COM-480 DATA VISUALIZATION

PROCESS BOOK

Glacier Lake Outburst Floods

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I. Introduction

Glacial lakes are bodies of water that form at the base of glaciers as a result of the melting ice. Occasionally, these lakes can experience a breach or collapse of their dams, which can occur either when they become filled to capacity or due to geological factors. This sudden release of a large amount of water downstream is known as a Glacial Lake Outburst Flood (GLOF). Predicting GLOFs is a difficult task, and they have the potential to cause extensive damage to infrastructure, communities, and ecosystems. Most importantly, they pose a significant risk to human lives.

Glaciers are highly sensitive to climate change. Alterations in temperature and precipitation patterns have substantial implications for the size, shape, and dynamics of glaciers. As global temperatures continue to rise, the rate of glacial melting surpasses the rate of snow and ice accumulation. Consequently, glaciers experience a reduction in both volume and mass, leading to a conspicuous retreat. In the context of our data visualization, we aim to observe the long-term evolution of glaciers and episodes of Glacial Lake Outburst Floods (GLOFs).

Our approach is original as the topic is niche but the consequences can be huge on populations and infrastructures. Moreover, by combining this dataset with climate change data, the GLOF events would be registered in a wider story. Even though GLOF events seem very randomly distributed, our goal is to show that this distribution is changing quickly with the rapid rate of global warming which is even more intense in glaciers (especially in the Alps).

A. Database

We use "Glacier Lake Outburst Flood Database V3.0" [1]. The source is very reputable, the creator of the dataset is Earth System Science Data (ESSD) which is an international journal which publishes articles which have used original research datasets. ESSD seems to have a high standard of data quality. The dataset is composed of various scientific experiments on glacier lake outburst floods (GLOFs) from different times and some of the data are manually mapped by the authors at ESSD (Natalie Lützow, Georg Veh, and Oliver Korup) such as the glacier lake areas before and after a GLOF has occurred. The fact that the dataset is a composition of many other datasets does however mean that there are a lot of missing values. Fortunately, the fields in the dataset we intend to use most do not have too many missing values.

The WGMs glacier data [2] has already been used around the world to make analyses and predictions about glacier evolution, especially about climate change. The GLOFs' data of the University of Potsdam are mainly a compilation of numerous datasets from historical archives or other available data. These data make it possible to visualise the different GLOFs episodes recorded spatially and temporally. These data make it possible to visualise spatially and temporally the different leakage episodes recorded and analyse the bias existing because of the increasing data recorded.

And finally, we added global temperature rise [3] and atmospheric carbon dioxide [4] data to add a climate change section

B. EDA

We've explored our main database so that we can extract information from it to better define our objectives and visualisations.

Firstly, there was a huge amount of missing data, which complicated the process and required us to add other datasets afterwards.

Next, we were able to observe the temporal distribution of GLOFs (Figure 1). The data is very spread out, starting in the 13th century. But as the resulting graph illustrates, most of the events recorded are from the 19th century and beyond. From this point onwards we have chosen to ignore earlier events.

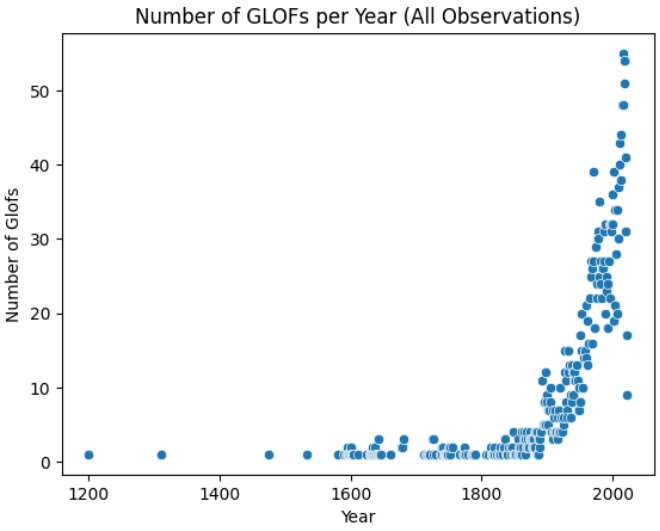

Fig. 1. Distribution of recorded GLOFs over time

Finally, one other important observation from our statistical analysis is the geographical distribution of GLOFs (Figure 2).

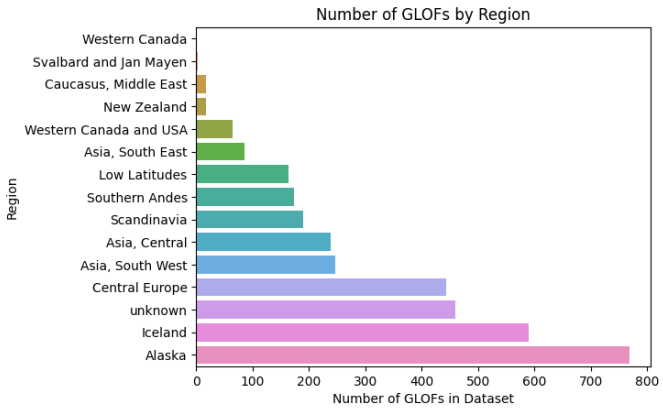

Fig. 2. Geographical distribution of recorded GLOFs

II. Visualization

A. Tools and inspirations

Our main source of inspiration for this project came from the lectures we attended throughout this semester. These lectures provided us with valuable knowledge and insights that helped shape our ideas and approach.

In addition to the lectures, we also drew inspiration from an interactive visualization of traffic in Oslo [5]. This visualization provided us with a unique perspective on traffic patterns and helped us envision how we could create engaging visualizations for our own project. Furthermore, we explored various maps available on a website [6]. These maps served as references and sources of inspiration for designing and implementing map-related features in our project.

To bring our visualizations to life, we used HTML, CSS, and JavaScript. These three technologies are fundamental building blocks for web development and will enable us to create interactive and dynamic elements for our project. Specifically, we utilised the three.js library for handling the 3D aspects of our visualizations, such as rendering objects and managing camera movements. Additionally, we will leverage the power of d3.js, another JavaScript library, to handle data manipulation and create insightful visual representations.

In terms of the website itself, we started with a free template provided by StyleShout. This template served as a foundation for our design but required significant modifications to align with our project's specific requirements and visual style.

In addition to the lectures that covered HTML, CSS, JavaScript, and d3.js, there are other specific lectures useful for our project. These include the lecture on maps, where we learned techniques and best practices for incorporating maps into our visualizations effectively. We also looked forward to the Do's & Don'ts lectures, which provide valuable insights on design principles and user experience considerations, helping us create a user-friendly and engaging website.

B. Selected statistics

We have selected a few specific statistics to highlight the significance of GLOFs on population and emphasize their classification as natural catastrophes comparable to earthquakes or typhoons. From our main dataset, we have extracted the most relevant statistics that effectively illustrate these points. However, we would have appreciated more in-depth reporting on the damage caused by those episodes. The last two statistics show that these climatic events are occurring with an increasing frequency.

C. Severity of GLOFs by Location through Time

For our first visualization, we aimed to create a 3D map showcasing the occurrence of GLOFs over time, providing users with a slider to navigate through different time periods. The slider will display relevant information about the CO2 atmospheric concentration and the average temperature increase since pre-industrial times.

In this visualization, GLOFs will be represented as localized tall cuboids that appear on the map. As time progresses, these cuboids will decrease in size while their bases expand, transitioning from a concentrated event at t=0 to a more widespread event at t=20y. The primary focus of the map will be on the Alps region, aiming to illustrate the geographical locations and timings of GLOFs, as well as explore any potential connections to climate change. A visual sketch of this proposed visualization can be found in this illustration 3. An inspiring project can be found in this repository. They analyse traffic data in Oslo [5], we aim to do something similar but for glacier lake outburst floods and with a toggle bar as mentioned above so that the user can move forwards and backwards in time.

For our final design, we have a 2D map, showing where GLOFs have been occured over time. Each GLOF event is represented by a bubble on the map, with the size and color of the bubble indicating the magnitude of the event. To determine the magnitude of a GLOF event, we calculate it as the ratio of the area of the glacial lake before the outburst divided by the area of the lake after the outburst. This calculation provides a relative measure of the magnitude, which is then used to determine the size and color of the corresponding bubble on the map. Larger bubbles represent GLOFs with greater magnitude, while smaller bubbles indicate

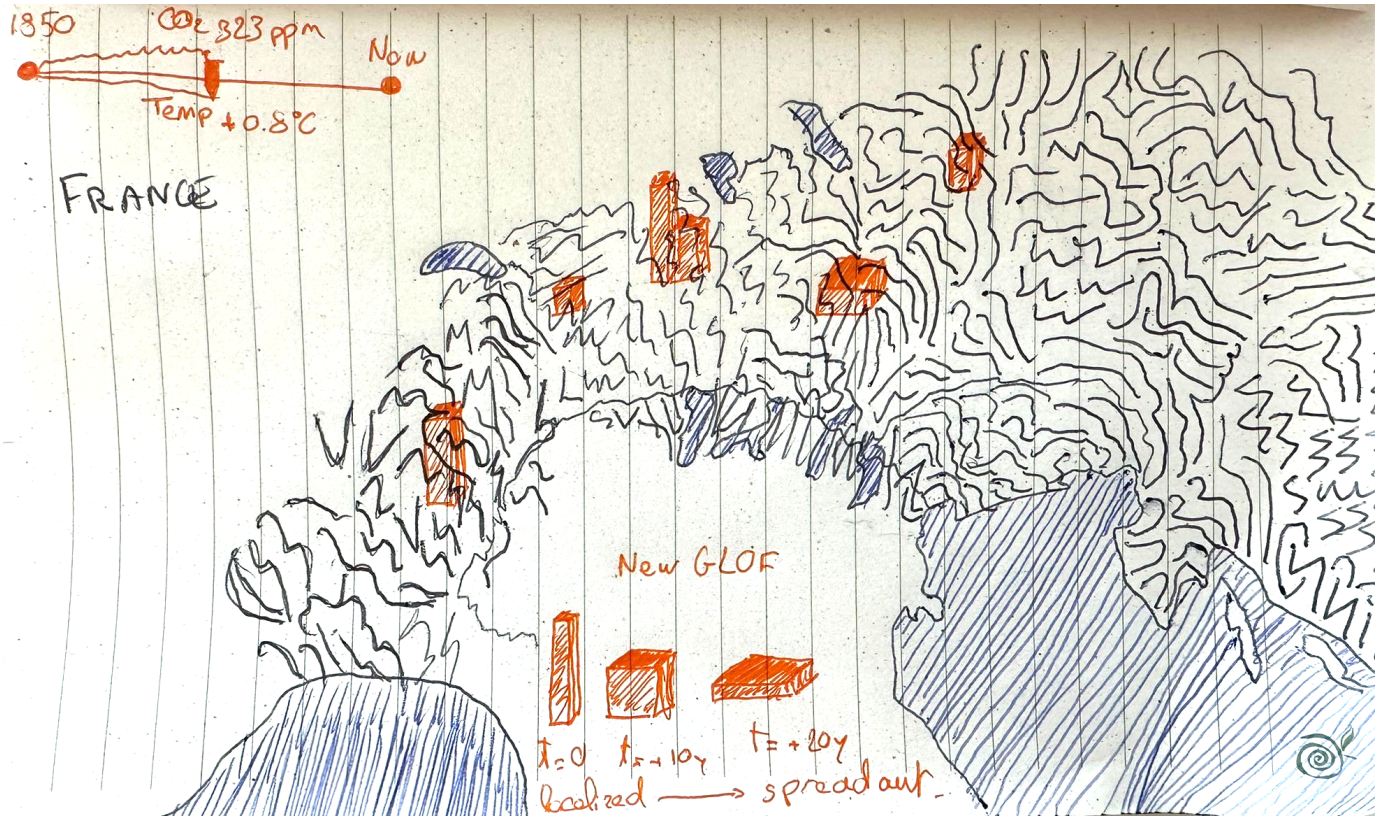

Fig. 3. Idea of Alpes visualisation

events with lower magnitude. By visualizing the GLOFs on this 2D map 4, users can easily identify the locations of GLOFs and gain insights into the relative severity of each event.

We have decided to abandon the initial idea of creating a 3D visualization for this one since we have already planned to utilize a 3D approach for the next visualization. Initially, we considered focusing on the Alps. However, due to a significant amount of missing data, we determined that this limitation would compromise the completeness and accuracy of this visualization. As a result, we have opted to expand the map to include a wider geographic area Additionally, we have chosen to separate the section on climate change.

D. Interactive Globe

As our initial visualisation was to focus exclusively on the Alps, we also wanted to get an overview of the global distribution of GLOFs in the rest of the world. To achieve this, we have decided to incorporate a visualization that resembles the ones found on this website [7]. By utilizing a 3D globe visualization, we aim to provide users with a comprehensive understanding of the geographic spread of GLOFs across the world. Users will have the ability to interact with the globe, zooming in and out, rotating, and exploring different regions to gain insights into the distribution patterns and prevalence of GLOFs globally.

We obtain a quite good representation of GLOF occurrences using peaks on a 3D globe.

The height of each peak accurately represents the cumulative number of recorded GLOF events in a country until a given year, while the color of the peaks corresponds to the continent they are associated with (Figure 5).

E. CO_2 and global warming

For the data about climate change, we thought that it would be appropriate to add it either to one of the previous visualizations or separately. We chose to implement it separately to ensure clarity and enhance understanding. We were thinking of adding data on atmospheric CO_2 concentrations [ppm] and data on the rise in global average temperatures.

Unfortunately, we didn't have the time to implement it fully. However, the files are in the git along with the others.

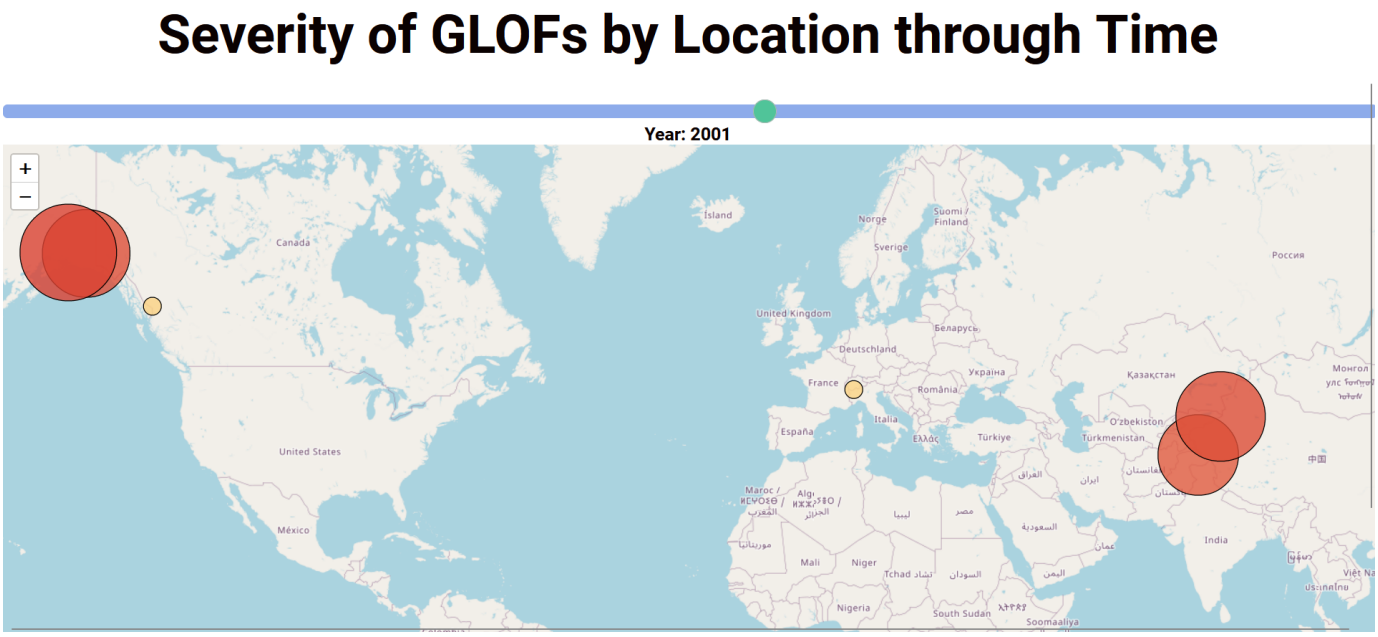

Fig. 4. Severity of GLOFs

Use the interactive map to see how the severity of GLOFs differ across the globe and through time

Fig. 5. Globe overview

Spin this interactive globe to get an overview of where in the world GLOFs occurs

III. Peer Assessment

- find interesting datasets : All
- literature search : Eva
- Problematic for Milestone 1 : Eva
- EDA for Milestone 1 : Axel
- Related work for Milestone 1 : Eva and Antoine
- Find skeleton for visualization : Axel
- Find tools and ideas : All
- Drawing of Alps visualization (Figure 3) : Antoine
- First and second final visualization : Axel
- Third visualization : Eva
- Screencast : Antoine
- Process Book : Eva

References

[1] N. Lützow and G. Veh, "Glacier Lake Outburst Flood Database V3.0," Nov. 2022. [Online]. Available: https://zenodo.org/record/7330345

[2] "database versions – world glacier monitoring service." [Online]. Available: https://wgms.ch/data_databaseversions/

[3] "Annual Surface Temperature Change." [Online]. Available: https://climatedata.imf.org/datasets/4063314923d74187be9596f10d034914_0/about

[4] N. US Department of Commerce, "Global Monitoring Laboratory - Carbon Cycle Greenhouse Gases." [Online]. Available: https://gml.noaa.gov/ccgg/trends/

[5] "3d-visning av statistikk." [Online]. Available: https://github.com/GeoForum/veiledning09

[6] "Global Data Lab - Innovative Instruments for Turning Data into Knowledge." [Online]. Available: https://globaldatalab.org/

[7] "Webgl globe." [Online]. Available: https://experiments.withgoogle.com/chrome/globe