# Title

Glacier Tracker

# Author

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# Importance

The magnitude of glacial ice loss is increasing exponentially as time goes on. Change is inevitable in the process of glaciation, but anthropogenic pollution has warmed the climate to an extent that is impacting glaciers heavily. Loss of ice that has been sequestered for an extended period has a variety of implications. These implications are most easily explained by the variety of feedback loops involved in this process.

First of which is related to the white ice reflecting much of the solar radiation while water readily absorbs it. This albedo feedback loop is often used in the context of sea ice loss, but it applies for glaciers as well. However, it may be most evident in tidewater glaciers. The release of this water itself also has impacts. Rapid influx of freshwater can disrupt the thermohaline circulation that fuels ocean currents. This oceanic feedback loop is caused by the rapid density changes when the top layer of water gets diluted (NOAA, 2023; NASA, n.d.). Finally, thermal expansion is often cited as increasing overall volume of the oceans, which in turn increases sea levels as water is less dense than ice. These are some of the most frequently discussed feedback loops related to ice loss.

These impacts to ice are not purely theoretical. Data published to the *Journal of Glaciology* attempts to measure the rate of erosion in Glacier Marinelli in at the southern end of Chile. The researchers employed the NCEP-NCAR reanalysis to establish an estimated ice velocity at the terminus over time. It appears they establish a correlation between ice velocity rate and ice retreat rate (Koppes & Anderson, 2009). Their research clearly demonstrates the gravity of glacial ice loss and how it is an issue that can rapidly increase in magnitude. A different study published in *Earth-Science Reviews* focuses on the Greenland Ice Sheet (GrIS) and reports a variety of models on how the sheet may melt and at what rate. The researchers suggest that meltwater from the GrIS could become a bigger driver on sea level rise than thermal expansion itself. A drastic model even depicts the disappearance of the GrIS within three thousand years (Vasskog et al., 2015). While this study focuses on sea ice rather than glaciers, the principle of sea level impacts still applies.

The variety of tumultuous effects caused by sea level rise have been well established, so these studies imply a grim future for humans on Earth. This is why my research and its takeaways are important. My Web App visually conveys similar sentiments to the research on the GrIS and on Glacier Marinelli. We need to make data on the magnitude of glacial retreat publicly accessible to anyone and everyone so that we can establish a societal state of emergency.

# Methodology

I. Landsat 5 (Left Map) & Landsat 8 (Right Map)
    a. Both Landsat datasets are used in the same manner, described below.
    b. First, we visualize the imagery as a true color.
    c. Next, we perform band arithmetic on the red and green bands to calculate the Normalized Difference Glacier Index (NDGI) for both individually.
    d. The NDGI layer is overlayed on the True Color layer at a default opacity of 0.5.

e. These visualizations update dynamically as the user modifies the UI elements (bottom-left and bottom-right). For example, if we change Cloud Cover these steps will occur again.

II. Sentinel-2 (GIF only)
   a. Sentinel-2 Imagery is only needed for GIF creation. It provides higher quality imagery making it better suited for dynamic GIF creation.
   b. Like Landsat filtering, Sentinel-2 filtering is performed according to the values set in the UI (top-left).
   c. When the user clicks a location, a Sentinel-2 Image Collection is created based on the user-specified filtering parameters.
   d. The GIF is created from the Image Collection that was returned.

## Code Links

Code Snapshot: https://code.earthengine.google.com/7caabec7c1295541b662c4841b8672c9

GEE App: https://wtfineberg.users.earthengine.app/view/glaciers

## Results

The results of this project are clear and they align with the hypothesis I held: glacial ice loss is rapidly accelerating. While this project does not establish a quantifiable correlation between glacial ice loss and the warming climate, it does utilize remote sensing techniques to support this sentiment. Figures 1 and 2 below each show how my Glacier Tracker reveals the true magnitude of glacial retreat to the users of the Web App.

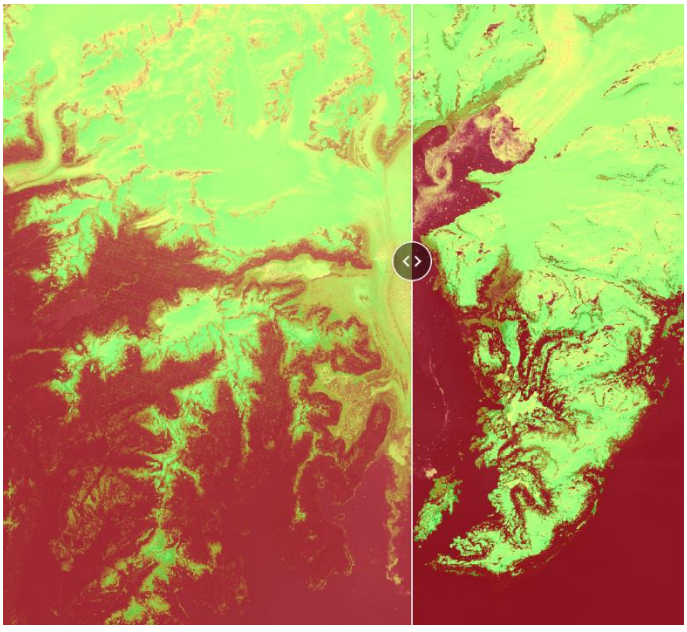

*Figure 1 – Split Map of Columbia Glacier NDGI from 1980s (left) to 2020s (right)*

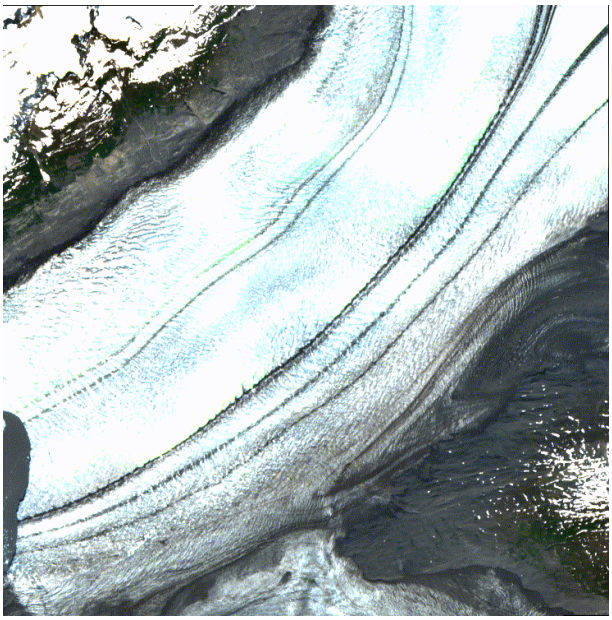

*Figure 2 - Sentinel-2 GIF of Columbia Glacier from 2015 to 2022 (Figure is animated, please see the GIF in Google Drive)*

Figure 1 above is a prime example of the results of this project. The Columbia Glacier rapidly retreated after it departed the terminus. This readily demonstrates how the warming planet contributes to glacial instability which, in turn, accelerates further ice loss and destabilization. As the user moves the slider, they can see how the terminus has retreated many miles back. It conceptualizes the magnitude of this issue by visualizing it in a quantifiable way.

I see this tool as comparable to watching videos of calving events, except it has the added benefit of some quantifiability. The user can measure ice differences over time with an accurate map scale. The downfall of passive sensing is that we cannot derive any information about what is below the surface ice, such as thickness or density. Even though we can only see surface differences, the results are still clear. Tidewater glaciers like Columbia Glacier tend to display these surface area changes readily, while glaciers with different topology might not loose surface area as quickly. These glaciers may be a good use case for active sensing methods.

Figure 2 is another example of how my project aims to establish concern for glacial ice loss and climate change. This GIF was created using Sentinel-2 Imagery of Columbia Glacier between 2015 and 2022 and only using images from June to September. To view the animation of Figure 2, please see the GIF in Google Drive. We already used the Landsat slider to see the differences over 30 years, but now we can use Sentinel-2 to reinforce the idea that these changes are not just historical. These changes are occurring constantly, and I feel using imagery that only dates to 2015 shows that massive changes are truly occurring constantly. Every year there is an obvious difference from the last. It forces the viewer to realize that glaciers are constantly changing, and anthropogenic impacts are accelerating this change to an unprecedented rate.

## Significance

The implications of my findings span far and wide. We established the slew of impacts that can arise from loss of sea ice. Massive and rapid release of water that has long been sequestered disrupts the ocean and marine life. Humans rely on our oceans for our well-being in many ways. If the sea becomes disrupted in any way, we are bound to feel those effects. The most direct of which might be in our food sources. Fish is a major food source globally, but dwindling marine life means the fisheries providing these fish dwindle as well. This also has massive economic impacts as there are many places where fishing is the primary economic source.

It might be easy to say that we can find food elsewhere, but this neglects the onslaught of other negatives that come from a disrupted ocean ecosystem. We have established that glacial instability exponentially accelerates glacial retreat. As glacial ice loss increases exponentially, the release of sequestered water into oceans also increases exponentially. We can now infer that increases in sea level will occur exponentially as well. Sea level increases are already poised to wipe out some island nations entirely within a single lifetime. It will also harm continental land masses with flooding and increased erosion. Sea level rise will also disrupt weather patterns and likely lead to the increased frequency of severe weather events. Furthermore, the thermohaline disruptions will alter the ocean currents we rely upon for global trade.

In essence, glacial ice loss is clearly an issue that poses great danger. While most people are aware of this issue and its connection to climate change, I suspect that most people do not conceptualize the magnitude. The goal is that my Glacier Tracker research will impact the viewer's perception of the importance of glacial ice loss and, more generally, climate change.

## Citations

Koppes, Hallet, B., & Anderson, J. (2009). Synchronous acceleration of ice loss and glacial erosion, Glaciar Marinelli, Chilean Tierra del Fuego. *Journal of Glaciology*, *55*(190), 207–220. https://doi.org/10.3189/002214309788608796

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