ELUSIVE AURORA BOREALIS: Geographic incidence of geomagnetic atmospheric disturbances in the Northern Hemisphere, terrain analysis, and multi-criteria suitability analysis for Aurora Borealis occurrence in Alaska

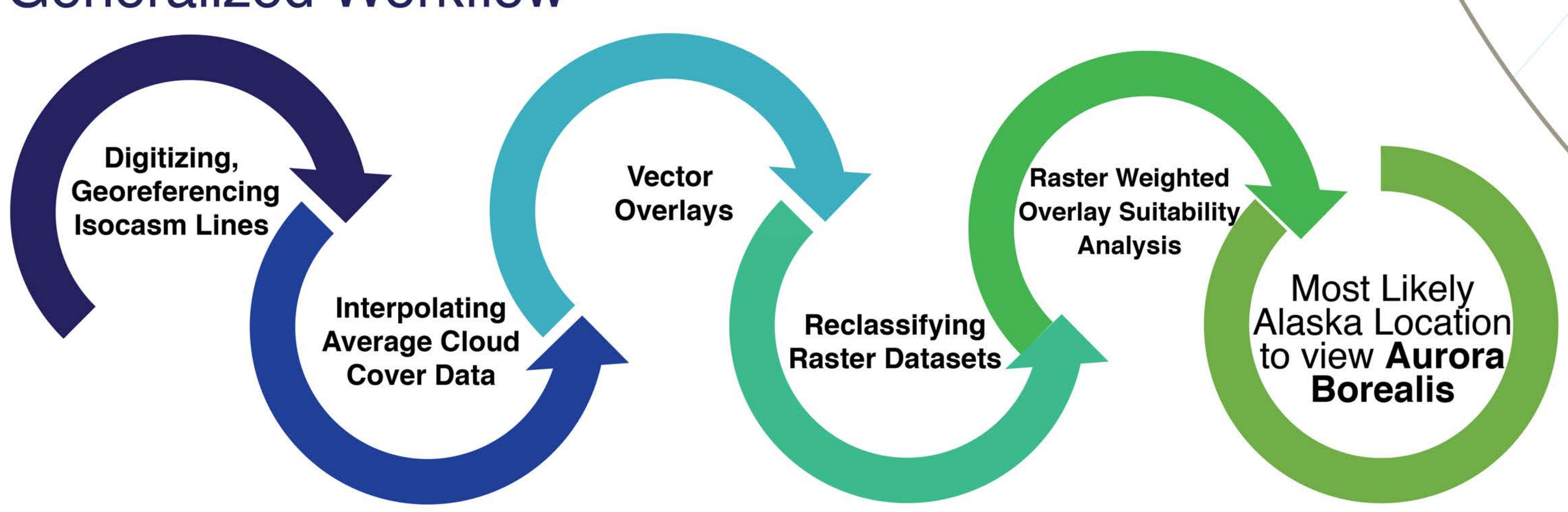
Introduction

Taking a trip to Alaska and do not want to miss the epic phenomenon of Aurora Borealis? The solar flares of the Northern Lights are a must-see multi-colored display that can be quite elusive as they form from interactions between the electrons from solar winds and the molecules in the Earth's atmosphere, and are typically only visible on a dark, clear night in high latitudes. Relying on climate and spatial data rather than chance will aid the curious in increasing their chances of being in the right place and the right time to experience the ocular majesty.

Methodology and Data

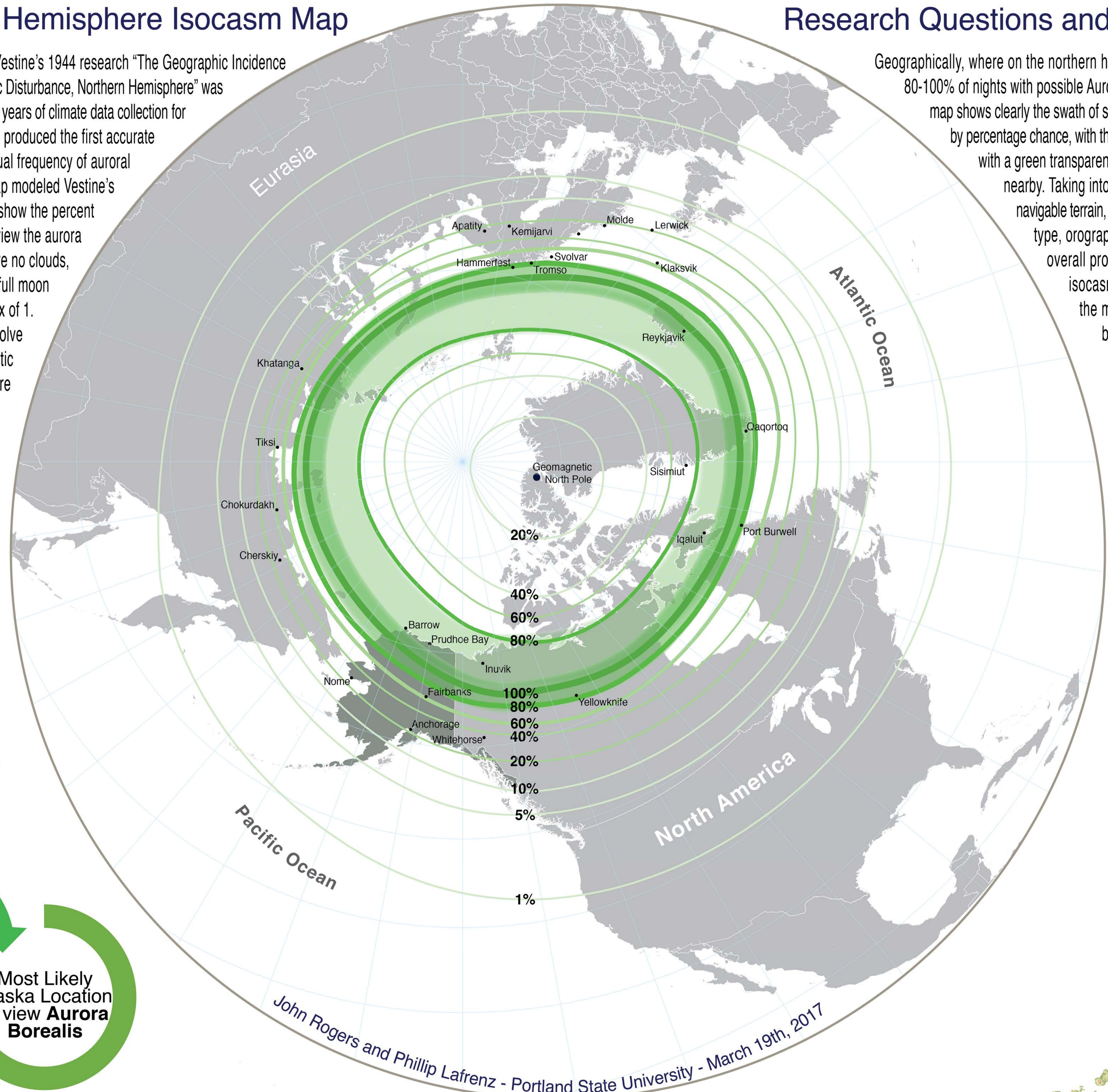
The digitization and georeferencing of Vestine's Aurora Borealis data was used as a base map to show the frequency and characteristics of Aurora Borealis observed in the Northern Hemisphere, while providing baseline locations of isocasm lines to run further proximity and spatial analyses. In order to determine suitable areas for viewing, raster data such as average percentage of clear nights, land cover type, terrain ruggedness, orographic viewshed of AB at a 100km height were weighted in an overlay analysis to meet multiple criteria. These results were then intersected with vector study areas that were determined by an overlay of mandatory criteria such as highway access, proximity to the 100% and 80% AB isocasm lines, airports, proximity to towns of significant population, cell phone service, and the buffered 100% AB swath. A weighted overlay was used to provide the most optimized zones for Aurora viewing based off of four separate factors: Areas with the least average cloud cover, within the viewing distance of the AB, view not obstructed by a mountain, types of land cover, and terrain roughness for navigability. Cloud cover was weighted at 35%, as cloudy skies are the most common impediment, viewshed was weighted 15%, land cover type was weighted 20% to ensure areas with the least vegetation obstruction and lack of built up space were given priority over densely vegetated or built up areas and waterbodies. The Terrain Ruggedness Index was also given a 20% to ensure that the viewable area are feasible to travel to. The Terrain Ruggedness Index measures roughness by taking focal min and max statistics of cell elevation and the mean of the surrounding 8 cells in the raster calculator using the same classification as Riley, 1999.

Generalized Workflow

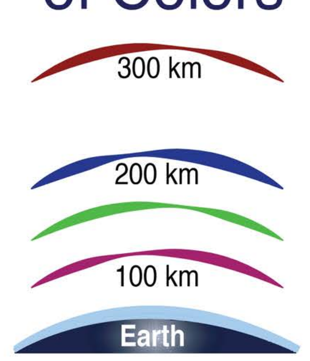


Northern Hemisphere Isocasm Map

Astrophysicist Harry Vestine's 1944 research "The Geographic Incidence of Aurora and Magnetic Disturbance, Northern Hemisphere" was based upon nearly fifty years of climate data collection for Aurora Borealis which produced the first accurate isocasm maps of equal frequency of auroral visibility. The main map modeled Vestine's work and is meant to show the percent chance that one can view the aurora providing that there are no clouds, bright city lights, or a full moon with a normal Kp index of 1. The isocasm lines revolve around the geomagnetic North Pole. Labeled are towns of significant population that are situated within 200 miles from the 100% chance auroral belt.



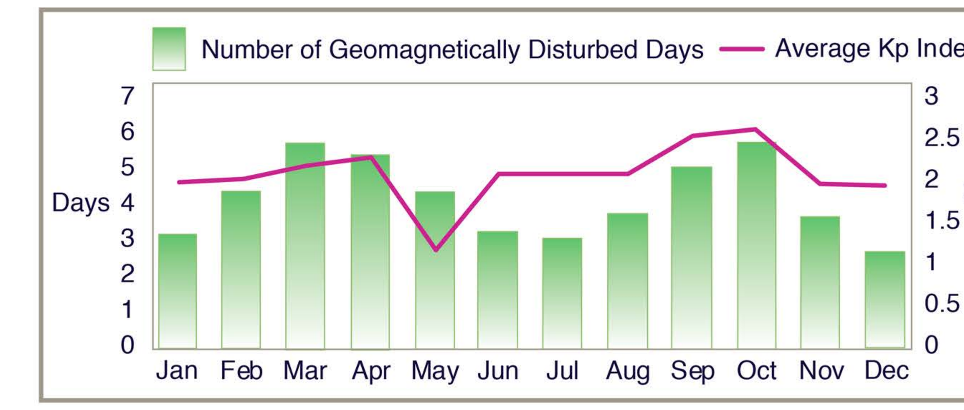
Elevation of Colors



Research Questions and Objectives

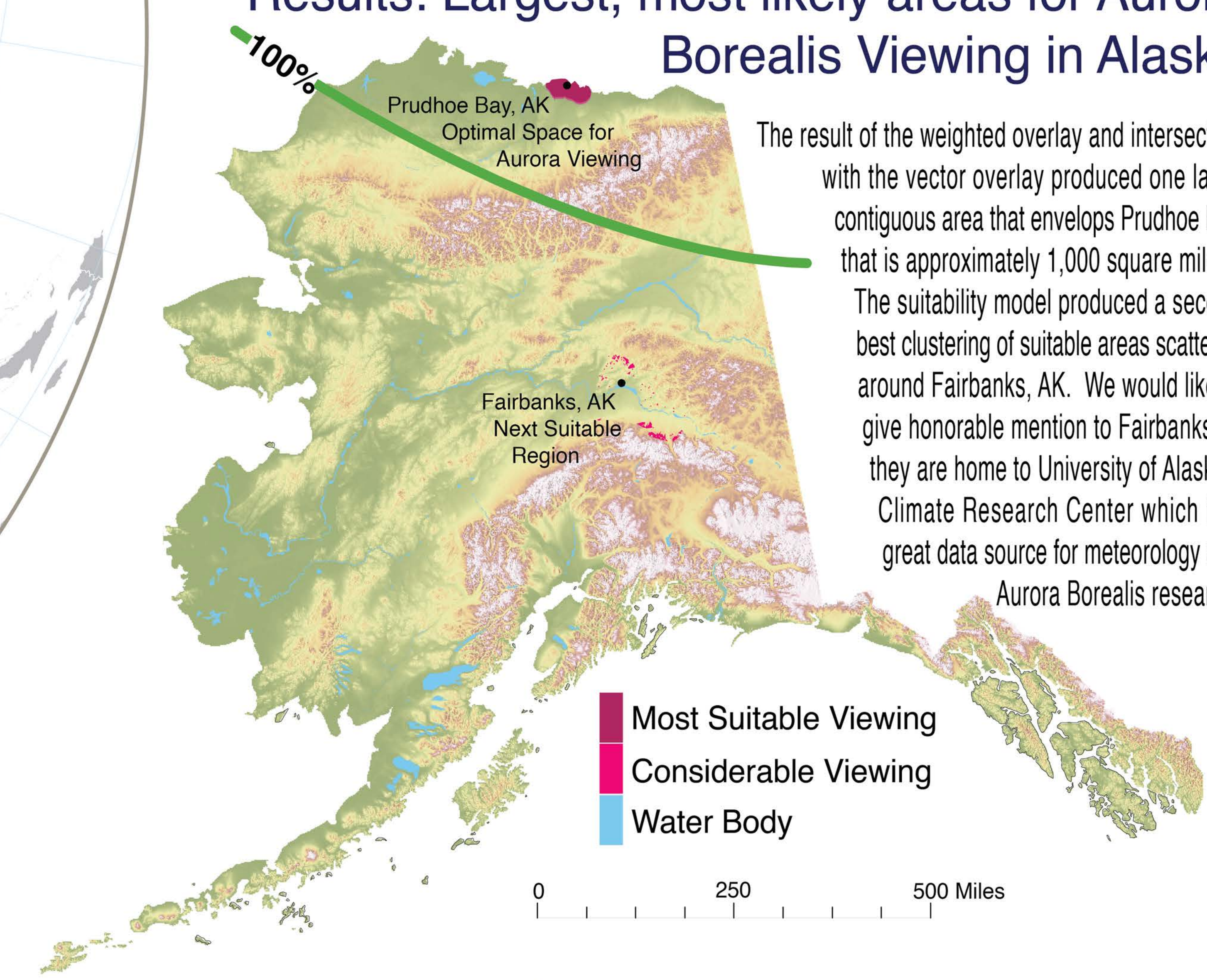
Geographically, where on the northern hemisphere is the swath of 80-100% of nights with possible Aurora Borealis? The Isocasm map shows clearly the swath of statistical auroral occurrence by percentage chance, with the 80-100% zone symbolized with a green transparency and the populated towns nearby. Taking into consideration cloud cover, navigable terrain, low density land cover, forest type, orographic viewshed barriers, and overall proximity to the highest value isocasm lines, where in Alaska is the most suitable region for the best chance at viewing the Aurora Borealis in March? A multi-criteria suitability approach with terrain analysis provided key insights to locations in Alaska for prime viewing.

Monthly Kp Index and Visible Hours



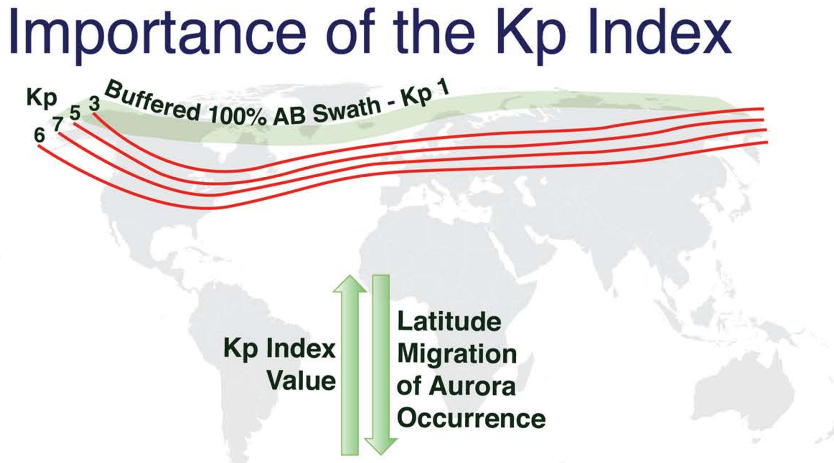
Source: NOAA / NWS Space Weather Prediction Center. Statistically, springtime (March/April) and autumn (September/October) contain the most geomagnetically disturbed days, which means more aurora activity. In Alaska, it is dark enough to see the Northern Lights from August-through-April, although full moons should be avoided. While the data is similar, the number of geomagnetically disturbed days measures the amount of days in a given month that are considered active, while the Kp index portion measures the average intensity of the of the geomagnetic disturbance within the given month. The monthly Kp index portion was created by combining the three hour planetary Kp data into a monthly average and placing it into a multi-variable graph with the monthly geomagnetically disturbed days.

Results: Largest, most likely areas for Aurora Borealis Viewing in Alaska



The result of the weighted overlay and intersection with the vector overlay produced one large contiguous area that envelops Prudhoe Bay that is approximately 1,000 square miles. The suitability model produced a second best clustering of suitable areas scattered around Fairbanks, AK. We would like to give honorable mention to Fairbanks as they are home to University of Alaska's Climate Research Center which is a great data source for meteorology and Aurora Borealis research.

Importance of the Kp Index



The Kp index is a measurement of disturbances within the geomagnetic poles measured on a scale of 0-9. Lower numbers mean that the disturbances are small so there will be less auroral activity, while numbers higher than 5 are considered "geomagnetic storms" and will result in more intense Auroras that can be seen further south than usual.

References

National Geographic, 2014. "Northern Lights Setting Skies Alight: Viewer's Guide to 2014's First Big Aurora Borealis Display".

NWS Space Weather Prediction Center, 30 year Kp Index Averages, March.

Feldstein et al, 2014. "Investigations of the auroral luminosity distribution and the dynamics of discrete auroral forms in a historical retrospective".

USGS Digital Elevation Data, 2017.

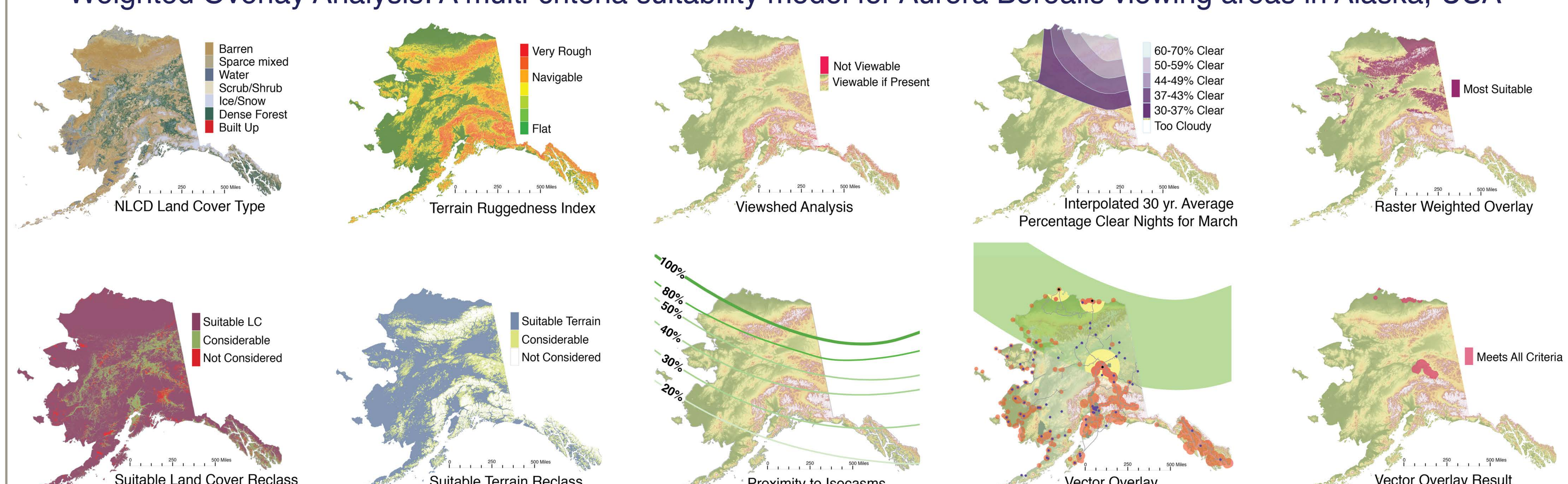
Riley et al., 1999. "A terrain ruggedness index that quatifies topographic heterogeneity".

Vasquez et al., 2015 "Long-term trends and Gleissberg cycles in aurora borealis records (1600–2015) ".

Vestine "The Geographic Incidence of Aurora and Magnetic Disturbance, Northern Hemisphere", 1944.

Portland State University

Weighted Overlay Analysis: A multi-criteria suitability model for Aurora Borealis viewing areas in Alaska, USA



Validation and Conclusions

Validating our findings required us to gather NOAA data that showed the location of the Aurora on March 16th so that it could be within the middle of the month of our study period. In conclusion, we believe that we have found the optimal areas of viewing for the month of March, which is the most active of months for Aurora viewing. Our findings run parallel with our original statement, along with showing what areas are better than others for viewing based on the parameters that we defined in our various analyses. For future analyses, we wish to create a spatio-temporal model for Kp index and AB migration.