National Aeronautics and Space Administration

2018 Summer | Virginia - Langley

US Urban Development

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

Maximilian Ioffe

Julia Hink

Tyler Jameson

Charlie McClay

What is light pollution?

Light pollution is a term used to describe the **illumination of night skies** as a result of **artificial light sources**, also known as sky glow.

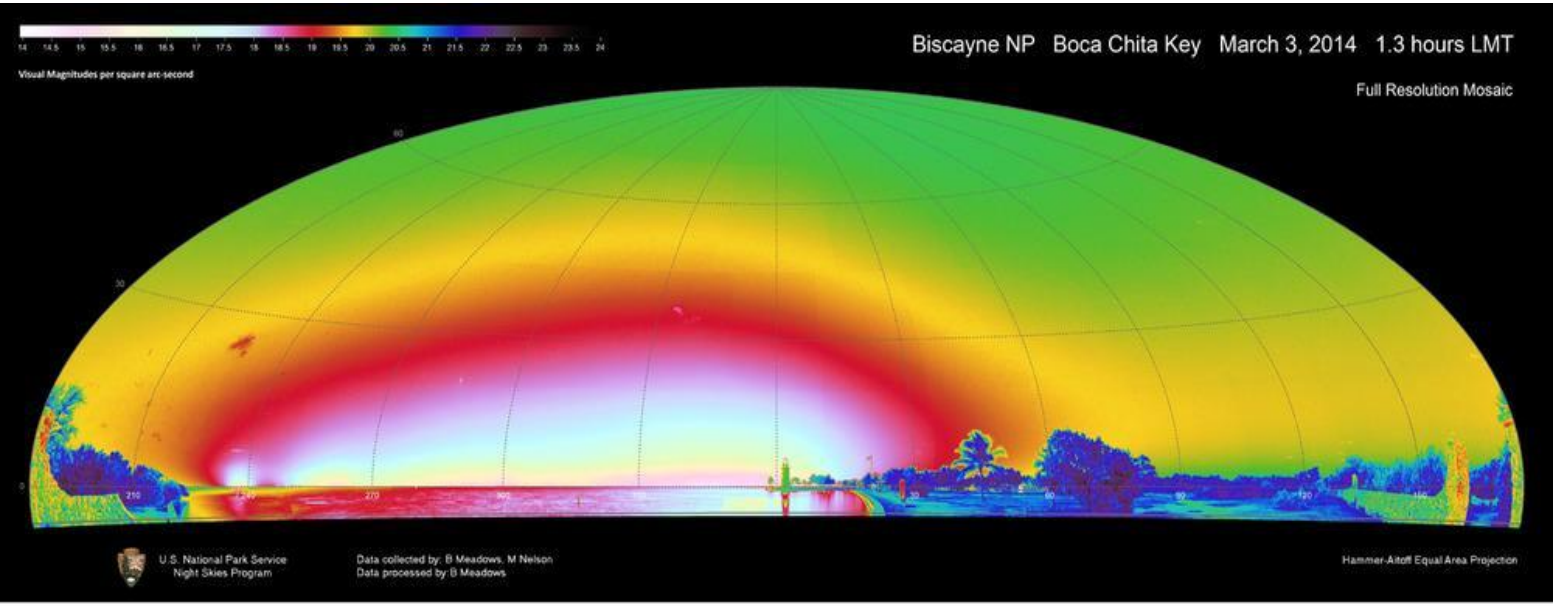
Image Credit: Bettymaya Foott, National Park Service

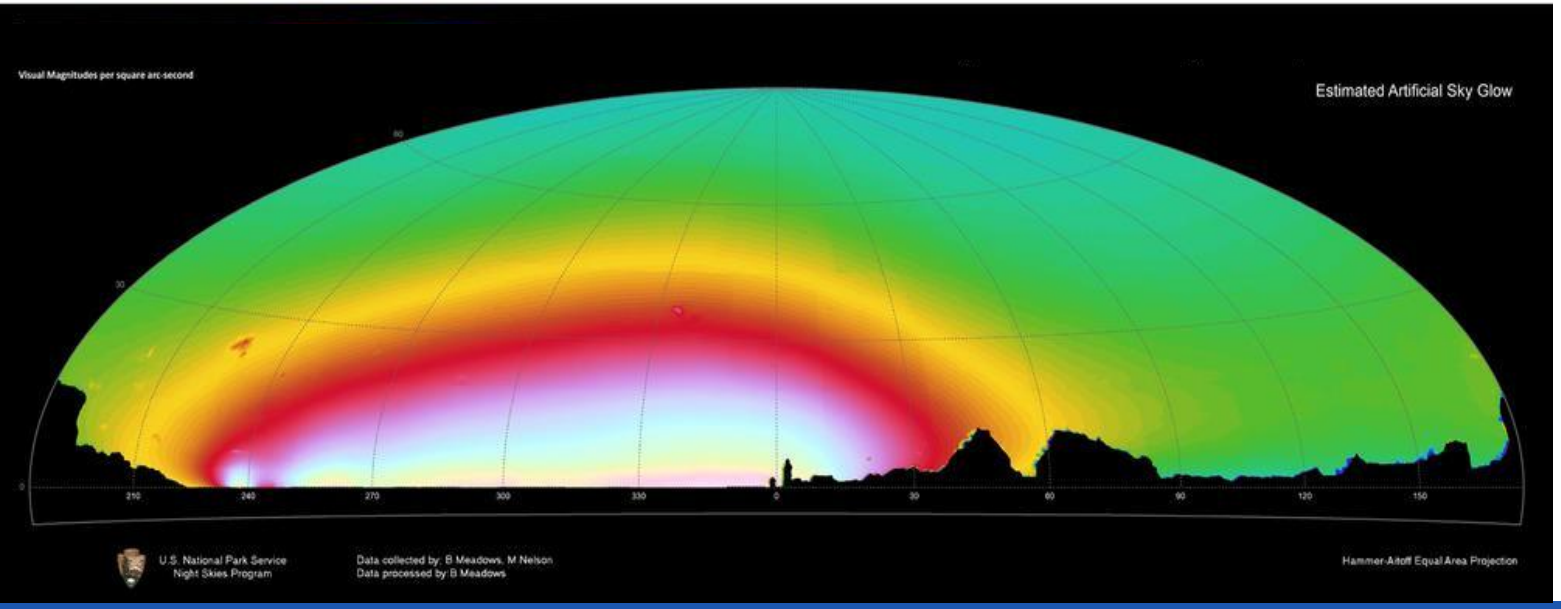
99%

of **United States** and **European** citizens **live** under light-polluted skies

Image Credit: Jake Holgerson

Community Concerns





Brightening night skies are detrimental to the **wildlife and visitors** of national parks.

Impact on Wildlife

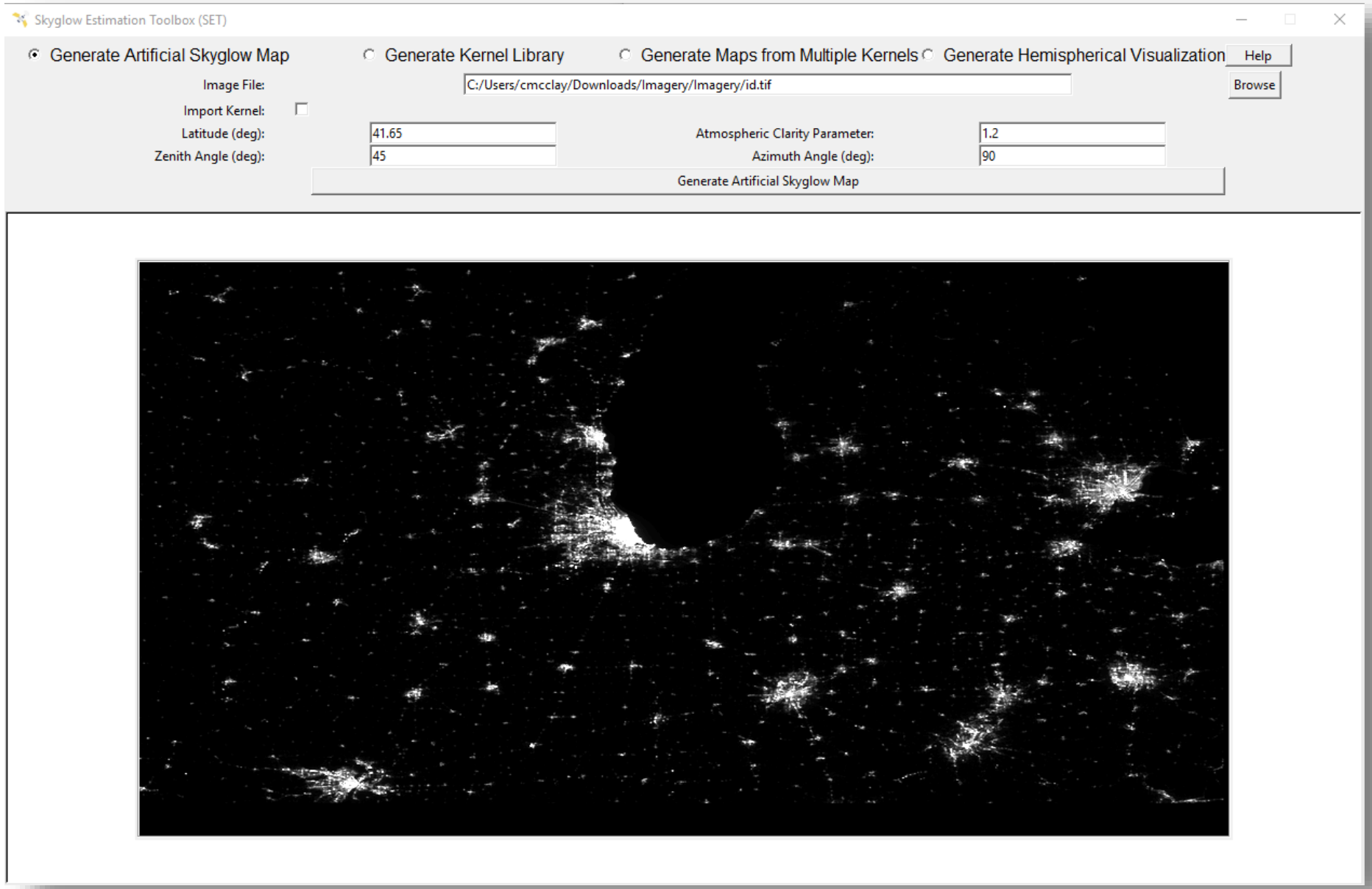
Hatchling **sea turtles** may **crawl inland or away from shore** due to the bright artificial light emitted from nearby areas.

Image Credit: National Park Service

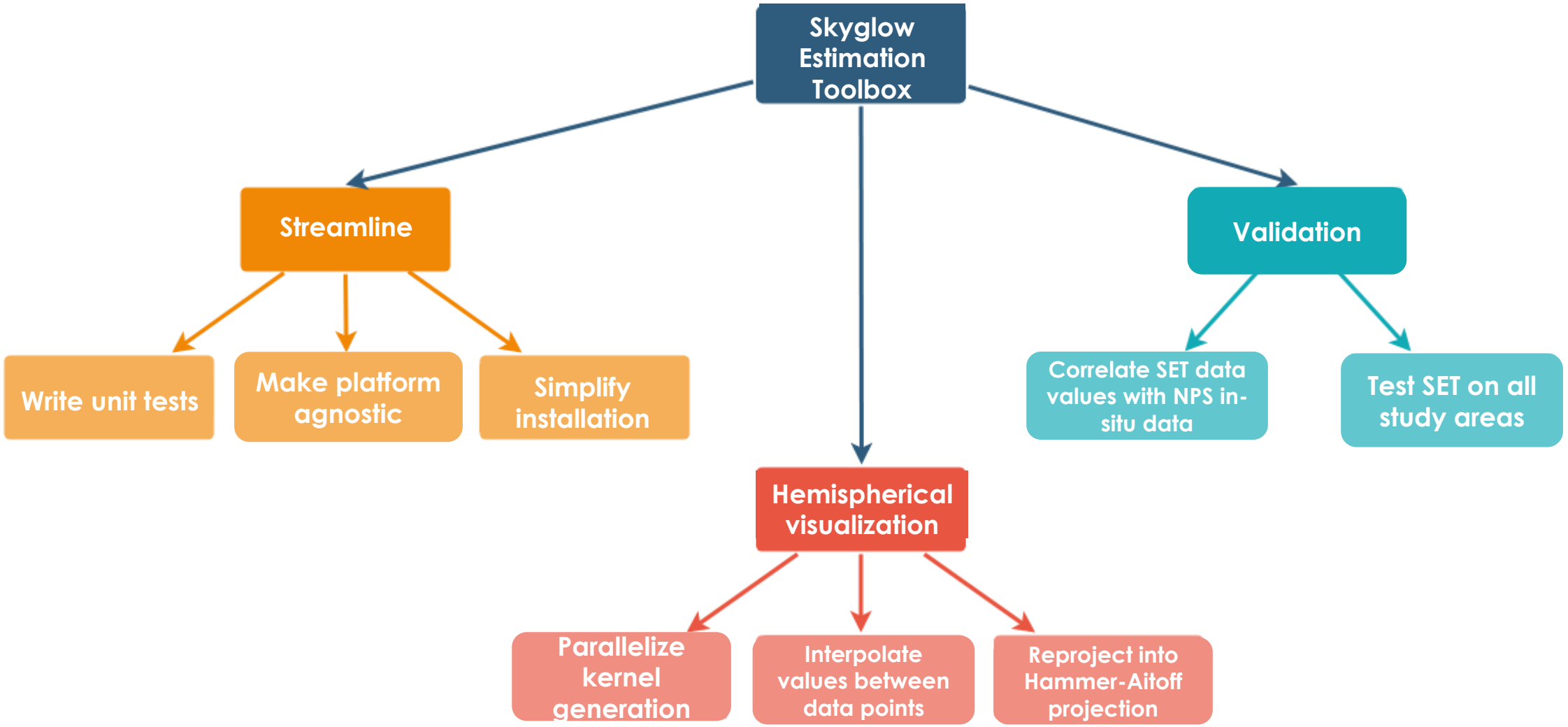
Human Health Effects

- Cancer
- Depression
- Insomnia
- Obesity
- Diabetes

The Skyglow Estimation Toolbox (SET)



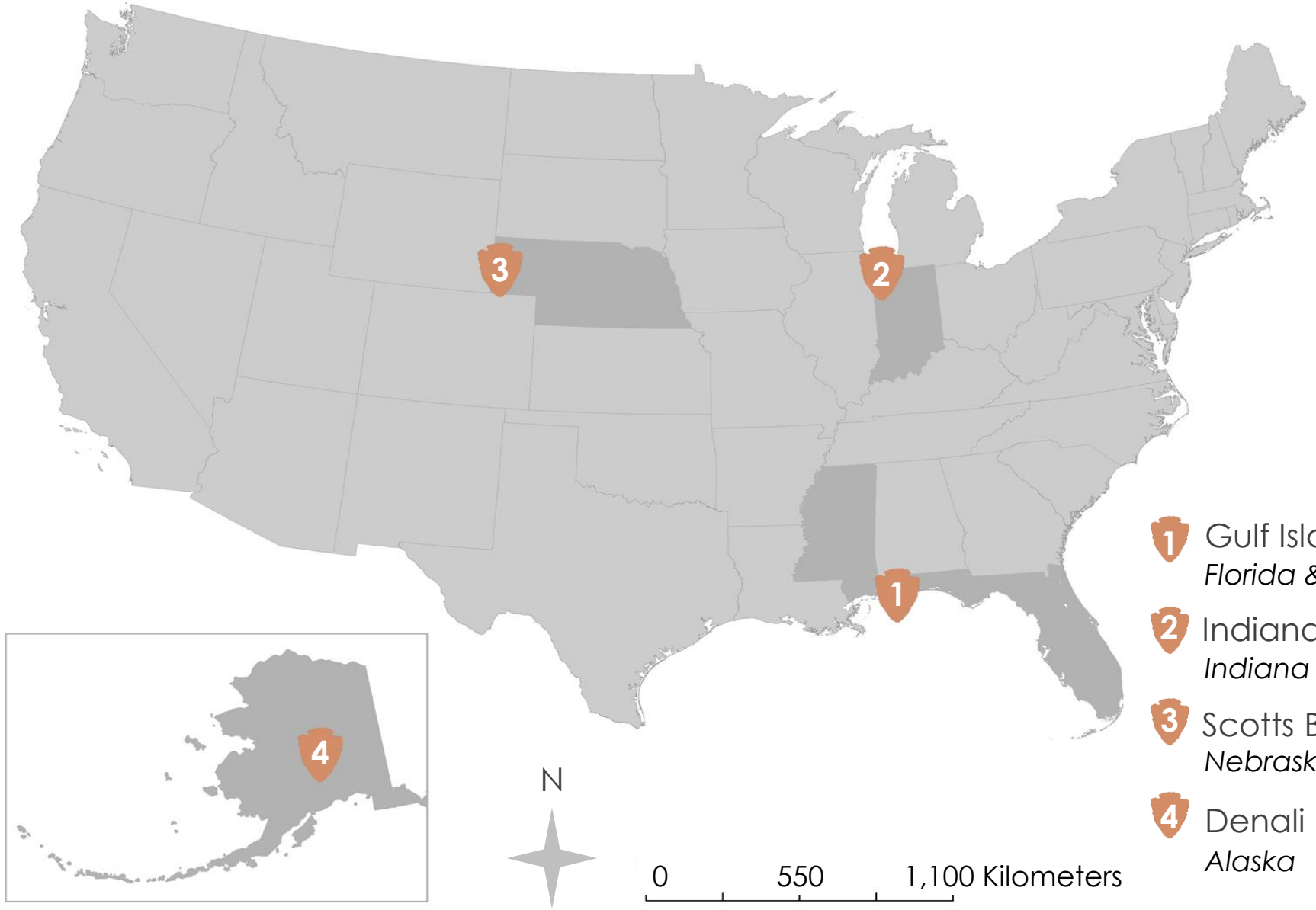
Objectives


Skyglow Estimation Toolbox
Streamline
Write unit tests
Make platform agnostic
Simplify installation
Validation
Correlate SET data values with NPS in-situ data
Test SET on all study areas
Hemispherical visualization
Parallelize kernel generation
Interpolate values between data points
Reproject into Hammer-Aitoff projection

Partners

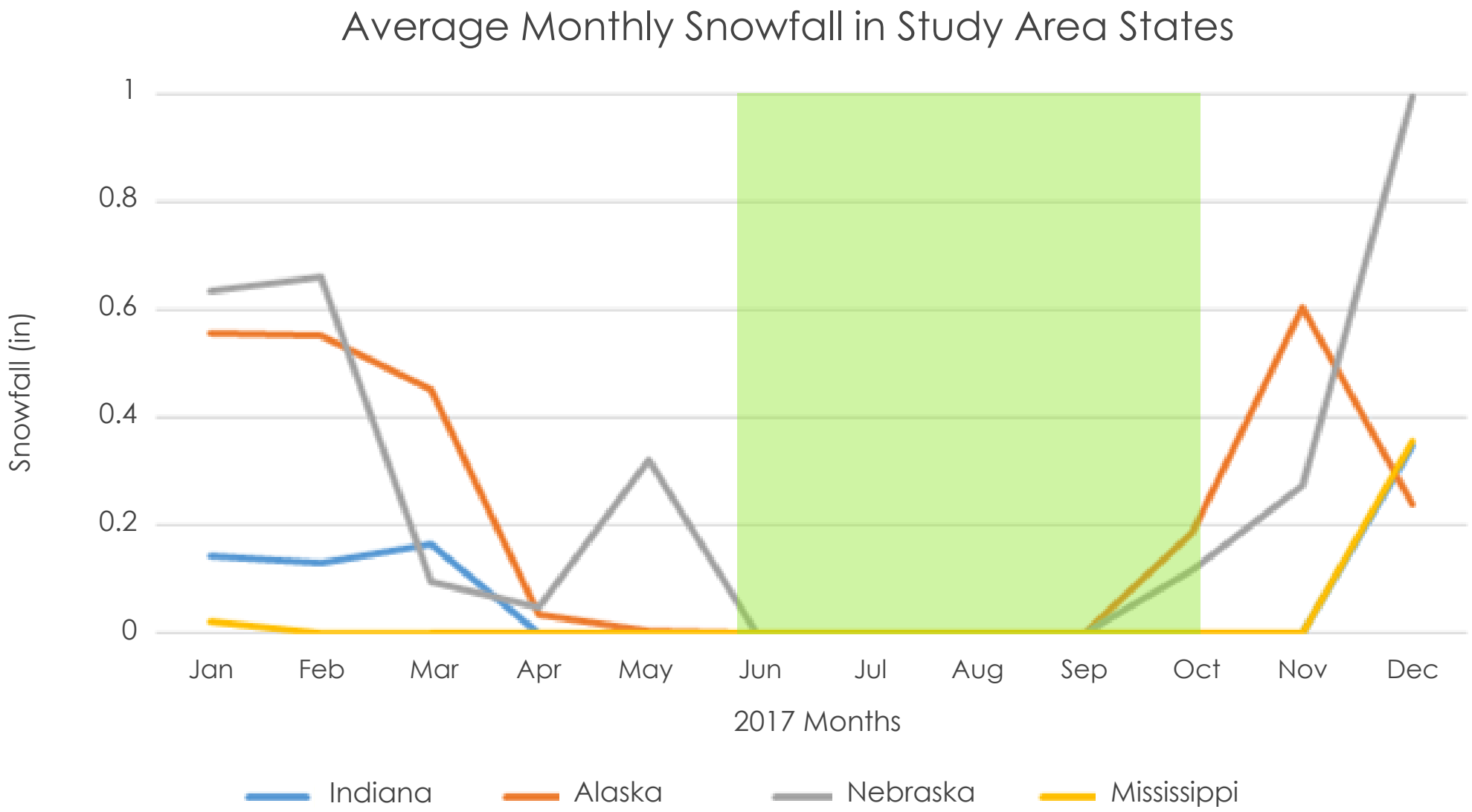
- National Park Service, Natural Sounds and Night Skies Division

Study Area



1. Gulf Islands National Seashore
   Florida & Mississippi
2. Indiana Dunes National Lakeshore
   Indiana
3. Scotts Bluff National Monument
   Nebraska
4. Denali National Park and Preserve
   Alaska

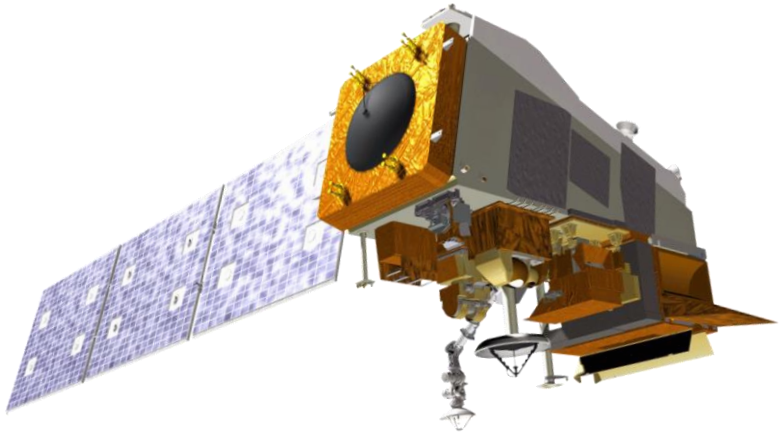
Study Period



Suomi-NPP VIIRS DNB

NOAA's National Centers for Environmental Information (NCEI), Earth Observations Group (EOG)

- Average radiance composite imagery
- Filtered to remove stray light
- 500 - 900 nm wavelengths



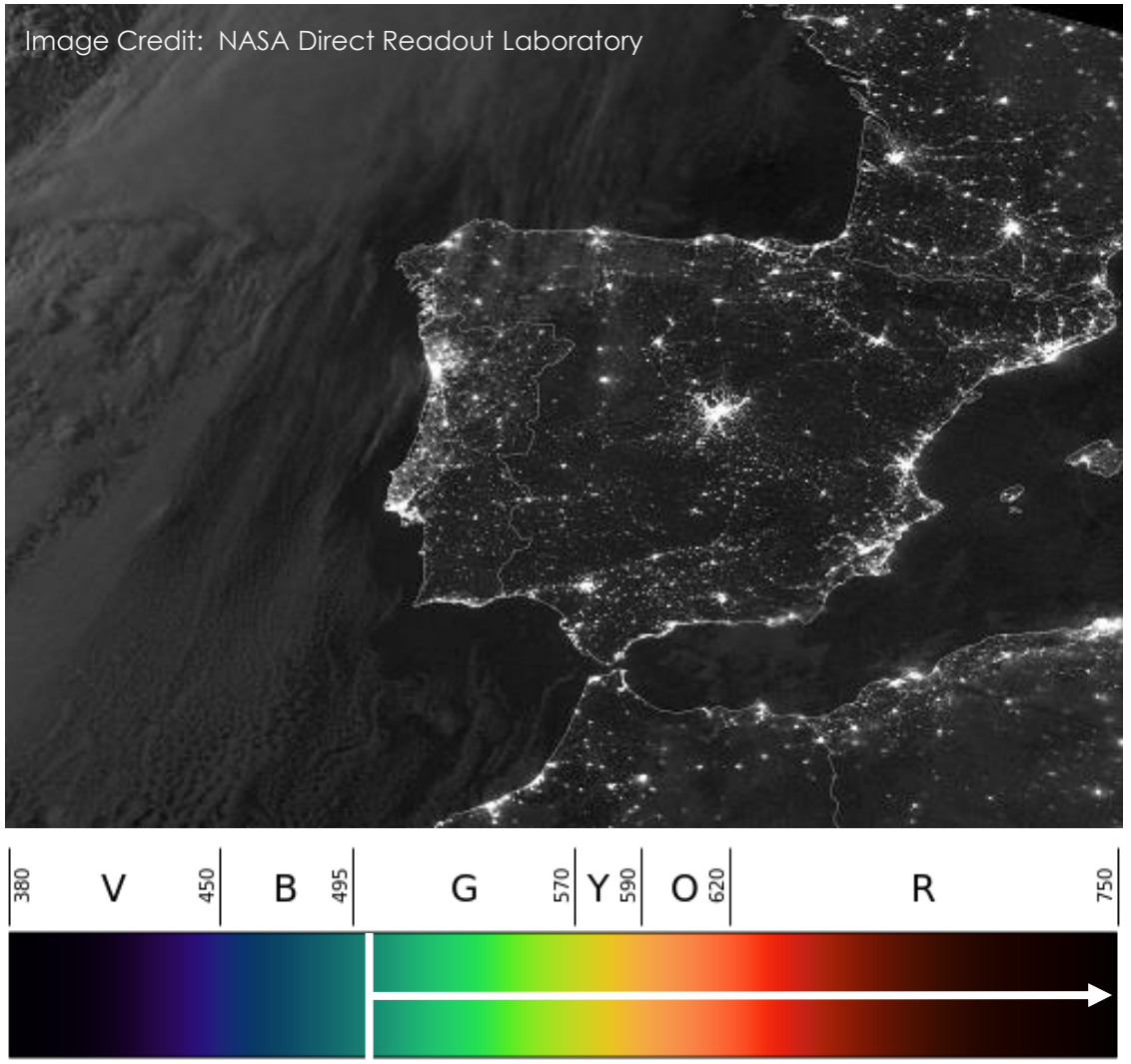


Image Credit: 2008 Gringer/Wikimedia Commons Public Domain

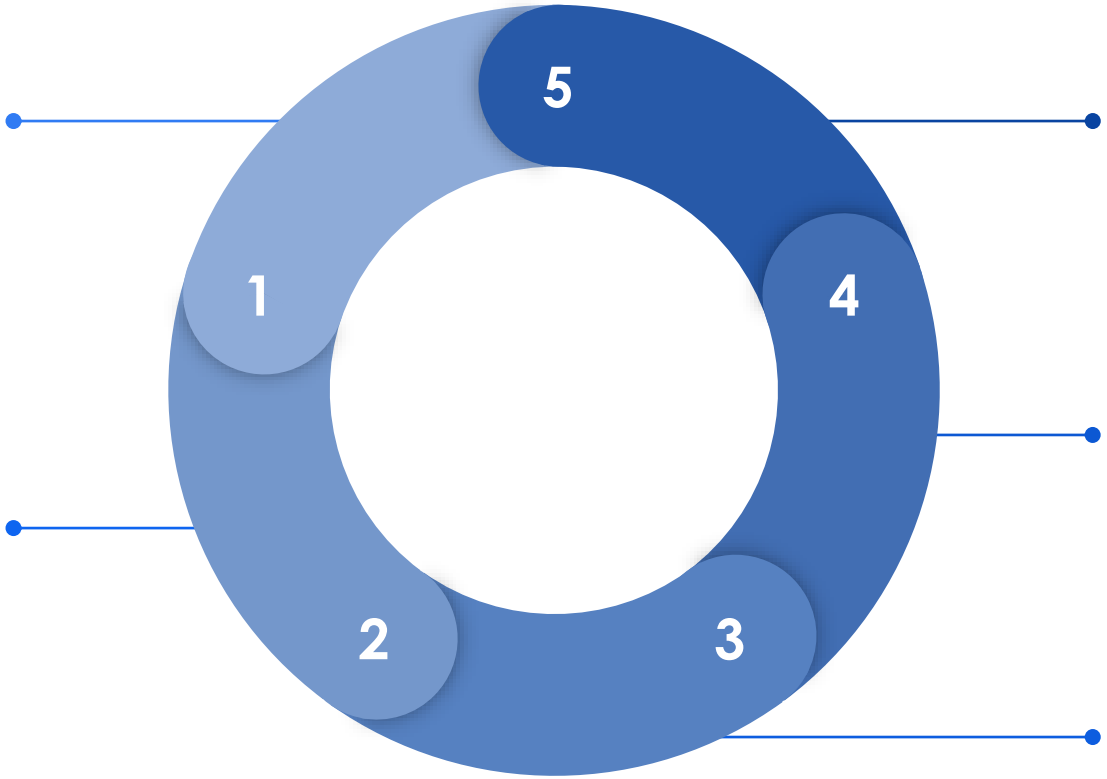
Methodology

Obtain VIIRS Raster Data

Suomi NPP VIIRS DNB Data is available on NOAA's Earth Observation Group's website.

Create Median Composite

Cell Statistics in ArcMap 10.5 can calculate the median value of inputs on a cell-by-cell basis. This helps in accounting for outliers in the data, such as wildfires



Generate Hemisphere Maps

SET generates a 3D hemispherical visualization by interpolating values between stitched-together artificial brightness maps.

Run SET

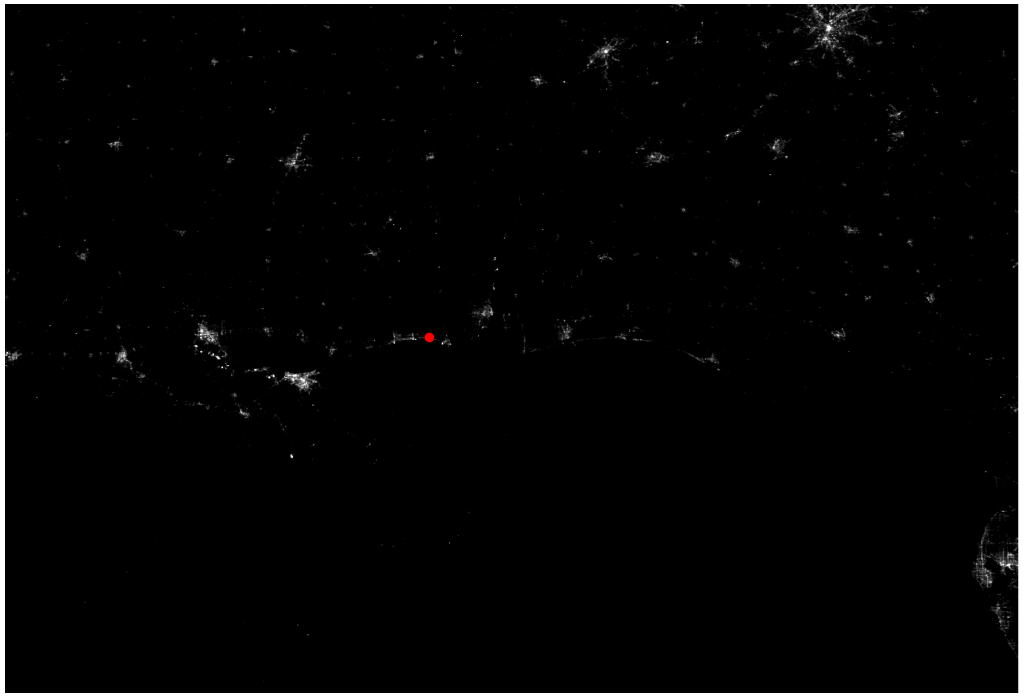
The user specifies input parameters such as latitude, atmospheric clarity, zenith angle, and azimuth angle.

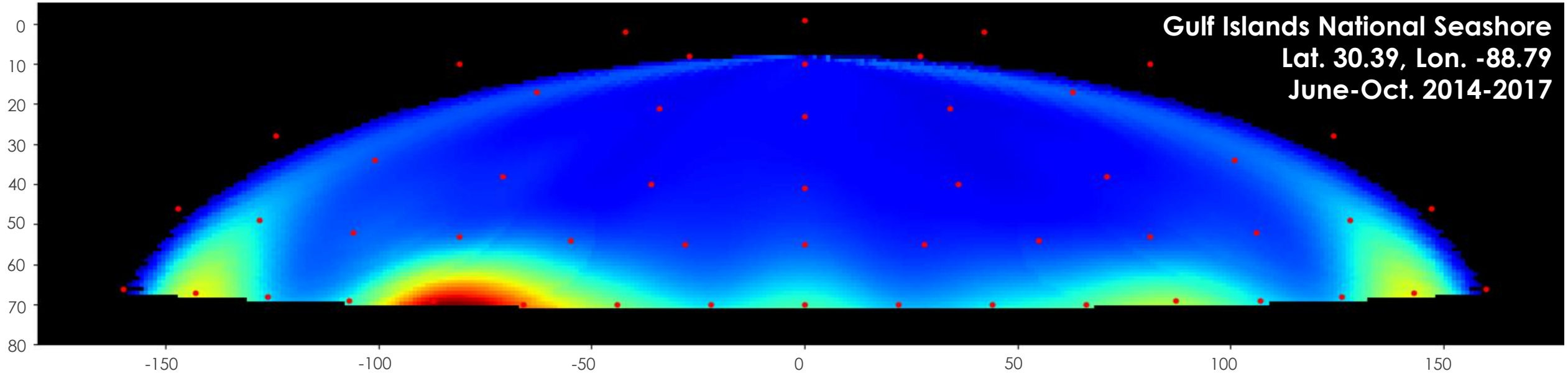
Clip Data to Study Areas

Light from up to 200 kilometers away can affect sky glow at a given observation point.

Results

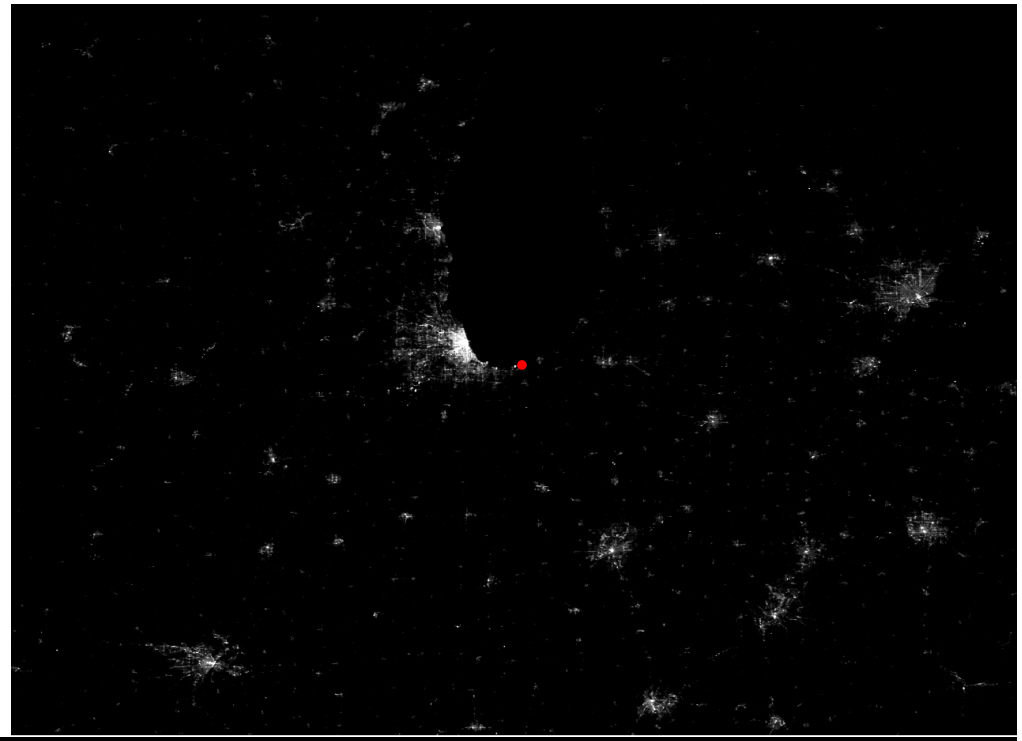
Gulf Islands National Seashore
Latitude: 30.3919
Longitude: -88.7911
June - October (2014-2017)

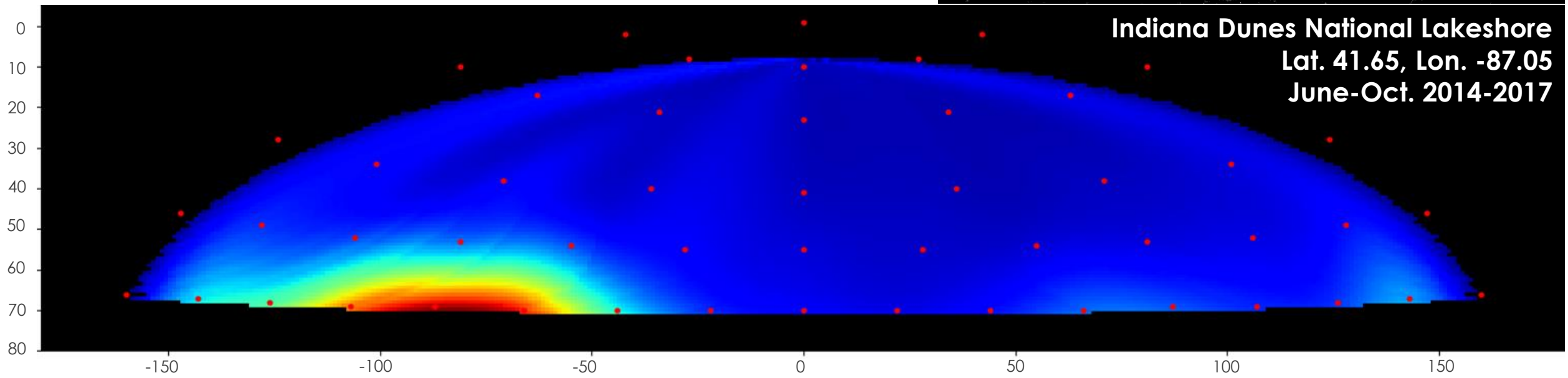




Results Cont.

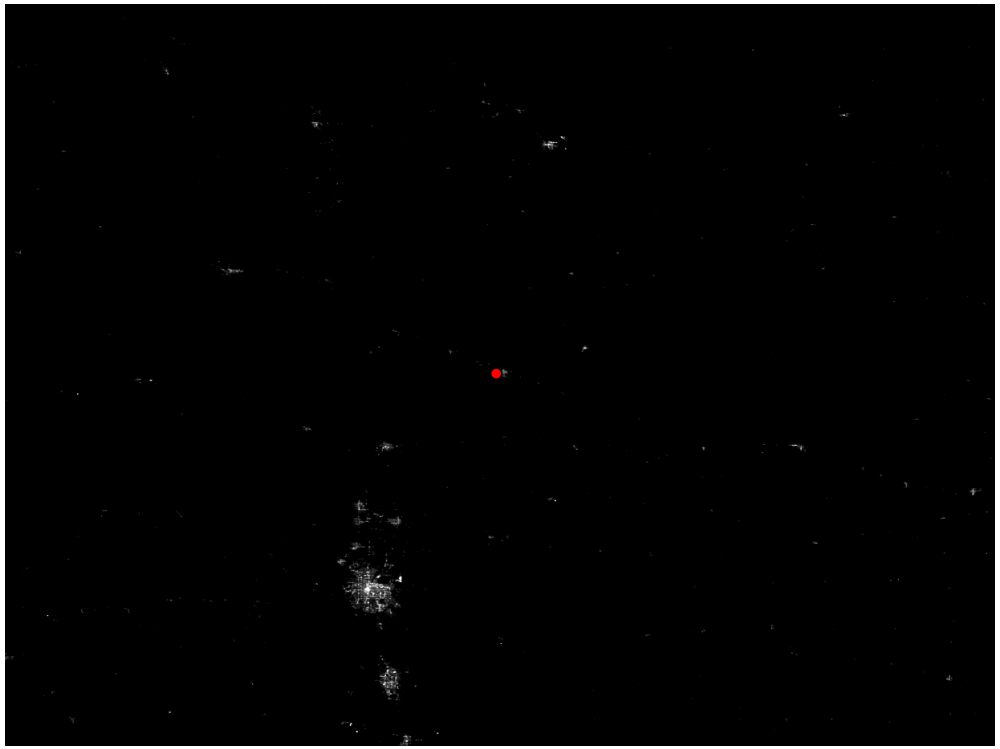
Indiana Dunes National Lakeshore
Latitude: 41.6501
Longitude: -87.0547
June - October (2014-2017)

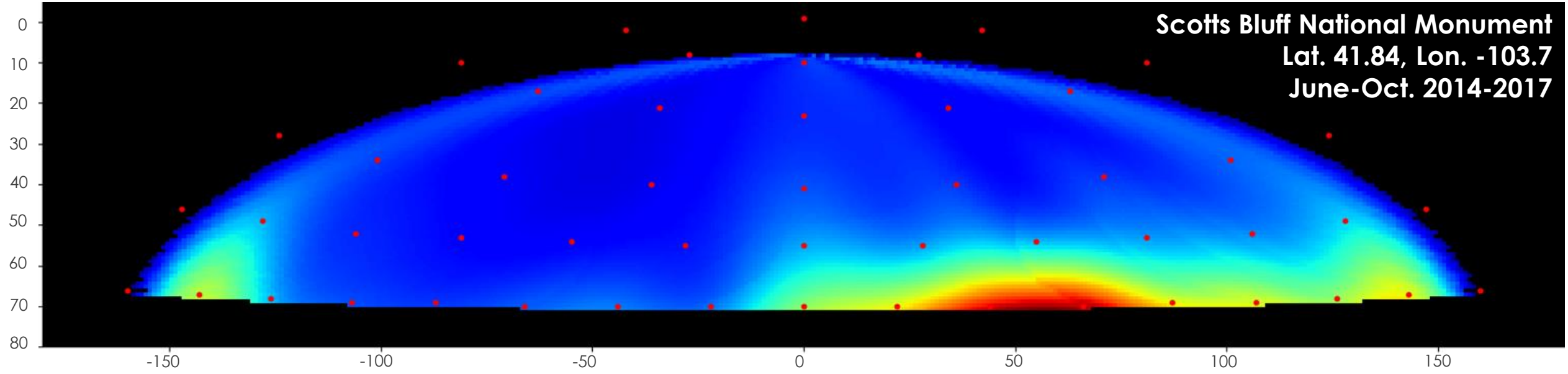




Results Cont.

Scotts Bluff National Monument
Latitude: 41.84
Longitude: -103.7
June - October (2014-2017)





Results Cont.

Suomi NPP VIIRS DNB Data

Gulf Islands National Seashore

June - Oct. (2014 - 2017)

Median Composite Image

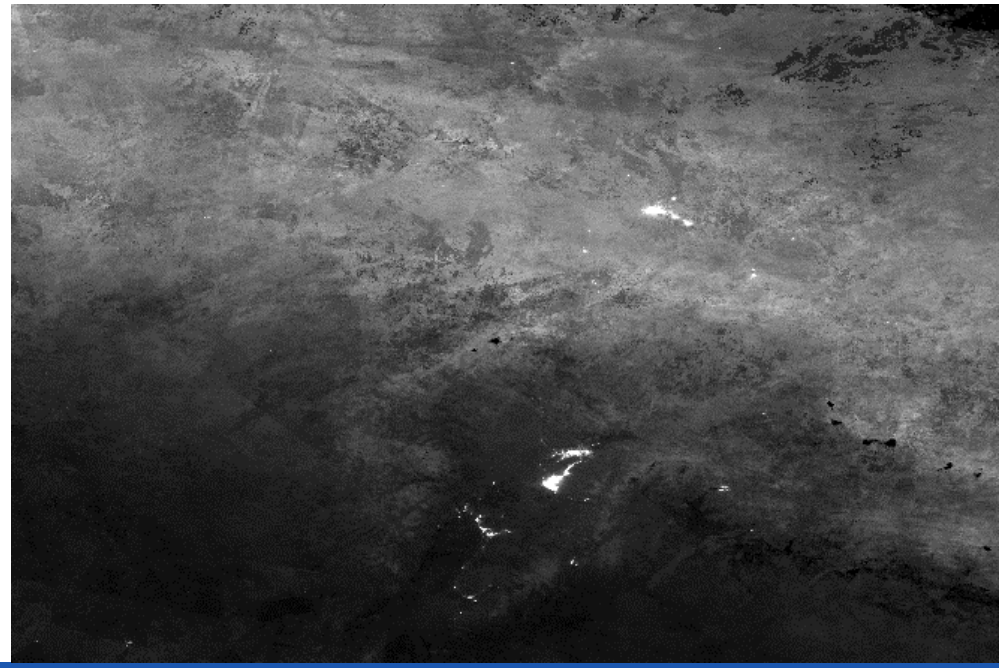
VS.

Suomi NPP VIIRS DNB Data

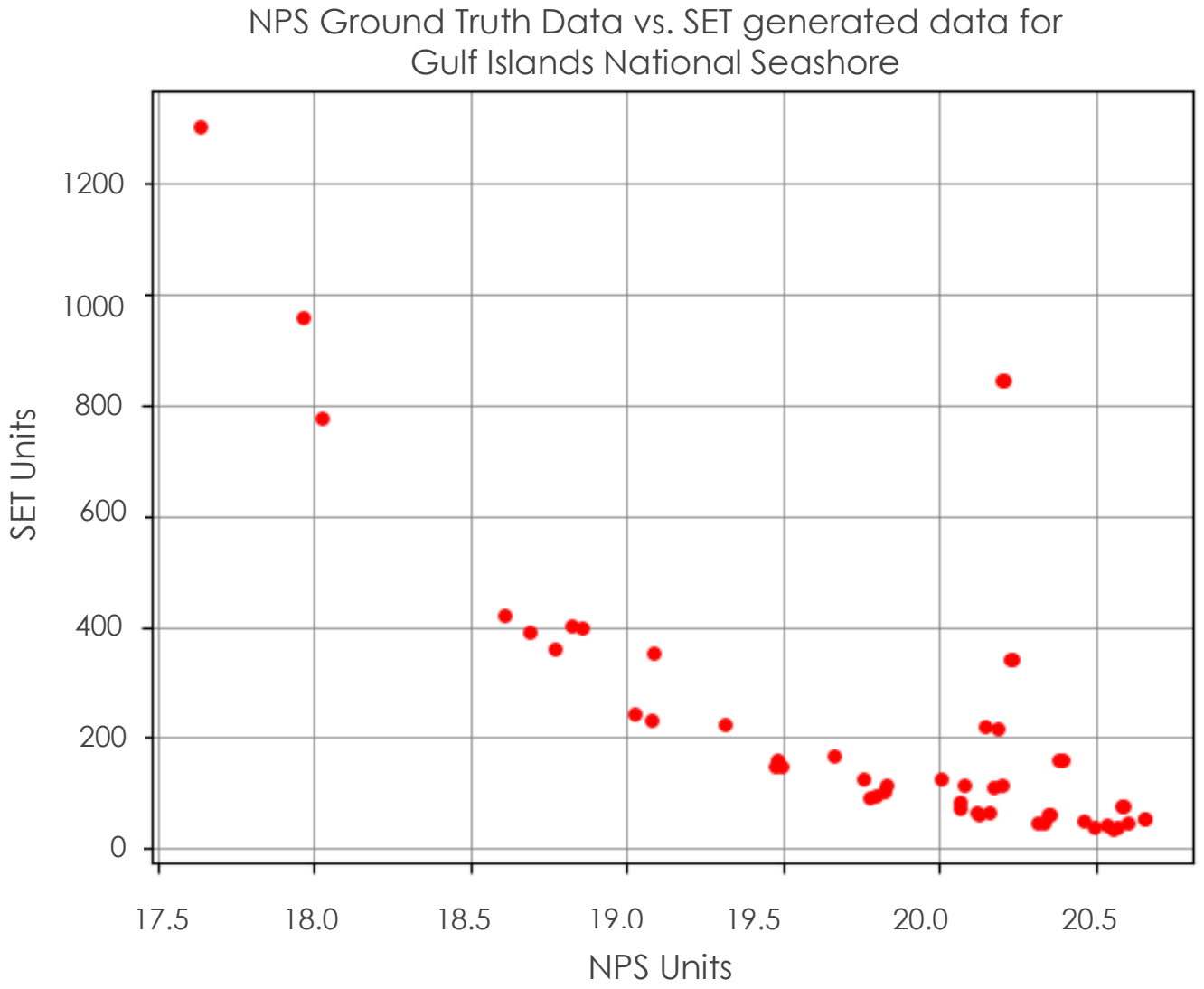
Denali National Park & Preserve

Sept. & Oct. (2014 - 2017)

Median Composite Image



Model Validation



Spearman's rank-order correlation coefficient: -0.72

Uncertainties

Topographical Shielding	Light Emission Model Bias	Water-Reflected Light
Not accounted for in the current model.	The current model used is a weighted average of three light emission models, but the weights are not set dynamically. This may make calculations biased toward the types of emission in the area they were set for originally.	Water-reflected light has a different emission model than the three models accounted for in the calculation, so light pollution calculations for areas near bodies of water may not be completely accurate.

Conclusions

- **Limitations** of the Day/Night Band prevent accurate radiance measurements in **high latitude** regions.
- Hemispherical visualizations provide **intuitive sky glow estimates** without conducting costly and timely field measurements
- **Exploring validation** methods will provide **a basis** for comparing hemispherical visualizations with on-the-ground measurements

Future Work

- Incorporate ***in situ*** measurement data to further validate model
- Account for model **inaccuracies** and **biases**
- Experiment with **integrating SET into other platforms** such as Google Earth Engine, a mobile or virtual reality application, or a standalone Python package install.

Acknowledgements

Center Lead, Science Advisor, and Partners

Jonathan O'Brien | Center Lead/Communications Fellow at DEVELOP Langley

Dr. Kenton Ross |Lead Science Advisor for NASA DEVELOP National Program

Sharolyn Anderson, PhD |Physical Scientist, National Park Service, Natural Sounds and Night Skies Division

Li-Wei Hung, PhD | Research Scientist, National Park Service, Natural Sounds and Night Skies Division

This material is based upon work supported by NASA through contract NNL16AA05C and cooperative agreement NNX14AB60A. Any mention of a commercial product, service, or activity in this material does not constitute NASA endorsement. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration and partner organizations.

Acknowledgements

NASA DEVELOP Past Contributors

Margaret Mulhern | Project Lead, Colorado Plateau Urban Development Team
Manda Au | Colorado Plateau Urban Development Team
Ian Brastow | Colorado Plateau Urban Development Team
Veronica Warda | Project Lead, Wyoming Cross-Cutting I and II Teams
Ryan Avery | Wyoming Cross-Cutting II Team
Steven Chao | Wyoming Cross-Cutting II Team
Stanley Yu | Wyoming Cross-Cutting II Team
Benjamin Marcovitz | Wyoming Cross-Cutting Team
Aubrey Hilte | Wyoming Cross-Cutting Team
Eric White | Center Lead at DEVELOP Virginia, Wyoming Cross-Cutting Team
Christine Stevens | Wyoming Cross-Cutting Team

This material is based upon work supported by NASA through contract NNL16AA05C and cooperative agreement NNX14AB60A. Any mention of a commercial product, service, or activity in this material does not constitute NASA endorsement. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration and partner organizations.

Thank You!

Max Ioffe
Project Lead

Julia
Hink

Tyler
Jameson

Charlie
McClay

Addenda

Additional Resources

Foundational Papers Used

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;

Falchi, F., Cinzano, P., Duriscoe, D., Kyba, C. C. M., Elvidge, C. D., Baugh, K., Furgoni, R. (2016). The new world atlas of artificial night sky brightness. *Science Advances*, *2*(6), e1600377. doi:10.1126/sciadv.1600377

Additional Resources

Human & Wildlife Impacts

Anisimov, V.N. (2006). Light pollution, reproductive function and cancer risk. *Neuro Endocrinology Letters, 27(1-2),* 35-52. Retrieved from http://europepmc.org/abstract/med/16648818

Chepesiuk, R. (2009). Missing the Dark: Health Effects of Light Pollution. *Environmental Health Perspectives,117(1),* 20-27. Retrieved June 25, 2018 from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2627884/

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. Retrieved June 25, 2018 from https://www.sciencedirect.com/science/article/pii/S030147971100226X

Gaston, K.J., Bennie, J., Davies, T.W., Hopkins, J. (2013). The ecological impacts of nighttime light pollution: a mechanistic appraisal. *Biological Reviews, 88(4)*

Documentation

SET 0.0.1 Index Page Program Overview » Source Search

Skyglow Estimation Toolbox

Current Version: v0.0.1

Skyglow is the brightening of the sky caused by various illuminated sources, including anthropogenic lighting, atmospheric factors, and celestial light. With the unprecedented growth of urbanization, artificial lighting has been rapidly increasing the brightness of the night sky around the world. This problem has attracted serious concerns from researchers, scientists, and communities to address the ramifications of what is now known as light pollution.

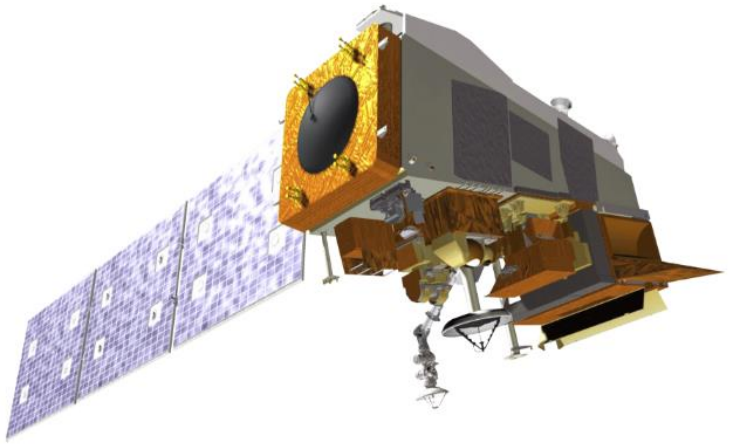
Previously the impact of light pollution on sky brightness was measured by handheld Sky Quality Meters and observations from the Defense Meteorological Satellite Program (DMSP) Operational Linescan System. Both have observational flaws: the Sky Quality Meter is limited in range and feasibility, the DMSP sensor in resolution.

To refine these measurements, the Wyoming Cross-Cutting team at the NASA DEVELOP National Program created the Skyglow Estimation Toolbox (SET) in partnership with the National Park Service and Wyoming Stargazing. The Toolbox is written in Python 2.7 and takes satellite measurements from NASA and NOAA's Suomi National Polar-orbiting Partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) satellite sensor to map images of skyglow using local parameters. Researchers using the Toolbox can identify sources of light pollution with far greater precision by factoring in light scattering at different viewing angles and apply SET's propagation model to varying locations.

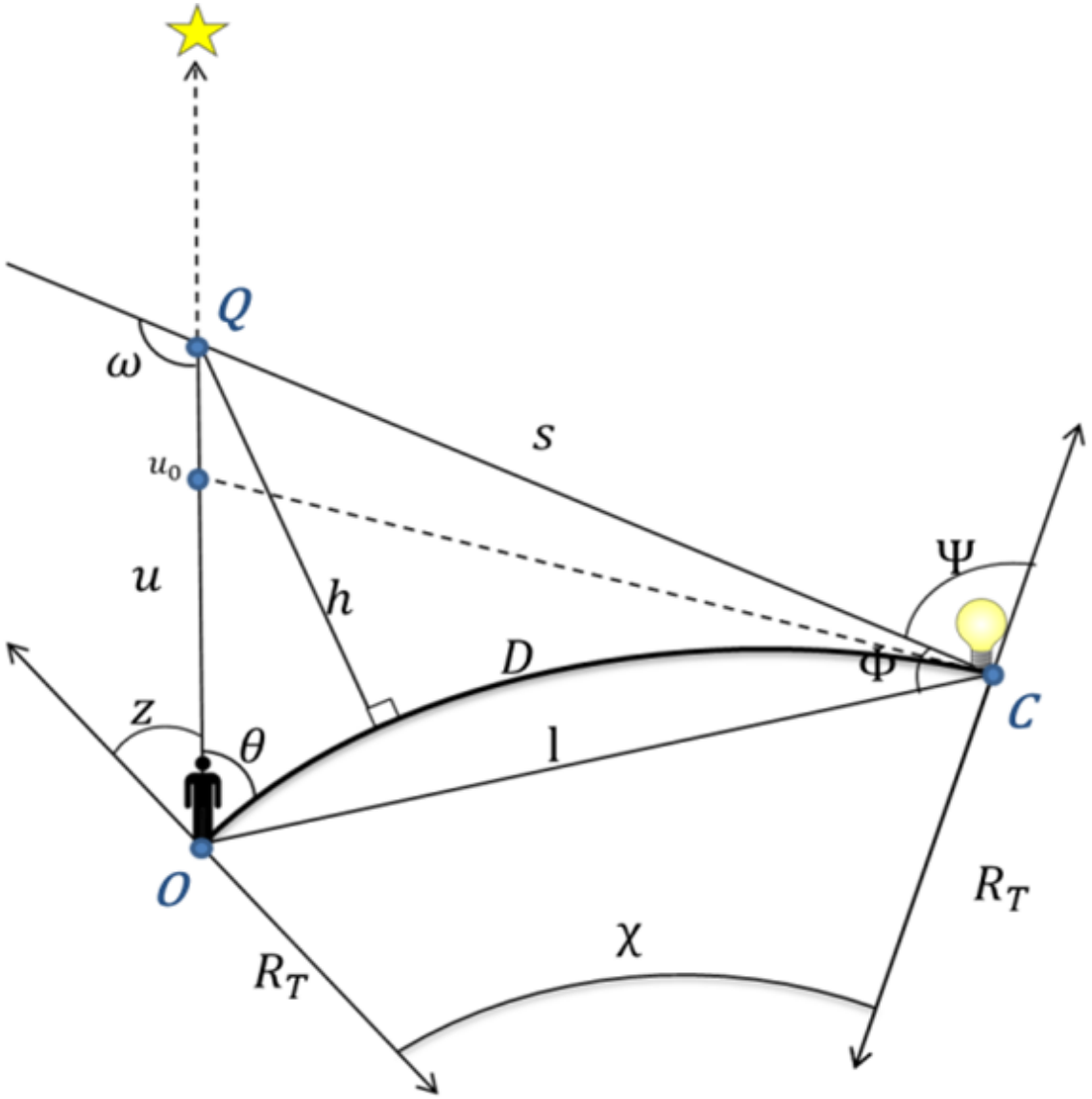
Summer 2017 Wyoming Cross-Cutting II Team Website Image. Teton Range, WY, displayed below a processed artificial skyglow map around Grand Teton National Park, generated from a nine-month composite image.

All the Toolbox's user and developer documentation can be found on this website. End-users can refer to the navigation bar's "Index" at the top of the page to find information on installing, running, and generating skyglow maps. Likewise, developers looking to contribute to the documentation or program can find guidelines through the index. Thank you for visiting!

Contents

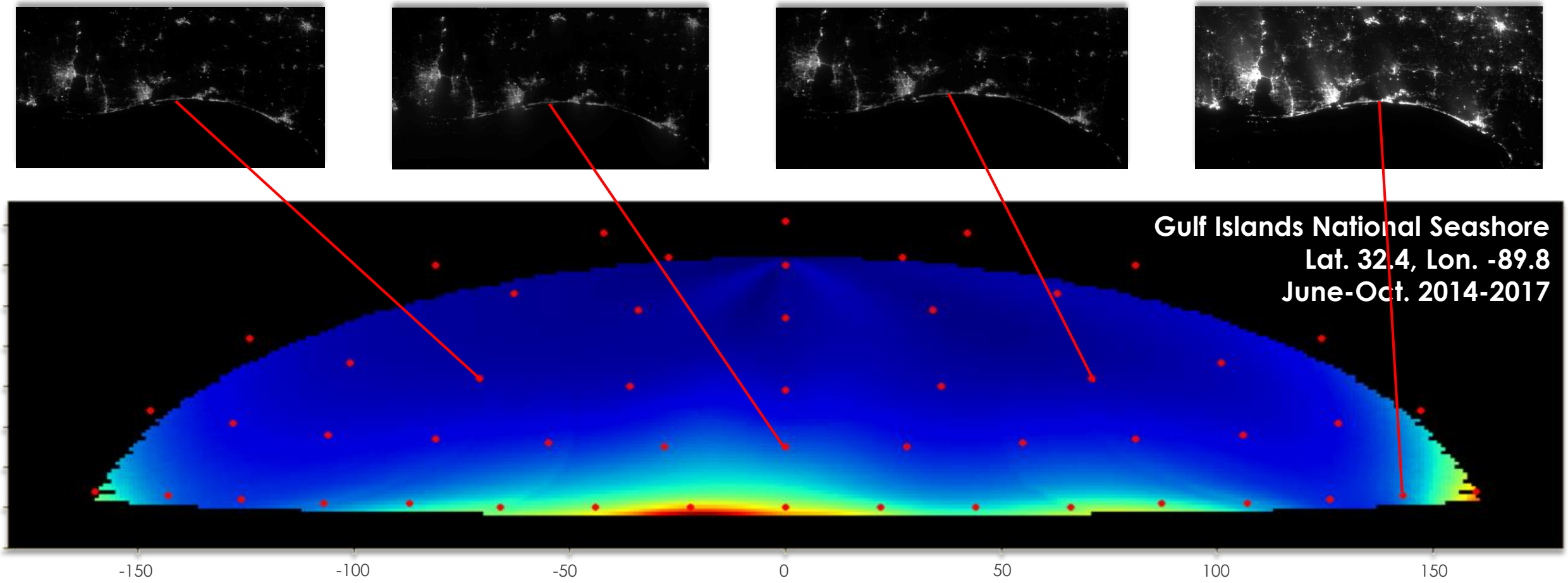


Geometric Relationships



Graphic Credit: Wyoming Cross Cutting I & II Teams

Hemispherical Visualization



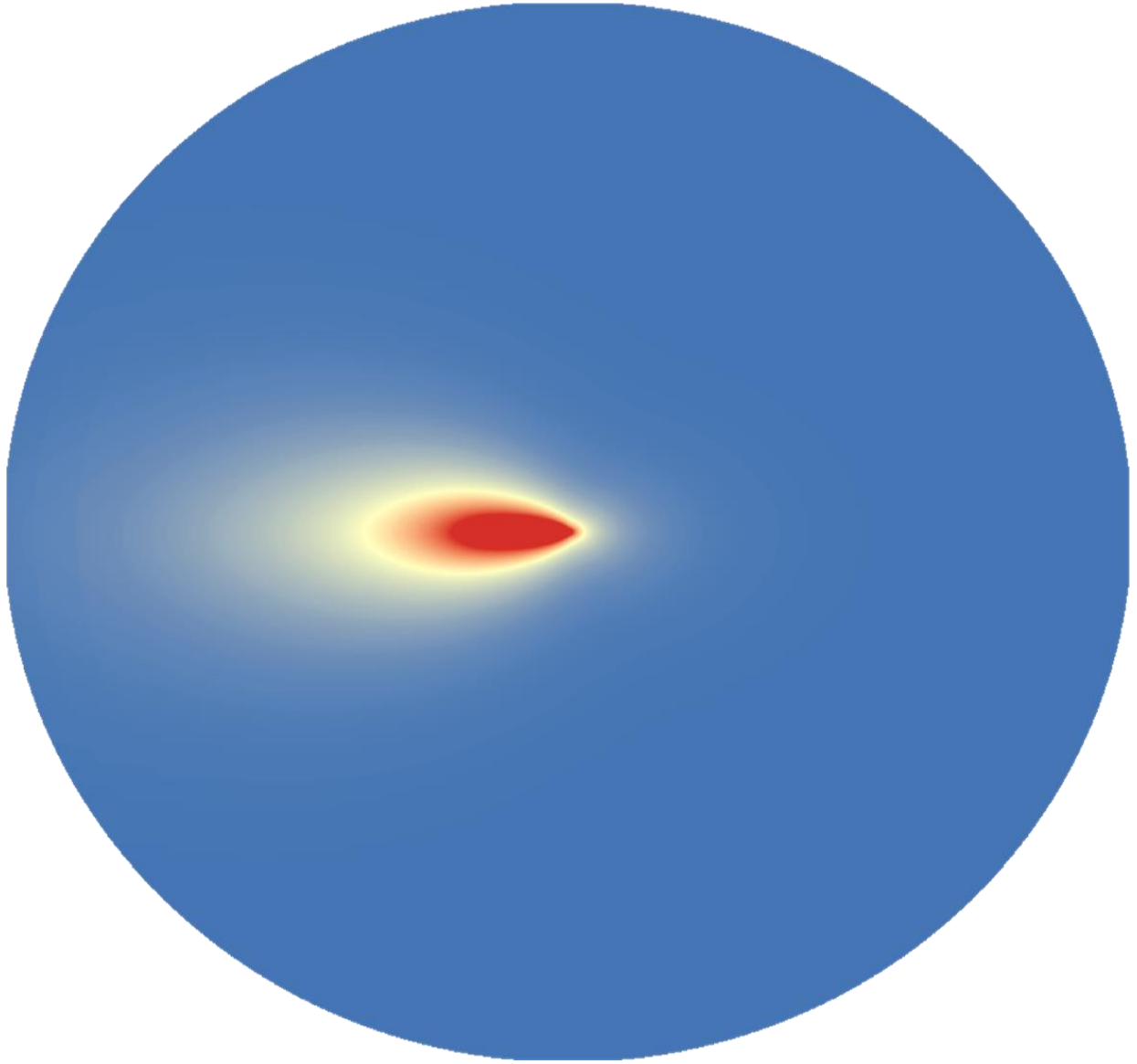
Light Propagation Kernel

- Toolbox Feature
- Relies on Input Parameters
- Fast Fourier Transform
- Time to complete kernel generation for brightness maps:

  ~40 min. per kernel

- Time to complete kernel generation for hemisphere:

  (~40 min. * 52 kernels)/number of CPU cores



Reducing Light Pollution

Light areas only **WHERE** it is needed

Light areas only **WHEN** it is needed

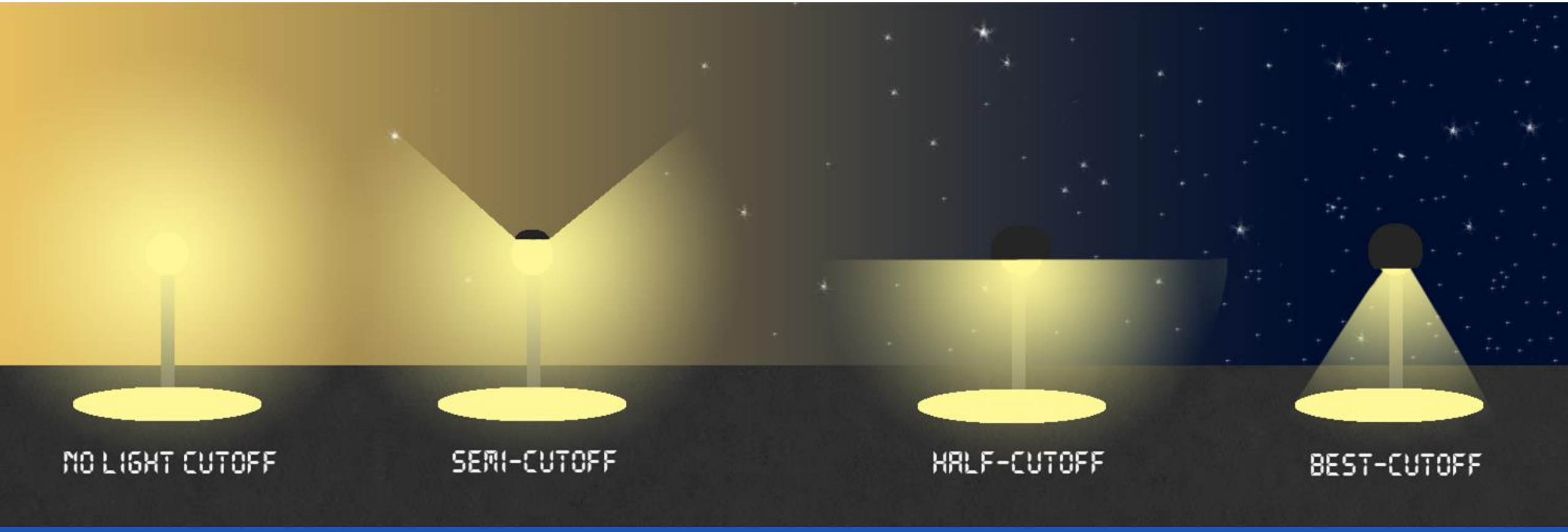
SHIELD lights and direct them downward

Select lamps with **WARMER** colors

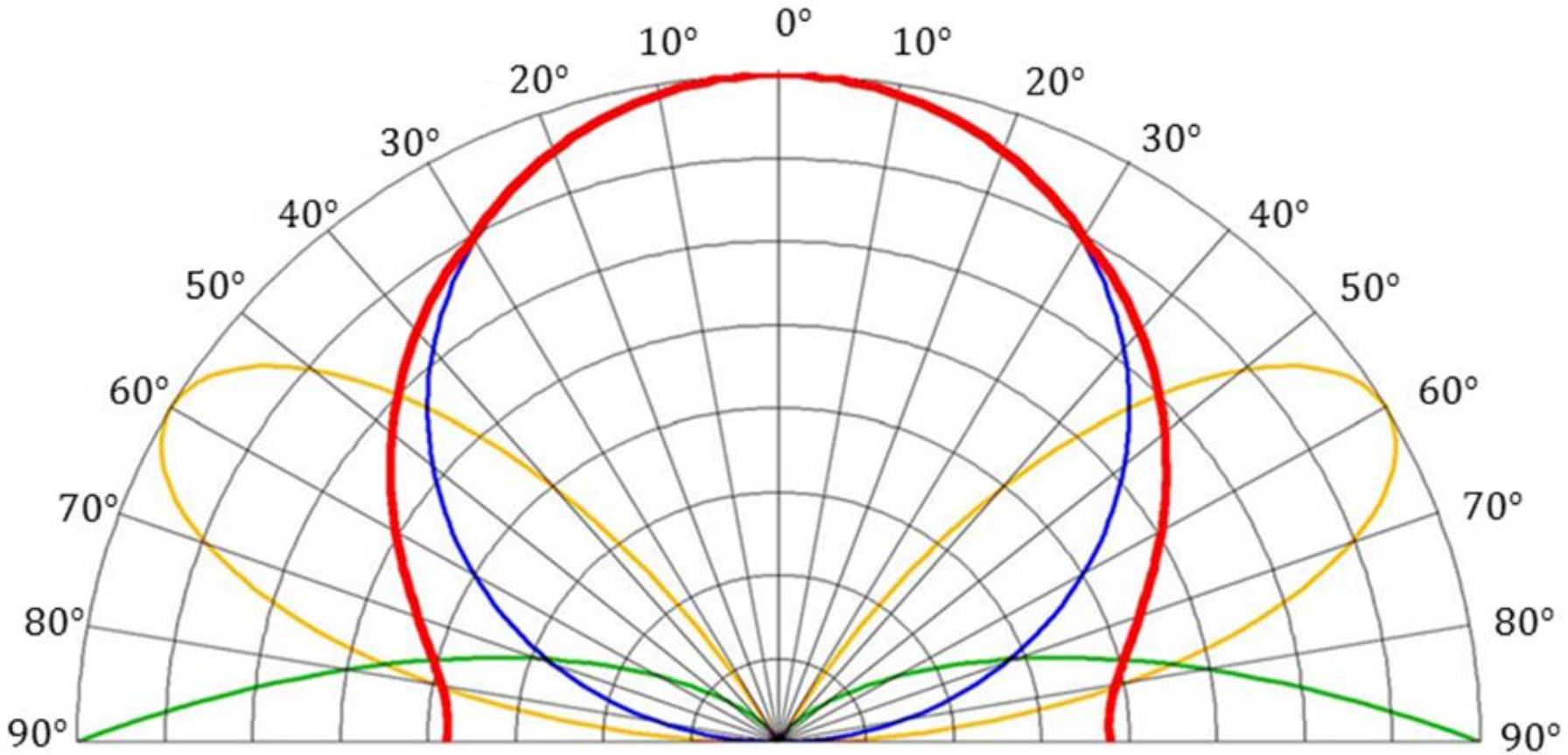
Select the most **ENERGY EFFICIENT** fixtures

Light Fixtures

Properly **shielded** light fixtures **decrease** the amount of artificial light directed into the atmosphere



Skyglow Emissions Functions



Graphic Credit: Falchi et al. (2016)