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# Spatial Analysis of Guangdong Province's GDP Based on NPP-VIIRSNight Light Remote Sensing

**BY**

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**Abstract**

*With the development of remote sensing technology, night light remote sensing is widely used in gross domestic product (GDP) estimation or spatial analysis. This study uses NPP-VIIRS night light data combined with yearbook statistical data to conduct a spatial analysis of Guangdong Province's GDP. Firstly, based on the distribution of lighting values and GDP output points, combined with the fitting of different models, it is verified that there is a significant correlation between nighttime lighting data and GDP, and the spatialization and feasibility of inversion are feasible. Utilize the pixel values of lighting brightness to spatially allocate GDP in 2012 and 2021, and analyze the overall and regional economic spatial trends. The analysis shows that the overall development trend is centered around the Pearl River Delta Greater Bay area, which has the characteristic of radiating outward from the central region. The other regions present a scattered economic pattern, extending to the northern region for common development. The economy driven by the agglomeration of the east and west wings is gradually developing. In the trend of regional development, the western wing has changed from a strip type to a cluster type, while the eastern wing has significant growth and changes along its southern coast and the mountainous areas have a scattered distribution pattern.*

**KEYWORDS:** *Night Light Remote Sensing; NPP-VIIRS Data; Gross Domestic Product (GDP); Model Fitting; Spatial Analysis*

## 1. Introduction

Guangdong Province, relying on its unique geographical environment, continuously develops its coastal economy. After its Gross Domestic Product (GDP) rose to the first place in the country in 1989, it has remained the first in the country for 32 consecutive years (Wang, 2021). The development of GDP in Guangdong Province has become a focus and concern for national economic development, as its increase or decrease has an indicator orientation for the overall development of China's economy. Therefore, the research on Guangdong Province's GDP has great practical significance for China's development.

At present, the commonly used nighttime lighting data include three Remote Sensing (RS) satellites: DMSP/OLS, NPP-VIIRS, and Luojia-1. The advantages of night light RS data include convenient accessibility, broad application prospects, high data objectivity, good data matching, and large data volume. Based on the above advantages and characteristics, this data has been widely applied by many scholars in various studies, among which the correlation between GDP and nighttime lighting is a common issue and also of great research significance.

In recent years, the topic of economic research based on night light RS has gradually become popular worldwide; For example, Chang et al. (2022) combined night light data and statistical data to make economic forecasting for Hainan Island. Henderson et al. (2003) obtained the location and status of regions with economic development differences based on DMSP/OLS. Wei et al. (2021) conducted a spatial simulation of GDP in Shanxi Province based on NPP-VIIRS nighttime lighting data. These analysis topics show that there is a relatively complete process for studying mesoscale regions and GDP based on nighttime light data. However, more research focuses on using nighttime light data to estimate GDP by industry, and there are still relatively few studies on analyzing GDP specialization using the total value of nighttime light.

According to the above research background, significance, and current situation, this paper aims to conduct a spatial analysis of Guangdong's GDP based on the nighttime lighting data and the GDP statistics of each city. The main objectives are as follows:

(1) By fitting and analyzing the total GDP of various cities in Guangdong Province from 2012 to 2020, a model is constructed. And use the total value of lighting in 2021 and GDP for precision analysis to explore the correlation and implications between the two.

(2) On the basis of lighting data, analyze the spatial pattern of economic development GDP in Guangdong Province.

## 2. STUDY AREA AND DATA SOURCES

### *2.1. Research Area*

Guangdong Province is located between 20°09′-25°31′N and 109°45′-117°20′E. With rapid economic development, as of 2022, the permanent population of Guangdong Province is 126.568 million, with a regional GDP of 12911.858 billion yuan. We compared to the GDP of 18.59 billion yuan in 1978, an increase of 694.5 times, showing a rapid growth trend. According to the division of national prefecture-level administrative units, Guangdong has 21 prefecture-level administrative units. The Guangdong Provincial Statistical Yearbook divides Guangdong Province into four regions based on terrain and economic development level: the west wing, the east wing, the mountainous areas, and the Pearl River Delta (Li et al., 2021). The specific prefecture-level cities are shown in Table 1 and Figure 1.

**Table 1 GDP regional division of 21 prefecture-level cities in Guangdong**

| Zone area | prefecture-level city |
|---|---|
| West Wing | Zhanjiang, Maoming, Yangjiang |
| East Wing | Shantou, Chaozhou, Jieyang, Shanwei |
| Mountain Area | Shaoguan, Meizhou, Qingyuan, Heyuan, Yunfu |
| Pearl River Delta | Guangzhou, Shenzhen, Foshan, Zhuhai, Dongguan, Zhongshan, Huizhou, Jiangmen, Zhaoqing |

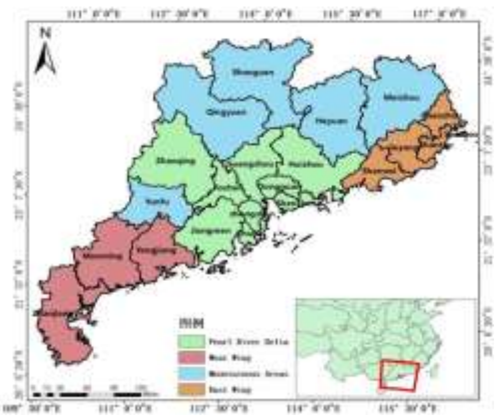


**Figure 1 Distribution of 21 prefecture-level cities in Guangdong Province**

### 2.2 Data Sources

The analysis data used in this study mainly include nighttime light RS data, Guangdong Province GDP data, and vector data.

**■*Night Light Remote Sensing Data***

At present, there are three main types of night light RS satellites used for social research, namely DMSP/OLS satellite, NPP/VIIRS satellite, and Luojia-1 satellite (relevant parameters are shown in Table 2).

**Table 2 Comparison of Three Nighttime Light Remote Sensing Satellites**

| Type | DMSP/OL Satellite | NPP/VIIRS satellite | Luojia-1 satellite |
|---|---|---|---|
| Launch country | United States | United States | China |
| Time period (year) | 1992-2013 | 2012-2022 | 2018-2021 |
| Resolution | 1000m | 500m | 130m |
| Difficulty of preprocessing steps | Complex | Simple | Simple |
| Research on the suitability of GDP | Low | high | Middle |

DMSP/OLS satellites can provide annual global stable lighting data, but only provide data from 1992 to 2013, with a resolution of 1000m, which is prone to pixel saturation values and leads to large errors in data extraction. Thus, it is not suitable for research on the rapid development of GDP in Guangdong Province.

Luojia-1 satellite is a new type of satellite launched in 2018, with a resolution of up to 130m. The problems of light overflow and saturation have been solved with high accuracy (Liu et al., 2022). However, due to its recent launch, the data volume is insufficient, which cannot meet the requirements of this study for the study of Guangdong Province's GDP long series.

The spatial resolution of NPP/VIIRS is 500m, which has an accurate effect on characterizing the distribution of small-scale surface lighting. The satellite can provide data since 2012, which is of good data significance for the analysis of the current GDP situation of Guangdong Province. Moreover, the satellite data has had an outlier affecting the weather before it was provided, and the accuracy is moderate through algorithm correction. Research has shown (Chai et al., 2015) that this satellite data is suitable for fitting analysis of socio-economic indicators. Based on this, this study uses NPP/VIIRS satellite data from 2012 to 2021 for spatial analysis of GDP.

**■ *Guangdong Province GDP Data and Vector Range Data***

The GDP data is selected from the Guangdong Statistical Yearbook, using the "Main Economic Indicators of Counties

(Cities) and Districts" from 2012 to 2021, and selecting the total GDP of cities at various levels in each year. In addition, vector data is downloaded from the National Geographic Information Resource Catalog Service, including vector maps of Guangdong Province and 21 prefecture-level cities.

## 3. STUDY METHODS

The analysis of this study is divided into four parts, including data processing, model construction, function fitting, and spatial analysis (Figure 2). The main steps are as follows:

1. Data processing: After downloading the original data, data correction is required to obtain directly usable lighting data.
2. Model construction: Due to the large scope of this study area and the need to process images over multiple years, the data volume appears to be very large. Thus, this study applies ArcGIS's "ModelBuilder" to establish a procedural model and solve the problem of processing a large amount of data. Subsequently, the corrected lighting data will be used to generate image maps and calculate the total lighting value through ModelBuilder.
3. Function fitting: Fit the processed total light value with the GDP value, and explore the correlation and inversion between the two.
4. Spatial analysis: use the light value to generate GDP specialization, and finally conduct overall spatial analysis and regional spatial analysis.

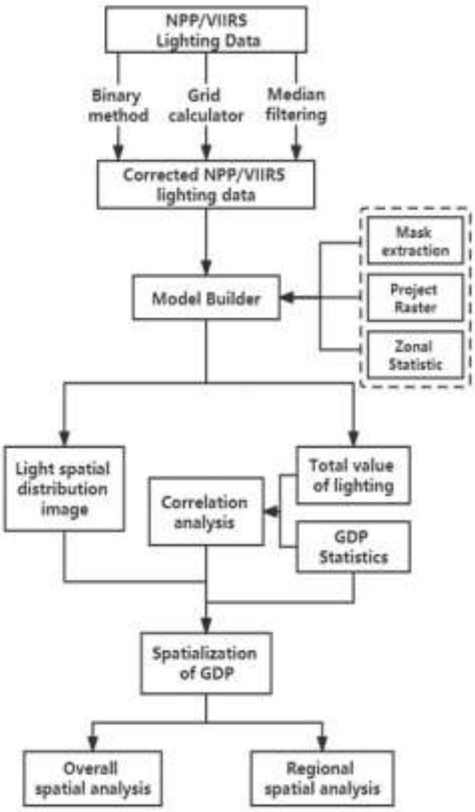



*Figure 2 The Schema of This Study*

### 3.1. Data Processing

Download nighttime light data from the NPP/VIIRS satellite from 2012 to 2021 on the official website of the Earth Observation Group (EOG) at the University of Colorado, USA, in the form of raster images. Due to the high sensitivity of the satellite sensor to nighttime lighting, noise may appear in the data, leading to data anomalies. Therefore, it is necessary to remove noise and outliers from the data.

This article uses the mask binary method to eliminate noise based on the method used by Wen et al. (2022) for noise processing. The main approach is to use recognition tools to identify the pixel values of the background, set the segmentation points of binarized pixels based on the pixel values, and then uses grid reclassification tools to reclassify the raster data to obtain the binarized data. The processed data may also have negative values and an extremely high outlier. Therefore, the principle of the grid calculator and median filter (Cheng, 2020) of ArcGIS can be used to remove the negative values and replace the outlier to obtain light data that can be analyzed directly.

Median filtering is a nonlinear signal processing method and also a statistical sorting filter. It sets the grayscale value of each pixel to the median of all pixel grayscale values within a neighborhood window of that point. The purpose is to propose good filtering effects for isolated noisy pixels, such as salt and pepper noise and pulse noise, to maintain the edge characteristics of the image and not cause significant blurring. The basic principle is to replace the values of points in a digital image with the median values of each point in the neighborhood of the point, so that the surrounding pixel values are close to the true values, thereby eliminating isolated noise points.

### 3.2. Model Construction

Due to the large amount of data and complex operational steps from 2012 to 2021, this study utilized ArcGIS's ModelBuilder to batch-process all image data (Figure 3). The construction model can output images and calculate the total value of lighting from the processed 2012 to 2021 lighting data, extract masks from the vector range map of Guangdong, and then perform grid projection to obtain lighting image maps for various regions. Finally, combined with the vector range map of Guangdong for calculation, partition statistics are displayed in a table to obtain the total lighting values of each city level in Guangdong, and exported to an Excel spreadsheet.

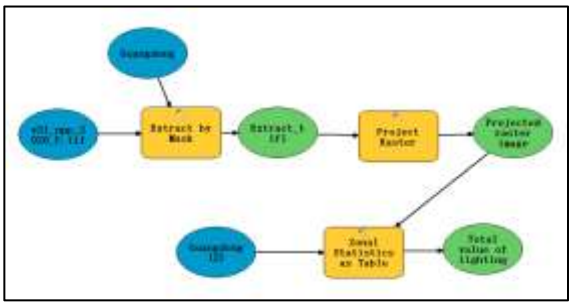


*Figure 3 Model Builder Processing for Lighting Data*

Extract the GDP data of 21 cities in Guangdong from 2012 to 2021, use Excel for statistics, and combine it with the total lighting value table of each city output by Model Builder to calculate the total lighting value and GDP value for 9 years, with a total of 189 values (Table 3).

*Table 3 Statistics of Data Volume in This Study*

| | City level (number) | Data duration (year) | Total value (number) |
|---|---|---|---|
| Total value of lighting | 21 | 9 | 189 |
| Total value of GDP | 21 | 9 | 189 |

### *3.3. Model Fitting*

Model fitting is proposed by Bentler (1990), which refers to the degree of difference between the variance or covariance matrix estimated by the evaluation model and the observed sample variance or covariance matrix. By observing the degree of consistency between the assumed theoretical model and actual data, $R^2$ is generally used as a representation of the degree of fit. The higher the model fit ($R^2$), the higher the consistency between the data produced by the theoretical model and the actual data.

On this basis, models with high fit can be used as regression models to compare the degree of relationship between data and estimate quantity values. Regression models are computational methods and theories that study the specific dependency relationship of one variable on another variable (Kuai, 2015), mainly divided into linear regression and nonlinear regression. This study uses these two regression methods to explore the fitting of regression models between lighting and GDP, specifically selecting the linear model, quadratic model, cubic model, and power model as the fitting equations (Table 4).

*Table 4 Regression Mathematical Models and Fitting Equations*

| Regression model | Fitted equation |
|---|---|
| Linear regression model | $Y=a_1X \pm b$ |
| Quadratic regression model | $Y=a_1X^2 \pm a_2X \pm b$ |
| Cubic regression model | $Y=-a_1X^3 \pm a_2X^2 \pm a_3X \pm b$ |
| Power regression model | $Y=aX^b$ |

*Note: Y is the dependent variable; X is the independent variable; $a_1$, $a_2$, and $a_3$ are coefficients; B is a constant.*

### *3.4. Spatial Analysis*

Spatial relation theory is one of the important theories of spatial analysis and plays a significant role in the process of spatial analysis. Mainly focusing on the description and expression of spatial relationships, and analysis based on spatial relationships. The commonly used analysis methods in spatial relationship theory generally use interaction and intersection methods (Qin et al., 2006). The interaction method refers to taking a spatial entity as a whole and judging the change of spatial relationship by comparing two entities according to a certain time change. The crossing method refers to decomposing spatial entities into several parts and judging the change of spatial relationship by comparing the differences between the components of two entities.

GDP spatialization is the reverse process of obtaining socioeconomic statistical data. It utilizes the potential spatial distribution characteristics of socio-economic data to spread GDP statistical data onto a certain resolution spatial grid unit, to simulate the distribution of socio-economic data in geographical space (Li et al., 2014). This study uses the natural breakpoint method in ArcGIS to distinguish three range categories of different increments based on GDP differences, namely low increment, medium increment, and high increment, to describe the increment interval of GDP corresponding to the difference between 2012 and 2021.

Based on this, this study will use the interactive analysis method and cross-analysis method of spatial relationship theory, as well as the GDP difference increment, to analyze the spatial relationship of GDP spatialization. And divide the spatial analysis of GDP into overall analysis and regional analysis. Combining time changes, in the overall analysis, Guangdong Province compares the time differences of the overall part. In regional analysis, Guangdong Province is divided into four regions to compare the temporal differences and changes in each region. Finally, complete the spatial analysis of Guangdong's GDP.

The main approach is to use nighttime light pixel values to allocate pixels to GDP statistical data. Due to the use of light data with a resolution of 500 meters, this study uses an equal grid size for spatial visualization of GDP. The pixel assignment formula is as follows:

$$G = \frac{N_i * i}{\sum_{i_{min}}^{i_{max}} N_i * i} * GDP_t \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

In the formula (1), G represents the spatial pixel value of GDP; irepresents the pixel brightness value, $N_i$ represents the number of pixel brightness values; $i_{max}$ represents the maximum value of pixel brightness, while $i_{min}$ represents the minimum value of pixel brightness; $GDP_t$ represents the total GDP of Guangdong Province. According to equation (1), the total GDP values of 2012 and 2021 can be allocated to corresponding pixel values, forming a spatial visualization of GDP.

## 4. ANALYSIS AND RESULTS

### *4.1. Correlation Analysis*

After data processing, the total value of lighting and GDP each have 189 values, which are input into SPSS software for fitting analysis. Select the linear model, quadratic model, cubic model, and power model to calculate the $R^2$, equations, and related parameter values of these four fitting models (Table 5). Meanwhile, perform fitting mapping, where the Y-axis represents the total GDP and the X-axis represents the total lighting value (Figure 4).

*Table 5 Fitting Model Equations*

| Regression model | $R^2$ | Equation |
|---|---|---|
| Linear regression model | 0.772 | $Y=0.0919X-1747.3$ |
| Quadratic regression model | 0.789 | $Y=2.15*10^{-7}X^2+0.0463X-351.19$ |
| Cubic regression model | 0.801 | $Y=-2.53*10^{-12}X^3+1.138*10^{-6}X^2-0.042X+1523.9$ |
| Power regression model | 0.881 | $Y=0.0059*X^{1.196}$ |

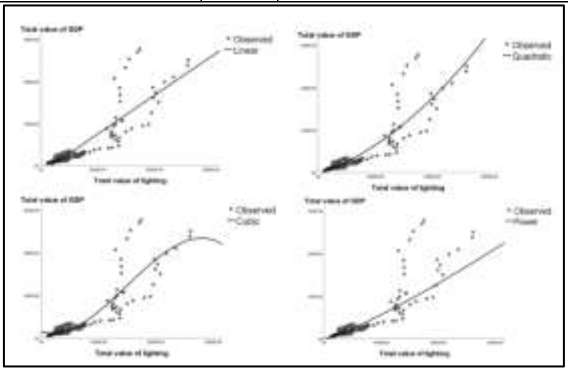


***Figure 4 Fitting Diagrams of Light Value and GDP Value***

Compare the different fitting models shown above. The power model has the highest fit, with an $R^2$ of 88.1%, while the linear model has the lowest fit, with an $R^2$ of 77.2%. When $R^2$ is closer to 1, it indicates a closer relationship between the two and also indicates that the model fits the equation better (Tang et al., 2011). The fitting degree of the four models to the lighting value and GDP value can all reach over 75%, indicating that the total lighting value and GDP value have a significant covariation, and the relationship between the two is close.

Calculate the total GDP of 21 prefecture-level cities in Guangdong Province in 2021, substitute them into different fitting models, and add the results to obtain the GDP fitting total. Compare the error with the GDP of Guangdong in the statistical yearbook, and adjust the formula to equation (2) based on the fitting error analysis by Zhang et al. (2021) to obtain the fitting error. The results are shown in Table 6.

$$E = \left|\frac{N-S}{S}\right| \times 100\% \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

In the formula (2), E is the fitting error; N is the fitting value; S is the actual value

***Table 6 Fitting Error of Guangdong Province's GDP in 2021***

| Fitted model | Fit value (100 million yuan) | Actual value (100 million yuan) | Fitting error |
|---|---|---|---|
| Linear regression | 145087.50 | | 12.3% |
| Quadratic regression | 159332.14 | 129118.57 | 23.3% |
| Cubic regression | 145790.32 | | 12.9% |
| Power regression | 128464.48 | | 0.5% |

As shown in Table 6, the minimum error rate of GDP fitting is only 0.5%, and the maximum error does not exceed 25%. Overall, the total value of lighting can explain at least 76.7% of GDP, indicating that the total value of lighting has strong inversion ability for GDP. In summary, the analysis of the fitting degree and fitting error between the total value of lighting and GDP indicates that there is a significant correlation between lighting and GDP, and it is feasible to spatially invert the total value of lighting on GDP.

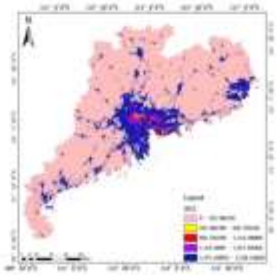
### *4.2. Spatial Analysis*

#### *4.2.1. Overall Spatial Analysis*

This study presents a spatial distribution pattern of GDP spatialization (Figures 5 and 6). The overall difference in the spatial pattern of GDP in Guangdong between 2012 and 2021 is very significant, with the main focus of the economic core being on the Pearl River Delta region, forming an economic agglomeration effect. However, the mountainous areas in Guangdong, due to their poor geographical location and relatively backward policy development, have become the most backward areas.

In 2012, the western and eastern wings were mostly in a state of economic dispersion, with weak GDP connectivity between different regions, forming a dominant economic pattern in the Pearl River Delta region and scattered distribution in other regions.

In addition, analyzing the spatial pattern of GDP in 2021, the radiation area of the Pearl River Delta has expanded, and the western and eastern wings have begun to exhibit agglomeration economic effects, gradually driving the GDP development of nearby areas. On the whole, Guangdong Province has formed an economic pattern driven by agglomeration and expansion, with the Pearl River Delta as the core of development and expanding the Spillover effect.



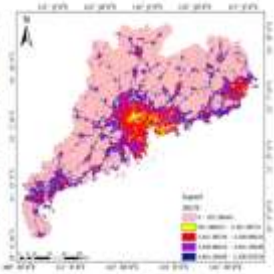


***Figure 5 Spatial Distribution of GDP in 2012 Figure 6 Spatial Distribution of GDP in 2021***

Using spatialized data from 2012 and 2021, calculate the overall GDP growth and growth rate of Guangdong Province. The relationship between growth rate and growth volume is represented by low increment, medium increment, and high increment (Table 7 and Figure 7).

***Table 7 GDP Increment Representation of Guangdong Province***

| Growth amount (100 million yuan) | Incremental type |
|---|---|
| 0 - 618.316079 | Low Increment |
| 618.3160791 - 1,892.695244 | Medium Increment |
| 1,892.695245 - 3,212.527936 | High increment |

From the spatial distribution map of GDP increment in Guangdong (Figure 7), it is found that the Pearl River Delta region exhibits a medium increment pattern. The GDP along its outer ring shows a high incremental change. Dense high increment areas appear on the east and west wings. The spatial distribution of GDP increment in the western wing is similar to that of the Pearl River Delta region, both radiating outward from the core development area (Cheng, 2019). In addition to expanding and developing in the core areas, the GDP of the eastern wing has also experienced rapid development in coastal areas. The GDP in mountainous areas is only a small portion of scattered areas with medium to high increments, while most areas still have low increments.

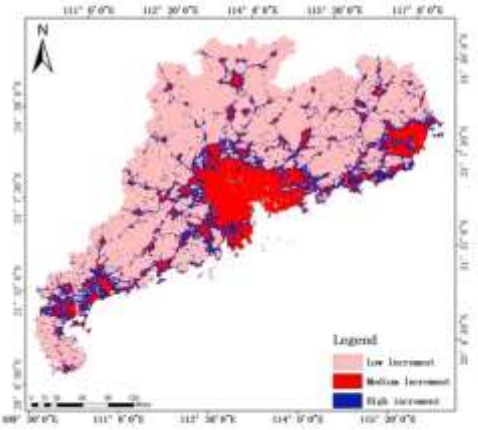



***Figure 7 Spatial Distribution of GDP Increment in Guangdong Province in 2021***

### *4.2.2. Regional Spatial Analysis*

This study uses the Guangdong Provincial Statistical Yearbook to classify regions and extracts masks from the spatial distribution of GDP in Guangdong Province in 2012 and 2021, resulting in the spatialized distribution maps of GDP in four regions. From the extracted analysis chart, the differences in economic growth and decline among different regions can be obtained and visualized.

#### *(1) Spatialization Analysis of GDP in the West Wing*

The GDP increment and growth rate of the western wing (Table 8) show that the GDP increment of Zhanjiang and Maoming is large, with growth rates exceeding 100%, and the growth rate is relatively fast. Compared to Zhanjiang and Maoming, Yangjiang lags slightly behind in terms of increment and growth rate, making it a relatively weak area for economic development in the West Wing.

***Table 8 GDP Increment and Growth Rate of the West Wing (in 100 million yuan)***

| Administrative District | 2012 year | 2021 year | Increment | Growth rate |
|---|---|---|---|---|
| Zhanjiang | 1789.0 | 3712.56 | 1923.56 | 107.5 % |
| Maoming | 1701.40 | 3904.63 | 2203.23 | 129.5 % |
| Yangjiang | 797.10 | 1535.02 | 737.92 | 92.6% |

Spatial analysis shows that the spatial change of GDP in the West Wing region is significant (Figure 8), with a rapid growth trend. In 2012, the southern part of Maoming on the west wing and the northern part of Zhanjiang showed a strip-shaped distribution of economic core development areas, while the economy of Yangjiang showed a small agglomeration with few economic connections. Compared to 2021, the GDP of the southern part of Maoming and the northern part of Zhanjiang showed a most dense form, with a spatially clustered and expanded form. From Zhanjiang to Yangjiang, Maoming was connected, and a small area of thin lines gradually expanded into a patchy aggregation form.

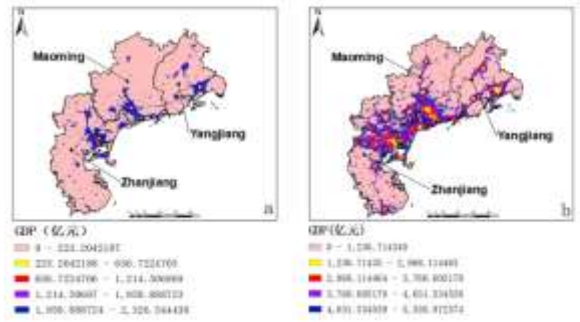



***Figure 8: Spatial distribution of GDP in the West Wing in 2012 (a) and 2021 (b)***

In addition, from the spatial distribution of GDP increment in 2021 on the West Wing (Figure 9), the concentrated areas with high increment and growth rate are mostly in the southern part of Maoming, the northern part of Zhanjiang, and the central part of Yangjiang. There is a large area of medium increment connecting Maoming and Zhanjiang, with obvious high increment in its outer ring. Yangjiang has two large mid to incremental regions, with a certain economic development momentum.

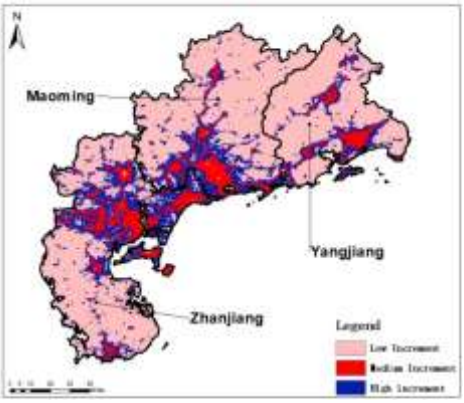



*Figure 9: Spatial Distribution of GDP Increment in the West Wing in 2021*

***(2) Spatial Analysis of GDP in the East Wing***

According to the GDP increment and growth rate of the East Wing (Table 9), Shantou and Jieyang are economically developed areas in the East Wing, while Shanwei has the highest GDP growth rate and is a new development area for the East Wing economy. Benefiting from the development of the coastal economy, Shanwei has achieved a growth rate of 138% despite a small increase in GDP, which is the highest growth rate in the East Wing. In addition, the GDP growth rates of Shantou and Chaozhou have both reached over 100%, indicating strong GDP growth momentum.

*Table 9 GDP Increment and Growth Rate of the East Wing (100 million yuan)*

| Administrative District | 2012 year | 2021 year | Increment | Growth rate |
|---|---|---|---|---|
| Shantou | 1433.80 | 3017.44 | 1583.64 | 110.5 % |
| Chaozhou | 656.10 | 1312.98 | 656.88 | 100.1 % |
| Jieyang | 1237.70 | 2260.98 | 1023.28 | 82.7% |
| Shanwei | 553.7 | 1322.02 | 768.32 | 138.8 % |

Spatial analysis shows that the spatial change of GDP in the East Wing region is very significant (Figure 10). In 2012, the core economic region of the East Wing was concentrated in the southern part of Chaozhou, the northern part of Jieyang, and the entire Shantou region, with close regional economic connections, but Shanwei appeared relatively sparse. In 2021, the economic agglomeration areas of Chaozhou, Jieyang, and Shantou continue to expand, and the southern part of Shanwei presents a form of strip-dense spatial distribution. Obviously, the southern coastal area of Shanwei has become a new development trend for the eastern wing economy.

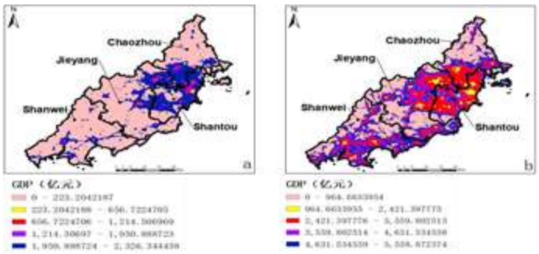



*Figure 10 Spatial Distribution of GDP in the East Wing in 2012 (a) and 2021 (b)*

In addition, from the spatial distribution of GDP increment in the East Wing in 2021 (Figure 11), Jieyang has a small portion of areas with medium to high GDP increment, but many areas have low GDP increment. Shantou has shown good economic growth performance, with almost all of the city's GDP showing moderate growth. There is a significant difference in the speed of economic growth between the north and south of Chaozhou, with the majority of GDP growth concentrated in the south. But the core areas of Jieyang, Chaozhou, and Shantou have converged into a large area, forming a new area of integration.

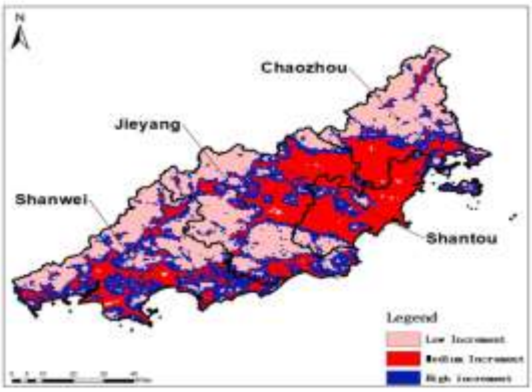



*Figure 11 Spatial Distribution of GDP Increment in the East Wing in 2021*

***(3) Spatial Analysis of GDP in Mountainous Areas***

According to the GDP increment and growth rate in mountainous areas (Table 10), the GDP increment of Shaoguan, Meizhou, Qingyuan, Heyuan, and Yunfu in these five regions did not exceed 80 billion yuan. Among them, the GDP growth rate of Yunfu is the highest in mountainous areas, but it is only 116.243 billion yuan, belonging to the economically backward region. The GDP growth rate of Qingyuan is the lowest, but due to the largest GDP base in 2012, Qingyuan remains the most developed region in the region, but the growth rate is the slowest.

*Table 10 Increment and Growth Rate of GDP in Mountainous Areas (100 million yuan)*

| Administrative District | 2012 year | 2021 year | Increment | Growth rate |
|---|---|---|---|---|
| Shaoguan | 779.70 | 1563.93 | 784.23 | 100.6 % |
| Meizhou | 724.80 | 1318.21 | 593.41 | 81.9% |

| | | | | |
|---|---|---|---|---|
| Qingyuan | 1268.70 | 2032.00 | 763.3 | 60.2% |
| Heyuan | 575.60 | 1294.57 | 718.97 | 124.9% |
| Yunfu | 481.30 | 1162.43 | 681.13 | 141.5% |

Spatial analysis shows that the spatial change of GDP in mountainous areas is not significant (Figure 12). That is, economic development lacks clustering. In 2012, the core economic development of Shaoguan, Yunfu, Qingyuan, Heyuan, and Meizhou was mostly scattered. By 2021, there still without presenting economic-intensive areas like the western or eastern wings in the mountainous areas, only a small portion of which will be scattered and concentrated.

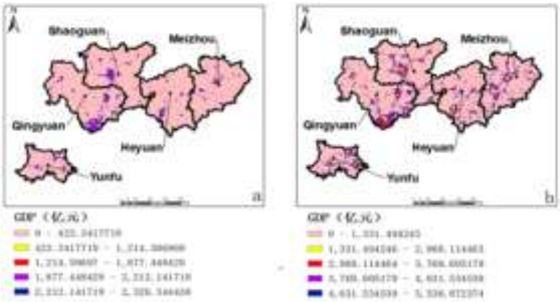



*Figure 12 Spatial Distribution of GDP in Mountainous Areas in 2012 (a) and 2021 (b)*

In addition, according to the spatial distribution of GDP increment in mountainous areas in 2021 (Figure 13), the GDP increment in most regions is low, and only a small portion of the five prefecture-level cities have medium increment regions, while the distribution of high increment regions shows a scattered pattern. No contiguous areas with medium or high increments.


*Figure 13 Spatial Distribution of GDP Increment in Mountainous Areas in 2021*

***(4) Spatial Analysis of GDP in the Pearl River Delta***

According to the GDP increment and growth rate of the Pearl River Delta (Table 11), the GDP growth rate in Zhongshan is too low and the increment is also the smallest, which poses certain obstacles to economic development. Secondly, although Zhaoqing has a high growth rate of 109.5%, its total GDP is too small, making it an economically underdeveloped region in the Pearl River Delta. Shenzhen and Guangzhou have a relatively high total GDP, accounting for first and second place respectively, and also have a high growth rate. They are critical components of the Pearl River Delta economy.

***Table 11 GDP Increment and Growth Rate of the Pearl River Delta (100 million yuan)***

| District | 2012 year | 2021 year | Increment | Growth rate |
|---|---|---|---|---|
| Guangzhou | 12,560.70 | 28,839.00 | 16278.3 | 129.6% |
| Shenzhen | 11,358.30 | 32,387.68 | 21029.38 | 185.1% |
| Foshan | 6,788.20 | 12,698.39 | 5910.19 | 87.1% |
| Zhuhai | 1,418.50 | 4,045.45 | 2626.95 | 185.2% |
| Dongguan | 4,698.90 | 11,200.32 | 6501.42 | 138.4% |
| Zhongshan | 2,225.30 | 3,631.28 | 1405.98 | 63.2% |
| Huizhou | 2,172.80 | 5,401.24 | 3228.44 | 145.6% |
| Jiangmen | 1,879.40 | 3,773.41 | 1894.01 | 100.8% |
| Zhaoqing | 1,291.20 | 2,705.05 | 1413.85 | 109.5% |

Spatial analysis shows that the spatial change of GDP in the Pearl River Delta region is significant (Figure 14). In 2012, the core economic regions of the Pearl River Delta gathered in large areas, mainly Guangzhou, Dongguan, Shenzhen, Zhuhai, Zhongshan, and Foshan, with close spatial economic connections. However, Zhaoqing, Huizhou, and Jiangmen are far from the core economic regions and only have close economic connections in the peripheral areas. In 2021, the economy was radiating outward, causing significant changes in the economic regions of Jiangmen and Huizhou, but the economic connection with Zhaoqing remained weak.

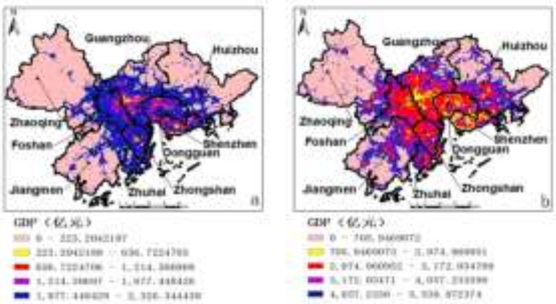


***Figure 14 Spatial Distribution of GDP in the Pearl River Delta in 2012 (a) and 2021 (b)***

In addition, according to the spatial distribution of GDP increment in the Pearl River Delta in 2021 (Figure 15), the growth rates of Guangzhou and Shenzhen are relatively high, but the growth rate is only moderate. Under the outward radiation of the core economic region of the Pearl River Delta, Huizhou and Jiangmen have seen their GDP increase significantly. Guangzhou, Dongguan, and Shenzhen have experienced scattered low increments internally, especially in Shenzhen. Zhaoqing still focuses on low increment, but there are scattered high increment areas within it, which are characterized by scattered characteristics but cover a wider area.


***Figure 15 Spatial Distribution of GDP Increment in the Pearl River Delta in 2021***

## 5. CONCLUSION

With the development of the application of night light RS data, this study uses NPP-VIIRS data as the study material. Through imagery processing technology, model construction, correlation fitting, and GDP spatial visualization analysis, the comprehensive economic development status of Guangdong is analyzed, and the following conclusions are obtained.

(1) Through four correlation fitting models, it has been proven that the nighttime light RS data has correlation and interpretable significance with the GDP growth of Guangdong, and can be used as an observation indicator for economic development.

(2) Regional spatial analysis

- The spatial changes in GDP in the West Wing are significant, with an overall high increase in GDP.

  Zhanjiang and Maoming have a large GDP increment and a fast growth rate. Yangjiang is a region with relatively weak economic development in the West Wing, but it has a relatively large area with medium to incremental growth and has a certain momentum of economic development.

- The spatial changes in GDP on the East Wing are very significant, with an overall high increase in GDP.

  The southern part of Chaozhou, the northern part of Jieyang, and the entire Shantou region are the economic centers of the East Wing, forming a trend of regional integration. However, the southern coastal area of Shanwei presents a spatial pattern of dense distribution in strips, with the highest GDP growth rate, which is a new development trend of the East Wing economy.

- The spatial changes in GDP in mountainous areas are not significant, and the overall GDP increment is the lowest. The core economic development in the five regions of Shaoguan, Yunfu, Qingyuan, Heyuan, and Meizhou is mostly scattered, with slow development and a lack of clustering.

- The spatial changes in GDP in the Pearl River Delta are significant, with the highest overall GDP increment.

  Guangzhou, Dongguan, Shenzhen, Zhuhai, Zhongshan, and Foshan are the core economic regions of the Pearl River Delta, among which Shenzhen and Guangzhou are critical components of the Pearl River Delta economy, but there is a scattered low increment situation internally. The economic regions of Jiangmen and Huizhou have undergone significant changes, but like Zhaoqing, their economic connections are still weak.

(3) The overall spatial analysis results show that the economic core of Guangdong radiates intensively in the Pearl River Delta and expands the Spillover effect. The East and West Wings also form agglomeration and expansion drive, while the mountainous areas develop slowly and show a backward economic pattern. From the spatial distribution and growth rate of GDP increment, the Pearl River Delta region presents a situation of medium increment. In its outer ring, there is a high incremental change. The spatial distribution of GDP increment in the West Wing is similar to that in the Pearl River Delta region, while the economy in the East Wing is developing rapidly in the coastal areas. There are only a few areas with medium to high GDP increments in mountainous areas, mainly with low increments.

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