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Remote sensing of nighttime light

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Abstract

Night light observations through remote sensing allow us to make accurate measurements of the location of human activities, so we can in various fields such as urban tracking and economic dynamism, conflict assessment and armed incidents, fisheries study, emission assessment They used greenhouse gases and energy consumption and analyzed light pollution and health effects. New and improved sensors, algorithms, and products for night lights, in conjunction with other ground observations and ancillary data (e.g., geographic location data), have great potential for in-depth understanding of human activities and their environmental consequences. This paper examines the advancement of night light sensors and products, and examines the contribution of night light remote sensing to the perception of a changing world with an emphasis on DMSP / OLS and VIIRS night light data.

1. Introduction

In general, the rapid growth of the human population has profound implications for land-based processes, both locally and globally, and poses great challenges for scientists and policymakers to understand and address global change and its consequences (Zhao, et al., 2019).

Today, as we grow and innovate in tools and techniques, our understanding of issues such as urbanization, environmental change, and global change will emerge deeper and more comprehensible. Undoubtedly, the most important indicator of the impact on the environment and ecosystem is human activities. Ground-based imaging from space, due to its high potential, provides the possibility of analyzing, evaluating and predicting unprecedented changes that occur on the surface of the earth, and is a great help in tracking human activities and environmental impacts. it has. In this regard, the role of satellite remote sensing in the comprehensive understanding of the changes facing the Earth and humans in the 21st century has been very colorful (Zhao, et al, 2019).

At the beginning of the 21st century, people realized that satellite remote sensing technology would play a key role in Earth observation. One of the most important ways to detect human footprints on the ground, light measured from the ground is very useful for identifying human habitats and economic dynamics. This will show the potential for continuous monitoring and monitoring of human activities and the identification and understanding of environmental effects of night light data compared to other satellite products used to monitor human activities [He et al., 2017].

Global nighttime running lights are one of the most important and well-known satellite data products that provide an accurate measure of human presence and activity across the globe. In addition, the mapping of light regions and their illumination levels are used by scientists in a variety of fields. [Levin, et al., 2020].

In this paper, we aim to examine the potential and effectiveness of NTL remote sensing in understanding human activities and related environmental changes in a changing world. As such, this paper will provide a comprehensive review of night-time remote sensing (NTL) data from data sets to applications and challenges and perspectives.

2. Method

Examining various studies that have been done using night light images, it is clear that each of these data sets has advantages and disadvantages that in

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combination with a series of data and ancillary information provide the desired result. In the following, we will introduce the main data of night light and review the summary of studies performed using these images.

3. An Overview of Major Nighttime Light Datasets

This section provides an overview of the main NTL datasets collected from the various sensors and operating systems and their features. DMSP-OLS and VIIRS sensors are the two main sensors in the field of night light images, which we will introduce in full below.

3.1. DMSP-OLS &NPP-VIIRS

The Defense Meteorological Satellite Program (DMSP) was launched in 1962, and since then its satellites have been using the Ground Surface Scanning System (OLS) as a valuable source of night light data (NTL). Since 1992, DMSP satellites have been broadcasting digital images, which, after being processed by NOAA (now Colorado Mining School), the Earth Observatory (EOG) became the global average of the year, and the NTL map background was removed. With the expansion of annual data from 1992 to 2013, DMSP turns night light into the longest range of remote sensing data available in human activities (Elvidg, et al.,1997). In 2011, the Suomi NPP satellite (SNPP) was launched with a set of Visible Infrared Imaging Radiometers (VIIRS). The VIIRS tool is also able to detect dim light sources at night. VIIRS annual maps of night lights have been published from 2013 to 2022 (Elvidge, et al, 2019). NTL maps made with DMSP (DNL) or VIIRS (VNL) are widely used in human activities, economics and environmental research (Levin, et al., 2020).

The DMSP-OLS nighttime stable light (NSL) data have a spatial resolution of 30 arc-seconds, a coverage spanning 180 to 180 degrees longitude and 65 to 75 degrees latitude. The digital number (DN) value for pixels ranges from 0 to 63. This means that value 0 represents the unlit area and the greater the value, the higher the light level of the region will be. VIIRS, a 22-band visible/infrared sensor, has a same swath width (i.e., 3000 km) as DMSP and a higher spatial resolution (i.e., 375 m and 750 m at nadir). Similar to OLS, VIIRS observes NTLs of the Earth every 24 hours, with the local overpass time after midnight—near 01:30. Among the 22 bands of VIIRS instrument, the Day/Night Band (DNB) with a spectral range of 0.5–0.9 μm shows an unprecedented capability of night observations (Zhao, et. al., 2019).

4. The contributions of night lights to various studies to understand the changing world

Through a range of new applications, NTL remote sensing improves our understanding of the rate of land change. In this section, we briefly review the major contribution of satellite NTLs in previous studies for various purposes.

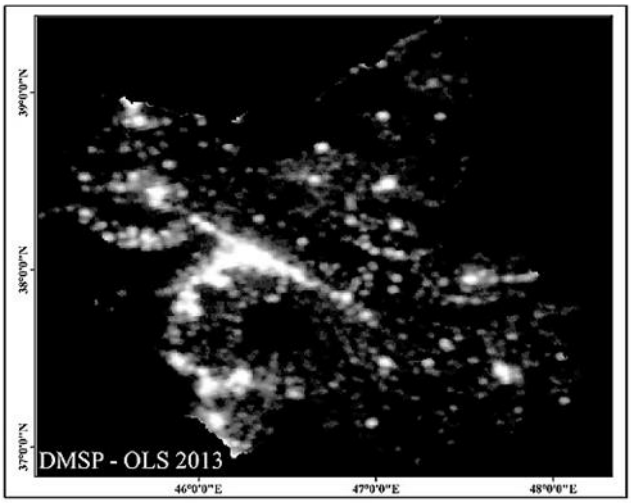

Figure 1. VIIRS Nighttime Light image for East Azerbaijan province

4.1. Urban studies

The use of artificial light data measured from satellites has made it possible to change research methods in geography and urban planning. The DMSP-OLS and VIIRS night optical data sets provide consistent and valuable data sources for the study of urbanization processes. To better understand, we summarize a number of studies conducted in this field.

Luqman et al. 2019 in their study. They introduced a new algorithm called BUNTUS (indoor areas, night light and travel time for urban size) using remote sensing techniques to draw urban boundaries. This method combines land cover data, night light and travel time to extract the boundaries of urban areas. This method is a universal method and uses data sets with sufficient time to create the process. They used Landsat-8 OLI images to confirm their work, and the results showed an overall accuracy of 60 to 95 percent. Therefore, this method is a practical method in collecting information from the urban area and in accordance with its criteria.

In their study, Dou et al 2017. Noted that the timely and accurate extraction of urban land using night light data from Visible Infrared Imaging Radiometers (VIIRS) is important for the national participation of the third polar orbit for urban studies. Extraction of urban land using VIIRS night light data requires consideration of various methods. Therefore, they first reviewed the relevant methods and selected three common methods for extracting urban areas using night light data. These methods included Local Optimal Threshold (LOT), Plant Adjusted Night Light Index (VANUI), Integrated Night Lights, Normalized Plant Index, and Surface Temperature Support Vector Classification (INNL-SVM). They evaluated the performance of these methods for extracting urban land area based on VIIRS night light with seven assessment areas with different economic and socio-economic conditions in China. The results showed that among the mentioned methods, INNL-SVM method has more potential for effective extraction of urban land from VIIRS data.

He, et al. 2017, colleagues have stated in their study that Quantifying the spatial and temporal changes of urban extent is important for understanding the burgeoning process of urbanization. Among the excellent methods used to map urban areas and detect urban change using night light data, many assume that the urban area is equivalent to areas with a high percentage of impenetrable surfaces or developed terrain. They selected the appropriate boundary criteria and urban indicators based on understanding the current urban situation of the study area and after object-based segmentation and identification of primary urban centers, urban plots were identified and urban centers through grouping algorithm, relative margins of urban area. The results showed that this method is able to identify urban plots with reliable accuracy on a regional scale.

4.2. Modeling GDP

Another application of night light images is to evaluate GDP. Many studies have been done in this regard. Zhao et al. 2019 Noted in their study that night light data from the Defense Meteorological Meteorological Program (DMSP-OLS) line-scan operating system in conjunction with the Visible Infrared Imaging Radiometer (NPP-VIIRS) with the participation of the Third National Polar Orbit Is obtained. It has great potential for measuring large-scale GDP dynamics (GDP). DMSP-OLS data coverage covers the period between 1992 and 2013, while NPP-VIIRS data are available from 2012. The integration of these two datasets has been important for the production of a time series of continuous and continuously monitored data since the 1990s. Understanding the Dynamics of Long-Term Economic Development In addition, since patterns of economic development vary with physical environment and geographic location, the quantitative relationship between night light and GDP should be designed for separate areas. Through a case study in China, this study attempted to integrate the DMSP-OLS and NPP-VIIRS databases, as well as to identify an optimal model for the long-term dynamics of spatio-temporal GDP in different parts of China.

4.3. Light pollution

A comprehensive definition of light pollution is that light pollution is the presence of unwanted, inappropriate, or excessive artificial light. In a descriptive sense, the term "light pollution" refers to the effects of any dim light during the day or night. Light pollution can not only be understood as a phenomenon caused by a particular source or type of pollution, but also can be considered as an effective factor in various studies.

Bagheri et al 2022. In their study. They have studied light pollution and pointed out that due to the increasing expansion of urbanization and the consequences of urbanization and uncontrolled migration of light, this pollution has also increased. Although this contamination is not comparable to the naked eye, it is an unfortunate environmental fact that has devastating effects on the health of organisms and humans. Using new methods and techniques for measuring distance, these pollutants can be mapped and appropriate measures can be taken to control and reduce them. For example, in an area with high light pollution and its negative effects, extinction of individuals and organisms may be prevented. Or moved them.

5. Result

By examining night light data and various studies performed using these data, it was found that night light data have a very high potential and efficiency in various fields such as urban studies, economics, light pollution, traffic, etc. These data, when combined with other data, give very accurate results that can be used in important planning, especially urban planning.

6.Discussion

Universal night light received by satellites shows us the location and brightness of light in different regions. In low light conditions, only specialized imaging sensors are able to receive source information for night light. To produce a universal product without additional features requires dozens of views per year. From the mid-1970s to 2011, the only instrument that met these criteria was the US Air Force DMSP OLS, which collected a complete set of night-time images of the Earth every 24 hours. NOAA builds a time series of annual global night light products with OLS data from 1992 to 2013. OLS products have been widely used by scientists and economists; however, OLS data has several drawbacks, including dynamic range limited by six-bit quantization, large spatial resolution, and in-flight calibration. In 2011, NASA and NOAA launched the SNPP satellite with VIIRS, which compared low-light imaging data with 14-bit quantization, fewer detection limits, wider dynamic range, and 45x smaller pixel footprint compared to DMSP OLS. Collects with OLS. VIIRS, like OLS, collects a complete set of Earth images every 24 hours. The purpose of this study was to investigate the applications and potentials of night light data in various studies (Elvidge,. et at, 2017). In all these studies, the effective role of these data was proven. The point that should be considered and mentioned in almost all studies is the choice of the optimal method in these studies.

7. Conclusion

The results of these studies show that by combining night light data with a set of other information and data, various phenomena such as urban growth trends can be easily calculated. Due to the quality and availability of this data and available methods, this data can be used in many studies.

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