Modeling Snow and Ice Melt in the Grand Canyon National Park

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Abstract
This project used data from the National Park Service, the Shuttle Radar Topography Mission (SRTM) data set, and recorded weather conditions to predict snow deposition and snow and ice melt in the Grand Canyon National Park. Two models were developed, using different solar radiation parameters. These models, simplified versions of previous research, show the location of persistent ice and snow on the Canyon slopes in March.

Introduction
The Grand Canyon is characterized by huge changes in elevation. The rim of the canyon measures between 2,100 and 2,400 meters high, while the base is 720 meters high. This results in huge differences in temperature across the elevation gradient. While it may feel like spring or summer on the canyon floor, freezing temperatures and snowfall will persist on the rim. This sets the stage for cold and icy conditions on the canyon’s rim to linger much longer than a visitor might expect.

Once the snow and ice accumulate, other climatic and topographic characteristics become important. The low humidity and temperature swings of the desert can create conditions cold enough for snow and ice even when the temperature gets quite warm during the day. While the warm day temperatures might be enough to melt all the ice and snow, the canyon’s steep sides shade out other parts of the canyon, particularly north-facing slopes. The snow and ice on these slopes receive little or no direct sunlight and refreeze as temperatures drop at night. As a result, snow and ice can persist much longer than expected, even into the tourist season. This creates a problem when the ice and snow remain on the trails of the Grand Canyon National Park (GRCA). This project aims to model the location of this snow and ice in GRCA in March. The goal of this project is to create a tool that could be used by GRCA to predict and delineate dangerous portions of trails.

Methods
This project relied on ArcGIS, a Geographic Information Systems software package for analysis. An elevation model for GRCA was developed using the global SRTM data set and the GRCA boundary. While Liston and Sturm (1998) developed the SnowTran-3D Model to predict snow fall based on weather conditions, this model assumes uniform snowfall in order to simplify the analysis. The elevation model, a solar isolation model, and a temperature model, based on weather conditions in March, were then used to predict snow and ice melt. The first version of this model (Model 1) identified areas that had an average low temperature below freezing and received less than 2500w/m² of solar radiation in March and identified these areas as snow and ice covered. A second version (Model 2) identified areas that had an average low temperature below freezing in March and received less than 2500w/m² of solar radiation in January through March and identified these areas as snow and ice covered. Average low temperature for March, based on actual observations on the Canyon rims and base, was calculated uniformly assuming a 0.0091m fall in elevation for every one degree Celsius decrease in temperature. Areas with average low temperature below zero degrees Celsius were assigned a value of one and everything else was assigned a value of two. The same procedure was repeated for areas with below 2500w/m² of solar radiation. These values were then summed, and areas with a total value of 2 were marked as snow and ice covered.

Results
Model 1 showed that 18.3% of GRCA was covered by snow and ice in March. Model 2 showed that 0.79% of GRCA was covered by snow and ice in March. Both models showed more snow and ice on the South Rim, where the Canyon slopes face northward and receive less direct sunlight. Snow and ice were more persistent on at the top of the canyon and none was predicted to be on the canyon floor.

Discussion
Model 1 predicted that a considerable portion of the canyon remains covered with snow and ice into March and Model 2 predicted that some snow and ice remained. By identifying these areas, GRCA staff can focus attention on these areas when informing visitors of the dangers on the trails. This model could also be expanded temporally to predict when snow and ice will completely disappear and when GRCA staff would no longer need these educational measures.

Models are inherently a simplification of reality. This model provides a very simplified version of actual processes at GRCA and it is possibly an oversimplification. Other research, such as Letsinger and Olyphant (2007), suggests that a more complex model is possible and this could be the focus of future research.

Works Cited

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