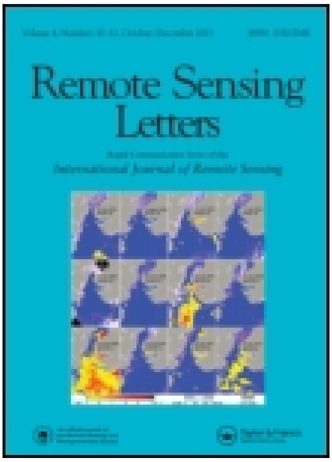

Remote Sensing Letters
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/trsl20

Evaluation of NPP-VIIRS night-time light composite data for extracting built-up urban areas

Kaifang Shi[a], Chang Huang[a], Bailang Yu[ab], Bing Yin[a], Yixiu Huang[a] & Jianping Wu[a]

[a] Key Laboratory of Geographic Information Science, Ministry of Education, East China Normal University, Shanghai, China

[b] Shanghai Key Laboratory for Urban Ecological Processes and Eco-Restoration, East China Normal University, Shanghai, China

Published online: 14 Apr 2014.

To cite this article: Kaifang Shi, Chang Huang, Bailang Yu, Bing Yin, Yixiu Huang & Jianping Wu (2014) Evaluation of NPP-VIIRS night-time light composite data for extracting built-up urban areas, Remote Sensing Letters, 5:4, 358-366, DOI: 10.1080/2150704X.2014.905728

To link to this article: http://dx.doi.org/10.1080/2150704X.2014.905728

Remote Sensing Letters, 2014
Vol. 5, No. 4, 358–366, http://dx.doi.org/10.1080/2150704X.2014.905728

Taylor & Francis
Taylor & Francis Group

Evaluation of NPP-VIIRS night-time light composite data for extracting built-up urban areas

Kaifang Shi[a], Chang Huang[a], Bailang Yu[a,b]*, Bing Yin[a], Yixiu Huang[a], and Jianping Wu[a]

[a]*Key Laboratory of Geographic Information Science, Ministry of Education, East China Normal University, Shanghai, China;* [b]*Shanghai Key Laboratory for Urban Ecological Processes and Eco-Restoration, East China Normal University, Shanghai, China*

(*Received 16 December 2013; accepted 14 March 2014*)

The first global night-time light composite data from the Visible Infrared Imaging Radiometer Suite (VIIRS) day–night band carried by the Suomi National Polar-orbiting Partnership (NPP) satellite were released recently. So far, few studies have been conducted to assess the ability of NPP-VIIRS night-time light composite data to extract built-up urban areas. This letter aims to evaluate the potential of this new-generation night-time light data for extracting urban areas and compares the results with Defense Meteorological Satellite Program–Operational Linescan System (DMSP-OLS) data through a case study of 12 cities in China. The built-up urban areas of 12 cities are extracted from NPP-VIIRS and DMSP-OLS data by using statistical data from government as reference. The urban areas classified from Landsat 8 data are used as ground truth to evaluate the spatial accuracy. The results show the built-up urban areas extracted from NPP-VIIRS data have higher spatial accuracies than those from DMSP-OLS data for all the 12 cities. These improvements are due to the relatively high spatial resolution and wide radiometric detection range of NPP-VIIRS data. This study reveals that NPP-VIIRS night-time light composite data would provide a powerful tool for urban built-up area extraction at national or regional scale.

1. Introduction

Accurate information about the current and historical spatial extents of built-up urban areas is crucial for monitoring urbanization process, evaluating the impacts of urbanization on environments and analysing the driving forces of urban development. Previous studies have demonstrated that remotely sensed data have advanced capabilities in urban extent delineation and urban impervious surface mapping (Weng 2012). Among various remote sensing images, the night-time light images from Defense Meteorological Satellite Program–Operational Linescan System (DMSP-OLS) can detect the artificial lights from cities, towns, industrial sites and other human activities at night (Elvidge et al. 1997; Elvidge, Cinzano, et al., 2007). The DMSP-OLS stable night-time light data (hereinafter referred to as 'DMSP-OLS data' in this letter) have been widely used for mapping urban settlements in a simple and economical manner at national or continental scale (Elvidge et al. 1999; Elvidge, Tuttle, et al., 2007; Sutton 2003; He et al. 2006; Ma et al. 2012). However, the relatively coarse spatial resolution (30 arc second, about 1 km) and saturated pixels of the DMSP-OLS stable night-time light data hamper the correct extraction of urban areas (Small, Pozzi, and Elvidge 2005).

*Corresponding author. Email: blyu@geo.ecnu.edu.cn

In the early 2013, the Earth Observation Group in National Oceanic and Atmospheric Administration's National Geophysical Data Center (NOAA/NGDC) of the United States released the first global night-time light composite data from the Visible Infrared Imaging Radiometer Suite (VIIRS) day–night band (DNB) carried by the Suomi National Polar-orbiting Partnership (NPP) satellite (Baugh et al. 2013; Elvidge, Baugh, et al. 2013; Elvidge, Zhizhin, et al., 2013), hereinafter referred to as 'NPP-VIIRS data' in this letter. The NPP-VIIRS data, at a resolution of 15 arc second (about 500 m) grids, were generated from VIIRS DNB data collected on nights with low moonlight during 18–26 April 2012 and 11–23 October2012 (Baugh et al. 2013). For detailed description about spatial and radiometric resolution of the original VIIRS DNB data, readers are recommended to refer to Baugh et al. (2013) and Elvidge, Baugh, et al. (2013). Some researchers have evaluated the potential of NPP-VIIRS data to estimate the socioeconomic indicators (Li et al. 2013; Shi et al. 2014), but to the best of our knowledge, no related work has reported its performance of urban area extraction at regional scale. Therefore, an evaluation will be able to provide a better understanding of the capability of NPP-VIIRS data in urban area extraction. In addition, a comparison of the accuracy of extracted urban area from NPP-VIIRS data with that from DMSP-OLS data will support a quantitative assessment of qualities of those data and benefit the applications of those data in future research.

This letter aims to investigate the ability of NPP-VIIRS data for extracting urban areas, with a comparative analysis with the DMSP-OLS data. Twelve Chinese cities are selected as case study areas. The description of study areas and data sources and result analysis will be presented in the following sections.

2. Study area and data

In this letter, 12 Chinese cities (Shanghai, Beijing, Tianjin, Nanjing, Chengdu, Wuhan, Zhenjiang, Meishan, Ma'anshan, Gaochun, Hanshan and Hechuan) with different levels of urbanization and socioeconomic development are selected as case study areas. Those cities can be classified into four categories. Shanghai (located in eastern China, economic centre), Beijing (the capital of China) and Tianjin (industrial centre of northern China) are three megacities, representing highly urbanized and developed areas. Nanjing (located in eastern China), Chengdu (located in western China) and Wuhan (located in central China) are the capitals of three provinces (Jiangsu, Sichuan and Hubei), representing big cities and economic centres of a region. Zhenjiang (a city of Jiangsu Province), Meishan (a city of Sichuan Province) and Ma'anshan (a city of Anhui Province) are three middle-size cities, representing cities undergoing fast urbanization. Hanshan (a city of Anhui Province), Hechuan (a city of Chongqing city) and Gaochun (a city of Jiangsu Province) are small cities in China.

Five types of data, including the 2012 NPP-VIIRS data, the 2012 DMSP-OLS data, Landsat 8 Operational Land Imager and the Thermal Infrared Sensor (OLI-TIRS) data, statistical data of land use investigation and the administrative boundaries of selected cities, were used in this study. The 2012 NPP-VIIRS data were obtained from the website of NOAA/NGDC (http://ngdc.noaa.gov/eog/viirs/download_viirs_ntl.html). The 2012 DMSP-OLS data are the annual stable night-time light composite, which were also available at the website of NOAA/NGDC (http://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html). Seventeen scenes of Landsat 8 OLI-TIRS images were downloaded from Geospatial Data Cloud (http://www.gscloud.cn/). Urban areas of the selected cities were classified from the Landsat data and then employed as the reference because of their high resolution (30 m). Due to the absence of the statistical urban areas in

2012, we utilized the statistical data of land use investigation of the year 2010 combined with the average annual growth rate of urban areas from 2008 to 2010 to estimate the urban areas in 2012. The estimated urban areas in 2012 were then employed as the ancillary statistical data in our study. The statistical data of land use investigation in 2010 were acquired from Land and Resources Bureau of each city. The administrative boundaries for the 12 cities of the year 2008 were obtained from the National Geomatics Center of China.

All the spatial data (including remotely sensed data and administrative boundary data) were projected into the Lambert Azimuthal Equal Area Projection with reference to WGS84 datum.

3. Methods

3.1. Urban built-up area extraction

As the built-up urban areas are illuminated artificially at night, their corresponding pixels in night-time light images have larger DN (digital number) values (in DMSP-OLS data) or radiance values (in NPP-VIIRS data) than the surrounding dark rural areas. In previous studies, a threshold value was often used to segment urban areas on DMSP-OLS data (Imhoff et al. 1997; Small, Pozzi, and Elvidge 2005; He et al. 2006; Liu et al. 2012). Pixels with a value equal to or larger than the threshold value will be considered part of an urban built-up area. Like DMSP-OLS data, the NPP-VIIRS data also record artificial lights at night. The threshold-based method can be used to extract the urban area from NPP-VIIRS data as well.

He et al. (2006) optimized the threshold value for urban area extraction from night-time light data by referencing the urban areas reported by government's statistical data. The threshold value that produced minimum difference between image-derived value and statistical data was selected as the threshold. This method results in high-accuracy results and is easily implemented (Shu et al. 2011).

In this study, we adopted a similar approach to determine the optimal threshold value of built-up urban area extraction for each individual city from two types of night-time light images. First, two types of night-time light images for each city were extracted from the global data sets by using a mask polygon of the administrative boundary. Then, a threshold of the minimum value (DN or radiance) was used to segment the images into urban area and non-urban area. The absolute difference between the extracted area and statistical data was recorded. Such processes were iterated by using increasing the threshold values until reaching the maximum pixel value of the image. The threshold value that produced minimum difference was selected as the threshold for urban built-up area extraction of the city. The determined optimal threshold values for the 12 cities are listed in Table 1.

3.2. Accuracy estimation

In this letter, we used Landsat 8 OLI-TIRS data (about 30 m spatial resolution) to assess the ability of NPP-VIIRS data in extracting built-up urban areas. Considering that the Landsat 8 OLI-TIRS data have much higher spatial resolution than any of the night-time light data, they are assumed to be able to represent the real patterns of built-up urban areas. Built-up urban areas of 12 selected cities are classified from Landsat 8 data using maximum likelihood classification method and regarded as the ground truth reference.

Table 1. Optimal threshold values for built-up urban area extraction of 12 selected cities.

City	Threshold of NPP-VIIRS (nW cm^{-2} sr^{-1})	Threshold of DMSP-OLS (DN)	City	Threshold of NPP-VIIRS (nW cm^{-2} sr^{-1})	Threshold of DMSP-OLS (DN)
Shanghai	17.150	56	Meishan	10.410	22
Beijing	14.145	61	Zhenjiang	9.200	53
Tianjin	21.470	55	Ma'anshan	20.600	50
Chengdu	23.700	55	Gaochun	2.900	33
Wuhan	16.880	52	Hanshan	3.000	29
Nanjing	12.550	54	Hechuan	7.520	36

Since the resolutions of DMSP-OLS, NPP-VIIRS and Landsat 8 OLI-TIRS data are about 1000 m, 500 m and 30 m, respectively, we first resampled them all into 10 m spatial resolution to facilitate the inter-comparison. After that, the urban extents derived from DMSP-OLS data and NPP-VIIRS data are compared with the classified results from Landsat images by using a pixel-by-pixel schema for each city respectively. The commission error, omission error and overall accuracy of extracted built-up urban areas from night-time light images are calculated and used for the accuracy estimation.

4. Results and discussions

By using the proposed method, the built-up urban areas of the selected cities were extracted. Due to limited space of this letter, we only illustrate the original remotely sensed data and extracted built-up urban areas from night-time light data and Landsat 8 data of four typical cities (Shanghai, Nanjing, Ma'anshan and Hechuan) in Figure 1.

The spatial accuracy of extracted urban areas from both NPP-VIIRS and DMSP-OLS data was evaluated by using the classified urban areas from Landsat 8 OLI-TIRS data as ground truth. Since all the remotely sensed images had been resampled into 10 m resolution, a pixel-by-pixel comparison was used to evaluate the spatial accuracy of the results. For each city, a false colour composite using three types of extracted built-up urban areas was adopted to analyse the spatial coherence of extracted results (Figure 2). In the composite image, the red, green and blue channels are the extracted urban areas from NPP-VIIRS, DMSP-OLS and Landsat 8 data, respectively. The white regions shown in the composite image (Figure 2) represent the urban areas extracted from all three types of remotely sensed data.

Three indices, including overall accuracy, commission error and omission error, were used to evaluate the spatial accuracy of extracted results quantitatively. The accuracy estimation of the results from NPP-VIIRS and DMSP-OLS are listed in Table 2.

Visual observations in Figure 2 and the accuracy estimations in Table 2 showed that the results extracted from NPP-VIIRS data had higher consistency of the urban areas identified from Landsat 8 data than those from DMSP-OLS data. This was due to the higher spatial resolution and wider radiometric detection range of NPP-VIIRS night-time light data. As can be seen from Figure 1, lit areas in DMSP-OLS data of four selected cities spread out the built-up urban areas (see Landsat 8 data) considerably. This 'blooming' phenomenon was also reported in previous studies (Small, Pozzi, and Elvidge 2005) and would obstruct the urban area identification from DMSP-OLS data. In contrast, the NPP-VIIRS data displayed spatial patterns of built-up urban areas that are more consistent

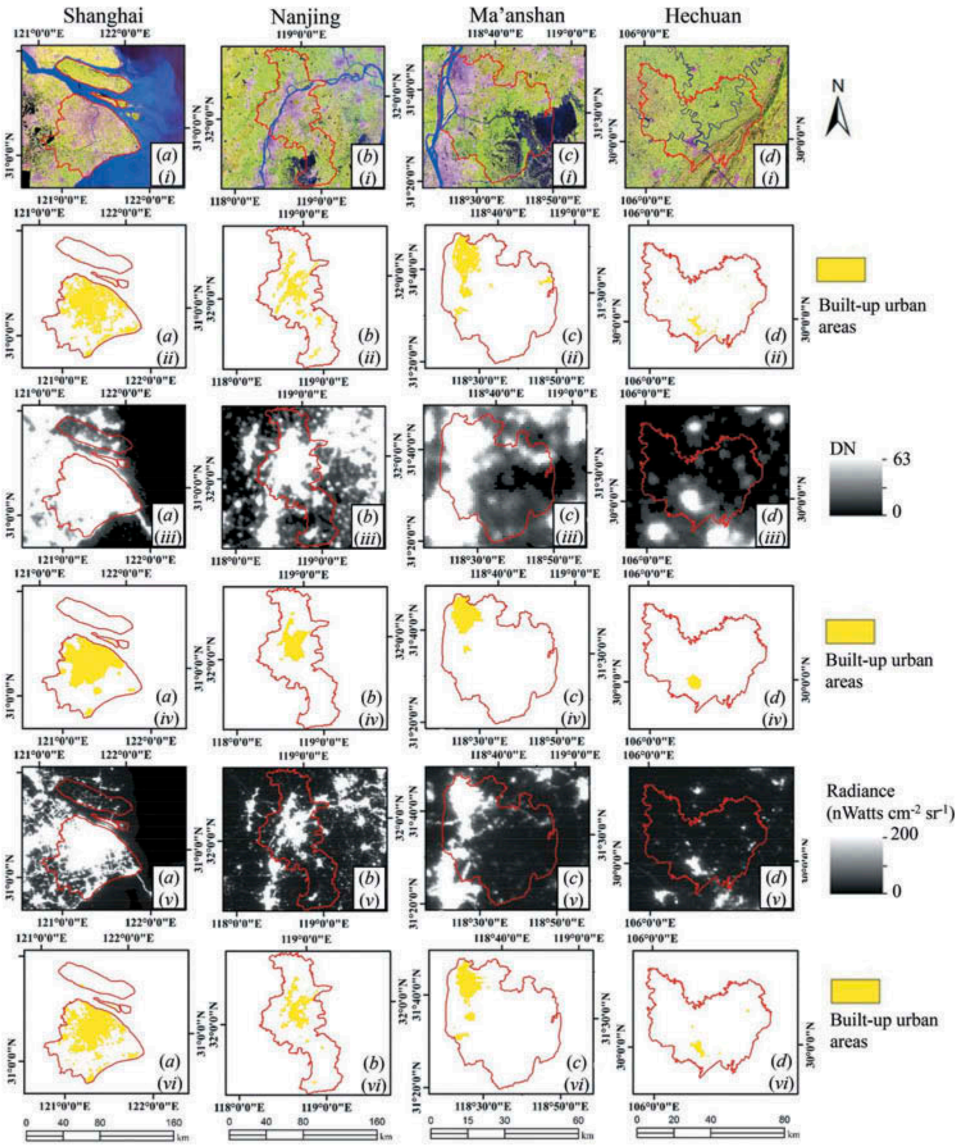

Figure 1. The built-up urban areas extracted from Landsat 8 OLI-TIRS data, NPP-VIIRS data and DMSP-OLS data of four typical cities (Shanghai, Nanjing, Ma'anshan and Hechuan). Note: (*a*)(*i*), (*b*)(*i*), (*c*)(*i*) and (*d*)(*i*) are Landsat 8 OLI-TIRS data and the red, green and blue channels are band 6, 5 and, 4 respectively; (*a*)(*ii*), (*b*)(*ii*), (*c*)(*ii*) and (*d*)(*ii*) are built-up urban areas classified from Landsat 8 OLI-TIRS data; (*a*)(*iii*), (*b*)(*iii*), (*c*)(*iii*) and (*d*)(*iii*) are DMSP-OLS data; (*a*)(*iv*), (*b*)(*iv*), (*c*)(*iv*) and (*d*)(*iv*) are built-up urban areas extracted from DMSP-OLS data; (*a*)(*v*), (*b*)(*v*), (*c*)(*v*) and (*d*)(*v*) are NPP-VIIRS data; (*a*)(*vi*), (*b*)(*vi*), (*c*)(*vi*) and (*d*)(*vi*) are built-up urban areas extracted from NPP-VIIRS data. The red lines in all the figures are the administrative boundary.

with the Landsat 8 OLI-TIRS data. From Table 2, it can be seen that overall accuracy of results from the NPP-VIIRS data is higher than those from the DMSP-OLS data for all the 12 cities regardless of the developed level and location of the city. Moreover, the

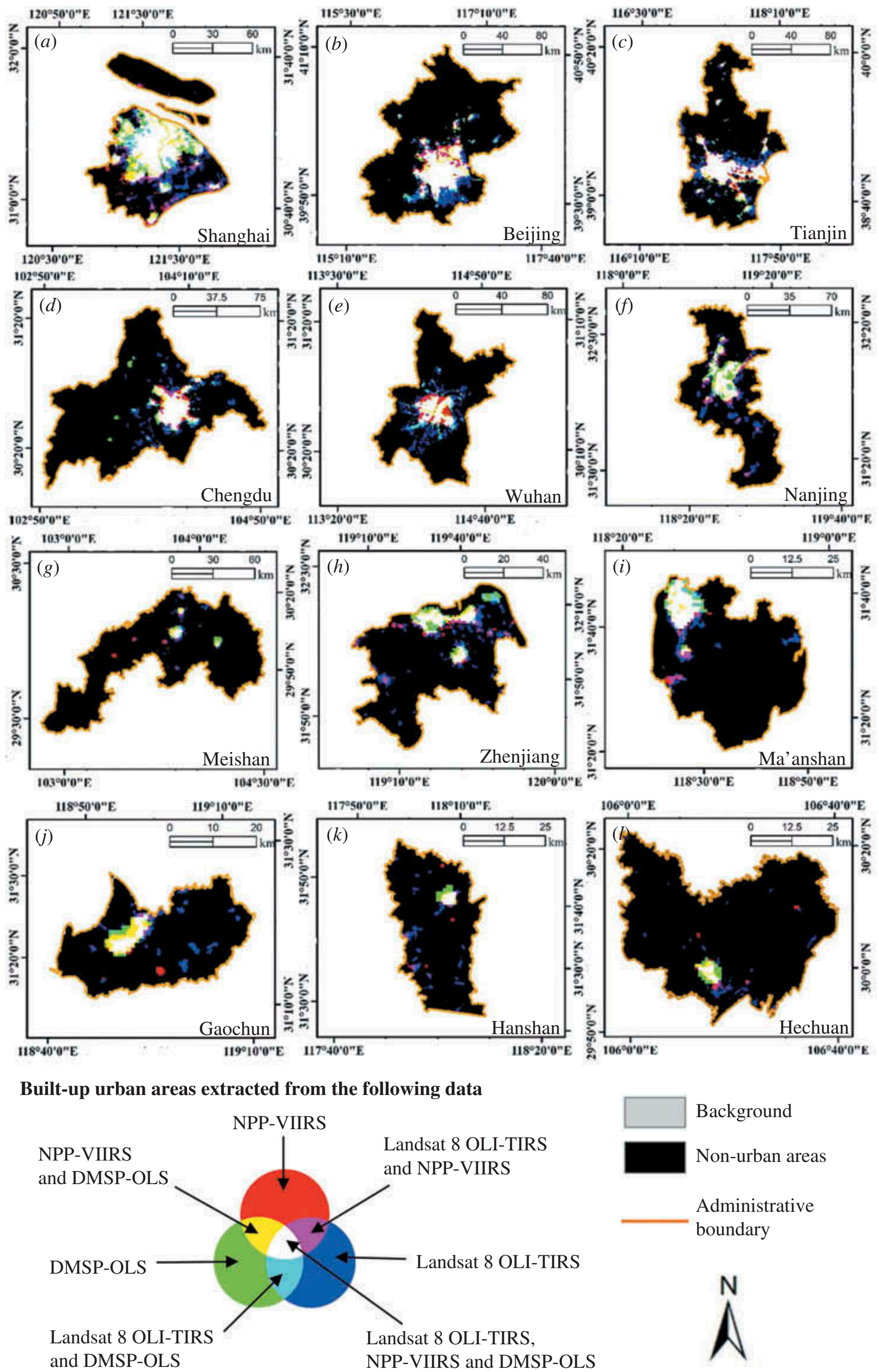

Figure 2. Comparison of built-up urban areas extracted from NPP-VIIRS data, DMSP-OLS data and Landsat 8 OLI-TIRS data of 12 cities: (*a*) Shanghai, (*b*) Beijing, (*c*) Tianjin, (*d*) Chengdu, (*e*) Wuhan, (*f*) Nanjing, (*g*) Meishan, (*h*) Zhenjiang, (*i*) Ma'anshan, (*j*) Gaochun, (*k*) Hanshan and (*l*) Hechuan.

Table 2. Accuracy assessment of the built-up urban areas extracted from NPP-VIIRS data and DMSP-OLS data in comparison with those from Landsat 8 OLI-TIRS data.

City	OA of NPP-VIIRS (%)	OA of DMSP-OLS (%)	CE of NPP-VIIRS (%)	CE of DMSP-OLS (%)	OE of NPP-VIIRS (%)	OE of DMSP-OLS (%)
Shanghai	84.38	82.87	6.54	8.02	9.08	9.11
Beijing	93.23	92.34	1.94	2.58	4.83	5.08
Tianjin	91.13	90.61	2.63	3.09	6.24	6.30
Chengdu	95.22	95.05	1.50	1.55	3.28	3.40
Wuhan	93.00	90.43	1.32	2.72	5.68	6.86
Nanjing	91.91	89.02	2.49	4.22	5.59	6.77
Meishan	98.03	97.98	0.87	0.89	1.11	1.14
Zhenjiang	92.19	90.54	2.24	3.24	5.56	6.22
Ma'anshan	95.61	94.98	1.03	1.39	3.35	3.63
Gaochun	92.95	92.38	3.89	4.05	3.16	3.57
Hanshan	96.25	95.18	3.01	3.47	0.74	1.34
Hechuan	99.66	97.68	0.20	1.18	0.14	1.14

Note: OA, overall accuracy; CE, commission error; OE, omission error.

commission error and omission error from the NPP-VIIRS data are smaller than those from the DMSP-OLS data. Therefore, we believe that the NPP-VIIRS data are more accurate in extracting built-up urban areas than the DMSP-OLS data.

The evaluation results also showed that both the NPP-VIIRS data and the DMSP-OLS data produced higher accuracy for smaller cities. With the NPP-VIIRS data, the average overall accuracies for megacities, big cities, middle-size cities and small cities are 89.58%, 93.38%, 95.28% and 96.29%, respectively. Using the DMSP-OLS data, the average overall accuracies for those four types of cities are 88.61%, 91.50%, 94.50% and 95.08%, respectively. However, a different pattern can be identified from the commission error. For two types of night-time light data, most commission error of small cities are higher than those of big ones. Using the NPP-VIIRS data, the commission error for megacities, big cities, middle-size cities and small cities are 3.70%, 1.77%, 1.38% and 2.37%, respectively. Using the DMSP-OLS data, the average commission errors for those four types of cities are 4.56%, 2.83%, 1.84% and 2.90%, respectively.

Although the NPP-VIIRS data were proven to derive better urban area extraction results, it should be noted that there are still some uncertainties. First, the reliability of area from reference data is a key factor affecting built-up urban area extraction. Second, fires, gas flares, volcanoes and other background noise have not been removed from the currently released NPP-VIIRS data. The quality of the NPP-VIIRS data still needs to be improved using some advanced techniques. Finally, at the time of writing this letter, there was only one NPP-VIIRS composite data product available, which hindered a more comprehensive evaluation. As long as NOAA/NGDC provides more NPP-VIIRS data with high accuracy, temporal and spatial analysis can be conducted in the future.

5. Conclusions

As a new-generation night-time light data, NPP-VIIRS data have higher spatial resolution and wider radiometric detection range than the DMSP-OLS data. Through a case study of 12 cities (Shanghai, Beijing, Tianjin, Nanjing, Chengdu, Wuhan, Zhenjiang, Meishan, Ma'anshan, Gaochun, Hanshan and Hechuan) representing megacity, big city, middle-size city and small city in China, this letter conducts an exploratory evaluation on the ability of the NPP-VIIRS night-time light composite data to extract built-up urban areas. By using the classified urban areas from high-resolution Landsat 8 OLI-TIRS data as ground truth, the spatial accuracies of built-up urban areas extracted from NPP-VIIRS and DMSP-OLS data are evaluated using a pixel-by-pixel comparison. The results reveal that the NPP-VIIRS data are able to achieve higher accuracy for urban area extraction in comparison with the DMSP-OLS data for all the 12 cities regardless of the developed level and location of the city.

Acknowledgements

The authors thank the editor, Dr Timothy Warner, and two anonymous reviewers for their constructive comments and suggestions.

Funding

This study is supported by the National Basic Research Program of China (973 Program) [Grant No. 2010CB951603], the National Natural Science Foundation of China [Grant No. 41001270], the Grant from Shanghai Key Lab for Urban Ecological Processes and Eco-Restoration [Grant No. SHUES2012A03] and the Fundamental Research Funds for the Central Universities of China.

References

Baugh, K., F.-C. Hsu, C. D. Elvidge, and M. Zhizhin. 2013. "Nighttime Lights Compositing using the VIIRS Day-Night Band: Preliminary Results." *Proceedings of the Asia-Pacific Advanced Network* 35: 70–86. doi:10.7125/APAN.35.8.

Elvidge, C. D., K. E. Baugh, J. B. Dietz, T. Bland, P. C. Sutton, and H. W. Kroehl. 1999. "Radiance Calibration of DMSP-OLS Low-Light Imaging Data of Human Settlements." *Remote Sensing of Environment* 68: 77–88. doi:10.1016/S0034-4257(98)00098-4.

Elvidge, C. D., K. E. Baugh, E. A. Kihn, H. W. Kroehl, and E. R. Davis. 1997. "Mapping City Lights with Nighttime Data from the DMSP Operational Linescan System." *Photogrammetric Engineering and Remote Sensing* 63: 727–734.

Elvidge, C. D., K. E. Baugh, M. Zhizhi, and F.-C. Hsu. 2013. "Why VIIRS Data are Superior to DMSP for Mapping Nighttime Lights." *Proceedings of the Asia-Pacific Advanced Network* 35: 62–19. doi:10.7125/APAN.35.7.

Elvidge, C. D., P. Cinzano, D. R. Pettit, J. Arvesen, P. Sutton, C. Small, R. Nemani, T. Longcore, C. Rich, J. Safran, J. Weeks, and S. Ebener. 2007. "The Nightsat Mission Concept." *International Journal of Remote Sensing* 28: 2645–2670. doi:10.1080/01431160600981525.

Elvidge, C. D., B. T. Tuttle, P. S. Sutton, K. E. Baugh, A. T. Howard, C. Milesi, B. L. Bhaduri, and R. Nemani. 2007. "Global Distribution and Density of Constructed Impervious Surfaces." *Sensors* 7: 1962–1979. doi:10.3390/s7091962.

Elvidge, C. D., M. Zhizhin, F.-C. Hsu, and K. E. Baugh. 2013. "VIIRS Nightfire: Satellite Pyrometry at Night." *Remote Sensing* 5: 4423–4449. doi:10.3390/rs5094423.

He, C. Y., P. J. Shi, J. G. Li, J. Chen, Y. Z. Pan, J. Li, L. Zhuo, and T. Ichinose. 2006. "Restoring Urbanization Process in China in the 1990s by using Non-Radiance Calibrated DMSP/OLS Nighttime Light Imagery and Statistical Data." *Chinese Science Bulletin* 51: 1614–1620. doi:10.1007/s11434-006-2006-3.

Imhoff, M. L., W. T. Lawrence, D. C. Stutzer, and C. D. Elvidge. 1997. "A Technique for Using Composite DMSP/OLS 'City Lights' Satellite Data to Map Urban Area." *Remote Sensing of Environment* 61: 361–370. doi:10.1016/S0034-4257(97)00046-1.

Li, X., H. Xu, X. Chen, and C. Li. 2013. "Potential of NPP-VIIRS Nighttime Light Imagery for Modeling the Regional Economy of China." *Remote Sensing* 5: 3057–3081. doi:10.3390/rs5063057.

Liu, Z. F., C. Y. He, Q. F. Zhang, Q. X. Huang, and Y. Yang. 2012. "Extracting the Dynamics of Urban Expansion in China using DMSP-OLS Nighttime Light Data from 1992 to 2008." *Landscape and Urban Planning* 106: 62–72. doi:10.1016/j.landurbplan.2012.02.013.

Ma, T., C. Zhou, T. Pei, S. Haynie, and J. Fan. 2012. "Quantitative Estimation of Urbanization Dynamics Using Time Series of DMSP/OLS Nighttime Light Data: A Comparative Case Study from China's Cities." *Remote Sensing of Environment* 124: 99–107. doi:10.1016/j.rse.2012.04.018.

Shi, K., B. Yu, Y. Huang, Y. Hu, B. Yin, Z. Chen, L. Chen, and J. Wu. 2014. "Evaluating the Ability of NPP-VIIRS Nighttime Light Data to Estimate the Gross Domestic Product and the Electric Power Consumption of China at Multiple Scales: A Comparison with DMSP-OLS Data." *Remote Sensing* 6: 1705–1724. doi:10.3390/rs6021705.

Shu, S., B. Yu, J. Wu, and H. Liu. 2011. "Methods for Deriving Urban Built-Up Area Using Night-Light Data: Assessment and Application." *Remote Sensing Technology and Application* 26: 169–176.

Small, C., F. Pozzi, and C. D. Elvidge. 2005. "Spatial Analysis of Global Urban Extent from DMSP-OLS Night Lights." *Remote Sensing of Environment* 96: 277–291. doi:10.1016/j.rse.2005.02.002.

Sutton, P. C. 2003. "A Scale-Adjusted Measure of 'Urban Sprawl' Using Nighttime Satellite Imagery." *Remote Sensing of Environment* 86: 353–369. doi:10.1016/S0034-4257(03)00078-6.

Weng, Q. 2012. "Remote Sensing of Impervious Surfaces in the Urban Areas: Requirements, Methods, and Trends." *Remote Sensing of Environment* 117: 34–49. doi:10.1016/j.rse.2011.02.030.