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P2: Dynamic Data Visualization   April 27, 2016

What's Really Warming the World?

A. Description of the Data

How we got the data:

We gathered data from a variety of online resources on observed land-ocean temperature and responses to climate forcings from 1880-2014[1] as well as change in co2 concentration from 1958-2013[2] as well as change in September sea ice extension from 1979-2015[3] and sea level from 1880-2013[4].

Nasa's Goddard Institute for Space Studies

Our data on observed land-ocean temperature and responses to climate forcings is based on csv files gathered by Kate Marvel and Gavin Schmidt from NASA's Goddard Institute for Space Studies (GISS). We took this data from the Bloomberg article: What's Warming the World?, which contains observed land-ocean temperatures and simulated data for climate forcings (factors.csv) on orbital changes, solar, volcanic, ozone, and greenhouse gases. The data looks at the deviation in temperature in degrees Fahrenheit for these factors from the 1880-1910 average over a period of time.

National Oceanic and Atmospheric Administration

Our data on co2 levels is based on data gathered by the National Oceanic and Atmospheric Administration and obtained by C. David Keeling of the Scripps Institution of Oceanography (SIO) and the Scripps website[5]. The mean value in CO2 measures the concentration of mid-tropospheric carbon dioxide in parts per million (ppm).

National Snow and Ice Data Center

Our data on sea ice extension is credited to Fetterer, Knowles, Meier, and Savoie from the National Snow and Ice Data Center. We found this data by inputting sea ice extent

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[1] http://www.bloomberg.com/graphics/2015-whats-warming-the-world/
[2] http://climate.nasa.gov/vital-signs/carbon-dioxide/
[3] http://nsidc.org/data/G02135
[4] https://www3.epa.gov/climatechange/science/indicators/oceans/sea-level.html
[5] http://www.scrippsco2.ucsd.edu

into the search query on http://nsidc.org/data/search from 1979 and retrieving data on monthly sea ice extension from 1979 to 2015.

United States Environmental Protection Agency
Our data on sea level is credited to researchers from the United States Environmental Protection Agency. It contains data in cumulative changes for the world's oceans since 1880 to 2013, which is called "CSIRO - Adjusted sea level (inches)" in the csv file.

Image File
We found a cute polar bear image and removed the background with PhotoShop[6].

Describe variables and how we reformat and filter data:
These are variables used in our datasets: (we chose to keep a wider range of years in the first visualization to show an overview of climate change and a narrower range of years in the second visualization to focus specifically on the effects of global warming).

In the first visualization, we chose to disregard land use and aerosols because they are declining compared to the other factors that are increasing with rising temperatures. Regardless of where our dates started we kept our end year consistent up to 2013. Moreover, we chose to focused on september arctic sea ice compared to the other months because it reaches its minimum at that time[7].

While the first visualization focused on all greenhouse gases, we decided to focus specifically on CO2 in the second visualization that accounts for 80.9% of all greenhouse gas emissions from human activities[8]. Since the focus of the first visualization is the rise of temperature caused by potential global warming factors, we transformed all absolute temperatures in factors.csv to relative values by calculating the average value for the first 30 years from 1880 - 1910 for each of the factors and subtracting that from the observed global land-ocean temperature for each year.

> V1: Years from 1880 - 2013
> V2: Years from 1979 - 2013
> V3: Change in Observed Global Land - Ocean Temperature (°F)
> V4: Deviation from Observed Global Land-Ocean Temperatures (°F)
> for Greenhouse gases
> V5: Deviation from Observed Global Land-Ocean Temperatures (°F)

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[6] http://img2.goodfon.su/wallpaper/middle/d/1f/medvezhonok-ldina-kraski.jpg
[7] http://climate.nasa.gov/vital-signs/arctic-sea-ice/
[8] https://www3.epa.gov/climatechange/ghgemissions/gases/co2.html

for Orbital Changes
V6: Deviation from Observed Global Land-Ocean Temperatures (°F)
for Ozone
V7: Deviation from Observed Global Land-Ocean Temperatures (°F)
for Solar
V8: Deviation from Observed Global Land-Ocean Temperatures (°F)
for Volcanic
V9: CO2 concentration in parts per million (ppm)
V10: September arctic sea ice extension (km²)
V11: Worldwide sea level (in)

B. Mapping Data to Visual Elements
How we transformed data and displayed them:
Overall, we assigned margin values for the sea level, co2 concentration, and sea ice extent bar graphs to adjust x,y position for each element. By adding or subtracting paddings with scaled data, we could put elements in the position we want them to be. Moreover, we specified coordinates for each of the points for all our svg elements in the cartoon representation and used a line function with interpolate('cardinal") or interpolate("basis") to smooth out the wave, polar bear, and co2 letter clouds. We used a regular line function without interpolate for our ice peaks so the edges are sharp. Our color scheme centered around blues and grays to reflect our arctic environment.

Overview of Factors Contributing to Global Warming
In the first visualization, we combined V1 with V3, V4, V5, V6, V7, and V8 in a line graph to show the deviation of temperature from -1°F to +1°F away from the 1880-1910 average and the influence of natural factors like orbital changes, solar, and volcanic, and global warming factors like ozone and greenhouse gases on the change of temperature. The x-axis is the range of observed years from 1880 to 2013. The y-axis is temperature deviation based on observed global land and ocean temperature record.

Our multi-line graph on the natural and human factors for global warming uses an invisible Voronoi tessellation[9] to handle mouseover; the closest point to the mouse on any line is highlighted. Note that because d3.geom.voronoi does not handle coincident points, d3.nest is used to collapse coincident points before constructing the Voronoi.

What's most important about these temperatures are the trends—the shape and trajectory of the line, and not any single year's temperature. The black "observed" line is

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[9] https://bl.ocks.org/mbostock/8033015

the Observed Global Land and Ocean temperature record. It starts in 1880. The colored temperature lines are the modeled estimates that each climate factor contributes to the overall temperature. Each factor was simulated five times, with different initial conditions; each slide here shows the average of five runs. GISS researchers laid out their historical simulations in detail up to 2013.

Analysis into the Effects of Higher Temperatures

In the second visualization, we combined V2 with V9, V10, and V11 in two sections. When you move the slider to the right from 1979 up to 2013, you will see that the sea level rises, sea ice area decreases and shifts to the left, and CO2 cloud color deepens. You will also see additional bars added or removed from each of the graphs based on that particular year's sea level, CO2 concentration level, and sea ice extension. The color of CO2 concentration, sea level and sea ice bars matches the color of CO2, sea level and sea ice in the cartoon representation.

The left section is the cartoon representation of the relationship between sea ice area, sea level and CO2 concentration level with a polar bear sitting on top of the ice. The goal of this cartoon is to provide user with intuitive view of the changes of sea ice, sea level and CO2 concentration.We drew multiple svg images for the polar bear, light blue ice bottom and ice peaks, deep blue sea bottom and sea waves, and cloud shapes for each individual CO2 letter.

Moreover, we translated the sea waves to move horizontally to the left to stimulate a wave motion. All the images are assigned a unique ID and linearly translated when you move the slider for years from 1979 - 2013 based on our updateTextInput function that takes the y values for co2 concentration, sea ice extent, and sea level from our co2year.csv, seaiceextent.csv, and sealevelyear.csv and shifts the images accordingly. We chose the year between 1979 - 2013 because this duration allows us to get all relative data from CO2, sea level and sea ice csv files.

The right section shows three different bar graphs showing the exact values of sea level, CO2 concentration level, and sea ice extension. The goal of these bar graphs is to show exact value changes for sea ice, sea level and CO2 concentration over the years. The exact value for the year and sea level change in the first bar graph, year and Co2 level in the second bar graph, and year and sea ice extent level in the third bar graph appears within a speech bubble when you hover over individual bars.

When page loads, the 1979 bars will first appear since the initial state of the slider is from 1979.We added bars inside the function updateTextInput so that each time user drag the slider to right, more bars will appear on bar graph. When user drags the slider to left, the number of bars will decrease based on the years. The three bar charts are refreshed each time by d3 remove function when user drags the slider. The color inside CO2, sea ice and sea level bars in the bar graphs match to the CO2, sea ice and sea level color inside the polar bear graph.

C. The Story

Global warming gradually increases the average temperature of the Earth's atmosphere and its oceans, a change that permanently changes the Earth's climate. Many people debate about whether global warming is real (some call it a hoax). Climate scientists that look at data and facts on climate change can tell that the planet is warming. We wanted to understand what natural and human factors contribute to global warming and then focus on their effects in terms of rising sea levels, increased co2 concentration, and diminished sea ice extension.

Skeptics of manmade climate changes offer various natural causes to explain why the Earth has warmed 1.4 degrees Fahrenheit since 1880. But, can these account for the planet's rising temperatures? The impacts of a dwindling ice cover in the Arctic are far-reaching, from species endangerment to enhanced global warming, to the weakening or shut-down of global ocean circulation. The user can see the polar bear losing its ice area and home in the cartoon visualization and look at concrete values for cumulative sea level, co2 level, and sea ice extent level in the bar graphs on the right.

Interestingly, in our first visualization we can see that a human factor like greenhouse gases contributed to rising temperatures the most compared to natural factors like solar, orbital changes, and volcanic or another human factor like ozone. There is a positive correlation with greenhouse gases influence on rising temperatures. In our second visualization, we can also see that the concentration of CO2 is always increasing over time compared to sea level and sea ice extent that fluctuate up and down a bit and don't increase as much over the years. Perhaps global warming is not just a fact of life on this planet, but is heavily influenced by human factors like the burning of oil, coal, and gas that increases CO2 concentration and encloses the world inside a heat blanket.

References:
https://d3js.org/
http://bl.ocks.org/