SINGAPORE INSTITUTE OF TECHNOLOGY

Visualizing Climate Change across the World

A. Hussin, N. Ong, O. C. Wong, S. Chan, X. Y. Lim

I. Introduction

Climate change, driven by human activities such as burning fossil fuels and deforestation, has led to a significant rise in global temperatures. This warming causes melting ice caps, rising sea levels, and more frequent extreme weather events. The year 2023 was the warmest year since global records began in 1850 at 1.18°C above the 20th century average of 13.9°C[1]. The 10 warmest years in the 174-year record have all occurred during the last decade (2014–2023). The impacts are widespread, affecting ecosystems, human health, agriculture, and water resources.

Despite the overwhelming scientific consensus on climate change, some skeptics persist[2], questioning the evidence and downplaying the urgency. Creating awareness and convincing skeptics is crucial for fostering the collective action needed to mitigate its effects.

In this project, we expanded upon a visualization of global temperature anomalies published by the National Oceanic and Atmospheric Administration[1] (Figure 1). While the original plot effectively summarizes the data, we believe there are several areas where it can be enhanced.

II. Original Visualization

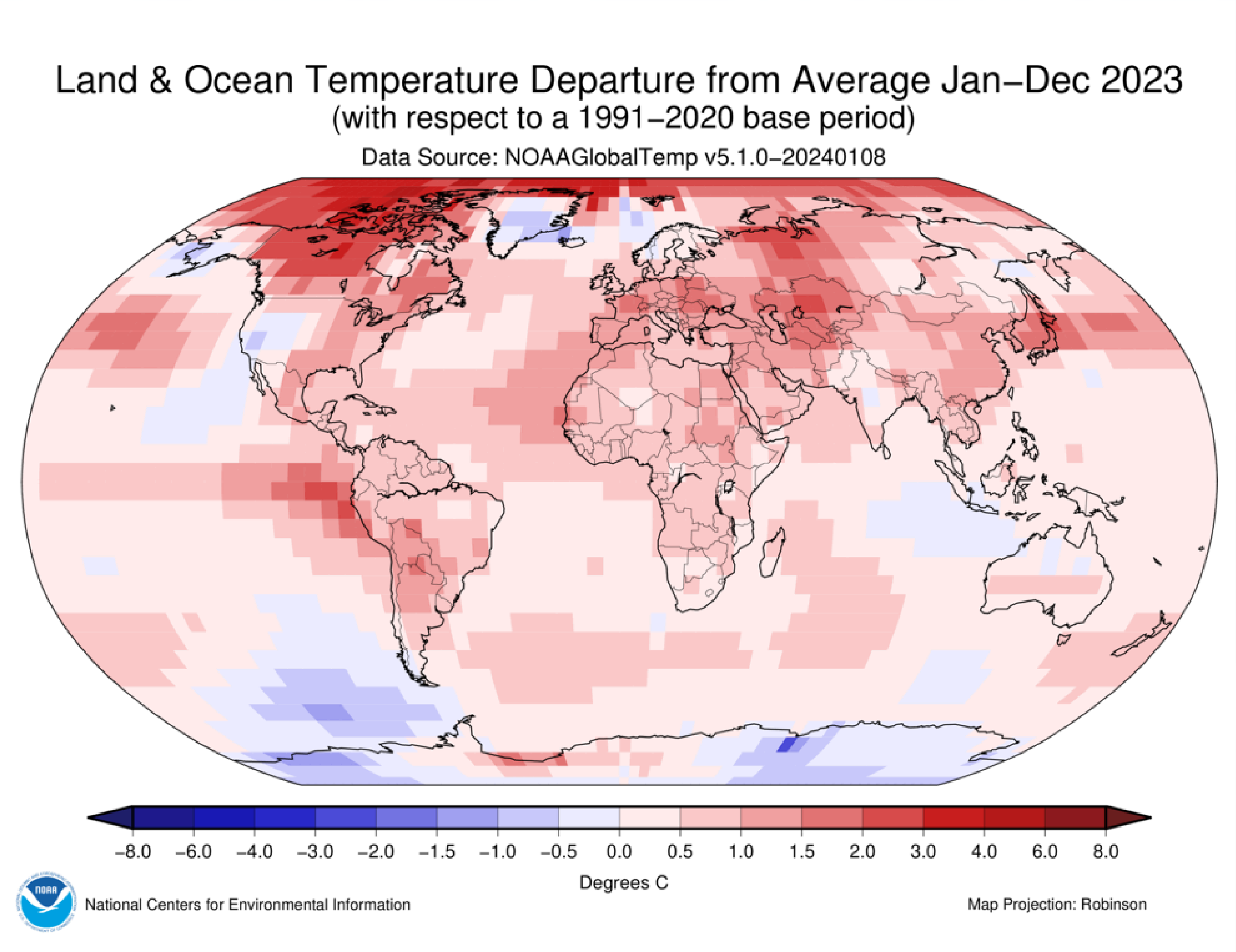

Figure 1: Land and Sea Surface Temperature Deviations in 2023 from the 1991-2020 Average Temperature of 14.4°C, published by the NOAA.

III. Critical Assessment of the Original Visualization

1. Interactivity: The visualization lacks interactive features that would allow users to explore the data further, such as hovering over data points to see exact values and region.
2. Grid and Colour Legend: The grid and colour legend is rather coarse, which does not allow viewers to distinguish between closer temperature differences and close regions.

IV. Suggested Improvements

1. Interactive Features: Implement interactive elements that allow users to explore the data in more detail, such as tooltips and filters.
2. More Granular Grid and Colour Legend: Use a smaller grid size and more granular colour scale to better differentiate between small temperature anomalies in close regions.
3. Dynamic Range Slider: Add a dynamic range slider to allow users to zoom into specific periods for detailed analysis.
4. Animation: Add an animation function to display a timelapse of temperature changes from 1960 to 2024, providing a dynamic view of climate change trends.

V. Implementation

i. Data

The gridded surface air temperature anomaly data was obtained from NASA[3]. The data is in NetCDF format and contains selected series on a regular 2°× 2° grid.

ii. Software

We used the Quarto publication framework and the R programming language, along with the following third-party packages:

- **ncdf4**: Handle NetCDF data files
- **reshape2**: Reshape data for analysis
- **plotly**: Interactive data visualization
- **dplyr**: Data manipulation and transformation
- **rnaturalearth**: Provides pre-made geographic datasets (maps)
- **zoo**: Time series data management
- **data.table**: Fast data manipulation
- **sf**: Work with spatial data (Shapefiles)

iii. Workflow

1) *Exploratory Data Analysis:*
- Filter the data to include only the past five decades (from 1960 to 2024).
- Randomly sample 1% of the data to speed up the initial exploration.
- Count the number of missing values (NAs) in each column of the dataframe.
- Visualize the pattern of missing values over time with a tile chart.
- Verify data integrity using:
  - A histogram to visualize the distribution of temperature anomalies in the sampled data.
  - A time series plot to visualize the trend of the global average temperature anomaly by month over the past five decades.

2) *Feature Engineering:*
- Perform linear interpolation to fill in missing values in the anomaly column.
- Compare the data before and after interpolation to ensure completeness.
- Calculate the mean temperature anomaly of each longitude, and latitude for each year.
- Plot a line graph to compare the temperature trends before and after interpolation, our interpolation was successful and does not introduce any new patterns.
- Round the mean_anomaly data to two decimal places for clarity.

3) *Data Visualization:*
- Define Colors: Create a color palette representing temperature anomalies, adjusted for smooth gradients.
- Map Properties: Configure projection, land color, subunit color, country color, and background color for readability.
- Add Markers: Place markers on the map to show mean temperature anomalies at different locations, with hover-over details.
- Add Colorbar: Include a colorbar to indicate the anomaly values, customized for clarity and fitting within the map layout.
- Layout: Set the title and overall layout properties for an informative and visually appealing map.

VI. Improved Visualization

VII. Further Improvements

The visualization can be enhanced by showing additional data, such as sea ice cover or atmospheric CO_2 concentrations. This would illustrate how these factors relate to climate change and provide a more comprehensive view of the issue.

VIII. Conclusion

In summary, several key enhancements were made to the global temperature anomalies graph to improve its clarity, accessibility, and interactivity. Interactive features such as tooltips and a dynamic range slider were introduced to allow users to explore the data in more detail. These improvements make the graph a more effective tool for communicating the reality and urgency of climate change.

IX. References

1. NOAA
2. World Economic Forum
3. Land-Ocean Temperature Index, ERSSTv5, 1200km smoothing, NASA