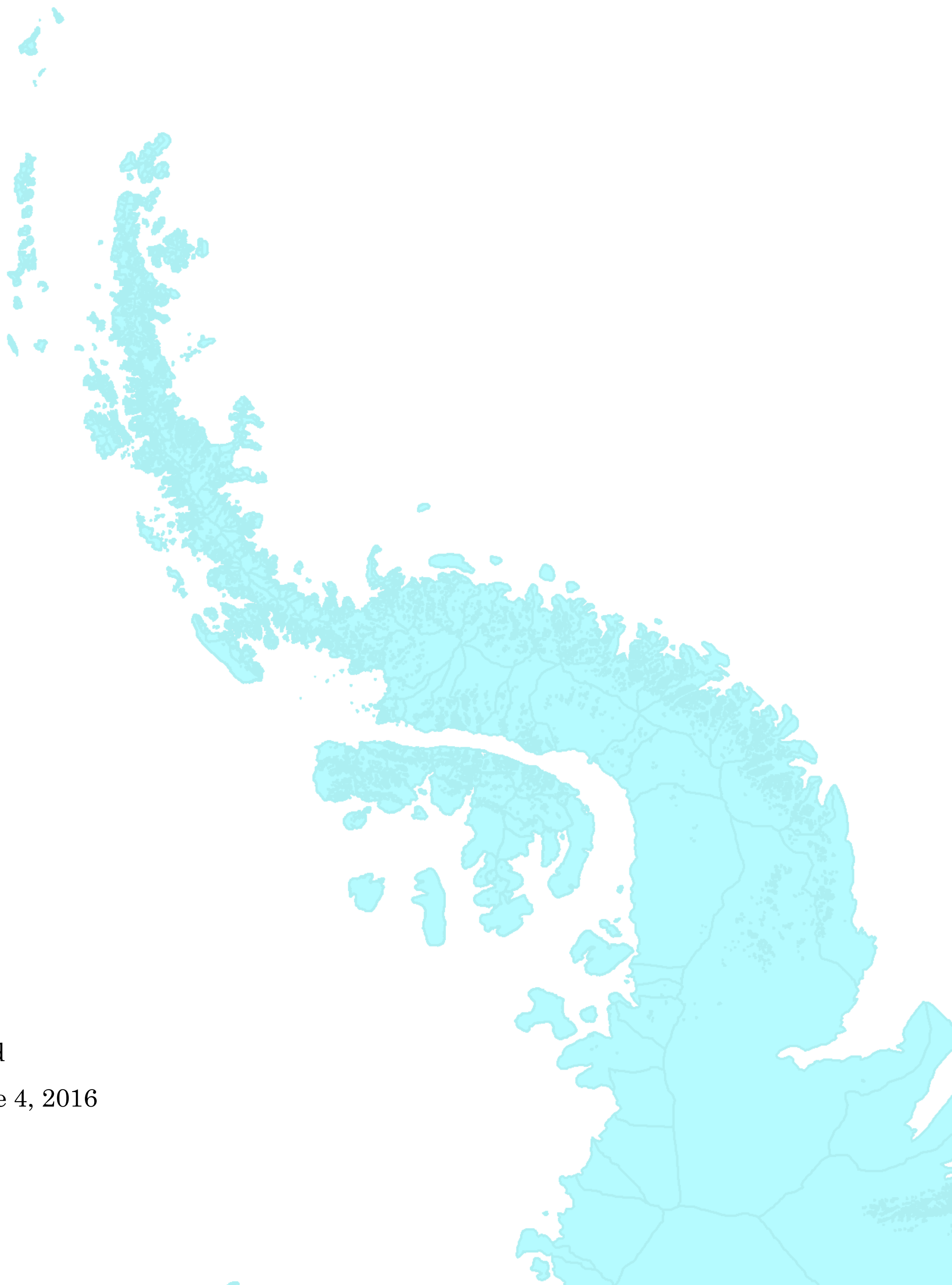
Surface Generation

Crane Glacier, Antarctica



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1 Introduction

Antarctica holds the vast majority, almost 90%, of Earth's ice mass – and changes to the climate have been causing ice shelves and glaciers to recede at an accelerating pace (USGS, 2016). To study these changes, and their impact, some background information is required; studying the surface properties of a glacier can help to give insights on how climate change is affecting the recession of Earth's ice masses.

This study focuses on Crane Glacier, and the heat it receives from the sun during a year (in Watt hours per square meter). A solar insolation surface information helps to assess the effect of the sun's energy on glacier recession. Producing this information, however, can be challenging: measuring solar insolation on-site is prohibitive, especially for a whole year. Instead, geospatial technologies (ArcGIS software) can be used to produce a simulation of the incident energy received from the sun on its surface; this study covers the process used to create such a surface map.

A digital elevation model (DEM) was necessary, as it provided the basis to calculate solar energy. In this study, the DEM was interpolated from evenly-spaced elevation points (from satellite data). This DEM surface was then used to compute the Slope, Aspect, Hillshade, and Viewshed of Crane Glacier, along with the Solar Insolation map; complementary information to help determine which surface aspect affects how much solar energy the glacier receives throughout a year, and why some areas are affected more than others.

This document covers the methods and analysis process, as well as the conclusion of this brief study. The model used in this study can be reproduced by following the method, and can be used for other areas in Antarctica, as needed.

2 Method & Analysis

2.1 Preliminary Assessment

Before producing a custom model to create and assess the surface of Crane Glacier, efficiency and accuracy tests were done first. Two files were used for the study: digital elevation points (in a *dbf* file), and a shape feature of Antarctica's Ice Catchments (as a *shapefile*). The digital elevation points cover only the Antarctic Peninsula, where Crane Glacier is located, yet it is a substantial file to process. As such, interpolating the entire surface isn't ideal, and requires substantial computer processing to produce. Instead, attributes and polygons found within the Ice Catchments file were used to extract the spatial information of just the Crane Glacier. This does reduce the accuracy of the solar radiation map, however, as it omits regions that may block sunlight from the glacier.

To determine the impact of this discrepancy, an analysis of the maximum viewing distance from the glacier was done. This can be done using ArcGIS's Viewshed tool, yet include prohibitive processing to produce a complete viewshed of the glacier and its surroundings. Instead, Young's model of the max viewing distance to the horizon was used, which incorporates the effects of atmospheric refraction and the curvature of the earth. Crane Glacier's maximum elevation point was determined to be approximately 2020 m from sea level, resulting in a maximum viewing distance of around 173 km (Young, 2013). This is a large viewing area; many features around the glacier can obscure the sun, as a result. Yet, since Crane Glacier is on a peninsula, most of this area is simply water, and won't obscure the path of sunlight to the glacier.

So, the impact of the area surrounding Crane Glacier can be assumed to affect insolation, yet *likely* not to a significant extent. The elevation varies greatly on the glacier, which reduces the possible viewshed greatly – any solar insolation map produced from a DEM surface of the glacier would then simulate most interior features accurately, with diminishing accuracy along the edges of the glacier (where data isn't modelled).

This was tested in various ways with manual use of tools in ArcGIS; from running solar radiation on a larger area, to determining actual viewshed using the Viewshed tool. In both cases, processing times were *much* greater, and the resulting differences were slight; which suggests it's safe to reduce the surface area being processed to only Crane Glacier.

2.2 Limiting the Study Area

Information for the whole Antarctic Peninsula was provided, yet only the points and shape of the Crane Glacier catchment were needed. The Ice Catchments file provided a shape specific to just Crane Glacier, and not mountain-tops or other gaps. The shape of the glacier was isolated by attribute (*name = 'Crane Glacier'*), and had its gaps filled using Union (no gaps). Then, to ensure only one polygon remained: a Dissolve function was used, creating a multi-part, single polygon for Crane Glacier (*'CraneGlacier_NoGaps_Dissolve'*).

2.3 Interpolating a Surface

The points provided for the surface elevation of the Antarctic Peninsula were spaced evenly 100 m apart. A surface model could be produced at a better resolution, but would be a larger approximation. Since Crane Glacier is rather large, relatively, a cell size of 100 m was adequate for this study, reducing the number of points that had to be interpolated.

Forming a surface in GIS software can be done in numerous ways; yet, for DEMs, Inverse Distance Weighted (IDW) and Natural Neighbour are typically used, if no other information is available (such as sinks, contours, and streams). For solar insolation, an approximation of the surface model is adequate. With spacing between points at 100 m, most valleys, dips, cliffs, hills, and mountain tops should be captured fairly well, and as such, IDW was used. Natural Neighbor was tested as well, and produced almost identical results. Comparing by efficiency of operation lead to slightly faster operation using IDW; and so, it was used within the automated model, which produces a DEM (*CraneGlacier_Surface*).

Note: the file provided for elevation points was not natively useable by ArcGIS surface modelling tools, and was imported by creating an XY event layer (Make XY Event Layer function).

2.4 DEM Clean-Up

The IDW interpolation function will interpolate to a full rectangular extent – beyond the limits of the Crane Glacier. To remove these outlying points, an Extract by Mask was used with the Crane Glacier gapless polygon ('CraneGlacier_NoGaps _Dissolve'), resulting in the final version of the DEM (*CraneGlacier_DEM*), as shown on the following page.

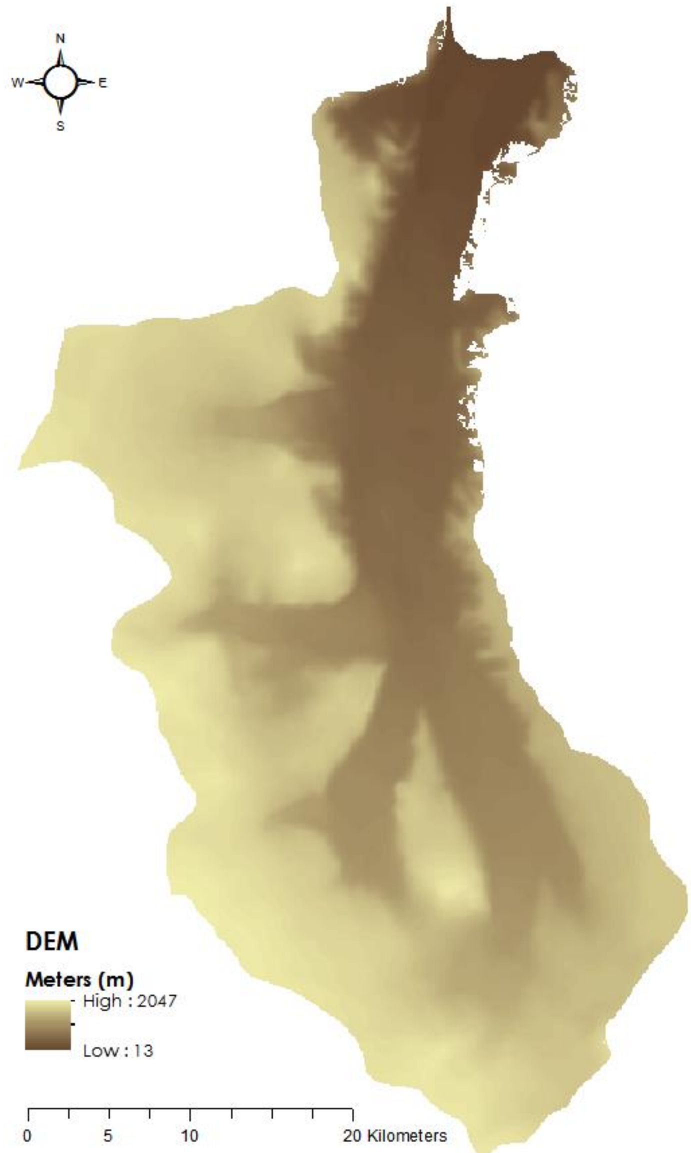

Figure 1 - Cleaned up Digital Elevation Model (DEM), produced in ArcGIS using IDW interpolation, and Extract by Mask to the shape of Crane Glacier

2.5 Slope

Creating a map of the slopes was straightforward once the DEM was produced: the Slope tool was used, set to degrees, and using the DEM as the input. This produced a clean Slope map (*CraneGlacier_Slope*).

Figure 2 - Slope Surface, created with the Slope Tool in ArcGIS, units represent the inclination of points, in degrees

2.6 Aspect

As with the slope map, producing the aspect map was also simple: use the DEM as an input for the Aspect tool, set to degrees for Azimuth. This produced the Aspect map (*CraneGlacier_Aspect*).

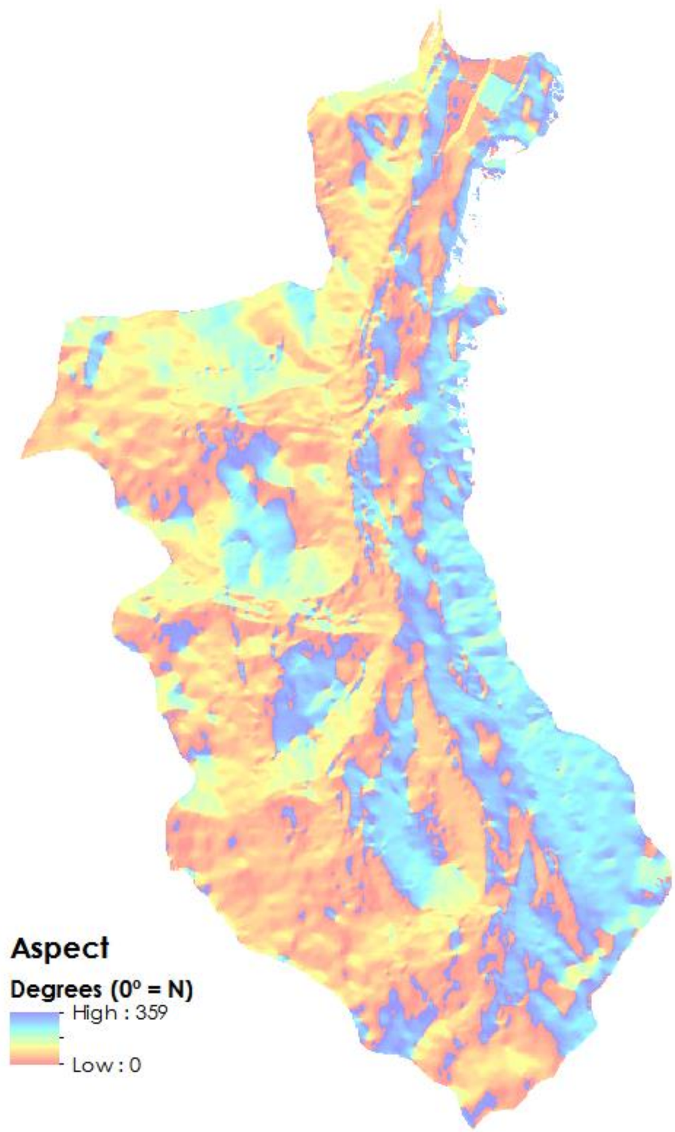

Figure 3 - Aspect Surface, created with the Aspect tool in ArcGIS; colours represent the direction of downward slopes, in degrees.

2.7 Hillshade

Like aspect and slope, producing the hillshade map only required the DEM surface as an input. For parameters, the studied Azimuth and Altitude were left as the defaults (a NW light-source), the Z factor was left as default, and Model shadows were disabled. This resulted in a raster with values from 0 to 254, where higher values had less shade (*CraneGlacier_Hillshade*).

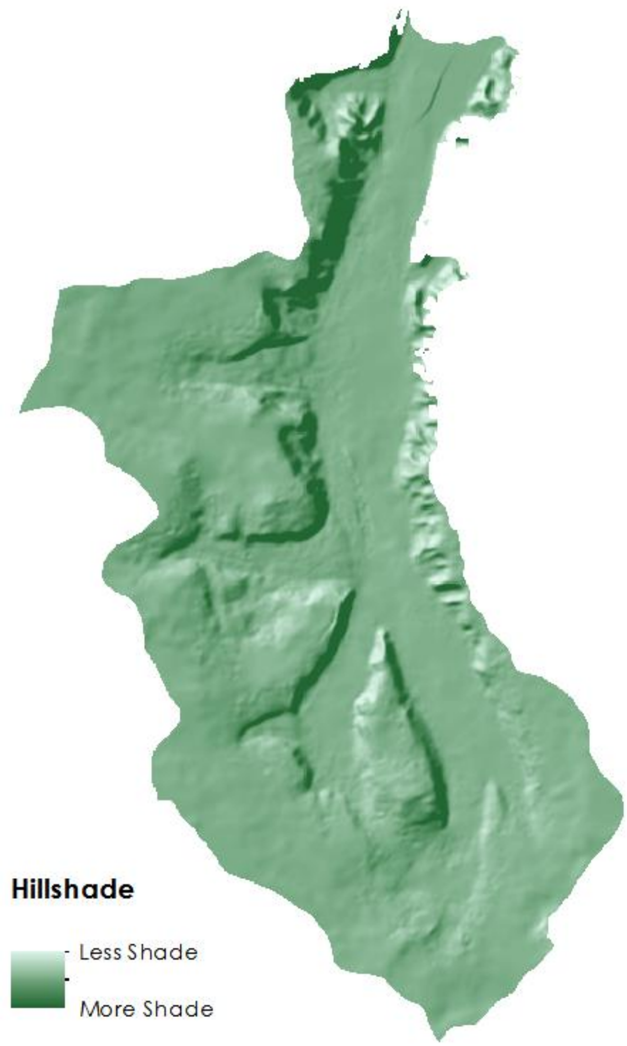

Figure 4 - Simulated Hillshade of Crane Glacier, using the Hillshade tool in ArcGIS, with a north-western light-source

2.8 Viewshed

Producing a helpful viewshed map required a few extra steps: the single-polygon version of the Crane Glacier shape was used as the constraining polygon to create a sample of random points (*Create Random Points* function). By default, the model only creates one point, but the user can input any positive integer value if they want more sample points. These points are used as observer locations in the Viewshed tool, which relies on the DEM, and earth's curvature corrections, to produce the viewshed map (*CraneGlacier_Viewshed*).

Figure 5 - Viewshed surface, with underlying digital elevation model. One random sample point was created for the Viewshed tool to use as an observer source. Created in ArcGIS.

2.9 Solar Insolation

To properly determine what areas of the glacier receive the most sunlight, however, a more elaborate tool was used: Area Solar Radiation. The surface DEM was used as the initial input, and the tool is set to run for a full calendar year, at 28 day interval for sun map calculations, and default settings otherwise. This ensures the tool runs efficiently, and still produces helpful information. The solar insolation map produced has units in Watts per square meter (*CraneGlacier_SolarInsolation*).

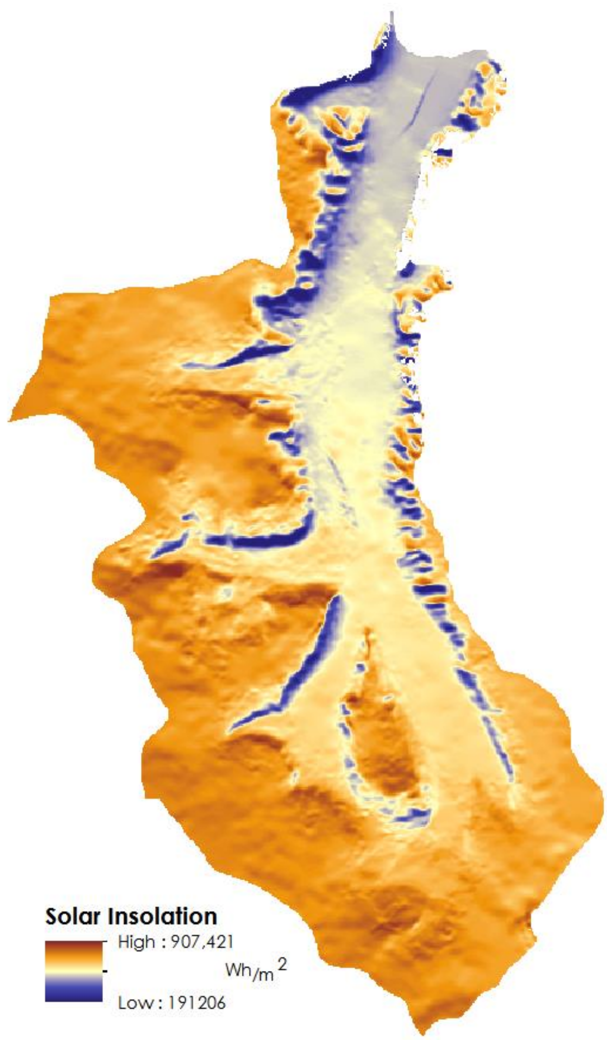

Figure 6 - Crane Glacier's Solar Insolation map, simulated for the whole year 2016. Produced in ArcGIS using the Area Solar Radiation tool

2.10 Map Layout

Finally, all six (6) maps produced were arranged in a map layout, using ArcMap, to easily compare and contrast the results. However, problems were encountered while exporting the map layout; for clarity, the data frames had to be close to each other, causing overlap – transparency and rasters, when exporting maps in ArcMap, is incompatible, leading to white backgrounds blocking most maps. As a work-around, each map was exported individually as PNG files with transparency, and recombined into a single document using Adobe Illustrator and Acrobat (found in ~\Documents\CraneGlacier_SurfaceGeneration.pdf). This was later redone in ArcGIS Pro, and produced the following map layout of Crane Glacier.

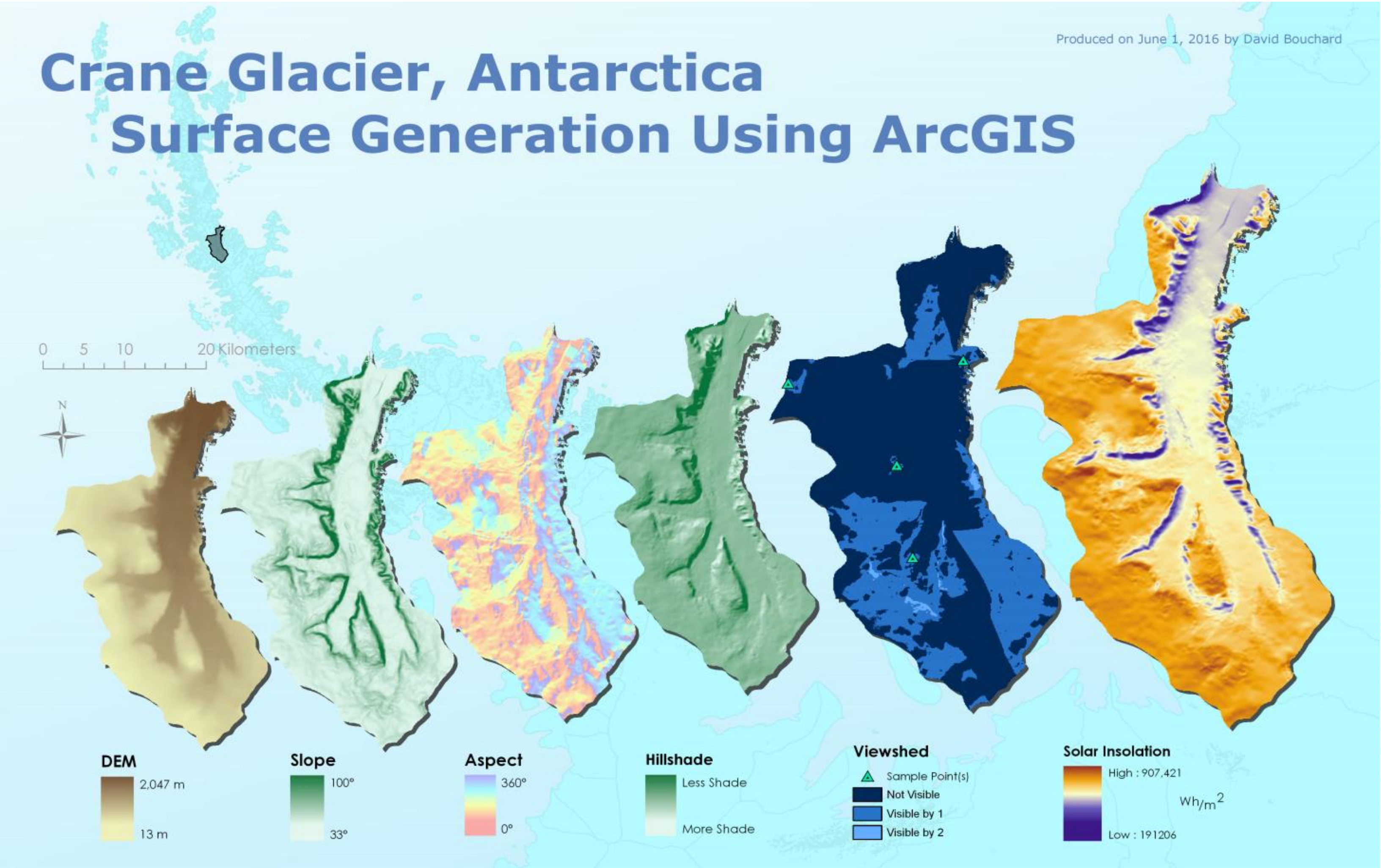

Figure 7 - Crane Glacier Surfaces Map, layout finalized with ArcGIS Pro

2.11 Custom Glacier Surfaces & Solar Heat Tool

After the model was refined for computing efficiency, it was saved as a tool (*Crane Glacier Catchment Tool*, in the *CustomGlacierTool* toolbox). This tool produces the outputs discussed in this section: DEM, Slope, Aspect, Hillshade, Viewshed, and Solar Insolation. It requires, for inputs: the Antarctic Ice Feature Catchments shape, the study elevation points as an XY table, the output data folder for database and raster creation, the number of desired viewshed sample points, and the time configuration desired for the solar area calculation. The tool has defaults assigned for 1 viewshed sample point, and a solar area simulation of a year. Output rasters and features are in Esri Grid and Feature Class formats, respectively.

The model can be found within the Custom Glacier Toolbox file provided with this document. And for future reference, a screen-capture of the model flow can be found on the next page.

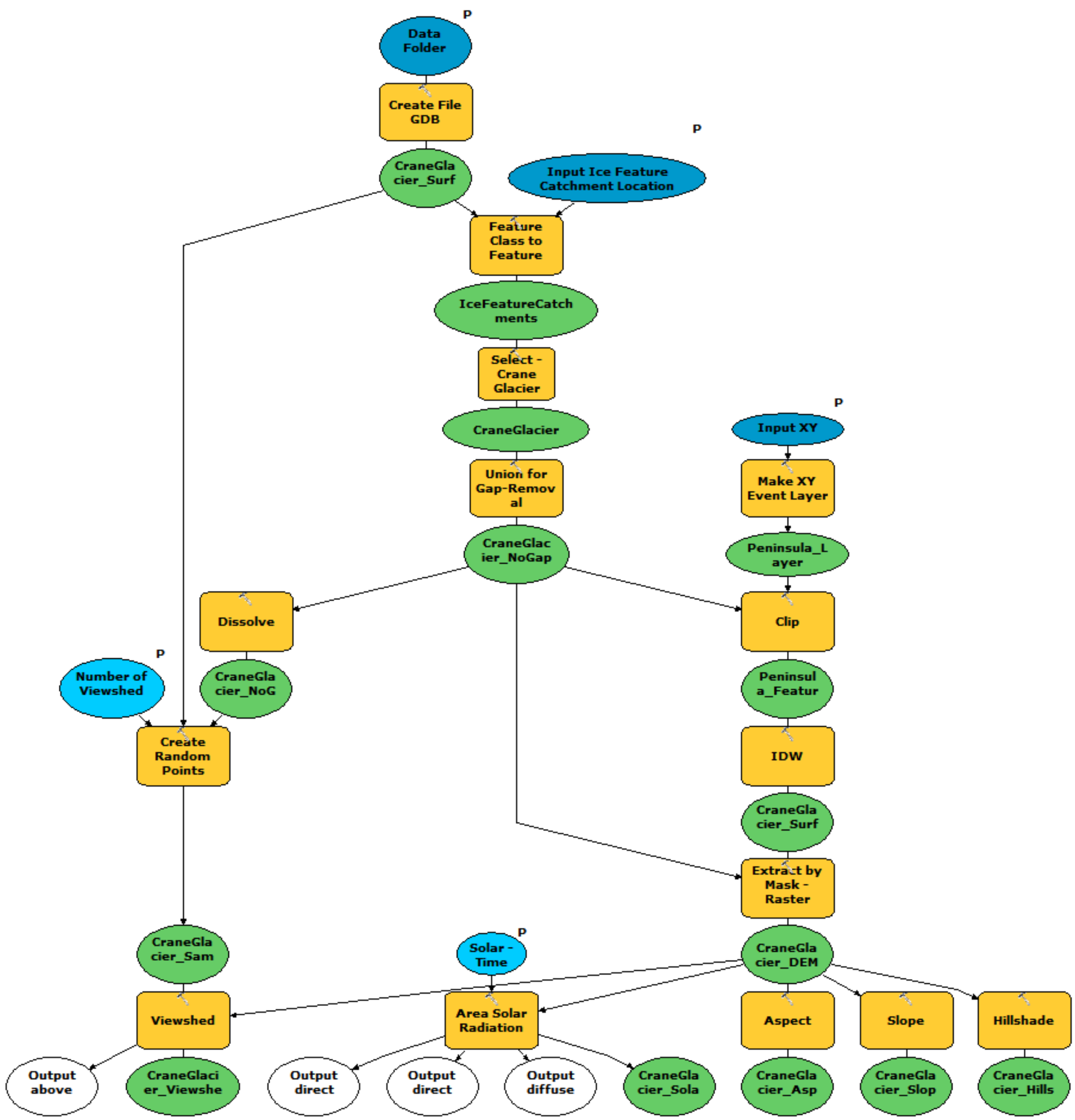

Figure 8 - Crane Glacier Catchment Tool, produces surfaces from elevation points. Outputs a DEM, Slope, Aspect, Hillshade, Viewshed, and Area Solar Radiation surfaces

3 Conclusion

After comparing and contrasting the resulting maps, it's clear that solar irradiance is affected by multiple factors on a particular surface. In Crane Glacier's case, the aspect, slope, and nearby elevation of any given point affect the incoming solar insolation – north-facing slopes, and open areas away from elevated points receive far more energy from the sun.

The Area Solar Radiation tool in ArcGIS has its limitations though; cloud-cover is only accounted for as an option (not selected by default), or via the Transmissivity factor (the fraction of radiation that passes through the atmosphere). Further studies of solar energy's effect on Crane Glacier should account for weather as well.

4 References

USGS. 2016. Ice, Snow, and Glaciers: the Water Cycle. Retrieved from: http://water.usgs.gov/edu/watercycleice.html on June 1, 2016.

Young, A. T. 2013. Dip of the Horizon. Retrieved from: http://www-rohan.sdsu.edu/~aty/explain/atmos_refr/dip.htmlon June 1, 2016.