Knowledge Map Analysis on the Application of Nighttime Light Data in Chinese Academic Research

Yahong Luo

Guangdong University of Foreign Studies Library. Guangzhou 510006, China.

School of International Studies/Academy of Overseas Chinese Studies. Jinan University. Guangzhou 510632, China.

Robin310@163.com

Abstract

This paper made a comprehensive and systematic analysis of the application of DMSP/OLS and NPP/VIIRS nighttime light data in Chinese academic research. A literature metrological analysis was carried out. All relevant literatures collected by database CNKI（China National Knowledge Infrastructure） were searched and screened. In addition, a research content analysis was conducted, based on the representative papers of the relevant research. The applied research of nighttime light data involved a wide range of fields, most of which were interdisciplinary, some of them stressed the importance of the optimal utilization and new progress of nighttime light data. The results indicated a trend that the application of nighttime light data has a broad prospect. It also showed a tendency of comprehensive application with other types of statistical data, index information and analysis tools. The application of nighttime light data in academic research also presented a sustainable development trend.

Keywords

DMSP/OLS,NPP/VIIRS, Nighttime light data, Applied research, Knowledge map analysis.

1. Introduction

1.1 The DMSP/OLS Data and the NPP/VIIRS Data.

The Defense Meteorological Satellite Program（DMSP）is a Department of Defense program run by the Air Force Space and Missile Systems Center of United States. Each DMSP satellite has a 101 minute, sun-synchronous near-polar orbit at an altitude of 830km above the surface of the earth. The visible and infrared sensors (OLS) collect images across a 3000km swath, providing global coverage images twice per day. The combination of day/night and dawn/dusk satellites allows monitoring of global information every 6 hours. [1]

The NPOESS Preparatory Project（NPP）is the result of a partnership between NASA, NOAA and the Department of Defense. NPP satellite orbits the Earth from North Pole to the South Pole about 14 times per day. Images of Earth were created using data from the Visible Infrared Imaging Radiometer (VIIRS) on the NOAA/NASA Suomi NPP (National Polar-orbiting Partnership) satellite. [2]

DMSP/OLS data and NPP/VIIRS data are widely used satellite data. They are mainly used in related fields of meteorology, oceanography and solar terrestrial physics. In addition, the application of nighttime light data of DMSP/OLS and NPP/VIIRS has gradually attracted the attention of other research fields due to it's stability, reliability, accessibility and versatility.

1.2 A Profile of the application of nighttime light data in academic research.

As stated in the NPP brochure: understanding, monitoring and predicting the course of long-term climate change and short-term weather fluctuations remain tasks of profound importance. Economic competitiveness, human health and welfare, and global security all depend in part on our ability to understand and adapt to environmental changes.

Therefore, DMSP/OLS data and NPP/VIIRS data are not only applicable to natural science research, but also can play a role in the research of other fields. Rsearch results show that DMSP/OLS data and NPP/VIIRS data are widely used in urbanization, human activities, energy consumption, ecological environment monitoring and other related studies. Also it can be applied in some interdisciplinary research. For example, studies on poverty indicators, land use, development policy preferences, spatial patterns, wars and their consequences, etc.

According to the results of a study, from 1997 to 2017, the Web of Science database included a total of 342 articles about the application of nighttime light data. Among the researchers in 15 countries, Chinese researchers contribued the largest number of the papers, with 157 articles published. American researchers published 142 articles. However, Americans were the first to conduct research on nighttime light data, with high citation rate and mediating centrality. The number of relevant research publication was not large in other countries, such as Japan, India, Australia, the United Kingdom, Italy, Sweden etc. The statistical analysis showed that the international research on nighttime light data began in 1997. Since 2005, relevant research have shown an obvious upward trend. Till now, the overall research heat is still in a hot state. [3]

2. The literature source and analytical method.

2.1 The source and quantity .

There were a large number of Chinese research applying nighttime light data, with diverse perspectives and a wide range of disciplines involved. However, there was barely any overall summary or analysis on the application of nighttime light data in Chinese academic research. Based on the existing research results, this paper investigated the current situation of Chinese research on the application of nighttime light data. The main purpose of the paper was to obtain the development trend of relevant research.

The sources of this study were relevant Chinese academic papers collected by one of the most widely used comprehensive database CNKI（China National Knowledge Infrastructure）. The key words nighttime light data, DMSP/OLS, NPP/VIIR were searched respectively. After duplicate checking and content screening of the data, it was concluded that the most relevant literatures totaled 328 (retrieval date: May 25, 2019), with a time span of 15 years (2004-2019).

2.2 The analytical methods.

This paper was mainly a quantitative study using literature metrology, data statistics, knowledge mapping and other analytical methods. By using some data visualization tools, document management tools, knowledge mapping software and other tools，this paper analyzed and visualized the research results of relevant Chinese research.

Meanwhile, representative Chinese research results were selected by every 5 years for qualitative research. Content analysis of relevant literature was carried out from the aspects of the earliest researchers, the most typical studies, the results with the highest citation rate, the sources of publications, the latest research progress and so on.

The main viewpoints and influences of relevent research results were summarized, and the trend of applied research of nighttime light data is obtained, which could provide reference for similar research and interdisciplinary research.

3. Status of the application of nighttime light data in Chinese academic research.

3.1 An visualized analysis of the research status.

3.1.1 The number of published papers and the trend.

Chinese research results of the application of nighttime light data began to appear in 2004. Figure 1 showed the annual publication numbers and the publication trend of Chinese relevant research. It indecated that the number of related publications was not large from 2004 to 2013. Since 2014, the

number of related research publications has shown a significant growth trend. Also the research trend is developing continuously.

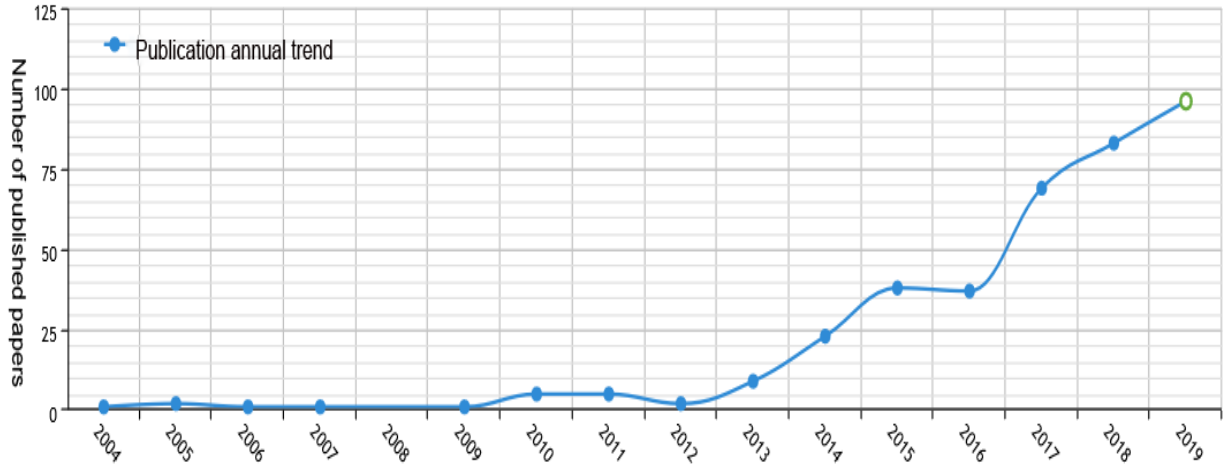

Fig. 1 The annual number of published papers on the applied research of nighttime light data in China

3.1.2 The discipline classification and publication sources.

According to the relevant literature collected by CNKI, there was a wide range of Chinese research fields using nighttime light data, involving all kinds of research fields. In terms of the publications number, the top ten research fields or disciplines were: urban economics, geomatics, regional economics, urban and rural planning, environics, national economics, sociology, control engineering, general technology, and agricultural economics. Figure 2 also showed other fields involved, which indicated that nighttime light data has been applied by researchers in social science research and interdisciplinary research fields.

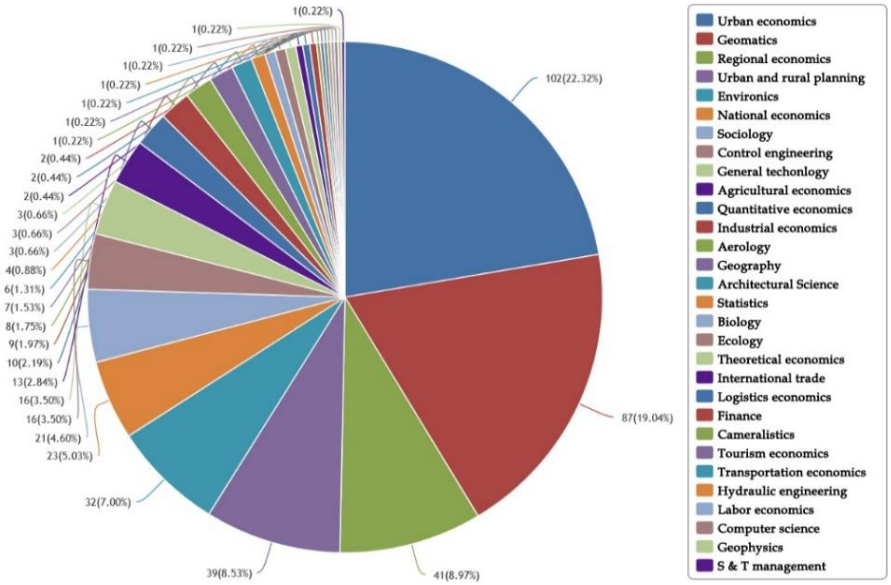

Fig. 2 The discipline classification of published papers on the application of nighttime light data in China

The publishing sources of relevant research could reflect the correlation between publications and research results. As it showed in figure 3, the top ten publishing sources in terms of the papers number were Science of Surveying and Mapping, Journal of Geo-Information Science, Remote Sensing Technology and Application, Resources and Environment in the Yangtze Basin, Geomatics & Spatial Information Technology, Acta Geographica Sinica, Remote Sensing for Land & Resources, Remote Sensing Information, Geography and Geo-Information Science, Geospatial Information. It indicated that the applied research of nighttime light data was concentrated in publications related to surveying and mapping, remote sensing, geography, land resources etc.

Other disciplines or studies such as economics, environics, urban and rural planning, society and engineering technology were also closely related, with a large number of publications. But it showed a feature of intersection, dispersion and extension of the topics.

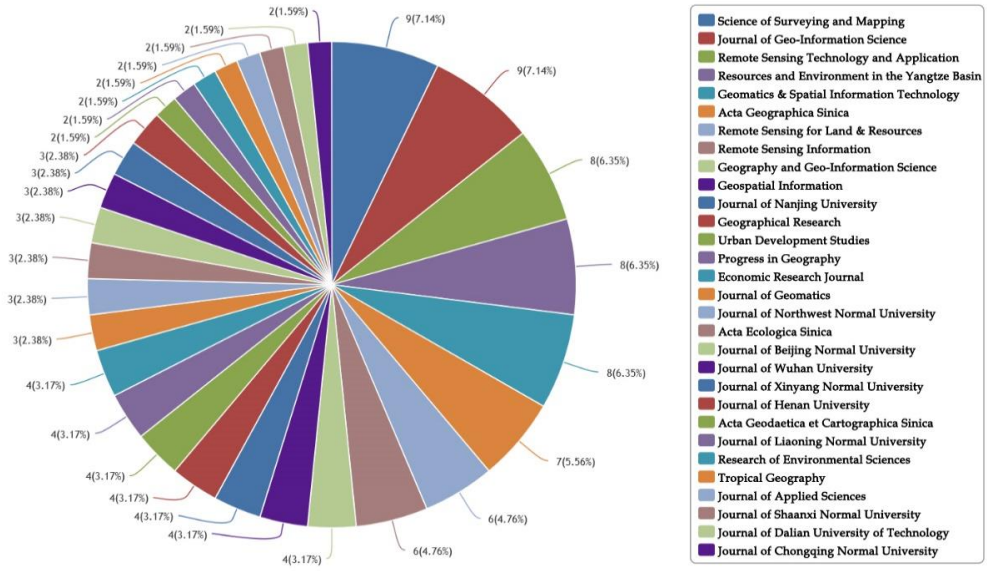

Fig. 3 The source of published papers on the application of nighttime light data in China

3.2 Analysis of keywords co-occurrence, cluster and information nodes.

3.2.1 Keywords co-occurrence matrix analysis.

As Figure 4 showed, the keywords in the Chinese research results of the application of nighttime light data mainly included: Nighttime light data, DMSP/OLS, Nighttime light, Urbanization, NPP/VIIRS Images, China, GDP, Remote Sensing, Urban expansion, Population, Spatial pattern, Land use, Regression analysis, Spatial-temporal pattern, Population spatial distribution, etc. Among them, the keywords nighttime light data and DMSP/OLS co-occured most frequently, followed by the keywords nighttime light and DMSP/OLS, which reached 13 and 12 times respectively. It indicated that there were many researches on the application of nighttime light data based on DMSP/OLS data. In addition, the co-occurrence of key words urbanization with nighttime light data and DMSP/OLS was also quite frequent, 8 and 7 times respectively. Key words GDP and night light data co-occured 8 times. Keywords spatial pattern and DMSP/OLS co-occured 6 times. It indicated that there was a high degree of DMSP/OLS nighttime light data used in urbanization research, economics research and spatial pattern research, and relevant research fields have a considerable degree of intersection.

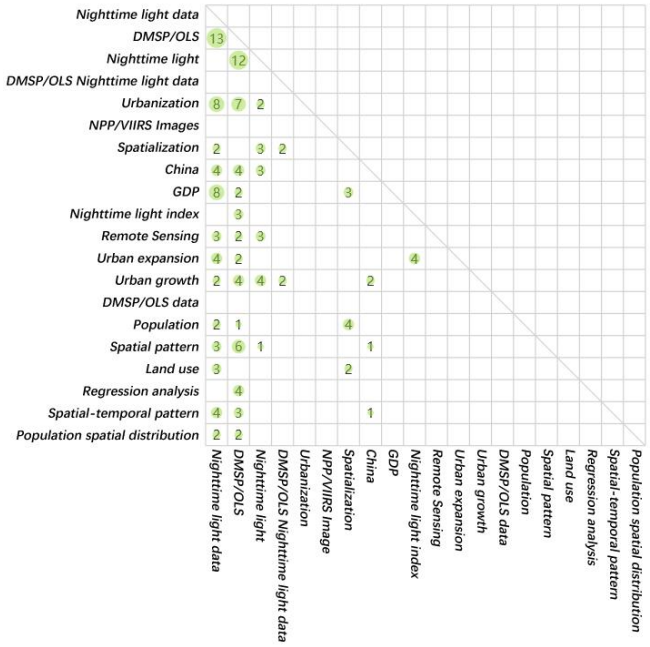

Fig. 4 The key words co-occurrence matrix of published papers on the application of nighttime light data in China

3.2.2 Keywords cluster analysis.

Figure 5 was the keywords clustering view of the Chinese research results on the application of nighttime light data. It showed a network of the keywords of the relevant papers, with six clusters of key words as following: nighttime light data, remote sensing, land use, urbanization, urban agglomeration in the middle reaches of the Yangtze river, DMSP/OLS nighttime light data, standard deviation ellipse. It proved that the relevant research were more concentrated in the above aspects. Meanwhile, it also showed that relevant research also involved energy consumption, temporal and spatial distribution, urbanization light index, poverty index, population spatialization, support vector machine, regional disparity and other related research. In addition, the key words in the network also appeared some name of a city or a region, such as the Yangtze river delta, Zhejiang province, Wuhan, Nanjing, Xiamen, LiuPanShan, showing the geographical location of the relevant research involved. Most of these place were fast developed and urbanized, except LiuPanShan which was a mountain area.

All in all, these results indicated that nighttime light data could be applied in various studies. There was aggregation and dispersion between relevant research results.

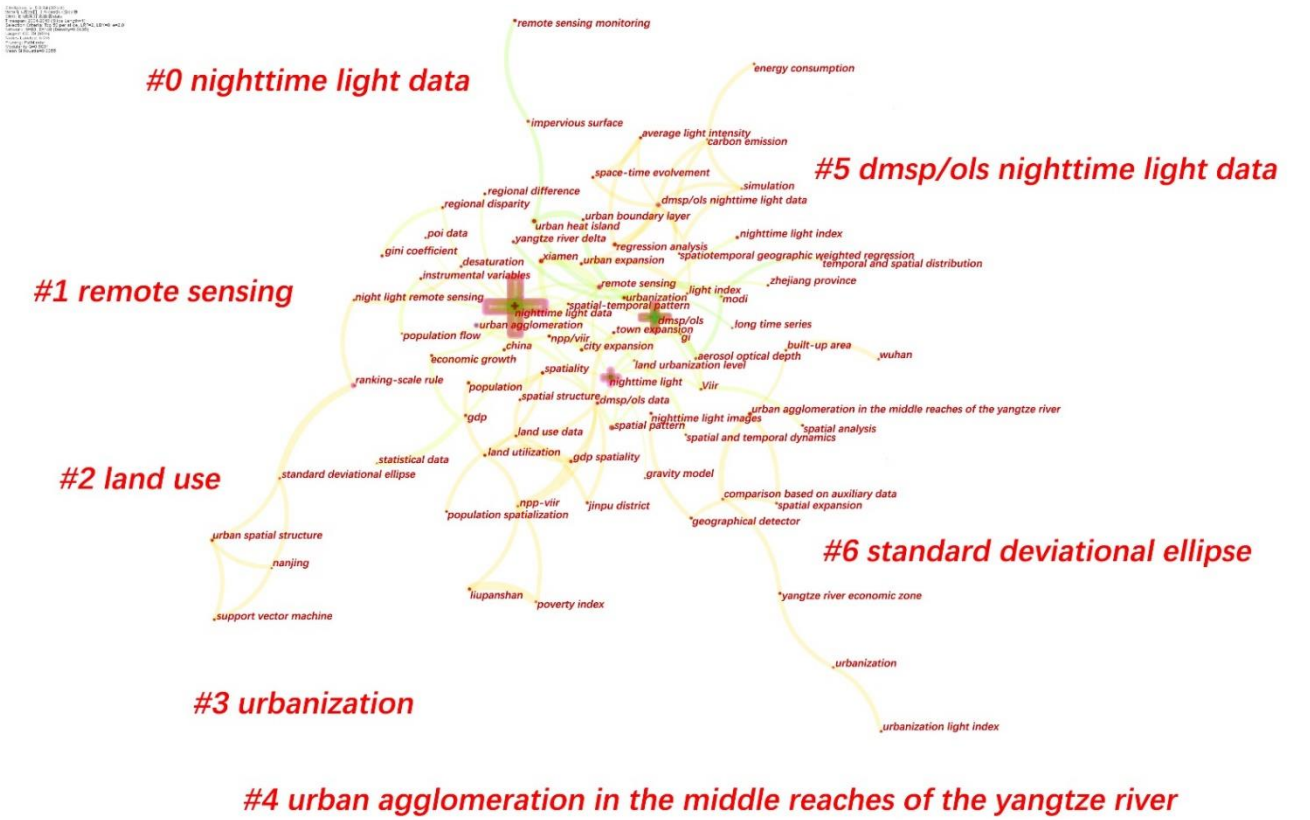

Fig. 5 The keywords clustering view of the published papers on the application of nighttime light data in China

3.2.3 Keyword information node analysis.

Figure 6 was the map of keywords node information of research results on the application of nighttime light data in China, displaying in a timeline view from 2004 to 2019. Nighttime light data was first used in urbanization research in 2004. From 2004 to 2010, relevant research focused on urbanization, night light data, remote sensing and other aspects. Since 2010, the number of relevant research in China has increased gradually. As square 1 in figure 6 showed, from 2010 to 2013, the information nodes were mostly concentrated on keywords nighttime light, urban agglomeration, and DMSP/OLS, which were the most relevant research in this period.

The map showed dense links and nodes in the years around 2016. As square 2 in figure 6 showed, studies on population spatialization, GDP, land use, DMSP/OLS data, town expansion, poverty index, etc. had a strong correlation with each other. Meanwhile, two large information node groups in square 3 showed that studies on built-up area, spatial expansion, nighttime light imagery, geographical detector, urban agglomeration in the middle reaches of the yangtze river, comparison based on auxiliary data, ect. had a strong correlation with each other. And studies on spatiotemporal geographic weighted regression, space-time evolvement, average light intensity, DMSP/OLS nighttime light data, urban expansion, light index, regression analysis, ect. had a strong correlation with each other.

In addition, according to figure 6, more and more information nodes of relevant research results have been emerged since 2016, including gini coefficient, regional disparity, gravity model, remote sensing monitoring, support vector machine, POI data, long time series etc. It also showed the feature of diffusivity, with the keyword information line also extended continuously. In figure 6, the information nodes and links showed the overall shape of "broom", illustrated the diffusion degree of the relevant research.

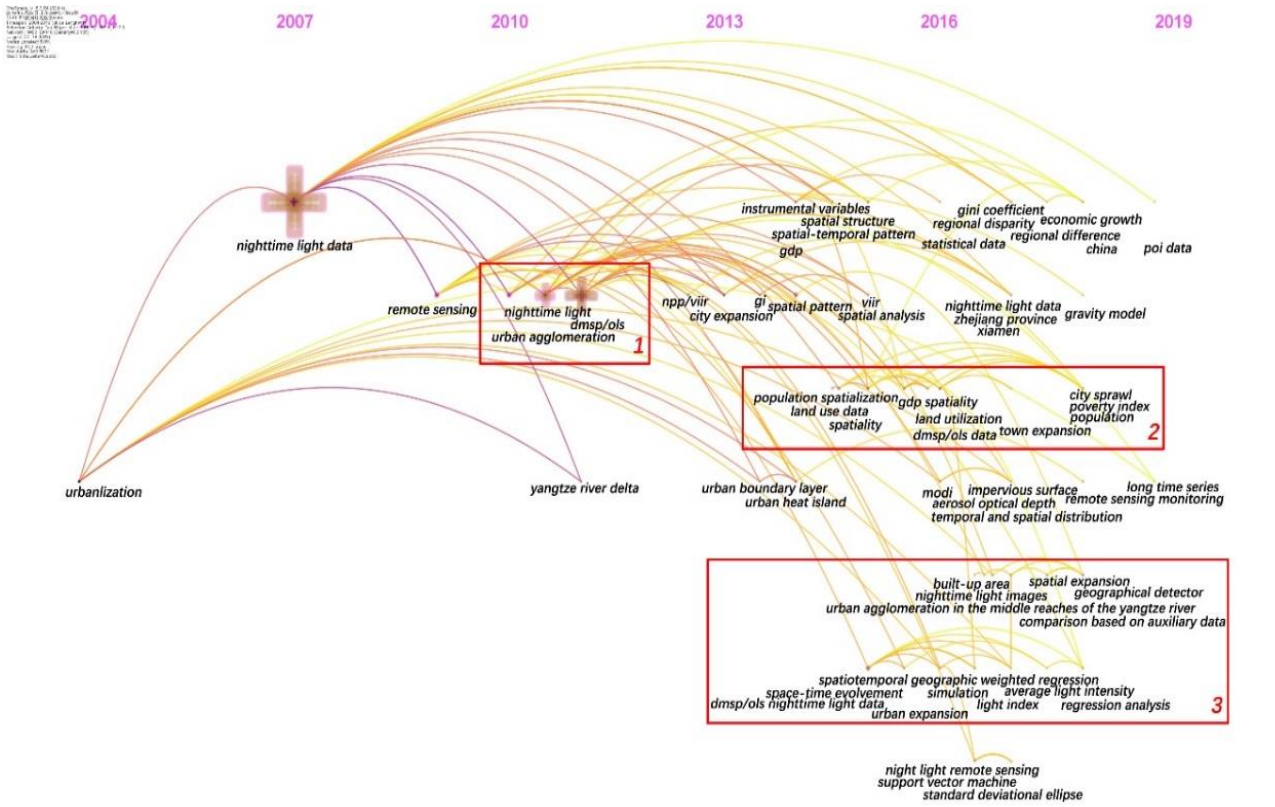

Fig. 6 The timeline view of keywords node information of the published papers on the application of nighttime light data in China

3.3 Representative scholars, papers and viewpoints in relevant Chinese researches.

According to the relevant literatures collected by CNKI, papers on the application of nighttime light data in China emerged in 2004. Figure 7 showed the representative scholars of relevant research and the number of their published papers. In terms of the number of published papers, Liu Xiuyan had the largest number of relevant achievements, with 7 articles. He mainly applied nighttime light data for empirical research in the field of economics. There were some of his papers with high citation rate, such as The Truth of China Economic Growth:Evidence from Global Night-time Light Data(2015), Does Urban Sprawl Lead to Urban Productivity Losses in China? Empirical Study Based on Nighttime Light Data(2015), Urban spatial structure and regional economic efficiency: on the model selection of China's urbanization development path(2017).

Other scholars with considerable achievements were Chen Jin, Liu Huajun and Peng Jian. Each of them published 5 articles. The most cited papers in their works were Modeling Population Density of China in 1998: Based on DMSP/OLS Nighttime Light Image(Chen,2005), Regional Inequality and Stochastic Convergence in China(Liu,2017), Hierarchical structure and spatial pattern of China's urban system: Evidence from DMSP/OLS nightlight data(Peng,2014).

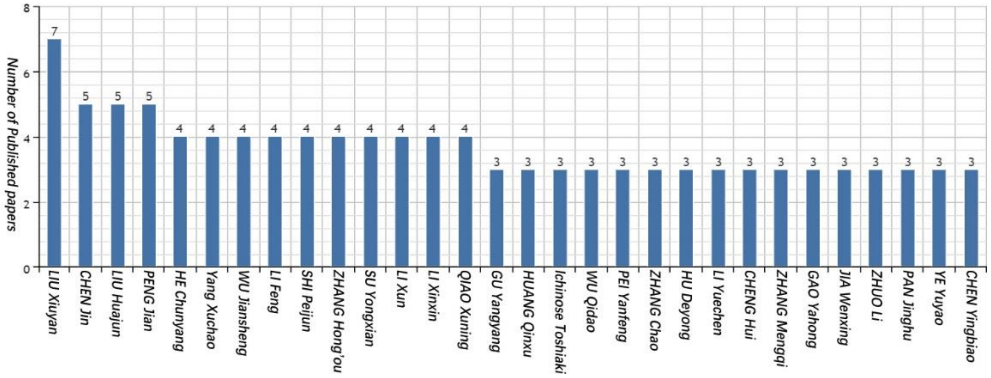

Fig. 7 Representative scholars and the number of their published papers

In addition, according to the time of publication, the rate of download and citation, the source of publication, the discipline or topic, latest progress and other aspects, about 10% of the total number of the relevant papers have been selected. By content analyzing and viewpoint summarizing, the main conclusions and influence of these representative papers were concluded, which was conducive to a comprehensive understanding of the current situation and the trend of relevant research in China.

3.3.1 Main contents and conclusions of relevant research results before 2010.

From 2004 to 2010, there were around 10 relevant papers published in China. The main research contents focused on population, urbanization and some other topics. Zhuo L, Chen J. et al. (2005) applied nighttime light data to the research on population density. Their study indicated that the 1-km resolution non-radiance calibrated DMSP/OLS nighttime lights image had the potential to provide population density estimation at 1-km grids. [4] Cao L.Q, LI P.X. et al. (2009) analyzed the relationship between the DMSP/OLS nighttime light data and the population of each county of Hubei province. They established the corresponing linear model to estimate the 76 urban population of the year 2002 and concluded results with accuracy of 98.94%. Their study showed that the DMSP/OLS nighttime light data could be well used to make short-term estimates of urban population. [5]

There were some studies of urbanization before 2010, applying nighttime light data. He C.Y, LI J.G. et al. (2005) derived urban information from DMSP/OLS data in 1992, 1996 and 1998. With these data, they developed three basic urbanization models of polygon-urbanization, line-urbanization and point-urbanization in urban agglomerations from view point of spatial analysis. [6] Zhang X.F. (2010) extracted the spatial information of urbanization in Inner Mongolia from the 1996-2008 years of DMSP/OLS data. He concluded that there was obvious increasing of urban expansion in Inner Mongolia from 1996 to 2008. But there was a difference in the proportion of urban expansion type and structure in all cities of Inner Mongolia. [7]

Relevant researches before 2010 were conducted from a comparatively narrow perspective. However, Chinese scholars realized the value of DMSP/OLS nighttime light data. They accurately grasped the function and meaning of this new types of data. The application of nighttime light data in population, urbanization and other related studies had innovative significance at that time, which laid a foundation for subsequent studies.

3.3.2 Main contents and conclusions of relevant research results from 2011 to 2015.

Since 2011, the number of research results on the application of nighttime light data in China has gradually increased, covered topics of various fields such as geography, geomatics, economics and environics.

(1) Researches related to urban built-up area and spatial pattern of urban system

There were a considerable number of studies has been stemmed from the research of urbanization. These studies were maining quantitative scientific analysis based on nighttime light data, combined with perspectives of geomatics, geographic space, statistics or other disciplines and research methods. Shu S, Yu B.L. et al. (2011) considered that DMSP/OLS nighttime light data has been widely utilized to derive the urban built-up areas. Compared and analyzed four kinds of methods: Empirical Thresholding, Sudden Change Detection, Statistics assisted Thresholding, and TM-assisted Thresholding, the researchers adopted Sudden Change Detection method to derive the urban built-up areas of Shanghai from 2000 to 2006. [8]

Wu J.S, Liu H. et al. (2014) built a gravity model based on DMSP/OLS nighttime light data to measure the interaction intensity among 341 cities in China. They concluded that China urban system were divided into 2 national urban systems, 8 regional urban systems, and 31 provincial urban systems. It further proved that it was feasible and scientific to analyze hierarchical structure and spatial pattern of urban system based on DMSP/OLS nighttime light data. [9]

By applying the analytical methods including city rank-size rule, spatial autocorrelation analysis and the weighted standard deviation ellipse, Zhang C, Wang C.Y. et al. (2015) systematically analyzed

the spatial structure and changing features of the city system in the Yangtze economy belt, based on the DMSP/OLS nighttime light data of 1996-2010. Their conclusion was that the city system in the area had a core-peripheral structure, relatively dense in the east and sparse in the middle and the west, with many uncertainties in the borders and spatial structures of city groups. [10]

(2) The application of nighttime light data in researches related to GDP

There was an increase of published papers of relevant researches on the application of nighttime light data in the field of economics, among which was the research on GDP related issues. Han X.D, Zhou Y. et al. (2012) explored the potential for estimating the GDP, by correlation analysis and regression analysis of relationship between the spatial patterns of nighttime light imagery and GDP in China. As the result, 1-km grid GDP map of China based on nighttime light data showed the obvious advantage to reflect complete details and characteristics of the national secondary industry and tertiary industry distribution. [11]

Wang Q, Yuan T. et al. (2013) established a GDP spatial model by using the regression analysis method based on analysis of the relationship between nighttime light intensity and GDP. Moreover, spatialization simulation at province-level in GIS platform was carried out. They held it is feasible that nighttime light satellite imagery applied in economic analysis. [12]

Xu K.N, Chen F.L. et al. (2015) estimated the rate of Chinese real economic growth using the global nighttime light data. It was an empirical study of the relationship between GDP and nighttime light with Chinese provincial panel data during 1992 to 2012. They argued that the nighttime light is a good proxy of GDP. They estimated the rate of Chinese real economic growth according to the fitted lights and official GDP statistics. It showed that the two kinds of data are not completely in consistent both in national and regional data. [13]

(3) Researches related to energy consumption and carbon emission

Chinese researchers realized that nighttime light data can be applied to the study of energy consumption, carbon emission and other related issues. Su Y.X, Chen X.Z. et al. (2013) estimated the China's city-level carbon emissions from 1992 to 2010 based on the DMSP/OLS nighttime light images. Their studies showed that the national CO2 emissions grew continually, but varied from place to place. They held that energy structures, energy efficiencies, industrial structures were the three main factors influencing the carbon intensities. [14]

Wu J.S, Niu Y. et al. (2014) simulated the spatiotemporal pattern of energy consumption among the cities of China from 1995 to 2009 in a prefecture-level city scale, based on DMSP/OLS nighttime light data. They held that DMSP/OLS nighttime light data reflected the spatial and temporal dynamics of energy consumption more reliably. They found that the energy consumption of most cities was lower in China from 1995 to 2009. Lower and middle intensity energy consumption area accounted for 72.66% of the country's total area. High intensity energy consumption areas were mainly located in the eastern part of China. [15]

(4) The application of nighttime light data to the research on haze

Along with the urbanization process, there were some Chinese researches concerning the environmental problems such as haze. Mao M.J, Yang X.C. (2015) investigated the influences of urbanization on climatic conditions, air pollutant concentrations and haze formation, based on nighttime light data combined with surface observational data. They found that serious haze pollution mostly occured in the northern part and the eastern coast of Zhejiang Province where urban development was fast and nighttime light was intensive. [16]

By using VIIRS nighttime light images and PM2.5 mass concentration data from March 20, 2014 to March 26, 2014 over Beijing, Li W, Zheng X.Q. (2015) analyzed the changing tendency of haze intensity and the spatial distribution of PM2.5 mass concentration with GIS spatial analysis. The result showed that the image features of VIIRS nighttime light data have close relationship with haze while its intensity changes from time to time. [17]

(5) Researches on DMSP/OLS data optimization

There were some studies on how to optimize nighttime light data from the technical perspective, combined with other tools, index, data etc. Zhou J.G, Chen Y.H. et al. (2014) proposed a systematic calibration procedure for DMSP/OLS nighttime light images of China. They constructed a calibration model based on ArcGIS desktop platform, which effectively eliminated the unstable lit pixels and the abnormal fluctuations appeared in DN values of the DMSP/OLS time series nighttime light images，and greatly enhanced the comparability and continuity of the data series. [18]

Zhuo L, Zhang X.F. et al. (2015) proposed a new urban index, i.e. the Enhanced Vegetation Index (EVI) adjusted nighttime light index, which combined MODIS EVI with nighttime light data. After some experiments and comparison, the researchers made an conclusion that the EVI adjusted nighttime light index can effectively reduce nighttime light saturation in urban centers and thus has great potential of wide range applications in the future. [19]

In short, the application of nighttime light data in Chinese academic research were becoming wider and wider from 2011 to 2015. The number of relevant research results also increased significantly, which reached a peak in 2015 (as Figure 1 shows). The applied research related to nighttime light data in China had a considerable accumulation both in quantity and in content.

3.3.3 Main contents and conclusions of relevant research results from 2016 till now.

Since 2016, the number of published papers related to the application of nighttime light data in China has further increased.The fields involved were mainly geomatics, geography, economics, environics etc. Considering the content of these results, some research had a certain degree of continuity. While some studies reflected the application of nighttime light data in new fields, disciplines or issues.

(1) The application of nighttime light data on the study of urban agglomeration, economic belt and spatial-temporal pattern

There were studies on urbanization, system spatial pattern, development pattern and other relevant issues, which applied nighttime light data, involving different scale of research auch as provinces, regions, cities etc. Yang Y, Li Y.J. et al. (2016) analyzed the similarities and differences of spatiotemporal dynamics of city size distribution among three urban agglomerations in Bohai Rim based on city primacy index, city Gini coefficient and rank-size rule, with the urban land data extracted from DMSP/OLS nighttime light data from 1992 to 2012.They found that urban land expanded quickly and the size-hierarchy of urban land raised quickly, and Multi-Core development pattern was initially apparent in Beijing-Tianjin-Hebei urban agglomeration. [20]

Zhong Y, Lin A.W. (2018) analyzed the spatial pattern of urban development in Yangtze River economic zone from 1992 to 2013, by using the Landsat satellite data, the comparison of auxiliary data and the FRAG STATS 4. 2 software. They found that the urbanization of the Yangtze River economic zone was rapid from 1992 to 2013, with characteristics of irregular and disorder. [21]

Li X, Zhu J. et al. (2019) explored the spatio-temporal pattern in Chinese economic development at different scales, using tools as DMSP/OLS nighttime light data, gravity center, standard deviation ellipse, and local Moran'I. They found that Chinese economic gravity center moved to the southeast from 2003 to 2013, but the moving distance was reduced year by year. [22]

(2) The application of nighttime light data on the study of poverty

There were some studies on the application of nighttime light data to poverty appeared in earlier stage. After 2012, DMSP/OLS data and NPP/VIIRS data were applied in poverty identification. The empirical researches showed that the nighttime light data has accuracy and timeliness in identifying poverty. Recently, the number of such research results has increased, which were mainly the application of nighttime light data on researches such as poverty degree identification, the impoverished county classification, the impoverished county economic development and so on.

Taken the Liupanshan mountain contiguous destitute area as examples, Shen D. (2018) constructed Multiple Poverty Index statistical and Average Light Index. The results of the study showed that the accuracy of poverty results based on nighttime light data could reflect the real poverty degree of the

region. The level of poverty has been reduced year by year in Liupanshan mountain area, and the poverty level in 78 counties has obvious agglomeration. [23]

Wang C.L, Zhou W. et al. (2018) analysized 592 poverty-stricken counties nationwide from 2003 to 2012 and constructed socioeconomic development index of poor counties based on nighttime light data. They applied quadratic polynomial model to reveal the trend of nighttime light intensity in poor counties. The results showed the average light intensity in the poor counties had a steady increase, which were mainly concentrated in the central, eastern and southwestern regions. [24]

(3) The application of nighttime light data on the study of the issue of urban heat island

The urbanization progress not only brings economic and social benefits to human beings, but also produces a series of ecological and environmental problems, among which urban heat island effect is one of the most important issues.

The Beijing Tianjin-Tangshan area, the Yangtze River Delta and the Pearl River Delta are three major urban agglomerations of the highest level of urbanization and the most developed economy in China. Lin Z.L, Xi H.Q. et al. (2018) analyzed urban heat island changes and their relationships to the urbanization of these three major urban agglomerations from 2001 to 2013, with MODIS land surface temperature and DMSP/OLS nighttime light data. They found that the heat island patches in these three urban agglomerations have sprawled to a large extent and gradually connected to form the heat island zones. [25]

Applying desaturated DMSP/OLS nighttime light data between 2000 and 2012 for dynamic monitoring the urban expansion of Beijing, Qu Y.T, Meng D. et al. (2017) investigated the contribution of urban expansion to urban heating effect, in combination with the monthly land surface temperature data of MODIS. They found that urban area in Beijing experienced a sustaining growth, along with the significant heat island effect. [26]

(4) The appplication of nighttime light data to assess war damage or to analyze violent conflict

Some Chinese researchers have realized nighttime light data could be applied to assess war damage. Fan J.F, He H.X. et al. (2018) used a quadratic polynormial model to correct the stable nighttime light images, carried out a segmentation operation on all of the corrected images and extracted the patches of all cities in Syria, then selected nine landscape ecology metrics to estimate the level of destruction and figure out the specificities of urbanization progress of cities in this area. The results showed that almost all of the cities in Syria were seriously damaged in the war. The connectivity between the core cities and circumjacent small cities was weaker, which indicates that neighboring cities were losing their connections. [27]

In addition, research on the application of nighttime light data in the field of political science has emerged. Chen C.(2018) stressed the spatio-temporal dependence in the study of the outbreak of violent conflict. By spatio-temporal modeling approach, he drawed data from geographic information system technique, nighttime light emission, and event data in Africa from 1992 to 2013 to reexamine and explain political violent conflict. The results showed that political violence was more likely to occur in areas with strong governments or ethnic settlement areas with more grievances. The implication of this study was to show how researchers could utilize new data and methods to resolve previous debates in the age of Big Data. [28]

(5) The application of nighttime light data on the study related to natural disaster

The change of nighttime light can reflect the impact of major natural disasters on the social economy in the disaster areas.There were some Catastrophology studies based on the nighttime light data in China. Zhang B.J. (2018) analyzed the interannual variation characteristics of nighttime lights distribution area and intensity in the most affected area of Wenchuan earthquake. Compared with the interannual variation of regional GDP and total investment in fixed assets, he explored the correlation between nighttime lights changes and disaster losses. The results showed that the reduction of nighttime lights after the disaster have a significant correlation with indicators such as death and missing population, mortality and missing rate, and collapse rate of houses. [29]

With multiple linear regression method, dataset including DMSP/OLS night light data, remote sensing background database, social-economic datum and basic geographic information, Mo J.F, Zhong S.Q. et al. (2018) built Guangxi Social-economic space model. On the basis of that, by virtue of GIS technology, social-economic exposure degree model of basin flood hazard of extreme precipitation events happened at different times was constructed. The results showed that, social-economic exposure degree of basin flood hazard of extreme precipitation events exhibit obvious spatial and temporal variation. [30]

(6) The application of nighttime light data on fishery resources research

In recent years, there appeared some researches on the management and protection of marine fishery resource based on nighttime light data.Guo G.G. Fan W. et al. (2018) designed a set of identification algorithm for operating pelagic light-fishing vessels according to the light radiation characteristics of its fishing gathering lamps in NPP/VIIRS low light image. It applied the vessel monitoring system data of Chinese operating light seiners vessels on the high seas of Northwest Pacific Ocean, with VIIRS/DNB image visual interpretation. The result showed that the identification algorithm worked well and its identification accuracy was above 92%. [31]

Zhang S.Y. (2017) extracted the operation point information of night fishing boats in the south China sea through NPP/VIIRS DNB nighttime light data. The study analyzed seasonal dynamic change of night light fishery on the south China sea. Combined with the results of different fishing zones, the spatio-temporal dynamic variation rules of fishing grounds in countries and regions around the south China sea were analyzed. The study provided support and decision-making assistance for the exploitation of fishery resources in the south China sea. [32]

(7) The application of nighttime light data on the research of foreign trade

There were some Chinese studies exploring the feasibility of the application of nighttime light data on the research of foreign trade. Li L.Y, Sun Z.X (2018) applied nighttime light data with gravity model to study the trade between China and the countries in the Belt and Road region. By the panel data, with the method of ordinary least squares, poisson pseudo-maximum-likelihood, and two stage least squares, they found that the significant effect of geographical distance, boundary and regional agreement on China’s trade with the Belt and Road countries validates the validity of the nighttime light data in trade research. [33]

Zong H.J, Wang M.Y. (2018) investigated the trade potential and trade efficiency of China and the Belt and Road countries, by applying the nighttime light data to the stochastic frontier gravity model. The measurement results of trade efficiency in this study showed that China has great trade potential with this region, and China's import efficiency from countries along the Belt and Road route is generally better than it’s export efficiency. [34]

(8) Research on the calibration of nighttime light data and the new progress

Some scholars held that it was necessary to calibrate data saturation when apply nighttime light data to a long-term socioeconomic research, so that the reliable research results could be obtained. Zhang M.Q, He Z.Y. et al. (2017) proposed a new method to calibrate nighttime light data, including mutual correction between sensors, continuity correction and oversaturation correction. After calibration, the continuity and stability of the images were greatly improved, and the linear correlation between nighttime light data and the economic data is stronger. [35] Wu J.S, Li S. et al. (2018) also presented a new method for correcting the saturation effects of DMSP/OLS stable light images based on normalized differential vegetation index data. [36]

Chen M.L, Cai H.Y. (2019) held that VIIRS/DNB nighttime light data are vulnerable to stray light and contain a large number of distorted values in mid and high latitudes. So they adopted cubic spline interpolation (spline), cubic Hermite interpolation (Hermite), gray model (GM), and triple exponential smoothing (exponent) to interpolate default data and then compared the results of these four interpolation algorithms. [37]

(9) Other innovative applications of nighttime light data

In recent years, some Chinese researches have adopted unique perspectives on the application of nighttime light data. ① The application of nighttime light data to evaluate the effect of foreign economic aid. Zhu W.W, Xu C.N. et al. (2018) analyzed the typical characteristics of China's aid and constructed an analytical framework to assess aid effectiveness. They used data on micro-aid to 38 recipients in Africa and nighttime light data over the period of 2001-2013 to apply a dynamic panel system GMM regression test to empirically measure the overall and case specific effectiveness of aid on economic growth. The results showed that China' s steady and continuous aid, including infrastructure aid and fiscal aid, significantly promoted Africa's economic growth. [38] ② The application of nighttime light data to demonstrate the promotion effect of high-speed railway on urban development. Yu L, Zhao J. (2019) investigated the influence of Beijing-Shanghai high-speed rail(HSR) on regional economy, by analyzing nighttime light data and other socio-economic data from 47 prefecture-level cities in China from 2005 to 2013. The results showed that Beijing-Shanghai HSR accelerated local economic development in HSR cities more than non-HSR cities, and the higher economic level of HSR cities promoted the development of the adjacent cities. The spatial spillover effect was also evident, indicating Beijing-Shanghai HSR's impact on the overall region. [39] ③ The application of nighttime light data to public health service research. Taking Guangzhou as the study area, based on the DMSP/OLS nighttime light data, Yang Z.W, Chen Y.B. et al.(2019) carried out the spatial treatment of Guangzhou's permanent population. At the same time, the improved Huff model was used to calculate the allocation of public medical resources in each grid unit. The study concluded that there is a high degree of coupling between the allocation of public medical resources of grid units and the density of public medical facilities in Guangzhou. [40]

4. Disscussion

4.1 Some discussion on the value of nighttime light data.

Nighttime light data can objectively reflect the production and living conditions of human society. Its value is particularly prominent in the field of economics. Researchers made significant progress in revising and improving GDP statistics, and led to the continuous growth of the application of nighttime light data on economic research.

Some scholars discussed the value of nighttime light data in social science research from the perspective of big data. They held that the leaping changes of data collection, statistical analysis and research methods provide a great opportunity for the development of Social Science in the era of Big Data. Taken DMSP/OLS nighttime light data as an example, big data is easier to reach, more objective, more widely used and matches better with the traditional small data. [41]

4.2 Characteristics of the application of nighttime light data in Chinese academic research.

Although the applied research of nighttime light data in China has only been about 15 years, the number of relevant Chinese research results has showed a trend of continuous increase, indicating that nighttime light data has attracted the attention of many researchers. The application of nighttime light data in Chinese academic research showed some obvious characteristics.

(1) The application of nighttime light data in Chinese academic research involved a wide range of research fields.

As representation of human activity intensity, nighttime light data were widely used in many studies. There was aggregation and dispersion among the relevant research achievements. Chinese research results mainly included the following fields: ① Economics. Nighttime light data has the advantages of easy access, wide coverage and high correlation with human social and economic activities. Therefore, researchers in the field of economics considered nighttime light data could be a substitute variable of economic development level under certain circumstances. Moreover, a systematic understanding of the spatial-temporal pattern of economic development could provide decision-making support for formulating economic development strategies. Hence, nighttime light data have gained attention in various studies in the field of economics, such as macro-economics, geographical economics, regional economics, econometrics, tourism economics etc., and topics related to GDP,

poverty, energy consumption, urbanization, urban expansion and so on. ② Geographical sciences. The application of nighttime light data in this field involved both physical geography and human geography, among which the most studies were on spatial systematization, spatial pattern of system, spatial expansion, urban and rural planning and other related issues. ③ Geomatics. Nighttime light data were largely based on infrared sensor or infrared imaging radiometer, which was a component of remote sensing technology in surveying and mapping. Therefore, it was of great relevance to the study of Geomatics. Nighttime light data were mostly used in the research of land, sea and air survey, land and resources utilization and other aspects in this field. ④ Environics. Nighttime light data were widely used in the research of ecological environment, especially for the research of carbon emission, haze, heat island and other environmental problems occurring in the urbanization process. ⑤ Anthropology. Nighttime light data could quantitatively measure the breadth and intensity of human activities on the earth surface. Therefore, it was of high application value in research on population density, human activity monitoring and relevant issues.

In addition, relevant Chinese research results showed that nighttime light data could also be applied to research on other fields or problems, such as war damage assessment, violent conflict analysis, catastrophology studies, fishery resources research, trade potential and efficiency, foreign aid effectiveness assessment, promotion effect of high-speed rail, public health service matching degree, etc.

(2) The application of nighttime light data in Chinese academic research was interdisciplinary.

Judging from the relevant Chinese research results, the application of night light data involved a wide range of fields or disciplines. However, the application of nighttime light data varied from one discipline to another discipline. In some fields, the application of such data started early, had high recognition and were relatively mature, such as geographical science, anthropology and economics. In other fields, the application of such data was not for a long time, but was highly recognized, such as studies about ecological environment, energy consumption, etc. In some fields, the application of such data is pretty new or is still in the stage of trial and exploration, such as sociology, politics, public health services, etc. In addition, due to different research contents and paradigms, the concerns of each field determine the angle from which it applies nighttime light data.

At the same time, the application of nighttime light data in Chinese academic research showed an obvious characteristic of interdisciplinary. This was, of course, largely due to the interdisciplinary nature of certain issues which applied nighttime light data. Such as studies related to geoeconomics, environmental economics, urban planning, land use, geographical mapping and so on. And it was also due to the characteristics of stability, accessibility, objectivity and universality of nighttime light data.

In a nutshell, nighttime light data has attracted the attention of research in various fields, and it is of high impact and value for some interdisciplinary studies.

(3) Chinese relevant research stressed the importance of the optimal utilization and new progress of nighttime light data.

Despite the advantages of nighttime light data, it's flaws were also be found by some researchers when it was applied in relevant research. For example, to tackle the problem of the over saturation of DMSP/OLS nighttime light images, researchers tried to implement such optimization measures as image calibration and saturation mitigation, using different methods and tools. After calibration, the continuity and stability of images were greatly improved. Optimized utilization of nighttime light data could make it show a stronger linear correlation with socio-economic data.

Meanwhile, some researchers also paid attention to the latest progress about nighttime light data. For instance, they analyzed and found the advantages of new VIIRS/DNB nighttime light data. Meanwhile, they realized that it also has obvious defect. VIIRS/DNB nighttime light data was vulnerable to stray light and contained a large number of distorted values in mid and high latitudes, especially in summer, which caused discontinuous in space and time of the data. Aiming at this defect,

researchers tried to apply and compare different methods for the data interpolation, and obtained the best interpolation algorithms under different circumstances.

In short, Chinese relevant research stressed the importance of the optimal utilization of DMSP/OLS nighttime light data. At the same time, they also paid attention to the new VIIRS/DNB nighttime light data, to analyze its advantages and disadvantages, and tried to interpolate the best algorithms. All these indicated that some Chinese scholars were rather technically sophisticated in their analysis and utilization of nighttime light data.

4.3 The trend of the application of nighttime light data in Chinese Academic research.

This paper made a comprehensive and systematic analysis of the relevant results Chinese Academic research. From the perspectives of bibliometrics analysis and content analysis, this paper summarized the general characteristics of the application of nighttime light data in Chinese research, and obtained the general trend of the relevant research.

(1) The application of nighttime light data in academic research has broad prospect.

Over the past ten years, the number of relevant published papers in China has been continuously increasing, which indicated that the application of this kind of data in research has becoming more and more extensive. From the content analysis of the results, the application of nighttime light data has already received the attention of urbanization, population, energy consumption and other related studies, which was closely related to China's sustained economic growth and deepening urbanization process for more than a decade. At the same time, the application of nighttime light data in ecological environment related researches was also frequent, indicating that the researches ralated to environment damage and governance were also increasing gradually, which was brought by economic development, urbanization, population density etc.

Therefore, nightime light data will continue to be concerned and applied in the research of the above fields. In addition, nighttime light data will be applied in more fields, especially in interdisciplinary research. Nighttime light data will play a more important role in the era of Big Data. In short, the number of the applied research of nighttime light data will further increase, the research content will be more multi-angle and diversified. The application of nighttime light data in academic research has broad prospect.

(2) An obvious tendency of the comprehensive application of nighttime light data with other types of statistical data, index information and analysis tools.

Nighttime light data has the characteristics of stability, accessibility, objectivity and universality. Yet, most researches tend to combine nighttime light data with other types of statistical data, index information, and analytical tools. It includes various socio-economic statistical data, ground observation data, Moran's I, Gini coefficient, normalized differential vegetation index and other data or indexes. And other tools or methods such as ArcGIS, standard deviation ellipse, support vector machine, gravity model, quadratic polynomial model etc.

All in all, different research applies nighttime light data from different angles, combined with other types of statistical data, index information, analysis tools. The comprehensive application of various data, information, tools makes it complement and verify each other. This scientific research method is an obvious trend of appling nighttime light data to carry out research in various fields.

(3) The application of nighttime light data in academic research shows the trend of sustainable development.

At present, the application of nighttime light data is mainly based on DMSP/OLS and NPP/VIIRS data, the advantages and characteristics of such data have been fully recognized by researchers, and the relevant applied research has been relatively mature.

It is notable that China launched Luojia-1A scientific experimental satellite in June 2, 2018. Filled the blank of luminous remote sensing technology in China, the satellite has a image resolution of 130 meters. Under ideal conditions, global nighttime light images can be completed within 15 days, providing GDP index, carbon emission index, urban housing vacancy rate index and other products.

At the same time, it can also be used to carry out research on key technology of new generation navigation signal enhancement in China. The Luojia-1 project plans to launch two more satellites in the next five years. [42] It will provide a new source of nighttime light data for researches of all fields and disciplines.

Luojia-1A scientific experimental satellite carried the navigation augmentation payload and it is capable of automatically calculating its orbit and clock by it self, generating and transmitting dual-frequency ranging signals. Luojia-1A satellite successfully demonstrates the navigation signal augmentation from low earth orbit platform. In addition to the estimation of social and economic parameters, Luojia-1A nighttime light data can also be applied to the evaluation of urban main functional area division. [43]

Wang L, Chen R.Z. et al.(2018) assessed the quality of the navigation augmentation signals from Luojia-1A, including precision of pseudorange and carrier phase and timing precision from single satellite. The results indicated the precision of the pseudorange and carrier phase at high elevation angle was 1.5 m and 1.7mm respectively, which could meet the requirement of the navigation signal augmentation. Single satellite based timing precision from Luojia-1A was approximately 10-30 ns, which proved the correctness and validity of the satellite-ground ranging signals. [44] At present, the data has been noticed by some users. The total data coverage of Luojia-1A satellite was 5,772 images and the total download volume was 68,812 images till Oct. 25, 2018. [45]

In short, nighttime lighting data based on DMSP/OLS, NPP/VIIRS, Luojia-1A and others will be further concerned by various research fields. These three kinds of nightime lighting data have advantages respectively. Users can select, compare or apply these data to meet their needs. At the same time, it is possible that new sources of nighttime light data emerge in the future. Therefore, the relevant applied research shows a trend of sustainable development.

References

[1] Information on https://ngdc.noaa.gov/eog/dmsp.html.

[2] Information on https://www.nasa.gov/pdf/596329main_NPP_Brochure_ForWeb.pdf.

[3] X.M. Li, X.Q.Zheng, T.Yuan: Knowledge mapping of research results on DMSP/OLS nighttime light data, Journal of Geo-information Science,vol.20/3(2018),351-359. (In Chinese).

[4] L. Zhou, J. Chen, P.J. Shi, Z.H. Gu, Y.D. Fan, T.S.K. Ichinose:Modeling Population Density of China in 1998 Based on DMSP/OLS Nighttime Light Image. Acta Geographica Sinica,vol.2 (2005),266-276. (In Chinese).

[5] L.Q. Cao, P.X. LI, L.P. Zhang:Urban Population Estimation Based onThe DMSP/OLS Night-time Satellite Data---A Case of Hubei Province, Remote Sensing Information,vol.1(2009),83-87.(In Chinese).

[6] C.Y. He, J.G. LI, J. Chen, P.J. Shi, Y.Z. Pan, J. LI, L. Zhou, T.S.K. Ichinose:The Urbanization Model and Process in Bohai Sea SurroundingArea in the 1990s by Using DMSP/OLS Data, Acta Geographica Sinica, vol.2(2005),266-276. (In Chinese).

[7] X.F.Zhang:Research on Remote Sensing Monitoring of Urban Spatial Expansion in Inner Mongolia (MS., Inner Mongolia Normal University.China 2010),p.5-7.

[8] S.Shu, B.L.Yu, J.P.Wu, H.X.Liu: Methods for Deriving Urban Built-up Area Using Night-lightData: Assessment and Application. Remote Sensing Technology and Application, vol.26/2(2011),169-176. (In Chinese).

[9] J.S.Wu, H.Liu, J. Peng, L. Ma: Hierarchical structure and spatial pattern of China's urbansystem: Evidence from DMSP/OLS nightlight data. Acta Geographica Sinica, vol.69/6(2014),759-770. (In Chinese).

[10] C. Zhang, C.Y. Wang, Y.Q. Lv, T.Y. Shen: Research on City System Spatial Structure of the Yangtze River Economic Belt: Based on DMSP/OLS Night Time Light Data, Urban Development Studies vol.22/3(2015),19-27. (In Chinese).

[11] X.D. Han, Y. Zhou, S.X. Wang, R. Liu, Y. Yao: GDP Spatialization in China Based on Nighttime Imagery, Journal of Geo-Information Science, vol.14/1(2012),128-136. (In Chinese).

[12] Q. Wang, T. Yuan, X.Q. Zheng: GDP Gross Analysis at Province-Level in China Based on Night-Time Light satellite Imagery, Urban Development Studies, vol.20/7(2013),44-48. (In Chinese).

[13] K.N. Xu, F.L. Chen, X.Y. Liu: The Truth of China Economic Growth:Evidence from Global Night-time Light Data, Economic Research Journal, vol.50/09(2015),17-29+57. (In Chinese).

[14] Y.X. Su, X.Z. Chen, Y.Y. Ye, Q.T. Wu, H.O. Zhang, N.S. Huang, Y.Q. Kuang: The characteristics and mechanisms of carbon emissionsfrom energy consumption in Chinausing DMSP/OLS night light imageries, ACTA GEOGRAPHICA SINICA, vol.68/11(2013),1513-1526. (In Chinese).

[15] J.S. Wu, Y. Niu, J. Peng, Z. Wang, X.L. Huang: Research on energy consumption dynamic among prefecture-level cities in China based on DMSP/OLS Nighttime Light, Geographical Research, vol.33/4(2014),625-634. (In Chinese).

[16] M.J. Mao, X.C. Yang: The Relationship between Haze Weather and Urbanization, Research of Environmental Sciences,vol.28/12(2015),1823-1832. (In Chinese).

[17] W. LI, X.Q. Zheng: A Haze Monitoring Method Combined VIIRS Images with Real-time Observation Data Interpolation in Beijing, Acta Geodaetica et Cartographica Sinica,vol.44/S1(2015),123-128. (In Chinese).

[18] J.G. Zou, Y.H. Chen, J. Tian, T.Wang: Construction of the Calibration Model for DMSP/OLS Nighttime Light Images Based on ArcGIS, Journal of Geomatics, vol.39/4(2014),33-37. (In Chinese).

[19] L. Zhuo, X.F. Zhang, J. Zheng, H.Y. Tao, Y.B. Guo: An EVI-based Method to Reduce Saturation of DMSP/OLS Nighttime Light Data, Acta Geographica Sinica, vol.70/8(2015),1339-1350. (In Chinese).

[20] Y. Yang, Y.J. Li, C.Y. He, Z.F. Liu, Q.X. Huang: A Comparative Study on Spatiotemporal Dynamics of City Size Distribution among Three Urban Agglomerations in Bohai Rim: Based on the Analysis and Perspective of Nighttime Light Data from 1992 to 2012, Economic Geography, vol.36/4(2016),59-69. (In Chinese).

[21] Y. Zhong, A.W. Lin, B.S. Hu, M. Ju: Spatial Pattern Evolution of Urban System in Yangtze River Economic Belt Based on DMSP-0LS Night Light Data(1992-2013). Resources and Environment in the Yangtze Basin, vol.25/6(2018),298-305. (In Chinese).

[22] X. Li, J. Zhu, X.D. Yin: Spatio-temporal pattern of Chinese economy development based on nightlight data, Journal of Geo-information Science, vol.21/3(2019),417-426. (In Chinese).

[23] D.Shen: Identification of poverty based on nighttime light remote sensing date: a case study on contiguous special poverty stricken areas in Liupan Mountains (MS., Lanzhou Jiaotong University. China 2018),p.3-6.

[24] C.L. Wang, W. Zhou, T. Yuan: Development in Poor Cunties of China Bsed on Nighttime Lighting Data, Remote Snsine g Information, vol.33/6(2018),97-102. (In Chinese).

[25] Z.L. Lin, H.Q. Xu, H. Chen: Urban heat island change and its relationship to the urbanization of three major urban agglomerations in China's easterncoastal region. Research of Environmental Sciences, vol.31/10(2018),1695-1704. (In Chinese).

[26] Y.T. Qu, , M. Dan, X.J. Li: Study on Urban Expansion and Its Influence onUrban Warming Effect in Beijing, Journal of Capital Normal University(Natural Science Edition), vol.38/2(2017),77-83. (In Chinese).

[27] J.F. Fan, H.X. He, T.Y. Hu, S.A. Yan, W.B. Cui: An assement method of urban destruction degree in Syria War, Science of Surveying and Mapping, vol.43/9(2018),129-134. (In Chinese)

[28] C. Chen: Rethinking Opportunity，Greed，Grievance and Internal Conflict: A Spatio-Temporal Analysis of African Political Violence. World Economics and Politics, 2018,(08),94-127+158-159. (In Chinese).

[29] B.J. Zhang: Analysis of the Inter-annual Variation of Nighttime Lights in the Most Affected Area of Wenchuan Earthquake from 2003 to 2013. Journal of Catastrophology, vol.33/1(2018),12-18, 22. (In Chinese).

[30] J.F. Mo, S.Q. Zhong, Y.L.Chen, M. Sun: Study on Social-economic Exposure Degree Model of Basin Flood Hazard of Extreme Precipitation Events in Guangxi, Journal of Catastrophology, vol.33/2(2018),83-88. (In Chinese).

[31] G.G. Guo, W. Fan, J.L. Xue, S.M. Zhang, H. Zhang, F.H. Tang, T.F. Cheng: Identification for operating pelagic light-fishing vessels based on NPP/VIIRS low light imaging data, Transactions of the Chinese Society of Agricultural Engineering, vol.33/10,(2017), 245-251. (In Chinese)

[32] S.Y Zhang: Research on fishing dynamic changes in the South China Sea using nighttime light data (MS., Nanjing University.China 2017),p.19-21.

[33] L.Y. Li, Z.X. Sun, X. Long: The Study of Trade Development between "One Belt andOne Road" Countries along the Line and China. The Journal of Quantitative and Technical Economics,35/3 (2018),39-58. (In Chinese).

[34] H.J. Zong, M.Y.Wang: On the Trade Potentialities of China and “One Belt and One Road” Countries: Based on the Investigation of Nocturnal Lighting Data, Journal of Zhongnan University of Economics and Law vol.6(2018),125-133. (In Chinese).

[35] M.Q. Zhang, Z.Y. He, Y. Fan: Calibration for DMSP/OLS Stable Nighttime Light Images, Bulletin of Surveying and Mapping, vol.12(2017),58-62+76. (In Chinese).

[36] J.S. Wu, S. Li, X.W. Zhang: Research on saturation correction for long-time series of DMSP-OLS nighttimelight dataset in China, Journal of Remote Sensing, 22/4(2018),621–632. (In Chinese).

[37] M.L. Chen, H.Y. Cai: Interpolation methods comparison of VIIRS/DNB nighttime light monthly composites: A case study of Beijing, Progress in Geography, vol.38/1(2019),126-138. (In Chinese).

[38] W.W. Zhu, K.N. Xu, M.C. Wang: Does China’s Aid Effectively Promote Africa’s Economic Growth, Journal of International Trade, vol.7(2018),108-120. (In Chinese).

[39] L. Yu, J. Zhao: Disentangling treatment effect, spatial spillover effect and quantile effect: An empiri-cal study of Beijing-Shanghai High Speed Rail, World Regional Studies, vol.28/1(2019),47-57. (In Chinese).

[40] Z.W. Yang, Y.B. Chen, Q.L. Qian, Y.L. Hu, Q.Y. Huang: Evaluation of the Matching Degree of Public Medical Service Level Based on Population Spatialization: A Case Study of Guangzhou, Geography and Geo-Information Scicncc, vol.35/2,(2019), 1-2, 74-82. (In Chinese).

[41] C.Y. Fan, Y.T. Zhu, Y.J. Gao: Value of Big Data Applied in Social Sciences:A Case of DMSP/OLS Night-Time Light Data. Journal of East China University of Science and Technology(Social Science Edition),vol.31/1(2016),1-9.(In Chinese).

[42] Information on http://news.cnhubei.com/xw/kj/201806/t4119344.shtml).

[43] Information on https://news.whu.edu.cn/info/1002/51346.htm.

[44] L. Wang, R.Z. Chen, D.R. Li, B.G. Yu, C.L. Wu: Quality Assessment of the LEO Navigation Augmentation Signals from Luojia-1A Satellite, Geomatics and Information Scicncc of Wuhan University, vol.43/12(2018),2191-2196. (In Chinese).

[45] Information on http://59.175.109.173:8888/app/login.html.