Lab 5 – Modeling the Reunion of Jackson & Blackfoot Glaciers, Glacier National Park, MT

Abstract

In this lab, I use the Open Global Glacier Model to predict how much the climate would have to shift in order to reconnect two formerly merged glaciers located within Montana's Glacier National Park. In 1911, Jackson Glacier and Blackfoot Glacier were merged as a single glacier, known as Blackfoot Glacier. By 1939, these glaciers had receded to the point of becoming 2 distinct glaciers, leading to the formation of Jackson Glacier. By studying the paleoclimatic conditions that allowed for the formation of the merged Blackfoot Glacier, we can better understand and contextualize the observed retreat and divergence of Blackfoot and Jackson Glaciers. I find that the two glaciers reconnect in the next 200 years in a climate that is 3.6° Celsius colder than the current climate.

Introduction

Situated in northwestern Montana, Glacier National Park (GNP) is one of the better-known national parks in the United States. Famous for its mountain peaks and backcountry recreation, alpine glaciers are also a large driver of visitation for the Park and thus communities on its periphery. Loss of glaciers within GNP may lead to a reduction in visitation to the Park, negatively impacting these communities which depend on tourism for their economic stability. Glaciers are also important sources of water, and their retreat could have impacts for the hydrological regime of and ecosystems within the Park boundaries.

In the early 20th century, Blackfoot Glacier extended much further down its valley than it does at present, encompassing both the current Blackfoot and Jackson Glaciers(McKeon, n.d.). However, by 1939 the Blackfoot Glacier had retreated so far that the Jackson Glacier became separate, leading to its naming. This retreat is just one of many such glacier shrinkages observed within GNP (e.g. Florentine et al., 2018), although not all result in the addition of another glacier to the region.

The Open Global Glacier Model (OGGM) is an open-source glacier model written in Python and hosted on a cluster at the University of Bremen. OGGM is an accessible tool for glaciology, allowing us to understand how glaciers may respond to various changes in climate, mass balance, topography, or myriad other factors. In this scenario, I use the glacier merging capabilities of OGGM to investigate the factors influencing the reunion of the Jackson and Blackfoot Glaciers into a single Blackfoot Glacier.

Methods

To model the advance of Blackfoot & Jackson Glaciers, an established method for merging glaciers is followed (*Merging Glaciers for Past Climate Simulations — OGGM Tutorials*, n.d.). First, the Randolph Glacier Inventory (RGI) outlines of both glaciers in question were compiled in OGGM into a single glacier directory. This allows OGGM to merge the outlines and treat the disparate glaciers as one, with Blackfoot Glacier as the primary glacier and Jackson Glacier as a tributary glacier. I then plotted the centerlines of these glaciers (Figure 1) to visualize their potential interaction as they advance. These centerlines run close to each other for a large stretch before officially merging, not accounting for width of the glacier. To produce a more realistic estimate of the rejoining of these 2 glaciers, I assume that the glaciers merge when their modeled lateral extents overlap (Figure 2).

After merging the two glaciers into a single directory, I initialized a standard climate model in OGGM run over a 200-year period. This model was executed multiple times with various temperature biases, keeping the time period constant. After each run, the glacier extent was plotted to identify any overlap. I adjusted the temperature bias until the glaciers just overlapped, indicating that that was the minimum climatic change needed to rejoin Jackson and Blackfoot Glaciers.

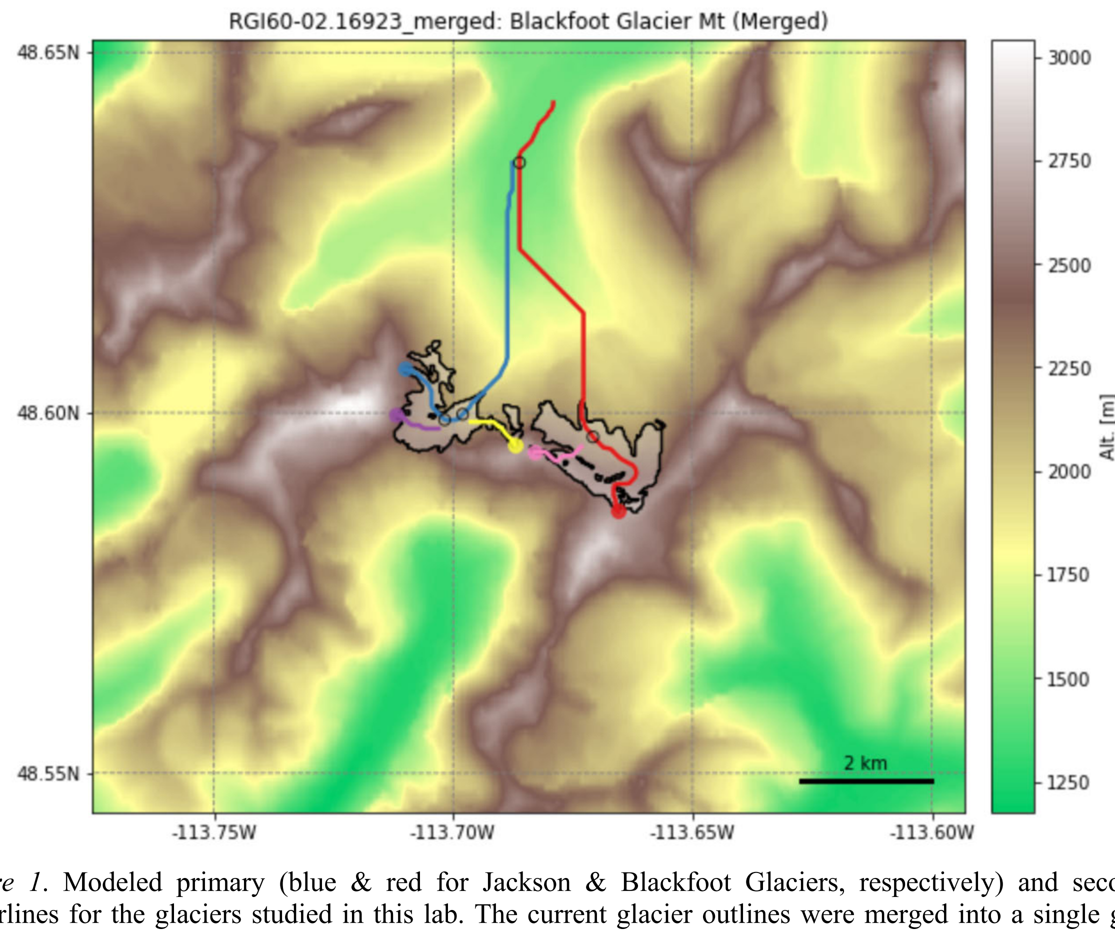

Figure 1. Modeled primary (blue & red for Jackson & Blackfoot Glaciers, respectively) and secondary centerlines for the glaciers studied in this lab. The current glacier outlines were merged into a single glacier directory, and their predicted flowlines were modeled downslope. A circle at the intersection of the red and blue lines marks where OGGM predicts the two glaciers will merge, although these primary flowlines run close together for some time before this point. This suggests that the glaciers may merge sooner than is modeled by OGGM.

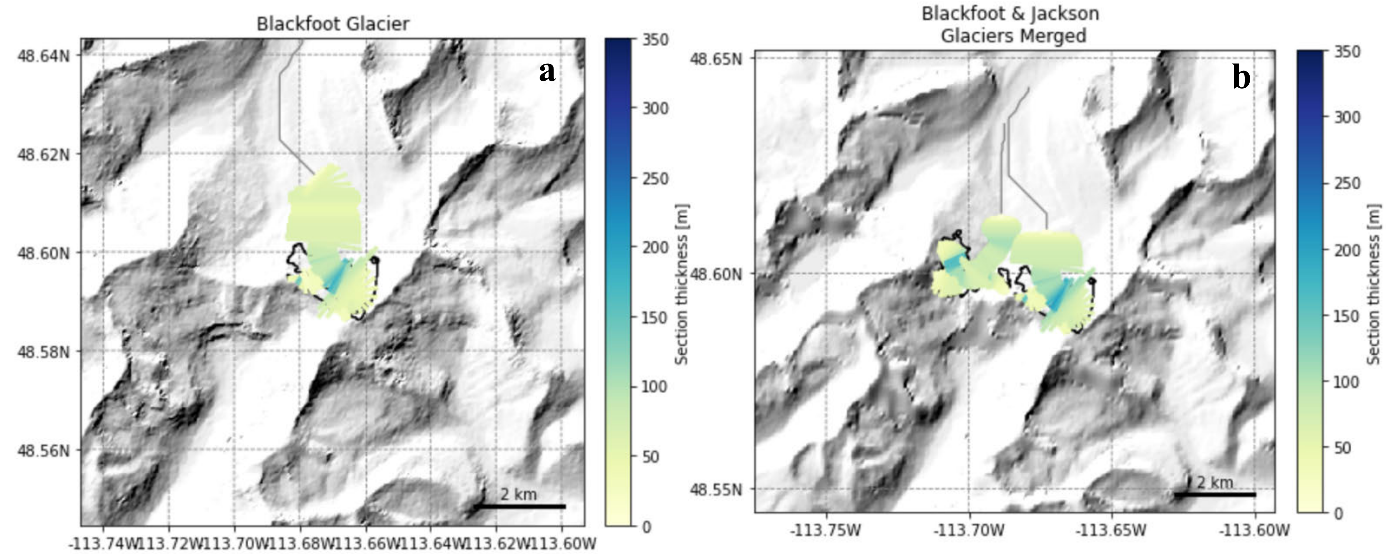

Figure 2. This figure shows the modeled extents of the current Blackfoot Glacier (a) and the merged glacier made up of both Jackson and Blackfoot Glacier (b) over the next 200 years in a climate that is 3.6°C cooler than the current climate. At this point, Jackson and Blackfoot Glacier contact each other, suggesting that these glaciers may reconnect at that time. Curiously, Blackfoot Glacier appears to have advanced to a different point in each scenario (merged and unmerged), despite being modeled in the same climatic conditions. The reason for this is unclear but may be due to a quirk in OGGM's simulation of merged glacier behavior prior to their modeled reconnection, particularly regarding the total area of the glacier in the ablation zone.

Results

I find that the climate would need to cool by approximately 3.6°C in order for Blackfoot and Jackson Glaciers to reconnect over the next 200 years. This does not necessarily represent their equilibrium state, as -3.6°C is a quite dramatic change, and likely will result in further advance beyond the 200-year scope of my study. During the model run, the unmerged Blackfoot Glacier advanced sooner than the merged Blackfoot and Jackson Glaciers did (Figure 3), although they both ultimately advance at roughly the same rate. This is unexpected and may be a result of an imperfection in the way that OGGM calculates glacier length rather than an accurate representation of glacier length change over this period.

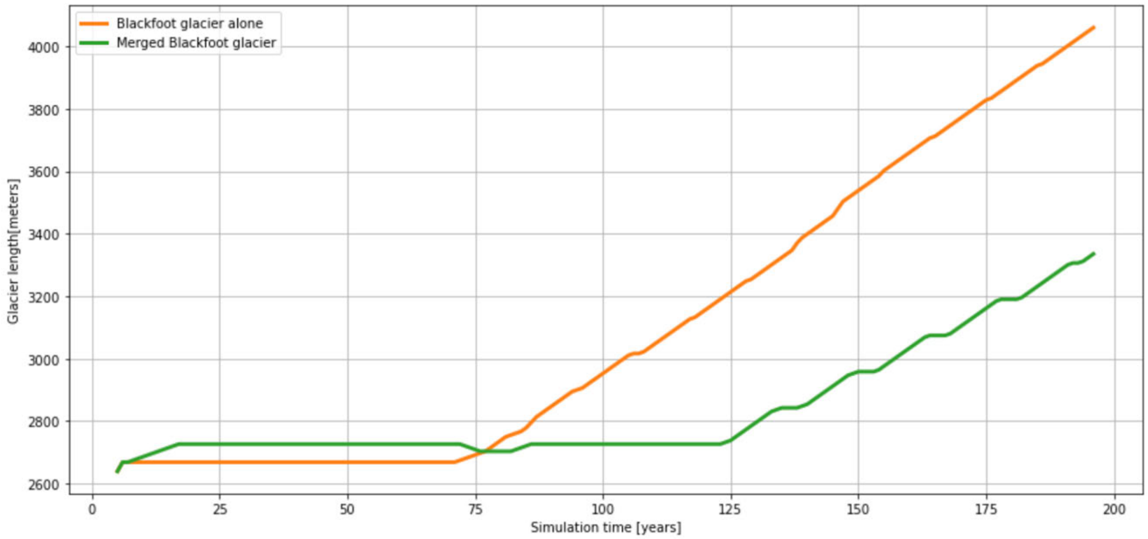

Figure 3. Glacier lengths over the model run are plotted here, with the current Blackfoot Glacier shown in orange and the merged Jackson & Blackfoot Glaciers shown in green. Although the merged glacier lengthens slightly at first, it varies very little before ultimately advancing at about the same rate that Blackfoot Glacier does, approximately 50 years after the unmerged glacier begins its advance. This offset may be due to differences in length calculation for the combined Jackson & Blackfoot Glaciers or a need for each individual glacier to change in length before there is a noticeable increase in overall glacier length. Comparatively, Blackfoot Glacier alone may be more prone to changes in length since it does not need to account for changes in two separate glaciers which will eventually merge.

Discussion

Glaciers are melting and are predicted to continue melting in GNP (Hall & Fagre, 2003). As this change occurs, it's imperative that we build an understanding of the climatic conditions that allowed glaciers to reach greater extents in the past so that we can contextualize any observed changes. This contextualization can improve community and conservation adaptation to a Park with shrinking glacier coverage.

I find that, over the next 200 years, the climate would have to cool by 3.6°C in order to reconnect Blackfoot and Jackson Glaciers. This is a dramatic climatic change, and unlikely over this timescale. However, the 200-year timescale is also a rather short window for glaciers to advance or retreat, necessitating a large climatic shift to trigger the readvance. This suggests that, upon initiation of western observation in the early 20th century, Blackfoot Glacier was either responding to a dramatic climatic shift or already in retreat due to a lower-intensity, longer-scale warming. Further studies of glacier retreat and paleoclimate conditions within the Blackfoot basin (e.g. Hall & Fagre, 2003) can help elucidate the factors which led to the retreat of Blackfoot Glacier.

While useful for a preliminary understanding of the retreat and potential readvance of Blackfoot and Jackson Glaciers, the OGGM simulation used in this study may not be the optimal model for glaciers in GNP. For example, the climate model used in producing the glacier mass balance model is based on global conditions and may not account for specific regional patterns in precipitation or temperature. Moreover, the climate model was not initialized based on meteorological observations, and thus omits some of the natural variation present in long-scale climate. However, this model nonetheless remains a reasonable, if imperfect, representation of a standard Earth climate.

Different timing of glacier length advance (Figure 3) may be the result of OGGM's method for calculating glacier advance in merged glaciers that have not yet reconnected. As glaciers advance further down valley, there is a greater area below the equilibrium line altitude (ELA), resulting in more ablation of the merged glacier, slowing its advance. This is especially true for the merged glacier, since its surface area is that of both Jackson and Blackfoot Glaciers, rather than Blackfoot alone. If OGGM treats the two tributaries as having a combined influence on mass balance even before they are actually reconnected, this may result in a greater area of ice in the ablation zone, unrealistically slowing the advance of the merged glacier.

Conclusions

Glaciers in GNP are melting considerably, impacting ecosystems, regional hydrology, and communities in the immediate region. In order to better contextualize the observed and predicted changes in GNP, it's important to understand the conditions that led to the retreat of these glaciers in the past and that could lead to their readvance in the future. In this study, I use OGGM to investigate the climatic shifts that would induce the once-joined Blackfoot and Jackson Glaciers to reconnect further down the Blackfoot basin. I find that the climate would need to cool by 3.6°C in order to rejoin these glaciers in the next 200 years. This suggests that the glaciers were responding to a comparable dramatic change in climate upon the arrival of western observers in the early 20th century, or to a longer-scale, lower-intensity change. Future work could investigate the modeled advance of these glaciers over a longer time period, or combine this and similar modeling studies with observational work related to glacier retreat in the Blackfoot basin.

Citations

- Florentine, C., Harper, J., Fagre, D., Moore, J., & Peitzsch, E. (2018). Local topography increasingly influences the mass balance of a retreating cirque glacier. *Cryosphere*, *12*(6), 2109–2122. Scopus. https://doi.org/10.5194/tc-12-2109-2018
- Hall, M. H. P., & Fagre, D. B. (2003). Modeled Climate-Induced Glacier Change in Glacier National Park, 1850–2100. *BioScience*, *53*(2), 131–140. https://doi.org/10.1641/0006-3568(2003)053[0131:MCIGCI]2.0.CO;2
- McKeon, L. (n.d.). *Jackson Glacier*. Retrieved November 16, 2021, from https://www.usgs.gov/centers/norock/science/jackson-glacier?qt-science_center_objects=0#qt-science_center_objects
- *Merging glaciers for past climate simulations—OGGM tutorials*. (n.d.). Retrieved November 16, 2021, from https://oggm.org/tutorials/master/notebooks/merging_glaciers.html