Foreword to the Special Issue on Advances in Remote Sensing of Nighttime Lights: Progresses, Challenges, and Perspectives

NIGHTTIME light (NTL) data provides unique observations of our Earth and receives increasing attentions from a variety of fields such as remote sensing, GIS, and urban planning. Since 1990s, the Defense Meteorological Satellite Program—Operational Linescan System (DMSP-OLS) NTL data have been explored to monitor human activities. Recently, new NTL satellites such as NPP-VIIRS, International Space Station (ISS), EROS-B, Jilin 1-3B, and Luojia 1-01, with better spatial and temporal resolutions, and even multispectral information, have been launched. These new satellites can provide a greater amount of detailed artificial light records at night and could improve our understanding the process of urbanization. On the other hand, the new NTL data pose new scientific and technological challenges in calibration, interpretation, applications, and potential assessment.

To collect and highlight recent progresses, current challenges, and future opportunities in remote sensing of NTLs, we organized a special issue in the IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing. This issue selected eight papers on the following topics of NTL remote sensing.

1) Data preprocessing such as noise elimination, image enhancement, and geometric correction.
2) Analyses of relationship between ground observations of artificial lights and spaceborne measurements of nighttime brightness.
3) Applications of NTL remotely sensed data such as urbanization mapping, environmental analysis, events detection, and change analyses.
4) Assessment of new remotely sensed NTL data potential, especially beyond traditional applications.

The paper by Wang *et al.* [item 1) in the Appendix] assesses the aerosol influence on NPP-VIIRS NTL data. A significantly negative relationship between the NTL radiance and aerosol optical depth (AOD) from AERONET and Himawari is found by using the linear and log-linear models. This article demonstrates that, with the consideration of the time scale of NTL data, city size, climate types, the influence of AOD on NTL data could be different, which is an essential factor in determining the quality of NTL data. In the future, an atmospheric correction is recommended before the applications of NTL data.

The paper by Sun *et al.* [item 2) in the Appendix] proposes a deep learning method for the NTL and landcover data to estimate the time-series gross domestic product (GDP) at the county level. The proposed method can bridge the multi-source remote sensing data and time-series GDP, and outperforms the traditional linear model of GDP estimation. With the availability of global NTL and landcover data, this method is applicable to other countries or regions.

The paper by Zhang *et al.* [item 3) in the Appendix] analyzes the NTL dynamics during the Venezuela's socioeconomic crisis by decomposing the sum of urban light (SUL) intensity into two components: the SUL trend (SULT) and SUL seasonal cycle. By analyzing the decreasing SULT and the change pattern of Venezuela-Colombia international border from April 2012 to December 2018, the Venezuela's socioeconomic crisis is evaluated, which implies that the SULT and NTL data can be used for monitoring the socioeconomic situation.

The paper by Chen *et al.* [item 4) in the Appendix] conducts a NTL-based urbanization analysis to assess the spatial-temporal changes of Yangtze river delta urban agglomeration (YRDUA) at three scales: urban agglomeration (UA) scale, metropolitan area (MA) scale, and city scale. By comparing with other five major UAs worldwide, YRDUA still maintains the greatest urbanization potential, which is mainly driven by national planning. The results also demonstrate that the MAs, especially Hefei MA, within YRDUA play an increasingly important role.

The paper by Zhao *et al.* [item 5) in the Appendix] uses the inverted NTL intensity as a continuous cost surface to detect the optimal routes with the minimum cost between any two urban patches in three representative UAs in China. These optimal routes come together as urban spatial connectivity network, which records the connectivity relationship and spatial pattern of UAs. The information of the detected urban connectivity is of great use in regional planning for sustainable development goals.

The paper by Li *et al.* [item 6) in the Appendix] incorporates the capacity of NTL for detecting the multicenter structure within urban agglomeration in Guangdong-Hong Kong-Macao Greater Bay Area. Then a method based on this multicenter structure is developed to estimate the surface urban heat island intensity. This paper concludes that the addition of NTL data and multicenter structure could improve the performance of urban heat island analysis.

The paper by Zhang *et al.* [item 7) in the Appendix] employs the NPP-VIIRS and new-generation NTL data from Luojia 1-01 satellite to estimate PM 2.5 concentration via the geographically weighted regression. The results show that the NTL data

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can reveal additional details and improve the performance of estimation model. In comparison with the NPP-VIIRS NTL data, Luojia 1-01 NTL data has a better performance of PM 2.5 estimation and spatialization.

The paper by Tang *et al.* [item 8) in the Appendix] proposes a novel sample selection method for impervious surface area (ISA) mapping by integrating the Jilin 1-3B high-resolution NTL and Sentinel-2 data. Compared to the conventional methods, the proposed method can automatically select reliable and diverse samples, and can improve the accuracy of ISA extraction, since it reduces the confusion between the ISA and bare land.

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APPENDIX
RELATED WORK

1) X. Wang, X. Mu, and G. Yan, "Quantitative analysis of aerosol influence on Suomi-NPP VIIRS nighttime light in China," *IEEE J. Sel. Top. Appl. Earth Observ. Remote Sens*., vol. 13, pp. 3557–3568, 2020, doi: 10.1109/JSTARS.2020.3003480.
2) J. Sun, L. Di, Z. Sun, J. Wang, and Y. Wu, "Estimation of GDP using deep learning with NPP-VIIRS imagery and land cover data at the county level in CONUS," *IEEE J. Sel. Top. Appl. Earth Observ. Remote Sens.*, vol. 13, pp. 1400–1415, 2020.
3) L. Zhang, X. Li, and F. Chen, "Spatiotemporal analysis of Venezuela's nighttime light during the socioeconomic crisis," *IEEE J. Sel. Top. Appl. Earth Observ. Remote Sens*., vol. 13, pp. 2396–2408, 2020.
4) J. Chen, H. Wei, N. Li, S. Chen, W. Qu, and Y. Zhang, "Exploring the spatial-temporal dynamics of the yangtze river delta urban agglomeration based on night-time light remote sensing technology," *IEEE J. Sel. Top. Appl. Earth Observ. Remote Sens.*, vol. 13, pp. 5369–5383, 2020.
5) X. Zhao, X. Li, Y. Zhou, and D. Li, "Analyzing urban spatial connectivity using night light observations: A case study of three representative urban agglomerations in China," *IEEE J. Sel. Top. Appl. Earth Observ. Remote Sens.,* vol. 13, pp. 1097–1108, 2020.
6) J. Li, F. Wang, Y. Fu, B. Guo, Y. Zhao, and H. Yu, "A novel SUHI referenced estimation method for multi-centers urban agglomeration using DMSP/OLS nighttime light data," *IEEE J. Sel. Top. Appl. Earth Observ. Remote Sens.*, vol. 13, pp. 1416–1425, 2020.
7) G. Zhang, Y. Shi, and M. Xu, "Evaluation of LJ1-01 nighttime light imagery for estimating monthly PM2.5 concentration: A comparison with NPP-VIIRS nighttime light data," *IEEE J. Sel. Top. Appl. Earth Observ. Remote Sens.*, vol. 13, pp. 3618–3632, 2020, doi: 10.1109/JSTARS.2020.3002671.
8) P. Tang, P. Du, C. Lin, S. Guo, and L. Qie, "A novel sample selection method for impervious surface area mapping using JL1-3B nighttime light and Sentinel-2 imagery," *IEEE J. Sel. Top. Appl. Earth Observ. Remote Sens.,* vol. 13, pp. 3931–3941, 2020.

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