Assignment 2 - CS 458

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Abstract— On a large scale, many recent studies link high air pollution levels to the larger problem of climate change. On a somewhat smaller scale, a large amount of air pollution can not only affect the climate of a certain geographic region - it can also negatively affect the quality of life for those who live there. Over time, the rate at which the air quality of a region is increasing or decreasing can single the area out for inspection by climate scientists or give the inhabitants of the area an indicator of the overall healthiness of the environment there.

To address both issues in a way that the average person can understand, we created a visualization of air pollution levels in the western United States. We use a treemap format to represent the magnitude of 11 states' air pollution levels over the span of ten years. We also make use of a color gradient to indicate the rate at which polltion levels are increasing or decreasing. This is a novel representation because much of this kind of data is presented in tables that are rather hard to parse. Our visualization, on the other hand, gives the user a good overview of general trends in the region at a glance, while still allowing them to drill down into the details if they want to. This can benefit both average people (for instance, someone looking at which state in the region they want to move to) and those with specialized needs such as climate scientists.

1 Introduction

1.1 Problem

Within the last decade, numerous works have surfaced that suggest climate change has detrimental effects on many aspects of the environment. One indicator of climate change in a geographic region is air quality, which is measured in parts per million of particulate matter. Generally, any particulate less than 2.5 microns in diameter meets the standards for dangerous particulates. An area that has a high concentration of dangerous particulates - a high number on the air quality index, which corresponds to bad air quality - can be both a symptom of or a catalyst for climate change. Identifying areas in which the air quality is markedly bad or decreasing over time can provide a way to focus climate change studies and environmental science efforts.

1.2 Motivation

Though there is much data available on the topic of air quality, very little of it is not simply presented in a table or list. Of the visualizations that do exist, many are simply colored maps that make darker or more saturated colors correspond to worse air qualities. Thus, it can be hard to see just which areas present a problem over time (signified by either a continual or sudden, severe decrease in air quality). A visualization that could clearly show both the magnitude of the air quality index and give an indication of how the quality was increasing or decreasing over time would be very useful to researchers in the field and those who want to see a simple version of the data to quickly grasp the concepts.

1.3 Potential Users

Our potential users include researchers and climate change/air quality scientists who study geographic regions in the western US. (We will focus our visualization on this region in order to make the scope appropriate for this project.) This visualization will ideally give scientists a quick overview of air quality trends in an area, which could indicate that the region requires more study or analysis in future work.

In addition, we should not forget that the general population might benefit from a good visualization of this data as well. For instance, perhaps a person who has asthma might view the data as part of a decision on whether or not to relocate to a certain state. A citizen activist might also be interested in this data in order to raise awareness in their region about the dangers of poor air quality. Multiple cases such as these exist and might be well served by this visualization. We will focus on this demographic when developing our visualization.

1.4 General Approach

We will pull data from the American Health Rankings site by the United Health Foundation. We will use this to aggregate data from the air quality measures of 13 western region states over the past 10 years. We then intend to make a series of tree maps that visualize two dimensions of the data: the magnitude of the air pollution levels (represented by the size of the block; larger = worse) and the rate of change in air quality levels (represented by the color of the block; blue = decreasing/getting better, orange = increasing/getting worse, more saturated = changing faster).

2 Visualization Tasks

- Our visualization aims to address the following questions:
  - How fast is the air quality increasing and decreasing in each state?
  - What states on the west coast are most at risk of bad air quality?
  - What trends in air quality can we identify in air quality on the west coast over the past 10 years?
  - Which states can be identified as danger zones for further research (air pollution that is quickly increasing)?

3 Related Work

Climate change has been studied by many research groups across different domains. However, how groups choose to visualize the data changes depending upon the focus of the group and what questions they're trying to answer. The teams software capabilities also come in to play, with some groups researching air pollution having little to no background in programming or information visualization. Zell et al. (2010) found that, between the years 1955 and 2006, 26,253 different titles were published relating to air pollution from 124 different countries [Zell et al. 2010].

Judging by this influx of publications, air pollution is clearly an issue that has garned interest from people of all backgrounds and interest. It is also important to note that humans play a large role in air pollution, with NASA releasing satellite visualizations of our impact on air quality [NASA]. Air pollution is also extremely dangerous, with an estimated 2.4 million fatalities occurring each year due to unsafe living conditions caused by air pollution[WHO]. Different groups of researchers have attempted to create visualizations that both inform experts and the

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general public while also being used to glean meaningful information about different atmospheric trends.

In an effort to inform city planners on how to structure future traffice schemes, Zahran et al. ran a case study to test their implementation of a 3D city model with an overlay of the changing air pollution through different types of visualizations[Zahran et al.]. Through their different tests, they found that users best understood the metaphor of smog clouds covering the more polluted areas and less clouds over the more clear areas. Perhaps an easily understandable metaphor is a good way to inform the public on levels of air pollution - however, how to do this on a state by state basis and capture the temporal aspect may not be possible with the cloud metaphor.

Elbir created a system to estimate the ambient air pollution levels temporally and spatially with the goal of mapping emissions and air quality levels [Elbir 2004]. The target users are policy makers in order to inform and predict air quality changes within the region they are evaluating. Elbir uses darker markings on a map of the area to show concentration of harmful air pollutants. The advantage of Elbir's system is that, not only does it visualize current air pollution, it also predicts future pollution levels based upon the data currently available. This might be an avenue of future research for our visualization to help citizens of the states we are visualizing to better understand whether their state is at risk or to see if it is imporiving over time.

Wang et al. created a viewpoint-based method for rendering of visualizations that promotes speed and interactivity [Wang et al 2010]. Speed is important as, if the data is consistently being sampled, being able to render and update on the fly leads to the most accurate and relevant information being shared. This type of sampling is important for government officials to keep their patrons informed if a certain area is reaching dangerous levels of pollution. The scope of our project does not reach that level of criticality, but if we shifted our audience towards government officials, their system might be an avenue for implementation efforts.

The kind of work Wang et al. are doing is similar to the work of Li et al. Li et al. aimed to create many different visualizations to inform policy makers in Beijing what is causing the rapid increase in air pollution and to analyze the trends in order to combat the air pollution [Li et al 2016]. The authors attempted different methods of visualizations and found certain types of visualizations lead to different information being conveyed (e.g. scatter plots helped locate where data was missing). The authors also found that wind speed affected change in air pollution. Li et al. also leveraged some open source software in order to create their visualization. One such open source software is Openair, an R software package used to visual air quality [Openair]. These findings suggest our visualization could be improved through supporting different visualizations depending upon what question the user is trying to answer through our visualization. For future work, we might also consider leveraging some of these open source software options in order to keep our product flexible and receptive to incoming data.

Another different type of visualization researchers have tried is Bi et al.'s tree visualization [Bi et al.]. The tree is used to represent different polutant levels for each day throughout a month in a given area. This metaphor allows for a high level of accuracy, but does not provide a broader scale view or allow for easy comparison between different regions.

Beyond purely visualizations but in the vein of informing the public, Bohler et al. developed a system called APNEE (Air Pollution Network for Early warning and online information Exchange in Europe) as a ways of informing select citizens through mobile messages, online posts, and street panels when air pollution reaches certain critical levels [Bohler et al.]. Perhaps if we leveraged our software beyond merely a visualization and created an app, we could also distribute our information to patrons. For now, that is outside of the scope of our assignment, and wouldn't make a lot of sense unless we had more frequent updates on climate change (currently our system functions on a year-long comparison level).

4 BACKGROUND

After doing a review of previous literature, we found most previous reseach was aimed at informing policy makers and other officials of the state of their local air pollution rates. These visualizations, while similar to our work, differ slightly in that they are made by experts for experts. In our case, we are seeking to inform the greater public on a more general level of how their state is doing in comparison to other states and whether their state's air pollution is increasing or decreasing. Our goal is to provide an easy to understand visualization for non-experts to track their state's pollution levels.

5 METHODS

5.1 Data Sources

We will be pulling data from the United Health Foundations website that catalogues data about each state by year. We will be studying 11 different states in the western US. We chose the western United States as the data set was relevant to our team's interest and to keep the project within a manageable scope. In addition, since we all live in the western US, this topic was of particular interest to our team: many of us intend to live and work in the Pacific Northwest. Therefore, we can use our visualization to help us determine what states we could end up in.

- Washington: http://www.americashealthrankings.org/explore/2015-annual-report/measure/air/state/WA
- Oregon: http://www.americashealthrankings.org/explore/2015-annual-report/measure/air/state/OR
- California: http://www.americashealthrankings.org/explore/2015-annual-report/measure/air/state/CA
- Alaska: http://www.americashealthrankings.org/explore/2015-annual-report/measure/air/state/AK
- Hawaii: http://www.americashealthrankings.org/explore/2015-annual-report/measure/air/state/HI
- Montana: http://www.americashealthrankings.org/explore/2015-annual-report/measure/air/state/MT
- Wyoming: http://www.americashealthrankings.org/explore/2015-annual-report/measure/air/state/WY
- Colorado: http://www.americashealthrankings.org/explore/2015-annual-report/measure/air/state/CO
- New Mexico: http://www.americashealthrankings.org/explore/2015-annual-report/measure/air/state/NM
- Idaho: http://www.americashealthrankings.org/explore/2015-annual-report/measure/air/state/ID
- Utah: http://www.americashealthrankings.org/explore/2015-annual-report/measure/air/state/UT
- Arizona: http://www.americashealthrankings.org/explore/2015-annual-report/measure/air/state/AZ
- Nevada: http://www.americashealthrankings.org/explore/2015-annual-report/measure/air/state/NV

5.2 Data Organization

We set up our data in the form of 3 tables: 1 for the states, one for the years, and one for the air pollution. The entity-relationship diagram for these tables can be seen in Figure 1. The state name and year are used as keys to index the values stored within the air pollution table. This data was retrieved from the United Health Foundation's report on air pollution across the United States.

This database was hosted on Oregon State University's ONID database service during early testing. For ease of development, we later moved to to Amazon Web Service databases. This allowed us to better leverage external JavaScript libraries when developing the interface.

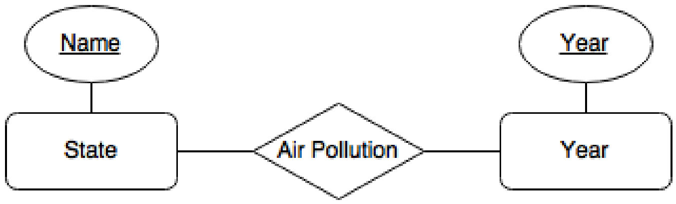
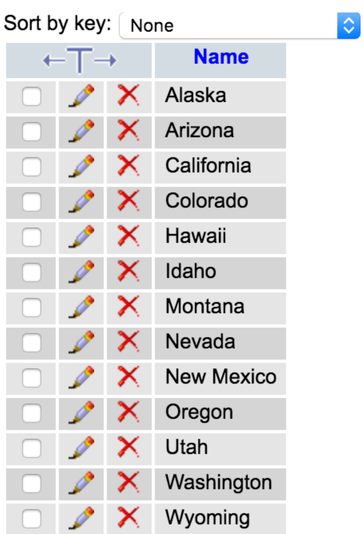
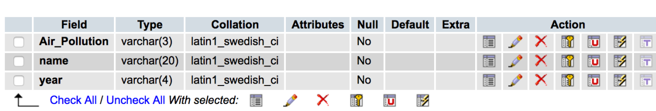


Fig. 1. An ER diagram showing the relationship between our 3 tables: the State table has a primary key ”name” and the Year table has a primary key ”year”, both of which are used to query on the Air Pollution table


Sort by key: None

Name
Alaska
Arizona
California
Colorado
Hawaii
Idaho
Montana
Nevada
New Mexico
Oregon
Utah
Washington
Wyoming

Fig. 2. A visualization of the contents of the ”state” table, with the ”name” column serving as the primary key and key to index the ”air pollution” table.



Field	Type	Collation	Attributes	Null	Default	Extra	Action
Air_Pollution	varchar(3)	latin1_swedish_ci		No			
name	varchar(20)	latin1_swedish_ci		No			
year	varchar(4)	latin1_swedish_ci		No			

Check All / Uncheck All *With selected:*

Fig. 3. The ”air pollution” table’s columns include ”air pollution”, ”name”, and ”year” with ”air pollution” containing all the values of the air pollution for each state and year, and ”name” and ”year” serving as keys.

5.3 Design of the Interface

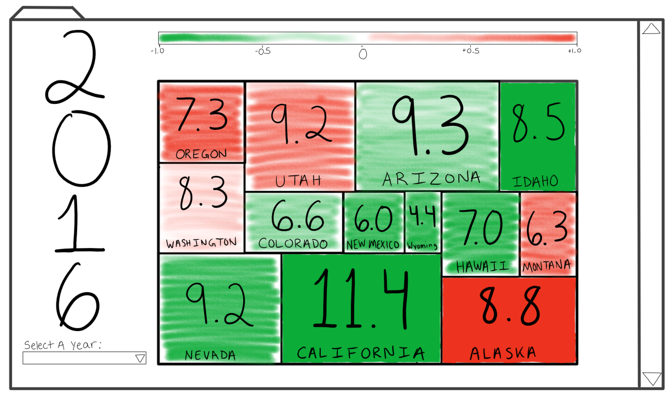


Fig. 4. Our initial design for a visualization using a tree map describing the levels of air pollution in the western region by block size. See the text for more description.

We represent our data using an interactive tree map on a webpage. On the left hand side, users can select what year they want to view from 2007 to 2016, giving them the ability to see the changes in air pollution over the years. The size of the boxes on the tree map represent the magnitude of air pollution in a state in parts per million of harmful particulate matter. The larger the box, the higher the level of air pollution. The color of each box represents the change in air pollution levels from the previous year to the one selected. There will also be a scale above the treemap indicating what the range of the changes are for that year. A more negative number represents a higer decrease in harmful particulate levels - that is, a negative number means that the state’s air quality improved since the last measurement. On the other hand, a positive number represents an increase in harmful particulate matter - and thus a decrease in air quality. The saturation of each box’s color will serve as an indicator for the state’s air quality. Our initial design for the visualization is represented in Figure 4.

5.4 Enhancement Over Existing Models

After reviewing the current models available, our model provides an enhancement by providing an easy-to-understand metaphor for non-experts to view how their state’s air pollution is changing over time. We achieve this through size and color changing to represent whether the air pollution levels are rising or lowering over time. For example, a dark orange block means that a state’s air pollution level is rapidly increasing.

Previous models require an understanding of atmospheric sciences and are designed in mind for policy makers in the domain of city planning[Zahran et al.]. While users with more experience in the domain of atmospheric sciences may use our software, we hope to create a visualization that is accessible to users of all backgrounds.

6 Implementation

6.1 Data Organization

We created a relational database with 3 tables to store our data. The ”state” table and ”year” database are used to index values stored within the ”air pollution” database, as seen in the ER diagram in Figure 1. We implemented the database on the ONID Database Server provided by Oregon State University. The contents of the ”state” diagram can be seen in Figure 2 and the ”air pollution” configuration can be found in Figure 3.

6.2 Website

To implement our design, we decided to create a webpage that would display the data and provide ways for the user to interact with the visualization. A screenshot of this website can be seen in Figure 5. This website is live, and can be viewed and interacted with at the following link: http://infovizhw2.s3-website-us-west-2.amazonaws.com/.

As mentioned before, we used Amazon Web Services to host our website and our database of information. This allowed us to use the Google Charts library as a framework for our treemap. We leveraged the Charts API to build our treemap, querying our database on page load and then feeding the resulting data into the JSON treemap object. Since we had ten years' worth of data to visualise, we decided to create each year's treemap on an "as needed" basis - that is, we create the 2007 (default) treemap when the page is initially loaded, then create each subsequent year's treemap as the user selects each year from the dropdown menu. This allowed us to optimize the initial loading speed of the page - since it only has to render one treemap on load, instead of ten, the page shows up much faster.

In addition, to provide some interactivity and clarity to the visualization, we give users the ability to hover over a block to gain more information about the state represented by that block (see Figure 6). This tooltip gives the user the exact measure of air pollution levels in parts per million of that state in the chosen year. It also provides the user information about how much the magnitude of pollution changed from the previous year. In this way, the user has direct access to the data if they so desire it - giving them flexibility in how they interact with the visualization and increasing its utility.

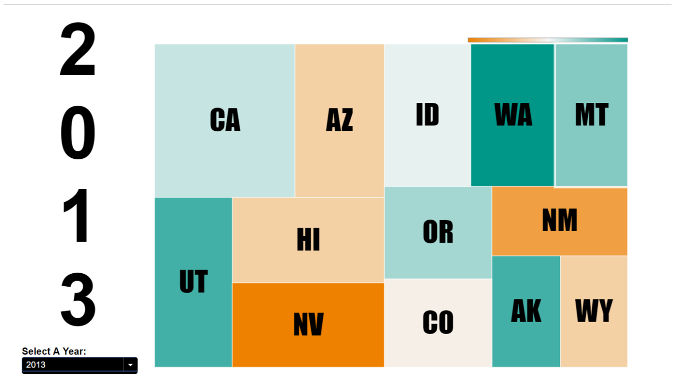


Fig. 5. A screenshot from our implemented website visualizing air pollution levels in the Western US. The user can select which year's data they would like to view using the dropdown menu.

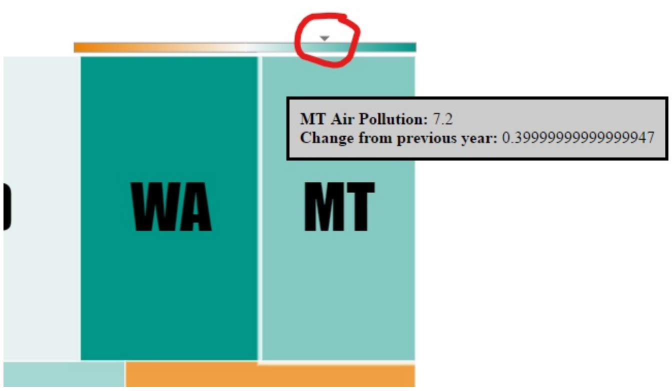


Fig. 6. A screenshot from our implemented website visualizinng air pollution levels in the Western US. The user can hover over a state's block to reveal a tooltip that contains information about a state's pollution levels for that year. Here, we see that Montana had a pollution level of 7.2ppm of harmful particulate matter in the given year, which is a decrease of 0.399 ppm from the previous year. The red circle highlights the arrow that appears on the scale when hovering over the block, to provide a means of comparison with other states.

6.3 Issues Encountered and Resulting Design Choices

As with any visualization project, there were some unexpected issues encountered in our implementation.

First, we initially intended to host our website and database on the OSU servers, since that was the platform that we were most familiar with. However, we found out during implementation that we could not leverage the Google Charts API if we did this. As a result, we moved our development to Amazon Web Service's databases and servers, which had fewer restrictions on how APIs could be used. Though this changed where our visualization was hosted, it required only minimal modifications to our code and overall allowed us to create a better end product.

Second, as seen in our initial design (Figure 4), we planned to use red and green coloring for the treemap components, mapping decreasing (better) air pollution levels to various saturations of green and increasing (worse) air pollution levels to reds. We believed that this would intuitively make the "most sense" to the user, since green is "good" and red is "bad" in many visualizations. However, when one of our group members spoke with the class's teaching assistant, he pointed out that red-green colorblindness is the most common form of colorblindness. Thus, by choosing red and green, we made our visulaization virtaully useless to a small but significant subset of the population. To address this, we changed our color scheme to orange and blue gradients, where blue is a decreasing (better) level of air pollution and orange is an increasing (worse) level of pollution. As before, more saturated colors represent higher rates of change from year to year. This simple change increased the usability of our visualization and furthered the ever-present goal of accessibility in public softwares.

Finally, when we finished the visualization and deployed it to a live site, we realized that there was a logical error in our code that caused the first year of information (2007) to show incorrectly. This arose from how we structured our code: when we build a treemap and determine what colors the blocks should be, we use the data from the previous year's measurements to determine the saturation and hue of each block's color. Since we do not have measurements from prior to 2007, we did not have a value to compare 2007's measurements against. Due to the way we calculated the change, this missing value caused all the blocks in the 2007 treemap to appear dark orange - implying every state's air pollution levels had increased drasically since the last year. Since this is likely incorrect, we decided to make 2007's blocks all grey in color, indicating no measured change from the previous year. Though this does make the 2007 treemap lack one dimension of the information we are visualizing, we thought this would be the best way to avoid misrepresenting data that we didn't have, leading to a more accurate visualization overall.

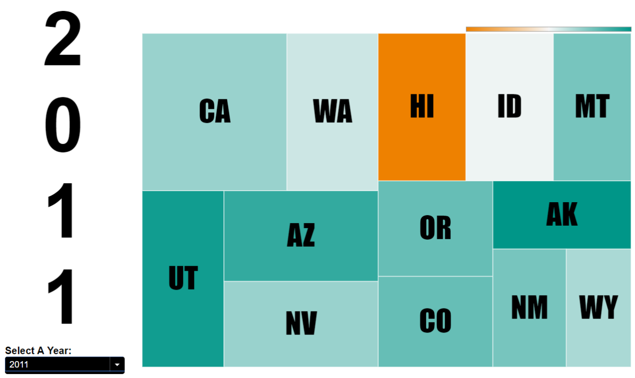


Fig. 7. A screenshot of our visualization for the year 2011. The majority of the states showed moderate to large increases in air quality from the year before, as evidenced by most of the blocks being a shade of blue rather than orange.

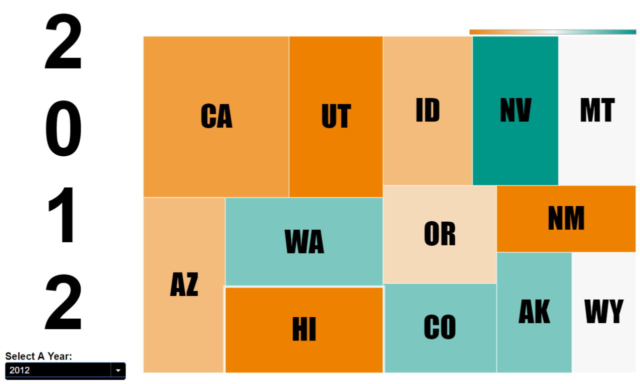


Fig. 8. A screenshot of our visualization for the year 2012, directly after the previous figure. Here, the majority of states showed decreases in air quality, as evidenced by most blocks being a shade of orange.

7 Results

7.1 Insights

Visualizing the air pollution data in this way reveals some interesting insights.

First of all, we found that there was no overall, unifying trend to the level of air pollution in the Western US over the past ten years. This was surprising, because we expected to see something - either a general increase in air quality (which would suggest that climate change initiatives were effective) or a general decrease in air quality (which would suggest that climate change was damaging air quality faster than we could combat it). Instead, we didn't see any clear trend to the direction of air quality fluctuations. There were periods of constantly increasing air quality for the majority of states (e.g., 2010-2011), but these periods were followed by a sharp decrease in air quality (e.g. 2012). See Figures 7 and **??** for a visual comparison of these phenomena.

When looking at individual states, however, we did see trends. For example, California consistently had the largest amount of air pollution over the time span of the visualization, regardless of whether the levels increased or decreased from the previous year. Interestingly, in 2015 and 2016, Idaho was almost tied with California for the highest amonut of air pollution - but at the end of the visualization time span, California's air quality was getting better whild Idaho's was getting worse.

Hawaii and Wyoming were roughly tied for the lowest consistent amount of pollution from the beginning until about 2011, when Hawaii experienced a sharp decline in air quality and Wyoming suddenly experienced better air. (An example of this can be seen in 7). Since that time, until the end of the visualization time span, Wyoming consistenly had the lowest amount of air pollution.

Looking at this model through the eyes of someone who might want to moove to one of these states, there are certainly better choices than others. For instance, a person with asthma or breathing difficulties would probably not want to move to Alaska in the near future - though the state was never the worst offender in terms of air quality levels, Alaska's pollution levels showed a sharp increase in the later few years of the visualization - indicating that Alaska might soon become a low air quality state. On the other hand, this person might consider a move to Montana - the rural state had a consistently low level of air pollution (though never the actual least), and was almost always colored blue, which indicates a steady increase in air quality.

7.2 Data Set

As mentioned in the Methods section, we sed ten years' worth of air pollution data from the United Health Foundation's website on the topic. See that section for a more detailed description of how we obtained the data. This gave us a set consisting of 110 data points (11 states x 10 years) that we leveraged to build our visualizaton.

7.3 Dimensions Used

Our visualization models two dimensions of the data. First, it maps the magnitude of a state's pollution levels to the spatial domain using the size of the block in the treemap. A larger block corresponds to higher levels of pollution, while a smaller block means lower pollution levels. In a way, the spatial dimensions of each block can be though of as "how big" the state's contribution is to the overally level of air pollution in the Western US.

Second, we represent the temporal dimension of the data (over a span of 10 years) through the relative, changing colors of each block in the treemap. When viewing a given year's treemap, the color of the blocks indicates the change in air pollution levels from the previous year. This gives a sense of time to the data and firmly grounds our model in the temporal domain. Without this dimension, it would be much harder to find interesting trends over time - we would have no mechanism to compare across years.

7.4 Performance

Our visualization performed well in its intended task. It gave an effecient and effective overview of air quality in this region of the country and allowed not only the identification of certain "problem" states that had persistently bad air quality, but also the states that would be more likely to maintain their good air quality in the future.

However, as with any visualization, there were a few drawbacks to representing data in this fashion. For instance, as discussed in the Insights section, we could not discern any overall trend to the data. One explanation for this is that there really was not any trend - that the fluctuations did not follow any pattern. Another explanation is that there was a trend that we were not able to figure out with this method of visualization. This is a possible idea for future work in this area.

7.5 Supplementary Materials

** alannah said: link to source code - so I guess here we could link to our github or something **

7.6 Domain Expert

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8 Conclusion and Future Work

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9 Acknowledgements

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