Megan Falk, Alex Hepler, Michelle Lopez

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# The Retreat of the Grinnell Glacier: 1990-Present

## *Introduction*

Grinnell Glacier is located within Glacier National Park in the state of Montana (**Figure 1**). It is a notable glacier that was named after a famous conservationist named George Bird Grinnell .The glacier has undergone heavy monitoring due to its significant retreating snowpack .Many scientists have theorized that the glacier is being affected by the greenhouse effect (National Park Services, 2014). The increased levels of carbon dioxide, which are affecting the snowpack, are said to be from climate change. This theory is not singular to Grinnell Glacier; this phenomenon is being seen around the world. The glacier area was researched in this report from 1990 to present day to determine its rate of retreat.

## ***Methods and Materials***

***1A*** (Falk):The LandSat images used to configure the area of Grinnell Glacier for this report were retrieved from Earth Explorer (http://earthexplorer.usgs.gov/), and projected in World Geodetic Systems 1984, Universal Transverse Mercator zone 12 North (WGS 84, UTM zone 12 North). Within the LandSat archives, satellites L8 OLI/TIRS (September 5, 2014), L7 Enhanced Thematic Mapper (ETM) + SLC-on (September 20, 1999), and LI-5 MSS (September

3, 1990) (September 1, 1995) were used. The glacier boundaries were then digitized using ArcMap version 10.1 (Esri, Inc.). The area for each glacier was found by using the calculate geometry function within ArcMap.

***1B*** (Hepler): First a shapefile for Glacier County was selected and separated from the shapefile of all the counties in Montana. In addition, the Grinnell Glacier shapefile was also selected and separated from a shapefile of all the glaciers in Glacier National Park. Next I used the polygon to raster tool to change the park boundary from a shapefile into a raster. This raster was then used to clip this region out of the digital elevation model for the Northwestern states. These processes were repeated with the Montana State boundary to produce a custom DEM for the state. This was done with the "extract by mask" tool. Hillshades were then created for both of these clipped DEM's. Shapefiles previously digitized for the years in glacial retreat were then placed on top of one another in layers to show its recession. After carrying out all executions in Esri's ArcMap the park boundary clipped DEM and its hillshade were loaded into ArcScene. I then floated the park boundary shapefile and hillshade on top of their custom DEM to show the park in three dimensions. I then brought all the glacier files in and laid them on top of one another and floated them on top of the DEM. Last, I used the extrusion to raise the first glacier and exaggerated each additional layer to stack them in a way which the retreat could be seen spatially from viewpoints which were far, close, and directly above.

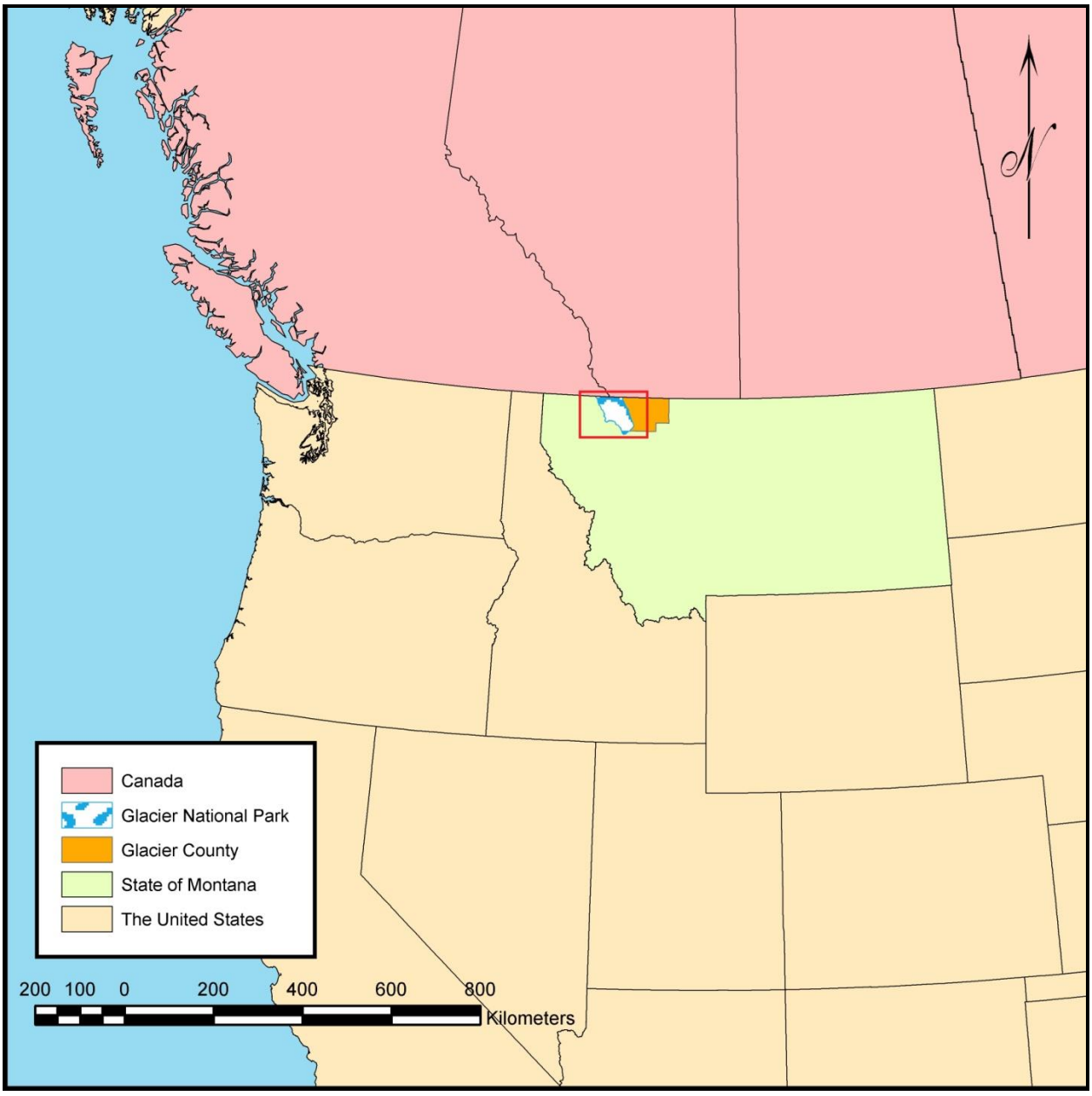


**Figure 1.** Locater map of Glacier National Park in Glacier County, Montana.

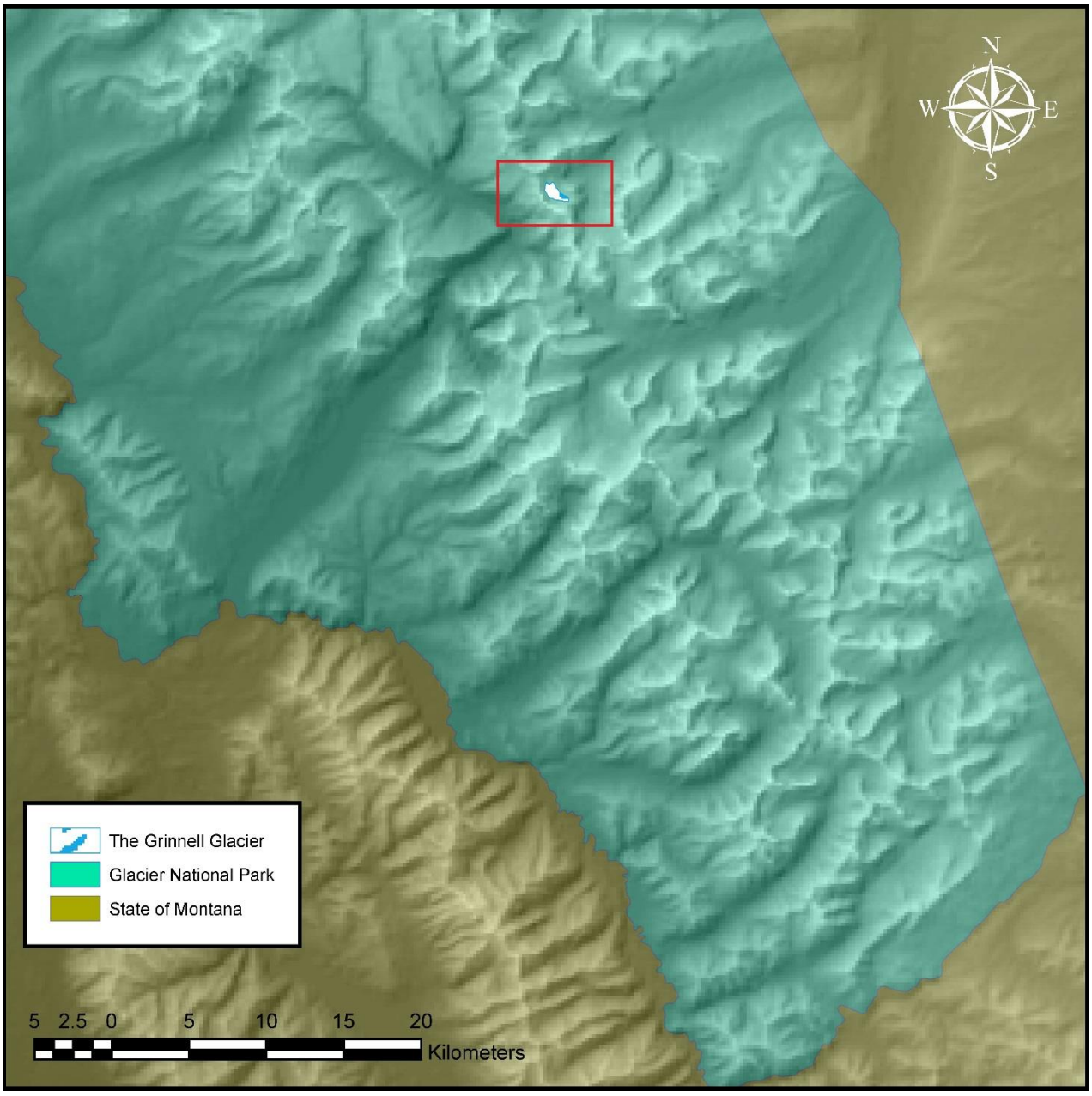


**Figure 2.** Locater map of the Grinnell Glacier in Glacier National Park.

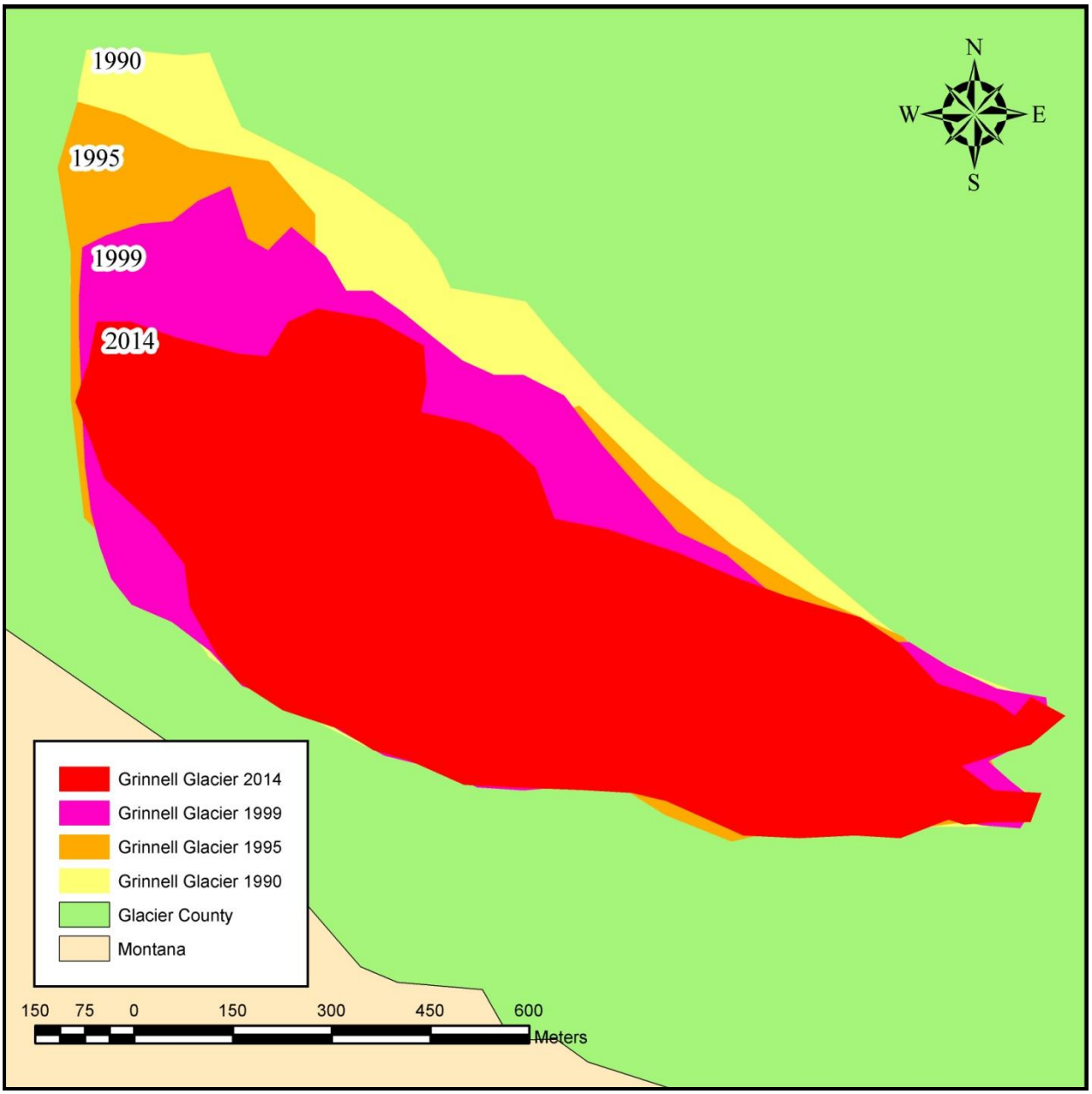


**Figure 3.** Map depicting Grinnell Glacier's rate of retreat between the years1990-2014.

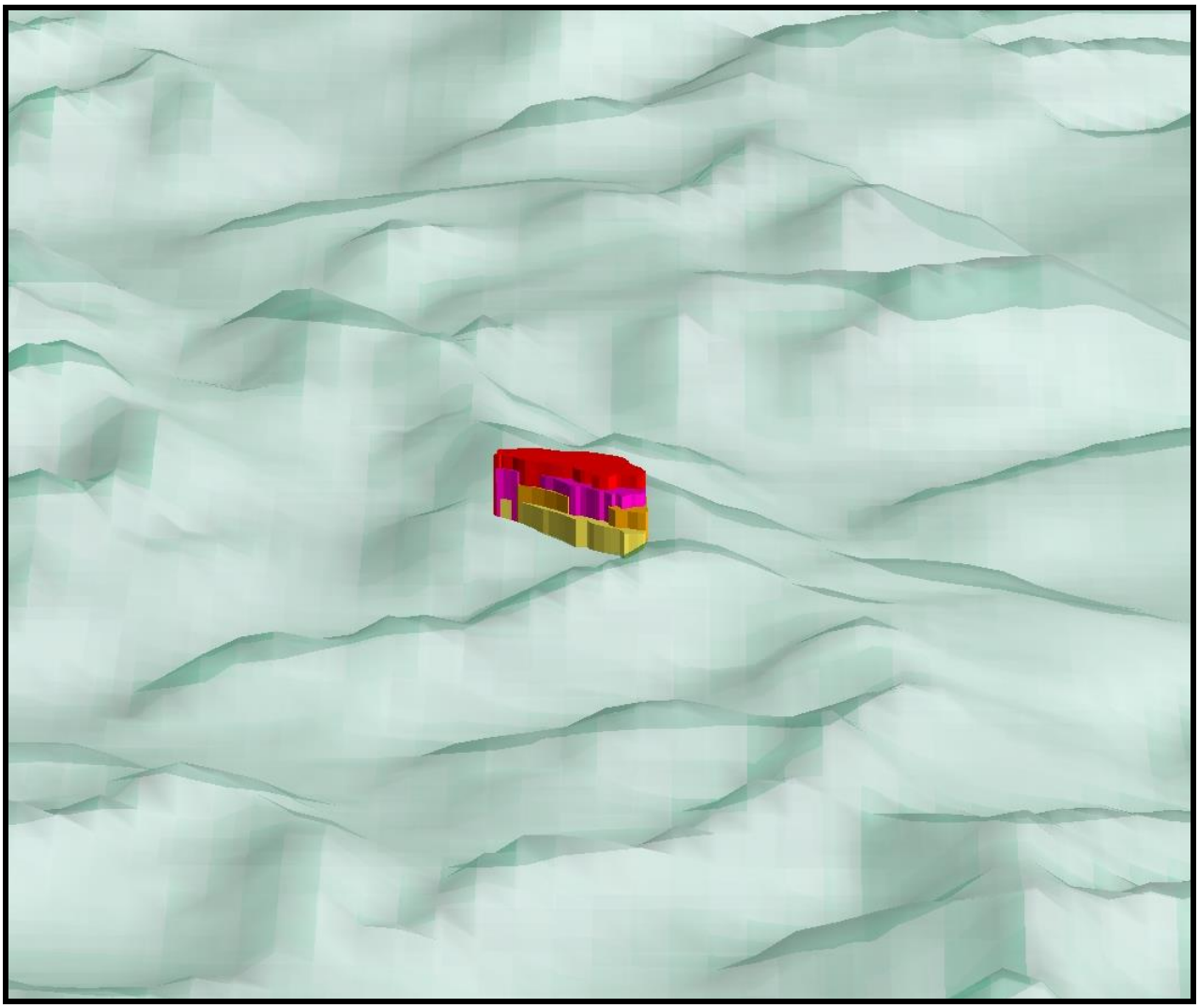

**Figure 4.** Three Dimensional visualization of Glacier National Park and The Grinnell Glacier's retreat between the years 1990-2014.

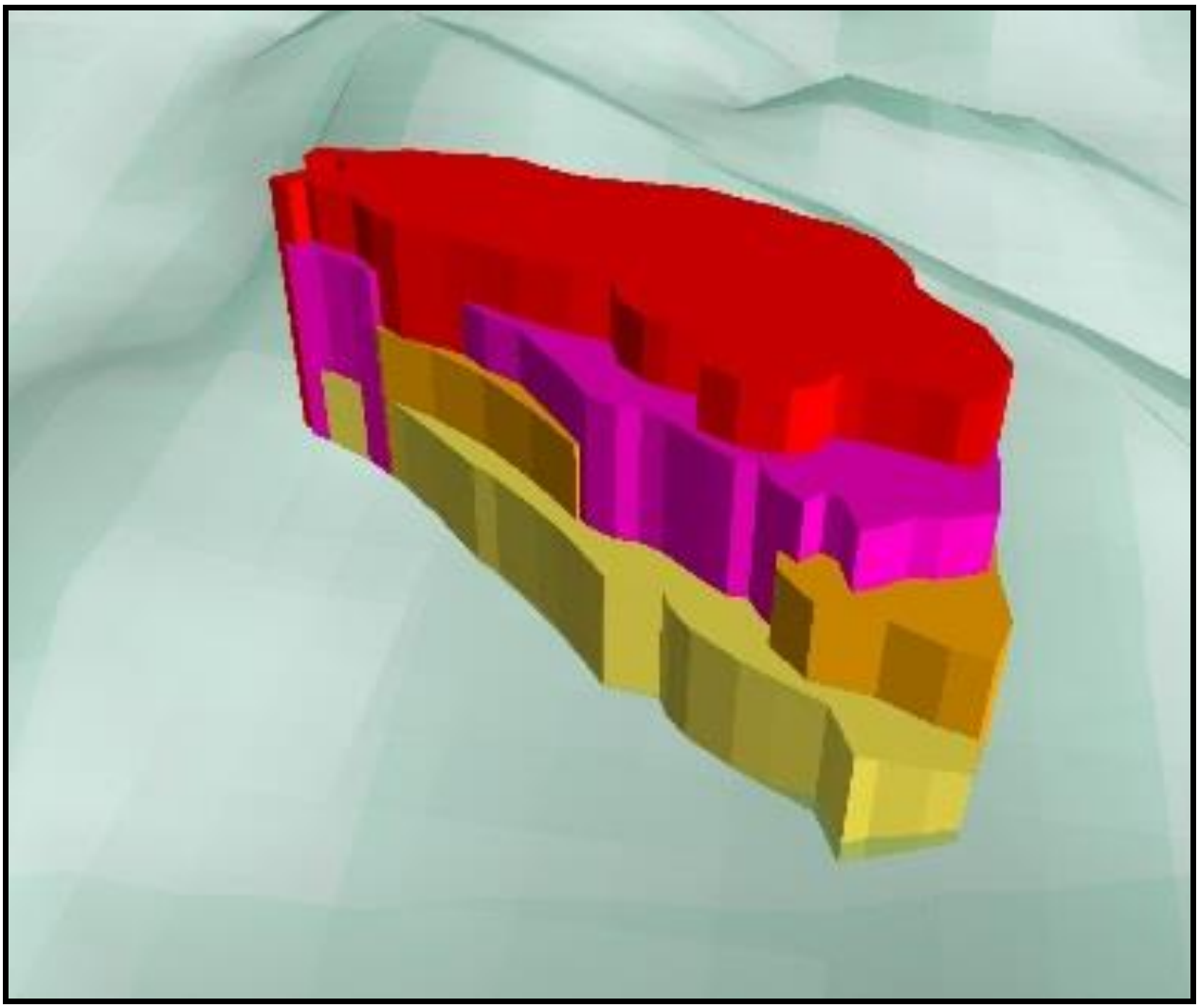

**Figure 5.** Three dimensional visualization of Grinnell Glacier's retreat between the years1990-2014 from an up close perspective.

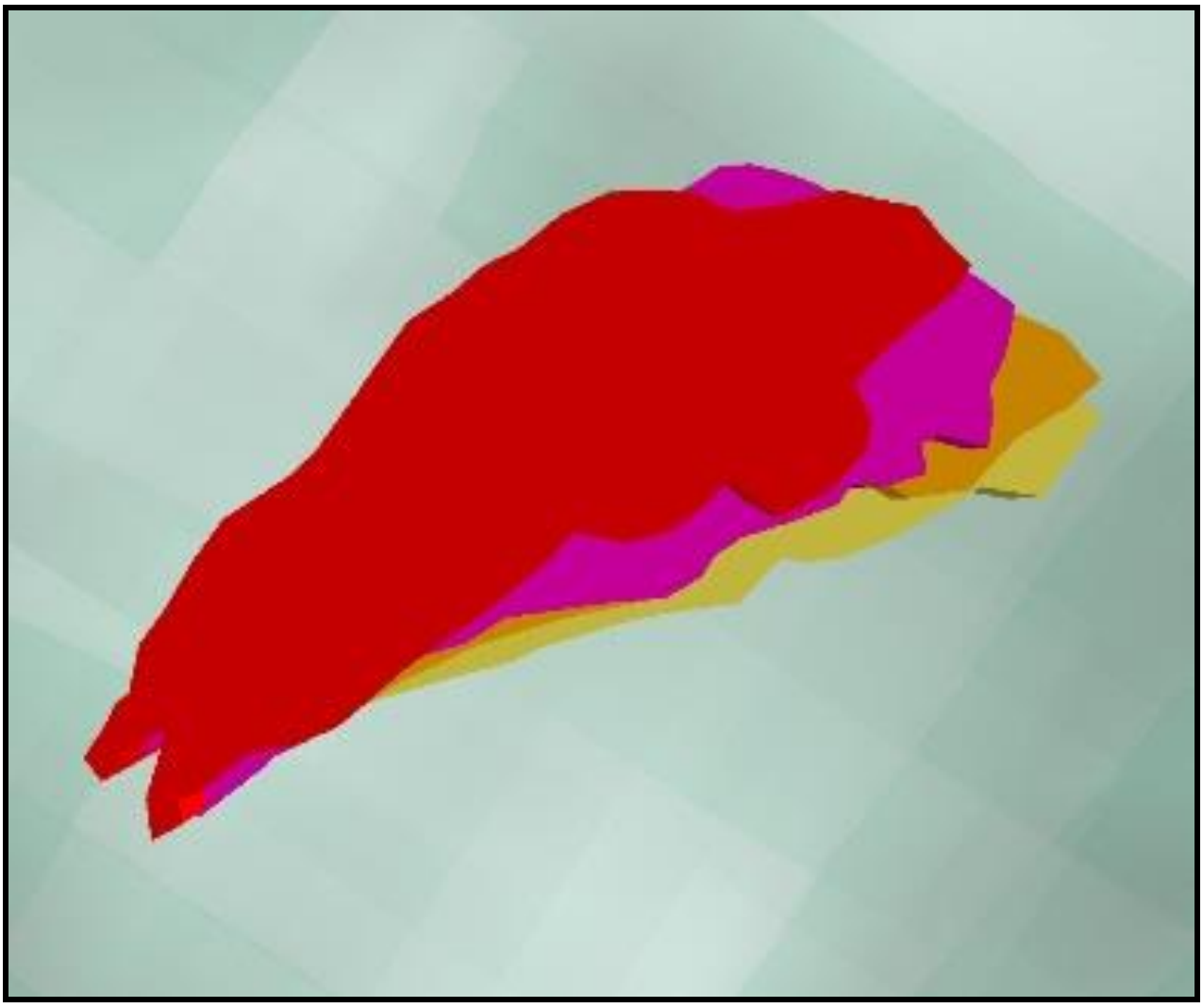

**Figure 6.** Three dimensional visualization of Grinnell Glacier's retreat between the years 1990-2014 from an overhead perspective.

## *Results*

The rate of retreat was evident once the glacier shapefiles were laid on top of one another (**Figure 3**). This was further emphasized and visually evident in the 3D visualizations (**Figures 5 and 6**). Each individual area from the different years was calculated (**Table 1**). The areas from the glacier in the present year and in 1990 were subtracted from one another. This

value was divided by the total number of years, which was a total of 24 years. This was done to find the rate of retreat in that time range. The rate of retreat was 12037.02 $m^2$ per year.

| Time (Years) | Area (square meters $m^2$) |
|---|---|
| 1990 | 874788.66 |
| 1995 | 723603.32 |
| 1999 | 714777.19 |
| 2014 | 585900.21 |

**Table 1.** Total ice loss in square meters due to melt for The Grinnell Glacier between the years 1990 and 2014.

## *Conclusion*

Various processes of GIS that were learned in class were applied in order to do this research. Finding accurate datasets proved to be the biggest challenge. Once the datasets were found and underwent the QAQC process, they were fit for use. The datasets were converted to shapefiles with the correct spatial reference, and digitized in ArcMap. They were then made into 3D visualizations on ArcScene. The significant decrease in snowpack since 1990 was evident in the maps that were produced (**Figures 2-6**). This study revealed that the glacier has been retreating at a rate of 12037.02 $m^2$ per year. Based on these calculations, the glacier is projected to have 48.66 years left before its snowpack completely disappears around 2061. When this happens, it will have significant impacts on the ecosystem in Glacier National Park.

## *Contributions*

The project was a collaborative team effort with specific tasks assigned to each group member. The team was called The Glaciators and consisted of three members; Megan Falk, Alex Hepler and Michelle Lopez. Megan Falk conducted a significant portion of the research and found most of the datasets used in the project. She sorted through a large volume of LandSat imagery to gather suitable images with limited cloud cover and then digitized polygons representative of each glacier for the years 1990, 1995, 1999, and 2014. Alex Hepler located Glacier National Park boundaries along with State and County shapefiles. He then conducted a majority of the analysis and created all locater maps, Maps, and 3D visualizations of the park and glaciers (**Figures 1-6**). Michelle Lopez conducted background research on the history of the glacier and compiled all the information for the report. The first draft was reviewed by Megan Falk and revisions for the rough draft were all done by Michelle Lopez. After receiving the report back from the instructor, Alex Hepler made all corrections to the text and map imagery and completed the all editing on this final draft.

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