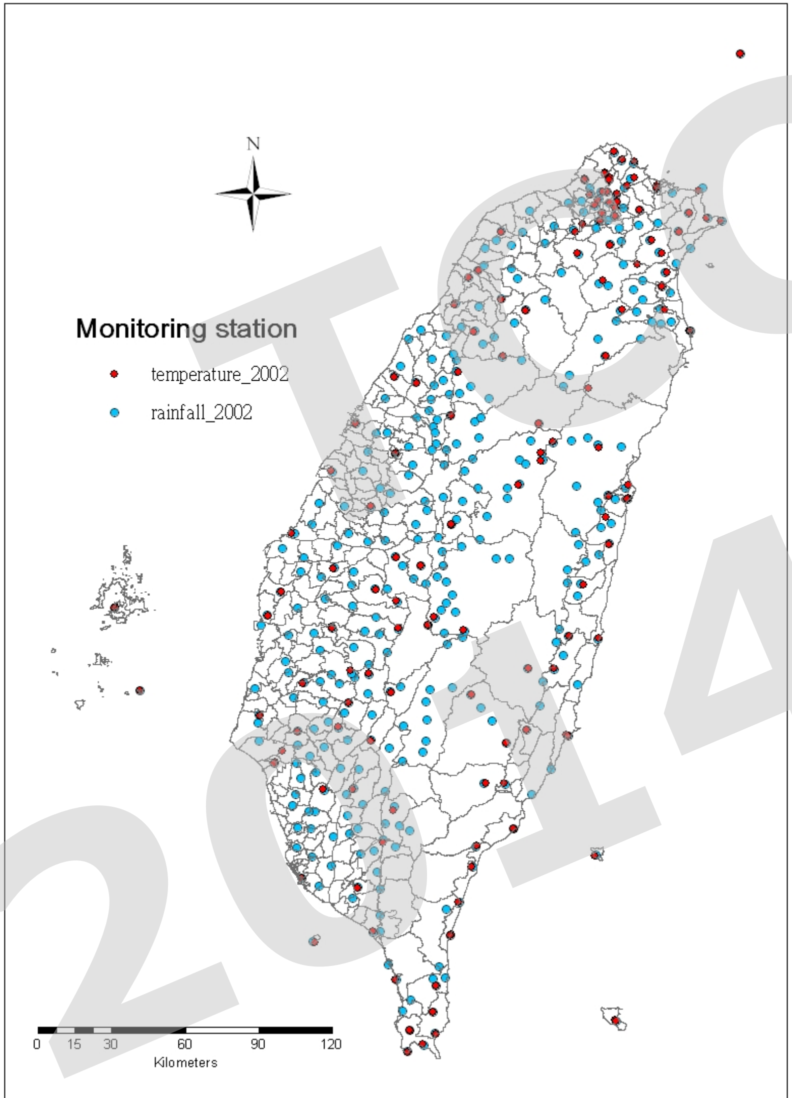
Weather data: recorded by administrative districts



(Interpolate to Raster; Kriging)

1. Cell size (1 km)

2. Monthly average data

Zonal estimation was further used to aggregate the estimation of weather parameters falling into each cell of target grid, and calculate the average temperature from the cells within the **township polygon** (range from 1 to 1633 cells).

Sites with complete weather monitoring data (2002 as example)

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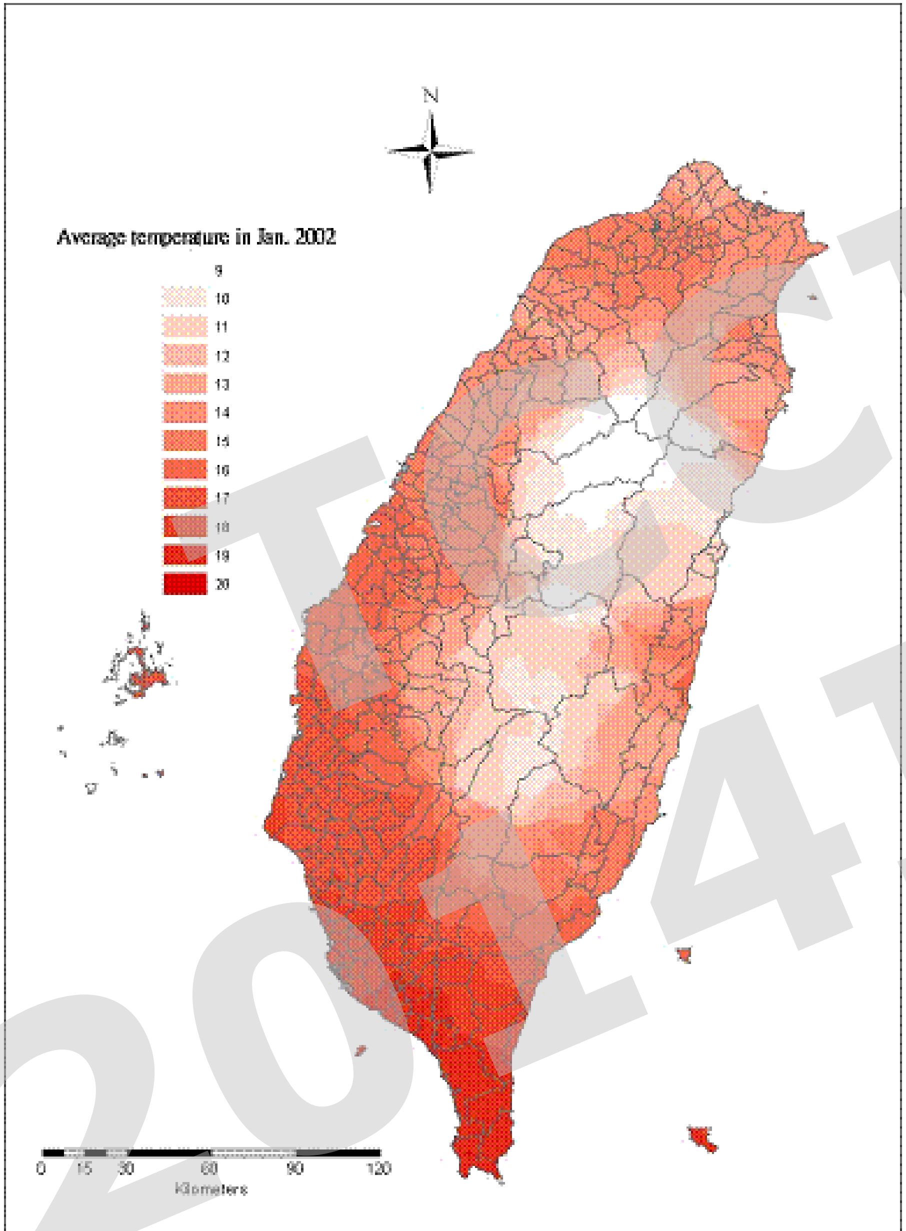
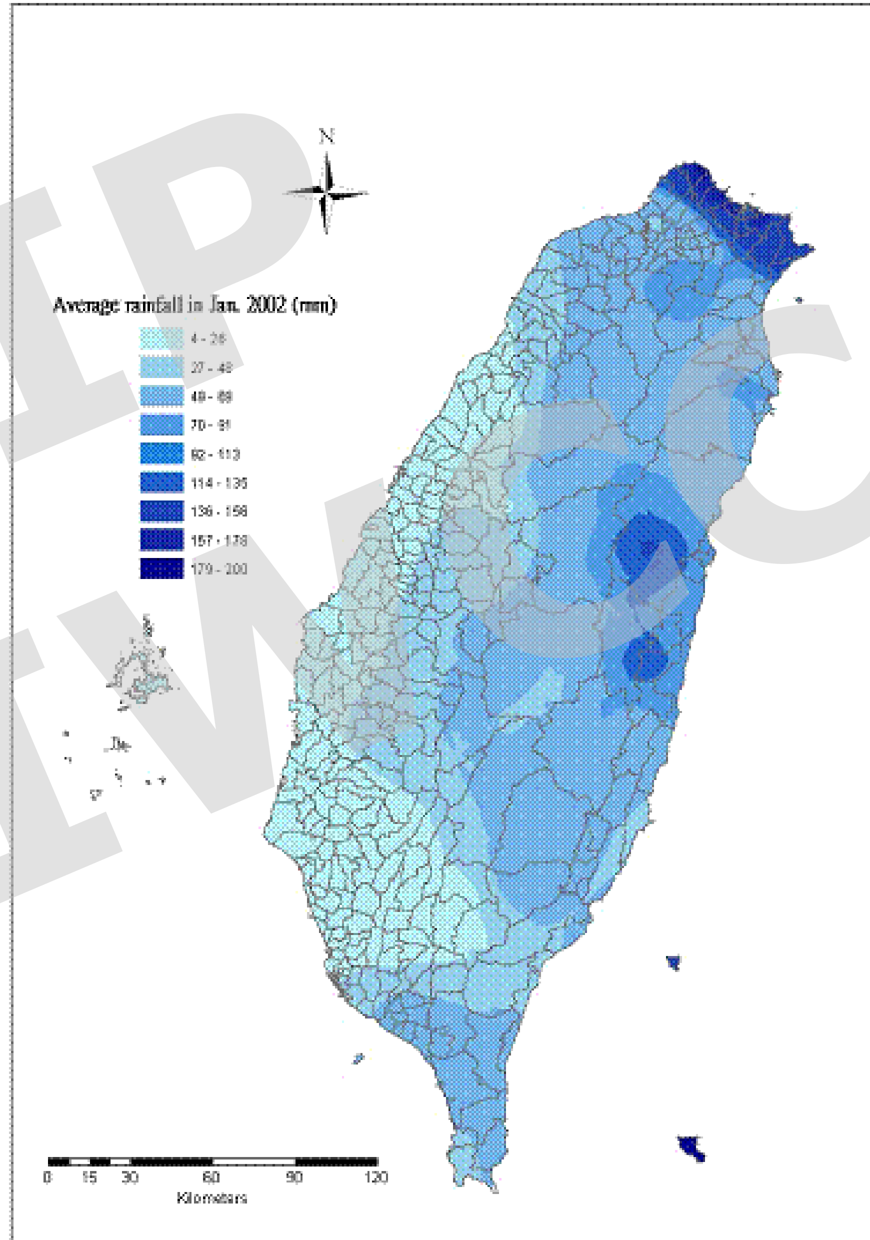
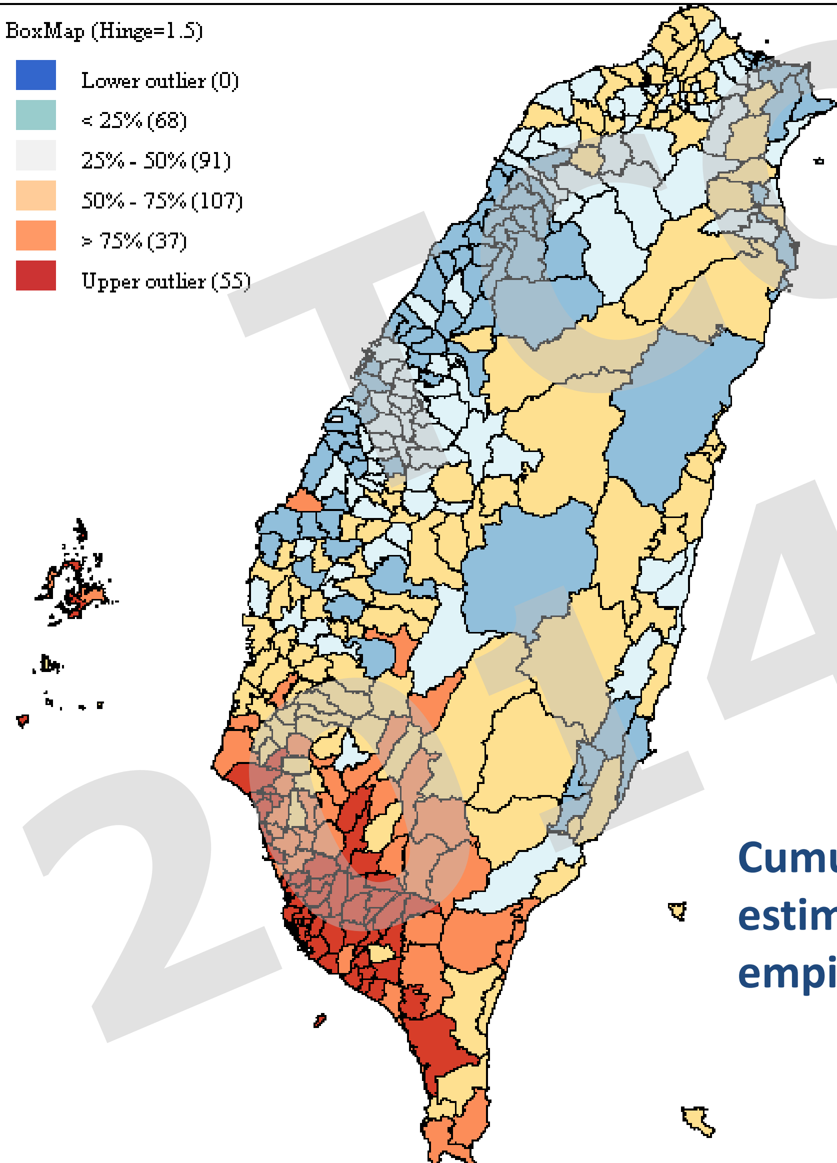


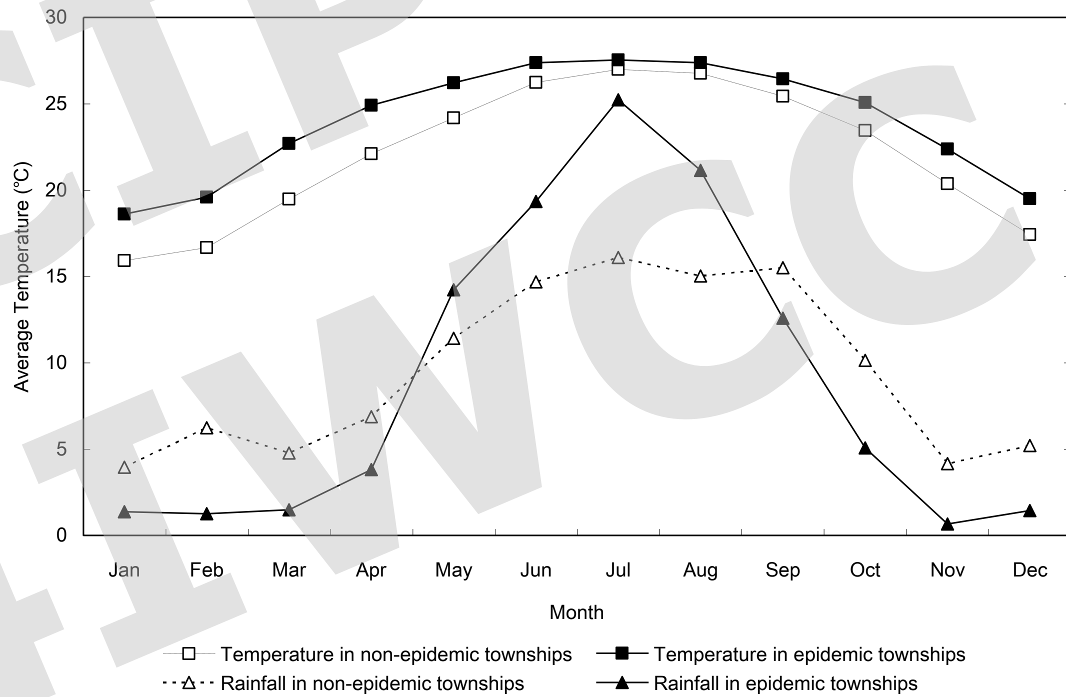
Average temperature (Jan. 2002)



Average rainfall (Jan. 2002)

Higher temperature and urbanization affect the spatial patterns of dengue fever transmission in subtropical Taiwan





Cumulative incidence during 1998-2002 estimated by estimated by using spatial empirical Bayes smoothing method

[Science of total Environment, 2009]

Factors loading and percentage of variance explained

Components	Variance explained	Loading
PCA 1: Urbanization	35.782%	
Average population density (person/km2)		0.840
Service industry (1/10000)		0.841
Agriculture industry (1/10000)		-0.625
House ownership (1/10000)		-0.741
Numbers of clinics		0.846
Median of income		0.722
PCA2: Elder population	24.189%	
Elders living alone (1/10000)		0.906
Elders (1/10000)		0.845
Disability (1/10000)		0.584
Over crowed in residence		0-.744
PCA3: Aborigine	14.119%	
Aborigine		0.920
Sum of variance explained	74.090**%**	

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Examining the **spatial relationships** among dengue occurrence during 1998 to 2002, climatic, environmental, socioeconomic and demographic factors by using spatial regression

	Cumulative incidence from 1998 to 2002[a]	
Coefficients	Ordinary Least Squares (OLS) **R^2=0.151**	Spatial lag model **R^2=0.446**
Imported incidence from 1998 to 2002	0.091	-0.248
The household vectors recovery rate	0.111	0.073
Annual rainfall	-0.073	-0.055
Annual numbers of months with average temperature higher than 18 ºC	9.373**	2.807**
Factor 1: Urbanization	15.798**	8.590**
Factor 2: Elder population	-0.373	0.287
Factor 3: Aborigine population	5.772	4.503
Constants	-69.709**	-17.176
Rho	--	0.870**
Moran's I value of residues	0.3088	-0.0487

**$p<0.05$

[Science of total Environment, 2009]

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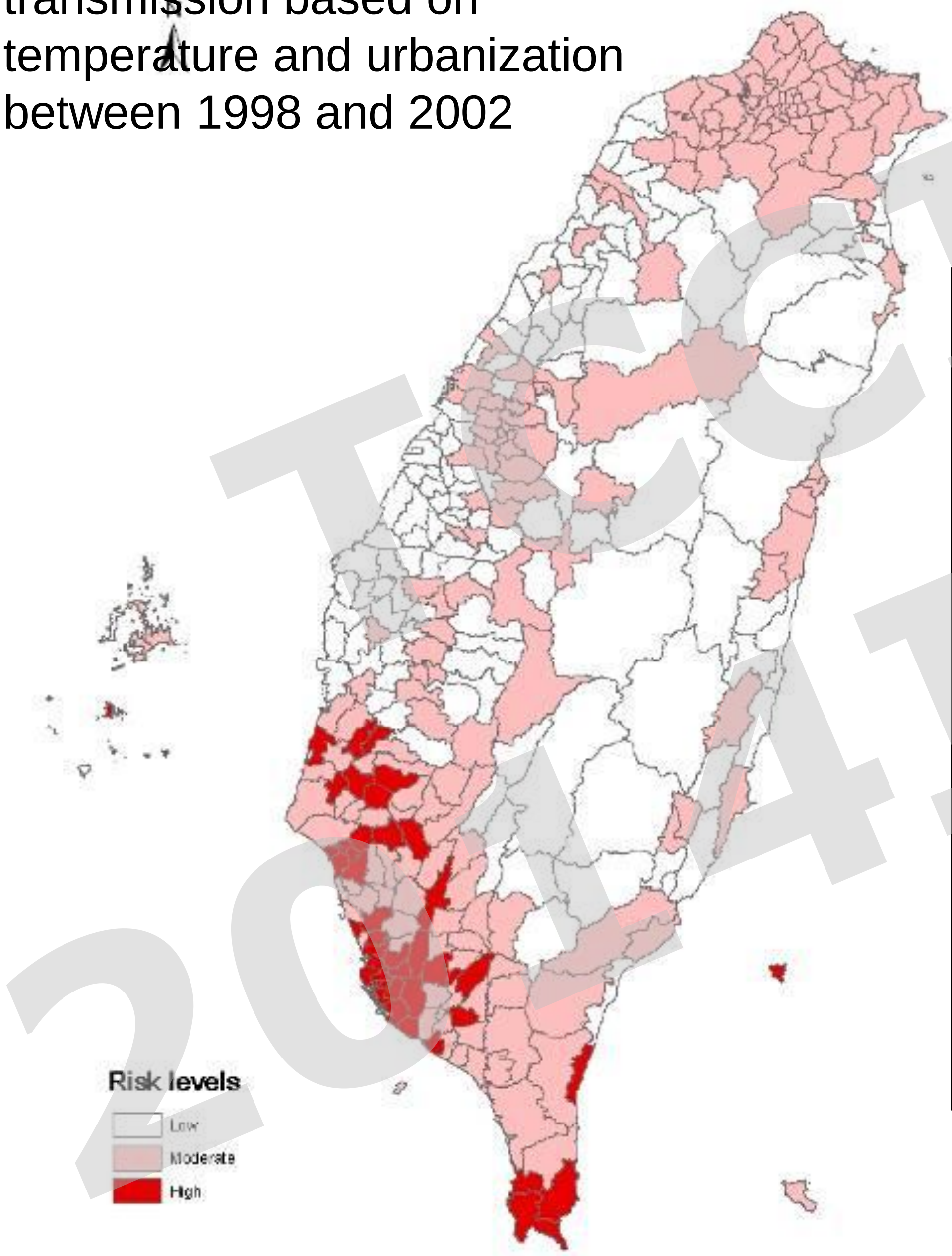
Risk map of dengue fever transmission based on temperature and urbanization between 1998 and 2002



Occurrence of dengue fever and population in the townships at different risk levels

	Risk level		
	Low	**Moderate**	**High**
Numbers of township	121	190	48
Population at risk	3,356,593	14,877,924	3,966,173
Indigenous case numbers from 1998 to 2002			
Case number (a%)	17 (0.3%)	227 (3.7%)	5,898 (96.0%)
Indigenous case numbers from 2003 to 2006			
Case number (a%)	22 (1.3%)	149 (8.5%)	1,587 (90.3%)

[Science of total Environment,, 2009]

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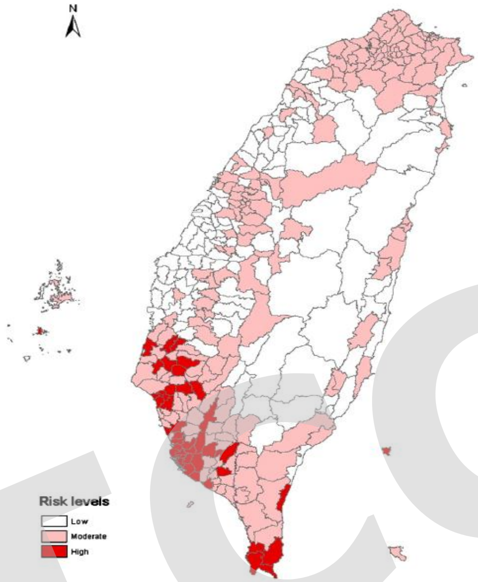

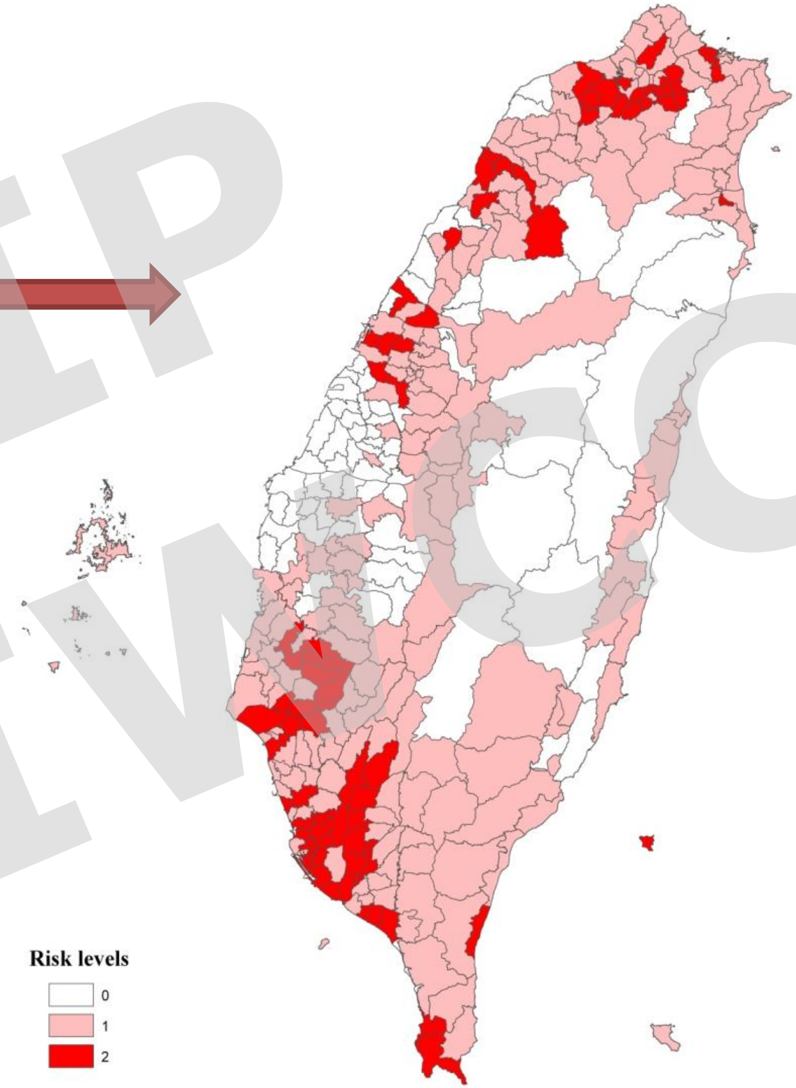

	Risk level		
	Low	Moderate	High
Numbers of township	120	190	48
Population at risk [a]	3,356,593	14,877,924	3,966,173
Demographic data forecasted by IPCC-AR4 a1b ensemble [b]			
Numbers of township	78	198	82
Population at risk [c]	2,278,997	11,538,434	9,468,469

[b] IPCC-AR4 a1b ensemble (Data from NCDR)

[c] 2020 Population data (Data from NCDR)

Risk map of dengue fever transmission estimated by using average monthly temperature in IPCC-AR4 a1b ensemble (Data from NCDR)

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Conclusions

- Warmer winter season appeared to have most predominant effects on dengue fever transmission. Numbers of warmer months and greater population density were found to be the determinant risk factors for dengue fever epidemics at township level.
- The risk of temperature threshold could adapt to predicting future impacts of global warming on vulnerable population distribution for dengue fever transmission in Taiwan.
- Preliminary estimation showed that trend of island-wide warming in the future would likely cause large-scale geographical expansion for areas at risk for dengue fever outbreak in Taiwan.
- This model and risk map could facilitate prioritize the regions of disease control program now and in the future under climate change threaten. Available climate change projection scenario should be adapted in this risk prediction model for better identify the vulnerable area for dengue fever transmission in the future.

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Impacts of heat and cold events: Determinants of regional vulnerability in Taiwan

Defining extreme temperature events

Cold Surges

- According to the Central Weather Bureau in Taiwan, cold surges are defined in terms of the following temperature changes:

(1) the surface maximum temperature dropping at least 8 ˚C within a 24 hours, or

(2) the minimum temperature in Taipei city being lower than 10˚C.

- There were 24 cold surges identified from 1994 to 2003 in our study period.

Heat events

- Our study defined the days with heat events using the following criteria:

(1) Maximum summer temperatures ≥35˚C for more than 6 hours per day, or

(2) Maximum temperatures ≥35˚C more than 9 hours within 3 days in Taipei, since

- **No prior guideline in this regard was promulgated by Taiwan's CWB.**

- A total of 13 heat events were identified from 1994 to 2003 in our study period.

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Mean cardiovascular mortality 14 days before/after events across all townships (N=358)

Cardiovascular mortality (1/100 000)*	Cold events (24 events)	Heat events (13 events)	p Value†
14 days before events	7.64 (3.63)	5.87 (3.06)	<0.001
14 days after events	8.29 (3.76)	5.91 (3.26)	<0.001
p Value‡	<0.001	0.782	

*Mean (SD).
†p Value for independent-sample t test.
‡p Value for paired-sample t test.

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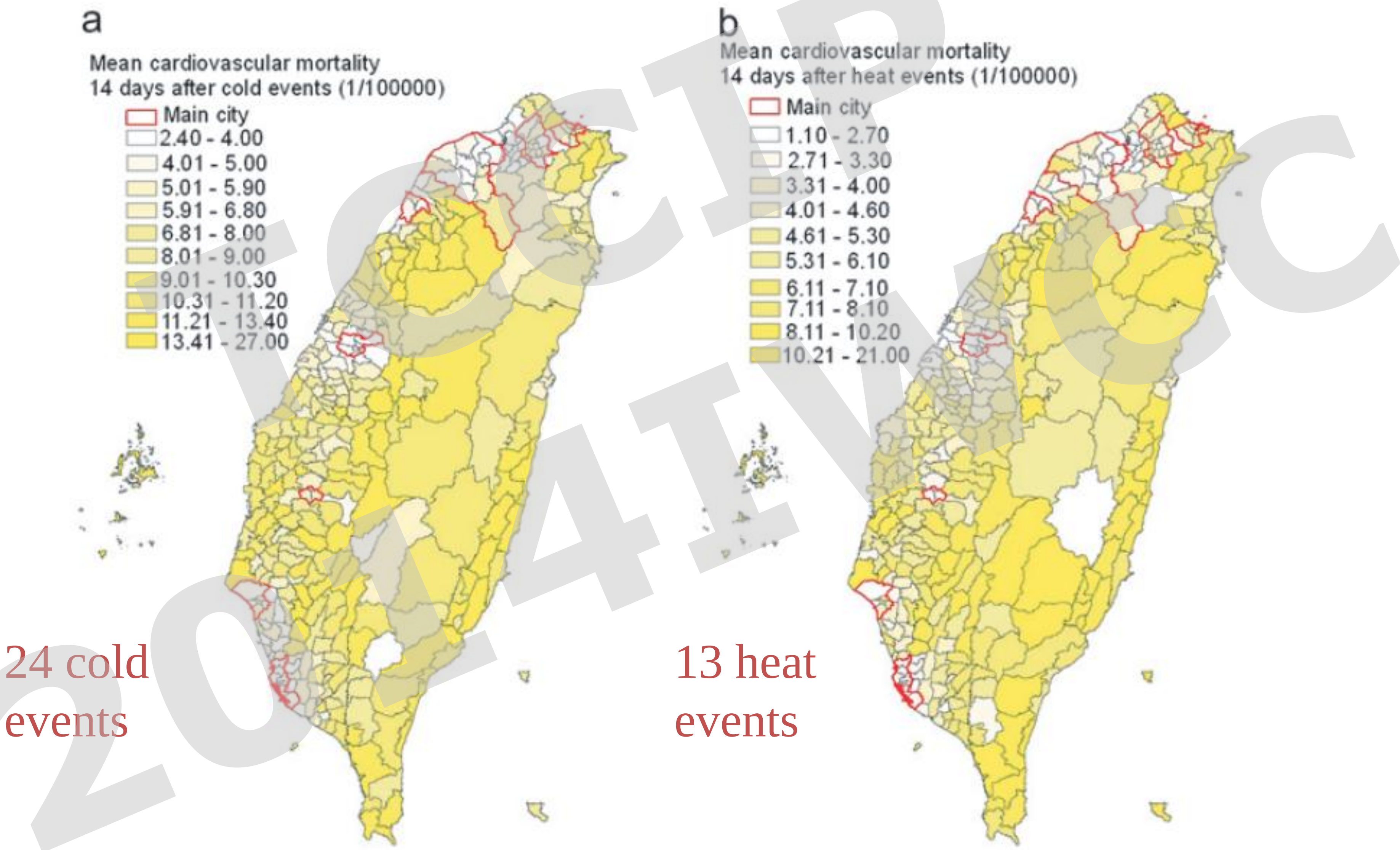
Cardiovascular mortality 2 weeks after cold and heat events



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[Occup Environ Med 2011;68:525e530]

Demographic and socioeconomic factors extracted by PCA

Components	Variance explained	Loading
Factor 1: Medical resources and urbanization	24.43%	
Numbers of clinics per 10000 population		0.820
Numbers of doctors per 10000 population		0.683
Percent of household ownership		- 0.812
Percent of service occupation		0.784
Percent of agriculture occupation		- 0.484
Factor 2: Susceptible population	21.57%	
Elders living alone		0.902
Elders		0.902
Disability		0.690
Factor 3: Higher percentage of Aborigine population	15.05%	
Percent of aborigine		0.873
Percent of uneducated population		0.770
Factor 4: Lack of economic opportunity	10.92%	
Unemployment rate		0.634
Percent of laborers working outside the county of residence		0.754
Sum of variance explained	**71.97%**	

[Occup Environ Med 2011;68:525e530]

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Examining the spatial relationships among cardiovascular mortality after the cold and heat events, baseline of mortality, event temperature, socio-economic and demographic factors by using the spatial lag model

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Extreme temperature events	Cold events (24 events) R^2=0.767		Heat events (14 events) R^2=0.569	
	Coefficients	95% C.I.	Coefficients	95% C.I.
Cardiovascular mortality before extreme temperature events	0.539**	(0.444, 0.635)	0.398**	(0.289, 0.507)
Mean temperature of extreme temperature events	0.002	(-0.080, 0.084)	0.025	(-0.066, 0.116)
Factor 1: Medical resources and urbanization	-0.601**	(-0.829,-0.374)	-0.456**	(-0.705, -0.206)
Factor 2: Susceptible population	1.338**	(1.014, 1.663)	0.954**	(0.614, 1.294)
Factor 3: Aborigine population	0.308**	(0.103, 0.514)	0.760**	(0.498, 1.020)
Factor 4: Lack of economic opportunity	-0.076	(-0.268, 0.115)	-0.210*	(-0.438, 0.018)
Constants	4.186**	(2.659, 5.713)	2.303*	(-0.438, 5.044)
Rho	-0.006	(-0.089, 0.078)	0.098*	(-0.012, 0.208)
Moran's I value residues	-0.022		-0.041	

Baseline of mortality, event temperature, socioeconomic and demographic factors by using spatial analysis.
***p<0.1 **p<0.05**

(Wu et al., 2010)

Conclusions

- Our data, using an island wide spatial analysis, suggest urban areas are with greater adaptive capability than rural areas, plausibly due to higher socioeconomic status and more medical resource available.

- Aborigine people and other vulnerable subgroups, especially the elders, often with more underlying diseases and having less preventive response to the event, were also the determinants of vulnerability.

- Social inequality across urban and rural townships is apparent, and developing customized adaptation program in vulnerable regions at the events of extreme heat and cold should be prioritized.

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~ Climate change will amplify existing hazards, deficits, and inequities, jeopardizing the already low status of population health and well-being of disadvantaged population ~

~ It is important to identify those populations most at risk of adverse effects from climate changes, to reduce their vulnerability~

[McMichael, 2004]

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Things to do:

Predicting the future in health impacts

- Establish the short/ long terms association between meteorological indicators (monthly temperature, days without rainfall, severity of events and frequency of temperature higher than a threshold value etc.) and incidence (regional/island wide)

- Identify the critical factors (population susceptibility, environment, socio-demographic and occupational factors) for population vulnerability

- Available scenarios and climate projection data

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Questions from data users

- Spatial resolution (1km*1km is best for township level analysis)
- Different temporal resolution for different outcomes (daily, weekly, and monthly)
- Definition of temperature extremes (heat waves in Taiwan?)
- Summarize and quantify the uncertainties of all downscaling models
- Generate the “secondary indicators” for user

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