RESEARCH ARTICLE

Open Access

Epidemiological characteristics and temporal-spatial analysis of overseas imported dengue fever cases in outbreak provinces of China, 2005–2019

Xinchang Lun[1], Yiguan Wang[1], Chunchun Zhao[1], Haixia Wu[1], Caiying Zhu[2], Delong Ma[1,3], Mingfang Xu[1], Jun Wang[1], Qiyong Liu[1], Lei Xu[4] and Fengxia Meng[1*]

Abstract

Background: Overseas imported dengue fever is an important factor in local outbreaks of this disease in the mainland of China. To better prevent and control such local outbreaks, the epidemiological characteristics and temporal-spatial distribution of overseas imported dengue fever cases in provincial-level administrative divisions (PLADs) where dengue fever is outbreak in the mainland of China were explored.

Methods: Using the Chinese National Notifiable Infectious Disease Reporting Information System (CNNDS), we identified overseas imported dengue fever cases in dengue fever outbreak areas in the mainland of China from 2005 to 2019 to draw the epidemic curve and population characteristic distribution of overseas imported cases in each PLAD. Based on spatial autocorrelation analysis of ArcGIS 10.5 and temporal-spatial scanning analysis of SaTScan 9.5, we analyzed the temporal-spatial distribution of overseas imported dengue fever in dengue fever outbreak areas in the mainland of China.

Results: A total of 11,407 imported cases, mainly from Southeast Asia, were recorded from 2005 to 2019 in these 13 PLADs. Of which 62.1% were imported into Yunnan and Guangdong Provinces. Among the imported cases, there were more males than females, mainly from the 21–50 age group. The hot spots were concentrated in parts of Yunnan, Guangdong and Fujian Provinces. We found the cluster of infected areas were expanding northward.

Conclusions: Based on the analysis of overseas imported dengue cases in 13 PLADs of the mainland of China from 2005 to 2019, we obtained the epidemiological characteristics and spatial distribution of imported dengue cases. Border controls need to pay attention to key population sectors, such as 21–50 years old men and education of key populations on dengue prevention. There is a need to improve the awareness of the prevention and control of imported cases in border areas. At the same time, northern regions cannot relax their vigilance.

Keywords: Imported case, Dengue fever, China, Epidemiology, Temporal-spatial distribution
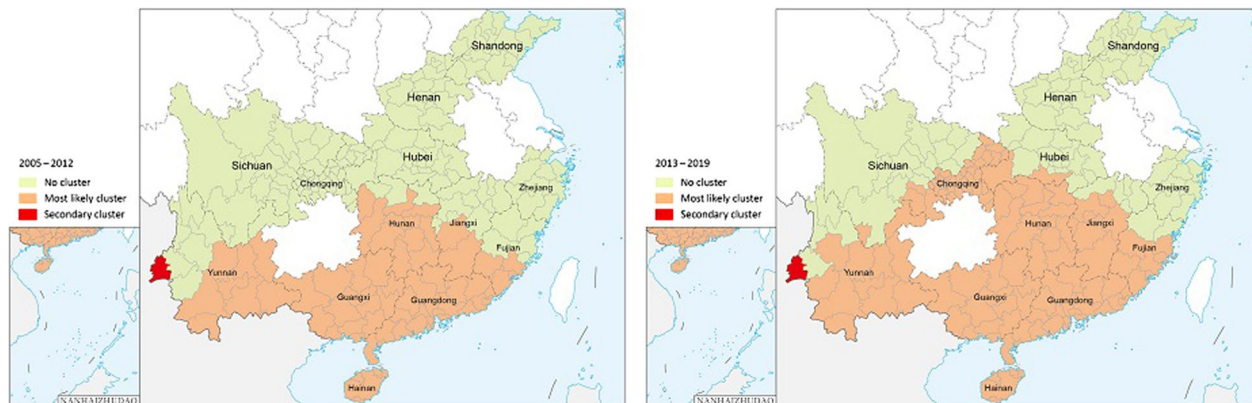
---

*Correspondence: mengfengxia@icdc.cn
[1] State Key Laboratory of Infectious Diseases Prevention and Control, National Institute for Communicable Disease Control and Prevention, Chinese Center for Disease Control and Prevention, Beijing 102206, People's Republic of China
Full list of author information is available at the end of the article

Graphical Abstract

Background

Dengue fever is a mosquito-borne disease that is caused by the dengue virus and vectored by *Aedes albopictus* and *Aedes aegypti* [1–3]. Dengue virus can be divided into four serotypes (DENV-1, DENV-2, DENV-3 and DENV-4) [4, 5]. As early as 1780, Benjamin Rush described a dengue fever epidemic in Philadelphia [6]. Before 1970, only nine countries recorded dengue epidemics [7]. However, the prevalence of dengue fever expanded dramatically to 128 countries by 2012 [8]. It was estimated that there were 390 million dengue infections worldwide in 2010 with 70% of cases in Asia [9]. The clinical manifestations of dengue fever are diverse, including fever, nausea, vomiting, skin rash and other symptoms. In severe cases, shock and death can occur [10, 11]. Dengue fever creates major economic and social burdens on affected countries and poses a great threat to public health [12].

The first outbreak of dengue fever in the mainland of China since 1949 occurred in Guangdong Province in 1978, and the province has had the most frequent outbreaks of dengue fever in the mainland of China [13–15]. In 2014, the number of dengue fever cases in Guangdong reached its peak with the number of reported cases exceeding 45,000 [16]. Furthermore, the geographic range of indigenous dengue fever in the mainland of China is gradually expanding northward [17]. As of 2019, there had been local outbreaks of dengue fever in 13 provincial-level administrative divisions (PLADs), and the northernmost line of the dengue fever outbreak had arrived in Jining city, Shandong Province in 2017 [18].

Imported cases of dengue is an important factor affecting local outbreaks of dengue fever in the mainland of China [19, 20]. As of 2019, overseas imported cases had been reported in all PLADs in the mainland of China except the Tibet Autonomous Region [21]. More importantly, the number of imported cases increased each year from 2005 to 2016. Most of the cases were imported from neighboring Asian countries [22]. These imported cases often lead to local outbreaks of dengue fever [23, 24]. However, few studies have focused on the epidemiological characteristics and temporal-spatial distribution of imported dengue fever cases in China.

Here we summarize the overseas imported dengue fever cases in 13 PLADs where there were local outbreaks of dengue fever from 2005 to 2019. We analyze the epidemiological characteristics and the temporal-spatial distribution of the cases in these PLADs. Based on the analysis we propose different prevention measures for geographical areas with different dengue outbreak characteristics. This study provides a basis for the reasonable allocation of medical resources and the effective prevention and control of dengue fever.

Materials and methods
Study area
As of 2019, there had been local outbreaks of dengue fever recorded in 13 PLADs in the mainland of China, namely, Hainan, Yunnan, Guangxi, Guangdong, Fujian, Hunan, Jiangxi, Sichuan, Zhejiang, Hubei, Henan and Shandong, and Chongqing City (see Additional file 1).

Data sources
Cases data
The dengue case data we used in this study were retrieved from the Chinese National Notifiable Infectious Disease Reporting Information System (CNNDS). We selected clinically diagnosed and confirmed cases of dengue fever from 1 January 2005 to 13 December 2019 based on the date of onset of disease symptoms. We used the 13 PLADs with local outbreaks of dengue fever as research sites to explore the population epidemic characteristics of overseas imported dengue cases, at the same time,

Lun *et al. Infectious Diseases of Poverty*   (2022) 11:12

Page 3 of 17

the temporal-spatial distribution of overseas imported cases was discussed at the municipal level. The sources of dengue fever cases were distinguished as indigenous dengue cases, overseas imported dengue cases, domestic imported dengue cases and cases of unknown origin. Indigenous dengue cases are cases that had not left the local city where they lived 14 days before the onset of illness. Overseas imported dengue cases are defined as those that had been to a dengue-endemic country or region within 14 days before the onset. Domestic imported dengue cases are cases that had left their current city of residence and went to another city in the country within 14 days before the onset of the disease, and cases of unknown origin are cases whose origin cannot be identified. In this study, we used overseas imported dengue cases as the research content. Overseas imported cases included both Chinese and foreign nationalities.

Geographical coordinate data
We imported the vector maps of 13 PLADs into ArcGIS 10.5 (ESRI, Redlands, CA, USA) and obtained their latitude and longitude coordinates by transforming the x and y planar coordinates of each city. These data are used for temporal-spatial scanning analysis.

Demographic data
From the statistical yearbooks, we obtained the annual permanent population data or household registration population data of each city from 2005 to 2019. These data are used for temporal-spatial scanning analysis.

Statistical analysis
WPS Office 2021 software (Kingsoft, Beijing, China) was used to sort the epidemiological characteristics of overseas imported dengue cases, including import source country or region, import region distribution, time characteristics and demographic distribution characteristics such as gender distribution, age distribution, and occupation distribution, in 13 PLADs from 2005 to 2019.

ArcGIS 10.5 software was used to perform spatial autocorrelation analysis of the overseas imported dengue cases. Spatial autocorrelation analysis [25], which includes global autocorrelation and local autocorrelation, can be used to analyze the spatial correlation of a variable. In this study, we used global Moran's I [26, 27] and Getis-Ord General G analysis [28, 29] to estimate the global autocorrelation. The value range of Moran's I index is between −1 and 1. When Moran's I index is closer to 1, the positive spatial correlation is stronger, that is, there is a spatial aggregation relationship between regions; when Moran's I index is closer to −1, the negative spatial correlation is stronger,

which means that the attributes between the regions are opposite; and when Moran's I index is closer to 0, it means that the spatial distribution of the variables in the research area follows a random distribution pattern. However, the index cannot determine the specific aggregation mode. The Getis-Ord General G index can indicate the degree and quantity of high and low values and is used to analyze the correlation of a variable between adjacent areas. The null hypothesis indicates that there is no space clustering for the research variable in the adjacent study area. When the calculated P value is statistically significant, we can judge it by observing the Getis-Ord general G value and Z score. When the Getis-Ord general G value is higher than the expected value and the Z score is positive, it indicates that the high value is clustered, that is, there is a hot spot; and when the Getis-Ord general G value is lower than the expected value and the Z score is negative, it indicates that the low values have a tendency to gather, that is, there is a cold spot.

Global Moran's I and Getis-Ord General G analysis can use the spatial statistics tools module in the ArcGIS software. The above two analyses are in the analyzing patterns of the spatial statistics tools module.

The local autocorrelation was analyzed using the Anselin local Moran's I [30, 31] and Getis-Ord Gi* [32]. The Anselin local Moran's I index, as a local index of spatial correlation, represents the spatial correlation between a research area and its neighboring areas for the research variables, including low-low, low-high, high-low, and high-high, and not significant. The low-low and high-high types indicate spatial aggregation, that is, cold spots and hot spots, respectively. These suggest that an area with a small number of imported cases of dengue fever is surrounded by a neighboring area with a small number of imported cases and an area with a large number of imported cases of dengue fever is surrounded by a neighboring area with a large number of imported cases, respectively. The low-high and high-low types indicate spatial outliers, which respectively indicate that an area with a small number of imported cases of dengue fever is surrounded by adjacent areas with a large number of imported cases and an area with a large number of imported cases of dengue fever is surrounded by an adjacent area with a small number of imported cases. Through Getis-Ord Gi* analysis, the specific spatial clustering positions of high and low values can be observed, and the specific distribution of cold spots and hot spots can be identified.

The Anselin Local Moran's I and Getis-Ord Gi* can use the spatial statistics tools module in the ArcGIS software. The above two analyses are in the mapping clusters of the spatial statistics tools module.

Lun *et al. Infectious Diseases of Poverty*   (2022) 11:12

Page 4 of 17

We used the SaTScan 9.5 software (Martin Kulldorff, Boston, MA, USA) to perform the temporal-spatial scanning analysis of overseas imported cases. The SaTScan 9.5 software detects the accumulation of a certain disease in time and space by scanning the studied areas using a cylindrical scan window. The log-likelihood ratio (*LLR*) can be used to identify the locations of the most likely clusters and secondary clusters and other clustering regions. Under Poisson's assumption, the log-likelihood ratio of the scanning window is:

$$LLR = (\frac{c}{E[c]})^c (\frac{C-c}{C-E[c]})^{(C-c)} I()$$

where C represents the total number of cases, c represents the number of observed cases in the window, and E(c) represents the expected number of cases adjusted by covariates in the window under the condition of the null hypothesis. Here, the null hypothesis is that for window scanning, the aggregation trend inside the window is the same as that outside of the window. C−E[c] represents the expected number of cases outside the window, and I() represents the indicator function. The *LLR* is related to the scan rate of the cluster. When the cluster is scanned only at a high rate and the number of cases in the window is higher than the expected number of cases under the null hypothesis, I()=1; otherwise, I()=0.

The Poisson model was used to analyze the spatial aggregation area. The circular window is selected as the scanning window, and the largest scanning area is 50% of the total population. The *P* value was determined by the combination of the Standard Monte Carlo method, Sequential Monte Carlo method and Gumbel Approximation. The test level α=0.05, and the number of Monte Carlo iterations was set to 999. The temporal-spatial scanning analysis was visualized using the ArcGIS 10.5 software.

Results

Overview of overseas imported dengue fever cases in the 13 PLADs

Sources of the imported cases

From 2005 to 2019, a total of 11,407 imported cases of dengue fever were reported in the 13 PLADs in China. Among these cases, 11,105 were imported from the Asian region, accounting for 97.3%. Specifically, the cases from Southeast Asia accounted for 91.9%. In addition, Africa, Oceania, South America and North America were sources of imported cases, accounting for 1.6%, 0.5%, 0.3% and 0.1%, respectively. The sources of the remaining 0.2% of imported cases were unknown.

Among the overseas imported cases in each PLAD, the proportions of Chinese and foreign nationals are slightly different. Foreign cases in Yunnan Province were the highest, accounting for 44.0%; but accounted for less than 10% in the other PLADs (Table 1).

Distribution and epidemic trend of imported cases

All the municipalities in the 13 studied PLADs, with a few exceptions for the northwestern part of Yunnan Province, the northwestern part of Sichuan Province, the Shennongjia forest region of Hubei Province and Rizhao city of Shandong Province and a few areas in Chongqing, had imported dengue fever cases from 2005 to 2019 (Fig. 1). The municipal area in western Yunnan Province bordering Myanmar had the largest number of overseas imported cases, reaching 2,485 cases, accounting for 21.8% of the total overseas imported cases in all 13 PLADs. In general, overseas

Table 1 Proportion of Chinese nationality and foreign nationality cases among overseas imported cases, 2005–2019

PLAD	Chinese nationality	Proportion (%)	Foreign nationality	Proportion (%)	Total
Yunnan	2,608	56.0	2,052	44.0	4,660
Guangdong	2,235	92.3	187	7.7	2,422
Fujian	1,018	92.2	86	7.8	1,104
Zhejiang	941	94.9	51	5.1	992
Sichuan	434	96.9	14	3.1	448
Hunan	434	98.6	6	1.4	440
Henan	261	100.0	0	0.0	261
Hubei	252	99.6	1	0.4	253
Chongqing	240	100.0	0	0.0	240
Jiangxi	200	99.5	1	0.5	201
Shandong	147	94.2	9	5.8	156
Guangxi	139	93.9	9	6.1	148
Hainan	74	90.2	8	9.8	82

PLAD provincial-level administrative division.

Lun *et al. Infectious Diseases of Poverty*   (2022) 11:12

Page 5 of 17
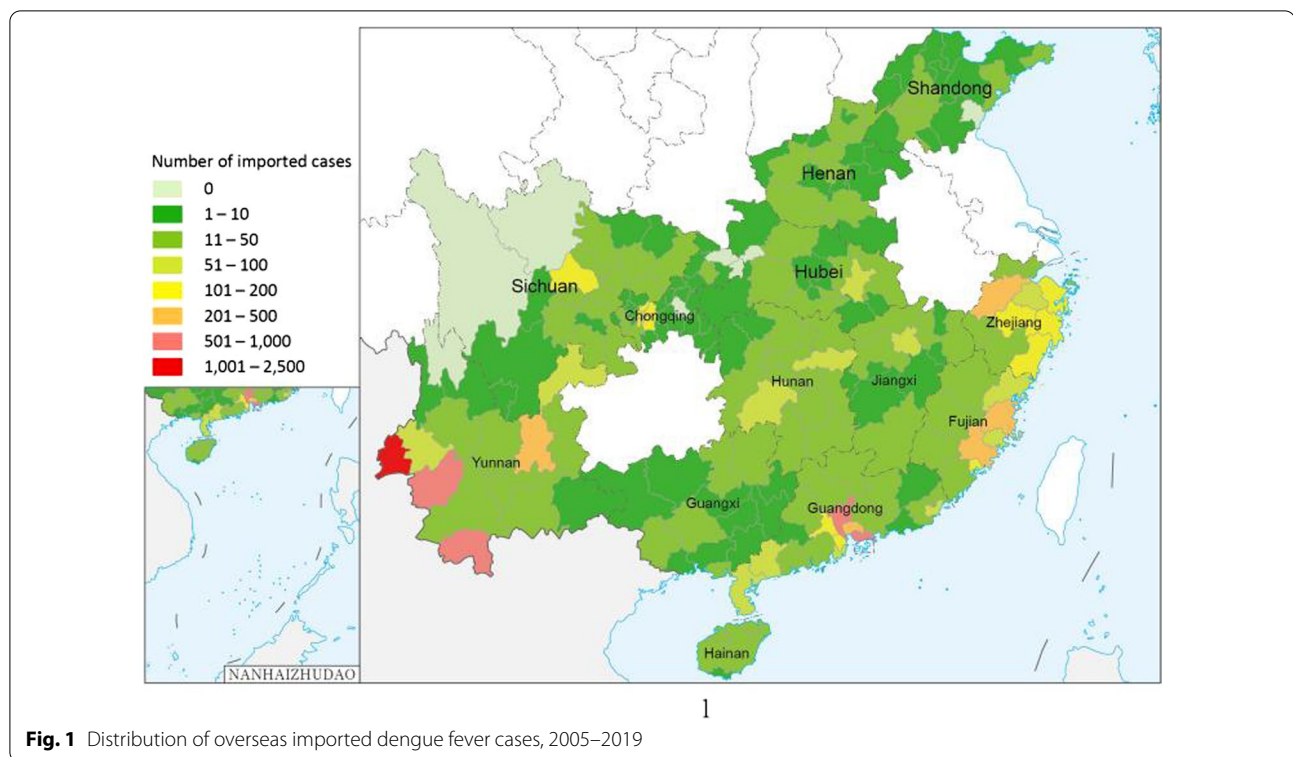
Fig. 1 Distribution of overseas imported dengue fever cases, 2005–2019

imported cases are more likely to be observed in the border areas of Yunnan Province, the southeast coastal areas and the capital areas with developed economies and convenient transportation (Fig. 1).

Overseas imported dengue fever cases in most of the provinces began to increase from 2013 and accounted for 94.9% of the total cases (Table 2 and Fig. 2), so here we focus on the prevalence of imported dengue fever cases from 2013 to 2019. During this period, Yunnan Province and Guangdong Province reported a large proportion of imported cases, accounting for 62.2% of the total. The prevalence curve of these cases from 2013 to 2019, in provinces with more imported cases, showed a clear seasonal trend with most from July to November (Fig. 2).

Population distribution characteristics of overseas imported dengue fever cases in the 13 PLADs
Gender characteristics
The number of males imported cases was higher than females from 2005 to 2019, with a male-to-female ratio of 2.0:1 (Fig. 3). The ratios in Yunnan Province and Hainan Province were relatively low, which were below the overall male-to-female ratio in the 13 PLADs, at 1.3:1 and 1.8:1, respectively. The highest ratio was observed in Shandong Province, at approximately 6:1.

Age characteristics
The age distribution of the imported dengue fever cases in the 13 PLADs exhibited similar patterns (Fig. 4). The young and middle-aged people aged 21–50 accounted for a large proportion (76.6%) of the imported cases. In Yunnan, Fujian, Henan, Chongqing, Guangxi and Hainan, the numbers of imported cases were the largest in the 21–30 age group and the second-largest imported cases in the 31–40 age group. In Jiangxi Province, there were the same number of people in these two age groups, and both were the most. The imported cases in other PLADs were more concentrated in the 31–40-year-old age group, followed by the 21–30-year-old age group.

Occupational characteristics
Farmers, business services, housework or unemployed, workers, students and public officials accounted for 87.7% of the total number of overseas imported cases. Those above occupations showed slightly different proportions in different provinces. Farmers accounted for the highest proportion of imported cases in Yunnan, Sichuan, Hunan, Henan, Hubei, Chongqing, Jiangxi, Shandong and Guangxi. In contrast, the proportion of commercial services was highest in Guangdong, Zhejiang and Hainan. Different from other PLADs, the occupation

Lun *et al. Infectious Diseases of Poverty*   (2022) 11:12

Page 6 of 17

Table 2 The proportion of overseas imported dengue fever cases for each PLAD overall (2005–2019) and broken into two periods, 2005–2012 and 2013–2019

PLAD	2005–2012		2013–2019		2005–2019	
	No. of overseas imported dengue fever cases	Proportion (%)	No. of overseas imported dengue fever cases	Proportion (%)	No. of overseas imported dengue fever cases	Proportion (%)
Yunnan	177	30.5	4,483	41.4	4,660	40.9
Guangdong	173	29.8	2,249	20.8	2,422	21.2
Fujian	95	16.4	1,009	9.3	1,104	9.7
Zhejiang	40	6.9	952	8.8	992	8.7
Sichuan	15	2.6	433	4.0	448	3.9
Hunan	28	4.8	412	3.8	440	3.9
Henan	4	0.7	257	2.4	261	2.3
Hubei	13	2.2	240	2.2	253	2.2
Chongqing	4	0.7	236	2.2	240	2.1
Jiangxi	9	1.5	192	1.8	201	1.8
Shandong	7	1.2	149	1.4	156	1.3
Guangxi	10	1.7	138	1.2	148	1.3
Hainan	6	1.0	76	0.7	82	0.7
Total	581	100.0	10,826	100.0	11,407	100.0
	5.1%		94.9%		100.0%	

PLAD provincial-level administrative division.

with the highest proportion of overseas imported cases in Fujian was housework and unemployed (Fig. 5) (Additional file 2).

Temporal-spatial distribution characteristics of overseas imported dengue fever cases in the 13 PLADs
Global autocorrelation statistics
The global Moran's *I* index as 0.11 and the *Z* score as 3.6 ($P < 0.01$) for all imported cases from 2005 to 2012. The results suggested that in the 13 PLADs with local outbreaks of dengue fever, the numbers of imported cases from abroad were clustered in the spatial distribution at the municipal level. The Getis-Ord General G value was estimated as 0.000001, and the *Z* score was estimated as 2.5 ($P < 0.05$), suggesting a tendency for high clusters of overseas imported dengue fever cases from 2005 to 2012. That is, municipal areas with more overseas imported cases and more overseas imported cases were aggregated in the spatial distribution.

From 2013 to 2019, the global Moran's *I* index was 0.08, and the *Z* score was 3.6 ($P < 0.01$). The results showed that in the 13 PLADs with local outbreaks of dengue fever, the numbers of imported cases from abroad were clustered in the spatial distribution at the municipal level. The Getis-Ord General G value was 0.000001, and the *Z* score was 1.8 ($P < 0.1$), suggesting a tendency for high clusters
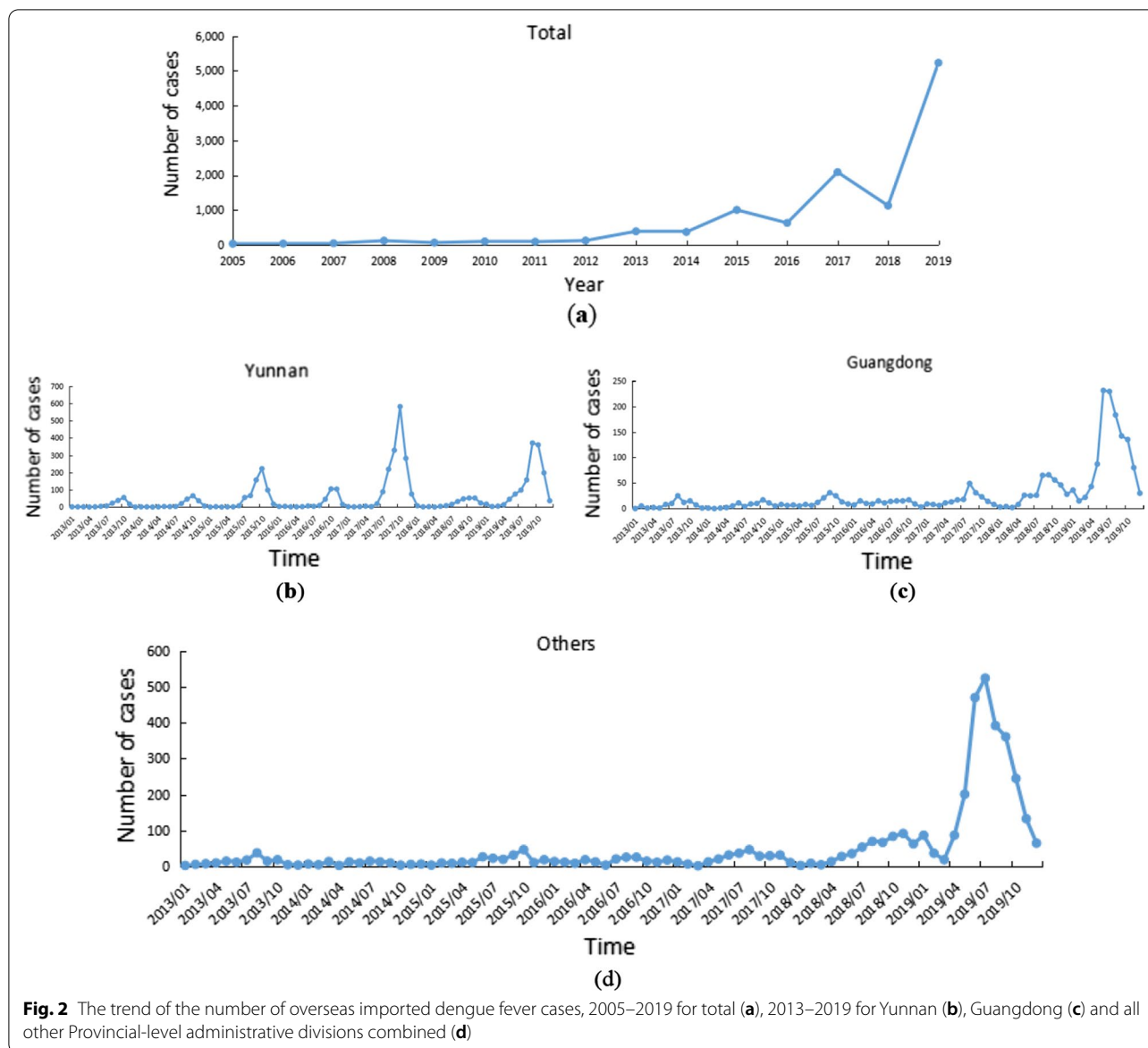
of dengue fever cases imported from 2013 to 2019. That is, municipal areas with more overseas imported cases and more overseas imported cases were aggregated in the spatial distribution.

Local autocorrelation analysis
The Anselin local Moran's *I* analysis of the imported cases from 2005 to 2012 revealed high-high clusters at the border area of Yunnan, southeastern Guangdong, and two coastal areas in Fujian. In contrast, low-low clusters were detected in most areas of Henan and Shandong and in one area or two areas in Guangxi, Jiangxi, Sichuan, and Hubei, respectively. Sichuan and Shandong had one region each that was a high-low cluster. Two border areas in Yunnan and the other 6 cities in the northern part of Guangdong were identified as low-high clusters (Fig. 6a).

From 2013 to 2019, the number of PLADs with local spatial autocorrelation areas decreased. Four border areas in Yunnan and a region in southeastern Guangdong were high-high clusters. The central part of Guangxi, the central part of Hubei, Henan and Shandong were mostly low-low clusters. The capital of Hubei was a high-low cluster. Two border areas in Yunnan and a city in eastern Guangdong were low-high clusters (Fig. 6.b).

Getis-Ord Gi* analysis showed that the imported cases from 2005 to 2012 had formed hot spots in some areas in Yunnan, Guangdong, and Fujian, including the border areas of Yunnan, most parts of Guangdong and the

Lun *et al. Infectious Diseases of Poverty*   (2022) 11:12

Page 7 of 17

Fig. 2 The trend of the number of overseas imported dengue fever cases, 2005–2019 for total (**a**), 2013–2019 for Yunnan (**b**), Guangdong (**c**) and all other Provincial-level administrative divisions combined (**d**)

coastal areas of Fujian (Fig. 6c). However, hot spots of the imported cases during 2013–2019 were only identified in Yunnan (Fig. 6d).
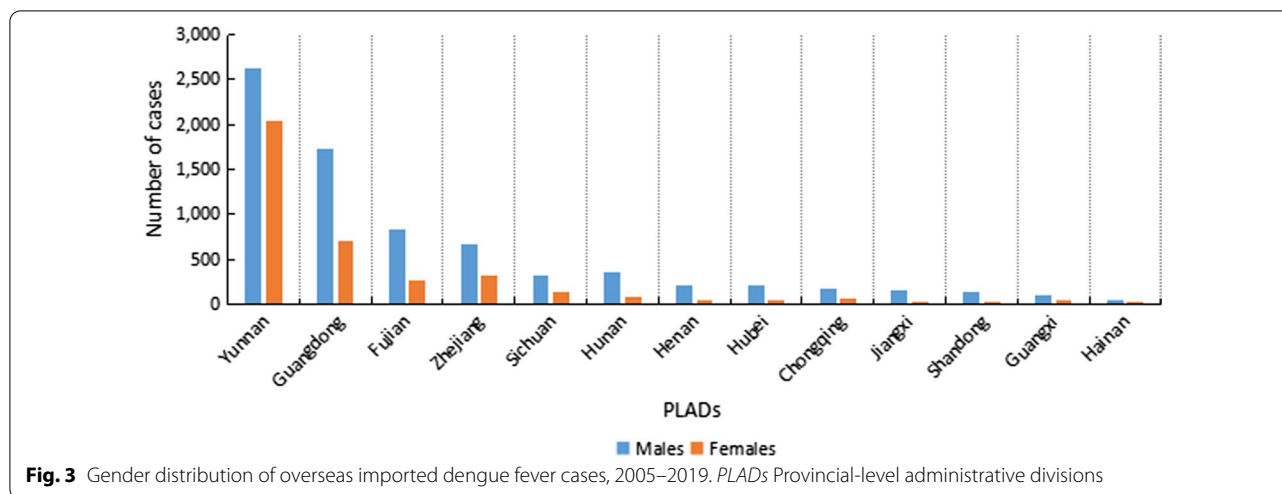
Temporal-spatial distribution characteristics of overseas dengue fever cases

Using SaTScan 9.5, we used the maximum spatial cluster size of 50% of the at-risk population to scan the clustering areas in the two time periods of 2005–2012 and 2013–2019. The results showed that the Dehong Dai and Jingpo Autonomous Prefectures in Yunnan were the most likely clusters for both time periods (*P* < 0.01). The regional scope of the secondary cluster was significantly larger from 2013 to 2019. During 2005–2012, secondary

clusters were identified in Hainan, eastern Yunnan, Guangxi, Guangdong, central and southern Hunan, southern Jiangxi, and southern Fujian (*P* < 0.01). During 2013–2019, the secondary cluster expanded westward and northward, reaching the areas around Chongqing (*P* < 0.01) (Fig. 7, Table 3).

Discussion

Dengue fever in the mainland of China is an imported vector-borne disease and has not yet formed epidemics [33], So, imported cases is an important factor affecting local outbreaks of dengue fever in the mainland of China. A better understanding of the epidemiological characteristics and temporal-spatial distribution of imported cases

Lun *et al. Infectious Diseases of Poverty*   (2022) 11:12

Page 8 of 17

Fig. 3 Gender distribution of overseas imported dengue fever cases, 2005–2019. *PLADs* Provincial-level administrative divisions

will be of great significance for the prevention and control of dengue fever, and provide a theoretical basis for the rational allocation of medical resources. In this study, we analyzed over eleven thousand overseas imported dengue fever cases in 13 PLADs in China from 2005 to 2019, including the locations of these cases, the onset dates, the gender and age distributions and the occupations. We also investigated the geographic autocorrelation of these cases and identified the hot spots and spatial clusters.

Most overseas imported cases were located in the border areas of Yunnan; the coastal areas of Zhejiang, Fujian, and Guangdong; provincial capitals of Chongqing city and some other provinces. The reasons for these locations being mostly affected by import cases may vary considerably. Yunnan which lies in southwestern China, is one of the provinces with the longest border. It shares a border that is approximately 4,060 km with Myanmar, Laos, and Vietnam. It is also a key region connecting Southeast Asia and South Asia. Given the prevalence of dengue fever in Southeast Asia and South Asia [34, 35] and the frequent cross-border migrants, this region has been a high-risk area for imported dengue fever. In contrast, the coastal areas of Zhejiang, Fujian, and Guangdong and the provincial capitals of Chongqing city and some other provinces, despite the absence of borders with neighboring countries, have relatively developed economies and high trade activities with large population flows. These factors increase the likelihood of importing cases of dengue fever cases. Studies [36, 37] have shown that a series of infectious diseases, such as dengue fever, have been imported into China amid the rapid development of globalization, the increase of migrants caused by tourism, and the exchange of a large number of laborers and products. The number of imported dengue fever

cases in China was closely related to the number of tourists from Southeast Asia and the number of overseas workers [37].
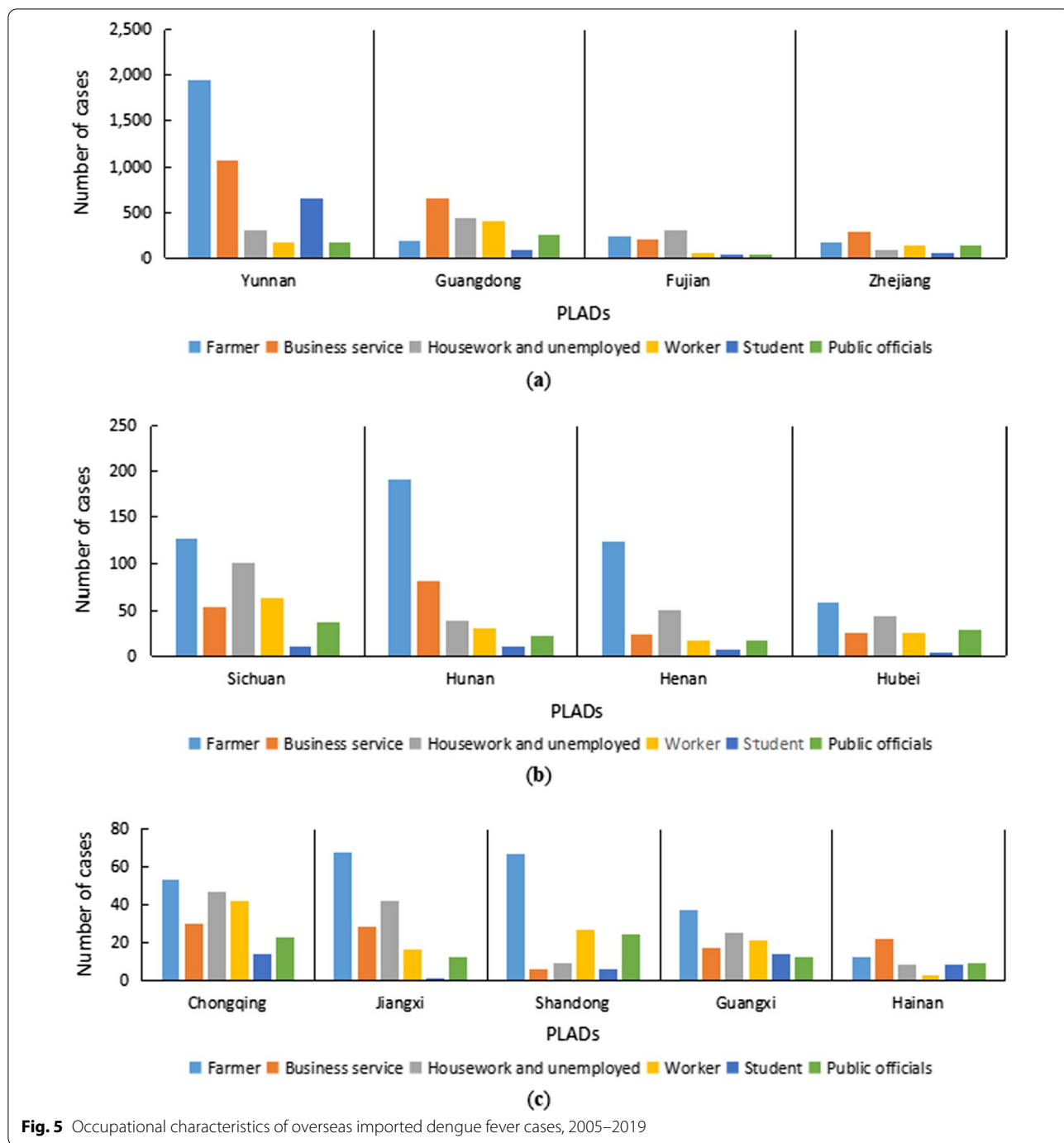
In a province such as Yunnan that has a long border with neighboring countries, cases imported via ground transportation may account for a large proportion of the total cases. Ground transportation includes road transportation by foot, car, bus, truck, etc., and by railway. For trade and family visits among border residents, frequent exchanges make it difficult to control. In contrast, in coastal provinces such as Guangdong without terrestrial international borders, more cases may be imported by air. Air transportation provides a better grasp of the passengers' departure location, destination and other information; and keep the conditions of passenger flow, time and space relatively fixed. Given these differences, prevention strategies should also be different. For the former case, attention should be given to the prevalence of dengue fever in China's neighboring countries; strengthening the publicity and education of border residents on dengue fever-related knowledge, including dengue fever prevention, symptoms, timely medical treatment and other related knowledge; and strengthening the management of border residents' mobility. For the latter case, we should pay close attention to countries with large amounts of air transportation with China, monitor the temperatures of passengers, place brochures on dengue fever prevention and control knowledge in airport waiting rooms, and publicize and educate passengers who go to dengue epidemic areas and return from dengue epidemic areas.

In the 13 PLADs studied the number of overseas imported dengue fever cases reached a peak in 2019, which may be closely related to the intensity of the dengue fever epidemic in neighboring countries. According to WHO statistics, the year with the highest number

Fig. 4 Age characteristics of overseas imported dengue fever cases, 2005–2019

Lun *et al. Infectious Diseases of Poverty*   (2022) 11:12

Page 10 of 17
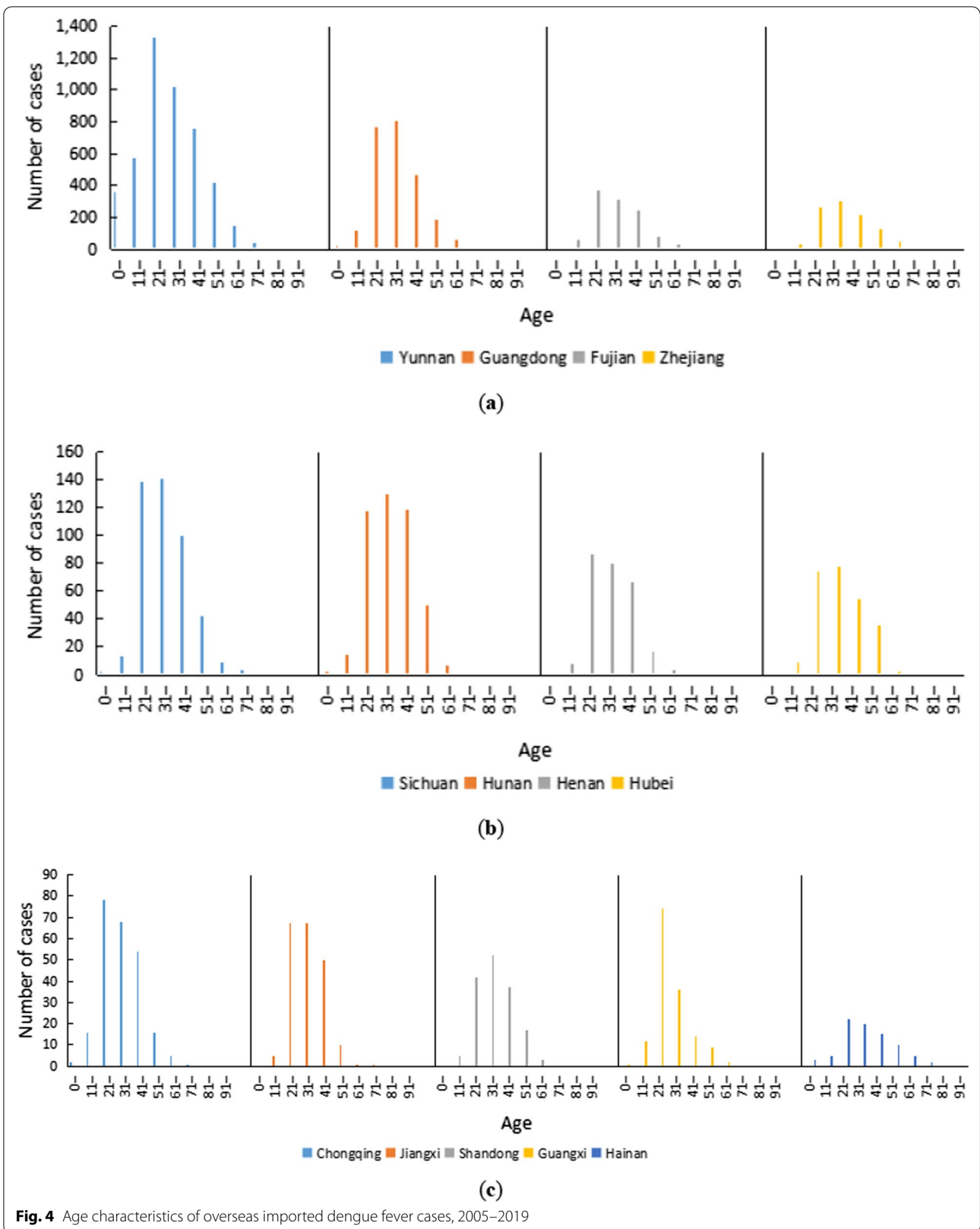
**Fig. 5** Occupational characteristics of overseas imported dengue fever cases, 2005–2019

of reported dengue fever cases in the world was 2019. All WHO regions were affected [7]. This year was also the year with the largest number of overseas imported cases in these 13 PLADs. Among the areas affected by dengue fever, the dengue fever epidemic in Southeast Asia, which is the largest source of imported cases, is very serious. For example, Myanmar is a country with a high burden of dengue fever in the Asia-Pacific region. During 2011–2015, there were 89,832 dengue-related admissions. In 2017 and 2018, there were 31,288 and 23,273 dengue fever patients, respectively [38]. A large number of cases were imported from Cambodia [39]. This may be related to the fact that after Chinese businessmen establish new factories in Cambodia, they summoned a large number of multinational migrant
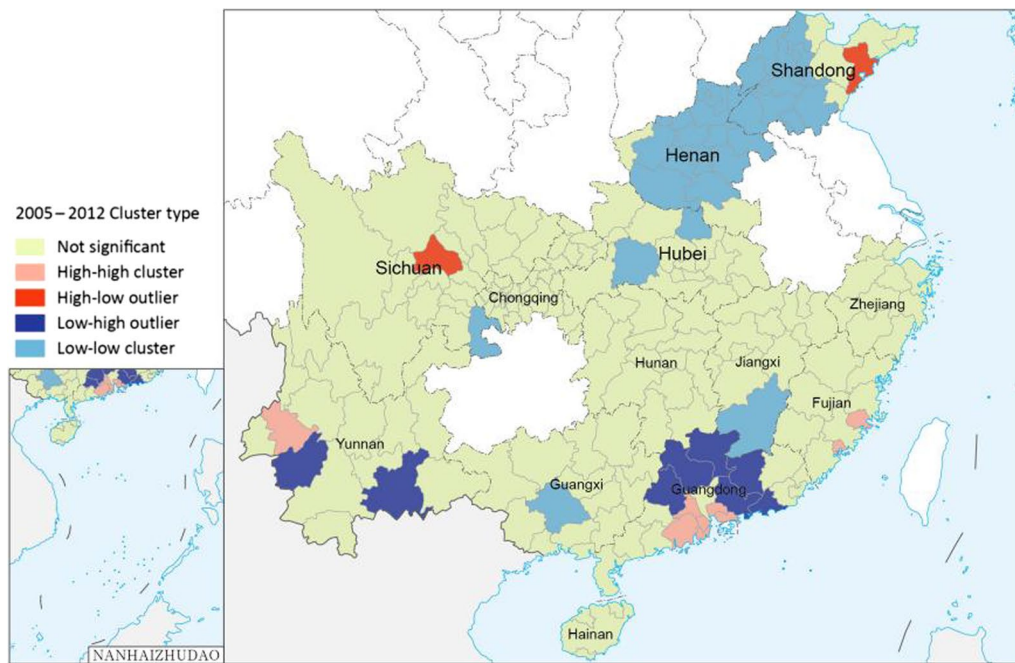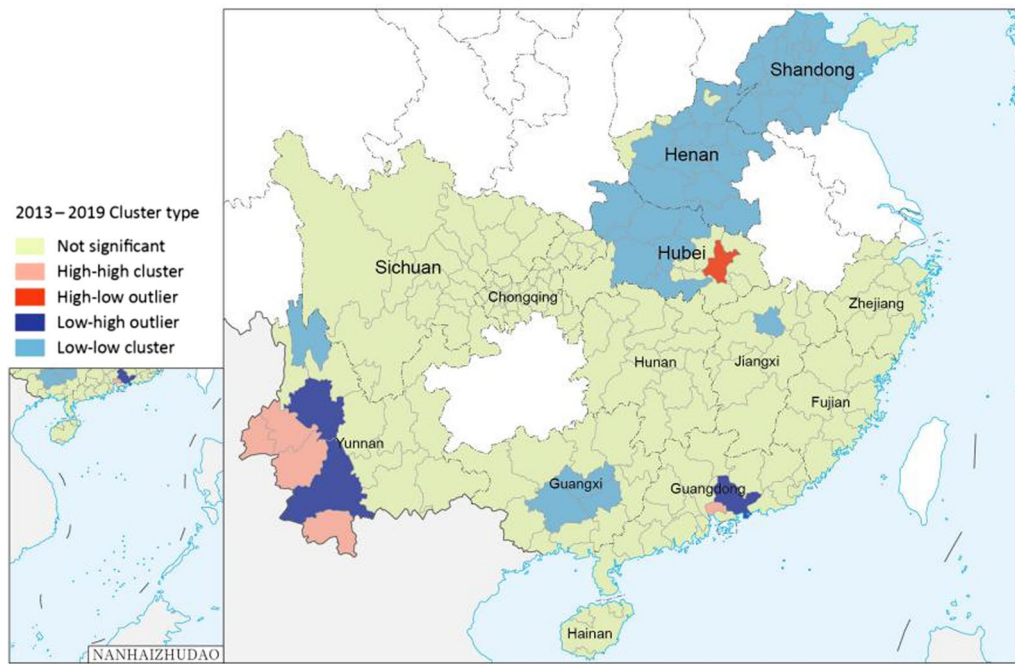
Fig. 6 Local spatial autocorrelation of overseas imported dengue fever cases, 2005–2019. (**a** is the result of the Anselin local Moran's *I* analysis in 2005–2012, **b** is the result of the Anselin local Moran's I analysis in 2013–2019, **c** is the result of the Getis-Ord Gi* analysis in 2005–2012, and **d** is the result of the Getis-Ord Gi* analysis in 2013–2019.)

Lun *et al. Infectious Diseases of Poverty*   (2022) 11:12

Page 12 of 17

Fig. 6 continued
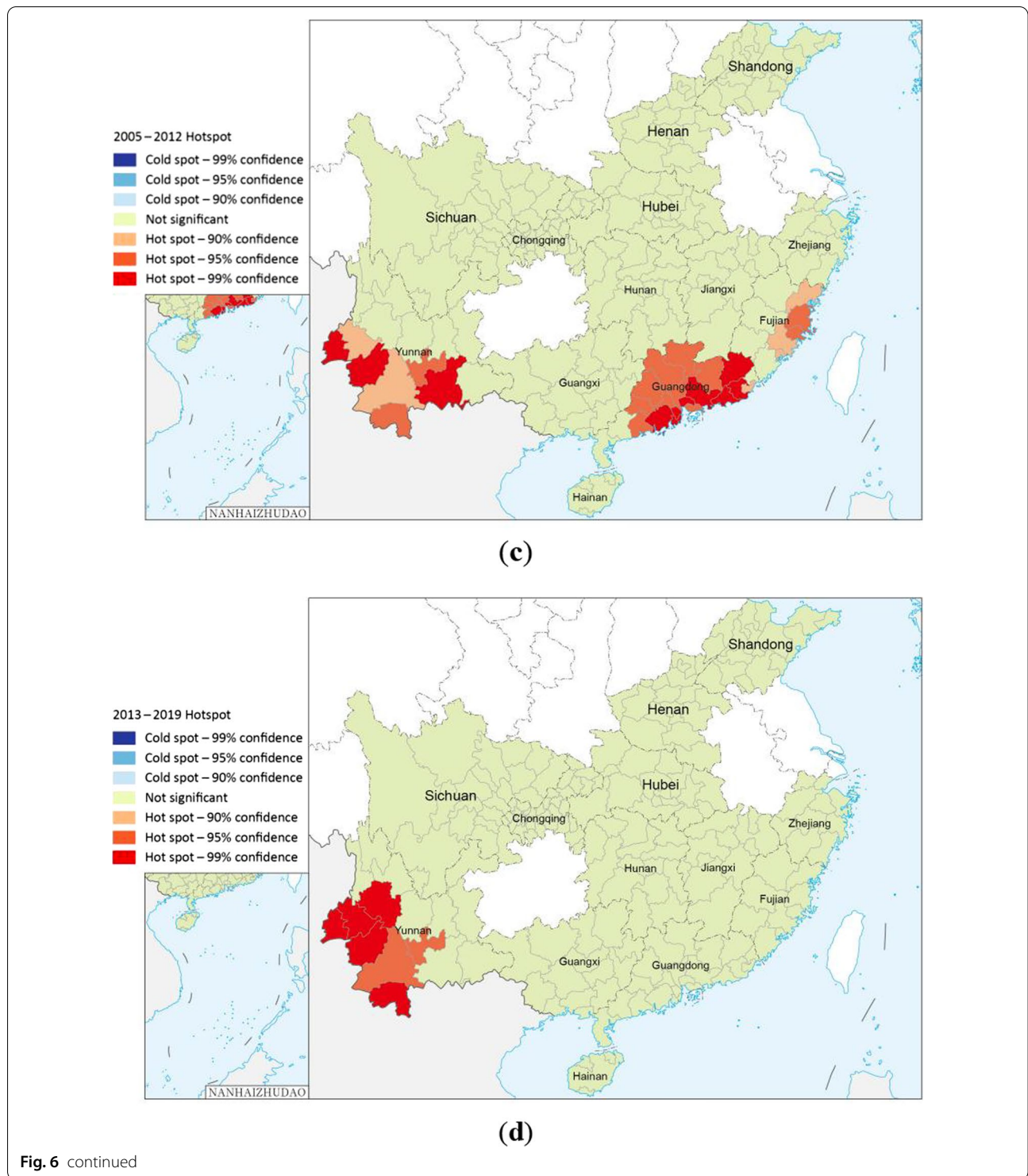
workers to work in Cambodia [40]. For provinces with a large number of imported cases, such as Yunnan and Guangdong, most of the imported cases were reported between July and November, which overlapped with the local outbreak of dengue fever in the mainland of China

[21, 41–43]. Studies have shown that rainfall, temperature and humidity are important climatic factors affecting the density of mosquitoes [44, 45], and the climatic conditions in this period are conducive to the breeding of mosquitoes. Therefore, the measures to prevent
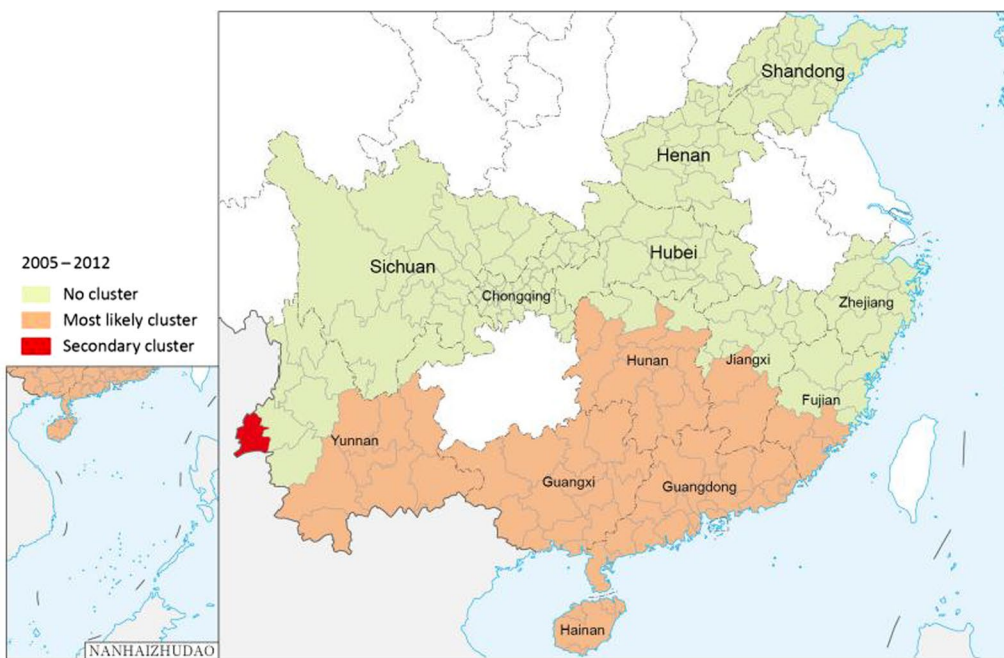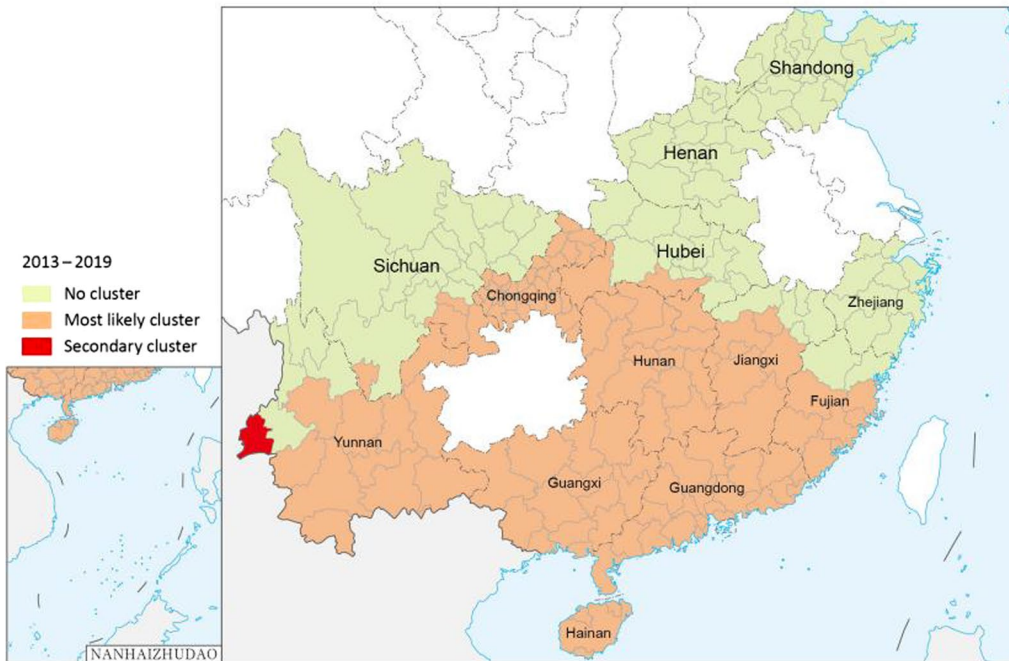
Fig. 7 Distribution of spatial clusters of overseas imported dengue fever cases, 2005–2019. **a** is the result of the temporal-spatial scan analysis from 2005 to 2012, and **b** is the result of the temporal-spatial scan analysis from 2013 to 2019

Lun *et al. Infectious Diseases of Poverty*   (2022) 11:12

Page 14 of 17

Table 3 Temporal-spatial scan results of overseas imported dengue fever, 2005–2019

Period	Cluster	Aggregation time	No. of observed cases	No. of expected cases	Relative risk	*LLR*	*P* value
2005–2012	I	2008/8/1–2008/11/30	46	0.04	1,321.4	282.7	< 0.01
	II	2010/7/1–2012/12/31	223	66.4	4.8	140.4	< 0.01
2013–2019	I	2014/8/1–2017/12/31	1,986	8.6	282.1	9,019.8	< 0.01
	II	2019/5/1–2019/11/30	3,266	463.8	9.7	3,991.1	< 0.01

LLR: The log-likelihood ratio can be used to identify the locations of the most likely clusters and secondary clusters and other clustering regions.

and control overseas imported dengue fever should be intensified between July and November.

In terms of gender, the number of imported cases from 2005 to 2019 was greater for men than women. This may be related to the difference in the social division of labor between men and women. Men more frequently move across borders, whether for business purposes or as migrant workers, which greatly exposes them to dengue fever. In terms of age, most of the imported cases were between 21 and 50 years old. Given that people in this age group are more likely to be laborers, they have a greater likelihood of contracting dengue fever.

In terms of occupation, the difference in the distributions in the 13 PLADs reflects a distinct economic status and overall occupational difference of residents in each PLAD. For example, the imported cases in the developed PLADs, such as Guangdong and Zhejiang, were more likely to be businessmen instead of farmers and workers than those in less developed PLADs. Farmers, especially those located in border areas, may work in areas where dengue fever is endemic and neglect the protection of mosquito bites during their work abroad, thus risking dengue fever. Personnel engaged in commercial services may be involved in overseas commercial trade and cooperation activities, especially in the context of the rapid development of economic globalization; and there will be increasingly more transnational economic and trade exchanges. If businessmen are not aware of dengue fever protection, then the risk of dengue fever will be very high in countries and regions where dengue fever is endemic. Housework or unemployed people do not have stable jobs but have plenty of free time, so they may have more time to travel to other countries around China. Furthermore, this group of people may follow their family members working abroad to temporarily live abroad. Workers may be dispatched abroad by their company or have stable jobs abroad and return home during vacation or after work. Students may follow their parents to go abroad or study abroad. Public officials may travel abroad for business or travel abroad during vacations. These people may not possess sufficient knowledge about dengue fever prevention and control, and they may not have taken preventive measures to prevent mosquito bites overseas

and thus become infected with dengue fever. Therefore, publicity and education on dengue prevention and control knowledge for entry and exit personnel, especially for people in countries or regions where dengue fever is prevalent, should be strengthened. It is also important to familiarize residents in risk areas with the common symptoms of dengue fever and to seek timely medical treatment.

This study combined spatial autocorrelation analysis and temporal-spatial scanning to explore the spatial clustering of overseas imported dengue fever cases in 13 PLADs in China. The results exhibited a trend of more cases in the south and less in the north, more cases in border and coastal areas, and fewer cases inland. The global autocorrelation revealed a spatially positive correlation, suggesting an uneven distribution of these imported cases and the presence of case clusters. This phenomenon may be related to the population flow, international business and employment, studying abroad, and some environmental factors, such as geographic location. The local autocorrelation identified the areas with outliers in southern Yunnan, northern Guangdong and some provincial capitals. The number of outliers in 2013–2019 decreased compared with that in 2005–2012. The clustering areas were mostly distributed in the border areas of Yunnan, Hubei, Henan and Shandong. The border areas of Yunnan and some coastal areas are high-value clusters while the other areas are low-value clusters. The number of high-high clusters and low-low cluster areas in 2013–2019 increased compared with that in 2005–2012.

Hot spots were identified in the southern and southwestern regions of Yunnan Province from 2005 to 2019. These regions are high-risk areas for imported dengue fever. Stringent measures should be implemented to prevent and control imported cases and public health education regarding dengue fever should be strengthened in these regions. From 2005 to 2012, most of the northern part of Guangdong and some coastal areas of Fujian were identified as hotspots, but by 2013–2019, most of the northern part of Guangdong and some coastal areas of Fujian were no longer hotspots. The temporal-spatial scan results obtained by SaTScan are

Lun *et al. Infectious Diseases of Poverty* (2022) 11:12

Page 15 of 17

different from Getis-Ord Gi* analysis, which may be due to their different principles [46]. The temporal-spatial scan also showed that the cluster areas of imported cases in 2013–2019 expanded northward compared with those in 2005–2012. Although we do not know whether the trend will continue in the future, attention should also be paid to the northern regions amid global warming and climate change. Global autocorrelation grasps the spatial relationship between imported cases as a whole, and local autocorrelation explores the relationship between imported cases at each city level. SaTScan can scan to the specific range of imported cases through a circular scanning window. The three methods of global autocorrelation, local autocorrelation and SaTScan gradually progress to make the results more comprehensive.

Imported dengue fever cases are the most important driver of dengue outbreaks in China. For better prevention and control of dengue fever, knowledge of dengue fever should be publicized for entry and exit personnel to increase their awareness of the disease. Greater health monitoring and surveillance should be implemented, particularly for people from dengue fever epidemic areas or countries. Regular training for medical personnel in private clinics, township health centers, community hospitals, and large central hospitals to improve their knowledge on dengue fever and their abilities to identify dengue fever is also necessary. This will help to achieve early detection, early diagnosis and early treatment of suspected dengue fever. It is pivotal to collaborate with other countries, particularly those experiencing dengue fever epidemics, by providing technical assistance, training relevant professional personnel, exchanging knowledge and sharing experience in dengue fever control. These efforts will eventually prevent the further spread of dengue fever and minimize the disease burdens resulting from dengue fever.

The study described and analyzed the overseas imported dengue fever cases recorded in 13 PLADs. It is too difficult to count the possible unreported asymptomatic dengue patients, which is a limitation of this study. In addition, the study only described and analyzed the epidemiological characteristics and temporal-spatial distribution of overseas imported dengue fever cases from 13 PLADs with local dengue outbreaks in the mainland of China, but the reasons behind the above epidemiological characteristics and temporal-spatial distribution were not further analyzed. Future research should focus on collecting data on socioeconomic factors such as population entry and exit through different modes of transportation, transnational tourism, economy and trade and meteorological data. Combining these data with the data of overseas imported cases and exploring the factors affecting the epidemic characteristics and temporal-spatial distribution of overseas imported cases will enable more effective prevention and control of overseas imported cases.

Conclusions

In this study, we characterized the imported dengue fever cases from 2005 to 2019 in 13 PLADs in China and identified the hot spots of these imported cases, which include the border areas of Yunnan, coastal areas of Fujian and Guangdong, and the area of imported cases tended to expand to the north. These findings provide valuable information for developing strategies and policies to prevent and control dengue fever.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40249-022-00937-5.

Additional file 1. Schematic diagram of the study areas.

Additional file 2. Classification of occupations.

Declarations

Author details
[1] State Key Laboratory of Infectious Diseases Prevention and Control, National Institute for Communicable Disease Control and Prevention, Chinese Center for Disease Control and Prevention, Beijing 102206, People's Republic of China.

Lun *et al. Infectious Diseases of Poverty*   (2022) 11:12

Page 16 of 17

2ChangSha Center for Disease Control and Prevention, Changsha 410004, Hunan, People's Republic of China. 3School of Public Health and Health Management, Shandong First Medical University and Shandong Academy of Medical Sciences, Jinan 250117, Shandong, People's Republic of China. 4Vanke School of Public Health, Tsinghua University, Beijing 100084, People's Republic of China.

References

1. Weaver SC, Reisen WK. Present and future arboviral threats. Antiviral Res. 2010;85(2):328–45.
2. Rosen L, Shroyer DA, Tesh RB, Freier JE, Lien JC. Transovarial transmission of dengue viruses by mosquitoes: *Aedes albopictus* and *Aedes aegypti*. Am J Trop Med Hyg. 1983;32(5):1108–19.
3. Brady OJ, Golding N, Pigott DM, Kraemer MU, Messina JP, Reiner RJ, et al. Global temperature constraints on *Aedes aegypti* and *Ae. albopictus* persistence and competence for dengue virus transmission. Parasit Vectors. 2014;7:338.
4. Martina BE, Koraka P, Osterhaus AD. Dengue virus pathogenesis: an integrated view. Clin Microbiol Rev. 2009;22(4):564–81.
5. Begum F, Das S, Mukherjee D, Mal S, Ray U. Insight into the tropism of dengue virus in humans. Viruses. 2019;11(12):1136.
6. Benjamin Rush MD. An account of the bilious remitting fever: as it appeared in philadelphia, in the summer and autumn of the year 1780. Am J Med. 1951;11(5):546–50.
7. World Health Organization: Dengue and severe dengue. https://www.who.int/news-room/fact-sheets/detail/dengue-and-severe-dengue. Accessed 19 May 2021.
8. Brady OJ, Gething PW, Bhatt S, Messina JP, Brownstein JS, Hoen AG, et al. Refining the global spatial limits of dengue virus transmission by evidence-based consensus. PLoS Negl Trop Dis. 2012;6(8): e1760.
9. Bhatt S, Gething PW, Brady OJ, Messina JP, Farlow AW, Moyes CL, et al. The global distribution and burden of dengue. Nature. 2013;496(7446):504–7.
10 Muller DA, Depelsenaire AC, Young PR. Clinical and laboratory diagnosis of dengue virus infection. J Infect Dis. 2017;215(suppl_2):S89–95.
11. Huy BV, Hoa L, Thuy DT, Van Kinh N, Ngan T, Duyet LV, et al. Epidemiological and clinical features of dengue infection in adults in the 2017 outbreak in Vietnam. Biomed Res Int. 2019;2019:3085827.
12. Shepard DS, Undurraga EA, Halasa YA, Stanaway JD. The global economic burden of dengue: a systematic analysis. Lancet Infect Dis. 2016;16(8):935–41.
13. Wu JY, Lun ZR, James AA, Chen XG. Dengue fever in mainland China. Am J Trop Med Hyg. 2010;83(3):664–71.
14. Luo H, He J, Zheng K, Li L, Jiang L. Analysis on the epidemiologic features of Dengue fever in Guangdong province, 1990–2000. Zhonghua Liu Xing Bing Xue Za Zhi. 2002;23(6):427–30 (In Chinese).
15. Zhang H, Mehmood K, Chang YF, Zhao Y, Lin W, Chang Z. Increase in cases of dengue in China, 2004–2016: a retrospective observational study. Travel Med Infect Dis. 2020;37: 101674.
16. Yue Y, Sun J, Liu X, Ren D, Liu Q, Xiao X, et al. Spatial analysis of dengue fever and exploration of its environmental and socio-economic risk factors using ordinary least squares: a case study in five districts of Guangzhou City, China, 2014. Int J Infect Dis. 2018;75:39–48.
17. Meng FX, Wang YG, Feng L, Liu QY. Review on dengue prevention and control and integrated mosquito management in China. Chin J Vector Biol Control. 2015;26(1):4–10 (In Chinese).
18. Liu H, Liu L, Cheng P, Yang L, Chen J, Lu Y, et al. Bionomics and insecticide resistance of *Aedes albopictus* in Shandong, a high latitude and high-risk dengue transmission area in China. Parasit Vectors. 2020;13(1):11.
19. Cheng Q, Jing Q, Spear RC, Marshall JM, Yang Z, Gong P. Climate and the timing of imported cases as determinants of the dengue outbreak in Guangzhou, 2014: evidence from a mathematical model. PLoS Negl Trop Dis. 2016;10(2): e0004417.
20. Sang S, Gu S, Bi P, Yang W, Yang Z, Xu L, et al. Predicting unprecedented dengue outbreak using imported cases and climatic factors in Guangzhou, 2014. PLoS Negl Trop Dis. 2015;9(5): e0003808.
21. Lin H, Wang X, Li Z, Li K, Lin C, Yang H, et al. Epidemiological characteristics of dengue in mainland China from 1990 to 2019: a descriptive analysis. Medicine (Baltimore). 2020;99(36): e21982.
22. Wang Y, Wang X, Liu X, Ren R, Zhou L, Li C, et al. Epidemiology of imported infectious diseases, China, 2005–2016. Emerg Infect Dis. 2018;25(1):33–41.
23. Jing QL, Cheng Q, Marshall JM, Hu WB, Yang ZC, Lu JH. Imported cases and minimum temperature drive dengue transmission in Guangzhou, China: evidence from ARIMAX model. Epidemiol Infect. 2018;146(10):1226–35.
24. Cheng Q, Jing Q, Spear RC, Marshall JM, Yang Z, Gong P. The interplay of climate, intervention and imported cases as determinants of the 2014 dengue outbreak in Guangzhou. PLoS Negl Trop Dis. 2017;11(6): e0005701.
25. Mollalo A, Mao L, Rashidi P, Glass GE. A GIS-based artificial neural network model for spatial distribution of tuberculosis across the continental United States. Int J Environ Res Public Health. 2019;16(1):157.
26. Vilinova K. Spatial autocorrelation of breast and prostate cancer in Slovakia. Int J Environ Res Public Health. 2020;17(12):4440.
27. Lei L, Huang A, Cai W, Liang L, Wang Y, Liu F, et al. Spatial and temporal analysis of lung cancer in Shenzhen, 2008–2018. Int J Environ Res Public Health. 2020;18(1):26.
28. Alves JD, Abade AS, Peres WP, Borges JE, Santos SM, Scholze AR. Impact of COVID-19 on the indigenous population of Brazil: a geo-epidemiological study. Epidemiol Infect. 2021;149: e185.
29. Rahimi PS, Kavousi A, Mirbagheri B, Shahsavani A, Etemad K. Temporal trend and spatial distribution of acute lymphoblastic leukemia in Iranian children during 2006–2014: a mixed ecological study. Epidemiol Health. 2020;42: e2020057.
30. Al-Ahmadi K, Al-Zahrani A. Spatial autocorrelation of cancer incidence in Saudi Arabia. Int J Environ Res Public Health. 2013;10(12):7207–28.
31. Zhang X, Chen X, Gong W. Type 2 diabetes mellitus and neighborhood deprivation index: a spatial analysis in Zhejiang, China. J Diabetes Investig. 2019;10(2):272–82.
32. Panahi MH, Parsaeian M, Mansournia MA, Khoshabi M, Gouya MM, Hemati P, et al. A spatio-temporal analysis of influenza-like illness in Iran from 2011 to 2016. Med J Islam Repub Iran. 2020;34:65.
33. Lai S, Huang Z, Zhou H, Anders KL, Perkins TA, Yin W, et al. The changing epidemiology of dengue in China, 1990–2014: a descriptive analysis of 25 years of nationwide surveillance data. BMC Med. 2015;13:100.
34. Ooi EE, Gubler DJ. Dengue in Southeast Asia: epidemiological characteristics and strategic challenges in disease prevention. Cad Saude Publica. 2009;25(Suppl 1):S115–24.
35. Shepard DS, Undurraga EA, Halasa YA. Economic and disease burden of dengue in Southeast Asia. PLoS Negl Trop Dis. 2013;7(2): e2055.
36. Gubler DJ. Dengue/dengue haemorrhagic fever: history and current status. Novartis Found Symp. 2006;277:3–16 (discussion 16-22, 71-3, 251-3).
37. Liu Q, Xu W, Lu S, Jiang J, Zhou J, Shao Z, et al. Landscape of emerging and re-emerging infectious diseases in China: impact of ecology, climate, and behavior. Front Med. 2018;12(1):3–22.
38 Linn NN, Kyaw K, Shewade HD, Kyaw A, Tun MM, Khine SK, et al. Notified dengue deaths in Myanmar (2017–18): profile and diagnosis delays. F1000Res. 2020;9:579.
39. Lun X, Zhao C, Zhu C, Wu H, Wang J, Wang Z, et al. Impact analysis of dengue fever epidemic in Cambodia and tourism to Cambodia on imported dengue fever in China from 2011 to 2019. Chin J Vector Biol Control. 2021;32(3):312–7 (In Chinese).
40. Yue Y, Liu X, Ren D, Wu H, Liu Q. Spatial dynamics of dengue fever in mainland China, 2019. Int J Environ Res Public Health. 2021;18(6):2855.
41. Sang S, Yin W, Bi P, Zhang H, Wang C, Liu X, et al. Predicting local dengue transmission in Guangzhou, China, through the influence of imported cases, mosquito density and climate variability. PLoS ONE. 2014;9(7): e102755.
42. Ren J, Ling F, Sun J, Gong Z, Liu Y, Shi X, et al. Epidemiological profile of dengue in Zhejiang Province, southeast China. PLoS ONE. 2018;13(12): e0208810.
43. Wang JZ, You LB, Kan NP, Lin Q, Weng YW, Zheng KC. Frequent import and multiple sources of dengue fever have changed the epidemic situation of the disease in Fujian Province, China. Biomed Environ Sci. 2020;33(2):123–32.

Lun *et al. Infectious Diseases of Poverty*　(2022) 11:12

Page 17 of 17

44. Lega J, Brown HE, Barrera R. *Aedes aegypti* (Diptera: Culicidae) abundance model improved with relative humidity and precipitation-driven egg hatching. J Med Entomol. 2017;54(5):1375–84.
45. Diallo D, Diagne CT, Buenemann M, Ba Y, Dia I, Faye O, et al. Biodiversity pattern of mosquitoes in Southeastern Senegal, epidemiological implication in arbovirus and malaria transmission. J Med Entomol. 2019;56(2):453–63.
46. Zhao F, Zhu R, Zhang LJ, Zhang ZJ, Li YP, He MZ, et al. Integrated detection and analysis on the clusters of schistosomiasis based on geographic information system. Zhonghua Liu Xing Bing Xue Za Zhi. 2010;31(11):1272–5 (In Chinese).