**NASA DEVELOP National Program**

**Virginia – Langley**

*Project Summary – Summer 2018*

**US Urban Development**

*Generating Hemispherical Visualizations of Artificial Sky Brightness Using Updated Sky Glow Estimation Tools on Suomi-NPP VIIRS Data*

**VPS Title:** All of the Lights! Measuring Light Pollution Across the US with the Skyglow Estimation Toolbox

**Project Team**

***Project Team*:**

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**Project Overview**

***Project Synopsis*:**

The US Night Skies Urban Development team used the recently created Skyglow Estimation Toolbox (SET) to assess light pollution in national parks across the country. Building on the work of past teams, the toolbox was enhanced to work across different environments using images from the Suomi National Polar-orbiting Partnership’s Visible Infrared Image Radiometer Suite. The team tested the toolbox on data from three different national parks of varying geographical characteristics within the United States and implemented a hemispherical visualization feature to design a more comprehensive tool that will be used to make changes in lighting policies and practices to better serve the needs of people and wildlife.

***Abstract*:**

The growth of the global population along with rapid industrialization has caused an increase in artificial light pollution, also known as artificial sky glow. Anthropogenic light pollution disturbs global ecosystems by interfering with the interconnected life of flora and fauna, degrading the night sky quality for astronomical and aesthetic viewing, and disrupting human circadian rhythms and melatonin production, which can have lasting negative effects on health. The previously developed Skyglow Estimation Toolbox (SET) calculates artificial sky glow 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). The previous iteration of SET was further expanded to include a hemispherical visualization feature compiled from individual sky glow maps with different zenith/azimuth angle combinations at one location. The graphical user interface (GUI) of SET was also updated to include all functions of the command line interface, and the code repository now works will all versions of Python 2.7 and above. Unit tests and a continuous integration system were installed to prevent future code breaks. Several issues were fixed such as logic errors, repository bloat, and lack of documentation. SET was tested on three United States national parks to ensure functionality across different environments. The results were provided to the National Park Service (NPS) as a tool that can be used by parks to monitor and assess sky glow, incorporate this information in park planning documents, and validate *in situ* measurements taken by NPS.

**Keywords:**

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

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

***Study Location:*** United States; FL, IN, MS, NE

***Study Period:*** June 2014 – October 2017

***Community Concern:***

* Artificial night sky brightness inhibits the ability of more than 60% of Europeans and 80% of North Americans to observe the Milky Way, a significant global cultural impact on viewing the night sky.
* Exposure to artificial light at night affects the foraging, reproduction, migration, and communication patterns of wildlife, especially nocturnal species.
* Light pollution can disrupt circadian rhythms in humans, causing a decrease in melatonin production, which can be associated with health complications like insomnia, depression and tumor growth.
* Similar to the effects of artificial light pollution on humans and animals, the growth of flora and fauna is also subject to alteration.
* The increase in light pollution degrades the aesthetic and astronomical viewing of the night sky by decreasing its quality and visibility, which discourages national park tourism.
* About 30% of light emitted by outdoor fixtures in the United States is wasted, amounting to a loss of $2.2 billion in energy costs per year.

***Project Objectives:***

* Update the toolbox to be functional across multiple physiographic and environmental regimes
* Test SET on several US national park units to validate the accuracy of the software
* Generate nighttime radiance maps for Denali National Park & Reserve, Scotts Bluff National Monument, Indiana Dunes National Lakeshore, and Gulf Islands National Seashore
* Improve and streamline toolbox installation, packaging, and running
* Expand the GUI to include all functions of the command line interface
* Implement a hemispherical visualization at a given location by stitching together multiple sky glow maps

***Previous Term:***

2017 Fall (VA) – Colorado Plateau Urban Development

2017 Summer (VA) – Wyoming Cross-Cutting II

2017 Spring (VA) – Wyoming Cross-Cutting I

**Partner Overview**

***Partner Organization:***

|  |  |  |  |
| --- | --- | --- | --- |
| **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 |

***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 dark 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, the Night Skies Division’s data and analyses are used in park mission documents and National Environmental Policy Act (NEPA) reports, both of which determine existing conditions of night skies. Further, the group is currently responsible for measuring artificial sky brightness by conducting natural sky modeling and making field observations across many national parks. This information is synthesized in a Night Skies Monitoring Database. The database includes information about night sky viewing quality within these parks based solely on *in situ* data collected by NPS staff. These data are used to help parks become certified by meeting 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***:

The end users are currently relying on a combination of *in situ* measurements and data from the New World Atlas to make monitoring and management decisions regarding night sky brightness in national park units across the country. These data are limited in scope in that taking *in situ* measurements is a lengthy and costly process, and the New World Atlas products only look directly above the monitoring instrument rather than the entire sky hemisphere. This toolbox provides a generated sky glow estimate at any location without the need to use *in situ* measurements. It also has the advantage of allowing the park to display the sky glow at a certain altitude (horizon to zenith), and not just at zenith (i.e. directly overhead). This work has the potential to provide a tool for parks to monitor or assess the sky glow in their region, find and incorporate night skies information in park planning documents and validate the *in situ* measurements and surveys taken by the National Park Service. This will help the NPS provide information to surrounding areas that will aid in mitigation of artificial light.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Suomi NPP VIIRS** | Day/Night Band (DNB) | Data from Suomi NPP VIIRS DNB were used to visualize where artificial lighting from urban areas may disturb national park units |

***Ancillary Datasets:***

National Park Service Night Skies Program Night Sky Monitoring Database – validate Suomi NPP VIIRS data

National Park Service Natural Sounds and Night Skies Division field data – calibrate Sky Glow Estimation Toolbox

National Park Service Integrated Resource Management Applications (IRMA) park boundaries - identify park boundaries during and throughout analysis

***Software & Scripting:***

Esri ArcMap 10.5 – raster manipulation, statistics, map making

Python – light path calculations, summation of sky glow contributions and creation of regional sky glow estimates

Bitbucket/Github – version control, code repository

Miniconda – package and environment manager

Skyglow Estimation Toolbox – Python script that uses VIIRS imagery to model light propagation

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **3D Hemispheric Artificial Brightness Maps** | Suomi NPP VIIRS DNB | This product will enable the user to look at the entire sky hemisphere rather than looking directly above an observation point. Radiance maps for each national park will assist in identifying areas that are affected by excessive emission. Partners will be able to use this product to incorporate night sky brightness into park planning documents and local policy. | N/A |
| **Sky Glow Estimation Toolbox** | Suomi NPP VIIRS DNB | This product allows parks to monitor and assess sky glow in their region at a certain altitude (horizon to zenith). This toolbox can be used to analyze the effect of artificial light on national parks across the United States. | IV |

**Project Handoff Package**

**Transition Plan:**

The project handoff was conducted via video conference in the first week of August 2018. The project presentation, poster, and video were presented to the partners. The team incorporated a training session to discuss the details of the code and show how the partners can use the revised Skyglow Estimation Toolbox.

*Software Release Plan*:

Since SET falls into Software Release Category IV, the US Night Skies Urban Development team will initialize a software release process to make the updated SET available via a NASA DEVELOP Github repository. The link to the updated SET will be the same as the one made available in the fall term of 2017 by the Colorado Plateau Urban Development team. Documentation for new features will be updated and displayed on the project’s Github page.

*Project Continuation Plan*:

The US Night Skies Urban Development II team will conduct a multi-day webinar handoff with the partners once the toolbox has completed the software release process to facilitate adoption of the toolbox by the end users.

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**Handoff Package:**

* Project Summary
* Poster
* Presentation
* Project Video
* Technical Paper
* Technical Image
* Website Image
* Creative Image
* 3D Hemispheric Artificial Brightness Maps
* Skyglow Estimation Toolbox Tutorial and Documentation

**References:**

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

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

Henderson D.A. (2010). Valuing the stars: On the economics of light pollution. *Environmental Philosophy, 7*(1), 17-26.

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