

NASA SCIENCE MISSION DIRECTORATE  
EARTH SCIENCE DIVISION

NASA ROSES LAND-COVER / LAND-USE CHANGE FOR EARLY CAREER SCIENTISTS  
(NNH11ZDA001N-LCLUC)

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**Summary of Research**

Year (12/2015 – 12/2016)

(March 05, 2017)

Project Title:

**Understanding and Simulating Spatially Explicit Global Urban Expansion in the Context of Climate Change**

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Grant Number: NNX16AC27G

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*Any opinions, findings, and conclusions or recommendations expressed in this report are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration.*

## Summary

This project contributes to the NASA ROSES LCLUC program by generating a consistent global urban map series and developing an integrated modeling framework to project future urban expansion. This research improved the understanding of global historical urban expansion, its socioeconomic drivers, and potential future urban expansion and its implications.

### 1. *The inter-calibration of nightlights data*

We developed methods to inter-calibrate continuous Defense Meteorological Satellite Program (DMSP) / Operational Linescan System (OLS) nighttime lights (NTL) series (1992 to 2013) for global urban mapping due to the lacking of on-board calibration in NTL data (Zhao et al, 2014; Li & Zhou, 2016, 2017). Inconsistencies of NTL series among satellites or particular periods were identified at first. Thereafter, they were systematically adjusted according to the relationship between the referenced and modified images. After the stepwise based calibration, our results significantly improved the raw NTL sequence with a consistent temporal pattern as well as notably reduced Normalized Difference Index. Comparing to outcomes that derived from other calibration approaches, we achieved a more reasonable NTL series in terms of the initial pattern of NTL segments derived from different satellites as well as the magnitude of the total DN digital number values at the global or regional scales. This calibrated results are basis to many urban related studies at global or regional scales, such as urban settlement change detection or energy consumption assessment over years.

### 2. *A cluster-based method to map urban area from DMSP/OLS nightlights*

As a keystone of our proposed activities, the project team developed a cluster-based method to estimate optimal thresholds and map urban extent using DMSP/OLS NTL and supplementary data (Zhou et al., 2014). This method includes five major steps: data preprocessing, urban cluster segmentation, logistic model development, threshold estimation, and urban extent delineation (Figure 1). First, we filtered NTL data by excluding water and gas flare pixels. Second, we identified potential urban clusters from filtered NTL data using a segmentation method. Third, we analyzed the relationship of optimal threshold derived from high spatial resolution land cover data with cluster size and NTL

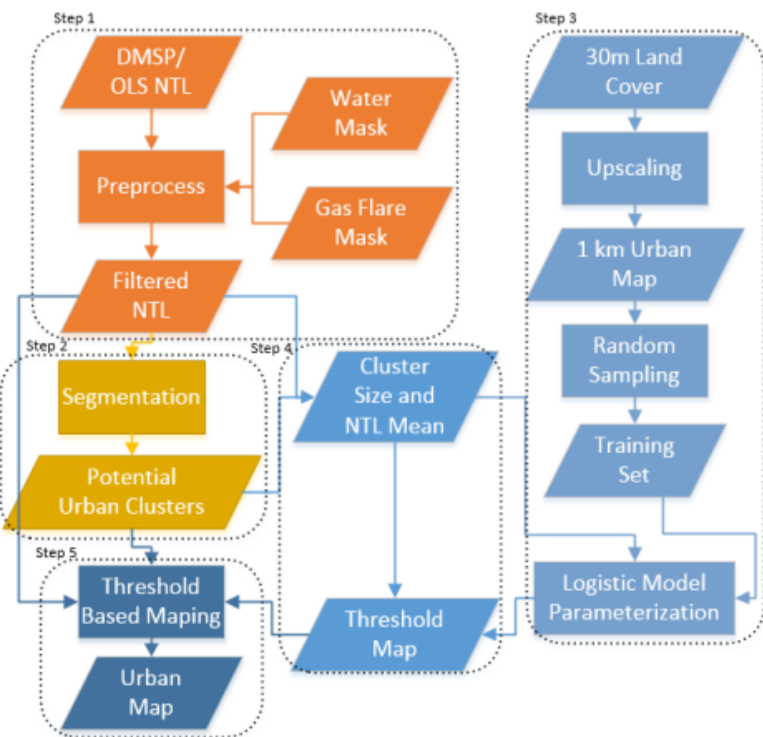


Figure 1. Flowchart of the cluster based method

magnitude in each cluster, and built a logistic model for optimal threshold estimation. Fourth, we estimated the optimal threshold in each cluster using the logistic model. Finally, we mapped the urban extent according to the estimated threshold in each cluster.

### 3. Global urban map series

The project team extended the cluster-based method through developing a parameterization scheme and built a new global urban extent map from the DMSP/OLS NTL data (Zhou et al., 2015, Figure 2). The product was compared to five global urban products with similar definition and close time period including MODIS 500m urban map, GlobCover, GLC2000, Global Rural–Urban Mapping Project, and NOAA's ISA map at the pixel and regional levels. The spatial pattern of urban extent from this product was also evaluated at a variety of levels, e.g., longitudinal and latitudinal scale (Figure 3). We also extended the cluster-based method in the temporal domain and built the urbanization dynamic from 1992 to 2012 (Figure 4).



Figure 2. A global map of urban extent from nightlights

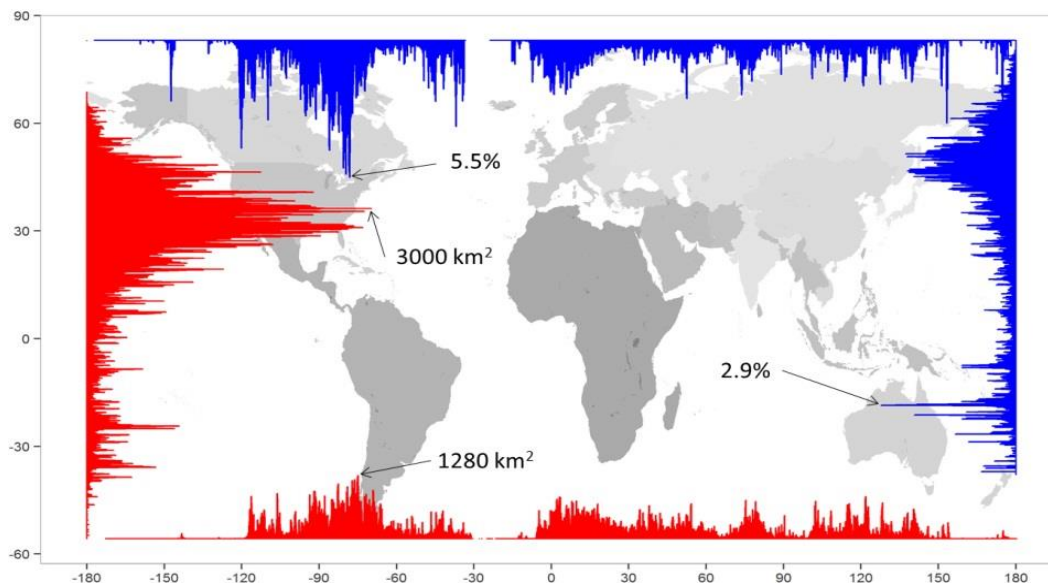


Figure 3. Urban area by longitude and latitude

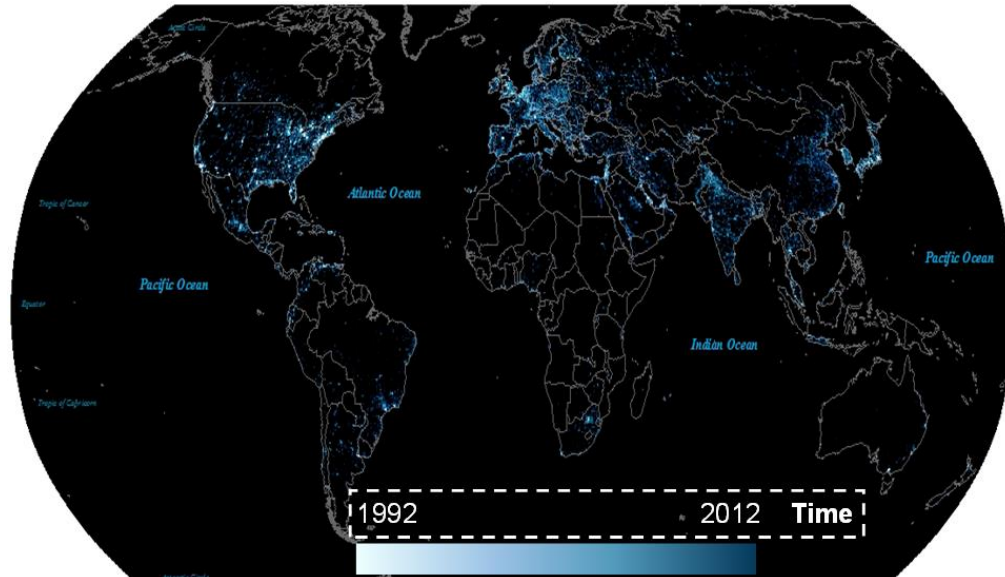


Figure 4. Urban extent from 1992 to 2012 from nightlights

#### 4. A prototype of online modeling and visualization system

The project team developed an integrated modeling framework to project future urban spatial sprawl by combining sub-models (e.g., regional urban area demand model) and supporting data (e.g., population). Based on the proposed modeling framework, the team developed a modeling and visualization system for urbanization (Figure 5). This modeling and visualization system provides the possibility to explore historical urbanization and future urban spatial sprawl under different scenarios.

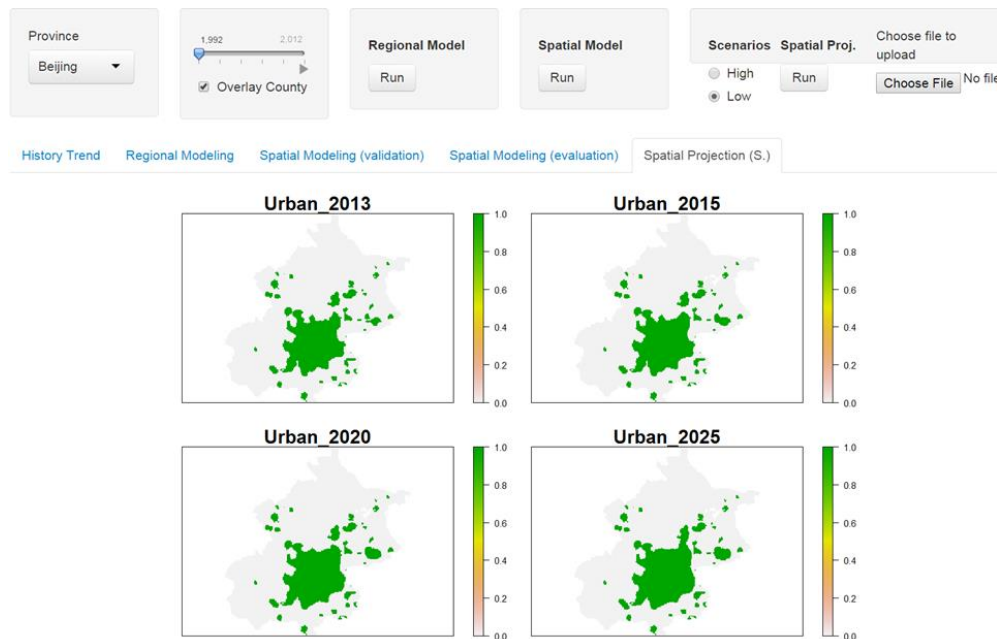


Figure 5. A modeling and visualization system of urbanization

## 5. Implications of urbanization

In a global perspective, understanding historical urban dynamics and future urban expansion, especially its spatial dynamics, will help to develop better strategies for mitigation and adaptation of urbanization's impacts on environment. In this project, we investigated the potential impacts of urbanization on environment including urban heat island (Li et al., 2017a), building energy use (Güneralp et al, 2017), and vegetation phenology (Figure 6, Li et al., 2016).

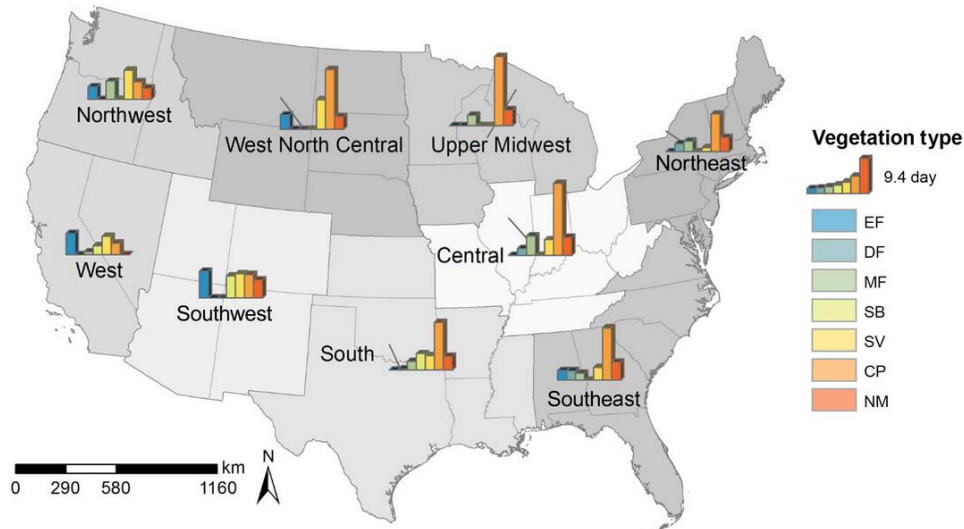


Figure 6. The difference of growth season length of seven vegetation types in different climate zones across the United States. EF: evergreen forest, DF: deciduous forest, MF: mixed forest, SB: shrubland, SV: savannas, CP: cropland, and NM: natural mosaic.

## 6. Publications and Presentations

### Publications:

1. Li, X. & **Y. Zhou\*** (Corresponding Author) (2017b). A stepwise calibration of global continuous DMSP/OLS stable nighttime light series (1992-2013). *Remote Sensing*, to be submitted.
2. Li, X., **Y. Zhou\*** (Corresponding Author), G. Asrar, Y. Zhu (2017a). Creating a seamless 1 km Resolution Daily Land Surface Temperature Dataset for Urban and Surrounding Areas in the Conterminous United States. *Remote Sensing of Environment*. Under review.
3. Güneralp, B., **Y. Zhou**, D. Ürgе-Vorsatz, M. Gupta, S. Yu, P. L. Patel, M. Fragkias, X. Li & K. C. Seto (2017) Global scenarios of urban density and its impacts on building energy use through 2050. *Proceedings of the National Academy of Sciences*. doi: 10.1073/pnas.1606035114
4. Li, X. & **Y. Zhou\*** (Corresponding Author) (2017) Urban mapping using DMSP/OLS stable night-time light: a review. *International Journal of Remote Sensing*, doi: 10.1080/01431161.2016.1274451
5. Li, X., **Y. Zhou\*** (Corresponding Author), Asrar, G. R., Mao, J., Li, X. and Li, W. (2016), Response of vegetation phenology to urbanization in the conterminous United States. *Global Change Biology*. doi: 10.1111/gcb.13562

6. **Zhou, Y.**, S. J. Smith, K. Zhao, M. Imhoff, A. Thomson, B. Bond-Lamberty, G. R. Asrar, X. Zhang, C. He & C. D. Elvidge (2015) A global map of urban extent from nightlights. *Environmental Research Letters*, 10, 054011
7. **Zhou, Y.**, S. Smith, C. Elvidge, K. Zhao, A. Thomson, M. Imhoff, 2014. A Cluster-based Method to Map Urban Area from DMSP/OLS Nightlights. *Remote Sensing of Environment*. 147, 173-185.
8. Zhao, N., **Y. Zhou\*** (Corresponding Author), E. Samson, 2014. Correcting incompatible DN values and geometric errors in nighttime lights time series images. *IEEE transactions on Geoscience and Remote Sensing*. 53 (4), 2039-2049.

*Presentations:*

1. Modeling Urbanization and its Implication in Building Energy Use, AAG 2016 Annual Meeting, San Francisco, CA, March 29 - April 2, 2016
2. Spatio-Temporal Dynamics of Global Urbanization: Historical and Future, AAG 2015 Annual Meeting, Chicago, IL, April 21-25, 2015
3. Scenarios for Urban Expansion in the Context of Climate Change, NASA LCLUC Spring Science Team Meeting, College Park, Maryland, USA, April 22-23, 2015
4. Global Urbanization Modeling Supported by Remote Sensing, AGU 2014 Annual Meeting, San Francisco, CA, USA, December 15-19, 2014
5. Spatio-Temporal Dynamics of Urbanization in China: Historical and Future, AGU 2014 Annual Meeting, San Francisco, CA, USA, December 15-19, 2014
6. Understanding and Simulating Global Urban Expansion in the Context of Climate Change, NASA LCLUC Spring Science Team Meeting, Rockville, Maryland, USA, April 23-25, 2014
7. Mapping Global Urban Area from DMSP/OLS Nightlights using a Cluster-based Method, AAG 2014 Annual Meeting, Tampa, Florida, USA, April 8-12, 2014
8. Understanding and Simulating Global Urban Expansion in the Context of Climate Change, NASA LCLUC 2013 Annual Spring Science Team meeting, Rockville, Maryland, USA, April 2-4, 2013