**US Urban Development II**

*Utilizing Skyglow Tools to Assist in the Management of Light Pollution in US National Parks*

**VPS Title:** A Sky Full of Stars: Estimating and Visualizing Artificial Light Pollution for National Parks Management

**Project Team**

***Project Team:***

Rachel Luo (Project Lead)

Sarah Parker

Charlotte Rivard

Elise Turrietta

***Advisors & Mentors:***

Dr. Kenton Ross (NASA Langley Research Center)

***Past or Other Contributors:***

Maximilian Ioffe

Julia Hink

Tyler Jameson

Charlie McClay

Margaret Mulhern

Manda Au

Ian Brastow

Veronica Warda

Benjamin Marcovitz

Aubrey Hilte

Christine Stevens

Eric White

Ryan Avery

Steven Chao

Stanley Yu

**Project Overview**

***Project Synopsis:*** The National Park Service protects its lands from many anthropogenic factors to maintain natural environments in its parks, but intrusive artificial light from urban areas encroaches upon these parks without limit. This project aimed to validate and implement the Skyglow Estimation Toolbox (SET), a program created by previous DEVELOP teams to estimate and visualize the presence of light pollution. The team compared estimations from SET against *in situ* observations from certain parks to assess the accuracy of the tool and trained the National Park Service to use the tool as part of the agency’s work in managing and mitigating skyglow.

***Abstract:***

The expansion of cities and infrastructure networks has raised concerns regarding the impact of growing artificial light pollution on wildlife and human well-being. In addition to degrading night skies for aesthetic viewing, this ‘skyglow’ interferes with ecosystems by disrupting plant life, animal behavior, and human circadian rhythms. In partnership with the National Park Service (NPS), this project created a tool to facilitate the estimation of skyglow in national parks. To conduct this work, the team used the Skyglow Estimation Toolbox (SET), a Python-based program that calculates artificial skyglow by applying a model of light propagation to visible light radiance imagery from the Suomi National Polar-orbiting Partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band (DNB). A previous group enhanced SET’s abilities and created a graphic user interface, and the current team focused on finalizing and validating SET. By comparing skyglow estimations from SET for select parks with the NPS’s ground truth data, the team confirmed that the two showed a tight linear correlation for most parks, and that SET outputs closely aligned with NPS data after some simple calibration factor. The team trained NPS officials to use SET and produced 3D hemispheric brightness maps for six parks and three additional regions to visualize the prevalence of light pollution.

***Keywords:***

Suomi NPP VIIRS Day/Night Band, artificial light, remote sensing

***National Application Area Addressed:*** Urban Development

***Study Location:*** United States; AR, FL, ID, IN, MS, MT, NE, UT, VA, WY

***Study Period:*** 2014 to 2018 (May to October)

***Community Concerns:***

* Artificial brightness significantly degrades aesthetic and astronomical viewing of the night sky, preventing observation of celestial bodies, such as stars, planets, and the Milky Way.
* Light pollution disrupts circadian rhythms in humans, which can decrease melatonin production and increase the risk of health complications, including depression and some cancers.
* Exposure to artificial light affects certain cyclical behaviors of wildlife, including foraging, breeding, nesting, migration, and communication. These effects are exacerbated for nocturnal species.
* In addition to impacting humans and animals, light pollution also affects plant life patterns.
* The combined effects of light pollution on plants, animals, and humans in addition to visual degradation of the night sky decreases the value of national parks, which are ideally meant to maintain natural landscapes unaltered by anthropogenic influences.

***Project Objectives:***

* Finalize the Skyglow Estimation Toolbox (SET) in Python to ensure proper functioning by fixing small code errors and completing test runs
* Use SET with data from six national parks and compare the results with *in situ* measurements to assess the accuracy of the program and exhibit its ability to perform across diverse geographies
* Create a comprehensive training system for SET, including written instructions and a recorded webinar, to ensure proper installation and implementation for future use
* Use SET to generate 3D hemispheric artificial brightness maps for other parks to showcase the tool’s abilities and provide a useful resource for the parks in their efforts to manage light pollution

***Previous Terms:*** 2018 Summer (LaRC) – US Urban Development, 2017 Fall (VA) – Colorado Plateau Urban Development, 2017 Summer (WC) – Wyoming Cross-Cutting II, 2017 Spring (WC) – Wyoming Cross-Cutting

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **National Park Service, Natural Sounds and Night Skies Division, Night Skies Program** | Sharolyn Anderson, Physical Scientist; Li-Wei Hung, Night Skies Research Scientist | End User | No |
| **Boise State University** | Neil Carter, Assistant Professor | Collaborator | No |

***Decision-Making Practices & Policies:***

The Natural Sounds and Night Skies Division provides field data, modeled data, tools, and analyses to support the National Park Service (NPS) in preserving night sky views for park visitors and wildlife. The division provides the scientific materials for park planning documents, including Natural Resource Condition Assessments (NRCA), Resource Stewardship Strategy Reports, and Wilderness Management Plans. In addition, its data and analyses are used in park mission documents and National Environmental Policy Act (NEPA) reports, both of which assess the existing condition of night skies. Furthermore, the group is currently responsible for measuring artificial sky brightness by making field observations across many national parks and conducting natural sky modeling. This information is synthesized in a Night Skies Monitoring Database. These data are used to help parks meet certain night sky quality standards and to create monitoring reports that provide tangible goals and metrics for park units to use in their management decisions.

***Project Benefit to End User:***

Currently, the end users mainly rely on *in situ* measurements and some Visible Infrared Imaging Radiometer Suite (VIIRS) observations to monitor and manage night sky brightness in national parks across the country. The frequency and coverage of *in situ* measurements are limited by cost and the difficulty of accessing remote wilderness areas. The SET program provides a generated skyglow estimate at any location without the need to use *in situ* measurements. SET offers additional functionality in that it calculates skyglow at any given altitude, not just at the zenith (directly overhead) like many *in situ* measurements. This tool and its widely applicable results will help parks to monitor or assess skyglow in their regions, incorporate night skies information into park planning documents, and validate *in situ* measurements taken in other parks. This, in turn, will help the NPS communicate with surrounding areas to aid in the mitigation of artificial light pollution. For parks that do not use the tool directly, the 3D hemispheric radiance maps we provided will allow them to experience the benefits of an informative visual tool for education and outreach to raise public concern for light pollution.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Suomi NPP VIIRS** | Day/Night Band (DNB) | Data from Suomi National Polar-orbiting Partnership (NPP) VIIRS DNB were used to quantify artificial light pollution and visualize its effect on national parks across the country. |

***Ancillary Datasets:***

* National Park Service Natural Sounds and Night Skies Division field data – used to calibrate and validate outputs from the Skyglow Estimation Toolbox
* National Park Service Integrated Resource Management Applications (IRMA) park boundaries – used to identify park boundaries and clip Suomi NPP VIIRS data to the relevant study locations

***Software & Scripting:***

* Esri ArcMap 10.6.1 – VIIRS data processing and SET output map visualization
* Python – light path calculations, summation of skyglow contributions, creation of regional skyglow estimates, and skyglow visualizations
* GitHub – version control and code repository
* Anaconda – package and environment manager
* Skyglow Estimation Toolbox – Python script that uses VIIRS imagery to model light propagation, run via a graphic user interface (GUI) or Anaconda Prompt command line

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Skyglow Estimation Toolbox (SET)** | Suomi NPP VIIRS | The NPS can use the updated Skyglow Estimation Toolbox based in Python to estimate artificial light pollution from any geographic location. The results of SET will help NPS evaluate and limit the effects of skyglow. | V |
| **3D Hemispheric Artificial Brightness Maps** | Suomi NPP VIIRS | Radiance maps provided for several parks will enable them to observe the effects of skyglow and prioritize management efforts without taking direct measurements. The maps will also be used to visually validate SET’s results against *in situ* data. | N/A |
| **SET Validation Summary Report** | N/A | After using field data from the NPS Natural Sounds and Night Skies Division to statistically validate the effectiveness of SET, the team summarized the validation results and highlighted the estimation accuracy of the tool for partners. | N/A |
| **SET Tutorial and Training Document** | N/A | This document served as a tutorial during partner handoff and can be used in the future as a reference for project partners implementing SET. | N/A |

**Project Handoff Package**

***Transition Plan:*** Sharolyn Anderson and Li-Wei Hung from the National Park Service traveled to NASA Langley Research Center during the week of July 22. The team trained them on preliminary data processing for SET and walked them through a tutorial demonstrating how to install and implement the tool. During the week of August 5, the project team held a webinar about SET and its applications for anyone in the NPS who was interested in the process. Unlike the written instructions and the live tutorial, this webinar focused on the results that SET produces and their potential uses. The webinar was recorded and is accessible along with the training documents as a reference for future use.

***Team POC:*** Rachel Luo, rlluo@mit.edu

***Partner POC:*** Sharolyn Anderson, Sharolyn\_anderson@nps.gov

Li-Wei Hung, li-wei\_hung@nps.gov

***Handoff Package:***

* Skyglow Estimation Toolbox (SET)
* SET Tutorial and Training Document
* SET Validation Summary Report
* 3D Hemispheric Artificial Brightness Maps
* Poster
* Presentation
* Project Video
* Technical Paper
* Website Image

**References**

Chepesiuk, R. (2009). Missing the dark: Health effects of light pollution. *Environmental Health Perspectives, 117*(1), A20-A27. doi:10.1289/ehp.117-a20

Cinzano, P., Falchi, F., & Elvidge, C. D. (2001). The first World Atlas of the artificial night sky brightness. *Monthly Notices of the Royal Astronomical Society,* *328*(3), 689-707. doi:10.1046/j.1365-8711.2001.04882.x

Cinzano, P., Falchi, F., Elvidge, C. D., & Baugh, K. E. (2000). The artificial night sky brightness mapped from DMSP satellite Operational Linescan System measurements. *Monthly Notices of the Royal Astronomical Society, 318*(3), 641-657. doi:10.1046/j.1365-8711.2000.03562.x

Falchi, F., Cinzano, P., Elvidge, C. D., Keith, D. M., & Haim, A. (2011). Limiting the impact of light pollution on human health, environment, and stellar visibility. *Journal of Environmental Management, 92*(10), 2714-2722. doi:10.1016/j.jenvman.2011.06.029

Longcore, T., & Rich, C. (2004). Ecological light pollution. *Frontiers in Ecology and the Environment, 2*(4),191-198. doi:10.1890/1540-9295(2004)002[0191:ELP]2.0.CO;2