Exploration of Global Temperature Trends

A creative data visualization project demonstrating the rise of global temperatures and related trends

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Creative Data Visualization

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1 Introduction

I want to begin this report by highlighting an important insight I gained during this course: almost anything can be represented as data. By collecting and visualizing data, even from everyday situations, we can often gain new insights and see things from a completely different perspective. A simple example is the act of waking up in the morning. Each day, you might wake up at a certain time, feel more or less tired, face a particular direction, and perhaps have one leg out from under the blanket. If you chose to, you could start observing and recording these details in a table. Here's a basic example of what that might look like:

Date	Wakeup Time	Tiredness	Facing	Leg Out
10.01.2025	08:15	0.5	Left	Yes
11.01.2025	06.45	0.9	Up	Yes
12.01.2025	12:15	0.3	Right	No
...				

Table 1: *Example illustrating the act of waking up represented as data*

This small dataset may seem trivial, but it illustrates a broader point: what makes data visualization so powerful is not always just the data itself, but the many creative ways it can be presented. Depending on the audience, that same dataset shown above could be visualized as a poster with multiple charts, an interactive webpage, or countless other formats. If I were to reflect on what I believe is the greatest strength of data visualization, it would be its ability to present information as simple and trivial as shown above, in a way that invites curiosity and encourages deeper exploration.

This inspiration has been the drive behind my project, where I have tried to use the power of visualization to trigger the audiences curiosity around the data visualized.

2 Project Scope

The overall scope of this project, based on the design brief, is to use data visualization to help explain, express, or explore scientific data related to nature, climate, and the environment. The aim is not just to communicate information, but to do so in a way that highlights the beauty and importance of the data. Scientists gather vast amounts of data to better understand the natural world, but much of this work remains hidden or difficult for the public to grasp. Through thoughtful visualizations, this project seeks to make that data more accessible and engaging.

2.1 Framing The Project

With this purpose in mind, choosing a topic became the first step. I spent a lot of time searching online and exploring different directions. At first, I considered *Topic 1: Invisible Nature*, with an idea about how trees might communicate. However, I struggled to find usable data and define a clear angle. I also explored the behavior of ants and related research on their invisible pheromone trails, but once again, a lack of data I personally could wrap my head around, made it hard to move forward. Eventually, I shifted focus to *Topic 2: Climate Tipping Points.* As I researched, I quickly realized that this topic encouraged me and spiked my curiosity. After some internet searches and looking through some existing work on this topic, I saw that rising global temperatures was strongly connected to climate change, which led me to dig deeper into that subject.

2.2 Climate Tipping Points

I think for most people its clear that global temperatures have been rising, but in recent years the increase has been much faster (NASA, n.d.). It makes sense that a change like this would affect the entire planet. There's a lot of data available on global temperature and its effects, but it can be hard to understand when it's just in tables and numbers. It is also difficult to see the bigger picture and understanding what it actually means that the global temperature is rising. What does it really mean if the global temperature is 1.47°C warmer in 2024 than in the late 19th-century (NASA, n.d.)?

These questions and reflections made me want to focus my project on the rise in global temperatures and the trends surrounding it, aiming to use the power of visualization to convey the data in a more meaningful way.

2.3 Audience and Goal

While exploring the topic, I became aware of how difficult it can be to fully understand the impact of rising global temperatures. I realized that if I found it confusing at first, many others probably do too. That insight shaped both the audience and the goal of my project. I chose to focus on people like myself in that early stage of learning, those who are curious about climate change and want to see the bigger picture. The goal was to create an interactive webpage with visualizations built using *d3.js*, designed to help users not only learn something from the data but also explore it in their own terms.

3 Design Process

My overall design process began with a sequence of brainstorming, prototyping and exploration of the topics. The figure below illustrates how i organized ideas and sketches using *Figma*.

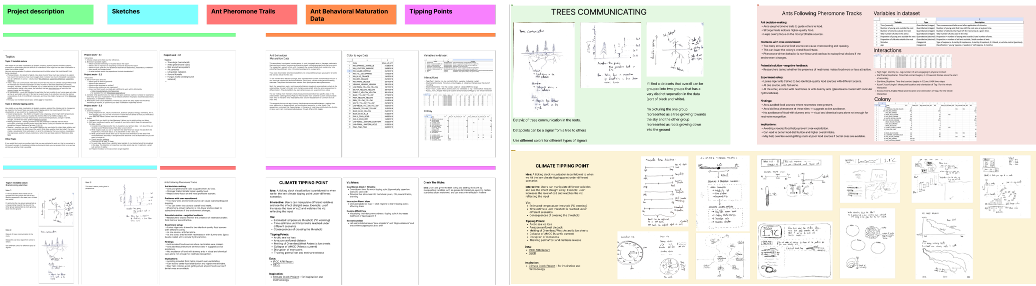

Figure 1: *Overview of activities in Figma*

After choosing my topic and shaping the direction of the project, I started working through several iterations. I moved beyond just brainstorming and sketching ideas, and began using *d3.js* to start experimenting with the real data. In this report, I will highlight two of those iterations: the first one, which I called *"Crash The Globe"*, that eventually led me to *"Exploration of Global Temperature Trends"*, which is the final concept I ended up developing for this project.

3.1 Iteration 1: Crash The Globe

The idea behind this concept was to give users the task of trying to manipulate the climate on earth by tweaking variables such as the global temperature and applying certain scenarios (e.g., arctic meltdown), and then watch the effects unfold in different types of visualizations created with *d3.js*. It was all about creating a fully interactive web page really inviting users to play around with toggles, sliders and other metrics and by doing so, see the effects. I started exploring how I could create a dataset allowing me to achieve this.

3.1.1 Data

In the process of trying to find a way of representing scenarios and the effects on the world as a form of data I stumbled over a term called *Shared Socioeconomic Pathways (SSP)*, which are scenarios used by climate scientists to model and analyze possible future developments in greenhouse gas emissions, climate change impacts, and societal responses (IPCC, 2021).

I started by creating a table consisting of these scenarios as shown in the table below:

Scenario	Description
SSP1	A world making good progress toward sustainability, reduced inequality, and low challenges to mitigation and adaptation.
SSP2	Continuation of historical trends, moderate population growth and emissions.
SSP3	Fragmented world, high population growth, and high challenges to both mitigation and adaptation.
SSP4	High inequality within and across countries, with vulnerable regions struggling to adapt.
SSP5	Rapid economic growth driven by fossil fuels, leading to high emissions and challenges for mitigation.

Table 2: *SSP Scenarios explained*

3.1.2 Prototyping

Looking at the description of the scenarios I saw a couple of metrics I could implement in my web page, like population growth, emissions, level of inequality and so on. The idea then was that based on how users manipulate these metrics it would reflect a certain SSP level, and based on the level I could visualize related impacts each SSP level probably would have on the world.

3.1.3 Low Fidelity Prototypes

I started out sketching some low fidelity prototypes of how I might could achieve this effect in the web page. At this point I had no idea of how to map the different metrics to a certain SSP level and I had no clear plan on how to visualize the effects this would have on the earth. It was all about playing around with the idea, and how I might could create a visualization of it. Below is a figure illustrating a couple of these low fidelity prototypes:

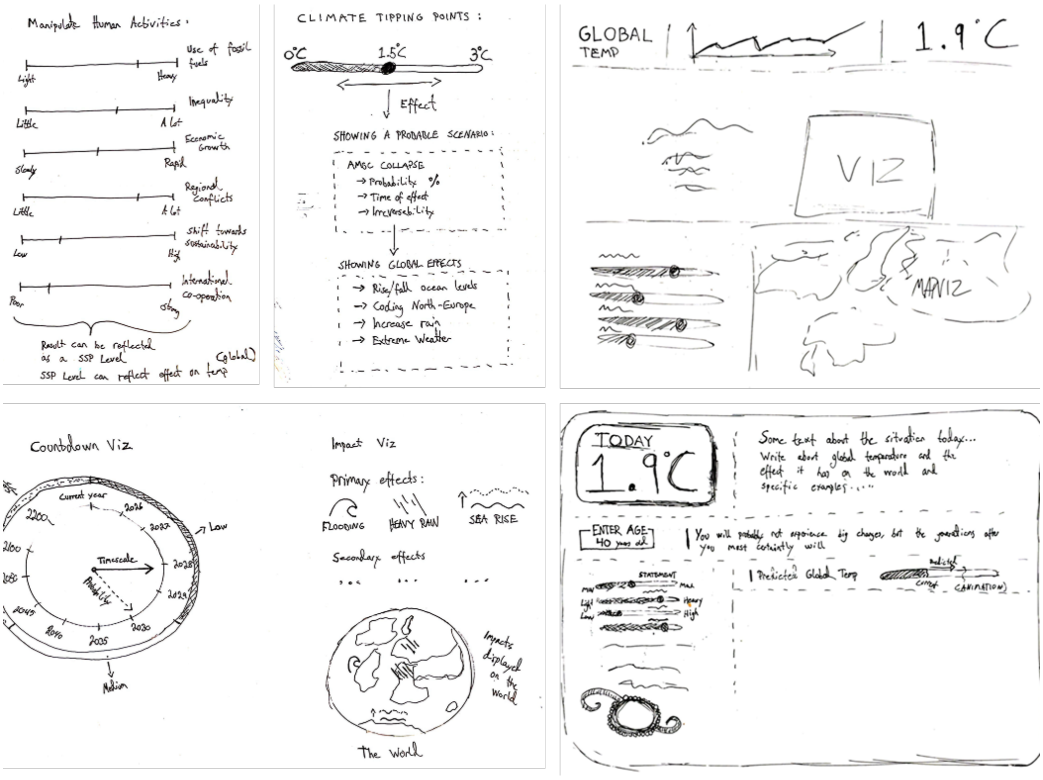

Figure 2: *Illstration of low fidelity sketches*

3.1.4 High Fidelity Prototype

Even though I hadn't fully figured out all the details of the data or exactly how to create the effect I had in mind, I started building a more refined prototype. I created a web page using *d3.js*. The figure below demonstrates how this web page turned out:

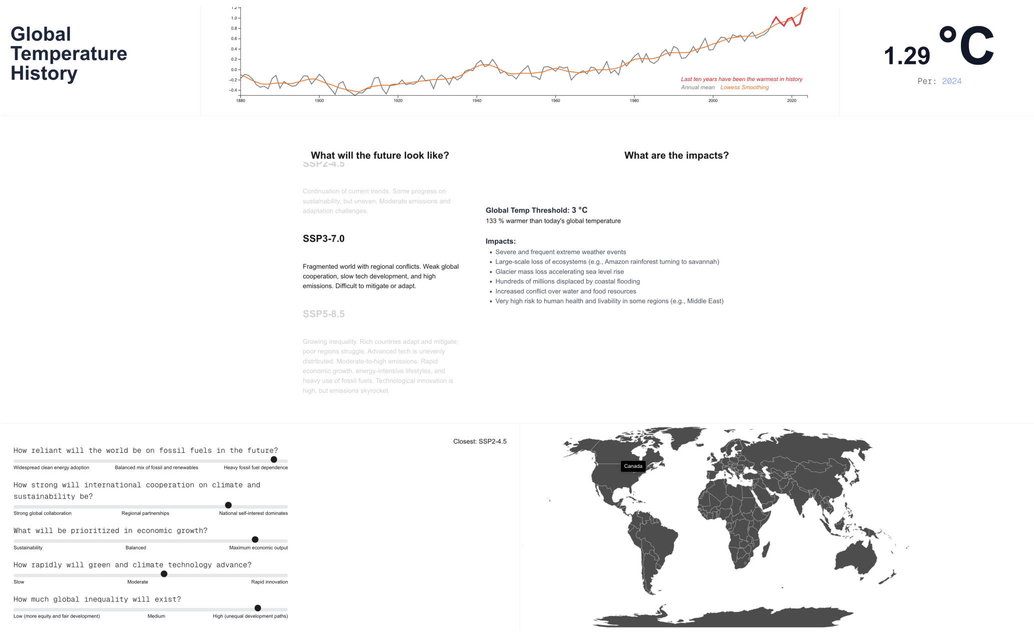

Figure 3: *High Fidelity Prototype: Page setup*

The page consisted of a header with a basic line chart showing the history of global temperature and the most recent recorded value. Below that, a section explained the different climate scenarios, and at the bottom, users were invited to interact with the data through adjustable sliders. While the design showed somewhat promise, it still needed refinement and functionality.

This led me to reflect more critically on the concept and evaluate how well it aligned with the overall scope of the project.

3.1.5 Rethinking My Project

I developed this idea quite far. Although I didn't implement full functionality for the sliders or the world map visualizations, this phase, like my earlier low-fidelity prototypes, was focused on exploring and testing ideas. Through working on this concept, I realized it wasn't helping me achieve the main goal of the project. I wanted to give the audience insight into the rise of global temperatures and related trends, but this idea got too caught up in these different specific scenarios, and the broader message wasn't coming through clearly.

Even though this concept didn't move forward, it sparked a new direction that led to the final prototype of this project.

3.2 Iteration 2: Exploration of Global Temperature Trends

Reflecting on the previous iteration helped me better understand what I actually wanted to achieve with this project. One major challenge was that I had very little concrete data to work with, aside from a dataset showing the history of global temperatures over time. This limited my ability to build and experiment with *d3.js*. To move forward, I went back to exploring the topic and came across a webpage called *Our World In Data* that offered a wide range of high-quality datasets related to climate change (Ritchie et al., 2024). While going through the data, I started noticing patterns across different datasets. For example, there were clear links between ice sheet mass loss in Antarctica and Greenland, and rising sea levels. This sparked a new idea: what if I could present several of these datasets in a way that helps users clearly see how different climate trends are connected?

3.2.1 Data

I began by working with a dataset on global temperature anomalies. After finishing the first visualization using *d3.js*, I had a solid codebase to reuse, which made it much easier to create new visualizations with other datasets. With each new visualization, I also improved my skills in both handling data and creating visualizations. I ended up using a total of five different datasets from *Our World In Data*:

1. Global temperature anomalies by month
2. Global warming: Contributions to the change in global mean surface temperature
3. Carbon dioxide concentrations in the atmosphere
4. Ice sheet mass balance
5. Sea level rise

After cleaning up the data I ended up with the following table structures:

month	year	anomaly
april	1940	-0.6047783
april	1941	-0.806757
⋮	⋮	⋮
september	2024	0.7279062

Table 3: *Global Temperature Anomalies*

country	code	year	value
Afghanistan	AFG	1940	0.15562129
Afghanistan	AFG	1941	0.15542437
⋮	⋮	⋮	⋮
Albania	ALB	2023	0.023767177

Table 4: *Country Contribution to Global Warming*

year	ppm
1900	294.22
⋮	⋮
2024	422.77

Table 5: *CO2 Concentration in Atmosphere*

country	year	change
Antarctica	2002	0
⋮	⋮	⋮
Greenland	2020	-4899.46

Table 6: *Ice Sheet Mass Balance*

year	sealevel
1940	-111.91
⋮	⋮
2020	61.74

Table 7: *Sea Level Rise*

3.2.2 Prototyping

The prototyping phase in this iteration was different from the previous one because I now had real data to work with. This allowed me to analyze the data and figure out which parts might be interesting to visualize. I used *d3.js* a lot during this stage, mainly to explore the data, try out different ways of structuring it, and see what formats would work best for the kinds of visualizations I had in mind.

At the same time, I sketched out different ideas for how the visualizations could look. Going back and forth between working directly with the dataset in *d3.js* and sketching helped me figure out what worked. I found that just playing around with the data often revealed interesting patterns or details I hadn't noticed before. Once I saw those, it became easier to sketch ideas that put the most interesting parts of the data in focus. The figure below shows a selection of sketches (low-fidelity prototypes) alongside some of the SVG visualizations created with *d3.js* (high-fidelity prototypes):

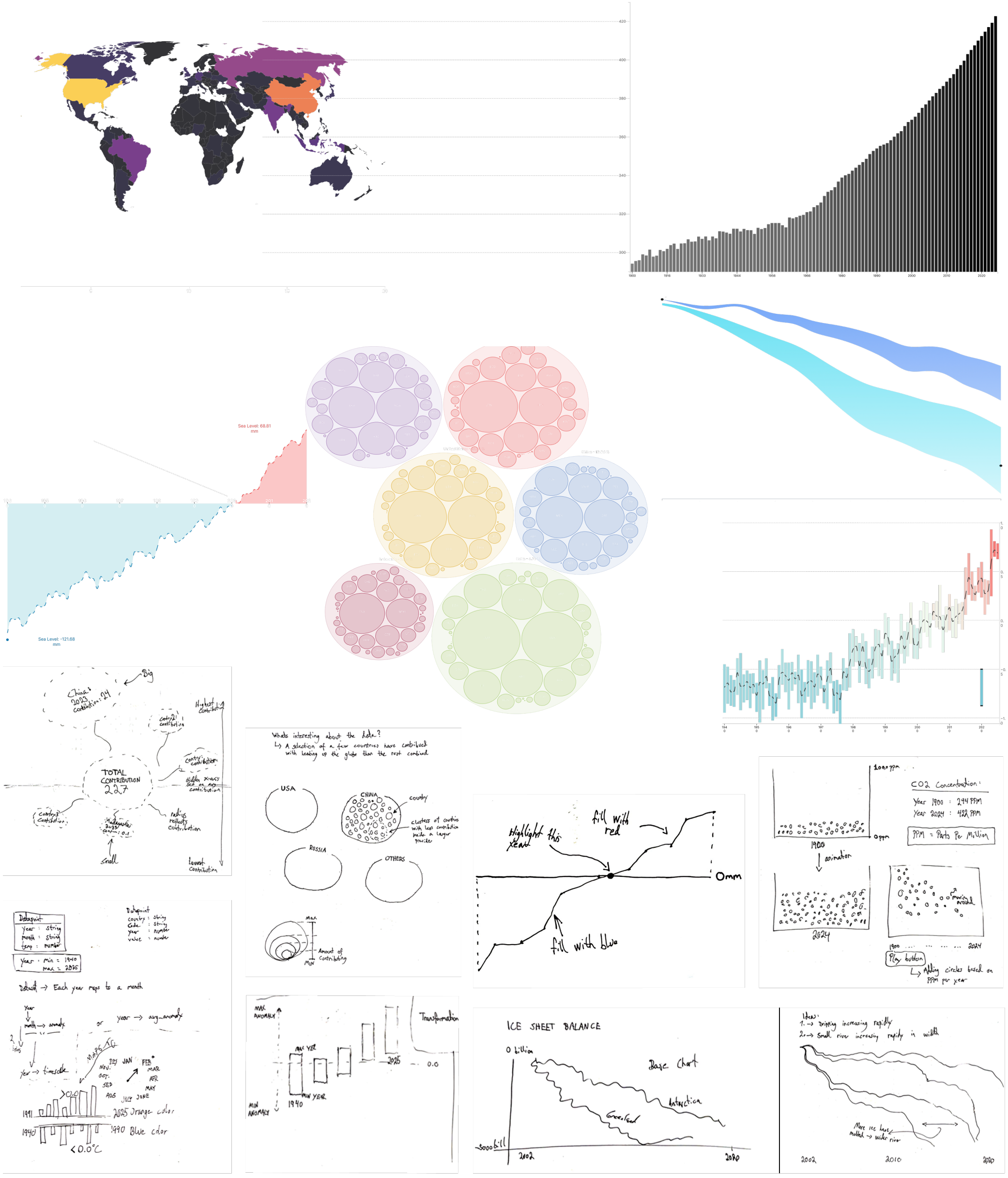

Figure 4: *Selection of sketches and SVG elements created with d3.js*

3.2.3 Global Temperature Anomalies

I started off creating a visualization based on a dataset of global temperature anomalies.[1] What stood out to me was how quickly the values shift from below 0°C to above, with some years never dropping below 0°C at all. With this in mind, I tried to sketch some ideas on how to visualize this and ended up with two ideas I liked, as shown below:

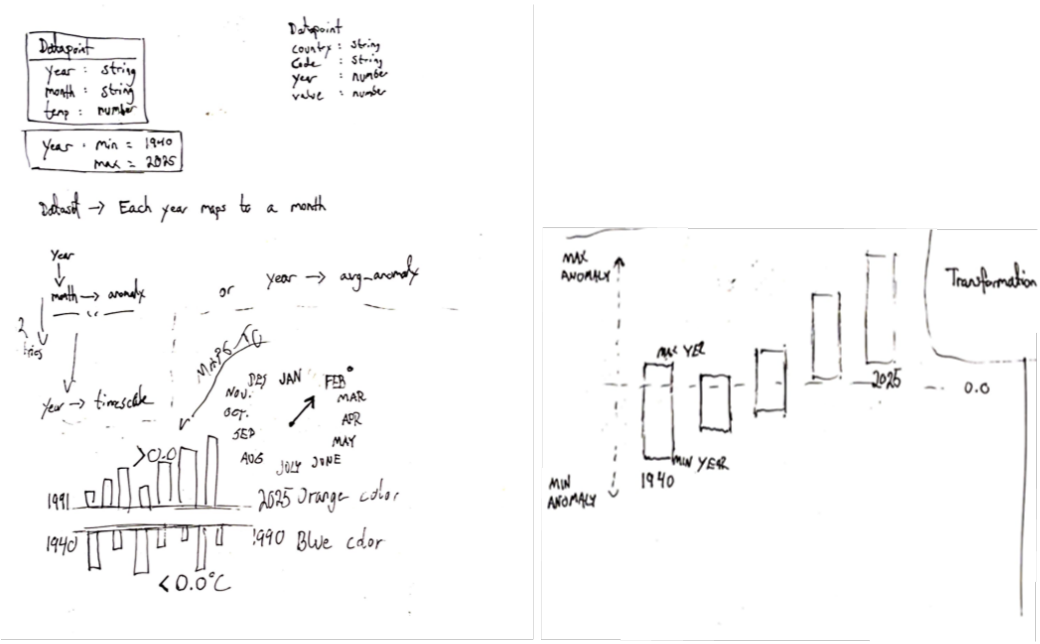

Figure 5: *Low fidelity prototype of visualizing anomalies*

I ended up moving on with the sketching on the right because I had a clear vision on exactly how to achieve it with *d3.js* and I wanted to start creating an actual visualization. I used rectangles where the height represents the range between the highest and lowest anomaly that year. I applied a color scale from blue (cold) to red (hot): blue for values below 0, white for values near 0, and red for values above 0. On top of this, I added a line chart to show the average anomaly over time. The figure below shows the final result:

[1] Anomalies are differences from the average. For example, *month: April, year: 1940, anomaly: -0.6047783* means April 1940 was about 0.6°C cooler than the average.

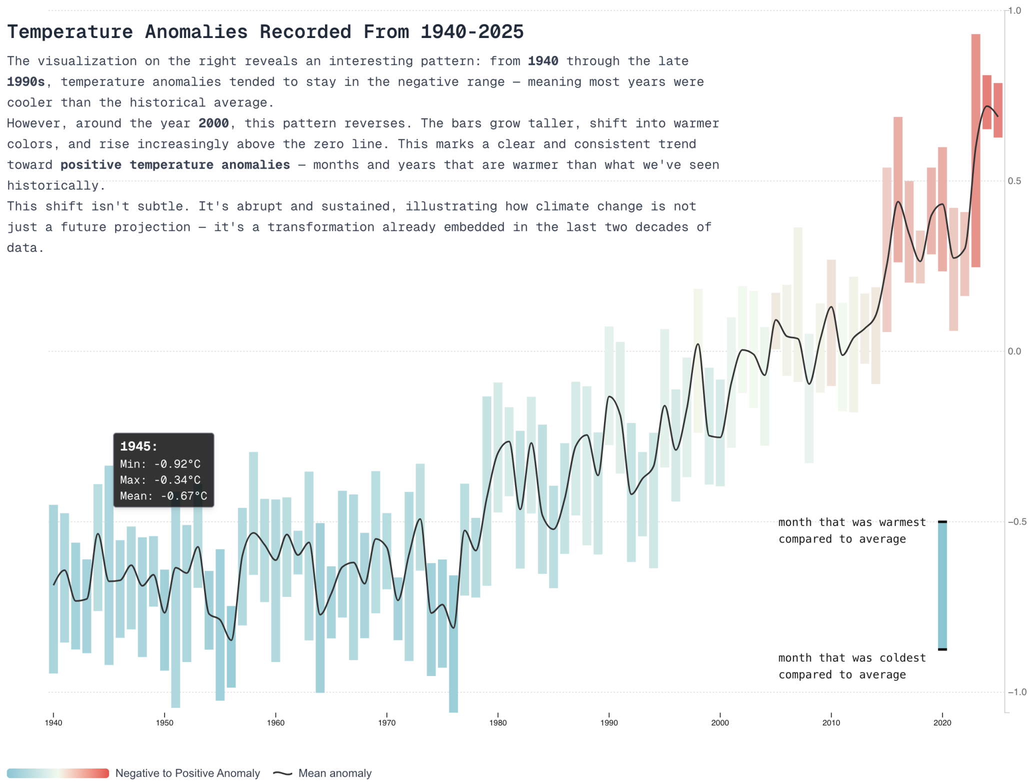

Figure 6: *Visualization of global temperature anomalies from 1940-2025*

The visualization shows one rectangle per year from 1940 to 2025. When users hover over a rectangle, a tool-tip appears with the minimum, maximum, and average temperature anomaly for that year. What stood out to me was the contrast between the minimum anomaly in 1940 (-0.95°C) and the maximum in 2023 (0.93°C), almost a full degree difference. That might not sound like much, but on a global scale, a 1°C rise in just 80 years highlights a concerning trend.

After working with the global temperature anomalies, I started wondering about human activity and how we are a big reason for this increasing trend. This gave me the idea of creating a visualization of how different countries have contributed to increasing the global temperature.

3.2.4 Country Contribution to Global Warming

I found a dataset containing information about countries and their contribution to global warming throughout the years. What I noticed was that the dataset had an id for each country that could directly be mapped to *geoJSON* country id. This would mean I easily could map the value of contribution of each country to a map visualization created with *d3.js* combined with *geoJSON*. The finished result is shown in the figure below:

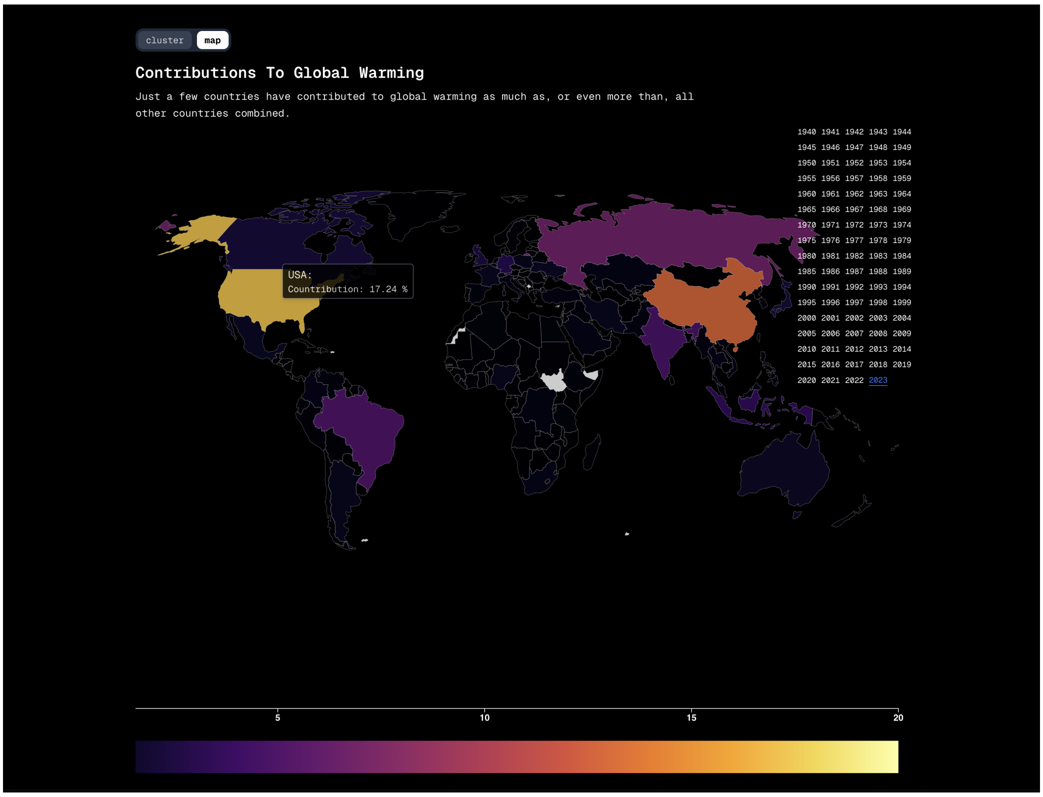

Figure 7: *Map visualization of different countries contribution to global warming in (%)*

What I wanted to show with this visualization is how just a few countries contribute much more than the others. In the figure above, you can see that most countries don't have any color. That's because their contribution is very small. I used a *d3.scaleSequential()* with a domain from 0 to 20. Since most countries have a value below 1, they fall too low on the scale to get a visible color. Only countries with higher contributions get colored, which helps highlight the ones that matter most in this context.

I used the color scale this way to make the high-contributing countries stand out clearly on the map and catch the viewer's eye right away. But if users want to learn more, they can hover over any country to see a tool-tip with its data. On the right side of the map, there's a list of years from 1940 to 2023. Users can click on a year to filter the data and see how contributions have changed over time.

While working on this map visualization, I realized that using a traditional map might not be the best way to achieve my goal. I wanted to highlight how just a few countries contribute as much or even more than all the others combined. That led me to a new idea: using shapes and sizes to represent contributions in a more direct way. I started thinking about a layout where smaller-contributing countries could be nested inside larger ones, visually showing how many of them it would take to match the impact of a single high-contributing country. I already had the dataset and was familiar with it after creating the map visualization, so all I had to do was figure out a new way of visualizing it. I started creating some sketches as shown in the figure below:

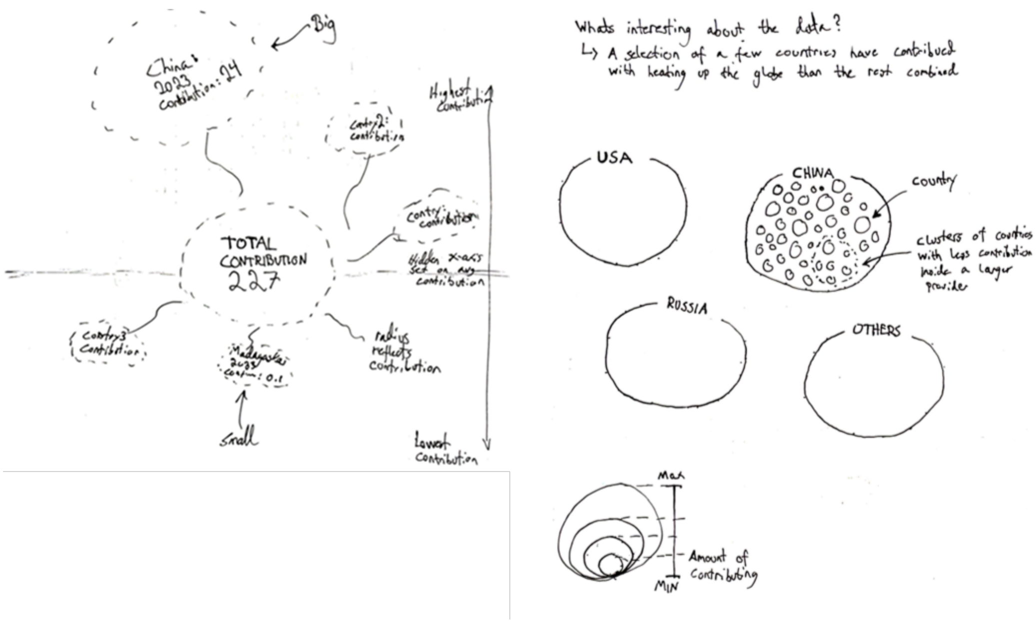

Figure 8: *Low fidelity prototype of visualizing country contribution to global warming*

After sketching, I started building the visualization using *d3.js*. Since I was working with nested components, I needed to create a new data structure. It became clear that I had to parse the data into a tree structure, where countries with higher contributions would be the root nodes, and countries with smaller contributions would be their child nodes. I did this by filtering out the countries with more than 3% contribution. This results in a list of six to eight countries (based on selected year), which I used as root nodes. The rest of the countries were evenly distributed as children among these roots.

With this structure, I was able to use *d3.hierarchy()* to create the layout. Each node was then connected to a circle, where the radius was based on the country's contribution value. The final component is shown in the figure below:

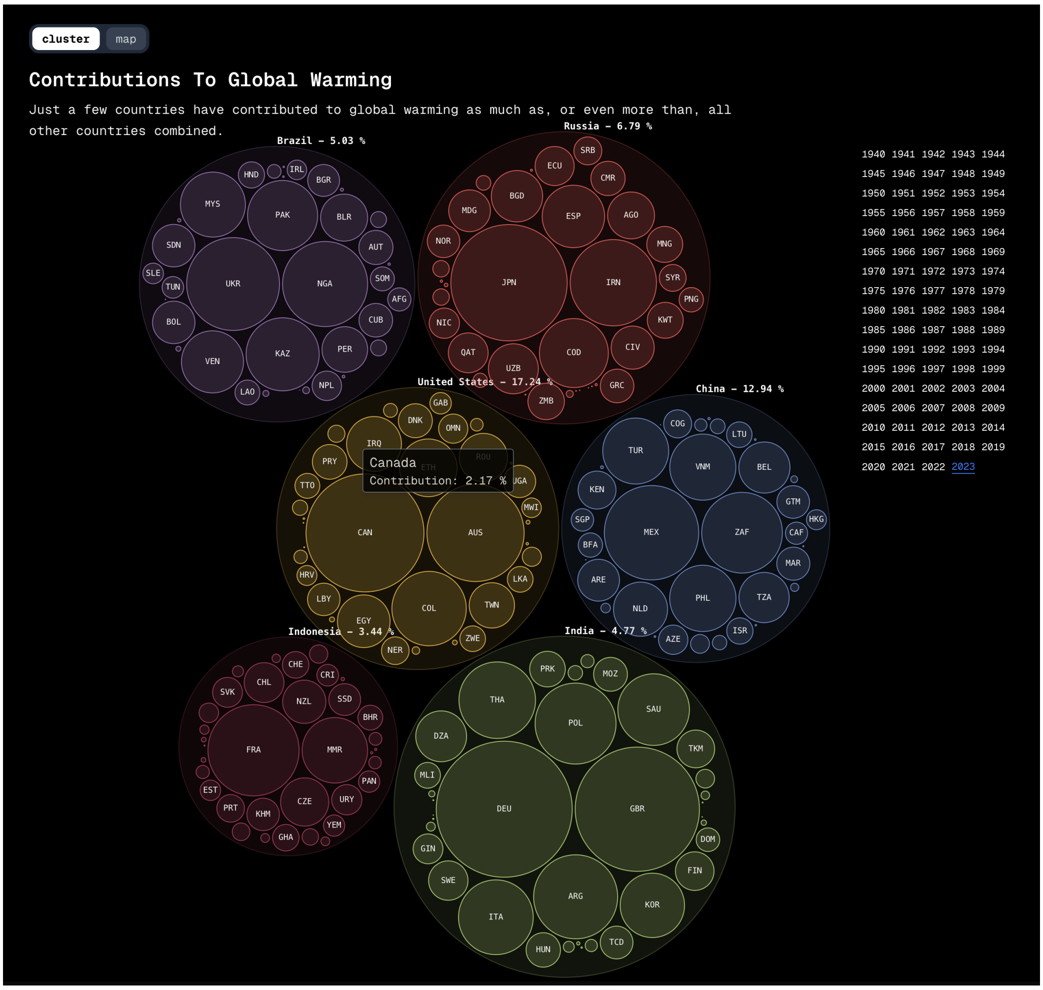

Figure 9: *Visualization of countries contribution to global warming as a nested component*

This way of visualizing the data really aims to give viewers a sense of scale, highlighting just how big the differences are in contribution between countries. The goal was to create a bit of a "wow" moment by showing how many low-contributing countries could fit inside just one high-contributing country.

After visualizing country-level contributions, it felt natural to move on to a broader view: the development of CO_2 levels in the atmosphere. Since country contributions are largely measured by how much CO_2 they release, looking at atmospheric CO_2 concentration felt like a logical next step in the order of the visualizations.

3.2.5 CO_2 Concentration in Atmosphere

When I started working with the dataset on CO_2 concentration in the atmosphere over time, I had the idea from the beginning to make a visualization with animation. I imagined gases as particles, moving, expanding, and shrinking, which inspired me to create something with many circles floating and moving around on the screen. Based on that idea, I began by sketching some simple concepts, as shown below:

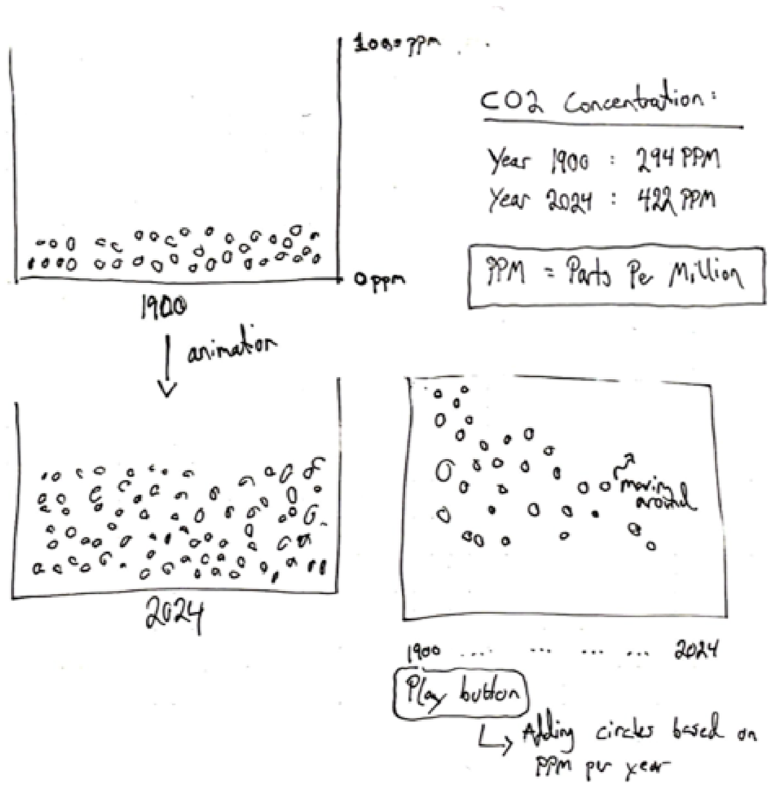

Figure 10: *Low fidelity prototype of visualizing co2 concentration in atmosphere*

The dataset was very straightforward, it included just the year and the CO_2 concentration value. So, I decided to keep the visualization simple as well. For example, if a year had a value of *320ppm*[2], I added 320 circles randomly placed within the SVG. I also added slight variations in their size and color to make the visualization feel more dynamic.

Next, I added a filter where users can select a year from the dataset, and the number of circles updates to match the CO_2 level for that year. Finally, I implemented an animation that automatically plays through the years, starting from the earliest one and slowly increasing over time. The final result is shown below:

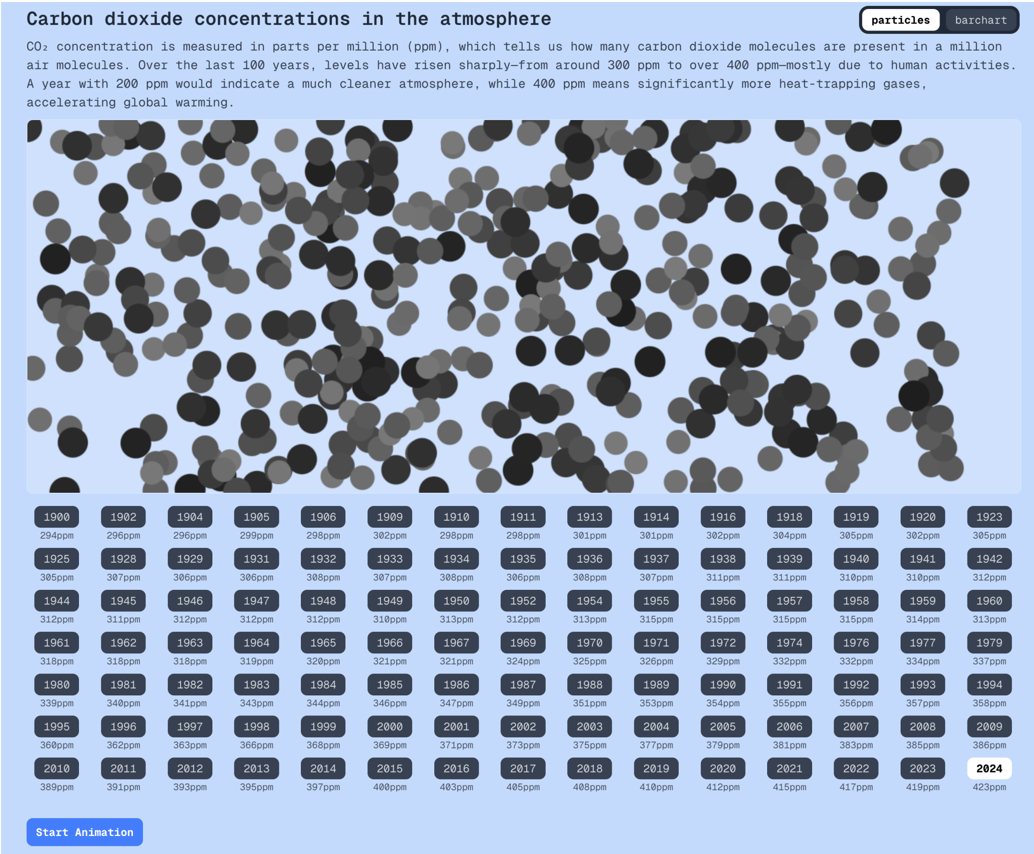

Figure 11: *Visualization of co2 concentration created using d3.js*

The idea behind this visualization was straightforward. As the years play out, more and more circles appear on the screen, making the space feel increasingly crowded. This represents how the atmosphere has become more filled with CO_2 in recent years. However, I realized that while the circle

[2] CO_2 ppm stands for "parts per million" of carbon dioxide in the air. For example, 420 ppm means that out of one million air molecules, 420 are CO_2.

animation creates a strong visual impression, it doesn't give viewers a clear sense of the actual values or make it easy to compare between years. That's why I also created a bar chart. A bar chart is much better for showing the exact increase in CO_2 levels over time and makes it easier to understand the trend at a glance. The bar chart visualization is shown in the figure below:

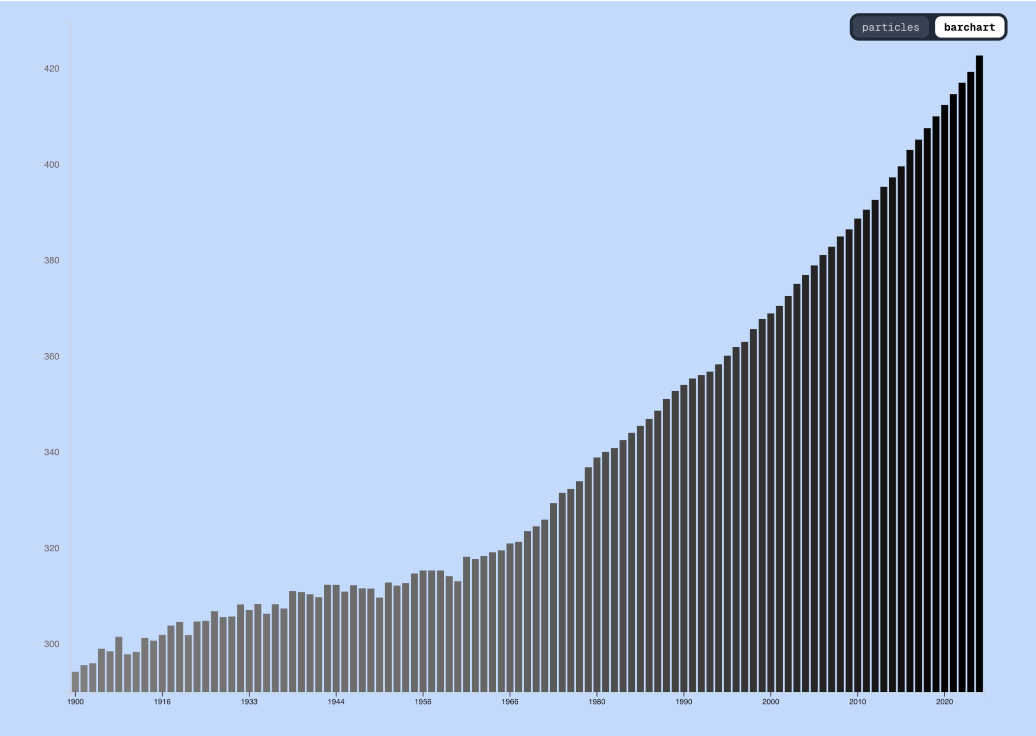

Figure 12: *Bar chart visualization of co2 concentration created with d3.js*

The bar chart itself is simple, I chose to fill the bars with a darker shade of black as the CO_2 value increases, emphasizing the buildup over time.

As I continued with the project, I returned to the topic of rising global temperatures and began thinking about the effects this has on the planet. One of the most visible and concerning consequences is the loss of Arctic sea ice. This led me to create a new visualization focusing on that issue.

3.2.6 Ice Sheet Mass Balance

I chose to work with a dataset showing the loss of Arctic ice in Greenland and Antarctica. While exploring the data, I came across a shocking fact: Greenland alone has lost over 5,000 billion tons of ice between 2002 and 2020. This really caught my attention, and I began thinking about how to visually express the scale and urgency of that loss.

I started by thinking about the process of ice melting and eventually came up with the idea of showing the loss as a river that grows wider over time, as the amount of ice loss increases, so does the width of the river. I developed this idea further and sketched out some early concepts, as shown below:

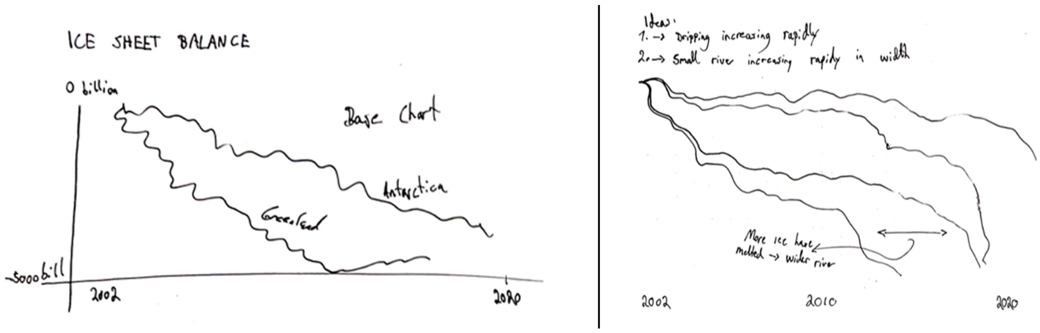

Figure 13: *Low fidelity prototype of visualizing ice sheet loss in Greenland and Antarctica*

I took inspiration from my sketches and began building the visualization using *d3.js*. At first, I created a basic line chart for each dataset, one for Greenland and one for Antarctica. My goal was to create a visual effect that looked like a river flowing from the top left corner down to the bottom right. I wanted to keep the design minimal, showing only the two "rivers" and a few explanatory annotations, without any extra or distracting elements. As I worked, I realized that using area charts instead of line charts gave me more control over the width of the rivers and helped better convey the idea of growing ice loss. To create the effect of a river expanding over time, I applied a scale, as demonstrated below:

```
const maxMagnitude =
  d3.max([...antarctica, ...greenland], (d) => Math.abs(d.mean)) ?? 1;

const riverWidthScale = d3
  .scaleLinear()
  .domain([0, maxMagnitude])
  .range([0, 1000]);

const areaBuilder = d3
  .area<RiverDataProps>()
  .x((d) => xScale(d.year))
  .y0((d) => yScale(d.mean + riverWidthScale(Math.abs(d.mean))))
  .y1((d) => yScale(d.mean - riverWidthScale(Math.abs(d.mean))))
  .curve(d3.curveBasis);
```

The result of this visualization is shown in the figure below:

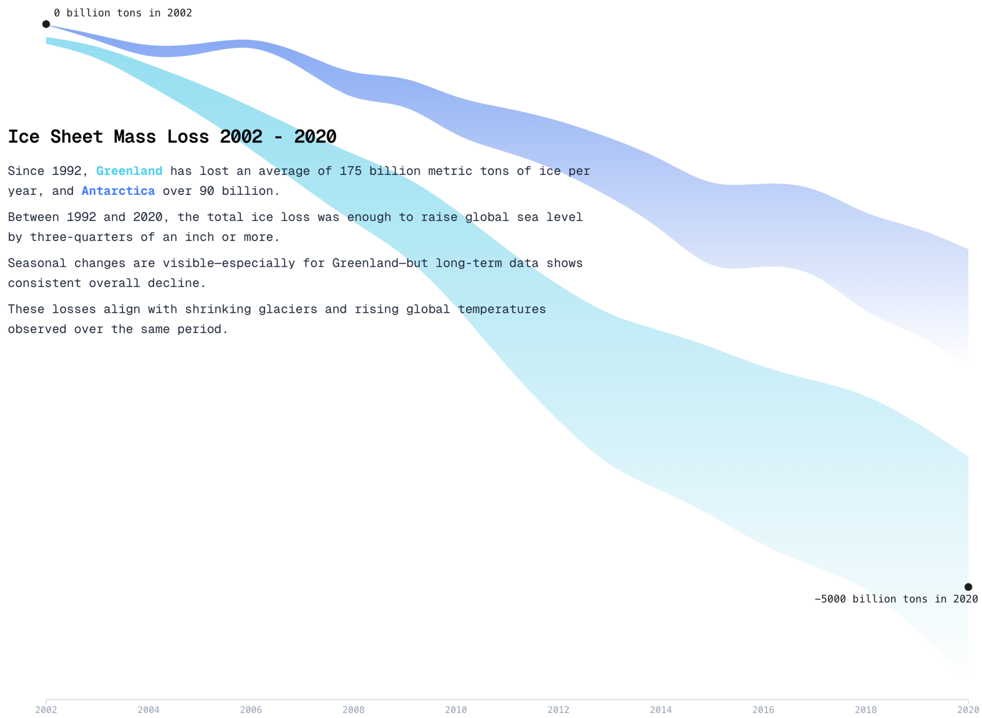

Figure 14: *Visualization of ice sheet loss created using d3.js*

When creating this visualization, I focused on its visual appearance and overall mood. I chose a white background to represent cold, icy conditions, and used two shades of cold blue for the rivers, giving the impression of melted ice water flowing across a frozen surface. To keep the design clean, I hid the y-axis ticks and only highlighted two key points: 0 billion tons (no ice loss) and 5000 billion tons (total loss). I also decided not to label the rivers directly as either Greenland or Antarctica. Instead, I used the same blue tones from the rivers in the explanatory text on the side, as shown in the figure above.

This approach allowed me to keep the visualization simple, while still providing the key information to the viewer. The large-scale loss of ice in Greenland and Antarctica is related to another major consequence of global warming: rising sea levels. As ice sheets melt, the water flows into the oceans, contributing to an overall increase in sea level worldwide. To highlight this connection, I decided to create one final visualization focusing on the rise of ocean sea levels over time.

3.2.7 Sea Level Rise

When I started looking at the sea level data, one detail immediately stood out to me, and I knew I wanted to highlight it in the visualization. There was a clear turning point in the year 2000: before that, all recorded sea level values were below 0mm, and from that point onward, the values consistently rose above 0mm. It felt like a natural dividing line in the data. I wanted the visualization to emphasize this shift, so I sketched a concept that I felt would effectively bring this moment into focus.

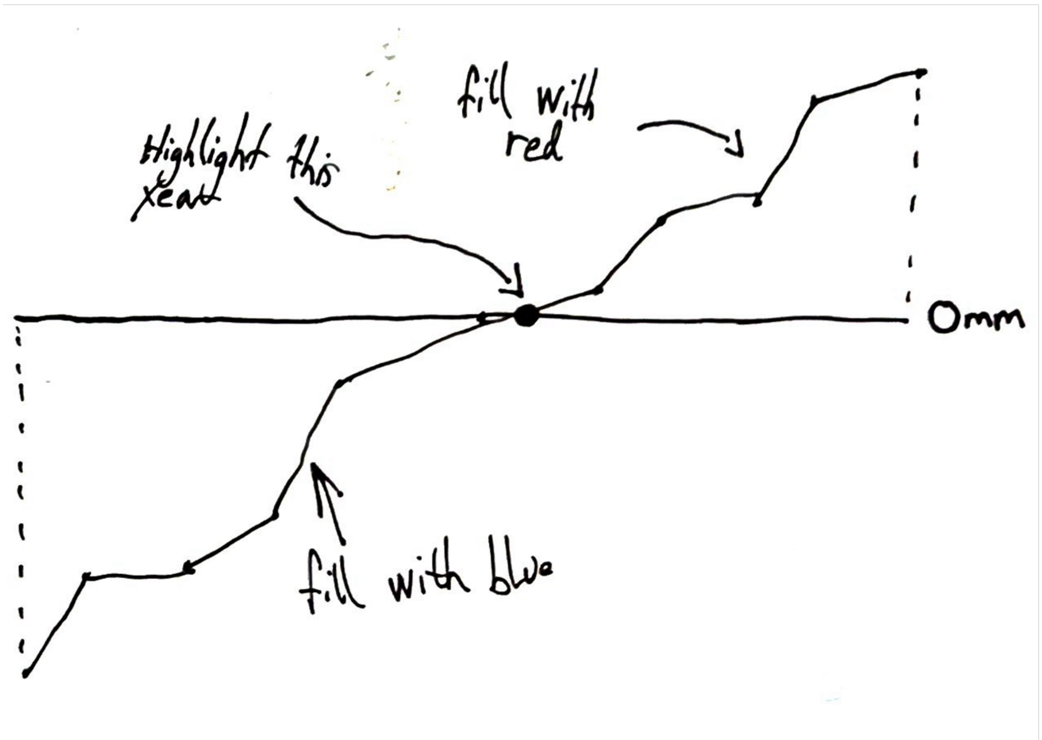

Figure 15: *Low fidelity prototype of visualizing sea levels rising*

As shown in the figure above, my idea was to take advantage of this natural division in the data. I imagined a line running across the visualization at the 0mm mark, splitting it into two sections. All data with values below 0mm would appear beneath the line, while values above 0mm would be shown above it. I also wanted to highlight the year 2000, where this shift occurs. To draw the viewer's attention, I planned to include an annotation pointing to that year, aiming to spark curiosity about its significance. With this in mind i started working with *d3.js* and ended up with this final visualization:

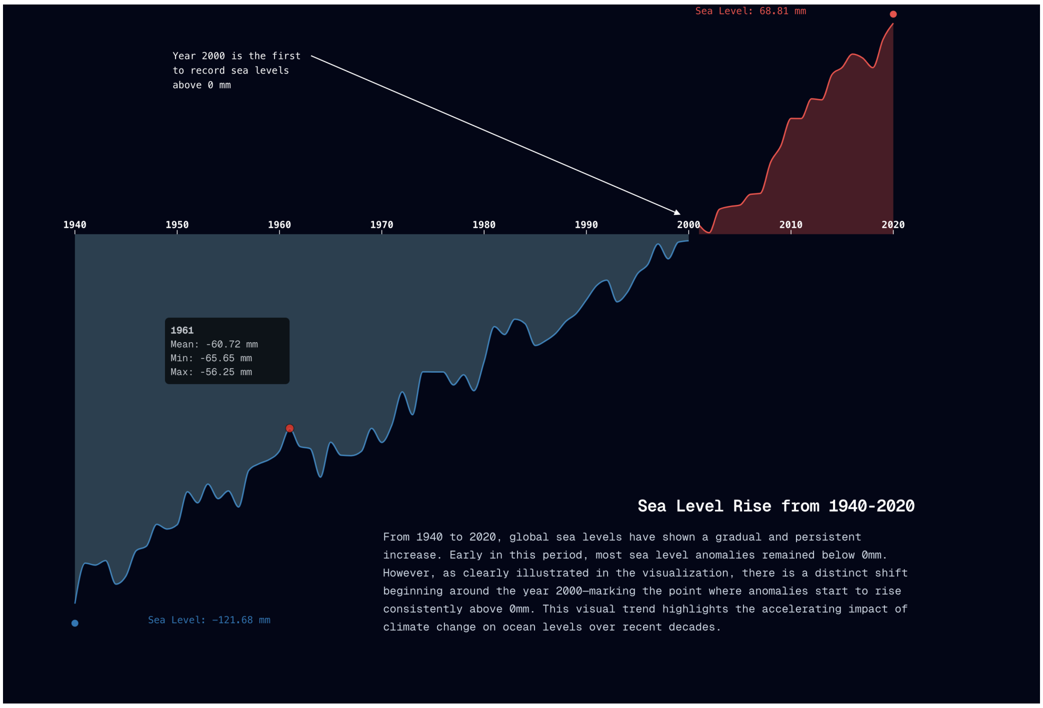

Figure 16: *Visualization of sea level rise created with d3.js*

This visualization ended up closely matching my original sketch, and I believe that's because I had a very clear vision from the beginning of how I wanted it to look and feel. The main goal was to highlight the significant shift in sea level data before and after the year 2000. I wanted to clearly show how, from that point onward, the recorded sea levels began consistently rising above 0mm, and to draw the viewer's attention specifically to that turning point.

To add more depth to the visualization, I included a tool-tip that gives viewers detailed information for each year. By moving the mouse horizontally across the screen, users can explore the data on the x-axis and see the mean, minimum, and maximum sea level values for the selected year.

There was also a more intentional reason why I chose to end the project with this particular visualization, focusing on the year 2000. If viewers scroll back through the website and reflect on that year, they may notice stronger connections between the datasets. The rapid loss of ice begins around 2000, CO_2 levels in the atmosphere increase more sharply, and global temperatures start to consistently rise above the average. This helps tie the different parts of the project together and can give viewers a clearer, more complete picture when exploring the visualizations as a whole.

3.3 The Full Story

To wrap up the second iteration, it's necessary to zoom out and look at the project as a whole. That was my main goal throughout this process, and it's also reflected in how the webpage is designed. The structure tells a story, moving through one dataset at a time, where each visualization naturally leads into the next. Each section takes up the full height of the screen to make the visualizations large, clear, and easy to focus on. As users scroll, one visualization smoothly pushes the previous one up, reinforcing the sense of connection between them. The figure below shows each screen from the webpage, with an arrow simply indicating how the next section would appear beneath the last one to the left:

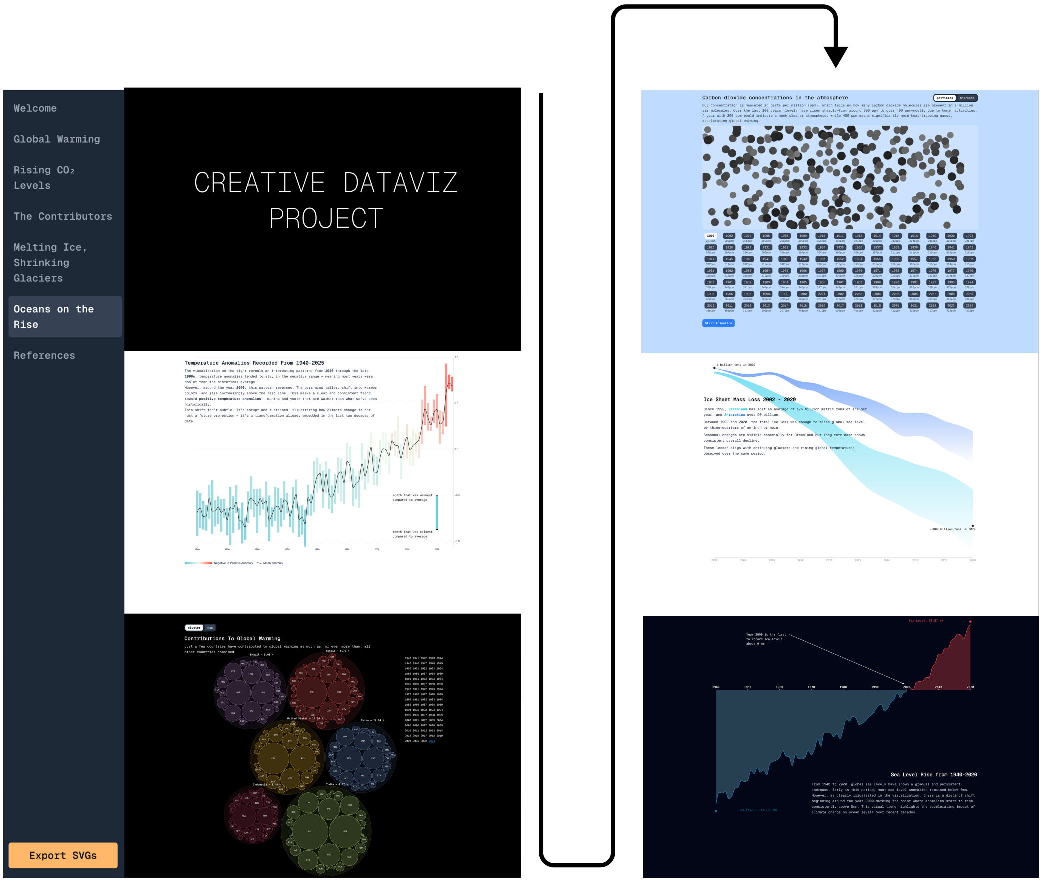

Figure 17: *All the different visualizations put together*

As users scroll through the webpage, each new visualization is animated as it comes into view. I added these animations to make the experience more dynamic and engaging. Simple effects, like a line chart gradually drawing from start to end, or the "rivers" in the ice sheet visualization flowing from the top left to the bottom right, help bring the visualizations to life and make the data feel more vivid and immersive. I included a sidebar, helping the viewer's keep track of where they are in the process and how much more is left. The sidebar also allows user to click the different topics and the page immediately scrolls to that section.

Together, the structure, animations, and flow of the webpage was designed to guide the viewer through a connected journey, from CO_2 emissions and global temperature changes to melting ice and rising sea levels. By placing each dataset in sequence and using visual storytelling, the aim was not only to present the data clearly, but to create a sense of buildup and context.

4 Final Reflections

Looking back at my project I realize that my personal step-by-step process of exploring and discovering how the data was related, directly influenced how I built the final project. The website is designed like a journey, guiding the user through each dataset in a specific order. Each visualization leads to the next one, and this sequence, from CO_2 emissions and temperature changes to melting ice and rising sea levels, mirrors the same process I went through when I explored and analyzed the different datasets.

The visualizations, made with *d3.js*, act like guides on this journey. By putting the datasets in a thoughtful order and using visual storytelling, the goal is not just to show the data clearly, but also to create a sense of flow and understanding. Animations make the experience more dynamic and engaging, helping bring the data to life. The structure, animations, and overall flow of the website are all meant to take the user on a connected journey, giving them a better and deeper understanding of climate change.

5 References

GitHub Repository

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