Visualizing Carbon Emission Data across Countries from 1960 to 2010

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Abstract

The goal of our visualization is to display how carbon emissions of different countries change over time. Our primary users are scientists and researchers who want to use the data to quickly gain a sense of overall carbon trends and patterns over the past 50 years worldwide, and how they relate to population size and economic output. By allowing users to interact with animated world maps and line charts, our visualization encourages researchers to develop scientific questions and specific analyses. In this paper, we will discuss related work that inspired our choice of visualization and details of our work.

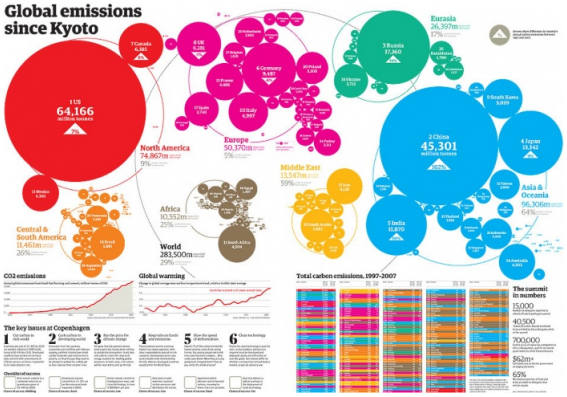
The creation of our visualization for this specific data set is inspired by the project one of us (Alec) is working on with Adrian Raftery (UW, Statistics, Sociology) and Dargan Frierson (UW, Atmospheric Sciences) from the Statistics department at University of Washington. With a large amount of data spanning 50 years, it is hard for researchers to develop strong intuition with this data. In addition, gaining insights from the data becomes an increasingly challenging task as the dimension of the data set grows and more variables are to be compared with emissions. In an attempt to allow researchers to better understand our data set, we use various visualization techniques including an animated world map projection that can effectively display the change of carbon emission across countries over time and several line charts that allow researchers to investigate the relationship between different variables in our data set.

1 Data

We are using carbon emissions data from the Global Carbon Budget [3], restricting data to fossil fuel emissions, which excludes emissions from deforestation and cement production. Gross Domestic Product (GDP) per capita data comes from the Maddison Project [2], and is normalized by purchasing power parity to 1990 United States Dollars. Population data comes from the United Nations World Population Prospects [1].

2 Prior Work

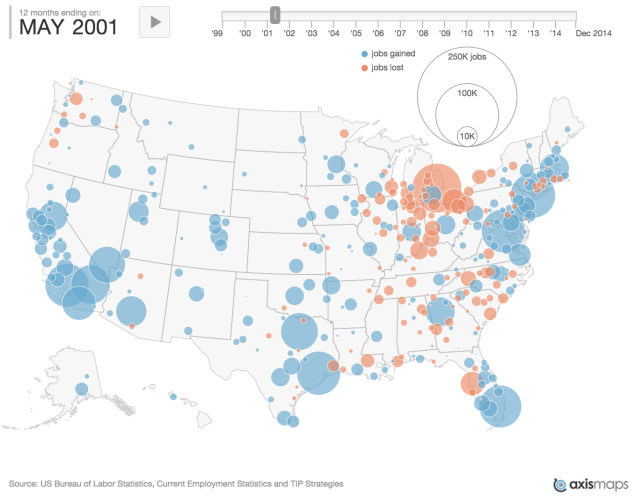
The Guardian had a map visualization of emissions over one time period [6] shown below. A downside with this graphic is that it shows emissions for a single year (and changes compared to previous year for some of the larger countries by emissions). In comparison, our visualization allows one to see changes over the years. We'll also be showing several variables in our map, allowing the viewer to view both total emissions as well as emissions per capita etc.



3 Maps

We chose to use a world map to display our data because it allows one to quickly compare the level of CO_2 across different countries. In addition to allowing users to make comparisons across countries, we also want to display the trend of CO_2 emission over time, which spurred us to adopt animated maps.

3.1 Related Work



The creation of our animated maps was inspired by the above map, displaying the geography of job, done by axismaps (the map can be found here: http://tipstrategies.com/geography-of-jobs/). Upon clicking the play button, the size and colors, which represent the numbers of job gain (loss), of the bubbles are displayed over time. The above map allows us to easily see how the job market changed from 1999 to 2014. It is especially interesting to see the surge in job loss around 2008 and the slow recovery in recent years.

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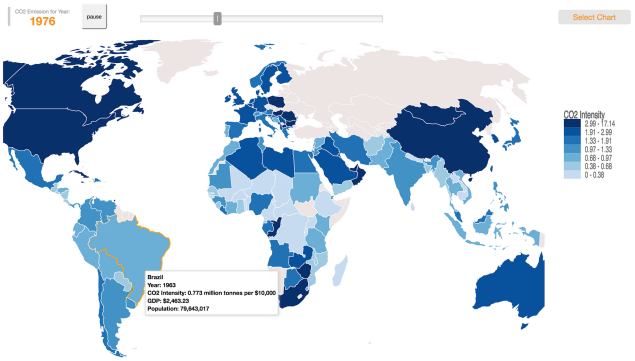
3.2 Our Work



Similar to the map of geography of jobs, upon clicking the play button, the shades of blue representing different levels of carbon intensity will change over time. In addition to playing the animation, one can also drag the slider to see how the carbon intensity changes in a certain year or in a certain period of time. We will discuss some design choices we made for this visualization.

- Map projection: We originally used the mercator projection since it allows a straightforward view of the entire world. However, since the mercator projection distorts the actual sizes of some countries badly, it might be misleading for our users interpret the data. Therefore, we chose the robinson projection instead. The robinson projection is similar to the mercator projection in a sense that it also allows an easy view of the globe, but not at cost of distorting the actual scale.

- Color: The major reason why we used blue and orange for the visualization is to make sure that the information our visualization is trying to convey can be delivered to all users, including users affected color blindness.

- Pop-up window: We included a pop-up window for each country to display more related information, which allows users to further investigate the information of a particular country of interest.

- Legend: The legend was designed based on quantiles, which ensures that each bin will contain a similar number of obervations.

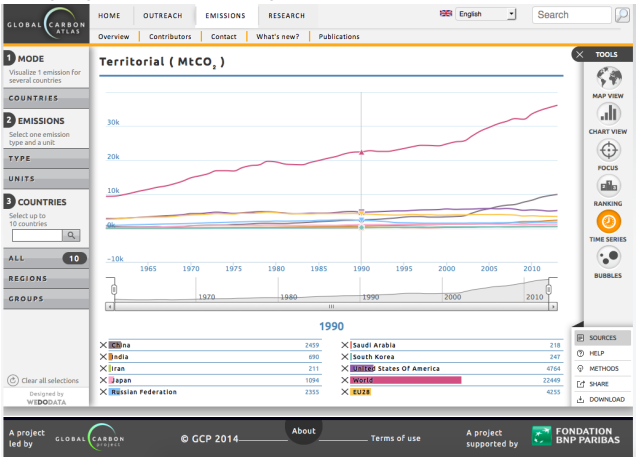
- Zooming: Since we shaded the entire country based on their intensity level, bigger countries will draw more attention while smaller countries will sometimes be hard to spot on the map. To compensate for this, we add a zooming function which allows user to zoom in to see the region or countries of interest. The legend is not affected by zooming; thus, users can still refer to the legend while zooming in (out).

- Dropdown Menu: We also included a dropdown menu to allow users to navigate among maps for different variables and line charts different variables.

4 Line Charts

4.1 Related Work

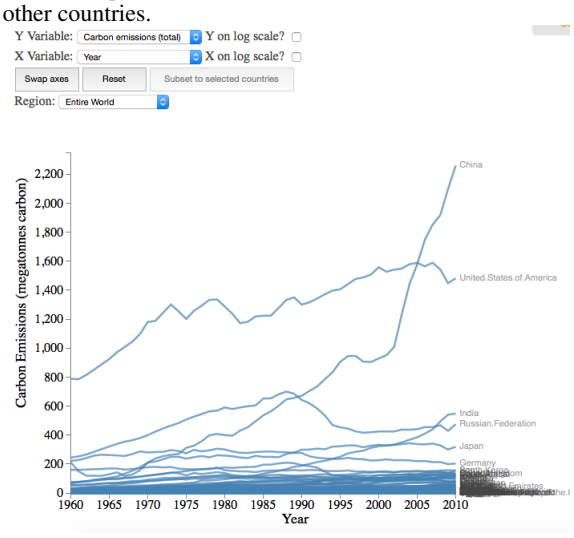
Most of the related work for interactive visualizations of emissions data is displayed in a map. One exception is the Global Carbon Atlas [4]. With this tool one can view carbon emissions over time by country, as well as carbon intensity (emissions per GDP). This is a nice tool that in some ways is broader than what we do, but in some ways is more limited - log scales aren't possible which can make the data difficult to view when a few countries have much larger emissions, it doesn't seem possible to view variables except by year, relevant other variables like GDP can't be viewed, and selecting regions was confusing.



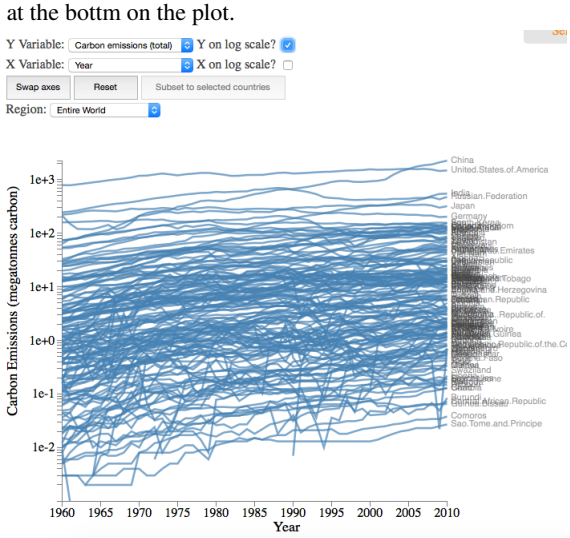
4.2 Our Work

We used D3.js to make line charts to display data for countries over time. While a map enables quick geographic comparison and facilitates spatial comparisons, maps are limited to displaying data at one point in time, and make analysis of temporal trends difficult. The crux of our lines visualization is displaying data such as emissions and related measurements over time, with each line representing a different country. This allows for viewing trends within countries, relative sizes of emissions and other variables between countries, and any trends that different countries may have in common.

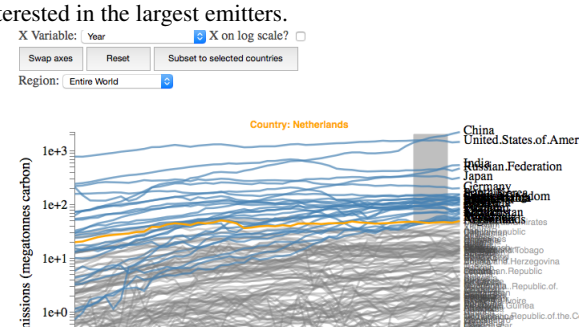
When the variable on the x axis is time, each country has a line that ends on the right side of the plot, so country names are displayed. With roughly 150 countries in the dataset, this quickly becomes too crowded, with both data lines for different countries and their textual labels heavily overlapping. Several solutions were devised for this. The most important is breaking up the data into different regions. The default region view on loading shows data for agglomerated regions ("Region summaries"), which are based on regions from the Global Change Assessment Model (GCAM), which are often used for summarizing data, and are used by the Intergovernmental Panel on Climate Change in their reports. The user can select specific regions from a drop-down menu, viewing country-level data for all countries within that region. If we still decide to try viewing all of the countries at once, such as to see total carbon emissions, we are confronted by heavy overlap at the bottom of the plot since China and the US dwarf the emissions of all other countries.



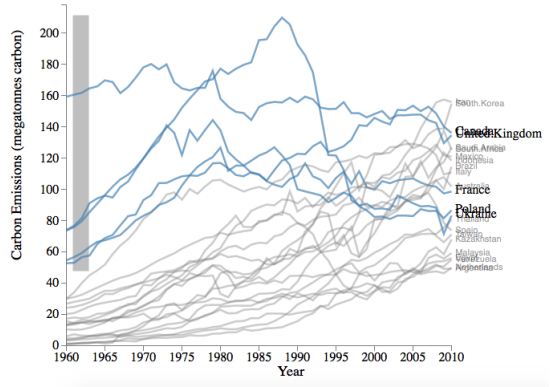
This is useful information, but renders unviewable information about most other countries. For this stuation, viewing the data on a log scale can help separate countries somewhat, preventing bunching at the bottm on the plot.



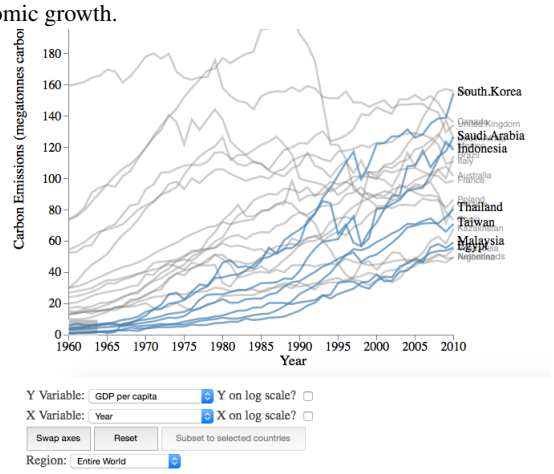
This shows that for most countries, carbon emissions have been relatively steadily increasing over this period, unsurprisingly. We could hover over different lines, displaying which countries they correspond to and highlighting these lines, but this data is still too dense with roughly 150 lines for that to be very useful. Instead, we can use brushing to focus in on countries at the top, if we are interested in the largest emitters.

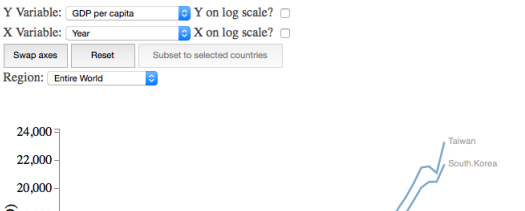


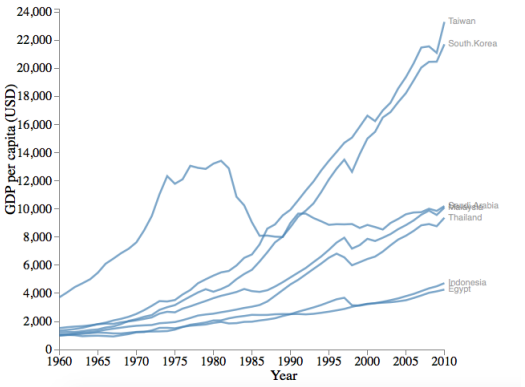
Subsetting again to remove the U.S. and China, we can switch off the log scale again, which improves viewability in this case. We can use hovering with the mouse to individually display which lines correspond to which countries at this point, and try focus in on any trends that seem exceptional to us. Focusing on a subgroup of the data, we can see the countries that started off with high emissions in 1960, which are primarily rich countries such as Canada and France.



Looking at countries that started off with very low emissions and subsetting to them, they are all east and southeast Asian countries except for Egypt and Saudi Arabia. Switching to viewing GDP, we see that GDP greatly rose for many of these countries, suggesting that the reason for their high emissions is large economic growth.

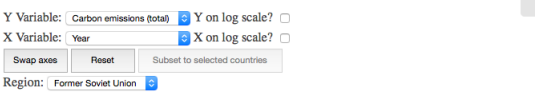


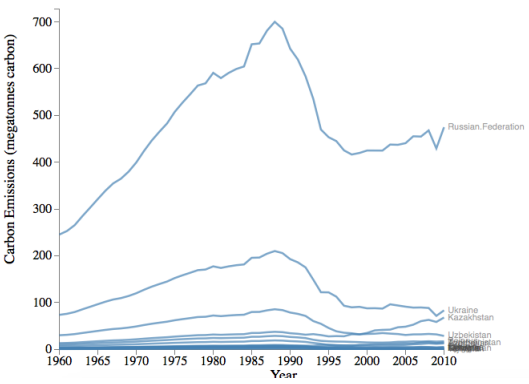




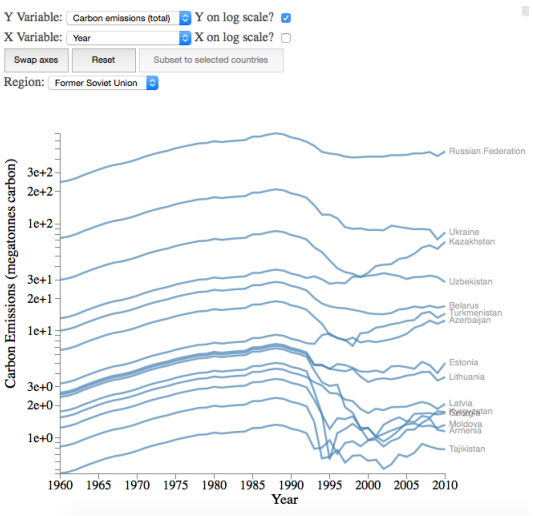
In this way, the small group of actions available can be chained together, enabling chains of analysis beyond just directly viewing the data. This helps complement the map data, which might enable us to view areas of interest.

For example, we might be curious what happened with the former Soviet Union. Economic data is missing for these countries prior to 1990 except for the exception in 1973, which is immediately viewed on the map due to the lack of intensity (emissions per GDP) data. Looking at total emissions, we see a steady rise in emissions, a fall after the collapse of the Soviet Union around 1990, followed by a slower rise.

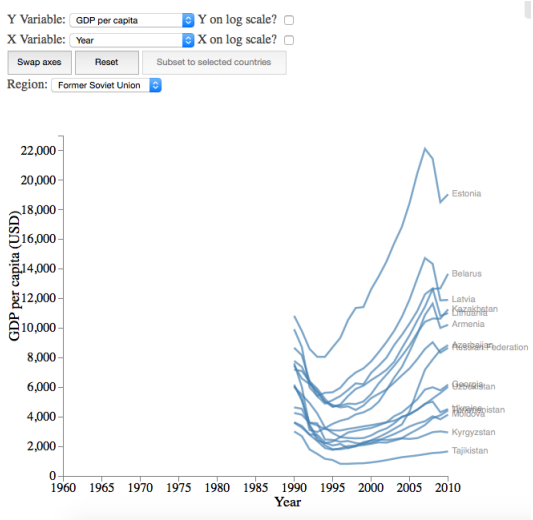




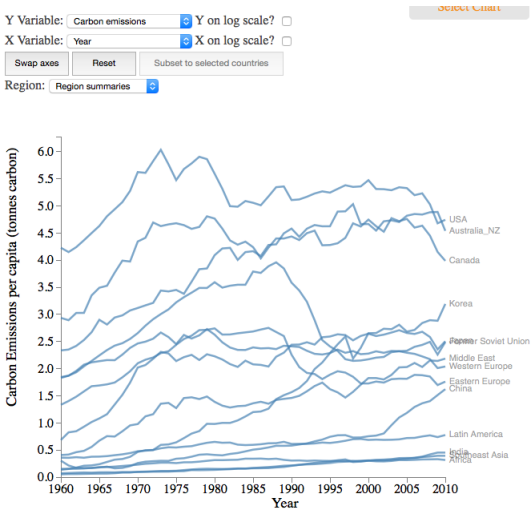
Switching to the log scale, we can see that this holds for other countries as well.



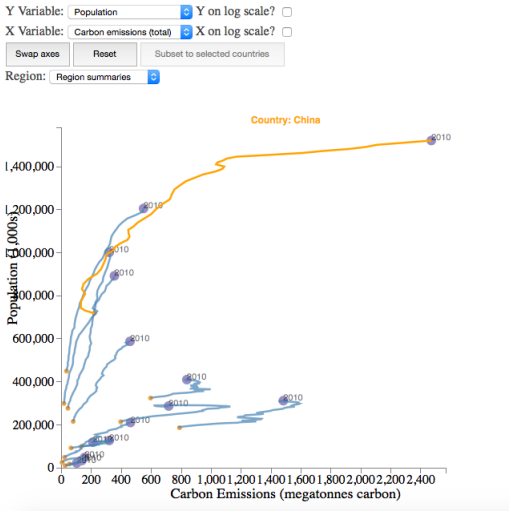
This happens to be a situation where the GDP data is useful. If we look at GDP, we see that GDP per capita collapsed after the fall of the Soviet Union, and has been rising in all countries since 1995.



Viewing by agglomerated region can be helpful to get a simplified initial view of the data. We chose to not allow brushing with the aggregated region data, as there are not very many regions to begin with and on the basis that options that are not useful should not be presented. With regions, we do not allow the use of brushing to subset the data, since there are not many regions to view. In the below image, this could be used to give us an immediate glance at how different regions rank in terms of carbon emissions per capita.



While we have demonstrated switching between different variables over time, something else that can be useful is a more direct comparison of one variable against another, in which line segments connect observations from year to year. For example, we can see how emissions vary with population for the combined regions.



We see that recently the GCAM region containing China (as well as a few other countries) has seen population growth slow but total carbon emissions accelerate greatly. Circles with different colors and sizes are used to consistently represent the starting and ending years of the data, with the final year of the relevant data displayed next to the line to unobtrusively display the trend.

Another option instead of lines would be to have points moving across the screen as time passes, in the same way as for the map, but we decided not to do this based on the arguments in [5].

5 Conclusion

References

[1] World population prospects: The 2012 revision, volume i: Comprehensive tables. 2013.

[2] The maddison-project. *http://www.ggdc.net/maddison/maddison-project/home.htm*, 2013 version.

[3] T. Boden, G. Marland, and R. Andres. Global, regional, and national fossil-fuel co2 emissions. *Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn.*, 2013.

[4] G. C. Project. Global carbon atlas. 2014.

[5] G. Robertson, R. Fernandez, D. Fisher, B. Lee, and J. Stasko. Effectiveness of animation in trend visualization. *Visualization and Computer Graphics, IEEE Transactions on*, 14(6):1325–1332, 2008.

[6] S. Rogers. World carbon emissions, by country: can the copenhagen climate summit bring these down? *The Guardian*, 2009.