Study on the relationship between the measurement of household carbon emissions and spatial correlation in Nanjing——Taking 4993 residential quarters as examples

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Abstract. In order to explore the spatial distribution of household carbon emissions of Nanjing, 4993 residential quarters in Nanjing are used as the research objects, the IPCC method is used to construct the calculation formula of living carbon emissions to calculate the amount in Nanjing, and the ArcGIS software is applied to carry out spatial analysis. The results show that the total carbon emissions of residential quarters in Nanjing in 2017 was 272,632 tons, of which Jiangning District, Gulou District, Pukou District and Qinhuai District had more carbon emissions, accounting for 53% of the total; The spatial distribution had a concentrated trend, and the central urban area exhibited a “low-to-low” correlation, while the outer area of the central urban region presented a “high-to-high” positive correlation. Finally, countermeasures and suggestions are proposed for the planning and emission reduction of residential quarters in Nanjing.

1. Introduction
With the optimization of the industrial structure, the proportion of industrial carbon emissions has continued to decline, while the percentage of living carbon emissions has been increasing. In developed countries, living carbon emissions which are the main source of carbon emissions account for about 20% of total carbon emissions [1]. Juan Fercovic et al. [2] measured household carbon emissions in 17 metropolitan areas in Canada, and conducted a comparative analysis of inter-annual changes and metropolitan areas. Moises Neil V. Seriño [3], Amir Hamzah Sharai, etc. [4] used different models to explore the main factors affecting household carbon emissions. At present, scholars' research on living carbon emissions in residential quarters has focused on influencing factors and differential analysis, while this article studies the spatial distribution characteristics of carbon emissions in various communities and their spatial correlations. Zhao Yuhuan et al. [5], Li Xudong [6] and Li Guozhi [7] measured the direct carbon emissions of life from the levels of the city, province, and country, respectively, and performed a quantitative analysis of their influencing factors. Liu Lina et al. [8] found that from 1995 to 2010, China’s per capita household carbon emissions continued to rise, and it decreased spatially from the southeast coast to the northwest inland. Wang Li et al. [9] and Zang Xueling et al. [10] compared the carbon emissions of urban and rural households at the national and provincial levels.
2. Research methods and data sources

2.1. Calculation method of carbon emissions in residential quarters
Based on the Nanjing Statistical Yearbook, the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, and the data from the Third National Economic Census, this article obtains Nanjing's household consumption of LPG (liquefied petroleum gas) and natural gas in 2017. The carbon emission factors of gas are 20.928 and 3.029 [11], and the carbon emission calculation formula for residential quarters is shown in formula (1): The formula for calculating the carbon sink is as follows:

$$C = 20.928 \times \alpha + 3.029 \times \beta$$

Among them, $C$ is the carbon emissions in residential quarters; $\alpha$ is the total amount of natural gas used by households in each district; $\beta$ is the total amount of liquefied petroleum gas used in households in each district.

2.2. Data sources
The dissertation uses Python to write a data scraping program to capture the geographic coordinates of a total of 4993 residential quarters in 11 administrative areas of Nanjing from the AMap website, and to capture data on the number of households in each community from housing sites such as Anjuke. According to the Nanjing Statistical Yearbook (2018), the per capita living energy use of urban residents and the number of resident households in Nanjing were calculated in 2018, and the living energy use of each household was obtained. Based on this, the energy use of households in each residential quarter was estimated.

3. Results and analysis

3.1 Study on the spatial distribution characteristics of residential quarters
A total of 2600 residential quarters in this study were distributed in the central urban area consisting of Gulou, Xuanwu, Qinhuai, and Jian'ou, accounting for 52.07% of the total residential area. Due to the early completion, the scale is small and the number of occupants is small; The residential quarters in Qixia, Pukou, Jiangning, Yuhua, Liuhe, Gaochun, and Lishui are mostly clustered and distributed around the district government. The residential area is relatively large and can accommodate more residents.

The study uses the standard deviation ellipse method to analyze the agglomeration characteristics of the residential area distribution. On the whole, Nanjing's residential quarters are mainly distributed in the central urban area, and the center of gravity is located at (118.799216° E, 32.022826° N), which is 1km north of Confucius Temple 60°. 77.05% of the residential quarters are distributed in a standard deviation ellipse that covers 11.78% of the target area. The density of the residential quarters is about 5.18 / km2, while the density is only 0.21 in a spatial area of 5561.19km2 outside the ellipse standard / km2, and 93.15% of the residential areas are distributed within two standard deviation ellipses of the entire study area (as shown in Figure 1).

3.2 Spatial distribution characteristics of carbon emissions in residential areas
Based on the calculated carbon emissions of each residential area in Nanjing and their corresponding point distributions(as shown in Table 1), the study uses ArcGIS 10.2 software to perform inverse distance spatial interpolation on the carbon emissions of residential quarters(as shown in Figure 2).

| District   | Carbon emission(t) | District   | Carbon emission(t) |
|------------|--------------------|------------|--------------------|
| Jiangning  | 45048              | Luhe       | 22274              |
| Gulou      | 33937              | Yuhuatai   | 21732              |
The overall distribution of carbon emissions in urban residential quarters in Nanjing shows a trend of increasing first and then decreasing outward from the central urban area, and the amount of carbon emissions of the central urban area are mainly distributed at a low value of 0.1776 tons, while the high value is distributed in a dotted pattern. The reasons for the characteristics of carbon emissions in residential districts in the central urban area are: (1) the interior of the central urban area is protected by historical and cultural heritage, and the building height is strict; (2) the central urban area has high land prices, and the buildings are mostly used for commerce. In the peripheral areas, due to lower housing prices and convenient transportation, more residents are attracted to buy a house. Therefore, high carbon emissions will occur in the periphery of the central urban area.

3.3 Spatial correlation analysis of carbon emissions in residential quarters

3.3.1 Global spatial autocorrelation of carbon emissions. Aiming at the carbon emission data, through spatial autocorrelation analysis, the Moran's I value of the carbon emission of the residential area is 0.0874, and the normal statistic Z value of the test is 9.54, and the P value is 0.0000. It can be seen from the above results that under the condition of a significance level of 0.05, the normal statistical value Z of 9.54 is greater than its critical value of 1.96, indicating that the spatial distribution of carbon emissions in residential communities in Nanjing has a significant positive spatial autocorrelation relationship, and there is room Dependency characteristics.
3.3.2 Local spatial autocorrelation of carbon emissions. In this paper, Anselin Local Moran I spatial statistical analysis tool is used to obtain the LISA agglomeration map of carbon emission distribution in residential communities in Nanjing. It can be seen that there is a certain agglomeration relationship between the carbon emissions of various residential communities, and the central urban area presents a positive spatial correlation, and at a significance level of 5%, it shows a "low-low" positive correlation; under the same conditions, carbon emissions The residential communities showing positive correlations in quantity are mainly concentrated in the four districts of Liuhe, Pukou, Jiangning and Qixia (see Figure 4).

4. Conclusions and suggestions
The residential quarters of Nanjing are mainly concentrated in Gulou District, Xuanwu District, Qinhuai
District, and Jian’ou District. Secondly, the overall distribution of living carbon emissions in Nanjing's residential quarters first increased and then decreased from the central urban area, and its spatial distribution has a centralized trend. And the following suggestions are proposed:

1) Reasonable planning for residential quarters. Aiming at the current layout of residential areas in Nanjing, combined with relevant planning regulations, the implementation of stock evacuation development in the downtown area of Nanjing limits the redevelopment of new residential quarters, while implementing incremental development goals for new districts such as Xianlin Vice City to attract population to live.

2) Use clean energy. To reduce the amount of liquefied petroleum gas used by residents, the goal of using clean energy such as electricity and natural gas should be achieved as far as possible, and households should be encouraged to install emission reduction devices to achieve green and low-carbon living.

3) Increase effective carbon sinks. Implement three-dimensional greening in the central urban area, including roof greening, wall greening, and fence greening, etc.; appropriately increase the greening rate requirements for the residential quarters in the new city to be developed; and ensure that the original public green space in the city is incrementally upgraded.

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