Biography

- Professor Wei Ma is the associate dean of the Shandong University School of Public Health, deputy director of the Shandong University Climate change and Health Center.
- He received his PhD in Epidemiology at School of Public Health, University of California, Los Angeles in 2006.
- He is also a member of the Future Earth Health Knowledge Action Network Steering committee.
- Prof. Ma's research interests include infectious disease epidemiology and impacts of climate change, especially the impacts of extreme weather events, on human...

The Impact of Climate Change and Extreme Weather Events on the Risk of Dengue Fever Transmission in China

Prof. Wei Ma

Vice Dean, School of Public Health, Shandong University

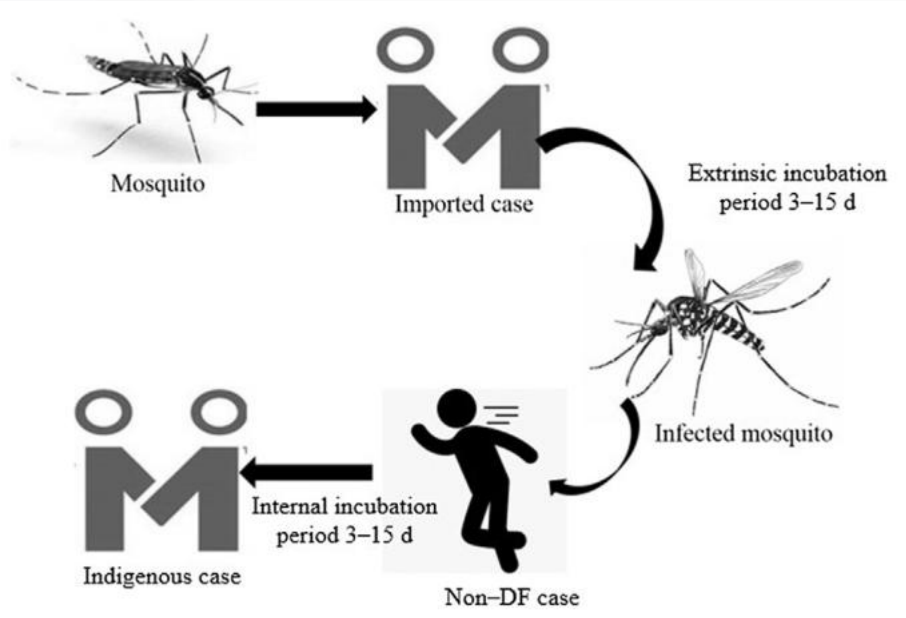
Deputy Director, Shandong University Climate Change and Health Center

Background: Dengue fever

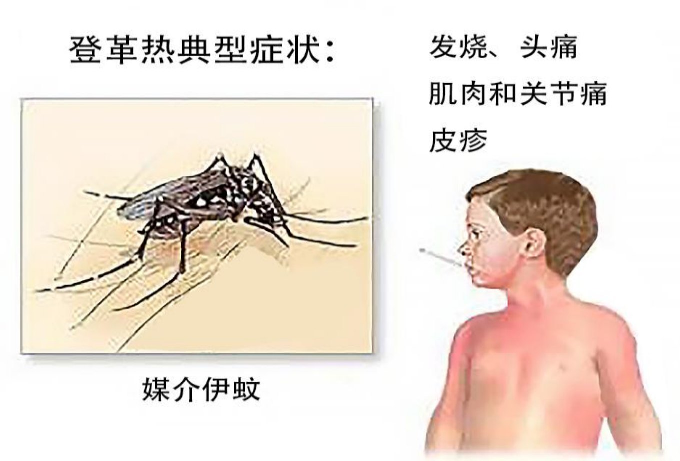
(1) Dengue fever (DF) is an infectious disease caused by four serotypes of dengue virus, mainly transmitted by Aedes albopictus and Aedes aegypti mosquitoes.

Aedes albopictus

Aedes aegypti



(2) WHO believes that climate change is the main cause of the global spread of dengue fever.



Background: Dengue fever

- Dengue fever is one of the most serious mosquito borne infectious diseases worldwide.
- Affected by the global dengue fever epidemic, the incidence of dengue fever in China has shown a continuous upward trend.

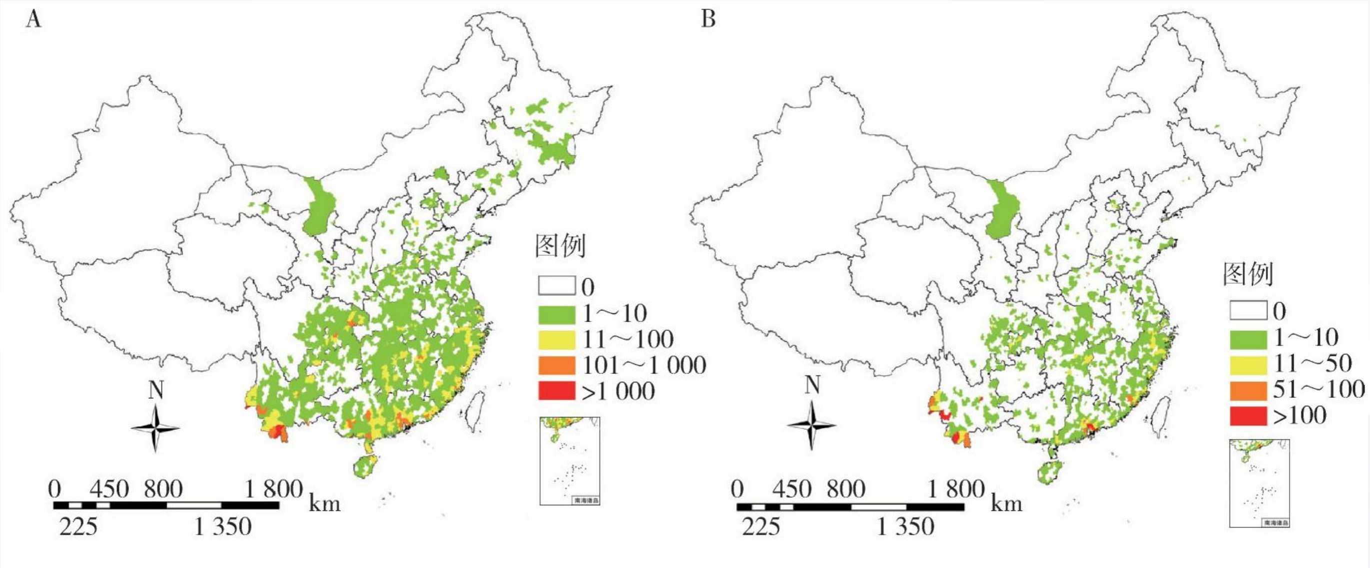


Figure Regional distribution of dengue reported cases in Chinese Mainland in 2019
A. Distribution of reported cases of dengue fever; B. Distribution of imported dengue fever...

- Dengue fever outbreaks in China are spreading from the southeast coastal areas to the northwest hinterland.

Liu et al. 2020

Background: Climate change, hydrological status, and dengue fever

- Climate change includes the long-term dynamic changes of climate elements, which will alter the current distribution patterns of temperature and precipitation.
- Climate change can also lead to frequent extreme weather events such as heatwaves, floods, and typhoons.
- Temperature, precipitation, humidity, and other factors can affect the reproduction of Aedes mosquitoes, the replication of dengue virus, and the transmission pathways and processes of dengue fever.

Background : The impact of temperature on dengue virus

Arch Virol.2014 Nov; 159(11):3053-7. doi: 10.1007/s00705-014-2051-1. Epub 2014 Jul 3.

The effect of temperature on the extrinsic incubation period and infection rate of dengue virus serotype 2 infection in Aedes albopictus

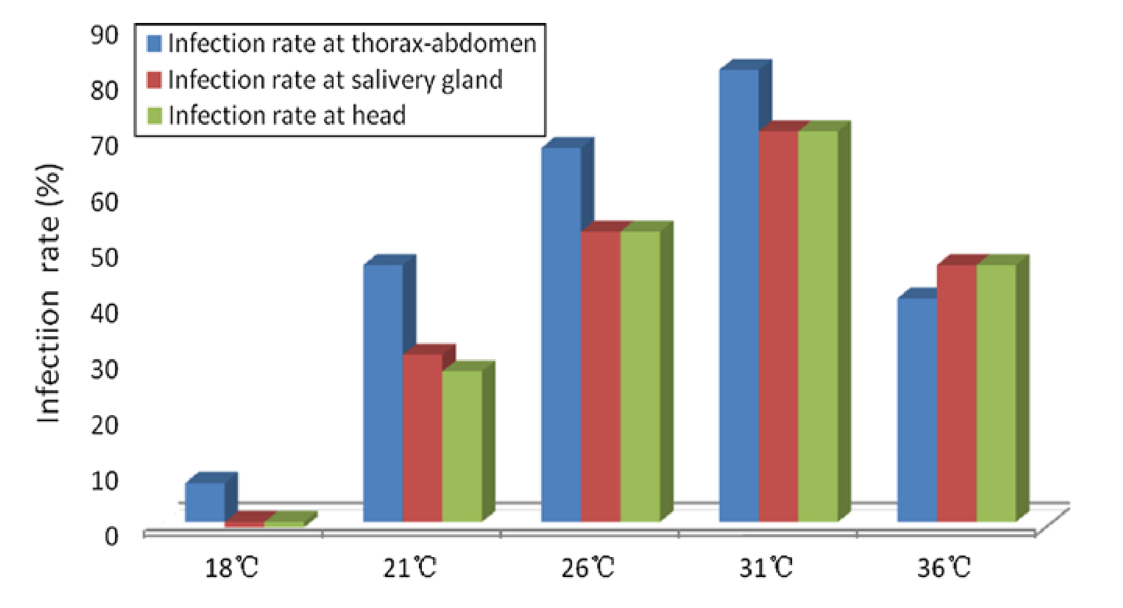


Fig. 1 Infection rates of head, salivary glands, and thorax-abdomen of *Ae. albopictus* at different temperatures after feeding on blood meals (the virus titer was 1 × $10^{7.9}$)

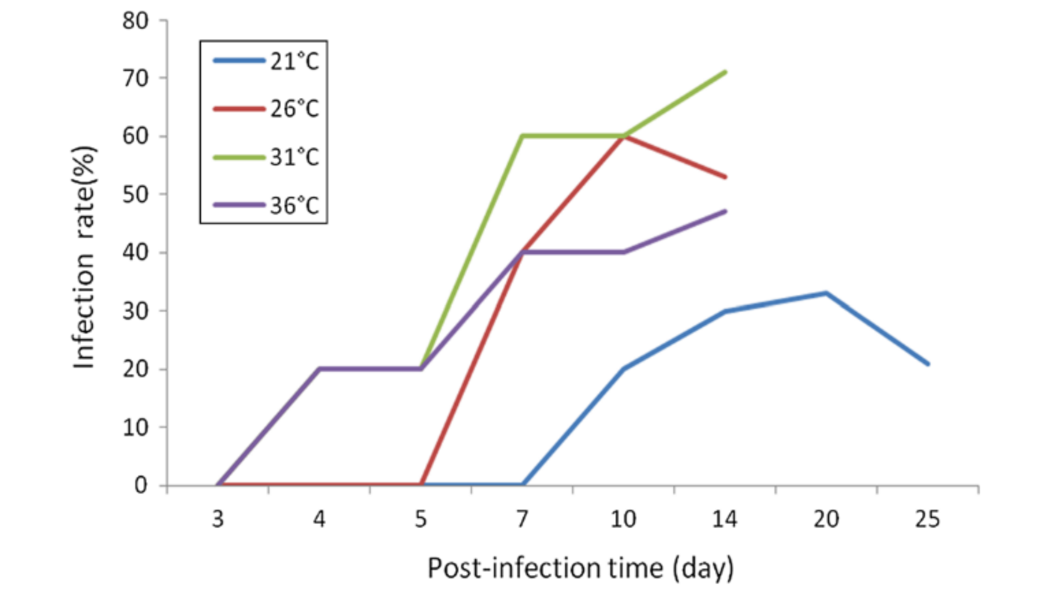


Fig. 3 Infection rates of *Ae. albopictus* salivary glands at different times postinfection after infectious blood meals. The mosquitoes were kept at 18, 21, 26, 31, and 36 °C, respectively

Within the temperature range of 18-31 ℃, the infection rate shows an increasing trend as the temperature rises. The highest infection rate occurs at 31 ℃, but the infection rate is lower at 36 ℃ than at 31 ℃.

As the temperature increases, the replication rate of the virus in Aedes mosquitoes accelerates, and the time for the first detection of dengue virus antigen gradually shortens.

Background: The impact of temperature and precipitation on mosquito vectors

Vector Borne Zoonotic Dis.2011 Aug; 11(8):1181-6. doi: 10.1089/vbz.2010.0032.

Distribution of Aedes albopictus in Northwestern China

Research on Aedes albopictus shows that most confirmed areas are located in regions with annual average temperatures above 11 ℃ and January average temperatures above -5 ℃.

The confirmed areas of Aedes albopictus have experienced annual precipitation of over 500 millimeters, which is a typical lower limit.

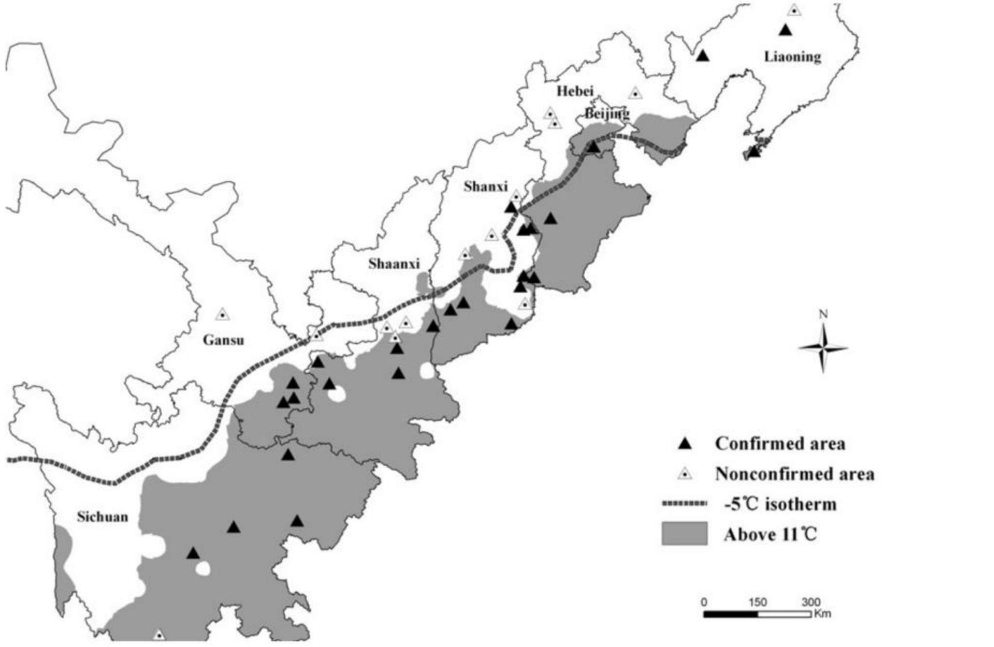


FIG. 2. Relationship between annual mean temperature and the distribution of *Ae. albopictus*, January mean temperature, and the distribution.

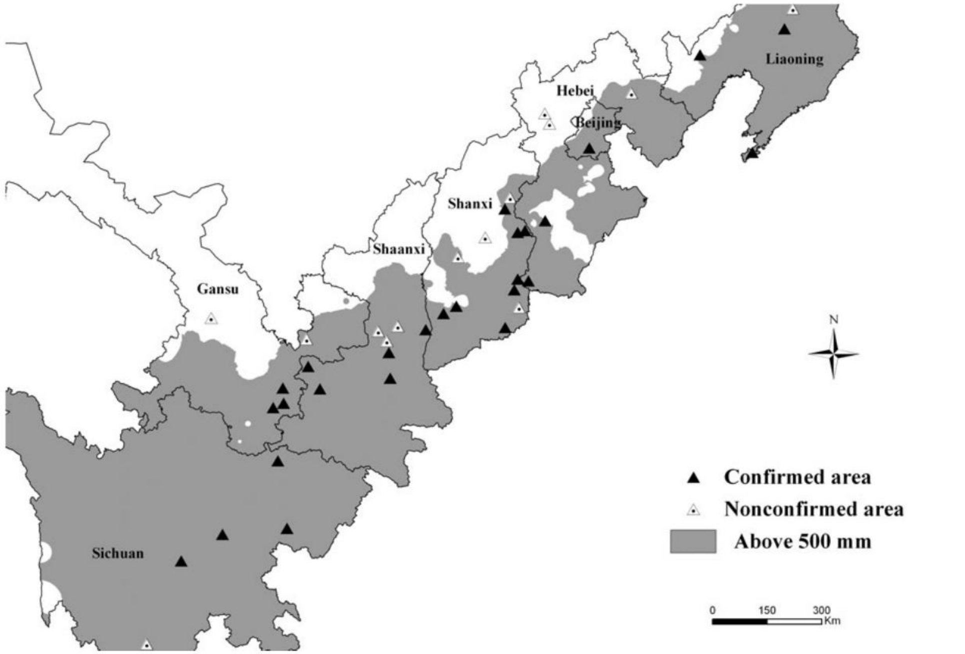


FIG. 3. Relationship between annual precipitation and the distribution of *Ae. albopictus*.

Background: The impact of climate factors on the incidence of dengue fever

Environ Res. 2021 May; 196:110900. doi: 10.1016/j.envres.2021.110900.

Extreme weather conditions and dengue outbreak in Guangdong, China: Spatial heterogeneity based on climate variability

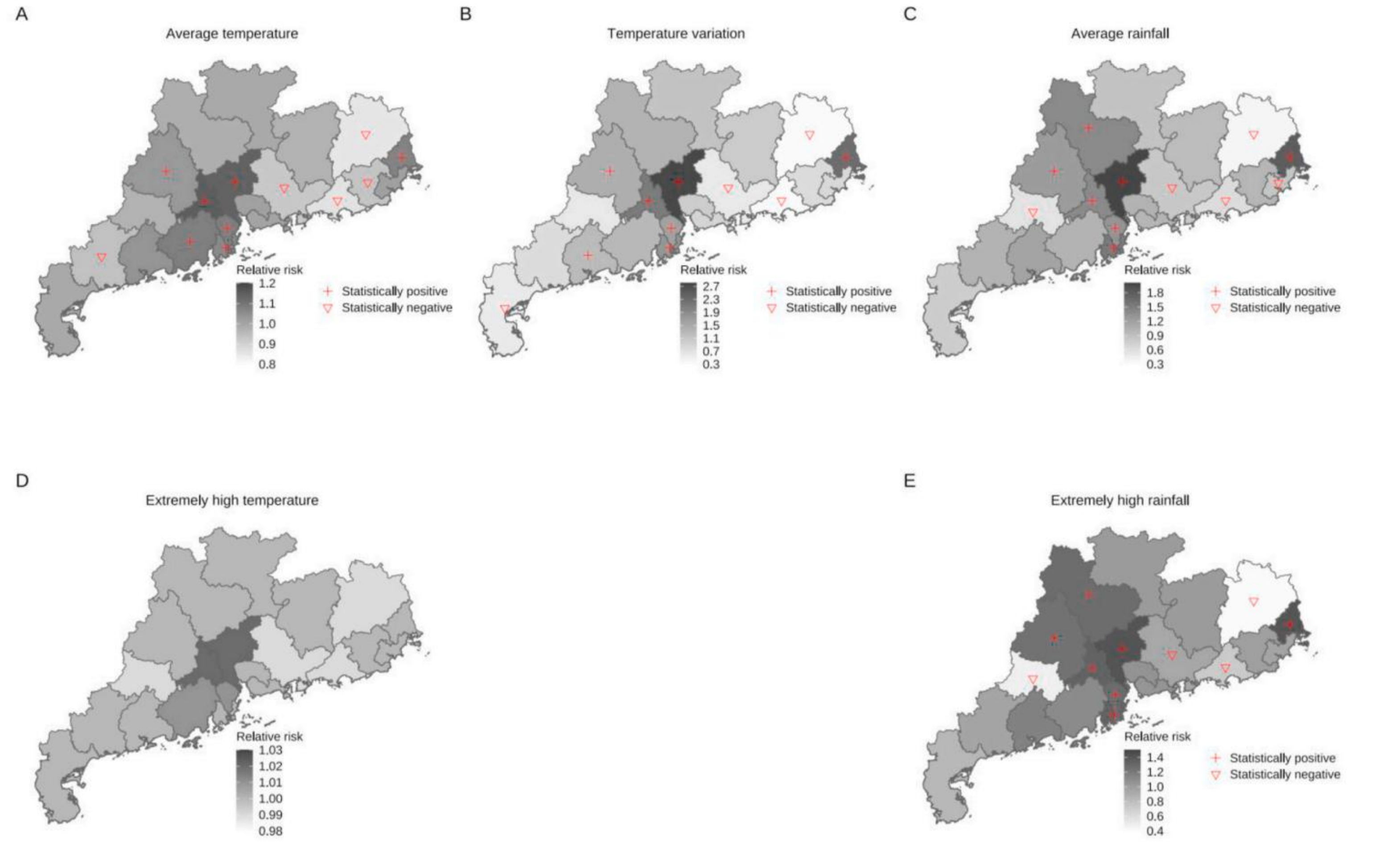


Fig. 4. Estimated associations of dengue incidence with weather conditions for each city in Guangdong province.

In seven cities of Guangdong Province, average temperature and average rainfall are positively correlated with the incidence rate of dengue fever, while five cities are negatively correlated.

Background: Climate change, hydrological status, and dengue fever

The local hydrological status (changes and movements of water in nature) is closely related to factors such as temperature and precipitation, and is a potential indicator for evaluating the comprehensive impact of climate factors on dengue fever outbreaks.

- **Moist state**: Rich static water source provides a natural breeding ground for Aedes mosquitoes
- **Drought state**: increase the use of water storage containers and mosquito human contact frequency

Background: Urbanization and Dengue Fever

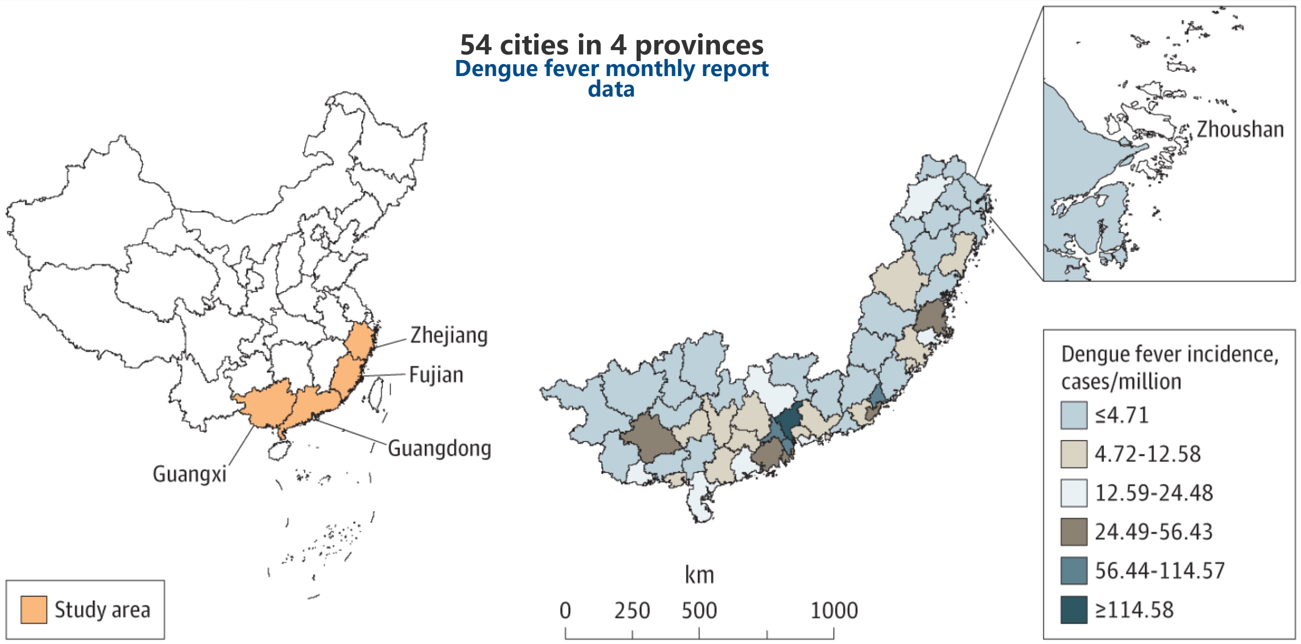
Urban development is a multidimensional and systematic concept, which can change the correlation between climate and hydrological factors and dengue fever from different dimensions, such as:

- Insufficient urban water supply and delayed garbage recycling will promote the breeding of mosquito vectors
- High population density and mobility will increase the frequency of mosquito human contact
- Abundant medical resources can improve the prevention and control of dengue fever and emergency response capabilities for dengue fever outbreaks

Study 1: Correlation Analysis between Climate and Hydrological Factors and Dengue Fever Transmission in China

JAMA Netw Open. 2023; 6(1):e2249440. doi:10.1001/jamanetworkopen.2022.49440

Association Between Hydrological Conditions and Dengue Fever Incidence in Coastal Southeastern China From 2013 to 2019



Climate and hydrological indicators

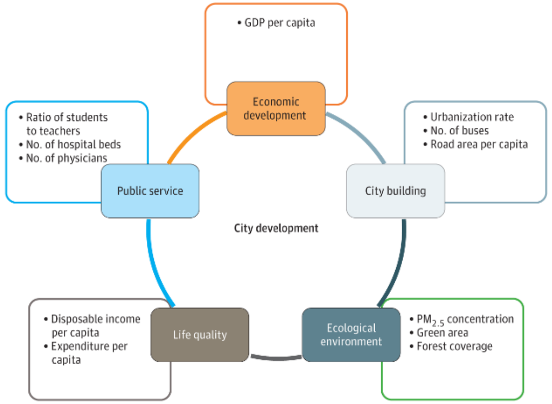
Standardized Precipitation Evapotranspiration Index (SPEI): The cumulative frequency distribution of the difference between standardized precipitation and evapotranspiration is used to classify dry and wet levels.

- **SPEI>0 indicates wetness, SPEI=2 indicates extreme wetness**
- **SPEI<0 indicates drought, SPEI=-2 indicates extreme drought state**

SPEI has multi-scale characteristics. In this study, monthly SPEI-3, SPEI-6, and SPEI-12 were calculated for each city, representing the seasonal, medium-term, and...

50 urban development indicators

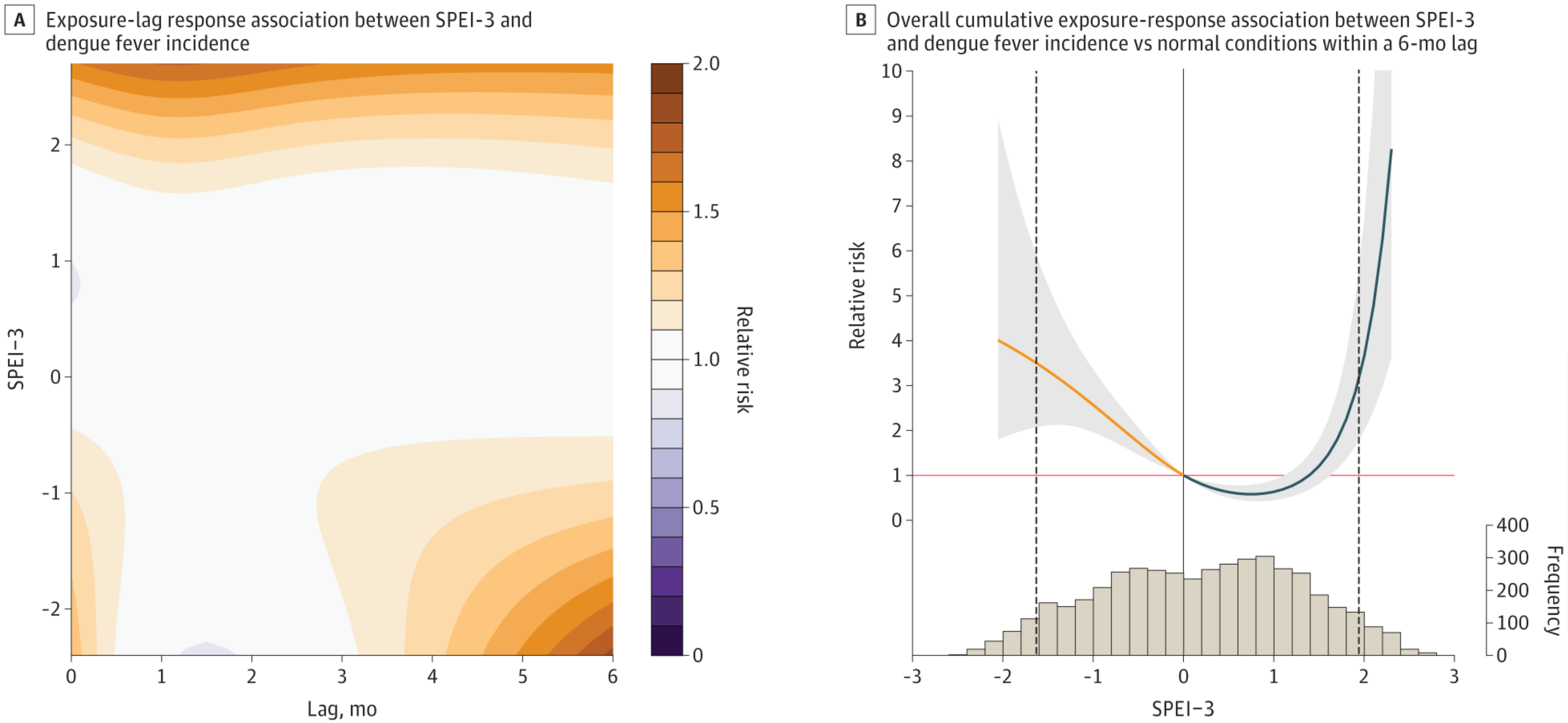
1. **Economic development: 11**
2. **Resident life: 10**
3. **Public services: 9**
4. **Urban construction: 9**
5. **Ecological environment: 11**



The correlation between climatic and hydrological factors and the transmission of dengue fever in China

Spatiotemporal Bayesian Mixed Effects Model+Distributed Lag Nonlinear Model:

- ✓ Extreme humidity and extreme drought can both increase the risk of dengue fever
- ✓ Extreme humidity has the greatest effect in the first month of lag, RR=1.27 (95%CI: 1.05-1.53)
- ✓ Extreme drought exhibits a longer lag, with the greatest effect in the sixth month, RR=1.63 (95%CI: 1.29-2.05)



The modifying effect of urban features

✓ **The modifying effects of economic development, public services, and residents' living standards are similar. The higher level of development has reduced the adverse effects of extreme hydrological conditions on dengue fever incidence, especially in extreme drought conditions:**

In cities with lower per capita GDP, number of doctors, and disposable income: the risk of dengue fever increases immediately under extreme drought conditions, with the greatest effect in the current month

Table. Maximum and Cumulative Relative Risk of Dengue Fever for Extreme Wet and Extreme Dry Conditions Within 6 Months by Different Scenarios of City Development Indicators

	Extreme wet conditions: SPEI-3 of 2			Extreme dry conditions: SPEI-3 of −2		
	Maximum RR and lag			Maximum RR and lag		
City development indicator	RR (95% CrI)	Lag, mo	Cumulative RR (95% CrI)	RR (95% CrI)	Lag, mo	Cumulative RR (95% CrI)
GDP per capita						
Low	1.41 (0.95-2.11)	0	4.47 (1.84-10.87)	1.76 (1.21-2.57)	0	7.15 (2.89-17.69)
Medium	1.28 (0.95-1.74)	0	4.00 (2.08-7.71)	1.52 (1.12-2.06)	0	4.61 (2.16-9.87)
High	1.30 (1.00-1.68)	1	2.73 (1.15-6.48)	1.67 (1.21-2.30)	6	1.69 (0.53-5.36)
No. of physicians per 10 000 people						
Low	1.62 (1.07-2.44)	0	5.56 (2.19-14.11)	2.04 (1.40-2.98)	0	11.81 (5.16-27.03)
Medium	1.38 (1.00-1.89)	0	4.29 (2.14-8.58)	1.60 (1.18-2.16)	0	4.90 (2.28-10.53)
High	1.21 (0.99-1.48)	2	2.16 (0.97-4.82)	1.27 (0.92-1.75)	6	0.82 (0.28-2.39)
Disposable income per capita						
Low	1.61 (1.05-2.49)	0	5.74 (2.18-15.14)	2.27 (1.52-3.38)	0	17.10 (7.17-40.78)
Medium	1.40 (1.01-1.93)	0	4.46 (2.22-8.96)	1.74 (1.27-2.39)	0	5.83 (2.73-12.44)
High	1.24 (0.97-1.58)	1	2.31 (1.02-5.24)	1.25 (0.92-1.70)	6	0.65 (0.23-1.89)

The modifying effect of urban features

- ✓ **In terms of ecological environment, after 3-6 months of extreme drought, cities with larger per capita green areas have a significantly increased risk of dengue fever**
- ✓ **The urbanization rate has a positive modifying effect on extreme humidity and a negative modifying effect on extreme drought.**

Table. Maximum and Cumulative Relative Risk of Dengue Fever for Extreme Wet and Extreme Dry Conditions Within 6 Months by Different Scenarios of City Development Indicators

	Extreme wet conditions: SPEI-3 of 2			Extreme dry conditions: SPEI-3 of −2		
	Maximum RR and lag			Maximum RR and lag		
City development indicator	RR (95% CrI)	Lag, mo	Cumulative RR (95% CrI)	RR (95% CrI)	Lag, mo	Cumulative RR (95% CrI)
Green area per 10 000 people						
Low	1.27 (1.00-1.61)	1	2.91 (1.43-5.90)	1.46 (1.11-1.91)	6	2.16 (0.91-5.10)
Medium	1.27 (1.02-1.59)	1	3.15 (1.64-6.07)	1.52 (1.18-1.96)	6	2.65 (1.19-5.90)
High	1.31 (0.94-1.81)	0	4.92 (2.20-10.98)	1.84 (1.37-2.46)	6	9.08 (3.17-26.00)
Urbanization rate						
Low	1.30 (0.94-1.80)	2	1.65 (0.57-4.73)	1.70 (1.11-2.60)	0	5.74 (2.36-13.98)
Medium	1.29 (1.03-1.63)	1	2.90 (1.51-5.58)	1.51 (1.09-2.08)	0	3.92 (1.81-8.49)
High	1.80 (1.26-2.56)	6	6.67 (2.16-20.62)	1.57 (1.13-2.16)	6	1.97 (0.69-5.60)

Study 2: Estimation of Dengue Fever Risk in China's Future by Climate and Hydrological Factors

Lancet Planet Health. 2023 May; 7(5):e397-e406. doi: 10.1016/S2542-5196(23)00051-7.

Projecting future risk of dengue related to hydrometeorological conditions in mainland China under climate change scenarios: a modelling study

- ✓ **Database: Dengue fever case data from 70 cities in China from 2013 to 2019**
- ✓ **Method: Ross Macdonald model (ecology)+spatiotemporal Bayesian mixed effects model (spatial epidemiology)**

Simultaneously considering the impact of climate change on the active distribution of dengue virus and Aedes mosquitoes, as well as the correlation between climate and hydrological factors and dengue fever incidence

- ✓ **Climate change scenario: RCP2.6、 4.5 and 8.5**

Study 2: Estimation of Dengue Fever Risk in China's Future by Climate and Hydrological Factors

Ross Macdonald Model (Ecology)

- ✓ The impact of climate on the survival and reproduction of mosquito vectors
- ✓ The impact of climate on the developmental cycle of dengue virus in mosquito vectors

$$n = \frac{K}{T - C}$$

$$L_i = \frac{p^n}{-\text{In}p}$$

其中，
n：外潜伏期
K：登革病毒在蚊媒体内正常发育所需的最低积温，为165.2℃·d
C：登革病毒在蚊媒体内正常发育所需的最低温度，为11.9℃
T：环境温度
L_i：感染性寿命
p：日存活率

当L_i=1，p=91%时，T=18.5℃

$$ADD_{DF(i)} = \sum_{j=1}^{30}(T_{mean(i)}/T_{p(i)} - C);$$

$$ADD_{a.a.(i)} = \sum_{j=1}^{30}(T_{mean(i)}/T_{p(i)} - T_0)$$

ADD_{DV}=K=165.2℃·d
$ADD_{a.a.}$=980℃·d
→

$$PTI_{DV(i)} = \frac{ADD_{DV(i)}}{ADD_{DV}}$$

$$PTI_{a.a.(i)} = \frac{ADD_{a.a.(i)}}{ADD_{a.a.}}$$

其中，
ADD_{DV}：登革病毒发育期间的积温（℃·d）
$ADD_{a.a.}$：白纹伊蚊发育期间的积温（℃·d）
C：登革病毒在蚊媒体内发育所需最低温度，为11.9℃
T_0：伊蚊发育所需最低温度，为11℃

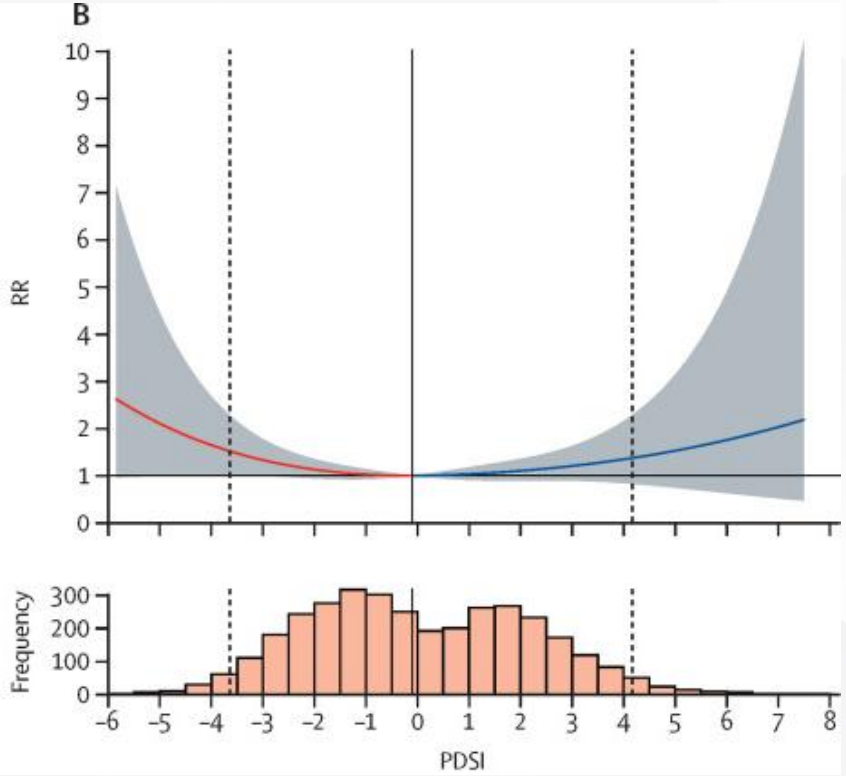
↓

$$PTI_{(i)} = PTI_{DV(i)} \cdot PTI_{a.a.(i)},\ PTI_{(i)} \geq 1, \text{otherwise } PTI_{(i)} = 0$$

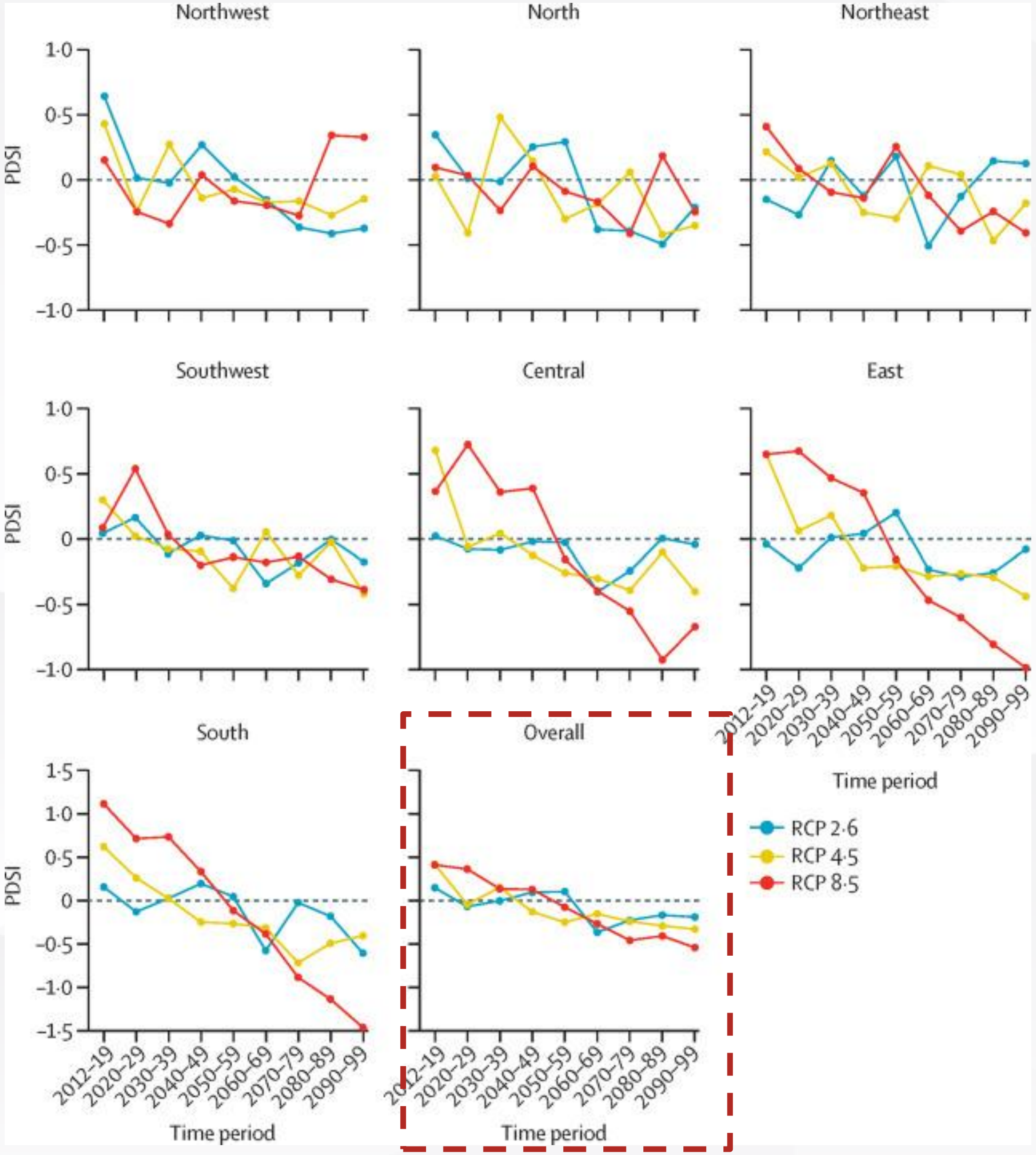
- ✓ **连续14天日均温≥18.5℃**
- ✓ **PTI>1**

Spatiotemporal Bayesian Mixed Effects Model (Spatial Epidemiology)

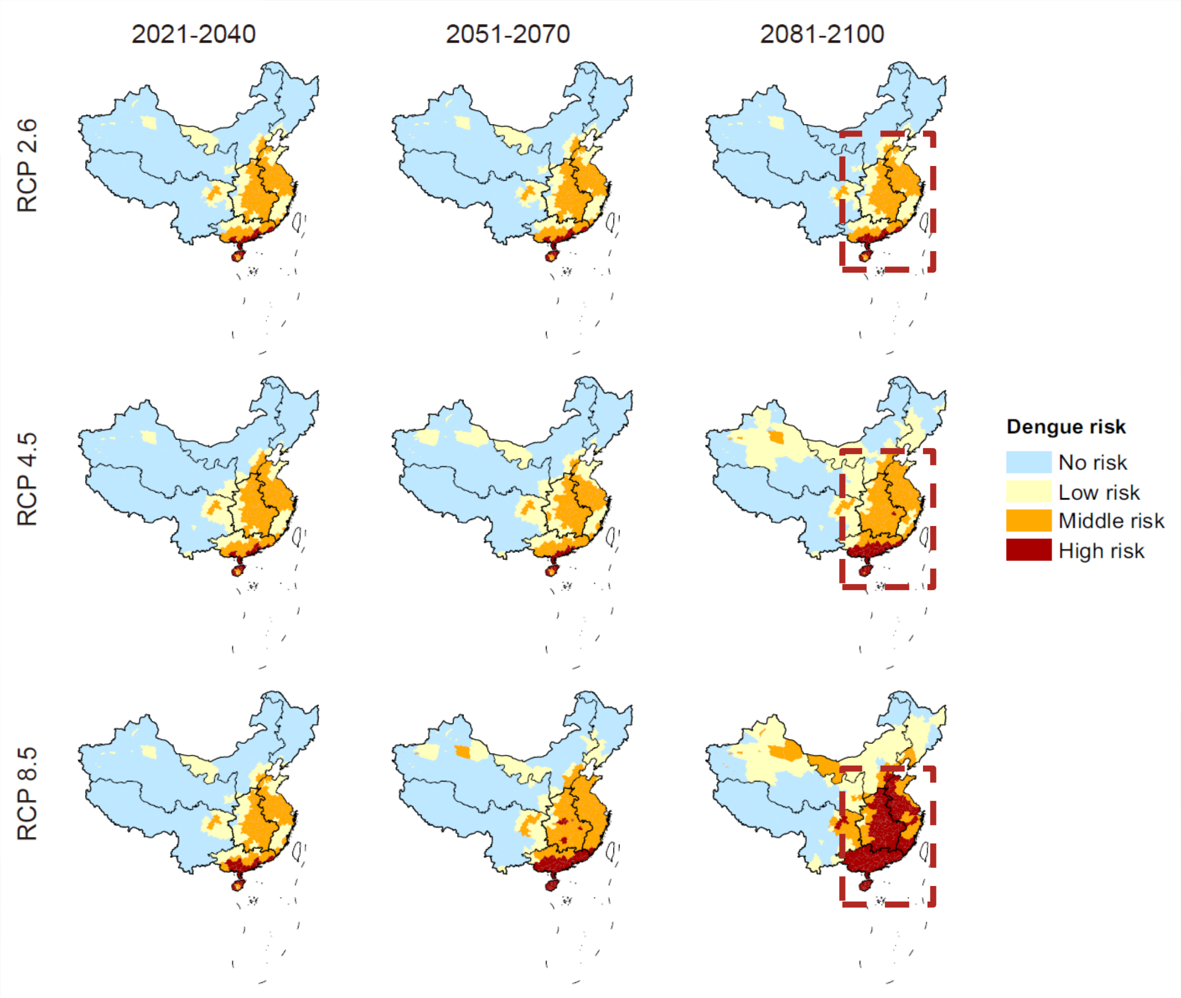
- ✓ Dose response relationship between PDSI (Palmer Drought Index) and dengue fever incidence



Trends of PDSI changes in China under different RCP scenarios



Distribution of active risk areas for dengue virus and Aedes mosquitoes...



The exposure risks are highest in South China, East China, and Central China regions

Hainan, Guangxi, and Guangdong have the longest duration of exposure risk (>4 months per year)

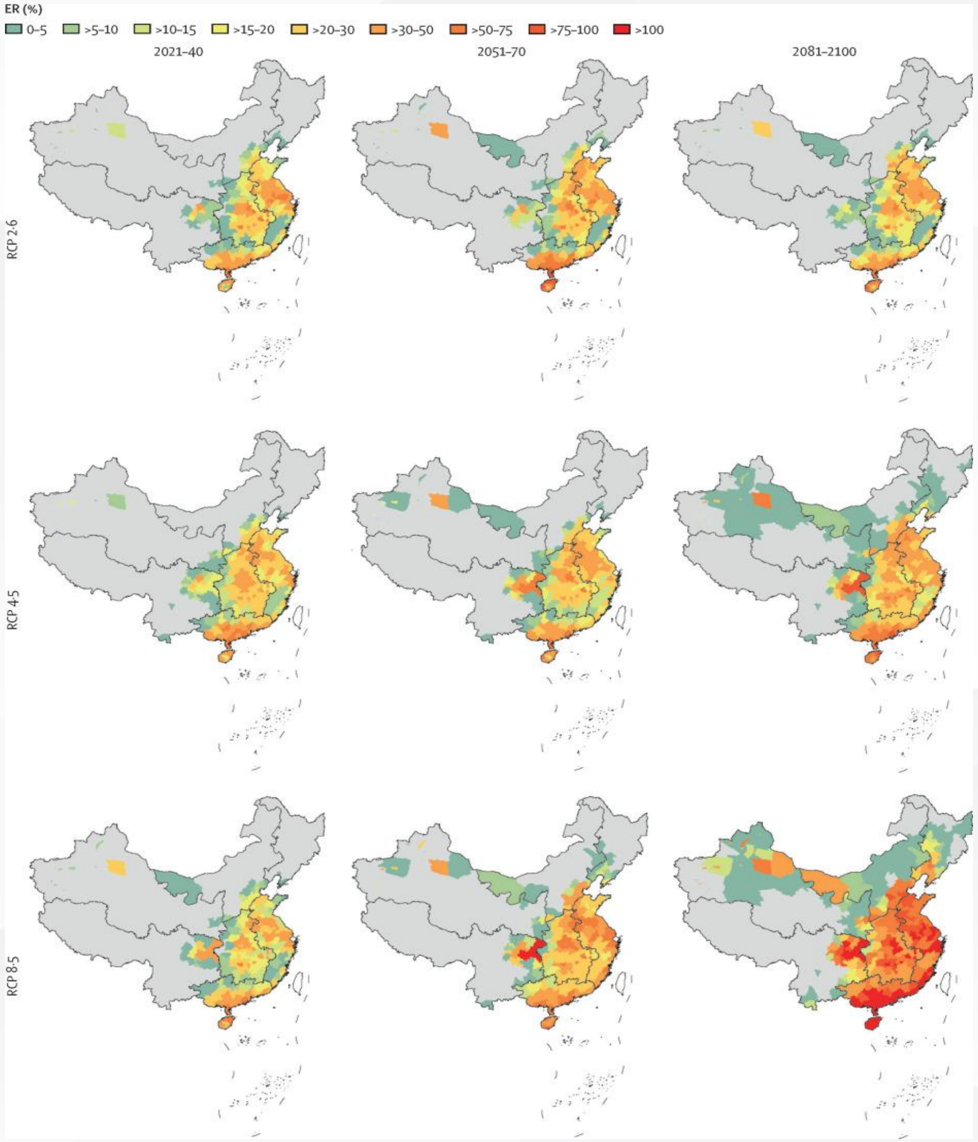
In the RCP8.5 scenario, there is a clear northward trend in the distribution of dengue virus and Aedes mosquitoes

Cities with no risk of dengue virus transmission by 2100

RCP2.6 Scenario: 150

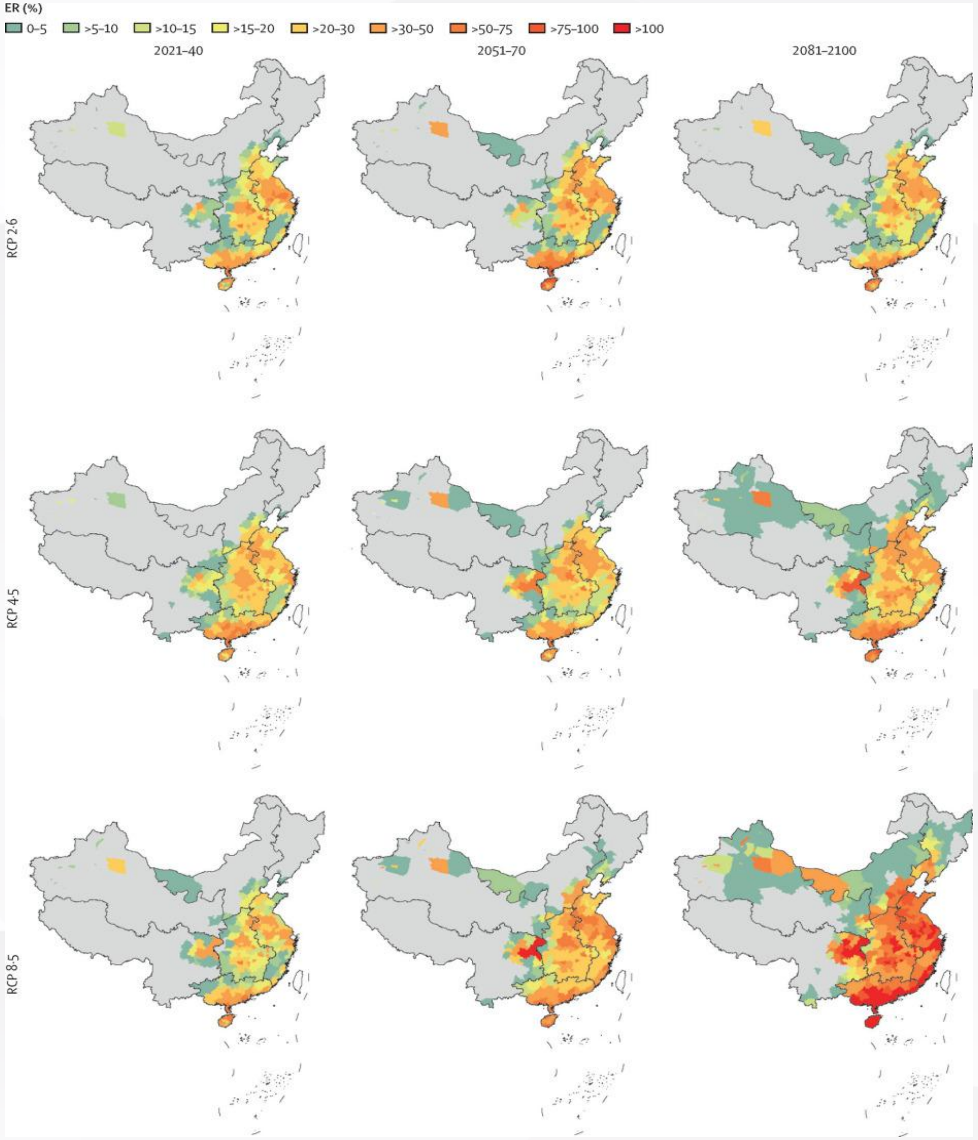
RCP8.5 scenarios: 55

Excess risk of dengue fever attributed to hydrological conditions under different RCP scenarios



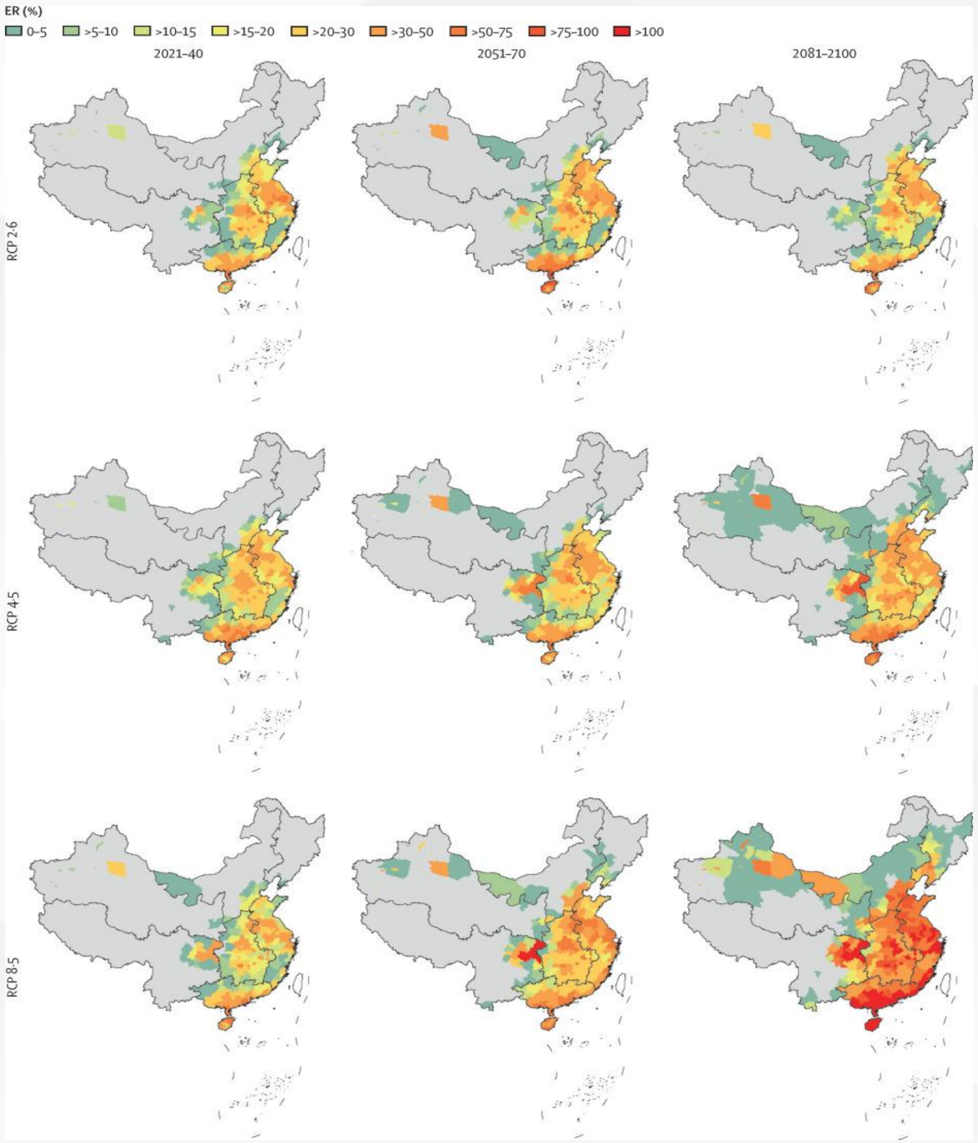
	RCP 2•6		RCP 4•5		RCP 8•5	
	2021–40	2081–2100	2021–40	2081–2100	2021–40	2081–2100
Northwest	0·63	0·81	1·55	4·56	1·05	12·56
North	3·99	6·20	5·54	10·51	3·53	27·93
Northeast	0·05	0·22	0·05	3·29	0·04	15·34
Southwest	3·34	1·84	4·84	8·21	3·14	26·18
Central	22·58	22·34	26·43	32·35	20·21	67·14
East	27·87	27·38	24·57	34·63	23·30	80·18
South	28·40	37·44	34·16	48·22	33·16	173·62
Overall	13·79	15·03	15·21	21·82	13·28	60·77

Excess risk of dengue fever attributed to hydrological conditions under different RCP scenarios



	RCP 2•6		RCP 4•5		RCP 8•5	
	2021–40	2081–2100	2021–40	2081–2100	2021–40	2081–2100
Northwest	0·63	0·81	1·55	4·56	1·05	12·56
North	3·99	6·20	5·54	10·51	3·53	27·93
Northeast	0·05	0·22	0·05	3·29	0·04	15·34
Southwest	3·34	1·84	4·84	8·21	3·14	26·18
Central	22·58	22·34	26·43	32·35	20·21	67·14
East	27·87	27·38	24·57	34·63	23·30	80·18
South	28·40	37·44	34·16	48·22	33·16	173·62
Overall	13·79	15·03	15·21	21·82	13·28	60·77

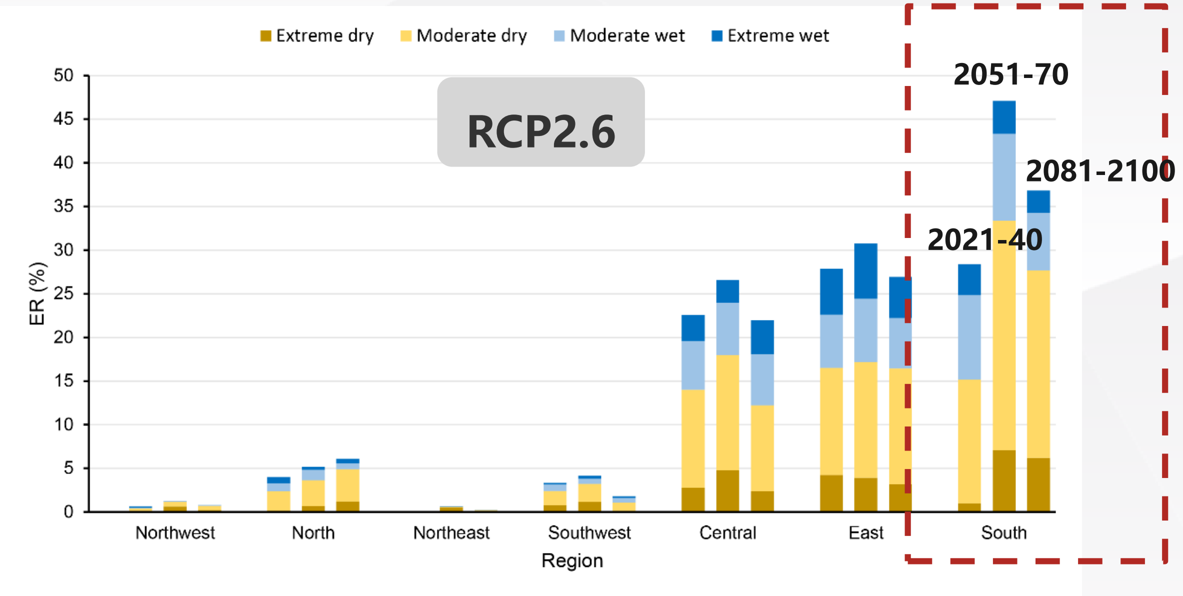
Excess risk of dengue fever attributed to hydrological conditions under different RCP scenarios

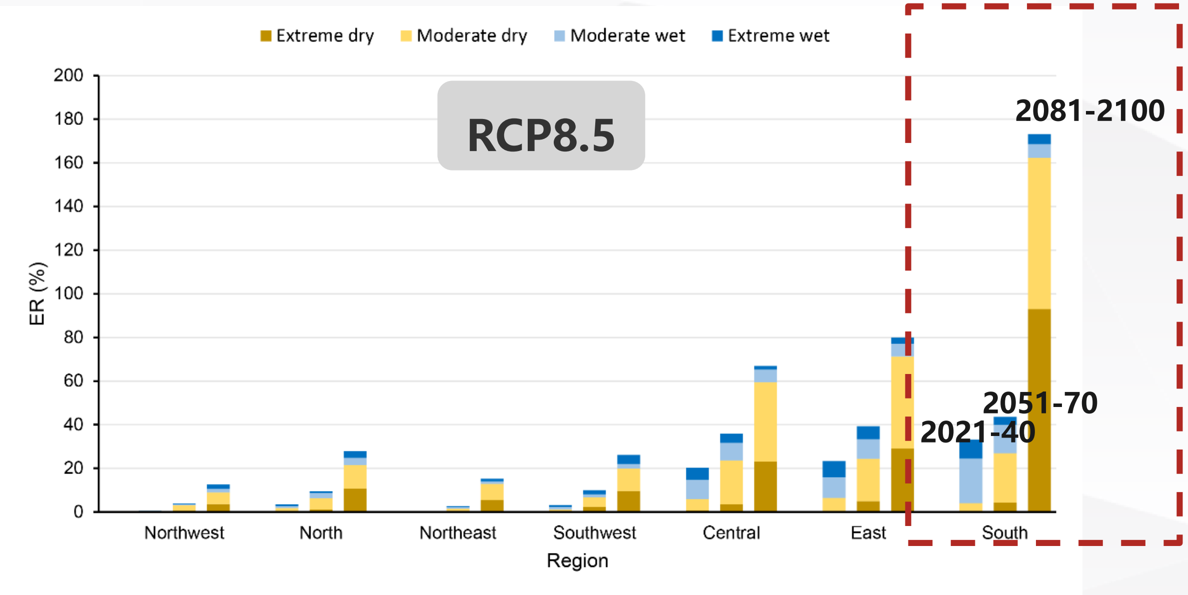


	RCP 2•6		RCP 4•5		RCP 8•5	
	2021–40	2081–2100	2021–40	2081–2100	2021–40	2081–2100
Northwest	0·63	0·81	1·55	4·56	1·05	12·56
North	3·99	6·20	5·54	10·51	3·53	27·93
Northeast	0·05					15·34
Southwest	3·34					26·18
Central	22·58	22·34	26·43	32·35	20·21	67·14
East	27·87	27·38	24·57	34·63	23·30	80·18
South	28·40	37·44	34·16	48·22	33·16	173·62
Overall	13·79	15·03	15·21	21·82	13·28	60·77

Coastal cities have an average annual increase in attributable disease risk of over 50%

Cumulative incidence risk of dengue fever attributed to dry and wet conditions under different RCP scenarios





Contribution of annual attributable incidence risk:

2021-40: Equal contribution of dry and wet

2051-70: Drought as the main contributing factor

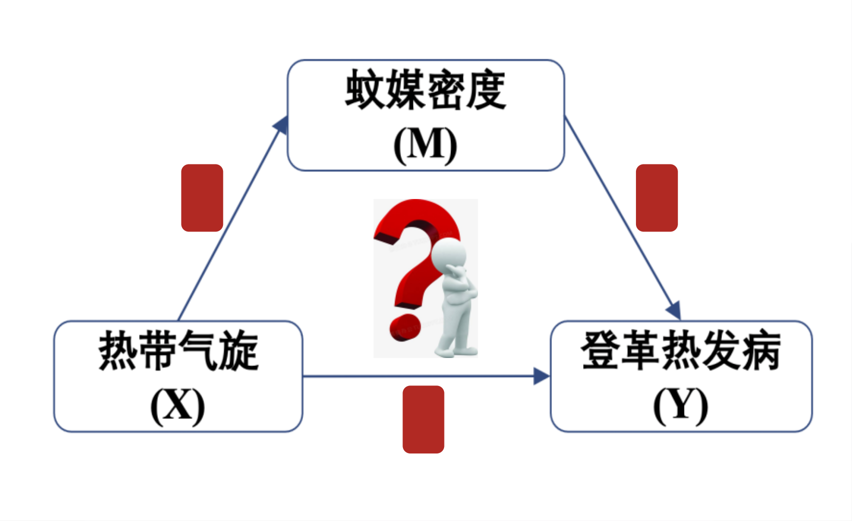
2081-2100: Drought as the main contributing factor

Under RCP2.6 scenario: moderate hydrological conditions as the main contributing factor

RCP8.5 scenario: rapid increase in contribution of extreme hydrological conditions

Study 3: The impact of extreme weather and climate events on the incidence of vector mosquitoes Aedes and dengue fever: A case study of tropical cyclones

- Tropical cyclones can affect the incidence of dengue fever. During a tropical cyclone, its energy is released in the form of wind, rainstorm and storm surge, providing suitable temperature and rainfall conditions for mosquito breeding, and may also create conditions for the occurrence and prevalence of dengue fever.



The impact of tropical cyclones on dengue fever in the the Pearl River Delta: a time stratified case-control study

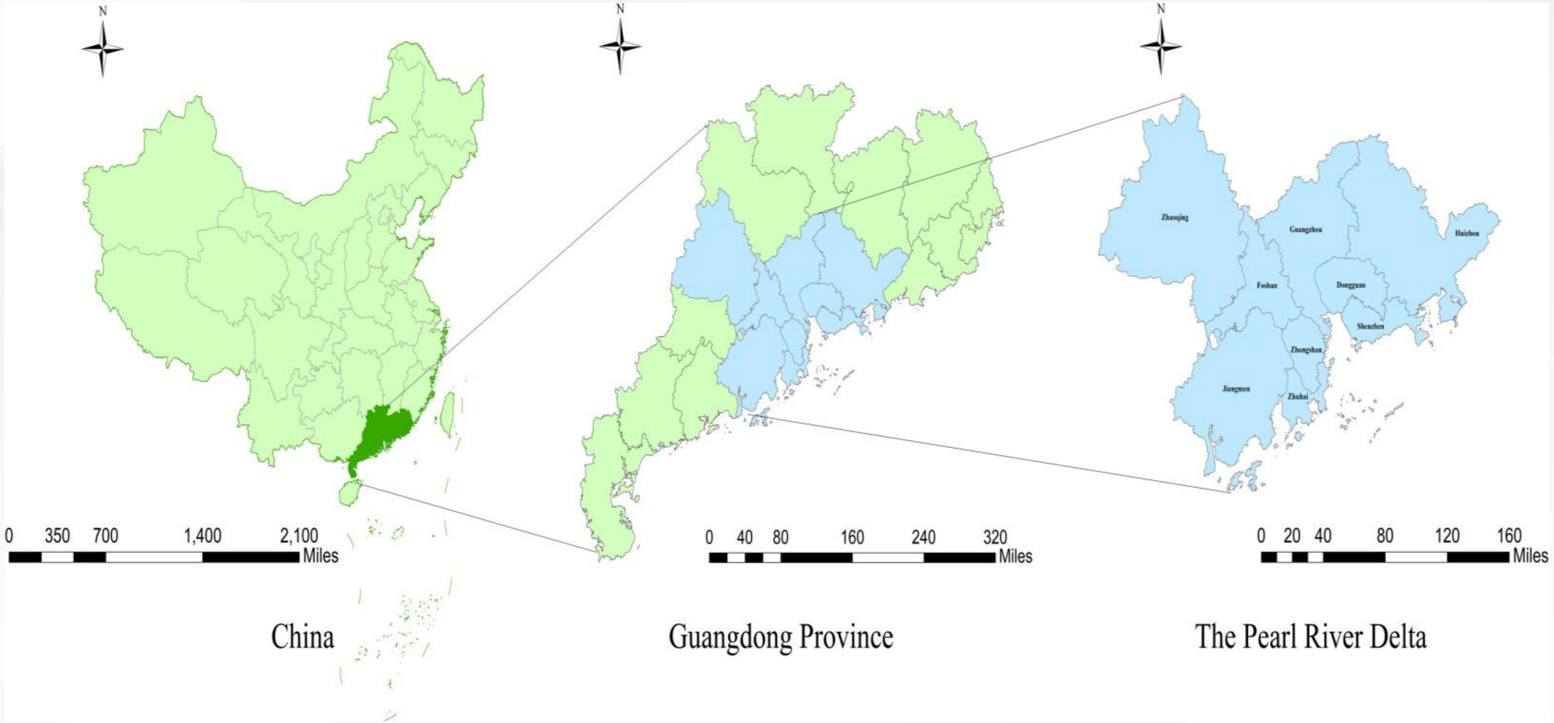
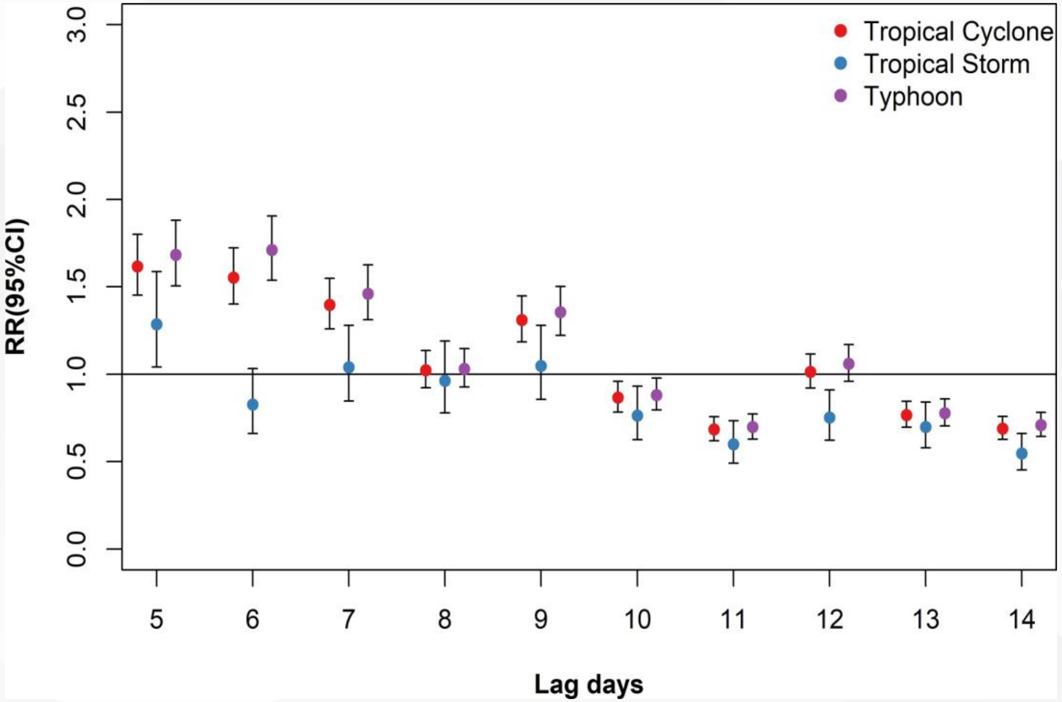


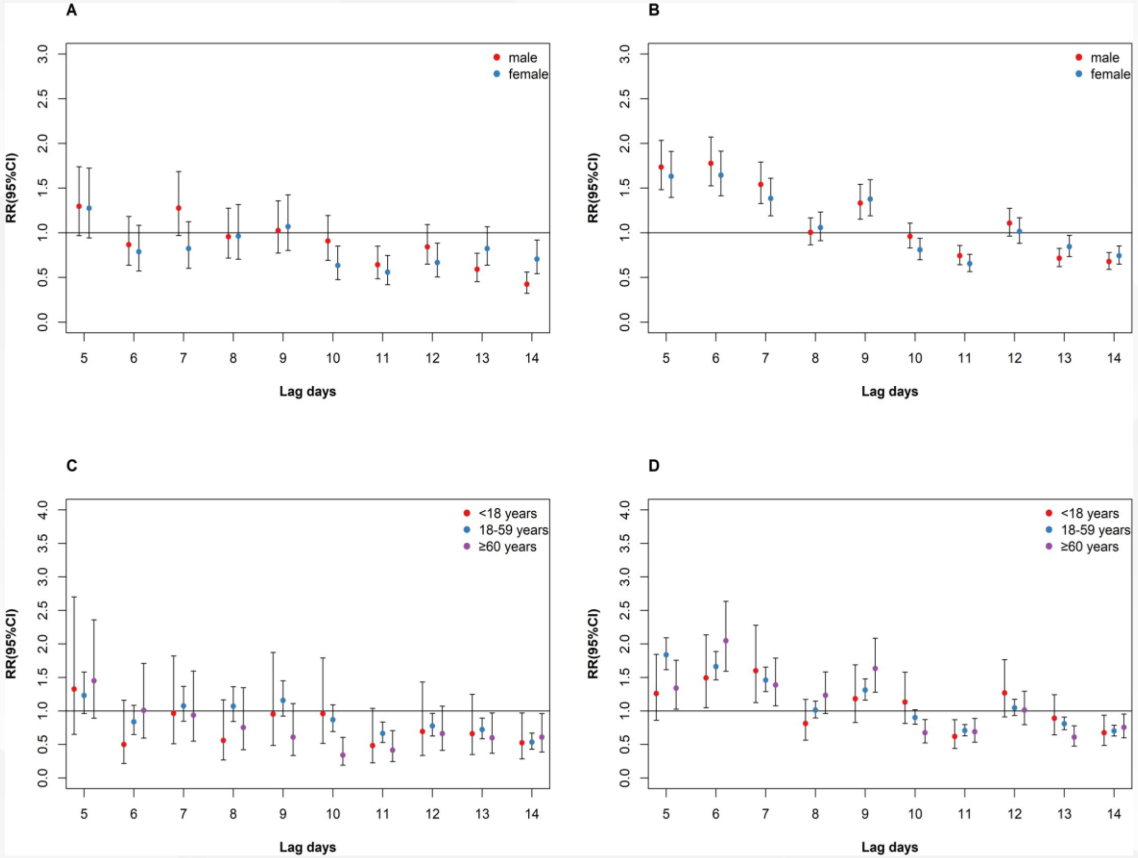
Figure. Location of the study area in China.

- **Research location: the Pearl River Delta, China (9 cities in total)**
- **Research period: 2015-2019 tropical cyclone season (June to October)**
- **Daily incidence data of dengue fever**

The association between tropical cyclones and dengue fever in the Pearl River Delta, China during 2013-2018: a time-stratified case-crossover study[J]. PLoS Negl Trop Dis, 2021, 15(9): e0009776.

The impact of tropical cyclones on dengue fever in the the Pearl River Delta: a time stratified case-control study





Tropical cyclones with a 5-9 day lag can increase the risk of dengue fever, with the greatest effect observed on the 5th day lag

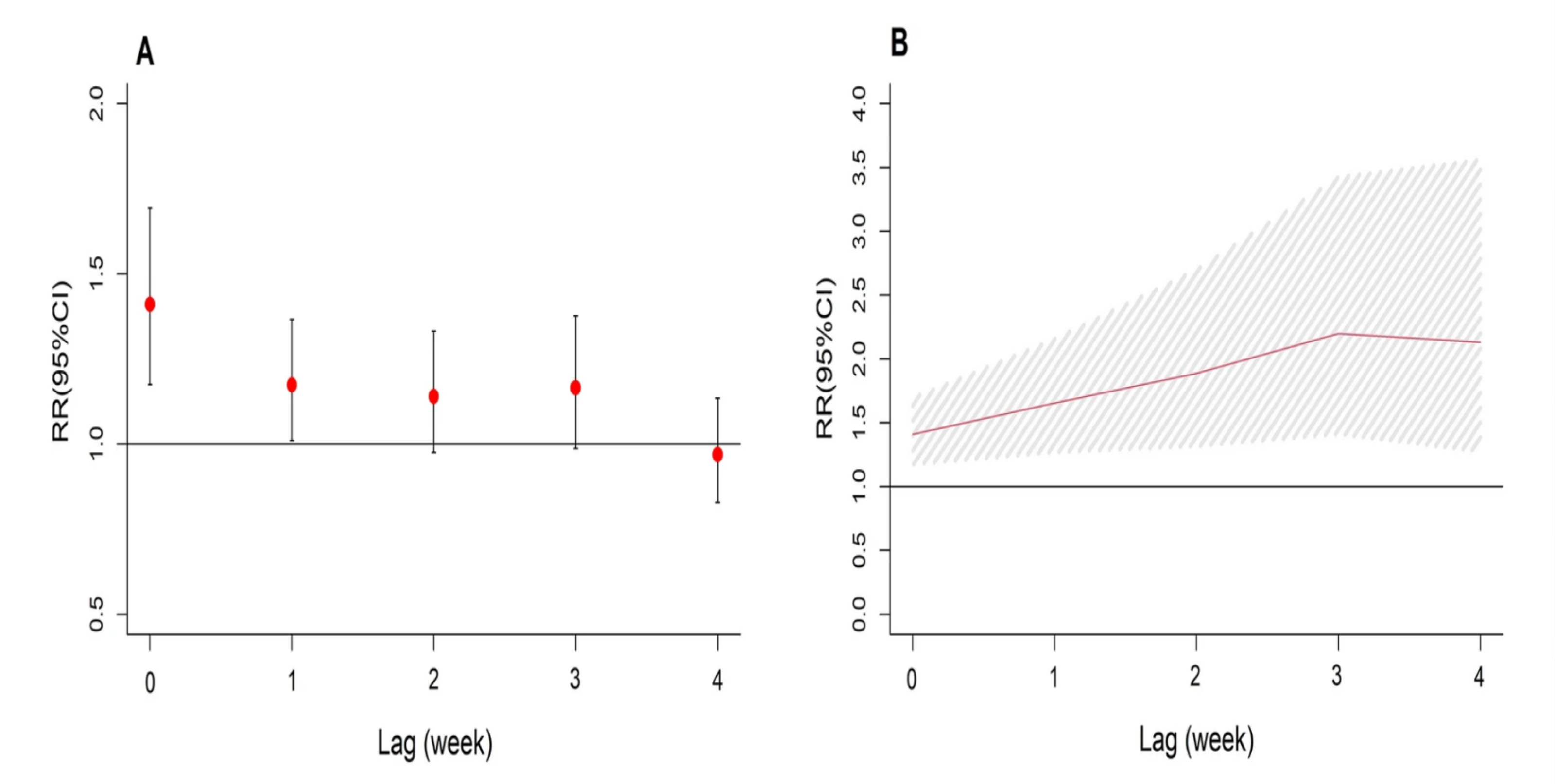
(RR=1.62, 95% CI: 1.45-1.80).

Typhoons have a greater impact and longer duration on the incidence of dengue fever than tropical storms.

The association between tropical cyclones and dengue fever in the Pearl River Delta, China during 2013-2018: a time-stratified case-crossover study[J]. PLoS Negl Trop Dis, 2021, 15(9): e0009776.

Short term impact of tropical cyclones on dengue fever incidence in Guangzhou - time series analysis

$$log[E(Yt)] = \alpha + cb(TCt,4, \beta) + ns(WAT, 3) + ns(WCP, 3) + ns(WARH, 3) + ns(time, 3) + ns(woy, 4)$$



- When the lag is 0 weeks, the risk of onset is highest (RR=1.41, 95CI%=1.17-1.69);
- The cumulative effect reached its maximum within 0-4 weeks (RR=2.13, 95% CI: 1.28-3.56).

Figure. Lag effects (A) and cumulative effects (B) of tropical cyclones on dengue cases in different lag periods

Short-term effects of tropical cyclones on the incidence of dengue: a time-series study in Guangzhou, China[J]. Parasit Vectors, 2022, 15(1): 358.

Short term impact of tropical cyclones on dengue fever incidence in Guangzhou - time series analysis

Table. RRs of tropical cyclones on dengue incidence among different subgroups during the study period in Guangzhou, China

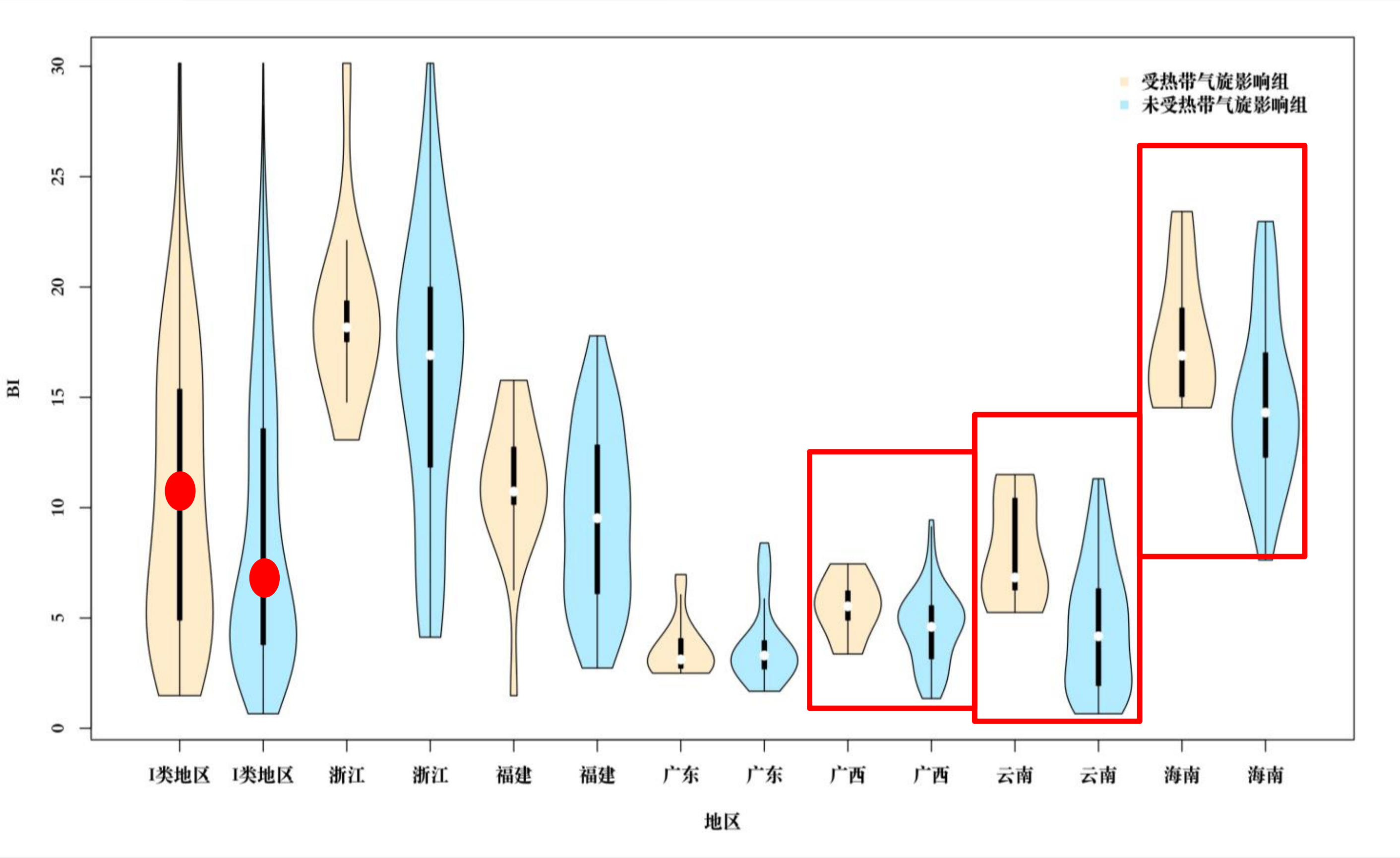
	lag0	lag1	lag2	lag3	lag4	lag0–4
Sex						
Male	**1.56(1.26,1.94)***	1.20(1.00,1.44)	**1.26(1.05,1.52)***	**1.28(1.05,1.55)***	1.04(0.86,1.25)	**3.14(1.71,5.77)***
Female	1.24(0.98,1.57)	1.15(0.95,1.38)	1.01(0.83,1.23)	1.05(0.84,1.29)	0.90(0.73,1.09)	1.34(0.70,2.58)
Age						
< 18 years	1.34(0.80,2.24)	1.28(0.81,2.02)	1.16(0.73,1.84)	1.34(0.82,2.19)	0.85(0.52,1.37)	2.25(0.54,9.41)
18–59 years	**1.40(1.13,1.74)***	1.05(0.87,1.27)	1.13(0.94,1.36)	1.15(0.95,1.39)	0.90(0.74,1.10)	1.73(0.97,3.07)
≥ 60 years	**1.67(1.14,2.44)***	1.42(1.00,2.01)	1.04(0.74,1.46)	**1.43(1.03,2.00)***	0.94(0.65,1.36)	**3.33(1.16,9.55)***

Men are the susceptible population, with the maximum effect occurring at a lag of 0 weeks (RR=1.56, 95% CI: 1.26-1.94).

The population aged 60 and above is susceptible, and the risk of dengue fever increases with a lag of 0 and 3 weeks.

Short-term effects of tropical cyclones on the incidence of dengue: a time-series study in Guangzhou, China[J]. Parasit Vectors, 2022, 15(1): 358.

The impact of tropical cyclones on the density of Aedes mosquitoes as vectors



The distribution of the Brett index in Class I areas and 6 provinces under and without the influence of tropical cyclones

The Breton index within half a month of being affected by a tropical cyclone is higher than when it is not affected by a tropical cyclone.

Guangxi, Yunnan, and Hainan experienced the most significant increase in the Bretu index within half a month of being affected by tropical cyclones.

Study on the Impact of Tropical Cyclones on Dengue Fever and Aedes Mosquito Density [D]. Shandong University, 2022

Limitations and Future Research Prospects

Limitations

- There is a lot of theoretical research, mostly from the perspective of big data, with fewer levels of models
- Evidence from the site and laboratory is still needed to support it

Prospects

- The construction of interdisciplinary coupling models can better fit the changing trends of socio-economic, ecological and physicochemical environment, health policies, etc. under the background of future climate change, as well as their impact on the trend of dengue fever epidemic
- More laboratory evidence and parameters to explore the relationship between dengue virus vector Aedes mosquitoes individual susceptibility

Related papers

1. Projecting future risk of dengue related to hydrometeorological conditions in mainland China under climate change scenarios: a modelling study. Lancet Planet Health. 2023 May; 7(5):e397-e406. doi: 10.1016/S2542-5196(23)00051-7. PMID: 37164516; PMCID: PMC10186180. First District of the Chinese Academy of Sciences, IF=28.75
2. The patterns and driving forces of dengue invasions in China. Infect Dis Poverty. 2023 Apr 21; 12 (1): 42. doi: 10.1186/s40249-023-01093-0. Chinese Academy of Sciences Zone 1, IF=10.485
3. Association Between Hydrological Conditions and Dengue Fever Incidence in Coastal Southeastern China From 2013 to 2019. JAMA Netw Open. 2023 Jan 3; 6 (1): e2249440. doi: 10.1001/jamanetworkopen.2022.49440. Chinese Academy of Sciences, Zone 1, IF=13.353
4. Short-term effects of tropical cyclones on the incidence of dengue: a time-series study in Guangzhou, China. Parasit Vectors. 2022 Oct 6; 15 (1): 358. doi: 10.1186/s13071-022-05486-2. Second District of the Chinese Academy of Sciences, IF=4.047
5. The impact of extreme precipitation events in Guangzhou on the incidence of dengue fever in different characteristic populations Journal of Shandong University (Medical Edition), 2021, 59 (12): 151-157
6. The impact of tropical cyclones on the density of Aedes albopictus and the incidence rate of dengue fever in Zhejiang Province from 2015 to 2020 Journal of Shandong University (Medical Edition), 2021, 59 (12): 143-150
7. The association between tropical cyclones and dengue fever in the Pearl River Delta, China during 2013-2018: A time-stratified case-crossover study. PLoS Negl Trop Dis. 2021 Sep 9; 15 (9): e0009776. doi: 10.1371/ournal.pntd.0009776. Second District of the Chinese Academy of...

acknowledgments

- Professor Liu Qiyong
- Professor Zhao Qi
- Dr. Wang Haitao
- Dr. Li Chuanxi
- Zhao Zhe (PhD student)
- Yan Yu (PhD student)

Thank You!