# Climate Horizons: Visualizing Earth's Transformation

## Introduction

The objective of the "Climate Horizons" project is to convert difficult-to-understand climate science into visually appealing and approachable representations that inform the user about the state of our planet today. The disconnect between public and scientific understanding continues to be a major obstacle to effective action as global climate change picks up speed. As a result, the goal was to develop a set of interrelated dashboards that walk viewers through the causes and effects of climate change while displaying reliable data in an approachable and scientifically sound manner.

I created the visualizations to gradually show the connections between various climate occurrences rather than overloading visitors with discrete data or academic jargon. In order to demonstrate how these factors create an interdependent system, the project tells a story that progresses from raising temperatures to melting ice to worsening extreme weather. This method turns disparate data into a coherent narrative that enables users to understand not just what is changing but also how these changes relate to one another and, eventually, to people's lives.

I used careful color schemes, interactive features, and contextual explanations to make complex climate data understandable to non-specialists while maintaining scientific integrity. I hope to bridge the information gap and promote the comprehension required for well-informed climate action by producing this visual tour of the changing climate.

## Dataset Description

For the project implementation, I integrated multiple climate datasets to present the story of our changing planet. The primary data sources included:

For the Temperature dashboard, I used NASA's Goddard Institute for Space Studies' GISTEMP dataset, which provides data on surface temperature anomalies from 1880 to the present. This dataset has to be preprocessed before it could be analyzed and mapped. The most evident pattern was the accelerated warming trend from the 1970s on, with northern hemisphere regions warming faster than the southern ones.

The Arctic Sea Ice dashboard employed monthly sea ice extent data from the National Snow and Ice Data Center (NSIDC). I processed these monthly files to extract key metrics such as annual minimum (September) and maximum (March) extents. The preprocessing involved filtering missing values (coded as -9999) and standardizing units to million square kilometers. The most worrying pattern emerged in the most recent September data - chosen since it is the lowest peak of ice surface of the year - which showed nearly 50% loss of summer sea ice since satellite monitoring began in 1979.

For the Extreme Weather dashboard, I worked with NOAA's Storm Events Database, which required extensive processing due to its complex structure. The data was split across multiple file types (locations, details, fatalities). I implemented custom decompression and merging logic to create standardized event records. A particularly challenging aspect was accounting for reporting bias – more recent decades show significantly more events partly due to improved monitoring technology rather than just climate change.

The Carbon Budget dashboard uses data from the EDGAR datasets, which track $CO_2$ emissions by country and sector between 1970 and 2023. After sector-wide aggregation and unit conversions, I integrated this historical data with the IPCC's carbon budget forecasts for several warming scenarios (1.5 and 2.0 degrees Celsius).

Across all datasets, I observed consistent patterns confirming climate change acceleration: rising temperatures, diminishing ice, increasing extreme weather events, and rapidly depleting carbon budgets – all telling parts of the same important story.

## Design Rationale

In designing the Climate Horizons visualizations, I made several choices to effectively communicate complex climate data while maintaining user engagement. My design philosophy centered on progressive disclosure, consistent visual language, and meaningful interactivity.

For color encoding, I employed diverging color schemes for the temperature and precipitation visualizations to intuitively represent departures from normal conditions. This choice leverages viewers' existing mental models where red typically indicates warming/danger and blue indicates cooling/normal conditions. I considered alternative palettes but found that diverging red-blue schemes provided the strongest perceptual alignment with the data's meaning while maintaining accessibility for users with color vision deficiencies.

The narrative framework progresses from cause (temperature rise) to consequence (melting ice, extreme weather) to context (carbon budget), which influenced the visualization sequencing. Each dashboard uses the chart types that are most suited to its specific data: line charts for temporal trends in temperature and ice extent, maps for spatial patterns, and stacked area charts for compositional data such as emissions by nation or sector. I tried with different styles, such as radial charts for Arctic ice, but felt that these compromised clarity for novelty.

For the main temperature timeline, I chose a line plot with dots to effectively show both the overall warming trend and individual yearly variations. For the hemisphere comparison, I avoided using red/blue to prevent confusion with the temperature scale, instead opting for distinct colors (orange and blue) that wouldn't be mistaken for temperature values, after receiving feedback from my group. I considered but rejected alternatives like stacked area charts or separate charts, as they would have made direct comparison more difficult.

For the geography of warming maps, I selected an equal-earth projection with a pixelated raster rendering to clearly show the underlying grid structure of the data. This approach was better than choropleth maps based on political boundaries, which would have averaged trends over entire countries and masked significant regional variations.

For the interactive elements, I prioritized functionality that enhanced understanding. The interactive map of extreme weather events, for example, allows users to filter by event type and damage threshold, revealing spatial patterns that would be obscured in a static visualization. Similarly, the carbon budget visualization enables users to explore different warming scenarios and probability levels, making abstract concepts more concrete and personally relevant.

For the Arctic Sea Ice visualizations, I chose a line and dot plot to highlight the dramatic downward trend, with a linear regression trendline to reinforce the rate of decline. For the monthly comparison, I used a multi-line plot to effectively show how the seasonal cycle has changed across different decades, rather than using multiple small charts or a stacked area chart which wouldn't have been appropriate for comparing time periods.

For the Carbon Budget dashboard, I selected a stacked area chart to show both the overall growth in global emissions and the relative contributions of different nations over time. For the cumulative emissions vs. budget visualization, an interactive line chart was ideal as it clearly shows the trajectory toward the budget limit and allows users to explore different scenarios through interactive controls.

Text annotations directly on charts eliminated the need for users to constantly reference legends, reducing the cognitive load and guiding the interpretation.

The most significant design challenge arose in balancing scientific accuracy with accessibility. For instance, in the extreme weather section, I needed to acknowledge reporting bias while still conveying the genuine increase in events. My solution was to present both raw counts and normalized metrics, accompanied by clear explanatory text—allowing users to understand nuance without oversimplification.

## Development Process

I started with an initial research and planning phase (around 5 hours) in which I found important climate datasets and sketched potential visualization methods. This required assessing numerous data sources for quality, accessibility, and story potential. I spent a decent amount of time researching visualizations made by institutions such as NASA, NOAA, and the IPCC to better understand effective approaches to climate data communication.

The data acquisition and preprocessing stage (approximately 10 hours) proved particularly challenging. For the extreme weather visualization, I faced significant technical challenges with the NOAA Storm Events Database due to its compressed format and complex structure. To solve this issue, I implemented custom JavaScript solutions to decompress and standardize these records. The EDGAR emissions data also required extensive cleaning and aggregation to ensure consistency across countries and time periods.

I devoted the bulk of my time (approximately 20 hours) to the iterative development of graphics using Observable Framework and D3.js. This framework was selected for its ability to create responsive, interactive visualizations that could be easily embedded in a cohesive dashboard structure. My process typically followed this pattern for each dashboard:

1. Create a basic static visualization of the key metrics
2. Implement interactive elements where they enhance understanding
3. Add contextual explanations and annotations
4. Optimize for performance and responsiveness

5. Apply consistent styling and accessibility features

The extreme weather map visualization was the most technically hard part, requiring significant optimization to handle the volume of event data while retaining smooth interactivity. The development of the carbon budget visualization with numerous selected scenarios needed careful consideration to data management and user interface design.

For testing and refinement (around 3 hours), the feedback I received from my group was helpful in identifying areas for improvement. Several reviewers noted color consistency issues, particularly in the hemisphere comparison, which used red and blue to represent the northern and southern hemispheres rather than temperature values, potentially confusing readers. The feedback also highlighted the need for more explanatory elements for certain visualization types, such as box plots, which might not be immediately intuitive to all users. These critical points were carefully considered in making targeted improvements to the visualizations.

The tools I relied on throughout the process included:

- D3.js for the core visualization components
- Observable Framework for dashboard structure and deployment
- JavaScript libraries including Pako for decompression
- Cursor with Claude 3.7 for code organization and improvement
- Git for version control and documentation

The last integration and deployment step (roughly 2 hours) focused on maintaining dashboard uniformity and optimizing for first-time visitors to follow the desired narrative flow from temperature to ice, extreme weather, and carbon budget.

## Final Thoughts

Developing Climate Horizons has greatly improved my technical and communication skills. Working closely with climate data revealed both the intricacy of Earth's systems and the significance of open scientific communication.

### Key Learnings

The project deepened my knowledge of D3.js and introduced me to the Observable Framework. I learned that good visualization combines compelling narratives with technical correctness, needing interdisciplinary collaboration across climate research, visualization, and web development.

### Future Developments

Further improvements could include more sophisticated interactive exploration choices, integration of projections for future emission paths, and the creation of localized representations to make climate impacts even more relatable. Furthermore, creating a powerful backend for real-time data updates could help the project remain relevant in the long run.

The most important takeaway from the project has been to recognize the value of creative visualizations in efficiently and simply explaining complicated research.

## Acknowledgments

### Data Sources

GISTEMP Team, NASA Goddard Institute for Space Studies; National Snow and Ice Data Center; NOAA Storm Events Database; EDGAR; IPCC AR6 Reports.