Research on energy consumption of China's prefecture-level scale based on DMSP/OLS night light data

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Abstract. Energy is an important support for the development of national economy. Accurate and convenient access to space-time dynamic information of energy consumption is of great significance for the rational formulation of energy policy. Based on the quantitative correlation between DMSP/OLS night lighting data and energy statistics, the spatial pattern of energy consumption in China from 2000 to 2013 was simulated at the prefecture-level scale. The results show that it is feasible to simulate energy consumption in different cities in China based on DMSP/OLS night lighting data, which can reliably reflect the temporal and spatial dynamics of energy consumption. This study provides a new method support for dynamic monitoring of energy consumption.

1. Introduction

The lack of China's urban-scale energy consumption data makes that almost impossible to analyze the energy consumption patterns of all cities in China through statistical data. Based on this, other means are needed to invert city-scale energy consumption data. Through literature review, we find that it is a feasible way to invert the national urban scale energy consumption data through night light remote sensing data. Remote sensing technology has unique advantages in terms of time and space consistency, and has gradually become an important means of monitoring the spatial and temporal changes of spatial information in the field of geography. The Operational Linescan System (OLS) sensor on the US Meteorological Satellite Program (DMSP) can effectively detect low-intensity nighttime lights generated by night lights, even small-scale residential areas, traffic, etc., and monitors the intensity of human activities. A good data source. Many scholars at home and abroad have successfully applied DMSP/OLS nighttime lighting images to urban extension monitoring, socioeconomic factor estimation, and energy consumption estimation [1] [2].

This study based on the DMSP/OLS nighttime lighting image from 2000 to 2013, this study verified the TM remote sensing image classification results, accurately extracted the built-up area of the study area, and combined the statistical data of 30 provinces or municipalities and 68 prefecture-level cities to establish DMSP/OLS night light data. The equation for the relationship between OLS light values and energy consumption statistics. On this basis, the total energy consumption is simulated in China's prefecture-level scale.
2. Data and preprocessing

2.1. DMSP/OLS night light image.

The 2000-2013 DMSP/OLS data was obtained from the National Geophysical Data Center (NGDC) under the National Oceanic and Atmospheric Administration (NOAA), which eliminates clouds and flares. The effect of accidental noise, the data gray value range is 0~63, and the spatial resolution is 0.00833 degrees (about 1km). Due to the slight difference between the nighttime light data acquired by different sensors in the same period and some optical noise, this paper uses the method established by Liu et al to combine the denoising, cutting, relative radiation calibration, geography and coordinate transformation [3] [4].

![Night light data spatial distribution map (2013)](image)

**Figure 1. Night light data spatial distribution map (2013)**

Due to the overflow characteristics of the lights, during the process of extracting the urban built-up area using the night light data, the detected light range exceeds the boundary of the real built-up area, so determining the optimal threshold becomes a hot research topic. Common methods for determining the optimal threshold are: statistical data comparison method, higher resolution influence comparison method, mutation detection method, and empirical threshold method.

The night light data and TM remote sensing image are extracted as basic data in the urban built-up area. The sample city is selected according to the urban form, and the night light data is preprocessed. The light data is binarized under different hypothesis thresholds to obtain the city under the hypothetical threshold. In the TM remote sensing image, the built-up area and the non-built-up area sample points are collected according to the performance characteristics of the urban built-up area in the remote sensing image, the sampling points are superimposed with the urban built-up area boundaries under different hypothetical thresholds, and the sample points are constructed. The district and non-built-up areas are the standard, and the optimal threshold for extracting the city's built-up area from night light data is determined.
2.2. **Landsat TM imagery.**
Selecting a number of better quality TM remote sensing images covering the Pearl River Delta, Yangtze River Delta, Beijing, Shanghai, Chongqing and other cities in 2000, 2005, 2009 and 2010 for surface type classification, testing and correcting DMSP/OLS nighttime The accuracy of the built-up area of the light image extraction.

2.3. **Panel data.**
Taking into account the possibility and accuracy of collecting statistical data, the statistical yearbook data of 30 provinces or municipalities (except Macao, Hong Kong, Taiwan and Tibet) and 68 prefecture-level cities in 2000, 2005, 2009 and 2010 were selected. The data used to calculate the total energy consumption comes from the primary energy end-use in the energy consumption balance sheet.

3. **Models and Analysis**
(1) Building land for night light image extraction based on DMSP/OLS [1] [5]. The DMSP/OLS nighttime light image is similar to the DEM elevation data. There are obvious “peaks” and “sinks”, which are referred to as “bright source” and “dark source” respectively. There is a distinct abrupt change between the bright source and the dark source, that is, the dividing line between the construction land and the non-construction land. In this study, ArcGIS’s Neighborhood Statistics surface analysis tool was used to analyze the boundary undulation analysis method and identify the boundary between construction land and non-construction land by using five grids as the unit to extract the construction land range. Using TM remote sensing image classification results, the verification accuracy is 95.27%, and the kappa coefficient is 0.91. The construction land extracted by this method will not miss the built-up area of small towns with relatively dark light values, and can effectively extract the wide road main roads and the residential areas distributed on both sides of the road between the suburbs [6] [7].
(2) Establish a relationship equation between the nighttime light value and the statistical value of the total energy utilization. Use the construction site boundary to cut the DMSP/OLS nighttime lighting image, obtain the nighttime lighting data within the construction land of each province and city, and collect the total nighttime light value of each province and city, and then fit and analyze the corresponding total energy utilization statistics. It shows that the total nighttime lighting data (SDN) has a good linear correlation with the total energy utilization statistics, which is significantly correlated at the 0.01 level, and $R^2$ is 0.823. Therefore, based on the relationship between the two, the total energy consumption data of other cities with missing data can be inverted.

\[ SDN = 0.102213 \times EN \]

There, SDN is the total light DN value of DMSP/OLS nighttime lighting data; EN is the total amount of urban energy consumption.

![Image of Figure 3](image3.png)

**Figure 3.** Total energy consumption change at province-level scale in China from 2000 to 2013

### 4. Result and Conclusion

Taking 2013 as an example, the inversion of total energy consumption at the prefecture-level city scale is shown in Figure 7 and Figure 8.

![Image of Figure 4](image4.png)

**Figure 4.** Spatial distribution map of the total energy consumption in China’s prefecture-level scale (2013)
Figure 5. Stretch map of the total energy consumption in China's prefecture-level scale (2013)

In order to ensure the reliability of the simulated total energy consumption, compare it with the total energy consumption of 30 provinces and municipalities and 66 prefecture-level cities based on statistical calculations. It is found that the simulated total energy consumption and statistics The root mean square error (RMSE) of the calculated value of the data is 3,875,700 tons, and the relative error (RE) is 7.23%. Through the comparison of the trend of China's provincial total energy consumption over the years and the remote sensing inversion trend of prefecture-level cities, the two have obvious consistency. At the same time, from the comparison of statistical data from 1995-2013 and remote sensing inversion energy consumption data, the basic trends of the two are highly consistent. It can be seen that the accuracy of total energy consumption based on nighttime lighting data simulation is good and can be used to conduct research on national urban scale energy consumption patterns.

Figure 6. Comparison of statistical data and remote sensing inversion energy consumption data
Acknowledgments
This work was supported by the Science and Technology Project of State Grid Corporation of China (Research and Development of Comprehensive Analysis and Forecasting Model System for Multi-regional Energy Supply and Demand in China) and the Young Talents Programme of State Grid Energy Research Institute Co., Ltd. (Research on the new urbanization development indicators of energy and electricity supply and demand analysis based on night lighting remote sensing data for smart grid, No. XM2018020037579).

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